

**RIETVLEI COLLIERY**  
**DETAILED GEOHYDROLOGICAL INVESTIGATION**

**Final**  
**07-2014**



water  earth  life

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**Report prepared for**  
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## **Executive Summary**

Aqua Earth Consulting (AEC) was appointed by WSP on behalf of Butsanani Joint Venture (Anglo Operations Limited), to carry out a detailed groundwater impact assessment as part of an environmental impact assessment (EIA) for the proposed Greenfields Open Cast Coal Mining Operation at Rietvlei. The site is located northeast of Mhluzi (formerly Middelburg) in the Mpumalanga Province, and will be call “proposed Rietvlei Mine” in the report.

The study was instigated by comment made by WSP on an existing baseline groundwater study conducted by Aqua Earth. Aqua Earth has completed a detailed groundwater impact assessment and the following conclusions are reached:

- Field investigations have been conducted according to WSP gap analysis recommendation;
- The conceptual model of the site has been updated base on field investigations results;
- The potential impacts (quality, quantity) have been identified and assessed accordingly;
- The overall project impacts (construction, operation, closure) significance is expected to be from Low to Very High without any appropriate mitigation;
- Thorough planning, design, suitable investment, management measures, workplace procedures and good housekeeping will generally mitigate the potential impacts rising from proposed Rietvlei Mine development will de reduced to Low, Except the for impacts at post closure phase;
- Specific measures have been proposed for certain infrastructure units to address particular potential impacts;
- Monitoring will be necessary to ensure that any impacts on water quality and quantity that do arise are dealt with rapidly;
- An initial monitoring network has been proposed for the management of groundwater resources.

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# 1 Introduction

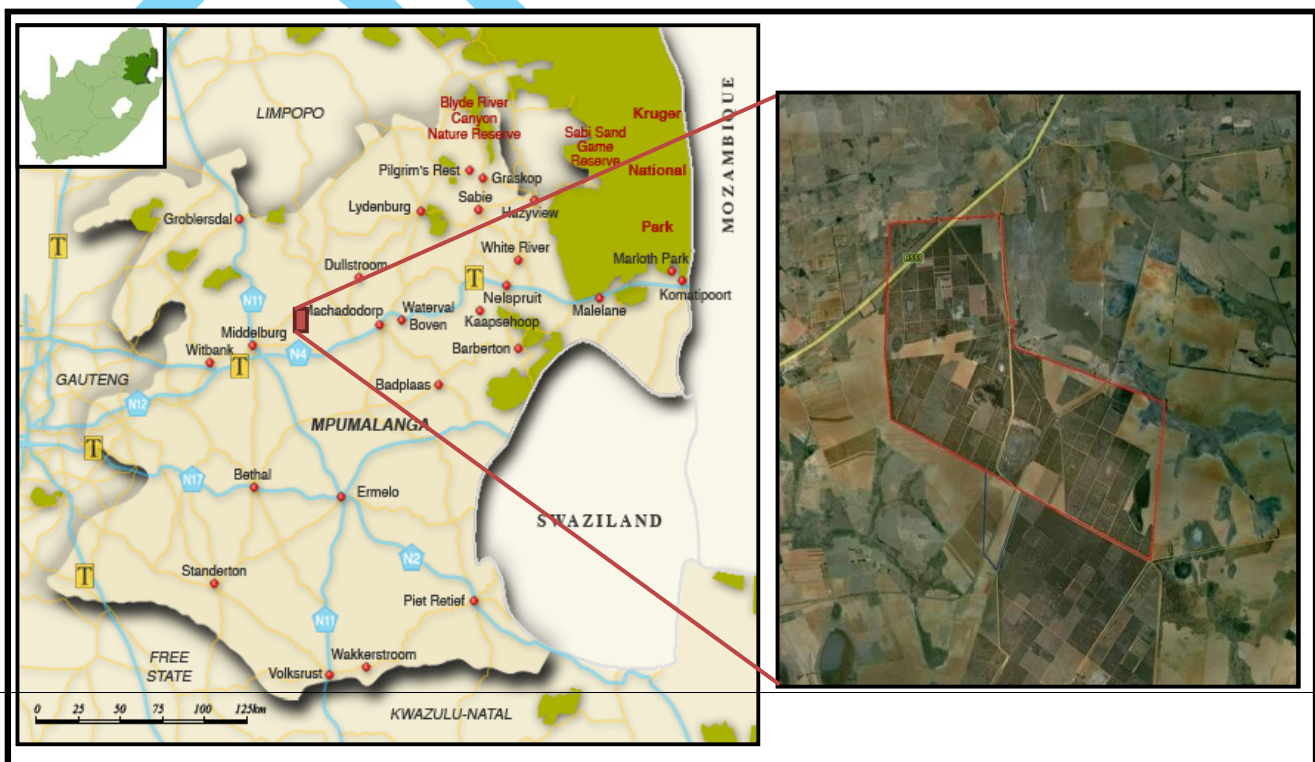
Aqua Earth Consulting (AEC) was appointed by WSP on behalf of Butsanani Joint Venture (Anglo Operations Limited), to carry out a detailed groundwater impact assessment as part of an environmental impact assessment (EIA) for the proposed Greenfields Open Cast Coal Mining Operation at Rietvlei. The site is located northeast of Mhluzi (formerly Middelburg) in the Mpumalanga Province, and will be call “proposed Rietvlei Mine” in the report.

The present study follows the comment made by WSP on the baseline groundwater study conducted by Aqua Earth.

## 1.1 Location

The study area lies approximately 50km northeast of the town of Emalahleni and 22km northeast of Mhluzi (formerly Middelburg) in the Mpumalanga Province (

Figure 1). It is linked to Mhluzi by the R555 provincial roadway. The prospecting area lies within a farming area and is bordered by private properties on all sides.



## **Figure 1: Locality of Rietvlei Colliery**

### **1.2 Scope of the works and specific tasks**

The present detailed study aims mainly to fill the gaps in the baseline groundwater studies conducted by Aqua Earth in 2011. The main objective here is the characterisation and the impacts assessment of the two aquifer systems identified from the previous studies. The following tasks have then been set to reach such objective:

- Review of existing geological and hydrogeological information;
- Geophysical survey to identify potential flow paths for preferential groundwater/contaminant migration;
- Siting and drilling of groundwater exploration/monitoring boreholes (at least four) to collect hydrogeological information over the study area. The additional boreholes should be sited with the aim of acquiring more information in the southern and eastern quadrant of the area under investigation. New borehole should allow accessing shallow (0m to 25 mbgl) and deep aquifers (up to 50 mbgl) separately;
- Sampling and testing of drill chips for Acid Potential Drainage;
- Sampling and analysis of water intercepted in all the additional boreholes;
- Aquifer testing to estimate hydraulic parameters of all aquifers present within and surrounding the study area;
- Update of the baseline numerical model with new characterisation information;
- Update the project (open cast mining) impacts assessments.

The report describes the study on groundwater management issues that may be associated with the development of proposed Rietvlei Mine. It also gives a prediction on the potential impacts to ground arising from different phases of the project (construction, the operation and closure).

### **1.3 Background information**

The following existing specialist studies on the project area were consulted to gain background information and an understanding of the present groundwater baseline conditions:

- Rietvlei Groundwater Baseline Assessment. Aqua Earth Consulting, 2011;
- Rietvlei Colliery Geohydrological Modelling. Aqua Earth Consulting, 2011;
- Gap Analysis of the Environmental Studies Undertaken for the Proposed Greenfields Rietvlei Open Cast Coal Mining Operation. WSP, 09-2013;
- Feasibility Report Section 3 Geology on Rietvlei Coal Asset For Anglo American Thermal Coal. Mindset Mining Consultants (Pty) Ltd, 04-2013;

In addition of these specialists' reports on specific to the proposed mining site, information has also been sourced from publically available map:

- 1/250 000 Geological Series: 2528 Pretoria published in 1978 by the Government Printer;
- An Exploration of the 1:500 000 general hydrogeology map by H.C. Barnard – October 2000;
- SRTM 90

#### **1.4 Legal aspects**

Section 26 of the National Water Act regulates any activity that may have an impact on a water resource and the conservation and protection of this water resource. Legislative requirements relevant to groundwater as administrated by the Department of Water Affairs (DWA) are:

- National Water Act, 1998 (Act 36 of 1998) (NWA, 1998);
- DWA Best Practice Guidelines, dated 2007;

The following overarching legislation was taken into account in the present groundwater assessment:

- National Environmental Management Act, 1998 (Act 107 of 1998) (NEMA).
- National Water Act, 1998 (Act 36 of 1998) (NWA).
- National Environmental Management: Waste Act, 2008 (Act 59 of 2008)
- (NEM: WA);
- Mineral and Petroleum Resources Development Act (No 28 of 2002) (MPRDA).

#### **1.5 Details of specialist**

The following groundwater study project has been conducted by experienced water specialists' team, and is managed by a fully qualified professional water scientist, who has been involved in leading relevant projects. The consultant details are giving as follow:

**Table 1 : Specialist details**

<b>PROJECT TITLE: Detailed groundwater impact assessment-</b>			
<b>Specialist:</b>	AQUA EARTH CONSULTING		
<b>Nature of specialist study compiled:</b>	Groundwater Assessment.		
<b>Contact person:</b>	AHOKPOSSI D P		
<b>Postal address:</b>	PO.BOX :1747 North Riding		
<b>Postal code:</b>	2162	<b>Cell:</b>	0735721424
<b>Telephone:</b>	0117913490	<b>Fax:</b>	0115076612
<b>E-mail:</b>	pacome@aquaeearth.co.za		
<b>Qualifications &amp; relevant experience:</b>	Bsc Civil Engineering - Msc Geohydrology (10 years)		
<b>Professional affiliation(s) (if any)</b>	SACNASP		

### 1.6 Declaration of Independence

Aqua Earth was appointed to conduct a specialist groundwater study as part of EIA and act as the independent specialist in this application. Aqua Earth will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant. Aqua Earth has the expertise in conducting the specialist report relevant to this application and will not engage in conflicting interests in the undertaking of this study.

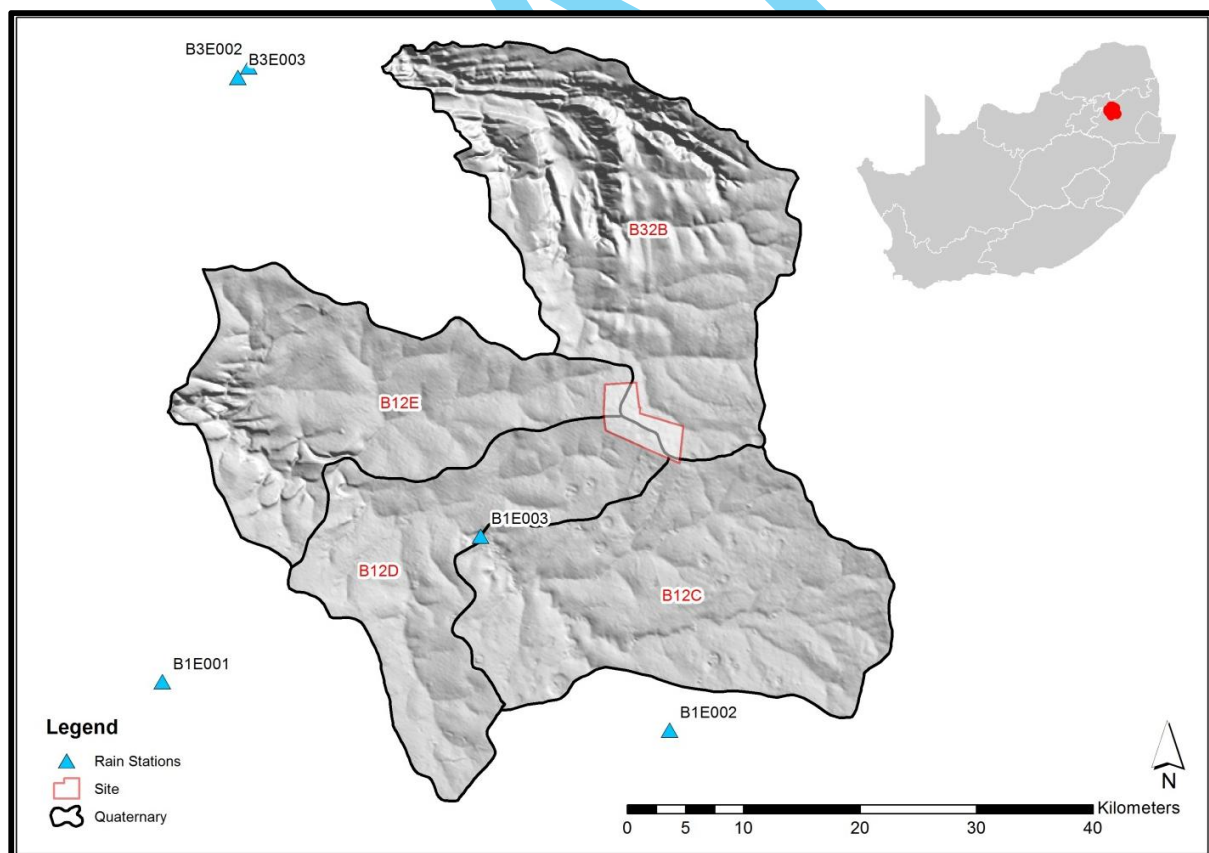
## 2 Methodology

### 2.1 Climate

Climatic data was collected from SA Explorer and DWA rainfall station. The closest DWA rainfall station, B1E003 (15 km south-west) was considered as a representative rain gauge for the area.

**Table 2: List of rainfall stations**

Station ID	Place	Lat	Long
B1E001	Witbank @ Witbank Dam	-25.88807	29.29973
B1E002	Rondevalley	-25.92557	29.69141
B1E003	Rondebosch @ Middelburg Dam	-25.77557	29.54557
B1E004	Rietfontein	-26.35776	29.21640
B1E005	Naauwpoort @ Witbank Dam	-25.97473	29.28057
B3E002	Loskop Nat. Res. @ Loskop Dam	-25.41310	29.36640
B3E003	Loskop Nat. Res. @ Loskop Dam	-25.42143	29.35807



**Figure 2: Quaternaries and available DWA rainfall stations around Rietvlei site**

Good continue daily rainfall data was available from 1980 to 2004 from B1E003 with the following quality DWA code distribution over this period:

- 86% good continuous data;
- 12% good monthly reading;
- 2% unaudited data;

## 2.2 Topography and drainage

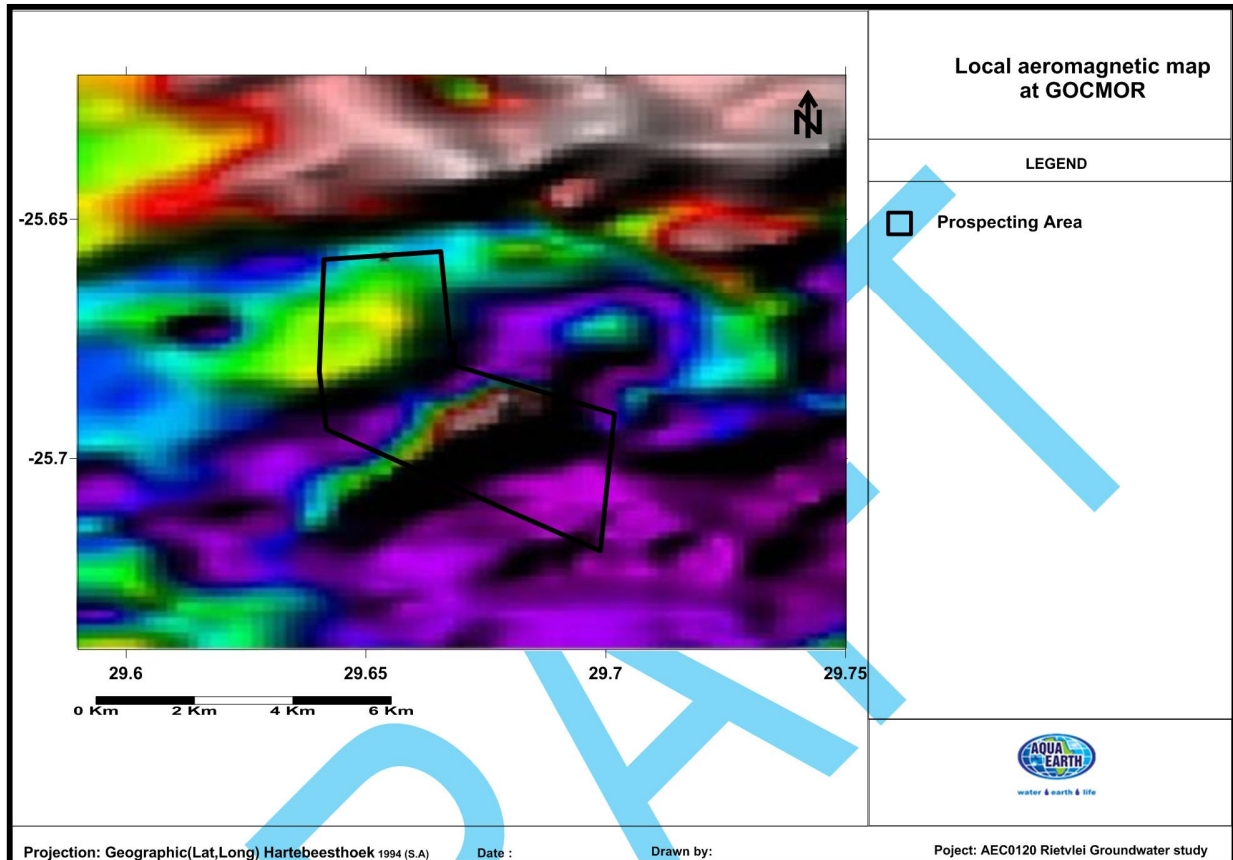
Digital information from the following 1:50 000 topographical maps were used together with the “Water Ressources of South Africa” (WR2005-Midgley et al., 1990) for the demarcation of the catchments as well as for the hydrological description of the area:

- 2529CB:
- 2529CD
- 2529DA
- 2529DB
- 2529DC
- 2529DD

## 2.3 Geophysical surveys

In sum, 6 geophysical survey traverses have been conducted, using magnetic method (Scintrex-G5-Magnetometer). Magnetometers are instruments used for measuring the magnetic field and by virtue of their sensitivity and range are able to measure the changes of magnetic field between two rock types with only small differences in magnetic content.

Analysis of geohydrological maps in this area has shown that the probability of striking water is greater on the fracturing associated with discontinuities and contact zones, in the saturated zones. Linear features depicted from the local aeromagnetic map strike NE-SW (Figure 3). The Southern, and Eastern, parts of proposed Rietvlei Mine property was prioritised for locating new monitoring borehole as not sufficient observation boreholes were located in these areas of the proposed Rietvlei mine. These targets have been used in combination with the accessibility to the sites and location of boundary fences to define the geophysical traverses.



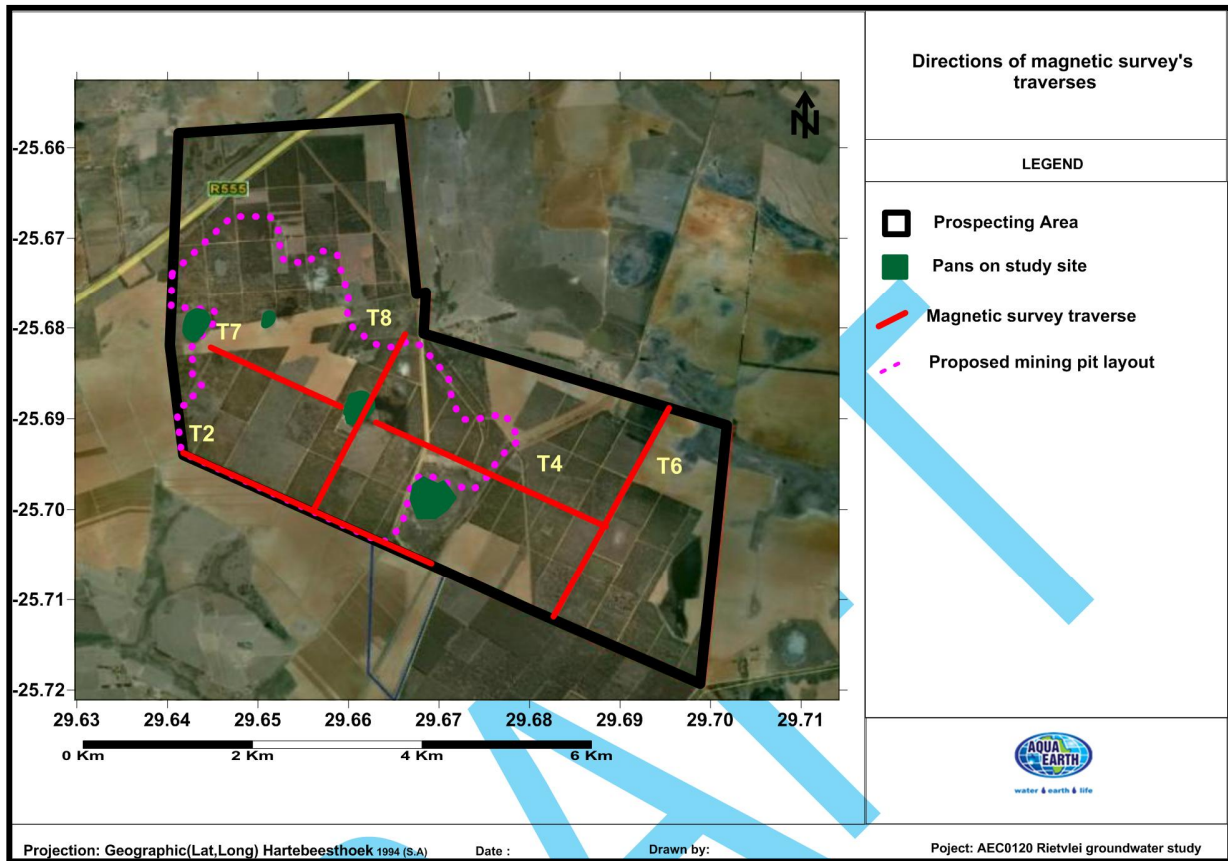
**Figure 3: Local Aeromagnetic map (From Council of Geo-Science)**

The geophysical traverses were set out in the following manner:

- Lines were set out perpendicular to the possible structures (dolerite intrusion) as indicated on the geological map and aeromagnetic map;
- Lines were walked with a station spacing of 10m in areas;
- Coordinates were taken at each station at the beginning and end of each traverses line.

Walked traverses are illustrated in Figure 4





**Figure 4: Geophysical survey lines**

## 2.4 Drilling of boreholes

Borehole drilling was carried out, using an air percussion drill rig with a 900cfm compressor with full time supervision by a geohydrologist. All the boreholes were drilled with a drill bit with a diameter of 6 inch. During drilling, the following information was recorded:

- Penetration rates at every 1m drilling;
- Water strikes;
- Borehole construction information;
- Geological formations intersected during drilling;
- Water level.

## 2.5 Rock chips sampling

During drilling, grab samples of rocks ship were taken, at prescribed depths for Acid drainage potential analysis. The samples were collected in 1L plastic bags and stored in a cooler box under appropriate conditions. The samples were recorded according to AEC's chain of custody

requirements (Appendix 1.) and submitted to a SANAS (South African National Accreditation Standards) accredited laboratory (WATERLAB (PTY) LTD) in Pretoria on the 14 February 2014.

Based on agreement with WSP geochemist, the following geochemical analyses have been requested from the Laboratory:

- Acid Base Accounting (ABA)
- Distilled water leach at liquid to solid ratio of 4 to 1 on all samples (pH; TDS (analysed, not by conductivity); alkalinity; Cl, F, SO<sub>4</sub>; ICP-scan for cations (Na, K, Ca, Mg, Fe, Mn, Al and trace metals)).

## **2.6 Water sampling**

Grab water samples were collected from the new boreholes by using a “single-check valve weighed poly” nylon bailers (1.6” OD, 36 “Length) and a labelled rope. Water samples were collected in standard 01 litre plastic sample bottles, and were stored in a cooler box together with ice packs (for preservation) conditions. They were submitted to UIS Laboratory, a SANAS accredited laboratory (South African National Accreditation Standards) in Pretoria on the 18 January 2013 for analysis.

The bailer was lowered to the possible sample depth. As the bailer is being lowered, valve located at the bottom opens, allowing water to flow through the sampler. When, reaching the possible sampling depth, the bailer is raised using the support cable. The weight of water and upward movement of the bailer keep the ball valve closed. The bottom ball valve keeps the water in the bailer. Once at the surface, the bailer is emptied by opening the valve with a sample release device, and allowing the water to drain slowly through the sample release device into the sample container.

The list of constituent measurements requested from the laboratory is given in Table 3

**Table 3: List of constituents analyzed for new boreholes water samples**

Physical constituents	Macro-constituents	Micro-constituents	Microbiological constituents
pH, Electrical Conductivity (EC), Turbidity, Dissolved Solids, Suspended Solids	Chemical Oxygen Demand (COD), Dissolved Oxygen, Total Alkalinity as CaCO <sub>3</sub> , Total Hardness as CaCO <sub>3</sub> , Fluoride (F), Sodium (Na), Potassium (K), Chloride (Cl), Nitrite (NO <sub>2</sub> ), Nitrate (NO <sub>3</sub> ), Sulphate (SO <sub>4</sub> ), Calcium (Ca), Magnesium (Mg), Ammonia as N	Aluminium (Al), Arsenic (As), Barium (Ba), Beryllium (Be), Boron (B), Bromide (Br), Cadmium (Cd), Cesium (Cs), Chromium (Cr), Cobalt (Co), Copper (Cu), Iron (Fe), Lead (Pb), Lithium (Li), Manganese (Mn), Mercury (Hg), Molybdenum (Mo), Nickel (Ni), Selenium (Se), Silver (Ag), Strontium (Sr), Tellurium (Te), Thallium (Tl), Tin (Sn), Titanium (Ti), Tungsten (W), Uranium (U), Vanadium (V)	Total Coliforms; Faecal Coliforms; and <i>E.Coli</i>

## 2.7 Aquifer testing

All the newly drilled boreholes were tested together with some selected existing boreholes. Based on the current knowledge of the site geohydrological conditions, the drilling results, and tests requirements, the following tests were proposed for the design of constant rate pumping test:

- Slug test;
- Calibration test;
- Step tests

Each calibration was systematically followed by a “recovery test” where the borehole was emptied, and recovery recorded.

## 2.8 Slug test

The slug test was proposed mainly for the determination of the yield of the boreholes present at site. It will also serve for the first estimate of the hydraulic conductivity values on relatively low yielding boreholes. The test is useful for a first approximation of the yield of the borehole (Van Tonder *et al.*, 2001).

A slug test involves the sudden addition, removal, or displacement of a known volume of water and the subsequent measurements (and records) of changes in water level in the well, as equilibrium conditions return. Slug tests were conducted by displacing water. Water displacement was done instantaneously by lowering manually the slug. The static water level in the borehole was measured prior to slug introduction. Water level measurements were taken with a dip meter (Solinst) and automatic data logger (Solinst). Manually, water level was measured every minute up to 10 minutes, and every 05 to 10 minutes (according to the response) after 10 minutes. The automatic water level logger was set to record water level every minute. Two slugs (closed PVC filled with concrete) constructed by AEC, and of different volumes ( $0.28 \text{ m}^3$ ,  $0.35 \text{ m}^3$ ) were used. Prior to the application of the slug, depth to water level has been measured in each borehole, and is used as static water level. No pre-test water level stabilisation has been assessed. The water level recording was continued until at least 85 percent of the initial (prior to test) water level measurement is obtained. The time required for a slug test to be completed is a function of the volume of the slug, the hydraulic conductivity of the formation and the type of well completion (Environmental Protection Agency, 1994).

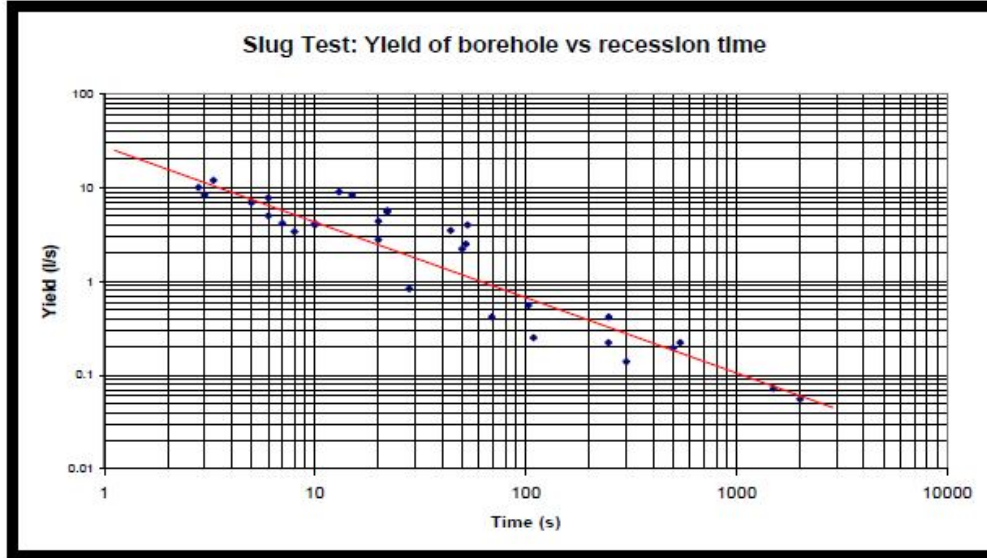


**Figure 5 Slug test equipment setup**

The graph below (Figure 6) was drawn from results obtained by testing 32 boreholes. On the graph, a straight line is obtained with the log-log scale. If the recession time for the borehole is entered on the x-axis, the possible yield can be read from the y-axis. The recession time to recover to at least 90% of its initial value was used in a formula (Vivier *et al.*, 1995) to determine the possible yield of a borehole.

$$Y = 117155X^{-0.824}$$

Where: X= recession time in seconds and Y= Yield of the borehole.



**Figure 6 Yield of borehole vs recession time (Vivier et al, 1995)**

The rate of water level changes is a function of the K of the formation and the geometry of the well or screened interval. It is only possible from slug test to determine the characteristics of a small volume of aquifer material surrounding the well, although fairly accurate parameters can be obtained from it (Kruseman and de Ridder, 1994). Well design information that were considered in the design of the tests are summarised in Table 4.

**Table 4: Borehole construction information considered in the design of the slug test**

BH Number	Well depth	Length of screen	Screen slot size	Distribution of the filter pack
	m	m	mm	mm
T4S	24	6	1.0	3
T4D2	50	36	1.0	3
T6D	50	18	1.0	3
T8D	50	15	1.0	3
t7D	50	33	1.0	3
T7S	24	3	1.0	3
Gw Obs BH3	30		1.0	3
Gw Obs BH4	30		1.0	3
Gw Obs BH2	30		1.0	3
Gw Obs BH1	30		1.0	3

### **2.8.1 Calibration and recovery tests**

Calibration tests have been conducted on the 10 selected boreholes to confirm their yielding capacity. Groundwater was pumped from the borehole sequentially at least two higher pumping rates over short periods of time. A Grundfox submersible pump (2kw) with a maximum capacity of 3.5l/s at 50m was used. Pumping rates during calibration tests generally varied between 0.06l/s to 1.2l/s depending on the boreholes. The pump was generally set at 2 m above the bottom of each pumped borehole. Each sequential period was about 15 minutes, and the total testing period was not more than 1 hour. Response (drawdown rate) to each pumping rate was then used to determine possible yielding capacity of the boreholes.

### **2.8.2 Step tests**

Prior to the CDT step tests were conducted on the 4 best yielding boreholes, to set up their respective CDT pumping rate.

The step drawdown test is a single-well test and it is performed that can be used to give an indication of the optimum yield at which the borehole can be subjected to CDT. Groundwater was pumped from the borehole sequentially at least two higher pumping rates over prescribed periods of time. During each step a steady state drawdown was observed prior to increasing of the pumping rate for the next step.

A positive displacement (mono diesel BP 12 HRCL-500RPM-7.5kw) pump, which can yield up to 100m<sup>3</sup>/hour at 300m head, was used. The selected boreholes were pumped at rates between 0.03l/s to 0.45l/s depending on the boreholes. Summary of field procedure is given in Table 5.

**Table 5 : Summary on the Step test field procedure**

BH Name	S.W.L	Pump Depth	Pumping Rate			Pumping Length	Recovery(90 %)
	(mbgl)	(mbgl)	(l/s)			(min)	(min)
GW OBS BH 1	17.02	27.50	0.04	0.15	0.45	75	30
GW OBS BH4	11.05	24.50	0.04	0.10	0.17	60*3	180
T4D2	11.80	39.00	0.03	0.08	0.11	60*3	120
T6D	13.47	39.00	0.09	0.18	0.27	60*3	60

**Description:** BH – borehole; S.W.L – Static Water Level; l/s– Litres per second; m – metre; min – minutes; mbgl- meters below ground level

**2.8.3 Constant discharge tests**

Based on results from the step tests, 3 boreholes were chosen to be pumped constantly for 12 hours (CDT). The testing period was decided by considering the low yielding capacity of the aquifer, and in the aim to record responses in closest observations within the proposed Rietvlei Mine. The outlet pipe should be at least 150 m length (50 + 100). During pumping of each tested borehole, the groundwater level responses were recorded in the closest accessible boreholes. The summary of field procedure is given in Table 6. Each CDT was followed by a recovery phase where residual drawdown was recorded up to at least 90% of recovery (except for GW OBS BH4). As for the calibration test a positive displacement (mono diesel BP 12 HRCL-500RPM-7.5kw) pump was used.

**Table 6: Constant discharge test and Observation boreholes**

BH Name	OBS BH	S.W.L	Pump Depth	Pumping Rate	Pumping Length	Recovery
		(mbgl)	(mbgl)	(l/s)	(min)	(min)
GW OBS BH 1	T7D(1852), T7S(1837)	17.02	27.50	0.25	720	600
GW OBS BH4	T7D(1282), T7S(1318)	11.05	24.50	0.11	720	--
T6D	T4D2(762) T4S(1032), T8D(2974)	13.47	39.00	0.28	720	180

**Description:** BH – borehole; S.W.L – Static Water Level; l/s– Litres per second; m – metre; min – minutes; mbgl- meters below ground level

The response (drawdown) of the aquifer during the aquifer constant pumping tests were analysed with different methods provided in the program “Flow Calculation” (FC) developed by the Institute of Groundwater Studies (IGS/UFS).



### 3 Description of the study area

#### 3.1 General description of the study area

The present section makes use of existing general, and background hydrogeological information prior to current investigations, to describe physically the study area.

##### 3.1.1 Climate

Based on data provided by SA Explorer, the climate is typical of the Highveld, with warm summers and cold winters. The area experiences an average of 8.3 hours of sunshine a day. The mean annual temperature is approximately 23°C (Figure 8). The area falls in the summer rainfall region with most rain occurring between October and March (Figure 9). The mean average annual rainfall for Optimum Mine (in close proximity of Rietvlei Colliery) is approximately 680 -700 mm. The mean monthly evaporation for a Class “A” pan is shown in Figure 7.

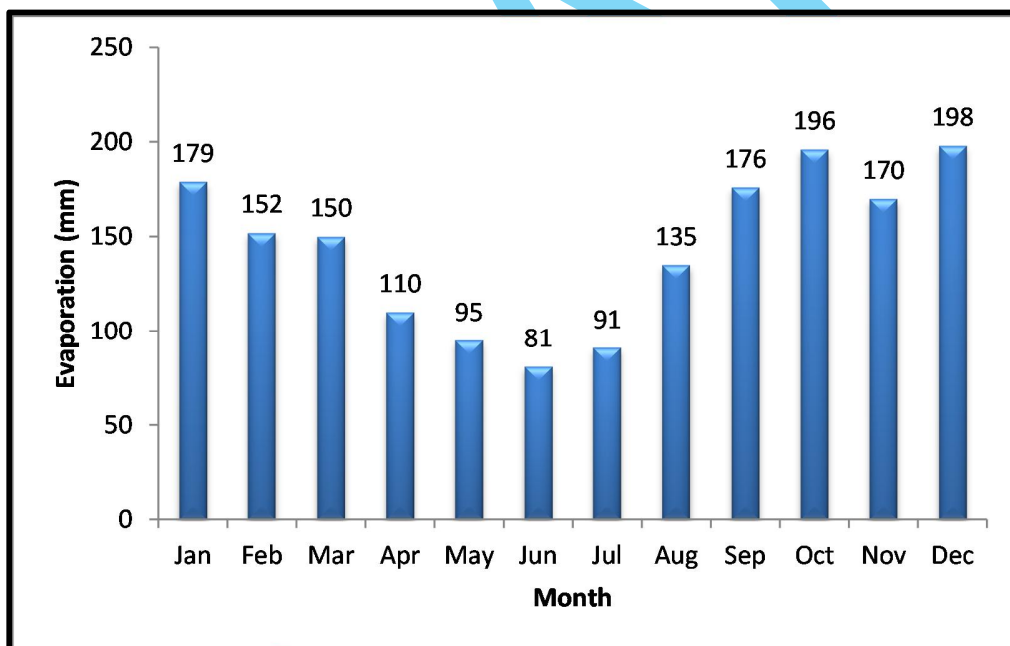
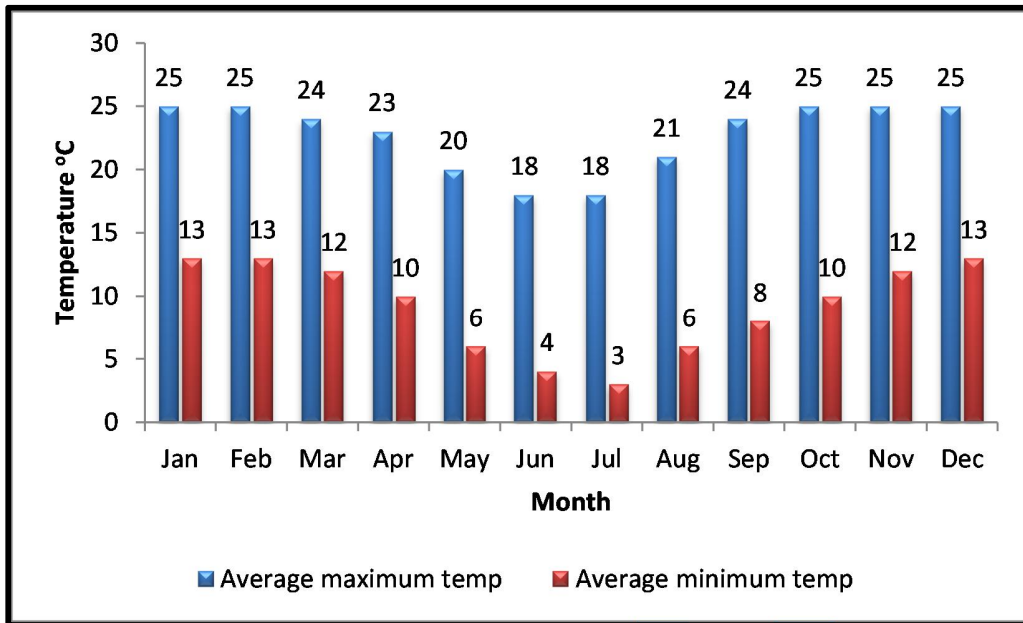
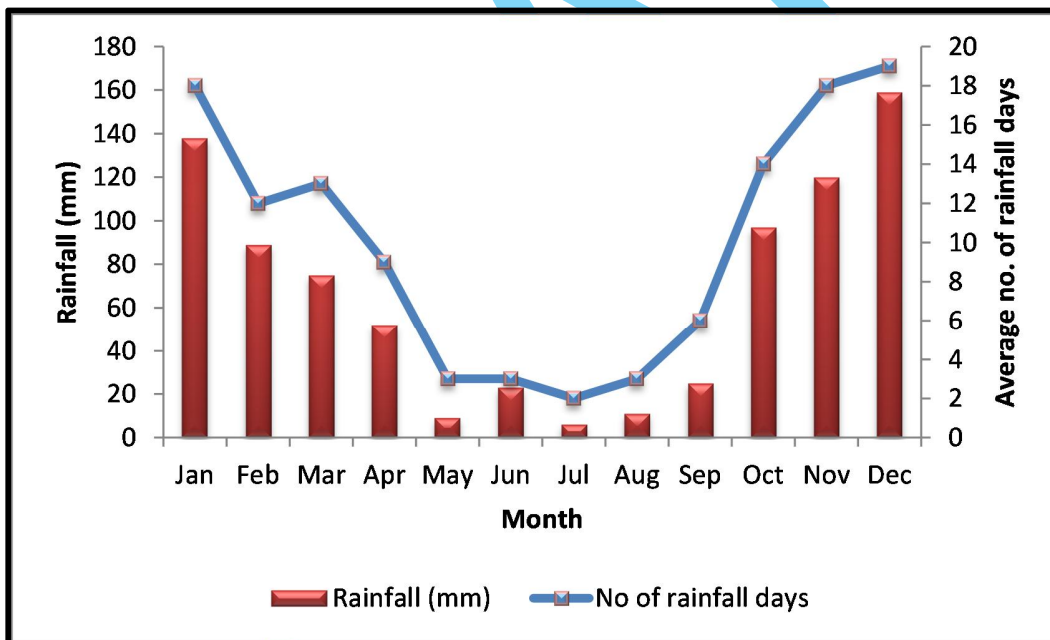


Figure 7: Average evaporation (SA Explorer)



**Figure 8: Average monthly temperatures (SA Explorer)**



**Figure 9: Average monthly rainfall with average number of rainfall days (SA Explorer)**

The rainfall record at B1E003 (DWA gauging station) for the above mentioned period, is shown in Figure 10. The associated average daily evaporation is shown in Figure 11.

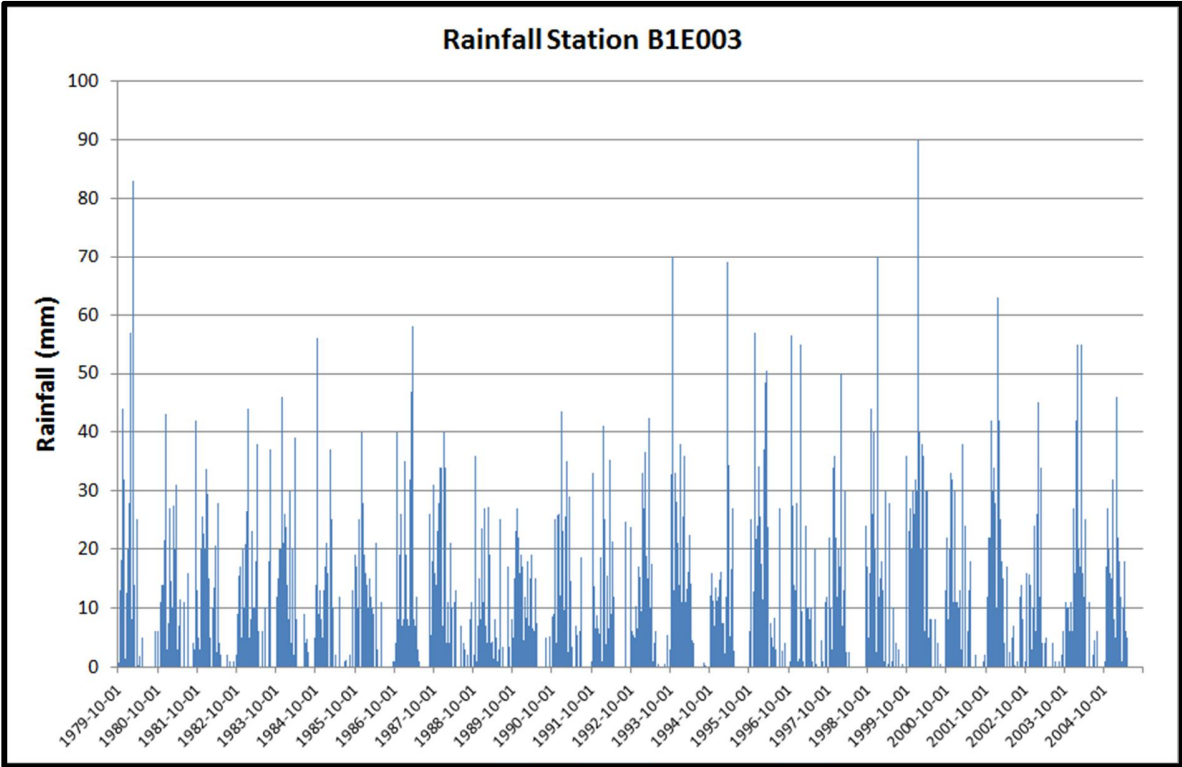


Figure 10: Rainfall record for B1E003 from 1980 to 2005 (DWA)

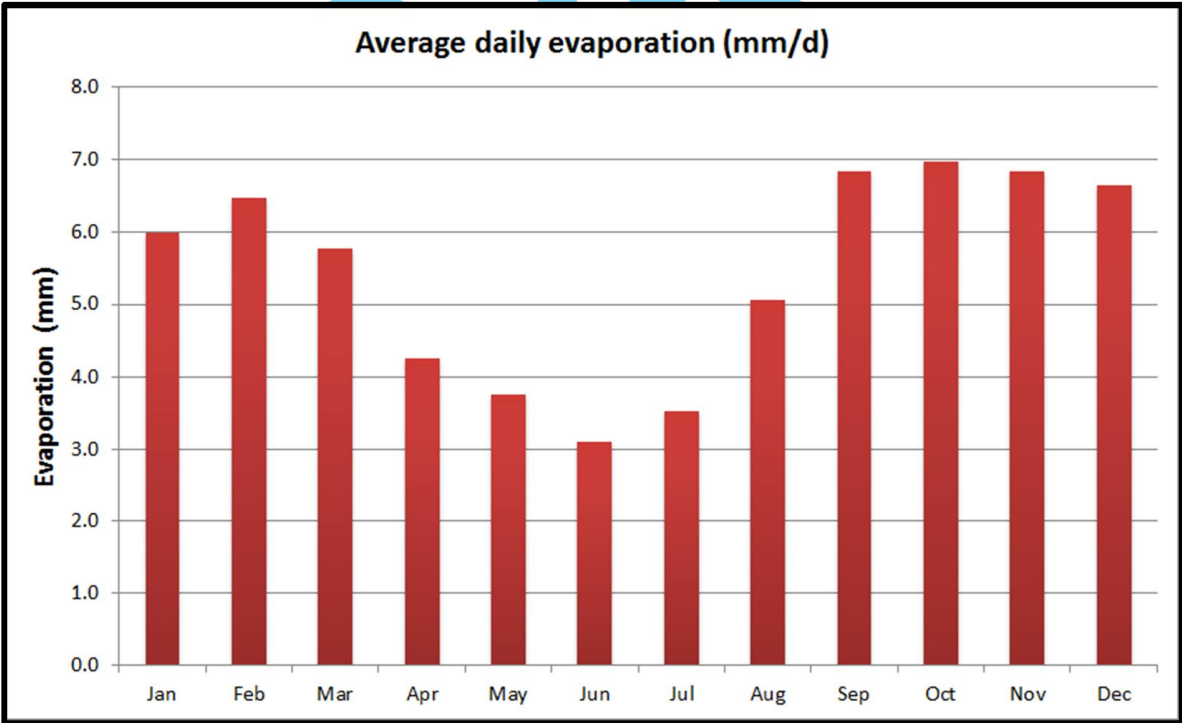


Figure 11: Average daily evaporation

## **3.2 Soils and land cover**

Rehab Green Monitoring Consultants cc conducted a detailed soil, land capability and land use assessment as well as wetland delineation during June 2011. The classification and mapping of soil forms (types) according to the South African Taxonomic Soil Classification System as documented is described in that report.

Soil background information and land cover distribution are useful in understanding the behaviour of surface water over the study area.

### **3.2.1 Vegetation**

The study area is located in the Grassland Biome of South Africa, across one regional vegetation unit, namely Eastern Highveld Grassland.

The site is covered by plantations, which in some areas have been cut and / or burned, and a number of “vlei” or wetland areas. Three habitat units were identified during the assessment, namely wetlands, grasslands and transformed habitats with historic disturbance as a result of cultivation, plantations and alien floral encroachment.

## **3.3 Wetlands**

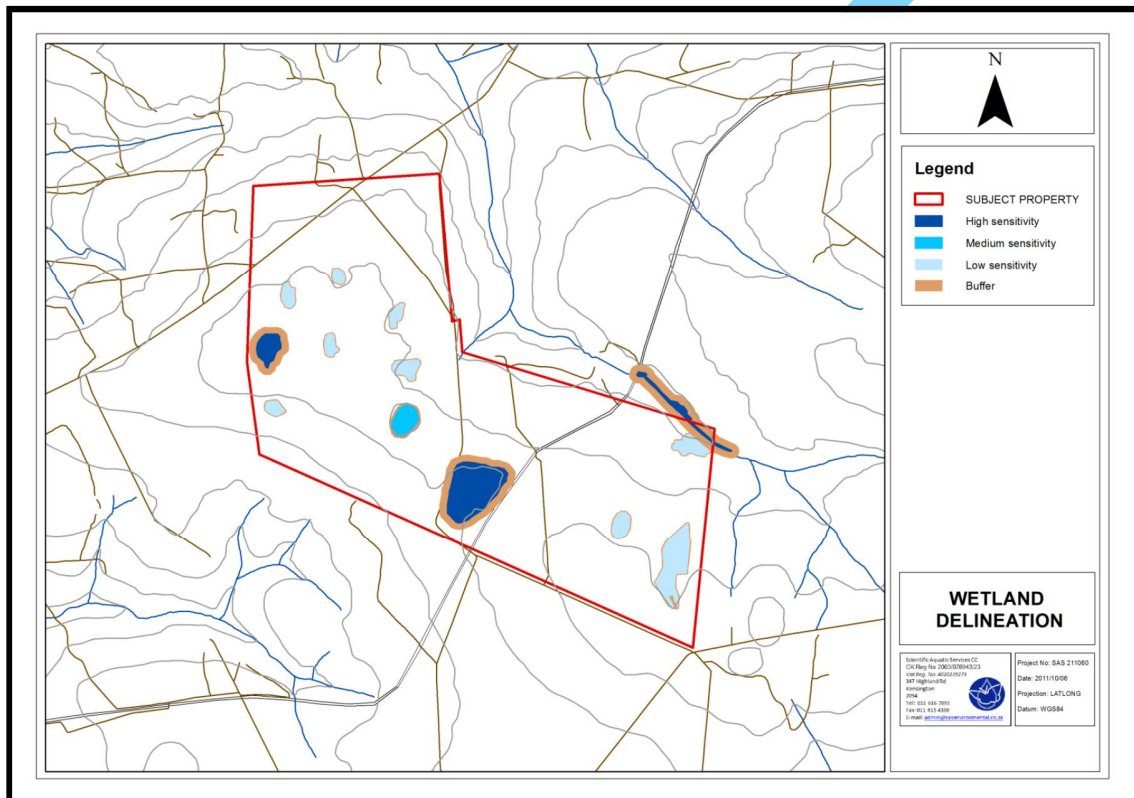
In 2011, Scientific Aquatic Services (SAS cc) conducted a wetland assessment as part of the EIA process for the proposed Rietvlei Colliery. The delineated wetlands inside the prospecting area are shown in Figure 12. All the wetlands in the study area have been considered sensitive and should be treated as required by Mpumalanga Biodiversity Conservation Plan. The varying sensitivities ascribed to the wetlands on site, range from Low Sensitivity to High Sensitivity, and are based on the varying degrees of degradation of the wetlands on site (Figure 12).

Wetlands present outside the boundary of the study area, have not been taken into account in the existing wetland mapping. This will however need to be considered in the mine water management and monitoring plans. Wetlands are connected to many of the streams on site and downstream sites.

Wetlands form where the water movement through the landscape slows down on or near the soil surface for a sufficient period to allow wetland conditions to develop. They are directly dependant on the water they receive from their catchment. Permanent and seasonal wetlands are present on site. Seasonal wetlands are firstly dependant on the surface water runoff from upstream areas and secondly, on the infiltrated water through soils (percolation) in these areas that end up in the ground water. The role of direct precipitation inputs in maintaining the

seasonal wetlands is undoubtedly not less important. Permanent wetlands are likely to be firstly supported by water percolating through different soil horizons, and a shallow perched water table mainly in winter and autumn. There could of course also be deeper groundwater inputs that may be associated with structural features.

The degree to which these wetlands depend on the groundwater seepage was not established and would require some form of eco-hydrological modelling of flows through the soil profile.



**Figure 12: Wetland delineation with associated buffers (SAS) cc**

### 3.4 Topography and drainage

The project area is located on the intersection of 03 quaternary catchments B12D, B12E and B32B (Table 7), with a small part (0.255km<sup>2</sup>) of the prospect area falling under B12C. The landscape slopes gently towards the different streams and rivers. The general elevations in the concerned catchments range between 1043 mamsl and 1831 mamsl (

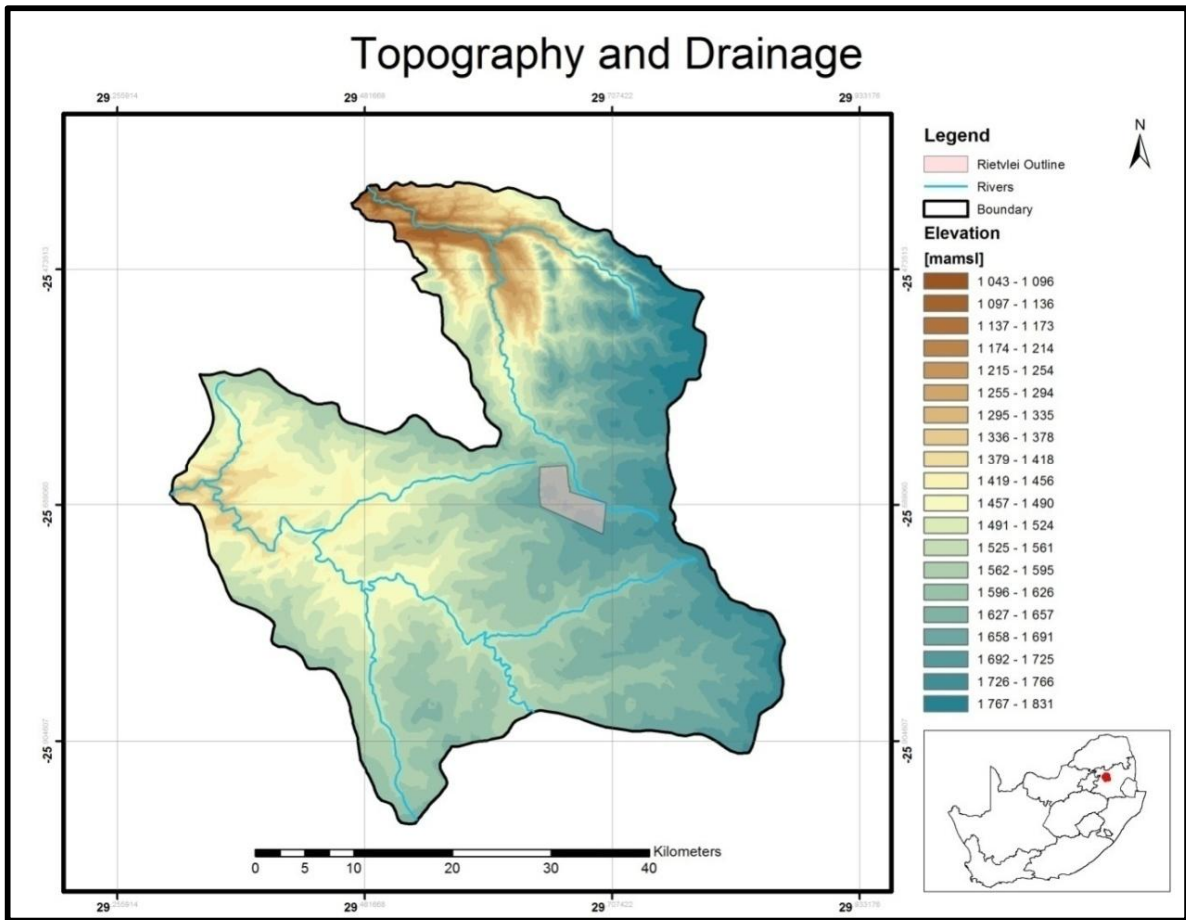
Figure 13). The study area is characterised by a land use of mainly agriculture, with blue gum plantations as the main agricultural activity.

**Table 7: Information concerning quaternary catchment**

Catchment	B12D	B12E	B32B
Area (km <sup>2</sup> )	362.3	435.8	613.8
Mean annual runoff (mm/a)	38	53	51
Groundwater contribution to base flow (mm/a)	7	18	16

The present study focuses on the three main catchments. Rietvlei forms the headwaters of:

- The Olifants River in B12D: number of small sized dams, intercepts the West-South-West furrows (Figure 15) that feed into Olifants River.
- The Selons River in B32B which flows North-West into Olifants River;
- The Keerom stream (B12E) which flows West-South-West into Olifants River: number of small sized dams, intercepts the South-West furrows (Figure 15) that feed into Keerom stream.



**Figure 13: General Topography and drainage**

The local elevations prior to mining ranges from 1590mamsl to 1720mamsl as indicated on Figure 14. The maximum decrease in elevation (from the highest point on site towards the lowest) is approximately 230m.

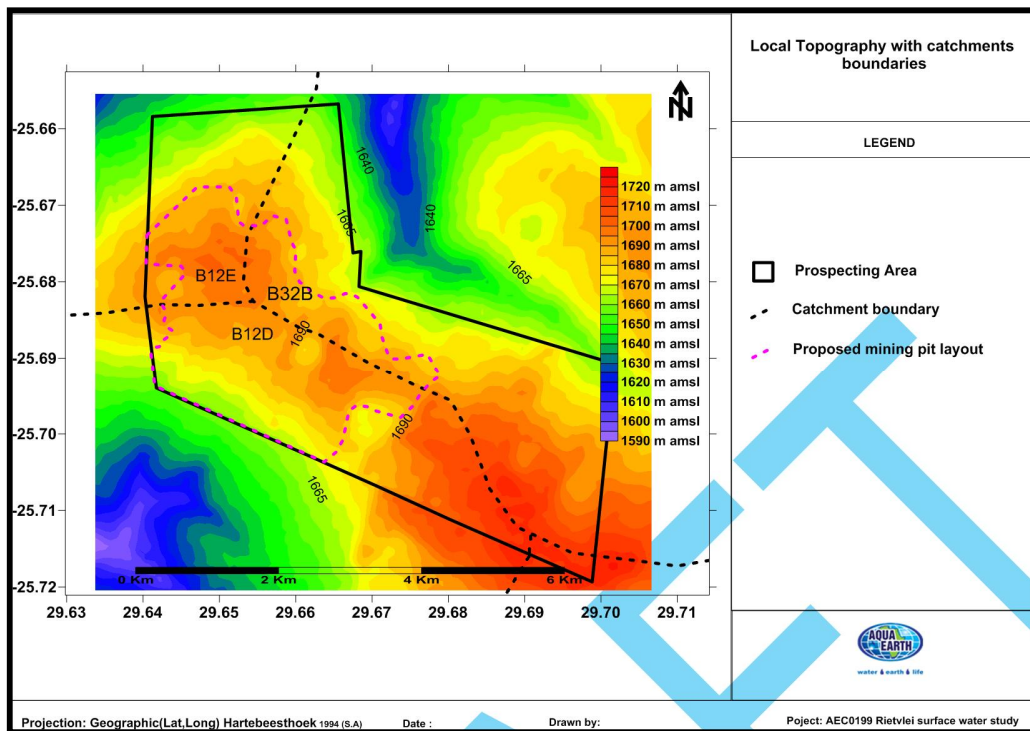


Figure 14: Local topography with catchments boundaries and mining pit.

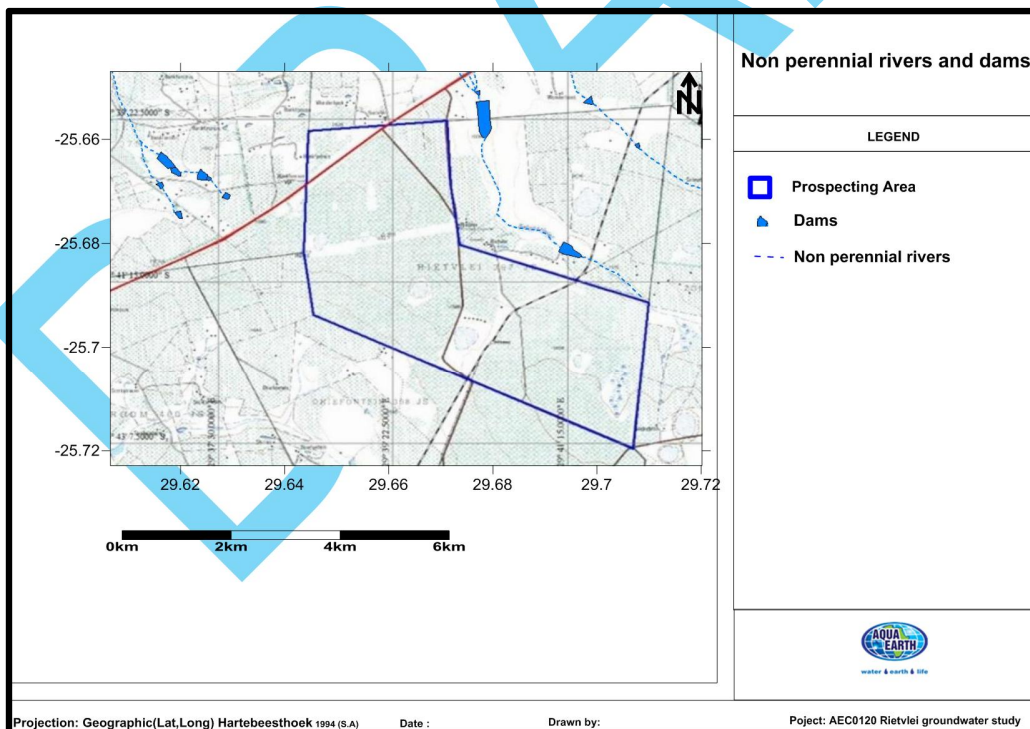


Figure 15: Non perennial rivers and dams surrounding the Rietvlei mine lease area.



Local surface runoff catchments with the associated local drainage are shown together with the mining layout in Section 3.7. The way that such local drainage is connected to the pans on the prospecting area is also illustrated.

### **3.5 Surface water quality**

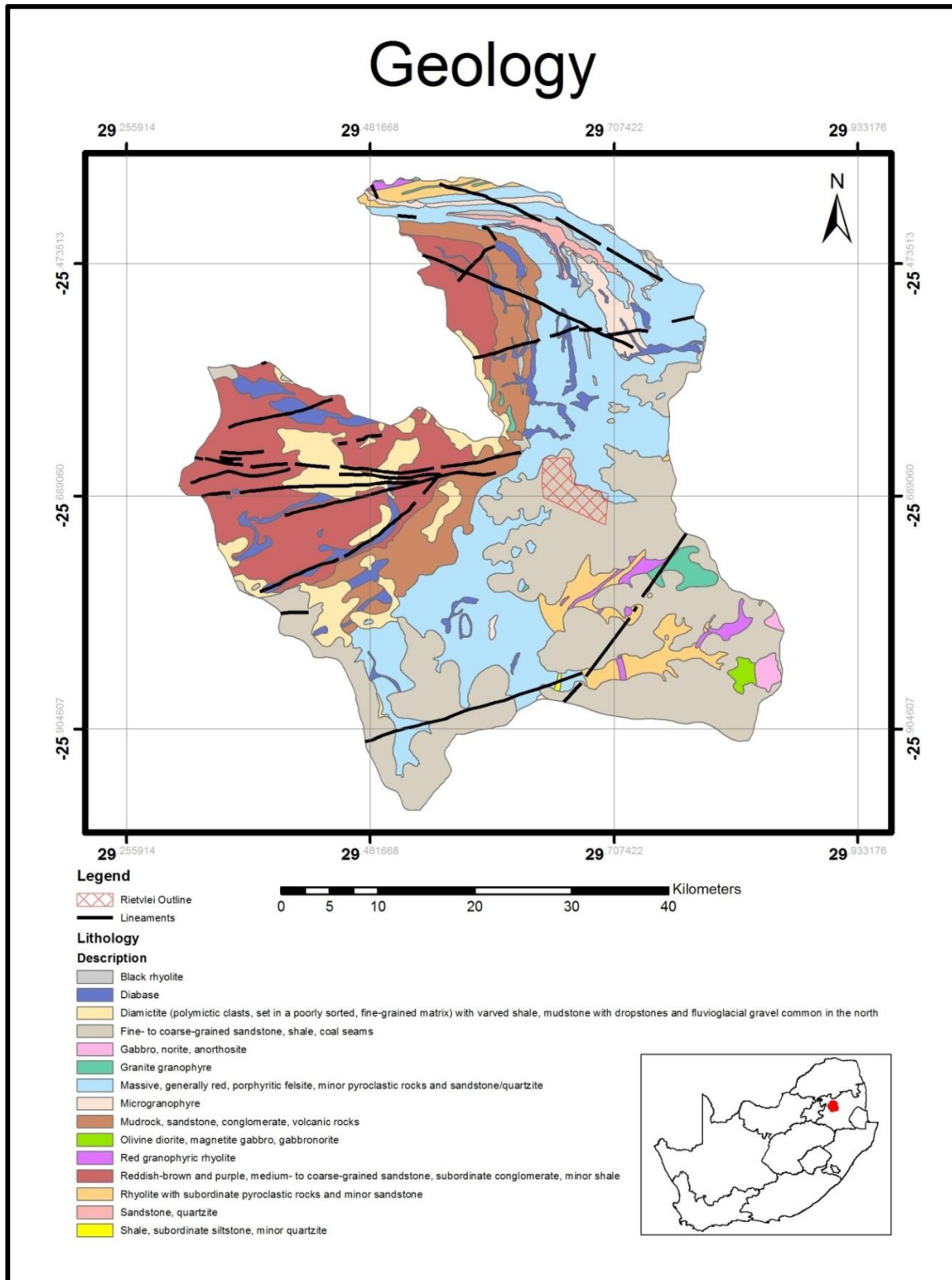
Surface water quality were analysed by AEC as part of the baseline groundwater study (2011). Selons River and the dam on the river showed a relatively neutral pH (7.12 and 7.46) and low electrical conductivity values (11mS/m and 13mS/m). All the major and minor constituents analysed for, fell within the recommended operational limits for drinking water (SANS 241; 2005) except for Aluminium, which exceeds the maximum allowable limit for both sampling points. This is likely due to clay particles from incomplete filtering of the sample.

### **3.6 General geology and groundwater occurrence**

The mine is located in the Karoo Sequence (Vryheid Formation). The Vryheid Formation consists of mudstone, shale, rhythmite, siltstone and fine- to coarse-grained sandstone (pebbly in places). The Formation contains up to five (mineable) coal seams (Figure 17). The different lithofacies are mainly arranged in upward coarsening deltaic cycles. Since the shales are very dense, they are often overlooked as significant sources of groundwater. The permeabilities of these sandstones are also usually very low. The main reason for this is that the sandstones are usually poorly sorted, and that their primary porosities have been lowered considerably by diagenesis. These sedimentary formations have been extensively intruded by dolerite dykes.

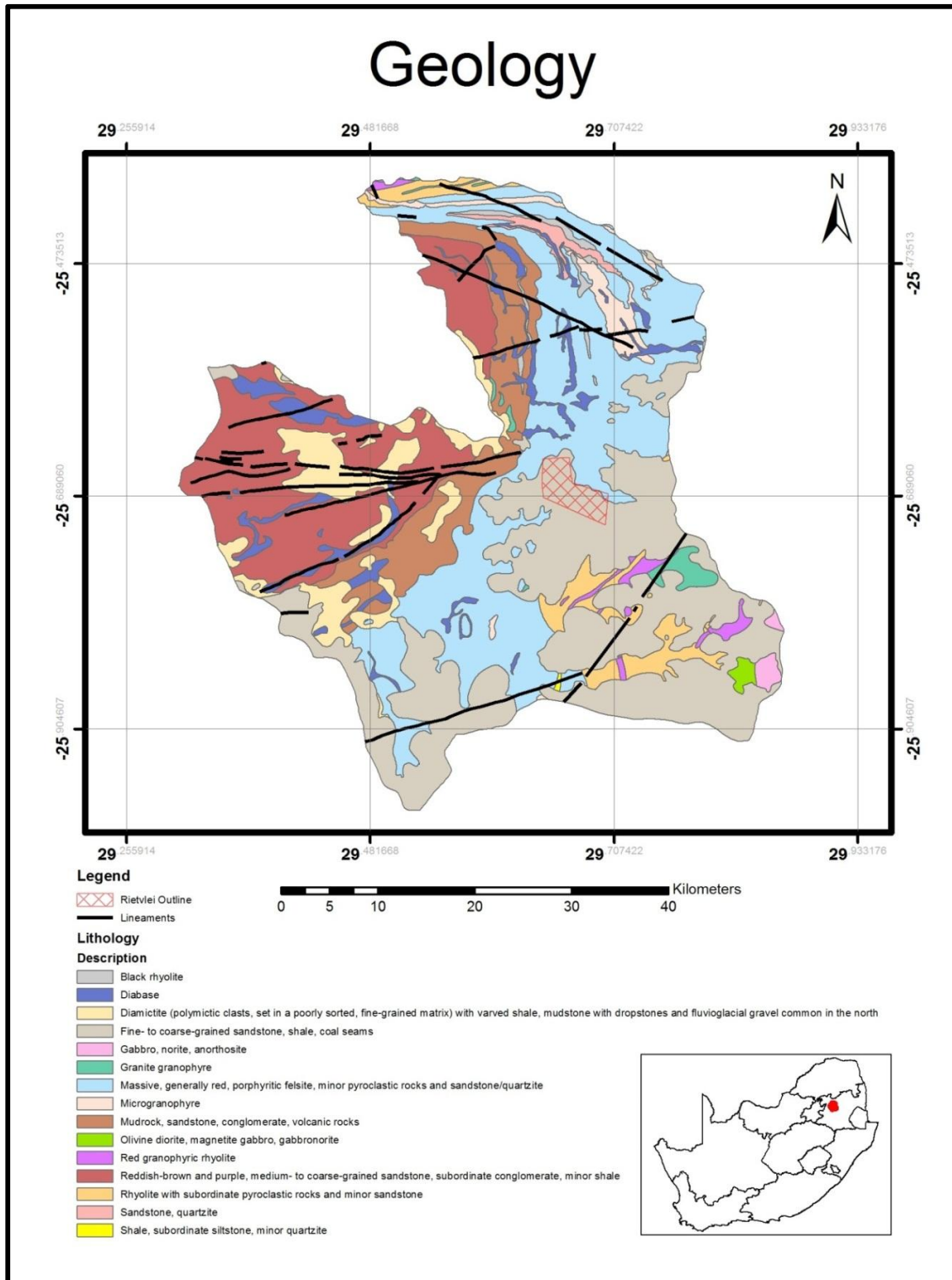
The Karoo dolerite, which includes a wide range of petrological facies, consists of an interconnected network of dykes and sills and it is nearly impossible to single out any particular intrusive or tectonic event. Dolerite dykes are vertical to sub-vertical discontinuities that, in general, represent thin, linear zones of a lower permeability sandwiched between fracture zones. These fracture zones can have a relatively higher permeability and can therefore act as conduits for groundwater flow within the aquifer. The dykes on the other hand may also act as semi- to impermeable barriers to the movement of groundwater. The dykes are commonly expressed on the surface as a line of green bushes, which can be readily observed during the dry season. The generalised stratigraphy is summarised in Figure 16. Geology of the area is shown in

# Geology



Figure

# Geology



Figure

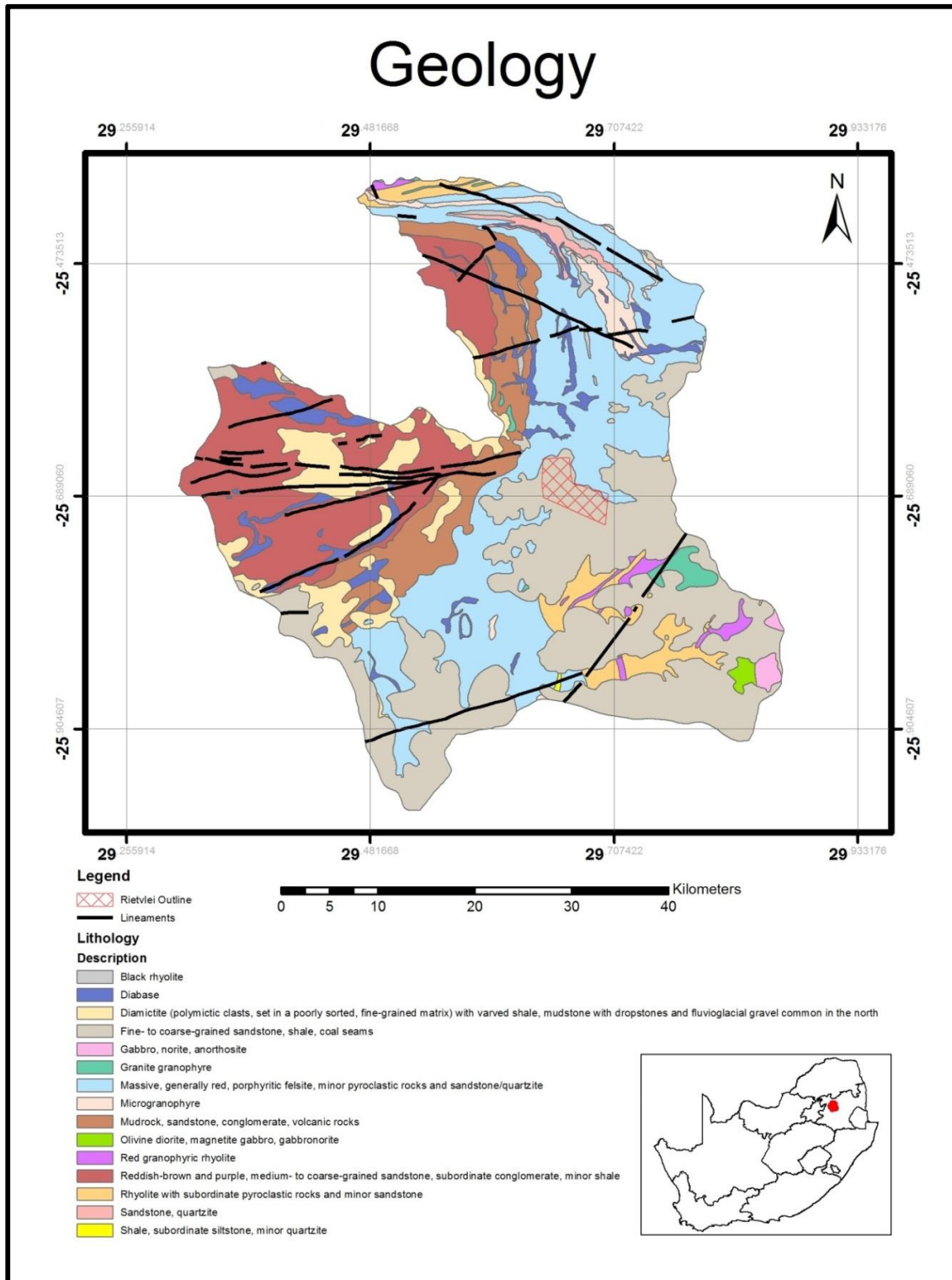


Figure 17.

Groundwater studies (GCS, 1999, Golder 2004) carried out in similar geology in the area, have indicated the presence of two aquifer systems (shallower and deeper), with little potential of yielding large volumes of water. Storage coefficients were estimated ranging from 0.001 to 0.01. Mean annual groundwater recharge was estimated at 35mm (Vegter, 1995).

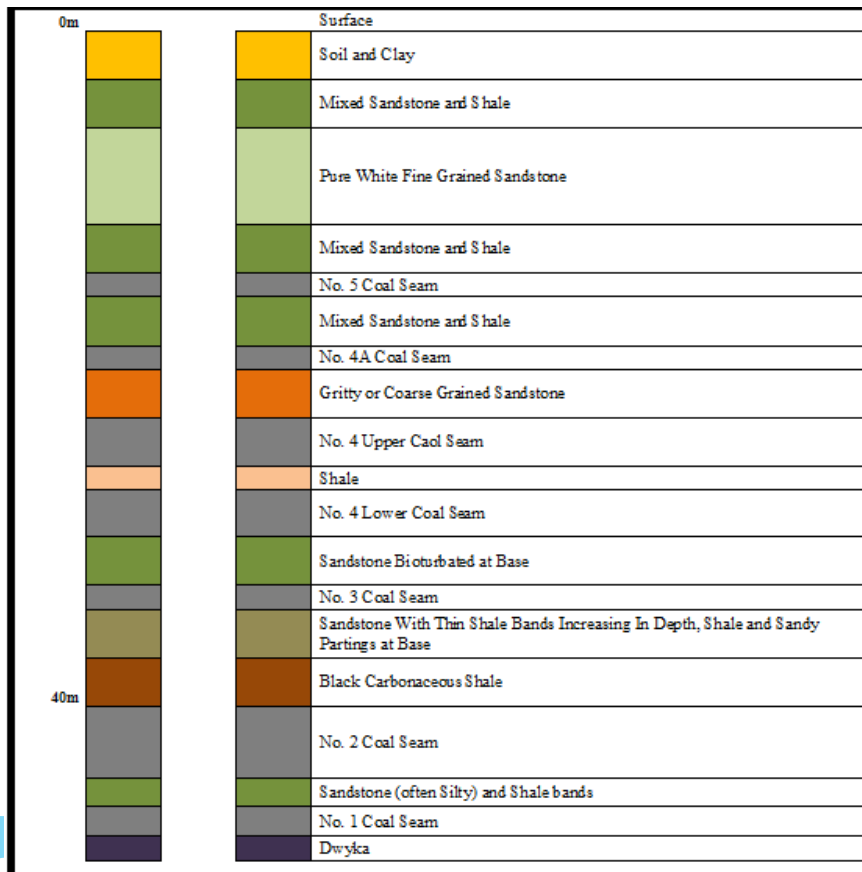
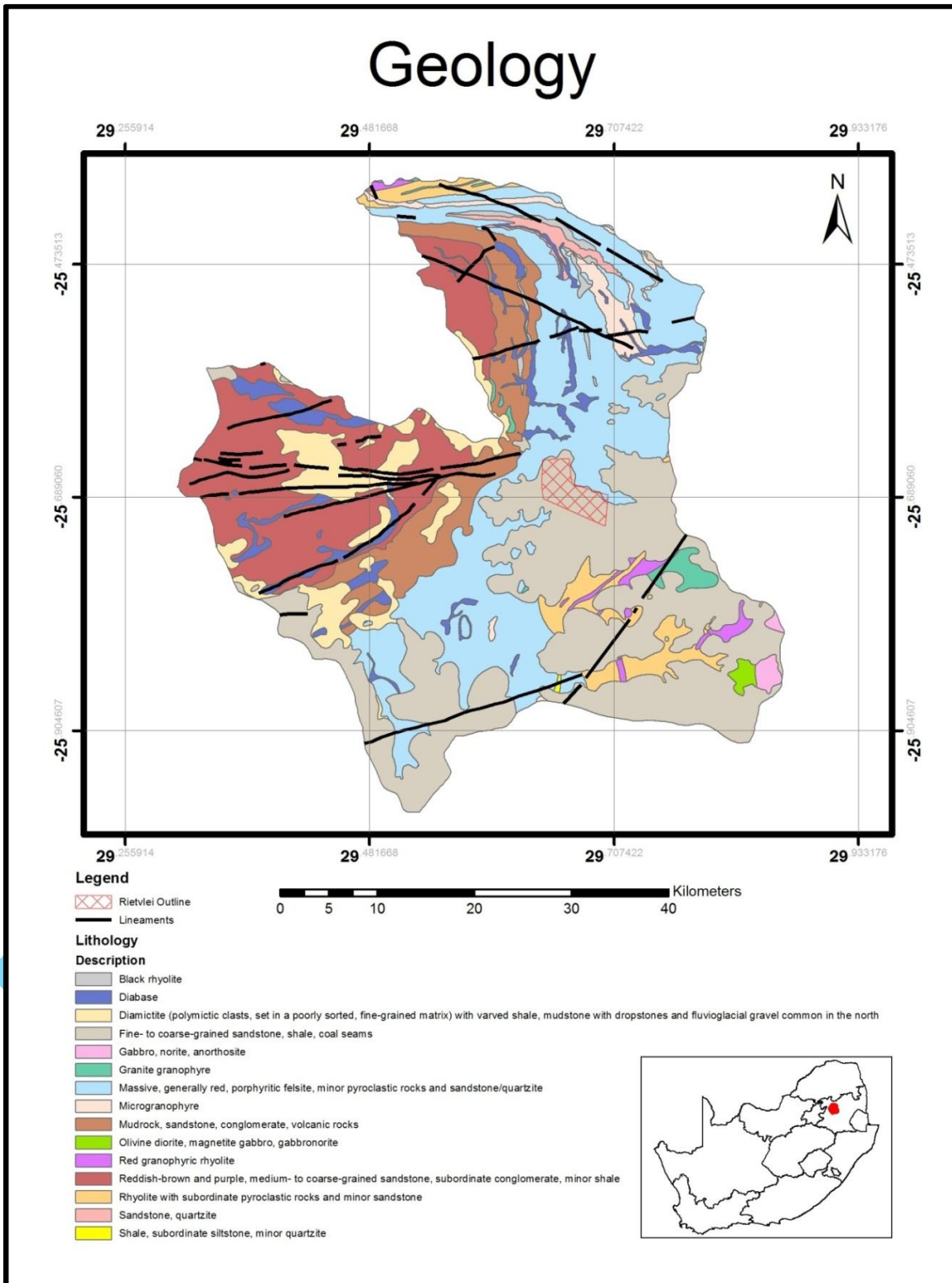


Figure 16: Generalized stratigraphy

# Geology



### 3.6.1 Local geology and groundwater occurrence

According to Mindset Mining Consultants “Feasibility report-Section 3” (04-2013), only the 2- and 1-Seams are currently present at the proposed Rietvlei Mine, since the other seams have been eroded. The aeromagnetic map of the area compiled by CGS shows a NE striking lineament at the SE of the proposed Rietvlei Mine.

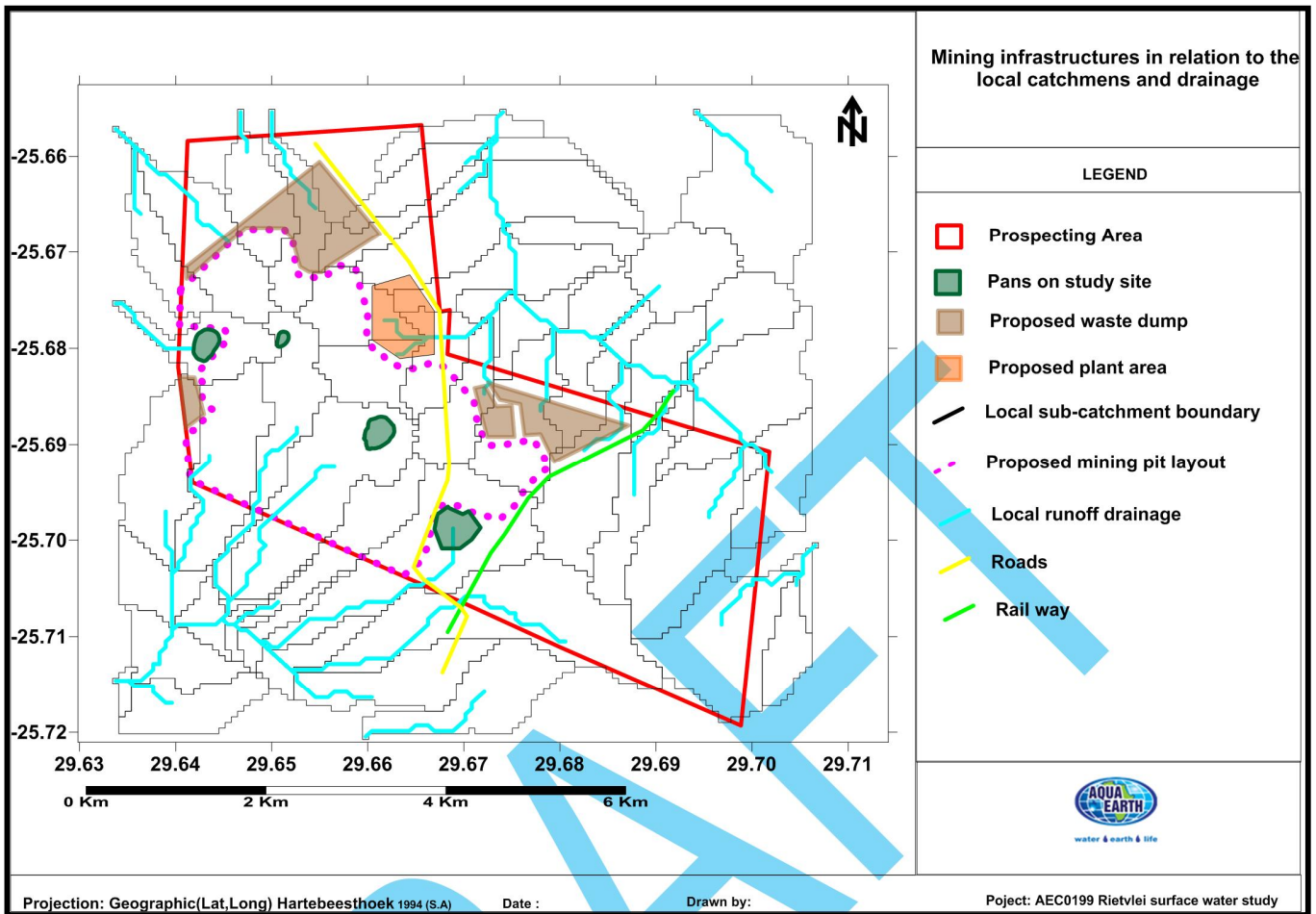
Analysis of existing information (including previous boreholes drilled by AEC) indicates fractures associated with sedimentary rocks within the study area. Such fractures are encountered from 8mbgl, up to 50mbgl (in the coal seams). These fractures, form conduits (preferential path) for groundwater flow. Table 8 depicts a typical borehole log of the proposed pit area. These need to be defined according to depth, yield, K.

**.Table 8: Typical borehole log**

Stratigraphic section	Description
Transport and residual soils	- topsoil
	- clayey hillwash
Vryheid Formation	- clayey siltstone and sandstone
	- silty, laminated shale
	- laminated siltstone with sandstone
	- No 2 seam (coal)
	- ripple cross-bedded fine grained sandstone
	- No 2 seam (coal)
Dwyka Group	Tillite, diamictite and glacial shales
Pre-Karoo basement	Paleo-weathered Selonsrivier felsite

### 3.7 Mining infrastructures

The positions of the surface infrastructure as reported in section 5 of the Rietvlei mining feasibility report are shown together with local runoff catchments and drainage in Figure 18. This map will be used in the establishment of surface water management plans related to each surface infrastructure.



**Figure 18: Surface infrastructure and local drainage**

The mining sequence (layout) and the associated mining schedule as designed by Mindset are presented respectively in Figure 19 and Figure 20.





## 4 Field investigation results and interpretation

As part the present detailed investigations, several field investigations have been conducted by AEC from February to April 2014 as part of the groundwater investigations, to better understand the prevailing geohydrological conditions (flow and water quality). These activities include geophysical survey, boreholes drilling, soil and water quality testing, and aquifer pumping tests.

### 4.1 Geophysical surveys

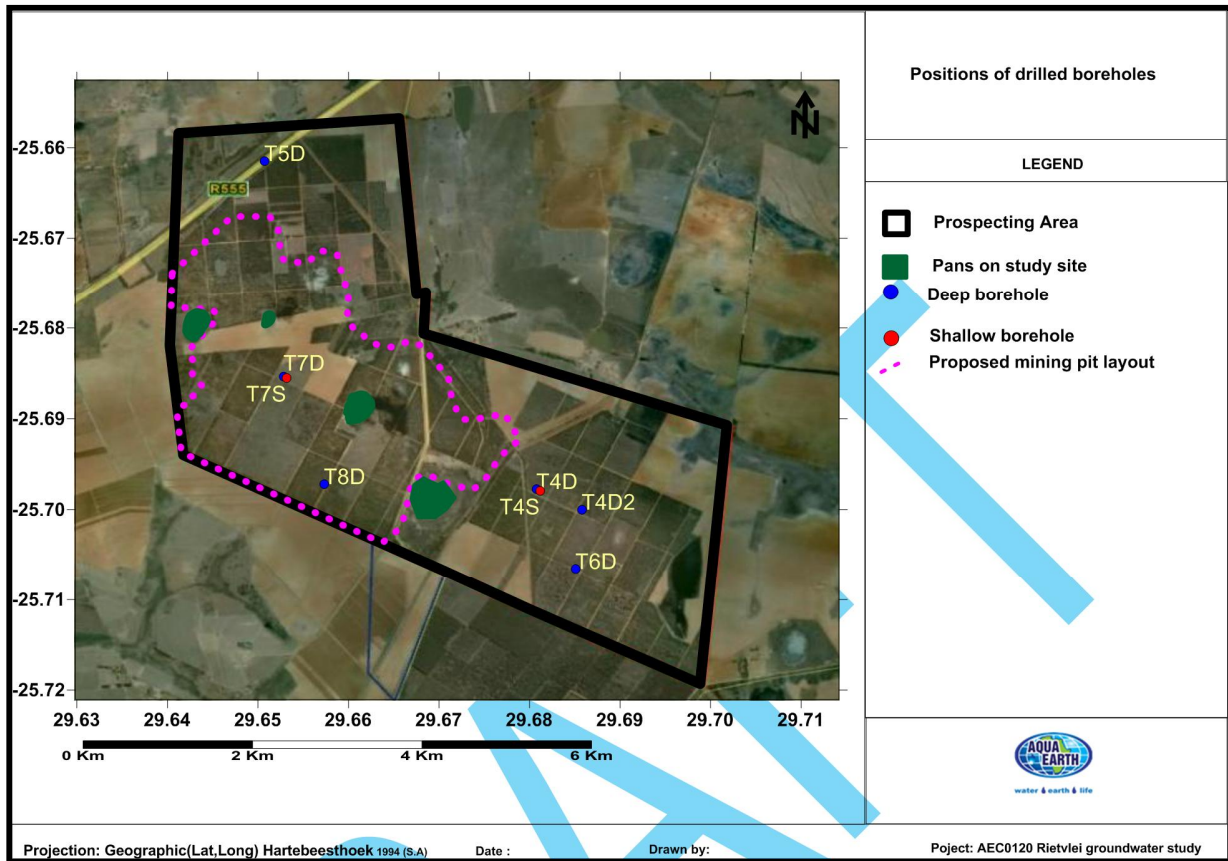
A site walkover and geophysical survey (magnetometer) was carried out from the 3th to 4th of February 2014. Geophysical survey results are presented in Appendix B.

Except for traverse T2, all the walked traverses showed magnetic field anomalies, which had been used for the siting of boreholes (Shallow and Deep) on site. Summary of the geophysical survey interpretation is given in Table 9, and targets' positions for borehole drilling are shown in

Figure 21.

**Table 9: Summary of the geophysical survey interpretation**

Target Name	Farm	Geographic Coordinates (WGS84)		Distance from starting points.
		Latitude	Longitude	m
T4D2	Rietvlei 397 JS	-25.700014	29.685798	1690
T4D	Rietvlei 397 JS	-25.697736	29.680776	1190
T4S	Rietvlei 397 JS	-25.697927	29.681179	1240
T5D	Rietvlei 397 JS	-25.661475	29.650723	--
T6D	Rietvlei 397 JS	-25.706538	29.685097	570
T8D	Rietvlei 397 JS	-25.697196	29.657317	290
T7D	Rietvlei 397 JS	-25.685354	29.652838	1500
T7S	Rietvlei 397 JS	-25.685504	29.653166	1450



**Figure 21: Positions of drilling targets**

#### 4.2 Drilling of exploration/monitoring boreholes

Borehole drilling was carried out from the 07<sup>th</sup> February to 12<sup>th</sup> February 2014. A total of six (6) deep and two (2) shallow boreholes were drilled on the targets sites as listed in Table 9. All deep boreholes were drilled to final depth of 50m, whereas all the shallow boreholes were drilled to final depth of 24m.

The borehole T4D had been drilled up to 50 m but the drilling crew had faced difficulties during its equipment. T4D was accessible up to only 09 m depth (as indicated on the provided T4D logs), and was then closed down. T4D2 was then drilled in replacement of T4D, and its location (700 m toward the south) was defined according to the closest identified magnetic anomalies (geophysics).

Figure 21 shows the positions of the drilled boreholes.

During drilling water strikes were recorded in six (6) of the boreholes, four at deep boreholes and two at shallow boreholes while borehole T5D drilled was dry. Water strikes in the shallow aquifer were intersected between 10m and 25mbgl, and concentrated at 45 mbgl in the deeper aquifer. 90 % of water strikes recorded during present drilling campaign are located in the

shallow aquifer with 80 % between 19m and 25 mbgl. Water levels in the boreholes were measured between 1.7m and 19.2mbgl. The recorded water levels did not show any difference in hydraulic heads between the two aquifers.

AEC constructed the monitoring/observation boreholes drilled as follows:

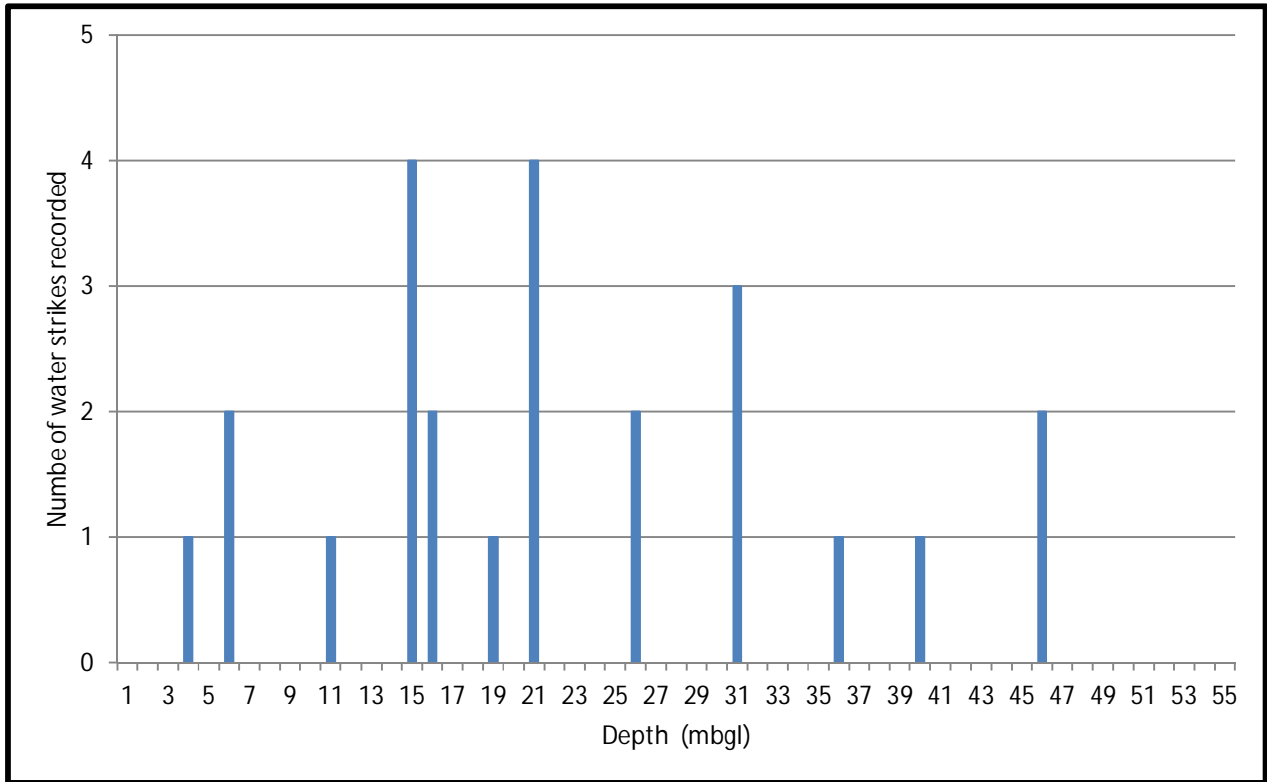
- Drilled 165mm diameter to bottom;
- Install 125mm steel solid and perforated PVC casing;
- Insert gravel pack to the top;
- Complete the hole with a concrete block, stand pipe, pump and lockable cap.

The drilling information is summarized in Table 10. Detailed drilling and construction logs with the different penetration rates are presented in Appendix C.

**Table 10: Summary of the drilling results**

Borehole Name	Lat	Long	Depth (mbgl)	Water Strike (mbgl)	S.W.L. (m)
T4D2	-25.700014	29.685798	50	moisture	6.6
T4D	-25.697736	29.680776	50	19 and 25	3.4
T4S	-25.697927	29.681179	24	10	3.1
T5D	-25.661475	29.650723	50	Dry	Dry
T6D	-25.706538	29.685097	50	19	14
T8D	-25.697196	29.657317	50	25	19.2
T7D	-25.685354	29.652838	50	19 and 44	1.7
T7S	-25.685504	29.653166	24	19	4.8

The vertical distribution of recorded water strikes suggests the main preferential path for the groundwater may be located at depth between 15 and 31 mbgl (Figure 22).



**Figure 22: Vertical distribution of recorded water strikes**

A shale layer was identified in the southern and western part of the prospecting area (GWOBSBH4, GWOBSBH3, T7D, T8D, T6D, and T4D2) at the headwater of quaternary catchment B12D (Figure 23, Figure 24, and Figure 25). This may be contributing to the occurrence of perennial wetland at this part of the site.

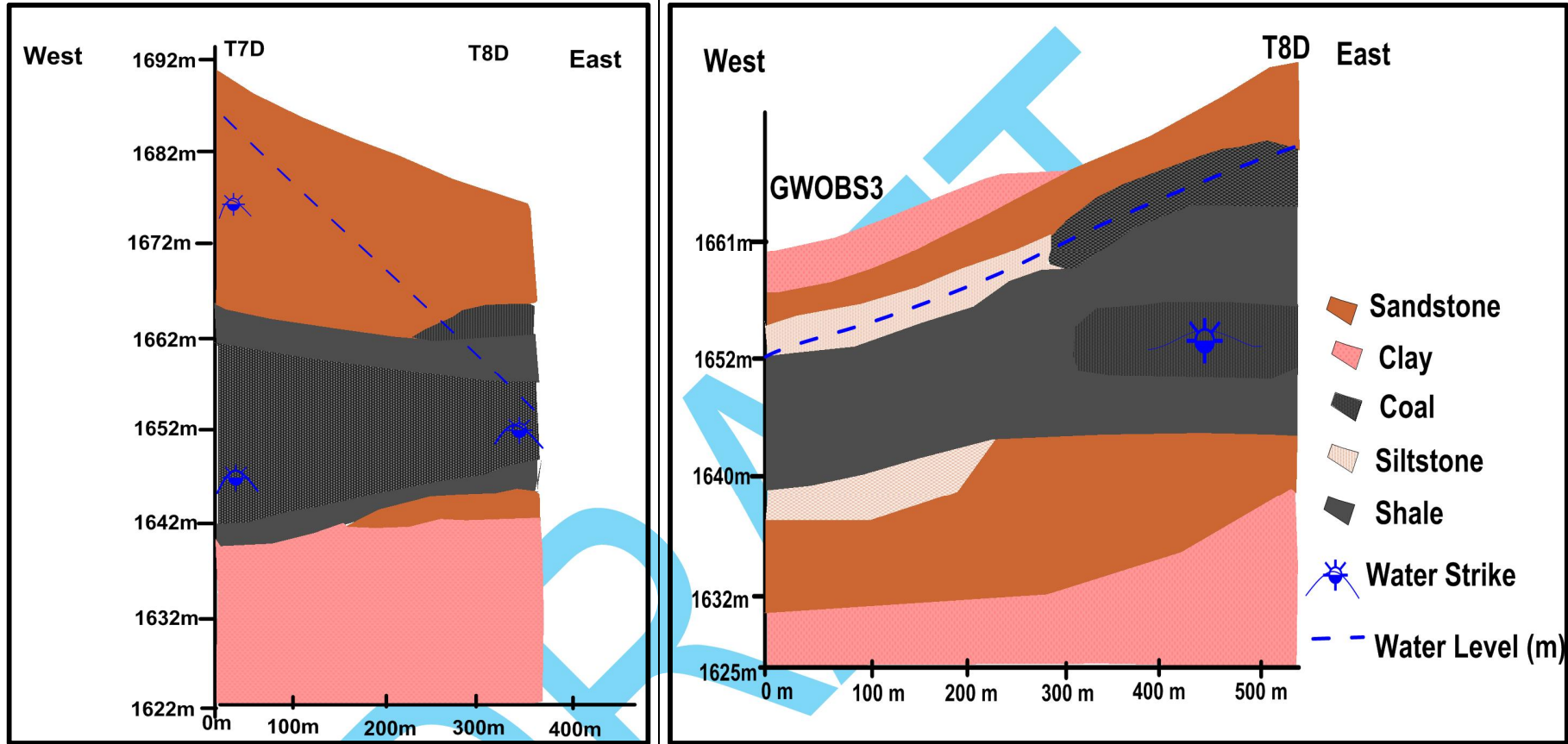


Figure 23: Fence diagrams from geohydrological drilling (T7D, T8D; GWOBSBHBH3)

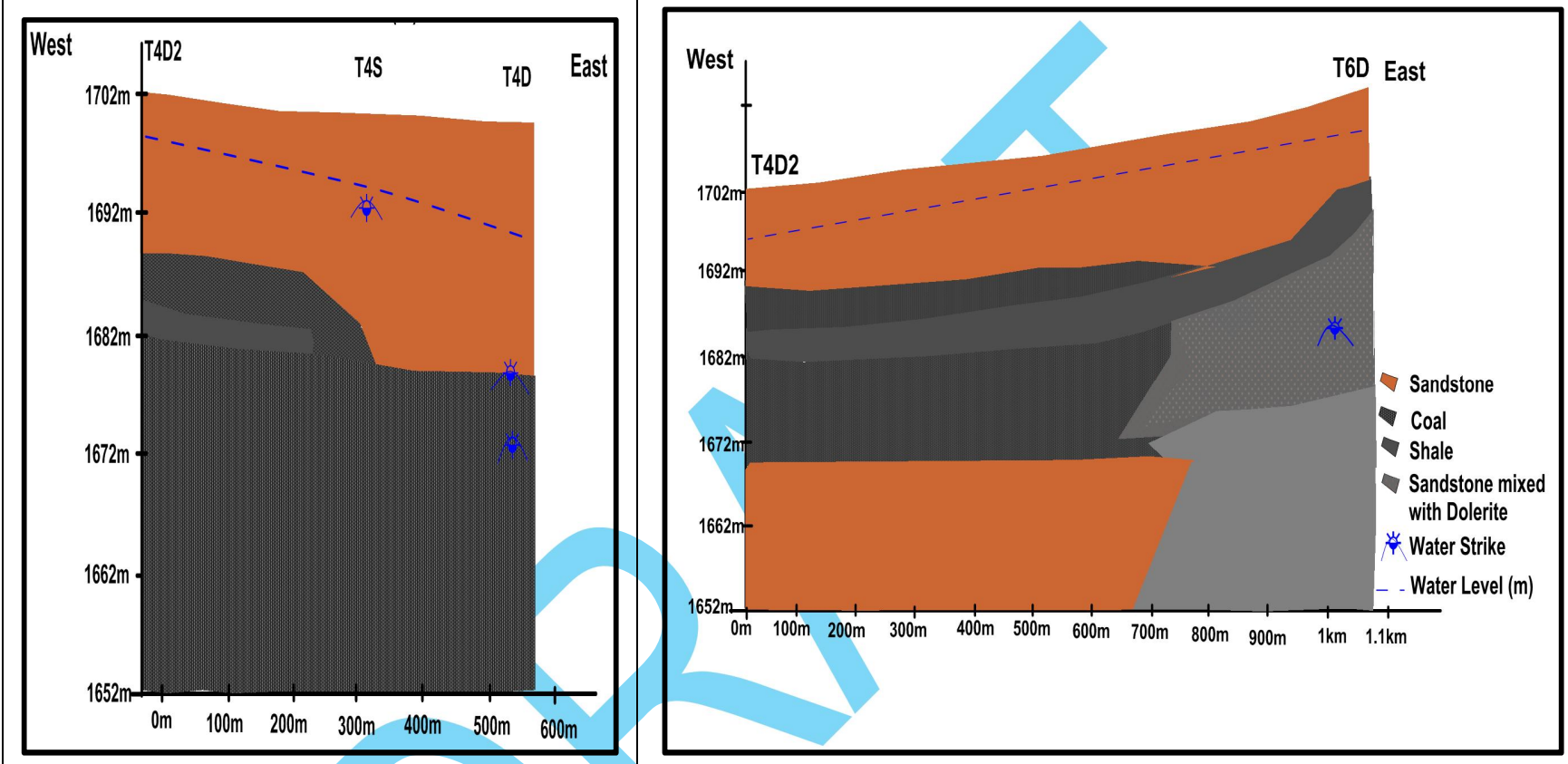


Figure 24: Fence diagrams from geohydrological drilling (T6D, T4D2, and T4D)

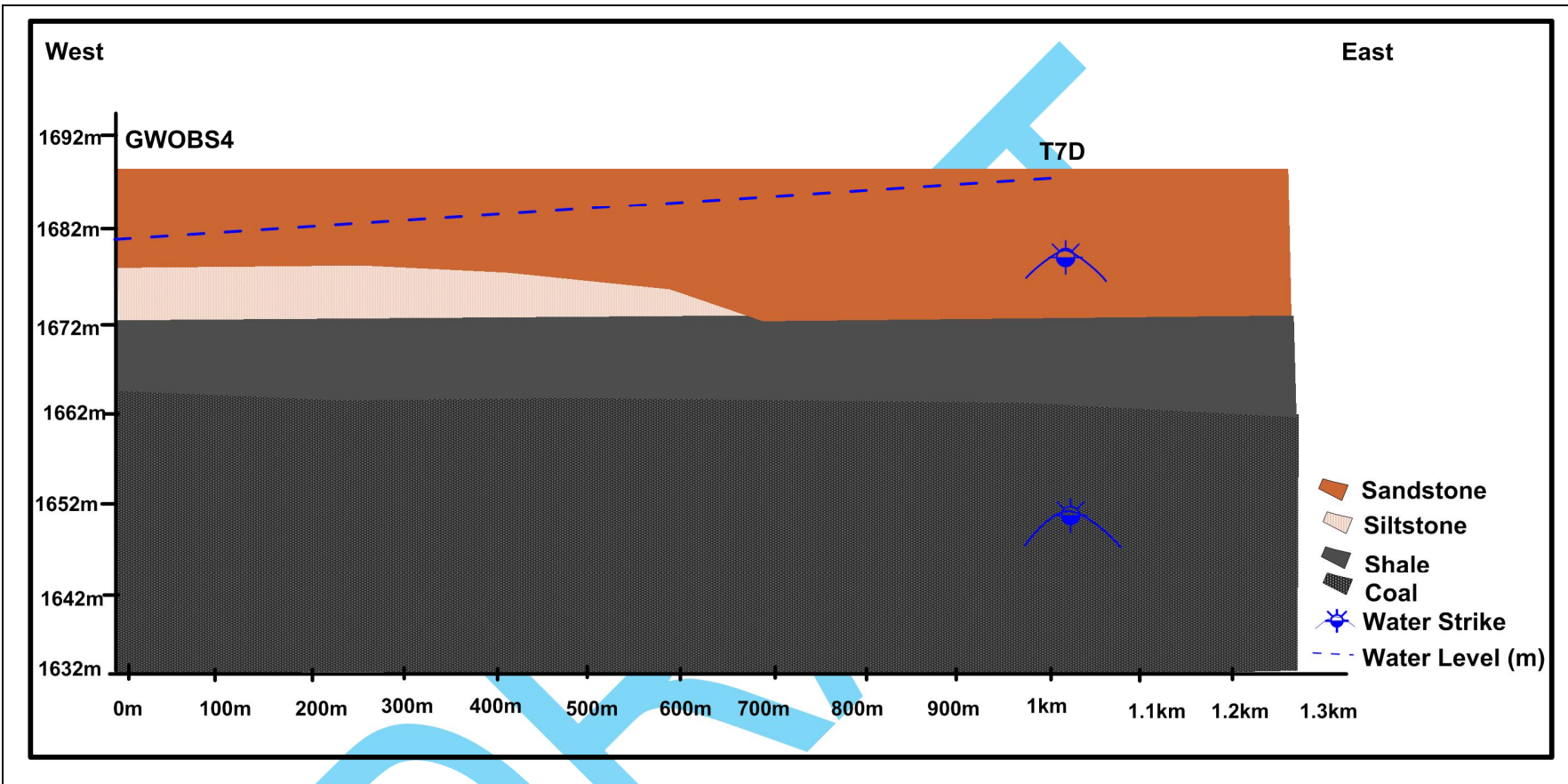
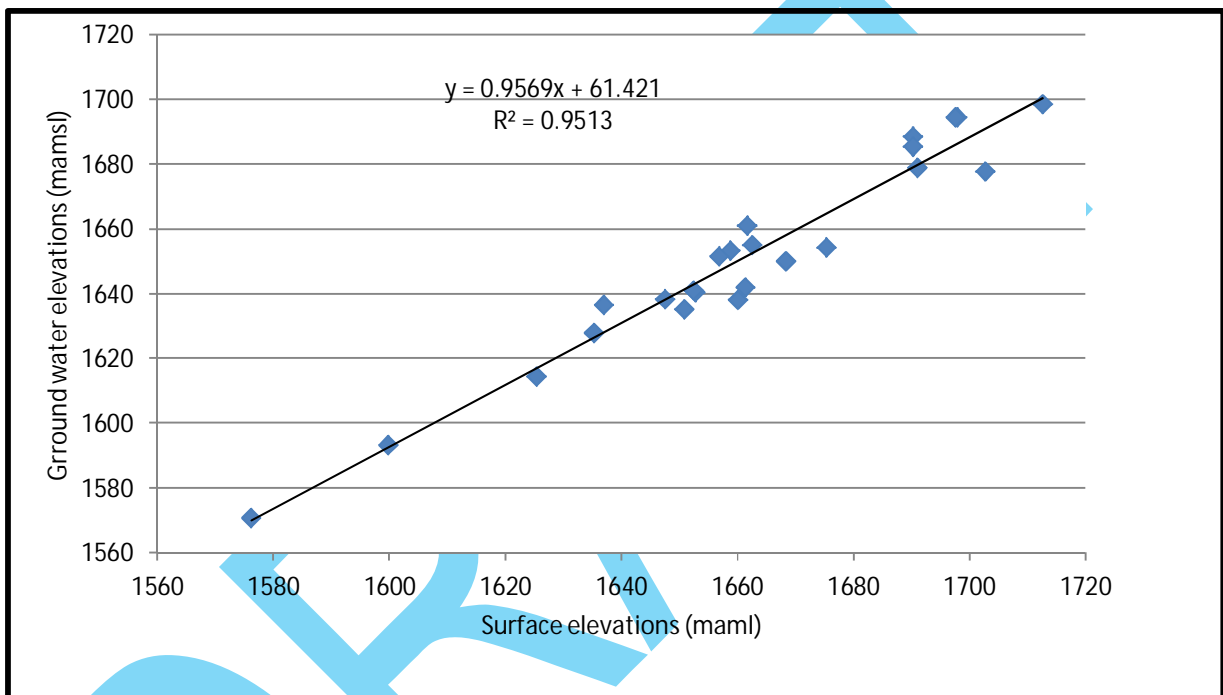


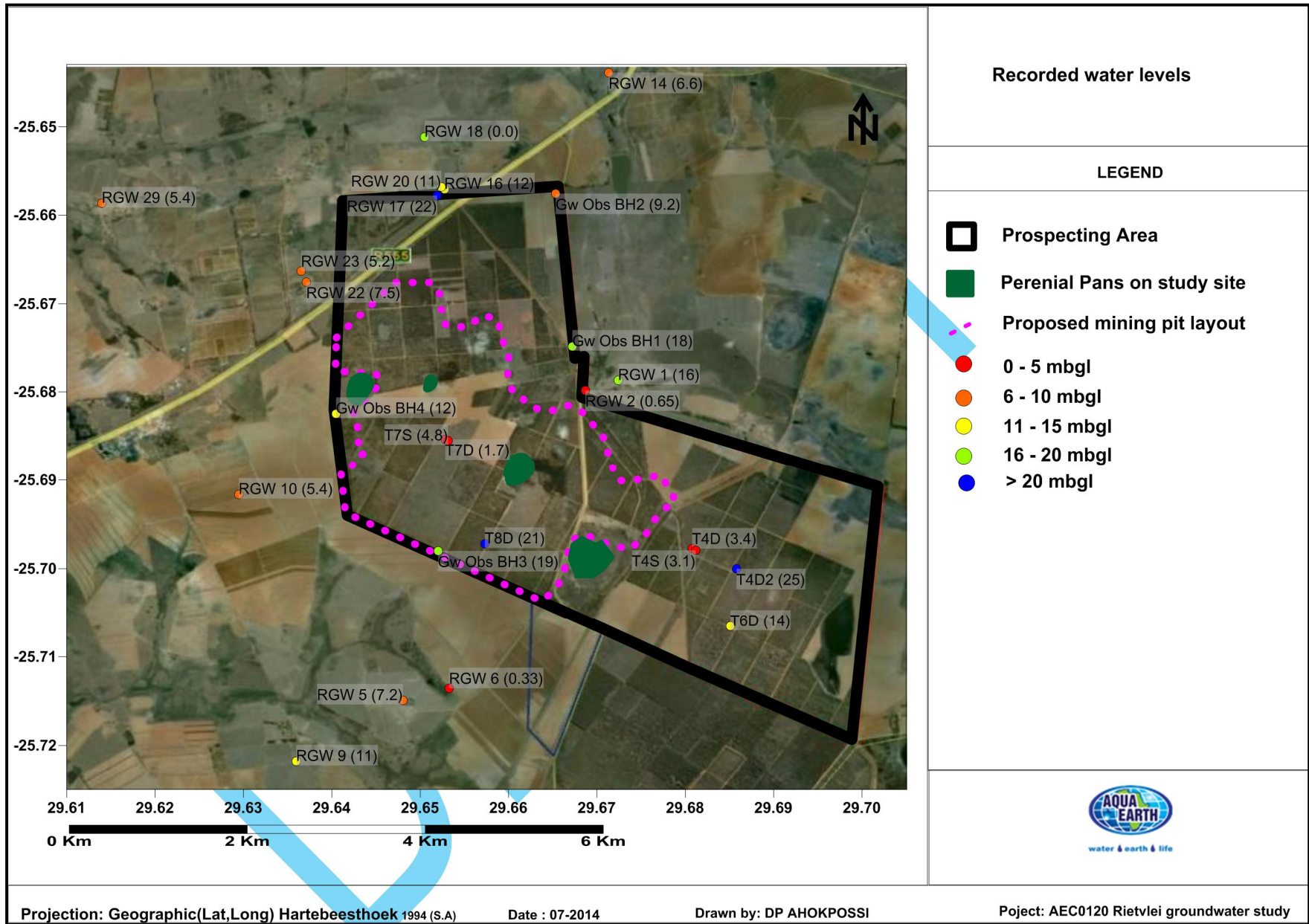
Figure 25: Fence diagram from geohydrological drilling (T6D, T4D2, and T4D)



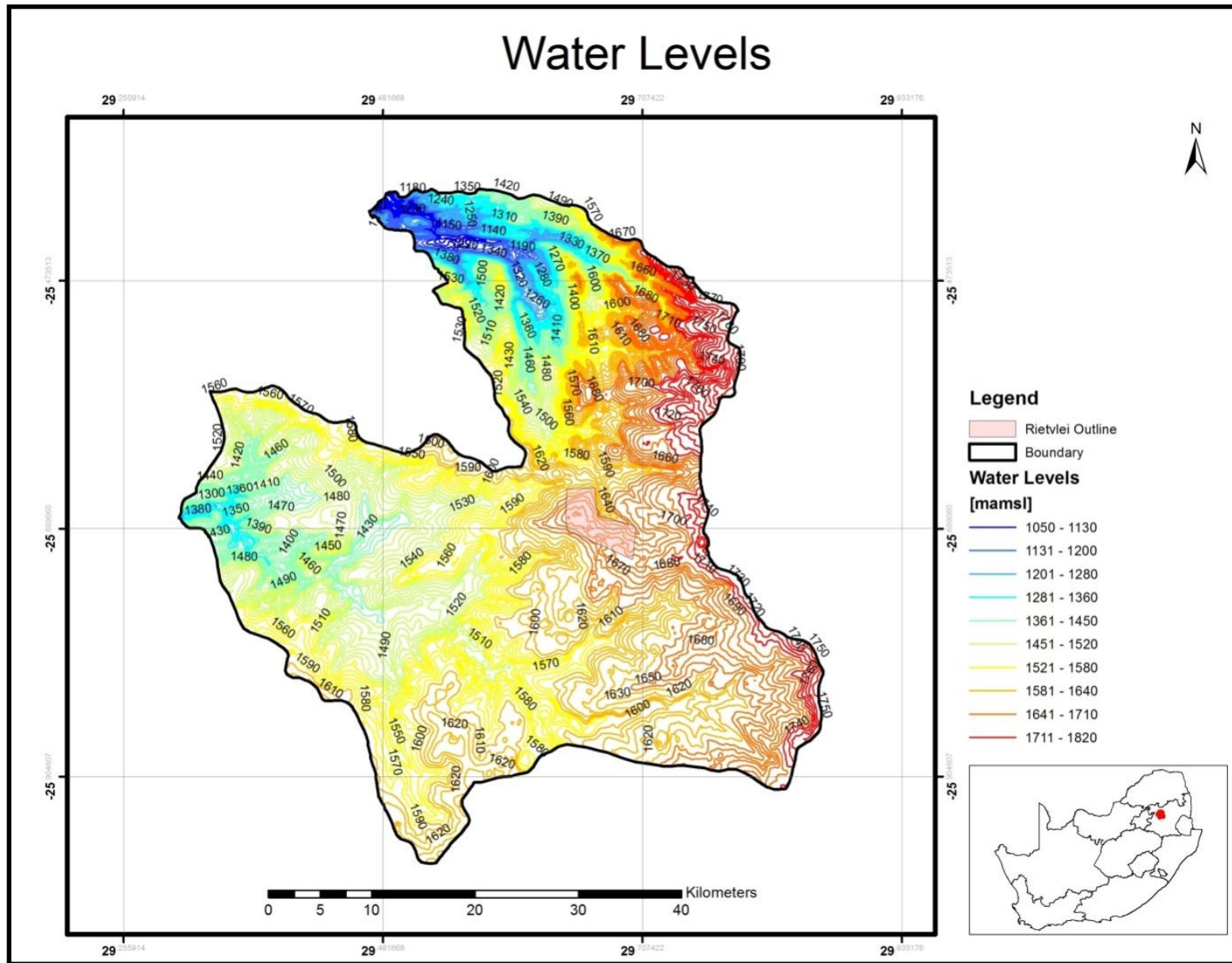
Using the available data (water elevations), an interpolation technique was used to simulate water elevations over the entire model area. The interpolation technique used is referred to as Bayesian interpolation where water elevations are correlated with the surface topography. All available levels were plotted against topography as shown in Figure 26. The results indicate a correlation of 95 % between the data sets. Therefore, Bayesian interpolation was valid and used to calculate water levels for the entire sets model area. The distribution of water levels is shown in Figure 27 and groundwater drainage Figure 28. As groundwater levels follow topography it can be assumed that groundwater flow takes place under unconfined to semi-confined conditions.



**Figure 26: Correlation between groundwater elevations and topography**



**Figure 27: Recorded water levels distribution**



**Figure 28: Groundwater elevations and drainage**

### 4.3 Soil analysis results

Acid drainage potential analysis results have been submitted to WSP for geochemistry investigations, and can be found in Appendix D as submitted by the Water Lab. Preliminary geochemical assessment of the proposed Rietvlei mine was conducted by WSP based on leachate test results. The assessment suggests that the rock dumps won't have short term acid generation potential. Further discussion on the results is given in section 7.

### 4.4 Groundwater water quality test results

When compared to South African National Standards for domestic use (SANS 241: 2005), the chemical results received from the laboratory, show a general baseline groundwater quality that falls within the recommended operational limits (Class 1) for all the constituents analyzed (Table 11). However F and Fe content are found to be above the maximum allowable limit in respectively T8D and T4S, and Fe in T6D fall in Class II (maximum allowable limit). Considering the location of T8D and T4S such quality may associated to contact with wetland water. The complete result as received from UIS is given in Appendix E. Expanded Durov diagram suggests unpolluted groundwater quality for all the samples collected at proposed Rietvlei Mine. Piper diagram shows calcium/magnesium bicarbonate water as result of freshly recharge to ground's water table. Such water quality results are in agreement with the surrounding general groundwater quality as established by the baseline groundwater investigation conducted by AEC (2011), except for RGW4, RGW1 which returned polluted quality due to high concentration of NO<sub>3</sub>-N

**Table 11: Water chemistry results**

	Sample Number	pH	EC	TDS	Ca	Mg	Na	K	Cl	SO4	NO3-N	F	Fe	Mn
			mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Groundwater	T4S	6.14	5.9	38.4	13.8	3.54	8.13	5.13	1.83	6.6	<0.3	<0.1	2.1	0.07
	T6D	6.11	4.6	29.9	10	2.26	2.88	3.85	0.796	2.29	<0.3	<0.1	0.99	<0.05
	T8D	7.98	20.1	131	33.5	3.66	32.9	2.57	2.43	3.44	<0.3	3.5	0.07	<0.05
	T7S	6.46	3.7	24.1	9.11	0.66	3.57	2.58	2.26	4.22	<0.3	<0.1	<0.05	0.05
	T7D	6.29	2.5	16.3	5.47	0.57	2.84	1.53	1.88	2.27	<0.3	<0.1	<0.05	<0.05
	T4D2	7.59	22.9	149	72.7	11.6	9.81	9.29	2.71	6.62	<0.3	0.5	<0.05	<0.05
<b>SANS 241; 2005</b>														
CLASS I: Recommended Operational Limit	5-9.5	<150	<1000	<150	<70	<200	<50	<200	<400	<10	<1	<0.2	<0.1	
CLASS II: Max Allowable	4.0- 10	150- 370	1000 - 2400	150- 300	70- 100	200- 400	50- 100	200- 600	400- 600	10.0-20	1-1.5	0.2-2	0.1-1	
Above Class II Limits	>10	>370	2400>	>2400	>100	>400	>100	>600	>600	>20	>1.5	>2	>1	

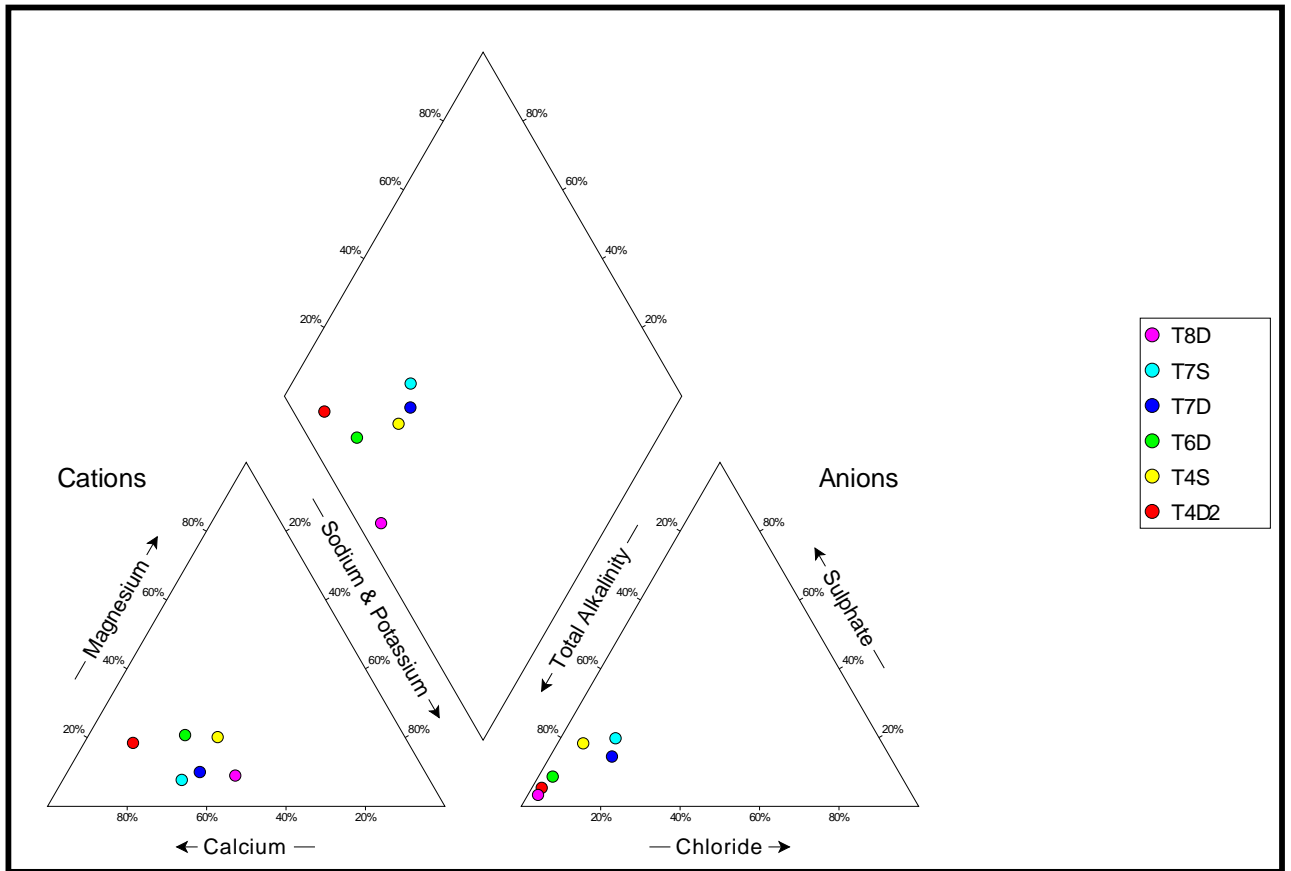
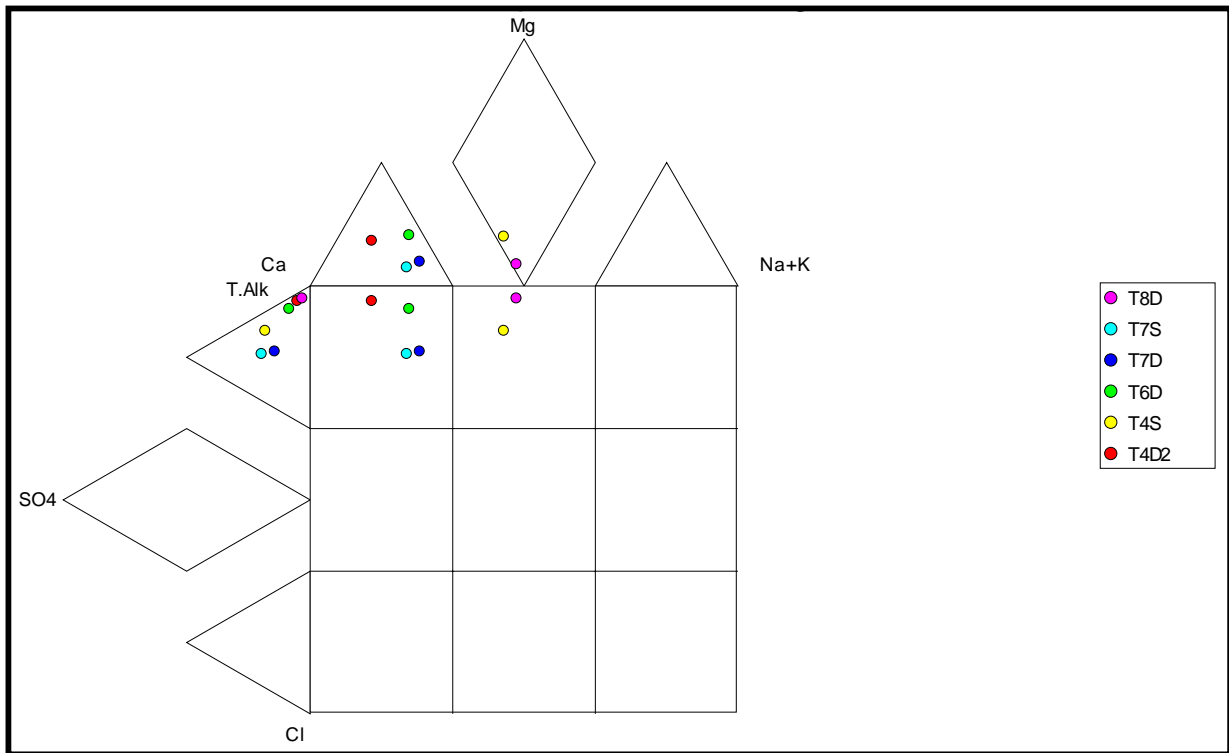


Figure 29: Piper diagram of boreholes within proposed RIETVLEI MINE

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**Figure 30: Expanded Durov diagram of boreholes around the proposed RIETVLEI MINE**

#### 4.5 Aquifer tests results and interpretation

The aquifer tests conducted in the present detailed groundwater investigation; aim to collect/confirm in-situ properties (flow and storage) to update the existing numerical model to be representative of both shallow and deeper water-bearing formations (shallow and deeper aquifer). The variability of the aquifer properties is also of importance and would be considered for a more representative aquifers numerical model.

##### 4.5.1 Slug tests

Slug tests were conducted from 19<sup>th</sup> to 20<sup>th</sup> February 2014 on the new boreholes that were - drilled and the existing Aqua Earth boreholes on the property. In total a sum of 10 slug tests were conducted. The results are illustrated on graphs in Appendix F. Table 12 presents a summary of the slug test results.

**Table 12: Slug test results**

BH Number	Slug	S.W.L	W.L after slug inserted	Water Rise	Water Drop/ Recovery	Recovery Length
	Mm	mbgl	mbgl	m	m	min
T4S	1500	3.76	3.254	0.506	0.28	128
T6D	1000	14.01	13.81	0.2	0.38	128
T8D	1000	21.69	21.181	0.509	0.45	122
T7D	1500	2.06	1.892	0.168	0.088	88
T7S	1000	4.06	3.41	0.65	0.37	37
Gw Obs BH3	1000	19.41	17.7	1.71	0.01	120
Gw Obs BH4	1500	12.09	11.38	0.71	0.72	98
Gw Obs BH2	1500	9.23	7.9	1.33	0.64	60
Gw Obs BH1	1000	18.31	17.849	0.461	0.47	58

The responses of the water levels in tested boreholes were used to predict borehole yields by correlating the recession time and the yield of borehole (Vivier et al., 1995). The estimated yields are summarised in Table 13.

**Table 13 : Borehole yields estimated from slug test**

BH Number	Recovery time	Percentage of recovery	Estimated Yield
T4S	128	55	<0.02
T6D	128	100	0.02
T8D	122	88	0.02
T7D	88	52	<0.02
T7S	37	57	<0.02
Gw Obs BH3	120	0.01	<0.02
Gw Obs BH4	98	100	0.03
Gw Obs BH2	60	48	<0.02
Gw Obs BH1	58	100	0.04



#### 4.5.2 Calibration tests

Calibration tests were conducted from 26<sup>th</sup> to 27<sup>th</sup> March 2014, to confirm the yielding capacity of the boreholes and determine the pumping rates and length of step test. Summary on the calibration test results is given in Table 14 and the resulting graphs in Appendix G.

Based on the test results, the step tests have been designed as presented in Table 15.

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**Table 14: Summary on calibration test results**

Borehole	Step 1			Step 2			Step 3			Recovery	
	Pumping rate	Step Length	Drawdown	Pumping rate	Step Length	Drawdown	Pumping rate	Step Length	Drawdown	Time Length	Percentage of recovery
	l/s	Min	m	l/s	min	m	l/s	min	m	min	%
T4S	0.06	20	7	0.42	18	3	--	--	---	90	80
T4D2	0.14	15	5	0.48	15	13.5	1.2	3	15.6	60	2.12
T6D	0.51	15	7.5	0.95	15	18.8			--	40	93.53
T8D	0.16	15	5	0.26	15	1.7	0.48	6	5	90	81.55
T7D	0.12	15	13	0.37	23	18	--	--	--	113	87.1
T7S	0.11	7	12	--	--	--	--	--	--	61	83.33
Gw Obs BH3	0.69	12	17	--	--	--	--	--	--	43	35.29
Gw Obs BH4	0.48	18	16	--	--	--	--	--	--	41	81.25
Gw Obs BH2	0.43	13	17	--	--	--	--	--	--	30	58.82
Gw Obs BH1	0.37	49	7.2	0.92	6	2	--	--	--	33	88.89

**Table 15 : Design of step tests**

BH Name	Pump Depth	Pumping Rate			Pumping Length
	(mbgl)	(l/s)			(min)
GW OBS BH 1	28	0.04	0.15	0.45	60*3
GW OBS BH4	25	0.04	0.10	0.17	60*3
T4D2	40	0.03	0.08	0.11	60*3
T6D	40	0.09	0.18	0.27	60*3

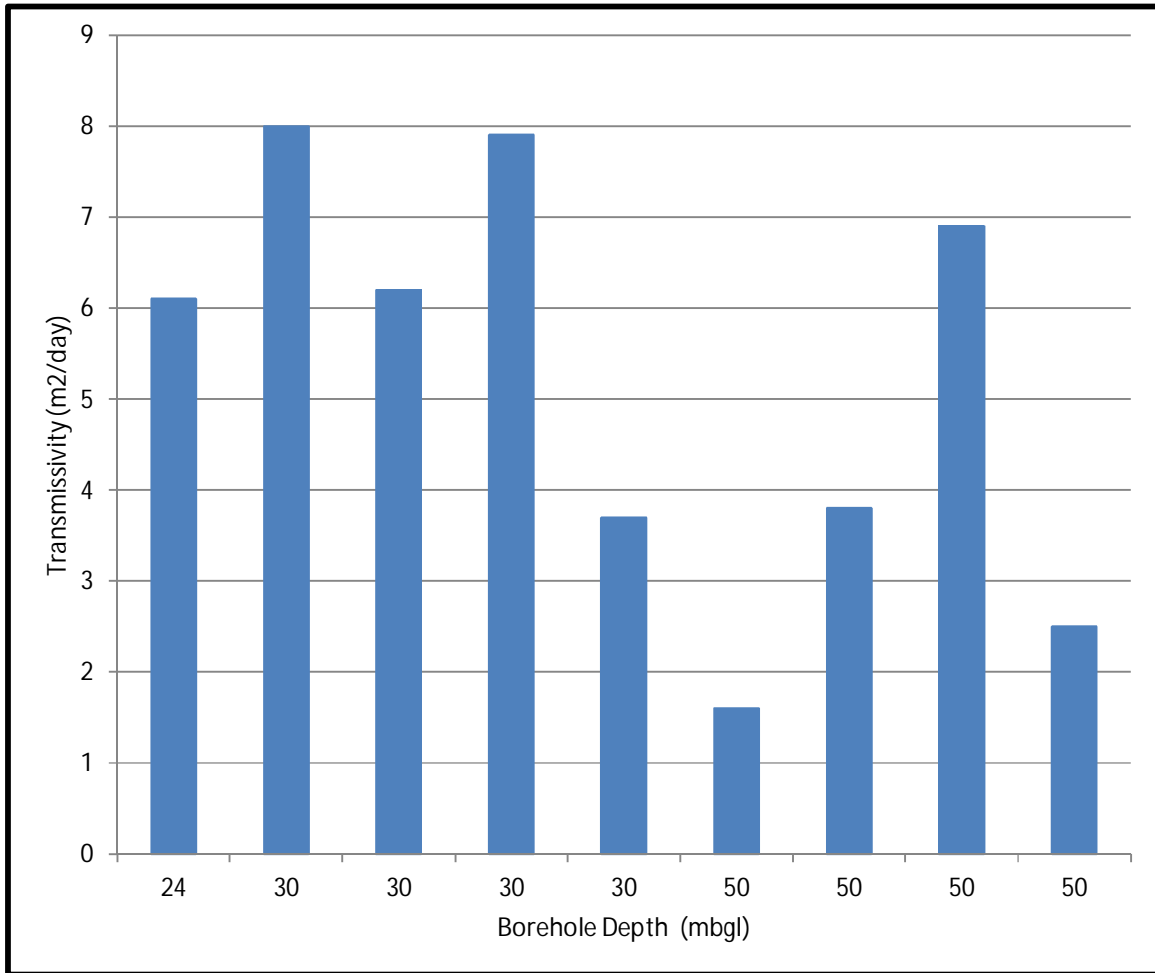
### 4.5.3 Recovery tests

Recovery data from the calibration has been used to get a first estimate of transmissivity values over the tested site. The results are summarised in Table 16, where as the distribution of estimated transmissivity with total borehole depth is given in Figure 31.

**Table 16: Estimated T values from recovery data**

Borehole number	Length of Recovery Phase	Residual Drawdown	Estimated T
	(min)	(m)	(m <sup>2</sup> /d)
GW OBS BH1	32.5	0.97	8
GW OBS BH2	35	7.89	6.2
GW OBS BH3	44	11.45	7.9
GW OBS BH4	42	2.99	3.7
T4S	88.5	1.88	6.1
T6D	40.5	1.7	1.6
T7D	115.5	4.52	3.8
T7S	62	2.33	6.9
T8D	600	3.41	2.5

T is estimated between 1.6 to 8 m<sup>2</sup>/d with an average of 5m<sup>2</sup>/d. Estimated transmissivity values are found to do not really depend on the depth, but rather on fractures, and weathered contact zones intersections. .



**Figure 31: Distribution of estimated transmissivity with total borehole depth**

#### 4.5.4 Step tests

Step tests were conducted from 3rd to 4th April 2014, to determine the appropriate pumping rate for the CDT. Except for the T4D, where the step length was not respected due field difficulties, the step tests have been conducted according the design. The summary on the calibration test results is given in Table 14 and the resulting graphs in Appendix H. Based on the step test results (Table 17); the CDT has been designed as presented in

Table 18.

**Table 17: Summary on step test results**

Borehole	Step 1			Step 2			Step 3			Recovery	
	Pumping rate	Step Length	Drawdown	Pumping rate	Step Length	Drawdown	Pumping rate	Step Length	Drawdown	Time Length	Percentage of recovery
	l/s	Min	m	l/s	min	m	l/s	min	m	min	%
T4D2	0.03	60	0.32	0.08	60	1	0.11	60	8.40	30	95
T6D	0.09	60	1.34	0.18	60	2	0.27	60	1.40	40	93.53
Gw Obs BH4	0.04	60	2.52	0.1	60	1.60	0.17	60	8.80	180	92
Gw Obs BH1	0.04	50	0.32	0.15	15	1	0.45	10	8.4	30	95

**Table 18: Design of Constant discharge tests**

BH Name	Obsevation BH	Pump Depth	Pumping Rate	Pumping Length
		mbgl	l/s	min
GW OBS BH 1	T7D,T7S	28	0.25	720
GW OBS BH4	T7D,T7S	25	0.11	
T6D	T4D2,T4S,T8D	40	0.28	

#### 4.5.5 Constant discharge tests

12 hours constant discharge tests were conducted on 03 selected boreholes from 03<sup>th</sup> to 05<sup>th</sup> May 2014. During the test, drawdown was recorded in pumping and observations boreholes. The tests were conducted successfully according to the design, followed by recovery recording for T6D and GWOBSBHBH4. 03 observations boreholes show responses to pumping. Responses were noticed in observation borehole T4S when T6D was pumped, and in both T7D and T7S when GWOBSBHBH4 was pumped. Observation boreholes did not return any response to the pumping of GWOBSBHBH1. Where no response could be recorded, an increase in water level was observed, instead of decrease. That may be a coincidence with a recovery phase following pumping by nearby farmers.

Table 19 gives the summary on the CDT results, and the time-drawdown plots of the pumped boreholes are presented from Figure 32 to Figure 34.

**Table 19: Constant discharge test results**

BH Name	Pumping Rate	Drawdown in pumping borehole	Drawdown in OBS BH					Residual Drawdown	Recovery Time
			T7D	T7S	T4D	T4S	T8D		
	l/s	m	m					m	min
GW OBS BH 1	0.25	2.15	--	--	--	--	--	0.4	600
GW OBS BH4	0.11	5.26	0.22	0.23	--	--	--	-	--
T6D	0.28	8.49	--	--	0.14	0.13	--	0.91	180

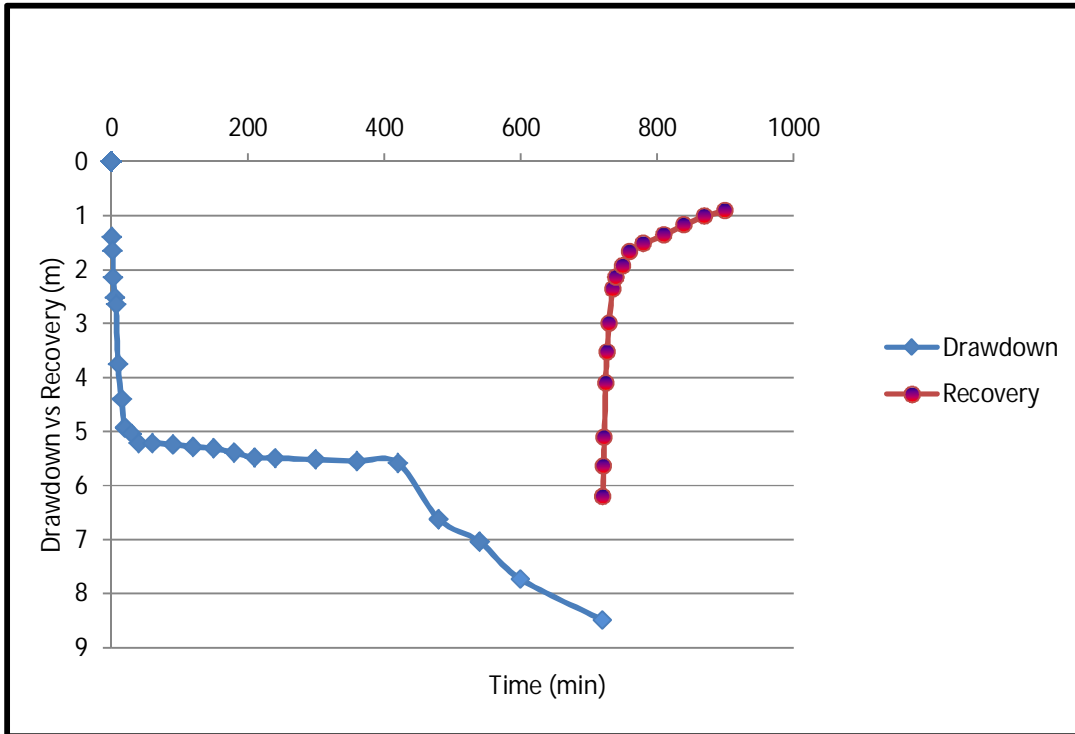


Figure 32: Drawdown to CDT in TD6

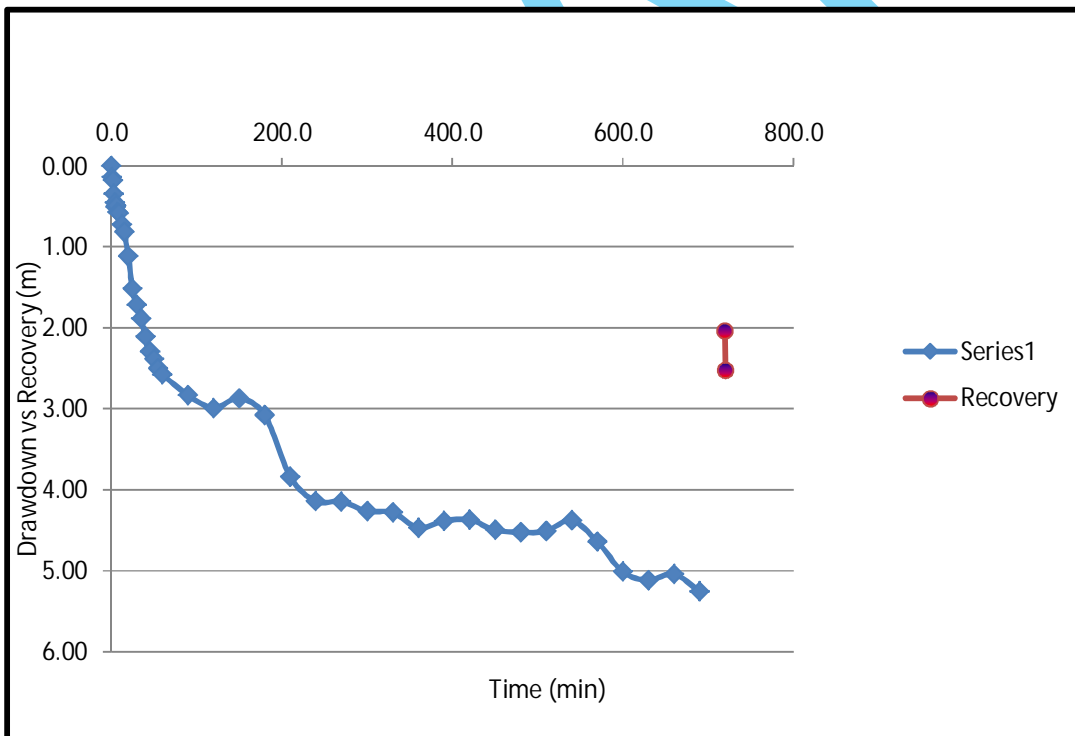
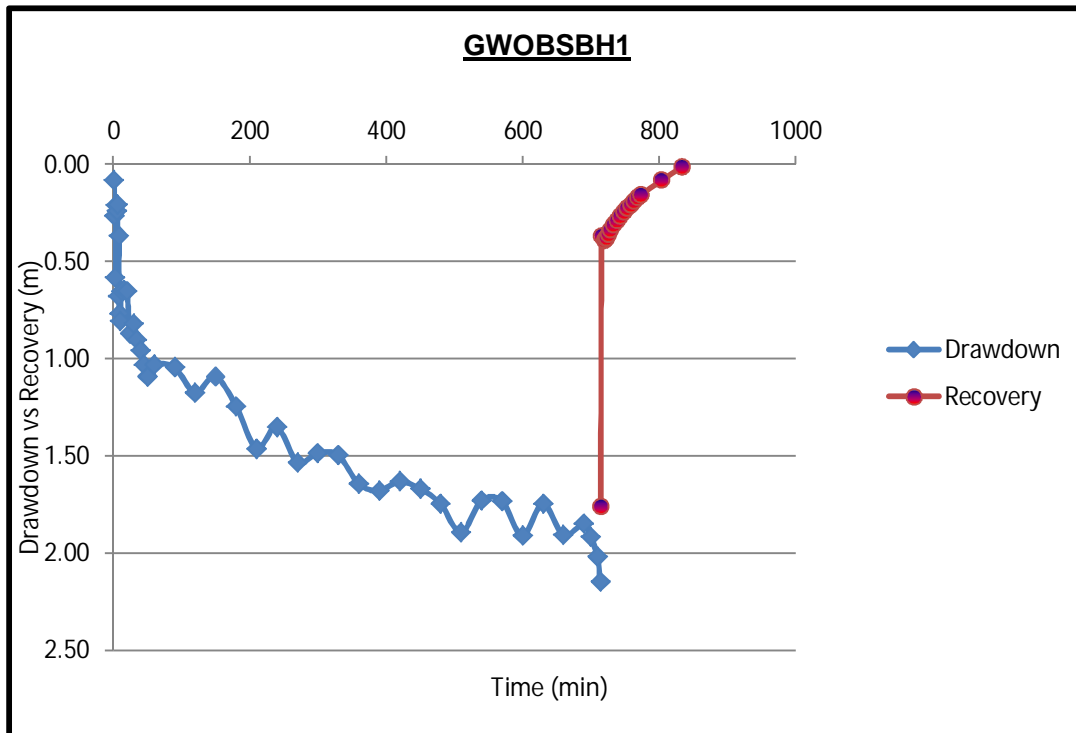


Figure 33: Drawdown to CDT in GWOSBHBH4



**Figure 34: Drawdown to CDT in TD6**

The CDT confirms the low yielding potential of the aquifer associated with the prospecting site. The maximum drawdown recorded (8.49m) is associated with a CD rate of 0.28 l/s over 12 hours. Estimated sustainable yield are less than 0.5l/s and are summarised in Table 20

**Table 20 Calculated sustainable yields**

BH Name	Cooper-Jacob yield	Basic FC yield
	l/s	l/s
GW OBS BH 1	0.06	0.06
GW OBS BH4	0.02	0.02
T6D	0.07	0.03

The diagnostic plots (log-log) of the pumping test data suggests linear (fractures) flow at the beginning of the pumping followed by bi-linear flow (GWOBSBHBH4, GWOBSBHBH1). This suggest that in the aquifer water is first directly discharged from the fractures, and then from the matrix (sandstone) through the fracture. This is a common behaviour of fractured aquifer in South Africa mainly in the Karoo sediments. The diagnostic plots also show a kind of limited closed reservoir from T6D. That may be related to the control that the intersected dolerite has on the aquifer part surrounding T6D.

Estimated transmissivity values, range from 0.6 to 6.1 m<sup>2</sup>/d, and are summarised in Table 21.



**Table 21 Calculated aquifer parameters**

BH Name	Cooper-Jacob Method		Theis Method		Recovery vs. Rise W/L
	T	S	T	S	m <sup>2</sup> /d
	m <sup>2</sup> /d		m <sup>2</sup> /d		
GW OBS BH 1	4	1.58	4	2.00E-04	6.1
GW OBS BH4	0.6	4.50E-01	1	3.00E-05	-
T6D	1.5	1.99E-2	1	3.00E-01	1.3

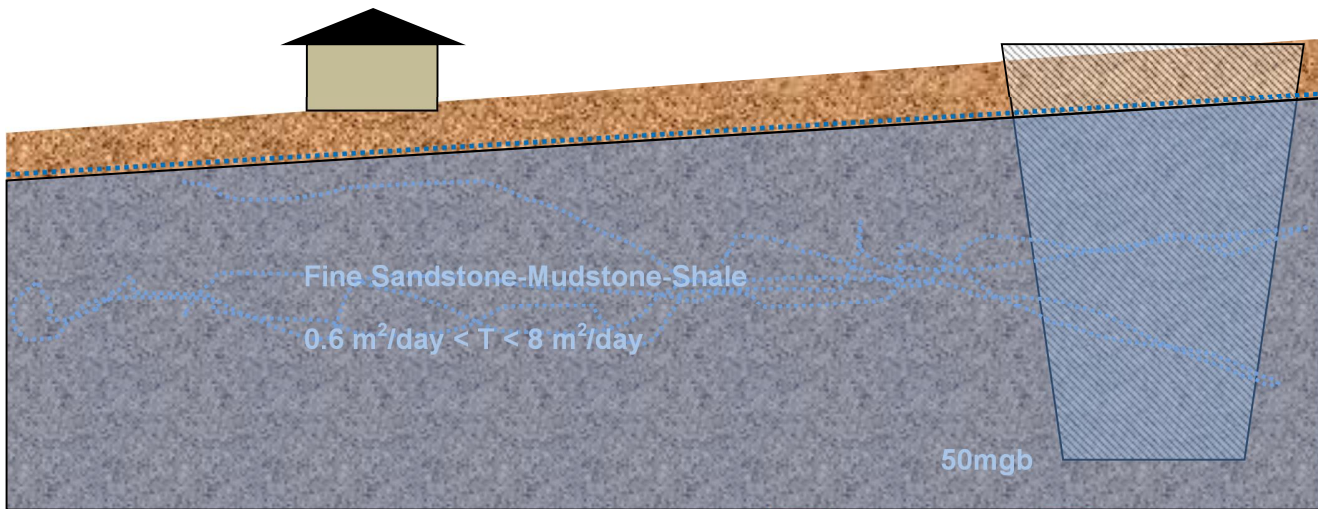
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## 5 Conceptualisation of the geohydrological system

This section used the current level of site characterization to simplify (conceptualize) the description of the aquifer systems. The conceptualization was done for the purpose of predicting the potential impacts of the opencast mining activities on the aquifer systems. It aims to design and construct equivalent but simplified conditions for the real world problem, which are acceptable in view of the objectives of the modelling and associated groundwater management problems. Transferring the real world situation into an equivalent model system, which can then be solved using existing program codes, is a crucial step in groundwater modelling. The following is included:

- The known geological and geohydrological features and characteristics of the area.
- The static water levels heads in the study area.
- The interaction of the geology and geohydrology on the boundary of the study area.
- A description of the processes and interactions taking place within the study area that will influence the movement of groundwater, and
- Any simplifying assumptions necessary for the development of a numerical model and the selection of a suitable numerical code.

Although it has been found ( based on distribution of water strikes) that the main preferential path for the groundwater may be located at depth between 15 and 31 mbgl (Figure 22), the distribution of estimated hydraulic parameters (mainly T), did not show any dependence of depth within the top 50 mbgl as investigated on site. This allows us to conceptualise the aquifer on site as a unique aquifer system. For simplification purpose the shale layer identified in the south western side of the site will not be modelled.



**Figure 35: Simplify conceptual model**

### 5.1 Lateral extent and thickness of the aquifers

Since the evidence of physical subsurface no-flow boundaries have been clearly identified at the present level of sites characterisation and a good correlation exists between the groundwater level elevations and the surface topography, it is assumed that the groundwater extends over the geometry of the surface water catchment system(s). Consequently, most of the groundwater recharges occurring within the study area are expected to discharges to the surface drainage systems via springs (wetland in depression) and discharge to the base of the main river drainage systems:

- Selons River in B32B;
- Olifants River in B12C, B12D, and B12E;
- and Keerom stream in B12E.

Aquifer systems are considered up to the 10 m below the bottom the last seam to mined (50mbgl), and are simplified as:

The thickness of the unsaturated zone is determined by the depth to the ground water level that varies between 0.33 and 21mbgl in the vicinity of the area, but range from 1.7 to 19.2mbgl within proposed Rietvlei Mine. In the saturated zone, the generated groundwater elevations contour is considered as the top of the aquifer system.

## 5.2 Permeability

Falling head tests carried out on auger holes in November 2011 (Aqua Earth Consulting, 2011) have shown that the overlying unsaturated zone is characterized by high hydraulic conductivities at an average of 12m/d.

## 5.3 Transmissivity

Estimated transmissivity values vary between 0.6 to 8 m<sup>2</sup>/d with an average of 4.5 m<sup>2</sup>/d. Initial model built by AEC used a transmissivity value of 4m<sup>2</sup>/d. However, transmissivities may be much higher in fracturing associated with contact zones between sediments, and dolerite.

## 5.4 Storativity and Porosity

Estimated storage coefficients fall within the range between  $2 \times 10^{-2}$  and  $3 \times 10^{-5}$  with an average of  $4 \times 10^{-3}$ . Initial one layer numerical model considered a Storativity of  $4 \times 10^{-3}$ , and a porosity value of 6%. It believes that pumping test data will help in inferring their values from numerical model calibration.

## 5.5 Recharge

Water qualities suggest that the aquifer consists of recently recharged groundwater. According to Vegter (1995) the recharge is 35mm/a, which is equal to approximately 5% of mean annual precipitation. Using the Chloride method, recharge was estimated at 4% (28mm/a). Considering the groundwater chemistry, and the position (water head) of proposed Rietvlei Mine, recharge to water table is expected to prevail in the system. The site vegetation (high evapotranspiration), the soil characteristics (low percolation rate), and depression occurring at the site (soil and groundwater seeping into wetlands) are probably the main factors that contribute at such reduce recharge rate.

## 5.6 Groundwater flow direction

The groundwater flow direction is as shown in Figure 28, and is considered to be the same for both considered aquifer systems, and groundwater is moving away from proposed Rietvlei Mine in the following direction:

- North-West, probably discharging into the furrows that feed into Olifants River;
- South West, probably discharging into Olifants River;
- And North East, discharging into Selons River which also flows North-West into Olifants River;

## 5.7 Ground water quality

Based on data from the new groundwater sampling analysis (onsite) and conducted hydrocensus, the groundwater quality is considered generally as unpolluted in proposed Rietvlei Mine and surrounding.

However F and Fe concentration found above the maximum allowable limits on site has to be mentioned and understand as associated with site conditions (geology, contact with wetlands), as no harmful previous activities have been reported.

## 5.8 Ground water use

Communities in the area surrounding the prospecting area are dependent on ground water sources for domestic use, livestock watering and small-scale irrigation. They abstract water from boreholes situated in the villages (Figure 36).

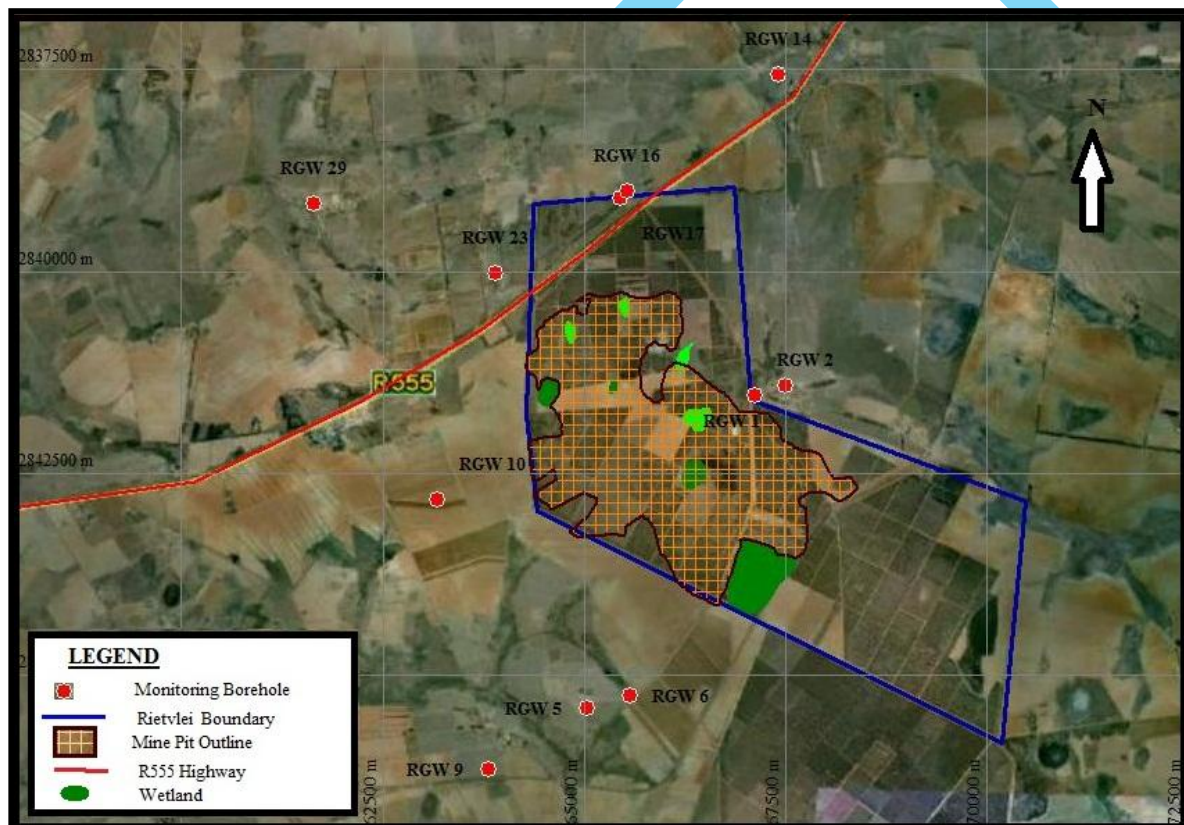


Figure 36: Groundwater abstraction points surrounding the prospecting site

## 5.9 Aquifer Classification

The classification scheme (Parsons, 1995) was created for strategic purposes as it allows the grouping of aquifer areas into types according to their associated supply potential, water quality and local importance as a resource. The aquifer underlying the prospecting site may be

classified in accordance with DWA's aquifer classification system (Parsons, 1995), and the modified version (minimum requirement (1998)) between minor aquifer system and non aquifer system (Table 22). The vulnerability classification (Parsons, 1995) is high considering the important number of users.

**Table 22: Aquifer Classification scheme**

Aquifer System	Defined by Parsons (1995)	Defined by DWAF Min Requirements (1998)
Sole Source Aquifer	An aquifer which is used to supply 50 % or more of domestic water for a given area, and for which there are no reasonably available alternative sources should the aquifer be impacted upon or depleted. Aquifer yields and natural water quality are immaterial.	An aquifer, which is used to supply 50% or more of urban domestic water for a given area for which there are no reasonably available alternative sources should this aquifer be impacted upon or depleted.
Major Aquifer	High permeable formations usually with a known or probable presence of significant fracturing. They may be highly productive and able to support large abstractions for public supply and other purposes. Water quality is generally very good (<150 mS/m).	High yielding aquifer (5-20 L/s) of acceptable water quality.
Minor Aquifer	These can be fractured or potentially fractured rocks, which do not have a high primary permeability or other formations of variable permeability. Aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large quantities of water, they are important both for local supplies and in supplying baseflow for rivers.	Moderately yielding aquifer (1-5 L/s) of acceptable quality or high yielding aquifer (5-20 L/s) of poor quality water.
Non-Aquifer	These are formations with negligible permeability that are generally regarded as not containing groundwater in exploitable quantities. Water quality may also be such that it renders the aquifer as unusable. However, groundwater flow through such rocks, although imperceptible, does take place, and need to be considered when assessing the risk associated with persistent pollutants.	Insignificantly yielding aquifer (< 1 L/s) of good quality water or moderately yielding aquifer (1-5 L/s) of poor quality or aquifer which will never be utilised for water supply and which will not contaminate other aquifers.
Special Aquifer	An aquifer designated as such by the Minister of Water Affairs, after due process.	An aquifer designated as such by the Minister of Water Affairs, after due process.

## 6 Numerical groundwater flow model (finite difference)

A modular three-dimensional finite difference groundwater flow model MODFLOW, developed by U.S. Geological Survey is used during the present modelling project. This modelling package, calculates the solution of the groundwater flow equation using the finite difference approach.

A steady state groundwater flow model is constructed to simulate undisturbed groundwater heads distribution, based on the generalised steady state conditions, groundwater flow Equation (1) is as follows:

$$\frac{\partial}{\partial x} \left( K_x \frac{\partial h}{\partial x} \right) + \frac{\partial}{\partial y} \left( K_y \frac{\partial h}{\partial y} \right) + \frac{\partial}{\partial z} \left( K_z \frac{\partial h}{\partial z} \right) \pm W = 0 \quad (1)$$

Where: h = hydraulic head [L]; K<sub>x</sub>,K<sub>y</sub>,K<sub>z</sub> = Hydraulic Conductivity [L/T]; t = time [T]; W = source (recharge) or sink (pumping) per unit area [L/T]; x,y,z = spatial co-ordinates [L]

These conditions serve as initial heads for the transient simulations of groundwater flow, in which changes with time are simulated, using the three-dimensional groundwater flow model equation:

$$\frac{\partial}{\partial x} \left( K_x \frac{\partial h}{\partial x} \right) + \frac{\partial}{\partial y} \left( K_y \frac{\partial h}{\partial y} \right) + \frac{\partial}{\partial z} \left( K_z \frac{\partial h}{\partial z} \right) \pm W = S \frac{\partial h}{\partial t} \quad (2)$$

Where: S = storage coefficient.

### 6.1 Models domain and boundaries conditions

One of the first and most demanding tasks in groundwater modelling is the identification of the appropriate model boundaries. Consequently, a model boundary is the interface between the model area and the surrounding environment. Conditions on the boundaries, however, have to be specified. Boundaries occur at the edges of the model area and at locations in the model area where external influences are represented, such as rivers, wells, and leaky impoundments. Criteria for selecting hydraulic boundary conditions are primarily topography, hydrology and geology. The topography, hydrology, and groundwater drainage have been used mainly in the definition of the lateral boundary, where as the geology and the hydrogeology have been used mainly for the

aquifer layer thickness. The boundaries conditions, considered for initial numerical model, have been kept:

- the Klein Olifants River to the west and south of the study area was set as a Dirichlet boundary condition.
- the boundary of quaternary catchment B32B was set as the eastern boundary (no-flow)
- and quaternary catchment B12E was set as the northern boundary (no-flow).

## 6.2 Initial conditions

Initial conditions are vital for modelling flow problems. Initial conditions have been specified for the entire area. The water elevations distributions shown in Figure 28 were used as initial conditions for the models' steady state calibration.

After steady state calibration, the resultant groundwater elevations (drainage) distributions was used as the new set of initial heads for transient state calibration, and scenarios simulation.

## 6.3 Sources and sinks

Only recharge due to precipitation was included in the model as explained in 5.5. The list of 10 boreholes that were used in the model as observation boreholes are provided in Table 23.

**Table 23 : List of the observations boreholes used in the steady state calibration**

Borehole	Main Aquifer intersected
T4S	1
T4D2	1
T6D	1
T8D	2
T7D	1
T7S	1
Gw Obs BH3	1
Gw Obs BH4	1
Gw Obs BH2	1
Gw Obs BH1	1



12 hours CDT data (03 abstraction and 03 observation holes) have been used for transient state calibration (Refer to CDT in 4.5.5.)

#### **6.4 General assumptions and model limitations**

A numerical model solves both complex and simple problems, and serves as basis for the simulation of various scenarios. However, it should be reiterated that, a numerical groundwater model is a simplified representation (approximation) of the real system, and the level of accuracy is sensitive to the quality of the data that is available. The available data constituted of information as described from section 3 to section 5.

Errors due to uncertainty in the data and the capability of numerical methods to describe natural physical processes are always associated with groundwater numerical models. The building of a numerical model requires some assumptions to make an easier representation of the real aquifer systems. Such assumptions involve mainly:

- Geological and hydrogeological features;
- Boundary conditions of the study area (based on the geology and hydrogeology);
- Initial water levels of the study area;
- The processes governing groundwater flow; and
- The selection of the most appropriate numerical code.

Based on the available field data, the following assumptions have been made behind the conceptual model develop in section 5:

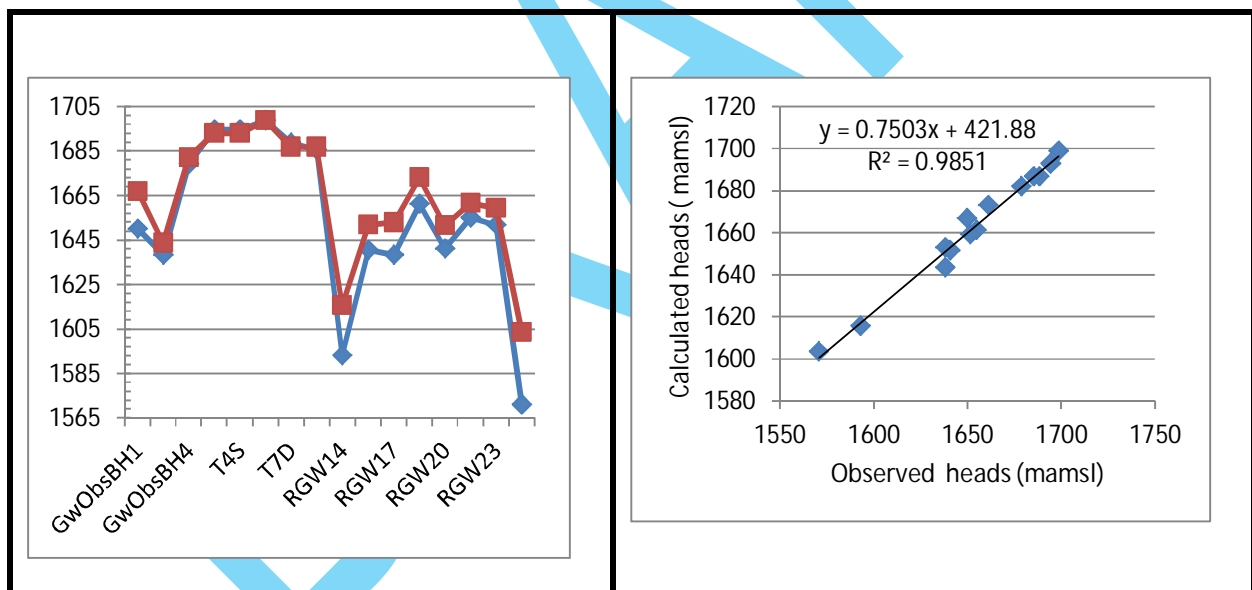
- The top of the aquifer is represented by the generated groundwater heads;
- Averages of the distribution of the determined parameters have been used as input of the model, and a homogenous and continuous aquifer system has been assumed;
- Where specific aquifer parameters have not been determined for some reason, text book values have been used where applicable, with reasonable estimates of similar geohydrological environments;
- The system is initially in equilibrium and therefore in steady state, even though natural conditions have been disturbed.
- The boundary conditions assigned to the model are considered correct.
- The impacts of other activities (agriculture, etc...) have not been taken into account.

The complexities associated with flow and transport in aquifer systems have not been taken into account. Any interpretation and decision from the model results should be based on these assumptions.

## 6.5 Flow model calibration

### 6.5.1 Steady state flow models calibration and numerical model sensitivity

In the present case, the “Preconditioned Conjugated-Gradient 2” (PCG2) solving package has been used. Boundary conditions, and hydrological parameters (recharge and conductivity/transmissivity), were selected by a combination of trial and error and inverse modelling, to generate the result that most strongly matches field measurements of hydraulics heads. Observations boreholes (Table 23) have been chosen to verify the conditions in the boundary of proposed Rietvlei Mine and surrounding. Considering varying transmissivity, the set of hydraulics parameters required for acceptable correlations between observed and calculated heads, are presented Table 24.



**Figure 37: Steady state calibration results**

**Table 24: Steady state model Calibrations results (input parameters)**

Transmissivity	Recharge
m <sup>2</sup> /day	mm/year
5	15

## 6.5.2 Transient state flow model calibration

The transient state flow calibration is highly recommended in groundwater numerical modelling for the following reasons:

- Groundwater flow is dependent on natural processes (geology, climate, ect...) and man-made changes, which may cause changes with time;
- Predictions are time related;
- The storage properties can only be assessed in transient state.

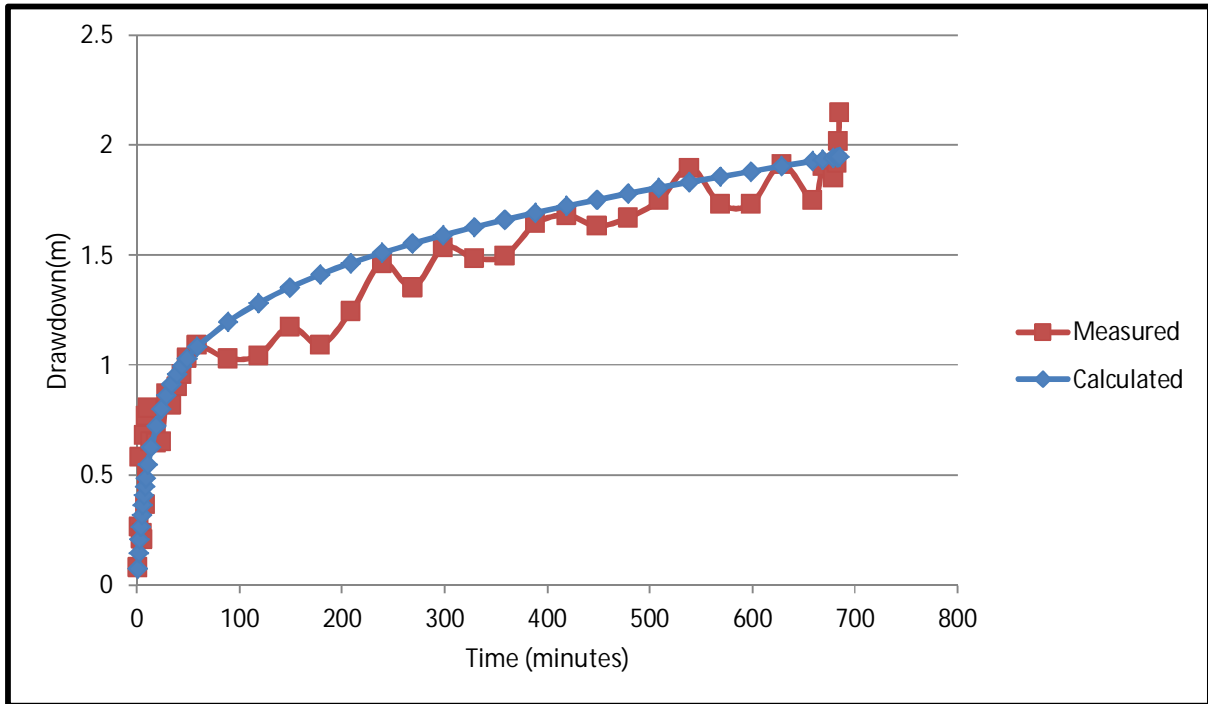
Ideally, transient state flow calibration should involve:

- Monthly hydraulic heads;
- Average monthly groundwater withdrawal;
- Average monthly evapotranspiration in case of shallow water levels (like in riparian zone)
- Monthly precipitation;
- Average monthly river stage;

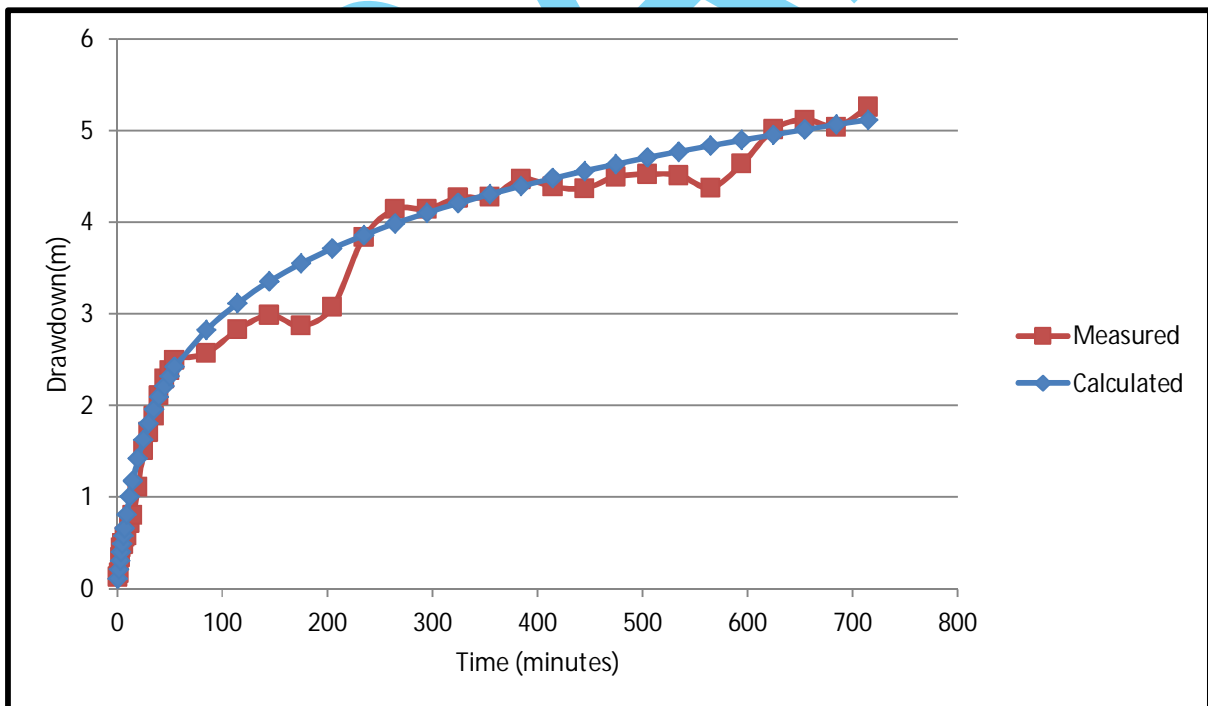
None of such data were available, and the CDT data were used for transient state model calibration. Specific storage and specific yield have been changed (Table 25) until the measured drawdown in the both abstraction and observation holes, matched with the calculated one (Figure 38, Figure 39, and Figure 40).

**Table 25: Transient state model calibrations results (Storativity)**

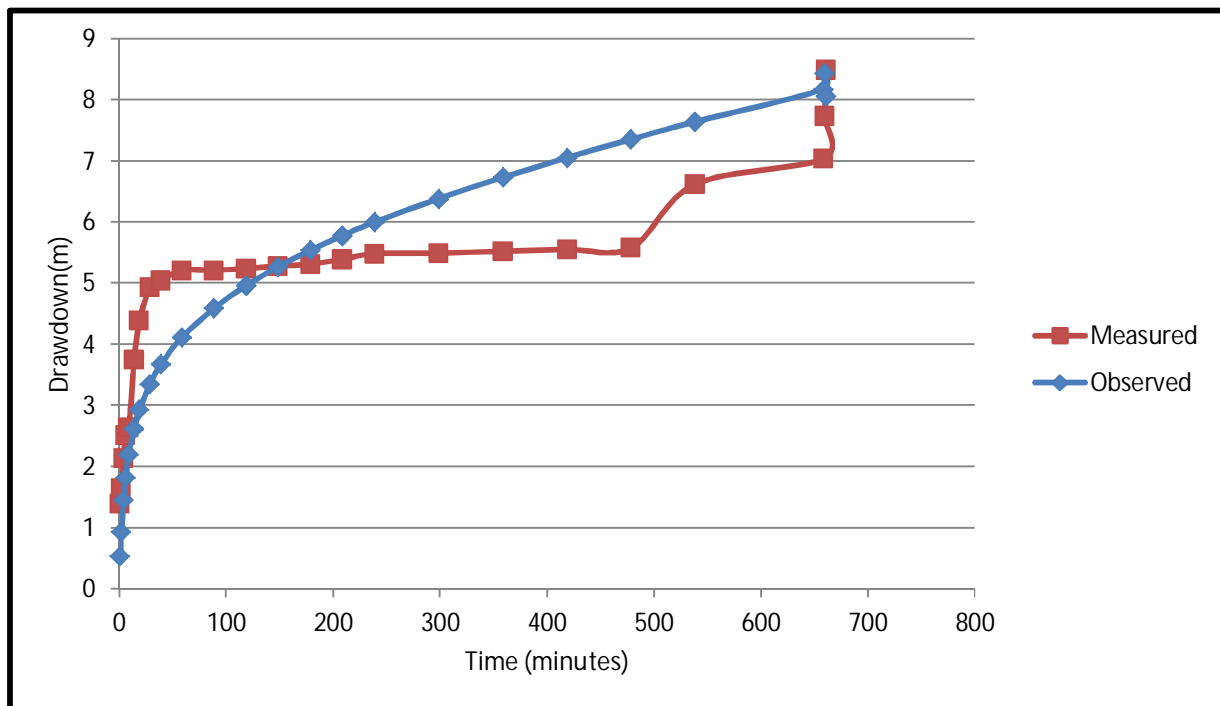
GWOBSBHBH1	GWOBSBHBH4	T6D
$1.5 \cdot 10^{-3}$	$1.8 \cdot 10^{-3}$	$3.1 \cdot 10^{-4}$



**Figure 38 : Transient calibration results (GWOBSBHBH1)**



**Figure 39: Transient calibration results (GWOBSBHBH4)**



**Figure 40: Transient calibration results (T6D)**

## 6.6 Numerical mass transport model

Mass transport modelling consists of the simulation of water contamination or pollution due to deteriorating water quality in response to man's disturbance of the natural system. The most important processes that involved in the transport through a medium are Advection, and the Hydrodynamic dispersion (Mechanical dispersion and Molecular diffusion). Other phenomena (sorption, adsorption, deposition, ion exchange, etc...) may affect the concentrations distribution of a contaminant as it moves through a medium. The effective porosity is required to calculate the average linear velocity of groundwater flow, which in turn is needed to track water particles and to calculate contaminant concentrations in the groundwater.

The MT3DS software was used to provide numerical solutions for the concentration values in the aquifer in time and space. Flow model input parameters (Boundaries conditions, hydraulic conductivity, Recharge, Specific Storage, and Specific Yield) values that serve in flow calibrations were specified for the aquifer. Among the biggest uncertain parameters used during transport modelling of pollutants are the kinematic porosity of the aquifer and the longitudinal

dispersivity. Bear and Verruijt (1992) estimated the average transversal dispersivity to be 10 to 20 times smaller than the average longitudinal dispersivity. The transport model input parameters are summarized in

Table 26.

**Table 26 Summary on the input for transport simulation**

Effective Porosity	Longitudinal Dispersivity	Transversal Dispersivity
--	(m)	(m)
0.06	50	5

## 6.7 Model Predictive scenarios

Two scenarios of groundwater modelling are necessary for the impact assessment of the extended mine plan:

- Changes (drainage, quality) in the groundwater system due to active mining opencast areas;
- Changes (drainage, quality) in the groundwater system due to backfill and rehabilitation of the opencast pits at closure.

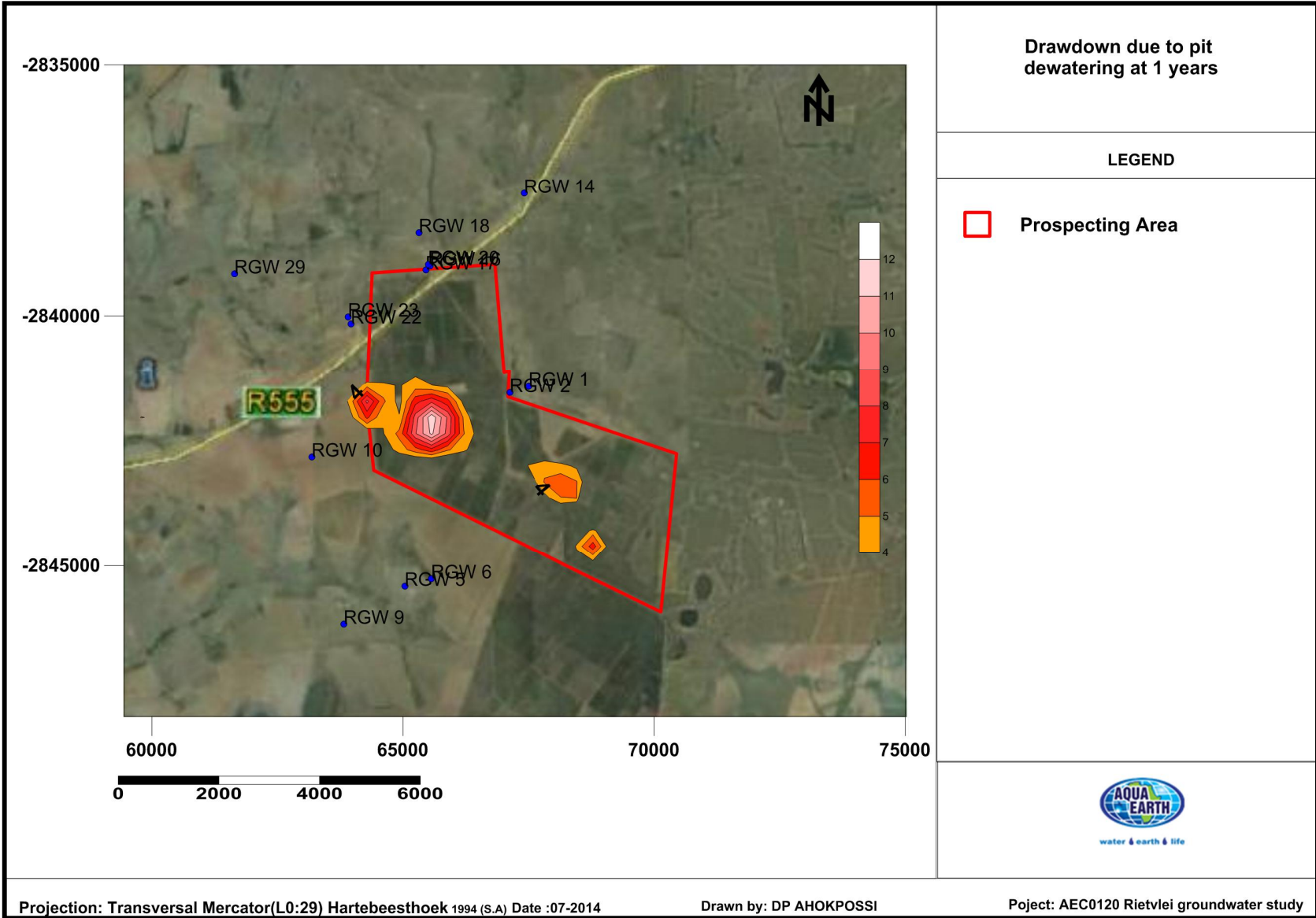
### 6.7.1 Active mining impact scenarios

#### 6.7.1.1 Scenario 1: Mine dewatering

In the first scenario the opencast pit is dewatered. The cone of depression extends up to 3km away from site when pit floor will reach lower seam bottom (50mg/l). The expected inflow is in the vicinity of 300m<sup>3</sup>/d. Please note no concurrent rehabilitation has been included in this scenario and therefore it can be seen as the 'worst-case' scenario. The wetlands are groundwater dependent and will be affected by the dewatering cone, but the current model did not account for such effect. The simulated cone of depressions for different project periods, are shown from Figure 41 to Figure 43. The effect of dewatering on selected boreholes surrounding proposed Rietvlei Mine, are illustrated in Figure 44 and Figure 45 shows the simulated groundwater elevations and drainage at 20 years of operation. All identified boreholes on site

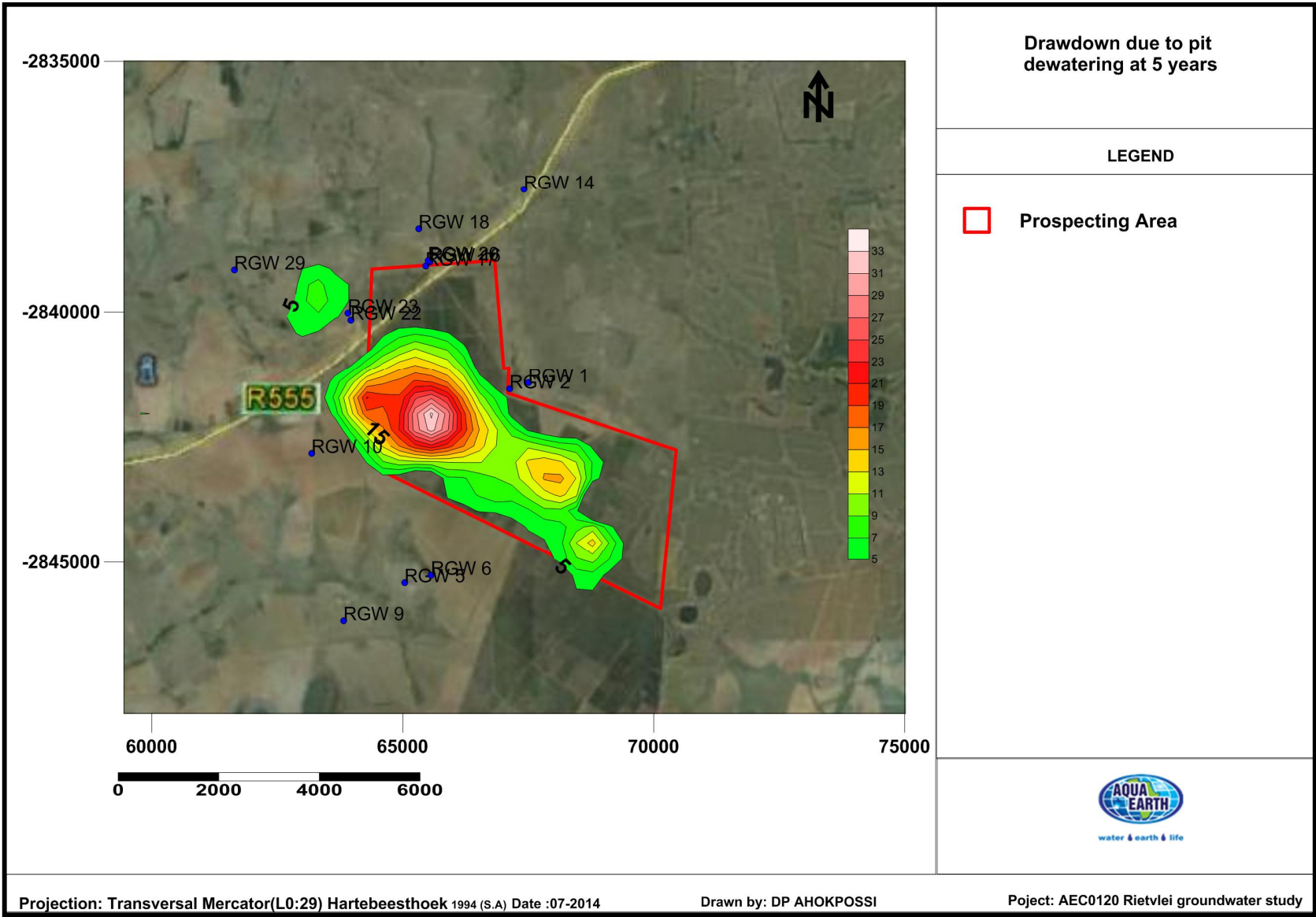
would be impacted together with few offsite boreholes (RGW10, RGW23, RGW22, RGW1, and RGW2).

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**Figure 41: Simulated drawdown due dewatering (1 year)**





**Figure 42 : Simulated drawdown due dewatering (5 year)**

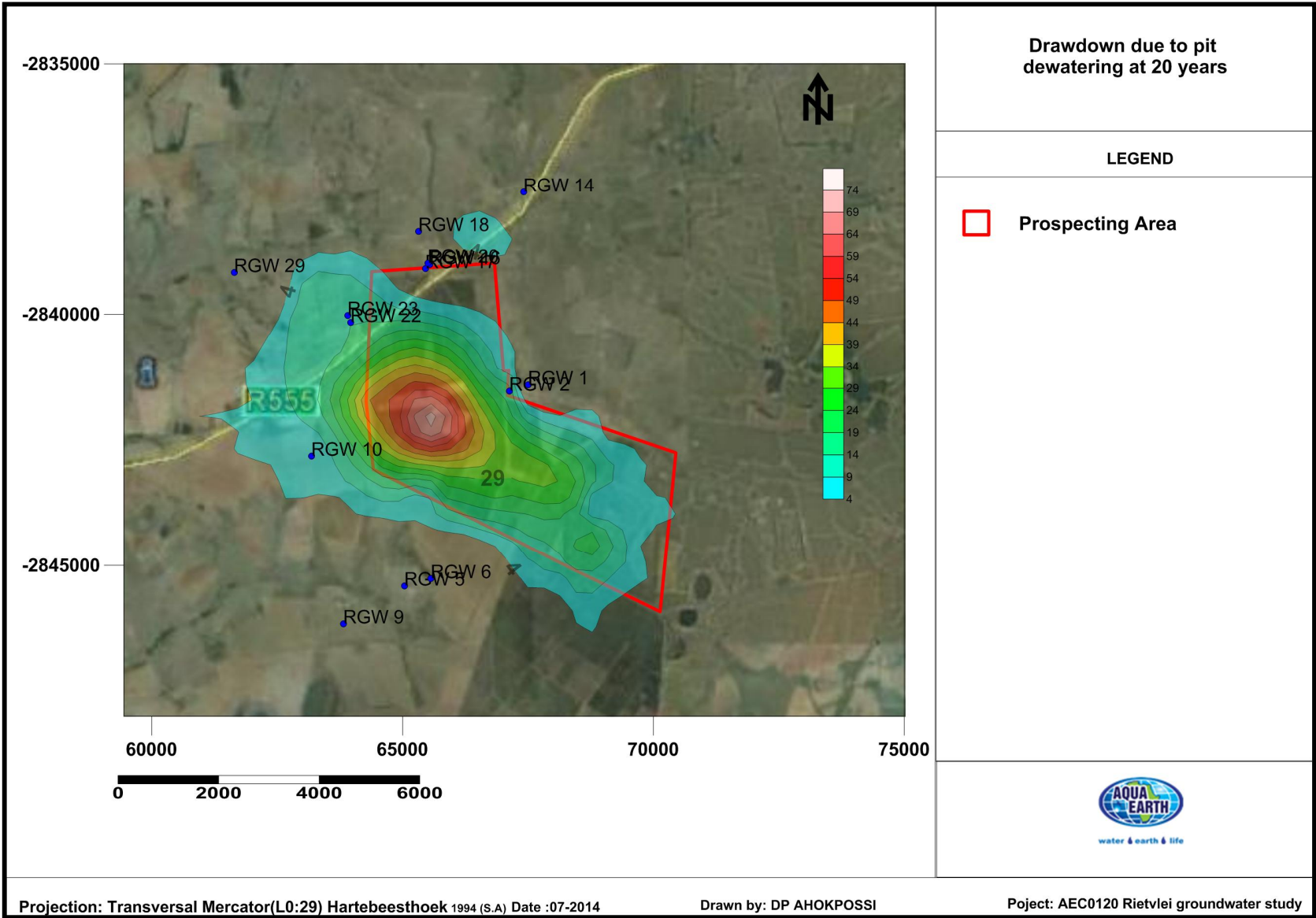
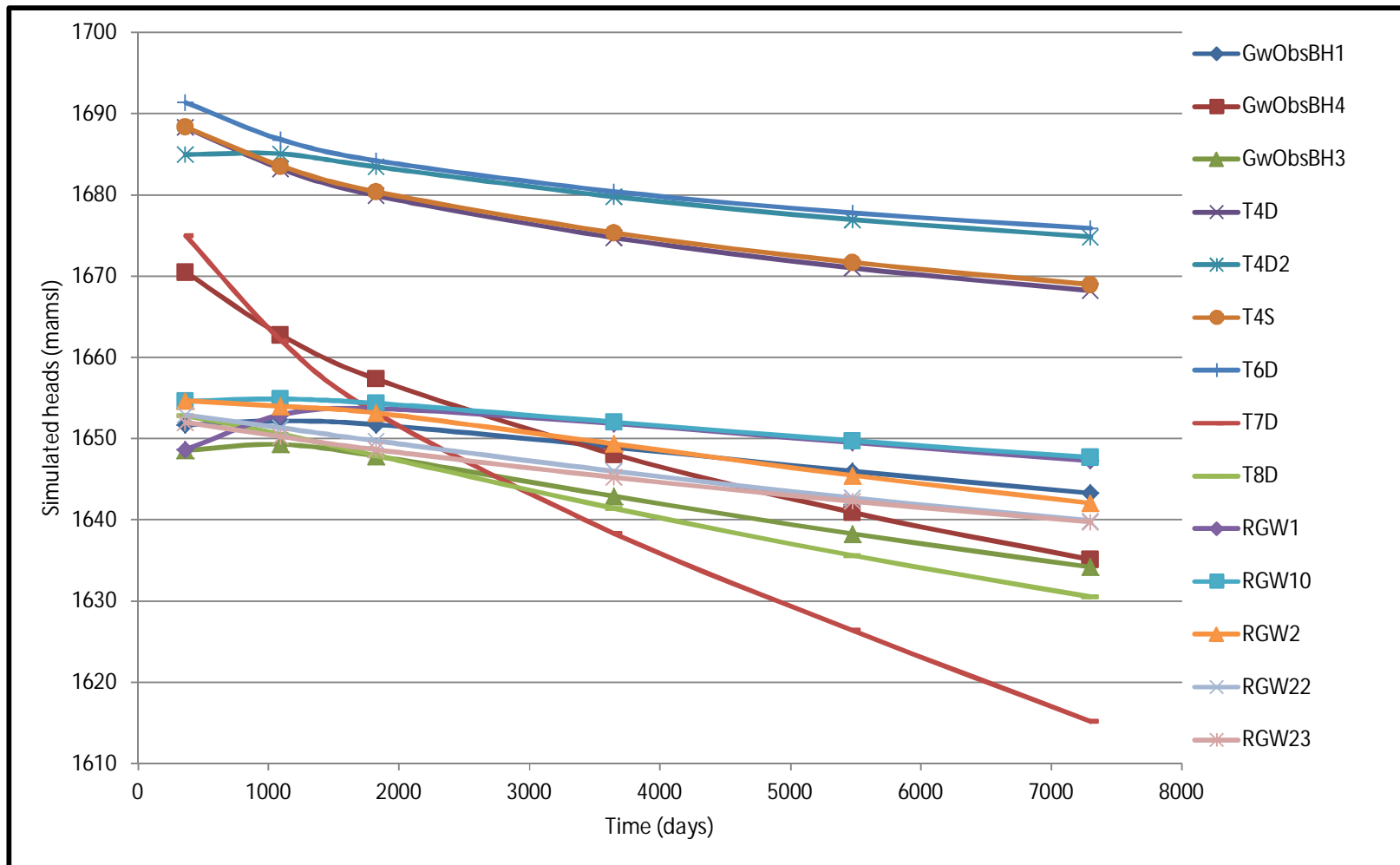
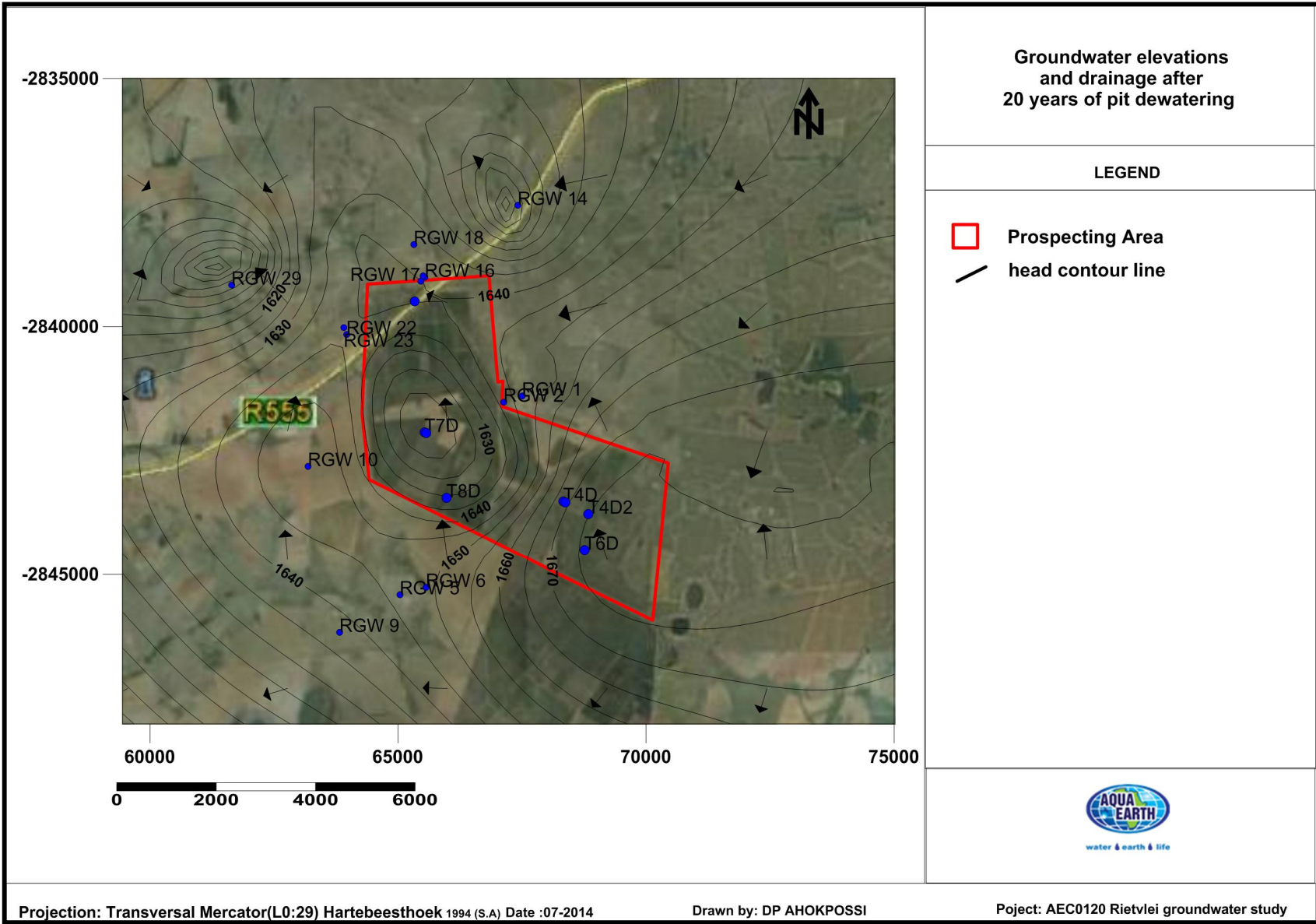


Figure 43: Simulated drawdown due dewatering (20 year)



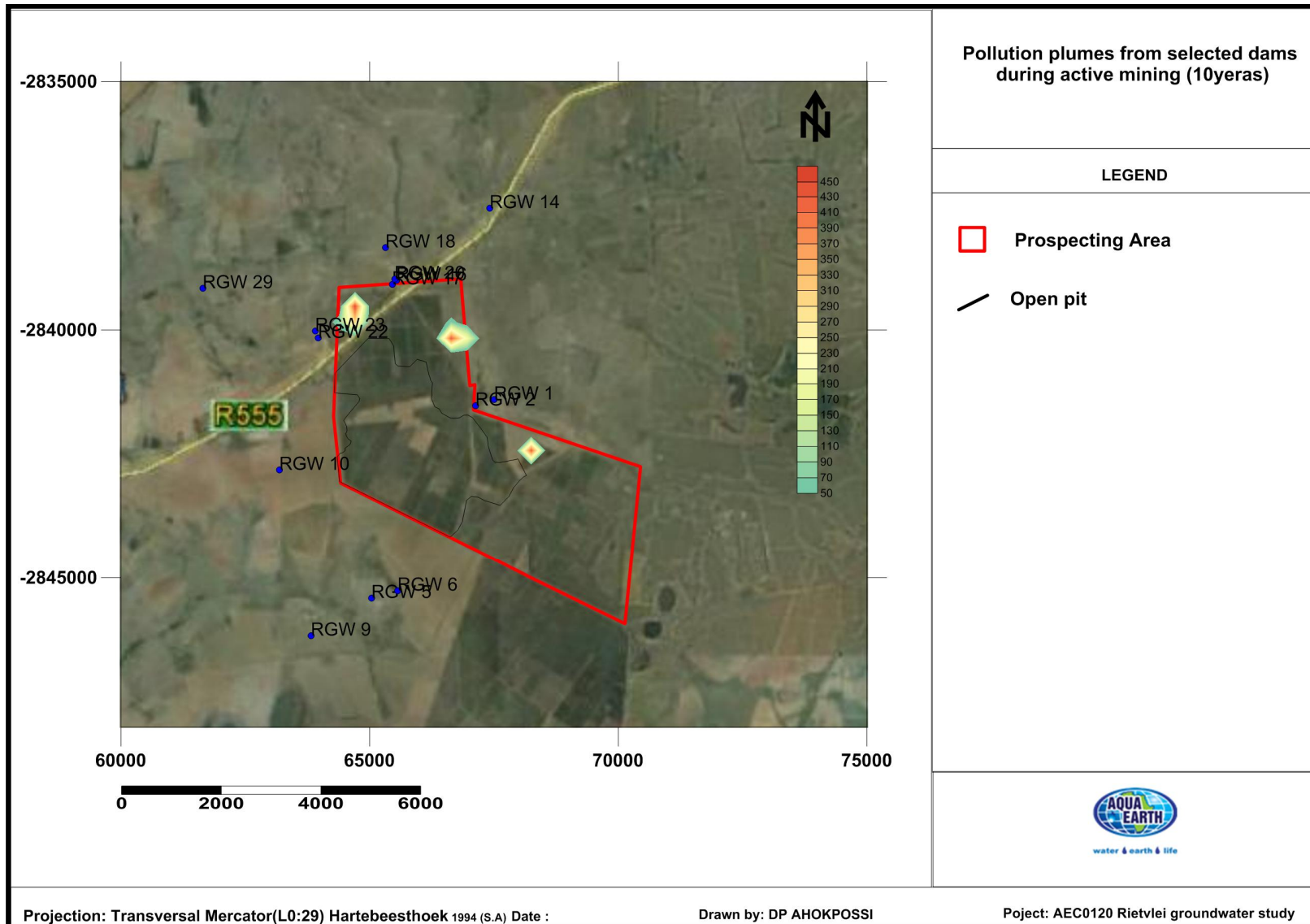
**Figure 44: Simulated drawdown over time**



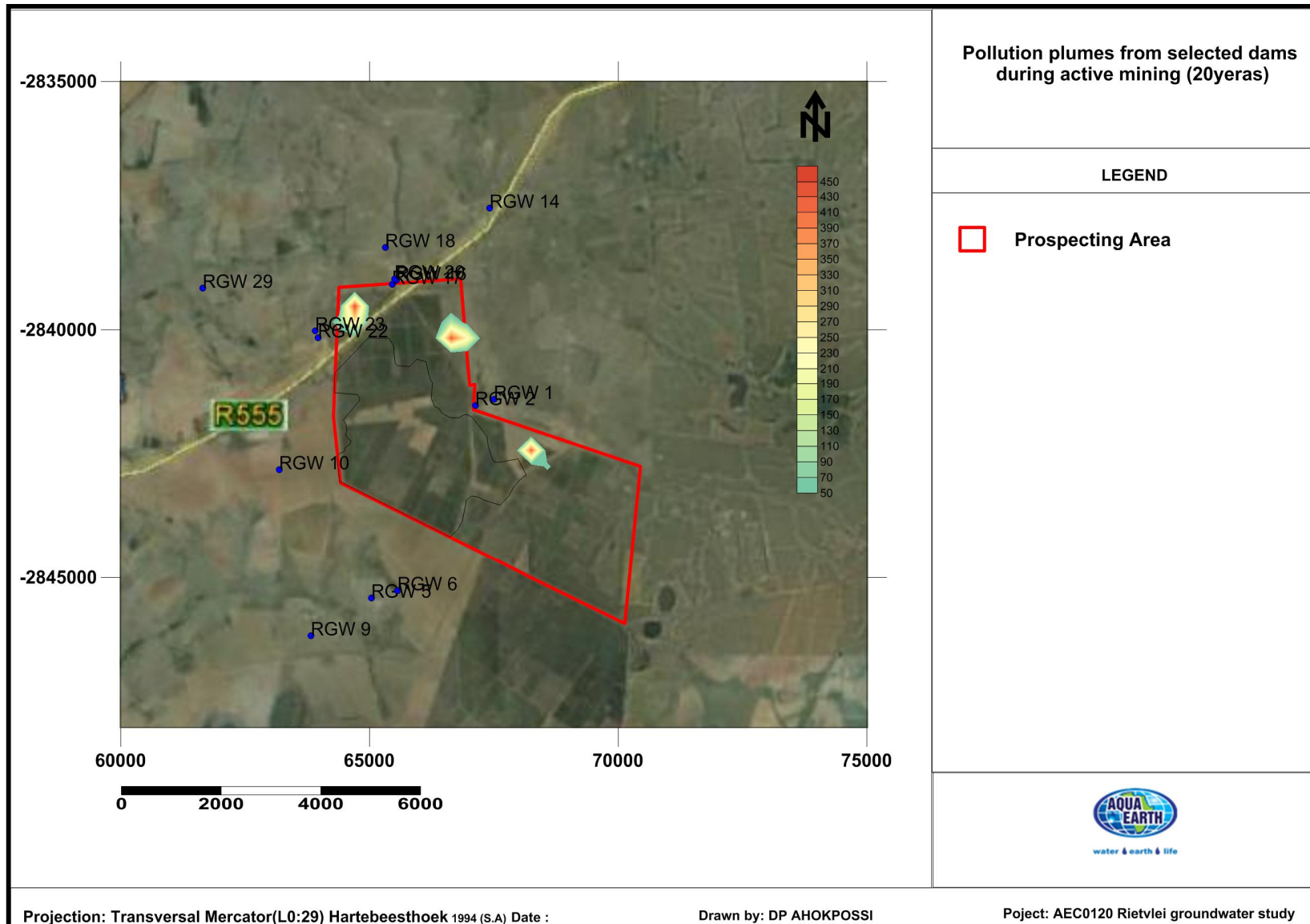
**Figure 45: Simulated groundwater elevations drainage after 20 years of pit dewatering**

#### **6.7.1.2 Scenario 2: Pollution plume**

Groundwater flow during active mining will be towards the open pit. Any pollution plumes emanating from mining activities (dumps, processing plant, water and tailing dams, drains, etc..) will move towards the open pit. The open pit area will be kept dry for mine safety and polluted water seeping through the backfill should be pumped to dirty water dams. Pollution during active mining is expected to be restricted to the mine property. Neighbouring boreholes will not be affected during active mining.



**Figure 46: Simulated pollution plumes from selected dams during active mining (10years)**



**Figure 47: Simulated pollution plumes from selected dams during active mining (20years)**

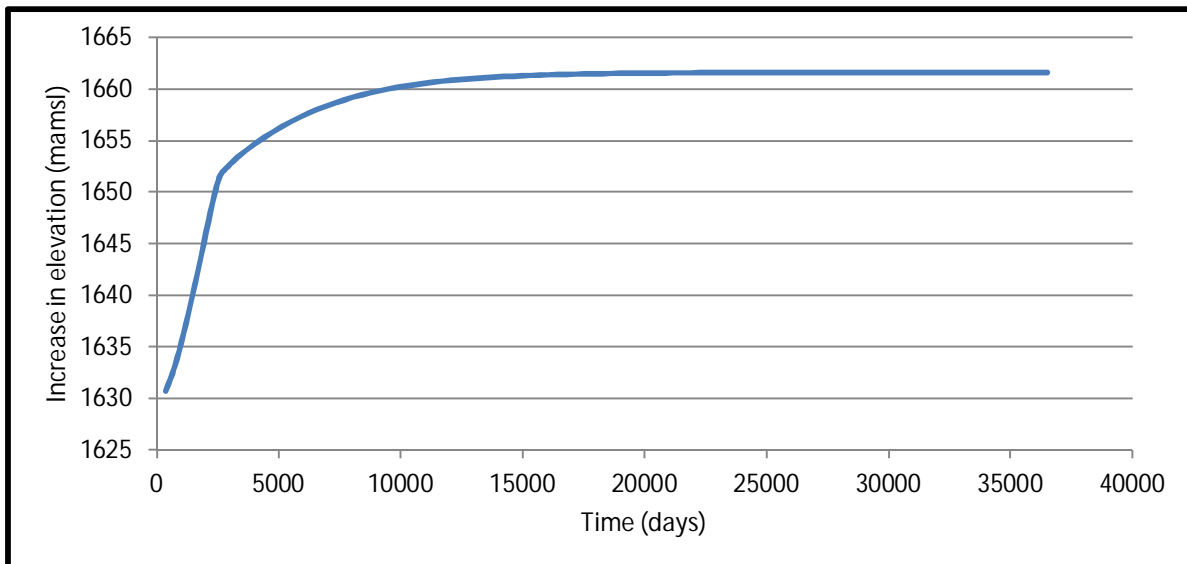
## 6.7.2 Closure and post closure impact scenario

### 6.7.2.1 Scenario 3: Backfilled pit flooding

Dewatering would be stopped when mining will reach its full capacity, and open pit flooding will occur, as recovering of groundwater levels. Groundwater flow directions will return to pre-mining conditions.

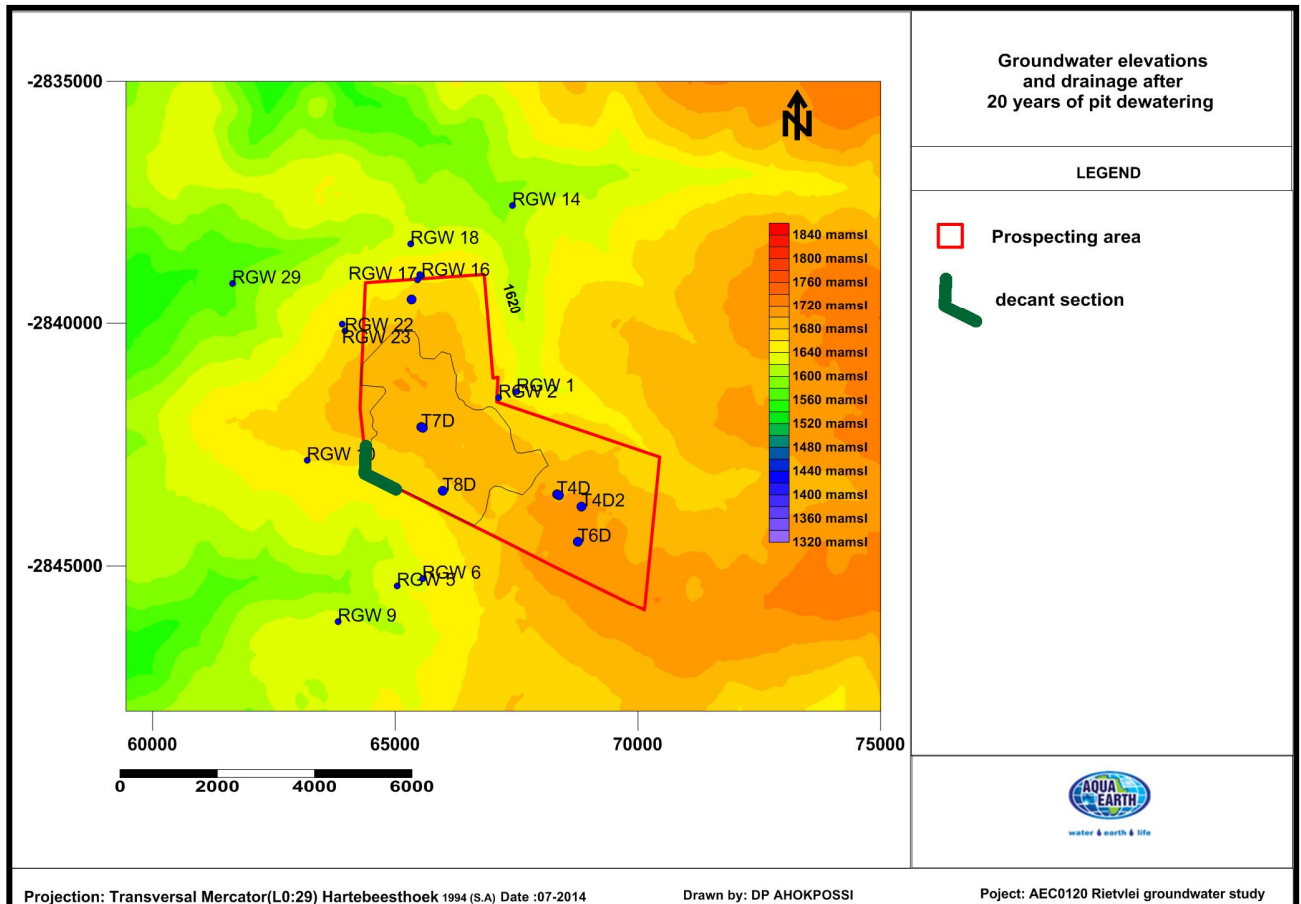
The flooding of the mine is dependent on a number of factors including preferential flow zones such as geological lineaments. Not all preferential influx zones are known at this point, so the volumes might increase, as more information becomes available.

It will take 40 years (Figure 48) for the pit to flood, thereafter decanting will commence. The position of the expected decant point is shown in Figure 49. The decant volume is estimated at 1420 m<sup>3</sup>/d, where as it was estimated (1200 m<sup>3</sup>/d) from the initial numerical model.



**Figure 48: Backfilled pit flooding**





**Figure 49 Decant zone shown in purple**

**6.7.2.1 Scenario 4: Pollution plume (post-closure)**

At this point in time it is calculated that it is likely for the mine to decant.

It is expected that poorer quality groundwater will be present in the backfilled pit when total flooding is completed, as result of chemical reaction between backfill material and oxygenated water. The polluted waters in the opencast pit will start to move into the groundwater system if no water management measures are implemented. The pollution plume at 10 and 20 years after flooding is shown respectively in Figure 50.and Figure 51. The boreholes affected by pollution include: RGW4 and RGW11. Slight impacts could be seen in RGW2 and RGW22.

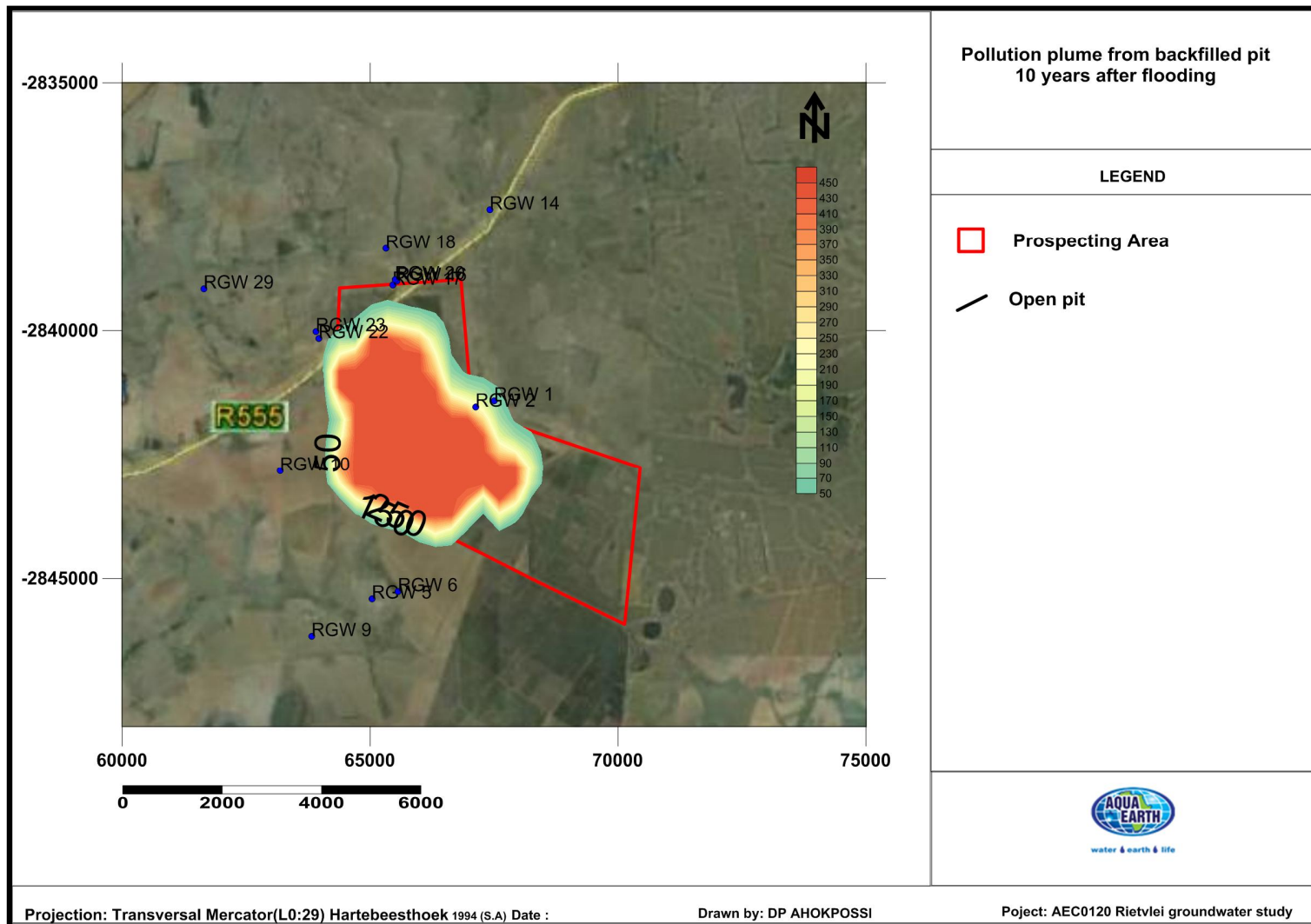


Figure 50: Pollution plume from backfilled pit 10 years after flooding

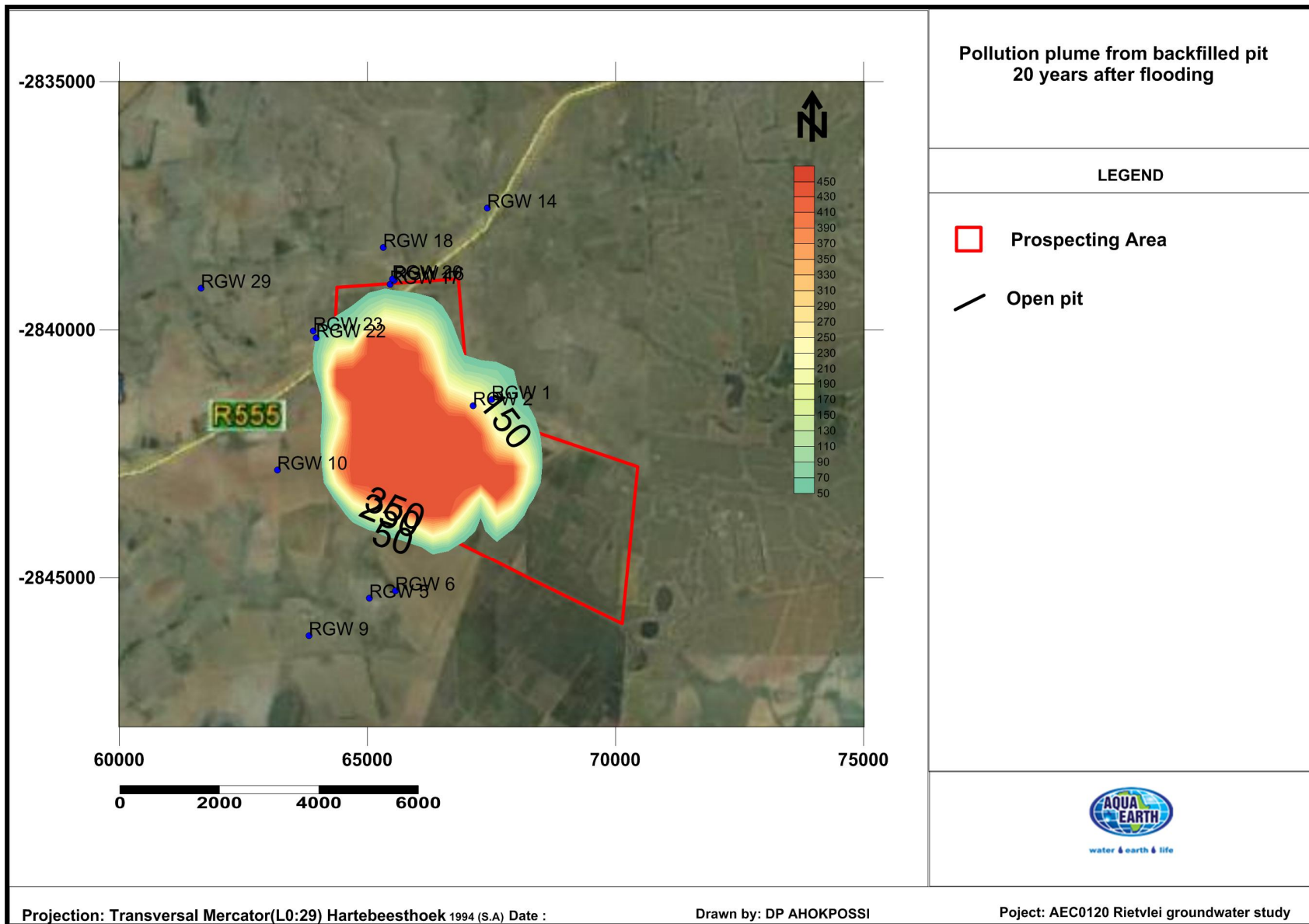


Figure 51: Pollution plume from backfilled pit 10 years after flooding

## 7 Legislative requirements

### 7.1 Environmental Impact assessment (EIA) and licensing

Key environmental legislation pertinent to the development of the proposed Rietvlei Mine development includes:

- Constitution of the Republic of South Africa (No 108 of 1996);
- National Environmental Management Waste Act (Act 59 of 2008) – NEM:WA
- National Environmental Management Act (No 107 of 1998) - NEMA and the National Environmental Management Amended Act (No 46 of 2003);
- National Water Act (No 36 of 1998) – NWA; and

Specific provisions of such legislation in relation to Rietvlei Mine development are illustrated in Table 27.

**Table 27 : Legislation and specific provisions**

Relevant Legislation	Specific provisions
Constitution of the Republic of South Africa (No 108 of 1996)	Section 24 stipulate: <ul style="list-style-type: none"> <li>• prevent pollution and ecological degradation</li> <li>• promote conservation</li> <li>• secure ecologically sustainable development, and use of natural resources while promoting justifiable economic and social development</li> </ul>
NEM: Waste Act (Act 59 of 2008)	<ul style="list-style-type: none"> <li>• the requirements for the environmentally sound management of waste</li> <li>• incorporates a requirements for licensing and control of waste management activities</li> <li>• puts in place a hierarchical approach for waste avoidance</li> <li>• Norms and Standards for the assessment of waste for landfill disposal (R635)</li> <li>• Norms and Standards for the disposal of waste to landfill site</li> </ul>
National Environmental Management Act (No 107 of 1998) - NEMA and the National	Principle for decision-making on : <ul style="list-style-type: none"> <li>• sustainable development</li> <li>• integrated environmental management</li> </ul>

<p>Environmental Management Amended Act (No 46 of 2003).</p>	<ul style="list-style-type: none"> <li>• polluter pays principle</li> <li>• cradle to grave responsibility</li> <li>• precautionary principle</li> <li>• Involvement of stakeholders in decision making.</li> </ul>
<p>National Water Act (No 36 of 1998) –NWA.</p>	<p>Chapter 4- Section 21 to 55 describes water uses that need to be licensed:</p> <ul style="list-style-type: none"> <li>• Water abstraction</li> <li>• Water storage</li> <li>• Alteration of flow in a watercourse</li> <li>• Disposal of waste water from industrial processes</li> <li>• Removing and/or discharging of underground water</li> <li>• Controlled activities (irrigation with waste water and intentional recharging of aquifers with waste)</li> </ul>

The current Regulations applicable to the EIA for proposed Rietvlei Mine development include: R543, R544 and R545 that were promulgated in terms of Section 24 (5) of the NEMA Act No. 107 of 1998.

The overburden waste will be disposed on site. Leachate test results of such waste, show for elements analysed for, concentrations that fall under Leachate Concentration Threshold “0”, based on NEMWA Norms and Standards (GN 36784-635-636) as effected in August 2013. Such waste is then classified as type 4 according to the same legislation and would require Class D contaminant barrier type.

At the time of present report, no leachate test has been conducted yet on tailings that would be generated from coal processing, but it anticipated from others experiences, that the tailings may require Class A contaminant barrier type.

## 8 Impacts on groundwater

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The environmental impact assessment has been undertaken using impact assessment methodology provided in Appendix I.

The overall objective of this assessment is to provide recommendations on how to prevent or minimise impacts arising from the proposed Rietvlei Mine development. The specific actions needed to meet this objective for each project phase are set out. The potential impacts are discussed in light of the following:

- potential groundwater impact : the effect on the groundwater with respect to who or what will be impacted and how this impact will be felt;
- natural and existing mitigation conditions : natural conditions, conditions inherent in project design and proposed management measures that modify impacts (control, moderate, enhance);
- significance of impact : the significance of the unmanaged and managed impacts taking into consideration the probability of the impact occurring, the extent over which the impact will be experienced, and the intensity/severity of the impacts (requires consideration of unknown risks, reversibility, violation of laws, precedents for future action and cumulative effects).

### 8.1 Potential project impacts

The potential impacts on groundwater are associated with activities during the construction phase, operation phase, and the closure and post-closure phases of the coal mining project.

#### 8.1.1 Construction phase

The clearing of topsoil for footprint areas associated with the waste site construction can increase infiltration rates of water to the groundwater system and decrease buffering capacity of soils to absorb contaminants from possible spills on surface. Groundwater recharge from surface may increase, especially in the potential recharge area.

During construction phase, it would be necessary to construct the berms to prevent storm water runoff to enter working area within the prospecting area. The cut and fill activities associated with the construction of infrastructures (waste site, water control infrastructures) may intercept shallow groundwater as static levels are found shallow as 1.7mbgl. In cases where the construction will intercept groundwater, lowering of the groundwater level by dewatering may be

needed during construction. This will cause localise cones of groundwater depressions around the waste site area.

Contamination of groundwater can occur as a result of groundwater seeps standing in the footprint area. The construction activities are likely to be associated with accidental spills of hydrocarbons (oils, diesel etc) from the construction vehicles, and other potentially hazardous chemicals during the construction phase. Such spills together with the construction waste can infiltrate and cause contamination of the groundwater system if not properly handled.

The design of the waste disposal sites (rock dumps, tailings) will take into account the specification stipulated in GN 36784. Thus construction will result in:

- the reduction of the recharge potential at proposed site,
- and the disturbance of Sub-catchment storm water runoff.

The following impacts have been considered and quantified during the construction phase:

- Decreasing of the soils buffering capacity and increasing of infiltration rates;
- Deterioration of water quality due to construction waste (Chemical in construction material);
- Deterioration of groundwater quality due to hydrocarbon spills from storage (organic contaminants);
- Altered flow systems due to probable dewatering (if required),
- Groundwater contamination due to groundwater seeps standing in the construction's footprint area.

Without any mitigation measures the impacts significance from construction of the proposed Rietvlei Mine are rated from very low to low (Table 28).

### **8.1.2 Operational phase**

Opencast mining of coal will result in groundwater inflows into the pits, which needs to be pumped out for mine safety. The dewatering of the groundwater system in the immediate vicinity of the pits will become more important and results in wider cone of depression as depth to pit floor will increase. According to the importance of cone of depression surrounding users' boreholes can be impacted.

Exposure of geological strata to rainfall in the opencast areas will result in deterioration in quality of groundwater flowing into the opencast areas. Groundwater will initially be of good quality but will with time deteriorate, due to oxidation of pyrite and/or other chemical processes that can occur as a result of mining activities. This can take place for years, until the neutralizing potential is depleted. Such dirty water in opencast pit, together with groundwater ingress, if not properly handle may infiltrate and contaminate deeper aquifer system. Others mine activities that may impact on groundwater quality are:

- Overburden dumping: the exposure of rock dumps, to water and oxygen, may result in dirty water that may contaminate groundwater systems, if not properly managed.
- Stockpiling and transport: the exposure of stockpiling and transporting of coal, to water and oxygen, together with hydrocarbon spills from storage (organic contaminants) may also result in contamination of the groundwater systems.
- Coal processing: coal will be exposed at the washing plant area to water and oxygen, resulting in dirty water, and spills/slurry from the site can contaminate groundwater.
- Tailing disposal: residual from coal processing will be disposed of onsite as tailings dam. Tailings constitute a potential source of groundwater contamination.

Dirty water from any of these activities should be drained, or pumped (where required) to pollution control dams. Pollution control dams, and contaminated water drains constitute potential sources of groundwater contamination as result of infiltration through improper barrier system (absent, or leaking). Unlined dams will contribute highly to contamination of the groundwater system, while lined dams might still contaminate but to a lesser degree.

Handling and transport of waste material have some potential of contaminating groundwater, including domestic waste, sewage water, hydrocarbons (storage).

The following impacts have been considered and quantified during the operation phase:

- Deterioration of groundwater quality due to rock dumps;
- Deterioration of groundwater quality due to open pit mining;
- Deterioration of groundwater quality due to coal processing;
- Deterioration of groundwater quality due to tailings disposal;
- Deterioration of groundwater quality due to leaks/spillages from dirty water quality dams and drain;
- Deterioration of groundwater quality due to handling and transport of waste material.



Without any mitigation measures the impacts significance from operation of the proposed Rietvlei Mine are rated from Low Medium to High (Table 29). The High impacts significance, are associated with the potential impacts of groundwater dewatering (Figure 43) and deterioration of groundwater quality due to tailing dams.

### 8.1.3 Closure phase

The closing of mining activities and rehabilitation will be concurrently undertaken. Compaction equipment will include driving vehicle. All disused infrastructure will be demolished, and waste from demolition has to be removed from site and disposed at designated site.

Contaminants from the mine (including backfilled opencast pits and return water dams) can seep through the unsaturated zone into the groundwater system. Lateral groundwater movement will allow the spread of the contamination within the groundwater system. If this groundwater feeds surface water bodies such as wetlands and streams, these can also be polluted. However dilution will take place therefore the impacts thereof are considered to be moderate.

Activities such as covering of the spillages with sand and collection and possibly treatment etc are likely to be associated with accidental spills of hydrocarbons (oils, diesel etc).

Dewatering would be stopped at that stage, and open pit flooding will occur, as recovering of groundwater levels. At this point in time it is calculated that it is likely for the mine to decant. It is expected that poorer quality groundwater will be present on the mine horizon when total flooding is completed.

Water management activities associated with closure activities will be conducted as appropriate. Generally decommissioning/closure phase is too short to see significant impacts on the groundwater, but in the present context where closure would be progressive, significant reduction of impacts could occur. The risk of such impacts will be reduced over time. With strong management options, the risk is expected to reduce even further. Decommissioning/closure is only complete once the proponent demonstrates no significant impacts

The following impacts have been considered and quantified during the closure phase:

- Flooding and decanting of open pit;
- Deterioration of groundwater quality due to waste, and spills related to closure activities;

Without any mitigation measures the impacts significance from closure of the proposed Rietvlei Mine are rated from Very Low to High (Table 30). The High impact is mainly associated with the potential impacts of flooding and decanting of the backfilled pit.

#### **8.1.4 Post-Closure phase**

At post closure phase, the main potential groundwater impacts to be considered and quantify is:

- Flooding and decanting of open pit;

Without any mitigation measures the impacts significance from closure of the proposed Rietvlei Mine are rated as Very High (Table 31).

### **8.2 Cumulative impacts**

No significant pollution source has been identified on site or surrounding, that may cumulatively with the project, impacts on background water quality. However the background high concentration of NO<sub>3</sub>-N noticed from two sampling points may be associated with surrounding agricultural activities (fertilizer, pumping). Slight cone of depressions are already developing at local points surrounding proposed Rietvlei Mine.

The following impacts have been considered as cumulative impacts:

- Cumulating of impacts due mine dewatering with existing local cone of depressions;
- Cumulating of contaminants from mine activities with existing contaminants.

### **8.3 Mitigation measures**

- The development of proposed Rietvlei Mine poses risks to groundwater as assessed. The proper design, construction and operation, and maintenance of the appropriate respective liner system below dirty water dams, tailing dams should be implemented as well as the rehabilitation of the open mine, are part of the key focus areas to mitigate groundwater impacts. The following precautions have to be taken into consideration to reduce possible groundwater risks posed by the development of proposed Rietvlei Mine:
  - Groundwater management strategies must be implemented to prevent risk of water pollution;
  - Groundwater monitoring network should be installed before the starting of any construction activities on site;

- The monitoring network can be updated according to the DWA minimum requirements, if required;
- Monitoring of groundwater must be done once per Quarter;
- Any waste and spills (specially during construction, operation and closure) need to be cleaned up immediately according to the DWA minimum requirements;
- Authorities need to be notified in the event of a spill or leachate during construction, operation and closure;
- Clean and dirty water is to be separated, and any containment of dirty water should be lined.
- Vehicle storage and maintenance areas to be hard-surfaced;
- Regular maintenance of vehicles must be implemented;
- Trucks need to be capped to minimise spillage of coal or wastes, on roads.
- Separate clean water from the stockpiling area to minimise water infiltrating from the site.
- The reusing dirty water from mine activities must be assessed and implemented as much as possible.
- All hazardous substances must be handle according to the requirements of relevant legislation relating to the transport, storage and use of the substance;
- The area to be used for storage of any hazardous waste and items which contains hazardous substance must be lined with bunded walls to prevent pollution of surface or groundwater should a leakage/spillage occur;
- Application for WULA amendment as per DWA requirements must be made for proposed new abstraction boreholes if any required;
- The migration of leachate into the groundwater regime around any potential pollution sources as identified must be prevented at all times;

### **8.3.1 Prior to construction**

- During design phase, the waste and water management infrastructures at proposed Rietvlei Mine (included dams, drains, waste area) must be designed with the appropriate water barrier system if required, and comply with the DWA minimum requirements (1998/2012/2013), with special focus on the R634, R635, R636 of the NEMWA 2008;
- Design of the mine facilities to be conducted by an accredited or recognised professional designer

- The design of the dirty water drains, dams, as well as the waste storage areas should ensure their long term integrity;
- All dirty surface water control facilities (dam, drain) must be designed to have a minimum freeboard above full supply level, at such manner that they can always handle 1:50 year flood-event on top of its mean operation level;

### **8.3.2 During construction**

- A proper construction phase should be carried out under the supervision of an accredited or recognised professional civil engineer, as approved by the designer;
- Storage area for hydrocarbons or any toxic construction material should be bunded according to DWA minimum requirement;

### **8.3.3 During operation**

- Contaminated water drain (within the waste site) and dam must be properly operated and maintained;
- All surface dirty water control facilities (dam, drain) must be operated to have a minimum freeboard above full supply level, at such manner that they can always handle 1:50 year flood-event on top of its mean operation level;
- Effectiveness of existing monitoring borehole position should be re-evaluated;
- The monitoring network can be updated according to the DWA minimum requirements, if required to incorporate the unsaturated zones around proposed Rietvlei Mine.
- Keep contamination to a minimum by keeping the pit as dry as possible (dewatering) to reduce contact time of water and oxygen with exposed strata.
- Spills from the coal processing (crushing, screening and washing) in the plant area needs to be cleaned up immediately according to the DWA minimum requirements and rehabilitation should follow.

### **8.3.4 At the closure and post closure**

- Implement closure of open pit progressively;
- Effectiveness of existing monitoring borehole position should be re-evaluated;
- Rubble from waste or contaminated areas should be dismantled and disposed of accordingly;
- Backfill material to be fully compacted and covered, and the entire foot print of waste to be shaped for free-draining. This will minimise infiltration of oxygen rich water, and reduce geochemical reactions that should occur.
- Rehabilitation to follow backfilling compaction;

- Rehabilitation should consist of re-vegetating the site using appropriately chosen indigenous grasses;
- A rehabilitation plan must be implemented and the plan should be done in the line with the contents of NWA (Act No 36 of 1998), to avoid subsequent negative environmental impacts that may occur.
- Continue monitoring until it can be demonstrated that vegetation is self-sustaining and no erosion channels exist.
- Effectiveness of existing monitoring borehole position should be re-evaluated;

**Table 28: Construction impacts assessment**

Potential groundwater Impact	Without mitigation								Recommended mitigation measures	With mitigation							
	S	SE	DI	C	FA	FI	L	IS		S	SE	DI	C	FA	FI	L	IS
Construction Phase																	
Decreasing of the soils buffering capacity and increasing of infiltration rates	1	1	2	4	1	4	5	20	Mitigation is not possible. Construction phase should be carried out under the supervision of an accredited or recognised professional civil engineer, as approved by the designer	1	1	2	4	1	4	5	20
Altered Flow systems due to probable dewatering (if required)	1	2	2	5	2	4	6	30	Mitigation is not possible. Construction phase should be carried out under the supervision of an accredited or recognised professional civil engineer, as approved by the designer	1	2	2	5	2	4	6	30
Deterioration of water quality due to construction waste (Chemical in construction material)	3	2	1	6	2	3	5	30	Any waste and spills (especially during construction and closure) need to be cleaned up immediately according to the departmental minimum requirements.	1	1	1	3	1	1	2	6
Deterioration of water quality due to hydrocarbon spills from storage (organic contaminants)	3	2	3	8	2	3	5	40	Any waste and spills (specially during construction and closure) need to be cleaned up immediately according to the departmental minimum requirements;	1	1	2	4	1	2	3	12

Groundwater contamination due to groundwater seeps standing in the construction's footprint area.	3	1	3	7	2	3	5	35	Groundwater seeps must be dewatered and contained in dirty water dams.	1	1	1	3	1	1	2	6
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**Table 29: Operation impacts assessment**

Potential groundwater Impact	Without mitigation								Recommended mitigation measures	With mitigation							
	S	SE	DI	C	FA	FI	L	IS		S	SE	DI	C	FA	FI	L	IS
Operation phase																	
Drop of groundwater levels due to open pit dewatering	4	4	4	12	4	5	9	108	Mine needs to agree with affected land owners on friendly solutions for issues related to drawdown cone. This impact needs to be monitored. Application for WULA amendment as per DWA requirements must be made for proposed new abstraction boreholes if any required;	4	4	4	12	4	5	9	108
Deterioration of groundwater quality due to rock dumps.	2	3	4	9	4	3	7	63	Separate clean water from the dumps area, drain dirty water to dirty water dam. Rock dumps areas must be designed with the appropriate water barrier system if required, and comply with the DWA minimum requirements (1998/2012/2013), with special focus on the R634, R635, R636 of the NEMWA 2008	1	1	1	3	1	2	3	9

Deterioration of groundwater quality due to open pit mining.	3	3	4	10	4	5	9	90	Keep contamination to a minimum by keeping the pit as dry (dewatering) as possible to reduce contact time of water and oxygen with exposed strata. Mine water must be contained and/or re used as much as possible. Trucks need to be maintained and capped to minimise loss of coal on roads. Separate clean water from the stockpiling area to minimise water infiltrating from the site. Regular maintenance of vehicles must be implemented; Trucks need to be capped to minimise spillage of coal, on roads.	3	2	3	8	3	3	6	48
Deterioration of groundwater quality due to coal processing;	4	3	4	11	4	5	9	99	Spills from the coal processing (crushing, screening and washing) in the plant area needs to be cleaned up immediately according to the DWA minimum requirements and rehabilitation should follow.	2	2	1	5	1	1	2	10
Deterioration of groundwater quality due to tailings disposal;	4	3	5	12	5	5	10	120	Tailings dam must be maintained and operated according to design as approved by DWA. Effectiveness of existing monitoring borehole position should be re-evaluated periodically according DWA requirements. Continuous monitoring should implement.	1	2	1	4	2	2	4	16
Deterioration of groundwater quality due to leaks/spillages from dirty water quality dams and drain;	4	3	4	11	4	3	7	77	Pollution control dams and associated drains should be maintained and operated according design as approved by DWA. Effectiveness of existing monitoring borehole position should be re-	1	1	1	3	1	2	3	9



										evaluated periodically according DWA requirements.								
Deterioration of groundwater quality due to handling and transport of waste material.	3	3	4	10	4	3	7	70		Waste needs to be discarded and spills cleaned up immediately according to the WULA conditions. DWA should be notified in the event of a spill.	1	1	2	4	1	2	3	12

**Table 30: Closure impacts assessment**

Potential groundwater Impact	Without mitigation								Recommended mitigation measures	With mitigation								
	S	SE	DI	C	FA	FI	L	IS		S	SE	DI	C	FA	FI	L	IS	
Closure phase																		
During decommissioning handling of waste and transport of building material can cause various types of spills (domestic waste, sewage water, hydrocarbons) which can infiltrate and cause contamination of the groundwater system.	3	3	3	9	2	3	4	36		Waste needs to be discarded and spills cleaned up immediately according to the WULA conditions. DWA should be notified in the event of a spill. Rubble from waste or contaminated areas should be dismantled and disposed of accordingly. Regular maintenance of vehicles must be implemented; Trucks need to be capped to minimise spillage of wastes, on roads.	2	2	3	7	2	2	4	28

Flooding and decanting of open pit	4	3	5	12	5	5	10	120	Monitoring should continue, and numerical groundwater model updated on annual basis. Backfill material to be fully compacted and covered, and the entire foot print of waste to be shaped for free-draining, rehabilitation to follow.	4	2	3	9	2	3	5	45
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**Table 31: Post closure impact assessment**

Potential groundwater Impact	Without mitigation								Recommended mitigation measures	With mitigation							
	S	SE	DI	C	FA	FI	L	IS		S	SE	DI	C	FA	FI	L	IS
Post closure phase																	
Flooding and decanting of open pit into surface water drainage channels.	4	4	5	13	5	5	10	130	Backfill material to be fully compacted and covered, and the entire foot print of waste to be shaped for free-draining, rehabilitation to follow. A rehabilitation plan must be implemented and the plan should be done in the line with the contents of NWA (Act No 36 of 1998), to avoid subsequent negative environmental impacts that may occur. Decant water if any, needs to be contained in appropriate dirty water dam.	4	2	5	11	5	5	10	110

## 9 Monitoring plan

### 9.1 Preamble

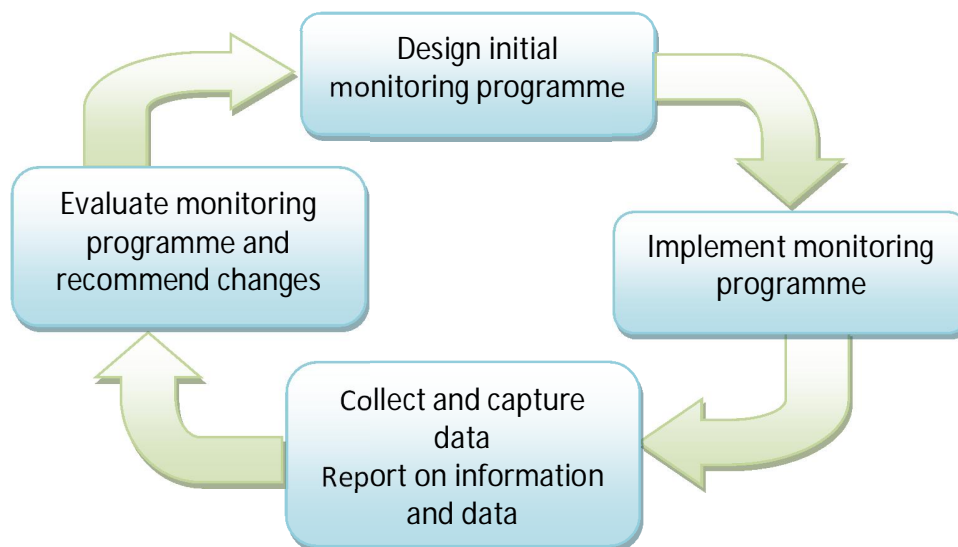
A long-term monitoring programme must be developed based on the guideline documented in Best Practice Guideline G3. Water Monitoring Systems (2007) available from DWA. These guidelines are summarised and implemented in the proposed monitoring plan.

A monitoring plan is necessary because (DWA, 2006):

- Accurate and reliable data forms a key component of many environmental management actions.
- Water monitoring is a legal requirement
- The most common environmental management actions require data and thus the objectives of water monitoring include the following:
- Development of environmental and water management plans based on impact and incident monitoring (facilitate in decision-making, serve as early warning to indicate remedial measures or that actions are required in certain areas) for the mine and region.
- Generation of baseline/background data before project implementation.
- Identification of sources of pollution and extent of pollution (legal implications or liabilities associated with the risks of contamination moving off site).
- Monitoring of water usage by different users (control of cost and maximizing of water reuse).
- Calibration and verification of various prediction and assessment models (planning for decommissioning and closure).
- Evaluation and auditing of the success of implemented management actions (ISO 14000, compliance monitoring).
- Assessment of compliance with set standards and legislation (EMPs, water use licenses).
- Assessment of impact on receiving water environment.

## 9.2 General principle of monitoring

Monitoring on a mine consists of various components as illustrated by the overall monitoring process (Figure 52). It must be recognized and understood that the successful development and implementation of an appropriate, accurate and reliable monitoring programme requires that a defined structured procedure be followed. A monitoring programme must include the location of all monitoring points (indicated on a map), the type of data to be collected, as well as the data collection (protocol/procedure/methodology, frequency of monitoring and parameters determined, quality control and assurance), management (database and assessment) and reporting procedures. This programme must then be implemented. The results from the monitoring programme should be representative of the actual situation. To ensure that the monitoring programme functions properly, an operating and maintenance programme should be developed and implemented. A data management system is necessary to ensure that data is stored/used optimally and is accessible to all the relevant users. The monitoring programme



must include quality control measures. It is important to note that this programme is dynamic and should change as the mine and water management needs change.

**Figure 52: Monitoring process (DWA, 2007)**

Effective groundwater monitoring systems on a mine consist of the following components:

- Groundwater quality monitoring system.
- Groundwater flow monitoring system.

- Data and information management system.

When designing the monitoring system the following issues must also be taken into consideration:

- Potential or actual water use
- Aquifer or catchment vulnerability
- Toxicity of chemicals
- Potential for seepage or releases
- Quantities and frequency of release to the environment (point and non-point).
- Management measures in place to minimize risk.

### **9.3 Monitoring tool**

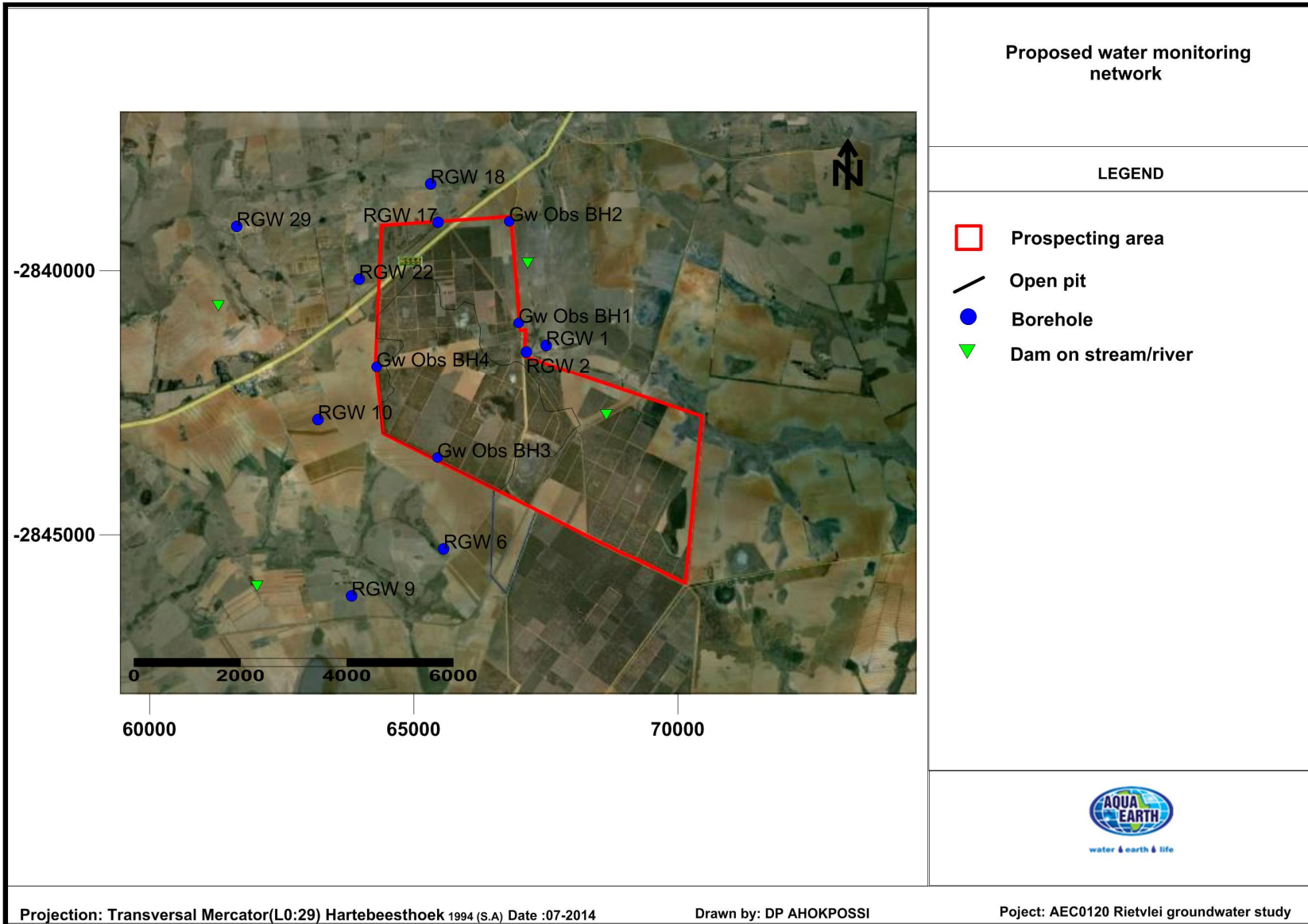
Sampling procedures are discussed in detail in:

- Weaver, J.M.C. 1992a. *Groundwater sampling: A comprehensive guide for sampling methods* (WRC Report No. TT 54/92). Pretoria: Water Research Commission.
- Weaver, J.M.C. 1992b. *Groundwater sampling: An abbreviated field guide for sampling methods* (WRC Report No. TT 56/92). Pretoria: Water Research Commission.

These sampling procedures should be adhered to.

### **9.4 Monitoring plan for Rietvlei Mine**

A comprehensive analysis must be conducted on samples from boreholes and dams locations within or close to the mine (Figure 53). The proposed initial monitoring boreholes consist essentially of existing boreholes (on and off site). In addition samples must be tested for trace elements once a year. The parameters that must be sampled for are listed in Table 32.



**Figure 53: Proposed initial monitoring points**

**Table 32: Sampling parameters**

A (Standard set of parameters)	B (Trace elements)
pH	Ba
EC	As
Ca	Co
Mg	Cr
Na	Ni
K	Pb
Total Alk	Se
F	Sr
Cl	V
NO <sub>2</sub> (N)	Zn
NH <sub>4</sub> (N)	Nb
NO <sub>3</sub> (N)	Mn
PO <sub>4</sub>	Cu
SO <sub>4</sub>	Ga
Al	Ge
Fe	Rb
Mn	Y
	Zr
	Sn

	W
	Bi
	Th
	U
	Hg

Boreholes and surface water points shown in Figure 53 should be sampled every 3 months for the standard list of parameter. Water levels should also be measured. In addition these boreholes must be sampled for trace elements once a year.

Every six months farmer's boreholes within a 2 km radius of the mine should be sampled for the standard list of parameters. Groundwater levels must also be measured.

A borehole must be drilled into backfilled opencast pit to monitor the rise in water level within the pit and the groundwater quality.



## 10 Conclusions

Based on the scope of work carried out under order from WSP, Aqua Earth has completed a detailed groundwater impact assessment and the following conclusions are reached:

- Field investigations have been conducted according to WSP gap analysis recommendation;
- The conceptual model of the site has been updated base on field investigations results;
- The potential impacts (quality, quantity) have been identified and assessed accordingly;
- The overall project impacts (construction, operation, closure) significance is expected to be from Low to Very High without any appropriate mitigation;
- Thorough planning, design, suitable investment, management measures, workplace procedures and good housekeeping will generally mitigate the potential impacts rising from proposed Rietvlei Mine development will de reduced to Low, Except the for impacts at post closure phase;
- Specific measures have been proposed for certain infrastructure units to address particular potential impacts;
- Monitoring will be necessary to ensure that any impacts on water quality and quantity that do arise are dealt with rapidly;
- An initial monitoring network has been proposed for the management of groundwater resources.

# 11 Appendixes

## 11.1 Appendix A: Chains of custody



water & earth & life

AQUA EARTH CONSULTING cc

(Consulting and Contracting Environmental Hydrogeologists)

72, 5th Avenue, Fourrainbleau, Randburg, Tel: 011787 5994; Fax: 0115078812

### CHAIN OF CUSTODY FOR SOIL SAMPLES

Client: **ANGLO AMERICAN**  
 Address:  
 Phone: **0737721421**  
 Fax:  
 Contacts: **pacome@aquaeath.co.za**  
 Sampled at (Project): **RIETVLEI**  
 Date: **14-02-2014**  
 Contact person on site: **D. P. AMOKPOSEN**  
 Signature of the contact person: *[Signature]*

Sampler: **FRANCOIS STASSEN**  
 Sampler's Signature: *[Signature]*  
 Method of shipment:

This Section is for Lab use only:  
 Laboratory Name: **WATER LAB**  
 Received at Laboratory by:  
 Date and Time:  
 Number of samples:  
 Comments:

T8D(11-2)

Site description/ name	Sample ID	Sampling Date	Sampling Time	Type of sample	Analysis requested Acid Base Accounting	Sampling method	Method of preservation	
							at the site	at the lab (intact?)
RIETVLEI	T4D(7-9)	07-02-2014		Soil	✓	Grab	✓	✓
RIETVLEI	T4D(8-14)	07-02-2014		Soil	✓	Grab	✓	✓
RIETVLEI	T5D(6-15)	12-02-2014		Soil	✓	Grab	✓	✓
RIETVLEI	T6D(11-18)	07-02-2014		Soil	✓	Grab	✓	✓
RIETVLEI	T7D(12-21)	07-02-2014		Soil	✓	Grab	✓	✓
RIETVLEI	T7D(24-50)	11-02-2014		Soil	✓	Grab	✓	✓
RIETVLEI	T8D(11-23)	10-02-2014		Soil	✓	Grab	✓	✓
RIETVLEI	T8D(22-50)	10-02-2014		Soil	✓	Grab	✓	✓



analytical services

UIS Analytical Services (Pty) Ltd • Reg. No. 2000/027788/07 • VAT No. 4820208958  
13 Esdoring Nook, Highveld Technopark, Centurion • PO Box 8285, Centurion, 0048  
Tel: +27 12 665 4291 • Fax: +27 12 665 4294 • info@uis-es.co.za • www.uis-es.co.za

ANALYSIS REQUEST FORM - Water

CUSTOMER INFORMATION

Company Name: Agua Earth Samples From Site Location: Rietvlei  
Order/Contract No.: 000479 No. of samples submitted: 6  
UIS-AS Quote No.: \_\_\_\_\_ Sample Type (Borehole Water, Surface Water, Effluent, etc): Borehole water  
Contact Name: \_\_\_\_\_ Land-line No.: \_\_\_\_\_ Mobile No.: \_\_\_\_\_ Email Address: \_\_\_\_\_  
Send Result Report To: D.P. Ahoiposs 073 672 1424 pacane@aguearth.co.za/melgale@aguearth  
Send Invoice To: Tracy 011 791 3490 tracy@aguearth.co.za

I have read and accept the UIS-AS Terms & Conditions of payment and services. I am a duly authorised signatory of the debtor company with regards to sample submission and analyses payment.

Date: 21/02/2014 Print Name: M. van der Merwe Designation: Gasbed Signature: [Signature]

Sample ID and/or Analyses Comments: T4S, T6D, T8D, T7S, T7D, T4D(2)

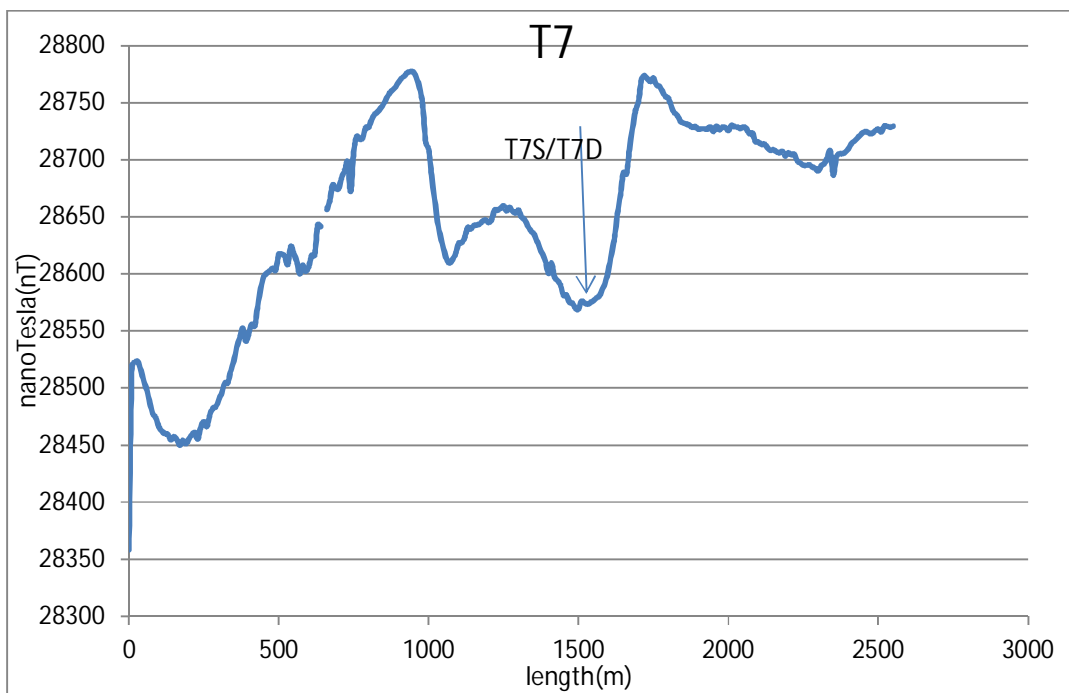
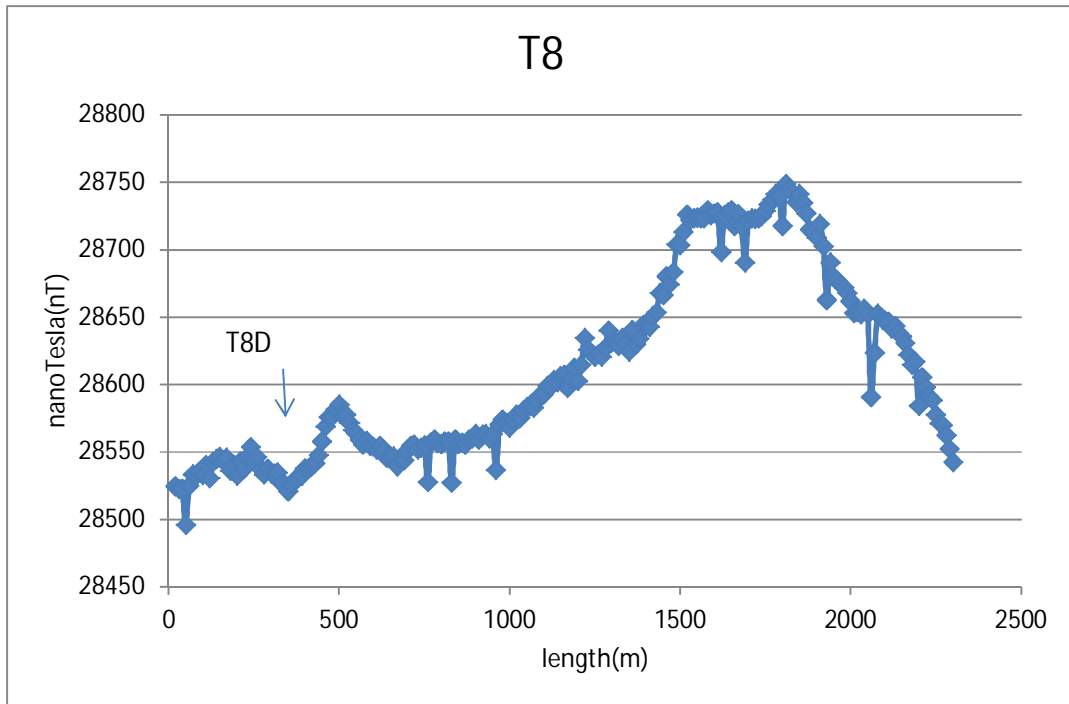
ANALYSES REQUIRED		ELEMENTS REQUIRED	
<input type="checkbox"/> Soluble Phosphorus	<input type="checkbox"/> Microbiology	<input type="checkbox"/> Total Organic Nitrogen	<input checked="" type="checkbox"/> Ag <input checked="" type="checkbox"/> Hg <input checked="" type="checkbox"/> Bi
<input checked="" type="checkbox"/> pH	<input type="checkbox"/> Escherichia Coli	<input type="checkbox"/> Total Kjeldahl Nitrogen	<input checked="" type="checkbox"/> Al <input type="checkbox"/> Hb <input type="checkbox"/> Br
<input checked="" type="checkbox"/> EC (Electrical Conductivity)	<input type="checkbox"/> Total Coliforms	<input type="checkbox"/> Biological Oxygen Demand	<input checked="" type="checkbox"/> As <input type="checkbox"/> V <input checked="" type="checkbox"/> Sn
<input type="checkbox"/> Nit (Nitrogen by LC)	<input type="checkbox"/> Plate Count (Yeasts & Mould)	<input checked="" type="checkbox"/> Chemical Oxygen Demand	<input type="checkbox"/> Au <input checked="" type="checkbox"/> K <input type="checkbox"/> S
<input checked="" type="checkbox"/> F (Fluoride by IC)	<input type="checkbox"/> Total Faecal Coliforms	<input type="checkbox"/> Dissolved Organic Carbon	<input checked="" type="checkbox"/> R <input checked="" type="checkbox"/> La <input checked="" type="checkbox"/> Sr
<input checked="" type="checkbox"/> Cl (Chloride)	<input type="checkbox"/> Standard Plate Count		<input checked="" type="checkbox"/> Ba <input checked="" type="checkbox"/> U <input checked="" type="checkbox"/> Si
<input checked="" type="checkbox"/> NO2 (Nitrite)	<input type="checkbox"/> Salmonella		<input checked="" type="checkbox"/> Be <input type="checkbox"/> Lu <input checked="" type="checkbox"/> Pr
<input checked="" type="checkbox"/> NO3 (Nitrate)			<input type="checkbox"/> B <input checked="" type="checkbox"/> Mg <input type="checkbox"/> Ti
<input checked="" type="checkbox"/> SO4 (Sulphate)	<b>ICP-OES</b>	<b>Calculated Parameters</b>	<input checked="" type="checkbox"/> Ca <input checked="" type="checkbox"/> Mn <input type="checkbox"/> Zr
<input type="checkbox"/> PO4 (Phosphate)	<input type="checkbox"/> Dissolved Calcium	<input type="checkbox"/> Langelier Index	<input checked="" type="checkbox"/> Co <input checked="" type="checkbox"/> Mo <input checked="" type="checkbox"/> Y
<input checked="" type="checkbox"/> Br (Bromide)	<input type="checkbox"/> Total Calcium	<input checked="" type="checkbox"/> Total Hardness	<input type="checkbox"/> Cr <input checked="" type="checkbox"/> Nb <input type="checkbox"/> T
<input checked="" type="checkbox"/> TSS (Total Suspended Solids)	<b>ICP-MS</b>		<input checked="" type="checkbox"/> Cd <input type="checkbox"/> Ni <input checked="" type="checkbox"/> W
<input checked="" type="checkbox"/> TDS (Total Dissolved Solids)	<input type="checkbox"/> Dissolved Trace Elements		<input checked="" type="checkbox"/> Cr <input checked="" type="checkbox"/> As <input type="checkbox"/> Tl
<input checked="" type="checkbox"/> P & Total (M) Alkalinity	<input type="checkbox"/> ICP-MS Scan		<input checked="" type="checkbox"/> Cu <input type="checkbox"/> Os <input checked="" type="checkbox"/> V
<input type="checkbox"/> Nit (Nitrogen by GB)	<input type="checkbox"/> Total Trace Elements		<input type="checkbox"/> Dy <input type="checkbox"/> F <input checked="" type="checkbox"/> I
<input type="checkbox"/> Total Oil & Grease			<input type="checkbox"/> Er <input checked="" type="checkbox"/> Pb <input checked="" type="checkbox"/> W
<input type="checkbox"/> Total Phosphate	<b>Leachate</b>		<input type="checkbox"/> Br <input type="checkbox"/> Pt <input type="checkbox"/> Y
<input checked="" type="checkbox"/> DO (Dissolved Oxygen)	<input type="checkbox"/> Acid Digestion		<input checked="" type="checkbox"/> Fe <input type="checkbox"/> Rh <input type="checkbox"/> Yb
<input type="checkbox"/> Redox Potential	<input type="checkbox"/> Water Leach		<input type="checkbox"/> Os <input type="checkbox"/> Ir <input checked="" type="checkbox"/> Sn
<input checked="" type="checkbox"/> Turbidity	<input type="checkbox"/> Acid Rain Leach		<input type="checkbox"/> Pt <input type="checkbox"/> Sc <input type="checkbox"/> Zr
<input checked="" type="checkbox"/> CRP (Recovery Control)	<input type="checkbox"/> TCLP Leach		<input type="checkbox"/> Co <input type="checkbox"/> Se <input type="checkbox"/> Zr
<input type="checkbox"/> DRP (Free Chlorine)			<input type="checkbox"/> Ni <input type="checkbox"/> S <input type="checkbox"/> Zr
<input type="checkbox"/> Total Cyanide			

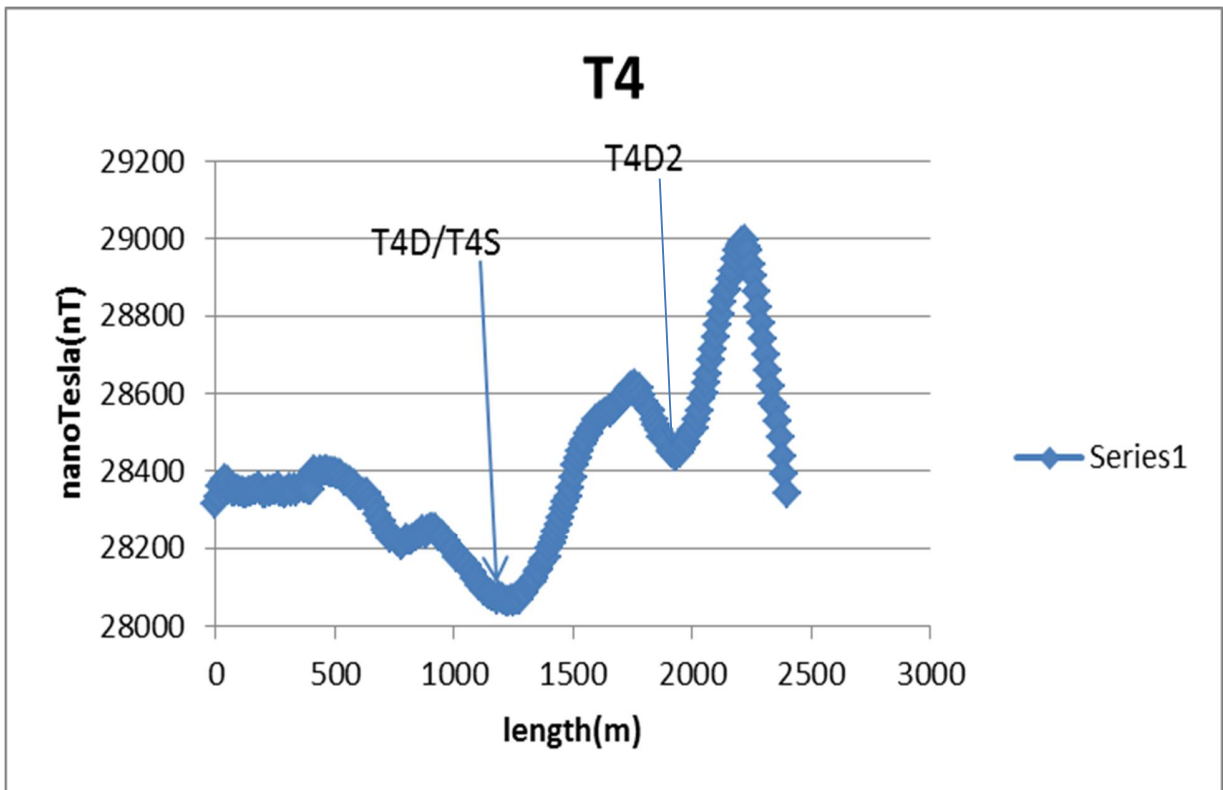
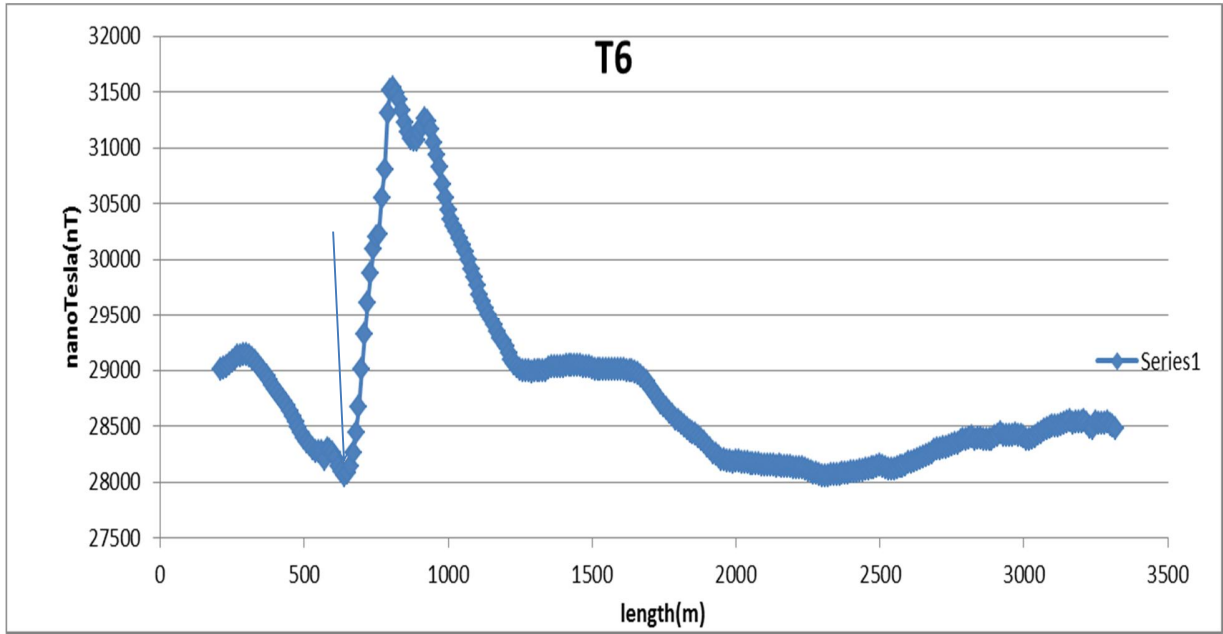


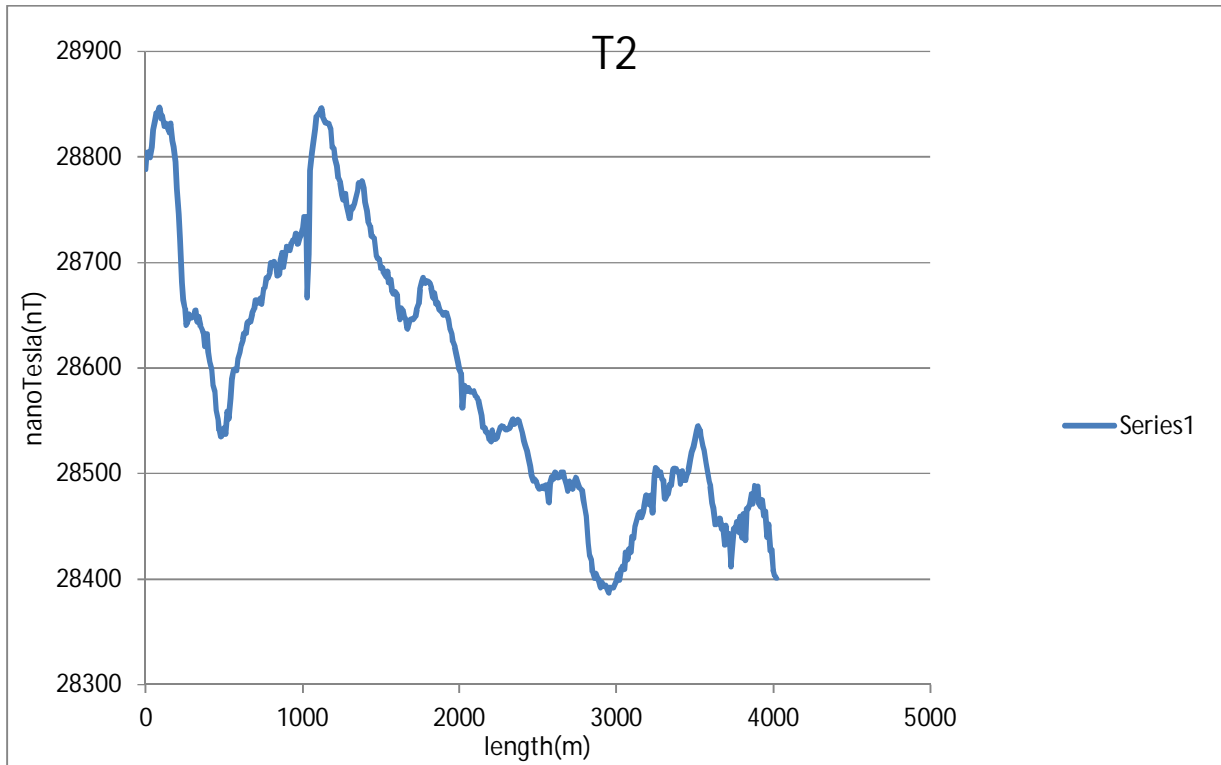
S. DITTOBE 21/02/2014

List of Orescore available from the registered client


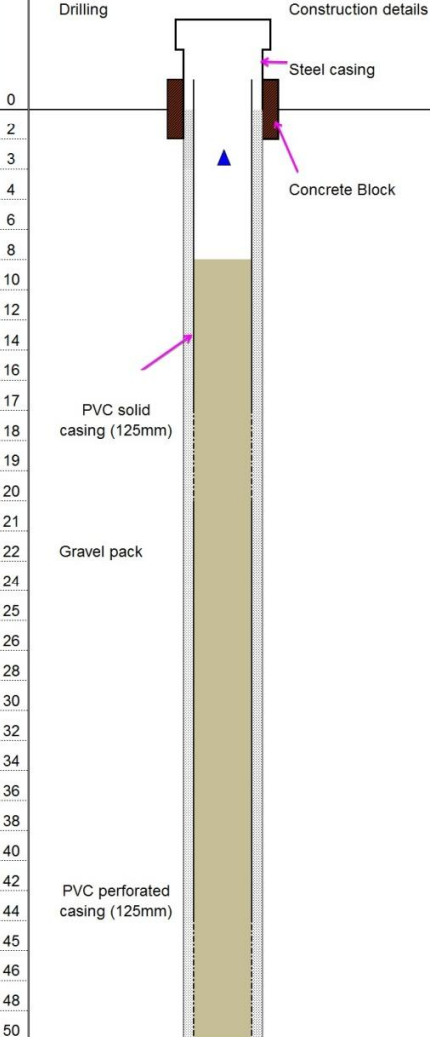
## 11.2 Appendix B: Geophysical Results







### 11.3 Appendix C: Drilling logs

		<h2 style="text-align: center;">BOREHOLE LOG</h2>					
<b>CLIENT:</b> Butsanani Joint Venture <b>PROJECT:</b> Rietvlei <b>SITE:</b> Rietvlei Colliery <b>DRILLER:</b> Aqua Earth <b>DATE DRILLED:</b> 2014/07/02 <b>LOGGED BY:</b> Francois Stassen		<b>BOREHOLE NO :</b> T4D <b>COORDINATES (WGS84)</b> X : 29.680776 Y : -25.697736 <b>PLUNGE:</b> Vertical <b>STATUS:</b> Completed					
BOREHOLE DRILLING AND CONSTRUCTION DETAILS		STRIKES	Water level (m)	Penetration Rate	DEPTH	PROFILE	LITHOLOGICAL DESCRIPTION
Borehole not accessible from 9m		(mbgl)	(m)	(mbgl)	(m)		
Drilling 							
0					0		
2				0.3	2		Topsoil: Reddish
3				0.45	3		
4				0.4	4		Sand: White
6			3.4m	1.25	6		
8				0.35	8		
10				0.3	10		
12				2.3	12		Soil and Sand: Reddish White
14				0.45	14		Sand: White
16				0.45	16		Sand and Coal: Grey
17				0.35	17		
18			19m	1.05	18		
19				0.35	19		
20				0.3	20		Coal Seam: Black, Shiny
21				0.4	21		
22				0.35	22		
24			25m	1.04	24		
25				0.42	25		
26				1.08	26		
28				0.53	28		
30				0.51	30		
32				1.07	32		
34				1.06	34		
36				0.49	36		
38				1	38		
40				0.53	40		
42				1.11	42		
44				1.16	44		
45				1.08	45		
46				1.4	46		
48				2.18	48		Soil: Brown
50				2.12	50		Clay: Reddish Brown



## BOREHOLE LOG

<b>CLIENT:</b> Butsanani Joint Venture <b>PROJECT:</b> Rietvlei <b>SITE:</b> Rietvlei Colliery <b>DRILLER:</b> Aqua Earth <b>DATE DRILLED:</b> 19/2/2014 <b>LOGGED BY:</b> Mlamleli Chopela	<b>BOREHOLE NO :</b> T4D(2) <b>COORDINATES (WGS84)</b> X : 29.685798 Y : -25.700014 <b>PLUNGE:</b> Vertical <b>STATUS:</b> Completed
--	---

BOREHOLE DRILLING AND CONSTRUCTION DETAILS	STRIKES	Water level (m)	Penetration Rate	DEPTH	PROFILE	LITHOLOGICAL DESCRIPTION
	(mbgl)	(m)	(mbgl)	(m)		Rock type, colour, grain size, texture, weathering and fracturing
<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>Drilling</p> </div> <div style="width: 45%;"> <p>Construction details</p> </div> </div>						
0				0		
1			0.12	1		Top reddish brown loamy soil
2			0.15	2		
3			1.11	3		
4			2.11	4		
5			1.24	5		Yellowish, heavily weathered fine grained sandstone
6			1.37	6		
7			1.16	7		
8			0.37	8		
9			0.47	9		
10			0.54	10		
11			1.07	11		
12			1.04	12		
13			1.02	13		
14			0.49	14		
15			0.41	15		Yellowish, moist, fine grained sandstone
16			0.57	16		Coal: Black
17			1.11	17		
18			0.51	18		
19			1.17	19		
20			1.16	20		Very fine grained (powder), yellowish, moist shale
21			1.03	21		Black angular fractured coal
22			1.24	22		
23			1.03	23		
24			1.07	24		
25	25m		1.27	25		
26			1.07	26		
27			0.39	27		
28			1.09	28		
29			0.46	29		
30			0.54	30		
31			1.01	31		
32			1.06	32		
33			1.12	33		Greyish angular to rounded fractured sandstone
34			0.55	34		
35			1.14	35		
36			1.12	36		
37			1.43	37		
38			1.48	38		
39			0.51	39		
40			2.17	40		
41			1.1	41		
42			2.42	42		
43			2.39	43		
44			3.24	44		
45			3.47	45		
46			3.52	46		
47			3.55	47		
48			4.12	48		
49			3.49	49		
50			3.24	50		





## BOREHOLE LOG

CLIENT:	Butsanani Joint Venture	BOREHOLE NO : T4S
PROJECT:	Rietvlei	COORDINATES (WGS84)
SITE:	Rietvlei Colliery	X : 29.681179
DRILLER:	Aqua Earth	Y : -25.697927
DATE DRILLED:	7/2/2014	PLUNGE: Vertical
LOGGED BY:	Francois Stassen	STATUS: Completed

BOREHOLE DRILLING AND CONSTRUCTION DETAILS	STRIKES	Water level (m)	Penetration Rate	DEPTH	PROFILE	LITHOLOGICAL DESCRIPTION
	(mbgl)	(m)	(mbgl)	(m)		Rock type, colour, grain size, texture, weathering and fracturing
<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>Drilling</p> </div> <div style="width: 45%;"> <p>Construction details</p> </div> </div>						
0				0		
1			0.3	1		Topsoil: Reddish
2			0.2	2		Topsoil: Reddish
3			0.4	3		Topsoil: Reddish
4		3.1m	0.55	4		Mixed Sand and Soil: Red
5			0.4	5		Sand: White
6			0.5	6		
7			0.5	7		
8			0.55	8		
9			1.2	9		Soil: Brownish
10	10m		3	10		
11			0.38	11		Mixed: Sand and Soil
12			1.45	12		Sand: Greyish
13			1.05	13		
14			0.55	14		
15			1.1	15		
16			0.3	16		Coal: Black
17			0.35	17		
18			0.4	18		Soil: Brownish
19			0.38	19		Coal: Black
20			0.35	20		
21			1.15	21		
22			1	22		Coal: Black
23			0.5	23		
24			1.05	24		



## BOREHOLE LOG

<b>CLIENT:</b> Butsanani Joint Venture <b>PROJECT:</b> Rietvlei <b>SITE:</b> Rietvlei Colliery <b>DRILLER:</b> Aqua Earth <b>DATE DRILLED:</b> 11/2/2014 <b>LOGGED BY:</b> Francois Stassen	<b>BOREHOLE NO :</b> T5D <b>COORDINATES (WGS84)</b> <b>X :</b> 29.650723 <b>Y :</b> -25.661475 <b>PLUNGE:</b> Vertical <b>STATUS:</b> Completed
--	--

DEPTH (m)	STRIKES (mbgl)	Water level (m)	Penetration Rate (mbgl)	DEPTH (m)	PROFILE	LITHOLOGICAL DESCRIPTION																																																																																																																																																																																																																																												
						Rock type, colour, grain size, texture, weathering and fracturing																																																																																																																																																																																																																																												
<div style="display: flex; justify-content: space-between;"> <div style="width: 30%;"> <p><b>BOREHOLE DRILLING AND CONSTRUCTION DETAILS</b></p> </div> <div style="width: 65%;"> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 5%;">DEPTH (m)</th> <th style="width: 10%;">STRIKES (mbgl)</th> <th style="width: 10%;">Water level (m)</th> <th style="width: 10%;">Penetration Rate (mbgl)</th> <th style="width: 5%;">DEPTH (m)</th> <th style="width: 5%;">PROFILE</th> <th style="width: 55%;">LITHOLOGICAL DESCRIPTION</th> </tr> </thead> <tbody> <tr><td>0</td><td></td><td></td><td></td><td>0</td><td></td><td></td></tr> <tr><td>1</td><td></td><td></td><td>0.2</td><td>1</td><td style="background-color: #d9534f;"></td><td rowspan="3">Topsoil: Red</td></tr> <tr><td>2</td><td></td><td></td><td>0.26</td><td>2</td><td style="background-color: #d9534f;"></td></tr> <tr><td>3</td><td></td><td></td><td>3.35</td><td>3</td><td style="background-color: #d9534f;"></td></tr> <tr><td>4</td><td></td><td></td><td>1.27</td><td>4</td><td style="background-color: #d9534f;"></td><td rowspan="2">Sand: Greyish White</td></tr> <tr><td>6</td><td></td><td></td><td>1.35</td><td>5</td><td style="background-color: #d9534f;"></td></tr> <tr><td>8</td><td></td><td></td><td>1.4</td><td>6</td><td style="background-color: #d9534f;"></td><td rowspan="2">Clay: Red</td></tr> <tr><td>9</td><td></td><td></td><td>2.58</td><td>7</td><td style="background-color: #d9534f;"></td></tr> <tr><td>10</td><td></td><td></td><td>1.32</td><td>8</td><td style="background-color: #d9534f;"></td><td rowspan="2">Sand: Greyish White</td></tr> <tr><td>12</td><td></td><td></td><td>1.54</td><td>9</td><td style="background-color: #d9534f;"></td></tr> <tr><td>14</td><td></td><td></td><td>1.16</td><td>10</td><td style="background-color: #d9534f;"></td><td rowspan="2">Clay: Red</td></tr> <tr><td>15</td><td></td><td></td><td>1.32</td><td>11</td><td style="background-color: 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<tr><td>42</td><td></td><td></td><td>5.58</td><td>18</td><td style="background-color: #d9534f;"></td></tr> <tr><td>44</td><td></td><td></td><td>6.26</td><td>19</td><td style="background-color: #d9534f;"></td></tr> <tr><td>45</td><td></td><td></td><td>5.48</td><td>20</td><td style="background-color: #d9534f;"></td></tr> <tr><td>46</td><td></td><td></td><td>6.47</td><td>21</td><td style="background-color: #d9534f;"></td></tr> <tr><td>48</td><td></td><td></td><td>7.14</td><td>22</td><td style="background-color: #d9534f;"></td></tr> <tr><td>49</td><td></td><td></td><td>8.42</td><td>23</td><td style="background-color: #d9534f;"></td></tr> <tr><td>50</td><td></td><td></td><td>6.31</td><td>24</td><td style="background-color: #d9534f;"></td></tr> </tbody> </table> </div> </div> <div data-bbox="1225 1982 1415 2020" data-label="Page-Footer"> <p>122   Page</p> </div>							DEPTH (m)	STRIKES (mbgl)	Water level (m)	Penetration Rate (mbgl)	DEPTH (m)	PROFILE	LITHOLOGICAL DESCRIPTION	0				0			1			0.2	1		Topsoil: Red	2			0.26	2		3			3.35	3		4			1.27	4		Sand: Greyish White	6			1.35	5		8			1.4	6		Clay: Red	9			2.58	7		10			1.32	8		Sand: Greyish White	12			1.54	9		14			1.16	10		Clay: Red	15			1.32	11		16			0.4			Mudstone: Reddish White	17			0.35			18			1.12			19			2.4			20			3.4			21			5.06			22			3.04			24			8.4			25			3.25			26			5.05			27			6.02			28			4.58			30			6.45	12		32			4.58	13		34			5.15	14		36			4.58	15		38			6.11	16		40			6.23	17		42			5.58	18		44			6.26	19		45			5.48	20		46			6.47	21		48			7.14	22		49			8.42	23		50			6.31	24	
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## BOREHOLE LOG

<b>CLIENT:</b> Butsanani Joint Ventre <b>PROJECT:</b> Rietvlei <b>SITE:</b> Rietvlei Colliery <b>DRILLER:</b> Aqua Earth <b>DATE DRILLED:</b> 7/2/2014 <b>LOGGED BY:</b> Francois Stassen	<b>BOREHOLE NO :</b> T6D <b>COORDINATES (WGS84)</b> <b>X :</b> 29.685097 <b>Y :</b> -25.706538 <b>PLUNGE:</b> Vertical <b>STATUS:</b> Completed
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	BOREHOLE DRILLING AND CONSTRUCTION DETAILS	STRIKES	Water level (m)	Penetration Rate	DEPTH	PROFILE	LITHOLOGICAL DESCRIPTION
		(mbgl)	(m)	(mbgl)	(m)		Rock type, colour, grain size, texture, weathering and fracturing
0	<div style="display: flex; justify-content: space-between;"> <span>Drilling</span> <span>Construction details</span> </div>						
2				0.3	2		<b>Topsoil: Red</b>
3				0.5	3		<b>Soil: Brownish</b>
4				1.35	4		<b>Soil: Yellowish Brown</b>
6				4.05	6		<b>Sand: Yellowish</b>
8				0.5	8		<b>Sand: Yellowish</b>
10				0.5	10		<b>Sand: Yellowish</b>
12				1.35	12		<b>Sand: Yellowish</b>
14			▲ 14m	2	14		<b>Shale: Greysih Black</b>
15				1.05	15		<b>Shale: Greysih Black</b>
16				0.35	16		<b>Shale: Greysih Black</b>
17				0.4	17		<b>Shale: Greysih Black</b>
18				0.3	18		<b>Shale: Greysih Black</b>
19				0.5	19		<b>Shale: Greysih Black</b>
20		19m		0.45	20		<b>Shale: Greysih Black</b>
21				0.3	21		<b>Shale: Greysih Black</b>
22				3	22		<b>Shale: Greysih Black</b>
24				2.45	24		<b>Shale: Greysih Black</b>
25				2.05	25		<b>Shale: Greysih Black</b>
26				2.15	26		<b>Shale: Greysih Black</b>
27				4	27		<b>Shale: Greysih Black</b>
28				3.15	28		<b>Shale: Greysih Black</b>
30				5.45	30		<b>Shale: Greysih Black</b>
32				4.5	32		<b>Shale: Greysih Black</b>
34				3.1	34		<b>Shale: Greysih Black</b>
36				6.45	36		<b>Shale: Greysih Black</b>
38				6.1	38		<b>Shale: Greysih Black</b>
40				5.35	40		<b>Shale: Greysih Black</b>
42				6.18	42		<b>Shale: Greysih Black</b>
44				6.02	44		<b>Shale: Greysih Black</b>
45				6.03	45		<b>Shale: Greysih Black</b>
46				3.11	46		<b>Shale: Greysih Black</b>
48				5.36	48		<b>Shale: Greysih Black</b>
49				3.47	49		<b>Shale: Greysih Black</b>
50				5.12	50		<b>Shale: Greysih Black</b>



## BOREHOLE LOG

<b>CLIENT:</b> Butsanani Joint Venture <b>PROJECT:</b> Rietvlei <b>SITE:</b> Rietvlei Colliery <b>DRILLER:</b> Aqua Earth <b>DATE DRILLED:</b> 11/2/2014 <b>LOGGED BY:</b> Francois Stassen	<b>BOREHOLE NO :</b> T7D <b>COORDINATES (WGS84)</b> <b>X :</b> 29.652838 <b>Y :</b> -25.685354 <b>PLUNGE:</b> Vertical <b>STATUS:</b> Completed
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	BOREHOLE DRILLING AND CONSTRUCTION DETAILS	STRIKES	Water level (m)	Penetration Rate	DEPTH	PROFILE	LITHOLOGICAL DESCRIPTION
		(mbgl)	(m)	(mbgl)	(m)		Rock type, colour, grain size, texture, weathering and fracturing
	<div style="display: flex; justify-content: space-between;"> <span>Drilling</span> <span>Construction details</span> </div>						
0					0		
1			▲ 1.7 m		0.1		Topsoil: Red
2				0.15			
3				0.2			
4				0.3			
6					0.4		Sand:Whitish Grey
8			0.45				
9			1.16				
10			0.28				
12			0.52				
14					0.55		Sand:Yellowish White
15			1.21				
16					0.52		Sand:Greyish White
17			1.02				
18			1.23				
19		19m	0.42				
20					1.1		Sand:Greyish White
21			1.15				
22			0.42				
24			1.43				
25					0.52		Carbonaceous Shale: Greyish Black
26			0.48				
27			2.03				
28					0.44		Coal: Black
30			1.35				
32			1.14				
34			0.34				
36			1.24				
38					0.38		Coal: Black
40			0.28				
42			0.55				
44					0.4		Coal: Black
45		44m	1.09				
46			1.25				
48					1.49		Coal: Black
49			0.38				
50			0.56				



## BOREHOLE LOG

<b>CLIENT:</b> Butsanani Joint Venture <b>PROJECT:</b> Rietvlei <b>SITE:</b> Rietvlei Colliery <b>DRILLER:</b> Aqua Earth <b>DATE DRILLED:</b> 11/2/2014 <b>LOGGED BY:</b> Francois Stassen	<b>BOREHOLE NO :</b> T7S <b>COORDINATES (WGS84)</b> <b>X :</b> 29.653166 <b>Y :</b> -25.685504 <b>PLUNGE:</b> Vertical <b>STATUS:</b> Completed
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	BOREHOLE DRILLING AND CONSTRUCTION DETAILS	STRIKES	Water level (m)	Penetration Rate	DEPTH	PROFILE	LITHOLOGICAL DESCRIPTION
		(mbgl)	(m)	(mbgl)	(m)		Rock type, colour, grain size, texture, weathering and fracturing
	<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>Drilling</p> </div> <div style="width: 45%;"> <p>Construction details</p> </div> </div>						
0					0		
1					0.08		Topsoil: Red
2				0.11			
3				0.17			
4				1.5			
5			4.8m ▲	1.12	5		
6				0.56	6		Sand: Greyish White
7				0.49	7		Clay: Red
8				0.51	8		Sand: Greyish White
9				1.23	9		
10				0.34	10		Clay: Red
11				1.28	11		Soil: Reddish White
12				0.29	12		
13				0.31	13		
14				0.58	14		
15		19m		1.4	15		
16				0.48	16		
17				0.51	17		
18				1.12	18		
19				0.56	19		
20				1.07	20		
21				0.42	21		Sand: Greyish White
22				0.4	22		
23				0.56	23		Mudstone: Reddish White
24				1.15	24		



## BOREHOLE LOG

CLIENT: Butsanani Joint Venture	BOREHOLE NO : T8D
PROJECT: Rietvlei	COORDINATES (WGS84)
SITE: Rietvlei Colliery	X : 29.657317
DRILLER: Aqua Earth	Y : -25.697196
DATE DRILLED: 10/2/2014	PLUNGE: Vertical
LOGGED BY: Francois Stassen	STATUS: Completed

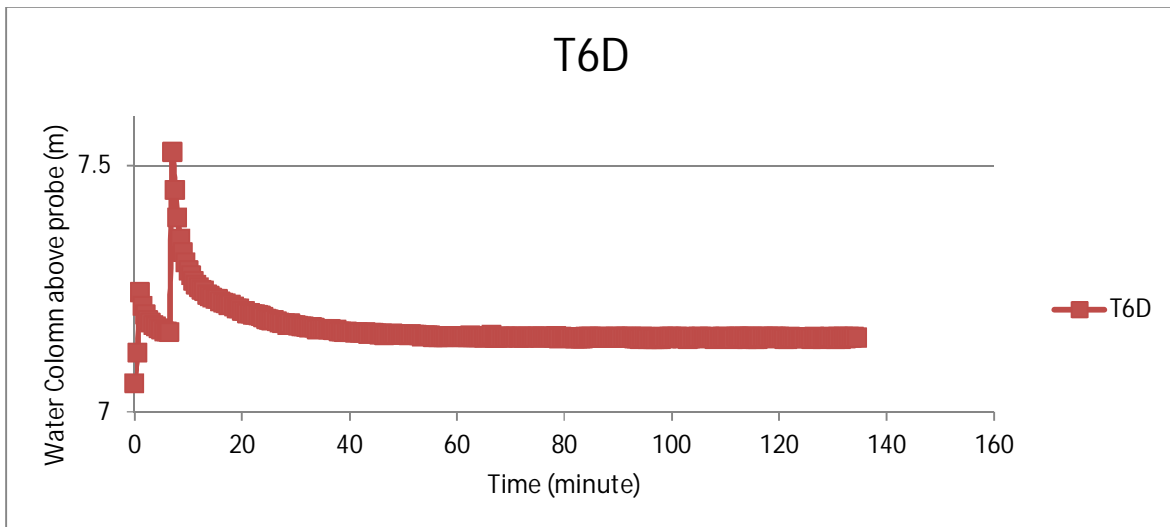
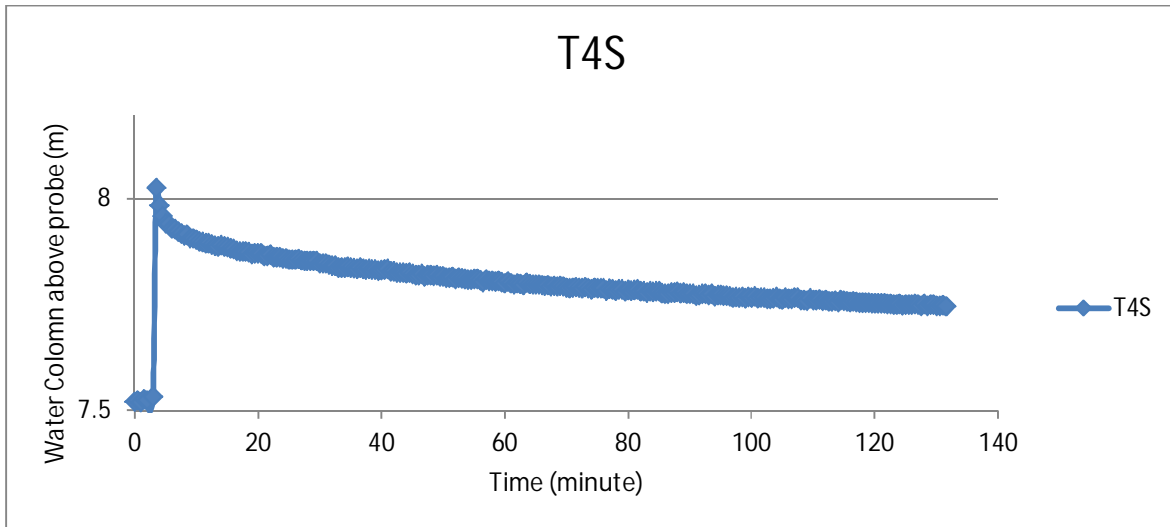
BOREHOLE DRILLING AND CONSTRUCTION DETAILS	STRIKES	Water level (m)	Penetration Rate	DEPTH	PROFILE	LITHOLOGICAL DESCRIPTION
	(mbgl)	(m)	(mbgl)	(m)		Rock type, colour, grain size, texture, weathering and fracturing
<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>Drilling</p> </div> <div style="width: 45%;"> <p>Construction details</p> </div> </div>						
0				0		
1			0.1	1		Topsoil: Red
2			0.15	2		Topsoil: Red
3			0.3	3		Topsoil: Red
4			0.27	4		Soil: Reddish White
6			0.55	6		Sand: Whitish Grey
8			0.28	8		Sand: Whitish Grey
9			1.04	9		Coal: Black
10			0.35	10		Coal: Black
12			1.1	12		Coal: Black
14			0.5	14		Coal: Black
15			0.32	15		Coal: Black
16			0.4	16		Coal: Black
17			1	17		Coal: Black
18			1.45	18		Coal: Black
19			0.5	19		Coal: Black
20			1.06	20		Coal: Black
21		21m	1.3	21		Coal: Black
22			0.25	22		Coal: Black
24			0.4	24		Coal: Black
25			0.3	25		Coal: Black
26			0.4	26		Coal: Black
27			1.55	27		Coal: Black
28			1.43	28		Coal: Black
30			1.45	30		Coal: Black
32			1.12	32		Sand: Whitish Grey
34			2.1	34		Sand: Whitish Grey
36			1.55	36		Coal: Black
38			1.4	38		Coal: Black
40			1.5	40		Coal: Black
42			3.05	42		Coal: Black
44			3.5	44		Coal: Black
45			3.55	45		Coal: Black
46			1.27	46		Coal: Black
48			2.35	48		Coal: Black
49			1.05	49		Coal: Black
50			2.07	50		Coal: Black

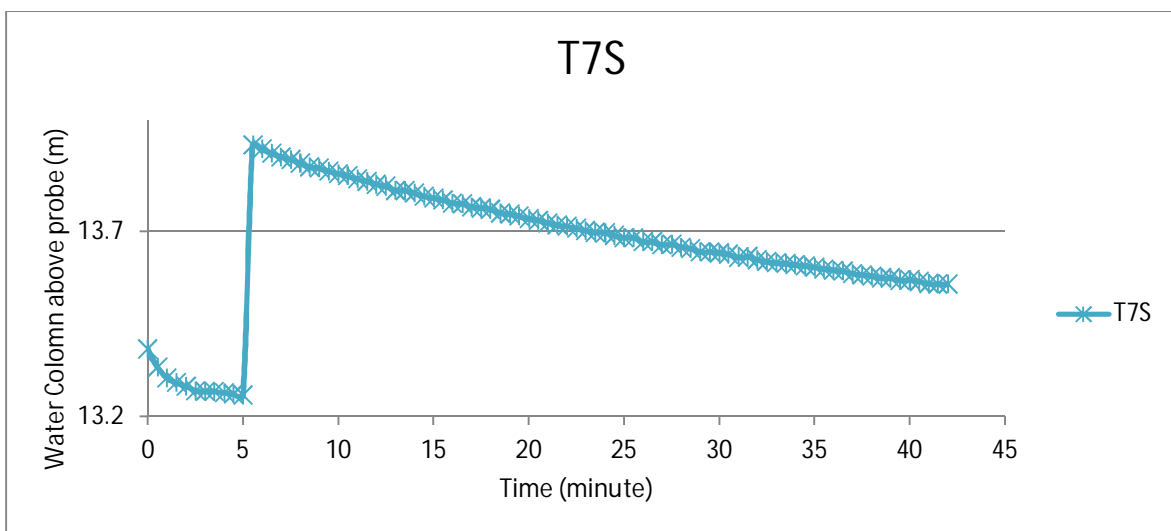
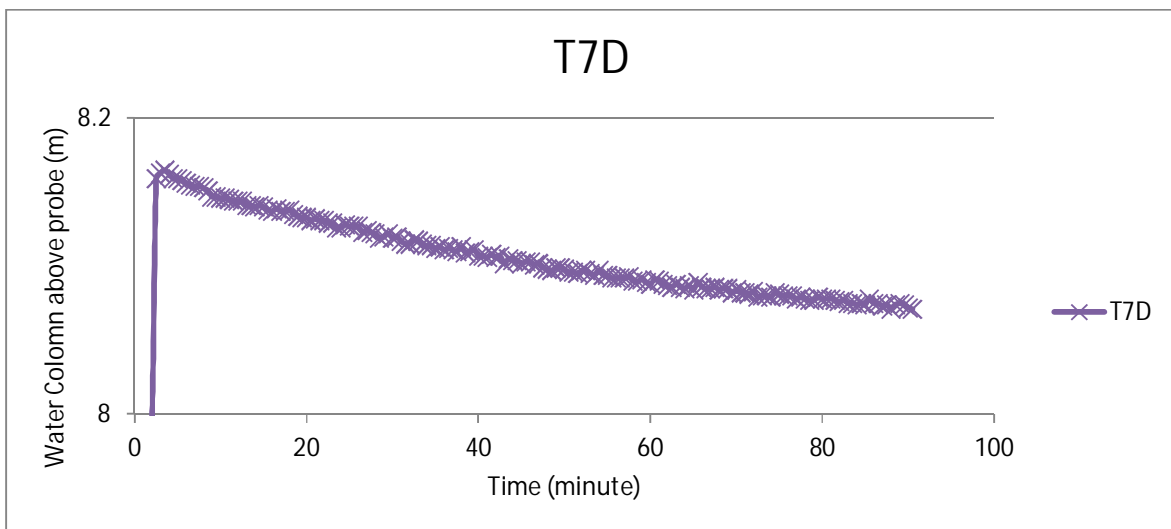
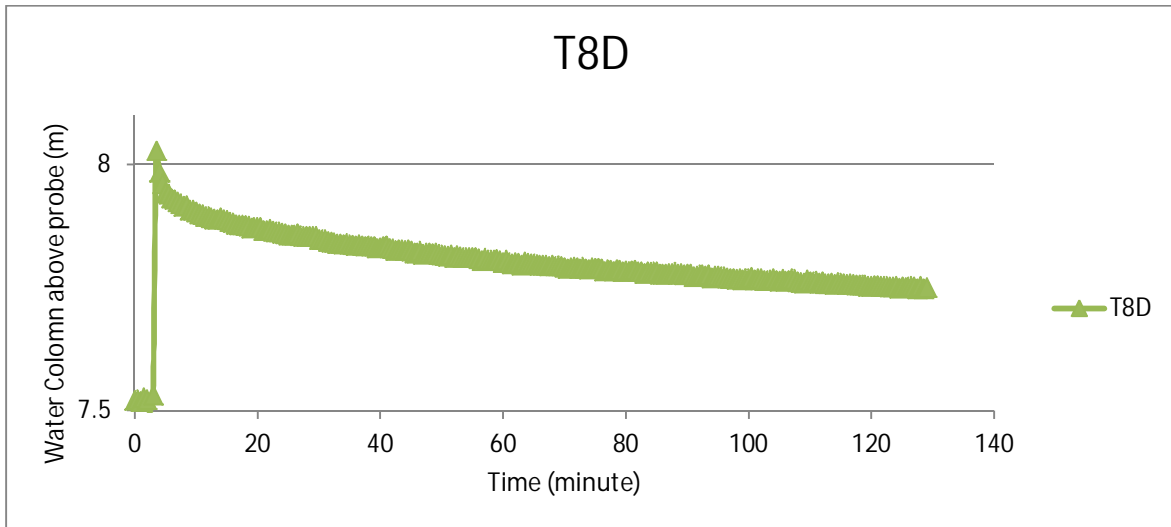
## 11.4 Appendix D Soil analysis results

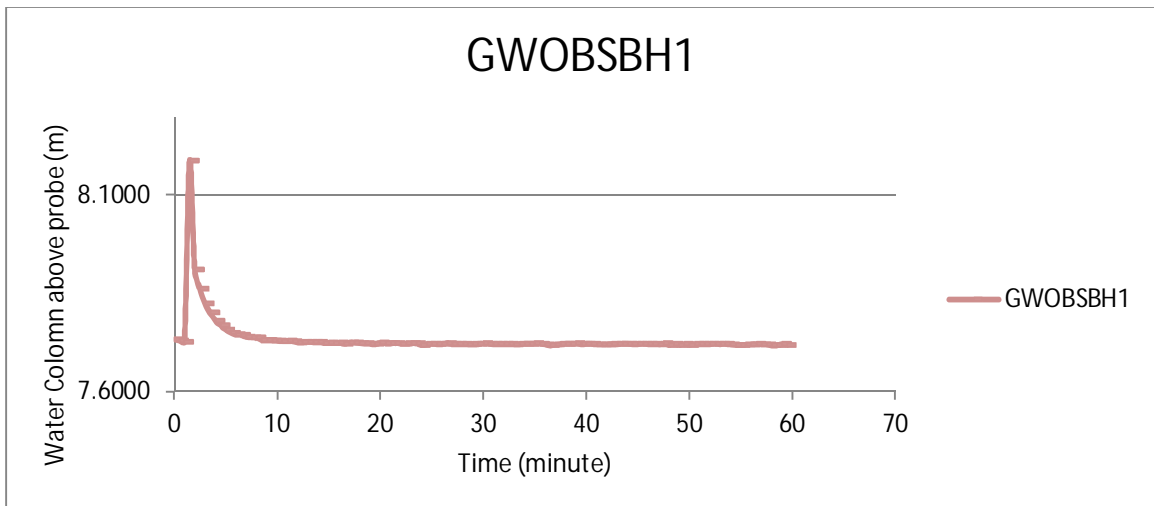
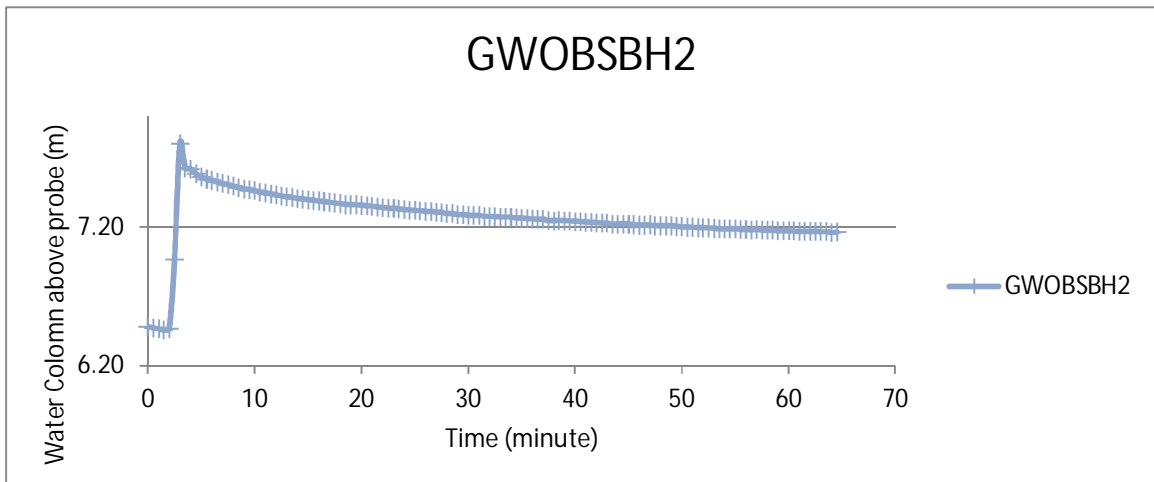
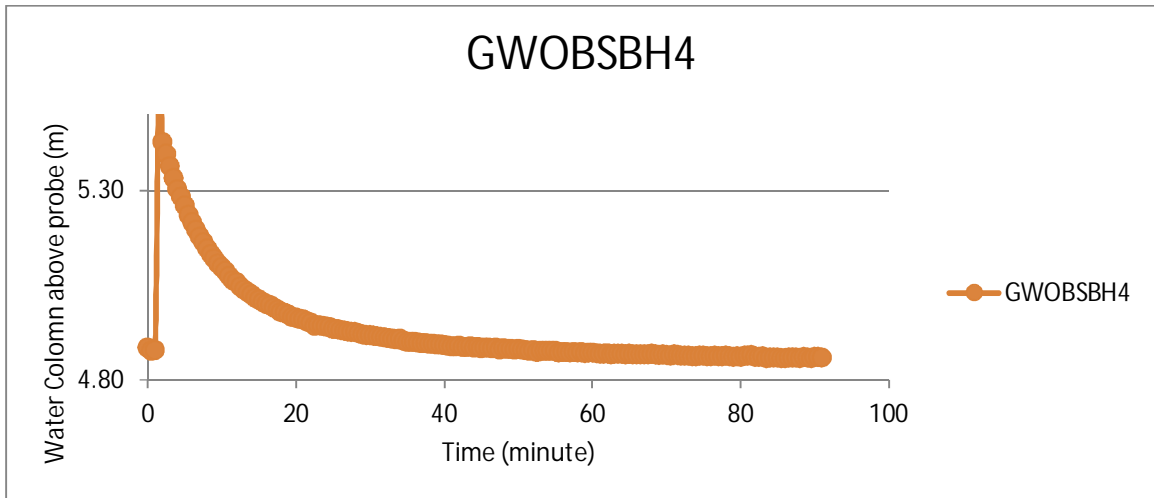
## 11.5 Appendix E Groundwater quality results



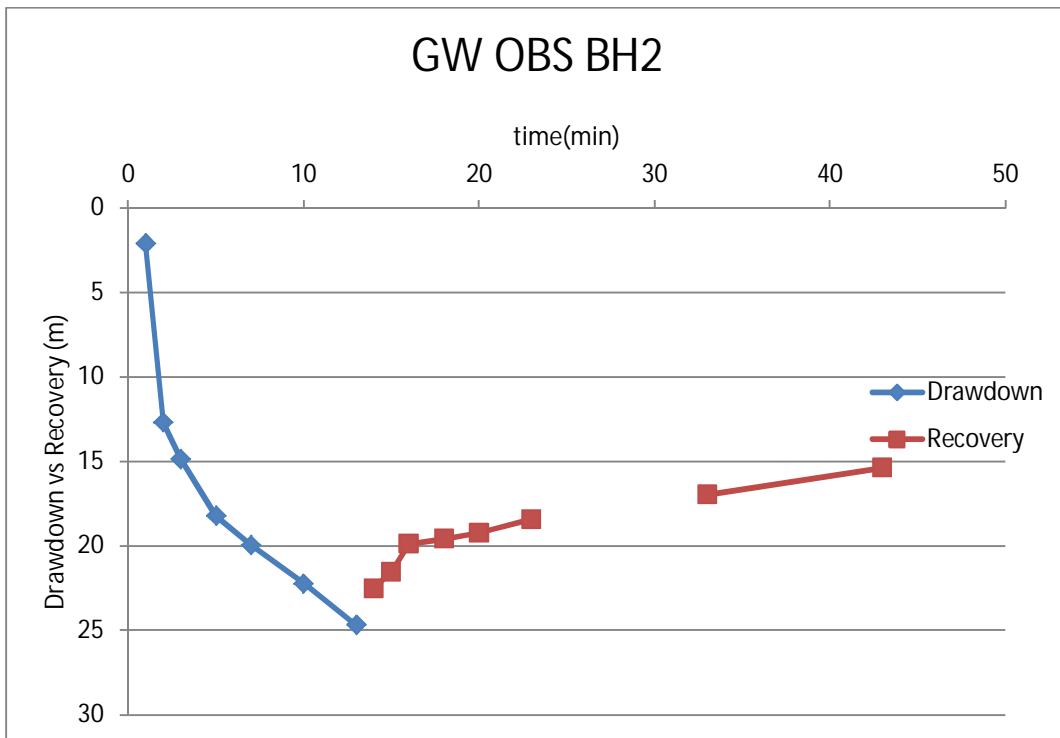
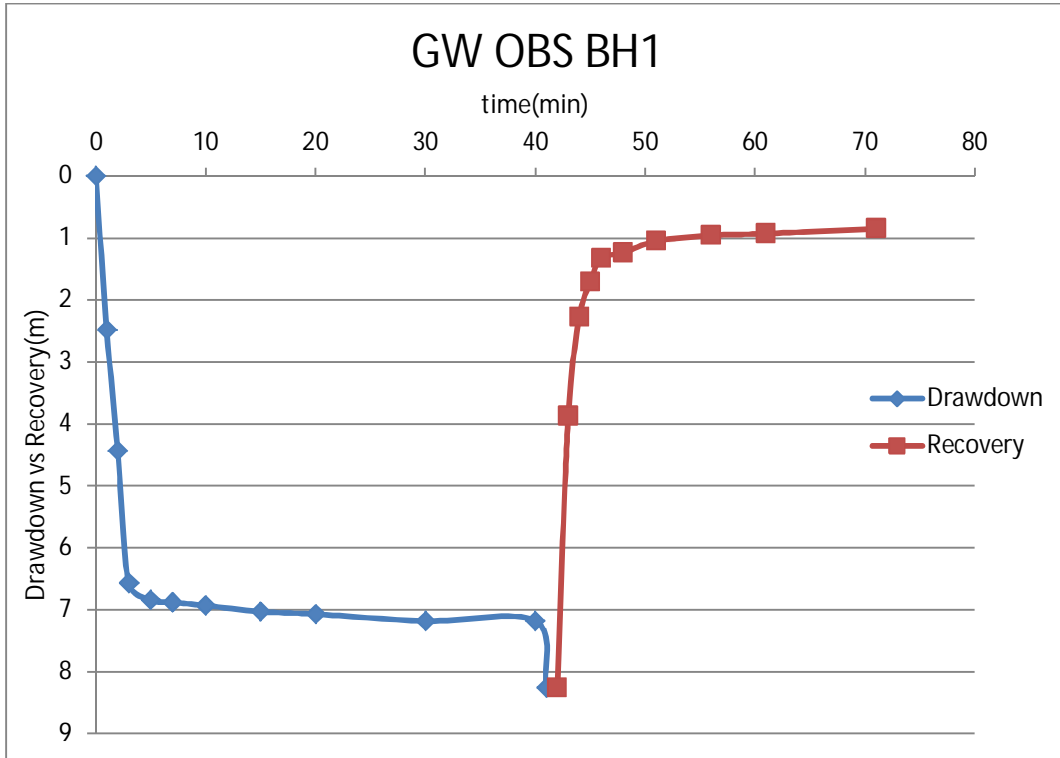
## 11.6 Appendix F: Slug test results

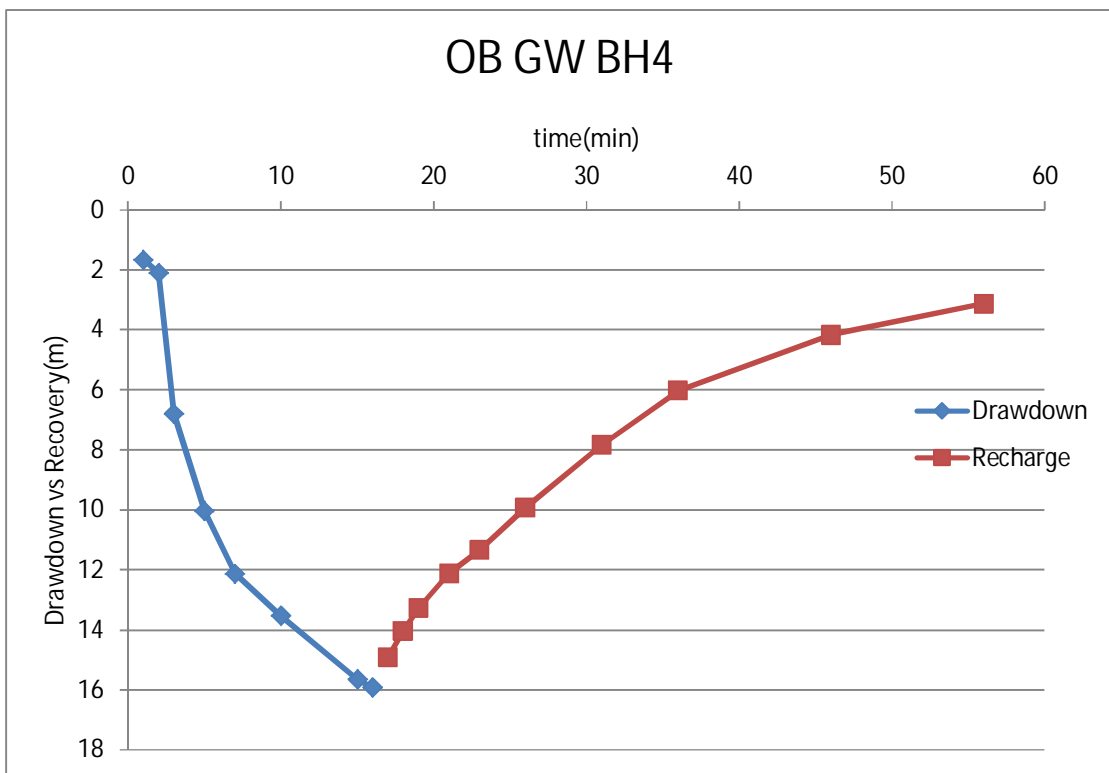
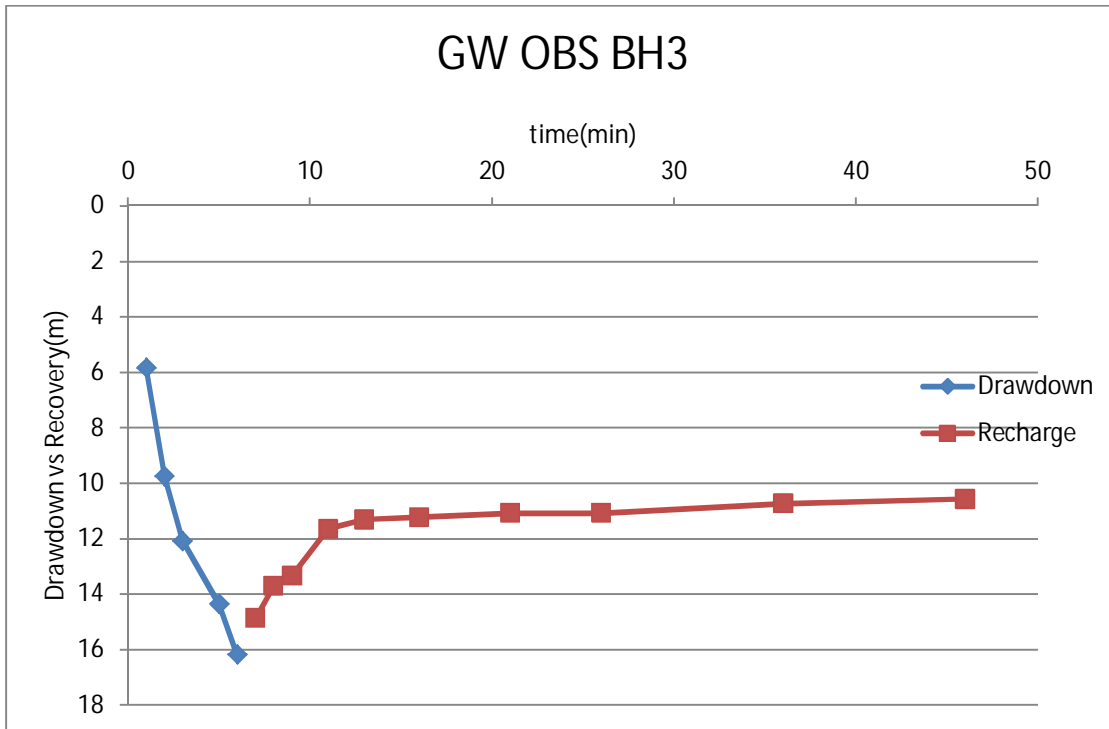


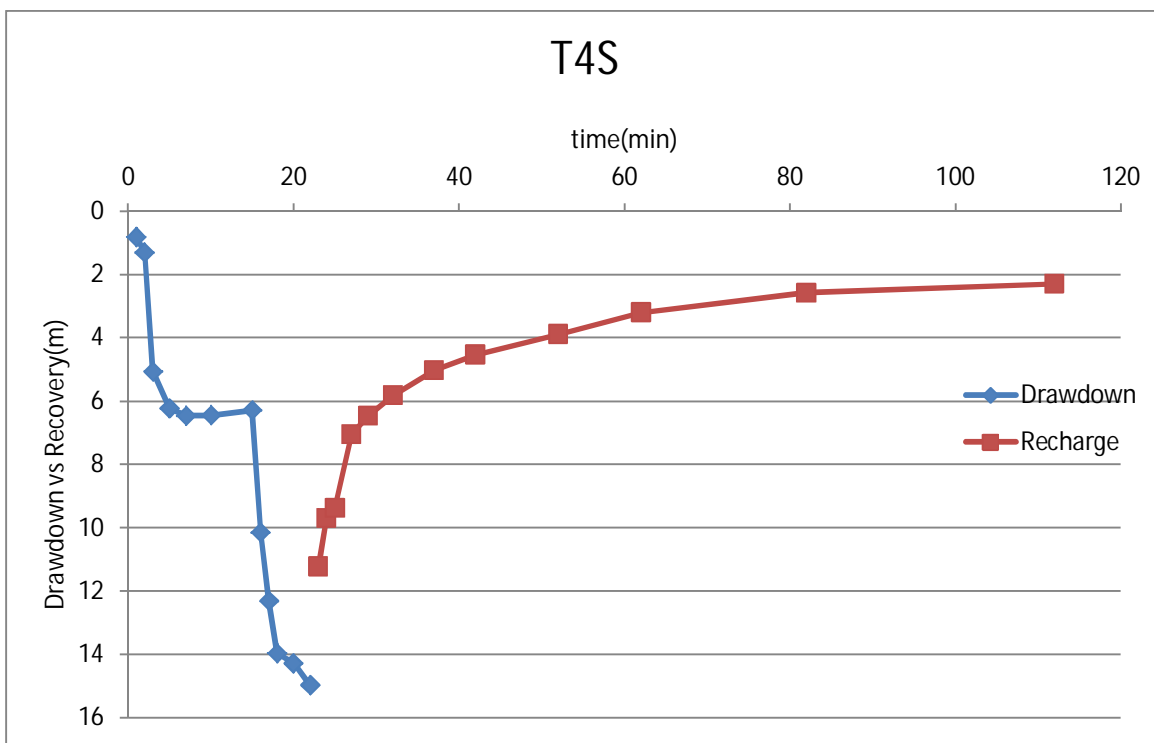
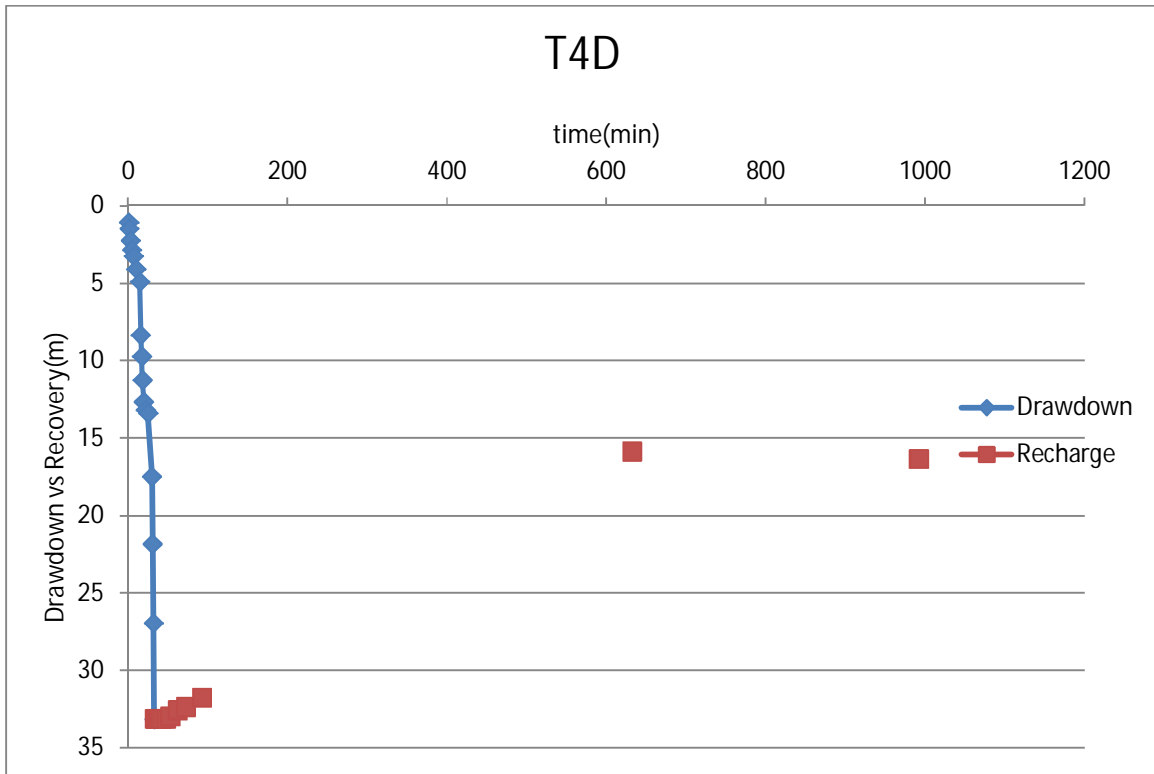


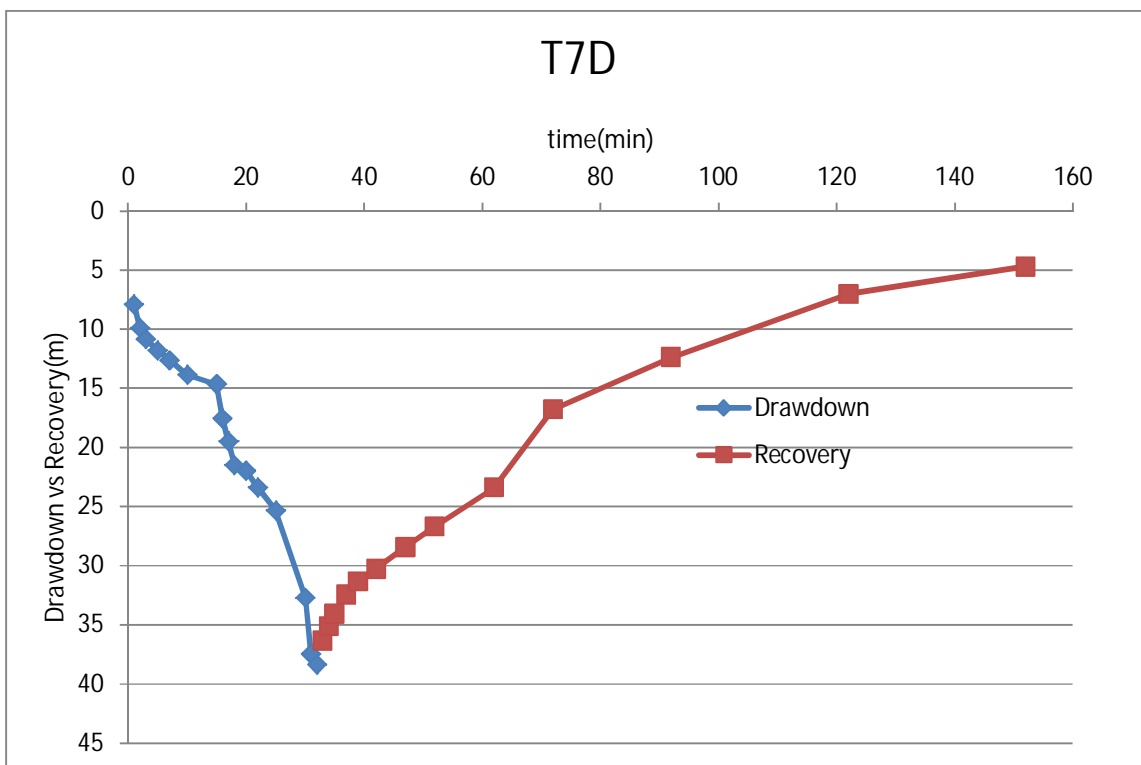
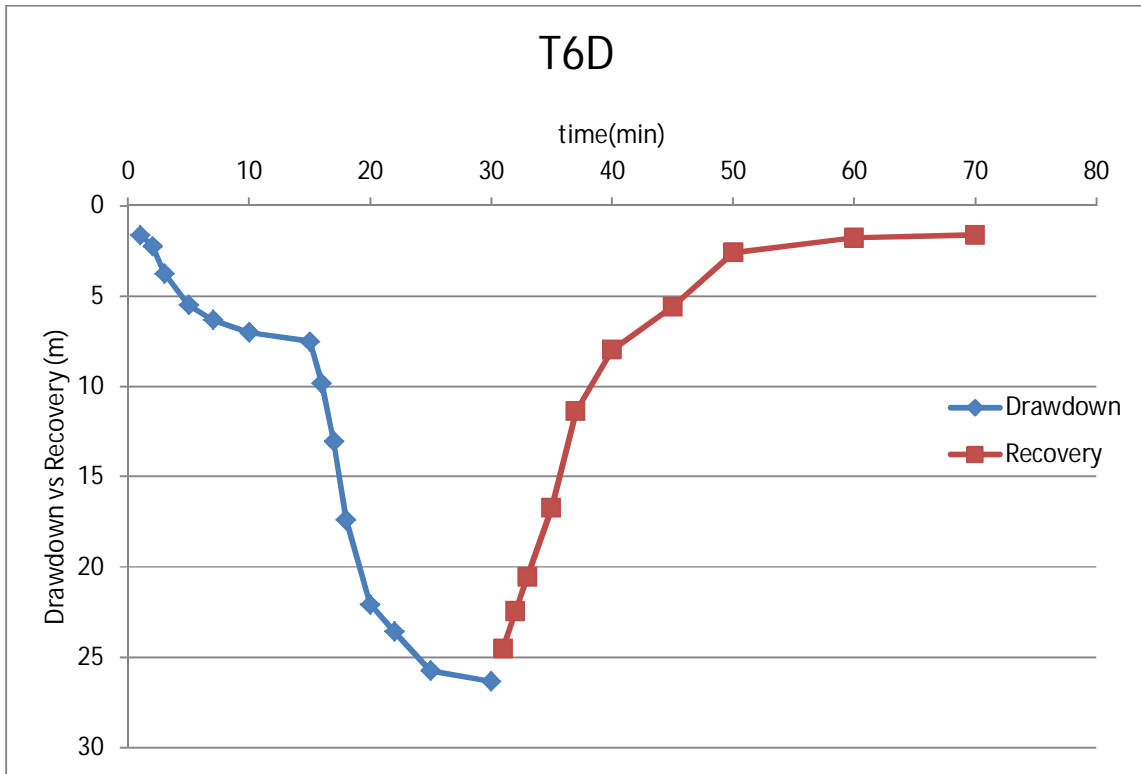


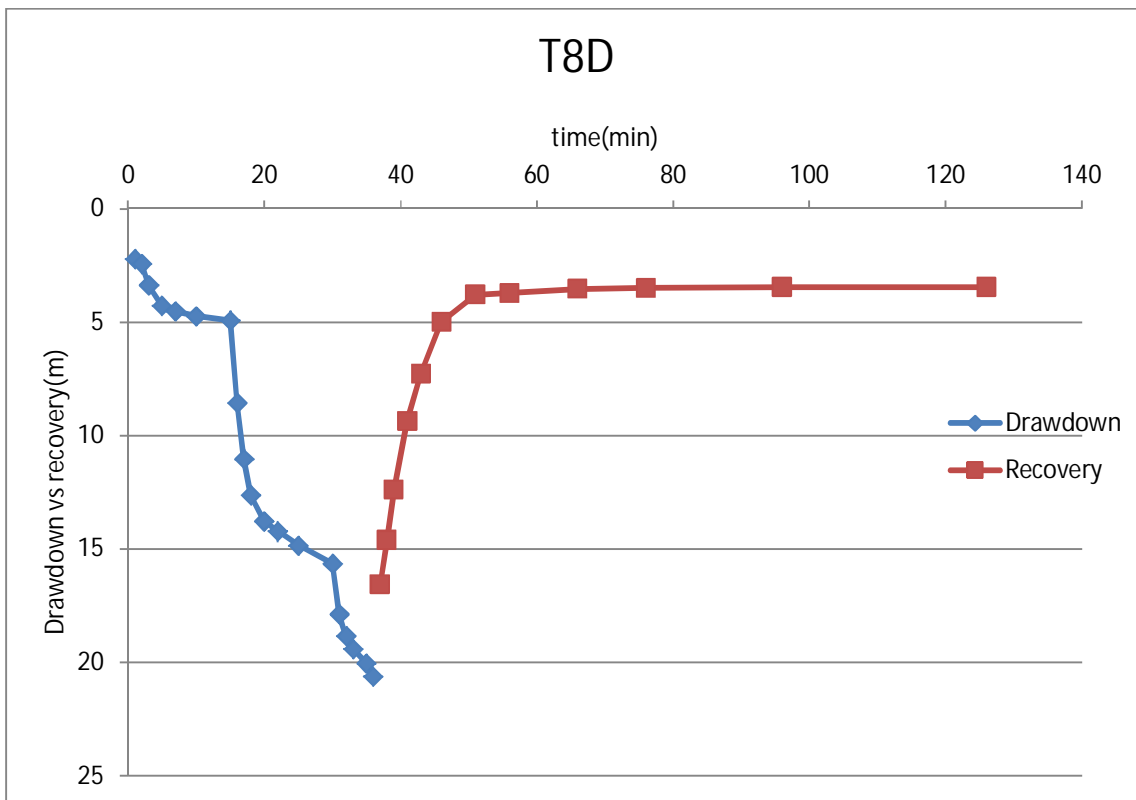
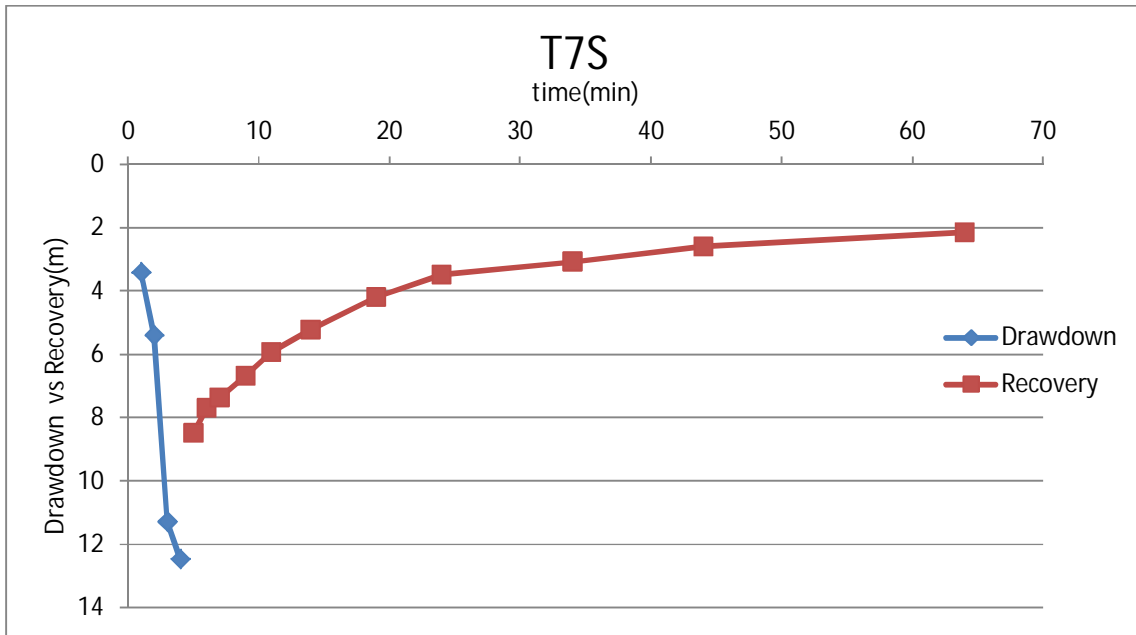
### 11.7 Appendix G Calibration test results





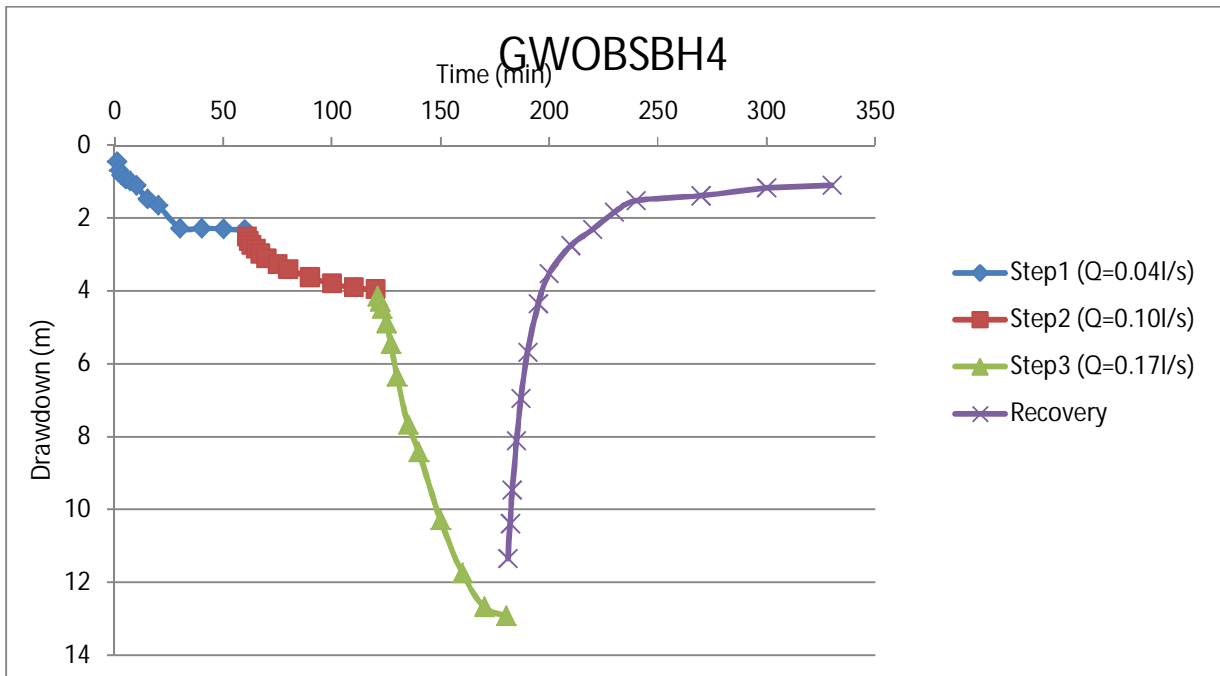
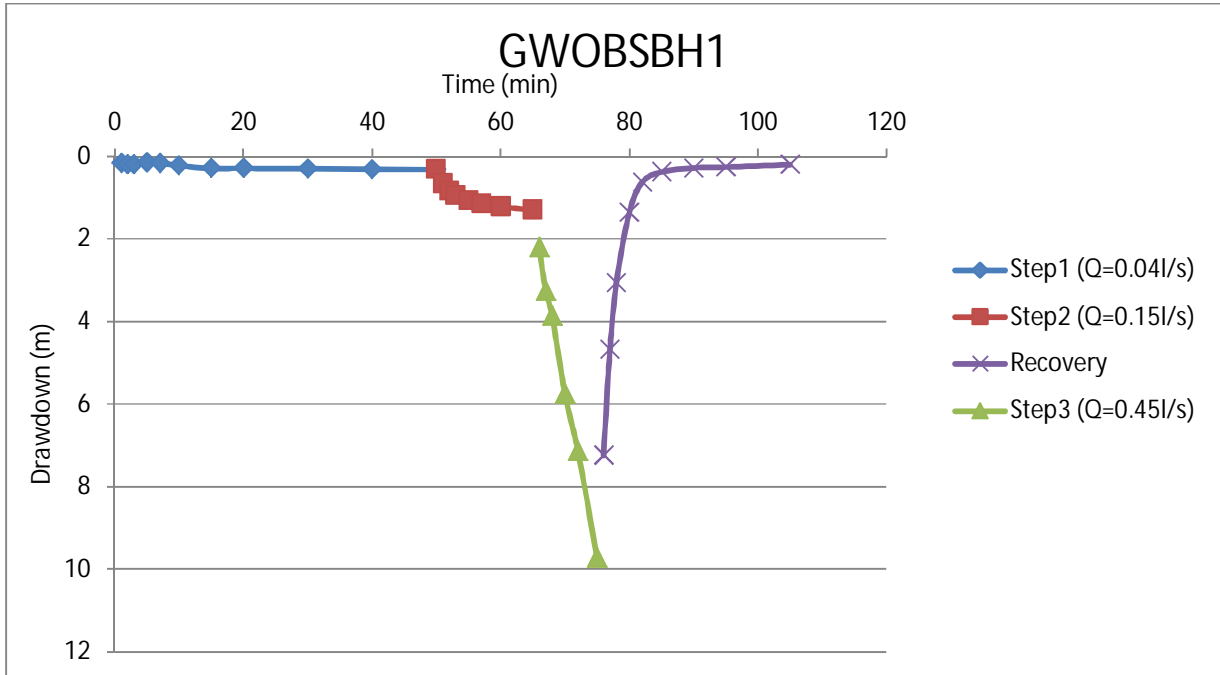


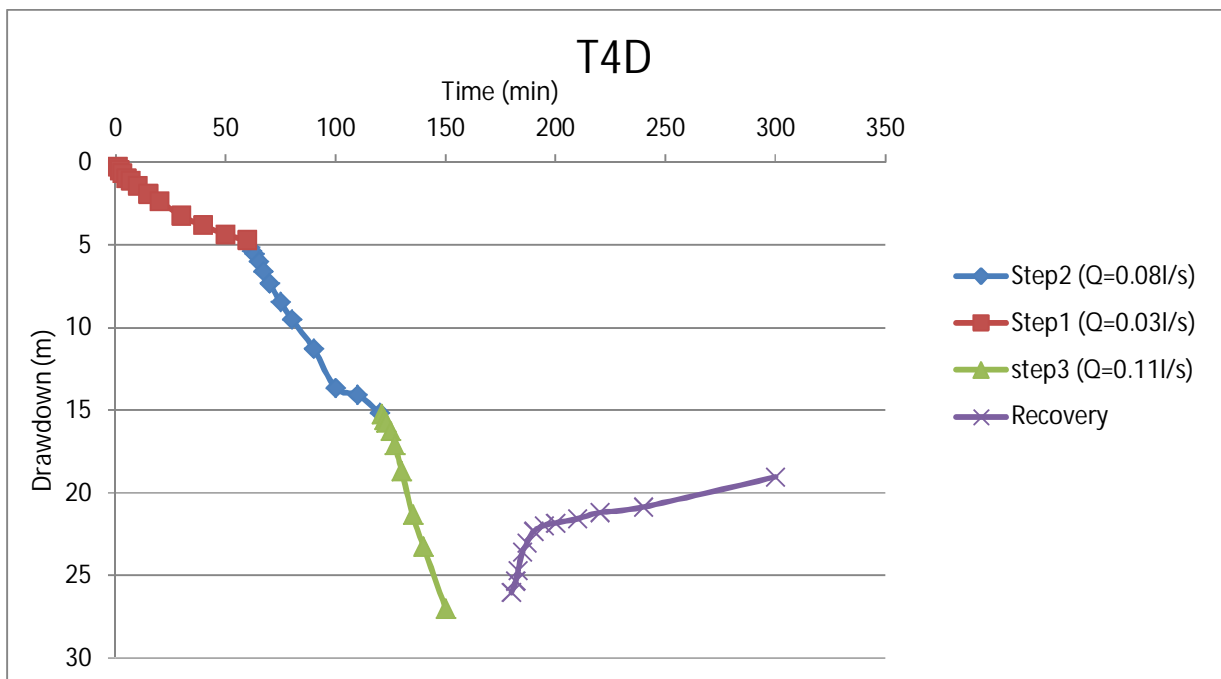
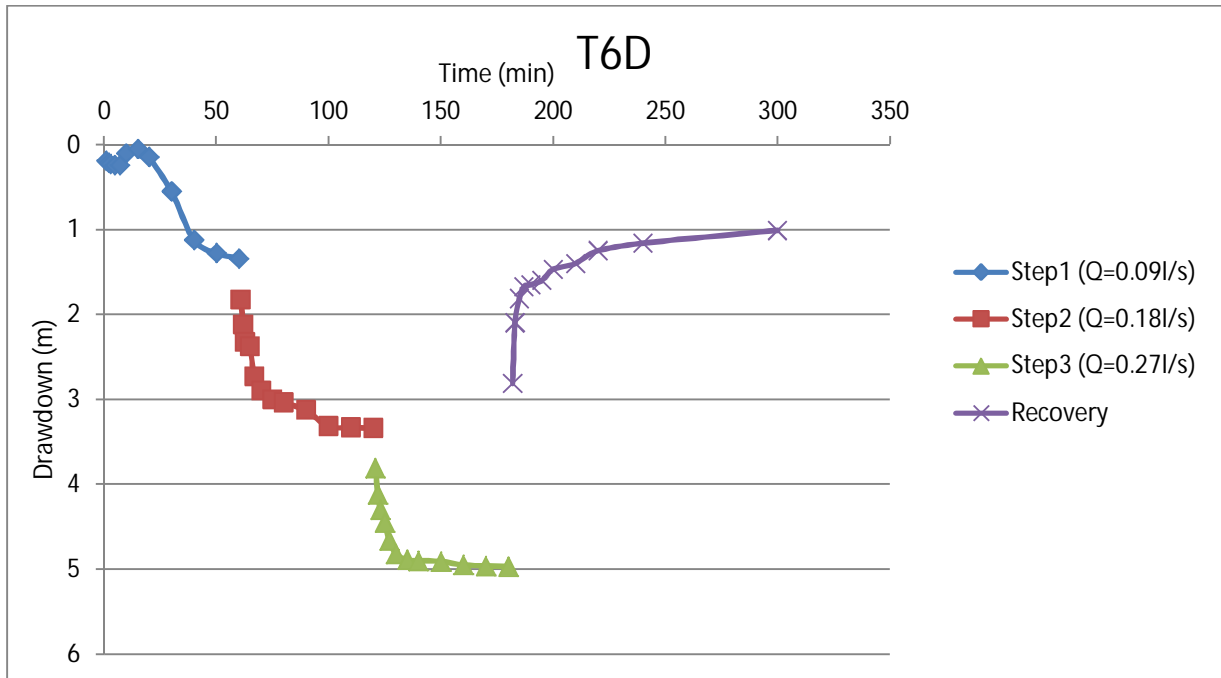






### 11.8 Appendix H: Step test results





## 11.9 Appendix I: Field activities' pictures



Calibration test using submersible pump



Clean water pumped from OB GW BH1



Water level measured in observation hole (while pumping the other hole)



Data recording during pumping test



Mono BP 12H RCL-50mm pump



Driver for Mono BP 12H RCL-50mm pump



Set up before commencing



Field yield recording

## 11.10 Appendix I: Impacts assessment methodology

Environmental impacts which could result from the project activities are described in this section. The following terms are used in describing the environmental impacts:

- Environmental issues – an “environmental issue” is an environmental concern encompassing a number of similar or related impacts that have been grouped under the issue heading;
- Environmental impact – a discrete (definable) interaction between a project activity and one or more components of the environment (biophysical and social);
- Natural and existing mitigation – natural conditions, conditions inherent in the project activities and existing management measures that alleviate (control, moderate, curb) impacts;
- Significance – the significance of the unmanaged and managed impacts is assessed through the consideration of the probability of the impact occurring, the extent of the area over which the impact will be experienced, the timing of the onset and the duration of the impact, and the intensity/severity of the impact.

The environmental impact assessment has been undertaken according to SRK Consulting’s standard criteria for impact assessment which are detailed below.

The first stage of impact assessment is the identification of environmental activities, aspects and impacts. This is supported by the identification of receptors and resources, which allows for an understanding of the impact pathway and an assessment of the sensitivity to change.

The above terms, used in relation to significance, are defined in Table 9-1. The cut-off points have been defined in relation to characteristics of mining, but those for Probability, Severity/Intensity and Significance are subjective, based on rule-of-thumb and experience.

The significance of the impact is then assessed by rating each variable numerically according to defined criteria as outlined in Table 9-1. The purpose of the rating is to develop a clear understanding of influences and processes associated with each impact. The severity, 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 occurring and can obtain a maximum value of 10. The values for likelihood and consequence of the impact are then read off a significance rating matrix as shown in Figure 9-1.

The results are tabulated for each identified impact. In the tables, a negative significant rating (results) indicates a negative impact while a positive rating indicate a positive impact, or benefit.

The assessment of significance has been undertaken twice. Initial significance should be based on only natural and existing mitigation measures (including built-in engineering designs). The subsequent assessment takes into account the recommended management measures required to mitigate the impacts.

Some of the specialist consultants have used variations of these procedures.

**Table 9-1: Criteria for assessing 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
Project specific (within the project boundary)	2
Local area (within 5 km of the activity boundary)	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 decommissioning / 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

**Figure 9-1: Significance Rating Matrix**

		CONSEQUENCE (Severity + Spatial Scope + Duration)														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
LIKELIHOOD (Frequency of activity + Frequency of impact)	1	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
	2	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60
	3	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90
	4	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120
	5	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
	6	12	24	36	48	60	72	84	96	108	120	132	144	156	168	180
	7	14	28	42	56	70	84	98	112	126	140	154	168	182	196	210
	8	16	32	48	64	80	96	112	128	144	160	176	192	208	224	240
	9	18	36	54	72	90	108	126	144	162	180	198	216	234	252	270
	10	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300

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**Table 9-2: Positive / negative migration ratings**

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

The impacts described below under the various environmental components are assessed for the different phases of the project, from preconstruction through to decommissioning and closure.