Groundwater Complete

COZA MINING (PTY) LTD
DRIEHOEKSPAN IRON ORE PROJECT

REPORT ON GEOHYDROLOGICAL INVESTIGATION AS PART OF THE EIA AND EMP

DECEMBER 2014

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DRIEHOEKSPAN IRON ORE PROJECT: REPORT ON GEOHYDROLOGICAL INVESTIGATION AS PART OF THE EIA AND EMP, DECEMBER 2014

EXECUTIVE SUMMARY:

Groundwater Complete was contracted by Synergistics Environmental Services (Pty) Ltd to conduct a geohydrological study and report on findings as specialist input to the Environmental Impact Assessment (EIA) and Environmental Management Program (EMP) for the proposed Coza Iron Ore Project (hereinafter referred to as Coza Project). The project area is located within the Tsantsabane Local Municipality in the Northern Cape Province, approximately 16 km north of the town of Postmasburg. Several historical and active iron ore mining operations occur in the region. The most significant active mines are the Sishen (Anglo American) and Khumani (Assmang) mines approximately 50 km north of the Coza Project and Kolomela (Anglo American) and Beeshoek (Assmang) mines approximately 20 km south west of the Coza Project.

The Environmental Impact Assessment related to the proposed Doornpan mining activities was completed in January 2014. The focus of this investigation is centered on determining the groundwater quality and quantity impacts related to the proposed Driehoekspan iron ore mining activities. Groundwater inflow into opencast mine workings is known to be problematic in the surrounding iron ore mines, hence the investigation also involved mine dewatering simulations and recommendations that will allow for safe mining conditions.

A hydrocensus and groundwater user survey was conducted within a ± 10 km radius of both the Doornpan and Driehoekspan mining areas. A total of 41 boreholes were located, however the survey could not be extended to the east of the R325 road as the area is largely the property of Assmang and locked gates restricted access at the time of the survey.

Yield information was not available for the majority of hydrocensus boreholes, however yields varying between ± 2 500 l/h and 25 000 l/h were indicated by Christiaan and Louis Claasens.

A geophysical investigation was conducted for the purpose of the geohydrological study to identify geological structures such as faults and intrusive features like dolerite dykes. The main aim of the survey was to site monitoring boreholes in areas where potential impacts from the mining related activities may occur. During the survey of five traverses a total of six anomalies were identified.

A total of four monitoring boreholes were drilled on anomalies identified during the geophysical survey.

The geohydrological regime in the project area is made up of two main aquifer systems. The first, the upper, unconfined to semi-confined aquifer occurs in the calcrete that cover most of the surface area. The second aquifer is associated with fractures, fissures, joints and other discontinuities within the consolidated bedrock and associated intrusives of the Transvaal/Griqualand West Sequences.

Mining in the Driehoekspan Project area will penetrate both the calcrete and deeper bedrock aquifers and the physical structure of these two aquifers will be destroyed in the pit. With the dewatering foreseen for the proposed Driehoekspan pit, groundwater gradients will be created towards the pit area and groundwater flow directions will change towards this area. The local change in groundwater flow directions is caused by the formation of a cone of depression due to mine dewatering.

Constant rate pump tests were performed on five exploration boreholes and a short summary of the pump tests are provided below:

BH	BH depth	Static WL	Pump duration	Pump rate	Drawdown	Recovery
Unit	*m*	*mamsl*	*min*	*l/s*	*m*	*%*
DPR28	>100	60.4	15	0.15	18.2	18% after 15 min
DPR63	>100	59.1	600	1.00	7.0	100% after 90 min
DPR66	>100	47.3	600	0.80	17.7	94% after 600 min
DPD-RC01	>100	44.1	480	0.13	20.9	56% after 360 min
WATER-BH	50	11.7	720	4.50	7.5	100% after 180 min

Note: *Borehole DPR28 was pumped dry within the first 15 minutes of the test.*

Data collected from the pump tests were used to determine aquifer parameters such as transmissivity and storativity for both the matrix- and fracture flow stages.

It follows that the representative transmissivity of the **aquifer matrix** (between fracture zones) in the proposed Driehoekspan area generally vary between ± 0.3 and 0.7 m^2/d with an **average of 0.5 m^2/d**. These transmissivities calculate to a representative **hydraulic conductivity** of ± **0.017 m/d** for the area.

The representative transmissivity of the **fractures** in the area vary between ± 1.1 and 3.4 m^2/day with an **average of 2.2 m^2/d**. The average **hydraulic conductivity** of the fractures is therefore in the region of **0.073 m/d**.

Groundwater quality data were collected from two sources, namely from **user boreholes** located during the hydrocensus/user survey and groundwater **monitoring boreholes** on the farm Doornpan. The groundwater quality data were evaluated with the aid of diagnostic chemical diagrams and by comparing the inorganic concentrations to the South African National Standards for drinking water *(SANS 241:2011)*.

Summary of groundwater quality evaluation:

- Groundwater sampled from surrounding groundwater users is of good quality and is suitable for human consumption according to the South African National Standards for drinking water *(SANS241:2011)*.
- Exceptions do however occur as the nitrate content measured in DO-BH04, DP04, FARM434, KOOT01/02/03, NIEMAND01 and WVR01/02 all exceed the permissible SANS concentration of 11 mg/, rendering the groundwater unfit for human consumption.
- The groundwater is mainly dominated by calcium and magnesium cations, while bicarbonate alkalinity dominates the anion content.

The time it will take the proposed Driehoekspan opencast void to fill with water was calculated with the use of volume/recharge calculations and the results are provided in the below table:

General information		
Surface area	m^2	87 990
Decant elevation	mamsl	1 414
Total void volume	m^3	2 339 980
Mean annual precipitation	m/a	0.3
Backfilled void volume		
20% Porosity	m^3	467 996
25% Porosity	m^3	584 995
30% Porosity	m^3	701 994
Decant/Recharge rate		
14% Recharge	m^3/y	3 696
16% Recharge	m^3/y	4 224
18% Recharge	m^3/y	4 751
Time to fill		
Worst case scenario (20% Ø and 18% RCH)	Years	98
Most probable scenario (25% Ø and 16% RCH)	**Years**	**139**
Best case scenario (30% Ø and 14% RCH)	Years	190

The proposed Driehoekspan pit is expected to decant at an elevation of approximately 1 415 mamsl. The most probable time it will take the backfilled void to fill with water to the decant elevation was calculated to be in the order of 140 years after active mining has ceased. Low rainfall combined with the relatively small surface area expected to be disturbed by the opencast pit contribute to the long time it will take the water level within the backfilled pit to reach the decant elevation.

Decanting of a mine void generally occurs as a result of an excess volume of water that cannot be “absorbed” by the aquifer system. The excess water is generated by the increased recharge from surface due to the destruction of the aquifer structure.

The evaporation rate of approximately 237 570 m^3/y calculated to occur from the surface of the backfilled pit far exceeds the expected recharge volume of ± 4 220 m^3/y, which in actual fact means that the water level within the backfilled opencast pit is unlikely to reach the surface and decanting should not occur.

The volumes of groundwater expected to discharge into the active mine workings were simulated with the numerical flow model and the results are provided in the below table:

Year	Minimum flow (m^3/d)	Maximum flow (m^3/d)
1	N/A	N/A
2	N/A	N/A
3	N/A	N/A
4	N/A	N/A
5	10	15
6	15	20

No groundwater discharge was simulated for the first four years of mining, as the pit floor elevation only decreases below the local groundwater level elevation during year five and six of mining. Approximately 5% of the proposed pit is expected to be ± 20 to 25 meters below the model calibrated groundwater level. During numerical flow model simulations a groundwater level drawdown of approximately six meters was simulated for the fifth year of active mining. Maximum groundwater level impacts are expected to occur during the sixth and final year of mining and a groundwater level drawdown of ± 11 meters was simulated. The cone of depression was simulated not to exceed the pit boundary by more than approximately 100 meters.

Four potential source areas of groundwater contamination were identified within the Driehoekspan Project area and were simulated in the mass transport model. Groundwater pollution was simulated with the mass transport model to migrate in a west/south-westerly direction away from the proposed Driehoekspan Pit. Contaminant migration is slow and was simulated not to exceed a maximum distance of approximately 100 meters in the down gradient direction at a time of 50 years post closure

A total of five source monitoring boreholes are recommended for the proposed Driehoekspan Project area:

BH	Coordinates (WGS84)		Depth (m)	Water strike (mbs)	Blow yield (l/h)	Lithology
	South	East				
DRP01	-28.14059	23.03856	45	26	300	SOIL, SHLE, DLMT, HEMT
DRP02	-28.14254	23.03887	50	46	2000	HEMT, SHLE, DLMT
DRP03	-28.14692	23.03193	25	17	6000	SHLE, DLMT
DRP04	-28.14678	23.02764	45	N/A	N/A	DLMT, SHLE
WaterBH	-28.14399	23.03446	50	30	N/A	N/A

Notes: *SOIL – Soil; SHLE – Shale; DLMT – Dolomite; HEMT – Hematite.*

1 GENERAL DESCRIPTION OF GEOHYDROLOGY

Groundwater Complete was contracted by Synergistics Environmental Services (Pty) Ltd to conduct a geohydrological study and report on findings as specialist input to the Environmental Impact Assessment (EIA) and Environmental Management Program (EMP) for the proposed Coza Iron Ore Project (hereinafter referred to as Coza Project). The project area is located within the Tsantsabane Local Municipality in the Northern Cape Province, approximately 16 km north of the town of Postmasburg. Several historical and active iron ore mining operations occur in the region. The most significant active mines are the Sishen (Anglo American) and Khumani (Assmang) mines approximately 50 km north of the Coza Project and Kolomela (Anglo American) and Beeshoek (Assmang) mines approximately 20 km south west of the Coza Project. A map of the Coza Project area is provided in **Figure 1-1**, while a regional map indicating the positions of surrounding active iron ore mines are provided in **Figure 1-2**.

Iron ore is planned to be extracted by means of the opencast truck and shovel mining method on the farms Driehoekspan 435 (Remaining Extent) and Doornpan 445 (Portion 1) as indicated in **Figure 1-1**. The iron ore is of high grade with an average iron content of approximately 62%. Topsoil will be stripped from the mining surface and carefully stockpiled for future rehabilitation purposes, while discard and overburden will be dumped at dedicated positions close to the opencast pits. Crushing and screening of the iron ore will occur on site, while blending may occur at the run-of-mine (ROM) stockpile.

The Doornpan Pit will be mined to a maximum depth of ± 80 meters below surface (mbs), while the lowest level of the Driehoekspan Pit is planned to be ± 50 mbs. An estimated 2% of the total surface area will be disturbed by the two proposed opencast pit areas and their associated discard dumps, ROM stockpiles, access roads and support infrastructure.

Infrastructure requirements for the two mining sites include:

- Access roads and entrance controls,
- Perimeter fences,
- Water management infrastructure (i.e. pollution control and water supply dams),
- Power supply,
- Office, change house and workshops,
- Sewage treatment facility, and
- Temporary accommodation during the construction phase.

The focus of this investigation is centered on determining the groundwater quality and quantity impacts related to the proposed Driehoekspan iron ore mining activities. Groundwater inflow into opencast mine workings is known to be problematic in the surrounding iron ore mines, hence the investigation also involved mine dewatering simulations and recommendations that will allow for safe mining conditions.

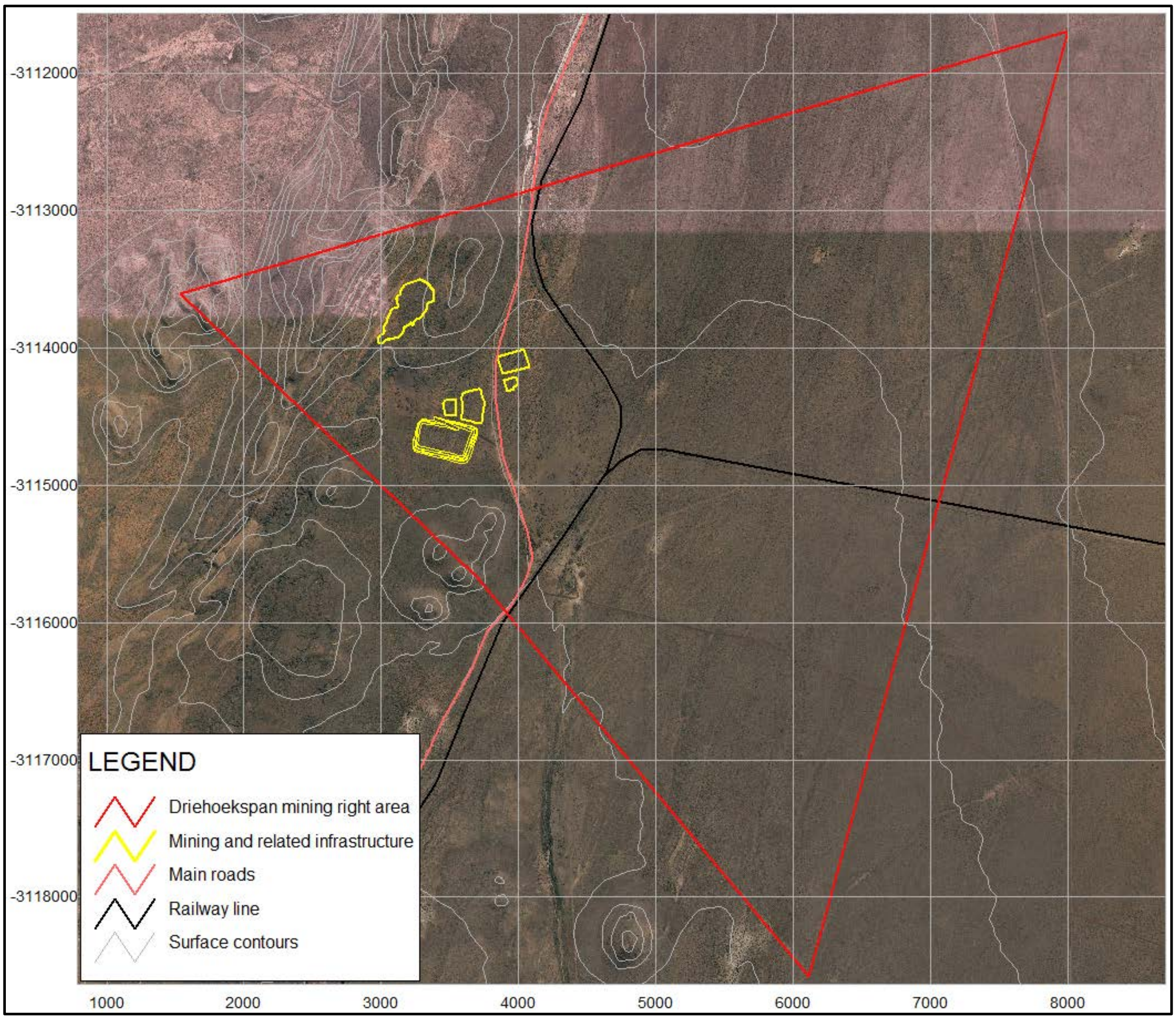


Figure 1-1: Locality map of the Driehoekspan Project area

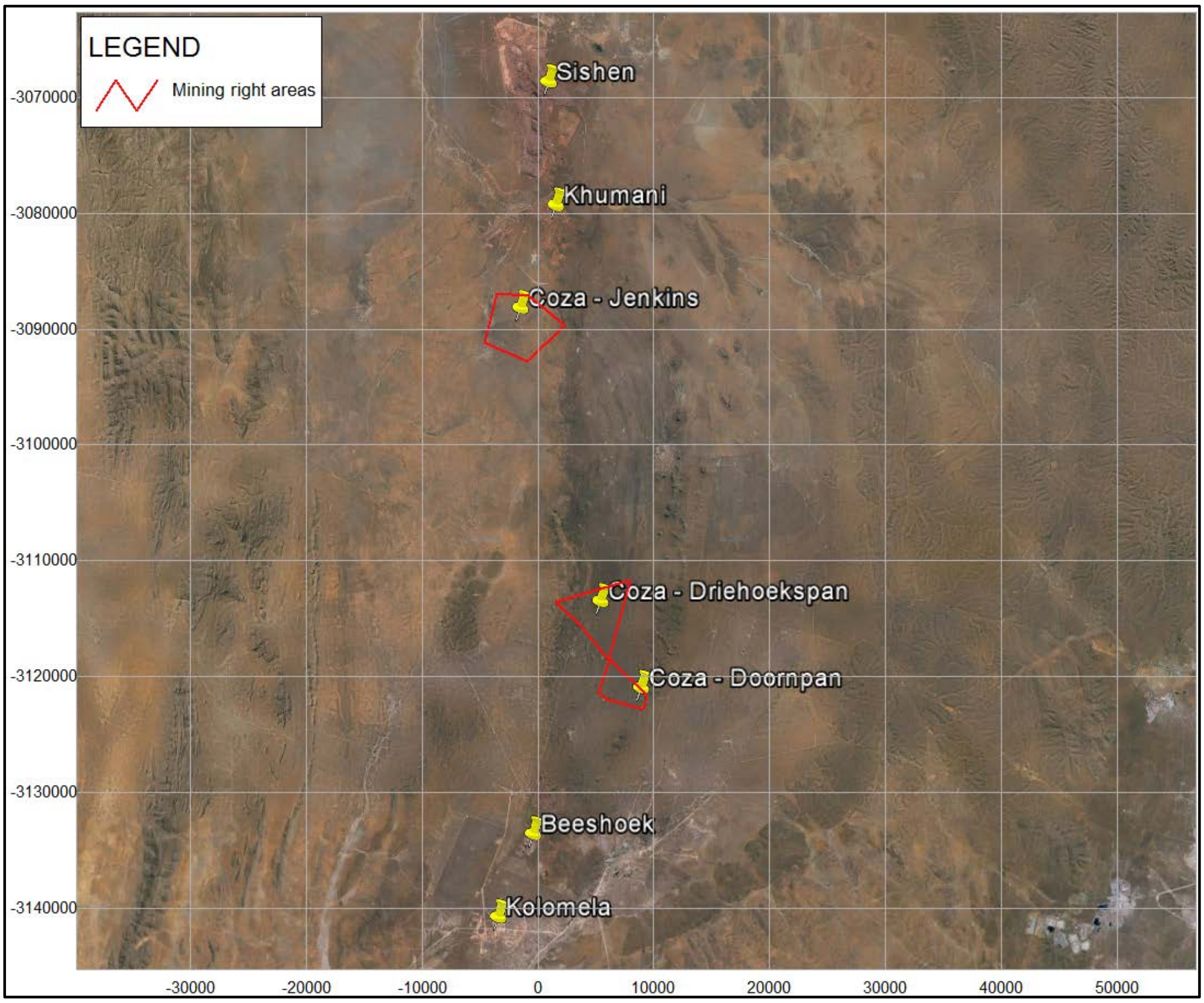


Figure 1-2: Positions of active iron ore mines relative to the proposed three Coza Project areas

1.1 DESK TOP STUDY

A groundwater survey was performed for both the Doornpan and Driehoekspan reserve areas for which the rights are held by Coza Mining (Pty) Ltd and which is known as the Coza Project area. The results of the baseline groundwater survey are presented in this document.

Groundwater information for the survey was obtained mainly from the following sources:

- Geophysical survey of geological structures such as dykes and faults,
- Dedicated information gathering through drilling of monitoring boreholes, groundwater quality analyses, water level and aquifer test measurements in boreholes committed for groundwater monitoring,
- Baseline groundwater information gathered during the hydrocensus surveys performed specifically for compilation of this EMP document,
- Data obtained from the National Groundwater Archive (NGA).

For the purpose of the study, the groundwater information as described above were combined and interpreted in a holistic manner. The groundwater regime was evaluated using the following methodology:

- Topographical and geological maps, orthographic photographs, satellite images and geophysical surveys were used to describe the **physical properties** of the groundwater domain,

- Hydrocensus surveys were conducted during which **groundwater users** around the Coza Project areas were identified, boreholes were surveyed in terms of positions, water levels and water quality and water **uses** were determined,

- Constant rate pumping and recovery tests were performed on exploration boreholes. The pumping tests were used to determine the **hydraulic properties** of the saturated zone,

- User and exploration boreholes were sampled for chemical analyses to assay the groundwater **quality characteristics**,

- Groundwater **flow velocities** were calculated from first principles,

All the above data types were interpreted with appropriate techniques in each case and were used to postulate a **conceptual model** of the groundwater regime.

1.2 AMBIENT GEOHYDROLOGICAL CONDITIONS

1.2.1 GROUNDWATER USE (USER SURVEY/HYDROCENSUS RESULTS)

A hydrocensus and groundwater user survey was conducted within a ± 10 km radius of both the Doornpan and Driehoekspan mining areas. The main aims and objectives of the hydrocensus field survey were as follow:

- To locate all interested and affected persons (I&APs),
- To collect all relevant information from the I&APs (i.e. name, telephone number, address, etc.),
- Accurately log representative boreholes on the I&APs properties, and
- To collect all relevant information regarding the logged boreholes (i.e. yield, age, depth, water level, etc.).

Summaries of the findings are provided in **Figure 1.2.1-2** and **Table 1.2.1**, while the complete hydrocensus report is provided in **Appendix A**. A total of 41 boreholes were located and their positions are indicated below in **Figure 1.2.1-1**.

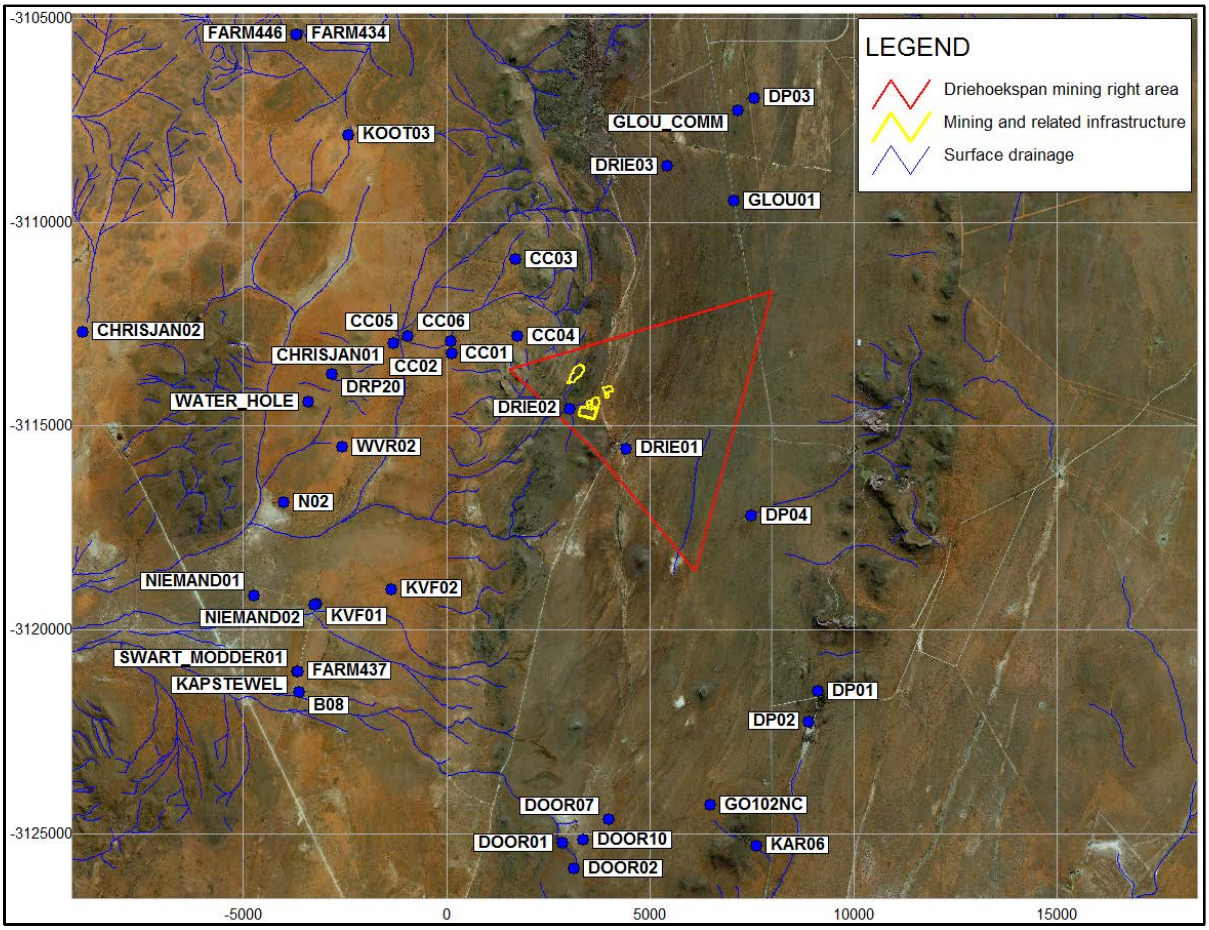


Figure 1.2.1-1: Localities recorded during the Coza user survey

More than half of the boreholes located were not in use at the time of the survey **(Figure 1.2.1-2)**. The survey could not be extended to the east of the R325 road as the area is largely the property of Assmang and locked gates restricted access at the time of the survey.

Yield information was not available for the majority of hydrocensus boreholes, however yields varying between ± 2 500 l/h and 25 000 l/h were indicated by two farmers located within the immediate vicinity of the Coza Project, namely Christiaan and Louis Claasens **(Table 1.2.1)**. These boreholes are to the west of the Driehoekspan reserves.

Widespread pollution or depletion of the groundwater resource will impact negatively on:

- The groundwater **resource itself** and interrelations with other natural resources (e.g. rivers and streams), and
- **The users** that depend on groundwater as **sole source** of domestic water as well as for livestock and gardening.

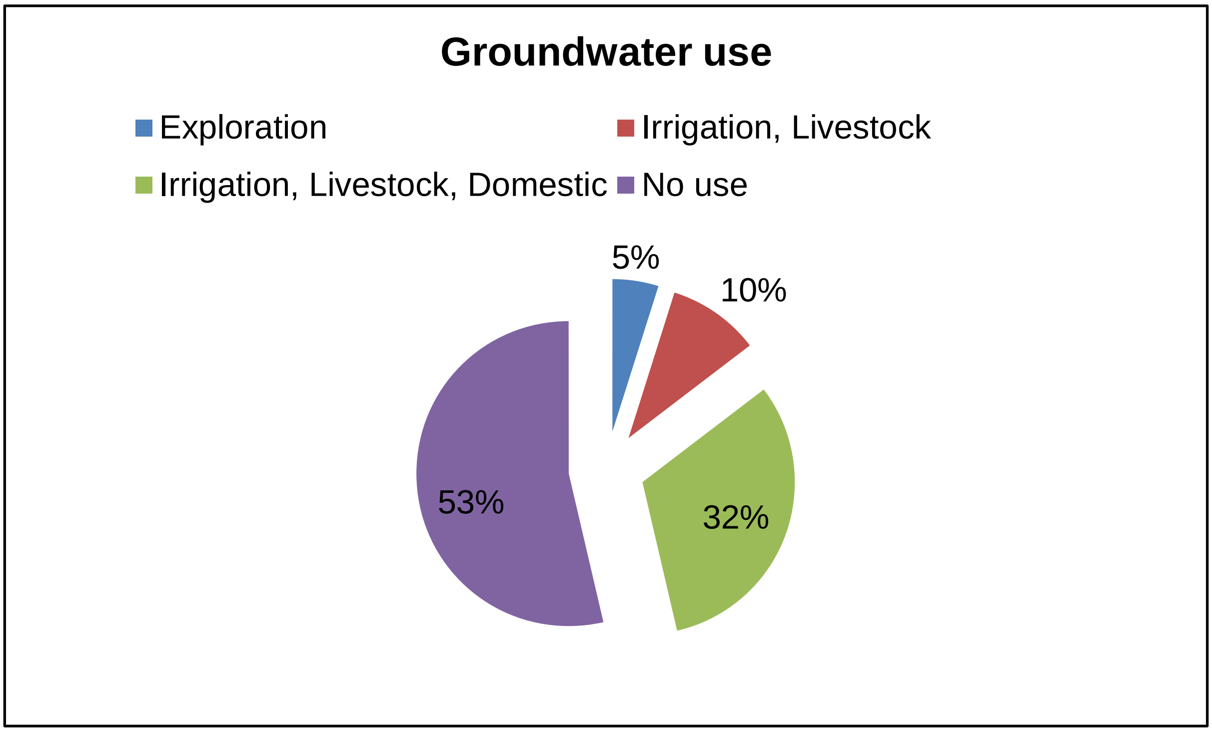


Figure 1.2.1-2: Results of groundwater user survey

Table 1.2.1: Summary of hydrocensus and groundwater user survey

Site Name	South	East	Elevation (mamsl)	Water level (m)	Owner	Water use	Sampled
B08	-28.20831	22.96312	1480	7.0	Adam Wahl & Mark Oosthuizen & Christiaan Claasens	N/A	Yes
CC01	-28.13076	23.00103	1315	-	Christiaan Claasens & Louis Claasens	Approx. 25 000 l/h	Yes
CC02	-28.13341	23.00146	1319	11.3	Christiaan Claasens & Louis Claasens	Approx. 6 000 l/h	Yes
CC03	-28.11254	23.01716	1340	32.9	Christiaan Claasens & Louis Claasens	6 000 - 9 000 l/h	Yes
CC04	-28.12964	23.01777	1343	36.3	Christiaan Claasens & Louis Claasens	Approx. 3 000 l/h	Yes
CC05	-28.12955	22.99029	1311	6.0	Christiaan Claasens & Louis Claasens	N/A	N/A
CC06	-28.12958	22.99044	1310	17.4	Christiaan Claasens & Louis Claasens	N/A	Yes
CHRISJAN01	-28.13119	22.98676	1310	12.1	Chrisjan Claasen	Irrigation, Livestock, Domestic	Yes
CHRISJAN02	-28.12869	22.90909	1306	-	Chrisjan Claasen	Irrigation, Livestock, Domestic	Yes
DOOR01	-28.24170	23.02900	1348	13.9	Mark Oosthuizen	N/A	Yes
DOOR02	-28.24740	23.03190	1356	7.4	Mark Oosthuizen	N/A	Yes
DOOR07	-28.23660	23.04070	1355	-	Mark Oosthuizen	N/A	N/A
DOOR10	-28.24120	23.03410	1353	3.1	Mark Oosthuizen	N/A	Yes
DP01	-28.20814	23.09285	1390	15.8	More Matsidi & Onkemetse Gill	N/A	Yes
DP02	-28.21489	23.09053	1390	14.9	More Matsidi & Onkemetse Gill	N/A	Yes
DP03	-28.07689	23.07689	1385	-	More Matsidi & Onkemetse Gill	N/A	Yes
DP04	-28.16928	23.07611	1385	-	More Matsidi & Onkemetse Gill	N/A	Yes
DRIE01	-28.15453	23.04500	1385	-	More Matsidi & Basil Louw	N/A	Yes
DRIE02	-28.14572	23.03075	1380	-	More Matsidi & Basil Louw	N/A	Yes
DRIE03	-28.09194	23.05519	1390	-	More Matsidi & Basil Louw	N/A	Yes
DRP20	-28.13800	22.97135	1438	74.6	Driehoekspan exploration	Exploration	Yes
FARM434	-28.06271	22.96260		-	Farm at Assmang property	Irrigation, Livestock	Yes

Site Name	South	East	Elevation (mamsl)	Water level (m)	Owner	Water use	Sampled
FARM437	-28.20382	22.96301	1279	-	Farm437	N/A	Yes
FARM446	-28.06285	22.96258	1338	12.0	Assmang	N/A	Yes
GLOU01	-28.09951	23.07181	1416	-	Gloucester	N/A	Yes
GLOU_COMM	-28.07956	23.07280	1412	-	Gloucester mining area	N/A	Yes
GO102NC	-28.23340	23.06590	1385	-	Mark Oosthuizen	N/A	Yes
KAPSTEWEL	-28.20391	22.96276	1416	7.0	Kapstewel	N/A	Yes
KAR06	-28.24250	23.07760	1435	36.0	More Matsidi & Onkemetse Gill	N/A	Yes
KOOT01	-28.08497	22.97538	1416	-	Koot Claasen	Irrigation, Livestock, Domestic	Yes
KOOT02	-28.08497	22.97538	1416	-	Koot Claasen	Irrigation, Livestock, Domestic	Yes
KOOT03	-28.08497	22.97538	1416	12.0	Koot Claasen	Irrigation, Livestock, Domestic	Yes
KVF01	-28.18895	22.96762	1278	-	Christiaan Claasens	Approx. 2 500 l/h	Yes
KVF02	-28.18558	22.98623	1296	-	Christiaan Claasens	N/A	Yes
N02	-28.16630	22.95929	1276	-	No Farmer	Irrigation, Livestock	Yes
NIEMAND01	-28.18706	22.95180	1276	-	No Farmer	Irrigation, Livestock	Yes
NIEMAND02	-28.18911	22.96706	1281	-	No Farmer	Irrigation, Livestock	Yes
SWART_ MODDER01	-28.20381	22.96295		-	Swartmodder farm	Irrigation, Livestock, Domestic	Yes
WATER_HOLE	-28.14399	22.96554	1389	11.3	Driehoekspan exploration	Exploration	Yes
WVR01	-28.15420	22.97397	1297	-	Willem van Rensburg	Irrigation, Livestock, Domestic	Yes
WVR02	-28.15420	22.97397	1297	-	Willem van Rensburg	Irrigation, Livestock, Domestic	Yes

Note: *Coordinates – WGS84.*

1.2.2 GROUNDWATER ZONE

The following aspects typically delineate the applicable "groundwater zone":

- The thickness, soil characteristics, infiltration rate and water bearing properties of the unsaturated zone,
- The geological properties and dimensions of each unit in the geological column that could potentially be impacted upon by groundwater contamination. This includes rock type, thickness of aquifer(s) and confining units, aerial distribution, structural configuration, storativity, water levels, infiltration or leakage rate, if appropriate,
- Aquifer recharge and discharge rates,
- The direction and rate of groundwater movement in potentially impacted units,
- Groundwater and surface water relationships,
- Background water quality of potentially impacted units,
- Potential sources and types of contamination.

1.2.2.1 UNSATURATED ZONE

Soil development in the project area is relatively poor and soils are mostly limited to Kalahari sands and calcrete or a combination thereof. The soil horizon consists mostly of the saprolite type with very little or no actual soil fraction. The unsaturated zone consists of calcrete or sandy alluvium of the Kalahari quaternary deposit type. Weathered calcrete and wind-transported sand of Kalahari-type occurs in depressions and topographical lower lying areas. The latter areas are also the only place where any degree of cultivation and crop irrigation is possible. The unsaturated zone impacts on the aquifer in terms of both groundwater quality and quantity.

The permeability and thickness of the unsaturated zone are some of the main factors determining the infiltration rate, the amount of runoff and consequently the effective recharge percentage of rainfall to the aquifer.

The type of material forming the unsaturated zone as well as the permeability and texture will significantly influence the mass transport of surface contamination to the underlying aquifer(s). Factors like ion exchange, retardation, bio-degradation and dispersion all play a role in the unsaturated zone.

The thickness of the unsaturated zone was determined by subtracting the pre-mining static water levels in the project area from the topography. Water level measurements in boreholes of users in the area as well as in exploration boreholes showed that the depth to water level, and thus the unsaturated zone, generally varies between ± 3 and 130 meters below surface **(Figures 1.3.1-3** and **1.3.1-4)**.

Although the calcrete is very hard and seemingly impermeable at surface, studies at the nearby mining operations have shown that infiltration rates through the unsaturated zone are high in places. Small cracks and openings cause high surface water infiltration areas that allow for significant recharge ratios under favorable conditions.

1.2.2.2 GEOLOGY OF THE PROJECT AREA

Regional Geology:

Iron ore in the Coza region is preserved in chemical and clastic sediments of the Proterozoic Transvaal Supergroup. These sediments define the western margin of the Kaapvaal Craton in the Northern Cape Province. The stratigraphy has been deformed by thrusting from the west and has also undergone extensive karstification. The thrusting has produced a series of open, north south plunging, anticlines, synclines and grabens. Karstification has been responsible for the development of deep sinkholes. The iron ore at Coza has been preserved from erosion as low hills due to high hardness. The iron ore deposits that are actively mined in the area are all located on the Maremane anticline structure.

The Transvaal Supergroup lithologies have been deposited on a basement of Archaean granite gneisses and greenstones, and/or lavas of the Ventersdorp Supergroup. In the Postmasburg region, the oldest rocks of the Transvaal Supergroup form a carbonate platform sequence (dolomites with minor limestone, chert and shale) known as the Campbell Rand Subgroup. The upper part of the Transvaal Supergroup comprises a banded iron formation unit, the Asbestos Hills Subgroup, which has been conformably deposited on the carbonates. The upper portion of the banded iron formations has in places been supergene-enriched to ore grade i.e. Fe $\geq$ 60%. The iron ore/banded iron formation zone is often referred to as the Kuruman Formation. The ores found within this formation comprise the bulk of the higher-grade iron ores in the region.

An altered, intrusive sill (originally of gabbroic composition) usually separates the ore bodies from the underlying host iron formation. It intruded into the Transvaal Supergroup in late Proterozoic times.

A thick sequence of younger clastic sediments (shale’s, quartzite’s and conglomerates) belonging to the Gamagara Subgroup unconformably overlies the banded iron formations. Some of the conglomerates consist almost entirely of hematite and are of lower-grade ore quality.

The unconformity separating the iron formations from the overlying clastic sediments represents a period of folding, uplift and erosion. At the time, solution and karstification took place in the upper dolomitic units. A residual solution breccia, referred to as the ‘Manganese Marker’ or ‘Wolhaarkop Breccia’, developed between the basal dolomites and overlying banded iron formations. This breccia is known to contain vast volumes of groundwater. In places, deep sinkholes developed in the dolomites, into which the overlying iron formation and mineralized iron ore bodies collapsed.

Diamictite of the Makganyene Formation and lava belonging to the Ongeluk Formation have been thrusted over the Gamagara sediments. It is now preserved only within the larger synclinal structures. A considerable portion of the upper parts of the stratigraphy have been eroded during Dwyka glaciation and re-deposited as tillite.

The entire, folded sequence was later truncated by Tertiary erosion. A thick (10 to around 60 m) blanket of calcrete, dolocrete, clays and pebble layers belonging to the Kalahari Supergroup was unconformably deposited over the older lithologies.

Site Specific Geology *(PGS Heritage, 2013)*:
According to Moen *(Moen HFG, 1977)* the farm **Driehoekspan** is underlain by rocks of the Gamagara Formation (Vg) of the Postmasburg Group as well as rocks of the Lime Acres Member of the Ghaapplato Formation (Vgl) of the Campbell Group. The rocks of the Gamagara Formation underlie the Western Corner of the Farm. This formation consists of quartzites, conglomerates, flagstones and shales and constitutes the base of the Postmasburg Group.

The formation lies unconformably upon the Ghaapplato and Asbesberge Formations. Lenticular basal conglomerates contain pebbles of jasper and banded iron stone and are completely ferruginised in places. The shales contain lenses of conglomerate and are also locally ferruginised or manganised. Ferruginous flagstone and white, purple and brown quartzites form the top of the formation.

Rocks of the Lime Acres Member of the Ghaapplato Formation of the Campbell Group consist of dolomitic limestone with subordinate coarsely crystalline dolomite and chert with lenses of limestone. Stromatolitic puckered limestone consisting of alternating dark and light bands can be found. Lenticular bodies of limestone occurring in the dolomite are probably the result of irregular dolomitisation of the original limestone.

The farm **Doornpan** according to Moen is mainly underlain by dolomitic limestone with subordinate coarsely crystalline dolomite, and chert with lenses of limestone of the Lime Acres Member of the Ghaapplato Formation of the Campbell Group. Some of the hills on the farm consist of rocks of the upper section of the Lime Acres Member of the Ghaapplato Formation. These rocks consist of chert and chert breccia (silica breccia or manganese marker) containing a thin ferruginous layer of shale that grades southwards into red jasper with chert. This ferruginous layer is fairly constant throughout the area and serves as a marker. Stromatolitic puckered limestone consisting of alternating dark and light bands lies underneath the chert member which forms the top of the Ghaapplato Formation. Lenticular bodies of limestone occurring in the dolomite are probably the result of irregular dolomitisation of the original limestone.

A simplified geological map of the Driehoekspan Project area is provided in **Figure 1.2.2.2**.

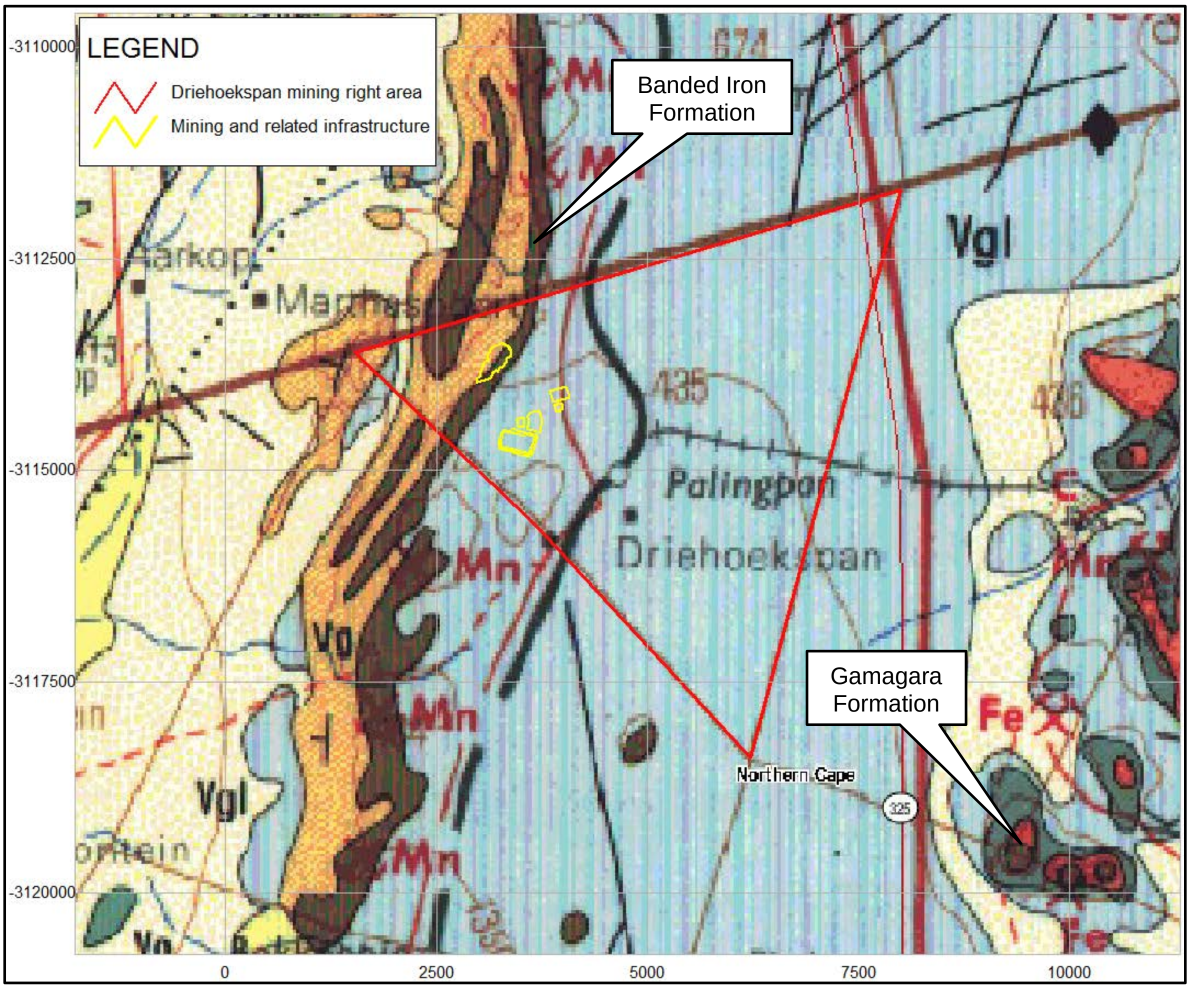


Figure 1.2.2.2: Simplified geological map (1:250 000) of the Driehoekspan Project area

Notes: *Qs* *- Relatively recent deposits of loose material,*
Vgl - Dolomitic limestone: Lime Acres Member of the Ghaapplato Formation, Campbell Group.

1.2.2.3 GEOPHYSICAL INVESTIGATION

A geophysical investigation was conducted for the purpose of the geohydrological study to identify geological structures such as faults and intrusive features like dolerite dykes. The main aim of the survey was to site monitoring boreholes in areas where potential impacts from the mining related activities may occur.

Geological structures such as dykes and faults are generally targeted when drilling for groundwater, as they may act as preferred pathways for groundwater flow and mass transport (contamination). Dykes are known to occur throughout the wider study area and some of the more prominent ones are easily identifiable on aerial and satellite imagery. Fractures are typically formed along the sides of a dyke due to rapid cooling during the intrusion process. These fractures are wholly responsible for most dykes being able to hold significant volumes of groundwater and also to act as preferred pathways. However, these fractures are generally superficial and do not affect the structural integrity of the dyke.

This means that a dyke may also act as an effective barrier for the flow of groundwater perpendicular to its strike. In an area, such as the project area, where numerous dykes occur in various strike directions, groundwater compartments are formed, which may be independent from one another with regards to groundwater levels and chemistry.

A combination of magnetic and electro-magnetic methods was used during the survey and the geophysical line survey graphs are provided in **Appendix B**. During the survey of five traverses a total of six anomalies were identified and their positions are indicated in **Figure 1.2.2.3**.

A total of four monitoring boreholes were drilled on anomalies identified during the geophysical survey. Please refer to **Section 4** of the report for a full discussion on the drilling results and proposed monitoring program.

Information gained from the drilling of the monitoring boreholes as well as pump tests performed in the project area was used in the postulation of a conceptual model and the construction and calibration of numerical flow and mass transport models.

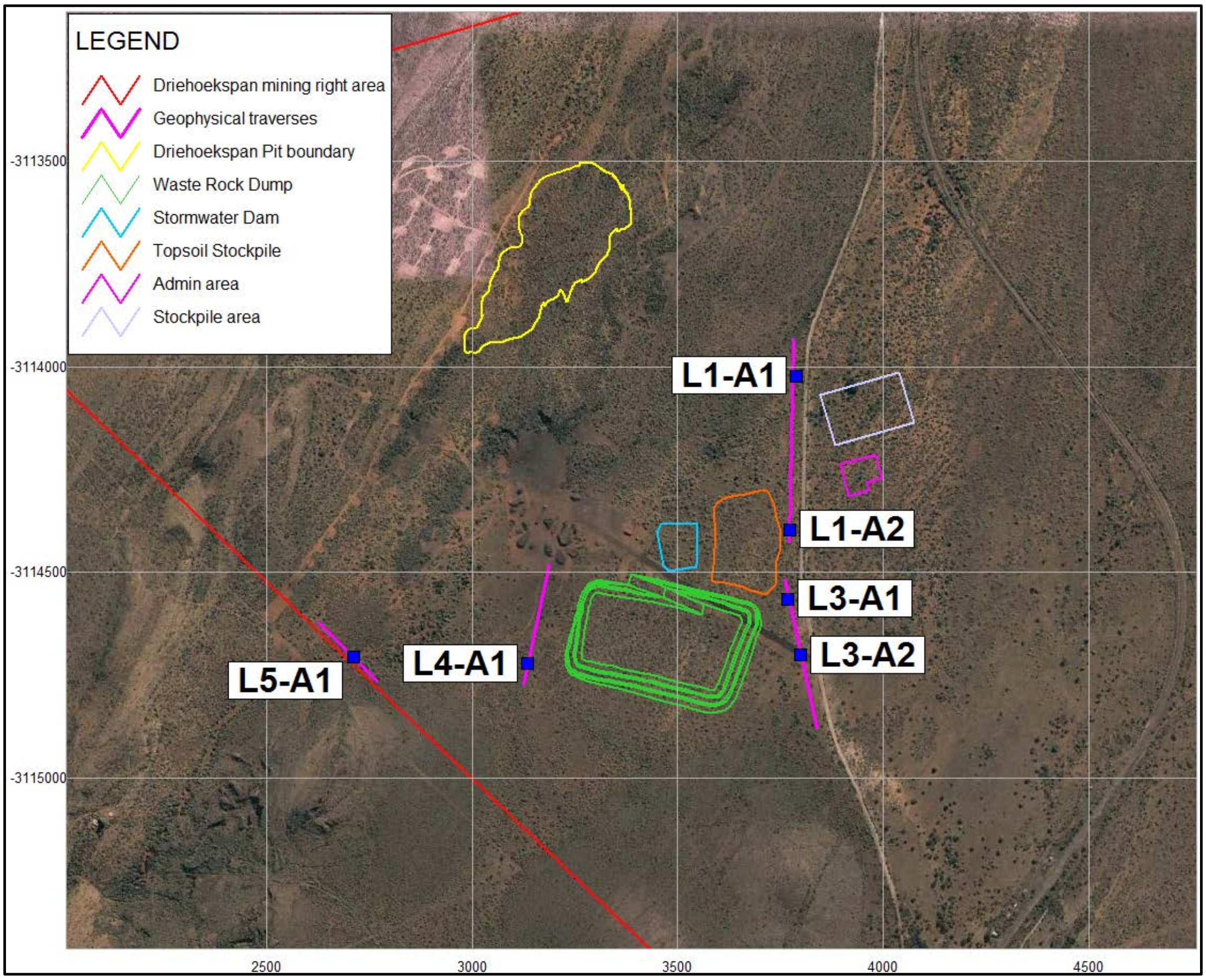


Figure 1.2.2.3: Positions of anomalies identified during geophysical survey

1.2.2.4 AQUIFER DELINEATION

Aquifer delineation is conducted to show which part of the aquifer was used or considered during simulation exercises (numerical modeling). Because the main aquifer is a fractured rock type and fractures could assume any geometry and orientation, the physical boundary or 'end' of the aquifer is very difficult to specify or quantify. More appropriately, the aquifer boundary conditions that were considered during numerical model simulations are described below.

No-flow boundaries in a model, as in nature, are groundwater divides (topographically high or low areas/lines) across which no groundwater flow is possible. Constant head boundaries are positions or areas where the groundwater level is fixed numerically/mathematically at a certain elevation and cannot change (perennial rivers/streams or dams/pans).

General head boundaries are boundaries through which groundwater movement is possible. The rate at which the groundwater will move through the boundary depends on the groundwater gradient as well as the hydraulic conductivity at the boundary position.

General head boundaries were used as model boundaries in the regional model constructed to include both the proposed Driehoekspan and Doornpan mining areas **(Figure 1.2.2.4)**. General head boundaries were chosen as a result of the absence of prominent no-flow and/or constant head boundaries within the immediate vicinity of the project area. The boundaries were constructed far away from the planned mining activities to ensure that they do not influence the groundwater flow and mass transport simulations discussed in **Sections 3.3.1** and **3.3.2** respectively.

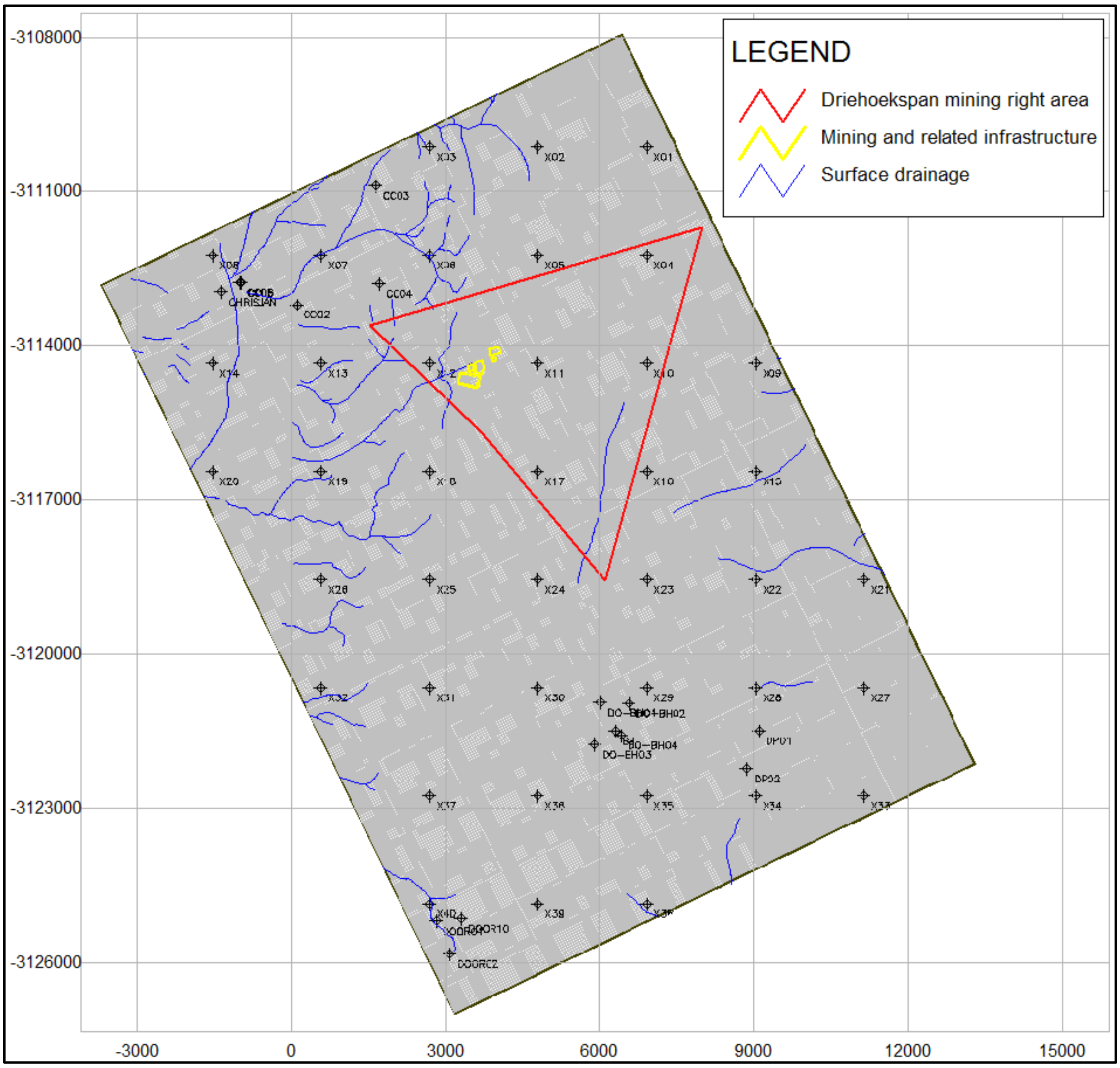


Figure 1.2.2.4: Regional numerical model grid

1.2.2.5 AQUIFER THICKNESS

Aquifer thickness in a fractured rock aquifer is virtually impossible to determine as the actual 'aquifer' consists of fractures with any orientation, dip, strike or aperture. Considering the fact that the actual 'aquifer' consists of transmissive fractures, fissures or cracks of any orientation, extent of aperture in any of the rock types underlying the site, an approximation can at best be made on the thickness of the aquifer.

Aquifer thickness for the project area is therefore considered to be the difference between the static groundwater level and the deepest water yielding fracture. Water level information is available for the planned Driehoekspan mining area, however the latter is unknown as no drilling was conducted for the purpose of this investigation. However, seeing that both Driehoekspan and Doornpan are located within similar geological and geohydrological environments, the aquifer thickness calculated for Doornpan should realistically also be representative of Driehoekspan.

In the boreholes drilled in the proposed Doornpan mine boundary area, numerous water-yielding fractures were intersected in different geological units. Such fractures occurred at depths varying between ± 18 and 63 meters below surface. The aquifer thickness in the proposed Doornpan and Driehoekspan mining areas is expected to vary between approximately 10 and 30 meters.

Please note that the estimation of the aquifer thickness includes both the shallow weathered zone aquifer and deeper fractured rock aquifer as additional drilling data is required to make a clear distinction. It is also our experience that there is often not a clear layer or formation that separates the shallow and deeper aquifer. The distinction is mainly made based on the degree of primary or secondary porosity of the aquifer(s) based mostly on weathering depth.

1.2.2.6 GENERALISED CONCEPTUAL MODEL

In order to predict the movement of water and mass in the subsurface, a conceptual geohydrological model of the area was formulated. The basis of such a model is the structural geological make-up of the project area. Most of the supporting data and information are discussed in detail in this report.

The geohydrological regime in the project area is made up of two main aquifer systems. The first, the upper, unconfined to semi-confined aquifer occurs in the calcrete that cover most of the surface area. The aquifer is usually developed on the contact between the calcrete and underlying clay formations of Kalahari age or in localized pebble horizons within the calcrete. Although relative low yields occur in this aquifer, it is developed widely throughout most of the project area and has been the sole reliable source of water supply to most of the farms in the area for more than a century. Yields of up to 2 liters per second occur in this aquifer with a shallow water table and spring formation common, especially in the lower-lying topography.

The second aquifer is associated with fractures, fissures, joints and other discontinuities within the consolidated bedrock and associated intrusives of the Transvaal/Griqualand West Sequences. The aquifer occurs at depths of more than 60 meters below surface in the project area. It is semi-confined and has greatly varying yields that are directly associated with the geology and geological structure.

The aquifer yield may be as high as 40 liters per second in mainly the chert breccia (Manganese Marker) and banded iron formation and iron ore formations. Contrary to general beliefs, the dolomite in the mining area is not a significant aquifer and yields of no more than 2 to 4 liters per second have been recorded. The dolomite is however considered to have good storage properties for groundwater.

Mining in the Driehoekspan mine boundary area will penetrate both the calcrete and deeper bedrock aquifers and the physical structure of these two aquifers will be destroyed in the pit. The shallow aquifer is mostly absent at the position of the proposed Driehoekspan pit due to the hill-like topography where the ore body occurs.

Water entering the system will migrate vertically downwards until a more impervious layer that forms a perched aquifer is encountered. Over the longer term (after a year and more) it is likely that the majority of recharge water will migrate downwards into the saturated zone of the deeper solid bedrock aquifer. From there it will migrate in the direction of the hydraulic gradient until it eventually reaches discharge areas.

With the dewatering foreseen for the proposed Driehoekspan pit, significant groundwater gradients will be created towards the pit and groundwater flow directions will change towards this area. The local change in groundwater flow directions is caused by the formation of a cone of depression due to mine dewatering. The concept of mine dewatering and subsequent formation of a depression cone is illustrated below in **Figure 1.2.2.6**.

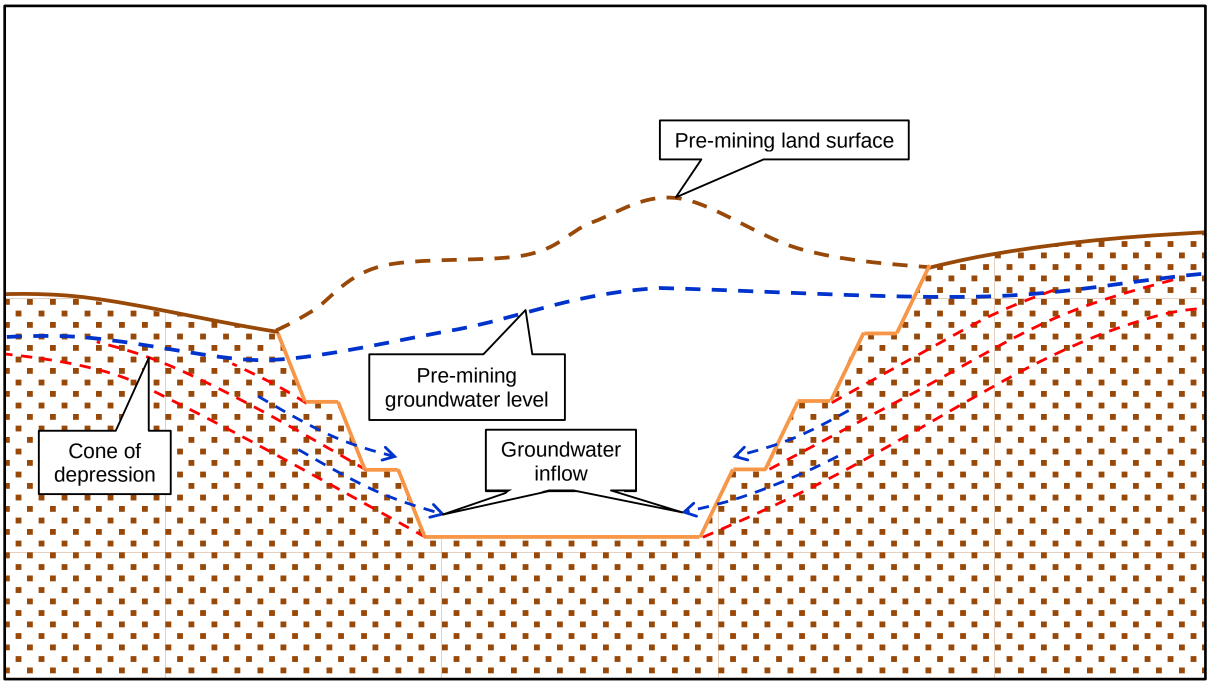


Figure 1.2.2.6: Section through typical opencast pit such as Driehoekspan

The lateral rate of migration usually exceeds the vertical rate, especially in a predominantly sedimentary rock environment where the layers are more or less horizontal. In the project area horizontal movement would be strongly determined by the presence, extent and orientation of the highly transmissive chert breccia and banded iron formation. Given the general north-south orientation of these deposits/formations, groundwater flow in a north-south direction will dominate and the impact of dewatering will also be orientated as such, i.e. the cone of depression is expected to be elongated in a north-south direction.

1.2.3 PRESENCE OF BOREHOLES AND SPRINGS

As mentioned previously, a hydrocensus survey was conducted as part of this study around the Coza mining right areas **(Table 1.2.1)**. As part of the survey, boreholes and springs were mapped within a ± 10 km radius of the involved areas.

The survey area was extended because the radius of influence depends strongly on geological structures such as faults and dykes (preferred groundwater flow paths), groundwater gradients, nearby mining operations and the presence of other groundwater production boreholes or dewatering from mining in the area.

Different types of groundwater information were obtained for a total of 41 points during the groundwater user survey conducted for the Coza Project. The water supply source of nearby users was sampled and analyzed for macro element inorganic chemistry. No springs were recorded in the area under investigation. Springs in a semi-confined or confined fractured rock aquifer usually occur where structural discontinuities in the aquifer bisect the confining layer/material and a fracture or fracture system reaches the surface. For a spring to occur, the water level or piezometric head at that point in the aquifer must be higher than the land surface.

Although the natural trend for the groundwater level or piezometric head is to follow the surface topography, the water level is the closest to surface in the topographically low-lying areas. For this reason, springs will mostly occur in these areas, or at least on the slopes of hills. In perched and confined aquifers however, groundwater or piezometric levels may also be high in topographical higher lying areas with subsequent spring formation.

1.3 GROUNDWATER FLOW EVALUATION

1.3.1 DEPTH TO WATER LEVEL

Groundwater levels in the project area are available from monitoring boreholes, surrounding groundwater user boreholes as well as exploration boreholes that were located during the hydrocensus survey. Two interacting aquifer systems were identified in the project area, although they are mostly of the same aquifer type.

In fractured bedrock (secondary) aquifers like those that dominate the project area, groundwater flow and mass transport are nearly fully restricted to open fissures, cracks or fractures in the relatively impermeable host rock matrix. Aquifer thickness, yield and other parameters thus fully depend on the characteristics of these fractures. Such characteristics include fracture aperture, extent, orientation, frequency and texture of the fracture-matrix interface.

Thematic water level maps of the entire project area are provided in **Figures 1.3.1-3** and **1.3.1-4**. These water levels are essential as they were used in the generation of static groundwater level elevations with the use of the Bayesian interpolation method and steady state numerical groundwater flow model calibration **(Figure 1.3.1-5)**.

Regional static groundwater levels around the project area generally vary between ± 3 meters below surface (mbs) in the topographically lower lying areas to approximately 130 mbs for the higher lying topographies **(Figures 1.3.1-3** and **1.3.1-4)**. Some of the deeper groundwater levels measured during the hydrocensus are affected by groundwater abstraction. Due to the generally low aquifer transmissivities the pumping causes deep drawdown of the groundwater levels/piezometric heads and depression cones form that are deep, but very limited in lateral extent. This concept is explained in **Figure 1.3.1-1**.

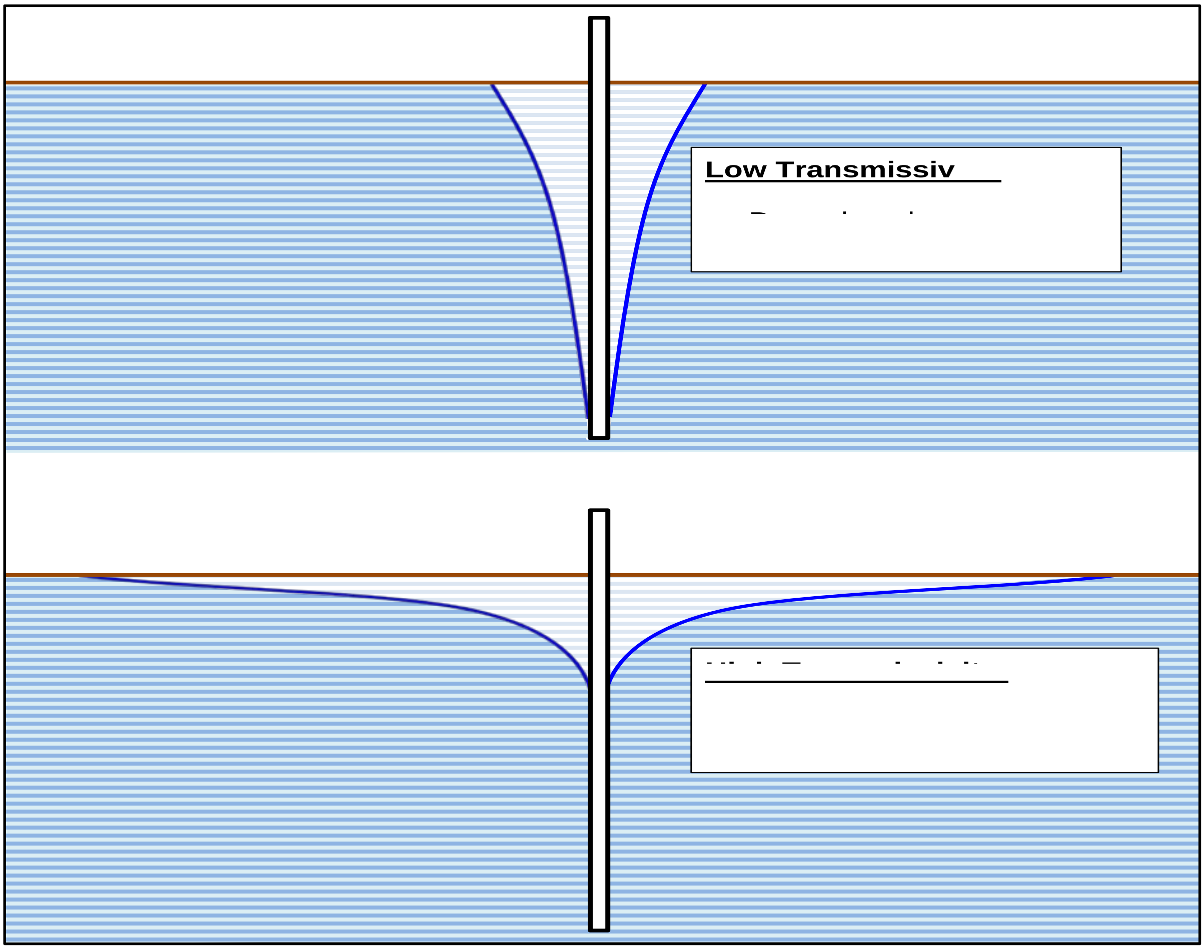


Figure 1.3.1-1: Effect of aquifer transmissivity on depression cone

The static groundwater elevation contour map provided in **Figure 1.3.1-5** was constructed through the utilisation of the Bayesian interpolation technique and steady state numerical groundwater flow model calibration. The Bayesian interpolation technique utilises the natural relationship that exists between the surface topography and the depth-to-groundwater level to estimate groundwater levels in areas where borehole data is scarce. Because impacts on the natural groundwater level already exist due to groundwater abstraction for domestic and irrigation purposes, only boreholes where the linear correlation between borehole collar elevation and groundwater level elevation exists were used in the interpolation.

A graph of borehole collar elevation versus groundwater level elevation is presented in **Figure 1.3.1-2** where the linear correlation of approximately 99% can be seen. It should be noted that groundwater levels from some boreholes were discarded because impacts from groundwater abstraction destroys the natural groundwater-topography relationship.

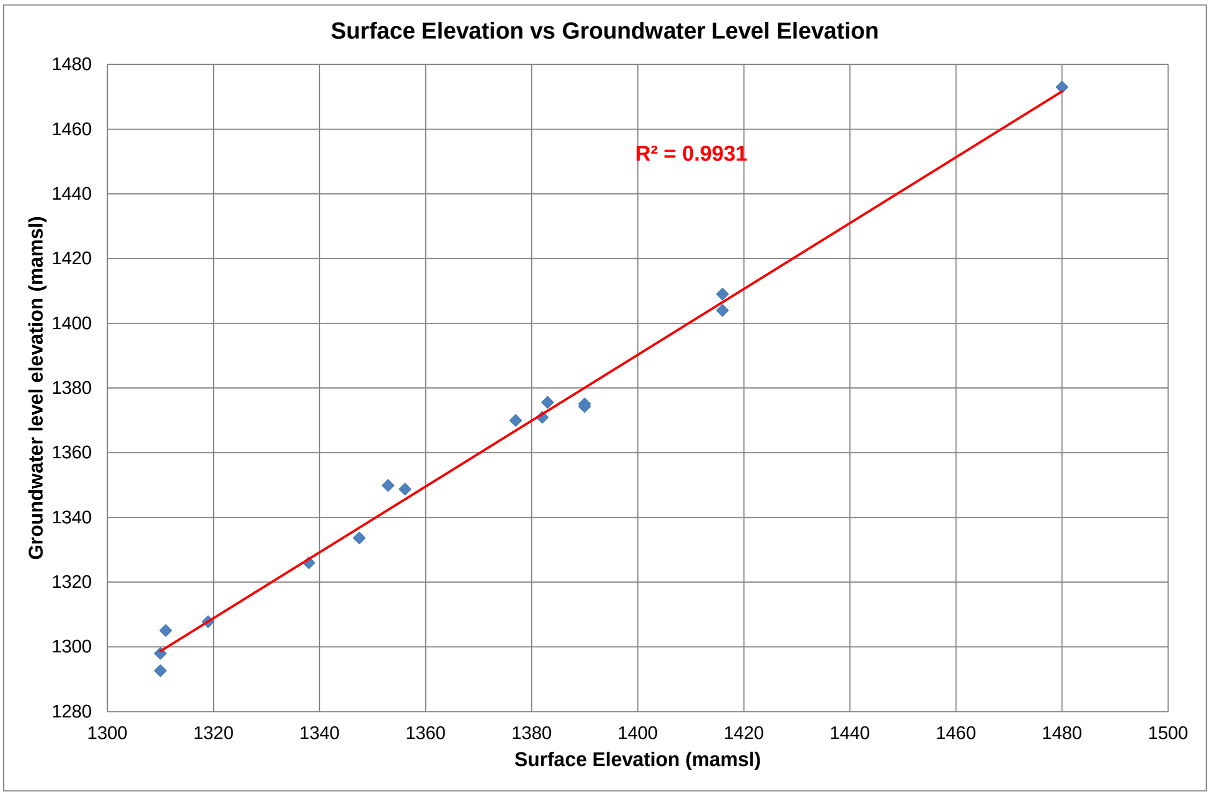


Figure 1.3.1-2: Relationship between surface and water level elevation

The highest static water level elevation in the model area is approximately 1 530 mamsl and occur in the topographically higher region towards the east of the mining right application area **(Figure 1.3.1-5)**. The lowest static water level elevation **where no impact from abstraction occurs** is at approximately 1 280 mamsl in the western down gradient direction. Groundwater flow directions within the project area are also indicated in **Figure 1.3.1-5** with the use of vectors.

Seen in the light of water level differences because of mining, pumping and recharge effects, filtering and processing of water levels is required to remove water levels considered anomalous high or low. **The final interpolated potentiometric surface of the water levels is thus bound to contain local over- or under estimations of the actual water levels but it will be representative of the general regional trend of the static groundwater level.**

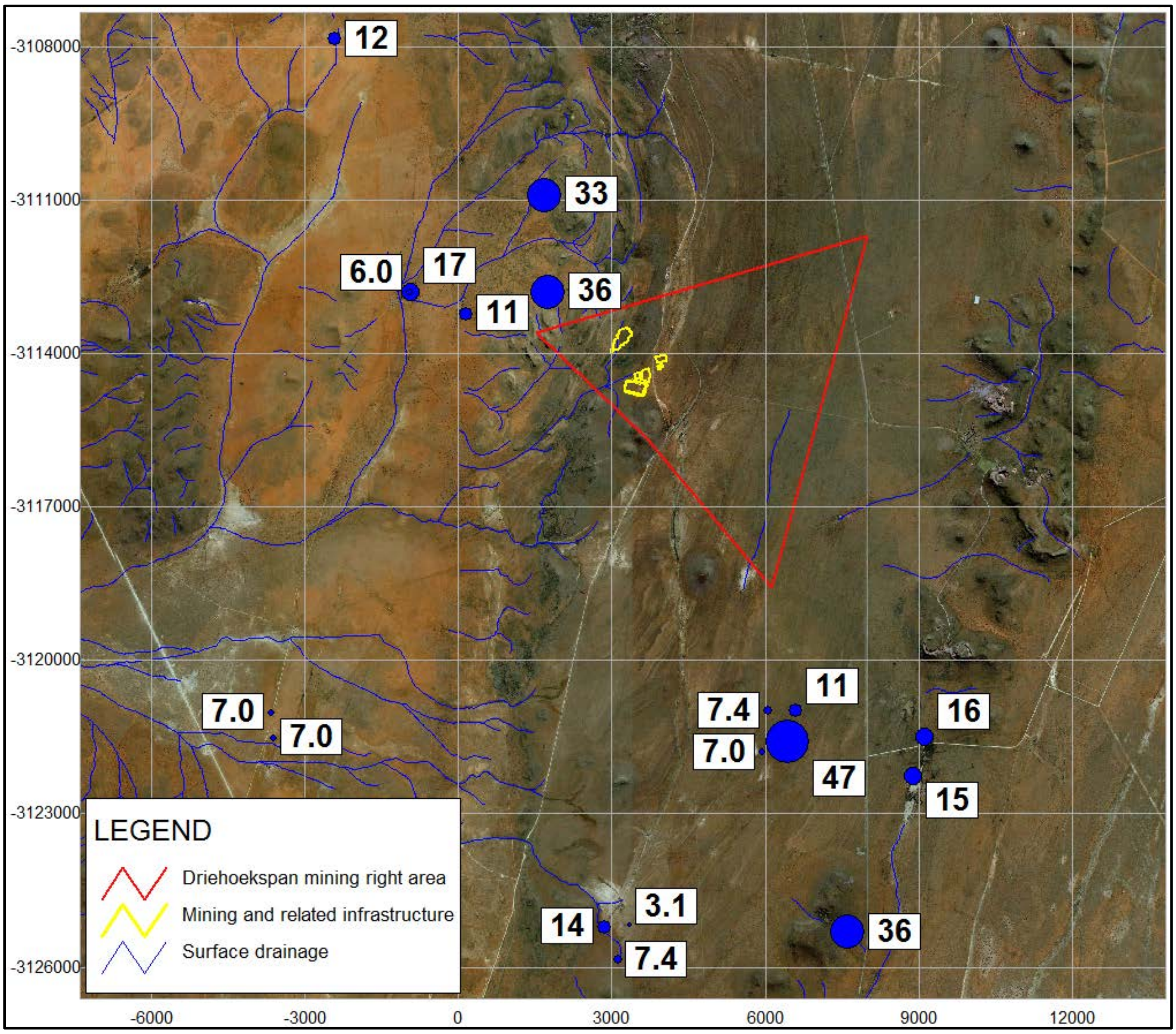


Figure 1.3.1-3: Thematic map of regional groundwater levels

Notes: *- The numbers in the above figure indicate the groundwater level depth below surface in meters,*
- The blue circles represent the positions of the user/monitoring boreholes,
- The size of the blue circles is directly proportional to the groundwater level depth, hence the largest circle represents the deepest water level.

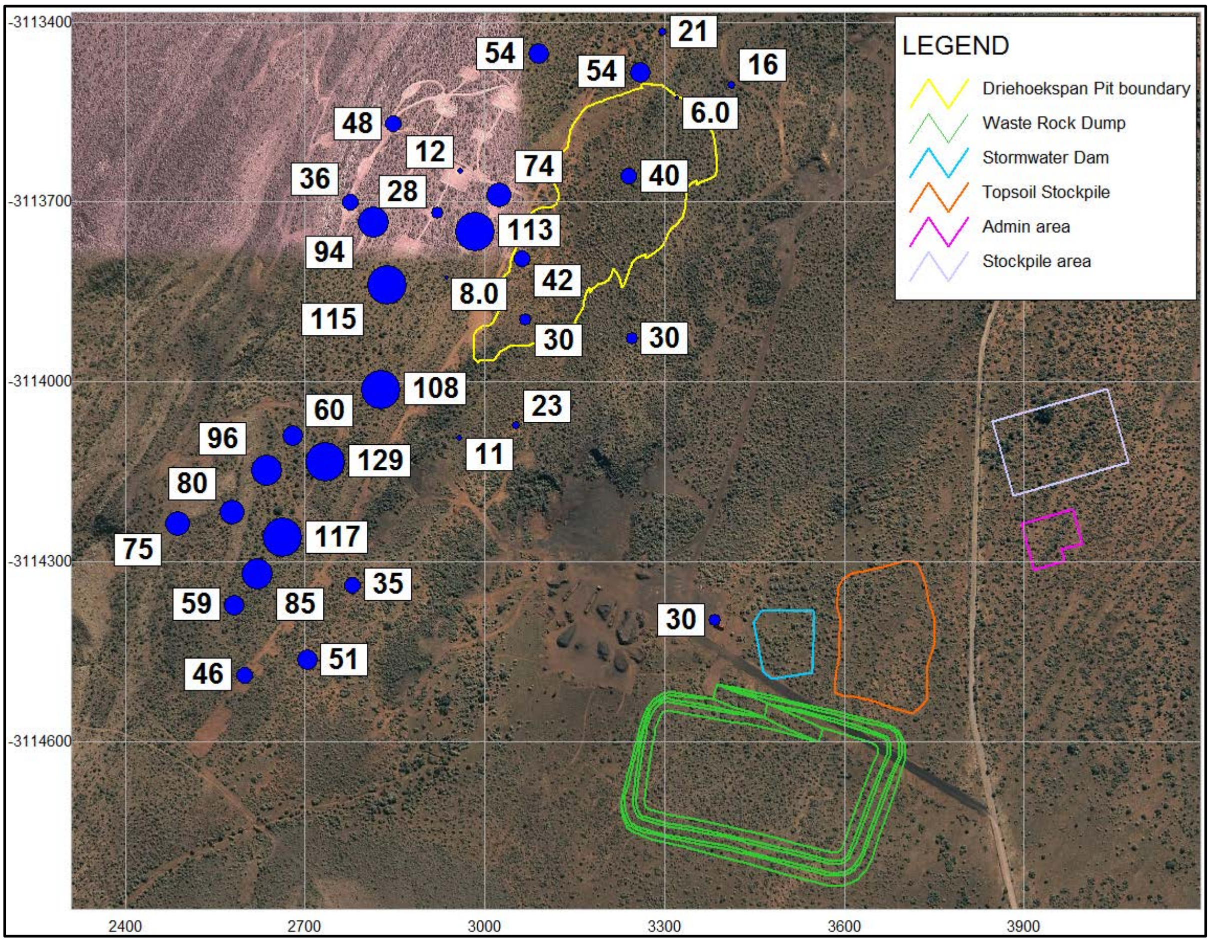


Figure 1.3.1-4: Thematic map of site specific groundwater levels

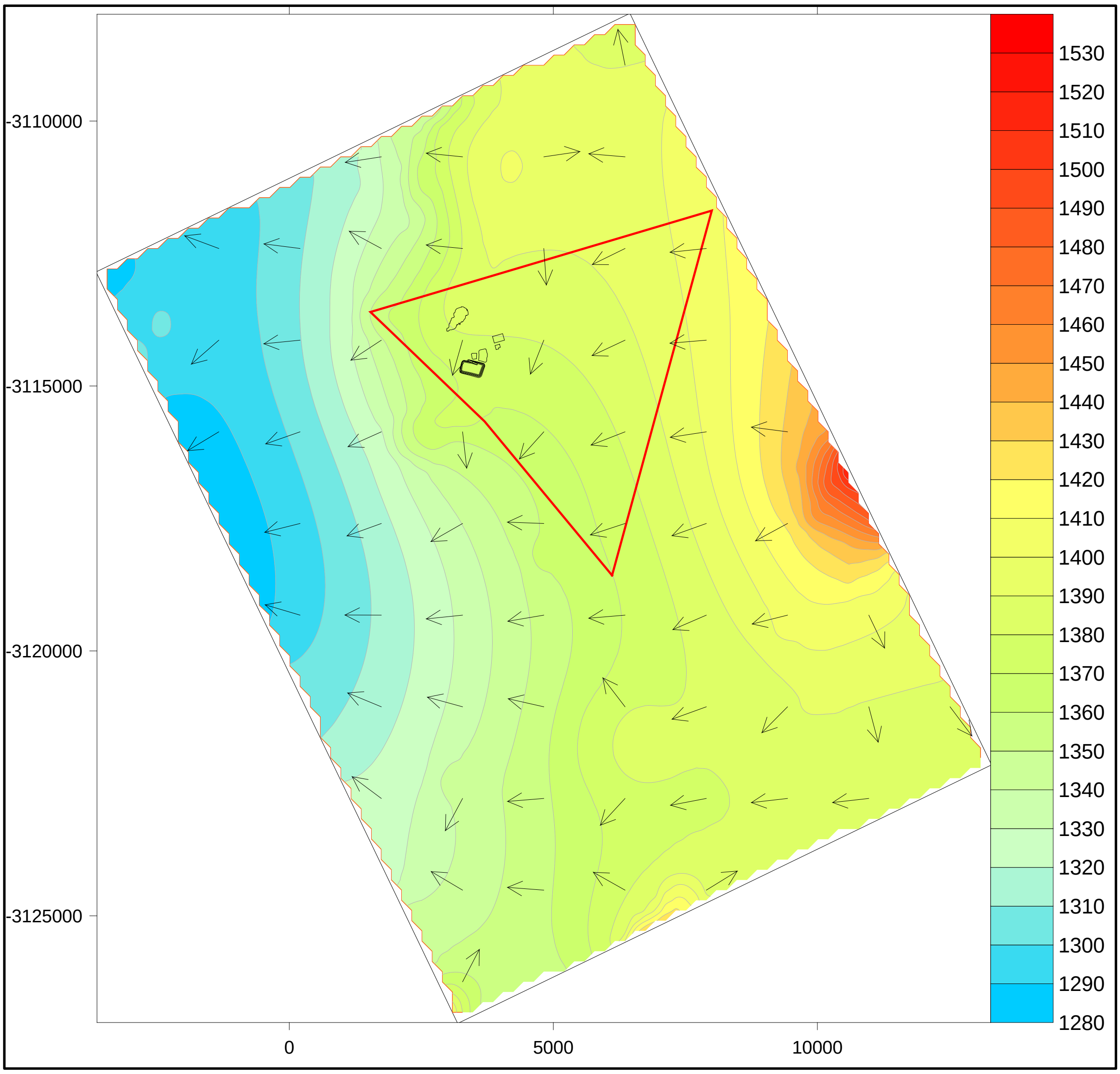


Figure 1.3.1-5: Bayesian interpolated and model calibrated groundwater level contour map of the Coza model area

1.3.2 FLOW GRADIENTS

Contours of the static water levels or piezometric heads in and around the project area are indicated in **Figure 1.3.1-5**. Path lines or flow lines of groundwater particles are lines perpendicular to the contours, as indicated with arrows. Flow occurs faster where contours are closer together and gradient are thus steeper.

On the relatively steeper sloping hillocks where groundwater gradients are higher, groundwater seepage rates are correspondingly higher. Seepage rates on the other hand are much lower in the flat plateaus and valley bottoms.

The groundwater gradient is obtained by the following formula:

$$i = dH / dL$$

Where:

i	=	*Hydraulic gradient*
dH	=	*Head difference*
dL	=	*Lateral distance over which gradient is measured*

Average groundwater gradients were calculated with the above formula from the water level elevation data **(Figure 1.3.1-5)**. By substituting the hydraulic head difference over lateral distance a hydraulic gradient of approximately 2% west/south-westwards was calculated for the proposed Driehoekspan mining area.

1.3.3 AQUIFER TYPES AND YIELD

Information from exploration boreholes shows two possible aquifer types to be present in the project area. For the purpose of this study an aquifer is defined as a geological formation or group of formations that can yield groundwater in economically useable quantities. Aquifer classification according to the Parsons Classification system is summarised in **Table 1.3.3**.

The **first aquifer** is a shallow, **semi-confined or unconfined calcrete aquifer** within the upper 10 to 30 meters of the geological profile. Farmers in the region use this aquifer widely for domestic and livestock water supply. Borehole yields in the calcrete aquifer generally vary from 0.2 to approximately 2 l/s. Where consideration of the shallow aquifer system becomes important is during seepage estimations into voids and mass transport simulations from mine-induced contamination sources, because a significant lateral seepage component often occurs. According to the Parsons Classification system the aquifer is usually regarded as a minor or even a non-aquifer system.

The **second aquifer** is the deeper, **secondary porosity bedrock aquifer** that occurs at depths usually exceeding 30 meters below surface and will be the major aquifer system in the affected groundwater zone. Fracturing in the aquifer usually occurs in the chert breccia (Manganese Marker), banded iron formation and to a lesser extent the underlying dolomite at depths between ± 50 and 150 m below surface. The yields in the aquifer may vary from 1 to more than 40 l/s. Fracturing is usually concentrated near the haematite ore bodies where mineralization and preservation of ore bodies occurred through folding, thrusting, fracturing and sinkhole formation/slumping.

This aquifer system usually displays semi-confined or confined characteristics with piezometric heads often significantly higher than the water-bearing fracture position. The fractures may occur in any of the co-existing host rocks due to different tectonic, structural and depositional processes. According to the Parsons Classification system the aquifer could be regarded as a major aquifer system.

Notable is the fact that **no significant blow yield** was recorded in the dolomites. Dolomite, a rock type usually considered a host rock for major aquifers, is in this case considered rather a subordinate aquifer with high storage properties for groundwater, but not highly transmissive. The younger banded iron formation and chert breccia, on the other hand, are highly transmissive due to fracturing, but the groundwater storage coefficients are much lower. The same phenomenon is also experienced at Sishen and Thabazimbi iron ore mines in the same geological environment.

Table 1.3.3: Parsons Aquifer Classification *(Parsons, 1995)*

Sole Aquifer System	An aquifer that is used to supply 50% or more of domestic water for a given area, and for which there is no reasonably available alternative sources should the aquifer be impacted upon or depleted. Aquifer yields and natural water quality are immaterial.
Major Aquifer System	Highly permeable formation, usually with a known or probable presence of significant fracturing. They may be highly productive and able to support large abstractions for public supply and other purposes. Water quality is generally very good (less than 150 mS/m).
Minor Aquifer System	These can be fractured or potentially fractured rocks that do not have a primary permeability, or other formations of variable permeability. Aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large volumes of water, they are important both for local suppliers and in supplying base flow for rivers.
Non-Aquifer System	These are formations with negligible permeability that are generally regarded as not containing groundwater in exploitable quantities. Water quality may also be such that it renders the aquifer unusable. However, groundwater flow through such rocks, although impermeable, does take place, and needs to be considered when assessing the risk associated with persistent pollutants.
Special Aquifer System	An aquifer designated as such by the Minister of Water Affairs, after due process.

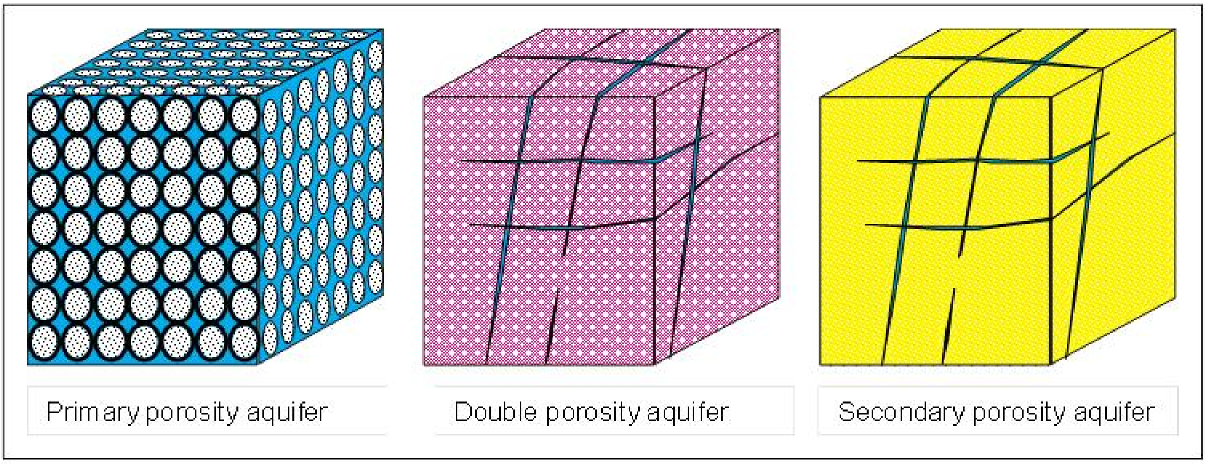


Figure 1.3.3: Types of aquifers based on porosity

In spite of relatively low expected blow-out yields, pump tests were performed on five exploration boreholes and their positions are indicated in **Figure 1.3.3.1-1**. These pump tests were performed using a low yield (< 1 l/s) pump with the main aim of determining the transmissivity and storage characteristics of the solid geological formation – the so-called aquifer matrix. These low rate pump tests are performed instead of the more commonly used slug tests because of the much improved accuracy obtained with the pump tests, resulting in much more reliable aquifer parameters calculated from the tests. The tests results are provided in **Table 1.3.3.1-2**.

1.3.3.1 AQUIFER TRANSMISSIVITY AND STORATIVITY

Constant rate pump tests were performed on five exploration boreholes and their positions are indicated in **Figure 1.3.3.1-1**. A short summary of the pump tests are also provided in **Table 1.3.3.1-1**.

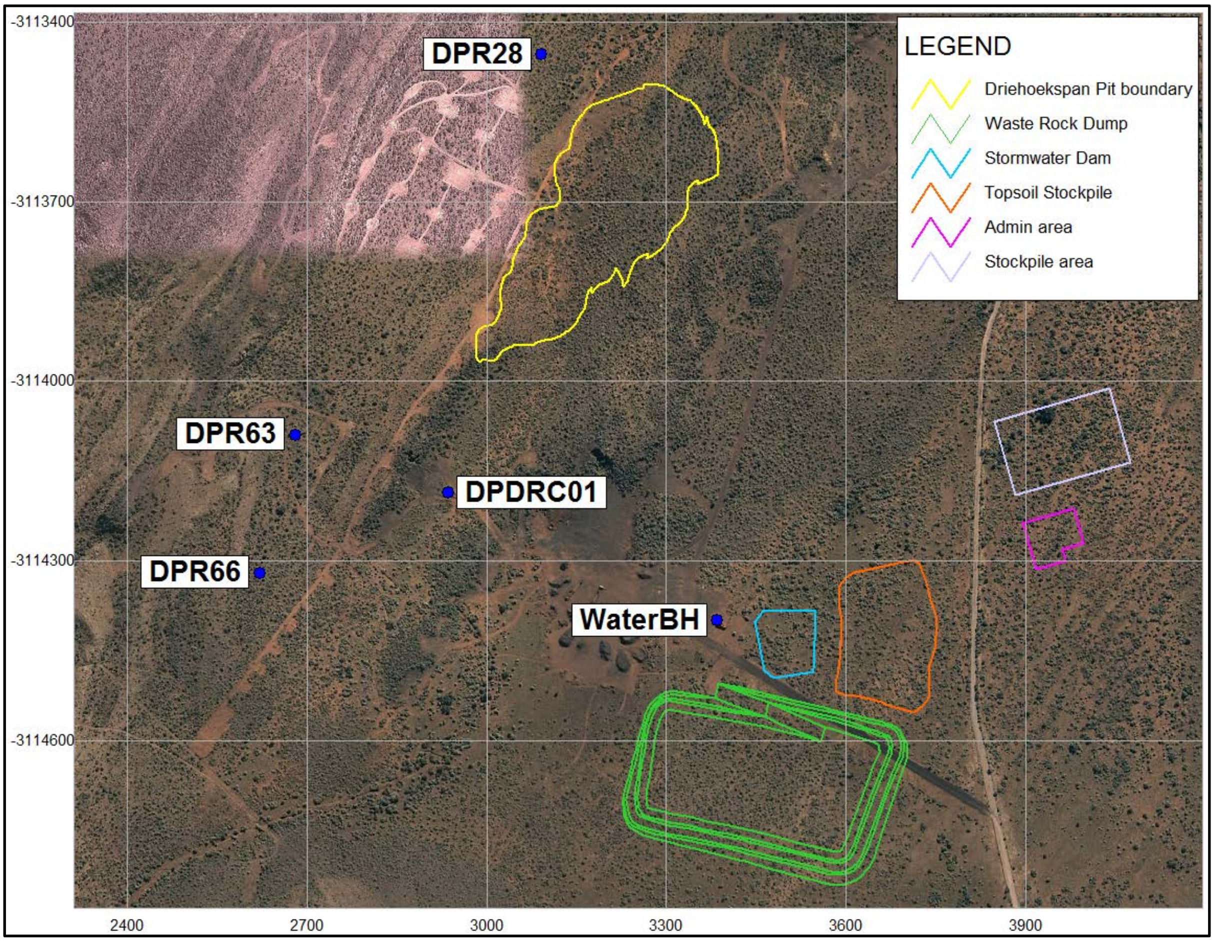


Figure 1.3.3.1-1: Positions of pump test boreholes

Data collected from the pump tests were used to determine aquifer parameters such as transmissivity and storativity for both the matrix- and fracture flow stages.

Table 1.3.3.1-1: Summary of pump tests

BH	BH depth	Static WL	Pump duration	Pump rate	Drawdown	Recovery
Unit	*m*	*mamsl*	*min*	*l/s*	*m*	*%*
DPR28	>100	60.4	15	0.15	18.2	18% after 15 min
DPR63	>100	59.1	600	1.00	7.0	100% after 90 min
DPR66	>100	47.3	600	0.80	17.7	94% after 600 min
DPD-RC01	>100	44.1	480	0.13	20.9	56% after 360 min
WATER-BH	50	11.7	720	4.50	7.5	100% after 180 min

Note: *Borehole DPR28 was pumped dry within the first 15 minutes of the test.*

Aquifer transmissivity is defined as a measure of the amount of water that could be transmitted horizontally through a unit width of aquifer by the full-saturated thickness of the aquifer under a hydraulic gradient of 1. Transmissivity is the product of the aquifer thickness and the hydraulic conductivity of the aquifer, usually expressed as m^2/day ($Length^2$/Time).

Storativity (or the storage coefficient) is the volume of water that a permeable unit will absorb or expel from storage per unit surface area per unit change in piezometric head. Storativity (a dimensionless quantity) cannot be measured with a high degree of accuracy in slug tests or even in conventional pumping tests. It has been calculated by numerous different methods with the results published widely and a value of 0.002 to 0.01 is taken as representative for the proposed mining area. The storage coefficient values calculated from the Driehoekspan pump tests proved to be in this order of magnitude.

The pump test data was analysed with the AQTESOLV Professional software package, which offers a wide range of mathematical equations/solutions for the calculation of aquifer parameters. The time-water level data collected during the constant rate pump test is plotted on a log-linear graph. A straight line can then be fitted to the different flow stages on the graph (process known as curve matching) and the aquifer transmissivity and storativity is calculated in accordance with the preselected analytical equation. All aquifer parameters provided in this report were calculated with the *Cooper-Jacob (1946)* equation. Examples of curve matching are provided in **Figures 1.3.3.1-2** to **1.3.3.1-6**, which illustrate aquifer parameters calculated for both the matrix- and fracture flow stages.

It is important to note that the *Cooper-Jacob* approximation algorithm for pump test analysis was designed for pump tests interpretation in a primary porosity aquifer environment with the following assumptions:

- The aquifer is a homogeneous medium,
- Of infinite extent,
- No recharge is considered, and
- An observation borehole is used for water level recording at a distance from the pumped borehole.

Although few of these assumptions apply at the project area, the method could still be used as long as the assumptions and 'shortcomings' are recognized and taken into account. It is for this reason that not one straight line is fitted but two different lines are fitted for the fracture and matrix flow periods respectively.

Because aquifer hydraulic parameters (like most geological parameters) usually display a log-normal distribution it is an accepted approach to calculate the harmonic or geometric mean in preference to the arithmetic mean. A generally accepted approach for calculating a representative hydraulic conductivity for an aquifer is to take the average of the harmonic and geometric means. These values have been calculated and are provided in **Table 1.3.3.1-2**.

It follows that the representative transmissivity of the **aquifer matrix** (between fracture zones) in the proposed Driehoekspan area generally vary between ± 0.3 and 0.7 m^2/d with an **average of 0.5 m^2/d**. These transmissivities calculate to a representative **hydraulic conductivity** of ± **0.017 m/d** for the area. The representative transmissivity of the **fractures** in the area vary between ± 1.1 and 3.4 m^2/day with an **average of 2.2 m^2/d**. The average **hydraulic conductivity** of the fractures is therefore in the region of **0.073 m/d**.

The extremely heterogeneous nature of the fractured rock aquifer regime may however cause significant variations in aquifer transmissivity/storativity within relatively short distances, which makes it difficult to determine representative values over large areas. In spite of these heterogeneities the values obtained correspond well to values used in the numerical modeling for flow and mass transport simulation.

Table 1.3.3.1-2: Aquifer parameters calculated for exploration boreholes

BH	Tf	Tm	Sf	Sm
DPR28	0.4	0.2	5.0E-03	2.9E-02
DPR63	31.3	8.5	3.1E-09	1.5E-01
DPR66	10.0	1.2	2.3E-10	2.6E-01
DPD-RC01	1.0	0.2	9.7E-06	3.0E-01
WATER-BH	254.0	15.4	1.6E-06	N/A
Geometric mean:	**3.4**	**0.7**	**4.3E-07**	**1.3E-01**
Harmonic mean:	**1.1**	**0.3**	**8.6E-10**	**8.2E-02**
Average:	**2.2**	**0.5**	**2.2E-07**	**1.1E-01**

***Note**:*
Tf – Fracture transmissivity (m^2/d),
Tm – Matrix transmissivity (m^2/d),
Sf – Fracture storativity/storage coefficient (dimensionless quantity),
Sm – Matrix storativity/storage coefficient (dimensionless quantity).

Please note that borehole WATER-BH is likely to have intersected a highly transmissive geological structure, which would explain the anomalously high aquifer parameters calculated from the pump test data. Such high parameters are not representative of the greater project area and were consequently excluded from the geometric- and harmonic mean calculations to avoid any misinterpretation.

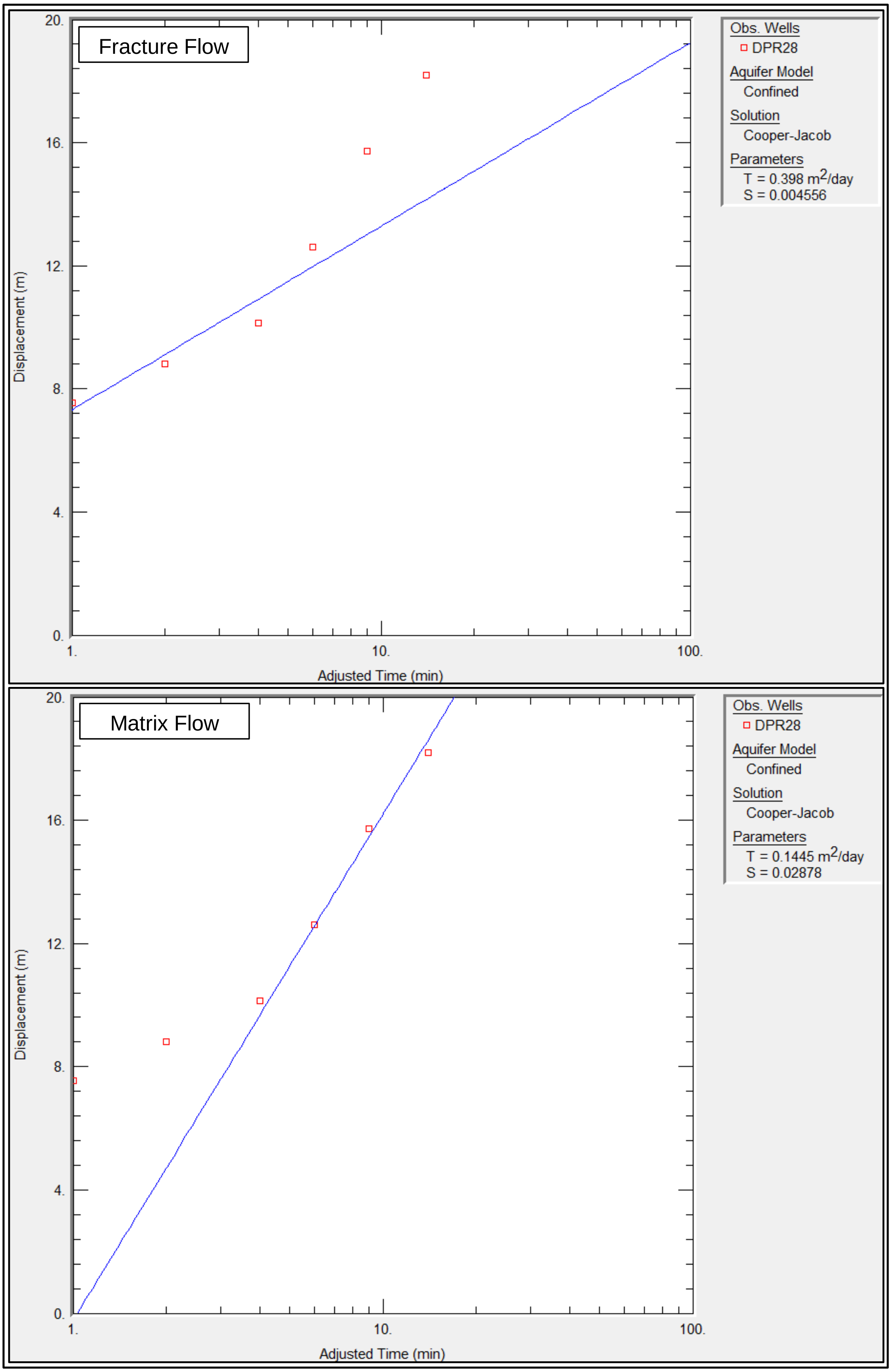


Figure 1.3.3.1-2: Analysis of pump test for borehole DPR28

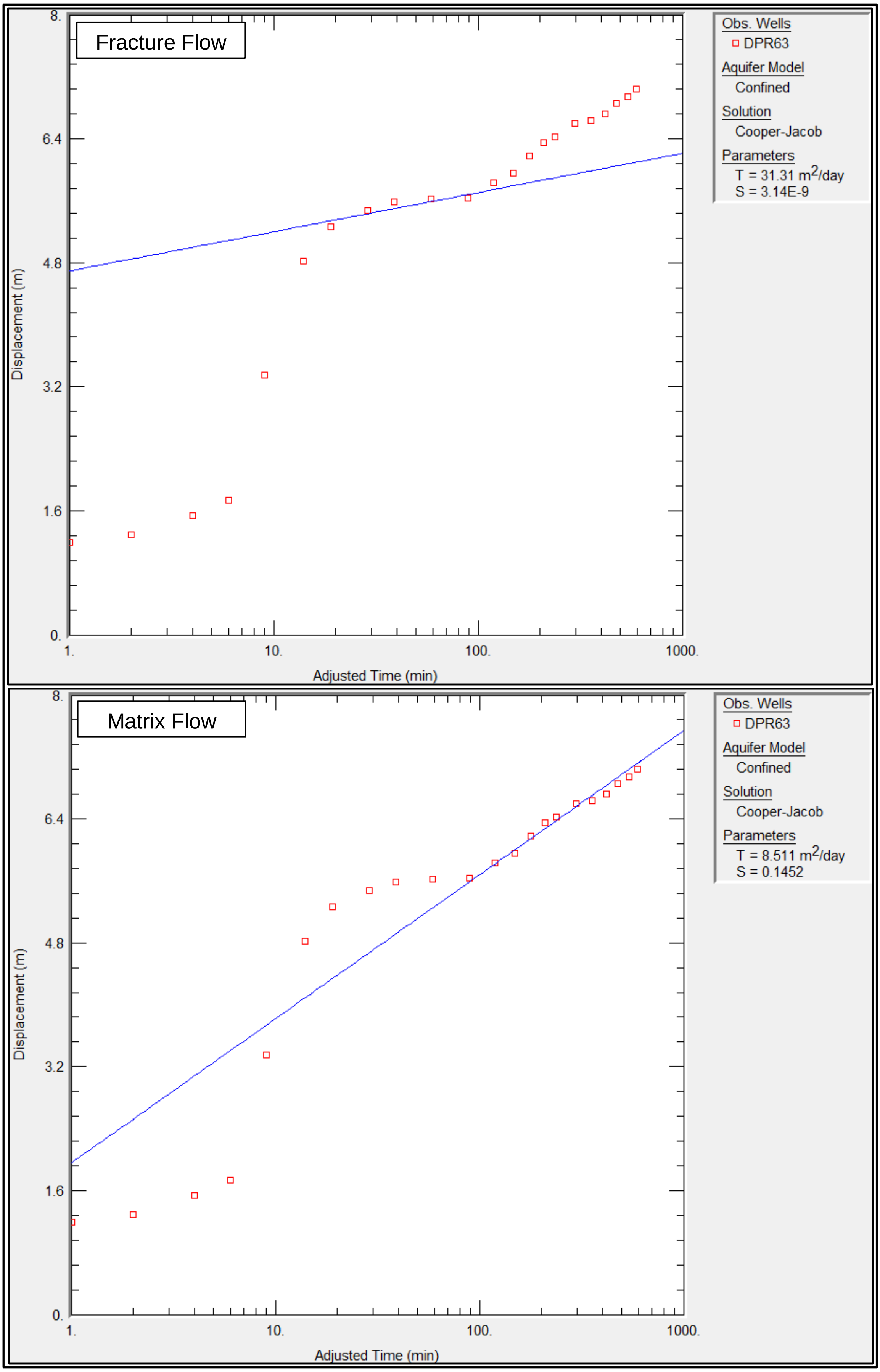


Figure 1.3.3.1-3: Analysis of pump test for borehole DPR63

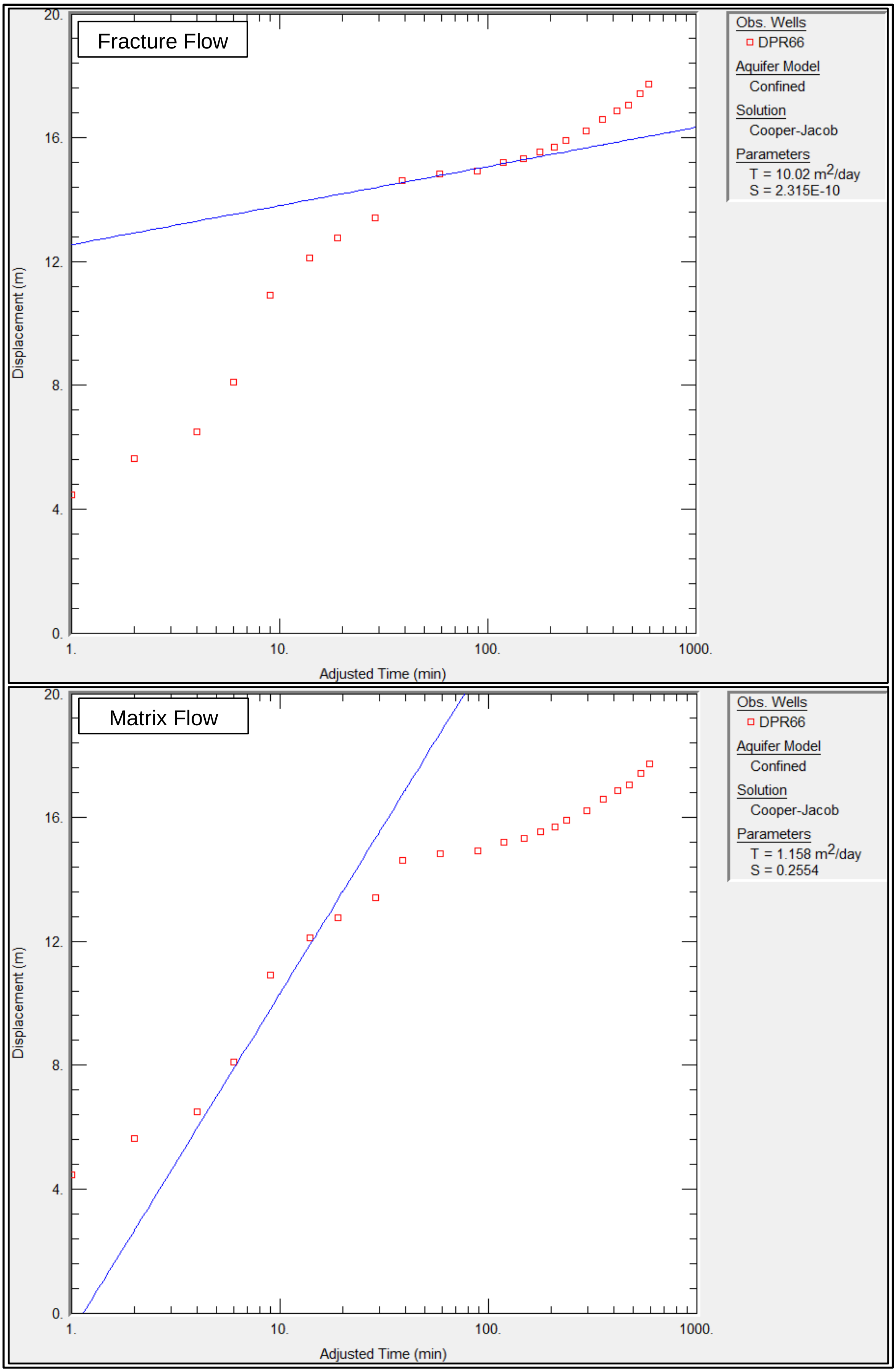


Figure 1.3.3.1-4: Analysis of pump test for borehole DPR66

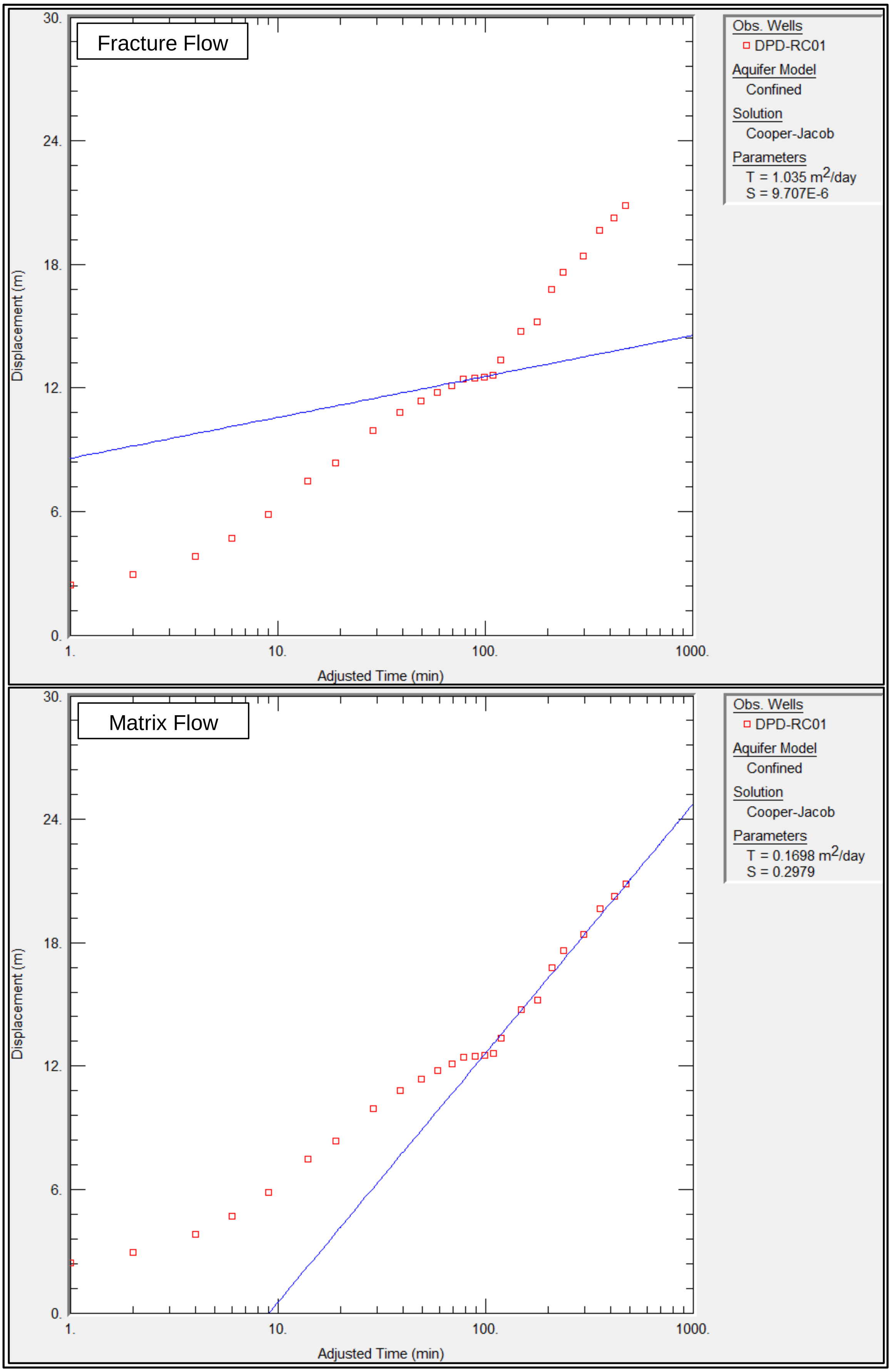


Figure 1.3.3.1-5: Analysis of pump test for borehole DPD-RC01

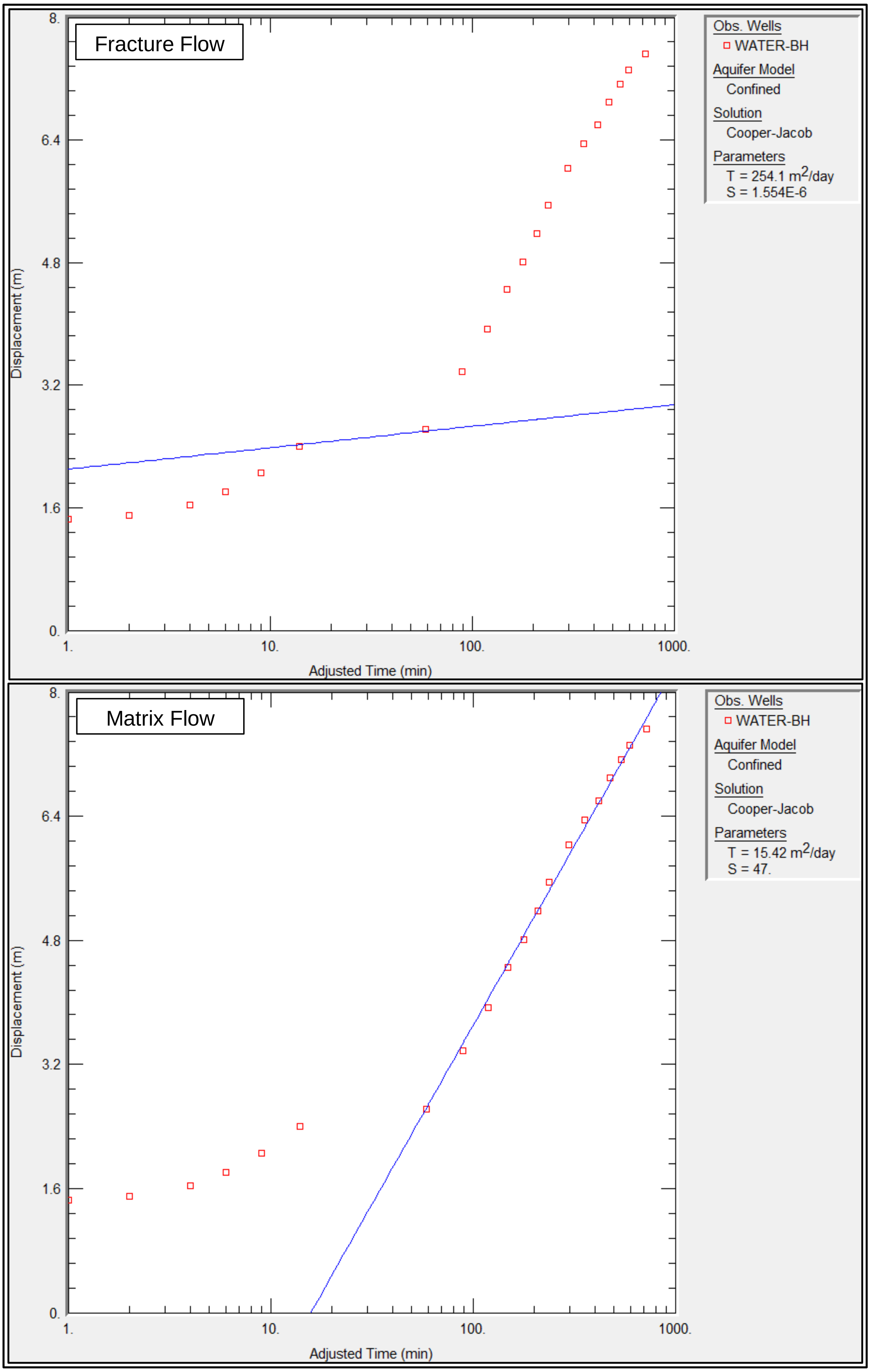


Figure 1.3.3.1-6: Analysis of pump test for borehole WATER-BH

1.3.3.2 AQUIFER RECHARGE AND DISCHARGE RATES

According to **Figure 1.3.3.2-3** the mean annual recharge to the aquifer underlying the project area varies between approximately 13.5 to 19.4 mm, which based on an average rainfall of approximately 300 mm/a **(Figure 1.3.3.2-1)** translates to a recharge percentage varying between anything from 5 to 7%. This recharge is much higher than in Karoo type aquifers (typically between 1 and 3%) found over large parts of South Africa. The main reasons for the relatively high effective recharge percentage are:

- The dolomitic aquifers occurring over large portions of the project area,
- Kalahari sand and transmissive calcrete cover where outcrop does not occur, and
- Very low clay content of soils that are present, allowing for easy infiltration.

Where outcrop occurs, the effective recharge percentage can be slightly higher while in low-lying topographies where discharge generally occurs and thicker sediment deposition, the effective recharge will be lower or even zero. Regions within the model area expected to receive higher recharge are indicated in **Figure 1.3.3.2-4**. Based on this estimate, the annual recharge to the Driehoekspan lease area should vary between ± 297 000 and 415 700 m^3.

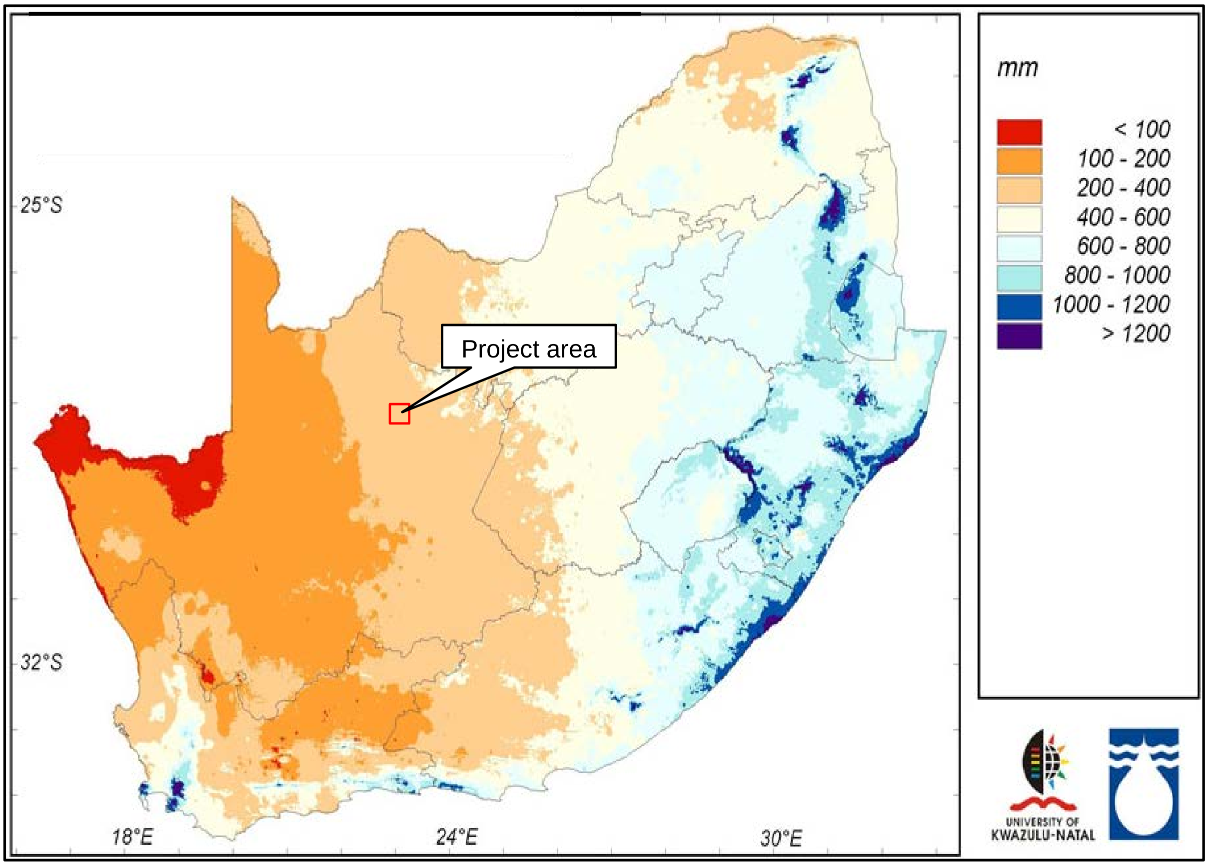


Figure 1.3.3.2-1: Mean annual precipitation for South Africa

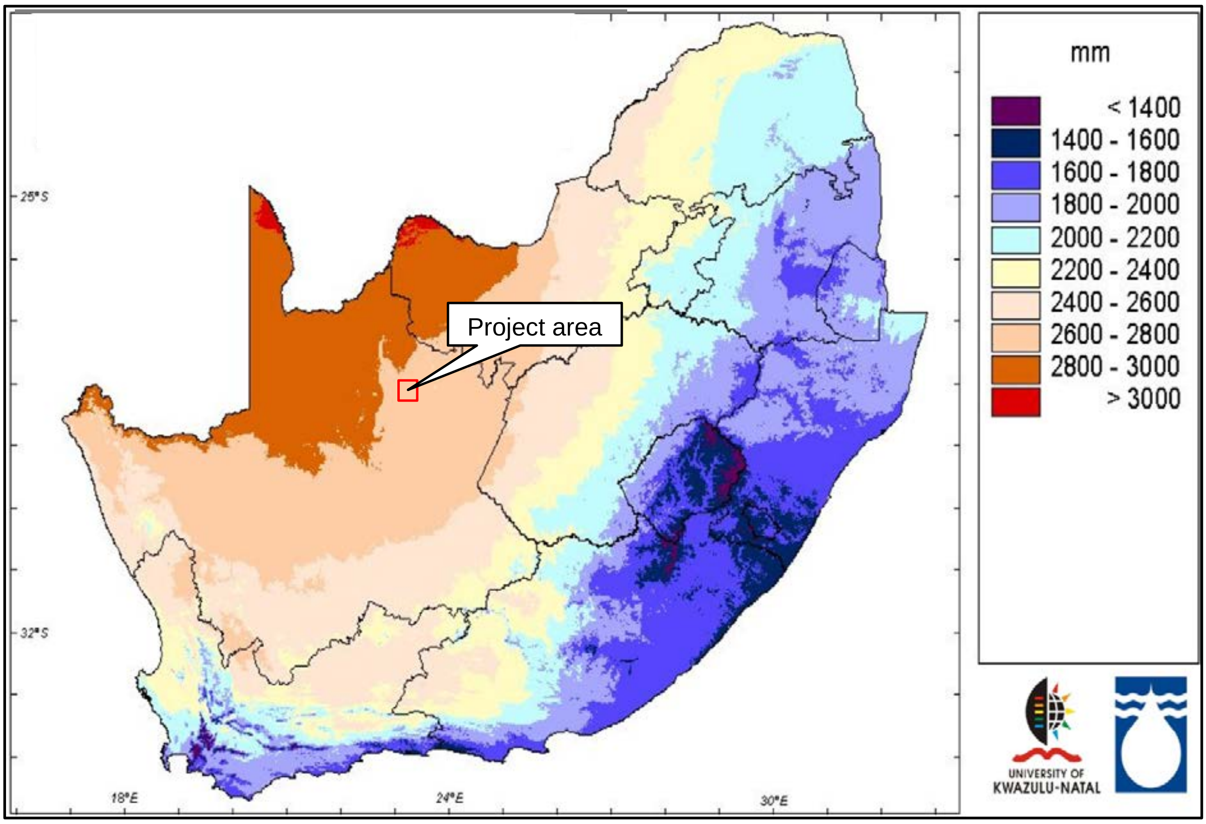


Figure 1.3.3.2-2: Mean annual evaporation for South Africa

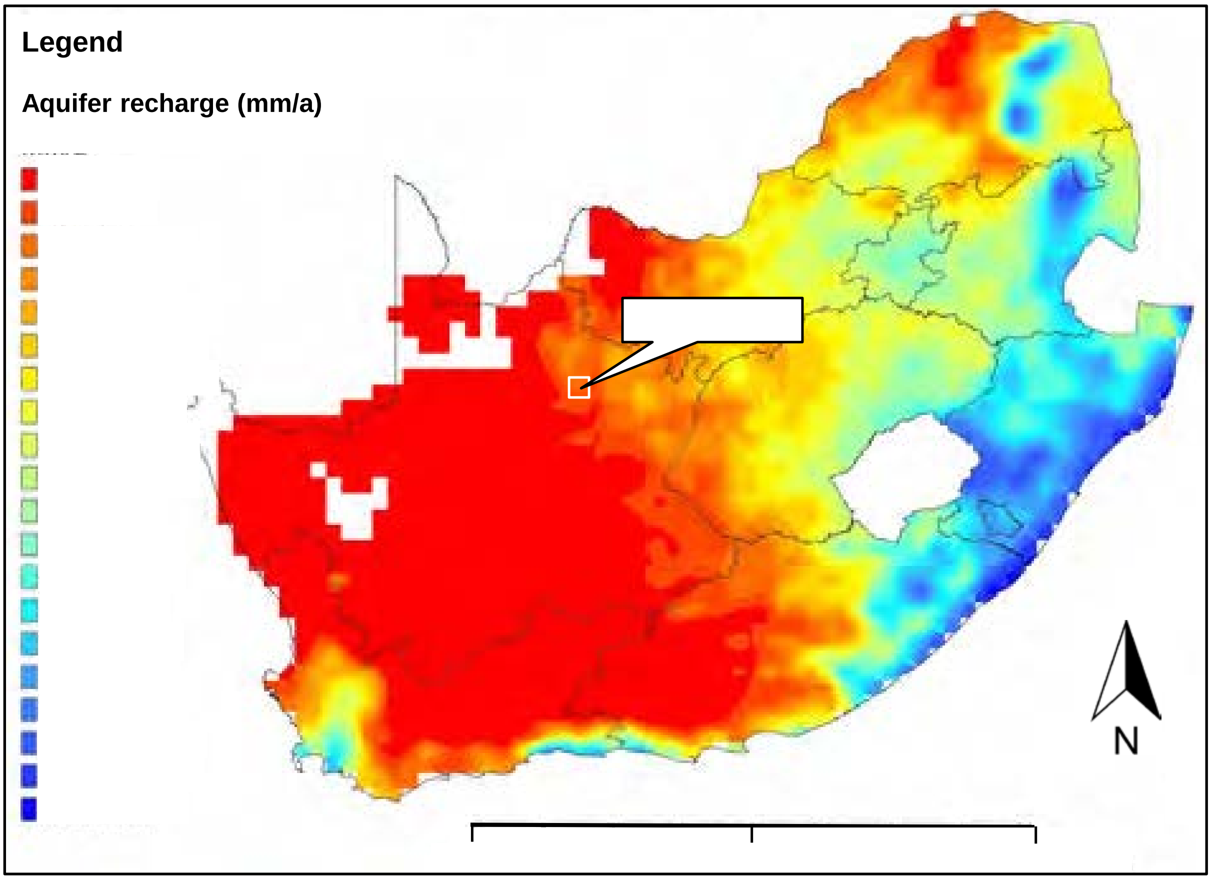


Figure 1.3.3.2-3: Mean annual aquifer recharge for South Africa *(Dennis et al, 2012)*

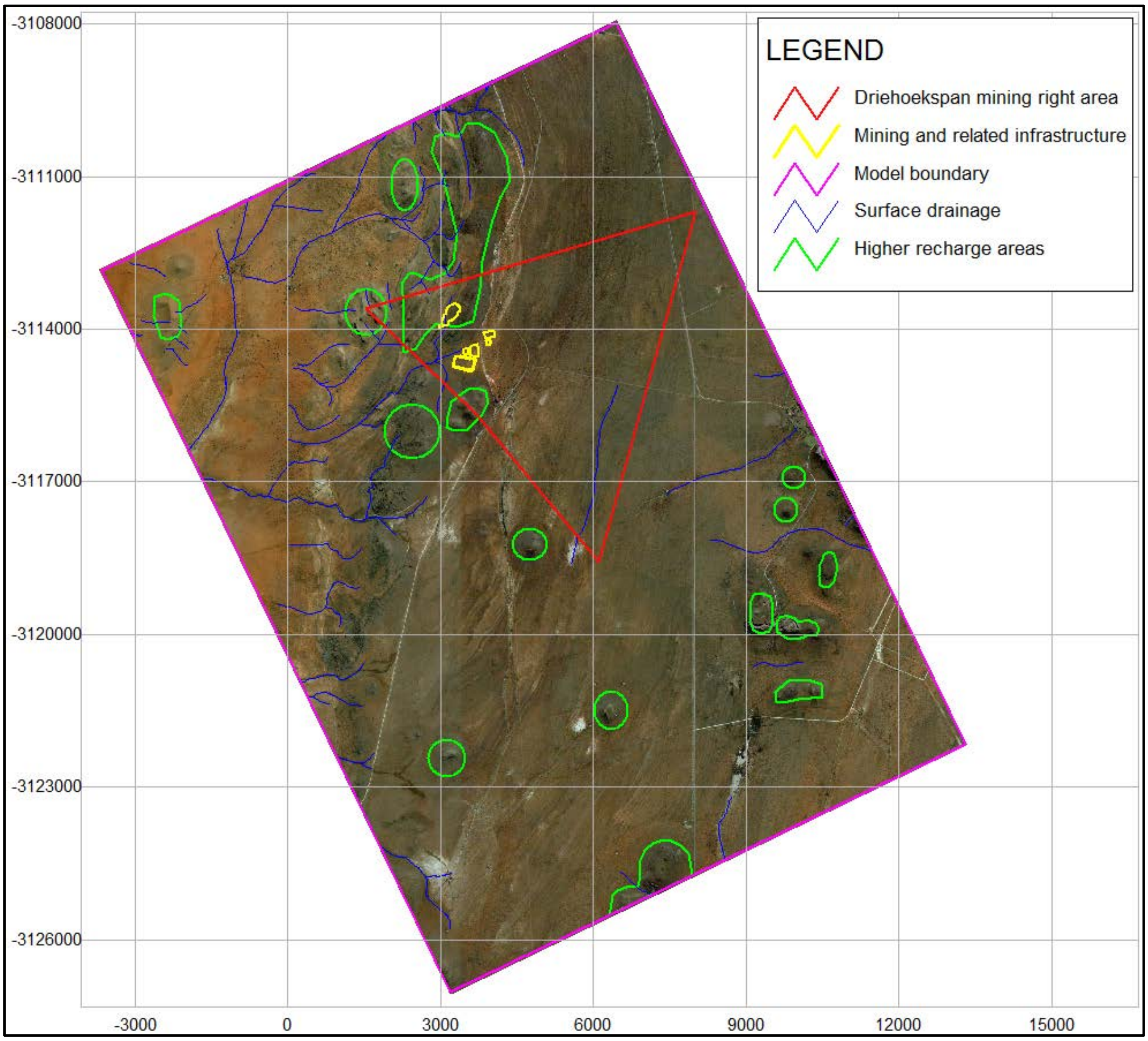


Figure 1.3.3.2-4: Expected areas of higher aquifer recharge

1.3.3.3 DIRECTION AND RATE OF GROUNDWATER MOVEMENT IN POTENTIALLY IMPACTED AREAS

The pre-mining static groundwater contours are presented in **Figure 1.3.1-5** and were constructed with the use of Bayesian interpolation and steady state numerical groundwater flow model calibration.

These contours represent conditions without impacts from sources or actions other than natural conditions. Groundwater flow gradients **(Section 1.3.2)** were used to calculate the rate of groundwater movement (the so-called 'Darcy flux') within the potentially impacted areas and the results are provided in **Table 1.3.3.3**.

Table 1.3.3.3: Direction and rate of groundwater movement in the proposed Driehoekspan mining area

Groundwater flow direction	Groundwater flow gradient	Groundwater flow velocity (m/d)	Groundwater flow velocity (m/y)
West/South-West	0.02%	0.008	3.0

Notes: *Flow velocity calculations were done by assuming an average aquifer porosity of 6% and hydraulic conductivity of 0.025 m/d.*

A large number of manmade actions could impact on the groundwater regime; including the aquifer structure, flow paths and directions, storage, discharges and recharge. Possible impacts relevant to the proposed project will be discussed briefly:

Aquifer structure, flow paths and directions

During active mining and thereafter, the voids created by opencast mining will impact on the natural groundwater movement. **The deepest floor elevation of the proposed Driehoekspan pit is estimated at approximately 1 365 mamsl, which is ± 20 meters below the current groundwater level elevation.** A local lowering of the groundwater levels is therefore expected to occur due to mine dewatering, which will lead to the formation of a cone of depression. Flow directions and velocities within the radius of the affected area will be altered and groundwater will move radially towards the center of the depression cone.

Mine voids also destroy the in situ aquifer structures and could be compared to areas of very high (even infinitely high) transmissivity and also high storativity. Because groundwater will follow the route of least resistance, groundwater will prefer to move through the mined-out areas. The final mined area will directly determine the post closure groundwater flow paths, directions and possible decant.

The transmissivity and storativity of the backfilled opencast void will always remain higher than the pre-mining natural aquifer(s). Because the sedimentary rocks surrounding the iron ore body have relatively low transmissivity values, impacts on the natural flow pattern in the project area are expected to be noticeable to a limited extent and in the immediate vicinity of the operations.

The extent of the impact however depends mostly on the transmissivity of geological structures and discontinuities that may or may not intersect the Driehoekspan pit. No such information was available at the time of completion of this report and dedicated geophysical surveys are recommended to identify and define structures that may influence groundwater level impacts caused by mine dewatering.

Aquifer discharge

A mining and processing operation may impact significantly on the discharge of an aquifer in different ways. If mining occurs and mine dewatering is required, the natural aquifer discharge will decrease by the volume of groundwater removed by dewatering. Aquifer discharge may also increase with the use of return water dams, slurry and other dams through leakage of water to the subsurface, especially if water is imported to the project from other sources. Other factors that may decrease the aquifer discharge are compacted surfaces, haul roads and concrete surfaces that prevent infiltration to the aquifer and decrease groundwater discharge, although increasing surface runoff. The relative surface area of these features is however usually a very small percentage of the total surface area of the operation.

After mine closure, however, recharge is expected to be higher to the backfilled opencast pit than to the pre-mining aquifer. The increased recharge will subsequently lead to an increase in discharge should the void decant. **Average evapotranspiration from the Driehoekspan pit area was estimated to be in the order of 650 m^3/d, which removes the risk for potential decant since the recharge rate was estimated to be ± 12 m^3/d (Figure 1.3.3.2-2).**

Aquifer recharge

All the aspects mentioned under aquifer discharge apply to aquifer recharge. The type of mining has the most direct and profound effect on groundwater recharge. With opencast mining recharge can be as high as 30% of the MAP and is seldom less than 10%.

Water retaining infrastructure such as the planned pollution control dam will also usually increase recharge to the underlying aquifer, but compacted or concrete surfaces and roads will decrease the recharge.

1.4 GROUNDWATER QUALITY EVALUATION

Groundwater quality data were collected from two sources, namely from **user boreholes** located during the hydrocensus/user survey and groundwater **monitoring boreholes** on the farm Doornpan. Groundwater quality data were evaluated with the aid of diagnostic chemical diagrams and by comparing the inorganic concentrations to the South African National Standards for drinking water **(Table 1.4-1)**. Because only once-off analyses data exist for the hydrocensus boreholes, time-series data, statistical analyses and trend analyses are not possible. The first step in the water quality interpretation was to classify the groundwater quality.

The classification was based on the following:

- The spatial distribution of the groundwater sampling points, and
- The proximity of the points to certain known pollution sources that are expected to impact on the groundwater and/or surface water in the downstream flow direction area.

The four main factors usually influencing groundwater quality are:

- **Annual recharge** to the groundwater system,
- **Type of bedrock** where ion exchange may impact on the hydrogeochemistry,
- **Flow dynamics** within the aquifer(s), determining the water age and
- **Source(s) of pollution** with their associated leachates or contaminant streams.

Where no specific **source of groundwater pollution** is present upstream of the borehole, only the other three factors play a role.

One of the most appropriate ways to interpret the type of water at a sampling point is to assess the plot position of the water quality on different analytical diagrams like a Piper, Expanded Durov and Stiff diagrams. Of these three types, the Expanded Durov diagram probably gives the most holistic water quality signature.

Although never clear-cut like a fail-safe recipe, the general characteristics of the different fields of the diagram could be summarized as follows:

Field 1:
Fresh, very clean recently recharged groundwater with HCO_3 and CO_3 dominated ions.

Field 2:
Field 2 represents fresh, clean, relatively young groundwater that has started to undergo mineralization with especially Mg ion exchange.

Field 3:
This field indicates fresh, clean, relatively young groundwater that has undergone Na ion exchange (sometimes in Na - enriched granites or felsic rocks) or because of contamination effects from a source rich in Na.

Field 4:
Fresh, recently recharged groundwater with HCO_3 and CO_3 dominated ions that has been in contact with a source of SO_4 contamination or that has moved through SO_4 enriched bedrock.

Field 5:
Groundwater that is usually a mix of different types – either clean water from fields 1 and 2 that has undergone SO_4 and NaCl mixing / contamination or old stagnant NaCl dominated water that has mixed with clean water.

Field 6:
Groundwater from field 5 that has been in contact with a source rich in Na or old stagnant NaCl dominated water that resides in Na rich host rock/material.

Field 7:
Water rarely plots in this field that indicates NO_3 or Cl enrichment or dissolution.

Field 8:
Groundwater that is usually a mix of different types – either clean water from fields 1 and 2 that has undergone SO_4, but especially Cl mixing/contamination or old stagnant NaCl dominated water that has mixed with water richer in Mg.

Field 9:
Old or stagnant water that has reached the end of the geohydrological cycle (deserts, salty pans etc.) or water that has moved a long time and / or distance through the aquifer or on surface and has undergone significant ion exchange because of the long distance or residence time in the aquifer.

The layout of the fields of the Expanded Durov diagram (EDD) is shown in **Figure 1.4-1**.

Another way of presenting the signature or water type distribution in an area is by means of Stiff diagrams. These diagrams plot the equivalent concentrations of the major cations and anions on a horizontal scale on opposite sides of a vertical axis. The plot point on each parameter is linked to the adjacent one resulting in a polygon around the cation and anion axes. The result is a small figure/diagram of which the geometry typifies the groundwater composition at the point. Groundwater with similar major ion ratios will show the same geometry. Ambient groundwater qualities in the same aquifer type and water polluted by the same source will for example display similar geometries.

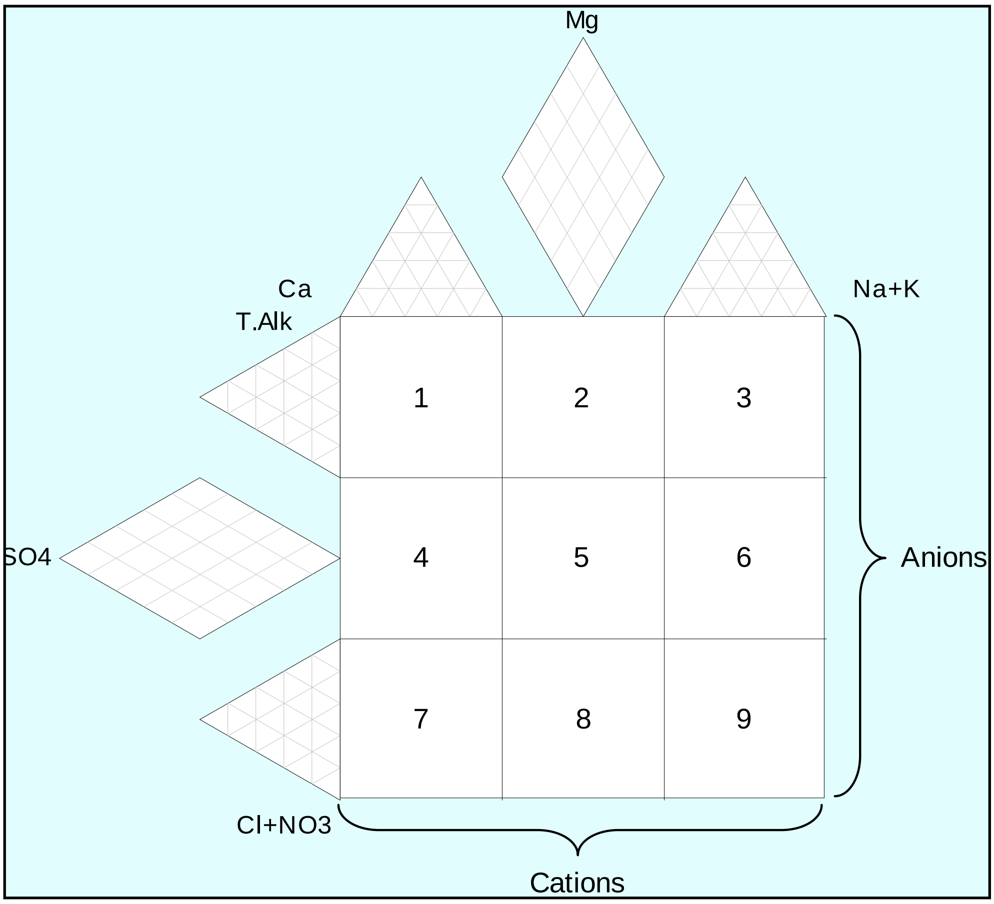


Figure 1.4-1: Layout of fields of the Expanded Durov diagram

Table 1.4-1: South African National Standards for drinking water *(SANS 241:2011)*

Determinant	Risk	Unit	Standard limits
Physical and aesthetic determinants			
Free chlorine	Chronic health	mg/L	≤ 5
Monochloramine	Chronic health	mg/L	≤ 3
Colour	Aesthetic	mg/L Pt-Co	≤ 15
Conductivity at 25 °C	Aesthetic	mS/m	≤ 170
Odour or taste	Aesthetic	–	Inoffensive
Total dissolved solids	Aesthetic	mg/L	≤ 1 200
Turbidity	Operational	NTU	≤ 1
	Aesthetic	NTU	≤ 5
pH at 25 C	Operational	pH units	≥ 5 to ≤ 9.7
Chemical determinants - macro-determinants			
Nitrate as N	Acute health – 1	mg/L	≤ 11
Nitrite as N	Acute health – 1	mg/L	≤ 0.9
Sulfate as SO_4^{2-}	Acute health – 1	mg/L	≤ 500
	Aesthetic	mg/L	≤ 250
Fluoride as F^-	Chronic health	mg/L	≤ 1.5
Ammonia as N	Aesthetic	mg/L	≤ 1.5
Chloride as Cl^-	Aesthetic	mg/L	≤ 300
Sodium as Na	Aesthetic	mg/L	≤ 200
Zinc as Zn	Aesthetic	mg/L	≤ 5
Chemical determinants - micro-determinants			
Aluminium as Al	Operational	µg/L	≤ 300
Antimony as Sb	Chronic health	µg/L	≤ 20
Arsenic as As	Chronic health	µg/L	≤ 10
Cadmium as Cd	Chronic health	µg/L	≤ 3
Total chromium as Cr	Chronic health	µg/L	≤ 50
Cobalt as Co	Chronic health	µg/L	≤ 500
Copper as Cu	Chronic health	µg/L	≤ 2 000
Cyanide (recoverable) as CN^-	Acute health – 1	µg/L	≤ 70
Iron as Fe	Chronic health	µg/L	≤ 2 000
	Aesthetic	µg/L	≤ 300
Lead as Pb	Chronic health	µg/L	≤ 10
Manganese as Mn	Chronic health	µg/L	≤ 500
	Aesthetic	µg/L	≤ 100
Mercury as Hg	Chronic health	µg/L	≤ 6
Nickel as Ni	Chronic health	µg/L	≤ 70
Selenium as Se	Chronic health	µg/L	≤ 10
Uranium as U	Chronic health	µg/L	≤ 15
Vanadium as V	Chronic health	µg/L	≤ 200

Water quality information is available for a total of 40 localities and their positions are indicated in **Figure 1.4.1-2**. No groundwater quality information is available for the area east of the R325 road as it is mostly the property of Assmang and access was restricted at the time of the hydrocensus and groundwater user survey.

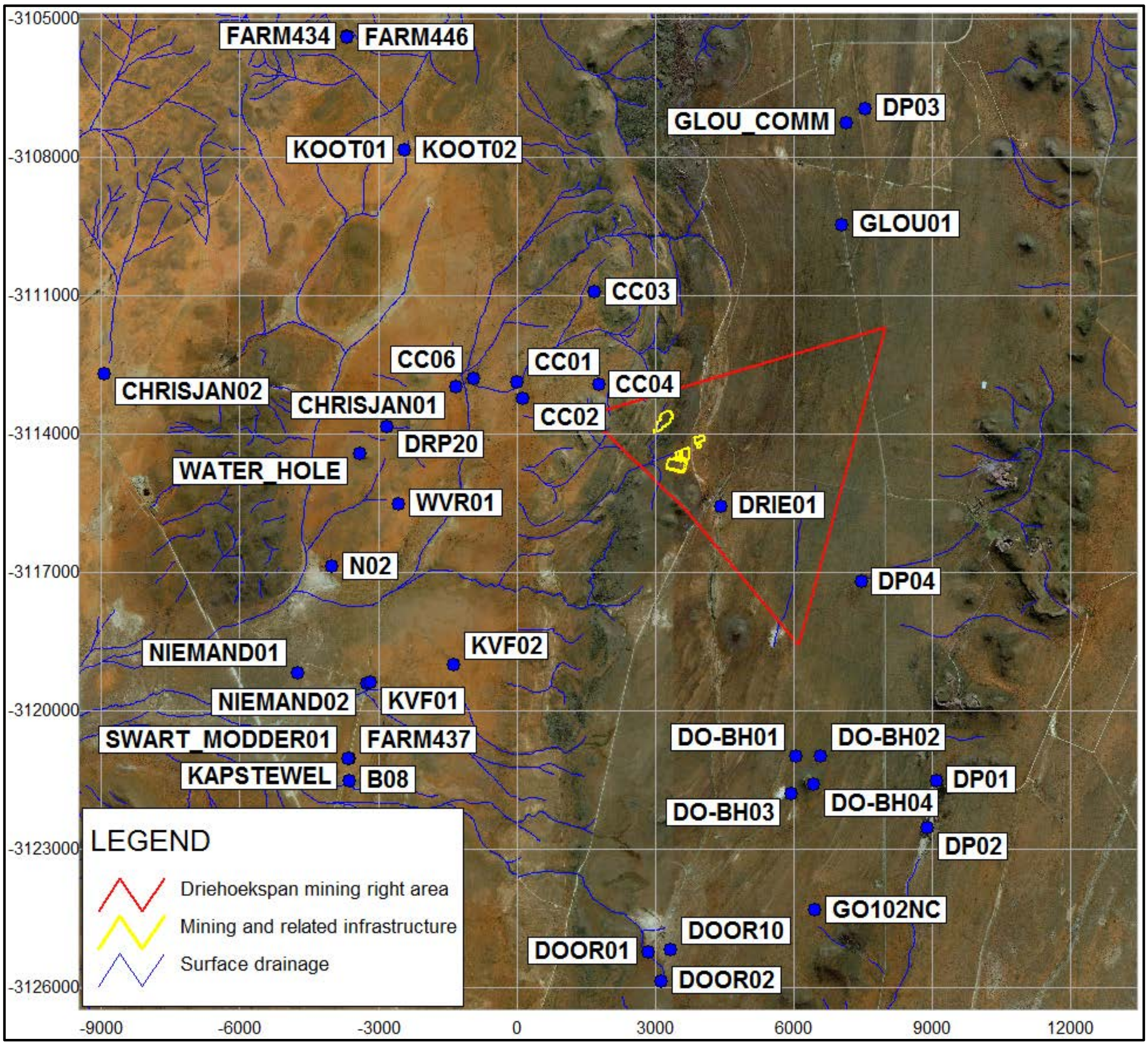


Figure 1.4-2: Distribution of regional water quality localities at Coza

Five chemical parameters (TDS, SO_4, NO_3, Cl and pH) were chosen from the full list of analytes as indicators of the specific type of contamination commonly occurring at iron ore mining operations. Although only the five parameters will be discussed, all inorganic parameters will be assessed and anomalies will be discussed.

The **total dissolved solids (TDS)** content of groundwater is a good indicator of the overall quality conditions, as it provides a measurement of the total amount/weight of salts that are present in solution. An increase in TDS will therefore also indicate an increase in the total inorganic content of the groundwater.

Groundwater TDS concentrations vary between ± 50 mg/l and 690 mg/l, which are well below the permissible SANS value of 1 200 mg/l **(Table 1.4-1)**. A positive linear correlation generally exists between groundwater salinity and aquifer residence time and because gravity dictates that groundwater moves from higher to lower hydraulic gradients, overall higher salinities are generally measured in the lower lying areas and valley bottoms. No such correlation was however identified within the project area.

The **sulphate** content of groundwater measured within a ± 10 km radius of the project area vary from below the detection limit of 0.04 mg/l to approximately 130 mg/l, which are below the permissible SANS value of 500 mg/l. Sulphate contamination is more often than not associated with the oxidation of sulphide bearing minerals (in particular pyrite), which is illustrated by means of the below reaction:

$$2FeS_2 + 7O_2 + 2H_2O \longrightarrow 2Fe^{2+} + 4SO_4^{2-} + 4H^+$$

The reaction requires both oxygen and water to take place, which is readily available in opencast mining environments and is commonly referred to as Acid Mine Drainage (AMD). The production of hydrogen ions will consequently lead to a decrease in the groundwater pH conditions. Acid mine drainage is however not as prominent in the iron ore mining environment in comparison to coal mining. This statement was also found to apply to the Driehoekspan Project area after Acid Base Accounting (ABA) tests were performed on two samples collected from the drilling of exploration boreholes. The test results are discussed in detail in **Section 3.2** of the document. The groundwater **pH** conditions are more or less neutral with values ranging between 7.7 and 9.1. The neutral pH conditions restrict the mobilisation of metals, which are also sensitive to groundwater redox conditions.

Nitrate contamination is generally associated with the usage of nitrate based explosives and leachate from sewage works. Health effects associated with high nitrate concentrations are impaired concentration, lack of energy and the formation of methahemoglobin in blood cells. Feedlots may also be significant sources of nitrate contamination. Groundwater nitrate concentrations measured in the majority of boreholes are below the permissible SANS value of 11 mg/l **(Table 1.4-2)**. Exceptions do however occur as the nitrate content measured in DO-BH04, DP04, FARM434, KOOT01/02/03, NIEMAND01 and WVR01/02 all exceed the permissible SANS concentration for drinking water **(Table 1.4.1)**. The once-off analyses do not allow for accurate source identification, however the nitrate contamination is likely to have originated from pit latrines and/or feedlots.

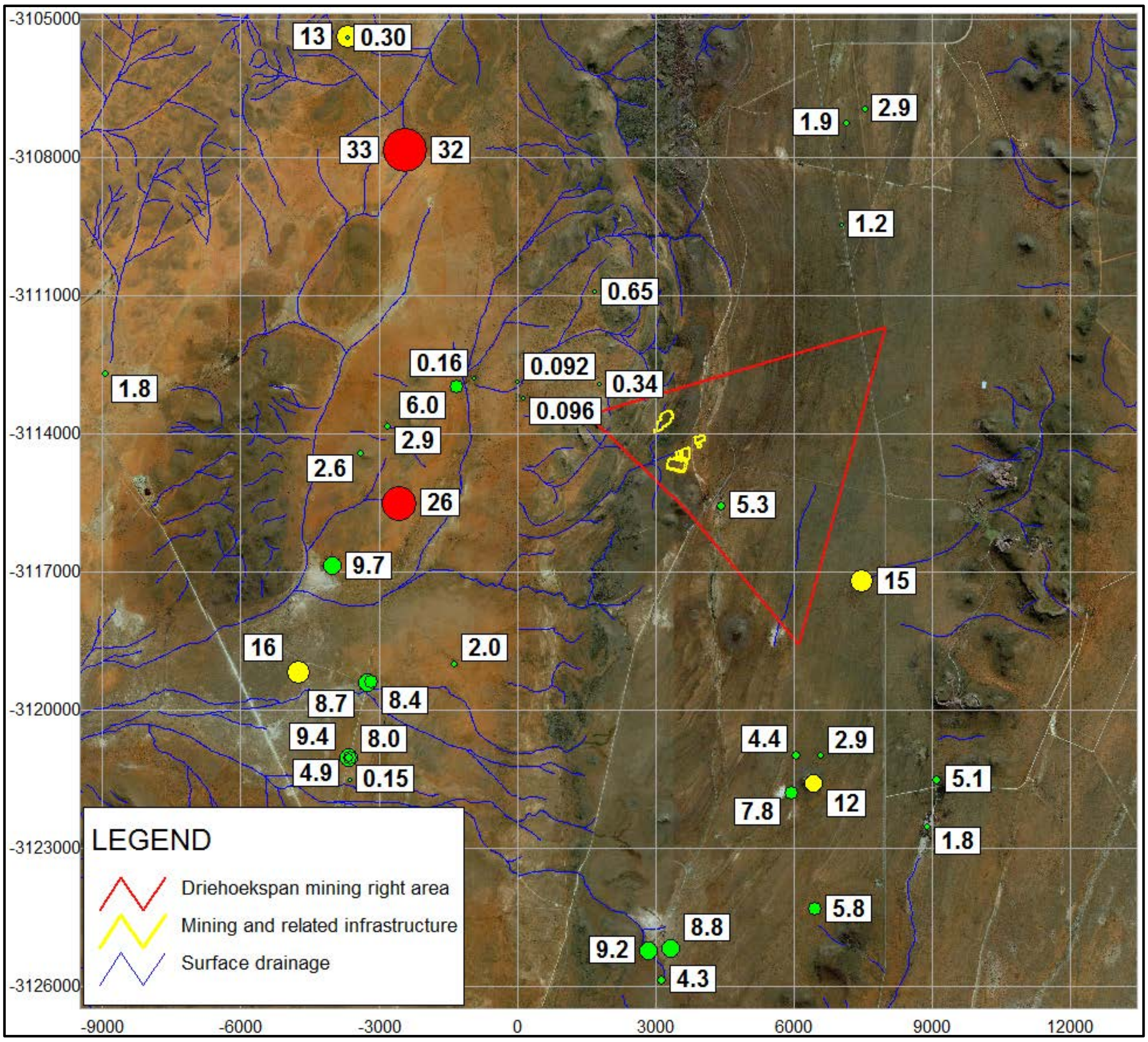


Figure 1.4-3: Thematic map of groundwater nitrate concentrations measured in regional hydrocensus boreholes

Groundwater **chloride** concentrations are all well below the permissible SANS value of 300 mg/l and vary from below the detection limit to approximately 100 mg/l **(Table 1.4-1)**.

According to the Expanded Durov diagram **(Figures 1.4-4)** and Stiff diagrams **(1.4-5)** the project area and its immediate surroundings are dominated by fresh, clean, relatively young groundwater that has started to undergo mineralization with especially magnesium ion exchange. The groundwater is dominated by calcium and **magnesium** cations, while **bicarbonate alkalinity** dominates the anion content. Interaction between the groundwater (ion exchange) and carbonate enriched aquifer host rocks (shallow calcrete aquifer and deeper dolomitic aquifer) is undoubtedly responsible for the plot positions in fields 1 and 2 of the Expanded Durov diagram.

Exceptions do occur and the plot positions of boreholes WVR01 and WVR02 in field 4 of the Expanded Durov diagram is the direct result of nitrate pollution, which is expected to originate from pit latrines and/or feedlots.

Summary:

- Groundwater sampled from surrounding groundwater users is of good quality and is suitable for human consumption according to the South African National Standards for drinking water *(SANS241:2011)*.
- Exceptions do however occur as the nitrate content measured in DO-BH04, DP04, FARM434, KOOT01/02/03, NIEMAND01 and WVR01/02 all exceed the permissible SANS concentration of 11 mg/, rendering the groundwater unfit for human consumption.
- The groundwater is mainly dominated by calcium and magnesium cations, while bicarbonate alkalinity dominates the anion content.

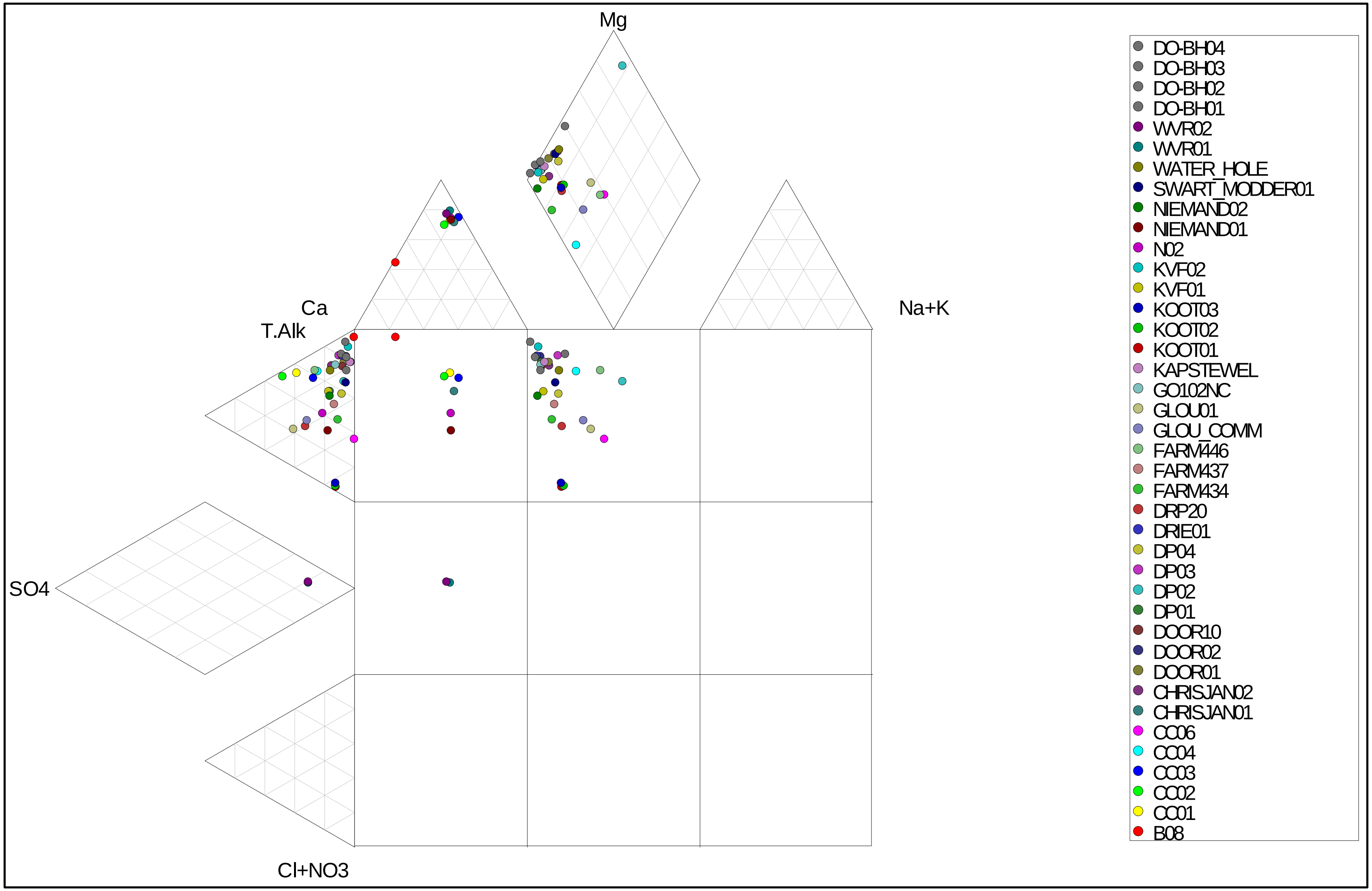


Figure 1.4-4: Expanded Durov diagram groundwater chemistries for the project area

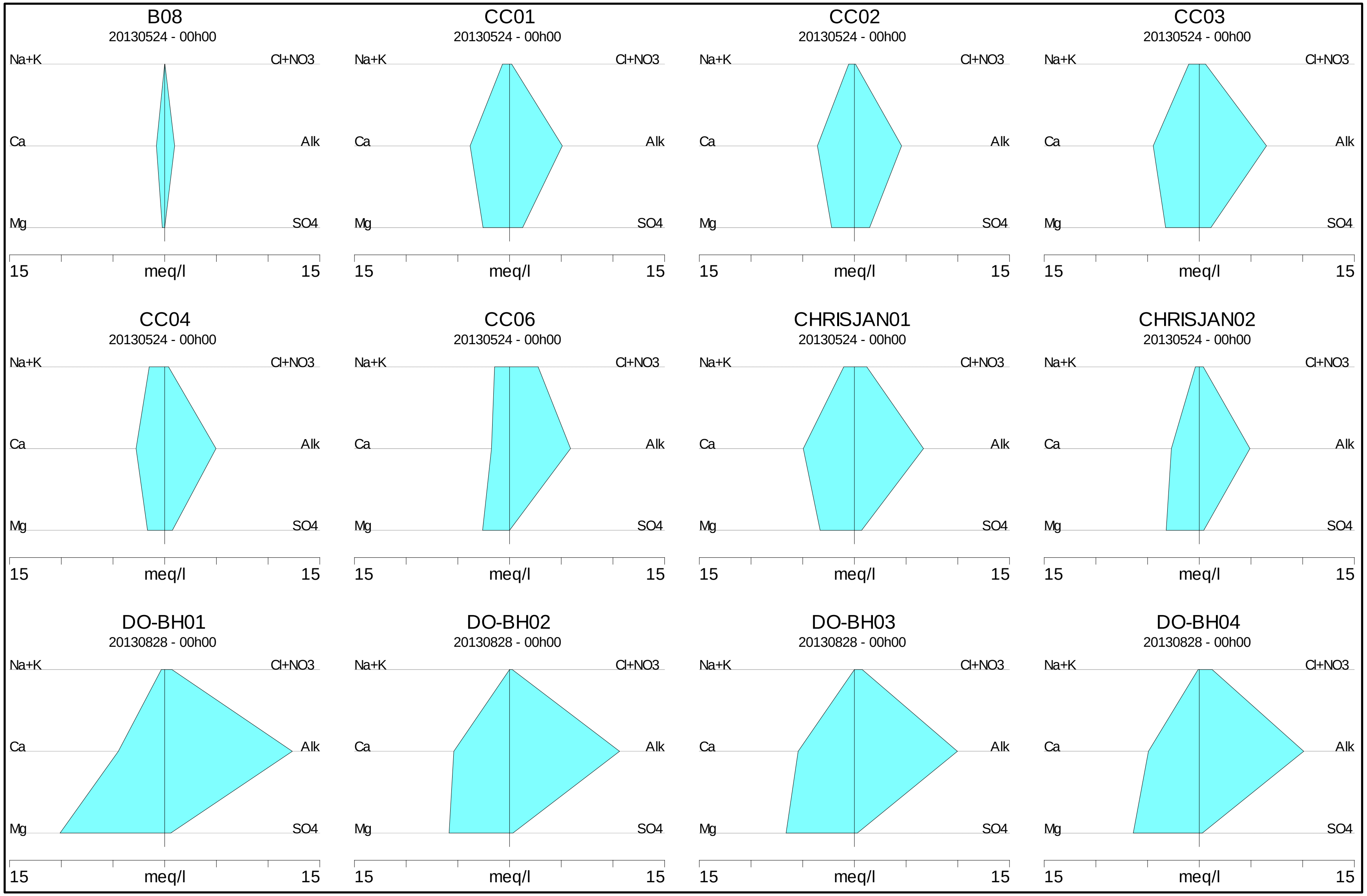


Figure 1.4-5: Stiff diagrams of groundwater chemistries for the project area

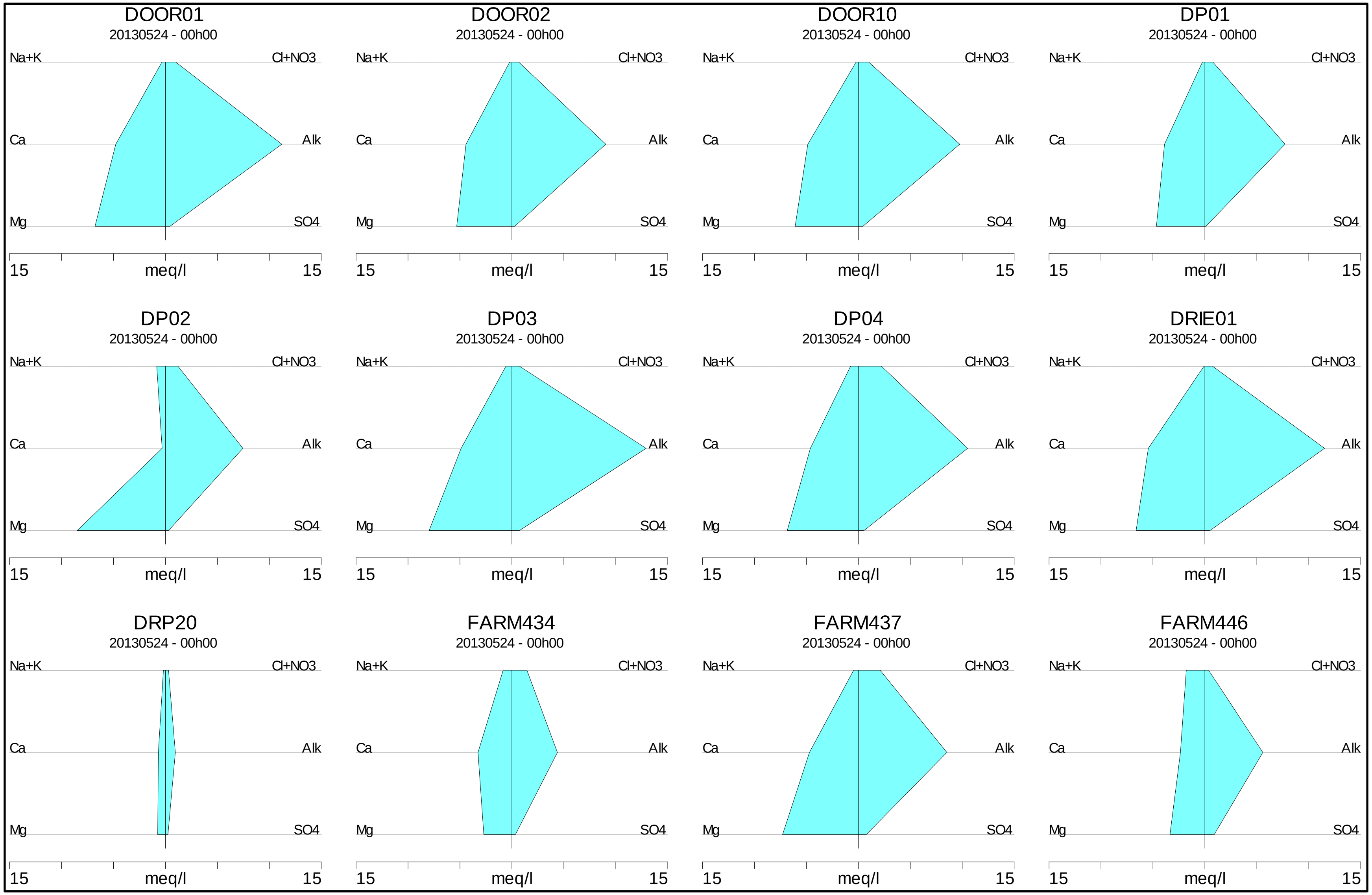


Figure 1.4-5: Stiff diagrams of groundwater chemistries for the project area (continue)

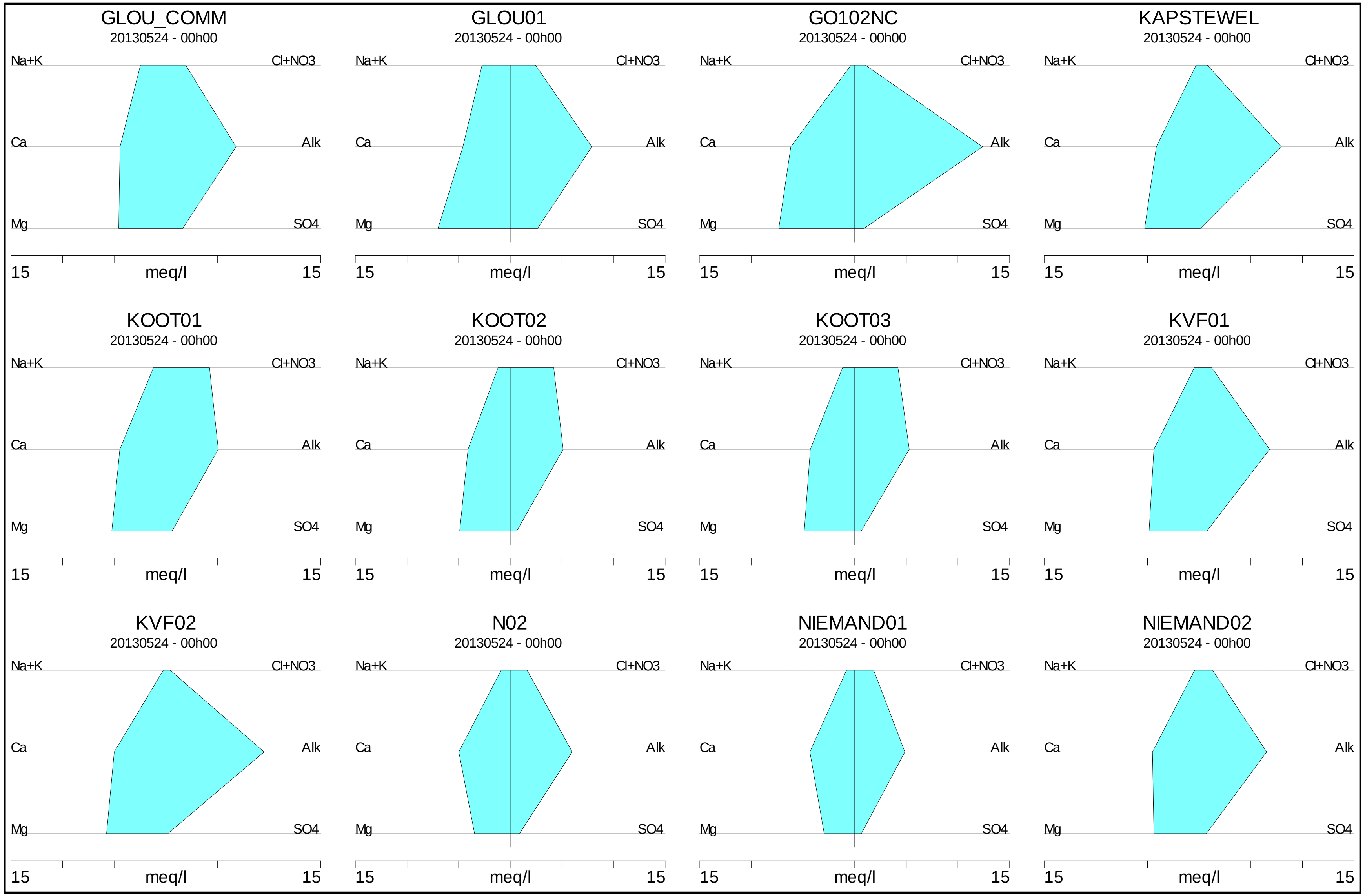


Figure 1.4-5: Stiff diagrams of groundwater chemistries for the project area (continue)

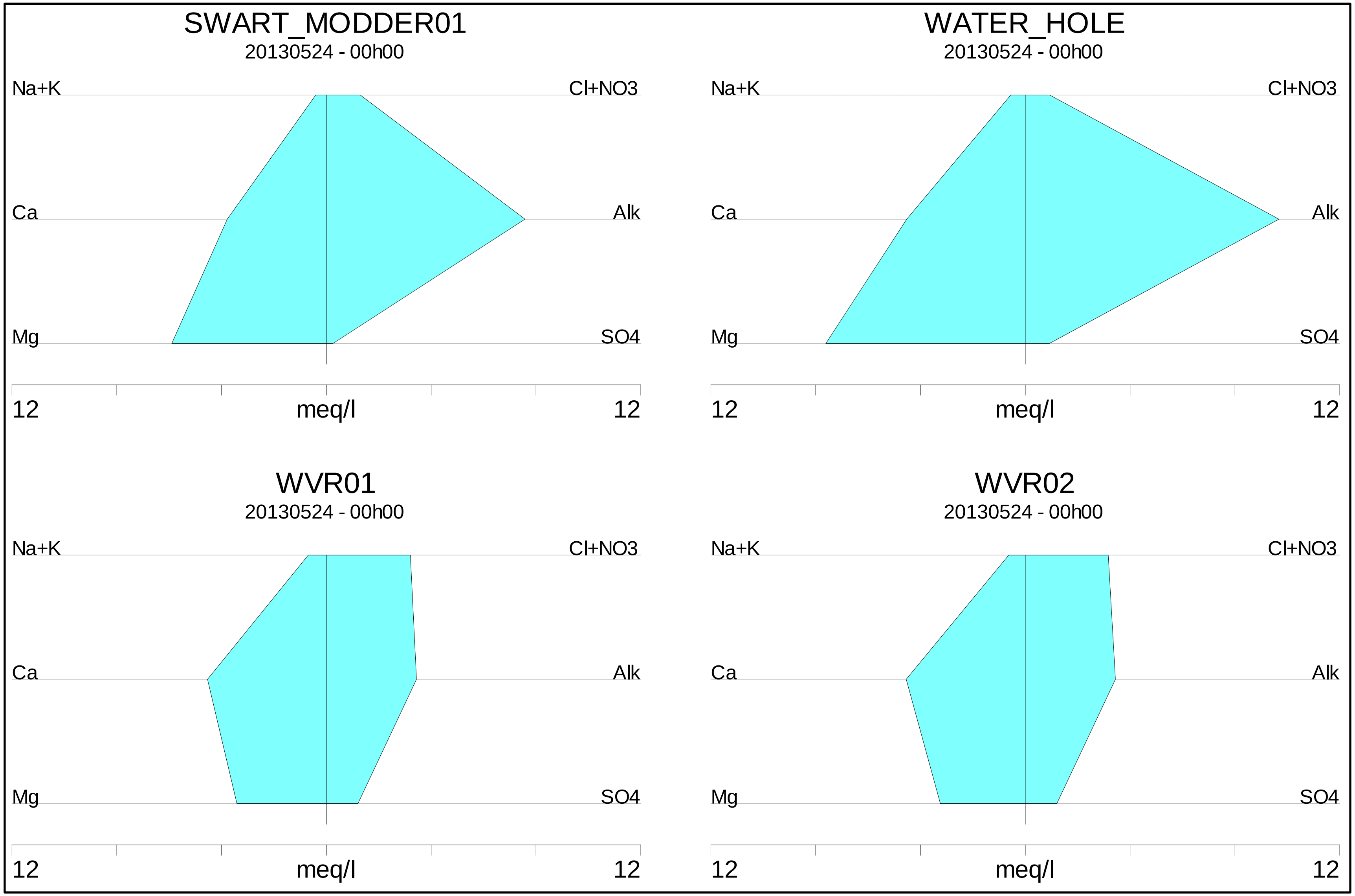


Figure 1.4-5: Stiff diagrams of groundwater chemistries for the project area (continue)

Table 1.4-2: Concentrations of indicator chemical parameters for sampling localities in the project area (mg/l)

BH	Al	Ca	Cl	F	Fe	K	Mg	Na	NO_3	pH	PO_4	SO_4	TDS
B08	<0.003	16.10	<0.423	0.19	<0.003	0.34	2.82	<0.013	0.15	8.45	0.08	<0.04	49.00
CC01	<0.003	76.50	7.03	0.66	<0.003	2.25	31.20	14.30	0.09	8.25	0.05	60.70	346.00
CC02	<0.003	71.70	3.66	0.81	<0.003	1.86	26.80	11.60	0.10	8.19	0.03	70.60	324.00
CC03	<0.003	89.30	19.90	0.36	<0.003	2.93	39.60	21.60	0.65	7.75	0.05	54.10	423.00
CC04	<0.003	55.50	12.40	0.28	<0.003	2.37	20.20	33.00	0.34	7.91	0.03	35.70	309.00
CC06	<0.003	35.10	97.60	0.22	1.71	26.60	31.70	17.70	0.16	7.92	<0.008	<0.04	436.00
CHRISJAN01	<0.003	99.10	27.30	0.37	<0.003	2.41	40.30	22.30	6.00	8.04	0.04	33.50	432.00
CHRISJAN02	<0.003	54.10	9.40	0.34	<0.003	0.97	38.90	8.04	1.76	8.44	0.21	20.90	281.00
DO-BH01	<0.003	89.90	13.70	0.39	<0.003	<0.018	123.00	7.50	4.38	7.72	0.02	28.20	637.00
DO-BH02	<0.003	108.00	1.96	0.23	<0.003	<0.018	71.10	<0.013	2.89	7.33	0.01	15.70	519.00
DO-BH03	<0.003	109.00	7.06	0.27	<0.003	<0.018	80.30	<0.013	7.82	7.43	0.01	13.80	517.00
DO-BH04	<0.003	98.50	14.60	0.26	<0.003	1.33	77.60	1.88	11.70	7.54	0.02	14.40	524.00
DOOR01	<0.003	95.80	12.10	0.33	<0.003	4.34	82.40	5.19	9.20	7.75	0.03	20.90	567.00
DOOR02	<0.003	88.50	12.50	0.31	<0.003	0.94	64.60	4.49	4.27	7.77	0.06	12.90	460.00
DOOR10	<0.003	97.50	13.00	0.30	<0.003	0.73	74.00	4.71	8.81	8.09	0.05	21.00	513.00
DP01	<0.003	77.80	14.40	0.26	<0.003	1.08	56.70	4.75	5.13	7.78	0.03	4.81	397.00
DP02	<0.003	6.39	38.30	0.24	<0.003	3.24	103.00	17.30	1.80	9.07	0.01	15.00	409.00
DP03	<0.003	97.90	18.80	0.34	<0.003	5.42	96.80	10.10	2.92	8.33	0.15	35.60	655.00
DP04	<0.003	92.60	41.00	0.26	<0.003	3.47	83.20	15.20	14.90	7.78	0.04	26.70	593.00
DRIE01	<0.003	109.00	12.80	0.26	<0.003	<0.018	80.40	1.92	5.34	7.66	0.04	24.50	580.00
DRP20	<0.003	13.60	3.35	0.26	<0.003	3.15	9.10	2.66	2.89	8.04	0.04	11.80	76.00
FARM434	<0.003	65.40	17.50	0.33	<0.003	0.76	32.90	19.00	13.40	8.54	0.04	16.30	297.00
FARM437	<0.003	94.40	54.30	0.35	<0.003	0.70	88.70	10.20	7.97	8.28	0.04	36.70	549.00
FARM446	<0.003	47.10	12.40	0.95	<0.003	0.75	40.80	40.70	0.30	8.70	0.04	43.30	355.00
GLOU_COMM	<0.003	88.80	63.40	0.42	<0.003	5.64	55.40	53.10	1.94	8.50	0.04	78.80	552.00

BH	Al	Ca	Cl	F	Fe	K	Mg	Na	NO_3	pH	PO_4	SO_4	TDS
GLOU01	<0.003	91.80	83.70	0.25	<0.003	0.47	85.00	62.50	1.23	8.47	0.04	127.00	689.00
GO102NC	<0.003	124.00	22.40	0.31	<0.003	0.19	89.30	8.08	5.75	8.01	0.04	43.20	665.00
KAPSTEWEL	<0.003	83.10	15.60	0.26	<0.003	1.04	64.10	6.03	4.91	8.59	0.04	5.91	420.00
KOOT01	<0.003	89.20	66.10	0.25	<0.003	2.91	63.50	25.80	33.20	8.42	0.04	29.50	463.00
KOOT02	<0.003	82.00	66.30	0.27	<0.003	2.63	59.50	25.60	32.80	8.30	0.05	30.20	453.00
KOOT03	<0.003	86.10	66.80	0.30	<0.003	2.69	59.40	25.40	32.30	8.47	0.04	30.50	462.00
KVF01	<0.003	87.80	21.80	0.31	<0.003	1.06	58.90	10.10	8.42	8.52	0.04	36.20	429.00
KVF02	<0.003	100.00	9.87	0.31	<0.003	1.23	69.70	4.75	2.05	8.44	0.04	9.82	484.00
NIEMAND01	<0.003	87.00	25.20	0.32	<0.003	0.16	35.90	18.10	15.80	8.10	0.04	31.10	359.00
NIEMAND02	<0.003	90.60	24.50	0.32	<0.003	0.77	53.20	9.51	8.66	8.55	0.04	33.60	417.00
SWART_MODDER01	<0.003	75.80	21.90	0.35	<0.003	0.99	71.70	8.71	9.43	8.67	0.04	12.30	429.00
N02	<0.003	99.80	33.30	0.42	<0.003	2.61	42.00	18.70	9.72	8.57	0.03	43.50	430.00
WATER_HOLE	<0.003	90.70	26.20	0.32	<0.003	1.19	92.50	12.00	2.63	8.32	0.05	44.30	560.00
WVR01	<0.003	90.90	46.10	0.24	<0.003	0.30	41.50	15.70	26.70	7.77	0.04	57.90	382.00
WVR02	<0.003	91.10	45.90	2.45	<0.003	0.19	39.40	14.40	26.20	7.73	0.04	57.80	380.00

Note: *Values shaded with red exceed the SANS guideline concentrations for drinking water **(Table 1.4-1)**.*

2 ENVIRONMENTAL IMPACT ASSESSMENT AND MITIGATION MEASURES FOR THE COZA DRIEHOEKSPAN PROJECT

This part of the geohydrological input to the EMP report describes and evaluates the potential impact of the Driehoekspan Project on the receiving environment. The management program proposed for the proposed new mining activities from a geohydrological perspective will also be discussed in this section. Generic aspects will be discussed together, but aspects pertaining to one project or source area specifically will be discussed as such with the specific areas.

Coza Mining (Pty) Ltd is committed to rehabilitate the Coza Driehoekspan Project area in a responsible manner, with a balanced approach by adequately managing negative environmental impacts to within acceptable limits. Remediation of negative impacts will, as far as possible, be based on the principle of Best Environmental Option (BEO), with the implementation of technically proven and best practice rehabilitation measures. New techniques will be evaluated when they become available and will be implemented should they prove effective within financial constraints. The criterion used for the risk evaluation is provided in **Table 2**.

It must be noted that many of the potential negative consequences can be mitigated successfully. It is however necessary to make a thorough assessment of all possible impacts in order to ensure that environmental considerations are taken into account in a balanced way, thus supporting the aim of minimizing any adverse impacts on the environment.

Groundwater contamination in the **operational phase** occurs when the rock is broken up either by blasting or excavation to expose the in situ aquifer host rock to oxygen. Apart from the exposure to the atmosphere the broken rock causes a much larger reaction surface, which greatly increases chemical reactions such as ion exchange. Connate water, if present, may also be released through the mining process and is often very saline. The results of both leaching and Acid Base Accounting tests have however shown that ore and waste rock sampled from the proposed Driehoekspan Project area are relatively inert and pose no significant contamination risks **(Section 3.2)**. **The most significant groundwater impact expected during the operational phase of mining is therefore considered to be the lowering of groundwater levels due to mine dewatering. Limited quality impacts are expected as a result of the usage of nitrate based explosives and hydrocarbons (i.e. petrol, diesel, etc.).**

Contrary to most other mining operations, the **post-closure impacts** of an iron ore mining operation are generally negligible as the waste material used to rehabilitate the mining areas is relatively inert. Low recharge and high evaporation rates are expected to prevent the pit from decanting, while the quality of pit water should vary from good to marginal.

The criteria used for assessing the significance of the impact are given in **Table 2**. The impact assessment method takes into account the current environment, the details of the proposed project and the findings of the geohydrological investigation. Cognisance will be given to both positive and negative impacts that may result from the development.

The significance of the impact is dependent on the consequence and the probability that the impact will occur.

Impact Significance = (Consequence x Probability)

Where:

Consequence = (Severity + Extent)/2

and

Severity = (Intensity + Frequency + Duration)/3

Each criterion is given a score from 1 to 5 based on the definitions provided in **Table 2**. Although the criteria used for the assessment of impacts attempts to quantify the significance, it is important to note that the assessment is generally a qualitative process and therefore the application of this criteria is open to interpretation. The process adopted will therefore include the application of scientific measurements and professional judgement to determine the significance of environmental impacts associated with the project. The assessment thus largely relies on experience of the environmental assessment practitioner (EAP) and the information provided by the specialists appointed to undertake studies for the EIA.

Where the consequence of an event is not known or cannot be determined, the "precautionary principle" will be adhered to and the worst-case scenario assumed. Where possible, mitigation measures to reduce the significance of negative impacts and enhance positive impacts will be recommended. The detailed actions, which are required to ensure that mitigation is successful, will be provided in the EMP, which will form part of the EIA report.

Consideration will be given to the phase of the project during which the impact occurs. The phase of the development during which the impact will occur will be noted to assist with the scheduling and implementation of management measures.

Table 2: Criteria for assessing the impact significance

Severity Criteria:

INTENSITY = MAGNITUDE OF IMPACT	RATING
Insignificant: impact is of a very low magnitude	1
Low: impact is of low magnitude	2
Medium: impact is of medium magnitude	3
High: impact is of high magnitude	4
Very high: impact is of highest order possible	5
FREQUENCY = HOW OFTEN THE IMPACT OCCURS	**RATING**
Seldom: impact occurs once or twice	1
Occasional: impact occurs every now and then	2
Regular: impact is intermittent but does not occur often	3
Often: impact is intermittent but occurs often	4
Continuous: the impact occurs all the time	5
DURATION = HOW LONG THE IMPACT LASTS	**RATING**
Very short-term: impact lasts for a very short time (less than a month)	1
Short-term: impact lasts for a short time (months but less than a year)	2
Medium-term: impact lasts for the for more than a year but less than the life of operation	3
Long-term: impact occurs over the operational life of the proposed extension	4
Residual: impact is permanent (remains after mine closure)	5
EXTENT = SPATIAL SCOPE OF IMPACT/FOOTPRINT AREA/NUMBER OF RECEPTORS	**RATING**
Limited: impact affects the mine site	1
Small: impact extends to the whole farm portion	2
Medium: impact extends to neighbouring properties	3
Large: impact affects the surrounding community	4
Very Large: The impact affects an area larger the municipal area	5

Note: *I = Intensity, F = Frequency, D = Duration, E = Extent, P = Probability.*

Probability:

PROBABILITY = LIKELIHOOD THAT THE IMPACT WILL OCCUR	RATING
Highly unlikely: the impact is highly unlikely to occur	0.2
Unlikely: the impact is unlikely to occur	0.4
Possible: the impact could possibly occur	0.6
Probable: the impact will probably occur	0.8
Definite: the impact will occur	1

Impact Significance:

Negative Impacts

≤1	Very low	Impact is negligible. No mitigation required.
>1 ≤2	Low	Impact is of a low order. Mitigation could be considered to reduce impacts. But does not affect environmental acceptability.
>2 ≤3	Moderate	Impact is real but not substantial in relation to other impacts. Mitigation should be implemented to reduce impacts.
>3 ≤4	High	Impact is substantial. Mitigation is required to lower impacts to acceptable levels.
>4 ≤5	Very High	Impact is of the highest order possible. Mitigation is required to lower impacts to acceptable levels. Potential Fatal Flaw.

Positive Impacts

≤1	Very low	Impact is negligible.
>1 ≤2	Low	Impact is of a low order.
>2 ≤3	Moderate	Impact is real but not substantial in relation to other impacts.
>3 ≤4	High	Impact is substantial.
>4 ≤5	Very High	Impact is of the highest order possible.

Cumulative Impacts

In accordance with Regulation 584 of NEMA, **cumulative impacts** are defined as: "the impact of an activity that in itself may not be significant but may become significant when added to the existing and potential impacts eventuating from similar or diverse activities or undertakings in the area". Taking into consideration the above definition, the **cumulative impacts** for the Driehoekspan Project will be assessed by considering the potential impacts of the mine and the current status of the environment in which the project will be developed.

Project Phases

The environmental impacts for the project will be assessed over the **five project phases,** i.e. the **planning and design**, **construction**, **operation**, **decommissioning** and **post-closure phase**:

- The **planning and design phase** refers to the stage when the feasibility studies are being undertaken, the project description is being developed and the mine is being designed. During this phase the EIA is completed and environmental authorisations are applied for. This phase commenced early 2013 and is anticipated to be completed in the third quarter of 2014. **No groundwater related impacts are expected to occur during this project phase, therefore it was excluded from the assessment.**

- The **construction phase** will commence after the mining right and environmental authorisations have been obtained. This phase will involve the physical construction of the mine and its associated infrastructure. Construction is anticipated to commence in last quarter of 2016 until the second quarter of 2017.
- The mine **operation** is anticipated to commence in 2017. Operational activities are anticipated to proceed for about 10 to 20 years.
- The **decommissioning phase** refers to the time in the mine life when mining operations are reduced in preparation for closure. This phase will occur once the resource has been mined optimally and economically. It is anticipated that mining activities will last 10 to 20 years.
- The **closure phase** refers to when the mine is shut down and no mining activities are undertaken, this phase will occur after successful decommissioning has been achieved.

Mitigation Measures

A no net loss approach will be adopted in terms of the management of impacts at the Coza Iron Ore Project:

- **Avoidance**: impacts are to be avoided where practicable e.g. through the implementation of alternatives.
- **Mitigation**: should it not be possible to avoid all impacts, the remaining impacts are to be mitigated to acceptable levels.
- **Offset**: should it not be possible to avoid and mitigate all impacts to acceptable levels it will be necessary to offset the remaining impacts. Suitable offsets will need to be identified.

Mitigation measures for significant impacts which cannot be avoided will be identified. The impacts will be ranked before and after the implementation of the mitigation measures. Consideration will also be given to the confidence level that can be placed on the successful implementation of the mitigation level as follows:

- **High Confidence**: mitigation measure easy and inexpensive to implement.
- **Medium Confidence**: mitigation measure expensive or difficult to implement.
- **Low Confidence**: mitigation measure expensive and difficult to implement.

2.1 LAND CLEARANCE

2.1.1 CONSTRUCTION PHASE

The following land clearance activities will take place during the construction phase:

- Vegetation clearance,
- Topsoil and sub-soil stripping and stockpiling.

2.1.1.1 POTENTIAL IMPACTS

The stripping and stockpiling of topsoil and subsoil from the infrastructure and pit surface areas is considered negligible since no chemical interaction is envisaged that could have an adverse impact on groundwater quality.

Impact	Mitigation	I	F	D	E	P	Impact Significance
Land clearance	Before mitigation	2	1	4	1	0.4	Very low
	After mitigation	2	1	4	1	0.4	Very low

2.2 CONSTRUCTION AND UTILISATION OF SURFACE INFRASTRUCTURE

2.2.1 CONSTRUCTION PHASE

The following surface infrastructure will be constructed during the construction phase:
- Access roads and entrance controls,
- Fuel depot,
- Perimeter fences,
- Power supply,
- Office, change house and workshops,
- Temporary accommodation during the construction phase,

2.2.1.1 POTENTIAL IMPACTS

The construction of infrastructure will cause a very small reduction in recharge to the underlying aquifer system due to the compaction of the surface of the roads and foundation layers.

Clean run-off from areas such as roofs and parking areas eventually contributes to catchment yields. Run-off from haul-roads will be diverted and contained in the dirty water system. No adverse impact is foreseen on groundwater quality since material used for construction is inert.

Impact	Mitigation	I	F	D	E	P	Impact Significance
Construction of surface infrastructure	Before mitigation	2	1	4	1	0.4	Very low
	After mitigation	2	1	4	1	0.4	Very low

2.2.2 OPERATIONAL PHASE

The following activities will take place during the operational phase:
- Utilisation of surface infrastructure (i.e. offices, workshops, change house, etc.),
- Utilisation of access and service roads.

2.2.2.1 POTENTIAL IMPACTS

Very little impact is expected since no water seepage or abstraction is involved that could affect water levels, and no leachate or contaminated seepage is involved that may affect groundwater quality.

Impact	Mitigation	I	F	D	E	P	Impact Significance
Utilisation of surface infrastructure	Before mitigation	2	1	4	1	0.4	Very low
	After mitigation	2	1	4	1	0.4	Very low

2.2.2.2 MANAGEMENT OBJECTIVES AND PRINCIPLES

Haul roads and other compacted surfaces will be kept free of potentially hazardous material by cleaning spillages, thereby reducing infiltration of contaminated water.

The size of compacted areas must be minimized to as small as practically possible. The surface area of the fuel depot will be covered with concrete to prevent fuel from seeping into the underlying aquifer system in the event of an accidental spillage and/or leakage.

Very little impact on groundwater quantity and quality is expected overall during the operational phase activities mostly because of the small surface area involved during this project life phase. Clean run-off from areas such as roofs and parking areas eventually contributes to catchment yield.

2.2.2.3 MANAGEMENT ACTIVITIES OR MITIGATION MEASURES

No significant groundwater impacts are expected. Run-off from haul-roads will be diverted and contained in the dirty water system.

2.3 CONSTRUCTION AND UTILISATION OF SURFACE AND WASTE WATER MANAGEMENT MEASURES

2.3.1 CONSTRUCTION PHASE

The following activities will take place during the construction phase:

- Construction of water management and reticulation infrastructure (i.e. pollution control dam, water supply dam, cut-off berms, canals, reservoirs, etc.),
- Construction of waste management infrastructure (i.e. sewage treatment facility),
- Pipelines for the bulk transportation of water, sewage or storm water,

2.3.1.1 POTENTIAL IMPACTS

The construction of surface and waste water management measures will cause a very small reduction in recharge to the underlying aquifer system due to the compaction of the surface of the foundation layers. No adverse impact is foreseen on groundwater quality since material used for construction is inert.

Impact	Mitigation	I	F	D	E	P	Impact Significance
Construction of surface/waste water management measures	Before mitigation	2	1	4	1	0.4	Very low
	After mitigation	2	1	4	1	0.4	Very low

2.3.1.2 MANAGEMENT OBJECTIVES AND PRINCIPLES

- An appropriate liner is recommended for all water retaining infrastructure,
- Prevent contact between clean and dirty areas,
- Recycle and reuse contaminated water as far as possible,
- All contaminated water will be contained for re-use and evaporation,
- To minimize the extent of disturbance of the aquifer,
- To limit degeneration of groundwater quality.

2.3.1.3 MANAGEMENT ACTIVITIES OR MITIGATION MEASURES

- No construction of any water management measures will be undertaken with potentially hazardous material,
- All dams will be constructed to comply with the relevant DWA requirements in an effort to minimize the seepage of poor quality leachate,
- Clean surface water will not come into contact with dirty water.

2.3.2 OPERATIONAL PHASE

The following activities will take place during the operational phase:

- Utilisation of water and waste management measures and pollution control facilities,
- Containment and re-use of contaminated water within isolated dirty water management areas.

2.3.2.1 POTENTIAL IMPACTS

The utilisation of water and waste management measures and pollution control facilities must inadvertently have some form of impact on groundwater, although the primary purpose of the facilities is to minimize or contain water contamination. Facilities (e.g. pollution control dam) will be constructed to comply with the relevant DWA requirements.

For wet management facilities (i.e. pollution control dam) seepage has a direct impact and is only governed by the hydraulic properties of the liner of the facility and the rest of the unsaturated zone.

The added seepage from the wet facilities (especially where no lining material occurs) causes artificial recharge to the aquifer and often result in mounding of the groundwater level below the facility. The mounding causes a local increase in the groundwater gradient, which leads to an increased flow rate of contaminated seepage.

For dry facilities (i.e. waste disposal sites, stockpile areas, discard dumps and the plant dirty footprint area) impact on the groundwater only occurs through leachate formation from surface. Impacts thus only occur as a result of rainfall recharge or when water is introduced in some form where leachate can form that seeps to the groundwater regime.

The artificial recharge and mounding concept does not come into play with dry sources and therefore the intensity and rate of contaminant transport are far less significant compared to wet sources.

Impact	Mitigation	I	F	D	E	P	Impact Significance
Utilisation of surface/waste water management measures	Before mitigation	4	5	4	4	1	Very High
	After mitigation	2	1	3	1	0.2	Very Low

2.3.2.2 MANAGEMENT OBJECTIVES AND PRINCIPLES

- An appropriate liner is recommended for all water retaining facilities in an effort to minimise poor quality seepage to the groundwater regime,
- Prevent contact between clean and dirty areas,
- Recycle and reuse contaminated water as far as possible,
- To minimize the extent of disturbance of the aquifer,
- To minimize the impact on groundwater quality.

2.3.2.3 MANAGEMENT ACTIVITIES OR MITIGATION MEASURES

- Clean surface water will not come into contact with dirty water or material,
- Wet facilities will be lined to prevent the seepage of poor quality leachate,
- Continuous monitoring of groundwater quality.

2.4 THE DEVELOPMENT AND UTILISATION OF THE WASTE ROCK DUMP

2.4.1 OPERATIONAL PHASE

The following activities will take place during the operational phase:

- The development and utilisation of the waste rock dump as waste material is produced by the extraction of the ore.

2.4.1.1 POTENTIAL IMPACTS

Nitrate contamination is more often than not associated with rock material (rock and discard dumps) that contains remnants of nitrate based explosives, which is highly soluble in water. Seepage emanating from such areas is therefore expected to contain high concentrations of nitrate and pose a significant groundwater contamination risk. Sporadic contamination of the groundwater regime therefore occurs whenever water seeps through the contaminated material during periods of rainfall.

The dump is not regarded as a wet facility and mounding of the underlying groundwater levels as a result of artificial aquifer recharge is not expected to occur.

Impact	Mitigation	I	F	D	E	P	Impact Significance
Development and utilization of the discard dumps	Before mitigation	1	2	4	3	1	Moderate
	After mitigation	1	1	3	1	0.4	Very Low

2.4.1.2 MANAGEMENT OBJECTIVES AND PRINCIPLES

- Prevent contact between clean and dirty areas,
- To minimize the extent of disturbance of the aquifer,
- To minimize the impact on groundwater quality.

2.4.1.3 MANAGEMENT ACTIVITIES OR MITIGATION MEASURES

- Clean surface water will not come into contact with dirty water or nitrate contaminated discard material,
- Continuous monitoring of groundwater quality.

2.5 THE DEVELOPMENT AND PROGRESSION OF THE OPENCAST PIT

2.5.1 OPERATIONAL PHASE

The following activities will take place during the operational phase:

- Progressive development of opencast mining cuts, including blasting and extraction of iron ore.

2.5.1.1 POTENTIAL IMPACTS

Groundwater levels are expected to decrease within the immediate vicinity of the opencast pit as a result of mine dewatering. The degree of aquifer dewatering depends on the extent and depth of the opencast pit below the local groundwater level as well as the hydraulic properties of the aquifer host rock.

Dewatering of the aquifer system will only begin once the pit floor elevation decreases below the local groundwater elevation, which is planned to occur only during year 5 and 6 of mining. The area affected by mine dewatering depends on the transmissivity and storativity of the aquifer host rock and geological structures. Depletion of the groundwater resource will impact negatively on:

- The groundwater **resource itself** and interrelations with other natural resources (e.g. pans and wetlands), and
- The users that depend on groundwater as **sole source** of domestic water as well as for livestock and gardening.

The aquifer structure will be destroyed wherever it is intersected by the opencast pit.

Mine dewatering will continue throughout the life of mine to ensure dry and safe mining conditions. Groundwater contamination of surrounding users is therefore not expected to take place while the opencast workings are still operational. Only after groundwater levels have recovered from the impacts of mine dewatering is contamination expected to migrate in the down gradient groundwater flow direction/s.

Affected storm water runoff will be contained in the purpose-built containment facilities.

Impact	Mitigation	I	F	D	E	P	Impact Significance
Development and progression of the opencast pit	Before mitigation	3	4	5	1	1	Moderate
	After mitigation	3	4	5	1	1	Moderate

Note: *Assessment provided above is related to groundwater level impacts rather than groundwater quality impacts.*

2.5.1.2 MANAGEMENT OBJECTIVES AND PRINCIPLES

No management action is available to prevent dewatering and the destruction of the aquifer structure.

2.5.1.3 MANAGEMENT ACTIVITIES OR MITIGATION MEASURES

The dewatering of the local aquifer system and destruction of its structure cannot be prevented. Quarterly monitoring of boreholes will be implemented to monitor the extent of the dewatering. If the monitoring program indicates that nearby groundwater users are affected negatively by the dewatering, the users need to be compensated for the loss.

2.6 TRANSPORTATION

2.6.1 OPERATIONAL PHASE

The following activities will take place during the operational phase:

- Hauling of iron ore from the opencast pit via road to the ROM stockpile.

2.6.1.1 POTENTIAL IMPACTS

A reduction in recharge will result due to the compaction of the surface of the roads relating to the hauling of ore. Since all contaminated surface water runoff from haul road areas will be collected in the dirty water management system, infiltration of contaminated water will be minimized.

Impact	Mitigation	I	F	D	E	P	Impact Significance
Transportation of ore	Before mitigation	2	1	4	1	0.4	Very low
	After mitigation	2	1	4	1	0.4	Very low

2.6.1.2 MANAGEMENT OBJECTIVES AND PRINCIPLES

To ensure that contaminated surface water runoff from haul roads do not come into contact with clean surface water runoff, or infiltrate into the groundwater system.

2.6.1.3 MANAGEMENT ACTIVITIES OR MITIGATION MEASURES

All contaminated surface water runoff from haul road areas will be collected in the dirty water management system, which means that the infiltration of contaminated water will be minimized.

2.7 STOCKPILING OF IRON ORE AT RUN-OF-MINE STOCKPILE

2.7.1 OPERATIONAL PHASE

The following activities will take place during the operational phase:

- Stockpiling of iron ore at a dedicated site.

2.7.1.1 POTENTIAL IMPACTS

The iron ore itself is inert and pose no significant contamination risk, however remnants from nitrate based explosive may lead to poor quality seepage being generated during times of rainfall.

Impact	Mitigation	I	F	D	E	P	Impact Significance
Stockpiling of iron ore at ROM stockpile	Before mitigation	1	2	4	3	1	Moderate
	After mitigation	1	1	3	1	0.4	Very Low

2.7.1.1 MANAGEMENT OBJECTIVES AND PRINCIPLES

- To prevent contact of clean runoff water with the ore,
- To minimize further degeneration of groundwater quality,
- To contain all dirty water in the pollution control dam,
- To minimize the impact of the proposed ROM stockpile on groundwater quality.

2.7.1.2 MANAGEMENT ACTIVITIES OR MITIGATION MEASURES

- Clean runoff water will be diverted away from the stockpile area,
- Quarterly monitoring of boreholes will be implemented to monitor the groundwater quality. If the monitoring program indicates that nearby groundwater users are affected negatively by the handling of iron ore, the users need to be compensated for their loss.

2.8 REHABILITATION

2.8.1 DECOMMISSIONING PHASE

The following activities will take place during the decommissioning phase:

- Removal of all mining and related infrastructure,
- Shaping and landscaping of the opencast pit and discard dump,
- Removal of potentially hazardous material from disturbed land use areas,
- Demolition and rehabilitation of redundant surface infrastructure, such as pollution control facilities and buildings, depending on the long-term groundwater management strategy and agreed end land use,
- Removal of exotic and invasive plants and the re-establishment of such species within the rehabilitated areas will be prevented,
- Final rehabilitation, including the placement of topsoil and establishment of vegetation on rehabilitated areas,
- Aim to establishment a sustainable and agreed end land use through final rehabilitation.

2.8.1.1 POTENTIAL IMPACTS

The rehabilitation of the disturbed surface areas will have a positive effect on the groundwater system.

Impact	I	F	D	E	P	Impact Significance
Rehabilitation of disturbed surface areas	4	5	5	3	1	High

2.8.1.2 MANAGEMENT OBJECTIVES AND PRINCIPLES

To establish a sustainable and agreed end land use through final rehabilitation.

2.8.1.3 MANAGEMENT ACTIVITIES OR MITIGATION MEASURES

Same as discussed in **Section 2.8.1.**

3 RESIDUAL IMPACTS AFTER CLOSURE

Two types of impacts can remain on groundwater long after mining has been completed, namely groundwater **quality** and **water level impacts**. The former (quality) impact is very common in the coal and base metal mining industry where chemical reactions and processes like oxidation, ion exchange and consequent acid mine drainage (AMD) influence the water quality where water comes into contact with the host rocks in the presence of oxygen and water. Acid Base Accounting (ABA) and leaching tests were performed on two samples collected from the drilling of exploration boreholes in the Driehoekspan Project area and the results are discussed in detail in **Section 3.2** of the document.

Contrary to most other mining operations, the residual impacts of an iron ore mining operation are generally small and are mostly related to contaminants such as nitrate and hydrocarbons that were brought onto site and used during the operational phase of mining.

Negligible negative groundwater level impacts are expected to occur after closure as water levels will begin to recover as soon as active mining has ceased.

3.1 GROUNDWATER LEVEL REBOUND, RECHARGE RATE AND DECANT

During decommissioning, and for a certain time after closure, the geohydrological environment will dynamically attain a new equilibrium after the dewatering effects of the opencast workings. Decant predictions in an opencast mining environment is affected by the following:

- The mean annual precipitation (MAP),
- Recharge to the mine void, expressed as a percentage of the MAP. Recharge on the other hand is affected by:
    - o The size of the surface area disturbed by mining activities,
    - o The transmissivity of the backfill material,
    - o Surface water runoff,
- The overall porosity of the rehabilitated pit area,
- The groundwater contribution to water inflow, which is determined by the hydraulic properties of the surrounding undisturbed aquifer/s.

The groundwater gradient within a rehabilitated opencast pit is generally very close to being zero as a result of the high transmissivity of the backfill material. Decanting of an opencast pit is therefore most likely to occur wherever the pit intersects the lowest surface elevation. This concept is further explained and schematically illustrated in **Figure 3.1-1** by means of a conceptual cross section through a typical opencast pit.

The time it will take the proposed Driehoekspan opencast void to fill with water was calculated with the use of volume/recharge calculations and the results are provided in **Table 3.1**, while the most probable decant position is indicated in **Figure 3.1-2.**

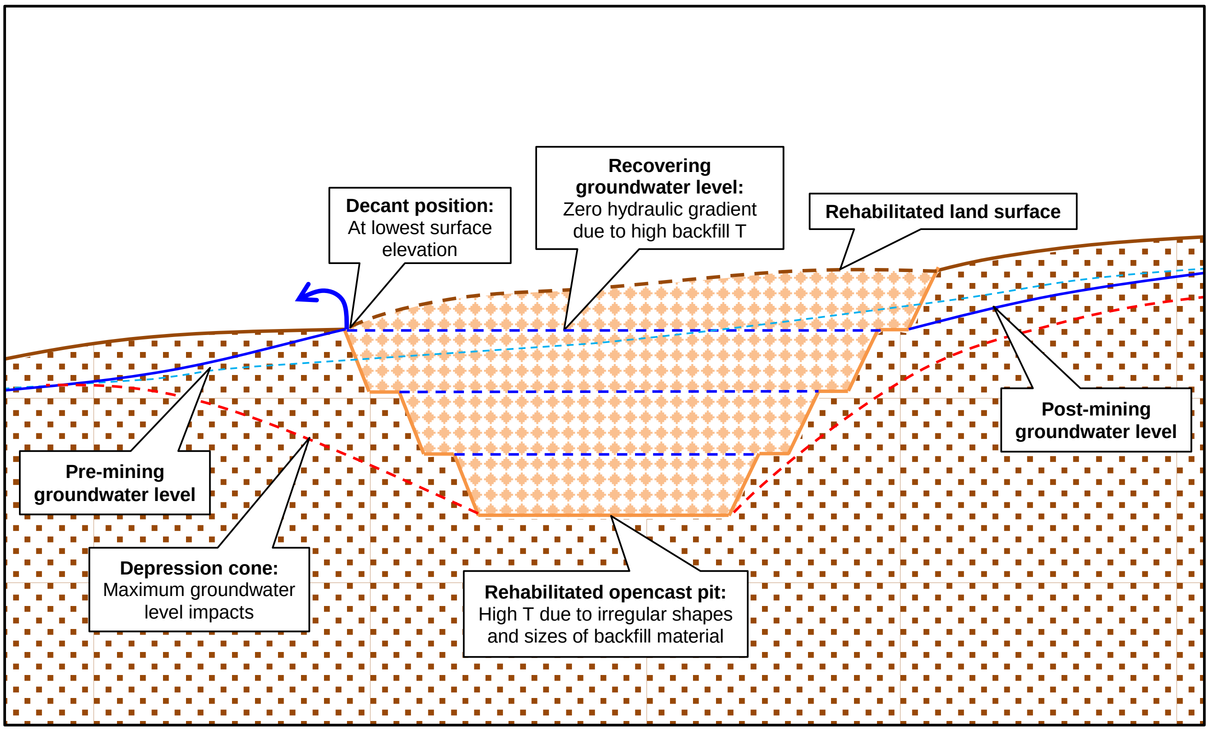


Figure 3.1-1: Conceptual model for the decanting of an opencast mine void

Table 3.1: Time-to-fill calculations for the Driehoekspan Pit

General information		
Surface area	m^2	87 990
Decant elevation	mamsl	1 414
Total void volume	m^3	2 339 980
Mean annual precipitation	m/a	0.3
Backfilled void volume		
20% Porosity	m^3	467 996
25% Porosity	m^3	584 995
30% Porosity	m^3	701 994
Decant/Recharge rate		
14% Recharge	m^3/y	3 696
16% Recharge	m^3/y	4 224
18% Recharge	m^3/y	4 751
Time to fill		
Worst case scenario (20% Ø and 18% RCH)	Years	98
Most probable scenario (25% Ø and 16% RCH)	**Years**	**139**
Best case scenario (30% Ø and 14% RCH)	Years	190

Notes: *Ø - Porosity,*
RCH - Recharge.

The most probable decant elevation of the proposed Driehoekspan Pit is approximately 1 415 mamsl and the decant position is indicated below in **Figure 3.1-2**. The most probable time it will take the backfilled void to fill with water to the decant elevation was calculated to be in the order of 140 years after active mining has ceased **(Table 3.1)**. Low rainfall combined with the relatively small surface area expected to be disturbed by the opencast pit contribute to the long time it will take the water level within the backfilled pit to reach the decant elevation.

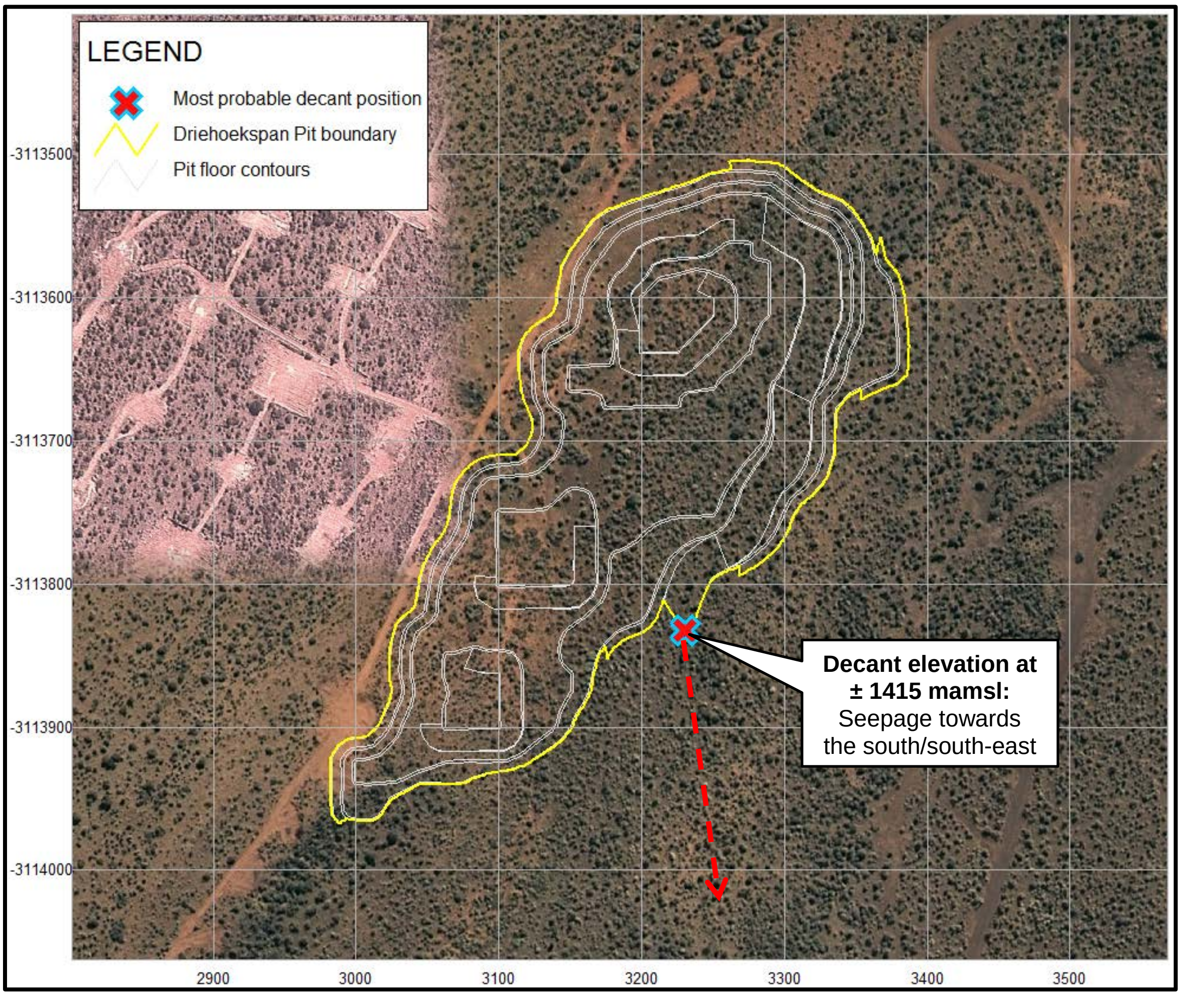


Figure 3.1-2: Most probable decant position for the Driehoekspan Pit

Decanting of a mine void generally occurs as a result of an excess volume of water that cannot be "absorbed" by the aquifer system. The excess water is generated by the increased recharge from surface due to the destruction of the aquifer structure.

The evaporation rate of approximately 237 570 m^3/y **(Figure 1.3.3.2-2)** calculated to occur from the surface of the backfilled pit far exceeds the expected recharge volume of ± 4 220 m^3/y **(Table 3.1)**, which in actual fact means that **the water level within the backfilled opencast pit is unlikely to reach the surface and decanting should not occur**.

3.2 GROUNDWATER QUALITY

The two most common processes by which groundwater are contaminated include **interstitial release** and **ion exchange release**. Argillaceous sediments such as shale and mudstone are known to contain pore water with high saline content. Significant amounts of contaminants may therefore be released as these sediment structures disintegrate because of weathering or when exposed and crushed through the mining process. The most commonly released ions during this weathering process are sodium and chloride.

Pyrite in coal-bearing material and base metal sulphides are very prone to oxidation when brought into contact with water under oxidation conditions. The chemical reactions are collectively referred to as acid mine drainage (AMD). The root of the problem lies in chemical and bacteriological oxidation of pyrite occurring in the coal, other carbonaceous material and base metals. The following are the most commonly occurring reaction train:

$$2FeS_2 + 7O_2 + 2H_2 – 2FeSO_4 + H_2SO_4 \quad (1)$$
$$4FeSO_4 + 2H_2SO_4 + O2 – 2Fe_2 (SO_4)_3 + 2H_2O \quad (2)$$
$$3Fe_2 (SO_4)_3 + 12H2O – 2HFe_3(SO_4)_2 (OH)_6 + 5H_2SO_4 \quad (3)$$

The pH and bicarbonate value of the water is expected to decrease. Metals go into solution and sulphate (SO_4) and Total Dissolved Solids (TDS) values increase. As the water leaves the mining area, it usually mixes with better quality water and the pH and bicarbonate values will be buffered back to more acceptable levels. Metals then also precipitate and the SO_4 and TDS concentrations decrease.

Results of various studies conducted for the surrounding iron ore mines have shown that none of these reactions or contaminants applies to the iron ore mining environment. The in situ ore and host rock are chemically inert and ion exchange and accompanying groundwater contamination do not occur (*Sishen South Iron Ore Project, 2005)*.

Even so, Acid Base Accounting (ABA) and leaching tests were performed by an accredited laboratory on two samples collected from the drilling of exploration boreholes in the Driehoekspan Project area. The Modified Sobek method was used for the ABA tests, while for the leaching tests the samples were leached with distilled water as a realistic scenario expected for the project area.

Acid Base Accounting is done to determine the net acid generating and neutralising potentials of material. The main principles of acid-base accounting are:

- Samples are exposed to complete oxidation of all sulphide-bearing minerals.
- This generates acid, which is counteracted by the natural base potential in the material.
- The initial pH before oxidation and the oxidised pH are recorded for each sample.

Little or no drop in pH occurs whenever the base potential exceeds the acid potential. The opposite holds true when the acid potential exceeds the base potential – such a sample is therefore expected to generate acidic conditions when exposed to oxygen and water.

The following criteria were used on the ABA test data to assess the potential for each of the samples to generate ARD:

- The difference between the acid-neutralising potential and acid-generating potential is known as the net-neutralising potential (NNP = NP – AP). Therefore, whenever the NNP is a negative value the acid potential exceeds the base potential, suggesting that water leaching through this material will tend to turn acidic **(Table 3.2-1),** and
- The ratio of NP:AP is termed the Net Potential Ratio (NPR). ARD screening criteria based on NPR and sulphur % are listed in **Table 3.2-2**.

Table 3.2-1: Classification of samples according to nett neutralising potential *(Usher et al., 2003)*

NNP < 0	Potentially acid forming
NNP > 0	Non-acid forming

Any sample with NNP < 20 is potentially acid-generating, while any sample with NNP > -20 might not generate acid.

Table 3.2-2: Classification of samples according to the neutralising potential ratio (NPR)

TYPE I	Potentially acid forming	Total S(%) > 0.25% and NP:AP ratio 1:1 or less
TYPE II	Intermediate	Total S(%) > 0.25% and NP:AP ratio 1:3 or less
TYPE III	Non-acid forming	Total S(%) < 0.25% and NP:AP ratio 1:3 or greater

The results of the ABA tests are provided in **Table 3.2-3**. Both samples collected from the Driehoekspan Project area are classified as Type III according to the **sulphur content and NPR classification (Table 3.2-2)**. Similar to the surrounding iron ore mines the conclusion is therefore drawn that both the ore and overburden material are non-acid forming.

In both samples the neutralising potential (NP) exceeds the acid potential (AP), which results in positive nett neutralising potential values. According to the **nett neutralising potential classification (Table 3.2-1)** both samples are therefore considered to be non-acid forming.

Table 3.2-3: Results of ABA tests

Acid – Base Accounting Modified Sobek (EPA-600)	**Sample Identification**	
	Driehoekspan Overburden Composites	**Driehoekspan Ore Composites**
Sample Number	17048	17049
Paste pH	7.8	7.6
Total Sulphur (%) (LECO)	0.13	0.03
Acid Potential (AP) (kg/t)	4.06	0.938
Neutralization Potential (NP)	9.08	1.97
Nett Neutralization Potential (NNP)	5.01	1.03
Neutralising Potential Ratio (NPR) (NP : AP)	2.23	2.10
Rock Type	**III**	**III**

In basic terms a **leaching test** involves the percolation of a liquid through a finely crushed rock sample after which the leachate retrieved from the sample (extract) is analysed to determine what chemical changes have occurred. Different liquids are used for different purposes and numerous documented leach procedures exist. For the Driehoekspan samples the so-called distilled Water Leach was used. The distilled water leach is considered a realistic scenario that can be expected to realise in the project area. The rainfall in the region is not acidic and the quality of the rain water is very similar to that of distilled water.

The distilled water leach procedure can be summarised as follows:

- 50g of the sample is weighed into a container and 1000 ml of distilled water is added.
- The sample is shaken for 20 hours.
- The sample is filtered and sent for analysis.

The extract was analysed for:

- Physical parameters (pH, Alkalinity, Electrical Conductivity) and
- Macro element anions (Chloride, Sulphate, Nitrate and Fluoride), after which
- It was sent for an ICP-OES metals scan.

The results of the leaching tests are provided in **Tables 3.2-4** and **3.2-5** and are compared against the South African National Standards for drinking water **(Table 1.4-1)**. Parameters highlighted with red are those that exceed the SANS guideline concentrations. All physical parameters and concentrations of macro element anions are below the permissible SANS values for drinking water. Metal concentrations are largely below the detection limits, however the aluminium content of the leachate from both samples exceeds the SANS permissible concentration of 0.3 mg/l.

The results of the leaching tests therefore conclude that both the ore and overburden from the project area are mostly inert and any leachate generated by planned ROM stockpiles and/or discard dumps should be of an acceptable quality. The only metal found to be present in the leachate at significant concentrations was aluminium.

Table 3.2-4: Results of leaching tests – physical parameters and macro element anions

Analyses	Driehoekspan Overburden Composites		Driehoekspan Ore Composites	
TCLP / Acid Rain / Distilled Water / H_2O_2	**Distilled Water**		**Distilled Water**	
Dry Mass Used (g)	**250**		**250**	
Volume Used (mℓ)	**1000**		**1000**	
pH Value at 25˚C	6.7		7.6	
Electrical Conductivity in mS/m at 25°C	6.8		3.8	
Inorganic Anions	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**
Total Alkalinity as $CaCO_3$	20	80	<5	<20
Chloride as Cl	5	20	<5	<20
Sulphate as SO_4	<5	<20	7	28
Nitrate as N	0.2	0.8	<0.2	<0.8
Fluoride as F	0.2	0.8	0.2	0.8
ICP-OES Scan	See **Table 3.2-5**		See **Table 3.2-5**	

Table 3.2-5: Results of leaching tests – metals (mg/l)

Sample Id	Ag	Al	As	Au	B	Ba
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Det Limit	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Driehoekspan Overburden Composites	<0.010	0.828	<0.010	<0.010	0.298	1.36
Driehoekspan Ore Composites	<0.010	0.658	<0.010	<0.010	0.267	0.337
Sample Id	**Be**	**Bi**	**Ca**	**Cd**	**Ce**	**Co**
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Det Limit	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Driehoekspan Overburden Composites	<0.010	<0.010	6.20	<0.010	<0.010	<0.010
Driehoekspan Ore Composites	<0.010	<0.010	1.28	<0.010	<0.010	<0.010
Sample Id	**Cr**	**Cs**	**Cu**	**Dy**	**Er**	**Eu**
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Det Limit	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Driehoekspan Overburden Composites	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Driehoekspan Ore Composites	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sample Id	**Fe**	**Ga**	**Gd**	**Ge**	**Hf**	**Ho**
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Det Limit	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Driehoekspan Overburden Composites	0.491	0.524	<0.010	<0.010	<0.010	<0.010
Driehoekspan Ore Composites	0.492	0.134	<0.010	<0.010	<0.010	<0.010

Sample Id	In	Ir	K	La	Li	Lu
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Det Limit	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Driehoekspan Overburden Composites	<0.010	<0.010	1.9	<0.010	0.019	<0.010
Driehoekspan Ore Composites	<0.010	<0.010	0.7	<0.010	0.100	<0.010
Sample Id	Mg	Mn	Mo	Na	Nb	Nd
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Det Limit	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Driehoekspan Overburden Composites	1.20	0.323	<0.010	6.38	<0.010	<0.010
Driehoekspan Ore Composites	0.591	0.176	<0.010	5.26	<0.010	<0.010
Sample Id	Ni	Os	P	Pb	Pd	Pt
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Det Limit	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Driehoekspan Overburden Composites	0.013	<0.010	<0.010	<0.010	<0.010	<0.010
Driehoekspan Ore Composites	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sample Id	Rb	Rh	Ru	Sb	Sc	Se
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Det Limit	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Driehoekspan Overburden Composites	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Driehoekspan Ore Composites	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sample Id	Si	Sm	Sn	Sr	Ta	Tb
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Det Limit	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Driehoekspan Overburden Composites	1.7	<0.010	<0.010	0.181	<0.010	<0.010
Driehoekspan Ore Composites	1.1	<0.010	<0.010	0.031	<0.010	<0.010
Sample Id	Te	Th	Ti	Tl	Tm	U
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Det Limit	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Driehoekspan Overburden Composites	<0.010	<0.010	0.034	<0.010	<0.010	<0.010
Driehoekspan Ore Composites	<0.010	<0.010	0.024	<0.010	<0.010	<0.010
Sample Id	V	W	Y	Yb	Zn	Zr
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Det Limit	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Driehoekspan Overburden Composites	<0.010	<0.010	<0.010	<0.010	0.185	<0.010
Driehoekspan Ore Composites	<0.010	<0.010	<0.010	<0.010	0.156	<0.010

The only water quality impacts that might occur result from the physical mining operation itself and from seepage or accidental spills of hazardous substances imported into the mining area for a variety of uses like fuel, lubricants, cleaning agents and solvents.

The types and sources of contamination that usually occur in the iron ore environment, and also expected at Driehoekspan, are:

- Organic/hydrocarbon contamination sources like **fuels**, **lubricants** and **organic cleaning agents**/solvents used in mining equipment and workshops.
- **Nitrate** contamination inside the pit areas where nitrate-based explosives are used in large quantities.

- Contamination by **suspended solids**, especially haematite dust and mud particles created by the physical impact of the mining operation.

Hydrocarbon/Organic contamination
Because macro-scale loading and moving equipment will be used in the proposed mining operation, millions of litres of diesel fuel and other hydrocarbons will be used per year. Fuel depots always have the risk of leakage and spillage incidents and the highest standards in design, monitoring and management at these sites will be used from construction to decommissioning. The same applies to storage, handling and disposal of all other hazardous substances like organic cleaning agents and solvents that will be used widely at workshops and service stations.

Nitrate contamination
Haematite ore is extremely hard and therefore high impact explosives are required for breaking and blasting of the in situ material. The explosives are usually nitrate based. Nitrate levels therefore tend to increase close to the blasting areas in the pit. It was found at comparative mining operations that the nitrate concentrations return to acceptable levels within one or two years after regular blasting has ended in the specific area.

Nitrate concentrations could be expected to become elevated in all areas where ROM material is stockpiled and waste material is discarded.

Suspended solids
Rainfall and run-off in the pits, discard stockpiles and ROM stockpiles has a high concentration of suspended solid material directly after rainfall events. Movement of heavy mining equipment through the water further creates mud and aggravates this contamination. The suspended material usually has a high iron content because of the hematite particles it consists of. Contamination by iron or any other heavy metals are, however, not a significant risk because the pH of the groundwater is high in the dolomitic aquifer environment. Iron and other metals do not stay in solution but form insoluble metal oxides and hydroxides and precipitate. Conventional settling of the suspended solids improves the water quality significantly.

Please note that groundwater quality within the rehabilitated pit will gradually improve due to recharge (dilution) with fresh rainwater. Minor groundwater quality impacts are therefore expected, but the surrounding groundwater users should not be affected.

3.3 NUMERICAL GROUNDWATER MODEL

3.3.1 FLOW MODEL

Numerical flow and mass transport groundwater models were constructed to simulate current aquifer conditions and impacts and to provide a tool for the evaluation of different management options for the future. A risk analysis could also be performed where effects of different flow and concentration parameters as well as the impacts of nearby existing operations and management options could be evaluated.

The modeling package Processing Modlfow 8 was used for the simulations. A single layered numerical groundwater flow model was constructed to include the entire Coza Mining Right Application area and covers an area of ± 176 km^2 (15.7 by 11.2 km). The iron ore bodies have been preserved from erosion to form low hills due to their high hardness in comparison to the surrounding geology. Much of the Driehoekspan ore body is consequently located above the local static groundwater level. Approximately 5% of the proposed pit is expected to be ± 20 to 25 meters below the model calibrated groundwater level and it is for this reason that a single layered model was considered to be sufficient. Aquifer parameters assigned to the model are provided below in **Table 3.3.1-1**.

Table 3.3.1-1: Numerical flow model grid layout and hydraulic parameters

Driehoekspan numerical flow model	
Grid size	Easting = 11 225 m Northing = 15 750 m
Rows and Columns	Rows = 630, Columns = 449
Cell size	25 m by 25 m
Layers	Layer 1: Confined/Unconfined
Transmissivity layer 1	0.9 m^2/day
Specific yield layer 1	0.06
Effective porosity layer 1	6%
Recharge	1 to 7.5% of MAP

Little information is available on the existence of geological structures such as dykes and faults within the Driehoekspan Project area. Such features, because the aquifer is of a secondary fractured nature, usually have higher transmissivities and serve as preferred flow paths or conduits for groundwater movement.

After the model was run and the steady state solution was used to calibrate simulated water levels with the available measured water level information, a groundwater mass transport model was constructed. Calibration of the flow model was aided largely by existing flow and water level information gathered from hydrocensus boreholes, which are situated within the same geological environment.

The model calibration results are indicated in **Figure 3.3.1-1** and a correlation of ± 98% was achieved with the steady state calibration of the Coza flow model.

The Coza model simulation was subdivided into a total of eight different stress periods to simulate the planned six years of active opencast mining and 50 years of post-closure impacts. A stress period in the model is a period where groundwater flow and mass transport conditions are constant. All time dependent parameters in the model, like drains, rivers, aquifer recharge, contaminant sources, sinks and contaminant concentrations remain constant during the course of a stress period.

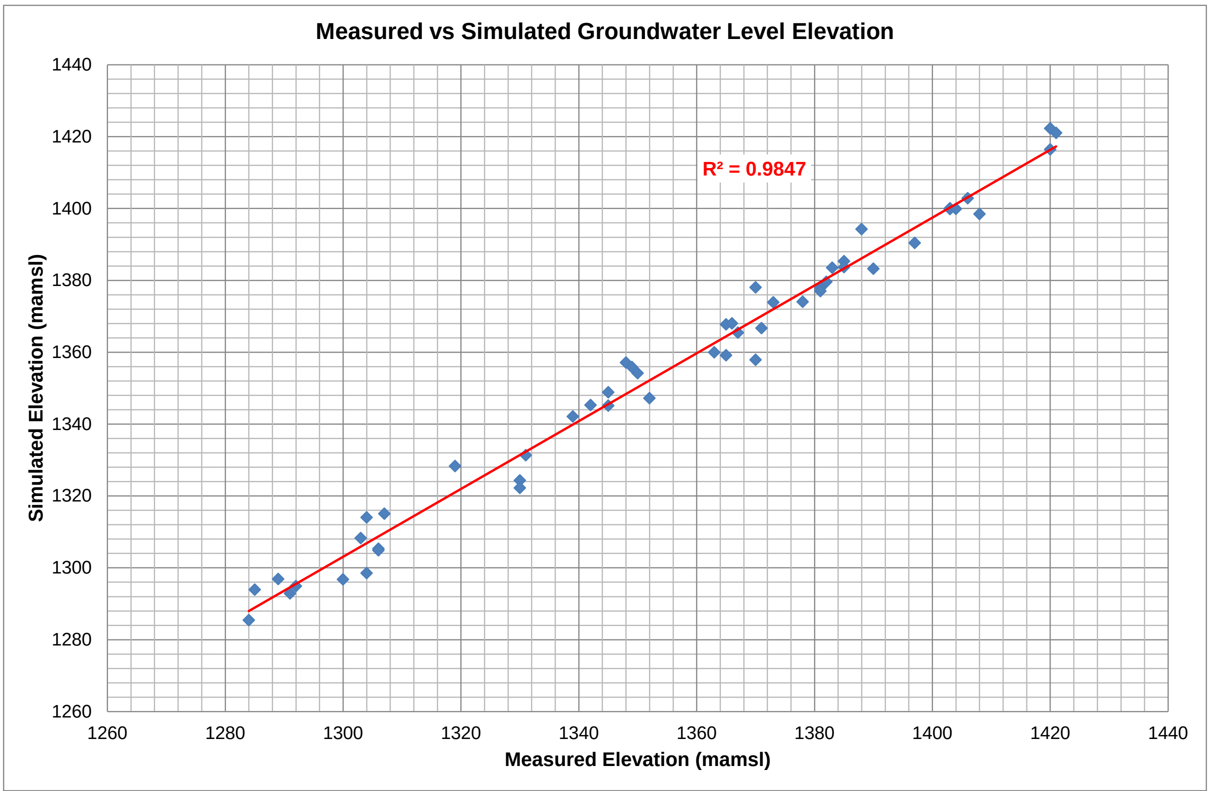


Figure 3.3.1-1: Numerical flow models calibration results

In order to better indicate the impact of opencast mining on the surrounding groundwater levels, groundwater elevations were exported from the flow and used to construct the simulated cone of depression, which is provided in **Figures 3.3.1-3** and **3.3.1-4**. No groundwater level impacts were simulated for the first four years of mining, as the pit floor elevation only decreases below the local groundwater level elevation of ± 1 382 mamsl during year 5 of mining.

The extent of the groundwater level impacts is greatly restricted by the overall low transmissivity of the aquifer host rock. The influence of aquifer transmissivity on the radius/extent of the cone of depression (water level impact) is explained by means of the following equation:

$$R(t) = 1.5(Tt/S)^{1/2}$$

Where	*R*	*= Radius (m),*
	T	*= Aquifer transmissivity (m^2/d),*
	t	*= Time (days),*
	S	*= Storativity.*

From the equation it is made clear that an increase in transmissivity will lead to an increase in the radius of influence (extent of depression cone), while the opposite holds true for aquifer storativity. Should the mine workings intersect transmissive geological structures, the groundwater level impacts may be extended along such structure.

Groundwater abstraction for the purpose of mine dewatering causes the local groundwater levels to decrease below the mining elevation. An increase in mining depth will consequently lead to an increase in groundwater level drawdown. The generally low transmissivity of the deeper fractured rock aquifer will however greatly restrict the formation of a drawdown cone (water level impacts). The depths of the proposed pits relative to the depth of the model calibrated groundwater level were calculated and are indicated in **Figure 3.3.1-2**. As already mentioned, approximately 5% of the proposed pit is expected to be ± 20 to 25 meters below the model calibrated groundwater level.

The model simulated drawdown cones are indicated in **Figures 3.3.1-3** and **3.3.1-4**, while the expected groundwater inflows are summarised below in **Table 3.3.1-2**.

Please note that no groundwater users are located within the area simulated to be affected by the proposed mine dewatering.

Table 3.3.1-2: Model simulated groundwater ingress into proposed pit

Year	Minimum flow (m^3/d)	Maximum flow (m^3/d)
1	N/A	N/A
2	N/A	N/A
3	N/A	N/A
4	N/A	N/A
5	10	15
6	15	20

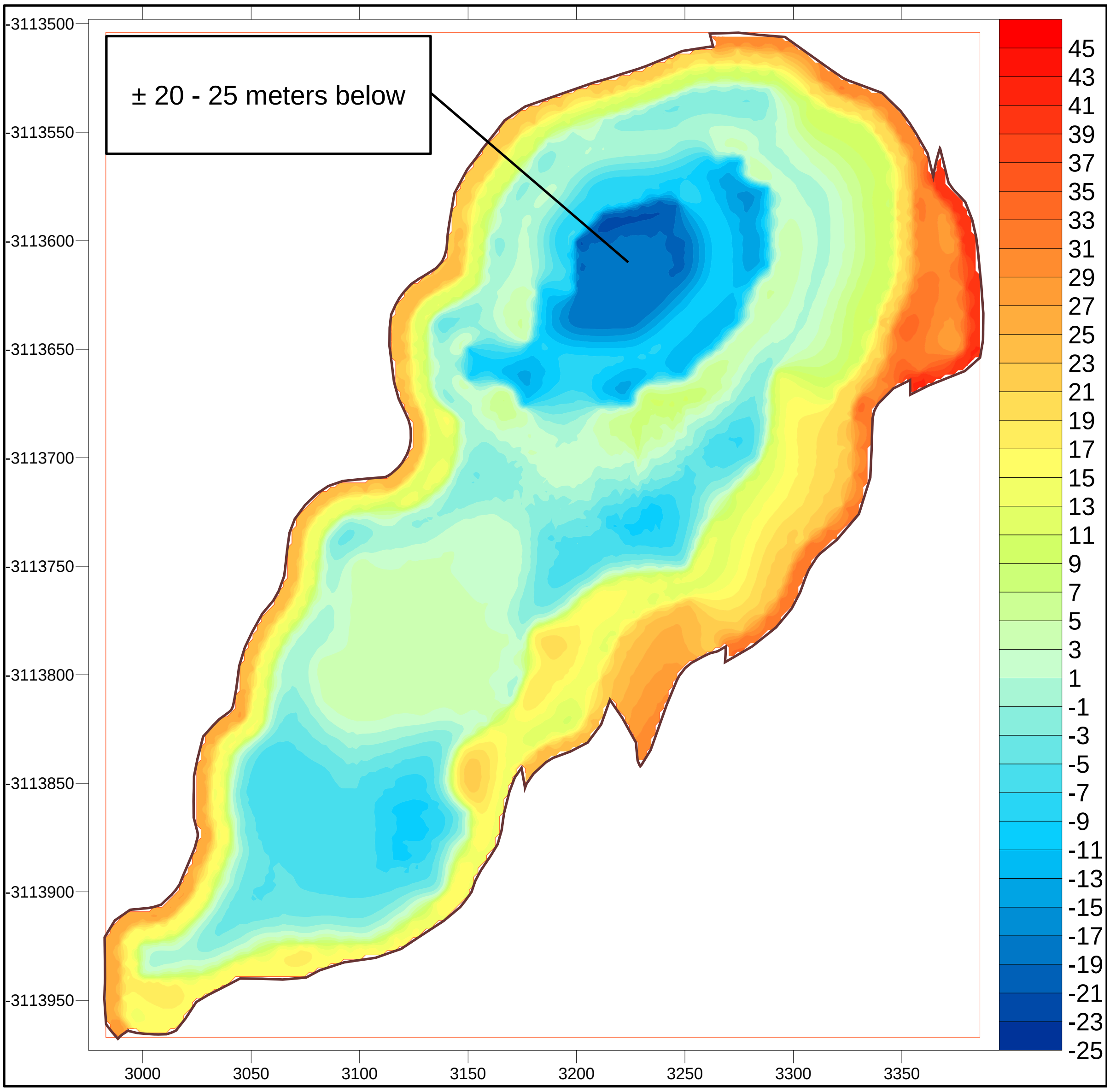


Figure 3.3.1-2: Depth of proposed pit floor relative to calibrated groundwater level

A groundwater level drawdown of approximately 6 meters was simulated for the fifth year of active mining and is indicated in **Figure 3.3.1-3**. Maximum groundwater level impacts are expected to occur during the sixth and final year of mining and a groundwater level drawdown of ± 11 meters was simulated **(Figure 3.3.1-4)**. The cone of depression was simulated not to exceed the pit boundary by more than approximately 100 meters. Transmissive geological structures have the potential to affect both the shape and extent of the depression cone. Such structures may also greatly increase groundwater discharge into the active mine workings.

Please note that such structural geological information was not available at the time of completion of this study. We therefore strongly recommend a revision of the Driehoekspan model simulations should relevant information become available in the future.

The volumes of groundwater expected to discharge into the active mine workings were simulated with the numerical flow model and the results are provided below in **Table 3.3.1-2**. No groundwater discharge was simulated for the first four years of mining, as the pit floor elevation only decreases below the local groundwater level elevation during the fifth year of mining. Due to the highly heterogeneous nature of the aquifer host rock a degree of uncertainty will always remain. Geological structures such as dykes and faults may intersect the proposed pit, which should then have a significant influence on the flow of groundwater to the mine void. For this reason a sensitivity analysis was conducted during which the minimum and maximum expected inflows were simulated for the proposed Driehoekspan pit **(Table 3.3.1-2)**.

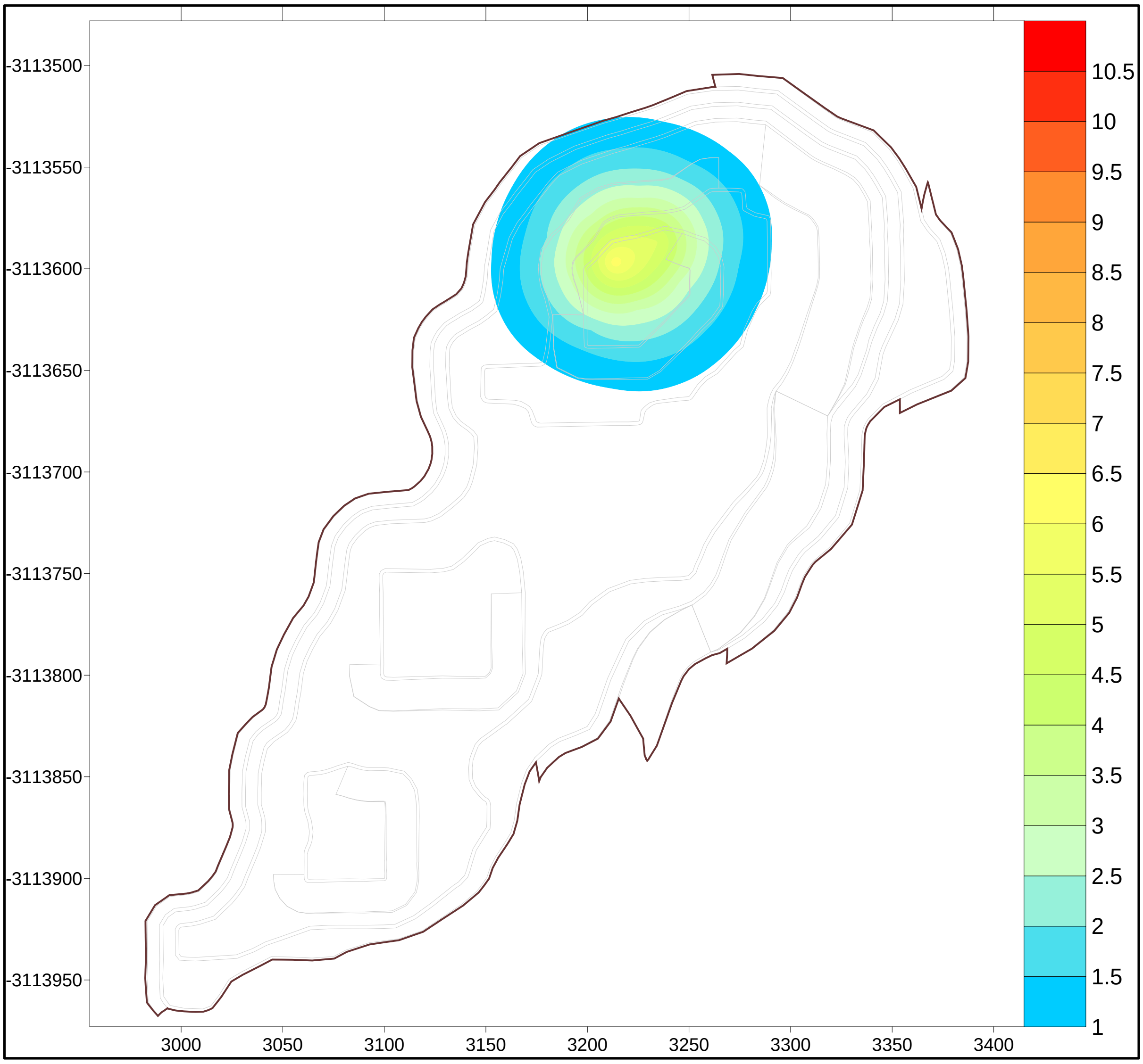


Figure 3.3.1-3: Simulated cone of depression at the end of year 5

Notes: *- Please note that all figures are provided in the WGS 84 Datum and Transverse Mercator coordinate system,*
- Grid lines provided in all figures therefore also serve as a scale bar.

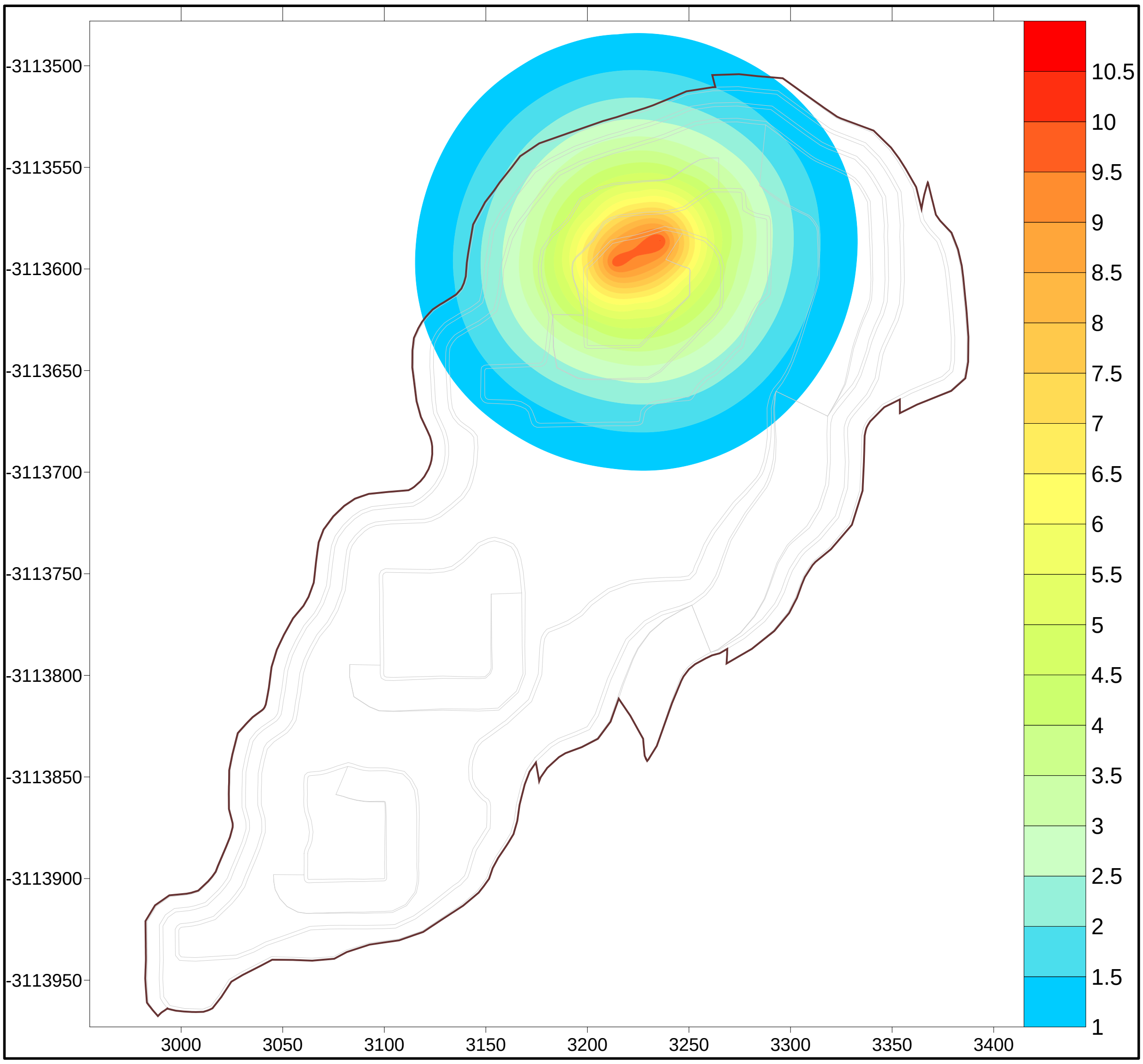


Figure 3.3.1-4: Simulated cone of depression at the end of year 6 (EOM)

One should however keep in mind that a secondary fractured rock aquifer (such as the one underlying the Driehoekspan Project area) is a highly complex system and is by no means homogeneous. Coupled with numerous model restrictions, one is expected to come across either over or under estimations of the predicted groundwater impacts. The model results should therefore only be regarded as being qualitative rather than quantitative for use in planning of management and mitigation measures. The model results/predictions also need to be verified and updated regularly by means of a comprehensive groundwater monitoring program as outlined later in this report.

3.3.2 MASS TRANSPORT MODEL – SIMULATED POLLUTION PLUMES AND MOVEMENT

In the case of a perched water table or an unconfined/semi-confined aquifer, the hydraulic gradient is equal to the slope of the water table, measured at different points in the aquifer. The hydraulic gradients in the Driehoekspan Project area were calculated from the difference in elevation of groundwater levels in each area. The averaged hydraulic conductivities of the saturated zone, as calculated from the low rate pumping tests, were used as approximations of the saturated hydraulic conductivity of the Driehoekspan Project area.

The average groundwater flow velocities in the project area were calculated using the following equation *(after Fetter, 1994)*:

$$v = \frac{KI}{\phi}$$

Where:	*v = flow velocity (m/day)*		
	K = hydraulic conductivity (m/day)	=	*0.025*
	I = average hydraulic gradient	=	*0.023 west/south-west*
	ϕ = probable average porosity	=	*0.06*

The hydraulic conductivity and average porosity were chosen so as to provide a liberal estimation of seepage velocity. The actual seepage through the aquifer matrix should be lower than the products calculated, but highly transmissive fracture zones or areas of steeper gradient might cause higher transport rates.

The hydraulic conductivity and the average hydraulic gradient are known parameters. By making use of these values, the average steady state flow velocity in the Driehoekspan Project area was calculated to be in the order of ± 0.008 m/d, or 3.0 m/y towards the west/south-west.

These estimates do however not take into account all known or suspected zones in the aquifer like preferential flow paths formed by igneous contact zones like the intrusive dykes that have higher than average flow velocities. In fractured aquifer media, the transport velocity is usually significantly higher than the average velocities calculated with this formula and may increase several meters or even tens of meters per year under steady state conditions. Under stressed conditions such as at groundwater abstraction areas the seepage velocities could increase another order of magnitude.

During active opencast mining and until a new groundwater equilibrium has been reached, the mine void acts as a groundwater sink and groundwater will move radially inwards towards the void. This means that during this period poor quality leachate generated by the mining activities is likely to move towards the mine void and should not drain towards the immediate surroundings.

Four potential source areas of groundwater contamination were identified within the Driehoekspan Project area and were simulated in the mass transport model. The four main source areas are discussed shortly in **Table 3.3.2**.

Table 3.3.2: Potential source areas and expected impacts

Source area	Potential impact
- Driehoekspan Pit	- Post closure decant of poor quality water. - Down gradient movement of pollution plume in shallow weathered zone aquifer.
- Waste Rock Dump - Hazardous Waste Dump - General Waste dump - Stockpiles	- Surface water run-off originating from the dumps and stockpiles, toe-seeps and seepage through the base of the facilities may potentially be of poor quality and could cause adverse groundwater quality impacts should it enter the aquifer regime. Nitrate is more often than not the dominant pollutant.
- Workshops - Fuel depots	- Spillages and leakages from hydrocarbon storage facilities may lead to the contamination of the underlying aquifer regime by harmful hydrocarbons.
- Pollution control dams - Storm water dam	- Spillages and leakages of poor quality water from pollution control dams and any water retaining facilities/dams may lead to adverse groundwater quality impacts and the down gradient movement of a pollution plume.

Potential sources on the surface pose a greater groundwater contamination risk compared to the opencast workings. As have already been mentioned, groundwater contamination emanating from the proposed opencast pit will only start to migrate in the down gradient direction after active mining has ceased and a new groundwater level equilibrium has been established. The overall low transmissivity of the fractured rock aquifer will also greatly restrict the rate of contamination movement away from the pit.

Contamination emanating on surface is in direct contact with the high transmissivity weathered zone aquifer and will migrate at rates varying from ± 3 to 15 m/y in the down gradient direction until it is discharged into surface water features such as rivers and/or streams.

In order to better indicate the impact of the proposed source areas **(Table 3.3.2)** on the surrounding groundwater quality conditions, contamination contours were exported from the mass transport model and used to construct the simulated contamination plumes, which are provided in **Figures 3.3.2-1** to **3.3.2-3**. The contamination was simulated by applying contaminated recharge to the entire surface areas of the potential sources as listed in **Table 3.3.2**.

Please note that no groundwater users are located within the area simulated to be affected by plume movement.

The exact concentrations of the expected sources of groundwater contamination cannot be estimated or predicted with a high degree of confidence. Source areas were therefore assigned a theoretical concentration of 100% and the figures provided should be regarded as qualitative rather than quantitative.

No significant groundwater quality impacts were simulated for the mining related surface infrastructure **(Figure 3.3.2-1)**, which is mainly the result of:

- Low groundwater recharge percentage,
- Low transmissivity of aquifer host rock,
- Dilution with fresh groundwater and contaminant dispersion, and
- Short simulation time (6 years of active mining).

Groundwater pollution was simulated with the mass transport model to migrate in a west/south-westerly direction away from the proposed Driehoekspan Pit. Contaminant migration is slow and was simulated not to exceed a maximum distance of approximately 100 meters in the down gradient direction at a time of 50 years post closure **(Figure 3.3.2-3)**.

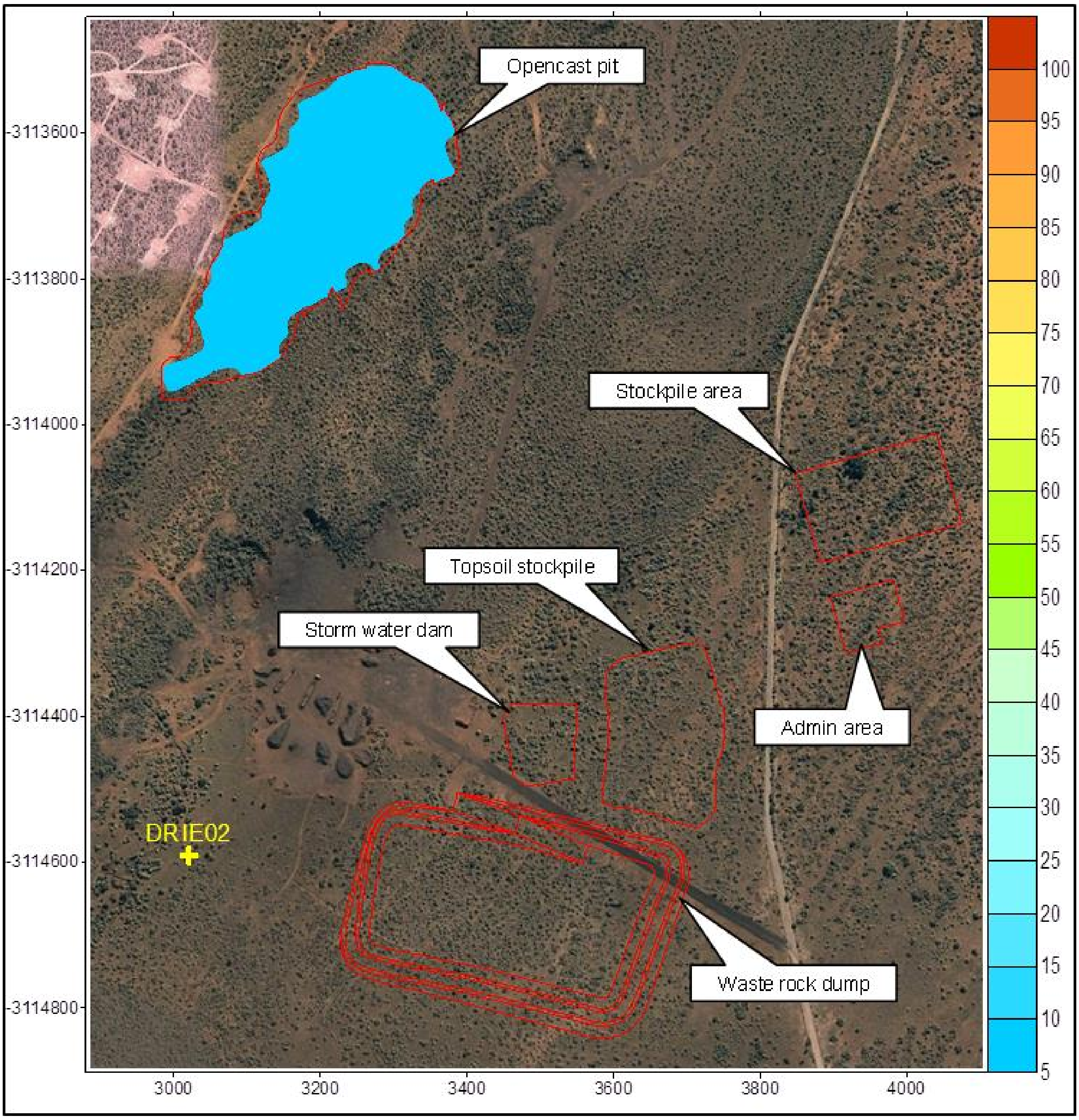


Figure 3.3.2-1: Model simulated pollution plumes at mine closure

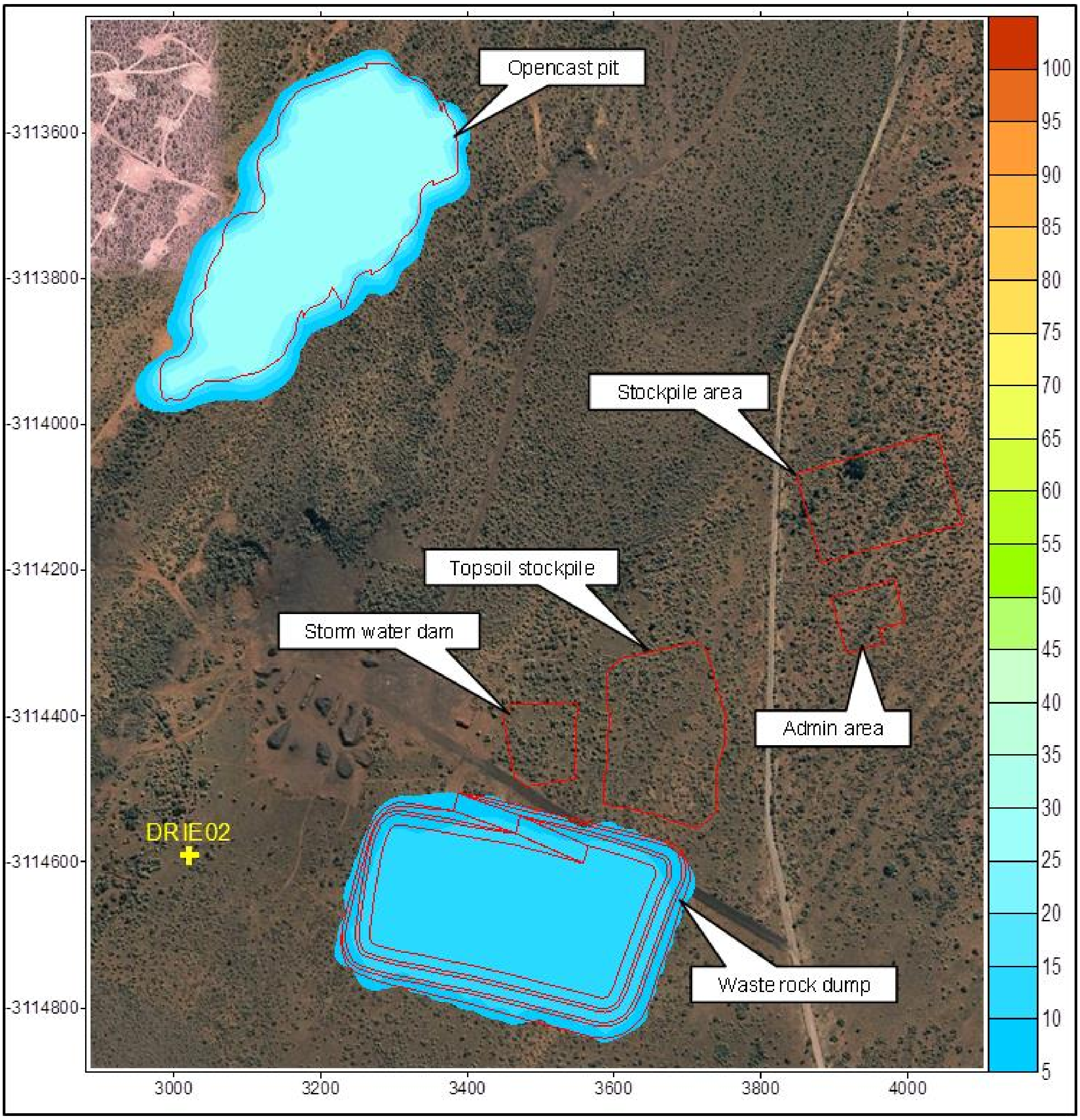


Figure 3.3.2-2: Model simulated pollution plumes at 25 years post closure

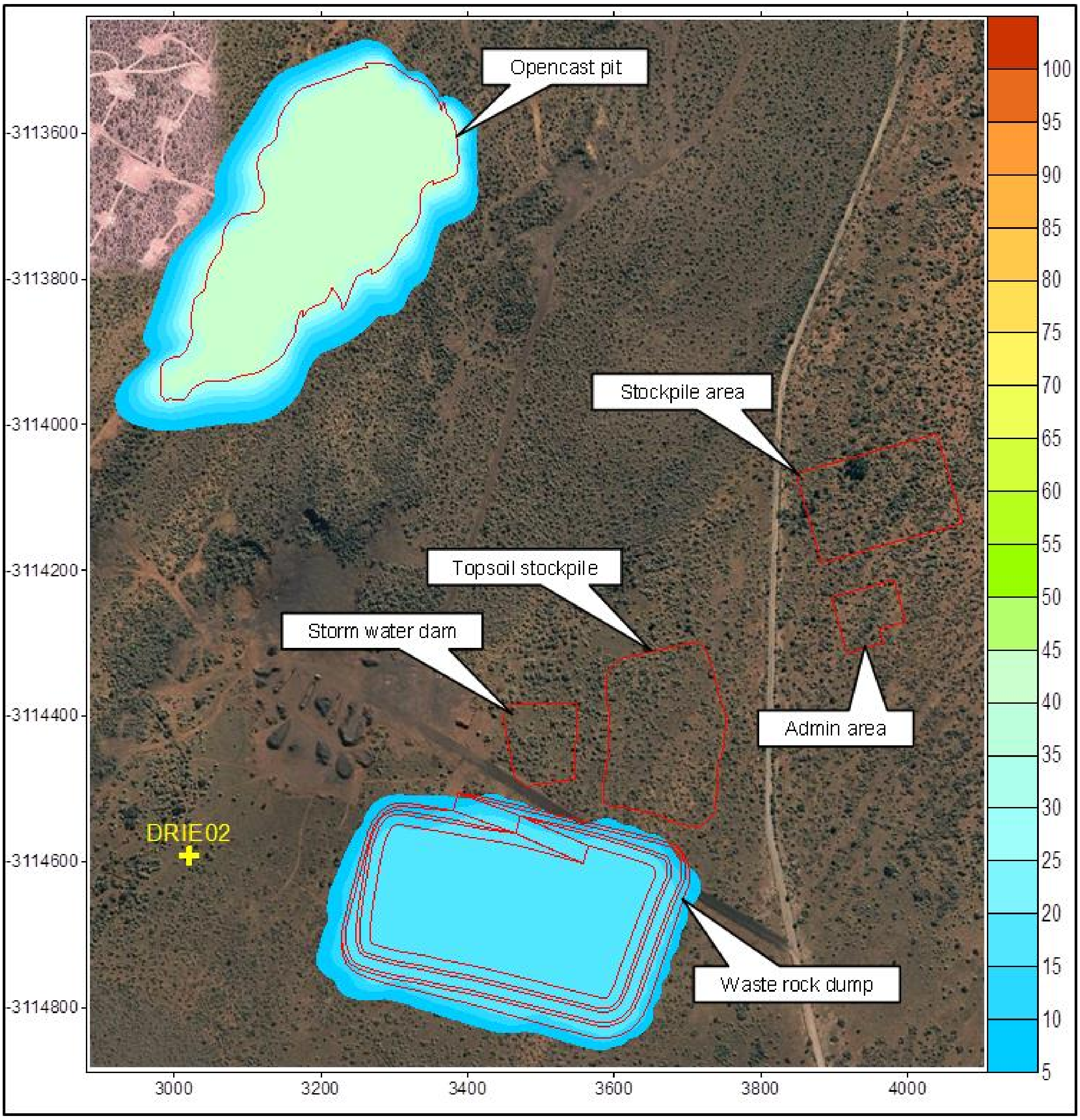


Figure 3.3.2-3: Model simulated pollution plumes at 50 years post closure

The long-term impacts on groundwater quality have been estimated through numerical modeling, but have to be confirmed through groundwater monitoring during the operational and decommissioning phases and updating and refinement of the models.

4 GROUNDWATER MONITORING PROTOCOL

4.1 MONITORING PLAN/PROTOCOL – WHERE, WHAT, HOW

Water samples will be taken around the Driehoekspan Project area as well as in the dams constructed for the purposes of dirty water management and water supply on a quarterly basis. A total of five source monitoring boreholes are recommended for the proposed Driehoekspan Project area and their positions are indicated below in **Figure 4.1**. Relevant information regarding the proposed monitoring boreholes is provided in **Table 4.1-1**, while borehole logs are also provided in **Appendix C**.

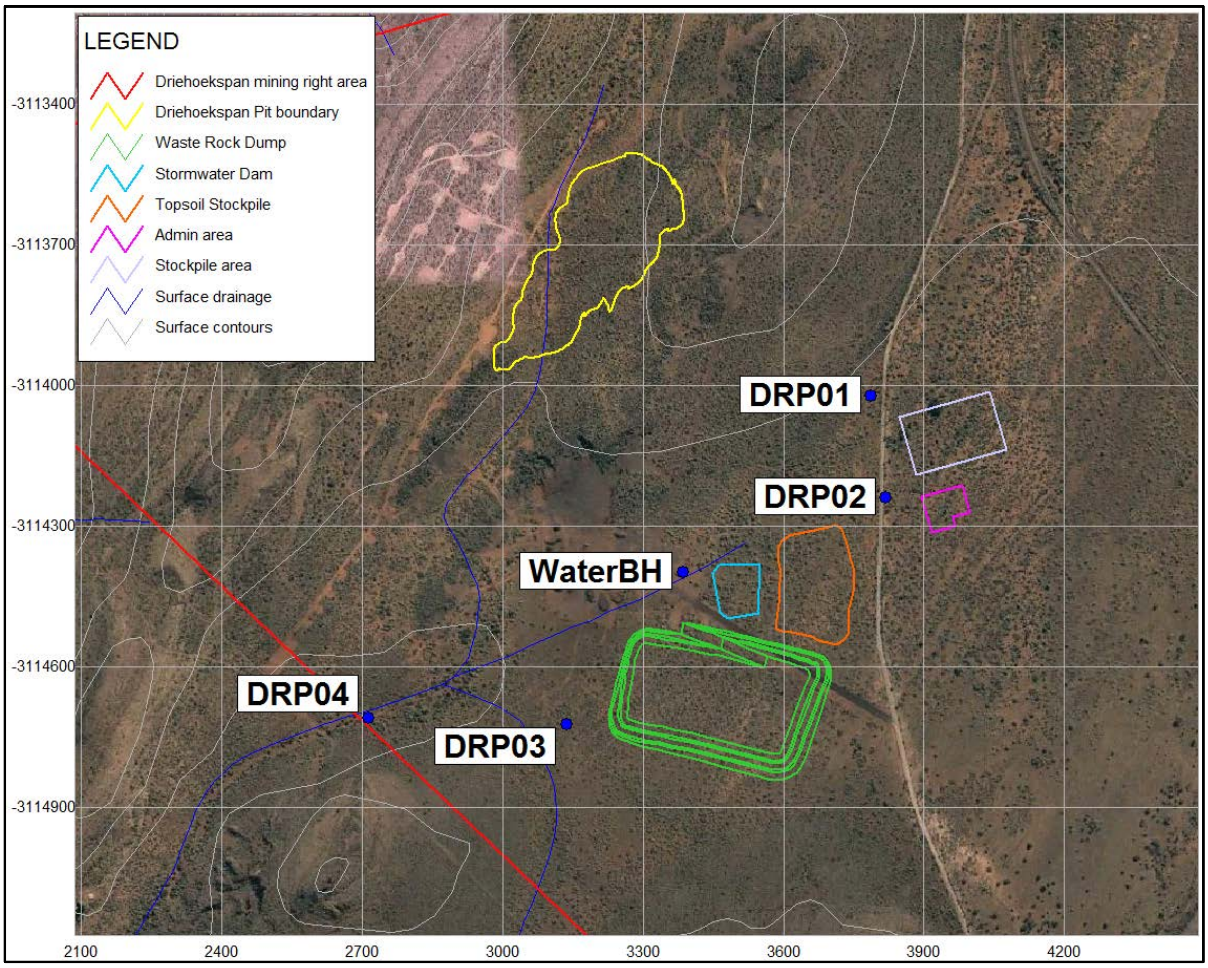


Figure 4.1: Positions of proposed source monitoring boreholes

Samples should also be taken in the proposed monitoring boreholes on a quarterly basis. Water levels of these boreholes will also be determined on a quarterly basis when the sampling is done. Samples will be analyzed for chemical and physical constituents normally associated with iron ore mining. These constituents are listed in **Table 4.1-2**.

Table 4.1-1: Summary of proposed source monitoring boreholes

BH	Coordinates (WGS84)		Depth (m)	Water strike (mbs)	Blow yield (l/h)	Lithology
	South	East				
DRP01	-28.14059	23.03856	45	26	300	SOIL, SHLE, DLMT, HEMT
DRP02	-28.14254	23.03887	50	46	2000	HEMT, SHLE, DLMT
DRP03	-28.14692	23.03193	25	17	6000	SHLE, DLMT
DRP04	-28.14678	23.02764	45	N/A	N/A	DLMT, SHLE
WaterBH	-28.14399	23.03446	50	30	N/A	N/A

***Notes:** SOIL – Soil; SHLE – Shale; DLMT – Dolomite; HEMT – Hematite.*

It must be mentioned that this monitoring schedule will be re-assessed by a qualified geohydrologist at a later stage in terms of stability of water levels and quality. Should the sampling program be changed, it should be done in consultation with the Department of Water Affairs (DWA).

Table 4.1-2: Groundwater constituents for routine analysis

Monitoring	Variable
Quarterly*	EC, pH, TDS, total hardness, total alkalinity, calcium, magnesium, sodium, potassium, chloride, sulphate, fluoride, nitrate, iron, manganese, aluminium and turbidity.

***Note**:*
** Once trends are established, some of these constituents may be sampled less frequent, while others found to be problematic may be added as determined on consultation with the relevant role players, such as the DWAF: Regional Office.*

The following maintenance activities will be adhered to:

- Monitoring boreholes will be capped and locked at all times,
- Borehole depths will be measured quarterly and the boreholes will be blown out with compressed air, if required and
- Vegetation around the boreholes will be removed on a regular basis and the borehole casings painted, when necessary, to prevent excessive rust and degradation.

Reporting on groundwater quality conditions will be included in the annual report.

The quarterly report will be an update of the database with time-series graphs and statistical analysis (average, maximum, minimum, 5 -, 50 – and 95 percentile values as well as linear performance). Data will also be presented in a map format to present a clear picture of the water quality situation. Laboratory results will be analyzed against the target water quality guidelines for domestic use, the aquatic environment, livestock watering and irrigation (according to the South African National Standards for drinking water; *SANS 241:2011*). The strictest value between the target water quality objectives or objectives through a reserve determination will be used.

In terms of flow, all water uses and discharges will be measured on an ongoing basis. The flows include:

Make-up water:

- Volumes of groundwater seepage into the opencast workings,
- Volumes of contaminated water used for dust suppression,
- An annual detailed evaluation report on the surface and groundwater quality will be prepared that will analyze the water quality situation in detail to investigate trends and non-compliance.

Data Management:

- Monitoring results will be entered into an electronic database as soon as results are available, and at no less than one quarterly interval, allowing:
- Data presentation in tabular format,
- Time-series graphs with comparison abilities,
- Statistical analysis (minimum, maximum, average, percentile values) in tabular format,
- Graphical presentation of statistics,
- Linear trend determination,
- Performance analysis in tabular format,
- Presentation of data, statistics and performance on diagrams and maps, and
- Comparison and compliance to the South African National Standards for drinking water *(SANS 241:2011)*.

As far as possible, the same monitoring points will be used from the construction phase through the operational and decommissioning phases to after mine closure to develop a long data record and enable trend analysis and recognition of progressive impacts with time.

4.2 SURFACE REHABILITATION INSOFAR IT AFFECTS GROUNDWATER

It was indicated that it is the purpose of the surface rehabilitation to re-establish surface drainage to the pre-mining conditions as far as practical.

The rehabilitation will aim to:

- Restore normal infiltration rates to areas where recharge were reduced due to surface compaction such as the access roads,
- Restore normal infiltration rates in areas where recharge was increased (i.e. pollution control dam), and
- Decrease seepage from the discard dumps.

The dams constructed for the purposes of dirty water management and water supply will also be rehabilitated and the disturbed areas sloped to be free draining and vegetated with the purpose of maximizing clean runoff.

4.3 LEGITIMATE REQUIREMENTS OF GROUNDWATER USERS

The proposed new project is in short expected to have the following impacts on the legitimate requirements of the surface or surrounding groundwater users in terms of quantity or quality:

- No adverse impact is expected on the nearby groundwater users in terms of groundwater availability since the groundwater level impacts should be restricted to the deeper fractured rock aquifer,
- Simulated pollution movement is also not further than approximately 100 m from the source areas at 50 years post closure,

All of the above predictions and estimates will however be verified during monitoring through the production, closure and post-closure phases according to the proposed monitoring program.

Management actions will be evaluated to deal with any potential decant predicted by this investigation at the proposed opencast pit. **The mine remains committed to a zero effluent operating principle and contaminated water will be prevented from entering the receiving surface water environment through actions like reuse or treatment.**

Should it be indicated through monitoring and investigation by a suitably qualified person that any legitimate groundwater users are impacted upon in terms of quantity or quality of borehole water, alternative water sources will be made available to such users by the mine.

Coza Mining (Pty) Ltd will comply with the target objectives set for the surface- and groundwater resources in terms of a reserve determination under the National Water Act 36 of 1998 (NWA).

4.4 REPORTING AND SUBMISSION OF INFORMATION

A report with regards to the following issues will be compiled and submitted to the relevant authorities on a yearly basis:

- Water quality results,
- Water levels of identified boreholes, and
- A copy of the complaints register.

5 REFERENCES

Bredenkamp et al. 1995. Manual on Quantitative Estimation of Groundwater Recharge and Aquifer Storativity, Water Research Commission.

Clean Stream Groundwater Services, 2005. Sishen Iron Ore Project: Report on Geohydrological Investigation as Part of the EMPR.

Dennis et al. 2012. Climate Change Vulnerability Index for South African Aquifers, Water SA.

Parsons, R. (1995). A South African Aquifer System Management Classification. WRC Report KV 77/95, Water Research Commission, Pretoria.

PGS Heritage, 2013. Coza Iron Ore Project.

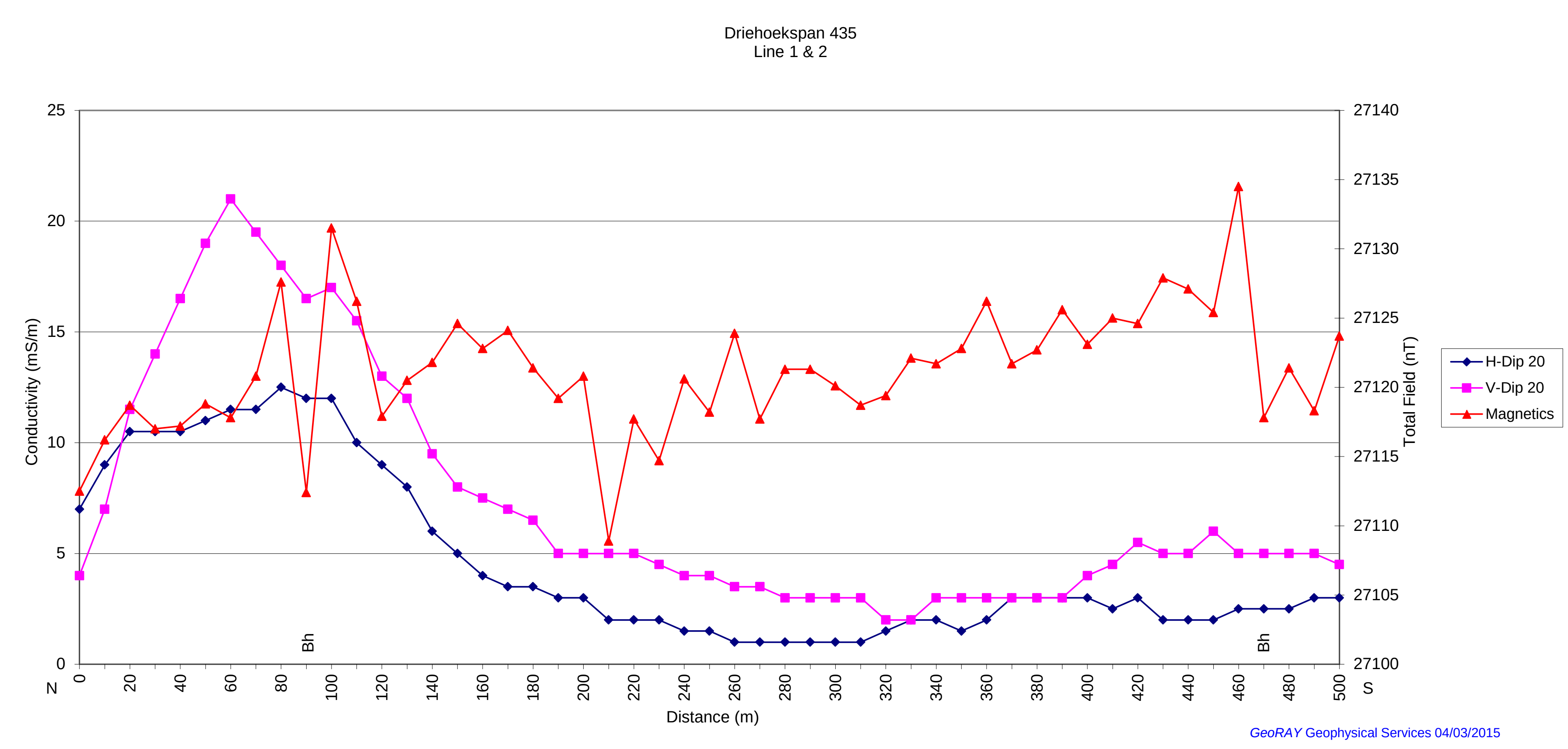
The South African Bureau of Standards (SABS), ISO 5667-1 to 5667-15, First Edition, 1999.

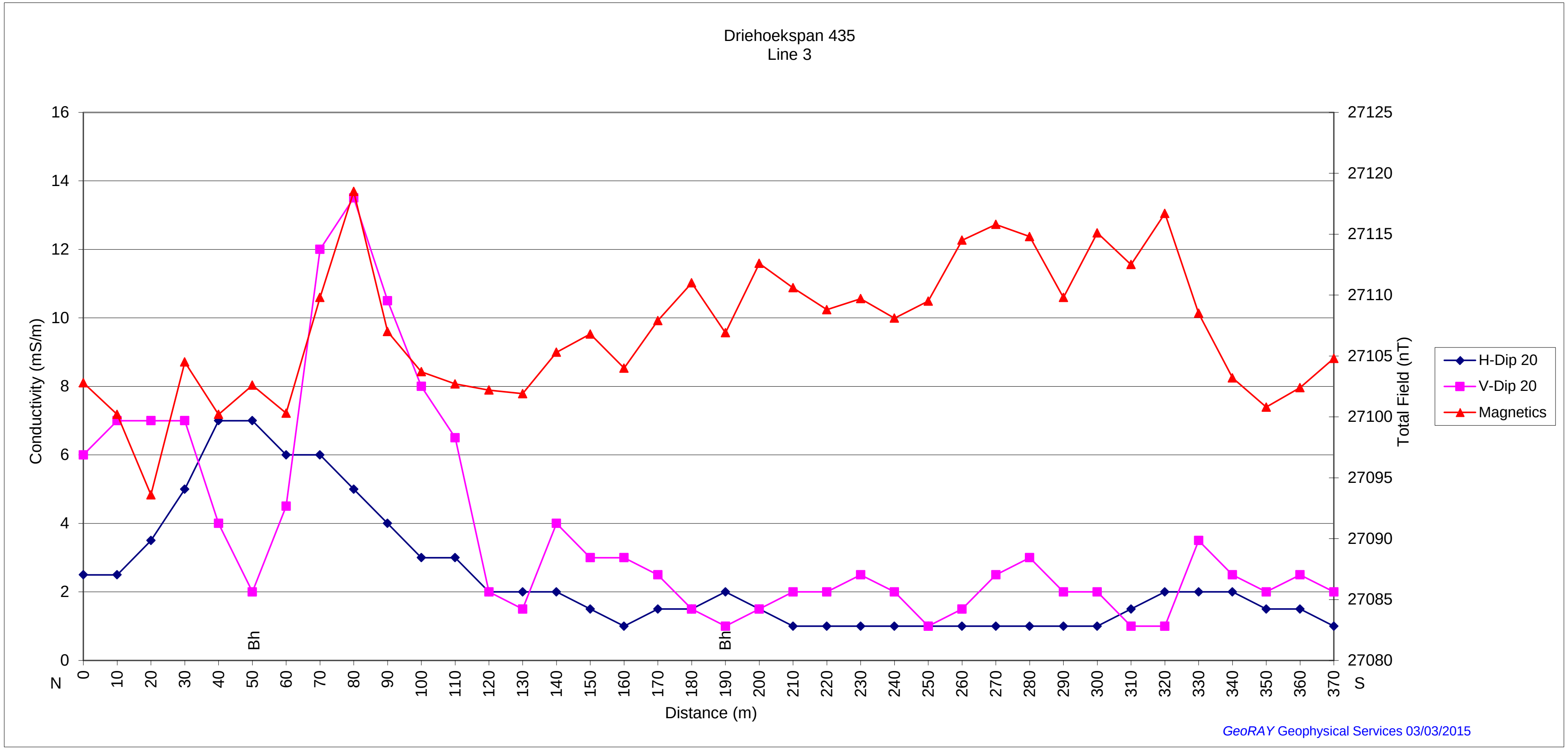
Van Tonder G, Bardenhagen I, Riemann K, van Bosch J, Dzanga P, Xu, Y,. 2001. Manual on pumping test analysis in fractured-rock aquifers, Part A3, IGS.

Van Tonder, G.J. and Kirchner, J. (1990). Estimation of Natural Groundwater Recharge in the Karoo Aquifers of South Africa. J. Hydrol., Vol. 121, pp 395-419.

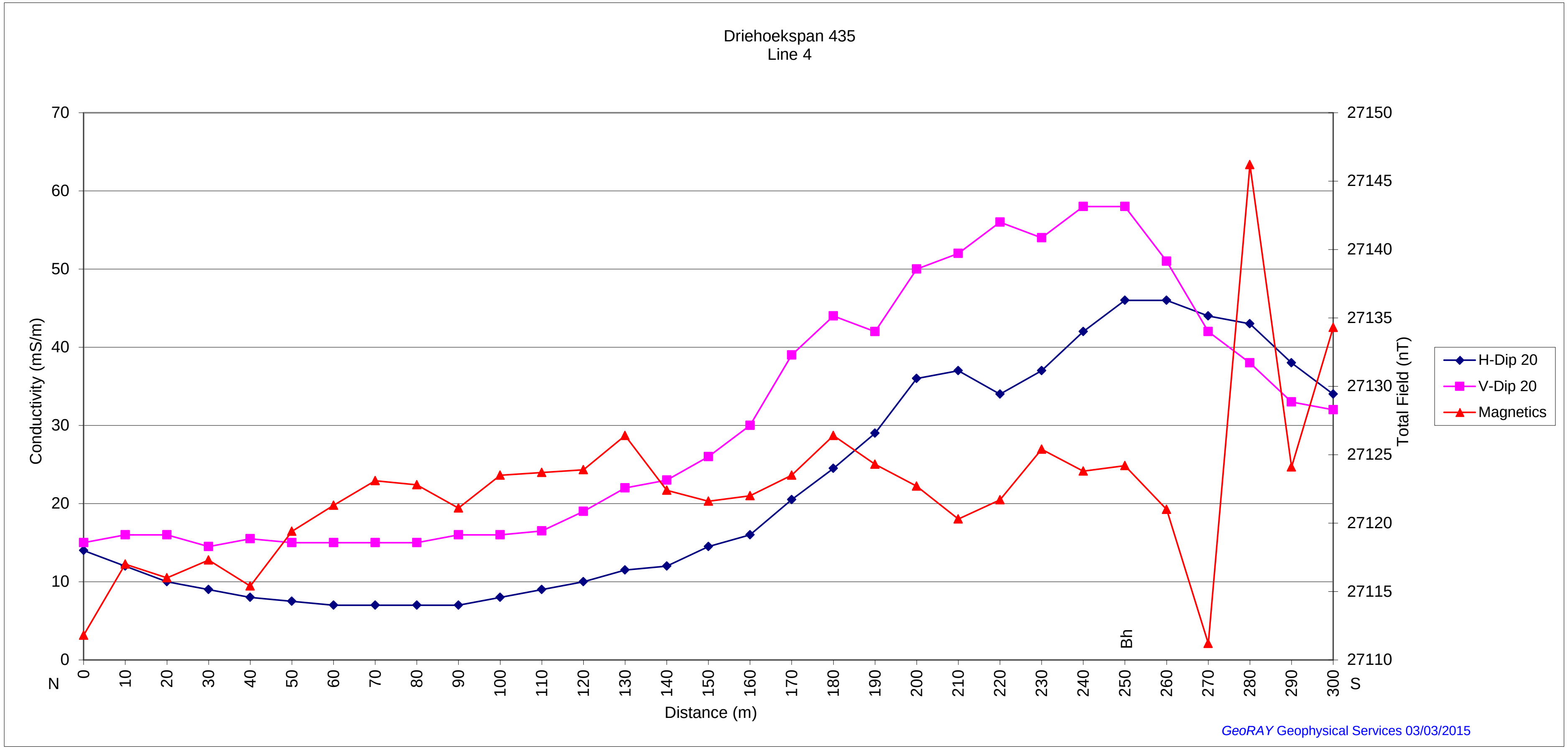
6 APPENDIX A: HYDROCENSUS REPORT

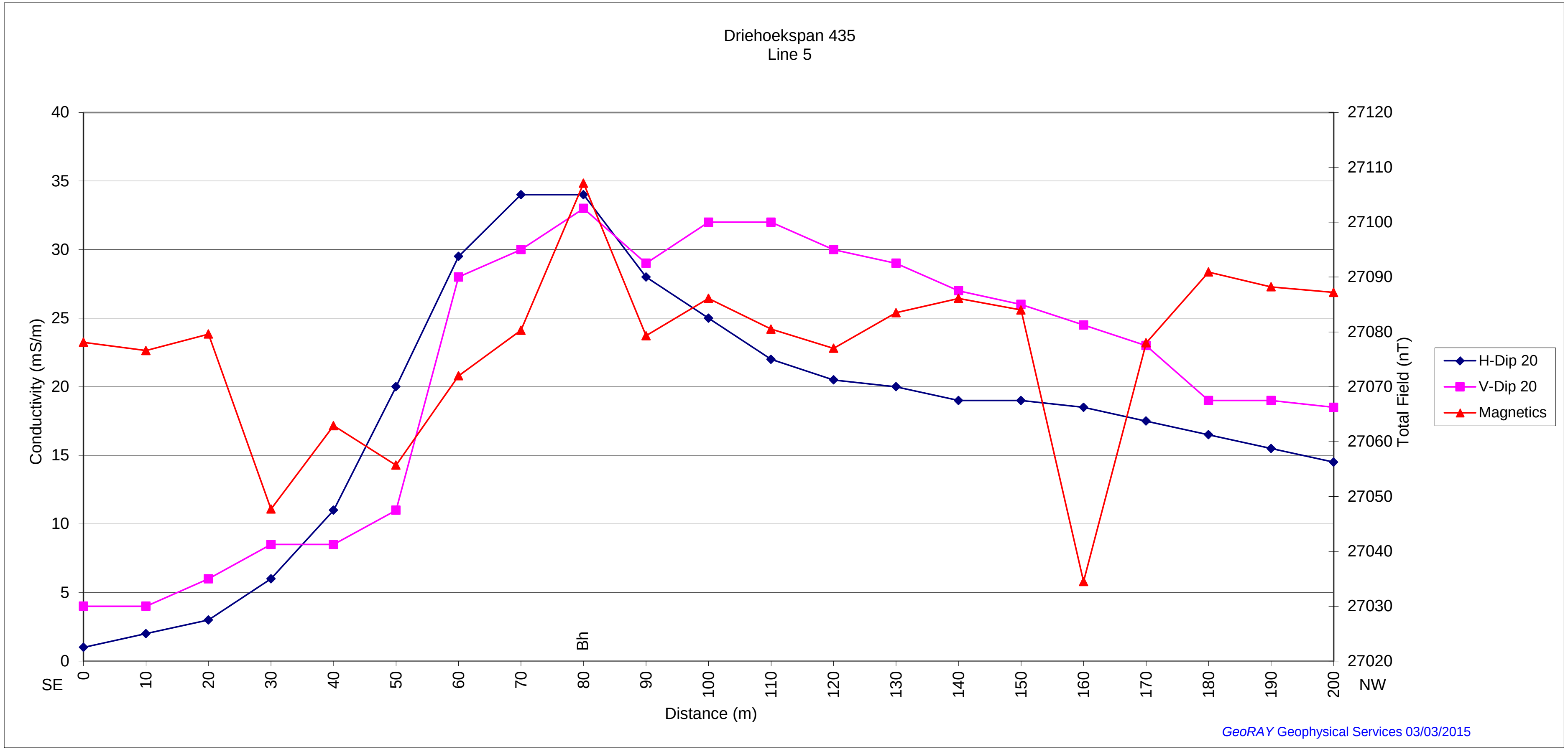
7 APPENDIX B: GEOPHYSICAL LINE SURVEY GRAPHS



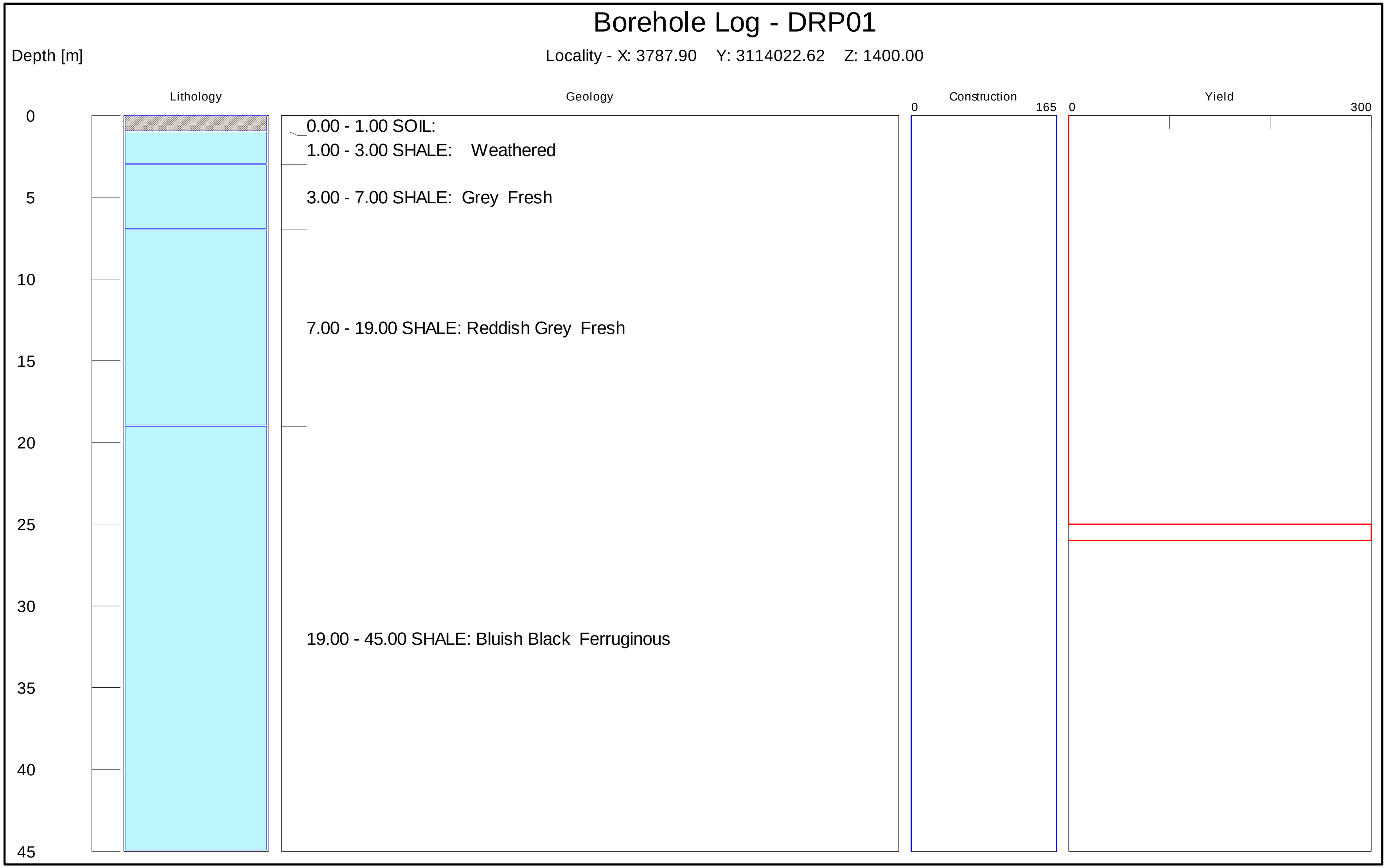


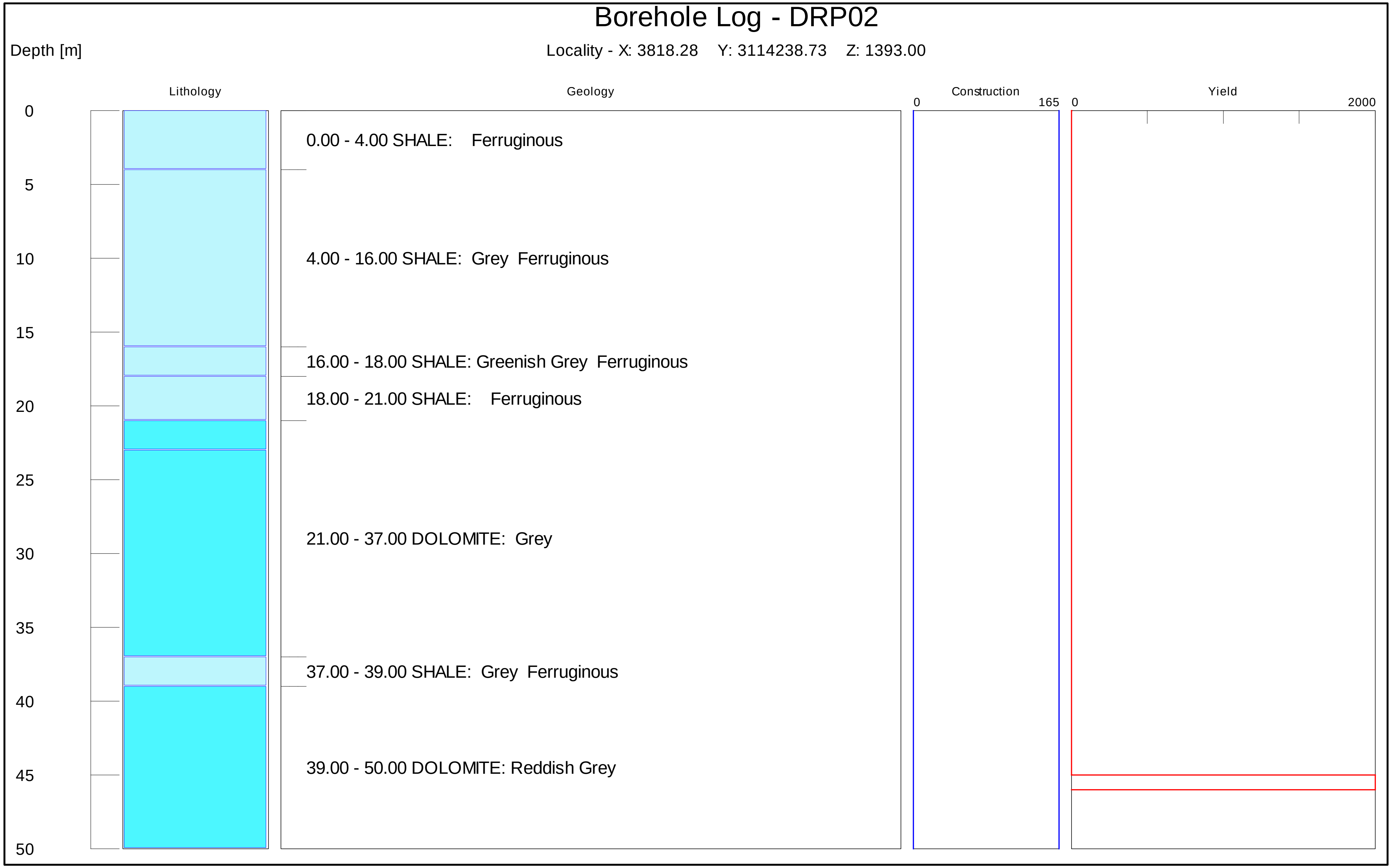
Driehoekspan 435
Line 3
Conductivity (mS/m)
Total Field (nT)
Distance (m)
N
S
Bh
Bh
H-Dip 20
V-Dip 20
Magnetics
GeoRAY Geophysical Services 03/03/2015

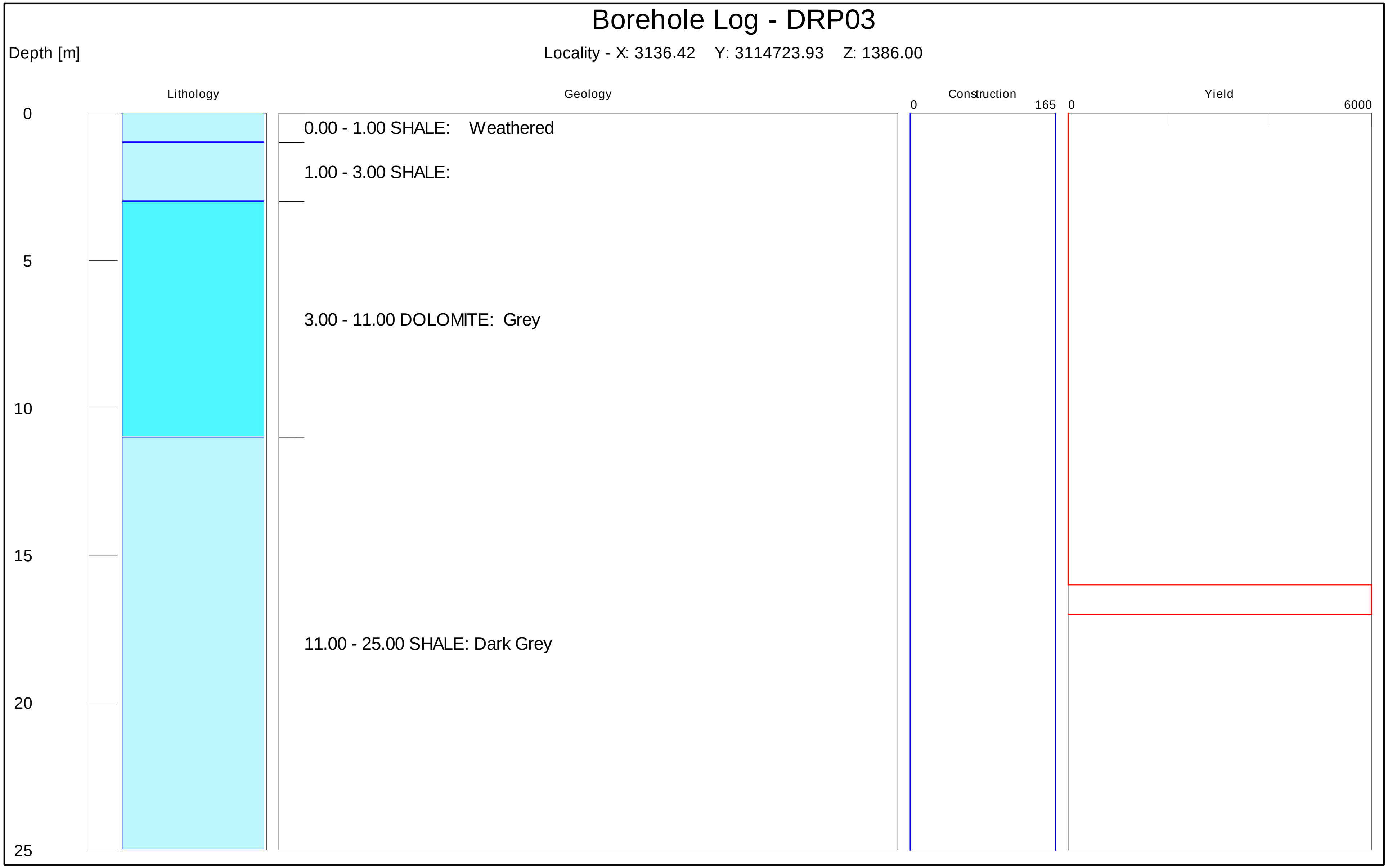

Driehoekspan 435
Line 4
Conductivity (mS/m)
Total Field (nT)
Distance (m)
N
S
Bh
H-Dip 20
V-Dip 20
Magnetics
0
10
20
30
40
50
60
70
27110
27115
27120
27125
27130
27135
27140
27145
27150
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300
GeoRAY Geophysical Services 03/03/2015


Driehoekspan 435
Line 5
Conductivity (mS/m)
Total Field (nT)
Distance (m)
SE
NW
Bh
0
5
10
15
20
25
30
35
40
27020
27030
27040
27050
27060
27070
27080
27090
27100
27110
27120
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
H-Dip 20
V-Dip 20
Magnetics
GeoRAY Geophysical Services 03/03/2015

8 APPENDIX C: MONITORING BOREHOLES LOGS



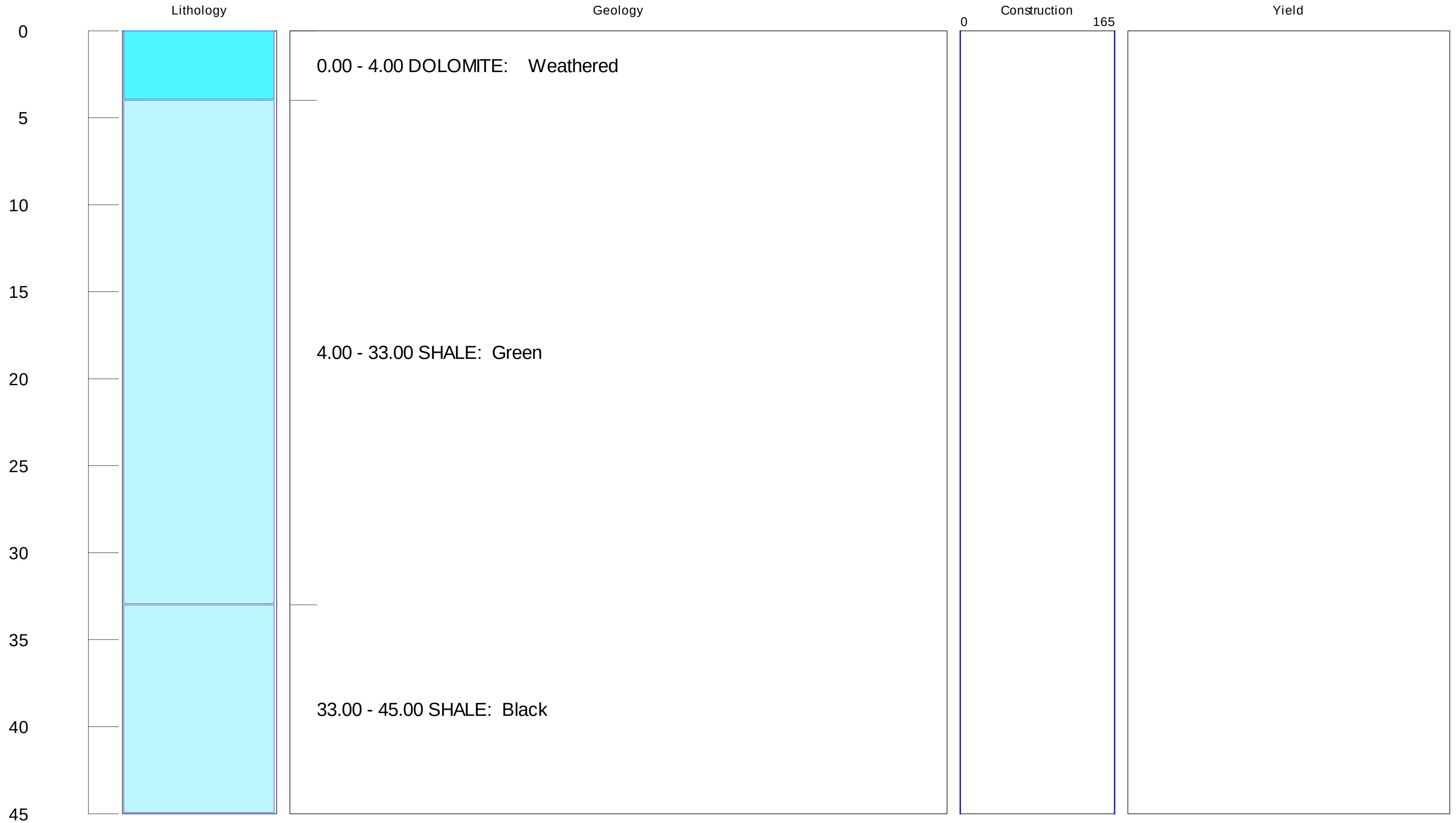

Borehole Log - DRP02
Depth [m]
Locality - X: 3818.28 Y: 3114238.73 Z: 1393.00
Lithology
Geology
Construction
0
165
Yield
0
2000
0
5
10
15
20
25
30
35
40
45
50
0.00 - 4.00 SHALE: Ferruginous
4.00 - 16.00 SHALE: Grey Ferruginous
16.00 - 18.00 SHALE: Greenish Grey Ferruginous
18.00 - 21.00 SHALE: Ferruginous
21.00 - 37.00 DOLOMITE: Grey
37.00 - 39.00 SHALE: Grey Ferruginous
39.00 - 50.00 DOLOMITE: Reddish Grey


Borehole Log - DRP03
Depth [m]
Locality - X: 3136.42 Y: 3114723.93 Z: 1386.00
Lithology
Geology
Construction
0
165
Yield
0
6000
0
5
10
15
20
25
0.00 - 1.00 SHALE: Weathered
1.00 - 3.00 SHALE:
3.00 - 11.00 DOLOMITE: Grey
11.00 - 25.00 SHALE: Dark Grey

Borehole Log - DRP04

Depth [m]

Locality - X: 2715.03 Y: 3114708.31 Z: 1379.00



Groundwater Complete

PO Box 448; Riversdale; 6670
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E-mail: gcomplete@outlook.com

1 December 2015

Miss Zama Khumalo
SLR Consulting

ASSESSMENT OF POTENTIAL GROUNDWATER LEVEL IMPACTS ASSOCIATED WITH THE ABSTRACTION OF GROUNDWATER FOR DOMESTIC AND MINE USE

1 INTRODUCTION AND SCOPE OF WORK

Groundwater Complete was contracted by Synergistics Environmental Services (Pty) Ltd to conduct a geohydrological study and report on findings as specialist input to the Environmental Impact Assessment (EIA) and Environmental Management Program (EMP) for the proposed Coza Driehoekspan Iron Ore Project (hereinafter referred to as Driehoekspan Project). After the completion of the study a decision was made by Coza management to source the water required for the Driehoekspan Project from an onsite borehole. This borehole was also used during the early exploration phase to supply the diamond drills with water. Groundwater Complete also performed a 12 hour aquifer test (pump test) on the borehole and the results indicated that it might be capable of yielding significant volumes of groundwater.

Groundwater Complete was consequently requested by Synergistics Environmental Services to assess the potential groundwater level impacts associated with the planned abstraction of groundwater from the said borehole.

2 POSITION OF BOREHOLE AND PLANNED ABSTRACTION RATES

The planned abstraction borehole is located directly west of the planned stormwater dam and north of the planned waste rock dump. The position of the borehole is indicated in **Figure 1**, while relevant borehole information and planned abstraction rates are also provided in **Tables 1** and **2** respectively.

From year 1 to 4 a total volume is 2 416 m^3/month is required for domestic and mine related use. This volume is planned to decrease to 1 961 m^3/month in year 5 and then again to 1 809 m^3/month in the sixth and final year.

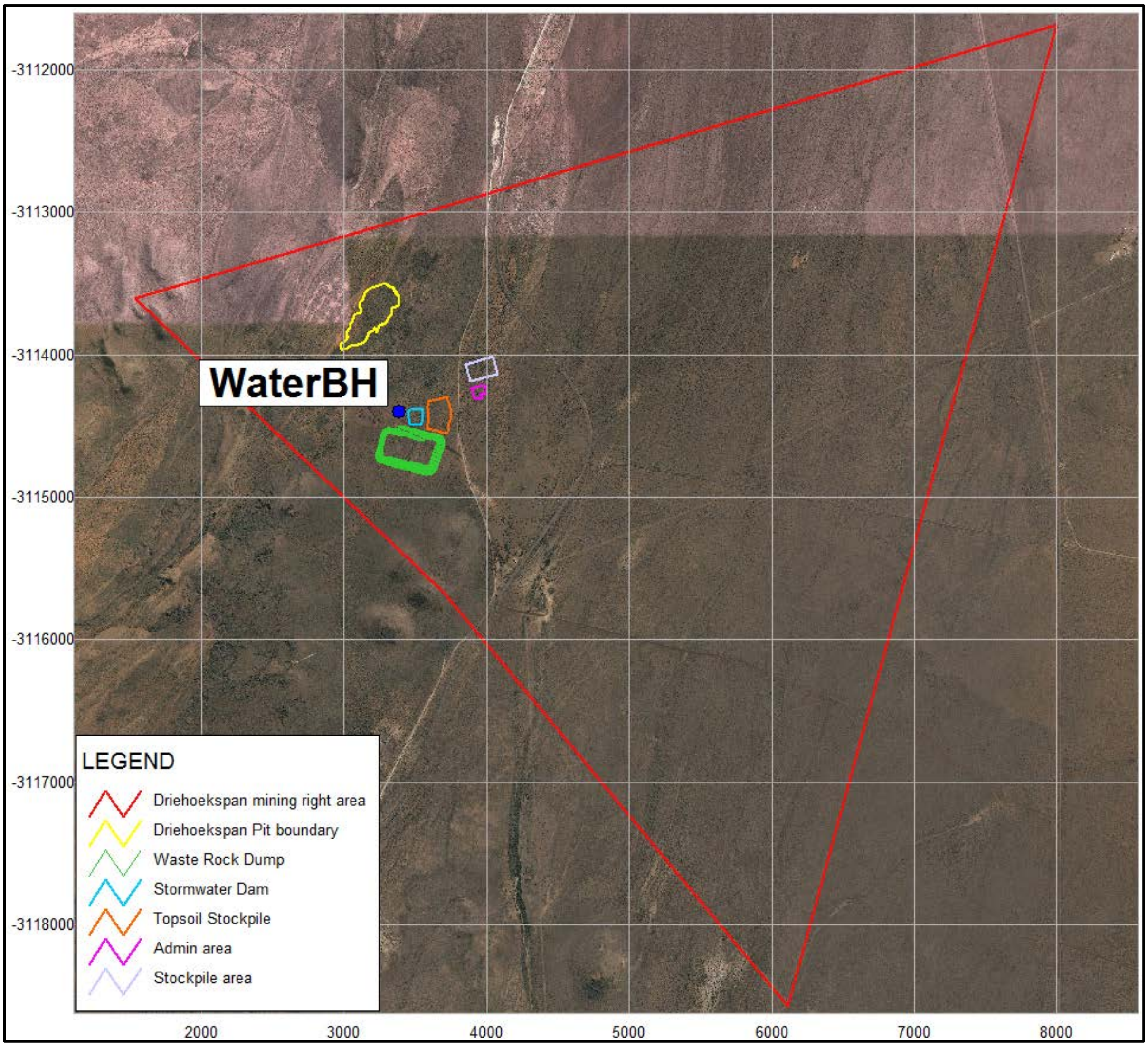


Figure 1: Position of planned abstraction borehole

Table 1: General borehole information

BH	Coordinates *(WGS 84)*		Elevation (mamsl)	Depth (mbs)	Water strike (mbs)	Water level (mbs)
	South	East				
WaterBH	-28.14399	23.03446	1389	50	30	11.7

Table 2: Planned abstraction rates

Year	Rate (m^3/month)	Rate (m^3/day)	Rate (l/s)
1	2 416	81	0.9
2	2 416	81	0.9
3	2 416	81	0.9
4	2 416	81	0.9
5	1 961	65	0.8
6	1 809	60	0.7

3 ASSESSMENT OF POTENTIAL GROUNDWATER LEVEL IMPACTS

The planned abstraction of groundwater will most certainly cause local groundwater levels to decrease. The extent of impacts (cone of depression or radius of influence) was calculated mathematically with the following equation:

$$R(t) = 1.5(Tt/S)^{1/2}$$

Where *R* = *Radius (m),*
T = *Aquifer transmissivity* (m^2/d)*,*
t = *Time (days),*
S = *Storativity.*

From the above equation it is made clear that aquifer transmissivity and storativity, as opposed to the actual pump rate, will determine the extent of impacts. The pump rate on the other hand plays an important role in determining the amount of drawdown expected in the pump borehole and the surrounding aquifer at any given distance *(Cooper-Jacob)*. The concept of a drawdown cone is illustrated in **Figure 2**.

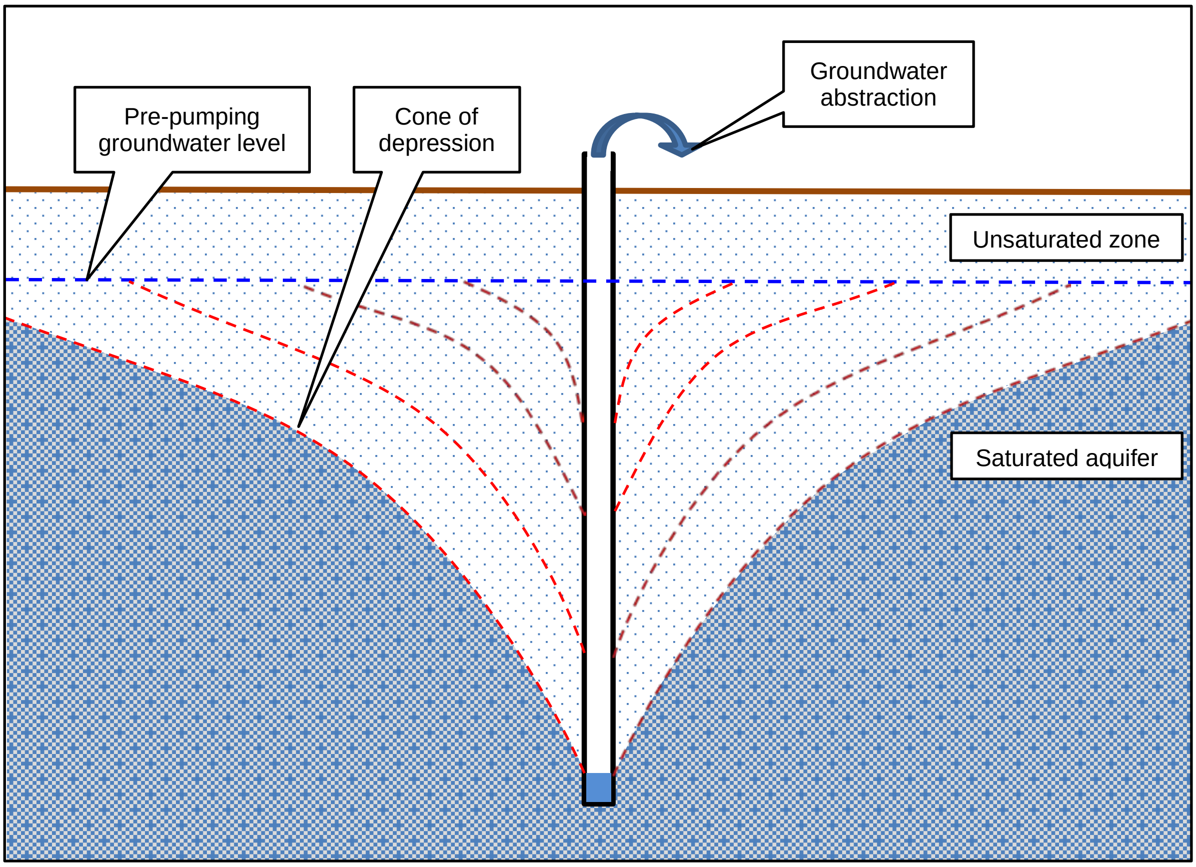


Figure 2: Cross section through typical drawdown cone

The radius of influence and drawdown expected were calculated mathematically and the results are provided in **Table 3**. The conceptual extent of the depression cone is also indicated in **Figure 3**.

Table 3: Analytical calculated radius of influence and predicted drawdown

Year	Predicted drawdown in borehole	Radius of influence (m)	Affected area (km^2)
1	13.4	500	0.8
2	16.2	660	1.4
3	17.9	810	2.1
4	19.2	930	2.7
5	17.6	1040	3.4
6	17.1	1140	4.1

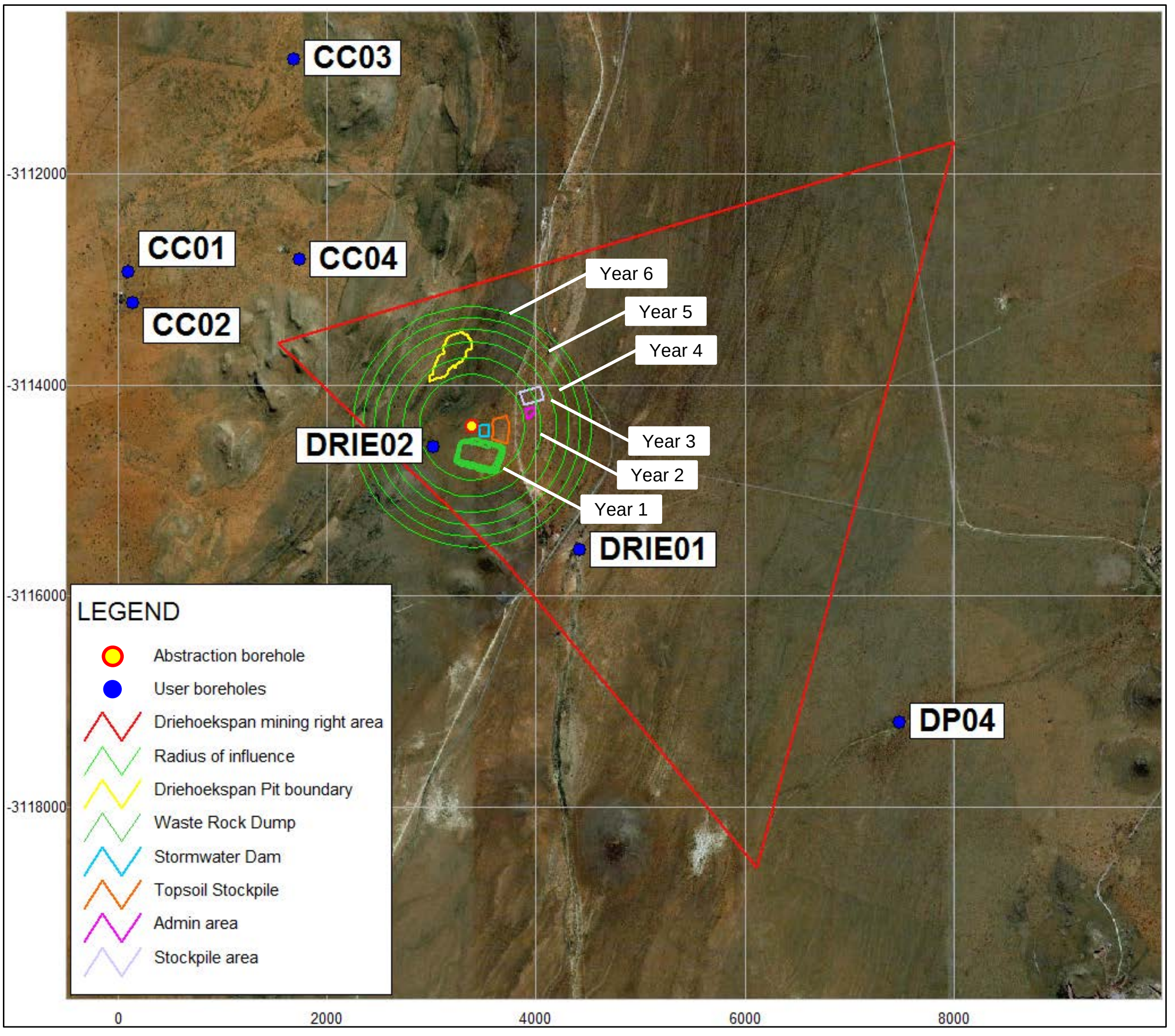


Figure 3: Estimated extent of groundwater level impacts

An area of approximately 4.1 km^2 was estimated to be affected by the planned groundwater abstraction at the end of year 6 **(Table 2)**. One user borehole is located within the expected area of influence, namely DRIE02 **(Figure 2)**. The predicted drawdown in this borehole is however low and in the order of 2 meters. Water level drawdown in the pump borehole was estimated to be approximately 19 meters at the end of year 4 and ± 17 meters at the end of year 6.

Please note that the shape and extent of the depression cone is entirely dependent on the hydraulic properties of the aquifer host rock and geological structures (as illustrated with the earlier formula). No structural geological information is however available, which is considered to be a significant shortcoming. The radius of influence as indicated in **Figure 2** represents a homogeneous aquifer system, which is certainly not the case at Driehoekspan and should be re-assessed once more information becomes available.

Gerhard Steenekamp

Groundwater Complete

PO Box 448

Riversdale

6670

0844091429

4 December 2015

DRIEHOEKSPAN GROUNDWATER IMPACT ASSESSMENT: SPECIALIST REPORTING REQUIREMENTS AS PER APPENDIX 6 OF THE EIA REGULATIONS 2014

This letter has been prepared to report on the compliance of Gerhard Steenekamp (Groundwater Complete) as part of the specialist reporting requirements listed in Appendix 6 of the Environmental Impact Assessment Regulations, 2014 from the National Environmental Management Act, 1998 (Act no. 107 of 1999).

1.(a)(i) Details of the specialist who prepared the report

Please refer to cover page of report for specialist information.

1.(a).(ii) The expertise of that specialist to compile a specialist report including a curriculum vitae

Company of Specialist:	Groundwater Complete		
Name / Contact person:	Gerhard Steenekamp		
Postal address:	PO Box 448, Riversdale		
Postal code:	6670	Cell:	0844091429
Telephone:	0844091429	Fax:	086-6950191
E-mail:	gcomplete@outlook.com		
Qualifications	M.Sc. Geohydrology		
Registration / Associations	Pr.Sci.Nat.(400385/04)		

1.(b) a declaration that the specialist is independent in a form as may be specified by the competent authority

I, Gerhard Steenekamp, 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 relevant legislation and any guidelines that have relevance to the proposed activity;
- I will comply with the 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.

Signature of the Specialist

1.(c) an indication of the scope of, and the purpose for which the report was prepared

Please refer to Section 1 in the report.

1.(d) the date and season of the site investigation and the relevance of the season to the outcome of the assessment

Site visit/investigation
Date: May 2013
Season: Summer
Relevance of the season to the outcome of the assessment: Season of groundwater study has insignificant influence on outcome of study.

1.(e) A description of the methodology adopted in preparing the report or carrying out the specialised process

Driehoekspan groundwater study

Please refer to Sections 1.1 and 1.2.1 in the report.

1.(f) The specific identified sensitivity of the site related to the activity and its associated structures and infrastructure

Please refer to Sections 1.3 and 1.4 in the report.

1.(g) An identification of any areas to be avoided, including buffers

Not applicable to groundwater study.

1.(h) A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers

Not applicable to groundwater study.

1.(i) A description of any assumptions made and any uncertainties or gaps in knowledge

Please refer to Sections 1.2.2.4, 1.2.2.5 and 3.3.1 in the report.

1.(j) A description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives on the environment

Please refer to Sections 2 and 3 in the report.

1.(k) Any mitigation measures for inclusion in the EMPR

Please refer to Section 2 in the report.

1.(l) Any conditions for inclusion in the environmental authorisation

Please refer to Section 2 in the report.

1.(m) Any monitoring requirements for inclusion in the EMPr or environmental authorisation

Please refer to Section 4 in the report.

1.(n)(i) A reasoned opinion as to whether the proposed activity or portions thereof should be authorised

Please refer to Sections 2 and 3 in the report.

1.(n)(ii) A reasoned opinion if the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan

Please refer to Sections 2 and 4 in the report.

1.(o) A description of any consultation process that was undertaken during the course of preparing the specialist report

Consultation with interested and affected parties was undertaken as part of the environmental impact assessment and environmental management program process conducted by SLR Consulting (Africa) (Pty) Ltd.

1.(p) A summary and copies of any comments received during any consultation process and where applicable all responses thereto

Comments and responses that were raised by interested and affected parties are included in the issues table, an Appendix of the EIA report.

1.(q) any other information requested by the competent authority

No.

If you have any queries regarding the above, please do not hesitate to contact me.

Yours Sincerely.

Gerhard Steenekamp

Consulting geohydrologist (Pr.Sci.Nat)

Plot 9; Riversdale; 6670
Phone: +2784 409 1429
E-mail: gcomplete@outlook.com

To Whom It May Concern

December, 2015

Dear Madam/Sir

<u>COMPANY PROFILE FOR GROUNDWATER COMPLETE AND CV'S OF PERSONNEL</u>

Groundwater Complete CC is a closed corporation with the main aim of providing personalized and professional groundwater consulting services to industry. We are classified as a micro enterprise. We consider our limited size to be a competitive advantage since we can deliver services on a personalized level, with a quick and direct approach to obtain practical results.

Groundwater Complete provides a high quality and competitive consulting service in all fields of geohydrology, including:

- groundwater supply and sustainable supply network design and operation,
- groundwater flow and pollution studies and management plans,
- mine dewatering design and simulation studies.
- groundwater impact assessments and management plans for proposed and existing developments.

All of the above is supported, where necessary, by numerical modeling after postulating a conceptual model as a sound basis for simulation.

We network with various other specialists in the industry and obtain expertise where necessary in aspects such as high level geochemistry and geochemical modeling, hydrocarbon clean-up and management etc.

Groundwater Complete was founded in October 2008 but the senior geohydrologist has been in consulting for nearly 20 years. The CV and experience of the senior consulting geohydrologist of Groundwater Complete will be provided where necessary, namely that of **Gerhard Steenekamp** (B.Sc Honns, M.Sc Geohydrology, *Pr.Sci.Nat*).

Gerhard Steenekamp was up to March 2009 the managing member and geohydrologist of **Clean Stream Groundwater Services** and was previously the **Principal, Geohydrology: Kumba Resources**.

The academic and work experience of Gerhard Steenekamp, who manages and oversees all groundwater studies is provided below.

<u>Academic Record Summary:</u>

Institution	Time/Period	Qualification
Warm Baths High School	1985-1989	Standard 10
P.U for CHE	1990-1992	B.Sc. Degree: Geology, Chemistry and Soil Science
P.U for CHE	1993	B.Sc. Honors Degree: Geology
UFS	1996-1997	M.Sc. Degree: Geohydrology (Cum Laude)

Work Experience:

Period	Position
1994	**Mine Geologist in training – Sishen Iron Ore Mine**
Work as a mine geologist in training exposed to all aspects of mining geology, including mine exploration drilling, pit mapping and planning, geotechnical engineering and geological databases and modeling.	
1995	**Exploration Geologist in training – Northern Cape VMS project**
Work as an exploration geologist in training exposed to most aspects of exploration geology, including structural and lithological mapping, sampling, camp administration, lithogeochemical sampling and interpretation and target generation.	
1996	**Full-time study: M.Sc. Geohydrology**
1997	**Geologist/Geohydrologist – Thabazimbi iron ore mine**
Manage all aspects of geohydrology at the mine, including mine and plant water supply, underground mine and open pit dewatering, aquifer testing as well as groundwater pollution management and mitigation. Also concerned with geological exploration drilling, logging and profiling.	
1997-1999	**Consulting Geohydrologist – Iscor Mining Consulting Services**
Geohydrological consultant for all Iscor Mining and Steel projects. Provide consulting service in all aspects of geohydrology. Perform 2- and 3-dimensional numerical modeling for groundwater flow and mass transport on numerous projects (Vanderbijlpark Steel Works, Thabazimbi Mine, Sishen Mine, Rosh Pinah Mine etc). Modeling work included more than five open pit dewatering models and some underground mine modeling exercises for different purposes. Modeling was also done to determine the long term yield capabilities of a number of different aquifer types, ranging from quartzite-shale-basalt to primary alluviums and banded iron formation-dolomite type aquifers. Groundwater pollution (mass transport) modeling was also performed on a number of projects.	
2000-2002	**Principal Geohydrologist – Iscor Corporate Business Development**
Manage the total geohydrology function in Iscor. Manage all groundwater related projects as well as a number of other projects like water optimization, re-use and treatment options. Perform whole range of geohydrological modeling where necessary, create or update dewatering strategies or groundwater pollution mitigation plans. Perform due diligence and feasibility studies as well as geohydrological risk assessments and dewatering designs on new projects, mostly outside the borders of the RSA. Modeling and related studies done at Group West (DRC), Kipushi Zinc (DRC) and Suzdal Gold (Kazakstan).	

2002-2004	**Principal Geohydrologist – Kumba Resources**
Geohydrological consultant. Provide consulting service in all aspects of geohydrology. Perform 2- and 3-dimensional numerical modeling for groundwater flow and mass transport on numerous projects. Perform geohydrological risk and impacts assessments and groundwater studies as part of EMPR investigations. Provide groundwater consulting service to the whole spectrum of geohydrological related projects. List of projects as consultant/modeler include, among others, Sishen Iron Ore Mine, Sishen South and Beeshoek Project (Postmasburg), Grootegeluk Coal, Xstrata Coal Tweefontein Collieries, De Beers Kimberley Mines, BRPM Platinum, Rosh Pinah Zinc, Black Mountain Zinc, Zincor Refinery, Kalbasfontein, Woestalleen and Stuart Collieries. Numerical models varied in purpose; from impact assessment tools, dewatering design models, recharge/discharge calculations, concept visualization tools to mine closure simulation models and water supply evaluation models.	
2004-2009	**Consulting Geohydrologist and Managing Member – Clean Stream Groundwater Services**
Geohydrological consultant (Pr.Sci.Nat. no. 400385/04). Provide consulting service in all aspects of geohydrology. Perform 2- and 3-dimensional numerical modeling for groundwater flow and mass transport on numerous projects. Perform geohydrological risk and impacts assessments and groundwater studies as part of EMPR investigations. Provide groundwater consulting service to the whole spectrum of geohydrological related projects, from groundwater supply, management plans, monitoring, interpretation, groundwater quality management and remediation of groundwater pollution. Regular reporting on groundwater and surface water quality characteristics and impacts on the environment. List of clients include, among others: Coal mining sector: Anglo American Coal, Xstrata Coal South Africa, SASOL, Stuart Colliery, Exxaro Leeuwpan, Tshikondeni, Inyanda Coal. Iron Ore mining: Sishen Iron Ore Mine, Sishen South, Thabazimbi. Base Metal mines: Rosh Pinah Zinc, Zincor. Platinum mining: Amplats Rustenburg Section, Twickenham, BRPM, Northam Platinum, Aquarius (Marikana, Kroondal). Chrome mines: Samancor Chrome (Buffelsfontein, Mooinooi, Millsel), Xstrata Chrome(Waterval, Kroondal). Diamond mines: De Beers Geology, De Beers Kimberley Mines, Virginia Diamond Fields.	

2009-present	Senior Consulting Geohydrologist - Groundwater Complete

Conduct the same work as in Clean Stream Groundwater Services but with an extended client base to other consultancies (e.g. Shangoni Management Services, Jacana Environmental, Menco), mine groups and industries.

Coal mining sector:
Anglo American Coal (Landau, Landau LEP, Kromdraai, Greenside, Kleinkopje, New Denmark), Glencore (Zonnebloem, Verkeerdepan, Elandspruit, Witbank Section: Goedgevonden, Oogiesfontein, Tweefontein Optimization, Tweefontein South), SASOL (Block 2 Project and Mahemsfontein Extension), Stuart Colliery – East, Weltevreden and South Block, Exxaro (Grootegeluk, Leeuwpan, Tshikondeni, Belfast, Blackhill, Inyanda Coal), Northern Coal (Hartbeesfontein), Delta Mining (Rietkuil), Optimum Colliery (Vlakfontein, Overvaal), Siphete Coal (Paardeplaats, Droogvallei), BECSA – Leandra Coal, Vandyksdrif Colliery.

Iron Ore mining:
Sishen Iron Ore Mine, Sishen South (Kolomela), Thabazimbi Iron Ore Mine, Aquila Steel (Meletsi Project), AEMR Kassinga iron ore projects: Jamba, Cateruca, Tchamutete, Kassala, Kitungo, Coza Iron Ore – Doornpan, Driehoekspan and Jenkins.

Base and Precious Metal mines:
Rosh Pinah Zinc, Zincor, Harmony Gold (Welkom Uranium), Gold One, Chemwes

Platinum mining:
Anglo Platinum (Rustenburg Section, Twickenham, BRPM, Amandelbult, Union), Northam Platinum, Aquarius Platinum (Marikana, Kroondal, Everest, Blue Ridge), Lonmin (Rustenburg area).

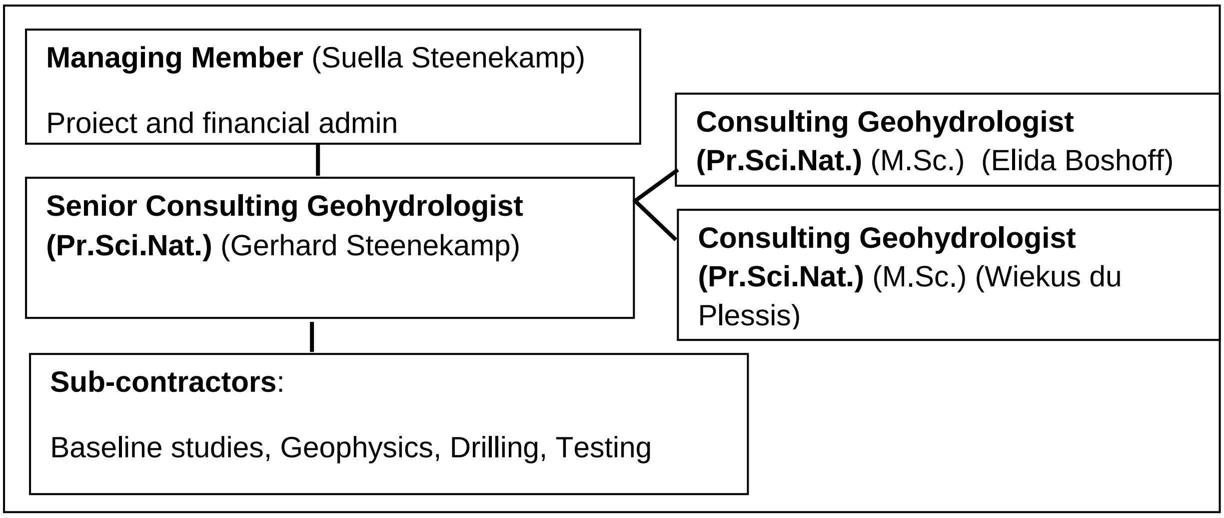
Chrome mines:
Samancor Chrome (Buffelsfontein, Mooinooi, Millsel), Xstrata Chrome (Waterval, Kroondal, Boshoek, Union), Assmang (Dwarsrivier), Sefateng Chrome (Zwartkoppies/Waterkop).

Diamond mines:
DeBeers (Geology, Kimberley Mines, Voorspoed, Lace) Virginia Diamond Fields, Petra Diamonds (Koffiefontein, Kimberley, Cullinan, Star).

Power Generation:
Kelvin Power, Eskom (Medupi Power Station).

Where necessary, we contract with a long-established network of reliable and professional people who knows the mining environment and can work independently while providing a product of high quality.

At present, the company structure is limited and simple and allow for personal service to the client and high flexibility should it be required. The company organogram is provided below.



The summarized CV's of the two other consulting geohydrologists are provided below.

Curriculum Vitae for Elida Boshoff

Academic Record Summary:

Institution	Time/Period	Qualification
Generaal Hertzog High School	1999 - 2003	Grade 12
University of Pretoria	2004 - 2007	B.Sc. Degree: Earth Science
University of the Free State	2008	B.Sc. Honors Degree: Geohydrology
University of the Free State	2011	M.Sc. Geohydrology

Work Experience:

Period	Position
2008	**Geohydrologist in training**
Work as a geohydrologist in training and exposed to most aspects of geohydrology, including fieldwork (hydrocensus/user survey, borehole drilling, groundwater sampling and water level measurements, aquifer/pump testing), processing of data (Wish, Aquitest, FC-Program, etc), numerical modeling and report writing (EIA, EMPR, etc.).	
2009 - Present	**Consulting Geohydrologist for Groundwater Complete CC**
Provide consulting service in all aspects of geohydrology. Perform 2- and 3-dimensional numerical modeling for groundwater flow and mass transport on numerous projects. Perform geohydrological risk and impacts assessments and groundwater studies as part of EMPR investigations. Provide groundwater consulting service to the whole spectrum of geohydrological related projects, from groundwater supply, management plans, monitoring, interpretation, groundwater quality management and remediation of groundwater pollution. Regular reporting on groundwater and surface water quality characteristics and impacts on the environment. List of clients include, among others: Coal mining sector: Xstrata Coal South Africa (Tweefontein, Oogiesfontein Colliery, Witbank Complex (iMpunzi, Witcons, Tweefontein, Zaaiwater), Goedgevonden), Anglo American (Kleinkopje Colliery, Greenside Colliery), Sasol (Impumelelo Shaft), Zululand Antracite Colliery, Stuart Coal, Exxaro (Belfast Colliery), Optimum Coal Holdings (Vlakfontein Colliery), Ibutho Coal, BECSA Leandra project, Steenkoolspruit Barrier Pillar – Glencore/BECSA. Dolomite Mining: Exxaro (Glen Douglas) Iron Ore mining: AEMR (Kassinga North and South). Base Metal mining: Exxaro (Zincor). Platinum mining: Aquarius (Kroondal, Marikana), Anglo Platinum Mines (Rustenburg Mines), Northam Platinum Limited (Northam Platinum Mine). Chrome mining: Samancor Chrome and Western Chrome, Xstrata Chrome Waterval, Xstrata Chrome	

Rustenburg, Assmang Chrome Dwarsrivier. Diamond mining: De Beers Kimberley Mines. Power Generation: ESKOM (Medupi Power Station), Kelvin Power Station.

Curriculum Vitae for Wiekus du Plessis

Academic Record Summary:

Institution	Time/Period	Qualification
Die Adelaar High School	2000 - 2004	Grade 12
University of Johannesburg	2005 - 2007	B.Sc. Degree: Geology and Geography
University of the Free State	2008	B.Sc. Honors Degree: Geohydrology
University of the Free State	2009 - 2010	M.Sc. Degree: Geohydrology

Work Experience:

Period	Position
2008	**Geohydrologist in training**
Work as a geohydrologist in training and exposed to most aspects of geohydrology, including fieldwork (hydrocensus/user survey, borehole drilling, groundwater sampling and water level measurements, aquifer/pump testing), processing of data (Wish, Aquitest, FC-Program, etc), numerical modeling and report writing (EIA, EMPR, etc.).	
2009 - Present	**Consulting Geohydrologist for Groundwater Complete CC**
Provide consulting service in all aspects of geohydrology. Perform 2- and 3-dimensional numerical modeling for groundwater flow and mass transport on numerous projects. Perform geohydrological risk and impacts assessments and groundwater studies as part of EMPR investigations. Provide groundwater consulting service to the whole spectrum of geohydrological related projects, from groundwater supply, management plans, monitoring, interpretation, groundwater quality management and remediation of groundwater pollution. Regular reporting on groundwater and surface water quality characteristics and impacts on the environment. List of clients include, among others: <u>Coal mining sector</u>: Xstrata Coal South Africa (Verkeerdepan Colliery, Zonnebloem Colliery, Elandspruit Colliery), Anglo Coal (Landau Colliery, New Denmark Colliery), Stuart Coal, Tshikondeni, Coastal Fuels (Droogvallei Colliery, Paardeplaats Colliery), Northern Coal (Hartbeesfontein Colliery), Exxaro (Inyanda Colliery), Optimum Coal Holdings (Overvaal Colliery), Delta Mining Consolidated (Rietkuil Colliery). <u>Iron Ore mining</u>: Anglo American (Kolomela Mine), Coza Iron Ore – Doornpan, Driehoekspan and Jenkins, AEMR Angola projects, Aquila Steel Meletse Project, Scaw Metals. <u>Base Metal mining:</u> Exxaro (Zincor). <u>Platinum mining:</u> Anglo American Platinum (Amandelbult Platinum Mine, Steildrift Platinum Mine, Rustenburg Section), Northam Platinum Limited (Northam Platinum Mine), Royal Bafokeng Mining (Bafokeng Rasimone Platinum Mine), Rustenburg Platinum Mines (Twickenham Hackney Platinum Mine). <u>Chrome mining</u>: Samancor Chrome (Buffelsfontein Chrome Mine), Corridor Mining Resources (Sefateng Chrome	

Mine). <u>Diamond mining:</u> Petra Diamonds, De Beers Geology, De Beers Kimberley Mines. <u>Power Generation</u>: ESKOM (Medupi Power Station), Kelvin power station. <u>Other:</u> Thusasang housing project, Mooiplaas dolomite mine