Environmental Impact Assessment for Sibanye Gold Limited's West Rand Tailings Retreatment Project

Groundwater Impact Assessment Report

Project Number:

GOL2376

Prepared for:

Sibanye Gold Limited

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I, Dr Robel Gebrekristos, as duly authorised representative of Digby Wells and Associates (South Africa) (Pty) Ltd., hereby confirm my independence (as well as that of Digby Wells and Associates (South Africa) (Pty) Ltd.) and declare that neither I nor Digby Wells and Associates (South Africa) (Pty) Ltd. have any interest, be it business, financial, personal or other, in any proposed activity, application or appeal in respect of Sibanye Gold Limited, other than fair remuneration for work performed, specifically in connection with the proposed West Rand Tailings Retreatment Project, Gauteng Province.

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EXECUTIVE SUMMARY

Sibanye Gold Limited is planning to re-mine historical Tailings Storage Facilities (TSFs) in the West Rand area. The resultant tailings will be deposited on a modern tailings storage facility (TSF) called the Regional TSF (RTSF).

This groundwater study is conducted to evaluate the potential impact and management plans related to the groundwater environment arising from the reclamation of the historical TSFs and deposition at the proposed RTSF. The study was conducted following a desktop study, hydrocensus, geophysical surveying, borehole drilling, aquifer testing, and numerical modelling.

The main findings that are relevant to the historical TSFs include:

- The existing historical TSFs are either located directly on dolomitic strata or on the Transvaal sequence that overlie the dolomite;
- These TSFs are all unlined; and
- Although a short-term acid generation during operation can occur due to the TSF disturbance and exposure to oxygen and moisture, the impact on groundwater as a result of the reclamation is anticipated to be positive in the long run since the TSFs, which are potential sources of contamination, will be removed.

The main findings in the area of the RTSF include:

- There is no dolomitic risk in the area of the RTSF, since the dolomite is found at a depth of more than 1 km below surface;
- The baseline groundwater quality is good, with uranium concentrations below the detection limit (<0.004 mg/L). The baseline sulfate concentration is less than 32 mg/L in all of the hydrocensus boreholes. This is well below the River Quality Objective (RQO) of 500 mg/L;
- The main elements of concerns that are expected to seep from the RTSF are sulfate and manganese, although arsenic, uranium and iron can be expected;
- In the area of the RTSF, the hydraulic gradient is approximately 0.0051. The average permeability of the top aquifer is 0.207 m/d and that of the deeper fractured aquifer some 30 m below the top aquifer is 0.180 m/d. The average groundwater flow velocity along the weathered zone (top aquifer) is therefore 0.001 m/d and in the fractured aquifer is 0.0009 m/d;
  - Considering the RTSF length of 3000 m, this is equivalent to a flow rate of 75 m^3/d in the top aquifer and 67.5 m^3/d in the fractured aquifer.
  - The average TDS of the boreholes in the vicinity of the RTSF is 201.4 mg/L. This corresponds to a salt load of 15.1 kg/d in the top weathered aquifer and 13.6 kg/d in the fractured aquifer.

- Groundwater flow mimics the topography and is towards surface water drainage courses as baseflow; generally from the northwest to southeast. Overall the local streams are fed by the groundwater and are at risk if the groundwater is contaminated;
- Seepage from the RTSF, without mitigation can negatively influence the groundwater quality in the underlying aquifers during operation and after closure;
- Contamination plumes are expected to reach approximately 2 km down-gradient (towards southeast) and can potentially impact private boreholes if no mitigation is undertaken; and
- Seepage from the RTSF can also impact the Leeuspruit (located immediately to the north) and its tributary in the south. Once the plume reaches the stream, it can migrate at a faster rate compared to the speed of groundwater flow and could have a negative impact on the down-gradient riverine ecosystem and communities without mitigation.

A number of options have been considered to minimise the potential impact of the RTSF. The blast curtain design (or extended depth cut off perimeter drains) is the preferred option from a financial perspective, while the application of a liner system was the most effective, environmentally. The following measures are recommended for the blast curtain or extended cut off drain to effectively intercept and contain the contamination plume:

- It should be approximately 30 m deep (the depth will vary according to the underlying geology, but will target a cut off of the upper aquifer), especially between the RTSF and the Leeuspruit in the north and its tributary in south.
- The drain has to be at least 5 times more permeable than the aquifer, otherwise contaminants can migrate through more permeable weathered or fractures zones and will not be intercepted by the curtain. The drain permeability must be maintained at all times and should not be reduced due to silting.
- It does not matter from a groundwater perspective if the water is pumped from a blast curtain or scavenger wells as long as the recommended pumping rate is maintained and as long as these are within 100 to 200 m of the RTSF footprint area. The further the blast curtain from the RTSF footprint, the more water will have to be pumped out.
- For the blast curtain/extended depth cut off drain to work effectively, it has to pump approximately 120% of what will seep from the RTSF. This is because the curtain is also draining the outer periphery. The plume can escape away from the curtain if it is pumped at less than this.
- The blast curtain/extended depth cut off drain needs to be pumped continuously since any pooling can result in the migration of contaminants to the Leeuspruit (in the north of the RTSF) and its tributary (in the south of the RTSF) and decrease its efficiency. There is a potential of lowering of the water table due to the dewatering at the blast curtain. This, however, is local and is of lesser environmental concern as

compared to a pollution plume and will be mitigated by the re-introduction of treated water into the downstream section of the Leeuspruit from the Advanced Water Treatment Facility (AWTF), amounting to 120% of the seeped water (approximately 4,810 m^3/d) through the RTSF foundation.

- Another option of impact mitigation (other than the use of a blast curtain) would be the use of a liner. The application of a competent liner is expected to significantly reduce the seepage rate. Since contaminants are mainly transported by the flowing water, the reduction of seepage rate will also reduce the salt load that seeps from the RTSF to the groundwater to insignificant levels, even if the sulphides are not removed (by the acid plant). It should be noted that this is valid only if the liner remains competent even after closure and block seepages effectively, with no failures due to unforeseen circumstances.

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1 Introduction

There is a long history of gold and uranium mining in the broader West Rand area with an estimated 1.3 billion tonnes of tailings, containing in excess of 170 million pounds of uranium and 11 million ounces of gold. Sibanye Gold Limited (SGL) currently owns the majority of the tonnage and its gold and uranium content. SGL plans to ultimately exploit all these resources to develop a strong, long life and high yield surface business. Key to the successful execution of this development strategy is the West Rand Tailings Retreatment Project (WRTRP). The concept of the WRTRP is well understood with an 8 year history of extensive metallurgical test work, feasibility studies and design by a number of major mining houses. A pre-feasibility study (PFS) completed during 2013 for the WRTRP has confirmed that there is a significant opportunity to extract value from the SGL surface resources in a cost effective sequence.

The ultimate WRTRP involves the construction of a large-scale Central Processing Plant (CPP) for the recovery of gold, uranium and sulfur from the available resources. The CPP, centrally located to the West Rand resources, will be developed in phases to eventually treat up to 4mt/month of tailings inclusive of current arisings. The resultant tailings will be deposited on a modern tailings storage facility (TSF) called the regional TSF (RTSF).

1.1 Ultimate Project

Simplistically, SGL’s historical TSF holdings in the West Rand can be divided into:

- Kloof Mining Right area;
- Driefontein Mining Right Area;
- Cooke Mining Right Area; and
- Ezulwini mining Right Area.

Each of these areas contains a number of historical TSFs and will be reclaimed in a phased approach. The Driefontein 3 TSF together with the Cooke TSF will be reclaimed first. Following reclamation of Driefontein 3 TSF, Driefontein 5 TSF (Western Block) and Cooke 4 Dam South (C4S) (Southern Block) will be reclaimed.

- Kloof Mining Right Area includes: Kloof 1 TSF, Kloof 2 TSF, Leeudoorn TSF, Libanon TSF, Venterspost North and Venterspost South TSFs. Venterspost North and South TSFs will be processed with the concurrent construction of Module 2 float and gold plants. The remainder of the TSFs will be processed once Module 3 of the CPP has been constructed;
- Driefontein Mining Right Area includes: Driefontein 1, 2, 3, 4 and 5 TSFs. Once the Driefontein 3 and 5 TSFs have been depleted the remainder of the Driefontein TSFs, namely Driefontein 1, 2 and 4 TSFs, will be processed through the CPP;

- Cooke Mining Right Area includes: Cooke TSF and the Millsite Complex (38, 39 and 40/41 and Valley) TSFs. Millsite Complex will be processed with the concurrent construction of Module 2 float and gold plants; and
- Ezulwini mining Right Area includes: C4S TSF, which will be processed subsequent to Driefontein 3 and 5 TSFs and in parallel with the Cooke TSF.

Once commissioned the project will initially reclaim and treat the TSFs at a rate of 1.5 Mt/m (1Mt/m from Driefontein 3 TSF (followed sequentially by Driefontein 5 and C4S TSFs) and 0.5 Mt/m from Cooke TSF). Reclamation and processing capacity will ultimately ramp up to 4 Mt/m over an anticipated period of 8 years. At the 4Mt/m tailings retreatment capacity, each of the blocks will be reclaimed and processed simultaneously.

The tailings material will be centrally treated in a CPP. In addition to gold and uranium extraction, sulfur will be extracted to produce sulphuric acid, an important reagent required for uranium leaching.

To minimise the upfront capital required for the WRTRP, only essential infrastructure will be developed during initial implementation. Use of existing and available infrastructure may be used to process gold and uranium until the volumetric increase in tonnage necessitates the need to expand the CPP.

The authorisation, construction and operation of a new deposition site for the residue from the CPP will be located in an area that has been extensively studied as part of the original West Wits Project (WWP) and Cooke Uranium Project (CUP). The deposition area on which the project is focussing has been termed the RTSF and is anticipated to accommodate the entire tonnage from the district. The RTSF, if proved viable will be one large facility as opposed to the two independent deposition facilities proposed by the WWP and CUP respectively.

1.2 Initial Implementation

Due to capital constraints in developing a project of this magnitude, it needs to be implemented over time. The initial investment and development will be focused on those assets that will put the project in a position to partially fund the remaining development.

This entails the design and construction of the CPP (gold module, floatation plant, uranium plant, acid plant and a roaster), to retreat up to 1.5 Mt/m from the Driefontein 3 and 5 TSFs, C4S TSF and the Cooke TSF. Driefontein 3, 5 and C4S TSFs will be mined sequentially over 11 years, whilst the Cooke TSF will be mined concurrent to these for a period of 16 years. The resultant tailings will be deposited onto the new RTSF.

A high grade uranium concentrate, produced at the CPP, will be transported to Ezulwini (50k tonnes per month) for the extraction of uranium and gold. The tailings from this process will be deposited on the existing operational Ezulwini North TSF.

The CPP and RTSF are likely to be the two components of the project with potential significant impacts and will be developed as the project matures. The CPP will be developed over a period of approximately eight years, however the EIA process and impact assessments are applying for it to be authorised as an entirety. The decision to take this approach, as opposed to authorising it in stages over eight years, is to provide the regulators and the public with an impact assessment that takes the whole project into consideration. The same logic is applied to the RTSF. It will be developed in two phases over the life of the project although the entire footprint is assessed from an environmental impact perspective.

1.3 Terms of Reference

The groundwater assessment was undertaken within the scope of work outlined below:

- Desktop study: This phase involved a review of available hydrogeological, geochemical and geological data of the historical TSFs and proposed RTSF area.
    - Available data was selected and stored into a Windows Interpretation System for Hydrogeologists (WISH) database. This was later used to develop a site conceptual model that was used for numerical modelling, impact assessment and mitigation planning.
    - The desktop study included a baseline screening assessment of the historical TSFs that will be re-mined as part of this project. This was conducted to evaluate the current groundwater conditions at each of the TSFs and predict the potential impact of the proposed reclamation.
- Hydrocensus: A hydrocensus was conducted within a 5 kilometre (km) radius of the proposed RTSF footprint and surveyed existing boreholes (community, mine monitoring and private boreholes). This was carried out to define the current groundwater usage in the area, as well as to gain information on activities and general groundwater related infrastructure.
- Geophysical Survey: Available aeromagnetic data that covers the RTSF was interpreted for the delineation of dolerite dykes and/or other geological structures that could potentially control the groundwater flow. In areas of uncertainty, a ground magnetic and electromagnetic survey was conducted to refine the structural analysis and delineate the suspected dykes and fold hinge zone with more accuracy.
- Percussion Drilling: Based on the interpretation of the geophysical survey, site geology and RTSF plan, 14 percussion boreholes were drilled. The drilling programme was aimed at refining the hydrogeological understanding of the site.
- Aquifer Testing: The most strategic and successful boreholes drilled during this investigation were aquifer tested to determine responses and to calculate the

parameters presenting the aquifer hydro dynamics underlying the RTSF investigation area.

- Numerical Model: A local numerical model was developed and used as a tool for the groundwater impact predictions. Transient state simulation was conducted to quantify the impacts of the proposed RTSF on the local aquifers and receptors over time (construction, operational, decommissioning and post-closure phases). Impacts on the streams, private boreholes and farms were also addressed. The numerical model was also used as a dynamic tool to test the effectiveness of recommended management and mitigation options, inducing the positioning of the proposed blast curtain and monitoring boreholes.
- Impact Assessment: The model output was used to assess the potential impact of the proposed mining activities on the groundwater and nearby streams during the entire life of the project. In this phase, the environmental impacts are rated based on their significance scoring before and after mitigation methods are implemented.
- Impact Mitigation: The recommended mitigation and management options to further minimise environmental impacts on the groundwater environment are addressed in this phase.

2 Details of the Specialist

The groundwater impact assessment was conducted by Dr Robel Gebrekristos. Robel is a senior groundwater modeller and the hydrogeology unit manager at Digby Wells, with more than 13 years of experience, both as a corporate consultant and a researcher. He achieved his Doctorate in Hydrogeology in 2007 from the University of the Free State.

Robel’s experience with groundwater modelling includes using finite difference (PMWIN and VMOD) and finite element (FEFLOW) software packages, tailings seepage modelling (using SEEP/W), water balance evaluations (using GoldSim or Excel Spreadsheet), hydrogeological database management, appraisals of mining and industrial impact assessments, and monitoring and analysis of contaminants (both organic and inorganic) in groundwater.

Robel has solid background on GIS mapping and is familiar with Surfer, QGIS, ArcGIS, Global Mapper, Map Source, WISH and Sketchup 3D modelling. He is competent in VB.net and C++ computer programming and is able to design databases. Robel has written more than 10 papers and documents on his field of expertise.

Recent assignments include various hydrogeological specialist and EIA investigations for mining and industrial projects in South Africa and other African countries. Robel was the principal groundwater modeller for the EIA study of the Geluksdal TSF in 2012 (located proximately 1.7 km south of the RTSF) and Doornfontein TSF in 2009 (located approximately 1 km northeast of the RTSF). In conjunction with other EIA specialists, Robel was instrumental in assessing the EIA when Gold One and Gold Fields were in the process of obtaining the environmental authorisations for the respective TSFs.

The Declaration of Independence and CV of the specialist is attached in Appendix A.

3 Aims and Objectives

The objectives of the groundwater investigation for the WRTRP and proposed RTSF are to:

- Provide a baseline assessment of the groundwater conditions of the historical TSFs from existing monitoring data from the mine.
- Predict the potential positive impact as a result of the re-mining of the historical TSFs.
- Assess the positive impact of the removal of the historical TSFs on the groundwater flow and contaminant transport conditions.
- Investigate the present groundwater conditions at the proposed RTSF area (water levels and quality). This represents the baseline groundwater conditions for the site considered for potential future liability claims and preparation to final closure application.
- Develop a conceptual and numerical model for the RTSF. This model forms the basis for the groundwater impact assessment, feeding into the overall EIA and IWULA applications.
- Assess the potential migration of groundwater contaminant plumes that might emanate from the proposed RTSF.
- Simulate the impacts on the nearby streams and boreholes (receptors) at the RTSF.
- Simulate mitigation options using the model, such as effectiveness of a blast curtain to minimise the long-term groundwater quality impacts at the RTSF.
- Simulate the post-closure fate and transport of contaminants at the RTSF.
- Recommend groundwater monitoring, management and pollution mitigation methods to minimise any potential impacts at the RTSF.

4 Methodology

The methodology followed to conduct the desktop study, fieldwork programmes, refine the groundwater conceptual model and develop a numerical model is discussed in this section. All coordinates in this report are expressed in Transverse Mercator Lo27 projection and WGS84 datum.

4.1 Literature Review and Desktop Assessment

The baseline assessment of the historical TSFs was conducted following a review of existing information, mainly from Golder (2009 and 2010) and ERM (2010). Other information reviewed includes:

- Existing monitoring data from the mine;
- The 1:250 000 Geological Map 2626 for the West Rand;
- The 1:500 000 Johannesburg Geohydrological Map;
- An explanation of a set of Groundwater maps by Vegter, 1995;
- Groundwater investigation Report for the Kloof No1 Slimes dam, 1998;
- DWS Guideline for the assessment, planning and management of Groundwater Resources within Dolomitic areas in South Africa, 2006;
- Hydrological/chemical aspects of the upper Wonderfonteinspruit, with specific reference to the impact water, pumped from the western basin mine void, 2006;
- Kloof Underground Mine Impact Assessment, 2006;
- Environmental Management Plan (EMP) Amendment for South Deep Mine, 2007;
- Acid Mine Drainage Report done by the Institute for Groundwater Studies (IGS), 2008;
- Cooke 4 Shaft Geohydrological Assessment of the Underground Mining Extension, 2013;
- SibanyeAmanzi Project Integrated Water Modelling Final Report, 2013;
- Cooke 4 Shaft Geohydrological Assessment of the Cooke 4 Tailings Dam, 2014; and
- Groundwater Monitoring at the Sibanye Pits, Randfontein, 2015.

The following reports and data were reviewed by Digby Wells in the area of the proposed RTSF. The total footprint of the RTSF was considered to ensure optimisation of the site for the ultimate tonnage capacity and deposition rate of 4 Mt/month:

- Digby Wells conducted a hydrogeological investigation in 2012 at the Geluksdal TSF and compiled a hydrogeological report (Digby Wells, 2012). This was conducted following the development of a site conceptual model and a groundwater numerical model. The Geluksdal TSF is 1.7 km south of the proposed RTSF site and located in similar hydrogeological conditions. The knowledge gained during this investigation was used to improve the hydrogeological understanding of the RTSF area.
- Golder conducted a hydrogeological investigation at the Geluksdal TSF site and compiled a hydrogeological report (Golder, 2009), as well as a preliminary

geochemical report (Golder, 2010). Both reports were reviewed as part of the desktop study. Related hydrogeological data that were also reviewed include:

  - Geophysical survey data;
  - Percussion drilling information of 28 boreholes, with half of them drilled to a shallow depth to investigate the existence of a shallow aquifer and the remaining 14 boreholes drilled to greater depth to investigate deeper aquifers; and
  - Aquifer and slug testing data of the 28 boreholes.

- ERM conducted a hydrogeological investigation at Gold Field's Doornpoort TSF (ERM, 2010). The TSF is approximately 1 km northeast of proposed RTSF and the aquifer systems of the two sites are assumed to be similar due to the geological and geographical similarities. The Gold Fields hydrogeological data include:
  - Hydrocensus data that covers up to the proposed Geluksdal TSF;
  - Geophysical survey data that was restricted to the Gold Fields CTSF area;
  - Percussion drilling information that was restricted to the Gold Fields TSF area;
  - Aquifer test data; and
  - Numerical model data.
- Digby Wells gathered available groundwater data from the National Groundwater Archive (NGA) and was utilised to calibrate the steady state numerical model.

4.2 Fieldwork and Seasonal Influence

4.2.1 Hydrocensus

Digby Wells conducted a hydrocensus within a 5 km radius of the proposed RTSF footprint. The investigation focused on a groundwater baseline assessment in the proximity of the proposed RTSF. The hydrocensus result was combined with that of the 2012 data collected by Digby Wells (2012) as part of the Geluksdal TSF study and data collected by ERM (2010) for the Gold Field's CTSF.

The survey, shown in Figure 4.1, covered all available environmental and monitoring boreholes, as well as community owned boreholes to obtain current ownership, water level and groundwater quality information. The hydrocensus was also conducted to obtain information on the current water quality, water use, site conditions and the location of each borehole. Information on volumes used is also recorded whenever available as listed in Appendix B. This will be used as a baseline reference when compared to potential future impacts of the proposed RTSF on the groundwater environment.

The hydrocensus was conducted in two parts due to land access restrictions. The first part was completed over a period from 14 January to 04 February 2015 and was conducted within a radius of 2 km. The second site assessment was conducted between 09 and 12 June 2015 and covered the zone between 2 and 5 km from the proposed RTSF. These results were interpreted in line with the wet and dry season hydrocensus data conducted for the Geluksdal TSF and Gold Fields CTSF to evaluate if the dilution effect of the rainy season has any impact on the groundwater chemistry, which was found to be insignificant.

To locate and access all known boreholes and surface water sites in the area, the relevant owners/lessee's were visited by Digby Wells and the land owners/lessee's then assisted in locating the sites. The coordinates of each site were recorded on a handheld Garmin GPS. The equipment and borehole protection was noted and recorded. Access for the dip meter was determined and the water level was measured where possible. The water use for the borehole was recorded after interviewing the land owner.

Groundwater samples were collected from 15 boreholes. The sites selected for sampling were chosen in an attempt to best represent the area within and bordering the proposed RTSF site. Samples were taken using single valve, decontaminated bailers, in the case of accessible boreholes, and from pumps or taps in the case of boreholes which were in use, in which case a grab sample was taken. Standard 500 millilitre (ml) sample bottles were used and filled to the top. Samples were delivered to M&L Laboratory in Johannesburg for analysis.

The details of the hydrocensus results are given in Appendix B. The laboratory certificates of the hydrocensus samples are given in Appendix C.

4.2.2 Geophysical Surveying

An aeromagnetic map of the project area (Figure 4.2) was interpreted for possible subsurface geological structures, such as dykes and fault zones.

Magnetic and electromagnetic ground geophysical surveys were also conducted in February 2015 along selected lines as shown in Figure 4.2. The surveys were conducted at 5 m station intervals to refine the aeromagnetic map resolution and identify small-scale geological anomalies.

Results of the airborne and ground geophysical assessments were used to position the new percussion boreholes for characterisation of the aquifer dynamics, as well as to monitor the groundwater conditions in the vicinity of the RTSF.

4.2.3 Borehole Drilling

Following the geophysical surveys and review of RTSF plans, 14 percussion boreholes were drilled for aquifer characterisation and baseline groundwater monitoring. These boreholes were assessed in conjunction with the existing boreholes drilled by Golder in 2009 for the Geluksdal TSF project and by ERM in 2010 for the CTSF project.

The position of the boreholes (both Sibanye and Gold One boreholes) in relation to the RTSF is shown in Figure 4.1 and listed in Table 4.1.

The drilling programme was carried out between 9 and 26 February 2015 and was supervised by Digby Wells. Drilling was performed using the rotary air percussion method with an outer diameter of 165 millimetre (mm). The boreholes were drilled between 20 and 80 m deep depending on the local geological structures.

The information recorded during drilling included:

- Lithological profile at 1 metre (m) intervals;
- Degree of rock weathering, as weathering may indicate groundwater content;
- Penetration rates;
- Positions of water strikes and corresponding blow yields;
- Details of the borehole construction;
- Rest groundwater level; and
- Final borehole blow yield.

The borehole construction details and hydrogeological conditions observed during drilling are provided in Appendix D.

Table 4.1: Coordinates of the newly drilled percussion boreholes

BH ID	X	Y	Z	BH depth (m)
SBNBH1	58656	-2930795	1542	80
SBNBH2	58935	-2930920	1538	40
SBNBH3	60340	-2929726	1545	80
SBNBH4	61724	-2929328	1529	20
SBNBH5	62284	-2930188	1521	20
SBNBH6	62864	-2930527	1516	80
SBNBH7	62880	-2930754	1517	20
SBNBH8	64201	-2931441	1509	80
SBNBH9	64122	-2931591	1508	20
SBNBH10	64767	-2932794	1503	80
SBNBH11	65125	-2934212	1500	80
SBNBH12	64602	-2935225	1496	80

BH ID	X	Y	Z	BH depth (m)
SBNBH13	59143	-2932460	1521	80
SBNBH14	59094	-2932402	1522	40
DM11	63089	-2935623	1495	70
DM12	63921	-2935830	1493	70
DM14	60251	-2934442	1503	70
DM3	61251	-2934456	1504	70
DM4	61282	-2934702	1498	70
DM5	61950	-2934447	1500	70
DM6	62305	-2934433	1502	70
DM7	61262	-2935060	1498	70
DM8	63123	-2934789	1499	70
SM11	63100	-2935623	1495	12
SM12	63915	-2935836	1493	12
SM14	60243	-2934442	1503	12
SM3	61301	-2934447	1504	12
SM4	61283	-2934678	1498	12
SM5	61960	-2934435	1500	12
SM6	62308	-2934431	1502	15
SM7	61262	-2935053	1498	18
SM8	63126	-2934780	1499	18

4.2.4 Aquifer Testing

Fourteen of the newly drilled boreholes were aquifer tested to calculate the hydraulic permeability and storativity values presenting the aquifer hydro-dynamics underlying the investigation areas.

Aquifer testing of the 14 boreholes was conducted as per the record listed in Table 4.2. In addition to this, the aquifer test data collected by Golder (2009) and ERM (2010) were also utilised for the aquifer characterisation.

Table 4.2: Aquifer test decision record of the tested boreholes

Borehole ID	Water level (m)	Water strike (m)	Yield of Water Strike (L/s)	Final blow yield (L/s)	Slug test	Step drawdown test	Constant discharge test
SBNBH1	16.17	27	0.9	0.9		X	
SBNBH2	11.20	31	-	seepage	X		

Borehole ID	Water level (m)	Water strike (m)	Yield of Water Strike (L/s)	Final blow yield (L/s)	Slug test	Step drawdown test	Constant discharge test
SBNB H3	6.45	21	2.5	2.5			X
SBNB H4	3.57	-	-	dry	X		
SBNB H5	3.78	-	-	dry	X		
SBNB H6	NA	15	0.5	0.5			
SBNB H7	3.59	-	-	dry	X		
SBNB H8	2.56	10	2.8	2.6			
SBNB H9	3.33	15	1.3	1.3			X
SBNB H10	3.85	21 and 56	0.3	0.3			X
SBNB H11	NA	15	1.5	1.5			
SBNB H12	NA	21	1	1			
SBNB H13	9.35	17	1.2	1.2			X
SBNB H14	5.37	21	-	seepage	X		

4.2.5 Numerical Modelling

A numerical model was developed to simulate the contamination plumes from the proposed RTSF at various stages of the life of the project.

The internationally recognised simulation package Processing Modflow Pro (PMWIN Pro), Version 8.0 (Chiang, 2005) was used to simulate groundwater flow. MODFLOW is a modular three-dimensional finite-difference groundwater model published by the U.S. Geological Survey. The flow module MODFLOW, PMWIN’s field interpolator package PMDIS and the parameter estimation program PEST were also used.

PMPATH is an advective transport model that runs independently from PMWIN Pro. Using a flow field computed by MODFLOW, PMPATH was used to track a set of fictitious particles to simulate the advective movement of particles through the aquifer (qualitative assessment).

MT3DMS is a modular three-dimensional transport model for the simulation of advection, dispersion, and chemical reactions of dissolved constituents (such as sulfate) in groundwater systems. MT3DMS was used in conjunction with MODFLOW in a phased flow and transport simulation approach.

4.2.6 Impact Assessment and Management Plan

The model output was used to assess the potential impact of the proposed RTSF on the groundwater environment. In this task, the environmental impacts are rated based on their significance scoring before and after mitigation methods are implemented.

The long-term fate and transport of the contamination plume is assessed as it spreads from the RTSF footprint for up to 100 years after closure.

Finally, the recommended mitigation and management options to further minimise environmental impacts on the groundwater environment are presented.

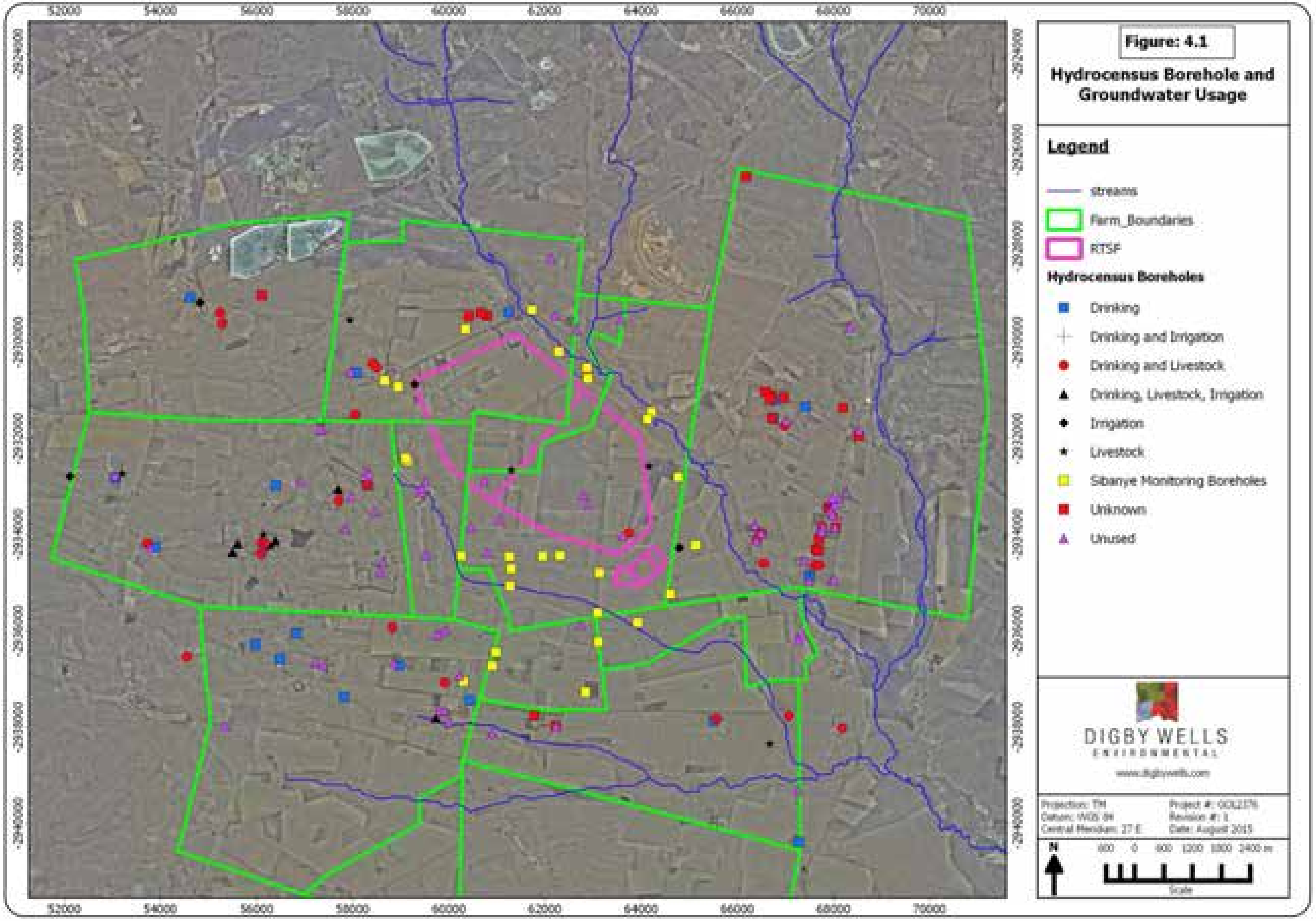


Figure: 4.1

Hydrocensus Borehole and Groundwater Usage

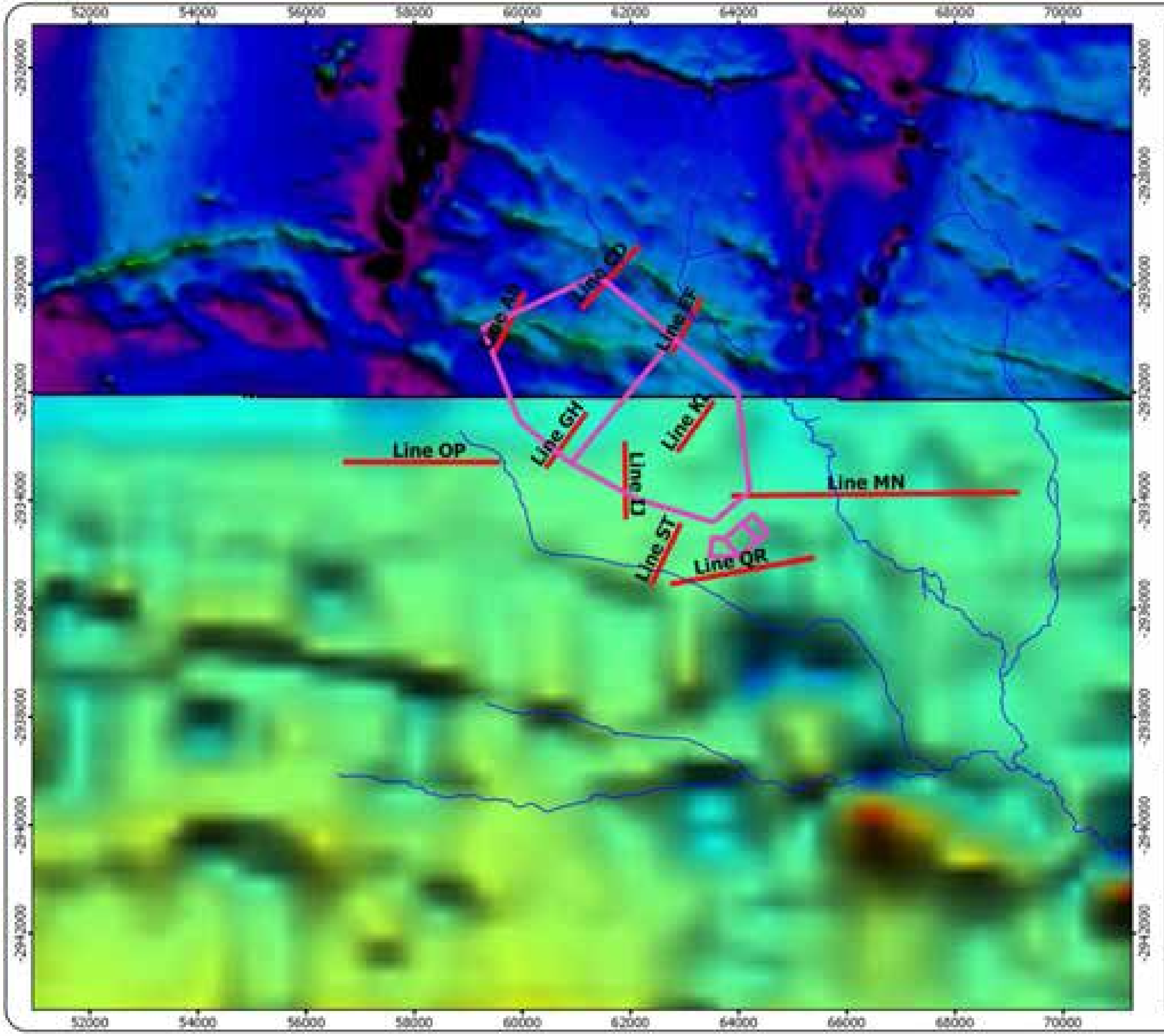


Figure: 4.2

Aeromagnetic Map and Ground Geophysical Survey Lines

Legend

Streams

RTSF

Geophysics Survey Lines

DIGBY WELLS
ENVIRONMENTAL

www.digbywells.com

Projection: TM
Datum: WGS 84
Central Meridian: 27 E

Project #: GOL2376
Revision #: 1
Date: Aug 2015

N

600 0 600 1200 1800 2400 m

Scale

5 Assumptions and Limitations

A numerical model was used to predict the potential impact of the RTSF on the groundwater environment. Numerical models are commonly used to simulate and develop hydrogeological management solutions, i.e. the prediction of contaminant plume migration, groundwater inflow rate and groundwater level changes over time. However, groundwater systems are often complex and the data input requirements are beyond current capability to evaluate in detail. A model, no matter how sophisticated, will never describe the investigated groundwater system without deviation of model simulations from the actual physical process (Spitz, 1996). Therefore, it is necessary to make some assumptions to simplify the complex, real world hydrogeological conditions into a simplified, manageable model.

All numerical modelling simulations require assumptions to be made during the translation of the numerical code into a site-specific model. These assumptions, which reflect data gaps in the conceptual model regarding the aquifer distribution and the aquifer parameters, can result in areas of uncertainty in the model output and predictions.

Based on the conceptual model a best approximation of the real world site conditions was simulated and calibrated with available information until a reasonable fit of simulated and measured data was obtained. A model sensitivity analysis was then carried out to give an indication of which assumptions in model input parameters were most likely to affect the model output.

The following assumptions have been made with regard to this groundwater investigation:

- All of the historical TSFs are assumed to be unlined;
- The life of the project is assumed to be 50 years;
- The Leeuspruit and its tributaries represent groundwater baseflow to the streams and were simulated as drains;
- It is assumed that the private boreholes, Leeuspruit and its tributaries are the main receptors of the potential contaminant plume at the RTSF area;
- Based on the geological composition of the site, an effective porosity and specific yield of between 0.03 and 0.02 were applied over the entire model domain;
- Recharge has been estimated from model calibration and varies between 0.5 to 1.5% of the mean annual precipitation;
- The closure phase of the RTSF is estimated to occur after 50 years of operation. During the closure phase the RTSF will be decommissioned, the deposition of tailings material will terminate and rehabilitated with proper covering. SLR (2015) has estimated the seepage rate from the RTSF during operation and 100 years after closure;

- Sulfate and Manganese are expected to be the main contaminants of concern at the RTSF site (SLR, 2015) and have been simulated in the mass transport model. Sulfate is a conservative element and is expected to mobilise at the same rate as groundwater flow. Mn is however a non-conservative element and will be retarded in the aquifer materials resulting in a reduced migration rate. In order to simulate the transportation of Mn, the retardation factor (R_f) needs to be determined for various geological units. R_f is defined as the ratio of the migration distance of the non-conservative substance to the migration distance of the conservative distance and is always between 0 and 1:
    - This property is site specific and references from literature will not reflect the hydrogeochemical conditions in the project area. In this study the retardation factor of Mn has been assumed to be 0.04. Model sensitivity has been done to evaluate the effect of this uncertainty on the size of the pollution plume;
    - Arsenic and Uranium are generally perceived to be contaminants of concern in the West Rand gold mines, although the seepage test conducted by SLR (2015) did not identify them to seep at levels of concerns. Regardless, both these elements have been simulated in this study and their results are given in Appendix E;
- The numerical model assumed that the blast curtain/extended cut off drains will be effective to intercept any plume that originates from the RTSF. For this to happen, the drain has to be at least 5 times more permeable than the aquifer. Otherwise, contaminants can migrate through more permeable weathered or fractures zones and will not be intercepted by the drain. The blast curtain will also need to be pumped continuously since any pooling in it can result in the migration of contaminants to the Leeuspruit. The proposed Advanced Water Treatment Facility (AWTF) will provide water treatment capacity both during the operational and post closure phases; and
- The implementation of the blast curtain will have a side effect as it can lower the water table. The water level in the area of the RTSF is shallow, ranging between 2.3 to 9.5 m below ground surface. The blast curtain will be extended up to a depth of 30 m below surface. Abstraction from the blast curtain (estimated to be 4,810 m^3/d, i.e. 120% of the seeped amount) is likely to create a depression of the water table. In this study, the curtain drain is assumed to impact the groundwater if the drawdown is more than 10 m.

6 Baseline Assessment of the Historical TSFs

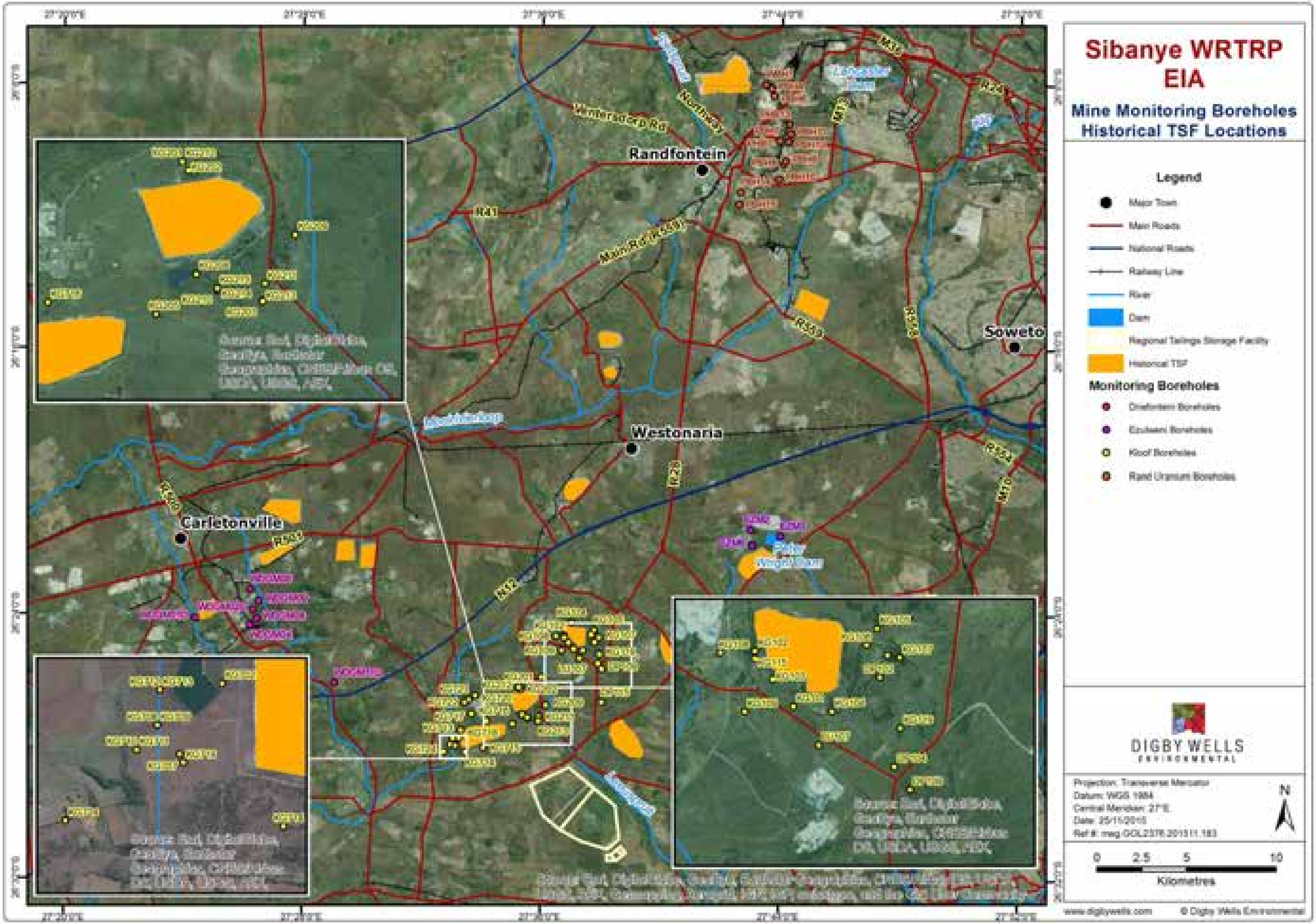
A baseline screening assessment is conducted for the historical TSFs to evaluate the current groundwater conditions at each of the TSFs and predict the potential impact of the proposed reclamation. In addition to literature reviews, existing mine monitoring boreholes (shown in Figure 6.1) have been used for the baseline water quality assessment.

The historical TSFs are either located directly on dolomitic strata (Figure 6.2) or on the Transvaal sequence that overlies the dolomite. Seepage from TSFs underlain by non-dolomitic rocks has historically developed contamination plumes in the shallow aquifer that potentially drain towards surface water courses. However, seepage from the TSFs on dolomite infiltrates into the dolomitic aquifer due to the permeability of the dolomitic aquifers being high. The impact on groundwater as a result of the reclamation is anticipated to be positive in the long run since the TSFs, which are potential sources of contamination, will be removed and centralising the deposition of the residues on a modern, engineered RTSF.

Dewatering of dolomite in the area of the historical TSFs and the accelerated drainage from the TSFs means that in addition to dewatering naturally occurring dolomitic water (also called fissure water by the mines), the mine also pumps significant quantities of water that percolates from the TSFs. Although the historical TSFs are not lined, the quantification of the total amount of water that infiltrates from the TSFs has not been undertaken to date. Nengovhela (2008) reported that that approximately one third of the total slurry water seeps into the subsurface, with the balance evaporating and one third going back to the system through return water dams.

For the purpose of the groundwater study, the historical TSFs (Figure 6.2) can be divided into two groups based on the foundation geology:

- The first group consists of TSFs that are completely or partially located on dolomite. These are:
    - Cooke Mining Right Area: Cooke and Millsite Complex (38, 39, 40/41 and Valley);
    - Driefontein Mining Right Area: Driefontein 1 to 5; and
    - Kloof Mining Right Area: Libanon, Venterspost North and South
- The second group consists of TSFs located on the Transvaal shale and quartzite. The dolomite is at least 100 m below the surface and is not in direct contact with the TSFs:
    - Kloof Mining Right Area: Kloof 1 TSF, Kloof 2 TSF and Leeudoorn TSF
    - Cooke Mining Right Area: Cooke 4 South (C4S) TSF
    - Ezulwini Mining Right Area: Ezulwini TSF



Sibanye WRTRP EIA

Mine Monitoring Boreholes Historical TSF Locations

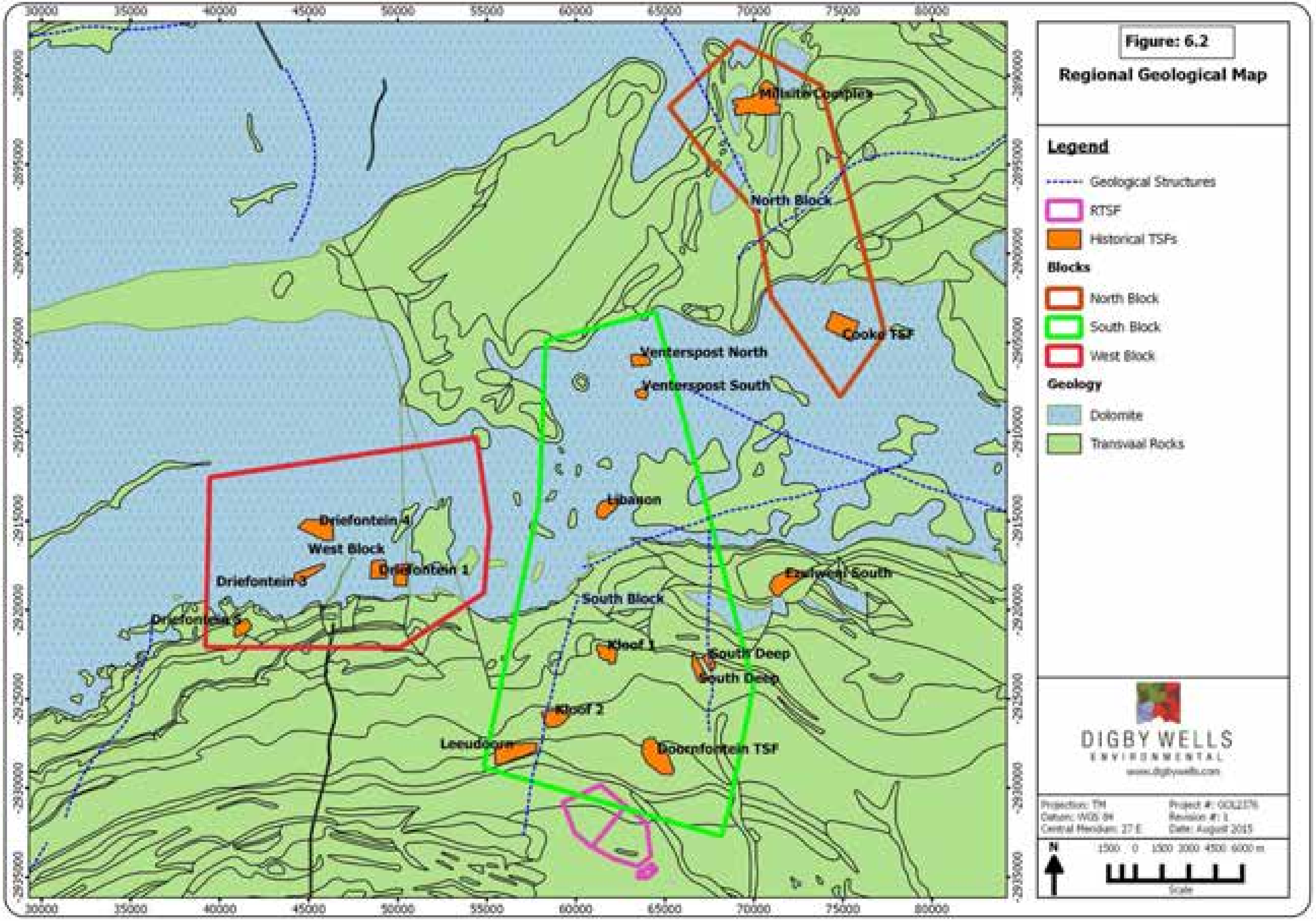


Figure: 6.2

Regional Geological Map

6.1 Historical TSFs Located on Dolomite

6.1.1 Geology

Dolomite of the Chuniespoort Group (Transvaal Supergroup) overlies the Witwatersrand Supergroup, and occurs over extensive areas within the West Rand goldfields. The dolomitic sequence is significant in terms of water resources in South Africa as it is a major aquifer, contributing to South Africa’s water resources and is highly susceptible and vulnerable to contamination.

Four of the five TSFs in the Western Block are located on dolomitic outcrops. The only exception is Driefontein No. 5 which is located on Pretoria Supergroup formations, which directly overlies the same dolomite on which the other TSFs are situated. To allow for safe mining operations the area has been dewatered in the past which resulted in sinkhole formation, which continues to affect the terrain to this day. The thickness of the dolomite ranges from surface to 1,500 m below ground surface. The dolomitic rocks historically contain vast quantities of water, but largely dewatered in the target areas.

In the Northern Block, the Cooke TSF, Venterspost North TSF and Venterspost South TSF lie entirely on Malmani Dolomite of the Transvaal Supergroup, while the Millsite and Ezulwini TSFs are partially on dolomite and partially on shale and quartzite of the Transvaal sequence, that in turn overlie the dolomite. The dolomite in this zone contains lenses and layers of chert. The dense, hard and fine-grained chert tends to stand out in relief. Chert replaces carbonate material.

The Karoo Supergroup includes dolerite dykes; geological features which cut through the dolomite forming a series of fault and dyke banded blocks.

6.1.2 Groundwater Level and Flow Direction

Local confined to semi-confined conditions exist where the dolomite is overlain by impermeable strata such as Ventersdorp lavas or Karoo sediments. The water level in the shallow aquifers is different from that of the dolomite, if they are separated by an impermeable layer.

Borehole yields in the shallow aquifer have been recorded between 0.5 and 2 litres per second (L/s). In the dolomitic aquifers, borehole yields are likely to exceed 5 L/s.

Groundwater levels in dolomite aquifers are controlled by topography, permeability, mine compartmentalisation, recharge and dewatering. Groundwater levels in the shallow aquifer zones tend to mimic the topography, while more complex groundwater flow paths exist in the deep dolomitic and fractured aquifers.

Pre-mining water levels were shallow and ranged from 1 to 30 m below surface (average 14.49 m). Nengovhela (2008) reported that dolomitic springs feeding into streams were common across the dolomitic area, but are now dry due to the dewatering activities of the underground mining.

Generally the groundwater table in the dolomitic aquifer does not mimic the topography. The groundwater table is relatively flat and influenced by compartmentalisation. Highly variable water level measurements were taken over short distances indicating the presence of groundwater barriers. Gold mining requires significant dewatering in order to keep the mine workings dry and safe and water levels are currently still being kept between 800 and 1,200 metres below ground level (mbgl).

The TSFs that are located directly on dolomite drain into the dolomitic system as none of them are lined. Due to the dewatered nature of the dolomite, the low pressure within the dolomite encourages drainage from the TSFs.

6.1.3 Groundwater Quality

6.1.3.1 Millsite TSF

Groundwater at the Millsite TSF complex (which is a composite of 5 dams; on the west 40 & 41 and on the east 38 & 39, joined by a valley infill) generally occurs in two aquifer systems based on the two discrete geological settings on which the TSF is located:

- Black Reef Formation: groundwater occurs in the weathered and fractured zones in rocks of the Black Reef Formation. The Black Reef consists mostly of quartzite which has no primary porosity. Therefore groundwater can only flow where space has been opened in the rock by weathering and fracturing. Most of the composite TSF lies on the Black Reef quartzite.
- Dolomite: a portion of the TSF is located on dolomite. In addition to weathering and fracturing, space can be opened in dolomite by the chemical action of rainwater and groundwater. This can result in large voids along which large volumes of groundwater can flow rapidly.

The quartzite is not regarded as a groundwater barrier, but is likely to restrict groundwater flow to a greater extent compared to the dolomite. Several springs are located near the TSF which occur due to this permeability contrast.

Based on available information, groundwater levels vary from 4 m to 26 m below ground level in the quartzite, and 5 m to 54 m below ground level in the dolomite and these levels are not affected by the mine dewatering of the nearby mines which currently are at decant level.

The TSF is located on the watershed between the Tweelopiespruit East and Tweelopiespruit West watercourses. Groundwater generally follows the topography. Underlying the TSF, groundwater tends to flow westwards to the Tweelopiesspruit West watercourse. Groundwater flows northeast towards the Tweelopiesspruit East from beneath the eastern portion of the TSF.

The quality of groundwater around the TSF has been significantly impacted by seepage from the tailings. Groundwater sampled from monitoring boreholes does not generally comply with SANS drinking water guidelines. Sulfate, an indicator of tailings seepage, has been measured at concentrations exceeding 1,000 mg/L (Figure 6.3); the drinking water guideline for sulfate is 250 mg/L. The pH in some boreholes is at 3.5 (Figure 6.4), indicating of mine related impact.

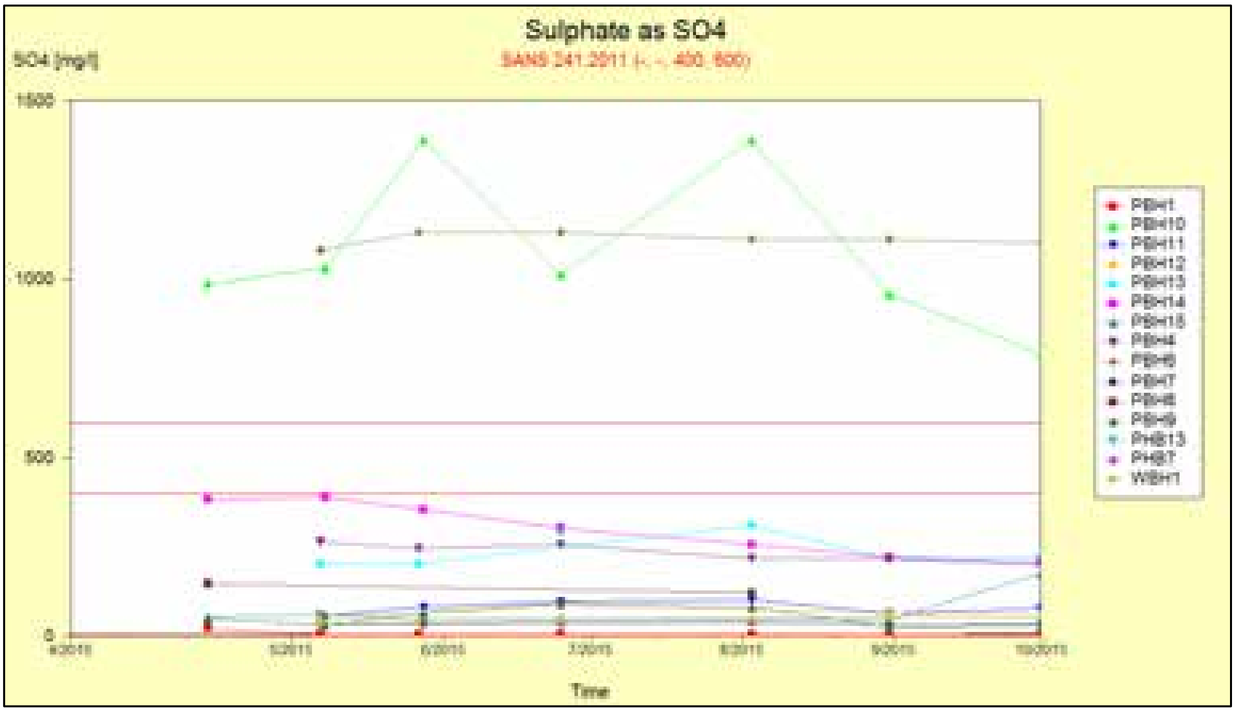


Figure 6.3: Sulfate value of the Rand Uranium monitoring boreholes

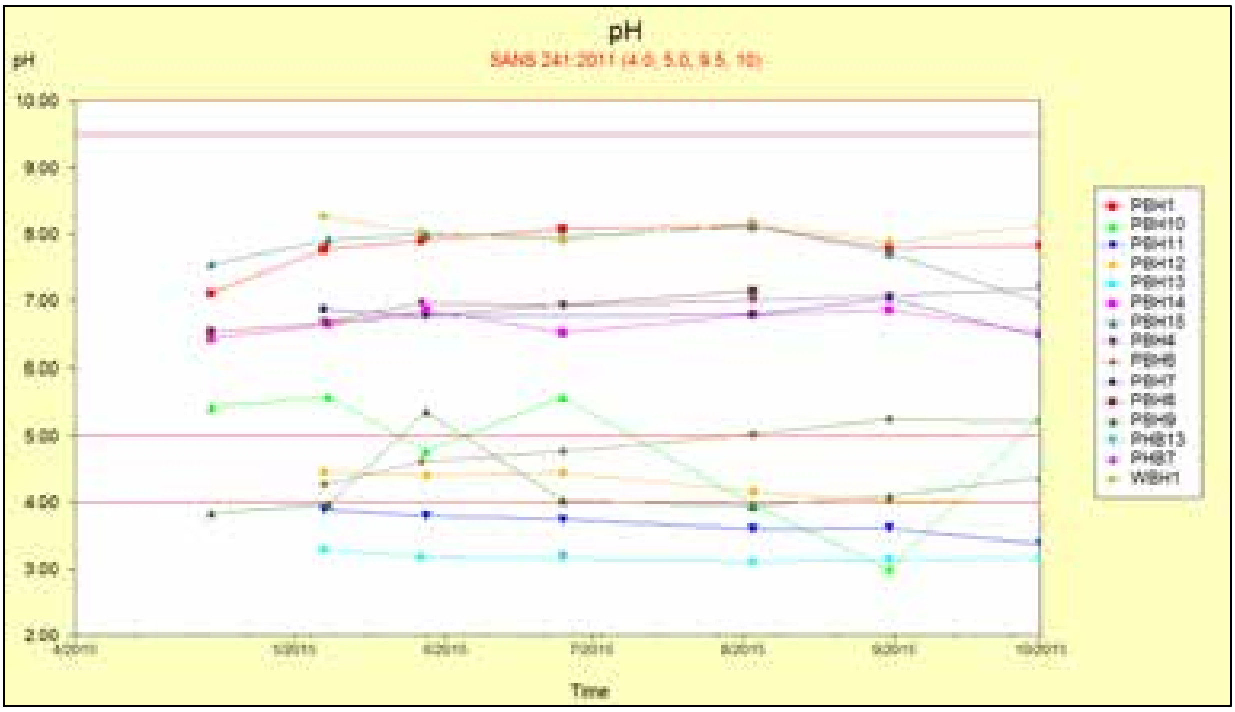


Figure 6.4: pH value of the Rand Uranium monitoring boreholes

6.1.3.2 Cooke TSF

Cooke TSF has not been operational since 2013, and together with its return water dam, is unlined.

Groundwater underlying the TSF is restricted to dolomitic and karst aquifers. This is locally known as the Zuurbekom Dolomite Compartment. The term compartment refers to a fault or dyke-banded block of rocks within which the groundwater has similar properties (water level and quality) relative to adjacent compartments.

A Rand Water supply borehole is situated approximately 10 km southeast of the Cooke Dump in the Zuurbekom Compartment. Mine monitoring data shows that the Rand Water supply borehole is not impacted by TSF seepage for the following reasons:

- The Rand Water supply borehole is located southeast of the TSF and the general groundwater flow direction is east to west; and
- There are sub-compartments within the Zuurbekom Compartment formed by dykes of very low permeability between the TSF and the Rand Water supply borehole.

The dolomitic aquifer underlying the TSF is nevertheless considered a potential water supply source and therefore sensitive.

The groundwater flow in proximity to the TSF is generally towards the Wonderfonteinspruit, to the west. Time-series water chemistry shows that the quality in the vicinity of the Cooke TSF is deteriorating. Concentrations of SO_4, Cl, Ca and Na have all increased significantly in the last decade. These parameters are commonly associated with tailings drainage and suggest that seepage from the TSF has impacted local groundwater since at least 2000.

A soil investigation conducted by Golder (2009) showed no signs of a sub-surface layer that would significantly restrict vertical flow of tailings seepage. The upper soils are homogenous and with a low clay content (15 to 20%). Underlying these upper soils is a layer of either chert and quartzite or ferricrete. Both layers are permeable. The report describes the hydrogeology of the area, but makes no mention of any restricting layer or perched aquifer. It was therefore assumed that no restricting layer is present that could reduce or mitigate vertical movement of seepage from surface to the aquifer, but is limited by the permeability of the slimes underlying the “sand”.

6.1.3.3 Driefontein 1 & 2 TSFs

Driefontein 1 and 2 are still in operation. Driefontein 1 is the only facility at Driefontein that shows and overall neutralizing capacity according to the geochemical testing conducted by the Institute for Groundwater Studies (IGS, 2008).

Monitoring data indicates a pH of neutral waters, ranging between 6.2 (borehole WDGM06) and 8.3 (WDGM09).

The groundwater in the area of Driefontein 1 and 2 is classified as being Class I and Class II.

The Driefontein 1 & 2 TSFs are underlain by dolomite and seepage from the TSFs is expected to migrate downwards due to the dewatered aquifer, with no lateral groundwater flow.

6.1.3.4 Driefontein 3 TSF

Driefontein 3 was decommissioned in 2003. Historical monitoring data shows that the groundwater is contaminated with SO_4, TDS and NO_3, which can be attributed to gold mining. The pH ranges from 4.1 to 8, indicating impacts of acid drainage from existing tailings.

The groundwater at Driefontein 3 is classified as being Class I and Class II. Some boreholes that are north of the TSF are within the Class II category due to their increased TDS values. This observation supports the current understanding that groundwater flows to the northwest from the TSF.

Driefontein 3 is underlain by dolomite and seepage from the TSF is expected to migrate downwards in response to the lower hydraulic pressure created by mine dewatering.

6.1.3.5 Driefontein 4 TSF

Driefontein 4 is still in operation. Limited water quality data exists for this site (Figure 6.1). The groundwater is classified as being Class II (not acceptable/fit for any consumption). However, the contamination detected in the vicinity of the TSF could have originated form the Driefontein 3 TSF and needs further investigation.

Groundwater in borehole WDGM04 (Figure 6.5) is contaminated with SO_4 that could possibly be attributed to the mine. The pH ranges from 4.5 to 8 (Figure 6.6).

The TSF is underlain by dolomitic rocks and any seepage is expected to migrate downwards into the aquifer.

6.1.3.6 Driefontein 5 TSF

Driefontein 5 is partially operational. Water quality assessments conducted by IGS (2008) showed that no acidification occurred in any of the tested samples. However, Acid Base Accounting (ABA) analysis showed that acid production is likely to occur due to the positive difference between the acid potential and neutralisation potential.

The groundwater is contaminated with SO_4, TDS, Ca, Mg and Cl and pH ranges between 4.1 and 9, with most of the samples showing a more alkaline signature with a pH between 7 and 9.

The groundwater in the vicinity of Driefontein 5 is classified as Class II.

The TSF is underlain by mudrock, quartzite and minor diamictite of the Pretoria Group geology, overlaying the dolomite. Seepage from the TSF is expected to migrate mainly to the north along the Pretoria Group aquifers. Vertical migration through the sedimentary rocks is also possible to eventually contaminate the dolomitic aquifer.

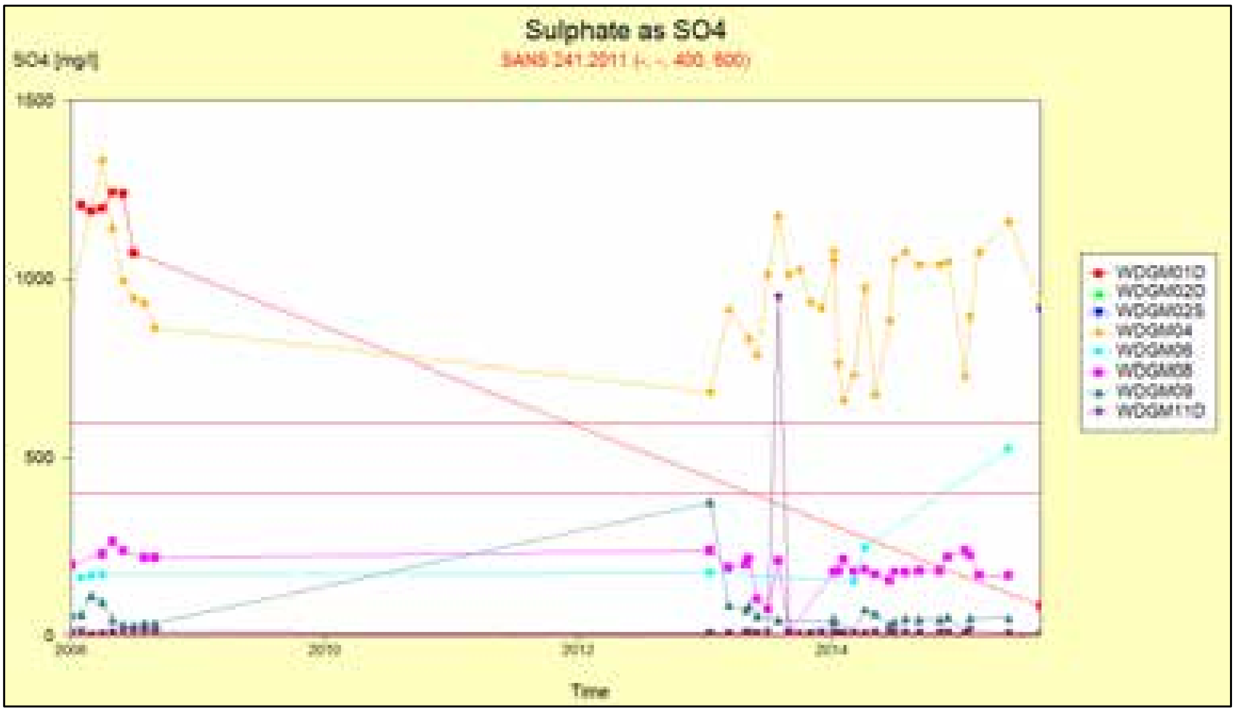


Figure 6.5: Sulfate value of the Driefontein monitoring boreholes

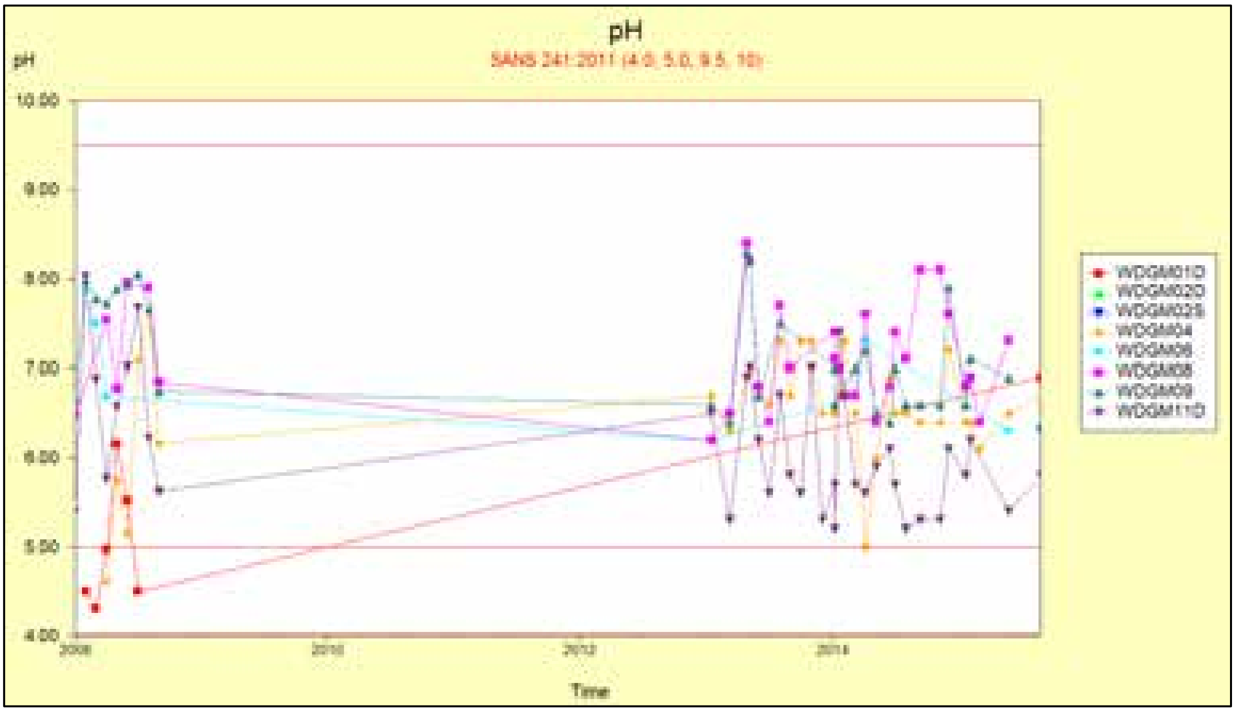


Figure 6.6: pH value of the Driefontein monitoring boreholes

6.1.3.7 Venterspost North and South TSFs

The Venterspost North and South TSFs have been decommissioned. Geochemical testing indicates that both TSFs are potentially acid producing (IGS, 2008).

Existing Department of Water and Sanitation (DWS) data reveals that water quality outside of the TSF footprints, but within the dolomitic aquifer, are generally good. All measured parameters fall within the SANS 241: 2015 drinking water quality standards (Class I), with TDS concentrations lower than 450 mg/L.

The Venterspost TSFs are underlain by dolomite and are expected to seep vertically, with limited or no lateral migration towards any surface streams.

6.1.3.8 Libanon TSF

No groundwater quality data was available for the Libanon TSF during this study, however geochemical tests indicate that the tailings material has acid producing potential (IGS, 2008).

The Libanon TSF has been decommissioned and located on a gently undulating topography; with the Gatsrand ridge extending to the south. The Libanon TSF is underlain by dolomite and it is expected that seepage will reach the dolomite with limited lateral migration.

6.2 Historical TSFs not Located on Dolomite

6.2.1 Geology

The Southern Block is situated directly north of the proposed RTSF.

According to the 1:250 000 geological map (2525 West Rand), the geology of the Southern Block is generally gentle (10 to 20º), southward dipping Magaliesberg, Silverton, Daspoort and Hekpoort Formations; part of the Pretoria Group of the Transvaal Supergroup. The Pretoria Group comprises predominantly mudrocks, alternating with quartzitic sandstone, significant inter-bedded basaltic-andesitic lavas, subordinate conglomerate, diamictite and carbonate rocks, all of which have been subjected to low grade metamorphism (ERM, 2010).

Several structures traverse the area in a predominantly an N-NE to S-SW trend.

The gold mining activities generally occur below the dolomitic rocks. As the fissure water remains locked within the dolomitic zone, the shallow aquifer is not impacted by the underground workings/activities.

6.2.2 Groundwater Level and Flow Direction

Groundwater occurrence in this area can be divided into three distinct aquifers (Geohydrological Map Series, 1:500 000 Johannesburg), namely:

- Shallow weathered aquifer: within the weathered formation as a result of increasing secondary porosity (Metago, 2007), located 5 to 10 m bgl, and is limited and variable in extent.
- Deeper semi-confined fracture zone aquifer: within the Pretoria Group sediments, overlain by weathered shale layers (Metago, 2007), and adjacent to dykes and faults.
- Deep confined compartmentalised dolomitic (karst) aquifer (Malmani dolomite): comprised of interconnected joints, weathered dykes contacts, fault planes, fractures, cavities and solution channels, within the dolomite beneath the thick cover of Pretoria Group sediments.

The borehole yields range between 0.5 L/s and 2 L/s (DWS, 1:500 000 Geohydrological Map Series), while the aquifers are classified as having a moderate to high susceptibility and vulnerability rating, based on the 1:3 000 000 Aquifer Vulnerability and Susceptibility Map Series (Vegter, 1998).

Groundwater levels in the shallow weathered aquifers tend to mimic the topography, while more complex groundwater flow paths are associated with deep semi-confined fractured aquifer and dolomitic zones.

6.2.2.1 Kloof No 1 (not operational)& 2 TSFs(operational)

Limited groundwater level data is available at present and groundwater flow is mainly derived from data collected during the 2009 proposed CTSF hydrocensus, conducted in the vicinity of the South Deep and Kloof TSFs.

The water level within the study area is relatively shallow, varying from surface to 7.48 m bgl. The linear relationship between topography and groundwater elevation indicates that groundwater flow follows the surface topography.

The hydraulic gradient is approximately 0.02 in a south-easterly direction. However, the gradient downgradient of the TSF No. 2 footprint deviates from this. Groundwater levels are deeper in these boreholes and are postulated to be a result of one or more of the following possibilities:

- Flow along a preferred groundwater flow pathway, namely the Gemsbokfontein dyke and Fold Hinge Zone which traverse the study area.
- Presence of shallow alluvial aquifer.
- The result of seepage from surface return water dams creating localized mounding of groundwater levels in the shallow groundwater zone.

The water level depth in the vicinity of the Kloof mine area is shown in Figure 6.7 and ranges between 0.5 to 30 m. The boreholes in this area are located in the shallow aquifer and no interconnectivity exists between these boreholes and the deeper mine workings.

6.2.2.2 Leeudoorn TSF

The Leeudoorn TSF is operational and located on a gently sloping, undulating topography, with a number of hills occurring in the vicinity. Two small watercourses originate in the TSF area and discharge into the Loopspruit where after it meets the Mooi Rivier approximately 60 km southwest.

A number of monitoring boreholes (Figure 6.1) exist in the vicinity of the Leeudoorn TSF. A good water level data set exists in the area as shown Figure 6.7. The water level is relatively shallow and is not expected to be interconnected with the deep underground mine.

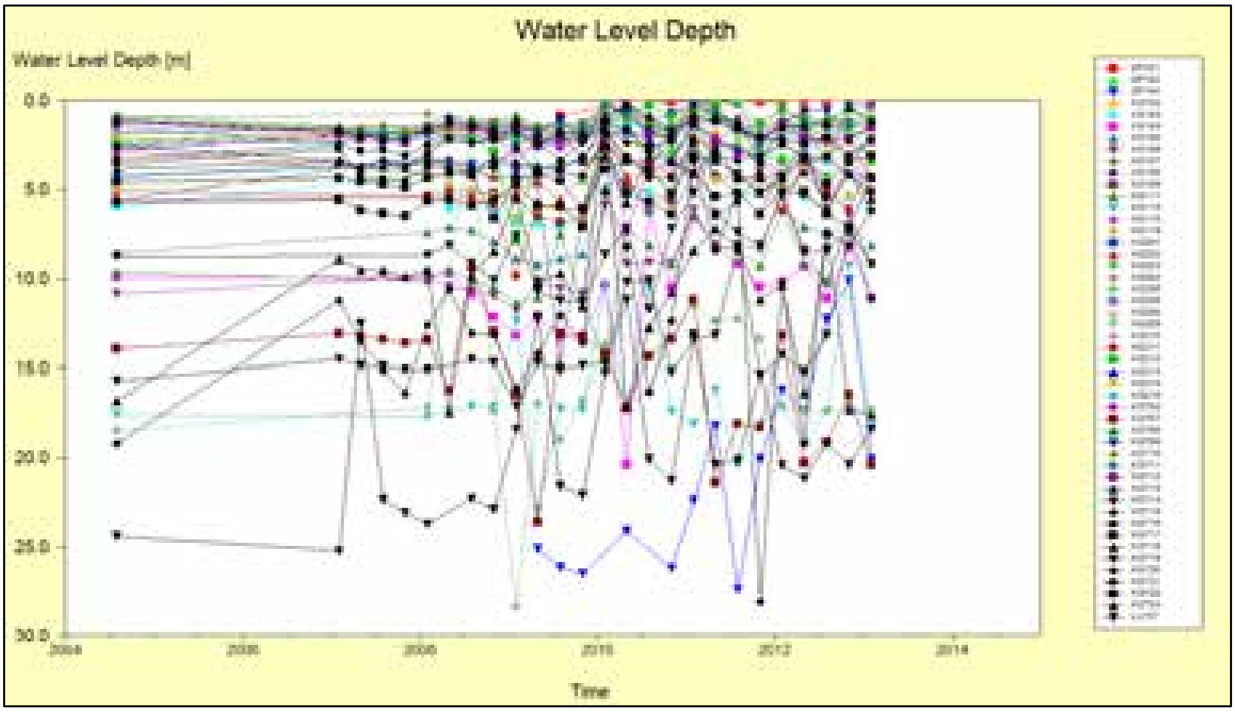


Figure 6.7: Groundwater depth in the Kloof area

6.2.2.1 Cook 4 South

The TSF lies within the Gemsbokfontein West dolomitic groundwater compartment (GWC). This compartment is bounded by largely impermeable dolerite dykes, the eastern boundary being the Magazine Dyke, the western boundary is the Gemsbokfontein No.1 Dyke and the northern boundary is the Panvlakte Dyke. The southern boundary is taken as the contact between the dolomite and the Transvaal rocks (Jones & Wagener, 2014).

There are two aquifers that underlie the Cooke 4 TSF. These are a perched weathered and fractured rock aquifer in the Transvaal and Karoo sediments, as well as the Gemsbokfontein dolomitic aquifer. The dolomite aquifer is the most prominent aquifer and largely controls the flow of potential contaminants from the TSF.

In the Transvaal sediments (weathered and fractured aquifer) the groundwater gradients and flow typically mimics the topography and is similar to surface water flow. This is similar for the Karoo remnants that underlie the TSF and an isolated perched aquifer may be present overlying the main dolomite aquifer. Due to the high transmissivity in the dolomite aquifer this rule does not apply and the groundwater gradients are typically much flatter in this aquifer.

The groundwater quality at the Cooke 4 TSF (boreholes EZM1, EZM2 and EZM3) is reasonable good considering the close proximity to the TSF. Chemical parameters that exceed the SANS 241 (2011) guideline limit only include ammonium, nitrate and manganese. The groundwater chemistry suggests that the TSF does not have an adverse impact on the groundwater quality. It is, however, possible that this is as a result of the current monitoring borehole placement.

Borehole EZM6, which was drilled as part of the TSF assessment in 2011, is the exception although this borehole monitors the impact from the plant area and not the TSF. Sample EZM6 shows definite contamination that is suspected to originate from the metallurgical plant area. Chemical parameters that fall within or exceed the SANS 241 (2011) guideline limits include pH, EC, sulfate, nitrate, manganese, cadmium and nickel.

6.2.2.2 Ezulwini TSF

Groundwater occurrence in the Ezulwini TSF area can be divided into two distinct aquifers, namely a shallow perched aquifer and a deep dolomite aquifer.

The shallow aquifer consists of a shallow, weathered and fractured aquifer varying from surface to 70 m below surface. The weathered aquifer has low aquifer parameters (transmissivity and storativity) and groundwater movement is slow. This is due to the nature of the weathered material, which consists mainly of silty sand and clay. Groundwater flow within the shallow aquifer is from the NNE to SSW, down-slope towards the Leeuspruit West drainage, mirroring the topography.

The shallow aquifer is separated from the underlying deep dolomitic aquifer by a thick succession of impermeable shale, approximately 400 m in thickness. The dolomite aquifer is situated in the Malmani dolomite with an approximate thickness of 1,200 m around the Ezulwini TSF area.

There is limited water monitoring data available (Figure 6.8 and Figure 6.9). The sulfate concentration of boreholes, around the TSF is within Class II (SANS 241:2015) in the shallow aquifer, but in Class I in the dolomite underneath.

Figure 6.8: Sulfate value of the Ezulwini monitoring boreholes

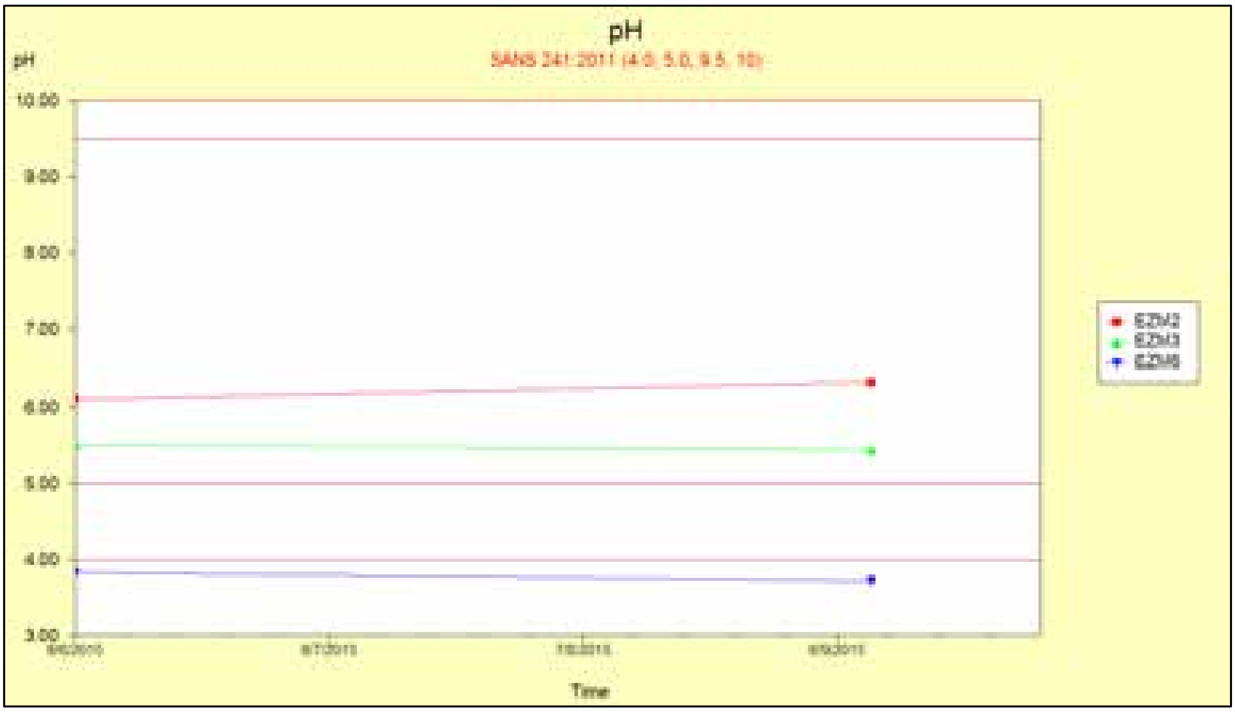


Figure 6.9: pH value of the Ezulwini monitoring boreholes

6.2.3 Groundwater Quality

6.2.3.1 Kloof 1 TSF

Kloof 1 is not operational at present. Limited monitoring boreholes are located in the immediate vicinity of the TSF.

Based on available (limited) data, the groundwater is classified as being Class II. However, seepage does occur from the TSF (which is unlined) into the shallow aquifer system. The seepage is expected to migrate within the shallow aquifer towards the southeast to the Leeuspruit.

The groundwater is classified as Class II due to the elevated sulfate, calcium and magnesium concentrations.

6.2.3.2 Kloof No 2 TSF

Kloof 2 is currently operational with limited water quality data available for the monitoring boreholes located in the immediate vicinity of the TSF.

The groundwater is classified as Class II. Data from the DWS database shows that water quality outside of the mining areas of Kloof 2 Shaft is good and all parameters measured fall within the SANS 241: 205 Class I drinking standards.

Seepage does occur from the TSF (which is unlined) into the shallow aquifer system. Seepage from the TSF could potentially flow in the shallow aquifer, towards the Leeuspruit, southeast of the facilities.

6.2.3.3 Leeudoorn TSF

The Leeudoorn TSF is still operational and geochemical testing indicates that the tailings material is likely to generate acid (IGS, 2008). Elevated concentrations of SO_4, TDS and NO_3, are recorded in the nearby aquifers, typical of groundwater contaminated by gold mining activities, with pH ranging between 3 (boreholes KG102) and 8 (a number of boreholes, Figure 6.11).

Groundwater north and south of the Leeudoorn TSF is classified as Class I. Groundwater east and west of the TSF is Class II.

Seepage from the TSF could potentially flow in the shallow aquifer, towards the Leeuspruit, approximately 750 m to the west.

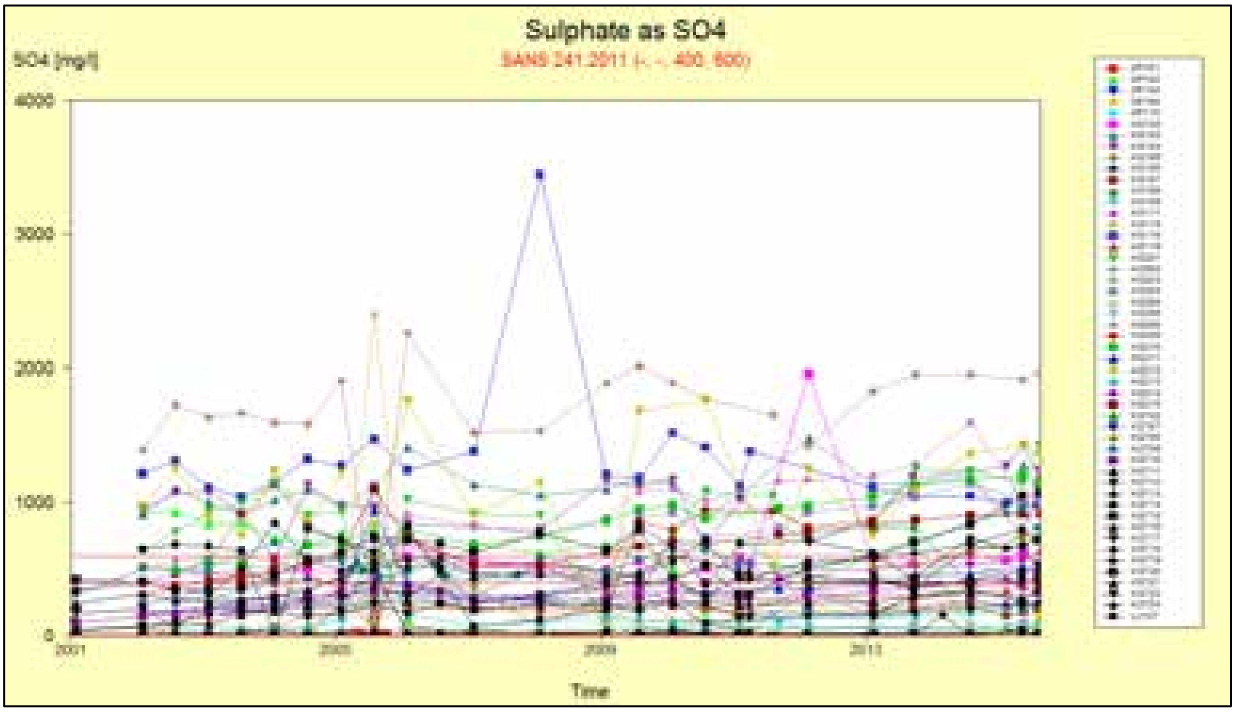


Figure 6.10: Sulfate value of the Kloof mine monitoring boreholes

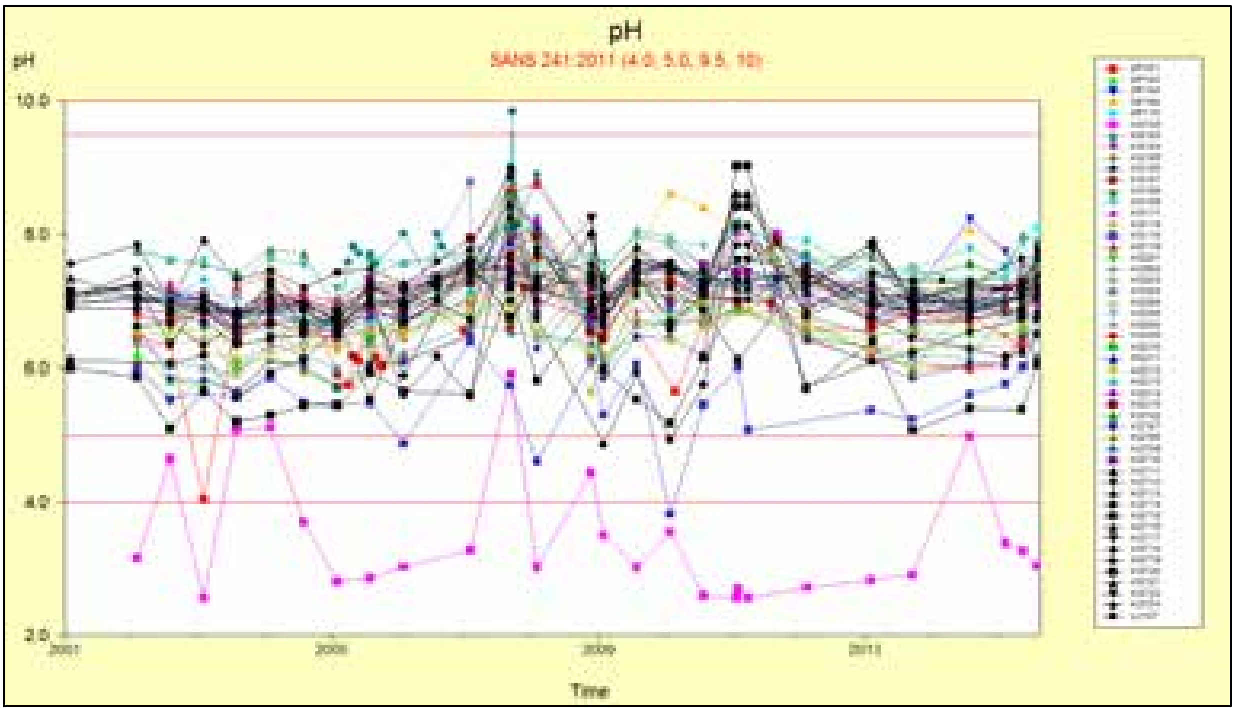


Figure 6.11: pH value of the Kloof mine monitoring boreholes

7 Baseline Assessment of the RTSF Environment

7.1 Location

The proposed RTSF is located within the C22J Quaternary Catchment, in Gauteng Province; approximately 32 kilometres (km) south of Westonaria and 34 km west of Vereeniging (Figure 7.1).

As shown in Figure 7.2, the proposed Geluksdal TSF is approximately 1.7 km south of the RTSF, while Gold Field’s Doornfontein TSF is approximately 1 km northeast of the RTSF.

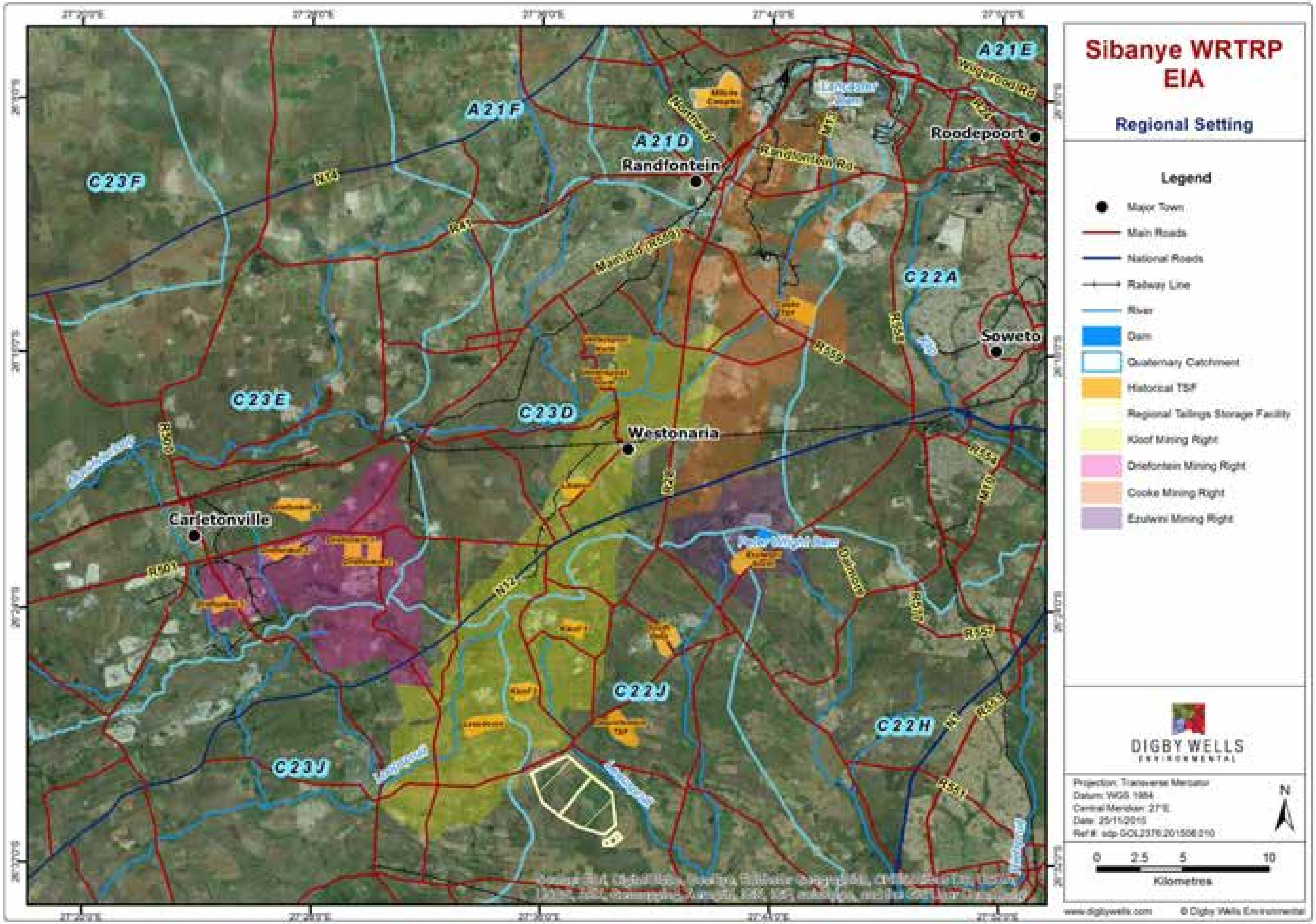
7.2 Climate

The study area falls within the summer rainfall region, with a Highveld climate of warm to hot summers and cold, dry winters. The Mean Annual Precipitation (MAP) ranges from 600 mm to 800 mm per annum and occurs mostly in the summer months (Digby Wells, 2012). The temperature for the area is relatively cool with the average maximum temperature at 24.6°C and the average minimum temperature at 9.2°C.

7.3 Topography and Drainage

The topography on site is gently sloping from west to east (Figure 7.1) with the highest elevation at 1 540 metres above mean sea level (mamsl) in the northwest corner of the site and the lowest point (1 505 mamsl) on the south-eastern side of the site.

Drainage within the proposed RTSF area is primarily from northwest to southeast, along the Leeuspruit.


Sibanye WRTRP EIA
Regional Setting
Legend
Major Town
Main Roads
National Roads
Railway Line
River
Dam
Quaternary Catchment
Historical TSF
Regional Tailings Storage Facility
Kloof Mining Right
Driefontein Mining Right
Cooke Mining Right
Ezulwini Mining Right
DIGBY WELLS
ENVIRONMENTAL
Projection: Transverse Mercator
Datum: WGS 1984
Central Meridian: 27°E
Date: 25/11/2015
Ref #: sdp.GOL2376.201508.010
N
0
2.5
5
10
Kilometres
www.digbywells.com
© Digby Wells Environmental
Randfontein
Roodepoort
Soweto
Westonaria
Carletonville
A21E
A21F
A21D
C23F
C22A
C23E
C23D
C22J
C22H
C23J
N14
N12
N1
R41
R28
R501
R559
R554
R557
R553
M10
Main Rd (R28)
Randfontein Rd
Peter Wright Dam
Lancaster Dam
27°20'0"E
27°28'0"E
27°36'0"E
27°44'0"E
27°52'0"E

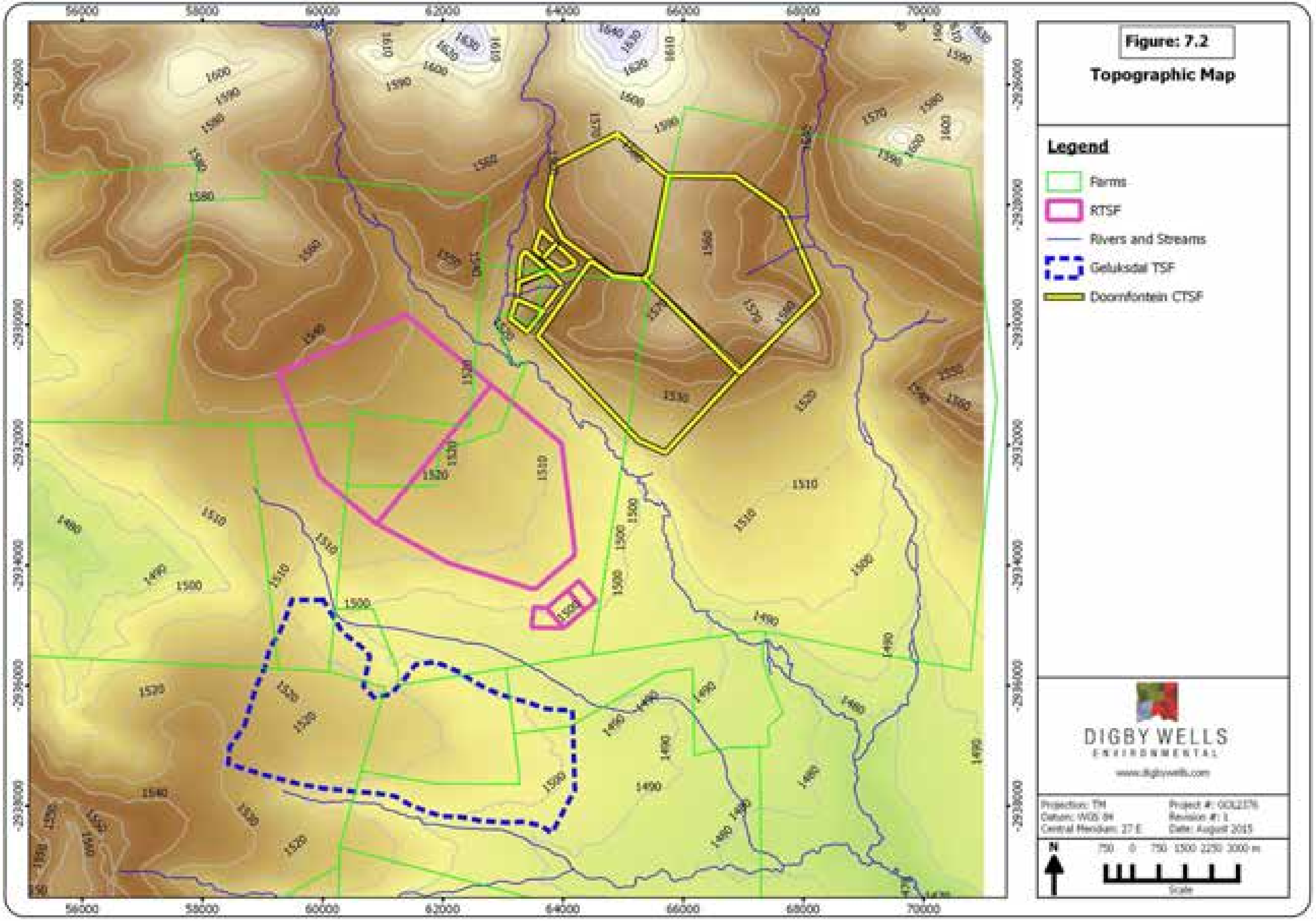


Figure: 7.2

Topographic Map

7.4 Site Geology

7.4.1 Regional Geology

The geology map of the area indicates that the proposed RTSF area is covered with Quaternary age sediments. However, the quaternary sediments were only found partially on the RTSF site, while shale and diabase outcrops are common.

The regional geology of the area is illustrated on the 1:250 000 Geology Map, 2626 West Rand series, published by the Council for Geoscience. The surface geology comprises of Pretoria Group lithologies of the Transvaal Supergroup, of the Vaalian Erathem (Figure 7.4). The Pretoria Group sediments comprise of shale, slate, quartzite, siltstone and conglomerate of approximately 2 200 million years of age. The Pretoria Group lithologies form prominent east-west trending ridges in the vicinity of the study area. Diabase sills of a younger geological age (Monkolian, 1 000 to 2 050 million years) are intruded into the Pretoria Group sediments (Figure 7.4).

The area is underlain by a gentle sloping stratum, generally dipping to the south at 10 to 20º. The stratigraphic succession along three deep exploration boreholes (more than 3,000 m deep) in a north-south geological cross section is illustrated in Figure 7.3 (ERM, 2008).

The oldest rocks of the Central Rand, Klipriviersberg and Chuniespoort Groups (3,100-2,200 My) appear on surface to the north of the study area with progressively younger rocks outcropping in the south.

Extensive diabase sill intrusions, as characterised by its highly positive magnetic signature in the aeromagnetic survey, is evident as intrusions in the Silverton shale and Timeball Hill siltstone-shale sequences.

Two north-south striking negative magnetic diabase dykes (Gemsbokfontein No.1 and No2 dykes), associated with the Pilanesberg tectonic event (1,300 My), pass approximately 1 km east of the proposed RTSF footprint area (Figure 7.4). The fold hinge zone that crosses along the Doornfontein TSF is expected to curve and strike approximately 3.7 km east of the RTSF.

7.4.2 Local Geology

The local geology is obtained from percussion-drilled borehole logs. Twenty eight percussion boreholes were drilled in the vicinity of the RTSF during this study, including those by Golder in 2009 and ERM in 2010. The positions of these boreholes are shown in Figure 4.1.

The geological profiles of the boreholes show that the footprint area of the proposed RTSF is underlain (from north to south) by Strubenkop shale, Daspoort quartzite and Silverton shale units of the Pretoria Group (2,200-2,050 My).

In addition to shale, diabase sills were also encountered in some boreholes. No dolomite was encountered in any of the boreholes. As shown in Figure 7.3, the dolomite is expected to exist between a depth of 1 km and 2 km underneath the RTSF, based on deep exploration boreholes drilled at the Gold Fields TSF site.

A lithological log of borehole SBNBH10 is given in Figure 7.5 to represent the local geology. The depth of weathering over the shale unit is in the order of 20 m to 26 m, with the deepest weathering along the watercourses. The depth of weathering over the diabase is approximately 20 m to 25 m, with the deepest weathering also encountered along the watercourses.

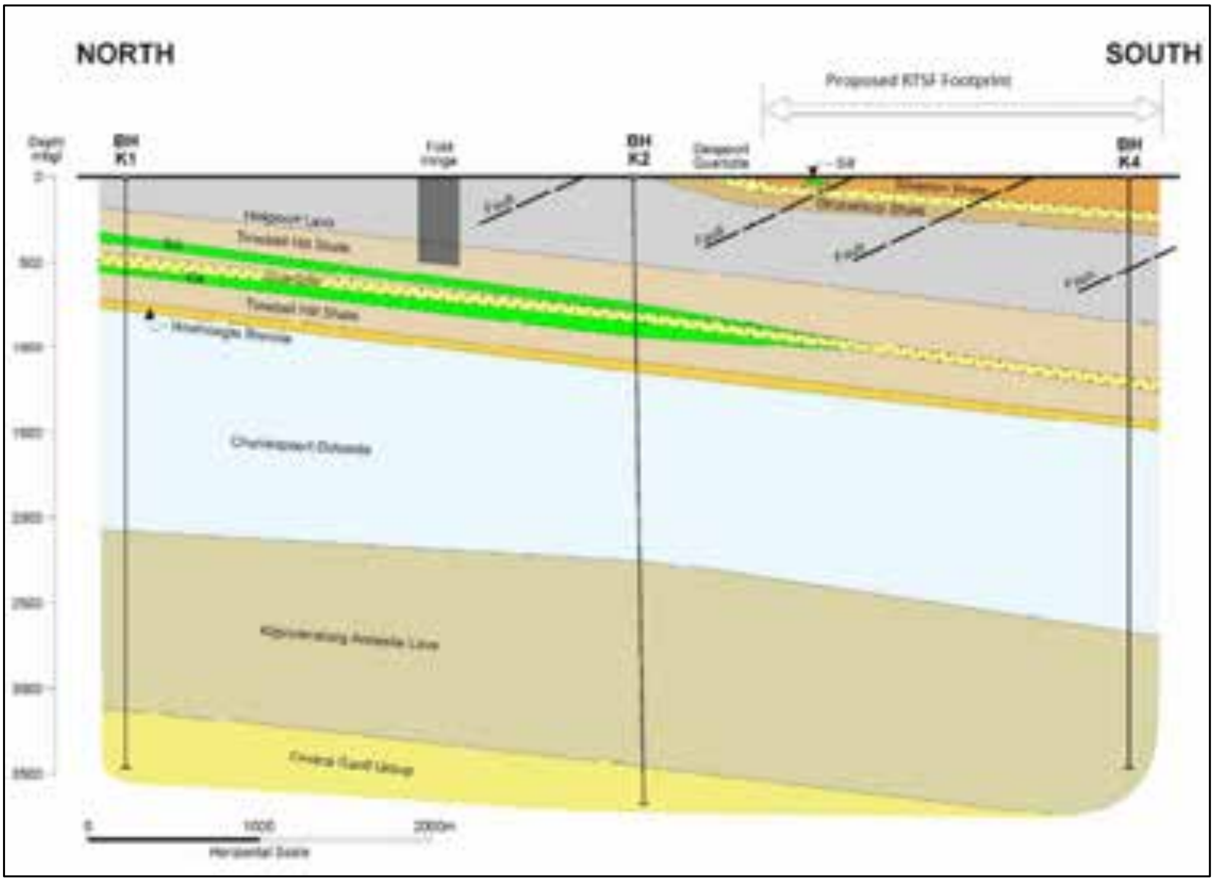


Figure 7.3: Geological cross-section over project area

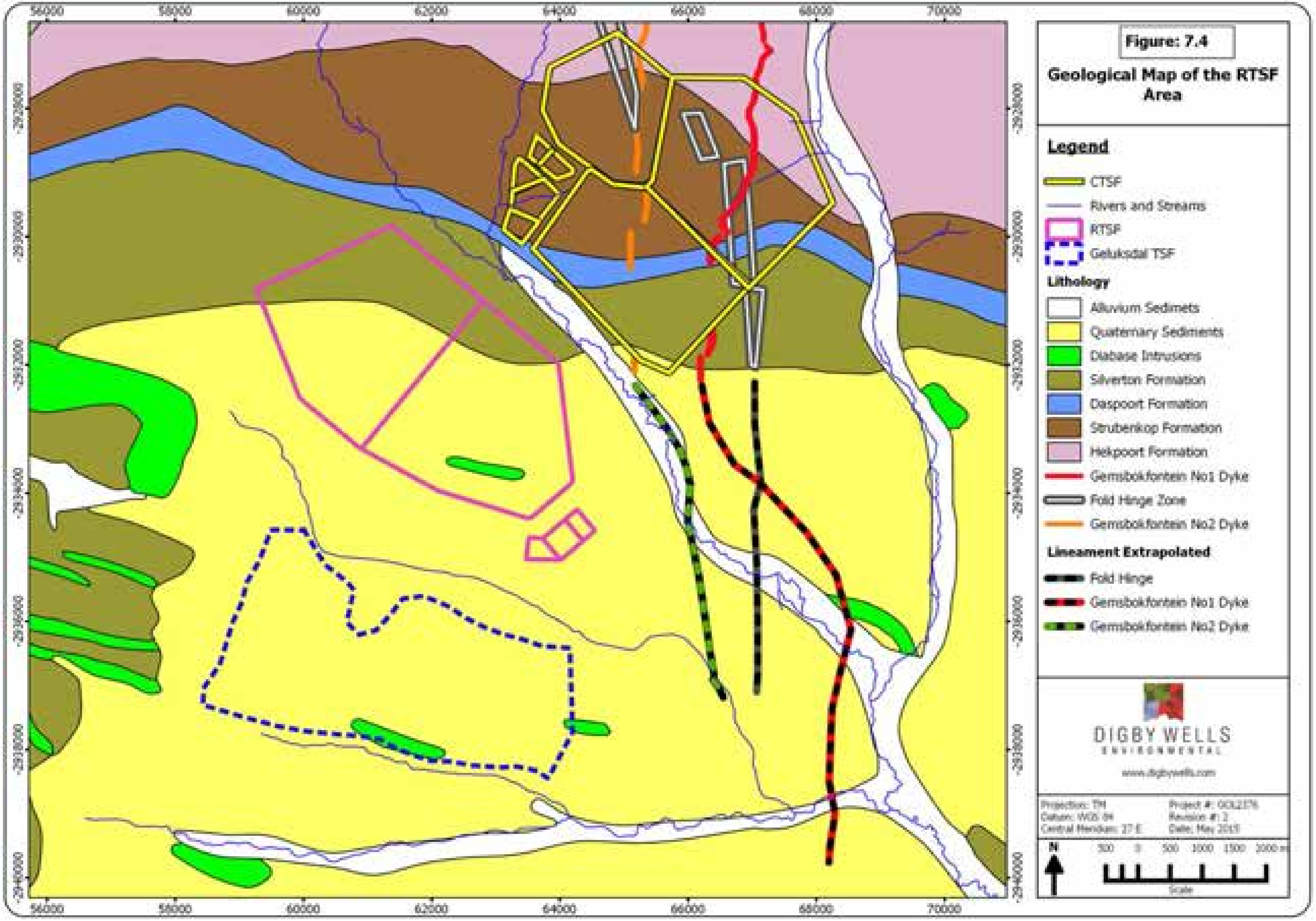


Figure: 7.4
Geological Map of the RTSF Area
Legend
CTSF
Rivers and Streams
RTSF
Geluksdal TSF
Lithology
Alluvium Sedimets
Quaternary Sediments
Diabase Intrusions
Silverton Formation
Daspoort Formation
Strubenkop Formation
Hekpoort Formation
Gemsbokfontein No1 Dyke
Fold Hinge Zone
Gemsbokfontein No2 Dyke
Lineament Extrapolated
Fold Hinge
Gemsbokfontein No1 Dyke
Gemsbokfontein No2 Dyke
DIGBY WELLS
ENVIRONMENTAL
www.digbywells.com
Projection: TM
Datum: WGS 84
Central Meridian: 27 E
Project #: GOL2376
Revision #: 2
Date: May 2015
N
500 0 500 1000 1500 2000 m
Scale
56000
58000
60000
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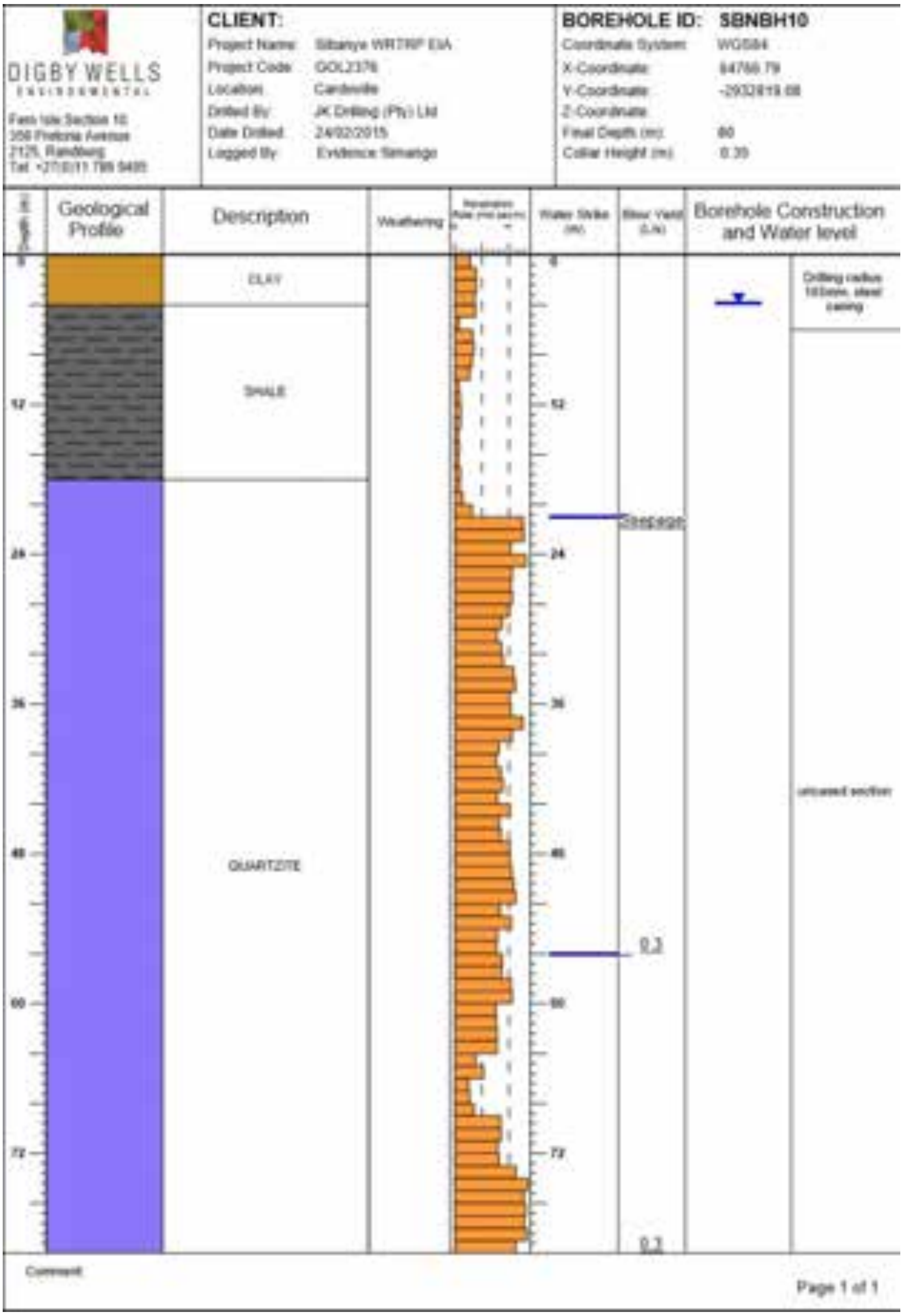
-2938000
-2940000



DIGBY WELLS ENVIRONMENTAL

Fern Isle Section 10
359 Pretoria Avenue
2125, Randburg
Tel: +27(0)11 789 9495

CLIENT:

Project Name: Sibanye WRTRP EIA
Project Code: GOL2376
Location: Cardoville
Drilled By: JK Drilling (Pty) Ltd
Date Drilled: 24/02/2015
Logged By: Evidence Simango

BOREHOLE ID: SBNBH10

Coordinate System: WGS84
X-Coordinate: 84766.79
Y-Coordinate: -2932819.68
Z-Coordinate:
Final Depth (m): 80
Collar Height (m): 0.35

Figure 7.5: Lithological profile at the project area

7.5 Groundwater Use

Water uses identified during the hydrocensus (Digby Wells, 2015) include human consumption, livestock watering, agricultural usage and groundwater monitoring as shown Figure 4.1.

A total of 193 water sources were located within a 5 km radius of the RTSF (Figure 4.1), out of which 165 were private boreholes and 28 were monitoring boreholes drilled by Sibanye Gold (and Gold One). The details of the hydrocensus results are given in Appendix B and show that currently:

- 24 (12%) boreholes are used for human consumption;
- 29 (15%) are used for drinking and livestock;
- 5 (3%) are used for drinking and irrigation;
- 6 (3%) are used for drinking, livestock and irrigation;
- 11 (6%) are used for livestock watering only;
- 4 (2%) is used for irrigation only;
- 28 (15%) are Sibanye monitoring boreholes;
- 68 (35%) are not used for any purpose; and
- The usage of the remaining 18 (9%) could not be confirmed.

7.6 Baseline Groundwater Quality

The hydro-chemical results of 21 groundwater samples collected during the hydrocensus and drilling programme are summarised in Table 7.1, while the position of the boreholes is given in Figure 7.6. These boreholes were sampled during this investigation, and the data was used in conjunction with the hydrocensus results of Digby Wells (2013), Golder (2009) and ERM (2010). Substantial amount of groundwater quality data exists for the Geluksdal TSF area and therefore only 21 boreholes were sampled during this investigation.

The results were compared to the South African National Standards (SANS) 241: 2015 Standards for Drinking Water, and will be grouped into Class I and Class II in accordance with the above stated Standard. The full set of laboratory results are given in Appendix C.

In general, the water quality of the area is good and the results can be summarised as follows:

7.6.1 Class I

All of the boreholes (except CDVBH2) fall within Class I water quality limits based on the SANS 241: 2015 Standards for Drinking Water and the water is safe for human consumption (based on parameters included in the analyses).

Noteworthy is that the concentration of uranium was below the detection limit (less than 0.004 mg/L) in all of the hydrocensus boreholes (Table 7.1). This is below the recommended WHO standard value of 0.03 mg/L for human drinking.

The baseline sulfate concentration is also less than 32 mg/L in all of the hydrocensus boreholes. This is well below the recommended value for drinking which is set at 250 mg/L. This is even less than the 500 mg/L limit of the River Quality Objective (RQO).

7.6.2 Class II

Borehole CDVBH2 (located on the south-eastern portion of the proposed RTSF footprint) has an ammonia concentration in excess of the SANS 241: 2015 guideline values. This borehole has been drilled in a wetland area. It is possible that the elevated ammonia is a result of the reducing environment created by the wetland, combined with decomposing organic matter. No other possible pollution sources were identified during the site visit. This borehole also has an elevated Manganese concentration (0.15 mg/L), within the Class II limits (defined at 0.1 mg/L for the SANS 2015 and 1.).

Table 7.1: Hydrocensus groundwater quality as compared to the SANS 241:2015

SANS 241:2015 Drinking water guideline values	Parameters	pH	EC	TDS	Sulfate,SO4	Chloride,Cl	Nitrate as N	Fluoride,F	Sodium as Na (mg/l)	Manganese as Mn (mg/l)	Ammonia as N	Aluminium as Al (mg/l)	Arsenic as As (mg/l)	Copper as Cu (mg/l)	Iron as Fe (mg/l)	Mercury as Hg (mg/l)	Lead as Pb (mg/l)	Uranium as U (mg/l)*
	Date	≥ 5 to ≤ 9,7	170	1200	250	300	11	1.5	200	0.1	1.5	0.3	0.01	2	0.3	0.006	0.01	0.03
COVBH7	2015/01/31	8.00	36.30	244.00	5.10	26.00	5.00	0.10	19.50	0.01	-0.10	0.01	0.00	0.02	0.04	0.00	0.00	0.00
SBNBH10	2015/03/27	8.33	54.80	304.00	2.15	11.00	4.39	0.32	60.80	0.00	0.93	0.00	-0.01	0.00	0.00	-0.01	0.00	0.00
SBNBH13	2015/03/27	8.19	25.20	142.00	1.64	6.36	0.30	0.22	20.60	0.00	0.61	0.00	-0.01	0.00	0.00	-0.01	0.00	0.00
SBNBH9	2015/03/27	7.84	50.10	293.00	16.40	16.60	2.10	0.22	30.30	0.00	0.23	0.00	-0.01	0.00	0.00	-0.01	0.00	0.00
SBNBH3	2015/03/27	7.84	37.40	242.00	2.34	4.94	0.97	-0.21	18.70	0.00	0.08	0.00	-0.01	0.00	0.00	-0.01	0.00	0.00
SBNBH5	2015/03/27	7.59	29.40	199.00	2.61	6.95	3.95	0.25	18.10	0.00	0.04	0.00	-0.01	0.00	0.00	-0.01	0.00	0.00
SBNBH14	2015/03/27	7.76	32.60	220.00	2.18	9.18	2.34	0.28	30.90	0.00	0.04	0.00	-0.01	0.00	0.00	-0.01	0.00	0.00
CDVBH6	2015/01/31	7.40	27.00	164.00	6.40	6.20	1.40	0.20	19.40	0.00	-0.10	0.02	0.00	0.02	0.11	0.00	0.00	0.00
CDVBH2	2015/01/31	7.60	39.10	182.00	0.50	25.00	-0.10	0.10	19.80	0.15	3.20	0.01	0.00	0.02	0.06	0.00	0.00	0.00
WDBBH2	2015/01/31	7.50	24.00	152.00	3.00	5.40	3.20	0.40	14.80	0.02	-0.10	0.01	0.00	0.06	0.05	0.00	0.00	0.00
RTNBH12	2015/01/31	7.40	14.20	76.00	3.90	1.30	0.20	0.40	9.00	0.00	-0.10	0.01	0.00	0.02	0.04	0.00	0.00	0.00
CDVBH4	2015/01/31	8.20	17.30	90.00	5.00	2.90	0.20	0.20	9.80	0.00	-0.10	0.01	0.00	0.01	0.03	0.00	0.00	0.00
RTNBH9	2015/01/31	7.50	21.70	158.00	4.50	5.50	3.80	0.10	11.20	0.00	-0.10	0.02	0.00	0.02	0.02	0.00	0.00	0.00
WDBBH6	2015/01/31	7.50	31.40	182.00	1.60	5.00	-0.10	0.10	11.90	0.00	0.20	0.01	0.00	0.02	0.02	0.00	0.00	0.00
DGV02	2015/01/31	7.80	32.70	198.00	9.50	9.50	4.70	0.20	21.00	0.00	-0.10	0.01	0.00	0.06	0.01	0.00	0.00	0.00
WDBBH1	2015/01/31	7.10	10.60	54.00	7.00	3.70	-0.10	0.20	12.40	0.00	-0.10	0.03	0.00	0.01	0.01	0.00	0.00	0.00
DM11	2015/01/31	7.90	48.20	296.00	12.90	9.80	7.90	0.20	39.00	0.00	-0.10	0.01	0.00	0.02	0.01	0.00	0.00	0.00

RTNBH1	2015/01/31	7.80	39.50	228.00	8.40	11.70	2.00	0.10	18.60	0.00	-0.10	0.01	0.00	0.02	0.01	0.00	0.00	0.00
RTNBH3	2015/01/31	7.80	50.20	324.00	22.00	19.70	7.20	0.10	19.90	0.00	-0.10	0.00	0.00	0.02	0.01	0.00	0.00	0.00
WDBBH7	2015/01/31	7.60	25.20	156.00	1.50	2.00	3.00	0.20	16.10	0.01	-0.10	0.01	0.00	0.09	0.00	0.00	0.00	0.00
RTNBH7	2015/01/31	7.80	48.40	326.00	32.00	19.90	6.60	0.30	18.90	0.00	-0.10	0.00	0.00	0.03	0.00	0.00	0.00	0.00

Note: "-" values should be read as "<" (e.g. "-1" = "<1")

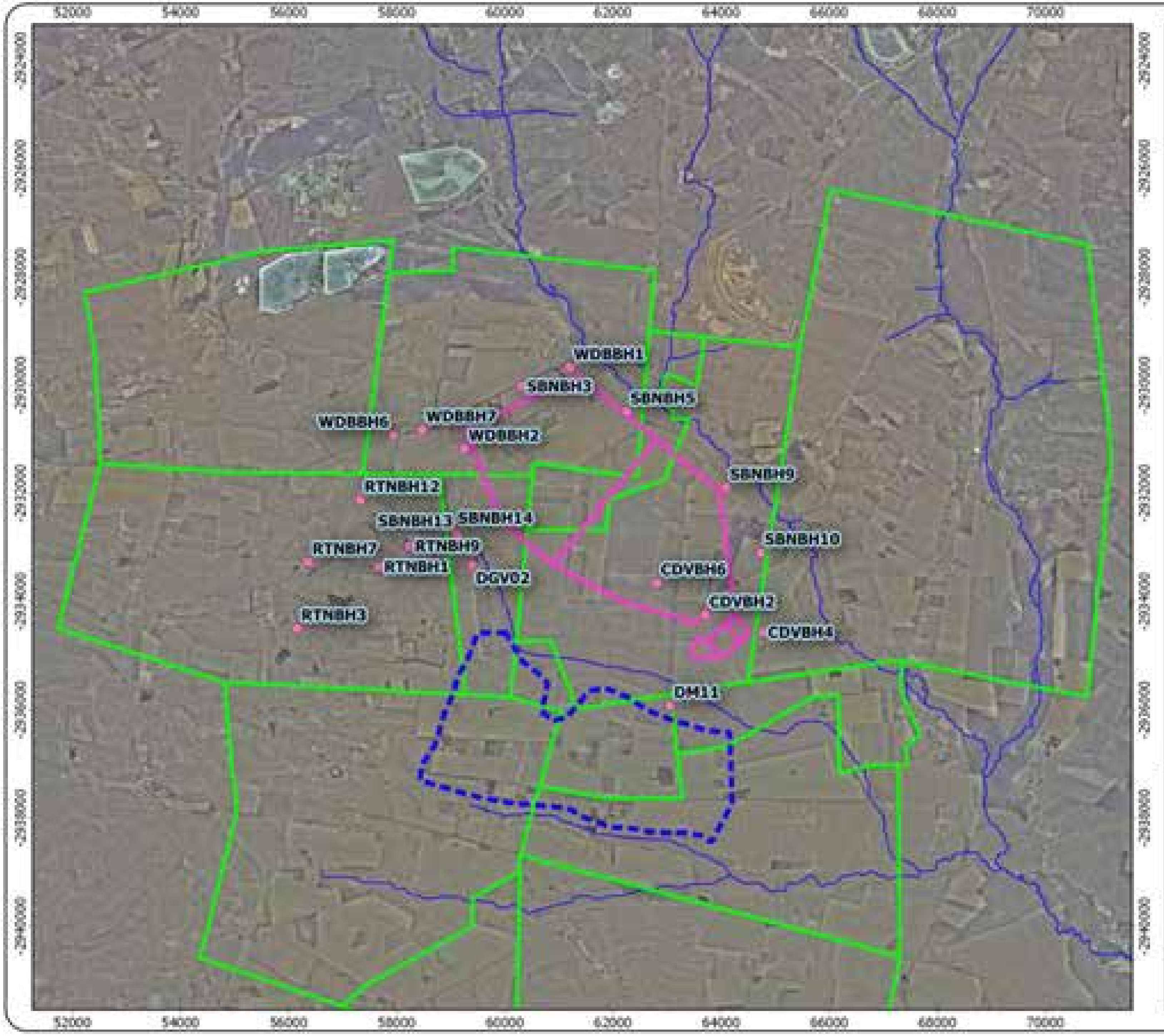


Figure: 7.6

Boreholes sampled during the hydrocensus and drilling programme

7.6.3 Diagnostic Plots

Stiff diagrams (Figure 7.7) were used to characterise the groundwater by analysing the concentrations of the major cations (Ca, Mg, Na+K) and anions (SO_4, Cl and HCO_3). In Stiff diagrams cations are plotted in meq/L on the left side of the zero axis and anions are plotted on the right side. This diagram is useful in making a rapid visual comparison between water of different sources.

The diagram shows that there are two types of water within the proposed RTSF area – those with Ca+Mg-HCO_3 signature (15 boreholes) and those that contain small amount of Na and are dominated by Na+Mg-HCO_3 (6 boreholes). The former signature is typically encountered in recently recharged groundwater. This means that the groundwater does not have significant residence time and is relatively freshly recharged. The remaining 6 boreholes (Na+Mg-HCO_3 type water) could be a result of natural ion exchange between Ca in the groundwater and Na in the rock matrix.

The water chemistry is also displayed using a Piper diagram as shown in Figure 7.8. A Piper diagram is used to classify the water type by plotting the ratios of the major cations (Ca, Mg, Na and K) and anions (Cl, SO_4 and HCO_3+CO_3) as two points in tri-linear fields. These two points are then extended into the main diamond-shaped field of the Piper diagram to plot as one point.

The Piper diagram also confirms the results observed in the Stiff diagrams. The dominant anion is HCO_3, typical of natural water that is not contaminated by mine activities. The lack of sulfate is another confirmation that the groundwater in the proposed RTSF area is currently not contaminated by mining activities. The dominant cations range from Ca to Mg to Na+K and are suspected to be results of ion exchanges between waters of higher residence time and those that are recently recharged.

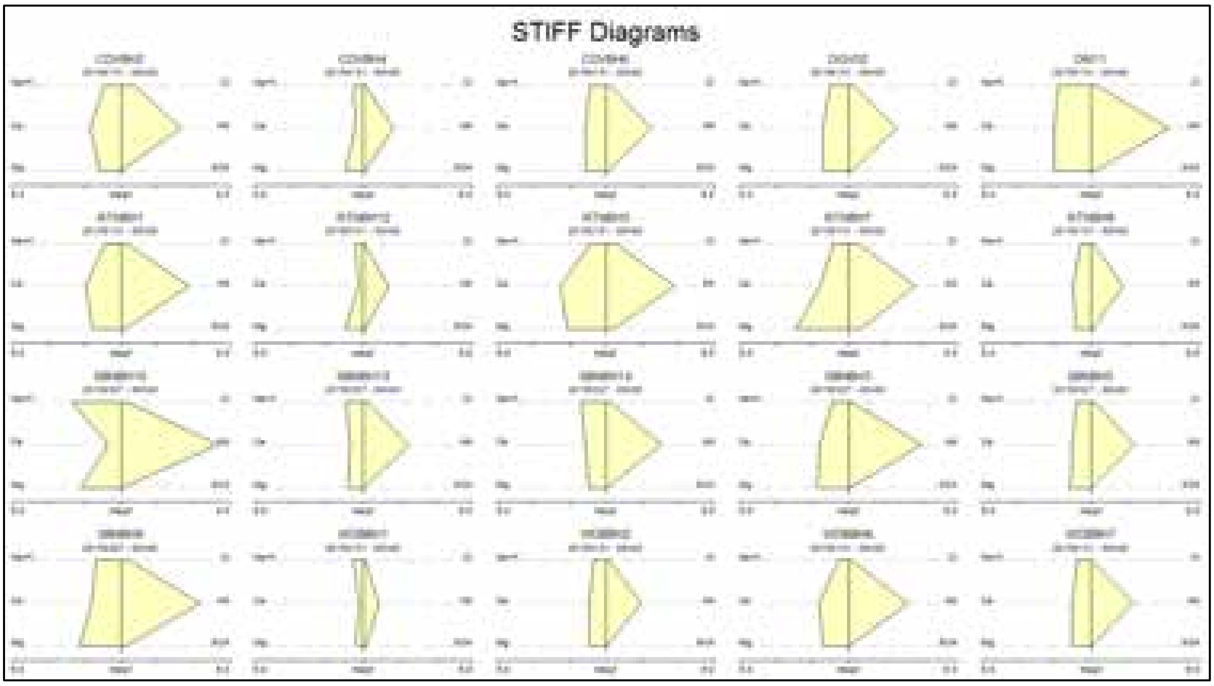


Figure 7.7: Stiff diagram of the hydrocensus boreholes

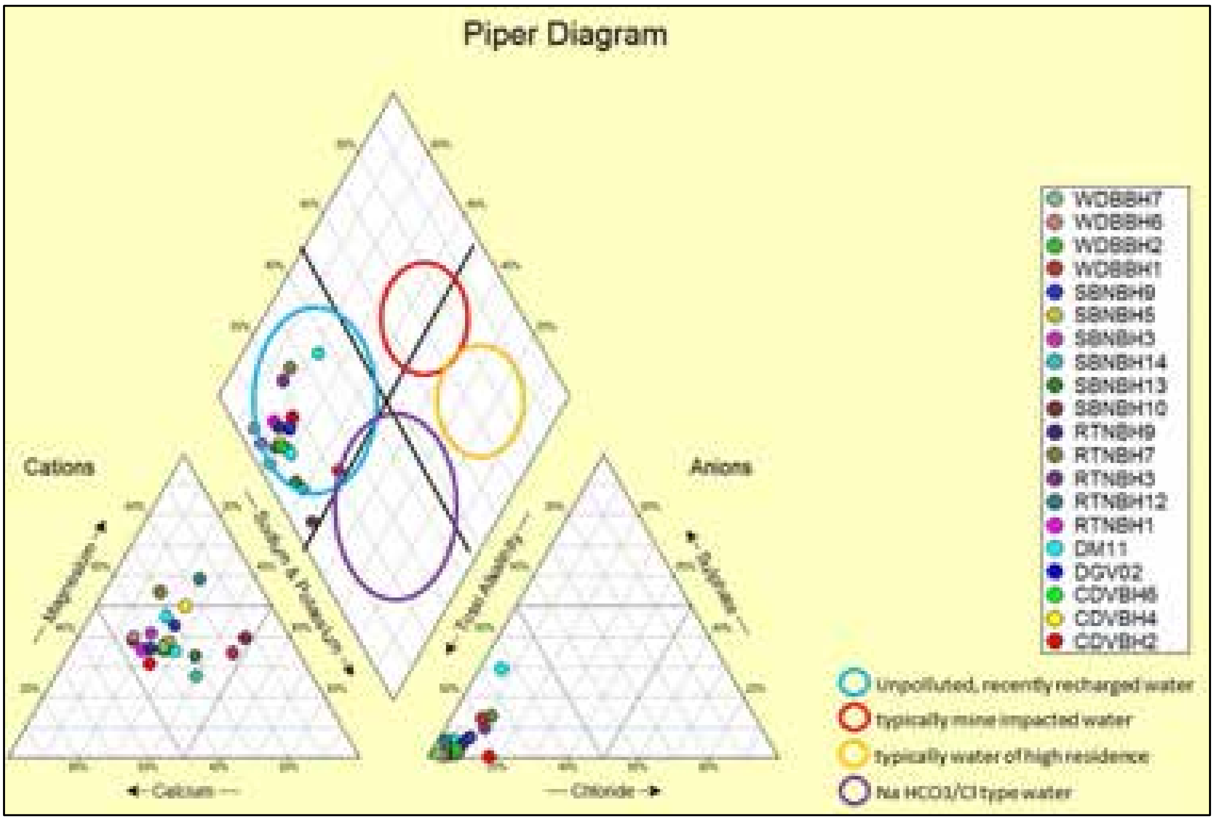


Figure 7.8: Piper diagram of the hydrocensus boreholes

7.6.4 Isotope Analysis

Isotopes of a particular element have the same atomic number, but different atomic weights due to varying numbers of neutrons in the nucleus. Environmental isotopes are naturally occurring isotopes. Stable isotopes are not involved with any natural radioactive decay process. Radioactive isotopes undergo spontaneous radioactive decay to form new elements or isotopes. Certain stable isotopes of hydrogen, oxygen, carbon, nitrogen and sulphur can be used in hydrogeological investigations to study processes that affect groundwater and surface water. Radioactive isotopes can be used to determine the age of groundwater (Mazor, 1991).

Two surface water samples (KLPSW01 and RFNSW01) and one groundwater sample (DFN08) were collected for stable isotope analysis and were analysed by iThemba Laboratory in Johannesburg. The samples were collected by Digby Wells (2012) as part of the Geluksdal TSF project, but are collected from within 5 km of the proposed RTSF. Sample KLPSW01 is located approximately 5.6 km east of the RTSF, RFNSW01 is 2.8 km west of the RTSF and borehole DFN08 is 3.4 km south of the RTSF.

A tritium analysis was only done on the groundwater sample collected from borehole DFN08. The isotope results are given in Table 7.2.

Table 7.2: Stable isotope and tritium results

Laboratory Number	**Sample** Identification	**d D** (‰)	**d18O** (‰)	**Tritium** (T.U.)	
DW 049	KLPSW01	+35.8	+6.93		
DW 050	RFNSW01	+44.4	+8.10		
DW 051	DFN08	-21.8	-3.69	1.1	±0.3

7.6.4.1 Stable Isotope Analysis Results

Environmental stable isotopes (^{2}H and ^{18}O) (Table 7.2) were analysed to identify the interaction of the surface and groundwater. The three samples plot below the Global Meteoric Water Line (GMWL) on an evaporation line (Figure 7.9). This indicates that evaporation has taken place to enrich the heavier oxygen-18 isotopes. This may also indicate surface and groundwater interaction whereby the groundwater is the source of the streams.

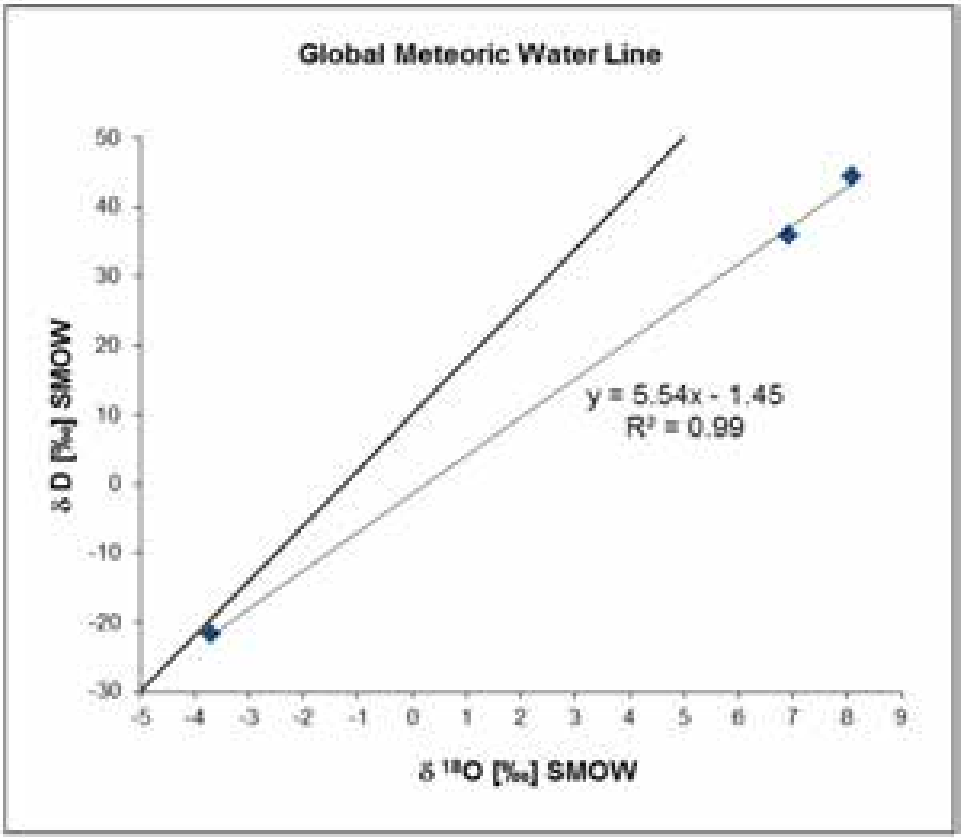


Figure 7.9: Stable isotope distribution

7.6.4.2 Tritium Analysis Results

Radioactive isotopes can be used for age dating. Tritium (^{3}H) is an unstable isotope of hydrogen with a half-life of 12.3 years. Prior to 1953, rainwater had less than 10 tritium units (TU) (Abbott, 1997). Thereafter, the manufacturing and testing of nuclear weapons has increased the amount of tritium in the atmosphere and in groundwater. Tritium can thus be used in a qualitative manner to date groundwater prior to and post 1953. If the tritium amount is less than 2 to 4 TU the water is dated prior to 1953; if the amount is greater than 10-20 TU, the water has been in contact with the atmosphere post-1953.

The presence of tritium at a concentration of 1.1 TU indicates that groundwater has long residence time in that part of the study area, i.e. more than 60 years. As observed from aquifer tests, the hydraulic conductivity of the aquifers west of the RTSF is approximately 0.007 m/d and the higher residence time could possibility be associated with the limited permeability. This, however, is inconsistent with the Ca-Mg-HCO_3 type of signature obtained from the inorganic analysis of the water chemistry. This may indicate the unsuitability of tritium as a tracer at the site and further investigation may be required to characterise and fingerprint the age and residence time of the groundwater.

7.7 Aquifer Characterisation

7.7.1 Groundwater Level and Flow Direction

Groundwater levels from 181 boreholes located within a 10 km area around the proposed RTSF was used to evaluate the groundwater level and flow direction. A comparison of the water elevation with topography shows a good correlation of 97.11% (Figure 7.10).

This means that groundwater flow mimics the topography and is towards surface water drainage courses as baseflow; generally from the northwest to southeast. This is displayed by a contour map (Figure 7.13) that shows the groundwater gradient and flow direction.

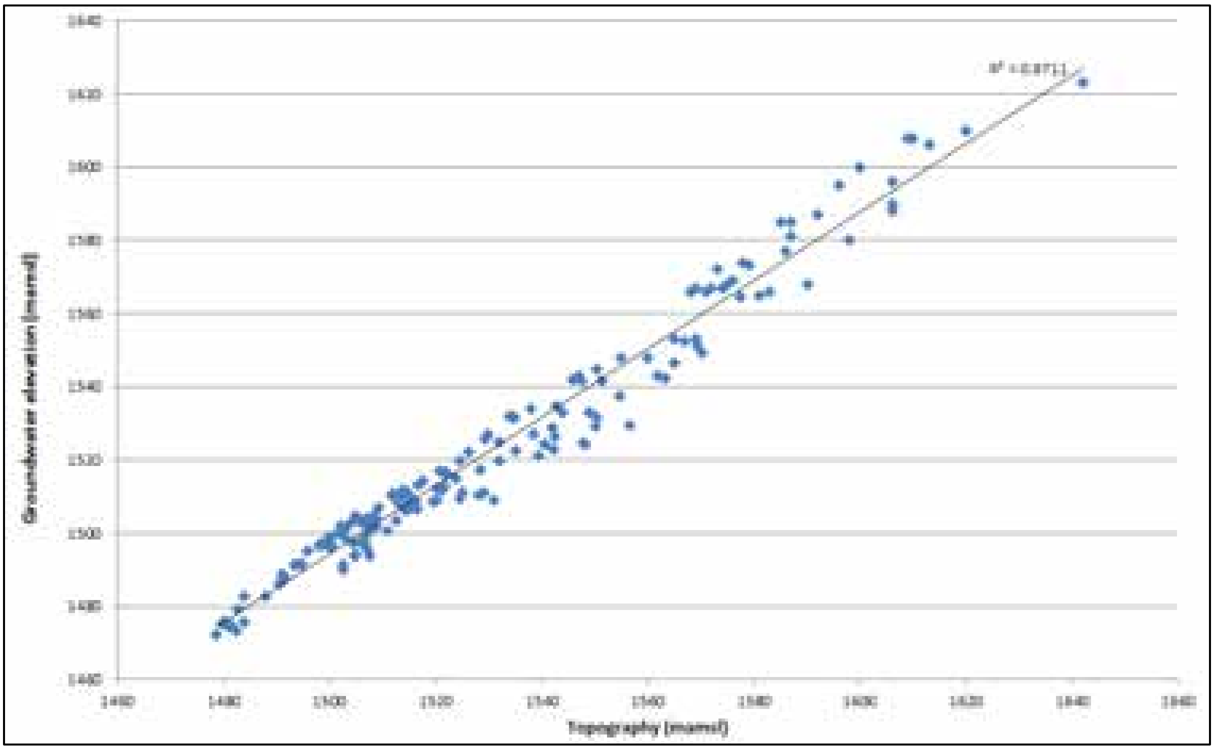


Figure 7.10: Correlation between topography and groundwater level

7.7.2 Aquifer Properties

The aquifers underlying the proposed RTSF site are characterised as low yielding, semi-confined, weathered (and fractured) aquifer systems, mostly composed of the Pretoria Group geology. This is based on the hydrogeological borehole information obtained from the borehole drilling and aquifer testing of the boreholes within 5 km of the RTSF.

A comparison of groundwater levels with water strikes in the boreholes indicates that the depth of water strikes are in most cases below the measured groundwater levels, which is indicative of confined groundwater flow conditions. The difference varies from a few centimetres to 52 m (Figure 7.11). However, a continuous confining layer appears to be absent and the aquifers underlying the site have been classified as being semi-confined.

Figure 7.11 indicates that the static water level in boreholes DM5 and 10307-03 are below the water strike positions. This is probably due to small scale fractures below the major water strike positions through which water seeps away from the boreholes, either laterally or vertically.

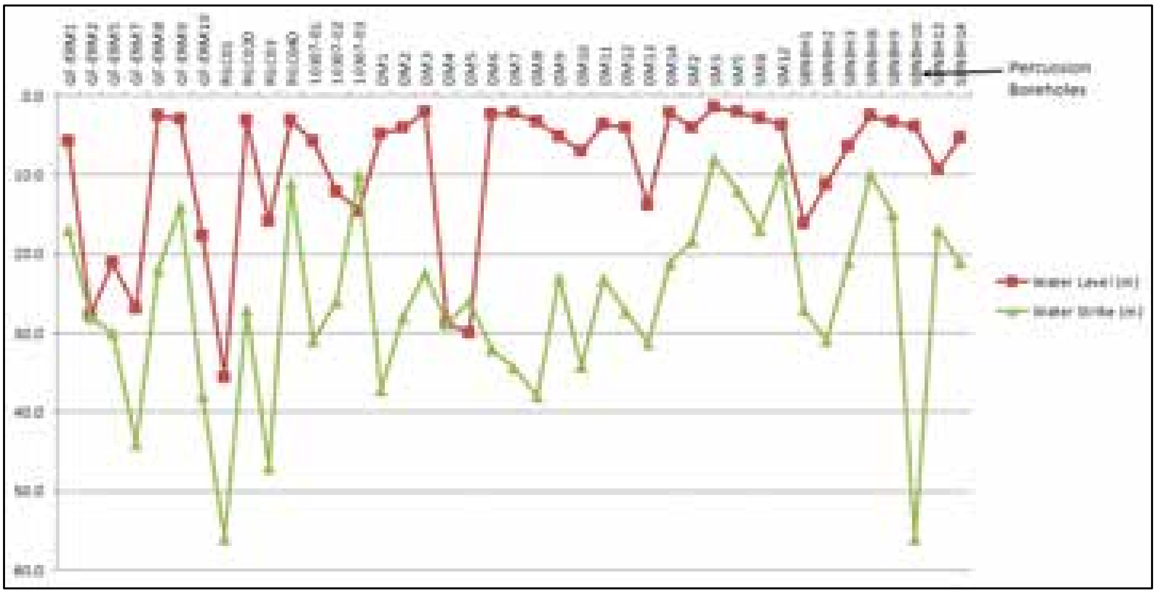


Figure 7.11: Correlation between water strike and water level

7.7.3 Aquifer Layers and Thickness

The frequency of the water strikes observed is illustrated in Figure 7.12. The water strikes are encountered at depths between 10 and 60 m below ground level (mbgl), with the majority occurring between 20 and 40 mbgl.

Approximately 14 of the 28 percussion boreholes drilled by Golder are shallow (12 to 24 m deep) and the remaining 14 are deep (70 m). As stated in the Golder (2009) report, the differences between the water levels of the shallow and deep boreholes are generally less than 0.1 m. This implies that there is no major head difference between the shallow and deep boreholes, which is a confirmation that they are intersecting the same aquifer. The water qualities in the shallow and deep boreholes also display the character of recent recharge from rainfall which is consistent with the connectivity between the two sets of boreholes. The connectivity of the two aquifers is also indicated by the aquifer testing where by pumping of deep boreholes will have an immediate influence on the shallow boreholes.

This conceptual model is also consistent with that of the Gold Fields boreholes which are on the northern boundary of the RTSF area. As discussed in Section 8.4, a blast curtain/extended cut off drain that will be established to a depth of up to 30 m below surface is one of the mitigation options considered for the RTSF plume containment. In order to more accurately simulate the blast curtain, the aquifer has been subdivided in two layers with a thickness of 30 m each.

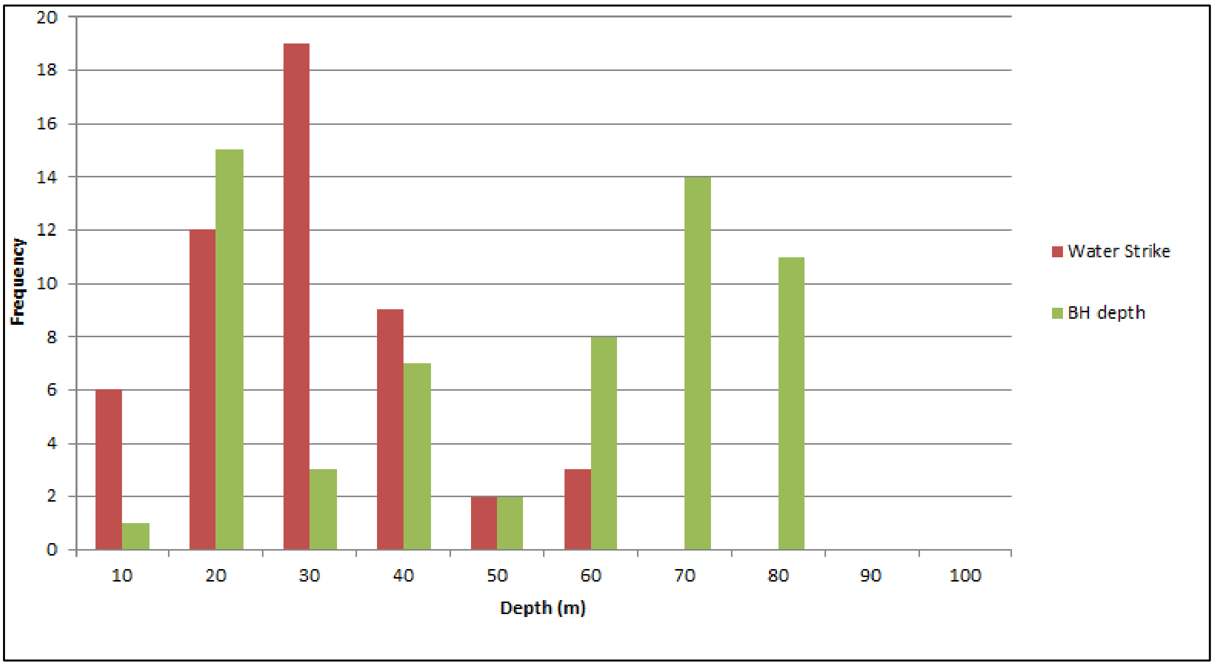


Figure 7.12: Water strike frequency

7.7.4 Aquifer Permeability

Aquifer tests were conducted during this study for rock permeability assessment. The results together with historically evaluated permeability values in the vicinity of the RTSF are displayed in Figure 7.14.

The aquifers underlying the proposed RTSF are characterised by low hydraulic conductivity, ranging between 0.0002 m/d (Borehole SBNBH2) to 0.806 m/d (Borehole DM12), with a harmonic mean of 0.005 m/d. This indicates that the groundwater flow rate is limited and the potential contamination plume from the RTSF will not migrate far from the RTSF footprint, even after mine closure. The plume will migrate very slowly, but high concentrations are expected to remain in the aquifer for a long time after loading has stopped. Although fractures are relatively more permeable than the matrix porosity, their permeability is not large enough to flush the contamination plume in a short time.

A significantly higher permeability of 4.1 m/d was noted in borehole SNBBH3. This is suspected to be a localized fracture zone that is not representative of the project area and can be considered as a potential upper limit of the permeable nature of the fractures.

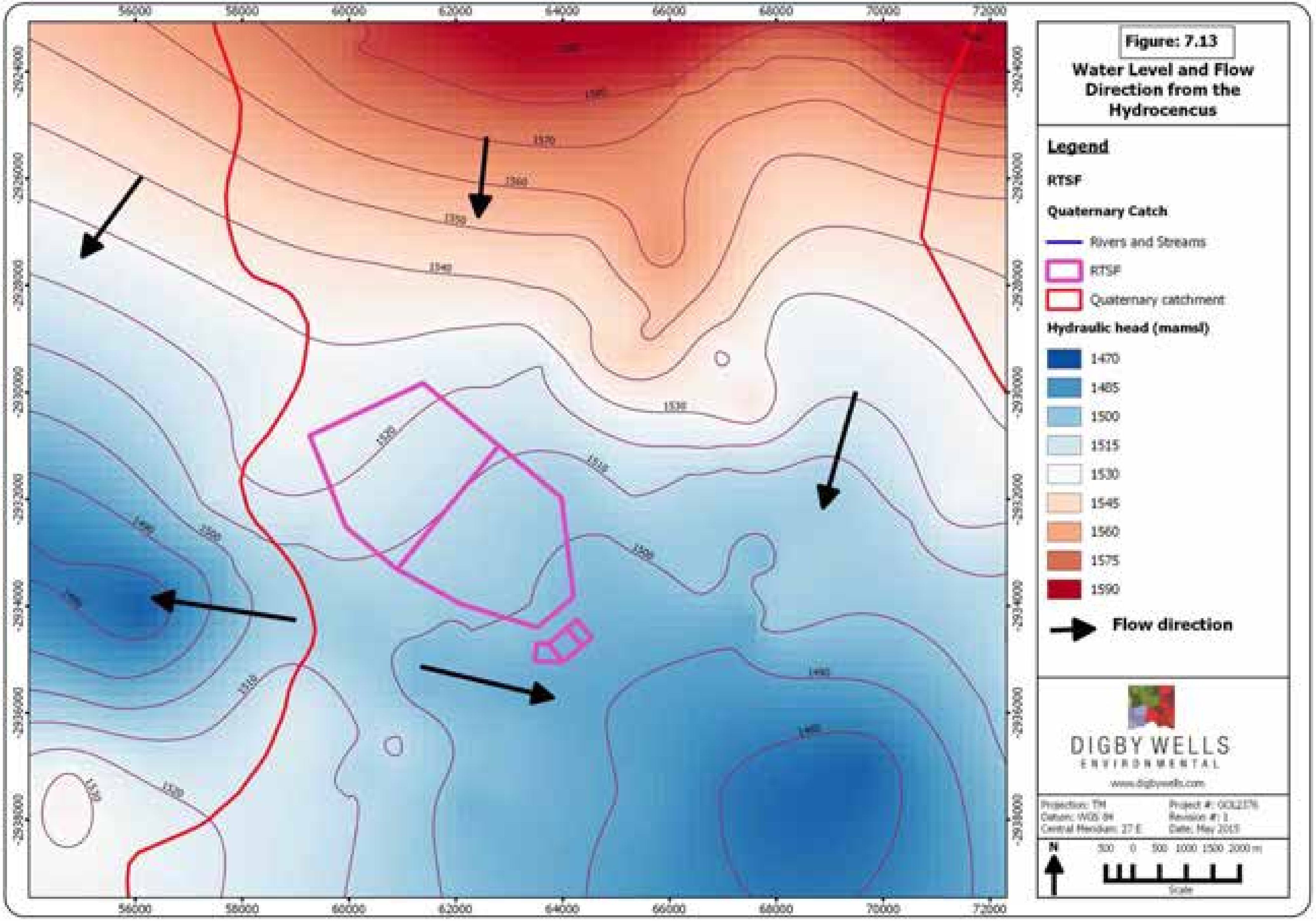


Figure: 7.13

Water Level and Flow Direction from the Hydrocencus

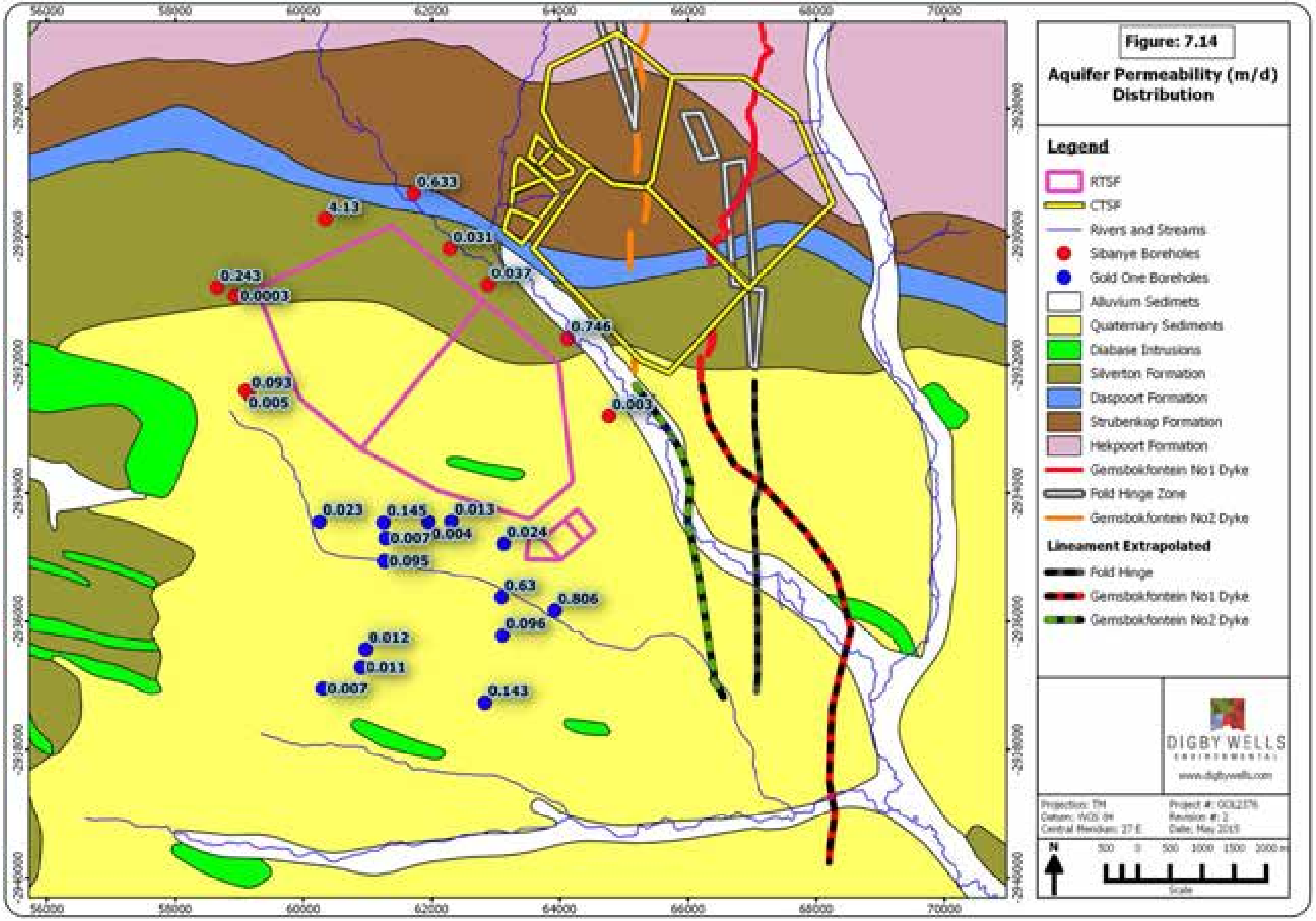


Figure: 7.14

Aquifer Permeability (m/d) Distribution

7.7.5 Aquifer Storage

Determination of storativity is only required for the transient state simulation. The storativity values obtained from the aquifer tests during this study and the previous Golder study (2009) are listed in Table 7.3 and range between 0.002 to 0.784, with an average value of 0.155.

Table 7.3: Hydraulic parameters of the boreholes in the RTSF area

BH	X	Y	K value	Storativity
DM1	60899	-2936717	0.011	0.019
DM10	62832	-2937268	0.143	
DM11	63089	-2935623	0.630	0.698
DM12	63921	-2935830	0.806	0.634
DM13	60300	-2937047	0.007	
DM14	60251	-2934442	0.023	0.019
DM2	60969	-2936437	0.012	0.014
DM3	61251	-2934456	0.145	0.137
DM4	61282	-2934702	0.007	0.012
DM5	61950	-2934447	0.004	
DM6	62305	-2934433	0.013	0.021
DM7	61262	-2935060	0.095	0.051
DM8	63123	-2934789	0.024	0.015
DM9	63102	-2936220	0.096	0.027
SBNBH1	58656	-2930795	0.243	0.473
SBNBH2	58935	-2930920	0.000276	
SBNBH3	60340	-2929726	4.13	0.016
SBNBH4	61724	-2929328	0.633	
SBNBH5	62284	-2930188	0.0308	
SBNBH7	62880	-2930754	0.037	
SBNBH9	64122	-2931591	0.746	0.055
SBNBH10	64767	-2932794	0.00321	0.784
SBNBH13	59143	-2932460	0.0934	0.0931
SBNBH14	59094	-2932402	0.00537	
SBNBH6A	62870	-2930754	1.3	0.00163
SBNBH8A	64193	-2931689	2.64	0.0021
SBNB11A	65126	-2934207	0.29	0.0083
SBNB12A	64612	-2935237	0.201	0.018

7.7.6 Contaminant Transport Parameters

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

7.7.6.1 Dispersion and Diffusion

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

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

The average distance of the RTSF footprint to the Leeuspruit is approximately 500 m. If it is postulated that the streams are the main receptor of the contaminant plume, a longitudinal dispersivity of 50 m and a transversal dispersivity of 1 m is estimated.

A diffusion coefficient of $1x10^{-5}$ m^2/day was selected, acceptable for sedimentary rocks (Gebrekristos *et al*, 2008).

7.7.6.2 Effective Porosity and Specific Yield

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

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

7.8 Source Areas

Sibanye Gold proposes to reprocess historical TSFs to recover gold, sulphur and uranium and the reprocessed tailings will be deposited on the proposed RTSF. The proposed RTSF is therefore expected to be the main source of contamination in the proposed project area.

The list of contaminants expected to leach from the RTSF is given in Table 7.4. The leachate analysis has been conducted for a range of chemical constituents and provides minimum, average and maximum expected leachate concentrations. In the model simulation the maximum expected concentration has been used for plume simulation and represents the worst case scenario.

From the statistical seepage quality assessment, SLR (2015) identified sulfate and manganese to be the two primary elements of concern, expected to seep at maximum concentrations of 2,600 mg/L and 22 mg/L, respectively. The details of the standards used for the classification are available in the SLR report (2015). The most stringent standard for sulfate and management is set at 250 mg/L and 0.1 mg/L, respectively.

In addition to these elements, the contamination plumes associated with Arsenic and Uranium were also simulated during this study and their results are included in Appendix E. Although they are not expected to leach at significant concentrations, As and U are generally perceived to be contaminants of concerns at gold mines and have been included into the groundwater model, along with SO_4 and Mn. All elements that have been considered for the contamination simulation are highlighted in yellow in Table 7.4 for easier visualisation. SLR (2015) predicted the maximum As and U concentrations to be 0.17 and 0.1 mg/L, respectively.

Table 7.4: Anticipated concentrations in drainage for the RTSF (SLR, 2015)

Contaminant	Unit	Minimum concentration expected	Average concentration expected	Maximum concentration expected	Most Stringent Standard	Standard
Al	mg/L	0.01	0.05	0.3	0.3	SANS 241 (2011) - (Operational)
As	mg/L	0.001	0.033	0.17	0.01	WHO (2011) / SANS 241 (2011) – (Chronic Health)
B	mg/L	0.01	0.054	0.2	2.4	WHO (2011)
Ba	mg/L	0.01	0.03	0.04	0.7	WHO (2011)
Cd	mg/L	0.001	0.0025	0.01	0.003	WHO (2011) / SANS 241 (2011) – (Chronic Health)
Co	mg/L	0.3	0.4845	1	0.5	SANS 241 (2011) – (Chronic health)
Cr	mg/L	0.002	0.0125	0.01	0.05	WHO (2011) / SANS 241 (2011) – (Chronic Health)
Cu	mg/L	0.001	0.0125	0.06	0.3	IFC Mining Effluent (2007)
Fe	mg/L	0.01	1.295	50	0.3	SANS 241 (2011) - Aesthetic
Mg	mg/L	5	91.5	200	500	DWAF TWQR Livestock Watering
Mn	mg/L	0.005	14.5	22	0.1	SANS 241 (2011) - Aesthetic
Mo	mg/L	0.002	0.0125	0.1	0.01	DWAF TWQR Livestock Watering
Na	mg/L	150	352.5	600	200	SANS 241 (2011) - Aesthetic
Ni	mg/L	0.002	0.028	1	0.07	WHO (2011) / SANS 241 (2011) – (Chronic Health)
Pb	mg/L	0.005	0.01	0.02	0.01	WHO (2011) / SANS 241 (2011) – (Chronic Health)
Sb	mg/L	0.005	0.005	0.005	0.02	WHO (2011) / SANS 241 (2011) – (Chronic

Contaminant	Unit	Minimum concentration expected	Average concentration expected	Maximum concentration expected	Most Stringent Standard	Standard
						Health)
Se	mg/L	0.005	0.01	0.05	0.01	SANS 241 (2011) – (Chronic Health)
Zn	mg/L	0.01	0.04875	0.5	0.5	IFC Mining Effluent (2007)
pH	pH	5.3	6.9	9.3	0	
Cl	mg/L	300	470	700	300	SANS 241 (2011) - Aesthetic
SO_4	mg/L	1000	1746.5	2600	250	SANS 241 (2011) - Aesthetic
U	mg/L	0.0005	0.01	0.1	0.03	WHO (2011)
Nitrate as N	mg/L	0.05	0.1	0.5	11	WHO (2011) / SANS 241 (2011) – (Acute Health)

7.8.1 Natural Recharge

At the proposed RTSF site, groundwater recharge is estimated (based on model calibrations) to be approximately 7 mm (1.1%) per annum. This is in line with the previous study (Digby Wells, 2012). ERM (2009) estimated the recharge at the Gold Fields TSF site in the order of 1.9% of the mean annual precipitation which is in good correlation with the results of this investigation.

7.9 Receptors

The hydrocensus (Digby Wells, 2015) was conducted within a radius of 5 km of the proposed RTSF. However, since the groundwater flow is the main mechanism for the transportation of contaminants from the RTSF, under natural gradient it is not possible for the pollution plume to migrate towards the northwest (opposite to the groundwater flow direction). If the natural gradient is however disturbed by groundwater abstraction, the flow direction will be towards the abstraction borehole in response to the hydraulic gradient.

The main receptors that are at risk of contamination are those in the immediate vicinity of the RTSF (with a radius of approximately 2 km), as well as those located down-gradient of the RTSF. The risk area is illustrated in Figure 9.2.

The following receptors will potentially be exposed to contaminated groundwater derived from the proposed RTSF, even after 50 years if no mitigation (with a blast curtain) is undertaken:

- The Leeuspruit that is north and east of the RTSF;
- The non-perennial tributary associated with the Leeuspruit that flows to the south of RTSF;
- Boreholes associated with farms down-gradient of the RTSF, in the southeast; and
- Boreholes used for irrigation that are in close proximity to the RTSF.

8 Numerical Model

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

8.1 Model Domain and Boundary Conditions

The model domain encompasses an area following no-flow boundaries, approximately 24 km (East to West) by 21 km (North to South) and is shown in Figure 8.1.

A rectangular mesh was generated over the model domain, consisting of 528 rows and 568 columns. The mesh was refined around the RTSF area to a cell size of 50 x 50 m in length. The remainder of the model domain was refined to a size of 100 x 100 m.

The boundary conditions are illustrated in Figure 8.1 and are defined by:

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

8.2 Model Calibration

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

A total of 122 observation boreholes were used for the steady state model calibration (Figure 8.3). The boreholes consisted of monitoring borehole and hydrocensus boreholes identified in the region. The monitoring points were relatively uniformly distributed over the RTSF area, assisting calibration.

During the calibration process the hydraulic conductivities and recharge values of the various geological units were adjusted within a reasonable range, until a good correlation of 97.3% (with a mean error of 0.5 m and mean absolute error of 1.92 m) was obtained between the simulated and observed groundwater elevation (Figure 8.2).

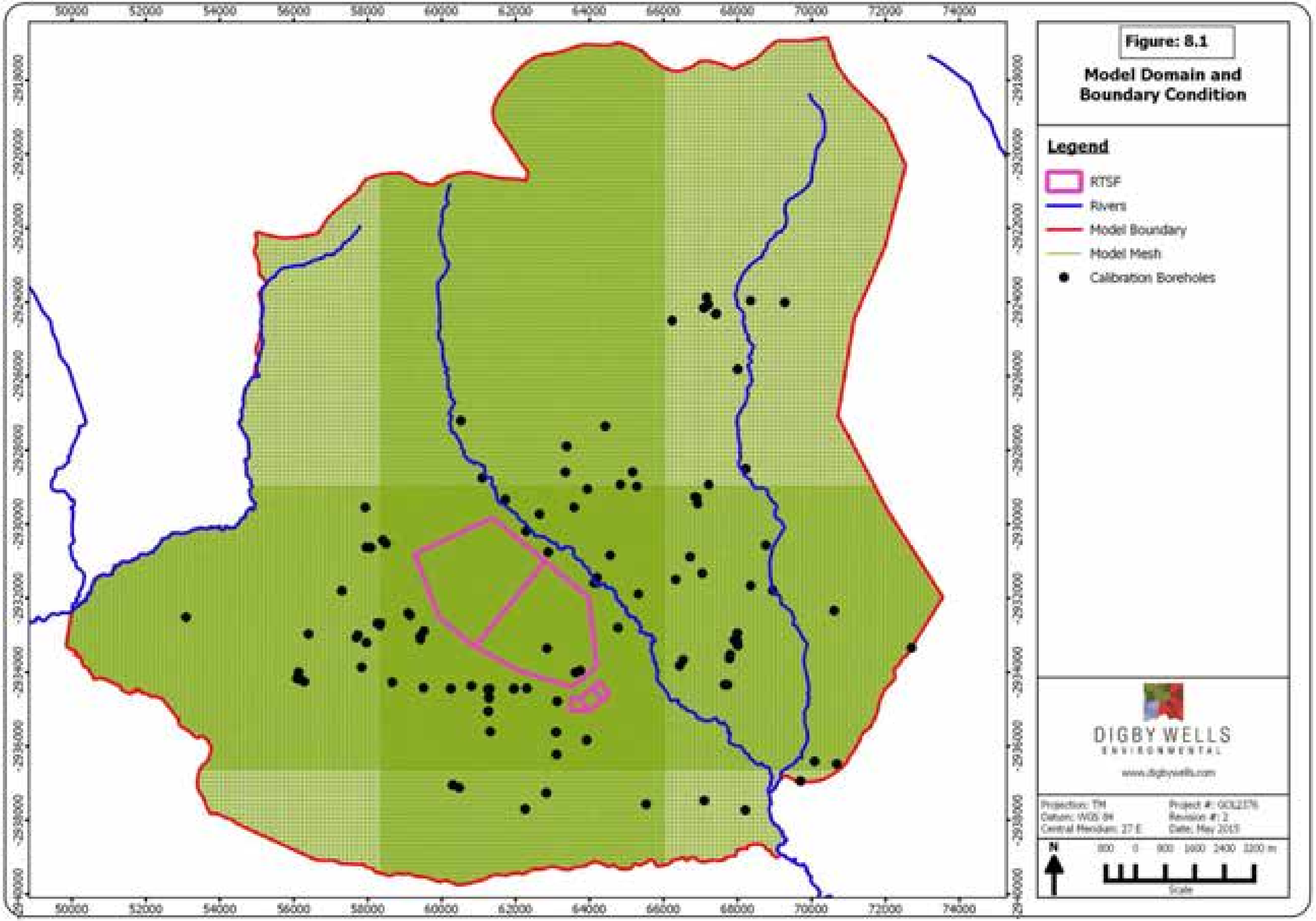


Figure: 8.1

Model Domain and Boundary Condition

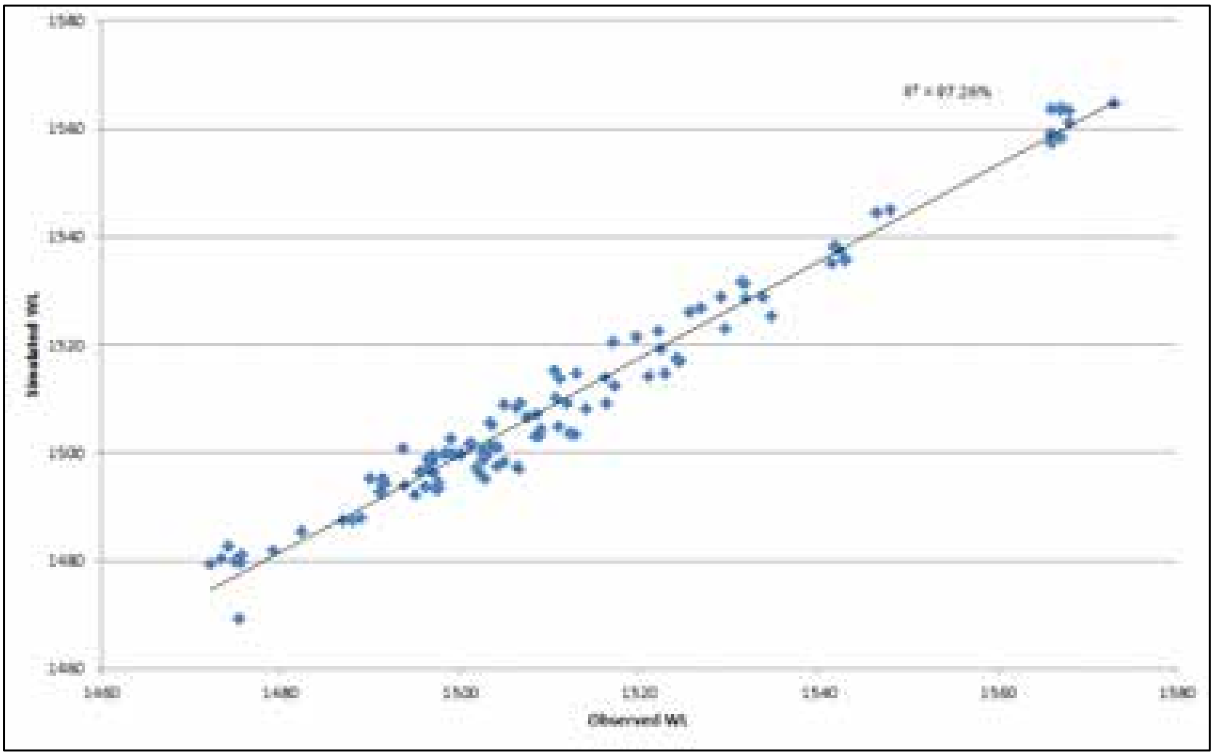


Figure 8.2: Correlation between the observed and simulated water levels

8.3 Flow Simulation Results

The steady state groundwater elevation follows the topography and is generally flowing from northwest to southeast as illustrated in Figure 8.3. The groundwater flow direction can vary on a local scale, directed towards the streams as baseflow or depending on the orientation of the weathered zones and fractures that act as preferential groundwater flow paths.

The flow gradient is variable from steep (0.014) on the northern model boundary to gentle (0.003) on the south. It is 0.0051 in the area of the RTSF. This is due to the site-specific topographical setting, as well as the hydraulic conductivities. The gradient in areas of relatively higher hydraulic conductivities is gentler than areas of lower hydraulic conductivities.

Within the RTSF area the hydraulic gradient is approximately 0.0051. The average permeability of the top aquifer is 0.207 m/d and that of the fractured aquifer is 0.180 m/d. The average groundwater flow velocity (Darcy velocity) along the weathered zone is therefore 0.001 m/d and in the fractured aquifer is 0.0009 m/d.

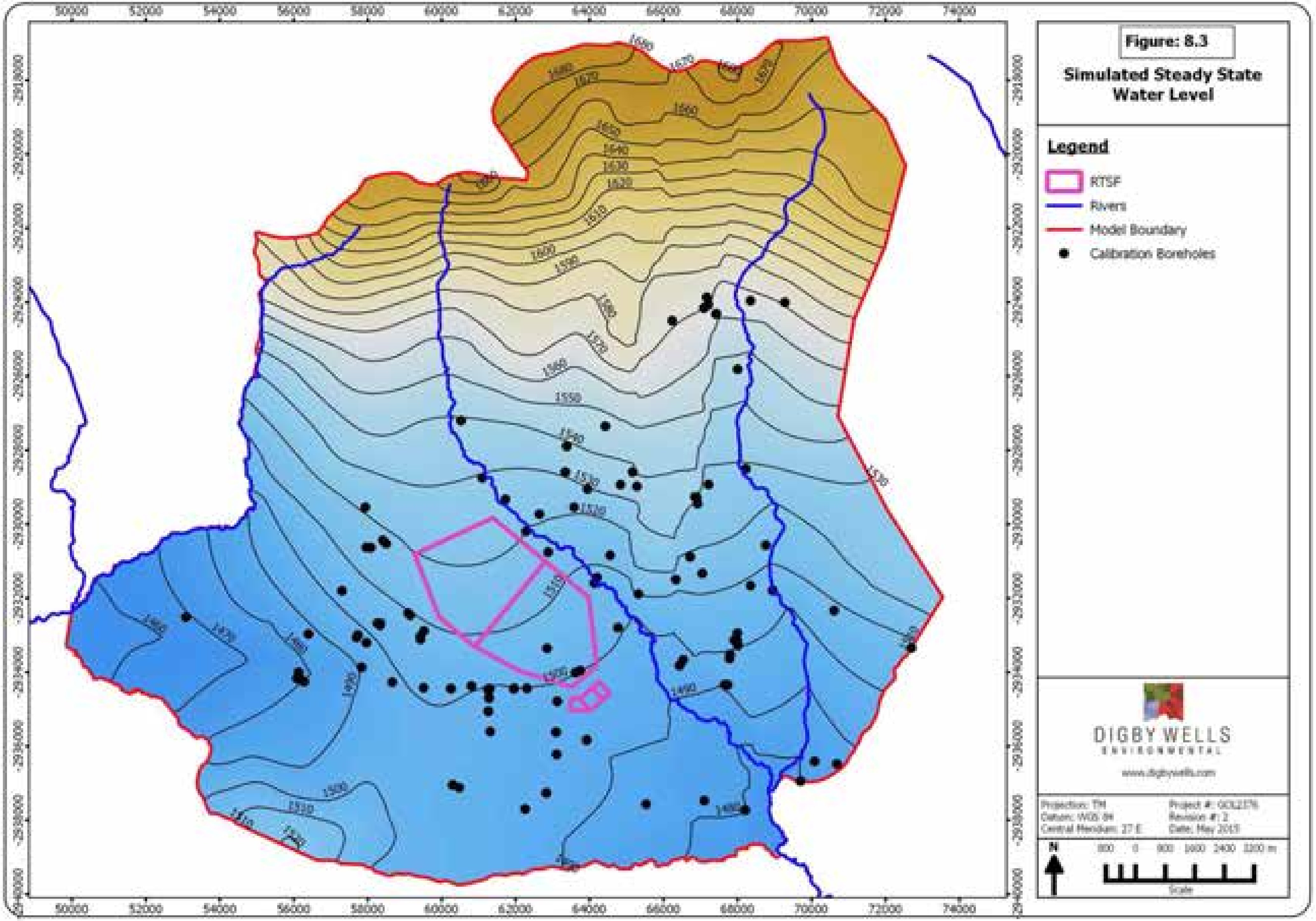


Figure: 8.3

Simulated Steady State Water Level

8.4 Contaminant Simulation

A numerical transport model was used to simulate and predict the impacts of the proposed RTSF on groundwater quality during operational and post closure phases.

Digby Wells simulated the following five options to evaluate various RTSF designs and corresponding environmental impacts. The options are listed in Table 8.1 and were formulated in line with SLR's seepage mitigation designs proposed for the RTSF. It should be noted that the return water dam (RWD) is assumed to be lined in all options with an average seepage rate of 6.45x10^{-5} m/d:

- Option 1 assumes a base case with no mitigation, whereby the RTSF only includes standard underdrains and tow drains, but not blast curtain or a liner. This means that significant volumes of water will infiltrate and join the groundwater environment. An average seepage rate of 3.21x10^{-4} m/day has been estimated for this option, for up to 100 years after closure.
- Option 2 assumes that a geomembrane liner will be implemented underneath the RTSF, with an average seepage rate of 4.90 x10^{-6} m/d.
- Option 3 assumes that a geomembrane liner enhanced with clay from the site will be implemented, with an average seepage rate of 4.15 x10^{-6} m/d.
- Option 4 assumes a Class C liner without underdrainage. The average seepage rate for this combination is 4.05 x10^{-6} m/d.
- Option 5 is the same as Option 1 (base case), but with the addition of blast curtain to a depth of 30 m below surface to intercept any pollution plumes that might originate from the proposed RTSF. A simplified design of the blast curtain is illustrated in Figure 8.4 (side view) and Figure 8.5 (top view).

Table 8.1: List of simulated options (SLR, 2015)

Option	Description	Years 0 – 100 seepage rate (m/d)		
		Minimum	Maximum	Average
1	Unlined	1.18x10^{-4}	5.25 x10^{-4}	3.21 x10^{-4}
2	Geomembrane liner only	3.00 x10^{-7}	9.50 x10^{-6}	4.90 x10^{-6}
3	Geomembrane & Clay liner	1.00 x10^{-7}	8.20 x10^{-6}	4.15 x10^{-6}
4	Class C barrier system without underdrainage (NEMWA)	2.00 x10^{-7}	7.90 x10^{-6}	4.05 x10^{-6}
5	Option 1 with blast curtain (30 m)	1.18 x10^{-4}	5.25 x10^{-4}	3.21 x10^{-4}

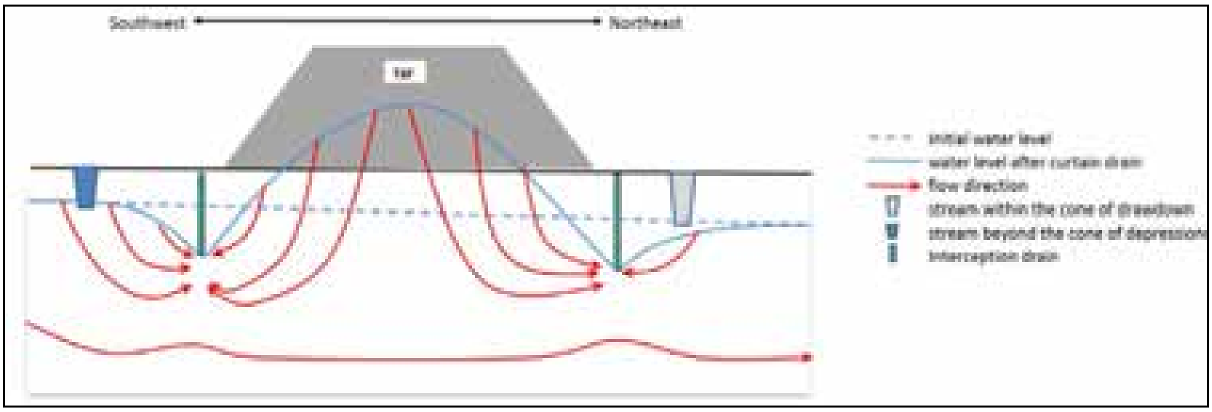


Figure 8.4: General conceptual design of the blast curtain

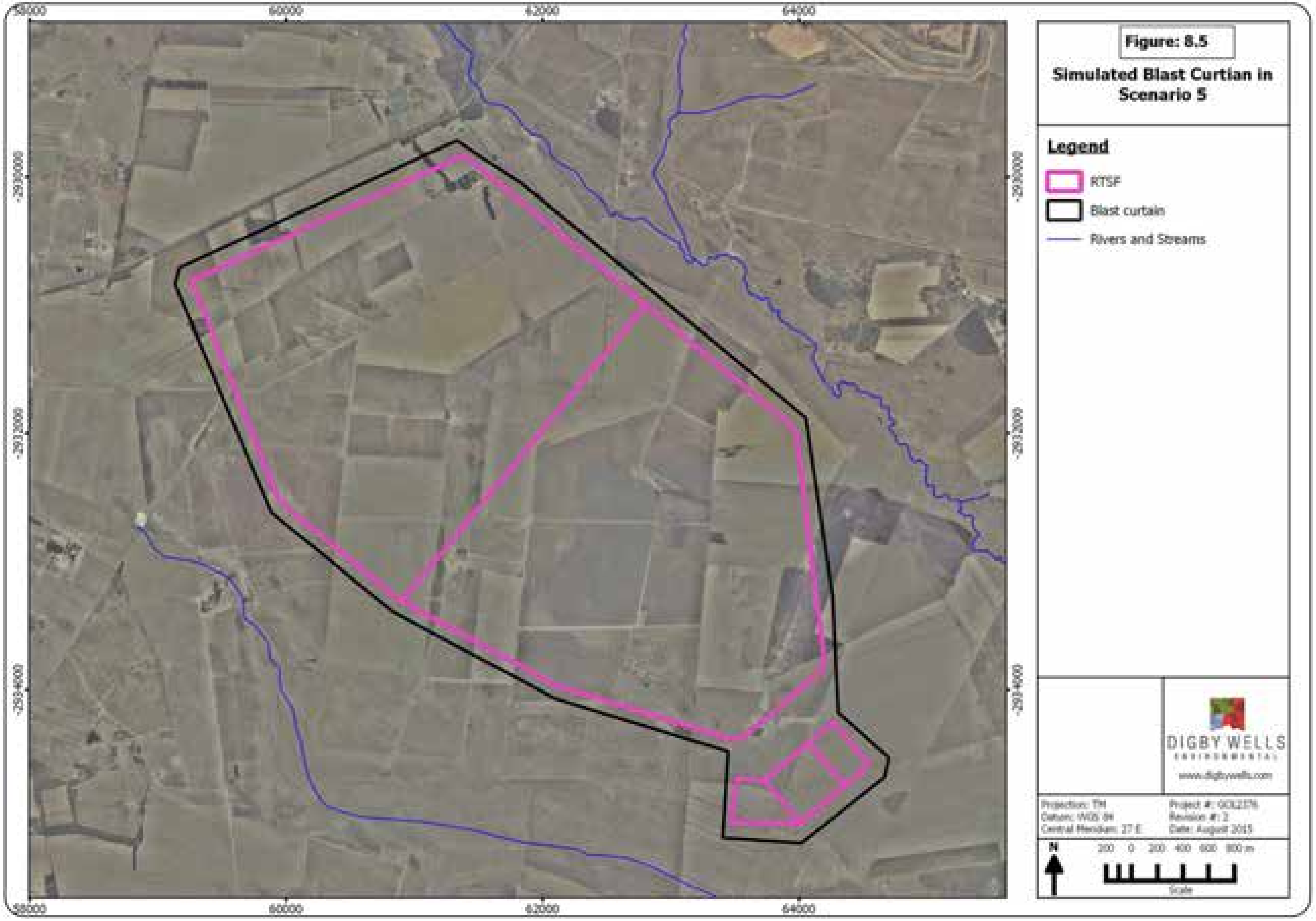


Figure: 8.5

Simulated Blast Curtian in Scenario 5

Projection: TM
Datum: WGS 84
Central Meridian: 27 E

Project #: GOL2376
Revision #: 2
Date: August 2015

9 Sensitivity Analysis and No-Go Areas

The RTSF is an area of concern due to the potential for groundwater contamination. The size of the no-go area, i.e. the aquifer that will be contaminated at concentrations exceeding the recommended water quality limits, is different for the different options. Being a conservative element, sulfate has the largest footprint area and is used to demarcate the sensitive zone. The contamination footprint area of the trace metals that have been simulated in this study (i.e. Mn, As and U) is smaller than that of sulfate and therefore only the sulfate plume is discussed in this section and used as a tracer for the delineation of the sensitive zone. The contamination plumes of the trace metals are given in Appendix E.

Out of the different options considered in this study, Sibanye Gold is likely to seek approval for Option 5 and the sensitivity map associated with the option is shown in Figure 9.2. The figure shows a predicted sensitive area, 100 years after closure, i.e. 150 years after commencement of the project.

For the purpose of comparison, the sensitivity map of Option 1 (base case with no mitigation) is also illustrated in the figure and shows that:

- The sensitive area considering Option 5 is 16.7 km^2; and
- The sensitive area for Option 1 is estimated at 36.4 km^2.

Option 5 (blast curtain) operates on the principle of dewatering along the RTSF boundaries to intercept the contaminant plume. This will have a side effect as a cone of dewatering will be formed. In addition to the contamination plumes, the sensitive area can also be defined in terms of the area that will be impacted by the cone of dewatering.

The sensitive area where the water level will be lowered by at least 10 m is shown in Figure 9.2 and covers an area of 23.7 km^2.

9.1 Model Sensitivity

The sensitivity of the model to the various hydraulic parameters was evaluated to quantify the uncertainty in the calibrated model caused by input parameters. Input parameters (horizontal permeability, vertical permeability, recharge, specific storage, specific yield and retardation factor) were varied within a factor of 0.5 and 2 of the calibrated value and the corresponding change of the contamination plume size was measured.

Figure 9.1 presents the results of the sensitivity analyses for the various hydraulic and transport parameters. The model is more sensitive to the horizontal and vertical permeabilities than the rest of the parameters (the recharge, specific storage, specific yield and retardation factor). This means that changes in permeabilities (vertical and horizontal) will have a greater impact on the model output than the other less sensitive parameters.

Since the model is most sensitive to permeability, any future groundwater study is recommended to mainly focus and refine this parameter of the aquifer.

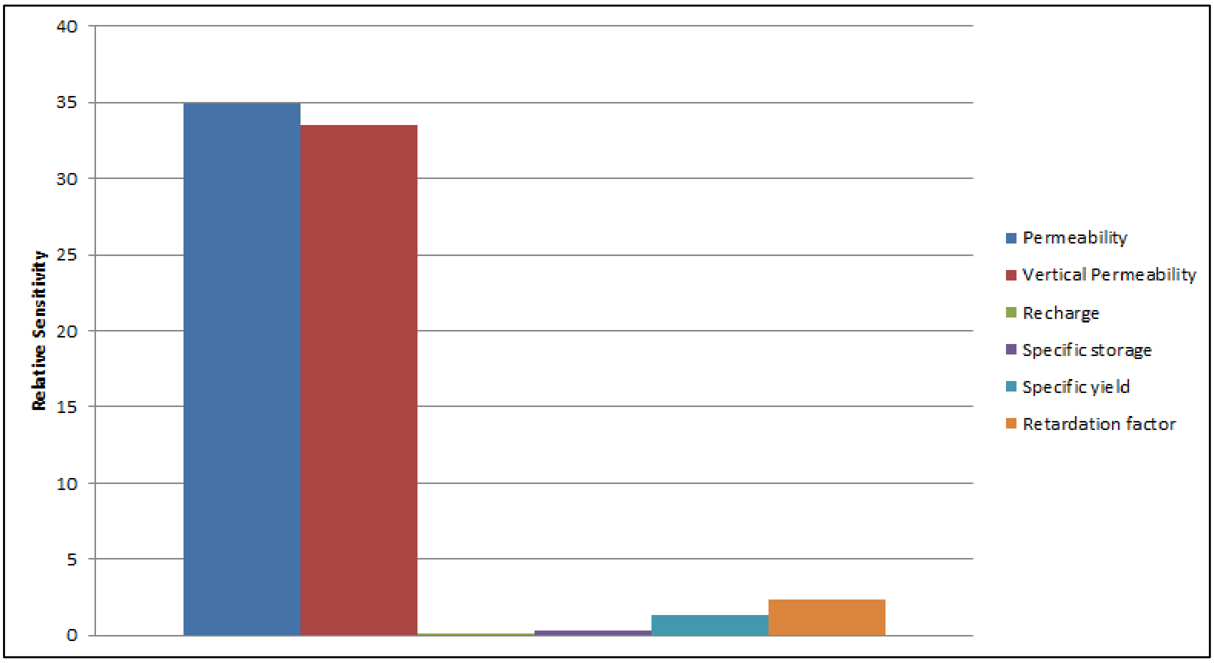


Figure 9.1: Model sensitivity to the hydraulic parameters

9.2 Comparison of the Effectiveness of the Various Options

The proposed RTSF footprint area will be approximately 13.8 km^2. The blast curtain is planned to enclose the RTSF as shown in Figure 8.5 and will have an area of approximately 16.7 km^2. This means that the area between the RTSF and blast curtain is approximately 2.9 km^2.

In this section, the total contamination plume has been used to compare the effectiveness of the different options. As an example, the plume footprint area for Option 1, 100 years after closure is 36.4 km^2. This is inclusive of the 13.8 km^2 RTSF area, as well as 2.9 km^2 area between the RTSF and the blast curtain. The contamination plume outside of the blast curtain is therefore 19.7 km^2 (i.e. 36.4 km^2 minus 16.7 km^2).

9.2.1 Plume Size at the End of Operation

The life of operation is assumed to be 50 years in this study. The total footprint area (i.e. inclusive of the RTSF and blast curtain areas) is shown in Table 9.1. The table shows that:

- The impact from the RTSF will be the highest in Option 1, with a sulfate plume area (for concentrations exceeding 250 mg/L) of approximately 26.1 km^2. In addition to this, the Mn plume area (concentrations exceeding 0.1 mg/L) will be 25.8 km^2. It should be noted that the concentrations of As and U in the groundwater will not exceed their recommended limits even when a base case is assumed.
- None of the contaminants are expected to seep at concentrations higher than their recommended limits if Options 2, 3 or 4 are implemented. This means that these options are the most effective in preventing groundwater contamination and are

preferred from an environmental perspective. However, the overall cost/benefit needs to be assessed with the use of liners.

- With the use of the blast curtain (Option 5), the surface area associated with the plume footprint for SO_4 and Mn can be reduced to approximately 16.3 km^2. If Options 2, 3 and 4 are not affordable, Option 5 is recommended to contain the pollution plume within the blast curtain.

Table 9.1: Plume size of the different options at the end of operation

Options 50 years	Plume area (km^2) that is above the recommended limit			
	SO_4	Mn	As	U
Option 1	26.1	25.8	-	-
Option 2	-	-	-	-
Option 3	-	-	-	-
Option 4	-	-	-	-
Option 5	16.3	16.3	-	-

9.2.2 Plume Size 100 Years after Closure

The numerical model was used to simulate the size of the pollution plume 100 years after closure. The simulation result is shown in Table 9.2 and it can be concluded that:

- The concentrations of As and U will be within the recommended limits even 100 years after the dump has been closed.
- The surface area associated with the SO_4 and Mn plumes will increase to a maximum of 36.3 km^2.
- The contamination plume can be contained within the RTSF footprint area if Options 2, 3 or 4 are implemented. These options have a smaller environmental impact compared to Option 1 or 5.
- With the use of a blast curtain, the contaminants can be contained within the footprint of the curtain area. This option is the preferred option considering the cost of liners that were proposed for Options 2, 3 and 4.

Table 9.2: Plume size of the different options 100 years after closure

Options 100 years	Plume area (km^2) that is above the recommended limit			
	SO_4	Mn	As	U
Option 1	36.3	35.9	-	-
Option 2	13.9	13.5	-	-
Option 3	13.5	13.0	-	-

Options 100 years	**Plume area (km^2) that is above the recommended limit**			
	SO$_4$	**Mn**	**As**	**U**
Option 4	13.4	12.9	-	-
Option 5	16.7	16.6	-	-

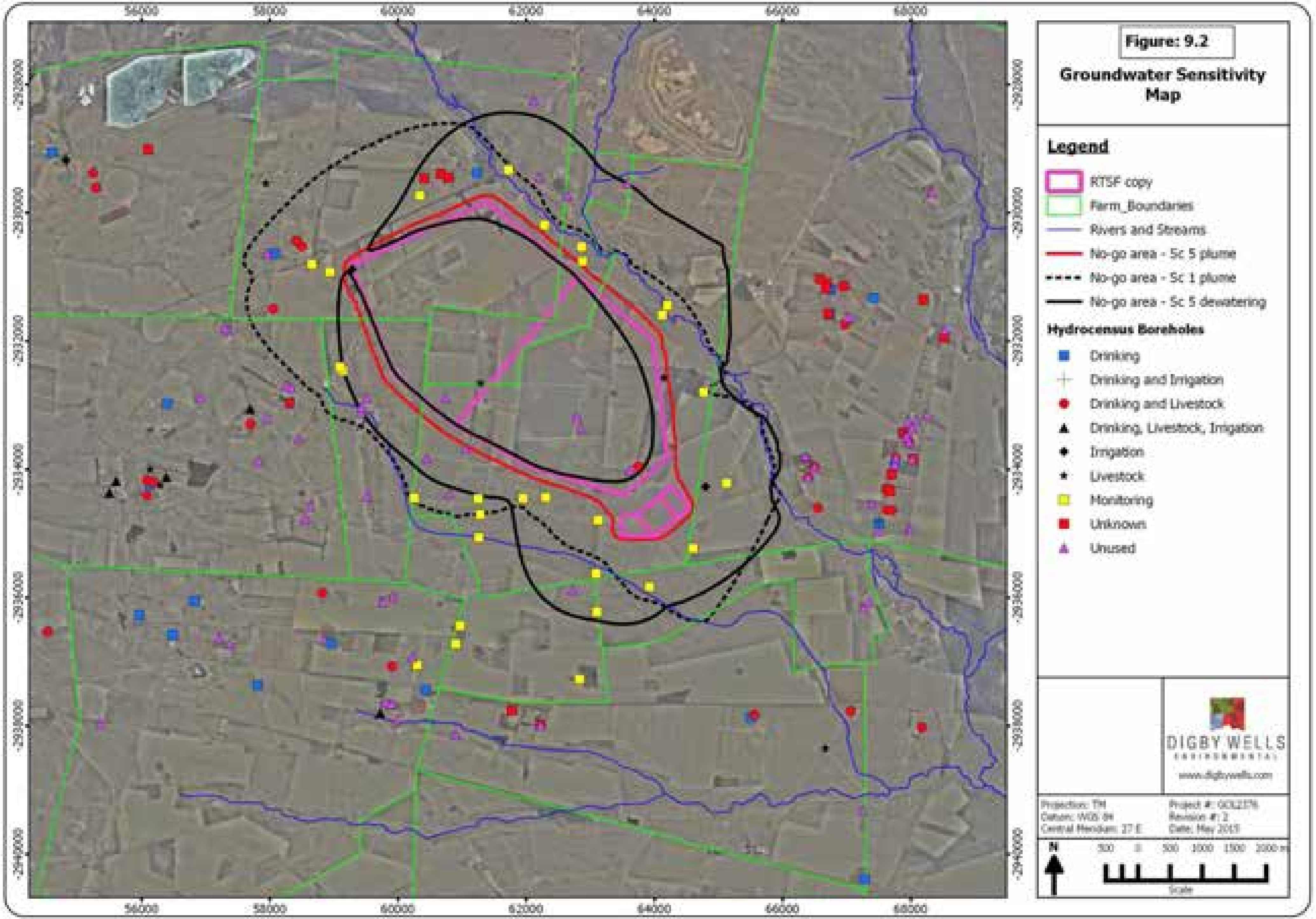


Figure: 9.2

Groundwater Sensitivity Map

10 Impact Assessment

The impacts are assessed based on the impact's magnitude, as well as the receiver's sensitivity, culminating in an impact significance which identifies the most important impacts that require mitigation.

Based on international guidelines and South African legislation, the following criteria are taken into account when examining potentially significant impacts:

- Nature of impacts (direct/indirect, positive/ negative);
- Duration (short/medium/long-term, permanent(irreversible) / temporary (reversible), frequent/seldom);
- Extent (geographical area, size of affected population/habitat/species);
- Intensity (minimal, severe, replaceable/irreplaceable);
- Probability (high/medium/low probability); and
- Possibility to mitigate, avoid or offset significant adverse impacts.

Details of the impact assessment methodology used to determine the significance of physical, bio-physical and socio-economic impacts are provided below.

The significance rating process follows the established impact/risk assessment formula:

Significance = Consequence x Probability x Nature

Where

Consequence = Intensity + Extent + Duration

And

Probability = Likelihood of an impact occurring

And

Nature = Positive (+1) or negative (-1) impact

Note: In the formula for calculating consequence, the type of impact is multiplied by +1 for positive impacts and -1 for negative impacts

The matrix calculates the rating out of 147, whereby Intensity, Extent, Duration and Probability are each rated out of seven as indicated in Table 10.3. The weight assigned to the various parameters is then multiplied by +1 for positive impacts and -1 for negative impacts.

Impacts are rated prior to mitigation and again after consideration of mitigation measures proposed in this EIA/EMP Report. The significance of an impact is then determined and categorised into one of eight categories, as indicated in Table 10.2, which is extracted from Table 10.1. The description of the significance ratings is discussed in Table 10.3.

It is important to note that the pre-mitigation ratings take into consideration the activity as proposed, i.e. there may already be certain types of mitigation measures included in the design (for example due to legal requirements). If the potential impact is still considered too high, additional mitigation measures are proposed.

Table 10.1: Impact assessment parameter ratings

RATING	INTENSITY/REPLACABILITY		EXTENT	DURATION/REVERSIBILITY	PROBABILITY
	Negative impacts	Positive impacts			
7	Irreplaceable damage to highly valued items of great natural or social significance or complete breakdown of natural and / or social order.	Noticeable, on-going natural and / or social benefits which have improved the overall conditions of the baseline.	International The effect will occur across international borders.	Permanent: The impact is irreversible, even with management, and will remain after the life of the project.	Definite: There are sound scientific reasons to expect that the impact will definitely occur. >80% probability.
6	Irreplaceable damage to highly valued items of natural or social significance or breakdown of natural and / or social order.	Great improvement to the overall conditions of a large percentage of the baseline.	National Will affect the entire country.	Beyond project life: The impact will remain for some time after the life of the project and is potentially irreversible even with management.	Almost certain / Highly probable: It is most likely that the impact will occur. <80% probability.
5	Very serious widespread natural and / or social baseline changes. Irreparable damage to highly valued items.	On-going and widespread benefits to local communities and natural features of the landscape.	Province/ Region Will affect the entire province or region.	Project Life (>15 years): The impact will cease after the operational life span of the project and can be reversed with sufficient management.	Likely: The impact may occur. <65% probability.
4	On-going serious natural and / or social issues. Significant changes to structures / items of natural or social significance.	Average to intense natural and / or social benefits to some elements of the baseline.	Municipal Area Will affect the whole municipal area.	Long term: 6-15 years and impact can be reversed with management.	Probable: Has occurred here or elsewhere and could therefore occur. <50% probability.

RATING	INTENSITY/REPLACABILITY		EXTENT	DURATION/REVERSIBILITY	PROBABILITY
	Negative impacts	**Positive impacts**			
3	On-going natural and / or social issues. Discernible changes to natural or social baseline.	Average, on-going positive benefits, not widespread but felt by some elements of the baseline.	<u>Local</u> Local extending only as far as the development site area.	Medium term: 1-5 years and impact can be reversed with minimal management.	Unlikely: Has not happened yet but could happen once in the lifetime of the project, therefore there is a possibility that the impact will occur. <25% probability.
2	Minor natural and / or social impacts which are mostly replaceable. Very little change to the baseline.	Low positive impacts experience by a small percentage of the baseline.	<u>Limited</u> Limited to the site and its immediate surroundings.	Short term: Less than 1 year and is reversible.	Rare / improbable: Conceivable, but only in extreme circumstances. The possibility of the impact materialising is very low as a result of design, historic experience or implementation of adequate mitigation measures. <10% probability.
1	Minimal natural and / or social impacts, low-level replaceable damage with no change to the baseline.	Some low-level natural and / or social benefits felt by a very small percentage of the baseline.	<u>Very limited</u> Limited to specific isolated parts of the site.	Immediate: Less than 1 month and is completely reversible without management.	Highly unlikely / None: Expected never to happen. <1% probability.

Table 10.2: Probability/Consequence matrix

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

Consequence

TABLE 10.3: Significance rating description[1]

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

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[1] It is generally sufficient to only monitor impacts that are rated as negligible or minor

10.1 RTSF Impact Assessment

The proposed RTSF has the potential to negatively impact the groundwater through seepage of undesired contaminants. The reclamation of the historical TSFs is however, likely to have a positive impact on the groundwater environment. Potential impacts are assessed in this section considering the construction, operational and closure phases.

10.1.1 Construction Phase

Seven of the hydrocensus boreholes are located within the proposed RTSF footprint area. The groundwater depths within the footprint, as observed in these boreholes, range between 2.3 to 9.5 m below surface. Potential impacts associated with the RTSF construction are therefore due to the relatively shallow groundwater table.

The project activities, interactions and potential impacts during the construction phase will be associated with the establishment of the blast curtain drain as shown in Table 10.4.

Table 10.4: Interactions and impacts during the construction phase

Interaction	Impact
Blast curtain drilling and blasting	Depleting of groundwater and contamination by explosives

No impact on the groundwater quantity is expected during site clearing and blasting as long as the activities are taking place above the groundwater table.

- The construction of blast drains and trenches below the groundwater table can impact the groundwater quantity as the groundwater will be dewatered to keep the working environment dry. This impact is rated as negligible since no tailings related AMD or metal leaching will occur.
- Construction will also be conducted in a relatively short period compared to the operational and post-closure phases. Impacts on the groundwater environment are therefore rated as Negligible (Table 10.5).

Table 10.5: Potential impact of the blast curtain excavation

Activity and Interaction during the construction phase			
Dimension	**Rating**	**Motivation**	**Significance**
Impact Description: Blast curtain excavation			
Prior to mitigation/ management			
Duration	Short term (2)	This will be limited during the construction phase	Minor (negative) – 24

Activity and Interaction during the construction phase			
Dimension	**Rating**	**Motivation**	**Significance**
Extent	Limited (2)	Impact will be limited to the footprint area	
Intensity	Minor (2)	Any dewatering will have minor environmental significance	
Probability	Probable (4)	Dewatering will be required considering the shallow water table	
Nature	Negative		
Mitigation/ Management actions			
▪ In areas where the trenches are going to be excavated below the water level, dewatering of the aquifer to locally lower the water table can be considered to ensure that the construction takes place in a dry environment and the water quality remains acceptable. The abstracted water can be utilised for dust suppression, vegetation or discharged to local stream (if quality permits). Since the groundwater is not expected to be polluted at this stage, the utilisation of the water for activities such as dust suppression or vegetation is not expected to cause negative environmental impacts. ▪ Install long term monitoring boreholes.			
Post- mitigation			
Duration	Short term (1)	Water level will recover after the construction phase is completed	Negligible (negative) – 12
Extent	Limited (1)	Only the area between RTSF and the rivers will be affected	
Intensity	Minimal natural impact (1)	Considering that the construction phase will be for a short period, the intensity will be minimal	
Probability	Probable (4)	Even with the mitigation plans proposed, dewatering will be required in shallow water levels	
Nature	Negative		

10.1.2 Operational Phase

The activities that could potentially impact the groundwater environment during the operational phase are listed in Table 10.6 and include seepage from the RTSF, pollution control dam and return water dams, and dewatering at the blast curtain drain.

Table 10.6: Interactions and Impacts during the operation phase

Interaction	Impact (Option 1)
Seepage from the RTSF	Groundwater contamination
Blast curtain drain dewatering	Water level lowering
Pollution control and return dams	Groundwater contamination due to seepage from the dams

Seepage from the RTSF can negatively influence the groundwater quality in the underlying aquifers during the operational phase, if no mitigation is undertaken, and as such the significance is rated as Moderate (Table 10.7). The sulfate contamination plume at the end of operational phase, for the unmitigated base case option is shown in Figure 10.1 (the plumes of the simulated trace metals is given in Appendix E).

- Contamination plumes associated with the RTSF are expected to reach down-gradient private boreholes for the unmitigated base case option (Option 1) as shown in Figure 10.1.
- Seepage from the RTSF can also impact the streams. Once the plume reaches the streams, it can migrate at a faster rate compared to the speed of the groundwater flow and could have Medium to High impact on the down-gradient riverine ecosystem and communities.

Although the blast curtain would be crucial to contain the pollution plume, it has a side effect since it will lower the water table from its natural position in the outer ring of the drain. Thus, the water quality impacts will be reduced, but the area/extent of the impact on the groundwater levels would increase.

The seepage rate from the RTSF is expected to increase and reach a maximum when it is fully operational. The average seepage rate (which is dependent on the permeability of the TSF material) is estimated to be 3.21×10^{-4} m/d (SRL, 2015). This is expected to last for up to 100 years after closure and it is only then the rate will start to decrease (assuming cover is in place). For the blast curtain to work effectively, it has to intercept at least 120% of the seeped water (i.e. 4,810 m^3/d). This is because the curtain is also draining from the outer periphery. The plume can escape away from the curtain if it is pumped at less than this. It does not matter from a groundwater perspective if the water is pumped from a blast curtain as long as the recommended pumping rate is maintained and as long as these are within 100 m to 200 m of the RTSF footprint area. The further the blast curtain from the RTSF footprint, the more water will have to be pumped out.

Dewatering the blast curtain will have a side effect in terms of lowering the water table around the periphery of the RTSF, outside the perimeter of the blast curtain drain. The predicted cone of dewatering at the end of operation is shown in Figure 10.3. Considering the shallow water level within the project area, the drawdown could be more than 25 m in some localities. Dewatering can also affect and reduce the flow rate of the Leeuspruit and its tributes, and therefore the impact significance has been rated as Minor (Table 10.7).The sensitive area where the water level will be lowered by at least 10 m is shown in Figure 9.2 and covers an area of 23.7 km^2.

No or limited environmental impact is expected from the pollution control dam (PCD) if it is lined. If unlined, however, seepage from the dam can potentially impact the environment. The significance rating is given as Moderate (Table 10.7).

Table 10.7: Potential impacts during the operation phase

Dimension	Rating	Motivation	Significance
Impact Description: Seepage from the RTSF			
Prior to mitigation/ management			
Duration	Permanent (7)	If unmitigated, seepage of contaminated water will occur for a prolonged period	Moderate (negative) – 107
Extent	Local (3)	The impact will be local and within 2 km of the RTSF footprint area	
Intensity	Serious (5)	Once contamination starts, it will be irreversible	
Probability	Definite (7)	Seepage from the RTSF will impact the groundwater environment	
Nature	Negative		
Mitigation/ Management actions			
▪ Blast curtain application (Option 5), i.e. create a cut off zone around perimeter of dam. ▪ Monitoring of groundwater quality and water levels. ▪ Compensation of farmers with impacted groundwater, where applicable. ▪ Re-introduce treated water from the AWTF into the Leeuspruit.			
Post- mitigation			
Duration	Permanent (7)	The contamination plume will be permanent inside the drain perimeter	Negligible (negative) – 30
Extent	Limited (2)	The blast curtain drain with intercept any pollution plumes to within the footprint area	
Intensity	Minimal (1)	Impact will be underneath the RTSF only	
Probability	unlikely (3)	Impact to the groundwater outside the RTSF area is unlikely	

Dimension	Rating	Motivation	Significance
Nature	Negative		
Impact Description: Lowering of the water table due to dewatering of the blast curtain drain			
Prior to mitigation/ management			
Duration	Permanent (7)	The dewatering process and its impact will be permanent	Minor (negative) – 72
Extent	Local (3)	The radius of influence will be of a local scale	
Intensity	Minor (2)	Drawdown in the nearby private boreholes will be less than 10 m	
Probability	Almost certain (6)	It is almost certain that there will be a linear drawdown of dewatering formed along the drain	
Nature	Negative		
***Mitigation/ Management actions*[2]**			
- Monitoring of groundwater water levels. - Compensation of farmers with impacted groundwater levels. - Re-introduce treated water from the AWTF into the Leeuspruit.			
Post management			
Duration	Permanent (7)	The depression of the water table will persist throughout the life of operation	Minor (negative) – 60
Extent	Limited (2)	With the re-introduction of the treated water into the Leeuspruit, the extent of impact will be limited	
Intensity	Minimal (1)	Once the abstracted water is treated and at the AWTF and introduced to the river, the environmental significance is rated as minimal	
Probability	Almost certain (6)	The lowering of the water table will almost certainly occur	
Nature	Negative		

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[2] This shouldn't be long. it is a brief, bulleted description of the mitigation

Dimension	Rating	Motivation	Significance
Impact Description: Groundwater contamination due to seepage from pollution control dams			
Prior to mitigation/ management			
Duration	Project life (5)	Seepage of contaminated water will occur during the operation of the dams	Minor (negative) – 70
Extent	Limited (2)	The impact from the pollution control dam alone will be local and within 150 m of the RTSF footprint area	
Intensity	Minor (3)	Once contamination starts, it take time to rehabilitate naturally	
Probability	Definite (7)	Seepage from unlined dams will definitely impact the groundwater	
Nature	Negative		
Mitigation/ Management actions[3]			
▪ Application of a liner. ▪ Monitoring of groundwater quality. ▪ Compensation of farmers with impacted groundwater or mine purchase land.			
Post management			
Duration	Project life (5)	The seepage from the pollution control dams will take place throughout the project life	Negligible (negative) – 21
Extent	Very limited (1)	With the application of a liner, the plume will be very limited	
Intensity	Minimal (1)	The intensity is minimal with the application of liners	
Probability	unlikely (3)	The impact is unlikely to occur	
Nature	Negative		

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[3] This shouldn’t be long. it is a brief, bulleted description of the mitigation

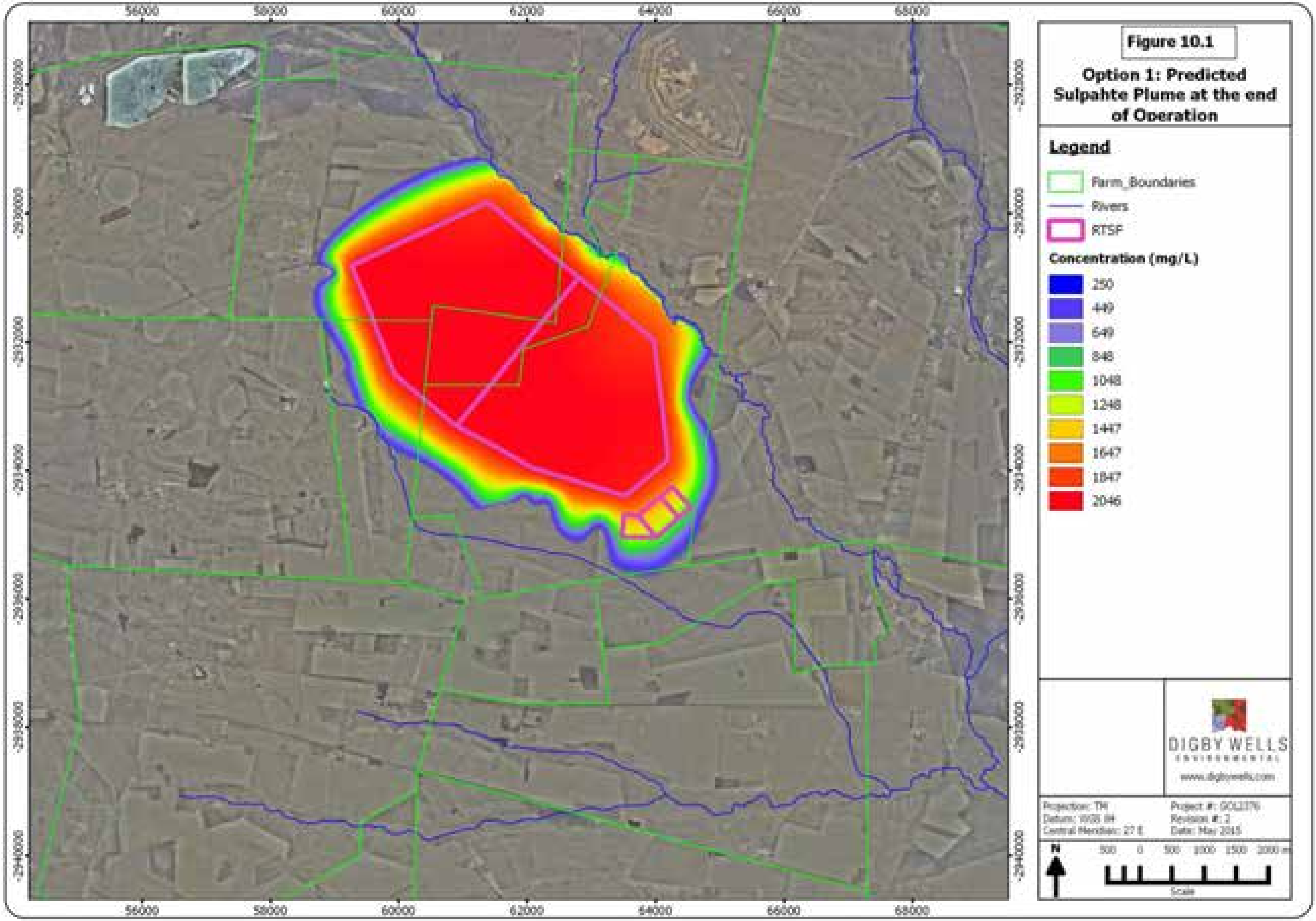

Figure 10.1

Option 1: Predicted Sulpahte Plume at the end of Operation

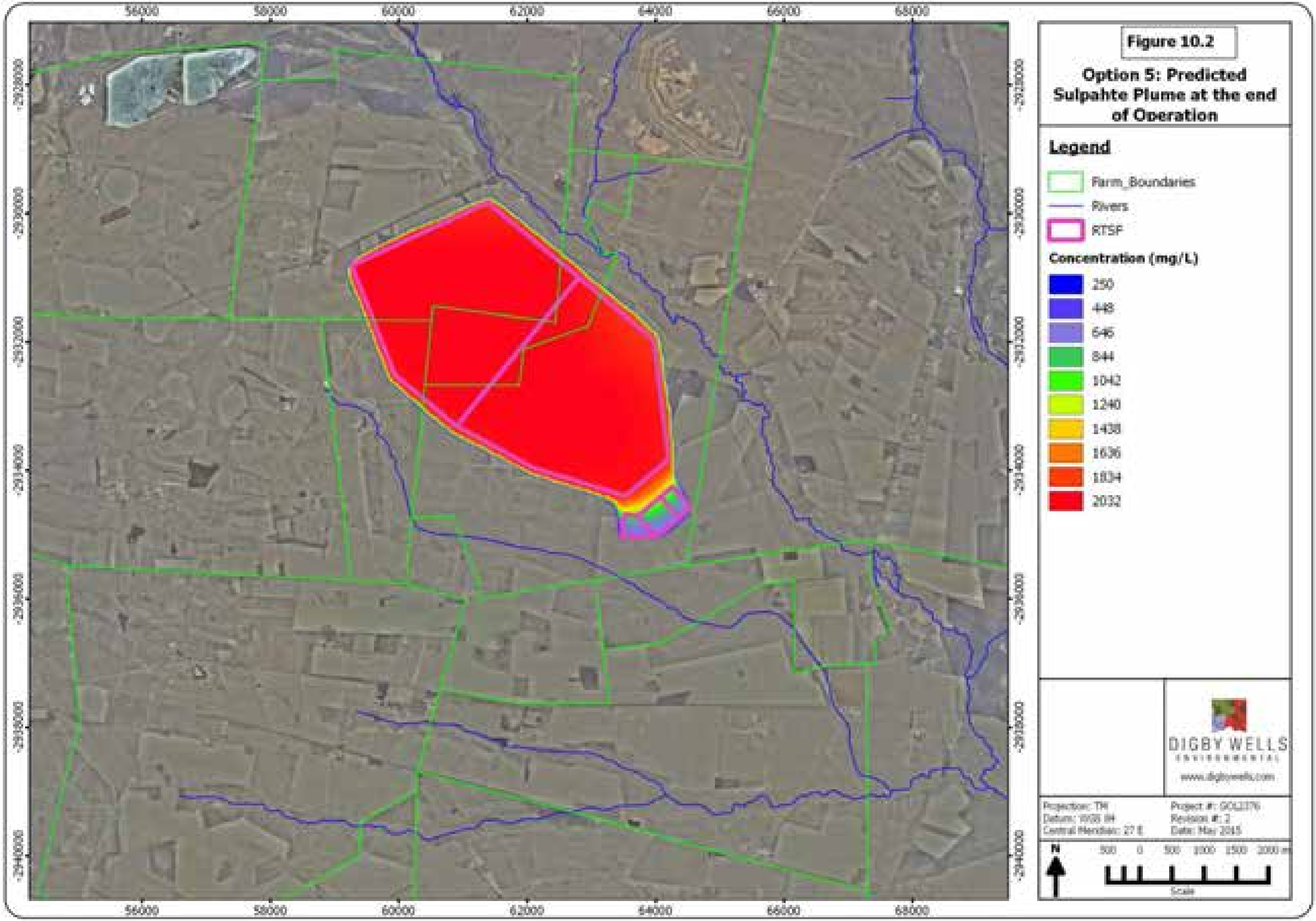

Figure 10.2

Option 5: Predicted Sulpahte Plume at the end of Operation

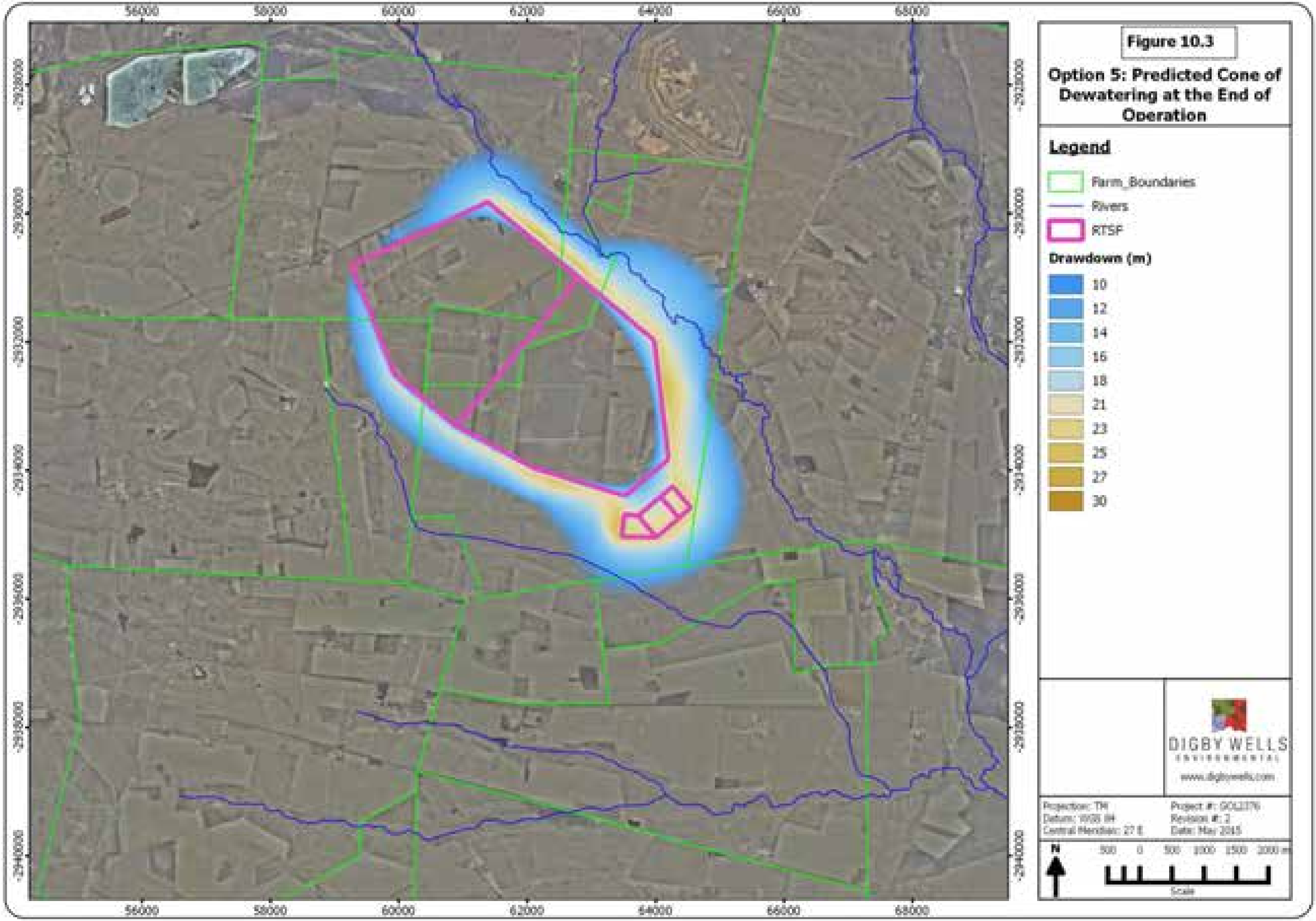

Figure 10.3

Option 5: Predicted Cone of Dewatering at the End of Operation

10.1.3 Closure Phase

The activities that could potentially impact the groundwater environment during the closure phase are listed in Table 10.8 and include seepage from the RTSF and dewatering at the blast curtain.

Table 10.8: Interactions and Impacts during the closure phase

Interaction	Impact
Seepage from the RTSF and RW dams	Groundwater contamination
Blast curtain dewatering	Water level lowering

Seepage from the RTSF and return water (RW) dams will continue even after mine closure and can have a negative impact on the groundwater environment, rated as Moderate (Table 10.9). The expected pollution plume for the unmitigated base case (Option 1), 100 years after dump closure is shown in Figure 10.4.

- Seepage from the RTSF and RW dams can impact the quality of the Leeuspruit and its tributaries via groundwater baseflow. Once the contamination plume reaches the stream, it can migrate at a higher rate compared to groundwater flow and could have a negative impact on the down-gradient riverine ecosystem and land owners.
- Contamination plumes from the RTSF and RW dams can also reach private boreholes down-gradient of the facility, particularly for Option 1 (unmitigated base case).

Since the blast curtain will be operational even after mine closure, the impact on the water level is expected to last long after the RTSF is closed. The radius of influence is also expected to grow due to the prolonged dewatering activities. The predicted cone of dewatering 100 years after mine closure is shown in Figure 10.6 and can negatively affect the nearby boreholes, Leeuspruit and its tributary.

All potential negative impacts associated with the blast curtain dewatering, as discussed during the operational phase, are also applicable here.

Although there will be no new deposition of tailings, it will take at least 100 years after closure before the seepage rate will be reduced naturally (SLR, 2015). This means that dewatering from the blast curtain has to continue in parallel. This will not only continue to lower the water table, but will also reduce the flow rate of the Leeuspruit and its tributaries and as a result the impact significance has been rated as Moderate (Table 10.9).

Table 10.9: Potential impacts after mine closure

Dimension	Rating	Motivation	Significance
Impact Description: groundwater contamination due to seepage from the RTSF and RW dams			
Prior to mitigation/ management			
Duration	Permanent (7)	Seepage of contaminated water even after mine closure	Moderate (negative) – 107
Extent	Local (3)	The impact will be local and within 2 km of the RTSF footprint area	
Intensity	Serious (5)	Once contamination starts, it will be irreversible	
Probability	Definite (7)	Seepage from the RTSF will impact the groundwater	
Nature	Negative		
Mitigation/ Management actions			
▪ Blast curtain application. ▪ Monitoring of groundwater quality and water levels. ▪ Compensation of farmers with impacted groundwater or mine purchase land ▪ Continue with re-introduction of treated water from the AWTF into the Leeuspruit.			
Post- mitigation – Blast curtain			
Duration	Permanent (7)	The contamination plume will be permanent	Negligible (negative) – 30
Extent	Limited (2)	The blast curtain will intercept any pollution plumes within the footprint area	
Intensity	Minimal (1)	Impact will be limited to the RTSF footprint	
Probability	unlikely (3)	Impact to the groundwater outside the RTSF area is unlikely	
Nature	Negative		
Impact Description: Water table lowering due to dewatering of the blast curtain			
Prior to mitigation/ management			
Duration	Permanent (7)	The dewatering process and its impact will be permanent	Minor (negative) – 72
Extent	Local (3)	The radius of influence will be of a local	

Dimension	Rating	Motivation	Significance
		scale (approximately 1.5 km radius in radius based on the model simulation)	
Intensity	Minor (3)	Drawdown in the nearby farms will be less than 20 m and might reduce the river quantity	
Probability	Almost certain (6)	It is almost certain that there will be a cone of dewatering formed	
Nature	Negative		
***Mitigation/ Management actions*[4]**			
▪ Monitoring of groundwater and water levels. ▪ Compensation of farmers with impacted groundwater or mine purchase land ▪ Continue with re-introduction of treated water from AWTF into Leeuspruit.			
Post management			
Duration	Permanent (7)	Pollution plume from the dams will persist throughout the life of operation	Minor (negative) – 66
Extent	Local (3)	Plume will extend locally as far as the development site area	
Intensity	Minimal (1)	Once the impacted parties are compensated with clean water, the environmental significance is rated as minimal	
Probability	Almost certain (6)	The lowering of the water table will almost certainly occur	
Nature	Negative		

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[4] This shouldn't be long. it is a brief, bulleted description of the mitigation

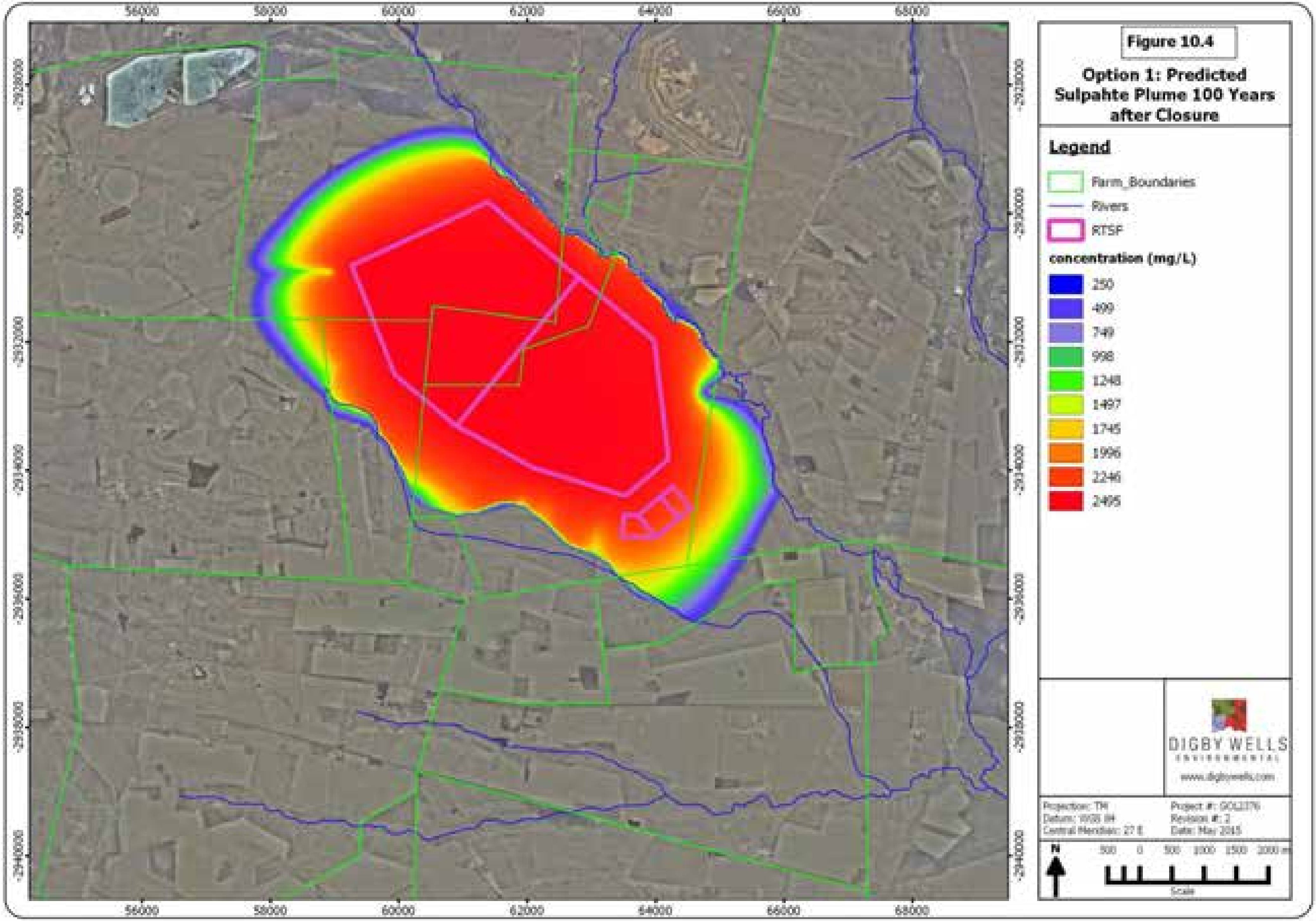
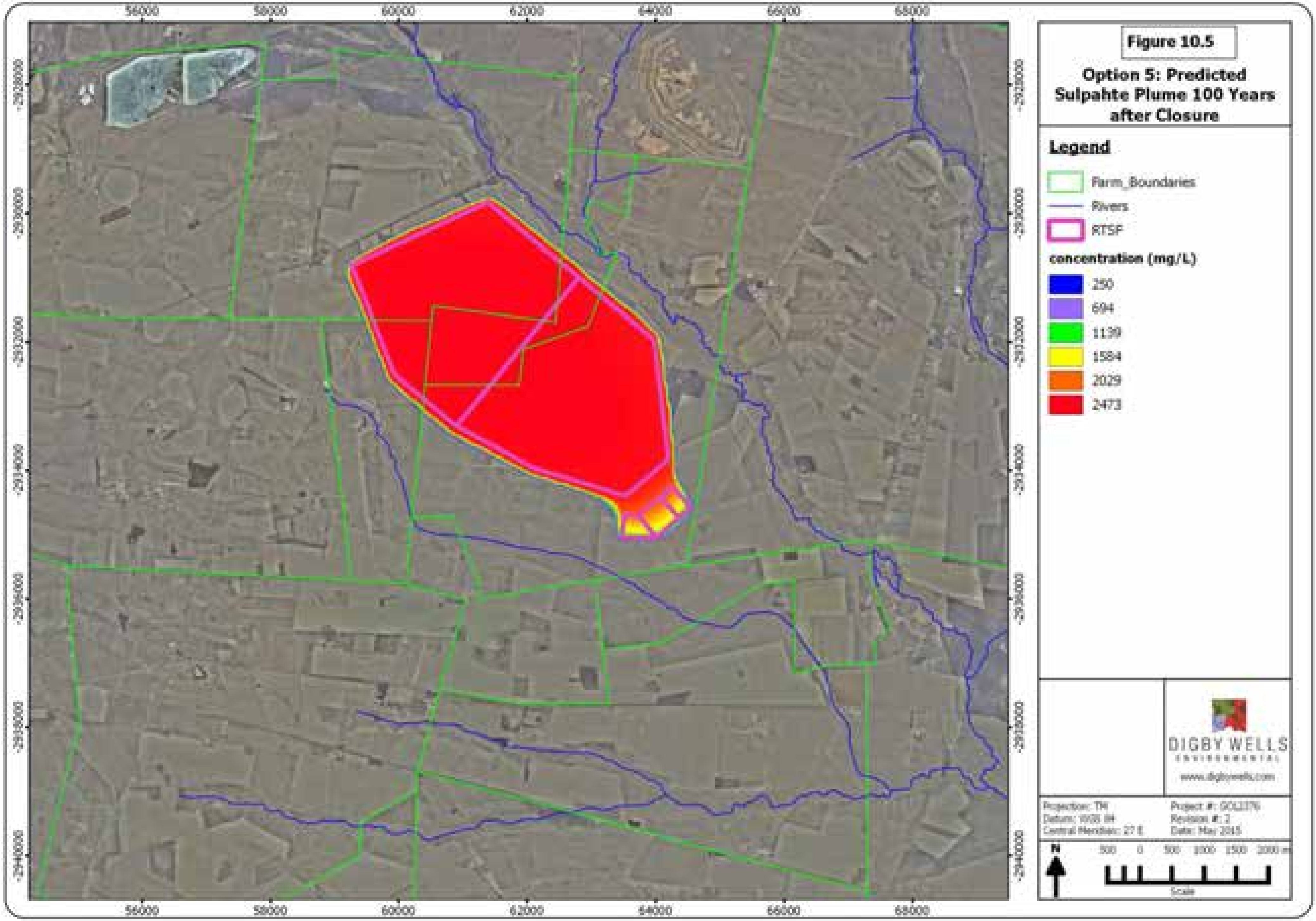


Figure 10.4

Option 1: Predicted Sulpahte Plume 100 Years after Closure

Figure 10.5

Option 5: Predicted Sulpahte Plume 100 Years after Closure



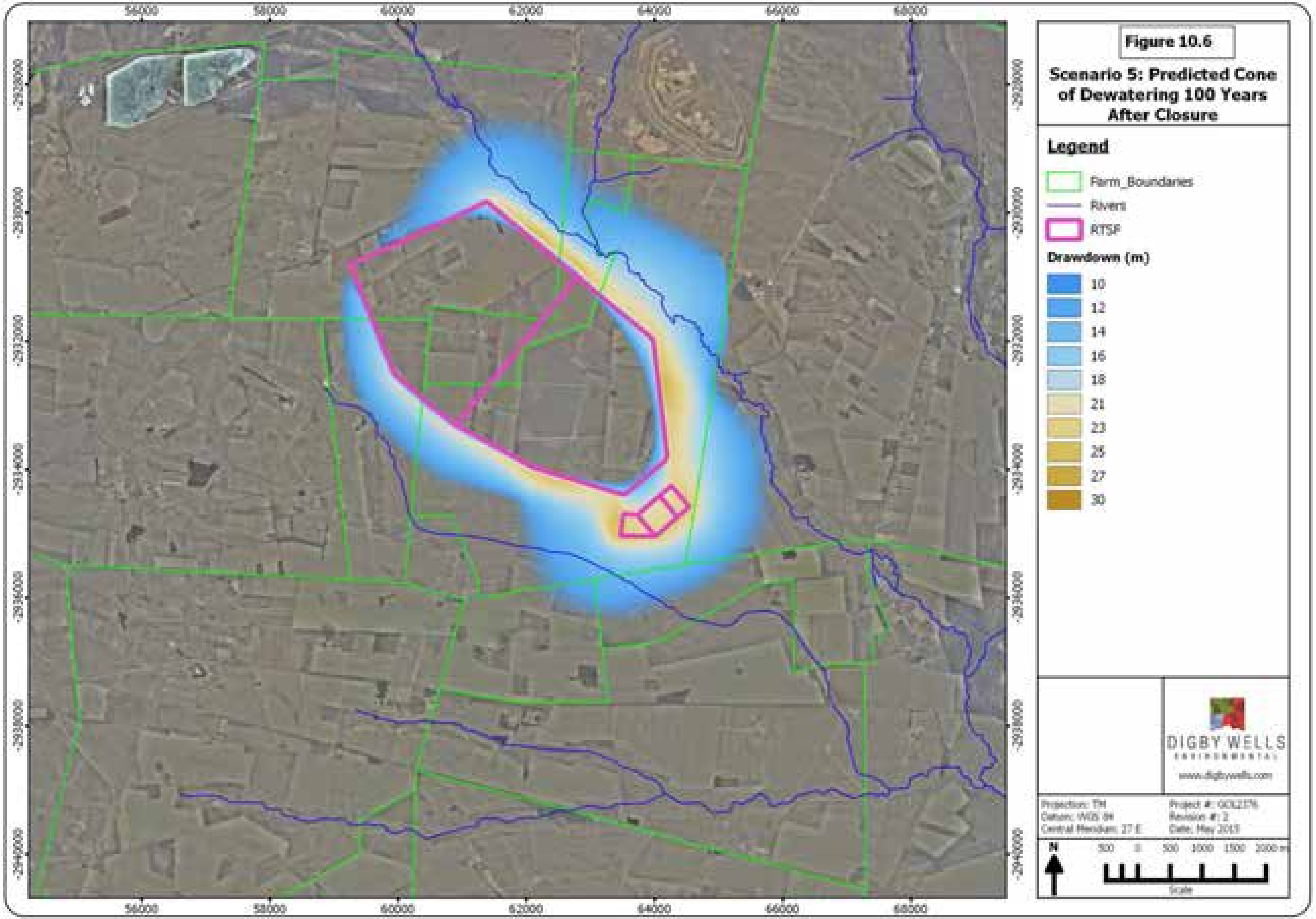


Figure 10.6

Scenario 5: Predicted Cone of Dewatering 100 Years After Closure

10.2 Kloof Mining Right Area Impact Assessment

The groundwater impact associated with the re-mining of all of the historical TSFs is expected to be positive since the source of contamination will be removed. Although the site specific hydrogeological conditions of the TSFs may differ, the identified impacts will essentially be the same and positive to all.

The historical TSFs are not lined and seepage is expected to drain into the underlying groundwater system. The current hypothesis is that if there were no TSFs located directly over the dolomites, it is likely that the dolomitic water (also called fissure water by the mines) pumped from the underground chambers would be of better quality than the current status. In addition, the pumping cost would be substantially less if the TSFs seepage portion could be eliminated. This implies that if infiltration of tailings seepage can be reduced, the contaminant loads will be less from a pollution perspective and pumping costs will be less. At present, the presence of the TSFs and the continued dewatering activities in these compartments will encourage continued infiltration of TSF seepage to the deeper aquifer units and mining areas, the consequent deterioration of water quality and increased volumes of water to be pumped from the underground chambers. The impact as a result of the reclamation is therefore anticipated to be positive in the long run since the TSFs, which are sources of contamination, will be removed.

10.2.1 Construction Phase

No impact on the groundwater is expected during the construction, since all the activities are expected to take place above the water table.

Diesel or other organic fluids and inorganic solvents might be spilled on the ground surface, or leak from underground storage tanks during the construction. Due to the depth of the water level in the dolomitic aquifer, however, they are expected to volatilise and unlikely to reach the groundwater.

10.2.2 Operation Phase

The impact as a result of the reclamation operations at the TSF is anticipated to be positive in the long run since the TSFs, which are sources of contamination, will be removed.

In the short-term, however, the hydraulic reclamation of the TSFs could result in the partial seepage through the TSFs (Table 10.11). The exposure of the tailings to oxygen and water can result in acid mine drainage.

Table 10.10: Interactions and impacts during the operation phase

Interaction	Impact
Hydraulic reclamation	Seepage through the TSFs of the water to be used for hydraulic reclamation inside the foot print

Interaction	Impact
Tailings exposure to oxygen and water	Acid mine drainage
Pump station or pipelines	Slime or process spillage from pump station or pipeline

The potential impacts associated with the reclamation of the historical TSFs are provided in Table 10.11.

Table 10.11: Potential impacts during the operation phase of the re-mining of the historical TSFs

Dimension	Rating	Motivation	Significance
Impact Description: Groundwater contamination due to seepage during hydraulic re-mining			
Prior to mitigation/ management			
Duration	Project Life (5)	Seepage of contaminated water could occur during the operation phase	Minor (negative) – 44
Extent	Local (3)	The impact is expected to be local	
Intensity	Moderate (3)	The contamination will be moderate as it will be local and an area that is already contaminated	
Probability	Probable (4)	Seepage due to the water used during hydraulic re-mining is probable	
Nature	Negative		
Mitigation/ Management actions			
▪ Monitoring of groundwater quality and water levels. ▪ Minimise ponding of water within the reclamation area.			
Post- mitigation			
Duration	Project Life (5)	Contamination due to the hydraulic reclamation will persist during the life of mine	Negligible (negative) – 24
Extent	Limited (2)	The seepage is expected to be limited to the TSF footprint area	
Intensity	Minimal (1)	Impact will be underneath the TSF only due to the dolomitic nature and vertical	

Dimension	Rating	Motivation	Significance
		hydraulic gradient	
Probability	Unlikely (3)	Impact to the groundwater outside the TSF areas is unlikely	
Nature	Negative		
Impact Description: Acid mine drainage due to the TSF disturbance and exposure to oxygen and moisture			
Prior to mitigation/ management			
Duration	Project Life (5)	Acid mine drainage can be generated and heavy metals can be mobilised. This is likely to persist throughout the life of operation	Minor (negative) – 54
Extent	Local (3)	The pollution plume is expected to be local laterally, but with a potential of migrating vertically to the underground mines	
Intensity	Minor (2)	The area is already contaminated. The existence of dolomite is also beneficial to buffer the acid	
Probability	Almost certain (6)	AMD generation is during the reclamation process and tailings disturbance is almost certain	
Nature	Negative		
Mitigation/ Management actions[5]			
▪ Monitoring of groundwater quality. ▪ Minimise area of disturbance to avoid AMD at multiple places.			
Post management			
Duration	Long-term (4)	AMD generation will stop once the TSFs have been reclaimed	Negligible (negative) – 21
Extent	Limited (2)	With the reclamation from one end of the TSF, instead of multiple areas is likely to render AMD generation at controlled sites	

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[5] This shouldn't be long. it is a brief, bulleted description of the mitigation

Dimension	Rating	Motivation	Significance
		only	
Intensity	Minimal (1)	Once the AMD generation is controlled, the environmental impact in the area that is already contaminated is expected to be minimal	
Probability	Unlikely (3)	AMD is unlikely to occur if the above recommended procedures are implemented	
Nature	Negative		

10.2.3 Closure Phase

As shown in Table 10.11, the impact as a result of the reclamation is anticipated to be positive after closure. This is due to the removal of the TSFs (Table 10.12), which are sources of contamination.

All historical TSFs are not lined and seepage is expected to drain into the underlying groundwater system. Seepage from the TSFs, which are directly over the dolomites, would increase the cost of pumping from the underground mine voids and impact the water quality negatively. The pumping cost would be reduced if the TSFs are removed since the seepage portion is eliminated. This implies that if infiltration of tailings seepage can be reduced, the contaminant loads will be less from a pollution perspective and pumping costs will be less. At present, the presence of the TSFs and the continued dewatering activities in these compartments will encourage continued infiltration of TSF seepage to the deeper aquifer units and mining areas, the consequent deterioration of water quality and increased volumes of water to be pumped from the underground chambers.

Table 10.12: Interactions and impacts during the closure phase

Interaction	Impact
TSF removal	No seepage and AMD drainage

The potential impacts associated with the reclamation of the historical TSFs are provided in Table 10.13.

Table 10.13: Potential impacts after the closure phase

Dimension	Rating	Motivation	Significance
Impact Description: Impact on groundwater contamination due to re-mining of the historical			

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

10.3 Driefontein Mining Right Area Impact Assessment

The activities in this mining area are the construction and operation of reclamation pump stations at the mining sites (initially Dri 3 then 5 TSF) and associated pipelines and closure of the mining sites and the west block thickener (WBT) complex.

10.3.1 Construction Phase

No impact on the groundwater is expected during the construction, since all the activities are expected to take place above the water table.

Diesel or other organic fluids and inorganic solvents might be spilled on the ground surface, or leak from underground storage tanks during the construction. Due to the depth of the water level in the dolomitic aquifer, however, they are expected to volatilise and unlikely to reach the groundwater.

10.3.2 Operation Phase

The impact as a result of the reclamation operations at the TSF is anticipated to be positive in the long run since the TSFs, which are sources of contamination, will be removed.

In the short-term, however, the hydraulic reclamation of the TSFs could result in the partial seepage through the TSFs (Table 10.14).

Table 10.14: Interactions and impacts during the operation phase

Interaction	Impact
Hydraulic reclamation	Seepage through the TSFs of the water to be used for hydraulic reclamation inside the foot print
Pump station or pipelines to the WBT	Slime or process spillage from pump station or pipeline

The Driefontein TSFs are not lined and seepage is expected to drain into the underlying groundwater system. This seepage can impact the water quality negatively and increase the cost of pumping from the underground mine voids as shown in Table 10.15.

Table 10.15: Potential impacts during the operation phase of the re-mining of the Driefontein TSFs

Dimension	Rating	Motivation	Significance
Impact Description: Groundwater contamination due to seepage during hydraulic re-mining			
Prior to mitigation/ management			
Duration	Project Life (5)	Seepage of contaminated water could occur during the operation phase	Minor (negative) – 44
Extent	Local (3)	The impact is expected to be local	
Intensity	Moderate (3)	The contamination will be moderate as it will be local and an area that is already	

Dimension	Rating	Motivation	Significance
		contaminated	
Probability	Probable (4)	Seepage due to the water used during hydraulic re-mining is probable	
Nature	Negative		
Mitigation/ Management actions			
▪ Monitoring of groundwater quality and water levels. ▪ Minimise ponding of water within the reclamation area.			
Post- mitigation			
Duration	Project Life (5)	Contamination due to the hydraulic reclamation will persist during the life of mine	Negligible (negative) – 24
Extent	Limited (2)	The seepage is expected to be limited to the TSF footprint area	
Intensity	Minimal (1)	Impact will be underneath the TSF only due to the dolomitic nature and vertical hydraulic gradient	
Probability	Unlikely (3)	Impact to the groundwater outside the TSF areas is unlikely	
Nature	Negative		
Impact Description: Acid mine drainage due to the TSF disturbance and exposure to oxygen and moisture			
Prior to mitigation/ management			
Duration	Project Life (5)	Acid mine drainage can be generated and heavy metals can be mobilised. This is likely to persist throughout the life of operation	Minor (negative) – 54
Extent	Local (3)	The pollution plume is expected to be local laterally, but with a potential of migrating vertically to the underground mines	
Intensity	Minor (2)	The area is already contaminated. The existence of dolomite is also beneficial to buffer the acid	

Dimension	Rating	Motivation	Significance
Probability	Almost certain (6)	AMD generation is during the reclamation process and tailings disturbance is almost certain	
Nature	Negative		
***Mitigation/ Management actions*[6]**			
- Monitoring of groundwater quality. - Minimise area of disturbance to avoid AMD at multiple places.			
Post management			
Duration	Long-term (4)	AMD generation will stop once the TSFs have been reclaimed	Negligible (negative) – 21
Extent	Limited (2)	With the reclamation from one end of the TSF, instead of multiple areas is likely to render AMD generation at controlled sites only	
Intensity	Minimal (1)	Once the AMD generation is controlled, the environmental impact in the area that is already contaminated is expected to be minimal	
Probability	Unlikely (3)	AMD is unlikely to occur if the above recommended procedures are implemented	
Nature	Negative		

10.3.3 Closure Phase

As shown in Table 10.16, the impact as a result of the reclamation is anticipated to be positive after closure. This is due to the removal of the TSFs which are sources of contamination, which will be removed.

The Driefontein TSFs are not lined and seepage is expected to drain into the underlying groundwater system. Seepage from the TSFs, which are directly over the dolomites, would increase the cost of pumping from the underground mine voids and impact the water quality negatively. The pumping cost would be reduced if the TSFs are removed since the seepage

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[6] This shouldn't be long. it is a brief, bulleted description of the mitigation

portion is eliminated. This implies that if infiltration of tailings seepage can be reduced, the contaminant loads will be less from a pollution perspective and pumping costs will be less. At present, the presence of the TSFs and the continued dewatering activities in these compartments will encourage continued infiltration of TSF seepage to the deeper aquifer units and mining areas, the consequent deterioration of water quality and increased volumes of water to be pumped from the underground chambers.

Table 10.16: Potential impacts during the closure phase of the re-mining of the Driefontein TSFs

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

Dimension	Rating	Motivation	Significance
		definitely occur	🟩
Nature	Positive		

10.4 Cooke Mining Right Area Impact Assessment

The potential groundwater impacts and management plans discussed for the Driefontein Mining Right Area are also applicable to the Cooke Mining Right Area.

10.4.1 Construction Phase

No impact on the groundwater is expected during the construction, since all the activities are expected to take place above the water table.

Diesel or other organic fluids and inorganic solvents might be spilled on the ground surface, or leak from underground storage tanks during the construction. Due to the depth of the water level in the dolomitic aquifer, however, they are expected to volatilise unlikely to reach the groundwater.

10.4.2 Operation Phase

The impact as a result of the reclamation is anticipated to be positive in the long run since the TSFs, which are sources of contamination, will be removed.

In the short-term, however, the hydraulic reclamation of the TSFs could result in the partial seepage through the TSFs (Table 10.17).

Table 10.17: Interactions and impacts during the operation phase

Interaction	Impact
Hydraulic reclamation	Seepage through the TSFs of the water to be used for hydraulic reclamation
pump station and water and slurry pipelines	Water/slurry leakage from pump station and or pipelines

The Cooke TSF is not lined and seepage is expected to drain into the underlying groundwater system. This seepage can impact the water quality negatively and increase the cost of pumping from the underground mine voids as shown in Table 10.18.

Table 10.18: Potential impacts during the operation phase

Dimension	Rating	Motivation	Significance
Impact Description: Groundwater contamination due to seepage during hydraulic re-mining			
Prior to mitigation/ management			
Duration	Project Life (5)	Seepage of contaminated water could occur during the operation phase	Minor (negative) – 44
Extent	Local (3)	The impact is expected to be local	
Intensity	Moderate (3)	The contamination will be moderate as it will be local and an area that is already contaminated	
Probability	Probable (4)	Seepage due to the water used during hydraulic re-mining is probable	
Nature	Negative		
Mitigation/ Management actions			
▪ Monitoring of groundwater quality and water levels. ▪ Minimise ponding of water within the reclamation area.			
Post- mitigation			
Duration	Project Life (5)	Contamination due to the hydraulic reclamation will persist during the life of mine	Negligible (negative) – 24
Extent	Limited (2)	The seepage is expected to be limited to the TSF footprint area	
Intensity	Minimal (1)	Impact will be underneath the TSF only due to the dolomitic nature and vertical hydraulic gradient	
Probability	Unlikely (3)	Impact to the groundwater outside the TSF areas is unlikely	
Nature	Negative		
Impact Description: Acid mine drainage due to the TSF disturbance and exposure to oxygen and moisture			
Prior to mitigation/ management			
Duration	Project Life (5)	Acid mine drainage can be generated and	Minor (negative) – 54

Dimension	Rating	Motivation	Significance
		heavy metals can be mobilised. This is likely to persist throughout the life of operation	
Extent	Local (3)	The pollution plume is expected to be local laterally, but with a potential of migrating vertically to the underground mines	
Intensity	Minor (2)	The area is already contaminated. The existence of dolomite is also beneficial to buffer the acid	
Probability	Almost certain (6)	AMD generation is during the reclamation process and tailings disturbance is almost certain	
Nature	Negative		
Mitigation/ Management actions[7]			
- Monitoring of groundwater quality. - Minimise area of disturbance to avoid AMD at multiple places.			
Post management			
Duration	Long-term (4)	AMD generation will stop once the TSFs have been reclaimed	Negligible (negative) – 21
Extent	Limited (2)	With the reclamation from one end of the TSF, instead of multiple areas is likely to render AMD generation at controlled sites only	
Intensity	Minimal (1)	Once the AMD generation is controlled, the environmental impact in the area that is already contaminated is expected to be minimal	
Probability	Unlikely (3)	AMD is unlikely to occur if the above recommended procedures are implemented	
Nature	Negative		

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[7] This shouldn't be long. it is a brief, bulleted description of the mitigation

10.4.3 Closure Phase

As shown in Table 10.19, the impact as a result of the reclamation is anticipated to be positive after closure. This is due to the removal of the TSFs which are sources of contamination, will be removed.

The Cooke TSF is not lined and seepage is expected to drain into the underlying groundwater system. Seepage from the TSF, which is directly over the dolomites, is increasing the cost of pumping from the underground mine voids and impact the water quality negatively. The pumping cost would be reduced if the TSFs are removed since the seepage portion is eliminated. This implies that if infiltration of tailings seepage can be reduced, the contaminant loads will be less from a pollution perspective and pumping costs will be less. At present, the presence of the TSFs and the continued dewatering activities in these compartments will encourage continued infiltration of TSF seepage to the deeper aquifer units and mining areas, the consequent deterioration of water quality and increased volumes of water to be pumped from the underground chambers.

Table 10.19: Potential impacts due the re-mining of the Cooke TSF

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

Dimension	Rating	Motivation	Significance
		permanently removed	– 105
Extent	Local (3)	The impact is expected to be local as the sites are already contaminated	
Intensity	Serious (5)	Environmental advantages once the unlined TSFs are removed	
Probability	Definite (7)	There are sound scientific reasons to expect that the positive impact will definitely occur	
Nature	Positive		

10.5 Ezulwini Mining Right Area Impact Assessment

The potential groundwater impacts and management plans discussed for the Driefontein and Cooke Mining Right Areas are also applicable to the Ezulwini Mining Right Area. Activities here are the booster station to located inside the existing plant area, water supply from the shaft area, reclamation pump station at the mining site of Cooke 4 South(C4S) and associated pipe lines.

10.5.1 Construction Phase

No impact on the groundwater is expected during the construction, since all the activities are expected to take place above the water table.

Diesel or other organic fluids and inorganic solvents might be spilled on the ground surface, or leak from underground storage tanks during the construction. Due to the depth of the water level in the dolomitic aquifer, however, they are expected to volatilise unlikely to reach the groundwater.

10.5.2 Operation Phase

The impact as a result of the reclamation is anticipated to be positive in the long run since the TSFs, which are sources of contamination, will be removed.

In the short-term, however, the hydraulic reclamation of the TSFs could result in the partial seepage through the TSFs (Table 10.20).

Table 10.20: Interactions and impacts during the operation phase

Interaction	Impact
Hydraulic reclamation	Seepage through the TSFs of the water to be used for hydraulic reclamation inside the foot print

Interaction	Impact
Tailings exposure to oxygen and water	Acid mine drainage
Pump station or pipelines	Slime or process spillage from pump station or pipeline

The Ezulwini TSFs are not lined and seepage is expected to drain into the underlying groundwater system. This seepage can impact the water quality negatively and increase the cost of pumping from the underground mine voids as shown in Table 10.21.

Table 10.21: Potential impacts during the operation phase

Dimension	Rating	Motivation	Significance
Impact Description: Groundwater contamination due to seepage during hydraulic re-mining			
Prior to mitigation/ management			
Duration	Project Life (5)	Seepage of contaminated water could occur during the operation phase	Minor (negative) – 44
Extent	Local (3)	The impact is expected to be local	
Intensity	Moderate (3)	The contamination will be moderate as it will be local and an area that is already contaminated	
Probability	Probable (4)	Seepage due to the water used during hydraulic re-mining is probable	
Nature	Negative		
Mitigation/ Management actions			
▪ Monitoring of groundwater quality and water levels. ▪ Minimise ponding of water within the reclamation area.			
Post- mitigation			
Duration	Project Life (5)	Contamination due to the hydraulic reclamation will persist during the life of mine	Negligible (negative) – 24
Extent	Limited (2)	The seepage is expected to be limited to the TSF footprint area	
Intensity	Minimal (1)	Impact will be underneath the TSF only due to the dolomitic nature and vertical	

Dimension	Rating	Motivation	Significance
		hydraulic gradient	
Probability	Unlikely (3)	Impact to the groundwater outside the TSF areas is unlikely	
Nature	Negative		
Impact Description: Acid mine drainage due to the TSF disturbance and exposure to oxygen and moisture			
Prior to mitigation/ management			
Duration	Project Life (5)	Acid mine drainage can be generated and heavy metals can be mobilised. This is likely to persist throughout the life of operation	Minor (negative) – 54
Extent	Local (3)	The pollution plume is expected to be local laterally, but with a potential of migrating vertically to the underground mines	
Intensity	Minor (2)	The area is already contaminated. The existence of dolomite is also beneficial to buffer the acid	
Probability	Almost certain (6)	AMD generation is during the reclamation process and tailings disturbance is almost certain	
Nature	Negative		
Mitigation/ Management actions[8]			
▪ Monitoring of groundwater quality. ▪ Minimise area of disturbance to avoid AMD at multiple places.			
Post management			
Duration	Long-term (4)	AMD generation will stop once the TSFs have been reclaimed	Negligible (negative) – 21
Extent	Limited (2)	With the reclamation from one end of the TSF, instead of multiple areas is likely to render AMD generation at controlled sites	

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[8] This shouldn't be long. it is a brief, bulleted description of the mitigation

Dimension	Rating	Motivation	Significance
		only	
Intensity	Minimal (1)	Once the AMD generation is controlled, the environmental impact in the area that is already contaminated is expected to be minimal	
Probability	Unlikely (3)	AMD is unlikely to occur if the above recommended procedures are implemented	
Nature	Negative		

10.5.3 Closure Phase

As shown in Table 10.22, the impact as a result of the reclamation is anticipated to be positive after closure. This is due to the removal of the TSFs which are sources of contamination, will be removed.

The Ezulwini TSF is not lined and seepage is expected to drain into the underlying groundwater system. Seepage from the TSFs, which are directly over the dolomites, is increasing the cost of pumping from the underground mine voids and impact the water quality negatively. The pumping cost would be reduced if the TSFs are removed since the seepage portion is eliminated. This implies that if infiltration of tailings seepage can be reduced, the contaminant loads will be less from a pollution perspective and pumping costs will be less. At present, the presence of the TSFs and the continued dewatering activities in these compartments will encourage continued infiltration of TSF seepage to the deeper aquifer units and mining areas, the consequent deterioration of water quality and increased volumes of water to be pumped from the underground chambers.

Table 10.22: Potential impacts due the re-mining of the Ezulwini TSFs

Dimension	Rating	Motivation	Significance
Impact Description: Impact on groundwater contamination due to re-mining of the Ezulwini TSFs			
Prior to mitigation/ management			
Duration	Permanent (7)	Seepage of contaminated water will permanently be removed	Moderate (positive) – 105
Extent	Local (3)	The impact is expected to be local as the	

Dimension	Rating	Motivation	Significance
		sites are already contaminated	
Intensity	Serious (5)	Serious environmental advantages once the unlined TSFs are removed	
Probability	Definite (7)	There are sound scientific reasons to expect that the positive impact will definitely occur	
Nature	Positive		
Mitigation/ Management actions			
- Monitoring of groundwater quality and water levels. - Rehabilitation of old TSF footprints.			
Post- mitigation			
Duration	Permanent (7)	The contamination plume will be permanently removed	Moderate (positive) – 105
Extent	Local (3)	The impact is expected to be local as the sites are already contaminated	
Intensity	Serious (5)	Environmental advantages once the unlined TSFs are removed	
Probability	Definite (7)	There are sound scientific reasons to expect that the positive impact will definitely occur	
Nature	Positive		

11 Cumulative Impacts

There are no industrial or mining activities in the vicinity of the proposed RTSF other than Gold Fields' Doornpoort TSF. Sources of future groundwater impacts around the proposed RTSF area will therefore be from the RTSF and Gold Fields' Doornpoort TSF.

The Gold Fields TSF is approximately 1 km northeast of the proposed RTSF as shown in Figure 7.1. The Leeuspruit flows between the two. The river is generally fed by groundwater and therefore any pollution from the Gold Fields TSF is expected to be intercepted by the river as baseflow. However, the closeness of the two TSFs means that if any local fractures exist (that were not identified during this study) connecting the two TSFs, pollution plumes from the Gold Fields TSF can possibly migrate beyond the river towards the proposed RTSF. Groundwater monitoring along a set of boreholes (refer Section 13.4) on both sides of the river is recommended to detect the sources of any contamination plume reaching the river.

The hydrocensus conducted by Digby Wells in the vicinity of the RTSF (2015) showed that irrigation (fertiliser) related, site-specific pollution exists in some boreholes which are usually manifested by the elevated nitrate or ammonia concentrations.

The current groundwater quality is good, with current sulfate concentrations recorded as 32 mg/L (note: a sulfate concentration up to 400 mg/L is considered to be of good quality). This could accordingly serve as the baseline for future monitoring.

12 Unplanned Events and Low Risks

The unplanned event that may happen at the project site and the proposed mitigation plan are listed in Table 12.1.

Table 12.1: Unplanned events, low risks and their management measures

Unplanned event	Potential impact	Mitigation/ Management/ Monitoring
Hydrocarbon spillage from pipelines, pump station and CPP	Deterioration of groundwater quality	■ It is recommended that diesel or other chemicals be used without spillage, and machinery should be properly maintained. ■ Fuel and oil reservoirs must be in a bunded area. ■ If a considerable amount of fluid is accidentally spilled, the contaminated soil should be scraped off and disposed of at an acceptable dumping facility. The excavation should be backfilled with soil of good quality. ■ Monitoring of pipelines for seepage. Seeping pipeline should be sealed. ■ Monitoring boreholes, particularly those located within the construction area, have to be monitored for both water level and quality to detect any changes in quality.

13 Environmental Management Plan

The objective of an Environmental and Social Management Plan (ESMP) is to present mitigation to manage undue or reasonably avoidable adverse impacts associated with the development of a project and to enhance potential positives.

13.1 RTSF Management Plan

13.1.1 Construction Phase

Since no groundwater impacts are expected during the construction of the RTSF, there is no need for mitigation measures. However, all boreholes that exist in the current footprint area need to be closed and sealed off properly in order to prevent seepage from the tailings once deposition starts.

- If trenches/foundations or RW dams are going to be excavated below the water level, dewatering of the aquifer to locally lower the water table can be considered to ensure that the construction takes place in a dry environment and the water quality remains acceptable. The abstracted water can be utilised for dust suppression, vegetation or discharged to local stream (if quality permits). Since the groundwater is not expected to be polluted at this stage, the utilisation of the water for activities such as dust suppression or vegetation is not expected to cause negative environmental impacts.
- Install long term monitoring boreholes. The positions of the monitoring boreholes are provided in Section 13.4.

13.1.2 Operational Phase

The application of liners could significantly minimise the infiltration of the contaminants from the RTSF to the subsurface. However, overall cost/benefit needs to be assessed with the use of liners, bearing in mind stability issues, damage to liners and their sustainability. As an alternative, the implementation of a blast curtain perimeter drain system could be considered to contain the contaminate plume to within the footprint area of the RTSF. The effect of the blast curtain drain system on the pollution plume is shown in Figure 10.2.

- The hydraulic conductivity of the blast curtain needs to be at least 5 times (preferably 10 times) higher than the local aquifers. If not, the contaminants can migrate along permeable, weathered or fractured aquifers and reach sensitive, local receptors. The drain also needs to be dewatered as soon as water flows into it and keep it at a lower hydraulic head than the surrounding aquifer. This way the blast curtain drain will be a hydraulic sink and groundwater will flow towards the drain and the chance of plume migrating away from the drain can be avoided.
- Monitoring of groundwater quality and water levels is recommended (particularly downgradient of the RTSF and in between the RTSF and rivers) with continuous

refining and updating of the monitoring network based on the monitoring results obtained. Since the operational phase will take place over a prolonged period compared to the construction phase, more monitoring boreholes will be required. The positions of the monitoring boreholes are shown in Figure 13.1.

- Numerical modelling has shown that private boreholes within a 1.5 km radius are at risk of contamination if Option 1 is implemented, however no private borehole will be at a risk if Option 5 is implemented. As such, no mitigation is required as no impact on private boreholes is envisaged. This however needs to be confirmed through continuous monitoring.
- The RTSF shape is recommended to be designed to control the ease with which water can run off from the facility.
- Apply a soil cover and vegetation on the rehabilitated portion of the RTSF to minimise rainfall infiltration.
- Refine the conceptual and numerical models every 5 years based on groundwater monitoring results.

The dewatered water is expected to be cleaner than the RTSF leachate as it will be diluted by the cleaner groundwater intercepted from outside the RTSF area. However, model simulations have shown that the water will not be pristine, particularly because Mn concentrations could potentially be more than the recommended 0.1 mg/L limit. This means that the abstracted water will require treatment before it is discharged to the environment.

Once the abstracted water is treated, it should be discharged to the Leeuspruit and tributaries to minimise the impact on the streams. Numerical modelling has shown that private boreholes within a radius of 1.5 km southeast and northeast could potentially be impacted due to the dewatering, as shown in Figure 10.6. The abstracted and treated water can be supplied to private boreholes users if required. With these mitigation methods, the impact of the mine dewatering can be reduced to Minor as shown in Table 10.7.

The following steps are recommended to minimise the potential impact of the PCD (RW dams):

- Application of a liner to minimise or avoid seepage.
- Implementation of adequate storm water management, following risk prioritisation, is required at evaporation paddocks, clean and dirty water canals, and storm water dams to contain all waste water and/or volatile organic compounds, for treatment and recycling.
- All contaminant, storm water, waste and hazardous waste storage facilities and other contaminated water storage areas (pollution control dams) should be lined to pro-actively prevent infiltration of contaminated seepage water.

- Monitoring of groundwater quality and water levels is recommended with continuous refining and updating of the monitoring network based on the results obtained.
- With the implementation of these remedial techniques, the potential impact of the PCD can be reduced to Negligible as shown in Table 10.7.

13.1.3 Closure Phase

Seepage from the RTSF will continue even after closure and will remain to have an impact on the groundwater environment. However, the impact can be reduced with the implementation of a blast curtain drain, dump rehabilitation and continuous groundwater monitoring. The predicted contamination plume, 100 years after closure is shown in Figure 10.5 and shows that the plume can be contained to within the RTSF footprint provided that the blast curtain perimeter drain operates efficiently even after closure. Efficient blast curtain drain operation refers to:

- The permeability of the drain conductance along the perimeter drains should be at least 5 times (preferably 10 times) higher than that of the local aquifers between extraction points.
- Numerical modelling has shown that the pumping rate has to be at least 120% of the RTSF seeped volumes (i.e. 4,810 m^3/d).
- The pumping programme has to continue until such time that the water quality being abstracted improves to acceptable levels.

With the implementation of these mitigation plans, the significance of pollution after closure can be reduced to Negligible (Table 10.9).

The impact of the perimeter dewatering drawdown can be reduced with the implementation of the following:

- The supply of water to the impacted farms (if not owned by the mine) as a result of the dewatering drawdown; and
- The abstracted water is likely to be poor in quality and should be treated in the AWTF and discharged to the Leeuspruit to compensate for water losses due to the blast curtain drain operational impacts.

With the implementation of these mitigation methods, the significance of the impact can be reduced to Minor (Table 10.9).

13.2 Historical TSFs

Sibanye is planning to remove a large percentage of sulphide sulphur from the historical TSF material to reduce acid-water impacts at the proposed RTSF. Soregaroli and Lawrence (1998) showed that for long-term acid generation, at least 0.3% Sulphide–Sulphur is needed. Values below this can yield acidity, but this is likely to be only of short-term significance since there is not a sufficient amount of Sulphide-Sulphur to sustainably generate acid. Sibanye is committed to reduce the sulphide-sulphur content within the RTSF tailings material to a maximum concentration of 0.3% should the containment system be approved.

The existing monitoring programme in the vicinity of the historical TSFs is recommended to continue to evaluate the positive impact of tailings removal, with continuous refining and updating of the monitoring network based on the results obtained.

The impact of the reclamation must be viewed in the light of the current situation. The groundwater quality is already negatively impacted by the current TSFs. Reclamation will speed up recovery of the groundwater quality and therefore will have a positive impact on the environment. This positive impact will be definite and permanent.

13.3 Summary of Mitigation and Management

A summary of the impacts anticipated are summarised in Table 13.1. Table 13.2 provides a description of the mitigation and management options for the environmental impacts anticipated during the construction, operational, decommissioning and closure phases. Table 13.1 to Table 13.3 provide a summary of the proposed project activities, environmental aspects and management plans. Information on the frequency of mitigation, relevant legal requirements, recommended management plans, timing of implementation, and roles / responsibilities of persons implementing the EMP is provided in Table 13.4.

Table 13.1: Potential Impacts

Activities	Phase	Size and scale of disturbance	Mitigation Measures	Compliance with standards	Time period for implementation
Blast curtain	Construction, operation and post-closure	23.7 km^2	Compensate the groundwater users that will be affected by the blast curtain drain drawdown	The groundwater users have the right to be compensated if affected by the drawdown	The dewatering at the blast curtain drain will start during the construction phase, but its impact will be felt during the operational phase. Any mitigation plans will therefore need to start as of the operational phase
Seepage from the RTSF	Operation and post-closure	16.7 km^2	Application of the blast curtain perimeter drain to contain contamination plume	The mitigation of contamination plume is in line with the National Water Act	The blast curtain needs to be developed during the construction phase
Seepage from the	Construction and	Within the PCD footprint	Application of liner and	The mitigation of	The liner needs to be implemented during the

Activities	Phase	Size and scale of disturbance	Mitigation Measures	Compliance with standards	Time period for implementation
Pollution Control Dams (PCDs)	operation phases	area	seepage monitoring	contamination plume is in line with the National Water Act	construction phase
Re-mining of historical TSFs	Operation phase	Approximately 100 m radius around each of the TSFs	Conduct a controlled disturbance of the historical TSFs during reclamation to avoid potential oxidation and acid generation at multiple places. Rehab of mined footprint as per closure plan	National Water Act	Operation phase

Table 13.2: Objectives and Outcomes of the EMP

Activities	Potential impacts	Aspects affected	Phase	Mitigation	Standard to be achieved/objective
Groundwater abstraction by the blast curtain perimeter drain	Lowering of the water table	Groundwater users, rivers	Construction, operational and post-closure phases	Compensate the groundwater users that will be affected by the blast curtain	No proven reduction in groundwater abstraction rates National Water Act, Constitution of South Africa
Seepage from the RTSF	Contamination plume in the groundwater	Groundwater users, natural ecosystem, rivers	Operational and post-closure phases	Application of the blast curtain	No proven reduction in the groundwater quality National Water Act, NEMWA
Seepage from the PCD	Contamination plume in the groundwater	Groundwater users, natural ecosystem, rivers	Operational phase	Application of a liner	National Water Act, NEMWA

Re-mining of historical TSFs	Positive impact since the source of contamination is removed	Groundwater users	Operation phase	Rehabilitation of mined footprint as per closure plan	National Water Act, NEMWA

Table 13.3: Mitigation measures

Activities	Potential impacts	Aspects affected	Mitigation type	Time period for implementation	Compliance with standards
Drilling and blasting of the blast curtain	Lowering of the water table	Groundwater users and the rivers	Provision of water supply to the affected parties	During operation and post-closure phases	National Water Act
Application of a liner for the pollution control dams	Minimisation of pollution plume	Groundwater users	Positive impact	During operational phase	National Water Act, NEMWA
Re-mining of historical TSFs	Positive impact	Groundwater users	Conduct a controlled disturbance of the historical TSFs during reclamation to avoid potential oxidation and acid generation at multiple places. Rehab of mined footprint as per closure plan	Operation phase	National Water Act, NEMWA

Table 13.4: Prescribed environmental management standards, practice, guideline, policy or law

Specialist field	Applicable standard, practice, guideline, policy or law
Groundwater	National Environmental Management Act (Act 107 of 1998), as amended (NEMA), GNR 544 and GNR 545 (Section 24 (1))
	National Water Act 36 of 1998 (Sections 19-22) and GN 704
	Water Services Act 108 of 1997
	National Environmental Management: Waste Act (Act 59 of 2008)

	(NEMWA) and List of Waste Management Activities requiring a Waste Management Licence (WML) GN 718 of 2008
	Hazardous Substances Act (Act 15 of 1973)
	Facilities Regulations (GNR 924 of 2004)
	Hazardous Chemical Substances Regulations (GN 1179 of 1995)

13.4 Monitoring Plan

Groundwater monitoring has to be implemented during all phases of the reclamation and RTSF operation to identify impacts on the groundwater over time, and effective measures can be undertaken at the early stage before negative impacts to the environment takes place.

13.4.1 Monitoring Boreholes

The main objective in selecting suitable monitoring boreholes is to monitor the movement of polluted groundwater moving away from the RTSF. The positions of the recommended monitoring points are listed in Table 13.5 and displayed in Figure 13.1.

The monitoring points consist of:

- There are a number of boreholes in the vicinity of the RTSF. It is not necessary to monitor each of the closely spaced boreholes as the water quality is expected to be the similar. A total of 45 boreholes have been selected consisting of:
  - 25 private boreholes located in the proximity of the proposed RTSF; and
  - 20 boreholes drilled by Sibanye Gold and Gold One;
- The boreholes located within the RTSF footprint are expected to be decommissioned during the operational phase and have been excluded from the monitoring list.

Table 13.5: Coordinates of the proposed monitoring points

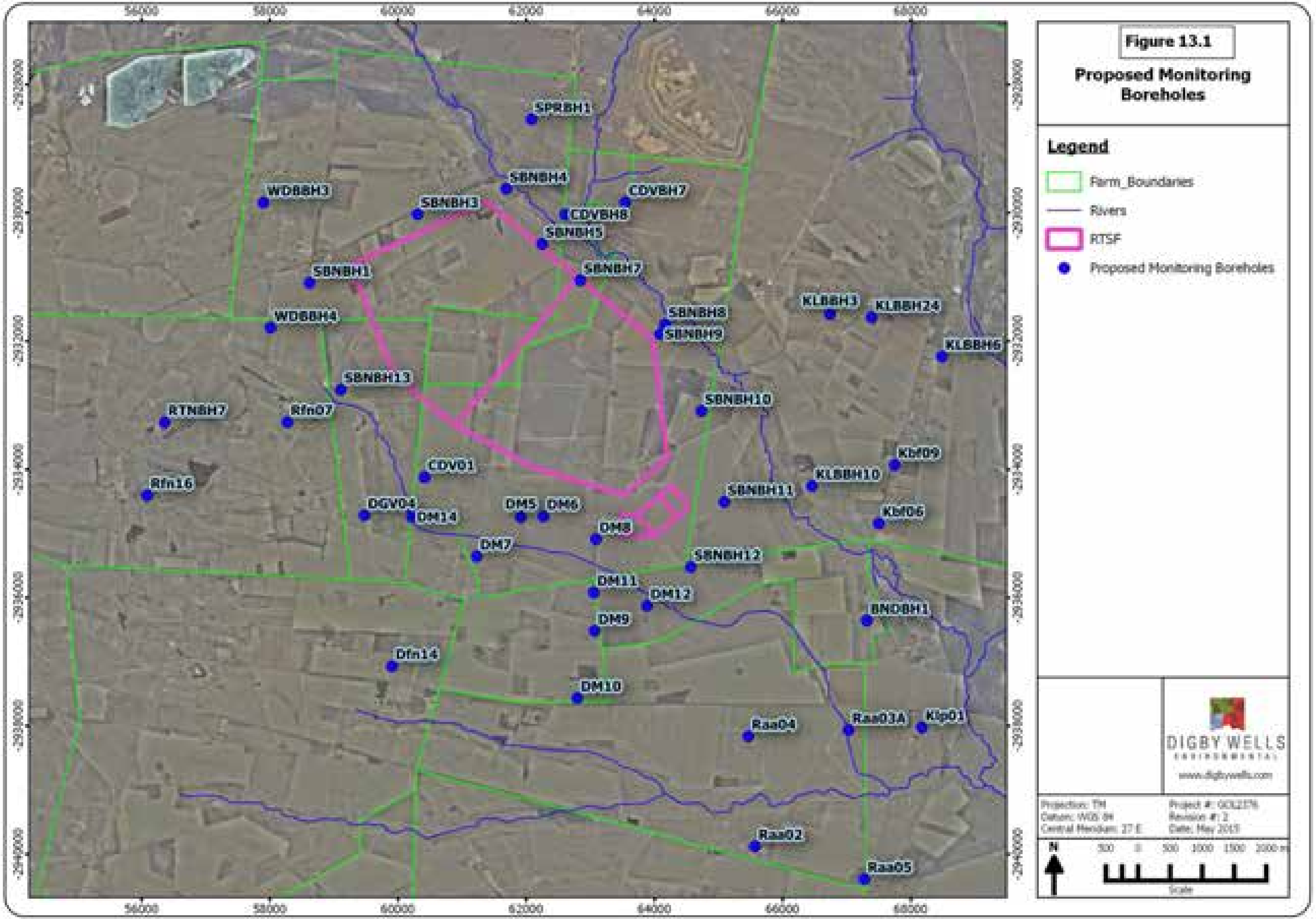
BH ID	Ycoord	Xcoord	Borehole Status
BNDBH1	-2936058	67348	Private Borehole
CDV01	-2933825	60449	Private Borehole
CDVBH8	-2929727	62643	Private Borehole
DGV04	-2934419	59511	Private Borehole
KLBBH10	-2933963	66494	Private Borehole

BH ID	Ycoord	Xcoord	Borehole Status
Raa03A	-2937767	67064	Private Borehole
Raa04	-2937864	65499	Private Borehole
Rfn07	-2932967	58309	Private Borehole
WDBBH3	-2929541	57935	Private Borehole
WDBBH4	-2931495	58049	Private Borehole
Dfn14	-2936771	59941	Private Borehole
Kbf06	-2934547	67535	Private Borehole
Kbf09	-2933631	67784	Private Borehole
KLBBH24	-2931332	67422	Private Borehole
KLBBH3	-2931280	66775	Private Borehole
KLBBH6	-2931943	68519	Private Borehole
Klp01	-2937727	68208	Private Borehole
Raa02	-2939584	65604	Private Borehole
Raa05	-2940092	67309	Private Borehole
Rfn16	-2934106	56122	Private Borehole
RTNBH7	-2932969	56396	Private Borehole
SPRBH1	-2928247	62118	Private Borehole
Tfn02	-2941820	65850	Private Borehole
Tfn05	-2942393	60961	Private Borehole
CDVBH7	-2929538	63581	Private Borehole
DM10	-2937268	62832	Sibanye Borehole
DM11	-2935623	63089	Sibanye Borehole
DM12	-2935830	63921	Sibanye Borehole
DM14	-2934442	60251	Sibanye Borehole
DM5	-2934447	61950	Sibanye Borehole
DM6	-2934433	62305	Sibanye Borehole
DM7	-2935060	61262	Sibanye Borehole
DM8	-2934789	63123	Sibanye Borehole
DM9	-2936220	63102	Sibanye Borehole
SBNBH1	-2930795	58656	Sibanye Borehole
SBNBH10	-2932794	64767	Sibanye Borehole
SBNBH11	-2934212	65125	Sibanye Borehole
SBNBH12	-2935225	64602	Sibanye Borehole
SBNBH13	-2932460	59143	Sibanye Borehole
SBNBH3	-2929726	60340	Sibanye Borehole
SBNBH4	-2929328	61724	Sibanye Borehole

BH ID	Ycoord	Xcoord	Borehole Status
SBNBH5	-2930188	62284	Sibanye Borehole
SBNBH7	-2930754	62880	Sibanye Borehole
SBNBH8	-2931441	64201	Sibanye Borehole
SBNBH9	-2931591	64122	Sibanye Borehole

Figure 13.1

Proposed Monitoring Boreholes



13.4.2 Groundwater Level

Groundwater levels must be recorded on a quarterly basis in all of the monitoring boreholes using an electrical contact tape or pressure transducer, to detect any changes or trends in groundwater flow direction.

13.4.3 Water Sampling and Preservation

When sampling the following procedures are proposed:

- One (1) litre plastic bottles, with a cap are required for sampling – these are provided by the laboratory; and
- Sample bottles should be marked clearly with the borehole name, date of sampling, sampling depth and the sampler's name and submitted to a laboratory that uses SANAS approved methods.

13.4.4 Sampling Frequency

Groundwater is a slow-moving medium and drastic changes in the groundwater composition are not normally encountered within days. Due to the proximity of private boreholes and streams to the proposed RTSF footprint, monitoring should be conducted quarterly.

Samples should be collected by a suitably qualified person, using SABS approved methods of analysis.

It is suggested that quarterly samples be collected, including up to two years post closure and based on the results it can be adjusted accordingly. Monitoring should continue until a sustainable situation is reached.

13.4.5 Parameters to be Monitored

Analyses of the following constituents are recommended:

- Macro Analysis i.e. Ca, Mg, Na, K, SO_4, NO_3, F, Cl;
- Initial full suite metals and then As, Al, Fe, Mn and other metals identified according to results of the initial analyses;
- pH and Alkalinity;
- TDS and EC; and
- Radio-active constituents, particularly uranium.

13.4.6 Data Storage

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

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

14 Consultation Undertaken

Before any of the hydrogeological fieldworks were carried out, the farmers were informed in advance of the proposed activities. Detailed information on what will be done, where and for how long it will be carried out was passed from the hydrogeology team to the Public Participation Practitioners (PPP) team within Digby Wells. The PPP Team contacted the relevant stakeholders and secured the access permit. The farmers then met with the hydrogeology team to guide them to the private boreholes.

A number of progress meetings were held during the course of the project between the hydrogeology team, the client and SLR consulting. This was carried out to consolidate the investigation results and align project progress with the project schedule.

A pre-consultation meeting was held between Digby Wells’ hydrogeology team, the client and the DWS (Mr. Kelvin Legge) on 18 July 2015. The objective of the meeting was to familiarise the DWS with the potential impacts and proposed mitigation plans before the final EIA document was submitted.

15 Comments and Responses

Table 15.1 presents a summary of the key issues related to groundwater which have been raised by the stakeholders.

Table 15.1: A summary of the key issues related to the groundwater raised by the stakeholders

Comment raised	contributor	Organisation/ community	Date	Method	Response
Will water be taken from other mines?	Portia Chawane	Department of Water and Sanitation	2 December 2014	One-on-one Authorities Meeting	The water will be sourced from existing underground operations at the Kloof and Cooke shafts. Currently 33 Mℓ/day is discharged from the Kloof 10 shaft, into the Wonderfonteinspruit, under licence. The first phase (1Mt/m) of this project will take 20 Mℓ of that for hydraulic reclamation and once it has gone through the process, it will be treated through an advanced water treatment facility (AWTF) at the toe of the RTSF. The treated water will either be discharged to the Leeuwspruit or can be supplied to nearby communities.
We recently received water balances from Hennie Pretorius /Jacques Cilliers and they indicated that the use of water will increase in the future.					Noted.
With dumps being located all over the area, how will water use be managed?	Victor Nkuna	Department of Water and Sanitation	2 December 2014	One-on-one Authorities Meeting	The removal of dumps as part of the tailings reclamation is expected to improve the water quality by removing the sources of contamination. The geochemistry of the proposed RTSF has been assessed and the seepage rate has been calculated. High risk areas have been identified and appropriate monitoring and management plans will be implemented at each site that is being reclaimed.
Where will the water to be used for reclamation be sourced from?					Water will be sourced from Cooke 1/2 and K 10 Shafts and correct water conditions will first need to applicable before Sibanye Gold will utilise these resources.
The beneficial use of water, does it include drinking of water?	Bashan Govender	Department of Water and Sanitation	11 December 2014	One-on-one Authorities Meeting	Currently Rand Water is being used for drinking, but Sibanye would like to reduce this use and make more water available for alternative use.
The Department of Water and Sanitation					

Comment raised	contributor	Organisation/ community	Date	Method	Response
(DWS) look to address issues coming from underground/surface water AMD experienced currently.					The water management will be integrated with the technology and recovery will be the focus for the area. Water migrating to groundwater resources will be reduced and it is aimed to close shafts and mines where required. For the WRTRP the use of Rand Water will be replaced with treatment of existing water resources to be used as part of the reclamation process. It is also envisaged that municipality(s) will be assisted with the treatment of their water.
How will the water management link into the Liquid Gold technology used? Will this be done in isolation?					
Cattle will be drinking poisonous water.	Johan Burger	Landowner	16 April 2015	Written Comment	Continuous monitoring will be undertaken and if any contamination is detected, appropriate measures have been proposed. All water that is to be discharged on surface will be of potable standards.
The mines just talk; our water is contaminated, but you still want to come and pollute it further. Our boreholes are contaminated with E. Coli and the Leeuspruit is also contaminated.	Piet Rheeder	Landowner	16 April 2015	Landowners Focus Group Meeting	Any water discharged into the Leeuspruit, will be treated to the SAN 241 drinking water standard or as approved by the DWS. These guidelines are very stringent, so therefore, any water discharged will be of a benefit as it will serve to promote dilution, of the current water quality of the Leeuspruit. The baseline assessment being done will identify current contaminants.
Rand Water is falling short with 40 Mℓ/day in terms of supplying the southern areas with water. It will be beneficial to take the water from the AWTF and supply it to communities there. All economic options would be considered.	Bashan Govender	Department of Water and Sanitation	04 June 2015	DWS Meeting	Thank you. Sibanye is more than willing to engage with the department on these matters.
The department would like to have a separate discussion with Sibanye regarding its potential to assist in supplying water to the people in the broader region, e.g. the Syferfontein village is being developed and they will also need water.	Marius Keet	Department of Water and Sanitation	04 June 2015	DWS Meeting	
You don’t think about environmental impacts	Jaco Taute	Landowner	16 April	Landowners	The proposed project will remove many of the current TSFs

Comment raised	contributor	Organisation/ community	Date	Method	Response
as our boreholes are already contaminated.			2015	Focus Group Meeting	that are impacting on the groundwater of the region. The baseline assessment being done will identify current contaminants.
What will happen to our water balance if you take our water? Our boreholes will be affected by the WRTRP.	Armand de Villiers	Landowner	16 April 2015	Landowners Focus Group Meeting	The water that will be used for reclamation is already being abstracted. No more water will be abstracted from the underground workings as is currently being taken out. Water abstracted from the perimeter drains will treated and discharged back into the Leeuspruit.
What must be acknowledged is that AMD is an issue. There must be mitigation measures put in place when the mine is busy with reclamation. Rivers and dams need to be monitored continuously.	Mariette Liefferink	Federation for a Sustainable Environment	21 April 2015	NGOs Focus Group Meeting	This is correct. Mitigation measures will be put into place. We say in the risk assessment that no mitigation will be implemented.
Communities in the area need to be educated on the issues associated with AMD in order to assist in awareness creation. Jobs need to be made available to communities to assist with monitoring and reporting of possible spillages and other related risks.					Noted.
On the maps provided, it is indicated that the RTSF will be built on “solid bedrock”. This unfortunately is not a geological term and does not cover salient points such as the following	Tom McGhee	Geologist	14 December 2015	Consulting Geologist	This is not correct. The hydrogeology report does not say that the foundation rocks are “solid bedrock”. The top aquifer is weathered to about 30 m, and the aquifer underneath the weathered aquifer is also fractured. Both layers are permeable, not solid bedrocks.
Type of bedrock – it is alluded that the bedrock is impervious and would not allow seepage into the underlying dolomites. No rocks are completely impervious and the amount of porosity will be based on rock type, strike and dip of the strata (if sedimentary rocks), the fracturing of the rocks, any faults or major lineaments that	Tom McGhee	Geologist	14 December 2015	Consulting Geologist	This is not what is reported in the groundwater report. The aquifers are permeable and rock permeability is given for the weathered and fractured aquifers. Please refer to the groundwater report. The rocks will seep and I recommend that you refer to SLR technical report as well as Digby Wells groundwater report for the seepage rates.

Comment raised	contributor	Organisation/ community	Date	Method	Response
pass through the area. The RTSF in fact is planned to be in an area of the extension of the well-known Pretorius Fault. Has any survey been done to confirm that offshoots of the fault or extensions do not underlie the proposed site?					The dolomite is at a depth of more than 1000 m underneath the proposed RTSF and is not in direct contact (or is not a dolomitic risk which is often defined by a depth of 60 m or less)
Thickness of bedrock from surface to underlying dolomites – the thickness of the bedrock above the underlying dolomites is once again important. As stated before that no rocks are impervious, the thinner the strata, the more likely and the greater the volume of water, that will seep through to the underlying dolomites.	Tom McGhee	Geologist	14 December 2015	Consulting Geologist	As stated above, the strata above the dolomite are more than 1 km thick, they are not thin.
Once the water has been treated at the Advanced Water Treatment Facility, where will it go?	Tom McGhee	Geologist	14 December 2015	Consulting Geologist	Treated water will be discharged to the Leeuspruit.

16 Conclusions

The potential impacts on the groundwater environment were assessed following a desktop study, hydrocensus, geophysical survey, borehole drilling, aquifer testing and numerical modelling.

16.1 Site Geology

16.1.1 Historical TSFS

The historical TSFs are either located directly on dolomitic strata or on the Transvaal sequence that overlie the dolomite.

Seepage from TSFs underlain by non-dolomitic rocks has developed contamination plumes in the shallow aquifer that drain towards surface water courses. However, seepage from the TSFs located on dolomite infiltrates into the dolomitic aquifer due to the high permeability of the dolomitic aquifers. Although a short-term acid generation during operation can occur due to the TSF disturbance and exposure to oxygen and water, the impact on groundwater as a result of the reclamation is anticipated to be positive in the long run since the TSFs, which are potential sources of contamination, will be removed.

For the purpose of the groundwater study, the historical TSFs can be divided into two groups based on the foundation geology:

- The first group consists of TSFs that are completely or partially located on dolomite. These are:
    - All of the TSFs within the Western Block except Driefontein 5; and
    - All of the TSFs within the Northern Block.
- The second group consists of TSFs sitting on the Transvaal shale and quartzite. The dolomite is at least 100 m below the surface and is not in direct contact with the TSFs:
    - All TSFs within the Southern Block; and
    - Driefontein 5 in the Western Block.

16.1.2 RTSF

The geology underlying the proposed RTSF is composed of the Pretoria Group lithologies, of the Transvaal Supergroup. The Pretoria Group sediments comprise of shale, slate, quartzite, siltstone and conglomerate. Dolomite is found at least 1 km below surface.

Extensive diabase sill intrusions, as characterised by a highly positive magnetic signature in the aeromagnetic survey, is evident as intrusions in the Silverton shale and Timeball Hill siltstone-shale sequences.

Two north-south striking magnetic diabase dykes (Gemsbokfontein No.1 and No2 dykes), associated with the Pilanesberg tectonic event pass approximately 1 km east of the proposed RTSF footprint area. The fold hinge zone that crosses along the Doornfontein TSF is expected to curve and strike approximately 3.7 km east of the RTSF.

16.2 Impact Assessment and Management Plans

16.2.1 Reclamation of Historical TSFs

The groundwater impacts associated with the re-mining of all of the historical TSFs is expected to be positive since the source of contamination will be removed. Although the site specific hydrogeological conditions of the TSFs may differ, the identified impacts will essentially be the same and positive to all. In this section the impacts and management options for all historical TSFs have been discussed, as it would be repetitive to discuss on individual TSFs, in each of the mining right areas.

The historical TSFs are not lined and seepage is expected to drain into the underlying groundwater system. The current hypothesis is that if there were no TSFs located directly over the dolomite, it is likely that the dolomitic water (also called fissure water by the mines) pumped from the underground chambers would be of better quality compared to the current status. In addition, the pumping cost would be reduced if the TSF seepage portion could be eliminated. This implies that if infiltration of tailings seepage can be reduced, the contaminant loads will be less from a pollution perspective and pumping costs will be less. At present, the presence of the TSFs and the continued dewatering activities in these compartments will encourage continued infiltration of TSF seepage to the deeper aquifer units and mining areas, the consequent deterioration of water quality and increased volumes of water to be pumped from the underground chambers. The impact as a result of the reclamation is therefore anticipated to be positive in the long run since the TSFs, which are sources of contamination, will be removed. A short-term acid mine drainage could be generated due to the exposure of the tailings during the operational phase. This, however, is expected to be short lived and buffered by the dolomitic carbonates underneath.

16.2.2 RTSF

The current groundwater depths within the RTSF footprint range between 2.3 to 9.5 m below surface. Potential impacts associated with the RTSF construction, operation and closure are therefore possible considering the relatively shallow groundwater table.

The RTSF activities that could potentially impact the groundwater environment include:

16.2.2.1 Construction Phase

No impact on the groundwater quantity is expected during site clearing as long as the activities are taking place above the groundwater table:

- The construction of blast drains and trenches below the groundwater table can impact the groundwater quantity as the groundwater will be dewatered to keep the working environment dry. This impact is rated as negligible since no active dewatering is expected to occur from the blast curtain at this stage.

- The construction will also be conducted in a relatively short period compared to the operational and post-closure phases. Impact on the groundwater is therefore rated as Negligible.
- Diesel or other organic fluids and inorganic solvents might be spilled on the ground surface, or leak from surface or underground storage tanks. This could have a potential negative impact on groundwater quality. As the water table in the project area is fairly shallow, it is possible that the spilled organic compounds can reach the groundwater.
- Depending on the duration and amount of a spillage, the impact is expected to be Negligible.

16.2.2.2 Operation Phase

Seepage from the RTSF can negatively influence the groundwater quality in the underlying aquifers during the operational phase and as such the significance is rated as Moderate:

- Contamination plumes from the RTSF are expected to reach down-gradient private boreholes for the unmitigated base case option (Option 1), but not for the proposed Option 5.
- Seepage from the RTSF can also impact the streams. Once the plume reaches the streams, it can migrate at a faster rate compared to the speed of the groundwater flow and could have Medium to High impact on the down-gradient riverine ecosystem and communities.

16.2.2.3 Decommissioning Phase

Seepage from the RTSF will continue even after dump closure and can have a negative impact on the groundwater environment, rated as Moderate:

- Seepage from the RTSF can impact the quality of the Leeuspruit and its tributaries via groundwater baseflow if no mitigation is undertaken (i.e. Option 1). Once the contamination plume reaches the streams, it can migrate at a higher rate as compared to the groundwater flow and could have a negative impact on the down-gradient riverine ecosystem and communities. The potential impact on the river will, however, be reduced if a blast curtain (Option 5) is implemented.
- Contamination plumes from the RTSF can also reach private boreholes down-gradient for Option 1 (unmitigated base case) but not for the proposed Option 5.
- Seepage from the RTSF will continue even after closure and can have an impact on the groundwater environment. However, the impact can be reduced with the implementation of a blast curtain drain and dump rehabilitation. Continuous groundwater monitoring would be required to evaluate the effect of the mitigation

activities. Model simulations show that the plume can be contained within the RTSF footprint provided that the blast curtain drain operates efficiently even after closure. Efficient blast curtain operation refers to:

  - The permeability of the drain conductance should be at least 5 times (preferably 10 times) higher than that of the aquifer.
  - The pumping rate has to be at least 120% of the RTSF seeped amount (approximately 4,810 m^3/d).
  - The pumping programme has to continue until such time that the water quality being abstracted improves to acceptable levels.

- The application of a competent liner is expected to significantly reduce the seepage rate. Since contaminants are mainly transported by the flowing water, the reduction of seepage rate will also reduce the salt load that seeps from the RTSF to the groundwater to insignificant levels, even if the sulphides are not removed (by the acid plant). It should be noted that this is valid only if the liner remains competent even after closure and block seepages effectively, with no failures due to unforeseen circumstances.

17 Recommendations

The following mitigation methods are recommendations to minimise the potential impacts:

17.1 Reclamation of Historical TSFs

No mitigation is required during the construction phase as no direct groundwater impact is expected.

During the operation phase:

- Monitoring of groundwater quality and water levels, in areas where the TSFs are not in dewatered compartments; and
- Minimise ponding of water within the mining area.

During the closure phase:

- Monitoring of groundwater quality and level;
- Minimise area of disturbance to avoid AMD at multiple places; and
- Rehabilitation of footprints.

17.2 RTSF

17.2.1 Construction Phase

Since no impacts on the groundwater are expected during the construction of the RTSF, there is no need for mitigation measures. However, all boreholes that exist in the current footprint area need to be closed and sealed off properly in order to prevent seepage from the tailings dam through the borehole directly into the deeper fractured aquifer zone:

- If trenches are going to be excavated below the water level, dewatering of the aquifer to locally lower the water table can be considered to ensure that the construction takes place above the groundwater level and the water quality remains acceptable. The abstracted water can be utilised for dust suppression, vegetation or discharged to pollution control dams for evaporation. Since the groundwater is not expected to be polluted at this stage, the utilisation of the water for activities such as dust suppression or vegetation is not expected to cause negative environmental impacts.
- Install long term monitoring boreholes.
- All precautions should be taken to prevent diesel or other chemicals spillages during the construction phase.
- Hydrocarbon reservoirs must be in a bunded area.
- If a considerable amount of fluid is accidentally spilled, the contaminated soil should be scraped off and dumped to a proper dumping site. The excavation should be backfilled with soil of good quality. If the spillage is insignificant, since the ground surface is exposed to the atmospheric environment, the fluid is expected to volatilise to the atmosphere or deplete forming gaseous plumes in the subsurface before reaching the groundwater.
- The proposed monitoring boreholes, particularly those located within the construction area have to be monitored for both water level and quality to detect any changes in quality during the construction phase.

17.2.2 Operation Phase

The application of liners could significantly minimise the infiltration of the contaminants from the RTSF to the subsurface. However, overall cost/benefit needs to be assessed with the use of liners, bearing in mind stability issues, damage to liners and their sustainability. As an alternative, the implementation of a blast curtain drain is proposed to contain the contaminate plume to within the footprint area of the RTSF:

- The hydraulic conductivity of the blast curtain needs to be at least 5 times (preferably 10 times) higher than the aquifer. Otherwise, the contaminants can migrate along permeable weathered or fractured aquifer and reach the stream. The drain also needs to be dewatered as soon as water flows into it and keep it at a lower hydraulic head than the surrounding aquifer. This way the blast curtain will be a hydraulic sink and groundwater will always flow towards the drain and the chance of plume migrating away from the drain can be avoided.
- Monitoring of groundwater quality and water levels is recommended (particularly downgradient of the RTSF and in between the RTSF and rivers) with continuous refining and updating of the monitoring network based on the results obtained. Since

the operational phase will take place over a prolonged period compared to the construction phase, more monitoring boreholes will be required.

- The RTSF shape is recommended to be designed to control the ease with which water can run off from the facility.
- Apply a proper soil cover and vegetation on the rehabilitated portion of the RTSF.
- Refine the conceptual and numerical models every second year in the first four years and thereafter every five years based on groundwater monitoring results.
- Annual audits of monitoring and management systems should be conducted by an independent environmental person in conjunction with the SGL environmental department.
- Water collected at the blast curtain is expected to be of better quality compared to the RTSF leachate as it will be diluted by the clean water intercepted from outside the RTSF area. However, model simulations have shown that the water will not be pristine, particularly because Mn could potentially exceed the recommended 0.1 mg/L limit. This means that the abstracted water would potentially have to be treated before it is discharged to the environment.

17.2.3 Closure Phase

Seepage from the RTSF will continue even after closure and can have an impact on the groundwater environment if unmitigated (Option 1). However, the impact can be reduced and managed with the implementation of a blast curtain and RTSF rehabilitation. The predicted contamination plume shows that the plume can be contained to within the RTSF footprint provided that the blast curtain drain operates efficiently, even after mine closure. The curtain drain is recommended to perform effectively to intercept the plume long after the mine is closed.

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Appendix A: Declaration of Independence

I, Dr Robel Gebrekristos, as duly authorised representative of Digby Wells and Associates (South Africa) (Pty) Ltd., hereby confirm my independence (as well as that of Digby Wells and Associates (South Africa) (Pty) Ltd.) and declare that neither I nor Digby Wells and Associates (South Africa) (Pty) Ltd. have any interest, be it business, financial, personal or other, in any proposed activity, application or appeal in respect of Sibanye Gold Limited, other than fair remuneration for work performed, specifically in connection with the proposed West Rand Tailings Retreatment Project, Gauteng Province.

Full name: Dr Robel Gebrekristos

Title/ Position: Unit Manager: Hydrogeology

Qualification(s): PhD in Hydrogeology

Experience (years): 13.5

Registration(s): Professional Natural Scientist (Pr. Sci. Nat 400175/08)

CV of the Groundwater Specialist

1. Education

- PhD in Hydrogeology, Institute for Groundwater Studies, University of the Free State, South Africa, 2007.
- Honours and MSc in Hydrogeology, Institute for Groundwater Studies, University of the Free State, South Africa, 2004.
- BSc major in Geology and minor in Physics, Geology Department, University of Asmara, Eritrea, 1999.

2. Employment

- Digby Wells and Associates, Johannesburg, South Africa (October 2011 to current)
- ERM Southern Africa (April 2009 to September 2011)
- Knight Piésold Engineering (July 2007 to March 2009)
- Institute for Groundwater Studies, University of the Free State, South Africa (July 2004 to July 2007)
- Umvoto Africa (Pty) Ltd, Cape Town, South Africa (November 2002 to July 2003)
- Geology Department, University of Asmara, Eritrea (September 1999 to February 2002)

3. Experience

Robel is a senior groundwater modeller and the hydrogeology unit manager at Digby Wells with more than 13 years of experience, both as a corporate consultant and a researcher.

Robel's experience in hydrogeology includes:

- Hydrogeological field data interpretation and conceptual modelling;
- Groundwater flow and mass transport modelling;
- Unsaturated flow modelling;
- Analytical Modelling;
- Geochemical investigations and interpretations;
- Groundwater monitoring (organic and inorganic);
- Mine dewatering management and EIA/EMP assessments;
- Groundwater resource assessment and management;
- Water and mass balance calculations (with Goldsim);
- Knowledge of Hydrogeology and GIS based software: WISH, Aquifer Test Pro, Surfer, QGIS, ArcView, Global Mapper, Map Source, RockWorks; Blender and Sketchup; and
- Computer programming, particularly C++, VB and SQL languages.

4. Project experience

Recent 10 assignments include:

Gold One – Geluksdal TSF: Evaluation of potential impact on the groundwater arising from the construction, operation and closure of the proposed Geluksdal TSF.

Anglo Platinum – Bokoni Mine: Groundwater inflow estimations using analytical methods for two proposed deep shafts in fractured aquifers of Bushveld Complex in the western limb.

BHP Energy Coal South Africa (South Africa) – Union Colliery: Volumetric calculations, mine decanting predictions and long-term water geochemistry assessment as part of the mine closure management plan

Anglo Platinum – Bokoni Mine: Groundwater investigation as part of the EIA study and IWULA applications.

Resource Generation – Boikarabelo Mine: Mass transport modelling to for the long-term assessment of the potential mine impacts in the nearby receptors (streams and private boreholes).

Anglo Platinum (South Africa) Aquifer characterization and numerical modelling for mine feasibility study in the Bushveld Igneous aquifers.

Exxaro Mine (South Africa) Regional numerical modelling for groundwater impact assessment and management planning of existing and proposed pits and associated mine infrastructures such as tailings storage facilities, rock and ash dumps in a coal mine.

Sasol Mafutha Project (South Africa) Regional and local numerical modelling for groundwater impact assessment and management planning of proposed Coal-fired Power Station as well as Coal Mine.

Anglo Platinum (South Africa) Aquifer characterisation and analytical modelling for groundwater management in future underground mine.

Sasol Midland Industrial Site (South Africa) Site characterization and numerical modelling for the evaluation of transport and fate of organic contaminants (particularly DNAPLs) in groundwater.

5. Professional Affiliations

Registered Professional Natural Scientist (PrSciNat) with the South African Council for Natural Scientific Professions – Registration Number: 400175/08

The Geological Society of South Africa: Membership number: 967074

International Association of Hydrogeologists (IAH)

Ground Water Division of the Geological Society of South Africa

6. Publications

a. Presentations at international conferences

Gebrekristos, R.A (2015). Packer Testing And Analytical Modelling For Groundwater Inflow Estimation For Proposed Shafts, (*Best Paper at Biennial South African Groundwater Conference, Bloemfontein, 21-23 September 2015).*

Gebrekristos, R.A, Trusler, G., James, A., (2015). Blast curtain optimized with a numerical model for TSF seepage control, Biennial South African Groundwater Conference, Stellenbosch, 21-23 September 2015.

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Mills, M.E, van Gool, J., Kotze, J. and Gebrekristos, R.A. (2011). Development of a Conceptual Model to Assist with Closure of a Contaminated Hydrogeologically Complex Sit. Submitted to the Biennial South African Groundwater Conference, Pretoria, 16 – 18 September 2011.

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Gebrekristos, RA and Usher, BH (2007) A column experiment to characterise DNAPL Saturation using Partitioning Interwell Tracer Test (PITT) Biennial South African Groundwater Conference, Bloemfontein, 8-10 October 2007.

b. Papers and Documents

Gebrekristos, R.A., Shapiro, A.M., and Usher, B.H., (2008), In Situ estimation of the effective chemical diffusion coefficient of a rock matrix in a fractured aquifer: Hydrogeology Journal, Vol 16, page 629-638.

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Appendix B: List of Hydrocensus Boreholes

BH ID	Date surveyed	Farm name	Owner	Ycoord	Xcoord	Zcoord	BH depth (m)	water level	Abstraction rate (L/h)	BH Usage	BH status	Field EC (mS/m)	Field pH	Field TDS (ppm)	T (0C)	Comment
CDV03	14-Jan-15	Cardoville 358 IQ	Badenhorst JCC	-2933668.938	61056.31918	1523.13	-	-		unused		-	-	-	-	old windmill not used anymore.
CDV01	14-Jan-15	Cardoville 358 IQ	Badenhorst JCC	-2933824.712	60448.79041	1444.29	-									bees on borehole, no water level measured.
CDV02	14-Jan-15	Cardoville 358 IQ	Badenhorst JCC	-2934371.29	60804.36185	1500.4	-	-		unused						bees on borehole, no water level measured.
DGV01	15-Jan-15	Droogheuvel 521 IQ	Badenhorst JCC	-2933108.394	59426.4557	1525.38	-	8.03		unused		848	7.17	601	22.7	cattle kraal about 10-20m from borehole. Rusted borehole
DGV02	15-Jan-15	Droogheuvel 521 IQ	Badenhorst JCC	-2933023.735	59423.85811	1524.77	-	7.61		unused		861	7.02	592	23.09	cattle kraal about 30m from borehole. Rusted borehole
DGV03	15-Jan-15	Droogheuvel 521 IQ	Badenhorst JCC	-2932883.487	59523.40433	1525.18	-	-		unused		-	-	-	-	blocked borehole
CDV04	15-Jan-15	Cardoville 358 IQ	Badenhorst JCC	-2932657.601	61289.34601	1530.34	-	-		stock watering		932	7.12	655	19.8	Borehole equipped with windmill, no water level was measured.
CDVBH1	16-Jan-15	Cardoville 364 IQ	Barry Van Wyk	-2934009.601	63618.47553	1515.82	-	7.64		unused		-	-	-	-	borehole equipped with submersible pump which is not working anymore. No water sample was obtained from borehole
CDVBH2	16-Jan-15	Cardoville 364 IQ	Barry Van Wyk	-2933952.611	63743.86379	1517.66	-	9.5		stock watering and irrigation		903	7.06	631	23.8	sample taken from a jojo tank.
CDVBH3	16-Jan-15	Cardoville 364 IQ	Barry Van Wyk	-2932571.78	64147.53295	1518.9	-	-		stock watering		1105	7.04	774	24.4	no water level measured as BH is equipped with windmill
CDVBH4	16-Jan-15	Cardoville 364 IQ	Barry Van Wyk	-2934271.785	64796.2192	1511.04	-	-		irrigation		832	7.08	581	26.4	windmill, no water level measured
CDVBH5	21-Jan-15	Cardoville 364 IQ	Badenhorst JCC	-2933165.451	62789.85346	1530.15	-	-		unused		-	-	-	-	blocked borehole
DGV04	21-Jan-15	Droogheuvel 521 IQ	Badenhorst JCC	-2934418.611	59511.07899	1517.19	-	-		unused		-	-	-	-	bees on borehole, no water level measured.
CDV05	21-Jan-15	Cardoville 358 IQ	Badenhorst JCC	-2932881.688	60743.75051	1528.2	-	-		unused		-	-	-	-	closed with concrete block.
CDVBH6	21-Jan-15	Cardoville 364 IQ	Badenhorst JCC	-2933353.644	62847.54744	1535.34	100	9.11		unused		998	7.12	681	20.9	borehole was used for stock watering previously, dead (rat) inside borehole
WDBBH1	23-Jan-15	Wildebeestkuil 360 IQ	Swanepoel A	-2929374.135	61233.36286	1526.79	-			drinking water		849	6.77	579	21.1	borehole equipped with hand pump, used by farm workers for drinking purposes
WDBBH2	23-Jan-15	Wildebeestkuil 360 IQ	Swanepoel A	-2930875	59285.9657	1536.87	-	7.05		irrigation		833	6.95	586	22.4	windmill
CDVBH7	26-Jan-15	Cardoville 358 IQ	Badenhorst JCC	-2929537.691	63581.16795	1470.01	-	12.48		unused		735	7.34	534	21.2	borehole located downstream of existing TSF
CDVBH8	26-Jan-15	Cardoville 358 IQ	Badenhorst JCC	-2929726.519	62642.88281	1518.42	-	4.08		unused		727	7.48	501	21.1	uncapped borehole at abondenned house
CDVBH9	26-Jan-15	Cardoville 358 IQ	Badenhorst JCC	-2929439.878	62208.10897	1523.53	-	-		unused		-	-	-	-	bees on borehole, no water level measured.
RTNBH1	27-Jan-15	Rietfontein 519 IQ	Karl Van Heerden	-2933059.152	57696.74764	1509.14	200	11.62	5000	Stock watering, irrigation and drinking		1006	7.1	707	23.6	sheep kraal 3m from borehole
RTNBH2	27-Jan-15	Rietfontein 519 IQ	Karl Van Heerden	-2933865.04	57836.36018	1491.38	200	0.94		uncapped borehole, next to stream.		945	7.27	678	22	
RTNBH3	27-Jan-15	Rietfontein 519 IQ	Keyser James Cecil	-2934196.971	56193.4002	1493.54	35	9		Stock watering and drinking		1020	8.12	709	20.9	used borehole
RTNBH4	27-Jan-15	Rietfontein 519 IQ	Keyser James Cecil	-2934168.476	56087.56366	1484.33	64	6.37	5000	stock watering and irrigation		1094	8.85	763	21.9	cattle about 10m from borehole
RTNBH5	27-Jan-15	Rietfontein 519 IQ	Keyser James Cecil	-2934000.363	56129.76897	1487.91	110	6.47	1000	stock watering		9.96 mS/m	10.3	7.11 ppt	22.2	borehole inside kraal, pigs, and cattle
RTNBH6	27-Jan-15	Rietfontein 519 IQ	Keyser James Cecil	-2934252.222	56286.06029	1494.88	-	8.2		stock watering		-	-	-	-	no sample was obtained as windmill was not pumping at the time.
RTNBH7	27-Jan-15	Rietfontein 519 IQ	Keyser James Cecil	-2932969.262	56396.48042	1492.42	-	3.7		drinking water		935	7.86	655	28.5	borehole pumps water to the house for drinking purposes
RTNBH8	27-Jan-15	Rietfontein 519 IQ	Keyser James Cecil	-2932876.845	56918.77504	1494.13	-	-		unused		-	-	-	-	over grown windmill
RTNBH9	27-Jan-15	Rietfontein 519 IQ	Berry John William	-2932678.919	58262.62897	1526.65	-	11.25		unused		877	7.65	612	23.8	borehole unused
RTNBH10	27-Jan-15	Rietfontein 519 IQ	Berry John William	-2932731.642	58332.07466	1524.07	-	11.12		unused		773	6.38	546	21.7	unused rusted borehole

BH ID	Date surveyed	Farm name	Owner	Ycoord	Xcoord	Zcoord	BH depth (m)	water level	Abstraction rate (L/h)	BH Usage	BH status	Field EC (mS/m)	Field pH	Field TDS (ppm)	T (0C)	Comment
RTNBH11	27-Jan-15	Rietfontein 519 IQ	Berry John William	-2933201.401	57963.8727	1513.48	-	3.11		unused		971	8.71	656	20.4	borehole located in the field,not capped
RTNBH12	27-Jan-15	Rietfontein 519 IQ	Berry John William	-2931822.055	57359.95341	1514.79	-	5.27		unused		996	8.45	695	20	uncapped borehole
RTNBH13	27-Jan-15	Rietfontein 519 IQ	Berry John William	-2931684.466	57388.68563	1519.43	-	8.9		drinking and irrigation		984	8.05	686	24.6	borehole pumping constantly, sample obtained from a jojo tank.
RTNBH14	27-Jan-15	Rietfontein 519 IQ	Berry John William	-2931795.43	57302.9443	1507.48	-	8.94		unused		975	8.15	702	21.3	uncapped borehole, not used.
GLDBH1	29-Jan-15	Geluksdal 396 IQ	Rabe Boerdery	-2935874.317	62724.42797	1509.73	-	-		unused		-	-	-	-	
DM11	29-Jan-15	Geluksdal 396 IQ	Rabe Boerdery	-2935682.168	63056.37977	1514.84	70	3.21		monitoring bh		921	8.16	627	18	
DM08	30-Jan-15	Cardoville 364 IQ	Rabe Boerdery	-2934848.356	63087.30557	1509.32	70	0.78		monitoring bh		930	8.57	646	20.8	borehole next to wetland
SM6	30-Jan-15	Cardoville 364 IQ	Rabe Boerdery	-2934486.703	62270.61123	1507.68	15	1.73		monitoring bh		835	9.5	581	17.5	
DM4	30-Jan-15	Cardoville 364 IQ	Rabe Boerdery	-2934748.324	61244.6426	1502.76	70	1.71		monitoring bh		921	7.97	643	20.1	
DM3	30-Jan-15	Cardoville 364 IQ	Rabe Boerdery	-2934513.337	61270.08994	1507.72	24			monitoring bh		840	7.6	653	21.4	
DM5	30-Jan-15	Cardoville 364 IQ	Rabe Boerdery	-2934502.075	61922.35249	1501.03	70	1.86		monitoring bh		911	11.26	624	19.9	
WDBBH7	04-Feb-15	Wildebeestkuil 360 IQ	Badenhorst GS	-2930524.281	58501.38124	1522.36	45	23.25	1500	stock watering and drinking water		883	7.18	617	22.8	borehole used for drinking
WDBBH8	04-Feb-15	Wildebeestkuil 360 IQ	Badenhorst GS	-2930431.937	58411.68272	1530.77	90	24.03		stock watering and drinking water		779	7.25	558	21.6	borehole used as backup- not used
WDBBH3	04-Feb-15	Wildebeestkuil 360 IQ	Badenhorst GS	-2929540.622	57935.01576	1530.53	60	12.69		stock watering		684	6.02	466	22.3	borehole not used, downstream of mine(leeudoring)
WDBBH4	04-Feb-15	Wildebeestkuil 360 IQ	Badenhorst A	-2931495.306	58049.43246	1552.64	75	19.38		stock watering and drinking water		799	6.91	554	22.8	borehole currently not used,
WDBBH5	04-Feb-15	Wildebeestkuil 360 IQ	Badenhorst A	-2930629.593	58083.86972	1552.88	34	18.31	8000	drinking water		665	7.23	455	30.8	
WDBBH6	04-Feb-15	Wildebeestkuil 360 IQ	Badenhorst GS	-2930624.332	57961.88252	1535.1	40	-		unused		-	-	-	-	old windmill not used anymore.
SPRBH1	09-Jun-15	Springbok kraal 359 IQ	Van Rensburg JF	-2928247.186	62117.64172	1557.21		10.74		Unused						
WLVBH1	09-Jun-15	Weltevreden 357 IQ	De Villiers AP	-2929605.689	55288.43079	1511.07		-		drinking and stock watering						borehole pumps to a dam, no water level measured, windmill
WLVBH2	09-Jun-15	Weltevreden 357 IQ	De Villiers AP	-2929382.229	55242.7269	1509.86		12.6		drinking and stock watering						borehole is about 15 m away from cattle kraal
BNDBH1	10-Jun-15	Barnardsrus 628 IQ	Rabe Boerdery	-2936058.197	67348.00237	1494.96		4.45		unused						
DNKBH1	11-Jun-15	Kalbasfontein 365 IQ	Badenhorst JCC	-2931351.208	68196.65001	1524.77		-								
DNKBH2	11-Jun-15	Kalbasfontein 365 IQ	Badenhorst JCC	-2929675.7	68332.81119	1544.71		16.65		unused						
DRNBH2	11-Jun-15	Doornfontein 522 IQ	Davel WJ	-2937987.779	62222.04903	1507.7		-								
DRNBH3	11-Jun-15	Doornfontein 522 IQ	Davel WJ	-2937658.424	59893.8274	1523.32		7.84		unused						
DRNBH1	11-Jun-15	Doornfontein 522 IQ	Davel WJ	-2937753.354	61772.65473	1500.01		-								
ESKBH1	11-Jun-15	Doornpoort 347 IQ	Eskom	-2926546.09	66181.08665	1599.99		-								
FRBBH1	11-Jun-15	Wildebeestkuil 360 IQ	De Bruyn FRJ	-2929446.894	60789.35891	1526.93		-								
FRBBH2	11-Jun-15	Wildebeestkuil 360 IQ	De Bruyn FRJ	-2929387.813	60667.38366	1537.5		-								
FRBBH3	11-Jun-15	Wildebeestkuil 360 IQ	De Bruyn FRJ	-2929454.951	60407.6982	1538.46		-								
KLBBH1	09-Jun-15	Kalbasfontein 365 IQ	Lutt WT	-2931733.125	66974.85732	1530.53		31.05		drinking and stock watering						
KLBBH2	09-Jun-15	Kalbasfontein 365 IQ	Lutt WT	-2931624.974	67016.00216	1533.42		18.17		unused						
KLBBH10	10-Jun-15	Kalbasfontein 365 IQ	Mr Sylvester Tshilwane-	-2933963.085	66494.27162	1510.35		5.07		unused						

BH ID	Date surveyed	Farm name	Owner	Ycoord	Xcoord	Zcoord	BH depth (m)	water level	Abstraction rate (L/h)	BH Usage	BH status	Field EC (mS/m)	Field pH	Field TDS (ppm)	T (0C)	Comment
			Department of Public works													
KLBBH11	10-Jun-15	Kalbasfontein 365 IQ	Rudman WA	-2933429.29	67876.6428	1519	40	5.35		Drinking water						
KLBBH12	10-Jun-15	Kalbasfontein 365 IQ	Rudman WA	-2933439.242	67956.34133	1519.24		5.22		unused						
KLBBH13	10-Jun-15	Kalbasfontein 365 IQ	Rudman WA	-2933497.273	67929.71531	1519		-		unused						borehole blocked at 5m
KLBBH14	10-Jun-15	Kalbasfontein 365 IQ	Rudman WA	-2933575.724	67971.86563	1511.07		5.03		unused						borehole collapsed at 6.37 m
KLBBH15	10-Jun-15	Kalbasfontein 365 IQ	Rudman WA	-2933360.434	68013.78244	1502.66		-		unused						
KLBBH16	10-Jun-15	Kalbasfontein 365 IQ	Rudman WA	-2933232.499	68084.54507	1501.45		-		unused						
KLBBH17	10-Jun-15	Kalbasfontein 365 IQ	Rudman WA	-2933130.998	68250.07474	1503.86		-		unused						blocked at 1.28m
KLBBH18	10-Jun-15	Kalbasfontein 365 IQ	Rudman WA	-2933239.582	67957.80045	1521.88		6.18		unused						
KLBBH19	10-Jun-15	Kalbasfontein 365 IQ	Rudman WA	-2934926.974	67992.09697	1494.96		-		unused						
KLBBH20	10-Jun-15	Kalbasfontein 365 IQ	Rudman WA	-2933839.777	68035.85686	1499.53		-								
KLBBH21	10-Jun-15	Kalbasfontein 365 IQ	Rudman WA	-2933834.906	68015.84585	1499.53		4.9		unused						
KLBBH22	10-Jun-15	Kalbasfontein 365 IQ	Rudman WA	-2933819.275	67763.72289	1508.9		4.14		unused						
KLBBH23	10-Jun-15	Kalbasfontein 365 IQ	Rudman WA	-2933925.47	67751.29784	1501.93		3.37		unused						
KLBBH24	10-Jun-15	Kalbasfontein 365 IQ	Simon DH	-2931331.815	67422.04121	1529.33		-	4500	Drinking water						
KLBBH25	10-Jun-15	Kalbasfontein 365 IQ	Burger HS	-2931194.815	66757.42145	1533.42		25.88		Drinking water						
KLBBH30	12-Jun-15	Kalbasfontein 365 IQ	Sarel	-2931096.313	66693.92294	1553.84		-								
KLBBH31	12-Jun-15	Kalbasfontein 365 IQ	Sarel	-2931033.338	66579.986	1539.43		-								
KLBBH33	12-Jun-15	Kalbasfontein 365 IQ	Sarel	-2931173.919	66681.05549	1543.51		-								
KLBBH34	12-Jun-15	Kalbasfontein 365 IQ	Sarel	-2931567.977	66710.31052	1530.05		-								
KLBBH35	12-Jun-15	Kalbasfontein 365 IQ	Laubscher CR	-2934302.47	67634.36736	1511.07		-								
KLBBH36	12-Jun-15	Kalbasfontein 365 IQ	Laubscher CR	-2934333.725	67677.86287	1511.07		-								
KLBBH4	09-Jun-15	Kalbasfontein 365 IQ	Lutt WT	-2931140.893	66955.81993	1546.15		-								
KLBBH5	10-Jun-15	Kalbasfontein 365 IQ	Mokotedi LA	-2931822.009	68528.24358	1521.64		-		unused						
KLBBH6	10-Jun-15	Kalbasfontein 365 IQ	Mokotedi LA	-2931942.515	68519.22371	1520.68		8.43								
KLBBH7	10-Jun-15	Kalbasfontein 365 IQ	Mlanjeni D	-2934077.859	67694.96671	1509.38		-								
KLBBH8	10-Jun-15	Kalbasfontein 365 IQ	Mr Sylvester Tshilwane-Department of Public works	-2933786.093	66358.82099	1514.91		5.71		unused						
KLBBH9	10-Jun-15	Kalbasfontein 365 IQ	Mr Sylvester Tshilwane-Department of Public works	-2934118.471	66395.176	1508.18		10.32		unused						
KLBBH3	09-Jun-15	Kalbasfontein 365 IQ	Lutt WT	-26.492531	27.669426	1530.53		27.7		drinking water						Borehole is currently being pumped
WLVBH4	09-Jun-15	Weltevreden 357 IQ	De Villiers AP	-2929010.459	56102.02838	1533.42		-								
WLVRIVER	09-Jun-15	Weltevreden 357 IQ	De Villiers AP	-2929174.206	54818.12067	1503.14		-		irrigation						
WLVBH3	09-Jun-15	Weltevreden 357 IQ	De Villiers AP	-2929058.833	54603.41775	1515.87		14.34		drinking water						

Appendix C: Laboratory Results

Test Report

Client: Digby Wells & Associates
Address: 359 Pretoria Ave, Fern Isle, Section 5, Ferndale, Randburg
Report no: 24043
Project: Digby Wells & Associates

Date of certificate: 29 April 2015
Date accepted: 17 April 2015
Date completed: 29 April 2015
Revision: 0

Lab no:				210121	210122	210123	210124	210125	210126
Date sampled:				27-Mar-15	27-Mar-15	27-Mar-15	27-Mar-15	27-Mar-15	27-Mar-15
Sample type:				Water	Water	Water	Water	Water	Water
Locality description:				SBNBH3	SBNBH5	SBNBH9	SBNBH10	SBNBH13	SBNBH14
	Analyses	**Unit**	**Method**						
A	pH @ 25°C	pH	ALM 20	7.84	7.59	7.84	8.33	8.19	7.76
A	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	37.4	29.4	50.1	54.8	25.2	32.6
A	Total dissolved solids (TDS)	mg/l	ALM 26	242	199	293	304	142	220
A	Total alkalinity	mg $CaCO_3$/l	ALM 01	201	119	219	268	125	152
A	Chloride (Cl)	mg/l	ALM 02	4.94	6.95	16.6	11.0	6.36	9.18
A	Sulphate (SO_4)	mg/l	ALM 03	2.34	2.61	16.4	2.15	1.64	2.18
A	Nitrate (NO_3) as N	mg/l	ALM 06	0.973	3.95	2.10	4.39	0.300	2.34
A	Ammonium (NH_4) as N	mg/l	ALM 05	0.075	0.043	0.227	0.931	0.612	0.036
N	Ammonia (NH_3) as N	mg/l	ALM 26	<0.005	<0.005	0.006	0.073	0.039	<0.005
A	Orthophosphate (PO_4) as P	mg/l	ALM 04	0.059	0.061	0.058	0.058	0.058	0.071
A	Fluoride (F)	mg/l	ALM 08	<0.213	0.245	0.223	0.320	0.220	0.280
A	Calcium (Ca)	mg/l	ALM 30	32.6	21.2	32.4	14.5	15.3	22.9
A	Magnesium (Mg)	mg/l	ALM 30	20.9	14.0	27.7	26.8	10.3	11.3
A	Sodium (Na)	mg/l	ALM 30	18.7	18.1	30.3	60.8	20.6	30.9
A	Potassium (K)	mg/l	ALM 30	1.63	0.794	1.59	1.44	1.42	1.68
A	Aluminium (Al)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
A	Iron (Fe)	mg/l	ALM 31	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
A	Manganese (Mn)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
A	Total chromium (Cr)	mg/l	ALM 31	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
A	Copper (Cu)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
A	Nickel (Ni)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
A	Zinc (Zn)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
A	Cobalt (Co)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
A	Cadmium (Cd)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
A	Lead (Pb)	mg/l	ALM 31	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
A	Turbidity	NTU	ALM 21	90.3	4.60	37.0	42.8	59.6	29.5
A	Total hardness	mg $CaCO_3$/l	ALM 26	168	110	195	147	81	103
N	Suspended solids (SS)	mg/l	ALM 25	18	5	20	38	14	61
N	Dissolved organic carbon (DOC)	mg/l	ALM 63	2.93	2.68	2.46	2.53	2.33	2.54

A = Accredited N = Non accredited O = Outsourced S = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine
The results relates only to the test item tested.
Results reported against the limit of detection.
Results marked 'Not SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory.
Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation.

Client: Digby Wells & Associates
Address: 359 Pretoria Ave, Fern Isle, Section 5, Ferndale, Randburg
Report no: 24043
Project: Digby Wells & Associates

Date of certificate: 29 April 2015
Date accepted: 17 April 2015
Date completed: 29 April 2015
Revision: 0

Lab no:				210121	210122	210123	210124	210125	210126
Date sampled:				27-Mar-15	27-Mar-15	27-Mar-15	27-Mar-15	27-Mar-15	27-Mar-15
Sample type:				Water	Water	Water	Water	Water	Water
Locality description:				SBNBH3	SBNBH5	SBNBH9	SBNBH10	SBNBH13	SBNBH14
	Analyses	**Unit**	**Method**						
N	Dissolved oxygen (DO)	mg/l	ALM 28	5.20	5.51	5.08	5.25	5.16	5.03
A	Arsenic (As)	mg/l	ALM 34	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
A	Selenium (Se)	mg/l	ALM 34	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
N	Mercury (Hg)	mg/l	ALM 35	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007
N	Silicon (Si)	mg/l	ALM 33	12.4	16.6	9.02	1.17	2.97	14.4
N	Silver (Ag)	mg/l	ALM 32	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
N	Boron (B)	mg/l	ALM 32	0.053	0.150	0.031	0.047	0.049	0.052
N	Barium (Ba)	mg/l	ALM 32	0.043	0.011	0.018	0.008	0.003	0.059
N	Beryllium (Be)	mg/l	ALM 32	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
N	Bismuth (Bi)	mg/l	ALM 32	0.015	0.030	0.018	0.012	0.009	0.014
N	Lithium (Li)	mg/l	ALM 32	0.002	0.006	0.004	0.002	0.001	0.001
N	Molybdenum (Mo)	mg/l	ALM 32	0.014	0.013	0.011	0.012	0.011	0.014
N	Strontium (Sr)	mg/l	ALM 32	0.111	0.064	0.129	0.027	0.061	0.096
N	Thallium	mg/l	ALM 32	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037
A	Dissolved Uranium (U)	mg/l	ALM 37	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
N	Vanadium (V)	mg/l	ALM 32	<0.001	0.005	<0.001	<0.001	<0.001	0.006
N	Antimony (Sb)	mg/l	ALM 36	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
N	Tin (Sn)	mg/l	ALM 36	0.024	0.023	0.022	0.019	0.022	0.023
N	Titanium (Ti)	mg/l	ALM 36	0.003	0.004	0.003	0.004	0.004	0.004
A	Calcium hardness	mg $CaCO_3$/l	ALM 26	81	53	81	36	38	57
A	Difference	%	ALM 26	-0.96	1.51	-0.84	-3.16	-3.00	-1.09
N	Acidity	mg $CaCO_3$/l	ALM 60	2.98	4.40	1.87	Nil	Nil	2.39

A = Accredited N = Non accredited O = Outsourced S = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine
The results relates only to the test item tested.
Results reported against the limit of detection.
Results marked 'Not SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory.
Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation.

Authenticated signature on first page

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0861 467 765

Ref. No. : ML2015-0606
Contract No. : 8665947
Date : 2015-03-10
Page 1 of 21

Registration Number 1974/001476/07 VATNumber 4780103505

M and L Laboratory Services (Pty) Ltd

Consulting Industrial Chemists, Analysts _Samplers

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Certificate / Report

COMPANY NAME	: DIGBY WELLS & ASSOCIATES (PTY) LTD
ADDRESS	: PRIVATE BAG X10046, RANDBURG, 2125
SUBJECT	: ANALYSIS OF 15 WATER SAMPLES
PROJECT REFERENCE	: G012376
INSTRUCTED BY	: ROBEL GEBREKRISTOS
ORDER NUMBER	: G012376
RECEIVED ON	: 2015-02-16
ANALYSIS COMPLETED	: 2015-03-10

BDL - Below Detection Limit

*** Denotes test method accredited to ISO17025**

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Printed Date : 2015-03-11

Certificate / Report

Lab Number			E21920	E21921	E21922
Sampled Date			2015-01-23	2015-01-23	2015-01-23
Sample Marks			DM11	CDVBH4	DGV02
Determinand	**Method References**	**Detection Limit**	**Result**	**Result**	**Result**
Chemical Analysis					
* pH Value @ 25℃	W044-27-O		7.9	8.2	7.8
* Conductivity @ 25℃ (mS/m)	W044-27-O		48.2	17.3	32.7
* TDS (mg/l)	W044-03-W	1	296	90	198
* Calcium as Ca (mg/l)	W044-30-C	0.118	41	9.7	28
* Calcium Hardness as CaCO3 (mg/l)	W044-30-C	1	102	24	70
* Magnesium as Mg (mg/l)	W044-30-C	0.034	25	12.0	17.5
* Magnesium Hardness as CaCO3 (mg/l)	W044-30-C	1	103	49	72
Total Hardness as CaCO3 (mg/l)			225	73	142
* Sodium as Na (mg/l)	W044-30-C	0.016	39	9.8	21
* Potassium as K (mg/l)	W044-30-C	0.093	3.7	3.2	3.6
Ammonia as NH4 (mg/l)	W044-50-W	0.10	<0.10	<0.10	<0.10
Ammonia as NH3 (mg/l)	W044-50-W	0.10	<0.10	<0.10	<0.10
Ammonia as N (mg/l)	W044-50-W	0.10	<0.10	<0.10	<0.10
Total Alkalinity as CaCO3 (mg/l)	W044-50-W	1	214	84	133
Bicarbonate as HCO3 (mg/l)	W044-50-W		261	102	162
Carbonate as CO3 (mg/l)	W044-50-W		0	0	0
Hydroxide as OH- (mg/l)	W044-50-W		0	0	0
Chloride as Cl (mg/l)	W044-50-W	0.10	9.8	2.9	9.5
Sulfate as SO4 (mg/l)	W044-50-W	0.2	12.9	5.0	9.5
Nitrate as NO3 (mg/l)	W044-50-W	0.100	35	0.7	21
Nitrate as N (mg/l)	W044-50-W	0.100	7.9	0.2	4.7
Nitrite as NO2 (mg/l)	W044-50-W	0.100	-	-	-
Fluoride as F (mg/l)	W044-50-W	0.10	0.2	0.2	0.2
TSS (mg/l)	A.P.H.A. 2540D	1	10	124	<1
Turbidity N.T.U	APHA 2130 B	0.1	0.2	1.6	0.3
Dissolved Oxygen as O2 (mg/l)	APHA 4500-O C	0.1	6.6	6.5	7.0
Dissolved Organic Carbon as C (mg/l)	Subcontracted to Aquadoc	1	12.0	2.9	4.8
Sum of Anions as meq/l (meq/l)			5.396	1.886	3.472
Sum of Cations as meq/l (meq/l)			5.890	2.437	3.809

BDL - Below Detection Limit

*** Denotes test method accredited to ISO17025**

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Golden No.
0861 467 765

Ref. No. : ML2015-0606
Contract No. : 8665947
Date : 2015-03-10

Registration Number 1974/001476/07 VATNumber 4780103505

M and L Laboratory Services (Pty) Ltd

Consulting Industrial Chemists, Analysts _Samplers

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Certificate / Report

Lab Number			E21920	E21921	E21922
Sampled Date			2015-01-23	2015-01-23	2015-01-23
Sample Marks			DM11	CDVBH4	DGV02
Determinand	**Method References**	**Detection Limit**	**Result**	**Result**	**Result**
Chemical Analysis					
% Error			4.377	2.431	4.628
Chemical Balance			In	In	In

Authorised Signature

Edward Khumalo
Supervisor

BDL - Below Detection Limit

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Printed Date : 2015-03-11

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Certificate / Report

Lab Number			E21920	E21921	E21922
Sampled Date			2015-01-23	2015-01-23	2015-01-23
Sample Marks			DM11	CDVBH4	DGV02
Determinand	**Method References**	**Detection Limit**	**Result**	**Result**	**Result**
Metals					
Arsenic as As (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Lead as Pb (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Selenium as Se (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Silver as Ag (mg/l)	W044-30-C	0.004	<0.004	<0.004	<0.004
Aluminium as Al (mg/l)	W044-30-C	0.003	0.01	0.009	0.005
Boron as B (mg/l)	W044-30-C	0.006	0.03	0.01	0.02
Barium as Ba (mg/l)	W044-30-C	0.001	0.001	0.001	0.08
Beryllium as Be (mg/l)	W044-30-C	0.002	<0.002	<0.002	<0.002
Bismuth as Bi (mg/l)	W044-30-C	0.005	<0.005	<0.005	<0.005
Cadmium as Cd (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Cobalt as Co (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Chromium as Cr (mg/l)	W044-30-C	0.003	<0.003	<0.003	<0.003
Copper as Cu (mg/l)	W044-30-C	0.002	0.02	0.01	0.06
Iron as Fe (mg/l)	W044-30-C	0.001	0.009	0.03	0.01
Manganese as Mn (mg/l)	W044-30-C	0.001	0.001	0.002	0.003
Molybdenum as Mo (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Nickel as Ni (mg/l)	W044-30-C	0.003	<0.003	<0.003	<0.003
Phosphorous as P (mg/l)	W044-30-C	0.04	<0.040	0.21	<0.040
Antimony as Sb (mg/l)	W044-30-C	0.010	<0.010	<0.010	<0.010
Silicon as Si (mg/l)	W044-30-C	0.007	17.9	6.2	25
Tin as Sn (mg/l)	W044-30-C	0.020	0.57	0.27	0.42
Strontium as Sr (mg/l)	W044-30-C	0.001	0.11	0.04	0.10
Thorium as Th (mg/l)	W044-30-C	0.002	0.003	<0.002	0.002
Titanium as Ti (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Thallium as Tl (mg/l)	W044-30-C	0.009	<0.009	<0.009	<0.009
Uranium as U (mg/l)	W044-30-C	0.004	<0.004	<0.004	<0.004
Vanadium as V (mg/l)	W044-30-C	0.002	0.05	0.02	0.05
Zinc as Zn (mg/l)	W044-30-C	0.005	0.02	<0.005	0.04
Zirconium as Zr (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001

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Golden No.
0861 467 765

Ref. No. : ML2015-0606
Contract No. : 8665947
Date : 2015-03-10
Page 5 of 21

Registration Number 1974/001476/07 VATNumber 4780103505

M and L Laboratory Services (Pty) Ltd

Consulting Industrial Chemists, Analysts _Samplers

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Certificate / Report

Lab Number			E21920	E21921	E21922
Sampled Date			2015-01-23	2015-01-23	2015-01-23
Sample Marks			DM11	CDVBH4	DGV02
Determinand	**Method References**	**Detection Limit**	**Result**	**Result**	**Result**
Metals					
Mercury as Hg (mg/l)	W044-33-C	0.001	<0.001	<0.001	<0.001

Authorised Signature

Ndileka Bangani
Supervisor

BDL - Below Detection Limit

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Ref. No. : ML2015-0606
Contract No. : 8665947
Date : 2015-03-10

Registration Number 1974/001476/07 VATNumber 4780103505

M and L Laboratory Services (Pty) Ltd

Consulting Industrial Chemists, Analysts _Samplers

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Certificate / Report

Lab Number			E21923	E21924	E21925
Sampled Date			2015-01-23	2015-01-23	2015-01-23
Sample Marks			CDVBH6	CDVBH2	COVBH7
Determinand	**Method References**	**Detection Limit**	**Result**	**Result**	**Result**
Chemical Analysis					
* pH Value @ 25℃	W044-27-O		7.4	7.6	8.0
* Conductivity @ 25℃ (mS/m)	W044-27-O		27.0	39.1	36.3
* TDS (mg/l)	W044-03-W	1	164	182	244
* Calcium as Ca (mg/l)	W044-30-C	0.118	23	34	34
* Calcium Hardness as CaCO3 (mg/l)	W044-30-C	1	57	85	85
* Magnesium as Mg (mg/l)	W044-30-C	0.034	13.9	14.4	15.1
* Magnesium Hardness as CaCO3 (mg/l)	W044-30-C	1	57	59	62
Total Hardness as CaCO3 (mg/l)			114	144	147
* Sodium as Na (mg/l)	W044-30-C	0.016	19.4	19.8	19.5
* Potassium as K (mg/l)	W044-30-C	0.093	2.0	3.7	2.7
Ammonia as NH4 (mg/l)	W044-50-W	0.10	<0.10	4.1	<0.10
Ammonia as NH3 (mg/l)	W044-50-W	0.10	<0.10	3.9	<0.10
Ammonia as N (mg/l)	W044-50-W	0.10	<0.10	3.2	<0.10
Total Alkalinity as CaCO3 (mg/l)	W044-50-W	1	127	167	123
Bicarbonate as HCO3 (mg/l)	W044-50-W		155	204	150
Carbonate as CO3 (mg/l)	W044-50-W		0	0	0
Hydroxide as OH- (mg/l)	W044-50-W		0	0	0
Chloride as Cl (mg/l)	W044-50-W	0.10	6.2	25	26
Sulfate as SO4 (mg/l)	W044-50-W	0.2	6.4	0.5	5.1
Nitrate as NO3 (mg/l)	W044-50-W	0.100	6.3	<0.1	22
Nitrate as N (mg/l)	W044-50-W	0.100	1.4	<0.1	5.0
Nitrite as NO2 (mg/l)	W044-50-W	0.100	-	-	-
Fluoride as F (mg/l)	W044-50-W	0.10	0.2	0.1	0.1
TSS (mg/l)	A.P.H.A. 2540D	1	878	128	2
Turbidity N.T.U	APHA 2130 B	0.1	39	9.0	1.1
Dissolved Oxygen as O2 (mg/l)	APHA 4500-O C	0.1	6.1	3.2	6.8
Dissolved Organic Carbon as C (mg/l)	Subcontracted to Aquadoc	1	6.4	9.7	5.7
Sum of Anions as meq/l (meq/l)			2.958	4.057	3.657
Sum of Cations as meq/l (meq/l)			3.169	3.864	3.862

BDL - Below Detection Limit

*** Denotes test method accredited to ISO17025**

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Ref. No. : ML2015-0606
Contract No. : 8665947
Date : 2015-03-10
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M&L LABS
Registration Number 1974/001476/07 VATNumber 4780103505

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Certificate / Report

Lab Number			E21923	E21924	E21925
Sampled Date			2015-01-23	2015-01-23	2015-01-23
Sample Marks			CDVBH6	CDVBH2	COVBH7
Determinand	**Method References**	**Detection Limit**	**Result**	**Result**	**Result**
Chemical Analysis					
% Error			3.444	-2.437	2.726
Chemical Balance			In	In	In

Authorised Signature

Edward Khumalo
Supervisor

BDL - Below Detection Limit

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Certificate / Report

Lab Number			E21923	E21924	E21925
Sampled Date			2015-01-23	2015-01-23	2015-01-23
Sample Marks			CDVBH6	CDVBH2	COVBH7
Determinand	**Method References**	**Detection Limit**	**Result**	**Result**	**Result**
Metals					
Arsenic as As (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Lead as Pb (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Selenium as Se (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Silver as Ag (mg/l)	W044-30-C	0.004	<0.004	<0.004	<0.004
Aluminium as Al (mg/l)	W044-30-C	0.003	0.02	0.007	0.01
Boron as B (mg/l)	W044-30-C	0.006	<0.006	<0.006	<0.006
Barium as Ba (mg/l)	W044-30-C	0.001	0.009	0.04	0.009
Beryllium as Be (mg/l)	W044-30-C	0.002	<0.002	<0.002	<0.002
Bismuth as Bi (mg/l)	W044-30-C	0.005	<0.005	<0.005	<0.005
Cadmium as Cd (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Cobalt as Co (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Chromium as Cr (mg/l)	W044-30-C	0.003	<0.003	<0.003	<0.003
Copper as Cu (mg/l)	W044-30-C	0.002	0.02	0.02	0.02
Iron as Fe (mg/l)	W044-30-C	0.001	0.11	0.06	0.04
Manganese as Mn (mg/l)	W044-30-C	0.001	0.001	0.15	0.008
Molybdenum as Mo (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Nickel as Ni (mg/l)	W044-30-C	0.003	<0.003	<0.003	<0.003
Phosphorous as P (mg/l)	W044-30-C	0.04	<0.040	<0.040	<0.040
Antimony as Sb (mg/l)	W044-30-C	0.010	<0.010	<0.010	<0.010
Silicon as Si (mg/l)	W044-30-C	0.007	17.7	4.6	24
Tin as Sn (mg/l)	W044-30-C	0.020	0.33	0.36	0.36
Strontium as Sr (mg/l)	W044-30-C	0.001	0.06	0.13	0.08
Thorium as Th (mg/l)	W044-30-C	0.002	0.003	0.003	0.005
Titanium as Ti (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Thallium as Tl (mg/l)	W044-30-C	0.009	<0.009	<0.009	<0.009
Uranium as U (mg/l)	W044-30-C	0.004	<0.004	<0.004	0.004
Vanadium as V (mg/l)	W044-30-C	0.002	0.03	0.03	0.04
Zinc as Zn (mg/l)	W044-30-C	0.005	<0.005	<0.005	0.09
Zirconium as Zr (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001

BDL - Below Detection Limit

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Certificate / Report

Lab Number			E21923	E21924	E21925
Sampled Date			2015-01-23	2015-01-23	2015-01-23
Sample Marks			CDVBH6	CDVBH2	COVBH7
Determinand	**Method References**	**Detection Limit**	**Result**	**Result**	**Result**
Metals					
Mercury as Hg (mg/l)	W044-33-C	0.001	<0.001	<0.001	<0.001

Authorised Signature

Ndileka Bangani
Supervisor

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Certificate / Report

	Lab Number			E21926	E21927	E21928
	Sampled Date			2015-01-24	2015-01-24	2015-01-24
	Sample Marks			WDBBH1	WDBBH2	WDBBH7
	Determinand	**Method References**	**Detection Limit**	**Result**	**Result**	**Result**
	Chemical Analysis					
*	pH Value @ 25℃	W044-27-O		7.1	7.5	7.6
*	Conductivity @ 25℃ (mS/m)	W044-27-O		10.6	24.0	25.2
*	TDS (mg/l)	W044-03-W	1	54	152	156
*	Calcium as Ca (mg/l)	W044-30-C	0.118	4.7	19.0	21
*	Calcium Hardness as CaCO3 (mg/l)	W044-30-C	1	11.7	47	52
*	Magnesium as Mg (mg/l)	W044-30-C	0.034	5.2	10.7	12.5
*	Magnesium Hardness as CaCO3 (mg/l)	W044-30-C	1	21	44	51
	Total Hardness as CaCO3 (mg/l)			33	96	103
*	Sodium as Na (mg/l)	W044-30-C	0.016	12.4	14.8	16.1
*	Potassium as K (mg/l)	W044-30-C	0.093	1.7	0.88	1.4
	Ammonia as NH4 (mg/l)	W044-50-W	0.10	<0.10	<0.10	<0.10
	Ammonia as NH3 (mg/l)	W044-50-W	0.10	<0.10	<0.10	<0.10
	Ammonia as N (mg/l)	W044-50-W	0.10	<0.10	<0.10	<0.10
	Total Alkalinity as CaCO3 (mg/l)	W044-50-W	1	44	98	116
	Bicarbonate as HCO3 (mg/l)	W044-50-W		54	119	141
	Carbonate as CO3 (mg/l)	W044-50-W		0	0	0
	Hydroxide as OH- (mg/l)	W044-50-W		0	0	0
	Chloride as Cl (mg/l)	W044-50-W	0.10	3.7	5.4	2.0
	Sulfate as SO4 (mg/l)	W044-50-W	0.2	7.0	3.0	1.5
	Nitrate as NO3 (mg/l)	W044-50-W	0.100	<0.1	14.0	13.4
	Nitrate as N (mg/l)	W044-50-W	0.100	<0.1	3.2	3.0
	Nitrite as NO2 (mg/l)	W044-50-W	0.100	-	-	-
	Fluoride as F (mg/l)	W044-50-W	0.10	0.2	0.4	0.2
	TSS (mg/l)	A.P.H.A. 2540D	1	92	44	44
	Turbidity N.T.U	APHA 2130 B	0.1	1.0	1.1	0.2
	Dissolved Oxygen as O2 (mg/l)	APHA 4500-O C	0.1	4.5	6.0	6.3
	Dissolved Organic Carbon as C (mg/l)	Subcontracted to Aquadoc	1	1.2	4.9	5.6
	Sum of Anions as meq/l (meq/l)			1.140	2.420	2.632
	Sum of Cations as meq/l (meq/l)			1.245	2.498	2.819

BDL - Below Detection Limit

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Ref. No. : ML2015-0606
Contract No. : 8665947
Date : 2015-03-10
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Registration Number 1974/001476/07 VATNumber 4780103505

M and L Laboratory Services (Pty) Ltd

Consulting Industrial Chemists, Analysts _Samplers

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Certificate / Report

Lab Number			E21926	E21927	E21928
Sampled Date			2015-01-24	2015-01-24	2015-01-24
Sample Marks			WDBBH1	WDBBH2	WDBBH7
Determinand	**Method References**	**Detection Limit**	**Result**	**Result**	**Result**
Chemical Analysis					
% Error			4.403	1.586	3.431
Chemical Balance			In	In	In

Authorised Signature

Edward Khumalo
Supervisor

BDL - Below Detection Limit

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Printed Date : 2015-03-11

Certificate / Report

Lab Number			E21926	E21927	E21928
Sampled Date			2015-01-24	2015-01-24	2015-01-24
Sample Marks			WDBBH1	WDBBH2	WDBBH7
Determinand	**Method References**	**Detection Limit**	**Result**	**Result**	**Result**
Metals					
Arsenic as As (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Lead as Pb (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Selenium as Se (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Silver as Ag (mg/l)	W044-30-C	0.004	<0.004	<0.004	<0.004
Aluminium as Al (mg/l)	W044-30-C	0.003	0.03	0.009	0.009
Boron as B (mg/l)	W044-30-C	0.006	0.03	<0.006	<0.006
Barium as Ba (mg/l)	W044-30-C	0.001	0.002	0.01	0.005
Beryllium as Be (mg/l)	W044-30-C	0.002	<0.002	<0.002	<0.002
Bismuth as Bi (mg/l)	W044-30-C	0.005	<0.005	<0.005	<0.005
Cadmium as Cd (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Cobalt as Co (mg/l)	W044-30-C	0.001	0.001	<0.001	<0.001
Chromium as Cr (mg/l)	W044-30-C	0.003	<0.003	<0.003	<0.003
Copper as Cu (mg/l)	W044-30-C	0.002	0.009	0.06	0.09
Iron as Fe (mg/l)	W044-30-C	0.001	0.010	0.05	0.003
Manganese as Mn (mg/l)	W044-30-C	0.001	0.003	0.02	0.005
Molybdenum as Mo (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Nickel as Ni (mg/l)	W044-30-C	0.003	<0.003	<0.003	<0.003
Phosphorous as P (mg/l)	W044-30-C	0.04	<0.040	<0.040	<0.040
Antimony as Sb (mg/l)	W044-30-C	0.010	<0.010	<0.010	<0.010
Silicon as Si (mg/l)	W044-30-C	0.007	1.9	16.6	13.9
Tin as Sn (mg/l)	W044-30-C	0.020	0.12	0.26	0.29
Strontium as Sr (mg/l)	W044-30-C	0.001	0.02	0.05	0.05
Thorium as Th (mg/l)	W044-30-C	0.002	<0.002	0.002	0.003
Titanium as Ti (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Thallium as Tl (mg/l)	W044-30-C	0.009	<0.009	<0.009	<0.009
Uranium as U (mg/l)	W044-30-C	0.004	<0.004	<0.004	<0.004
Vanadium as V (mg/l)	W044-30-C	0.002	0.01	0.02	0.03
Zinc as Zn (mg/l)	W044-30-C	0.005	<0.005	0.18	1.2
Zirconium as Zr (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001

BDL - Below Detection Limit

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Ref. No. : ML2015-0606
Contract No. : 8665947
Date : 2015-03-10
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Registration Number 1974/001476/07 VATNumber 4780103505

M and L Laboratory Services (Pty) Ltd

Consulting Industrial Chemists, Analysts _Samplers

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Certificate / Report

Lab Number			E21926	E21927	E21928
Sampled Date			2015-01-24	2015-01-24	2015-01-24
Sample Marks			WDBBH1	WDBBH2	WDBBH7
Determinand	**Method References**	**Detection Limit**	**Result**	**Result**	**Result**
Metals					
Mercury as Hg (mg/l)	W044-33-C	0.001	<0.001	<0.001	<0.001

Authorised Signature

Ndileka Bangani
Supervisor

BDL - Below Detection Limit

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Certificate / Report

Lab Number			E21929	E21930	E21931
Sampled Date			2015-01-24	2015-01-24	2015-01-24
Sample Marks			WDBBH6	RTNBH12	RTNBH1
Determinand	**Method References**	**Detection Limit**	**Result**	**Result**	**Result**
Chemical Analysis					
* pH Value @ 25℃	W044-27-O		7.5	7.4	7.8
* Conductivity @ 25℃ (mS/m)	W044-27-O		31.4	14.2	39.5
* TDS (mg/l)	W044-03-W	1	182	76	228
* Calcium as Ca (mg/l)	W044-30-C	0.118	32	5.4	39
* Calcium Hardness as CaCO3 (mg/l)	W044-30-C	1	80	13.5	97
* Magnesium as Mg (mg/l)	W044-30-C	0.034	17.5	11.9	19.1
* Magnesium Hardness as CaCO3 (mg/l)	W044-30-C	1	72	49	79
Total Hardness as CaCO3 (mg/l)			152	63	176
* Sodium as Na (mg/l)	W044-30-C	0.016	11.9	9.0	18.6
* Potassium as K (mg/l)	W044-30-C	0.093	2.3	1.1	3.5
Ammonia as NH4 (mg/l)	W044-50-W	0.10	0.2	<0.10	<0.10
Ammonia as NH3 (mg/l)	W044-50-W	0.10	0.2	<0.10	<0.10
Ammonia as N (mg/l)	W044-50-W	0.10	0.2	<0.10	<0.10
Total Alkalinity as CaCO3 (mg/l)	W044-50-W	1	165	69	189
Bicarbonate as HCO3 (mg/l)	W044-50-W		201	84	230
Carbonate as CO3 (mg/l)	W044-50-W		0	0	0
Hydroxide as OH- (mg/l)	W044-50-W		0	0	0
Chloride as Cl (mg/l)	W044-50-W	0.10	5.0	1.3	11.7
Sulfate as SO4 (mg/l)	W044-50-W	0.2	1.6	3.9	8.4
Nitrate as NO3 (mg/l)	W044-50-W	0.100	<0.1	1.1	8.7
Nitrate as N (mg/l)	W044-50-W	0.100	<0.1	0.2	2.0
Nitrite as NO2 (mg/l)	W044-50-W	0.100	-	-	-
Fluoride as F (mg/l)	W044-50-W	0.10	0.1	0.4	0.1
TSS (mg/l)	A.P.H.A. 2540D	1	12	2	26
Turbidity N.T.U	APHA 2130 B	0.1	0.6	0.3	0.8
Dissolved Oxygen as O2 (mg/l)	APHA 4500-O C	0.1	3.3	6.2	5.5
Dissolved Organic Carbon as C (mg/l)	Subcontracted to Aquadoc	1	9.9	3.2	10.0
Sum of Anions as meq/l (meq/l)			3.476	1.535	4.427
Sum of Cations as meq/l (meq/l)			3.621	1.668	4.425

BDL - Below Detection Limit

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Registration Number 1974/001476/07   VATNumber 4780103505

M and L Laboratory Services (Pty) Ltd

Consulting Industrial Chemists, Analysts _Samplers

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Certificate / Report

Lab Number			E21929	E21930	E21931
Sampled Date			2015-01-24	2015-01-24	2015-01-24
Sample Marks			WDBBH6	RTNBH12	RTNBH1
Determinand	**Method References**	**Detection Limit**	**Result**	**Result**	**Result**
Chemical Analysis					
% Error			2.043	4.152	-0.023
Chemical Balance			In	In	In

Authorised Signature

Edward Khumalo
Supervisor

BDL - Below Detection Limit

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Certificate / Report

Lab Number			E21929	E21930	E21931
Sampled Date			2015-01-24	2015-01-24	2015-01-24
Sample Marks			WDBBH6	RTNBH12	RTNBH1
Determinand	**Method References**	**Detection Limit**	**Result**	**Result**	**Result**
Metals					
Arsenic as As (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Lead as Pb (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Selenium as Se (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Silver as Ag (mg/l)	W044-30-C	0.004	<0.004	<0.004	<0.004
Aluminium as Al (mg/l)	W044-30-C	0.003	0.006	0.008	0.01
Boron as B (mg/l)	W044-30-C	0.006	<0.006	<0.006	<0.006
Barium as Ba (mg/l)	W044-30-C	0.001	0.004	0.004	0.009
Beryllium as Be (mg/l)	W044-30-C	0.002	<0.002	<0.002	<0.002
Bismuth as Bi (mg/l)	W044-30-C	0.005	<0.005	<0.005	<0.005
Cadmium as Cd (mg/l)	W044-30-C	0.001	0.001	<0.001	<0.001
Cobalt as Co (mg/l)	W044-30-C	0.001	<0.001	0.001	<0.001
Chromium as Cr (mg/l)	W044-30-C	0.003	<0.003	<0.003	<0.003
Copper as Cu (mg/l)	W044-30-C	0.002	0.02	0.02	0.02
Iron as Fe (mg/l)	W044-30-C	0.001	0.02	0.04	0.006
Manganese as Mn (mg/l)	W044-30-C	0.001	0.001	0.001	<0.001
Molybdenum as Mo (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Nickel as Ni (mg/l)	W044-30-C	0.003	<0.003	<0.003	<0.003
Phosphorous as P (mg/l)	W044-30-C	0.04	<0.040	<0.040	<0.040
Antimony as Sb (mg/l)	W044-30-C	0.010	<0.010	<0.010	<0.010
Silicon as Si (mg/l)	W044-30-C	0.007	14.9	6.5	16.0
Tin as Sn (mg/l)	W044-30-C	0.020	0.41	0.27	0.45
Strontium as Sr (mg/l)	W044-30-C	0.001	0.06	0.009	0.09
Thorium as Th (mg/l)	W044-30-C	0.002	0.003	0.003	0.004
Titanium as Ti (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Thallium as Tl (mg/l)	W044-30-C	0.009	<0.009	<0.009	<0.009
Uranium as U (mg/l)	W044-30-C	0.004	<0.004	<0.004	<0.004
Vanadium as V (mg/l)	W044-30-C	0.002	0.03	0.02	0.04
Zinc as Zn (mg/l)	W044-30-C	0.005	0.20	2.1	0.07
Zirconium as Zr (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001

BDL - Below Detection Limit

*** Denotes test method accredited to ISO17025**

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40 Modulus Road
Ormonde, 2091
Tel: (011) 661 7900
Fax: (011) 496 2238
Golden No.
0861 467 765

Ref. No. : ML2015-0606
Contract No. : 8665947
Date : 2015-03-10
Page 17 of 21

Registration Number 1974/001476/07 VATNumber 4780103505

M and L Laboratory Services (Pty) Ltd

Consulting Industrial Chemists, Analysts _Samplers

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Certificate / Report

Lab Number			E21929	E21930	E21931
Sampled Date			2015-01-24	2015-01-24	2015-01-24
Sample Marks			WDBBH6	RTNBH12	RTNBH1
Determinand	**Method References**	**Detection Limit**	**Result**	**Result**	**Result**
Metals					
Mercury as Hg (mg/l)	W044-33-C	0.001	<0.001	<0.001	<0.001

Authorised Signature

Ndileka Bangani
Supervisor

BDL - Below Detection Limit

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0861 467 765

Ref. No. : ML2015-0606
Contract No. : 8665947
Date : 2015-03-10

Registration Number 1974/001476/07 VATNumber 4780103505

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Certificate / Report

Lab Number			E21932	E21933	E21934
Sampled Date			2015-01-24	2015-01-24	2015-01-24
Sample Marks			RTNBH3	RTNBH7	RTNBH9
Determinand	**Method References**	**Detection Limit**	**Result**	**Result**	**Result**
Chemical Analysis					
* pH Value @ 25℃	W044-27-O		7.8	7.8	7.5
* Conductivity @ 25℃ (mS/m)	W044-27-O		50.2	48.4	21.7
* TDS (mg/l)	W044-03-W	1	324	326	158
* Calcium as Ca (mg/l)	W044-30-C	0.118	50	31	20
* Calcium Hardness as CaCO3 (mg/l)	W044-30-C	1	125	77	50
* Magnesium as Mg (mg/l)	W044-30-C	0.034	26	35	10.5
* Magnesium Hardness as CaCO3 (mg/l)	W044-30-C	1	107	144	43
Total Hardness as CaCO3 (mg/l)			232	221	93
* Sodium as Na (mg/l)	W044-30-C	0.016	19.9	18.9	11.2
* Potassium as K (mg/l)	W044-30-C	0.093	1.6	1.2	2.4
Ammonia as NH4 (mg/l)	W044-50-W	0.10	<0.10	<0.10	<0.10
Ammonia as NH3 (mg/l)	W044-50-W	0.10	<0.10	<0.10	<0.10
Ammonia as N (mg/l)	W044-50-W	0.10	<0.10	<0.10	<0.10
Total Alkalinity as CaCO3 (mg/l)	W044-50-W	1	188	182	89
Bicarbonate as HCO3 (mg/l)	W044-50-W		229	222	108
Carbonate as CO3 (mg/l)	W044-50-W		0	0	0
Hydroxide as OH- (mg/l)	W044-50-W		0	0	0
Chloride as Cl (mg/l)	W044-50-W	0.10	19.7	19.9	5.5
Sulfate as SO4 (mg/l)	W044-50-W	0.2	22	32	4.5
Nitrate as NO3 (mg/l)	W044-50-W	0.100	32	29	17.0
Nitrate as N (mg/l)	W044-50-W	0.100	7.2	6.6	3.8
Nitrite as NO2 (mg/l)	W044-50-W	0.100	-	-	<0.10
Fluoride as F (mg/l)	W044-50-W	0.10	0.1	0.3	0.1
TSS (mg/l)	A.P.H.A. 2540D	1	4	8	186
Turbidity N.T.U	APHA 2130 B	0.1	0.2	0.1	0.7
Dissolved Oxygen as O2 (mg/l)	APHA 4500-O C	0.1	6.2	5.8	4.2
Dissolved Organic Carbon as C (mg/l)	Subcontracted to Aquadoc	1	10.0	9.0	3.4
Sum of Anions as meq/l (meq/l)			5.291	5.347	2.306
Sum of Cations as meq/l (meq/l)			5.539	5.315	2.424

BDL - Below Detection Limit

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Certificate / Report

Lab Number			E21932	E21933	E21934
Sampled Date			2015-01-24	2015-01-24	2015-01-24
Sample Marks			RTNBH3	RTNBH7	RTNBH9
Determinand	**Method References**	**Detection Limit**	**Result**	**Result**	**Result**
Chemical Analysis					
% Error			2.290	-0.300	2.495
Chemical Balance			In	In	In

Authorised Signature

Edward Khumalo
Supervisor

BDL - Below Detection Limit

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Golden No.
0861 467 765

Ref. No. : ML2015-0606
Contract No. : 8665947
Date : 2015-03-10

Registration Number 1974/001476/07 VATNumber 4780103505

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Certificate / Report

Lab Number			E21932	E21933	E21934
Sampled Date			2015-01-24	2015-01-24	2015-01-24
Sample Marks			RTNBH3	RTNBH7	RTNBH9
Determinand	**Method References**	**Detection Limit**	**Result**	**Result**	**Result**
Metals					
Arsenic as As (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Lead as Pb (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Selenium as Se (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Silver as Ag (mg/l)	W044-30-C	0.004	<0.004	<0.004	<0.004
Aluminium as Al (mg/l)	W044-30-C	0.003	<0.003	<0.003	0.02
Boron as B (mg/l)	W044-30-C	0.006	<0.006	<0.006	<0.006
Barium as Ba (mg/l)	W044-30-C	0.001	0.001	0.003	0.02
Beryllium as Be (mg/l)	W044-30-C	0.002	<0.002	<0.002	<0.002
Bismuth as Bi (mg/l)	W044-30-C	0.005	<0.005	<0.005	<0.005
Cadmium as Cd (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Cobalt as Co (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Chromium as Cr (mg/l)	W044-30-C	0.003	<0.003	<0.003	<0.003
Copper as Cu (mg/l)	W044-30-C	0.002	0.02	0.03	0.02
Iron as Fe (mg/l)	W044-30-C	0.001	0.006	0.001	0.02
Manganese as Mn (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Molybdenum as Mo (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001
Nickel as Ni (mg/l)	W044-30-C	0.003	<0.003	<0.003	<0.003
Phosphorous as P (mg/l)	W044-30-C	0.04	<0.040	<0.040	<0.040
Antimony as Sb (mg/l)	W044-30-C	0.010	<0.010	<0.010	<0.010
Silicon as Si (mg/l)	W044-30-C	0.007	15.8	19.8	19.0
Tin as Sn (mg/l)	W044-30-C	0.020	0.59	0.76	0.24
Strontium as Sr (mg/l)	W044-30-C	0.001	0.12	0.14	0.05
Thorium as Th (mg/l)	W044-30-C	0.002	0.004	0.004	0.003
Titanium as Ti (mg/l)	W044-30-C	0.001	<0.001	<0.001	0.001
Thallium as Tl (mg/l)	W044-30-C	0.009	<0.009	<0.009	<0.009
Uranium as U (mg/l)	W044-30-C	0.004	<0.004	<0.004	<0.004
Vanadium as V (mg/l)	W044-30-C	0.002	0.05	0.06	0.03
Zinc as Zn (mg/l)	W044-30-C	0.005	0.007	0.005	0.009
Zirconium as Zr (mg/l)	W044-30-C	0.001	<0.001	<0.001	<0.001

BDL - Below Detection Limit

*** Denotes test method accredited to ISO17025**

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0861 467 765

Ref. No. : ML2015-0606
Contract No. : 8665947
Date : 2015-03-10
Page 21 of 21

Registration Number 1974/001476/07 VATNumber 4780103505

M and L Laboratory Services (Pty) Ltd

Consulting Industrial Chemists, Analysts _Samplers

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Certificate / Report

Lab Number			E21932	E21933	E21934
Sampled Date			2015-01-24	2015-01-24	2015-01-24
Sample Marks			RTNBH3	RTNBH7	RTNBH9
Determinand	**Method References**	**Detection Limit**	**Result**	**Result**	**Result**
Metals					
Mercury as Hg (mg/l)	W044-33-C	0.001	<0.001	<0.001	<0.001

Authorised Signature

Ndileka Bangani
Supervisor

BDL - Below Detection Limit

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Appendix D: Borehole Logs

DIGBY WELLS
ENVIRONMENTAL

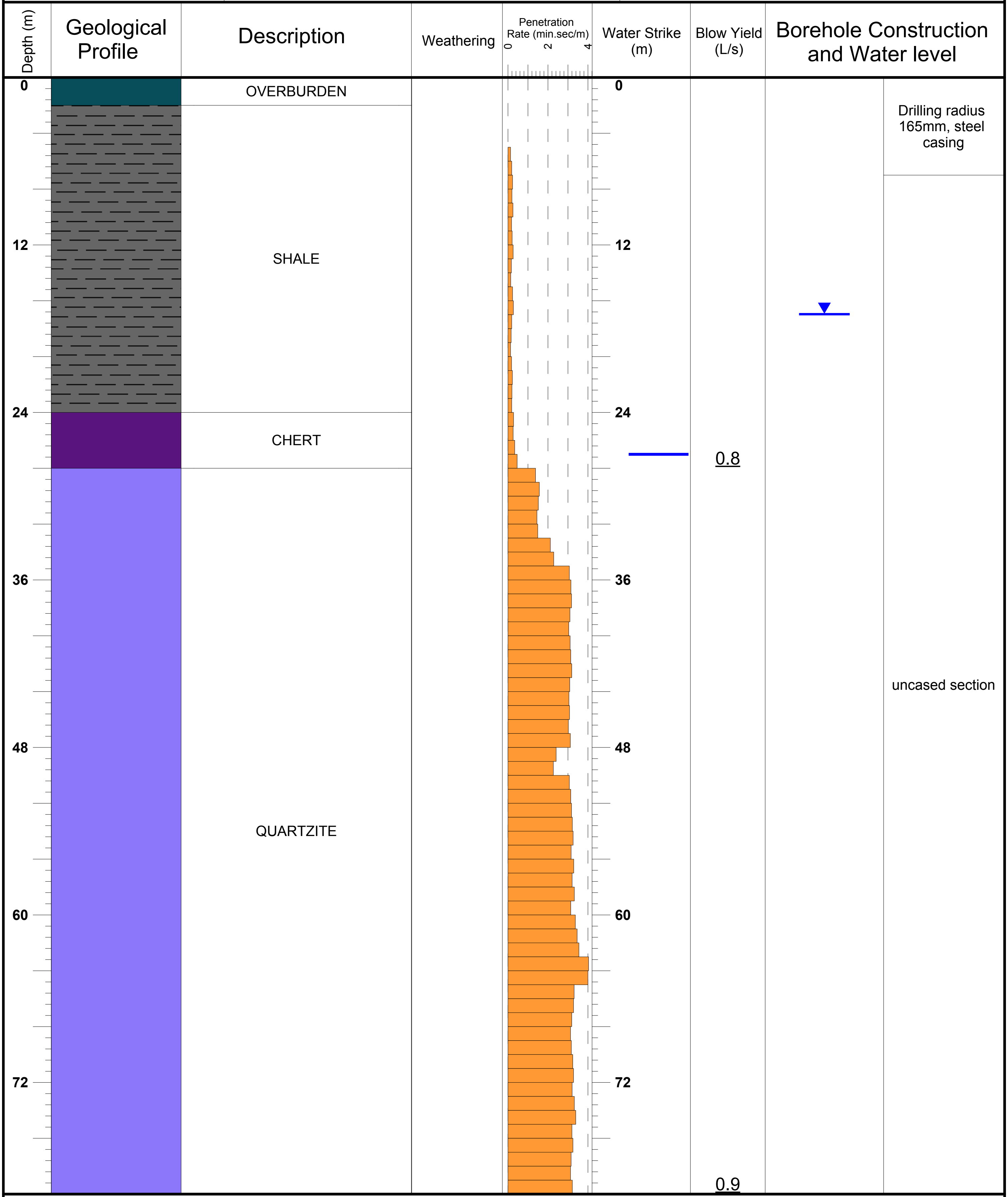
Fern Isle,Section 10
359 Pretoria Avenue
2125, Randburg
Tel: +27(0)11 789 9495

CLIENT:

Project Name:	Sibanye WRTRP EIA
Project Code:	GOL2376
Location:	Cardoville
Drilled By:	JK Drilling (Pty) Ltd
Date Drilled:	17/02/2015
Logged By:	Evidence Simango

BOREHOLE ID: SBNBH1

Coordinate System:	WGS84
X-Coordinate:	58655.93
Y-Coordinate:	-2930819.81
Z-Coordinate:	1547
Final Depth (m):	80
Collar Height (m):	0.43



Comment:

DIGBY WELLS
ENVIRONMENTAL

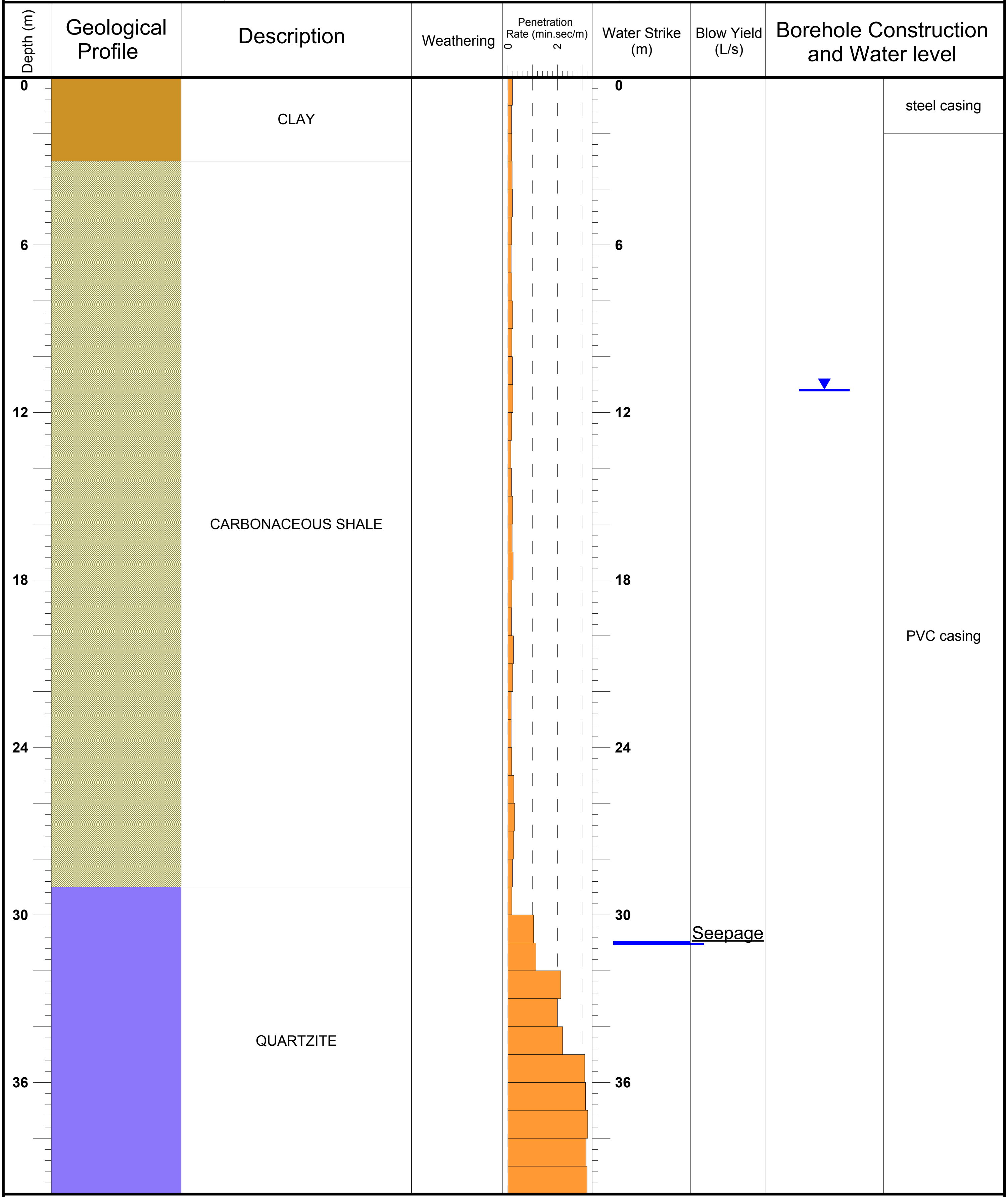
Fern Isle,Section 10
359 Pretoria Avenue
2125, Randburg
Tel: +27(0)11 789 9495

CLIENT:

Project Name: Sibanye WRTRP EIA
Project Code: GOL2376
Location: Cardoville
Drilled By: JK Drilling (Pty) Ltd
Date Drilled: 18/02/2015
Logged By: Evidence Simango

BOREHOLE ID: SBNBH2

Coordinate System: WGS84
X-Coordinate: 58935.14
Y-Coordinate: -2930934.97
Z-Coordinate: 1550
Final Depth (m): 40
Collar Height (m): 0.4



Comment:

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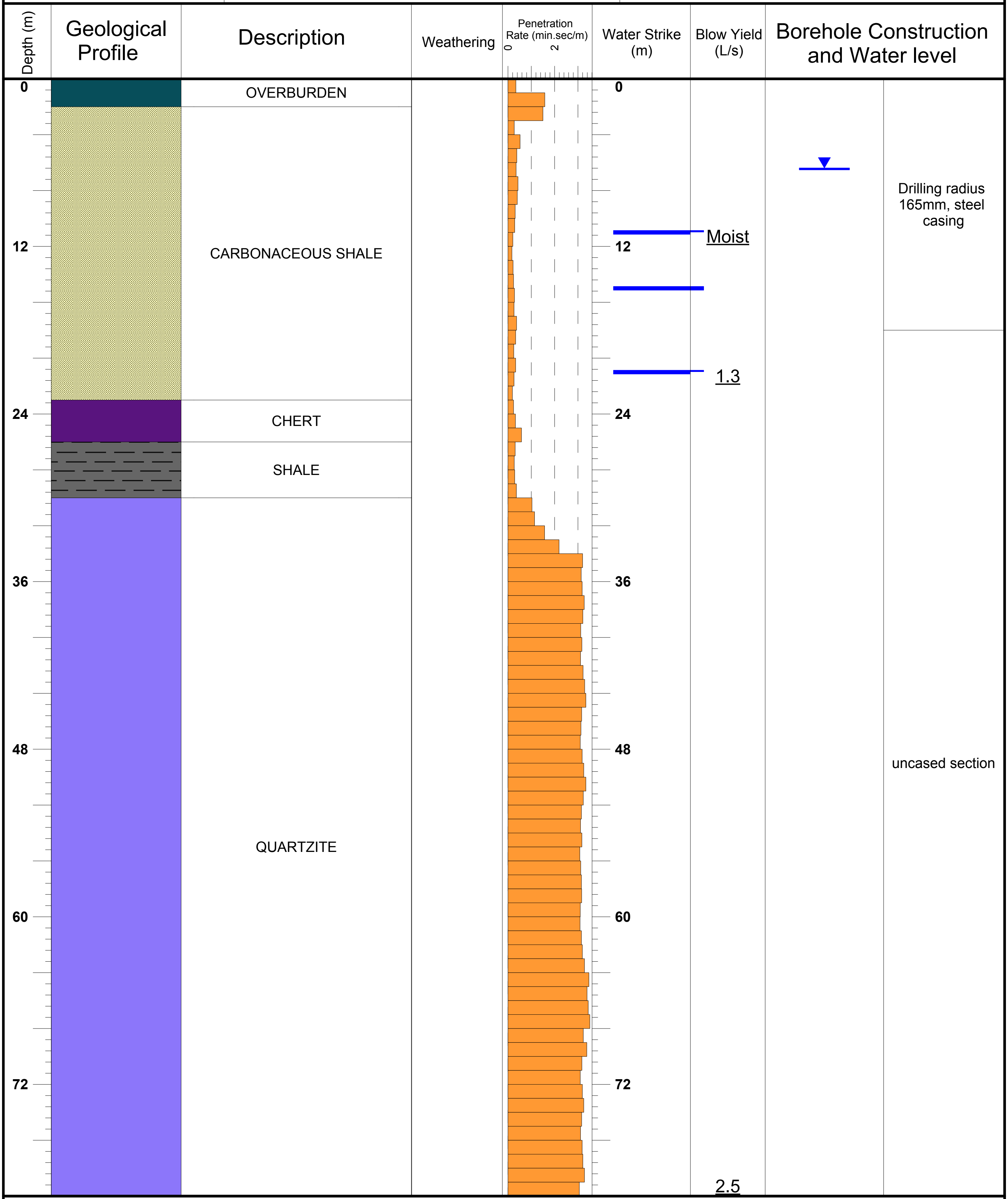
Fern Isle,Section 10
359 Pretoria Avenue
2125, Randburg
Tel: +27(0)11 789 9495

CLIENT:

Project Name: Sibanye WRTRP EIA
Project Code: GOL2376
Location: Cardoville
Drilled By: JK Drilling (Pty) Ltd
Date Drilled: 16/02/2015
Logged By: Evidence Simango

BOREHOLE ID: SBNBH3

Coordinate System: WGS84
X-Coordinate: 60340.26
Y-Coordinate: -2929739.01
Z-Coordinate:
Final Depth (m): 80
Collar Height (m): 0.48



Comment:

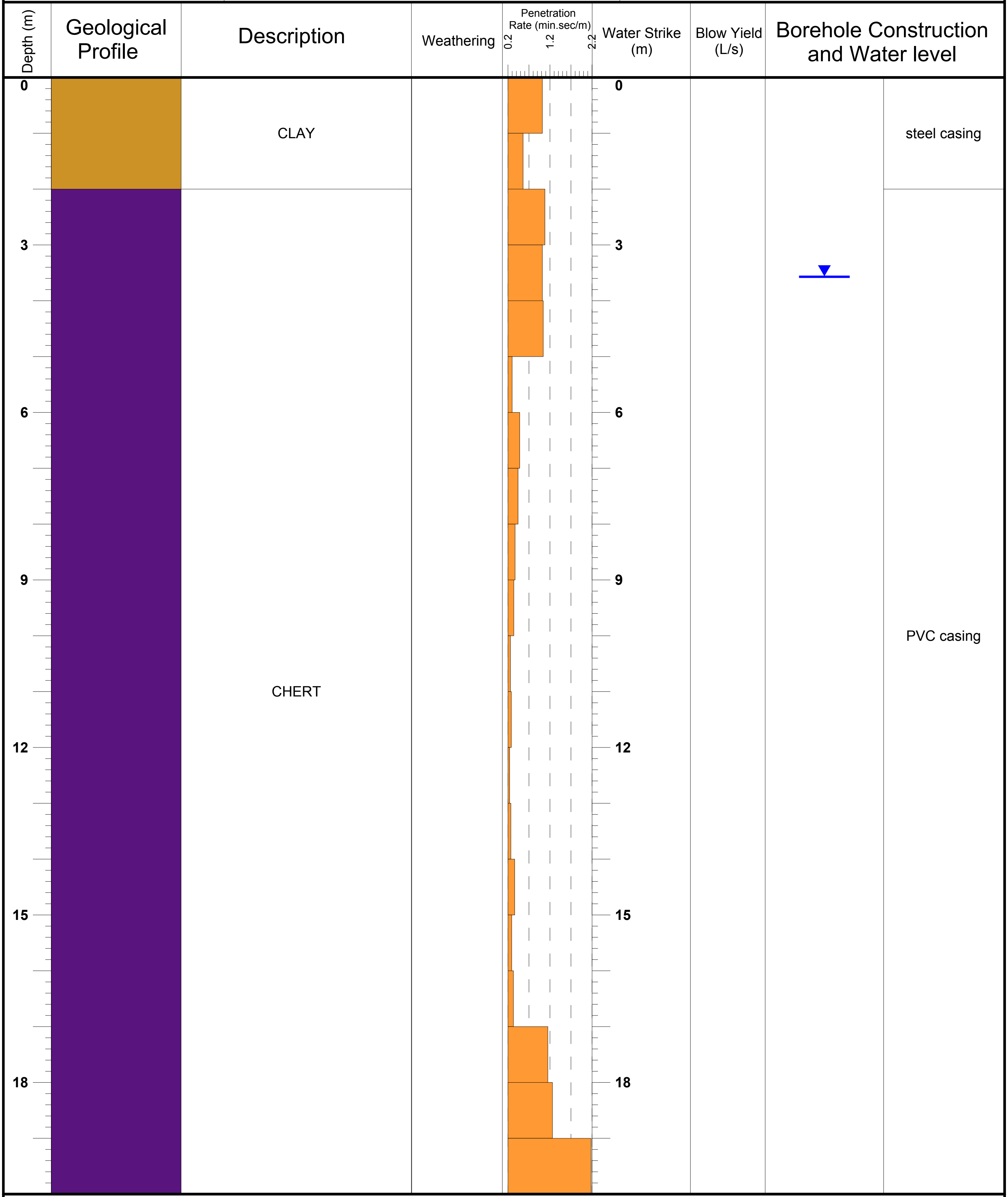
Fern Isle,Section 10
359 Pretoria Avenue
2125, Randburg
Tel: +27(0)11 789 9495

CLIENT:

Project Name:	Sibanye WRTRP EIA
Project Code:	GOL2376
Location:	Cardoville
Drilled By:	JK Drilling (Pty) Ltd
Date Drilled:	09/02/2015
Logged By:	Evidence Simango

BOREHOLE ID: SBNBH4

Coordinate System:	WGS84
X-Coordinate:	61723.79
Y-Coordinate:	-2929327.96
Z-Coordinate:	
Final Depth (m):	20
Collar Height (m):	0.37



Comment:

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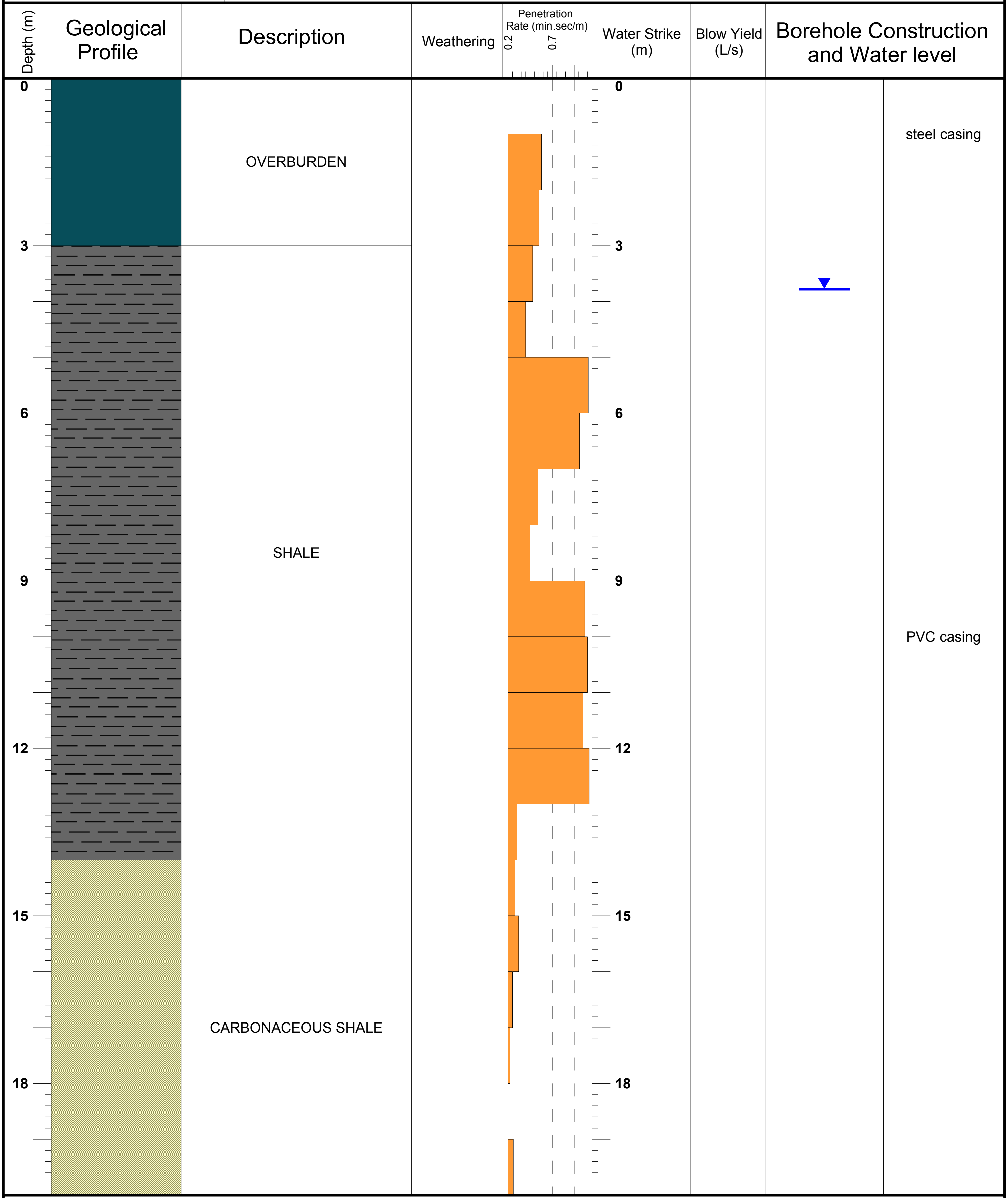
CLIENT:

Project Name:	Sibanye WRTRP EIA
Project Code:	GOL2376
Location:	Cardoville
Drilled By:	JK Drilling (Pty) Ltd
Date Drilled:	10/02/2015
Logged By:	Evidence Simango

BOREHOLE ID: SBNBH5

Coordinate System:	WGS84
X-Coordinate:	62284.45
Y-Coordinate:	-2930188.29
Z-Coordinate:	
Final Depth (m):	20
Collar Height (m):	0.36



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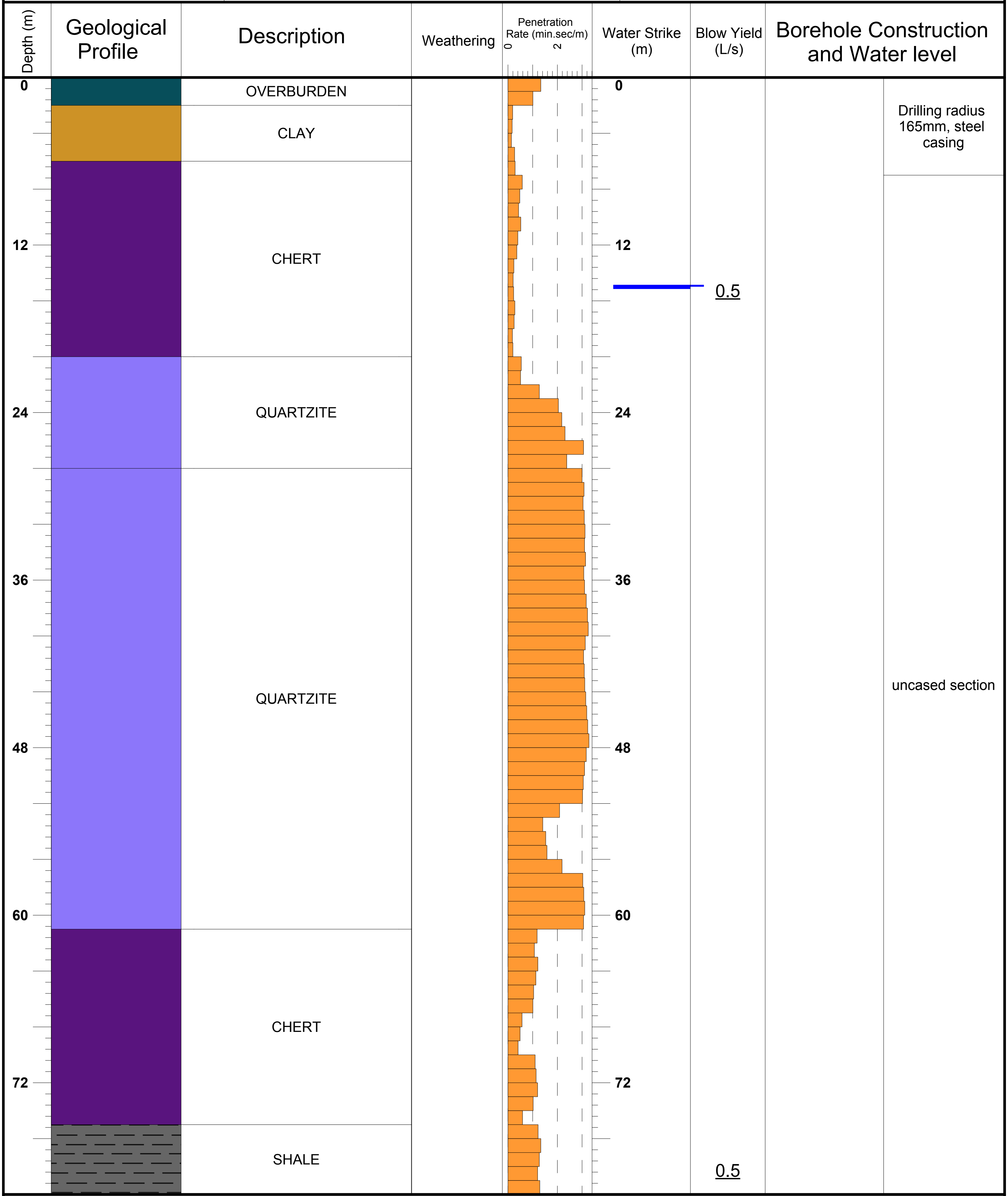
Project Name:	Sibanye WRTRP EIA
Project Code:	GOL2376
Location:	Cardoville
Drilled By:	JK Drilling (Pty) Ltd
Date Drilled:	20/02/2015
Logged By:	Evidence Simango

BOREHOLE ID: SBNBH6

Coordinate System:	WGS84
X-Coordinate:	62864.45
Y-Coordinate:	-2930526.62
Z-Coordinate:	1527
Final Depth (m):	80
Collar Height (m):	0.41



Comment:

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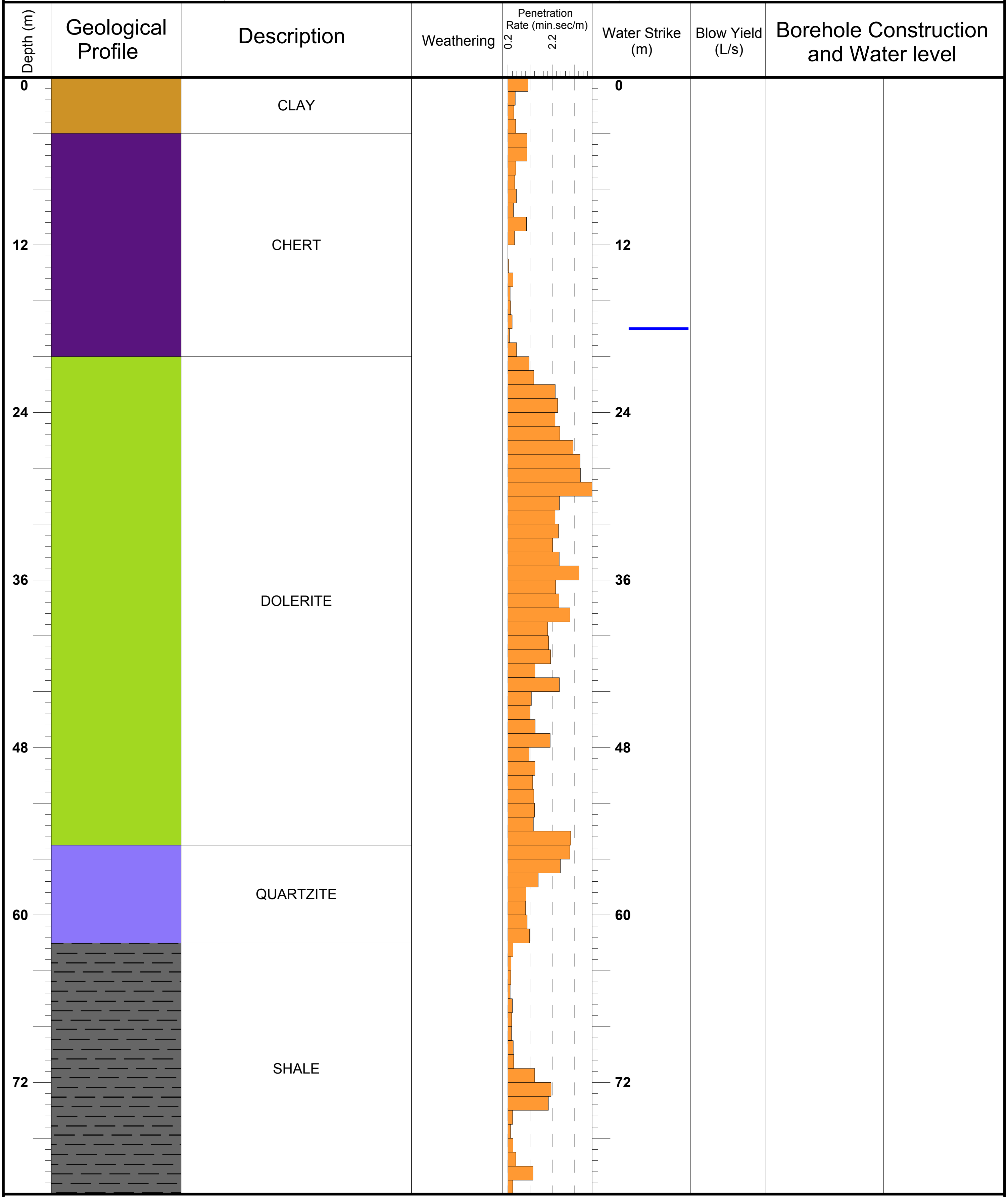
CLIENT:

Project Name:	Sibanye WRTRP EIA
Project Code:	GOL2376
Location:	Cardoville
Drilled By:	JK Drilling (Pty) Ltd
Date Drilled:	08/05/2015
Logged By:	Evidence Simango

BOREHOLE ID: SBNBH6A

Coordinate System:	WGS84
X-Coordinate:	62870
Y-Coordinate:	-2930754
Z-Coordinate:	
Final Depth (m):	80
Collar Height (m):	



Comment:

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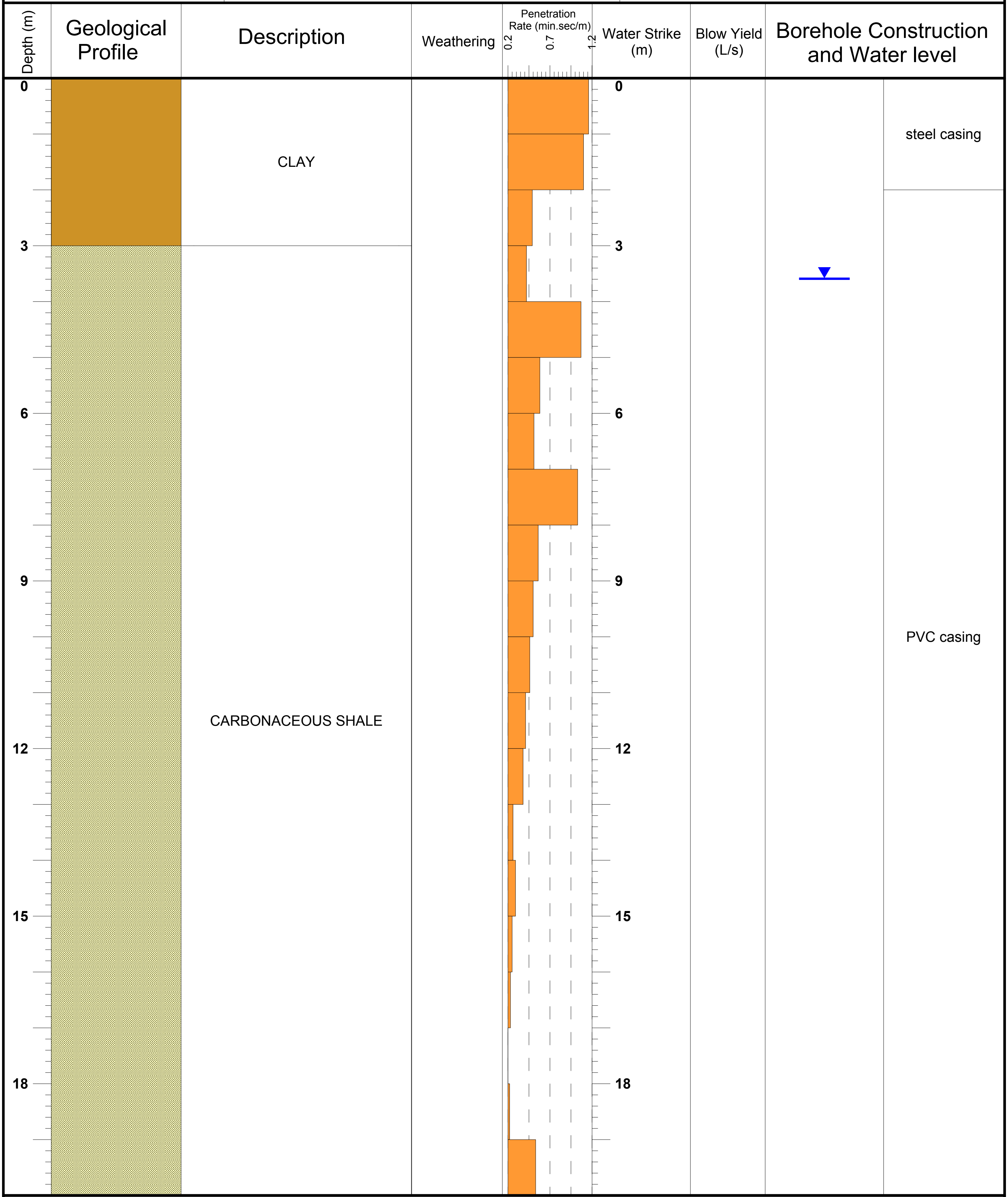
2125, Randburg
Tel: +27(0)11 789 9495

CLIENT:

Project Name:	Sibanye WRTRP EIA
Project Code:	GOL2376
Location:	Cardoville
Drilled By:	JK Drilling (Pty) Ltd
Date Drilled:	10/02/2015
Logged By:	Evidence Simango

BOREHOLE ID: SBNBH7

Coordinate System:	WGS84
X-Coordinate:	62879.93
Y-Coordinate:	-2930765.98
Z-Coordinate:	1528
Final Depth (m):	20
Collar Height (m):	0.27



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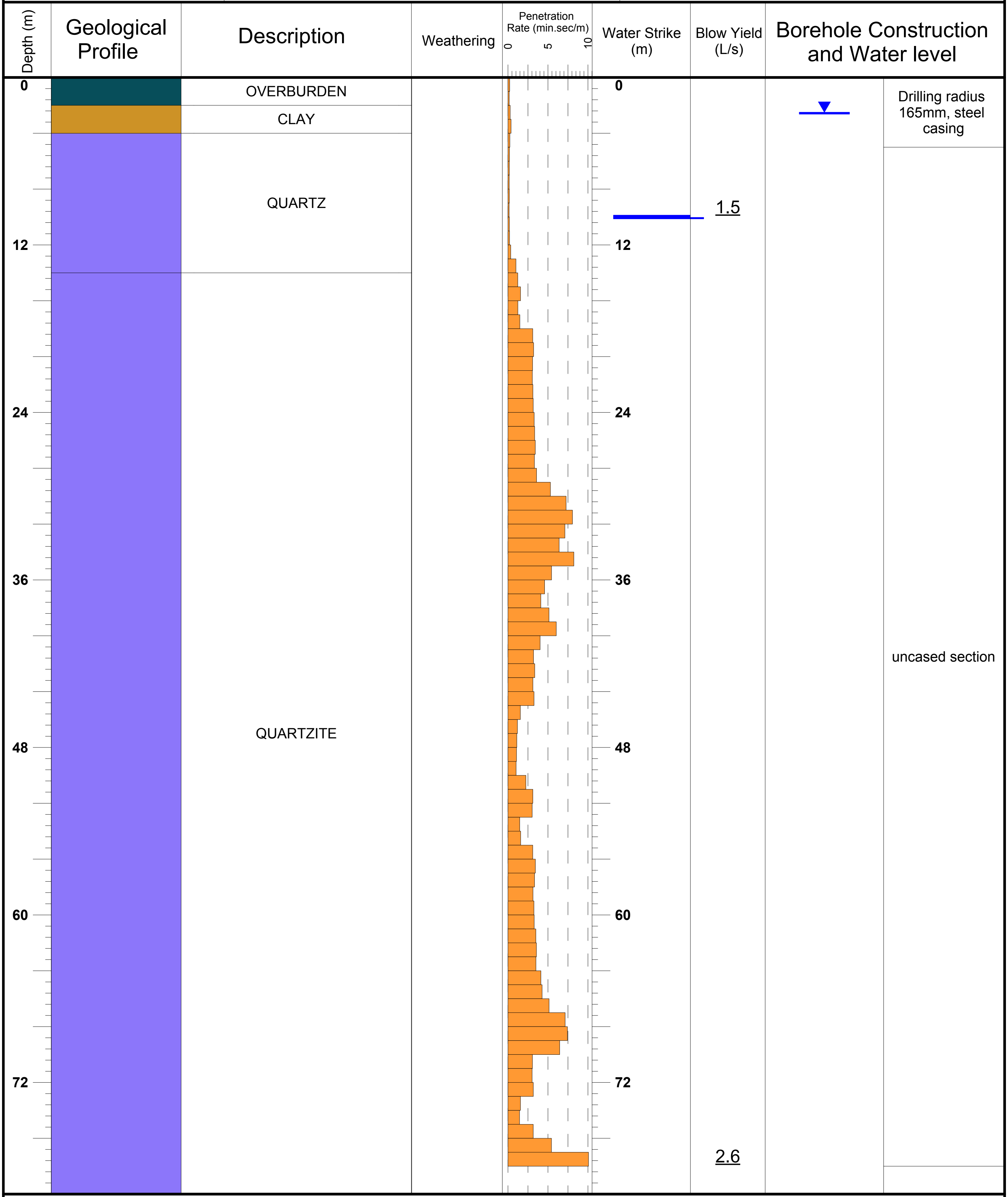
CLIENT:

Project Name:	Sibanye WRTRP EIA
Project Code:	GOL2376
Location:	Cardoville
Drilled By:	JK Drilling (Pty) Ltd
Date Drilled:	23/02/2015
Logged By:	Evidence Simango

BOREHOLE ID: SBNBH8

Coordinate System:	WGS84
X-Coordinate:	64200.98
Y-Coordinate:	-2931440.68
Z-Coordinate:	
Final Depth (m):	80
Collar Height (m):	0.46



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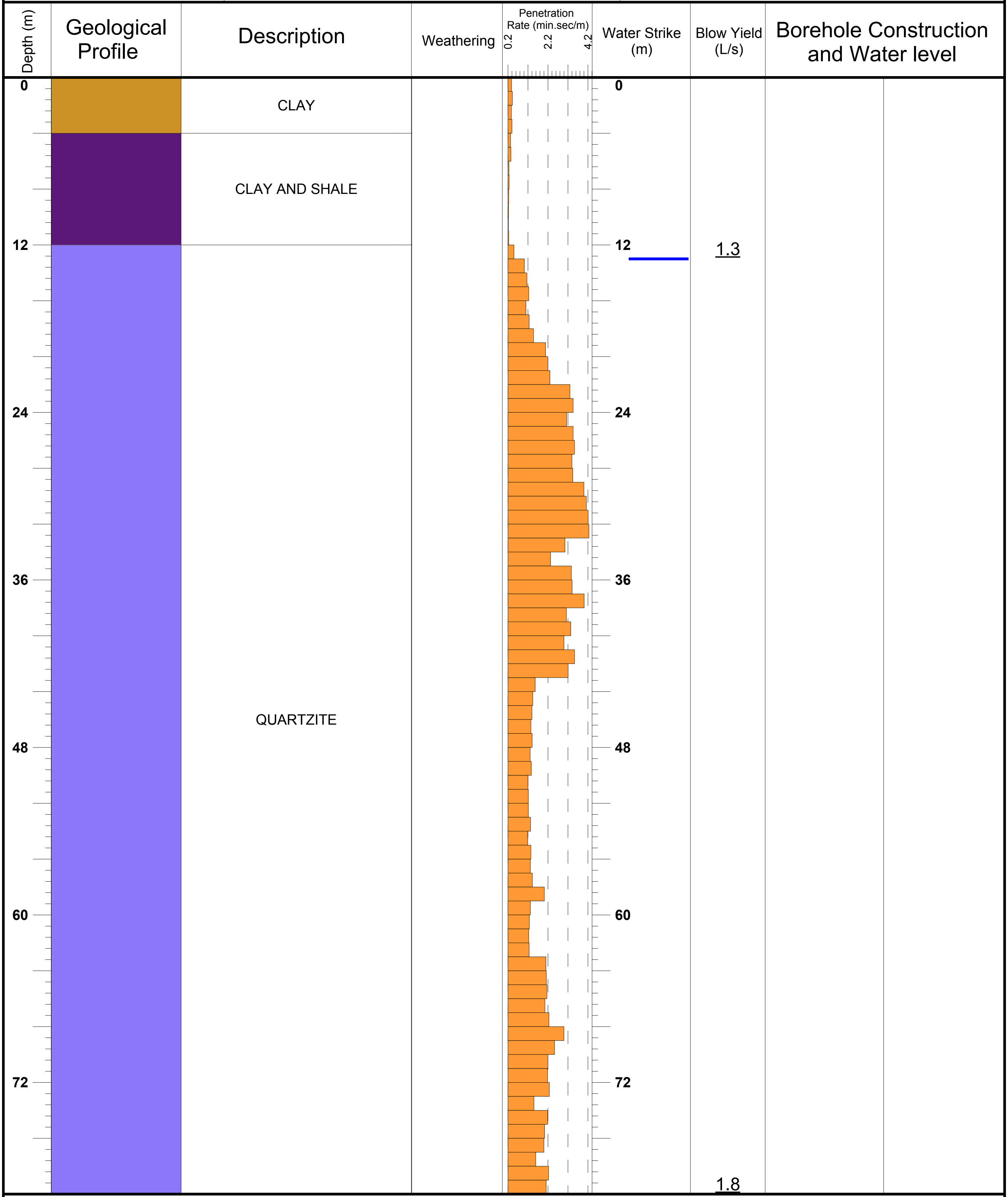
CLIENT:

Project Name:	Sibanye WRTRP EIA
Project Code:	GOL2376
Location:	Cardoville
Drilled By:	JK Drilling (Pty) Ltd
Date Drilled:	07/05/2015
Logged By:	Evidence Simango

BOREHOLE ID: SBNBH8A

Coordinate System:	WGS84
X-Coordinate:	64193
Y-Coordinate:	-2931689
Z-Coordinate:	
Final Depth (m):	80
Collar Height (m):	



Comment:

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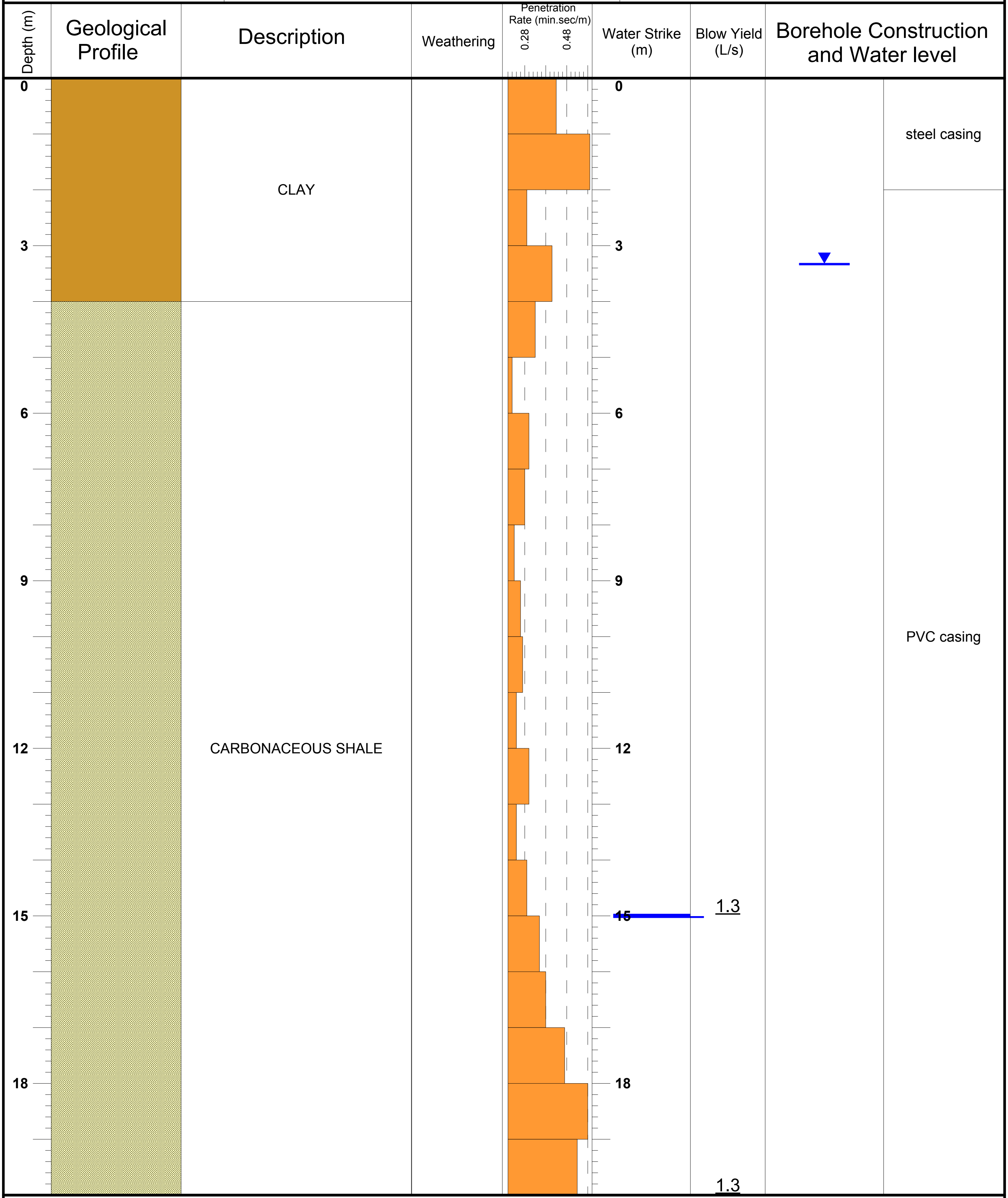
2125, Randburg
Tel: +27(0)11 789 9495

CLIENT:

Project Name:	Sibanye WRTRP EIA
Project Code:	GOL2376
Location:	Cardoville
Drilled By:	JK Drilling (Pty) Ltd
Date Drilled:	24/02/2015
Logged By:	Evidence Simango

BOREHOLE ID: SBNBH9

Coordinate System:	WGS84
X-Coordinate:	64121.63
Y-Coordinate:	-2931590.57
Z-Coordinate:	
Final Depth (m):	20
Collar Height (m):	0.3



Comment:

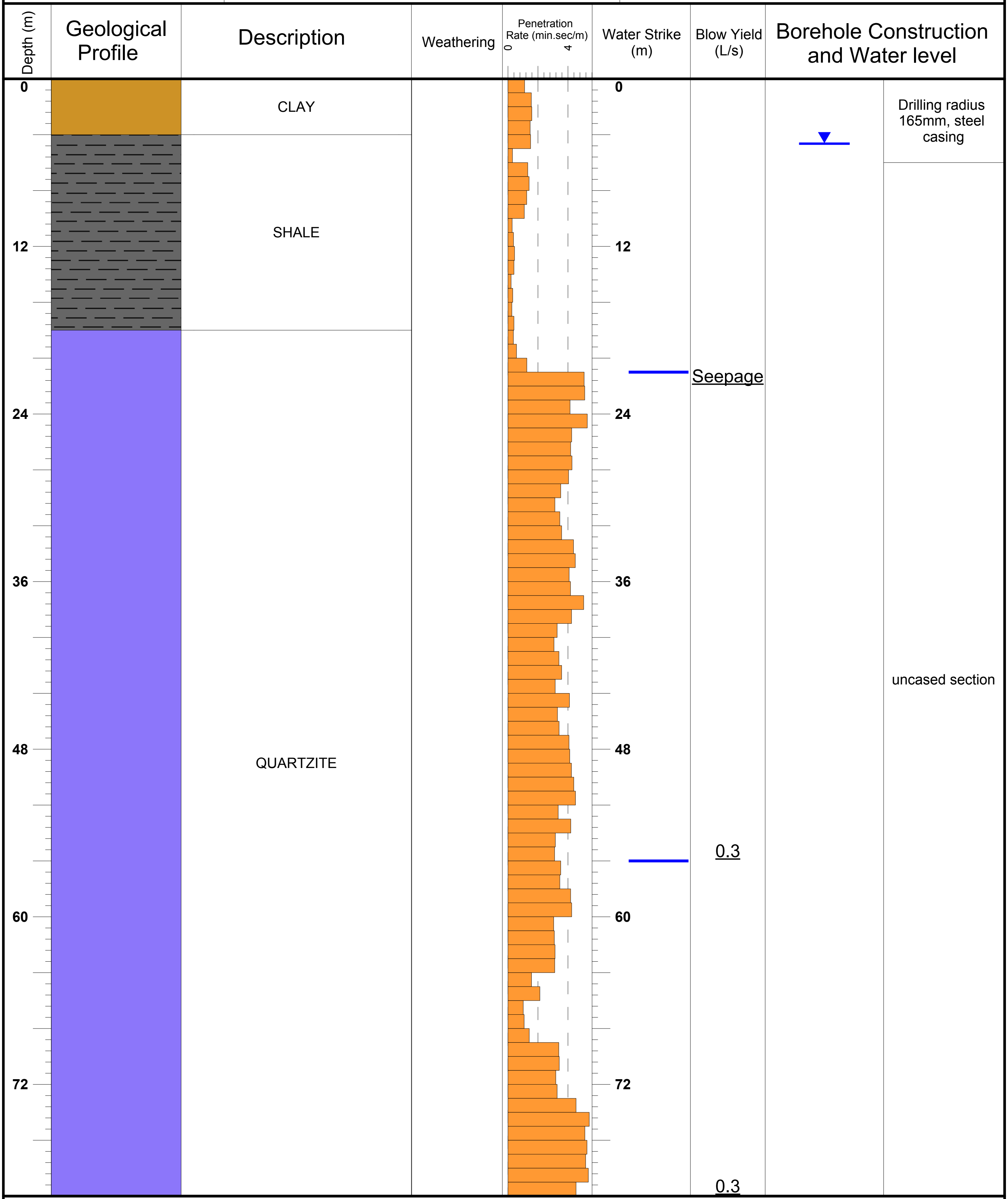
Fern Isle,Section 10
359 Pretoria Avenue
2125, Randburg
Tel: +27(0)11 789 9495

CLIENT:

Project Name:	Sibanye WRTRP EIA
Project Code:	GOL2376
Location:	Cardoville
Drilled By:	JK Drilling (Pty) Ltd
Date Drilled:	24/02/2015
Logged By:	Evidence Simango

BOREHOLE ID: SBNBH10

Coordinate System:	WGS84
X-Coordinate:	64766.79
Y-Coordinate:	-2932819.08
Z-Coordinate:	
Final Depth (m):	80
Collar Height (m):	0.35



Comment:

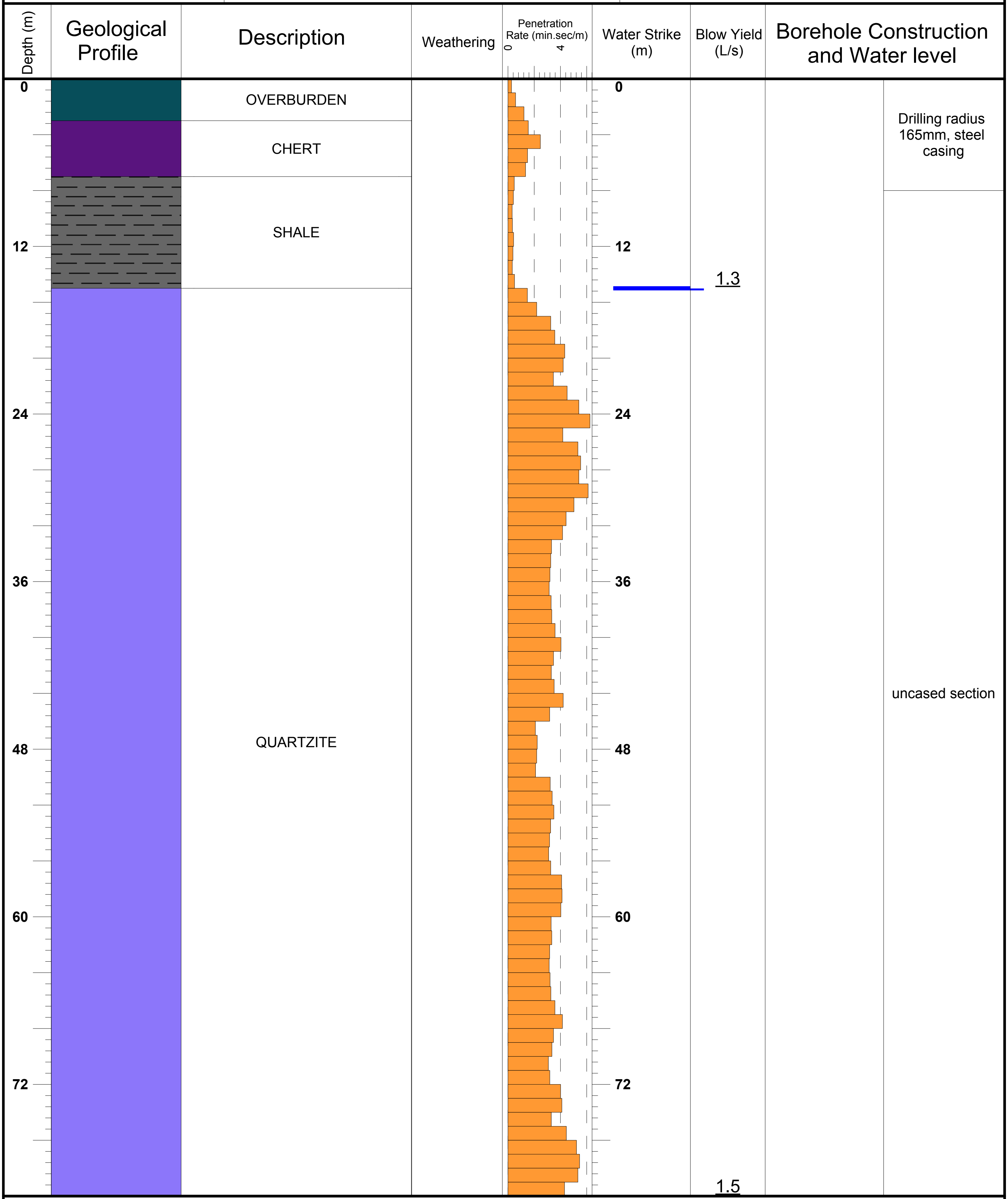
Fern Isle,Section 10
359 Pretoria Avenue
2125, Randburg
Tel: +27(0)11 789 9495

CLIENT:

Project Name: Sibanye WRTRP EIA
Project Code: GOL2376
Location: Cardoville
Drilled By: JK Drilling (Pty) Ltd
Date Drilled: 25/02/2015
Logged By: Evidence Simango

BOREHOLE ID: SBNBH11

Coordinate System: WGS84
X-Coordinate: 65125.19
Y-Coordinate: -2934221.32
Z-Coordinate: 1497
Final Depth (m): 80
Collar Height (m): 0.4



Comment:

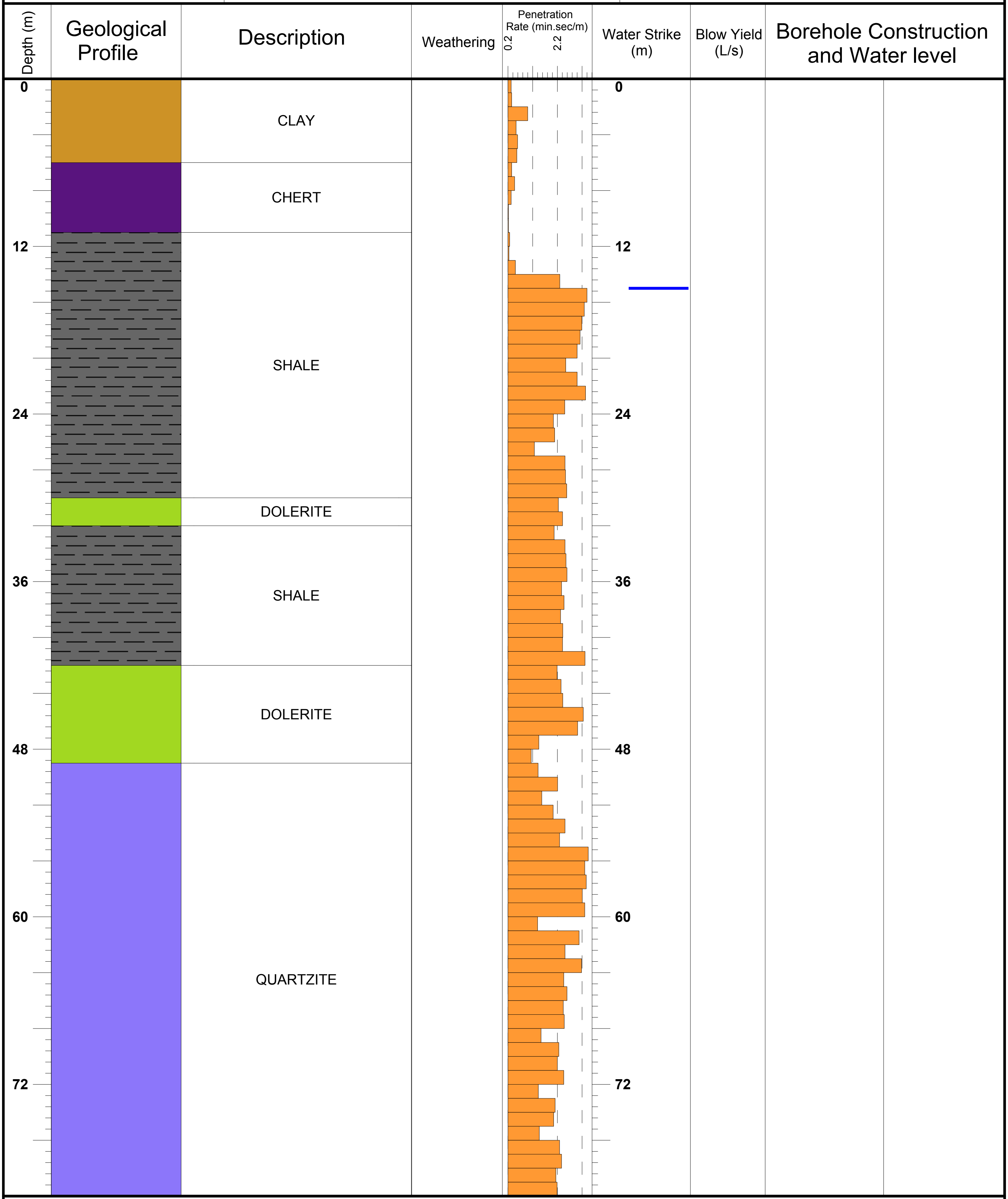
Fern Isle,Section 10
359 Pretoria Avenue
2125, Randburg
Tel: +27(0)11 789 9495

CLIENT:

Project Name: Sibanye WRTRP EIA
Project Code: GOL2376
Location: Cardoville
Drilled By: JK Drilling (Pty) Ltd
Date Drilled: 12/05/2015 12:00 AM
Logged By: Evidence Simango

BOREHOLE ID: SBNBH11A

Coordinate System: WGS84
X-Coordinate: 65126
Y-Coordinate: -2934207
Z-Coordinate:
Final Depth (m): 80
Collar Height (m):



Comment:

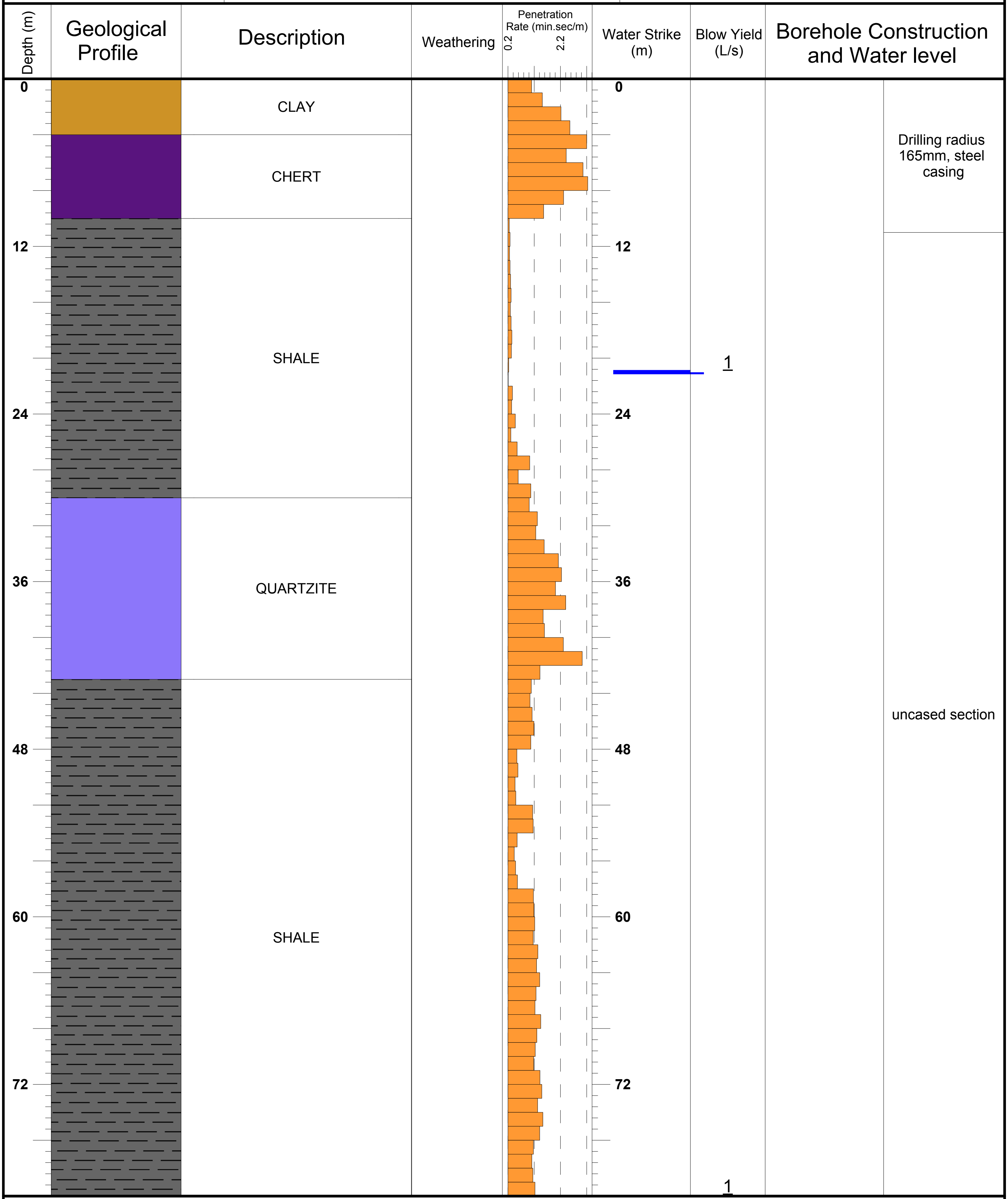
Fern Isle,Section 10
359 Pretoria Avenue
2125, Randburg
Tel: +27(0)11 789 9495

CLIENT:

Project Name:	Sibanye WRTRP EIA
Project Code:	GOL2376
Location:	Cardoville
Drilled By:	JK Drilling (Pty) Ltd
Date Drilled:	26/02/2015
Logged By:	Evidence Simango

BOREHOLE ID: SBNBH12

Coordinate System:	WGS84
X-Coordinate:	64602.22
Y-Coordinate:	-2935246.68
Z-Coordinate:	1500
Final Depth (m):	80
Collar Height (m):	0.39



Comment:

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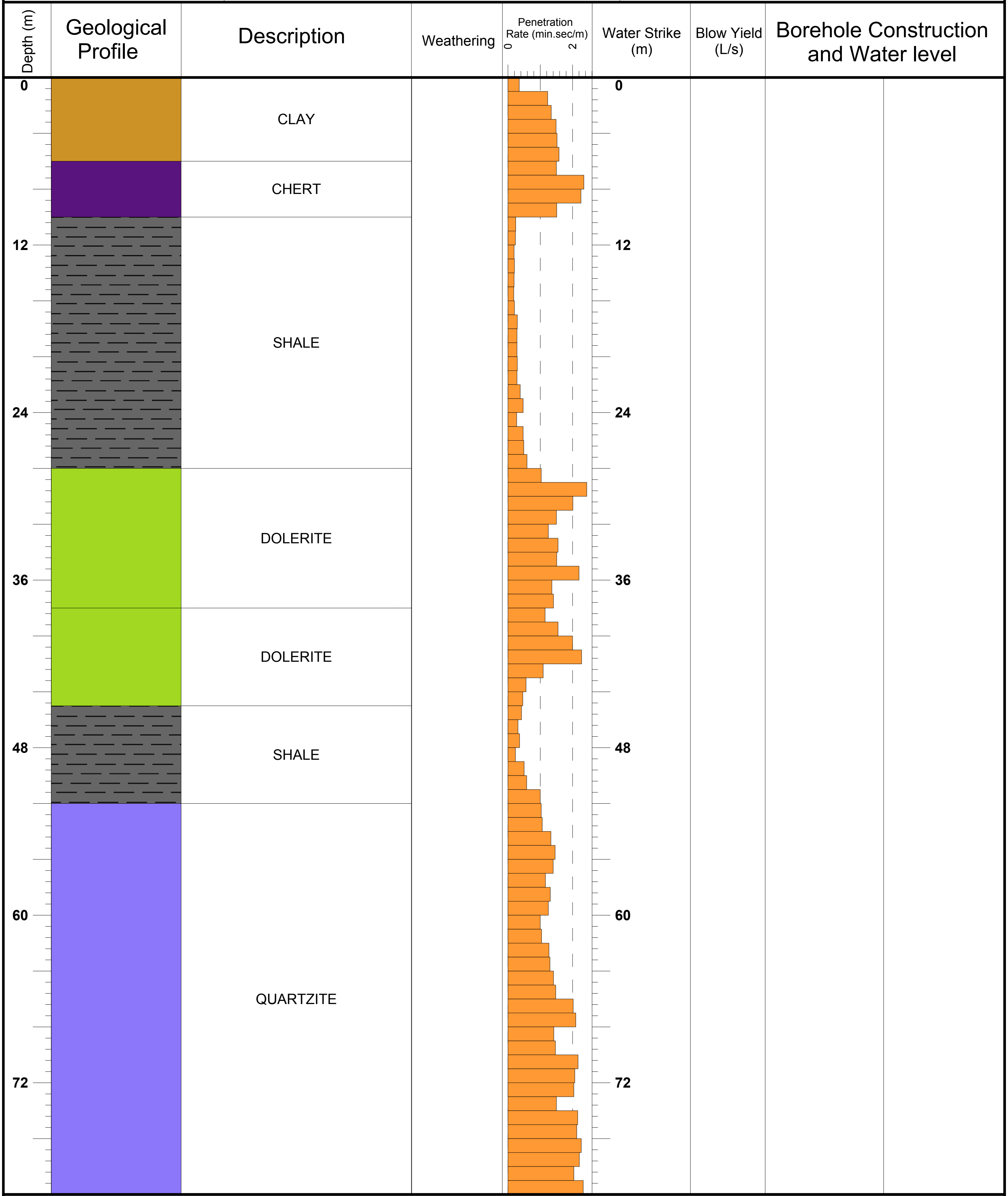
Fern Isle,Section 10
359 Pretoria Avenue
2125, Randburg
Tel: +27(0)11 789 9495

CLIENT:

Project Name: Sibanye WRTRP EIA
Project Code: GOL2376
Location: Cardoville
Drilled By: JK Drilling (Pty) Ltd
Date Drilled: 11/05/2015 12:00 AM
Logged By: Evidence Simango

BOREHOLE ID: SBNBH12A

Coordinate System: WGS84
X-Coordinate: 64612
Y-Coordinate: -2935237
Z-Coordinate:
Final Depth (m): 80
Collar Height (m):



Comment:

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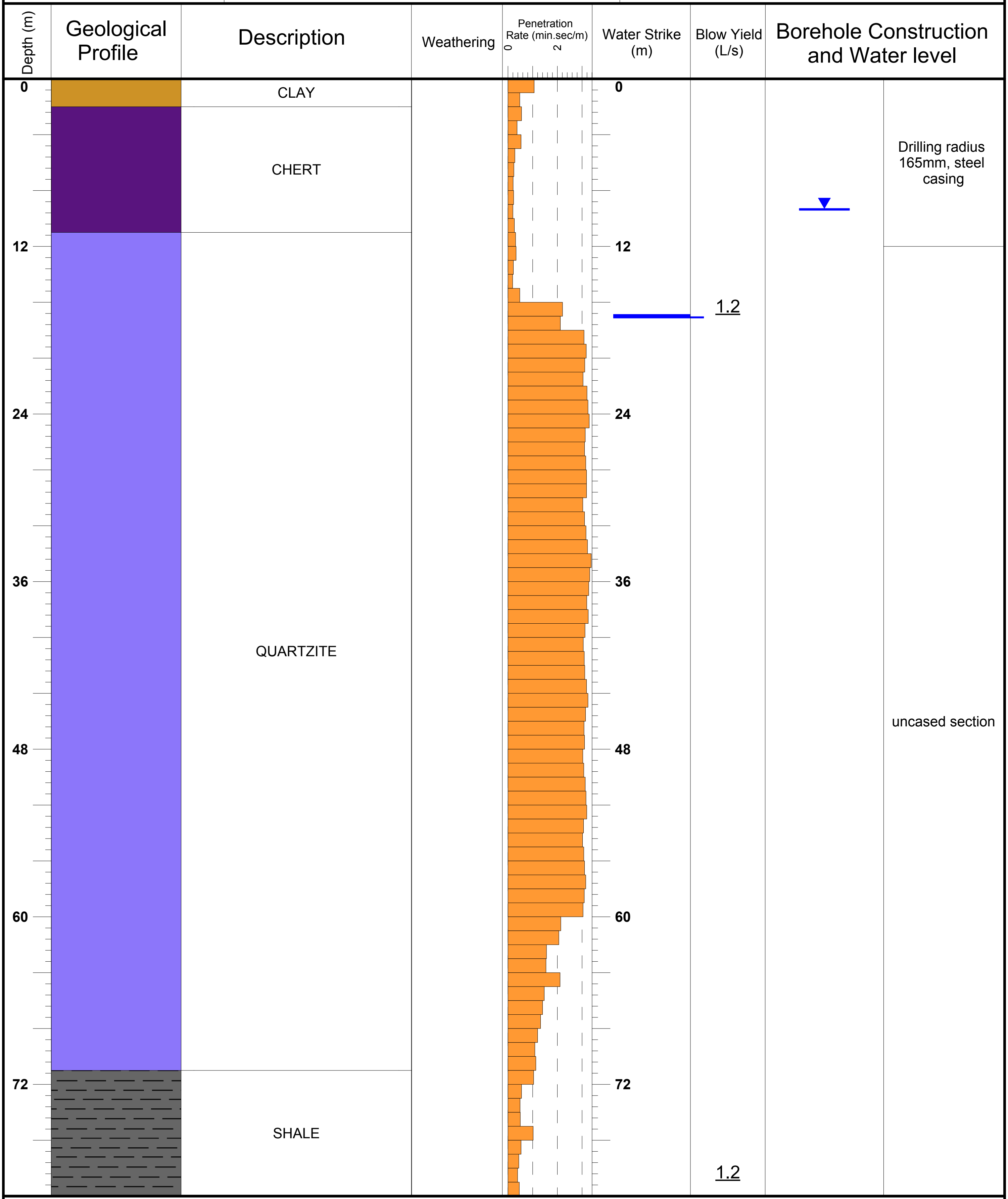
Fern Isle,Section 10
359 Pretoria Avenue
2125, Randburg
Tel: +27(0)11 789 9495

CLIENT:

Project Name:	Sibanye WRTRP EIA
Project Code:	GOL2376
Location:	Cardoville
Drilled By:	JK Drilling (Pty) Ltd
Date Drilled:	19/02/2015
Logged By:	Evidence Simango

BOREHOLE ID: SBNBH13

Coordinate System:	WGS84
X-Coordinate:	59142.81
Y-Coordinate:	-2932459.94
Z-Coordinate:	
Final Depth (m):	80
Collar Height (m):	0.61



Comment:

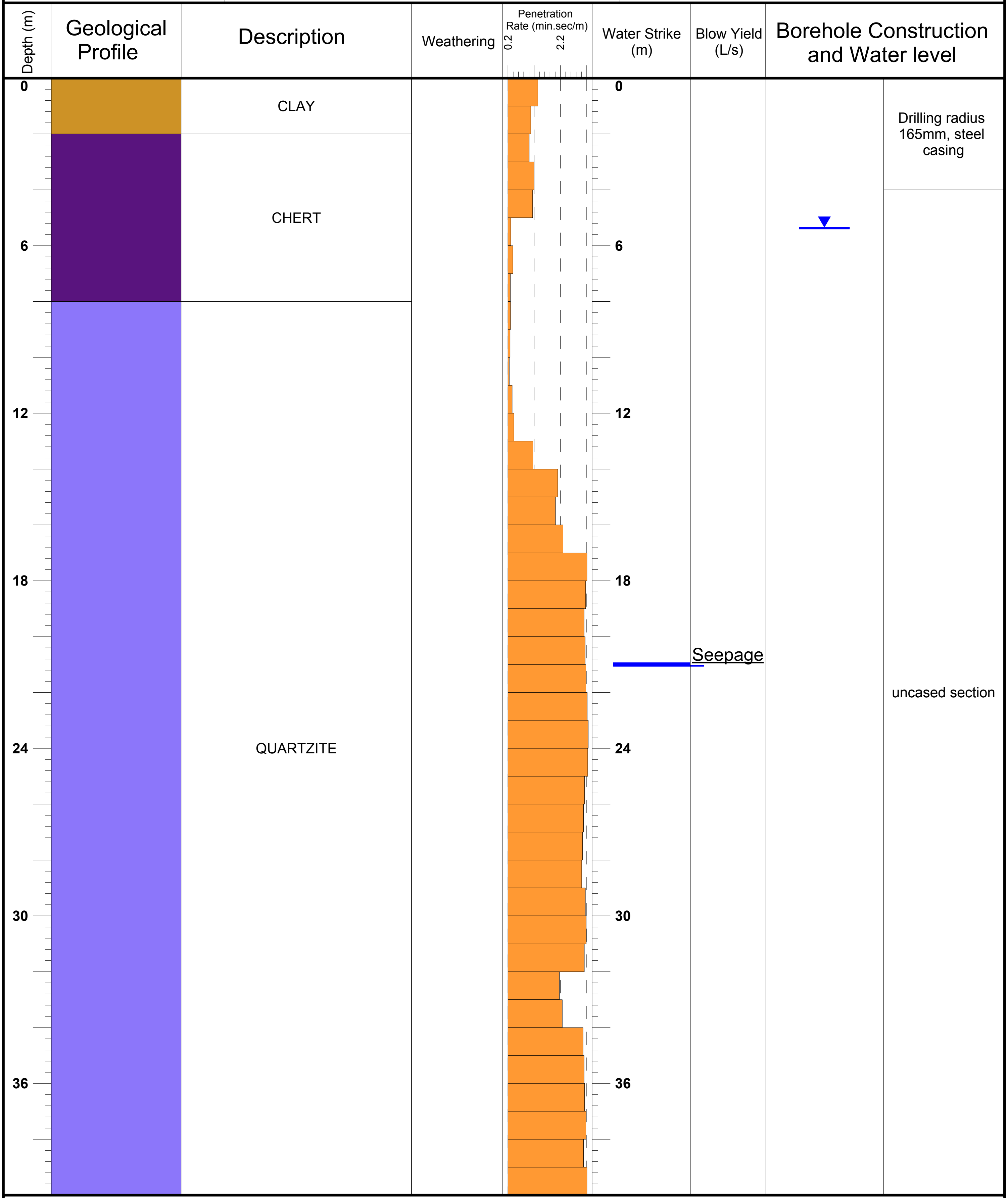
Fern Isle,Section 10
359 Pretoria Avenue
2125, Randburg
Tel: +27(0)11 789 9495

CLIENT:

Project Name:	Sibanye WRTRP EIA
Project Code:	GOL2376
Location:	Cardoville
Drilled By:	JK Drilling (Pty) Ltd
Date Drilled:	18/02/2015
Logged By:	Evidence Simango

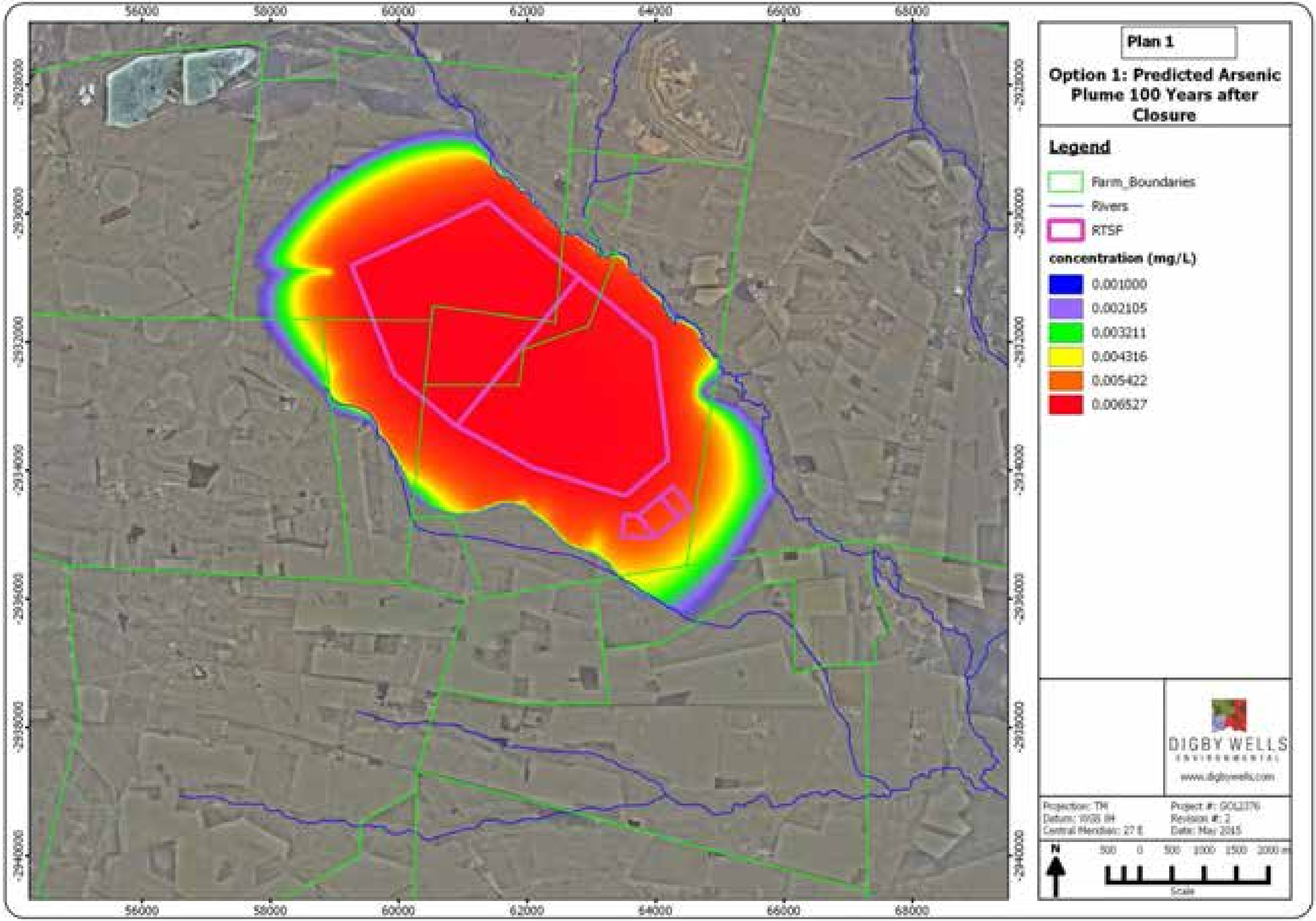
BOREHOLE ID: SBNBH14

Coordinate System:	WGS84
X-Coordinate:	59094.47
Y-Coordinate:	-2932401.94
Z-Coordinate:	
Final Depth (m):	40
Collar Height (m):	0.49



Comment:

Appendix E: Simulated Pollution Plumes

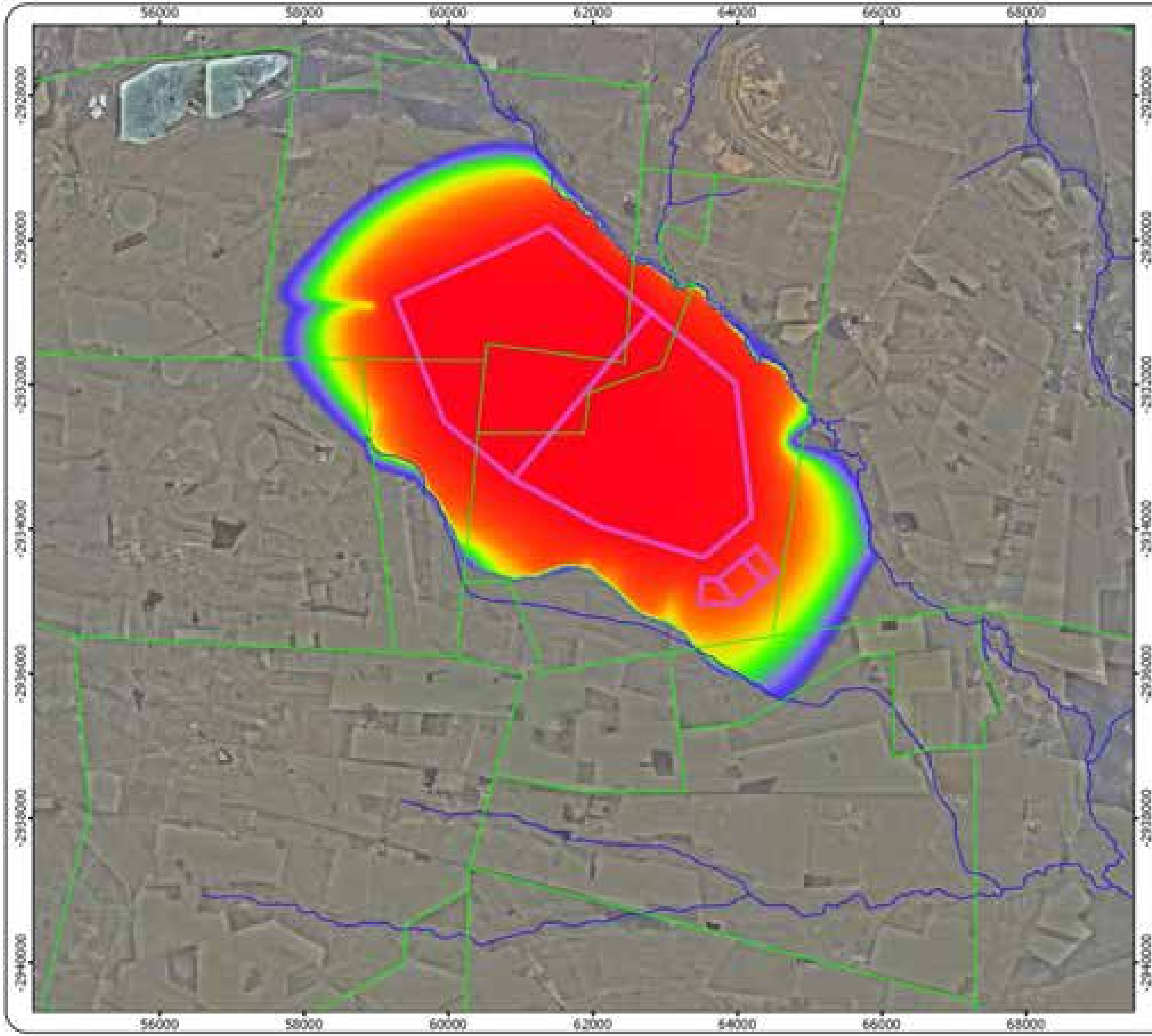


Plan 1

Option 1: Predicted Arsenic Plume 100 Years after Closure

Projection: TM
Datum: WGS 84
Central Meridian: 27 E

Project #: GOL2376
Revision #: 2
Date: May 2015



Plan 2

Option 1: Predicted Mn Plume 100 Years after Closure

Legend

- 🟩 Farm_Boundaries
- — Rivers
- ▭ RTSF

concentration (mg/L)

■	0.100000
■	0.182743
■	0.265486
■	0.348229
■	0.430972
■	0.513716
■	0.596459
■	0.679202
■	0.761945
■	0.844688

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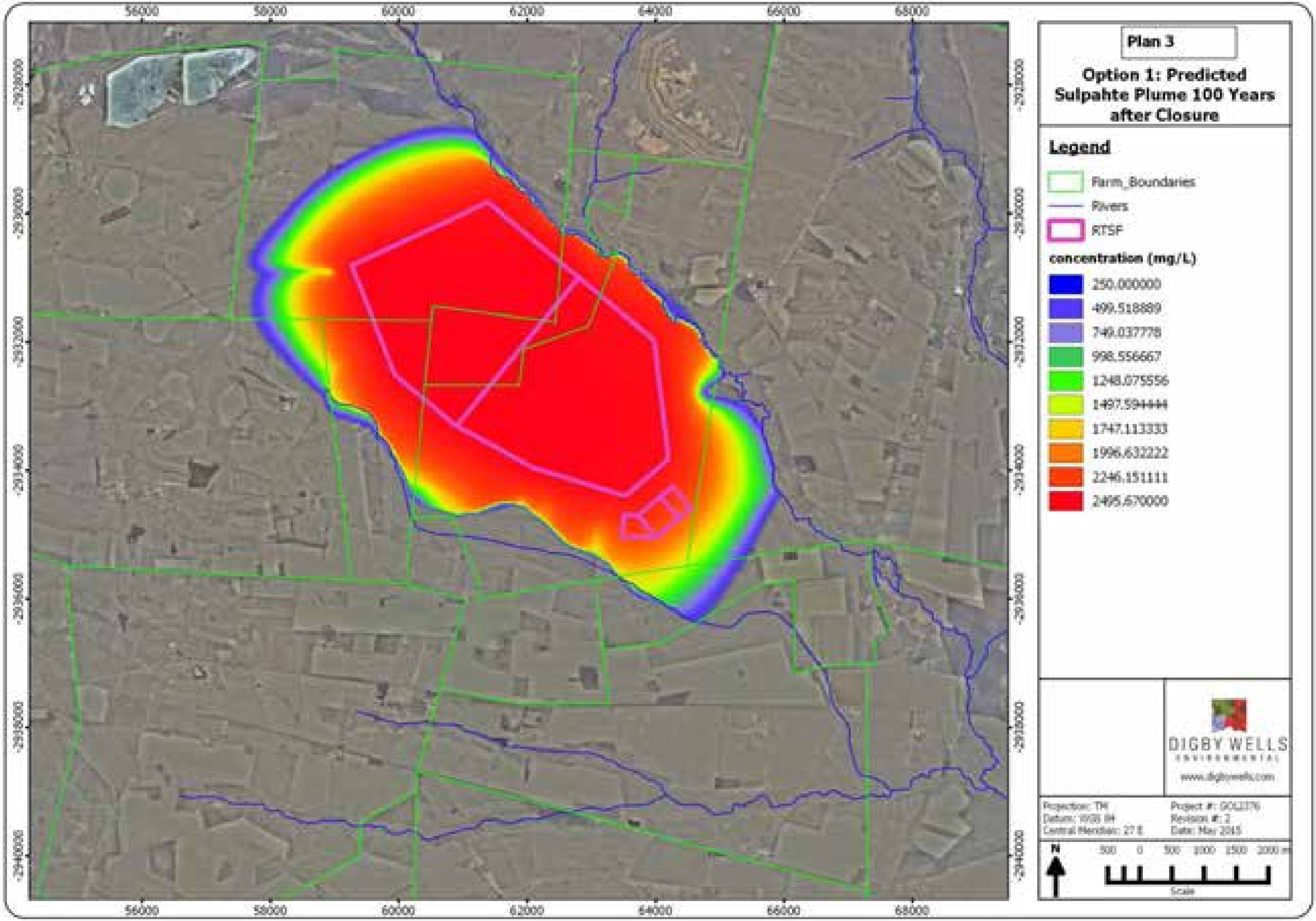
Projection: TM
Datum: WGS 84
Central Meridian: 27 E

Project #: GOL2376
Revision #: 2
Date: May 2015

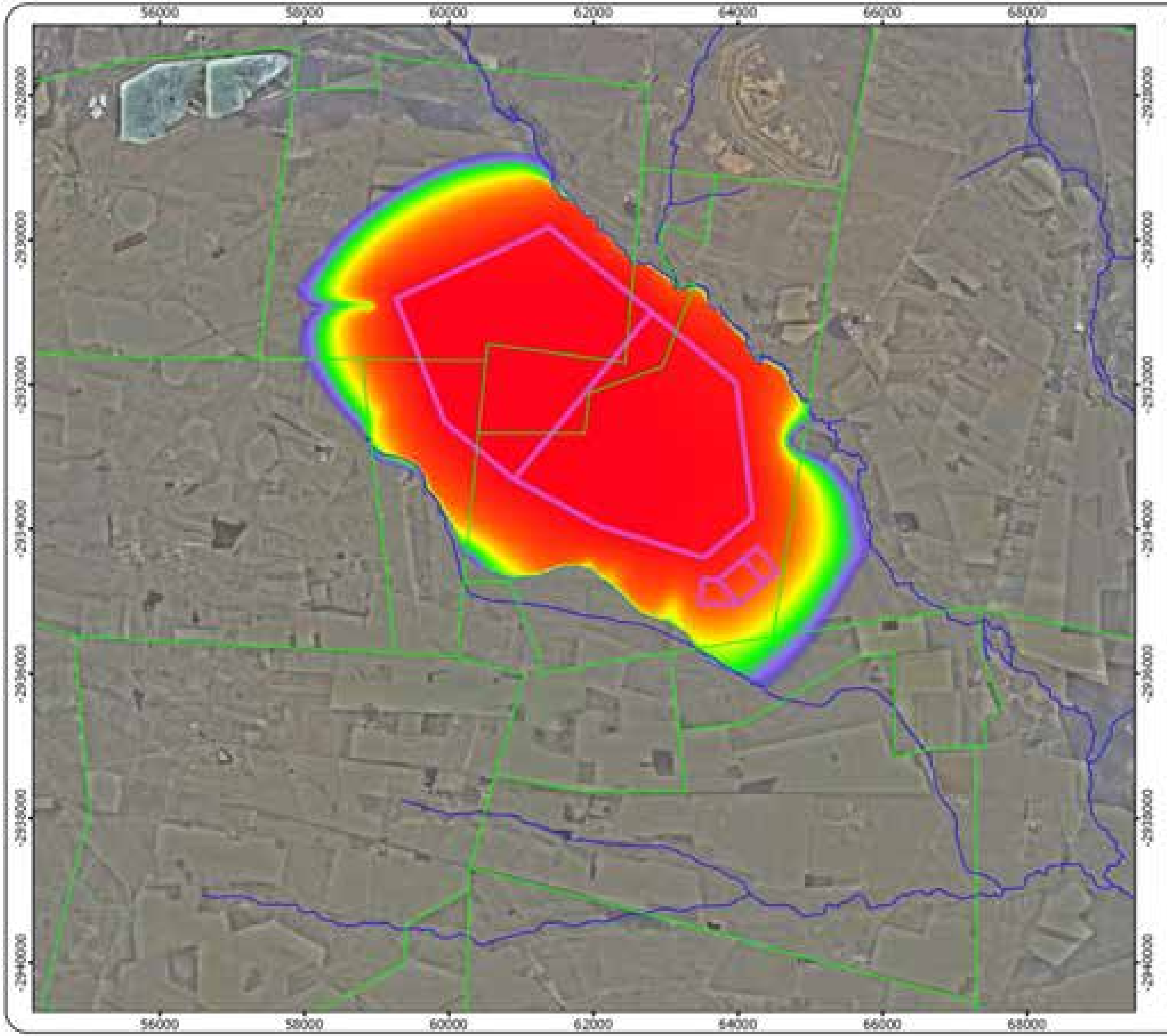
N

500 0 500 1000 1500 2000 m
Scale



Plan 3

Option 1: Predicted Sulpahte Plume 100 Years after Closure



Plan 4

Option 1: Predicted Uranium Plume 100 Years after Closure

Legend

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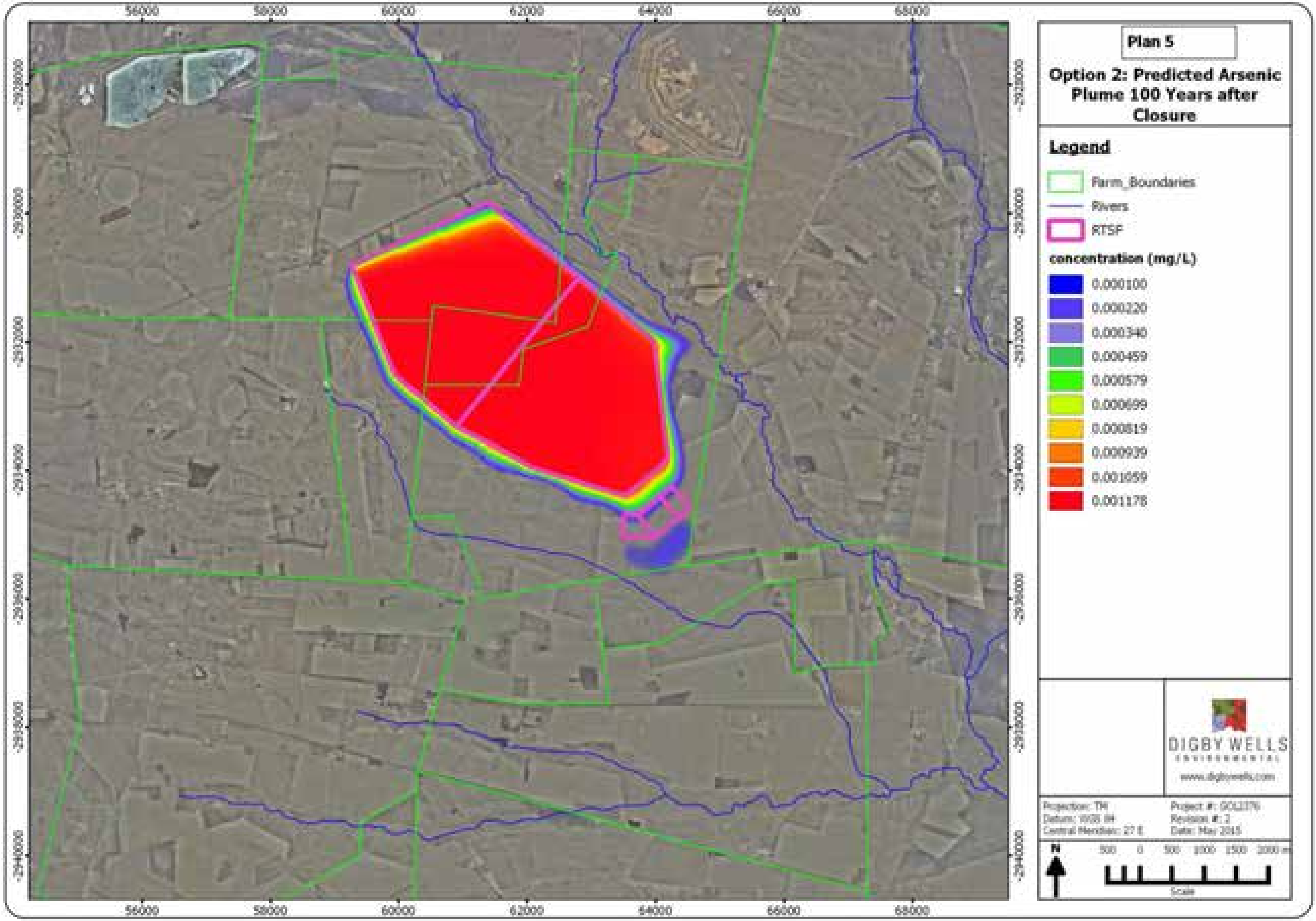
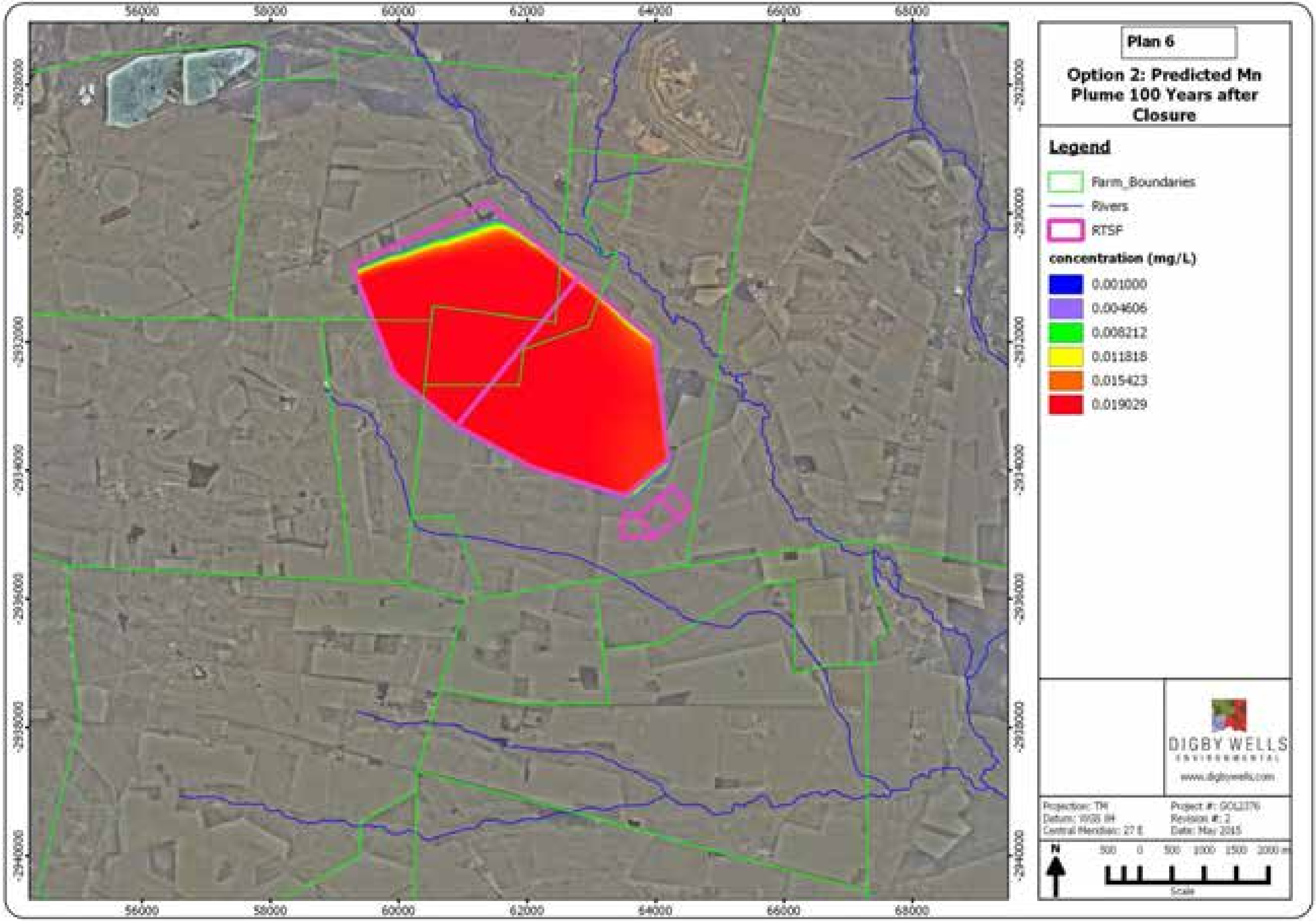
Projection: TM
Datum: WGS 84
Central Meridian: 27 E

Project #: GOL2376
Revision #: 2
Date: May 2015



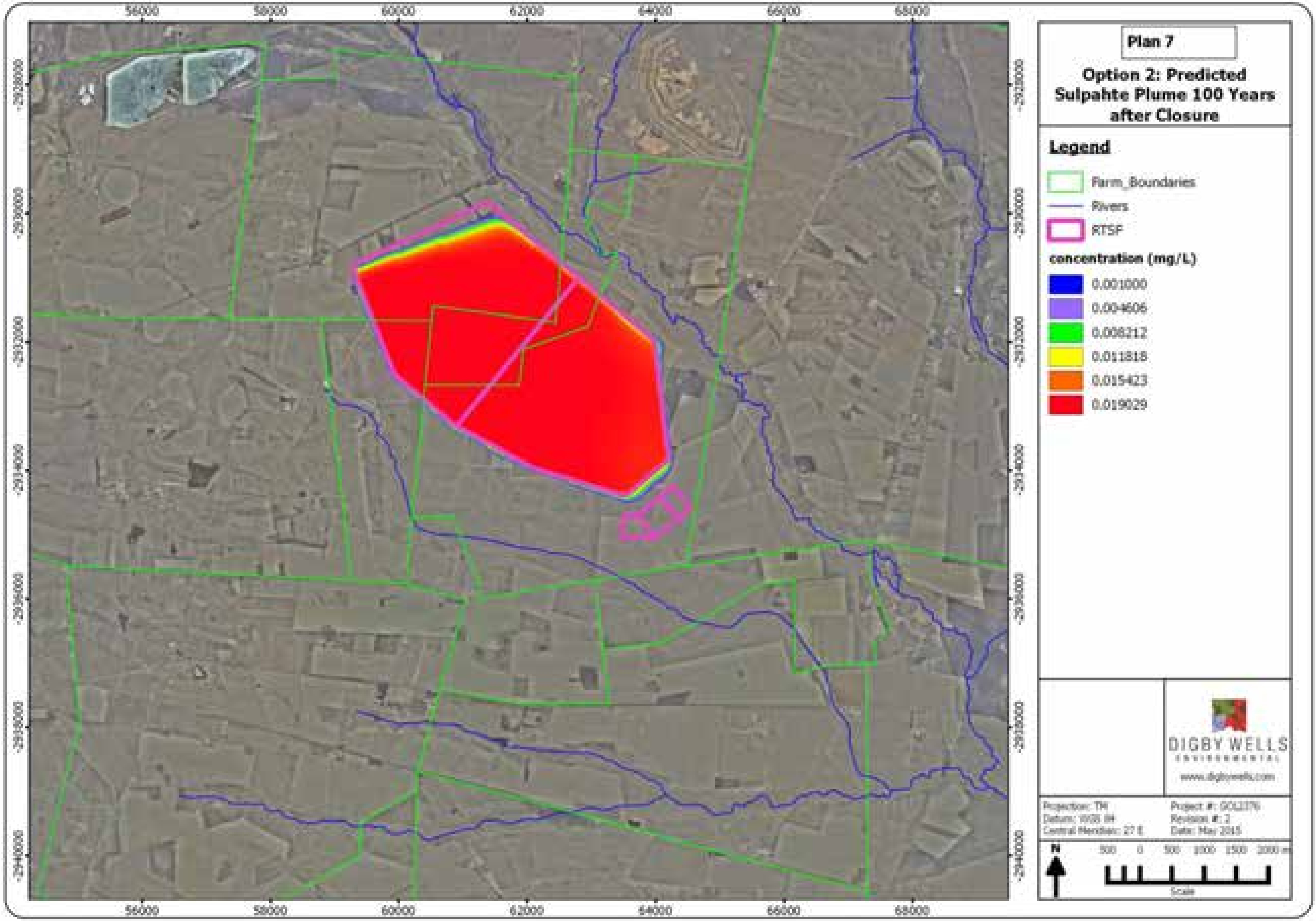
Plan 5

Option 2: Predicted Arsenic Plume 100 Years after Closure



Plan 6

Option 2: Predicted Mn Plume 100 Years after Closure



Plan 7

Option 2: Predicted Sulpahte Plume 100 Years after Closure

Plan 8

Option 2: Predicted Uranium Plume 100 Years after Closure

Legend

🟩	Farm_Boundaries
—	Rivers
🟪	RTSF

concentration (mg/L)

🟦	0.001000
🟪	0.004606
🟩	0.008212
🟨	0.011818
🟧	0.015423
🟥	0.019029

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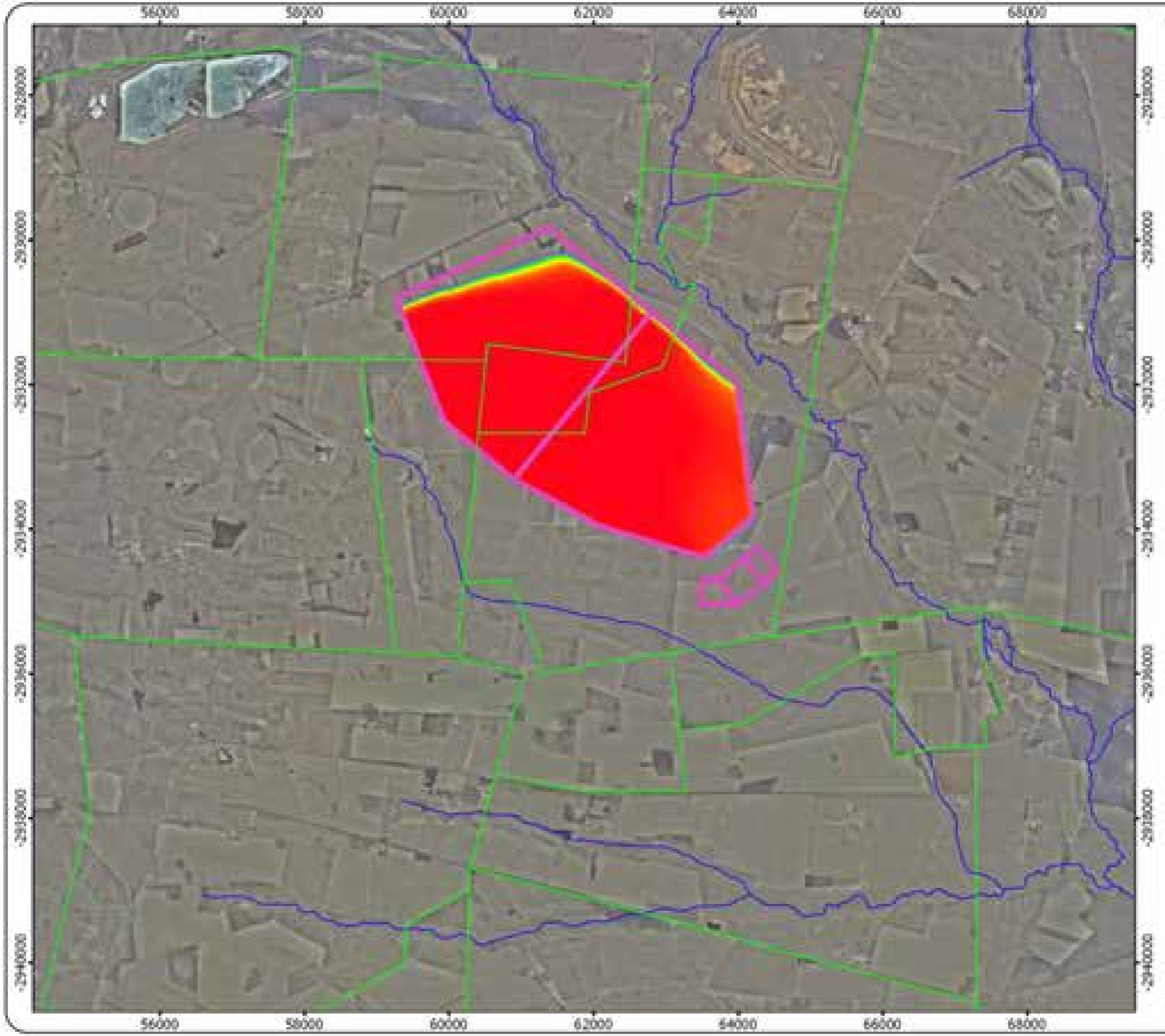
Projection: TM
Datum: WGS 84
Central Meridian: 27 E

Project #: GOL2376
Revision #: 2
Date: May 2015

N

500 0 500 1000 1500 2000 m
Scale



Plan 9

Option 3: Predicted Mn Plume 100 Years after Closure

Legend

🟩 Farm_Boundaries

— Rivers

▭ RTSF

concentration (mg/L)

🟦	0.100000
🟪	0.106456
🟩	0.112912
🟨	0.119368
🟧	0.125824
🟥	0.132280

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Projection: TM
Datum: WGS 84
Central Meridian: 27 E

Project #: GOL2376
Revision #: 2
Date: May 2015

N

500 0 500 1000 1500 2000 m

Scale

Plan 10

Option 3: Predicted Sulpahte Plume 100 Years after Closure

Legend

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Projection: TM
Datum: WGS 84
Central Meridian: 27 E

Project #: GOL2376
Revision #: 2
Date: May 2015

Plan 11

Option 3: Predicted Uranium Plume 100 Years after Closure

Legend

🟩 Farm_Boundaries

— Rivers

🟪 RTSF

concentration (mg/L)

🟦 0.000010

🟪 0.000128

🟩 0.000247

🟨 0.000365

🟧 0.000483

🟥 0.000601

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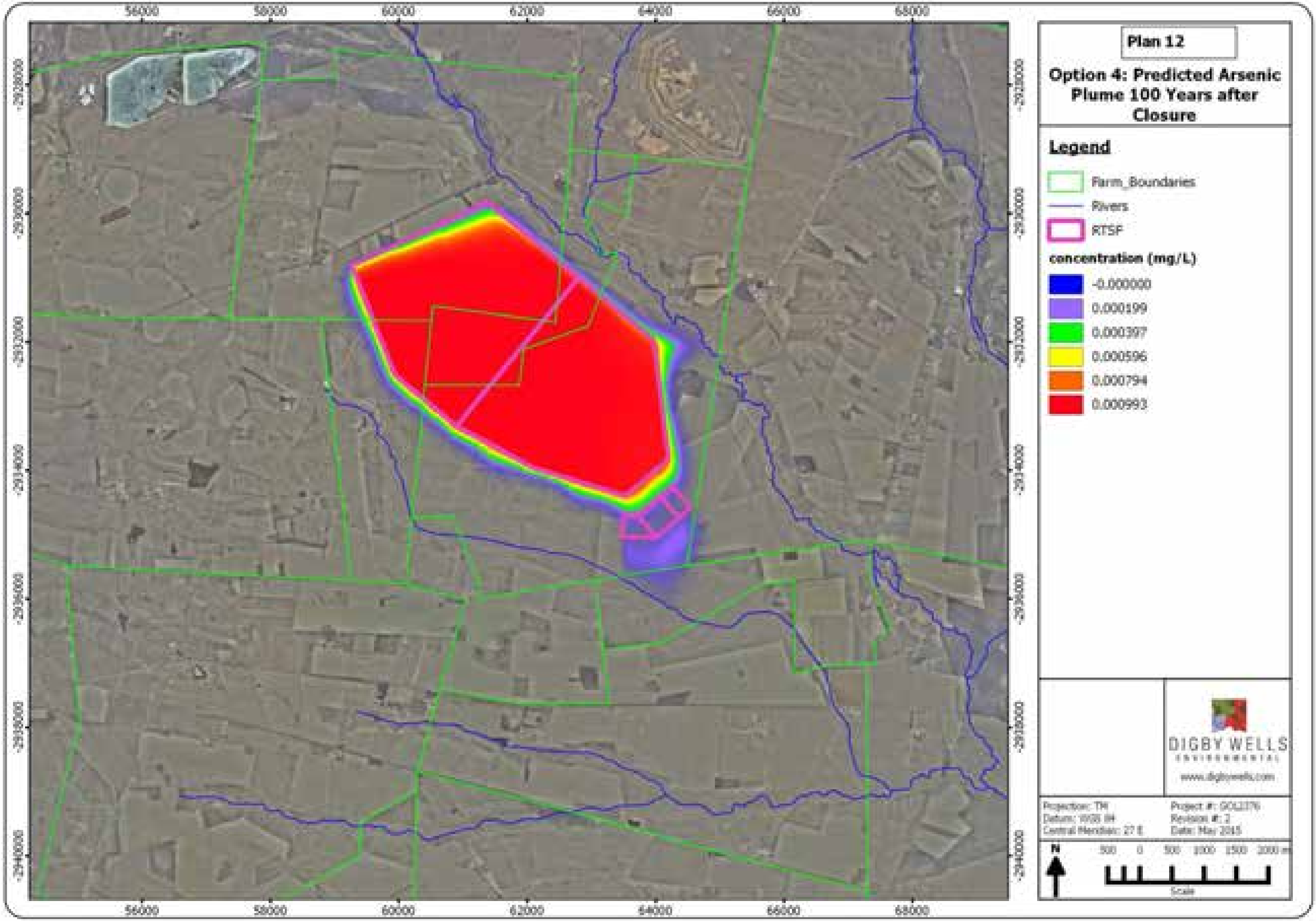
Projection: TM
Datum: WGS 84
Central Meridian: 27 E

Project #: GOL2376
Revision #: 2
Date: May 2015

N

500 0 500 1000 1500 2000 m
Scale

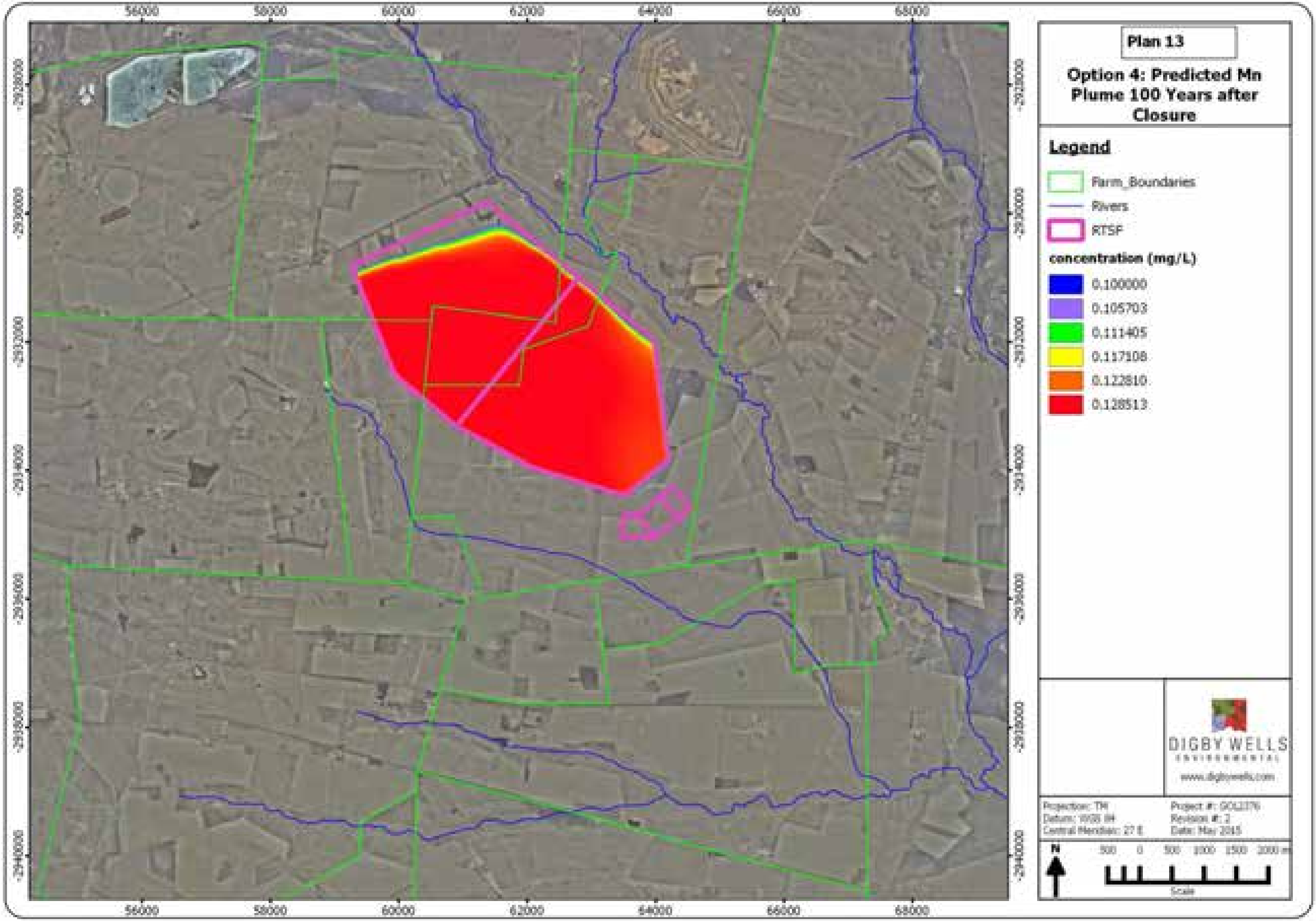


Plan 12

Option 4: Predicted Arsenic Plume 100 Years after Closure

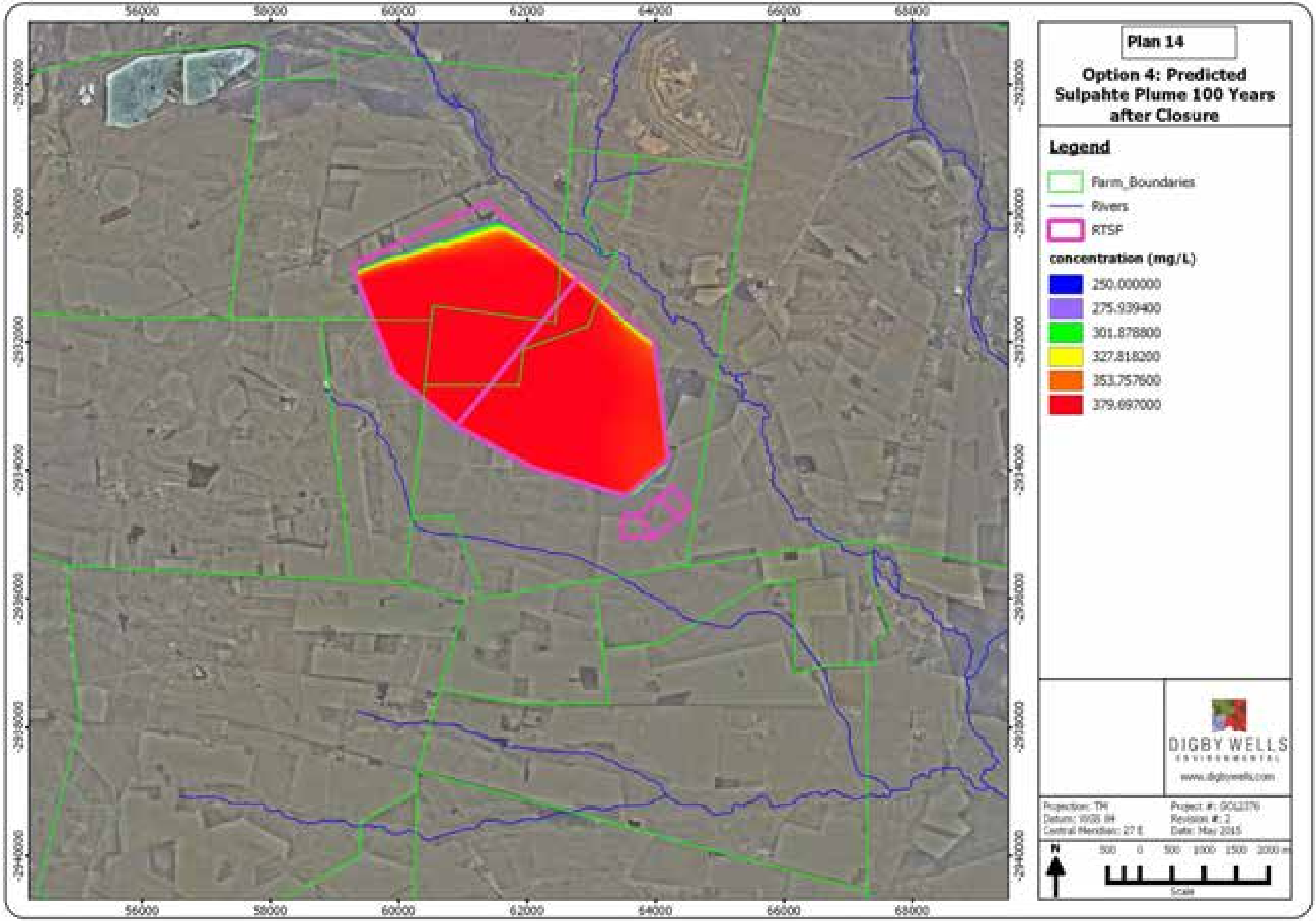
Plan 13

Option 4: Predicted Mn Plume 100 Years after Closure



Projection: TM
Datum: WGS 84
Central Meridian: 27 E

Project #: GOL2376
Revision #: 2
Date: May 2015



Plan 14

Option 4: Predicted Sulpahte Plume 100 Years after Closure

Plan 15

Option 4: Predicted Uranium Plume 100 Years after Closure

Legend

🟩 Farm_Boundaries

— Rivers

▭ RTSF

concentration (mg/L)

🟦	-0.000000
🟪	0.000117
🟩	0.000234
🟨	0.000350
🟧	0.000467
🟥	0.000584

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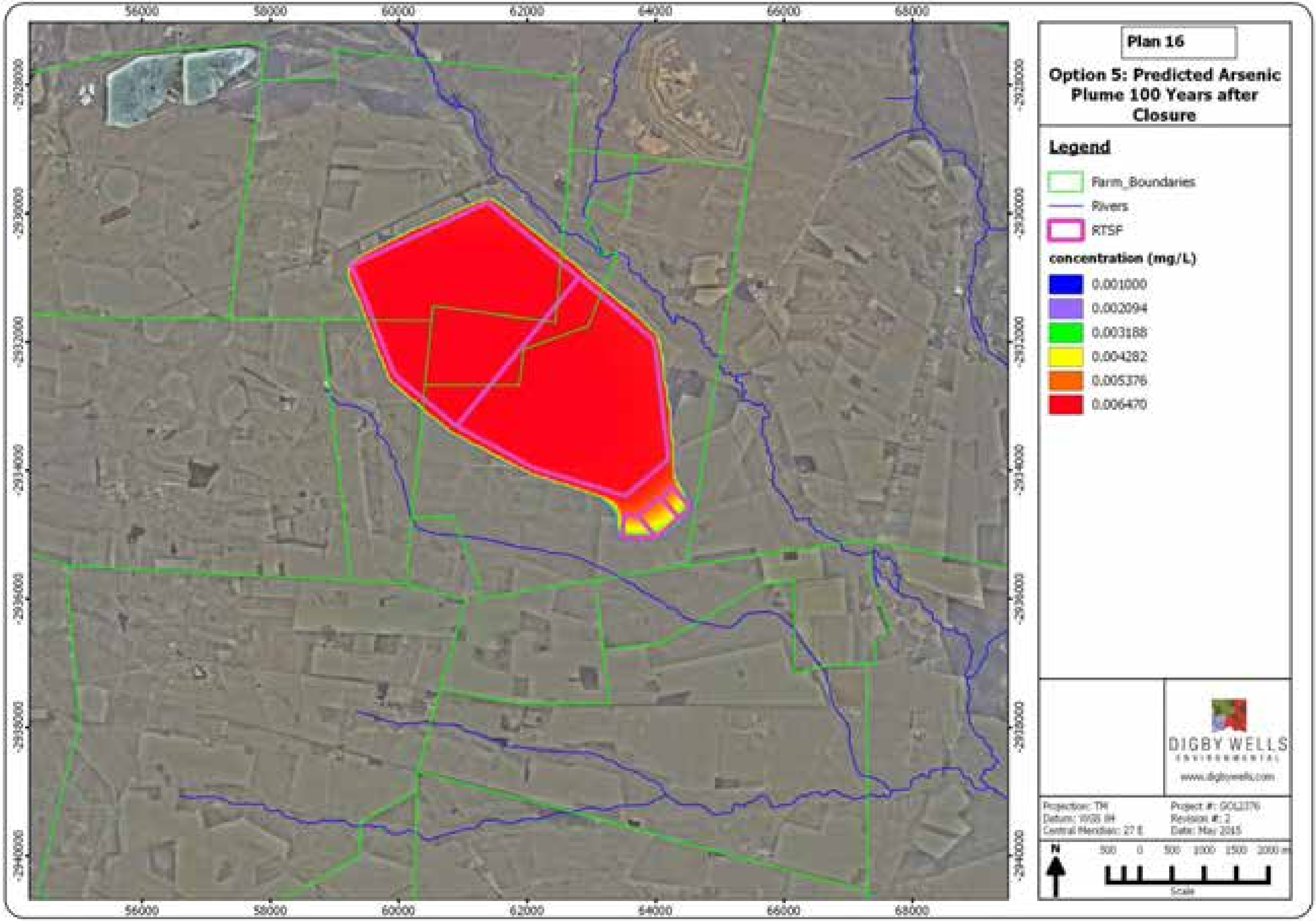
Projection: TM
Datum: WGS 84
Central Meridian: 27 E

Project #: GOL2376
Revision #: 2
Date: May 2015

N

500 0 500 1000 1500 2000 m
Scale



Plan 16

Option 5: Predicted Arsenic Plume 100 Years after Closure

Plan 17

Option 5: Predicted Mn Plume 100 Years after Closure

Legend

- 🟩 Farm_Boundaries
- — Rivers
- 🟪 RTSF

concentration (mg/L)

- 🟦 0.100000
- 🟪 0.247457
- 🟩 0.394914
- 🟨 0.542372
- 🟧 0.689829
- 🟥 0.837286

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Projection: TM
Datum: WGS 84
Central Meridian: 27 E

Project #: GOL2376
Revision #: 2
Date: May 2015

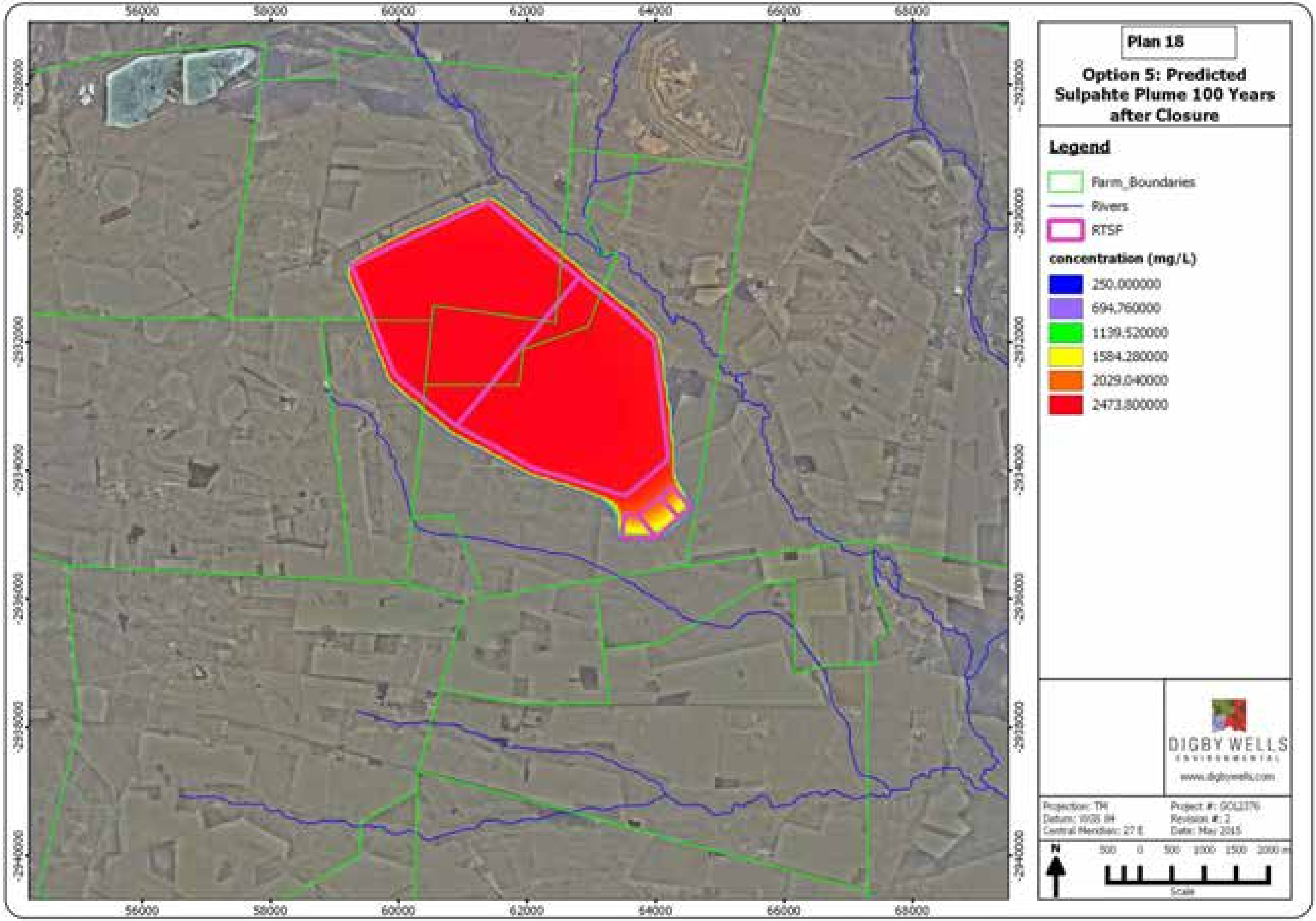
N

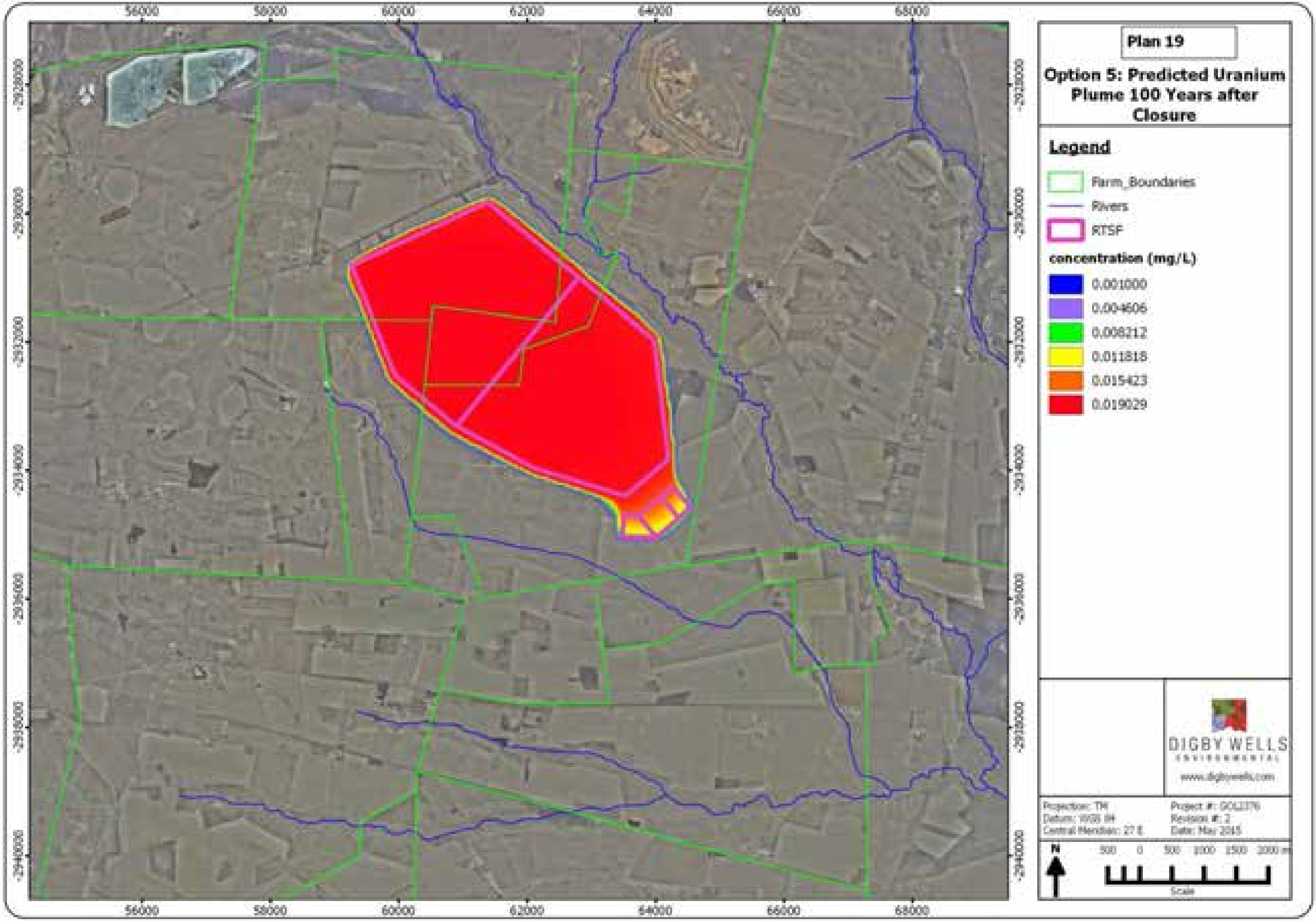
500 0 500 1000 1500 2000 m

Scale

Plan 18

Option 5: Predicted Sulpahte Plume 100 Years after Closure





Plan 19

Option 5: Predicted Uranium Plume 100 Years after Closure