IRENE LEA ENVIRONMENTAL & HYDROGEOLOGY

GEOHYDROLOGICAL SPECIALIST STUDY
ORION MINERALS LTD
PRIESKA ZINC-COPPER PROJECT
VARDOCUBE MINING SECTION

FINAL REPORT

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EXECUTIVE SUMMARY

A geohydrological specialist study was completed to determine and assess the potential impacts of the proposed Vardocube underground mining activities as part of integrated mining planned for the Prieska Copper-Zinc Project. The copper-zinc ore body is situated in a large volcanogenic massive sulphide deposit that is highly deformed and metamorphosed.

The historical mining operations will be re-commissioned as part of the project and both opencast and underground mining of the deposit is planned over a life of mine of 11 years. Underground mining will take place in two stages, shallow mining to a depth of 105m and deep mining to depths of 900 - 1125m. Void stabilisation will be implemented in the shallow underground workings beneath the existing pits and sinkholes to ensure safe mining conditions.

The Vardocube resource will be mined as part of underground mining planned for the Repli Trading 27 (Pty) Ltd (Repli) mining right application, which was already submitted in August 2018. No opencast mining is planned for the Vardocube mining rights area.

Ore mined from both Repli and Vardocube underground and opencast mining will be processed on site. Plant residue will be deposited on a new tailings storage facility (TSF). Waste rock generated during mining will be piled on a new waste rock dump (WRD).

Aquifer characterisation

From a geohydrological perspective three aquifers are present. The upper 15m of the geological succession comprises unconsolidated sand, calcrete and clay, which is expected to be dry except after a rainfall event. The unconsolidated sediments are underlain by a fractured gneiss aquifer, which is estimated to be approximately 100m thick. Groundwater is associated with fractures and faults. The fieldwork data suggests the transmissivity of the gneiss varies between 0,2 and 32 m^2/d. The matrix of this aquifer is expected to have a low transmissivity, probably around 0,2 m^2/d or lower. The average depth to groundwater in this aquifer is 18m, but it is dewatered locally around the historical Prieska Copper Mine (PCM) underground workings. This aquifer is regionally important, as it is used for private groundwater abstraction.

A lower fractured rock aquifer is present at depths greater than 100m. There is currently no information available to characterise this aquifer. The monitoring boreholes drilled during the current project extended to depths of between 80 and 150m below surface and target the upper fractured rock aquifer discussed above. Literature-based aquifer characteristics were therefore used to assess impacts associated with the deep fractured rock aquifer.

A hydrocensus was completed as part of this assessment in order to identify and characterise private groundwater use in the vicinity of the PCM operations. A total of 32 boreholes were located. These boreholes are drilled to an average depth of 40m. Half of the boreholes identified were dry or not in use. Groundwater is solely used for stock watering and none of the boreholes identified during the hydrocensus are used for potable supply. A borehole on the farm Vogelstruisbult, situated east of the PCM mining area is reported to have a high yield, but on average the yields of boreholes identified are low.

A total of 12 groundwater monitoring boreholes were drilled around the proposed project as well as around the historical TSF. One borehole was drilled to a depth of 150m at the historical TSF. The remainder of the boreholes drilled to 80m below surface. The depth to groundwater in these boreholes varies between 6 and 35m below surface, with an average depth of 20m. Regionally, groundwater flows in a southwesterly direction at a gradient of 1:125. Groundwater flow patterns indicate a lowering in groundwater levels around the historical PCM mine and a mound in groundwater levels around the historical TSF.

The sparse intersection of water-bearing features in the boreholes drilled suggests that the aquifers have been dewatered to a large extent in the immediate vicinity of the mine. The information also confirms that groundwater occurrence is erratic in this arid environment. Aquifer tests were completed on the five boreholes that intersected groundwater. The results indicate that two boreholes had yields of 4,5l/s (150 000lph) and 1,9 l/s (82000lph). The yields of the remainder of the boreholes are low, on average 0,06 l/s (2500 lph). The results of the aquifer tests were also used to calculate the transmissivity and storage coefficients for the boreholes. These parameters describe the aquifer conditions intersected in each borehole. Higher transmissivity and storage coefficient values are associated with stronger aquifers. The results indicate that the fractured rock aquifers present are heterogeneous with transmissivities varying between 0,2 and 6,2 m^2/d. The average calculated storage coefficient from the tests is $1,16x10^{-3}$. These values are typical of the rock formations intersected.

The outcome of the chemical analysis of the groundwater samples taken from the hydrocensus boreholes indicate that regionally, groundwater is saline with elevated total dissolved solids, chloride and in some instances sulphate concentrations. The groundwater in private boreholes has also been contaminated with nitrates that are most probably associated with agricultural activities. Elevated selenium and uranium levels are typical for the region, but may result in chronic health risks if ingested over prolonged periods of time.

Groundwater quality in the mining area is characterised by increased sulphate and manganese concentrations. The most significant impact on groundwater quality at the PCM operations is associated with the historical TSF. Sulphate concentrations in this area exceed 2500 mg/l in two of the monitoring boreholes.

The potential sources to groundwater contamination for both the Vardocube and Repli mining areas identified from the available dataset includes the following:

- The historical TSF. Groundwater monitoring information indicates that this facility is already impacting on groundwater quality.
- The proposed new TSF. It is noted that the new TSF will be lined, thus reducing the impact on groundwater quality associated with the facility significantly.
- The underground workings.
- The effluent dam, which will contain poor quality water pumped to surface from the underground workings. This dam will also be lined, thus significantly reducing the risk of groundwater contamination.
- Contamination from these sources may reach the aquifers vertically through the unsaturated soil horizon and the weathered aquifer from surface sources of contamination like the historical TSF. Once the potential contamination reaches the fractured rock aquifer, the preferential flow paths would be the faults and fractures present. Groundwater will also flow through the rock matrix, but at much lower rates compared to the preferential pathways.

The receptors to groundwater contamination includes the following:

- Existing private groundwater users.
- Non-perennial streams near the mining area. It is however noted that these streams are dry and this impact is therefore not anticipated to be of significance.

Geohydrological impact assessment

The assessment of impacts associated with the Vardocube mining rights area was undertaken as in conjunction of the planned Repli mining activities in order to demonstrate the cumulative impact of mining. The impacts were assessed with the calibrated numerical groundwater flow and contaminant transport model constructed during the Repli mining rights geohydrological study in 2018.

In order to gain access to the flooded historical underground workings, mine dewatering will be undertaken prior to the commencement of underground mining. The workings are flooded to a level of 330m below surface. A lined effluent dam will be constructed to contain the extraneous mine water pumped to surface. Even though the deeper rock formations in the immediate vicinity of the underground workings and the shallow aquifers around the sinkholes are dewatered, groundwater seepage may still take place during opencast mining, especially during the wet season. The seepage may be associated with the calcrete, which is expected to retard the infiltration of rainwater. Model simulations suggest that groundwater seepage associated with mining of the Vardocube resource may vary between 0,3 and 23 l/s, but would most probably be around an average of 4,6 l/s.

The cone of depression in the upper fractured rock aquifer as a result of cumulative mine dewatering by Repli and Vardocube is expected to be fault controlled. The drawdown cone may therefore extend up to 1200m from the underground mining area in a southeasterly direction. West and east of the mining area, the cone of depression is not expected to extend further than 600m from the mining area. Two private boreholes are located close to the edge of the simulated cone of depression. It is possible that the impact of mine dewatering could affect these boreholes during mining and it would therefore be prudent to include these in the monitoring programme to ensure that adverse impacts are picked up early.

It is estimated that groundwater levels may take up to 100 years to recover after mine dewatering ceases at closure. It is furthermore unlikely that groundwater levels would fully recover, based on the current level of flooding and the low permeabilities of the rock formations intersected.

Simulations indicate that the most significant impact on groundwater during the operational phase of mining by Repli and Vardocube is associated with the historical TSF.

In the long-term, simulations show that if the new TSF is lined and the liner remains intact, that no groundwater contamination is anticipated from this area. Groundwater contamination associated with the historical underground workings are also not expected to migrate significantly post closure, as groundwater levels will remain reversed towards the mine as groundwater levels rebound after mine closure. No private boreholes fall within the delineated long-term zone of influence on groundwater quality associated with the new TSF and the Repli and Vardocube mining areas.

The impact of the historical TSF will most probably result in the most significant long-term impacts. The fault present underneath the facility is expected to act as a preferential flow path to groundwater. The sulphate plume may migrate up to 1km along the fault from the facility in the long-term. Contamination may also migrate up gradient of the historical TSF in a southeasterly direction along this fault due to the mound in groundwater that forms as a result of recharge from the facility. No private boreholes fall in the zone of influence, but it is possible that two boreholes (BH10 and 116BH9) may be impacted on, as these boreholes may fall on the fault structure mapped in this area.

Groundwater management measures

A number of groundwater management measures are proposed to be integrated into both the Repli and Vardocube mining rights. These are aimed at reducing and/or eliminating adverse impacts and to monitor the effectiveness of groundwater management measures implemented.

A set of over-arching groundwater management measures were provided for the planning, construction, operational and the decommissioning and closure phases of mining.

In addition, specific groundwater management measures are provided to address the impacts on groundwater availability and on groundwater quality.

A detailed groundwater monitoring programme was developed based on the outcome of the study. This includes both hydrocensus and mine monitoring boreholes. Monitoring locations, requirements and frequency is provided.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

LIST OF ACRONYMS USED

BH	Borehole
BPG	Best Practice Guideline
CAF	Cement Aggregate Fill
DTM	Digital Terrain Model
DWS	Department of Water and Sanitation
DWAF	Former Department of Water Affairs and Forestry
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
IAP	Interested and Affected Party
HDPE	High-density polyethylene
iLEH	Irene Lea Environmental and Hydrogeology cc
K	Hydraulic conductivity (unit: m/d)
ktpm	Kilo tonnes per month
LOM	Life of mine
LOW	Limit of weathering
Lph	Litres per hour
mamsl	Metres above mean sea level
MAP	Mean Annual Precipitation
MAE	Mean Annual Evaporation
mbgl	Metres below ground level
Ml/d	Megalitres per day
Mt	Million tonnes
NA	Not applicable
OB	Overburden
Orion	Orion Gold NL
PCD	Pollution Control Dam
PCM	Prieska Copper Mine
PCMA	Prieska Copper Mine Assemblage
Repli	Repli Trading No 27 (Pty) Ltd
ROM	Run of Mine
S	Storage coefficient (-)
S_y	Specific yield (-)
SANS	South African National Standards
SWL	Static Water Level
T	Transmissivity (unit: m^2/d)
TSF	Tailings Storage Facility
TSF2	Tailings Storage Facility Option 2 (preferred alternative)
WRD3	Waste Rock Dump Option 3 (preferred alternatively)

1 INTRODUCTION

The project is situated near the town of Copperton, which is 60km southwest of the town of Prieska, Northern Cape Province, South Africa, as indicated on Figure 1.

A Prospecting Right was granted over the historical Prieska Copper Mine (PCM) to Repli Trading No 27 (Pty) Ltd (Repli), a subsidiary of Orion Minerals Ltd (Orion) in May 2010. Following the acquisition of Agama Exploration and Mining (Pty) Ltd (Agama) by Orion, Orion now holds 73,3% interest in the Repli prospecting right and 70% interest in the Vardocube prospecting right.

Historically the zinc-copper deposit was mined by Prieska Copper Mine Limited between 1971 and 1991. PCM closed in 1991 and received a conditional Closure Certificate in October 1995. The Prieska Copper Mines Nature Conservation Trust No 723/89 (the Trust) was established at the time to manage any post-closure environmental liabilities. The Trust is managed by Repli.

Based on recent studies completed by Orion, it is believed that there is remnant mining value in the existing underground workings as well as potential to expand the project through additional exploration. Surface mining is also planned at the operations. It is therefore Orion’s intention to recommission the mining operations and to use both opencast and underground mining methods to extract the ore. An application for a mining right for these activities were submitted on 6 April 2018 to the Department of Mineral Resources (DMR) (Reference NC30/5/1/2/2/10138MR).

A separate mining right application is currently being prepared for the Vardocube prospecting right. The Vardocube right forms the south-eastern continuation of the resource within the Repli prospecting right.

A specialist geohydrological study was completed by iLEH as part of the April 2018 mining right application (iLEH, 2018). The work presented in this report is an update of the existing geohydrological study geared at addressing the impact of mining the Vardocube section on groundwater. No additional fieldwork was completed during the compilation of this report.

1.1 Historical mining activities

The historical mining infrastructure that remains on site includes four vertical shafts, two inclined shafts, a decline ramp, a mining village, plant infrastructure and a historical tailings storage facility (TSF). The main shaft, Hutching Shaft, was sunk to a depth of 1024m below surface.

A conditional closure certificate was issued to PCM in 1995. The closure certificate is subject to the Prieska Copper Mines Nature Conservation Trust’s acceptance of the financing of any post-closure environmental management or maintenance. The latter includes the historical tailings storage facility (TSF) and associated infrastructure, fencing around the are of subsidence, the waste rock dump (WRD) and the warning light on the shaft headgear.

Orion is in the process of assessing the environmental impacts of the historical TSF. It is understood that Orion intends to ringfence the facility and to manage it as a stand-alone project until such time as various management options have been evaluated and concluded. A detailed assessment of the TSF falls outside the scope of this study. The historical TSF will however be included during this geohydrological assessment in order to provide an indication of cumulative impacts on groundwater. In order to do so, it will be assumed that Option 1a described in the project Scoping Report (Orion, 2018) will be implemented. This will entail maintaining the historical TSF in its present state, accoding to the conditional Closure Certificate issued to the mine. Under this scenario, Orion will undertake no further work on the TSF, but will maintain the monitoring programme.

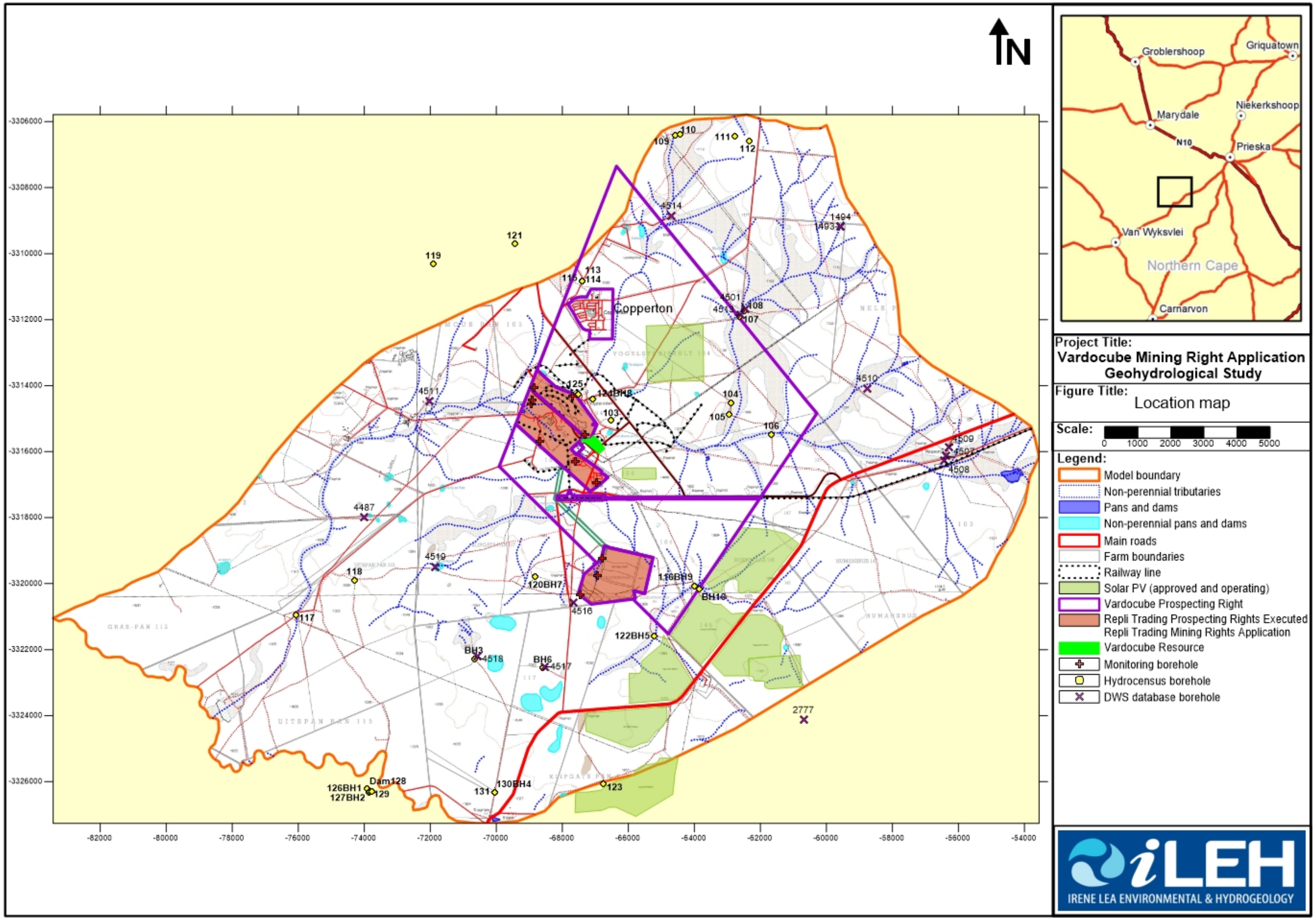

Figure 1 **Location map**

2 PROJECT DESCRIPTION

The discussion presented here is based on the 2018 Scoping Report for the project (Orion, 2018). Where applicable, information presented in the geohydrological study completed for the Repli mining right application (iLEH, 2018) is included for the sake of completeness and ease of reading the report.

2.1 Mineral resources

The deposit is naturally split into two zones, which are defined by its depth below surface and the level of oxidation (Orion, 2018):

- The +105 Level Zone: this is the surface mineral resource present in the oxidised and supergene zone. This zone was not historically exploited by PCM, as all mining took place below the oxidized zone at depths greater than 90m. This resource is earmarked for opencast mining as part of the Repli mining right to a depth of 105m. Opencast mining will be undertaken at the end of life of the underground workings. This is different to the original mine plan presented in iLEH (2018), where it was understood that opencast mining would take place during the initial stages of mining. It is estimated that the 1,5 million tonnes of zinc-copper ore is available in this zone. This resource will not be mined as part of the Vardocube mining right.
- The Deep Sulphide Zone: this is the deep mineral resource present in the hypogene zone. This resource will be mined from the existing underground workings as part of the Repli and Vardocube mining rights. Underground mining will focus on exploiting what remainse of the Deep Sulphide Deposit. There is currently no mining schedule or mine plan available for the Vardocube underground mining activities. Orion made the extent of underground mining for the Vardocube resource available to the study. This is indicated on Figure 2. It is understood that the depth of mining will vary between 900 and 1125m below surface in the Vardocube resource. The expected life of mine for this section is 10 years. Orion (2018) reports that the Repli Deep Sulphide Resource comprises 22,6 million tonnes and the Vardocube Deep Sulphate Resource 5,2 million tonnes of zinc-copper ore.

2.2 Mining schedule

The mining schedule for the operations has not yet been finalised. Orion (2018) reports that production will start from the existing 957 level in the underground workings and ramp up over 18 months. Phase 1 of the underground Deep Sulphide ore body mining is anticipated to be completed in 10 years. Mining is expected to start in the Repli north-western section where existing development is in place. Production will then continue in the south-eastern Vardocube section. Detailed extent of mining per year was not made available at the time of compilation of this report. In order to complete the assessment, the maximum impact will be simulated over the total extent of the delineated mining areas (Figure 2) to the maximum mining depth of 1125m. It is however recommended once a more detailed mine plan is available, that these details are used to improve the impact assessment presented in this report.

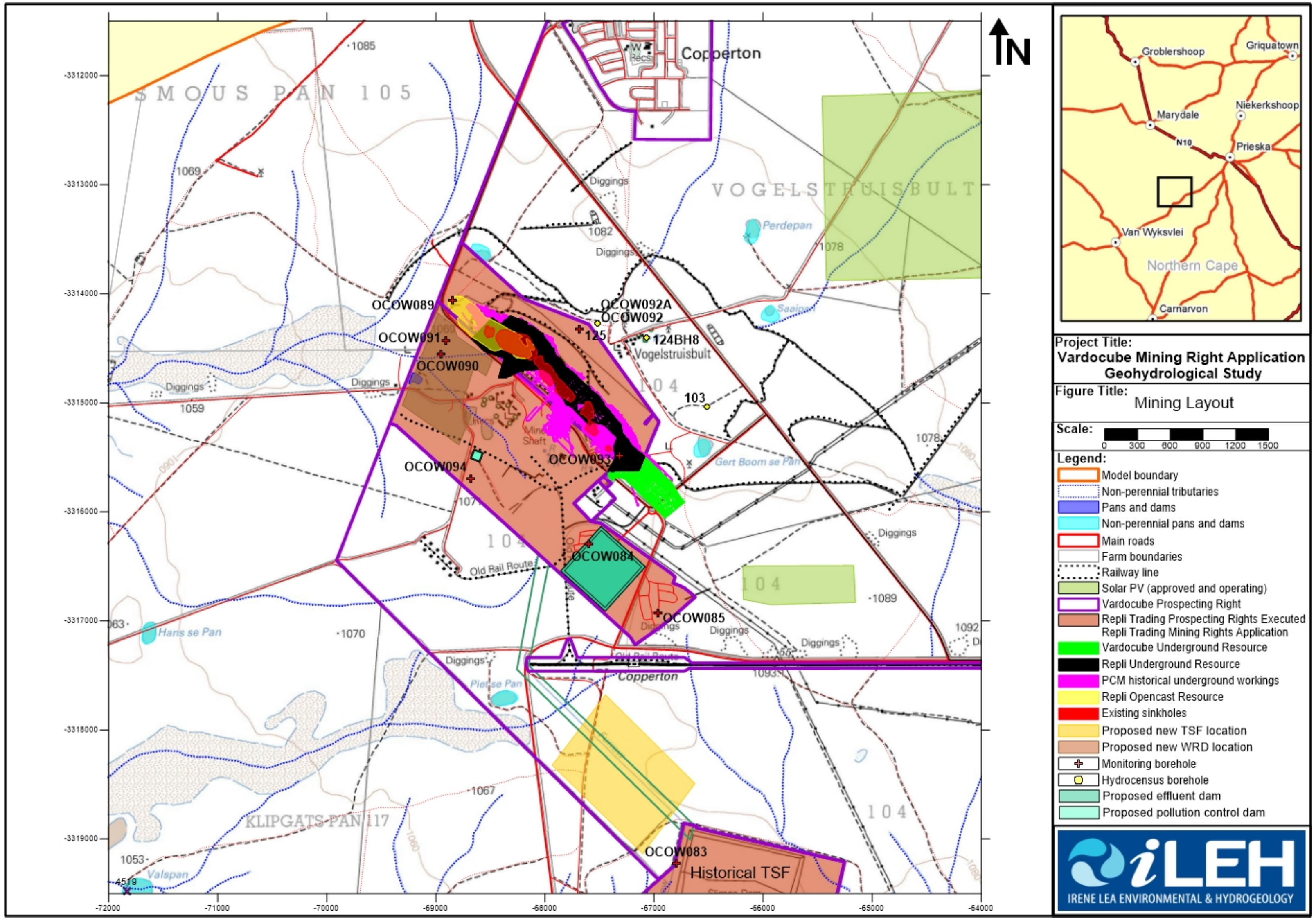

Figure 2 Mining layout plan

Once Phase 1 of the underground mining programme has been completed, surface mining will be considered. An open-pit assessment of the +105 Level Mineral Resource as part of the Repli Mining Right. A geotechnical survey completed for the pit indicates that the depth of weathering extends to 24m below surface. This is underlain by a transitional zone to a depth of 34m from surface. Below this depth, fresh rock will be excavated during opencast mining.

Portions of the pit will be mined in the area where sinkholes have formed (Figure 2). The sinkholes formed where the original crown pillar was in place. Failure of the crown pillar is thought to have caused the sinkholes on surface. Orion will implement several measures to improve mining safety and access during opencast mining.

The pit mining layout plan presented in Orion (2018) indicates that the pit will have a length of 970m, a width of 150m and mining will take place to a depth of 100m. Mining will commence in the northeastern section and progress towards the sinkholes.

It is estimated that pre-stripping will take place over a period of 9 months, followed by opencast mining for an estimated 11 months. Concurrent rehabilitation will not be implemented during opencast mining to allow access to the pit during mining. Rehabilitation will be completed once mining has come to an end.

2.3 Mine residue disposal facility options

The ore will be processed using differential flotation to produce copper zinc concentrates. Mine residue will be deposited on a TSF. During the Repli mining right application in April 2018, Orion considered three site options for the tailings storage facility (TSF). For the purpose of this assessment, the preferred option will be used during simulations, as indicated on Figure 2. The preferred TSF option has the following characteristics applicable to the geohydrological study:

- The new TSF will be constructed separately of the historical TSF for which a closure certificate has been issued.
- The new TSF is within a reasonable distance from the plant (3km) and not within any of the buffer zones identified for wetlands and floodlines.
- The new TSF will have an external footprint of 110 ha.
- There is sufficient space available at the new TSF to construct a lined return water dam that will allow for water transfer from the new TSF to the return water dam (RWD) via gravity.

Three waste rock dump (WRD) site options were considered as part of Repli mining right application in April 2018. As for the TSF options, the preferred alternative will be included in this assessment, as indicated on Figure 2.

It is understood that provision is currently made for the installation of a liner at the new TSF that includes a 1,5mm HDPE layer. The WRD will not be lined.

2.4 Mine dewatering

The historical underground workings are currently flooded to a level of 330m below surface (Orion, 2018). It is estimated that 8,5 million m^3 of water is present in the historical underground workings. It is assumed that Orion still plans to dewater the existing underground workings over a period of 12 - 18 months in order to gain access to the mine. During this time, the underground water level will be lowered from the current level to 1200m below surface. It is estimated that the underground workings will be dewatered at a rate of 1000m^3/hr.

A 1 million m^3 lined effluent dam, with a dimension of 575 x 575 x 3,8m, will be built during the construction phase of mining to contain mine dewatering. The position of the dam is indicated on

Figure 2. The dam will be designed according to the requirements of GN704 and will be lined with high-density polyethylene (HDPE). Forced evaporators will be installed at the effluent dam to accelerate the rate of evaporation of extraneous water, as discussed below. Orion (2018) indicates that each evaporator will eject water at a rate of 137m^3/hr, which will increase the evaporation efficiency by 35 – 60%, depending on the season. Based on the current understanding of the mine dewatering mechanisms, it is estimated that 30 evaporators would be required. The remaining water will fall back into the effluent dam for recirculating back to additional evaporators. This is to ensure that the fall out of salts and heavy metals are contained and cannot escape into the environment. The predominant salt that will concentrate in the water after evaporation is sodium sulphate.

Once the mine is dewatered, Orion (2018) reports that groundwater is expected to seep into the underground workings at a rate of 450m^3/d (450 000 litres per day). Additional sources to the underground water balance includes drill and washing water (2 800 m^3/d) and backfill flushing (150 m^3/d). During the operational phase of mining, 3400m^3/d of water would have to be pumped from the underground workings.

A pollution control dam (PCD) will be constructed at the operations, the location of which is indicated on Figure 2. This dam will comply with the requirement of GN704 and will be constructed with an HDPE liner.

It is estimated that 8.5 million m^3 of water will be evaporated over 12 - 18 months using this method.

2.5 Void stabilisation options

During the mining right application for the Repli area of responsibility in April 2018, Orion considered four options to stabilise underground workings. The stoping methods used will require the use of backfill. Orion (2018) reports that paste backfill was selected as the most effective method. For this purpose, a backfill plant will be constructed at the site.

Plant tailings will be used with cement at various mixing ratios, depending on the fill and strength requirements. The tailings:cement ratios wil depend on the position where fill will take place . The ratios will vary between 8:1 – 25:1. Development waste rock will also be used for backfill, where possible.

Orion (2018) reports that paste backfill does not produce drain-off water, but that limited water management would still be required for flushing of the fill pipelines.

2.6 Conceptual design of new TSF

Knight Piesold (2018) completed a conceptual study on the design of the new PCM TSF. This study was completed at a high level due to limited available information and is mostly a professional opinion based on past experiences. A more detailed study will be completed during the feasibility study for the mining project. This was not available at the time of compilation of this report. As the new TSF does not form part of the Vardocube mining right application, this is not considered a significant short-coming in the application.

The life of the new TSF is estimated to be 14 years with a capacity of 15,5 million tonnes. The external footprint of the facility was calculated to be 110 ha. The calculations presented indicate that the RWD capacity must be around 163 000m^3.

The location of the preferred TSF option is indicated on Figure 2.

3 CONCEPTUALISATION

3.1 Geological setting

This section was presented in the Repli mining right application study (iLEH, 2018) and was updated with information presented in Orion (2018).

The Copperton deposit is a large volcanogenic massive sulphide deposit. It is highly deformed and metamorphosed and is not yet fully understood. It lies in the Kakamas Terrain of the Namaqua Mobile Belt in rocks of the Areachap Group of the Morannaland Supergroup. The published geological map presented in Figure 3, indicates that the mine is covered by quaternary unconsolidated Kalahari sand and calcrete. The average thickness of the sand and calcrete is 15m, based on exploration borehole logs made available. The southern and western parts of the study area comprise Dwyka Tillites of the Karoo Supergroup at surface.

The Cu-Zn ore body is hosted in the highly metamorphosed Copperton Formation, which comprises of the Smouspan Gneiss (the footwall of the ore body), the Prieska Copper Mines Assemblage which hosts the sulphide mineralisation and the Vogelstruisbult Gneiss Member (the hangingwall of the orebody).

The Souspan Gneiss is a homogeneous gneiss and is interpreted as a metamorphosed dacitic volcanic rock.

The PCMA deposit outcrops at surface at the mine and dips steeply to a hinge zone at about 1km below surface (Orion, 2018). It comprises a 10 – 100m thick layered sequence. The footwall is a coarse-grained gedrite fels, which is overlain by gneiss with a graditional contact. The ore body is situated on the north-eastern flank of a tight NW-SE striking and SE plunging asymmetric anticlinal synform developed in the Copperton Formation. The structural hanging wall is therefore the Smouspan Gneiss. At depth, the ore body flattens out before returning to surface at a shallow dip, as demonstrated in the schematic cross section presented in Figure 4, adapted from Orion (2018). The ore body has a 2,4km strike length at an orientation of 135° true-north. Mineralisation is between 2 and 35m wide, on average 7- 9m wide, to a depth of 1250m below surface.

The extent of the Vogelstruisbult Member, is indicated on Figure 3 (Orion, 2018). The gneiss is mostly covered by surficial sand and calcrete in the mining area. It comprises banded hornblende gneiss, laminated amphibolite and metapelites.

The orebody as well as the Vogelstruisbult and Smouspan gneiss is intruded by massive amphibolite mafic dykes or sills. Cross-cutting pegmatite veins are present throughout.

Where the ore body outcrops, a well-developed massively textured gossan, oxide, partly oxidized and supergene sulphide mineralisation is present, typical of this type of orebody. The area is capped by a thin layer of sand and 1 – 5m of calcrete. The ore body has been oxidised and leached to a depth of 100m below surface. The surface deposit extents to approximately 35m from surface. The gossan and oxide ore body is composed of hard iron oxides with some secondary copper minerals. A barren leach zone is present between the oxide and supergene zones, with the supergene zone present between 50 – 100m below surface.

A open pitable mining target was identified in the oxidised zone to a depth of 100m, referred to as the +105 Level Target. A large portion of the open pit target was left as the mine's crown pillar. Parts of this pillar have failed, creating sink holes adjacent to the ore zone. These sink holes are indicated on Figure 2.

PCM mined the steeply-dipping section of the ore-body down to the hinge zone. Before the mine was shut down in 1991, exploration drilling indicated the presence of a deep shallow dipping, largely flat sulphide target at a depth of 1km below surface. This is the Deeps Mining Target proposed by Orion, the extent of which is indicated on Figure 4.

Three major deformational events took place in the region (Orion, 2018). The first gave rise to the main penetrative foliation and is present as intrafolial folds. The second deformation gave rise to the tight NW-NNW orientated folds with a steep easterly dip. The third deformation gave rise to the open NE-ENE oriented folds, but was only a minor effect. The latter phases of deformation are however thought to give rise to the development of shears. The Copperton deposit is bound to the east by the Copperton shear zone, which is the most westerly exposure of the Brakbos Fault, as indicated on Figure 3. Several other faults were mapped in the area. The strike of these faults is consistent with the deformational events, as indicated on the Figure 3.

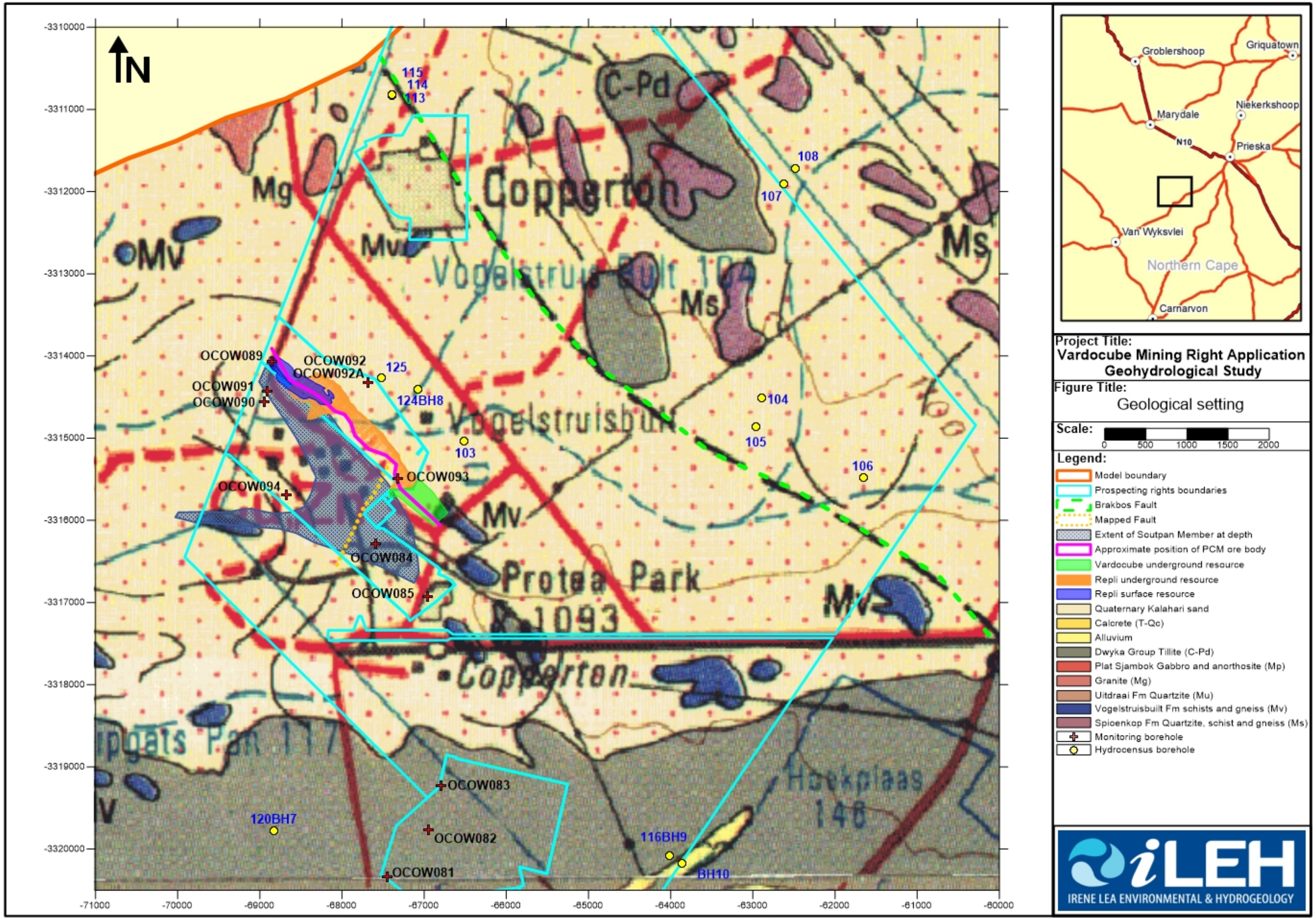

Figure 3 **Geological setting**

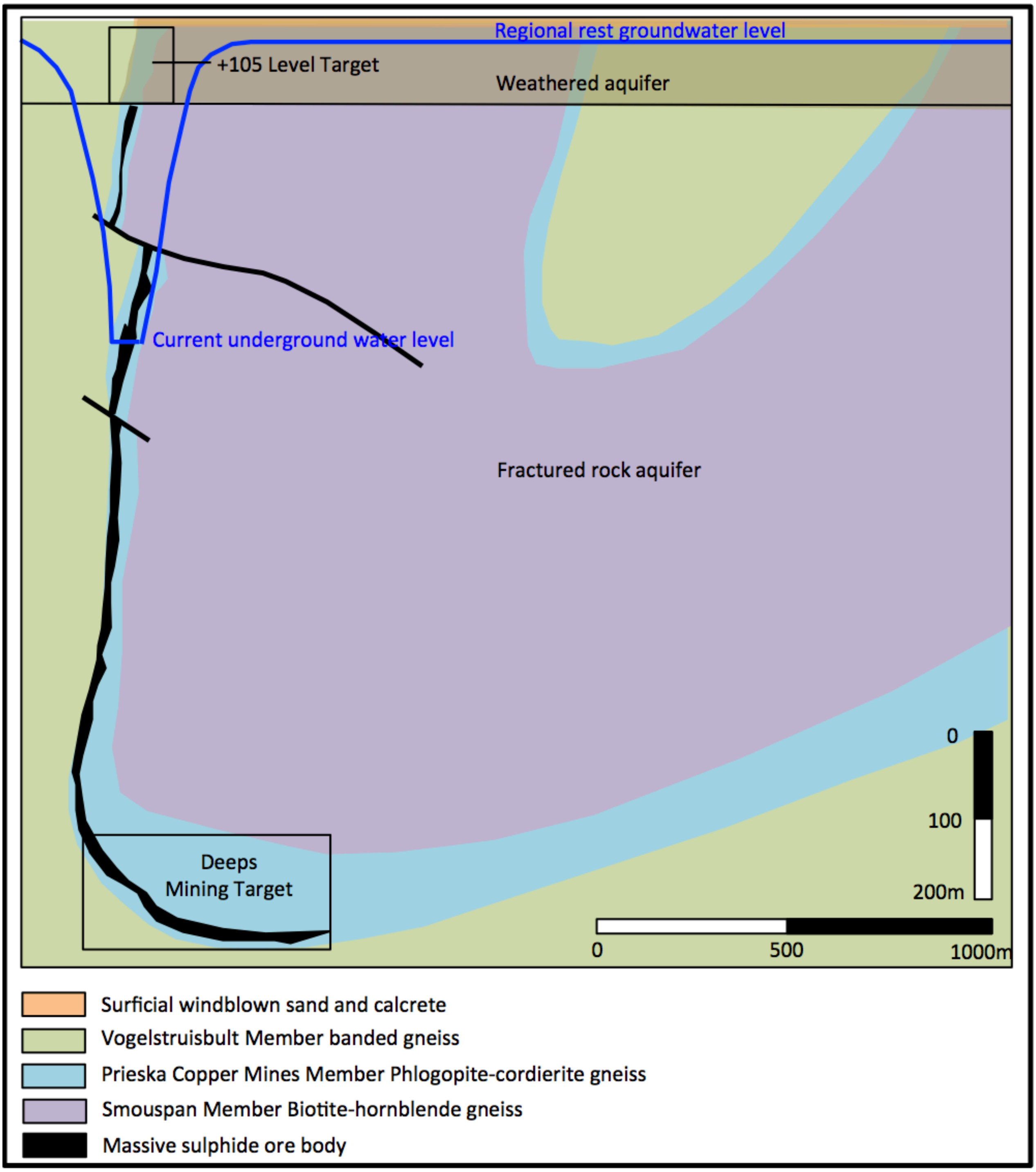

Figure 4 **Schematic cross section (adapted from Orion, 2018)**

3.2 Hydrogeological setting

This section provides a summary of the information obtained from a fieldwork programme undertaken as part of the Repli Mining Right application (iLEH, 2018). No additional fieldwork was completed as part of the Vardocube Mining Right application.

3.2.1 Hydrocensus

A hydrocensus was completed as part of iLEH (2018) to record private groundwater use in the vicinity of the PCM operations. The outcome of the hydrocensus is presented in Table 1 and the locations of the boreholes identified are presented in Figure 1.

A total of 32 boreholes were located during the hydrocensus. The boreholes are drilled to an average depth of 40m, as calculated from boreholes to which access could be gained.

Sixteen of the boreholes are not currently in use or are dry. Groundwater is used solely for stock watering. None of the boreholes identified are used for potable supply.

Yields were recorded for nine of the boreholes. Five of these boreholes are currently in use, namely 126BH1, 103, 105, 109 and 113. Borehole 105, has a reported yield of 35000 litres per hour (lph). This borehole is situated 4km east of the Vardocube mining area on the farm Vogelstruisbult and belongs to Mr Henry Tredoux. The remainder of the boreholes have lower yields, on average below 2000 lph. If it is assumed that the boreholes are pumped for 12 hours per day, the combined volume of groundwater that is abstracted on an annual basis from the existing boreholes is just over 200 000 m^3/a.

Groundwater levels could be measured in four of the hydrocensus boreholes. The depth to groundwater varies between 1 and 25 m, with an average depth of 13 m.

Groundwater samples were taken from eleven of the boreholes visited during the hydrocensus. The results of the analyses are discussed below.

Table 1 **Hydrocensus information**

Farm Name	Owner	Date visited	Borehole ID	X Coordinate	Y Coordinate	Elevation (mamsl)	Borehole use	Depth	Water level	Surface observations	Yield	Condition
				WGS84	WGS84			m	mbgl		l/h	
Uitspan Pan	Frans Eckard	2017/10/18	126BH1	-73927	-3326206	1009	stock water	-	-	windpump	2000l/h	in use
Uitspan Pan	Frans Eckard	2017/10/18	127BH2	-73861	-3326332	992	stock water	-	-	windpump	-	not in use
Klipgats Pan	Koenie Viljoen	2017/10/19	BH3	-70666	-3322279	1052	stock water	-	-	windpump	-	in use
Uitspan Pan	Frans Eckard	2017/10/18	130BH4	-70057	-3326324	1009	stock water	-	-	windpump	-	in use
Klipgats Pan	Henry Tredoux	2017/10/12	122BH5	-65229	-3321598	1109	stock water	-	-	windpump	-	in use
Klipgats Pan	Koenie Viljoen	2017/10/19	BH6	-68579	-3322561	1043	stock water	-	-	windpump	-	in use
Klipgats Pan	Johan Wentzel	2017/10/11	120BH7	-68826	-3319777	1054	stock water	-	-	windpump	-	in use
Vogelstruisbult	Henry Tredoux	2017/10/18	124BH8	-67072	-3314401	1053	stock water	48,43	24,78	windpump	-	not in use
Vogelstruisbult	Henry Tredoux	2017/10/10	116BH9	-64008	-3320077	1064	stock water	-	-	-	-	not in use
Vogelstruisbult	Henry Tredoux	2017/10/10	BH10	-63859	-3320175		no access			-		
Uitspan Pan	Frans Eckard	2017/10/18	Dam - 128	-73839	-3326288	1008	stock water	-	-	dam - dry during visit	-	dry
Vogelstruisbult	Henry Tredoux	2017/10/10	103	-66514	-3315041	1075	stock water	40,00	-	windpump converted to submersible	4000l/h	in use
Vogelstruisbult	Henry Tredoux	2017/10/10	104	-62893	-3314515	1075	no use	36,00	-	old water supply - destroyed	-	dry
Vogelstruisbult	Henry Tredoux	2017/10/10	105	-62958	-3314865	1073	stock water	40,00	-	submersible used to supply water	35000l/h	in use
Vogelstruisbult	Henry Tredoux	2017/10/10	106	-61656	-3315483	1075	no use	42,00	-	unused bh in kraal	1000l/h	not in use
Vogelstruisbult	Henry Tredoux	2017/10/10	107	-62622	-3311905	1088	no use	40,00	-	old windpump - destroyed	1000l/h	not in use
Vogelstruisbult	Henry Tredoux	2017/10/10	108	-62486	-3311723	1091	no use	-	-	destroyed when drill equip broke in hole	-	not in use
Vogelstruisbult	Henry Tredoux	2017/10/10	109	-64564	-3306406	1103	stock water	40,00	0,75	submersible used to stock water	3000l/h	in use
Vogelstruisbult	Henry Tredoux	2017/10/10	110	-64434	-3306398	1105	no use	40,00	-	unused, Bees in bh, No casing	-	not in use
Vogelstruisbult	Henry Tredoux	2017/10/10	111	-62768	-3306450	1125	no use	40,00	-	unused, Bees in bh, No casing	1000l/h	not in use
Nels Poortje	Henry Tredoux	2017/10/10	112	-62345	-3306576	1116	no use	40,24	13,41	-	1000l/h	not in use
Vogelstruisbult	Henry Tredoux	2017/10/10	113	-67393	-3310828	1084	stock water	-	-	submersible with solar	2000l/h	in use
Vogelstruisbult	Henry Tredoux	2017/10/10	114	-67390	-3310825	1081	no use	-	-	destroyed - filled with rocks	-	not in use
Vogelstruisbult	Henry Tredoux	2017/10/10	115	-67390	-3310826	1084	stock water	-	-	windpump converted to submersible	-	in use
Klipgats Pan	Johan Wentzel	2017/10/11	117	-76059	-3320938	1034	stock water	-	-	old windpump not working	-	not working
Klipgats Pan	Johan Wentzel	2017/10/11	118	-74287	-3319891	1038	stock water	-	-	-	-	in use
Klipgats Pan	Johan Wentzel	2017/10/11	119	-71900	-3310319	1051	stock water	-	-	-	-	in use
Smous Pan	Sandra/ Aletta de Jager	2017/10/18	121	-69431	-3309708	1127	stock water	-	-	-	-	in use
Klipgats Pan	Frans Eckard	2017/10/12	123	-66744	-3326056	1043	stock water	-	-	-	-	in use

Farm Name	Owner	Date visited	Borehole ID	X Coordinate	Y Coordinate	Elevation (mamsl)	Borehole use	Depth	Water level	Surface observations	Yield	Condition
				WGS84	WGS84			m	mbgl		l/h	
Klipgats Pan	Henry Tredoux	2017/10/18	125	-67514	-3314271	1055	no use	-	-	destroyed bh close to mine	-	not in use
Uitspan Pan	Frans Eckard	2017/10/18	129	-73782	-3326295	1008	stock water	48,00	13,24	old windpump - no equipment	-	not in use
Uitspan Pan	Frans Eckard	2017/10/18	131	-70038	-3326323	1023	no use	-	-	open bh filled by rocks	-	not in use

3.2.2 Monitoring boreholes

A total of 12 groundwater monitoring boreholes were sited with ground geophysical methods and drilled to characterise the aquifers present as part of the iLEH (2018) study. No new monitoring boreholes were drilled for the Vardocube Mining Rights application, as it was assumed that the existing dataset would be sufficient to complete the geohydrological impact assessment.

The monitoring boreholes were drilled to depths of between 80 and 150 m. Their positions are indicated on Figure 2 and details regarding each borehole are presented in Table 2. The following areas were targeted:

- **Historical TSF**: OCOW081, OCOW082 and OCOW083. Several faults were mapped around the historical TSF, as indicated on Figure 2. The positions of these faults may not be very accurate. Boreholes situated near the mapped faults may in fact be drilled into the fault. It is thought that borehole OCOW081 and possibly OCOW083 were drilled into two of the faults identified.
- **Historical mine village area** (proposed Repli Effluent Dam area): OCOW084 and OCOW085, both of which are thought to be drilled into the fault mapped in this area.
- **Historical mining area**: OCOW089, OCOW090, OCOW091, OCOW092 and 92A, OCOW093 and OCOW094. If the faults mapped in the mining area are extrapolated, boreholes OCOW92 and 92A as well as OCOW90 and 91 may intersect the faults mapped in this area.

Monitoring borehole logs indicate the first five meters comprises of highly weathered calcrete, alluvium or clay. The boreholes intersected mafic and felsic gneiss of various degrees of weathering. The depth of weathering varies between 3 and 88 m below surface, but is on average 15 – 18 m deep. This is consistent with that recorded in the exploration borehole logs made available by Orion to complete this study.

Five of the monitoring boreholes drilled intersected groundwater, namely OCOW081, OCOW082, OCOW083, OCOW084 and OCOW091. The remaining monitoring boreholes were dry. The depth of the groundwater strikes vary between 34 and 120 m below surface and are all associated with fractures in the fresh gneiss.

Two of the boreholes that intersected groundwater are associated with the historical mining and mine village area. The other three boreholes that intersected groundwater are situated at the historical TSF. The sparse intersection of water-bearing features in the boreholes drilled suggests that the aquifers are not well developed or have been dewatered in the immediate vicinity of the mine. The information also confirms that groundwater occurrence is erratic in this arid environment.

The depth to groundwater in the boreholes is variable, ranging from 6 to 35 m below surface. The average depth to the rest groundwater level in the boreholes that intersected groundwater was 20 m. Shallow groundwater was recorded in OCOW081 and OCOW082 drilled down gradient of the toe paddocks of the historical TSF. It is possible that the shallow groundwater levels are indicative of the impact of recharge down gradient of the old TSF, creating a mound in groundwater levels in this area. The groundwater level in OCOW083 is deeper.

Aquifer tests were completed on the five boreholes that intersected groundwater. These tests involved constant discharge pumping tests followed by a recovery period. The rate at which the boreholes were pumped was inferred from the blow yields measured during drilling. The results of the tests indicate that borehole OCOW081 has the strongest yield of 3,45 l/s (150 000lph). Borehole OCOW091 reported a yield of 1,9 l/s (82 000lph). The yields of the remainder of the boreholes are low, on average 0,06 l/s (2500 lph).

Table 2 Summary of groundwater monitoring borehole information

BH ID	X Coordinate (WGS84)	Y Coordinate (WGS 84)	Elevation (mamsl)	Depth from (m)	Depth to (m)	Thick ness (m)	Lithology	Depth to water strike (m)	Sustainable yield (l/s)	SWL (m)	Average transmissivity (m^2/d)	Average storage coefficient (-)
OCOW0 81	-67444	-3320337	1056	0	5	5	Residual fine grained brownish grey soil	87, 120	3,45	7,0	6,3	2,73E-03
				7	88	81	Moderately weathered mottled yellowish grey mafic rock					
				88	150	62	Fresh greenish grey mafic gneiss					
OCOW0 82	-66945	-3319769	1067	0	4	4	Highly weathered brown calcrete and clay	48	0,11	6,1	0,73	9,92E-04
				4	12	8	Highly weathered greenish clay					
				12	34	22	Moderately weathered greenish clay					
				34	80	46	Greenish grey fresh mafic gneiss					
OCOW0 83	-66793	-3319226	1079	0	3	3	Highly weathered brownish yellowish grey calcrete and clay	38	0,02	20,3	0,2	6,75E-04
				3	6	3	Moderately weathered greyish mafic gneiss					
				6	65	59	Fresh greyish mafic gneiss					
				65	80	15	Fresh greyish red mafic gneiss					
OCOW0 84	-67593	-3316292	1062	0	3	3	Brown residual soil	60	0,04	31,9	0,27	5,80E-04
				3	30	27	Highlly weathered brownish yellow residual calcrete					
				30	42	12	Highly weathered brownish felsic gneiss					
				42	80	38	Fresh greyish black mafix gneiss					
OCOW0 85	-66960	-3316933	1063	0	3	3	Highly weathered light brown calcrete	None	Zero	-	-	-
				3	72	69	Fresh light greyish black mafic gneiss					
OCOW0 89	-68847	-3314063	1075	0	2	2	Brown residual soil	None	Zero	-	-	-
				2	28	26	Highly weathered brown residual calcrete					
				28	38	10	Moderately weathered reddish gossan					
				38	80	42	Fresh greyish black mafic gneiss					
OCOW0 90	-68950	-3314557	1075	0	8	8	Highly weathered pinkish brown calcrete	None	Zero	-	-	-
				8	15	7	Highly weathered pinkish brown mafic gneiss					
				15	80	65	Fresh greyish black mafic gneiss					
OCOW0 91	-68908	-3314426	1066	0	7	7	Highly weathered reddish pink calcrete	34	1,90	34,5	32,2	8,40E-04
				7	33	26	Fresh ligh grey mafic gneiss					
				33	36	3	Fresh pinkish grey pegmatite					
				36	75	39	Fresh greyish black mafic gneiss					
				75	76	1	Fresh greyish white mafic gneiss with quartz					
				76	80	4	Fresh greyish black mafic gneiss					

BH ID	X Coordinate (WGS84)	Y Coordinate (WGS 84)	Elevation (mamsl)	Depth from (m)	Depth to (m)	Thickness (m)	Lithology	Depth to water strike (m)	Sustainable yield (l/s)	SWL (m)	Average transmissivity (m^2/d)	Average storage coefficient (-)
OCOW092	-67681	-3314328	1071	0	7	7	Brown alluvium	None	Zero	-	-	-
				7	15	8	Highly weathered brown residual clay					
				15	28	13	Fresh greyish black mafic gneiss					
OCOW092A	-67681	-331432	1071	0	5	5	Light brown alluvium	None	Zero	-	-	-
				5	9	4	Brown weathered calcrete					
				9	80	71	Fresh greyish black mafix gneiss					
OCOW093	-67316	-3315489	1078	0	10	10	Weathered brownish yellow calcrete	None	Zero	-	-	-
				10	24	14	Fresh greyish brown mafic gneiss					
				24	27	3	Fresh light grey mafic gneiss					
				27	29	2	Quartz vein					
				29	47	18	Fresh greenish grey gneiss					
				47	48	1	Fresh pinkish grey pegmatite					
				48	80	32	Fresh greenish grey mafic gneiss					
OCOW094	-68677	-3315694	1073	0	3	3	Brown residual clay	None	Zero	-	-	-
				3	31	28	Fresh greenish white mafic gneiss					
				31	80	49	Fresh greyish black mafic gneiss					

The results of the aquifer tests were also used to calculate the transmissivity and storage coefficients for the boreholes (iLEH, 2018). These parameters describe the aquifer conditions intersected in each borehole. Higher transmissivity and storage coefficient values are associated with stronger aquifers. The values presented in Table 2 are based on averages calculated from several techniques used to interpret the results of the aquifer tests. It is shown that the fractured rock aquifers intersected during drilling are heterogeneous with transmissivities varying between 0,2 and 6,2 m^2/d.

The higher transmissivity obtained for OCOW081, drilled into a fault down gradient of the old TSF suggests that this structure could act as a preferential flow path to groundwater. Not all faults are however highly transmissive, for example the fault intersected in OCOW084 has a transmissivity of 0,27m^2/d. Borehole OCOW091, situated near the historical mining area and not obviously associated with a fault, yielded a transmissivity of 32,2 m^2/d. The results of the aquifer tests on the five boreholes indicate the presence of a heterogeneous fractured rock aquifer in the fresh gneiss, associated with the faults mapped in the area.

The storage coefficients vary between 5,8E-4 and 2,73E-3, with an average of 1,16E-3. As these parameters were not calculated from observation borehole data, the level of confidence in these values is low. The lower calculated storage coefficient values are however typical of the rock formations intersected.

3.2.3 Groundwater quality

3.2.4 Monitoring boreholes

Water samples taken from the five boreholes that intersected groundwater were submitted to an accredited laboratory for analysis (iLEH, 2018). The results of the analysis are presented in Table 3 and are compared to the SANS241:2015 Drinking Water Standard.

The results indicate that the electrical conductivity, total dissolved solids and sulphate concentrations exceed the SANS241:2015 limits. In most instances the exceedances relate to aesthetic risks, which means that taints with respect to taste, odour and colour are expected, but the exceedances do not pose unacceptable heath risks.

The exceptions are the elevated sulphate concentrations in boreholes OCOW82 – 84 and OCOW91, which poses an acute health risk. At these concentrations the sulphate may cause diarrhoea when ingested. A very strong salty and bitter taste would also be experienced. Elevated concentrations of chloride were recorded in boreholes OCOW81, 84 and especially in OCOW91. This water will also have a salty taste and will cause corrosion in appliances. Fluoride concentrations in boreholes OCOW81 and 82 may pose a chronic health risk, for example dental mottling.

Metal concentrations were generally below the laboratory detection limits. The exceptions are manganese, selenium and uranium. Manganese concentrations in OCOW82 and 83 may result in staining, but health effects are expected to be rare at concentrations below 14 mg/l. Care must however be taken as a precaution to avoid ingestion of this groundwater. Elevated selenium concentrations were measured in boreholes OCOW84 and 91. At the concentrations observed, chronic health risks associated with selenium toxicity and possible liver damage need to be highlighted. The uranium concentrations in boreholes OCOW84 and 91 exceed the SANS241:2015 limit and may therefore be associated with chronic health risks.

Table 3 Groundwater quality analysis for the monitoring boreholes

Element	**OCOW81**	**OCOW82**	**OCOW83**	**OCOW84**	**OCOW91**	**SANS241:2015 Drinking Water Standard**	**Risk**
pH – Value at 25°C	8	7,4	7,6	7,4	7,5	5 - 9,7	Operational
Electrical Conductivity in mS/m	246	498	499	540	561	170	Aesthetic
Total Dissolved Solids	1 630	4 960	5 144	4 298	4 488	1200	Aesthetic
Total Alkalinity as $CaCO_3$	356	192	288	284	400		
Bicarbonate as HCO_3	356	192	288	284	400		
Total Hardness as $CaCO_3$	129	1 875	2 348	1 566	1 874		
Sodium as mg/l Na	517	576	520	640	589		
Calcium as mg/l Ca	22	398	586	324	302		
Potassium as mg/l K	6,0	20	18,0	22	33		
Chloride as Cl	311	291	288	904	1 104	300	Aesthetic
Sulphate as SO_4	474	2 700	2 705	1 412	1 253	500	Acute health
						250	Aesthetic
Fluoride as F	4,7	1,7	1,3	1,2	1,4	1,5	Chronic health
Nitrate as N	0,1	<0,1	<0,1	4,1	2,2	11	Acute health
Nitrite as N	<0,05	<0,05	<0,05	<0,05	0,4	0,9	Acute health
Total Nitrogen as N	1,2	1,7	22	4,7	3,2		
Ortho Phosphate as P	<0,1	<0,1	<0,1	<0,1	<0,1		
Chemical Oxygen Demand as O_2	<10	<10	12	12	28		
Free & Saline Ammonia as N	0,4	1	1,7	0,1	0,1	1,5	Aesthetic
Silver as mg/l Ag	0,001	< 0,001	< 0,001	< 0,001	< 0,001		
Aluminium as mg/l Al	< 0,100	< 0,100	< 0,100	< 0,100	< 0,100	0,3	Operational
Arsenic as mg/l As	0,001	0,001	0,001	0,001	0,002	0,01	Chronic health
Gold as mg/l Au	0,004	0,003	0,002	0,002	0,003		
Boron as mg/l B	1,56	2,04	1,18	2,11	2,36	2,4	Chronic health
Barium as mg/l Ba	0,049	0,030	0,026	0,027	0,067	0,7	Chronic health
Beryllium as mg/l Be	< 0,001	< 0,001	< 0,001	< 0,001	0,001		
Bismuth as mg/l Bi	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001		
Cadmium as mg/l Cd	0,001	< 0,001	0,001	< 0,001	0,001	0,003	Chronic health
Cerium as mg/l Ce	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001		
Cobalt as mg/l Co	0,001	0,001	0,007	0,006	0,014		
Chromium as mg/l Cr	0,001	0,001	0,001	0,002	0,002	0,05	Chronic health
Caesium as mg/l Cs	0,003	0,001	0,001	< 0,001	0,001		
Copper as mg/l Cu	0,007	0,005	0,004	0,015	0,001	2	Chronic health
Dysprosium as mg/l Dy	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001		
Erbium as mg/l Er	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001		
Europium as mg/l Eu	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001		
Iron as mg/l Fe	< 0,025	0,059	0,082	0,190	0,177	2	Chronic health
						0,3	Aesthetic
Gallium as mg/l Ga	0,009	0,004	0,002	0,005	0,007		
Gadolinium as mg/l Gd	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001		
Germanium as mg/l Ge	0,001	0,001	< 0,001	< 0,001	< 0,001		
Hafnium as mg/l Hf	0,015	0,002	0,001	< 0,001	< 0,001		
Mercury as mg/l Hg	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001	0,006	Chronic health
Holium as mg/l Ho	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001		
Inium as mg/l In	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001		
Iridium as mg/l Ir	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001		
Lanthanum as mg/l La	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001		
Lithium as mg/l Li	0,057	0,236	0,185	0,123	0,161		
Lutetium as mg/l Lu	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001		
Magnesium as mg/l Mg	18	214	216	184	272		
Manganese as mg/l Mn	< 0,025	1,11	10	< 0,025	0,089	0,4	Chronic health
						0,1	Aesthetic
Molybdenum as mg/l Mo	0,019	0,039	0,013	0,008	0,015		
Niobium as mg/l Nb	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001		
Neodymium as mg/l Nd	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001		
Nickel as mg/l Ni	0,006	0,006	0,006	0,002	0,002	0,07	Chronic health
Osmium as mg/l Os	0,003	0,002	0,002	0,002	0,001		
Phosphorus as mg/l P	0,324	0,504	0,503	0,540	0,500		
Lead as mg/l Pb	0,001	< 0,001	< 0,001	< 0,001	0,103	0,01	Chronic health
Palladium as mg/l Pd	0,001	< 0,001	< 0,001	< 0,001	< 0,001		
Praseodymium as mg/l Pr	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001		
Platinum as mg/l Pt	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001		
Rubidium as mg/l Rb	0,022	0,008	0,009	0,001	0,016		
Rhodium as mg/l Rh	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001		

Element	OCOW81	OCOW82	OCOW83	OCOW84	OCOW91	SANS241:2015 Drinking Water Standard	Risk
Ruthenium as mg/l Ru	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001		
Antimony as mg/l Sb	0,001	0,001	0,001	< 0,001	0,001	0,02	Chronic health
Scandium as mg/l Sc	0,002	0,002	0,002	0,002	0,002		
Selenium as mg/l Se	0,028	0,018	0,036	0,070	0,079	0,04	Chronic health
Silicon as mg/l Si	11,7	17,9	26	17,1	22		
Samarium as mg/l Sm	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001		
Tin as mg/l Sn	< 0,001	< 0,001	0,001	< 0,001	< 0,001		
Strontium as mg/l Sr	0,883	7,15	4,08	6,91	9,06		
Tantalum as mg/l Ta	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001		
Terbium as mg/l Tb	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001		
Tellurium as mg/l Te	< 0,001	< 0,001	0,001	< 0,001	< 0,001		
Thorium as mg/l Th	0,004	0,001	< 0,001	< 0,001	< 0,001		
Titanium as mg/l Ti	0,011	0,186	0,212	0,119	0,099		
Thallium as mg/l Tl	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001		
Thulium as mg/l Tm	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001		
Uranium as mg/l U	0,003	0,018	0,021	0,077	0,209	0,03	Chronic health
Vanadium as mg/l V	0,002	0,007	0,027	0,012	0,008		
Tungsten as mg/l W	0,001	0,001	0,001	0,001	0,001		
Yttrium as mg/l Y	< 0,001	0,001	< 0,001	< 0,001	< 0,001		
Ytterbium as mg/l Yb	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001		
Zinc as mg/l Zn	0,577	0,238	0,097	0,058	0,257		
Zirconium as mg/lZr	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001		

Acute health	Determinant poses an immediate unacceptable health risk if present at concentration values
Aesthetic	Determinant that taints water with respect to taste, odour and colour and that does not pose an unacceptable heath risk if present at concentration values exceeding the numerical limit
Chronic health	Determinant that poses an unacceptable health risk if ingested over an extended period if present at concentration values exceeding the limits specified
Operational	Determinant that is essential for assessing the efficient operation of treatment systems and risks to infrastructure

3.2.5 Hydrocensus boreholes

The results of the chemical analysis of water samples taken from the hydrocensus boreholes sampled are presented in Table 4 (iLEH, 2018). The hydrocensus boreholes fall outside the current perceived zone of influence of the historical PCM mining activities and as such present an indication of the ambient groundwater quality.

The analysis indicates that the groundwater in boreholes 105 and 113 is of good quality in terms of total dissolved solids and electrical conductivity. Groundwater from these boreholes show elevated concentrations of fluoride and selenium, which is thought to be a natural occurrence as a result of the geology. The groundwater in both boreholes however has high concentrations of nitrate. If ingested, this groundwater may lead to methaemoglobinaemia in infants. The nitrate can also be converted in the gastrointestinal tract to nitrite as a result of bacterial reduction. The elevated nitrate concentrations in these as well as most of the other hydrocensus boreholes are most probably attributed to the impact of agricultural activities. Nitrate is the end product of the oxidation of ammonia or nitrite. It is not easily removed from groundwater and will probably require water treatment through reverse osmosis or ion exchange.

The regional groundwater quality further confirms that the water is generally saline, with elevated concentrations of chloride, fluoride and in some instances sulphate. The health risks of these elements are discussed above. In terms of metal concentrations, elevated concentrations of selenium were recorded in most of the boreholes. Four of the boreholes yielded elevated concentrations of uranium (BH6, 122BH5, 126BH1 and 130BH4). Elevated uranium concentrations in Karoo groundwater is considered a natural phenomena (Eilers et al, 2015) and is thought to originate in the Karoo Uranium Province.

Table 4 Hydrocensus borehole groundwater quality analysis

Element (mg/L)	BH3	BH6	105	113	118	119	121	122BH5	123	126BH1	130BH4	SANS241:2015 Drinking Water Standard	Risk
pH – Value at 25°C	7,7	7,8	7,6	7,6	7,7	7,6	7,6	7,8	7,6	7,7	7,5	5 - 9,7	Operational
Electrical Conductivity in mS/m at 25°C	654	610	158	138	192	314	176	854	401	356	288	170	Aesthetic
Total Dissolved Solids at 180°C	4244	3996	1032	956	1212	2108	1204	5996	2708	2292	1960	1200	Aesthetic
Total Alkalinity as $CaCO_3$	280	328	340	300	332	240	360	296	296	320	304		
Bicarbonate as HCO_3	341	400	414	366	405	293	439	361	361	390	371		
Total Hardness as $CaCO_3$	1458	1139	383	434	374	812	499	2047	1092	574	759		
Sodium as mg/l Na	831	911	195	145	250	380	183	1236	480	527	353		
Chloride as Cl	1742	1507	228	134	281	546	216	2210	830	632	496	300	Aesthetic
Calcium as mg/l Ca	257	181	60	83	68	150	96	281	194	121	142		
Magnesium as mg/l Mg	166	134	43	40	38	89	52	266	115	62	86		
Potassium as mg/l K	24	17,9	11,4	7,2	9,0	12,8	22	26	12,5	11,9	12,0		
Sulphate as SO_4	607	612	140	221	211	544	234	1227	586	539	420	500 250	Acute health Aesthetic
Fluoride as F	2	2,1	1,3	1,6	2,4	1,8	1,4	1,8	1,7	3,8	2,4	1,5	Chronic health
Nitrate as N	51	47	14	12	15	22	15	2,9	22	17	24	11	Acute health
Nitrite as N	<0,05	0,7	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	0,7	<0,05	0,9	Acute health
Total Nitrogen as N	51	48	14	12	15	22	15	2,9	22	18	24		
Ortho Phosphate as P	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1		
Chemical Oxygen Demand as O_2	32	32	16	40	40	16	16	40	56	16	16		
Free & Saline Ammonia as N	0,2	1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	<0,1	1,3	<0,1	1,5	Aesthetic
Silver as mg/l Ag	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Aluminium as mg/l Al	< 0,100	< 0,100	< 0,100	< 0,100	< 0,100	< 0,100	< 0,100	< 0,100	< 0,100	< 0,100	< 0,100	0,3	Operational
Arsenic as mg/l As	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	0,01	Chronic health
Gold as mg/l Au	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Boron as mg/l B	1,27	1,37	0,410	0,398	0,575	0,714	0,417	1,99	1,28	1,46	0,723	2,4	Chronic health
Barium as mg/l Ba	0,032	0,027	0,042	0,031	0,024	0,047	0,039	< 0,010	0,030	< 0,010	0,032	0,7	Chronic health
Beryllium as mg/l Be	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Bismuth as mg/l Bi	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Cadmium as mg/l Cd	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	0,003	Chronic health
Cerium as mg/l Ce	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Cobalt as mg/l Co	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Chromium as mg/l Cr	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	0,05	Chronic health
Caesium as mg/l Cs	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Copper as mg/l Cu	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	2	Chronic health
Dysprosium as mg/l Dy	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Erbium as mg/l Er	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Europium as mg/l Eu	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Iron as mg/l Fe	0,081	0,650	< 0,025	< 0,025	0,054	0,108	0,139	0,411	0,052	0,128	0,123	2 0,3	Chronic health Aesthetic

Element (mg/L)	BH3	BH6	105	113	118	119	121	122BH5	123	126BH1	130BH4	SANS241:2015 Drinking Water Standard	Risk
Gallium as mg/l Ga	< 0,010	< 0,010	0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Gadolinium as mg/l Gd	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Germanium as mg/l Ge	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Hafnium as mg/l Hf	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Mercury as mg/l Hg	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	0,006	Chronic health
Holium as mg/l Ho	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Inium as mg/l In	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Iridium as mg/l Ir	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Lanthanum as mg/l La	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Lithium as mg/l Li	0,043	0,036	0,019	0,013	0,025	0,024	0,015	0,058	0,032	0,026	0,036		
Lutetium as mg/l Lu	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Manganese as mg/l Mn	< 0,025	0,046	< 0,025	< 0,025	< 0,025	< 0,025	< 0,025	< 0,025	< 0,025	< 0,025	< 0,025	0,4 0,1	Chronic health Aesthetic
Molybdenum as mg/l Mo	< 0,010	0,010	0,010	0,011	0,022	0,010	0,010	< 0,010	< 0,010	0,032	< 0,010		
Niobium as mg/l Nb	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Neodymium as mg/l Nd	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Nickel as mg/l Ni	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	0,011	0,084	< 0,010	0,07	Chronic health
Osmium as mg/l Os	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Phosphorus as mg/l P	< 0,010	< 0,010	< 0,010	< 0,010	0,094	0,283	0,287	0,181	< 0,010	0,090	0,085		
Lead as mg/l Pb	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	0,01	Chronic health
Palladium as mg/l Pd	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Praseodymium as mg/l Pr	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Platinum as mg/l Pt	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Rubidium as mg/l Rb	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Rhodium as mg/l Rh	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Ruthenium as mg/l Ru	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Antimony as mg/l Sb	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	0,02	Chronic health
Scandium as mg/l Sc	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Selenium as mg/l Se	0,515	0,450	0,083	0,056	0,031	0,209	0,075	0,637	0,315	0,094	0,157	0,04	Chronic health
Silicon as mg/l Si	8,7	5,6	16,4	13,3	10,6	9,9	31	9,3	10,3	8,0	11,4		
Samarium as mg/l Sm	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Tin as mg/l Sn	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Strontium as mg/l Sr	5,52	4,12	1,32	2,02	1,38	3,03	1,68	7,02	3,80	2,36	2,55		
Tantalum as mg/l Ta	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Terbium as mg/l Tb	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Tellurium as mg/l Te	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Thorium as mg/l Th	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Titanium as mg/l Ti	0,167	0,099	0,038	0,042	0,033	0,105	0,050	0,164	0,116	0,077	0,081		
Thallium as mg/l Tl	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Thulium as mg/l Tm	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Uranium as mg/l U	0,036	0,055	0,027	0,029	0,026	0,024	0,019	0,058	0,030	0,034	0,042	0,03	Chronic health

Element (mg/L)	BH3	BH6	105	113	118	119	121	122BH5	123	126BH1	130BH4	SANS241:2015 Drinking Water Standard	Risk
Vanadium as mg/l V	< 0,010	< 0,010	0,016	0,015	< 0,010	< 0,010	0,025	< 0,010	< 0,010	< 0,010	< 0,010		
Tungsten as mg/l W	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Yttrium as mg/l Y	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Ytterbium as mg/l Yb	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		
Zinc as mg/l Zn	0,012	0,129	0,032	0,013	0,152	0,015	1,56	0,062	0,014	0,076	0,061		
Zirconium as mg/lZr	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010		

Acute health	Determinant poses an immediate unacceptable health risk if present at concentration values
Aesthetic	Determinant that taints water with respect to taste, odour and colour and that does not pose an unacceptable heath risk if present at concentration values exceeding the numerical limit
Chronic health	Determinant that poses an unacceptable health risk if ingested over an extended period if present at concentration values exceeding the limits specified
Operational	Determinant that is essential for assessing the efficient operation of treatment systems and risks to infrastructure

3.2.6 Summary of groundwater quality

The outcome of the chemical analysis of the groundwater samples taken during the fieldwork phase of the project indicates that regionally, groundwater is saline with elevated total dissolved solids, chloride and in some instances sulphate concentrations (iLEH, 2018). The groundwater in private boreholes has also been contaminated with nitrates that are most probably associated with agricultural activities. Elevated selenium and uranium levels are typical for the region, but may result in chronic health risks. The groundwater can therefore not be considered suitable for potable use and care must be taken not to ingest the water over prolonged periods of time.

Groundwater quality in the mining area is characterised by increased sulphate and manganese concentrations, in addition to what is observed for the private boreholes above. This is evident when comparing regional sulphate concentrations, as presented in Figure 5. The most significant impact on groundwater quality at the operations is associated with the historical TSF. Sulphate concentrations in this area exceed 2500 mg/l in two of the monitoring boreholes. The third borehole, drilled into a strong aquifer associated with the fault mapped in this area, has lower sulphate concentrations (474 mg/l). Sulphate concentrations in the two boreholes sampled at the historical mining area have sulphate concentrations above 1200 mg/l.

It is noted that some private boreholes also have elevated sulphate concentrations, as discussed earlier. As these boreholes fall outside the perceived zone of influence of the mining activities, elevated sulphate concentrations are also typical of the geohydrological setting of this arid region. The average sulphate concentration of the hydrocensus boreholes sampled is 485 mg/l.

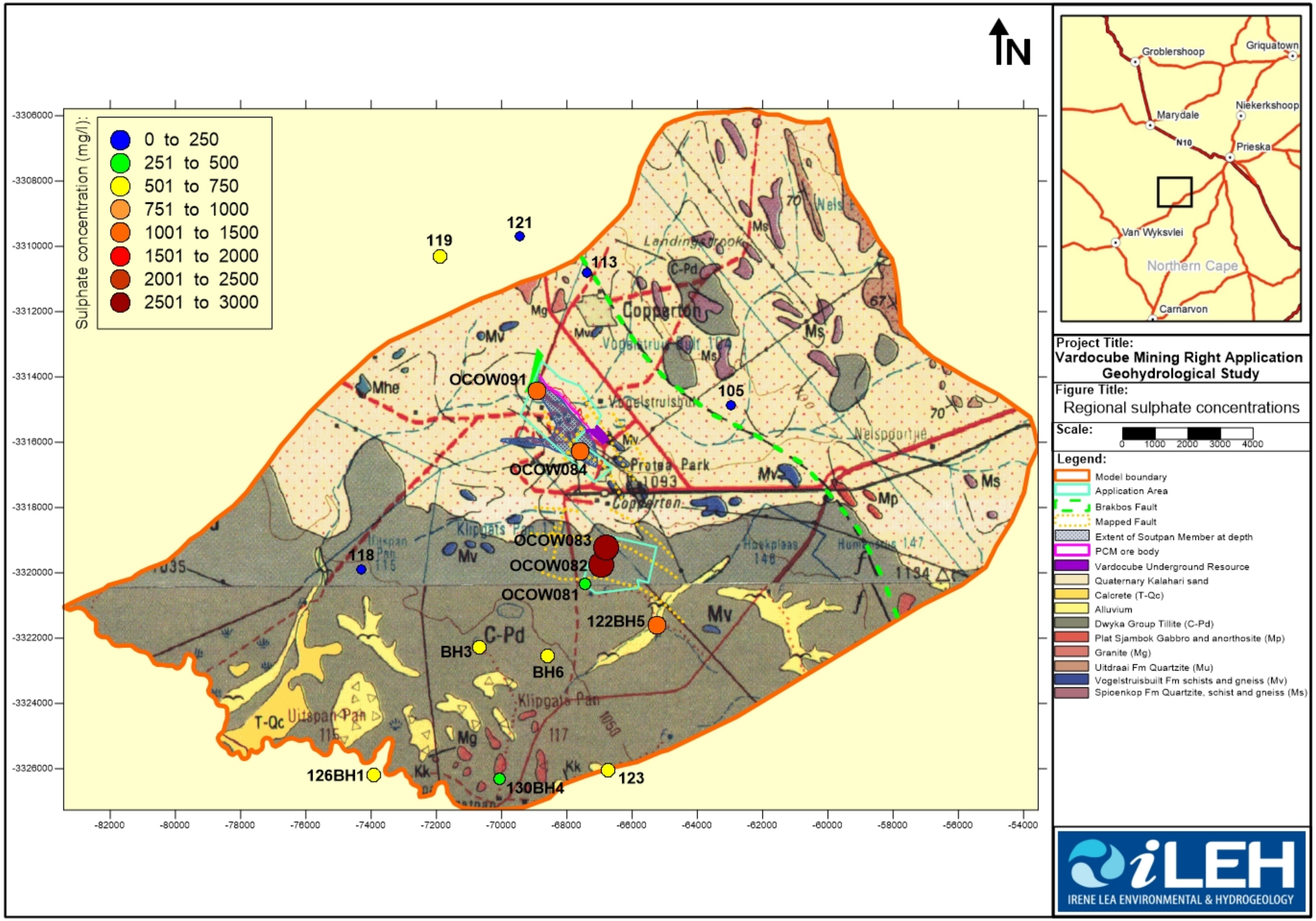

Figure 5 Class posted map indicating regional sulphate concentrations

A Piper Diagram was prepared with the results of all of the groundwater samples and is presented in Figure 5 (iLEH, 2018). These diagrams are used to plot the equivalent concentrations of several elements to characterise the types of groundwater in the study area.

Most of the samples plot in the central part of the diagram where no dominant groundwater type can be distinguished. Samples that plot in the central part of the diagram further suggest that the groundwater is affected by cation exchange through calcite precipitation and sulphate reduction. Samples that plot on this part of the diagram may also indicate mixing of groundwater and gypsum dissolution.

The ambient groundwater quality is spread out over the diagram suggesting that different types of groundwater are present, most probably affected by the geology intersected in the boreholes and the low rainfall conditions. Four of the samples (105, 113, 118, and 121) are bicarbonate dominant. The results of the chemical analysis indicate that groundwater from two of these boreholes (105 and 113) have low total dissolved solids and is generally of good quality.

The diagram indicates that groundwater at the PCM mining area, most notably at the historical TSF, is Na/Cl-SO_4 dominant.

3.3 Groundwater flow patterns

Nine groundwater level measurements are available from the monitoring and hydrocensus boreholes. These are indicted in Table 5. The depth to groundwater levels varies between 1 and 35m below surface, with an average depth 17m.

Groundwater flow often follows the topography as groundwater drains with gravity towards local rivers and streams. In order to test whether this is the case, the correlation between the topographical elevations of boreholes and groundwater levels was calculated.

Figure 7 shows that this correlation is 0,89, which suggests that groundwater flow patterns would broadly follow the topography. The level of correlation is affected by the historical mining activities that resulted in a lowering of the groundwater level; and by the historical TSF that increases recharge to the aquifers thus forming a mound in the groundwater levels.

Table 5 Available groundwater level measurements

Borehole ID	X Coordinate	Y Coordinate	Elevation (mamsl)	Depth (m)	SWL (mamsl)	Water level (m)
124BH8	-67072	-3314401	1053	48	1028,22	24,78
109	-64564	-3306406	1103	40	1102,79	0,75
112	-62345	-3306576	1116	40	1103,27	13,41
129	-73782	-3326295	1008	48	994,76	13,24
OCOW081	-67444	-3320337	1056	150	1049,00	7,00
OCOW082	-66945	-3319769	1067	80	1060,90	6,10
OCOW083	-66793	-3319226	1079	80	1058,70	20,30
OCOW084	-67593	-3316292	1062	80	1030,10	31,90
OCOW091	-68908	-3314426	1066	80	1031,30	34,50

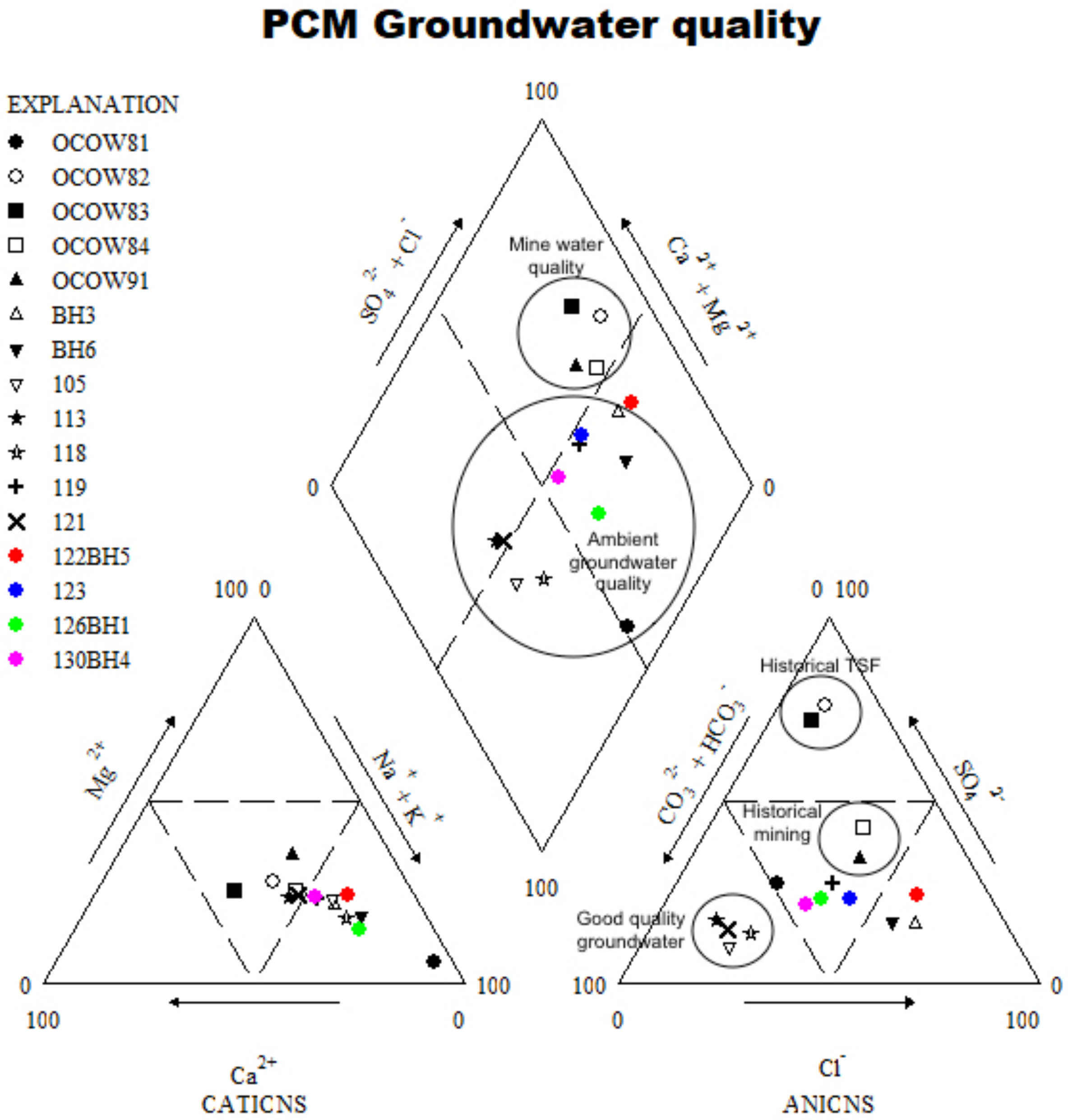

Figure 6 Piper diagram

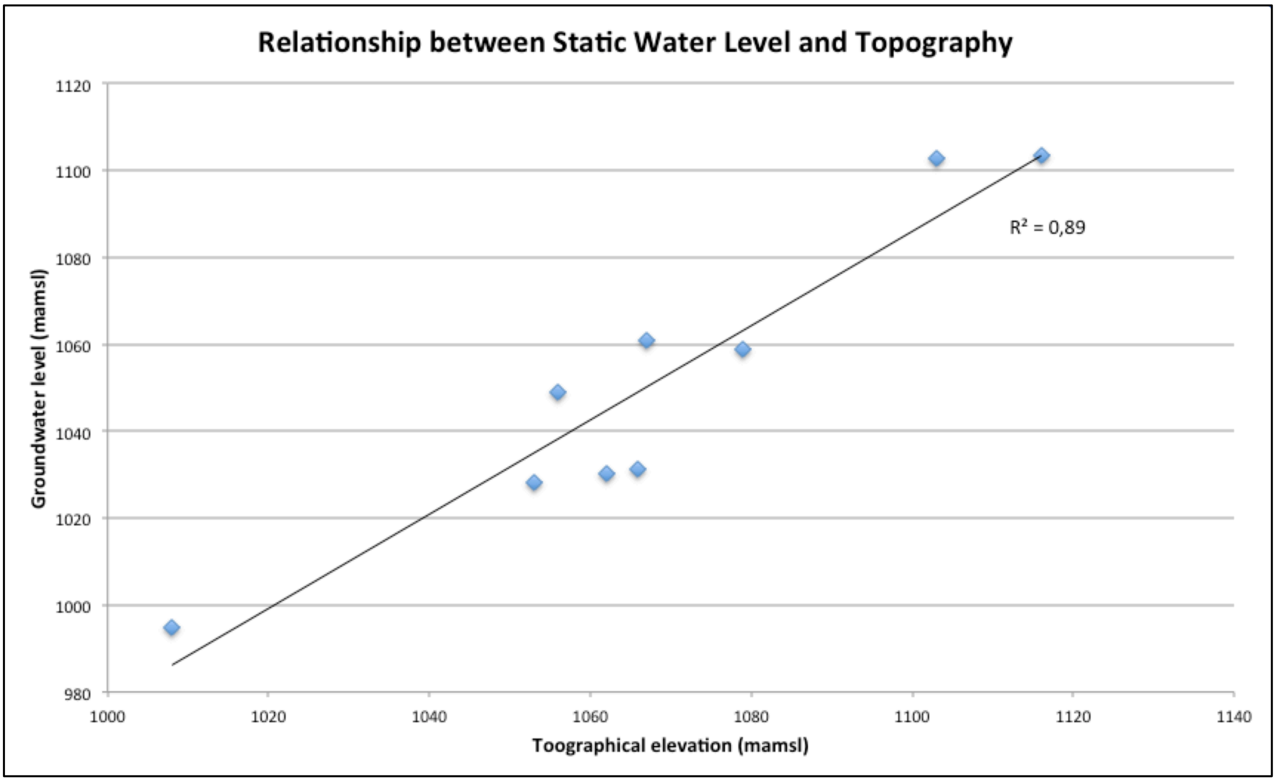

Figure 7 Relationship between static water level and topography

Groundwater flow contours were generated using the field-measured data points. The contours are presented in Figure 8. The following can be concluded from the contours:

- Regionally, groundwater flows in a southwesterly direction.
- The regional flow gradient is estimated to be 0,008 (1:125). If the maximum and minimum transmissivities obtained from the pumping tests (Table 2) are taken into consideration, the groundwater flow rate can be calculated using Darcy's Law. The flow rate may vary between 3 and 400 m/a, depending on the aquifer conditions.
- Historical mining at PCM has resulted in a lowering in groundwater levels around the mine. In this area, groundwater flow is reversed towards the mining area and deviates from the regional trend.
- Recharge is taking place from the historical TSF. In this area, groundwater levels are higher than the regional trend. A groundwater mound has formed below the historical TSF (that is not lined) and groundwater flows radially from the facility.

3.4 Conceptual groundwater model

The information presented above was used to construct a conceptual hydrogeological model that forms the basis of the numerical model developed for the project. The conceptual model is based on the information presented in iLEH (2018). The conceptual model is based on the following aspects and is demonstrated in the schematic cross section in Figure 4:

- The upper 15m of the geological succession comprises of unconsolidated sand, calcrete and clay or a mixture thereof. This unit is expected to be dry, but may carry groundwater for short periods of time after a rainfall event that has resulted in recharge to the aquifers.
- A 100m thick fractured rock aquifer is formed in the upper part of the geological succession. The thickness of this unit was chosen based on the depth of oxidation and leaching in the ore body as well as on the outcome of monitoring borehole drilling. In the mining area, this aquifer is formed in fractured gneiss. This aquifer may in places be enhanced by the presence of water-bearing faults. The transmissivities of the faults are variable, ranging from 0,2 – 32m^2/d. The matrix of this aquifer is expected to have a low transmissivity, probably around 0,2 m^2/d or lower. The average depth to groundwater in this aquifer is 18m. This aquifer is dewatered locally around the historical PCM underground workings. This aquifer is regionally used for private groundwater abstraction. Available information suggests that private boreholes are shallow, typically drilled to 40m. The groundwater is saline and generally not fit for human consumption.
- A lower fractured rock aquifer is present from 100m over a thickness of 1300m. This depth was chosen to coincide with the planned depth of future mining. There is currently no information available to characterise this aquifer. The monitoring boreholes drilled during the EIA phase of the project extended to depths of between 80 and 150m below surface. The information obtained from these boreholes characterise the upper parts of the fractured rock aquifer that is targeted for private groundwater supply on a regional scale. As there is no specific information available to characterise the aquifers that will be intersected in the Deeps, permeabilities and specific storage values were obtained from literature (Anderson and Woessner, 1992 and Domenico and Schwartz, 1990). The ranges of permeabilities obtained from literature vary greatly, as indicated in Table 6. Groundwater levels in this aquifer are currently lowered to a depth of 400m below surface, resulting in dewatering of the aquifer locally around the historical PCM underground workings.

Table 6 Literature-based aquifer parameters used during simulations

Geological unit	Rock type	Min K (m/d)	Max K (m/d)	Min K (m/d)	Max K (m/d)	Specific storage	
		Anderson and Woessner (1992)		Domenico and Schwartz (1990)		Anderson and Woessner (1992)	
Kalahari	Sand/calcrete			1,73E-02	1,73E+01	1,00E-04	4,90E-05
Dwyka	Tillite	1,00E-07				1,50E-06	
Vogelstruisbuilt	Gneiss/amphibolite	1,00E-02	10	6,91E-04	2,59E+01	6,90E-05	3,30E-06
Prieska Copper Member	Massive sulphide, gneiss, fels	1,00E-08	1,00E-02	2,59E-09	1,73E-05	3,30E-06	3,30E-06
Smouspan Member	Gneiss	1,00E-08	1,00E-02	2,59E-09	1,73E-05	3,30E-06	3,30E-06

The parameters that will be used during groundwater modelling, as derived from field data, assumed or obtained from literature presented above, are presented in Table 7.

A MAP of 198mm/a will be used during simulations.

Table 7 Conceptual aquifer parameter values

Description	Thickness (m)	T (m^2/d)	Recharge (% of MAP)	S_y (-)	S (-)	Effective porosity (%)
Soil/calcrete (weathered)	15	0,3	1	1,5E-3	NA	10
Upper fractured rock aquifer	100	0,2	NA	1E-4	NA	5
Lower fractured rock aquifer	1300	0,02	NA	NA	NA	1
Faults	100	6 - 32	NA	1E-4	NA	5

MODFLOW, the modelling software used during simulations, is based on the assumption that aquifers are continuous porous media. For this reason, average aquifer parameters are assigned during simulations. The heterogeneous nature of a fractured rock aquifer is therefore approximated by a homogenous porous flow field. This is the nature of all groundwater modelling software and not just of MODFLOW.

4 SOURCE TERM

Sulphate was identified as the indicator element for the operations. It is associated with the impact of both the historical mining and tailings deposition activities. Elevated sulphate originates from the oxidation of sulphide minerals to produce sulphate and metals during the process of acid mine drainage.

A geochemical study, including static and kinetic leach tests, is currently underway (Van Hille, 2018). The kinetic leach tests are still underway, but the following results are available:

- The initial five columns have been running for approximately 200 days and the fresh tailings sample for 140 days.
- The historical TSF at times exceed the maximum (LCT3[1]) leachable concentration threshold for a number of metals at time. It is noted that the historical TSF does not form part of the Vardocube mining right application.
- Leachate from the saprolite and waste rock in general yield low concentration leachate. The exception is some metals for the first few weeks.
- Leachate from the low-grade ore exhibit concentrations exceeding the LCT0 and LCT1 threshold values.
- The fresh tailings samples did not generate acidity consistently during the kinetic testing.
- The acidity and alkalinity data obtained from the tests indicate that the percolation rate has little effect on the leaching of alkalinity from the samples. This suggests that the process is controlled by solubility.
- Acidity appears to be time-dependent, irrespective of the percolation rate. The higher the flow-through, the more dilute the acidity becomes. It was further found that the acid-generating reactions do not stop during periods of zero percolation (undertaken to simulate the impact of dry periods). This probably means that a spike in acidity and sulphate concentrations can be

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[1] The leachable concentration threshold (LCT) values refer to the of the National Environmental Management: Waste Act (Act 59 of 2008) and the Waste Classification and Management Regulations (R635) as amended. LCT0 is the lowest concentration threshold, while LCT3 is the highest.

expected once irrigation of the columns start again.

The provisional results from the kinetic leach tests are presented in Table 8. The information shows that the amount of sulphate that leaches out under the conditions of the static tests are significantly higher compared to the kinetic tests. This is due to the nature of the static tests, where an acid is used to digest the rock completely. The results of the static tests are therefore not representative of natural leaching conditions expected at the operations.

Table 8 Sulphate concentrations from static and kinetic leach tests (after Van Hille, 2018)

	Saprolite (mg/l)	Waste rock (mg/l)	LG3 (mg/l)	LG1 (mg/l)	Tails Old (mg/l)	Tails Fresh (mg/l)
Static test results:	123 - 456	629 - 1577	28 071	2 269	105 088 – 125 147	NA
Kinetic test results: Elapsed time (d)	**Saprolite (mg/l)**	**Waste rock (mg/l)**	**LG3 (mg/l)**	**LG1 (mg/l)**	**Tails Old (mg/l)**	**Tails Fresh (mg/l)**
2	55,21	605,23	1563,22	1489,23	2822,40	277,97
10	43,51	481,25	892,12	937,96	1742,40	557,26
17	30,12	301,38	364,90	362,68	1117,70	433,64
24	22,62	262,21	394,04	406,86	785,11	560,77
31	18,94	296,94	376,33	443,44	664,25	437,55
38	16,68	256,58	297,13	354,36	597,75	442,72
45	10,95	202,26	205,14	256,37	578,42	438,25
54	10,95	164,03	204,10	244,07	377,30	364,60
62	16,61	169,54	193,27	243,33	452,06	393,25
69	7,87	153,86	217,17	211,11	434,60	354,22
77	7,11	156,11	163,47	211,17	434,19	415,65
84	8,09	137,05	124,42	196,42	338,12	415,96
91	6,24	128,56	126,45	176,44	450,35	
98	6,67	129,47	122,35	171,13	289,89	
105	6,35	94,04	110,86	166,28	259,93	
112	6,56	91,38	90,86	224,27	205,15	
119	27,52	154,25	133,30	240,24	219,32	
126	12,99	149,89	147,62	241,92	230,90	
133	23,02	169,33	163,15	279,35	228,15	
140	182,82	185,62	298,25	301,41		

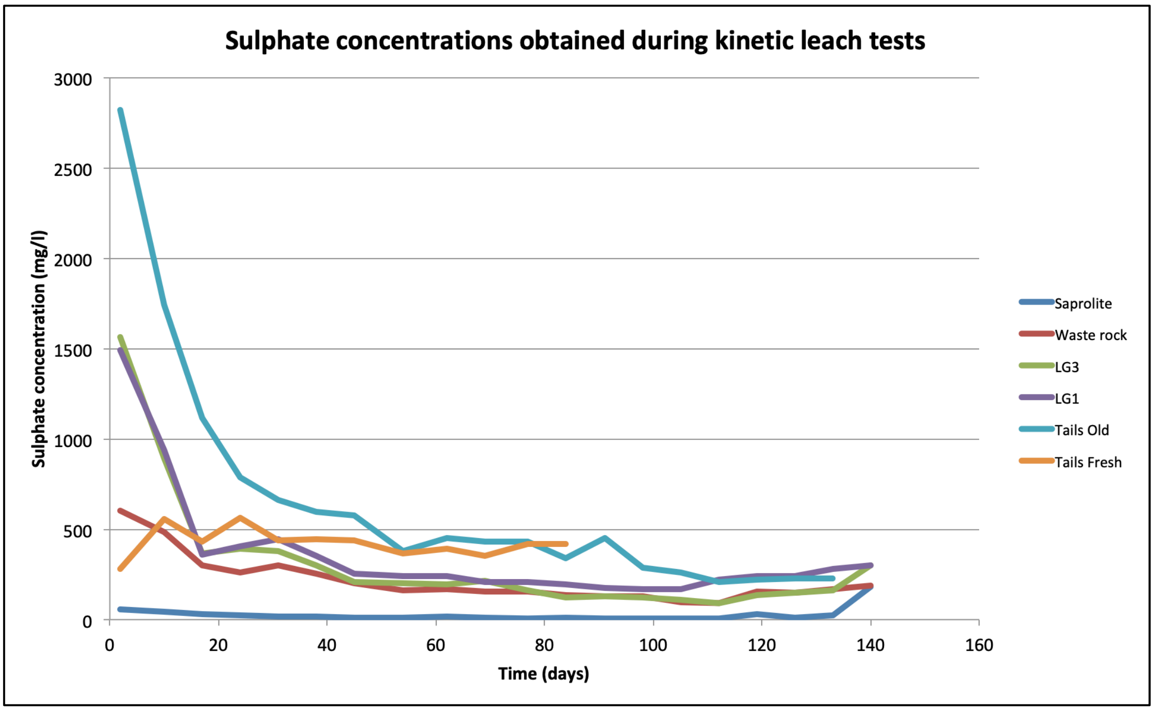

Figure 9 Time series graph indicating sulphate concentrations from the kinetic leach tests

The time series graph of sulphate concentrations from the kinetic tests presented in Figure 9 indicates that a dramatic reduction in sulphate concentrations occur after the first 20 – 40 days of the tests. After that, concentrations stabilise. Highest sulphate concentrations are associated with the historical TSF (Old Tails sample), as expected.

None of the activities proposed as part of the Vardocube mining right application are expected to significantly contribute to groundwater contamination. The following sources to groundwater contamination were identified (iLEH, 2018), all relating to the Repli mining right application:

- The historical TSF. Groundwater monitoring information indicates that this facility is already impacting on groundwater quality.
- The proposed new TSF. It is noted that the new TSF will be lined, thus reducing the impact on groundwater quality associated with the facility significantly.
- The underground workings.
- The effluent dam, which will contain poor quality water pumped to surface from the underground workings. This dam will also be lined, thus significantly reducing the risk of groundwater contamination.

Four underground water samples were submitted for analysis (iLEH, 2018). The sulphate concentrations are presented in Table 9. It is shown that sulphate concentrations vary between 900 and 1420mg/l in the underground workings. For the purpose of model simulations, a value of 1420 mg/l was used to represent underground water quality, based on the principles of the precautionary approach.

Table 9 Sulphate concentration in underground water quality

Sample Name	Prieska Shaft	Hutchins Shaft 600m	Decline at 360m	Shaft at 900m
Date sampled	April 2017	14-Aug-17	28-Aug-17	14-Sep-17
Sulphate as SO_4	1420	900	1000	1100

5 POTENTIAL PATHWAYS AND RECEPTORS

Based on the available dataset, the following aquifer pathways are identified for the project:

- Vertical and horizontal flow through the weathered aquifer from surface sources of contamination as well as mining areas that intersect this aquifer.
- Once the possible contamination reaches the fractured rock aquifer, the preferential flow paths would be the mapped faults. Groundwater will also flow through the rock matrix, but at much lower rates compared to the preferential pathways.
- Vertical flow through the unsaturated soil horizon from surface sources of contamination like the historical TSF. It is noted that the Vardocube mining right application does not include the historical or new TSF, but these areas are included in this assessment in order to obtain an indication of the cumulative impact of mining. The new TSF, the effluent dam and the PCD dam will be HDPE lined and as such should not impact on groundwater quality unless these facilities overflow or if the liners leak. The rate at which the vertical flow can take place is governed by the permeability of the soils underlying these areas.

The following receptors were identified:

- Existing private groundwater users.
- Non-perennial streams near the mining area. It is however noted that these streams are dry and this impact is therefore not anticipated to be of significance.

6 KEY ASSUMPTIONS AND LITERATURE-BASED DATA INPUTS

The numerical modelling is based on the following assumptions:

- Aquifer parameters were inferred from aquifer tests data discussed above. Aquifer parameters used to construct the numerical model are presented in Tables 2, 6 and 7, as discussed above.
- The source characterisation used for the project was taken from monitoring data in the absence of the geochemistry report that is currently being compiled, but was not available at the time of compilation of this report.
- Only advective transport of contaminants was simulated. Assumptions made regarding advection, are discussed below. While it is acknowledged that attenuation will take place in the soils and clays, there is currently insufficient information available to quantify the extent to which this takes place. As such, simulations are based on the precautionary principle and take the worst-case scenario into consideration.
- The extent of the numerical model is based on natural groundwater barriers, as discussed below. These include water divides as well as rivers and streams.

7 GEOHYDROLOGICAL IMPACT ASSESSMENT

No additional monitoring or other information became available subsequent to the completion of the geohydrological study completed for the Repli Mining Right (iLEH, 2018) with which to update the information presented below. The numerical model prepared as part of the Repli study could therefore not be updated. A description of the mathematical modelling is presented in Appendix 1 for ease of reference. The existing model was updated to include the proposed Vardocube mining activities. These are presented below.

7.1 Mining scenarios tested

7.1.1 Mine schedule used

The calibrated numerical model constructed for the Repli Mining Right application was used to test several scenarios in order to quantify the risk associated with the project on groundwater levels and quality. In order to do so, the mine schedule, as detailed in Table 10, was incorporated.

Table 10 Mine schedule used during simulations

Activity	From	To	Years
Historical underground mining	1971	1991	20
Dormant phase	1992	2018	26
Proposed underground mining (Repli and Vardocube)	2019	2029	10
Proposed opencast mining	2029	2030	1

7.1.2 Pollution sources

The impact of mining on groundwater quality was simulated using sulphate as an indicator element, as discussed in Section 4.

The impact of the Vardocube mining area is related to underground mining alone. In order to complete an assessment of the cumulative impact of mining, the Repli areas of responsibility were also included during simulations. These include:

- The new TSF, the effluent dam and the PCD, all of which will be lined with HDPE and will be designed to meet the requirements of GN704. As such, these facilities are not expected to leak or spill during the operational phase, which should eliminate contamination of the underlying aquifers. If leaks and spills occur, it would not be impossible to predict when, where and how these would take place, thus not allowing realistic simulations with the model.
- The simulations presented below addresses the preferred option (TSF2) identified as part of the Repli mining rights application. The facility will be lined according to the outcome of the Waste Classification study completed for the facility, as mentioned above. The liner system is expected to include at least a 1,5mm thick HDPE layer according to feedback received from the engineers appointed to the project. If the liner is installed correctly and it remains intact, no leakage is expected. Under these conditions, the new TSF will not impact on groundwater quality.
- The new TSF will remain on surface and will be rehabilitated in situ. Both the new TSF and the WRD will be capped with overburden and topsoil during rehabilitation. This will reduce the rate at which rainwater can infiltrate, thus reducing the associated long-term risk of groundwater contamination.

- Upon closure, the effluent and PCD dams will be removed and fully rehabilitated, leaving no long-term risk to groundwater contamination. For the purpose of this impact assessment, it was therefore assumed that the effluent dam and PCD would not pose a risk to groundwater quality during the project or in the long-term.

The quality of leachate associated with the TSF and WRD are listed in Table 8.

7.1.3 Void stabilisation options

Orion is considering three void stabilisation options for the Repli and Vardocube mining areas to ensure safe mining conditions during opencast and underground mining. The effect of backfilling the mining voids with various combinations of waste rock, tailings and cement would result in a reduction in permeability of the formations in the mining area. There is currently no information available to quantify the modified permeability of the backfilled areas, as backfilling options have not yet been finalised and the affected areas are not delineated. As such, it is not possible to include this impact to any level of confidence in the groundwater modelling discussed here. It is noted that this backfilling will reduce the seepage of groundwater to the opencast and shallow mining areas.

This activity is not expected to adversely impact on underground water quality, as the water that will drain from backfilled areas will be removed to surface. Should additional information become available once this option is finalised, it is recommended that the modelling is updated and the report amended accordingly.

7.1.4 Rehabilitation measures included

Limited details are currently available to quantify the impact of rehabilitation measures proposed for the operations on groundwater. The following information is currently available:

- All underground shafts will be sealed at closure.
- No subsidence is expected as a result of the Vardocube underground mining.
- The existing and planned opencast pits will not be backfilled and rehabilitated, but will remain open post closure. The underground voids underneath the existing pits and sinkholes as well as the planned opencast pit will however be backfilled and capped to facilitate mining of the +150 Level Target. This backfilling and capping will remain in place post-closure.
- The new TSF and WRD will be rehabilitated in-situ. This will entail shaping of the side slopes and capping of the facilities to reduce infiltration. Provisional indications are that the WRD will be capped with 0,3m and the TSF with 0,2m of overburden and topsoil. Stormwater management will be maintained post-closure at both facilities to reduce the risk of erosion. It is currently estimated that the rehabilitation of the new TSF will take 24 – 36 months to complete. Details of the rehabilitation methods to be implemented at these mine residue facilities are not currently available and for this reason, it is not possible to accurately estimate the reduction in the rate of recharge of rainwater to these facilities.
- During long-term simulations, it was however assumed that mine dewatering will cease and that groundwater levels will recover.

7.2 Impact prediction: Operational phase

7.2.1 Rate of groundwater seepage to mining areas

It is known that underground water levels have stabilized at a depth of 330m (Orion, 2018). This water level, as well as the timing of the project presented in Table 10, was used to estimate the permeability of the rock formations intersected in the underground workings. Simulations suggest that an average permeability of 2,2E-4m/d for the rock formations intersected achieves the best match. When compared to the literature-based values presented in Table 11, it is shown that the permeability of the rock formations intersected in the historical underground workings trend towards the higher range of permeabilities reported.

Table 11 Literature-based aquifer parameters assigned during simulations

Geological unit	Rock type	Min K (m/d)	Max K (m/d)	Min K (m/d)	Max K (m/d)	Specific storage	
		Anderson and Woessner		Domenico and Schwartz		Anderson and Woessner	
Kalahari	Sand/calcrete			1,73E-02	1,73E+01	1,00E-04	4,90E-05
Dwyka	Tillite	1,00E-07				1,50E-06	
Vogelstruisbuilt	Gneiss/amphibolite	1,00E-02	10	6,91E-04	2,59E+01	6,90E-05	3,30E-06
Prieska Copper Member	Massive sulphide, gneiss, fels	1,00E-08	1,00E-02	2,59E-09	1,73E-05	3,30E-06	3,30E-06
Smouspan Member	Gneiss	1,00E-08	1,00E-02	2,59E-09	1,73E-05	3,30E-06	3,30E-06

Based on the results of the simulations undertaken, the estimated volume of groundwater that will seep to the underground workings, are presented in Table 12. The results are provided in both m^3/a and l/s. The minimum, maximum and geometric mean values are reported for each phase of the proposed mining activities. The geometric mean, rather than the average, was calculated to indicate the central tendency of the dataset and to ensure that very high or low results do not skew the outcome of the assessment.

Underground mining to the +105 Level is expected to intersect the aquifers present, which will result in the inflow of groundwater. As these rock formations are expected to be weathered and fractured, the rate of groundwater seepage may be higher compared to deeper mining areas. The revised mining schedule and layout does not affect the seepage assessment completed for the +105 Level mining during the Repli mining right application (iLEH, 2018). The same rates are reported. The maximum seepage rate obtained for the higher literature-based permeability values is not considered realistic. It is thought that groundwater seepage at this mining depth would be closer to the average 8 – 9l/s, but may be lower, closer to the minimum value, considering the impact of historical mine dewatering.

The rate of groundwater seepage to the Deep Sulphide Target underground mining area is expected to be very low, as these rock formations are most probably tight, thus not transmitting significant volumes of groundwater. For the purpose of this assessment, the extent of mining was revised based on the information made available and distinction is made between the Repli and Vardocube underground mining areas. It is noted that the Repli and Vardocube underground mining areas reported by Orion (2018) are slightly smaller in size compared to what was made avialble for the Repli mining right application (iLEH, 2018). The groundwater seepage rates obtained during this assessment are therefore similar, but slightly lower compared to what was previously reported.

In the Vardocube mining area, the assessment indicates groundwater seepage rates that may vary between 0,3 and 23 l/s. As discussed above, the high seepage rate, based on literature-based rock permeability values, is thought to be unrealistic and should be disregarded. The rate of groundwater seepage will probably be closer to the average value of 1 l/s for the Vardocube underground section.

Groundwater seepage rates to the Repli underground mining area may vary between 1 and 79 l/s, but with an expected rate of 3,6l/s.

The total seepage rate to the underground workings is expected to be on average around 4,6l/s, but may vary between 1,3 and 102l/s depending on conditions.

During previous simulations, the opencast mining activities were planned at the start of the mining operations (iLEH, 2018). Orion however plans to complete opencast mining after underground mining has been completed (Orion, 2018). Even though the deeper rock formations in the immediate vicinity of the underground workings and the shallow aquifers around the sinkholes are dewatered, groundwater seepage may still take place during opencast mining, especially during the wet season. The seepage may be associated with the calcrete, which is expected to retard the infiltration of rainwater. Model simulations suggest that seepage rates to the pits may vary between 0,03 and 9 l/s, but would be around 0,5 l/s on average under the new assumed mining schedule.

Table 12 Estimated groundwater seepage to mining areas

Activity	Minimum (m^3/a)	Maximum (m^3/a)	Geometric mean (m^3/a)
Underground mining: +105 Level (Repli mining)	22995	11919075	277834
Underground mining: Deep Sulphide Target Level (Repli mining)	31375	2503611	112689
Underground mining: Deep Sulphide Target Level (Vardocube mining)	9031	720616	32435
Total Underground mining : Deep Sulphide Target Level	40406	3224228	145124
Opencast Mining	1005	282728	16334
Activity	**Minimum (m^3/a)**	**Maximum (m^3/a)**	**Geometric mean (m^3/a)**
Underground mining: +105 Level (Repli mining)	0,7	378,0	8,8
Underground mining: Deep Sulphide Target Level (Repli mining)	1,0	79,4	3,6
Underground mining: Deep Sulphide Target Level (Vardocube mining)	0,3	22,9	1,0
Total Underground mining : Deep Sulphide Target Level (Repli and Vardocube mining)	1,3	102,2	4,6
Opencast Mining	0,03	9,0	0,5

7.2.2 Extent of aquifer dewatering

The underground water level is currently at a depth of 330m below surface, which is positioned in the lower fractured rock aquifer and is well below the depth of private groundwater abstraction. Groundwater level measurements in two of the boreholes at the old mine indicate that groundwater levels are lowered in this area due to the impact of historical mining and that groundwater flow is locally reversed towards the mining area. This is demonstrated in Figure 10. Furthermore, six of the monitoring boreholes drilled to a depth of 80m at the mine are dry.

Orion intends to dewater the underground workings to a depth of 1200m below surface to enable mining at depths of 900 – 1125m below surface. This activity will be restricted to the lower fractured rock aquifer. It is anticipated that the vertical interaction between the upper and lower fractured rock aquifers will be low. Despite this, deep mine dewatering is expected to impact on the upper fractured rock aquifer due to the effect of the flow gradients dewatering will create.

The model was used to simulate the extent of the cone of depression in the upper fractured rock aquifer. This is the aquifer from which groundwater is abstracted on a regional scale. Impacts associated with mine dewatering in this aquifer are therefore of significance to the receptors, most notably private groundwater users, identified. The results of simulations are presented in Figure 10. It is noted that these results are very similar to what was obtained for the Repli mining right application (iLEH, 2018) due to the fact that the total mining area for the planned Repli and Vardocube underground workings is similar in size to what was previously indicated.

The position of the zero meter drawdown delineates the impact zone around the mining area. Groundwater levels will be lowered over areas inside the impact zone. Areas that fall outside the impact zone will most likely not be affected by mine dewatering. Simulations suggest that the cone of depression will be narrow and will dip steeply around the underground workings. This is due to the low permeabilities of the host rocks.

The overlying sand and calcrete layer will be completely dewatered over the zone of impact that is delineated by the zero-meter drawdown contour.

The cone of depression in the upper fractured rock aquifer is expected to be fault controlled. The drawdown cone may therefore extend up to 1200m from the underground mining area in a southeasterly direction. West and east of the mining area, the cone of depression is not expected to extend further than 600m from the mining area. Seven boreholes fall within the zone of impact, as indicated in Table 13. Private boreholes 124BH8 and 103 as well as monitoring boreholes OCOW084 and 94 are located close to the edge of the simulated cone of depression. It is possible that the impact of mine dewatering could affect these boreholes during mining and it would therefore be prudent to include these in the monitoring programme to ensure that adverse impacts are picked up early.

The drawdown in each affected borehole, presented in Table 13 below, represents a lowering in groundwater from the rest water levels.

Table 13 Boreholes that fall in the simulated zone of impact of mine dewatering

Borehole ID	Expected drawdown in groundwater level (m)
OCOW89	<65
OCOW090	<5
OCOW091	<10
OCOW093	dry
OCOW092 and 92A	<40
125	<10
124BH8 and 103	Possible impact

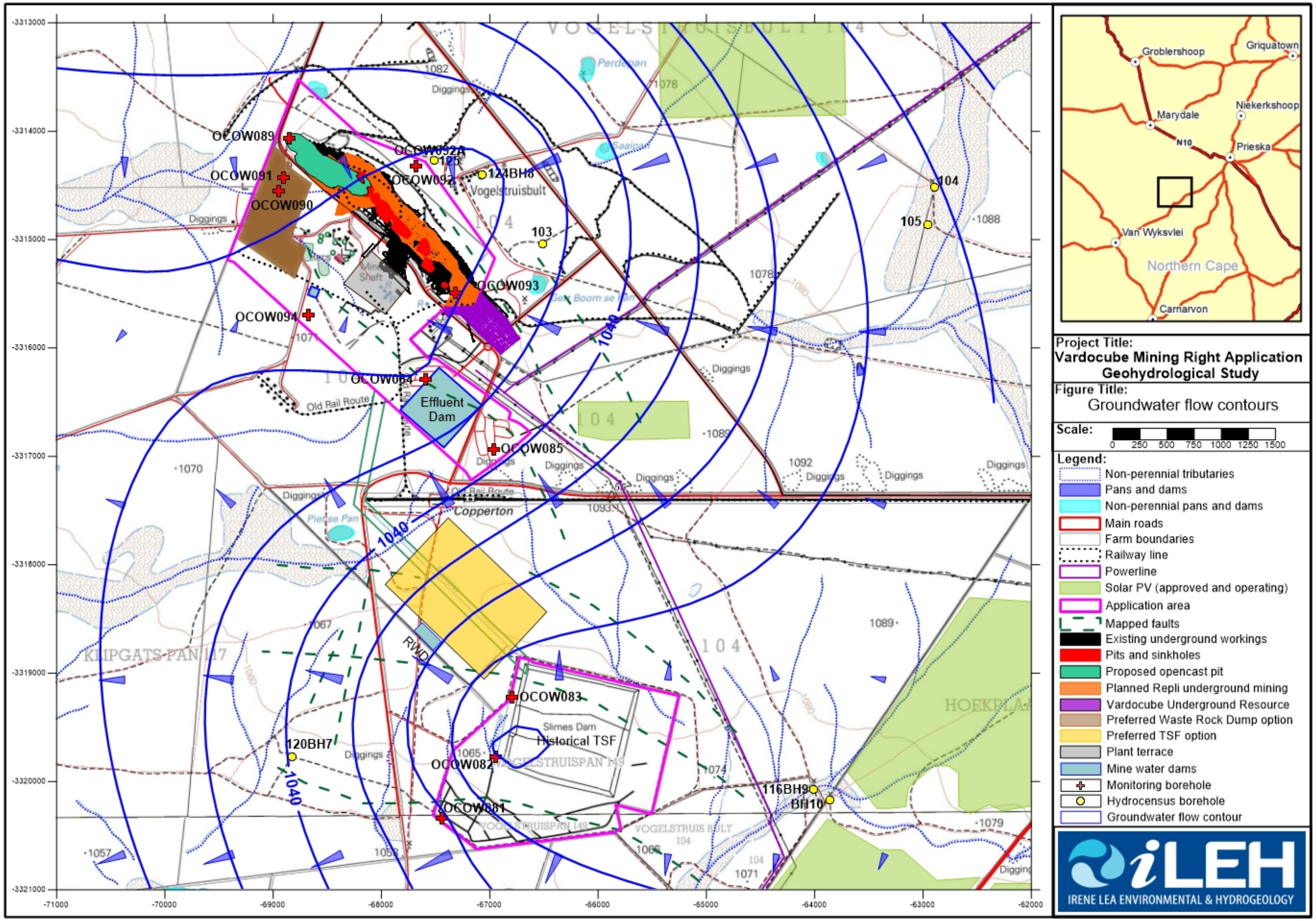

Figure 8 Groundwater level contour map generated from field-measured data

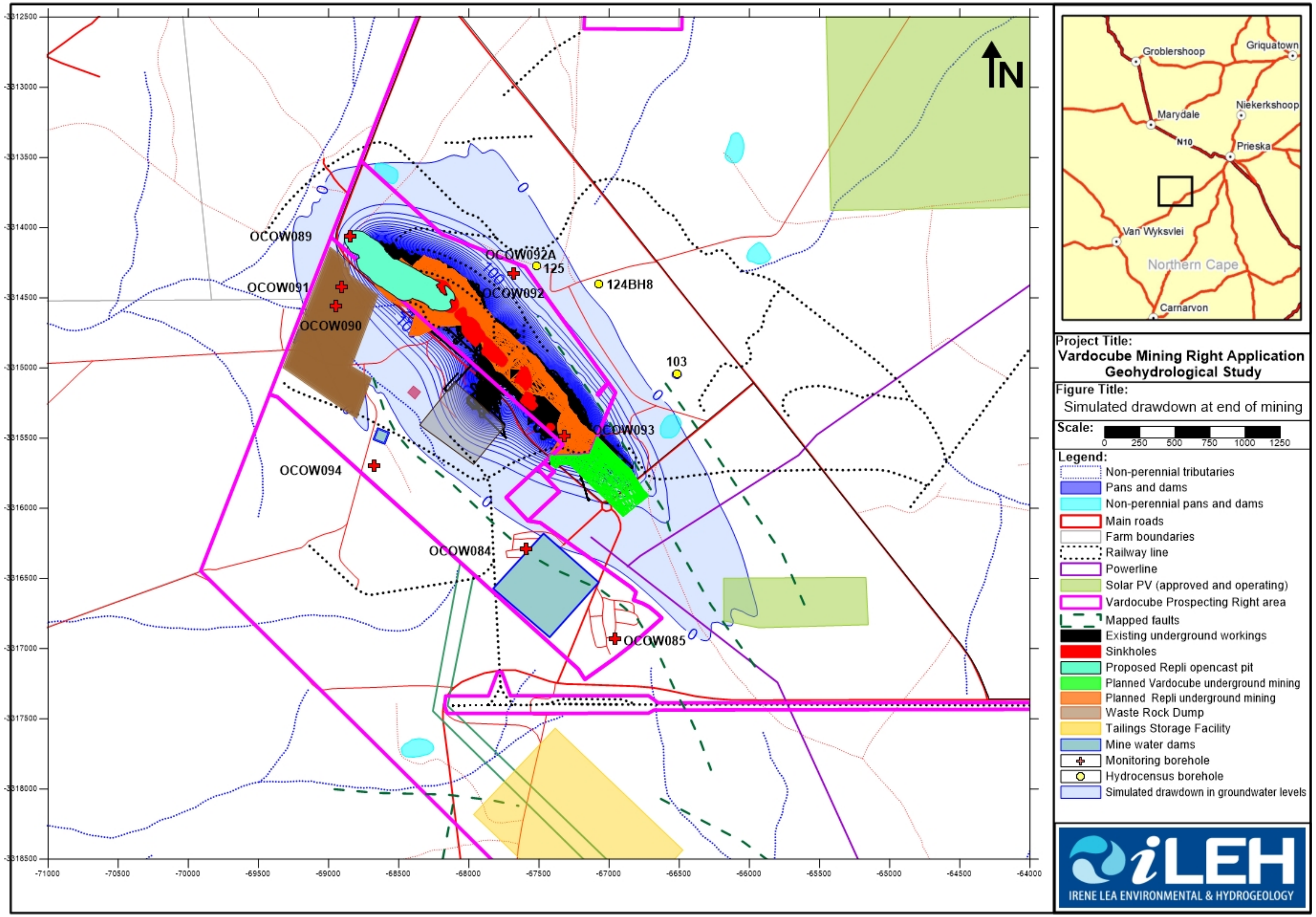

Figure 10 Simulated drawdown in the upper fractured rock aquifer at the end of the operational phase

7.2.3 Impact of mining on groundwater quality

The Vardocube underground mining area is not expected to impact on shallow groundwater quality, only possibly on groundwater in the deeper fractured rock aquifer. It is noted that the Vardocube mining area is significantly deeper than the depth from which private groundwater users abstract water from.

The historical mining and TSF areas are expected to continue to impact on groundwater quality during the operational phase of mining. The maximum impact is expected at the end of the operational phase. The model was used to simulate the extent of the sulphate plumes in the upper fractured rock aquifer at this stage of mining. Note that the ambient sulphate concentration, used as the initial concentrations in the model, is 480 mg/l.

During conceptualisation of the impact of mining on groundwater it was assumed that the historical TSF would leach sulphates at a concentration of 5000mg/l. Simulations with the contaminant transport model however indicated that sulphate concentrations of around 18000mg/l are required to match the data from the observation boreholes drilled at the historical TSF. This concentration is well below that analysed in surface water ponding at the historical TSF, but is comparable to the concentrations reported for the leach columns discussed in Section 4.

7.2.3.1 Impact on groundwater quality for the TSF areas

The impact of the historical TSF is not well understood at present. Two of the three boreholes (OCOW82 and 83) drilled down gradient of the facility yielded groundwater quality with elevated sulphate concentrations. The impact of the toe paddocks present down gradient of the historical TSF is most probably reflected in the groundwater quality of OCOW081, which yielded lower sulphate concentrations compared to the other two boreholes. Analysis of water ponding in the toe paddocks however yielded very high sulphate concentrations. How this water impacts on groundwater quality is however not clearly understood.

Based on the available dataset, the simulated extent of the sulphate plume emanating from the historical TSF at the end of the operational phase of mining is shown in Figure 11. Sulphate concentrations exceeding 500 mg/l are not expected to migrate more than 600m from this facility during the operational phase due to the low permeabilities of the unfractured gneiss. The fractures mapped underneath the facility may however act as preferential flow paths to groundwater, as indicated.

Simulations based on the available dataset suggest that the cone of depression as a result of mine dewatering is not expected to extend to the historical TSF during the operational phase of mining. For this reason, it is unlikely that contaminated groundwater associated with the historical TSF would be reversed towards the underground mine and would flow into the working.

Historical mining activities are however expected to impact on groundwater quality in the upper fractured rock aquifer and sulphate concentrations above 500mg/l may extend up to 500m from the mining area, as shown in Figure 11. It is unlikely the groundwater quality will be affected in any of the private boreholes identified during the operational phase of mining.

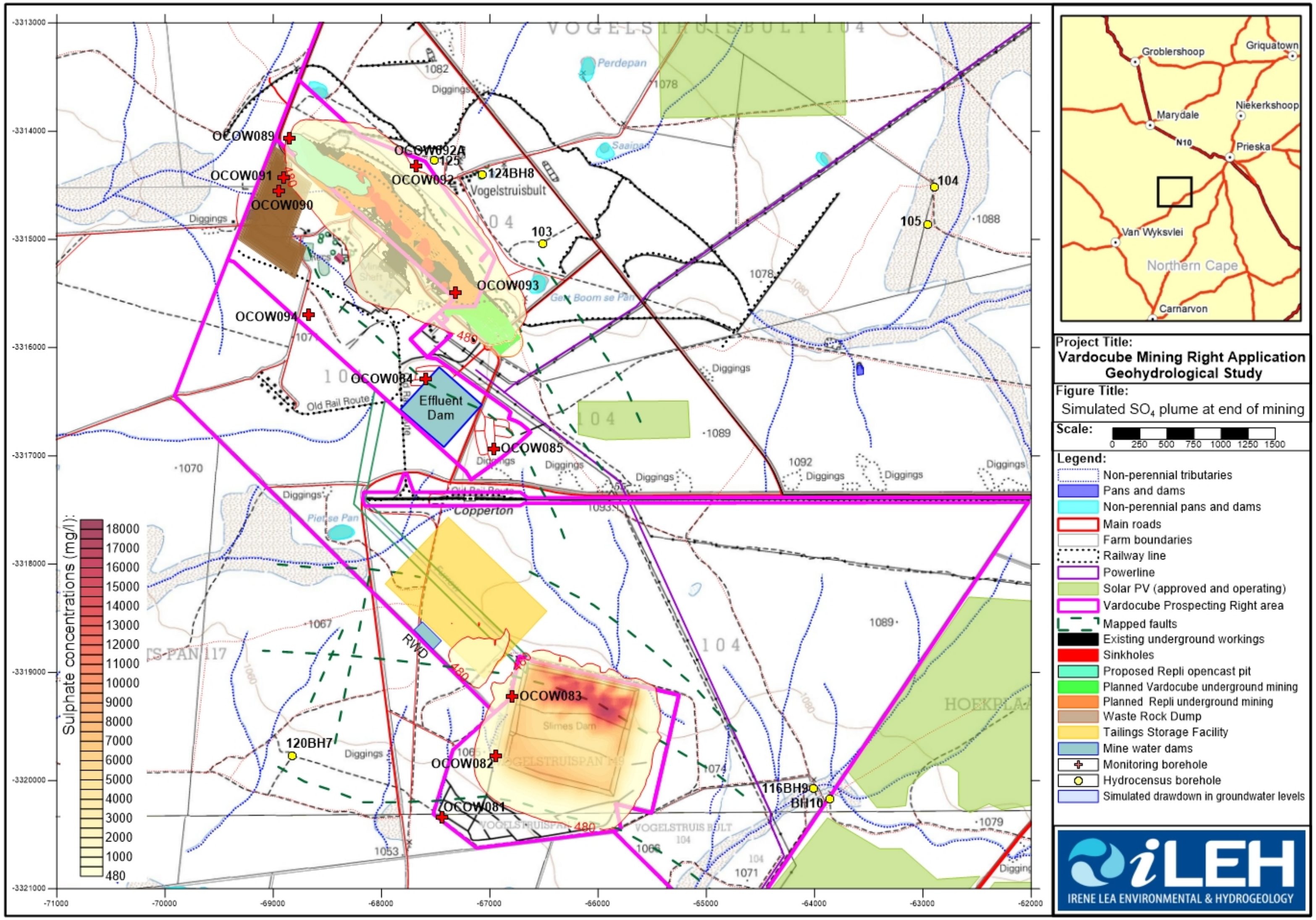

Figure 11 Simulated SO_4 at the end of mining operations

7.3 Impact prediction: Long-term

7.3.1 Groundwater level recovery upon mine closure

The rate at which groundwater levels will recover upon mine closure was assessed with the model as part of the Repli mining right application (iLEH, 2018). The mining configuration used during the Vardocube mining right application presented in this report is not expected to change the rate of groundwater recovery at closure.

The rate of recovery is dependent on the permeability of the rocks intersected in the underground workings. If faults/fractures are intersected with high yields, the rate of flooding will increase. The model is based on average permeabilities for the gneiss rock matrix and the assumptions made regarding the faults mapped. Under these assumptions, it is estimated that groundwater levels would take up to 100 years to fully recover, as demonstrated in Figure 12. During this time, groundwater levels will be reversed towards the mine, thus preventing significant contamination of the aquifers around the underground workings. It must be noted that it is unlikely that groundwater levels would fully recover, based on the current level of flooding and the low permeabilities of the rock formations intersected.

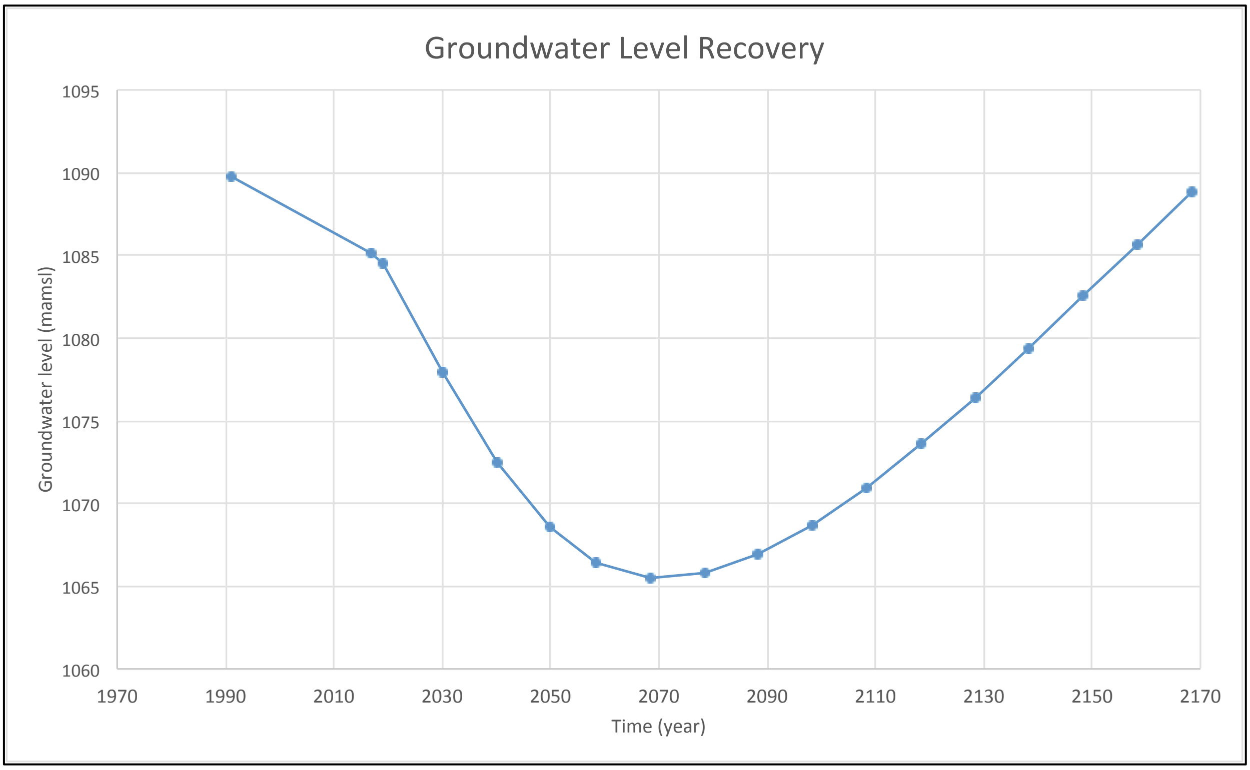

Figure 12 Rate of groundwater level recovery after mine closure

7.3.2 Long-term impact on groundwater quality

Although the new TSF will not form part of the Vardocube mining right, simulations were undertaken to assess the cumulative impact of all potential sources of contamination to groundwater. The results of simulations to estimate the long-term impact of the mining operations are presented in Figure 13. It is shown that if the new TSF is lined and the liner remains intact, that no groundwater contamination is anticipated in this area.

Groundwater contamination associated with the historical underground workings are also not expected to migrate significantly post closure, as groundwater levels will remain reversed towards the mine as groundwater levels rebound after mine closure. As discussed above, groundwater levels may take up to 100 years to recover. The extent of the sulphate plume with concentrations exceeding 500mg/l therefore remain similar to what was simulated for the operational phase. This is the remnant of the historical impact of the underground workings.

No private boreholes fall within the delineated long-term zone of influence on groundwater quality associated with the new TSF and the Repli and Vardocube mining areas.

The impact of the historical TSF will most probably result in the most significant long-term impacts. The fault present underneath the facility is expected to act as a preferential flow path to groundwater, as indicated on Figure 13. The sulphate plume may migrate up to 1km along the fault from the facility during the simulation period. Contamination may also migrate up gradient of the historical TSF in a southeasterly direction along this fault due to the mound in groundwater that forms as a result of recharge from the facility.

No private boreholes fall in the zone of influence, but it is possible that BH10 and 116BH9 may be impacted on, as these boreholes may fall on the fault structure mapped in this area.

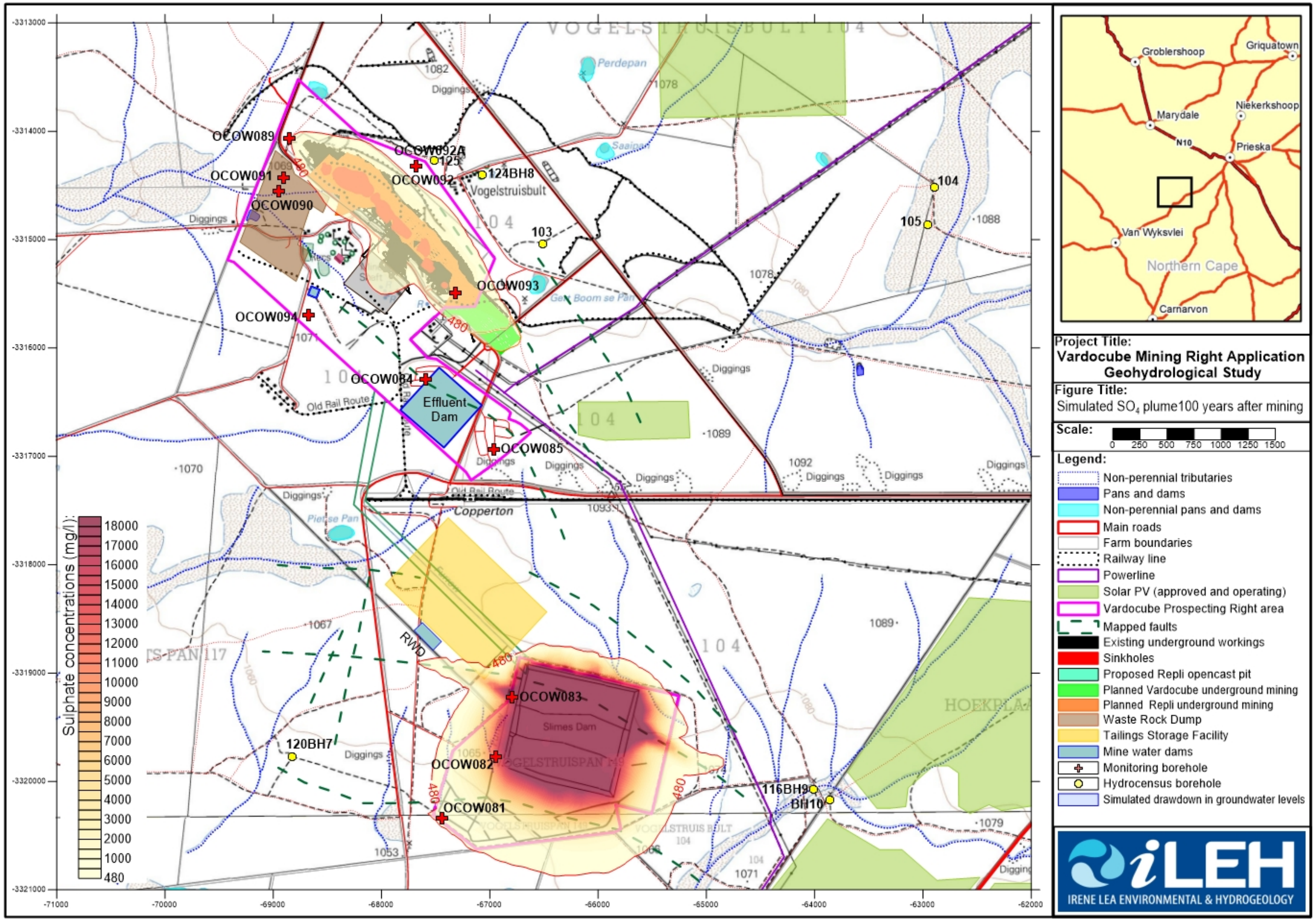

Figure 13 Simulated SO_4 100 years after mining ceases for the preferred TSF alternative

7.3.3 Risk of decant

Decant from mining areas refers to the day-lighting of mine void water on surface, most often in the long-term. At mine closure, active mine dewatering ceases and groundwater levels start to recover. The likelihood of whether or not decant will take place, depends on the volume of water that enters the mining area at this time and the void space that must be filled in the underground workings to allow a rise of groundwater to surface.

Inflow to the mining areas post closure will take place from two main sources, namely the recharge of rainwater and natural groundwater through flow. If this combined volume is higher than natural rates, it is likely that the mining area would decant. If the inflow volume is less than or equal to natural rates, it is unlikely that decant would take place.

The available dataset suggests that groundwater levels will most probably not recover to surface in the long-term and decant from the mining area is therefore not expected. The plugs that will be inserted underneath the existing pits and sinkholes to ensure safe underground mining during the operational phase will not be impermeable. Rainwater that collects in the proposed opencast mine is therefore expected to seep through the plug into the underground workings. This, in addition to the high evaporation rates applicable to this region, is expected to prevent flooding of the proposed opencast pit and thus decanting of mine water to surface.

Should the assumptions on which the assessment are based change, it is recommended that the risk of decant from the mining areas is re-evaluated.

8 PROPOSED GROUNDWATER MANAGEMENT MEASURES

The groundwater management plan presented in this section of the report is similar to that provided in the Repli mining right application (iLEH, 2018). It would not be practical to implement two separate groundwater management plans and for that reason, the same measures apply to both mining rights.

8.1 Groundwater objectives and targets

The following objectives and targets are proposed for groundwater management at the operations:

- Implement a management plan aimed at reducing and/or eliminating adverse impacts on the receptors identified. These include existing private groundwater users.
- Track and record the progress of implementation of all groundwater management measures.
- Implement sufficient monitoring procedures to measure the effectiveness of groundwater management measures in both mine monitoring and private boreholes located within the delineated zones of influence.
- Analyse the information obtained from all monitoring programmes against compliance targets to establish trends.
- Should the trends indicate adverse impacts on groundwater levels and/or quality, implement suitable measures within the shortest possible time to remediate and/or eliminate such adverse impacts identified.

8.2 Over-arching groundwater management measures

A number of broad over-arching groundwater management measures should be implemented by Orion in order to minimise impacts on groundwater during all phases of mining. Most of these form part of good house-keeping measures, as detailed in Table 14.

Table 14 General groundwater management measures

Planning Phase
Ensure that sufficient information is available on all private boreholes inside the zone of influence to quantify existing groundwater use and demand. This information will form the basis for future assessments.
Plan for and provide sufficient budget to implement the groundwater monitoring programme before any mining starts.
Develop sound operating procedures that takes cognisance of impacts associated with groundwater, including spill procedures, dam design, oil and diesel storage area design, on-site environmental incident reporting, etc.
Develop sound surface runoff management plans to ensure that all dirty runoff is contained and diverted to the PCD.
Ensure that PCD are designed to contain all dirty water generated to prevent overflows and spillages.
Construction Phase
Drill additional monitoring boreholes that may be required based on the outcome of the impact assessment.
Implement and maintain a groundwater monitoring programme in mine and private boreholes situated in the zone of influence identified for the mining areas.
Implement sound house-keeping measures to prevent and clean spills, address leaks and undertake regular inspections. Ensure that the record-keeping procedure is in place and that instructions given are carried out.
Measure rainfall daily on site
Operational Phase
Complete regular inspections of the PCD, specifically noting incidences of overflow and leakage. If the latter is identified, measures must be taken to rectify non-compliances immediately.
Maintain sound house-keeping measures to prevent spills and leaks.
Maintain the groundwater monitoring programme in mine and private boreholes located
Measure rainfall daily on site
Record all groundwater-related complaints and deal with each complaint within the agreed upon timeframe.
Develop a sound rehabilitation plan to ensure that long-term impacts are minimised
Plan for mine closure by completing a final groundwater impact assessment at least five years before closure.
Decommissioning and Closure Phase
Complete all rehabilitation to a satisfactory level. Effective rehabilitation of these areas must aim to reduce the rate of recharge of rainwater as far as possible. No ponding must be allowed over backfilled areas.
Plan for and budget to continue with the groundwater monitoring period for a minimum of two years after mine closure. The continued need for groundwater monitoring will depend on the outcome of the final mine closure groundwater impact assessment.

8.3 Measures to address impacts on groundwater availability

The following specific measures are recommended to minimise and/or eliminate the impacts on groundwater levels and availability:

- Private boreholes that fall within the zones of impact identified for both the mine dewatering scenarios and long-term sulphate plume simulations must be included in the groundwater monitoring programme. Should monitoring information indicate adverse impacts, Orion must enter into negotiations with the affected landowners to negotiate alternative water supply options.
- Modelling scenarios suggest that borehole 105 will not be affected by mine dewatering. As this is a strong borehole on which the landowner is reliant, it may however be prudent to complete a pumping test on the borehole prior to the commencement of mining to ensure that the safe yield of the borehole is confirmed for future reference. This borehole should further be included in the mine's monitoring programme as a precautionary measure.
- Feedback must be provided to owners of boreholes within the affected zones regarding progress made with mining activities, concurrent rehabilitation and the outcome of monitoring programmes on a quarterly basis, when groundwater monitoring will take place, to ensure that they are informed of aspects of mining that may be of significance.
- Private boreholes destroyed during mining must be replaced by Orion or alternative water supply options must be negotiated with the affected landowners.
- The numerical model used in this assessment should be updated, verified and re-calibrated on

a regular basis as monitoring information becomes available in order to increase the level of confidence in modelling outcome.
- Final mine closure modelling must be prepared at least five years prior to mine closure to ensure that predictions of long-term impacts are undertaken with the highest possible level of confidence.

8.4 Measures to address impacts on groundwater quality

The following specific measures are recommended to minimise and/or eliminate the impacts on groundwater quality:

- It is recommended that the final results of the geochemistry specialist study as well as subsequent water monitoring results are incorporated into future numerical modelling to be undertaken to confirm the impact of all mine activities on groundwater quality. This should be undertaken once at least one wet and dry season groundwater monitoring results are available. During these simulations, contamination associated with trace metals should be considered in addition to sulphate contamination. The source term should be defined based on the outcome of the geochemical study, which is currently underway.
- If preferential flow paths to groundwater are identified during mining, it is recommended that these features are characterised and quantified. Such geological structures include water-bearing fractures, faults and contact zones. The conceptual model for the project area should be updated and numerical model simulations revised to include the impact of preferential flow paths on groundwater and potential pollution movement. Simulations undertaken as part of this assessment suggests that faults associated with the historical and new TSFs may act as preferential flow paths to groundwater contamination.
- Updated contaminant transport simulations must be undertaken once this information is available in order to improve the confidence levels in long-term predictions. These simulations must be completed once the final results of the geochemical study and one wet and dry season groundwater monitoring information are available. In addition, the contaminant transport model must be updated with all available information at least five years prior to mine closure to ensure that effective measures are developed to manage long-term impacts.

9 GROUNDWATER MONITORING PROGRAMME

As with the groundwater management measures proposed in the previous section, the groundwater management plan for the Vardocube mining right application remains the same as that presented for the Repli study (iLEH, 2018).

9.1 Monitoring locations

All existing monitoring boreholes as well as the private boreholes that fall within the zones of influence delineated in this study must be included in the quarterly monitoring programme. Private boreholes that fall inside the identified zones of influence include:

- Private boreholes that may be affected by mine dewatering: 125, 124BH8 and 103.
- Borehole 105 must also be included in the quarterly monitoring programme as a precautionary measure.
- Private boreholes that may be affected by contamination associated with the historical TSF: BH10 and 116BH9.

All hydrocensus boreholes that fall within a 5km radius from the mining area should be monitored on an annual basis as a precautionary measure. These boreholes include:

- Private boreholes within a 5km radius of all proposed new mining activities that are not already included in the quarterly monitoring programme: 104, 113, 114, 115, 119, 121, 120BH7, 122BH5, BH3 and BH6.

In addition to these, the following additional monitoring boreholes are recommended, based on the outcome of model simulations:

- Replacement boreholes for OCOW090 and 91 if they will be destroyed during waste rock deposition.
- Dedicated groundwater monitoring boreholes down gradient of the new TSF as well as the RWD, to act as an early warning system in the case of liner failure.

9.2 Monitoring requirements

The parameters to be included during monitoring as well as the proposed frequency of monitoring are presented in Table 15.

Table 15 Groundwater monitoring requirements

Monitoring parameter	Element for analysis	Monitoring frequency
Depth to groundwater level	Groundwater level	Quarterly
Water quality in monitoring boreholes and hydrocensus boreholes in the affected zones	pH, EC, TDS, Hardness, Ca, Mg, N, K, Cl, SO_4, NO_3, NO_2, F, PO_4, F, Fe, Cu, Zn, Mn, Se, U	Quarterly (Apr, Jul, Oct, Jan)
Water quality in hydrocensus boreholes in a 5km radius	pH, EC, TDS, Hardness, Ca, Mg, N, K, Cl, SO_4, NO_3, NO_2, F, PO_4, F, Fe, Cu, Zn, Mn, Se, U	Annually (Jan)
Rainfall	Rain depth (mm)	Daily on site

All monitoring information must be entered into a spreadsheet for record keeping and analysis. Copies of the certificates of analyses must be kept on file at each mine for inspection.

If a significant exceedances is recorded during the monitoring programme, the following actions should be taken:

- Log the exceedances in the incident reporting system within 24-hours of it occurring.
- Report the exceedances to the Environmental and General Managers as well as to the regulatory authority.
- Undertake an investigation to identify causes of the exceedances.
- Consult with any landowner or affected party that may be impacted by the exceedances to determine their concerns and to negotiate remedial actions.
- Implement the necessary remedial actions according to the outcome of the investigation and consultation with the affected parties.
- Track the incident until completion.

Regular monitoring reports must be prepared for internal use as well as for submission to the authorities, as required by the operations' water use licenses.

10 IMPACT ASSESSMENT ACCORDING TO ABS METHODOLOGY

An impact assessment was completed for the geohydrological specialist study presented in this report. The impact assessment is based on the ABS methodology, as presented in Appendix 2, and on the discussions presented above.

The results of the impact assessment are presented in Table 16.

It is noted that none of the activities listed for the construction phase in Appendix 2 is expected to impact on groundwater quality.

During the operational phase, the following Vardocube activities are included in the impact assessment:

- Mine dewatering
- Underground mining

Long-term impacts that will impact on groundwater during the decommissioning and closure phases include:

- Rehabilitation of the shafts.
- Cummulative long-term impacts on groundwater quality associated with the above infrastructure.

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Table 16 Groundwater Impact Assessment

GROUNDWATER								
Project Activity		Groundwater	Likelihood		Consequence			Significance Rating
Lowering of groundwater levels as a result of mine dewatering	Phase of Project	Operational	Frequency of Activity	Frequency of Impact	Severity	Spatial Scope	Duration	
	Impact Classification	Direct Impact	Significance Pre-Mitigation					
	Resulting Impact from Activity	Lowering of groundwater levels in private boreholes, thus affecting the performance of the boreholes that fall within the dewatering cone	4	4	4	3	4	88
			Significance Post-Mitigation					
			4	4	2	3	4	72

Project Activity		Groundwater	Likelihood		Consequence			
Spread of contamination from underground and opencast mining areas	Phase of Project	Operational	Frequency of Activity	Frequency of Impact	Severity	Spatial Scope	Duration	Significance Rating
	Impact Classification	Direct impact	Significance Pre-Mitigation					
	Resulting Impact from Activity	Contamination of groundwater in private boreholes, making the groundwater unfit for use	4	4	3	2	5	80
			Significance Post-Mitigation					
			4	3	2	2	4	56

Project Activity		Groundwater	Likelihood		Consequence			
Spread of contamination from underground and opencast mining areas	Phase of Project	Closure and decommissioning	Frequency of Activity	Frequency of Impact	Severity	Spatial Scope	Duration	Significance Rating
	Impact Classification	Direct impact	Significance Pre-Mitigation					
	Resulting Impact from Activity	Contamination of groundwater in private boreholes, making the groundwater unfit for use	1	2	3	2	5	30
			Significance Post-Mitigation					
			1	2	2	2	4	24

APPENDIX 1 – MATHEMATICAL MODELLING

The information presented in the appendix was taken from iLEH (2018). No additional monitoring or other information became available subsequent to the completion of the geohydrological study completed for the Repli Mining Right with which to update the information presented below.

Description of the model

The numerical modelling was undertaken according to accepted industry principles and standards, including the South African Department of Water and Sanitation's Best Practice Guideline for Impact Prediction (DWS BPG G4, 2008)

The numerical model for the project was constructed using MODFLOW and MT3DS. MODFLOW is a modular three-dimensional groundwater flow model and MT3DS a modular three dimensional solute transport model published by the United States Geological Survey. MODFLOW and MT3DS use 3D finite difference discretization and flow codes to solve the governing equations. MODFLOW and MT3DS are a widely used simulation codes, which is well documented. MODFLOW is used to simulate groundwater flow rate and direction. MT3DS is superimposed on the MODFLOW simulation results and is used to predict the rate and direction of contaminant movement in the aquifers.

In order to accommodate the large area over which simulations will be undertaken, the model area was refined into block cells of 25 x 25m around the mining areas (Figure A-1). The finer grid allowed more detailed simulations around the areas of interest. Towards the model boundaries and away from the area of interest, the model grid size increases to 400 x 600m. The position where the non-perennial stream exits the model are in the southwest of the model grid was simulated with a constant head cell. The length of this boundary, which coincides with a topographical contour chosen sufficiently far enough from the mining area not to affect simulations, was simulated as a general head boundary. This configuration allows groundwater to flow out of the model domain at this position. The rest of the model boundaries were included as no-flow boundaries. Non-perennial rivers and streams inside the model boundary were simulated with MODFLOW's Drain Package. The drains will remove groundwater from the model if the groundwater level rises above the specified drain elevation. This allows the simulation of baseflow to the streams during the wet season and ensures that the rivers remain dry in the dry summer season. The upper sand and calcrete layer is however expected to be dry, as the average depth to groundwater is 18m.

Three layers were included in the model. The upper layer presents the soil and calcrete horizon and facilitates a more accurate simulation of the interaction between the historical and planned TSF and the underlying aquifers. The second layer represents the upper fractured rock aquifer. The lower fractured rock aquifer is simulated in the third layer.

The upper layer was simulated as an unconfined aquifer. The second layer was allowed to vary between confined and unconfined conditions depending on the depth of the groundwater level during simulations. The fractured rock aquifer simulated in the third layer was assumed to be confined.

All units used during simulations were presented in metres (length) and days (time).

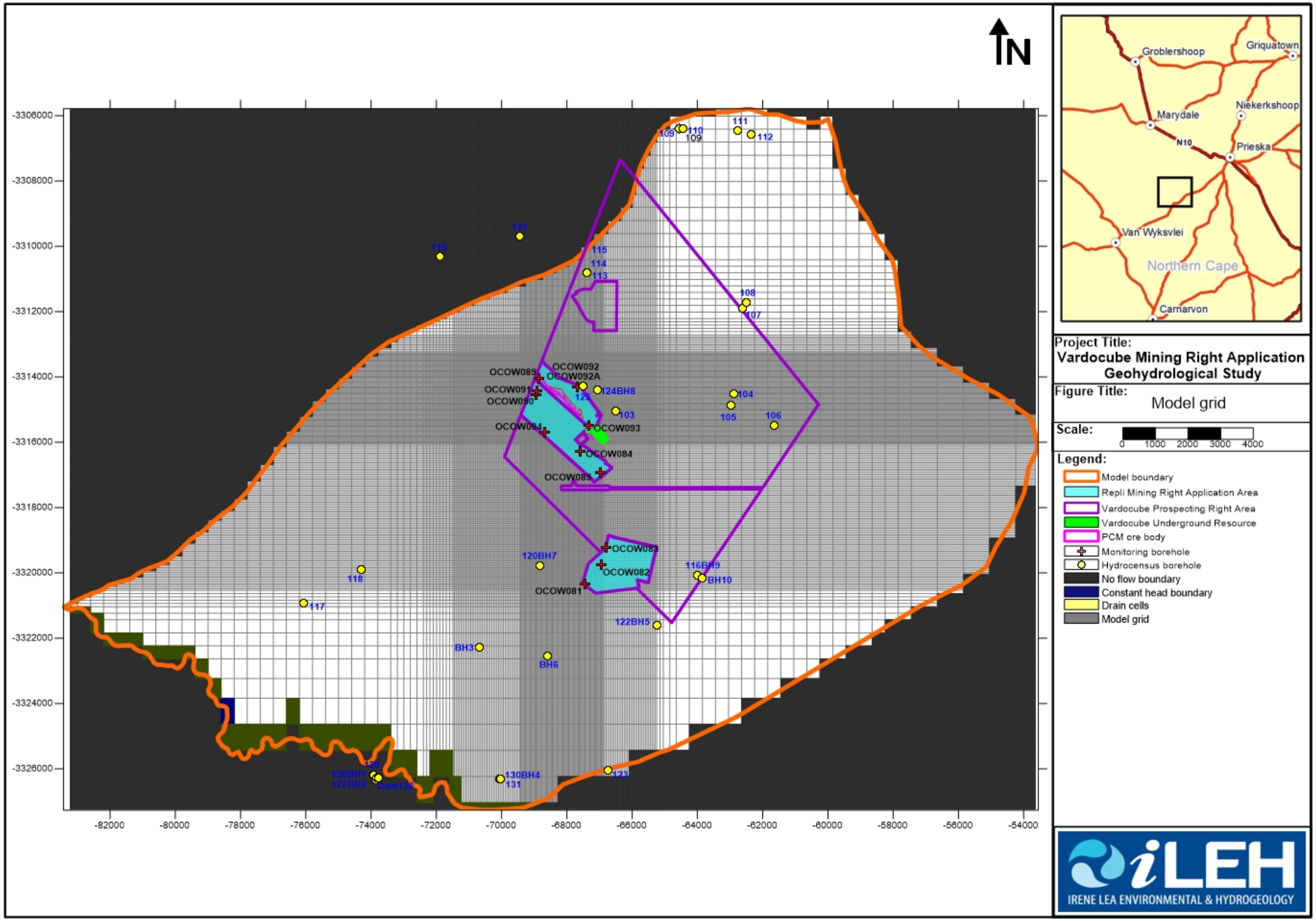

Figure A-1 Model grid

Model input files and integration

The conceptual model discussed above was used to construct the numerical model for the project area. The initial aquifer parameters used are presented in Table 6 and 7 in the main body of the report. These were gradually adjusted during calibration, as discussed below.

The geometry of the numerical model, based on the conceptualisation of the aquifers, is based on the regional geological setting presented in Figure 3 in the main body of the report and includes the mapped faults indicated.

The topographical surface was interpolated from the Digital Terrain Model (DTM) (i.e. the surface topography) and incorporated into the model to ensure that the elevations of the drains used to simulate the streams and the Constant Head Boundary conditions reflect the topography.

The top of the upper layer of the model was simulated with the surface contours for the project, which was obtained from the DTM for the catchment.

The initial water levels in the model layers of the model were kriged from available information. This is based on the fact that there is a linear relationship between the topographical elevation of boreholes and the depth to groundwater level, as demonstrated in Figure 7 in the main body of the report.

The MT3DS contaminant transport model advection input parameters are indicated in Table A-1 below.

Table A-1 Contaminant transport advection parameters

PERCEL	WD	DCEPS	NPLANE	NPL	NPH
0.75	0.5	10^{-5}	2	1	8
NPMIN	**NPMAX**	**SRMULT**	**NLSINK**	**NPSINK**	**DCHMOC**
2	8	1	2	8	0.0001

It was assumed that horizontal and vertical transverse dispersivity is 0.1; that the effective molecular diffusion coefficient is 8,64E-5 m^2/d and that the longitudinal dispersivity is between 50 and 100m.

No chemical reaction was taken into consideration during simulations.

Calibration results

Calibration of a numerical model refers to the demonstration that the model is capable of reproducing field-measured data, which are the calibration values. Calibration is achieved when a set of parameters, boundary conditions, source terms and stresses are found that produce simulated heads and concentrations that match field measured data within the calibration criteria set for the project. This is an important step in the modelling project, which ensures that model results are reliable.

The calibration criteria set for the project are presented in Table A-2.

Table A-2 Calibration criteria

Requirement	Acceptability criteria	Compliance
Calibration error	<5m for water level measurements taken	Complied with (see discussion below)
Water level calibration	80% of data points complies with calibration error	Complied with (see discussion below)

Model calibration was undertaken with field-measured groundwater levels obtained from the hydrocensus as well as in monitoring boreholes that met the calibration criteria discussed above. Eight of the boreholes fall inside the model domain and could be used for model calibration.

The results of the calibration process are presented in Table A-3. It is shown that the calibration error (the difference between measured and simulated head) is less than 5m for 7 of the 8 data points, which is equivalent to an 88% compliance to the calibration error. The groundwater level in OCOW084 could not be matched within the calibration criteria set. The average error for the calibration exercise is however 4,2m, which is within the calibration criteria set.

Table A-3 Calibration results

Borehole ID	Measured head (mamsl)	Simulated head (mamsl)	Calibration error (m)
OCOW081	1047,57	1049,00	1,43
OCOW082	1052,31	1056,90	4,59
OCOW083	1055,67	1058,70	3,03
OCOW084	1058,97	1050,10	8,87
OCOW091	1057,15	1052,30	4,85
124BH8	1063,97	1059,22	4,75
109	1104,52	1102,79	1,73
129	1010,08	1005,76	4,32

Factors that influence the calibration process and results include the following:

- Errors in the coordinates and elevations recorded for the hydrocensus boreholes. These boreholes were captured with a hand-held GPS, which is not always accurate.
- Errors in groundwater level measurements.
- The effect of groundwater abstraction by private groundwater users on the measured groundwater level measurements.
- The absence of borehole logs with which to characterise the aquifer conditions that groundwater levels in hydrocensus boreholes represent. For the purpose of calibration, it was assumed that all hydrocensus and monitoring boreholes target the fractured rock aquifer.
- As mentioned earlier in this report, the modelling code assumes a continuous porous medium, which means that the aquifers are simulated using average parameters. This does not allow for local variations in permeability that affects groundwater levels in the aquifers. Discrete zones were however included to represent the mapped faults.

The calibrated aquifer parameters, based on the outcome of model calibration, are presented in Table A-4.

Table A-4 Calibrated aquifer parameters

Description	Thickness (m)	T (m^2/d)	Recharge (% of MAP)	S_y (-)	S (-)
Soil/calcrete (weathered)	15	0,64	0,6	1,7E-3	NA
Upper fractured rock aquifer	100	0,2	NA	1E-4	7E-4
Lower fractured rock aquifer	1300	0,02	NA	NA	7E-5
Faults	100	6 - 32	NA	NA	7E-4

A groundwater level and quality monitoring programme will be implemented at the operations, if the project is successful. Model calibration can be improved once additional monitoring information becomes available from the operations. Model-recalibration and verification can be undertaken with this data. It is important that both groundwater monitoring and private boreholes are included in the monitoring programme.

Model sensitivity

A sensitivity analysis was completed on the model. The purpose of the sensitivity analysis is to quantify the uncertainty in the calibrated model caused by uncertainty in the estimates of aquifer parameters, stresses and boundary conditions. The level of heterogeneity of the aquifer material can never be accurately measured with field data. The uncertainty of the impact of heterogeneity on simulations is therefore assessed as part of the sensitivity analysis.

The results of a sensitivity analysis can be used to identify data gaps and to plan for additional fieldwork, including monitoring requirements, once the modelling has been completed.

The comparative sensitivity for the parameters included during calibration is presented in Figure 10. The comparative sensitivity provides an indication of how sensitive the model is to changes in each parameter compared to the other parameters tested. A low value indicates a low sensitivity and a high value a high sensitivity. It is shown that the model is most sensitive the transmissivity of the faults and the rate of recharge to the aquifers. The model is also comparatively sensitive to the transmissivity of the gneiss fractured rock aquifer and the storage coefficient of the faults.

The model is least sensitive to changes in the permeability and specific yield of the sand and calcrete.

As discussed in the calibration section above, model sensitivity can be addressed through additional calibration with groundwater monitoring data that will become available from the operations once the monitoring programme is implemented.

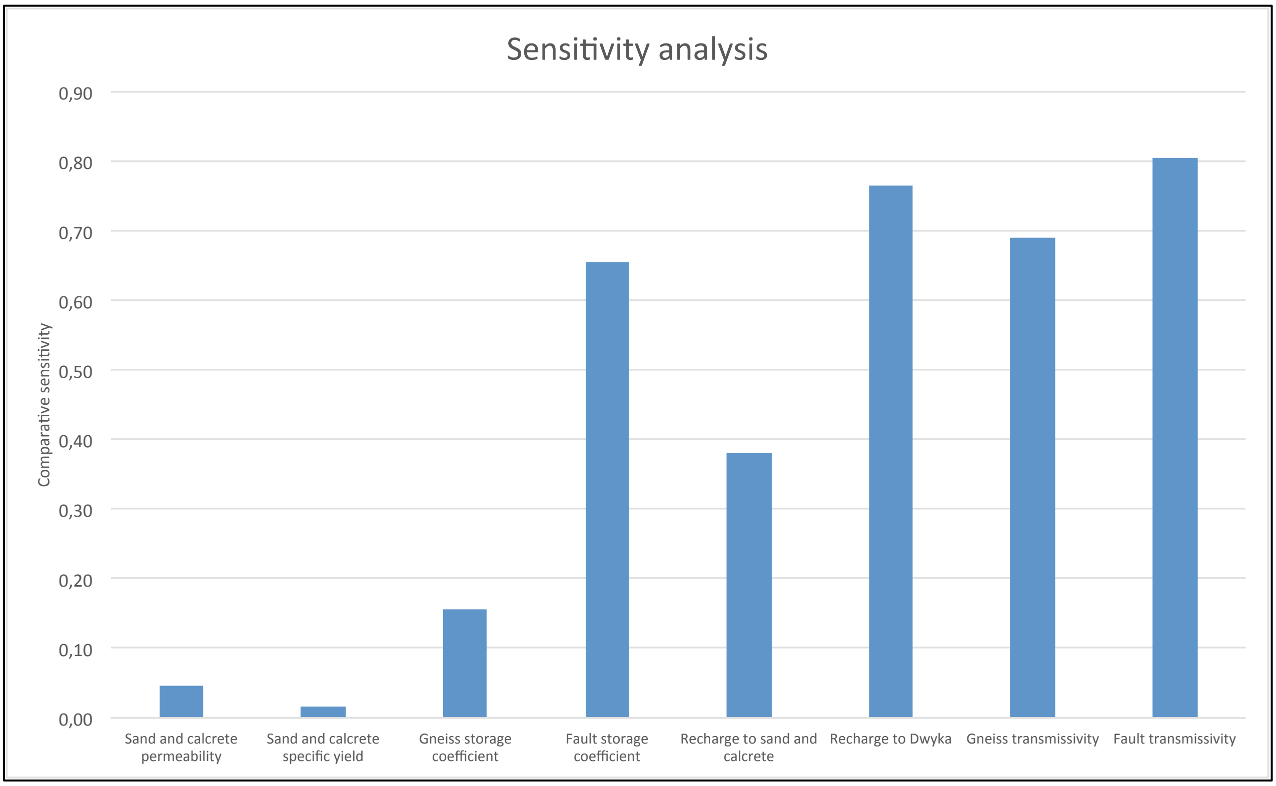

Figure A-2 Sensitivity analysis

Assessment uncertainties

The accuracy of the modelling project depends on the quality of the input data, the available information, time available to complete the calibration process and to test the outcome of scenario modelling. Even with an unchanging environment, impacts are difficult to predict with absolute certainty. Predictions were calculated with the calibrated flow model, which is a simplified version of reality. The model represents a tool that can be used to assess the impact of the proposed mining areas on the aquifers and to identify data gaps.

The calibration error is discussed above and is thought to be acceptable. Monitoring boreholes that may be destroyed during mining operations must be replaced to ensure that the data points available for calibration and verification of the information presented in this report are not reduced. The model should be updated and verified with additional monitoring information, as it becomes available.

Uncertainties are approached conservatively, based on the precautionary principle, in order to ensure that the predictions and impact assessment in this report addresses the maximum potential impact of the proposed development. The uncertainties in the model include:

- **Uncertainties regarding borehole depth, construction and geology intersected**: This information is not available for the hydrocensus boreholes. For this reason, it was assumed that all hydrocensus boreholes target the upper fractured rock aquifer.
- **Uncertainties regarding the private borehole pumping rates**: The accuracy of the pumping rates used during simulations may not be high.
- **Uncertainties regarding the borehole elevations**: The elevations used for the hydrocensus boreholes during simulations were inferred from hand-held GPS measurements and inaccuracies may occur. It is however thought that the error in elevation will not exceed the calibration error of 5m.
- **Mathematical modelling uncertainties**: It is not possible with the available information to quantify the heterogeneity present in the aquifers simulated. For this reason, there are inherent uncertainties in the model. The level of confidence in the model can be improved with the incorporation of additional monitoring data.

The uncertainties listed above can be reduced or eliminated through implementing an on-going groundwater monitoring programme at the landfill. This information can be used to improve aquifer parameter estimation and model calibration.

APPENDIX 2 –

IMPACT ASSESSMENT METHODOLOGY

ABS Africa
Sustainability Advisors

1 INTRODUCTION

The first phase of impact assessment is the identification of the various project activities which may impact upon the identified environmental aspects. The identification of significant project activities is supported by the identification of the various receiving environmental receptors and resources. These receptors and resources allow for an understanding of the impact pathways and assessment of the sensitivity of the receiving environment to change. The significance of the impact is then assessed by rating each variable numerically, according to defined criteria as provided in Table 2-1.

2 IMPACT SIGNIFICANCE RATING

The purpose of the significance rating of the identified impacts is to develop a clear understanding of the influences and processes associated with each impact. The severity (magnitude), spatial scope and duration of the impact together comprise the consequence of the impact; and when summed can obtain a maximum value of 15. The frequency of the activity and the frequency of the impact together comprise the likelihood of the impact, and can obtain a maximum value of 10. The values for likelihood and consequence of the impact are then read from a significance rating matrix as shown in Table 2-2 and Table 2-3.

The model outcome of the impacts is then assessed in terms of impact certainty and consideration of available information. The Precautionary Principle is applied in instances of uncertainty or lack of information by increasing assigned ratings or adjusting final model outcomes. In certain instances where a variable or outcome requires rational adjustment due to model limitations, the model outcomes are adjusted. Arguments and descriptions for such adjustments, as well as arguments for each specific impact assessments are presented in the text and encapsulated in the assessment summary table linked to each impact discussion.

TABLE 2-1: CRITERIA FOR ASSESSING THE SIGNIFICANCE OF IMPACTS

SEVERITY OF IMPACT	**RATING**
Insignificant / non-harmful	1
Small / potentially harmful	2
Significant / slightly harmful	3
Great / harmful	4
Disastrous / extremely harmful	5
SPATIAL SCOPE OF IMPACT	**RATING**
Activity specific	1
Area specific	2
Whole project site / local area	3
Regional	4
National	5
DURATION OF IMPACT	**RATING**
One day to one month	1
One month to one year	2
One year to ten years	3
Life of operation	4
Post closure / permanent	5
FREQUENCY OF ACTIVITY / DURATION OF ASPECT	**RATING**
Annually or less / low	1
6 monthly / temporary	2
Monthly / infrequent	3
Weekly / life of operation / regularly / likely	4
Daily / permanent / high	5
FREQUENCY OF IMPACT	**RATING**
Almost never / almost impossible	1
Very seldom / highly unlikely	2
Infrequent / unlikely / seldom	3
Often / regularly / likely / possible	4
Daily / highly likely / definitely	5

CONSEQUENCE

LIKELIHOOD

Activity: a distinct process or task undertaken by an organisation for which a responsibility can be assigned.

Environmental aspect: an element of an organisation's activities, products or services which can interact with the environment.

Environmental impacts: consequences of these aspects on environmental resources or receptors.

Receptors: comprise, but are not limited to people or man-made structures.

Resources: include components of the biophysical environment.

Frequency of activity: refers to how often the proposed activity will take place.

Frequency of impact: refers to the frequency with which a stressor will impact on the receptor.

Severity: refers to the degree of change to the receptor status in terms of the reversibility of the impact; sensitivity of receptor to stressor; duration of impact (increasing or decreasing with time); controversy potential and precedent setting; threat to environmental and health standards.

Spatial scope: refers to the geographical scale of the impact.

Duration: refers to the length of time over which the stressor will cause a change in the resource or receptor.

Table 2-2: Significance Rating Matrix

	CONSEQUENCE (Severity + Spatial Scope + Duration)														
LIKELIHOOD (Frequency of activity + Frequency of impact)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45
	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75
	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90
	7	14	21	28	35	42	49	56	63	70	77	84	91	98	105
	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120
	9	18	27	36	45	54	63	72	81	90	99	108	117	126	135
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150

Table 2-3: Positive/Negative Mitigation Rating

Colour Code	Significance Rating	Value	Negative Impact Management Recommendation	Positive Impact Management Recommendation
⬛	Very High	126-150	Improve current management	Maintain current management
🟥	High	101-125	Improve current management	Maintain current management
🟧	Medium-High	76-100	Improve current management	Maintain current management
🟨	Low-Medium	51-75	Maintain current management	Improve current management
🟨	Low	26-50	Maintain current management	Improve current management
⬜	Very Low	1-25	Maintain current management	Improve current management

3 ACTIVITIES HAVING AN IMPACT

The key project activities for the Project upon which the impact assessment was based are described in Chapter 2 of Title II of the EIS. These activities are summarised below per project phase.

3.1.1 CONSTRUCTION PHASE ACTIVITIES

- Clearing and grubbing of vegetation;
- Site perimeter fencing and internal fencing of different sections of the mine;
- Removal and stockpiling of topsoil;
- Delivery and storage of vehicles, equipment, machinery and materials;
- Construction of access roads, platforms and drainage structures;
- Construction of process plant infrastructure and installation of required equipment and machinery;
- Construction of the main mine administration complex; and

- Installation of power and water supply infrastructure.

3.1.2 OPERATIONAL PHASE ACTIVITIES

- Clearing and grubbing of vegetation;
- Dewatering;
- Open-cast mining of two pits through a combination of excavation and blasting;
- Construction and operation of the WRDs and TSF;
- Hauling of ore to the process plant and waste rock to the WRDs;
- Management of clean and dirty water runoff;
- Ore processing at the process plant;
- Concurrent rehabilitation of exposed areas (as is practicable); and
- Delivery and storage of vehicles, equipment, machinery and materials.

3.1.3 CLOSURE AND DECOMMISSIONING PHASE ACTIVITIES

- Dismantling and removal of all identified above-ground infrastructure;
- Rehabilitation of the open-cast pits, TSF and WRDs; and placement of topsoil and re-vegetation of exposed areas.