APPENDIX D

Groundwater Impact Assessment
REPORT

Groundwater Baseline and Impact Assessment Report for the Proposed Metsimaholo Underground Coal Mine Project

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Executive Summary

Golder Associates Africa Pty Ltd (Golder) has been appointed by Seriti Coal (Pty) Ltd (Seriti) to undertake an Environmental Impact Assessment (EIA) for the proposed Metsimaholo underground coal mining project, comprising the proposed development of identified mining areas over various properties situated in the magisterial districts of Heilbron and Sasolburg in the Free State Province. Anglo Operations Proprietary Limited (“AOPL”) was the holder of the prospecting rights granted in terms of Section 17(1) of the Mineral and Petroleum Resources Development Act 28 of 2002 (“MPRDA”). AOPL and Seriti applied in terms of Section 11 of the MPRDA to cede the prospecting rights to Seriti.

The mining right application area is located in the Metsimaholo Local Municipality, Fezile Dabi District Municipality, Free State Province. The nearest towns to the proposed mining shaft complex infrastructure are Refengkgotso to the north-east, and Denysville which lies a further 3km to the east.

The main objectives of the hydrogeological impact study are to:

- Characterise the prevailing groundwater situation,
- Define the water bearing strata in the area,
- Determine current groundwater level distribution and flow directions,
- Determine baseline groundwater quality,
- Assess potential groundwater inflow into the open cast and underground workings, and
- Assess the impact of mining on the groundwater system including quantity and likely quality impacts on existing users, during construction, operational and post-operational phases.

The regional climate in the area is defined by the South African Weather Bureau as moderate and is locally described as warm in summer and cold in winter. The groundwater recharge value is estimated at approximately 6.2 mm per year corresponding to 1 % of the annual precipitation (MAP) of 620 mm. The mean annual S-Pan evaporation (MAE) is 1,625 mm per year (Midely et al 1990). Hence, on average evaporation exceeds precipitation by about 1 000 mm per year.

The geology comprises sedimentary deposits of the Karoo Supergroup, mainly sandstone, mudstone, siltstone and shale with thin layers of coal. The sequence dips towards the south-south-east. Intrusive dolerite sills and dykes dominate the structural setting with minor faulting reported.

The groundwater systems in the study area are described as a complex multi-level aquifer system that is already affected by various existing activities (i.e. defunct underground mines, domestic and agricultural groundwater abstraction).

The shallow (upper) aquifer has been intersected in most boreholes drilled during the baseline investigation even if no or low measurable water strikes were recorded. Groundwater occurrence in the shallow water bearing horizon is controlled by the degree and depth of weathering of the underlying Karoo lithologies and alluvium deposits along drainages with their associated flood plains.

The deep water bearing horizon is controlled by the lateral and vertical distribution of the deeper fractures within the shale, sandstone and coal beds as well as the contact zones with dolerite sill and dyke intrusions. Only some exceptions of elevated yields were obtained during the drilling of boreholes into the deep aquifer. For the most part water interceptions were very low yields suggesting the presence of a localised poorly
developed anisotropic deeper aquifer. These intersections were typically made in the sandstone located close to the upper coals seam (TMH). Mixing of the upper and lower aquifer can occur where there is no dolerite sill present or in defunct underground workings.

A baseline groundwater assessment was completed in July 2010. A conceptual hydrogeological model and consequently a groundwater numerical model was constructed for the New Vaal Lifex Project (Block 1 and Vaalbank) to the north of the proposed Metsimaholo mining right application area by Golder in 2012. The current baseline studies and conceptual and numerical groundwater model rely heavily on the information gathering and interpretation undertaken in those previous studies.

Current model simulations included steady state calibration and the transient simulations up to 200 years post-closure. The numerical modelling results show that the most significant impacts on the groundwater systems are related to dewatering of the proposed Metsimaholo underground mine. Due to the low permeability of the host rock formation the water level decline is rapid will impact an area of up to 0.5 - 2 km from the of underground mining activity limits in the shallow aquifer. There are groundwater users that depend on the groundwater as a resource. Therefore monitoring of groundwater levels is also critical to ascertain how affected groundwater users may be compensated for losses of groundwater related to the mining operations and to distinguish such from seasonal or possibly draught related groundwater level drops. An alternative source of water will need to be supplied to these water users should the monitoring illustrate this.

Associated with the decline in water table, the base flow contribution to both the Taabosspruit and Vaal Dam will be reduced. The impact on the Vaal River is expected to be insignificant due to the distance of the operations from the river. There will also be no significant impact on the Robspruit. The reduction of base flow contribution to the Taabosspruit is likely to have impacts on the aquatic ecology and the wetlands associated with the stream as discussed within the wetland assessment report. Further investigations during the Water Use Licence phase of the project would be required to further increase confidence levels and enhance mitigation measures proposed so that the impact on the Taabosspruit is reduced.

A pollution plume is expected from any unlined surface waste rock or discard facility that may be established, therefore all discard facilities must be lined. This will require further hydrogeological and waste classification investigations, followed by contaminant transport modelling during the Water Use Licence phase of the project.

Good housekeeping, appropriate water and waste management, and adherence to good health and safety practices should minimise any other potential groundwater contamination impacts.

Although a limited groundwater monitoring network was put in place in 2011, continued monitoring has not taken place and some of these monitoring boreholes are now inaccessible for various reasons. The groundwater monitoring borehole needs to be re-established and updated with the latest understanding developed by this impact assessment. Since the most anticipated adverse effect from the proposed mine will be the lowering of water levels caused by dewatering of the underground mine, it is important that water level monitoring is done on a continued basis and with high accuracy. Automatic water level loggers should be installed in all existing and recommended new monitoring boreholes. The recommended groundwater monitoring programme must be implemented going forward.

The most effective mitigation measures for the mining impacts on groundwater is to have a groundwater numerical model as a management and predictive tool. Long term monitoring data and a continuously optimised groundwater monitoring network will provide valuable information to update and re-run the model annually. Such regular updates will increase the prediction accuracy of long term trends and allow timely intervention if required.
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APPENDICES

APPENDIX A
Document Limitations

APPENDIX B
Specialist CV and Declaration
1.0 INTRODUCTION

Golder Associates Africa (Pty) Ltd (Golder) has been appointed by Seriti Coal (Pty) Ltd (Seriti) to undertake the Environmental Impact Assessment (EIA) for the proposed Metsimaholo underground coal mine project, comprising the development of identified mining areas located in the northern Free State Province. Seriti obtained the remaining Metsimaholo reserves (previously known as Coalbrook 1 & 3) as part of a purchase agreement that saw Seriti take ownership of the Anglo American Coal mines supplying coal to Eskom. The project aims to start Metsimaholo colliery with these remaining reserves. The new mining reserves will supply additional coal to Lethabo Power Station, which will be kept operational until 2050.

1.1 Proposed mining area location

The Metsimaholo prospecting right covers an area of approximately 34,377.63 ha in extent (FS 30/5/1/1/2/10292 PR and FS 30/5/1/1/2/10383 PR). The proposed Metsimaholo colliery is straddled by the town Refengkgotso, to the north-east of the project site, and to the east by Deneysville town located 3km from site (Figure 1).

For the purposes of this assessment, we define two spatial scales of analysis, namely:

- The ‘project site’ – which comprises the land where the proposed shaft complex will be constructed (i.e. the proposed surface infrastructure footprint); and

- The broader ‘study area’ – which comprises the Metsimaholo mining right application area.

The proposed study area is situated within the Metsimaholo Local Municipality of the Fezile Dabi District Municipality in the Free State Province of South Africa.

The study area is gently undulating at 1,525 metres above mean sea level (“AMSL”). The perennial Taabbosspruit River meanders from south to north, through the western side of the study area. The Vaal Dam, in part, forms the eastern edge of the project. Grazing dominates agricultural activities with limited areas of dry land farming, predominantly maize. The climate is typical of the Northern Free State with warm to hot and wet summers and cool to cold, dry winters.
Figure 1: General location of the Metsimaholo mining right application area.
1.2 General Project Description

The proposed Metsimaholo mine is to be an independent mine producing thermal coal from one operational decline shaft. The run of mine production profile is approximately 3 million tonnes per annum (Mtpa), depleting in 2054. The project is planned to commence in 2023 with the pre-construction and construction phase. Mine establishment and access development are scheduled to commence in quarter 3 of 2023. The project is planned to commence initial production in 2025. The operational phase of the mine will run for 24-hours a day, seven days a week. Access to the orebody is planned through a box-cut development, with a twin decline shaft system to intersect the top seam (“TMH”) floor (Figure 2) and the middle seam (“MLMH”) floor (Figure 3) from which the shaft bottom development and main primary development would be initiated. MLMH will be accessed from underground via a developed decline. Main access development is planned from the decline shaft floor as a 7-road development providing access to men, material and services. The total depth of the decline will reach approximately 240m below ground. Bord and pillar mining using continuous miners (CM’s) was selected as the primary coal extraction method.

In bord and pillar mining, parallel roadways are developed in the mining direction. Perpendicular roads, called splits, are developed at predetermined intervals to the parallel roads. These roads interlink, creating pillars. The roads that are mined concurrently are determined by the size of the pillars required to support the overburden above the coal seam and the length of the production equipment’s trailing cables. The road widths were designed at 7.2m wide with an average mining height of 3m. The pillar strength divided by the pillar load is the safety factor which determines the pillar size. The main development and production sections consist of either seven or nine roadways which constitutes a mining panel.

The following main mining activities are part of the bord and pillar mining method:

- Coal cutting and loading – the CM uses the cutting head which is a rotating drum with cutting picks attached to cut the coal face. A loading mechanism picks up cut coal and delivers it into the central part of the machine. A conveying system, usually a chain conveyor, is used to run the coal in a steel trough from front to rear of the miner. A rear jib section capable of vertical and horizontal movement is used to enable the coal to be delivered into a shuttle car.

- Coal hauling and tipping – the loaded shuttle car is used to haul the coal to the section feeder breaker which crushes and feeds the coal on the conveyor belt system.

- Roof support – a roof bolt machine is used for making safe the roadways by installing roof bolts according to a systematic support procedure.

- Coal transportation – a conveyor belt system is used to transport the coal from the mining section to surface silos, ready for distribution to the market.
Figure 2: TMH underground mining layout (supplied by Seriti).
Figure 3: MLMH underground mining layout (supplied by Seriti).
The mining method chosen is believed to have less adverse impacts on the environment and society. Furthermore, underground mining will still give allowance to agricultural activities. The potential life of mine is anticipated to be 30 years delivering an average of 2.8 to 3.0 million tonnes per annum of coal to steady state production. The total saleable product is estimated at approximately 80 million tons over the life of mine with an average calorific value of 19 megajoules per kilogram.

Based on the above tonnages, the mine will start producing approximately 900 000 tonnes a year in 2025 and slowly ramp up to full production of 3.0 million tonnes per annum in 2031.

1.3 Objectives of the hydrogeological study

The main objectives of the hydrogeological study are to:

- Characterise the prevailing groundwater situation;
- Define the water bearing strata in the area;
- Determine current groundwater level distribution and flow directions;
- Determine baseline groundwater quality;
- Assess potential groundwater inflow into the underground workings; and
- Assess the impact of mining on the groundwater system including quantity and quality impacts on existing users, during both operational and post closure phases.

1.4 Previous investigations

Golder was appointed in 2010 by Anglo American Thermal Coal (AATC) to undertake the Environmental Impact Assessment (EIA) for the proposed New Vaal Colliery (NVC) Life Extension (Lifex) Project. This study (although not focussed on) included collection of baseline data for the proposed Metsimaholo study area (Golder Report no. 12111-9878-6 and 10612111-11604-7).

Therefore, the field investigations included the collection of data from this area. The data specifically collected for the NVC-Lifex project purposes covering the Metsimaholo study area can be summarised as follows:

- **Hydrocensus** data dating back to 1977. Three sets of hydrocensus investigations were performed in the study area; data for the 1977, 2005 and 2009 studies have been collated into a useable database and in GIS formats.

- **A geophysical survey** that assisted with the selection of sites for the drilling of the test/monitoring boreholes was carried out. The purpose of the survey was to ground truth the aerial geophysics (ACGS, 2009) and assist with the selection of sites for the drilling of the test/monitoring boreholes. The high resolution airborne magnetic and radiometric data that was collected in the South Vaal area by ACGS was used to plan the ground geophysical survey and site potential groundwater investigation boreholes locations. Six traverses were completed in the Metsimaholo study area.

- A total of 31 clusters totalling 65 boreholes were drilled at New Vaal Lifex Project site. Of these 34 boreholes are located within the Metsimaholo study area. The sites were selected to obtain a representative spatial distribution but at the same time be representative of the geology and structural influences of the area.

- **Aquifer testing** was carried out in order to establish the hydraulic properties of the deep, intermediate and shallow aquifers. The aquifer hydraulic properties information is required for numerical groundwater flow model simulation. Short term testing of the boreholes with blow yields greater than 0.2 l/s was undertaken, to determine aquifer parameters ranges. Falling head tests (FHT) and slug tests were done...
in boreholes with a blow yield of less than 0.2 l/s and hydraulic parameters determined from the test data.

- **Groundwater samples** were collected from a representative set of existing and newly drilled boreholes. The samples were analysed by an accredited laboratory. All hydrochemical data was interpreted and used during the geochemistry specialist study. The chemical data from newly drilled boreholes were integrated with all available existing chemical data and used to confirm the baseline groundwater quality assessment for the study area against which future impacts was determined.

- In addition, selected boreholes were hydrochemically profiled (pH, DO, Eh, Temp, EC and depth) to confirm flow and geochemical zones within the boreholes.

- The data collected were interpreted and used to prepare a conceptual model as a representation of the dynamics of the groundwater system for each lease area and for the entire coal basin study area, including geological cross sections, aquifer distribution, role of structure and groundwater flow directions. The conceptual model provides the basic input to the groundwater modelling.

In addition to the above field data a monitoring network was established for the Lifex project and long-term monitoring on groundwater levels and water quality was collected. Two of these monitoring points are in the Metsimaholo study area.

### 1.5 Approach

From the above description of the existing data collected the hydrogeological data is sufficient to determine generic outputs and conduct the assessment of the mining impacts. Therefore, that the scope of work for this specialist study includes the following tasks:

- Desktop study – collation of all field data, geochemical data into a hydrogeological conceptual model for the proposed Metsimaholo mining area.

- Hydrocensus – an update of the water level and groundwater quality was carried out by collecting data from the drilled monitoring boreholes.

- A simplified groundwater model was generated to provide outputs for the impact assessment and support to other specialist studies undertaken.

### 2.0 FIELD INVESTIGATION

The field investigation was restricted to an updated hydrocensus of the Metsimaholo study area, which included the survey of all the boreholes drilled during the 2010 field investigations. The following section documents the field observations, and the results are included and discussed further in this report.

#### 2.1 Hydrocensus

A detailed hydrocensus was conducted within the study area. The objectives of this hydrocensus was to compile a complete assessment of all boreholes drilled in 2010. During the 2018 study the following were considered for each borehole:

- The conditions of the borehole, with the description of the appearance of the borehole from the outside and the condition when cap is removed.

- Groundwater level for each borehole was recoded where possible with the use of an electronic dip meter.

- Depth of the borehole where possible.

- Use of borehole or status of borehole.
Sampling of selected boreholes
GPS coordinates were recorded using a hand-held GPS
Land owner or farm in which boreholes are located for database update

2.1.1 Approach

Farmers were notified of the study and visits to their sites were communicated via telephone. Access was granted to field team by the respective land owners before any work was done on their land. The boreholes within the Metsimaholo Municipality namely GCLB016D, GCLB016M and GCLB016S were surveyed on the 20th of December 2018. Three (3) water level loggers were retrieved from borehole GCLB007D, GCLB007M and GCLB014S. Water level logger in GCLB014D could not be retrieved due to the borehole cap being welded on.

Water samples were collected from accessible monitoring boreholes as presented in Table 1. Samples were collected with a low flow submersible pump for the boreholes with water levels shallower than 20 meters below ground level (mbgl) and bailers were used to collect samples with water levels deeper than 20 mbgl. 11 water samples were collected in total.

Table 1: Boreholes surveyed for 2018 study

<table>
<thead>
<tr>
<th>Borehole ID</th>
<th>Sampled</th>
<th>Condition</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>GCLB001D</td>
<td>No</td>
<td>Good</td>
<td>Water level around 60m mud interfered with dip meter</td>
</tr>
<tr>
<td>GCLB002D</td>
<td>No</td>
<td>Good</td>
<td>Borehole equipped with pump</td>
</tr>
<tr>
<td>GCLB003D</td>
<td>Yes</td>
<td>Good</td>
<td>Borehole sampled</td>
</tr>
<tr>
<td>GCLB003S</td>
<td>no</td>
<td>Good</td>
<td>Borehole blocked at 1.90m</td>
</tr>
<tr>
<td>GCLB004S</td>
<td>Yes</td>
<td>Good</td>
<td>Borehole sampled</td>
</tr>
<tr>
<td>GCLB004D</td>
<td>Yes</td>
<td>Good</td>
<td>Borehole sampled. Borehole slightly tilted.</td>
</tr>
<tr>
<td>GCLB005D</td>
<td>Yes</td>
<td>Good</td>
<td>Borehole tilted but useable</td>
</tr>
<tr>
<td>GCLB005M</td>
<td>Yes</td>
<td>Good</td>
<td>Borehole sampled</td>
</tr>
<tr>
<td>GCLB005S</td>
<td>Yes</td>
<td>Good</td>
<td>Borehole sampled</td>
</tr>
<tr>
<td>GCLB006D</td>
<td>No</td>
<td>Unable to ascertain</td>
<td>The borehole could not be found, we assume it was destroyed</td>
</tr>
<tr>
<td>Borehole ID</td>
<td>Sampled</td>
<td>Condition</td>
<td>Comments</td>
</tr>
<tr>
<td>------------</td>
<td>---------</td>
<td>----------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>GCLB006M</td>
<td>No</td>
<td>Good Condition</td>
<td>Borehole infested with bees</td>
</tr>
<tr>
<td>GCLB006S</td>
<td>No</td>
<td>Good Condition</td>
<td>Borehole in good condition</td>
</tr>
<tr>
<td>GCLB007M</td>
<td>Yes</td>
<td>Good Condition</td>
<td>Borehole sampled</td>
</tr>
<tr>
<td>GCLB007D</td>
<td>Yes</td>
<td>Good Condition</td>
<td>Borehole sampled</td>
</tr>
<tr>
<td>GCLB008S</td>
<td>No</td>
<td>Unable to ascertain</td>
<td>Borehole could not be opened. Alan key threads damaged</td>
</tr>
<tr>
<td>GCLB008M</td>
<td>No</td>
<td>Good Condition</td>
<td>Borehole in good condition</td>
</tr>
<tr>
<td>GCLB008D</td>
<td>No</td>
<td>Good Condition</td>
<td>Borehole in good condition</td>
</tr>
<tr>
<td>GCLB009D</td>
<td>No</td>
<td>Good Condition</td>
<td>Borehole equipped with pump</td>
</tr>
<tr>
<td>GCLB009M</td>
<td>No</td>
<td>Good Condition</td>
<td>Water level around 60m mud interfered with dip meter</td>
</tr>
<tr>
<td>GCLB009S</td>
<td>No</td>
<td>Good Condition</td>
<td>Borehole in good condition</td>
</tr>
<tr>
<td>GCLB010D</td>
<td>No</td>
<td>Collapsed</td>
<td>Borehole blocked at 5.02m</td>
</tr>
<tr>
<td>GCLB010S</td>
<td>No</td>
<td>Collapsed</td>
<td>Borehole blocked at 1.90m</td>
</tr>
<tr>
<td>GCLB011D</td>
<td>Yes</td>
<td>Good Condition</td>
<td>Borehole sampled</td>
</tr>
<tr>
<td>GCLB011S</td>
<td>No</td>
<td>Unable to ascertain</td>
<td>Borehole cannot be opened as the cap is cemented in.</td>
</tr>
<tr>
<td>GCLB012D</td>
<td>No</td>
<td>Collapsed</td>
<td>Borehole blocked at 21.77m</td>
</tr>
<tr>
<td>GCLB012S</td>
<td>No</td>
<td>Collapsed</td>
<td>Borehole blocked at 3.99m</td>
</tr>
<tr>
<td>GCLB013D</td>
<td>No</td>
<td>Unable to ascertain</td>
<td>Borehole could not be opened. Alan key threads damaged</td>
</tr>
<tr>
<td>GCLB013S</td>
<td>No</td>
<td>Good Condition</td>
<td>Borehole in good condition</td>
</tr>
<tr>
<td>GCLB014D</td>
<td>Yes</td>
<td>Good Condition</td>
<td>Borehole equipped with pump</td>
</tr>
<tr>
<td>Borehole ID</td>
<td>Sampled</td>
<td>Condition</td>
<td>Comments</td>
</tr>
<tr>
<td>-------------</td>
<td>---------</td>
<td>------------</td>
<td>------------------------------</td>
</tr>
<tr>
<td>GCLB014S</td>
<td>Yes</td>
<td>Good Condition</td>
<td>Borehole Sampled</td>
</tr>
<tr>
<td>GCLB015D</td>
<td>No</td>
<td>Good Condition</td>
<td>Borehole in good condition</td>
</tr>
<tr>
<td>GCLB015S</td>
<td>No</td>
<td>Collapsed</td>
<td>Borehole blocked at 11.96m</td>
</tr>
<tr>
<td>GCLB016D</td>
<td>No</td>
<td>Good Condition</td>
<td>Borehole Sampled</td>
</tr>
<tr>
<td>GCLB016S</td>
<td>No</td>
<td>Good Condition</td>
<td>Borehole blocked at 7.7m</td>
</tr>
<tr>
<td>GCLB016M</td>
<td>No</td>
<td>Good Condition</td>
<td>Borehole Sampled</td>
</tr>
</tbody>
</table>

### 3.0 STUDY AREA DESCRIPTION

#### 3.1 Topography, Drainage, and Climate

##### 3.1.1 Drainage Catchment

The study area falls within the Leeuspruit and Taibosspruit catchment (C22G) which is a sub-catchment of the Vaal Dam to Vaal Barrage catchment in the Upper Vaal Water Management Area (WMA) (Figure 4 and Figure 5).

The Upper Vaal WMA is located in the eastern interior of South Africa. It is considered to be a vital WMA from a water resources management perspective as large quantities of water are transferred into and out of this WMA, with the impacts of these transfers affecting a total of ten WMAs and all the neighbouring countries of South Africa.

The water resources of the Upper Vaal WMA are highly developed and regulated due to the high level of urbanisation and economic activity in the area and its central role as a water transfer point to other WMAs. This situation thus only allows for marginal potential for further water resource development in the WMA.
Figure 4: Study area relative to the Upper Vaal water Management Area.
Figure 5: Drainage and topography of the study area
3.1.2 Topography
The area is located on the escarpment, at an average altitude of 1440 metres above mean sea level (mamsl). The topography is characterised as flat and gently sloping in the central, with gradients that are generally very low and seldom exceed 0,02 mamsl. The flat topography is mainly due to the horizontal strata forming part of the Karoo formations which underlie the greater part of the study area.

3.1.3 Climate
The catchment can be described as moderate with warm summers, with daily average temperatures ranging between 19°C and 22°C, and cold winters, with daily average temperatures ranging between 10°C and 17°C. Highveld thundershowers occur during the summer months with the winters left generally dry but with frost and fog occurring in the mornings.

The rainfall is highly seasonal and occurs mainly as thunderstorms from October to April, with the highest amount of rainfall in January (average 110mm). The winter months (June to July) are generally dry but with frost and fog occurring in the mornings. The lowest rainfall occurs in July (average 3 mm). Long term rainfall records exist for the Deneysville Weather station from 1938 to 2018, Figure 6.

The prevailing wind direction is north-westerly although south-westerly winds are common during the months of May to July.

The mean annual potential evaporation for the period from 1965 to 2009 is 1553 mm/year. This value exceeds mean annual rainfall by more than 2 orders of magnitude. This indicates that the area has a negative moisture index (Golder Associates, 2013).

Figure 6: Daily rainfall recorded for Deneysville Weather Station 1938 to 2018.
3.2 Regional Geology

The study area is located in the Vereeniging Sasolburg Coalfield. The 1:250 000 geological map describes the lithologies as recent alluvium with underlying mudstone, sandstones and shale of the Volksrust Formation and Vryheid Formation of the Permian age Ecca Group.

The geology of the area is made up of various lithological successions of mostly the Karoo Super Group. The geological description below was compiled using information obtained from the South African Geological Survey 1:250 000 Geological series 2626, 2628, 2726 and 2728 and supported by background data and field observations. The stratigraphy is summarised in Table 2 and the distribution of lithologies is shown on Figure 7).

The Volksrust Formation consists predominantly of grey to black shale with thin siltstone and sandstone beds occurring near the upper and lower boundaries of the succession. This formation is not known to contain significant coal in the Vereeniging - Sasolburg Coalfield.

The Vryheid Formation underlies the Volksrust Formation as the main coal bearing formation. The coal zone in this coalfield is approximately 40 m thick and consists of three coal units:

- Lower coal unit with average thickness of 3m;
- Middle coal unit consists of two seams that is mostly separated by shale and sandstone;
- Upper coal unit with a thickness of less than 5 meter often referred to as the No3 Seam or Coal Marker Seam.

The lower coal unit is underlain by shale and tillite of Dwyka Group sediments which vary in thickness but seldom exceeds 20 meter. The tillite is normally described as impermeable (aquatard) and could therefore act as a horizontal barrier to groundwater movement.

The Dwyka Group sediments are underlain by lava of the Klipriviersberg Group in the Ventersdorp Supergroup on the eastern and central and southern portion of the study area. The Dwyka Group sediments are underlain by dolomite from the Chuniespoort Group of the Transvaal Supergroup in the northern portion of the Vaalbank and New Cornelia study area.

The general dip in the area is to the south-south-east following the basin morphology.
Table 2: Summary of the Stratigraphy of the area (From Moodley, et al. 2006)

<table>
<thead>
<tr>
<th>Age</th>
<th>Supergroup</th>
<th>Group</th>
<th>Subgroup</th>
<th>Formation</th>
<th>Lithology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary</td>
<td>Karoo</td>
<td>Beaufort</td>
<td>Adelaide</td>
<td>Estcourt</td>
<td>Shale and Mudstone</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ecca</td>
<td></td>
<td>Volksrust</td>
<td>Shale and Sandstone</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Vryheid</td>
<td>Shale, Sandstone and Coal</td>
</tr>
<tr>
<td>Jurassic</td>
<td>Diabase</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mokolian</td>
<td>Transvaal</td>
<td>Pretoria</td>
<td>Hekpoort</td>
<td>Timeball Hill</td>
<td>Andesite</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chuniespoort</td>
<td></td>
<td></td>
<td>Shaie and Quartzite</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Malmari</td>
<td></td>
<td></td>
<td>Dolomite</td>
</tr>
<tr>
<td>Vaalian</td>
<td>Venterdorp</td>
<td>Kipriviersberg</td>
<td>Black Reef</td>
<td></td>
<td>Quartzite</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Basaltic lavas</td>
</tr>
<tr>
<td>Randian</td>
<td>Witwaters and</td>
<td>Central Rand</td>
<td>Tufffontein</td>
<td>Quartzite, Conglomerate and Shale</td>
<td></td>
</tr>
<tr>
<td></td>
<td>West Rand</td>
<td></td>
<td>Johannesburg</td>
<td>Quartzite and Conglomerate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Jeppesotn</td>
<td>Shale, Quartzite and Conglomerate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Government</td>
<td>Quartzite, Greywacke and Conglomerate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hospital Hill</td>
<td>Shale, Quartzite and Banded ironstone</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Orange Grove</td>
<td>Quartzite and Shale</td>
<td></td>
</tr>
<tr>
<td>Swazian</td>
<td>Basement Complex</td>
<td></td>
<td></td>
<td></td>
<td>Granite and Gneiss</td>
</tr>
</tbody>
</table>
Figure 7: Geology of the Study Area.
3.3 Local Geology

3.3.1 Field investigations

During the 2010 field investigations the detailed geophysics was used to delineate areas of potential structuring which was verified with drilling of boreholes. The sites were selected to obtain a representative spatial distribution but at the same time be representative of the geology and structural influences of the area.

Borehole clusters were drilled at different locations to intersect shallow, intermediate and deep aquifers. The target of the deep boreholes was determined by the depth of the coal seams which varies across the study area:

- Deep borehole ranges between 100 to 300mbgl.
- Intermediate boreholes 30 to 100 mbgl
- Shallow boreholes 10 to 30 mbgl

3.3.2 Structural Features

Younger intrusions in the form of dolerite dykes and sills have displaced the sedimentary strata. Displacements of up to 85 meter, by the sills, are a common occurrence in the coalfield. The main sill in the Metsimaholo study area intruded approximately 25 metres above the Upper coal unit (No3 seam). Minor faults with maximum displacements of 5 meter are also reported in the region. One major east-west trending fault zone provides the boundary between the northern coal fields and the Metsimaholo study areas, which is published on the geological sheet.

The aim of the geophysical survey was to ground truth the aerial (Figure 7) geophysics at specific locations. The survey results were successful in locating several of these structures, especially dolerite dyke intrusions. The resistivity results also indicated zones of weathering and layering of sediments. Drilling confirmed many of these inferred structures, however in a few cases the dykes acted as groundwater barriers. Higher yielding boreholes were not always associated with these structures but are rather controlled by the presence of localised fracturing or weathering of the sediments. No faults were intersected during the drilling, but minor faulting is reported from prior mining activities that displaced the coal units by less than 5m.

3.3.3 Metsimaholo Geology

Drilling information at GCLB008D near the central north part of the Metsimaholo study area revealed the succession as shown in Table 3 and supports the main general geological description. The main difference in geological succession between northern coal fields towards the Vaal River and the Metsimaholo study area is the presence of a thick extensive dolerite sill.

<table>
<thead>
<tr>
<th>Depth from surface</th>
<th>Lithology</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 1m</td>
<td>Alluvium</td>
<td>Fine sand</td>
</tr>
<tr>
<td>1 – 42m</td>
<td>Dolerite</td>
<td></td>
</tr>
<tr>
<td>42 – 66m</td>
<td>Shale &amp; Siltstone</td>
<td></td>
</tr>
<tr>
<td>66 – 79m</td>
<td>Sandstone</td>
<td></td>
</tr>
<tr>
<td>79 – 130m</td>
<td>Dolerite</td>
<td>Main Sill (±50m thick)</td>
</tr>
</tbody>
</table>
Drilling along with existing data has enabled the following geological conclusions to be reached:

- The whole of the area is covered by a layer of alluvium.
- Mudstone, shale, siltstone, sandstones and coal of the Vryheid Formation were intersected.
- Dolerite sills and dykes were intersected with the main sill varying in thickness from 40m to >100m. Numerous east-west trending dykes also traverse the area.
- Dolerite dyke were penetrated by drilling in borehole GCLB006M. With the exception of borehole GCLB003D and GCLB006D sites, dolerite sills were identified in all borehole sites in the southern section of the study area. The upper coal unit is situated approximately 20m above the middle coal unit and is located in close proximity (±50m) to the main dolerite sill in the Metsimaholo study area.
- The upper, middle and lower coal units are separated by sandstone and shale with the middle and lower units separated by more than 10 metre of shale.
- The Vryheid Formation is underlain by basement rocks comprising tillite of the Dwyka Group followed by lava, quartzite or dolomite.
- Drilling in borehole GCLB003D penetrated quartzite (indicative of basement formations) from 47 m to the bottom of a hole at 100 m. The lateral and vertical extent of this formation is unknown as it was not penetrated in the other boreholes, but is expected to extend further north from this vicinity.
- Faults and joints were not identified during the boreholes drilling. However, fracturing (characterised with Fe staining) was logged in some boreholes.

### 3.4 Hydrogeological Setting

The hydrogeological setting is described through the following components:

- Aquifer parameters;
- Groundwater gradients, flow directions and;
- Aquifer types;
- Groundwater quality;

<table>
<thead>
<tr>
<th>Depth from surface</th>
<th>Lithology</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>130 – 140m</td>
<td>Sandstone</td>
<td></td>
</tr>
<tr>
<td>140 – 165m</td>
<td>Shale</td>
<td></td>
</tr>
<tr>
<td>165 – 174m</td>
<td>Coal</td>
<td>Upper Coal Unit (No3 seam)</td>
</tr>
<tr>
<td>174 – 194m</td>
<td>Shale</td>
<td></td>
</tr>
<tr>
<td>194 – 200m</td>
<td>Coal</td>
<td>Middle Coal Unit (No2A and 2B seams)</td>
</tr>
<tr>
<td>200 – 203m</td>
<td>Shale</td>
<td></td>
</tr>
<tr>
<td>203 – 209m</td>
<td>Coal</td>
<td>Lower Coal Unit</td>
</tr>
<tr>
<td>209 – 215m</td>
<td>Tillite</td>
<td></td>
</tr>
</tbody>
</table>
Groundwater users and Hydrogeological conceptualisation

3.4.1 Aquifer parameters

3.4.1.1 Water Strikes and Blow Yield

The depths of the shallow boreholes in the Metsimaholo study area range from 18mbgl to 30mbgl, whereas deep boreholes are between 100mbgl and 292mbgl. Intermediate boreholes were drilled to depths ranging from 43mbgl to 94mbgl.

The majority of the shallow boreholes intersected insignificant quantities of groundwater (Table 4) with the exception of GCLB006 intersecting 7.1l/s at 24mbgl. Water strikes in the deep boreholes were encountered at depths ranging from 9mbgl to 236mbgl with a water strike blowing yield range between seepage (0.1l/s) and >12l/s.

Table 4: Water strikes depth and static water levels as measured in March 2010 (From Golder, 2010)

<table>
<thead>
<tr>
<th>Borehole ID</th>
<th>Latitude (°)</th>
<th>Longitude (°)</th>
<th>DTM Elevation (mamsl)</th>
<th>Investigated Aquifer</th>
<th>Water strike/Seepage depth (m)</th>
<th>Blow Yield (l/s)</th>
<th>SWL (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GCLB001D</td>
<td>26.94385</td>
<td>28.06763</td>
<td>1510</td>
<td>Deep</td>
<td>DRY</td>
<td>DRY</td>
<td></td>
</tr>
<tr>
<td>GCLB002D</td>
<td>26.93513</td>
<td>28.02122</td>
<td>1479</td>
<td>Deep</td>
<td>137</td>
<td>0.9</td>
<td>73.6</td>
</tr>
<tr>
<td>GCLB003D</td>
<td>26.88899</td>
<td>28.05901</td>
<td>1502</td>
<td>Deep</td>
<td>74</td>
<td>0.4</td>
<td>3.04</td>
</tr>
<tr>
<td>GCLB003S</td>
<td>26.8892</td>
<td>28.059</td>
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### Borehole Data

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<th>Longitude (°)</th>
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<th>Investigated Aquifer</th>
<th>Water strike/Seepage depth (m)</th>
<th>Blow Yield (l/s)</th>
<th>SWL (m)</th>
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<td>DRY</td>
<td>DRY</td>
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<td>DRY</td>
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<td>27.91717</td>
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<td>DRY</td>
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<td>27.91753</td>
<td>1452</td>
<td>Intermediate</td>
<td>33</td>
<td>0.7</td>
<td>17.1</td>
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### 3.4.2 Aquifer Types

The static water level (SWL), water strikes and blow-out yield measured during drilling of new boreholes are summarised in Table 4. Three aquifer systems (description used in Table 4) were defined during drilling which was based on the geological formations and other borehole measurements, however after data evaluation the shallow and medium aquifers were grouped together (Table 5).

#### 3.4.2.1 Shallow aquifer

The shallow boreholes were drilled through the clay and weathered mudstone and shale, occurring at depths between 1 and 20 mbgl. The shallow aquifer is localized in low lying areas. The aquifer was not observed in boreholes which are characterised by dolerite intrusions at surface (i.e. GCLB006D, drilled GCLB001D, and GCLB002D).
Table 5: General hydrogeology of the aquifers identified for the study area

<table>
<thead>
<tr>
<th>Aquifer</th>
<th>Lateral extent</th>
<th>General geology</th>
<th>Blow yield (l/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shallow aquifer</td>
<td>Well developed in low lying areas, extensive where sandstone layers are present</td>
<td>Weathered shale, mudstone, interbedded sandstone and siltstone</td>
<td>&lt;0.1 - 7</td>
</tr>
<tr>
<td>Deep aquifer</td>
<td>Poorly developed, localized, mainly controlled by fracturing in the shale and deeper lying sandstones</td>
<td>Limited fractures in shales, weathered siltstone and sandstone interlayering with coal</td>
<td>0.1 – 0.9</td>
</tr>
</tbody>
</table>

Generally, there was no measurable water strikes encountered from the alluvium and shallow sediments during drilling. Seepages were observed between 4 and 9 mbgl in borehole GCLB003S. The shallow aquifer water level was recorded between 0 and 10 mbgl in 88.5% of the shallow aquifer boreholes monitored in March 2010. Only 11.5% of these boreholes have the water level between 10 and 13 mbgl.

Higher water strikes in the shallow system are related to fracturing of the thick sandstone layer present below the shallow sediments. A number of boreholes were targeted at this zone and was described initially as the intermediate aquifer. These boreholes intersected sandstone, inter layered with siltstone and shale. A blow-out yield ranging between 0.1 and 5.2 litres per second (l/s) were recorded with a 90° V-notch from the boreholes drilled in this sandstone layer and is the aquifer that is mainly target by agricultural users of groundwater.

The sandstone occurs at depth between 115 and 160 meters below surface. In this vicinity, this “intermediate aquifer” occurs either as a confined aquifer between dolerite and shale or semi-confined above dolerite sill. This is typical in borehole GCLB009M, wherein sandstone aquifer is underlain by dolerite and overlain by shale and mudstone. Upon further investigation and data evaluation it was observed that what is described here as the “intermediate aquifer” is in fact not a separate aquifer system from the shallow system. The sandstone layer can be grouped with the shallower sediments and hydraulic connectivity will depend on the sedimentary layers’ porosity. Measured difference in piezometric levels was a delayed effect caused by this poor hydraulic connectivity soon after drilling.

3.4.2.2 Deep aquifer

The water strikes recorded below the dolerite sill, is considered to represent the deep aquifer system. The deep aquifer comprises of sandstone, fractured shale and siltstone lenses between coal seams (i.e. in GCLB009D).

The deep aquifer is generally poorly developed, localized, and mainly controlled by fracturing of the sediments. The separation of piezometric levels between deep and shallow boreholes is more pronounced in areas where the dolerite sill is extensive.

3.4.3 Aquifer parameters

Aquifer parameters were derived from an extensive testing programme undertaken in 2010, (Golder. 2010).
Aquifer Transmissivity, and Specific capacity were estimated from the constant rate pump testing data analytically using Cooper Jacob time distance drawdown method, Kruseman (2000). The Transmissivity were estimated using equation 1 below:

$$T = \frac{Q}{4\pi(h_0-h)}$$  \hspace{1cm} (1)

Where $T$ is the Transmissivity (m$^2$/day)

$(h_0-h)$ refers to the change in drawdown (m) over one log cycle

$Q$ is the discharge rate (m$^3$/day)

The specific capacity was estimated as the relationship between the abstraction rate ($Q$) and maximum drawdown (m) in the pumping boreholes. Table 6 summarizes the constant discharge recovery test (CDRT) results and analyses curves are shown in Appendix B of the Anglo Coal New Vaal Life Expansion: Groundwater Baseline Study.

Falling head tests were conducted for boreholes that had a blow-out yield of > 0.2l/s. Falling head test and Slug test data were analysed using Aquifer Test (version 2.5) for windows software developed by Waterloo Hydrogeologic (Table 7).

Table 6: Aquifer parameters as estimated using Cooper Jacob method (Golder, 2010)

<table>
<thead>
<tr>
<th>Borehole ID</th>
<th>CDRT duration (minutes)</th>
<th>Pumping rate (m$^3$/d)</th>
<th>T (m$^2$/day) Drawdown</th>
<th>T (m$^2$/day) Recovery</th>
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<td>79.08</td>
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<td>49.41</td>
<td>59.9</td>
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<td>1.4</td>
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<td>25.9</td>
<td>1.7</td>
<td>0.93</td>
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Table 7: Aquifers Permeability as estimated with Aquifer Test (Golder, 2010)

<table>
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<th>Test section (m)</th>
<th>b (m)</th>
<th>L (m)</th>
<th>r (m)</th>
<th>K (m/s)</th>
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<td>1.96E-07</td>
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<tr>
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<td>9-18</td>
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</table>
From these results it can be seen that the aquifer systems are generally poorly developed except where specific structural features were targeted and intersected in the boreholes. The higher yielding boreholes are associated with fracturing or weathering of the sediments.

Monitoring of observation boreholes during pump testing showed very slight water level changes in the observation boreholes during pumping. This suggests that there is restricted hydraulic continuity between the deep aquifer and the shallow aquifer.

### 3.4.4 Groundwater elevation and flow direction

#### 3.4.4.1 Historical data

Historical data showed that for the shallow aquifer system, the groundwater levels remained stable across the majority of the study area for the past 35 years. Water level monitoring at the old Coalbrook Colliery indicated that dewatering effects at Coalbrook Colliery had limited impacts on the shallow aquifer system. The Anglo Coal New Vaal (ACNV) database data (2012) showed the existence of two sets of water level elevations. A shallow system associated with sedimentary sequence above the coal and a deeper system associated with the dewatering effects from mining. The effects from the dewatering have been more pronounced since 2000 on the deeper boreholes and seem to have stabilised after 2004.

Water level data collected from the newly drilled sets of boreholes (2010) enabled the piezometric surface for both shallow and deep aquifers to be constructed separately. However, although a static water level difference between the shallow, intermediate and deep borehole shows the presence of up to three aquifers, the piezometric surface of the intermediate aquifer is similar in shape to either the deep or shallow system depending on the location within the study area and is therefore not distinguished as a separate system.

The piezometric surface for the deep and shallow aquifers was calculated, contoured, and visualised on (Figure 8 and Figure 9). The deep aquifer water levels vary from a high of 1525 mamsl at GCLB004D located south-east in the Coalbrook area to a low of 1488 mamsl at NVL91012D located north-west in the Vaalbank area. The shallow aquifer water levels vary from a high of 1519 mamsl at GCLB004S to a low of 1449 mamsl at NVL91012S.
Deep aquifer water levels were comparable to those of the shallow aquifer in the south-east but the water level difference became more pronounced closer to old workings. This indicated that the workings were not completely flooded and supported the concept of aquifers separated by the extensive dolerite sill.

The groundwater was generally flowing from the south-east draining towards the Taabospruit to the Vaal River in the north and north-east of the study area. This relates closely to the topography of the area, which slopes to the Vaal River flowing to the north of the project site.

The Metsimaholo study area is relatively flat and groundwater gradients for the shallow aquifer were calculated to be gentle, at 0.006 (1:160) as measured between GCLB004S in the extreme SE and GCLB009S central north in the area. From GCLB009S to the extreme NW near GCLB016S the gradients were flat and entirely controlled by the Taabospruit drainage. Figure 8 shows the shallow groundwater flow direction rotates to a direction from east to west in the northern extremity of the Coalbrook area but the gradient remains constant at 0.006.

The groundwater gradients for the deep aquifer in the Metsimaholo study area varied from a steep 0.03 (1:30) as measured between GCLB004D and GCLB002D to a very gentle gradient of 0.003 (1:300) as measured between GCLB015D and GCLB010D. This gradient difference along with the groundwater flow direction that rotates towards Coalbrook mine indicated the presence of structural interference in groundwater flow along with prolonged dewatering effects from the existing mining dewatering.
Figure 8: Piezometric contours for the shallow aquifer system (taken from Golder, 2012).
Figure 9: Piezometric contours for the deep aquifer system (taken from Golder, 2012).
### 3.4.4.2 2018 Groundwater elevation and flow direction assessment

From the hydrocensus undertaken in 2018, water levels were obtained from 17 boreholes (Table 8). These boreholes monitor the shallow, intermediate and deep aquifers. Water levels were used to determine the current flow directions at the proposed Metsimaholo mine. The old Coalbrook workings are considered in the area to determine the possible dewatering impact from these mining activities and possible geological structures acting as preferred pathways. No continuous monitoring of water levels exists.

<table>
<thead>
<tr>
<th>Borehole ID</th>
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<th>Long (WGS84)</th>
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<th>SWL (mbgl)</th>
<th>WLZ (mamsl)</th>
<th>Investigated Aquifer</th>
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</thead>
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<td>1502</td>
<td>3.04</td>
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<td>Intermediate</td>
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<td>30.25</td>
<td>1437.39</td>
<td>Deep</td>
</tr>
<tr>
<td>GCLB013S</td>
<td>-26.98598</td>
<td>27.9353</td>
<td>1466</td>
<td>17.76</td>
<td>1448.27</td>
<td>Shallow</td>
</tr>
<tr>
<td>GCLB014S</td>
<td>-26.93815</td>
<td>27.91015</td>
<td>1466</td>
<td>5.44</td>
<td>1460.70</td>
<td>Shallow</td>
</tr>
<tr>
<td>GCLB015D</td>
<td>-27.00404</td>
<td>27.9738</td>
<td>1488</td>
<td>17</td>
<td>1471.00</td>
<td>Deep</td>
</tr>
<tr>
<td>GCLB016D</td>
<td>-26.87274</td>
<td>27.91734</td>
<td>1459</td>
<td>20.46</td>
<td>1438.54</td>
<td>Deep</td>
</tr>
<tr>
<td>GCLB016M</td>
<td>-26.87268</td>
<td>27.91754</td>
<td>1459</td>
<td>18.95</td>
<td>1440.05</td>
<td>Intermediate</td>
</tr>
</tbody>
</table>
Figure 10: All boreholes with Water levels
3.4.4.2.1 Shallow Aquifer

The shallow aquifer water levels and flow direction was determined by five boreholes (GCLB004S, GCLB005S, GCLB006S, GCLB013S and GCLB014S). The water level in the shallow aquifer ranges from 5.4 – 17.76 mbgl. Borehole GCLB013S seems to be potentially impacted by underground mining with a water level of 17.76 mbgl. Overall, the shallow aquifer is not impacted by mining in the area based on the information available.

Table 9: Shallow Aquifer water levels measured in 2018

<table>
<thead>
<tr>
<th>Borehole ID</th>
<th>Lat (WGS84)</th>
<th>Long (WGS84)</th>
<th>DEM Elevation (mamsl)</th>
<th>SWL (m) 2018</th>
<th>WLZ (mamsl)</th>
<th>Investigated Aquifer</th>
</tr>
</thead>
<tbody>
<tr>
<td>GCLB004S</td>
<td>26.95347</td>
<td>28.05106</td>
<td>1526.59</td>
<td>5.4</td>
<td>1521.18</td>
<td>Shallow</td>
</tr>
<tr>
<td>GCLB005S</td>
<td>26.88662</td>
<td>28.00341</td>
<td>1459.97</td>
<td>7.93</td>
<td>1452.03</td>
<td>Shallow</td>
</tr>
<tr>
<td>GCLB006S</td>
<td>26.91256</td>
<td>28.03102</td>
<td>1486.87</td>
<td>8.5</td>
<td>1478.36</td>
<td>Shallow</td>
</tr>
<tr>
<td>GCLB013S</td>
<td>26.98598</td>
<td>27.9353</td>
<td>1466.03</td>
<td>17.76</td>
<td>1448.27</td>
<td>Shallow</td>
</tr>
<tr>
<td>GCLB014S</td>
<td>26.93815</td>
<td>27.91015</td>
<td>1466.14</td>
<td>5.44</td>
<td>1460.70</td>
<td>Shallow</td>
</tr>
</tbody>
</table>

A scatterplot of the shallow boreholes is given below in Figure 11. From the scatterplot borehole GCLB013S plots slightly below the majority of the boreholes, which means that that water level is lower than expected. This could be due to various reasons, possibly including the impact of mining.

![Figure 11: Scatterplot for the Shallow Aquifer in 2018](image-url)
Figure 12: Shallow Aquifer Groundwater Levels and flow directions 2018.
3.4.4.2  Deep and Intermediate Aquifer

The intermediate and Deep aquifer water levels and flow directions was determined by 12 boreholes (Table 10). The water level ranges from 1.3 mbgl to 68.27 mbgl. Boreholes GWLB04D and GWLB11D is potentially impacted by the old Coalbrook Colliery underground workings. A regional east to west structure exists possibly connecting the old underground workings with the deep aquifer to the east. These boreholes may have been drilled into the dyke or local abstraction by farmers and could be the reason for lowering of the water table.

The groundwater impact of the old Coalbrook underground workings is potentially seen in the Deep aquifer towards the east along the geological structure. Further investigation would however be needed.

Table 10: Intermediate and Deep Aquifer water levels measured in 2018.

<table>
<thead>
<tr>
<th>Borehole ID</th>
<th>Lat (WGS84)</th>
<th>Long (WGS84)</th>
<th>Elevation (DEM) (mamsl)</th>
<th>SWL (mbgl)</th>
<th>WLZ (mamsl)</th>
<th>Investigated Aquifer</th>
</tr>
</thead>
<tbody>
<tr>
<td>GCLB003D</td>
<td>-26.88899</td>
<td>28.05901</td>
<td>1502</td>
<td>3.04</td>
<td>1499.26</td>
<td>Deep</td>
</tr>
<tr>
<td>GCLB004D</td>
<td>-26.95364</td>
<td>28.05108</td>
<td>1527</td>
<td>68.27</td>
<td>1458.42</td>
<td>Deep</td>
</tr>
<tr>
<td>GCLB005D</td>
<td>-26.88634</td>
<td>28.00341</td>
<td>1460</td>
<td>7.255</td>
<td>1453.11</td>
<td>Deep</td>
</tr>
<tr>
<td>GCLB005M</td>
<td>-26.88634</td>
<td>28.00322</td>
<td>1460</td>
<td>5.41</td>
<td>1454.74</td>
<td>Intermediate</td>
</tr>
<tr>
<td>GCLB007M</td>
<td>-26.87353</td>
<td>27.96787</td>
<td>1469</td>
<td>1.34</td>
<td>1467.37</td>
<td>Intermediate</td>
</tr>
<tr>
<td>GCLB007D</td>
<td>-26.87369</td>
<td>27.96778</td>
<td>1468</td>
<td>1.51</td>
<td>1466.75</td>
<td>Deep</td>
</tr>
<tr>
<td>GCLB008M</td>
<td>-26.90061</td>
<td>27.96199</td>
<td>1448</td>
<td>5.919</td>
<td>1441.63</td>
<td>Intermediate</td>
</tr>
<tr>
<td>GCLB008D</td>
<td>-26.90084</td>
<td>27.96199</td>
<td>1448</td>
<td>6.316</td>
<td>1441.80</td>
<td>Deep</td>
</tr>
<tr>
<td>GCLB011D</td>
<td>-26.95551</td>
<td>27.9703</td>
<td>1468</td>
<td>30.25</td>
<td>1437.39</td>
<td>Deep</td>
</tr>
<tr>
<td>GCLB015D</td>
<td>-27.00404</td>
<td>27.9738</td>
<td>1488</td>
<td>17</td>
<td>1471.00</td>
<td>Deep</td>
</tr>
<tr>
<td>GCLB016D</td>
<td>-26.87274</td>
<td>27.91734</td>
<td>1459</td>
<td>20.46</td>
<td>1438.54</td>
<td>Deep</td>
</tr>
<tr>
<td>GCLB016M</td>
<td>-26.87268</td>
<td>27.91754</td>
<td>1459</td>
<td>18.95</td>
<td>1440.05</td>
<td>Intermediate</td>
</tr>
</tbody>
</table>

A scatterplot of the deep aquifer where surface elevation is plotted against water level elevation confirms that boreholes GWLB04D and GWLB11D are lower than expected (Figure 13).
Figure 13: Scatterplot for the Intermediate and Deep Aquifer in 2018.
Figure 14: Deep Aquifer groundwater levels and flow direction in 2018.
### 3.4.4.2.3 Comparison between 2010 and 2018

A comparison between the 2010 and 2018 water levels was accessed to help with the understanding of the current system and whether the system has recovered from previous mining that has taken place in the old Cornelia/Coalbrook Collieries. The assumption to be made is that the 2010 levels are indeed static water levels measured after drilling.

Table 11 provides the 2010 and 2018 static water level for each borehole.

**Table 11: Comparison between 2010 and 2018 static water levels**

<table>
<thead>
<tr>
<th>Borehole ID</th>
<th>Investigated Aquifer</th>
<th>2010 SWL (m)</th>
<th>2018 SWL (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GCLB003D</td>
<td>Deep</td>
<td>3.04</td>
<td>3.04</td>
</tr>
<tr>
<td>GCLB004S</td>
<td>Shallow</td>
<td>5.4</td>
<td>5.4</td>
</tr>
<tr>
<td>GCLB004D</td>
<td>Deep</td>
<td>DRY</td>
<td>68.27</td>
</tr>
<tr>
<td>GCLB005D</td>
<td>Deep</td>
<td>9.3</td>
<td>7.255</td>
</tr>
<tr>
<td>GCLB005M</td>
<td>Intermediate</td>
<td>13.87</td>
<td>5.41</td>
</tr>
<tr>
<td>GCLB005S</td>
<td>Shallow</td>
<td>7.29</td>
<td>7.93</td>
</tr>
<tr>
<td>GCLB006S</td>
<td>Shallow</td>
<td>11.27</td>
<td>8.5</td>
</tr>
<tr>
<td>GCLB007M</td>
<td>Intermediate</td>
<td>0</td>
<td>1.34</td>
</tr>
<tr>
<td>GCLB007D</td>
<td>Deep</td>
<td>37.09</td>
<td>1.51</td>
</tr>
<tr>
<td>GCLB008M</td>
<td>Intermediate</td>
<td>4.5</td>
<td>5.919</td>
</tr>
<tr>
<td>GCLB008D</td>
<td>Deep</td>
<td>4.58</td>
<td>6.316</td>
</tr>
<tr>
<td>GCLB011D</td>
<td>Deep</td>
<td>42.29</td>
<td>30.25</td>
</tr>
<tr>
<td>GCLB013S</td>
<td>Shallow</td>
<td>3.37</td>
<td>17.76</td>
</tr>
<tr>
<td>GCLB014S</td>
<td>Shallow</td>
<td>4.77</td>
<td>5.44</td>
</tr>
<tr>
<td>GCLB015D</td>
<td>Deep</td>
<td>93.01</td>
<td>17</td>
</tr>
<tr>
<td>GCLB016D</td>
<td>Deep</td>
<td>DRY</td>
<td>20.46</td>
</tr>
<tr>
<td>GCLB016M</td>
<td>Intermediate</td>
<td>17.1</td>
<td>18.95</td>
</tr>
</tbody>
</table>

Most of the levels of the shallow aquifer have not changed between 2010 and 2018, except borehole GCLB013S which has declined by about 14m over the past 8 years. Figure 15 shows the comparison in a bar chart between 2010 and 2018.
Figure 15: Bar chart comparing the shallow aquifer 2010 and 2018 static water levels

The deep aquifer had boreholes GCLB004D, GCLB007D, GCLB015D shows recovery. This could be due to mining impacts/dewatering and that the boreholes are still recovering, or boreholes water level did not recover after drilling at the time (2011) when the measurement was taken.

Figure 16: Bar chart comparing the deep aquifer 2010 and 2018 static water levels.
3.4.5 Groundwater quality

3.4.5.1 Historical data

There is an extensive database for the groundwater chemistry of the study area. This database includes water quality from the active mining, defunct mining and undisturbed areas (Figure 17). The data is from a combination of previous hydrocensus studies, mining databases and from the Golder 2012 investigations.

With the exception of the Golder 2012 study, the data sets were limited to the shallow aquifer systems from boreholes on farms and long-term monitoring data from existing mines in the north of the study area. Salinity was used as a general description of water quality and it observed that higher salinities were measured in the southern portion of the study area and in the north-eastern portion of the New Vaal Colliery (NVC) area. Generally, the groundwater in the shallow aquifer was of a good quality with a few exceptions observed in boreholes GCLB004S, GCLB013S, GCLB012S and NVL91005S. At NVC the water can be classified as Na-Mg-Ca bicarbonate which is expected due to the source water being mostly derived from the underlying dolomitic type aquifers. However elevated concentrations of sodium (Na) and sulphate (SO₄) were observed in many of the boreholes affected by existing mining activities.

The majority of the samples taken in the greater “Lifex study area” (Figure 17), could be classified as Na-Magnesium (Mg)- bicarbonate (HCO₃⁻) type water, and increase in salinity is associated with enrichment in Na and Cl associated with the sediments where the water is derived from.

The following conclusions were drawn from the Lifex boreholes sampled and analysed in 2010/2012 (Golder 2012):

- Generally, the water quality of the study area was very good, the 50% percentile for salinity expressed as Electrical Conductivity (EC) in mS/m is at 90.4 mS/m.

- The drinking water quality standards (SANS:241 2005) are only exceeded in two boreholes (GCLB009D and NVL91005D) with respect to salinity. Both these boreholes were drilled into or near old flooded workings. Higher salinity is area generally associated with the deeper aquifer and the shallow aquifer being generally less saline. Two boreholes in the Metsimaholo study area (GCLB004 and GCLB002) showed increase an in salinity associated with elevated concentrations of Na and Cl.

- The measured pH values of groundwater samples ranged between less than 7 and above 10. However, the majority of the pH values measured were within the slightly too strongly alkaline ranges. Such alkaline pH values can contribute to the presence of selected elevated metals such as aluminium (Al), manganese (Mn) and iron (Fe). Overall the trace metals were found to be below detection for the range of metals analysed, with the exception of Al, Mn and Fe. The elevated values were mostly measured in the deep aquifer systems and the boreholes associated with the old workings.

- Fluoride (F) was another parameter that exceeded the standard for drinking water quality (SANS:241 2005) in some of the sampled boreholes (GCLB011D, NVL91005D, NVL91006D, NVL91008D, NVL91001D, NVL91012D and NVL91002D). The exact cause of these elevated values was not clear but is likely linked to the geological formations associated with the groundwater in those areas.

- SO₄ was only elevated in GCLB009 which is known to be linked to the old mine workings.

The groundwater of the Lifex Project was classified as mainly Na-bicarbonate type waters (Figure 18) (Golder, 2010). Exception to these two main groupings were GCLB009D and NVL91005D which were associated with the old workings, where elevated sulphate concentrations were measured, and GCLB004 and GCLB002 which is more of a NaCl type water. The NaCl type water in boreholes GCLB004 and GCLB002 is likely caused by exposure to the shale host rock associated with the deeper aquifer in the southern portion of the
Figure 17: Hydrogeological boreholes drilled as part of New Vaal Lifex Project in 2010.
Metsimaholo mining right application area. Many of the private hydrocensus boreholes sampled showed a similar NaCl character in this area (Golder, 2010).

No definitive difference could be detected between the water type of the deeper aquifer and the shallow system, except with regard to increased salinity which is expected due to longer residence time.

Down-hole water profiling was also undertaken to investigate hydrochemical changes with depth in the subsurface in 2010 after drilling of the study boreholes. The down-hole probe measured pH, EC, dissolved oxygen (DO), temperature and redox potential. Depths of water strikes and or lithology changes could be confirmed on some of these profiles, indicated by water quality changes with depth.

The DO profiles were stable with depth and measured less than 0.5 mg/l from approximately 1 meter below the rest water levels of the boreholes. The redox potential measured in most boreholes between -300 to -75 mV, indicating reducing groundwater conditions. These reducing conditions generally increased with depth. These conditions were confirmed by the geochemical modelling where anaerobic reduction of sulphate played a major role in reducing sulphate levels with depth. SO4 comparisons between deep and shallow boreholes confirmed these findings. Although SO4 concentrations are generally very low, there are slightly higher values associated with the shallow groundwater system.

3.4.5.2 2018 Water Quality Assessment

During the 2018 hydrocensus groundwater samples were collected to determine the current hydrochemistry and water quality of the Metsimaholo mining right application area (Figure 19). The water quality results for the 2018 study are also compared to previous water qualities reported by Golder (2012) to determine changes in water quality.
### Table 12: Groundwater Quality results obtained from analyses of samples collected on the Metsimaholo mining right application area in November 2018.

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Units</th>
<th>GCLB003D</th>
<th>GCLB004S</th>
<th>GCLB004D</th>
<th>GCLB005M</th>
<th>GCLB005D</th>
<th>GCLB011D</th>
<th>GCLB014S</th>
<th>GCLB005S</th>
<th>GCLB005S-D</th>
<th>GCLB007M</th>
<th>GCLB007D</th>
<th>GCLB009S-D</th>
<th>GCLB009D</th>
<th>GCLB009M</th>
<th>GCLB016M</th>
<th>GCLB0016D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissolved Arsenic</td>
<td>mg/l</td>
<td>0.0025</td>
<td>0.0065</td>
<td>0.0055</td>
<td>0.0055</td>
<td>0.0041</td>
<td>0.0046</td>
<td>0.004</td>
<td>0.0034</td>
<td>0.0036</td>
<td>0.0037</td>
<td>0.0078</td>
<td>0.0091</td>
<td>0.0005</td>
<td>0.0005</td>
<td>0.0005</td>
<td>0.0001</td>
</tr>
<tr>
<td>Dissolved Boron</td>
<td>mg/l</td>
<td>0.022</td>
<td>0.068</td>
<td>1.265</td>
<td>0.275</td>
<td>0.302</td>
<td>0.188</td>
<td>0.193</td>
<td>0.83</td>
<td>0.056</td>
<td>0.298</td>
<td>0.08</td>
<td>0.079</td>
<td>0.984</td>
<td>0.401</td>
<td>0.01</td>
<td>5.01</td>
</tr>
<tr>
<td>Dissolved Cadmium</td>
<td>mg/l</td>
<td>0.0005</td>
<td>0.0005</td>
<td>0.0005</td>
<td>0.0005</td>
<td>0.0005</td>
<td>0.0005</td>
<td>0.0005</td>
<td>0.0005</td>
<td>0.0005</td>
<td>0.0005</td>
<td>0.0005</td>
<td>0.0005</td>
<td>0.0005</td>
<td>0.0005</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Dissolved Calcium</td>
<td>mg/l</td>
<td>14.1</td>
<td>41</td>
<td>5.1</td>
<td>17</td>
<td>0.7</td>
<td>3.6</td>
<td>2</td>
<td>0.9</td>
<td>78.6</td>
<td>1</td>
<td>20.9</td>
<td>18.9</td>
<td>32.6</td>
<td>3.1</td>
<td>1000</td>
<td>ng</td>
</tr>
<tr>
<td>Total Dissolved Chromium</td>
<td>mg/l</td>
<td>0.0015</td>
<td>0.0015</td>
<td>0.0015</td>
<td>0.0015</td>
<td>0.0015</td>
<td>0.0015</td>
<td>0.0015</td>
<td>0.0015</td>
<td>0.0015</td>
<td>0.0015</td>
<td>0.0015</td>
<td>0.0015</td>
<td>1.5</td>
<td>1.5</td>
<td>ng</td>
<td>ng</td>
</tr>
<tr>
<td>Dissolved Copper</td>
<td>mg/l</td>
<td>0.007</td>
<td>0.007</td>
<td>0.007</td>
<td>0.007</td>
<td>0.012</td>
<td>0.007</td>
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<td>0.007</td>
<td>0.007</td>
<td>0.007</td>
<td>0.007</td>
<td>0.007</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Dissolved Magnesium</td>
<td>mg/l</td>
<td>16.4</td>
<td>37.4</td>
<td>1.1</td>
<td>10.1</td>
<td>0.3</td>
<td>6.6</td>
<td>9.3</td>
<td>0.2</td>
<td>38.1</td>
<td>0.2</td>
<td>35.7</td>
<td>35.7</td>
<td>24</td>
<td>2.9</td>
<td>500</td>
<td>ng</td>
</tr>
<tr>
<td>Dissolved Potassium</td>
<td>mg/l</td>
<td>2.8</td>
<td>81.3</td>
<td>1.9</td>
<td>0.9</td>
<td>0.05</td>
<td>4.2</td>
<td>10</td>
<td>0.5</td>
<td>8.3</td>
<td>0.7</td>
<td>0.9</td>
<td>2.6</td>
<td>2.8</td>
<td>2.1</td>
<td>ng</td>
<td>ng</td>
</tr>
<tr>
<td>Dissolved Sodium</td>
<td>mg/l</td>
<td>55.7</td>
<td>75.3</td>
<td>286.8</td>
<td>148.9</td>
<td>182.9</td>
<td>203.8</td>
<td>200</td>
<td>241.9</td>
<td>83.4</td>
<td>197.7</td>
<td>138.3</td>
<td>141.5</td>
<td>58.6</td>
<td>80.3</td>
<td>2000</td>
<td>70</td>
</tr>
<tr>
<td>Dissolved Lead</td>
<td>mg/l</td>
<td>0.005</td>
<td>0.005</td>
<td>0.005</td>
<td>0.005</td>
<td>0.005</td>
<td>0.005</td>
<td>0.005</td>
<td>0.005</td>
<td>0.005</td>
<td>0.005</td>
<td>0.005</td>
<td>0.005</td>
<td>0.005</td>
<td>0.005</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Dissolved Mercury</td>
<td>mg/l</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>ng</td>
</tr>
<tr>
<td>Dissolved Nickel</td>
<td>mg/l</td>
<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
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<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
<td>0.02</td>
<td>1.02</td>
</tr>
<tr>
<td>Dissolved Selenium</td>
<td>mg/l</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
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<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
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<td>0.003</td>
<td>0.003</td>
<td>0.02</td>
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<tr>
<td>Dissolved Zinc</td>
<td>mg/l</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
<td>0.003</td>
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<tr>
<td>Fluoride</td>
<td>mg/l</td>
<td>14.7</td>
<td>4</td>
<td>2.8</td>
<td>0.6</td>
<td>0.5</td>
<td>0.3</td>
<td>0.3</td>
<td>5.8</td>
<td>0.5</td>
<td>0.9</td>
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<tr>
<td>Chloride</td>
<td>mg/l</td>
<td>51.5</td>
<td>138</td>
<td>279.4</td>
<td>69.2</td>
<td>36.7</td>
<td>98.3</td>
<td>122.6</td>
<td>164.8</td>
<td>64.2</td>
<td>42.3</td>
<td>46.6</td>
<td>45.3</td>
<td>21.6</td>
<td>32</td>
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<tr>
<td>Ortho Phosphate as PO4</td>
<td>mg/l</td>
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<td>0.06</td>
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<td>Sulphate</td>
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<td>Total Alkalinity as CaCO3</td>
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<td>324</td>
<td>196</td>
<td>300</td>
<td>338</td>
<td>331</td>
<td>329</td>
<td>235</td>
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<td>352</td>
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<td>518</td>
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<td>186</td>
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<tr>
<td>Electrical Conductivity @25°C</td>
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<td>43.1</td>
<td>117.1</td>
<td>143.4</td>
<td>78.6</td>
<td>76.2</td>
<td>93.9</td>
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<td>110.5</td>
<td>110.3</td>
<td>56</td>
<td>38.3</td>
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<tr>
<td>pH</td>
<td>pH units</td>
<td>7.82</td>
<td>7.18</td>
<td>8.39</td>
<td>7.98</td>
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<td>8.33</td>
<td>6.5-8.4</td>
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<tr>
<td>Total Dissolved Solids</td>
<td>mg/l</td>
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<td>685</td>
<td>781</td>
<td>476</td>
<td>376</td>
<td>519</td>
<td>567</td>
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<td>628</td>
<td>313</td>
<td>269</td>
<td>1000</td>
<td>ng</td>
</tr>
</tbody>
</table>
Samples were collected within both the defunct Coalbrook underground mining area and in undisturbed areas of the Metsimaholo mining right application area. The water quality results from the 2018 study are shown in Table 12 and compared to previous water qualities and assessed against South African drinking water standards, livestock watering and irrigation guidelines.

Salinity is used to describe the water quality as almost all sampled boreholes have Na concentrations above the DWA water guideline for irrigation (≤ 70 mg/l), except for GCLB003D and GCLM016M which have values within this guideline limit. The water quality in the shallow aquifer is good but falls short of irrigation water quality as Na and EC are above guideline limits for all shallow boreholes.

The groundwater sampled in the monitoring boreholes on the Metsimaholo mining right application area is characterised by:

- Generally, the water quality of the study area is good, but exceeds the irrigation guideline limits for EC. All boreholes were non-compliant in this respect.
- The drinking water quality standard (SANS:241 2015) is exceeded with respect to salinity in four boreholes, GCLB004D, GCLB007D, GCLB007M and GCLB011D. These boreholes are located near or down-gradient of the old abandoned Coalbrook underground workings. The salinities are also higher in the deeper aquifer than in the shallow aquifer.
- The pH of the groundwater sampled ranges between 7 and 9.4. However, the majority of the pH values are within the alkaline range. Overall the trace metals were found to be below detection for the range of metals analysed, with the exception of Arsenic (As). The elevated concentration of As occurs in borehole GCLB004D which monitors the deep aquifer system close to the old Coalbrook underground workings.
- Fluoride concentrations exceed the SANS 241:2015 drinking water standard in boreholes GCLB003D, GCLB004D and GCLD011D.
- Sulphate was within the DWA 1996 irrigation water guideline limit and meets SANS 241:2015 drinking water quality standards.

No definitive difference could be detected between the water type of the deeper aquifer and the shallow system, excepting the generally higher salinity in the deeper aquifer, which is likely due to a longer residence time of the groundwater in this aquifer zone. The groundwater quality is not significantly dissimilar to the groundwater sampled in 2010. The groundwater composition and trends for the groundwater samples
collected in 2010, 2012 and 2018 is summarised below and shown in the piper diagram (Figure 20).

The shallow aquifer west of the old Coalbrook mine workings has changed from a Ca-Mg-Na-Cl composition in 2010 to a Na-Mg-HCO₃-Cl composition for 2018 with reference to borehole GCLB004S i.e., there is a decrease in Cl concentration and EC.

The groundwater within the old Coalbrook mine workings has also shown a change in water type from 2010 in monitoring borehole GCLB014S, which was dominated by Ca-Na-Mg- HCO₃-Cl, in 2012 but has shifted to a Ca-Na-Mg- HCO₃-SO₄ type in 2018 with an increase in SO₄ concentration.

The intermediate (medium) aquifer monitored in borehole GCLB007M shifted significantly in composition from HCO₃-SO₄ in 2010 to Na-HCO₃-Cl in 2012 and 2018, brought on by increased concentrations of Na and Cl and a decrease in SO₄ concentration. Increased Na concentrations in borehole GCLB016M in 2012 and 2018 have shifted the water composition from Ca-Mg-Na-HCO₃ to Na-Mg-Ca-HCO₃.

The deep aquifer is predominately dominated by Na-HCO₃ but has experienced a notable increase in Cl and decrease in SO₄ concentration in the majority of the monitoring boreholes on the Metsimaholo mining right application area.
Figure 19: Location of monitoring boreholes in the Metsimaholo mining right application area.
Figure 20: Piper Plot showing groundwater composition of groundwater sampled at the planned Metsimaholo Mine.

3.5 Underground mining

There are two existing underground mining areas that influence groundwater systems. The first is the old Cornelia mine in the north and the Coalbrook mine east of the Metsimaholo mining right application area. The old Cornelia working are significantly far removed to not be expected to have significant influence on proposed mining operations.

Water level monitoring between old Cornelia and New Vaal opencast mine to the north of the Metsimaholo mining right application area has been ongoing for several years. The data shows that the underground mine voids have flooded and water levels are stable since 2004. The dewatering from the New Vaal Colliery has an effect on the aquifers. This system is linked to alluvial deposits of the Vaal River and lower Taalbospruit, shallow sediments and the underlying dolomitic aquifer. Water quality of the flooded workings are typical mine water quality with high salinity and increased Na-SO4 signature, but generally alkaline to neutral pH. Water quality influences are limited to the areas around the workings and no adverse water quality affects are observed in surrounding shallow aquifer system (Golder 2012).
In the Metsimaholo mining right application area no long-term water level or water quality monitoring data is available for the Coalbrook workings. From the 2010 field investigation it was seen that the workings at Coalbrook have not stabilised and deep groundwater flow was still towards the workings (Golder 2012). The data showed no evidence that the shallow aquifer system above the extensive dolerite sill were adversely affected by the mining activities. Water quality in the workings was also characterised by higher salinity but has a distinct Na-Cl signature rather than Na-SO4. This is likely due to the limitation of oxygen ingress in the system due to depth of the workings and no other active mining in close proximity.

It can, therefore, be concluded that cognisance of possible influences from new mine workings on these two abandoned mines need to be taken when determining the impacts on the aquifer systems. Water quality and groundwater flow patterns will be altered by new activities and may adversely impact on the systems already affected by underground mining.

### 3.6 Groundwater Users

Several hydrocensus within the mining area boundaries have been carried out. In the New Vaal area between Vaalpark (Sasolburg) and Deneysville (Golder, 2010), the hydrocensus involved the collection of data from each facility including GPS co-ordinates, land owner, existing equipment, current use, reported yield, reported or measured depth, the static water level and field measurements of pH and conductivity. A previous hydrocensus undertaken in 2005 under instruction of DWAF, for the Leeu-Taibosch study was used as a starting reference point.

In addition to the 2005 hydrocensus data collected, a hydrocensus of the study area was undertaken by Coalbrook Colliery during mining operations to assess the impacts from the mining activities. This hydrocensus was conducted in 1977 (ACGS Archived reports, 1977). This data set was added to the database to be used as a baseline data set and compared to the 2005 and 2009 data sets.

From the available data sets it can be seen that the groundwater use and occurrence seem to have been stable over the past 35 years. The yields from the boreholes surveyed were generally low to moderate (~1.8L/s) and uses were mainly for domestic and stock watering purposes. The data showed that the landowners are utilising the shallow (upper) aquifer for water supply and the existing underground mining has had limited impact on this aquifer system.

The current hydrocensus (2018) has confirmed that the status quo of groundwater users has remained the very similar.

### 4.0 CONCEPTUAL GROUNDWATER MODEL

The data gathered during the field investigation phases described in the preceding section of this report was used to develop the conceptual hydrogeological model of the area. The conceptual model forms the basis for the understanding of the groundwater occurrence and flow mechanisms in the area and is used as the starting point for the numerical modelling.

The regional climate in the area is defined by the South African Weather Bureau as moderate and can be locally described as warm in summer and cold in winter. The recharge value is estimated at approximately 6.2 mm per year corresponding to 1 % of the annual precipitation (MAP) of 620 mm. The mean annual S-Pan evaporation (MAE) is 1,625 mm per year (Midely et al, 1990). Hence, on average, potential evaporation exceeds precipitation by about 1 000 mm per year.

The geology comprises sedimentary deposits of the Karoo Supergroup, mainly sandstone, mudstone, siltstone and shale with thin layers of coal. The sequence dips towards the south-south-east intrusive sills and dykes dominate the structural setting with minor faulting reported.
The shallow (upper) aquifer has been intersected in most boreholes drilled even if no or low measurable water strikes were recorded. Groundwater occurrence in the shallow water bearing horizon is, where present along water courses, also controlled by the alluvium deposits associated with flood plains.

The deep aquifer horizon is controlled by the lateral and vertical distribution of deeper fractures within the shale, sandstone and coal beds as well as the contact zones with dolerite sill and dyke intrusions. Mostly seepage and very low yields were obtained during drilling proving the presence of a localized, poorly developed and anisotropic aquifer. These water strikes were typically made in the sandstone located close to the upper coal seam (TMH). The bottom of the deep aquifer is represented by a Dwyka age tillite which is assumed to act as an aquitard, due to its low permeability (Figure 21).
Figure 21: 3D Conceptual Hydrogeological Model of the Metsimaholo mining right application area (taken from Golder 2012).
4.1 Geological Modelling

*Leapfrog Works* is a dynamic 3D modelling package which allows the build of geological models directly from borehole data. Simplified lithological information from a subset of 50 coal exploration boreholes was transformed into a 3D hydro stratigraphic model (Figure 22). The complete set of data comprises approximately 300 exploration boreholes drilled in the Metsimaholo mining right application area. The hydro stratigraphic model (Figure 23) complexity has, however, been kept at a level commensurate with a preliminary hydrogeological model (Figure 23).

![Figure 22: Image showing the exploration boreholes used to assist in creating the 3D hydro-stratigraphic model.](image)

![Figure 23: Image of the simplified hydrostratigraphic 3D model based on the 50 exploration boreholes lithological data.](image)
5.0 GROUNDWATER NUMERICAL MODELLING

5.1 Introduction

A 3D numerical model was constructed to represent the conceptual groundwater system of the study area as presented in Section 4.1. The purpose of the model is to develop a tool that can be used to assess the potential groundwater conditions during development, operation as well as post-closure.

5.2 Modelling Objectives

The main objectives of the numerical model are to determine the inflows into the proposed Metsimaholo underground mine pit over the operational phase and to simulate the rebound of the water levels post mine closure. A further objective is to determine potential impacts on the water levels in the shallow aquifer in space over time with the associated impacts on the baseflow to surface water systems.

5.3 Software Selection

The code selected for conducting the modelling of the study area is FEFLOW VER 7.1 developed by the WASY Institute for Water Resources Planning and Systems Research, Ltd Berlin, Germany. FEFLOW is an interactive groundwater modelling system for three and two-dimensional, areal and cross-sectional, fluid density-coupled, thermohaline or uncoupled, variably saturated, transient or steady state flow, mass and heat transport in subsurface water resources with or without one or multiple free surfaces.

Since its creation in 1979 FEFLOW has been continuously improved. The FEFLOW source code is written in ANSI C/C++ and contains more than 1.1 million programme lines. FEFLOW is used worldwide as a high-end groundwater-modelling tool at universities, research institutes, government offices and engineering companies.
5.4 Model Construction

5.4.1 Introduction

The groundwater flow modelling depends on the physical properties of the site. For a numerical model to be relevant as a predictive tool, it is necessary to integrate the physical geometry and properties of the site into the model. Controlling factors are the topography and relief, surface hydrology and rainfall, geology, as well as the properties of the aquifer system.

As discussed in Section 4.1 above Leapfrog Hydra Works was used to interpret a select number of geological exploration boreholes obtained from Seriti to construct lithological contact surfaces and merge them the discretised FEFLOW model domain.

5.4.2 Conceptualisation of the Groundwater System for numerical model

The first step in the modelling procedure is the construction of a conceptual model of the problem and the relevant aquifer domain. The conceptual model consists of a set of assumptions that reduce the real problem and the real domain to simplified versions that are acceptable in view of the objectives of the modelling and of the associated management problem.

The data gathered during the desk study and data evaluation phase of the study has been used to develop a hydrogeological conceptual model for the area, which forms the basis for the numerical modelling. A description of the conceptual model is provided in the preceding sections of this report.

The conceptual model is outlined below.

In a typical hydrogeological setting groundwater flow and aquifer development are closely linked to the geology and structural geology of an area. There is no reason to believe that the area under investigation will not conform to this assumption and therefore the geology forms the basis on which the conceptual hydrogeological model is based spatially. The nature and distribution of the geological units, and possibly geological structures control the hydrogeology of the study area.

The aquifer underlying the study area consists mainly of shale/sandstone/siltstone/mudstone and coal beds of the Vryheid and Volksrust Formations of the Ecca Group of the Karoo Sequence. Sections of the model domain, especially along river and stream floodplains, are underlain by alluvium. Extensive post-Karoo dolerite sills have intruded into the sedimentary sequence. Both these mentioned lithologies influences groundwater flow.

The Ecca Formations are underlain by impermeable Dwyka tillite. It is assumed that the Dwyka tillite is impermeable and that the formation will not be compromised during mining operations.

Recharge to the aquifer is from precipitation during the rainy season. Groundwater flow is from areas of higher piezometric elevations to lower elevations. Groundwater flow directions mimic the surface topography in large parts of the model domain. This is confirmed by the general correlation between groundwater levels and the surface topography (Figure 11). It must, however, be noted that some water levels do no correlate well especially in the deeper aquifer (Figure 13). This is attributed to the impact of abstraction for agricultural purposes close to the constructed monitoring boreholes across the area. There is also a distinct remaining, possibly permanent, influence of the old abandoned and collapsed underground Coalbrook workings on the local and regional groundwater flow patterns in the model domain and study area.
5.4.3 Model Domain

As a result of local recharge and discharge, groundwater divides developed approximately beneath the major surface water divides. In the absence of evidence of physical subsurface no-flow boundaries, the modelling area was therefore selected based on topographical control i.e. along surface catchment boundaries.

According to standard modelling practice, this is a reasonable approach to follow since a fair correlation exists between the groundwater level elevation and the surface topography. Boundaries of the numerical model were therefore chosen to reflect the geometry of the surface water catchment system as shown in Figure 25.

The Robspruit, Taaibosspruit, Vaal River and Vaal Dam form the western, northern and eastern model boundaries respectively. The majority of the groundwater flow is towards the Taaibosspruit which form the northern-western boundary but also forms a significant internal drain to the model. The southern boundary is considered a no flow boundary even though the Taaibosspruit crosses into the model domain from the south, this added inflow is currently considered insignificant enough to discount as the remaining catchment of the Taaibosspruit to the south is aerially small. The northern and eastern part of the study area also drains towards the Vaal River and Dam in the east. The boundaries to the north and east are therefore comprised by the Vaal River and Vaal Dam respectively.

To the south model the boundary coincides to groundwater divides present beneath the surface water divides. The base of the model domain is set to be the base elevation of the Dwyka tillite formation.

5.4.4 Boundary Conditions

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

- Dirichlet Type (or constant head) boundary conditions or;
- Neuman Type (or specified flux) boundary conditions; and
- or a mixture of the above.

5.4.4.1 Model Perimeter Boundary Conditions

Groundwater flow directions largely follow topography, and the groundwater basin geometry can be approximated by the surface water drainage geometry. The boundary conditions of the numerical model are shown in. The model area perimeter coincides to the north and east to the Vaal River/Dam where constant head boundary conditions (seepage faces) were specified. These boundary conditions are numerically represented as a Type I boundary condition (also known as a Dirichlet condition). To the south the model perimeter coincides with no-flow boundaries where no-flow boundary conditions were specified. These boundaries are represented numerically by what is referred to as a “specified” boundary condition (Zero specified flux or Neuman Type II boundary condition).

To the west a Type I boundary condition (Dirichlet condition) were also specified along the Robspruit and the Taaibosspruit north its confluence with the Robspruit.

5.4.4.2 Internal Model Boundaries

The groundwater system within the study area is largely recharged via infiltration of precipitation. It is thought that most of the groundwater recharge occurring within the study area discharges internally to the surface drainage systems via springs and discharge to the base of river drainage systems (base flow). Constant head
Figure 25: Extent of the numerical model domain and boundary zones.
boundary conditions were therefore specified along the major surface drainages, which are known to receive base flow from groundwater.

The constant head boundary condition allows groundwater to discharge, in this case, from the model area at a rate dependent on the hydraulic conductivity and hydraulic gradient across the boundary.

The constant head boundaries were constrained (seepage faces) at the elevation of the ground surface so that water can only be simulated to leave the groundwater system and not enter the groundwater system.

5.4.4.3 Model Base Boundary Conditions
The model domain was assumed to extend vertically to the base of the Dwyka tillite. It is assumed that the base of the model is impermeable.

5.4.4.4 Model Surface Boundary Conditions
Boundary conditions applied to the top surface area of the model include the following. A defined quantity of effective background recharge is assigned (3mm/a) to the entire surface area for the steady state simulation (calibration). This constitutes about 0.5-1% of MAP and is in line with the low hydraulic conductivity values of the area, which restricts vertical percolation of rainfall recharge into the subsurface.

5.4.5 Hydrogeological Units and Model Structure
The following hydrogeological units were included in the model domain:

- The alluvium and soft weathered horizon (Layer 1).
- The Ecca Formation below the alluvium and weathered horizon generally above the thick dolerite sill. (generally, Layer 2-3).
- The Dolerite Sill (generally Layer 4 where present).
- The Ecca Formation above the Top Mining Horizon (TMH) (Layer 3-5).
- Top Coal Seam to be mined (TMH) (Layer 6).
- The Ecca Formation between the TPH and the Middle Mining Horizon (MLMH) (Layer 7).
- Middle Coal Horizon seam to be mined (MLMH) (Layer 8).
- The Ecca Formation below the MLMH (Layer 9).
- The Dwyka Horizon (Layer 10).

The model structure can be best illustrated by cross sections. For this purpose, a west to east cross-section indicated in the general layer configuration in Figure 26.

5.4.6 Hydraulic Stresses
The conceptualized water balance components that are considered were simulated in the numerical model using the available components of the FEFLOW software package. This included the “In-Out flow from surface” package to simulate natural groundwater recharge and the constant head boundary condition Type I to simulate outflow from the internal model boundaries and to simulate the open pit and underground mines.
Figure 26: General Vertical discretization of the FEFLOW model domain.
5.4.7 Aquifer Parameters

Aquifer tests are usually conducted to determine aquifer hydraulic parameters (transmissivity, hydraulic conductivity, and storativity). These data are essential for the numerical flow modelling exercise.

5.4.7.1 Hydraulic Conductivity

Hydraulic conductivity (K) can be defined as the rate of flow of water in cubic metres per day through a cross section of one square metre of aquifer under a unit hydraulic gradient (Units: m³/day/m² or m/day). Estimates of the K value of the aquifer were obtained from the results of slug tests conducted during a field exploration programme. Multiplying the K value with the saturated thickness of the aquifer provides the aquifer transmissivity (T, Units: m²/day or m/day/m). The hydraulic conductivity value obtained from the field tests are presented in Table 6 and Table 7.

In previous studies (Golder 2012) separate frequency distributions were constructed for the NVL Boreholes and GCLB Boreholes (Figure 35). It is evident from the data presented that the spread in K-values are wider for the GCLB boreholes than for the NVL Boreholes. The K-values for the NVL Boreholes range between 10⁻⁶ – 10⁻⁹ m/s whilst the range for the GCLB Boreholes is in the range 10⁻⁴ – 10⁻¹⁰ m/s. It is noted from the orders of magnitude differences obtained from the field test results that the aquifer(s) displays highly heterogeneous characteristics.

Averaging statistics for the hydraulic conductivity data set for the GCLB boreholes are presented in Table 13 taken from Golder (2012).

It was stated in Golder (2012) that it is clear from the enormous variations in K-values obtained from the field tests that it is a problematic task to select a representative K-value to represent the aquifer within a numerical modelling context. K is never the property of a "point" but is always an average over some representative elementary volume (REV).

When K is a function of position within an aquifer, i.e. K = K(x,y,z) the aquifer is considered to be heterogeneous. Heterogeneity can be abrupt, trending, or "uniform". In the last case K varies locally, but the statistical distribution of K is similar in different portions of the aquifer. In some cases, we can use an "equivalent homogeneous medium" approximation, replacing the spatially variable K with some type of equivalent average K. This is the type of assumption we are using to analyse our permeameter experiments and it is also an assumption invoked by Darcy in his original experiment. The types of averages are defined in the text:

- the arithmetic mean;
- the harmonic mean; and
- the geometric mean.

The harmonic mean is always less than the arithmetic mean, and the geometric mean in between these. The geometric mean has been suggested as the best estimate of an equivalent average K for uniformly heterogeneous materials. The geometric mean is also often close to the K value determined from the arithmetic mean of log transformed K's. This rationale was considered in the selection and specification of the K-values in the numerical model.
Table 13: Hydraulic conductivity statistics for the GCLB Boreholes.

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<th>Harmonic Mean (m/s)</th>
<th>Geometric Mean (m/s)</th>
</tr>
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<td>3.80247E-09</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.4.7.2 Aquifer Storitivity

For the steady-state model, storativity is not required. For transient state simulations a specific storage value of $2 \times 10^{-5}$/m was used – this would provide an equivalent aquifer storage coefficient of 0.002 or 0.2 percent for a 100m saturated aquifer material.

5.4.8 Model Area and Finite Element Mesh

The numerical model encompasses the area of 411 km$^2$, to the south of the Vaal River, east of the Vaal Dam and west of the Robspruit and Taaibosspruit. A finite element network (grid) was designed to provide a high resolution for the numerical solution while at the same time be able to cover a large area as shown in Figure 27. The finite element network was compiled using the FEFLOW pre-processing software, which facilitated the construction of 6-noded triangular prism elements over the area of investigation. The triangular grid comprises of 111 4110 mesh node and 624 110 mesh elements. The positions of the different geological units and mines are incorporated in the modelling grid as well as the various surface catchments. The model consists of nine layers with variable thicknesses and 10 slices. The elevation of the top slice coincides with the surface topography.

5.4.9 Recharge

The annual effective recharge is estimated to be in the order of 0.5-1% of MAP. This is a low value but relates directly to the low permeabilities of the aquifer(s).

5.4.10 Evaporation

Evapotranspiration was not specified in the model. It is assumed that the (effective) recharge specified in the model has already overcome the effect of evapotranspiration losses from the system.

5.4.11 Initial Hydraulic Head Condition

The initial head conditions specified in the model were interpolated from the measured groundwater levels using the Kriging technique and extrapolated to the nodes in the model.

5.4.12 Numerical Groundwater Flow Model

A steady state groundwater flow model for the study area was constructed to simulate undisturbed groundwater flow conditions. These conditions serve as starting heads for the transient simulations of groundwater flow and mass transport where the effect of mining operations will be taken into consideration.

A dynamic flow model using the modelling package FEFLOW (Diersch, 1979) was constructed for the study area. The simulation model (FEFLOW) used in this modelling study is based on three-dimensional groundwater flow and may be described by the following equation:
Figure 27: Finite element FEFLOW grid applied over the model domain.
\[
\frac{\partial}{\partial x}(K_x \frac{\partial h}{\partial x}) + \frac{\partial}{\partial y}(K_y \frac{\partial h}{\partial y}) + \frac{\partial}{\partial z}(K_z \frac{\partial h}{\partial z}) \pm W = S \frac{\partial h}{\partial t}
\]  

(1)

Where:

- \(H\) = hydraulic head [L]
- \(K_x, K_y, K_z\) = Hydraulic Conductivity [L/T]
- \(S\) = Storage Coefficient
- \(t\) = Time [T]
- \(W\) = source (recharge) or sink (pumping) per unit area [L/T]
- \(x, y, z\) = spatial co-ordinates [L]

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

\[
\frac{\partial}{\partial x}(K_x \frac{\partial h}{\partial x}) + \frac{\partial}{\partial y}(K_y \frac{\partial h}{\partial y}) + \frac{\partial}{\partial z}(K_z \frac{\partial h}{\partial z}) \pm W = 0
\]  

(2)

According to the conceptual model for the system the calculated hydraulic head distribution \((h_x, h_y, h_z)\) is dependent upon the recharge from rainfall, hydraulic conductivity and boundary conditions. For a given hydraulic conductivity value (or transmissivity value) and a set of boundary conditions, the head distribution across the aquifer can be obtained for a specific recharge value. This simulated head distribution can then be compared to the measured head distribution and the effective recharge values can be altered until and acceptable correspondence between measured and simulated heads is obtained.

### 5.4.12.1 Steady State Calibration Approach

Steady state calibration was accomplished by varying the hydraulic conductivity values and keeping the recharge rate constant, until a reasonable match between the measured groundwater elevations and the simulated groundwater elevations was obtained. A constant recharge was used because localized recharge variations (based on slope or soil type) cannot be determined with the limited data available at this time. For this modelling study, a constant recharge rate is considered reasonable and likely to result in similar regional predictions compared to spatially distributed recharge. Figure 28 show the locations of target boreholes and water level elevations used for calibration purposes.
Figure 28: Position of observation boreholes across model domain and error bars showing margins of error in steady state calibrations

5.4.12.2 Simulation of Steady State Water Levels

Figure 29 shows the simulated steady state groundwater elevations and groundwater flow directions for the steady state calibration. There are insufficient boreholes with groundwater level data to create an observed water table map for the entire model area. Therefore, the model output has been evaluated in a qualitative manner by observing the shape of the water table contours near known hydraulic boundaries, divides and drainages. The calibrated model water table is similar to what would be expected at the location of internal watersheds divides and major drainages and is reasonable in the vicinity of the proposed mining operations. As shown in Figure 29 the water table closely conforms to local topographic features.
American Society for Testing and Materials (ASTM) guidelines, as well as widely accepted methods presented in Anderson and Woessner (1992) and Spitz and Moreno (1996) were followed for calibration of the model.

Table 14: Steady State Calibration Measures for Steady State Model

<table>
<thead>
<tr>
<th>Borehole</th>
<th>Observed SWL (mamsl)</th>
<th>Simulated Water Level (mamsl)</th>
<th>ME (m)</th>
<th>MAE (m)</th>
<th>RMS (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>(WLM- WLS)</td>
<td></td>
<td>(WLM- WLS)</td>
</tr>
<tr>
<td>GCLB007M</td>
<td>1467.82</td>
<td>1466.674</td>
<td>8.2</td>
<td>8.2</td>
<td>67.24</td>
</tr>
<tr>
<td>GCLB007D</td>
<td>1467.02</td>
<td>1466.202</td>
<td>7.497</td>
<td>7.497</td>
<td>56.20501</td>
</tr>
<tr>
<td>GCLB005D</td>
<td>1453.305</td>
<td>1461.978</td>
<td>-8.802</td>
<td>8.802</td>
<td>77.4752</td>
</tr>
<tr>
<td>GCLB005M</td>
<td>1454.92</td>
<td>1461.601</td>
<td>-6.978</td>
<td>6.978</td>
<td>48.69248</td>
</tr>
<tr>
<td>Borehole</td>
<td>Observed SWL (mamsl)</td>
<td>Simulated Water Level (mamsl)</td>
<td>ME (m)</td>
<td>MAE (m)</td>
<td>RMS (m)</td>
</tr>
<tr>
<td>-------------</td>
<td>----------------------</td>
<td>-------------------------------</td>
<td>--------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td></td>
<td>(WLm- WLs)i</td>
<td></td>
<td>[WLm- WLs]i</td>
<td>(WLm-WLs)i^2</td>
<td></td>
</tr>
<tr>
<td>GCLB005S</td>
<td>1452.38</td>
<td>1460.988</td>
<td>-8.481</td>
<td>8.481</td>
<td>71.92736</td>
</tr>
<tr>
<td>GCLB003D</td>
<td>1499.04</td>
<td>1498.422</td>
<td>1.962</td>
<td>1.962</td>
<td>3.849444</td>
</tr>
<tr>
<td>GCLB008M</td>
<td>1441.051</td>
<td>1441.133</td>
<td>-4.629</td>
<td>4.629</td>
<td>21.42764</td>
</tr>
<tr>
<td>GCLB008D</td>
<td>1441.434</td>
<td>1441.123</td>
<td>-4.292</td>
<td>4.292</td>
<td>18.42126</td>
</tr>
<tr>
<td>GCLB006S</td>
<td>1478.16</td>
<td>1478.382</td>
<td>0.42</td>
<td>0.42</td>
<td>0.1764</td>
</tr>
<tr>
<td>GCLB014S</td>
<td>1460.41</td>
<td>1460.007</td>
<td>-0.903</td>
<td>0.903</td>
<td>0.815409</td>
</tr>
<tr>
<td>GCLB004S</td>
<td>1520.93</td>
<td>1503.819</td>
<td>12.641</td>
<td>12.641</td>
<td>159.7949</td>
</tr>
<tr>
<td>GCLB004D</td>
<td>1458.19</td>
<td>1503.098</td>
<td>-48.376</td>
<td>48.376</td>
<td>2340.237</td>
</tr>
<tr>
<td>GCLB011D</td>
<td>1437.390015</td>
<td>1456.883</td>
<td>-25.847</td>
<td>25.84699</td>
<td>668.0666</td>
</tr>
<tr>
<td>GCLB013S</td>
<td>1448.18</td>
<td>1448.104</td>
<td>-18.659</td>
<td>18.659</td>
<td>348.1583</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-6.8748</td>
<td>11.26336</td>
<td>3,882.49</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>14.00</td>
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<td></td>
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<td></td>
<td>277.32</td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>RMSE</td>
<td>16.65</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NRMSE%</td>
<td>19.93</td>
</tr>
</tbody>
</table>

- ME = 1/n Σ(WLm- WLs)i
- MAE = 1/n Σ |(WLm- WLs)i|.

A small ME is not necessarily an indication of a good calibration, because negative and positive residuals, even if large, can cancel each other out, resulting in a small ME. The MAE addresses this as the mean of the absolute value of the differences in measured and simulated water levels:
The RMS error is the average of the squared differences in measured and simulated water levels.

\[ \text{RMS} = \left[ \frac{1}{n} \sum (\text{WL}_m - \text{WL}_s)^2 \right]^{0.5}. \]

In keeping with standard practice, the RMS error was evaluated as a ratio to the total water level change across the model domain. If the ratio is small, the errors are only a small part of the overall model response (Anderson and Woessner 1992). The ME, MAE, and RMS error were calculated using all the calibration targets for the available data set. The Mean Error for the data set is -6.87 metres. The Mean Absolute Error for the data set is 11.2 metres. The Root Mean Squared error of 20 percent of the range of water level change across the model domain (see Table 9).

The observed groundwater levels were plotted against the simulated water levels in a scatter plot for the data set (Figure 30). Deviations from the straight line, indicating a perfect match between the observed and simulated values, should be randomly distributed indicating that there is no bias toward over or under predicting the groundwater levels (Anderson and Woessner 1992). A correlation coefficient of 97% was obtained between the simulated and observed groundwater elevations for the data set. The plot of the modelling errors for the water level data set (Figure 30) indicates that the model is generally not under or over-predicting the groundwater elevations since a normal distribution is fitting the data set well.

![Steady State Calibration Results Scatter Plot](figure30)

**Figure 30: Steady State Calibration Results-Scatter Plot**

5.4.12.3 **Specified (Calibrated) Aquifer Hydraulic Parameters Conditions**

**Alluvial and Soft Weathered Aquifer (Layer 1):**

The specified aquifer hydraulic conductivity for the model hinged around the following reasoning and rationale:

For the shallow alluvial and “soft weathered aquifer” represented by conducted by Hodgson (2005):

“In view of the fine-grained nature of the alluvial material, its water-yielding properties from boreholes are limited. Yields are usually less than 0.1 l/s, except where boulder beds are developed. Even in these instances, prolonged yield from the boulder beds is limited, because of the limited extent of the beds.”

In consideration of the above K-values in the order of 0.1 m/d was assigned to the first model layer. For a layer thickness varying between 10 and 20m this would yield T-values ranging between 1-2 m²/day. This range of T-values would support borehole yields of 0.1 l/s as reported by Hodgson (2005).
Ecca and Coal Aquifers (Layers 2-8)

For the Ecca Formations and Coal: In cases where large variations in field observations for K-values are encountered the best approximation for this parameter a suggested in literature by several authors is to assign values in the range: arithmetic mean to geometric mean. The field observation statistics indicate that this range lies somewhere between $1 \times 10^{-6}$ m/s and $8 \times 10^{-6}$ m/s (for the Metsimaholo study area). For an average Ecca thickness in the order of 150m this would yield T-values in the order of $0.1 m^2/\text{day} - 1 m^2/\text{day}$. Again, this range in T-values support the majority of borehole blow yields observed during field testing undertaken previously (Golder 2012).

Dolerite (Partly Layer 3)

A separation in water levels between the shallow and deep aquifer is observed where the dolerite sill is extensive. Conceptually it is therefore acceptable to assign (very) low hydraulic conductivity values for these dolerite zones. A low permeability value of $5 \times 10^{-10} \text{m/s}$ was assigned for the dolerite where present. The distribution of hydraulic conductivity values presenting Ecca/Dolerite is presented in Figure 43.

5.4.12.4 Steady State Calibration Conclusions

The following is concluded from the groundwater flow calibrations:

- The hydraulic conductivity values specified in the model corresponds with the nature and distribution of the geological units and controls the hydrogeology of the study area. The large-scale, effective hydraulic conductivity values identified in the model calibration compare well with the hydraulic conductivity (transmissivity) data from the tests conducted and what are widely accepted values for this type of formations/aquifers.

- The background recharge values used in the model are consistent with estimates for Karoo-type aquifers.

- The steady state water balance for the modelled area indicates groundwater outflow from the total modelled area in the order of 4 500 m$^3$/day into the drainages. This is balanced by recharge. No flow-measurements to verify this result are available. About half of this flow is simulated to report to the Taaibosspruit and the other half to the Vaal River.

- Overall, the model structure and parameters used in the calibrated model appear appropriate and reasonable for the planned use. The model-calculated hydraulic heads are consistent with the overall shape of the water table and is consistent with that expected and discussed in the conceptual model. The model shows groundwater recharge occurring and discharging within the surface drainages consistent with the conceptual model.

- Due to the marked divergence of the observed water levels from simulated water levels in the limited number of observation boreholes available in the model domain, the model should be considered preliminary. It will require additional investigations to fully understand the groundwater flow dynamics associated with the geology, past mining as well as current abstraction for agricultural purposes that occur in the catchments that comprise the model domain.

- The calibration process indicated that the results are most sensitive to changes in the K-value of the first modelling layer – the alluvial and soft weathered horizons. This is expected since groundwater recharge is specified on this layer. Any change in K-value within the first layer will have a large effect on simulated water levels for the same recharge value. Lower situated layers in the model structure do not present the same sensitivity since they are not directly subject to recharge and the river drain nodes specified. The "insensitivity" of the lower situated layers emphasizes the non-uniqueness of the flow model solution.
The model should form part of the long-term monitoring and assessment for the Metsimaholo Underground Mining Project and the preliminary model updated with monitoring data. This is important to validate the model since it was demonstrated that the hydraulic parameters are non-unique to the solution of the flow equation.

The current steady state calibration process has shown that the system is not sufficiently steady to calibrate very well. However, a preliminary model such as this can still be used for its proposed purpose of predicting first order, low confidence groundwater inflows into the proposed underground mine. This is done on the basis that the information provided by Seriti is also at this stage sufficiently limited. The preliminary model can therefore still highlight the likely impact the underground mining project will have on the groundwater flow dynamics in the study area and direct further studies to improve confidence in future model updates.

5.4.13 Groundwater Impact Assessment Using the Numerical Groundwater Model

Based on the conclusions of the Steady state calibration process the numerical groundwater model was made transient and used to assess the groundwater impacts.

5.4.13.1 Mine Plans

To determine the objectives, the evolution of the mining for activities for the proposed Metsimaholo underground mine were obtained from Seriti.

The provided mine plans comprise the TMH and MLMH footprint areas of the proposed Metsimaholo underground mine as well as the surface location of the mine access portal (Figure 1). These underground footprints are shown in Figure 2 and Figure 3 respectively.

The Metsimaholo coal resource will be mined by using underground mining methods. The coal will be extracted by using continuous miners employing bord and pillar underground mining methods. The coal resource will be accessed via a twin decline shaft system connecting the surface portal with the TMH and MLMH coal resources. The mining method was chosen to maximise coal extraction but still provide sufficient stability at surface to prevent subsidence.

The current available mine planning schedule is shown Figure 31. The complexity of this schedule is primarily driven by coal quality providing a consistent grade of coal for the market. To make preliminary annual inflow estimates, the mine plan has been simplified into 5-year mining blocks, commencing with mine development and operations on the shallower TMH for three 5-year periods, namely (2020-2025, 2026-2030, and 2031-2035) followed by three similar periods (2036-2040, 2041-2045 and 2046-2050) on the deeper MLMH. These approximate the mine plan schedule provided by Seriti. This is shown in Figure 32 and Figure 33, which adequately represents the sequence of mine dewatering for the current level of assessment.
Figure 31: Mine Planning Schedule provided by Seriti

Time dependant constant head nodes were specified on slice 6 (for the TMH) and on slice 8 (MLMH) across the spatial extent of the mining areas (Figure 35 and Figure 36). The bottom (floor) of slice 8 in the model represents the bottom (floor) of the MLMH Coal Seam. The bottom (floor) of slice 6 in the model represents the bottom (floor) of the TMH Coal Seam.
The specification of constant head nodes on specific slices 6 and 8 represent the underground mining and dewatering advances. The elevations specified for the constant head nodes on the slices were set equal to the elevation of the slice as per the hydrogeological model. Mine dewatering is performed by activation of these nodes.
Figure 32: Simulated TMH mining advance areas 2020 – 2035.

Figure 33: Simulated MLMH advance areas 2036- 2050.
5.4.13.2 Simulation of the expected Inflow Rates into the Proposed Metsimaholo Underground Mine for the Top and Middle Seams over the Operational Life of Mine

From Figure 34 it is evident that flow into the underground mine will commence in 2020 when it is assumed that mining will commence. The anticipated Life of Mine (LOM) is 30 years. Flow rates into the underground will progressively rise as underground development and operations increase, however, as there is currently no detailed mine plan available and the total footprint of the mine on both the Top Mining Horizon (TMH) and Middle Mining Horizon (MLMH) is being considered.

Inflow rates are expected to increase progressively over the first years of operations to be in the order of 55-65 L/s (4.8-5.6 ML/day) on the TMH and then peak to approximately 72 L/s (6.2 ML/day) towards the end of LOM (2050) after mining advances to the deeper MLMH.

Figure 34 also illustrates the cumulative inflow volume over the LOM in Mega Litres which reaches a total of 400 000 ML over the LOM. This volume is obtained primarily from storage in the lithology and recharge from rainfall. The overall rainfall recharge to the entire model domain is roughly equal to the amount abstracted at about 52 L/s.

![Figure 34: Expected inflow rates for the planned Metsimaholo Underground Mine.](image)

5.4.13.3 Expected Impacts of mining on Water Levels over the Operational Phase of Mining

The simulated water levels in the aquifer for the operational phase of mining (2020-2050) are depicted for years 2019, 2025, 2031, 2035, 2040, 2045 and 2050 in Figure 37 to Figure 43. The total simulated water level drawdown in the upper aquifer over the period 2020 to 2050 is depicted Figure 44 and Figure 45.

The development of the cones of dewatering over the proposed Metsimaholo underground mine operations can be observed from the series of figures below.
Figure 35: Time dependant constant head boundaries applied to model slice 6 (TMH).

Figure 36: Time dependant constant head boundaries applied to model slice 8 (MLMH).
Figure 37: Simulated groundwater levels pre-mining (2019).
Figure 38: Simulated groundwater levels 5 years after mining commences (2025).
Figure 39: Simulated groundwater levels 10 years after mining commences (2030).
Figure 40: Simulated groundwater levels 15 years after mining commences (2035).
Figure 41: Simulated groundwater levels 20 years after mining commences (2040).
Figure 42: Simulated groundwater levels 25 years after mining commences (2045).
Figure 43: Simulated groundwater levels at end of mining (2050).
Figure 44: Simulated groundwater drawdown at the end of mining (2050) in the shallow unconfined aquifer (Model Slice 1).
Figure 45: Simulated groundwater level drawdown at the end mining on MLMH (2050) in the lower confined aquifer (Model Slice 8).
From the groundwater level and drawdown figures at the end of the operational mining phase the following is evident:

- Drawdown of more than 1 m extends in the shallow aquifer approximately 500-2000m to the north, west and south of the proposed Metsimaholo underground workings. To the south-east where the underground workings are in very close proximity to the Vaal Dam, the drawdown of the water table extends to the Vaal Dam and may extend below the Vaal Dam. Baseflow into a limited number of drainages into the Vaal Dam in this area are likely to be impacted.

- Drawdown of more than 1 m is expected to be contained to the east of the Taibosspruit. It may influence of baseflow to some of its eastern tributaries that are in close proximity to the proposed operations.

- There should be no major impact on the baseflow to the Vaal River.

- A maximum water level drawdown of about approximately 95-100 m is simulated in the proposed Metsimaholo mine in the upper shallow aquifer.

- A maximum water level drawdown of approximately 235-240 m is simulated in the planned Metsimaholo mine underground operations in the lower confined aquifer.

Figure 46 identifies the location of two cross sections, which show the simulated zero pressure line that also represents the piezometric water level over time (2019-2050) in the subsurface surrounding the proposed Metsimaholo underground mine at these locations. Figure 47 to Figure 60 show the actual cross-sections along these lines.

![Figure 46: Location of two cross sections discussed and illustrated below.](image-url)
Figure 47: Southern Cross Section. Simulated piezometric level Pre-Mining (2019).

Figure 48: Southern Cross Section. Simulated piezometric level in the year 2025.
Figure 49: Southern Cross. Simulated piezometric level in the year 2030.

Figure 50: Southern Cross Section. Simulated piezometric level in the year 2035.
Figure 51: Southern Cross. Simulated piezometric level in the year 2040.

Figure 52: Southern Cross Section. Simulated piezometric level in the year 2045.
Figure 53: Southern Cross Section. Simulated piezometric level in the year 2050.

Figure 54: Northern Cross Section. Simulated piezometric level in the year 2019.
Figure 55: Northern Cross Section. Simulated piezometric level in the year 2025.

Figure 56: Northern Cross Section. Simulated piezometric level in the year 2030.
Figure 57: Northern Cross Section. Simulated piezometric level in the year 2035.

Figure 58: Northern Cross Section. Simulated piezometric level in the year 2040.
Figure 59: Northern Cross Section. Simulated piezometric level in the year 2045.

Figure 60: Northern Cross Section. Simulated piezometric level in the year 2050 (EOM).
5.4.13.4 Expected Impacts of the mining on the base flow to the streams, rivers and surface water storage facilities.

Based on the model calibration groundwater recharge to the model domain equals groundwater discharge from the model domain. The model is such that the Vaal River, Vaal Dam, the Taaibosspruit and the Robspruit receive base flow from the aquifers (primarily the shallow aquifer) under steady state conditions.

In the transient mode the model is stressed and the lowering of the water levels in response to these stresses leads to reductions in the base flow to these drainages. Figure 61 shows the simulated base flow to the Taaibosspruit, Vaal River and total base flow over the operational mining period (2020-2050). Base flow to the Taaibosspruit and its tributaries within the model domain will reduce from approximately 2500 m³/day to 1900 m³/day. Baseflow to the Robspruit and Vaal River are not expected to reduce. The model simulates a reduction of baseflow to the Vaal Dam from approximately 200 m³/day to 150 m³/day.

Figure 61: Simulated baseflow contribution of groundwater prior, during and 50 years post closure of the proposed Metsimaholo underground mine operations.

The model set up does however not consider the possibility that the Vaal Dam may be captured by the cone of depression and contribute flow towards the shallow aquifer and that this, in turn, may drain towards the proposed underground mine. The rate of leakage will depend to a large extent on the permeability of the surface immediately beneath the dam footprint (containment layer) and the extent to which the cone of depression extends beneath the dam.

The current model assumes that the constant head boundary conditions remain unchanged and that the cone of depression can only extend as far as this model boundary. The model does not account for potential flow of groundwater from outside the model domain. Due to the proximity of the proposed underground workings to the Vaal Dam, future model upgrades should consider this in greater detail. It is considered that field investigations to determine this possibility are therefore recommended.

5.4.14 Post closure rebound of Water Levels

One of the objectives of the study is to determine the expected rebound of water levels post mine closure.

5.4.14.1 Simulated water levels (2050 – 2250)

The simulated water levels after 20, 50, 100, and 200 years after mine closure are depicted in Figure 70 to Figure 83. The simulated rebound in the water levels can be observed from these contour maps.
5.4.14.2 Assumptions

The following assumptions are made in the predictive modelling for the simulation of water level recovery in the mining areas:

- The post-closure modelling is conducted over a period of 200 year after operations cease (i.e. 2250).
- The hydraulic properties post closure of the lithologies overlying the proposed Metsimaholo underground mine has been assumed to remain the same as before and during mining.
No allowance has been made for the change in storage capacity of the proposed underground workings. It must be noted that these voids need to be filled before the drawdown effect caused by mining can be considered as nil. This often leads to continued drawdown and/or lags in the simulated recovery of the groundwater levels post mining.

Decant positions and likely times to decant have not been considered, due to the depth of mining, which is in excess of 200m and is not expected to decant.

Mass transport modelling was also not considered part of the objectives of this investigation due to the lack of information provided regarding possible surface contaminant sources.
Figure 64: Groundwater Level recovery 100 years post mining.

It can be observed from these contour maps how the initially depressed water level in the mining area recovers over time from an elevation of around 1275 mams to 1355 mams 100 years after mining ceases. 200 years post mining the water level over the mined-out areas recover to approximately 1400 mams. The water level recovery is shown to be very slow, full recovery is expected to be more than 300 years before the water levels are close to the near pre-mining levels which are in the order of 1475 mams above the worked-out areas. The recovery simulated also does not consider the mining voids that have to be filled before recovery can be considered complete. The total recovery is therefore likely to require a period more than 400 - 500 years. Simulation considering more realistic void spaces and possible subsidence enhanced permeability of the overlying lithologies should be considered in further model upgrades.
Figure 65: Groundwater Level recovery 200 years post mining.
6.0 GROUNDWATER IMPACT ASSESSMENT

6.1 Methodology

The significance of identified impacts was determined using the approach outlined below (terminology from the Department of Environmental Affairs and Tourism Guideline document on EIA Regulations, April 1998). This approach incorporates two aspects for assessing the potential significance of impacts, namely occurrence and severity, which are further sub-divided as follows:

**Table 15: Impact Assessment Factors**

<table>
<thead>
<tr>
<th>Occurrence</th>
<th>Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability of Occurrence</td>
<td>Duration of Occurrence</td>
</tr>
</tbody>
</table>

To assess these factors for each impact, the following four ranking scales are used:

**Table 16: Impact Assessment Scoring Methodology**

<table>
<thead>
<tr>
<th>Magnitude</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>10- Very high/ unknown</td>
<td>5- Permanent (&gt;10 years)</td>
</tr>
<tr>
<td>8- High</td>
<td>4- Long term (7-10 years, impact ceases after site closure has been obtained)</td>
</tr>
<tr>
<td>6- Moderate</td>
<td>3- Medium-term (3 months- 7 years, impact ceases after the operational life of the activity)</td>
</tr>
<tr>
<td>4- Low</td>
<td>2- Short-term (0-3 months, impact ceases after the construction phase)</td>
</tr>
<tr>
<td>2- Minor</td>
<td>1- Immediate</td>
</tr>
</tbody>
</table>

**Scale**

<table>
<thead>
<tr>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>5- International</td>
</tr>
<tr>
<td>4- National</td>
</tr>
<tr>
<td>3- Regional</td>
</tr>
<tr>
<td>2- Local</td>
</tr>
<tr>
<td>1- Site Only</td>
</tr>
<tr>
<td>0- None</td>
</tr>
</tbody>
</table>

The significance of the two aspects, occurrence and severity, is assessed using the following formula:
SP (significance points) = (magnitude + duration + scale) x probability

The maximum value is 150 significance points (SP). The impact significance points are assigned a rating of high, medium or low with respect to their environmental impact as follows:

Table 17: Significance of impact based on point allocation

<table>
<thead>
<tr>
<th>Points</th>
<th>Significance</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP&gt;60</td>
<td>High environmental significance</td>
<td>An impact which could influence the decision about whether or not to proceed with the project regardless of any possible mitigation.</td>
</tr>
<tr>
<td>SP 30-60</td>
<td>Moderate environmental significance</td>
<td>An impact or benefit which is sufficiently important to require management and which could have an influence on the decision unless it is mitigated.</td>
</tr>
<tr>
<td>SP&lt;30</td>
<td>Low environmental significance</td>
<td>Impacts with little real effect and which will not have an influence on or require modification of the project design.</td>
</tr>
<tr>
<td>+</td>
<td>Positive impact</td>
<td>An impact that is likely to result in positive consequences/effects.</td>
</tr>
</tbody>
</table>

For the methodology outlined above, the following definitions were used:

The **Magnitude** is a measure of the degree of change in a measurement or analysis (e.g., the area of pasture, or the concentration of a metal in water compared to the water quality guideline value for the metal), and is classified as none/negligible, low, moderate or high. The categorization of the impact magnitude may be based on a set of criteria (e.g. health risk levels, ecological concepts and/or professional judgment) pertinent to each of the discipline areas and key questions analysed. The specialist study must attempt to quantify the magnitude and outline the rationale used. Appropriate, widely-recognised standards are to be used as a measure of the level of impact;

The **Scale/Geographic** extent refers to the area that could be affected by the impact and is classified as site, local, regional, national, or international;

The **Duration** refers to the length of time over which an environmental impact may occur: i.e. immediate/transient, short-term (0 to 7 years), medium term (8 to 15 years), long-term (greater than 15 years with impact ceasing after closure of the project), or permanent; and

The **Probability of Occurrence** is a description of the probability of the impact actually occurring as improbable (less than 5% chance), low probability (5% to 40% chance), medium probability (40% to 60% chance), highly probable (most likely, 60% to 90% chance) or definite (impact will definitely occur).
Potential impacts were assessed using the above calculation and rating system, and mitigation measures were proposed for all relevant project phases (construction to decommissioning).

### 6.2 Groundwater Impact Assessment for the Proposed Metsimaholo Underground Mining Project

A summary of the groundwater impact assessment for construction, operation and decommissioning/closure of proposed Metsimaholo underground mining project with regards to potential negative impacts on the geology and groundwater are presented in Table 18.

Table 18: Summary of the environmental impact assessment for the proposed Metsimaholo underground mining project.

<table>
<thead>
<tr>
<th>Details</th>
<th>Construction</th>
<th>Operation</th>
<th>Decommission &amp; Closure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundwater</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

The results of the EIA (impact matrix) for the construction, operational and decommissioning/closure phases are detailed in the following sections and described in Table 19, Table 20 and Table 21.

### 6.3 Impact Assessment - Construction Phase

The activities during the construction phase of the proposed Metsimaholo underground mine will include:

- Earthworks works required to prepare the area at all construction sites;
- Excavation for establishment of water management dams and systems;
- Establishment of roads, pipelines and other logistics infrastructure;
- Establishment of construction offices and other temporary infrastructure;
- Establishment of the waste rock dump from shaft construction; and
- Blasting at the proposed Metsimaholo shaft area.

The identified negative impacts on the groundwater resource include (Table 19):

- The destruction of the localised geological units at the shaft portals and underground developments. This impact is permanent and not reversible and has a high impact rating;
- Dewatering of construction sites and resultant altering of the localised groundwater flow regime. The natural groundwater table of the shallow aquifer is normally less than 10 mbgl, it is therefore expected that groundwater inflow is likely to have an impact on excavations at the shaft construction site. Dewatering at excavations for construction purposes can cause localised altering of the flow and levels of the groundwater in the shallow aquifer at the shaft construction site. This impact should however be very localised due to the low permeability of the overall system and the aquifer should not be affected for more than a few metres beyond the proposed shaft construction site;
- Blasting at the proposed shaft construction site could cause fracturing of the nearby geological formations that will increase the permeability in close proximity to the shaft;
- Increased permeability could cause localised altering of the flow and levels of the groundwater in the shallow aquifer. It is expected that dewatering of the shaft during construction will be required to allow safe working conditions. This impact should, however, be very localised due to the low permeability of the overall system and the aquifer should not be affected for more than a few metres beyond the shaft construction site;

- Potential for acid generating seepage to groundwater from shaft construction waste rock dump. Geochemical investigation at New Vaal Colliery (Golder 2012) has shown that the lithological types in the overburden that are potentially acid generating include carbonaceous shale, grit, and sandstone/mudstone. However, results for composite samples are classified as “uncertain”. The predominant lithological types in these samples included dolerite and shale/sandstone that are non-acid generating and sandstone/siltstone that is 65% non-acid generating. It can therefore be concluded that the waste rock dump consisting of mostly overburden materials could be potentially acid generating depending on the mineralogical composition of the waste rock material. The impact during the construction period will however be low;

- Potential groundwater contamination caused by spillages and accidents during construction activities from vehicle maintenance, accidents, and fuel storage (e.g. diesel and oil); and

- Potential groundwater contamination from poor waste management and sanitation practices at the construction sites by contractors.

6.3.1 Management and Mitigation - Construction Phase

No mitigation can be performed for the destruction of the geology, and this impact can thus be classified as a permanent impact. As discussed above, dewatering is likely to be required at constructions sites, especially at the dam and shaft construction sites. To minimise the effect of dewatering, the size of open excavations should be minimised where possible and dewatering should be limited only to ensure safe working conditions.

Blasting at the shaft installation will be required, and the potential impact of increasing the formation permeability and associated increase in shaft inflow will be a permanent impact. However, the inflow can be managed by sealing of the shaft walls and grouting of intersected fractures/fissure where higher inflows are observed.

Mitigation measures to minimise the potential groundwater contamination impacts from construction activities include Table 19):

- Good housekeeping, and adherence to good health and safety practices on site during construction;

- Supply of chemical toilets and regular maintenance of the toilets at sites where worker/contractor numbers are high;

- Establishment of good waste management practices on site, i.e. recycling, separation and storage of hazardous waste at suitable lined/bunded areas; and

- Have available oil spill kits in case of spills of hydrocarbon chemicals.

The establishment and continuation of the groundwater monitoring plan during construction should be focussed on the areas that are likely to be impacted on by construction activities. This will ensure that water quality and water levels are continuously monitored. The collected information should be used as part of an active water management system and act as an early warning system which should be used for the application of mitigation measures - should the data show unacceptable levels of impacts.
With the exception of the destruction of the geology, which is an expected impact from any mining project, the other identified impacts during the construction phase are rated low after mitigation and management measures are applied. These identified construction phase impacts are therefore not likely to negatively affect any decisions on whether the proposed project should proceed.

6.4 Impact Assessment – Operational Phase

The operational phase of the mine will include all the mining operations until the end of life of mine. The activities identified to have an impact on the geology and groundwater are detailed in Table 20 and include:

- Underground mining;
- Underground mine dewatering;
- Pollution control and balancing dams for dewatered pit/underground water (not included in current scope);

The identified negative impacts on the groundwater regime include:

- Localised increased permeability of the geology at proposed Metsimaholo underground mine;
- Dewatering and resultant altering of the groundwater flow regime;
  - The extent of the proposed Metsimaholo underground operational footprint is approximately 12km x 8km. Measured from the lateral underground mining limits the limit of dewatering in the shallow extends a further distance of approximately 500-2000m to the north and west and south of the proposed Metsimaholo underground operation. To the east of the underground operation, the Vaal Dam limits the extent of the simulated dewatering to the model boundary.
  - A maximum water level drawdown of about 95m is simulated in the Metsimaholo underground operations in the overlying shallow aquifer. A maximum water level drawdown of 235 m is simulated for the Metsimaholo underground operations in the deep aquifer.
- Reduction of base flow to the Taaibosspruit and its tributaries as well as the Vaal Dam;
  - With the lowering of the water levels in the aquifer the contribution of aquifer discharge to base flow will reduce according to the reduction in aquifer water levels. Base flow to the Taaibosspruit and its tributaries will reduce from approximately 2500 to 1900 m$^3$/day. This a 25% reduction in baseflow locally and represents a 10 – 25% reduction in baseflow in total reserve baseflow of the Taaibosspruit Quaternary catchment (C22G) (from groundwater) according to the DWA 2012 estimates of catchment baseflow. These reduction estimates are obtained by comparing the simulated reductions to the range of baseflow values obtained using the WRP baseflow method as tabled by DWA (2012) and approximately 1% reduction in mean annual runoff (MAR) from this quaternary catchment.
  - Base flow to the Vaal Dam, in the affected area pre-mining amounts to approximately 200 m$^3$/day only. This will reduce locally to 150 m$^3$/day. The Vaal Dam storage is, however, not dependant on this groundwater baseflow contribution, which represents an insignificant amount of the water in storage in the Vaal Dam.
  - Base flow contribution to the Vaal River and Robspruit are not expected to be affected as a result of planned underground mining.
Pollution Plume development at proposed Metsimaholo mine;

Contaminant transport modelling was not undertaken. Based on the depth of the operation, a pollution plume is unlikely to develop from the proposed Metsimaholo underground mine during the operational phase. This is due to active dewatering of the mine workings during mining, causing the hydraulic gradient to be toward the dewatering point in the mine.

Potential groundwater contamination resulting from seepage from the waste rock dump at the proposed Metsimaholo mine;
### Table 19: Potential environmental impact during construction phase.

<table>
<thead>
<tr>
<th>Potential Environmental Impact: Construction Phase</th>
<th>Rating – Pre-Mitigation</th>
<th>Rating Post-Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Probability</td>
<td>Scale</td>
</tr>
<tr>
<td>Lowering of water levels due to dewatering of excavations for construction</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Increased fracturing and altering of flow patterns due to blasting at shaft area</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Potential for acid generating seepage to groundwater from waste rock dump</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Potential groundwater contamination caused by spillages and accidents</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Potential groundwater contamination from poor waste management and sanitation practices</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>
This was discussed under the construction phase of the impact assessment. Once the initial development during construction phase reaches the coal mining horizons development is mostly in the coal seam and very little additional waste rock will be produced.

- Potential groundwater contamination from pollution control and dewatering balancing dams;

  Water quality of the contents of the dams are expected to be poor as it will be the product from dewatering water and other mine processing water sources. However, the construction of the dams is expected to include linings, and with water management actions in place, impacts should be low and limited to the dam sites only.

- Potential groundwater contamination resulting from the water treatment plant and brine handling facility;

  Spillage and overflow from these facilities can potentially have a negative impact on the localised groundwater quality. However, water management procedures and triple lining brine holding facilities should prevent seepage.

- Potential groundwater contamination from poor waste and sanitation management;

- Potential groundwater contamination from spillages and accidents during operational activities such as vehicle maintenance, accidents and hydrochemical storage (e.g. diesel and oil);

- Blasting can cause fracturing of nearby geological formations which can increase the rock permeability;

  This increased permeability could cause altering of localised flow patterns in the shallow and deep aquifers, and increase the expected inflow at the mining sites. However, the impact should result in an overall localised and low impact rating.

### 6.4.1 Management and Mitigation – Operational Phase

Dewatering is required for safe working conditions and stability of mine workings, and the impacts during mining will be very high. Water levels in both aquifer systems will be affected up to 9 km from the centre point of the mining areas (which is 0.5 – 2 km from edge of mine workings) and both the base flow contribution to the Taalbospruit and Vaal Dam will be affected. No mitigation measures can be applied to minimise the impact of dewatering the aquifer, however additional options to divert dewatered water to the Taalbospruit to be investigated during the WULA phase.

The update and continuation of the groundwater monitoring plan during operation should be focussed on the areas and groundwater users likely to be impacted by dewatering. The collected monitoring information should be used as part of an active water management system and to act as an early warning system for unacceptable levels of impacts. Where it is evident that groundwater users are impacted by dewatering, an alternative water supply / compensation should be made available to the affected parties.

Suitable rock from the Metsimaholo rock dump can be used in the construction of the civil works which could reduce this dump. The dump could be capped with topsoil to minimise the impact on groundwater quality. This is an aspect that needs to be incorporated into mine planning.

The installation of lining systems in all water holding facilities would minimise any potential seepage of poor water quality to the underlying groundwater systems. Any brine holding ponds should be triple lined for additional protection.
### Table 20: Potential environmental impact during operational phase

<table>
<thead>
<tr>
<th>Potential Environmental Impact: Operational Phase</th>
<th>Rating – Pre-Mitigation</th>
<th>Rating Post-Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability</td>
<td>Scale</td>
<td>Duration</td>
</tr>
<tr>
<td>Lowering of water levels due to dewatering – Shallow Aquifer</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Lowering of water levels due to dewatering – Deep Aquifer</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Decrease of base flow contribution to the Taaibospruit</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Decrease of base flow contribution to the Vaal Dam</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Potential dewatering of the old Coalbrook mine and resultant altering of the groundwater flow regime</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Pollution plume from underground mine</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Potential groundwater contamination resulting from seepage from waste rock dump</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Potential groundwater contamination resulting from seepage from pollution control and dewatering balancing dams</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Potential groundwater contamination resulting from water treatment plant and brine handling facility</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Potential groundwater contamination from poor waste and sanitation management</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Potential groundwater contamination caused by spillages and accidents</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Potential groundwater contamination caused by hydrocarbon chemicals storage</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Blasting in underground could cause fracturing of nearby geological formation that will increase the permeability</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Potential groundwater contamination caused by pipeline failure.</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>
Mitigation measures to minimise the potential groundwater contamination impacts from other operational activities could include (Table 20):

- Good housekeeping, and adherence to good health and safety practices on site during construction;
- Supply of chemical toilets and regular maintenance of the toilets at sites where no permanent ablution facilities are available;
- Proper management of sewage treatment plant and associated infrastructure;
- Regular testing and maintenance of pipeline infrastructure; and
- Having available oil spill kits in case of spills of hydrocarbon chemical.

Limited blasting will be required in mining areas with the potential impact of increasing of formation permeability and associated increase in water inflow will be a permanent impact. However, inflows can be managed by sealing of the walls and grouting of intersected fractures/fissure where higher inflows are observed in the underground mine.

With exception of the destruction of the geology and the lowering of the water table in both aquifers, which is an expected impact from any mining project, the other identified impacts during the operational phase are rated moderate to low after mitigation and management measures are applied and it is not likely to negatively affect any decisions on the proceeding of the project.

One of the most effective mitigation measures is the use of the existing groundwater and numerical model as a management and predictive tool. Long term monitoring data and an optimised groundwater monitoring network will provide valuable information to update and re-run the model annually. Monitoring of groundwater levels is also critical to ascertain how affected groundwater users may be compensated for losses of groundwater related to the mining operations and to distinguish such from seasonal or possibly draught related groundwater level drops.

Updates to the model will have to include rainfall, geological, mining plan and infrastructure data updates. Regular updates will increase the prediction accuracy as well as providing long term trends and allowing for intervention and timely prevention measures.

### 6.5 Impact Assessment – Closure Phase

The closure phase will be in accordance with an agreed and approved closure plan of the proposed Metsimaholo project.

The closure phase of the mine will include the cessation of mining operations, demolition of plant infrastructure, and rehabilitation waste dumps. Other activities identified to have an impact on the groundwater include (Table 21):

- Destruction of all surface infrastructure;
- Backfill and closure of the Metsimaholo shafts with waste rock dump material; and
- Flooding of mining works and resultant altering of the groundwater flow regime.

The identified negative impacts on the groundwater resource include (Table 21):

- The water levels in the upper aquifer above the proposed Metsimaholo underground mine void recover extremely slowly – at 200 years after mine closure there is still a large cone of water level depression present in this area. From the water level contour maps and water levels for the upper/lower aquifers modelled it can be observed that over the 200-year simulation period water levels in the aquifer only
recovers about 40m. This does not, however, consider the mining void which may slow recovery of the water table even more. The slow recovery is also a result of the low permeability of the overlying formations.

- Potential groundwater contamination caused by spillages and accidents during closure and decommissioning activities from vehicle maintenance, accidents, and fuel storage (e.g. diesel and oil).
- Potential groundwater contamination from poor waste management and sanitation practices at the demolition sites by contractors.
<table>
<thead>
<tr>
<th>Potential Environ. Impact: Closure and Post-Operational Phase</th>
<th>Rating – Pre- Mitigation</th>
<th>Rating Post- Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Probabili ty</td>
<td>Scal e</td>
</tr>
<tr>
<td>Continued depressed groundwater levels due to dewatering during mining.</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Continued decreased of base flow contribution to the Taaibospruit</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Continued decrease of base flow contribution to the Vaal Dam</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Surface and sub- surface decant from Metsimaholo underground mine</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Potential groundwater contamination from Metsimaholo underground mine</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Potential groundwater contamination resulting from seepage from waste rock dump.</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Potential groundwater contamination resulting from remaining surface infrastructure</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Potential groundwater contamination from poor waste and sanitation management</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Potential groundwater contamination caused by spillages and accidents</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>
6.6 Management and Mitigation - Decommissioning and Closure Phase

Dewatering is required for safe working conditions and stability of mine workings during mining. Even after closure the impact of dewatering will remain pronounced for a few hundred years following mining. This slow recovery of the water levels is due to the low permeability of the host rock formation. Water levels in both aquifer systems will be affected up to 8-9 km from the centre of the mining areas (0.5 – 2km from the edge of the workings) and both the localised base flow to the Vaal Dam and Taabosspruit will be affected.

The update and continuation of the groundwater monitoring plans should continue post-closure and be focussed on the areas and groundwater users impacted on by dewatering. The collected monitoring information should be used as part of an active post-closure water management. Where it is evident that groundwater users are impacted by the dewatering alternative water supplies / compensation should be maintained or made available to the affected parties.

All surface infrastructure should be removed during the closure phase, and therefore no surface source of potential groundwater contamination should remain. Waste rock can be used to back-fill the underground shafts where possible. Any remaining water in holding dams should be treated and released if possible.

Effective mitigation measures to minimise the potential groundwater contamination impacts should be carried over from the operational activities as long as is necessary and while rehabilitation activities continue:

- Good housekeeping, and adherence to good health and safety practices on site during demolition phase;
- Supply of chemical toilets and regular maintenance of the toilets at sites where no permanent ablution facilities are available;
- Proper management of sewage treatment plant and associated infrastructure until this is removed unless pre-agreed post closure use is identified;
- Have available oil spill kits in case of spills of hydrocarbon chemical during demolition phase.

With exception of the cone of depression remaining at Metsimaholo for a few hundred years the other identified impacts during closure and post-closure phase are rated moderate to low after mitigation and management measures are applied and it is not likely to negatively affect any decisions on the proceeding of the project.

6.7 Impacts Summary

The hydrogeological information collected during the baseline and EIA phases of the proposed Metsimaholo underground project draws largely on field data collected during NVC Lifex Project (Golder, 2012). The follow up field investigations have shown that the ground water flow dynamics are still transient following the mining activities which ceased at the Coalbrook Underground Mine in the 1960’s.

It is shown that the most significant impacts on the groundwater systems are related to the further planned dewatering (i.e. in addition to current dewatering occurring at the abandoned Coalbrook workings) of the proposed Metsimaholo underground mine. Due to the low permeability of the host rock formation the water level decline is rapid and will impact an area of up to 0.5 - 2 km from the of underground mining activity limits in the shallow aquifer.

There are groundwater users dependant on the groundwater as a resource, and these users will be affected by the decline in water table. Monitoring of groundwater levels is also critical to ascertain how affected groundwater users may be compensated for losses of groundwater related to the mining operations and to
distinguish such from seasonal or possibly draught related groundwater level drops. An alternative source of water will need to be supplied to these water users should the monitoring illustrate this.

Associated with the decline in water table, the base flow contribution to both the Vaal Dam and Taabosspruit will be reduced. No impact is expected on the Vaal River. The reduction of base flow contribution to the Taabosspruit is likely to have impacts on the ecology and the wetlands associated with the affected and downstream sections the stream as discussed within the wetland assessment report. Further investigations during the Water Use Licence phase of the project would be required to further increase confidence levels and enhance mitigation measures proposed so that the impact on the Taabosspruit is reduced.

The expected impact on groundwater quality is rated moderate to low. This is because the surface infrastructure has not really been incorporated in the scope of this investigation due to the lack of information regarding planned surface waste storage facilities often associated with pollution of groundwater (i.e. coal (stock piles and discard dumps). For the purposes of the impact assessment it has been assumed that any infrastructure that will be established at the proposed Metsimaholo mine will be appropriately lined. A waste rock dump, consisting of mainly overburden sediments has been considered for impact assessment and rating purposes only.

Good housekeeping, appropriate water and waste management, and adherence to good health and safety practices should minimise any other potential groundwater contamination impacts.

7.0 GROUNDWATER MONITORING PLAN

7.1 Rationale

As part of the baseline investigations for the EIA, a total of 65 boreholes were drilled for the New Vaal Lifex Project site during the period from November 2009 to March 2010. The borehole sites were selected to obtain a representative spatial distribution while at the same time be representative of the geology and structural influences of the area. All boreholes were constructed for potential incorporation into the long-term monitoring network to avoid duplication of effort.

Borehole pairs were drilled at different locations to intersect shallow, intermediate and deep aquifers. The depth of deep boreholes was determined by the depth of the coal seams which varies across the study area.

The purpose of a groundwater monitoring network is to provide an early warning of possible adverse effects of the proposed mining activities on both quantity and quality of the affected groundwater systems. In the case of the proposed Metsimaholo project, the groundwater specialist study has recorded baseline conditions prior to any development of the mine or associated infrastructure. It is important that water levels and water quality of potentially affected aquifer systems continue to be monitored over an extended time to confirm these baseline conditions prior to any development.

The recent hydrocensus (2018) for the proposed Metsimaholo project identified 12 functional and accessible monitoring boreholes from which groundwater levels could be obtained of the 35 original monitoring boreholes that remain in the study area. Information from some of these borehole locations is further compromised by active abstraction from nearby boreholes. This has led to lower confidence in the results of this investigation than would have been the case if the monitoring network had been maintained as per its original intention.

The groundwater systems in the study area is a complex multi-level aquifer system that is already affected by various existing activities (i.e. defunct underground mines and domestic and agricultural groundwater abstraction). These issues need to be considered when a monitoring plan is constructed.

The following specific recommendations are made to re-establish the required level of monitoring prior to commencement of underground mining at Metsimaholo underground mine:
A detailed hydrocensus must be undertaken with the objective of gaining a better understanding of the uses and dependencies of groundwater in the study area and a better understanding of the dynamics of the groundwater relating to the old Coalbrook workings and its potential interaction with the Taaibosspruit. The water level data from installed water level loggers must continue to be collected quarterly;

In order to compensate for the lost monitoring network, allow for the drilling of 10 borehole pairs (one deep, one shallow across the Metsimaholo mining right application area. Each of the deep boreholes must be drilled and constructed to exclude the shallow aquifer system. Each of these boreholes must be equipped with water level loggers and secured to prevent unauthorised access or vandalism;

The selection of new groundwater monitoring sites requires the following considerations:

- Proximity of existing monitoring sites;
- Spatial distribution of planned mining infrastructure and planned underground operations (mine plans);
- Aquifer systems targeted (i.e. deep or shallow);
- Existing groundwater users;
- Defunct mines both flooded and semi-flooded; and
- Geophysical survey techniques should be used to site the exact locations of each borehole in order to take into consideration the location of potential geological structures.

At least one deep borehole must be drilled into the old Coalbrook mine workings (this may depend on the outcome of the hydrocensus information);

The existing operational monitoring boreholes must also be equipped with water level loggers and suitable protected against theft and vandalism;

At least two borehole pairs should be drilled between the proposed Metsimaholo underground workings and the Vaal Dam;

All existing geological borehole data that is available should be incorporated into a more detailed and geological model update using a software such as Leapfrog-Hydra;

Collect and record specific groundwater information to fulfil the license monitoring requirements. Establish and maintain database, generate graphs that illustrate trends to allow risk analysis, propose mitigation and/or remedial actions after a year of continuous water level recordings have been collected; and

Update the existing numerical groundwater model to incorporate all the information collected as detailed above. Incorporate detailed mine plans of the planned Metsimaholo underground mine and use the updated groundwater model to predict inflows, groundwater impacts and appropriate mitigation measures based on higher confidence model predictions. A contaminant transport model can be added to predict any pollution plume development from potential surface and underground contamination sources.

It is important to note that the groundwater monitoring system will be a dynamic network with boreholes being added or removed as data is collected and mining progresses. This proposed network aims to confirm and monitor the baseline groundwater conditions in the areas most likely to be impacted within the next 10 years.
In addition, it is proposed that accessible private boreholes are included in the regular quarterly monitoring of groundwater levels on or adjacent to the Metsimaholo mining right application area.

### 7.2 Water Level Monitoring

Since the most adverse predicted effect from the proposed Metsimaholo underground mine will be the lowering of water levels caused by dewatering of the underground mine, it is important that water level monitoring is done on a continuous basis and with high accuracy. Accordingly, automatic water level loggers should be installed/maintained in the groundwater monitoring points. Continuous water level monitoring has the following benefits:

- The loggers provide very accurate and continuous water level measurements (water level recorded every 6 hours);
- These loggers are robust and have a lifetime of up to 10 years if maintained correctly;
- Should data show that monitoring points need to be added or removed to the network, the loggers can be removed and installed at other points;
- No additional head gear needs to be added to the boreholes as the loggers are installed on the inside of the casing which has the benefit of being out of sight, thus reducing security/theft risks of equipment; and
- Software and download cables will be provided to Seriti after the groundwater monitoring network as described above and an initial monitoring report is complete. This will allow continued maintenance and data management in-house.

The data should be downloaded at quarterly intervals from the loggers and added to the existing database.

### 7.3 Water Quality Monitoring

The baseline study concluded that the water quality of both the deep and the shallow aquifer systems are of good quality. There are exceptions, due mainly to the historical mine workings area. It is therefore important to have accurate records of water quality and monitor any changes over time.

Biennial sampling of all boreholes included in the monitoring network should be undertaken. Samples should be submitted for analyses to an accredited laboratory and are analysed for Salinity, pH and major cations/anions (including speciation of nitrates). Details for all parameters to be analysed are provided in Table 22.

**Table 22: Details of chemical parameters to be analysed for in the groundwater samples**

<table>
<thead>
<tr>
<th>Physical Constituents</th>
<th>Macro-Constituents and Metals</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH, Electrical Conductivity (EC), Dissolved Solids, Suspended Solids, Chemical Oxygen Demand (COD), Dissolved Oxygen.</td>
<td>Total Alkalinity as CaCO₃, Total Hardness as CaCO₃, Fluoride (F), Sodium (Na), Potassium (K), Chloride (Cl), Nitrite (NO₂), Nitrate (NO₃), Sulphate (SO₄), Calcium (Ca), Magnesium (Mg), Ammonia as NH₃, Iron (Fe), Manganese (Mn) and Aluminium (Al)</td>
</tr>
</tbody>
</table>

### 8.0 CLOSURE

The baseline groundwater assessment was completed in July 2010 and re-assessed in 2018. Consequently, this preliminary groundwater model was constructed to determine the hydrogeological regime and the
potential impacts on the groundwater system from the proposed mining activities. The groundwater modelling is based on hydrogeological conceptualisation from the available baseline data.

The overall results for the groundwater impact assessment show that impacts range from low to high. The most significant impacts on the groundwater systems are related to dewatering of the proposed Metsimaholo underground mine. Due to the low permeability of the host rock formation the water level decline is rapid and will impact an area of up to 0.5 - 2 km from the of underground mining activity limits in the shallow aquifer.

There is an overall low to medium level of confidence to the numerical modelling results and the findings confirm the observations made during investigations and monitoring as a result of the transient nature of the water levels recorded during the hydrocensus.

9.0 REFERENCES

Signature Page

Golder Associates Africa (Pty) Ltd.

Thomas Demmer
Senior Hydrogeologist

Gerhard van der Linde
Mine Water Africa - Group Lead

TD/GvdL/ab

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APPENDIX A

Document Limitations
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ii) The scope and the period of Golder’s Services are as described in Golder’s proposal, and are subject to restrictions and limitations. Golder did not perform a complete assessment of all possible conditions or circumstances that may exist at the site referenced in the Document. If a service is not expressly indicated, do not assume it has been provided. If a matter is not addressed, do not assume that any determination has been made by Golder in regard to it.

iii) Conditions may exist which were undetectable given the limited nature of the enquiry Golder was retained to undertake with respect to the site. Variations in conditions may occur between investigatory locations, and there may be special conditions pertaining to the site which have not been revealed by the investigation and which have not therefore been taken into account in the Document. Accordingly, additional studies and actions may be required.

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v) Any assessments made in this Document are based on the conditions indicated from published sources and the investigation described. No warranty is included, either express or implied, that the actual conditions will conform exactly to the assessments contained in this Document.

vi) Where data supplied by the client or other external sources, including previous site investigation data, have been used, it has been assumed that the information is correct unless otherwise stated. No responsibility is accepted by Golder for incomplete or inaccurate data supplied by others.

vii) The Client acknowledges that Golder may have retained sub-consultants affiliated with Golder to provide Services for the benefit of Golder. Golder will be fully responsible to the Client for the Services and work done by all its sub-consultants and subcontractors. The Client agrees that it will only assert claims against and seek to recover losses, damages or other liabilities from Golder and not Golder’s affiliated companies. To the maximum extent allowed by law, the Client acknowledges and agrees it will not have any legal recourse, and waives any expense, loss, claim, demand, or cause of action, against Golder’s affiliated companies, and their employees, officers and directors.

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GOLDER ASSOCIATES AFRICA (PTY) LTD
APPENDIX B

Specialist CV and Declaration
SPECIALIST DECLARATION

As required under Appendix 6 of the Environmental Impact Assessment Regulations, 2014 (as amended), I, Thomas Demmer, declare that:

- I act as an 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 Acts, Regulations and any guidelines that have relevance to the proposed activity;
- I will comply with all applicable Acts and Regulations in compiling this report;
- I have not, 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 declaration are true and correct.

Signature of the specialist:

Golder Associates Africa (Pty) Ltd

Name of company (if applicable):

28 February 2019

Date:
Golder Associates Africa (Pty.) Ltd. – Johannesburg

Specialist Hydrogeologist
Thomas is a strategic and technical groundwater management specialist with 23 years’ experience primarily in the resources and mine engineering sectors. His hydrogeological project experience extends to several countries in Southern, Central and West Africa. Thomas also worked on several projects in South Australia in 2009 and 2010 before returning to Golder in South Africa. His main interests are focused around mining, both open pit and underground dewatering, groundwater control, mine stability and safety. Technical capability covers general ground water resources management. Experience also includes technical, team management, business development and external liaison.

Sectors include mining, oil and gas, international development projects, and general industrial groundwater management.

Thomas’s experience covers the project cycle from program design and field investigation through to implementation, operation and closure. It also includes strategic water management for national agencies and governments (South Africa and Australia).

Thomas has also been involved in general groundwater and groundwater resources management, strategic water management, water management in unconventional gas, mine water management, mine closure planning, internal environmental and quality auditing, due diligence and review of mining projects. Specialties: Thomas is currently involved in various projects which require project management, client interaction, numerical groundwater flow and solute transport modelling and related reporting.

Employment History

Golder Associates Africa (Pty) Ltd – Johannesburg, South Africa
Senior Hydrogeologist (2010 to Present)
Responsible and involved in numerous groundwater exploration, development and environmental impact assessment projects.

Sinclair Knight Merz Pty Ltd – Adelaide, Australia
Principal Hydrogeologist (2009 to 2010)
Team Leader for the Mine Water Services Group in Adelaide.

Project Manager for mining related groundwater impact and water supply studies for the mineral, coal and UCG industry in South Australia and Queensland.

Golder Associates Africa (Pty) Ltd – Johannesburg, South Africa
Senior Hydrogeologist (2004 to 2009)
Responsible for numerous groundwater exploration, development and environmental impact assessment projects.

Palabora Mining Company – Limpopo, South Africa
Environmental Project Specialist (2003 to 2004)
Responsible for managing all environmental related projects on mine. Assisting
with day-to-day air quality management from smelter and acid plant. Responsible for all surface and groundwater monitoring and reporting. Reported to Environmental Superintendent.

Northern Environmental – Limpopo, South Africa
Owner/Environmental Consultant (2000 to 2003)
Independent consultant primarily to Palabora Mining Company on Environmental/Groundwater projects.

Palabora Mining Company – Limpopo, South Africa
Contract Hydrogeologist (1998 to 2000)
Responsible for all environmental groundwater pollution studies at Palabora Mining Company. Assisting with day-to-day air quality management from smelter and acid plant. Reported to SHEQ manager.

Anglo American Corporation of SA Ltd – Gauteng, South Africa
Hydrogeologist (1995 to 1998)
Consulting to clients in Mining Industry on matters concerning groundwater supply, de-watering and contamination.

Anglo American Corporation of SA Ltd – Gauteng, South Africa
Staff Geologist (1993 to 1995)
Seconded to Western Deep Levels Gold Mine to provide geological support to mining department. Started as graduate geologist gaining practical experience in stop, raise and haulage mapping, siting boreholes for cover drilling as well as structural interpretation.

Anglo American Corporation of SA Ltd – Gauteng, South Africa
Geological Field Assistant (1988 to 1989)
Sampling and mapping in Barberton Greenstone Belt and day-to-day running of an exploration field camp.
PROJECT EXPERIENCE – HYDROGEOLOGY

**RBM Zulti South Expansion Project – 2018 Model Upgrade**
Kwazulu-Natal Province, South Africa

Project Manager and responsible to update groundwater flow model with latest (June 2017) mine plan to determine likely environmental impacts associated with the proposed Zulti-South mining operations on the ground and surface water environment to the south of Richards Bay. This upgrade will also include newly drilled piezometers to test model validity and update hydrogeology in and surrounding wetlands, estuaries and steep coastal front dunes.

**Eurasian Resources Group – Frontier Mine**
Katanga Province, DRC

Responsible for conceptual understanding of hydrogeological regime and quantification of environmental impact on groundwater and surface water related to the re-mining of the Kingamyambo and Mussinoi River tailings facilities near Kolwezi, DRC. Also responsible for the construction of a Numerical Groundwater Model to quantify impacts related to the construction of a new tailings storage facility.

**Eurasian Resources Group – RTR Metalkol**
Katanga Province, DRC

Responsible for conceptual understanding of hydrogeological regime and quantification of environmental impact on groundwater and surface water related to the re-mining of the Kingamyambo and Mussinoi River tailings facilities near Kolwezi, DRC. Also responsible for the construction of a Numerical Groundwater Model to quantify impacts related to the construction of a new tailings storage facility.

**HEMA – Amasra**
Amasra, Turkey

Responsible to lead hydrogeological and hydrological environmental impact assessment for the proposed and already constructed Amasra B Underground coal mine along the Black Sea Coast Line. Also, responsible to construct regional numerical groundwater model and simulate groundwater and surface water environmental impacts associated with abstraction of groundwater from overlying limestone to meet mine and coal processing needs. Mass transport modelling used to quantify groundwater and surface water impacts associated with various waste rock and tailings storage facilities.

**Grootegeluk Coal Mine - Basalt Aquifer Modeling**
Limpopo Province, South Africa

Compilation of a conceptual and numerical groundwater model in support of WUL application for the artificial recharge of the Grootegeluk Basalt Aquifer.

**Sasol - Secunda Sewage Treatment Plant**
Mpumalanga, South Africa

Responsible for construction and simulations of groundwater model to assist in the dewatering of groundwater surrounding Sasol Treatment plant reactor units to avoid damage during emptying and repairs, due to shallow surrounding water table.

**Tenke Fungurume NW TSF Project**
Katanga Province, DRC

Phase Manager and responsible to investigate the hydrogeological risks associated with the location and construction of a new lined tailings facility to the north west of the existing Kwatebala TSF

**RBM Zulti South Expansion Project – Integrated GW/SW monitoring programme implementation**
Kwazulu-Natal, South Africa

Assessment of the requirements to implement groundwater surface water interactions around key environmental systems on and surrounding the Zulti-South Mine Lease area, which is located along the northern KwaZulu-Natal coastal dune zone.
Resumé

THOMAS DEMMER

RBM Zulti South Expansion Project – 2016 Model Upgrade
Kwazulu-Natal Province, South Africa

Project Manager and responsible to update groundwater flow model with latest (April 2016) mine plan to determine likely environmental impacts associated with the proposed Zulti-South mining operations on the ground and surface water environment to the south of Richards Bay.

Mopani Copper Mufulira Mine
Copper Belt, Zambia

Compilation of a conceptual and numerical groundwater model to predict future dewatering requirements to manage groundwater impacts on the operations as well as surrounding environments at Mufulira Copper Mine in North-East Copper Belt in Zambia.

Newmont Subika Underground Project - Ahafo South
Ahafo South, Ghana

Senior oversight of the modelling of additional groundwater impacts on community wells as a result of the planned dewatering of the Subika underground mine at Ahafo South Gold Mine in Ghana.

RBM Zulti South Expansion Project – 2015 Model Upgrade

Project Manager and responsible to update earlier FEFLOW (Ver 6.2) numerical groundwater flow model with latest (December 2014) mine plan to determine likely environmental impacts associated with the proposed Zulti-South mining operations on the ground and surface water environment to the south of Richards Bay.

Mopani Copper Mufulira Mine
Copper Belt, Zambia

Team member investigating the current status of the mines groundwater control and future requirements to manage groundwater impacts on the operations as well as surrounding environments at Mufulira Copper Mine in North-East Copper Belt in Zambia.

Samancor Varkensvlei Project – Phase 2 Field Investigations
Northwest Province

Task management and responsible to report on groundwater field investigations including geophysical resistivity survey, drilling and aquifer testing of boreholes with the view for this to be included.

Glencore Impunzi North Pit
Mpumalanga, South Africa

Team member and responsible for the construction of a groundwater flow model to investigate and predict the likely environmental groundwater impacts associated with the mining of the North Pan adjacent to the existing mine.

Palabora Mining Company - STSF hydrogeological Investigations
Limpopo Province, South Africa

Project Manager and responsible to investigate historical deposition of tailings and waste at Palabora and to investigate likely future and active seepage zones associated with the deposition on the Eastern and Southern Tailings Paddocks.

AngloCoal – Mafube LiFEX Project
Mpumalanga Province, South Africa

Phase Manager and responsible to establishing the groundwater monitoring system at the proposed Nootgedacht and Wolvekrans mining operations.

Amadwala_Hazardous Waste Site EIA
Gauteng Province, South Africa

Responsible to construct preliminary groundwater numerical model based on conceptual groundwater model to determine groundwater flow paths from potential hazardous sources on the proposed new waste site location.

Dundee Metals Nambian Custom Smelters
Tsumeb, Namibia

Phase manager and team member of the Environmental and Social Impact Assessment responsible for the 1 groundwater impact assessment for a new sulphuric acid plant at the existing copper smelter close to Tsumeb in northern Namibia.
Resumé

THOMAS DEMMER

RBM _Zulti South Expansion Project – Phase 3 & 4
Kwazulu-Natal, South Africa

Project Manager and responsible to update earlier FEFLOW (Ver 6.2) numerical groundwater flow model with latest (January 2014) mine plan to determine likely environmental impacts associated with the proposed Zulti-South mining operations on the ground and surface water environment to the south of Richards Bay. Project Manager and responsible to undertake specialist groundwater EIA and risk rating reporting of the proposed mining operations (September 2013 mine plan) on the groundwater and related environments.

SRK – RBM _Zulti South Expansion Project – Phase 2
Kwazulu-Natal, South Africa

Project Manager responsible for Phase 2 Field Investigations and updating of conceptual hydrogeological model to determine the likely impacts of the proposed Zulti-South mining operations on the ground and surface water environment to the south of Richards Bay.

Debswana - Orapa Mine Expansion Project
Botswana

Task management and responsible and updating of existing FEFLOW (Ver 5.4) numerical groundwater transport model to determine additional dewatering requirements associated with the proposed pit expansion.

AngloCoal – Mafube LIFEX Project
Mpumalanga, South Africa

Phase Manager and responsible to create numerical groundwater flow model with latest mine plan to determine likely environmental impacts associated with the proposed Nooitgedacht and Wolvekrans mining operations on the ground and surface water environment.

SAMANCOR CHROME
Northwest and Limpopo Provinces, South Africa

Task management and responsible to report on baseline groundwater conditions and qualitative assessment of groundwater impacts associated with the proposed remediation options at Varkensvlei, Nooitgedacht and Haakdooringsdrift sites.

KUSILE POWER STATION
Mpumalanga, South Africa

Task management of and updating of FEFLOW Ver 5.4 numerical groundwater transport model to determine environmental impacts associated with the proposed remediation options.

SAPPI ENSTRA
Gauteng Province, South Africa

Task management of and updating of FEFLOW numerical groundwater transport model to determine environmental impacts associated with the proposed remediation options.

SRK – RBM _Zulti South Expansion Project – Phase 1
Kwazulu Natal, South Africa

Project Manager and responsible to undertake the Phase 1 Situation Assessment and Gap Analysis to determine the likely impacts on the ground and surface water environment associated with the proposed dune mining on the Zulti-South Mine Lease area to the south of Richards Bay.
Project Manager and responsible for expanding and updating the existing numerical Groundwater Model 2011 (FEFLOW) to include the Pumpi Pit, the new Dipeta Valley Area Pits (approximately 5 pits) and Fungurume Hill Pits (7 pits) dewatering together with the existing mine plans for the Kwatebala, Fwaulu and Tenke Pits. The objective of the groundwater model update was to predict changes in the baseflow in the Dipeta, Mofia and Tshilongo rivers as a result of dewatering and the volumes to be discharged from each of these pits during mining. Furthermore the model was used to predict time that it would take for the groundwater levels to reach new steady state equilibrium levels after closure. Particle tracking was also used to determine travel times and travel paths during the mine years of operation.

Project Management of initial phase of water balance and potential groundwater risks associated with the planned second lift underground expansion of the Palabora Underground Copper Mine. The extension of the underground workings is vital to the continued operation of the Palabora Underground Mine beyond 2015.

Taking over project management responsibilities from April 2011 and responsible for the completion of the Phase 1 - Situation Analysis Report. The project aims to complete a Preliminary Numerical Groundwater Flow and Solute Transport Model to predict the extent of groundwater contamination plumes from contamination sources on the Palabora Mine Site. The Preliminary Groundwater Model will also be used to recommend further field investigations required to monitor areas of uncertainty and to recommend mitigatory measures.

Responsible for the updating the existing numerical Groundwater Model (FeFlow) to include the Tenke-Fwaulu Pit dewatering together with a new mine plan for the Kwatebala Pit. The objective of the groundwater model update was to predict changes in the baseflow in the Dipeta and Mofia River as a result of dewatering and the volumes to be discharged from each of these pits during mining. Furthermore the model was used to predict the size and area of pit lakes that will develop after closure. Particle tracking was also used to determine travel times and travel paths during the mine years of operation and once pit lakes have established themselves.

Involved in updating information to address questions raised by authorities concerning the impact the dewatering activities at Olympic Dam Copper and Iron Mine would have on groundwater systems such as the Great Artesian Basin. (GAB) With specific emphasis on the connection between the Arkaringa Basin margin and GAB springs at Margret Creek, South Australia. Client Olympic Dam Mine.

Project Manager and providing technical hydrogeological input to the drilling and construction of deep mud rotary pumping boreholes and observation piezometers into Quaternary sediments to test the impact of the proposed depressurisation of coal seams by UCG. Also provided technical input and undertook the installation of multiple vibrating wire piezometers into deep exploration drillholes to be used for monitoring purposes. Client: Linc Energy.

Project Manager and providing technical input and finalising preliminary groundwater impact assessment report, groundwater supply report and water supply design and costing report for the proposed Wilcherry Hill Iron Ore Report. Client: IronClad Mining Ltd.
## Resumé

**THOMAS DEMMER**

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Location</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warratah Coal Mining Project</td>
<td>Queensland, Australia</td>
<td>Project Manager and providing technical input and finalising preliminary groundwater impact assessment report to obtain required environmental approvals from the Queensland Environmental and Mining Authorities for the proposed Warratah Coal Mining Project, in the Galilee Coal Basin, the Rail Corridor and Port Facilities near Bowen. Client E3 Consult.</td>
</tr>
<tr>
<td>Brukanga Sulphide Mine Site</td>
<td>South Australia, Australia</td>
<td>Project Manager for the final phases of the field investigations including drilling (Ultrasonic Drilling) through rock dumps, auger hole drilling and percussion drilling to install monitoring boreholes around mine, rock dumps and tailings facility. Reporting of field results to Technical Advisory Group and liaison with the client representative. Client: Primary Industry Resources of South Australia (PIRSA).</td>
</tr>
<tr>
<td>Cumulative Impacts Assessment for Mining Activities</td>
<td>Australia, Australia</td>
<td>Providing technical input in the collection of publically available hydrogeological information on all groundwater provinces across Australia for the compilation of a quick reference CD. The CD would allow authorities and proponents of new mining ventures to easily assess the existing groundwater situation, based on existing knowledge, in any groundwater management area across all seven states of Australia. Client National Water Association.</td>
</tr>
<tr>
<td>Akanani Platinum Project</td>
<td>Limpopo, South Africa</td>
<td>Finite Element Groundwater Flow Modelling of impacts of seepage from the proposed tailings dam on the groundwater system and surface water catchment and the proposed abstraction of 1 ML/day of groundwater from a proposed borefield.</td>
</tr>
<tr>
<td>Sappi Enstra</td>
<td>Gauteng, South Africa</td>
<td>Investigation to determine whether the hazardous landfill at Sappi Enstra is contaminating the underlying and surrounding dolomitic groundwater. Two borehole sets (a shallow bore into the waste and a deeper bore into the underlying dolomite aquifer zone) were drilled through the landfill into the underlying aquifer zone. All bores were sampled and analysed to compare the groundwater quality in and underlying the landfill with upgradient groundwater quality.</td>
</tr>
<tr>
<td>Tenke Fungurume</td>
<td>Katanga, Democratic Republic of Congo</td>
<td>Responsible for the site supervision of the drilling and construction of wide diameter dewatering/production boreholes for the supply of process and portable water for the Tenke Fungurume mine site. On site liaison with client (GRD Minproc).</td>
</tr>
<tr>
<td>Sappi Enstra</td>
<td>Gauteng, South Africa</td>
<td>Collection and review of existing wide body of hydrogeological information and literature review report for long term investigation of the contribution of impact from Sappi Enstra Operation on the Blesbokspruit in the Far East Rand Basin.</td>
</tr>
<tr>
<td>Akanani Platinum Project</td>
<td>Limpopo, South Africa</td>
<td>Project management of the baseline groundwater investigation, which includes numerical groundwater modelling to determine the impacts of proposed mining operation on the groundwater environment.</td>
</tr>
<tr>
<td>Foskor Phalaborwa</td>
<td>Mpumalanga, South Africa</td>
<td>Undertaking and managing a pilot groundwater investigation which included ground geophysical survey, drilling and testing of boreholes. Completion of report and recommending next phase of investigation to include modelling of impact across site and mitigation options.</td>
</tr>
<tr>
<td>Bravo (New ESKOM Power Station)</td>
<td>Mpumalanga, South Africa</td>
<td>Involved in the setting up of a model to predict the impact of proposed ash dump on the groundwater regime in the vicinity of the proposed coal power station.</td>
</tr>
<tr>
<td>Location</td>
<td>Description</td>
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</tr>
<tr>
<td><strong>Tenke Fungurume</strong> Katanga, Democratic Republic of Congo**</td>
<td>Involved in the setting up of monitoring network, installation of monitoring equipment and training of local mine staff to undertake spring and groundwater sampling with specialised groundwater sampling equipment. Measuring of spring flow and groundwater levels throughout the mine concession area.</td>
<td></td>
</tr>
<tr>
<td><strong>Tenke Fungurume</strong> Katanga, Democratic Republic of Congo**</td>
<td>Detailed groundwater investigation including particularly managing the undertaking of gravity survey, to site dewatering boreholes for proposed Kwatebala pit and water supply boreholes for the contractors camp.</td>
<td></td>
</tr>
<tr>
<td><strong>Rolfes Factory</strong> Gauteng, South Africa</td>
<td>Groundwater investigation, involving the sampling of groundwater for analysis and assisting in decision on way forward.</td>
<td></td>
</tr>
<tr>
<td><strong>Tenke Fungurume</strong> Katanga, Democratic Republic of Congo**</td>
<td>Groundwater investigation including hydrocensus, geophysical survey, siting, drilling and testing of boreholes for Baseline Environmental Assessment, Impact Assessment for proposed Kwatebala pit and plant, and preparation of conceptual modelling and assisting in the generation of a numerical groundwater model.</td>
<td></td>
</tr>
<tr>
<td><strong>Munali Nickel Project</strong> Kafue, Zambia</td>
<td>Groundwater investigation including drilling and testing of water supply boreholes, reporting and first order modelling of groundwater availability for mining and processing.</td>
<td></td>
</tr>
<tr>
<td><strong>Konkola Copper Mine/Mufulira</strong> Zambia</td>
<td>Groundwater investigation for EIA at Konkola Mine and Mufulira Smelter</td>
<td></td>
</tr>
<tr>
<td><strong>Lumbumbashi Copper Mine</strong> Democratic Republic of Congo</td>
<td>Due diligence and pre-feasibility groundwater investigation for proposed open-pit mining operation</td>
<td></td>
</tr>
<tr>
<td><strong>Venetia Diamond Mine</strong> Limpopo, South Africa</td>
<td>Groundwater Contamination investigation at Venetia Diamond Mine tailings dam.</td>
<td></td>
</tr>
<tr>
<td><strong>Bank Colliery</strong> Mpumalanga, South Africa</td>
<td>Initial groundwater investigating for EMP for two proposed new collieries. Set up of groundwater monitoring network at Bank Colliery.</td>
<td></td>
</tr>
<tr>
<td><strong>Landau Colliery</strong> Mpumalanga, South Africa</td>
<td>Groundwater contamination investigation at the Blaauwkrans co-disposal facility</td>
<td></td>
</tr>
<tr>
<td><strong>Marievale Wetland</strong> Mpumalanga, South Africa</td>
<td>Hydrogeological investigation for EIA on the impact of the removal of gold bearing tailings from the Marievale wetland.</td>
<td></td>
</tr>
<tr>
<td><strong>Daggafontein, Ergo</strong> Gauteng, South Africa</td>
<td>Groundwater contamination investigation at Daggafontein tailings dam. Setting up of monitoring network at various ERGO reclamation sites and plants.</td>
<td></td>
</tr>
<tr>
<td><strong>Deelkraal Gold Mine</strong> North West Province, SA</td>
<td>Investigating the groundwater contamination at Deelkraal tailings dam</td>
<td></td>
</tr>
<tr>
<td><strong>Western Deep Levels &amp; Elandsrand Gold Mines</strong> North West Province, SA</td>
<td>Reporting of groundwater conditions and setting up of monitoring network at Western Deep Levels and Elandsrand gold mines.</td>
<td></td>
</tr>
<tr>
<td>Company</td>
<td>Description</td>
<td></td>
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</tr>
<tr>
<td><strong>Palabora Mining</strong></td>
<td><strong>Fluorescence tracer investigation to determine the rate of inflow into underground mine through caved area.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Company</strong></td>
<td><strong>Provide geohydrological assessment of the proposed Spitzrand Industrial Park near Magoebaskloof.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Limpopo, South Africa</strong></td>
<td><strong>Supporting Engineering Services during the construction of a seepage capture system to the east of the Palabora Copper tailings and magnetite stockpiles</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Palabora Mining</strong></td>
<td><strong>Setting up and managing a ground and surface water database for Palabora Mining Company.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Company</strong></td>
<td><strong>Investigating the groundwater contamination impact on the Tshutshi Spruit in the Kruger National Park</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Limpopo, South Africa</strong></td>
<td><strong>Investigating the groundwater contamination impact on the Selati River</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Palabora Mining</strong></td>
<td><strong>Investigating the feasibility of using stable isotopes to assess the pollution status of groundwater at Palabora Mining Company</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Company</strong></td>
<td><strong>Seismic refraction survey to determine shallow ground conditions along proposed seepage installations.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Limpopo, South Africa</strong></td>
<td><strong>Geohydrological investigation to determine the feasibility of a scavenging well filed to eliminate contamination of ground and surface water in to the Kruger National Park</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Palabora Mining</strong></td>
<td><strong>Geohydrological investigation to determine the best dewatering configuration of the vermiculite open pit.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Company</strong></td>
<td><strong>Geohydrological investigation to minimise impact of poor quality groundwater into underground service shaft damaging the concrete lining.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Limpopo, South Africa</strong></td>
<td><strong>Compilation of closure motivation report for Heavy Minerals Plant and Zirconia Plant.</strong></td>
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<tr>
<td><strong>Palabora Mining</strong></td>
<td><strong>Responsible for five yearly update of closure report, including scope and cost.</strong></td>
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<tr>
<td><strong>Company</strong></td>
<td><strong>Limpopo, South Africa</strong></td>
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<tr>
<td>Project</td>
<td>Location</td>
<td>Description</td>
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<tr>
<td><strong>Palabora Mining Company</strong>&lt;br&gt; Limpopo, South Africa</td>
<td>Implementation of Integrated Water Management Use Licenses.</td>
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<tr>
<td><strong>Moatize Coal Fields</strong>&lt;br&gt; Tete, Mozambique</td>
<td>Groundwater contamination investigation at Pappas Quarry waste disposal facility.</td>
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<tr>
<td><strong>Far West Rand Dolomite Study</strong>&lt;br&gt; Gauteng, South Africa</td>
<td>Groundwater management guideline for the re-watering of the Malamani Dolomite once gold mining in the Far West Rand ceases.</td>
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<tr>
<td><strong>Dolomite Guidelines</strong>&lt;br&gt; South Africa</td>
<td>Generic guidelines for assessment planning and management of groundwater resources in dolomitic terrain in South Africa.</td>
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<tr>
<td><strong>Coal Bed Methane Project</strong>&lt;br&gt; Limpopo, South Africa</td>
<td>Feasibility assessment of the quantity and quality of groundwater to be derived from a methane gas extraction well field planned in Limpopo, South Africa.</td>
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<td><strong>Far East Rand Basin Project</strong>&lt;br&gt; Limpopo, South Africa</td>
<td>Site characterisation of the hydrogeological parameters associated with the shallow sub-surface close to and away from surface water sources suspected of infiltrating into mined out areas below surface.</td>
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<td><strong>Sappi Ngodwana Paper Mill – Irrigation Fields</strong>&lt;br&gt; Limpopo, South Africa</td>
<td>Geochemical site characterisation of the hydrogeological parameters associated with the unsaturated sub-surface underlying the irrigation fields at Sappi-Ngodwana.</td>
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<tr>
<td><strong>Metalloys</strong>&lt;br&gt; Gauteng, South Africa</td>
<td>Review of the hydrogeological regime and current pollution status of the Metalloys site near Meyerton and recommendations to reduce the risk of further pollution from surface sources.</td>
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<tr>
<td><strong>Buzwagi Gold Project</strong>&lt;br&gt; Kahama, Tanzania</td>
<td>First order probabilistic modelling of the potential impact on the groundwater regime and recommendations of work required to investigate and possible measures to reduce the potential impact of the proposed Tailings Storage Facility at the Buzwagi Gold Project, Tanzania.</td>
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<tr>
<td><strong>Bulyanhulu Gold Mine</strong>&lt;br&gt; Kahama, Tanzania</td>
<td>First order probabilistic modelling of the reduced impact on the groundwater regime by lining the existing unlined sedimentation pond at the Bulyanhulu Gold Mine, Tanzania.</td>
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<tr>
<td><strong>Mittal Steel</strong>&lt;br&gt; Gauteng, South Africa</td>
<td>Hydrocensus, geophysical siting, drilling and testing of 20 additional monitoring boreholes at Mittal Steel in Vanderbijlpark in order to update the existing numerical groundwater model and allow for monitoring of organic and inorganic contaminants along a drainage line to the west of the plant.</td>
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</tbody>
</table>
Resumé

THOMAS DEMMER

Seismically induced flooding of deep South African Gold Mines
Gauteng, South Africa

Review of existing information for contribution to a high level ministerial investigation of the risk to mines, miners and the community as a result of flooding induced by seismicity as well as the potential of flooding of old mine workings to induce seismicity.

SUPPLEMENTAL SKILLS

LEAPFROG - HYDRA
Geological Modelling - Basic Skill

FEFLOW
Groundwater Modelling - Advanced Skill

PROFESSIONAL AFFILIATIONS

Council for Professional Natural Scientists