DIGBY WELLS ENVIRONMENTAL

Your Preferred Environmental and Social Solutions Partner

Providing innovative and sustainable solutions throughout the resources sector

Pan African Resources PLC (PAR) Environmental Application Process

Hydrogeological Specialist Study

Prepared for:
Pan African Resources PLC (PAR)

Project Number:
PAR7273

July 2022

Digby Wells and Associates (South Africa) (Pty) Ltd
Company Registration: 2010/008577/07

Turnberry Office Park, Digby Wells House. 48 Grosvenor Road, Bryanston,2191

Phone: +27 (0) 11 789 9495
Fax: +27 (0) 11 789 9495
E-mail: info@digbywells.com
Website: www.digbywells.com

Directors:
DJ Otto, J Mkhabela, L Ratsoenyane, M Rafundisani

This document has been prepared by Digby Wells Environmental.

Report Type:	Hydrogeological Specialist Study
Project Name:	Pan African Resources PLC (PAR) Environmental Application Process
Project Code:	PAR7273

Name	Responsibility	Signature	Date
Robel Gebrekristos, PhD	Writer		June 2022
Brett Coutts	Reviewer		June 2022

This report is provided solely for the purposes set out in it and may not, in whole or in part, be used for any other purpose without Digby Wells Environmental prior written consent.

DETAILS AND DECLARATION OF THE SPECIALIST

Digby Wells and Associates (South Africa) (Pty) Ltd

Contact person: Robel Gebrekristos

Digby Wells House
Turnberry Office Park
48 Grosvenor Road
Bryanston
2191

Tel: 011 789 9495
Fax: 011 789 9498
E-mail: robel.gebrekristos@digbywells.com

Full name:	Robel Gebrekristos
Title/ Position:	Hydrogeologist
Qualification(s):	PhD
Experience (years):	20
Registration(s):	SACNASP: 400175/08

I, Robel Gebrekristos, declare that: –

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

	11 December 2021
Signature of the Specialist	*Date*

Findings, recommendations and conclusions provided in this report are based on the best available scientific methods and the author's professional knowledge and information at the time of compilation. Digby Wells employees involved in the compilation of this report, however, accepts no liability for any actions, claims, demands, losses, liabilities, costs, damages and expenses arising from or in connection with services rendered, and by the use of the information contained in this document.

No form of this report may be amended or extended without the prior written consent of the author and/or a relevant reference to the report by the inclusion of an appropriately detailed citation.

Any recommendations, statements or conclusions drawn from or based on this report must clearly cite or make reference to this report. Whenever such recommendations, statements or conclusions form part of a main report relating to the current investigation, this report must be included in its entirety.

EXECUTIVE SUMMARY

Digby Wells Environmental (hereafter Digby Wells) has been appointed to undertake an Environmental Application Process and associated specialist studies for the Mogale Cluster - Mining Right (GP) 30/5/1/2/2 (206) Mining Right (MR) and, more specifically for the proposed construction of a large-scale gold tailings retreatment operation. Pan African Resources PLC (PAR) has entered into a Sale and Purchase Agreement for the acquisition of the shares in and claims against Mogale Gold (Pty) Ltd (Mogale Gold). The agreement was entered into between PAR and the liquidators of Mintails Mining SA (Pty) Ltd (in liquidation) (MMSA). MMSA is the holding company of Mogale Gold. The intended transaction is subject to a due diligence investigation which is in the process of being concluded.

The project entails the reclamation of historical unlined Tailings Storage Facilities (TSFs). The reprocessed tailings will be first discarded into West Wit Pit and possibly other nearby small pits. Any extra processed tailings will be stored on a ground TSF. The new TSF will also be unlined.

This hydrogeological specialist study is conducted to evaluate the baseline groundwater conditions. The potential impacts (negative or positive) of the proposed mining activities are also assessed and optimum mitigation measured proposed.

The study is conducted following a desktop study, hydrocensus, water quality sampling, geophysical surveying, borehole drilling, aquifer testing and numerical modelling.

Baseline Conditions

There are four aquifer layers at the project site: the top weathered aquifer, the fractured aquifer, the dolomitic aquifer and the mine void aquifer.

The shallow aquifer is in direct contact with the existing historical TSFs and is vulnerable to contamination due to seepage. Many of the shallow boreholes (less than 30 m deep) are highly contaminated with sulphate reaching up to a maximum of 6000 mg/L. This is significantly higher than the 400 mg/L drinking standards (SAWQG, 1998). The unlined TSFs are also rich with pyrite and are exposed to oxidation reaction which results in acidic (low pH) solution. As rainfall infiltrates through the tailings, the acidic water infiltrates to the shallow aquifer, dissolving and transporting Fe, Mn and other metals on its way.

The average groundwater flux (Darcy velocity) along the weathered zone is in the order of mm/year at the project site. This is not unusual rate for groundwater, but it means that, even if the tailings are removed, it will take decades for the plume that is already existing on site to be flushed away under natural groundwater flow. One option of enhancing the removal of the plume is to pump and treat the polluted water from boreholes.

The fractured aquifer and dolomitic aquifers are generally cleaner than the weathered aquifer. Once the shallow aquifer is contaminated from the TSF seepage, the groundwater dominantly flows laterally towards the local streams and rivers. Unless there are sub-vertical permeable structures connecting the fractured aquifer with the shallow aquifer, the contamination plume

is mostly restricted in the shallow aquifer and the streams. The sulphate level in the fractured and dolomitic aquifers are usually less than 150 mg/L.

The mine void aquifer is sampled at the shafts for quality assessment. The water quality of all the shafts is similar as they are interconnected. The mine void quality has been improving continuously from approximately 4000 mg/L in 2009 to 648 mg/L in 2021. Dissolved metals and TDS have also shown similar improving trends. The Department of Water and Sanitation (DWS), through Trans Caledon Tunnel Authority (TCTA) pumping and treatment activities of the mine void aquifer seem to be playing a major role on this.

The groundwater elevation in the top weathered aquifer is not connected with the mine void, as it mimics the topography. The flow direction follows the topography and is towards the local streams.

The hydraulic head and groundwater flow direction in the mine void is controlled by the decant, abstraction that is taking place at 9 Shaft, mine interconnectivity, and geological structures connecting the mine void with the shallow aquifer. When mining was discontinued in the area, it started to flood and, in September 2002, the mine water started to decant at the Black Reef Incline next to the Tweelopie East Stream. The decant point, referred to as the Black Reef Incline (BRI), is at an elevation of 1662.98 m amsl. This decant is currently under control with the ongoing pump and treat taking place from 9 shaft.

Impact Assessments

The historical TSFs in the region are not lined and seepage is contaminating the underlying aquifer. The current hypothesis is that if there were no TSFs located directly over the mine void, the current decant volume would have decreased, and it is likely that the water pumped from the underground chambers would be of better quality than the current status. In addition, the pumping and treatment cost would be substantially less if the TSFs seepage portion could be eliminated.

Further to this, infiltration from the TSFs will be reduced if the tailings are removed from surface and the contaminant loads will be less from a pollution perspective. At present, the presence of the TSFs and the continued dewatering activities in the compartment will encourage continued infiltration of seepage to the deeper aquifer units, the consequent deterioration of water quality, increased decant rates and increased volumes of water to be pumped from the underground chambers.

In the short-term (during operation), the hydraulic reclamation could result in the partial seepage through the TSFs. The exposure of the tailings to oxygen and water can result in Acid Mine Drainage (AMD) during the reclamation process.

The long-term impact as a result of the reclamation operations at the TSFs is anticipated to be positive. The TSFs, which are a source of contamination, will be discharged into the pits, with the extra remaining to be deposited on a new TSF. The new TSF will not be lined and is expected to seep and contaminate the nearby aquifers and streams. The construction of interception drains around the TSF can reduce horizontal seepage in the topsoil/weathered aquifer but vertical seepage to the deep aquifer is expected to occur.

The reprocessed tailings is treated with lime in the metallurgical plant and is generally deposited at high pH values (around 10 – 11). This is expected to have a positive impact in the groundwater quality as the pH of the mine void will increase and precipitate the dissolved metals. The deposition of the slurry is, however, expect to increase the salt load which overall has a negative impact.

The impact as a result of the reclamation is anticipated to be positive after closure. This is due to the removal of the multiple TSFs, which are sources of contamination.

Mitigation Plans

The following mitigation plans will be implemented.

- After the pits are completely backfilled and rehabilitated, they will be shaped in a way that runoff is maximised and pooling of rainwater is minimised. This will reduce the seepage of water into the aquifers. This also applies to the new TSF.
- The new TSF should be constructed with interception drains along the perimeter of the TSF to capture shallow seepage.
- Ensuring that the deposited tailings into WWP is alkaline;
- In line with the Cyanide Code: Standard of Practice No. 4.4, ensure that WAD cyanide concentration of 50 mg/l WAD cyanide is not exceeded in any open TSF or pit water.
- Minimise area of disturbance to avoid AMD at multiple places.
- Monitoring of groundwater quality and water levels.
- Abstract equal volume of water from the Shafts (which is connected with the pits) to ensure that the water level or decant rate does not increase. Currently abstraction is expected to take place from Winze 17 or 8 East Shaft.
- The abstracted water can be used for the reclamation of the tailings or discharged to the environment after treatment.
- Monitoring of groundwater quality and water levels.
- Rehabilitation of old TSF footprints.
- Rehabilitation of the pits by properly shaping and capping with a soil/weathered material layer that will prevent ponding and minimise infiltration of rainwater.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ACRONYMS, ABBREVIATIONS AND DEFINITION

AMD	Acid mine drainage
BRI	Black Reef Incline
CMA	Catchment Management Agency
DMRE	Department of Mineral Resources and Energy
DWS	Department of Water and Sanitation
ECL	Environmental critical level
EIA	Environmental Impact Assessment
EMPr	Environmental Management Programme Report
MPRDA	Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002)
MR	Mining Right
MRA	Mining Rights Area
MTIS	Mineable tonnes in-situ
NEMA	National Environmental Management Act, 1998 (Act No. 107 of 1998)
PAR	Pan African Resources
PCD	Pollution Control Dam
SAWQG	South African Water Quality Guidelines
SWMP	Storm Water Management Plan
TSF	Tailings Storage Facility
WMA	Water Management Area
WUL	Water Use Licence
WWP	West Wits Pit

Legal Requirement		**Section in Report**
(1)	A specialist report prepared in terms of these Regulations must contain	
(a)	details of-	
	(i) the specialist who prepared the report; and	Section 1
	(ii) the expertise of that specialist to compile a specialist report including a curriculum vitae;	Section 1
(b)	a declaration that the specialist is independent in a form as may be specified by the competent authority;	Section 1

Legal Requirement		Section in Report
(c)	an indication of the scope of, and the purpose for which, the report was prepared;	Section 4
cA	And indication of the quality and age of the base data used for the specialist report;	Section 5
cB	A description of existing impacts on site, cumulative impacts of the proposed development and levels of acceptable change;	Section 6
(d)	The duration, date and season of the site investigation and the relevance of the season to the outcome of the assessment;	Section 4
(e)	a description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of the equipment and modelling used;	Section 4
(f)	Details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure inclusive of a site plan identifying site alternatives;	Section 6
(g)	an identification of any areas to be avoided, including buffers;	Section 5
(h)	a map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	Section 1
(i)	a description of any assumptions made and any uncertainties or gaps in knowledge;	Section 3
(j)	a description of the findings and potential implications of such findings on the impact of the proposed activity or activities;	Section 6
(k)	any mitigation measures for inclusion in the EMPr;	Section 8
(l)	any conditions/aspects for inclusion in the environmental authorisation;	Section 3
(m)	any monitoring requirements for inclusion in the EMPr or environmental authorisation;	Section 9
(n)	a reasoned opinion (Environmental Impact Statement) -	Section 12
	whether the proposed activity, activities or portions thereof should be authorised; and	Section 12
	if the opinion is that the proposed activity, activities or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan;	Section 8
(o)	a description of any consultation process that was undertaken during the course of preparing the specialist report;	Section 10

Legal Requirement		Section in Report
(p)	a summary and copies of any comments received during any consultation process and where applicable all responses thereto; and	Section 10
(q)	any other information requested by the competent authority.	Section 3

1. Introduction

Digby Wells Environmental (hereafter Digby Wells) has been appointed to undertake an Environmental Application Process and associated specialist studies for the Mogale Cluster - Mining Right (GP) 30/5/1/2/2 (206) Mining Right (MR) and, more specifically for the proposed construction of a large-scale gold tailings retreatment operation. Pan African Resources PLC (PAR) has entered into a Sale and Purchase Agreement for the acquisition of the shares in and claims against Mogale Gold (Pty) Ltd (Mogale Gold). The agreement was entered into between PAR and the liquidators of Mintails Mining SA (Pty) Ltd (in liquidation) (MMSA). MMSA is the holding company of Mogale Gold. The intended transaction is subject to a due diligence investigation which is in the process of being concluded.

Mogale Gold owns the right to extract and process gold from tailings recourses by reprocessing old gold mine slimes dams and sandy mine dumps left by the extensive historic mining activities that have taken place in the area since 1888. PAR is only interested in the surface operations associated with Mining Right (MR) 206 (i.e., Tailings Storage Facilities (TSFs) for reclamation, processing and deposition), and therefore the focus of this application process.

The project consists of 120 Mt of tailings to be reprocessed and firstly deposited into the West Wits Pit (current authorisation in place for in-pit deposition) and then undertake deposition of the footprint of 1L23-1L25 footprint (New Tailings Facility) once capacity has been reached within the West Wits Pit. Eventually there will be two TSFs: one at the current WWP and the other at the current 1L23-1L25 TSF.

Alternatives are being considered for potential deposition of tailings material into the other pits associated with Mintails, such as Monarch and Emerald Pits.

It must be noted that once the West Wits Pits reaches capacity the surface deposition will extend in a northern direction from the pit onto surface, expanding the deposition footprint associated with West Wits Pit.

There are six dumps being considered to be reprocessed, the largest of which amounts to 57.9 Mt, while the smallest contains 0.57 Mt. The primary location of processed tailings storage has been earmarked for deposition in the West Wits Pit. There are three smaller dumps which could also be included and reprocessed as part of the project namely 1L4, 1L5 and 1L6.

1.1. Project Description

PAR plan to undertake activities relating to reclamation associated with gold-bearing Tailings Storage Facility (TSFs) through hydraulic reclamation. Digby Wells were appointed as the Independent Environmental Consultant to undertake the EIA Application process which comprises of an Air Emission Licence (AEL) and Water Use Licence (WUL) for the proposed gold-bearing tailings storage facility (TSFs).

The site is located in the West Rand, in Gauteng Province. The site comprises of existing infrastructure such as sand dumps, Lancaster Dam and an open pit that will be used for the deposition of tailings materials. A process plant, overland pumping and piping inclusive of associated water management infrastructure will form part of the proposed infrastructure that will require an authorisation. Once the open pit is filled to capacity, a new TSF will potentially be constructed on the footprint area of one of the reclaimed TSF sites (1L23-1L25) (Figure 1-1). The footprint of the area is 2,923.3 ha which considers MR 206 and associated infrastructure.

Ancillary infrastructure such as pipelines, powerlines and pumps will be required for the proposed reclamation activities and will be included in support of the Environmental Application Process, which will be undertaken.

1.2. Project Locality

The Mining Right Area of the Mintails Mogale Cluster includes: Gl, G2 plant; Cams North Sand; South Sand; 1L23-1L25; 1L28; 1L13; 1L8; 1Ll0; West Wits Pit (WWP) and Lancaster Dam. An existing Water Use License (WUL) No. 27/2/2/C423/1/1 was issued on 22 November 2013 to Mintails Mining SA (Pty) Ltd: Mogale Gold. The mining right is located on Portions 66 and 99 of the farm Waterval 174 IQ and portions 136 and 209 of the farm Luipaardsvlei 246 IQ.

The project is within the Mogale City Local Municipality (MCLM), which is located within the West Rand District Municipality (WRDM). MCLM is the regional services authority, and the area falls under the jurisdiction of the Krugersdorp Magisterial District.

The site is mostly located in the catchment of the Upper Wonderfonteinspruit, quaternary catchment C23D, which forms part of the Vaal River Water Management Area (WMA) within the Vaal Catchment Management Agency (CMA). The project is about 4 km south of Krugersdorp and north-east of Randfontein, approximately 10 km off the N14 National Road in the Gauteng Province, in an area that has been transformed by past gold mining activities.

The West Wits Pit is in the A21D quaternary catchments of the Limpopo WMA. The catchment is drained by the Tweelopiespruit and flows in a northerly direction to form the Rietspruit, which eventually joins the Crocodile River that drains into the Hartbeespoort dam.

The project locality of the site is illustrated in Figure 1-1.

Table 1-1: Summary of the PAR Project Location Details

Province	Gauteng
District Municipality	West Rand District Municipality
Local Municipality	Mogale Local Municipality
Nearest Town	Krugersdorp (4 km), Randfontein (4 km)
GPS Co-ordinates (relative centre point of study area)	26°07'45.54"S
	27°45'40.85"E

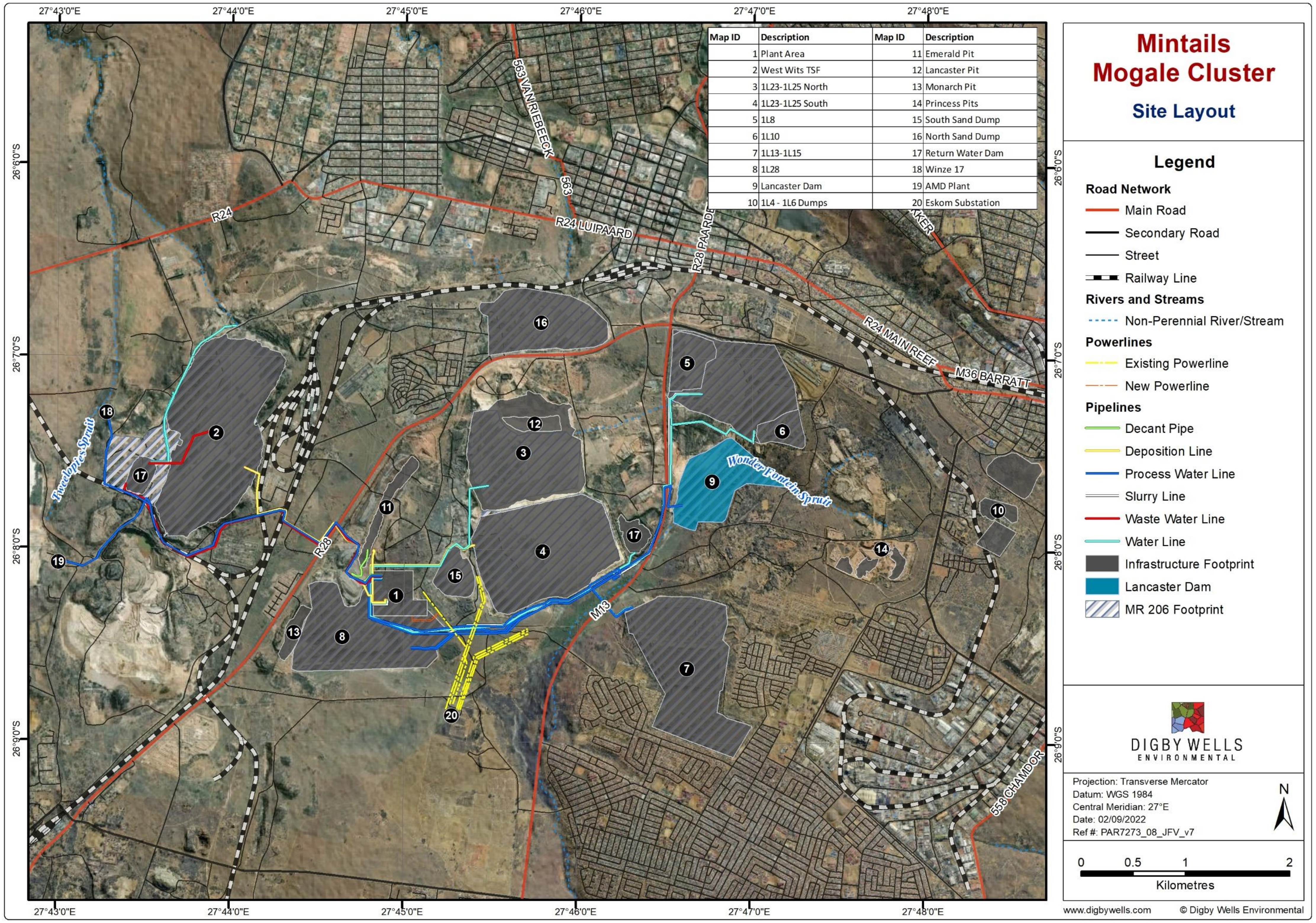


Figure 1-1: Site layout map

1.3. Proposed Infrastructure and Activities

The proposed activities of the Project per phase are provided in Table 1-2 below.

Table 1-2: Project Phases and Associated Activities

Project Phase	Associated Activities
Construction Phase	Site clearing for the construction of the new processing plant facility and ancillary infrastructure such as pipelines, pump stations, electrical supply etc.
	Construction of the new processing plant and ancillary infrastructure such as pipelines, pump stations, electrical supply etc.
	Employment and procurement for construction related activities.
Operational Phase	Hydraulic reclamation of the associated historic tailings facilities and sand dumps
	Operation of pump stations during the operational phase.
	Maintenance of pipeline routes during the operational activities.
	Infilling of processed tailings material into the West Pits Pit and other potential pits.
	Surface tailings deposition within the West Wits Pit.
	Tailings deposition onto the historic footprint of 1L23-1L25.
	Production of Gold.
	Progressive rehabilitation of the new tailings facility footprints (West Pits TSF and 1L23-1L25 TSF.
	Employment and procurement for operational related activities.
Decommissioning Phase	Removal, decommissioning and rehabilitation of surface infrastructure such as pipelines, powerlines, pumps etc. footprints.
	Removal, decommissioning and rehabilitation of the processing plant footprint.
	Rehabilitation of the old TSF footprints.
	Rehabilitation of the old Mintails Processing Plant footprint.
	Final rehabilitation of this facility.
	General rehabilitation of the surrounding area, including wetland rehabilitation.

1.4. Topography and Drainage

The study area falls into two quaternary catchments; more than three-fourth of the area is within C23D and the rest is within A21D. West Wits pit is located in the A21D quaternary catchments of the Limpopo water management area (WMA), while all the TSFs are located within C23D catchment of the Vaal WMA. The topography and drainage of the area is shown in Figure 1-3.

The topography is generally rolling to gently sloping with relatively flat stretches in some places. Elevation in topography varies between approximately 1,600 m in the south to 1800 m above mean sea level (amsl) in the central part of the study area where the two catchments meet (A21D and C23D).

The A21D catchment is drained by two tributaries situated east and west (Tweelopiespruit) and flows in a northerly direction to form the Rietspruit, which eventually joins the Crocodile River that drains into the Hartbeespoort dam. The West Wits pit falls in the A21D catchment.

The C23D catchment is drained by the Wonderfonteinspruit which flows in to the south. Most of the mining right area, including all the TSFs and open pits relevant to this study fall in the C23D catchment (Figure 1-3). The Wonderfonteinspruit is a tributary of the Mooi River, which flows into the Vaal River.

1.5. Rainfall and Evaporation

The study area is situated along the south-western perimeter of the Gauteng province, on the interior elevated plateau of South Africa, known as the "Highveld". The area is known for its cold, dry frosty winter and moderate summer temperatures (Digby Wells, 2012).

Summer rainfall predominates with associated thunderstorms and occasional hail. The Mean Annual Precipitation (MAP) is approximately 664 mm (for C23D) and 713 mm (for A21D). The Mean Annual Evaporation (MAE) for the C23D and A21D quaternary catchment is between 1,600 and 1,700 mm. Since majority of the study area is within the C23D catchment, groundwater recharge calculations are conducted taking the rainfall in this catchment into consideration.

The average monthly rainfall and evaporation for C23D catchment is indicated in Figure 1-2 and listed in Table 1-3. The monthly evaporation exceeds the rainfall in all months.

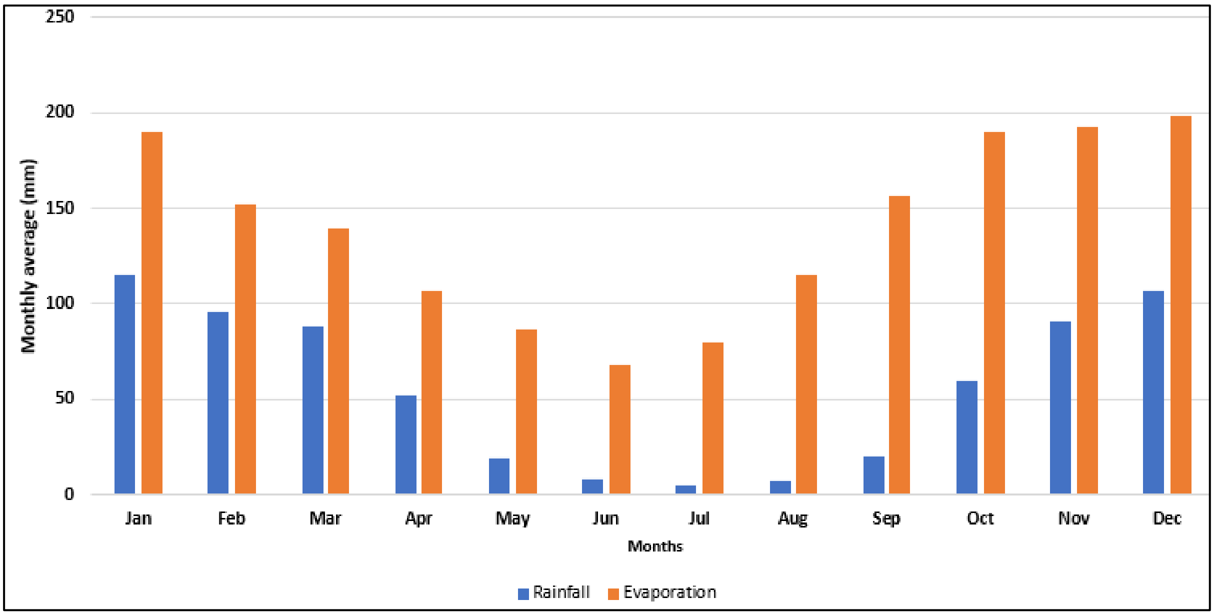


Figure 1-2: Monthly rainfall and evaporation of the site

Table 1-3: Mean monthly rainfall and evaporation

Month	Rainfall (mm)	Potential Evaporation (mm)
Jan	114.96	190
Feb	95.93	152
Mar	88.53	139
Apr	51.94	106
May	18.97	87
Jun	8.26	68
Jul	4.95	80
Aug	7.49	115
Sep	19.68	156
Oct	59.51	190
Nov	90.34	193
Dec	107.05	199
Average annual	**664**	**1675**

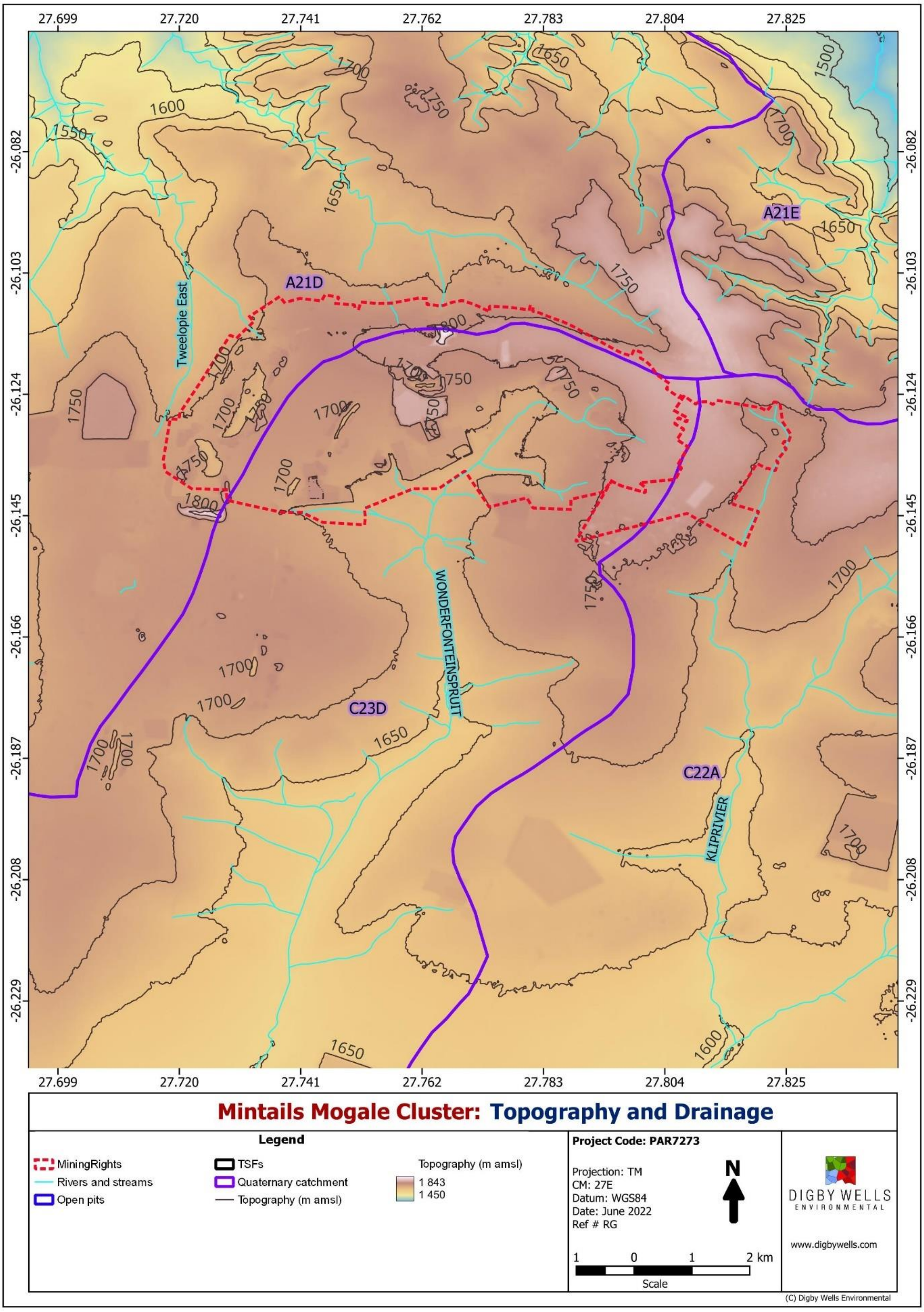


Figure 1-3: Site Hydrological Setting

2. Relevant Legislation, Standards and Guidelines

The Project is required to comply with all the obligations in terms of the provisions of the National legislations, regulations, guidelines and by-laws. The guidelines directing the Hydrogeological Impact Assessment are detailed in Table 2-1.

Table 2-1: Applicable Legislation, Regulations, Guidelines and By-Laws

Legislation, Regulation, Guideline or By-Law	Applicability
DWS[1] Best Practice Guideline – G1: Storm Water Management Plan (SWMP) These are guidelines provided by the DWS for the development of a SWMP. The following will be undertaken to develop the conceptual SWMP: • Delineate the clean and dirty area contributing to runoff (based on the final layout plans) and site-specific hydrological assessments to determine volumes that require to be handled. The SWMP should ensure that temporary drainage installations should be designed, constructed, and maintained for recurrence periods of at least a 25-year, 24-hour event, while permanent drainage installations should be designed for a 50-year, 24-hour recurrence period; and • Site specific assessments to establish the appropriate mitigation measures and surface water monitoring programme.	Uncontrolled stormwater is currently flowing into the old pits which are connected with the underground workings. This enhances the flooding of the mine void, which increases the decant rate at the Black Reef Incline (BRI). Currently DWS and TCTA are pumping and treating the acid mine drainage (AMD) from 9 shaft. If uncontrolled stormwater infiltrates to the mine void, the treatment volume (and cost) will increase. Management of stormwater is required not only to control ingress at open pits, but also to minimise infiltration through the unlined Tailings Storage Facilities (TSFs).
DWS Best Practice Guideline – G4: Impact Prediction The impacts of mine activities on the groundwater environment must be assessed as part of the MRA, as well as for the IWULA. The baseline conditions must be assessed to define the current aquifer systems, groundwater use and groundwater conditions before mine commencement and to determine the extent of possible future impacts on the groundwater resources.	The old TSFs are impacting the aquifer system underneath. The TSFs are not lined, and their leachate chemistry is acidic with high TDS and dissolved metals. An impact prediction is required by characterising the source-pathway-receptor dynamics of the aquifer system. Proper mitigation measures can only be implemented if the potential impacts are predicted.

1 Previously the Department of Water Affairs (DWA)

3. Assumptions, Limitations and Exclusions

Numerical models are commonly used to simulate and develop hydrogeological management solutions, i.e., the prediction of contaminant plume migration and groundwater level changes over time. However, groundwater systems are often complex, and the data input requirements are beyond human capability to evaluate in detail. A model, no matter how sophisticated, will never describe the investigated groundwater system without deviation of model simulations from the actual physical process.

Therefore, it is necessary to make several assumptions to simplify the complex, real world hydrogeological conditions into a simplified, manageable model. These assumptions, which reflect data gaps in the conceptual model regarding the aquifer distribution and the aquifer parameters, can result in areas of uncertainty in the model output and predictions.

The following assumptions and limitations are applicable:

- Groundwater quality in the West Wits pit area is based on monitoring conducted pre-2017 and may not be representative of the current water quality. With the ongoing treatment activities at 9 Shaft, the groundwater quality could have improved in the recent years. No TCTA monitoring data and water management plans were available during this study to confirm this.
- Within the project area, there is a track record of monitoring data at many boreholes and shafts up until 2017 (and 2018 in some boreholes). However, no monitoring data is available at any borehole since then. This is a limitation to inform how the groundwater quality has changed (if any) since 2017.
- There is no historical monitoring data in the northern section of the project area, including around the North Sand, TSFs IL8, IL10, IL4-6. Interpolation with a scientific guess has been made to predict the current contamination plume in this area.
- Based on the geochemical studies done by Digby Wells (2022), the sulphate concentration of the reprocessed IL13-IL15 is found to be approximately 2500 mg/L. However, there is no leachate quality for the other TSFs after they are reprocessed. During this study, they are assumed to leach at sulphate concentration of 2500 mg/L.
- This groundwater model is developed in support of the planned reclamation of the TSFs which are sitting on ground surface. The model has been set up to simulate the potential impact (positive or negative) of the reclamation of the TSFs on the weathered (30 m depth) and fractured aquifer (up to 70 m depth). All available aquifer characterisation and monitoring boreholes in the project area were drilled to this depth. The numerical model does not simulate the deep underground mine workings as available mine void maps are limited and the exact extent of the underground workings is unknown. However, the model extent can be increased to incorporate the underground workings if needed in the future. DWS (2013) reported that the underground mines were historically operated to depths of 1 to 3 km. Available underground mine plans should be incorporated if the mine voids are to be modelled

since the hydraulic property of the deep aquifer is highly altered by the underground workings.

- There were several shafts and inclines within the project area that are currently buried or destroyed. Some of them include Flora Shaft, NE Shaft and Rand Shaft but their exact location and their hydraulic interconnections with the known shafts (BRI, 8 and 9 shafts, 17 and 18 Winzes) is unknown.
- There is no monitoring data to confirm if the defunct Turk shaft located within the project site is still recovering or has reached a steady state. The connectivity of the shaft with the 9 shaft is also not fully confirmed. If it is connected, there is no risk of decant occurring at Turk shaft in the future.
- Reclaimed tailings will initially be disposed of to WWP. However, the extent of the connectivity of the West Wits Pit with the underground mine void is not fully known. It is not easy to calculate how much tailings the pit will take as historical mine void volumetric calculations are hard to come by. As observed at the nearby Sibanye mine, the Millsite Pit is taking more tailings than initially thought due to the previously unknown extent of connectivity with the mine voids.
- The Life of Mine is understood to be 14 years. The reclamation sequence is given in Table 3-1 and has been incorporated into the numerical model.

Table 3-1: Assumed TSF reclamation sequence

<table>
<tr><th>Year 1</th><th>Year 2</th><th>Year 3</th><th>Year 4</th><th>Year 5</th><th>Year 6</th><th>Year 7</th><th>Year 8</th><th>Year 9</th><th>Year 10</th><th>Year 11</th><th>Year 12</th><th>Year 13</th><th>Year 14</th></tr>
<tr><td colspan="8">IL23-IL25</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td colspan="6">North Sand</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="4">South</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="5">IL13-IL15</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="3">IL28</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">IL8 and IL10</td></tr>
</table>

4. Methodology

This study has assessed the potential groundwater impacts (negative or positive) as a result of the proposed reclamation and deposition into the West Pits as well as on the new proposed TSF. The hydrogeological activities conducted include:

4.1. Desktop Study

Several reports and monitoring data were reviewed for aquifer characterisation and conceptual model development. Reference has been made to each of the reviewed reports whenever applicable.

4.2. Hydrocensus

A hydrocensus was conducted in May and October 2021 to assess the baseline groundwater conditions and the current monitoring network. A total of 24 groundwater monitoring points were identified, of which 4 were shafts and 20 were boreholes. The positions of these points are shown in Figure 4-1.

The shafts include:

- 9 Shaft from which TCTA and DWS are pumping and treating AMD from the mine void to avoid decant from occurring at the BRI incline, 17 Winze or 18 Winze.
- 8 Shaft from which Sibanye-Stillwater is pumping for the hydraulic reclamation of old TSFs.
- 17 and 18 Winzes. They are currently not in use.

The 20 boreholes are consisted of Mintails monitoring boreholes, and other old boreholes with no background record. Water samples were collected from 11 representative boreholes for baseline groundwater quality in the shallow and fractured aquifer. The positions of the sampled boreholes are shown in Figure 4-1.

In addition, 9 shaft was also sampled for mine void water quality study. DWS (2013) indicate that the mine voids in the West Rand are interconnected, hence the water quality of 9 shaft will be indicative of the qualities of the other nearby shafts. The interconnection of the shafts is also confirmed during this study due to the similarity of their water qualities (more on this in Section 5).

4.3. Geophysical Resistivity Survey

Geophysical resistivity survey was conducted in October 2021. The survey was carried out along a total of 22 km to delineate geological structures and contamination plumes that are released from the historical TSFs. The Schlumberger configuration was used to read resistivity profiles at every 10 m intervals.

The survey lines were conducted along the TSFs footprint areas and other sources of contamination such as the Lancaster Dam. The position of the survey lines is displayed in Figure 4-2 and the survey results are given in Appendix B.

The resistivity surveys were then used to site monitoring boreholes along geological structures that are preferential pathways.

As it can be seen in Figure 4-2, Line 1 and 2 are not connected on the south-eastern corner of the IL23-IL25 TSF. The area was inaccessible due to a deep wetland and thick bush. Line 18 was surveyed further away from the wetland to fill the un-surveyed gap between Line 1 and 2.

4.4. Borehole Drilling

Following the geophysical surveys and review of available boreholes on site, 7 percussion boreholes were drilled for aquifer characterisation and to fill the monitoring gaps. The boreholes were also pump tested for rock permeability calculations.

The position of the newly drilled boreholes as well has those discovered during the hydrocensus are shown in Figure 4-1 and listed in Table 4-2.

The drilling programme was carried out between 11 and 21 February 2022 and was supervised by Digby Wells. Drilling was performed using the rotary air percussion method with a diameter of 165 millimetre (mm). Perforated uPVC casings with diameter of 114 mm were inserted to support the boreholes from collapsing. A drilling summary of each borehole is given in Table 4-2.

The borehole logs, including the construction details and hydrogeological information obtained during drilling is provided in Appendix D.

- The boreholes were drilled between 20 and 60 m to monitor the shallow and fractured aquifers.
- Boreholes with names ending in “S” means that they are shallow, while those ending with “D” are deep.
- The blow yields are as follows:
  - Borehole TSFBH1S has the highest yield at 2 L/s.
  - Boreholes BH68D and LPVBH1D yielded 0.8 L/s
  - Borehole NSBH1D yielded 0.3 L/s
  - Boreholes BH68S and LPVBH1S yielded <0.1 L/s.
  - Borehole NSBH1S was dry. However, water is expected to seep in the long-run and the borehole should be sufficient for monitoring.
  - The borehole yields are low, typical of the hydrogeology of the study area. However, the yields are relatively higher than the 5 boreholes drilled by Golder (2016), whereby 3 were dry and two yielded <0.1 L/s. The dry boreholes were MGP9, MGP10, MGP11 and those with <0.1 L/s yield were MGP7 and MGP12.

4.5. Aquifer Testing

Six of the seven newly drilled boreholes were aquifer tested to calculate the hydraulic permeability and storativity values presenting the aquifer hydrodynamics underlying the investigation areas. Borehole NSBH1S was, however, dry and was not tested.

Aquifer testing was conducted as per the record listed in Table 4-1. A complete list of the testing data is given in Appendix E.

In addition to this, the aquifer test data collected by Golder (2016) were also utilised for the aquifer characterisation.

Table 4-1: Aquifer test decision record of the tested boreholes

Borehole ID	Water level (m)	Water strike (m)	Yield of Water Strike (L/s)	Final blow yield (L/s)	Slug test	Step drawdown test	Constant discharge test
BH68S	2.42	18	seepage	seepage	X		
BH68D	2.58	23	0.8	0.8		X	X
LPVBH1S	11.76	13	seepage	seepage			
LPVBH1D	10.57	28	0.8	0.8	X	X	X
TSFBH1S	0.25	22	2	2		X	X
NSBH1S	Dry	none	dry	dry			
NSBH1D	43.96	48	0.3	0.3	X	X	X

4.6. Numerical Modelling

A numerical model was developed to simulate the fate of the contamination plumes following the reclamation of the different TSFs and re-deposition them into the centralised one.

The internationally recognised simulation package Modflow 6 (USGS, 2022) was used to simulate groundwater flow. MODFLOW is a modular three-dimensional finite-difference groundwater model published by the U.S. Geological Survey. ModelMuse was used as interface for pre and post processing interface. ModelMuse is also developed by USGS.

The flow module MODFLOW 6 was used to estimate the groundwater flow rate and flow direction.

The potential contaminant plumes originating from the TSFs are simulated using the transport module MT3D-USGS. MT3D is a modular three-dimensional transport model for the simulation of advection, dispersion, and chemical reactions of dissolved constituents (such as sulphate) in groundwater systems. MT3D was used in conjunction with MODFLOW 6 in a phased flow and transport simulation approach.

4.7. Impact Assessment Rating

Impact identification was performed by using an Input-Output model which serves to guide Digby Wells in assessing all the potential instances of ecological and socio-economic change, pollution and resource consumption that may be associated with the mining operations.

Details of the impact rating methodology is discussed in Appendix A.

Table 4-2: Summary of the newly drilled boreholes

	Borehole ID	BH68S	BH68D	LPVBH1S	LPVBH1D	TSFBH1S	NSBH1S	NSBH1D
Borehole Location	**X**	27.7607	27.7604	27.78245	27.78259	27.771121	27.76526	27.76527
	Y	-26.1457	-26.1456	-26.1235	-26.1236	-26.1376	-26.1095	-26.1095
	Z (masl)	1677	1677	1704	1704	1684	1715	1715
Aquifer data	**Borehole Depth (m)**	20	60	20	60	30	30	60
	Water Strike depth (m)	7, 18	23	13	28	22	none	48
	Final Blow Yield (L/s)	seepage	0.8	seepage	0.8	2	Dry	0.3
	Major water strike (m)	18	23	13	28	22	none	48
	Blow Yield (L/s)	seepage	0.8	seepage	0.8	2	dry	0.3
	Static Water Level (m bgl)	2.42	2.58	11.76	10.57	0.25	Dry	43.96
Borehole Construction Data	**Solid Steel casing (Diameter - ID mm)**	171	171	171	171	171	171	171
	Depth from, to (m)	3	3	3	3	3	3	3
	Solid UPVC casing (diameter -ID mm	114	114	114	114	114	114	114
	Depth from, to (m)	0-6	0-30	0-6	0-30	0-6	0-6	0-30
	Perforated Casing (Diameter - ID mm)	114	114	114	114	114	114	114
	Depth from, to (m)	6--20	6--60	6--20	6--60	6--30	6--30	6--60
	Date Drilled	11.02.22	15.02.22	16.02.22	17.02.22	21.02.22	18.02.22	17.02.22

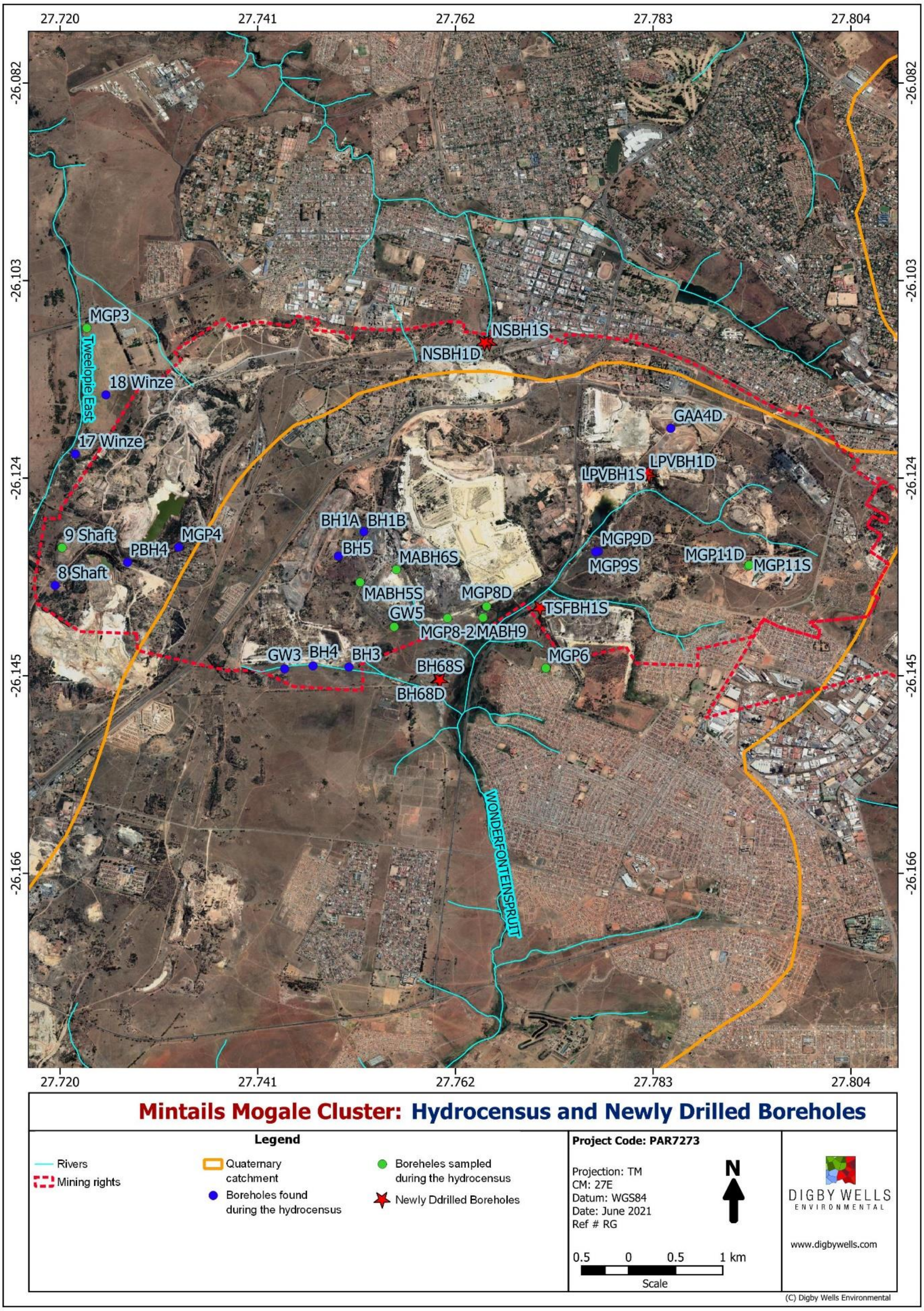


Figure 4-1: Hydrocensus and newly drilled boreholes

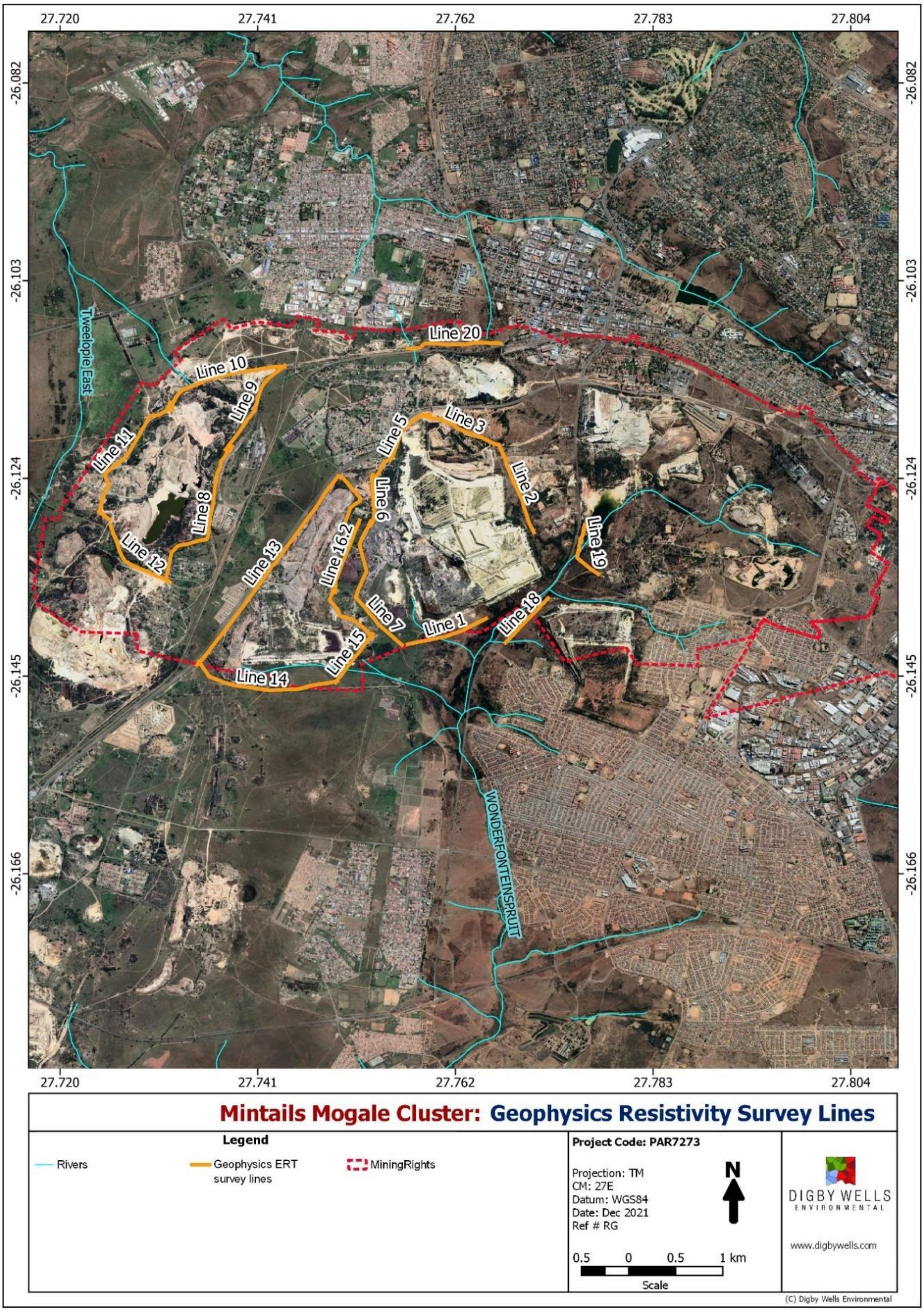


Figure 4-2: Positions of the geophysical resistivity survey lines

5. Hydrogeological Baseline Conditions

5.1. Geology

The geological information presented below is summarised from Truswell (1977), Digby Wells (2012), and Rison (2008), DWS (2012) and Hobbs et al. (2007).

A regional geological map of the project site is given in Figure 5-1 and the stratigraphic sequence is listed in Table 5-1. In chronological order (oldest first) the site geology is composed of:

- Witwatersrand Supergroup;
- Ventersdorp Supergroup;
- Transvaal Supergroup; and
- Karoo Supergroup.

Table 5-1: Simplified lithological sequence in the study area

Lithology	Lithostratigraphic Unit			Approximate age
Alluvium	Quaternary sediments			Late Cenozoic (<10 000 yrs)
Dolerite	post-Karoo dyke / sill intrusive structures			Early Mesozoic (150 - 190 Ma)
Tillite	Dwyka Formation		Karoo Supergroup	345 Ma
Ferruginous shale & quartzite, hornfels	Timeball Hill Formation			
Quartzite, shale, chert, breccia	Rooihoogte Formation	Pretoria Group		
Dolomite	Malmani Formation	Chuniespoort Group		2 225 Ma to 2 430 Ma
Quartzite, conglomerate, shale	Black reef formation		Transvaal Supergroup	2 650 Ma
Andesitic lava, pyroclastics	Westonaria formation	Klipriversberg Group	Ventersdorp Supergroup	2 700 Ma
Quartzite, conglomerate, shale	Turfontein subgroup			2 750 Ma
Quartzite, conglomerate	Johannesburg subgroup	Central Rand Group		
Shale, quartzite	Jeppestown subgroup			
Quartzite, greywacke	Government subgroup			
Ferruginous shale, quartzite	Hospital Hill subgroup	West Rand Group	Witwatersrand Supergroup	3 000 Ma

5.1.1. Witwatersrand Supergroup

The Witwatersrand Basin is a thick sequence of shale, quartzite and conglomerate. The average dip of the strata varies between 10º and 30° south, although localised dips of up to 80° have been encountered in mine workings closer to the reef outcrop. There are two main divisions, a lower predominantly argillaceous unit, known as the West Rand Group and an upper unit, composed almost entirely of quartzite and conglomerates, known as the Central Rand Group. The West Rand Group is divided into three subgroups namely the Hospital Hill, Government Reef and Jeppestown. These rocks comprise mainly shale, but quartzite, banded ironstones, tillite and intercalated lava flows are also present. The rocks were subjected to low - grade metamorphism causing the shale to become more indurated and slaty. The original sandstone was recrystallised to quartzite.

5.1.2. Ventersdorp Supergroup

The younger Ventersdorp Supergroup overlies the Witwatersrand rocks. Although acid lavas and sedimentary intercalations occur, the Ventersdorp is composed largely of andesitic lavas and related pyroclastics. The Ventersdorp Supergroup consists of the Platberg Group and the Klipriviersberg Group.

The Alberton Formation is composed of green – grey amygdaloidal andesitic lavas, agglomerates and tuffs. The thickness amounts to 1 500 m. The lack of sediments in this sequence indicates a rapid succession of lava flows, which probably came from fissure eruptions. Material of similar composition forms the oldest dykes that have intruded the Witwatersrand rocks. The abundant agglomerates provide indications of periodic explosive activity. The removal of huge volumes of volcanic material from an underlying magma chamber gave rise to tensional conditions and as a result a number of faulted structures, horst and grabens, were formed.

5.1.3. Transvaal Supergroup

Overlying the Ventersdorp Lavas are the Black Reef Quartzite and dolomites of the Transvaal Supergroup. The Black Reef quartzite comprises coarse to gritty quartzite with occasional economically exploitable conglomerates (reefs). The entire area was peneplained in post-Ventersdorp time and it was on this surface that the Transvaal Supergroup was deposited, some 2 400 million years ago. The deposition commenced with the Kromdraai Member with the Black Reef at its base. The Black Reef is formed from material that has been eroded from the Witwatersrand outcrop areas. As a result, the Black Reef contains zones (reefs) in which gold is present. The occurrence of the gold is not as widespread as in the Witwatersrand and is mainly restricted to north-south trending channels. The Black Reef is overlain by a dark, siliceous quartzite with occasional grits or small pebble bands. The quartzite grades into black carbonaceous shale. The shale then grades into the overlying dolomite through a transition zone approximately 10 m thick.

Overlying the Kromdraai Member is the dolomite of the Malmani Subgroup of the Chuniespoort Group. The dolomites that are 1 500 m thick are known for their huge water storage potential.

The dolomite also contains lenses and layers of chert. The dense, hard and fine-grained chert tends to stand out in relief. Chert (silica) replaces carbonate material.

The dolomites are overlain in the south by the Pretoria Group rocks. The Rooihoogte Formation forms the basal member of the Pretoria Group, consisting predominantly of shale and quartzite.

5.1.4. Karoo Supergroup

The Karoo Supergroup was deposited approximately 345 million years ago. It commenced with glacial period during which most of South Africa was covered by a thick sheet of ice. This ice cap slowly moved towards the south, causing extensive erosion of the underlying rocks. The erosion debris was eventually deposited as the Dwyka tillite. The latter is only partially preserved in the study area, as are the younger sedimentary deposits of the Karoo Supergroup comprising mudstone, shale and sandstone.

5.1.5. Structural Geology

The development and preservation of the Witwatersrand Basin is structurally controlled. The main structures detected in the project site are illustrated in Figure 5-2.

The structural patterns control the regional flow of groundwater. It is important to understand which structural features act as conduits and which act as groundwater flow barriers. Dykes and sills of at least four different ages have intruded the Witwatersrand strata. The intrusion of the dykes has often taken place along fault planes. The oldest dykes are usually diabase, representing feeder dykes to the overlying Ventersdorp lavas. The second are intrusions of pyroxenite, gabbro and dolerite probably of Bushveld age. A third group belongs to the basic or alkaline dyke swarm related to the Pilansberg alkaline complex. Finally, the youngest intrusions are of Karoo dolerite.

The following significant features are noteworthy:

- *The Witpoortjie Horst.* This feature is an uplifted block of ground (horst) where the younger and gold-bearing Central Rand strata has been eroded. What remained is an unmined block that effectively separates the West Rand Mining Basin (that includes the old Randfontein section) just north of the Cooke TSF as shown in Figure 5-2 from the more southerly and westerly workings. As shown in the figure, the horst is bounded by the Witpoortjie Fault in the north and Roodepoort Fault in the south.
- *The West Rand Fault.* The West Rand fault is a prominent north – south striking feature on which the Millsite TSF is resting. Previous investigations (Krantz, 1999) indicated that this fault is in a state of compression and can be regarded as a groundwater barrier.
- *The Rietfontein Fault.* This fault is an east-west trending fault located just to the north of the West Wits Pit. This fault is still active and is believed to be responsible for structural damage at the Percy Stewart water treatment facility that is located in Krugersdorp West (Rison, 2008). This fault is a potential water-bearing conduit.

- *Compartmentalisation of the Sterkfontein Dolomite.* A study undertaken by Bredenkamp et al. (1986) included geophysical investigations such as gravity, ground magnetic, electromagnetic and resistivity surveys. Based on these investigations the Sterkfontein Dolomites were divided into various groundwater compartments and sub-compartments (Figure 5-2).
- *Compartmentalisation of the Southern Dolomite.* Similar investigations to that mentioned above were undertaken by mining companies to delineate compartments within these dolomite formations. Several of the southern dolomitic compartments have been dewatered by mining, showing their hydrogeological independence. The various compartments in the southern dolomite are shown in (Figure 5-2).

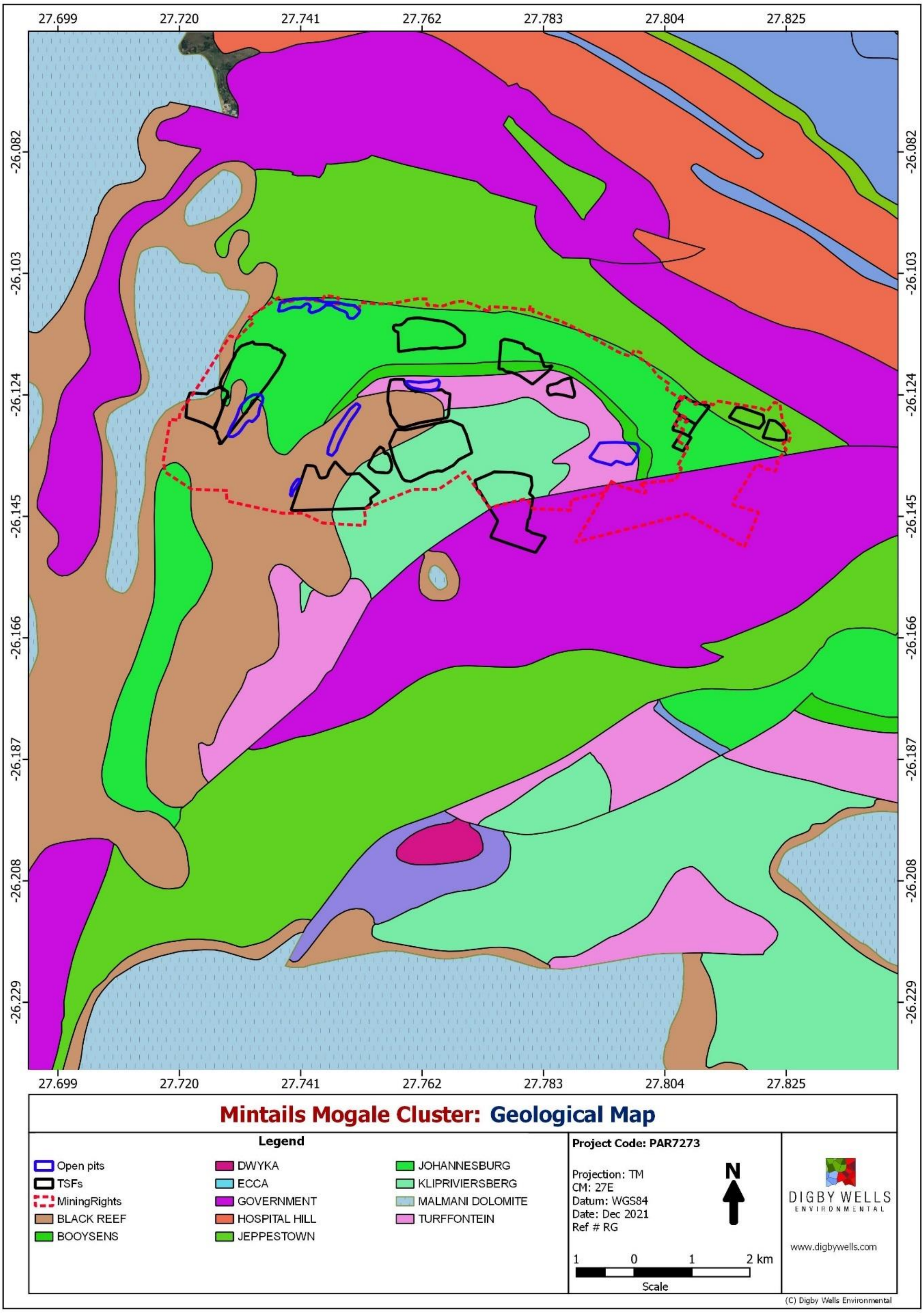


Figure 5-1: Geological Map

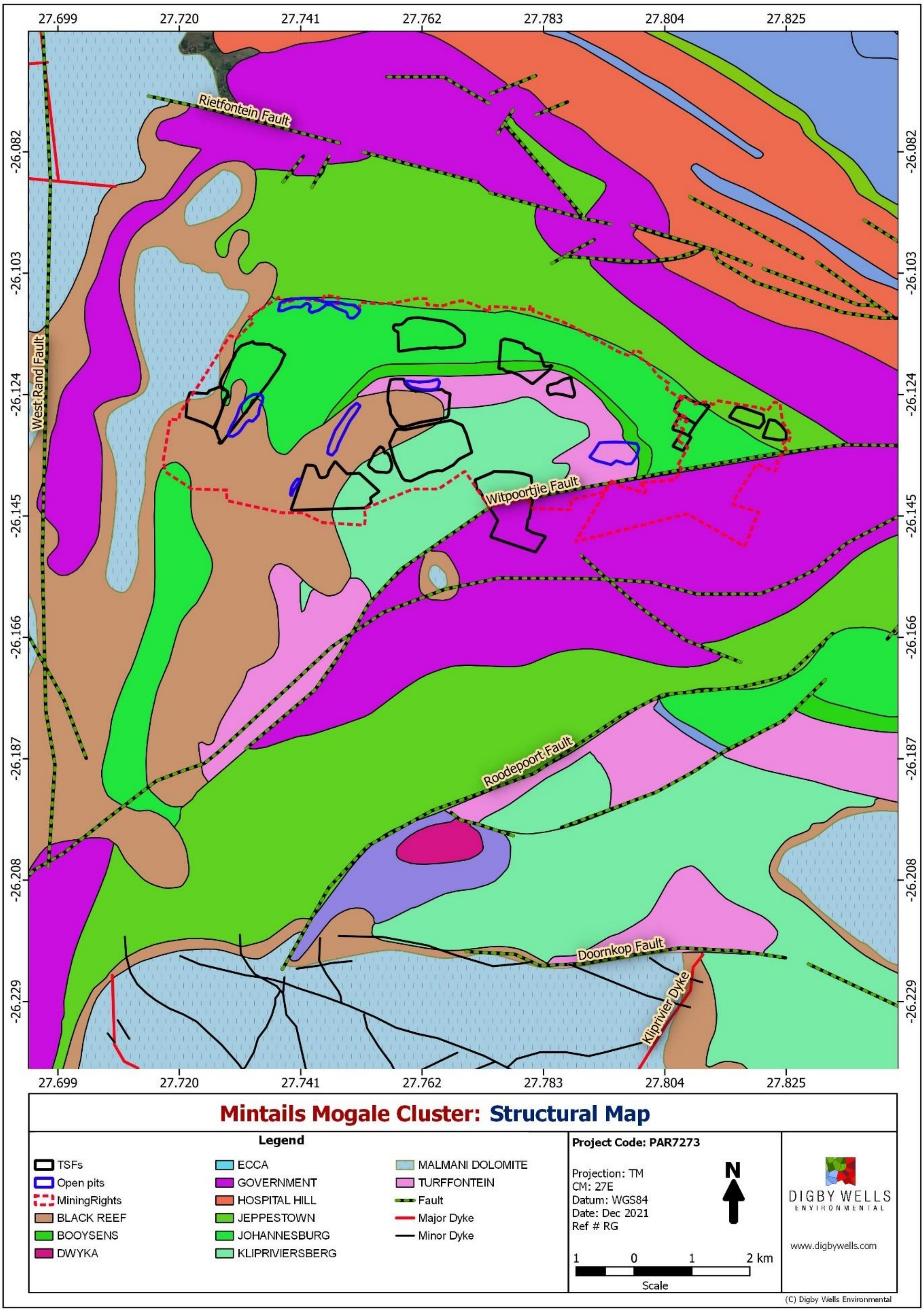


Figure 5-2: Structural Geology

5.2. Aquifer Layers

Groundwater occurrences in the study area are predominantly restricted to the following aquifers.

- Weathered rock aquifer in the Witwatersrand, Ventersdorp and Transvaal Formations;
- Fractured rock aquifer in the Witwatersrand, Ventersdorp and Transvaal Formations;
- Dolomitic and Karst Aquifers; and
- Mine void aquifer.

Figure 5-3 shows the conceptual hydrogeological model for the Western Basin in a cross-section from north-west to south-east. The relation between the four aquifer layers and the mine voids are displayed in the figure. A more detailed description of the aquifer layers is discussed below.

5.2.1. Weathered and Fractured Aquifers

Groundwater occurs in the weathered sedimentary deposits (quartzite and shale) of the Witwatersrand and Transvaal strata as well as in the lavas of the Ventersdorp Supergroup. Both rock types (sedimentary and igneous) have similar weathering characteristics and therefore aquifer characteristics. These formations are not considered to contain economic and sustainable aquifers, but localised high yielding boreholes may, however, exist where significant fractures are intersected.

Groundwater occurrences are mainly restricted to the weathered formations, although fracturing in the underlying fresh bedrock may also contain water. Experience has shown that these open fractures seldom occur deeper than 60 m. The base of the aquifer is the impermeable quartzite, shale and lava formations, whereas the top of the aquifer would be the surface topography. The groundwater table is affected by seasonal and atmospheric variations and generally mimics the topography.

These aquifers are classified as semi-confined. The two aquifers (weathered and fractured) are mostly hydraulically connected but confining layers such as clay and shale often separates the two. In the latter instance the fractured aquifer is classified as confined. The aquifer parameters, which includes transmissivity and storativity is generally low and groundwater movement through this aquifer is therefore also slow.

When mining ceases, the mine voids re-water, resulting in the formation of an artificial “aquifer” in the tunnels, drives and shafts. The vertical hydraulic connectivity of the mine voids with the overlying shallow weathered aquifer is limited, as indicated by field observations where the depth to the water table is still in the order of 0.5 m to 17 m below surface, indicating that the weathered aquifer is not dewatered.

5.2.2. Dolomite Aquifers

Dolomite aquifers are known to contain large quantities of groundwater and are commonly associated with sustainable groundwater abstraction. The dolomite occurs on the western end of the project area, west of the West Wits pit (Figure 5-1). The pit is located in close proximity to the Sterkfontein Dolomite Aquifer, which hosts the Cradle of Humankind World Heritage Site. The dolomite is not gold bearing and as such none of the pits is located within the dolomitic aquifers.

The Sterkfontein Dolomite and in particular the Zwartkrans groundwater compartment represents the most prominent aquifer in close proximity to the project area. DWS (1986) described the formation of this aquifer in detail and a brief description is included below.

Carbonate rocks are practically impermeable and therefore devoid of any effective primary porosity. During its geological history, the dolomite strata have been subjected to at least four periods of karstification and erosion (tertiary to recent). The potential for large-scale groundwater exploitation depends solely on the extent to which the dolomite has been leached by percolating rainfall to and groundwater drainage and the degree to which it has been transformed into aquifers capable of yielding significant quantities of water and sustaining high abstraction capacities.

During dissolution processes, the carbonate is removed from the dolomite and residual products such as silica, iron and manganese oxides and hydroxides are left behind. The residual mass is of low density and high void volume. This residuum is called “wad”, which is a geological term meaning “weathered and altered dolomite”. Fissures and caves also develop.

There is almost certainly a lithostratigraphical control on the leaching of dolomite, and the subsequent development of high storage and permeable horizons. The aquifer therefore comprises of an extensive cover of residual solution debris and in places younger sediments. Then underlying this is karstified dolomite, which is irregular and heterogenous, with hydraulic conditions varying from phreatic to confined. The karstified superficial zone of the strata acts as the main aquifer although fractures could extend to considerable depths.

The area south of the Doornkop fault is covered by the Malmani Dolomite, which is locally known as the Zuurbekom Dolomite Compartment. Although the pits are located within the C23D quaternary catchment where the Zuurbekom Compartment is found, the two are hydraulically disconnected due to the Witpoortjie Fault and Witpoortjie Horst (as shown in Figure 5-2).

The Kliprivier Dyke in the east, the Panvlakte Dyke in the south and the Magazine Dyke in the west mark the boundaries of the Zuurbekom – East Compartment. The northern boundary is marked by the sub-outcrop of the dolomite against the Doornkop fault. The Zuurbekom – East Groundwater Compartment, which underlie the Cooke TSF area, is a non-dewatered compartment, although significant abstraction has taken place via a Rand Water borehole. The latter is used to supplement the water supply to the greater Johannesburg.

Due to extensive erosion only the lowermost Oaktree Formation is present in the study area. This formation consists of chert-poor homogeneous dark-grey dolomite with interbedded carbonaceous shale. The dolomite has a gentle regional dip to the south and attains a total thickness of approximately 200 m (Parsons, 1990) in the study area. As a result of superficial deposits, the dolomites are not visible on surface.

About 1300 Ma ago the region was subjected to tension resulting in the formation of a number of large north to north-easterly striking faults. Many of the faults penetrated the full Transvaal sequence as well as the underlying Ventersdorp and Witwatersrand Supergroups. Some of the faults were filled by Pilanesberg age dykes, which subdivided the dolomite into the abovementioned watertight compartments. The Zuurbekom – East groundwater compartment is further divided into sub-compartments by a number of smaller dykes. The weathered dolomite, together with its dissolution products (wad) forms the main aquifer in the area.

5.2.3. Mine Void Aquifer

Over 100 years of gold mining in the Randfontein and Krugersdorp area created an underground mine void, referred to as the West Rand Basin Mine Void. Pumping as much as 40 Megalitres per day (Ml/d) during mining was reported to lower the water levels at Randfontein and West Rand Consolidated Mines.

Disposal of reclaimed tailings by Sibanye-Stillwater from the Dump 20 has shown that the pits are interconnected with the underground mine voids. As an example, the Porges and Millsite Pits are still receiving processed tailings that is reclaimed from the old TSFs, years after they were predicted to fill up.

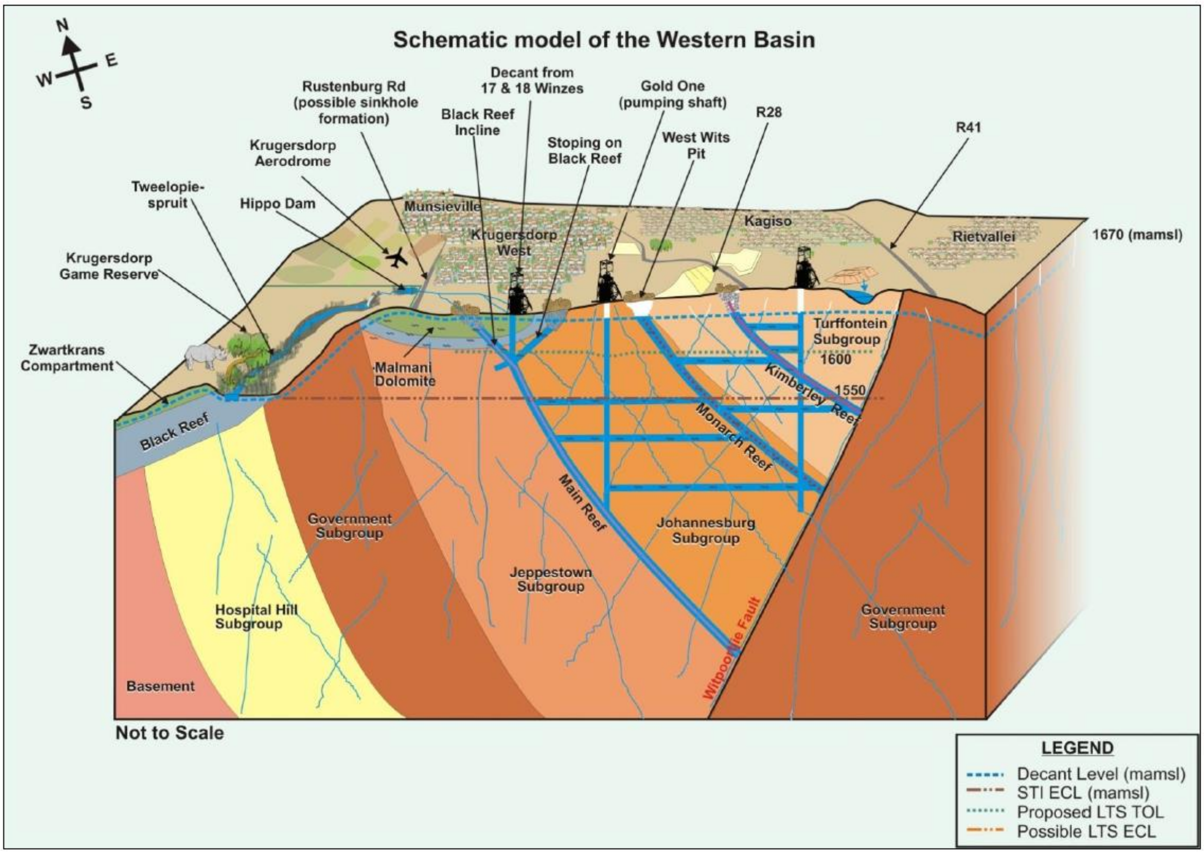


Figure 5-3: Schematic illustration of a conceptual hydrogeological model for the Western Basin

5.3. Aquifer Characterisation

There are a total of 12 boreholes drilled at the project site that contain hydrogeological information for aquifer characterisation. These are the 7 boreholes drilled during this study, and 6 boreholes by Golder (2016). The aquifer characterisation is conduced based on the information obtained from these boreholes, which are drilled between 20 and 60 m.

5.3.1. Water Strike Depth

The frequency of the water strikes observed is illustrated in Figure 5-4. The water strikes are encountered at depths between 10 and 60 m below ground level (mbgl), with the majority occurring between 20 and 40 mbgl.

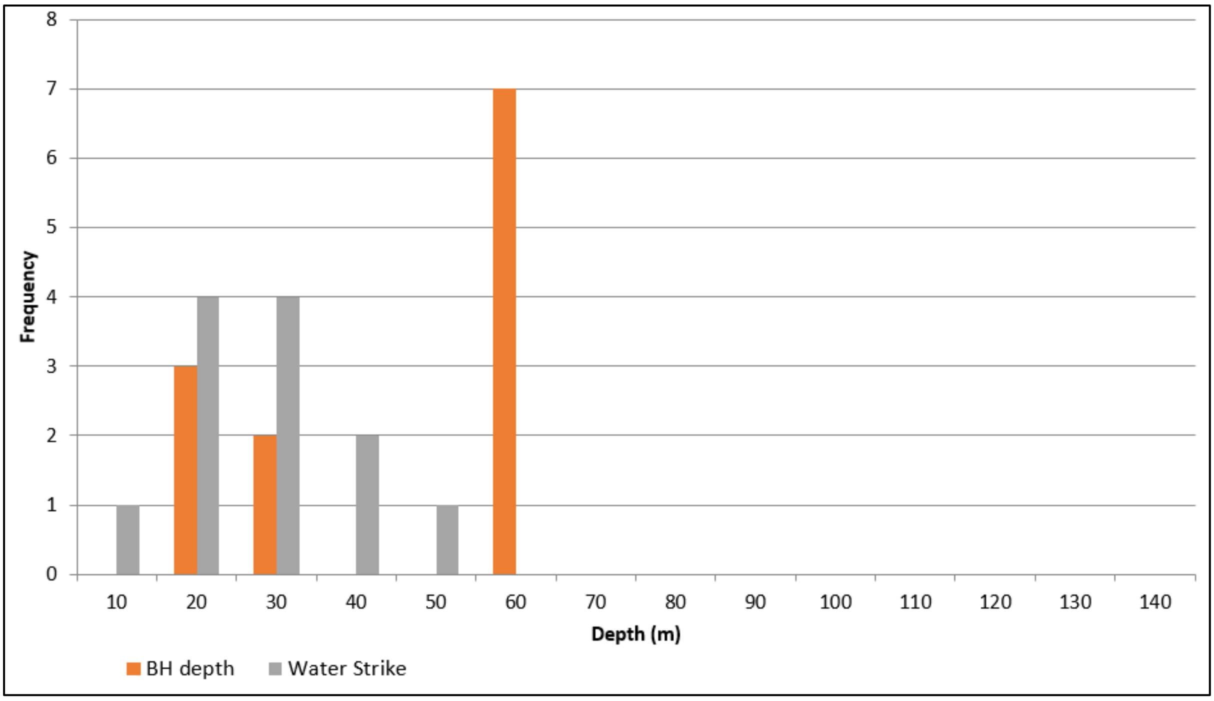


Figure 5-4: Water strike frequency

5.3.2. Aquifer Property

The aquifers underlying the project site are characterised as low yielding, semi-confined, weathered (and fractured) aquifer systems, mostly composed of the Pretoria Group geology. This is based on the hydrogeological borehole information obtained from the borehole drilling and aquifer testing.

A comparison of groundwater levels with water strikes in the boreholes indicates that the depth of water strikes is in most cases below the measured groundwater levels, which is indicative of confined groundwater flow conditions. The difference varies from 8 m (borehole MGPD) to 31 m (borehole MGP8D) (Figure 5-5). However, a continuous confining layer appears to be absent and the aquifers underlying the site have been classified as being semi-confined.

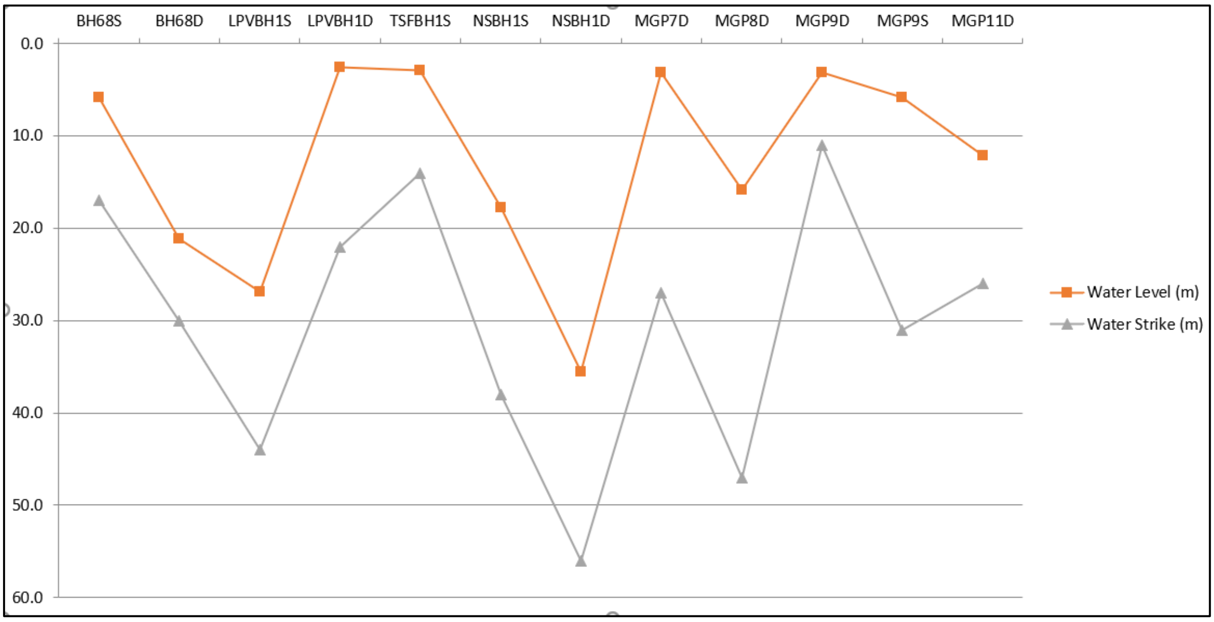


Figure 5-5: Correlation between water strike and water level

5.4. Water Level and Flow Direction

5.4.1. Shallow Aquifer

The groundwater elevation in the top weathered aquifer is not connected with the mine void, as it mimics the topography. Although the gradient is generally flatter in the dolomitic aquifer, the flow direction follows the topography and is towards the local streams. The interpolated water level is displayed Figure 5-6. It is evident that the groundwater level divide is similar to the surface watershed areas.

The natural groundwater flow direction in the A21D quaternary catchment (where Wet Wits and Tweelopiespruit are located) is generally from south to north, while in the C23D catchment (where the all the TSFs and pits are located) is generally from north to south.

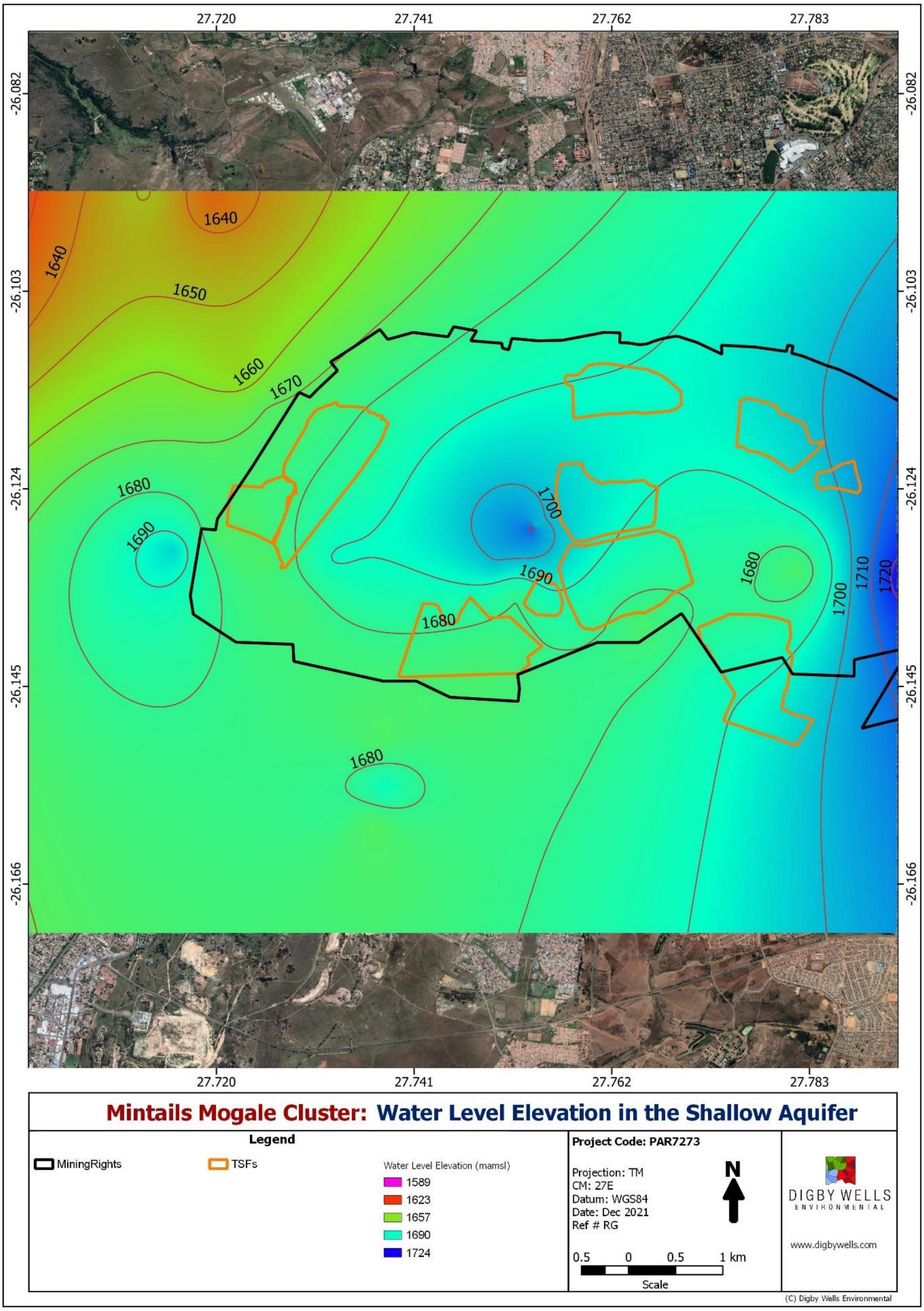


Figure 5-6: Groundwater elevation and flow direction in the weathered aquifer

5.4.2. Mine Void Aquifer

The hydraulic head and groundwater flow direction in the mine void is controlled by the decant, abstraction that is taking place at 9 Shaft, pit deposition, mine interconnectivity, and geological structures connecting the mine void with the shallow aquifer. A conceptual flow direction in the mine void (after Hobbs et al., 2007) is illustrated in Figure 5-7.

When mining was discontinued in the area, the defunct workings started to flood and, in September 2002, the mine water started to decant from a previously unknown Black Reef Incline next to the Tweelopie East Stream. The decant point, referred to as the Black Reef Incline (BRI), is at an elevation of 1662.98 m amsl. The water level in the mine void continued to rise even after the decant level was reached. This indicated that the BRI is restricted and that the outflow at that point does not represent the inflow into the void.

The decant rate is approximately 27 ML/d (Turton, 2016). Plans were presented to lower the water level in the mine void to below an environmental critical level (ECL), to minimise impact on surface and groundwater. The discharge was proposed from a low-lying shaft (9 Shaft). Pumping to achieve this objective commenced in April 2012 (Borralho, 2014).

The ECL is defined as the highest potentiometric head in the mine workings at which mine water will not daylight in the dolomite outlier. This elevation was initially set at 1 636 m amsl (JFA, 2006), which corresponds to that of the Hippo Dam in the Krugersdorp Game Reserve. It was then lowered to 1 530 mamsl (Hobbs et al. 2007) which corresponds to the elevation of the Aviary Spring downgradient of the Hippo Dam.

Although the pumping of 9 Shaft at the appropriate abstraction rate can avoid decanting, the lowering of the hydraulic head can affect the regional water level which could result in drying of springs and streams.

All the TSFs that will be reclaimed are in the C23D catchment while the West Wits and decant point are in the A21D. However, the flow in the mine void aquifer is from the TSFs is towards the 9 Shaft against the topographic gradient. This is due to the lowering of the hydraulic head at the shaft together with the Witpoortjie Fault south of the pits which is predominantly a flow barrier.

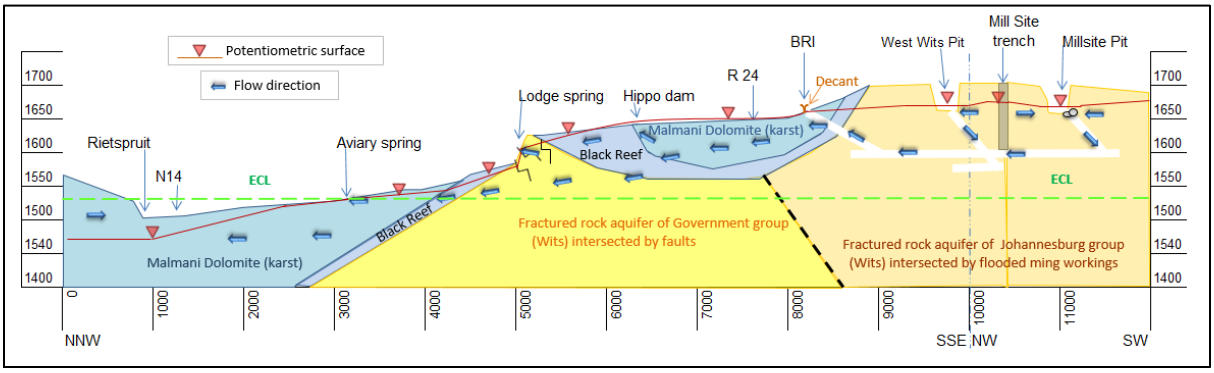


Figure 5-7: Groundwater flow direction and the concept of ECL

5.5. Groundwater Quality

5.5.1. Shallow Aquifer

All the newly drilled boreholes are sited within the shallow aquifer, having a maximum depth of 60 m. The boreholes were sampled, and their water quality results, as compared with the South African Water Quality Guideline (SAWQG) for drinking, are displayed in Table 5-2.

According to the SAWQG guidelines, water quality has two benchmarks: Class I and Class II:

- Concentrations within the Class I water quality limits are considered of ideal quality and suitable for human consumption
- Concentrations within Class II are considered marginal. This is the maximum allowable concentration and may not be suitable to be consumed for a prolonged period especially by sensitivity people
- Concentrations exceeding the Class II limits (also referred as Class III) are unacceptable for human consumption

All the boreholes are poor in quality (i.e., above Class II) and are not suitable for drinking unless treated. Many parameters were analysed, including anions and cations. Of these, sulphate is chosen during this study to show the extent of contamination as sulphate is almost entirely generated by mine related activities, and not by natural processes. It is also more conservative and is hardly retarded by geochemical reactions in the aquifer matrix. Other elements and metals can also be used to plot the contamination plume, but sulphate generally shows the largest contamination footprint due to its conservative nature and is good indicator of mine impact on the groundwater quality.

The ideal sulphate level in drinking water is 200 mg/L, while concentration up to 400 mg/L is acceptable. The concentration in the newly drilled boreholes, however, ranges between 516 mg/L to 2720 mg/L, with an average of 1745 mg/L. This indicates that the shallow aquifer is highly contaminated due to seepage from the historical TSFs.

Noteworthy is that the concentration of uranium was below the detection limit (less than 0.1 mg/L) in all the boreholes except at BH68D (0.92 mg/L) and NSBH1D (0.23 mg/L). This is most likely due to the limited solubility of uranium but does not mean that the mine has not contaminated the groundwater, as it is evident by many other elements that are dissolved at higher concentrations (Table 5-2). In summary:

- TDS, SO_4, Mg and Mn were above the maximum allowed concentrations in all the boreholes.
- Ca was above the maximum allowed limit in all boreholes, except in LPVBH1S.
- The pH, Al, Fe, Na and Cl were above the maximum allowed limits in at least one borehole.

The Stiff diagram of the water samples is displayed in Figure 5-8. Four of the boreholes have Ca+Mg-SO_4 type water which is a typical contamination from the TSFs.

Two boreholes (LPVBH1D and LPVBH1S), however, have different signatures whereby chloride is one of the main anion constituents. These boreholes are drilled immediately south of the Luipaardsvlei waste site, and their quality is characteristic of a domestic waste, rather than TSF water. The contamination plume at the project site is therefore not only seepage from the TSFs but other sources too, such as the Luipaardsvlei waste site. It is interesting to note that the deeper borehole (LPVBH1D with a TDS of 5158 mg/L) is more contaminated than the shallower borehole (LPVBH1S with a TDS of 1290 mg/L). This indicates vertical seepage from the waste site to the deeper fractured aquifer.

Historical monitoring data also complements the water quality obtained from the newly drilled boreholes. The shallow aquifer is in direct contact with the TSFs and is vulnerable to contamination due to seepage. Many of the shallow boreholes (less than 30 m deep) are highly contaminated with sulphate reaching up to a maximum of 6000 mg/L in the Lancaster Dam area. This is significantly higher than the 400 mg/L drinking standards (SAWQG, 1998).

The baseline (current) contamination plume in the weathered aquifer is shown in Figure 5-9. The TSFs are unlined and are rich with pyrite. Considering that the TSFs are on the ground surface, they are exposed to oxidation reaction which results low pH solution. As rainfall infiltrates through the tailings, the acidic water infiltrates to the shallow aquifer, dissolving and carrying Fe, Mn, and other metals on its way.

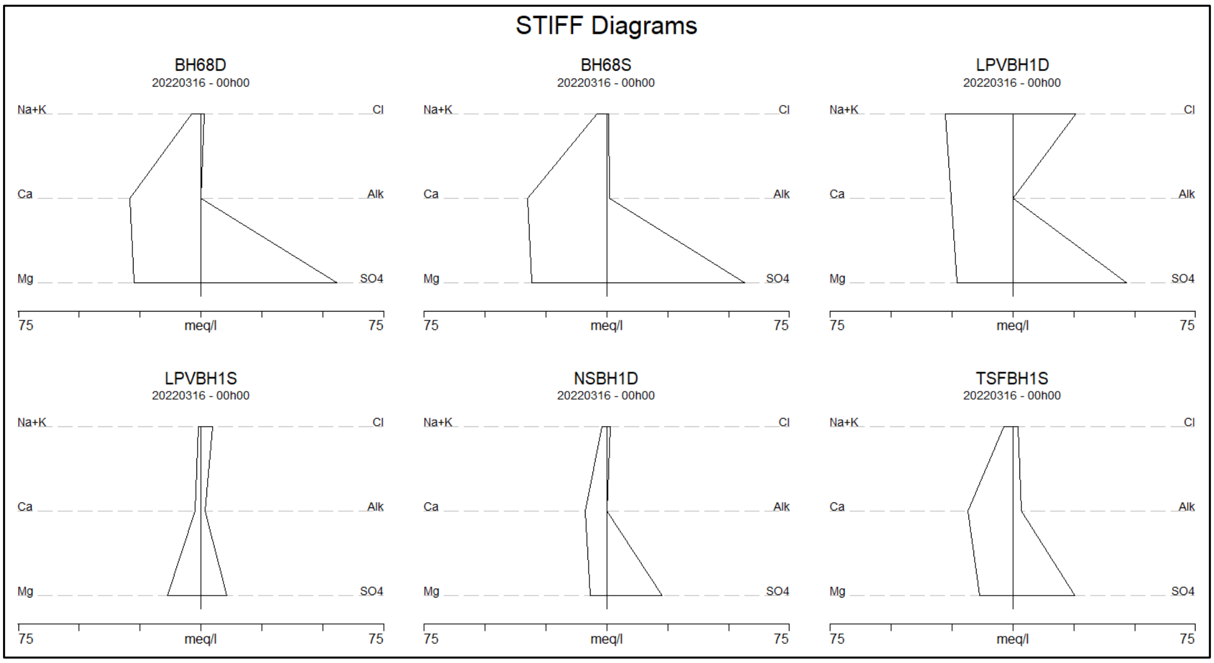


Figure 5-8: Stiff diagram of the newly drilled boreholes

DIGBY WELLS ENVIRONMENTAL

Table 5-2: Groundwater quality of the newly drilled boreholes

		pH	EC mS/m	TDS mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Cl mg/l	SO4 mg/l	NO3_N mg/l	F mg/l	Al mg/l	Fe mg/l	Mn mg/l	NH3_N mg/l	Cu mg/L	Pb mg/L	Zn mg/L	U mg/L	Cd mg/L	As mg/l	Cr mg/l
Ideal		<6, >9	<70	<450	<32	<30	<100	<50	<100	<200	<6	<1	<0.15	<0.1	<0.05	<0.1	<1	<0.01	<3	<0.03	<0.005	<0.01	<0.05
Acceptable		6	70	450	32	30	100	50	100	200	6	1	0.15	0.1	0.05	0.1	1	0.01	3	0.03	0.005	0.01	0.05
Unacceptable		9	150	1000	80	50	200	100	200	400	10	1.5	0.5	0.3	0.1	2	3	0.02	5	0.1	0.01	0.2	0.06
BH68S	16/03/2022	5.70	387.00	4374.00	652.00	375.00	87.00	6.90	21.00	2720.00	6.90	0.40	<0.1	0.03	28.00	1.20	0.01	<0.001	1.05	0.01	0.01	0.00	<0.025
BH68D	16/03/2022	4.40	386.00	4586.00	582.00	332.00	82.00	8.60	45.00	2678.00	5.30	0.20	22.00	0.26	74.00	2.50	1.64	0.00	4.90	0.92	0.02	0.02	<0.025
LPVBH1D	16/03/2022	4.90	629.00	5158.00	505.00	278.00	615.00	38.00	916.00	2248.00	0.90	0.60	3.10	2.12	60.00	75.00	0.28	0.00	4.24	0.04	0.01	0.04	<0.025
LPVBH1S	16/03/2022	6.10	162.00	1290.00	51.00	168.00	25.00	1.00	169.00	516.00	0.20	0.30	<0.1	<0.025	0.95	0.30	<0.01	<0.001	0.09	<0.001	<0.001	<0.001	<0.025
NSBH1D	16/03/2022	4.00	192.00	1916.00	175.00	84.00	41.00	5.60	50.00	1096.00	5.70	0.20	33.00	0.33	48.00	1.20	0.83	0.00	6.70	0.23	0.01	0.02	<0.025
TSFBH1S	16/03/2022	7.00	235.00	2262.00	369.00	166.00	85.00	5.80	75.00	1215.00	0.70	0.30	<0.1	<0.025	0.78	0.50	<0.01	<0.001	<0.025	0.00	<0.001	<0.001	<0.025

Table 5-3: Quality of the slurry water of a reprocessed tailings sample from IL13-15 TSF

		pH	EC mS/m	TDS mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Cl mg/l	SO4 mg/l	NO3_N mg/l	F mg/l	Al mg/l	Fe mg/l	Mn mg/l	NH3_N mg/l	Cu mg/L	Pb mg/L	Zn mg/L	U (WHO) mg/L	Cd mg/L	As mg/l	Cr mg/l
Ideal		<6, >9	<70	<450	<32	<30	<100	<50	<100	<200	<6	<1	<0.15	<0.1	<0.05	<0.1	<1	<0.01	<3	<0.03	<0.005	<0.01	<0.05
Acceptable		6	70	450	32	30	100	50	100	200	6	1	0.15	0.1	0.05	0.1	1	0.01	3	0.03	0.005	0.01	0.05
Unacceptable		9	150	1000	80	50	200	100	200	400	10	1.5	0.5	0.3	0.1	2	3	0.02	5	0.1	0.01	0.2	0.06
IL13-L15 (Processed tailings)	22/06/2022	9	456.00	4116.00	554.00	44	476.00	219.00	174	2267.00	<0.1	1.1	0.456	0.61	2.35		3.93	<0.001	13.00	0.31	0.03	0.06	<0.025

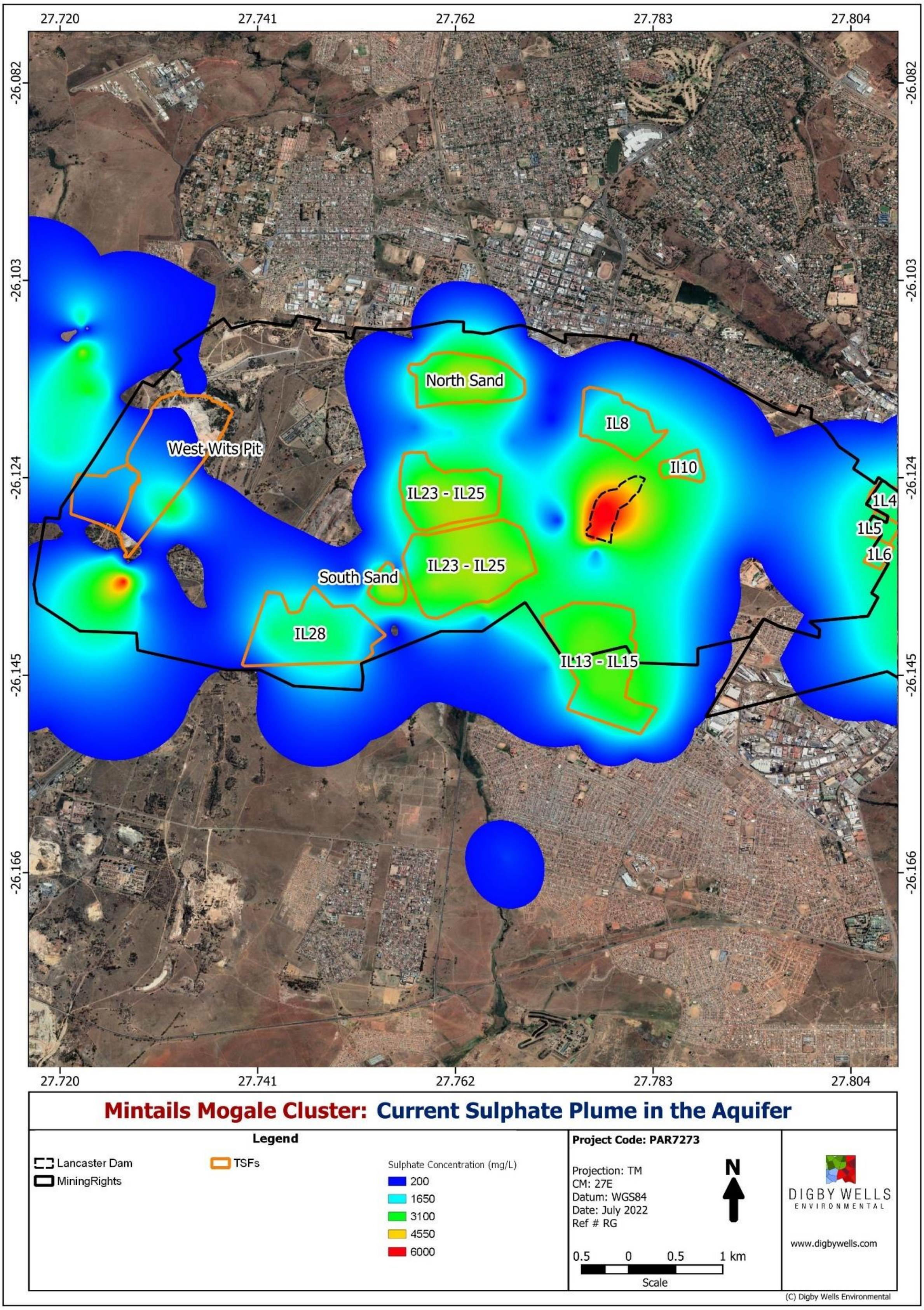


Figure 5-9: Current sulphate plume in the aquifer

5.5.2. Dolomitic and Fractured Aquifers

The dolomitic and fractured aquifers that are found below the shallow weathered aquifer are generally clean from contamination. Once the shallow aquifer is contaminated from the TSF seepage, the groundwater dominantly flows laterally towards the local streams and rivers.

Unless there are sub-vertical permeable structures connecting the fractured aquifer with the shallow aquifer, the contamination plume mostly flows to the rivers. Typical examples that illustrate this are boreholes MGP9S and MGP9D, which are 15 m apart from each other. Borehole MGP9S is 20 m deep and is in the shallow aquifer, while MGP9D is 60 m deep and is in the fractured aquifer. As shown in Figure 4-1, both boreholes are 120 m south of the Lancaster dam.

The Lancaster dam water quality is poor, with sulphate concentration of about 6000 mg/L (although it may range between 2000 and 8000 mg/L. The shallow borehole MGP9S is contaminated at a concentration of 1050 mg/L, while the deeper borehole (MGP9D) is cleaner at only 105 mg/L.

There is mostly no dolomitic aquifer within the project site, except for a small outcrop west of the West Wits. However, there are several boreholes drilled in this aquifer to monitor the dolomitic aquifer. The water quality is clean and is similar to the fractured aquifer, with sulphate levels being less than 100 mg/L.

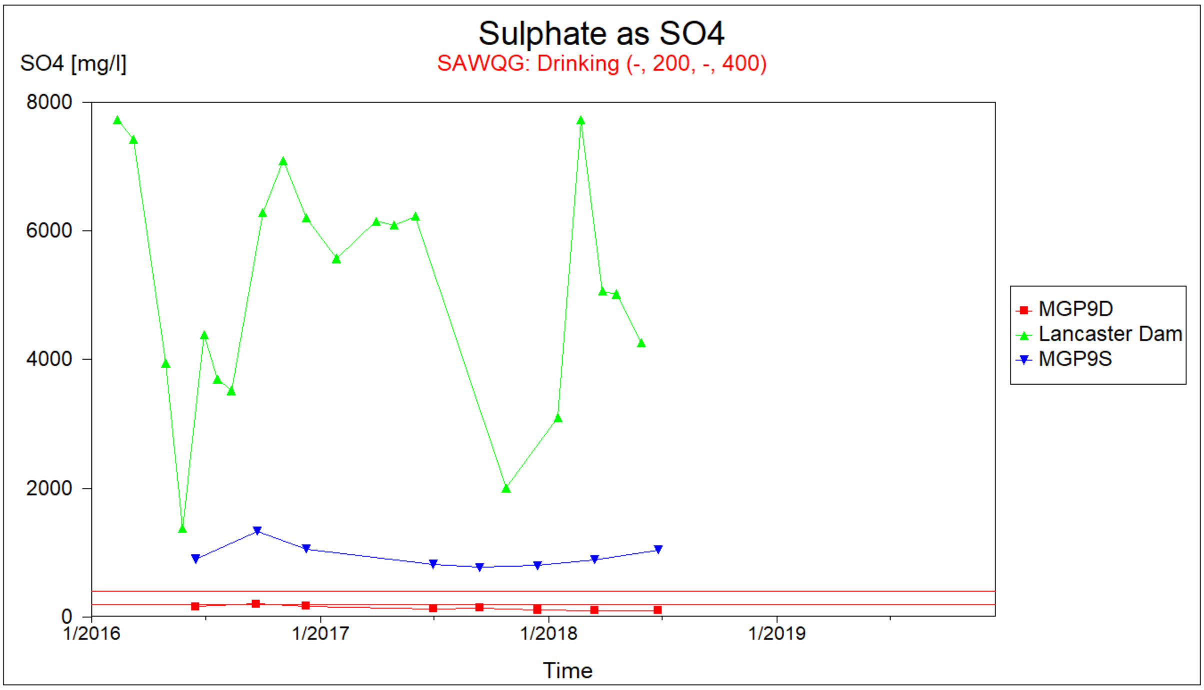


Figure 5-10: Water quality of the Lancaster Dam and its monitoring boreholes

5.5.3. Mine Void Aquifer

The time-series sulphate concentration in the mine void aquifer, as monitored in the shafts, is presented in Figure 5-11. Monitoring data is available from 2009 to 2018. Thereafter, no monitoring data was available until the hydrocensus conducted during this study at 9 Shaft.

The water quality of all the shafts is similar as they are interconnected. The water quality has been improving continuously from approximately 4000 mg/L in 2009 to 648 mg/L in 2021. During the same period, the pH of the mine void has also increased which precipitated many metals. The trends of Mn, Fe, and TDS is also similar to that of the sulphate and have improved over the years.

The TCTA and DWS treatment activities started in April 2012, but the water actually started improving before then. There could be many geochemical factors affecting this including dilution as the mine void fills up. The increase in pH is suspected to be a result of the discharge of the reclaimed mine residue, such as Dump 20 tailings which has a pH of between 10 and 11. This is one of the positive impacts associated with the discharging of alkaline tailings into the pits, as this would mean that metals will precipitate from the solution.

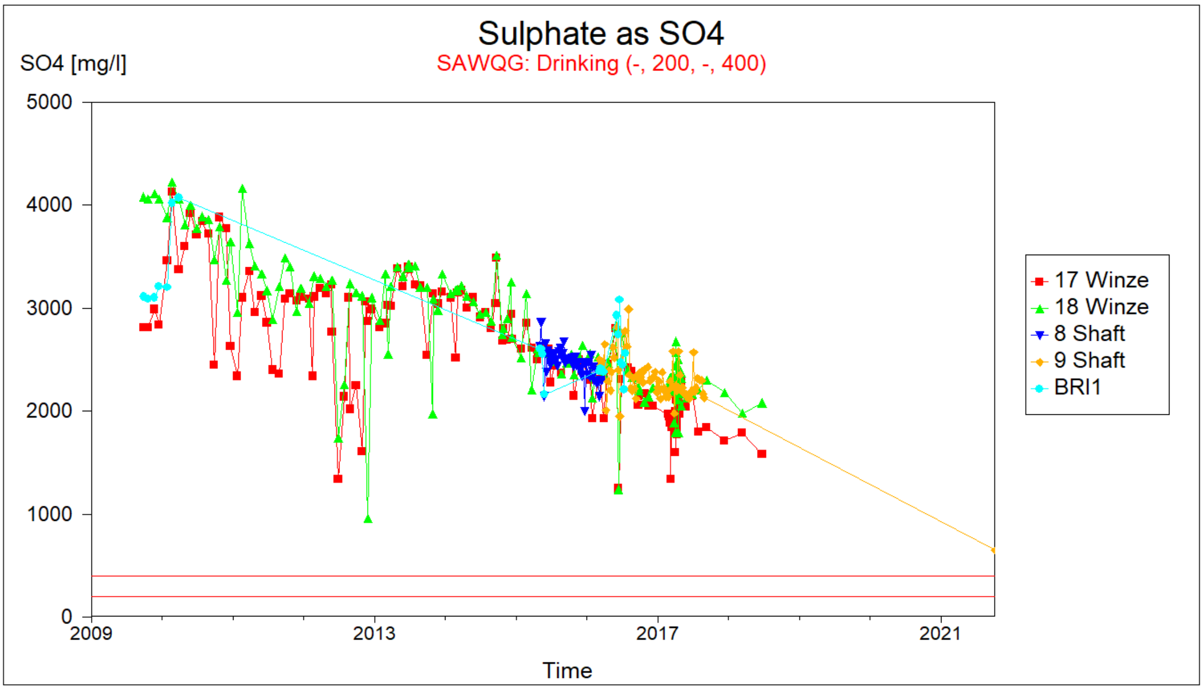


Figure 5-11: Sulphate trend in the mine void aquifer

5.6. Aquifer Permeability

According to Bliss et al (194), aquifer permeabilities are classified into 7 groups from Very Low to Very High. These classifications are listed in Table 5-4 and have been applied to categorise the aquifer permeabilities of the project site.

A total of 11 boreholes were used to assess the permeability of the aquifers at the site. These are consisted of the 6 boreholes that were aquifer tested during this study as well as the 5 boreholes tested by Golder (2016).

Generally, the aquifer permeability is limited, with no value recorded in the High and Very High ranges. The boreholes are drilled to a maximum depth of 60 m and are within the Pretoria group geology. The permeability ranges between the Very Low (2% of the boreholes), Low (36%), Medium (18%) and Moderate (36%).

The distribution of the permeabilities in the shallow and deep aquifers are displayed in Figure 5-12.

Table 5-4: Aquifer classification based on permeability values (Bliss et al, 1984)

Permeability (m/d)	Classification	Condition of Rock Mass Discontinuities
< 0.009	Very Low	Very tight
0.009 - 0.052	Low	Tight
0.052 - 0.173	Moderate	Few partly open
0.173 - 0.518	Medium	Some open
0.518 - 0.864	High	Many open
> 0.864	Very High	Open closely spaced or voids

Table 5-5: Permeability values at the project area

Borehole	X	Y	K value (m/d)	Permeability Classification
LPVBH1S	27.78245	-26.1235	0.000737	Very Low
MGP11S	27.79322	-26.13323	0.00027	Very Low
MGP9S	27.7769	-26.13183	0.048	Low
LPVBH1D	27.78259	-26.1236	0.0126	Low
NSBH1D	27.76527	-26.1095	0.042	Low
MGP9D	27.77718	-26.13177	0.0096	Low
TSFBH1S	27.77112	-26.1376	0.294	Medium
MGP7D	27.74058	-26.14478	0.209	Medium
BH68S	27.7607	-26.1457	0.0794	Moderate
BH68D	27.7604	-26.1456	0.128	Moderate
MGP11D	27.7931	-26.13332	0.055	Moderate

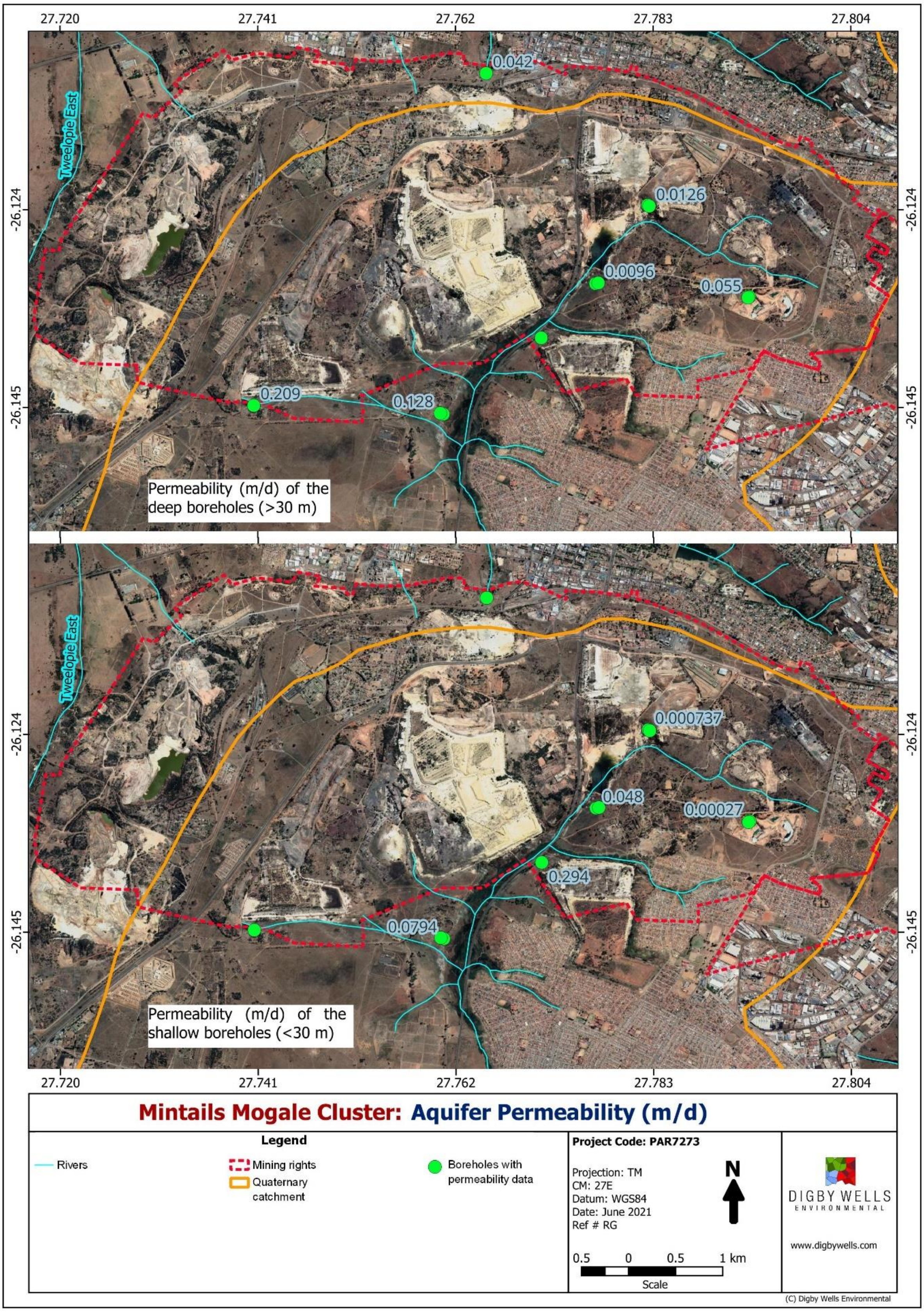


Figure 5-12: Aquifer permeability

5.7. Contaminant Transport Parameters

In most cases, contaminant transport is driven by advection, i.e., groundwater flow is the main mechanism controlling the movement of solutes in groundwater. Advection implies that contaminants migrate at a rate similar to the groundwater flow velocity and in the same direction as the hydraulic gradient. Therefore, knowledge of groundwater flow patterns and hydraulic parameters can be used to predict solute transport under advection. Other parameters to consider include dispersion, diffusion, effective porosity, and the specific yield.

5.7.1. Dispersion and Diffusion

Dispersion of contaminants in groundwater is also important in terms of contaminant transport. Dispersive transport is caused by the tortuous nature of pores or fracture openings that result in variable flow velocity distributions within an aquifer and movement of contaminants due to the difference in concentration gradient.

Dispersion has two components: longitudinal and transversal dispersivity. Longitudinal dispersivity is scale dependent and is usually approximately 10% of the travel distance of the plume (Fetter, 1993). Transversal dispersivity is approximately 10% of the longitudinal dispersivity. The higher the dispersivity, the smaller the maximum concentration of the contaminant, as dispersion causes a spreading of the plume over a larger area.

The average distance of the IL23-IL25 TSF footprint to the Wonderfonteinspruit is approximately 200 m. If it is postulated that the streams are the main receptors of the contaminant plume, a longitudinal dispersivity of 20 m and a transversal dispersivity of 2 m is estimated.

A diffusion coefficient of $1x10^{-5}$ m^2/day was selected, acceptable for sedimentary rocks.

5.7.2. Effective Porosity and Specific Yield

The percentage of void volume that contributes to groundwater flow is expressed by the term porosity. Not all pores are interconnected and therefore cannot contribute equally to groundwater flow, leading to the derivation of the term effective porosity, used to express the interconnected void volume that effectively contributes to groundwater flow and therefore contaminant transport. The higher the effective porosity, the slower the contamination migration rate, because more pore voids have to be filled. The specific yield of a unit volume within the aquifer is the quantity of water that can be released or drained as a result of gravity. This implies that the specific yield is either equal or less than the effective porosity.

Based on the geological composition of the area, an effective porosity and specific yield of between 0.03 and 0.02 are applied across the entire model domain.

5.8. Groundwater Receptors

Groundwater usage in the area occurs on agricultural holdings immediately north, east and south of the project site and small farms west of the West Wits pit. Groundwater usage is primarily for domestic purposes although large scale irrigation takes place from the

Sterkfontein dolomite. The tailings dam also has the potential to impact on the Wonderfonteinspruit and Tweelopiespruit that flow through the Krugersdorp Game Reserve and ultimately into the Cradle of Humankind World Heritage Site.

Surface water and groundwater interactions occur when the water level elevations intersect the surface topography. Such interactions are often expressed as springs, wetlands and base flows. The groundwater contribution to base flow, in the Randfontein area, is estimated to be 25 mm per annum (Vegter, 1995). Significant streams that could be impacted if the groundwater quality deteriorates include the Wonderfonteinspruit, Tweelopiespruit, and their tributaries. These streams are particularly vulnerable to AMD seepage and salt loading as a result of tailings seepage in the shallow groundwater zone and decant of mine water through old shafts.

5.9. Source Areas

5.9.1. Source of Contamination

PAR proposes to reprocess the historical TSFs to recover gold and the reprocessed tailings will initially be disposed of into the West Wits Pit and the excess will be deposited on where IL23-25 TSF is currently located at. The IL23-25 is therefore expected to be the main source of contamination in the project area.

The details of geochemical characteristics of the reprocessed tailings are available in the Digby Wells Geochem Report (2022) and only a summary is discussed here. During this study, only one sample of slurry water was obtained from the reprocessed tailings for geochemical assessment. This sample was obtained from the IL13-15 TSF (Digby Wells Geochem, 2022) and the quality is assumed to be representative of all the other tailings that will be reprocessed.

The laboratory analysis of the reprocessed slurry is shown in Table 5-3. A number of constituents are detected in the slurry water that are above the recommended concentration limits including SO_4 (2267 mg/L), Mn (2.35 mg/L), Zn (13 mg/L) and U (0.31 mg/L).

Arsenic is often perceived as one of the main contaminants of concerns at the gold mines. However, As is found to be below detection limit in the boreholes as wells as the slurry water.

5.9.2. Groundwater Recharge

At the project area, groundwater recharge is estimated (based on model calibrations) to be approximately 9.96 mm (1.5%) per annum. This is in line with the previous study (Digby Wells, 2015) at the nearby Sibanye operations. ERM (2009) estimated the recharge at the Gold Fields TSF site in the order of 1.9% of the mean annual precipitation which is in good correlation with the results of this investigation.

6. Numerical Model

Following the identification and characterisation of the aquifers, contaminant source and groundwater receptors, the conceptual model was transformed into a numerical model so that the groundwater flow conditions, and mass transport can be solved numerically. The numerical model was calibrated with groundwater level data collected from historical records, as well as during this investigation.

6.1. Model Domain and Boundary Conditions

The model domain encompasses an area following rivers and watersheds, approximately 17.7 km (East to West) by 12.9 km (North to South) and is shown in Figure 6-1.

A rectangular mesh was generated over the model domain, consisting of 130 rows and 177 columns. The mesh was refined throughout the model domain to a cell size of 50 x 50 m in length.

The boundary conditions are illustrated in Figure 6-1 and are defined by:

- Drain package on the north, east, south, and west to represent the groundwater convergence along the stream channels. The drain package was used to simulate the steams within the model domain as well; and
- A no-flow boundary was used for the rest of the model as it coincides with surface water divide.

6.2. Model Calibration

Model calibration is the process of varying model input parameters over realistic ranges, until a satisfactory match between simulated and historically observed data can be reproduced. To avoid over-fitting of the model, the number of unknown input parameters (i.e., the degrees of freedom) has to be kept at a minimum.

A total of 23 observation boreholes were used for the steady state model calibration (Figure 6-2). The boreholes consisted of the newly drilled boreholes and historical boreholes encountered in the region during the hydrocensus.

During the calibration process the hydraulic conductivities and recharge values of the various geological units were adjusted within a reasonable range, until a good correlation of 93.1% (with a mean error of 1.5 m and mean absolute error of 2.92 m) was obtained between the simulated and observed groundwater elevation (Figure 6-2).

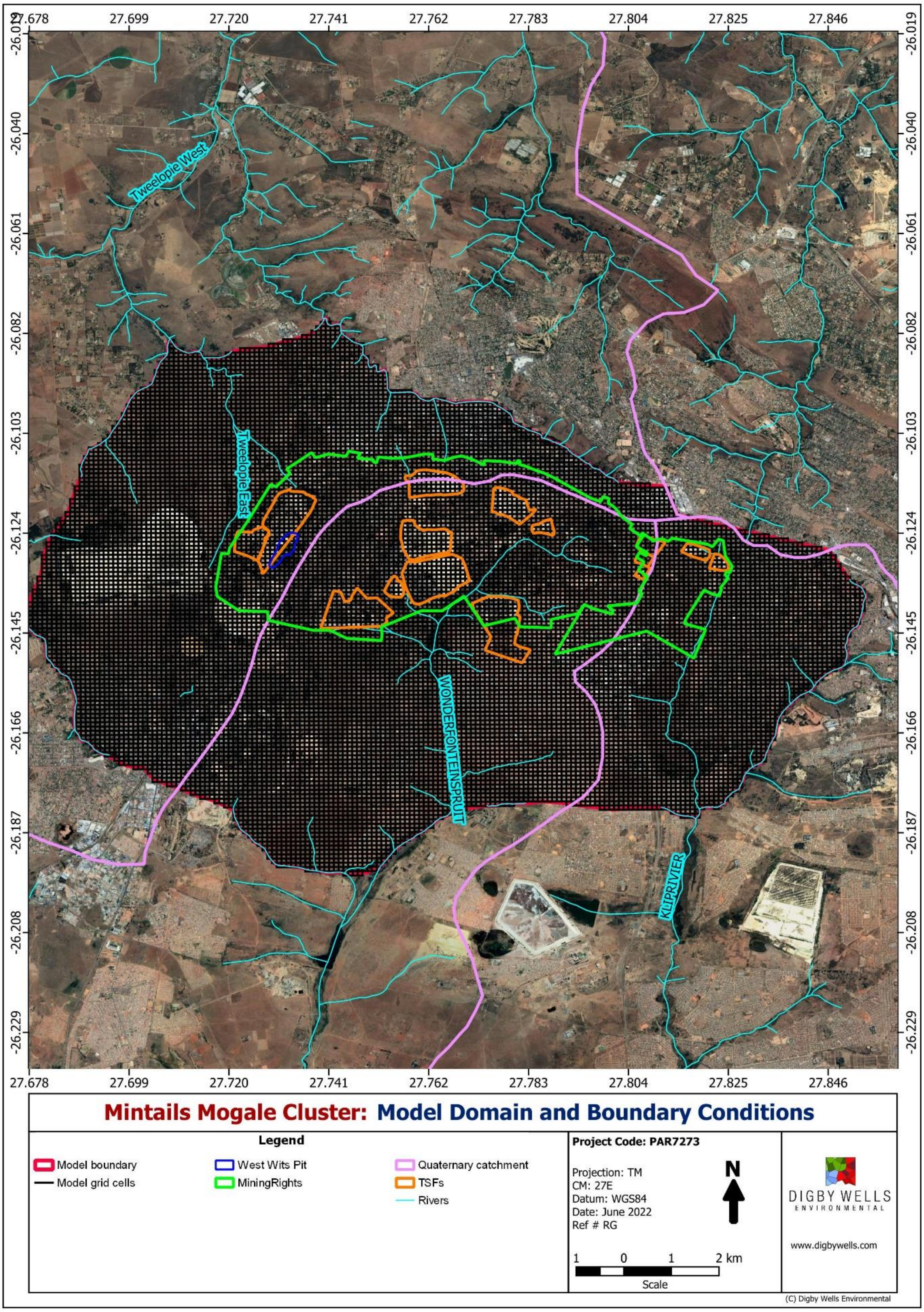


Figure 6-1: Model domain and boundary conditions

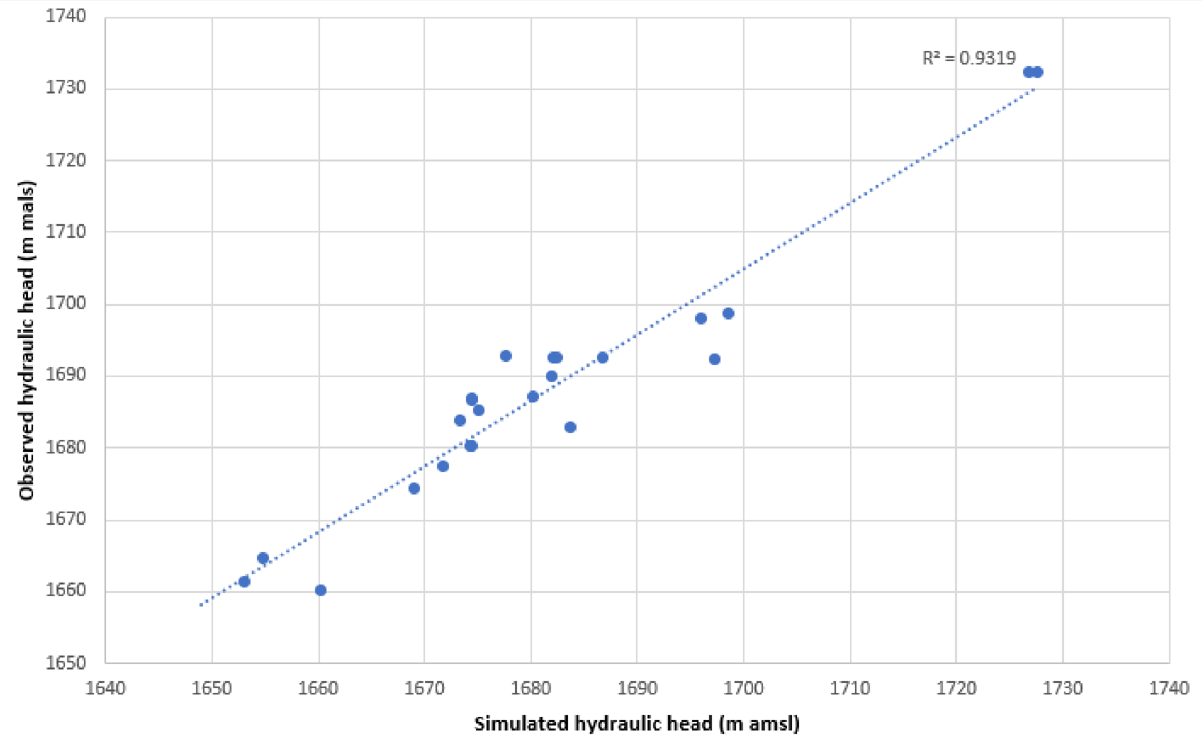


Figure 6-2: Correlation between the observed and simulated water levels

6.3. Flow Simulation Results

The steady state groundwater elevation follows the topography and is generally flowing towards the northwest and south as illustrated in Figure 6-3. The groundwater divide of these two flow directions is approximately parallel to the catchments divide for A21D and C23D quaternary catchments. Under natural conditions, the groundwater divide and surface water catchment divide are expected to coincide but due to the ongoing dewatering at 9 and 8 shafts (by TCTA and Sibanye) as well as possible evaporation loss from West Wits Pit, the two divides are not on the exact position. The groundwater divide is pushed approximately 500 m south of the quaternary catchment divide.

The flow gradient is variable from flat (zero) on the groundwater divide, to 0.0139 on the banks of the Wonderfonteinspruit and 0.0096 on the banks of the Tweelopiespruit East. These changes in gradient are due to the site-specific topographical setting, as well as the hydraulic conductivities. The gradient in areas of relatively higher hydraulic conductivities is gentler than areas of lower hydraulic conductivities.

Considering the average (geometric mean) of the permeability of the weathered aquifer of 0.0117 m/d, the average groundwater flow velocity (Darcy velocity) along the weathered zone is in the order of 0.15 mm/year. This is not unusual groundwater flow rate but what it means is that, even if the tailings are removed, it will take decades for the plume that is already existing on site to be flushed away under natural groundwater flow.

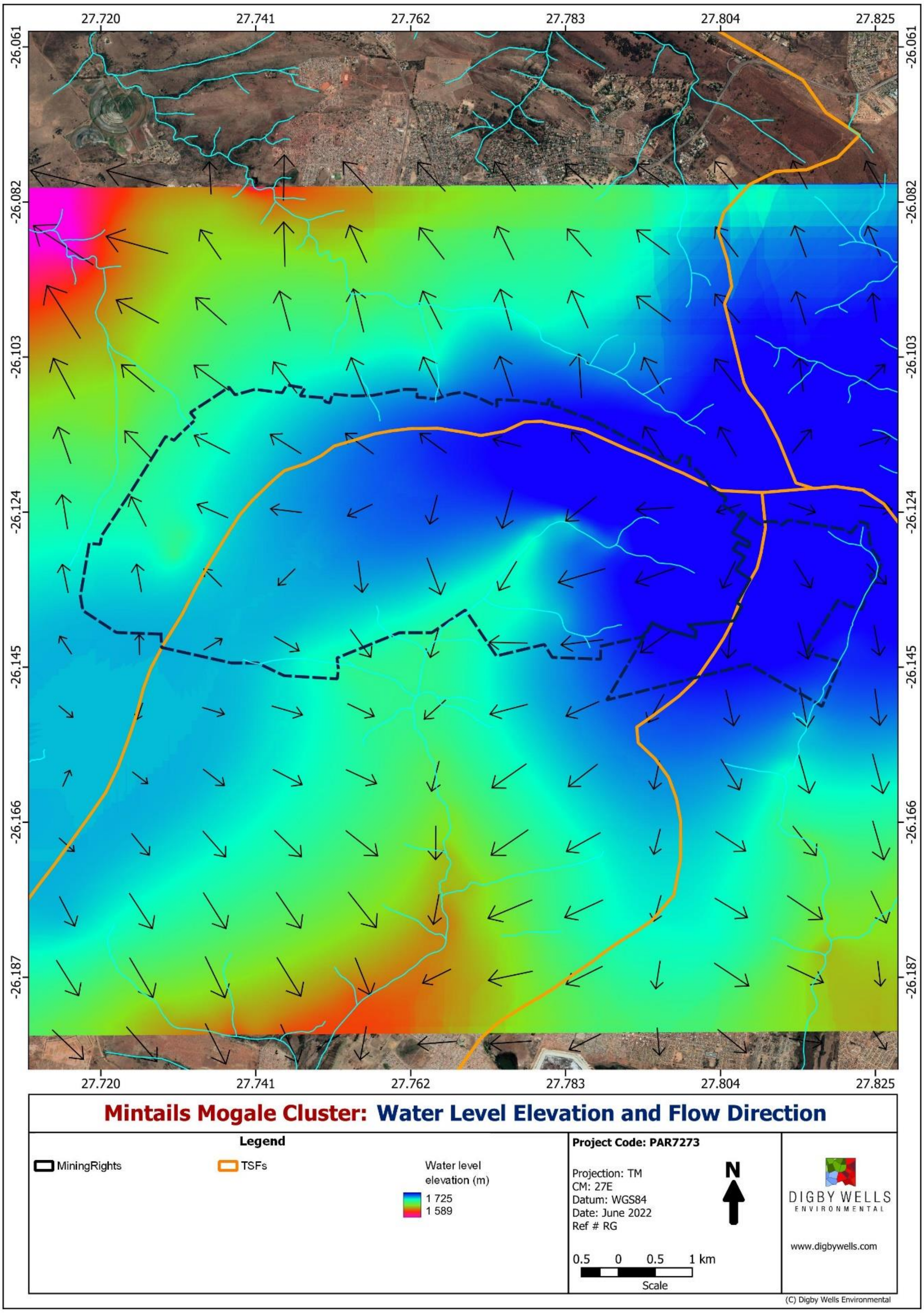


Figure 6-3: Steady state water level and flow direction

7. Impact Assessment

This section rates the significance of the potential impacts before and after mitigation. The impacts below are a result of both the environment in which the activity takes place, as well as the activity itself. The impacts associated with the proposed project include the NEMA EIA Regulations, 2014 (as amended) Listed Activities, as well as the mining and associated activities to take place at the project area. The methodology utilised to assess the significance of the potential impacts is described in Appendix A.

The proposed reclamation of the historical TSFs and deposition of reprocessed tailings into the pits could have both positive and negative impacts on the groundwater environment. Potential impacts are assessed in the subsequent subsections considering the construction, operational and closure phases.

7.1. Construction Phase

Activities during the Construction Phase that may have potential impacts on the groundwater environment are listed in Table 7-1.

Table 7-1: Interactions and impacts during the construction phase

Interaction	Impact
Construction of the surface infrastructure (installation of pipelines, access roads, site clearing and storm water trenches)	Groundwater contamination

7.1.1. Impact Description

The water table at the proposed infrastructure area is between 0.5 m and 17 m below ground surface. Any site clearing or construction activities that would involve excavation below the water table depth will have a potential impact on the groundwater quantity and quality.

7.1.1.1. *Management Objectives*

The following are management objectives defined for the construction phase:

- Site clearance and construction activities should take place above the water table, if applicable. No impact on the groundwater is expected if the activities take place above the water table;
- Site clearance should be kept to a minimum area and short duration, if possible;
- If trenches are going to be excavated below the water level, dewatering of the aquifer to lower the water table locally can be considered to ensure that the construction takes place above the groundwater level and the water quality remains acceptable. The abstracted water can be utilised for dust suppression, vegetation, irrigation or discharged to pollution control dams for evaporation. Since the groundwater in the shallow aquifer is already contaminated, the utilisation of the water for activities such

as dust suppression or irrigation could cause negative environmental impacts and should be used only after the quality meets the intended use;

- The PCD should not be placed on areas with the potential for increased infiltration to groundwater, such as over fault zones; and
- The PCD should be lined to pro-actively prevent infiltration of contaminated seepage water.

7.1.1.2. Management Actions

The following actions and targets are required:

- Restrict areas that must be cleared of vegetation for construction activities to those absolutely necessary;
- Avoid constructing below the water table as far as possible;
- Apply a liner underneath the PCD to minimise or avoid infiltration;
- Implementation of adequate storm water management to contain all wastewater and/or volatile organic compounds, for treatment and recycling; and
- Install long term monitoring boreholes. The positions of the monitoring boreholes are provided in Section 9.

7.1.1.3. Impact Ratings

No impact on the groundwater is expected as long as these activities are taking place above the water table. Diesel or other organic fluids and inorganic solvents might be spilled on the ground surface, or leak from storage tanks during the construction. Considering the depth of the water level, however, they are expected to volatilise and unlikely to reach the groundwater.

Construction will also be conducted in a relatively short period compared to the operational and post-closure phases. Impacts on the groundwater environment are therefore rated as Negligible as provided in Table 7-2 below.

Table 7-2: Potential impact on groundwater quality during the construction phase

Dimension	Rating	Motivation	Significance
Impact Description: Groundwater quality deterioration			
Prior to mitigation/ management			
Duration	Short term (2)	The construction activities are expected to take place over less than 1 year.	Negligible (negative) – 8
Extent	Very limited (1)	Impact will be limited to specific isolated parts of the site	

Dimension	Rating	Motivation	Significance
Intensity	Minimal (1)	Considering the depth of the water table and the current groundwater quality, the impact intensity (if any) is expected to be minimal.	
Probability	Rare (2)	It is unlikely for any seepage during the construction activity to seep and contaminate the groundwater, considering the construction duration and construction activities	
Nature	Negative		
Mitigation/ Management actions			
▪ Restrict areas that must be cleared of vegetation for construction activities to those of absolute necessity; ▪ Avoid constructing below the water table as far as possible; and ▪ Continue the existing monitoring programme.			
Post- mitigation			
Duration	Short term (1)	Any impact on the groundwater is expected to recover after the construction phase is completed	Negligible (negative) – 6
Extent	Limited (1)	Only isolated areas where there will be spillages or site cleaning below the water table (if any) will be affected	
Intensity	Minimal natural impact (1)	Considering the duration of the construction period and water table depth, the intensity will be minimal	
Probability	Improbable (2)	It is unlikely for groundwater impact to occur during the construction phase, especially with the implementation of the above proposed management plan	
Nature	Negative		

7.2. Operational Phase

The activities during the operational phase that are relevant to the groundwater environment are the hydraulic reclamation of the old TSFs, the discharge of the reprocessed tailings into the West Wits pit and new TSF. These are listed in Table 7-3.

Table 7-3: Interactions and impacts during the TSF reclamation

Interaction	Impact
Hydraulic reclamation	Seepage through the TSF of the water to be used for hydraulic reclamation inside the footprint
Tailings exposure to oxygen and water	Acid mine drainage
Pump station or pipelines	Slime or process spillage from pump station or pipeline
Pit deposition	Rising of water level in the vicinity of the pits
	Increase of decant rates
	Deterioration of groundwater quality
New TSF	Deterioration of groundwater quality
	Mounding of the water table due to seepage

7.2.1. Impact Description

7.2.1.1. Management Objectives

The historical TSFs in the region are not lined and seepage is draining into the underlying groundwater system. The current hypothesis is that if there were no TSFs located directly over the mine void, dolomite and fractured aquifers, the current decant volume would have decreased, and it is likely that the water pumped from the underground chambers would be of better quality than the current status. In addition, the pumping and treatment cost would be substantially less if the TSFs seepage portion could be eliminated.

Further to this, infiltration from the TSFs will be reduced if the tailings is removed from surface. The contaminant loads will be less from a pollution perspective. At present, the presence of the TSF and the continued dewatering activities in the compartment will encourage continued infiltration of seepage to the deeper aquifer units, the consequent deterioration of water quality, increased decant rates and increased volumes of water to be pumped from the underground chambers.

The long-term impact as a result of the reclamation operations at the TSFs is therefore anticipated to be positive since the TSFs, which are a source of contamination, will be removed and filled into the pits. If the pits are all filled, a new TSF will be constructed on surface. The new TSF will be unlined, and no underdrains are planned to be constructed. Interception drains will be constructed on its perimeter to capture seepage in the shallow aquifer.

In the short-term, however, the hydraulic reclamation could result in the partial seepage through the TSF. The exposure of the tailings to oxygen and water can result in AMD.

Backfilling of the open pits with the reprocessed tailings is likely to result in the increase of the groundwater level, increase of decant rate and potentially impact on the groundwater quality. The impact rating for all the pits is expected to be similar.

The water in the underground mine void is affected by AMD and is already of poor quality with low pH. Without backfilling, the open pits are a constant source of water ingress into the Western Basin mine void as rainwater falls into the pits and enters the mine voids. This rainwater then comes into contact with pyrite on the exposed pit walls and assumes the characteristics of acid mine drainage, similar to that of the underlying mine void. Filling the pits with tailings would therefore reduce the groundwater recharge thereby reducing decant and subsequent water treatment costs.

The reprocessed tailings is treated with lime in the metallurgical plant and is generally deposited at high pH values (around 10 – 11). This is expected to have a positive impact in the groundwater quality as the pH of the mine void will increase and precipitate the dissolved metals. As described in the water quality section above, the mine void represent poor water quality of pH less than 5 up until 2012. This has been improving since then to its current value of 6.5. This is likely to be due to the alkaline slurry deposited from the reclaimed TSFs from the nearby mines and is one of the positive impacts associated with the discharging of alkaline tailings into the pits, as this would mean that dissolved metals will precipitate.

The deposition of the slurry is, however, expect to increase the salt load which overall has a negative impact.

During the operational phase, water will be added to the pits in the tailings slurry. This will result in an increase in the pits and mine void water levels. As the pits are filled with tailings slurry, water levels in the pits will be higher than the surrounding groundwater level. This is however expected to only be in the short-term if a 1:1 ratio to the amount of slurry deposited. The pumping will potentially take place from 17 Winze or 8 East Shaft with the intent of maintaining the groundwater level and the abstracted water will be used for the reclamation of the old TSFs.

7.2.1.2. Management Actions

After the pits are completely backfilled and rehabilitated, they will be shaped in a way that runoff is maximised and pooling of rainwater is minimised. This will reduce the seepage of water into the aquifers. This also applies to the new TSF.

- The new TSF should be constructed with interception drains on its perimeter, within 50 m of the TSF footprint area. This will help to capture seepage leaving the TSF in the topsoil/weathered aquifer. The depth of the trench will depend on the soil profile that can be excavated but is expected to be up to 3 m deep
- Minimise ponding of water within the reclamation area by shaping the backfilled pit and TSF to enhance runoff rather than pooling on top;
- Ensuring that the deposited tailings is alkaline;
- In line with the Cyanide Code: Standard of Practice No. 4.4, ensure that WAD cyanide concentration of 50 mg/l WAD cyanide is not exceeded in any open TSF or pit water.

- Minimise area of disturbance to avoid AMD at multiple places.
- Monitoring of groundwater quality and water levels;
- Abstract equal volume of water from 9 Shaft (which is connected with the pits) to ensure that the water level or decant rate does not increase; and
- The abstracted water can be used for the reclamation of the tailings or discharged to the environment after treatment.

7.2.1.3. Impact Ratings

The predicted contamination plume at the end of operation is displayed in Figure 7-1. The potential impacts associated with the reclamation of the TSF are provided in Table 7-4.

Table 7-4: Potential impact during the operation phase due to hydraulic reclamation process

Dimension	Rating	Motivation	Significance
Impact Description: Groundwater contamination due to seepage during hydraulic re-mining			
Prior to mitigation/ management			
Duration	Project Life (5)	Acid mine drainage can be generated and heavy metals can be mobilised. This is likely to persist throughout the life of operation	Minor (negative) – 54
Extent	Local (3)	The pollution plume is expected to be local laterally, but with a potential of migrating vertically to the underground mines	
Intensity	Moderate (3)	The area is already contaminated. The existence of dolomite is also beneficial to buffer the acid generated. The centre of the tailings dam is probably alkaline and will not become acidic if it is removed quickly.	
Probability	Almost certain (6)	AMD generation is during the reclamation process and tailings disturbance is almost certain	
Nature	Negative		
Mitigation/ Management actions			
▪ Monitoring of groundwater quality and water levels. ▪ Minimise ponding of water within the reclamation area.			

Dimension	Rating	Motivation	Significance
▪ Minimise area of disturbance to avoid AMD at multiple places.			
Post- mitigation			
Duration	Project Life (5)	Contamination due to the hydraulic reclamation will persist during the life of mine	Negligible (negative) – 24
Extent	Limited (2)	With the reclamation from one end of the TSF, instead of multiple areas is likely to render AMD generation at controlled sites only	
Intensity	Minimal (1)	Once the AMD generation is controlled, the environmental impact in the area that is already contaminated is expected to be minimal	
Probability	Unlikely (3)	Impact to the groundwater outside the TSF areas is unlikely	
Nature	Negative		

The potential impacts associated with the in-pit deposition are given in Table 7-5.

Table 7-5: Potential impact during the operation phase due to pit deposition

Dimension	Rating	Motivation	Significance
Impact Description: Impact on the groundwater due to pit deposition			
Prior to mitigation/ management			
Duration	Project Life (5)	Contaminants will be added as part of the slurry throughout the life of mine The water level is expected to increase due to the pit deposition throughout the life of mine	Minor (negative) – 45
Extent	Local (3)	The impact is expected to be local	
Intensity	Minimal (1)	The intensity is rated as minimal since the area is already contaminated. In fact, the reprocessed tailings is alkaline pH and is expected to have a positive impact as it will neutralise the acidic mine water, but the salt load is expected to increase.	

Dimension	Rating	Motivation	Significance
Probability	Likely (5)	The salt load of the mine void water is likely to increase	
Nature	Negative		
Mitigation/ Management actions			
▪ Monitoring of groundwater quality and water levels; ▪ Ensuring that the deposited tailings is alkaline; ▪ In line with the Cyanide Code: Standard of Practice No. 4.4, ensure that WAD cyanide concentration of 50 mg/l WAD cyanide is not exceeded in any open TSF or pit water. ▪ Abstract equal volume of water from 17 Winze (which is connected with the pits) to ensure that the water level or decant rate does not increase; ▪ The abstracted water can be used for the reclamation of the tailings or discharged to the environment after treatment.			
Post- mitigation			
Duration	Project Life (5)	Contamination due to the hydraulic reclamation will persist during the life of mine	Negligible (negative) – 32
Extent	Limited (2)	The impact is expected to be local The rise in water level is expected to only be in the immediate vicinity of the pits	
Intensity	Minimal (1)	Impact will be underneath the TSF only due to the dolomitic nature and vertical hydraulic gradient No impact on the water level or decant rate is expected with the abstraction of equal volume of water	
Probability	Probable (4)	The impact is likely to occur even with the above proposed mitigation measures	
Nature	Negative		

The potential impacts associated with the new TSF deposition are given in Table 7-6.

Table 7-6: Potential impacts during the operation phase due to the new TSF

Dimension	Rating	Motivation	Significance
Impact Description: Seepage from the TSF			

<table>
<tr><th>Dimension</th><th>Rating</th><th>Motivation</th><th>Significance</th></tr>
<tr><td colspan="4">Prior to mitigation/ management</td></tr>
<tr><td>Duration</td><td>Permanent (7)</td><td>If unmitigated, seepage of contaminated water will occur for a prolonged period</td><td rowspan="5">Moderate (negative) – 84</td></tr>
<tr><td>Extent</td><td>Local (3)</td><td>The impact will be local and within 2 km of the TSF footprint area.</td></tr>
<tr><td>Intensity</td><td>Serious (4)</td><td>Once contamination starts, it will be irreversible, as it will pollute the nearby streams and rivers</td></tr>
<tr><td>Probability</td><td>Almost likely (6)</td><td>Seepage from the new TSF will impact the groundwater environment. However, it should be noted that the area is not a greenfield area and is already contaminated from historical TSFs</td></tr>
<tr><td>Nature</td><td>Negative</td><td></td></tr>
<tr><td colspan="4">Mitigation/ Management actions</td></tr>
<tr><td colspan="4">
The TSF will be rehabilitated concurrently with vegetation to minimise infiltration.
The TSF will be shaped in a way that runoff is maximised and pooling of rainwater is minimised.
The new TSF should be constructed with interception drains on its perimeter, within 50 m of the TSF footprint area. This will help to capture seepage leaving the TSF in the top soil/weathered aquifer. The depth of the trench will depend on the soil profile that can be excavated but is expected to be up to 3 m deep.
Ensuring that the deposited tailings is alkaline;
In line with the Cyanide Code: Standard of Practice No. 4.4, ensure that WAD cyanide concentration of 50 mg/l WAD cyanide is not exceeded in any open TSF or pit water.
Monitoring of groundwater quality and water levels;
Compensation of farmers with impacted groundwater, where applicable.
</td></tr>
<tr><td colspan="4">Post- mitigation</td></tr>
<tr><td>Duration</td><td>Permanent (7)</td><td>Seepage could potentially impact the nearby streams and rivers permanently</td><td rowspan="2">Minor (negative) – 65</td></tr>
<tr><td>Extent</td><td>Local (3)</td><td>With the application of the interception drains, some reduction is expected on the aquifer and stream contamination.</td></tr>
</table>

Dimension	Rating	Motivation	Significance
Intensity	Moderate (3)	The interception drains will minimise seepage but will not stop vertical seepage, unlike liners or underdrains	
Probability	Likely (5)	Impact to the groundwater is likely to occur as interception drains will not stop the seepage completely.	
Nature	Negative		

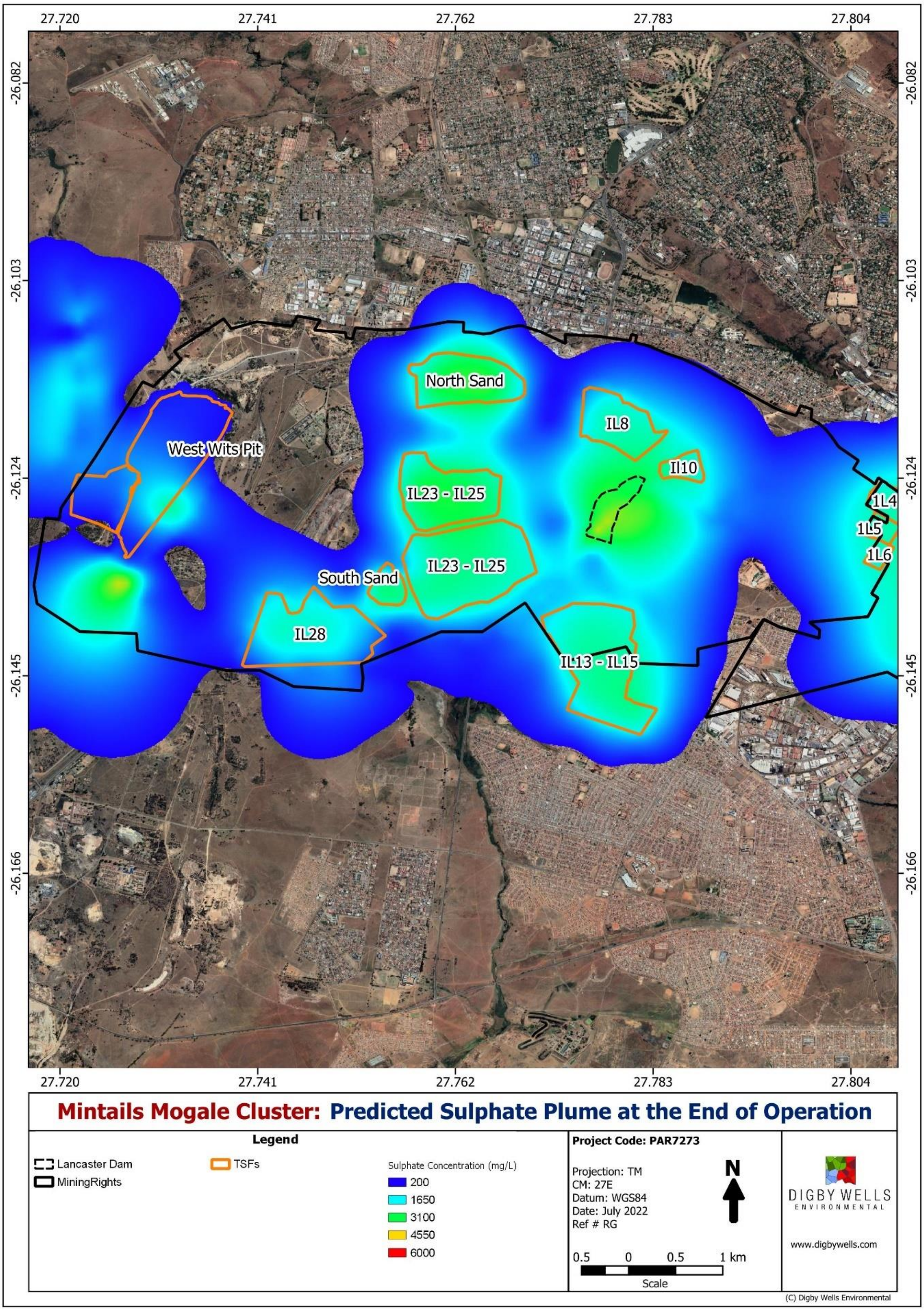


Figure 7-1: Predicted sulphate plume at the end of operation

7.3. Decommissioning Phase

The interactions and potential impacts after the TSF reclamation is listed in Table 7-7.

Table 7-7: Interactions and impacts after the TSF reclamation

Interaction	Impact
Removal of the historical TSFs	No seepage and AMD drainage
Pit rehabilitation	No seepage from the pits Decrease of decant rate
New TSF	Seepage and AMD drainage

7.3.1. Impact Description

7.3.1.1. Management Objectives

The impact as a result of the reclamation is anticipated to be positive after closure. This is due to the removal of the TSFs, which are sources of contamination.

As discussed above, the old TSFs are not lined, and seepage is expected to drain into the underlying groundwater system. Seepage from the TSFs would impact the water quality negatively. This implies that if infiltration of tailings seepage can be reduced, the contaminant loads will be less from a pollution perspective and decant rates will be less.

After the pits have been backfilled, the tailings will be left to dewater and consolidate. The tailings backfill should be domed, shaped, profiled and capped with a soil/weathered material layer that will prevent ponding and minimise infiltration of rainwater. The recharge from the pits to the underground mine void will be significantly less than the recharge prior to backfilling. During this period sulphide oxidation and AMD formation is expected to be limited significantly as a result of the soil cap that excludes exposure of the deposited tailings to atmospheric oxygen.

The filling of the underground mine void will also minimise the volume available for decant, meaning that the decant rate will be minimised.

The predicted contamination plumes 50 and 100 years after mine closure are displayed in Figure 7-2 and Figure 7-3.

7.3.1.2. Management Actions

- Monitoring of groundwater quality and water levels;
- Rehabilitation of old TSF footprints; and
- Rehabilitation of the pits by properly shaping and capping with a soil/weathered material layer that will prevent ponding and minimise infiltration of rainwater.

7.3.1.3. Impact Ratings

The potential impacts associated with the reclamation of the TSF are provided in Table 7-8.

Table 7-8: Potential impacts after closure due to the removal of the historical TSFs

Dimension	Rating	Motivation	Significance
Impact Description: Impact on groundwater contamination due to re-mining of the old TSFs			
Prior to mitigation/ management			
Duration	Permanent (7)	Seepage of contaminated water will permanently be removed	Moderate (positive) – 105
Extent	Local (3)	The impact is expected to be local as the site is already contaminated	
Intensity	Serious (5)	There will be significant environmental advantages when the unlined TSF is removed	
Probability	Definite (7)	There are sound scientific reasons to expect that the positive impact will definitely occur	
Nature	Positive		
Mitigation/ Management actions			
▪ Monitoring of groundwater quality and water levels; and ▪ Rehabilitation of old TSF footprints.			
Post- mitigation			
Duration	Permanent (7)	The source of the contamination plume will be permanently removed	Moderate (positive) – 105
Extent	Local (3)	The impact is expected to be local as the area is already contaminated	
Intensity	Serious (5)	There are positive environmental advantages once the unlined TSF is removed	
Probability	Definite (7)	There are sound scientific reasons to expect that the positive impact will definitely occur	
Nature	Positive		

The potential impacts associated with the closure of the pits are given in Table 7-9.

Table 7-9: Potential impacts after closure due to pit rehabilitation

Dimension	Rating	Motivation	Significance
Impact Description: Impact on groundwater contamination			
Prior to mitigation/ management			
Duration	Permanent (7)	When the pits are completely filled, there will be no source of AMD ingress into the underground	Moderate (positive) – 78
Extent	Local (3)	The impact is expected to be local as the site is already contaminated and improvement in the pit recharge quality will only have a local extent	
Intensity	Moderate (3)	The backfilling of the pits will reduce recharge of poor quality and will have positive environmental significance	
Probability	Highly probable (6)	The closure of the pits will definitely have a positive impact	
Nature	Positive		
Mitigation/ Management actions			
▪ Monitoring of groundwater quality and water levels; and ▪ Rehabilitation of the pits by properly shaping and capping with a soil/weathered material layer that will prevent ponding and minimise infiltration of rainwater.			
Post- mitigation			
Duration	Permanent (7)	The source of the contamination plume and groundwater ingress will be permanently removed	Moderate (positive) – 98
Extent	Local (3)	The impact is expected to be local as the sites are already contaminated	
Intensity	Moderate (4)	The rehabilitation and vegetating of the pits will have a positive impact of moderate intensity	
Probability	Definite (7)	The closure and rehabilitation of the pits will definitely have a positive impact	
Nature	Positive		

The potential impacts associated with the closure of the new TSF is given in Table 7-10.

Table 7-10: Potential impacts after closure due to the new TSF

Dimension	Rating	Motivation	Significance
Impact Description: groundwater contamination due to seepage from the new TSF			
Prior to mitigation/ management			
Duration	Permanent (7)	Seepage of contaminated water even after mine closure	Moderate (negative) – 107
Extent	Local (3)	The impact will be local and within 2 km of the TSF footprint area. The nearby Wonderfonteinspruit and its tributaries could be impacted	
Intensity	Serious (5)	Once contamination starts, it will be irreversible	
Probability	Definite (7)	Seepage from the unlined TSF will impact the groundwater	
Nature	Negative		
Mitigation/ Management actions			
• The TSF will be rehabilitated with vegetation to minimise infiltration. • The TSF will be shaped in a way that runoff is maximised and pooling of rainwater is minimised. • Monitoring of groundwater quality and water levels; • Compensation of farmers with impacted groundwater, where applicable.			
Post- mitigation – New TSF			
Duration	Permanent (7)	The contamination plume will be permanent	Moderate (negative) – 84
Extent	Local (3)	With the application of the mitigation measures, such as revegetation and shaping of the TSF to minimise infiltration, the plume in the aquifer is expected to be local, within 1 km. This can also affect the local streams that are fed by the groundwater.	
Intensity	Serious (4)	It may not be practical to maintain and operate interception drains after mine closure. Seepage from the aquifer is likely to impact the aquifers and streams.	

Dimension	Rating	Motivation	Significance
Probability	Almost certain (6)	Seepage from the unlined TSF with no underdrains will impact the aquifers and nearby streams.	
Nature	Negative		

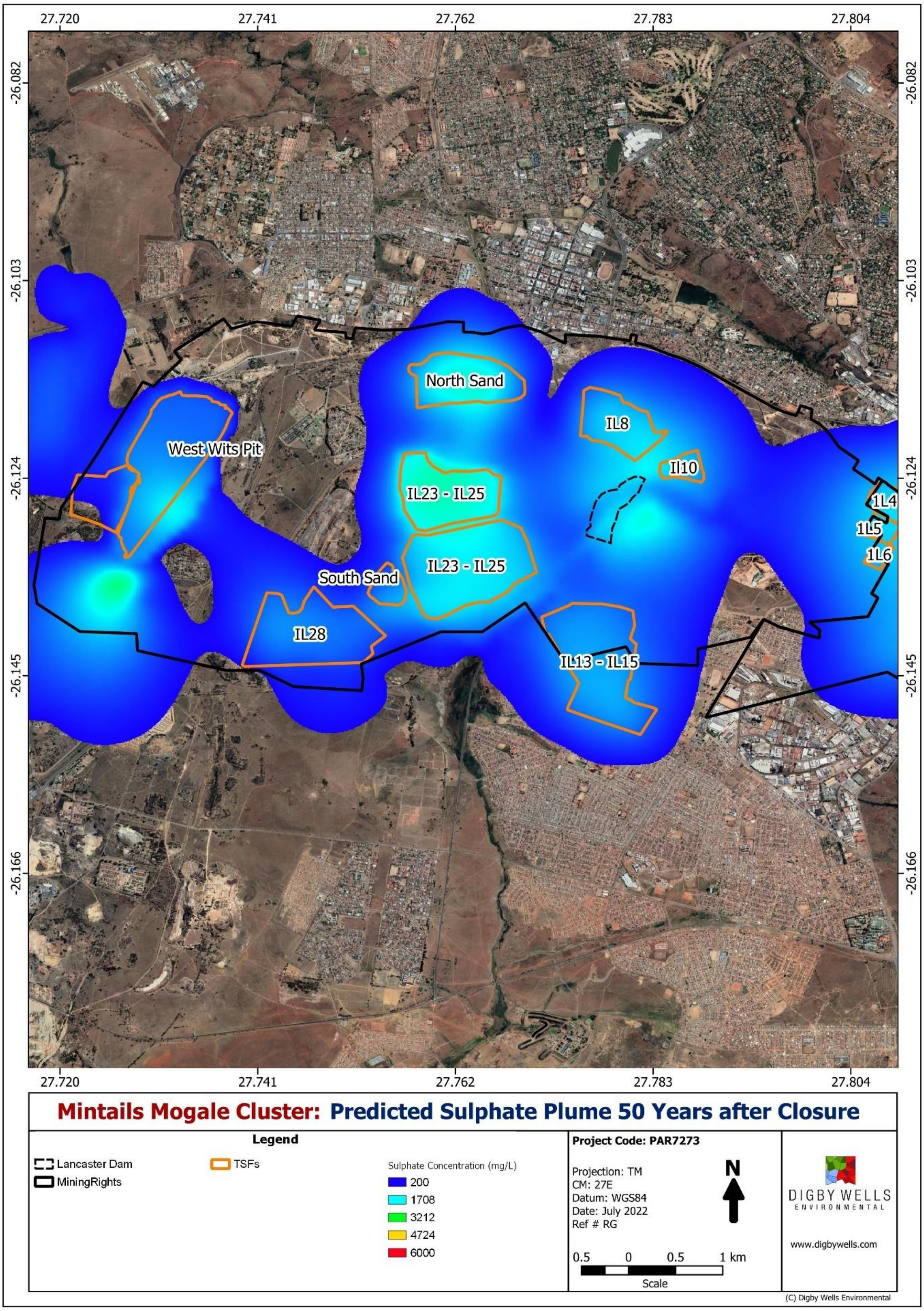


Figure 7-2: Predicted sulphate plume 50 years after closure

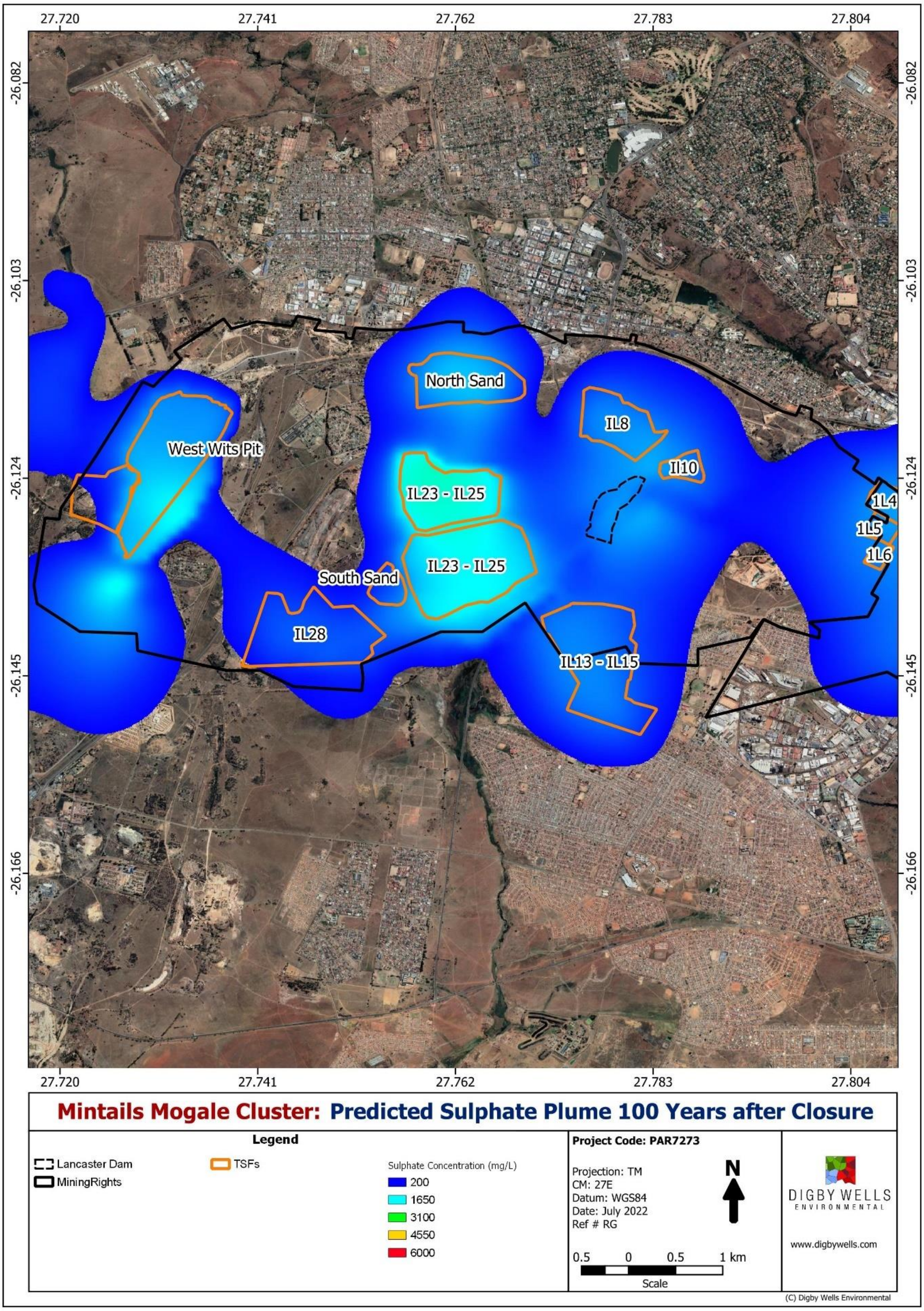


Figure 7-3: Predicted sulphate plume 100 years after closure

7.4. Cumulative Impacts

There are a few municipal waste dump, sewage wastewater treatment plants and mines operating in West Rand. Sources of future surface and groundwater impacts in the affected catchments will therefore not be from the old TSFs reclamation only.

The current water qualities of the Tweelopiespruit and the Wonderfonteinspruit are poor. This is mainly due to decant from the old mine workings, seepage from the unlined TSFs and also discharge of partially treated mine water. There is also a Waste Water Treatment Plant that discharges into the catchments and this could possibly have contributed onto the existing water quality status.

The closure and rehabilitation of the old TSFs and surrounding pits will definitely have a positive impact on the surface and groundwater environment. However, a rehabilitation strategy that encompasses the nearby mines and municipal treatment activities is required for a lasting improvement with a regional footprint.

7.5. Unplanned and Low Risk Events

The unplanned event that may happen at the project site and the proposed mitigation plan are listed in Table 7-11.

Table 7-11: Unplanned Events and Associated Mitigation Measures

Unplanned Risk	Mitigation Measures
Hydrocarbon spillage and spillages from pipelines, and pump station	• It is recommended that diesel or other chemicals be used without spillage, and machinery should be properly maintained. • Fuel and oil reservoirs must be in a bunded area. • If a considerable amount of fluid is accidentally spilled, the contaminated soil should be scraped off and disposed of at an acceptable dumping facility. The excavation should be backfilled with soil of good quality. • Monitoring of pipelines for seepage should be conducted. Seeping pipeline should be sealed. • Monitoring boreholes, particularly those located within the environs of the Mintails Mogale Cluster and pits have to be monitored for both water level and quality.

8. Environmental Management Plan

Table 8-1: Environmental Management Plan

Activity/ies	Potential Impacts	Aspects Affected	Phase	Mitigation Measure	Mitigation Type	Time period for implementation
• Site clearing; • Construction of the surface infrastructure (installation of pipelines, access roads, site clearing and storm water trenches)	Reduction of groundwater quality	Groundwater quality	Construction	• Restrict areas that must be cleared of vegetation for construction activities to those absolutely necessary; • Avoid constructing below the water table as far as possible; • Apply a liner underneath the PCD to minimise or avoid infiltration; • Implementation of adequate storm water management to contain all waste water and/or volatile organic compounds, for treatment and recycling; and • Install long term monitoring boreholes.	• Control by minimising disturbed area. • Maximizing the re-use of contaminated water instead of discharging it	Throughout the construction phase
• Hydraulic reclamation • Tailings exposure to oxygen and water • Pump station or pipelines • Pit deposition	• Seepage through the TSF of the water to be used for hydraulic reclamation inside the foot print • Acid mine drainage • Slime or process spillage from pump station or pipeline • Rising of water level in the vicinity of the pits • Increase of decant rates • Deterioration of groundwater quality	Groundwater quality and quantity	Operation	• Minimise ponding of water within the reclamation area; • Ensuring that the deposited tailings is alkaline; • In line with the Cyanide Code: Standard of Practice No. 4.4, ensure that WAD cyanide concentration of 50 mg/l WAD cyanide is not exceeded in any open TSF or pit water. • Minimise area of disturbance to avoid AMD at multiple places. • Monitoring of groundwater quality and water levels; • Abstract equal volume of water from 9 Shaft (which is connected with the pits) to ensure that the water level or decant rate does not increase; and • The abstracted water can be used for the reclamation of the tailings or discharged to the environment after treatment.	• Controlling by minimising disturbed area • Treating the processed slurry to destroy cyanide by rendering it alkaline	Throughout the operational phase

Activity/ies	Potential Impacts	Aspects Affected	Phase	Mitigation Measure	Mitigation Type	Time period for implementation
• TSF removal • Pit rehabilitation	• No seepage and AMD drainage • No seepage from the pits • Decrease of decant rate	Groundwater quality and decant volumes	Closure	• Rehabilitation of old TSF footprints; • Rehabilitation of the pits by properly shaping and capping with a soil/weathered material layer that will prevent ponding and minimise infiltration of rainwater. • Monitoring of groundwater quality and water levels.	• Active intervention and rehabilitation	During the closure phase

9. Monitoring Programme

A monitoring programme is essential as a management tool to detect negative impacts as they arise and to ensure that the necessary mitigation measures are implemented. It also ensures that storm water management structures are in working order. Available information shows that no monitoring works has been conducted since 2018.

Monitoring needs to start immediately and has to continue monitoring to identify the potential impact on the groundwater on time, and effective measures can be undertaken at the early stage before serious damage to the environment takes place.

9.1. Monitoring Boreholes

The main objective in positioning the monitoring boreholes is to intersect contaminated groundwater and record the water levels that will affect mine decant. The positions of the recommended monitoring points are listed in Table 9-1 and displayed in Figure 9-1.

The monitoring points consist of:

- 24 existing shallow and deep boreholes
- 7 additional new boreholes in areas where there is scarcity of monitoring data. The location of these boreholes was refined following the outcome of the resistivity survey result (Appendix C).

Table 9-1: Coordinates of the proposed monitoring points

Borehole ID	X	Y	Depth (m)	Status	Comment
LPVBH1S	27.7824512	-26.1235432	20	Newly drilled	Luipaardsvlei waste site, shallow aquifer
LPVBH1D	27.78258735	-26.1235709	60	Newly drilled	Luipaardsvlei waste site, deep aquifer
TSFBH1S	27.76942403	-26.1392363	30	Newly drilled	IL13-IL15 TSF, shallow aquifer
NSBH1S	27.76525697	-26.1095405	30	Newly drilled	North Sand, shallow aquifer, flowing to Mogale City
NSBH1D	27.76526706	-26.1095031	60	Newly drilled	North Sand, deep aquifer, flowing to Mogale City
BH68S	27.7624177	-26.1477655	20	Newly drilled	Shallow aquifer, drainage of the Wonderfontein Spruit
BH68D	27.76260232	-26.1481347	60	Newly drilled	Deep aquifer, drainage of the Wonderfontein Spruit
17 Winze	27.72161667	-26.1214167	NA	Existing monitoring point	Shaft
18 Winze	27.72488611	-26.1151389	NA	Existing monitoring point	Shaft
8 Shaft	27.71948611	-26.1353944	NA	Existing monitoring point	borehole
9 Shaft	27.72021758	-26.1313806	NA	Existing monitoring point	borehole
BH1A	27.75218	-26.12966	NA	Existing monitoring point	Shaft
BH1B	27.75227	-26.12968	NA	Existing monitoring point	borehole
BH3	27.75069	-26.14407	NA	Existing monitoring point	borehole
BH4	27.74688	-26.14395	NA	Existing monitoring point	borehole

Borehole ID	X	Y	Depth (m)	Status	Comment
BH5	27.74957	-26.13228	NA	Existing monitoring point	borehole
GAA4D	27.78488	-26.1187	33.85	Existing monitoring point	borehole
GW3	27.74386	-26.14427	NA	Existing monitoring point	borehole
GW5	27.7555	-26.1398	38.46	Existing monitoring point	borehole
MABH5S	27.75187	-26.13506	35.67	Existing monitoring point	borehole
MABH6S	27.75573	-26.13371	15.13	Existing monitoring point	borehole
MABH9	27.76494	-26.13882	16.33	Existing monitoring point	borehole
MGP11D	27.7931	-26.133317	30	Existing monitoring point	borehole
MGP11S	27.793217	-26.133233	20	Existing monitoring point	borehole
MGP3	27.72285	-26.10804	NA	Existing monitoring point	borehole
MGP4	27.7326	-26.13133	NA	Existing monitoring point	borehole
MGP6	27.771606	-26.144186	50.16	Existing monitoring point	borehole
MGP8D	27.765317	-26.137633	60	Existing monitoring point	borehole
MGP9D	27.777183	-26.131767	60	Existing monitoring point	borehole
MGP9S	27.7769	-26.131833	20	Existing monitoring point	borehole
PBH4	27.72717	-26.13294	55	Existing monitoring point	Shaft

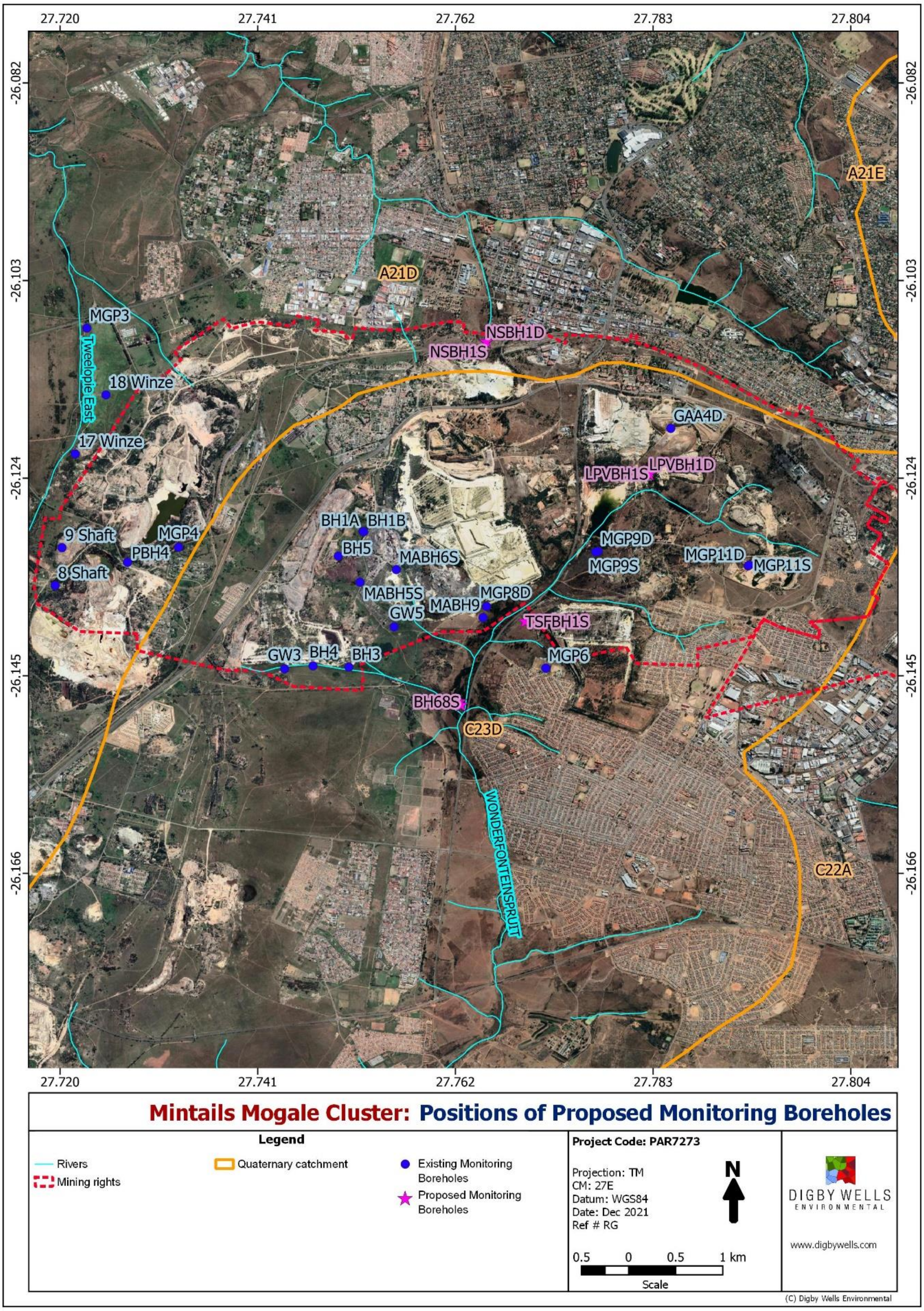


Figure 9-1: Proposed monitoring points

9.2. Groundwater Level

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

9.3. Water Sampling

Groundwater is a slow-moving medium and drastic changes in the groundwater composition are not normally encountered within days. Due to the proximity of residential houses and streams to the TSFs, monitoring should be conducted monthly.

Samples should be collected by an independent groundwater consultant, using best practice guidelines and should be analysed by a SANAS accredited laboratory. Both water levels and qualities should be interpreted and a monitoring report compiled on quarterly basis.

After mine closure, monitoring should continue until steady sate condition prevails, or at least for 3 years.

The sampling frequency and parameters to be analysed are summarised in Table 9-2.

9.4. Data Storage

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

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

Table 9-2: Groundwater monitoring guideline

Monitoring Element	Comment	Frequency	Responsibility
Groundwater	• Ensure water quality monitoring as per sampled and proposed monitoring locations • Parameters should include but not limited to pH; Electrical Conductivity; Sulphate; major cations (K, Ca, Mg & Na); trace metals (Al, Fe, Zn, Cu, Mn, Co, Se, Mo, Cd, Ni, Cr (VI), Pb, Hg & As); Anions (NO_3, NO_2, NH_4, Cl, F, PO_4); Total Dissolved Solids; Total Suspended solids.	• Monthly monitoring during construction, operation, and until steady state is reached after closure (at least for 3 years.	• Environmental Officer

Monitoring Element	Comment	Frequency	Responsibility
	• It is also recommended to monitor water quality within the mine water dams or water containment facilities to determine the concentration levels in case of an overflow or need for discharge.	• Data should be interpreted quarterly.	

10. Stakeholder Engagement Comments Received

Please refer to the Comments and Response Report, attached as Appendix C of the EIA Report for comments raised and responses provided.

11. Recommendations

The following recommendations have been made:

- Groundwater quality in the West Wits area is based on monitoring conducted pre-2017 and may not be representative of the current water quality. With the ongoing treatment activities at 9 Shaft, the groundwater quality could have improved in the recent years. TCTA monitoring data and water management plans should be made available during this study to confirm this.

Other recommendations that will be useful to mitigate environmental impacts during the construction, operation and closure of the mine include:

- After the pits are completely backfilled and rehabilitated, they will be shaped in a way that runoff is maximised and pooling of rainwater is minimised. This will reduce the seepage of water into the aquifers. This also applies to the new TSF as well as the TSF that will be constructed at the WWP.
- The new TSF should be constructed with interception drains within 50 m of the TSF footprint area. The trenches should be deep to penetrate the topsoil/weathered rock.
- Ensuring that the deposited tailings is alkaline;
- In line with the Cyanide Code: Standard of Practice No. 4.4, ensure that WAD cyanide concentration of 50 mg/l WAD cyanide is not exceeded in any open TSF or pit water.
- Minimise area of disturbance to avoid AMD at multiple places.
- Monitoring of groundwater quality and water levels.
- Abstract equal volume of water from 9 Shaft (which is connected with the pits) to ensure that the water level or decant rate does not increase.
- The abstracted water can be used for the reclamation of the tailings or discharged to the environment after treatment.

- Monitoring of groundwater quality and water levels.
- Rehabilitation of old TSF footprints.
- Rehabilitation of the pits by properly shaping and capping with a soil/weathered material layer that will prevent ponding and minimise infiltration of rainwater.
- The average groundwater flux (Darcy velocity) along the weathered zone is in the order of mm/year at the project site. This is not unusual rate for groundwater, but it means that, even if the tailings are removed, it will take decades for the plume that is already existing on site to be flushed away under natural groundwater flow. One option of enhancing the removal of the plume is to pump and treat the polluted water from boreholes.

12. Reasoned Opinion Whether Project Should Proceed

There are significant environmental advantages if the project proceeds.

The historical TSFs are impacting the groundwater environment. This will be significantly mitigated if the project proceeds.

Existing pits, which are infiltration zones into the mine voids will be rehabilitated if the project proceeds. The existing unlined TSFs will be reclaimed and a new TSF will be constructed to handle the final residue.

It is the professional opinion of the hydrogeologist involved in this project that the project should proceed.

13. Conclusion

This hydrogeological specialist study is conducted to evaluate the baseline groundwater conditions. The potential impacts (negative or positive) of the proposed mining activities are also assessed and optimum mitigation measured proposed.

The hydrogeological study is conducted following a desktop study, hydrocensus, water quality sampling, geophysical surveying and conceptual modelling. This study will be updated following additional hydrogeological investigations including borehole drilling, aquifer testing and numerical modelling.

There are four aquifer layers at the project site: the top weathered aquifer, the fractured aquifer, the dolomitic aquifer and the mine void aquifer.

The shallow aquifer is in direct contact with the unlined TSFs and is vulnerable to contamination due to seepage. Many of the shallow boreholes (less than 30 m deep) are highly contaminated with sulphate reaching up to a maximum of 6000 mg/L. This is significantly higher than the 400 mg/L drinking standards (SAWQG, 1998). The TSFs are unlined and are rich with pyrite and are exposed to oxidation reaction which results in acidic (low pH) solution. As rainfall infiltrates through the tailings, the acidic water infiltrates to the shallow aquifer, dissolving and transporting Fe, Mn and other metals on its way.

The fractured aquifer and dolomitic aquifers are generally clean from contamination. Once the shallow aquifer is contaminated from the TSF seepage, the groundwater dominantly flows laterally towards the local streams and rivers. Unless there are sub-vertical permeable structures connecting the fractured aquifer with the shallow aquifer, the contamination plume is mostly restricted in the shallow aquifer and the streams. The sulphate level in the fractured and dolomitic aquifers are less than 150 mg/L.

The water quality of all the shafts is similar as they are interconnected. The mine void quality has been improving continuously from approximately 4000 mg/L in 2009 to 648 mg/L in 2021. Dissolved metals and TDS have also shown similar trends. The TCTA and DWS treatment activities seem to be playing a major role on this.

The groundwater elevation in the top weathered aquifer is not connected with the mine void, as it mimics the topography. The flow direction follows the topography and is towards the local streams.

The hydraulic head and groundwater flow direction in the mine void is controlled by the decant, abstraction that is taking place at 9 Shaft, mine interconnectivity, and geological structures connecting the mine void with the shallow aquifer. When mining was discontinued in the area, the defunct workings started to flood and, in September 2002, the mine water started to decant at the Black Reef Incline next to the Tweelopie East Stream. The decant point, referred to as the Black Reef Incline (BRI), is at an elevation of 1662.98 m amsl. This decant is currently under control with the ongoing pump and treat taking place from 9 shaft.

The historical TSFs in the region are not lined and seepage is contaminating the underlain aquifer. The current hypothesis is that if there were no TSFs located directly over the mine void, dolomite and fractured aquifers, the current decant volume would have decreased, and it is likely that the dolomitic water pumped from the underground chambers would be of better quality than the current status. In addition, the pumping and treatment cost would be substantially less if the TSFs seepage portion could be eliminated.

Further to this, infiltration from the TSFs will be reduced if the tailings are removed from surface, the contaminant loads will be less from a pollution perspective. At present, the presence of the TSFs and the continued dewatering activities in the compartment will encourage continued infiltration of seepage to the deeper aquifer units, the consequent deterioration of water quality, increased decant rates and increased volumes of water to be pumped from the underground chambers.

The long-term impact as a result of the reclamation operations at the TSFs is therefore anticipated to be positive since the TSFs, which are a source of contamination, will be removed. In the short-term, however, the hydraulic reclamation could result in the partial seepage through the TSFs. The exposure of the tailings to oxygen and water can result in AMD.

The reprocessed tailings is treated with lime in the metallurgical plant and is generally deposited at high pH values (around 10 – 11). This is expected to have a positive impact in the groundwater quality as the pH of the mine void will increase and precipitate the dissolved metals. The deposition of the slurry is, however, expect to increase the salt load which overall has a negative impact.

The impact as a result of the reclamation is anticipated to be positive after closure. This is due to the removal of the TSFs, which are sources of contamination.

14. References

Bliss, J., Rushton, K. (1984). The reliability of packer tests for estimating the hydraulic conductivity of aquifers. Q. J. Eng. Geol. Vol. 17, pp. 81-91.

Borralho, C. (2014). "Central basin pumps set to solve AMD issue." Retrieved 27-04-2016, 2016, from http://www.miningweekly.com/article/central-basin-pumps-set-to-solve-amd-issue-2014-05-02.

Bredenkamp DB, Van der Westhuizen C, Wiegmans FE and Kuhn CM (1986). Groundwater Supply Potential of Dolomite Compartments West of Krugersdorp. Technical Report No. GH3440. Directorate of Geohydrology, Department of Water Affairs.

DEA, 2013a, National Norms and Standards for the Assessment of Waste for Landfill Disposal. Department of Environmental Affairs.

DEA, 2013b, National Norms and Standards for the Assessment of Waste for Landfill Disposal. Department of Environmental Affairs.

DEA, 2013c, National Waste Classification and Management Regulations. Department of Environmental Affairs.

DEA, 2012, National of Waste Information Regulations, 2012. Department of Environmental Affairs.

Digby Wells Environmental (2015), Sibanye Gold Limited: Environmental Impact Assessment for Sibanye Gold Limited's West Rand Tailings Retreatment Project.

Digby Wells (2012). Groundwater Report For The Gold One Cooke Optimisation Project (Cop).

DWS (2013). Assessment of the Water Quantity and Quality of the Witwatersrand Mine Voids. Study Report No. 5.2, P RSA 000/00/16512/2

Environmental Resources Manage (ERM, 2009), Final Report: Groundwater Investigation for the Gold Fields Centralised Tailings Storage Facility, Prepared for EnviroServe Waste Management (Pty) Ltd.

Ezendalo Environmental Solution (2009). Amendment To Rand Uranium's Environmental Management Programme For The Proposed Millsite Interim Disposal Component Of The Cooke Uranium Project- Pits Deposition (Permit 3a).

Global Acid Rock Drainage Guide (GARD, 2017). http://www.gardguide.com

Golder Associates (2016). Hydrogeological Study for the MinTails MR 132 and MR133 Mining Areas, Submitted to: Mintails Mining SA (Pty) Ltd

Hobbs PJ and Cobbing JE (2007). A Hydrogeological Assessment of Acid Mine Drainage Impacts in The West Rand Basin, Gauteng Province

JFA, 2006. Environmental Impact Document : Proposed Discharge of Treated Mine Water via the Tweelopies receiving Water Body into the Rietriver, Mogale City, Gauteng Province. Final draft for comment before 30 July 2006. Ref. no. DWAF 16/2/7/C221/C/24. Johan Fourie & Associates for Harmony Gold Mining (Ltd). Paardekraal. RSA.

Krantz, R.M. (1999). Conceptual Groundwater Model for the Western Basin. Report submitted on behalf of JCI Projects by RISON Consulting.

Miller, S.D. 1998. Predicting acid drainage. Groundwork, 2 (September), p.8-9. Australian Minerals and Energy Environment Foundation.

Rison (2008). Harmony Gold Limited – Randfontein Operations Groundwater Monitoring.

Parsons CF (1990). Cooke 1 Water Project. Report prepared by the Technical Services Division, Geological Department, Research Unit.

SAWQG (1996). South African Water Quality Guidelines for human drinking.

Truswell J.F. (1977). The Geological Evolution of South Africa. *Purnell & Sons,*

Cape Town.

Umvoto Africa (2013). Numerical Groundwater Modelling for the West Wits Pit – Mogale Gold Mine, Western Basin, Johannesburg

Vegter, J.R. (1995) An Explanation of a set of National Groundwater Maps, Water Research Commission Report No. TT74/95.

Appendix A: Impact Assessment Methodology

Impact identification was performed by using an Input-Output model which serves to guide Digby Wells in assessing all the potential instances of ecological and socio-economic change, pollution and resource consumption that may be associated with the mining operations.

Outputs may generally be described as any changes to the biophysical and socio-economic environments, both positive and negative in nature, and also included the product and anticipated waste produced by the proposed mining activities. Negative impacts could include, dust, noise, vibration, water pollution, safety issues and changes to the bio-physical environment such as destruction of habitats. Positive impacts may include skills transfer or benefits to the socio-economic environment. During the determination of outputs, the effect of outputs on the various components of the environment (e.g. soils and water quality) is considered.

The methodology utilised to assess the significance of potential environmental and social impacts is discussed in detail below. The significance rating formula is as follows:

Significance = Consequence x Probability

Where

Consequence = Type of Impact x (Intensity + Spatial Scale + Duration)

And

Probability = Likelihood of an Impact Occurring

In addition, the formula for calculating consequence:

Type of Impact = ***+1*** *(Positive Impact) or* ***-1*** *(Negative Impact)*

The matrix calculates the rating out of 147, whereby Intensity, Extent, Duration and Probability are each rated out of seven as indicated in Table 14-1. The weight assigned to the various parameters is then multiplied by +1 for positive and -1 for negative impacts.

Impacts are rated prior to mitigation and again after consideration of the mitigation measure proposed. The significance of an impact is then determined and categorised into one of eight categories, as indicated in Table 14-2, which is extracted from Table 14-1. The description of the significance ratings is discussed in Table 14-3.

Table 14-1: Impact Assessment Parameter Ratings

Rating	Severity		Spatial scale	Duration	Probability
	Environmental	**Social, cultural and heritage**			
7	Very significant impact on the environment. Irreparable damage to highly valued species, habitat or eco system. Persistent severe damage. The positive impact will result in a significant improvement to the initial/post disturbance environmental status and will benefit ecological and natural resources.	Irreparable damage to highly valued items of great cultural significance or complete breakdown of social order. The positive impact will be of high significance which will result the improvement of the socio-economic status of a greater area beyond the boundary of the directly affected of the community and/or promote archaeological and heritage awareness and contribute towards research and documentation of sites and artefacts through phase two assessments.	International The effect will occur across international borders.	Permanent: The impact is irreversible, even with management, and will remain after the life of the project.	Definite: There are sound scientific reasons to expect that the impact will definitely occur. >80% probability.
6	Significant impact on highly valued species, habitat or ecosystem. The positive impact is of high significance which will result in a vast improvement to the environment such as ecological diversification and/or rehabilitation of endangered species.	Irreparable damage to highly valued items of cultural significance or breakdown of social order. The positive impact will be of high significance and will result in the upliftment of the surrounding community and/or contribute towards research and documentation of sites and artefacts through phase two assessments.	National Will affect the entire country.	Beyond project life: The impact will remain for some time after the life of the project and is potentially irreversible even with management.	Almost certain/Highly probable: It is most likely that the impact will occur. <80% probability.
5	Very serious, long-term environmental impairment of ecosystem function that may take several years to rehabilitate. The positive impact will be moderately high and will have a long term beneficial effect on the natural environment.	Very serious widespread social impacts. Irreparable damage to highly valued items. The positive impact will be moderately high and will result in visible improvements on the socio-economic environment of the local and regional community, and/or promote archaeological and heritage awareness through mitigation.	Circle/Region Will affect the entire Circle or Region	Project Life (>15 years): The impact will cease after the operational life span of the project and can be reversed with sufficient management.	Likely: The impact may occur. <65% probability.
4	Serious medium term environmental effects. Environmental damage can be reversed in less than a year The positive impact on the environment will be moderate with visible improvement to the natural resources and regional biodiversity.	On-going serious social issues. Significant damage to structures/items of cultural significance The positive impact on the socio-economic environment will be of a moderate extent and benefits should be experience across the local extent and/or potential benefits for archaeological and heritage conservation.	Commune Area Will affect the whole municipal area.	Long term: 6-15 years and impact can be reversed with management	Probable: Has occurred here or elsewhere and could therefore occur. <50% probability.
3	Moderate, short-term effects but not affecting ecosystem functions. Rehabilitation requires intervention of external specialists and can be done in less than a month. The positive impact will be moderately beneficial to the natural environment, but will be short lived.	Ongoing social issues. Damage to items of cultural significance. The positive impact will be moderately beneficial for some community members and/or employees, but will be short lived and/or there will be a moderate possibility for archaeological and heritage conservation	Local. Local extending only as far as the development site area.	Medium term: 1-5 years and impact can be reversed with minimal management.	Unlikely: Has not happened yet but could happen once in the lifetime of the project, therefore there is a possibility that the impact will occur. <25% probability.
2	Minor effects on biological or physical environment. Environmental damage can be rehabilitated internally with/without help of external consultants. The positive impacts will be minor and slight environmental improvement will be visible.	Minor medium-term social impacts on local population. Mostly repairable. Cultural functions and processes not affected. Minor positive impacts on the social/cultural and/or economic environment.	Limited Limited to the site and its immediate surroundings.	Short term: Less than 1 year and is reversible.	Rare/improbable: Conceivable, but only in extreme circumstances. The possibility of the impact materialising is very low as a result of design, historic experience or implementation of adequate mitigation measures. <10% probability.

Rating	Severity		Spatial scale	Duration	Probability
	Environmental	Social, cultural and heritage			
1	Limited damage to minimal area of low significance, (e.g. ad hoc spills within plant area). Will have no impact on the environment. The positive impact on the environment will be insignificant and will not result in visible improvements	Low-level repairable damage to commonplace structures. The positive impact on social and cultural aspects will be insignificant.	Very limited Limited to specific isolated parts of the site.	Immediate: Less than 1 month and is completely reversible without management.	Highly unlikely/None: Expected never to happen. <1% probability.

Table 14-2: Probability / Consequence Matrix

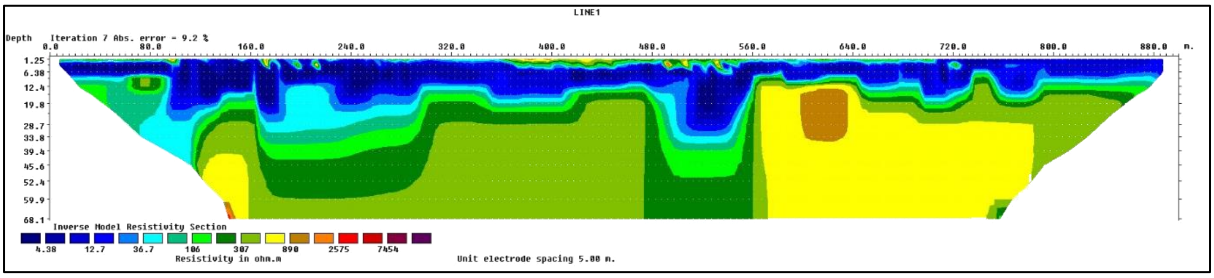
Probability	Significance																																					
7	-147	-140	-133	-126	-119	-112	-105	-98	-91	-84	-77	-70	-63	-56	-49	-42	-35	-28	-21	21	28	35	42	49	56	63	70	77	84	91	98	105	112	119	126	133	140	147
6	-126	-120	-114	-108	-102	-96	-90	-84	-78	-72	-66	-60	-54	-48	-42	-36	-30	-24	-18	18	24	30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

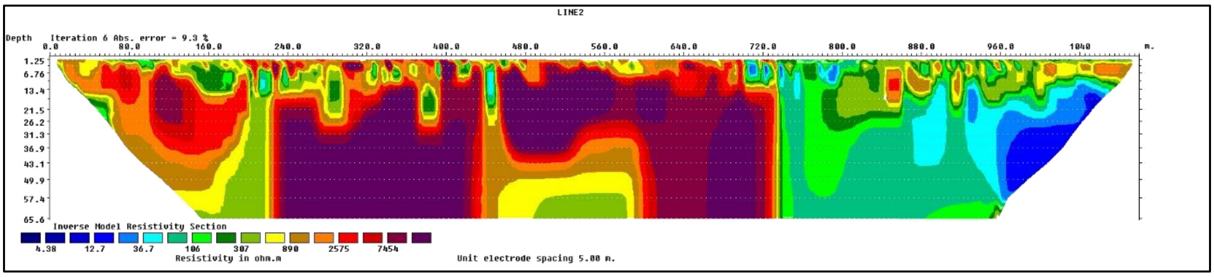
Table 14-3: Significance Ratings

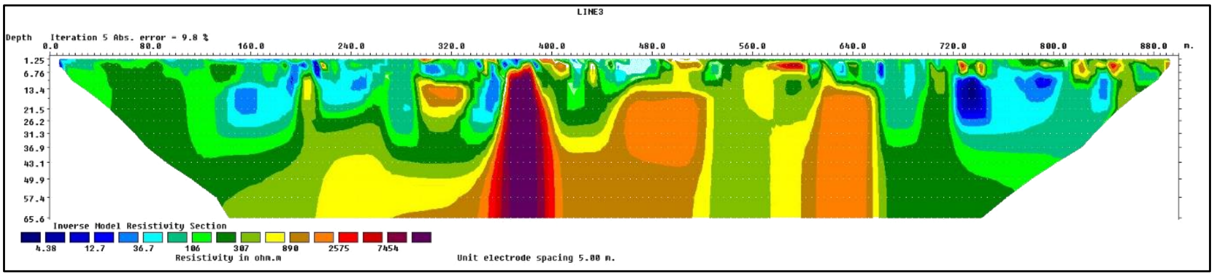
Score	Description	Rating
109 to 147	A very beneficial impact which may be sufficient by itself to justify implementation of the project. The impact may result in permanent positive change.	Major (positive)
73 to 108	A beneficial impact which may help to justify the implementation of the project. These impacts would be considered by society as constituting a major and usually a long-term positive change to the (natural and/or social) environment.	Moderate (positive)
36 to 72	An important positive impact. The impact is insufficient by itself to justify the implementation of the project. These impacts will usually result in positive medium to long-term effect on the social and/or natural environment.	Minor (positive)
3 to 35	A small positive impact. The impact will result in medium to short term effects on the social and/or natural environment.	Negligible (positive)
-3 to -35	An acceptable negative impact for which mitigation is desirable but not essential. The impact by itself is insufficient even in combination with other low impacts to prevent the development being approved. These impacts will result in negative medium to short term effects on the social and/or natural environment.	Negligible (negative)
-36 to -72	An important negative impact which requires mitigation. The impact is insufficient by itself to prevent the implementation of the project but which in conjunction with other impacts may prevent its implementation. These impacts will usually result in negative medium to long-term effect on the social and/or natural environment.	Minor (negative)
-73 to -108	A serious negative impact which may prevent the implementation of the project. These impacts would be considered by society as constituting a major and usually a long-term change to the (natural and/or social) environment and result in severe effects.	Moderate (negative)

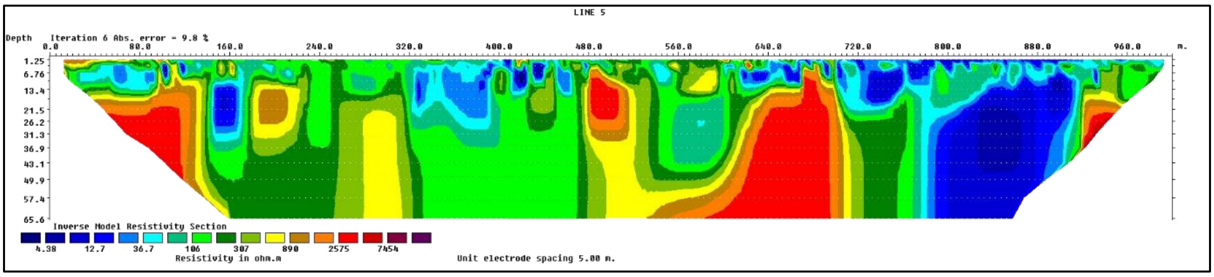
Score	Description	Rating
-109 to -147	A very serious negative impact which may be sufficient by itself to prevent implementation of the project. The impact may result in permanent change. Very often these impacts are immitigable and usually result in very severe effects.	Major (negative)

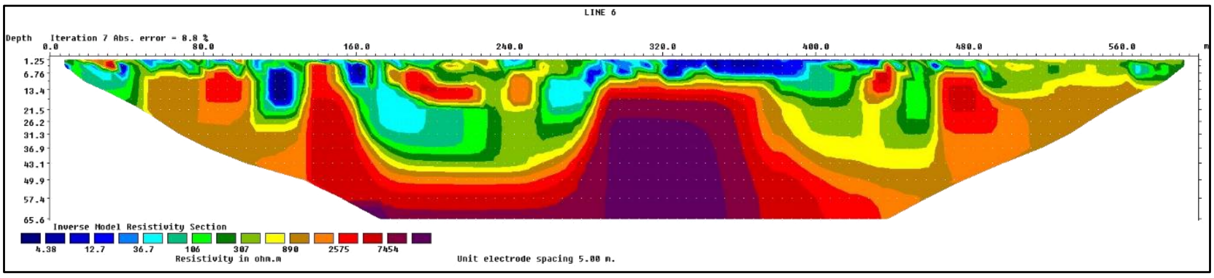
Appendix B:Geophysics Resistivity Results

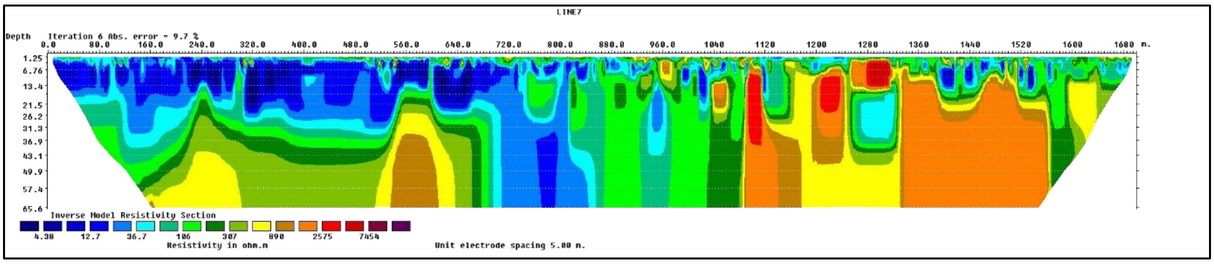

LINE1
Depth
Iteration 7 Abs. error = 9.2 %
0.0
80.0
160.0
240.0
320.0
400.0
480.0
560.0
640.0
720.0
800.0
880.0
m.
1.25
6.38
12.4
19.8
28.7
33.8
39.4
45.6
52.4
59.9
68.1
Inverse Model Resistivity Section
4.38
12.7
36.7
106
307
890
2575
7454
Resistivity in ohm.m
Unit electrode spacing 5.00 m.

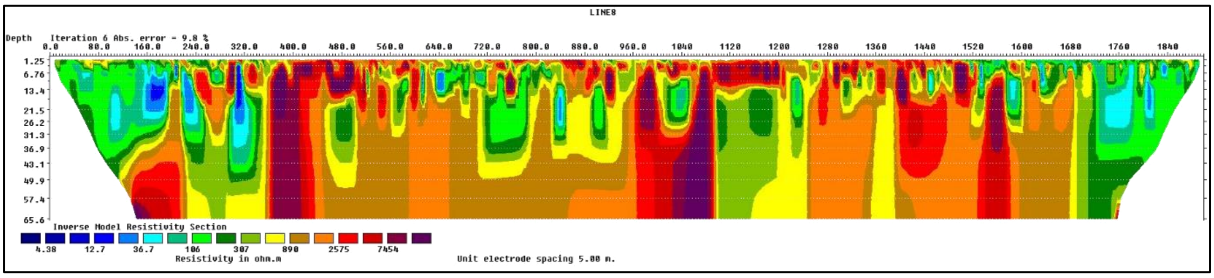

LINE2
Depth
Iteration 6 Abs. error = 9.3 %
0.0
80.0
160.0
240.0
320.0
400.0
480.0
560.0
640.0
720.0
800.0
880.0
960.0
1040
m.
1.25
6.76
13.4
21.5
26.2
31.3
36.9
43.1
49.9
57.4
65.6
Inverse Model Resistivity Section
4.38
12.7
36.7
106
307
890
2575
7454
Resistivity in ohm.m
Unit electrode spacing 5.00 m.

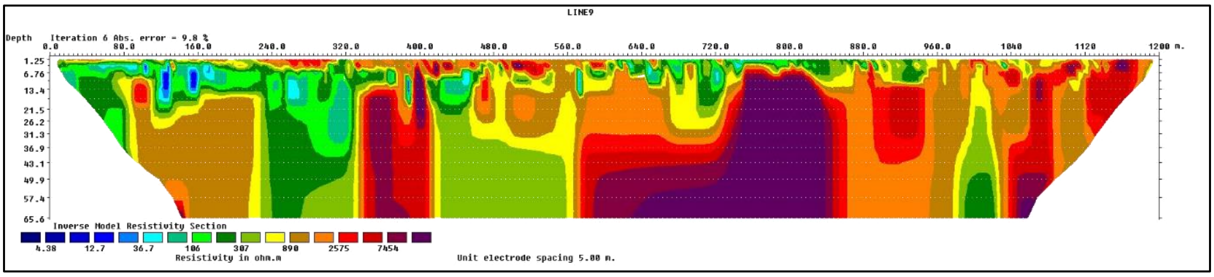

LINE3
Depth
Iteration 5 Abs. error = 9.8 %
0.0
80.0
160.0
240.0
320.0
400.0
480.0
560.0
640.0
720.0
800.0
880.0
m.
1.25
6.76
13.4
21.5
26.2
31.3
36.9
43.1
49.9
57.4
65.6
Inverse Model Resistivity Section
4.38
12.7
36.7
106
307
890
2575
7454
Resistivity in ohm.m
Unit electrode spacing 5.00 m.

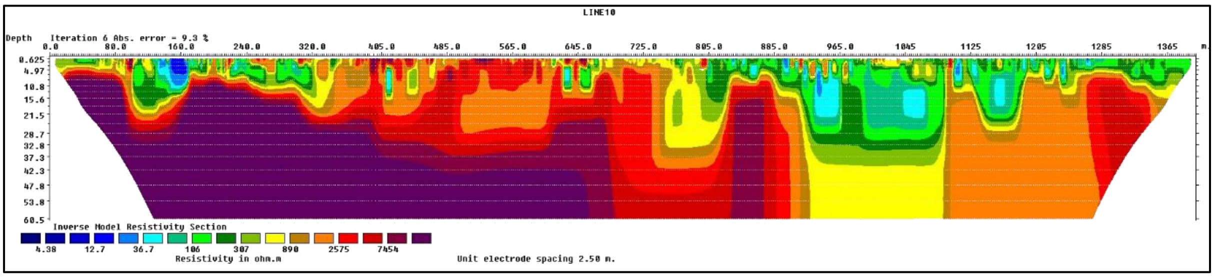

LINE 5
Depth
Iteration 6 Abs. error = 9.8 %
0.0
80.0
160.0
240.0
320.0
400.0
480.0
560.0
640.0
720.0
800.0
880.0
960.0
m.
1.25
6.76
13.4
21.5
26.2
31.3
36.9
43.1
49.9
57.4
65.6
Inverse Model Resistivity Section
4.38
12.7
36.7
106
307
890
2575
7454
Resistivity in ohm.m
Unit electrode spacing 5.00 m.

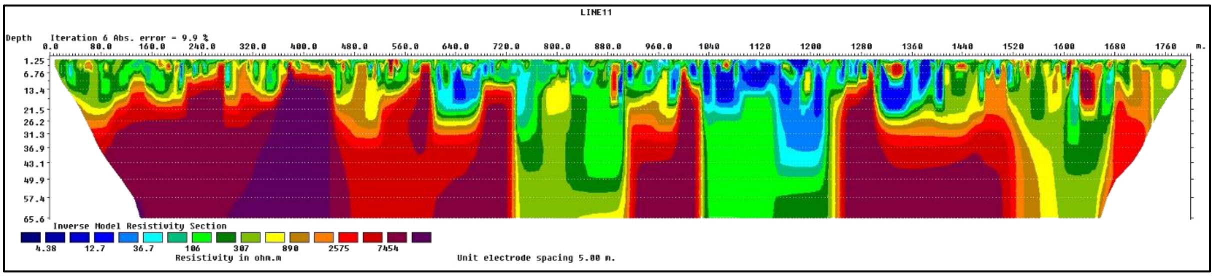

LINE 6
Depth
Iteration 7 Abs. error = 8.8 %
Inverse Model Resistivity Section
Resistivity in ohm.m
Unit electrode spacing 5.00 m.

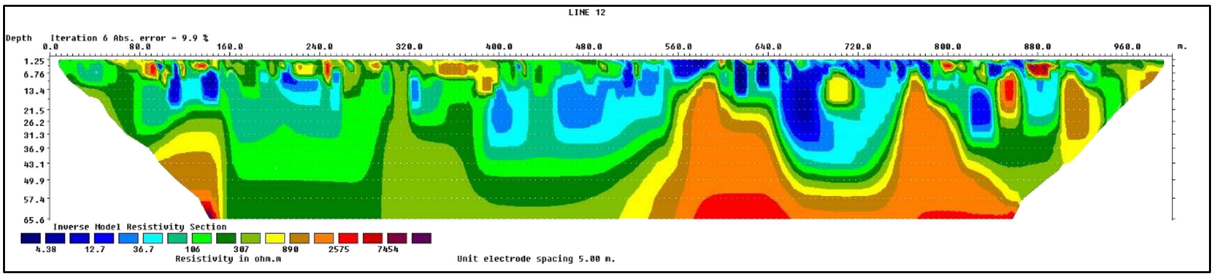

LINE7
Depth
Iteration 6 Abs. error = 9.7 %
Inverse Model Resistivity Section
Resistivity in ohm.m
Unit electrode spacing 5.00 m.

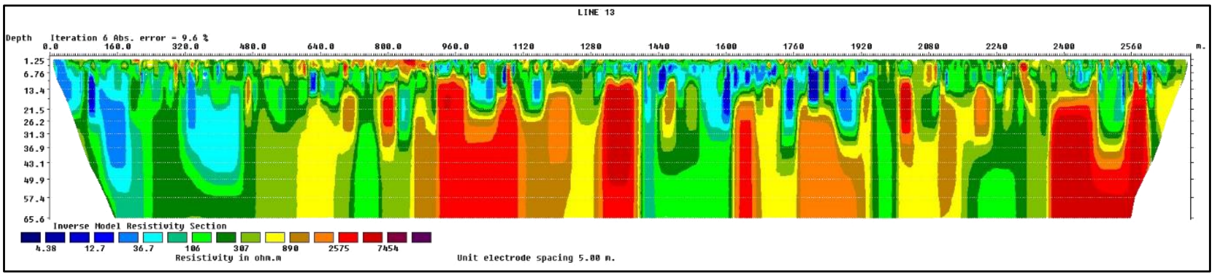

LINE8
Depth
Iteration 6 Abs. error = 9.8 %
Inverse Model Resistivity Section
Resistivity in ohm.m
Unit electrode spacing 5.00 m.

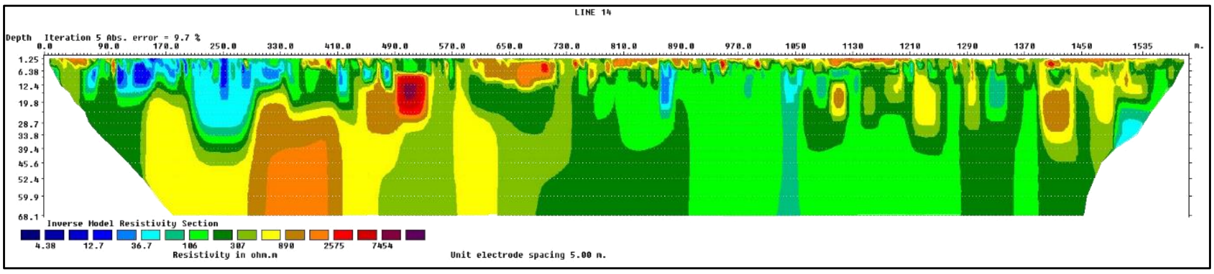

LINE9
Depth
Iteration 6 Abs. error = 9.8 %
Inverse Model Resistivity Section
Resistivity in ohm.m
Unit electrode spacing 5.00 m.

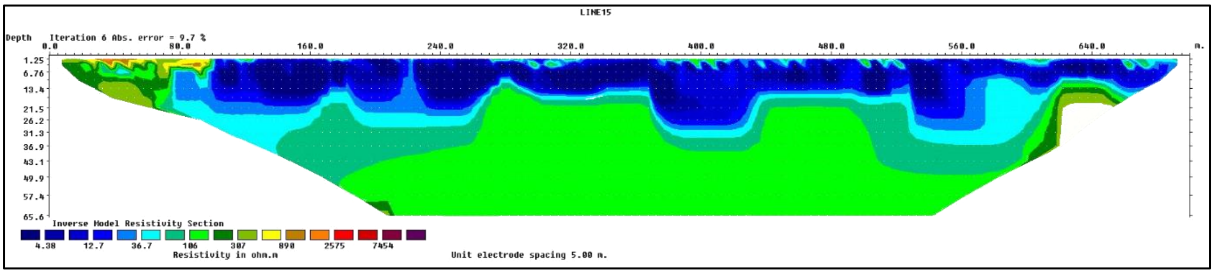

LINE10
Inverse Model Resistivity Section
Resistivity in ohm.m
Unit electrode spacing 2.50 m.

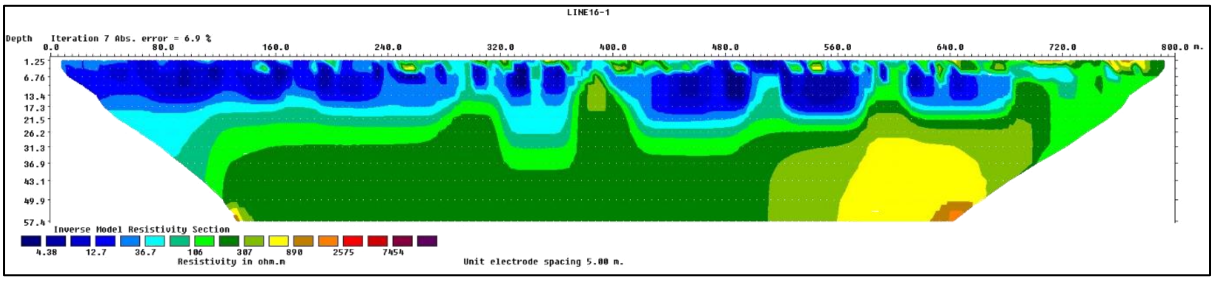

LINE11
Inverse Model Resistivity Section
Resistivity in ohm.m
Unit electrode spacing 5.00 m.

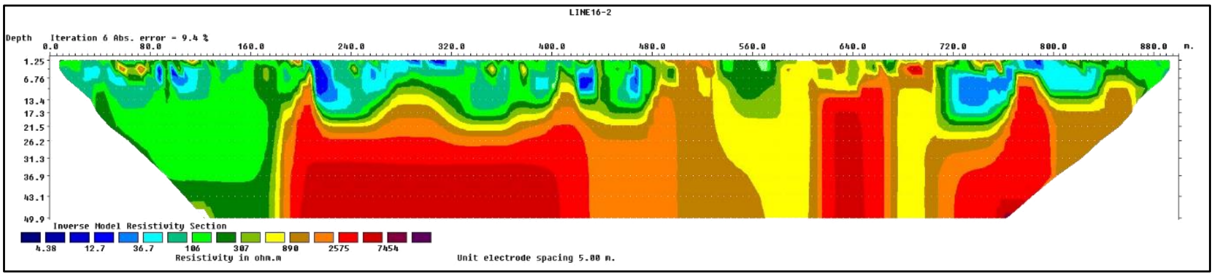

LINE 12
Inverse Model Resistivity Section
Resistivity in ohm.m
Unit electrode spacing 5.00 m.

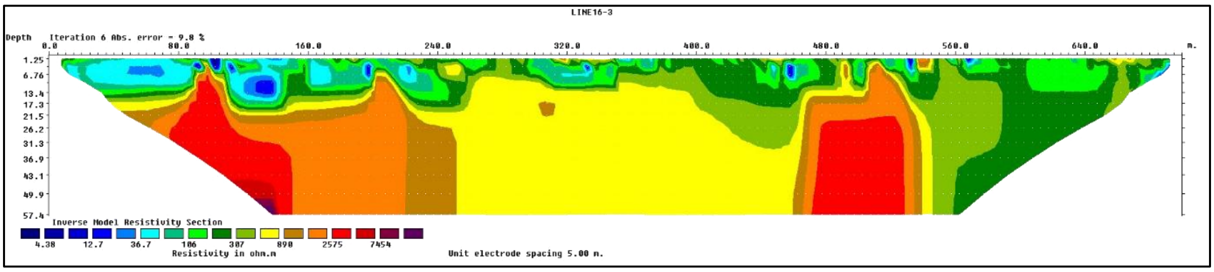

LINE 13
Inverse Model Resistivity Section
Resistivity in ohm.m
Unit electrode spacing 5.00 m.

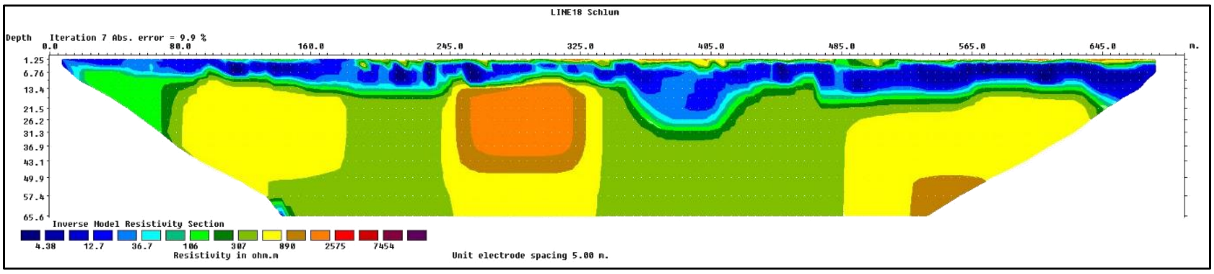

LINE 14
Depth
Iteration 5 Abs. error = 9.7 %
Inverse Model Resistivity Section
Resistivity in ohm.m
Unit electrode spacing 5.00 m.

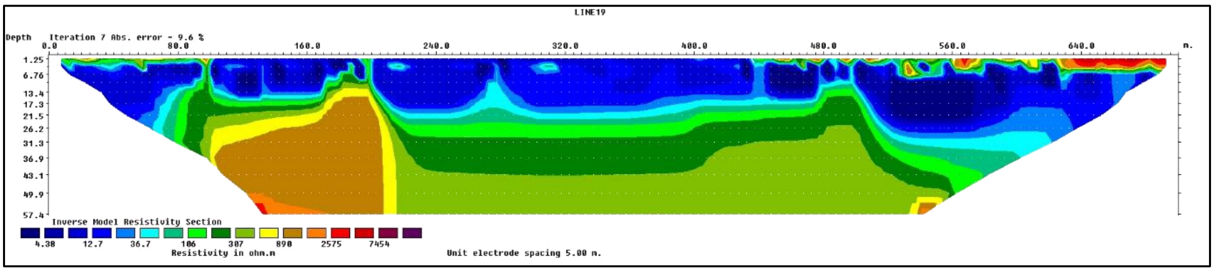

LINE15
Depth
Iteration 6 Abs. error = 9.7 %
Inverse Model Resistivity Section
Resistivity in ohm.m
Unit electrode spacing 5.00 m.

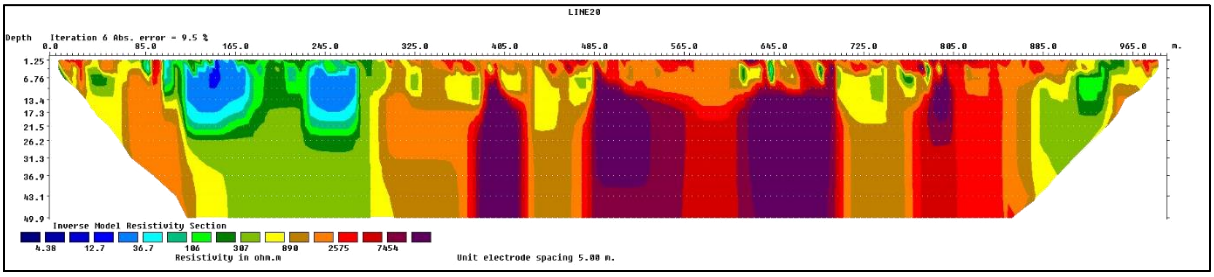

LINE16-1
Depth
Iteration 7 Abs. error = 6.9 %
Inverse Model Resistivity Section
Resistivity in ohm.m
Unit electrode spacing 5.00 m.


LINE16-2
Depth
Iteration 6 Abs. error = 9.4 %
Inverse Model Resistivity Section
Resistivity in ohm.m
Unit electrode spacing 5.00 m.


LINE16-3
Depth
Iteration 6 Abs. error = 9.8 %
0.0 80.0 160.0 240.0 320.0 400.0 480.0 560.0 640.0 m.
1.25 6.76 13.4 17.3 21.5 26.2 31.3 36.9 43.1 49.9 57.4
Inverse Model Resistivity Section
4.38 12.7 36.7 106 307 890 2575 7454
Resistivity in ohm.m
Unit electrode spacing 5.00 m.


LINE18 Schlun
Depth
Iteration 7 Abs. error = 9.9 %
0.0 80.0 160.0 245.0 325.0 405.0 485.0 565.0 645.0 m.
1.25 6.76 13.4 21.5 26.2 31.3 36.9 43.1 49.9 57.4 65.6
Inverse Model Resistivity Section
4.38 12.7 36.7 106 307 890 2575 7454
Resistivity in ohm.m
Unit electrode spacing 5.00 m.


LINE19
Depth
Iteration 7 Abs. error = 9.6 %
0.0 80.0 160.0 240.0 320.0 400.0 480.0 560.0 640.0 m.
1.25 6.76 13.4 17.3 21.5 26.2 31.3 36.9 43.1 49.9 57.4
Inverse Model Resistivity Section
4.38 12.7 36.7 106 307 890 2575 7454
Resistivity in ohm.m
Unit electrode spacing 5.00 m.


LINE20
Depth
Iteration 6 Abs. error = 9.5 %
0.0 85.0 165.0 245.0 325.0 405.0 485.0 565.0 645.0 725.0 805.0 885.0 965.0 m.
1.25 6.76 13.4 17.3 21.5 26.2 31.3 36.9 43.1 49.9
Inverse Model Resistivity Section
4.38 12.7 36.7 106 307 890 2575 7454
Resistivity in ohm.m
Unit electrode spacing 5.00 m.

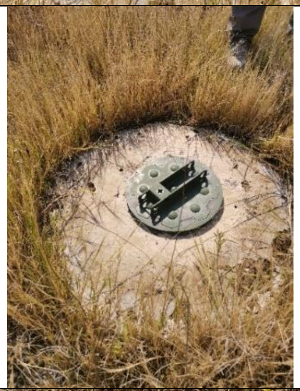
Appendix C:Hydrocensus Results

BH ID	Date surveyed	Lat	Long	water level (mbgl)	BH Usage	BH status	Comment
GW5	13/09/2021	-26.139800	27.755490	9.09	Monitoring	Fair	covered by concrete ring with lid removed
MABH 5S	13/09/2021	-26.135060	27.751850	31.84	Monitoring	Good	Located adjacent to old abandoned plant. Equipped with closed concrete borehole ring as protection
BH1A	13/09/2021	-26.129660	27.752180	43.18	Monitoring	Good	Borehole initially not on hydrocensus list. Sampled water almost milky in colour. Borehole is not equipped
BH1B	13/09/2021	-26.129680	27.752270	-	Monitoring	Damaged	Borehole located about 5m away from BH1A. Borehole is dry/blocked at 15m
MABH6	13/09/2021	-26.133800	27.755710	8.27	Monitoring	Good	Borehole located between two dumps with a power station 40m north of it. Equipped with closable concrete ring
MABH9	13/09/2021	-26.138830	27.764930	0.7	Monitoring	Fair	Borehole not protected, with the pvc casing cut to ground level. Small diameter hole (50mm). Located next to a wetland
MABH8D	13/09/2021	-26.12798	27.75376	-	Monitoring	-	Access to assess boreholes was denied by Bright Alloys. Permission to be requested from Tankiso Baloyi.
MABH8S	13/09/2021	26.12803	27.75371	-	Monitoring	-	Access to assess boreholes was denied by Bright Alloys. Permission to be requested from Tankiso Baloyi.
Winze 18	13/09/2021	-26.114930	27.724790	-	Shaft	Poor	Shaft looks very old and not operational. Located in area referred to as Black Reef Incline (BRI). Sample taken from stream discharging from shaft. Water from shaft is currently being pumped to the BRI dam
Shaft 9	13/09/2021	-26.125220	27.726740	-	Shaft	Good	Sample take from shaft. Shaft operational under Sibanye Gold.
Winze 17	13/09/2021	-26.121552	27.721654	-	Shaft	-	Shaft not located with only a steel pipe descending into the ground found at this location
Shaft 8	14/09/2021	-26.135616	27.719991	-	Shaft	Good	Shaft operational under Sibanye Gold. Access denied for sampling
GAA4D	14/09/2021	-26.118790	27.784720	-	Monitoring	Damaged	Borehole dry/blocked at 15m. Borehole located within a small domestic waste dump
AA2S	14/09/2021	-26.124550	27.781170	-	Monitoring	Damaged	Blocked at 2m. Borehole located next to a small plastic lined dam. Borehole looks damaged located in area populated by illegal miners
MGP12	14/09/2021	-26.133260	27.793170	12.3	Monitoring	Poor	Borehole surrounded by a soil beam barrier and is flat on the surface with its special lock/lid removed. Sample taken here has a strong unpleasant smell.
MGP8-2	14/09/2021	-26.139320	27.760370	5.96	Monitoring	Good	Located about 500m west of original MGP8.
PBH4	14/09/2021	-26.132940	27.727200	-	Monitoring	Damaged	Borehole blocked dry 24,9m. No lock or cap on the borehole. Located about 10m away from a railway line.
MGP1	07/05/2021	-26.114233	27.734750	-	Monitoring	-	Borehole not located
MGP2	07/05/2021	-26.120683	27.730267	-	Monitoring	-	No Access, roads were closed off
MGP3	07/05/2021	-26.108000	27.722817	5	Monitoring	Good	Used as a community borehole, water pumped into a tank. Directly sampled from the borehole
MGP4	07/05/2021	-26.131333	27.732600	-	Monitoring	Damaged	Borehole open with no cap, covered by a makeshift concrete block. Borehole blocked at 48 m
MGP5	07/05/2021	-26.122883	27.735917	-	Monitoring	-	Borehole not located

BH ID	Date surveyed	Lat	Long	water level (mbgl)	BH Usage	BH status	Comment
MGP6	07/05/2021	-26.144186	27.771606	-	Monitoring	Good	Borehole is equipped with a submersible pump and used for irrigation purposes. Sample collected from the discharge pipe. Equipment blocked access for water level measurement
MGP7	07/05/2021	-26.144783	27.740583	-	Monitoring	-	Borehole could not be located
MGP8	07/05/2021	-26.137633	27.765317	4	Monitoring	Good	Borehole is in a good condition, equipped with a lockable cap
MGP9	07/05/2021	-26.131767	27.777183	-	Monitoring	Good	Borehole locked
MGP10	07/05/2021	-26.131833	27.776900	-	Monitoring	Good	Borehole locked
MGP11	07/05/2021	-26.133233	27.793217	10	Monitoring	Fair	Borehole was previously equipped with a lockable cap that laid flat at ground level. However, the cap has been removed
West Wits Pit	07/05/2021	-26.125828	27.731689	-	Monitoring	-	Pit is being backfilled. Monitoring location does not exist anymore

ID	Coordinates		Borehole Status	Water Level (mbgl)	Additional Comments	Picture
	Longitude	Latitude				
MGP1	27.734750°	-26.114233°	Not located	-	Borehole not located	
MGP2	27.730267°	-26.120683°	Not located	-	No Access, roads were closed off	
MGP3	27.722817°	-26.108000°	Good condition	5	Used as a community borehole, water pumped into a tank. Directly sampled from the borehole	

ID	Coordinates		Borehole Status	Water Level (mbgl)	Additional Comments	Picture
	Longitude	Latitude				
MGP4	27.732600°	-26.131333°	Blocked	Blocked at 48.39 m	Borehole open with no cap, covered by a makeshift concrete block	
MGP5	27.735917°	-26.122883°	Not located	-	Borehole not located	
MGP6	27.771606°	-26.144186°	Good condition	Not measured	Borehole is equipped with a submersible pump and used for irrigation purposes. Sample collected from the discharge pipe. Equipment blocked access for water level measurement	
MGP7	27.740583°	-26.144783°	-	-	Borehole could not be located	
MGP8	27.765317°	-26.137633°	Good condition	4	Borehole is in a good condition, equipped with a lockable cap.	
MGP8-2	27.761167°	-26.138874°	Good condition	7	Located close to MGP8, it was initially part of the hydrocensus list but the	

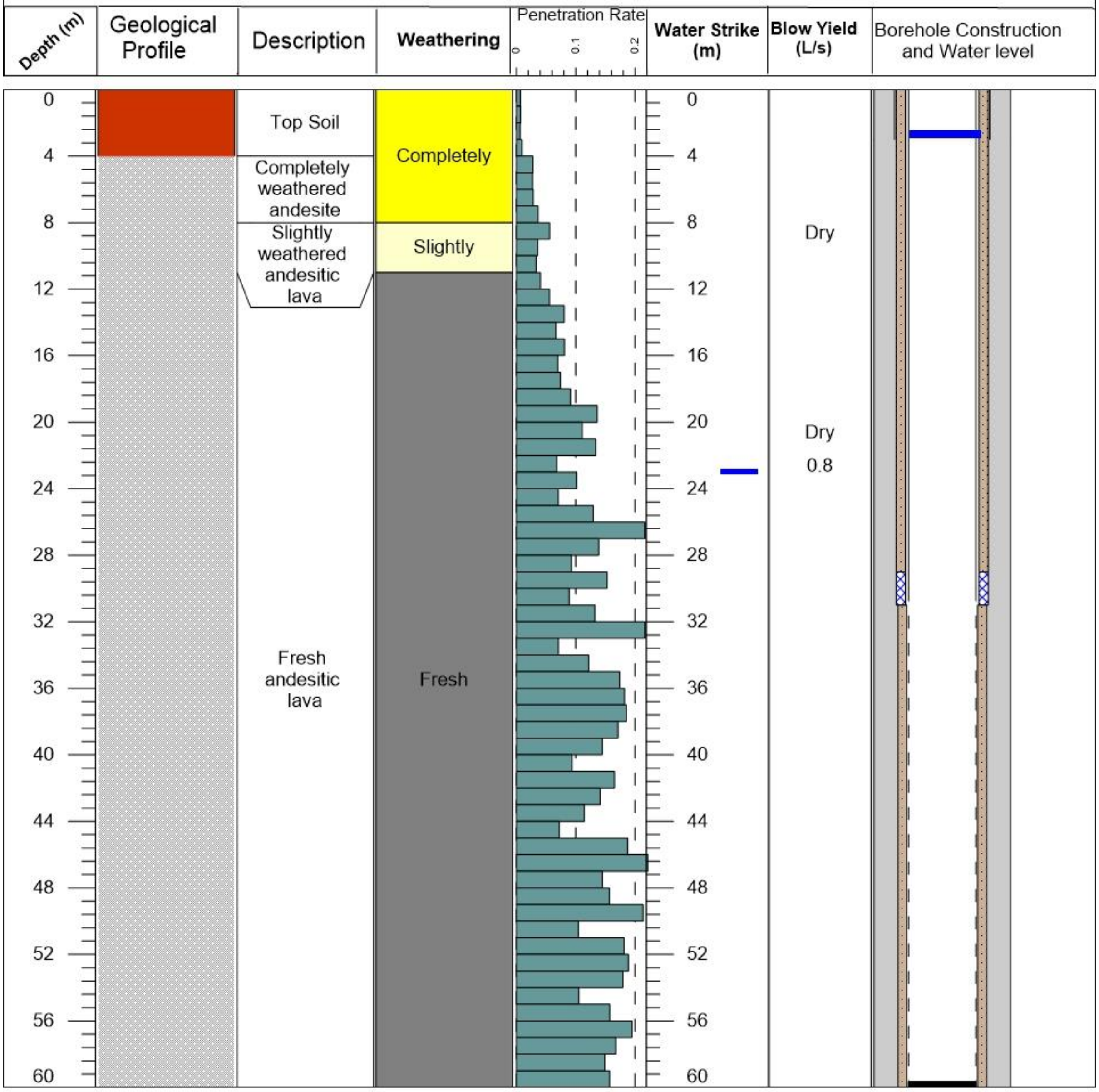
ID	Coordinates		Borehole Status	Water Level (mbgl)	Additional Comments	Picture
	Longitude	Latitude				
MGP9	27.777183°	-26.131767°	Good condition	Not measured	Borehole locked	
MGP10	27.776900°	-26.131833°	Good condition	Not measured	Borehole locked	
MGP11	27.793217°	-26.133233°	Fair condition	10	Borehole was previously equipped with a lockable cap that laid flat at ground level. However, the cap has been removed	
MGP12	27.793100°	-26.133317°	Not located	-	Not located due to illegal miners and security personnel advised not to go into the area	
17 Winze	27.721694°	-26.121528°	Not located	-	Not located due to illegal miners and security personnel advised not to go into the area	

ID	Coordinates		Borehole Status	Water Level (mbgl)	Additional Comments	Picture
	Longitude	Latitude				
18 Winze	27.724919°	-26.115181°	Not located	-	Located in an area with radioactive material - no access	
West Wits Pit – South Pit	27.731689°	-26.125828°	Not located	-	Pit is being backfilled. Monitoring location does not exist anymore	

Appendix D: Borehole Hydrogeological Logs

DIGBY WELLS ENVIRONMENTAL
Turnberry Office Park
48 Grosvenor Road
Bryanston
2191
Tel: +27(0)11 789 9495

Client:	**Pan African Resources**	**BOREHOLE ID:**	**BH68D**
Project Name:	Mintails Acquisition	X-Coordinate:	27.75993
Project Code:	PAR7273	Y-Coordinate:	-26.1448
Location:	Krugersdorp	Z-Coordinate:	1679
Drilled By:	Ubuntu Drilling	Coordinate System:	WGS84, Lo29
Date Drilled:	15 Februaty 2022	Collar Height (m):	0
Logged By:	Kgaugelo Thobejane	Final Depth (m):	60



Comment:

DIGBY WELLS ENVIRONMENTAL

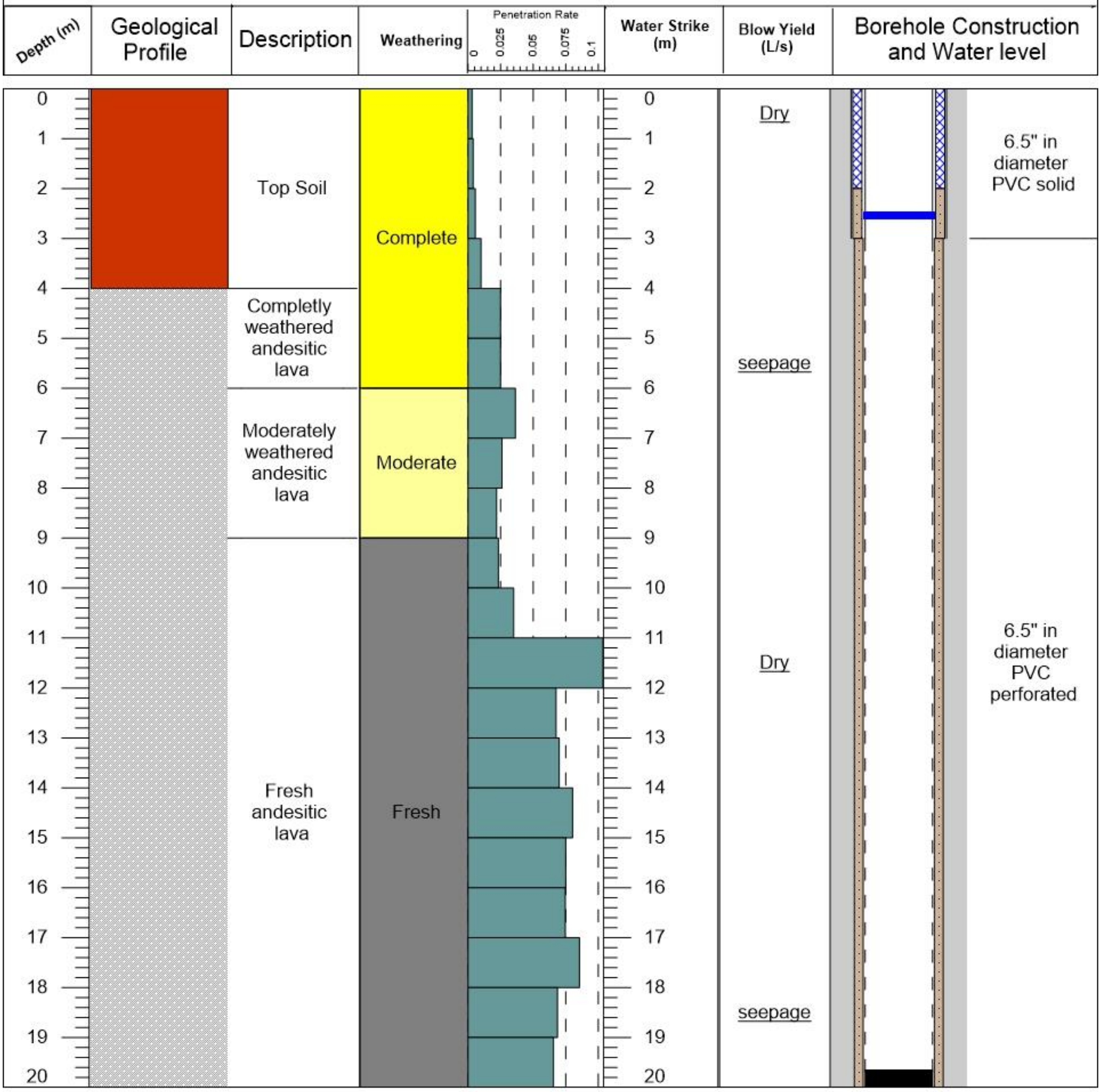
Turnberry Office Park
48 Grosvenor Road
Bryanston
2191
Tel: +27(0)11 789 9495

Client: Pan African Resources

Project Name:	Mintails Acquisition
Project Code:	PAR7273
Location:	Krugersdorp
Drilled By:	Ubuntu Drilling
Date Drilled:	11 Februaty 2022
Logged By:	Kgaugelo Thobejane

BOREHOLE ID: BH68S

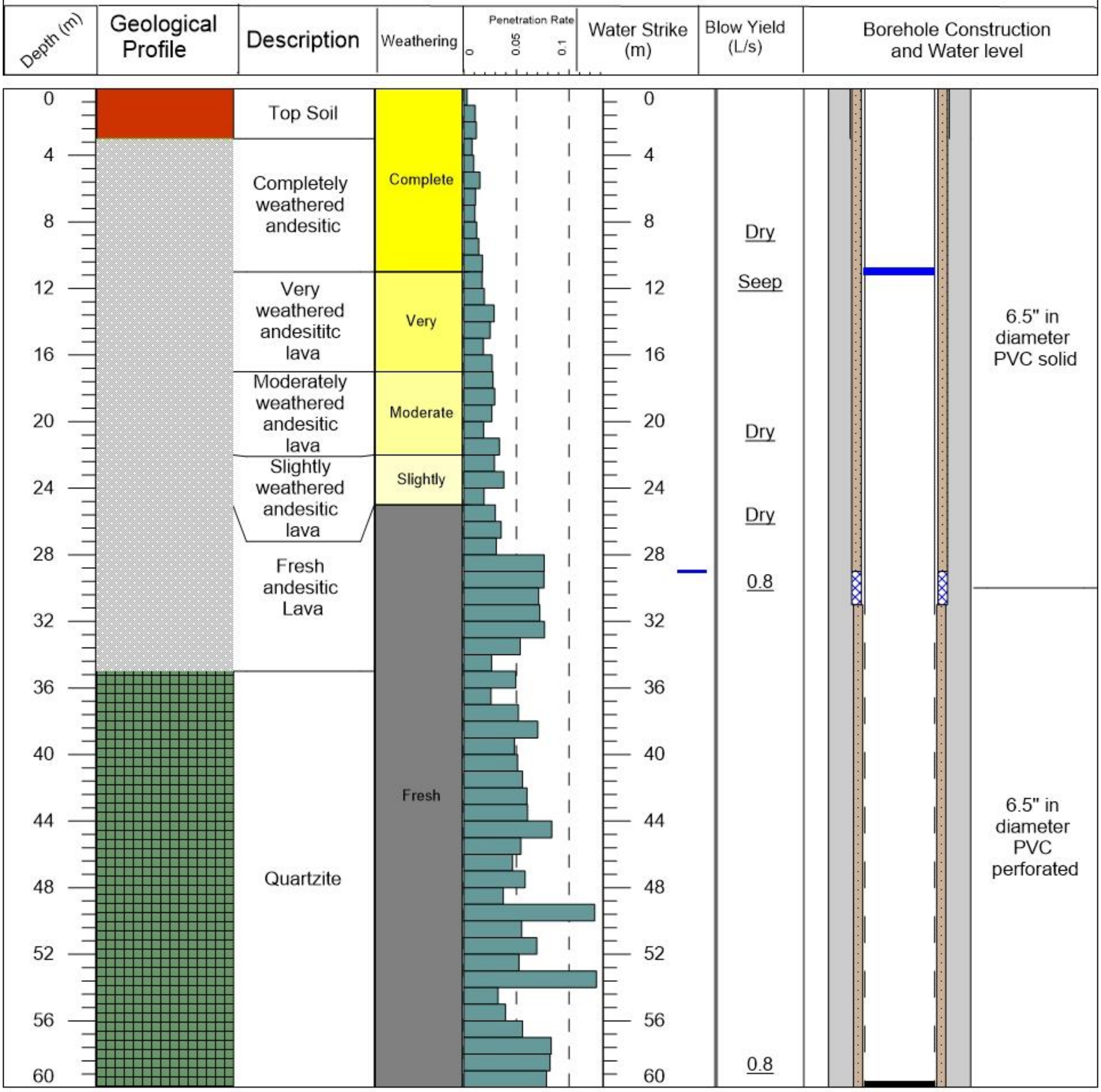
X-Coordinate:	-26.14475
Y-Coordinate:	27.75996
Z-Coordinate:	1679
Coordinate System:	WGS84, Lo29
Collar Height (m):	0
Final Depth (m):	20



Comment:

DIGBY WELLS ENVIRONMENTAL
Turnberry Office Park
48 Grosvenor Road
Bryanston
2191
Tel: +27(0)11 789 9495

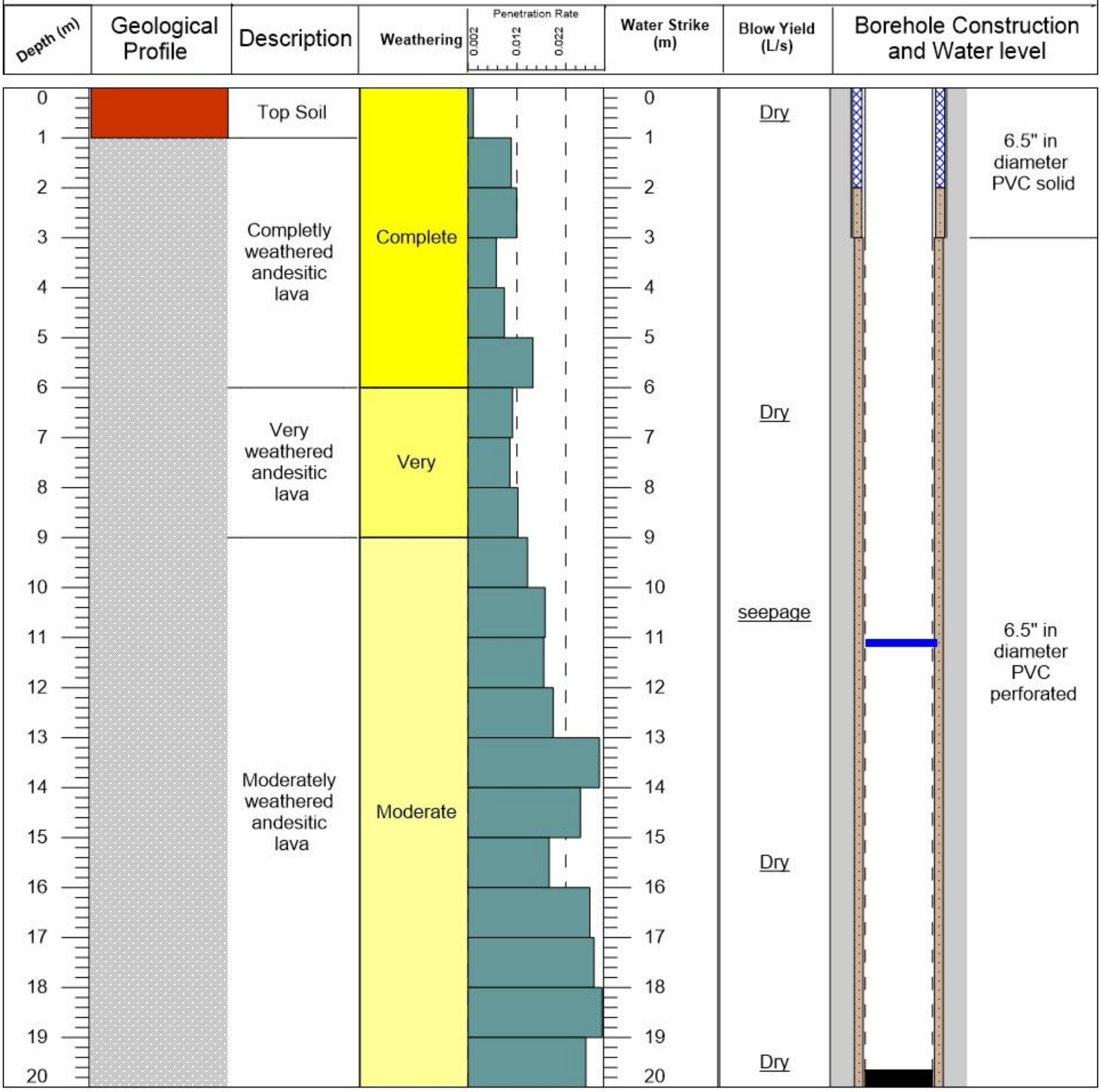
Client:	**Pan African Resources**	**Borehole ID:**	**LPVBH1D**
Project Name:	Mintails Acquisition	X-Coordinate:	27.78253
Project Code:	PAR7273	Y-Coordinate:	-26.12359
Location:	Krugersdorp	Z-Coordinate:	1704
Drilled By:	Ubuntu Drilling	Coordinate System:	WGS84, Lo29
Date Drilled:	17 Februaty 2022	Collar Height (m):	0
Logged By:	Kgaugelo Thobejane	Final Depth (m):	60



Comment:

DIGBY WELLS ENVIRONMENTAL
Turnberry Office Park
48 Grosvenor Road
Bryanston
2191
Tel: +27(0)11 789 9495

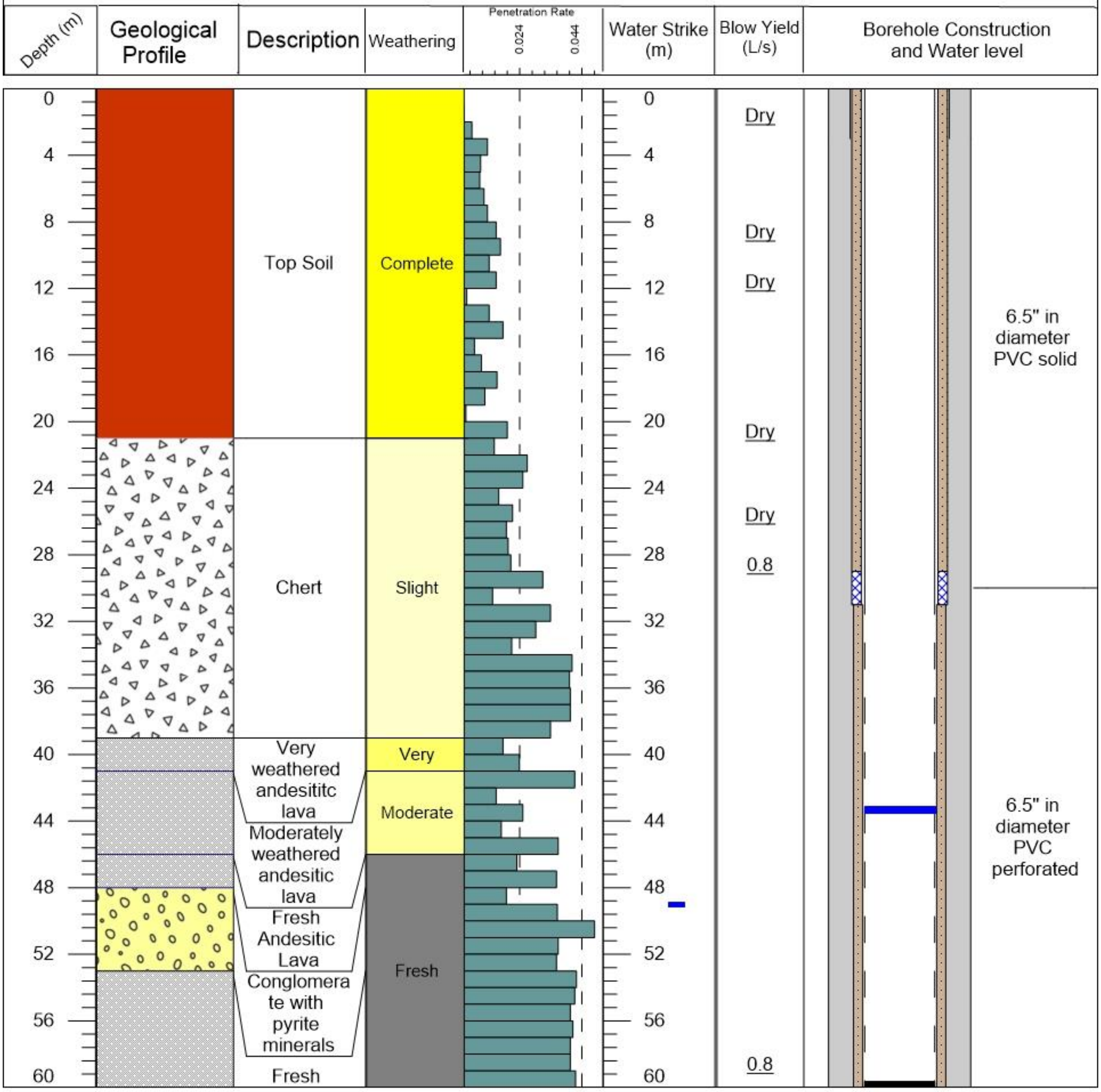
Client:	**Pan African Resources**	**BOREHOLE ID:**	**LPVBH1S**
Project Name:	Mintails Acquisition	X-Coordinate:	-26.12344
Project Code:	PAR7273	Y-Coordinate:	27.78247
Location:	Krugersdorp	Z-Coordinate:	1704
Drilled By:	Ubuntu Drilling	Coordinate System:	WGS84, Lo29
Date Drilled:	16 Februaty 2022	Collar Height (m):	0.11
Logged By:	Kgaugelo Thobejane	Final Depth (m):	20



Comment:

DIGBY WELLS ENVIRONMENTAL
Turnberry Office Park
48 Grosvenor Road
Bryanston
2191
Tel: +27(0)11 789 9495

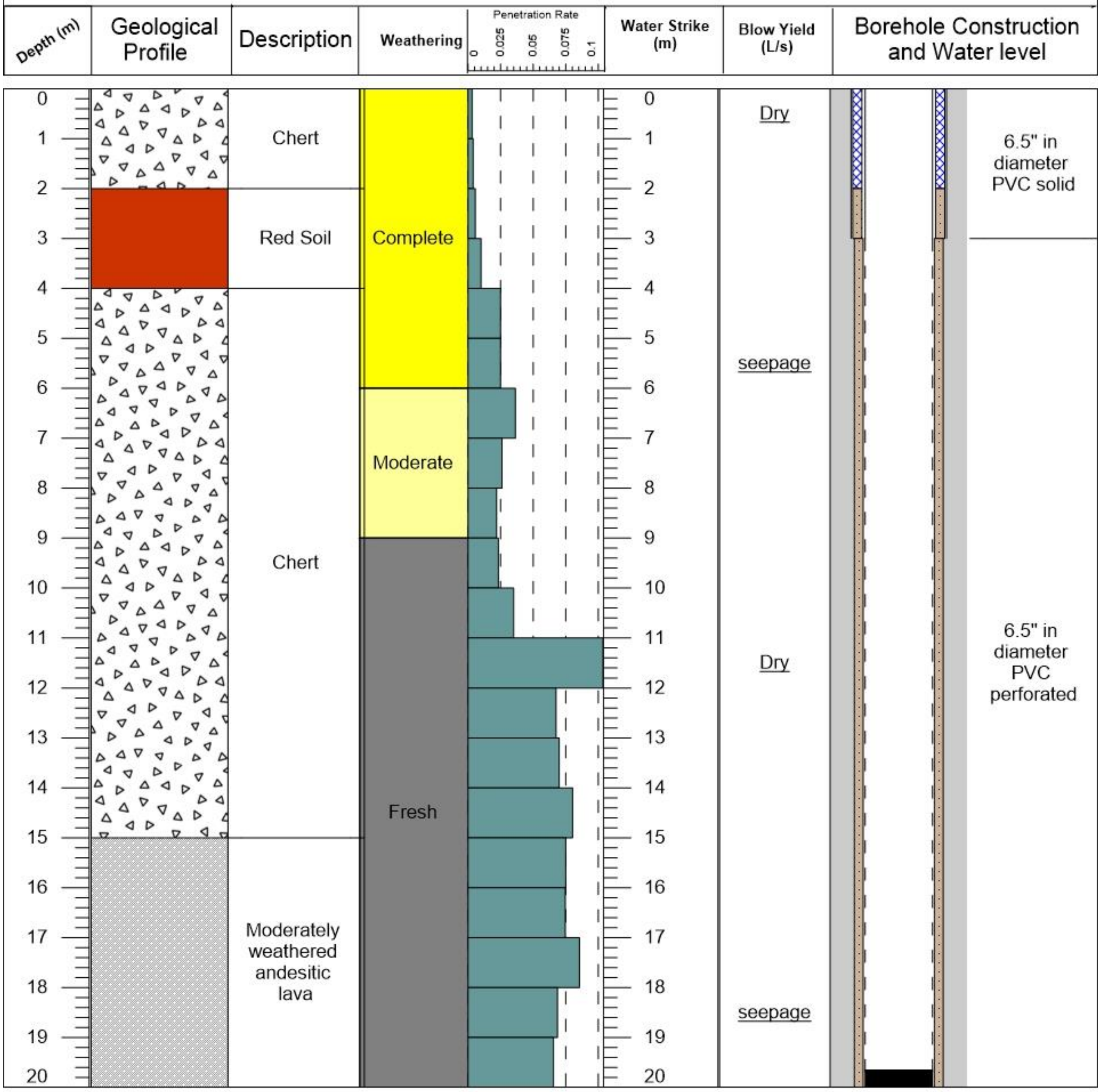
Client:	**Pan African Resources**	**Borehole ID:**	**NSBH1D**
Project Name:	Mintails Acquisition	X-Coordinate:	27.76592
Project Code:	PAR7273	Y-Coordinate:	-26.10946
Location:	Krugersdorp	Z-Coordinate:	1718
Drilled By:	Ubuntu Drilling	Coordinate System:	WGS84, Lo29
Date Drilled:	17 Februaty 2022	Collar Height (m):	0.13
Logged By:	Kgaugelo Thobejane	Final Depth (m):	60



Comment:

DIGBY WELLS ENVIRONMENTAL
Turnberry Office Park
48 Grosvenor Road
Bryanston
2191
Tel: +27(0)11 789 9495

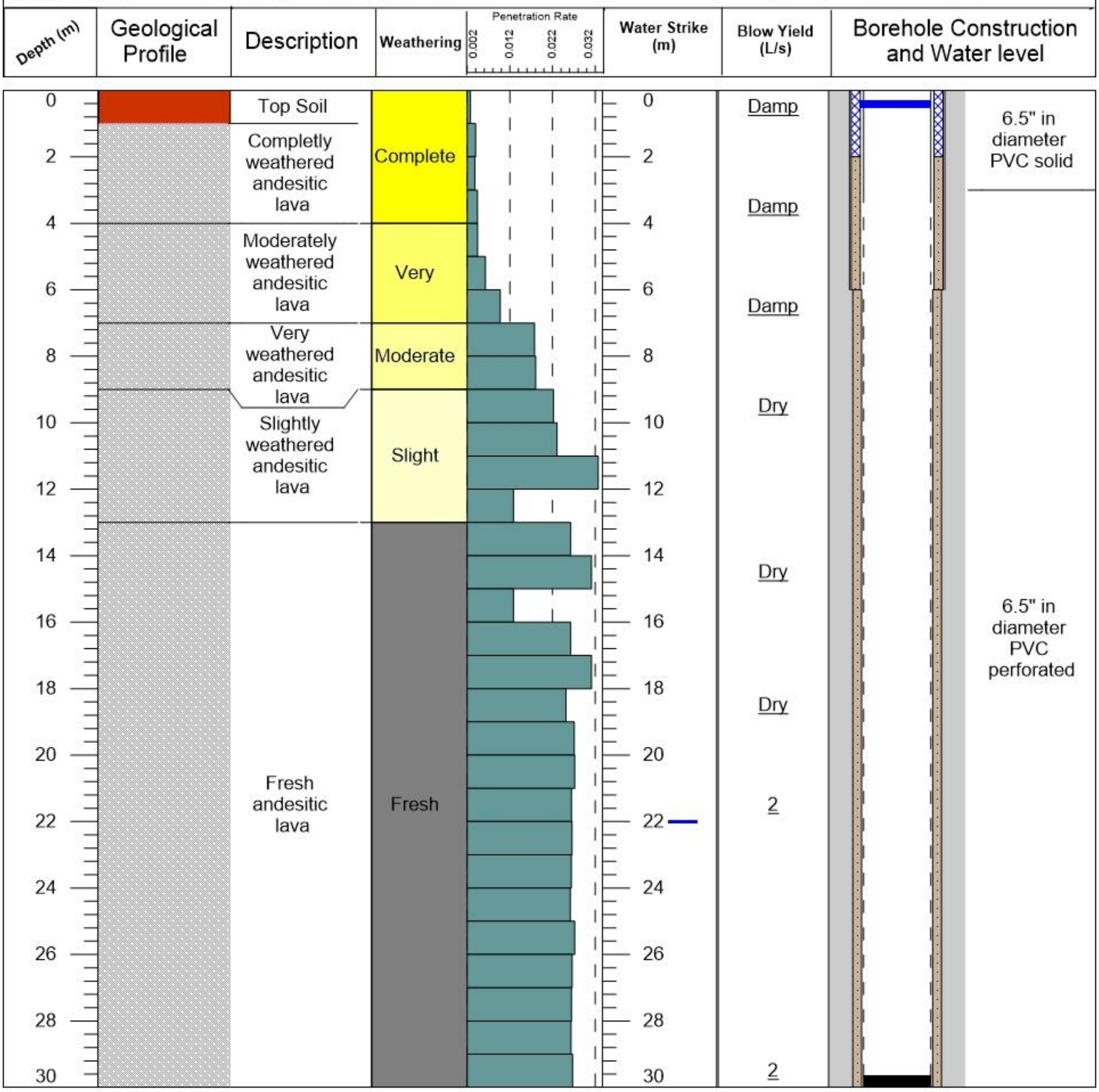
Client:	**Pan African Resources**	**BOREHOLE ID:**	**NSBH1S**
Project Name:	Mintails Acquisition	X-Coordinate:	-26.10946
Project Code:	PAR7273	Y-Coordinate:	27.76592
Location:	Krugersdorp	Z-Coordinate:	1719
Drilled By:	Ubuntu Drilling	Coordinate System:	WGS84, Lo29
Date Drilled:	18 Februaty 2022	Collar Height (m):	0
Logged By:	Kgaugelo Thobejane	Final Depth (m):	30



Comment:

DIGBY WELLS ENVIRONMENTAL
Turnberry Office Park
48 Grosvenor Road
Bryanston
2191
Tel: +27(0)11 789 9495

Client:	**Pan African Resources**	**BOREHOLE ID:**	**TSFBH1S**
Project Name:	Mintails Acquisition	X-Coordinate:	-26.12354322
Project Code:	PAR7273	Y-Coordinate:	27.7824512
Location:	Krugersdorp	Z-Coordinate:	1684
Drilled By:	Ubuntu Drilling	Coordinate System:	WGS84, Lo29
Date Drilled:	21 Februaty 2022	Collar Height (m):	0
Logged By:	Kgaugelo Thobejane	Final Depth (m):	30



Comment:

Appendix E: Aquifer Test Data

				STEPPED DISCHARGE TEST & RECOVERY										
BOREHOLE TEST RECORD SHEET														
PROJ NO :		P2636		MAP REFERENCE:						PROVINCE:		GAUTENG		
BOREHOLE NO:		BH68D		LATITUDE:	S 26.14463					DISTRICT:		WEST RAND		
ALT BH NO:		0		LONGITUDE :	E 027.76000					SITE NAME:		KRUGERSDORP		
ALT BH NO:		0												
BOREHOLE DEPTH (m)			59.90		DATUM LEVEL ABOVE CASING (m):				0.60	EXISTING PUMP:		NEW BOREHOLE		
WATER LEVEL (mbdl):			3.07		CASING HEIGHT: (magl):				0.07	CONTRACTOR:		AB PUMPS		
DEPTH OF PUMP (m):			57.50		DIAM PUMP INLET (mm):				114.00	PUMP TYPE:		BP16		
STEPPED DISCHARGE TEST & RECOVERY														
DISCHARGE RATE 1			RPM	147	DISCHARGE RATE 2			RPM	259	DISCHARGE RATE 3			RPM	386
DATE:	05/03/2022	TIME:	09H00		DATE :	05/03/2022	TIME:	09H30		DATE :	05/03/2022	TIME:	10H00	
TIME	DRAW	YIELD	TIME	RECOVERY	TIME	DRAW	YIELD	TIME	RECOVERY	TIME	DRAW	YIELD	TIME	RECOVERY
(MIN)	DOWN (M)	(L/S)	(MIN)	(M)	(MIN)	DOWN (M)	(L/S)	(MIN)	(M)	(MIN)	DOWN (M)	(L/S)	(MIN)	(M)
1	1.24		**1**		**1**	2.99		**1**		**1**	4.17		**1**	
2	1.54		**2**		**2**	3.15	0.32	**2**		**2**	4.23		**2**	
3	1.86	0.23	**3**		**3**	3.41		**3**		**3**	4.28	0.67	**3**	
5	2.14		**5**		**5**	3.62	0.45	**5**		**5**	5.02	0.83	**5**	
7	2.34	0.22	**7**		**7**	3.80		**7**		**7**	5.88		**7**	
10	2.37		**10**		**10**	3.88	0.44	**10**		**10**	5.97	0.81	**10**	
15	2.40	0.23	**15**		**15**	3.95		**15**		**15**	6.14		**15**	
20	2.63		**20**		**20**	4.02	0.44	**20**		**20**	6.25	0.83	**20**	
30	2.79		**30**		**30**	4.10		**30**		**30**	6.40		**30**	
40			**40**		**40**			**40**		**40**			**40**	
50			**50**		**50**			**50**		**50**			**50**	
60			**60**		**60**			**60**		**60**			**60**	
70			**70**		**70**			**70**		**70**			**70**	
80			**80**		**80**			**80**		**80**			**80**	
90			**90**		**90**			**90**		**90**			**90**	
100			**100**		**100**			**100**		**100**			**100**	
110			**110**		**110**			**110**		**110**			**110**	
120			**120**		**120**			**120**		**120**			**120**	
pH			**150**		**pH**			**150**		**pH**			**150**	
TEMP	19.90	°C	**180**		**TEMP**	18.90	°C	**180**		**TEMP**	19.20	°C	**180**	
EC	3999	µS/cm	**210**		**EC**	3780	µS/cm	**210**		**EC**	3785	µS/cm	**210**	
DISCHARGE RATE 4			RPM	647	DISCHARGE RATE 5			RPM		DISCHARGE RATE 6			RPM	
DATE:	05/03/2022	TIME:	10H30		DATE :	05/03/2022	TIME:	11H00		DATE :		TIME:		
TIME	DRAW	YIELD	TIME	RECOVERY	TIME	DRAW	YIELD	TIME	RECOVERY	TIME	DRAW	YIELD	TIME	RECOVERY
(MIN)	DOWN (M)	(L/S)	(MIN)	(M)	(MIN)	DOWN (M)	(L/S)	(MIN)	(M)	(MIN)	DOWN (M)	(L/S)	(MIN)	(M)
1	8.07	1.39	**1**		**1**	39.70		**1**	42.80	**1**			**1**	
2	8.96	1.55	**2**		**2**	42.60	1.81	**2**	31.40	**2**			**2**	
3	10.72		**3**		**3**	48.10		**3**	20.95	**3**			**3**	
5	13.70	1.60	**5**		**5**	54.40	1.82	**5**	13.63	**5**			**5**	
7	15.80		**7**			54.40	1.20	**7**	8.98	**7**			**7**	
10	17.51	1.63	**10**			54.40	1.14	**10**	6.28	**10**			**10**	
15	20.90		**15**			54.40	1.02	**15**	3.02	**15**			**15**	
20	22.50	1.61	**20**					**20**	2.40	**20**			**20**	
30	25.15		**30**					**30**	1.42	**30**			**30**	
40			**40**					**40**	1.02	**40**			**40**	
50			**50**					**50**	1.00	**50**			**50**	
60			**60**					**60**	0.88	**60**			**60**	
70			**70**					**70**	0.80	**70**			**70**	
80			**80**					**80**	0.75	**80**			**80**	

90			**90**					**90**	0.72	**90**			**90**	
100			**100**					**100**	0.66	**100**			**100**	
110			**110**					**110**	0.62	**110**			**110**	
120			**120**					**120**	0.59	**120**			**120**	
pH			**150**		**pH**			**150**		**pH**			**150**	
TEMP	19.60	°C	**180**		**TEMP**		°C	**180**		**TEMP**		°C	**180**	
EC	3788	µS/cm	**210**		**EC**		µS/cm	**210**		**EC**		µS/cm	**210**	
			240					**240**					**240**	
			300					**300**					**300**	
			360					**360**					**360**	

			CONSTANT DISCHARGE TEST & RECOVERY									
BOREHOLE TEST RECORD SHEET												
PROJ NO :		P2636		MAP REFERENCE:		S 26.14463			PROVINCE:		GAUTENG	
BOREHOLE NO:		BH68D				E 027.76000			DISTRICT :		WEST RAND	
ALT BH NO:		0							SITE NAME:		KRUGERSDORP	
ALT BH NO:		0										
BOREHOLE DEPTH:		59.90		DATUM LEVEL ABOVE CASING (m):				0.60	EXISTING PUMP:		NEW BOREHOLE	
WATER LEVEL (mbdl):		3.07		CASING HEIGHT: (magl):				0.07	CONTRACTOR:		AB PUMPS	
DEPTH OF PUMP (m):		57.50		DIAM PUMP INLET(mm):				114	PUMP TYPE:		BP16	
CONSTANT DISCHARGE TEST & RECOVERY												
TEST STARTED				**TEST COMPLETED**								
DATE :	06/03/2022	TIME:	07H40		DATE :	06/03/2022	TIME:	17H10	TYPE OF PUMP:			BP16
					OBSERVATION HOLE 1			OBSERVATION HOLE 2			OBSERVATION HOLE 3	
					NR:			NR:			NR:	
	DISCHARGE BOREHOLE				Distance(m);			Distance(m);			Distance(m);	
TIME (MIN)	DRAW DOWN (M)	YIELD (L/S)	TIME MIN	RECOVERY (M)	TIME: (min)	Drawdown m	Recovery (m)	TIME: (min)	Drawdown (m)	Recovery	TIME: (min)	Drawdown (m)
1	2.66		**1**	11.46	**1**			**1**			**1**	
2	3.20	0.67	**2**	8.50	**2**			**2**			**2**	
3	3.78		**3**	7.38	**3**			**3**			**3**	
5	3.95		**5**	5.45	**5**			**5**			**5**	
7	5.50	0.80	**7**	3.46	**7**			**7**			**7**	
10	8.05		**10**	2.40	**10**			**10**			**10**	
15	8.41	0.82	**15**	1.95	**15**			**15**			**15**	
20	8.49		**20**	1.82	**20**			**20**			**20**	
30	8.95	0.84	**30**	1.43	**30**			**30**			**30**	
40	9.25		**40**	1.25	**40**			**40**			**40**	
60	14.75	0.81	**60**	0.88	**60**			**60**			**60**	
90	16.32		**90**	0.63	**90**			**90**			**90**	
120	16.87	0.83	**120**	0.62	**120**			**120**			**120**	
150	17.20		**150**	0.54	**150**			**150**			**150**	
180	17.41	0.82	**180**	0.47	**180**			**180**			**180**	
210	17.53	0.84	**210**	0.42	**210**			**210**			**210**	
240	17.66		**240**		**240**			**240**			**240**	
300	17.84	0.81	**300**		**300**			**300**			**300**	
360	18.10		**360**		**360**			**360**			**360**	
420			**420**		**420**			**420**			**420**	
480			**480**		**480**			**480**			**480**	
540			**540**		**540**			**540**			**540**	
600			**600**		**600**			**600**			**600**	
720			**720**		**720**			**720**			**720**	
840			**840**		**840**			**840**			**840**	
960			**960**		**960**			**960**			**960**	
1080			**1080**		**1080**			**1080**			**1080**	
1200			**1200**		**1200**			**1200**			**1200**	
1320			**1320**		**1320**			**1320**			**1320**	

1440			**1440**		**1440**			**1440**			**1440**	
1560			**1560**		**1560**			**1560**			**1560**	
1680			**1680**		**1680**			**1680**			**1680**	
1800			**1800**		**1800**			**1800**			**1800**	
1920			**1920**		**1920**			**1920**			**1920**	
2040			**2040**		**2040**			**2040**			**2040**	
2160			**2160**		**2160**			**2160**			**2160**	
2280			**2280**		**2280**			**2280**			**2280**	
2400			**2400**		**2400**			**2400**			**2400**	
2520			**2520**		**2520**			**2520**			**2520**	
2640			**2640**		**2640**			**2640**			**2640**	
2760			**2760**		**2760**			**2760**			**2760**	
2880			**2880**		**2880**			**2880**			**2880**	
3000			**3000**		**3000**			**3000**			**3000**	
3120			**3120**		**3120**			**3120**			**3120**	
3240			**3240**		**3240**			**3240**			**3240**	
3360			**3360**		**3360**			**3360**			**3360**	
3480			**3480**		**3480**			**3480**			**3480**	
3600			**3600**		**3600**			**3600**			**3600**	
3720			**3720**		**3720**			**3720**			**3720**	
3840			**3840**		**3840**			**3840**			**3840**	
3960			**3960**		**3960**			**3960**			**3960**	
4080			**4080**		**4080**			**4080**			**4080**	
4200			**4200**		**4200**			**4200**			**4200**	
4320			**4320**		**4320**			**4320**			**4320**	
Total time pumped(min):				360		**W/L**			**W/L**			**W/L**
Average yield (l/s):				0.82								

				STEPPED DISCHARGE TEST & RECOVERY										
BOREHOLE TEST RECORD SHEET														
PROJ NO :		P2636		MAP REFERENCE:						PROVINCE:		GAUTENG		
BOREHOLE NO:		LPV BH1D		LATITUDE:	S 26.12359					DISTRICT:		WEST RAND		
ALT BH NO:		0		LONGITUDE :	E 027.78253					SITE NAME:		KRUGERSDORP		
ALT BH NO:		0												
BOREHOLE DEPTH (m)			57.50		DATUM LEVEL ABOVE CASING (m):				0.63	EXISTING PUMP:		NEW BOREHOLE		
WATER LEVEL (mbdl):			11.05		CASING HEIGHT: (magl):				0.07	CONTRACTOR:		AB PUMPS		
DEPTH OF PUMP (m):			57.50		DIAM PUMP INLET (mm):				114.00	PUMP TYPE:		BP16		
STEPPED DISCHARGE TEST & RECOVERY														
DISCHARGE RATE 1			RPM	234	DISCHARGE RATE 2			RPM	344	DISCHARGE RATE 3			RPM	471
DATE:	10/03/2022	TIME:	11H10		DATE :	10/03/2022	TIME:	11H40		DATE :	10/03/2022	TIME:	12H10	
TIME	DRAW	YIELD	TIME	RECOVERY	TIME	DRAW	YIELD	TIME	RECOVERY	TIME	DRAW	YIELD	TIME	RECOVERY
(MIN)	DOWN (M)	(L/S)	(MIN)	(M)	(MIN)	DOWN (M)	(L/S)	(MIN)	(M)	(MIN)	DOWN (M)	(L/S)	(MIN)	(M)
1	1.44		**1**		**1**	9.40		**1**		**1**	16.08		**1**	39.40
2	1.70		**2**		**2**	10.51	0.35	**2**		**2**	16.80	0.58	**2**	36.52
3	2.55	0.24	**3**		**3**	11.30	0.41	**3**		**3**	17.30		**3**	33.53
5	3.45		**5**		**5**	12.32		**5**		**5**	20.61	0.71	**5**	27.50
7	4.34	0.22	**7**		**7**	13.26	0.42	**7**		**7**	24.68		**7**	23.00
10	5.30		**10**		**10**	13.88		**10**		**10**	28.91	0.70	**10**	18.84
15	6.93	0.23	**15**		**15**	14.08	0.41	**15**		**15**	34.96		**15**	13.72
20	7.52	0.21	**20**		**20**	14.42		**20**		**20**	39.41	0.72	**20**	10.70
30	8.57		**30**		**30**	15.87		**30**		**25**	46.40		**30**	6.93
40			**40**		**40**			**40**		**28**	46.40	0.41	**40**	5.70
50			**50**		**50**			**50**		**29**	46.40	0.37	**50**	5.10
60			**60**		**60**			**60**		**30**	46.40	0.30	**60**	4.48
70			**70**		**70**			**70**					**70**	3.10
80			**80**		**80**			**80**					**80**	2.54

90			**90**		**90**			**90**					**90**	2.29
100			**100**		**100**			**100**					**100**	2.04
110			**110**		**110**			**110**					**110**	1.88
120			**120**		**120**			**120**					**120**	1.45
pH			**150**		**pH**			**150**		**pH**			**150**	
TEMP	23.40	°C	**180**		**TEMP**	23.70	°C	**180**		**TEMP**	24.10	°C	**180**	
EC	3999	µS/cm	**210**		**EC**	3999	µS/cm	**210**		**EC**	3999	µS/cm	**210**	

			CONSTANT DISCHARGE TEST & RECOVERY									
BOREHOLE TEST RECORD SHEET												
PROJ NO :		P2636		MAP REFERENCE:		S 26.12359			PROVINCE:		GAUTENG	
BOREHOLE NO:		LPV BH1D				E 027.78253			DISTRICT :		WEST RAND	
ALT BH NO:		0							SITE NAME:		KRUGERSDORP	
ALT BH NO:		0										
BOREHOLE DEPTH:		57.50		DATUM LEVEL ABOVE CASING (m):				0.63	EXISTING PUMP:		NEW BOREHOLE	
WATER LEVEL (mbdl):		11.10		CASING HEIGHT: (magl):				0.07	CONTRACTOR:		AB PUMPS	
DEPTH OF PUMP (m):		57.50		DIAM PUMP INLET(mm):				114	PUMP TYPE:		BP16	
CONSTANT DISCHARGE TEST & RECOVERY												
TEST STARTED				**TEST COMPLETED**								
DATE :	11/03/2022	TIME:	08H40		DATE :		TIME:		TYPE OF PUMP:			BP16
					OBSERVATION HOLE 1			OBSERVATION HOLE 2			OBSERVATION HOLE 3	
					NR:			NR:			NR:	
	DISCHARGE BOREHOLE				Distance(m);			Distance(m) ;			Distance(m);	
TIME (MIN)	DRAW DOWN (M)	YIELD (L/S)	TIME MIN	RECOVERY (M)	TIME: (min)	Drawdown m	Recovery (m)	TIME: (min)	Drawdown (m)	Recovery	TIME: (min)	Drawdown (m)
1	1.58		**1**	39.05	**1**			**1**			**1**	
2	2.52		**2**	32.40	**2**			**2**			**2**	
3	3.05	0.30	**3**	30.13	**3**			**3**			**3**	
5	4.47		**5**	27.92	**5**			**5**			**5**	
7	6.44	0.35	**7**	25.07	**7**			**7**			**7**	
10	7.91		**10**	21.60	**10**			**10**			**10**	
15	9.95	0.36	**15**	15.63	**15**			**15**			**15**	
20	11.40		**20**	13.04	**20**			**20**			**20**	
30	13.80	0.35	**30**	8.54	**30**			**30**			**30**	
40	14.10		**40**	6.78	**40**			**40**			**40**	
60	15.37	0.35	**60**	4.61	**60**			**60**			**60**	
90	17.40		**90**	3.15	**90**			**90**			**90**	
120	19.60	0.36	**120**	2.19	**120**			**120**			**120**	
150	22.27		**150**	1.27	**150**			**150**			**150**	
180	25.40	0.35	**180**	0.86	**180**			**180**			**180**	
210	28.73		**210**	0.54	**210**			**210**			**210**	
240	31.70	0.35	**240**	0.31	**240**			**240**			**240**	
300	46.40		**300**		**300**			**300**			**300**	

				STEPPED DISCHARGE TEST & RECOVERY										
BOREHOLE TEST RECORD SHEET														
PROJ NO :		P2636		MAP REFERENCE:						PROVINCE:		GAUTENG		
BOREHOLE NO:		TFS BH1S		LATITUDE:	S 26.13765					DISTRICT:		WESTRAND		
ALT BH NO:		0		LONGITUDE :	E 27.77096					SITE NAME:		KRUGERSDORP		
ALT BH NO:		0												
BOREHOLE DEPTH (m)			29.35		DATUM LEVEL ABOVE CASING (m):				0.59	EXISTING PUMP:		NEW BOREHOLE		
WATER LEVEL (mbdl):			1.09		CASING HEIGHT: (magl):				0.20	CONTRACTOR:		AB PUMPS		

DEPTH OF PUMP (m):			27.50		DIAM PUMP INLET (mm):				114.00	PUMP TYPE:		BP16		
STEPPED DISCHARGE TEST & RECOVERY														
DISCHARGE RATE 1			RPM	212	DISCHARGE RATE 2			RPM	411	DISCHARGE RATE 3			RPM	764
DATE:	07/03/2022	TIME:	11H30		DATE:	07/03/2022	TIME:	12H00		DATE:	07/03/2022	TIME:	12H30	
TIME (MIN)	DRAW DOWN (M)	YIELD (L/S)	TIME (MIN)	RECOVERY (M)	TIME (MIN)	DRAW DOWN (M)	YIELD (L/S)	TIME (MIN)	RECOVERY (M)	TIME (MIN)	DRAW DOWN (M)	YIELD (L/S)	TIME (MIN)	RECOVERY (M)
1	0.66		**1**		**1**	3.24		**1**		**1**	6.87	1.87	**1**	
2	0.94	0.36	**2**		**2**	3.47	0.98	**2**		**2**	7.42	2.02	**2**	
3	1.22		**3**		**3**	3.82		**3**		**3**	8.70		**3**	
5	1.73	0.50	**5**		**5**	4.49	1.01	**5**		**5**	11.17	2.01	**5**	
7	1.99		**7**		**7**	5.30		**7**		**7**	13.06		**7**	
10	2.08	0.54	**10**		**10**	5.60	1.00	**10**		**10**	14.58	2.04	**10**	
15	2.70		**15**		**15**	5.95		**15**		**15**	15.97		**15**	
20	2.87	0.53	**20**		**20**	6.09	1.02	**20**		**20**	16.47	2.05	**20**	
30	3.07		**30**		**30**	6.25		**30**		**30**	17.13		**30**	
40			**40**		**40**			**40**		**40**			**40**	
50			**50**		**50**			**50**		**50**			**50**	
60			**60**		**60**			**60**		**60**			**60**	
70			**70**		**70**			**70**		**70**			**70**	
80			**80**		**80**			**80**		**80**			**80**	
90			**90**		**90**			**90**		**90**			**90**	
100			**100**		**100**			**100**		**100**			**100**	
110			**110**		**110**			**110**		**110**			**110**	
120			**120**		**120**			**120**		**120**			**120**	
pH			**150**		**pH**			**150**		**pH**			**150**	
TEMP	21.30	°C	**180**		**TEMP**	20.30	°C	**180**		**TEMP**	20.00	°C	**180**	
EC	1770	µS/cm	**210**		**EC**	1655	µS/cm	**210**		**EC**	1890	µS/cm	**210**	
DISCHARGE RATE 4			RPM		DISCHARGE RATE 5			RPM		DISCHARGE RATE 6			RPM	
DATE:	07/03/2022	TIME:	13H00		DATE:		TIME:			DATE:		TIME:		
TIME (MIN)	DRAW DOWN (M)	YIELD (L/S)	TIME (MIN)	RECOVERY (M)	TIME (MIN)	DRAW DOWN (M)	YIELD (L/S)	TIME (MIN)	RECOVERY (M)	TIME (MIN)	DRAW DOWN (M)	YIELD (L/S)	TIME (MIN)	RECOVERY (M)
1	17.68		**1**	9.85	**1**			**1**		**1**			**1**	
2	19.12	2.98	**2**	8.56	**2**			**2**		**2**			**2**	
3	23.19		**3**	6.94	**3**			**3**		**3**			**3**	
5	25.60		**5**	5.24	**5**			**5**		**5**			**5**	
	25.60	2.17	**7**	3.36	**7**			**7**		**7**			**7**	
	25.60	2.10	**10**	2.24	**10**			**10**		**10**			**10**	
	25.60	2.01	**15**	1.65	**15**			**15**		**15**			**15**	
			20	1.40	**20**			**20**		**20**			**20**	
			30	0.89	**30**			**30**		**30**			**30**	
			40	0.70	**40**			**40**		**40**			**40**	
			50	0.51	**50**			**50**		**50**			**50**	
			60	0.42	**60**			**60**		**60**			**60**	
			70	0.35	**70**			**70**		**70**			**70**	
			80	0.27	**80**			**80**		**80**			**80**	
			90	0.22	**90**			**90**		**90**			**90**	
			100	0.19	**100**			**100**		**100**			**100**	
			110		**110**			**110**		**110**			**110**	
			120		**120**			**120**		**120**			**120**	
pH			**150**		**pH**			**150**		**pH**			**150**	
TEMP		°C	**180**		**TEMP**		°C	**180**		**TEMP**		°C	**180**	
EC		µS/cm	**210**		**EC**		µS/cm	**210**		**EC**		µS/cm	**210**	
			240					**240**					**240**	
			300					**300**					**300**	

			360					**360**					**360**	

			CONSTANT DISCHARGE TEST & RECOVERY									
BOREHOLE TEST RECORD SHEET												
PROJ NO :		P2636		MAP REFERENCE:		S 26.13765			PROVINCE:		GAUTENG	
BOREHOLE NO:		TFS BH1S				E 27.77096			DISTRICT :		WESTRAND	
ALT BH NO:		0							SITE NAME:		KRUGERSDORP	
ALT BH NO:		0										
BOREHOLE DEPTH:		29.35		DATUM LEVEL ABOVE CASING (m):				0.59	EXISTING PUMP:		NEW BOREHOLE	
WATER LEVEL (mbdl):		1.09		CASING HEIGHT: (magl):				0.20	CONTRACTOR:		AB PUMPS	
DEPTH OF PUMP (m):		27.50		DIAM PUMP INLET(mm):				114	PUMP TYPE:		BP16	
CONSTANT DISCHARGE TEST & RECOVERY												
TEST STARTED				**TEST COMPLETED**								
DATE :	08/03/2022	TIME:	08H00		DATE :		TIME:		TYPE OF PUMP:			BP16
					OBSERVATION HOLE 1			OBSERVATION HOLE 2			OBSERVATION HOLE 3	
					NR:			NR:			NR:	
	DISCHARGE BOREHOLE				Distance(m);			Distance(m) ;			Distance(m);	
TIME	DRAW	YIELD	TIME	RECOVERY	TIME:	Drawdown	Recovery	TIME:	Drawdown	Recovery	TIME:	Drawdown
(MIN)	DOWN (M)	(L/S)	MIN	(M)	(min)	m	(m)	(min)	(m)		(min)	(m)
1	1.89		**1**	11.13	**1**			**1**			**1**	
2	3.02		**2**	9.02	**2**			**2**			**2**	
3	3.58	1.53	**3**	7.64	**3**			**3**			**3**	
5	5.36		**5**	6.71	**5**			**5**			**5**	
7	7.61	1.70	**7**	4.73	**7**			**7**			**7**	
10	9.92		**10**	3.49	**10**			**10**			**10**	
15	11.37	1.74	**15**	2.61	**15**			**15**			**15**	
20	12.48		**20**	1.96	**20**			**20**			**20**	
30	14.11	1.72	**30**	1.48	**30**			**30**			**30**	
40	15.01		**40**	1.20	**40**			**40**			**40**	
60	15.30	1.75	**60**	0.76	**60**			**60**			**60**	
90	15.55		**90**	0.48	**90**			**90**			**90**	
120	15.59	1.70	**120**		**120**			**120**			**120**	
150	15.61		**150**		**150**			**150**			**150**	
180	15.61	1.72	**180**		**180**			**180**			**180**	
210	15.58		**210**		**210**			**210**			**210**	
240	15.58	1.70	**240**		**240**			**240**			**240**	
300	15.65		**300**		**300**			**300**			**300**	
360	16.54	1.73	**360**		**360**			**360**			**360**	
420	16.93		**420**		**420**			**420**			**420**	
480	17.34	1.72	**480**		**480**			**480**			**480**	