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Groundwater Assessment for the Kalabasfontein Project and Routine Numerical Groundwater Model Calibration for the Forzando Coal Mines

Report

14 November 2018

GCS Project Number: 18-0809

Client Reference: POHFZOS180901526

Report

14 November 2018

18-0809

DOCUMENT ISSUE STATUS

Report Issue	1st DRAFT for Review - 1 November 2018 2nd Submission – Final 26 November 2018		
GCS Reference Number	GCS Ref - 18-0809		
Client Reference	Kalabasfontein and Groundwater Model Calibration		
Title	Groundwater Assessment for the Kalabasfonetin Project and Routine Numerical Groundwater Model Calibration for the Forzando Coal Mines		
	Name	**Signature**	**Date**
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GLOSSARY

A confined aquifer *- a formation in which the groundwater is isolated from the atmosphere at the point of discharge by impermeable geologic formations; confined groundwater is generally subject to pressure greater than atmospheric pressure.*

An unconfined, water table or phreatic aquifer *- are different terms used for the same aquifer type which is bounded from below by an impermeable layer. The upper boundary is the water table, which is in contact with the atmosphere so that the system is open.*

Aquifer *– A body of rock, consolidated or unconsolidated, that is sufficiently permeable to conduct groundwater and to yield significant quantities of water to wells and springs.*

Bedrock *– A general term for the rock that underlies soil or other unconsolidated superficial material.*

Cone of depression *– A depression in the potentiometric surface of a body of groundwater that has the shape of an inverted cone and develops around a well/mine shaft/open pit mine from which water is being withdrawn.*

Drawdown *– The decline of the water table or potentiometric surface as a result of withdrawals from wells or excavations.*

DW&S *- Department of Water and Sanitation (Used to be DWAF and then DWA)*

Effective porosity *- is the percentage of the bulk volume of a rock or soil that is occupied by interstices that are connected.*

Fault *– A fracture or fracture zone along which there has been displacement of the sides relative to one another parallel to the fracture.*

Fracture *– A crack, joint, fault or other break in rocks caused by mechanical failure.*

Groundwater table *- is the surface between the zone of saturation and the zone of aeration; the surface of an unconfined aquifer.*

Heterogeneous *-indicates non-uniformity in a structure.*

Hydraulic conductivity (K) *- Measure of the ease with which water will pass through the earth's material; defined as the rate of flow through a cross-section of one square metre under a unit hydraulic gradient at right angles to the direction of flow.*

Hydraulic gradient - *is the rate of change in the total head per unit distance of flow in a given direction.*

Hydraulic head *– Generally the altitude of the free surface of a body of water above a given datum.*

Interflow – *The lateral movement of water in the unsaturated zone during and immediately after precipitation. Interflow occurs when the zone above a low permeability horizon becomes saturated and lateral flow is initiated parallel to the barrier.*

Joint – *A fracture in rock along which there has been no visible movement.*

Mechanical dispersion *– is the process whereby the initially close group of pollutants are spread in a longitudinal as well as a transverse direction because of velocity distributions.*

Observation borehole *- is a borehole drilled in a selected location for the purpose of observing parameters such as water levels.*

Perched Water Table *– The upper surface of a body of unconfined groundwater separated from the main body of groundwater by unsaturated material.*

Permeability *- the ease with which a fluid can pass through a porous medium and is defined as the volume of fluid discharged from a unit area of an aquifer under unit hydraulic gradient in unit time. Permeability is not to be confused with hydraulic conductivity. While similar, permeability considers the properties of the fluid being transmitted.*

pH *- is a measure of the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity.*

Piezometric head *- is the sum of the elevation and pressure head. An unconfined aquifer has a water table and a confined aquifer has a piezometric surface, which represents a pressure head. The piezometric head is also referred to as the hydraulic head.*

Porosity – *The ratio of the aggregate volume of interstices in a rock or soil to its total volume. It is usually stated as a percentage.*

Pumping tests *- are conducted to determine aquifer or borehole characteristics.*

Recharge *- is the addition of water to the zone of saturation; also, the amount of water added.*

Specific yield *- the ratio of the volume of water that drains by gravity to that of the total volume of the saturated porous medium. Specific yield is a ratio between 0 and 1 indicating the amount of water released due to drainage, from lowering the water table in an unconfined aquifer.*

Static water level *- is the level of water in a borehole that is not being affected by withdrawal of groundwater.*

Storativity *- the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. It is a volume of water per volume of aquifer released as a result of a change in head. For a confined aquifer, the storage coefficient is equal to the product of the specific storage and aquifer thickness.*

Total dissolved solids (TDS) *- is a term that expresses the quantity of dissolved material in a sample of water.*

Transmissivity (T) *- is a measure of the ease with which groundwater flows in the subsurface. It is the two-dimensional form of hydraulic conductivity and is defined as the hydraulic conductivity multiplied by the saturated aquifer thickness.*

Vadose zone *- is the zone containing water under pressure less than that of the atmosphere, including soil water, intermediate vadose water, and capillary water. This zone is limited above by the land surface and below by the surface of the zone of saturation, that is, the water table.*

Water table - *is the surface between the vadose zone and the groundwater, that surface of a body of unconfined groundwater at which the pressure is equal to that of the atmosphere.*

LIST OF ACRONYMS

ABA	Acid-Base Accounting
AD	Acid Drainage
Al	Aluminium (mg/l)
AMD	Acid Mine Drainage
ANC	Acid Neutralising Capacity
ARD	Acid Rock Drainage
As	Arsenic
BH	Borehole
Ca	Calcium (mg/l)
Cd	Cadmium (mg/l)
Cl	Chloride (mg/l)
CO_3	Carbonate (mg/l)
DEM	Digital Elevation Model
DW&S (DWS)	Department of Water and Sanitation (previously DWA and DWAF)
DWA	Department of Water Affairs
DWAF	Department of Water and Forestry
EC	Electrical Conductivity (mS/m)
EMPR	Environmental Management Plan Report
F	Fluoride (mg/l)
Fe	Iron (mg/l)
FZ-N and FZ-S	Forzando North and Forzando South (refer to the mining areas discussed in this report)
GCS	GCS Water and Environment (Pty) Ltd
GRIP	Groundwater Information Project
GW	Groundwater
h	Potentiometric head
HCO_3	Bicarbonate (mg/l)
HDPE	High-Density Polyethylene (Plastic)
HMP	Hydrogeological Management Plan
INAP	The International Network for Acid Prevention
IWULA	Integrated Water Use License Application
IWWMP	Integrated Water and Waste Management Plan
K	Potassium (mg/l)
K (k)	Hydraulic Conductivity (m/day)
Kxx	Hydraulic Conductivity on x-axis (m/day)
Kyy	Hydraulic Conductivity on y-axis (m/day)
Kzz	Hydraulic Conductivity on z-axis (m/day)
LFCR	Linear flow channel reactor
LOM	Life of Mine
m	metres
MALK	Measured Alkalinity
mamsl	Meters above mean sea level
MAP	Mean Annual Precipitation
mbgl	Meters below ground level
Mg	Magnesium (mg/l)
Mn	Manganese (mg/l)
MTPa	Million Tons Per Annum
n	Porosity
Na	Sodium (mg/l)

NAG	Net Acid Generation
ND	Neutral Drainage
NEMA	National Environmental Management Act
NGDB	National Groundwater Database
NO_3	Nitrate (mg/l)
Non-PAG	Non-Potentially Acid Generation
NWA	National Water Act
OC (O/C)	Opencast Workings
PAG	Potentially Acid Generating
PAN	Potentially Acid Neutralising
Pb	Lead (mg/l)
PCD	Pollution Control Dam
PEST	Parameter Estimation Simulation
PUMPS	Passive underground mine-water purification
Re	Recharge (%)
RMS	Root Mean Squared / Normalised Distribution
RO	Reverse Osmosis
ROM	Run of Mine
S	Storativity
SANS	South African National Standards
Sb	Antimony (mg/l)
SD	Saline Drainage
SD	Saline Drainage
SMD	Saline Mine Drainage
SO_4	Sulphate (mg/l)
SS	Specific Storage / Suspended Solids (mg/l)
Ss	Specific Storage
Sy	Specific Yield
T	Transmissivity (m^2/d)
t	Time (days)
Talk	Total Alkalinity (mg/l)
TDS	Total Dissolved Solids (mg/l)
W	Groundwater Flux
WQ	Water Quality
WUL	Water Use License
WULA	Water Use License Application
XRD	X-Ray Diffraction
XRF	X-Ray Fluorescence
Y	years
Zn	Zinc (mg/l)
ZOI	Zone of Influence
θ	Porosity

EXECUTIVE SUMMARY

GCS (Pty) Ltd was retained by Exxaro Coal Central Proprietary Limited to undertake a follow up groundwater study in support of the Kalabasfontein Project. The proposed underground mine expansion will be linked to the existing Forzando South Mine (FZ-S). The scope of work for this project included site hydrogeological characterization by means of a hydrocensus and application of existing air magnetic survey data, aquifer data, hydrochemistry and geochemistry analysis, and 3D numerical groundwater modeling.

Predictions regarding the potential impact of the Kalabasfontein Project on the local groundwater system are addressed in this report. The data that has been gathered to develop a site hydrogeological characterization and model calibration:

- Updated hydrocensus within the Kalabasfontein Project Area;
- Application of the 2014/5 numerical groundwater model and geochemical assessment;
- Application of newly sourced (2018) water monitoring data and underground pump data.

Groundwater level data and newly obtained groundwater quality data is discussed, and the data was added to the active Forzando groundwater database, managed by GCS. Similar water qualities were observed to the regional farm boreholes sampled previously in the area (2002, 2010 and 2014). Generally low, or limited, concentrations of typical hydrochemical mine indicator parameters were observed with generally only calcium, chloride and nitrate concentrations exceeding the SAWQG Domestic Use Target Values in some of the boreholes. These can mainly be attributed to natural Karoo Aquifer characteristics and traces of agricultural influences (nutrient rich fertilizers). The data will be used as baseline conditions for future references.

No abnormal agricultural groundwater consumption was identified for the Kalabasfontein project area and fairly shallow groundwater levels were measured; between 2.7 and 3.6 mbch (meters below collar height) with one borehole at 13.7 mbch, but this borehole was in production during the time of measurement.

Groundwater level data obtained from observation and farm boreholes were applied to re-calibrate the numerical groundwater flow model developed in 2014/2015 for the Forzando Coal Mine. The new expansion area and life of mine works plan were applied and the proposed aquifer drawdown over the operational life and post closure are discussed in this report.

It was established that some of the identified farm boreholes fall within the predicted zone of impact; these are highlighted in the impact assessment section. It is recommended that annual monitoring of groundwater levels be implemented from these boreholes. This will establish a database of baseline data that can be used for comparison purposes going forward and to understand aquifer behaviour better.

The flow model was applied and mass transport was simulated to predict sulphate plume migration from the proposed Kalabasfontein project area as well as the rest of the Forzando South proposed underground workings. The model indicates limited sulphate seepage to migrate from the deeper mine workings into the upper weathered aquifer zone after mine closure and during the period of groundwater rebound. However, the model did highlight some sensitive zones along lower topographical areas and where the mine workings is shallower (i.e. <45m). The probability of saline drainage and saline load into the surface water bodies is discussed and the operational and post closure monitoring of this potential salt load is proposed in this report.

According to the existing information and hydrocensus data, none of the privately owned/farm boreholes are affected by the current and predicted seepage sulphate plumes. However, continuous groundwater monitoring will be applied to monitor any changes. The numerical groundwater model will be calibrated routinely to ensure that sound and pro-active groundwater management practices can be applied.

Farm boreholes in the vicinity of the Bolton Pan and Bankpan areas need to be monitored as a pre-caution. The pans itself also need to be monitored at regular intervals to ensure a proper understanding of any water quality fluctuations are in place. In general, the deeper flow will not affect the farm boreholes which are usually intersecting the upper aquifer zones only.

Overall, the Kalabasfontein Project appears to have a low to medium impact on the regional hydrogeological environment according to the numerical predictions. If sound environmental management practices are applied (according to the monitoring, management and mitigation mentioned in this report), it is our opinion that groundwater related impacts will be acceptable and the project may be authorised from a hydrogeological perspective.

CONTENTS PAGE

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

Exxaro Coal Central Proprietary Limited (Client / Exxaro) appointed GCS (Pty) Ltd (GCS) to undertake a hydrogeological investigation for the Kalabasfontein project and numerical model update for Forzando North and South Coal Mine Operations (also referred to as FZ-N and FZ-S).

The Kalabasfontein project and the associated Forzando Coal Mines are situated in Mpumalanga, 20 kilometres north of Bethal. Kalabasfontein project is located to the south-east of the existing Forzando South 380MR and south of Forzando North 381MR which fall within the Msukaligwa Local Municipality (Refer to Figure 4-1).

The main objectives of this hydrogeological assessment are:

- To update the existing hydrogeological conceptual model for the two mining areas with the inclusion of the Kalabasfontein project area and a ventilation shaft located within the existing Forzando South underground workings;
- To numerically simulate the potential impact that mine de-watering might have on groundwater quantity and quality in the local aquifer systems;
- To report on hydrogeological impacts and mitigation requirements.

2 SCOPE OF WORK

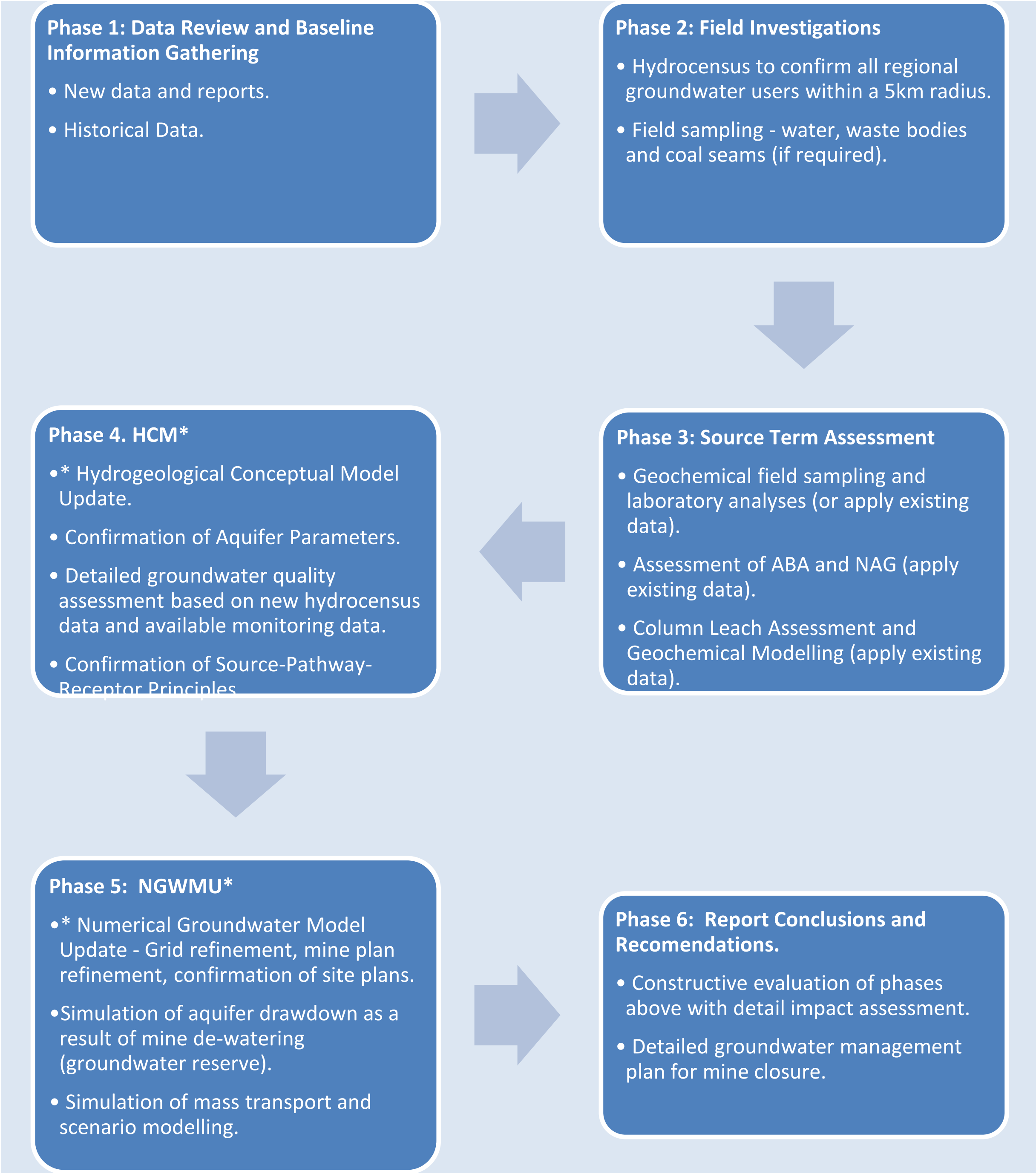
The following items were agreed to form part of this hydrogeological assessment report:

- To undertake a hydrocensus within the proposed Kalabasfontein project area which includes measuring of regional groundwater levels and obtaining groundwater samples for water quality analyses.
- To update the existing conceptual and numerical groundwater model with the new proposed mine plans and calibrate it to incorporate new and updated groundwater monitoring data.
- To submit a technical report.

3 METHODOLOGY

A systematic phased approach was followed in order to adhere to the objectives and agreed scope of work of the assessment. The tasks were subdivided into different project phases and can be presented as follows (refer to Table 3-1).

Table 3-1: Project method flow diagram



4 BACKGROUND AND BASELINE DATA

It is important to note that detailed environmental and hydrogeological base line data has been obtained since the initial stages of FZ-N prior to 1999. Several technical reports dealt with this historically. The intention is not to re-discuss this in this assessment report but to add to the discussion where applicable. It is therefore important to read this report in conjunction with the 2014 hydrogeological assessment report.

4.1 Climate, Topography and Drainage

FZ-N and FZ-S are both situated in quaternary catchment B11A in the upper Olifants River catchment. The general drainage of the mining area is from the south and south east to the north. On the western side is the Joubertvlei Spruit, in the centre the Diepsloot Spruit, and in the east and south-east the Viskuile Spruit which eventually drains into the Olifants River system. The Viskuile Spruit drains the Kalabasfontein project area, which flows in a north westerly direction past the FZ-S Adit area.

There are some blind drainages into pans, the largest of which is Boltons Pan Area to the west of the FZ-S Adit and the Bankpan Area which is situated south east of the FZ-N Mine. Some smaller pans exist to the west of the Kalabasfontein project area.

Mean Annual Rainfall (MAR) is approximately 710 mm/annum while the Mean Annual Evaporation (MAE) is in excess of 2000 mm/annum. Rainfall peaks early in the season, in November and then again in January, while the winter months are characterised by a long and very dry period.

The infrastructural site of FZ-N is situated on a gentle (1:40) north-facing slope. The elevation varies between 1 580 mamsl along the Olifants River and 1 640 mamsl along the southern boundary of the site. Surface runoff is therefore from south to north and towards the tributary streams.

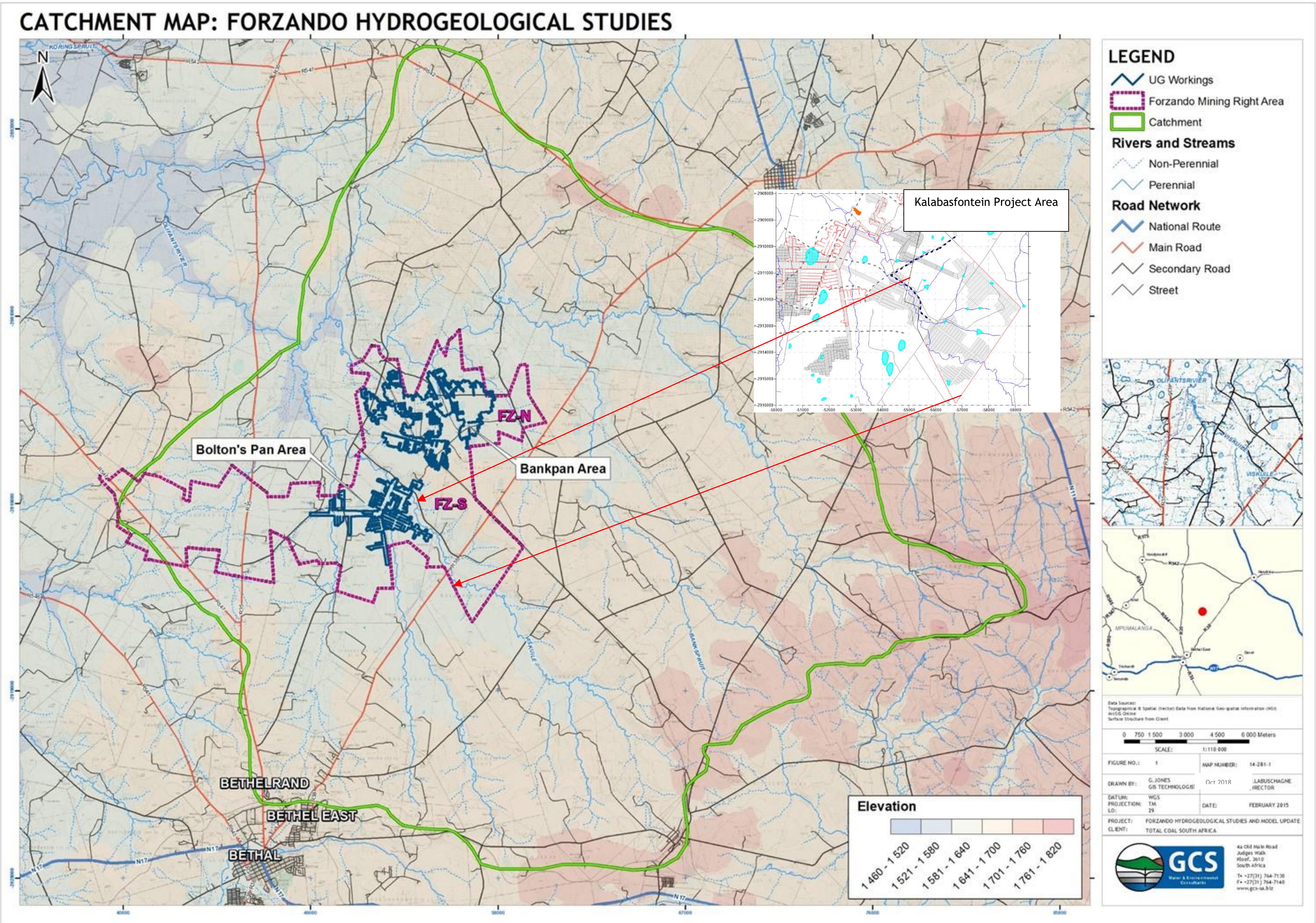


Figure 4-1: Forzando and Kalabasfontein project area locality map

4.2 Regional Geology

The coal mined in the project area is associated with the Vryheid Formation of the Ecca Group, which forms part of the Karoo Supergroup.

Five coal seams, numbered from bottom to top as No. 1 – 5 are present (Figure 4-2). Only two of the seams are feasible over most of the area. These are the No. 2 and No. 4 coal seams, which are usually separated by sediments in the order of 20 – 30 m thick.

Refer to Figure 4-7 for the regional geology map.

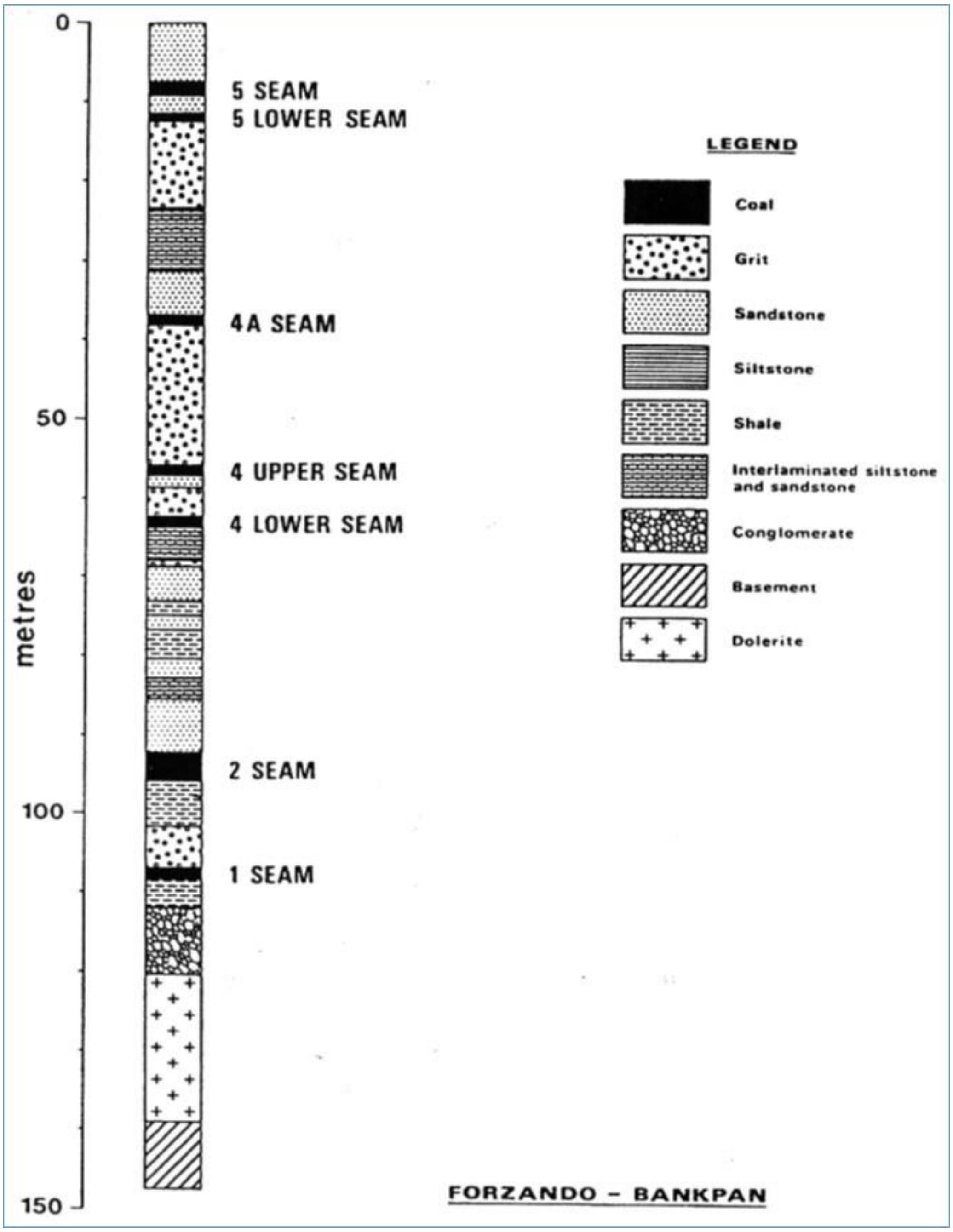


Figure 4-2: Generalised Stratigraphic Column

4.3 Structural Geology

The delineation of local dolerite structures (dykes and sills) were obtained from aerial magnetic survey data (Exxaro, 2018), (refer to Figure 4-8), these are mapped on Figure 4-5.

4.4 Mine Setup

Forzando Coal Mines (Pty) Ltd (FZ-N and FZ-S) is an underground mining operation, exploiting the No. 4 Lower seam since 1996. As the Kalabasfontein project will use the existing Forzando South and Forzando North infrastructure, additional infrastructure requirements will be minimal.

Currently, Forzando South mine is scheduled until 2037. However, the Kalabasfontein project portion will be mined as soon as permission is granted, in order to ensure sustained production volumes. The mine will maintain its production rate of 2.2Mt per annum. Commissioning of Kalabasfontein project will not add to the production of Forzando South but will provide relocation areas for existing Forzando South sections. Table 4-1 below indicates the production schedule over the estimated LoM of 17 years.

Table 4-1: Seam 4 Lower ROM tonnes (Scoping Report, EIMS, 2018)

Description	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
ROM Tonnes [Mt]	0.3	0.6	0.7	0.7	0.8	0.7	0.7	0.7	0.8
RD [t/m³]	1.79	1.79	1.76	1.66	1.74	1.76	1.8	1.78	1.77
Ash Content [%]	43.5	43.5	44.3	35.9	39.2	42.2	46.9	46	42.8
Calorific value [MJ/kg]	17.5	17.6	17.7	20	18.6	17.2	15.7	15.9	16.6
Total sulphur [%]	1.40	1.40	1.30	1.30	1.40	1.60	1.50	1.40	1.30
Description	**Year 10**	**Year 11**	**Year 12**	**Year 13**	**Year 14**	**Year 15**	**Year 16**	**Year 17**	**Total**
ROM Tonnes [Mt]	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.5	11.7
RD [t/m³]	1.79	1.8	1.85	1.81	1.74	1.74	1.74	1.74	1.77
Ash Content [%]	44.7	46.1	48.7	46.4	41.8	40.7	40.5	40.8	43.3
Calorific value [MJ/kg]	16.2	15.4	14.8	15.8	17.5	17.7	17.8	17.9	17.0
Total sulphur [%]	1.30	1.50	1.30	1.30	1.40	1.60	1.70	1.60	1.42

4.4.1 Geological Cross Sections

Cross-section graphs which graphically presenting the 4L coal seam were drawn based on available data and are presented below in Figure 4-3.

During late Jurassic times the Karoo strata were intruded by transgressive dolerite dykes/sills resulting in the displacement of seams and the de-vitalisation of coal in certain areas. Over the greater part of the area, dolerite sills lie below the coal-bearing sediments, either within the Dwyka or on the basement horizon. The No. 4 lower seam ranges in thickness from 0 to 3 m and is separated in certain areas by a horizontal dolerite sill or siltstone parting (also refer to Figure 4-4).

4.4.2 Coal Floor Contours

Coal floor contours for the current and future mining of the No. 4 Lower Seam is shown in Figure 4-5. The data was obtained from Exxaro and interpolated utilising Kriging Interpolation by applying the Surfer contouring software (Surfer ver. 12.8, Golden Software Inc.). The No. 4 lower seam is between 30 m and 60m deep at the Kalabasfontein Project Area and dips slightly north-west towards the Forzando South Incline Adit.

4.4.1 Overburden Thickness

The thickness between the No. 4 lower coal seam and the surface, or overburden thickness, was interpolated and presented in Figure 4-6. The areas where overburden is less than 30m can be regarded as sensitive zones.

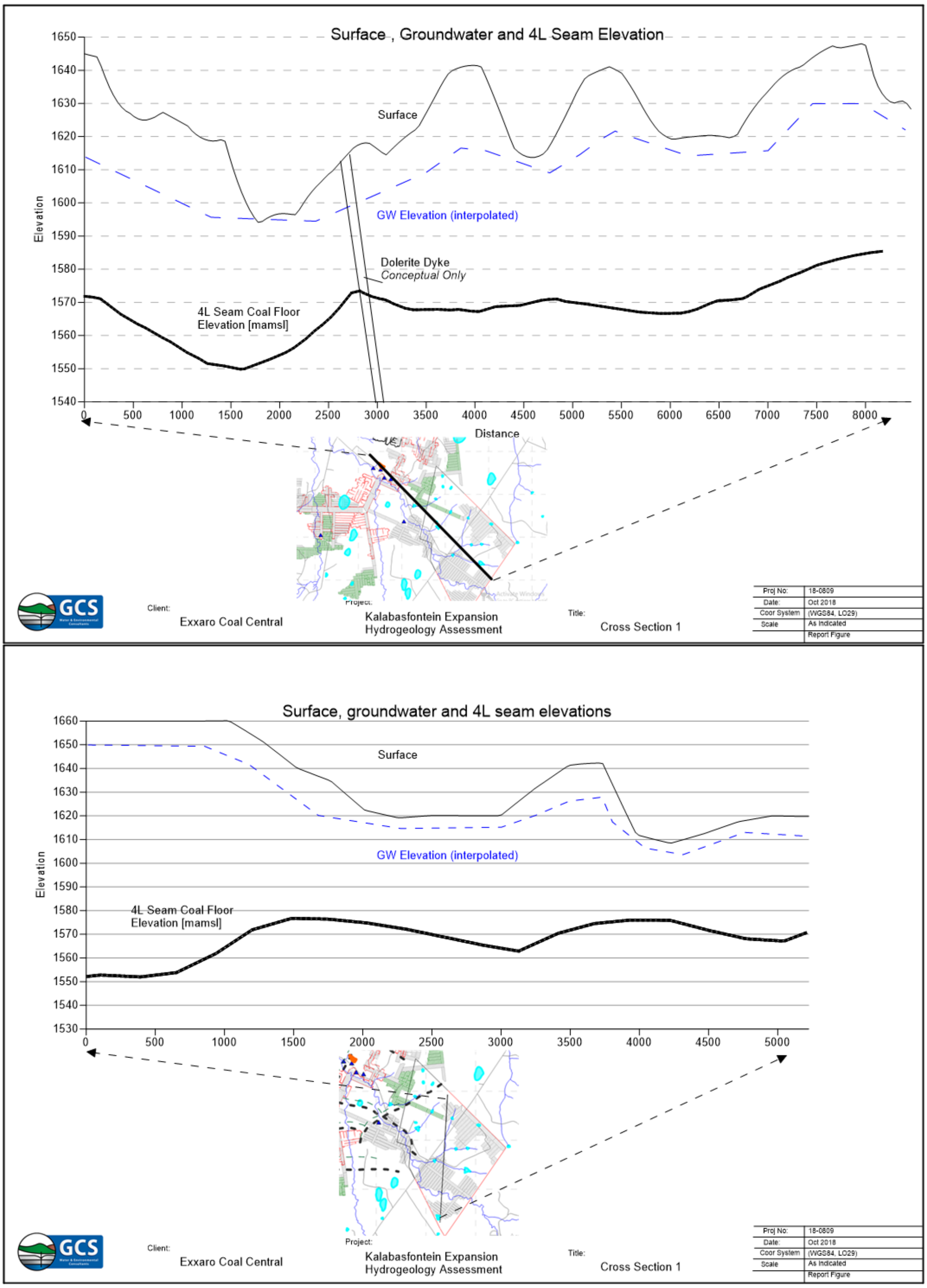


Figure 4-3: Cross Sections through proposed Kalabasfontein project area (vertical over exaggerated)

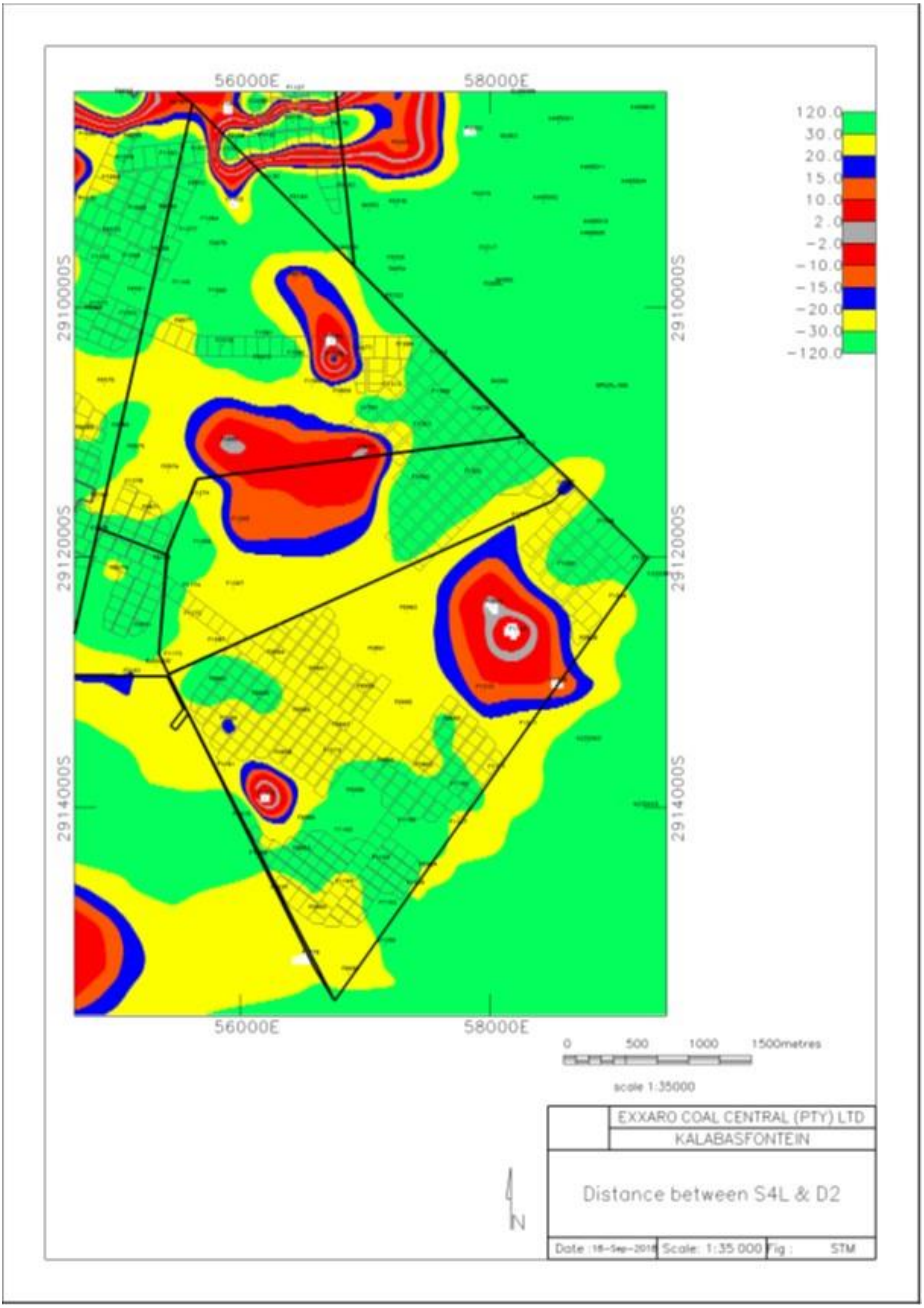


Figure 4-4: Distance between S4L and D2 Dolerite Sill

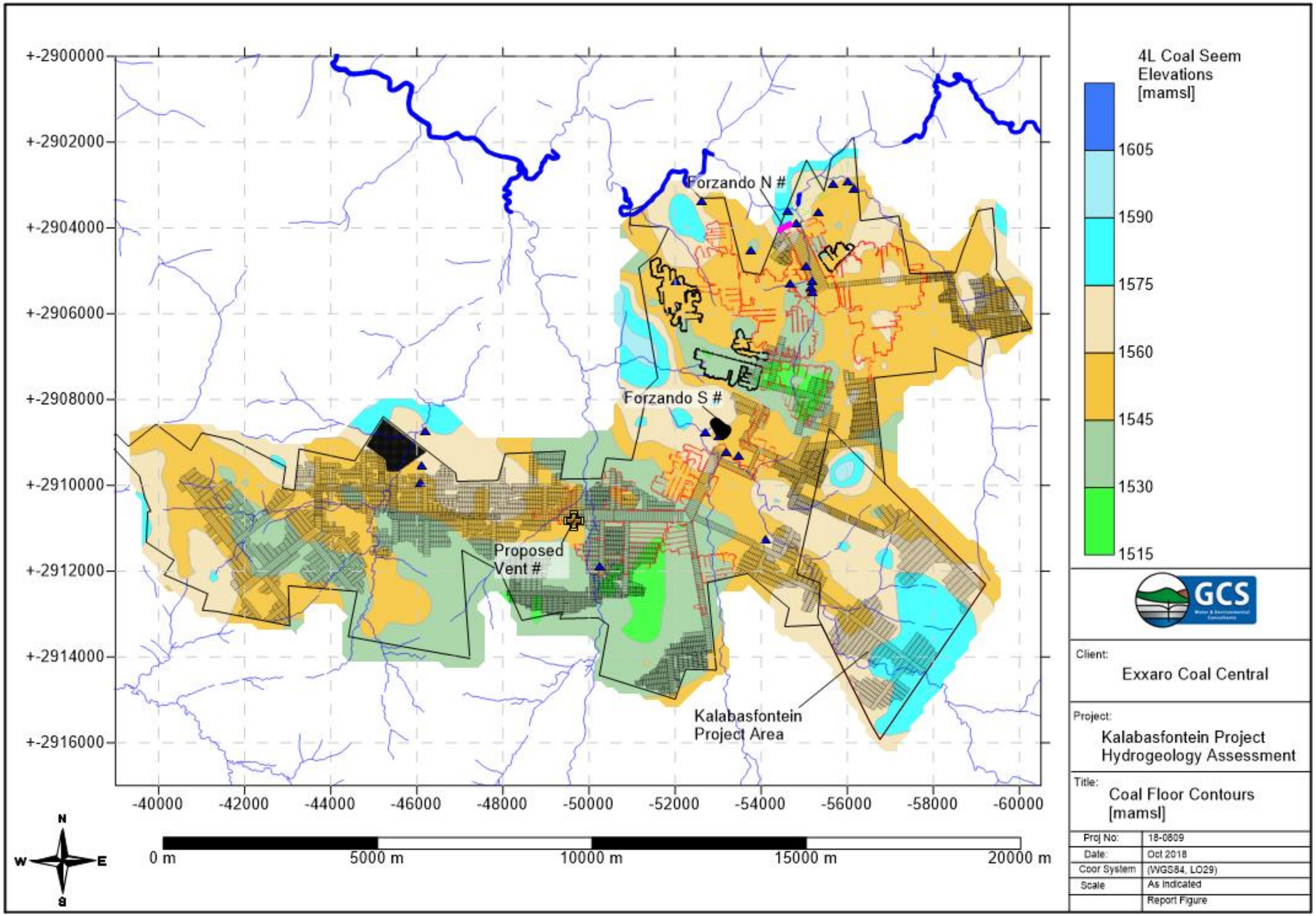


Figure 4-5: Forzando Coal Floor Contours (Kriging Interpolation)

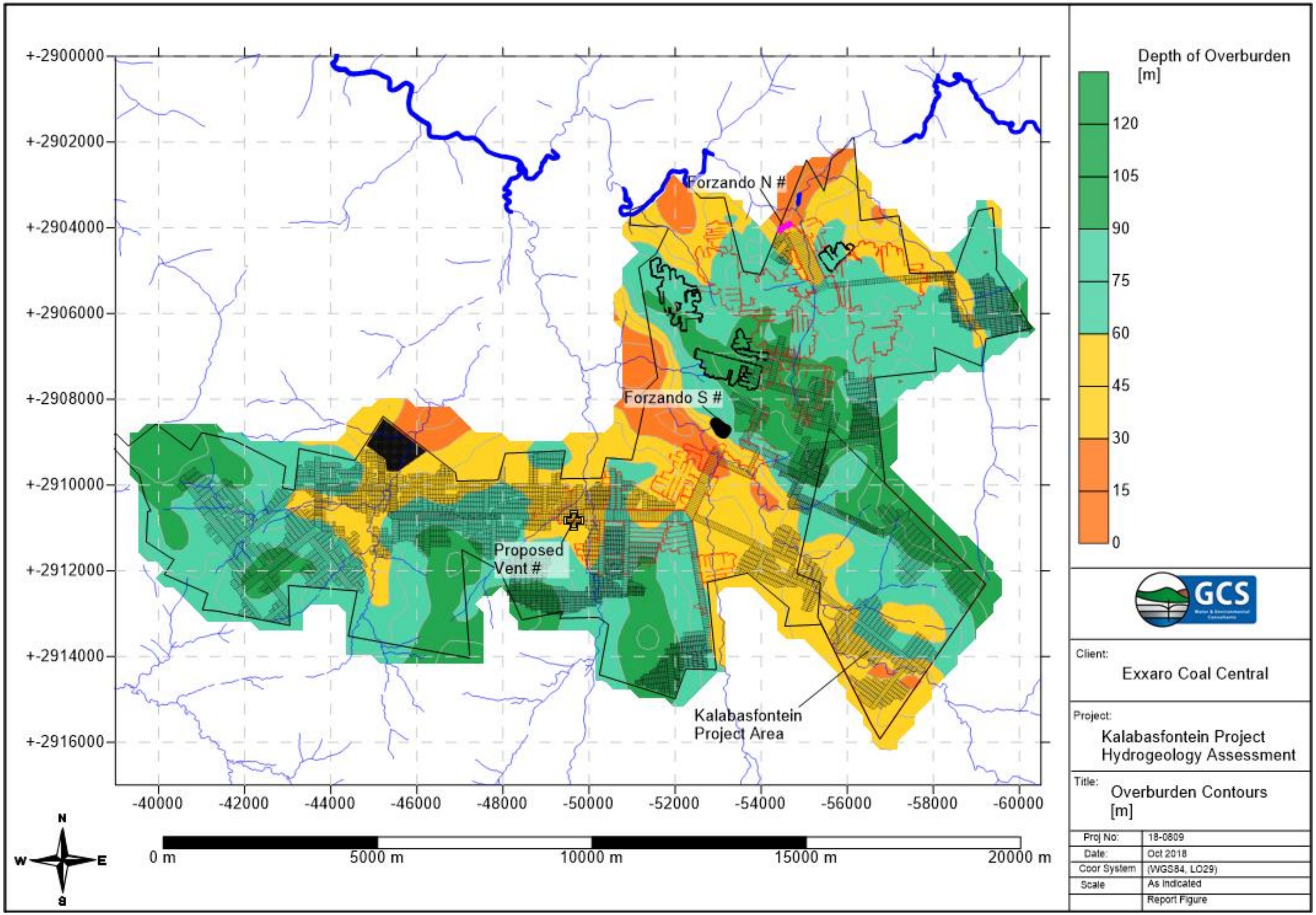


Figure 4-6: Overburden Thickness Contour Map (Kriging Interpolation)

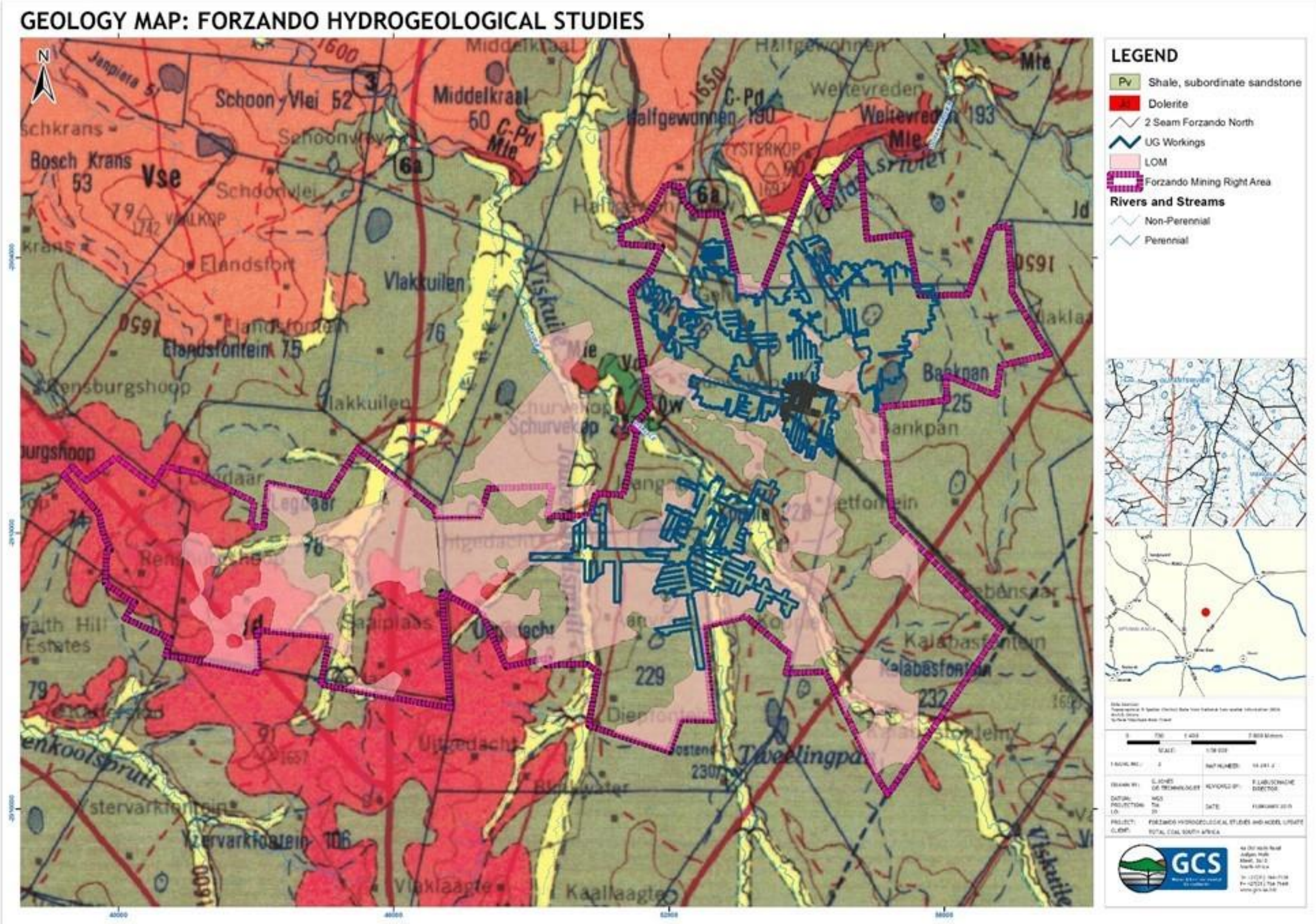


Figure 4-7: Regional Geology Map

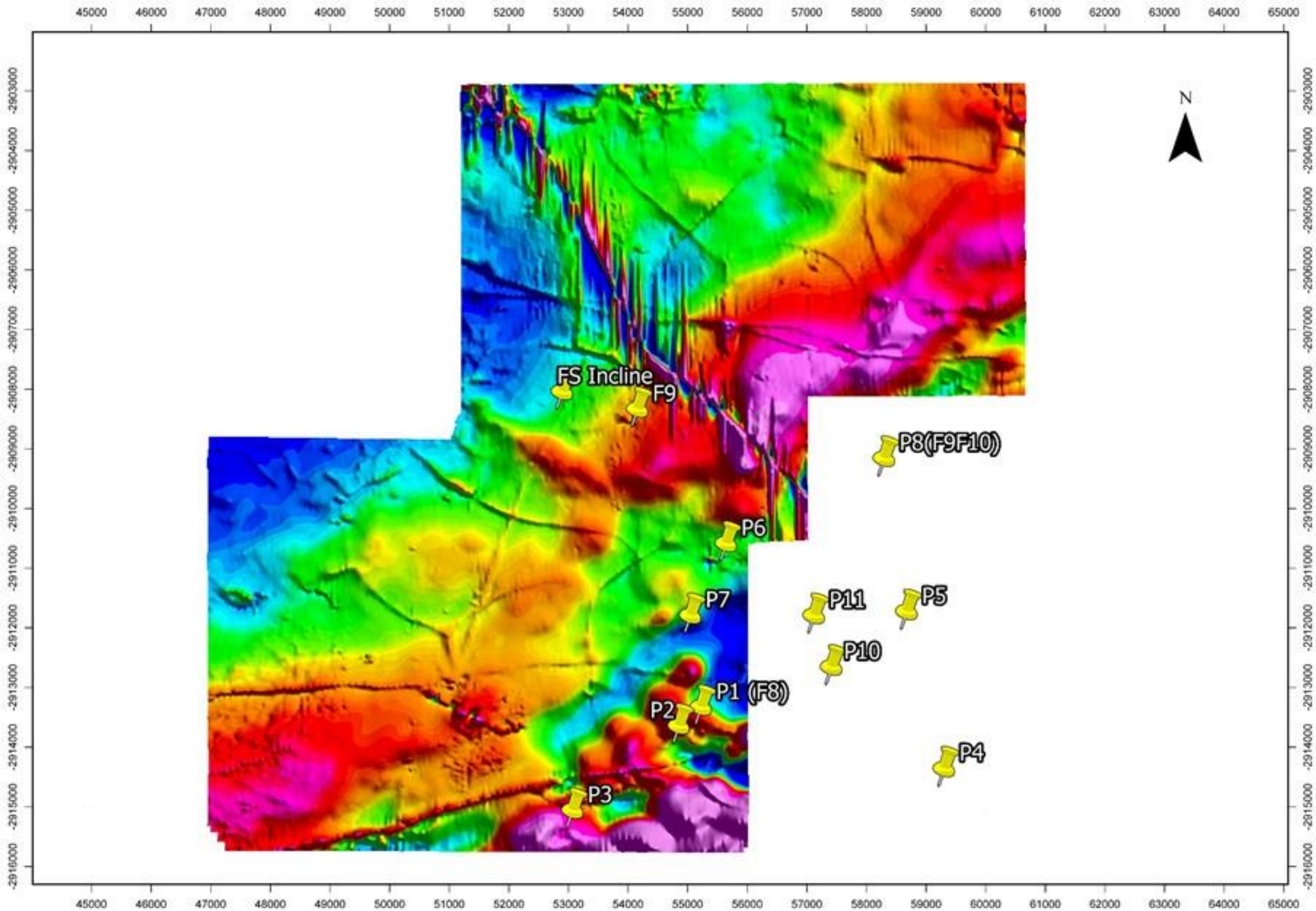


Figure 4-8: Aerial Magnetic Survey Data

4.5 General Aquifer Description

Two distinct superimposed groundwater systems are present within the Olifants River Catchment. They can be classified as (Hodgson & Krantz, 1998 and WRC report 291/1/98):

- The upper weathered Ecca aquifer (shallow aquifer formed in the weathered zone of the Karoo sediments which is locally perched on the fresh bedrock);
- The aquifer below the Ecca sediments (deeper aquifer formed by fracturing of the Karoo sediments and dolerite intrusions).

4.5.1 Shallow Weathered Aquifer

The Ecca sediments are weathered to depths between 5 to 12 meters below surface throughout the Olifants River Catchment. The upper aquifer is associated with this weathered zone and groundwater is often found within a few meters below surface. This aquifer is recharged by rainfall. The percentage recharge to this aquifer is estimated to be in the order of 1 – 3 % of the annual rainfall, based on work by Kirchner *et al.* (1991) and Bredenkamp (1978) in other parts of the country.

Rainfall that infiltrates the weathered rock soon reaches an impermeable layer of shale underlying the weathered zone. The movement of groundwater on top of this shale is lateral and in the direction of the surface slope. This water reappears at the surface as fountains where the flow paths are obstructed by a barrier, such as a dolerite dyke, paleo-topographic highs in the bedrock, or where the surface topography cuts into the groundwater level at streams. It is suggested that less than 60% of the water recharged to the weathered zone eventually emanates in streams and pans.

The aquifer within the weathered zone is generally low-yielding (ranging 100 – 2000 l/h) due to its minor thickness. Few farmers therefore tap this aquifer by borehole. Wells or trenches, dug into the upper aquifer, are often sufficient to secure a constant water supply of excellent quality.

4.5.2 Fractured Rock Karoo Aquifers

The pores within the Ecca sediments are too well cemented to allow any significant permeation of water. All groundwater movement is therefore along secondary structures, such as fractures, cracks and joints in the sediments. These structures are better developed in competent rocks such as sandstone, hence the better water-yielding properties of the latter rock type.

Of all the un-weathered sediments in the Ecca, the coal seams often have the highest hydraulic conductivity. Packer testing of the No. 2 seam and underlying Dwyka tillite has the hydraulic conductivity distribution as indicated in Table 4-2.

Table 4-2: Statistics for Results on Packer Tests (WRC Report No 291/1/98)

Statistics	2 Seam – K (m/day)	Dwyka – K (m/day)
Mean (m/d)	0.1017	0.0034
Median (m/d)	0.0743	0.0024
Standard deviation (m/d)	0.1295	0.0034
Min (m/d)	0.0007	0.0002
Max (m/d)	0.5	0.018
Number of tests	21	21

The data listed in Table 4-2 suggests that seepage of water through the No. 2 seam is possible. Due to its low hydraulic conductivity, the Dwyka tillite forms a hydraulic barrier between the overlying mining activities and the basal floor.

In terms of water quality, the fractured Karoo aquifer always contains higher salt loads than the upper weathered aquifer. These higher concentrations are attributed to the longer contact time between the water and the rock. The occasional high chloride and sodium levels are attributed to boreholes in the vicinity of areas where salts naturally accumulate on the surface, such as pans or fountains.

5 HYDROGEOLOGICAL BASELINE INFORMATION

The following section supplies an overview of the available data that was applied to establish the baseline conceptual groundwater model for the Forzando Mine as well as the proposed Kalabasfontein Expansion. **The Hydrocensus completed in 2018 for the Kalabasfontein Project Area is also discussed in this section.**

It is important to note that this report presents an amendment of the previous Hydrogeological reports and will not supply all the hydrogeological information for the entire Forzando area; this can be obtained from previous reports on request. The main objective of this report is to incorporate the Kalabasfontein project area into the 2014/2015 groundwater assessment report (GCS Ref 14-0281).

5.1 Available Documents and Data

All baseline studies discussed in this section were sourced from the following documents:

- Digby Wells & Associates, 2002. Environmental Management Programme Report for Forzando South.
- Golder Associates, 2003. Environmental Management Programme Report for Forzando Coal Mines (PTY) Ltd, Report No: 4458/2849/1/E.
- Golder Associates, 2003. Forzando Coal Mine, Technical information for 21(g) licence application in terms of M4 DWAF guidelines, Report No: 4458/6113/2/w.
- GCS, 22 November 2007. Forzando North Hydrogeological Investigation – Current Situation Assessment, Report No.: TCSA.F.07.020.
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- GCS, 20 February 2009. Siting and Drilling of additional monitoring boreholes at the Forzando North and South Operations. Project Number: 08-283.
- GCS, 14 May 2009. Hydrogeological Assessment for the Total Coal Forzando Mining Sections for Mine Infrastructure Expansion and EMP Amendment. Report No.: 08-377.
- GCS, 23 April 2010. Discussion document on potential mine decant from the Total Coal Forzando Mining Sections. GCS Project Number: 09-398.
- GCS, 26 March 2010. Hydrogeological Assessment for the Total Coal Proposed Forzando West Expansion area. Project Number: 10 – 010.
- GCS, 04 June 2012. Forzando North Borehole Drilling Report. GCS Project Number: 11-205.
- The Forzando geohydrological investigation, (Hodgson 1994).

- Annual water monitoring reports by SRK, 1994 to 1996.
- Annual water monitoring reports by GCS, 2001 to 2002
- Annual water monitoring data by DWA, 2003 to 2006.
- Annual water monitoring reports conducted by GCS since 2009.
- Water Monitoring Report, Aquatico, 2018.
- Groundwater Update Report, GCS 2014.

5.2 Groundwater Use and Regional Data Points

To determine the groundwater usage in the area, available information was applied and a field work phase was conducted. Two hydrocensus investigations were conducted, one in August and November 2014 and a more recent hydrocensus completed in September 2018 for the Kalabasfontein Project Area.

- ***2014 and 2018 Hydrocensus***

GCS conducted a hydrocensus in the project area during August and November 2014 and a total of 25 boreholes were visited. A follow-up Hydrocensus was conducted in September 2018 and 13 boreholes were visited. Refer to Figure 5-1 and Table 5-1 below for the locality map and data table of these boreholes.

It was evident that the boreholes are used for mainly domestic supply, small scale and semi-large scale irrigation (gardens and crop fields) and livestock watering.

Refer to **Appendix A** for the historical hydrocensus data.

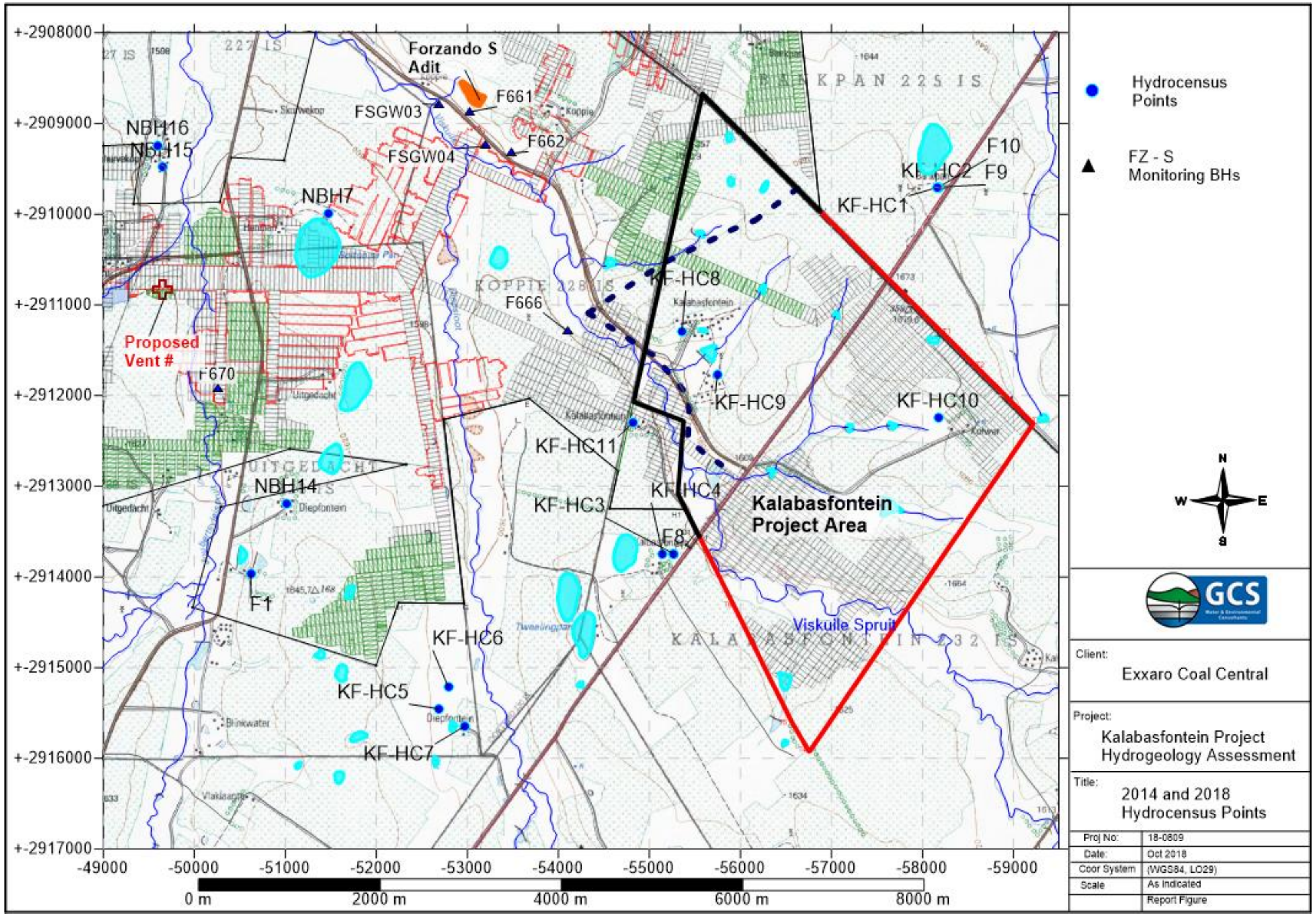


Figure 5-1: Locality map of the 2014 and 2018 borehole hydrocensus data points

Table 5-1: Field data collected during the 2018 hydrocensus

2018 ID	2014 ID	Farm Name	Farm Owner	Contact Details	Description	X (WGS84 LO29)	Y (WGS84, LO29)	Alt (mamsl)	WL (mbgl)	Equipment	Use	Sampled	Sample ID	Site Photograph
KF-HC1	F9	Portion 8, Bankpan.	J Coetzer	071 679 3308	Windpump. No WL access. Not pumping. Directly next to F10.	58175.52	-2909700.79	1665	-	Wind pump	Drinking water	No	No	
KF-HC2	F10	Portion 8, Bankpan.	J Coetzer	071 679 3308	Submersible pump. At farm house.	58165.50	-2909707.39	1660	3.58	Submersible pump	Drinking water	yes	P8	
KF-HC3	F8	Prt 13, Bankpan.	R Hirschowitz.	082 277 5334	Old wind pump NE of old farm house	55270.926	-2913745.45	1616	2.81	Wind Pump	Cattle watering and domestic	no		
KF-HC4	F9	Prt 13, Bankpan.	R Hirschowitz.	083 277 5334	Old farm house BH next to farm dam No WL access.	55147.94	-2913746.67	1616		Wind Pump	Cattle watering and domestic	yes	P1B	
KF-HC5		Diepfontein			Newly Drilled exploration BH	52684.41	-2915452.54	1618	3.55	none	none	yes	P3A	
KF-HC6		Diepfontein			Newly Drilled exploration BH	52789.693	-2915209.3	1615	2.7	none	none	No		

2018 ID	2014 ID	Farm Name	Farm Owner	Contact Details	Description	X (WGS84 LO29)	Y (WGS84, LO29)	Alt (mamsl)	WL (mbgl)	Equipment	Use	Sampled	Sample ID	Site Photograph
KF-HC7		Diepfontein			Old Farm house BH next to catchment dam.	52968.66	-2915642.91	1616		hand pump	Farm domestic	yes	P3C	
KF-HC8		Kalabasfontein, 232IS, PTN8	R Hirschowitz.	083 277 5333	Old Wind pump replaced with submersible SE of main farm house and setup. Obtain water samples at main farm setup from tap.	55358.5	-2911285.69	1602.6	13.7	Submersible pump	Farm domestic	yes	P6A	
KF-HC9		Kalabasfontein, 232IS, PTN11	R Hirschowitz.	083 277 5333	Wind pump at workers houses. No WL measured. Obtained water sample from JoJo	55748.036	-2911772.18	1623		Wind Pump	Farm domestic	yes	P6B	
KF-HC10		Kalabasfontein, 232IS, PTN7	R Hirschowitz.	083 277 5333	East of R38, Mono pump installed, BH 100m away from farm setup. Obtain Water sample at tap at farm setup. No WL	58176.76	-2912242.85	1655		Mono Pump	Farm domestic	yes	P5	
KF-HC11		Kalabasfontein, 232IS, PTN13	R Hirschowitz.	083 277 5333	Borehole western side of R38 and Viskuile spruit. Equipped with hand pump, no WL measured. Obtain water sample.	54818.27	-2912295.29	1609		hand pump	Farm domestic	yes	P7	

5.3 Aquifer Characteristics

Aquifer hydraulic data was obtained from aquifer tests completed on the boreholes drilled in 2008, 2010 and 2012. The available data is summarised in Table 5-2; the following is observed:

- Groundwater was intersected at an average depth of 14 m with an average blow yield of 0.3 l/sec for the upper Karoo formations and an order of magnitude higher for dolerite contact zones.

Table 5-2: Summary of available aquifer data

BH ID	Possible old number	X (LO 29, WGS84)	Y (LO 29, WGS84)	Date Drilled	Depth	Water Strike (m)	Blow Yield (l/sec	K (m/day)
FNGW1	F440	2903642.63	-54622.9	1993	40			
FNGW2	F439	2903905.01	-54827.49	1993	73			
FNGW3	M7	2905270.25	-55175.29	1993	61.53	6	3	
FNGW4	M5	2905417.84	-55146.65	1993	62.33	19	12	
FNGW5	M6	2905532.64	-55191.66	1993	61.67	29	1.7	
FNGW6		2904556.96	-53771.3	4/11/2008	50	13	0.1	0.00389
FNGW7		2905317.81	-54662.28	3/11/2008	30	15	0.2	0.0135
FNGW8		2904911.37	-55055.3	3/11/2008	30	13	1	0.016
FNGW9		2903389.21	-52613.43	1993				
FNGW 10		2903389.21	-52027.37	1993				
FNGW 11		2905260.41	-52027.37	24/04/2012	25	5	0.1	0.100
FNGW 12		2902946.93	-56001.6	24/04/2012	45	4	0.1	0.035
FNGW 13		2903113.83	-56163.75	24/04/2012	45	12	0.1	0.045
FNGW 14		2903675.34	-55336.99	24/04/2012	50	5	0.1	0.045
FSGW03		2908794.05	-52691.35	5/11/2008	12	6	0.2	0.378
FSGW04		2909248.53	-53198.87	4/11/2008	10	8	0.7	15.2**
FWGW01				11/6/2010	34	4	0.1	0.027
FWGW02				11/7/2010	49			
FWGW03				11/7/2010	44	30	0.1	0.045

The aquifer characteristics can be summarised as follows:

- Transmissivity values decreased with depth.
- The average hydraulic conductivity is around 0.1 m/day for the upper Karoo formation.
- Shales and sandstone at depths exceeding 15 m has a hydraulic conductivity between 0.004 and 0.02 m/day.
- The shallow boreholes close to the streams at the Forzando South box-cut exhibit hydraulic conductivities an order of magnitude higher, ranging from 0.3 m/day to >1 m/day. It is fair to assume that the alluvial sediments along the streams have higher permeability values.
- Boreholes drilled along a north-east, south west trending dyke, directly south of the old discard complex, by Hodgson et al (1993) did indicate high yields along the dolerite contact zones according to the old reports. Boreholes FNGW3, 4 and 5 are either next to these old boreholes or near them. However, these boreholes do not indicate any significant yields or are currently depleted in terms of groundwater levels and appears to be drilled within the shallower zones. It is proposed to investigate this area to confirm if the old "M" boreholes can be detected.

A summary of transmissivity and storage values is given in Table 5-3 from old literature sources.

Table 5-3: Aquifer parameters (extracted from Pulles et al, 1994)

Aquifer	Transmissivity T (m^2/day)	Storativity S	Comments
0-35 m Fractured bedrock	6-10	0.001	Significant inflow into mine workings
Coarse-grained sandstone between No. 4 Upper and Lower coal seams	0.05	0.0001	Low T and S values
Sediments in igneous rocks. Un-fractured material greater than 35 m.	No data	No data	No significant contribution to groundwater seepage/flow into workings

5.3.1 Aquifer Classification

The weathered / fractured aquifer that underlies the site may be classified as a minor aquifer (Parsons, 1995) due to the general yields of less than 2.0 l/s. The Minor Aquifer System is defined as "fractured or potentially fractured rocks which do not have a high primary permeability, or other formations of variable permeability. Aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large quantities of water, they are important both for local supplies and in supplying base flow to rivers".

5.4 Regional Groundwater Level

A linear correlation is observed between groundwater levels and surface topography in general, refer to Figure 5-2. The correlation obtained for the 2014 and 2018 hydrocensus boreholes is 94% and 97% respectively. The boreholes from the Bankpan Area show deeper groundwater level data with an average water level elevation of 19 mbgl. The other boreholes show an average water level elevation of 6.2 mbgl. The difference in groundwater levels may be a result of:

- Deeper boreholes connected to the zone of de-watering from mining activities;
- Over utilisation of boreholes from farming activities.

This evidence suggests that the groundwater levels for the area generally mimic topography in the absence of anthropogenic activities in the identified aquifers. The correlation of groundwater levels versus surface topography further indicates that mining activities has a minor impact on the monitoring borehole groundwater levels in the area in general except for the Bankpan area, which needs to be confirmed with more detailed hydrogeological testing. Once it has been established that a correlation between the groundwater table and the topography exists, a Bayesian Interpolation[1], that incorporates both the topography and the measured groundwater elevations, can be done. The groundwater contours are graphically presented in Figure 5-3.

[1] *Environmental phenomena (e.g. rainfall and the occurrence of groundwater) cover such vast areas, that it is not always possible to measure their associated variables at all relevant points in space and time. Interpolation is a method to obtain values for these variables at points where no measurements were taken.*

Groundwater levels often follow the surface topography of the aquifer. If the latter variable can be sampled more frequently than the first one, then one can use this information to improve estimates of the first variable. Bayesian Kriging is an interpolation method that uses this principle. In this approach, the classical statistical analysis of Ordinary Kriging is replaced by a Bayesian statistical analysis. The beauty of the Bayesian approach is that it allows one to express prior knowledge of the variable with a qualified guess that can be included in the estimation.

Bayesian interpolation is done with the estimator

$$Z^*(\mathbf{x}_o) = \sum_{i=1}^{n} \alpha_i \left[Z(\mathbf{x}_i) - \mu(\mathbf{x}_i) \right] + \mu_0(\mathbf{x}_0)$$

where $\mu(\mathbf{x}_i)$ is the qualified guess for site $\mathbf{x}_i$. The coefficients α_i, i=1, ,n can again be determined from a system of linear equations and is a function of the parameters σ(Sigma) , k and ρ(Rho).

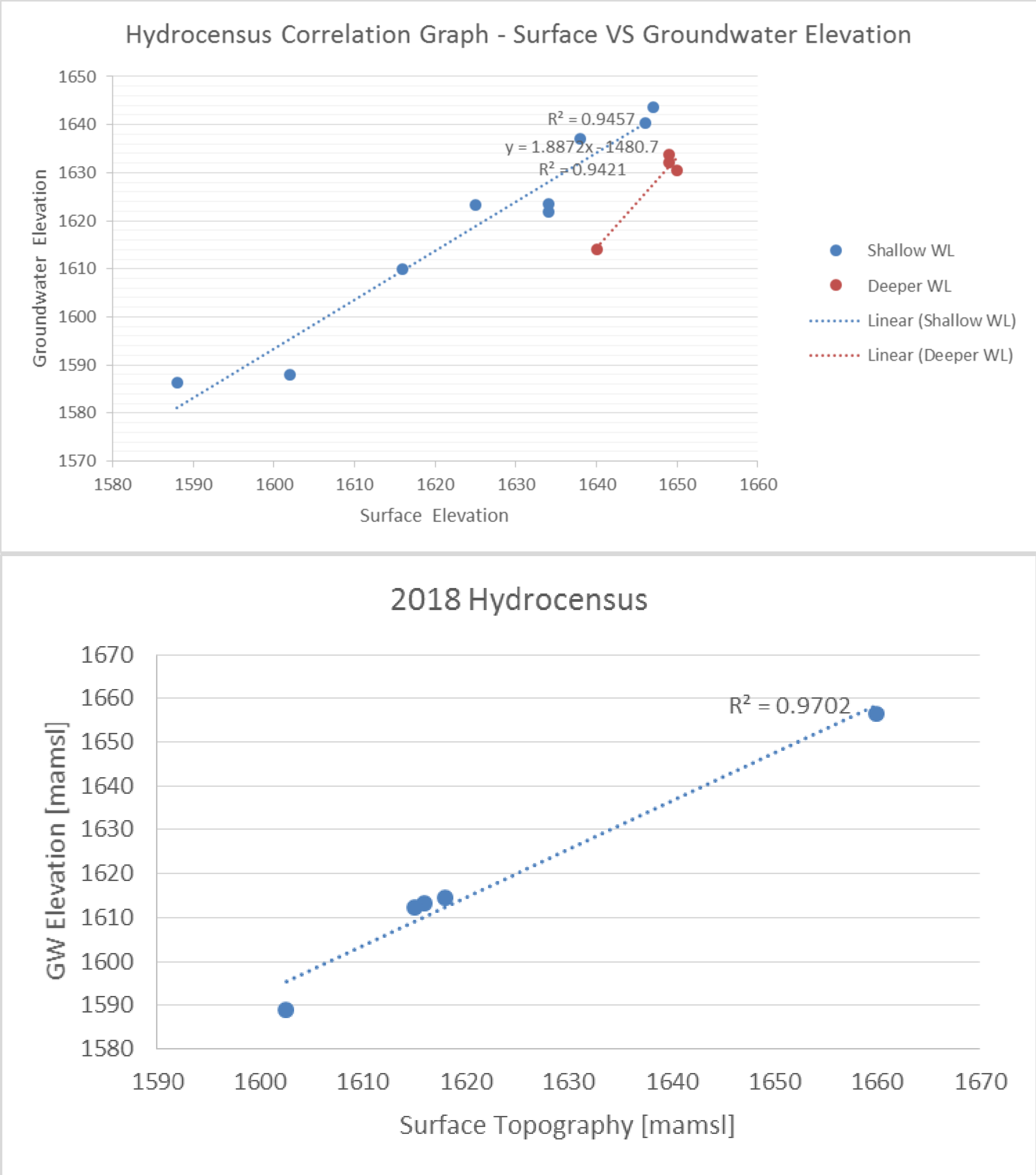


Figure 5-2: Correlation between GW levels and elevation – Hydrocensus BHs 2014 and 2018

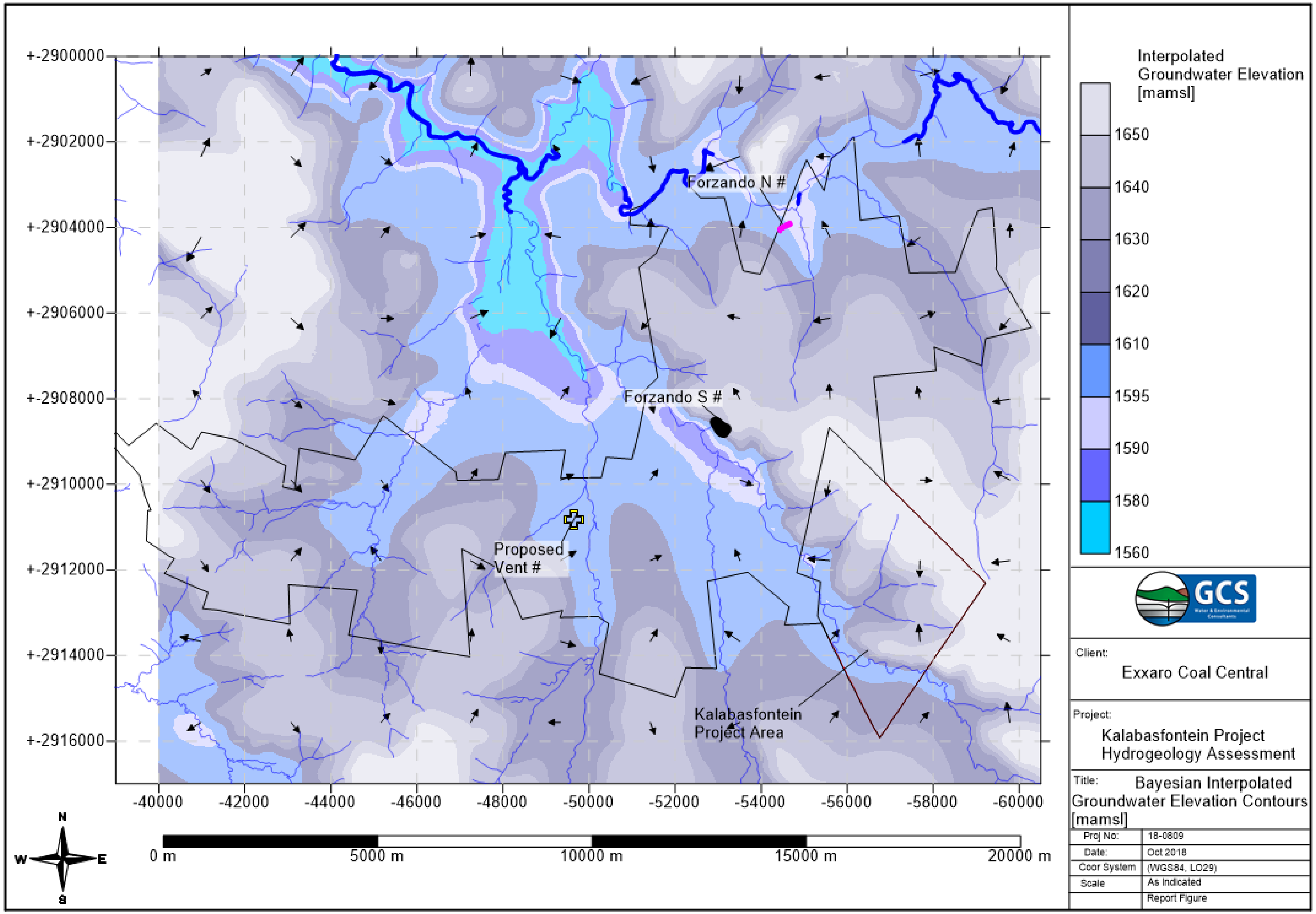


Figure 5-3: Bayesian Interpolated Groundwater Levels for the Forzando Mine Area

5.5 Groundwater Level Data from Monitoring Boreholes

The water levels at Forzando South show seasonal trends around 2 to 4 mbgl (Figure 5-4 and Figure 5-5). In general, the water levels of the boreholes at Forzando North followed seasonal trends during the 2014 to 2018 monitoring period (Figure 5-6).

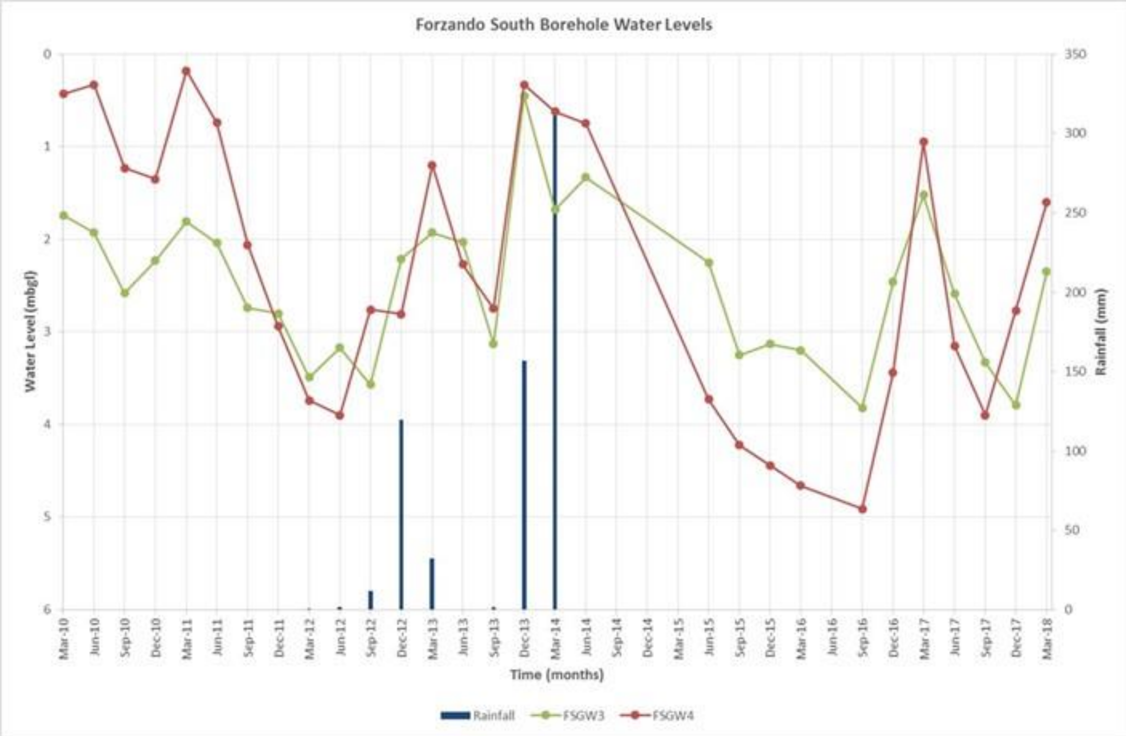


Figure 5-4: Forzando South groundwater levels for the boreholes close to the Adit Area

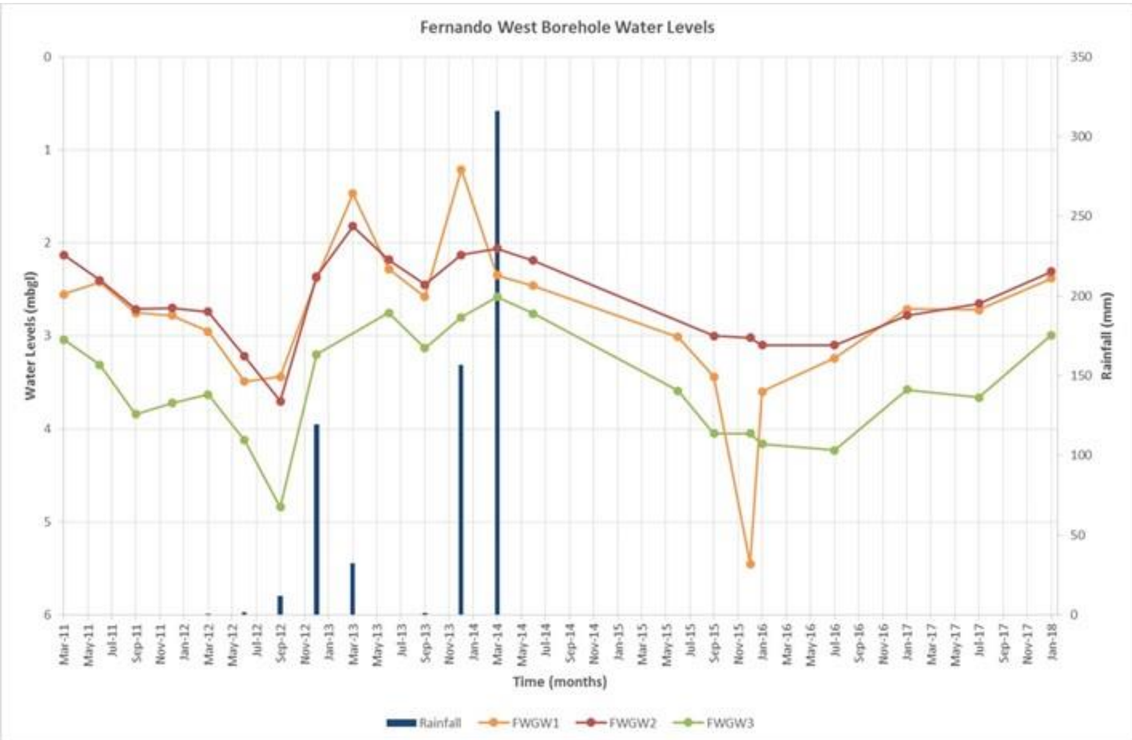


Figure 5-5: Forzando South groundwater levels for the western boreholes

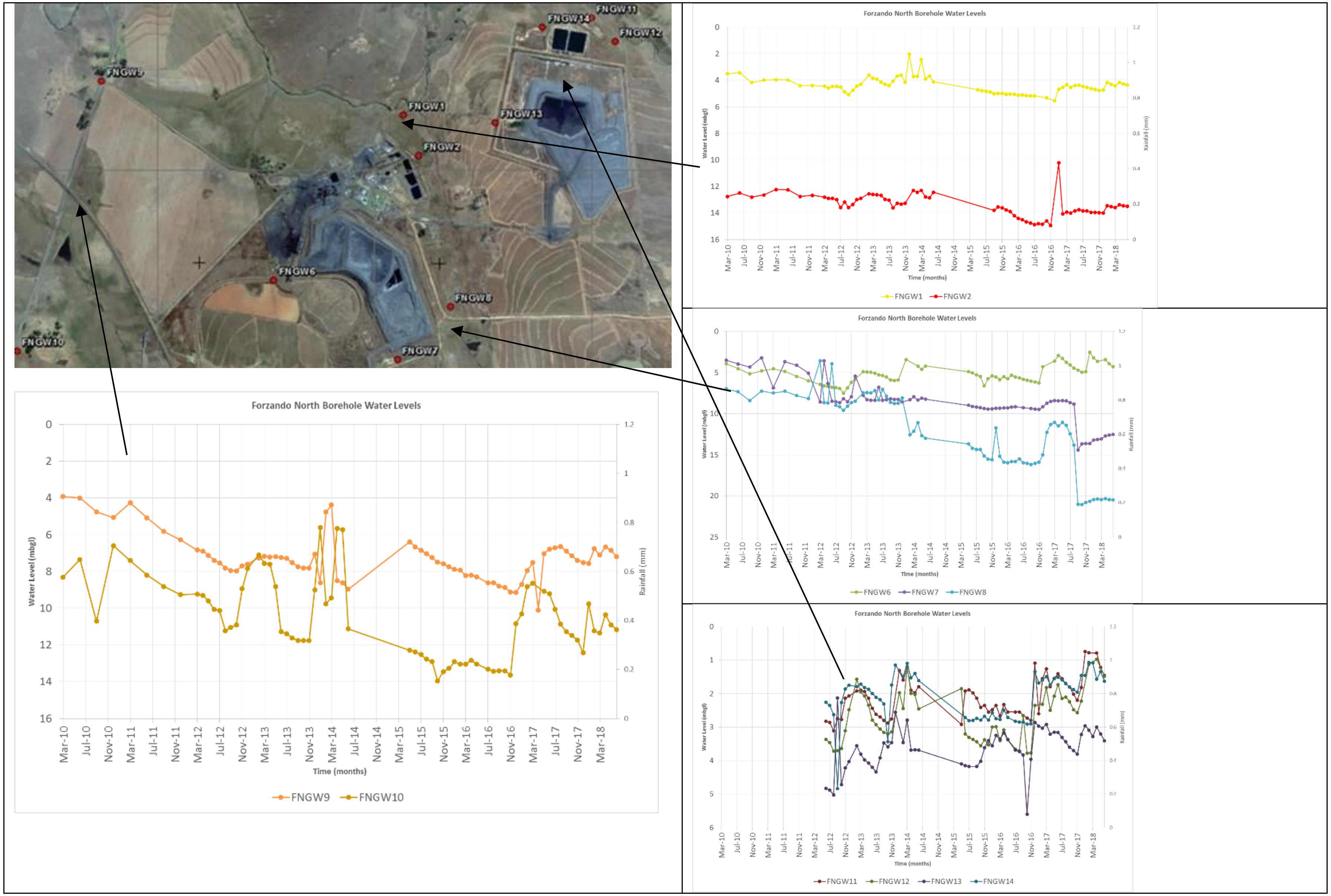


Figure 5-6: Forzando North groundwater levels

6 GROUNDWATER QUALITY ASSESSMENT

The analytical results were compared to the Department of Water Affairs' and Forestry (now DWS) South African Water Quality Guidelines for Domestic Use Target Water Quality Range (DWA SAWQ TWQR) and the South Africa National Standard (SANS 241-1:2011) for Drinking Water in order to evaluate the groundwater quality. It should be noted that these guidelines are intended for potable water use and not environmental compliance. The hydrochemistry results should be analysed in context of the natural ambient groundwater quality of the area.

6.1 Regional and Ambient Water Quality Data

The hydrocensus boreholes exceeded the following compliance objectives (Table 6-1 and Table 6-2):

- Electrical conductivity of samples NBH7, NBH13 and KF-HC9 exceeded the least stringent limits as set by the SAWQG Domestic Use TWQR.
- Although the Ca concentrations are all fairly low (between 38 and 70 mg/l) it exceeded the SAWQG Domestic Use TWQR which is 32 mg/l.
- High Mg concentrations at NBH13 exceeded the SAWQG Domestic Use TWQR.
- Three sites (KF HC 8, 9 and 11) exceeded the 100mg/l concentration level which marks the SAWQG Domestic Use TWQR.
- Three sites, KF HC 2, 4 and 8, indicates NO_3 concentrations above TWQR.

Figure 6-1 supplies an explanation of typical fields where water can plot within a Piper diagram. The piper plots (refer to Figure 6-2 and Figure 6-3) indicate naturally occurring HCO_3 and $CaCO_3$ (T.Alk.) rich water and that the samples plot within the temporary hardness segment with respect to Mg and Ca. There is currently only one borehole indicating slight SO_4 domination, sample P1, which represents hydrocensus borehole KF HC 4. It can therefore be concluded that the groundwater qualities observed are a good representation of ambient conditions with slight agricultural influence evident.

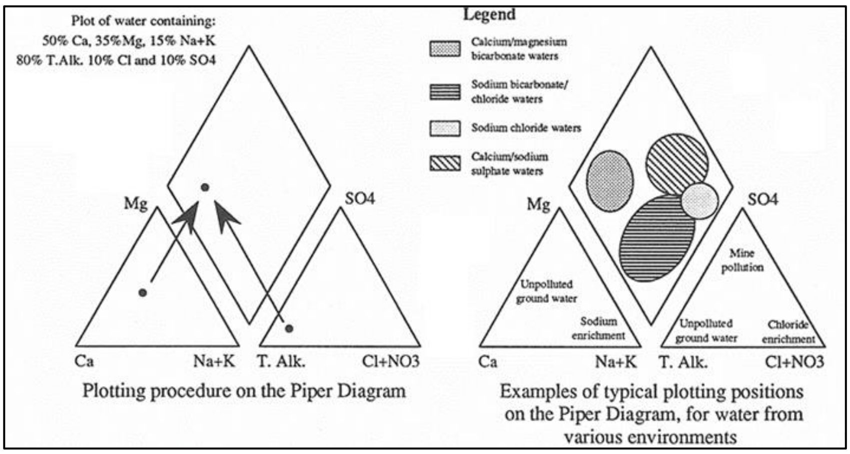


Figure 6-1: Typical plot positions on a Piper Diagram to determine water type

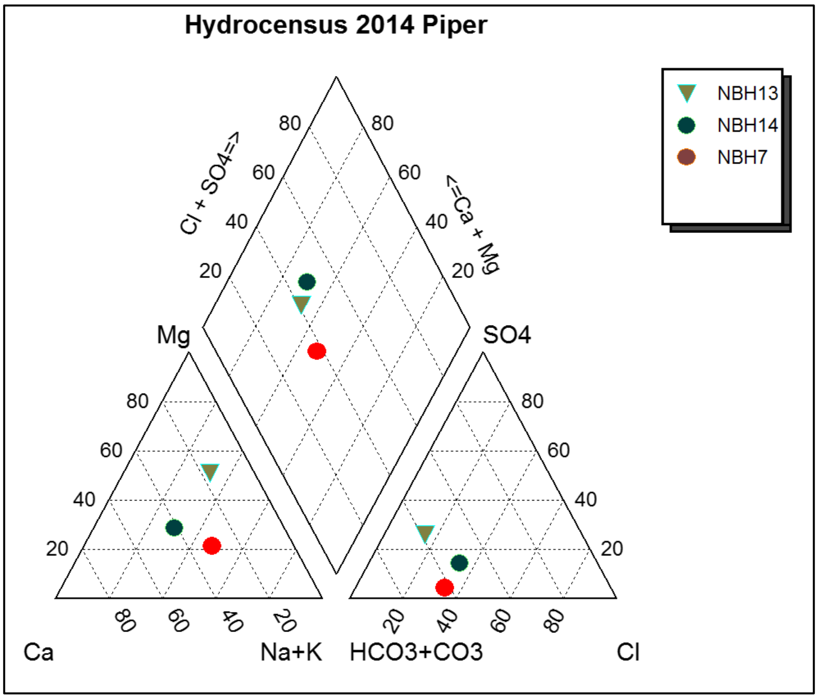


Figure 6-2: Hydrocensus Piper Plot 2014 Data

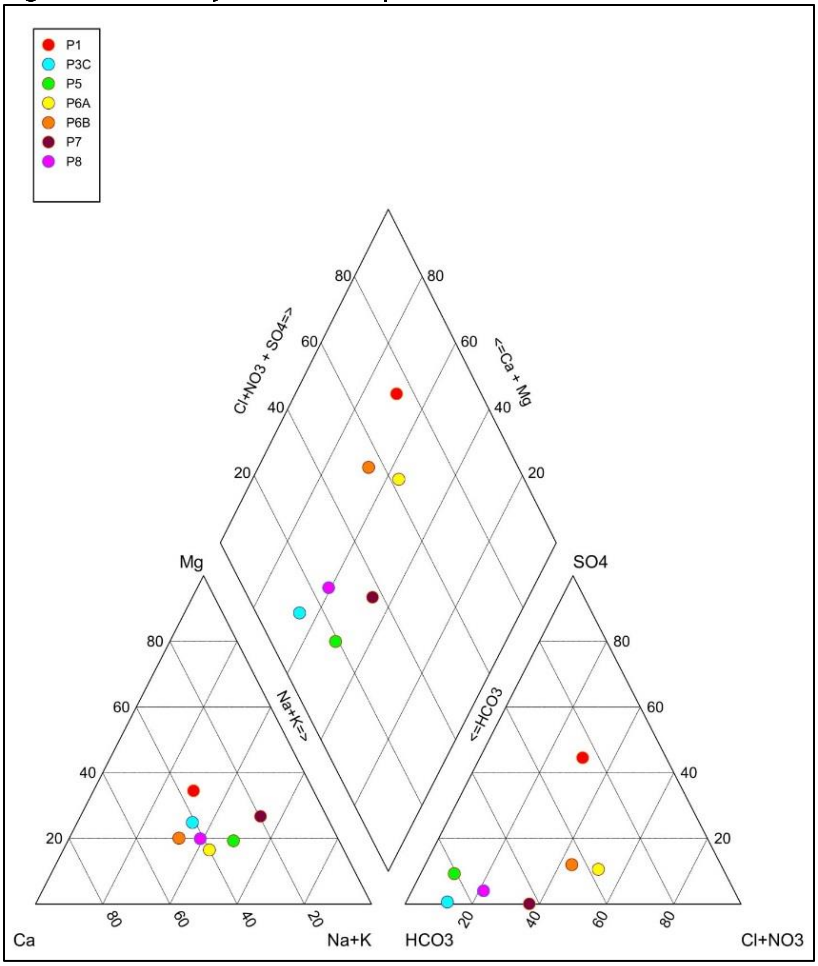


Figure 6-3: Hydrocensus Piper Plot 2018 Data

Table 6-1: Hydrocensus Hydrochemistry Results - 2014

Parameter (mg/l)	SAWQG Domestic Use Target Values	SANS 241-1: 2011 Drinking Water Standards	NBH7	NBH11	NBH13	NBH14
pH at 22ºC	6-9	5-9.7	7.87	7.9	8.36	7.97
Conductivity mS/m @ 25°C	<70	<170	104.20	36.7	92.3	66.6
Total Dissolved Solids	<450	<1200				
Calcium, Ca	<32	NS	57.2		28.7	46.3
Magnesium, Mg (mg/l)	<30	NS	24.2		52.9	19.7
Sodium, Na	<100	<200	97.7		50.7	32.8
Potassium, K	<50	NS	7.63		22.2	10.7
Total Hardness as CaCO3	NS	NS				
Bicarbonate, HCO_3	NS	NS	274.1	91.6	261.1	147.1
Chloride, Cl	<100	<300	86.4	82.3	39.6	56.6
Sulphate, SO_4	<200	<500	15.6	28.4	91.7	32.3
Nitrate as NO_3	<6	<11	<0.1	2.81	<0.1	4.91
Fluoride, F	1	1.5	0.32	<0.1	0.74	0.2
Aluminium, Al	<0.15	NS	<0.02		<0.02	<0.02
Manganese, Mn	<0.05	0.5	0.052		<0.02	0.043
Iron, Fe	<0.1	2	<0.02		0.036	<0.02
Zinc, Zn	<3	5	0.032		0.036	0.175
Cobalt, Co	NS	<0.5	<0.02		<0.02	<0.02
Copper, Cu	<1.0	2	<0.02		<0.02	<0.02
Exceeding least stringent limit						
Exceeding most stringent limit						

** NBH11 was damaged during courier transport and the container leaked. ICP-OES was thus not performed on the sample.*

Table 6-2: Hydrocensus Hydrochemistry Results - 2018

Parameter (mg/l)	SAWQG Domestic Use Target Values	SANS 241-1: 2011 Drinking Water Standards	KF-HC4 (P1)	KF-HC7 (P3C)	KF-HC10 (P5)	KF-HC8 (P6A)	KF-HC9 (P6B)	KF-HC11 (P7)	KF-HC2 (P8)
pH @ 25°C	6.0-9.0	5.0-9.7	6.4	7.1	8.5	7.7	7.7	8.0	7.5
Conductivity mS/m @ 25°C	<70	<170	42	43	52	65	74	70	60
Total Dissolved Solids	<450	<1200	400	270	400	490	440	420	350
Calcium, Ca	<32	NS	29	38	35	52	70	28	51
Magnesium, Mg (mg/l)	<30	NS	17	14	13	13	18	23	15
Sodium, Na	<100	<200	22	32	60	60	51	83	47
Potassium, K	<50	NS	9.8	7.7	5.1	8.3	7.7	7.6	15.0
Total Alkalinity as $CaCO_3$	NS	NS	50	190	190	110	170	255	250
Bicarbonate, HCO_3	NS	NS	61	232	232	134	207	311	305
Chloride, Cl	<100	<300	27	19	16	102	118	106	41
Sulphate, SO_4	<200	<500	86.0	1.3	21.0	30.0	44.0	0.3	13.0
Nitrate as NO_3	<6	<11	29.0	<0.1	1.2	13.0	0.5	<0.1	17.0
Aluminium, Al	<0.15	NS	0.018	<0.003	<0.003	<0.003	<0.003	<0.003	0.004
Manganese, Mn	<0.05	0.5	0.006	0.200	<0.002	0.002	0.006	0.064	0.004
Iron, Fe	<0.1	2	<0.05	<0.050	<0.050	<0.050	<0.050	0.050	<0.050
Exceeding least stringent limit									
Exceeding most stringent limit									

6.2 Forzando Groundwater Monitoring Water Quality Overview

Sulphate concentrations at the two Forzando South Boreholes are consistently low with some seasonal fluctuations for monitoring borehole FSGW3 (Figure 6-4).

Sulphate (SO_4) concentrations exceeded the Forzando North WUL limit for Groundwater at FNGW02 (borehole downgradient of the pollution dams, Figure 6-5), FNGW08 (down gradient of discard dump, Figure 6-6), FNGW11 (borehole downgradient of PCD), FNGW12 (borehole downgradient of PCD) and FNGW14 (downgradient of PCD), Figure 6-7. The sulphate concentrations of FNGW08, FNGW11 and FNGW14 remain within the SANS 241-1:2015 Drinking Water Limits, while the sulphate concentration of FNGW02 & FNGW12 exceeded the SANS 241- 1:2015 Drinking Water Limits (Figure 6-7).

The pH values were neutral for all monitoring boreholes as can be seen from Figure 6-4 and Figure 6-7.

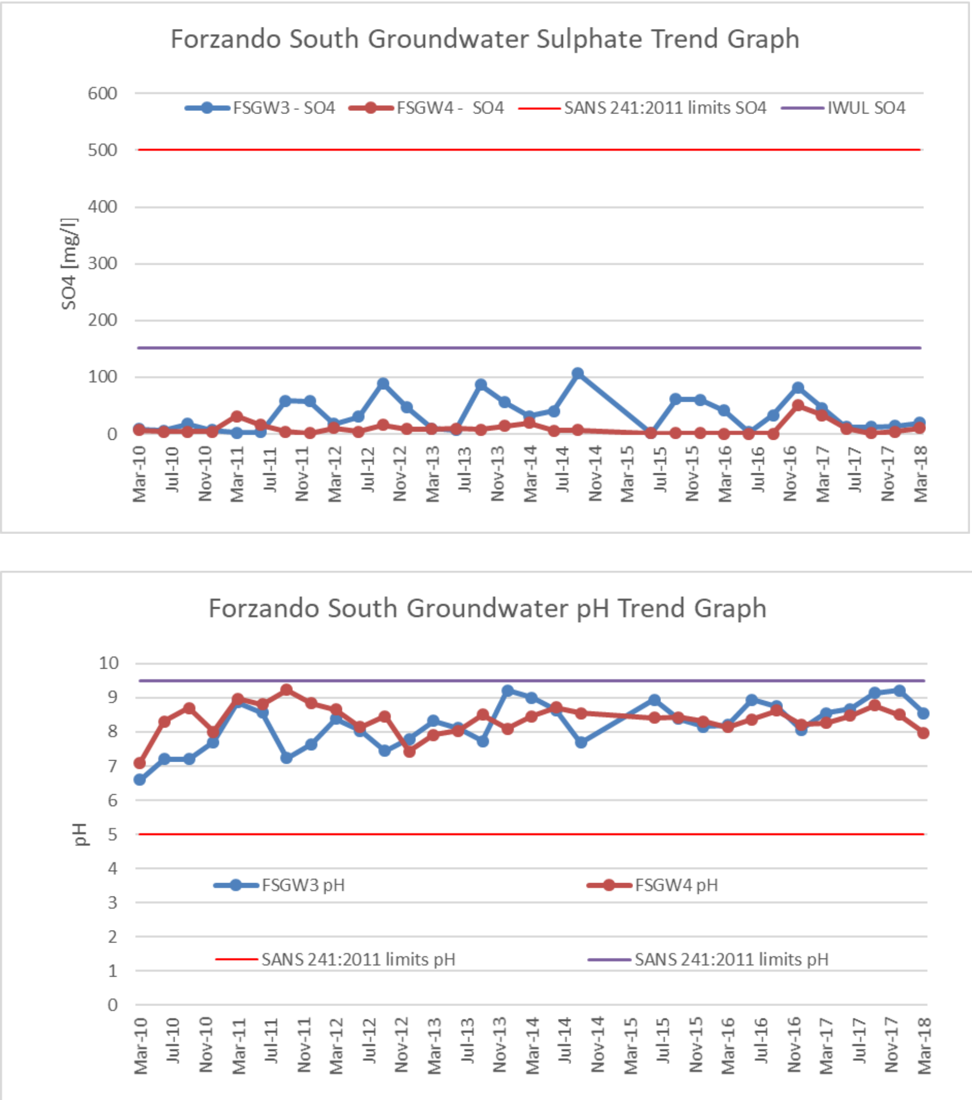


Figure 6-4: Forzando South Groundwater Sulphate and pH trend Graph

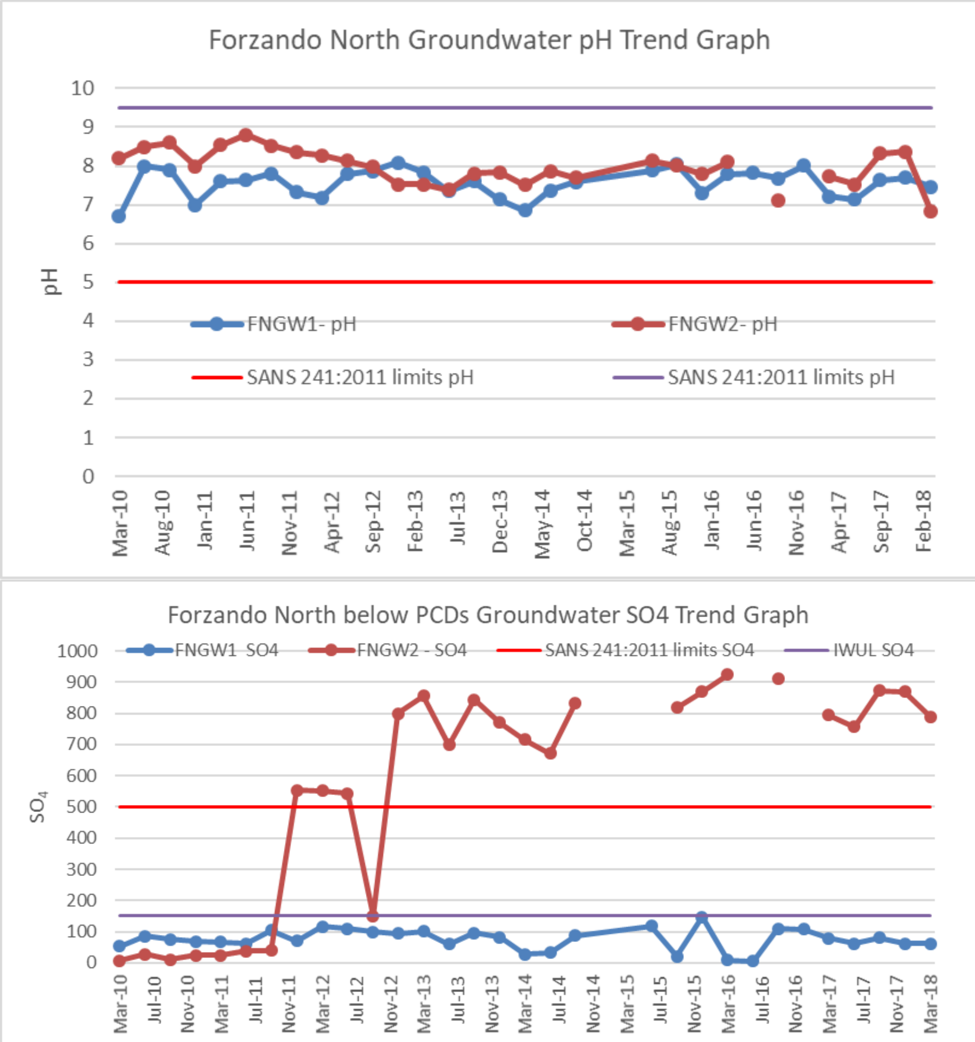


Figure 6-5: Forzando North Groundwater Sulphate and pH trend Graph for FGW1 and 2 below PCDs at Plant area

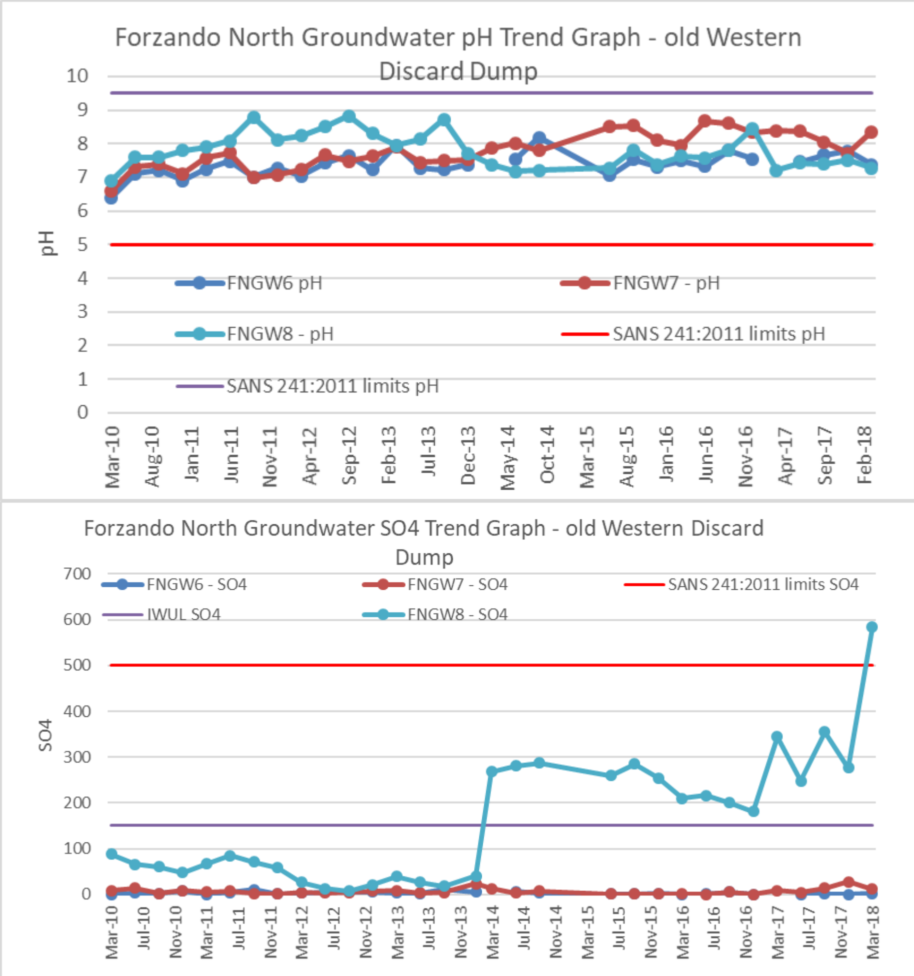


Figure 6-6: Forzando North Groundwater Sulphate and pH trend Graph for boreholes at the old western discard dump

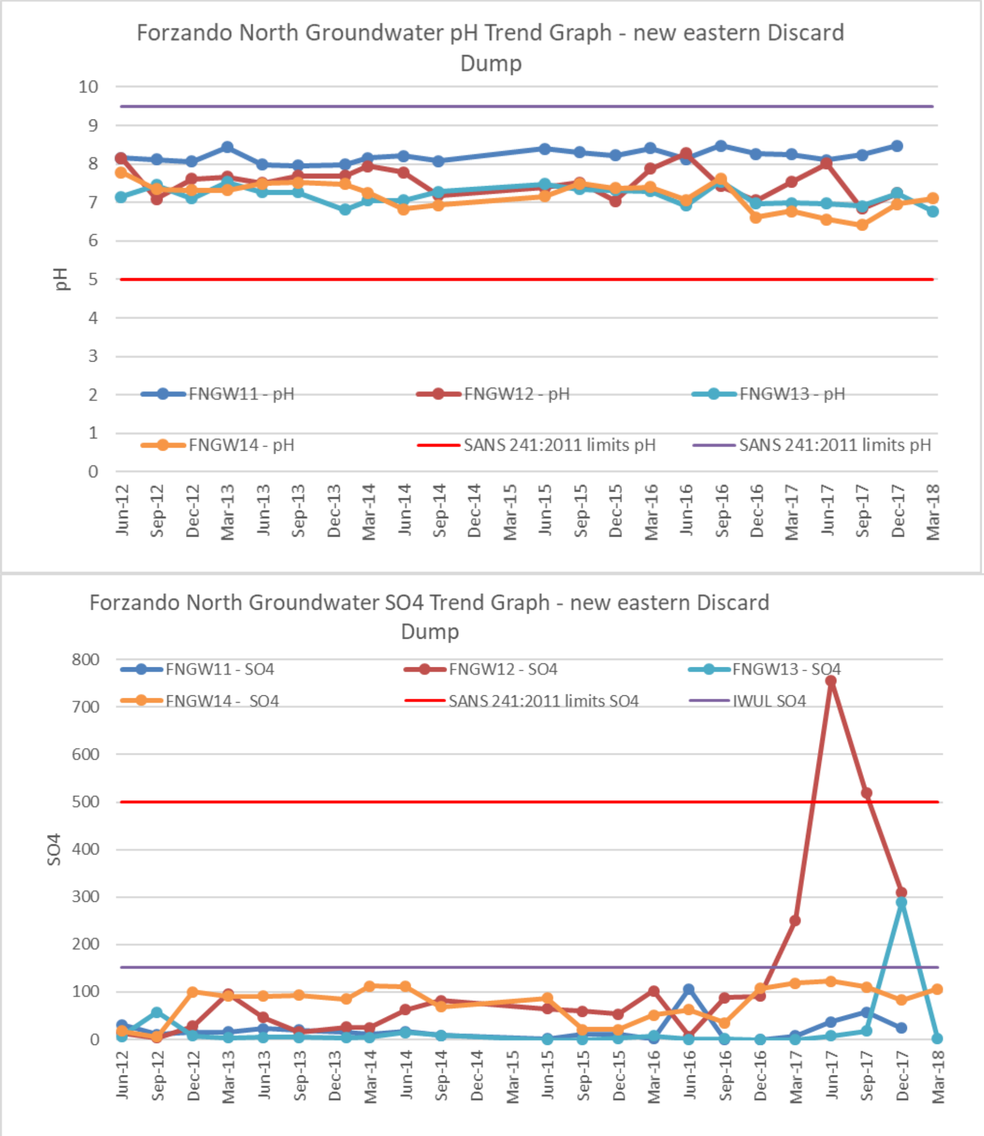


Figure 6-7: Forzando North Groundwater Sulphate and pH trend Graph

6.3 Underground Water Chemistry

Water quality data for three underground water dams at Forzando North area are included in this section. These samples are FNSW17 (Delta), FNSW18 (Section 29) and FNSW19 (Triangle-Junction). In our opinion, this data is critical towards understanding the behavior of underground water quality in mining sections that are not currently mined.

Seven years' worth of data is considered and the results of the ABA testing will also be considered when predicting potential mine water qualities that may develop over time

Two (FNSW17 & FNSW18) of the three underground sampling localities were sampled during the quarterly period in 2018. FNSW19 was not sampled during the quarterly period. Refer to Table 6-3 for the 2018 data summary.

Sulphate and pH data usually supply an indication of the leachate potential of host rock and available coal pillars.

- It can be seen from the sulphate time (SO_4) graph in Figure 6-8 that generally an increasing trend occurs.
- Figure 6-9 shows stable and neutral pH.

Table 6-3: Summary of the 2018 quarterly water quality for the underground FN samples

Parameter	FNSW17	FNSW18
pH @ 25°C	7.81	7.96
(EC) @ 25°C mS/m	195	318
TDS mg/l	1748	3080
Sulphate (SO_4) mg/l	1063	1988
Iron (Fe)	0.002	0.002

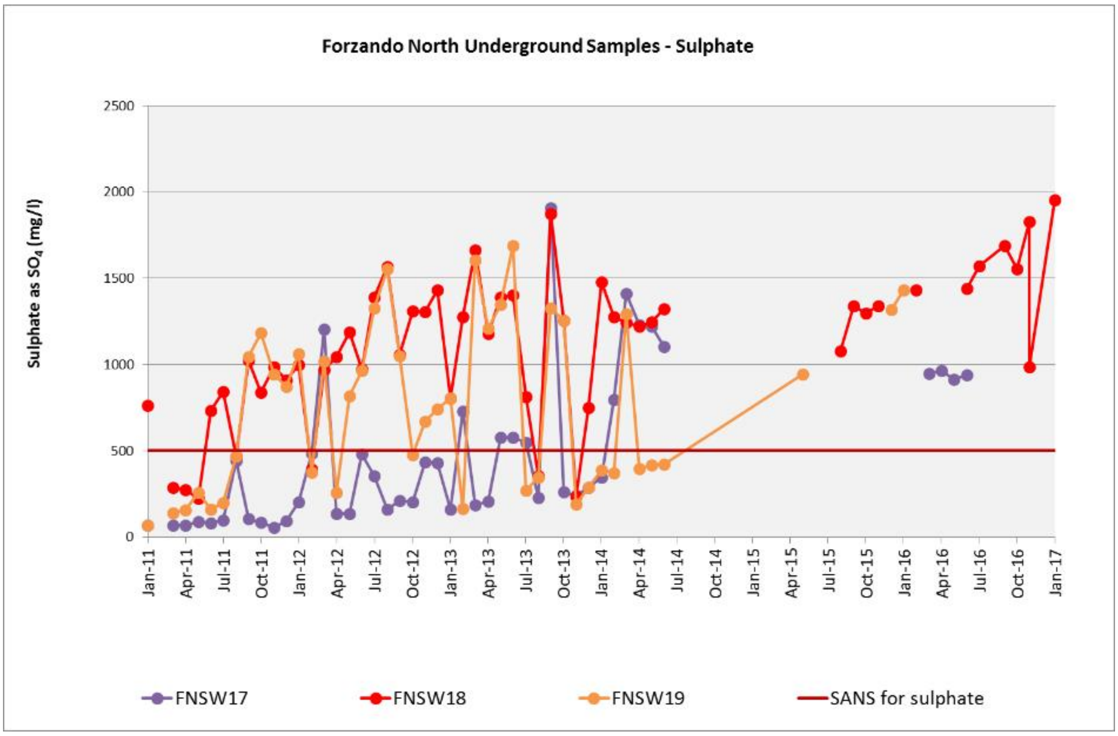


Figure 6-8: Sulphate time graph for the underground mine water

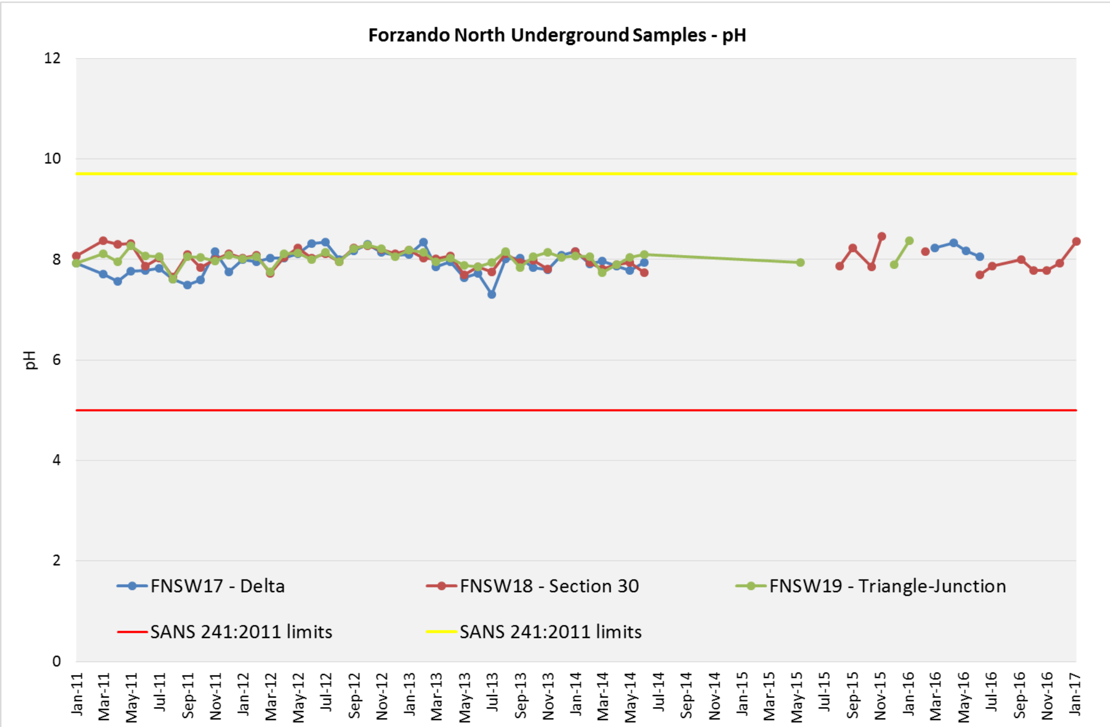


Figure 6-9: pH time graph for the underground mine water

7 GEOCHEMICAL ASSESSMENT

The Geochemical data was generated through three phases, two preliminary acid base accounting (ABA) exercises (2002 and 2010) and 1 detailed geochemical assessment phase conducted in 2014. The 2002 and 2010 data as well as the detailed 2014 report is attached in **Appendix C** of this report. The data will be used for the Kalabasfontein project also since the coal characteristics are similar to the samples already analysed.

7.1 Geochemical Assessment 2014

A total of fourteen (14) samples were collected for geochemical testing. A description of the samples is given in Table 7-1 below. The ICP, XRF and XRD lab result data is attached as part of the full report in **Appendix C.**

The following samples were analysed (refer to Table 7-1):

Table 7-1: Sample description

Sample	*	Rock Type	Description
FZ-S and FZ-N product (conveyed to FZ-N) 1 sample		ROM coal	ROM from both Forzando south and north. Both are stockpiled together (mixed)
FZ-S UG Section 44 SP 14 Floor		Coal (floor)	Fresh underground coal sample. Floor Sample.
FZ-S UG Section 44 SP14 Roof		Coal (roof)	Fresh underground coal sample. Roof Sample.
FZ-N Dump 1a Discard		Coal discard	
FZ-N Dump 1a Slurry		Coal slurry	
FZ-N Dump 2b Discard		Coal discard	
FZ-N Dump 2b Dry Slurry		Coal slurry (dry)	
FZ-N Dump 2c Discard		Coal discard	
FZ-N Dump 3 Discard fresh		Coal discard	
FZ-N Dump 3 Discard Old		Coal discard	
FZ-N Dump 3 Slurry		Coal slurry	
FZ-N UG Section 1 Roof		Coal (roof)	Coal form the underground workings. Roof Sample.
FZ-N UG Section 1 Floor		Coal (floor)	Coal from the underground workings. Floor Sample.

*** Black = Coal (Coal seams and product), Dark Grey = Coal Discard, Light Grey = Coal Slurry, Blue = ROM.**

From the data and report attached in Appendix C, the following concluding remarks can be made:

Sampling

A total of 14 samples from the discard dump and the underground roof and floor were collected for geochemical testing.

Mineralogy

- Pyrite was the only sulphide mineral detected in the samples. Pyrite is generally elevated in coal with respect to clastic rocks due to formation under reducing conditions. In general, oxidation of pyrite is a major source of acid-mine drainage generation;
- Carbonate minerals detected include calcite, dolomite and siderite. Calcite and dolomite are important minerals in the neutralization of acidity produced by pyrite oxidation in acid-mine drainage (AMD) and frequently occurs in Karoo sedimentary rocks. Siderite does not contribute to the neutralization of AMD as it only neutralizes the acid generated by the oxidation of its own Fe;

Acid-base Accounting and Net Acid Generation tests

- The 4 roof and floor coal samples have a %S higher than ~1% and 1 sample with very high %S of 5.17%. The neutralization potential of 2 samples are very low compared to the acid potential and have a significant potential to generate acid mine drainage. The other 2 samples have a higher neutralization potential but are still likely to generate acid mine drainage. The NAG test results confirmed that the first samples have the potential to generate acid mine drainage, but the latter 2 did not acidify during the test;
- 4 of the 5 discard samples have a %S higher than ~1% and 1 sample 0.46%. The samples have a relative low, to no, neutralization potential compared to the acid potential and are most likely to generate acid mine drainage. Only 2 of the 5 samples acidified during the NAG test;
- The 3 slurry samples have a %S higher than 0.3%, 1 sample has a very high %S of 2.60%. The samples have a high acid potential and low neutralization potential and have a significant potential to generate acid mine drainage. 1 sample acidified during the NAG test and the other 2 were classified as uncertain;
- The run of mine sample has a %S of 0.78%. The sample has almost no neutralization potential and is likely to generate acid mine drainage. During the NAG test the samples also acidified;
- Overall, it could be concluded that both the coal samples from the underground as well as the discard samples have a significant potential to generate acid mine drainage/seepage under oxidizing conditions. Whether acidification will actually takes place will depend on the availability of oxygen and the ability of the host rock to buffer any ARD (which is fortunately high in Ca and Mg minerals).

Potential impact on drainage quality

- Discard dump: Most discard will form hot-spot material and will acidify over the long-term. Hot-spot interburden material will have a SO_4 of probably up to 4 500 mg/l although it will vary over the dump (even up to 8 000 mg/l in high %S discard);
- Underground: Acid-mine drainage generation in the underground will depend on the oxygen ingress vs time for the mine to flood. While oxygen is still present, the underground mine water will reach SO_4 concentrations of about 2 700 - 2 900 mg/l for the higher (4% of MAP) and lower recharge rates (2% MAP) respectively. After oxygen is depleted no more SO_4 is generated and the mine water will slowly be flushed with infiltrating groundwater. The recharge on the underground mine is however so low that SO_4 will remain at a fairly constant concentration of around 2 500 - 2 800 mg/l for several decades;
- It is not foreseen that metals will be significantly present in neutral drainage conditions. Al, Fe and Mn will be present at elevated concentrations in acidic mine drainage conditions. Other metals that may leach in acidic drainage conditions include Ni, Co and Pb.

8 NUMERICAL GROUNDWATER MODEL

The numerical model used in this modelling study was based on the hydrogeological conceptual model and numerical groundwater model developed in the previous studies (GCS, 2009 and 2014). The model was updated with the recent field work data as well as monitoring, geology and mine plan data received from the client. Updated changes were also applied to the model and includes grid and layer refinement as well as model boundary refinement. The model setup can be viewed from **Appendix D** and successful calibration was achieved.

The scenarios to be simulated using the Forzando regional model include the following and will be discussed in the next section:

- Potential groundwater ingress;
- Groundwater drawdown; and
- The potential extent of groundwater contamination from both the mine workings and the surface infrastructure.

9 GROUNDWATER IMPACTS – THE STATUS QUO AND OPERATIONAL PHASE

The objective of this section is to apply all available hydrogeological and geological assessment data and to interpret the data, via numerical modelling, into an understandable risk or impact to the environment. In the context of this report, an impact is defined as a source of potential harm or a situation with a potential for causing harm, in terms of the environment, with special focus on the groundwater and surface water environments (CSA 2009).

To ensure uniformity, the assessment of potential impacts has been addressed in a standard manner so that a wide range of impacts are comparable. The methodology utilised is obtained from the client and based on NEMA EIA Regulations (2010). The methodology is explained in **Appendix E** of this report.

Usually, the impacts are explained per mining phase (i.e. construction, operational, closure and post closure), but for this assessment the current situation or status quo will be discussed and the focus will then be on the closure of the facilities.

9.1 Status Quo of Groundwater Quantity (Groundwater level drawdown) –

Underground mining commenced in the 1990s at the Forzando North Section and later at the South Section. The mine workings will have an impact in terms of groundwater flow because of the current zone of de-watering or “cone of depression” around the underground workings.

Influx rates of water into underground bord-and-pillar areas are usually low. Water seeps are usually present in the coalface of a new and existing development within the South African coal fields and Karoo formations. The vertical hydraulic conductivity of the over- and underlying sediments is too low to convey significant amounts of water into underground mines. Sub-vertical fissures that yield water for a limited period (weeks rather than months) may be intersected on occasion. In exceptional cases, a sustained but low flow of groundwater may be intersected. Instances where coal mining had to stop for a length of time because of groundwater influx are almost non-existing.

The accurate quantification of groundwater influx into bord-and-pillar workings is difficult. A vast number of depressions in the coal floor exist where water accumulates. Water on the coal seam is usually only notable when it interferes with mining.

Mining and associated dewatering activities will result in some inflow of groundwater into the mine which could reduce the groundwater available to local farm users. The extent of dewatering of the upper aquifer system is expected to be minimal and will be confined to parts of the existing (FN, FS) and proposed mining (Kalabasfontein) area where the depth to the seam is shallow (i.e.25- 30 m below surface) and where geology structures connects the upper weathered zone with the lower S4 seam and associated geological formations.

9.1.1 Forzando North Area

The Forzando North Area has been assessed previously and this section only supplies an update.

Due to the low vertical transmissivities, this uncertainty greatly affects the estimation of the influx values. Several dyke systems intersect the coal seam over the mine area and these are areas of potentially higher ingress. Observations at Forzando North mine have indicated that an increase in ingress occurs along intrusive dyke contacts, but that the influx is not excessive (DWA, 2002).

The following lists some of the important findings from both historical data and the recent numerical groundwater model simulations:

- Original estimates indicated that the groundwater inflow into the mine workings should not exceed about 750 m^3/day. However, experience indicated that once mining has commenced, inflow into the mine workings is limited (WMB, 2002).
- An analysis of the water management information indicates an average influx of 5 Ml/month for 2001 (166 m^3/day) for Forzando North Mine. The mined seam area was about 350 ha, thus relating to an influx of 0.5 m^3/ha/day of mined seam. This is equal to 0.04 l/m^2/day of mined seam, and correlates well with the visual observations

made during a visit underground (DWA, 2002). Heavier influxes are associated with the contacts with intrusive dykes in Forzando Mine.

- For this assessment the simulated inflow (i.e. data obtained from the calibrated numerical groundwater model) in 2014 and 2018 into the Forzando North Workings was in the order of 1 700 m^3/day as the upper range (refer to **Figure 9-1**) for a mined out area of approximately 1 240 ha; thus relating to an influx in the order of 1.3 m^3/ha/day of mined seam. It must be cautioned that these calculations have been done using simplified assumptions of homogeneous aquifer conditions and a simplified mining schedule. The reality could deviate substantially from this and the model should thus be updated as more information becomes available.

This volume of water relates to 2.5% of MAP over the surface area of the mine. The recharge estimates from various studies indicate a recharge of 2.5 to 4% of MAP for areas underlain by the Vryheid Formation of the Karoo Supergroup (DWA, 2002).

Water Balance Considerations

The results of the Water Balance (GCS, 2014 /Ref13-608) indicates:

- At least 68 238 m^3/annum of groundwater ingress is treated at the purification plant.
- A total of 71 508 m^3 (195m^3/day) is pumped to the underground workings per annum.
- A total "IN" from underground for the average water balance is in the order of 1 964 m^3/day.
- If the amount of water pumped back to underground workings is subtracted the total estimated underground ingress is in the order of 1 750m^3/day.

The groundwater model was calibrated to more or less reflect the figures obtained from the mine and the different time steps can be seen in Figure 9-1 where the maximum inflow is in the order of 1 750 m^3/day.

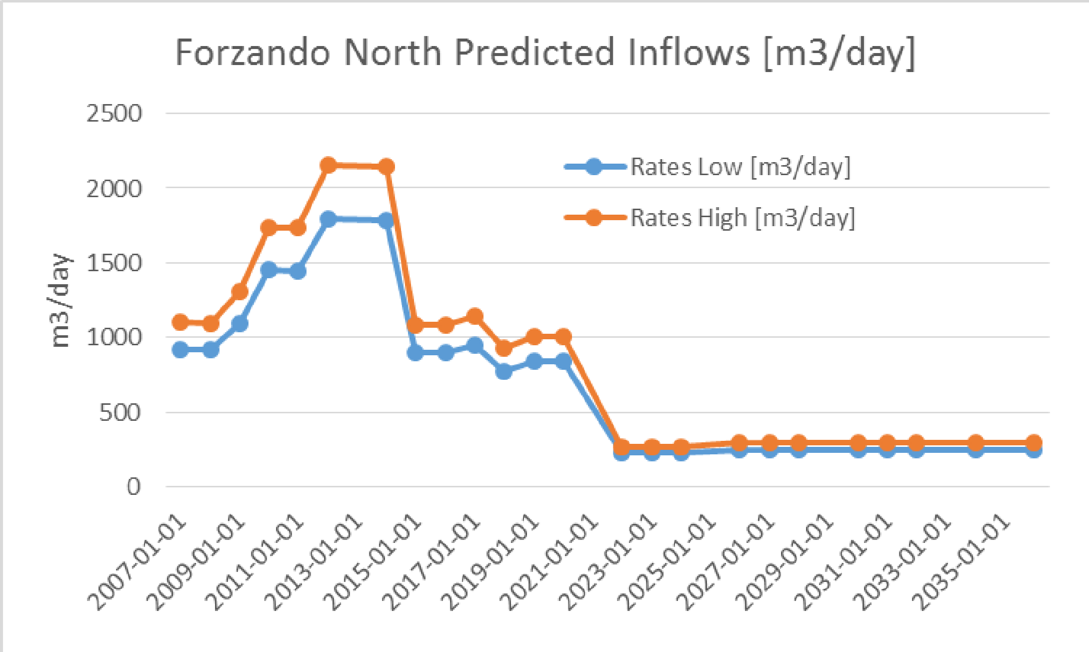


Figure 9-1: Simulated inflow rates for the Forzando North Area

9.1.2 Forzando South Area

For the calibration of the Forzando South/West area the proposed Kalabasfontein project area was included. Refer to Figure 9-3 for the simulated underground mine inflow rates, the model was calibrated on the current predicted and assumed inflow rates which is in the order of 500 to 1000 m^3/day. However, current figures from the client suggest significantly lower pump rates to surface; volumes between 200 and 500 m^3/day were historically measured but since Oct 2016 these reduced significantly to below 100 m^3/day (Figure 9-2). It is uncertain how much water is used underground and how much is stored underground.

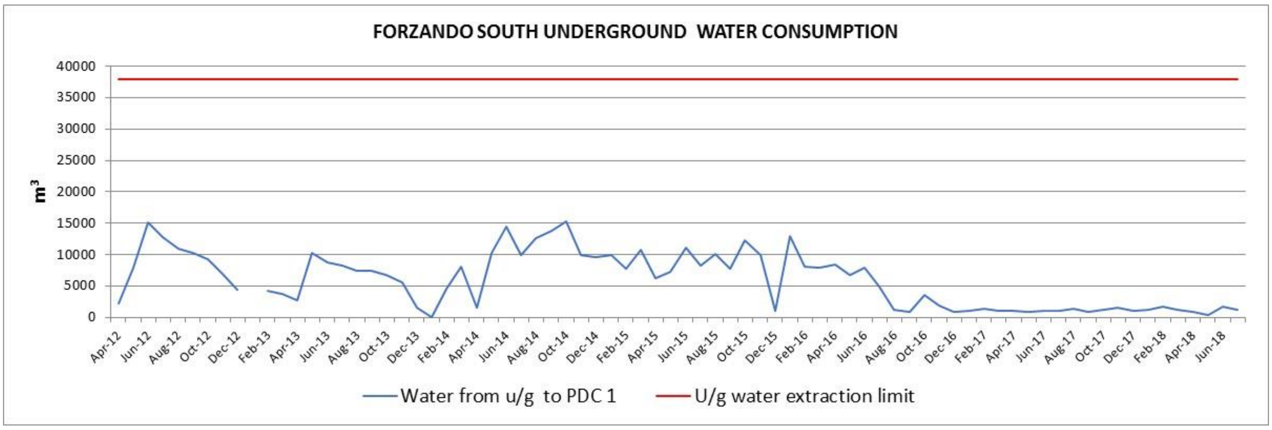


Figure 9-2: Data graph Water pump from FS UG workings (Exxaro, 2018)

Water Balance Considerations

The results of the Water Balance (GCS, 2014 /Ref13-609) show that:

- From the results it can also be seen that the process unit that accounts for the largest amount of water is the underground workings - a total of 418 752m^3/a (1 147.26 m^3/day) flows in and out of the underground workings. An average of 887 m^3/day was applied.
- The Water Balance also shows that water from PCD 1 and PCD 3 is pumped into PCD 2, where a total of 334 611 m^3/a is then pumped to Erickson Dam 1 and Erickson Dam 2. Water from Erickson Dams 1 and 2 is then pumped into the underground workings and the crusher, where it is re-used. The remaining water is then used for dust suppression - an annual average of 272 379 m^3/a.

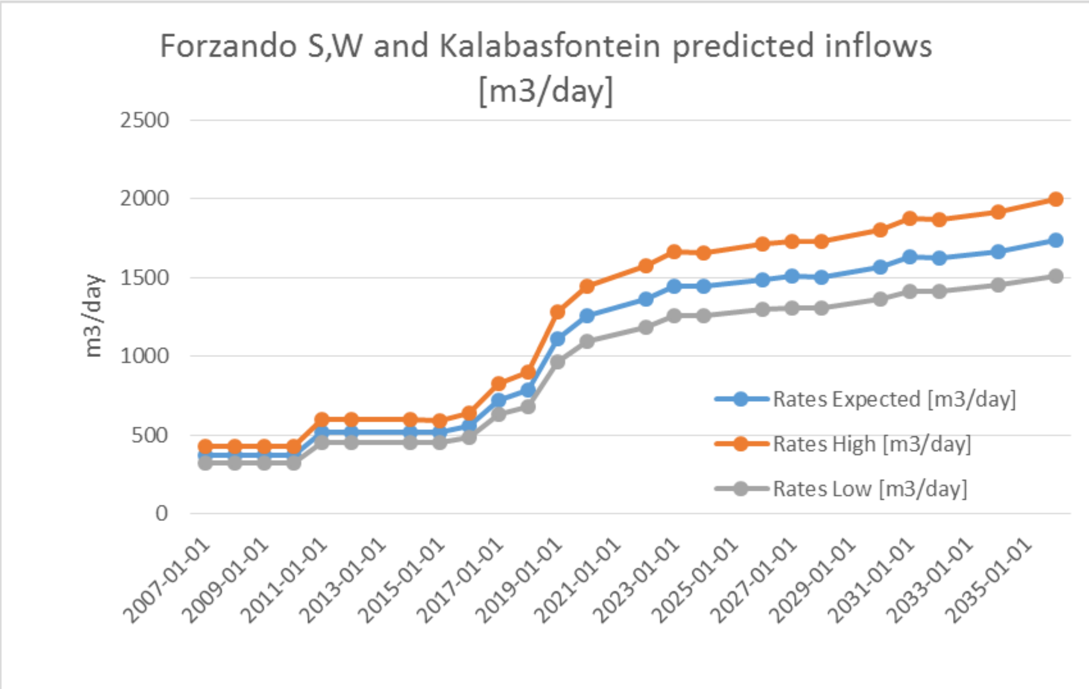


Figure 9-3: Simulated inflow rates for the Forzando South Area

9.1.3 Regional Aquifer Drawdown Prediction

The current status (2018) of regional aquifer drawdown is presented in Figure 9-4; the numerical groundwater models' drawdown simulation was completed in transient state and available groundwater level trends were applied together with the calibrated or pre-defined inflow rates discussed above.

The maximum aquifer drawdown is in the region of 3 to 5m within the shallow upper aquifer system but in certain areas this may be higher. No trend graphs exist for the regional farm boreholes and this can be highlighted as a critical feature going forward. No real evidence can be used to simulate any potential or current farm boreholes in the numerical model because not enough data for trends exist. Also, it is uncertain if aquifer drawdown at farm boreholes are caused by farming activities or de-watering activities from the mine or a combination of the two.

The life of mine (LOM) predicted aquifer drawdown zone can be viewed in Figure 9-5.

The identified farm boreholes that are, and may be in future, impacted on are marked on the map.

9.1.4 Potential for stream flow reduction due to shallow aquifer drawdown

It is not foreseen that any significant stream flow reduction will occur within the Viskuile Spruit and/or the Olifants River due to the aquifer drawdown in the area. The numerical model indicated a short period of maximum drawdown and restricted to the area around the Forzando South Adit area. Baseflow may be slightly reduced in this area and this will only be evident during the dry winter months.

To start with monitoring shallow aquifer characteristics within the Forzando South and Kalabasfontein Project Area it is proposed that shallow groundwater monitoring sites be installed during the operations phase to determine any impact on shallow groundwater flow conditions. This information will be used to update impact assessment and model calibration. Refer to Figure 9-5.

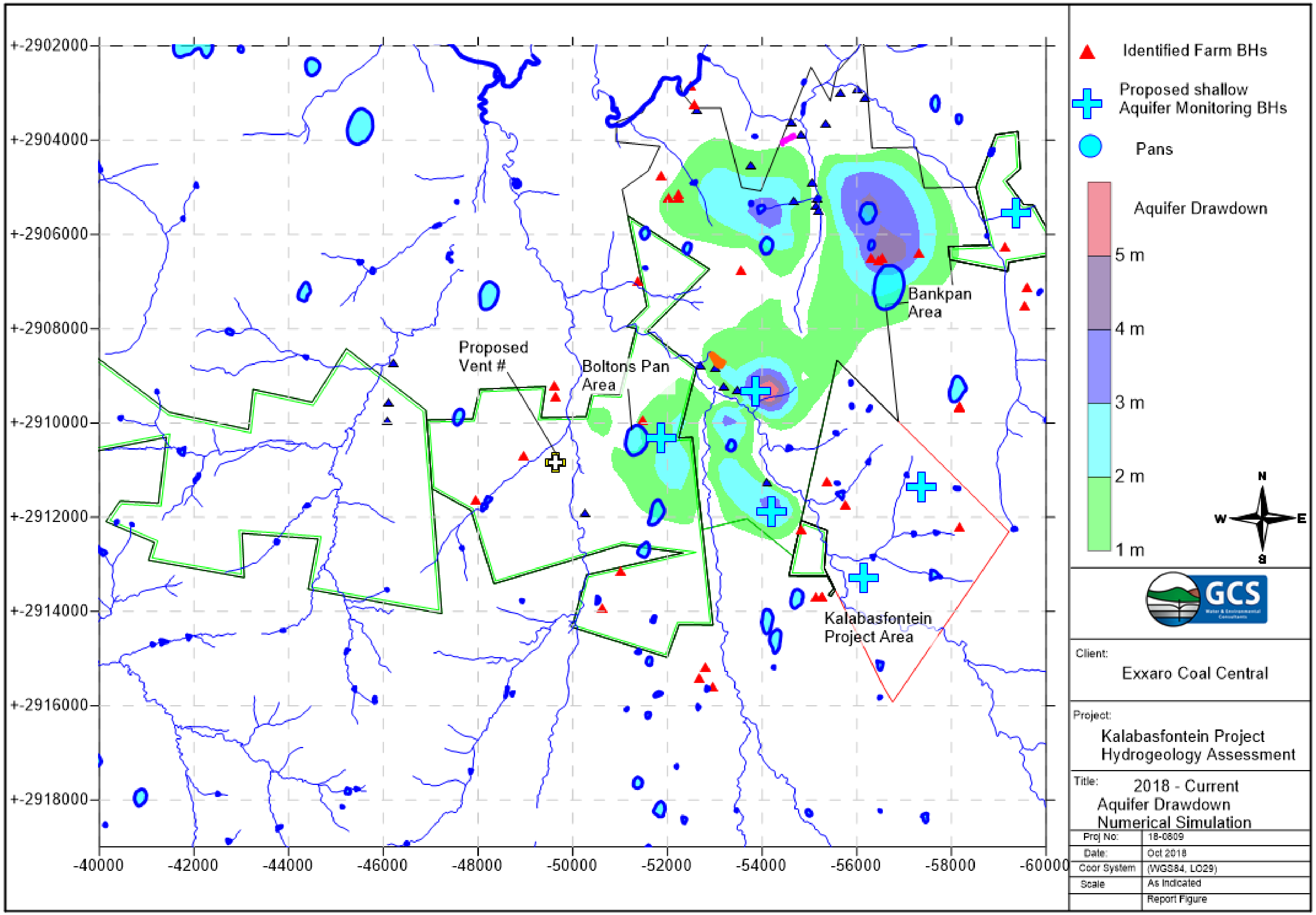


Figure 9-4: Forzando North and South regional groundwater dewatering contours in meter [m] - Status Quo

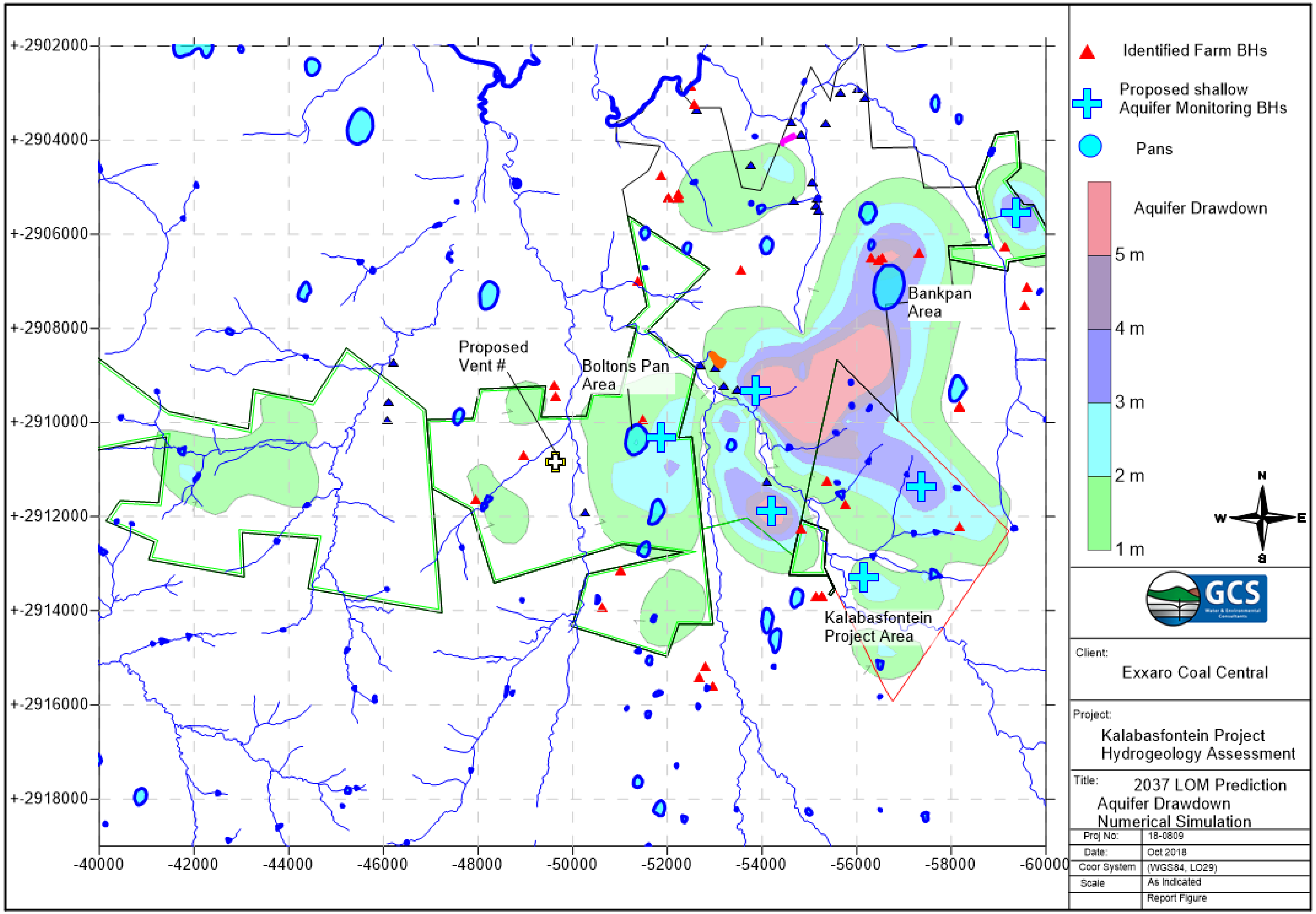


Figure 9-5: Forzando North and South regional groundwater dewatering contours in meter [m] - LOM prediction

9.2 Status Quo Groundwater Quality (Contamination of the Surrounding Aquifers)

9.2.1 Mass Transport Model Input Considerations

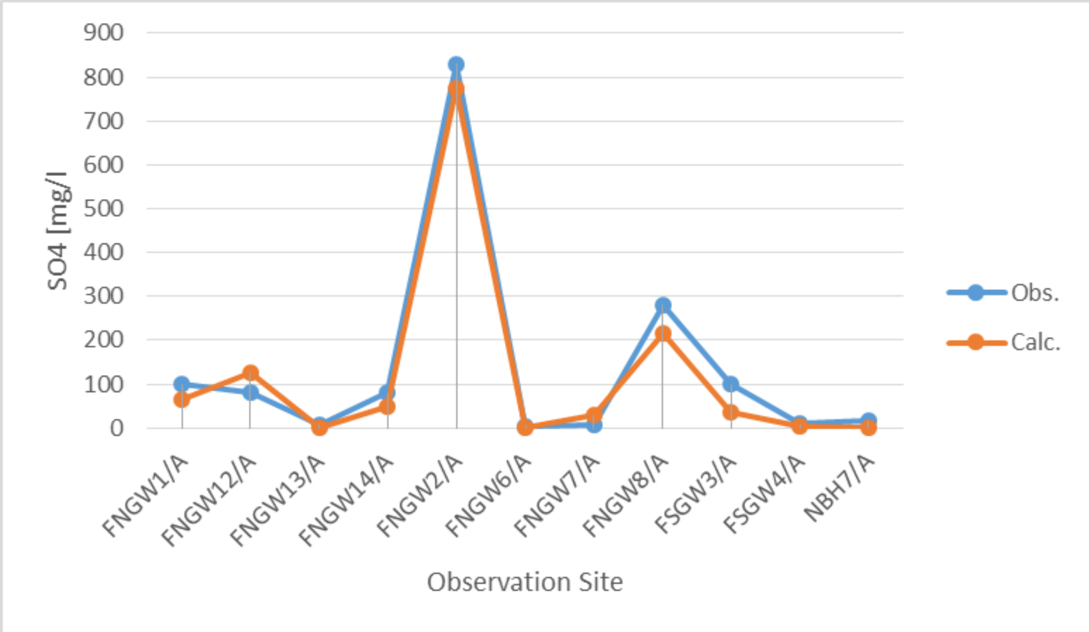
To facilitate mass transport simulations real sulphate trend data for the groundwater monitoring sites and hydrocensus sites, as well as from the underground workings (refer to water quality discussions above) were applied.

Data from the geochemical assessment were applied for the discard and underground source term:

- Seepage from the discard dump will have a potential SO_4 concentration around 2000 mg/l and as high as 4 500 mg/l over time;
- Underground mine water will reach SO_4 concentrations of about 2 700 – 2 900 mg/l for the higher (4% of MAP) and lower recharge rates (2% MAP) respectively. After oxygen is depleted no more SO_4 is generated and the mine water will slowly be flushed with infiltrating groundwater. The recharge on the underground mine is, however, so low that SO_4 will remain at a fairly constant concentration of around 2 500 - 2 800 mg/l for several decades. Sulphate monitoring data from the underground workings shows sulphate concentrations in the order of 1000 to 1500 mg/l depending on how water is stored and where it originated from. Older areas will show higher concentrations and newly opened areas will show lower concentrations. The values in the trend graph below were considered as a good starting point for the underground mining sulphate input parameter.
- It is not foreseen that metals will significantly be present in neutral drainage conditions. Al, Fe and Mn will be present at elevated concentrations in acidic mine drainage conditions. Other metals that may leach in acidic drainage conditions include Ni, Co and Pb.

9.2.2 Mass Transport calibration

As mentioned previously, the calibrated flow model was applied to simulate the transport or potential transport of mass which, for the purpose of the model, will be sulphate. The mass transport model is calibrated against available sulphate data as received from the monitoring phases; Figure 9-6 shows the correlation achieved between the monitoring data and the model simulated or “calculated” sulphate values. The correlation achieved was satisfactory and it is fair to assume that the sulphate plumes, as presented below, reflects the real field scenario and current status scenario.



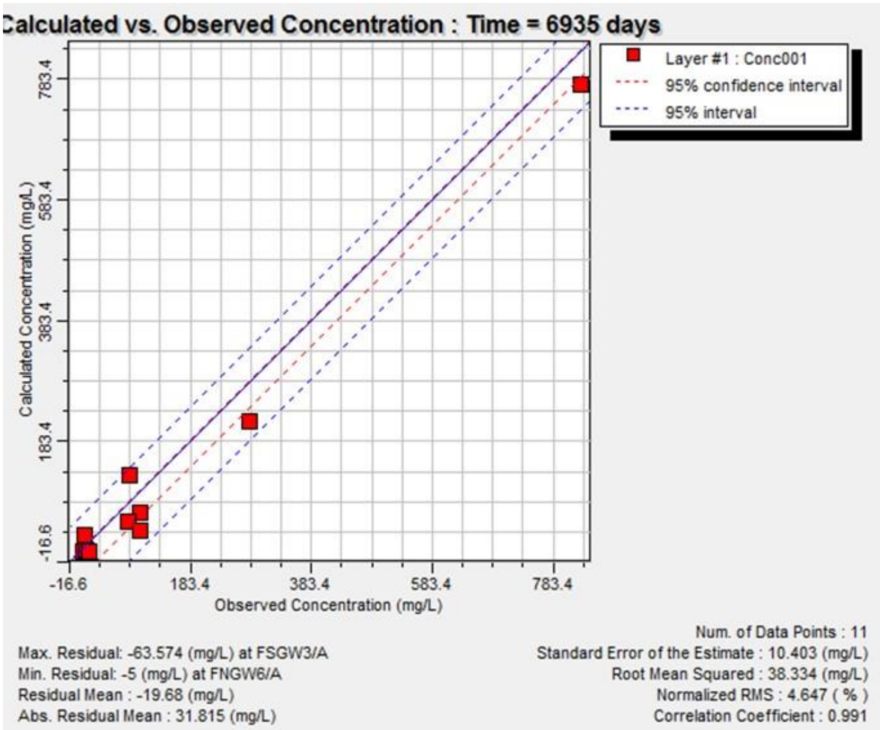


Figure 9-6: Current status Mass Transport calibration outcome for the Forzando Operations – shallow aquifer

9.2.3 Current Status Sulphate Plumes

The Forzando North underground mining sections became operational in the late 1990's; the Life of Mine was reached in 2014. This allows sufficient time for chemical reactions to have taken place in the mined-out areas, discard dumps and other potential pollution sources to produce saline seepage conditions.

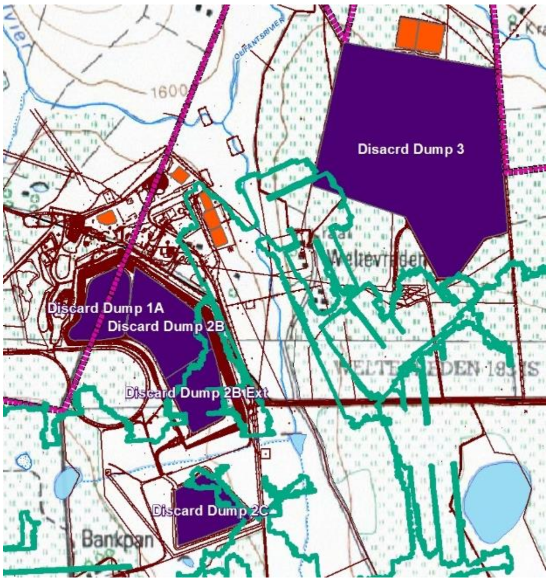
Shallow Sulphate Plumes:

Three main pollution sources exist on surface, of which the discard and slurry disposal areas located at Forzando North make up the majority. Approximately 94% consists of discard and slurry (refer to Figure 9-7), 2% are PCD's (all are lined according to communications with Exxaro) and 4% constitutes the stockpile and plant area.

As most of the surface infrastructure, like the processing plant and waste storage facilities, are located at Forzando North, the majority of sulphate leachate or potential leachate will occur in this area. Leachate from the discard dumps will follow the shallow weathered zones and topographical settings of the area. These shallow seepage or sulphate plumes will eventually discharge into streams and rivers as baseflow[2]. The extent of the sulphate plumes in the shallow aquifer are available in Figure 9-8 below.

Monitoring boreholes FNGW2 and FNGW8, located down gradient of the PCDs and discard dump area, are impacted by typical mining related contaminants (i.e. sulphate). However, none of the other monitoring sites currently indicate sulphate seepage or saline mine drainage. As mentioned earlier, the pH readings remain neutral and metal concentrations low.

Some degree of shallow seepage from the underground mine workings may occur and these zones are also demarcated on the map in Figure 9-8. These were only demarcated as a precautionary management toll and need to be re-calibrated after field confirmations. Field confirmations will include EC profiling of streams during wet and dry seasons.



Discard Area	Footprint (ha)	Percentage
1A	*14.04*	
2B	*18.01*	
2B Ext	*16.06*	
2C	*4.1*	
3	*83.33*	
Total Area	***135.54***	**94%**
PCDs	**Footprint (ha)**	
West	0.5	
Weast (new)	2.8	
Total Area	**3.3**	**2%**
Plant and Stockpile	**Footprint (ha)**	
Total Area	5.5	**4%**
Total Area	**144.34**	**100%**

Figure 9-7: Overview of Forzando North Surface Infrastructure

[2] *Baseflow (also called drought flow, groundwater recession flow, low flow, low-water flow, low-water discharge and sustained or fair-weather runoff) is the portion of streamflow that comes from "the sum of deep subsurface flow and delayed shallow subsurface flow". It should not be confused with groundwater flow.*

Deeper Aquifer or Coal Horizon Zone:

Groundwater flow directions will be directed towards the mining areas during the Operational Phase due to mine dewatering. Therefore, contamination will be contained within the mining area, and little contamination will be able to migrate away from the mining area within the deeper horizons.

No monitoring boreholes exist within the underground workings to monitor the re-bound rate or recharge of the underground mine area. Sulphate is currently monitored at three different locations as previously discussed.

The plume map in Figure 9-9 can be regarded as a simplified version of current sulphate distribution in the deeper horizons. However, the mass transport has been modelled based on the worst-case scenario, therefore the model represents the maximum expected extent of the sulphate plume within the deeper aquifer systems.

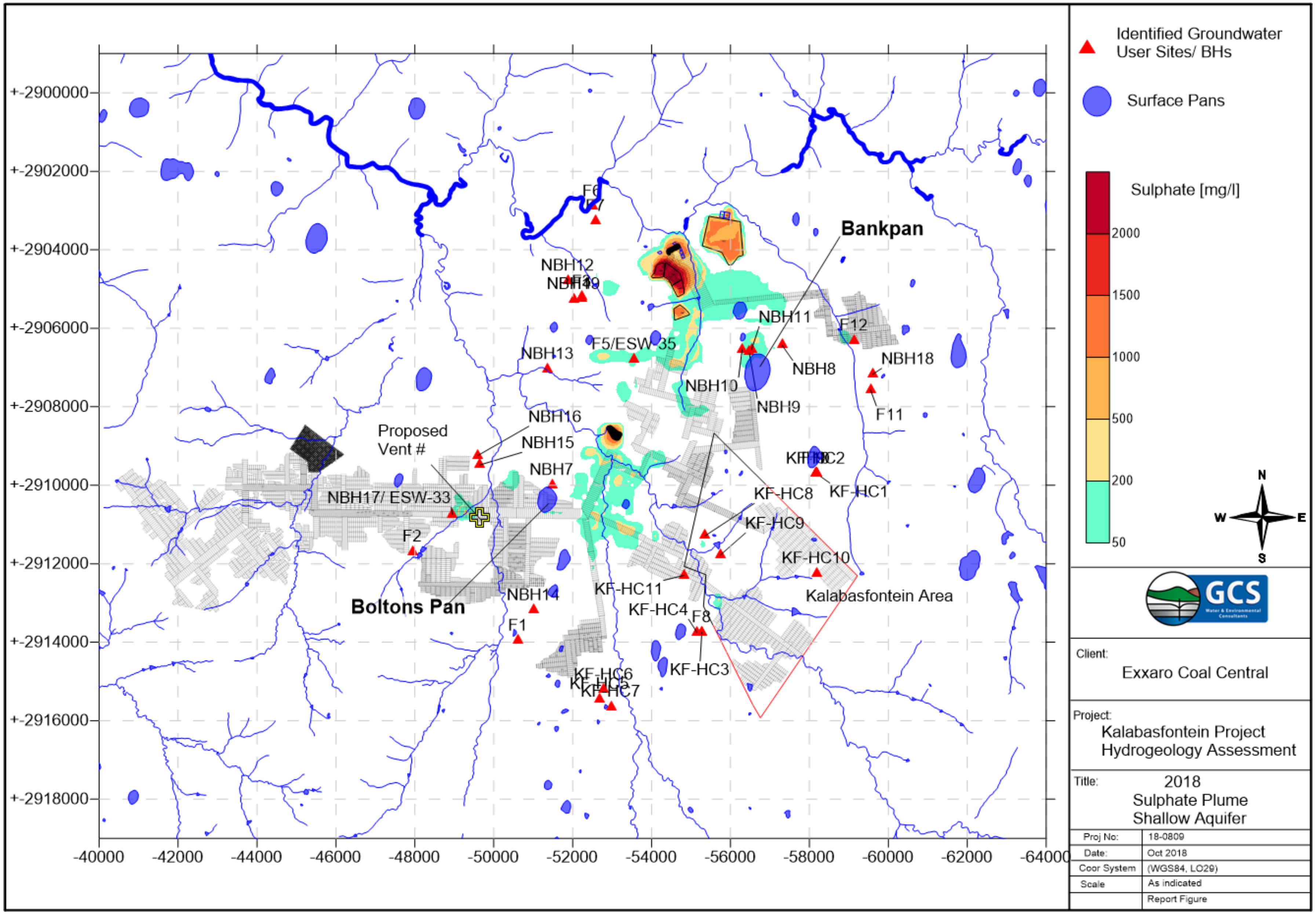


Figure 9-8: Current status sulphate contour map for the Forzando Coal Mines - Shallow Aquifer

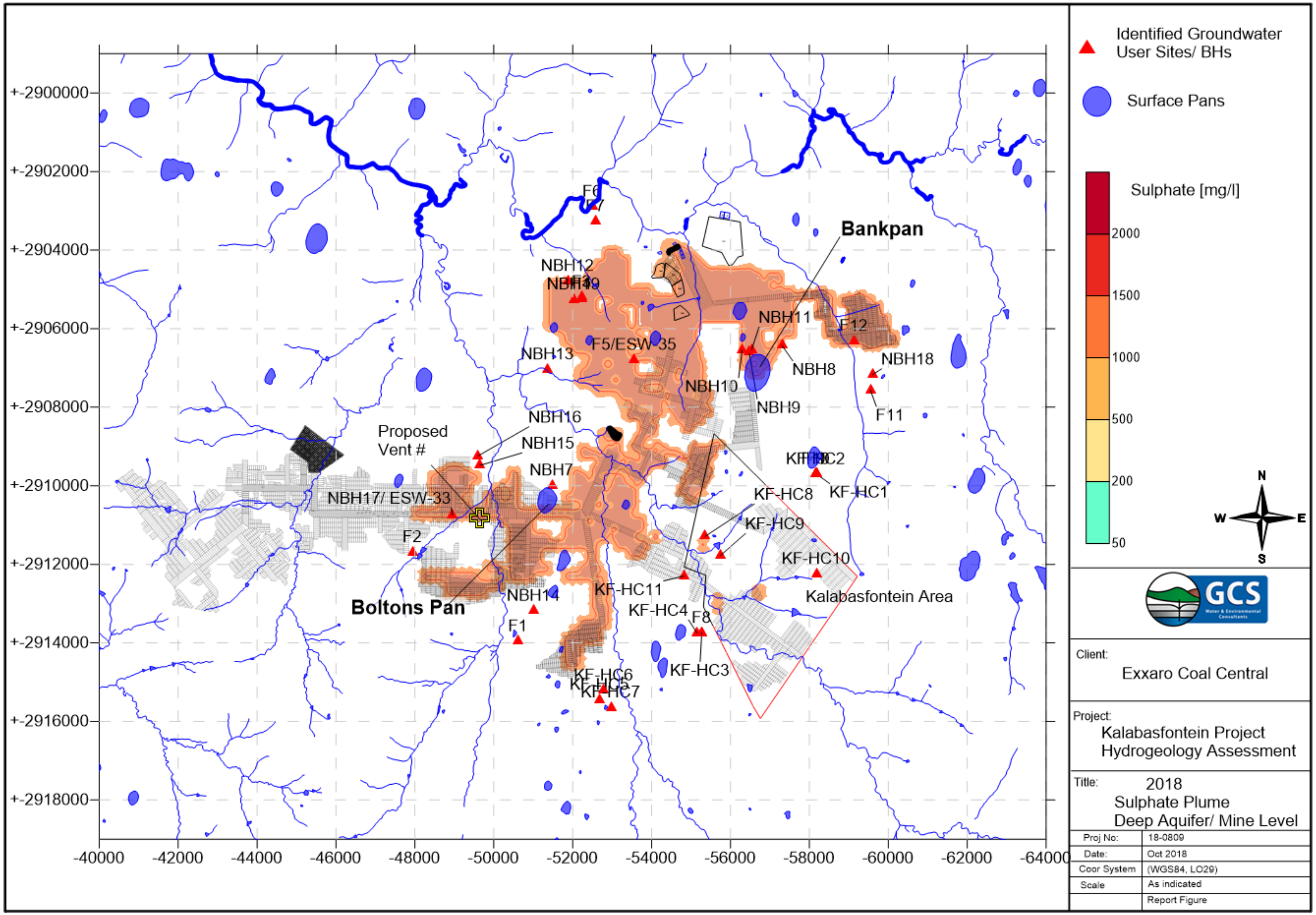


Figure 9-9: Current status sulphate contour map for the Forzando Coal Mines - Deeper Aquifer / Coal Horizon

9.3 Operational Impact Assessment

The operational risk and groundwater liability were discussed in detail in the 2014/2015 Hydrogeological Assessment. This section will only discuss the Kalabasfontein Project and Ventilation Shaft and must be seen as an amendment to previous hydrogeological impact assessments. Further to this, the future prediction of sulphate seepage and contamination plume were calibrated and updated by applying the newly sourced data.

The main identified and potential impacts can be listed as follows and the proposed mitigation and required actions are discussed in Section 9.4.

- Decline in groundwater quality due to sulphate / saline seepage from underground workings into the shallow aquifer system (Refer to Table 9-1).
- Water quality deterioration due to seepage from coal stockpiles (Table 9-2).
- Aquifer drawdown during and after operation at the Kalabasfontein project Area will be in the region of 2 to 5m and the identified farm boreholes may be affected (Table 9-3).
- The potential for surface streams to be affected by shallow sulphate seepage (Table 9-4).

Table 9-1: Impact Table: Operational Risk Decline in Groundwater Quality (Seepage)

Impact Name	**Contamination of Groundwater**				
Alternative	**Alternative 1**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	3
Extent of Impact	3	3	Reversibility of Impact	4	3
Duration of Impact	4	3	Probability	4	3
Environmental Risk (Pre-mitigation)					-14.00
Mitigation Measures					
Environmental Risk (Post-mitigation)					-9.00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.33
Final Significance					-12.00

Table 9-2: Impact Table: Operational Risk Seepage from Coal Stockpiles

Impact Name	**Water Quality Deterioration: Stockpiles**				
Alternative	**Alternative 1**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	2	2
Extent of Impact	3	2	Reversibility of Impact	2	2
Duration of Impact	3	2	Probability	4	3
Environmental Risk (Pre-mitigation)					-10.00
Mitigation Measures					
Environmental Risk (Post-mitigation)					-6.00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.33
Final Significance					-8.00

Table 9-3: Impact Table: Operational Risk Aquifer Drawdown

Impact Name	**Altered Hydrogeological Regime (Aquifer Drawdown)**				
Alternative	**Alternative 1**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	2
Extent of Impact	3	3	Reversibility of Impact	3	3
Duration of Impact	4	4	Probability	4	3
Environmental Risk (Pre-mitigation)					-13.00
Mitigation Measures					
Environmental Risk (Post-mitigation)					-9.00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					2
Issue has received a meaningful and justifiable public response					
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					3
The impact may result in the irreplaceable loss of resources of high value (services and/or functions).					
Prioritisation Factor					1.67
Final Significance					-15.00

Table 9-4: Impact Table: Operational Risk - Surface Water Contamination

Impact Name	**Surface Water Contamination**				
Alternative	**Alternative 1**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	3
Extent of Impact	4	3	Reversibility of Impact	3	3
Duration of Impact	3	3	Probability	4	2
Environmental Risk (Pre-mitigation)					-13.00
Mitigation Measures					
Environmental Risk (Post-mitigation)					-6.00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.33
Final Significance					-8.00

9.4 Operational Mitigation and Management Actions Required

9.4.1 Decline in groundwater quality due to sulphate / saline seepage from underground workings into the shallow aquifer system and potential deterioration of surface water bodies.

- Some degree of shallow seepage from the underground mine workings may occur and these zones are also demarcated on the map in Figure 9-8. These were demarcated as a precautionary management tool and need to be re-calibrated after field confirmations. Field confirmations will include EC profiling of streams during wet and dry seasons.
- The groundwater and surface water monitoring results must be interpreted annually by a qualified hydrogeologist and the monitoring network must be audited annually to ensure compliance with regulations. The monitoring network should be re-evaluated by a qualified hydrogeologists at least 2 years before mine closure so that decommissioning and closure strategies pertaining to groundwater level rebound and decant assessments can be confirmed.
- The rate of flooding and water level recovery as well as water quality in the underground voids should be monitored towards mine closure. Stage curves should be calibrated with the updated information to aid in the management of the Closure Phase (refer to the "Post Closure Impact" section below for the existing stage curve prediction.
- It is recommended that the geochemical assessment is updated during the life of the mine in order to calibrate and validate its results and to construct an effective closure plan.

9.4.2 Water quality deterioration due to seepage from surface infrastructure.

- Minimise the footprint of dirty areas like coal stockpiles, workshops and oil and diesel storage areas. Proper storm water management should be implemented. Berms should be constructed to ensure separation of clean water and dirty water areas.
- Compaction of coal discard and concurrent rehabilitation methods will be applied. The objective is to reduce rainfall infiltration into coal discard by aiming for <1% of recharge per annum.
- Interception of contaminated groundwater may be required where seepage is observed and saline drainage enters surface water bodies. Normal pump and treat / re-use applications will be required.

9.4.3 Aquifer drawdown at the Kalabasfontein project Area.

- Static groundwater levels should be monitored monthly to ensure that any deviation of the groundwater flow patterns and water levels from the idealised predictions is detected in time.
- If the mining operation is indeed affecting the quantity of groundwater available to identified farm users, the affected parties should be compensated. A monitoring program must be implemented where groundwater levels are measured on a routine basis. If it is established that the mine de-watering activities have impacted the farm boreholes the mine must install additional boreholes for water supply purposes or supply an alternative water source.

9.4.4 General

- During the Operational Phase the groundwater pumped from the underground mine workings must be re-used as far as possible. The volumes de-watered and re-used must be measured by flow meters and reported in a database on a monthly basis.
- Adequately sized pollution control facilities should be constructed and lined. Contain poor quality runoff from dirty areas and divert this water to pollution control dam for re-use.
- Excess water must be pumped to dedicated underground storage dams and/or surface dirty water dams or pollution control facilities. Longer residence times in the underground workings results in higher overall TDS values due to prolonged exposure.
- The numerical model should be updated at least every three (3) years by using the measured water ingress, mine schedule and water levels to re-calibrate and refine the impact prediction scenarios.
- A detailed mine closure plan should be prepared during the Operational Phase, including a risk assessment, water resource impact prediction etc. as stipulated in the DWAF Best Practice Guidelines. The implementation of the mine closure plan, and the application for the closure certificate can be conducted during the Closure Phase.

10 POST-CLOSURE PHASE IMPACT ASSESSMENT

10.1 Groundwater Quality

Once mining has ceased, AMD is likely to form in the underground workings given the unsaturated conditions in the facility causing oxidation of sulphide minerals which, when in contact with infiltrated groundwater, creates sulphuric acid. Influx of groundwater into the underground workings results in plume migration. Therefore, groundwater contaminant plumes are likely to migrate from the mining areas once the water level in the underground voids have reached long term steady state conditions.

10.1.1 Shallow Aquifer contaminated seepage

The predicted sulphate plumes for the shallow aquifer system can be seen Figure 10-1 for 50 years after mine closure.

10.1.2 Deeper Contaminated Seepage

The contaminant plume emanating from the underground voids will have an impact on the groundwater quality as seen in the post mining simulations, refer Figure 10-1 and Figure 10-2. The sulphate plume is basically restricted to the mine workings area and limited down-stream migration will occur after closure.

Several “sensitive” areas can be highlighted from the predicted sulphate contour maps. These areas represent a worst-case scenario of expected groundwater seepage from the underground workings which may reach the shallow upper aquifer zone (Figure 10-1, Shallow Aquifer). It is recommended that groundwater and surface water monitoring points be installed in certain areas to monitor any seepages; this will be discussed later in this report.

Experience has shown that the plume stagnates after about 50 years, and no further movement after such time is expected. This statement is also supported by the geochemical modelling which indicates either a decrease or flattening of predicted concentrations.

According to the existing information and hydrocensus data, none of the privately-owned boreholes are affected by the deeper seepage plumes “rising” into the upper weathered aquifer as indicated on Figure 10-1.

However, farm boreholes in the vicinity of the Bolton Pan and Bankpan areas need to be monitored as a pre-caution. The pans itself also need to be monitored at regular intervals to ensure a proper understanding of any water quality fluctuations are in place. In general, the deeper flow will not affect the farm boreholes which are usually only within the upper aquifer zones.

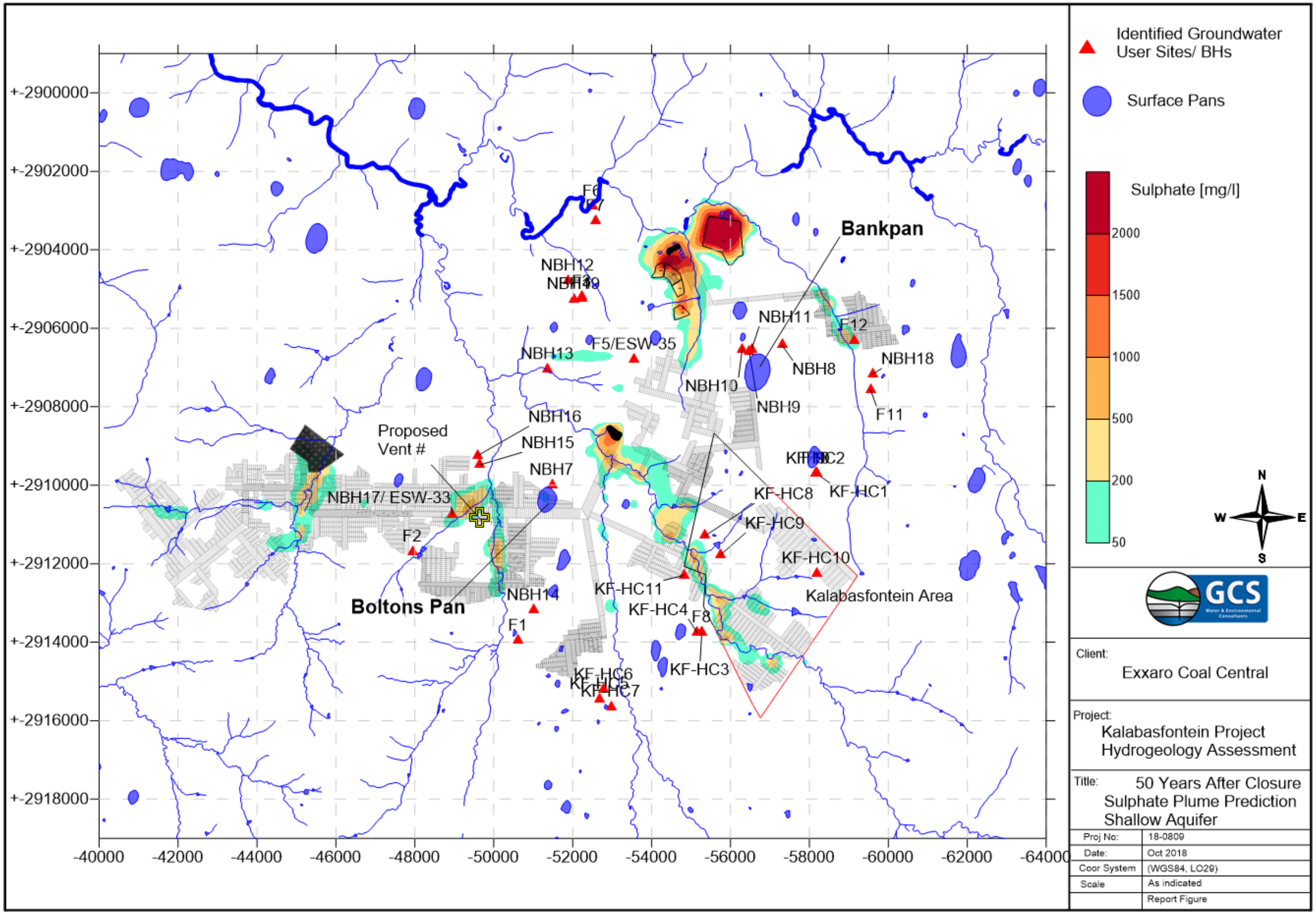


Figure 10-1: Forzando Coal Mines sulphate contours in [mg/l] 50 years after final closure - Shallow Aquifer

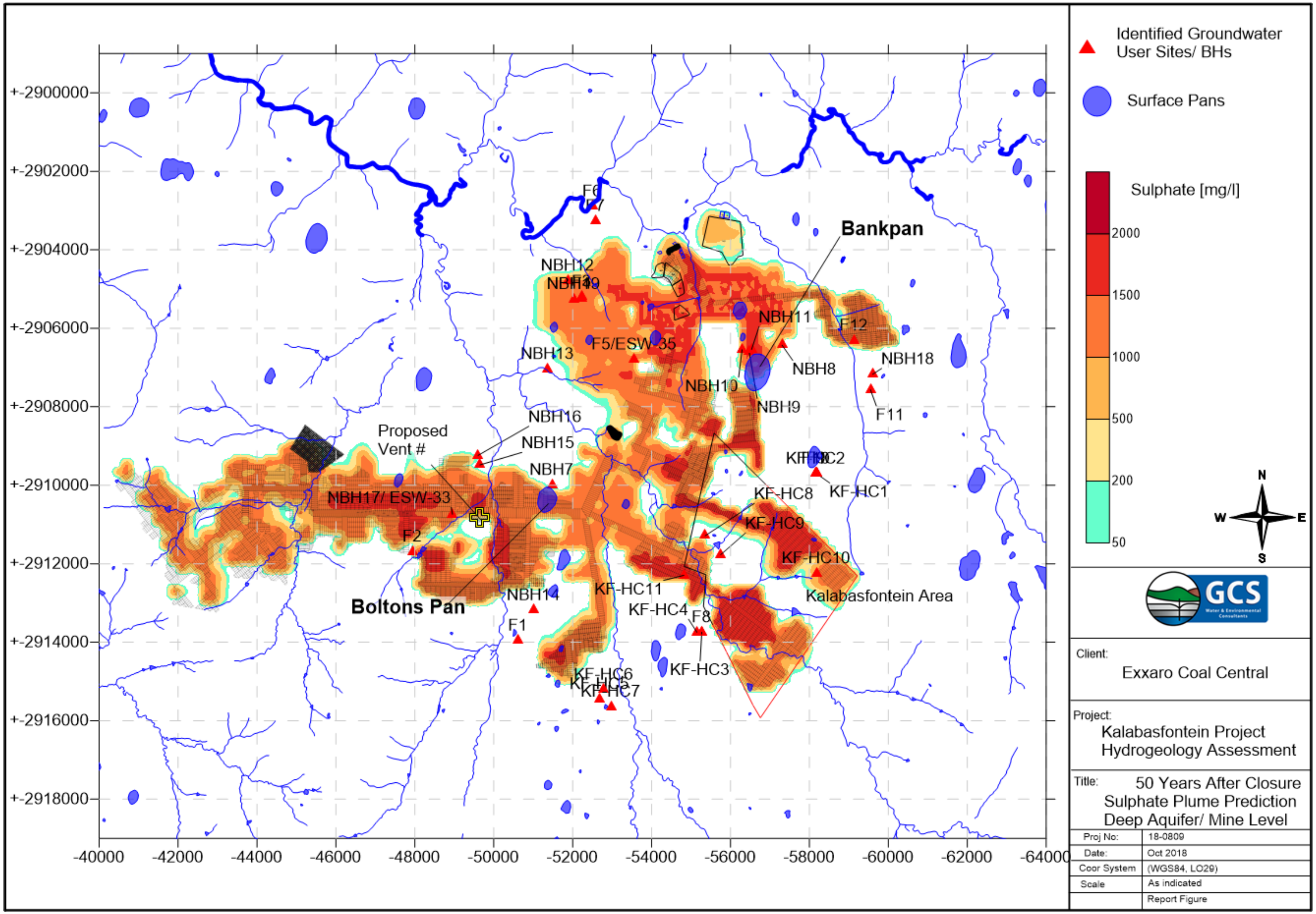


Figure 10-2: Forzando Coal Mines deeper coal seam horizon sulphate contours in [mg/l] 50 years after closure

10.2 Mine Water Decant

The Forzando North and South adits are situated along the up-dip of the coal seam. The coal seam (No. 4 L) is about 20 m below surface at the North Adit and slightly shallower at the South Adit. Total recovery of groundwater levels will be in the region of 40 to 50 years after closure based on 3 % recharge (refer to Table 10-1). As the underground workings will recover due to normal rainfall recharge and regional aquifer inflow, water should rise to its original level. However, if the recharge is different in comparison to pre-mining conditions, groundwater levels can "recover" to a higher level.

In principle, the possibility of decanting is dependent on the dip of the coal floor, the topography, the characteristics of the static groundwater levels, the presence of any geological feature that acts as a conduit /barrier and the rate of recharge to the mining area. It is therefore critical that the rate of recharge be as close to natural conditions as possible (i.e. between 2 and 3% of annual rainfall). This requires that all "conduits" like exploration boreholes, emergency boreholes and ventilation shafts be sealed off after closure. The assessment indicates that it is highly unlikely that direct decant will occur according to the existing layout and adit positions.

Table 10-1: Forzando Underground water storage and re-bound calculations

Parameter	Forzando South		Forzando North	
	Upper Re Range	Lower Re Range	Upper Re Range	Lower Re Range
Area (m^2)	1 584 125	1 584 125	10 345 707	10 345 707
Minimum floor elevation (mamsl)	1 529	1 529	1 510	1 510
Maximum floor elevation (mamsl)	1 565	1 565	1 512	1 512
Minimum roof elevation (mamsl)	1 531	1 531	1 580	1 580
Maximum roof elevation (mamsl)	1 568	1 568	1 582	1 582
No. 4 L coal volume (Mm3)	3 485 075	3 485 075	22 760 555	22 760 555
Pillar Ratio	0.5	0.5	0.5	0.5
Water storage (Mm3)	1 742 537	1 742 537	11 380 278	11 380 278
Recharge (% MAP)	**3.0**	**2.5**	**2.5**	**2.0**
Water make (m3/a)	39 207	32 673	213 380	170 704
Years to flood (a)	44	53	53	67

10.2.1 Management and Mitigation

Figure 10-1 above and Figure 10-3 below indicate areas where shallow and deeper aquifers could be connected through mining. It is generally recommended that no mining occur <20-30 mbgl, typically along topographically low areas like rivers and streams.

It is also suggested that no stooping or any other pillar mining along dyke/sill contact zones and / or along areas where mining is shallower than 40 to 50 m. It is important to ensure that natural recharge conditions continue and that no additional recharge occurs. The risk of subsidence becomes greater where underground mining occurs along shallow zones. Subsidence will subsequently result in additional recharge. Sound geotechnical and/or rock mechanical principles must be applied during mining to prevent subsidence, especially in areas where the underground workings are shallow.

Other possible issues that can lead to decant or shallow seepage is:

- Additional recharge from rainfall into the underground workings: If recharge becomes higher than what is naturally occurring, surplus water will be generated that exceeds the aquifers storage capacity and will subsequently migrate along the shortest route to the surface. The natural recharge is between 2 and 4% of annual rainfall. If more recharge is allowed through old exploration boreholes, surface cracks, shallow underground workings, etc then upward plume migration will occur.
- Decant can also take place from the monitoring borehole (FNGW03) drilled into the underground workings, depending on the hydraulic pressure exerted on the borehole. An unplugged borehole acts as a conduit for flow and a preferential pathway for decant if no other pathways exist. Unless this borehole will be used for monitoring (see comment below), it should be sealed at closure to limit the possibility of decanting. It is also critical that any future monitoring boreholes that will be installed to measure rebound in the underground workings be placed outside the sensitive areas marked on Figure 10-3.
- The “Up-thrust” compartment is bound by dolerite dykes; the degree of weathering and possible recharge into this compartment must be confirmed by looking at current inflows and possible connection from ground surface to the underground workings.

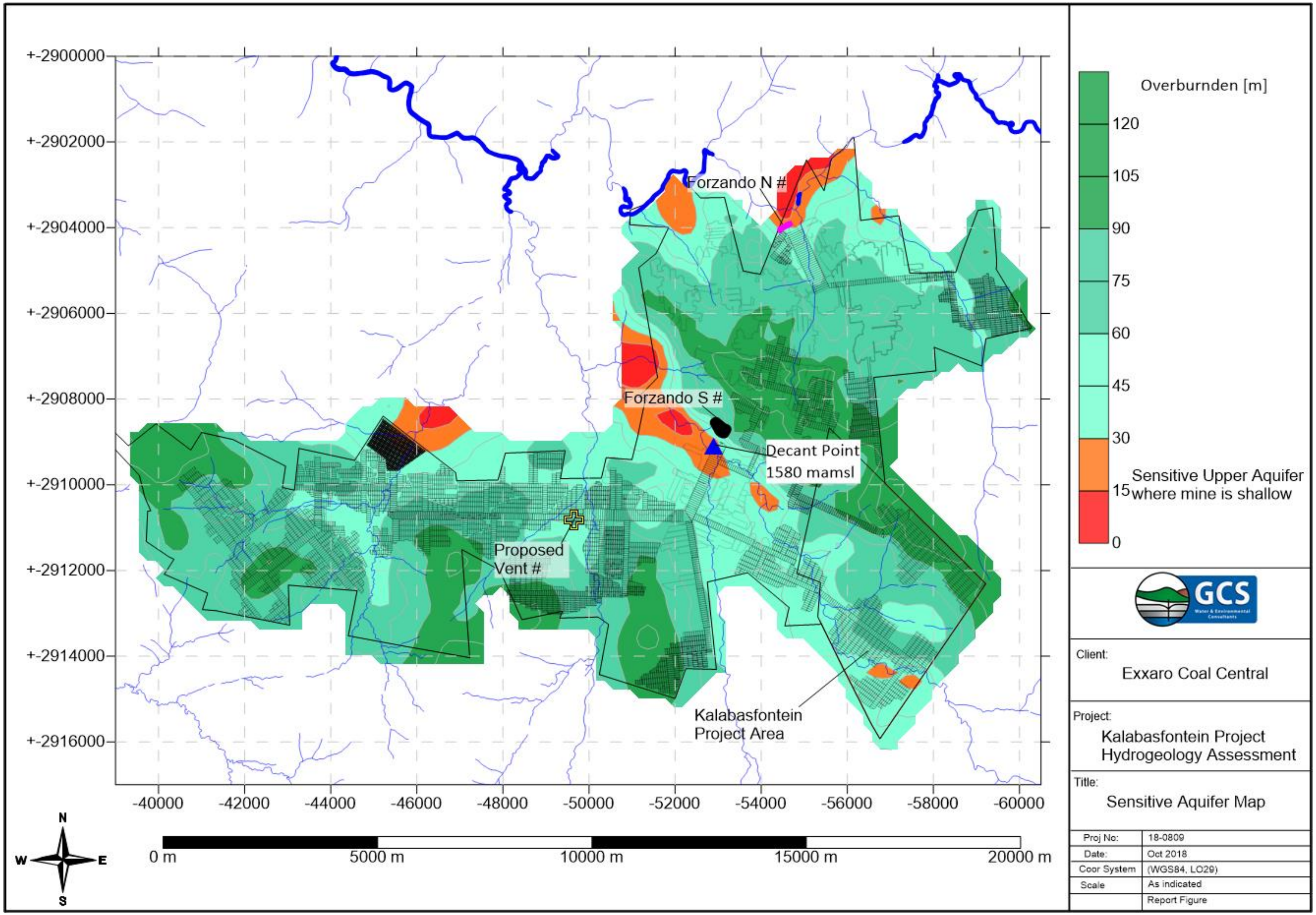


Figure 10-3: Potential decant point

10.3 Groundwater and Surface Water Interaction

After discussion of the potential migration of salinity from a deeper aquifer system to the shallow system (Section 10.1), as well as the identification of sensitive areas (Section 10.2) the discussion can continue to define groundwater and surface water interaction and potential post closure impacts.

Naturally, base-flow contributes to most of the stream and river flow in the area (refer to Figure 10-4 for a typical illustration). This flow generally is not connected to the deeper aquifer flow where mining occurs but might be connected along geological structures in some places and manmade features like boreholes and adits or where the 4L coal seam is shallow and interconnects shallow weathering. This might connect deeper flow with shallow flow, poor quality water can filter through the weathered zone and add saline underground water to the shallow base-flow component

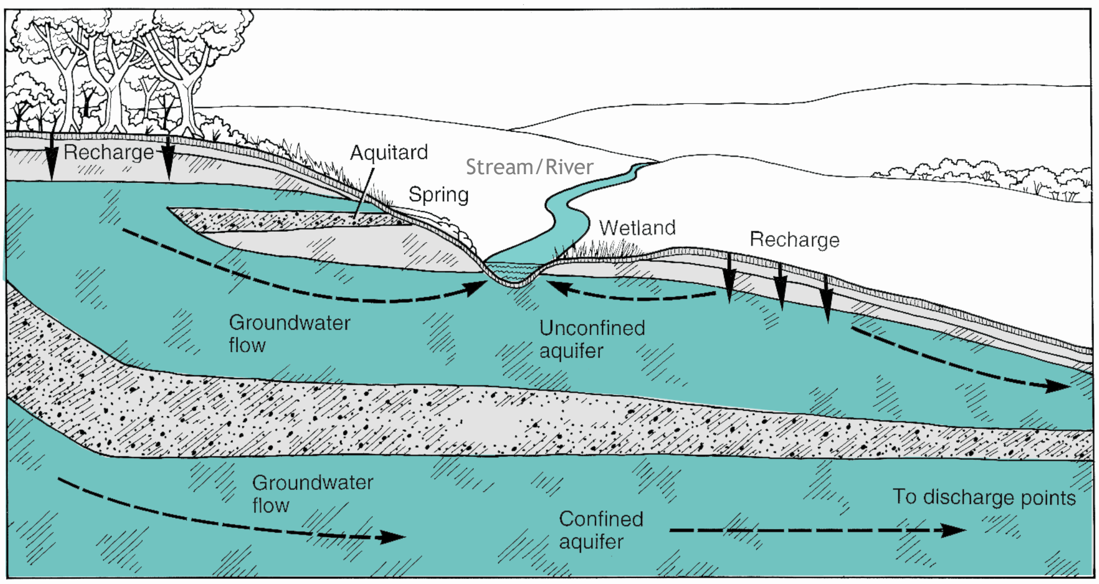


Figure 10-4: Graphical illustration of shallow groundwater interaction with streams and wetlands

10.3.1 Forzando North

Shallow contaminated seepage may impact the unnamed perennial tributary and the Olifants River. The cumulative SO_4 salt load contribution from contaminated groundwater seepage in the stream and in The Olifants River may vary between 10 to 200mg/l and TDS between 20 and 400 mg/l. The discard dump and the PCD's are likely to be the main contaminant sources which may impact on the salt load of the Olifants River. This impact is however likely to be small to moderate after closure. The impact will be adequately mitigated by sound discard dump rehabilitated best practice which will be applied in the Forzando Mine Closure Plan.

Currently qualities obtained for the Olifants River upstream (FNSW15) differ from the qualities obtained from the downstream (FNSW05) locality (Table 10-2). The EC, TDS, total hardness, Ca, Na total alkalinity and sulphate (SO_4) concentrations showed a relatively high increase from the upstream to the downstream locality.

This salt load will be mainly operational of nature and sound decommissioning strategies will be applied to overcome similar loads after closure. However, it is predicted that a certain level of salt load will continue during the post-closure phase as indicated from Figure 10-6. **The situation must be monitored for at least 5 to 10 years after closure to confirm trends and characteristics of salinity load after mine closure.**

Table 10-2: Spatial Assessment Table indicating potential impacts on the downstream aquatic environment for the Olifants River at Forzando North and the new dump during April to June 2018

DATE RANGE			2018/04/01 to 2018/06/30		
ASSESSMENT SET			SANS 241-1:2015		
VARIABLE	UNIT	ASSESSMENT VALUE	Locality		CALCULATED CHANGE
			Upstream	Downstream	
			FNSW15 (Further upstream of Olifants)	FNSW05 (Further downstream of Olifants)	
pH @ 25°C	pH	5.0-9.7	8.05	8.04	-0.01
Electrical Conductivity (EC) @ 25°C	mS/m	170	49.3	80.8	31.5
Total Dissolved Solids (TDS)	mg/l	1200	309	558	249
Total Hardness	mg $CaCO_3$/l	-	175	265	90
Calcium (Ca)	mg/l	-	35.5	55.5	20
Magnesium (Mg)	mg/l	-	21.1	30.6	9.5
Sodium (Na)	mg/l	200	46.4	83.9	37.5
Potassium (K)	mg/l	-	5.09	5.27	0.18
Total Alkalinity	mg $CaCO_3$/l	-	134	149	15
Chloride (Cl)	mg/l	300	27.8	27.7	-0.1
Sulphate (SO_4)	mg/l	500	89.9	262	172

10.3.2 Forzando South and Kalabasfontein

The Viskuile Spruit and the Boltons Pan Area are the main surface water bodies in this area. The Viskuile Spruit flows through the proposed Kalabasfontein project area and next to the Forzando South Adit area in a northerly direction.

The following bullet points were copied from the latest water monitoring report (Aquatico, 2nd Q March to June 2018):

- Water from Boltons pan (FSSW07) was classified as Poor (Class 03) water quality due to the Fluoride concentrations in the water, high TDS, high alkaline pH, high Na and Cl.
- Refer to Figure 10-5 for the TDS time graph.
- It can be seen that the TDS concentrations is generally higher in the up-stream Viskuile samples sites FSSW1 and 2, when comparing to the downstream site FSSW5.
- Spatial Assessment Table 10-3 was used to compare the upstream and downstream sampling localities of the Viskuile Stream. This table quantifies the potential impacts observed from the upstream aquatic environment towards the downstream environment by highlighting any variable concentrations in red which can be assumed as contributions to the total degradation or improvement (indicated in green) of downstream water quality, by the Forzando South Area situated between these two localities or any other potential contributor residing between them. This does not necessarily mean the contribution of any particular parameter exceeded the permissible concentration of that variable, but is merely an indication of impact. Qualities obtained for the Viskuile Upstream (FSSW01) was more or less the same than the qualities obtained from the Viskuile River at Bridge – downstream of mine (FSSW05) with slight improvements. The water qualities for both localities were neutral, non-saline and slightly hard (FSSW05) to hard (FSSW01) (DWAF, 1996 & 1998).

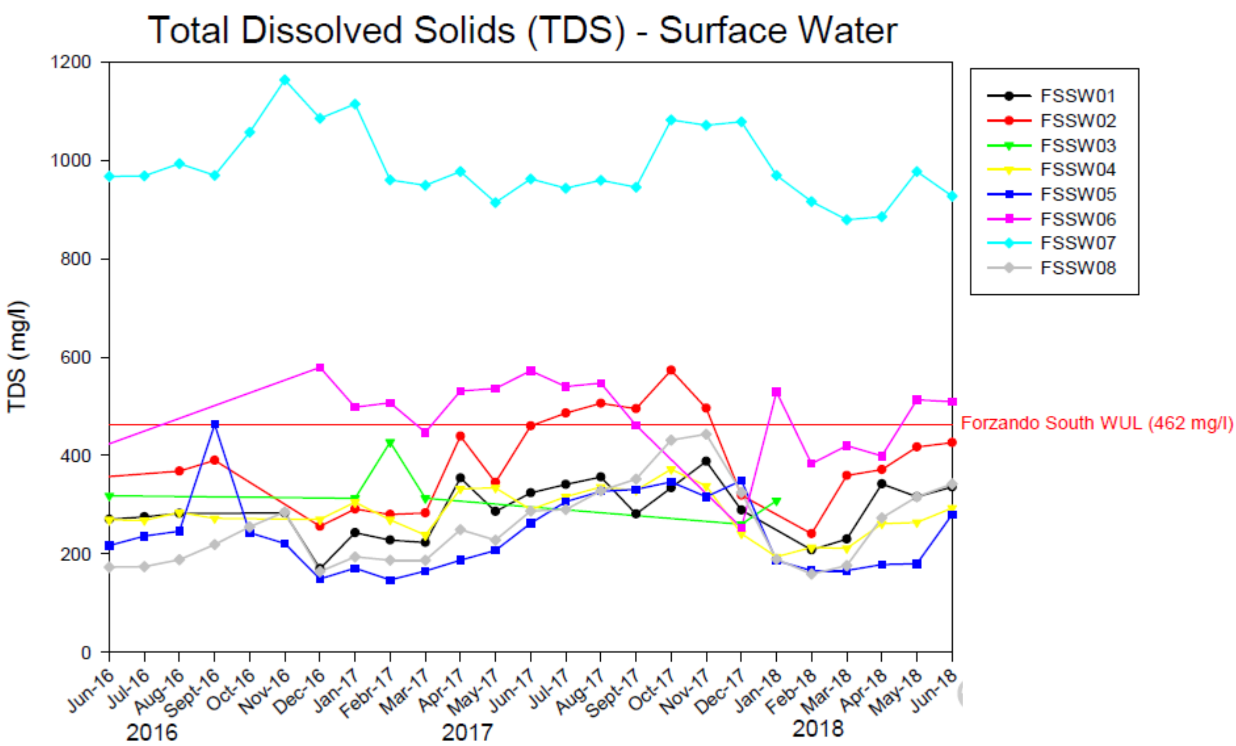


Figure 10-5: TDS time graph for the Forzando South Surface Water Monitoring Sites

Table 10-3: Viskuile Spruit Up and Down-Stream Comparison (June 2018)

PROJECT NAME			Forzando Coal Mines		
DATE RANGE			2018/04/01 to 2018/06/30		
ASSESSMENT SET			Forzando South Water Resource		
VARIABLE	UNIT	ASSESSMENT VALUE	Locality		CALCULATED CHANGE
			Upstream	Downstream	
			FSSW01 (Viskuile River by R38)	FSSW05 (Viskuile on bridge)	
pH @ 25°C	pH	5.0-9.5	8.31	8.17	-0.14
Electrical Conductivity (EC) @ 25°C	mS/m	-	53.7	33.6	-20.1
Total Dissolved Solids (TDS)	mg/l	462.0	331	213	-118
Total Hardness	mg $CaCO_3$/l	-	209	131	-78
Calcium (Ca)	mg/l	45.0	40.8	26.6	-14.2
Magnesium (Mg)	mg/l	24.0	26	15.7	-10.3
Sodium (Na)	mg/l	36.0	43.9	26.7	-17.2
Potassium (K)	mg/l	6.5	4.15	5.18	1.03
Total Alkalinity	mg $CaCO_3$/l	-	211	128	-83
Chloride (Cl)	mg/l	23.0	22.8	14.4	-8.4
Sulphate (SO_4)	mg/l	152.0	56	38.1	-17.9
Nitrate (NO_3) as N	mg/l	-	0.21	0.456	0.246

The overall predicted and cumulative salinity load to the Viskuile Spruit system, just before the confluence of the Olifants River will be in the order of 20 to 50 mg/l of TDS. This is graphically presented in Figure 10-6.

It is not foreseen that the proposed new Kalabasfontein project and Forzando South will have any related impacts after closure on the Viskuile Spruit due to seepage from any surface mine infrastructure; the coal stockpile areas will be removed and the areas rehabilitated after closure.

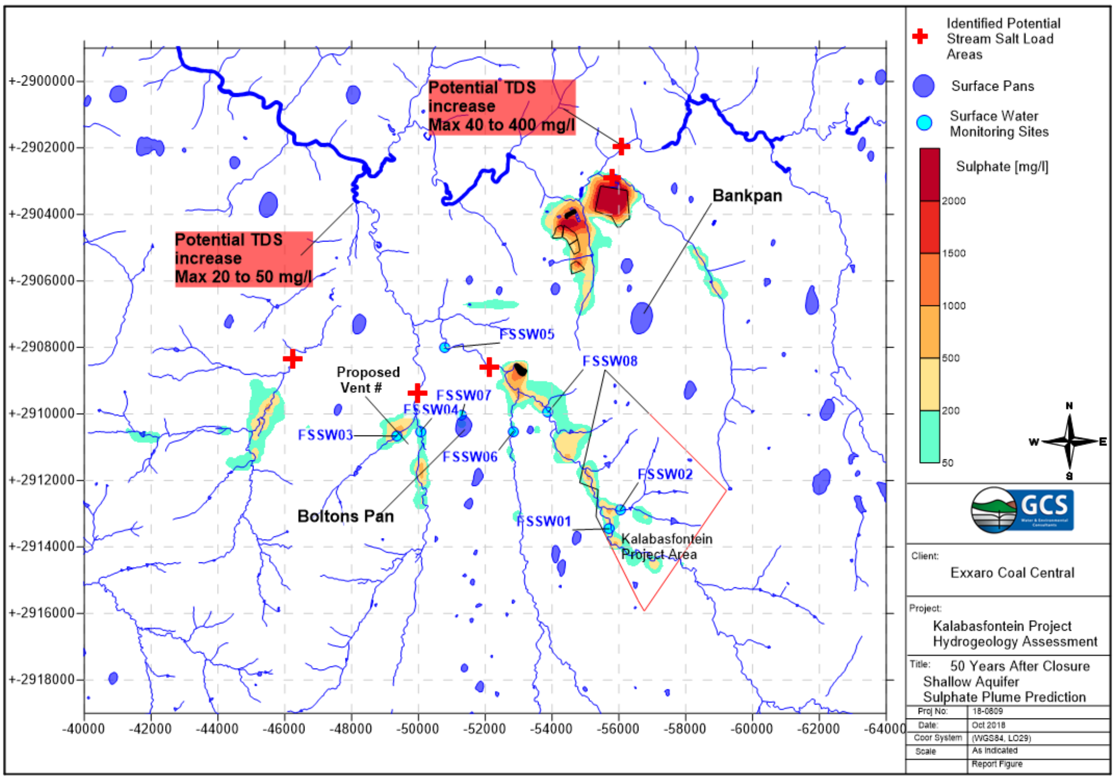


Figure 10-6: Maximum salinity increase / load prediction within the post-closure phase and areas where post closure monitoring will be required

10.3.3 Management and Mitigation

- It is recommended that the adits be sealed off along the weathered zone after closure to overcome mixing and that other conduits (as mentioned above) also be sealed.
- Prevent underground mining underneath streams and rivers and along areas where the 4L coal seam is shallower than 30m.
- Undertake routine EC profiling of the Viskuile spruit during operational phase and continue for at least 10 years after closure to determine any EC variations.

10.4 Post Closure Risk Assessment and Mitigation

The following supplies the main risk components for Post Closure:

- To ensure that mine decant can be prevented, the actions, as stipulated above, must be followed (refer to sections 10.2.1 and 10.3.3).

- To prevent poor quality seepage from the discard dumps, it is proposed that reclamation opportunities be explored to attempt to decrease the dump sizes. A trade off assessment must be followed to determine if it will be feasible to combine all discard waste in one discard disposal site which can then be closed and rehabilitated.
- Old surface infrastructure areas, which currently add to the cumulative sulphate seepage, must be closed and rehabilitated. Remaining pollution control dams must be lined and managed.

The following impacts were identified and mitigation is discussed in previous and following sections. Refer to Table 10-4 to Table 10-6 for the three main post closure impacts.

Table 10-4: Impact Table: Post Closure Risk - Surface Water Contamination due to seepage from rehabilitated Discard Dump

Impact Name	**Contaminated groundwater seepage to streams (salt load) from Rehabilitated surface areas - Discard, Plant, PCDs, etc**				
Alternative	**Alternative 1**				
Phase	**Rehab and closure**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	2
Extent of Impact	4	3	Reversibility of Impact	3	2
Duration of Impact	4	4	Probability	3	2
Environmental Risk (Pre-mitigation)					-10.50
Mitigation Measures					
Environmental Risk (Post-mitigation)					-5.50
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-5.50

Table 10-5: Impact Table: Post Closure Risk - Surface Water Contamination due to seepage / decant from UG Workings after complete rebound (flooding)

Impact Name	**Contamination of Streams due to Mine decant and weathered aquifer seepage from old mine workings**				
Alternative	**Alternative 1**				
Phase	**Rehab and closure**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	2
Extent of Impact	4	4	Reversibility of Impact	4	4
Duration of Impact	4	4	Probability	3	2
Environmental Risk (Pre-mitigation)					-11.25
Mitigation Measures					
Environmental Risk (Post-mitigation)					-7.00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					2
Issue has received a meaningful and justifiable public response					
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.50
Final Significance					-10.50

Table 10-6: Impact Table: Post Closure Risk - Groundwater Contamination due to seepage / decant from UG Workings after complete rebound (flooding)

Impact Name	**Contamination of farm boreholes due to Mine decant and weathered aquifer seepage from old mine workings**				
Alternative	**Alternative 1**				
Phase	**Rehab and closure**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	2
Extent of Impact	3	3	Reversibility of Impact	5	5
Duration of Impact	4	4	Probability	3	2
Environmental Risk (Pre-mitigation)					-11.25
Mitigation Measures					
Environmental Risk (Post-mitigation)					-7.00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					2
Issue has received a meaningful and justifiable public response					
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.50
Final Significance					-10.50

10.5 Long term management strategy for AMD

Best Practice Guideline - A6: Water Management for Underground Mines – DWA, July 2008 states the following: Plan, design, operate and close the underground mining operations in a manner that reduces the ingress of clean water into the mine, minimizes the volume of water used in mining operations, maximizes water reuse, minimizes the water quality deterioration within the mine and minimizes the impacts on the water resource.

10.5.1 General

The following general management strategies must be considered to manage any long term AMD:

- Plan for closure with regard to understanding where water enters the mine and would normally accumulate, how it flows, how it should preferably flow in order to minimize water quality deterioration.
- Adits can be major sources of surface and groundwater ingress if not properly sealed. It is therefore recommended that all potential mine entry points like boreholes, old ventilation shafts, old rescue bays and mine portals/adits be sealed off as per the DMR regulations.
- Sufficient pillars must be left underground, as part of sound mine planning, to avoid subsidence of the roof to surface along the shallower areas (where underground mining is less than 40m from surface). This will ensure that the rate of recharge to the underground workings remain at natural rates and will minimise decant from the workings post-closure.

10.5.2 Site Specific

The main focus areas for AMD management should be:

1. To reduce oxygen ingress into the old mine workings. Oxygen usually enters the mine where mine workings are not flooded or via excessive rainfall recharge/inflows. Shallow areas where the overburden is less than 30m are more susceptible to higher rainfall ingress, oxygen ingress and AMD.
2. To reduce excessive rainfall recharge/inflows into the underground workings after flooding.

Shallow underground mines (e.g. coal mines) are, due to their relatively shallow nature, more susceptible to water ingress problems associated with seasonal rainfall patterns as they are often located within or at least very close to the upper weathered aquifer zones. The water ingress problems and the water balance are also closely linked to the type of underground mining method employed, i.e. bord and pillar mining or maximum extraction mining. Generally the Forzando Mine can be classified as one of the deeper coal mines in South Africa but it can be seen from Figure 10-3 that limited shallow areas (<30m) exist.

It can be concluded from available data that:

- Probability for AMD generation in the underground workings is low if oxidation can be reduced.
- Certain areas will be more sensitive and prone to oxygen ingress into the UG working than other areas. The sensitive areas are typically associated with shallower areas as indicated in Figure 10-3 in the next section of this report.
- Saline drainage will be more likely to occur where sulphate concentration dominates the underground water quality after closure. It is normally restricted to the underground workings and only migrates away from the workings along zones of higher aquifer hydraulic conductivity. Such zones are normally associated with geological structures like fault zones and dolerite dykes.
- Saline drainage may also enter the shallow weathered aquifer zones along the shallow mining areas at the sensitive mapped areas in Figure 10-3 below.
- Implement as many closure measures during the Operational Phase, while conducting appropriate monitoring programmes to demonstrate actual performance of the various management actions during the life of mine.
- Audit the monitoring network annually.
- Rehabilitation must include closing of the adit locations so no open connection exists between the surface and the underground mine voids. Covering with a topsoil layer as well as vegetation must be included. Installation of a soil cover will significantly decrease water infiltration and contamination;
- The discard dump closure and rehabilitation plan must ensure that the amount of seepage from rainfall into the discard dump is minimised.
- One of the long term groundwater management options should include the planning of an active water treatment plant for the Forzando Operations. This ensures a pro-active approach towards mine water management. Water treatment must be implemented if the salt loads to the identified streams exceeds the acceptance criteria of the catchment reserve determination criteria.

Monitoring:

Operational: Multiple-level monitoring wells must be constructed to monitor base-flow quality within the identified sensitive zones (Figure 10-3) and to monitor groundwater level behaviour in the underground workings.

At and After Closure: As discussed earlier, deep underground boreholes will only be required towards mine closure.

Use the results of the monitoring programme to confirm/validate the predicted impacts on groundwater availability and quality after closure.

Update existing predictive tools to verify long-term impacts on groundwater, if required.

10.6 Forzando Water Monitoring System

The Forzando North and South Coal Mines have active groundwater monitoring programmes, with several monitoring boreholes including the boreholes described in **Appendix B**.

Currently, eleven (11) groundwater monitoring sites exist at the Forzando North Mine and are included in the quarterly monitoring program. Five (5) groundwater monitoring sites exists for the Forzando South region.

10.7 Actions Required

- Multiple-level monitoring boreholes must be constructed to monitor base-flow quality and water levels within the identified sensitive zone areas and to monitor groundwater level behaviour at the identified farm areas. Refer to Figure 9-5 in the previous section.
- Water quantity and quality upstream and down-stream in the Olifants River must be measured and monitored during and after closure to identify any anomalies in flow and quality under normal conditions, especially in the dry season. It is evident from the down-gradient borehole, FNGW1, that sulphate levels increase over time; this can be due to seepage from the existing surface infrastructure. It is recommended that current aquifer flow patterns be confirmed in this area.
- Use the results of the monitoring programme to confirm/validate the predicted impacts on groundwater availability and quality after closure.
- Update existing predictive tools to verify long-term impacts on groundwater, if required.

11 CONCLUSIONS AND RECOMMENDATIONS

Overall, the Kalabasfontein Project will have a low to medium impact on the regional hydrogeological environment. If sound environmental management practices are applied and the monitoring, management and mitigation mentioned in this report, it is our opinion that the project may be authorised.

The following points relate aquifer and groundwater use characteristics in the Forzando and the proposed Kalabasfontein project area:

- Groundwater at the identified farm boreholes is mainly used for domestic supply, small scale irrigation (gardens) and livestock watering. The groundwater quality in the area is generally good.
- Groundwater levels generally follow topography at an average water level of approximately 5.5 mbgl.
- Hydraulic conductivity values for the weathered layer are in the order of 2- 10 m/d. Hydraulic conductivity of the fractured Karoo unit decreases with depth and will range between 10^{-2} m/d in the upper layers and 10^{-4} m/d for the lower layers. These values are typical of the Karoo type aquifers.
- Groundwater monitoring shows only minor fluctuations since 2010 and most groundwater levels are within 5 to 8m below ground level.

The following points relate to key water quality aspects in the Forzando area:

- Forzando Coal Mines are existing operations and as a result there are contaminant sources already present such as operational underground workings, two discard dump complexes at FZ-N, coal stock piles, pollution control dams, return water dams and plant areas (FZ-N).
- Monitoring boreholes at the Forzando North Area indicates localised sulphate plumes at both the older western and newer eastern coal discard dumps.

The following outlines the predicted impacts to groundwater quantity and quality:

- As a result of dewatering groundwater levels could be lowered over a relatively large area around the underground mine.
- Groundwater flow directions will be directed towards the mining areas due to the mine dewatering. Therefore contamination will be contained within the mining area, and little contamination will be able to migrate away from the mining area. It is anticipated that groundwater contamination during the Operational Phase will be highest in the area around the surface infrastructure.

- The contaminant plume emanating from the discard dump facility at Forzando North will move in a northerly direction towards the Olifants River. Shallow contaminated seepage may impact on the unnamed perennial tributary to the Olifants River. This impact is likely to be moderate.
- Several farm boreholes were identified that falls within the potential post closure impact and sensitive zones. These are:
    - Bolton Pan Area – Hydrocensus borehole NBH17 (2014 HC data),
    - Kalabasfontein Area – Hydrocensus Borehole KF- HC11 (2018 HC data), and
    - Bankpan Area – Hydrocensus boreholes NBH9, 10 and 11 (2014 HC Data).
- At Forzando South the potential decant point is located south west of the Adit area.

11.1 General Recommendations

The following recommendations are made:

- The groundwater monitoring network should be expanded for the existing and future mining activities at Forzando, including the Kalabasfontein project area.
- The rate of water level recovery in the underground voids should be monitored. Stage curves should be developed which would aid in the management of Closure Phase.
- The numerical model should be updated and calibrated according to agreed EMPs and IWULA timeframes using the measured water ingress and water levels to re-calibrate and refine the impact prediction scenarios. Should there be any significant change in mining plan or water volumes then that will be done a year after such a change has been realised.
- Decant volumes and time-to-decant should be re-assessed once more information regarding rehabilitation is obtained.

11.2 Discard Closure

Two distinct closure scenarios should be considered for the Forzando Coal discard dumps to ensure chemical stability for groundwater management purposes. As mentioned above the objective is to reduce infiltration and seepage and therefore long term risks and environmental liabilities. To achieve this the two options, or a combination of the two, must be implemented:

i. Reclamation of the discard dumps for use in the energy sector. It is recommended that a feasibility assessment be planned and commissioned as soon as possible to identify the viability of the reworking of the discard dumps. Such a rehabilitation program has the benefit of cash inflow and waste minimization. Capital can then be re-invested in further rehabilitation programs.

ii. Total cover of the dumps with an impermeable cover. It is documented in the WRC Document (THE EVALUATION OF SOIL COVERS USED IN THE REHABILITATION OF COAL MINES, WRC Report No. 1002/1/04 Water Research) that cover layers of at least 1m in thickness shows proper reduction in oxygen and water ingress. Natural recharge, over the long post closure phase, must be at least <1% of MAP.

12 REFERENCES

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13 APPENDIX A: OLD HYDROCENSUS DATA TABLES

Table 13-1: Historical data obtained from the EMPR's for both North and South

Site ID	X	Y	Comments	BH Depth	AVG WL
BH	2903383.526	-52366.45162	Included in the 1996 SRK monitoring reports		Sealed
BH0	2902889.444	-57739.35229			Sealed
BH02	2902742.556	-56619.44215			1.59 – 3.3
BHA	2904011.143	-53899.66181			Sealed
BHX	2904144.68	-57899.3403			5.46 – 9.48
F262	2905613.571	-55312.88198	Included in the 1996 SRK monitoring reports Included in the 2002/3 GCS monitoring reports		0.20
F437 S	2905680.337	-55792.84204			3.62 – 6.01
F437 D				80	15.26 – 17.2
F438 S	2904425.103	-55352.87799			2.75 – 5.84
F438 D				60	2.95 – 6.72
F439 S	2903890.962	-54846.25192			4.23 – 6.28
F439 D				73	6.74 – 9.15
F440 S	2903610.536	-54752.92591			1.41 – 3.85
F440 D				40	1.42 – 3.85
F441	2903850.902	-54379.62386	Production BHs drilled in 2002/3 but destroyed	30	
F442	2903784.133	-54419.61987		29	
F443				30	
F661	2908871.837	-53019.7317	Monitoring BHs drilled by DWA in 2002/2003. Double boreholes were drilled - 4 in weathered aquifer and 4 in fractured aquifer		
F662	2909325.859	-53486.36175			
F666	2911288.831	-54099.64583			
F670	2911929.801	-50259.95535			
GW01	2910687.921	-49140.04521	Fractured aquifer		
GW02	2910768.043	-49286.69923	Fractured aquifer		
GW03	2910220.546	-49046.7192	Fractured aquifer		
GW04	2909886.707	-49086.71521	Fractured aquifer		
GW05	2909953.476	-49660.00328	Fractured aquifer		
GW06	2909900.061	-49819.9893	Fractured aquifer		
GW07	2909953.476	-49846.6553	Fractured aquifer		
GW08	2909993.536	-49753.32929	Fractured aquifer		
GW09	2909205.677	-49713.33128			
GW10	2909673.05	-49753.32929	Fractured aquifer		
GW11	2913251.804	-50979.89744	Fractured aquifer		
GW12	2912116.752	-50966.56344	Fractured aquifer		
GW13	2912263.64	-50473.27138	Weathered aquifer		
GW14	2910046.951	-51433.1935	Fractured aquifer		
GW15	2911742.851	-51553.18351			
GW16	2911809.62	-51379.86349	Weathered aquifer		
GW17	2911956.508	-51326.53548			
GW18	2913692.47	-48820.07117			
GW19	2913759.239	-48380.10512			
GW20	2913358.632	-49473.35125			
GW21	2912851.197	-49646.67127	Fractured aquifer		
GW23	2913198.388	-49726.66329			
GW24	2911489.135	-55299.54798			
GW25	2911355.598	-55686.18403			
GW26	2911222.063	-55779.51004	Weathered aquifer		
GW27	2909886.707	-54272.96386			
GW28	2912303.702	-58379.30037			
GW29	2912276.993	-58472.62638			
GW30	2913238.45	-57206.06222			
GW31	2912437.237	-56979.41419			
GW32	2912410.53	-54832.91992			

Site ID	X	Y	Comments	BH Depth	AVG WL
GW33	2911676.083	-55766.17804			
GW36	2909486.1	-54099.64583			
GW37	2909659.697	-54259.63185			
GW38	2909512.809	-53872.9978			
GW39	2909659.697	-53939.65781			
GW40	2909713.11	-54366.28987			
GW41	2909819.939	-54312.96186			
GW42	2908524.645	-54392.95587			
GW43	2911569.254	-54179.63984			
M2	2905920.702	-55286.21598	Included in the 1996 SRK monitoring reports		
M3	2905386.561	-55299.54798			4.70
M4	2904985.954	-55259.55198			
M5	2905893.994	-55179.55797	Included in the 2002/3 GCS monitoring reports. Included in the 1996 SRK monitoring reports	62.33	0 - 2.63
M6	2905760.459	-55152.89396		61.67	0 - 2.71
M7	2905466.68	-55166.22597		61.53	0 - 6.36
M8	2904278.215	-54792.92392			
M9	2904117.972	-54619.6039			
P1	2905773.812	-53299.70973	Included in the 1996 SRK monitoring reports		Sealed
P2	2905893.994	-53406.36775			Sealed
SP01	2909299.15	-53046.3977			
SP02	2909232.384	-53099.72571			
SW	2904478.519	-55059.56795			
WM01	2910554.386	-48926.72918			
WM4	2909552.869	-49593.34127			

** The above water levels were obtained from the 1996 SRK Report, 2002, GCS Report and EMPRs*

Table 13-2: Hydrocensus information for Forzando South, 2001

ID #	Site Description	Owner	Sampled	Sampling Method	Equipment	Use	Remarks
GW1	BH at Large Dam	Mr Jas Wasserman	Yes	At Tap on Pipe	Submersible	Stock	Iron Bacteria
GW2	BH East of Large Dam	Mr Jas Wasserman	No		Submersible	Stock	WL > 20m
GW3	BH at Johan's House	Mr Jas Wasserman	Yes	From Storage Tank	Submersible	Domestic and Stock	
GW4	BH east of Johan's House	Mr Jas Wasserman	Yes	Bailer	Submersible	Domestic and Stock	Not often used
GW5	BH at Joubertspruit	Mr Jas Wasserman	No		Submersible	Stock	
GW6	BH at Joubertspruit	Mr Jas Wasserman	No		Submersible	Stock	Pump Removed
GW7	BH at Joubertspruit	Mr Jas Wasserman	No		Submersible	Stock	
GW8	BH at Joubertspruit	Mr Jas Wasserman	No		Submersible	Stock	
GW9	Main Water Supply BH at Stadt	Mr Jas Wasserman	Yes	At tap on Pump	Submersible	Domestic and Stock	30 m downsteam of Stadt
GW10	BH Between Joubertspruit and Stadt	Mr Jas Wasserman	No		Submersible	Stock	
GW11	Gert Slabber House	Mr Gert Slabber	Yes	From Tap in House	Submersible	Domestic and Stock	Between Sheds
GW12	Martin Slabber House	Mr Gert Slabber	Yes	From Storage Tank	Submersible	Domestic and Stock	
GW13	Handpump at Workers	Mr Gert Slabber	Yes	From Handpump	Handpump	Domestic	No access for WL
GW14	Hennie Salbber House	Mr Gert Slabber	Yes	From Tap in House	Submersible	Domestic and Stock	BH at Bolton's Pan
GW15	Windmill at Martin's	Mr Gert Slabber	No		Submersible		Windmill Broken
GW16	Handpump #2	Mr Gert Slabber	Yes	From Handpump	Handpump	Domestic	
GW17	Windmill behind old house	Mr Gert Slabber	No		Windmill	not in use	No access
GW18	Joubert Dam at Stadt	Mr Henk Joubert	Yes	From Windmill outlet	Windmill	Domestic and Stock	
GW19	Joubert old house	Mr Henk Joubert	No		Windmill	????	No Access
GW20	Joubert open borehole	Mr Henk Joubert	No		None	not in use	
GW21	Joubert House	Mr Henk Joubert	Yes	From Tap in House	Submersible	Domestic and Stock	GPS Position
GW22	Joubert House	Mr Henk Joubert					Water sample for GPS Position GW21
GW23	Between small house and dam	Mr Henk Joubert	No		Submersible	Stock	
GW24	Windmill below Kalbasfontein workshop	Mr Hirschowitz	No		Windmill	Domestic	
GW26	Handpum at Labourers	Mr Hirschowitz	Yes	Pumped	Handpump	Domestic	
GW 28	In middle of pasture	Mr Hirschowitz	Yes	Flow	None	Stock	Artesian
GW 30	Open borehole	Mr Hirschowitz	No		None	Blocked	
GW 33		Mr Hirschowitz	Yes				
WM03	Handpump at Workers	Mr Jas Wasserman	Yes	From Handpump	Handpump	Domestic	

WL – water level

Table 13-3: Summary of boreholes identified during the 2010 Hydrocensus (WGS84)

Site ID	Farm Name	Farm Owner/ Manager	Contact Details	S Coord	E Coord	WL (mbgl)	Equipment	pH	EC (mS/m)	Use	Comments
BH1	Legdaar	Mr B. J. Grobler	082 388 0550	26.31652	29.46863	5.54	Submersible pump			Domestic	
BH2	Legdaar	Mr B. J. Grobler	082 388 0550	26.31564	29..46261		Windmill			Domestic	The pump is broken, but the borehole is still in use.
BH3	Legdaar	Mr B. J. Grobler	082 388 0550	26.31383	29.48013	1.08	Windmill			Unused	
BH4	Legdaar	Mr B. J. Grobler	082 388 0550	26.31593	29.47898		None			Unused	Artesian borehole located on a marshy area.
BH5	Legdaar	Gerald Burger	082 570 7609	26.32976	29.46071		Submersible pump			Domestic and stock watering	Water level could not be measured.
BH6	Legdaar	Gerald Burger	082 570 7609	26.33004	29.46243	2.57	Submersible pump			Domestic and stock watering	Borehole located on a marshy area, about 50m north east of a dam.
BH7				26.28428	29.47085	1.62	None	6.85	0	Monitoring	Depth = 30m Reference no. ESW14
BH8				26.28743	29.46264	0.79	None	8.16	220	Monitoring	Depth = 30m Reference no. ESW12
BH9	Legdaar	Mr B. J. Grobler	082 388 0550	26.31266	29.44092		Windmill			Irrigation and stock watering	
BH10	Legdaar	Mr B. J. Grobler	082 388 0550	26.32214	29.43132		Windmill			Unused	
BH11	Legdaar	Mr B. J. Grobler	082 388 0550	26.30129	29.46263		Windmill			Irrigation and stock watering	
BH12	Legdaar	Mr B. J. Grobler	082 388 0550	26.33706	29.46095		Windmill			Irrigation and stock watering	
BH13	Legdaar	Mr B. J. Grobler	082 388 0550	26.32322	29.42004		Windmill	6.99	5	Stock watering	Depth = 22m
BH14	Legdaar	Mr B. J. Grobler	082 388 0550	26.30799	29.42004		Handmill	6.99	5	Domestic	The borehole does not seem to be used extensively.
BH15	Legdaar	Mr B. J. Grobler	082 388 0550	26.30685	29.41962		Windmill	6.91	230	Domestic	

Site ID	Farm Name	Farm Owner/ Manager	Contact Details	S Coord	E Coord	WL (mbgl)	Equipment	pH	EC (mS/m)	Use	Comments
BH16	Legdaar	Mr B. J. Grobler	082 388 0550	26.31435	29.42132	0.45	Submersible pump			Domestic	Very wet area around the borehole.
BH17	Legdaar	Jacques Grobler	082 8294794	26.31497	29.42372	6.23	Submersible pump			Domestic	
BH18	Legdaar	Jacques Grobler	082 8294794	26.31059	29.42897		Submersible pump	5.89	330	Domestic	Borehole located next to the farm workshop.
BH19	Legdaar	Jacques Grobler	082 8294794	26.30868	29.42662		Windmill			Domestic	Borehole located about 300m south of the stream. The land is very wet.
BH20	Legdaar	Jacques Grobler	082 8294794	26.28827	29.41698		Windmill	6.55	5	Domestic	Borehole located next to graves.
BH21	Legdaar	Jacques Grobler	082 8294794	26.28792	29.41236		Windmill			Unused	The pump is broken.
BH22	Horbe	Mr F. R. Grobler	082 388 0060	26.30631	29.40491	30.27	Submersible pump			Domestic	Water level could have been measured just after pumping.
BH23	Horbe	Mr F. R. Grobler	082 388 0060	26.29254	29.38504		Hand pump	6.65	5	Domestic	Borehole located on a marshy area.
BH24	Hirsaw Estate	Mr Moya	082 556 8210	26.26376	29.45581	3.54	Submersible pump			Domestic	
BH25	Hirsaw Estate	Mr Moya	082 556 8210	26.26631	29.45401	8.71	Submersible pump			Domestic and stock watering	
BH26	Hirsaw Estate	Mr Moya	082 556 8210	26.27287	29.45555	26.7	Submersible pump	7.89	220	Domestic	Water level seems to have been measured just after pumping.
BH27	Hirsaw Estate	Mr Moya	082 556 8210	26.7784	29.45872		Windmill	7.91	5	Domestic	Borehole located about 30m north of the primary school. Pump is currently broken.
BH28	Hirsaw Estate	Mr Moya	082 556 8210	26.31593	29.47898		None			Unused	Artesian borehole

Table 13-4: Summary of boreholes identified during the 2014 Hydrocensus

ID	Farm Name	Farm Owner	Contact Details	Description	X (m WGS84 / Mercator Projection LO29)	Y (m in WGS84 / Mercator Projection LO29)	Alt (mamsl)	WL (mbgl)	Collar Height (m)	Equipment	Use	Sampled
NBH7	Portion 3-4, Schurvekop.	D te Water	082 388 0082	Borehole with pump installed. Water is filtered before use. Pumped to collection dam next to farm house.	51473.35459	-2909990.546	1602	14.1	0.2	Submersible pump	Drinking water	Yes
NBH8	Portion 1, Bankpan. MLGW van der Merwe.	Lood van der Merwe	082 553 0513	Borehole. Not used. Historically dry.	57304.7604	-2906429.796	1640	25.957	0.19	NA	Dormant	No
NBH9	Portion 16, Bankpan.	Phillip Hattingh	013 293 7211	Borehole. No pump and not in use.	56469.71977	-2906591.987	1650	19.609	0.24	NA	Dormant	No
NBH10	Portion 16, Bankpan.	Phillip Hattingh	013 293 7211	Borehole with pump installed. Water used for cattle, house and crop.	56292.903	-2906546.786	1649	15.273	0.31	Submersible pump	Domestic use	No
NBH11	Portion 16, Bankpan.	Phillip Hattingh	013 293 7211	Borehole covered by rock. Not in use due to historic water level fluctuations.	56532.57589	-2906541.184	1649	16.885	0.205	NA	Dormant	Yes
NBH12	Portion 22 or 7, Schurvekop.	BJ Grobler	082 388 0550	Old Wind pump. No bailer access. Blocked with a dead rodent (can be smelled).	51878.23326	-2904784.385	1646	5.63	0.19	Wind pump	Dormant	No
NBH13	Anglo Coal.	BJ Grobler	082 388 0550	Old Wind pump. Blocked.	51363.35287	-2907037.483	1612			Wind pump	Blocked	No
NBH14	Portion 18, Uitgedacht. Dewald te Water.	D te Water	082 388 0082	Borehole with pump. Water is pumped to a collection dam where it is filtered. Used for household. No WL access. Sample taken.	51012.61692	-2913186.105	1633			Submersible pump	Drinking water	Yes
NBH15	Portion 20, Schurvekop.	Johan Malan	083 272 1503	Hand pump near community on Groblers farm.	49649.4377	-2909481.164	1599			Hand pump	Drinking water	Yes

ID	Farm Name	Farm Owner	Contact Details	Description	X (m WGS84 / Mercator Projection LO29)	Y (m in WGS84 / Mercator Projection LO29)	Alt (mamsl)	WL (mbgl)	Collar Height (m)	Equipment	Use	Sampled
NBH16	Unknown, Schurvekop.	Johan Malan	083 272 1503	Wind pump installed with solid cement block. No water level access. Water pumped to pen, however, pens are empty.	49601.93304	-2909238.226	1600			Wind pump	Livestock watering	No
NBH17/ ESW-33	Portion 3 MA1, Legdaar.	Unknown	Unknown	Old monitoring borehole. 30 meters deep. Flag attached. Too many bugs in water to obtain a clean sample.	48953.85245	-2910741.259	1616	6.116	0.35	Collar with locked cap	Monitoring	No
NBH18	Portion 5, Vlaklaagte.	G Delport	017 647 0318	Old Wind pump. Next to road. Pump is not active and locked by chain.	59603.35456	-2907171.675	1638	0.91	0	Wind pump	Livestock and crop watering	No
NBH19	Portion 2, Geluk.	J Grobler	082 388 0550	Monitoring borehole next to road. Monitoring Borehole so no duplicate sample taken.	52027.3875	-2905258.528	1634	12.224	0.5	Collar with locked cap	Monitoring	No
F1	Portion 5, Uitgedagt.	BJ Grobler	082 388 0550	Wind pump. No dip meter access. Farmer says the borehole yield is very low and that the water level is deep.	50619.59305	-2913960.138	1629			Wind pump	Livestock and crop watering	No
F2	Unknown, Uitgedagt.	Unknown	Unknown	Wind pump. Dip meter access however no water. Dip meter however indicates saturated conditions. WL deeper than 1.65mbgl.	47943.43778	-2911687.438	1625	1.65	0	Wind pump	Not used	No
F3	Portion 2, Geluk.	J Grobler	082 388 0550	Wind pump. No WL access. Not pumping.	52232.46198	-2905191.436	1633			Wind pump	Livestock and crop watering	No
F4	Portion 2, Geluk.	J Grobler	082 388 0550	Wind pump in good condition. Sealed with bolts. No WL access.	52239.22259	-2905249.077	1633			Wind pump	Livestock and crop watering	No

ID	Farm Name	Farm Owner	Contact Details	Description	X (m WGS84 / Mercator Projection LO29)	Y (m in WGS84 / Mercator Projection LO29)	Alt (mamsl)	WL (mbgl)	Collar Height (m)	Equipment	Use	Sampled
F5/ESW-35	Portion 2, Koppie.	G Kotzen	836 264 555	Old monitoring borehole. 30 meters deep. No flag.	53562.54126	-2906796.781	1647	3.334	0.57	Collar with locked cap	Monitoring	No
F6	Anglo Coal, 4MA1, Halfgewonnen.	Unknown	Unknown	Monitoring borehole. Located some distance north of the FZ-N near river crossing. Flag attached. 24 m deep.	52502.52823	-2902894.611	1588	1.7	0.47	Collar with locked cap	Monitoring	No
F7	Portion 17, Halfgewonnen.	JB Kourie	Unknown	Old wind pump. No water access.	52579.95419	-2903267.201	1609			Wind pump	Livestock and crop watering	No
F8	Portion 13, Bankpan.	R Hirschowitz.	832 775 333	Old wind pump. No WL access.	55270.92561	-2913745.453	1616			Wind pump	Livestock and crop watering	No
F9	Portion 8, Bankpan.	WJA Bester	Unknown	Wind pump. No WL access. Not pumping. Directly next to F10.	58175.51581	-2909700.786	1665			Wind pump	Drinking water	No
F10	Portion 8, Bankpan.	WJA Bester	Unknown	Submersible pump. Completely sealed with no WL access.	58165.49897	-2909707.389	1660			Submersible pump	Drinking water	No
F11	Portion 4, Bankpan.	Lood van der Merwe	082 553 0513	Old wind pump. No WL access.	59545.60411	-2907564.964	1638			Wind pump	Livestock and crop watering	No
F12	MAT no longer exists.	Lood van der Merwe	082 553 0513	Submersible pump. Used for crop watering. Pumped into tractors.	59132.79141	-2906314.707	1634	10.47	0.2	Submersible pump	Crop watering.	No

*WL – Static Water Level

14 APPENDIX B: WATER MONITORING PROGRAM

Table 14-1: Forzando North monitoring schedule (2018)

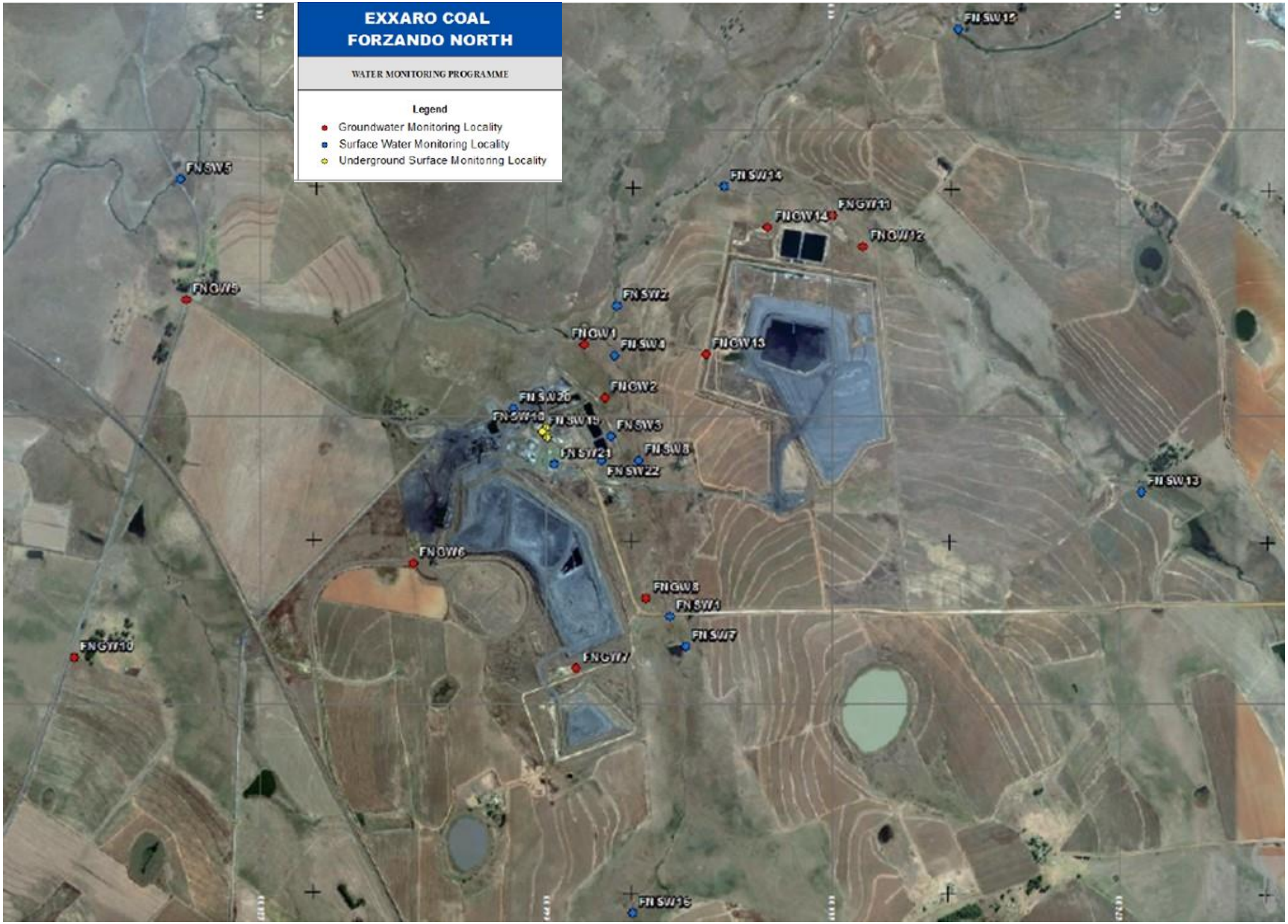
Points	Latitude (S)	Longitude (E)	Groundwater Locations	Monitoring Status	Monitoring Frequency
FNGW1	-26.24075	29.5475	Close to Olifants River	Sampled Mar, Jun, Sep and Dec.	Levels MONTHLY Samples QUARTERLY
FNGW2	-26.24326	29.54856	Down-gradient of the pollution dams		
FNGW6	-26.25111	29.53855	In close proximity to the west gate	Sampled Jun, Sep and Dec. Too wet to access in Mar.	
FNGW7	-26.25608	29.54712	Adjacent of the discard dump (South side)	Sampled Mar, Jun, Sep and Dec.	
FNGW8	-26.25276	29.55078	Down gradient of the discard dump		
FNGW9	-26.23872	29.52658	Near Forzando North West entrance		
FNGW10	-26.25563	29.52079	Along road to Forzando North		
FNGW11	-26.2346	29.56047	Downgradient of PCD		
FNGW12	-26.2361	29.5621	Downgradient of PCD		
FNGW13	-26.2412	29.55385	Adjacent to discard dump		
FNGW14	-26.2352	29.5571	Downgradient of PCD		
Points	**Latitude (S)**	**Longitude (E)**	**Surface Water Locations**	**Monitoring Status**	**Monitoring Frequency**
FNSW1	-26.2536	29.55203	At the bridge, east side of dump.	Sampled monthly throughout 2014.	Samples MONTHLY
FNSW2	-26.23892	29.54921	Upstream point in Olifants River.		
FNSW3	-26.24511	29.54892	Seepage from dam		
FNSW4	-26.24126	29.54905	Downstream of tributary to Olifants.		
FNSW5	-26.23305	29.52625	Far downstream from Olifants		
FNSW6	-26.24516	29.54849	Pollution dam 1. Water from dam outlet.		
FNSW7	-26.25501	29.55284	Upstream of FNSW1		
FNSW8	-26.24621	29.55036	Downstream of FNSW1		
FNSW9	-26 14' 42.2"	29 32' 51.9"	PCD 2		
FNSW10	-26 14' 38.7"	29 32' 51.1"	PCD 3		
FNSW11	-26 14' 33.6"	29 32' 45.8"	PCD 4	Sampled Jan, May,Jun, Jul, Aug, Oct. Too wet to access from Feb to Apr. Dry in Sep, Nov and Dec.	
FNSW12	-26 14' 40.8"	29 32' 33.2"	PCD 5	Sampled monthly throughout 2014.	
FNSW13	-26 14' 51.39"	29 34' 36.25"	Upstream of new dump		
FNSW14	-26 13' 59.8"	29 33' 17.2"	Downstream of new dump	Sampled monthly throughout 2014, except in Feb due to wet conditions	
FNSW15	-26 13' 33.0"	29 34' 01.2"	Further upstream in Olifants	Sampled monthly throughout 2014.	
FNSW16	-26.2676	29.55017	Upstream of mine in Olifants River tributary	Sampled monthly throughout 2014, except in Feb and Apr due to wet conditions	
FNSW22	-26.24622	29.54838	Inflow into PCD 1	Sampled monthly throughout 2014.	
FNSW23	-26.24469	29.54644	Big Erikson Dam	Sampled monthly throughout 2014 except Sep (dry)	
FNSW24	-26.23673	29.55755	PCD 6	Sampled monthly throughout 2014.	
Points	**Latitude (S)**	**Longitude (E)**	**Underground Water Locations**	**Monitoring Status**	**Monitoring Frequency**
FNSW17			Delta	Sampled monthly throughout 2014.	Samples supplied to GCS MONTHLY
FNSW18			Section 29		
FNSW19			Triangle-Junction	Sampled monthly throughout 2014, except in Aug, Oct and Nov when samples were not supplied.	
Points	**Latitude (S)**	**Longitude (E)**	**Potable Water Locations**	**Monitoring Status**	**Monitoring Frequency**
FNSW21	-26.24642	29.54595	Potable Water (Kitchen) Office	Sampled monthly throughout 2014.	MONTHLY - chemistry and bacteria
Points	**Latitude (S)**	**Longitude (E)**	**Sewage Water Locations**	**Monitoring Status**	**Monitoring Frequency**
FNSW20	-26.24381	29.54375	Sewage Water Effluent	Sampled for bacteria monthly throughout 2014. Chemical analysis done in Mar, Jun, Sep, Dec.	QUARTERLY – chem & bacteria MONTHLY - bacteria

Table 14-2: Forzando South monitoring schedule (2018)

Points	Latitude (S)	Longitude (E)	Groundwater Locations	Monitoring Status	Monitoring Frequency
FSGW3	-26.28695	29.52782	North west of PCDs	Levels recorded and sampled Mar, Jun, Sep, Dec.	Levels quarterly Samples QUARTELY
FSGW4	-26.29106	29.53298	South east of PCDs		
Points	**Latitude (S)**	**Longitude (E)**	**Surface Water Locations**	**Monitoring Status**	**Monitoring Frequency**
FSSW1	-26.32802	29.55813	Viskuile River by R38 (upstream of site)	Sampled monthly throughout 2014.	Samples MONTHLY
FSSW2	-26.32456	29.56104	Viskuile River by R38 (upstream of site)		
FSSW3	-26.30266	29.49747	Joubertvleispruit by dirt road off R35	Sampled monthly throughout 2014 except in Sep (Dry).	
FSSW4	-26.30242	29.50141	Joubertvleispruit by dirt road off R35	Sampled monthly throughout 2014.	
FSSW5	-26.27858	29.50839	Viskuile on the bridge		
FSSW6	-26.296573	29.52873	Tributary of the Viskuile river	Sampled monthly throughout 2014, except Feb and Oct when dry.	
FSSW7	-26.29887	29.51355	Boltons' pan	Sampled monthly throughout 2014.	
FSSW8	-26.29346	29.53528	Upstream of mining area		
FSSW9	-26.2902	29.53303	Pollution dam 1	Sampled monthly throughout 2014.	
FSSW10	-26.28868	29.52979	Pollution dam 2	Sampled Jan to Aug. Dry from Sep to Dec.	
FSSW11	-26.28785	29.52883	Pollution dam 3	Sampled monthly throughout 2014.	
FSSW12	-26.28798	29.52927	Erikson Dam 1		
FSSW13	-26.28799	29.52928	Erikson Dam 2		
Points	**Latitude (S)**	**Longitude (E)**	**Potable Water Locations**	**Monitoring Status**	**Monitoring Frequency**
FSSW15	-26.28689	29.53064	Potable water (Kitchen)	Sampled monthly throughout 2014.	MONTHLY - chemistry and bacteria
Points	**Latitude (S)**	**Longitude (E)**	**Sewage Water Locations**	**Monitoring Status**	**Monitoring Frequency**
FSSW14	26.28930	29.53276	Sewage Outflow	Sampled for bacteria monthly throughout 2014. Chemical analysis done in Mar, Jun, Sep, Dec.	QUARTERLY – chemistry and bacteria MONTHLY - bacteria only

Table 14-3: Forzando West monitoring schedule (2018)

Points	Latitude (S)	Longitude (E)	Groundwater Locations	Monitoring Status	Monitoring Frequency
FWGW1	-26.291245	29.461769	Adjacent to R35	Levels recorded and sampled Mar, Jun, Sep, Dec.	Levels QUARTELY Samples QUARTELY
FWGW2	-26.298234	29.460816	Adjacent to R35		
FWGW3	-26.294847	29.461483	Adjacent to R35		
Points	**Latitude (S)**	**Longitude (E)**	**Surface Water Locations**	**Monitoring Status**	**Monitoring Frequency**
FWSW1	-26.28716	29.46228	North of boreholes, where stream crosses R35	Sampled monthly throughout 2014.	Samples MONTHLY
FWSW2	-26.297405	29.47562	Small pan, east of R35	Sampled Apr to Dec. Not sampled Jan to Mar, too wet to access.	
FWSW3	-26.277131	29.481499	Large pan, east of R35	Sampled monthly throughout 2014, except Mar, too wet to access.	
FWSW4	-26.31622	29.45025	Small tributary south west of site	Sampled monthly throughout 2014, except Apr, too wet to access.	
FWSW5	-26.26922	29.49504	Viskuile Stream	Sampled monthly throughout 2014.	


EXXARO COAL
FORZANDO NORTH
WATER MONITORING PROGRAMME
Legend
Groundwater Monitoring Locality
Surface Water Monitoring Locality
Underground Surface Monitoring Locality


TOTAL COAL: FORZANDO SOUTH MINE (FOURTH QUARTER 2013)
FSSW5
FSGW3
FSSW15
FSSW11
FSSW12
FSSW13
FSSW14
FSSW10
FSSW9
FSGW4
FSSW8
FSSW6
FSSW7
FSSW3
FSSW4
FSSW2
FSSW1
LEGEND
SURFACE WATER MONITORING POINTS
GROUNDWATER MONITORING POINTS
Road Network
Rivers and Streams
GCS

15 APPENDIX C: GEOCHEMISTRY LAB RESULTS

The methodology in the collection and preservation of groundwater samples is important for the reliability of the analysis. Samples were taken and preserved to ensure a correct version of the on-site conditions at the site area. This work was undertaken in accordance to the following publications:

- SABS ISO 5667-11:1993 Guidance on sampling of groundwater;
- SABS ISO 5667-2:1991 Guidance on sampling techniques; and
- SABS ISO 5667-3:1994 Guidance on the preservation and handling of samples.

Table 15-1: X-ray diffraction results (weight %)

Sample ID	FZ-S and FZ-N Product	FZ-S UG section 44 SP14 Floor	FZ-S UG Section 44 SP14 Roof	FZ-N Dump 1a Discard	FZ-N Dump 1b Discard	FZ-N Dump 3 Discard Fresh	FZ-N UG Section 1 Roof	FZ-N UG Section 1 Floor
Description/ Rock Type								
Calcite	0.19	1.59	-	3.69	0.65	3.66	1.79	1.44
(Error)	0.07	0.19	-	0.51	0.13	0.60	0.23	0.23
Dolomite	0.33	0.44	-	0.21	0.66	0.69	3.43	2.73
(Error)	0.14	0.22	-	0.19	0.24	0.22	0.36	0.29
Graphite	85.34	53.47	93.63	40.70	60.58	26.60	73.21	77.53
(Error)	0.60	2.64	0.51	4.20	2.10	5.10	2.07	1.11
Gypsum	0.46	1.92	1.01	2.46	1.88	12.30	2.91	2.30
(Error)	0.20	0.36	0.24	0.45	0.28	8.40	1.92	0.87
Hematite	0.11	0.40	0.14	0.77	0.46	0.29	0.24	0.17
(Error)	0.09	0.12	0.10	0.16	0.13	0.18	0.12	0.08
Kaolinite	10.94	17.69	5.68	22.66	21.25	21.93	9.73	10.80

Sample ID	FZ-S and FZ-N Product	FZ-S UG section 44 SP14 Floor	FZ-S UG Section 44 SP14 Roof	FZ-N Dump 1a Discard	FZ-N Dump 1b Discard	FZ-N Dump 3 Discard Fresh	FZ-N UG Section 1 Roof	FZ-N UG Section 1 Floor
Description/ Rock Type								
(Error)	0.45	1.02	0.36	1.65	1.17	2.94	0.60	0.54
Microcline	-	5.60	-	6.67	-	8.43	-	-
(Error)	-	0.63	-	0.87	-	1.23	-	-
Muscovite	0.92	4.02	-	4.76	4.48	6.24	2.02	1.48
(Error)	0.25	0.45	-	0.57	0.42	0.96	0.36	0.22
Pyrite	0.38	0.56	2.22	0.57	0.39	0.75	0.48	0.24
(Error)	0.07	0.14	0.14	0.16	0.12	0.20	0.10	0.18
Quartz	1.32	14.16	0.32	17.37	9.41	18.98	5.67	3.33
(Error)	0.10	0.87	0.08	1.32	0.54	2.55	0.33	0.18
Rutile	-	-	-	-	0.23	-	0.51	-
(Error)	-	-	-	-	0.10	-	0.09	-
Siderite	-	0.16	-	0.14	-	0.07	-	-
(Error)	-	0.10	-	0.16	-	0.08	-	-

Table 15-2: XRF major oxide results (weight %)

Sample	LOI	Al_2O_3	CaO	Cr_2O_3	Fe_2O_3	K_2O	MgO	MnO	Na_2O	P_2O_5	S	SiO_2	TiO_2
FZ-S UG Section 44 SP14 Floor	55%	13.26	2.49	<0.02	0.91	0.77	0.46	<0.02	0.12	0.03	0.75	25.32	0.74
FZ-S UG Section 44 SP14 Roof	88%	2.99	1.06	0.41	3.80	0.07	0.32	<0.02	0.04	0.04	0.48	3.30	0.45
FZ-N Dump 1a Discard	31%	18.05	3.65	<0.02	2.05	1.02	0.39	<0.02	0.05	0.07	1.27	42.09	1.17
FZ-N Dump 2b Discard	54%	12.67	2.08	<0.02	2.25	0.48	0.33	<0.02	0.05	0.13	0.80	24.80	0.84

Sample		LOI	Al_2O_3	CaO	Cr_2O_3	Fe_2O_3	K_2O	MgO	MnO	Na_2O	P_2O_5	S	SiO_2	TiO_2
FZ-N Dump 3 Discard Fresh		24%	18.36	4.46	<0.02	1.84	1.33	0.55	<0.02	0.16	0.04	1.36	48.39	1.26
FZ-N UG Section 1 Roof		69%	5.58	5.28	<0.02	2.17	0.36	1.06	0.06	0.11	0.02	2.40	13.70	0.45
FZ-N UG Section 1 Floor		81%	4.29	3.04	<0.02	0.88	0.04	0.67	0.02	0.05	0.01	0.99	8.99	0.23
*AUC	AUC		15.40	3.59	See trace	11.20	2.80	2.48	0.10	3.27	0.15	0.06	66.60	0.64
	3-5 times higher		46.2	10.77	See trace	33.6	8.4	7.44	0.3	9.81	0.45	0.18	199.8	1.92
	> 5 times higher		77	17.95	See trace	56	14	12.4	0.5	16.35	0.75	0.3	-	3.2

*** Black = Coal (Coal seams and product), Dark Grey = Coal Discard, Light Grey = Coal Slurry Brown = Sand and coal slurry, Orange = Sandstone, shale and coal, Blue = ROM.**

** Average Upper Crust, Rudnick and Gao (2003).*

Table 15-3: XRF trace elements results (ppm)

Sample ID	LOI	As	Ba	Cl	Co	Cr	Cu	F	Ga	Nb	Nd	Ni	Pb	Rb	Sr	Th	U	V	Y	Yb	Zn	Zr
FZ-S UG Section 44 SP14 Floor	55%	114	253	35	<20	37	27	230	15	249	<20	41	98	30	245	23	<20	88	46	8	31	279
FZ-S UG Section 44 SP14 Roof	88%	<20	88	<20	59	387	<20	315	25	9	<20	212	34	<20	65	<20	171	995	<30	3	<20	208
FZ-N Dump 1a Discard	31%	179	333	48	48	85	36	304	21	333	<20	47	148	44	294	35	<20	146	62	9	23	814
FZ-N Dump 2b Discard	54%	104	358	37	<20	60	35	337	19	176	21	45	98	28	429	24	<20	124	37	7	30	277
FZ-N Dump 3 Discard Fresh	24%	183	365	64	<20	94	40	82	21	355	<20	50	164	51	370	36	<20	140	73	12	48	574
FZ-N UG Section 1 Roof	69%	27	154	31	31	<20	<20	251	9	19	<20	41	184	<20	348	<20	39	50	<30	4	<20	153
FZ-N UG Section 1 Floor	81%	<20	85	<20	<20	<20	<20	110	5	23	<20	<20	84	<20	341	<20	<20	20	<30	2	<20	100
*AUC	Above Limit	4.8	628	294	17.3	92	28	557	17.5	12	27	47	17	82	320	10.5	2.7	97	21	2	67	193
	3-5 times higher	14.4	1884	882	51.9	276	84	1671	52.5	36	81	141	51	246	960	31.5	8.1	291	63	6	201	579
	> 5 times higher	24	3140	1470	86.5	460	140	2785	87.5	60	135	235	85	410	1600	52.5	13.5	485	105	10	335	965

*** Black = Coal (Coal seams and product), Dark Grey = Coal Discard, Light Grey = Coal Slurry Brown = Sand and coal slurry, Orange = Sandstone, shale and coal, Blue = ROM.**

** Average Upper Crust, Rudnick and Gao (2003)*

Table 15-4: Hydrocensus water sample analysis results

Sample ID		pH (Value)	EC (mS/m)	SO_4 (mg/l)	Total Alkalinity (mg/l)	Cl (mg/l)	PO_4 as P(mg/l)	Nitrate as N (mg/l)	Ammonia as N (mg/l)	F (mg/l)
NBH7		7.87	104.20	15.6	274.1	86.4	<0.1	<0.1	0.14	0.32
NBH11		7.90	36.70	28.4	91.6	82.3	<0.1	2.81	<0.1	<0.1
NBH13		8.36	92.30	91.7	261.1	39.6	<0.1	<0.1	1.02	0.74
NBH14		7.97	66.60	32.2	147.1	56.6	<0.1	4.91	0.12	0.20
SANS 241:2011	0-50% of limit	6 - 8.4	<85	<250	-	<150	-	<5.5	<0.75	-
	50-100% of limit	5-6; 8.4-9.7	85-170	250-500	-	150-300	-	5.5-11	0.75 -1.5	-
	Above limit	<5 ; >9.7	>170	>500	-	>300	-	>11	>1.5	-

Table 15-5: ICP results of weekly leach (FZ-N Dump 3 Discard Fresh)

Parameters (mg/l)	FZ-N Dump 3 Fresh					SANS 241:2011		
Leach	0	1	2	3	6	0-50% of limit	50%-100% of limit	Above limit
Al	0.071	0.026	0.022	<0.02	<0.02	<0.15	0.15-0.3	>0.3
As	<0.02	<0.02	<0.02	<0.02	<0.02	<0.005	0.005-0.01	>0.01
Ba	0.133	0.101	0.081	0.095	0.082	-	-	-
Be	<0.02	<0.02	<0.02	<0.02	<0.02	-	-	-
Ca	8.71	10.7	10.3	6.56	11.7	-	-	-
Cd	<0.02	<0.02	<0.02	<0.02	<0.02	<0.0015	0.0015-0.003	>0.003
Co	<0.02	<0.02	<0.02	<0.02	<0.02	<0.25	0.25-0.5	>0.5
Cr	<0.02	<0.02	<0.02	<0.02	<0.02	<0.025	0.025-0.05	>0.05
Cu	<0.02	<0.02	<0.02	0.060	<0.02	<1	1-2	>2
Fe	0.062	<0.02	<0.02	<0.02	<0.02	<1	1-2	>2
K	1.96	2.46	2.31	2.23	2.49	-	-	-
Mg	<1	1.47	1.78	1.08	2.35	-	-	-
Mn	0.090	<0.02	<0.02	<0.02	<0.02	<0.25	0.25-0.5	>0.5
Na	17.9	61.9	62.8	43.3	58.8	-	-	-
Ni	<0.02	<0.02	<0.02	<0.02	<0.02	<0.035	0.035-0.07	>0.07
Pb	<0.02	<0.02	<0.02	<0.02	<0.02	<0.005	0.005-0.01	>0.01
Se	<0.02	<0.02	<0.02	<0.02	<0.02	<0.045	0.045-0.09	>0.09
Sr	0.518	0.490	0.441	0.285	0.568	-	-	-
V	<0.02	<0.02	<0.02	<0.02	<0.02	<0.1	0.1-0.2	>0.2
Zn	<0.02	<0.02	<0.02	<0.02	<0.02	<2.5	2.5-5.0	>5

Table 15-6: ICP results of weekly leach (FZ-N UG Section 1 Roof)

Parameters (mg/l)	FZ-N UG Section 1 Roof					SANS 241:2011		
Leach	0	1	2	3	6	0-50% of limit	50%-100% of limit	Above limit
Al	7.19	<0.02	<0.02	0.058	<0.02	<0.15	0.15-0.3	>0.3
As	<0.02	<0.02	<0.02	<0.02	<0.02	<0.005	0.005-0.01	>0.01
Ba	0.146	0.048	0.037	0.035	0.025	-	-	-
Be	<0.02	<0.02	<0.02	<0.02	<0.02	-	-	-
Ca	411	329	329	358	329	-	-	-
Cd	<0.02	<0.02	<0.02	<0.02	<0.02	<0.0015	0.0015-0.003	>0.003
Co	4.41	0.979	0.174	0.065	<0.02	<0.25	0.25-0.5	>0.5
Cr	<0.02	<0.02	<0.02	<0.02	<0.02	<0.025	0.025-0.05	>0.05
Cu	0.291	<0.02	<0.02	<0.02	<0.02	<1	1-2	>2
Fe	1,430	4.07	0.104	0.035	0.026	<1	1-2	>2
K	2.62	2.35	2.01	1.75	1.67	-	-	-
Mg	784	647	253	117	30.9	-	-	-
Mn	16.1	12.1	4.13	2.41	1.21	<0.25	0.25-0.5	>0.5
Na	88.393	68.494	30.695	16.350	7.387	-	-	-
Ni	5.75	1.37	0.325	0.217	0.187	<0.035	0.035-0.07	>0.07
Pb	0.054	<0.02	<0.02	<0.02	<0.02	<0.005	0.005-0.01	>0.01
Se	<0.02	0.032	<0.02	<0.02	<0.02	<0.045	0.045-0.09	>0.09
Sr	2.55	3.03	2.58	2.30	2.26	-	-	-
V	<0.02	<0.02	<0.02	<0.02	<0.02	<0.1	0.1-0.2	>0.2
Zn	7.90	0.864	0.347	0.158	0.167	<2.5	2.5-5.0	>5

Table 15-7: ICP results of weekly leach (FZ-N UG Section 1 Floor)

Parameters (mg/l)	FZ-N UG Section 1 Floor					SANS 241:2011		
Leach	0	1	2	3	6	0-50% of limit	50%-100% of limit	Above limit
Al	0.549	<0.02	<0.02	<0.02	<0.02	<0.15	0.15-0.3	>0.3
As	<0.02	<0.02	<0.02	<0.02	<0.02	<0.005	0.005-0.01	>0.01
Ba	0.072	0.072	0.031	0.059	0.046	-	-	-
Be	<0.02	<0.02	<0.02	<0.02	<0.02	-	-	-
Ca	127	399	228	184	185	-	-	-
Cd	<0.02	<0.02	<0.02	<0.02	<0.02	<0.0015	0.0015-0.003	>0.003
Co	0.092	0.052	<0.02	<0.02	<0.02	<0.25	0.25-0.5	>0.5
Cr	<0.02	<0.02	<0.02	<0.02	<0.02	<0.025	0.025-0.05	>0.05
Cu	<0.02	<0.02	<0.02	<0.02	<0.02	<1	1-2	>2

Parameters (mg/l)	FZ-N UG Section 1 Floor					SANS 241:2011		
Leach	0	1	2	3	6	0-50% of limit	50%-100% of limit	Above limit
Fe	276	1.80	<0.02	0.051	<0.02	<1	1-2	>2
K	2.03	2.86	2.09	2.14	1.83	-	-	-
Mg	56.7	214	87.6	50.3	32.5	-	-	-
Mn	1.26	2.26	0.613	0.293	0.116	<0.25	0.25-0.5	>0.5
Na	7.19	34.1	17.8	11.7	10.6	-	-	-
Ni	0.258	0.553	0.104	0.063	0.050	<0.035	0.035-0.07	>0.07
Pb	0.032	<0.02	<0.02	<0.02	<0.02	<0.005	0.005-0.01	>0.01
Se	<0.02	0.049	<0.02	<0.02	<0.02	<0.045	0.045-0.09	>0.09
Sr	0.837	3.13	2.05	1.72	1.92	-	-	-
V	<0.02	<0.02	<0.02	<0.02	<0.02	<0.1	0.1-0.2	>0.2
Zn	0.158	0.022	<0.02	0.035	0.033	<2.5	2.5-5.0	>5

Table 15-8: Mine water quality ICP-OES results

Parameters (mg/l)	FZ-N Seepage Dump 3	FZ-N Discard Dump 3	FZ-N Dump 2C	FZ-N Dump 1A Toe Seepage	SANS 241:2011		
					0-50% of limit	50%-100% of limit	Above limit
Al	<0.02	<0.02	<0.02	<0.02	<0.15	0.15-0.3	>0.3
As	<0.02	<0.02	<0.02	<0.02	<0.005	0.005-0.01	>0.01
Ba	0.023	<0.02	<0.02	<0.02	-	-	-
Be	<0.02	<0.02	<0.02	<0.02	-	-	-
Ca	233	209	227	217	-	-	-
Cd	<0.02	<0.02	<0.02	<0.02	<0.0015	0.0015-0.003	>0.003
Co	<0.02	<0.02	<0.02	<0.02	<0.25	0.25-0.5	>0.5
Cr	<0.02	<0.02	<0.02	<0.02	<0.025	0.025-0.05	>0.05
Cu	<0.02	<0.02	<0.02	<0.02	<1	1-2	>2
Fe	0.049	0.138	<0.02	<0.02	<1	1-2	>2
K	12.4	14.5	17.2	11.6	-	-	-
Mg	86.1	86.7	134	63.2	-	-	-
Mn	0.203	<0.02	<0.02	3.568	<0.25	0.25-0.5	>0.5
Na	667	714	1,128	511	-	-	-
Ni	<0.02	<0.02	<0.02	<0.02	<0.035	0.035-0.07	>0.07
Pb	<0.02	<0.02	<0.02	<0.02	<0.005	0.005-0.01	>0.01
Se	<0.02	<0.02	<0.02	<0.02			
Sr	6.350	6.308	7.817	4.060	-	-	-
V	<0.02	<0.02	<0.02	<0.02	<0.1	0.1-0.2	>0.2
Zn	0.029	0.034	0.038	0.029	<2.5	2.5-5.0	>5

Table 15-9: Hydrocensus water sample ICP-OES results

#Parameters (mg/l)	NBH7	NBH13	NBH14	SANS 241:2011		
				0-50% of limit	50%-100% of limit	Above limit
Al	<0.02	<0.02	<0.02	<0.15	0.15-0.3	>0.3
As	<0.02	<0.02	<0.02	<0.005	0.005-0.01	>0.01
Ba	0.320	0.044	0.170	-	-	-
Be	<0.02	<0.02	<0.02	-	-	-
Ca	57.2	28.7	46.3	-	-	-
Cd	<0.02	<0.02	<0.02	<0.0015	0.0015-0.003	>0.003
Co	<0.02	<0.02	<0.02	<0.25	0.25-0.5	>0.5
Cr	<0.02	<0.02	<0.02	<0.025	0.025-0.05	>0.05
Cu	<0.02	<0.02	<0.02	<1	1-2	>2
Fe	<0.02	0.036	<0.02	<1	1-2	>2
K	7.63	22.2	10.7	-	-	-
Mg	24.2	52.9	19.7	-	-	-
Mn	0.052	<0.02	0.043	<0.25	0.25-0.5	>0.5
Na	97.7	50.7	32.8	-	-	-
Ni	<0.02	<0.02	<0.02	<0.035	0.035-0.07	>0.07
Pb	<0.02	<0.02	<0.02	<0.005	0.005-0.01	>0.01
Se	<0.02	<0.02	<0.02	-	-	-
Sr	0.608	0.188	0.451	-	-	-
V	<0.02	<0.02	<0.02	<0.1	0.1-0.2	>0.2
Zn	0.032	0.036	0.175	<2.5	2.5-5.0	>5

15.1 Acid Base Accounting in 2002

Tests were conducted on various samples of the coal seam floor and roof. The objective of this test program was to perform acid base accounting (ABA) testing on 11 different coal samples representing the proposed extension of the Forzando South Mine (DWA, 2002). This was done using static ABA tests, which include neutralising potential (NP), sulphur species and carbonate determination.

Static ABA testing, using the modified ABA test, was completed on a pulverised portion of each of the coal samples. The modified ABA test is a static prediction test method, designed to examine the balance between the acid producing and acid consuming components of a sample. The method does not consider the relative rates of acid production and consumption.

The acid production (AP) is calculated by assuming that all the sulphide sulphur present converts to sulphuric acid (sulphate) at a production of four moles of hydrogen ion per mole of pyrite oxidised. The neutralising potential (NP) is determined by treating a portion of the sample with excess hydrochloric acid (HCl) at ambient temperature for 24 hours. The amount of standardised HCl to be added initially is determined using a fizz test. Sufficient acidity for the reaction is maintained by adding acid as necessary. After the acid treatment, any unconsumed acid is titrated with standardised base to pH 8.3. The calcium carbonate ($CaCO_3$) equivalent of the acid consumed is then calculated. The sulphide content of each sample was determined by LECO furnace. In this test an initial total sulphur assay is completed, the oxidisable sulphur component is roasted off and a second LECO assay is performed to determine the residual sulphur content (defined as the sulphate concentration). The difference between the total and residual sulphur assays is defined as the sulphide sulphur concentration. As elemental sulphur (S_o) will also be oxidised and removed through the roasting process, where S_o is present in significant quantities this will result in overestimation of the sulphide sulphur content.

A summary of the test results is provided in Table 15-10 below.

Table 15-10: Summary of Modified ABA Results (DWA, 2002)

Sample ID	Paste pH	S %	CO2 %	AP	NP	CO2 NP (Calculated)	Net AP	NP/AP
F661/4L/1	8.77	1	0.12	31.25	16.87	1.99	-14.38	0.54
F662/4L/1	7.88	0.96	0.42	30	50.55	6.97	20.55	1.69
F669/4L/1	7.18	1.15	0.14	35.94	28.84	2.32	-7.10	0.80
F670/4/1	7.2	1.7	0.18	33.44	31.82	2.99	-1.62	0.95
F671/4L/1	7.62	0.84	0.11	26.25	25.67	1.83	-0.58	0.98
F667/1/1	8.41	0.22	0.19	6.88	35.51	3.15	28.63	5.16
F667/2/1	8.3	0.37	0.28	11.56	52.76	4.65	41.20	4.56
F668/4A/1	6.82	1.31	<0.05	40.94	34.22	<0.83	-6.72	0.84
F668/2/2	6.84	3.12	0.28	97.5	17.69	4.65	-79.81	0.18

Sample ID	Paste pH	S %	CO2 %	AP	NP	CO2 NP (Calculated)	Net AP	NP/AP
F668/2/1	8	0.57	0.31	17.81	49.17	5.15	31.36	2.76
F668/1/1	7.4	1.56	0.08	48.75	13.69	1.33	-35.06	0.28

In general, the variability of test results indicates a clear heterogeneity in the samples collected. Some samples indicate a strong potential to generate acidity, some a potential to provide a net neutralising capacity while others are borderline or uncertain with regards to their acid generation potential. Table 15-11 below groups the samples analysed according to these broad categories.

All the NP's determined by the modified ABA test method were higher than that which would be available from the measured carbonate content alone. This indicates that other minerals are providing the bulk of the NP reported. Assuming all and only carbonate minerals provide NP for reaction would result in all eleven samples reporting a high potential to generate acidic drainage.

Table 15-11: Summary of Modified ABA Interpretation (DWA, 2002)

Acid Generation Potential (AGP)	Sample Identifiers	General Reasons for Classification (with some exceptions)
Strong positive acid generation potential	F668/2/2; F668/1/1	Sulphide > 0.3%; Negative net NP (<-20); Ration NP/AP < 1
Medium acid generation potential	F661/4L/1; F669/4L/1; F670/4/1; F671/4L/1; F668/4A/1	Sulphide > 0.2%; Negative net NP (>-20); Ratio NP/AP < 1
Low acid generation potential	-	Sulphide < 0.3%; Low NP; Negative net NP; NP/AP < 1
Uncertain possible acid generation/neutralising potential	F662/4L/1	Low AP's and low NP's or high AP's and high NP's with NP/AP between 1 and 3
Low neutralising potential	-	Sulphide < 0.1%; Low NP
Medium neutralising potential	F667/1/1; F667/2/1; F668/2/1	Low Sulphide < 0.5%; Positive net NP's > 10; Ratio NP/AP > 3
Strong neutralising potential	-	Strongly positive net NP's > 20; Ratio NP/AP > 4; High carbonate content

15.2 2010 Assessment for the Proposed Western Area

Six rock samples were obtained from the drilling cuts obtained from the percussion borehole drilling during the construction of the monitoring boreholes in June 2010. Two of the boreholes were sampled and samples were obtained from the hanging wall (sandstone/shale above the No. 4 coal seam), No. 4 coal seam and floor (sandstone/shale below the No. 4 coal seam). The following tables supply an overview of the samples and the results.

It is evident from the results that the roof material have a lesser potential to leach AMD (acid mine drainage) related contaminants into the underground workings and aquifer.

Table 15-12: ABA Analyses – NAG (net acid generation) analyses

Sample Nr	Depth (m)	Description	NAG PH	Final pH	NAG (H2SO4/t)
FWGW 01	20-22	Roof - Sandstone/ shale	5.39	5.39	0
FWGW 01	25-26	coal	2.3	4.47	38.8
FWGW 01	32-34	Floor - Sandstone/ shale	2.15	4.55	23.5
FWGW 03	25-26	Roof - Sandstone/ shale	5.96	5.96	0
FWGW 03	38-39	coal	2.45	4.51	29
FWGW 03	40-42	Floor - Sandstone/ shale	2.46	4.43	21.2

Table 15-13: Distilled Water Extraction Test (500 g: 1000 ml)

Sample Nr	Depth (m)	Description	pH	SO4	Cl	Ca	Mg	Na	Alk (CaCO3)
				mg/l					
FWGW 01	20-22	Roof	7.4	88	6	34	11	12	84
FWGW 01	25-26	coal	8.1	31	12	10	4	33	84
FWGW 01	32-34	Floor	8.9	85	33	4	<2	84	<5
FWGW 03	25-26	Roof	7.7	108	28	27	15	17	84
FWGW 03	38-39	coal	8.2	14	12	8	4	23	<5
FWGW 03	40-42	Floor	8.1	42	8	10	3	40	<5

Table -15-14: Peroxide Extraction Test (2.5 g: 250 ml)

Sample Nr	Depth (m)	Description	pH	SO4	Cl	Ca	Mg	Na	Alk (CaCO3)
				mg/l					
FWGW 01	20-22	Roof	5.7	124	<5	56	56	11	32
FWGW 01	25-26	coal	3.4	163	<5	60	13	13	<5
FWGW 01	32-34	Floor	2.4	189	<5	16	16	15	<5
FWGW 03	25-26	Roof	5.4	29	<5	32	13	12	24
FWGW 03	38-39	coal	3.7	151	<5	56	12	12	<5
FWGW 03	40-42	Floor	2.7	210	<5	43	12	14	<5

16 APPENDIX D: NUMERICAL GROUNDWATER MODELLING

16.1 Objective of the Model

Scenario modelling is typically used to run future scenarios on varying changes in the natural environment or anthropogenic inputs. The potential scenarios to be simulated using the Forzando regional model include the following:

- Potential groundwater ingress;
- Groundwater drawdown; and
- The potential extent of groundwater contamination from both the mine workings and the surface infrastructure.

16.2 Governing Equations

The numerical model used in this modelling study was based on the conceptual model developed from the findings of the desktop and the baseline investigations. The simulation model simulates groundwater flow based on a three-dimensional cell-centred grid and may be described by the following partial differential equation:

(1) $$\frac{\partial}{\partial x}(K_{xx}\frac{\partial h}{\partial x})+\frac{\partial}{\partial y}(K_{yy}\frac{\partial h}{\partial y})+\frac{\partial}{\partial z}(K_{zz}\frac{\partial h}{\partial z})\pm W = S_s\frac{\partial h}{\partial t}$$

where:

- Kxx, Kyy, and Kzz are values of hydraulic conductivity along the x, y, and z coordinate axes, which are assumed to be parallel to the major axes of hydraulic conductivity (L/T);
- h is the potentiometric head (L);
- W is a volumetric flux per unit volume representing sources and/or sinks of water,

with:

- W < 0.0 for flow out of the ground-water system, and W>0.0 for flow in (T-1);
- Ss is the specific storage of the porous material (L-1); and
- t is time (T).

Equation 1, when combined with boundary and initial conditions, describes transient three-dimensional ground-water flow in a heterogeneous and anisotropic medium, provided that the principal axes of hydraulic conductivity are aligned with the coordinate directions (Harbaugh et al. 2000).

16.3 Model Software Package

The numerical model for the project was constructed using the classic version of Visual Modflow, Pro, Build 4.6.0.169 (2018), a pre- and post- processing package for the modelling code MODFLOW. MODFLOW is a modular three dimensional groundwater flow model developed by the United States Geological Survey (Harbaugh et al., 2000). MODFLOW uses 3D finite difference discretisation and flow codes to solve the governing equations of groundwater flow.

16.4 Boundary Conditions

Boundary conditions express the way in which the considered domain interacts with its environment. In other words, they express the conditions of known water flux, or known variables, such as the hydraulic head. Different boundary conditions result in different solutions, hence the importance of stating the correct boundary conditions. Boundary condition options in MODFLOW can be specified either as:

- Specified head or Dirichlet; or
- Specified flux or Neumann; or
- Mixed or Cauchy boundary conditions.

From the conceptual point of view it is essential to meet two criteria to the maximum extent possible:

- The modelled area should be defined by natural geological and hydrogeological boundary conditions, i.e. the model domain should preferably encompass entire hydrogeological structures; and
- The mesh size of model grid has to correspond to the nature of the problem being addressed with the model.

Local hydraulic boundaries were identified for use as Model boundaries. They were represented by local watershed boundaries, topographical highs, constant head and general head and delineated the entire model domain. These hydraulic boundaries were selected far enough from the area of investigation to not influence the numerical Model behaviour in an artificial manner. The Model boundaries and model grid are shown in Figure 16-1. Table 16-1 provides a summary of the boundaries, boundary descriptions and boundary conditions specified in the hydrogeological model.

Table 16-1: Identification of the real-world boundaries and the adopted model boundary conditions.

Boundary	Boundary Description	Boundary Condition
Top	Top surface of water table	Mixed type: River cells for main rivers; drains for non-perennial streams. Recharge is constant for the model area. Recharge flux is applied to the highest active cell.
North	No-flow boundary	Olifants River
East	No-flow boundary	Topographical high
South	No-flow boundary	Topographical High
West	No-flow boundary	Constant head/Topographical high and tributary of the Olifants River.

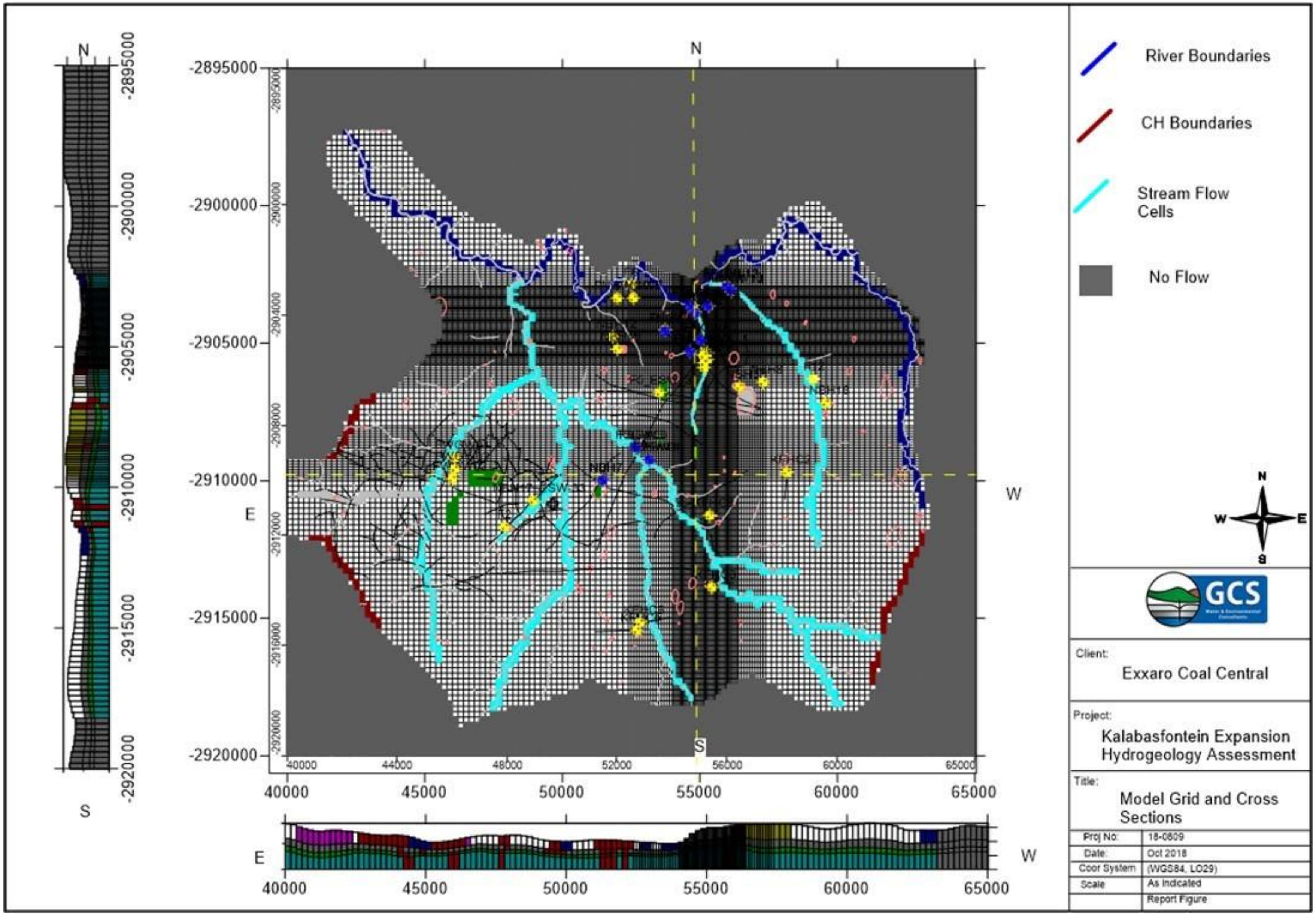


Figure 16-1: Model Boundary types and model grid

16.5 Construction of the Finite Difference Grid

Compilation of the finite difference grid using the Visual Modflow graphic user interface facilitated the construction of a rectangular horizontal grid, as well as vertical geometry provided for each of the layers. The grid consists of 4 layers. The positions of the different geological boundaries are incorporated in the modelling grid. A grid refinement of 50m x 50m cells around the Forzando North mining areas with gradually coarser grid cell sizes away from the mining areas (Figure 16-1). This is standard practise and does not influence the accuracy of the results obtained.

16.6 Vertical Discretization

Along the vertical direction, the steady state hydrogeological model is structured in 4 model layers (Figure 16-1). The layer positions were selected to best incorporate the conceptual model and to allow for accurate horizontal and vertical groundwater flow in the model. The following layers were defined:

1. Layer 1 weathered Karoo layer and grit (~15 m thickness);
2. Layer 2, sandstone and shales, above coal seam, ~5 to 10m,
3. Layer 3 coal seam (4 lower coal seam, 5m);
4. Layer 4 lower fractured Karoo (40 m thickness) and Pre-Karoo.

16.7 Time Discretization

Time parameters are relevant when modelling transient (time-dependent) conditions. They include time unit, the length and number of time periods and the number of time steps within each time period. All model parameters associated with boundary conditions and various stresses remain constant during one time period. Having more time periods allows these parameters to change in time more often (Kresic, 2007).

The steady state groundwater flow model was used for sensitivity analysis.

16.8 Mine Schedule

The mine schedules for the No. 4 seam for Forzando South as presented in Figure 16-2, were used as input for the model. The mining operations were simulated by means of drain cells and according to the life of mine (LOM) a time frame up to 2032 was included. The Forzando North UG mine was also included and modelled as a closed mine void with some areas filled with water, refer to Figure 16-3.

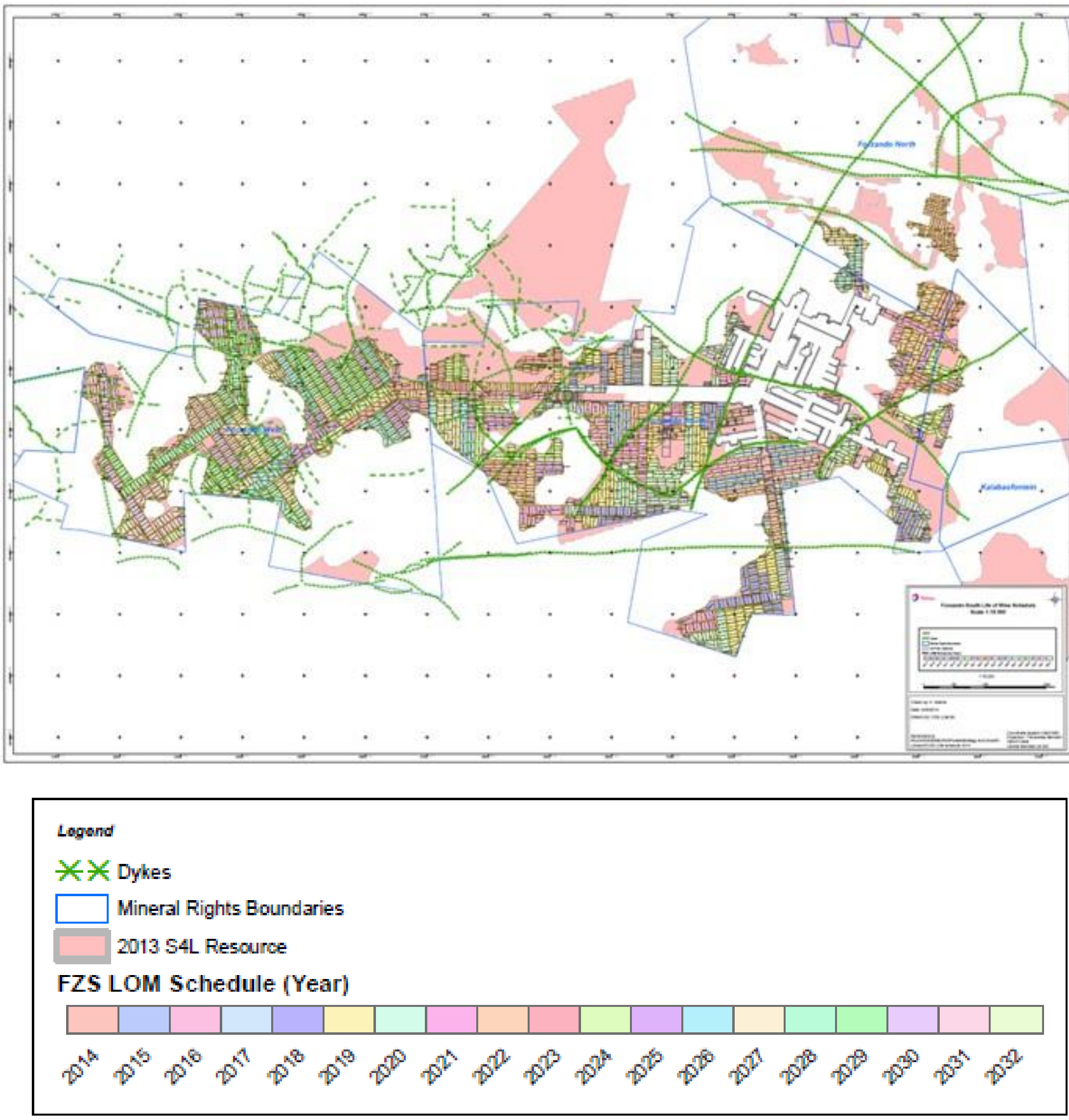


Figure 16-2: Forzando South Mine Plan

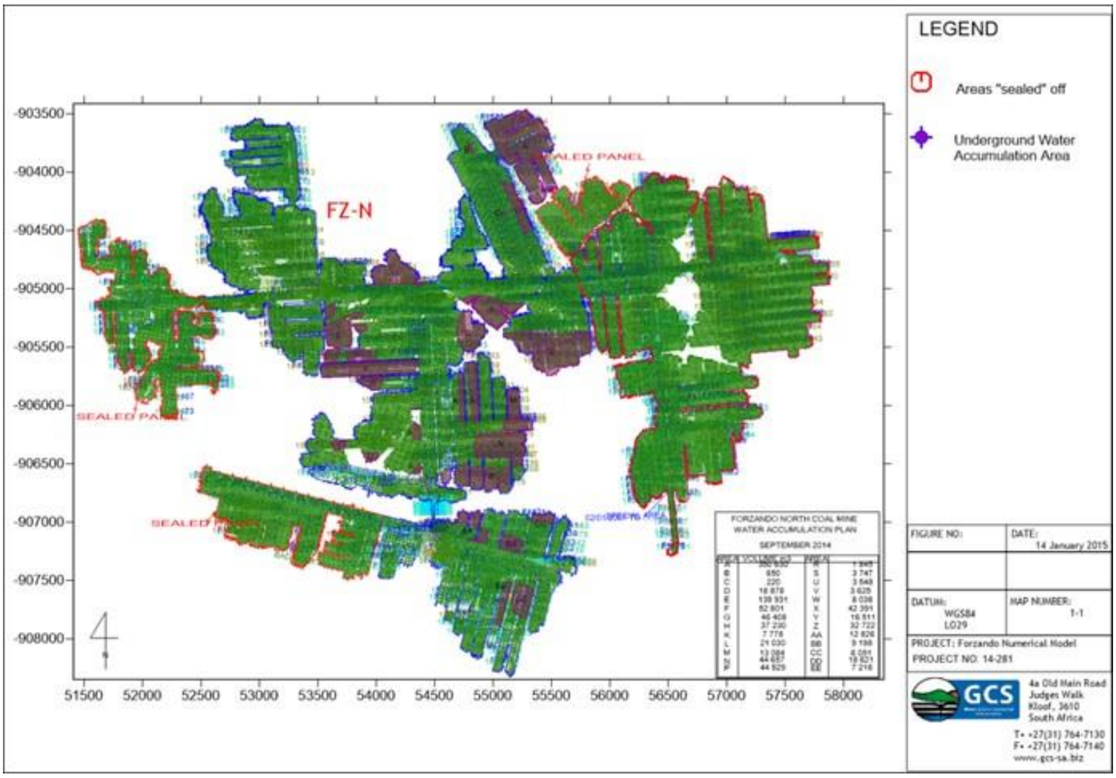


Figure 16-3: Forzando North UG workings and compartments

16.9 Input Parameters

Model input parameters for this flow model are divided into two groups:

- Hydrogeological parameters; and
- Initial conditions.

The initial estimates for hydraulic properties were assigned based on the falling head and pump testing results as carried out as part of the fieldwork for this project. The initial head conditions, specified in the steady state model, were estimated from topography. Initial transient model heads were derived from the steady state model results.

16.10 Model Calibration

Calibration is the process of finding a set of boundary conditions, stresses and hydrogeological parameters that produce results that most closely matches field measurements of hydraulic heads and flows. In a regional groundwater flow model a difference between calculated and measured heads of up to several meters can be tolerated and is usually expressed as a function of the total range of observations.

A scaled absolute mean value of below 10% is generally regarded as acceptable for a regional model. This calibration was done under steady state conditions. When calibrated, the model can be used to predict the influence of various management scenarios. A model limitation was that current mining activities are taking place which may influence the groundwater levels near the underground mine.

16.10.1 Calibration Targets

The groundwater levels of on-site monitoring boreholes for 2010 – 2018 and 2014/2018 hydrocensus data were available for Model Calibration. Trends were also considered; for the steady state "initial conditions" were simulated and these were applied in a transient state model for current and future predictions.

16.10.2 Steady State Calibration

For steady state conditions the groundwater flow equation (1) reduces to the following equation:

$$\frac{\partial}{\partial x}(K_x\frac{\partial h}{\partial x})+\frac{\partial}{\partial y}(K_y\frac{\partial h}{\partial y})+\frac{\partial}{\partial z}(K_z\frac{\partial h}{\partial z})\pm W=0 \quad (2)$$

The numerical model Calculated Head distribution ($h_{x,y,z}$) is dependent upon the recharge, hydraulic conductivity and boundary conditions. For a given set of boundary conditions the head distribution across the aquifer can be obtained for a given set of hydraulic conductivity values and specified recharge values. This simulated head distribution can then be compared to the measured head distribution and the hydraulic conductivity or recharge values can be altered until an acceptable correspondence between measured and simulated heads is obtained.

Steady state calibration of the Forzando model area was accomplished by refining the vertical and horizontal hydraulic conductivity relative to average recharge values until a reasonable resemblance between the measured piezometric levels and the simulated piezometric levels were obtained.

Figure 16-4 indicates the correlation achieved between the real field observation data and the numerical groundwater model values. The correlation achieved is in the order of 91%, a correlation error of <10% can be regarded as acceptable and the model is sufficient to be used for the transient simulations for current status qua conditions and model prediction purposes.

The calibrated flow model's groundwater elevation contour map can be viewed from Figure 16-5.

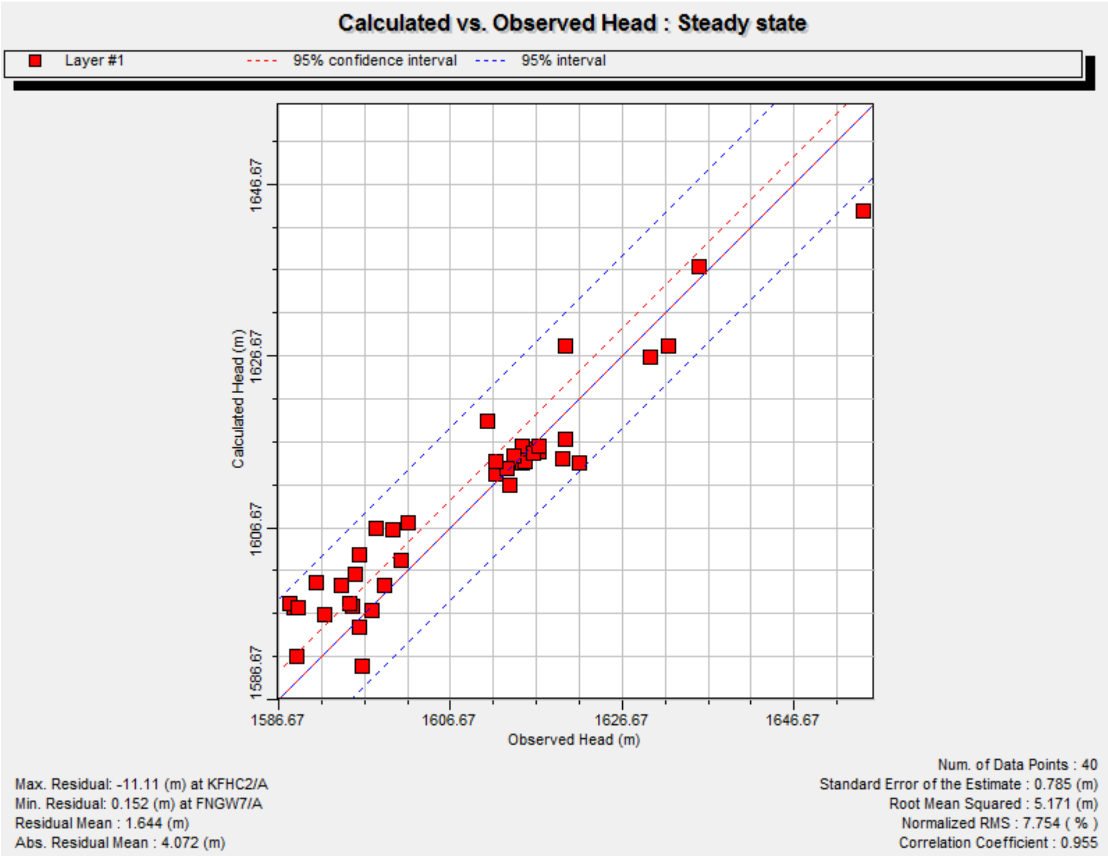


Figure 16-4: Forzando numerical groundwater model steady state calibration results

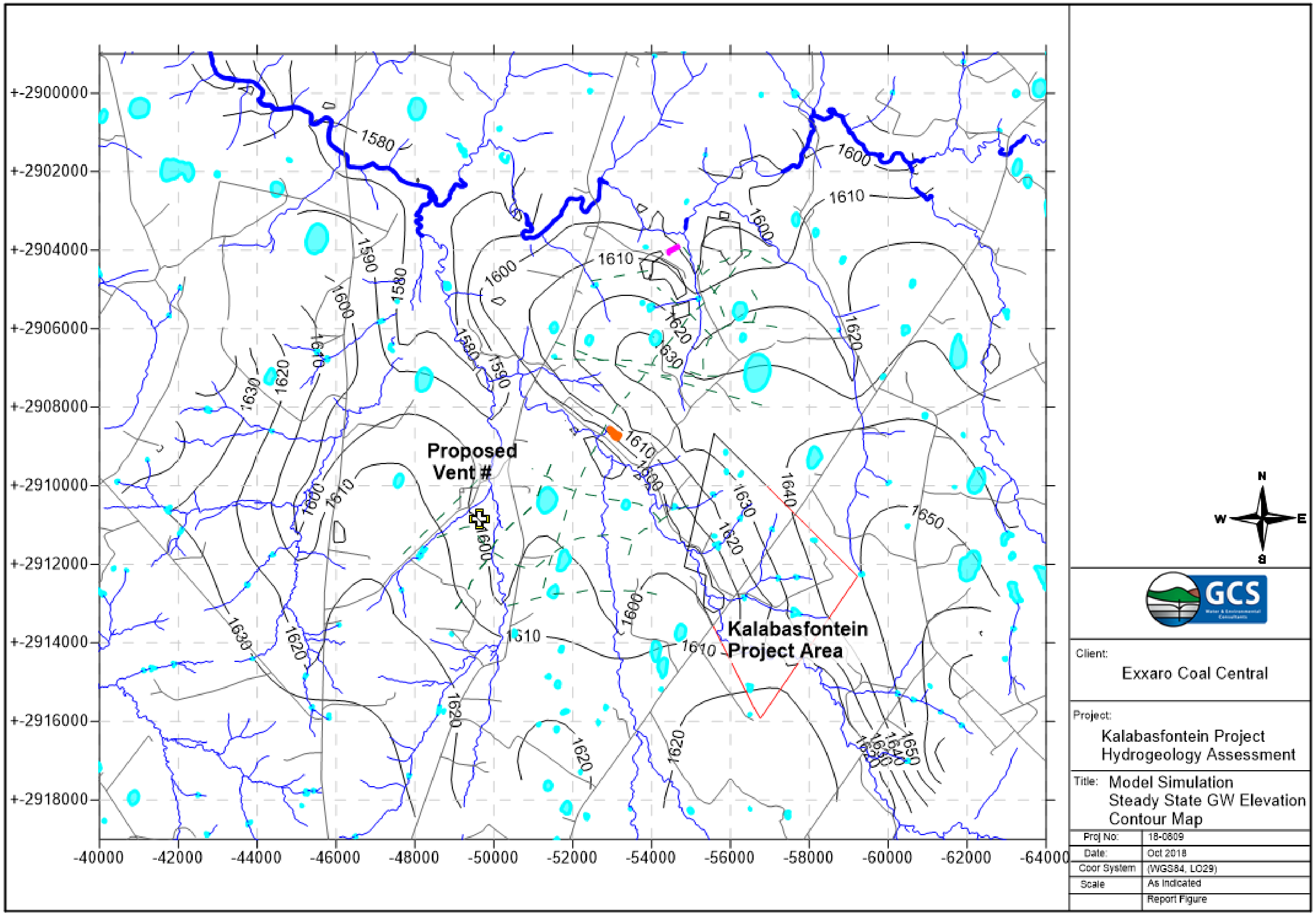


Figure 16-5: Pre-mining groundwater levels

16.10.3 Aquifer Hydraulic Conductivity

Initial estimates of the hydraulic conductivity for the different geological units were obtained from the aquifer test data collected as part of this investigation. These hydraulic conductivity values were assigned to geologic layers in the model area. The initial estimates were used for a combination of PEST and manual calibration. An average value of 0.1 m/day was used for the 2^{nd} or coal void layer and 0.01 m/day for the lower fractured rock layer. The hydraulic conductivity values of the model is in the same order of magnitude as the average values determined from the aquifer test.

16.10.4 Sensitivity Analysis

A sensitivity analysis was carried out on the calibrated model. The purpose of the sensitivity analysis was to quantify the uncertainty in the calibrated model caused by the uncertainty in the estimates of aquifer parameters. During the sensitivity analysis horizontal and vertical hydraulic conductivity and recharge were assessed. The parameter sensitivities can be seen in Figure 16-6 below.

Results of the sensitivity analysis indicate that the water levels in the model are mainly sensitive to changes in recharge and, to a lesser extent, to the hydraulic conductivity of layer 1 (weathered aquifer) and least for hydraulic conductivity to the 2^{nd} and 3^{rd} layers. Based on these results it is recommended that the mine should consider groundwater monitoring programmes to provide improved data regarding these parameters. Time series of groundwater level data from these aquifer units will benefit future calibrations of the model significantly.

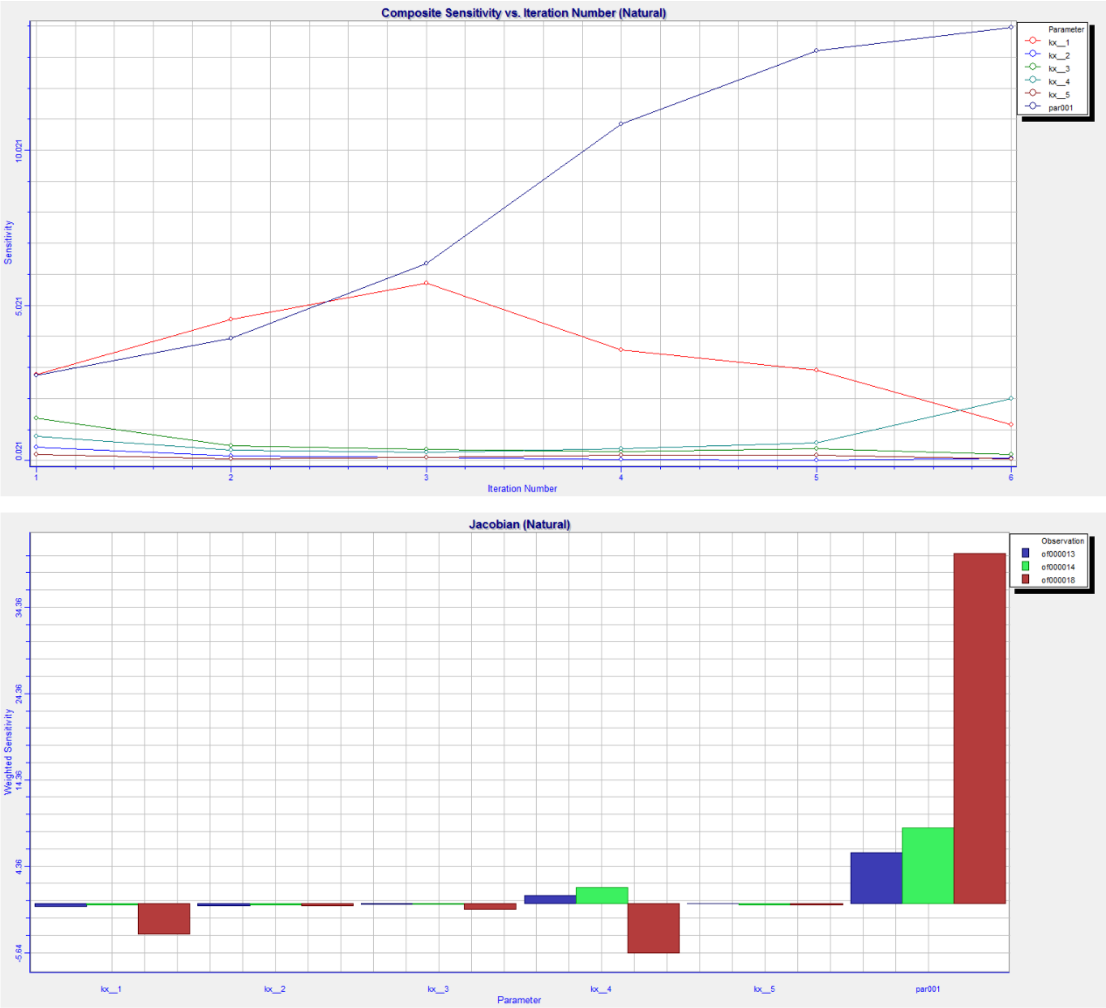


Figure 16-6: Parameter sensitivity (relative composite)

17 APPENDIX E - METHOD OF ASSESSING IMPACTS:

The impact assessment methodology is guided by the requirements of the NEMA EIA Regulations (2010). The broad approach to the significance rating methodology is to determine the environmental risk (ER) by considering the consequence (C) of each impact (comprising Nature, Extent, Duration, Magnitude, and Reversibility) and relate this to the probability/likelihood (P) of the impact occurring. This determines the environmental risk. In addition other factors, including cumulative impacts, public concern, and potential for irreplaceable loss of resources, are used to determine a prioritisation factor (PF) which is applied to the ER to determine the overall significance (S). Please note that the impact assessment must apply to the identified Sub Station alternatives as well as the identified Transmission line routes.

Determination of Environmental Risk:

The significance (S) of an impact is determined by applying a prioritisation factor (PF) to the environmental risk (ER).

The environmental risk is dependent on the consequence (C) of the particular impact and the probability (P) of the impact occurring. Consequence is determined through the consideration of the Nature (N), Extent (E), Duration (D), Magnitude (M), and reversibility (R) applicable to the specific impact.

For the purpose of this methodology the consequence of the impact is represented by:

$$C = \underline{(E+D+M+R)} \times N \qquad 4$$

Each individual aspect in the determination of the consequence is represented by a rating scale as defined in Table 17-1.

Table 17-1: Criteria for Determining Impact Consequence

Aspect	Score	Definition
Nature	- 1	Likely to result in a negative/ detrimental impact
	+1	Likely to result in a positive/ beneficial impact
Extent	1	Activity (i.e. limited to the area applicable to the specific activity)
	2	Site (i.e. within the development property boundary),
	3	Local (i.e. the area within 5 km of the site),
	4	Regional (i.e. extends between 5 and 50 km from the site
	5	Provincial / National (i.e. extends beyond 50 km from the site)
Duration	1	Immediate (<1 year)
	2	Short term (1-5 years),
	3	Medium term (6-15 years),
	4	Long term (the impact will cease after the operational life span of the project),
	5	Permanent (no mitigation measure of natural process will reduce the impact after construction).
Magnitude/ Intensity	1	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected),

Aspect	Score	Definition
	2	Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected),
	3	Moderate (where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way),
	4	High (where natural, cultural or social functions or processes are altered to the extent that it will temporarily cease), or
	5	Very high / don't know (where natural, cultural or social functions or processes are altered to the extent that it will permanently cease).
Reversibility	1	Impact is reversible without any time and cost.
	2	Impact is reversible without incurring significant time and cost.
	3	Impact is reversible only by incurring significant time and cost.
	4	Impact is reversible only by incurring prohibitively high time and cost.
	5	Irreversible Impact

Once the C has been determined the ER is determined in accordance with the standard risk assessment relationship by multiplying the C and the P (refer to **Error! Reference source not found.**). Probability is rated/scored as per Table 17-2.

Table 17-2: Probability Scoring

Probability	1	Improbable (the possibility of the impact materialising is very low as a result of design, historic experience, or implementation of adequate corrective actions; <25%),
	2	Low probability (there is a possibility that the impact will occur; >25% and <50%),
	3	Medium probability (the impact may occur; >50% and <75%),
	4	High probability (it is most likely that the impact will occur- > 75% probability), or
	5	Definite (the impact will occur),

The result is a qualitative representation of relative ER associated with the impact. ER is therefore calculated as follows:

ER= C x P

Table 17-3: Determination of Environmental Risk

Consequence	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
		1	2	3	4	5
	Probability					

The outcome of the environmental risk assessment will result in a range of scores, ranging from 1 through to 25. These ER scores are then grouped into respective classes as described in Table 17-4.

Table 17-4: Significance Classes

Environmental Risk Score	
Value	**Description**
< 9	Low (i.e. where this impact is unlikely to be a significant environmental risk),
≥9; <17	Medium (i.e. where the impact could have a significant environmental risk),
≥ 17	High (i.e. where the impact will have a significant environmental risk).

The impact ER will be determined for each impact without relevant management and mitigation measures (pre-mitigation), as well as post implementation of relevant management and mitigation measures (post-mitigation). This allows for a prediction in the degree to which the impact can be managed/mitigated.

Impact Prioritisation:

In accordance with the requirements of Regulation 31 (2)(l) of the EIA Regulations (GNR 543), and further to the assessment criteria presented in the Section above it is necessary to assess each potentially significant impact in terms of:

- Cumulative impacts; and
- The degree to which the impact may cause irreplaceable loss of resources.

In addition it is important that the public opinion and sentiment regarding a prospective development and consequent potential impacts is considered in the decision making process.

In an effort to ensure that these factors are considered, an impact prioritisation factor (PF) will be applied to each impact ER (post-mitigation). This prioritisation factor does not aim to detract from the risk ratings but rather to focus the attention of the decision-making authority on the higher priority/significance issues and impacts. The PF will be applied to the ER score based on the assumption that relevant suggested management/mitigation impacts are implemented.

Table 17-5: Criteria for Determining Prioritisation

Public response (PR)	Low (1)	Issue not raised in public response.
	Medium (2)	Issue has received a meaningful and justifiable public response.
	High (3)	Issue has received an intense meaningful and justifiable public response.
Cumulative Impact (CI)	Low (1)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.
	Medium (2)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.
	High (3)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/definite that the impact will result in spatial and temporal cumulative change.

Irreplaceable loss of resources (LR)	Low (1)	Where the impact is unlikely to result in irreplaceable loss of resources.
	Medium (2)	Where the impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited.
	High (3)	Where the impact may result in the irreplaceable loss of resources of high value (services and/or functions).

The value for the final impact priority is represented as a single consolidated priority, determined as the sum of each individual criteria represented in Table 11. The impact priority is therefore determined as follows:

Priority = PR + CI + LR

The result is a priority score which ranges from 3 to 9 and a consequent PF ranging from 1 to 2 (Refer to Table 17-6).

Table 17-6: Determination of Prioritisation Factor

Priority	Ranking	Prioritisation Factor
3	Low	1
4	Medium	1.17
5	Medium	1.33
6	Medium	1.5
7	Medium	1.67
8	Medium	1.83
9	High	2

In order to determine the final impact significance the PF is multiplied by the ER of the post mitigation scoring. The ultimate aim of the PF is to be able to increase the post mitigation environmental risk rating by a full ranking class, if all the priority attributes are high (i.e. if an impact comes out with a medium environmental risk after the conventional impact rating, but there is significant cumulative impact potential, significant public response, and significant potential for irreplaceable loss of resources, then the net result would be to upscale the impact to a high significance).

Table 17-7: Final Environmental Significance Rating

Environmental Significance Rating	
Value	**Description**

< 10	Low (i.e. where this impact would not have a direct influence on the decision to develop in the area),
≥10 <20	Medium (i.e. where the impact could influence the decision to develop in the area),
≥ 20	High (i.e. where the impact must have an influence on the decision process to develop in the area).

18 DISCLAIMER

The opinions expressed in this Report have been based on the information supplied to GCS Water and Environment (Pty) Ltd (GCS) by Exxaro Coal Central Proprietary Limited, historical specialist studies undertaken by GCS and other consulting reports, data extracted from the National Groundwater Archive (NGA) and DWAF databases. The opinions in this Report are provided in response to a specific request from Exxaro Coal Central Proprietary Limited to do so.

GCS has exercised all due care in reviewing the supplied information. Whilst GCS has compared key supplied data with expected values, the accuracy of the results and conclusions are entirely reliant on the accuracy and completeness of the supplied data. GCS does not accept responsibility for any errors or omissions in the supplied information and does not accept any consequential liability arising from commercial decisions or actions resulting from them.

Opinions presented in this report, apply to the site conditions and features as they existed at the time of GCS's investigations, and those reasonably foreseeable. These opinions do not necessarily apply to conditions and features that may arise after the date of this Report, about which GCS had no prior knowledge nor had the opportunity to evaluate.

19 DETAILS OF THE SPECIALIST, DECLARATION OF INTEREST

DETAILS OF THE SPECIALIST, DECLARATION OF INTEREST AND UNDERTAKING UNDER OATH

Application for authorisation in terms of the National Environmental Management Act, Act No. 107 of 1998, as amended and the Environmental Impact Assessment (EIA) Regulations, 2014, as amended (the Regulations)

PROJECT TITLE

Kalabasfontein project – Hydrogeological Assessment

SPECIALIST INFORMATION

Specialist Company Name:	GCS Water and Environment Pty Ltd			
B-BBEE	Contribution level (indicate 1 to 8 or non-compliant)	4	Percentage Procurement recognition	
Specialist name:	Pieter Labuschagne			
Specialist Qualifications:	MSc Hydrogeology and M Environmental Management			
Professional affiliation/registration:	PR SCI NAT 400386			
Physical address:	4A Old Main Road Kloof, 3610			
Postal address:				
Postal code:		Cell:		
Telephone:	031 764 7130	Fax:		
E-mail:	pieterl@gcs-sa.biz			

DECLARATION BY THE SPECIALIST

I, Pieter Labuschagne, declare that –

- I act as the independent specialist in this application;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, Regulations and all other applicable legislation;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- all the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of regulation 48 and is punishable in terms of section 24F of the Act.

Signature of the Specialist

GCS

Name of Company:

14 Nov 2018

Date