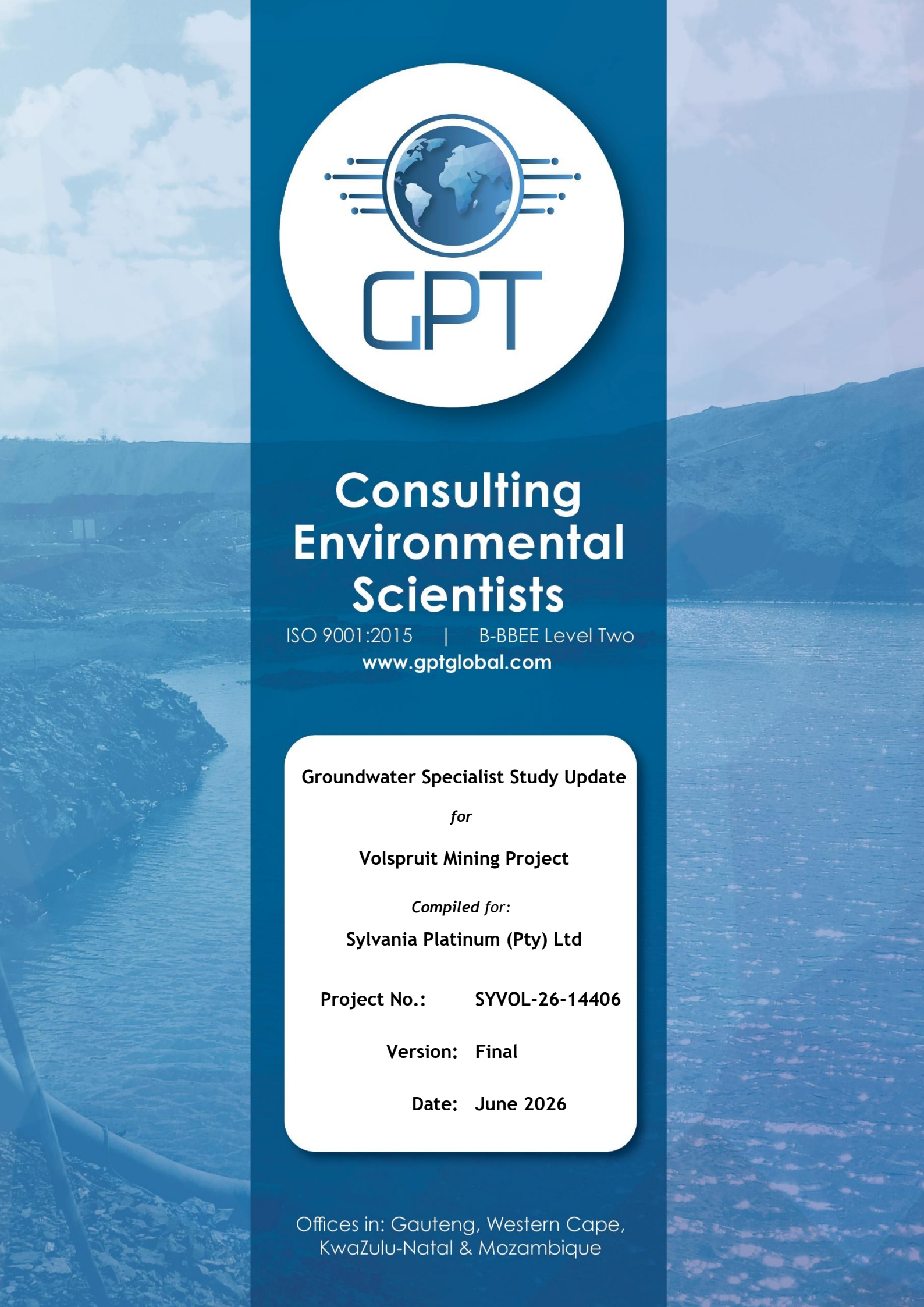


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Groundwater Specialist Study Update

for

Volspruit Mining Project

***Compiled** for:*

Sylvania Platinum (Pty) Ltd

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NEMA Regs (2014)	Relevant section in report
Details of the specialist who prepared the report	G. J. Du Toit; PhD; Pr. Sci. Nat (400043/86)
The expertise of that person to compile this specialist report including a curriculum vita	G. J. Du Toit; B.Sc. (Physics); M.Sc. (Nuclear Physics); B.Sc. (Hon.) (Engineering Geology); D.Sc. (Physics-Fluid Dynamics). Twenty-five (25) years' experience in numerical groundwater modelling.
A declaration that the person is independent in a form as may be specified by the competent authority	See page i
An indication of the scope of, and the purpose for which, the report was prepared	See Section 3
The date and season of the site investigation and the relevance of the season to the outcome of the assessment	See Section 5
A description of the methodology adopted in preparing the report or carrying out the specialised process	See Section 4
The specific identified sensitivity of the site related to the activity and its associated structures and infrastructure	See Section 8
An identification of any areas to be avoided, including buffers	See Section 7 and 8
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;	See Section 8
A description of any assumptions made and any uncertainties or gaps in knowledge;	See Section 8
A description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives, on the environment	See Section 7 and 8
Any mitigation measures for inclusion in the EMPr	See Section 8, 9 and 11
Any conditions for inclusion in the environmental authorisation	See Section 8, 9 and 10
Any monitoring requirements for inclusion in the EMPr or environmental authorisation	See Section 9
A reasoned opinion as to whether the proposed activity or portions thereof should be authorised and	See Section 8 and 12
If the opinion is that the proposed activity 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	
A description of any consultation process that was undertaken during the course of carrying out the study	Not applicable
A summary and copies if any comments that were received during any consultation process	Not applicable
Any other information requested by the competent authority.	Not applicable

EXECUTIVE SUMMARY

This report has been prepared at the request of Sylvania Platinum (Pty) Ltd following discussions held during a recent meeting, where it was agreed that an update of the existing numerical groundwater model is required prior to submission of the Water Use Licence (WUL) application.

For this report, the existing numerical groundwater model has been updated using the most recent available data, site information, and design inputs available at the time of modelling. The updated report will form part of the planned Water Use Licence (WUL) application.

The following new and updated information have been incorporated into the model:

- Abstraction of water at Grassvally to dewater the mine.
- Integration of the revised contamination source term developed by Dr Merris Mills.
- Incorporation of the most recent groundwater level data obtained from the latest hydrocensus.
- Incorporation of the most recent groundwater chemistry data available at the time of modelling.
- As part of this scope, the cumulative impact of groundwater dewatering of both Volspruit and Grasvally was calculated.

Numerical Modelling (Water Quality): Once the normal groundwater flow conditions have been re-instated, polluted water can migrate away from the rehabilitated opencast. Although the overburden has been shown to be non-acid generating, the geochemical study predicted limited production of sulphate. Thus, seepage from the backfilled opencasts will most likely be contaminated as a result of neutral mine drainage. As sulphate is normally a significant solute in such drainage, it has been modelled as a conservative (non-reacting) indicator of mine drainage pollution. The geochemical model indicated that the sulphate concentration in the pit will be about 100 mg/L over a period of 100 years after the discard rock has been backfilled into the pit. The period of 100 years was selected because various studies have shown that contamination can decrease substantially over long time scales through processes such as adsorption and dilution.

Firstly, the migration of contaminated water from the mining area has been modelled with current irrigation included. The results are presented in Figure 39. It follows from this figure that:

- The plume is drawn towards the irrigation areas to the west of the Nyl River and underflow the river, but is deep below the floodplain bed and does not affect the surface water.
- There is also a substantial plume migration to the irrigation areas south of the mining area but is not predicted to reach those boreholes in the forecast period.
- It thus follows that the direction of plume migration is dominated by groundwater abstraction, as result of the almost horizontal water table. The groundwater flow will thus always be to where the water table is lowered.

Secondly, the migration of contaminated water from the mining area has been modelled with irrigation as well as abstraction from the Grasvally mine for Mokopane after closure. The flow patterns in the aquifer changed significantly in this scenario as illustrated in Figure 40:

- Plume movement is now significantly in the direction of Grasvally and is a more important factor of influence on groundwater flow than the abstraction for irrigation in the groundwater.

- This change in groundwater flow direction is due to the proximity of the underground mine to the Volspruit site as well as the depth of the defunct underground mine.

It is therefore concluded that:

- Groundwater flow direction is dominated by groundwater abstraction rather than topographical features.
- Migration of potential pollution will thus be towards the most prominent groundwater abstraction areas rather than the topographical downstream regions as would be intuitively expected.
- However, the impact on the underlying aquifer and groundwater receptors will be insignificant due to the low acid generation capacity of the ore and bedrock.

Significance Rating:

Impacts	Significance = Irreplaceability (Reversibility + Intensity + Duration + Extent) X Probability		Mitigation Efficiency (ME)	Significance Rating (WM) = Significance Rating (WOM) x Mitigation Efficiency	
Drawdown of North Pit	60	Medium	1	60	High
Drawdown of South Pit	60	Medium	1	60	High
Decanting of North Pit	15	Very low	0.6	9	Very low
Decanting of South Pit	15	Very low	0.6	9	Very low
Groundwater Quality of Pits	60	High	0.6	36	Low
Groundwater Quality of YSF & RWD	45	Medium	0.6	27	Low

Recommendations: Based on the finding in this report and previous work conducted, the following recommendation can be made:

- It was seen in this report that the biggest groundwater impact risk of this mine is the cone of depression extending to the aquifer below the Nyl River, but it has been proved to be unlikely to have a major influence on the normal flood progression due to the impermeable clay layer underneath river. Nevertheless, ensuring a well-constructed flood protection berm downstream of the North Pit is considered essential to ensure that no flood can overtop to the east of the Nyl River in the North Pit. Another option is to construct a similar berm west of the Nyl as well, thus creating a natural clay-bottomed channel for the unimpeded passing of floods. The berm should be as impermeable to water as possible.
- During numerical modelling of various scenarios, grouting has not been successful in containing the cone of depression, nor influence decanting significantly. Therefore, grouting can thus no longer be recommended as an ultimate solution.
- The next risk of importance is that the pit could decant during high rainfall periods. But it has been shown to be rather unlikely, and the pit water is predicted to be of acceptable quality. Nevertheless, it is essential that the post mining pit water is managed to ensure that decant cannot occur. Should future quality monitoring provide proof of acceptable pit water quality, connection with the river for ecological purposes can be considered.
- Lastly, there will be the development of a plume of contamination from the North Pit, as well as from the surface facilities such as the tailings facility and waste rock dump. It has been shown in this report that acid mine drainage is unlikely to develop and the predicted water quality should thus be at an acceptable level. It could be that nitrate contamination might occur due to the use of groundwater as process water, but that must be proved by monitoring. It is thus essential that groundwater quality be monitored regularly during and post mining on a quarterly basis to provide a reliable database to facilitate eventual closure of the mining operation. Water samples must

be taken from all the monitoring boreholes by using approved sampling techniques and adhering to recognised sampling procedures. Samples should be analysed for both organic as well as inorganic pollutants, as mining activity often leads to hydrocarbon spills in the form of diesel and oil. At least the following water quality parameters should be analysed for:

- Major ions (Ca, K, Mg, Na, SO4, NO3, Cl, F)
- pH
- Electrical Conductivity (EC),
- Total Petroleum Hydrocarbons (TPH)
- Total Alkalinity

In conclusion, the following measures are recommended:

- Mining at the eastern section of North Pit must be used as a proving phase for groundwater control measures. Regular monitoring must be done and be safeguarded in a database for evaluation and updating of the impact prediction.
- Dewatering rates from the opencasts must be measured on a continuous basis and records be kept for analyses.
- Progressive detection of major fractures that could endanger the mine and the environment must be conducted, followed by confirmation through advanced drilling and localised grouting.
- The piezometer levels at the edge of the Nyl River must be measured monthly during the dry season, and the frequency should be doubled during high rain seasons.
- A groundwater monitoring network should be designed once the mine design has been completed. The network should comply with the requirements of an ISO 14000 monitoring system. The boreholes identified during the hydrocensus as well as the newly drilled boreholes can be used in the network.
- Quarterly groundwater sampling must be done to establish a database of plume movement trends, to aid eventual mine closure.
- All groundwater data (prior to and during mining) must be analysed annually by a qualified hydrogeologist and interpreted in terms of the reaction of the groundwater to mine dewatering to date and extrapolated to the future mining depths according to the latest mining plans.
- Based on such reports, an annual update of the groundwater management plan must be performed.
- These reports must also be submitted to authorities and presented to interested and affected parties annually, to satisfy all role players that sound groundwater management practices is adhered to.
- The recommended Department of Water and Sanitation (DWS) best practice guidelines must be adhered to at all times.

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LIST OF ABBREVIATIONS

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

DEFINITIONS

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

Definition	Explanation
Karst (Karstic) Aquifer	A body of soluble rock that conducts water principally via enhanced (conduit or tertiary) porosity formed by the dissolution of the rock. The aquifers are commonly structured as a branching network of tributary conduits, which connect together to drain a groundwater basin and discharge to a perennial spring.
Monitoring	The regular or routine collection of groundwater data (e.g. water levels, water quality and water use) to provide a record of the aquifer response over time.
Observation Borehole	A borehole used to measure the response of the groundwater system to an aquifer test.
Phreatic Surface	The surface at which the water level is in contact with the atmosphere: the water table.
Piezometric Surface	An imaginary or hypothetical surface of the piezometric pressure or hydraulic head throughout all or part of a confined or semi-confined aquifer; analogous to the water table of an unconfined aquifer.
Porosity	Porosity is the ratio of the volume of void space to the total volume of the rock or earth material.
Production Borehole	A borehole specifically designed to be pumped as a source of water supply.
Recharge	The addition of water to the saturated zone, either by the downward percolation of precipitation or surface water and/or the lateral migration of groundwater from adjacent aquifers.
Recharge Borehole	A borehole specifically designed so that water can be pumped into an aquifer in order to recharge the ground-water reservoir.
Saturated Zone	The subsurface zone below the water table where interstices are filled with water under pressure greater than that of the atmosphere.
Specific Capacity	The rate of discharge from a borehole per unit of drawdown, usually expressed as m3/d•m.
Specific Yield	The ratio of the volume of water that drains by gravity to that of the total volume of the saturated porous medium.
Storativity	The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.
Transmissivity	Transmissivity is the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. It is expressed as the product of the average hydraulic conductivity and thickness of the saturated portion of an aquifer.
Unsaturated Zone (Also Termed Vadose Zone)	That part of the geological stratum above the water table where interstices and voids contain a combination of air and water.
Watershed (Also Termed Catchment)	Catchment in relation to watercourse or watercourses or part of a watercourse means the area from which any rainfall will drain into the watercourses or part of a watercourse through surface flow to a common point or points. Source: National Water Act (Act No. 36 of 1998).
Water Table	The upper surface of the saturated zone of an unconfined aquifer at which pore pressure is equal to that of the atmosphere.

GROUNDWATER SPECIALIST STUDY UPDATE

VOLSPRUIT MINING PROJECT

1 INTRODUCTION

This report has been prepared at the request of Sylvania Metals (Pty) Ltd following discussions held during a recent meeting, where it was agreed that an update of the existing numerical groundwater model is required prior to submission of the Water Use Licence (WUL) application.

For this report, the existing numerical groundwater model has been updated using the most recent available data, site information, and design inputs available at the time of modelling. The updated report will form part of the planned Water Use License (WUL) application.

The following new and updated information have been incorporated into the model:

- Abstraction of water at Grassvally to dewater the mine.
- Integration of the revised contamination source term developed by Dr Merris Mills.
- Incorporation of the most recent groundwater level data obtained from the latest hydrocensus.
- Incorporation of the most recent groundwater chemistry data available at the time of modelling.

As part of this scope the cumulative impact of groundwater dewatering of both Volspruit and Grassvally where calculated.

1.1 Modelling History

Geo Pollution Technologies - Gauteng (Pty) Ltd (GPT) was appointed during April 2010 by EScience Associates (Pty) Ltd to conduct a hydrogeological study for the proposed Volspruit Mine (North Pit). An expansion of the scope of the project took place during October 2010 to include the South pit area. The study aimed to quantify the impacts that both the mining activities would have on the groundwater environment.

In January 2014 the report was submitted to the Institute for Groundwater Studies (IGS) of the University of the Free State for peer review. The IGS responded with the report “Review of the proposed Volspruit Mine (North- and South pit) near Mokopane, Limpopo Province”, by Professors G van Tonder and D Vermeulen (report number Report number: 2014/18/PDV). In this report the IGS concluded that “We studied the above report in detail and found it scientifically sound. Technically, the report is presented in an efficient way and most of the important issues were dealt with. The main issues related not to work done but to work that had not been done.” an abbreviated report was inter alia requested, which was conducted in August 2014.
In April 2021 GPT was appointed by EcoPartners (Pty) Ltd to conduct a groundwater specialist study update for the Proposed Volspruit Mining Project. This study was carried out within the framework of the National Water Act (Act No. 36 of 1998) in support of an application for the amendment of the current environmental authorisation. Furthermore, the updated report included the procedures for the assessment and minimum criteria for reporting on identified environmental themes in terms of Sections 24(5)(A) and (H) and 44 of the National Environmental Management Act, 1998, when applying for environmental authorisation.

The latest update of the Volspruit project was done in 2023 (Groundwater Specialist Study Update for the Volspruit Mining Project: EPVOL-23-9279). This update was done to correspond to the latest Volspruit Pit designs. The scenarios modelled were:

- Predicting the drawdown of the groundwater levels at Vospruit.
- Determining the possibility of decanting of the pits.
- Modelling contaminant transport to predict the sulphate plume movement.

1.2 Normative Reports

- Geo Pollution Technologies (Pty) Ltd (GPT), August 2014, Final geohydrological report for the proposed Volspruit Mine (North- and South Pit) near Mokopane, Limpopo Province, GPR Reference Number: ESVOL-13-447F.
- Geo Pollution Technologies (Pty) Ltd (GPT), 2020. Hydrogeological Study for Grassvally. GPT Reference Number: PRPRE-20-5083.
- Geo Pollution Technologies (Pty) Ltd (GPT), November 2012, Geohydrological report for the Proposed Volspruit Mine (North-and South Pit) near Mokopane, Limpopo Province, GPT Reference Number: EAV-11-053.
- IGS, June 2010, Geological and Resource Estimation Report On The Grass Valley Project, Volspruit 326KR, Limpopo Province, South Africa
- Department of Water Affairs, 1965. Verslag oor die Grondwateraangeleenthede op die Springbok Vlakte. Report No GH3056
- Escience Associates (Pty) Ltd, January 2014, Nyl River Hydrological Modelling, Project No: W00/JNB/000029
- Escience Associates (Pty) Ltd, September 2012, Draft Acid Mine Drainage Potential Assessment: Volspruit Waste Rock and Tailing Samples
- Prof A Claassens, May 2013. Report on the Soil Survey and Land Capability Classification of the Farms Volspruit and Zoetveld.
- Wetland Consulting Services, 2022. Hydropedological Assessment for the Volspruit Opencast Mining Project.
- SRK Consulting, January 2012, Volspruit TSF Site Selection, Report Number: 438050/01 Rev
- Wetland Consulting Services (Pty) Ltd, 2012, Biodiversity Assessment for the Proposed Sylvania Resources Volspruit Mine near Mokopane in the Limpopo Province, Reference: 590/2012
- Wetland Consulting Services (Pty) Ltd, 2012, Biodiversity Assessment for the Proposed Sylvania Resources Volspruit Mine on the Farm Volspruit 326 KP, Limpopo Province, Reference 590/2010
- Geo Pollution Technologies (Pty) Ltd (GPT), May 2024, Groundwater Specialist Study Update for Volspruit Mining Project. Reference EPVOL-23-9279
- Mills Water, January 2025, Simulation of water quality from North Pit, Volspruit Mine. Final Report.
- Geo Pollution Technologies (Pty) Ltd (GPT), April 2026, Quarterly Monitoring. Reference SYVOL-26-14256
- Geo Pollution Technologies (Pty) Ltd (GPT), June 2026, Hydrocensus Investigation. Reference SYVOL-26-14283

2 SCOPE OF WORK

This study focused on incorporating the new mining plans for the Grasvally Underground Mine, owned by Forward Africa Mining. The existing numerical groundwater model was modified to incorporate this underground mine in more detail, especially incorporating the depth of mining. The update also used the most recent available data, site information, and design inputs available at the time of modelling. The updated report was tailored to form part of the planned Water Use Licence (WUL) application.

The following new and updated information has been incorporated into the model and report:

- Estimation of the abstraction of water to dewater the proposed Grassvally Mine.
- Integration of the revised source term as defined by the Mills Water - Simulation of water quality from North Pit, Volspruit Mine
- The most recent groundwater level data obtained from the latest hydrocensus.
- Incorporation of the most recent groundwater chemistry data available.
- Estimating the cumulative impact of groundwater dewatering of both Volspruit and Grassvally

3 METHODOLOGY

Existing and recent supplied data will be used to quantify the potential impact on the receiving environment. A hydrogeological report will be drafted which can be submitted to regulators.

3.1 Desktop Study

Relevant historical reports and previous investigations will be reviewed to identify information pertinent to the objectives of this assessment. Applicable findings and supporting information will be incorporated into this report where relevant.

3.2 Hydrocensus

A hydrocensus survey was undertaken. The updated hydrocensus was undertaken to support the numerical groundwater model update, and the key findings are summarised in this report.

3.3 Numerical Groundwater Modelling

The existing groundwater model was updated to reflect the most recent mining layout plans as described in the scope of work.

3.4 Reporting

A report detailing the findings of the study are provided in the format of regulations regarding the procedural requirements for water use licence applications and appeals, specialist groundwater study (published, March 2017).

4 GEOGRAPHICAL SETTING

4.1 Site Location, Topography and Drainage

The Volspruit Project is located approximately 15 km south of the town of Mokopane (previously Potgietersrus) in the Limpopo Province of South Africa. as illustrated in Figure 1. The project area is located on the farm Volspruit 326 KP. The north Pit area is located on the portion of the Volspruit

property owned by Mr. P. de Klerk, while the South Pit area is located on the portion of the Volspruit property owned by Mr. D. de Beer.

The topography (shown in Figure 2) can normally be used as a good first approximation of the hydraulic gradient in the aquifer. This discussion will focus on the slope and direction of fall of the area under investigation, features that are important from a groundwater point of view.

The area is characterised by a generally flat topography and around the site the slope is more or less in the order of 1.7% towards the Nyl River, approximately 150 m west of North Pit and 1 km west of South Pit.

The site is located adjacent to the Nyl River which flows in a north-easterly direction towards the town of Mokopane. Locally the surface drainage is in a western direction, towards the Nyl River. Regionally the drainage is in a north easterly direction. The area of interest forms part of the A61E Quaternary catchment.

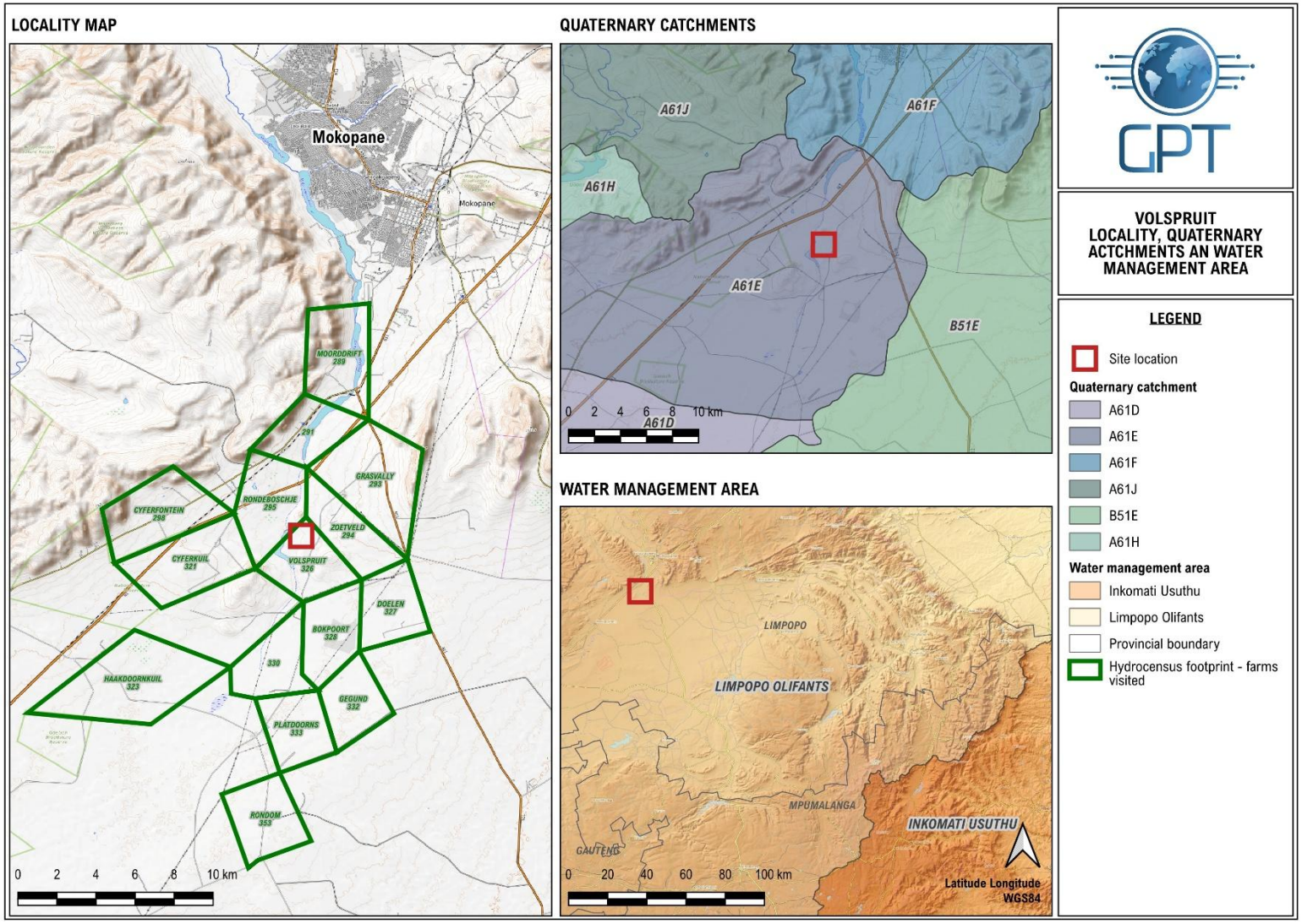


Figure 1: Site Location

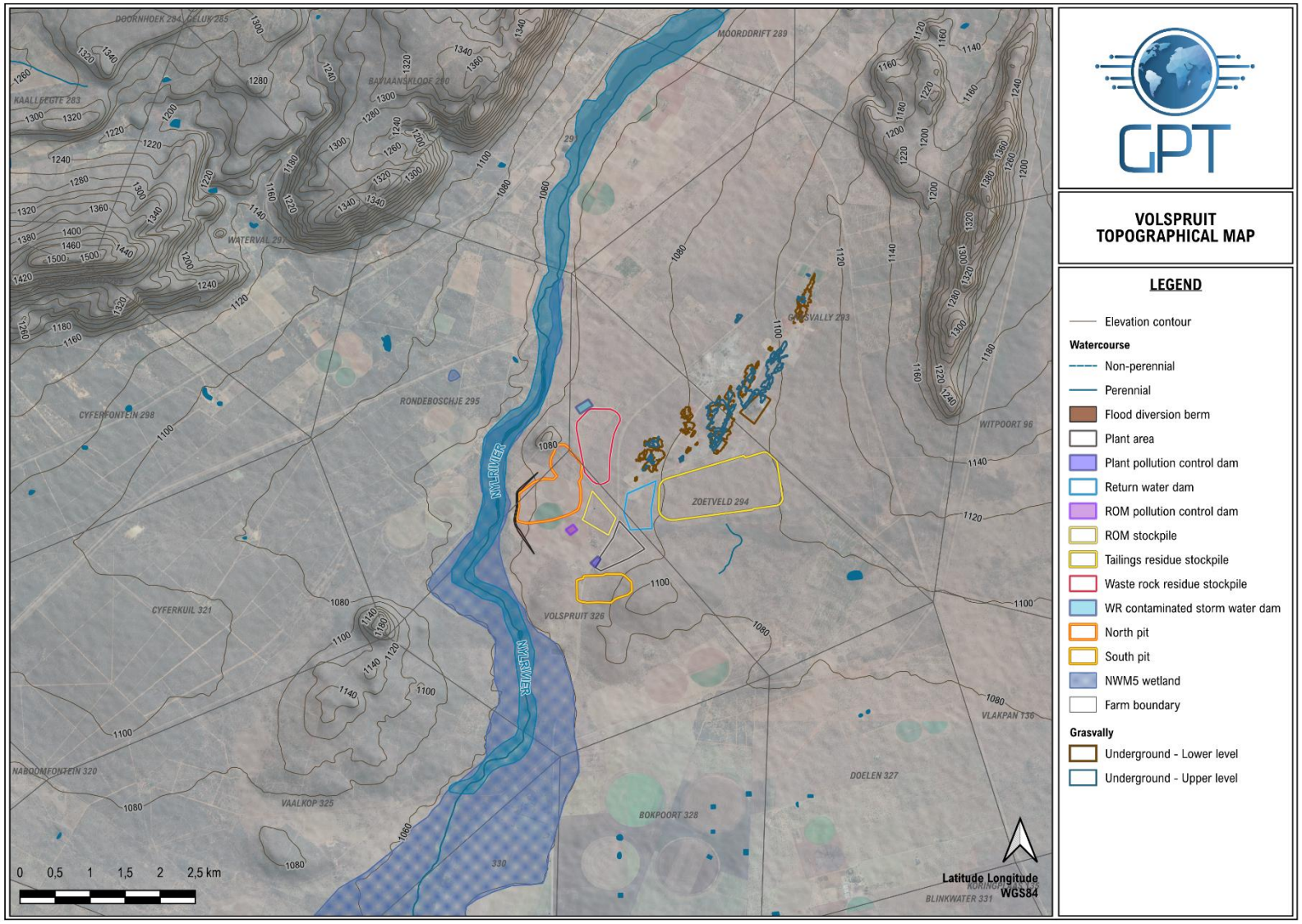


Figure 2: Site Topography

4.2 Climate

Climatic data was obtained from the Samsam Climate tool.[1] The average annual rainfall for this location is 529 mm per year, with the high rainfall months between November and March. The proposed Volspruit Mine is located in the summer rainfall region of Southern Africa with precipitation usually occurring in the form of convectional thunderstorms.

Table 1: Climatic Data

Month	Average Monthly Rainfall (mm)	Mean Monthly Evaporation (mm)
January	84	207
February	82	178
March	51	174
April	33	146
May	10	132
June	4	112
July	5	115
August	4	152
September	14	187
October	39	211
November	95	200
December	108	204
Annual	529	2023

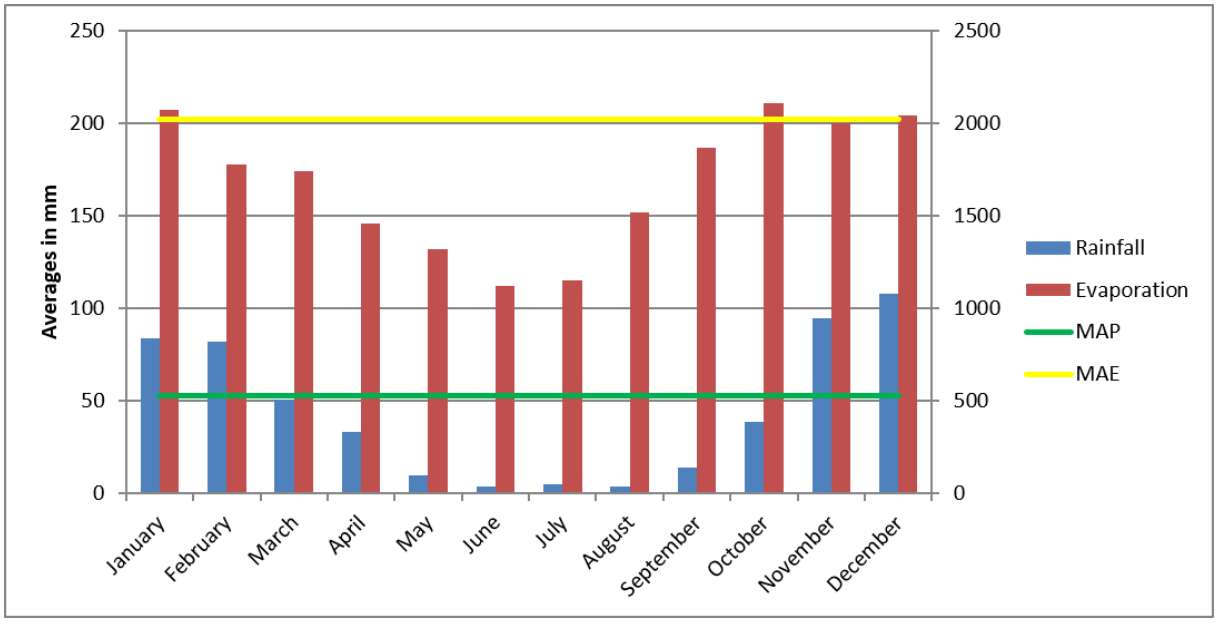


Figure 3: Climatic data representation

[1] https://www.samsamwater.com/climate Date of access:2026/06/01

4.3 Rainfall Data

Mr Ken Smith, who was visited during the hydrocensus, has maintained rainfall records for his property since the early 1900s. During the survey, Mr Smith shared his rainfall records with GPT. The rainfall data for the most recent 20-year period are presented in the table and figures below.

The records indicate a 20-year average annual rainfall of 548 mm, which compares well with the long-term average annual rainfall of 529 mm derived from the Samsam Climate Tool. Over the 20-year period, annual rainfall ranged from a minimum of 276 mm to a maximum of 798.5 mm.

Table 2: Ken Smith Rainfall Data

Month/Year	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	2022-2023	2023-2024	2024-2025	2025-2026	Average
SEP		68.5				70	3		26					12	3				15	**28.21**
OCT	26	29		22	10	85	44		32	28	55		17	110	20	44	25	7	72	**39.13**
NOV	176	218	171	163	159	46	39	61	43	244	39	19	150	113	137	164	45	107	49	**112.79**
DEC	19	177	126	173	173	103	167	259	54	202	99	85	38	126	113	163	200	224	127	**138.32**
JAN	26	242	353	144	113	66	50	139	33	51	26	128	180	109	138	102	254	154	131	**128.37**
FEB	29	39	146		15		75	5	84		70	43	107	13	27	60	28	170		**60.73**
MAR		25			48	65	144	38	75	20	36	9		20	65	28	34		144	**53.64**
APR					91		16	50	17		34	50	45	5	111	15	20	134	106	**53.38**
JUN									19											**19.00**
Total	**276**	**798.5**	**796**	**502**	**609**	**435**	**538**	**552**	**383**	**545**	**359**	**334**	**537**	**508**	**614**	**576**	**606**	**796**	**644**	**547.82**

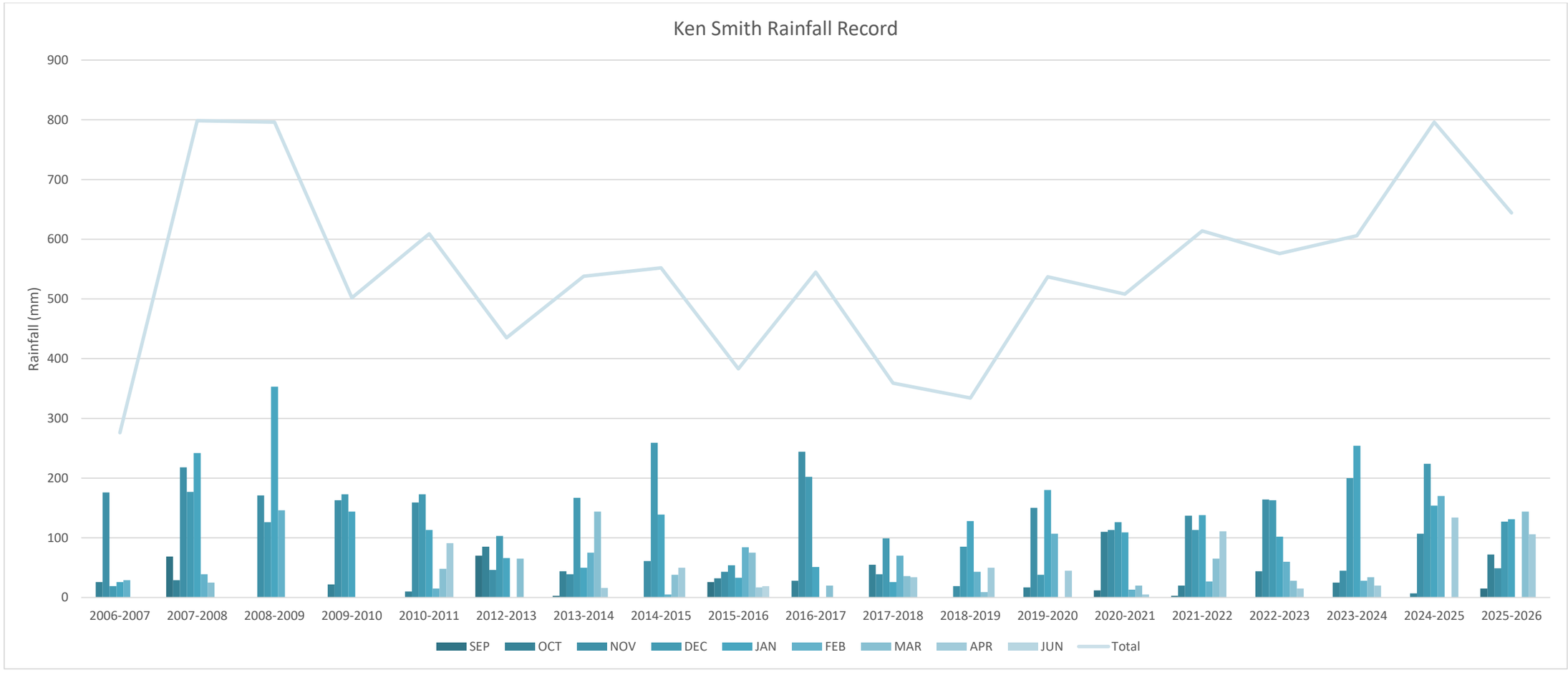


Figure 4: Ken Smith Rainfall Record

4.4 Geology

The proposed Volspruit Mine falls within the 2428 Nylstroom 1:250 000 geology series maps. An extract of these maps is shown in Figure 4.

The Bushveld Igneous Complex consists of the eastern, western, northern and southern limbs as well as satellite outcrops at Nietverdiend (far west) and Villa Nora (far north). According to dating of the rocks, they fall partly into the Vaalian Erathem and partly in the Mokolian Erathem. The commonly accepted intrusion age of the Bushveld Complex is 2.065 Ga. The main Bushveld Igneous Complex intruded into rocks of the Transvaal Supergroup, largely along an unconformity between the Magaliesberg quartzite of the Pretoria Group and the overlying Rooiberg felsites. The total extent of the Bushveld Complex is approximately 66,000km2, just over half of which is covered by younger formations[2].

The proposed Volspruit Mine is situated on the northern limb of the Bushveld Igneous Complex. In contrast to the prominent layering of the other limbs, the ore in the northern limb is in a more dispersed form. The mineralisation is classified as a disseminated, PGE bearing base metal within the Lower Zone of the Bushveld Complex, overlying floor rocks of the Transvaal Supergroup. The zone of PGE and base metal sulphide mineralisation which has been targeted by the Volspruit exploration (informally referred to as the Volspruit PGE-Ni Reef) is hosted in pyroxenites (orthopyroxenite cumulates) in the lower portion of the upper Volspruit sub-zone. The ore body has a fairly flat lying disposition: the ore zone is shallowest in the north-east, but downfaulted to the south and west to a depth of approximately 70 to 90 metres at the south western extent of the body.

[2] IGS, June 2010, Geological And Resource Estimation Report On The Grass Valley Project, Volspruit 326KR,Limpopo Province, South Africa

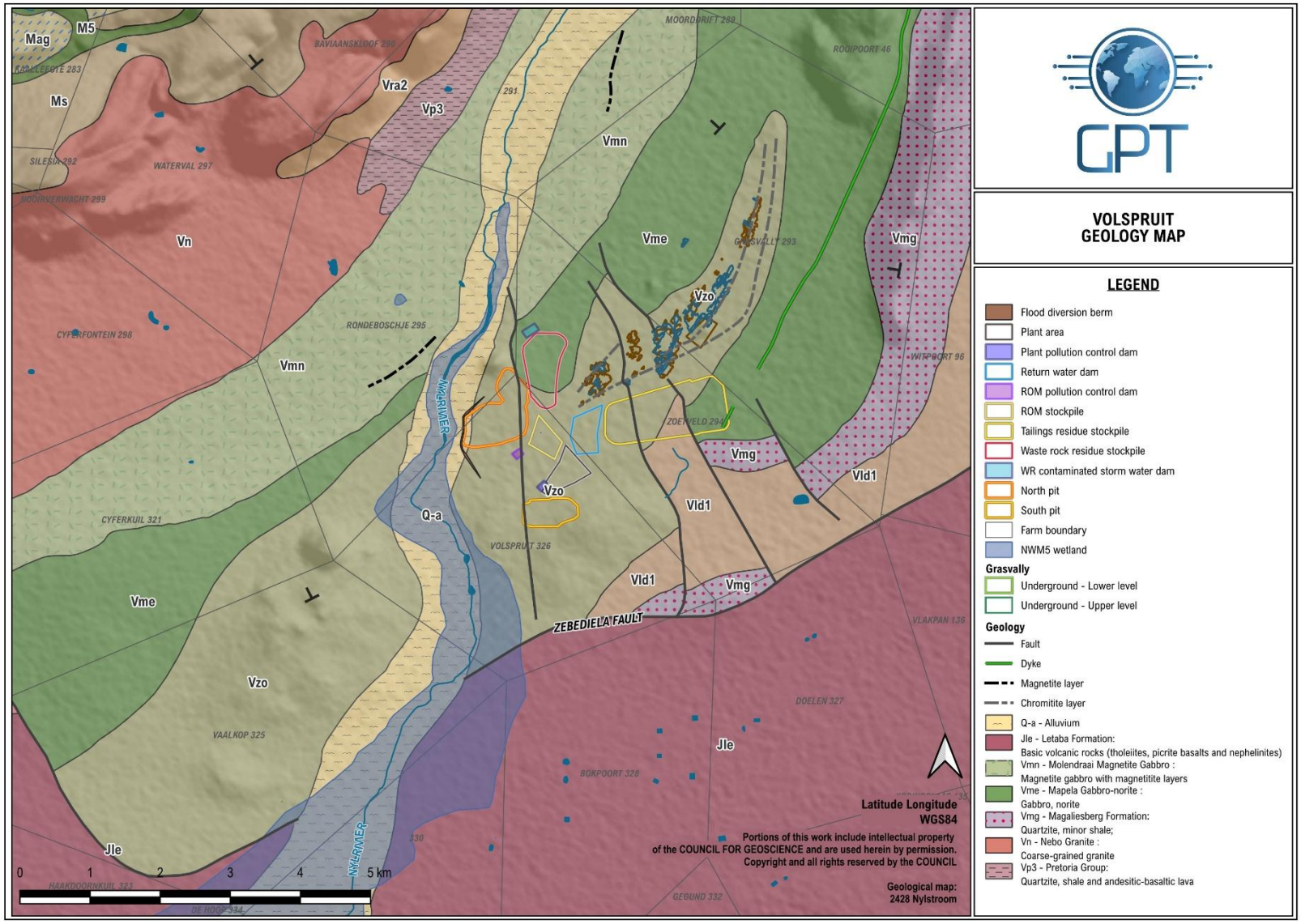


Figure 5: Regional Geology Map (1:250 000 geology series map).

4.5 Hydrogeology

The hydrogeology of the site is dominated by secondary porosity and hydraulic conductivity produced by faulting and fracturing. Faulting most likely occurred in three phases: an initial, block faulting episode resulted in horsts of Lower Zone being emplaced into the upper portions of the Rustenburg Layered Suite and into higher sediments. The second generation of faulting resulted in a stepped arrangement in the Rustenburg Layered Suite. The third phase of faulting along a south-westerly trend resulted in the uplift of wedges of Transvaal sediments into the Rustenburg Layered Suite.

Recovery percentage and RQD (rock quality designation) in the exploration borehole database was used to estimate depth of the weathering and fracturing as shown in Figure 6. It is evident that the depth of weathering (and/or fracturing) is dominant in the first 50-60mbgl. The figure also suggests that fractures or conduits are found deeper in the rock profile at around 90-100mbgl as well, which is also the depth that irrigation boreholes in the area is targeted to.

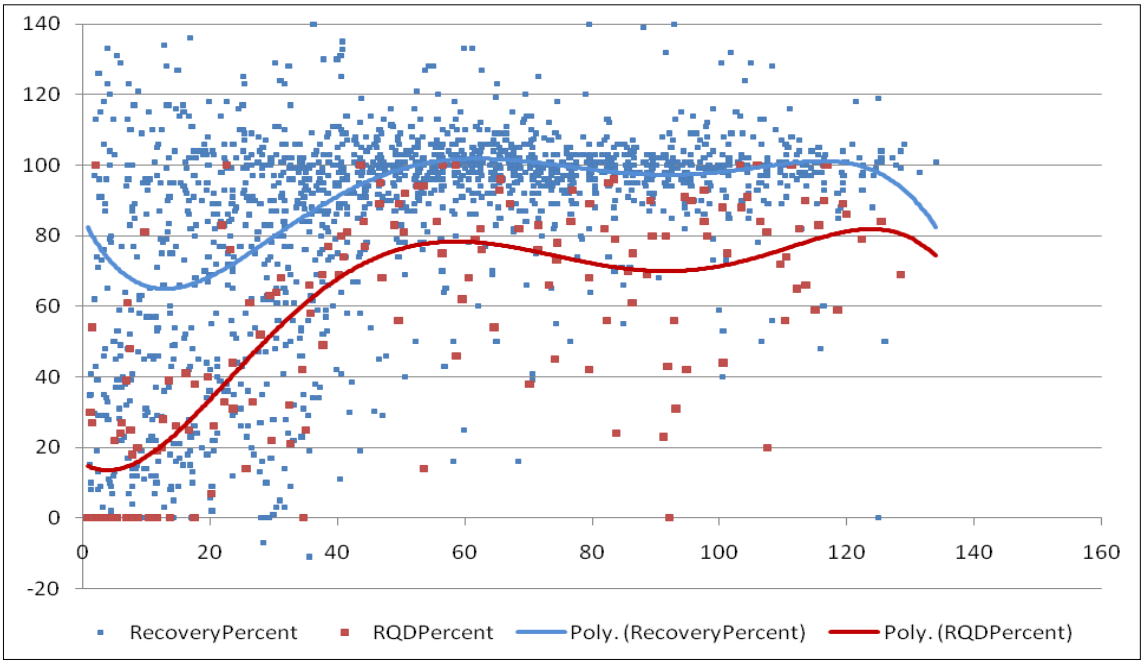


Figure 6: Core recovery and RQD variation with depth.

While the groundwater yield potential in the Western and Eastern Limb of the Bushveld Complex is regarded as low, there is an abundance of groundwater at Volspruit with yields regularly exceeding 5l/s. This is mainly due to the extreme fracturing of the bedrock during the various episodes of faulting.

Groundwater use in the A61E catchment is at the limit of the estimated sustainable yield. A present status category of D, (80-100 % of recharge) is already used[3].

5 GEOPHYSICAL SURVEY

Two geophysical surveys were carried out during May 2010 and May 2011. The main purpose of the geophysical surveys on the farm Volspruit 326 KP was to identify areas where possible preferential flow paths could be located on which boreholes may be targeted.

[3] Department of Water Affairs and Forestry, South Africa. 2005. Groundwater Resource Assessment Phase II Project 4 Methodology for Classification Final Report: National Water Resource Planning. Report No. P WMA 01/000/00/0304.

For the surveys, the Geometrics "Stratagem" EH 4 CSAMT instrument and the ABEM "Lund" resistivity imaging system were used. The ABEM "Lund" system measures bulk resistivity from the surface as apparent resistivity (Rho) vs. Geometric factor (dc resistivity) and the CSAMT measures frequency against apparent resistivity. This was then converted to true resistivity vs. depth during the interpretation process.

The May 2010 survey consisted of four traverses of CSAMT (Controlled Source Array Magneto Telluric), and five traverses of direct current resistivity profiling. The May 2011 survey consisted of five traverses of CSAMT (Controlled Source Array Magneto Telluric), and eight traverses of direct current resistivity profiling. The positions of the traverses can be seen in Figure 7. The following observations were made:

5.1 Survey Performed in 2010

Traverse 1 was located on the western limit of the survey area and was surveyed from south to north for a total distance of 1200 m to investigate the inferred fault at approximately 850 m along the traverse, and to test for possible structures along the river towards the south. Borehole VOL17 was drilled on this anomaly. The AMT data indicate the presence of a sub-horizontal conductive zone below the resistive basement signature of the DC (direct current) resistivity image and two sub-vertical conductive zones. The northern sub-vertical conductor coincides well with the expected fault position. An anomaly inferred to be deep weathering was identified at 230 m distance along the traverse, borehole VOL20 was drilled on this anomaly.

Traverse 2 was surveyed from SE to NW for 800 m to intersect a range of inferred fault systems. The AMT data was insensitive to the near surface but indicates a vertical conductor to the south of the traverse. The expected fault zone(s) approximately 400 m along the traverse were not clearly discernible on either of the resistivity images although there was some indication of vertical fracturing along the profile. Borehole VOL18 was drilled on the expected fault zone on 430 m distance along the profile. The existing borehole VOL22 was also found on this fault system.

Traverse 3 was surveyed roughly from south to north for a total distance of 700 m. The expected fault zone at approximately 100 m along the traverse appears to manifest as a weak sub-vertical conductive anomaly in both the resistive and less resistive horizons.

Traverse 4 was surveyed in the same direction as traverse 3 for a total distance of 500 m. The AMT resistivity image was not clear and appears to be influenced by power line noise. There was however an indication of a sub vertical conductive anomaly at depth on the expected fault position 300 m along the traverse. Borehole VOL19 was drilled at 280 m on this anomaly.

Traverse 5 was surveyed for a distance of 1200 m with the DC resistivity method only as the power line interference along this traverse saturated the AMT magnetic coils. The data did not, however, have the depth penetration / resolution to identify any of the fault systems with a deeper signature in this area. The geophysical traverses can be seen in Figure 7.

5.2 Survey Performed in 2011

Traverse 1 was located on the north-eastern limit of the survey area and was surveyed from northeast to southwest for a total distance of 900 m to investigate the inferred range of fault systems with a confirmed fault at approximately 700 m along the traverse. Borehole BH103 was drilled on this anomaly. The AMT data indicate the presence of a sub-horizontal conductive zone below the resistive basement signature of the DC (direct current) resistivity image. The south-eastern sub-vertical conductor coincides well with the expected fault position. An anomaly inferred to be a deep-seated fault zone was identified at 700 m on the traverse. Borehole BH103 was drilled on this anomaly.

Traverse 2 was surveyed from NW to SE for 500 m to intersect a range of inferred fault systems. The AMT data indicates a sub vertical structure at approximately 260 m. This was interpreted as a fault zone based on existing data and is also visible on the resistivity image. A power line was encountered at approximately 200 m in this profile and therefore the remaining structures indicated by the resistivity line could not be confirmed with confidence. The borehole BH101 was drilled on the interpreted fault zone at 260 m on the traverse.

Traverse 3 was surveyed roughly from SW to NE for a total distance of 400 m. The expected fault zone, at approximately 200 m along the traverse, was identified by the AMT and resistivity data. The data indicates a sub vertical, conductive structure inferred to be the expected fault.

Traverse 4 was surveyed in the approximate same direction as traverse 3 for a total distance of 400 m. No AMT survey was performed on this traverse. However, resistivity data obtained for this traverse indicates an anomaly dipping to the northeast which is inferred to be the expected fault zone located at approximately 250 m along the traverse.

Traverse 6 was surveyed for a distance of 400 m from S to N to intersect 2 inferred fault zones. Resistivity data indicated two anomalies which coincided well with the inferred fault zones. However, the obtained AMT data for this traverse indicated that these anomalies became more resistive with depth which was interpreted to indicate that the inferred fault zones were less weathered with depth. This may indicate that the inferred fault zones are not of a deep-seated nature.

Traverse 7 was surveyed for a distance of 400 m from SW to NE to intersect a single inferred fault zone. Resistivity data indicated an anomaly which coincided well with the inferred fault zone. However, the elevated conductivity of the shallow surface is illustrated well in this traverse and the exact location of the fault zone was not clear. The AMT data for this traverse, however, indicates that the inferred fault zone is possibly located in the area of deepest weathering at approximately 150 m along the traverse and possibly extends to approximately 120 mbgl.

Traverse 8 was surveyed for a distance of 700 m from S to N to intersect three inferred fault zones. Resistivity data indicated anomalies which coincided well with the three inferred fault zones. The data illustrated deep weathering down to 40 mbgl as well as an anomaly at approximately 520 m along the traverse which dips to the north. This was interpreted to possibly indicate a deeper-seated fault zone. Another anomaly, inferred to represent two fault zones at approximately 220 m and 300 m along the traverse, was identified between 200 m and 300 m along the traverse and extends to the full investigative depth of 80 mbgl. This was interpreted to possibly indicate shallow seated fault zones. No AMT data was collected along this traverse.

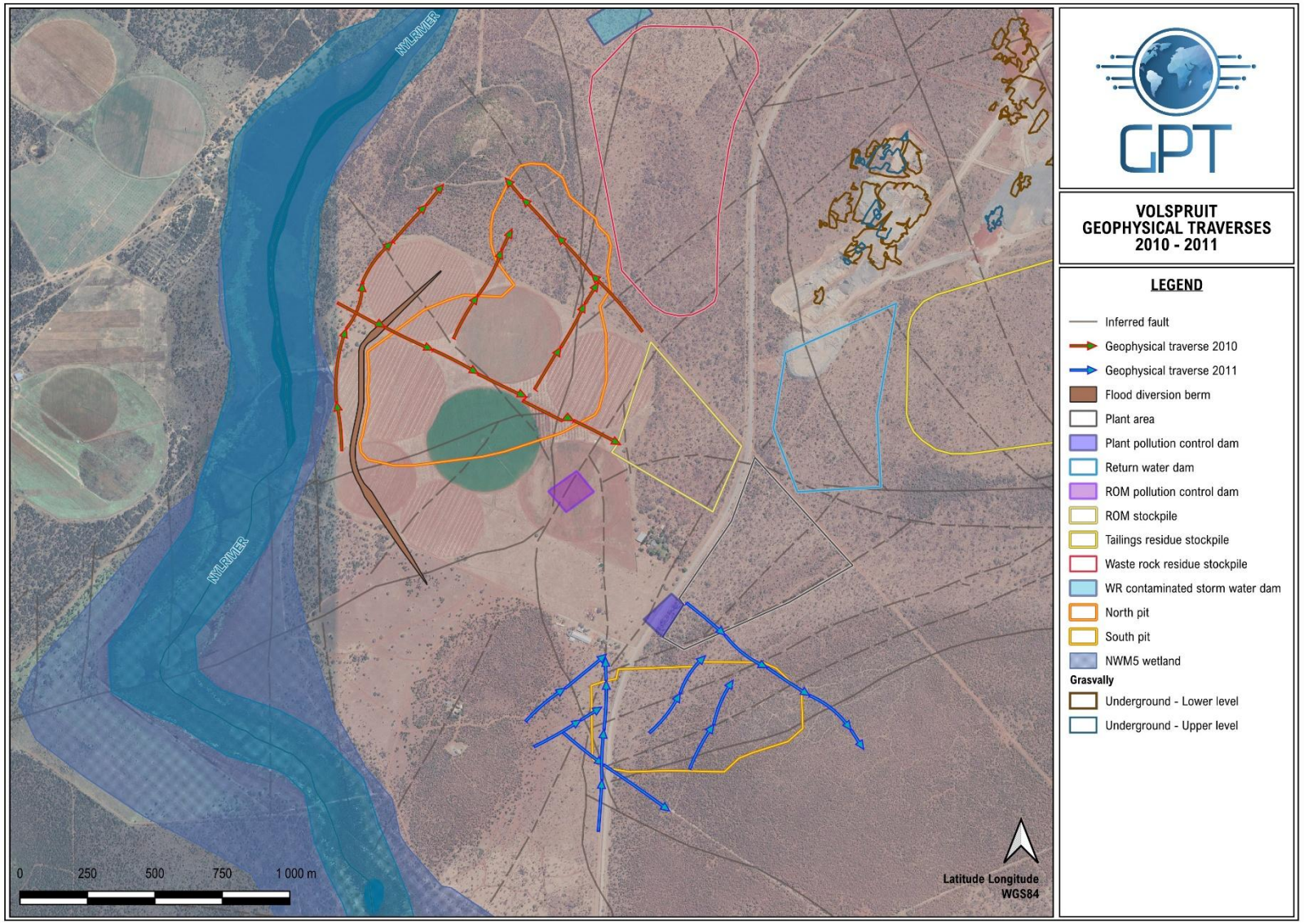


Figure 7: Geophysical Traverses.

6 BOREHOLE DRILLING

Makulu Manzi drilling contractors were commissioned to drill five monitoring wells at the project site during May 2010. The holes were drilled using the rotary percussion drilling method. Four of the boreholes were drilled on targets identified during the geophysical survey (VOL17, VOL18, VOL19, VOL20). One borehole (VOL21) was drilled in the centre of the ore body in the north pit area to a depth of 170 meters below ground level to be representative of the ore body. The depth of mining is likely to approach 160 m.

A second set of percussion boreholes were also drilled during the week of 27 June 2011 on the project site, by Makulu Manzi. Five boreholes were drilled on targets identified during the geophysical survey (BH101, BH102, BH103, BH104 and BH105). The borehole depths range from 60.14 mbgl to 174.7 mbgl.

A total of ten boreholes were drilled by percussion drilling on identified geophysical anomalies to depths varying between 40 meters and 175 meters, mainly to perform pump tests on but also to serve as monitoring boreholes. The position of the boreholes is shown in Figure 8.

Table 3: Summary of boreholes drilled.

Borehole no.	Drilling Target	Depth (mbgl)	Blow yield (l/s)	Solid Casing (m)	First Water strike (mbgl)	Purpose
VOL17	Fault	80	1.6	10	12	Monitor, Pump Test
VOL18	Fault	40	0.5	8	25	Monitor, Pump Test
VOL19	Fault	70	3	10	20	Monitor, Pump Test
VOL20	Weathering Zone	70	3	10	5	Monitor, Pump Test
VOL21	Centre of Pit	170	2	11	13	Monitor, Pump Test
BH 101	Fault	120	3.3	13	24	Monitor, Pump Test
BH102	Fault	60	1.6	9	40	Monitor, Pump Test
BH103	Fault	145	0.2	15	55	Monitor, Pump Test
BH104	Fault	174	3	6	25	Monitor, Pump Test
BH105	Fault	165	4	6	39	Monitor, Pump Test

The geological logs from the newly drilled boreholes conformed to adjacent core holes' logs, thus substantiating the geological situation. The depth of weathered rock varied between 20 meters and 45 meters. First water strikes varied between 5 meter and 55 meters. In all cases the blow yield did not increase with depth, this is indicative of most of the water bearing structures being within the upper weathered zone, although some chips displayed fractured surfaces as deep as 100 meters.

Nine piezometer boreholes were also drilled during the week of 12 July 2011. These holes were drilled using the rotary air percussion method, to a maximum depth of 30 mbgl, in the floodplain of the Nyl River. Each percussion hole was fitted with 3 PVC casings of 63 mm and 20 mm diameters to different depths. The reason for these is to determine whether a hydraulic gradient exist between the river and underlying water table. For a losing river, a higher water table would exist closer to the river, with a lower water table further away, and vice versa for a gaining river. In addition, different piezometric heads would be observed in the 3 different depth piezometers in a single borehole due to varying potentials with depth (Table 4). Thus, different piezometers were inserting at different

depths and sealed off so that only the hydraulic potential head at that specific depth is reflected in a piezometer pipe. No significant differences could be observed between the piezometric levels in each piezometer hole as measured by hand during the entire monitoring period, which indicates that the Nyl river and the underlying aquifer are unlikely to be hydraulically connected.

Table 4: Water Levels Measured by Hand in Newly Drilled Piezometer Holes.

Borehole name	Piezo depth	Diameter	X_Coordinate	Y_Coordinate
PO1a	8.4	63	28.9442	24.34505
PO1b	11.6	20	28.9442	24.34505
PO1c	29.4	20	28.9442	24.34505
PO2a	11	63	28.94365	24.34513
PO2b	15.26	20	28.94365	24.34513
PO2c	19.75	20	28.94365	24.34513
PO3a	8.3	63	28.9442	24.34512
PO3b	13.75	20	28.9442	24.34512
PO3c	25.6	20	28.9442	24.34512
PO7a	10.21	63	28.94593	24.36198
PO7b	14.8	20	28.94593	24.36198
PO7c	24	20	28.94593	24.36198
PO8a	14.25	20	28.94506	24.36206
PO8b	20.6	20	28.94506	24.36206
PO8c	24.6	20	28.94506	24.36206
PO9a	9.9	63	28.94507	24.36208
PO9b	14.62	20	28.94507	24.36208
PO9c	27.08	20	28.94507	24.36208
P04a	11.2	63	28.94028	24.34498
P04b	20.3	20	28.94028	24.34498
P04c	24.6	20	28.94028	24.34498
P05a	5.6	63	28.93985	24.34497
P05b	11.38	20	28.93985	24.34497
P05c	22.8	20	28.93985	24.34497
P06a	8.4	63	28.939036	24.34481
P06b	13.82	20	28.939036	24.34481
P06c	21.7	20	28.939036	24.34481

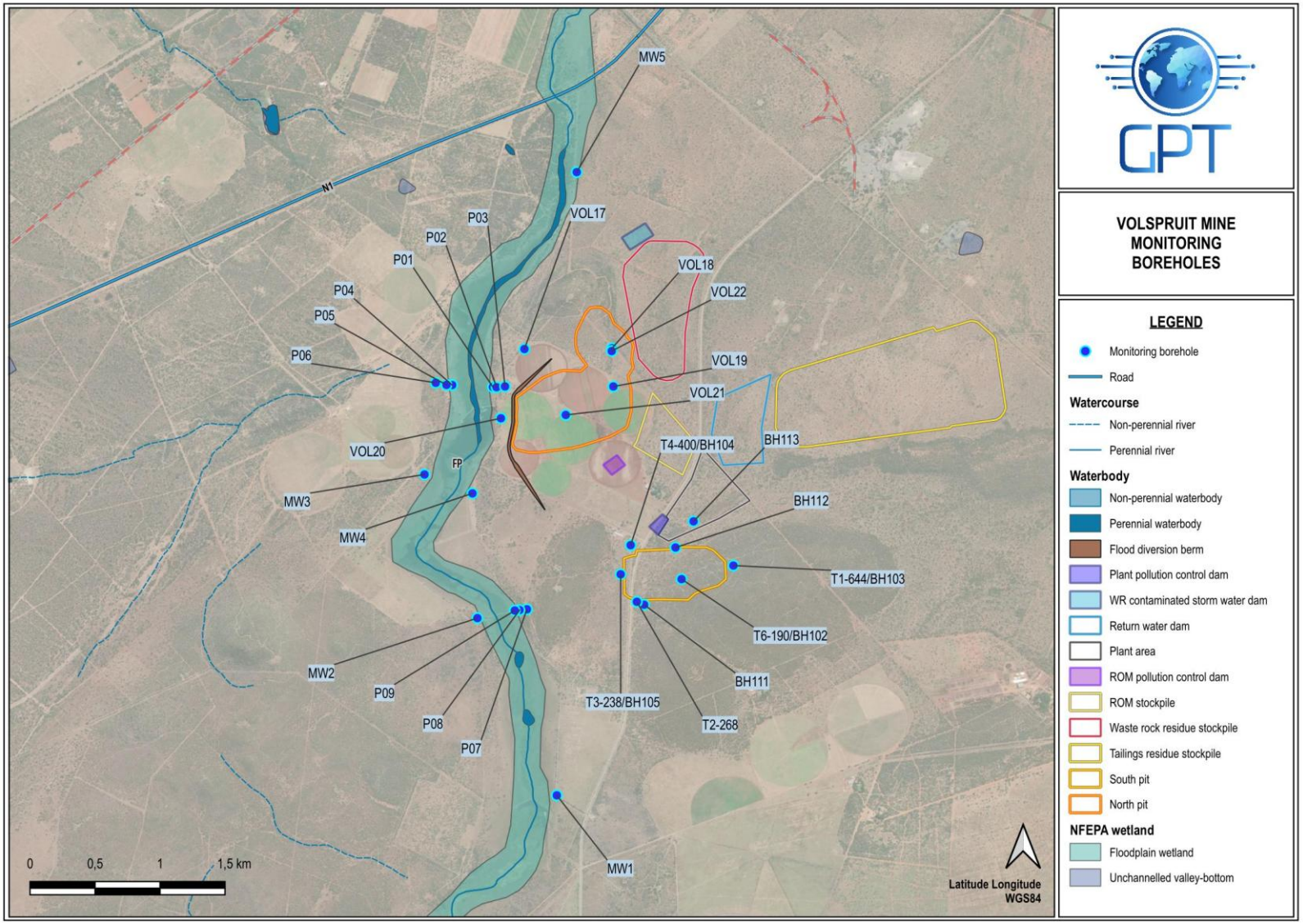


Figure 8: Drilled boreholes at the Volspruit project site.

7 AQUIFER TESTING

7.1 Pumping Tests

Test pumping were conducted on twelve boreholes to determine the aquifer parameters using FC, AQTESOLV Pro Version 4.0 and Aquifer Test Pro. A 24-hour constant discharge test followed by a 12-hour recovery (preceded by a 4-hour step discharge test) was conducted on each of the holes. The boreholes achieved 91% -100% recoveries within 12-24hrs.

The actual measured values and averages of the aquifer transmissivities for the various methods of pump test analyses are listed below in Table 5 below. There are two distinct mathematical methods to calculate the averages, namely the well-known arithmetic mean and the geometric mean. It was shown by Neuman[4] that hydraulic conductivity and transmissivity characteristics tend to be log distributed. Thus, the geometric mean in the table below would be the most appropriate mean value to use.

Table 5: Calculated Transmissivity Values.

Borehole	T (m^2/day)	Borehole	T (m^2/day)
VOL17	3.22	BH103	3.20
VOL19	36.43	BH104	14.11
VOL20	30.05	BH105	7.55
VOL21	2.58	BH-E111	55.35
VOL22 (10 l/s)	69.90	BH-E112	132.28
BH102	38.91	BH-E113	168.60
Arithmetic Mean	46.85	Geometric Mean	21.62
Standard Deviation	51.29	Standard Deviation	4.06
Lower Limit (-1σ)	~0	Lower Limit (-1σ)	17.6
Upper limit (+1σ)	98	Upper limit (+1σ)	25.7

Based on information received from various sources, including the local farmers, intuition gained by experience in similar studies and deliberately erring on the high side, the following transmissivity values were used in the rest of the report:

- The lower value of about 20 m^2/day as obtained from the geometric mean is feasible and is suggested as lower limit.
- With the above taken as lower limit, it is suggested that the algebraic mean of ~ 45 m^2/day is regarded as the average value, knowing that it might well be an overestimation.

As upper value, the arithmetic means plus one standard deviation (about 100 m^2/day) is regarded as the best practical estimate. Values higher than this were only found in two of the pump tests, and it is thus highly unlikely that this could be representative of the whole aquifer.

7.2 Packer testing

The packer test hydraulic conductivity measurements were less successful than hoped for. Due to the immense fracturing in the area, it was very difficult to obtain good sealing of the packer and then

[4] Neuman, S P, 1982. Statistical Characterization of Aquifer Heterogeneities: An Overview. In "Recent trends in hydrogeology" Geological Society of America Special Paper 189, p. 81-102.

mostly at depths of several tens of metres below surface. The upper highly conductive areas were thus impossible to measure.

However, the hydraulic conductivities calculated for each test section are low compared to pumping test values. The highest hydraulic conductivity value calculated was 0.819m/d. This supports the conceptual model that the upper weathered zone is the major water carrier.

Packer testing took place on the Volspruit property on 12 and 13 December 2011 as well as 2 and 3 April 2012. Six exploration core holes were chosen to represent the geology of the area viz. GVN 151, GVS 052, GV007, GV008, GV013 and GV011. The construction details of each hole are tabulated below in Table 6.

Table 6: Packer Test Core holes.

Hole	Date Tested	Depth (m)	Hole Diameter (mm)	SWL (mbgl)	Casing (mbgl)	Packer Type
GVN 151	12-12-2011	183.73	76	12	47	56mm Double
GVS 052	13-12-2011	90.50	76	25	15	56mm Double
GV 007	03-04-2012	27	76	10	0	56mm Double
GV 008	03-04-2012	100	76	12.2	-	56mm Double
GV 011	02-04-2012	32	76	32	-	56mm Double
GV 013	02-04-2012	-	76	-	-	56mm Double

It should be noted that holes GV011 and GV013 were obstructed and the only full packer tests that could be performed to the full depth of the selected core holes were GVN 151, GVS 052, GV 007 and GV 008.

Packer tests are performed to determine the hydraulic conductivity of a fractured rock aquifer at different sections in a borehole as well as the subsequent transmissivity of that section. Three to five tests are performed by pumping water into the test section, which is sealed off by two air bladders, under a specified hydraulic pressure to determine the flow rate at that specific water pressure. These values are then used to determine the hydraulic conductivity and transmissivity of that test section using the following equation:

$K = (Q * \text{Log}_e(L/r)) / (2W * L * H)$

Where:

K = hydraulic conductivity

Q = Volumetric flow rate of water pumped into the test section

L = Length of the test interval

r = Radius of the tested borehole section

H = Excess pressure head

Packer tests are not intended to determine conventional porous media flow rates but rather water release through fractures.

The values obtained from packer testing can also be used to determine Lugeon values. A Lugeon value is defined as the hydraulic conductivity required to achieve a flow rate of 1 litre/minute per meter of test interval under a reference water pressure equal to 1 MPa and can be calculated according to the following equation:

$$Lugeon\ value = \propto \frac{q}{L}\frac{P_0}{P}$$

Where:

α = A dimensionless factor to accommodate different units. For SI units as used in South Africa, this unit becomes 1.

q = Flow rate into the packer of L/min

L = Length of the test interval

P_0 = A reference pressure of 1 MPa

P = the pressure observed in the test interval as noted by a pressure gage or excess head in a piezometer

Lugeon values are of interest to determine fracture and water flow behaviour under the hydraulic pressures exerted during the test.

The packer test hydraulic conductivity values obtained as well as corresponding Lugeon values are graphically illustrated in Figure 9 to Figure 12 below. The Lugeon values computed for each test section are indicative of laminar flow taking place through the fractures in the test section. This is indicated by the bell curve trend of each graph illustrated. Therefore, fractures are considered not to dilate under pressure and no fines were washed out of the fractures. Fracture apertures are also considered to be small enough not to allow tortuous flow.

The hydraulic conductivities calculated for each test section are considered to be low compared to pumping test values. The highest hydraulic conductivity value calculated for GVN 151 is 0.013 m/day while that of GVN 052 is 0.0049 m/day. The highest hydraulic conductivity of GVN 008 was calculated at 0.137 m/d, while that of GV 007 was calculated at 0.819 m/d. These values are low compared to pumping test values of up to 1.6 m/day.

Also, the core logs for these holes indicate weathered zone/ saprolite depths of 25.5 m for GVN 151 and 28.25 m for GVN 052 with “moderate” as the weathering qualifier. The shallowest test section for each hole is performed in competent rock which can withstand the pressure of the inflatable bladder. Therefore, the degree of weathering is assumed to be low. The shallowest test section for GVN 151 and GVN 052 is located at 50 mbgl and 18.3 mbgl respectively. This may be indicative of higher flow rates in the weathered zone indicating that this unit is the major water carrier throughout the boreholes with porous media flow taking place. This idea may explain the discrepancy in values between the pumping test hydraulic conductivities and those of the packer tests.

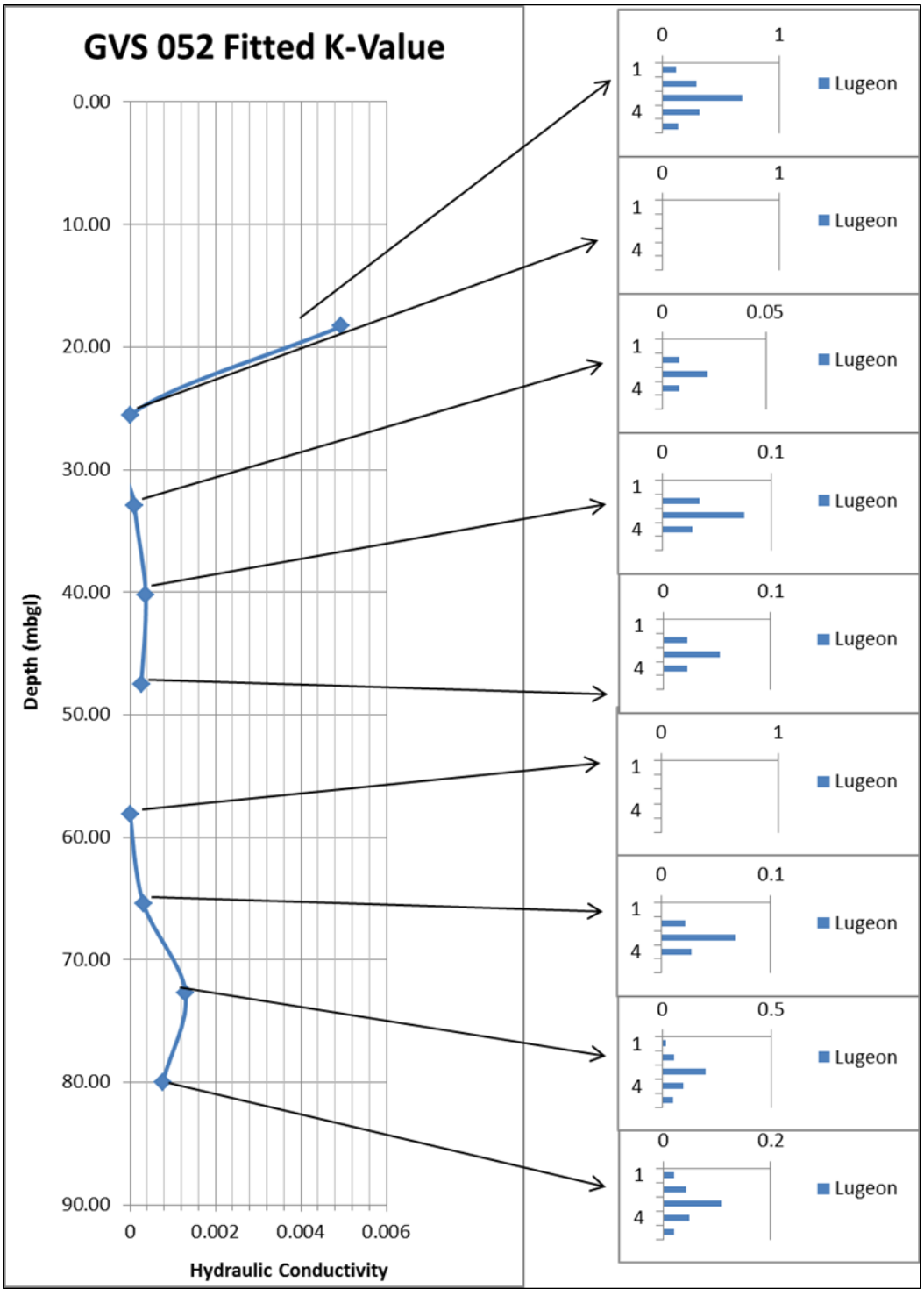


Figure 9: Packer test Hydraulic Conductivities measured for GVS 052.

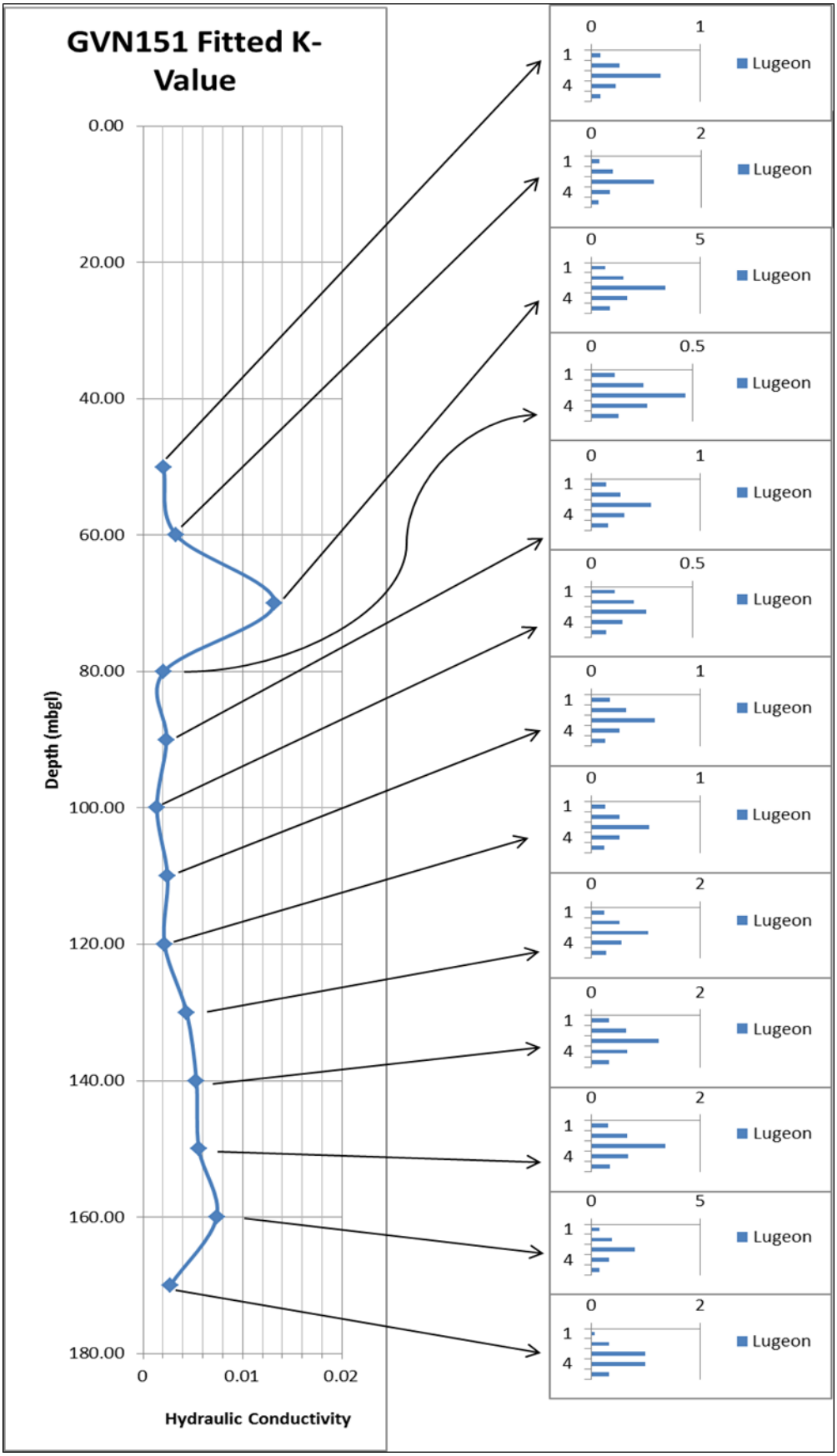


Figure 10: Packer test Hydraulic Conductivities measured for GVN151.

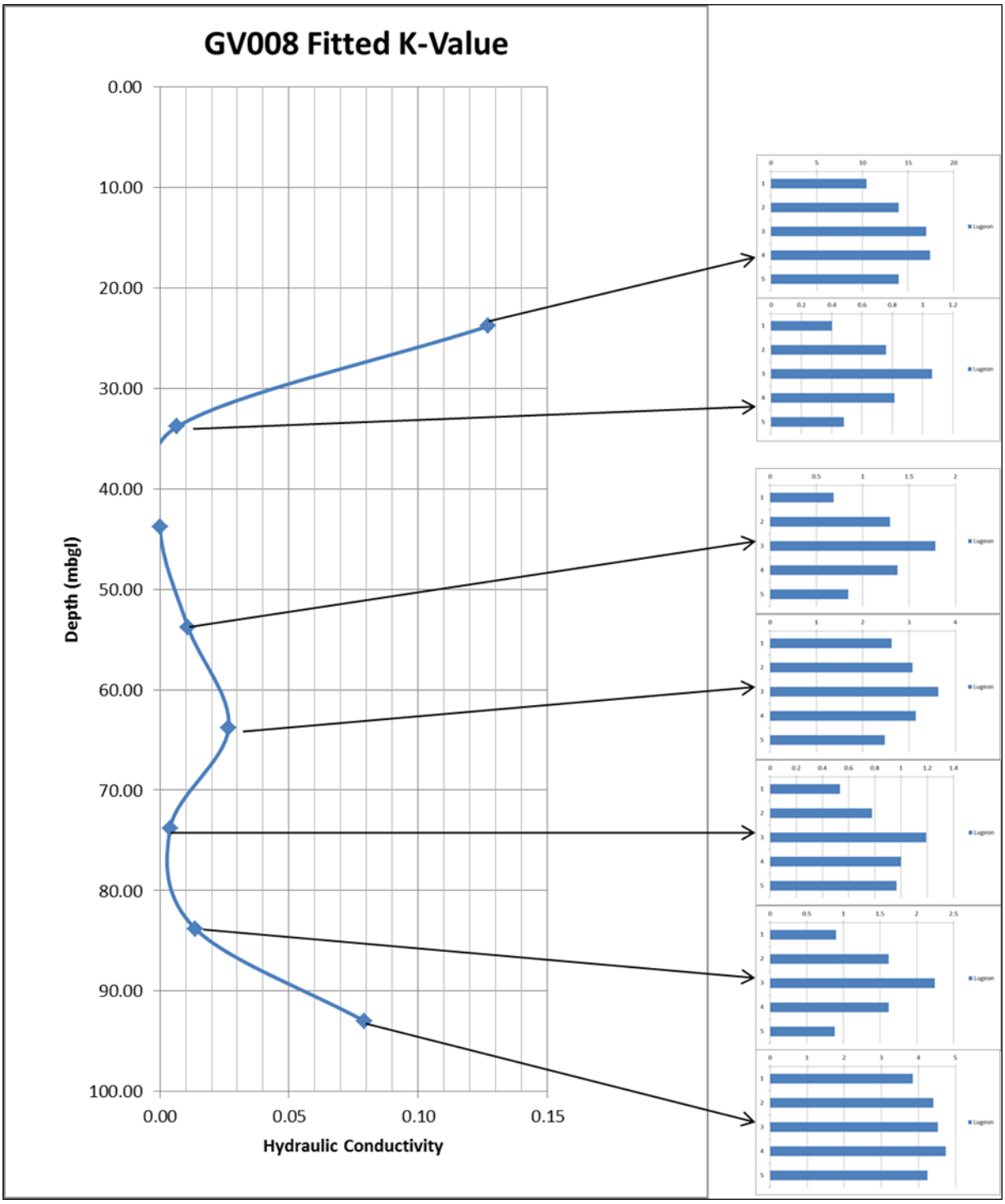


Figure 11: Packer test Hydraulic Conductivities measured for for GV 008.

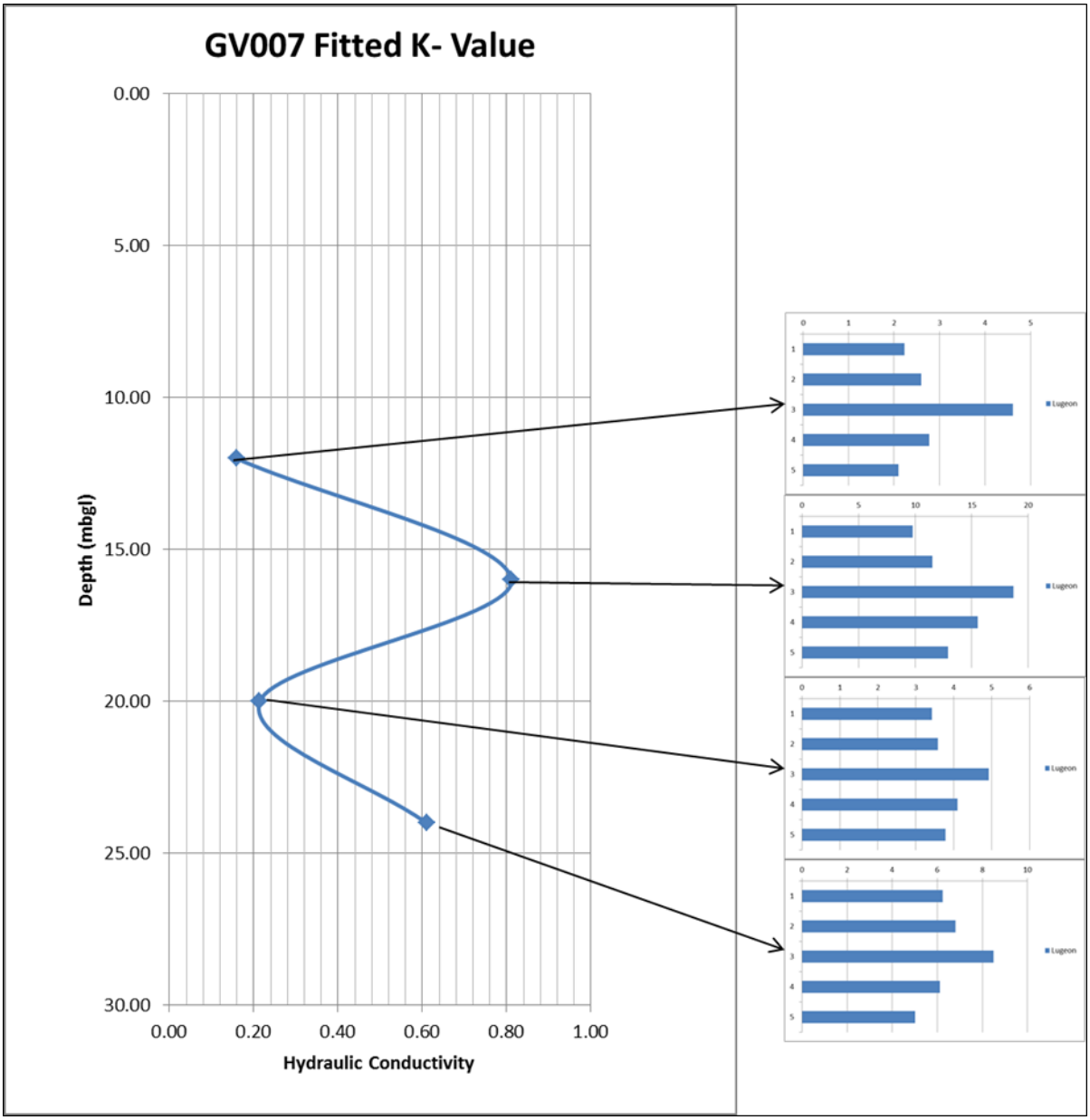


Figure 12: Packer test Hydraulic Conductivities measured for GV 007.

8 GROUNDWATER LEVEL MONITORING

8.1 Groundwater monitoring network

A monitoring network has been established at the Volspruit site. Information and locations of the monitoring network is presented in Table 7 and mapped in Figure 13. The groundwater level monitoring data is presented in Table 7 and Table 8, with the spatial positions of the boreholes displayed in Figure 13.

The network comprises two types of monitoring points, each serving a distinct purpose, namely:

- Monitoring boreholes equipped with Pressure Transducers. These boreholes are aimed at recording the reaction of the aquifer to rainfall and flooding events in the Nyl River, as well as recording the decline of the groundwater during the dryer periods.

- Piezometer boreholes are dedicated to measure vertical groundwater pressure gradients. These are important during flood events to determine whether water is flowing from or towards the river.

Table 7: Volspruit Monitoring Network

Piezometer name	X-coordinate	Y-coordinate	Property Owner	Casing Height (m)	Method
P07 a,b,c	28.945950	-24.362000	Sylvania	0.09	Field measurement
P08 a,b,c	28.945389	-24.362057	Sylvania	0.82	Field measurement
P09 a,b,c	28.945030	-24.362090	Sylvania	0.13	Field measurement
MW1	28.948217	-24.376117	Sylvania	0.73	Pressure Transducers
MW2	28.942194	-24.362667	Sylvania	0.27	Pressure Transducers
MW3	28.938183	-24.351767	Sylvania	0.6	Pressure Transducers
MW4	28.941817	-24.353200	Sylvania	0.83	Pressure Transducers
MW5	28.949730	-24.328820	Karl Charmers	0.785	Pressure Transducers
BH104	28.953765	-24.357076	Sylvania	0.44	Pressure Transducers
BH Quarry	28.952192	-24.368893	Sylvania	CNM	Field measurement

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Table 8: Difference in water level from 2011 till 2019.

Name	18-Oct-11	02-Nov-11	28-Nov-11	07-Feb-12	13-Dec-12	22-Jan-13	05-Apr-13	10-Jul-13	11-Oct-13	11-Feb-14	11-Mar-14	14-Mar-14	16-Mar-14	17-Mar-14	18-Mar-14	19-Mar-14	11-Apr-14	25-Oct-16	15-Nov-19
MW1	NM	NM	NM	NM	NM	9.3	9.8	10.23	10.94	11.7	12.57	NM	NM	NM	NM	10.34	6.17	13.55	15.28
MW2	NM	NM	NM	NM	NM	8.82	9.21	9.3	9.93	10.67	11.05	10.21	NM	NM	6.28	5.94	2.44	12.26	Dry
MW3	NM	NM	NM	NM	NM	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	6.71	NM	2.77	Dry	Dry
MW4	NM	NM	NM	NM	NM	8.53	9.08	8.99	9.96	10.53	11.28	NM	NM	NM	5.575	NM	3.09	12.9	15.5
MW5	NM	NM	NM	NM	NM	7.42	NM	7.98	NM	8.54	NM	NM	NM	NM	NM	8.335	7.39	11.27	Dry
PO1a	5.26	5.49	5.65	5.375	7.162	7.6	Dry	Dry	Dry	Dry	Dry	Dry	NM	NM	NM	5.68	7.38	NM	Dry
PO1b	5.26	5.49	5.62	5.36	7.189	7.62	8.76	8.06	8.89	10.72	9.96	9.96	Inundated	Inundated	NM	9.27	7.08	NM	Dry
PO1c	5.26	5.53	5.63	5.375	7.184	7.6	8.75	8.03	8.92	10.1	9.95	9.94	Inundated	Inundated	NM	8.81	6.92	NM	18.3
PO2a	6.18	6.23	6.61	6.37	8.181	8.55	9.65	8.95	9.8	Dry	10.78	10.77	10.54	10.43	NM	10.06	7.65	NM	Dry
PO2b	6.18	6.26	6.59	6.36	8.196	8.55	9.64	8.92	9.81	10.95	10.69	10.69	10.42	10.37	NM	9.96	7.55	NM	Dry
PO2c	6.18	6.23	6.61	6.38	8.222	8.56	9.68	8.92	9.83	10.94	10.66	10.65	10.42	10.34	NM	9.91	7.54	NM	19.03
PO3a	7.52	7.39	7.72	7.45	Dry	Dry	Dry	7.54	Dry	Dry	NM	Dry	Dry	NM	NM	Dry	Dry	NM	Dry
PO3b	7.45	7.31	7.73	7.45	9.38	9.64	11.37	9.84	11.37	12.46	NM	11.96	11.76	NM	NM	11.43	8.5	NM	Dry
PO3c	7.45	7.3	7.69	7.415	9.37	9.57	11.34	9.84	11.35	12.44	NM	11.98	11.76	NM	NM	11.43	8.45	NM	20.43
P04a	7.74	7.73	8.02	5.607	7.074	NM	7.59	NM	8.84	9.09	9.07	NM	Inundated	Inundated	NM	8.71	8.47	NM	Dry
P04b	7.66	7.66	7.84	5.645	7.116	NM	7.65	NM	8.91	9.14	9.19	NM	Inundated	Inundated	NM	8.67	8.38	NM	Dry
P04c	7.65	7.63	7.93	5.645	7.147	NM	7.65	NM	8.9	9.15	9.23	NM	Inundated	Inundated	NM	8.65	8.34	NM	17.95
P05a	6.3	6.45	6.71	5.495	Dry	NM	Dry	NM	Dry	Dry	Dry	NM	Inundated	Inundated	NM	Dry	6.25	NM	Dry
P05b	6.3	6.45	6.71	6.263	7.71	NM	8.19	NM	9.52	9.67	9.7	NM	Inundated	Inundated	NM	NM	NM	NM	Dry
P05c	6.3	6.43	6.72	6.27	7.694	NM	8.18	NM	9.51	9.68	9.7	NM	Inundated	Inundated	NM	9.2	9.19	NM	18.59
P06a	5.56	5.62	5.86	6.883	8.184	NM	Dry	NM	Dry	Dry	Dry	NM	Dry	NM	NM	Dry	Dry	NM	Dry
P06b	5.44	5.5	5.66	6.883	Dry	NM	8.77	NM	10.14	10.24	10.22	NM	10.18	NM	NM	10.1	9.07	NM	Dry
P06c	5.57	5.63	5.77	6.88	Dry	NM	8.76	NM	10.14	10.25	10.26	NM	10.18	NM	NM	10.11	9.02	NM	19.25
BH104	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	25.38	30.34	32.66
PO7a	NM	5.31	5.43	8.17	9.951	Dry	Dry	Dry	Dry	Dry	Dry	Dry	NM	Dry	Dry	Dry	5.54	Dry	Dry
PO7b	NM	5.31	5.51	8.075	9.958	10.15	10.68	10.58	11.43	12.14	12.22	11.97	NM	11.08	10.61	10.26	5.56	13.51	Dry
PO7c	NM	5.31	5.48	8.073	9.988	10.14	10.69	10.59	11.45	12.15	12.24	11.95	NM	11.03	10.56	10.2	5.51	13.52	16
PO8a	NM	Dry	Dry	6.88	8.758	8.94	9.54	9.4	10.29	11	11.1	10.61	NM	9.67	8.92	8.39	4.51	13.06	15.89
PO8b	NM	5.92	6.09	6.88	8.783	8.94	9.53	9.39	10.26	10.99	11.1	10.61	NM	9.58	8.79	8.5	4.5	13.04	15.84
PO8c	NM	5.93	6.12	6.88	8.86	8.94	9.52	9.39	10.27	10.98	11.1	10.6	NM	9.55	8.76	8.36	4.53	13.05	15.59
PO9a	NM	6.51	6.62	6.07	7.824	8.01	8.56	8.48	9.3	Dry	Dry	NM	Inundated	Inundated	NM	5.69	3.51	Dry	Dry
PO9b	NM	6.5	6.71	5.94	7.85	8.02	8.68	8.48	9.41	10.74	10.23	NM	Inundated	Inundated	NM	NM	NM	12.3	14.87
PO9c	NM	6.5	6.71	6.08	7.881	8.01	8.53	8.46	9.28	9.91	10.11	NM	Inundated	Inundated	NM	8.1	3.59	12.28	14.83

Table 9: Difference in water level from September 2021 to April 2026

Name	21 November 2021	10 September 2021	10 January 2022	01 April 2022	13 February 2023	08 August 2023	07 December 2023	22 February 2024	12 December 2024	17 March 2025	17 November 2025	26 January 2026	09 April 2026	Difference between January 2026 - April 2026
MW1	13.5498	14.1968	14.1709	11.5664	2.74	3.75	5.5	5.75	8.43	CNS	13.95	-0.65	-0.17	-0.48
MW2	8.2912	9.8465	9.8767	9.3406	1.03	2.32	4.46	4.93	7.85	0.73	2.43	0.16	0.21	-0.05
MW3	Dry	Dry	Dry	Dry	1.89	3.43	6.42	7.23	Dry	1.46	3.4	0.68	0.47	0.21
MW4	8.1275	8.9293	8.9374	8.9412	1.36	2.84	5.28	5.34	8.8	CNS	2.48	-0.03	0.02	-0.05
MW5	Dry	Dry	Dry	Dry	11.8	9.23	10.82	11.21	Dry	CNS	CNM	CNM	CNM	-
BH104	30.03	30.04	30.04	27.0142	20.18	18.84	19.97	19.72	22.63	18.96	17.62	16.89	16.28	0.61
PO7a	Dry	Dry	Dry	Dry	2.86	3.64	5.81	6.12	9	2.3	3.99	NM	1.81	-
PO7b	12.8	12.92	13.1	10.3	2.92	3.73	5.75	6.12	9.09	2.31	4.09	NM	1.71	-
PO7c	12.81	12.92	13.1	10.29	2.91	3.73	5.74	6.12	9.08	2.25	4	NM	1.64	-
PO8a	11.25	11.55	11.78	9.83	2.14	Dry	Dry	Dry	Dry	1.75	2.77	NM	0.5	-
PO8b	11.23	11.56	11.62	9.79	2.18	2.56	5.28	5.7	8.63	1.77	2.77	NM	0.51	-
PO8c	11.28	11.56	11.7	9.78	2.18	2.44	5.28	5.7	8.65	1.77	2.8	NM	0.4	-
PO9a	10.4	10.5	10.64	9.2	Blocked	Blocked	Blocked	Blocked	8.03	CNS	1.96	NM	Inundated	-
PO9b	10.62	10.66	10.62	9.05	1.33	2.56	4.68	5.07	7.89	CNS	1.98	NM	Inundated	-
PO9c	10.63	10.64	10.63	9.04	1.28	2.44	4.51	4.96	7.88	CNS	1.99	NM	Inundated	-
Average	**12.58**	**12.94**	**13.02**	**11.18**	**4.06**	**4.73**	**6.88**	**7.23**	**9.66**	**3.70**	**4.73**			**0.05**
NM- Not measured														
CNM - Could not measure														

Note: Water levels are in metres below ground level

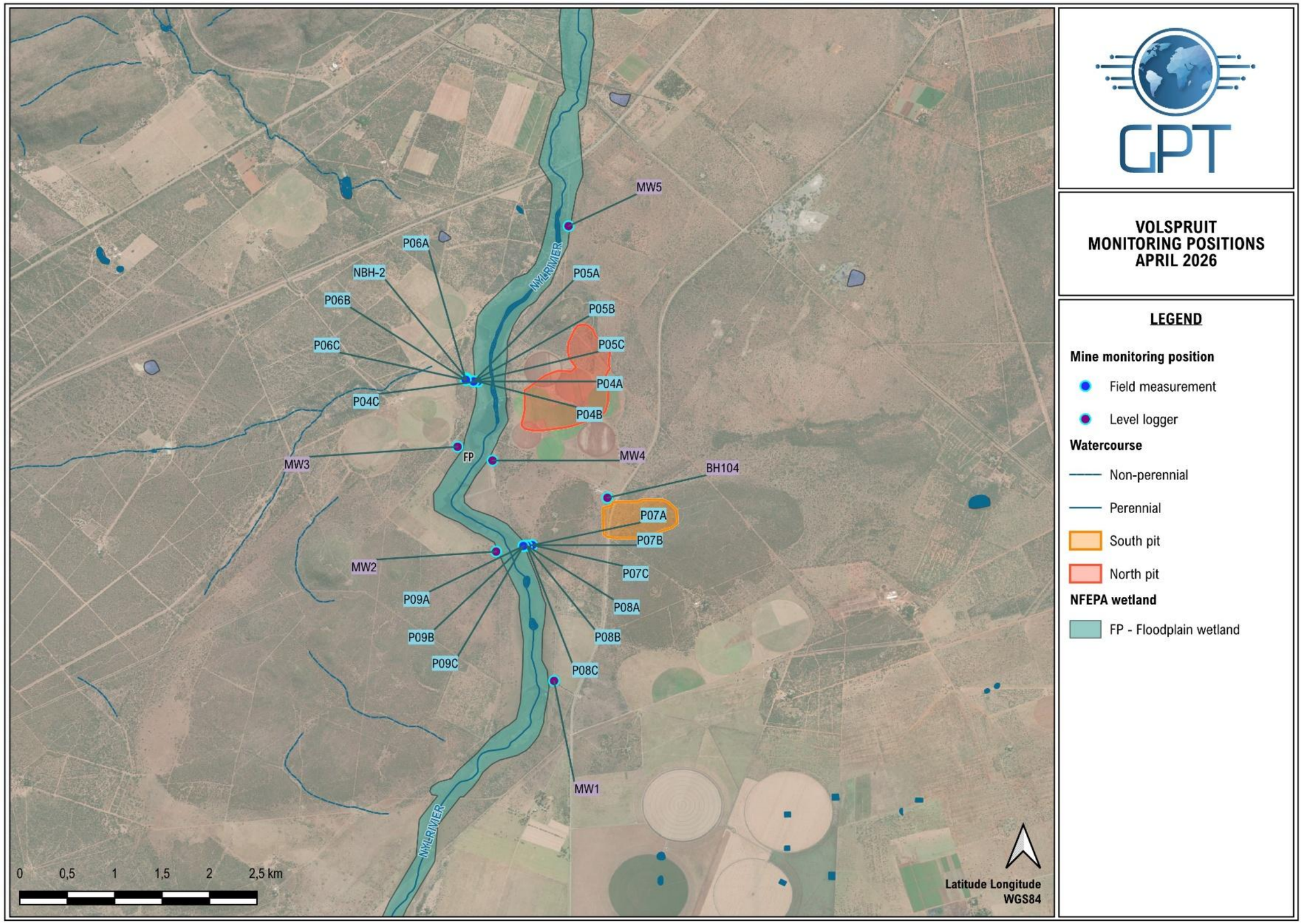


Figure 13: Piezometer & Pressure Transducers positions

8.2 Historical Nyl River Piezometer Data (surface & groundwater investigation)

The groundwater reaction to rainfall and flooding events is central in understanding the surface water-groundwater interrelationship in the Volspruit area

A flood in the Nyl River was studied in February 2014. The years between 2011 and 2014 were not extreme wet or dry and can be considered a normal period. As it was found that the groundwater reaction during normal seasons differed considerably to those during a flood, these periods are addressed separately below.

Data are firstly shown for the normal period where piezometer holes were drilled on both banks (Figure 14). The time series (Figure 15) illustrates that during the normal seasons the groundwater levels decrease constantly, despite reasonable rain in the summers of 2012 and 2013. The groundwater level never intersected the Nyl riverbed and remains at approximately 5 to 12 mbgl. Although surface water has been observed in the river during the rainy periods, there seems to be little recharge and no interaction with the groundwater. The cross sections (Figure 10), also indicates a general decrease in water level. The very flat groundwater table is indicative of the high hydraulic conductivity of the area and there are no lateral indications that the groundwater has ever been recharged from or to the river.

However, during the flooding period in the summer of 2014, the trends changed. This can be seen in similar graphs than those above, as depicted in Figure 16 to Figure 19 below. It is apparent that there is now a sudden rise in the groundwater levels, synchronised with the flood. The groundwater in the upstream piezometers (MW2 – PO7) is significantly faster than those downstream (PO6 - PO3), though the last measurements show some stabilization 2-3 metres below surface. This is most likely due to this area having less of a clay layer underneath. At the North Pit area (PO6-PO3) the rise is significantly slower with groundwater levels still at least 4 meters below surface underneath the Nyl three months into the flood arrival.

Considerable recharge did thus occur with the flood, and the outstanding question is how and where. This can be calculated with the vertical groundwater gradient. As a conceptual illustration, a hypothetical slight groundwater mounding (due to infiltration on the sides of the river) was modelled using SEEP2D as depicted in Figure 22 below. A borehole containing three piezometers is shown in the middle-right of this figure. It can be deduced from the figure that the deeper piezometer will have a groundwater level of -3.7m below ground level (bgl), while water levels of -4.1m and -4.7m bgl will be encountered in the middle and shallow piezometers respectively. It clearly demonstrates that, if flow is upwards, the observed groundwater gradients will also be positive upwards.

As the piezometer boreholes PO1 to PO9 were equipped with three separate PVC pipes targeted at different depths and sealed in-between, gradient could be calculated from these data. The results are graphed in Figure 20 and Figure 21. It is evident that there are no significant vertical gradients during the normal period (except for erratic data such as PO1, maybe due to measurement induced error), indicating very little vertical flow. But after the flood this changed dramatically. At PO6-PO3 there is now a pronounced and sustained upwards vertical gradient, especially in the vicinity of the river. While the gradient has been insignificant before the flood, it changed to vertical in the days following the flood and became even more pronounced upwards at a month after the flood established. In contrast, at PO7-PO9 vertical gradients developed a temporary upward gradient in some boreholes, which disappeared in April. This is further proof that the flood recharged the groundwater relatively quickly in the vicinity of South Pit. But at North Pit there is clear indication that the flow of water is upwards from the water table.

Thus, the unsaturated zone underneath the river is filled from below, and not from the river. The deduction is that the clay layer in this area is indeed impermeable and that the flood needed to overtop the clay before infiltrating.

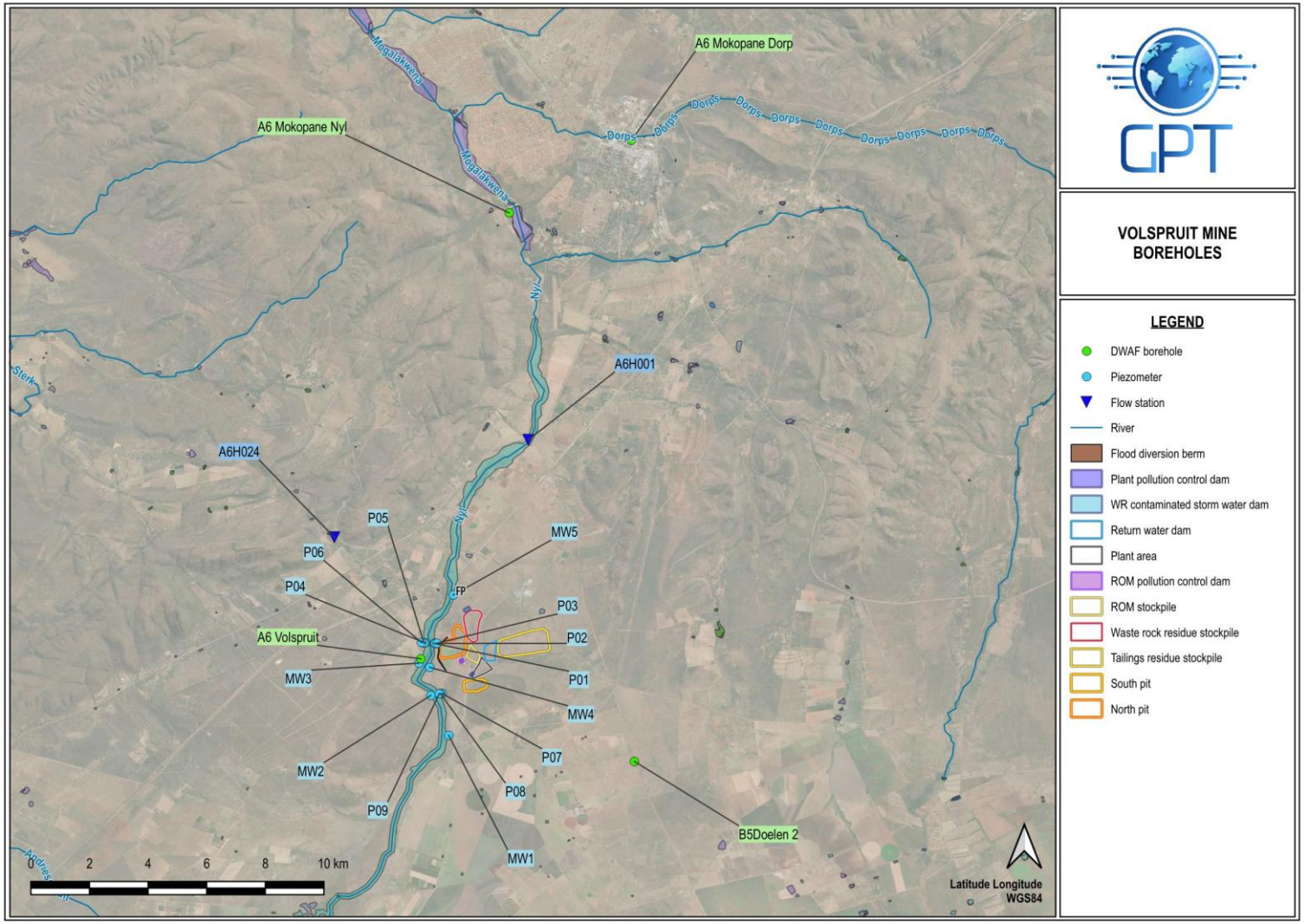


Figure 14: Piezometer boreholes spread across the Nyl.

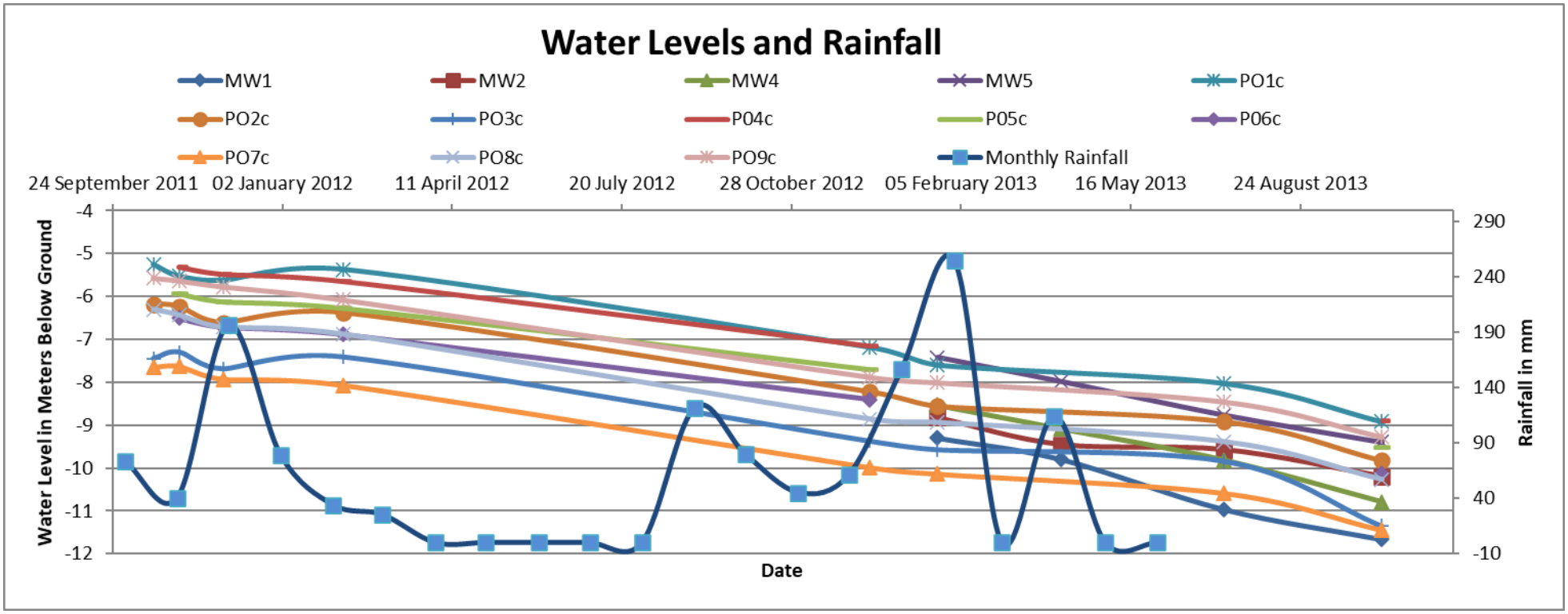
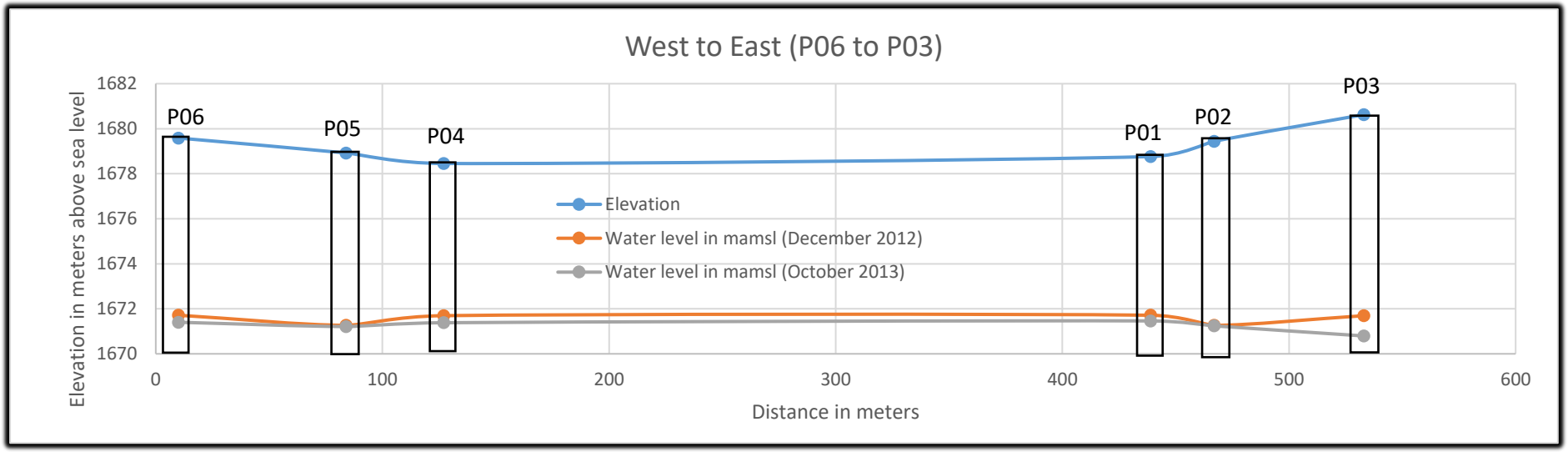


Figure 15: Water level Fluctuation & Rainfall data – Normal Seasons.



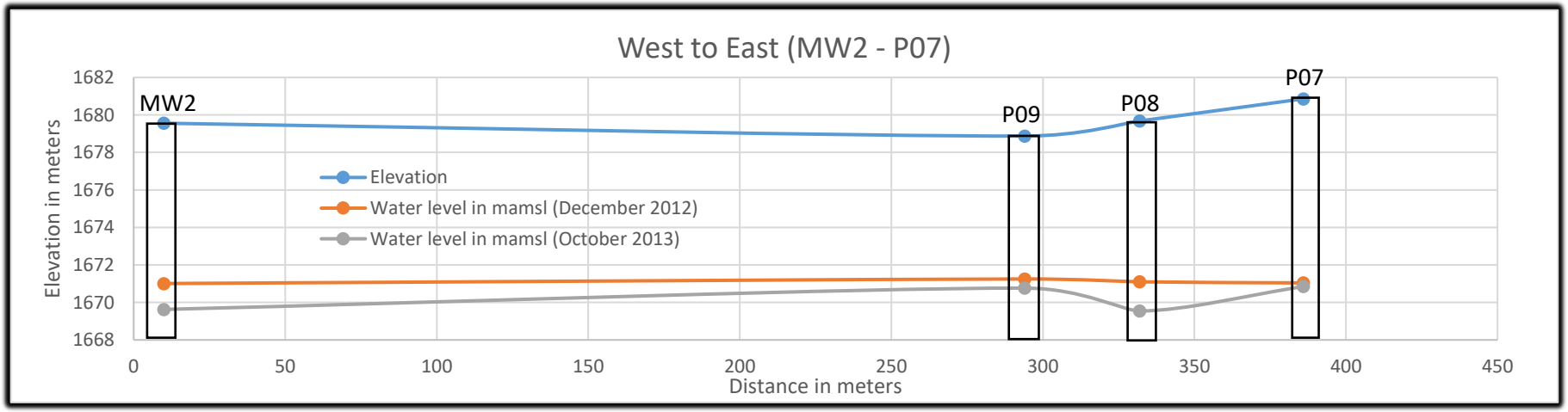


Figure 16: Cross Sections through Piezometers - Normal Seasons.

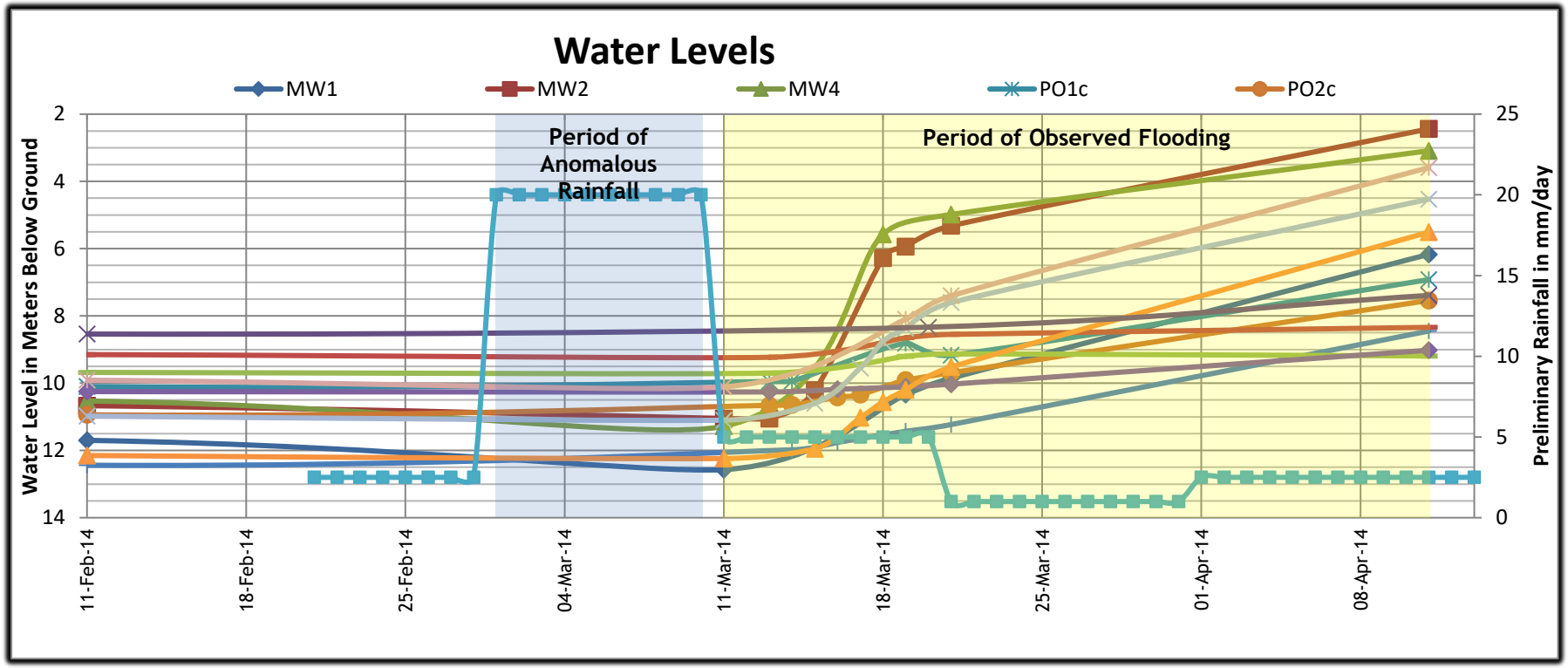


Figure 17: Water level Fluctuation & Rainfall data – Flood Period.

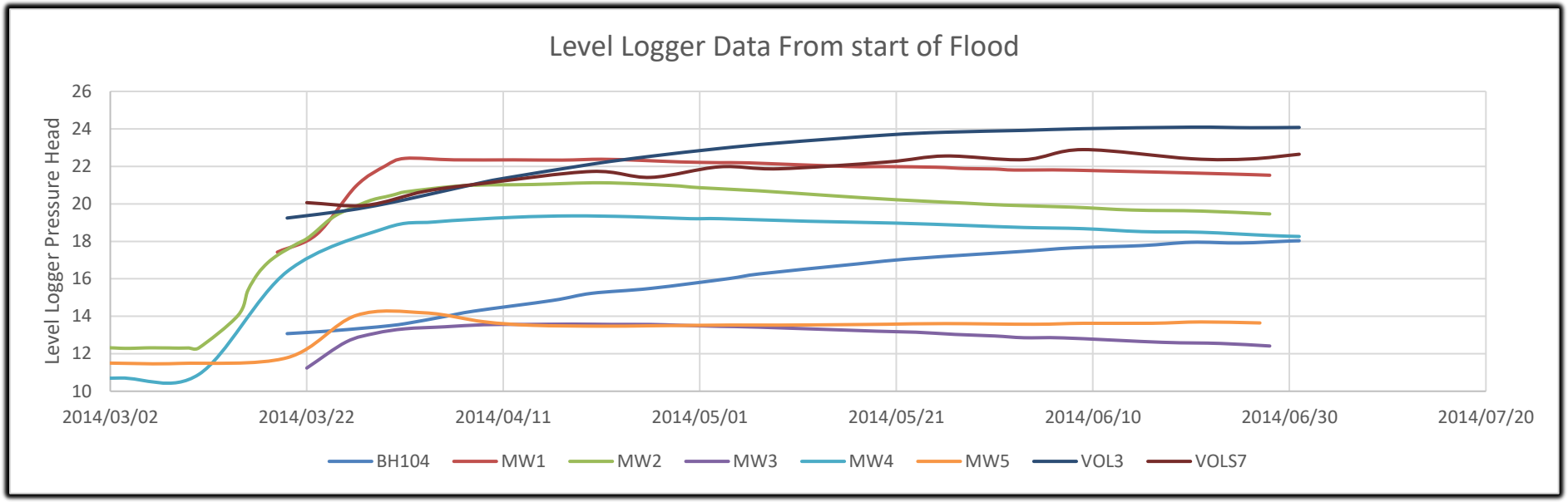
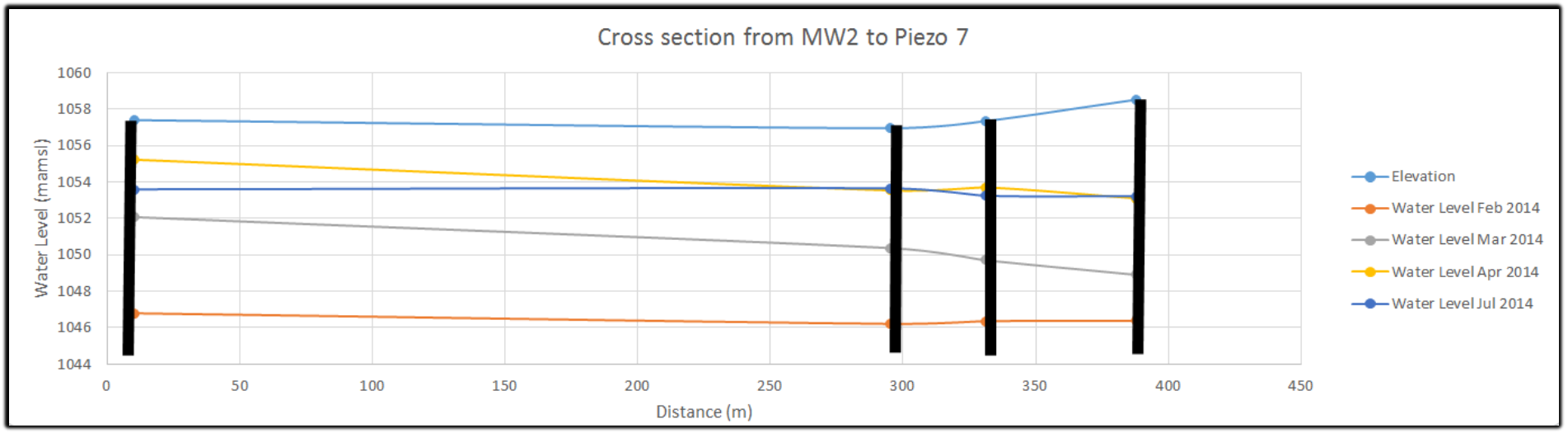


Figure 18: Water Level Fluctuation from Start of Flood - Level Loggers.



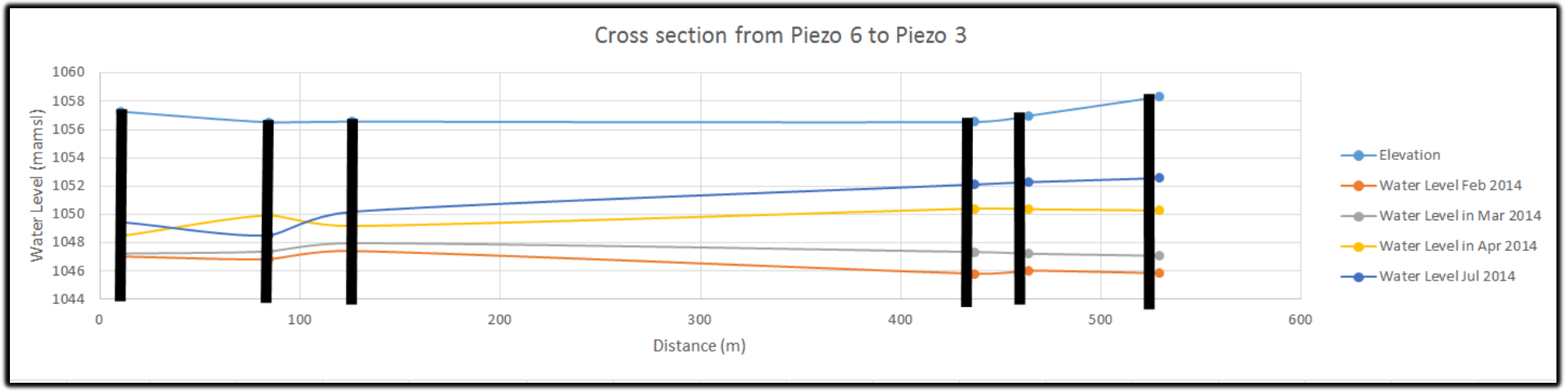


Figure 19: Cross Sections through Piezometers - Flood Period.

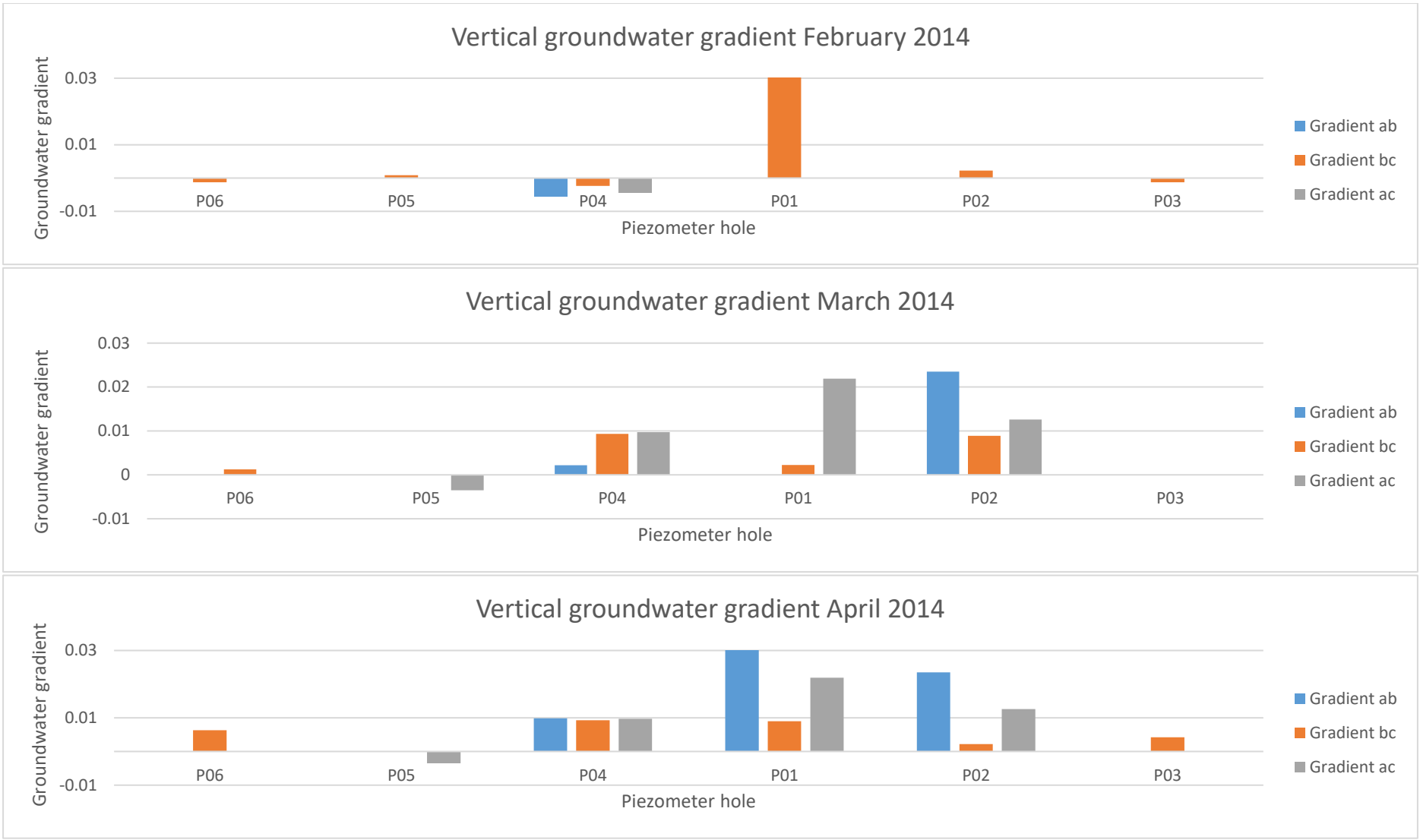


Figure 20: Vertical groundwater gradients - Flood PO3-PO6.

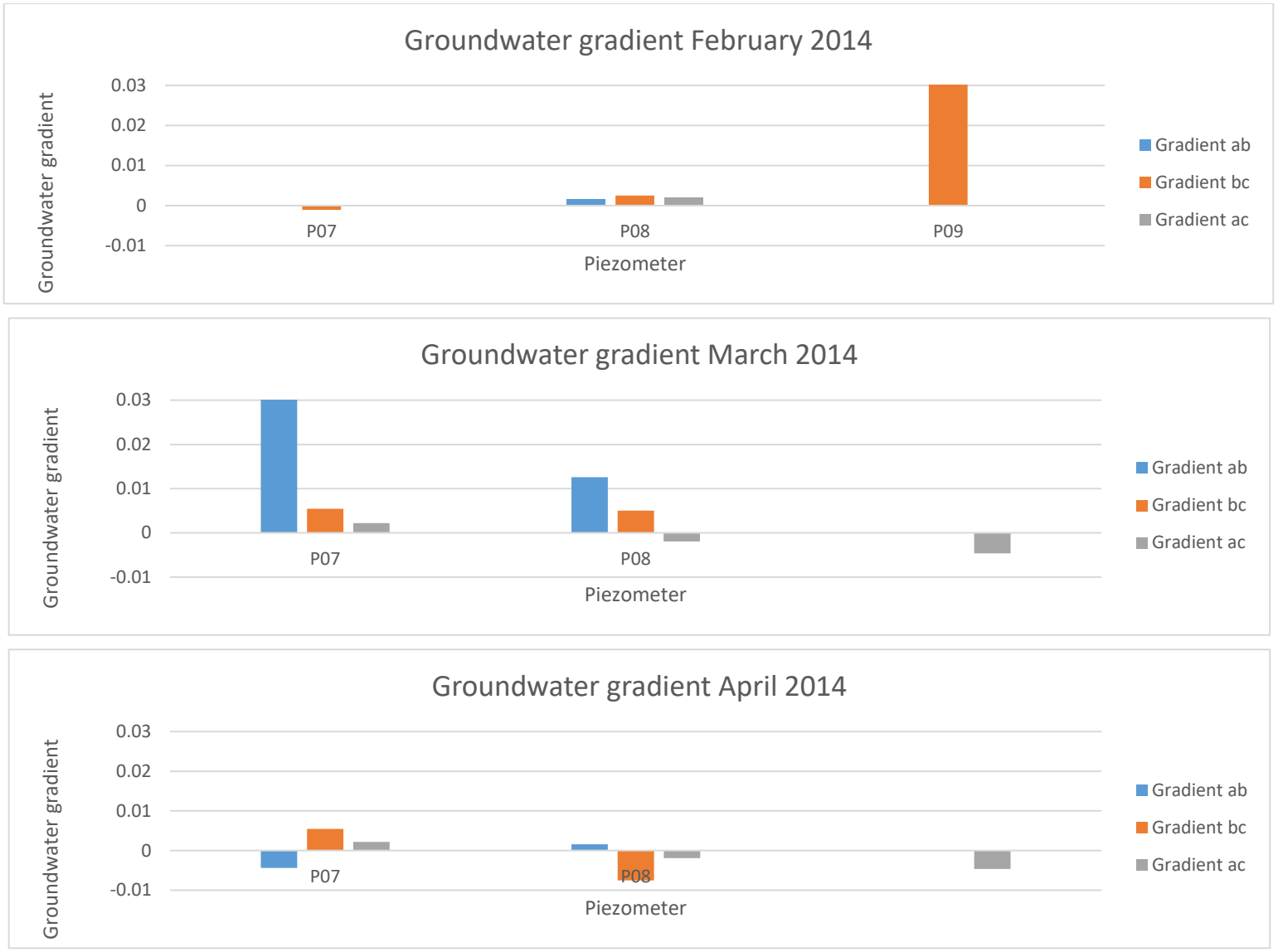


Figure 21: Vertical groundwater gradients - Flood PO7-PO9.

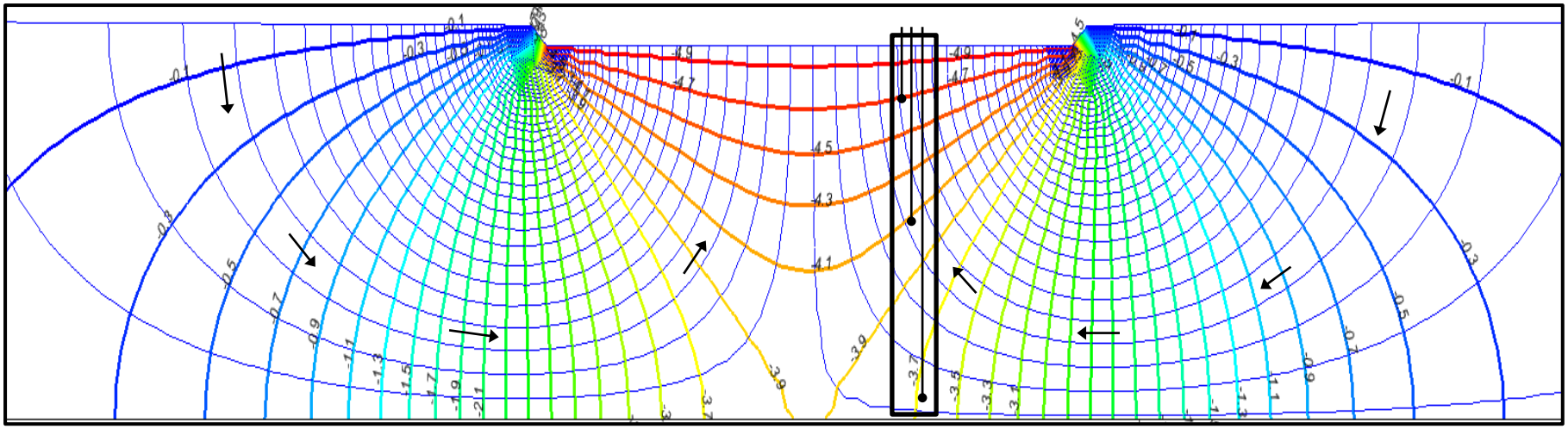


Figure 22: Schematic illustration of piezometric pressure.

8.3 2010-2011 Hydrocensus

Extensive regional hydrocensuses were conducted on and around the site during 11 to 13 May 2010, 30 September 2011 and 30 November 2011. A total of 72 hydrocensus boreholes and one surface water body (Nyl River) was located in specifically targeted areas which fall within a 2 km radius around the project area, and up to 50 km in the Zebediela Fault. The censuses were performed to obtain a representative population of the boreholes in the area. The area was investigated to such a large scale to focus on the entire extent of the Zebediela fault that runs through the area. This would ensure that background values were obtained for the groundwater at the Zebediela fault, and eventually also aid in the characterisation of the influence of the proposed opencast mining activity on the Volspruit property on the hydrogeological properties of the fault in terms of possible dewatering of the fault. The results of the hydrocensus are summarised in Table 10 below.

Water levels could not be measured in 24 of the 72 identified boreholes as they were equipped with pumps which prevented access. The water levels ranged from 1.5 to 38 mbgl. Boreholes which were found inside the 2 km radius around the pits are inferred to be relevant and may potentially be impacted on by the activities of the mine. Only 7 boreholes identified around the mine area are not being used for specific activities and are not equipped with any abstraction equipment.

Groundwater is intensively used for pivot irrigation, potable water and livestock watering. Large amounts of water are abstracted from the aquifer for irrigation purposes especially on the farms Volspruit and Bokpoort. The large-scale groundwater abstraction may stress the aquifer especially if more groundwater is being abstracted than what is recharged to the aquifer.

The boreholes identified during the hydrocensuses around the proposed mine have an average yield of 6.25 l/s. The yields experienced in the Volspruit area are significantly higher than expected for the northern limb of the Bushveld Complex. These higher yields may be attributed to deep weathering and fracturing, as well as fault structures forming preferential flow paths.

Table 10: Hydrocensus Summary 2010-2011.

Borehole No.	Coordinates		Owner	Est. Yield (l/s)	When last pumped	Use	SWL (mbgl)	Collar Height (mm)
	Y	X						
ABDUL	24.34726	28.9371	Abdulla	unknown	more than 24	Irrigation	6.18	450
DEK1	24.37587	28.97	De Klerk	unknown	within24	Domestic	24.86	0
NYL1	24.31476	28.9507	-	-	-	River	-	-
GV1	24.29885	28.9847	E. Wroe	unknown	within24	Domestic	31.15	200
GV2	24.29966	28.9816	E. Wroe	unknown	within24	Domestic	25.3	0
GV3	24.29395	28.9907	Not at home	unknown	within24	Domestic	29.8	350
GV4	24.29729	28.9913	Mandev	unknown	within24	Domestic	29.4	0
GV5	24.31797	28.9866	K. Kusbach	unknown	currently	Domestic	28.8	315
GV6	24.32036	28.9707	Mine	unknown	within24	Domestic	no access	NA
GV7	24.31494	28.9621	Not at home	unknown	24+	Irrigation	23.42	550
GV8	24.33496	28.9737	Niemcor	unknown	24+	Irrigation	37.75	270
VOLS1	24.3678	28.9636	D. De Beer	9	within24	domestic and Irrigation	27.85	0
VOLS2	24.36994	28.9646	D. De Beer	5	currently	Irrigation	no access	NA
VOLS3	24.37002	28.9641	D. De Beer	4	currently	Irrigation	23.81	0
VOLS4	24.3699	28.965	D. De Beer	unknown	never	Not in use	24.3	0
VOLS5	24.37435	28.9631	D. De Beer	5	currently	Irrigation	16.1	0
VOLS6	24.3749	28.9636	D. De Beer	6	currently	Irrigation	14.73	220
VOLS7	24.37607	28.9546	D. De Beer	unknown	24+	Irrigation	no access	0
VOLS8	24.37545	28.9546	D. De Beer	unknown	24+	Irrigation	9.98	0
VOLS9	24.3747	28.955	D. De Beer	unknown	24+	Not in use	10.7	490
VOLS10	24.37377	28.9558	D. De Beer	unknown	24+	Irrigation	no access	NA
VOLS11	24.37355	28.9603	D. De Beer	4	24+	Irrigation	15.17	0
VOL1	24.3463	28.9479	P.J. De Klerk	unknown	never	Not in use (old core holes)	6.42	500
VOL2	24.34568	28.9479	P.J. De Klerk	unknown	never	Not in use (old core holes)	6.85	500

Borehole No.	Coordinates		Owner	Est. Yield (l/s)	When last pumped	Use	SWL (mbgl)	Collar Height (mm)
	Y	X						
VOL3	24.3459	28.9481	P.J. De Klerk	unknown	never	Not in use (old core holes)	7.6	600
VOL4	24.34185	28.9463	P.J. De Klerk	3.3	24+	Irrigation	no access	NA
VOL5	24.35399	28.9543	P.J. De Klerk	6	24+	Irrigation	no access	NA
VOL6	24.35235	28.9512	P.J. De Klerk	7	24+	Irrigation	no access	NA
VOL7	24.34757	28.9515	P.J. De Klerk	8	24+	Irrigation	no access	NA
VOL8	24.34806	28.9523	P.J. De Klerk	unknown	24+	Irrigation	no access	NA
VOL9	24.34882	28.9533	P.J. De Klerk	3	24+	Irrigation	no access	NA
VOL10	24.34799	28.9554	P.J. De Klerk	unknown	24+	Irrigation	no access	NA
VOL11	24.34753	28.9558	P.J. De Klerk	unknown	24+	Not in use	20.08	100
VOL12	24.34806	28.9571	P.J. De Klerk	3	24+	Irrigation	no access	0
VOL13	24.35341	28.9561	P.J. De Klerk	3	within24	Domestic	24.19	350
VOL14	24.35528	28.9533	P.J. De Klerk	3	within24	Domestic	no access	NA
VOL15	24.35458	28.9538	P.J. De Klerk	unknown	24+	Irrigation	no access	NA
VOL16	24.35048	28.9472	P.J. De Klerk	unknown	24+	Irrigation	no access	NA
BOK1	24.37809	28.9726	J. De Klerk	unknown	within24	Domestic	7.53	0
BOK2	24.37719	28.9733	J. De Klerk	unknown	within24	Domestic	no access	0
BOK3	24.37763	28.9723	J. De Klerk	unknown	within24	Domestic	11.88	0
BOK4	24.39179	28.9668	J. De Klerk	unknown	24+	Not in use	15	0
BOK5	24.39167	28.9662	J. De Klerk	unknown	24+	Irrigation	15.26	0
BOK6	24.39013	28.9673	J. De Klerk	unknown	24+	Irrigation	15.2	0
BOK7	24.39196	28.9679	J. De Klerk	unknown	24+	Irrigation	15.32	250
BOK8	24.39198	28.9659	J. De Klerk	unknown	24+	Irrigation	no access	NA
BOK9	24.39184	28.9709	J. De Klerk	unknown	24+	Irrigation	no access	NA
BOK10	24.38975	28.972	J. De Klerk	unknown	24+	Irrigation	15.15	0
BOK11	24.39257	28.9746	J. De Klerk	unknown	24+	Irrigation	16.34	0
BOK12	24.39579	28.9721	J. De Klerk	unknown	24+	Irrigation	no access	NA
VOL17	24.34225	28.9458	P.J. De Klerk	2	never	Newly Drilled	8.38	150

Borehole No.	Coordinates		Owner	Est. Yield (l/s)	When last pumped	Use	SWL (mbgl)	Collar Height (mm)
	Y	X						
VOL18	24.34219	28.9524	P.J. De Klerk	1	never	Newly Drilled	19.5	NA
VOL19	24.34509	28.9525	P.J. De Klerk	3	never	Newly Drilled	15.3	340
VOL22	24.3424	28.9524	P.J. De Klerk	15	never	Not in use	13.53	0
VOL20	24.3475	28.944	P.J. De Klerk	8	never	Newly Drilled	1.6	500
VOL21	24.34725	28.9489	P.J. De Klerk	3	never	Newly Drilled	7.8	230
Zebediela02	24.29434	29.22038	Zebediela citrus	8	currently	Fruit and cattle	no access	500
Z04	24.29407	29.2201	Zebediela citrus	8	currently	Fruit and cattle	23.11	0
Z01	24.29405	29.22157	Zebediela citrus	8	currently	Fruit and cattle	no access	600
Z08	24.2984	29.22159	Zebediela citrus	8	unknown	Fruit and cattle	16.28	800
Z09	24.29909	29.22175	Zebediela citrus	8	currently	Fruit and cattle	14	0
Z10	24.29948	29.22067	Zebediela citrus	0	unknown	Fruit and cattle	14	200
Z06	24.29954	29.22071	Zebediela citrus	8	currently	Fruit and cattle	14	500
EAS pigs	24.44922	28.93058	EAS Pork	unknown	currently	Pigs	no access	400
BHNYL1OOS	24.44251	28.91216	EAS Pork	0	never	Not in use	Dry	1000
BHNYL2WES	24.44218	28.91168	EAS Pork	0	never	Not in use	11.6	1000
BHHUIS	24.4487	28.9272	EAS Pork	unknown	unknown	Irrigation-veg	no access	300
Euphoria	24.54988	28.63961	Euphoria Golf Estate	10	currently	Garden	no access	0
MB1	24.35565	29.01835	Wayne Knight	unknown	unknown	Cattle&hunting farm	38.2	
MB2	24.33757	29.03349	Wayne Knight	unknown	unknown	Cattle&hunting farm	11.8	
MB3	24.40833	28.87036	Piet Prinsloo	4	unknown	Irrigation	28.5	
MB4	24.41908	28.89861	Piet Prinsloo	unknown	unknown	open hole	18.5	
MB5	24.42033	28.89162	Piet Prinsloo	unknown	unknown	open hole	18	

The static water level/topography relationship of the borehole data from the hydrocensuses is shown in Figure 23: Correlation Graph Including All Boreholes.. There seem to be two aquifer systems in the area. The boreholes in the highly fractured Bushveld lithology, where hydraulic conductivity is high, all plot in one cluster at the bottom of the graph. This is indicative of a flat topography with a similar flat groundwater table. In the rest of the area (mostly mountainous to the east and west), the groundwater level emulates the topography. However, most of the boreholes at elevation of about 1080 and 1120mamsl are pumped and do not reflect the rest water levels.

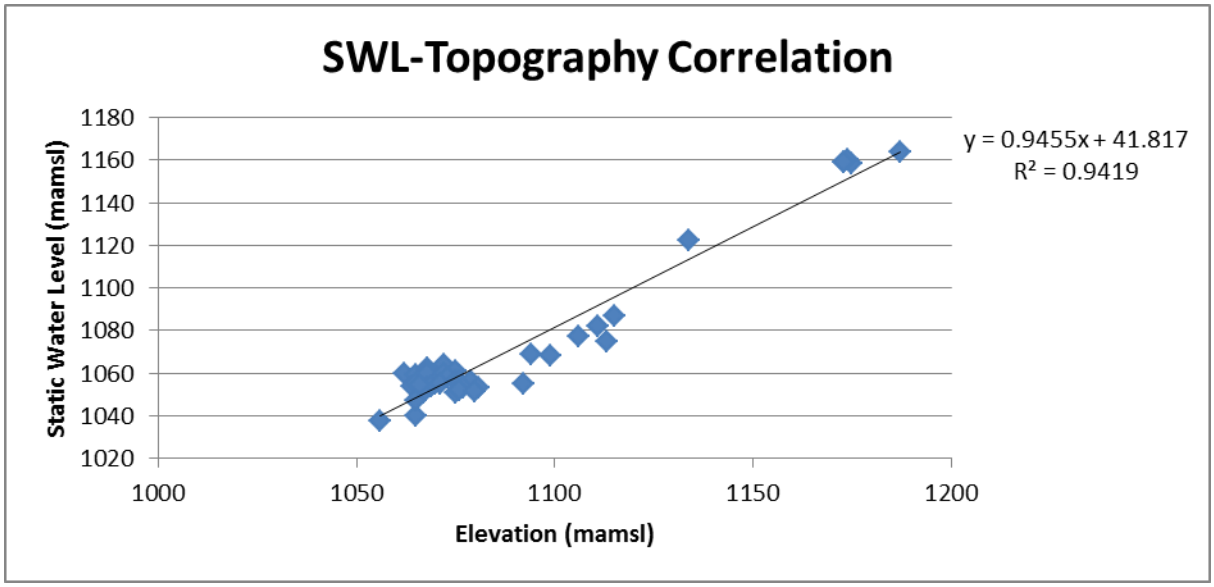


Figure 23: Correlation Graph Including All Boreholes.

8.4 2026 Hydrocensus

A hydrocensus was conducted between 1 and 5 June 2026 within the area surrounding the proposed Volspruit site. The survey area was initially delineated using the local quaternary catchment boundaries. To focus the investigation on hydrogeological receptors most likely to be influenced by the proposed development, the upstream extent of the survey was limited to approximately 10 km from the site, while the natural quaternary catchment boundaries were retained in all other directions. This defined the maximum extent of the hydrocensus.

Access to boreholes was obtained through consultation with neighbouring landowners. Properties immediately adjacent to the proposed site were prioritised, with the survey progressively extending outward across the catchment. Landowners assisted in identifying borehole locations and provided information regarding borehole utilisation, abstraction rates, yields, water level fluctuations, borehole construction details, and other groundwater-related observations. Information obtained during these engagements supplemented field observations and contributed to the understanding of the local hydrogeological setting.

A total of 107 borehole localities and one surface water weir were visited during the survey. Numerous additional borehole locations, representing drilled boreholes that were never equipped or developed with groundwater abstraction infrastructure, were identified within the study area. These sites were generally not included in the hydrocensus due to time constraints, with preference given to boreholes that are actively abstracting groundwater and therefore represent current groundwater receptors.

Data collected during the hydrocensus is presented in Table 11 and localities are presented below in Figure 24.

Water level measurements were successfully obtained from 78 boreholes. Measured water levels ranged from 0.51 m to 76.63 m below ground level (mbgl), with an overall average water level of 22.06 mbgl.

An initial water level/topography relationship analysis showed a moderate positive correlation (R = 0.64) between groundwater elevation and surface elevation, but this was largely influenced by boreholes located at higher elevations on one property. After excluding these boreholes, the correlation dropped to R = 0.008 (Figure 25), indicating no meaningful relationship between surface topography and groundwater elevation. This suggests that groundwater flow gradients cannot be inferred from surface topography in the study area.

Table 11: Hydrocensus Survey

BH ID	X	Y	Owner	Date	Collar Height	Water Level (mbcl)	Water Level (mbgl)	Pump Type	Water Use	Estimated Usage from Farmers	Notes
JAAGBAAN 34BH	28.95513397	-24.28872001	Andre Pretorius	01/06/2026	0.37	9.56	9.19	Mono		4500l/s pumped 8h every 2nd day	
JR01	28.95204297	-24.31465102	Jopie Riekert	01/06/2026	0.13	2	1.87	Subm	Domestic & Livestock		
332 BH	28.981328	-24.25623301	Ken Smith	01/06/2026	0.64	7.61	6.97	Subm	Domestic & Selling of Water to Lepele	1 000 000l per day over 18h	Active Pumping at time of measurement
333 BH	28.98009603	-24.26593498	Ken Smith	01/06/2026	0.92	2.5	1.58	Subm	Domestic & Selling of Water to Lepele	500 000l per day over 18h	Active Pumping at time of measurement
WEIR	28.97650204	-24.24110703	Ken Smith	01/06/2026			0				Weir at 1.5m height
PO01	28.98743003	-24.30320797	Phillip Olivier	01/06/2026	0.33	34	33.67	Subm	Domestic & Livestock		
AB01	28.966213	-24.29650697	Abel	02/06/2026	0.26	14.65	14.39	Subm	Domestic & Agriculture		
AW01	28.95399696	-24.30022904	Ahee vd Westhuizen	02/06/2026	0.29	0.8	0.51	Subm	Agriculture	10 000l/h between 3 bh's over 12h pumping cycles	
AW02	28.95392898	-24.30096899	Ahee vd Westhuizen	02/06/2026	0.44	1.92	1.48	Subm	Agriculture		
AW03	28.952694°	-24.299975	Ahee vd Westhuizen	02/06/2027		CNM		Subm	Agriculture		Could not access, across flooded river. Strongest bh of the three
BOORGAT NYL	28.93635398	-24.41766302	CG Kruger	02/06/2026	0.31	7.85	7.54	Subm	Agriculture	11 000 gallons per 4-day cycle for 4-5 months per year	
BOORGAT NYL 2	28.943721	-24.42654599	CG Kruger	02/06/2026	0.25	CNM		Subm	Agriculture		wl usually at ~11m
CG GEGUND	28.97947904	-24.42033802	CG Kruger	02/06/2026	0.13	16.61	16.48	Subm	Agriculture		Active pumping at time of visit
CG GEGUND 2	28.976827	-24.42371299	CG Kruger	02/06/2026		CNM		Mono			No Access
CG HUIS	28.93715797	-24.428359	CG Kruger	02/06/2026	0.06	9.78	9.72	Subm	Domestic		
BH4	28.97484996	-24.33140804	Grass Valley	02/06/2026	0.46	74.66	74.2	None			BH not in use
BH1	28.97500603	-24.33289499	Grass Valley	02/06/2026		CNM		Subm	Domestic & Production		No Acecess, gate locked
BH2	28.97475801	-24.33241798	Grass Valley	02/06/2026	0.41	CNM		Subm	Domestic & Production		No Access
BH3	28.97325103	-24.33296104	Grass Valley	02/06/2026	0.25	76.88	76.63	Subm	Domestic & Production		Pump removed just for maintenace last week.
KV01	28.962358	-24.2878	Koos Viljoen	02/06/2026		CNM		Subm	Domestic, Agriculture		Inundated by Nyl River
KV02	28.962139	-24.288083	Koos Viljoen	02/06/2026		CNM		Subm	Domestic, Agriculture		
KV03	28.961975	-24.288281	Koos Viljoen	02/06/2026		CNM		Subm	Domestic, Agriculture		
KV04-06	28.962217	-24.287514	Koos Viljoen	02/06/2026		CNM		Subm	Domestic, Agriculture		
A01	28.93442396	-24.34905102	Abdul Tayob	03/06/2026	0.48	9	8.52	Subm	Domestic, Livestock, Agriculture	1687m3 pumped per day over 8h over entire bh network	
A02	28.93407301	-24.34879504	Abdul Tayob	03/06/2026	0.28	8.71	8.43	Subm	Domestic, Livestock, Agriculture		
A03	28.93337304	-24.34823597	Abdul Tayob	03/06/2026	0.12	10.33	10.21	Subm	Domestic, Livestock, Agriculture		Active pumping for 3,5h at time of visit
A06	28.93705303	-24.34724799	Abdul Tayob	03/06/2026	0.3	6.19	5.89	Subm	Domestic, Livestock, Agriculture		
A07	28.93692696	-24.346213	Abdul Tayob	03/06/2026	0.1	6.04	5.94	Subm	Domestic, Livestock, Agriculture		

BH ID	X	Y	Owner	Date	Collar Height	Water Level (mbcl)	Water Level (mbgl)	Pump Type	Water Use	Estimated Usage from Farmers	Notes
A08	28.93690903	-24.34498999	Abdul Tayob	03/06/2026	0.03	6.02	5.99	Subm	Domestic, Livestock, Agriculture		
A09	28.93910701	-24.33990897	Abdul Tayob	03/06/2026	0.86	8.85	7.99	Subm	Domestic, Livestock, Agriculture		
A10	28.93979098	-24.34031499	Abdul Tayob	03/06/2026	0.27	12.27	12	Subm	Domestic, Livestock, Agriculture		Active pumping at time of visit
HUIS01	28.93922604	-24.33974703	Abdul Tayob	03/06/2026	0.15	8.9	8.75	Subm	Domestic		
HUIS02	28.93982098	-24.339297	Abdul Tayob	03/06/2026	0.27	7.52	7.25	Subm	Domestic		
CK01	28.98247196	-24.36841104	Anton Keet	03/06/2026	0.05	48.77	48.72	Subm	Domestic, Livestock, Agriculture	12h pumping cycle daily	
CK02	28.98205798	-24.36855999	Anton Keet	03/06/2026	0.48	CNM		Subm			Dip meter stuck at 18m
CK03	28.97920897	-24.36552599	Anton Keet	03/06/2026		CNM		Subm			Dip meter stuck at 10m
LJT01	28.86897798	-24.35812502	Jaco Theunessin	03/06/2026	0.44	63.88	63.44	Subm	Domestic & Livestock	20 000 l/h pumped on daily basis, volume as needed	Main fracture on ~80m
LSJT02	28.87219302	-24.355791	Jaco Theunessin	03/06/2026	0.52	65	64.48	Subm	Domestic & Livestock	3000 l/h	Active pumping at time of visit, recharge into bh audable
SVJT04	28.905927	-24.33484797	Jaco Theunessin	03/06/2026	0.38	45	44.62	Subm	Domestic & Livestock	20 000 l/h pumped as needed	
VJT03	28.90080398	-24.33142296	Jaco Theunessin	03/06/2026	0.7	40.43	39.73	Subm	Domestic & Livestock		
LS01	28.935395	-24.47221798	Lucius van Schalkwyk	03/06/2026	0.05	8.59	8.54	Subm	Domestic & Livestock	1500 l/h pumper for 20h per week	
NV01	28.92991802	-24.44122598	Nico Venter	03/06/2026	0.15	5.38	5.23	Subm	Domestic & Agriculture		
NV02	28.937436	-24.43627504	Nico Venter	03/06/2026	0.15	CNM		Subm	Domestic & Agriculture		Bees in bh
NV03	28.93770698	-24.435924	Nico Venter	03/06/2026		CNM		Subm	Domestic & Agriculture		No Access, closed shut
NV04	28.93948	-24.43335	Nico Venter	02/06/2027	0.55	10.9	10.35	Subm	Domestic & Agriculture		
NV05	28.94169702	-24.43015298	Nico Venter	03/06/2026		CNM		Subm	Domestic & Agriculture		No Access
NV06	28.94217798	-24.42941001	Nico Venter	03/06/2026	0.55	11.1	10.55	Subm	Domestic & Agriculture		
NV07	28.94242398	-24.42782499	Nico Venter	03/06/2026	0.34	10.73	10.39	Subm	Domestic & Agriculture		
RS01	28.894566	-24.322226	Robbie Smith	03/06/2026		CNM		Subm	Domestic & Agriculture	400l/h pumped until dry	No Access
RS02	28.89293103	-24.32193498	Robbie Smith	03/06/2026	0.25	CNM		Subm	Domestic & Agriculture	4-600 l/h pumped daily for 2h at a time until dry.	No Access, estimated 50 wl
RS03	28.89252601	-24.32115404	Robbie Smith	03/06/2026		CNM		Subm	Domestic & Agriculture	6-800 l/h pumped until dry.	No Access, estimated 120 wl
WDM01	29.00174598	-24.39299801	WD Malherbe	03/06/2026	0.37	18.19	17.82	Subm	Domestic & Agriculture	35 000l/h puped daily for 12h during irrigation season	
WDM02	28.998556	-24.389739	WD Malherbe	03/06/2026		CNM		Mono	Domestic & Agriculture	30 000l/h puped daily for 12h during irrigation season	No Access
WDM03	28.98672603	-24.38926396	WD Malherbe	03/06/2026		CNM		Mono	Domestic & Agriculture	50 000l/h pumped daily for 12h during irrigation season	No Access

BH ID	X	Y	Owner	Date	Collar Height	Water Level (mbcl)	Water Level (mbgl)	Pump Type	Water Use	Estimated Usage from Farmers	Notes
WDM04	28.984492	-24.39030097	WD Malherbe	03/06/2026	0.32	18.09	17.77	Subm	Domestic & Agriculture	15 000l/h pumped daily for 12h during irrigation season	
CK04	28.98608096	-24.36999698	Anton Keet	04/06/2026	0.26	CNM		Subm	Livestock & Agriculture		No Access
CK05	28.98645404	-24.37071296	Anton Keet	04/06/2026	0.3	48.54	48.24	Subm	Livestock & Agriculture		Pumped during the morning of visit
CK06	29.00384397	-24.36738803	Anton Keet	04/06/2026	0.08	42.95	42.87	Subm	Livestock & Agriculture		
CK07	29.00506597	-24.36782003	Anton Keet	04/06/2026	0.08	42.36	42.28	Subm	Livestock & Agriculture		
CK08	29.00783703	-24.37907601	Anton Keet	04/06/2026	0.24	16.18	15.94	Subm	Livestock & Agriculture		
CK09	29.00570501	-24.37808602	Anton Keet	04/06/2026	0.25	16.26	16.01	Subm	Livestock & Agriculture		
CK10	28.97780903	-24.39123002	Anton Keet	04/06/2026	0.15	6.8	6.65	Subm	Livestock & Agriculture		
VOL13	28.95607702	-24.35377398	Phlippie de Klerk	04/06/2026	0.21	20.35	20.14	Subm	Domestic		
VOL12	28.95711503	-24.34805701	Phlippie de Klerk	04/06/2026	0.36	20.74	20.38	Subm	Agriculture		
BP01	28.95645596	-24.38907302	Phlippie de Klerk	04/06/2026	0.22	9.14	8.92	Subm	Livestock & Agriculture		Double borehole next to each other.
BP02	28.95379596	-24.38937804	Phlippie de Klerk	04/06/2026	0.37	8.71	8.34	Subm	Agriculture		
BP03	28.95427097	-24.39236803	Phlippie de Klerk	04/06/2026	0.3	CNM		Subm	Agriculture		No Access
BP04	28.95458001	-24.39255998	Phlippie de Klerk	04/06/2026	0.25	7.8	7.55	Subm	Agriculture		
BP05	28.95474798	-24.39369698	Phlippie de Klerk	04/06/2026	0.6	10.63	10.03	Subm	Agriculture		
BP06	28.95945199	-24.39452603	Phlippie de Klerk	04/06/2026	0	CNM		Subm	Agriculture		No Access
BP07	28.959397	-24.39582498	Phlippie de Klerk	04/06/2026	0.12	CNM		Subm	Agriculture		No Access
BP08	28.95941201	-24.39699199	Phlippie de Klerk	04/06/2026	0.07	CNM		Subm	Agriculture		No Access
BP09	28.96010703	-24.39978199	Phlippie de Klerk	04/06/2026		CNM		Subm	Agriculture		Bees in BH
BP10	28.95942	-24.40234	Phlippie de Klerk	04/06/2027		CNM		Subm	Agriculture		Bees in BH
BP11	28.95796102	-24.39748401	Phlippie de Klerk	04/06/2026	0.18	12.25	12.07	Subm	Agriculture		
BP12	28.95886299	-24.39516197	Phlippie de Klerk	04/06/2026		CNM		Subm	Agriculture		Bees in BH
BP13	28.96118503	-24.39292199	Phlippie de Klerk	04/06/2026		CNM		None			Bees in BH
BP14	28.961668	-24.37813397	Phlippie de Klerk	04/06/2026		CNM		Mono	Agriculture		No Access
BP15	28.96761202	-24.38110401	Phlippie de Klerk	04/06/2026	0.24	12	11.76	Subm	Domestic		
BP16	28.96898699	-24.38333401	Phlippie de Klerk	04/06/2026		CNM		Mono	Agriculture		No Access
BP17	28.96981998	-24.37575996	Phlippie de Klerk	04/06/2026	0.13	17.23	17.1	None			Not in Use
WB01	28.92913699	-24.31918303	Willem Barnard	04/06/2026	0.09	36.93	36.84	None			Backup BH for house
WB02	28.93169498	-24.32328396	Willem Barnard	04/06/2026	0.12	22.38	22.26	Subm	Domestic & Livestock	20 000l per week	
WD03	28.92295601	-24.32172099	Willem Barnard	04/06/2026	0.19	34.09	33.9	None			BH not in use
WD04	28.928118	-24.31603102	Willem Barnard	04/06/2026	0.24	55.56	55.32	Subm	Domestic & Livestock		Active Pumping at time of measurement
WD05	28.92834398	-24.31604904	Willem Barnard	04/06/2026	0.24	47	46.76	None			BH not in use
WD06	28.94270101	-24.31237098	Willem Barnard	04/06/2026	0.41	17.07	16.66	Subm	Domestic & Livestock		
WD07	28.94723897	-24.32715598	Willem Barnard	04/06/2026	0.4	9.69	9.29	Subm	Domestic & Livestock		Active Pumping at time of measurement
WD08	28.94531004	-24.32714702	Willem Barnard	04/06/2026	0.22	9.95	9.73	Subm	Domestic & Livestock		
BB01	28.89473196	-24.41607297	Brian Brooks	05/06/2026	0.22	19.56	19.34	Subm	Livestock & Agriculture	30 000l/h pumper 10h per day during irrigation season	

BH ID	X	Y	Owner	Date	Collar Height	Water Level (mbcl)	Water Level (mbgl)	Pump Type	Water Use	Estimated Usage from Farmers	Notes
BB02	28.876244	-24.41551801	Brian Brooks	05/06/2026	0.14	32.07	31.93	Subm	Agricultural	30 000l/h pumped 6h per day	Active Pumping at time of measurement
BB03	28.87037499	-24.408298	Brian Brooks	05/06/2026	0.06	35.07	35.01	Subm	Domestic, Livestock, Agriculture	75 000l/h pumped 8h per day	Strongest bh on farm, every day pumping
BB04	28.8653	-24.41591598	Brian Brooks	05/06/2026	0.06	25.4	25.34	Subm	Domestic & Livestock	10-15 000l per day	
VOLS Hek 01	28.95413199	-24.361372	Dewald De Beer	05/06/2026	0.1	15.48	15.38	Subm	Domestic & Livestock		
VOLS01	28.96365199	-24.36780704	Dewald De Beer	05/06/2026	0.09	23.57	23.48	Subm	Agriculture		
VOLS10	28.95575	-24.37377	Dewald De Beer	05/06/2026	0.33	7.32	6.99	Subm	Agriculture		
GJ01	29.00477001	-24.306393	GJ Swart	05/06/2026	0.43	30.45	30.02	Subm	Domestic & Livestock	2900l/h	Active pumping at time of visit
GJ02	29.004424	-24.30768097	GJ Swart	05/06/2026	0.1	22.75	22.65	Subm	Domestic & Livestock		
GJ03	29.00404003	-24.30967896	GJ Swart	05/06/2026	0	24	24	Subm			Backup bh
GJ04	29.00529999	-24.30958299	GJ Swart	05/06/2026	0.26	12.6	12.34	None			Newley drilled bh
GJ05	29.00167096	-24.30642704	GJ Swart	05/06/2026	0.32	25.9	25.58	Subm	Domestic & Livestock		
GJ06	28.99095998	-24.29407203	GJ Swart	05/06/2026	0.24	36.2	35.96	None			Water Stink
GJ07	28.99046704	-24.293161	GJ Swart	05/06/2026	0.45	35.85	35.4	Subm	Domestic & Livestock		Borehole just finished pumping cycle at time of visit.
GJ08	28.99017803	-24.29208904	GJ Swart	05/06/2026	0.13	69.8	69.67	Subm	Domestic & Livestock		Borehole just finished pumping cycle at time of visit.
JLV1	28.90125501	-24.36178196	Jan Louis Venter	05/06/2026	0.18	51.03	50.85	Subm	Livestock		Active Pumping at time of measurement
JLV2	28.908458	-24.35301801	Jan Louis Venter	05/06/2026	0.22	46.52	46.3	Subm	Domestic & Livestock		Active Pumping at time of measurement
MV01	28.94062699	-24.30216802	Melany Venter	05/06/2026	0.32	6.81	6.49	None			BH not in use
MV02	28.93942201	-24.30137199	Melany Venter	05/06/2026	0.18	8.47	8.29	Subm	Domestic & Livestock		
*CNM = Could Not Measure											

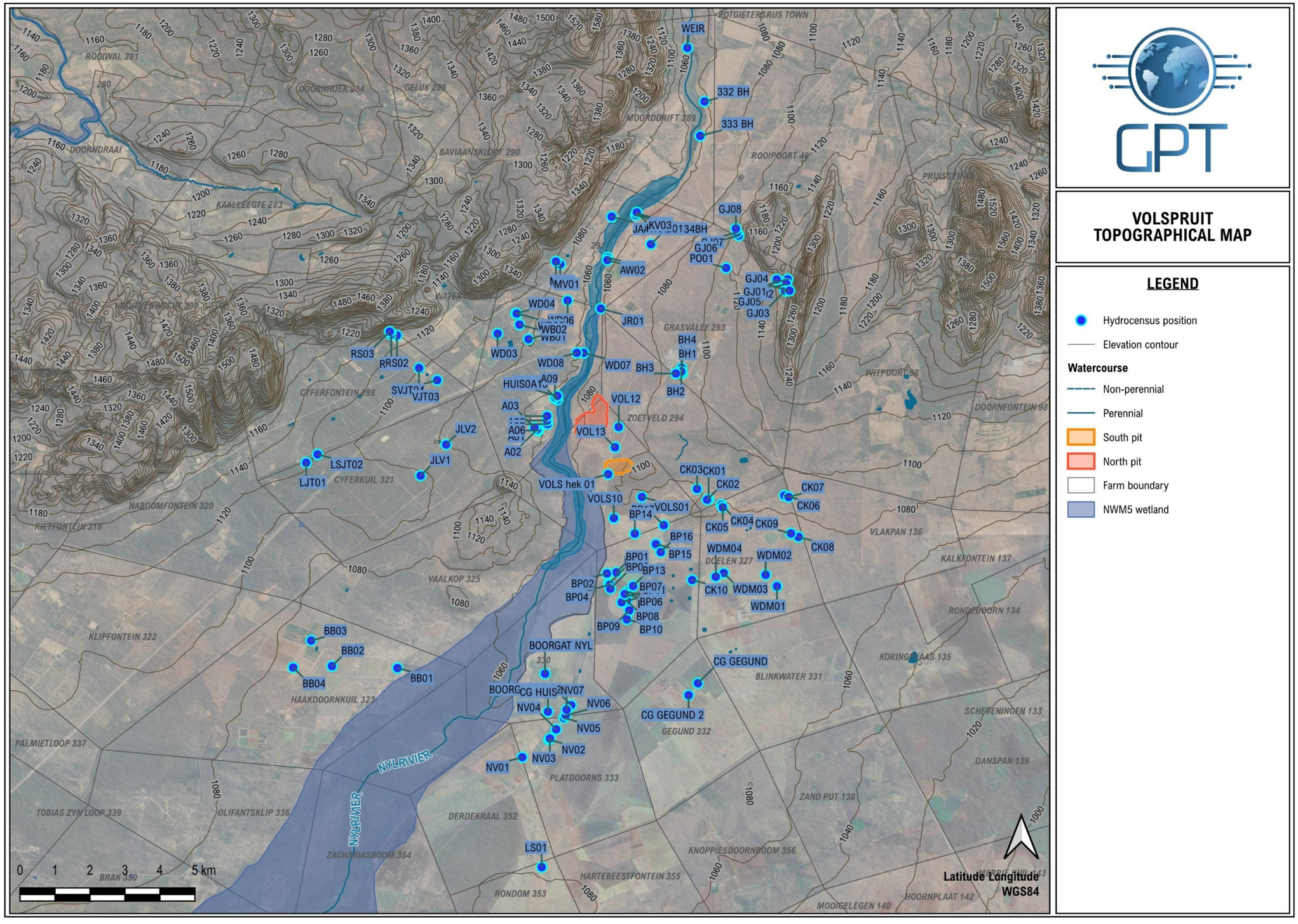


Figure 24: Hydrocensus map -Topography

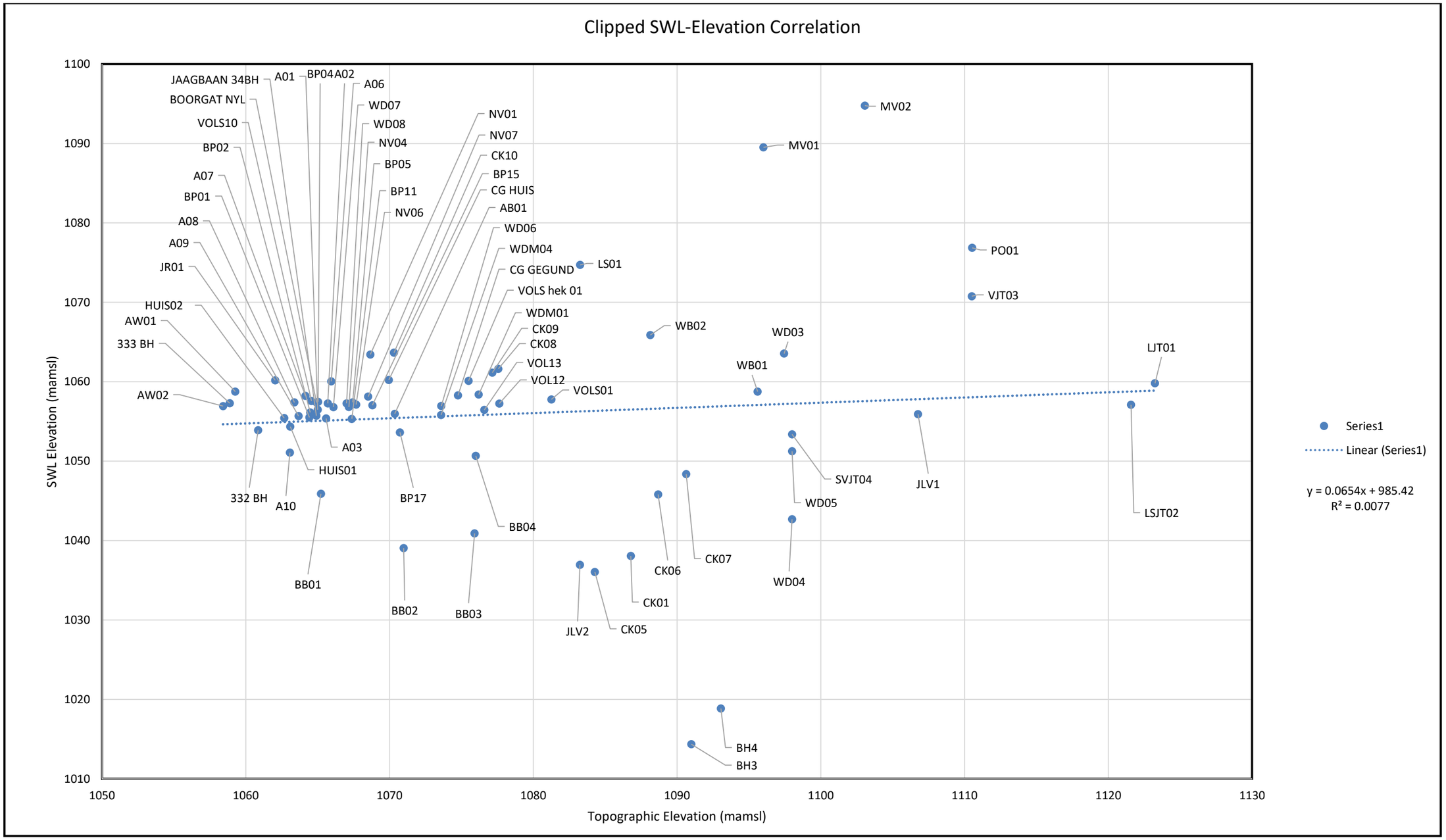


Figure 25: Clipped SWL-Elevation Correlation

8.5 Neighbouring properties

Groundwater level measurements and selected sampling were undertaken on two neighbouring properties surrounding the proposed mining area on 9-10 April 2026. During this investigation, groundwater level measurements were collected, and water samples were obtained from selected boreholes where access was granted. These data provide site-specific information on groundwater conditions and water quality in the surrounding area at the time of monitoring and contribute to the current pre-mining groundwater baseline dataset. Refer to Table 12.

Table 12: Adjacent Landowners Boreholes

BH ID	X-coordinate	Y-coordinate	Property Owner	Casing Height (m)	Method
VOLS1	28.963630	-24.367800	Dewald De Beer	0.08	Field Measurement
VOLS2	28.964550	-24.369940	Dewald De Beer	0.20	Field Measurement
VOLS3	28.964110	-24.370020	Dewald De Beer	0.21	Field Measurement
VOLS4	28.964950	-24.369900	Dewald De Beer	0.41	Field Measurement
VOLS5	28.963100	-24.374350	Dewald De Beer	CNM	Field Measurement
VOLS6	28.963550	-24.374900	Dewald De Beer	0.25	Field Measurement
VOLS7	28.954550	-24.376070	Dewald De Beer	0.27	Field Measurement
VOLS8	28.954640	-24.375450	Dewald De Beer	0.25	Field Measurement
VOLS9	28.955010	-24.374700	Dewald De Beer	0.32	Field Measurement
VOLS10	28.955750	-24.373770	Dewald De Beer	0.40	Field Measurement
VOLS11	28.960300	-24.373550	Dewald De Beer	0.02	Field Measurement
VOLS12	28.962242	-24.373797	Dewald De Beer	0.60	Field Measurement
VOLS13	28.955483	-24.373331	Dewald De Beer	0.07	Field Measurement
VOLS14	28.955759	-24.373326	Dewald De Beer	CNM	Field Measurement
VOLS HEK 01	28.954138	-24.361395	Dewald De Beer	0.10	Field Measurement
VOL4	28.946260	-24.341850	Phlippie De Klerk	CNM	Field Measurement
VOL5	28.954260	-24.353990	Phlippie De Klerk	CNM	Field Measurement
VOL6	28.951170	-24.352350	Phlippie De Klerk	CNM	Field Measurement
VOL7	28.951480	-24.347570	Phlippie De Klerk	CNM	Field Measurement
VOL8	28.952310	-24.348060	Phlippie De Klerk	CNM	Field Measurement
VOL9	28.953250	-24.348820	Phlippie De Klerk	CNM	Field Measurement
VOL10	28.955380	-24.347990	Phlippie De Klerk	CNM	Field Measurement
VOL11	28.955790	-24.347530	Phlippie De Klerk	CNM	Field Measurement
VOL12	28.957090	-24.348060	Phlippie De Klerk	0.33	Field Measurement
VOL13	28.956100	-24.353410	Phlippie De Klerk	CNM	Field Measurement
VOL14	28.953320	-24.355280	Phlippie De Klerk	0.3	Field Measurement
VOL15	28.953810	-24.354580	Phlippie De Klerk	CNM	Field Measurement
VOL16	28.947220	-24.350480	Phlippie De Klerk	CNM	Field Measurement
VOL17	28.945761	-24.342247	Phlippie De Klerk	0.34	Field Measurement
VOL19	28.952506	-24.345089	Phlippie De Klerk	0.63	Field Measurement
VOL20	28.943976	-24.347501	Phlippie De Klerk	0.2	Field Measurement
VOL21	28.948895	-24.347248	Phlippie De Klerk	0.3	Field Measurement
Vol 23	28.943800	-24.346478	Phlippie De Klerk	CNM	Field Measurement
vol 24	28.947078	-24.350850	Phlippie De Klerk	CNM	Field Measurement

BH ID	X-coordinate	Y-coordinate	Property Owner	Casing Height (m)	Method
Vol 25	28.949095	-24.347089	Phlippie De Klerk	0.3	Field Measurement
Abdul Dam	28.932287	-24.347293	Abdul Tayob	CNM	Field Measurement
CNM: Could Not Measure due to BH inaccessibility					

Of the 35 boreholes identified, water levels could be measured in 20, with the average groundwater level determined to be 12.92 mbgl.

Table 13: Groundwater Levels in surrounding boreholes

Borehole Name	Date Measured	Water level (mbgl)
Vol Hek 01	10-Apr-26	16.13
Vols 1	10-Apr-26	23.68
Vols 2	10-Apr-26	18.6
Vols 3	10-Apr-26	18.79
Vols 4	10-Apr-26	18.6
Vols 5	10-Apr-26	CNM
Vols 6	10-Apr-26	11.46
Vols 7	10-Apr-26	12.04
Vols 8	10-Apr-26	12.61
Vols 9	10-Apr-26	8.38
Vols 10	10-Apr-26	7.2
Vols 11	10-Apr-26	7.77
Vols 12	10-Apr-26	CNM
Vols 13	10-Apr-26	18.39
Vols 14	10-Apr-26	CNM
Vol 13	10-Apr-26	CNM
Vol 6	10-Apr-26	CNM
Vol 5	10-Apr-26	CNM
Vol 10	10-Apr-26	CNM
Vol 11	10-Apr-26	Dry
Vol 12	10-Apr-26	21.58
Vol 19	10-Apr-26	14.1
Vol 4	10-Apr-26	CNM
Vol 7	10-Apr-26	CNM
Vol 8	10-Apr-26	CNM
Vol 9	10-Apr-26	CNM
Vol 17	10-Apr-26	6.59
Vol 21	10-Apr-26	6.03
Vol 20	10-Apr-26	0.3
Vol 23	10-Apr-26	0
Vol 24	10-Apr-26	CNM
Vol 16	10-Apr-26	CNM
Vol 15	10-Apr-26	CNM
Vol 14	10-Apr-26	15.24
Vol 25	10-Apr-26	20.98

*CNM denotes Could Not Measure

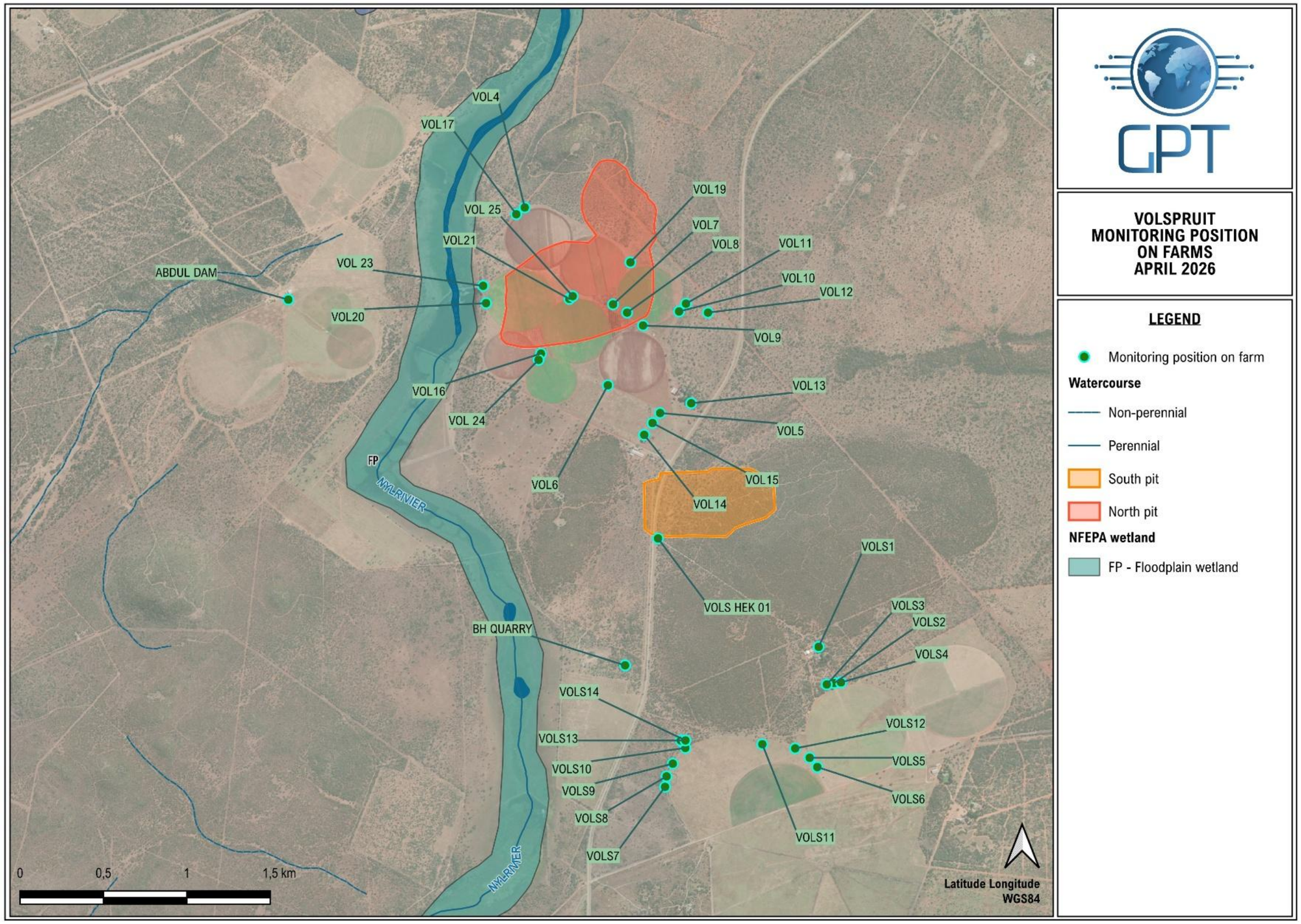


Figure 26: Adjacent landowner positions

9 GROUNDWATER QUALITY MONITORING

9.1 Monitoring Network & Neigboring Properties[5]

During the April 2026 monitoring event a total 19 groundwater samples were taken at the Volspruit site and adjacent properties. To assess the groundwater quality present at the site, the analytical results were compared against the SANS 241:2015 drinking water quality guidelines (Table 17).

The following exceedances were recorded:

SANS 241:2015 drinking water quality guidelines:

- Electrical conductivity and Total dissolved solids exceeds aesthetic limits for Vols 2, Vols 3 and Vols 5.
- Nitrate as N exceed acute limits in VOL-Dam1, Vol 12, Vol 13, Vol 21, Vol 25, Vol 5, Vol 6 and Vols 2.
- Arsenic exceeds chronic limits in Abdul Dam, BH Quarry, Vol 12, Vol 20, Vol 6, Vol Hek 01, Vols 1, Vols 10, Vols 14 and Vols 2
- Total chromium[6] exceeds chronic limits for Vol 12, Vol 13, Vol 25, Vol 5, Vol 6, Vols 1, Vols 2, Vols 3, Vols 5
- Iron exceeds aesthetic limits for Vol 17, Vol Hek 01 and Vols.10
- Manganese exceed aesthetic limits for Vol 17.

9.2 2010-2011 Hydrocensus Quality[7]

Twenty-five groundwater samples and one surface water sample from the Nyl River were collected during the hydrocensuses and the drilled boreholes. The results of the water chemical analyses are contained in Table 15 and compared to the SANS Drinking Water Standards (SANS 241:2015)

The groundwater quality of almost all samples contained constituent concentrations that exceed the maximum allowable standard for domestic use (SANS 241:2015). The elevated constituents are mostly, EC, TDS, nitrate and chloride. Natural sulphate concentrations (the main contaminant of concern in mining) are low in all samples. It is interesting to note that the composition of the surface water in the Nyl River is significantly different from the groundwater, especially in concentration of magnesium. This is an indication that the origin of the river water was not from groundwater.

It is also noticeable that the Grass Valley boreholes in the vicinity of the old mine and tailings, recorded sulphate concentrations of typically 100mg/l and less. This supports the observation that the sulphates in the area are not nearly as reactive as the pyrite found in coal and gold mines.

[5] Quarterly Groundwater Monitoring Report For Volspruit, Mokopane, Limpopo (Project No: SYVOL-26-14256)

[6] The total chromium concentrations are assumed to comprise the two major oxidation states of chromium, namely Cr(III) and Cr(VI). Hexavalent chromium [Cr(VI)] was determined by spectrophotometry using a Discrete Analyser, whereas total chromium concentrations were determined using ICP-OES. In instances where the measured Cr(VI) concentration exceeds the reported total chromium concentration, it can be assumed that all chromium present in the sample occurs predominantly in the Cr(VI) oxidation state.

[7] Geohydrological Report For The Proposed Volspruit Mine (North- And South Pit) Near Mokopane, Limpopo Province. Report EAV-11-053, Nov 2012

9.3 2026 Hydrocensus Quality[8]

During the 2026 hydrocensus survey, a total of eight groundwater samples were collected for laboratory analysis. Sampling locations were selected to provide representative spatial coverage of the study area relatively parallel along the stretch of the river. The localities comprised three boreholes located progressively upstream of the proposed Volspruit Mine, three boreholes located progressively downstream, two borehole situated opposite the proposed mining area on the opposite side of the river.

To assess the groundwater quality within the study area, the analytical results were compared against the SANS 241:2015 drinking water quality limits (Table 17).

SANS 241:2015 drinking water quality guidelines:

- Electrical conductivity and Total dissolved solids exceeds aesthetic limits in BP01 and CG Huis.
- Nitrate as N and Sulphate exceed acute limits in CG Huis.
- Arsenic is at or exceeds the chronic limits in A06, AW01, BH1, BP15 WD07and JR01
- Chloride exceeds aesthetic limits in BP01 and CG Huis.

[8] Hydrocensus Investigation Report For Volspruit, Mokopane, Limpopo. (Project No: SYVOL-26-14283) June 2026

Table 14: April 2026 Monitoring network and Neighbouring properties Analysis Results

Determinant	Risk	Unit	Standard limits	Apr-26																	
				Volspruit Results			De Klerk Results									De Beer Results					
				Abdul Dam	BH 104	BH Quarry	Vol 12	Vol 13	Vol 17	Vol 20	Vol 21	Vol 25	Vol 5	Vol 6	Vol Hek 01	Vols 1	Vols 10	Vols 13	Vols 14	Vols 2	Vols 3	Vols 5
Physical and aesthetic determinants																					
Conductivity at 25 °C	Aesthetic	mS/m	170	121.2	34	98.4	142.8	95.6	110.7	80.5	126.3	91	86.4	88.7	77.5	166.1	138.6	122.2	127.4	274.1	280.3	291.2
Total dissolved solids	Aesthetic	mg/L	1 200	848	238	689	1000	669	775	564	884	637	605	621	543	1163	970	855	892	1919	1962	2038
pH at 25 °C [b]	Operational	pH units	5 to 9.7	7.97	8.78	8.04	7.62	7.84	7.7	8.02	7.71	7.75	7.72	7.95	7.75	7.59	7.68	8.22	7.82	7.85	7.58	7.68
Chemical determinants — macro-determinants																					
Nitrate as N (NO_3 - N)	Acute health	mg/L	11	9.71	BDL	BDL	40.7	19.62	2.97	4.05	34.9	14.77	14.27	12.99	1.37	10.78	1.43	1.1	BDL	29.31	27.15	28.5
Nitrite as N (NO_2 - N)	Acute health	mg/L	0.9	BDL	BDL	BDL	BDL	BDL	0.34	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Sulfate as SO_4^{2-}	Acute health	mg/L	500	64.05	14.53	41.02	129.1	75.27	87.49	20.26	160	53.27	61.28	64.2	6.7	67.33	83.04	70.68	76.83	228.7	224.7	243.6
	Aesthetic	mg/L	250	64.05	14.53	41.02	129.1	75.27	87.49	20.26	160	53.27	61.28	64.2	6.7	67.33	83.04	70.68	76.83	228.7	224.7	243.6
Fluoride as F^-	Chronic health	mg/L	1.5	0.3	0.07	0.41	0.24	0.18	0.28	0.22	0.19	0.2	0.19	0.16	0.19	0.29	0.58	0.27	0.44	0.55	0.48	0.6
Ammonia as N	Aesthetic	mg/L	1.5	0.526368	BDL	0.4358985	0.485246	0.49347	0.633287	0.509919	0.065796	BDL	BDL	BDL	BDL	BDL	BDL	0.337205	BDL	BDL	BDL	BDL
Chloride as Cl^-	Aesthetic	mg/L	300	116.7	38.32	106	97.87	56.52	103.3	17.66	82.47	52.54	47.92	40.72	31.31	260.9	206	184.1	139.6	557	601.4	593.6
Sodium as Na	Aesthetic	mg/L	200	26.14	22.41	84.37	13.51	15.96	16.37	15.57	11.51	16.66	14.98	17.51	14.28	71.45	102.1	106.7	101.1	105.7	104	177.8
Zinc as Zn	Aesthetic	mg/L	5	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.07	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.05	BDL	BDL
Chemical determinants — micro-determinants																					
Arsenic as As	Chronic health	mg/L	0.01	0.014	BDL	0.011	0.013	BDL	BDL	0.011	BDL	BDL	BDL	0.017	0.021	0.021	0.024	BDL	0.028	0.013	BDL	BDL
Barium as Ba	Chronic health	mg/L	0.7	0.18	0.07	0.1	0.17	0.14	0.07	0.17	0.15	0.14	0.13	0.11	BDL	0.2	0.13	0.08	0.11	0.18	0.24	0.14
Boron as B	Chronic health	mg/L	2.4	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cadmium as Cd	Chronic health	mg/L	0.003	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Total chromium as Cr	Chronic health	mg/L	0.05	BDL	BDL	BDL	0.22	0.28	BDL	BDL	BDL	0.21	0.28	0.26	BDL	0.14	BDL	BDL	BDL	0.71	0.78	0.37
Copper as Cu	Chronic health	mg/L	2	BDL	BDL	0.017	0.019	0.014	0.01	0.025	0.019	0.013	0.017	BDL	BDL	BDL	0.012	BDL	BDL	0.014	BDL	0.015
Iron as Fe	Aesthetic	mg/L	0.3	BDL	BDL	0.18	0.09	BDL	0.8	BDL	0.18	BDL	0.09	BDL	1.21	0.06	0.83	BDL	BDL	0.28	0.12	BDL
Lead as Pb	Chronic health	mg/L	0.01	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	Chronic health	mg/L	0.4	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Manganese as Mn	Aesthetic	mg/L	0.1	BDL	BDL	BDL	BDL	BDL	0.51	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Nickel as Ni	Chronic health	mg/L	0.07	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Selenium as Se	Chronic health	mg/L	0.04	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.014	BDL	BDL
Aluminium as Al	Operational	mg/L	0.3	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.05	BDL	BDL	BDL	0.1	BDL	BDL	BDL	0.05	BDL
Hexavalent Chromium	Not defined	mg/L		BDL	BDL	BDL	0.26	0.31	BDL	BDL	BDL	0.23	0.31	0.31	BDL	0.12	BDL	BDL	BDL	0.63	0.7	0.26
NR - Not Requested																					
Exceeded the SANS 241:2015 limits																					
BDL = Below Detection Limit																					

Table 15: 2010-2011 Hydrocensus Analysis Results

Determinant	Risk	Unit	Standard limits	ABDUL	BOK1	BOK8	DEK1	GV1	GV5	GV7	GV8	NYL1	VOL20	VOL21	VOL22	VOL22 (10l/s)
Physical and aesthetic determinants																
Conductivity at 25 °C	Aesthetic	mS/m	170	112.9	346.5	384	279.8	70.8	160.9	124.2	126.6	13.15	123	92.4	141.5	141.1
Total dissolved solids	Aesthetic	mg/L	1200	457	1713	2061	1526	333	766	622	665	80	634.0	445.0	660.0	607.0
pH at 25 °C b	Operational	pH units	5 to 9.7	7.59	7.47	7.22	7.45	7.77	8.06	7.69	8.84	7.39	7.7	7.6	7.6	8.0
Chemical determinants — macro-determinants																
Nitrate as N (NO3 - N)	Acute health	mg/L	11	0.75	35.37	46.37	48.75	43.49	63.87	21.66	BDL	BDL	132.18	169.05	292.0	265.1
Sulfate as SO4	Aesthetic	mg/L	250	18.46	71.90	128.26	117.07	18.42	10.42	30.69	16.17	4.32	59.22	60.98	121.1	98.8
Fluoride as F-	Chronic health	mg/L	2	BDL	BDL	BDL	0.51	BDL	BDL	BDL	BDL	BDL	0.22	0.27	0.7	0.7
Chloride as Cl-	Aesthetic	mg/L	300	51.30	886.30	1228.20	716.80	39.30	370.80	224.50	259.50	20.30	44.50	42.10	76.0	78.4
Sodium as Na	Aesthetic	mg/L	200	33.20	232.80	90.32	209.16	23.30	26.70	28.28	46.39	15.90	12.40	11.71	13.8	12.8
Calcium as Ca	Aesthetic	mg/L	-	46.07	185.97	341.11	129.91	24.42	78.23	78.90	10.13	5.58	52.91	32.40	53.8	47.3
Magnesium as Mg	Aesthetic	mg/L	-	73.61	152.24	188.66	145.73	63.40	122.48	83.28	121.21	4.08	141.29	101.10	151.7	132.1
Potassium as K	Aesthetic	mg/L	-	5.21	5.22	5.67	5.21	1.69	1.91	3.01	28.35	4.61	4.42	5.60	5.5	5.3
Chemical determinants — micro-determinants																
Iron as Fe	Aesthetic	mg/L	0.3	BDL	BDL	BDL	0.506	BDL	BDL	BDL	BDL	BDL	0.2	0.3	0.7	0.7
Manganese as Mn	Aesthetic	mg/L	0.1	0.008	0.01	0.03	0.006	0.005	0.007	0.005	0.071	0.004	BDL	0.1	BDL	BDL
Aluminium as Al	Operational	mg/L	0.3	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.128	BDL	BDL	BDL	BDL

Table 16: 2010-2011Hydrocensus Analysis Results (Continued)

Determinant	Risk	Unit	Standard limits	VOLS1	VOLS3	VOLS5	M15	M19	M2	M20	M24	M25	M3	M4	M5	M6
Physical and aesthetic determinants																
Conductivity at 25 °C	Aesthetic	mS/m	170	183.6	278.9	186.5	70	445	440	187	305	305	485	490	495	490
Total dissolved solids	Aesthetic	mg/L	1200	908.0	1435.0	940.0	496.0	2200.0	2200.0	1200.0	1470.0	1430.0	2190.0	2200.0	2470.0	2530.0
pH at 25 °C [b]	Operational	pH units	5 to 9.7	7.8	7.5	7.7	8.0	7.5	7.8	8.3	8.4	7.7	7.8	7.8	7.5	7.5
Chemical determinants — macro-determinants																
Nitrate as N (NO_3 - N)	Acute health	mg/L	11	26.6	46.2	31.5	90.1	99.1	61.5	58.1	156.0	146.0	61.1	61.2	195.0	198.0
Sulfate as SO_4	Aesthetic	mg/L	250	50.2	94.5	55.6	53.1	367.0	118.0	79.5	153.0	136.0	114.0	115.0	480.0	505.0
Fluoride as F^-	Chronic health	mg/L	2	0.3	0.5	0.0	0.4	0.5	0.4	0.2	0.3	0.3	0.2	0.2	0.1	0.2
Chloride as Cl^-	Aesthetic	mg/L	300	397.7	704.4	353.1	15.5	779.0	997.0	356.0	488.0	481.0	995.0	1010.0	979.0	977.0
Sodium as Na	Aesthetic	mg/L	200	62.8	95.3	107.7	28.3	269.0	226.0	72.2	82.4	79.6	226.0	226.0	72.6	74.9
Calcium as Ca	Aesthetic	mg/L	-	39.5	82.0	51.4	90.0	186.0	306.0	43.4	97.1	95.0	301.0	302.0	380.0	396.0
Magnesium as Mg	Aesthetic	mg/L	-	157.3	231.5	130.2	35.4	211.0	204.0	222.0	231.0	226.0	201.0	203.0	251.0	262.0
Potassium as K	Aesthetic	mg/L	-	4.4	4.8	3.3	8.9	6.0	3.2	6.0	4.3	4.1	3.1	3.2	6.7	6.2
Chemical determinants — micro-determinants																
Iron as Fe	Aesthetic	mg/L	0.3	0.3	0.5	0.0	0.4	0.5	0.4	0.2	0.3	0.3	0.2	0.2	0.1	0.2
Manganese as Mn	Aesthetic	mg/L	0.1	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Aluminium as Al	Operational	mg/L	0.3	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL

Table 17: 2026 Hydrocensus Analysis Results

Determinant	Risk	Unit	Standard limits	A06	AW01	BH1	BP01	BP15	CG Huis	JR01	WD07
Physical and aesthetic determinants											
Conductivity at 25 °C	Aesthetic	mS/m	170	93.4	83.3	109.6	216.1	75.5	343.3	85.4	62
Total dissolved solids	Aesthetic	mg/L	1 200	654	583	767	1513	529	2403	598	434
pH at 25 °C [b]	Operational	pH units	5 to 9.7	7.74	7.58	8.8	7.89	7.89	7.59	7.98	7.5
Chemical determinants — macro-determinants											
Nitrate as N (NO_3 - N)	Acute health	mg/L	11	BDL	BDL	BDL	BDL	2.46	59.26	BDL	BDL
Nitrite as N (NO_2 - N)	Acute health	mg/L	0.9	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Sulfate as SO_4^{2-}	Acute health	mg/L	500	19.12	BDL	45.5	157.4	12.28	754.2	11.11	2.35
	Aesthetic	mg/L	250	19.12	BDL	45.5	157.4	12.28	754.2	11.11	2.35
Fluoride as F^-	Chronic health	mg/L	1.5	0.26	0.26	0.12	0.23	0.5	0.22	0.26	0.24
Ammonia as N	Aesthetic	mg/L	1.5	0.03	0.04	1.04	0.08	0.60	0.02	0.04	0.05
Chloride as Cl^-	Aesthetic	mg/L	300	54.32	79.1	176	533.1	12.51	858.5	63.89	44.97
Sodium as Na	Aesthetic	mg/L	200	35.07	38.36	41.39	58.39	37.44	192.9	45.73	49.59
Zinc as Zn	Aesthetic	mg/L	5	0.08	BDL	0.09	BDL	BDL	BDL	BDL	BDL
Chemical determinants — micro-determinants											
Arsenic as As	Chronic health	mg/L	0.01	0.017	0.01	0.01	BDL	0.01	BDL	0.02	0.01
Barium as Ba	Chronic health	mg/L	0.7	0.13	0.06	BDL	0.09	0.14	BDL	0.13	0.15
Boron as B	Chronic health	mg/L	2.4	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cadmium as Cd	Chronic health	mg/L	0.003	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Total chromium as Cr	Chronic health	mg/L	0.05	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Copper as Cu	Chronic health	mg/L	2	0.03	0.02	0.01	0.02	0.02	0.02	0.02	0.01
Iron as Fe	Aesthetic	mg/L	0.3	BDL	BDL	BDL	0.08	BDL	BDL	0.06	BDL
Lead as Pb	Chronic health	mg/L	0.01	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Manganese as Mn	Aesthetic	mg/L	0.1	BDL	BDL	0.09	BDL	BDL	BDL	BDL	BDL
Nickel as Ni	Chronic health	mg/L	0.07	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Selenium as Se	Chronic health	mg/L	0.04	BDL	BDL	BDL	BDL	BDL	0.01	BDL	BDL
Aluminium as Al	Operational	mg/L	0.3	BDL	BDL	BDL	BDL	BDL	BDL	0.05	BDL

10 GROUNDWATER RECHARGE ESTIMATION

Rainfall recharge to the aquifer occurs through two mechanisms in this unique area, namely regional from recharge and locally at the Nyl River from flooding events.

10.1.1 Regional Recharge

Recharge to the shallow, unconfined aquifer was estimated using the RECHARGE program developed by the Institute for Groundwater Studies at the University of the Free State, South Africa. The program applies the chloride mass balance (CMB) recharge estimation method described by Bredenkamp et al. (1995).

The RECHARGE program utilizes chloride concentration in rainfall from literature and then incorporates regional hydrogeological datasets, thematic maps, and field observations collected during the hydrocensus to estimate groundwater recharge across the study area.

The calculated recharge percentages (expressed as a percentage of MAP) are presented in Table 18 below. Due to the high variability in groundwater chloride concentrations across the study area, recharge was calculated using both (i) the average chloride concentration of all groundwater samples and (ii) a clipped average including only groundwater chloride concentrations below 100 mg/L. The latter approach was adopted to reduce the influence of anomalously high chloride concentrations, which may reflect localized evaporation, anthropogenic impacts, or other processes unrelated to regional recharge.

The calculated recharge estimates range from 2.6% to 4.8% of the Mean Annual Precipitation (MAP), based on the clipped average groundwater chloride concentration and interpretation of the schematic hydrogeological maps (average of 3 highest certainty level maps). This gives a range of 14 to 25.5 mm/a. Considering the extensive irrigation practices within the study area, groundwater chloride concentrations are likely elevated by irrigation return flows and other anthropogenic chloride inputs. As a result, even the clipped average groundwater chloride concentration may overestimate the true background chloride concentration, leading to an underestimation of recharge. For this reason, the upper end of the calculated recharge range, approximately 4.8% of MAP, is considered the more representative estimate for the study area.

Table 18: Recharge calculation for the shallow unconfined aquifer.

Recharge Estimation			
Method	**mm/a**	**% of rainfall**	**Certainty Level (Very High = 5; Low = 1)**
Chloride (Average)	3	0.6	1
Chloride (Clipped Average)	14	2.6	3
Various schematic maps			
Soil	17.8	3.4	2
Geology	25.5	4.8	3
Vegter	26.0	4.9	3
Acru	10.0	1.9	1
Harvest Potential	25.0	4.7	3

10.1.2 Recharge from Flooding Events

It is evident from groundwater reaction to flooding (paragraph 8.2) that considerable recharge occurs in the floodplain of the Nyl during flooding. This is difficult to calculate and will depend on the extent and duration of the flood. But evidence of this can be found in the groundwater chemistry. Groundwater chemistry changes with age underground, with especially chloride and bicarbonate as indicators. Fresh rainwater contain almost no chloride, while underground water generally gain chloride through interaction with bedrock. Bicarbonate in contrast, is abundant in fresh water but it decreases with age for similar reasons.

It would be expected that chloride will increase with distance from the Nyl floodplain. Bicarbonate, in contrast, would be expected to decrease with distance from the river. An examination of the chemistry in the Volspruit area indicate that such a relationship is indeed found for chloride (Figure 27), but not for bicarbonate which stays rather constant on a similar graph. An explanation for the latter will require a more detailed study, beyond the scope of this investigation. But the results obtained for chloride is indeed an indicator of the importance of this recharge mechanism.

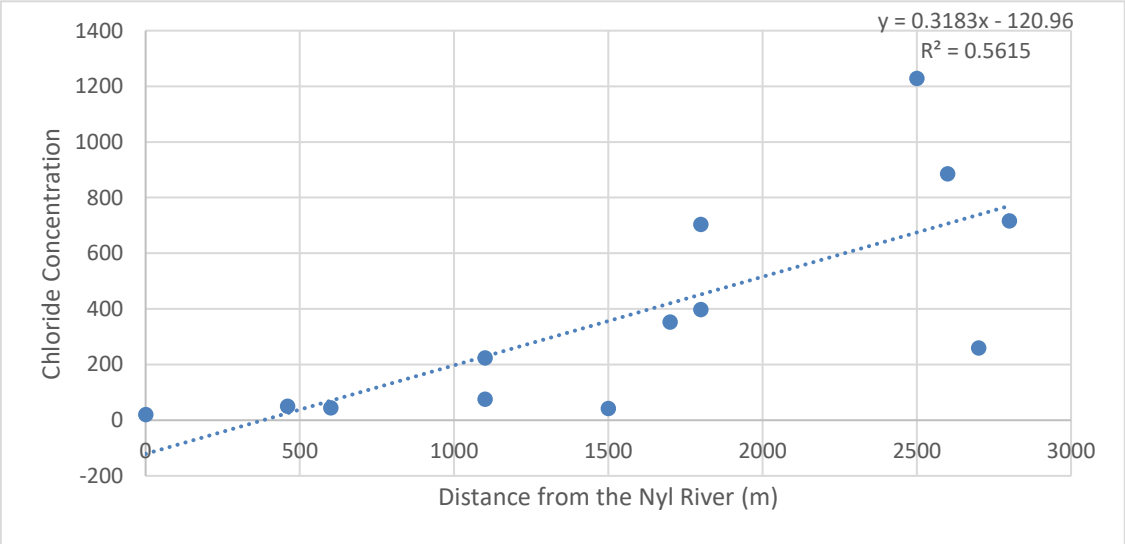


Figure 27: Chloride concentration as indicator of recharge from flood events

11 AQUIFER CHARACTERISATION

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

11.1 Aquifer Vulnerability

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

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

The following factors influence groundwater vulnerability:

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

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

- Depth to groundwater below the site was estimated from water levels measured during the hydrocensus inferred to be at mean of ~22 mbgl.
- Groundwater recharge of 4.8%.
- A Bushveld geology & Sandy-clayey Clay (SaCl-Cl) vadose zone.
- Gradient of 1.7% were used in the estimation.

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

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

The GDT calculated a vulnerability value of 46%.

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

11.2 Aquifer Classification

The aquifer(s) underlying the subject area were classified in accordance with "A South African Aquifer System Management Classification, December 1995. [9]"

The aquifers were classified by using the following definitions:

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

According to the Aquifer classifications map of South Africa from the department of Water Affairs the aquifer in the regions is classified as a major aquifer system.

The Aquifer within the area is used by the farming community as their primary water supply and the aquifer on Ken Smith's farm is used to sell water to Lepelle water supply agency. This also meets the criteria for a sole aquifer.

In order to achieve the Aquifer System Management Classifications, as well as the Groundwater Quality Management Index, a points scoring system as presented in Table 19 was used.

Table 19: Ratings – Groundwater Quality Management (GQM) Classification System

Aquifer System Management Classification		
Class	Points	Study area
Sole Source Aquifer System:	6	6
Major Aquifer System:	4	4
Minor Aquifer System:	2	
Non-Aquifer System:	0	
Special Aquifer System:	0 – 6	

Aquifer Vulnerability Classification		
Class	Points	Study area
High:	3	
Medium:	2	2
Low:	1	

As part of the aquifer classification, a Groundwater Quality Management (GQM) Index is used to define the level of groundwater protection required. The GQM Index is obtained by multiplying the rating of the aquifer system management and the aquifer vulnerability. The GQM index for the study area is presented in Table 20.

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

GQM Index for Sole Aquifer = Aquifer System Management x Aquifer Vulnerability

= 6 x 2 = 12

GQM Index for Major Aquifer = Aquifer System Management x Aquifer Vulnerability

= 4 x 2 = 8

The GQM Index ranges between 8-12 with an average of 10.

Table 20: GQM Index for the Study Area

GQM Index	Level of Protection	Study Area
<1	Limited	
1 – 3	Low Level	
3 – 6	Medium Level	
6 – 10	High Level	8
>10	Strictly non-degradation	12

11.3 Aquifer Protection Classification

A Groundwater Quality Management Index average of 10 was estimated for the study area from the ratings for the Aquifer System Management Classification. According to this estimate, a **high to strictly non-degradation groundwater protection level** is required for the aquifer. Reasonable and sound groundwater protection measures are recommended to ensure that no cumulative pollution affects the aquifer, even in the long term.

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

- The protection of the underlying aquifer.
- The protection of the boreholes in use surrounding the proposed site.
- The protection of the Nyl river flowing past the proposed site.

11.4 Proposed Nyl River Strategic Groundwater Source Area

There are two guiding reports of importance on Strategic Water Source Areas:

- J Nel, C Colvin, D Le Maitre, J Smith, I Haines, 2013. South Africa's Strategic Water Source Areas. CSIR, Report No CSIR/NRE/ECOS/ER/2013/0031/A

- D Le Maitre, H Seyler, MHolland, L Smith-Adao, JNel, A Maherry, KWitthüser, 2018. Identification, Delineation and Importance of the Strategic Water Source Areas of South Africa, Lesotho and Swaziland for Surface Water and Groundwater. WATER RESEARCH COMMISSION, Report No. TT 754/1/18

In the 2018 report, it was recommended:

That SWSAs for surface water and groundwater be agreed to and accepted by all Departments and spheres of government responsible for land use and land protection and water use management on the basis of the framework developed through this research. Attention needs to be given, in collaboration with DEA and SANBI, to establish how best to delineate SWSAs so that they can be declared as formally protected areas for water source protection.

However, consideration is given to these reports by comparing of some aquifer characteristics with especially groundwater abstraction at Volspruit as predicted by the model:

- The total area of the Nyl Area is 2 036 km^2 compared to the area of the numerical model of 335 km^2. The modelled area (chosen to cover an area well beyond the extents of the opencasts within which all groundwater impact will be contained) covers thus only 16% of the proposed protection area.

- The recharge to the proposed Nyl protection area is given as 2036 million m^3/a (Table 10: of the WRC report). This is unlikely to be correct and a number of 76 million m^3/a was calculated, corresponding to 5% recharge from rainfall. If this is compared to the modelled abstraction of 3 million m^3/a for the North Pit and South Pit combined, it relates to an abstraction of groundwater of 3.9% of recharge to the proposed protection area. The two proposed pits will most likely not be dewatered simultaneously, in which case the abstraction will be half of the above.

- The contribution of groundwater to the surface water is given as 13.5% (Table 12), but it is shown in this report that there is currently no contribution to the Nyl River in the Volspruit area specifically, due to the depth of the groundwater table (Paragraph 14 of this report).

- The registered agricultural plus industrial groundwater use is 13 518 631 m^3/a, compared to the modelled abstraction at Volspruit of about 300 000 m^3/a, thus about adding 2% at most to these uses if both pits are dewatered simultaneously, but only 1% if the pits are mined sequentially. However, during the previous study of the Volspruit area it was found that the agricultural use is most likely much larger than the registered numbers. The 1% additional use is thus most likely an overestimation.

- According to the Le Maitre et al report, the proposed mine is situated in an aquifer vulnerability zone of <50% (Very Low). If that is viewed in conjunction with the conclusions on potential contaminant at the mine (paragraph 12.6 of this report, which indicate that the contamination potential of both the ore and bedrock is very low), the risk of detrimental chemical impact on the aquifer is low.

Table 21: Calculated maximum impact of the Volspruit Mine on the SWSA

Criterium	Strategic Groundwater Source	Maximum Volspruit Impact	Percentage Impact of the Volspruit Mine
Area (km^2)	2036	335	16.5%
Recharge (Mm^3/a)	76*	3	3.9%
Groundwater to surface water (%)	13	0	0.0%
Agricultural and industrial use (ML/a)	135189	300	0.2%

**Note: The number given in the WRC report is 2036 Mm^3/a. This is unlikely to be correct and the GPT calculation of 76 Mm^3/a was used instead.*

It is thus concluded that the dewatering abstraction of the proposed Volspruit mine will be small compared to the inflows and outflows of the proposed Nyl Strategic Groundwater Source Area and no significant additional impact on the larger aquifer is foreseen.

12 GROUNDWATER POTENTIAL CONTAMINANTS

The contaminant associated with the proposed mining activities could emanate from backfilled open pits, tailings dams, waste rock dumps, open pit voids/walls and metallurgical processing plants. The contaminants would be dominated by elevated major ion concentrations, salinity, metals and raised pH. The mobility and concentrations of most metals in the subsurface is likely to be governed by pH.

In general, contaminated water characterised by a low pH can be formed as a result of sulphide oxidation, also contribute to the mobility of metals. It may be possible that due to certain buffer reactions, the pH of the contaminated water will be normalised. Thus, sulphate is the most likely contaminant that could be of concern.

Nitrate is another possible contaminant that is often found in mining environments. However, nitrate is seldom found in ore or rock bodies and if present, most likely originate from incomplete blasting operations at the mine or other natural sources such as groundwater used as process water.

Workshops and fuel and oil handling facilities are likely sources of hydrocarbon related contaminants. Oils, grease and other hydrocarbon products (such as petrol and diesel) handled in these areas may contaminate the environment by spillages and leakages. Oils and greases are normally removed and collected in oil traps. Run-off (contaminated with hydrocarbons) which is not collected may enter the storm water system from where it may contaminate surface water bodies and groundwater.

Septic tanks and sewage treatment plants potentially contaminate groundwater. Contaminants associated with these plants include coliforms (e.g. E. coli), bacterial viruses, ammonia, phosphate, sulphate and nitrate. Effluent from these systems usually contains elevated concentrations of organic matter which may lead to elevated COD and BOD. Waste disposal areas may source a wide range of contaminants, ranging from metals, organic matter, hydrocarbons, phosphates, etc.

The potential contaminant will be further discussed and quantified in the following paragraphs.

12.1 Acid generation capacity of the rock

The acid generation capacity of core samples was determined by acid base accounting. Three core samples were taken from an exploration borehole GVN 132 M drilled in the ore body to determine the acid generation capacity of the ore. It was concluded that the ore is intermediate to potentially acid forming. However, the sulphides in the ore are mostly chalcopyrite and pentlandite, which are not reactive enough for long term acid generation.

An additional 15 composite samples were also taken from the roof bedrock. The results indicated that sulphides are present in very low concentrations, at least an order of magnitude lower than 0.3% considered to be the minimum percentage at which extended acid-rock drainage can be produced. Furthermore, the neutralisation potential exceeds the acid forming potential by one to two orders of magnitude. It is thus very unlikely that the pit backfill material will produce acid rock drainage.

12.2 Leach testing

The core samples collected in 2010 were also analysed for leachable major ions and metals. Results confirm that very little leachable contaminants are to be expected. Sulphate specifically leached at concentrations ranging from below detection level to 20mg/L maximum. These values are low compared to SANS 241 standards and fall well within Class I (ideal) water with a limit of 200mg/L.

12.3 Acid rock drainage (ARD) formation

The reactions of acid and sulphate generation from sulphide minerals are discussed according to the three-stage stoichiometric example of pyrite oxidation after James, (1997) and (Ferguson & Erickson, 1988) in which one mole of pyrite oxidized forms two moles of sulphate:

Reaction (2.1) represents the oxidation of pyrite to form dissolved ferrous iron, sulphate and hydrogen. This reaction can occur abiotically or can be bacterially catalysed by *Thiobacillus ferro-oxidans*.

$$FeS_2 + 7/2\ O_2 + H_2O \rightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+ \qquad (2.1)$$

The ferrous iron, (Fe^{2+}) may be oxidised to ferric iron, (Fe^{3+}) if the conditions are sufficiently oxidising, as illustrated by reaction (2.2). Hydrolysis and precipitation of Fe^{3+} may also occur, shown by reaction (2.3). Reactions (2.1), (2.2) and (2.3) predominates at pH > 4,5.

$$e^{2+} + 1/4O_2 + H^+ \rightarrow Fe^{3+} + 1/2H_2O \qquad (2.2)$$

$$Fe^{3+} + 3H_2O \rightarrow Fe(OH)_3\,(s) + 3H^+ \qquad (2.3)$$

Reactions (2.1) to (2.3) are relatively slow and represent the initial stage in the three-stage ARD formation process. Stage 1 will persist as long as the pH surrounding the waste particles is only moderately acidic (pH > 4,5). A transitional stage 2 occurs as the pH decreases and the rate of Fe hydrolysis (reaction 2.3) slows, providing ferric iron oxidant. Stage 3 consists of rapid acid production by the ferric iron oxidant pathway and becomes dominant at low pH, where the Fe^{2+} (ferric iron) are more soluble (reaction 4):

$$FeS_2 + 14\ Fe^{3+} + 8H_2O \rightarrow 15Fe^{2+} + 2SO_4^{2-} + 16H^+ \qquad (2.4)$$

Without the catalytic influence of the bacteria, the rate of ferrous iron oxidation in an acid medium would be too slow to provide significant ARD generation. As such the final stage in the ARD generation process occurs when the catalytic bacteria *Thiobacillus ferro-oxidans* have become established. Reactions (2.2) and (2.4) then combine to form the cyclic, rapid oxidation pathway mainly responsible for the high contamination loads observed in mining environments.

12.4 Acid Mine Drainage (AMD)

From the ABA undertaken by Escience Associates (Pty) Ltd[10], it was found that both the waste rock and the tailings samples have virtually no potential for AMD formation, but instead have the tendency to neutralise AMD generation. The Proposed Volspruit mine residues themselves are, therefore, expected to have no risk of acid mine drainage formation due to the results obtained through the representative sampling and analyses undertaken.

12.5 Nitrate as a contaminant

Nitrate is often found in mining environments in the platinum and chromium mining in the Bushveld Complex, and normally originate from incomplete blasting operations at the mine or other natural sources such as groundwater used as process water.

Nitrate originating from blasting operations is most difficult to predict and will have to be verified once mining has commenced. However, the nitrate concentrations in the groundwater at the Volspruit and Grasvally farms are already extreme. Typical nitrate values of 100 to 200 mg/L is common (paragraph 13 below). If these values are compared to the recommended drinking water standards of 44 mg/l, it is evidently already a problem in the area, and the water is this not suitable for drinking water without treatment. The nitrates at Volspruit likely originates from the usage of nitrate as fertiliser, while those at Grasvally could be as a result of mining of the old underground.

Thus, if groundwater is used at the Volspruit mine as process water and concentrated through recycling, it could well be the most prominent contaminant emerging from the mine facilities. But to predict the contaminant values is almost impossible as it dependent on the details of operational procedures that is as yet not known.

12.6 Potential contaminants conclusions

It follows from the above that both the ore and bedrock are relatively inert and is thus not expected to contaminate the aquifer to the extent that it will render the groundwater unusable for domestic and agricultural purposes. This view is confirmed by the waste classification report[11] for this project, which states that: *Low-risk wastes have a low potential for contaminant release but do require some level of control and ongoing management to protect health and the environment. T*he current Type 3 waste classification could be reclassified to Type 4 which will require a Class D liner, is motivated by (among others):

- None of the LCT concentrations exceeded the LCT0 limits,
- Only the norite and pyroxenite waste rock will be disposed of at the designated site,
- Acid generation from the waste rock is not expected; thus no acidic leaching is expected.

[10] Escience Associates (Pty) Ltd, September 2012, Draft Acid Mine Drainage Potential Assessment: Volspruit Waste Rock And Tailing Samples

[11] Eco Elementum (Pty) Ltd, 2026. Sylvania Platinum Limited Volspruit PGM Project – Waste Classification. REPORT REF: 19-918-GEOH

- Based on the geology, the waste rock holds a very low risk to cause impact on the ground- or surface water since it is inert.

Although four of the five materials assessed (Rougher Tails Composite, ROM2, Pyroxenite and Norite) have been reclassified from Type 3 to Type 4 and may therefore be disposed of at a Class D barrier system. ROM1 remains classified as Type 3 and requires disposal at a Class C barrier system based solely on its mercury leachable concentration. Although the updated Waste Classification indicates that the majority of the materials may be managed as Type 4 waste, the initial Waste Classification undertaken in 2012 by Escience classified the waste as Type 3. Considering the historical classification and the presence of ROM1, it is recommended, as a precautionary and conservative measure, that the waste rock dump continue to be managed as Type 3 waste and that a Class C barrier system be provided.

In addition to the solid waste streams, the wastewater expected to be contained in the proposed irrigation dam was also classified in accordance with GN R635, using modelled North Pit sump water quality (Mills Water, 2026). Across all six modelled operating scenarios, the water is classified as Type 3, primarily due to nitrate concentrations associated with background groundwater influenced by historical agricultural fertiliser use. The wastewater therefore also requires a Class C barrier system.

13 GEOCHEMICAL MODELLING

13.1.1 Geo Pollution Technologies 2012

The objective for the geochemical modelling was to predict the maximum possible impacts on groundwater quality that may be caused by the Proposed Volspruit opencasts. The interaction between the mineral-, water- and the gas phases was modelled using the Geochemist's Workbench geochemical modelling software package.

Two model scenarios were conducted. Firstly, waste rock will be removed from the pit and be stored adjacent to the pit where it will be exposed to permeating rainwater in an oxidising environment. The material will therefore undergo weathering and dissolution which may liberate contaminants in a leachate. At closure, the excavated waste rock is planned to be used as backfill where it may liberate contaminants which may adversely affect groundwater quality.

The results of the geochemical modelling indicate that sulphate concentration in the leachate produced by the waste rock dump may reach a peak of 200 mg/L after approximately 5 years of mining and decline to less than 100mg/L at 20 years. Concentrations of Ca become elevated to 80 mg/L and may aid in the precipitation of sulphate minerals such as gypsum. The pH of the leachate is predicted to be slightly alkaline at a value of approximately 8.

After mining, precipitated sulphates, possible relict sulphide fragments and sulpho-salts may be the cause of sulphate contamination to groundwater with concentrations of up to 60mg/L in the initial stages of the backfilled pit. Elevated amounts of Ca (up to 200 mg/L) are also liberated into the groundwater environment, which may aid in the precipitation of gypsum and calcite. Groundwater pH is predicted to remain slightly elevated to an approximate value of 8.

13.1.2 Mills Water 2025

Dr Meril Mills conducted geochemical modelling on the North Pit in 2025, and summarised the report as follows:

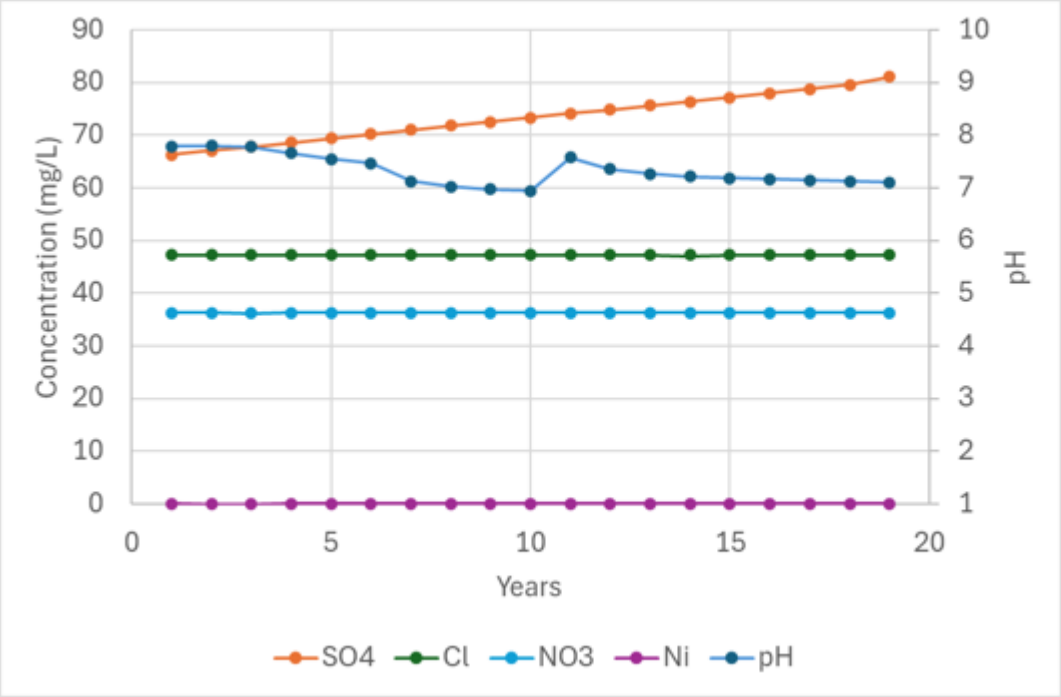
"The quality of sump water generated during operation is determined by evaporation of a mixture of rainwater and groundwater, modified by reactions occurring on the pit walls. Data from GPT (2023) and Water Hunters (2024) were used to develop a salt balance for the system, which was then used to calculate the water quality in the sump. Groundwater was estimated to contribute between 72 and 98% of the water in the sump, with the remainder originating as rainfall. Evaporation occurs as the inflowing water runs down the walls and floor of the pit, concentrating the sump water by 1.006 to 9.0 times. Geochemical reactions were also incorporated into the model, including weathering of rock forming minerals, including trace levels of nickel sulphides, precipitation of minerals which have reached saturation in solution, and adsorption of chemical elements to iron oxide and clay minerals. Six different scenarios were modelled to incorporate the variation in the inflow and evaporation volume estimates from different sources and methods, and to assess the effect of seasonal variation in rainfall and evaporation.

"The sump water in all modelled scenarios was found to exceed the TWQR for irrigation for EC and nitrate. EC and nitrate already exceed the TWQR in the background groundwater, and the evaporation in the pit results in an increase in the EC by up to 4 times compared to background. Worse water quality would be expected if there are low inflows and in the summer months due to increased evaporation. Use of the sump water for irrigation would therefore require treatment, or management in terms of finding appropriate crops, ensuring a sufficient leaching fraction, adjusting fertilization amounts, and monitoring of groundwater quality to ensure the baseline quality does not deteriorate.

"The quality of water in the backfilled pit post closure becomes slightly fresher than surrounding groundwater due to the increased recharge expected into the backfill. Backfilling is expected to prevent evaporation, and the pumped-out water quality would be expected to be better than during operation. A slight increase in concentration with time might occur for EC and sulphate assuming that some nickel sulphide oxidation occurs. Nickel mobility is limited by adsorption to iron oxide and smectite weathering products. However, although a slight improvement in quality is expected, the post-closure water quality does not meet the TWQR for irrigation water for EC and nitrate because of the concentrations of these parameters in the background groundwater. The model does not account for reactions which may remove nitrates from the system, and presents a worst case scenario for the set of input parameters. Development of reducing conditions within the backfilled pit is likely to lead to denitrification, resulting in decreasing nitrate concentrations in irrigation water, and will also limit sulphide oxidation."

The figure below is a screenshot of this report:

Figure 18: Evolution of backfilled water quality as the water table recovers post closure



14 CONCEPTUAL SITE MODEL (CSM)

The site conceptual model was developed using a risk-based approach, whereby impact source areas are identified, pathways are characterised and potential receptors identified.

14.1 Impact source

The potential impact source areas are the opencast mine, waste rock dumps, tailings dams, workshops and petroleum storage tanks, septic tanks and general waste facilities.

During mining, the opencast will have to be dewatered, with the result that the local groundwater in and immediately around the opencast will be drawn down to the bottom of the ore body by end of mining, as conceptually illustrated by Figure 28. But the current groundwater levels are not pristine. Large scale abstraction of groundwater for irrigation has led to substantial decrease of the water table at least since 1960[12]. In some areas the groundwater was considered "depleted" and artificial recharge from the Nyl River was recommended.

Mining dewatering will further decrease the water table, although mostly locally. The bottom of mining of the northern ore body will be at 170 metres below ground level, while the south pit will have to be dewatered to an approximate depth of mining of 100mbgl. This will result in a cone of depression in the groundwater around the opencast.

Post mining, the groundwater will return to equilibrium that can be above pre-mining levels in the lower sections of the opencast due to the very high hydraulic conductivity of the backfilled material that will tend to flatten the water level in the opencast. Should the water level in the lower sections rise above the surface level, decanting could result. Contamination emerging from the backfilled opencast is considered the most important post mining impact.

14.2 Pathways

Pathways along which contaminants may be mobilised and migrate toward groundwater receptors include:

- The vadose zone (unsaturated zone)
- Groundwater (fractured aquifers)
- Surface runoff in storm water or water courses (rivers and streams)

The scope of this study is to characterise the pathway of concern for groundwater. Seepage from the tailings dams, waste rock dumps and other surfaced sources will be vertical through the vadose zone and fracture systems to the saturated deeper aquifers. Except for direct surface run-off, the saturated aquifers will thus be the main pathway.

From the boreholes drilled in the area, this subsurface was conceptually envisaged to consist of the following hydrogeological units:

- The upper few meters below surface consist of completely weathered material. This layer is anticipated to have an extremely variable hydraulic conductivity, ranging from high in sandy areas to low in clayey soil, but in general unsaturated due to the deep groundwater levels in the area.

[12] Department of Water Affairs, 1965. Verslag oor die Grondwateraangeleenthede op die Springbokvlakte. Hidrologiese Navorsingsafdeling.

- The next few tens of meters are fractured bedrock with a high hydraulic conductivity, as has been concluded from pump and packer tests. The permanent groundwater level resides in this unit.
- Below a few tens of meters, the fracturing of the aquifer is less frequent and fractures less significant due to increased pressure. This results in lower hydraulic conductivity and slower groundwater flow velocities with depth.

Fracturing of the bedrock consist of both major fault structures and/or minor pressure-relieve joints, both vertical and horizontal. These structures are numerous, largely unknown and impossible to quantify. However, on a large enough scale (bigger than the Representative Elemental Volume) the effect of these structures become less important and can be considered as a relative homogeneous aquifer. But the Zebediela and Magogo Faults were considered as prominent linear structures with hydraulic conductivity two orders of magnitude than the surrounding bedrock.

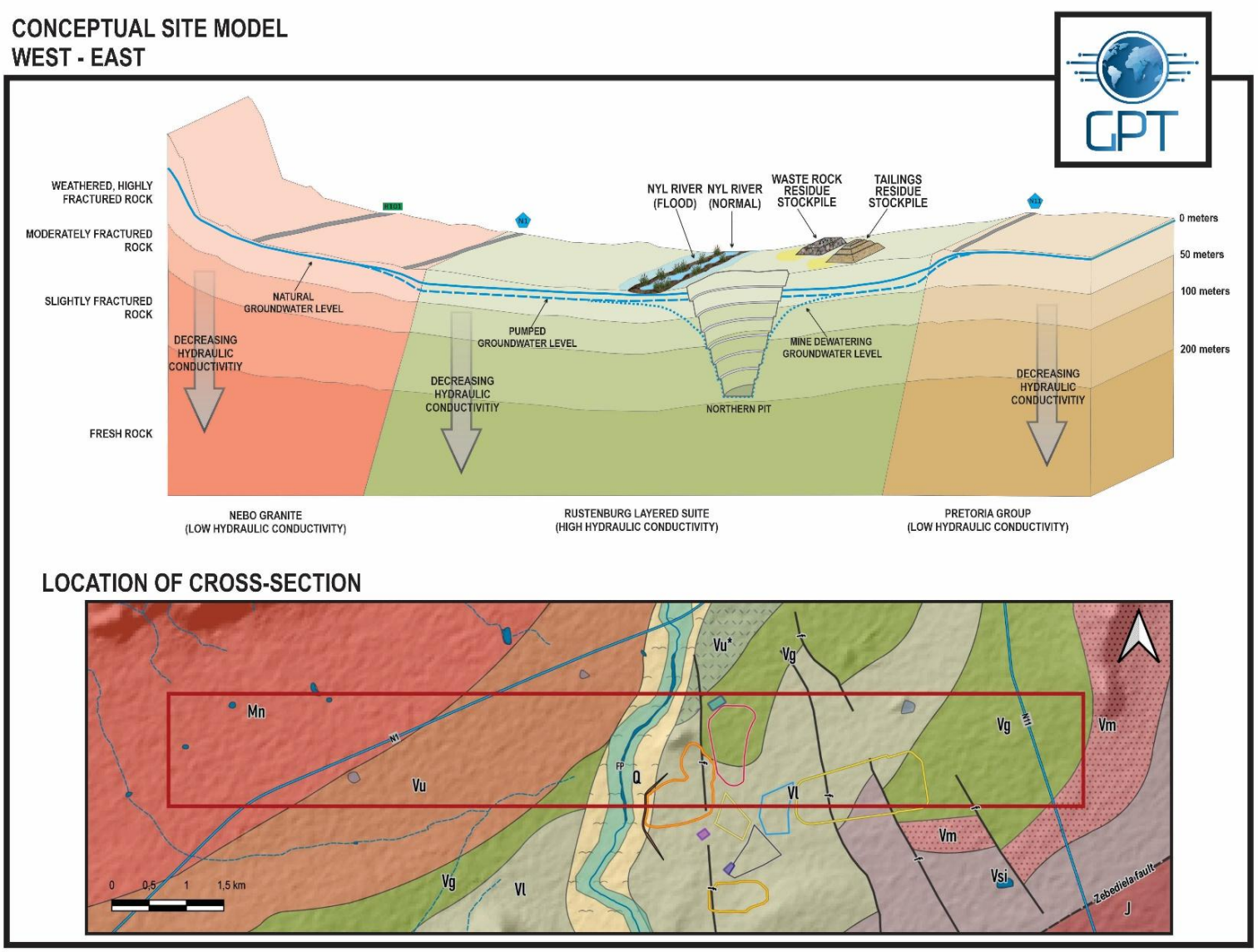


Figure 28: Conceptual hydrogeological model.

14.3 Receptors

Any user of a groundwater or surface water resource that is affected by drawdown of the groundwater level or contamination from any of the above-mentioned sources is defined as a receptor. The following receptors are important:

- Water courses, specifically the Nyl River.
- Groundwater users, mainly for irrigation and a smaller percentage domestic.

14.4 Conceptual Understanding of Nyl River Flooding Events

The conceptual understanding of the behaviour of groundwater levels in the vicinity of the Nyl was developed by the observation of groundwater levels during the floods in 2014 and 2017 as described in Section 8, and will be described below in more detail, since it is central to the understanding of surface water and groundwater interactions in the Volspruit area.

It can be assumed that the groundwater and surface water was connected (as it is in most of wetter regions of South Africa) before human intervention in the area. This scenario is illustrated in Figure 29. In this scenario river water will recharge the aquifer during periods of floods, while groundwater should have provided base flow to the river in dryer periods.

However, this all changed when groundwater abstraction was used for irrigation. There are indications in old Department of Water Affairs reports[13] that the large-scale abstraction of groundwater for irrigation started at about 1956 and increased from then.

From measurements of groundwater levels the author(s) of the mentioned DWA reports declines of between 10 and 60 feet (3 to 20 metres) in the Springbok Flats by 1965. This decline separated groundwater below the Nyl from the river flow, given the presence of the thick clay layer below the Nyl floodplain (Figure 30).

However, during period of flood when the Nyl River overflows its banks, surface water can seep through the more permeable gravelly soil to recharge the groundwater (Figure 31), which was witnessed during the floods of 2014 and 2017.

While mining in the area will further decrease the groundwater levels (paragraph 15.3.1), it will not change the basic behaviour of groundwater water flow from and to the Nyl River, as is illustrated in Figure 32 and Figure 33 below. The clay layer below the Nyl floodplain will continue to prevent normal infiltration of surface water to the aquifer below, while separation of the waters will prevent groundwater flow to the surface water in the Nyl.

During periods of flood surface water that overflow the clay layer underneath the Nyl River will continue to seep to the aquifer at rates currently witnessed, as unsaturated flow is gravitationally driven and not dependent on total hydraulic head as is the case with saturated flow.

It is thus concluded from this conceptual understanding that further lowering of the groundwater levels in the area will not change the intrinsic dynamics of groundwater / surface water interaction in the Volspruit area, if direct flow from the river to the opencast pit is prevented by an impermeable berm as is currently planned.

[13] Department of Water Affairs, 1965. Verslag oor die Grondwateraangeleenthede op die Springbok Vlakte. Report No GH3056

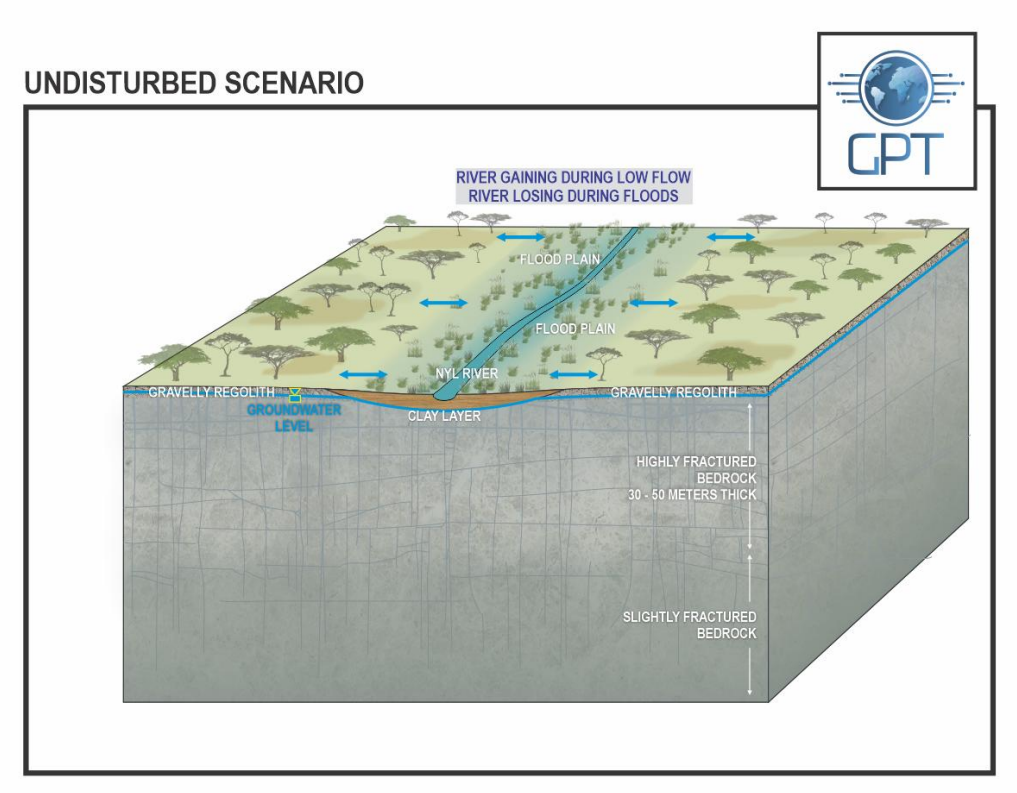


Figure 29: Natural groundwater levels and flow before large scale irrigation

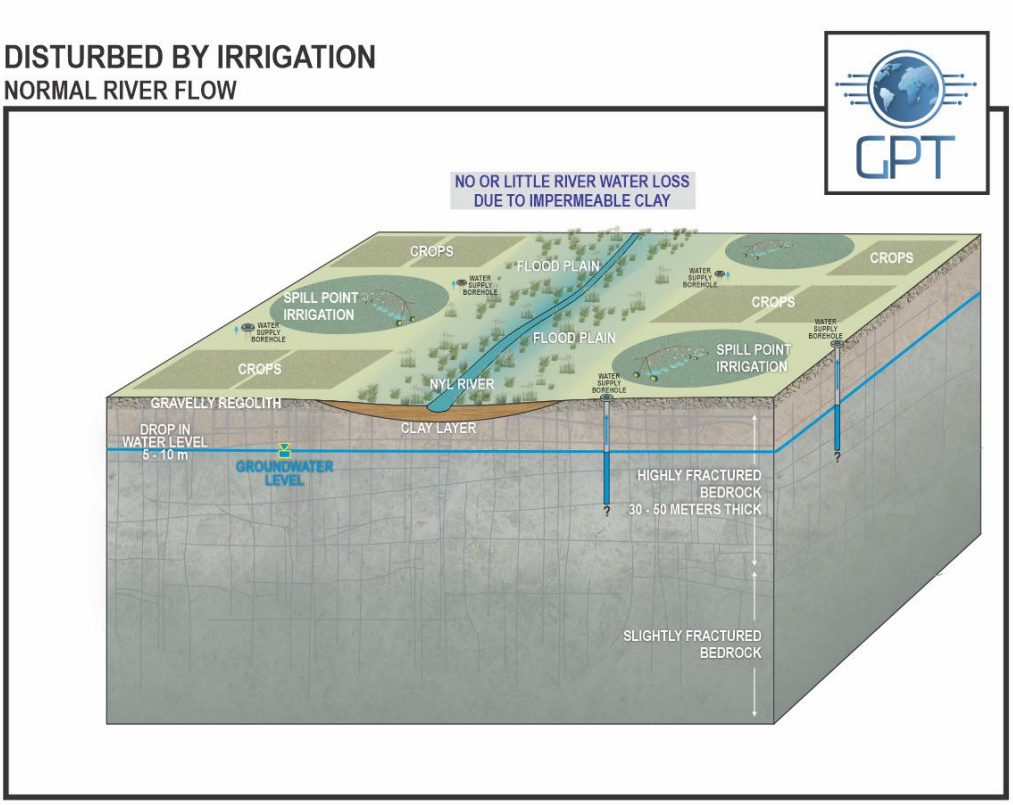


Figure 30: Groundwater levels as a result of irrigation - normal river flow

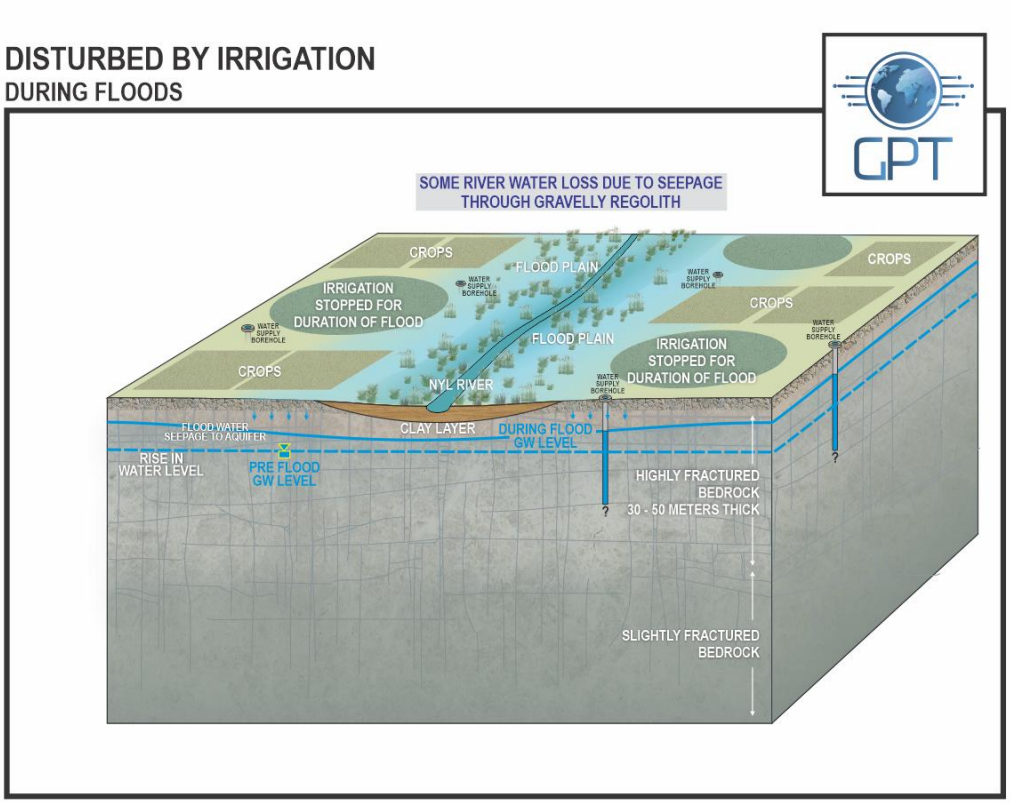


Figure 31: Groundwater levels and flow with irrigation – during river floods

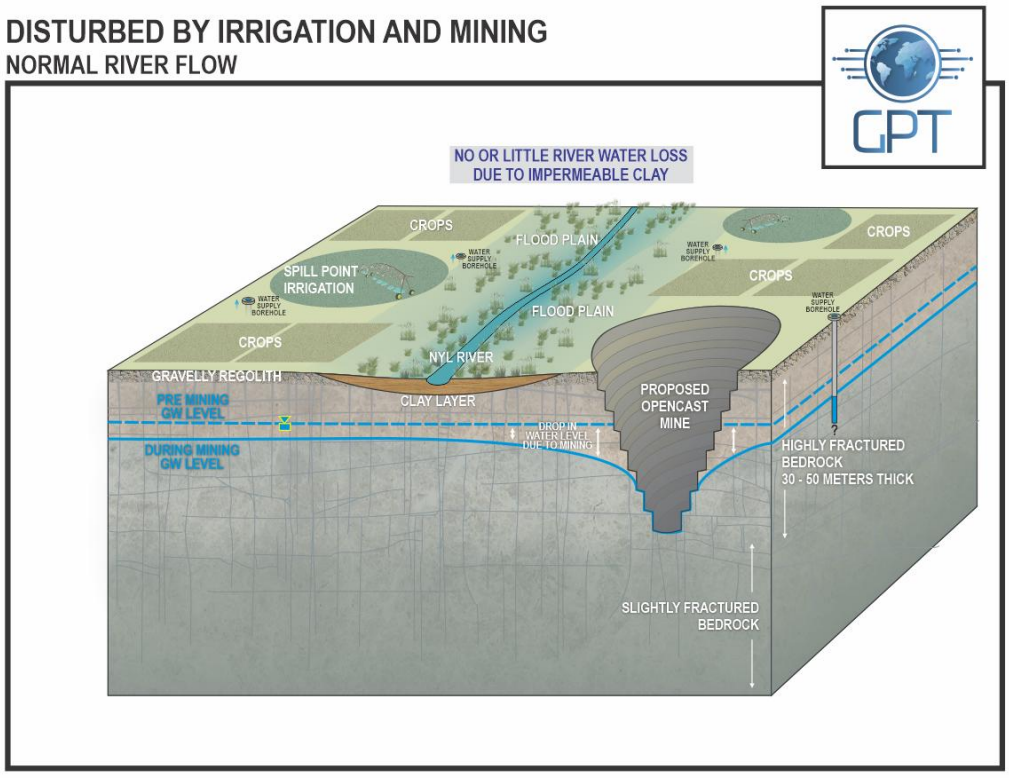


Figure 32: Groundwater with irrigation and mining – normal river flow

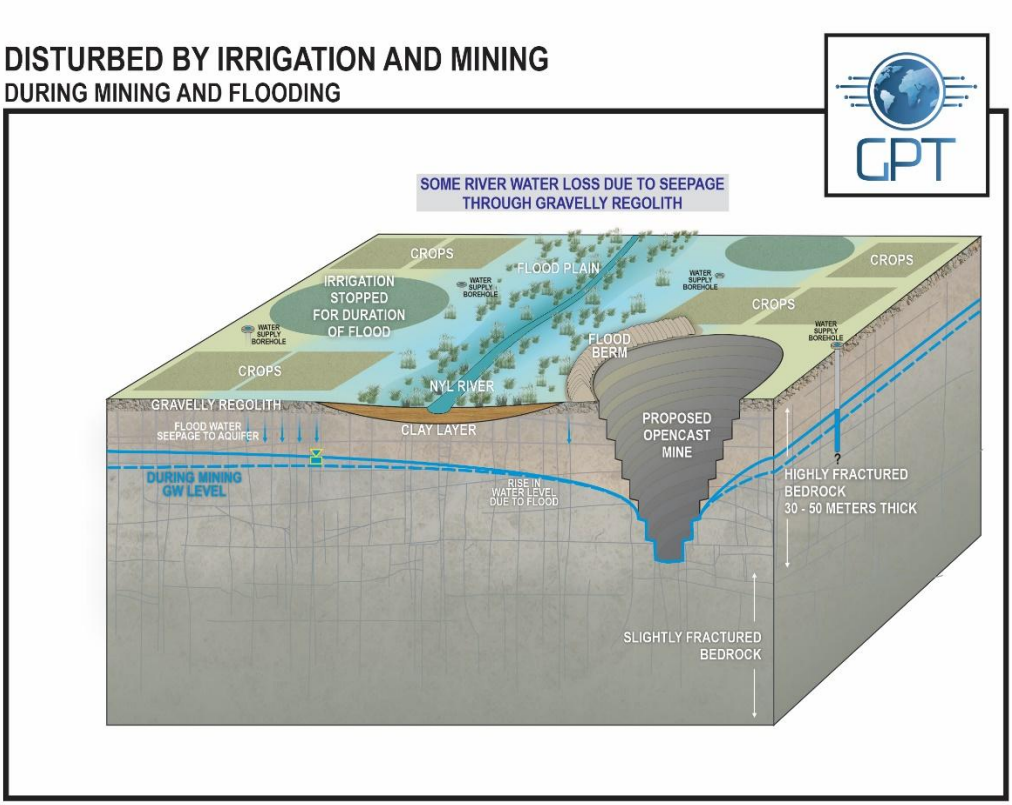


Figure 33: Groundwater with irrigation and mining – during river floods

15 GROUNDWATER FLOW AND TRANSPORT MODELLING

The purpose of this modelling study is to determine the impacts that the groundwater might have on the proposed opencast mining, and to assess the likely hydrogeological impact that the mining operations might have on the receiving environment. It will also serve to predict the inflow of groundwater into the proposed Volspruit North and South Pits as an input to water balance calculations.

Numerical groundwater modelling was also used to quantify the likely impacts on the groundwater regime and to calculate the monthly flows. A finite difference numerical model was created using the US Department of Defence Groundwater Modelling System as Graphical User Interface (GUI) for the well-established Modflow and MT3DMS numerical codes.

The structure of the remainder of this report is divided into the following main sections:

- Construction of the numerical model, including the boundaries and subdivision.
- Verification of the model with pump tests.
- Prediction of the groundwater impacts due to dewatering pits, decant and pollution transport.
- Updating the numerical model with the latest North Pit transient design.
- Model the cumulative impact to include the neighbouring Grasvally Underground Mine.

15.1 Review of previous model

A steady state model was done in 2010 for the north pit only. The construction of the model is reported in detail in the GPT report EaGrn-10-115 (“Hydrogeological Report for the Proposed

Volspruit Mine (North Pit) near Mokopane"). The model was constructed with similar boundaries as those of the new model described below and was also a five-layer model. As with the new model, the total hydraulic conductivity multiplied with the layer thickness and summarised over the model, was based on the average results of the pump tests. However, it was recognised at that time that the distribution of hydraulic conductivity with depth is largely unknown, and packer tests were recommended to reduce this uncertainty.

Subsequently, further pump tests were done at the South Pit location and a few packer tests were also executed, as described previously in this report. Unfortunately, most of the exploration boreholes were no longer available for testing, and only a few boreholes could be tested. Based on these tests and visual inspection of exploration cores, the expert opinion in the packer test report[14] (Prof A van Schalkwyk), concluded:

"The undersigned is of the opinion that that most of the water pumped during the pump tests originated from the upper 50 m weathered layer and that the hydraulic conductivity values used in the groundwater model are conservative (higher than actual) and that the rate of seepage might be lower and the development of the dewatering cone might be considerably slower."

The new model strived to incorporate these latest findings, adopted slightly different layer thicknesses as well as the required changes to the hydraulic conductivity, while keeping the transmissivity of the model the same.

15.2 Numerical Model Update

The structure of the remainder of this report is divided into the following main sections:

- Construction of the numerical model, including the boundaries and subdivision.
- Verification of the model to pump test results.
- Prediction of the groundwater impacts due to dewatering pits, decant and pollution transport. A new North Pit mining design was supplied in May 2023, and is incorporated in this report.
- Prediction of the cumulative impact of Volspruit and abstraction of groundwater from the defunct Grasvally underground mine.

15.2.1 Model construction

For this update, a series of steady state models was run on the request of the client to have a worst-case impact prediction. The requested steady state scenarios were:

1. Volspruit before mining, with abstraction by farmers only and at Grasvally for surface water mining.
2. Volspruit North Pit at full production and South Pit not yet mined. Grasvally first phase mining to the upper level (350mbg); including farmers irrigation abstraction.
3. Volspruit North and South Pit at full production and abstraction, Grasvally at peak production (600mbgl) with abstraction; including farmers irrigation abstraction.
4. Volspruit North Pit completely backfilled and South Pit at full production, Grasvally at peak production (600m); including farmers irrigation abstraction.
5. Post closure for both mines, supply to Mokopane continues from Grasvally

The previous model was a transient model, running over a period of 20 years to simulate the currently planned life of mine. A transient TIN (Triangular Irregular Network) was used to simulate progressive

mining on an annual basis. Elevation data was derived from the SRTM (Shuttle Radar Tomography Mission) DEM (Digital Elevation Model) data.

As the groundwater elevations follow topography (especially at the higher elevations) natural water divides could be used as no-flow boundaries in the eastern and western extents of the model. In the north and south, the model was terminated with parallel flow boundaries, on the assumption that groundwater will flow perpendicular to the surface contours. A small inflow and outflow area in the south and north, coinciding with the Nyl River, was used as a constant head boundary at ground level in the south, and 10 metres below ground level in the north to simulate worst case northward subsurface flow.

As the geology (and thus also expected hydrogeological parameters) varies considerably over the modelled area, the model was delineated accordingly. The hydrogeological areas coincide with the geology and continue at depth to lower layers as the same material, but with less weathering/fracturing. The exception is the basalt that is only present in the first layer, with sandstone underlying. The diverse hydrogeological regimes were allocated appropriate hydrogeological parameters, as will be described below.

The Zebediela Fault was incorporated as an east-west highly conductive linear feature about 2 kilometres south of the proposed mine. The lesser Magoga Fault branch northwards and was purposefully connected to both the opencasts to represent a worst-case scenario.

Vertically, the model consists of five layers with decreasing hydraulic conductivity and specific yield. Fractures in bedrock decrease in frequency and narrow with depth, resulting in the lowering of hydraulic parameters. Based on the results of the packer testing and the interpretation[14], the first two layers were chosen to be 30 metres thickness each. The next two layers were taken as 60 metres each, followed by a 70 metres final layer, for a full model depth of 250 metres. For this model the lower layer was extended to 600 mbgl to include the depth of Grasvally.

Due to the flat groundwater table and extensive pumping, groundwater levels could not be used to calibrate hydraulic conductivity. The aquifer parameters were thus based on the statistical analyses of the pump tests to determine the T (transmissivity) values, and these then distributed in depth as K (hydraulic conductivity) values, based on packer tests and RQD and later validated against pump test drawdown.

In lithologies where pump tests were not conducted, best literature and expert advice were used to estimate hydraulic parameters. Although these values are not insignificant, the effect of error in these will not have substantial consequence on the results obtained at Volspruit.

Since the hydraulic conductivities of the faults are unknown, values of two orders of magnitude higher than the surrounding bedrock were allocated, again to model worst case. Grouting was simulated as horizontal flow barriers.

In the previous models, groundwater extraction volumes were calculated based on irrigation requirements[15] due to the lack of information on the volumes pumped by the farmers in as to be mined.

[14] van Schalkwyk A: Volspruit Mine, Report on Packer Permeability Testing and Proposals for Control of Groundwater during Mining. AVS Consulting, 21 April 2012.

[15] Steyn, J M. Estimation of The Irrigation Water Requirements of Crops Produced on the Farm Volspruit. martin.steyn@up.ac.za. Oct 2012

However, for this model, it was requested that only registered extractions be used, as listed in Table 22 below.

The meteorological aquifer parameters normally must be calculated and/or judged by conventional means. A recharge average of 21 mm/a ≈ 0.00005 m/d were used as described earlier in this report. However, it was found that a steady state recharge did not mimic the system adequately. A transient recharge with high recharge periods at the river was thus introduced to simulate the flooding events. Maximum evapotranspiration of 942 mm/a was used, based on the E-pan evaporation data for this area[16]. Evapotranspiration extinction depth (the estimated average root depth) was equated to 3 m.

The model was set to run for a period of 20 years, which is somewhat more than the estimated live of mine.

To imitate flooding events with river bottom conductance proved unrealistic. In reality, the flood water overtops the clay layer during these events and recharges the aquifer through permeable regolith on the sides over widths that could be several hundreds of metres and for extended periods of several months. This phenomenon is rare and is described in detail in various publications[17] mainly by Prof McCarthy. The flooding events were thus modelled as regular spaced periods of much higher-than-average recharge.

The dewatering of the mine was simulated in Modflow using drains. The bottom elevation of the pits was set as transient TIN (Triangulated Irregular Network) elevations.

[16] http://www.dwaf.gov.za/hydrology

[17] McCarthy T S et al: The origin and development of the Nyl River floodplain wetland, Limpopo Province, South Africa. South African Geographical Journal, DOI:10.1080/03736245. 2011.619324.

Table 22: Existing lawful water uses registered for the properties applicable to the VPM project (DWS, 2025)

Number	Status	Name	WU status	Sector	Source	Volume (m^3/a)	Farm
27056275	Closed	Freek Wagner Trust	Closed	Agriculture: Irrigation	Borehole	50 400	Volspruit KR 326/5
27056934	Active	CM Genis	Registered	Agriculture: irrigation	Borehole	6 810	Grasvally KR 293 ptn 16
27057746	Active	E de Beer	Registered	Agriculture: irrigation	Borehole	828 895	Volspruit KR 326/2
27059637	Active	Terra Nominees	Registered	Mining	Borehole	39 015	Grasvally KR 293 Ptn 18
27057489	Active	Faer Glen Properties No 55	Registered	Agriculture: Irrigation	Borehole	453 500	Volspruit KR 326/1
27075138	Active	Samancor Manganese	Registered	Agriculture: Irrigation	Borehole	58 548	Grasvally KR 293 Ptn 4
27111769	Active	Wiepe 7 Boerdery (Pty) Ltd	Registered	Agriculture: Irrigation	Borehole	833 920	Vaalkop KR 325
27105338	Active	Zoetveld Mining and Prospecting (Pty) Ltd	Registered	Mining	Borehole	160 600	Zoetveld KR 294 RE
27100823	Active	Zoetveld Mining and Prospecting (Pty) Ltd	Registered	Agriculture: Irrigation	Borehole	81 475	Grasvally KR 293 ptn 4
27056257	Active	Abdul Kader Tayob Holding Trust	Registered	Agriculture Irrigation	Borehole	680 658	Rondeboschje KR 778
27056934	Active	S. Van der Hoven	Registered	Agriculture Irrigation	Borehole	6 810	Grasvaly KR 294 ptn 16
27104071	Active	Tswalanang Trading (Pty) Ltd	Registered	Agriculture Irrigation	Borehole	580 014	Zoetfontein KR 330
27107979	Active	Bokpoort Beleggings Gedeelte 2 (Pty) Ltd	Registered	Agriculture Irrigation	Borehole	973 658	Bokpoort KR 328
27056391	Active	Bokpoort Beleggings Gedeelte 1 (Pty) Ltd	Registered	Agriculture Irrigation	Borehole	960 608	Bokpoort KR 328 ptn 1
27106015	Active	H. C. Keet	Registered	Agriculture Irrigation	Borehole	15 750	Doelen KR 327 ptn 2

15.2.2 Verification of the model

As reported previously, various pump tests have been conducted in the Volspruit area. These provide opportunity to verify the model and aquifer parameters as described in the previous paragraph independently. By running the model with these pumped volumes, it could be established whether the average drawdown of the model correspond to the average measured drawdown.

The average drawdown of about 15-20 metres was reasonable well satisfied. Similarly, the range of about 3- 50 metres is also well satisfied. It can thus be concluded that the chosen aquifer parameters are at least of the correct range and can thus be used with reasonable confidence.

15.3 Hydrogeological impacts

It is the aim of this chapter to assess the likely hydrogeological impact that the proposed mining of the Volspruit opencasts might have on the environment, assuming worst case steady-state conditions.

The following impacts will be presented in this chapter:

- Volspruit before mining, with abstraction by farmers only and at Grasvally for surface water mining.
- Volspruit North Pit at full production and South Pit not yet mined. Grasvally first phase mining to the upper level (350mbgl);
- Volspruit North Pit completely backfilled and South Pit at full production, Grasvally at peak production (600mbgl);
- Volspruit North and South Pit at full production and abstraction, Grasvally at peak production (600mbgl) with abstraction;
- Post closure for both mines, supply to Mokopane continues from Grasvally

All scenarios will include registered groundwater abstraction.

Groundwater drawdown for all figures is terminated at 7 meters. In theory, the groundwater drawdown extends to infinity with decreasing amplitude. However, it is unfeasible to contour to small unimportant values. Thus, a termination value of 7 meter was chosen, which corresponds to the typical rise of groundwater during flooding of the Nyl.

15.3.1 Drawdown before mining due to registered water use

The registered groundwater users were supplied by the client, as in Table 22 above. This scenario was modelled as a steady state model with the boreholes at a depth of 100 metres below ground surface. The results are depicted as Figure 34 below. It can be deduced that:

- Drawdown of the groundwater is predicted to be in the order of 5 to 50 metres, with only the abstraction at Bokpoort that could be more than 50 metres. In many of the boreholes the theoretical drawdown is less than the 7 meters cutoff value.
- If all groundwater users extract only the registered groundwater volumes, the lowering of the groundwater is not excessive.
- However, a previous specialist report (paragraph 20.1.4: Estimation of the Irrigation Water Requirements of Crops calculated that more ground water must be pumped to sustain irrigated crops. Thus, there is a possibility that the actual drawdown could be more in reality.

15.3.2 Drawdown of the groundwater due to mining

The mining scenario modelled was:

- Volspruit North Pit at full production and South Pit not yet mined. Grasvally first phase mining to the upper level (350mbg); including farmers irrigation abstraction.
- Volspruit North and South Pit at full production and abstraction, Grasvally at peak production (600mbgl) with abstraction; including farmers irrigation abstraction.
- Volspruit North Pit completely backfilled and South Pit at full production, Grasvally at peak production (600m); including farmers irrigation abstraction.

The results of the modelling are shown as Figure 35, Figure 36 and Figure 37 below. The following van be deduced from these figures:

For Volspruit:

- The groundwater drawdown at Volspruit during mining of the North Pit is about 130 metres, the depth of mining.
- The cone of depression could extend to about 1 kilometre in all directions due to the high hydraulic conductance of the faulted bedrock.
- At the Nyl, the drawdown could extend west to the river and is predicted to be in the order of 10 metres for a limited period while the deeper western section of North Pit is mined.
- The predicted drawdown at the river is illustrated in Figure 34 below. The drawdown at the river is expected to drop only for a limited time of about 2 years to more than 10 metres. For the rest of the time, it is mostly in the order of 2 - 4 metres, which is very similar to what is currently occurring due to irrigation.
- For South Pit, the drawdown is also about 130 meters, down to the level of mining. The extent of the cone of depression is also in the order of 1 km.
- However, as South Pit is further from the Nyl River, the drawdown is not expected to have a significant impact at the river.

For Grasvally:

- At Grasvally the calculated drawdown is about 30 metres directly above the underground stopes. However, this prediction is highly uncertain as the conductance of the mine roofs are unknown, and there are no data of the previous mining available to calculate it.
- The cone of depression due to Grasvally is similarly about 1 kilometre in all directions.
- The aquifer above the stopes is not completely dewatered due to the limited vertical hydraulic conductivity at this depth. The fracturing of bedrock becomes less frequent with depth and water bearing fractures becomes less permeable. However, the exact value of the vertical hydraulic conductivity is unknown, and the value used in this model was based on previous experience in deep Mpumalanga coal mines. Vertical fracturing at Grasvally could thus be different. A more precise estimate can only be obtained once dewatering has begun and enough groundwater volume and - level data has been collected.

Cumulative impact of Volspruit and Grasvally

- Lastly, in the extreme worst case with both opencast mines at Volspruit South at maximum and Grasvally Lower-Level stopes dewatered (Figure 37), the cone of drawdown extend to about 500 metres beyond the Nyl River, and the calculated drawdown increase to about 20 metres.
- There is also a merged groundwater depression between Grasvally and Volspruit of ≈ 30 metres and the drawdown at the Nyl is somewhat increased by 5 metres at most.

Lowering of the Groundwater Level below the Nyl River

It was mentioned above that the drawdown of the groundwater at the Nyl River is transient. This influence is illustrated in Figure 38. It can be concluded from this simulation that:

- Drawdown at the river is modelled to be about 5 metres below surface with irrigation only.
- The groundwater level recedes very slowly until about year 6 when mining progress to the west in the direction of the Nyl river.
- The groundwater the groundwater level then deepens to about 12 metres at the maximum depth of the pit at year 9.
- As mining is discontinued the groundwater level will start rebounding to reach normal levels of five metres below surface at year 12.
- Thereafter the reaction of the groundwater will depend on the use of the water, especially at Grasvally.
- However, should the extracted groundwater water be used for irrigation and water supply to Mokopane, the groundwater levels could stabilise at levels of at least 5 to 10 metres below surface.

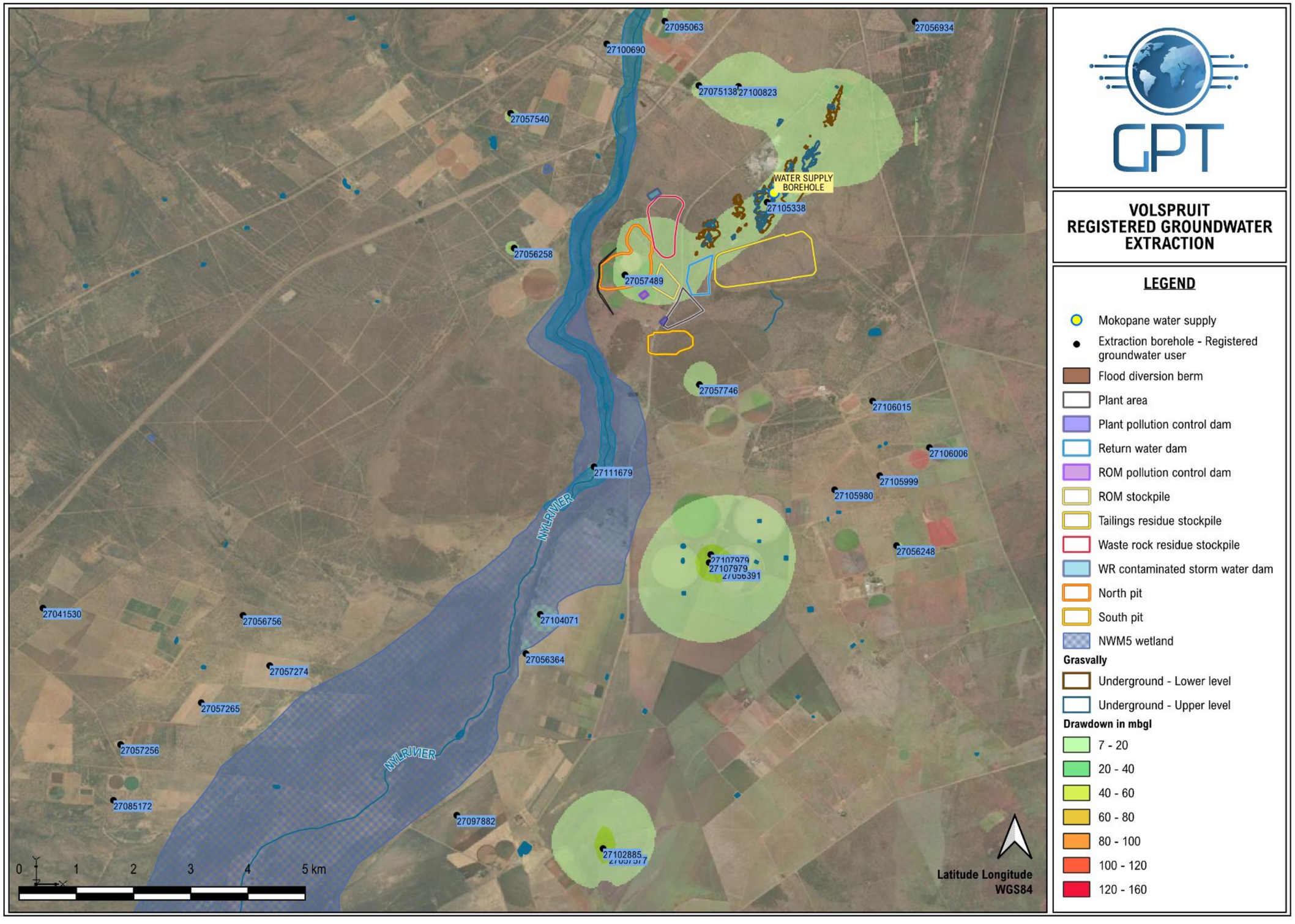


Figure 34: Predicted Groundwater Drawdown due to Registered Groundwater Users

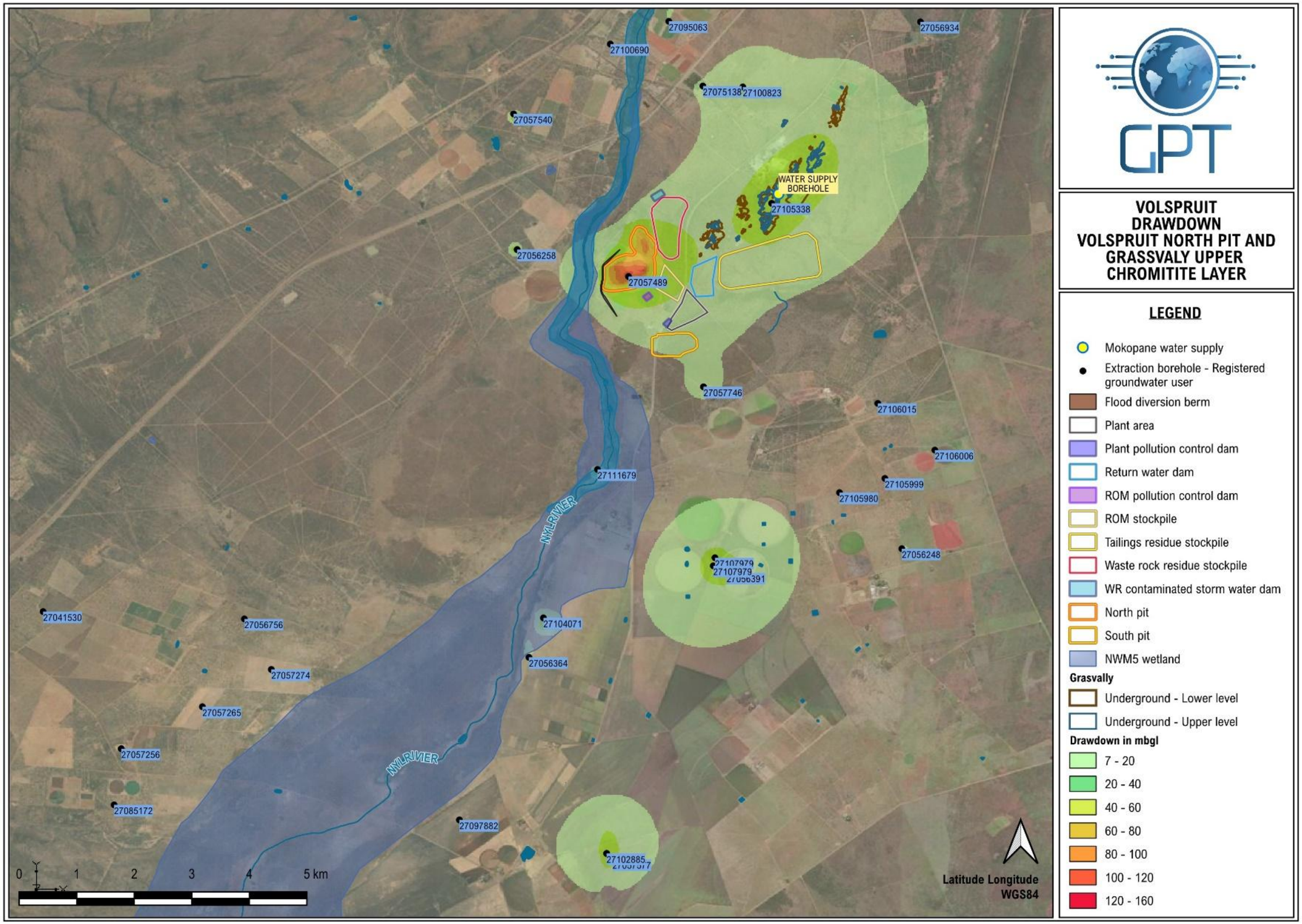


Figure 35: Predicted Groundwater Drawdown with North Pit and Grasvally Upper Level.

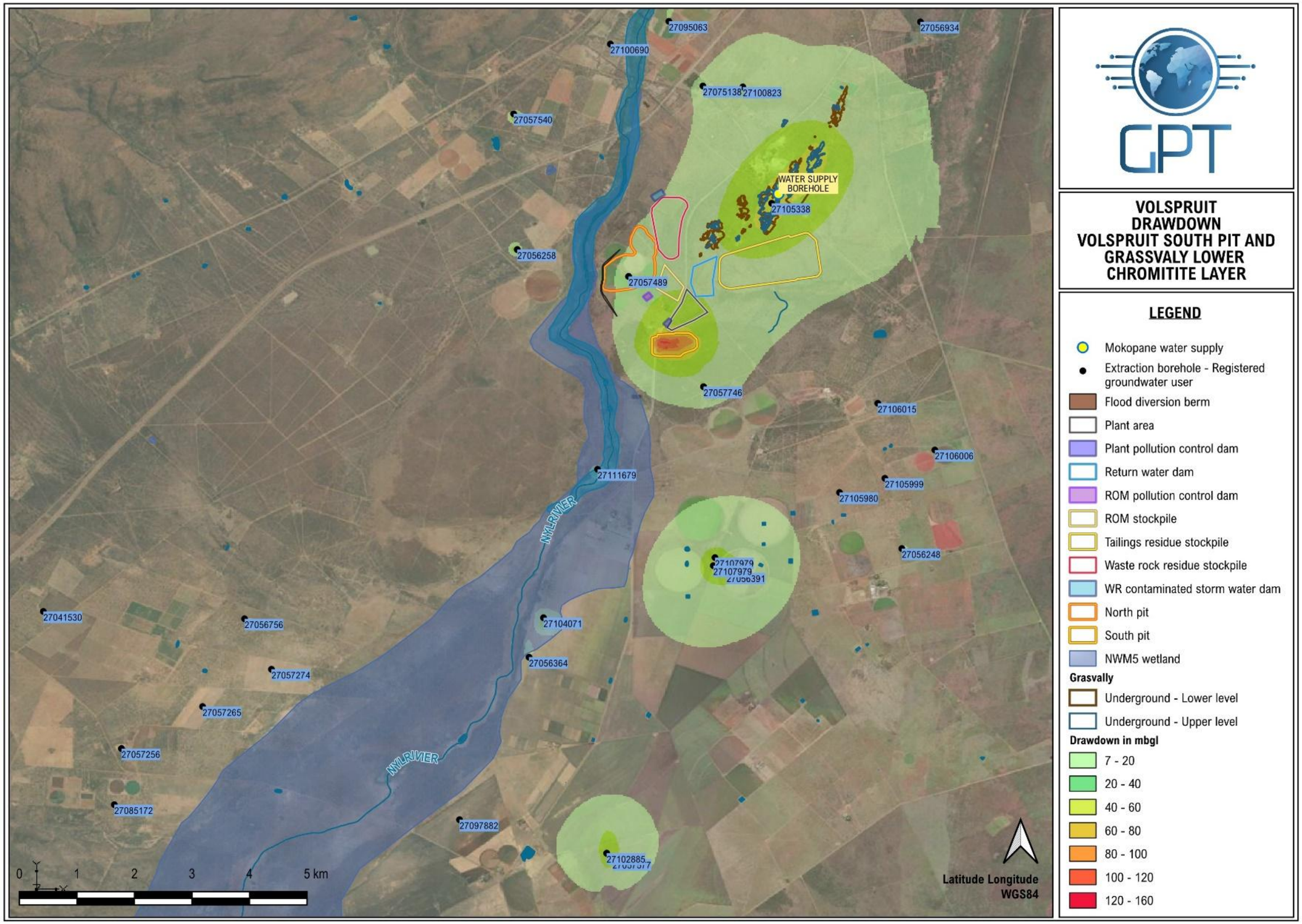


Figure 36: Predicted Groundwater Drawdown with South Pit and Grasvally Lower Level.

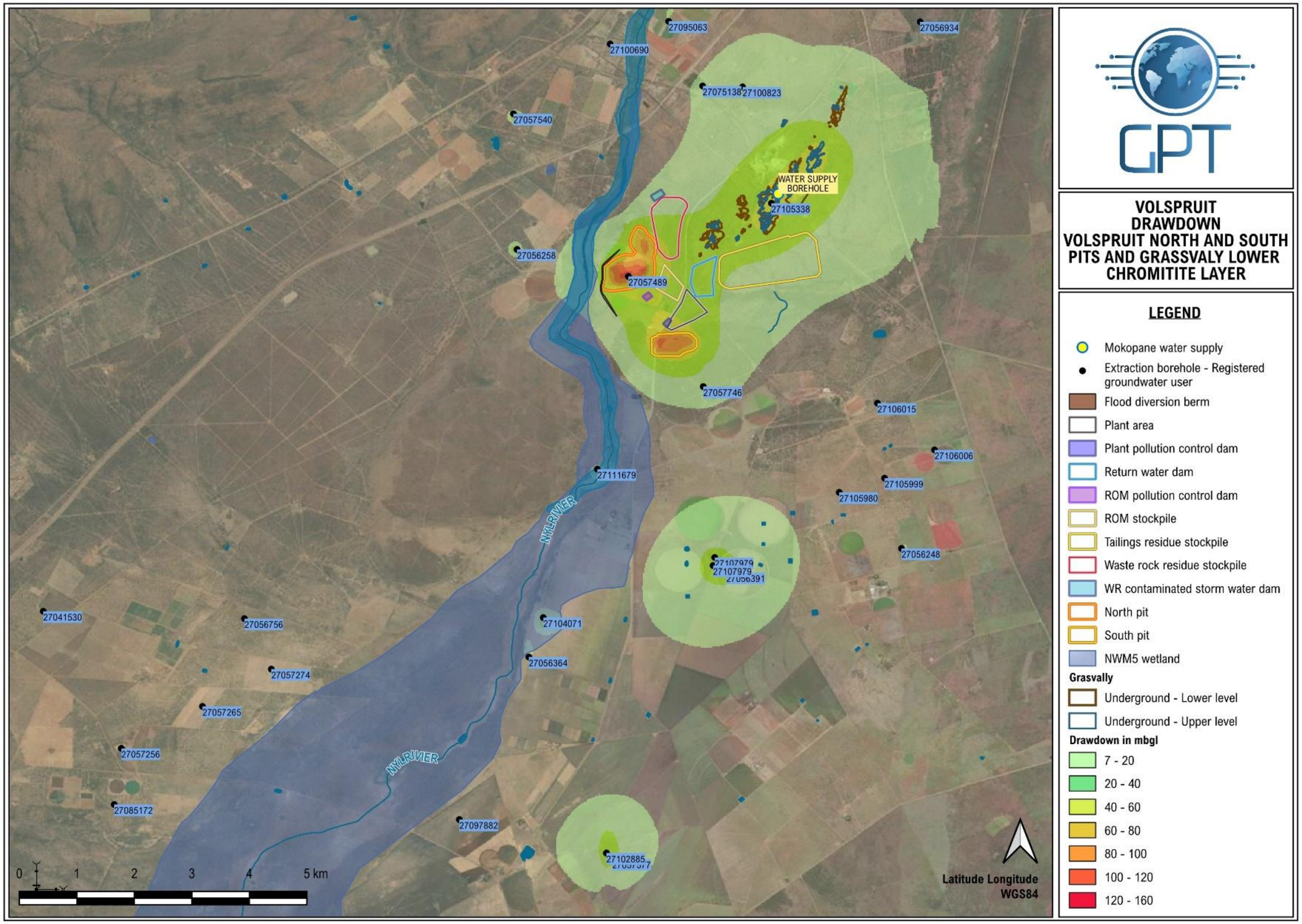


Figure 37: Predicted Groundwater Drawdown with North and South Pit and Grasvally Lower Level.

15.3.3 Sensitivity of the model for Bedrock Hydraulic Conductivity

As a test for the sensitivity of the model for the assumptions on hydraulic conductivity, the maximum possible hydraulic conductivity of the bedrock (based on the pump tests as described in previously Table 5, paragraph 7) have been used. In general, the extent of the cone of groundwater depression increase somewhat, as can be expected. However, the effect is small considering the doubling the hydraulic conductivity.

It is thus concluded that the model is relative unsensitive to the hydraulic conductivity of the pyroxenite host rock. The reason for this is that due to the extraordinary high value of the hydraulic conductivity, the exact value is less important.

15.3.4 Verification of the Model

The IGS (Institute for Groundwater Studies) recommended in their review of this report that the zone of impact must also be modelled using a drain in both pits at an elevation of 30m below surface (based on the assumption that most water is in the upper 30m). The zone of impact is somewhat less than those calculated for the deeper pits, but of the same scale.

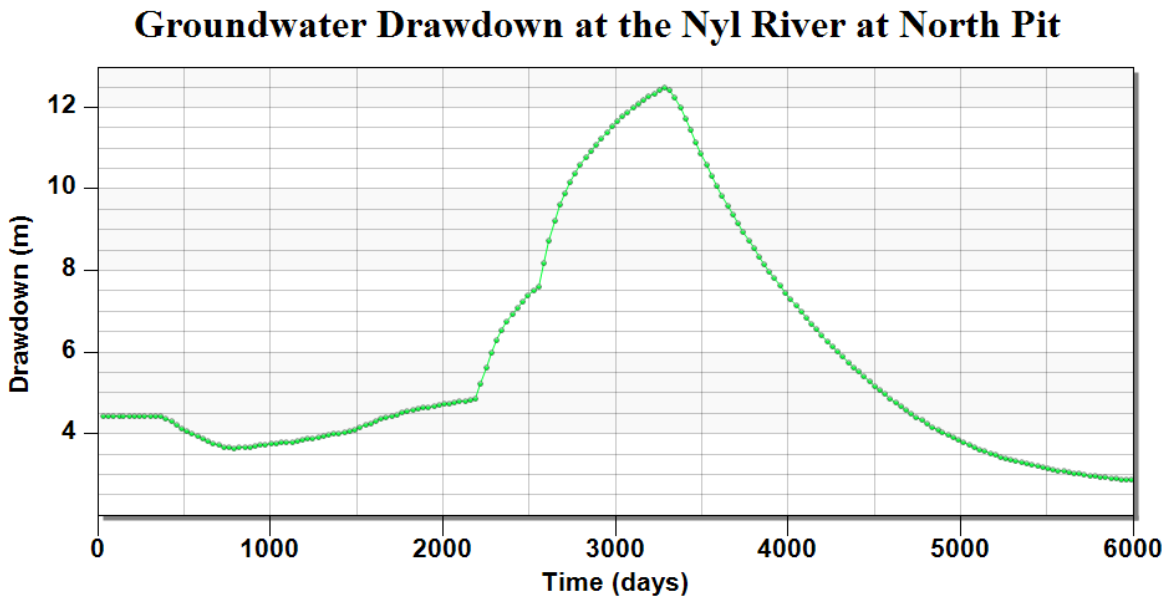


Figure 38: Transient drawdown below the Nyl River at North Pit – Cumulative Impact

15.3.5 Impact of evaporation from South Pit

At a later stage of the project the environmental consultants requested by that the evaporation from South Pit be taken into account as it might be that it will left open and not backfilled. The model was thus rerun with evaporation from South Pit Included and compared to previous results. It was found that the additional impact is indeed very low and will not change the drawdown or the movement of contamination after mining to any significant extent. The following was found:

- The additional drawdown at South Pit will be in the order of 5 - 10 metres in the long term.
- This is small compared to the drawdown to either mining or irrigation abstraction that is predicted to be several 10s of metres insert, even approaching 100 metres in places.

This can be confirmed by simple calculation:

Area of the South Pit = 300 000 square metres.

Evaporation is typical = 0.0025m/d (Paragraph 15.2.1)

Thus, evaporation = 300 000m^2 x 0.0025m/d, = 750 m^3/d

This value is small in comparison to the other abstractions in the area, being at least an order of magnitude less than the volume of water being extracted for irrigation, and about 1/4 of the volume that is planned to be extracted from Grass Valley

Furthermore, evaporation the pit could even be less that calculated due to the shielding effects of the walls of the pit and the depth of the groundwater below the air movement at the surface. It could even be less than 50% of that calculated above.

Remodelling of the plume movement indicated that there are no significant changes to that presented In the paragraphs above. Thus, backfilling or leaving South Pit open will not have substantial consequences in the post mining plume transport.

15.4 Decanting of the pits

After closure, the water table will rise in the rehabilitated pit to reinstate equilibrium with the surrounding groundwater systems. The mined areas will have a large hydraulic conductivity compared to the pre-mining situation. This will result in a relative flattening of the groundwater table over the extent of the rehabilitated opencast. The end result of this will be a permanent lowering of the groundwater level in the higher topographical area and a rise in lower lying areas.

It is this rise in groundwater that normally results in decanting of opencasts. However, with the latest model input parameters no decanting is predicted. But the groundwater is modelled to be very close to surface after mining and could lead to decant should layout or parameters change. But then a berm is planned downstream between the pit and the river, increasing the freeboard to the point that decanting is not possible.

- It is thus concluded that direct surface decanting of the pits is unlikely.

15.5 Groundwater Quality

16 Once the normal groundwater flow conditions have been re-instated, polluted water can migrate away from the rehabilitated opencast. Although the overburden has been shown to be likely non-acid generating, both the geochemical studies (paragraph 11: AQUIFER CHARACTERISATION

The term aquifer refers to a strata or group of interconnected strata comprising of saturated earth material capable of conducting groundwater and of yielding usable quantities of groundwater to

boreholes and /or springs (Vegter, 1994). In the light of South Africa's limited water resources, it is important to discuss the aquifer sensitivity in terms of the boundaries of the aquifer, its vulnerability, classification and finally protection classification, as this will help to provide a framework in the groundwater management process.

16.1 Aquifer Vulnerability

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

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

The following factors influence groundwater vulnerability:

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

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

- Depth to groundwater below the site was estimated from water levels measured during the hydrocensus inferred to be at mean of ~22 mbgl.
- Groundwater recharge of 4.8%.
- A Bushveld geology & Sandy-clayey Clay (SaCl-Cl) vadose zone.
- Gradient of 1.7% were used in the estimation.

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

- Highly vulnerable (> 60), the natural factors provide little protection to shield groundwater from contaminating activities at the land surface.
- Medium Vulnerable = 30 to 60%, the natural factors provide some protection to shield groundwater from contaminating activities at the land surface, however based on the

contaminant toxicity mitigation measures will be required to prevent any surface contamination from reaching the groundwater table.

- Low Vulnerability (< 30 %), natural factors provide relatively good protection and if there is little likelihood that contaminating activities will result in groundwater degradation.

The GDT calculated a vulnerability value of 46%.

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

16.2 Aquifer Classification

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

The aquifers were classified by using the following definitions:

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

According to the Aquifer classifications map of South Africa from the department of Water Affairs the aquifer in the regions is classified as a major aquifer system.

The Aquifer within the area is used by the farming community as their primary water supply and the aquifer on Ken Smith's farm is used to sell water to Lepelle water supply agency. This also meets the criteria for a sole aquifer.

In order to achieve the Aquifer System Management Classifications, as well as the Groundwater Quality Management Index, a points scoring system as presented in Table 19 was used.

Table 19: Ratings – Groundwater Quality Management (GQM) Classification System

Aquifer System Management Classification		
Class	Points	Study area
Sole Source Aquifer System:	6	6

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

As part of the aquifer classification, a Groundwater Quality Management (GQM) Index is used to define the level of groundwater protection required. The GQM Index is obtained by multiplying the rating of the aquifer system management and the aquifer vulnerability. The GQM index for the study area is presented in Table 20.

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

GQM Index for Sole Aquifer = Aquifer System Management x Aquifer Vulnerability

= 6 x 2 = 12

GQM Index for Major Aquifer = Aquifer System Management x Aquifer Vulnerability

= 4 x 2 = 8

The GQM Index ranges between 8-12 with an average of 10.

Table 20: GQM Index for the Study Area

GQM Index	Level of Protection	Study Area
<1	Limited	
1 – 3	Low Level	
3 – 6	Medium Level	
6 – 10	High Level	8
>10	Strictly non-degradation	12

16.3 Aquifer Protection Classification

A Groundwater Quality Management Index average of 10 was estimated for the study area from the ratings for the Aquifer System Management Classification. According to this estimate, a **high to strictly non-degradation groundwater protection level** is required for the aquifer. Reasonable and sound groundwater protection measures are recommended to ensure that no cumulative pollution affects the aquifer, even in the long term.

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

- The protection of the underlying aquifer.
- The protection of the boreholes in use surrounding the proposed site.

- The protection of the Nyl river flowing past the proposed site.

16.4 Proposed Nyl River Strategic Groundwater Source Area

There are two guiding reports of importance on Strategic Water Source Areas:

- J Nel, C Colvin, D Le Maitre, J Smith, I Haines, 2013. South Africa's Strategic Water Source Areas. CSIR, Report No CSIR/NRE/ECOS/ER/2013/0031/A

- D Le Maitre, H Seyler, MHolland, L Smith-Adao, JNel, A Maherry, KWitthüser, 2018. Identification, Delineation and Importance of the Strategic Water Source Areas of South Africa, Lesotho and Swaziland for Surface Water and Groundwater. WATER RESEARCH COMMISSION, Report No. TT 754/1/18

In the 2018 report, it was recommended:

That SWSAs for surface water and groundwater be agreed to and accepted by all Departments and spheres of government responsible for land use and land protection and water use management on the basis of the framework developed through this research. Attention needs to be given, in collaboration with DEA and SANBI, to establish how best to delineate SWSAs so that they can be declared as formally protected areas for water source protection.

However, consideration is given to these reports by comparing of some aquifer characteristics with especially groundwater abstraction at Volspruit as predicted by the model:

- The total area of the Nyl Area is 2 036 km^2 compared to the area of the numerical model of 335 km^2. The modelled area (chosen to cover an area well beyond the extents of the opencasts within which all groundwater impact will be contained) covers thus only 16% of the proposed protection area.

- The recharge to the proposed Nyl protection area is given as 2036 million m^3/a (Table 10: of the WRC report). This is unlikely to be correct and a number of 76 million m^3/a was calculated, corresponding to 5% recharge from rainfall. If this is compared to the modelled abstraction of 3 million m^3/a for the North Pit and South Pit combined, it relates to an abstraction of groundwater of 3.9% of recharge to the proposed protection area. The two proposed pits will most likely not be dewatered simultaneously, in which case the abstraction will be half of the above.

- The contribution of groundwater to the surface water is given as 13.5% (Table 12), but it is shown in this report that there is currently no contribution to the Nyl River in the Volspruit area specifically, due to the depth of the groundwater table (Paragraph 14 of this report).

- The registered agricultural plus industrial groundwater use is 13 518 631 m^3/a, compared to the modelled abstraction at Volspruit of about 300 000 m^3/a, thus about adding 2% at most to these uses if both pits are dewatered simultaneously, but only 1% if the pits are mined sequentially. However, during the previous study of the Volspruit area it was found that the agricultural use is most likely much larger than the registered numbers. The 1% additional use is thus most likely an overestimation.

- According to the Le Maitre et al report, the proposed mine is situated in an aquifer vulnerability zone of <50% (Very Low). If that is viewed in conjunction with the conclusions on potential contaminant at the mine (paragraph 12.6 of this report, which indicate that the contamination potential of both the ore and bedrock is very low), the risk of detrimental chemical impact on the aquifer is low.

Table 21: Calculated maximum impact of the Volspruit Mine on the SWSA

Criterium	Strategic Groundwater Source	Maximum Volspruit Impact	Percentage Impact of the Volspruit Mine
Area (km^2)	2036	335	16.5%
Recharge (Mm^3/a)	76*	3	3.9%
Groundwater to surface water (%)	13	0	0.0%
Agricultural and industrial use (ML/a)	135189	300	0.2%

*<u>*Note:*</u> The number given in the WRC report is 2036 Mm^3/a. This is unlikely to be correct and the GPT calculation of 76 Mm^3/a was used instead.*

It is thus concluded that the dewatering abstraction of the proposed Volspruit mine will be small compared to the inflows and outflows of the proposed Nyl Strategic Groundwater Source Area and no significant additional impact on the larger aquifer is foreseen.

GROUNDWATER POTENTIAL CONTAMINANTS and paragraph 13: GEOCHEMICAL MODELLING), predicts limited production of sulphate. The first study predicts sulphate production of 60mg/L and the second 80mg/L.

Although nitrate is the main chemical of concern, it is not a product of the mine and none of the bedrock being mined contain nor produce nitrate. Nitrate in the area is a mainly a product of fertilisers used in the extensive agriculture. While the mine will use groundwater for operations, and might concentrate it, the nitrate of groundwater released by the mine is not predictable. In addition, groundwater in the area already exceed the standards for domestic and agricultural use.

Thus, sulphate has been modelled as a conservative (non-reacting) indicator of mine drainage pollution with a concentration of 100mg/l, to simulate the worst-case. The transport model was simulated over a 100-year timeframe to capture long-term plume dynamics. This extended temporal scale is required because solute dissipation in subsurface systems is heavily protracted by rate-limited, biphasic sorption kinetics and long-term tailing effects (**Pignatello & Xing, 1995**), as well as natural attenuation via hydrodynamic dispersion and dilution (**Gelhar et al., 1992**). Thus, in the long term the contamination will likely decrease to minimal values.

Results of the modelling

Currently groundwater is extracted in the area for crop irrigation and could change groundwater flow directions. Thus, two scenarios have been modelled:

- With abstraction of groundwater based on registered groundwater users.
- The above with additional abstraction of water from Grasvally for Mokopane.

As the North Pit are currently planned to be backfilled and covered with normal vegetation, recharge and evaporation similar to the modelled region have been assumed. South Pit, in contrast, is currently planned to be left open with no backfilling and has thus not been modelled as a potential pollution

source. The only possible source of pollution would be the sides of the pit exposed to the water in the pit, and the reacting surface will be minuscule in comparison to a backfilled opencast.

It was further assumed that the waste rock dump, the tailings storage facility as well as the product stockpile could also be potential sources of pollution at a similar concentration of 100mg/l. The return water dam and pollution control dams were excluded as sources as they will have to be properly lined and isolated from the underlying aquifer. Similarly, it was assumed the plant area will be designed and operated such that it will not pollute the subsurface. However, all these structures are mostly in the impacted areas of the sulphate plumes and including it as sources will thus not change the figures substantially.

Firstly, the migration of contaminated water from the mining area has been modelled with current irrigation included. The results are presented in Figure 39. It follows from this figure that:

- The plume is drawn towards the irrigation areas to the west of the Nyl River and underflow the river, but is deep below the floodplain bed and does not affect the surface water.
- There is also a substantial plume migration to the irrigation areas south of the mining area but is not predicted to reach those boreholes in the forecast period.
- It thus follows that the direction of plume migration is dominated by groundwater abstraction, as result of the almost horizontal water table. The groundwater flow will thus always be to where the water table is lowered.

Secondly, the migration of contaminated water from the mining area has been modelled with irrigation as well as abstraction from the Grasvally mine for Mokopane after closure. The flow patterns in the aquifer changed significantly in this scenario as illustrated in Figure 40:

- Plume movement is now significantly in the direction of Grasvally and is a more important factor of influence on groundwater flow than the abstraction for irrigation in the groundwater.
- This change in groundwater flow direction is due to the proximity of the underground mine to the Volspruit site as well as the depth of the defunct underground mine.

It is therefore concluded that:

- Groundwater flow direction is dominated by groundwater abstraction rather than topographical features.
- Migration of potential pollution will thus be towards the most prominent groundwater abstraction areas rather than the topographical downstream regions as would be intuitively expected.
- However, the impact on the underlying aquifer and groundwater receptors will be insignificant due to the low acid generation capacity of the ore and bedrock.

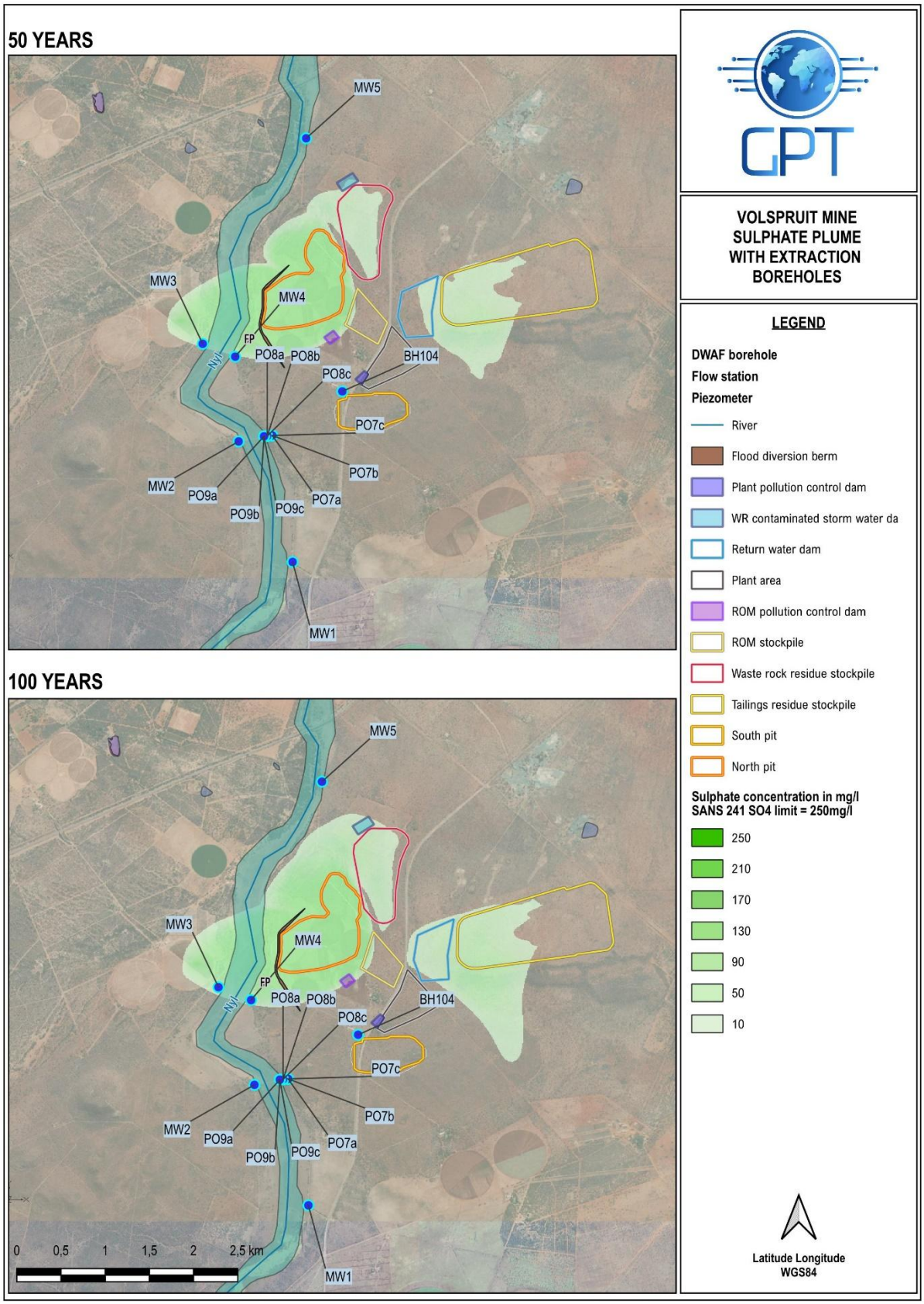


Figure 39: Plume migration with groundwater abstraction for irrigation only.

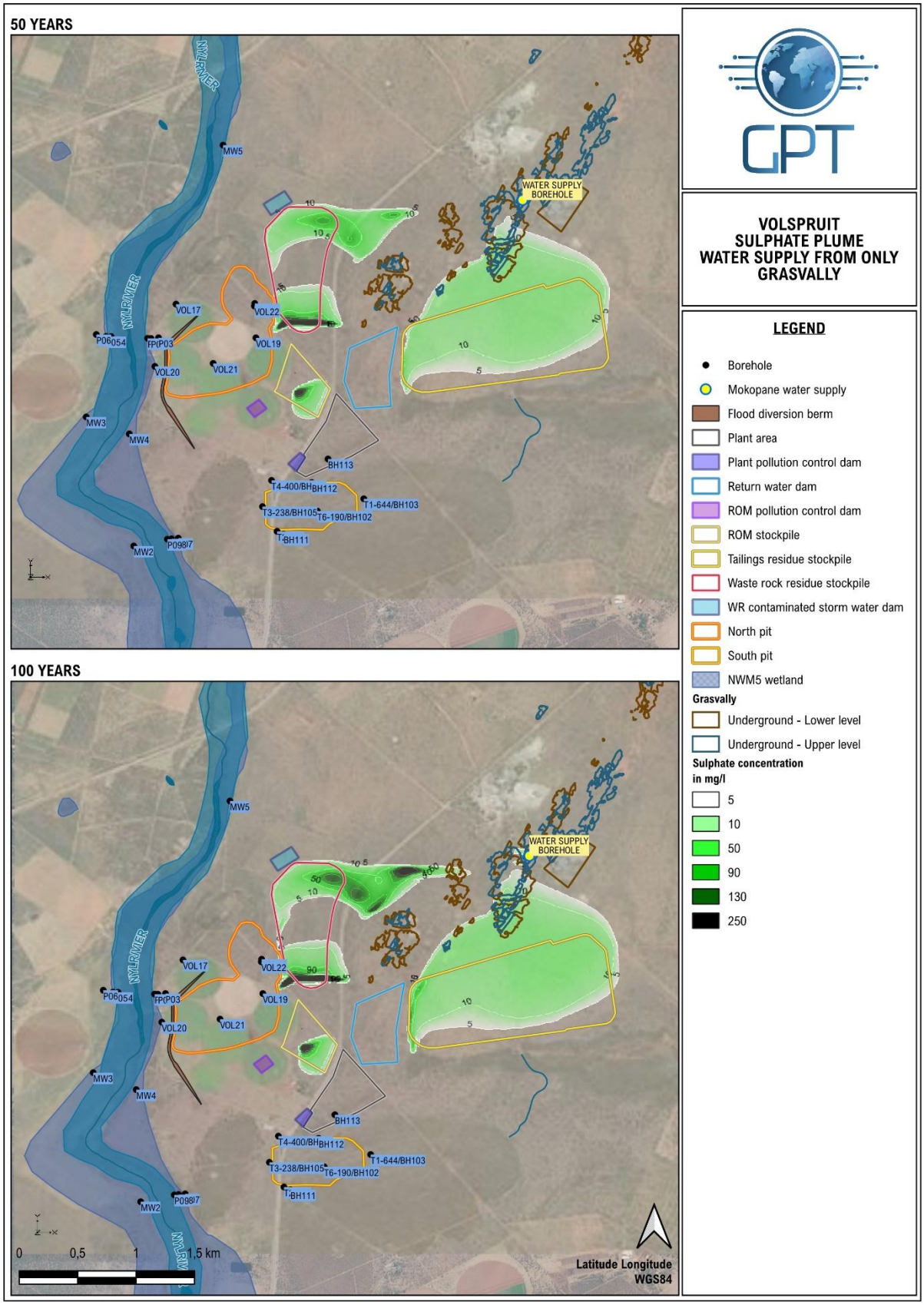


Figure 40: Plume migration with abstraction for irrigation + Grasvally (shallow aquifer).

17 Mitigations Considered

As there could be impacts on the groundwater due to the proposed mining, applicable mitigations need to be considered.

17.1.1 Drawdown of the groundwater

It was reported in the previous paragraph that little impact on the flow of the Nyl River is predicted, both during floods and normal seasonal flow, beyond that already imposed by irrigation abstraction. However, due to the slight possibility of surface water from the Nyl seeping to the opencast, grouting of the mine was considered as described in the previous unabridged groundwater report of GPT[18]. The following is an extract from the Executive Summary of the report:

"*The specialist grouting study proposed that a clay barrier followed by grouting at depth is used. Modelling of such a grout curtain provided the following information:*

- *The effect of the clay and grout curtain is pronounced in the first year, but the difference is becoming less pronounced as mining progress.*
- *At year 4 there is very little difference in groundwater drawdown between the grouted and ungrouted scenarios. The reason is that groundwater inflow to the opencast increase below the levels of grouting as time progress, and lowers surrounding groundwater levels.*
- *Thus, it seems as if grouting is not an effective mitigation measure at isolating mine, putting much more focus on the connection between the surface water in the Nyl and the groundwater."*

Groundwater studies conducted since this report during periods of flooding, proved that there is indeed minimal contact between groundwater and surface water in the Volspruit area. It is thus considered unlikely that flood water will enter the opencasts, especially if adequate flood diversion berms are constructed between the opencasts and the river. It is thus concluded that mitigation to minimise surface water flow to the opencasts via the groundwater pathway will be ineffective and is also not deemed essential.

Concerning impact on the irrigation in the area of groundwater drawdown, alternative water supply could be considered.

However, during the previous 2014 study, the relationship between crop area under irrigation and volumes extracted from boreholes was calculated by EScience. According to this estimate, the abstraction in the Volspruit area was estimated at about 3 000 m^3/day. The numerical model prediction of dewatering at Volspruit was at least 4 000 m^3/day. Thus, there would most likely be enough water to substitute the potential loss for irrigation.

17.1.2 Groundwater Quality

Based on the results of the hydrogeological and geochemical studies presented in this report, no mitigation for deterioration of groundwater quality is deemed necessary (paragraph 12.1 to paragraph 12.4). However, should the actual situation during mining differ markedly from predictions, mitigation was considered and modelled that can be applied even at a late stage after mining.

[18] GPT, 2012. Geohydrological Report for the Proposed Volspruit Mine (North- and South Pit) near Mokopane, Limpopo Province. Report EAV-11-053 Final Version 1.2

Since South Pit is planned to be left open, it would be logical to consider groundwater abstraction from the pit to create a cone of groundwater depression at the pit with the anticipation that contaminated groundwater could be drawn into this area and extracted at the pit. The proposition was tested by lowering the groundwater level in the South Pit progressively until contaminated water was seen to be drawn towards the pit. The following was observed:

- Lowering the groundwater by less than 10 metres serve no purpose, as the groundwater level at South Pit is about 5 to 10metres higher than at the North Pit.
- Natural evaporation will not be able to lower the groundwater level to 10 metres or more and will thus not be an effective capturing measure for the plume.
- From 20 to 30 metres lowering of the water level, marginal success could be achieved with some visible directional change in the flow of contaminants from especially the Tailings Storage Facility.
- However, to be able to draw most of the contamination to South Pit, a drawdown of 50 to 60 metres was needed. To draw down this amount (to about 1020 mamsl), a pump rate of 700 m^3/day had to be modelled.
- Although the main plume originating from the surface infrastructure is clearly drawn towards the South Pit, some contamination from the North Pit still migrate directly west towards irrigation wells west of the Nyl River, as depicted in Figure 41 below.
- Further lowering of the groundwater level at South Pit serve little purpose as the groundwater gradient from North Pit to the abstraction boreholes west of the Nyl is high and cannot be overcome by South Pit abstraction.

Alternatively, a fully complaint liner can be installed at the TSF and that will remove it as a potential pollution source. But the North Pit and the WRD will remain as sources.

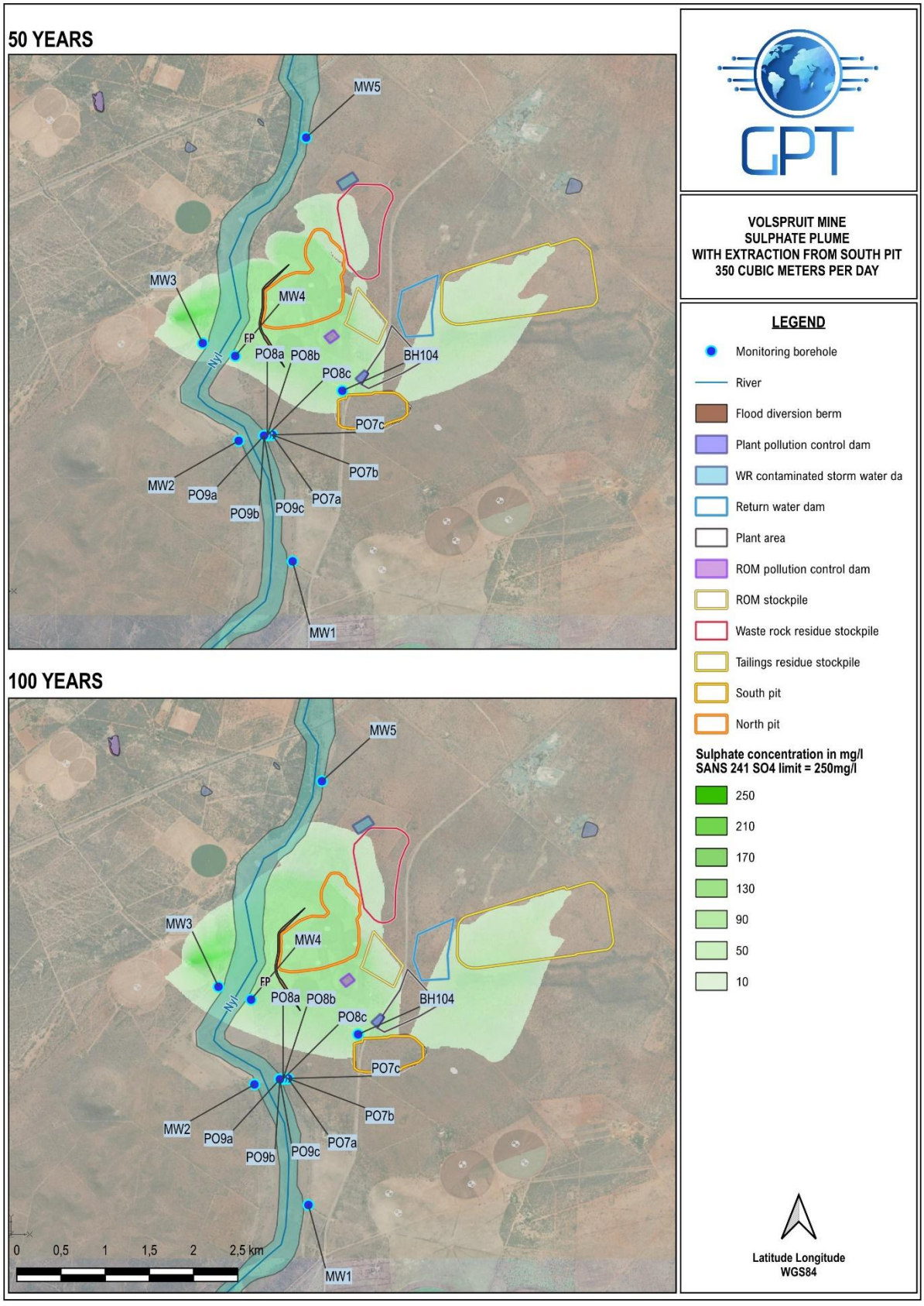


Figure 41: Plume migration with groundwater abstraction from South Pit

17.2 Conclusions based on modelling.

Drawdown before mining due to registered water use:

- Drawdown of the groundwater is predicted to be in the order of 5 to 50 metres, with only the extraction at Bokpoort that could be more than 50 metres. In many of the boreholes the theoretical drawdown is less than the 7 meters cutoff value.
- If all groundwater users extract only the registered groundwater volumes, the lowering of the groundwater is not excessive.
- However, a previous specialist report (paragraph 21.1.4: Estimation of the Irrigation Water Requirements of Crops calculated that more ground water must be pumped to sustain irrigated crops. Thus, there is a possibility that the actual drawdown could be more in reality.

Drawdown of the groundwater due to mining:

For Volspruit:

- The cone of depression could extend to about 1 kilometre in all directions due to the high hydraulic conductance of the faulted bedrock.
- At the Nyl, the drawdown could extend west to the river and is predicted to be in the order of 10 metres for a limited period while the deeper western section of North Pit is mined.
- The predicted drawdown at the river is predicted to drop only for a limited time of about 2 years to more than 10 metres. For the rest of the time, it is mostly in the order of 2 - 4 metres, which is very similar to what is experiencing now due to irrigation.
- The extent of the cone of depression is also in the order of 1 km. However, as South Pit is further from the Nyl River, the drawdown is not expected to have a significant impact at the river.

For Grasvally:

- At Grasvally the calculated drawdown is about 30 metres directly above the underground stopes. However, this prediction is highly uncertain as the conductance of the mine roofs are unknown, and there are no data of the previous mining available to calculate it.
- The cone of groundwater drawdown due to Grasvally is similarly about 1 kilometre in all directions.
- The aquifer above the stopes is not completely dewatered due to the limited vertical hydraulic conductivity at this depth. The fracturing of bedrock becomes less frequent with depth and water bearing fractures becomes tighter.

Cumulative impact of Volspruit and Grasvally:

- In the extreme worst case with both opencast mines at Volspruit at maximum and Grasvally Lower-Level stopes dewatered, the cone of drawdown extend to about 500 metres beyond the Nyl River, and the calculated drawdown increase to about 20 metres.
- There is also a merging of the cones of groundwater depression between Grasvally and Volspruit to ≈ 30 metres and the drawdown at the Nyl is somewhat increased by 5 metres at most.

Lowering of the Groundwater Level below the Nyl River:

The drawdown of the groundwater at the Nyl River is transient because of mining progress. It can be concluded from the transient simulation that:

- Drawdown at the river is modelled to be about 5 metres below surface with irrigation only. However, large scale irrigation abstraction has already lowered the groundwater levels in the Volspruit and surrounding areas by at least 5 to 10 metres.
- The groundwater level recedes very slowly until about year 6 when mining progress to the west in the direction of the Nyl river.
- The groundwater level then deepens to about 12 metres at the maximum depth of the pit at year 9.
- As mining is discontinued the groundwater level will start rebounding to reach normal levels of five metres below surface at year 12.
- Thereafter the reaction of the groundwater will depend on the use of the water, especially at Grasvally.
- However, should the extracted groundwater water be used for irrigation and water supply to Mokopane, the groundwater levels could stabilise at levels of at least 5 to 10 metres below surface.
- Due to the thick clay layer separating the river surface water from the aquifer below during periods of normal flow, the normal flow of the Nyl River will not be affected.
- It is only when the river is in flood and overflowing its banks that surface water could seep through the gravelly and sandy regolith to the aquifer below.
- This is normal behaviour for a flood in the Nyl River as a result of the separation of surface water and groundwater following the large-scale irrigation in the area for several decades.
- Thus, if surface water ingress into the open pits is prevented by adequate berms, the normal flow the river and the progression of mayor floods should not be changed significantly.

From the numerical modelling of the flow of contamination post mining, it is concluded that:

- Groundwater flow direction is dominated by groundwater abstraction rather than topographical features.
- Migration of potential pollution will thus be towards the most prominent groundwater abstraction areas rather than the topographical downstream regions as would be intuitively expected.
- Thus, groundwater extraction for irrigation determine the direction of groundwater flow before mining, while the flow will be towards the Grasvally Mine during mining.
- However, the impact on the underlying aquifer and groundwater receptors will be insignificant due to the low acid generation capacity of the ore and bedrock.

17.3 Limitations of the flow and transport moddeling

The modelling was done within the limitations of the scope of work of this study and the amount of data available. Although all efforts have been made to base the model on sound assumptions and it has been calibrated and validated to the best available knowledge and measurements, the results obtained from this exercise should be considered in accordance with the assumptions made. The assumption that a fractured aquifer will behave as a homogeneous porous medium can especially be questioned. However, on a large enough scale (bigger than the REF [Representative Elemental Volume]) this assumption should hold reasonably well.

18 IMPACTS QUANTIFICATION

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

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

18.1 Impact Assessment Criteria

An explanation of the impact assessment criteria is defined in Table 23.

Table 23: Impact Assessment Criteria

EXTENT	
Classification of the physical and spatial scale of the impact	
Footprint	The impacted area extends only as far as the activity, such as footprint occurring within the total site area.
Site	The impact could affect the whole, or a significant portion of the site.
Regional	The impact could affect the area including the neighbouring farms, the transport routes and the adjoining towns.
National	The impact could have an effect that expands throughout the country (South Africa).
International	Where the impact has international ramifications that extend beyond the boundaries of South Africa.
DURATION	
The lifetime of the impact that is measured in relation to the lifetime of the proposed development.	
Short term	The impact will either disappear with mitigation or will be mitigated through a natural process in a period shorter than that of the construction phase.
Short to Medium term	The impact will be relevant through to the end of a construction phase (1.5 years).
Medium term	The impact will last up to the end of the development phases, where after it will be entirely negated.
Long term	The impact will continue or last for the entire operational lifetime i.e. exceed 30 years of the development, but will be mitigated by direct human action or by natural processes thereafter.
Permanent	This is the only class of impact, which will be non-transitory. Mitigation either by man or natural process will not occur in such a way or in such a time span that the impact can be considered transient.
INTENSITY	
The intensity of the impact is considered by examining whether the impact is destructive or benign, whether it destroys the impacted environment, alters its functioning, or slightly alters the environment itself. The intensity is rated as	
Low	The impact alters the affected environment in such a way that the natural processes or functions are not affected.
Medium	The affected environment is altered, but functions and processes continue, albeit in a modified way.
High	Function or process of the affected environment is disturbed to the extent where it temporarily or permanently ceases.

PROBABILITY	
This describes the likelihood of the impacts actually occurring. The impact may occur for any length of time during the life cycle of the activity, and not at any given time. The classes are rated as follows:	
Improbable	The possibility of the impact occurring is none, due either to the circumstances, design or experience. The chance of this impact occurring is zero (0 %).
Possible	The possibility of the impact occurring is very low, due either to the circumstances, design or experience. The chances of this impact occurring is defined as 25 %.
Likely	There is a possibility that the impact will occur to the extent that provisions must therefore be made. The chances of this impact occurring is defined as 50 %.
Highly Likely	It is most likely that the impacts will occur at some stage of the development. Plans must be drawn up before carrying out the activity. The chances of this impact occurring is defined as 75 %.
Definite	The impact will take place regardless of any prevention plans, and only mitigation actions or contingency plans to contain the effect can be relied on. The chance of this impact occurring is defined as 100 %.

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

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

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

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

18.2 Mitigation

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

18.3 Determination of Significance without mitigation

Significance is determined through a synthesis of impact characteristics as described in the above paragraphs. It provides an indication of the importance of the impact in terms of both tangible and intangible characteristics. The significance of the impact “without mitigation” is the prime

determinant of the nature and degree of mitigation required. Where the impact is positive, significance is noted as "positive". Significance is rated on the following scale:

Table 24: Significance without mitigation

NO SIGNIFICANCE	The impact is not substantial and does not require any mitigation action.
LOW	The impact is of little importance but may require limited mitigation.
MEDIUM	The impact is of importance and is therefore considered to have a negative impact. Mitigation is required to reduce the negative impacts to acceptable levels.
HIGH	The impact is of major importance. Failure to mitigate, with the objective of reducing the impact to acceptable levels, could render the entire development option or entire project proposal unacceptable. Mitigation is therefore essential.

18.4 Determination of significance with mitigation

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

Table 25: Significance with mitigation measures

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

18.5 Assessment Weighting

Each aspect within an impact description was assigned a series of quantitative criteria. Such criteria are likely to differ during the different stages of the project's life cycle. In order to establish a defined base upon which it becomes feasible to make an informed decision, it was necessary to weigh and rank all the criteria. For each impact under scrutiny, a scaled weighting factor is attached to each respective impact (refer to Table 26) . The purpose of assigning weights serves to highlight those aspects considered the most critical to the various stakeholders and ensure that each specialist's element of bias is taken into account. The weighting factor also provides a means whereby the impact assessor can successfully deal with the complexities that exist between the different impacts and associated aspect criteria.

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

Table 26: Description of assessment parameters with its respective weighting

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

MITIGATION EFFICIENCY (ME)		SIGNIFICANCE FOLLOWING MITIGATION (SFM)	
High	0.2	Low	0 - 19
Medium to High	0.4	Low to Medium	20 - 39
Medium	0.6	Medium	40 - 59
Low to Medium	0.8	Medium to High	60 - 79
Low	1.0	High	80 - 100

18.6 Identifying the Potential Impacts Without Mitigation Measures (WOM)

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

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

18.7 Identifying the Potential Impacts With Mitigation Measures (WM)

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

18.8 Mitigation Efficiency (ME)

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

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

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

18.9 Significance Following Mitigation (SFM)

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

The impact quantification was done using the procedures for the assessment and minimum criteria for reporting aquatic biodiversity in terms of sections 24(5)(a) and (h) and 44 of the National Environmental Management Act, 1998. In terms of groundwater the proposed development impact on the functioning of the aquatic feature in terms of:

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

18.10 Environmental Impact Assessment (EIA) Regulations, 2017

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

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

The impact assessment methodology (as defined below) whereby the Significance of a potential impact is determined through the assessment of the relevant temporal and spatial scales determined of the Extent, Magnitude and Duration criteria associated with a particular impact. This method does not explicitly define each of the criteria but rather combines them and results in an indication of the overall significance.

18.11 Impact Quantification Results

The results of the impact assessment is presented in Table 27.

Table 27: Significance Rating of Impact(s).

Impacts	Extent	Duration	Intensity	Reversibility	Probability	Significance = Irreplaceability (Reversibility + Intensity + Duration + Extent) X Probability		Mitigation Efficiency (ME)	Significance Rating (WM) = Significance Rating (WOM) x Mitigation Efficiency	
Drawdown of North Pit	3	3	4	2	5	60	High	0.6	36	Low to medium
Drawdown of South Pit	3	3	4	2	5	60	High	0.6	36	Low to Medium
Decanting of North Pit	3	4	4	4	1	15	Very low	0.6	9	Very low
Decanting of South Pit	3	4	4	4	1	15	Very low	0.6	9	Very low
Groundwater Quality of Pits	2	4	3	3	5	60	High	0.6	36	Low
Groundwater Quality of TSF & RWD	2	3	2	2	5	45	Medium	0.6	27	Low
TSF & RWD with fully compliant liner	2	3	2	2	5	45	Medium	0.3	13	Low

19 GROUNDWATER MONITORING SYSTEM

19.1 Groundwater Monitoring Network

A groundwater monitoring system must adhere to the criteria mentioned below. As a result, the system should be developed accordingly.

19.1.1 Source, plume, impact and background monitoring

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

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

19.1.2 System response monitoring network

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

19.1.3 Monitoring frequency

In the operational phase and closure phase, monthly monitoring of groundwater quality and groundwater levels is recommended. It is important to note that a groundwater-monitoring network should also be dynamic. This means that the network should be extended over time to accommodate the migration of potential contaminants through the aquifer as well as the expansion of infrastructure and/or addition of possible pollution sources.

19.2 Monitoring Parameters

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

19.2.1 Abbreviated analysis (pollution indicators)

Physical Parameters:

- Groundwater levels

Chemical Parameters:

- Field measurements:
    - pH, EC
- Laboratory analyses:
    - Major anions and cations (Ca, Na, Cl, SO_4)
    - Other parameters (EC)

19.2.2 Full analysis

Physical Parameters:

- Groundwater levels

Chemical Parameters:

- Field measurements:
    - pH, EC
- Laboratory analyses:
    - Anions and cations (Ca, Mg, Na, K, NO3, Cl, SO_4, F, Fe, Mn, Al, & Alkalinity)
    - Other parameters (pH, EC, TDS)
    - Petroleum hydrocarbon contaminants (where applicable, near workshops and petroleum handling facilities)
    - Sewage related contaminants (E. coli, faecal coliforms) in borehole in proximity to septic tanks or sewage plants.

19.3 Monitoring Boreholes

DWAF (1998) states that "A monitoring hole must be such that the section of the groundwater most likely to be polluted first, is suitably penetrated to ensure the most realistic monitoring result."[19]

Currently a monitoring network does exist for the proposed mine, however only water level data is measured as discussed in Section 8. The boreholes are listed in Table 7: Volspruit Monitoring Network and the areas of these monitoring boreholes are shown in Figure 8. These boreholes can be utilised for water level monitoring during operations, as well as groundwater quality monitoring after decommissioning of the site.

However, a monitoring network should be dynamic. This means that the network should be extended over time to accommodate the migration of contaminants through the aquifer as well as the

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

expansion of infrastructure and/or addition of possible pollution sources. An audit on the monitoring network should be conducted annually.

20 GROUNDWATER MANAGEMENT

It was seen in this report that the biggest groundwater impact risk of this mine is the cone of depression extending to the aquifer below the Nyl River. The fear was that this could curtail the normal flooding of the Nyl wetland downstream. It has been proved in the EIA study (including other specialist studies) that this is unlikely. The proof has been witnessed during the 2014 flooding; the flood developed normally downstream, despite large scale groundwater abstraction for irrigation and lowering of the groundwater table by about 10 metres.

Nevertheless, ensuring a well-constructed berm downstream of the North Pit is considered essential to ensure that no flood can overtop to the east of the Nyl River in the North Pit impacted zone. An even better option is to construct a similar berm west of the Nyl as well, thus creating a natural clay-bottomed channel for the unimpeded passing of floods. The berm should be as impermeable to water as possible.

The next risk of importance is that the pit could decant. It it has been shown to be rather unlikely, and in addition, the pit water is predicted to be of acceptable quality. Nevertheless, it is essential that the post mining pit water is managed to ensure that decant cannot occur unless it can be proved that the pit water is indeed acceptable. Thus, the level of water in the pit must be managed below the bottom elevation of the Nyl River in that area. Should monitoring provide proof of pit water quality, connection with the river for ecological purposes can be considered.

It is thus essential that groundwater quality be monitored regularly during and post mining on a quarterly basis. This is essential to provide a reliable database to facilitate eventual closure of the mining operation. The sampling methods and recommended substances to be sampled for, is briefly described below.

Water samples must be taken from all the monitoring boreholes by using approved sampling techniques and adhering to recognised sampling procedures. Samples should be analysed for both organic as well as inorganic pollutants, as mining activity often lead to hydrocarbon spills in the form of diesel and oil. At least the following water quality parameters should be analysed for:

- Major ions (Ca, K, Mg, Na, SO4, NO3, Cl, F)
- pH
- Electrical Conductivity (EC),
- Total Petroleum Hydrocarbons (TPH)
- Total Alkalinity

These results should be recorded on a data sheet. It is proposed that the data should be entered into an appropriate computer database and reported to the Department of Water Affairs.

In conclusion, the following measures are recommended:

- Mining at the eastern section of North Pit must be used as a proving phase for groundwater control measures. Regular monitoring must be done and be safeguarded in a database for evaluation and updating of the impact prediction.
- Dewatering rates from the opencasts must be measured on a continuous basis and records be kept for analyses.

- Progressive detection of major fractures that could endanger the mine and the environment must be conducted, followed by confirmation through advanced drilling and grouting.
- The piezometer levels at the edge of the Nyl River must be measured monthly during the dry season, and the frequency should be doubled during high rain seasons.
- A groundwater monitoring network should be designed once mining is imminent. The network should comply with the requirements of an ISO 14000 monitoring system. The boreholes identified during the hydrocensus as well as the newly drilled boreholes can be used in the network.
- Quarterly groundwater sampling must be done to establish a database of plume movement trends, to aid eventual mine closure.
- All groundwater data must be analysed annually by a qualified hydrogeologist, and interpreted in terms of the reaction of the groundwater to mine dewatering to date and extrapolated to the future mining depths according to the latest mining plans.
- Based on such reports, an annual update of the groundwater management plan must be performed. This groundwater management plan must include the grouting and dewatering plans for the life of mine as well as the monitoring plan.
- These reports must also be submitted to authorities and presented to interested and affected parties annually, to satisfy all role players that sound groundwater management practices is adhered to.
- The recommended Department of Water and Sanitation best practice guidelines must be adhered to at all times.
- Finally, all mined areas should be flooded as soon as possible to bar oxygen from reacting with remaining sulphides.

In this report it was pointed out in various sections that some parts of the study were done with limited data and that assumptions had to be made. This paragraph aims to summarise the most important of these shortcomings that will need attention in further phases:

- From a hydrogeological point of view, the biggest unknown in this complex area is to determine the variation of hydraulic conductivity with depth. Through the modelling done in this report, it has been shown to be a determining factor in both the extent of impact of groundwater drawdown, as well as in the amount of water that would flow into the pit. In the specialist grouting report (van Schalkwyk A: Volspruit Mine, Report on Packer Permeability Testing and Proposals for Control of Groundwater during Mining. AVS Consulting, 21 April 2012) it is inter alia proposed that: “In order to confirm the variation of permeability and the groutability of the rock in the zone between the proposed clay or membrane cut-off and rock with a permeability of less than about 1 Lugeon, it is recommended that about 8 additional cored boreholes be drilled and packer tested around the rim of each pit. Some of these holes must be sited to intersect known fracture zones, while other must be sited between fracture zones.” Whilst supporting this recommendation, it is furthermore proposed that at least five additional cored boreholes be drilled and packer tested inside each pit to clarify the variation of hydraulic conductivity with depth inside the pits. At the initiation of this project, it was hoped that more cored boreholes would be available for packet testing, but that unfortunately did not materialise.
- In the same league is the uncertainty in the spatial distribution of the aquifer transmissivity. It has been suggested by interested and affected neighbours that the average obtained from the boreholes pump tested during this groundwater study is not necessarily applicable, as none of the drilled boreholes have had yields comparable to the existing irrigation wells. It was also proposed that drilling into a fault zone was proved by experience to be not trivial, and that the measured transmissivities is thus too low. (It should be also be noted at this point that the

grouting specialist study proposed that, since the drilled boreholes were targeted by geophysics, the measured transmissivity would be too high). To resolve this, it would be essential to measure the pumping rates of the irrigation on Volspruit and the resulting drawdown of the groundwater levels in these and adjacent boreholes. This was indeed planned for the current phase of the groundwater study, but access to the borehole pumping rates was not allowed. Applicable measurements at these boreholes would also significantly improve the estimation of inflow into the proposed opencasts.

- Another crucial issue, on which more clarity is essential, is the connectivity between the Nyl River and the groundwater. It has been described in this report that the nine piezometers installed on the banks of the river have already made a vital contribution in proving this separation between the water bodies. During a flood event, the frequency of measurement must be increased significantly to ensure enough data is captured to understand the groundwater interaction with the flood of the Nyl.
- It has also been seen in this report that the impact of faults in the area could significantly affect the inflow into the pits and increase the area of drawdown of groundwater around the pits. Although thorough geophysical investigations have been done at each pit and several boreholes have been drilled based on these data, it is also realised at the end of this phase that the characteristics and extents of the faults are still a major source of uncertainty. It is thus recommended that this is further explored during a next phase. A suggestion is that this is done in conjunction with both the geological and the grouting experts. A methodical inspection of the existing exploration cores would be needed. Further geophysical investigation directed to areas outside the pits (even at the controversial Zebediela Fault) followed by drilling and pump testing, is recommended.
- A further factor that might be very significant is to determine the regional groundwater flow direction under natural conditions. It has been proposed in the specialist surface water report that groundwater might flow in a general easterly direction towards the lower lying areas of the Springbok Flats. This could not be verified by this hydrogeological study. If this is indeed the case, pollutants emerging from the Volspruit Mine could spread easterly instead of westerly towards the Nyl River. This would have a significant impact on the environmental impact of the proposed opencast and is worth considering. The work to prove or disprove this postulate will be rather simple and entail no more than extending the measuring of groundwater levels significantly to the east. A problem is that groundwater levels in the immediate vicinity of the Volspruit area is affected by large scale groundwater abstraction and measured levels are rarely rest levels. This could be overcome by measuring water levels during periods of low abstraction, typically at the end of a rainy season.

21 SUMMARY OF OTHER SPECIALIST REPORTS REFERRING TO GROUNDWATER

Some issues regarding groundwater were also addressed by other specialists in their study fields. Although some comments do not necessary align with this groundwater study, they are quoted verbatim. These comments are referred to below:

21.1.1 Wetland Assessment

An impact assessment was undertaken by Wetland Consulting Services (Pty) Ltd[20,21] to determine potential impacts of the proposed development on wetlands. The most significant impacts can be summarized as follows and recommendations made are listed below:

"A single large floodplain wetland with two associated dams was delineated within the study area, covering approximately 110.7ha. The floodplain is associated with the Nyl River and forms part of the extreme lower end of the Nyl floodplain.

The upper reaches of the Nyl floodplain has been recognized as a wetland of international importance under the Ramsar Convention, as well as an Important Bird Area, highlighting the importance of the wetland system in terms of biodiversity. Many of the important and threatened species found within these upper reaches are also likely to occur on site during periods of high-water levels.

The proposed opencast pits are likely to result in numerous highly significant impacts to the Nyl floodplain, though a lack of information in certain key areas makes the accurate assessment of the impacts impossible. It is recommended that further studies be undertaken to fill the information gaps detailed in the impact assessment above before the application to mine can be considered. In the absence of such additional information it is considered highly unlikely that the mining application will be authorized as the precautionary principle would have to be applied in assessing potential impacts.

It is our opinion that, given the current proposed layout of the mine and the current understanding of the floodplain system on site that the presence of the Nyl floodplain in such close proximity to the proposed opencast pits and the potential impacts of the mine on the Nyl floodplain, poses a considerable obstacle to the proposed mining application. It will need to be proven beyond reasonable doubt that the proposed mine and the Nyl floodplain (and its associated biodiversity and functionality) will be able to coexist without any significant negative impacts to the floodplain for the mining application to be approved."

It was however proven by work conducted by GPT[22] that the unsaturated zone underneath the river is filled from below, and not from the river. The deduction is that the clay layer in this area is indeed impermeable and that the flood needed to overtop the clay before infiltrating.

21.1.2 Hydrologic Investigation

This section will discuss work conducted by Escience Associates (Pty) Ltd[23]. The following is a summary from this report:

"It was concluded that apart from two observed streamflow gauging stations in quaternary catchment A61A, there is only one other gauge on the Nyl River of relevance to the mine situation

[20] Wetland Consulting Services (Pty) Ltd, 2012, Biodiversity Assessment for the Proposed Sylvania Resources Volspruit Mine near Mokopane in the Limpopo Province, Reference: 590/2012

[21] Wetland Consulting Services (Pty) Ltd, 2012, Biodiversity Assessment for the Proposed Sylvania Resources Volspruit Mine on the Farm Volspruit 326 KP, Limpopo Province, Reference 590/2010

[22] Geo Pollution Technologies (Pty) Ltd, August 2014, Final Geohydrological report for the proposed Volspruit Mine (North- and South Pit) near Mokopane, Limpopo Province. GPT Reference Number: ESVOL-13-447F.

[23] Escience Associates (Pty) Ltd, January 2014, Nyl River Hydrological Modelling, Project No: W00/JNB/000029

which is A6H033, just downstream of the wetland. There are two other gauges on tributaries leading to the wetland and gauging at Doorndraai Dam further downstream. Unfortunately, the record period at A6H033 is only of the order of 9 years. The observed gauges A6H006, A6H011, A6H012 and A6H010 are not of a very high accuracy. Despite all the above-mentioned facts, a reasonable calibration of streamflow was achieved at the relevant gauges which should provide for a reasonably good analysis of surface and groundwater at the site of the mine.

Under the existing situation with current irrigation, groundwater is recharged by surface water via transmission losses due to the lowering of water levels. Evapotranspiration from groundwater is also significantly reduced. The increase in transmission losses increases the duration of zero flow in the river. Mining will result in a net increase of 17.4% in transmission losses and a 4.4% decrease in MAR from that sub-area. The overall impact on the MAR is only 0.76 Mm^3/a, since most of the MAR is generated upstream. The main impact of mining is to increase transmission losses to the alluvium during periods of high flow."

21.1.3 Hydropedological Assessment

In general, the soil surveys conducted in the area support the conceptual site model presented in this report (paragraph 14). This paragraph addresses the main results from the soil surveys from a hydrogeological perspective only.

A hydropedological assessment was conducted by Prof Claassens in 2013, in which it was concluded that: "*Due to the level of the water table and the low permeability of the clay layer in the river it is suspected that the water originates mostly due to the geology of the environment and not due to the seepage from the river."*

In 2022, Wetland Consulting Services also conducted a soil survey of the area and concluded that: "*The clay rich soils within the floodplain prevent sub-surface water movement either laterally or horizontally causing saturated conditions in the soil profile during wet conditions. The soils within the floodplain are poorly drained due to their low hydraulic conductivity and are therefore responsive in nature".*

21.1.4 Estimation of the Irrigation Water Requirements of Crops

A crucial report for the groundwater study, was submitted by Prof Steyn (Steyn J.M., Estimation of the Irrigation Water Requirements of Crops Produced on the Farm Volspruit, 26 Oct 2012). The following is an abstract of this report:

"The purpose of this study was to estimate the water requirements of a range of crops produced under centre pivot irrigation on the farm Volspruit near Mokopane, Limpopo Province. Seed maize, sugar beans and wheat (or oats) are produced in rotation under centre picot irrigation. There is a total of 18 centre pivots in the study area, covering a total area of about 370 ha.

"…crop water use and irrigation requirements were estimated with the help of a simulation model. Soil Water Balance (SWB) model simulations were carried out for the period January 2006 to December 2008 and January 2011 to June 2012.

"Simulated daily irrigation requirements of the different crops were summed over weekly periods and are given in (various tables)"

These tables are extensive, and were condensed and averaged for the purpose of projection of the Groundwater Numerical Model into the future, as will be described in the modelling section below.

21.1.5 Simulation of water quality from North Pit, Volspruit Mine

In 2025, Mills Water assessed the potential for using groundwater inflow into an open pit of the proposed Volspruit Mine for irrigation purposes. This report provides a summary of available water quality and geochemical data, and the results of geochemical modelling of pit water quality expected in the North Pit during operation and post-closure.

The conclusions of this report were:

"The sump water in all modelled scenarios was found to exceed the TWQR for irrigation for EC and nitrate. EC and nitrate already exceed the TWQR in the background groundwater, and the evaporation in the pit results in an increase in the EC by up to 4 times compared to background. Worse water quality would be expected if there are low inflows and in the summer months due to increased evaporation. Use of the sump water for irrigation would therefore require treatment, or management in terms of finding appropriate crops, ensuring a sufficient leaching fraction, adjusting fertilization amounts, and monitoring of groundwater quality to ensure the baseline quality does not deteriorate.

"The quality of water in the backfilled pit post closure becomes slightly fresher than surrounding groundwater due to the increased recharge expected into the backfill. Backfilling is expected to prevent evaporation, and the pumped-out water quality would be expected to be better than during operation. A slight increase in concentration with time might occur for EC and sulphate assuming that some nickel sulphide oxidation occurs. Nickel mobility is limited by adsorption to iron oxide and smectite weathering products. However, although a slight improvement in quality is expected, the post-closure water quality does not meet the TWQR for irrigation water for EC and nitrate because of the concentrations of these parameters in the background groundwater. The model does not account for reactions which may remove nitrates from the system, and presents a worst-case scenario for the set of input parameters. Development of reducing conditions within the backfilled pit is likely to lead to denitrification, resulting in decreasing nitrate concentrations in irrigation water, and will also limit sulphide oxidation.

"The models that have been developed have several limitations, namely:

- The model during operation is developed based on the final pit dimensions and does not consider changes in water quality with time as the pit expands during mining.

- The model does not account for changes in the background groundwater quality which may occur due to seepage from mine infrastructure, such as the TSF or return water dams, or changes in groundwater flow direction due to dewatering.

- The models are based on groundwater quality data from 2010/2011 which may not reflect current conditions and do not include trace element concentrations other than iron, manganese and aluminium.

The post-closure model is based on simplistic calculations which do not take into account the likely decrease in groundwater inflows with time"

22 CONCLUSIONS AND RECOMMENDATIONS

This section will briefly summarise the findings of this report and previous work conducted by GPT. The conclusions will summarise the findings of each of the actions performed by GPT to address the scope of work:

Numerical modelling (Drawdown): Results obtained from pump and packer testing was used to allocate hydraulic parameters to all the different model layers. These values were later verified by comparing the model's reaction to the actual measured response of the pump tests. The scenarios modelled were:

- Drawdown of the groundwater levels.
- Decanting of the pits
- Contaminant transport to predict the sulphate plume movement

Using the model as described, the following were concluded for the drawdown of the groundwater levels due to pit dewatering using the most likely hydraulic conductivity:

Drawdown before mining due to registered water use:

- Drawdown of the groundwater is predicted to be in the order of 5 to 50 metres, with only the extraction at Bokpoort that could be more than 50 metres. In many of the boreholes the theoretical drawdown is less than the 7 meters cutoff value.
- If all groundwater users extract only the registered groundwater volumes, the lowering of the groundwater is not excessive.
- However, a previous specialist report (paragraph 21.1.4: Estimation of the Irrigation Water Requirements of Crops calculated that more ground water must be pumped to sustain irrigated crops. Thus, there is a possibility that the actual drawdown could be more in reality.

Drawdown of the groundwater due to mining:

For Volspruit:

- The cone of depression could extend to about 1 kilometre in all directions due to the high hydraulic conductance of the faulted bedrock.
- At the Nyl, the drawdown could extend west to the river and is predicted to be in the order of 10 metres for a limited period while the deeper western section of North Pit is mined.
- The predicted drawdown at the river is predicted to drop only for a limited time of about 2 years to more than 10 metres. For the rest of the time, it is mostly in the order of 2 - 4 metres, which is very similar to what is experienced now due to irrigation.
- The extent of the cone of depression is also in the order of 1 km. However, as South Pit is further from the Nyl River, the drawdown is not expected to have a significant impact at the river.

For Grasvally:

- At Grasvally the calculated drawdown is about 30 metres directly above the underground stopes. However, this prediction is highly uncertain as the conductance of the mine roofs are unknown, and there are no data of the previous mining available to calculate it.
- The cone of groundwater drawdown due to Grasvally is similarly about 1 kilometre in all directions.
- The aquifer above the stopes is not completely dewatered due to the limited vertical hydraulic conductivity at this depth. The fracturing of bedrock becomes less frequent with depth and water bearing fractures becomes tighter.

Cumulative impact of Volspruit and Grasvally:

- In the extreme worst case with both opencast mines at Volspruit at maximum and Grasvally Lower-Level stopes dewatered, the cone of drawdown extend to about 500 metres beyond the Nyl River, and the calculated drawdown increase to about 20 metres.
- There is also a merging of the cones of groundwater depression between Grasvally and Volspruit to ≈ 30 metres and the drawdown at the Nyl is somewhat increased by 5 metres at most.

Lowering of the Groundwater Level below the Nyl River:

The drawdown of the groundwater at the Nyl River is transient because of mining progress. It can be concluded from the transient simulation that:

- Drawdown at the river is modelled to be about 5 metres below surface with irrigation only. However, large scale irrigation abstraction has already lowered the groundwater levels in the Volspruit and surrounding areas by at least 5 to 10 metres.
- The groundwater level recedes very slowly until about year 6 when mining progress to the west in the direction of the Nyl river.
- The groundwater level then deepens to about 12 metres at the maximum depth of the pit at year 9.
- As mining is discontinued the groundwater level will start rebounding to reach normal levels of five metres below surface at year 12.
- Thereafter the reaction of the groundwater will depend on the use of the water, especially at Grasvally.
- However, should the extracted groundwater water be used for irrigation and water supply to Mokopane, the groundwater levels could stabilise at levels of at least 5 to 10 metres below surface.
- Due to the thick clay layer separating the river surface water from the aquifer below during periods of normal flow, the normal flow of the Nyl River will not be affected.
- It is only when the river is in flood and overflowing its banks that surface water could seep through the gravelly and sandy regolith to the aquifer below.
- This is normal behaviour for a flood in the Nyl River as a result of the separation of surface water and groundwater following the large-scale irrigation in the area for several decades (see paragraph 8).
- Thus, if surface water ingress into the open pits is prevented by adequate berms, the normal flow the river and the progression of mayor floods should not be changed significantly.

From the numerical modelling of the flow of contamination post mining, it is concluded that:

- Groundwater flow direction is dominated by groundwater abstraction rather than topographical features.
- Migration of potential pollution will thus be towards the most prominent groundwater abstraction areas rather than the topographical downstream regions as would be intuitively expected.
- Thus, groundwater extraction for irrigation determine the direction of groundwater flow before mining, while the flow will be towards the Grasvally Mine during mining.
- However, the impact on the underlying aquifer and groundwater receptors will be insignificant due to the low acid generation capacity of the ore and bedrock.

Numerical Modelling (Water Quality): Once the normal groundwater flow conditions have been re-instated, polluted water can migrate away from the rehabilitated opencast. Although the overburden has been shown to be non-acid generating, the geochemical study predicted limited production of sulphate. Thus, seepage from the backfilled opencasts will most likely be contaminated as a result of neutral mine drainage. As sulphate is normally a significant solute in such drainage, it has been modelled as a conservative (non-reacting) indicator of mine drainage pollution. The geochemical model indicated that the sulphate concentration in the pit will be about 100 mg/litre over a period of 100 years after the discard rock have been backfilled into the pit. The period of 100 years were chosen as various studies have shown that contamination are decreased to almost nothing through various processes such as absorption, dilution etc, over long time scales.

Firstly, the migration of contaminated water from the mining area has been modelled with current irrigation included. The results are presented in Figure 39. It follows from this figure that:

- The plume is drawn towards the irrigation areas to the west of the Nyl River and underflow the river, but is deep below the floodplain bed and does not affect the surface water.
- There is also a substantial plume migration to the irrigation areas south of the mining area but is not predicted to reach those boreholes in the forecast period.
- It thus follows that the direction of plume migration is dominated by groundwater abstraction, as result of the almost horizontal water table. The groundwater flow will thus always be to where the water table is lowered.

Secondly, the migration of contaminated water from the mining area has been modelled with irrigation as well as abstraction from the Grasvally mine for Mokopane after closure. The flow patterns in the aquifer changed significantly in this scenario as illustrated in Figure 40:

- Plume movement is now significantly in the direction of Grasvally and is a more important factor of influence on groundwater flow than the abstraction for irrigation in the groundwater.
- This change in groundwater flow direction is due to the proximity of the underground mine to the Volspruit site as well as the depth of the defunct underground mine.

It is therefore concluded that:

- Groundwater flow direction is dominated by groundwater abstraction rather than topographical features.
- Migration of potential pollution will thus be towards the most prominent groundwater abstraction areas rather than the topographical downstream regions as would be intuitively expected.
- However, the impact on the underlying aquifer and groundwater receptors will be insignificant due to the low acid generation capacity of the ore and bedrock.

Significance Rating:

Impacts	Significance = Irreplaceability (Reversibility + Intensity + Duration + Extent) X Probability		Mitigation Efficiency (ME)	Significance Rating (WM) = Significance Rating (WOM) x Mitigation Efficiency	
Drawdown of North Pit	60	Medium	1	60	High
Drawdown of South Pit	60	Medium	1	60	High
Decanting of North Pit	15	Very low	0.6	9	Very low
Decanting of South Pit	15	Very low	0.6	9	Very low
Groundwater Quality of Pits	60	High	0.6	36	Low
Groundwater Quality of YSF & RWD	45	Medium	0.6	27	Low

Recommendations: Based on the finding in this report and previous work conducted, the following recommendation can be made:

- It was seen in this report that the biggest groundwater impact risk of this mine is the cone of depression extending to the aquifer below the Nyl River, but it has been proved to be unlikely to have a major influence on the normal flood progression due to the impermeable clay layer underneath river. Nevertheless, ensuring a well-constructed flood protection berm downstream of the North Pit is considered essential to ensure that no flood can overtop to the east of the Nyl River in the North Pit. Another option is to construct a similar berm west of the Nyl as well, thus creating a natural clay-bottomed channel for the unimpeded passing of floods. The berm should be as impermeable to water as possible.
- Although four of the five materials assessed (Rougher Tails Composite, ROM2, Pyroxenite and Norite) have been reclassified from Type 3 to Type 4 and may therefore be disposed of at a Class D barrier system. ROM1 remains classified as Type 3 and requires disposal at a Class C barrier system based solely on its mercury leachable concentration. Although the updated Waste Classification indicates that the majority of the materials may be managed as Type 4 waste, the initial Waste Classification undertaken in 2012 by Escience classified the waste as Type 3. Considering the historical classification and the presence of ROM1, it is recommended, as a precautionary and conservative measure, that the waste rock dump continue to be managed as Type 3 waste and that a Class C barrier system be provided.
- In addition to the solid waste streams, the wastewater expected to be contained in the proposed irrigation dam was also classified in accordance with GN R635, using modelled North Pit sump water quality (Mills Water, 2026). Across all six modelled operating scenarios, the water is classified as Type 3, primarily due to nitrate concentrations associated with background groundwater influenced by historical agricultural fertiliser use. The wastewater therefore also requires a Class C barrier system.
- During numerical modelling of various scenarios, grouting has not been successful in containing the cone of depression, nor influence decanting significantly. Therefore, grouting can thus no longer be recommended as an ultimate solution.
- The next risk of importance is that the pit could decant during high rainfall periods. But it has been shown to be rather unlikely, and the pit water is predicted to be of acceptable quality. Nevertheless, it is essential that the post mining pit water is managed to ensure that decant cannot occur. Should future quality monitoring provide proof of acceptable pit water quality, connection with the river for ecological purposes can be considered.
- Lastly, there will be the development of a plume of contamination from the North Pit, as well as from the surface facilities such as the tailings facility and waste rock dump. It has been shown in this report that acid mine drainage is unlikely to develop an the predicted water quality should thus be at an acceptable level. It could be that nitrate contamination might occur due to the use of groundwater as process water, but that must be proved by monitoring. It is thus essential that groundwater quality be monitored regularly during and post mining on a quarterly basis to provide a reliable database to facilitate eventual closure of the mining operation. Water samples must be taken from all the monitoring boreholes by using approved sampling techniques and adhering to recognised sampling procedures. Samples should be analysed for both organic as well as inorganic pollutants, as mining activity often lead to hydrocarbon spills in the form of diesel and oil. At least the following water quality parameters should be analysed for:
    - Major ions (Ca, K, Mg, Na, SO4, NO3, Cl, F)
    - pH
    - Electrical Conductivity (EC),

- Total Petroleum Hydrocarbons (TPH)
- Total Alkalinity