Future Flow
GROUNDWATER & PROJECT MANAGEMENT SOLUTIONS

Future Flow Reference: PEM.19.003
Client Reference:

21 November 2019

Prism EMS
PO Box 1401
Wilgeheuwel
Johannesburg
1736

Attention: Monica Niehof

NORTHAM PLATINUM ZONDEREINDE 3 SHAFT DEVELOPMENT

GROUNDWATER ASSESSMENT

Good day Monica,

Please see attached the groundwater report for the Northam Platinum Zondereinde – 3 Shaft Development Project. The report details baseline groundwater conditions as well as the environmental impact assessment that was done.

Please do not hesitate to contact me should you have any questions or comments.

Best regards,

Martiens Prinsloo Pr.Sci.Nat
Future Flow GPMS cc

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M.J. Prinsloo (Pr.Sci.Nat)

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NORTHAM PLATINUM ZONDEREINDE 3 SHAFT DEVELOPMENT

GROUNDWATER ASSESSMENT

For

Prism EMS

Future Flow Document: PEM.19.003/Groundwater Report
21 November 2019

NORTHAM PLATINUM ZONDEREINDE 3 SHAFT DEVELOPMENT

GROUNDWATER ASSESSMENT

For

Prism EMS

Report Issue	FINAL		
Reference Number	PEM.19.003		
Title	Northam Platinum Zondereinde – 3 Shaft Development Project. Groundwater EIA assessment		
	Name	**Signature**	**Date**
Author	Martiens Prinsloo (M.Sc.; Pr.Sci.Nat)	[signature]	21 November 2019
Reviewed			
Review / Comment			

EXECUTIVE SUMMARY

Introduction

Future Flow was contracted by Prism Environmental Management Services ("Prism") to conduct a geohydrological investigation for the proposed extension of the Zondereinde 3 Shaft Development.

Due to the distance of the Western Block from the existing No 1 and 2 Shaft which access the ore body it was decided to provide additional access to the ore body nearer to the mining operations. This access will be via two raise bored shafts from surface to 5 level which is 1 520 m below collar. In addition, these new mining areas will require additional ventilation which will be provided by a downcast ventilation shaft and 2 up-cast ventilation shafts; five vertical shafts in total.

The shafts will be positioned on two constructed terraces one for the up-cast ventilation shafts (Terrace 2) and one for the two access shafts and one downcast ventilation shaft (Terrace 1). The two terraces will require a servitude between them for services. The servitude will carry buried power cables from the main consumer substation to the ventilation shafts.

Desktop studies from previous groundwater investigations at the area held under the Zondereinde Mining Rights were used to characterise the baseline groundwater environment and develop a conceptual groundwater flow and contaminant transport model.

General Site Description

The Zondereinde Mine is located approximately 16 km north east of Northam and 25 km south of Thabazimbi within the Limpopo Province in the Republic of the South Africa.

The proposed No 3 shaft development study area is situated in a relatively flat area with an elevation that ranges between 960 and 980 mamsl. It slopes gently to both the north and the northwest. There is a cluster of low hills located to the southwest.

The surface water drains into the Bierspruit located west of the study area. There are a number of non-perennial rivers that are seasonal and flow only after periods of rainfall.

Prevailing Groundwater Conditions

Geology

Regional Geology

The PGM deposits in South Africa are situated within the Bushveld Igneous Complex, which extends 480 km from east to west and 240 km north-south over the North West and Limpopo Provinces.

The Proterozoic (2.06Ga to 2.058Ga) Bushveld Complex is divided into the lower Rustenburg Layered Suite, the Lebowa Granite Suite and the felsic extrusive rocks of the Rashoop Granophyre Suite.

The study area is located in the Upper Critical Zone of the western lobe of the Rustenburg Layered Suite of the Bushveld Igneous Complex (Smith, Basson, & Reid, 2015). It is located north of the Pilanesberg and comprises of the Swartklip Facies, which is characterised by the much smaller UG2-Merensky separation.

The Merensky Reef within the study area is divided into Normal and "Pothole" Reef Sub-Facies. The regional pothole Sub-Facies are further divided into three different reef types. Reef type changes are difficult to predict. The UG2 Reef occurs between 20 and 40 m below the Merensky Reef and displays more consistent characteristics than the Merensky Reef, with insignificant reef disturbances. The UG2 Reef is largely mined below where the Merensky Reef was previously mined.

Local Geology

Site specific geology is obtained from previous reports and the available geological map. The ultramafic / mafic rocks of the Rustenburg Layered Suite dominate the study area.

The study area is underlain by gabbro norite, magnetite gabbro and granites of the Bushveld Complex. The deeper geology of the study area comprises anorthosite, norite and pyroxenite. Alluvium overlies the rocks in the eastern part of the study area along the Crocodile River.

Diabase Pilanesberg dykes and faults associated with the northwest-southeast trending Middelaagte Graben extends beyond the study area. The maximum thickness of the steeply dipping diabase dykes is estimated to be 50 m.

<u>Hydrogeology</u>

Three aquifers occur in the study area, associated with the alluvial aquifer material, shallow weathered fractured material and the underlying competent and fractured rock material.

Alluvial Aquifer

The alluvial aquifer is composed of unconsolidated layers of sand and silt deposits. The aquifer is unconfined and laterally discontinuous, localised within the immediate vicinity of the river banks and the floodplains, and therefore does not extend regionally throughout the total study area. These aquifers are usually fairly high yielding due to their interaction with the surface water bodies, coupled with the relatively high storage capacity of the unconsolidated sediments.

Shallow Weathered Material Aquifer

The upper 2 m of the soil consists of the semi-confining black turf layer. The Bushveld Igneous Complex norite weathers to form a dark brown to black, very clayey vertisol soil horizon. During dry weather the soil forms deep open fissures or shrinkage cracks, while the soil becomes sticky and slow draining during wet weather. This results in varying hydraulic conductivities in the expansive clay layer. When saturated the clays are highly impermeable but allow for infiltration and recharge through the surface cracks during dry conditions.

The upper weathered aquifer is below the turf layer and has an average depth of approximately 9 to 12 m. These average values are not absolute values for the entire study area.

The borehole yields in this aquifer are seasonally variable, due to the strong dependence on rainfall recharge. The groundwater quality in undisturbed areas is good due to the dynamic recharge from rainfall. This aquifer is, however, more likely to be affected by contaminant sources situated on surface.

Fractured Rock Aquifer

The ultramafic / mafic Rustenburg Layered Suite consists of relatively low permeability sediments that have been subjected to extensive faulting associated with the intrusion of the Bushveld sediments.

Groundwater flows in the fractured rock aquifer are associated with the secondary fracturing in the competent rock and, as such, will be along discrete pathways associated with the fractures. Faults and fractures in the competent rock can be a significant source of groundwater, depending on whether the fractures have been filled with secondary mineralisation.

<u>Groundwater Levels</u>

None of the geotechnical pits within the Shaft 3 footprint area, which in general were dug to between 2 and 3 m depth before refusal occurred, intercepted the groundwater level. Therefore, reference was made to the groundwater monitoring program that is in place for the wider Northam Zondereinde MRA. The groundwater levels vary throughout the study area. The deepest groundwater levels are observed in borehole NPG13, which is located east of the Smelter area. There is no certainty around the reason for the low groundwater level in borehole NPG13. The depth to groundwater levels in the other Zondereinde monitoring boreholes are shallower, ranging between 1.02 and 23.09 mbgl.

The groundwater levels within individual boreholes remained within a similar range over time (July 2016 to April 2019), indicating that the existing underground mine dewatering has no impact on the near surface groundwater levels.

Plotting groundwater level elevation versus topographical elevation for this study area yields an 85.7% correlation. From this it is concluded that the groundwater levels generally mimic topography in the areas where the boreholes are located. Bayesian interpolation is used to interpolate the groundwater levels throughout the study area.

Groundwater Potential Contaminants

Reef storage silo: The Reef disposal site will store reef rock from underground. It will hold 1 day hoisting capacity that is 4 500 tons. Hydraulically operated discharge chutes will be fitted below the silo. The chutes will discharge into road trucks that transfer the reef to the concentrator.

The material stored within the silo will not be in contact with open ground and therefore, there is no risk of contamination to the underlying aquifers.

Waste storage silo: The Waste storage silo will store waste rock from underground. It will hold 2 days hoisting capacity that is 1 500 tons. Hydraulically operated discharge chutes will be fitted below the silo. The chutes will discharge into road trucks that transfer the reef to the existing waste dump.

The material stored within the silo will not be in contact with open ground and therefore, there is no risk of contamination to the underlying aquifers.

Storm water dam: Storm water will be collected in drains and gravity fed to a storm water dam for evaporation or to be used to top up the service water on the shaft. The dam will be excavated from the heaving clay layer and lined with PVC sheeting. The dam will be approximately 30 m × 50 m.

It is assumed that the lining of the dam will be maintained. In addition, the dam will be sized by a competent person to be able to contain runoff during rainfall event without accidental spillage. Therefore, there is no risk of contamination to the underlying aquifers.

Aquifer Characterisation

For aquifer vulnerability, reference is made to the aquifer vulnerability map of South Africa which shows a low aquifer vulnerability for the study area. Impacts to the aquifers from the proposed shaft development are discussed in Section 6 of this report.

The aquifers present in the study area are classified as minor aquifers but of high importance to the local landowners, as they are their sole source of water for domestic and agricultural (stock watering and irrigation) purposes.

Environmental Impact Assessment

Construction Phase

Underground mining operations are in progress and there is existing surface infrastructure operational. Mined material is brought to surface, processed, and the tailings material deposited on the TSF. The proposed No 3 and no 4 Shaft development will only be to access the underground mine at a closer point and current production volumes will be maintained.

Impacts on groundwater volumes

Construction of the No 4 shaft will be completed by December 2021. The shaft will be excavated to 1 546 m depth. The shaft will be lined with shotcrete, thereby reducing, or eliminating, groundwater inflows into the shaft. It is expected that due to the lining the shaft will have minimal impact on the groundwater levels in the surrounding aquifers.

Construction of the No 3C Shaft will lead to a maximum vertical drawdown in groundwater level of around 150 m. The maximum zone of influence for the groundwater level drawdown is calculated to be 175 m. The dewatering cone does not impact any private owned groundwater boreholes or surface streams.

The No 3 shaft will be lined using shotcrete, similar to the No 4 shaft. The shotcrete will reduce or eliminate groundwater inflows into the shaft. Similar to the No 4 shaft it is expected that the No 3 shaft will have minimal impact on the groundwater levels in the surrounding aquifers.

Similar to the No 3C Shaft the No 3B Shaft will be unlined, allowing groundwater to seep into the shaft. The zone of influence of the groundwater level drawdown cone is calculated to be approximately 175 m. The dewatering cone does not impact any private owned groundwater boreholes or surface streams.

Similar to the No 3c and 3A Shafts the No 3B Shaft will be unlined. As with the No 3A and 3B Shafts it is assumed that there is a 150 m extinction depth to the underlying aquifers. The zone of influence of the groundwater level drawdown cone is calculated to be approximately 175 m. The dewatering cone does not impact any private owned groundwater boreholes or surface streams.

Impacts on groundwater qualities

The material excavated during construction of the different shaft areas will be stored in the waste storage silo before being moved to the existing waste rock dump. This material in the waste storage silo will not be in direct contact with the soil or the underlying aquifers and is not expected to impact the groundwater qualities.

The groundwater flow directions around the No 3A, 3B, and 3C Shafts will be directed towards the individual shafts due to drawdown of the groundwater levels in the shafts. This will prevent contaminant migration away from these 3 shafts. Lining, or sealing off, of individual seepage zones will further mitigate contaminant migration.

Lining of the No 3 and No 4 shafts will also prevent contaminant migration away from those 2 shafts. Based on this, it can be said that it is expected that there will be little to no impact on the groundwater qualities from the excavation of the various shafts as long as the lining is maintained properly.

The storm water dam will be lined. Therefore, no impacts on the underlying aquifers from the SWD on the underlying groundwater qualities are expected assuming the dam will be constructed correctly and maintained properly.

Operational Phase

Impacts on groundwater volumes

It is expected that there will be minimal impact on the groundwater levels in the aquifers around the No 3 and No 4 shafts due to the fact that the shafts will be lined.

Drawdown in groundwater level around the unlined shafts (No 3A, No 3B, and No 3c) is expected to be around 150 m to the limit of the active aquifer, while the zone on influence of the groundwater level drawdown cone is expected to be in the order of 175 m. Sealing off of individual seepage zones will further reduce the impact.

Impacts on groundwater qualities

The material excavated from the underground mine via the proposed No 3 and No 4 shaft development area will be stored in the Reef and Waste storage silos before being moved to the existing concentrator and waste rock dump areas. The material stored in these silos is not in direct contact with the soil or underlying aquifers and is not expected to have an impact on the groundwater qualities, assuming that all the mined material is stored, and the silos are properly maintained.

The groundwater flow directions around the unlined No 3A, 3B, and 3C Shafts will be directed towards the individual shafts due to drawdown of the groundwater levels in the shafts. This will prevent contaminant migration away from these 3 shafts. Lining of the No 3 and No 4 shafts will also prevent contaminant migration away from those 2 shafts. Based on this, it can be said that it is expected that there will be little to no impact on the groundwater qualities from the various shafts.

The storm water dam will be lined. Therefore, no impacts on the underlying aquifers from SWD on the underlying groundwater qualities are expected.

Mitigating and Management Measures to be included in the EMP and IWULA

Monitoring Program

There are no monitoring boreholes around the proposed No 3 Shaft infrastructure. It is recommended that monitoring boreholes be installed:

- Down gradient of the storm water dam;
- Down gradient of the Reef and waste storage silos.

Remediation of the Physical Activity

The shaft entrances will be closed at the end of life of operations.

Remediation of Environmental Impacts

Mitigation and remediation measures contained in the approved EMPs and WUL should be complied with by Northam in respect of the Existing MRA (including the Western Block), including continuing the existing groundwater monitoring program for at least 5 years after mine closure to monitor the contaminant migration.

Reasoned Professional Opinion

It is recommended that the Project be authorized. This recommendation is based on:

- The impact assessment shows that it not expected that there will be any measurable impact on the groundwater levels in the area. No privately-owned boreholes around the proposed No 3 shaft development area will be impacted by the groundwater level drawdown in the fractured rock aquifer;
- It is not expected that there will be a notable impact on the groundwater qualities within the proposed No 3 shaft development area.

Conditions for Authorisation

There are no conditions for authorisation, except commitment to optimal management and monitoring of the expected impacts as described in Sections 8 and 9 of this report.

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1. Introduction

1.1 Background introduction

Future Flow was contracted by Prism Environmental Management Services ("Prism") to conduct a geohydrological investigation for the proposed extension of the Zondereinde 3 Shaft Development.

Due to the distance of the Western Block from the existing No 1 and 2 Shaft which access the ore body it was decided to provide additional access to the ore body nearer to the mining operations. This access will be via two raise bored shafts from surface to 5 level which is 1 520 m below collar. In addition, these new mining areas will require additional ventilation which will be provided by a downcast ventilation shaft and 2 up-cast ventilation shafts; five vertical shafts in total.

The shafts will be positioned on two constructed terraces one for the up-cast ventilation shafts (Terrace 2) and one for the two access shafts and one downcast ventilation shaft (Terrace 1). The two terraces will require a servitude between them for services. The servitude will carry buried power cables from the main consumer substation to the ventilation shafts.

A servitude will be required between the current Zondereinde operations and terrace. This servitude will carry service water, sewerage, backfill slurry, power cables and overhead power lines.

Overhead power lines will be installed to connect terrace 1 to the adjacent Eskom high voltage overhead lines. The existing two potable water pipelines will be diverted within the terrace area (1) and an off-take to the new facility will be done from the existing line.

The current paved road from the R510 to the current shaft and concentrator facility will be diverted around terrace 1 and an additional unpaved road will be required from the existing paved road to terrace 2.

Desktop studies from previous groundwater investigations at the area held under the Zondereinde Mining Rights were used to characterise the baseline groundwater environment and develop a conceptual groundwater flow and contaminant transport model.

1.2 Description of the development

Please note there is other infrastructure listed in the background information document not listed and described here. This includes the salvage yard, explosive bay, compressor house, winder houses, refrigeration plant and others. However, because these areas are located above the groundwater level and/or sealed and operated in such a way that no impact on the groundwater environment is expected, these points are not discussed here.

The existing infrastructure at Zondereinde that fall outside the footprint area of the proposed shaft development is not covered in this document.

1.2.1 Terrace 1

The Project will provide access to the reef horizon for men, material and mining services as well as ore removal to surface. This section provides a functional description of the infrastructure that will be installed on terrace 1.

1.2.2 No 3 Shaft

No 3 Shaft is a men and material hoisting shaft that will transport men and material to and from 3 level (1,320 m below collar) to surface. The shaft is 4.6 m diameter, equipped with a steel headgear, and will be lined with shotcrete and equipped with steel shaft guides.

Hoisting will be done with a ground mounted double drum winder housed in a winder house adjacent to the shaft and headgear.

The shaft will be equipped with a single conveyance and a counterweight and various mining services will be installed into the shaft.

The shaft will be an intake shaft for ventilation and air will be cooled by passing it through a bulk air cooler via a ventilation duct into the shaft.

1.2.3 No 4 Shaft

No 4 Shaft is a rock hoisting shaft that will hoist rock from 4 level (1,380 m below collar) to surface. The shaft is 4.6 m diameter and will be lined with shotcrete and equipped with steel shaft guides. Various mining services will also be installed into the shaft. The shaft will be equipped with a steel headgear which allows for the discharge of rock from underground into a headgear bin from where it will be discharged onto an overland conveyor belt and transported to surface reef and waste silos. The ore and waste will be trucked from the silos to the existing concentrator and existing waste rock dump (No new waste rock dump will be required).

Hoisting will be done with a ground mounted double drum winder housed in a winder house adjacent to the shaft and headgear.

The shaft will be equipped with two conveyances mounted in bridles.

The shaft will be an intake shaft for ventilation and air will be cooled by passing it through a bulk air cooler via a ventilation duct into the shaft.

1.2.4 No 3C Shaft

No 3C Shaft is a bald downcast shaft. The shaft is 4.6 m diameter and will be unlined. The shaft will be equipped with a cover connected to a ventilation duct. The shaft will be an intake shaft for ventilation and air will be cooled by passing it through a bulk air cooler via a ventilation duct into the shaft.

1.2.5 Reef storage silo

The reef storage silo will store reef rock from underground. It is sized to hold 1-day hoisting capacity of approximately 4,500 tons. Hydraulically operated discharge chutes will be fitted below the silo. The chutes will discharge into road trucks that transfer the reef to the concentrator.

1.2.6 Waste storage silo

The waste storage silo will store waste rock from underground. It is sized to hold 2-days hoisting capacity of approximately 1,500 tons. Hydraulically operated discharge chutes will be fitted below the silo. The chutes will discharge into road trucks that transfer the reef to the existing waste dump.

1.2.7 Storm water dam

Storm water will be collected in drains and gravity fed to a storm water dam for evaporation or to be used to top up the service water on the shaft. The dam will be excavated from the heaving clay layer and lined with PVC sheeting. The dam will be 30 m × 50 m.

The purpose of Terrace 2 is to house the two up-cast ventilation shafts (3A and 3B Shafts) each equipped with two ventilation fans. The shafts will be positioned 75 m apart. The ventilation shafts will be raise-bored, unlined and will be 4.6 m diameter hole once completed. The fans are connected to the shafts by means of steel ventilation ducts. The fans will discharge the underground air vertically from the fan chambers. Overhead medium voltage (11 kV) power lines will feed a substation which will provide the fans and its ancillary equipment with power.

The terrace will be constructed by excavating and removing the heaving clay layer of approximately 2 m and filling and compacting graduated fill to provide a stable base for the mounting of the fans and substation (The clay will be stored for rehabilitation on the existing topsoil storage facility and the fill material will be sourced from waste rock available on the mine site). The storm water runoff will be collected in a drain that is constructed around the perimeter of the terrace. The water will be collected in a sump and pumped to terrace 2 where it will flow into the storm water reservoir. A gate house with single toilet and hand basin will be constructed at the entrance to the terrace (A septic take will serve as waste collection for the toilet and basin). The terraced area will be secured with fencing and a gate to prevent unauthorised entry to the machinery. To the terrace will be by unpaved road from the existing mine paved road.

1.3 Existing Impacts

There are currently no existing impacts on the groundwater environment within the proposed development area. Therefore, there is no discussion of cumulative impacts in this report.

1.4 Potential Impacts

The following potential impacts from the Project on the surrounding groundwater environment were assessed:

- Impacts from construction and operation of the shaft areas;
- Impacts from construction and operation of the surface storage stockpiles (reef storage silo and the waste storage stockpile);
- Impacts from the construction and operation of the storm water dam;
- Expected impacts on the surface water quality due to contaminant migration away from the proposed infrastructure within the Shaft 3 development area.

It should be noted that impacts from the existing Zondereinde surface infrastructure outside of the proposed Shaft 3 footprint area is not included in this document as it has been addressed in previous studies and do not form part of this investigation.

1.5 Aim of the Investigation

The aim of the groundwater investigation is to characterise the current baseline groundwater environment. This includes aspects such as:

- Identification and characterisation of the aquifers present in the area;
- Aspects that control groundwater flow through the area (geological structures etc.)
- Groundwater flow patterns;
- Recharge from rainfall;
- Predevelopment groundwater quality; and
- Surface water / groundwater interaction.

In addition to the baseline characterisation the expected impacts are identified, characterised and quantified for the constriction and operational phases.

1.6 Timing of the Investigation

The study relies on field investigations that were done during groundwater investigations done by Future Flow at Zondereinde during 2016 and 2018. These field studies were conducted during both the rainy and dry seasons and therefore incorporate seasonal changes in aspects, such as:

- Depth to groundwater level; and
- Groundwater quality.

1.7 Specialist Expertise

Future Flow is a privately held consulting company based in Pretoria, South Africa that has been in operation since 2008. We provide specialist groundwater consulting services. Our clients range from mining companies and energy suppliers to private developers operating throughout Africa.

Key staff allocated to this project includes:

Martiens Prinsloo: Martiens is a principal hydrogeologist at Future Flow and holds an MSc degree in hydrogeology from the University of the Free State, South Africa. He has more than 19 years' experience in water management studies and environmental impact assessments and has been involved in more than 200 groundwater studies during the past two decades. Martiens is responsible for data analysis, the conceptual model, the 3D numerical modelling and reporting.

Martiens has been involved in a number of other mining related studies in the region during the past decade. His CV can be viewed in Appendix A.

1.8 Consultation process

The client was consulted for any pertinent issues raised by I&APs.

1.9 Declaration of Independence

We, Future Flow Groundwater & Project Management Solutions cc, act as the independent specialists in the environmental authorisation for the Project. We will perform the work relating to the environmental authorisation application in an objective manner, even if this results in views and findings that are not favourable to the applicant.

We declare that there are no circumstances that may compromise our objectivity in performing such work. We have expertise in conducting the groundwater specialist study and report relevant to the environmental authorisation application. We confirm that we have knowledge of the relevant environmental Acts, Regulations and Guidelines that have relevance to the proposed activity and my/our field of expertise and will comply with the requirements therein.

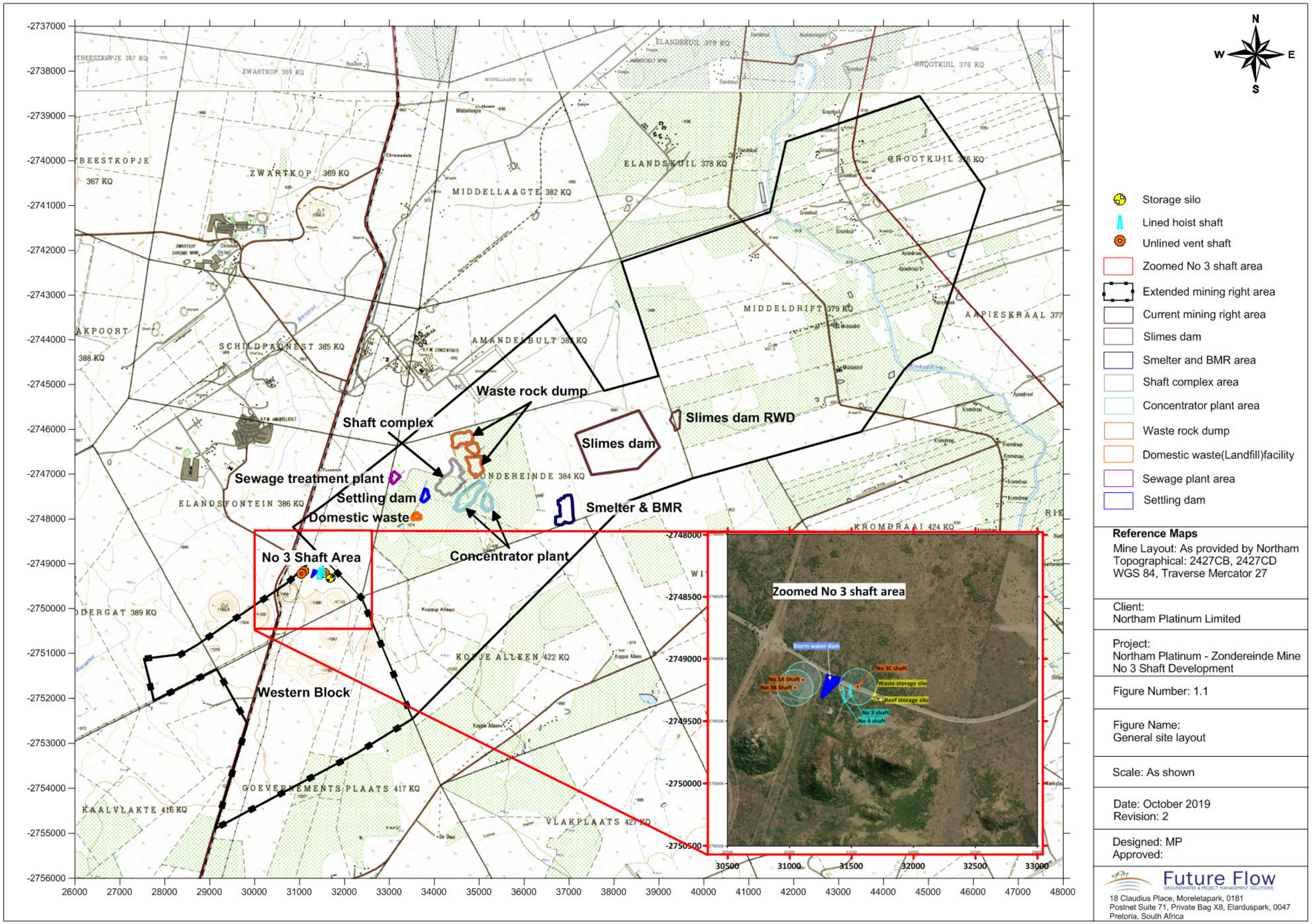
We have not, and will not engage in, conflicting interests in the undertaking of the activity that will impact the objectivity of any report, plan or document to be prepared by ourselves for submission to the competent authority.

We undertake to disclose to the applicant and the competent authority all material information in our possession that reasonably has, or may have, the potential of influencing any decision to be taken with respect to the application by the competent authority.

All particulars furnished by me/us in this report are true and correct. We realise that a false declaration is an offence in terms of regulation 48 of the National Environmental Management Act, 107 of 1998 (NEMA) and is punishable in terms of section 24F of the Act.

__________________________ _____2019/11/21_____

Signed Date



Reference Maps
Mine Layout: As provided by Northam
Topographical: 2427CB, 2427CD
WGS 84, Traverse Mercator 27

Client:
Northam Platinum Limited

Project:
Northam Platinum - Zondereinde Mine
No 3 Shaft Development

Figure Number: 1.1

Figure Name:
General site layout

Scale: As shown

Date: October 2019
Revision: 2

Designed: MP
Approved:

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2. Geographical Setting

2.1. Topography and Drainage

The Zondereinde 3 Shaft development falls within the Zonderdeinde Western Block and falls on the Remainder of the Farm Elandsfontein 386-KQ and the Remainder of the Farm Zondereinde 384-KQ, situated in the Magistrate District of Thabazimbi, Limpopo Province.

The study area is located approximately 16 km north east of Northam and 25 km south of Thabazimbi within the Limpopo Province in the Republic of the South Africa. A general locality map is shown in Figure 1.1. Maps relevant to the study area include:

- 1: 50 000 scale topographical maps (2427CC and 2427CD);
- 1: 250 000 scale geological map (2426 - Thabazimbi);
- Surface layouts provided by Northam;
- Satellite image of the area (Google Earth); and
- Other published data on the study area. These sources are of varying age but is considered to be representative of current conditions (geology, climate, groundwater).

The proposed No 3 shaft development study area is situated in a relatively flat area with an elevation that ranges between 960 and 980 mamsl. It slopes gently to the north and the northwest. There is a cluster of low hills located to the south.

The No 3 Shaft study area falls within the A24F Quaternary Catchment, within the Limpopo Water Management Area (WMA). The immediate No 3 Shaft area drains into the Bierspruit, located west of the study area, via unnamed, non-perennial tributaries (Figure 2.2). There are a number of non-perennial rivers that are seasonal and flow only after periods of rainfall.

2.2. Climate

The study area is situated in the Limpopo Province, a semi-arid rainfall region which is characterised by cool, dry winters (May to August) and warm, wet summers (October to March). Temperatures vary from an average monthly maximum and minimum of 31.8°C and 19.4°C for January to 23.7°C and 2.7°C for June respectively. Figure 2.1 shows the average rainfall and temperature data for Northam.

Rainfall station data for Northam indicate average annual rainfall of between 500 and 550 mm/a. However, the evapotranspiration in the study area is expected to be relatively high compared to the average annual rainfall, thereby reducing the gross recharge from rainfall. Effective recharge to the aquifers ranges between 1 and 2 % of the mean annual rainfall.

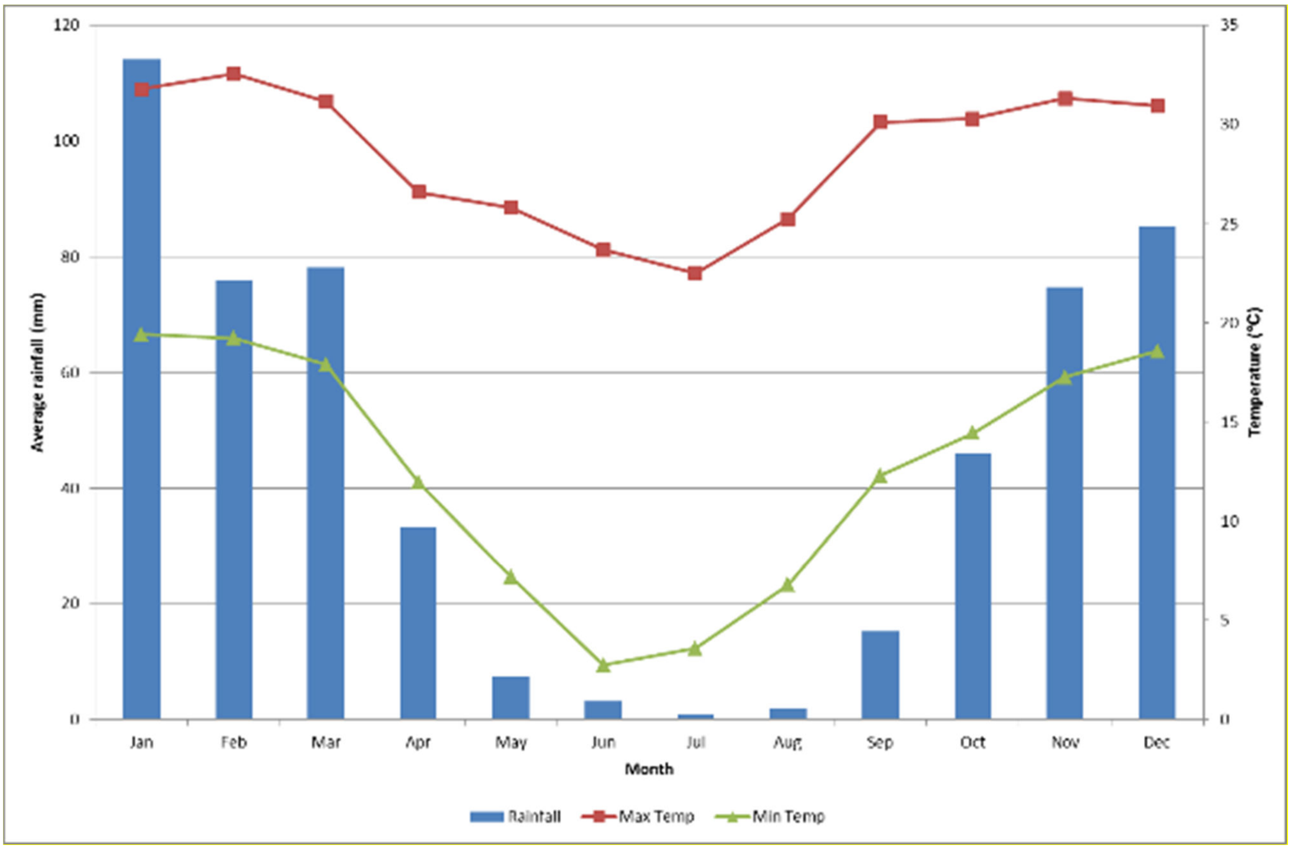
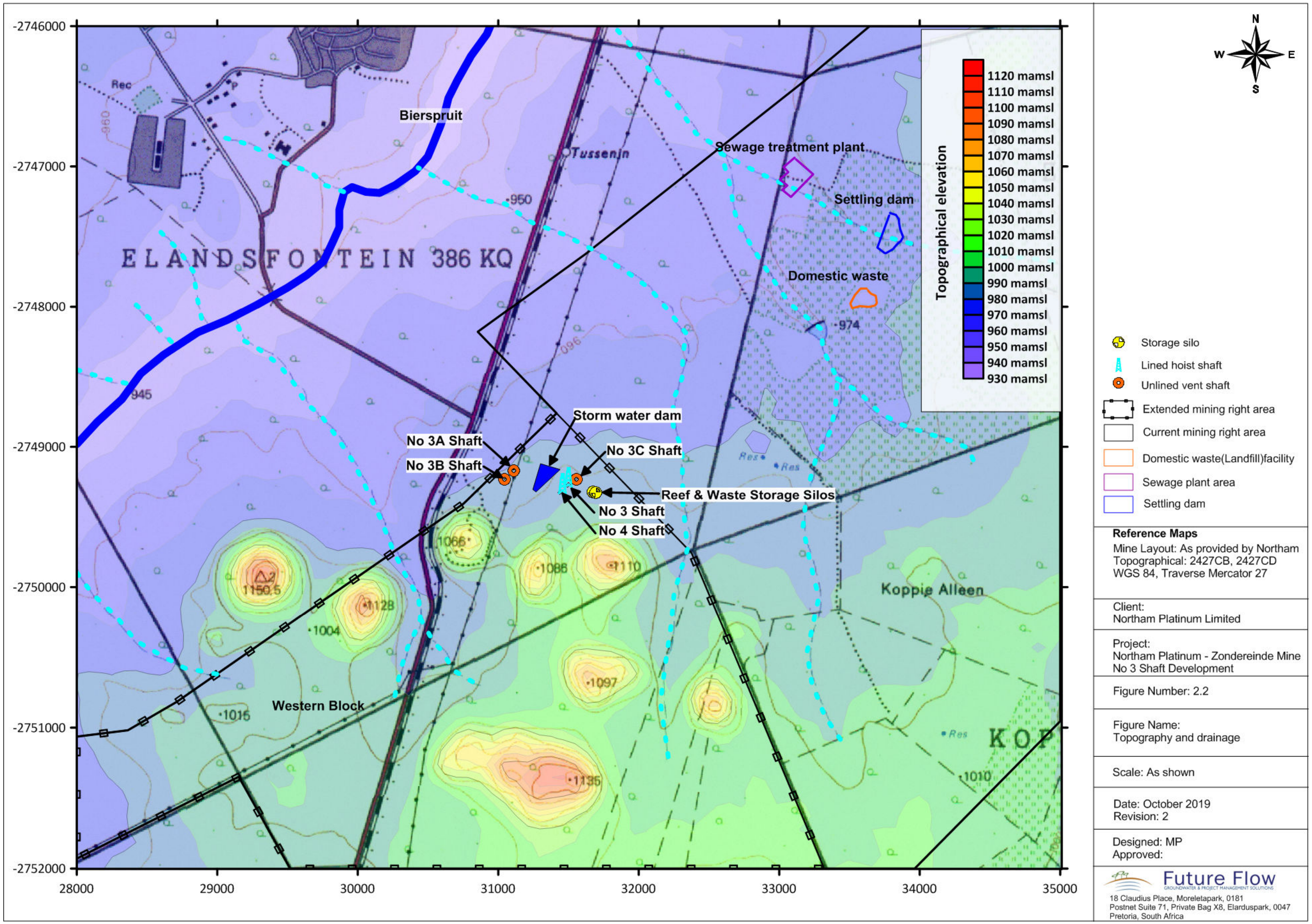


Figure 2.1: Rainfall and temperature distribution in Northam


Biersspruit
ELANDSFONTEIN 386 KQ
Sewage treatment plant
Settling dam
Domestic waste
Storm water dam
No 3A Shaft
No 3B Shaft
No 3C Shaft
Reef & Waste Storage Silos
No 3 Shaft
No 4 Shaft
Western Block
Koppie Alleen
Topographical elevation
1120 mamsl
1110 mamsl
1100 mamsl
1090 mamsl
1080 mamsl
1070 mamsl
1060 mamsl
1050 mamsl
1040 mamsl
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-2751000
-2752000
28000
29000
30000
31000
32000
33000
34000
35000
N
W
E
S
Storage silo
Lined hoist shaft
Unlined vent shaft
Extended mining right area
Current mining right area
Domestic waste(Landfill)facility
Sewage plant area
Settling dam
Reference Maps
Mine Layout: As provided by Northam
Topographical: 2427CB, 2427CD
WGS 84, Traverse Mercator 27
Client:
Northam Platinum Limited
Project:
Northam Platinum - Zondereinde Mine
No 3 Shaft Development
Figure Number: 2.2
Figure Name:
Topography and drainage
Scale: As shown
Date: October 2019
Revision: 2
Designed: MP
Approved:
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Pretoria, South Africa

3. Scope of Work

The scope of work includes:

3.1 Phase 1 – Project Initiation and Desk Study

The existing data was collected and reviewed. Data that was assessed included:

- Any available data that Northam could provide. This included results from the existing groundwater monitoring program, details of the proposed shaft development, and geological information; and
- Public domain information (geological maps, topographical maps, publications on previous studies in the region etc.).

3.2 Phase 2 – Groundwater Risk and Impact Assessment

The risk to the surrounding and overlying aquifers was assessed using analytical methods. In particular impacts on underlying and surrounding groundwater:

- Flow patterns due to dewatering;
- Qualities due to seepage from the contaminant sources at the Zondereinde 3 Shat development area.

4. Prevailing Groundwater Conditions

4.1. Geology

1.9.1 Regional Geology

The PGM deposits in South Africa are situated within the Bushveld Igneous Complex, which extends 480 km from east to west and 240 km north-south over the North West and Limpopo Provinces.

The Proterozoic (2.06 Ga to 2.058 Ga) Bushveld Complex is divided into the lower Rustenburg Layered Suite, the Lebowa Granite Suite and the felsic extrusive rocks of the Rashoop Granophyre Suite.

The ultramafic / mafic rocks of the Bushveld Igneous Complex are collectively referred to as the Rustenburg Layered Suite and are divided, from the lower to the upper layers, into the Marginal, Lower, Critical, Main and Upper Zones. The Critical Zone is the host to all PGM mineralisation within the Bushveld Complex.

The Zondereinde Mine is situated in the Upper Critical Zone of the western lobe of the Rustenburg Layered Suite of the Bushveld Igneous Complex (Smith, Basson, & Reid, 2015). It is located north of the Pilanesberg and is comprised of the Swartklip Facies, which is characterised by the much smaller UG2-Merensky separation.

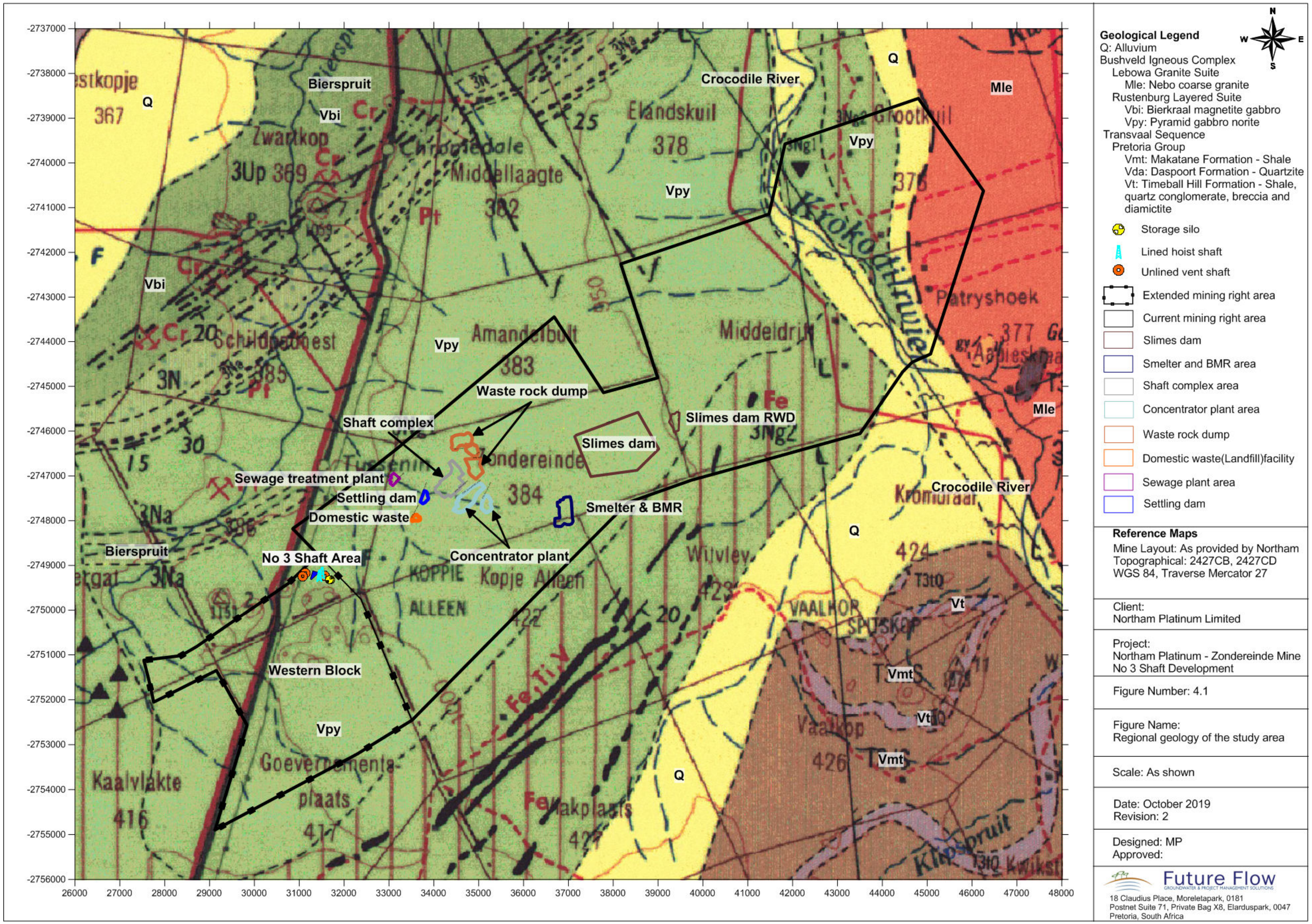
The Merensky Reef in the study area is divided into Normal and “Pothole” Reef Sub-Facies. The regional pothole sub-facies are further divided into three different reef types. Reef type changes are difficult to predict. The UG2 Reef occurs between 20 and 40 m below the Merensky Reef and displays more consistent characteristics than the Merensky Reef, with insignificant reef disturbances. The UG2 Reef is largely mined below where the Merensky Reef was previously mined

1.9.2 Local Geology

Site specific geology is obtained from previous reports and the available geological map (Figure 4.1), 1:250 000 2426 Thabazimbi. The ultramafic / mafic rocks of the Rustenburg Layered Suite dominate the study area.

The study area is underlain by gabbro norite, magnetite gabbro and granites of the Bushveld Complex. The deeper geology of the study area comprises anorthosite, norite and pyroxenite as described in a previous geological report (Northam Platinum Limited, 1998). Alluvium overlies the rocks in the eastern part of the study area along the Crocodile River.

Diabase Pilanesberg dykes and faults associated with the northwest-southeast trending Middelaagte Graben extends beyond the license boundary (Northam Platinum Limited, 1998). The maximum thickness of the steeply dipping diabase dykes is estimated to be 50 m.


Geological Legend
Q: Alluvium
Bushveld Igneous Complex
Lebowa Granite Suite
Mle: Nebo coarse granite
Rustenburg Layered Suite
Vbi: Bierkraal magnetite gabbro
Vpy: Pyramid gabbro norite
Transvaal Sequence
Pretoria Group
Vmt: Makatane Formation - Shale
Vda: Daspoort Formation - Quartzite
Vt: Timeball Hill Formation - Shale, quartz conglomerate, breccia and diamictite
Storage silo
Lined hoist shaft
Unlined vent shaft
Extended mining right area
Current mining right area
Slimes dam
Smelter and BMR area
Shaft complex area
Concentrator plant area
Waste rock dump
Domestic waste(Landfill)facility
Sewage plant area
Settling dam
Bierspruit
Crocodile River
Waste rock dump
Shaft complex
Slimes dam
Slimes dam RWD
Sewage treatment plant
Settling dam
Domestic waste
Smelter & BMR
Concentrator plant
No 3 Shaft Area
Western Block
Vpy
Vbi
Q
Mle
Vt
Vmt
Reference Maps
Mine Layout: As provided by Northam
Topographical: 2427CB, 2427CD
WGS 84, Traverse Mercator 27
Client:
Northam Platinum Limited
Project:
Northam Platinum - Zondereinde Mine
No 3 Shaft Development
Figure Number: 4.1
Figure Name:
Regional geology of the study area
Scale: As shown
Date: October 2019
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Pretoria, South Africa

4.2. Hydrogeology

Three aquifers occur in the study area. These three aquifers are associated with a) the alluvial aquifer material; b) shallow weathered fractured material; and c) the underlying competent and fractured rock material.

4.2.1. Alluvial Aquifer

The alluvial aquifer is composed of unconsolidated layers of sand and silt deposits. The aquifer is unconfined and laterally discontinuous, localised within the immediate vicinity of the river banks and floodplains, and therefore does not extend regionally throughout the total study area. These aquifers are usually fairly high yielding due to their interaction with the surface water bodies, coupled with the relatively high storage capacity of the unconsolidated sediments. The interaction between the alluvial aquifer and the river depends on the differences between the surface water and groundwater levels and the presence or absence of an impervious streambed, which would affect the hydraulic connection.

4.2.2. Shallow Weathered Material Aquifer

The upper aquifer forms due to the vertical infiltration of recharging rainfall through the weathered material being retarded by the lower permeability of the underlying competent rock material. Groundwater collecting above the weathered / unweathered material contact migrates down-gradient along the contact to lower lying areas.

Based on data collected from the geotechnical drilling program conducted within the Shaft 3 footprint area, it is concluded that the upper 2 m of the soil consists of the semi-confining black turf layer. The Bushveld Igneous Complex norite weathers to form a dark brown to black, very clayey vertisol soil horizon. During dry weather the soil forms deep open fissures or shrinkage cracks, while the soil becomes sticky and slow draining during wet weather. This results in varying hydraulic conductivities in the expansive clay layer. When saturated the clays are highly impermeable but allow for infiltration and recharge, through the surface cracks during dry conditions.

The upper weathered aquifer is below the turf layer and has an average depth of approximately 9 to 12 m. These average values are not absolute values for the entire study area. Deeper weathering can also occur. However, the mentioned values are considered to provide a good general indication of the study area's conditions.

The borehole yields in this aquifer are seasonally variable, due to the strong dependence on rainfall recharge. The groundwater quality in undisturbed areas is good because of the dynamic recharge from rainfall. This aquifer is, however, more likely to be affected by contaminant sources situated on surface.

4.2.3. Fractured Rock Aquifer

Although the lower permeability of the unweathered rock material will retard vertical infiltration of groundwater, a percentage of the water in the shallow aquifer will recharge the fractured rock aquifer.

The ultramafic / mafic Rustenburg Layered Suite consists of relatively low permeability sediments that have been subjected to extensive faulting associated with the intrusion of the Bushveld sediments.

Groundwater flows in the fractured rock aquifer are associated with the secondary fracturing in the competent rock and, as such, will be along discrete pathways associated with the fractures. Faults and fractures in the competent rock can be a significant source of groundwater, depending on whether the fractures have been filled with secondary mineralisation.

4.3. Groundwater Levels

None of the geotechnical pits within the Shaft 3 footprint area, which in general were dug to between 2 and 3 m depth before refusal occurred, intercepted the groundwater level. Therefore, reference was made to the groundwater monitoring program that is in place for the wider Northam Zondereinde MRA. The monitoring is conducted on a monthly basis. A total of 40 monitoring borehole points were found from the latest Zondereinde Aquatico monitoring report for April 2019 (please refer to Figure 4.5 for the borehole positions). The April 2019 groundwater levels, as well as details of the monitoring boreholes, are summarised in Table 4.1. The depth to groundwater level in April 2019 at each of the monitoring boreholes is shown graphically in Figure 4.2.

The groundwater levels vary throughout the area. The deepest groundwater levels are observed in borehole NPG13, which is located east of the Smelter area. There is no certainty around the reason for the low groundwater level in borehole NPG13. The depth to groundwater levels in the other monitoring boreholes are shallower, ranging between 1.02 and 23.09 metre below ground level (mbgl).

The changes in groundwater levels over time between July 2016 and April 2019 are shown graphically in Figure 4.4. From the figure it can be seen that the groundwater levels within individual boreholes remained within a similar range over time, indicating that the underground mine dewatering has no impact on the near surface groundwater levels.

In areas where there are no large scale external impacts on the groundwater environment, such as the lowering of groundwater level through dewatering, it is expected that the groundwater level contours will reflect topographical contours. Plotting groundwater level elevation versus topographical elevation yields an 85.7 % correlation as shown in Figure 4.3. From this it is concluded that the groundwater levels generally mimic topography in the areas where the boreholes are located and there is no indication of the aquifers being dewatered. Groundwater level elevation contours for the upper weathered material aquifer are shown in Figure 4.5.

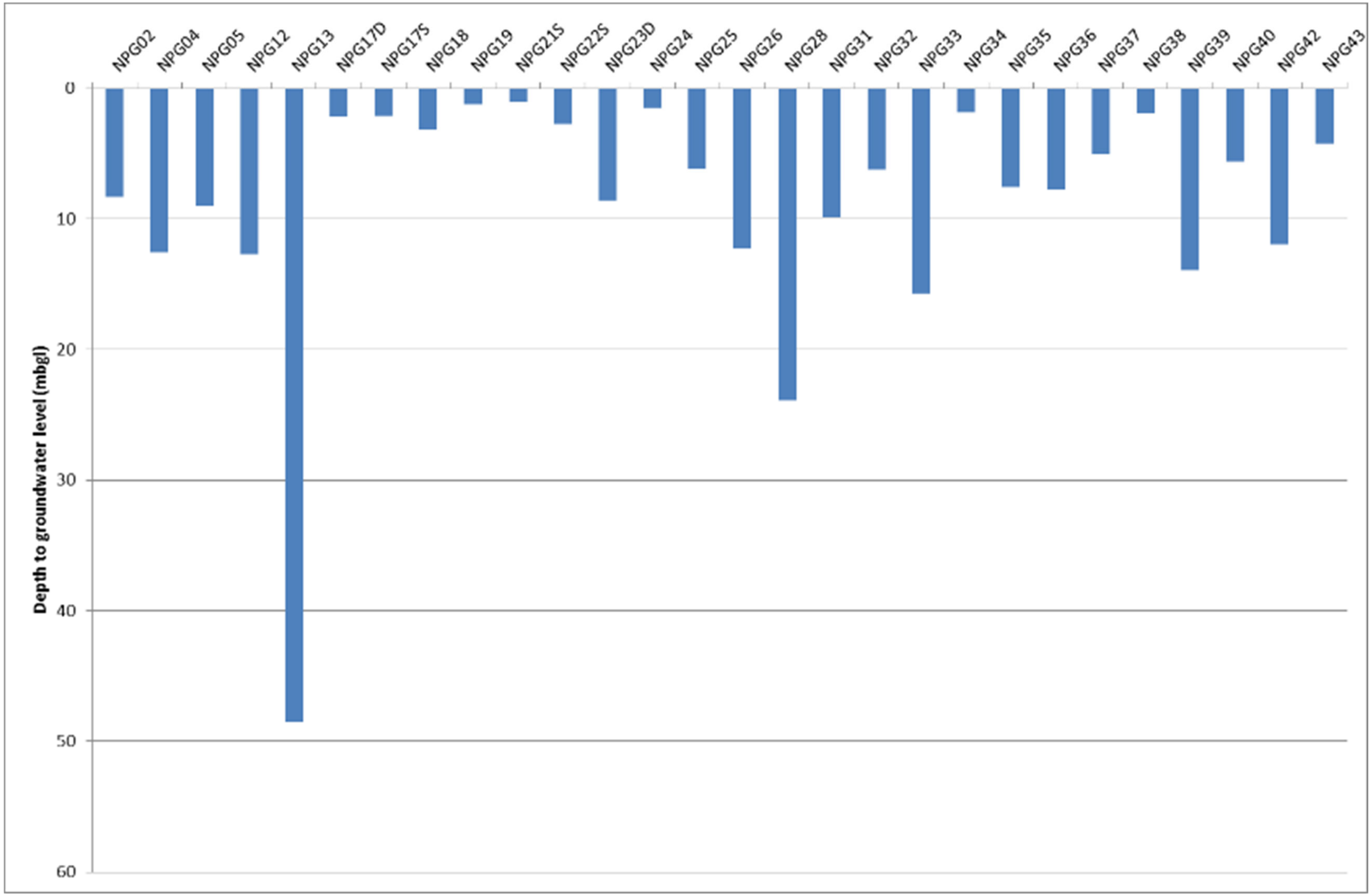


Figure 4.2: Depth to groundwater level.

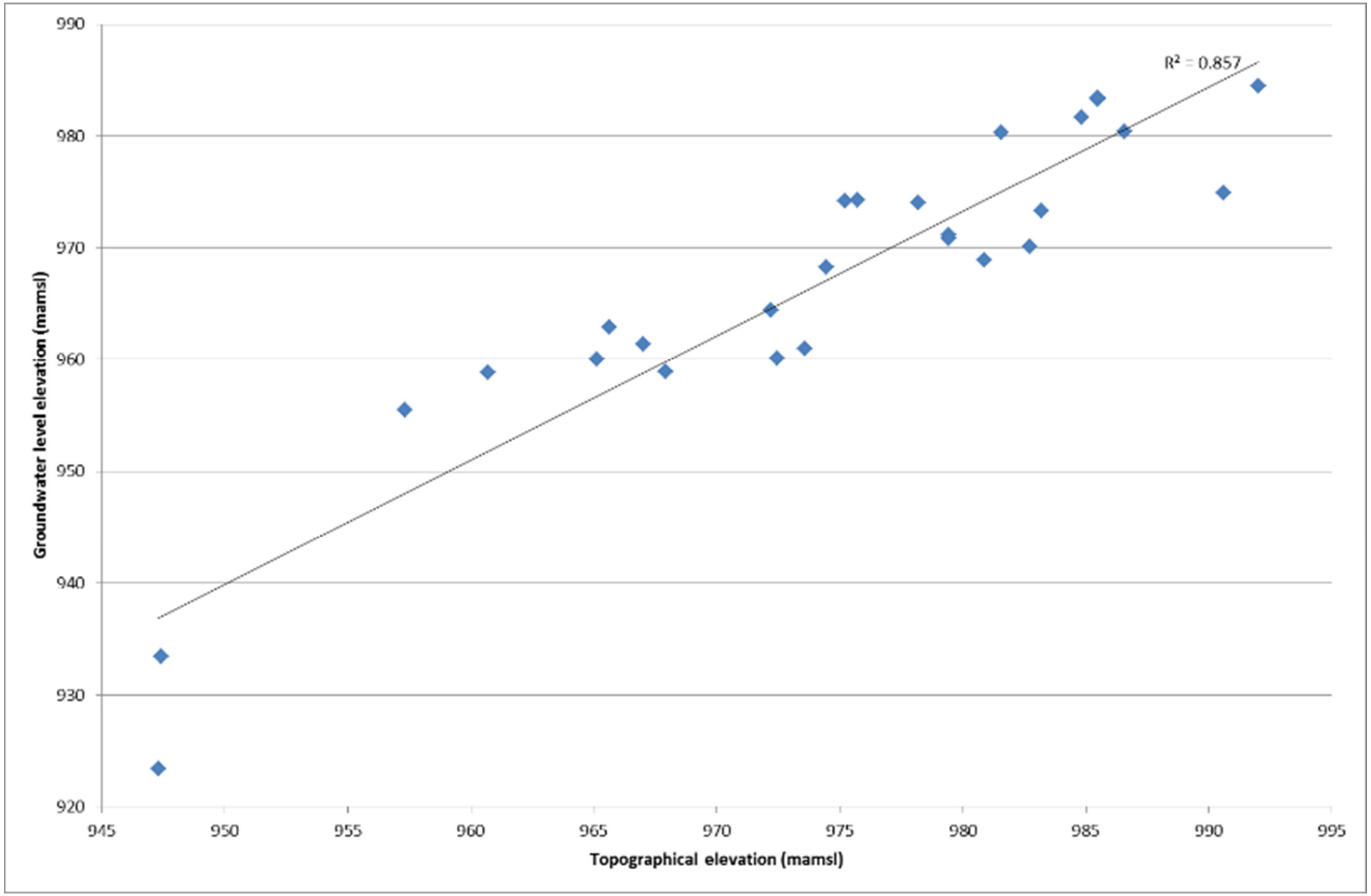


Figure 4.3: Topographical versus groundwater level elevation plot.

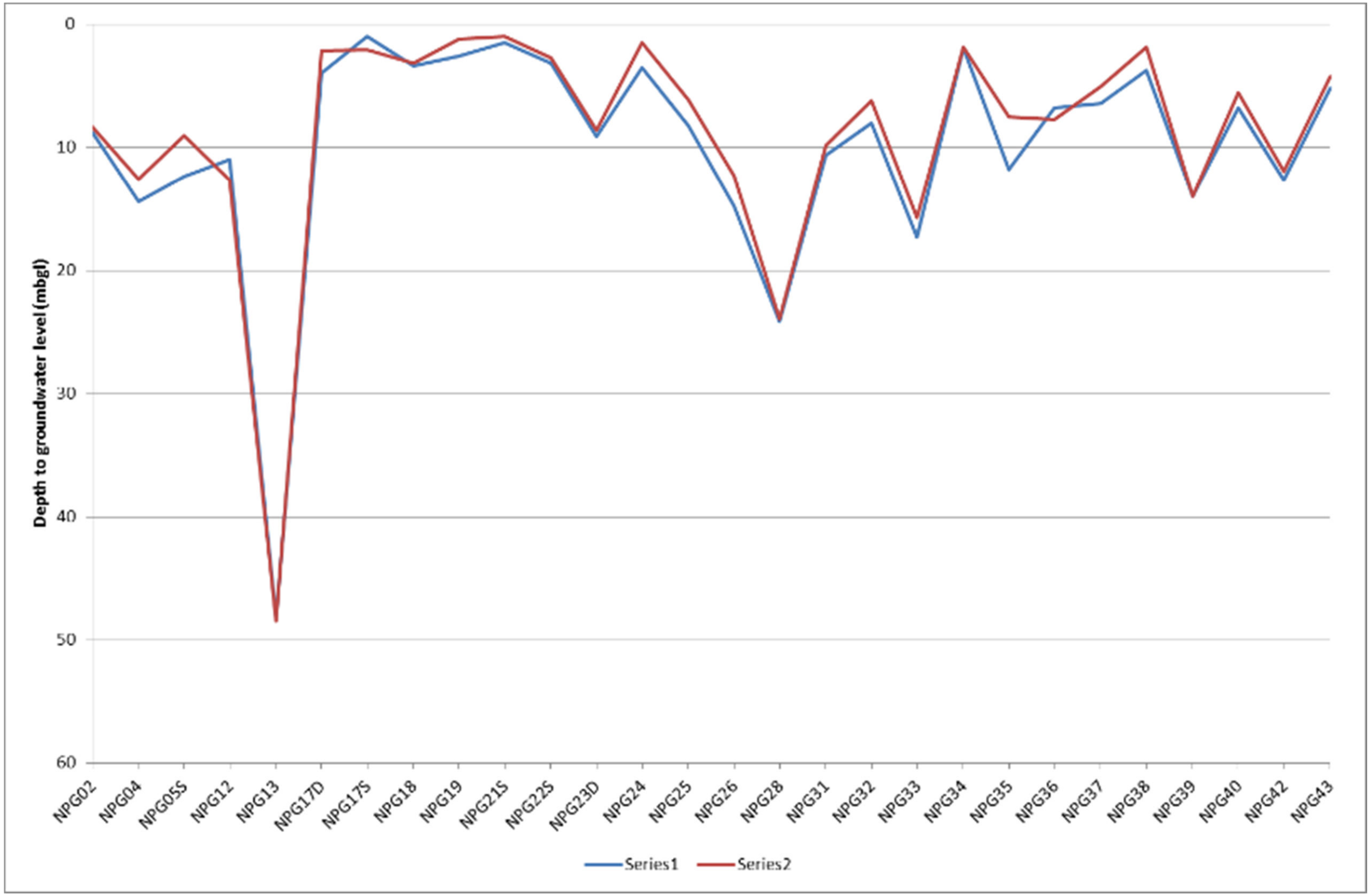
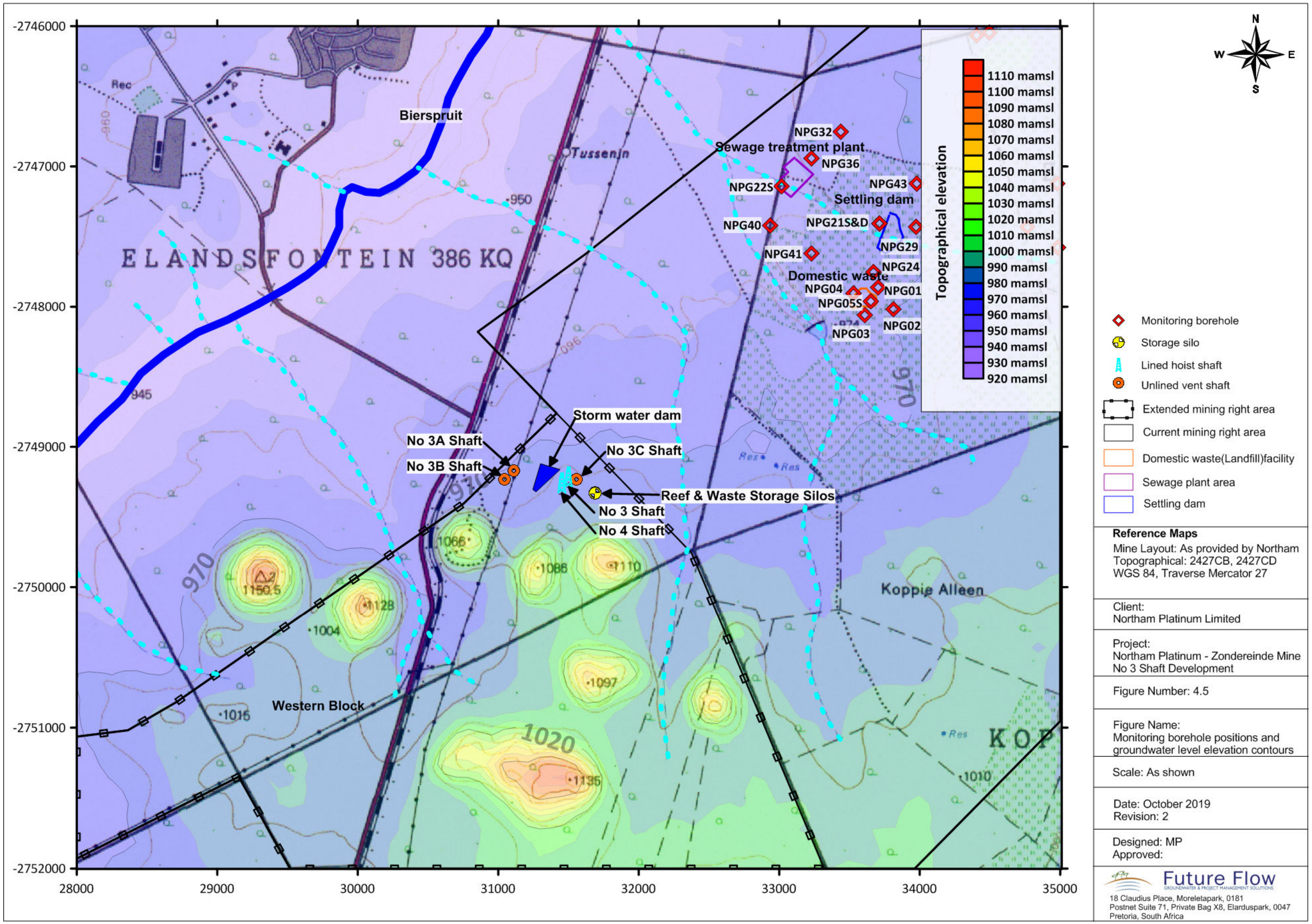


Figure 4.4: Groundwater levels over time (July 2016 and April 2019)


Biersprui
Tussenin
ELANDSFONTEIN 386 KQ
Sewage treatment plant
Settling dam
Domestic waste
NPG32
NPG36
NPG22S
NPG43
NPG40
NPG21S&D
NPG29
NPG41
NPG24
NPG04
NPG01
NPG05S
NPG02
NPG03
Storm water dam
No 3A Shaft
No 3B Shaft
No 3C Shaft
Reef & Waste Storage Silos
No 3 Shaft
No 4 Shaft
Koppie Alleen
Western Block
KOP
Topographical elevation
1110 mamsl
1100 mamsl
1090 mamsl
1080 mamsl
1070 mamsl
1060 mamsl
1050 mamsl
1040 mamsl
1030 mamsl
1020 mamsl
1010 mamsl
1000 mamsl
990 mamsl
980 mamsl
970 mamsl
960 mamsl
950 mamsl
940 mamsl
930 mamsl
920 mamsl
-2746000
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-2750000
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W
E
S
Monitoring borehole
Storage silo
Lined hoist shaft
Unlined vent shaft
Extended mining right area
Current mining right area
Domestic waste(Landfill)facility
Sewage plant area
Settling dam
Reference Maps
Mine Layout: As provided by Northam
Topographical: 2427CB, 2427CD
WGS 84, Traverse Mercator 27
Client:
Northam Platinum Limited
Project:
Northam Platinum - Zondereinde Mine
No 3 Shaft Development
Figure Number: 4.5
Figure Name:
Monitoring borehole positions and
groundwater level elevation contours
Scale: As shown
Date: October 2019
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Pretoria, South Africa

Table 4.1: Monitoring borehole details

BH	East	South	Elevation	Groundwater level (July 2016)		Groundwater level (April 2019)	
	WGS84, LO27	WGS84, LO27	mamsl	mbgl	mamsl	mbgl	mamsl
NPG01	33 702	-2 747 862	972.67	7.27	965.40	-	-
NPG02	33 812	-2 748 018	979.44	8.75	970.69	8.34	971.10
NPG03	33 610	-2 748 062	974.39	11.95	962.44	-	-
NPG04	33 530	-2 747 906	973.58	14.40	959.18	12.59	960.99
NPG05S	33 651	-2 747 962	967.93	12.40	955.53	9.02	958.91
NPG07	35 006	-2 747 533	986.61	-	-	-	-
NPG08	35 007	-2 747 478	986.88	-	-	-	-
NPG09	39 520	-2 745 884	954.72	3.70	951.02	-	-
NPG10	39 702	-2 745 785	950.96	10.00	940.96	-	-
NPG12	34 495	-2 746 048	982.74	11.00	971.74	12.68	970.06
NPG13	37 442	-2 747 706	978.24	48.27	929.97	48.50	929.74
NPG15D	39 631	-2 745 685	952.71	5.10	947.61	-	-
NPG15S	39 631	-2 745 685	952.71	5.45	947.26	-	-
NPG17D	34 986	-2 747 578	985.48	3.95	981.53	2.18	983.30
NPG17S	34 986	-2 747 578	985.48	1.00	984.48	2.08	983.40
NPG18	34 764	-2 747 433	984.82	3.39	981.43	3.16	981.66
NPG19	34 390	-2 747 576	981.55	2.60	978.95	1.24	980.31
NPG21D	33 713	-2 747 408	975.20	1.72	973.48	-	-
NPG21S	33 713	-2 747 408	975.20	1.54	973.66	1.02	974.18
NPG22S	33 016	-2 747 141	965.65	3.16	962.49	2.72	962.93
NPG23D	34 839	-2 745 971	979.41	9.10	970.31	8.60	970.81
NPG24	33 672	-2 747 751	975.72	3.56	972.16	1.50	974.22
NPG25	34 977	-2 747 123	986.56	8.26	978.30	6.16	980.40
NPG26	37 735	-2 747 795	972.47	14.75	957.72	12.32	960.15
NPG27	40 066	-2 745 830	949.48	20.45	929.03	-	-
NPG28	40 358	-2 746 185	947.30	24.11	923.19	23.91	923.39
NPG29	33 976	-2 747 431	975.93	2.25	973.68	-	-
NPG30	34 526	-2 745 682	975.63	8.17	967.46	-	-
NPG31	35 020	-2 746 304	983.20	10.65	972.55	9.88	973.32
NPG32	33 441	-2 746 754	974.46	8.02	966.44	6.20	968.26
NPG33	36 515	-2 746 474	990.59	17.30	973.29	15.72	974.87
NPG34	38 983	-2 746 325	960.70	1.93	958.77	1.85	958.85
NPG35	35 593	-2 747 535	992.00	11.83	980.17	7.55	984.45
NPG36	33 229	-2 746 942	972.21	6.80	965.41	7.77	964.44
NPG37	38 498	-2 745 412	965.14	6.45	958.69	5.08	960.06
NPG38	39 306	-2 746 209	957.33	3.76	953.57	1.88	955.45
NPG39	40 501	-2 746 153	947.41	14.00	933.41	13.95	933.46
NPG40	32 934	-2 747 419	967.02	6.80	960.22	5.60	961.42
NPG41	33 232	-2 747 621	971.50	8.37	963.13	-	-
NPG42	34 407	-2 746 067	980.87	12.64	968.23	11.94	968.93
NPG43	33 977	-2 747 122	978.21	5.23	972.98	4.24	973.97

mbgl = metres below ground level
mamsl = metres above mean sea level
All coordinates are provided in Transverse Mercator projection (LO27), and WGS84 datum

4.4. Specific Site Sensitivities

4.4.1. Underground Mining Area

The existing underground workings are located at depths of 1 294 to 2 300 mbgl. The underground workings in the Western Block will be at similar and greater depths. It is not expected that there will be an active aquifer at those depths. The No 3 Shaft and No 4 Shaft will be lined and it is not expected that there will be significant seepage from the No 3 and No 4 Shaft areas into the surrounding aquifers during the construction and operational phases.

The No 3A, 3B and 3C Shafts will be unlined. Seepage into the shafts will be dewatered and groundwater flow patterns around the shafts will be directed towards the shafts during the construction and operational phases. No contamination is expected to migrate away from the shafts. Please refer to Figure 1.1 for the positions of the shafts.

4.4.2. Surface Infrastructure

As mentioned previously in the report, the fact that the life of mine, as well as the volume of material handled on site, does not increase compared to the originally approved EMP specifications, no significant increase in the impacts at the existing infrastructure is expected.

However, there are new infrastructure areas associated with the proposed Shaft 3 development that could act as pollution sources. These include the reef and waste storage silos as well as the return water dam and the storm water dam. Please refer to Figure 1.1 for the positions of the sensitive areas described below.

<u>Reef storage silo:</u> The Reef disposal site will store reef rock from underground. It will hold 1 day hoisting capacity that is 4 500 tons. Hydraulically operated discharge chutes will be fitted below the silo. The chutes will discharge into road trucks that transfer the reef to the concentrator.

The material stored within the silo will not be in contact with open ground and therefore, there is no risk of contamination to the underlying aquifers.

<u>Waste storage silo:</u> The Waste storage silo will store waste rock from underground. It will hold 2 days hoisting capacity that is 1 500 tons. Hydraulically operated discharge chutes will be fitted below the silo. The chutes will discharge into road trucks that transfer the reef to the existing waste dump.

The material stored within the silo will not be in contact with open ground and therefore, there is no risk of contamination to the underlying aquifers.

<u>Storm water dam:</u> Storm water will be collected in drains and gravity fed to a storm water dam for evaporation or to be used to top up the service water on the shaft. The dam will be excavated from the heaving clay layer and lined with PVC sheeting. The dam will be approximately 50 m x 30 m.

It is assumed that the lining of the dam will be maintained. In addition, the dam will be sized by a competent person to be able to contain runoff during rainfall event without accidental spillage. Therefore, there is no risk of contamination to the underlying aquifers.

4.5. Groundwater Quality

There is no information available on the groundwater qualities within the proposed Shaft 3 development footprint area. However, there are no known pollution sources nearby, and it is accepted that the groundwater quality in this area reflects the background groundwater quality seen from the Zondereinde groundwater quality monitoring program.

The monitoring data indicates that there is no widespread contamination in the mining rights area (MRA). General background groundwater quality trends as seen from the existing groundwater monitoring program can be summarised:

- Background chloride concentrations in monitoring boreholes range within 100 – 250 mg/L:
  - Borehole NPG24;
  - NPG32 and NPG36; and
  - NPG33.
- Background sulphate concentrations in monitoring boreholes range within 10 – 100 mg/L:
  - NPG24;
  - NPG17D, NPG25 and NPG35;
  - NPG12;
  - NPG22S, NPG32 and NPG36;
  - NPG13; and
  - NPG33.

5. Aquifer Characterisation

5.1. Groundwater Vulnerability

For aquifer vulnerability reference is made to the aquifer vulnerability map of South Africa, which shows a low aquifer vulnerability for the study area.

5.2. Aquifer Classification

The aquifers present in the study area are classified as minor aquifers but of high importance to the local landowners, as it is their sole source of water for domestic and agricultural (stock watering and irrigation) purposes.

6. Geohydrological Impacts

The environmental impact assessment is conducted based on the available information and analytical assessments. Reference was also made to the numerical model results from the Numerical Contaminant Transport Model Update Study that was done for the Zondereinde Mine during November 2016.

Impacts from the proposed underground mining activities and from the existing surface infrastructure were evaluated and include impacts on:

- Groundwater levels, flow patterns and volumes;
- Groundwater qualities and plume migration; and
- Surface water qualities due to poor quality groundwater seeping into the surface water in the form of baseflow contribution.

During the risk assessment the risk to the groundwater levels and quality were evaluated. Each of the identified risks was then rated. The rating methodology used is as described in Table 6.1.

The rating is described as follows:

Score out of 100	Significance
1 to 20	Low
21 to 40	Moderate to Low
41 to 60	Moderate
61 to 80	Moderate to high
81 to 100	High

Will **<u>mitigation</u>** be possible (yes or no)? <u>Mitigation measures are further discussed in the EMP section, where post mitigation significance of impacts is also given.</u>

The **<u>Degree of irreplaceable loss of resource</u>** has also been evaluated in the impact assessment table. This has been rated in three categories, including:

Degree of loss	
Low	The resource is renewable or able to recover and therefore negligible loss expected.
Moderate	Resource is at risk of permanent loss but management measures can reduce risk of loss or resource can recover over time or with rehabilitation efforts.
High	Resource will be severely affected and loss will be irreplaceable or very long term, or rehabilitation efforts would be unduly expensive and not economically viable.

Table 6.1: Impact rating methodology

The status of an impact		
Score	**Status**	**Description**
Pos	Positive:	a benefit to the holistic environment
Neg	Negative:	a cost to the holistic environment
Neut	Neutral:	no cost or benefit
The duration of the impact		
Score	**Duration**	**Description**
1	Short term	Less than 2 years
2	Short to medium term	2 – 5 years
3	Medium term	6 – 25 years
4	Long term	26 – 45 years
5	Permanent	46 years or more
The extent of an impact		
Score	**Extent**	**Description**
1	Site specific	Within the site boundary
2	Local	Affects immediate surrounding areas
3	Regional	Extends substantially beyond the site boundary
4	Provincial	Extends to almost entire province or larger region
5	National	Affects country or possibly world
The reversibility of the impact		
Score	**Reversibility**	**Description**
1	Completely reversible	Reverses with minimal rehabilitation & negligible residual affects
3	Reversible	Requires mitigation and rehabilitation to ensure reversibility
5	Irreversible	Cannot be rehabilitated completely/rehabilitation not viable
The effect (severe or beneficial) of the impact		
Score	**Severe/beneficial effect**	**Description**
1	Slight	Little effect - negligible disturbance/benefit
2	Slight to moderate	Effects observable - environmental impacts reversible with time
3	Moderate	Effects observable - impacts reversible with rehabilitation
4	Moderate to high	Extensive effects - irreversible alteration to the environment
5	High	Extensive permanent effects with irreversible alteration
The probability of the impact		
Score	**Rating**	**Description**
1	Unlikely	Less than 15% sure of an impact occurring
2	Possible	Between 15% and 40% sure of an impact occurring
3	Probable	Between 40% and 60% sure that the impact will occur
4	Highly Probable	Between 60% and 85% sure that the impact will occur
5	Definite	Over 85% sure that the impact will occur
The Consequence		= Severity + Spatial Scale + Duration + Reversibility.
The Significance		= Consequence x Probability.

6.1. Construction Phase

Underground mining operations are in progress and there is existing surface infrastructure operational. Mined material is brought to surface, processed, and the tailings material deposited on the TSF. The proposed No 3 and No 4 Shaft development will only be to access the underground mine at a closer point and current production volumes will be maintained.

The construction phase for the proposed shaft developments will entail (in the following order):

- No 3 shaft – construction to be completed by December 2012 and equipping completed by December 2022;
- No 3A Shaft - timing unknown;
- No 4 shaft – timing unknown;
- No 3B Shaft – timing unknown; and
- No 3C Shaft – timing unknown.

As shown above the timing for only the No 3 shaft is known. It is currently estimated that construction will continue until 2030.

6.1.1. Impacts on groundwater volumes

6.1.1.1. No 4 shaft

Construction of the No 4 shaft will be completed by December 2021. The shaft will be excavated to 1 546 m depth. The shaft will be lined with shotcrete, thereby reducing, or eliminating, groundwater inflows into the shaft. It is expected that due to the lining the shaft will have minimal impact on the groundwater levels in the surrounding aquifers should the lining be effective.

6.1.1.2. No 3C Shaft

The No 3C Shaft will be unlined and excavated and 4.6 m diameter. Because the shaft will be unlined groundwater can seep into the shaft over the thickness of the active aquifers. It is currently estimated that the active aquifer will not extend deeper than 150 m from surface. The zone of influence of the groundwater level around the shaft can be calculated using Sichardt's equation:

$$R_i = 3000 D_0 \sqrt{k}$$

Where:

R_i = radius of the zone of influence;

D_0 = maximum drawdown in groundwater level (assumed to be 150 m to the bottom of the active aquifer); and

k = aquifer hydraulic conductivity (3.858 x 10^{-8} m/sec for the fractured rock aquifer).

Thus, it can be calculated that the maximum zone of influence for the groundwater level drawdown around the No 3C Shaft is 88 m. Sichardt's equation is widely acknowledged to under estimate the zone of influence somewhat. Therefore, a value of 175 m is assumed to be conservative. Based on this calculation the dewatering cone (shown in Figure 6.1) does not impact any private owned groundwater boreholes or surface streams.

6.1.1.3. No 3 shaft

The No 3 shaft will be lined using shotcrete, similar to the No 4 shaft. The shotcrete will reduce or eliminate groundwater inflows into the shaft. Similar to the No 4 shaft it is expected that the No 3 shaft will have minimal impact on the groundwater levels in the surrounding aquifers should the lining be affective.

6.1.1.4. No 3A Shaft

Similar to the No 3C Shaft the No 3A Shaft will be unlined, allowing groundwater to seep into the shaft. As with the No 3C Shaft it is assumed that there is a 150 m extinction depth to the underlying aquifers. The zone of influence of the groundwater level drawdown cone is calculated using Sichardt's equation to be approximately 175 m. The dewatering cone (shown in Figure 6.1) does not impact any private owned groundwater boreholes or surface streams.

6.1.1.5. No 3B Shaft

Similar to the No 3c and 3A Shafts the No 3B Shaft will be unlined, allowing groundwater to seep into the shaft. As with the No 3A and 3C Shafts it is assumed that there is a 150 m extinction depth to the underlying aquifers. The zone of influence of the groundwater level drawdown cone is calculated using Sichardt's equation to be approximately 175 m. The dewatering cone (shown in Figure 6.1) does not impact any private owned groundwater boreholes or surface streams.

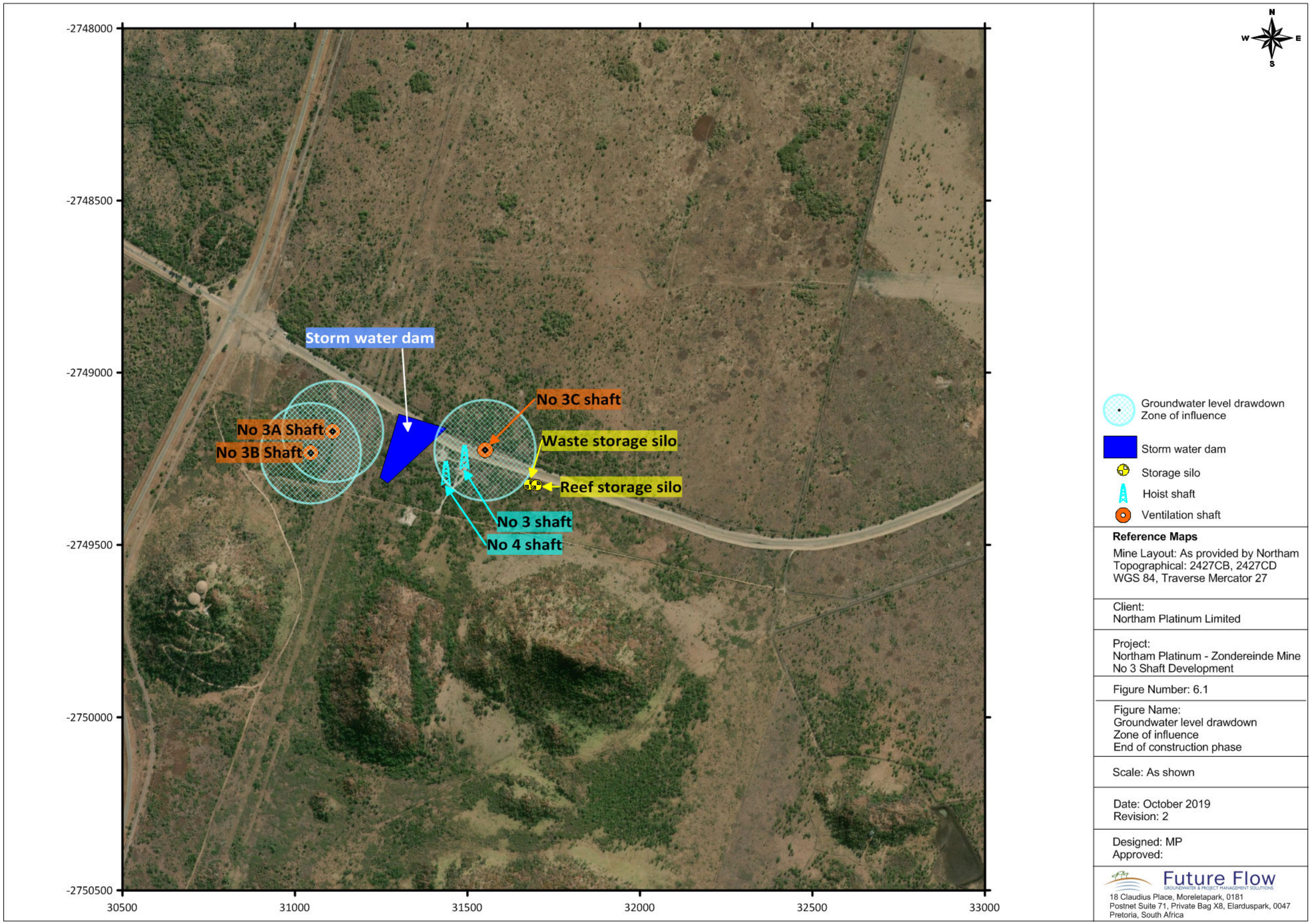
6.1.2. Impacts on groundwater qualities

The material excavated during construction of the different shaft areas will be stored in the waste storage silo before being moved to the existing waste rock dump. The groundwater flow directions around the No 3A, 3B, and 3C Shafts will be directed towards the individual shafts due to drawdown of the groundwater levels in the shafts. This will prevent contaminant migration away from these 3 shafts. Lining of the No 3 and No 4 shafts will also prevent contaminant migration away from those 2 shafts. Based on this, it can be said that it is expected that there will be little to no impact on the groundwater qualities from the excavation of the various shafts.

The storm water dam (SWD) will be lined. Therefore, no impacts on the underlying aquifers from the SWD on the underlying groundwater qualities are expected assuming the dam will be constructed correctly and maintained properly.

6.1.3. Areas to be avoided and buffer zones to be observed

Due to the fact that the impacts on groundwater levels and qualities are not expected to impact any private groundwater users of surface water bodies, none of the proposed development areas have to be avoided. The impacts do not reach any buffer zones around surface water bodies (streams or wetlands).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Storm water dam
No 3C shaft
No 3A Shaft
No 3B Shaft
Waste storage silo
Reef storage silo
No 3 shaft
No 4 shaft
N
W
E
S
Groundwater level drawdown
Zone of influence
Storm water dam
Storage silo
Hoist shaft
Ventilation shaft
Reference Maps
Mine Layout: As provided by Northam
Topographical: 2427CB, 2427CD
WGS 84, Traverse Mercator 27
Client:
Northam Platinum Limited
Project:
Northam Platinum - Zondereinde Mine
No 3 Shaft Development
Figure Number: 6.1
Figure Name:
Groundwater level drawdown
Zone of influence
End of construction phase
Scale: As shown
Date: October 2019
Revision: 2
Designed: MP
Approved:
Future Flow
18 Claudius Place, Moreletapark, 0181
Postnet Suite 71, Private Bag X8, Elarduspark, 0047
Pretoria, South Africa

Table 6.2: Impact rating – Construction phase

Impact	Status	Effect	Extent	Duration	Reversibility	Consequence	Probability	Significance	Mitigation	Degree of irreplaceable loss	Mitigation	Status	Effect	Extent	Duration	Reversibility	Consequence	Probability	Significance
Impacts on groundwater volumes due to dewatering of the lined No 3 and No 4 shafts	Neg	1	2	3	3	9	3	27	Y	Low	Lining of shaft Maintenance of lining	Neg	1	1	3	1	6	2	12
Impacts on groundwater volumes due to dewatering of the unlined No 3A, 3B, and 3C Shafts	Neg	1	2	3	3	9	5	45	Y	Low	Lining / sealing off of individual inflow areas Maintenance of lining	Neg	1	2	3	1	7	4	28
Impacts on groundwater qualities due to construction of the lined No 3 and No4 shafts	Neg	2	2	3	3	10	2	20	Y	Low	Lining of shaft Maintenance of lining	Neg	1	1	3	3	8	1	8
Impacts on groundwater qualities due to construction of the unlined No 3A, 3B and 3C Shafts	Neg	2	2	3	3	10	2	20	Y	Low	Lining / sealing off of individual inflow areas Maintenance of lining	Neg	1	2	3	3	9	1	9
Impacts on groundwater qualities due to seepage from the SWD	Neg	2	2	3	3	10	2	20	Y	Low	Proper construction and maintenance Regular inspection of the lining system	Neg	1	2	3	3	9	1	9

6.2. Operational Phase

6.2.1. Impacts on groundwater volumes

As discussed in Section 6.1.1 for the construction phase, it is expected that there will be minimal impact on the groundwater levels in the aquifers around the No 3 and No 4 shafts due to the fact that the shafts will be lined.

Drawdown in groundwater level around the unlined shafts (No 3A, No 3B, and No 3c) is expected to be around 150 m to the limit of the active aquifer, while the zone of influence of the groundwater level drawdown cone is expected to be in the order of 175 m.

Please refer to Figure 6.1 for a representation of the expected drawdown cones. Note it is similar to that during the construction phase, therefore the same figure is referenced.

6.2.2. Impacts on groundwater qualities

As noted previously in this report groundwater contamination from the existing surface infrastructure has a limited extent and will not impact on the No 3 shaft development area.

The material excavated from the underground mine via the proposed No 3 and No 4 shaft development area during the operational phase will be stored in the Reef and Waste storage silos before being moved to the existing concentrator and waste rock dump areas. The material stored in these silos is not in direct contact with the soil or underlying aquifers and is not expected to have an impact on the groundwater qualities, assuming that all the mined material is stored, and the silos are properly maintained.

The groundwater flow directions around the unlined No 3A, 3B, and 3C Shafts will be directed towards the individual shafts due to drawdown of the groundwater levels in the shafts. This will prevent contaminant migration away from these 3 shafts. Lining of the No 3 and No 4 shafts will also prevent contaminant migration away from those 2 shafts. Based on this, it can be said that it is expected that there will be little to no impact on the groundwater qualities from the various shafts.

The storm water dam will be lined. Therefore, no impacts on the underlying aquifers from the SWD on the underlying groundwater qualities are expected.

6.2.3. Areas to be avoided and buffer zones to be observed

Due to the fact that the impacts on groundwater levels and qualities are not expected to impact any private groundwater users of surface water bodies, none of the proposed development areas have to be avoided. The impacts do not reach any buffer zones around surface water bodies (streams or wetlands).

Table 6.3: Impact rating – Operational phase

Impact	Status	Effect	Extent	Duration	Reversibility	Consequence	Probability	Significance	Mitigation	Degree of irreplaceable loss	Mitigation	Status	Effect	Extent	Duration	Reversibility	Consequence	Probability	Significance
Impacts on groundwater volumes due to dewatering of the lined No 3 and No 4 shafts	Neg	1	2	3	3	9	3	27	Y	Low	Lining of shaft Maintenance of lining	Neg	1	1	3	1	6	2	12
Impacts on groundwater volumes due to dewatering of the unlined No 3A, 3B, and 3C Shafts	Neg	1	2	3	3	9	5	45	Y	Low	Lining / sealing off of individual inflow areas Maintenance of lining	Neg	1	2	3	1	7	4	28
Impacts on groundwater qualities due to operation of the lined No 3 and No4 shafts	Neg	2	2	3	3	10	2	20	Y	Low	Lining of shaft Maintenance of lining	Neg	1	1	3	3	8	1	8
Impacts on groundwater qualities due to operation of the unlined No 3A, 3B and 3C Shafts	Neg	2	2	3	3	10	2	20	Y	Low	Lining / sealing off of individual inflow areas Maintenance of lining	Neg	1	2	3	3	9	1	9
Impacts on groundwater qualities due to seepage from the SWD	Neg	2	2	3	3	10	2	20	Y	Low	Proper maintenance Regular inspection of the lining system	Neg	1	2	3	3	9	1	9
Impacts on groundwater qualities due to seepage from the Reef and Waste Storage Silos	Neg	2	2	3	3	10	2	20	Y	Low	Proper maintenance Regular inspection of the silos	Neg	1	2	3	3	9	1	9

7. Groundwater Monitoring System

7.1. Groundwater Monitoring Network

7.1.1. Source, Plume, Impact and Background Monitoring

Water monitoring is currently undertaken for the existing Zondereinde Mine's operations. A number of boreholes are being monitored for groundwater quality and levels. The monitoring boreholes cover relevant potential pollution sources at the Existing Surface Infrastructure (Smelter and BMR area, slimes and return water dams, waste rock dump, sewage plant area, setline dam etc.). Please refer to Table 4.1 for the monitoring borehole details.

There are no monitoring boreholes around the proposed No 3 Shaft infrastructure. It is recommended that monitoring boreholes be installed:

- Down gradient of the storm water dam;
- Down gradient of the Reef and waste storage silos.

7.1.2. Monitoring Frequency

The current groundwater monitoring takes place on a quarterly basis.

7.2. Monitoring Parameters

Parameters and elements monitored for compliance with the Zondereinde Mine's WUL.

7.3. Monitoring Boreholes

Please refer to Table 4.1 for details on the groundwater monitoring boreholes.

8. Groundwater Environmental Management Programme

8.1. Current Groundwater Conditions

Please refer to Section 4 of this report.

8.2. Predicted Impacts of Facility

Please refer to Section 6 of this report.

8.3. Mitigation Measures

8.3.1. Lowering of Groundwater Level during Facility Construction

Drawdown in groundwater level around the unlined shafts (No 3A, No 3B, and No 3c) is expected to be around 150 m to the limit of the active aquifer, while the zone of influence of the groundwater level drawdown cone is expected to be in the order of 175 m. The drawdown in groundwater level can be mitigated by sealing off individual seepage zones along the shaft lengths.

Lining of the No 3 and No 4 shaft, as well as any lining of the No 3A, 3B, and 3C Shafts should be inspected on a regular interval and maintained / repaired as required.

8.3.2. Lowering of Groundwater Levels during Facility Operation

Drawdown in groundwater level around the unlined shafts (No 3A, No 3B, and No 3c) is expected to be around 150 m to the limit of the active aquifer, while the zone of influence of the groundwater level drawdown cone is expected to be in the order of 175 m. The drawdown in groundwater level can be mitigated by sealing off individual seepage zones along the shaft lengths.

Lining of the No 3 and No 4 shaft, as well as any lining of the No 3A, 3B, and 3C Shafts should be inspected on a regular interval and maintained / repaired as required.

8.3.3. Spread of Groundwater Pollution during Facility Construction

The groundwater flow directions around the No 3A, 3B, and 3C Shafts will be directed towards the individual shafts due to drawdown of the groundwater levels in the shafts preventing contaminant migration away from these 3 shafts. Lining of the No 3 and No 4 shafts will also prevent contaminant migration away from those 2 shafts.

The storm water dam will be lined. Therefore, no impacts on the underlying aquifers from the SWD on the underlying groundwater qualities are expected assuming the dam will be constructed correctly and maintained properly.

8.3.4. Spread of Groundwater Pollution during Facility Operation

The material excavated from the underground mine via the proposed No 3 and No 4 shaft development area during the operational phase will be stored in the Reef and Waste storage silos before being moved to the existing concentrator and waste rock dump areas. The material stored in these silos is not in direct contact with the soil or underlying aquifers and is not expected to have an impact on the groundwater qualities as long as the silos are properly maintained. It is recommended that the silos be inspected on a regular basis and repaired as required.

Lining of the No 3 and No 4 shafts will prevent contaminant migration away from the 2 shafts. It is recommended that the lining of the No 3 and No 4, as well as the No 3A, 3B, and 3C Shafts (where applicable) be inspected and maintained on a regular basis.

The storm water dam will be lined. It is recommended that the structure and the lining of the dam be inspected and maintained on a regular basis to prevent contamination of the underlying aquifers.

9. Post Closure Management Plan

9.1. Remediation of Physical Activity

The shaft excavations cannot be remediated. Closure of the shaft entrances will take place.

9.2. Remediation of Storage Facilities

Surface storage facilities should be cleared and remediated in accordance with the Zondereinde Mines approved EMP and WUL. An application for decommissioning will be required in terms of NEMA and the rehab and closure plan should be amended to include the shaft area.

9.3. Remediation of Environmental Impacts

The groundwater monitoring program should be continued for a period of at least 5 years after mine closure to monitor the contaminant migration, in accordance with the Zondereinde Mines approved EMP and WUL. Based on these results remediation requirements can be identified and a remediation plan put in place.

9.4. Remediation of Water Resources Impacts

Groundwater qualities should be managed and remediated in accordance with the Zondereinde Mines approved EMP and WUL.

10. Conclusions and Recommendations

10.1. General Conclusions

- The study area's topography is in a relatively flat area with an elevation that ranges between 960 and 980 mamsl. It slopes gently to the north and the northwest;
- The study area falls within the A24F Quaternary Catchment of the Limpopo Water Management Area WMA;
- The study area drains into the Bierspruit River, which is located west of the study area;
- There are a number of non-perennial rivers that are seasonal and flow only after periods of rainfall.

10.2. Baseline Groundwater Conditions

- There are three aquifers associated with the alluvial aquifer material, shallow weathered fractured material and the underlying competent and fractured rock material;
- The alluvial aquifer is unconfined and laterally discontinuous, localised within the immediate vicinity of the river banks and the floodplains and therefore does not extend regionally throughout the total study area;
- The upper 2 m of the soil consists of the semi-confining black turf layer;
- When saturated, the black clays are highly impermeable but allows for infiltration and recharge through the surface cracks during dry conditions;
- The upper weathered aquifer is below the turf layer and has an average depth of approximately 9 to 12 m;
- The borehole yields in this aquifer are seasonally variable due to the strong dependence on rainfall recharge;
- Groundwater flows in the fractured rock aquifer are associated with the secondary fracturing in the competent rock and, as such, will be along discrete pathways associated with the fractures;
- The general depth to groundwater levels range between 1.02 and 23.09 mbgl;
- The groundwater levels within individual boreholes remained within a similar range over time (July 2016 to April 2019), indicating that the existing underground mine dewatering has no impact on the near surface groundwater levels;
- Plotting groundwater level elevation versus topographical elevation for this project area yields an 85.7 % correlation;
- Groundwater qualities are currently impacted due to the historic / current activities within the mining right area. Current groundwater contamination around the existing surface infrastructure points has limited plume extents and will not migrate onto the proposed No 3 shaft development area.
- The Bierspruit water quality is consistently poorer down gradient than up-gradient of the MRA. However, monitoring program results show that the contaminant plumes from the MRA do not extend to the Bierspruit. In addition, there are other Mines in the area which are also located up-gradient of the Bierspruit. Based on this, it cannot be said with certainty

that the negative impact on the Bierspruit water qualities can be attributed to the Zondereinde MRA;

- The general water quality in the Bierspruit and Crocodile Rivers comply with the SANS 241: 2015 domestic water quality guidelines.

10.3. Environmental Impact Assessment

10.3.1. Construction Phase

10.3.1.1. Impacts on groundwater volumes

- Construction of the No 4 shaft will be completed by December 2021. The shaft will be excavated to 1 546 m depth. The shaft will be lined with shotcrete, thereby reducing, or eliminating, groundwater inflows into the shaft. It is expected that due to the lining the shaft will have minimal impact on the groundwater levels in the surrounding aquifers;
- Construction of the No 3C Shaft will lead to a maximum vertical drawdown in groundwater level of around 150 m. The maximum zone of influence for the groundwater level drawdown is calculated to be 175 m. The dewatering cone does not impact any private owned groundwater boreholes or surface streams;
- The No 3 shaft will be lined using shotcrete, similar to the No 4 shaft. The shotcrete will reduce or eliminate groundwater inflows into the shaft. Similar to the No 4 shaft it is expected that the No 3 shaft will have minimal impact on the groundwater levels in the surrounding aquifers;
- Similar to the No 3C Shaft the No 3A Shaft will be unlined, allowing groundwater to seep into the shaft. The zone of influence of the groundwater level drawdown cone is calculated to be approximately 175 m. The dewatering cone does not impact any private owned groundwater boreholes or surface streams;
- Similar to the No 3c and 3A Shafts the No 3B Shaft will be unlined. As with the No 3c and 3A Shafts it is assumed that there is a 150 m extinction depth to the underlying aquifers. The zone of influence of the groundwater level drawdown cone is calculated to be approximately 175 m. The dewatering cone does not impact any private owned groundwater boreholes or surface streams.

10.3.1.2. Impact on groundwater qualities

- The material excavated during construction of the different shaft areas will be stored in the waste storage silo before being moved to the existing waste rock dump. This material in the waste storage silo will not be in direct contact with the soil or the underlying aquifers and is not expected to impact the groundwater qualities;
- The groundwater flow directions around the No 3A, 3B, and 3C Shafts will be directed towards the individual shafts due to drawdown of the groundwater levels in the shafts. This will prevent contaminant migration away from these 3 shafts. Lining, or sealing off, of individual seepage zones will further mitigate contaminant migration;

- Lining of the No 3 and No 4 shafts will also prevent contaminant migration away from those 2 shafts. Based on this, it can be said that it is expected that there will be little to no impact on the groundwater qualities from the excavation of the various shafts as long as the lining is maintained properly;
- The storm water dam will be lined. Therefore, no impacts on the underlying aquifers from the SWD on the underlying groundwater qualities are expected assuming the dam will be constructed correctly and maintained properly.

10.3.2. Operational Phase

10.3.2.1. Impacts on groundwater volumes

- It is expected that there will be minimal impact on the groundwater levels in the aquifers around the No 3 and No 4 shafts due to the fact that the shafts will be lined;
- Drawdown in groundwater level around the unlined shafts (No 3A, No 3B, and No 3c) is expected to be around 150 m to the limit of the active aquifer, while the zone on influence of the groundwater level drawdown cone is expected to be in the order of 175 m. Sealing off of individual seepage zones will further reduce the impact.

10.3.2.2. Impact on groundwater qualities

- The material excavated from the underground mine via the proposed No 3 and No 4 shaft development area will be stored in the Reef and Waste storage silos before being moved to the existing concentrator and waste rock dump areas. The material stored in these silos is not in direct contact with the soil or underlying aquifers and is not expected to have an impact on the groundwater qualities, assuming that all the mined material is stored, and the silos are properly maintained;
- The groundwater flow directions around the unlined No 3A, 3B, and 3C Shafts will be directed towards the individual shafts due to drawdown of the groundwater levels in the shafts. This will prevent contaminant migration away from these 3 shafts. Lining of the No 3 and No 4 shafts will also prevent contaminant migration away from those 2 shafts. Based on this, it can be said that it is expected that there will be little to no impact on the groundwater qualities from the various shafts;
- The storm water dam will be lined. Therefore, no impacts on the underlying aquifers from the SWD on the underlying groundwater qualities are expected.

10.4. Reasoned Professional Opinion

It is recommended that the project be authorized. This recommendation is based on:

- The impact assessment shows that it not expected that there will be any measurable impact on the groundwater levels in the area. No privately-owned boreholes around the proposed No 3 shaft development area will be impacted by the groundwater level drawdown in the fractured rock aquifer;

- It is not expected that there will be a notable impact on the groundwater qualities within the proposed No 3 shaft development area.

10.5. Conditions for Authorisation

There are no conditions for authorisation, except commitment to optimal management and monitoring of the expected impacts as described in Sections 8 and 9 of this report.

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APPENDIX A:

CURRICULUM VITAE

PERSONAL DETAILS

NAME:	Martiens Prinsloo
DATE OF BIRTH:	14 January 1976
NATIONALITY:	South African
MARITAL STATUS:	Married

ACADEMIC QUALIFICATIONS

Year	Qualification & Institution
2008	MBA: Graduate School of Business, University of Cape Town
2005	M.Sc. (Geohydrology): University of the Free State (Bloemfontein)
1997	B.Sc. (Hons) (Geohydrology): University of the Free State (Bloemfontein)
1996	B.Sc. (Earth Sciences): University of Pretoria

PROFESSIONAL REGISTRATION AND AFFILIATIONS

Registered Professional Natural Scientist S.A. (SACNASP Reg. No. 400248/04)
Groundwater Division of the Geological Society of South Africa (Membership no. 234)
International Association of Hydrogeologists (IAH membership no. 122757)
International Mine Water Association (IMWA membership no. 1121)

OTHER COURSES

Course	Institution
FeFlow (2009)	DHI WASY (Johannesburg)
Geochemical and reactive transport modelling – PHREEQC, MT3DMS and PHT3D (2006)	University of the Western Cape (Cape Town)
Model sensitivity analysis, data assessment, calibration and uncertainty evaluation (2006)	USGS (Cape Town)
Contaminant Site Risk Assessment and Groundwater Modelling (2004)	Waterloo Hydrogeologic Inc. (Johannesburg)
Groundwater Modelling Course (2002)	Summer University of Bremen (Germany)

EMPLOYMENT HISTORY

Date	Company & Position
July 2008 - Present	Future Flow Groundwater & Project Management Solutions cc Founding Member
Feb 2007 – June 2008	GCS (Pty) Ltd Manager: Water Resources Unit
Jan 2006 – Jan 2007	GCS (Pty) Ltd Manager: Mining & Modelling Sub-Unit (part of Water Resources Unit)
Apr 2002 – Dec 2005	GCS (Pty) Ltd Hydrogeological modeller / Senior hydrogeologist
Sept 2000 – Mar 2002	GCS (Pty) Ltd Field hydrogeologist
Feb 1998 – Aug 2000	Council for Geoscience Scientific Officer - Hydrogeology

SCIENTIFIC EXPERIENCE

Mining related hydrogeology:

- Hydrogeological investigations for various types of mines including: coal, gold, platinum, nickel, copper, cobalt, uranium, heavy mineral sands and diamond. Work experience range from field data collection to data analysis, chemical characterisation, acid base accounting and waste classification, numerical flow and contaminant transport modelling, water balance calculations and compilation of reports;
- Groundwater monitoring and audit reports. The evaluation of groundwater level fluctuation and water chemical data and the compilation of monthly, quarterly and annual monitoring reports;
- Groundwater monitoring well field designs. The siting and design of monitoring boreholes for the assessment of the influence of mining activities on the regional groundwater environment;
- Groundwater investigations and numerical modelling of both fractured rock and primary aquifers;
- Hydrogeological assessments for both opencast and underground mines;
- Water supply for mining activities;
- Mine dewatering assessments and dewatering program designs; and
- Tailings and waste storage facility site selection and impact assessments.

Groundwater resource assessment and development:

- Water supply studies and well field design ranging from rural water supply (hand pump) to large scale water supply for construction and irrigation projects (4 000 m^3/hr);
- Assessment of geological controls, geophysical exploration methods and the quantification of groundwater exploitation potential in complex and problematic terrain;
- Hydrogeological mapping investigations and catchment resource analysis; and
- Regional hydrogeological and chemical investigations involving reconnaissance investigations, geophysical surveys, drilling and test pumping for the planning and development and utilisation of groundwater resources in Southern Africa.

Waste disposal management:

- Environmental Impact Assessments for the manufacturing and petroleum industries. Experience includes field data collection, hydrogeological and chemical data analysis and report compilation;
- Environmental Impact Assessments and site suitability assessments for waste disposal sites (including HH classified sites); and
- Characterisation and numerical modelling of contaminant plume migration.

Energy:

- Conventional coal powered power stations, including underground coal gasification: Site selection and risk assessment, environmental impact assessments, geochemical characterisation of fly ash disposal facilities, and impact mitigation;
- CSP and PV renewable energy: Site selection and risk assessment and environmental impact assessments;
- Bio-mass-to-energy (various energy sources from plant matter to biological waste products): Site selection and risk assessment and environmental impact assessments.

COUNTRIES WORKED IN

Australia, Burkina Faso, Democratic Republic of the Congo (DRC), Ivory Coast, Lesotho, Madagascar, Mali, Mozambique, Senegal, South Africa, Tanzania, Zambia, and Zimbabwe.

LANGUAGE PROFICIENCY

English and Afrikaans – Speak, read, write.

TEACHING

- Part time lecturing at the University of Johannesburg (2001 – 2005): Civil Engineering Course – Hydrogeology.
- Ad hock lecturing at the University of the Witwatersrand (2007 – 2008): Postgraduate / Industrial Masters Course: Coal mining extraction and exploitation – Groundwater contaminant transport modelling;
- Annual course lecturing at the University of Pretoria (2009, 2001 – 2016): Postgraduate course: Groundwater Numerical Modelling.

PAPERS AND PUBLICATIONS

- Prinsloo, M.J. (2004). "Characterisation of the dolomitic aquifer in the Copperbelt Province, Northern Zambia". Waternet / WARFSA Symposium, Windhoek, Namibia.
- Prinsloo, M.J. (2006). "Prediction of mine inflow volumes". Mine Water Conference, Johannesburg, South Africa.
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- Prinsloo, M.J. (2011). "Using groundwater modelling to facilitate your mining operations". Strategic Water Drainage Summit 2011 – Optimising Water Usage and Minimising Impact on Water Quality in Mining Operations. Johannesburg, South Africa.

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