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Matla Consolidation Project: Groundwater Impact Assessment

Report

Final

February 2018

Exxaro Coal (Pty) Ltd

GCS Project Number: 16-1208

Client Reference: GCS 16-1208

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EXECUTIVE SUMMARY

GCS (Pty) Ltd was contracted by Exxaro Coal's Matla Colliery to consolidate all previously conducted and approved groundwater Environmental Management Program Reports (EMPR's) and Environmental Impact Assessment (EIA's) into one single master document. Numerous reports formed part of this process, which was done following a holistic approach to ensure that no important information was lost among the mass.

The involved groundwater studies initially formed part of the larger EMPR and EIA reports that were compiled for:

- Underground mining operations at Mine 1, Mine 2 and Mine 3 (?, 1997 & GCS, 2006),
- Re-routing of the Riet Spruit at Mine 3 (Golder Associates Africa, 2006),
- New access shaft and overland conveyor for Mine 1 (Groundwater Square, 2008),
- Stooping and opencast mining at Matla Colliery *(Golder Associates, 2011)*,
- Water treatment plant (Golder Associates Africa, 2012), and
- The stooping of existing underground mining areas located on Eskom and Exxaro owned land surface areas *(GCS, 2016)*.

Key Issues: *The main aim/objective of this study was to consolidate all previously conducted groundwater EMPR and EIA studies into one single master document and in doing so develop a better understanding of the collective potential impacts on groundwater levels and quality.*

A hydrocensus was conducted by GCS in August 2014, which focused on the identification and/or verification of groundwater use, groundwater recharge and discharge points and possible sources of contamination across the greater project area. A total of 150 boreholes were identified during the desktop review of the previous hydrocensus/user surveys conducted by Groundwater Square (2007) and Golder Associates (2011), which included the existing Matla Colliery monitoring boreholes. GCS visited 79 of these boreholes during their survey in August 2014 (Figure 3.1). Due to the size of the project area, data was gathered within pre-selected areas, spatially distributed across the project area. Thirty four (34) of the 79 boreholes were accessible for groundwater level measurement, with the remaining 45 boreholes being either blocked/vandalised, collapsed or inaccessible. The remaining 71 boreholes weren't visited and/or could not be found.

Two more surveys were also conducted by GCS in 2006 and Groundwater Square in 2008 and their findings are summarised in **Error! Reference source not found.**and **Error! Reference source not und.** respectively.

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

- *The groundwater resource itself and interrelations with other natural resources (e.g. rivers and streams), and*

- *The users that depend on groundwater as sole source of domestic water as well as for livestock and gardening.*

Regional static groundwater levels generally vary between ± 2 and 22 meters below surface (Figure 3.5). The highest static water level elevation within the mine lease area is approximately 1 650 mamsl and occurs in the topographic higher regions. The lowest static water level elevation where no impact from abstraction occurs is at approximately 1 560 mamsl (Figure 3.6).

Key Issues*: On a regional scale, groundwater mimics the natural/unaffected flow patterns/directions of the surface topography. Impacts on groundwater levels and subsequent flow patterns do however occur (be it from groundwater abstraction for domestic/other purposes or mine dewatering), but are largely restricted due to the generally low hydraulic properties of the aquifer host rock.*

Information from geological maps and previously conducted hydrogeological studies shows two possible types of aquifers to be present in the mining area:

- The **first** aquifer is a shallow, semi-confined or unconfined aquifer that occurs in the transitional soil and weathered bedrock zone or sub-outcrop horizon. According to the Parsons Classification system, this aquifer is usually regarded as a minor- and in some cases a non-aquifer system.
- The **second**, main aquifer system is the deeper secondary fractured rock aquifer that is hosted within the sedimentary rocks of the Karoo Supergroup. According to the Parsons Classification system, the aquifer could be regarded as a minor aquifer system, but also a sole aquifer system in some cases where groundwater is the only source of domestic water.

No aquifer testing was performed for the purpose of this investigation. All previously conducted groundwater related studies were consulted in order to obtain a better indication of the average hydraulic properties of the aquifer underlying the mining area. The average hydraulic conductivity (permeability) of the shallow weathered zone aquifer is 0.14 m/d, which based on an average aquifer thickness of approximately 12 meters, translates to a transmissivity of around 1.7 m^2/d *(GCS, 1998)*.

Pumping tests that were performed on the deeper fractured rock aquifer revealed transmissivity values of between 0.1 m^2/d and 7 m^2/d *(GCS, 1998)*, confirming the aquifer to be highly heterogeneous.

According to Figure 3.9 the mean annual recharge to the aquifer underlying the Matla mine lease area is in the region of 32 mm, which based on an average rainfall of approximately 754 mm/a (Figure 2.3) translates to a recharge percentage of just over 4%. During the model calibration process, changes are made to the aquifer recharge (among other model input parameters) until an acceptable correlation is achieved between the model simulated and measured/actual groundwater elevations. During this calibration process for the Matla Stooping Project, a much lower recharge of between 0.6% and 1.2% was eventually assigned to the aquifer regime underlying the mine lease area **(Section 5)**.

Groundwater samples were collected from six hydrocensus/user boreholes and were analysed for a range of chemical and physical parameters. The positions of these six boreholes are indicated in Figure 3.11, while the results of the analyses are provided in Table 3.3 together with the guidelines used in the assessment.

Key Issues:

- *Groundwater is considered to be of good quality according to the two sets of guidelines used in the assessment.*
- *Boreholes are situated in the open field and far away from potential surface sources of groundwater contamination.*
- *Typical impacts associated with coal mining related activities include elevated groundwater salinity (TDS/EC), elevated concentrations of sulphate and iron and a decrease in groundwater pH conditions. Groundwater from all six boreholes displays no such signs of coal mining related impacts.*
- *Please note that the underground workings will continue to act as a sink for both groundwater and any potential contamination that may originate from the Matla mining activities for as long as it takes groundwater levels to recover from the impacts of mine dewatering.*
- *Groundwater from the sampled boreholes is considered to be representative of the ambient/unaffected groundwater quality conditions. This information can therefore be used quite effectively to assess groundwater quality impacts that may potentially originate from the coal mining and/or related activities at Matla.*

No acid base accounting was performed for the purpose of this investigation, however the surrounding mines are known to generate acid *(GCS, 1998)*. The weathered sandstone, shale and coal have the potential for acidification. Groundwater flowing through these areas is likely to generate acid when exposed to oxygen and water. The coarse sandstone, on the other hand, has a very large neutralising potential and will give groundwater flowing through it an alkaline character *(GCS, 2006)*.

Key Issues:

- *The coal and overburden material have the potential to generate an acidic leachate high in sulphate and iron content due to acid mine/rock drainage. This characteristic behaviour of material containing metal sulphide minerals (usually pyrite), significantly increases a source's potential to adversely affect the quality of groundwater.*
- *Water collecting in the mine workings will stratify with time, i.e. the "heavier" polluted water will sink to the bottom or floor of the mine leaving the "lighter" water of better quality to occupy the upper parts of the water column. The water that will eventually decant should therefore be of a better quality than that in the reactive coal horizon.*
- *This stratified system may however be disturbed in areas experiencing high water ingress and consequent mixing of the water columns, thus adversely affecting the quality of the decanting water.*
- *High extraction mining has led to surface subsidence (especially above shortwall panels) in the Matla mine lease area. Wherever subsidence has occurred, recharge to the underground workings is expected to have increased significantly. If the Matla underground workings are to decant, the water is expected to be of poor quality.*

For a negative groundwater quality impact to be registered the following three components should be present:

- A source to generate and release the contamination,
- A pathway along which the contamination may migrate, and
- A receptor to receive the contamination.

All three these components are present within the Matla mine lease area, which stresses the importance of a comprehensive early detection groundwater monitoring program (source monitoring) and ongoing water management and containment of source effects.

Numerous water balance models have been done for Matla throughout the years, of which the most recent one was completed in June 2015 by Mine Water Consultants.

Key Issues:

- *The planned stooping areas are either partially or completely flooded and would require dewatering before Matla can safely commence with mining.*
- *The planned stooping activities are expected to cause an increase in the vertical recharge component. The areas earmarked for stooping are however small in comparison with the larger mining area and their effect/impact on the water balance is therefore expected to be small.*

- *The average vertical recharge to the underground workings of approximately 12 900 m^3/d is also the average expected decant volume once the entire underground void has been flooded. Potential decant positions/areas are indicated in Figure 3.16.*

The Processing Modflow 8 modelling package was used for the proposed stooping model simulations. The finite difference model grid constructed to include the entire Matla mine lease area is indicated in Figure 4.3. Model dimensions and aquifer parameters used in the construction and calibration of the model are provided in Table 4.1.

Key Issues:

- *Ten groundwater user boreholes were simulated to be affected by the planned stooping activities.*
- *These boreholes were simulated to experience water level decreases of between two and six meters.*
- *We therefore recommend quarterly monitoring (at least) of groundwater levels in the model simulated affected areas.*
- *Monitoring data should be assessed on a regular basis to determine/quantify the impact (if any) on groundwater levels.*
- *Groundwater users should be compensated for their loss should the monitoring program indicate adverse groundwater level impacts.*

Numerical flow- and mass transport models were also constructed to simulate the potential groundwater impacts related to the new access shaft at Mine 1 and water treatment plant. The modelling results are summarised in **Section 4.1**and **Section 4.2** respectively.

The potential impacts associated with all mining and related activities were assessed according to an impact and risk assessment criterion (**Table 5.1**). The results are provided in Table 5.2 to Table 5.21.

A total of 42 boreholes are currently included in Matla's groundwater monitoring program and their positions are indicated below in Figure 6.1.

Key Issues:

- *The current sampling frequency and range of chemical and physical parameters are considered to be sufficient.*
- *There are however room for improvement, especially in terms of source monitoring. At least four additional source monitoring boreholes are recommended down gradient from pollution control dams and the old opencast workings.*
- *For as long as the underground mine workings remain sinks, groundwater level monitoring should take priority over groundwater quality monitoring.*

- *Dedicated monitoring of water levels in the abandoned underground mine workings plays a crucial role in the development of an accurate water balance model.*
- *Diligent water level monitoring at nearest users to proposed stooping areas to detect impacts timeously.*

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1 INTRODUCTION

1.1 Background Information and Project Summary

GCS (Pty) Ltd was contracted by Exxaro Coal's Matla Colliery to consolidate all previously conducted and approved groundwater Environmental Management Program Reports (EMPR's) and Environmental Impact Assessment (EIA's) into one single master document. Numerous reports formed part of this process, which was done following a holistic approach to ensure that no important information was lost among the mass.

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- Water treatment plant *(Golder Associates Africa, 2012), and*
- The stooping of existing underground mining areas located on Eskom and Exxaro owned land surface areas *(GCS, 2016)*.

Please note that for the groundwater quality and water level baseline assessments only the most recent data was used, i.e. data collected during the GCS hydrocensus of 2014 (Appendix A).

Matla Colliery is an existing Eskom-tied mega-colliery with a three shaft complex (named Mine 1, Mine 2 and Mine 3) across an approximately 22 000 hectares area, along the northern margins of the Highveld Coalfield of South Africa. Matla Colliery is located approximately 100 km east of Johannesburg, 45km south of Witbank (eMalahleni), in-between the towns of Kriel (±10 km to the east) and Leandra (±25 km to the west). A locality map of the mining area is provided in Figure 1.1.

Key Issues: *The main aim/objective of this study was to consolidate all previously conducted groundwater EMPR and EIA studies into one single master document and in doing so develop a better understanding of the collective potential impacts on groundwater levels and quality.*

1.2 Scope of Work

The scope of work and structure of the report can be summarised as follow:

- Assessment of all previously conducted groundwater related studies, which provided the information for this study *(Section 1.3)*.
- Topographic maps were consulted and used in the general description of the surface topography and major water courses located within the immediate vicinity of the Matla mining area *(Section 2.1)*.

- Climatic conditions namely the mean annual rainfall, temperatures and evaporation were evaluated and discussed *(Section 2.2)*.
- Relevant reports from previously conducted studies and the 1:250 000 scale geological map of the mining area were consulted in the assessment and applied in the discussion of the local geology *(Section 2.3)*.
- The findings of previously conducted hydrocensus/user surveys were assessed and summarised as part of the baseline study (Section 3.1).
- Topographic and geological maps were used in the delineation of the aquifer underlying the mining area *(Section 3.2)*.
- Groundwater level information collected during the GCS hydrocensus/user survey of 2014 was used in the assessment of the groundwater level depth *(Section 3.3)*.
- Groundwater level information was also used to calculate groundwater flow directions, gradients and velocities as accurate as possible *(Section 3.4)*.
- Geological information together with the findings of previous studies were used to identify and characterise the aquifer/s underlying the mining area *(Section 3.5)*.
- Relevant reports from previously conducted studies were consulted for aquifer parameters such as transmissivity and storativity *(Section 3.6)*.
- Dedicated groundwater recharge studies *(Vegter, 1995)* were consulted in the assessment of aquifer recharge and discharge rates for the mining area *(Section 3.7)*.
- Groundwater quality information collected during the GCS hydrocensus/user survey of 2014 was used in the assessment of the local groundwater quality conditions *(Section 3.8)*.
- The findings of previous studies were consulted and provided an indication of the acid generating potential of the Karoo Supergroup rocks underlying the mining area *(Section 3.9)*.
- Maps and all relevant information were assessed and used in the identification of potential source areas *(Section 3.10)*.
- Geological maps and all relevant information were used in the identification of preferred pathways that may possibly conduit/assist the flow of contamination *(Section 3.11)*.
- All possible receptors were identified within the mining area with the help of information gathered during previous hydrocensus/user surveys and topographic maps *(Section 3.12)*.
- Previous studies were consulted to improve our understanding of the mine water balance *(Section 3.13)*.
- All relevant information was combined in a holistic manner to construct the conceptual model of the mining area (Section 3.14).
- Numerical flow- and mass transport models were constructed and used in the assessment/prediction of groundwater level impacts associated with the planned stooping activities. Plume migration from potential surface source areas was also simulated. The modelling results of previous groundwater studies were assessed and summarised *(Section 4)*.
- The potential impacts associated with all mining and related activities were assessed according to an impact and risk assessment criterion *(Section 5)*.

- A comprehensive groundwater monitoring plan/protocol was proposed and discussed in detail *(Section 6)*.

1.3 Review of Relevant Hydrogeological Investigations

This consolidation report was compiled as a desk top assessment. The following hydrogeological investigation reports provided background information on the general hydrogeological setting (conceptual model) and input data for flow directions, gradients, mine water volumes and other:

- Geohydrological Investigation: Matla Coal Ltd, GCS Water and Environmental, June 1998 *(Report No 98.06-123)*,
- M01 Water Use License Application for the Re-Routing of the Rietspruit River at No. 3 Mine, Matla Colliery, Ogies, Mpumalanga Province, Golder Associates, May 2006 *(Report No 8035/8346/1/W)*.
- Matla Colliery: Environmental Management Programme Report (EMPR) Amendment, Volume 1, GCS, June 2006 *(Project No 2004.01.006)*,
- Groundwater Supplement to EMP Addendum, Matla Coal No. 1 Shaft, Groundwater Square, April 2008 *(Report No 092)*,
- Phase I Hydrogeological report to support the EIA for stooping and opencast mining; Matla Colliery, Golder Associates, August 2011 *(Report No 10613143-11209-3)*,
- Hydrogeological Impact Assessment, Matla Water Treatment Plant, Golder Associates, March 2012 *(Report No 10613143-11209-3)*,
- Matla Colliery: Update of the Groundwater Balance, Mine Water Consultants, June 2015 *(Report No 03/2015/PDV)*, and
- Matla Stooping Project: Groundwater Impact Assessment, GCS Water and Environmental, December 2016 *(Report No 13-400)*.

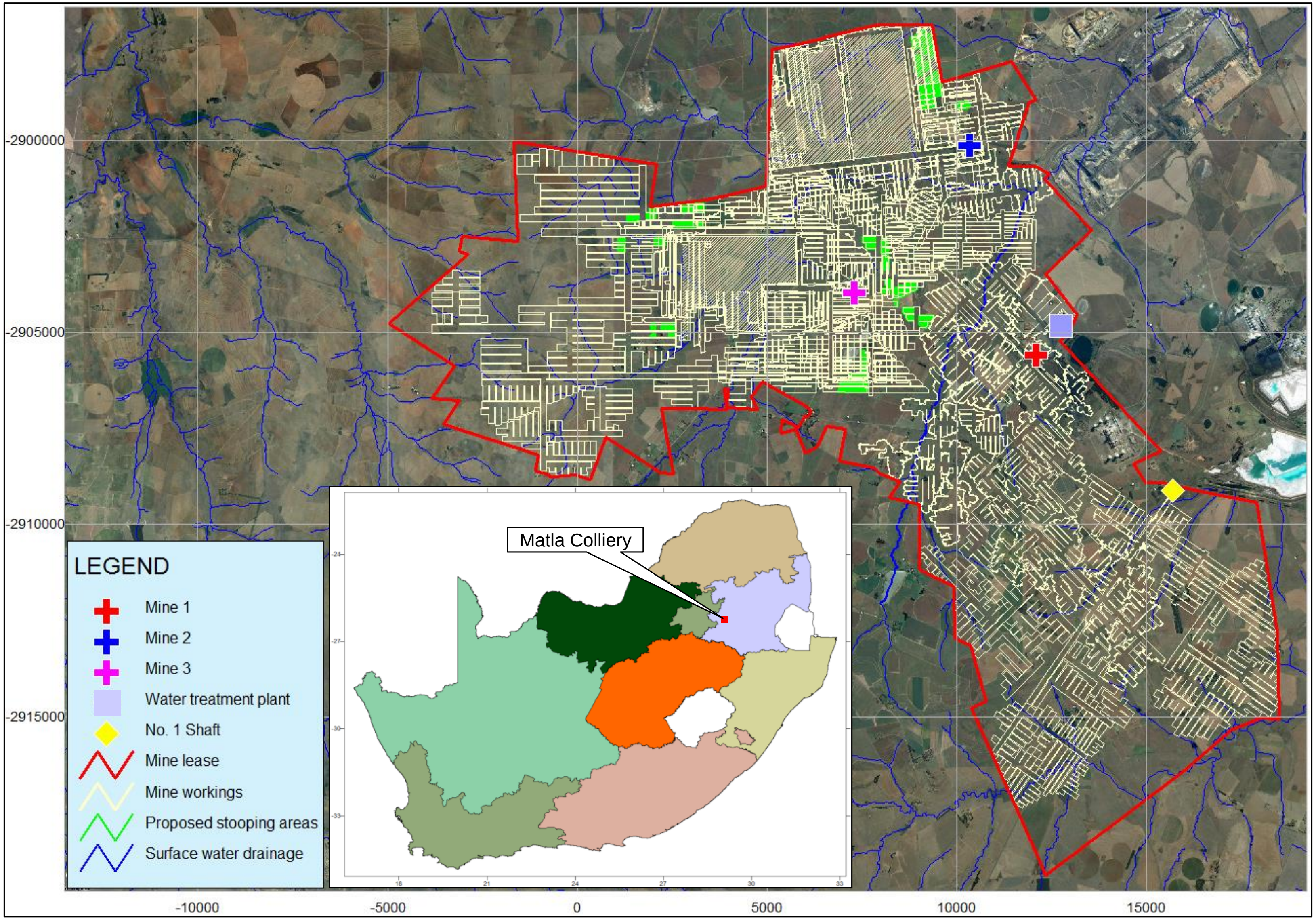

Figure 1.1: Locality map of the mining area

2 SITE SETTING

2.1 Surface Topography and Water Courses

The surface topography of the mine lease area is characterised by gently rolling hills and valleys that drain towards the north. Surface elevations generally vary between approximately 1 565 and 1 650 meters above mean sea level (mamsl). The surface slope varies between 3 % and 8 %. The slope length varies from 500 m to 1 000 m and the slope shape varies from convex to concave. In various areas the topography has been altered due to surface subsidence of undermined areas. Surface subsidence (collapse of the roof strata above the high extraction mining areas) has resulted in an uneven topography, which in some places has resulted in the formation of ponds and wetlands *(GCS, 2006)*.

Matla Colliery stretches over three quaternary catchments, namely B11D, B11E and B20E. These three catchments are located within the Upper Olifants Water Management Area. The southern bounds of the Matla reserve are constituted by the Vaalbank Spruit and the Dwars-in-die-weg Spruit, while the northern portion of the reserve is transected by the Blesbok Spruit and the Riet Spruit. The central reserve area is transected by a tributary of the Riet Spruit.

Surface elevations of the wider project area are indicated in Figure 2.1 together with the surface water courses.

Key Issues:

- *High extraction of coal has led to roof collapse and ensuing subsidence of the surface. This will greatly increase recharge to the underground mine workings.*
- *The mine lease area is transected by numerous perennial streams, which may be vulnerable to contaminated groundwater base flow.*

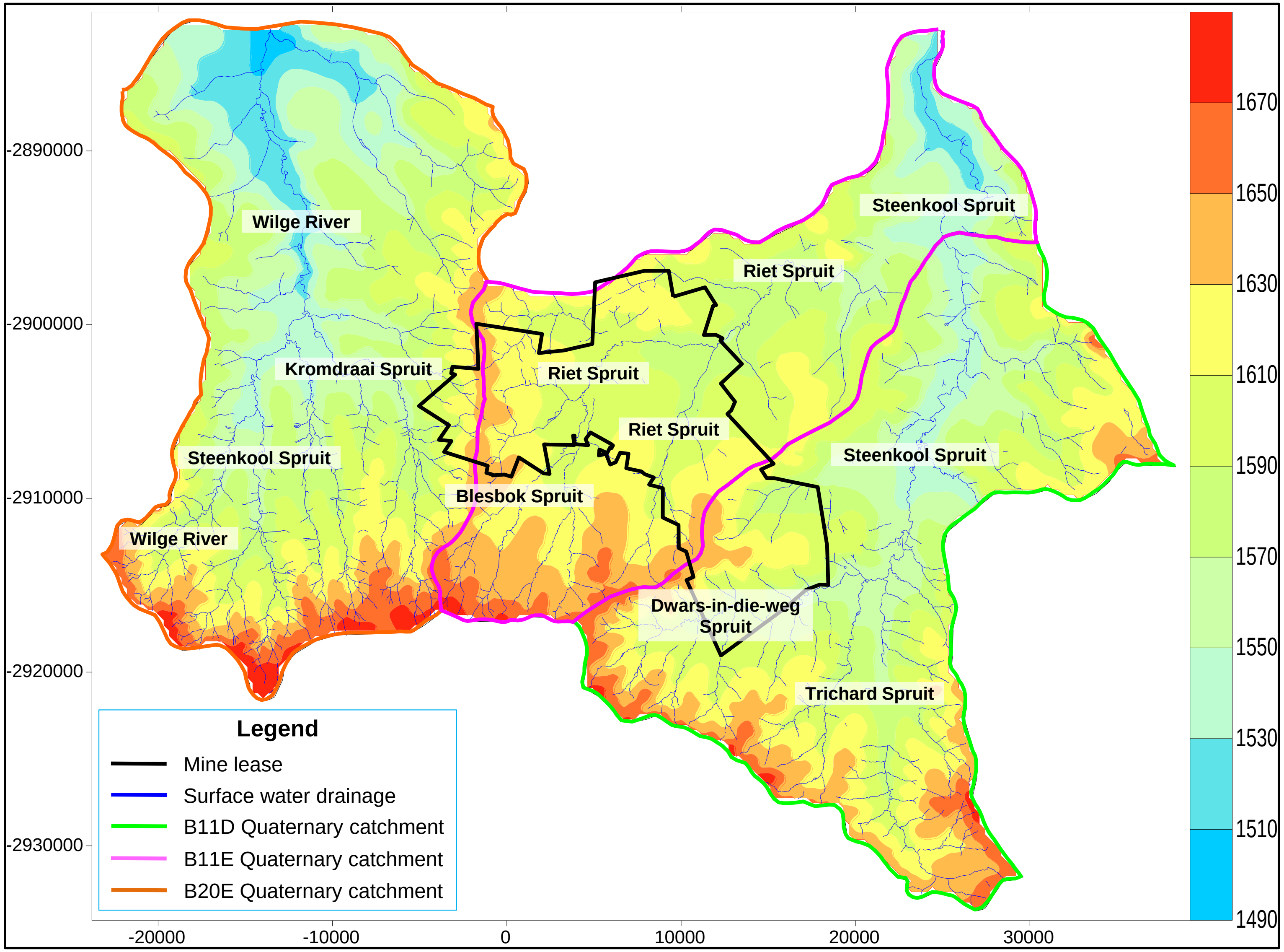

Figure 2.1: Surface elevation contours for the project area (mamsl)

2.2 Climatic Conditions

Matla Colliery is located in an area that is characterised by warm to hot summers and cool winters *(GCS, 2006)*. Temperatures in the vicinity of the mine vary from 26°C in the summer to 15°C in the winter (Figure 2.2). Most of the precipitation occurs from November to January with an average of approximately ninety (90) rain days per annum. Rainfall over the period May to September is generally low or absent, with a noticeable increase in the months of October to April. Rainfall events in the region occur mainly in the form of thunderstorms and heavy showers. The annual average precipitation at Matla Colliery is relatively low and variable. Annual rainfall values range from 550 mm – 800 mm with an average of approximately 754 mm per annum (Figure 2.3).

The mean annual evaporation rate for the B11E quaternary catchment is in the order of 1 600 mm (Figure 2.4), which far exceeds rainfall (Figure 2.3).

Key Issues*: The Matla area has a net environmental moisture deficit for the entire year.*

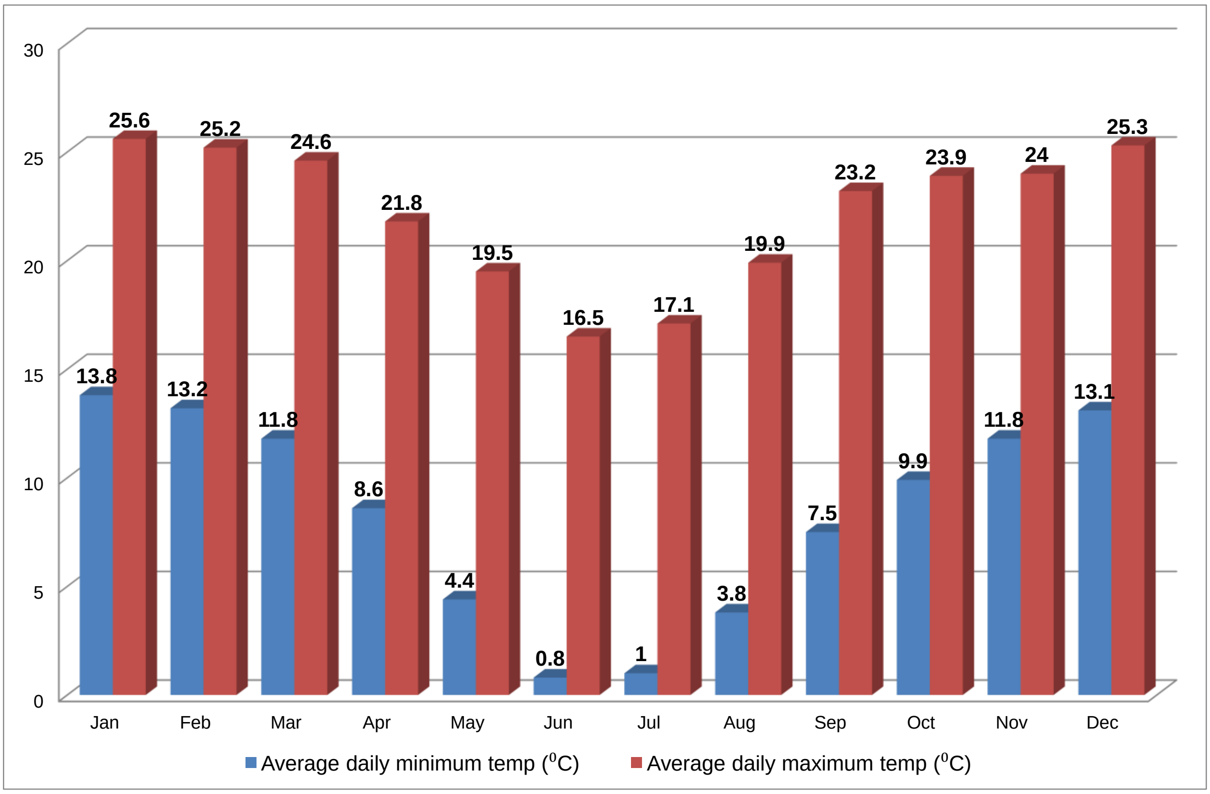

Figure 2.2: Mean monthly minimum and maximum temperatures for Matla Colliery

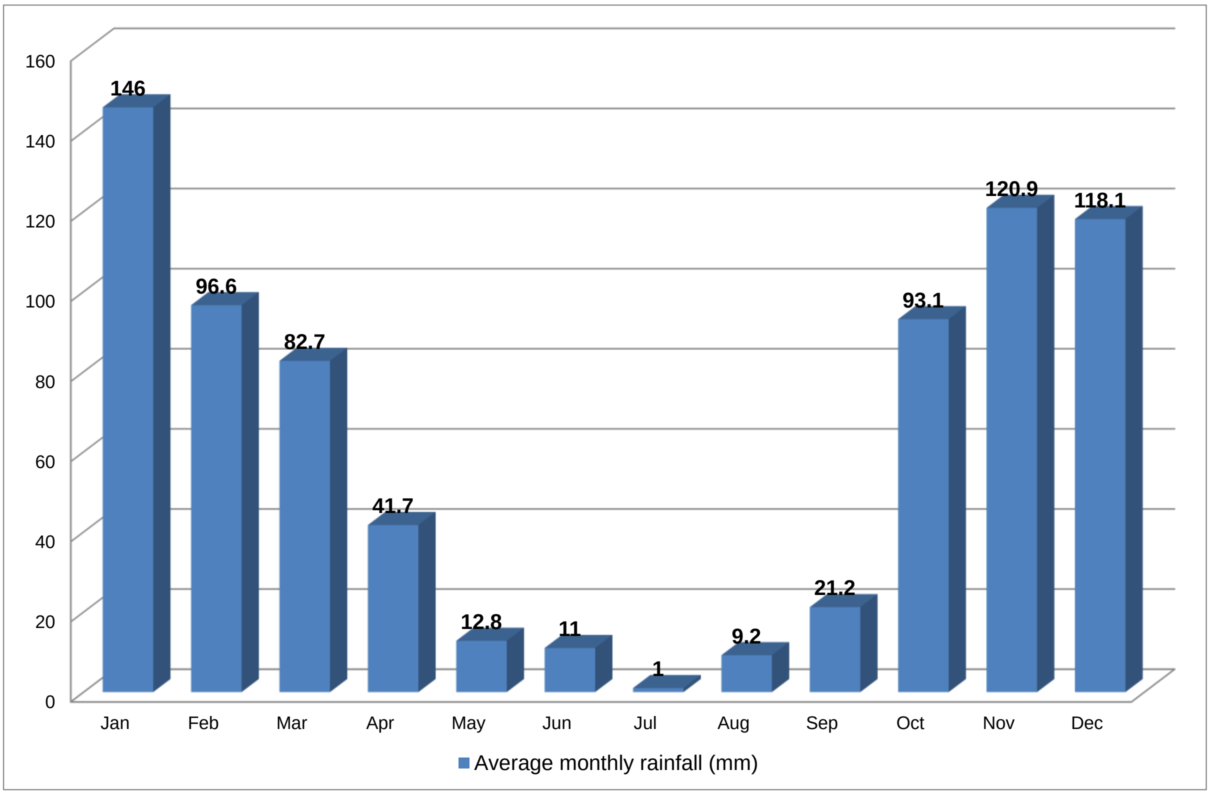

Figure 2.3: Mean monthly rainfall for Matla Colliery

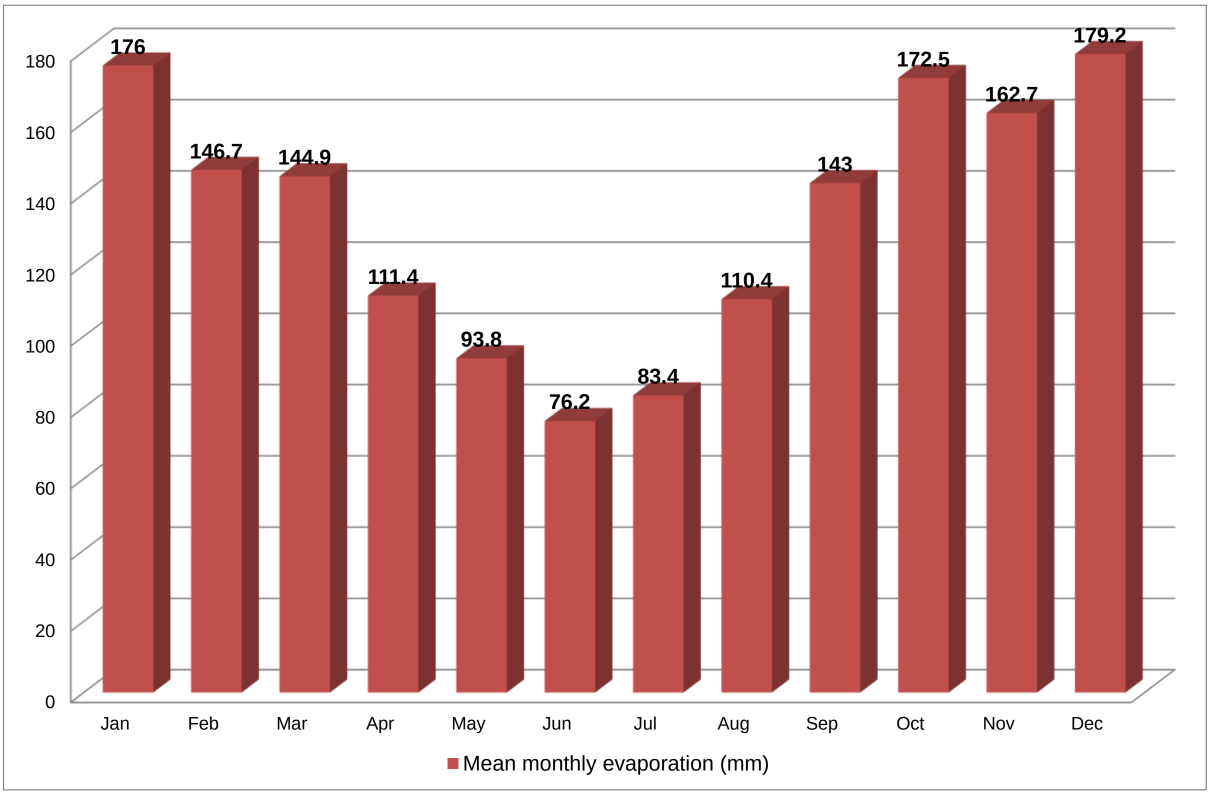

Figure 2.4: Mean annual evaporation for B11E quaternary catchment

2.3 Geology

The Matla Colliery coal reserves form part of the Highveld Coal Field *(GCS, 2006)*. The coal seams are found within the Vryheid Formation of the Karoo Sequence (Figure 2.5). The Karoo Supergroup in the Matla area comprises the Ecca Group and the Dwyka Formation. The Ecca sediments consist predominantly of sandstone, siltstone, shale and coal. Combinations of these rock types are often found in the form of interbedded siltstone, mudstone and coarse-grained sandstone. The Ecca sediments overlie the Dwyka Formation (loosely referred to as the Dwyka tillite). The latter consists of a proper tillite, sandstone and sometimes a thin shale development. The upper portion of the Dwyka sediments may have been reworked, in which case carbonaceous shale and even inclusions of coal may be found. The Dwyka sediments are underlain by felsitic rocks of the Bushveld Complex.

The stratigraphic sequence within the Matla area includes five coal seams that are numbered from the bottom upwards from 1 to 5. Economic reserves are found in the 2 seam, 4 seam (lower) and the 5 seam. The seam depths vary, but are on average as follows:

- 5 Seam: - 35 to 50 m below surface,
- 4 Seam: - 75 to 85 m below surface, and
- 2 Seam: - 100 to 120 m below surface.

The number 1, 3 and 4 upper seams only sporadically attain acceptable qualities and thickness.

Tectonically, the Karoo sediments are practically undisturbed. Faults are rare, however fractures are common in rocks such as sandstone and coal. Dolerite intrusions in the form of sills or dykes cause various mining problems, i.e. devolatised coal, weakened roof strata and/or displaced coal seams. The intrusion of a sill in the Mine 1 area caused extensive devolatisation of the overlying 2 Seam, resulting in the exclusion of the 2 seam from mineable reserves in Mine 1. Pressure on the overlying strata, due to the intrusion, resulted in two intersecting joint patterns, which generally have a NE to SW and NW to SE strike respectively. Dolerite from the underlying sill intruding the overlying strata through the joint patterns resulted in a high frequency of dykes in the Mine 1 area. In the Mine 2 total extraction area there are almost no intrusions, except for one small dyke, which affords Matla Colliery the opportunity to utilise total extraction mining methods.

Key Issues:

- *The dolerite occurrences in the area have specific significance with regard to the geohydrology. Not only can groundwater compartments exist as a result of these features, but the possible groundwater interaction between mines will also be a function of the dolerite distribution.*
- *Geological structures also have the ability to act as preferred pathways for groundwater flow and any potential contamination.*

- *The limit of weathering roughly averages in depth between 9 and 12 meters, deeper zones of weathering are however present. This weathered zone, wherever located below the local groundwater level, may also act as a preferred pathway.*

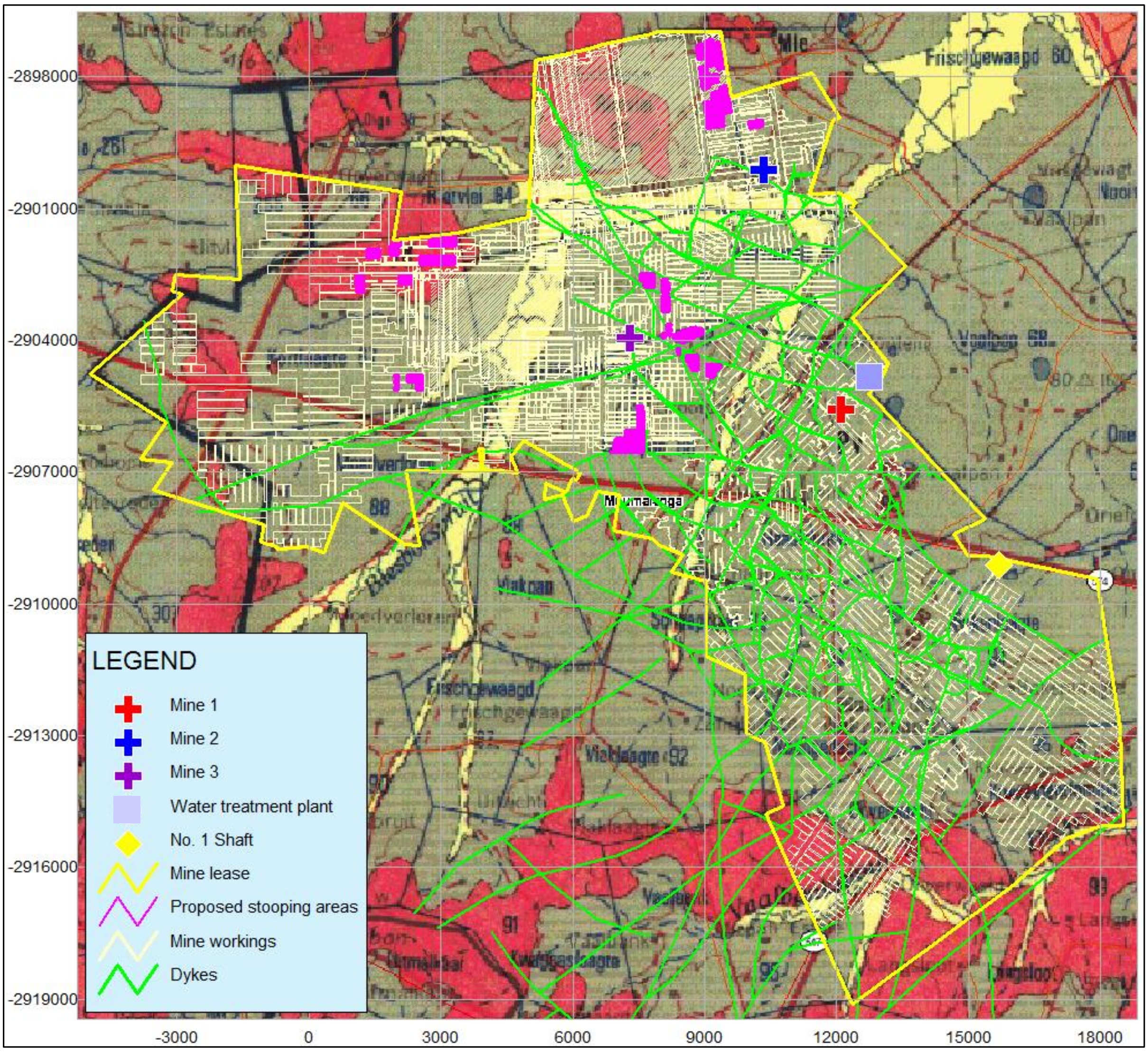

Figure 2.5: 1:250 000 scale geological map of the mine lease area

Notes: *Jd (pink) = Dolerite, Pv (light brown) = Sandstone/siltstone/shale/coal of the Ecca Group, Karoo Supergroup, Qs (yellow) = Unconsolidated quaternary deposits.*

3 HYDROGEOLOGICAL CONCEPTUAL MODEL

A conceptual model is in reality our holistic understanding of the workings and nature of the aquifer regime underlying the Matla mining area. A good understanding of the hydrogeological environment is key to the accurate assessment of potential groundwater impacts associated with the mining activities. All components of the conceptual model are discussed in as much detail as possible in the following subsections.

3.1 Results of the Hydrocensus/User Survey

Comprehensive hydrocensus/users surveys were conducted for the Matla mine lease area and immediate surrounding during four individual groundwater related studies:

- Mining operations at Mine 1, Mine 2 and Mine 3 *(GCS, 2006)*,
- New access shaft and overland conveyor for Mine 1 *(Groundwater Square, 2008)*,
- Information review and gap analysis to support the EIA for stooping and opencast mining *(Golder 2011)*, and
- The stooping of existing underground mining areas located on Eskom and Exxaro owned land surface areas *(GCS, 2016)*.

The main aims and objectives of the hydrocensus field surveys were as follow:

- To locate all interested and affected persons (I&APs) with respect to groundwater – thus groundwater users,
- To collect all relevant information from the I&APs (i.e. name, telephone number, address, etc.),
- Accurately log representative boreholes on the I&APs properties, and
- To collect all relevant information regarding the logged boreholes (i.e. yield, age, depth, water level, use etc.) in order to establish a representative baseline of groundwater conditions.

The results of the hydrocensus surveys are summarised in Appendix A, while borehole positions are indicated in Figure 3.1.

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

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

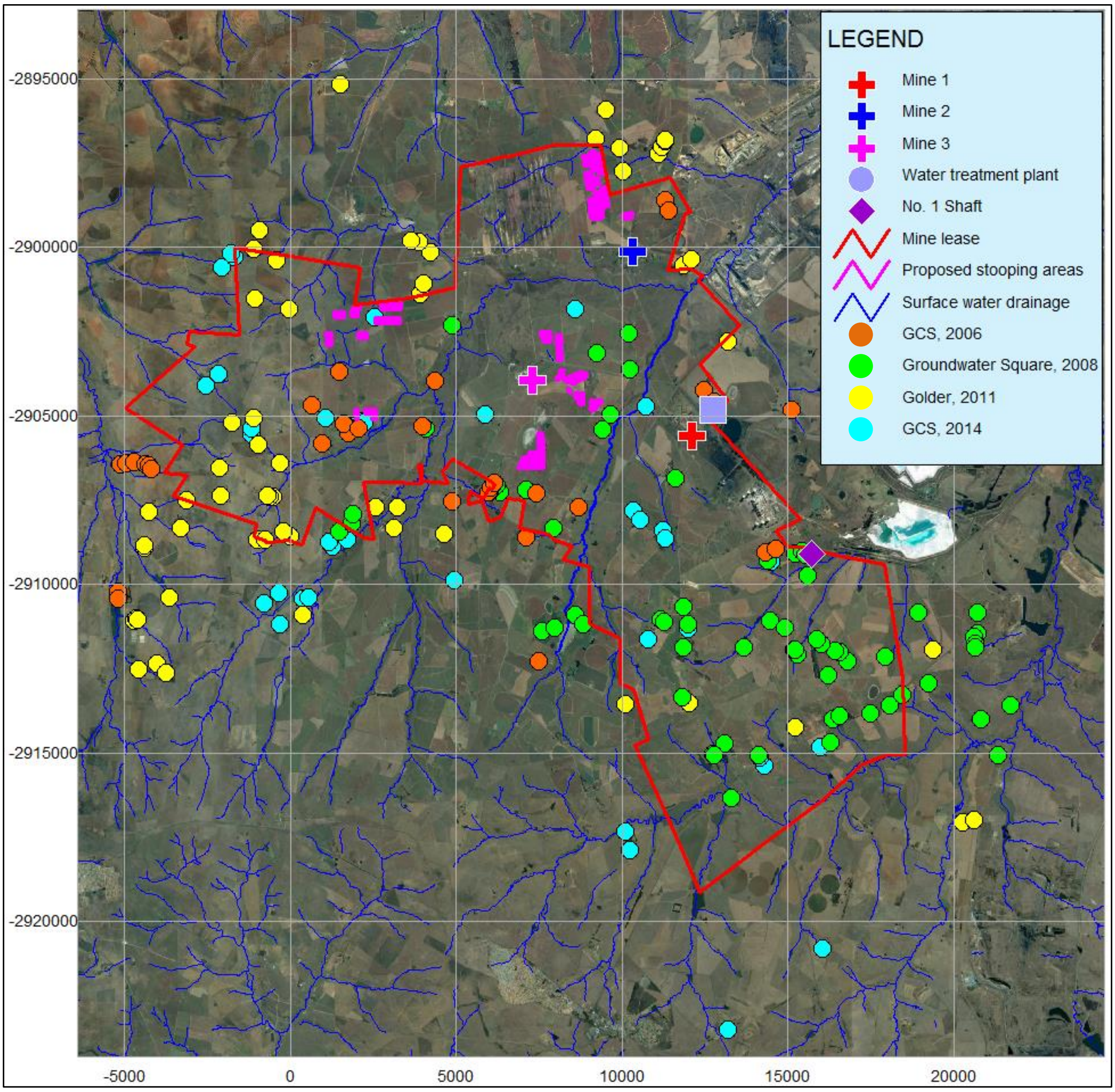

Figure 3.1: Positions of boreholes located during the various hydrocensus and user surveys

3.2 Aquifer Delineation

Because the main aquifer is a fractured rock type and fractures could assume any geometry and orientation, the physical boundary or 'end' of the aquifer is very difficult to specify or quantify. Aquifer boundary conditions that are generally considered during the delineation process are described below:

- **No-flow** boundaries are groundwater divides (topographic high or low areas/lines) or impermeable geological structures across which no groundwater flow is possible.
- **Constant head** boundaries are positions or areas where the groundwater level is fixed at a certain elevation and does not change (perennial rivers/streams or dams/pans).

Topographic highs and lows were used to roughly delineate the aquifer system underlying the Matla mine lease area (Figure 3.2). The aquifer was estimated to cover an area of roughly 1 000 km^2. Please note that geological structures such as dykes are known to occur within the area and have the ability to act as aquifer boundaries, thus subdividing the regional aquifer into various 'sub-aquifers' or compartments. The structural integrity of these potential boundaries remains an uncertainty, therefore aquifer boundaries as indicated in Figure 3.2 are considered to be conceptual and based on topographic controls only.

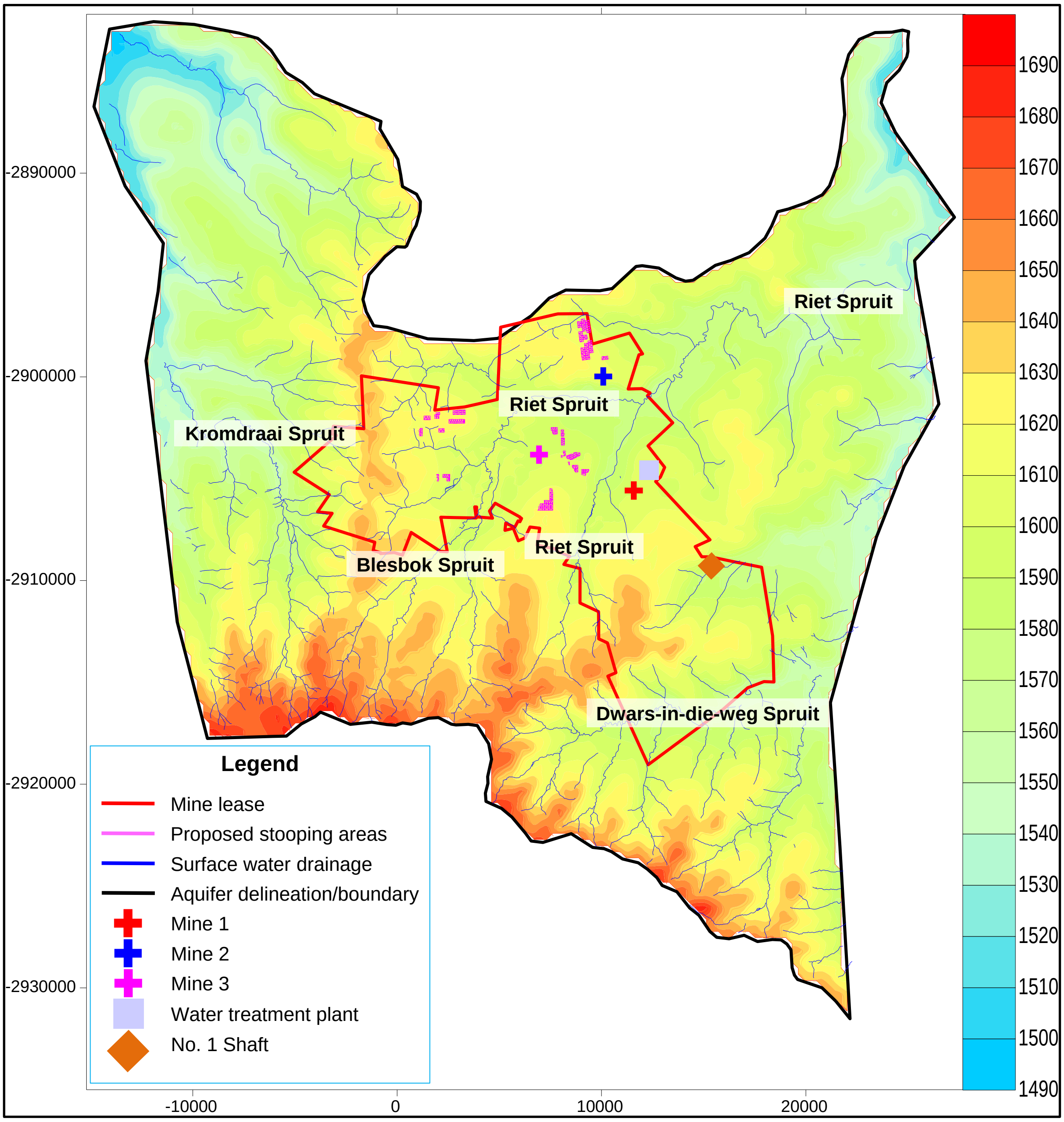

Figure 3.2: Aquifer delineation for project area

3.3 Groundwater Level Depth

Groundwater level information was collected during a hydrocensus conducted by GCS in 2014 (Appendix A). A thematic groundwater level map of the entire mining area is provided in Figure 3.5. These water levels are essential as they were used in the generation of static groundwater level elevations with the use of the Bayesian interpolation method (Figure 3.6).

Regional static groundwater levels generally vary between ± 2 and 22 meters below surface (Figure 3.5). Due to the generally low aquifer transmissivity the pumping causes deep drawdown of the groundwater level/piezometric head and a depression cone forms that is deep, but very limited in lateral extent. This concept is explained in Figure 3.3.

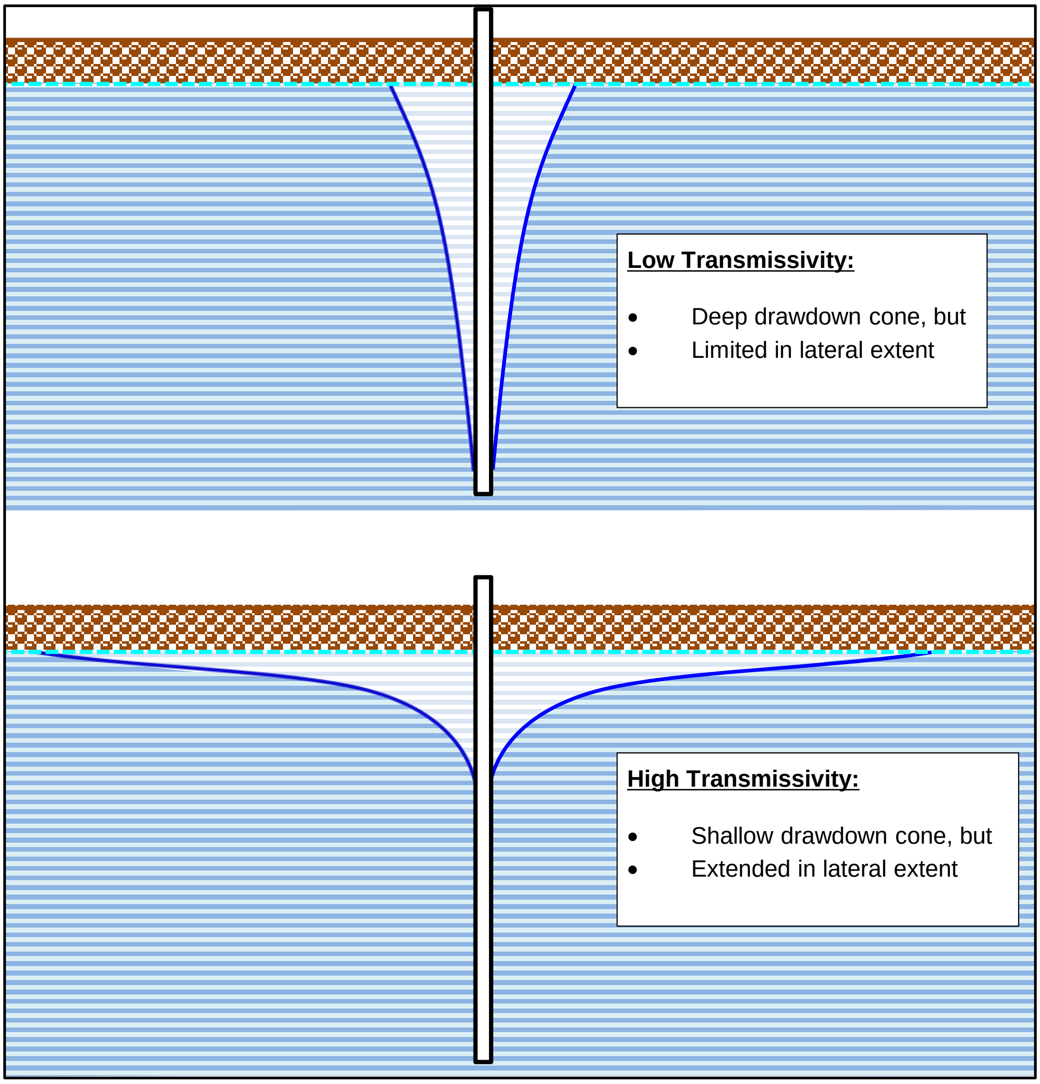

Figure 3.3: Effect of aquifer transmissivity on depression cone

The static groundwater elevation contour map provided in Figure 3.6 was constructed through the utilisation of the Bayesian interpolation technique. The Bayesian interpolation technique utilises the natural relationship that exists between the surface topography and the depth-to-groundwater level to estimate groundwater levels in areas where borehole data is scarce.

Because impacts on the natural groundwater level already exist due to mine dewatering and/or groundwater abstraction for domestic, irrigation and mining purposes, only boreholes where the linear correlation between borehole collar elevation and groundwater level elevation exists were used in the interpolation.

The static groundwater contours presented in Figure 3.6 therefore represent conditions without impacts from sources or actions other than natural conditions.

A graph of borehole collar elevation versus groundwater level elevation is presented in Figure 3.4 where the linear correlation of approximately 97% can be seen. It should be noted that groundwater levels from some boreholes (generally those in excess of ten meters deep) were discarded because impacts associated with groundwater abstraction affect the natural groundwater level/topography relationship.

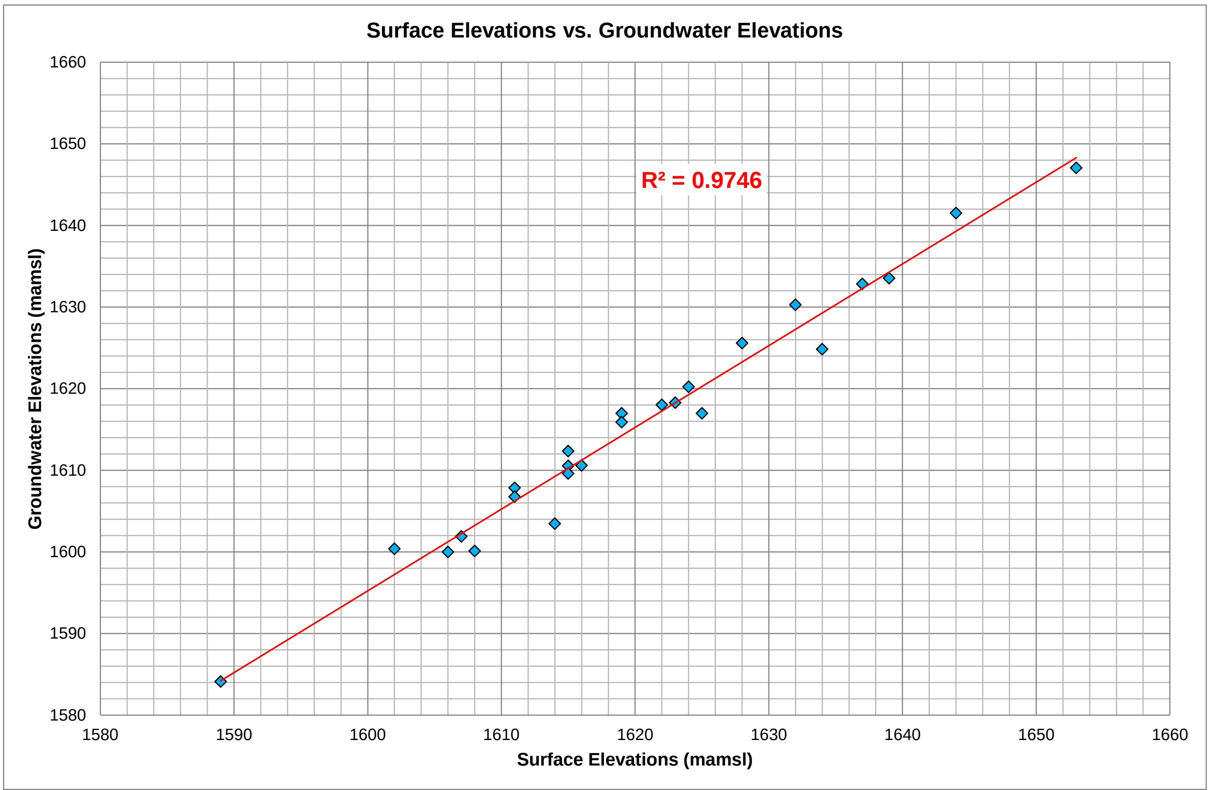

Figure 3.4: Relationship between surface- and groundwater elevations

The highest static water level elevation within the mine lease area is approximately 1 650 mamsl and occurs in the topographic higher regions. The lowest static water level elevation where no impact from abstraction occurs is at approximately 1 560 mamsl. Groundwater flow directions within the modelled area are also indicated in Figure 3.6 with the use of blue arrows.

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

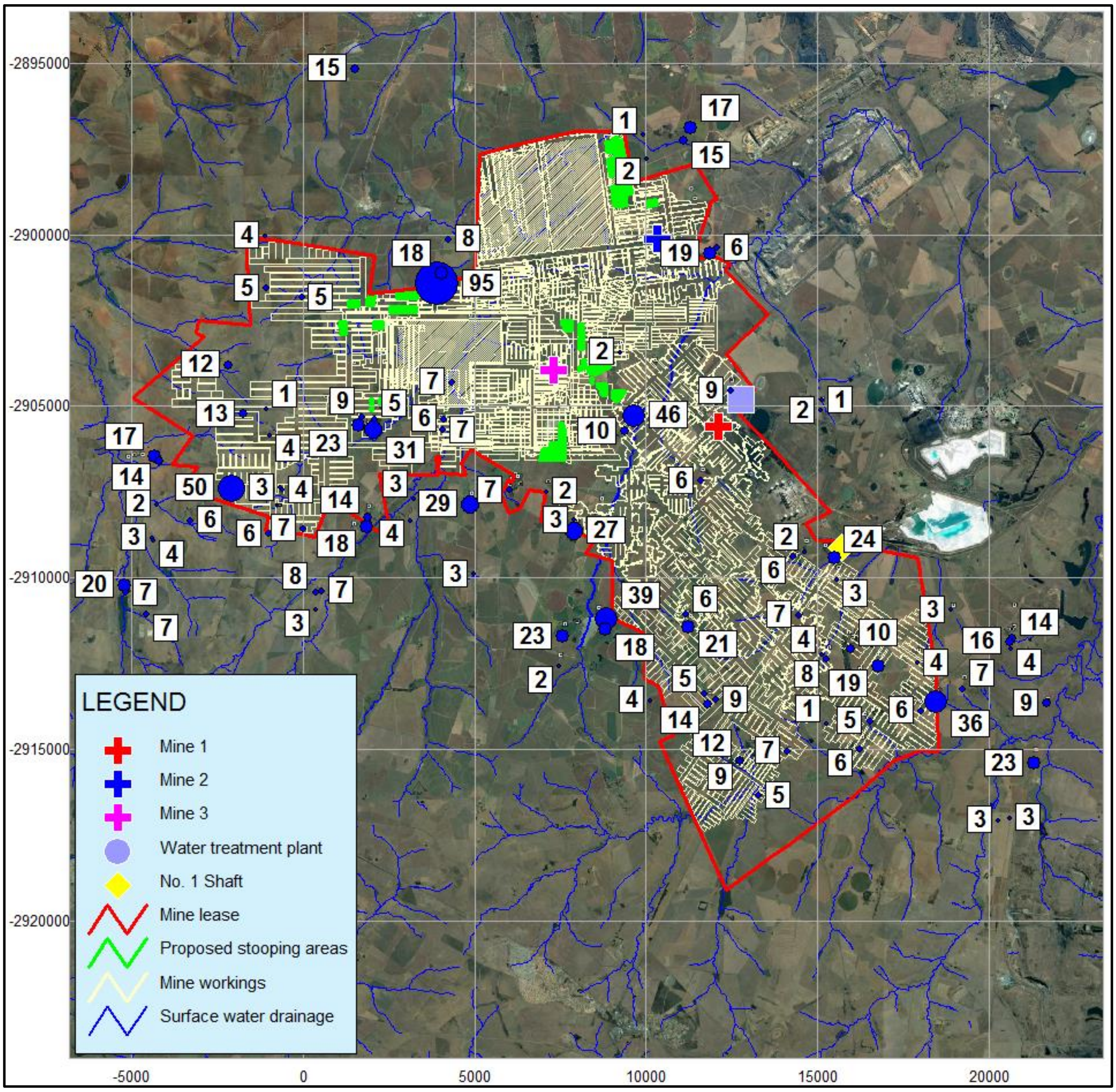

Figure 3.5: Thematic map of measured groundwater level depths (mbs)

Notes: *- The numbers in the above figure indicate the groundwater level depth below surface in meters,*

- The size of the blue circles is directly proportional to the groundwater level depth, hence the largest circle represents the deepest water level.

***Key Issues:** On a regional scale, groundwater mimics the natural/unaffected flow patterns/directions of the surface topography. Impacts on groundwater levels and subsequent flow patterns do however occur (be it from groundwater abstraction for domestic/other purposes or mine dewatering), but are largely restricted due to the generally low hydraulic properties of the aquifer host rock.*

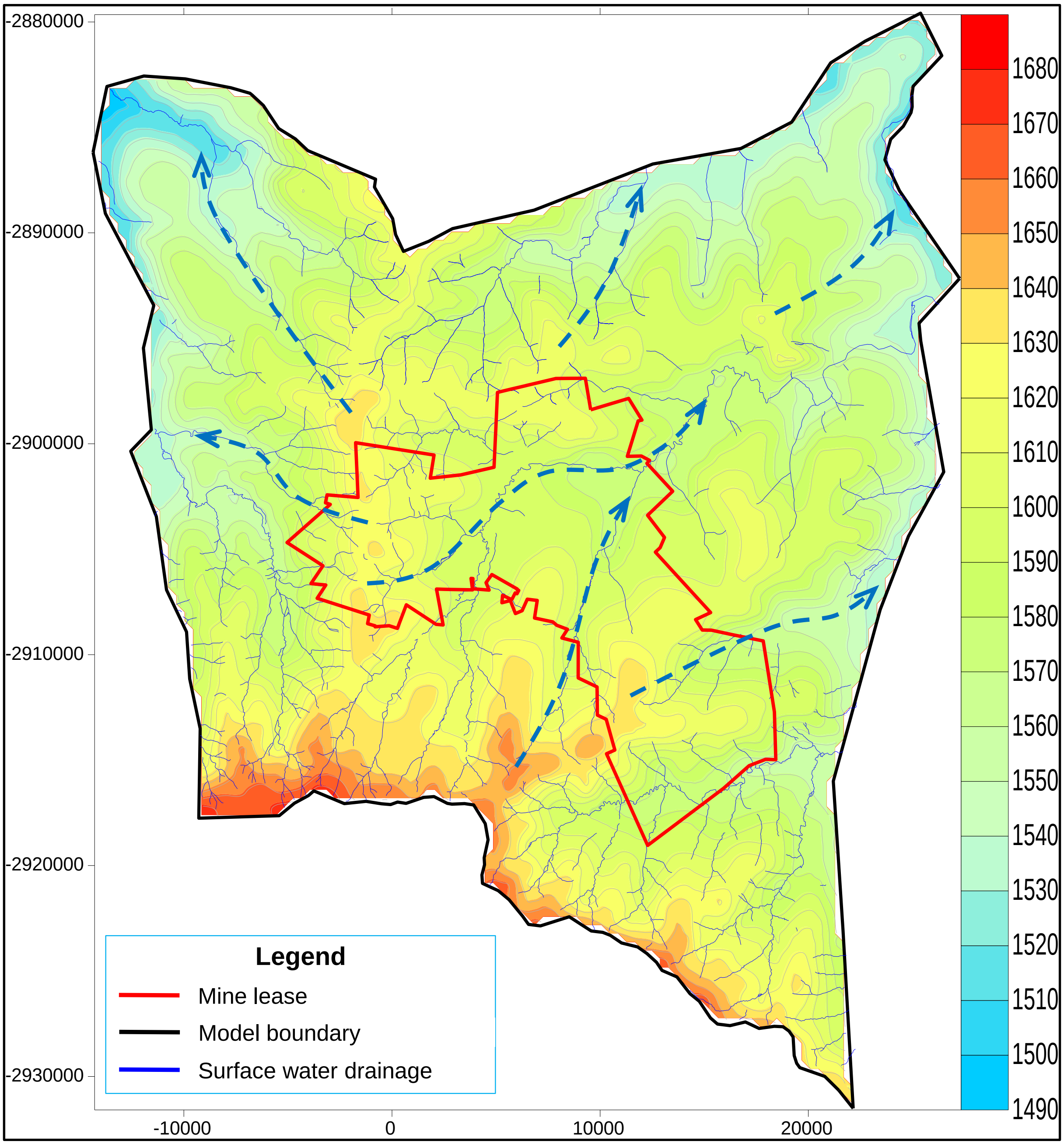

Figure 3.6: Bayesian interpolated groundwater elevation contour map of the modeled area (mamsl)

3.4 Groundwater Flow Evaluation (directions, gradients and velocities)

Contours of the static water levels or piezometric heads in and around the mining area are indicated in Figure 3.6. Path lines or flow lines of groundwater particles are lines perpendicular to the contours, as indicated with arrows. Flow occurs faster where contours are closer together and gradients are thus steeper. Natural groundwater drainage from the Matla mine lease area is towards the west/north-west and north-east.

The groundwater gradient is calculated with the following formula:

$$i = dH / dL$$

Where: *i* = *Hydraulic gradient*

dH = *Head difference*

dL = *Lateral distance over which gradient is measured*

Groundwater gradients were calculated with the above formula from the water level elevation data (Figure 3.6). By substituting the hydraulic head difference over lateral distance an average hydraulic gradient of approximately 0.7% was calculated for the mine lease area (Figure 3.7).

The groundwater flow gradient was in turn used to calculate the rate of groundwater movement (the so-called 'Darcy flux') in the mine lease area, which is also indicated in Figure 3.7. The following equation was used in the calculations *(after Fetter, 1994)*:

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

Where: *v = flow velocity (m/day)*

K = hydraulic conductivity (m/day) = 0.14 (GCS, 1998)

I = average hydraulic gradient (%) = 0.7%

ϕ = probable average porosity = 0.06 (Groundwater Square, 2008)

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

The hydraulic conductivity and the average hydraulic gradient are known parameters. By making use of these values, the average steady state flow velocity *(Darcy flux)* in the mining area was calculated to be in the order of 5.8 m/y (Figure 3.7).

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

Table 3.1: Summary of groundwater flow evaluation

Groundwater flow direction	Groundwater flow gradient	Groundwater flow velocity (m/d)	Groundwater flow velocity (m/y)
West/north-west and north-east	0.7%	0.016	5.8

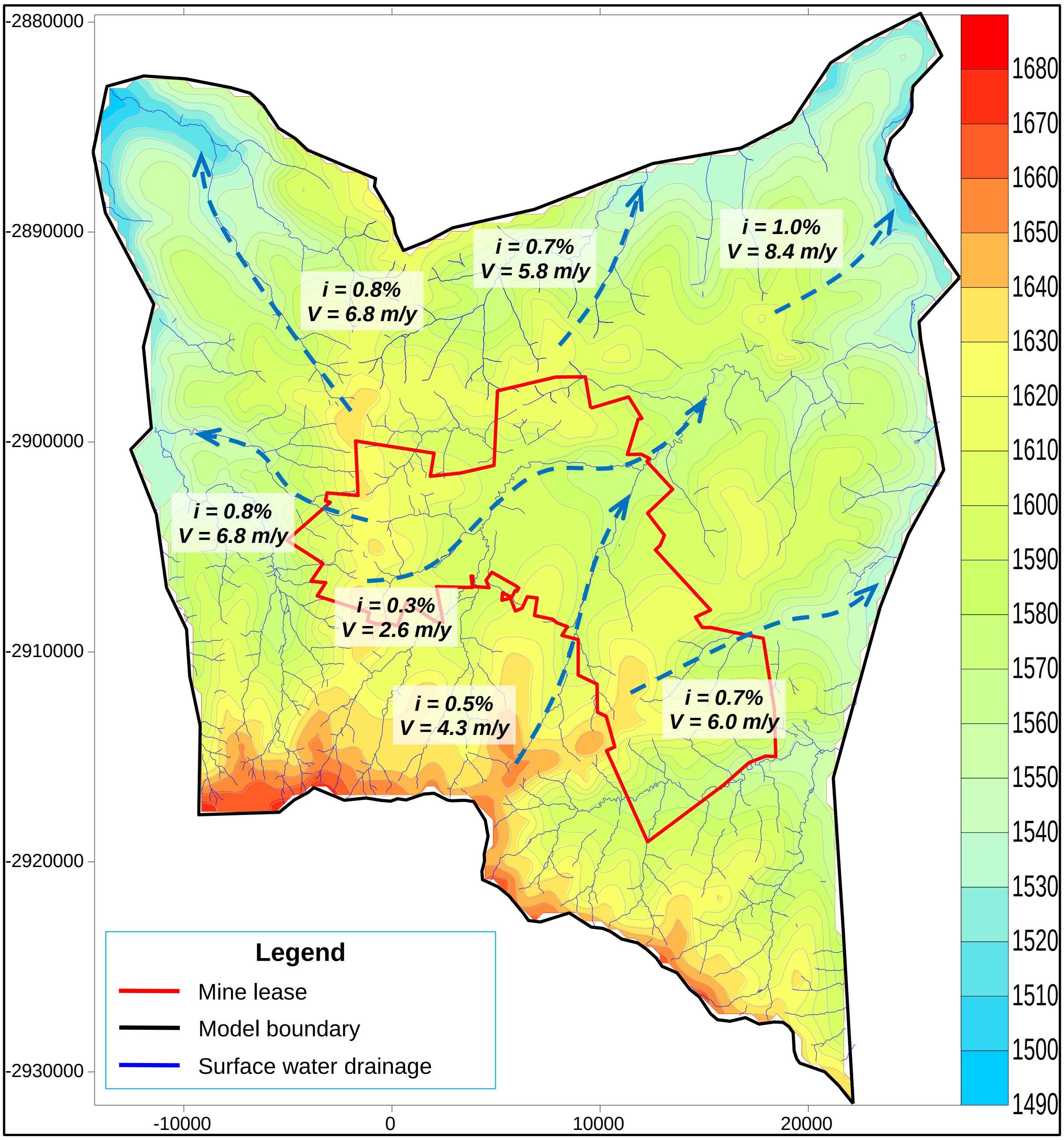

Figure 3.7: Average groundwater gradients and velocities

3.5 Aquifer Types

Two main types of aquifers are believed to be present in the mine lease area. For the purpose of this study an aquifer is defined as a geological formation or group of formations that can yield groundwater in economically useable quantities. Aquifer classification according to the Parsons Classification system is summarised in Table 3.2.

The **first aquifer** is a shallow, **semi-confined or unconfined aquifer** that occurs in the transitional soil and **weathered bedrock zone** or sub-outcrop horizon. Depending on the depth of the groundwater level and extent/depth of weathering, this aquifer may occur at depths of between 0 and 12 meters. Yields in this aquifer are generally low (less than 0.5 l/s) and the aquifer is usually not fit for supplying groundwater on a sustainable basis. Consideration of the shallow aquifer system becomes important during seepage estimations from pollution sources to receiving groundwater and surface water systems. The shallow weathered zone aquifer plays the most important role in mass transport simulations from process and mine induced contamination sources because the lateral seepage component in the shallow weathered aquifer often dominates the flow.

According to the Parsons Classification system, this aquifer is usually regarded as a minor- and in some cases a non-aquifer system.

Due to the mainly lateral flow and sometimes phreatic nature of the weathered zone aquifer, it is usually only affected by opencast mining or by high extraction or shallow underground mining where subsidence occurs and the entire roof strata above the mined area is destroyed. Where mining becomes deeper the weathered zone aquifer is usually affected to a very limited extent. The shallow aquifer system is undeveloped/absent in areas where the groundwater level is deeper than the contact between the weathered zone and fresh bedrock.

The **second aquifer** system is the deeper **secondary fractured rock aquifer** that is hosted within the sedimentary rocks of the Karoo Supergroup and occurs at depths generally exceeding 12 meters below surface. Groundwater yields, although more heterogeneous, can be higher. This aquifer system usually displays semi-confined or confined characteristics with piezometric heads often significantly higher than the water-bearing fracture position. Fractures may occur in any of the co-existing host rocks due to different tectonic, structural and genetic processes. Groundwater flow is fully restricted to open fractures and discontinuities, which become increasingly scarce at depths exceeding 30 meters below surface.

According to the Parsons Classification system, the aquifer could be regarded as a minor aquifer system, but also a sole aquifer system in some cases where groundwater is the only source of domestic water.

Table 3.2: Parsons Aquifer Classification *(Parsons, 1995)*

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

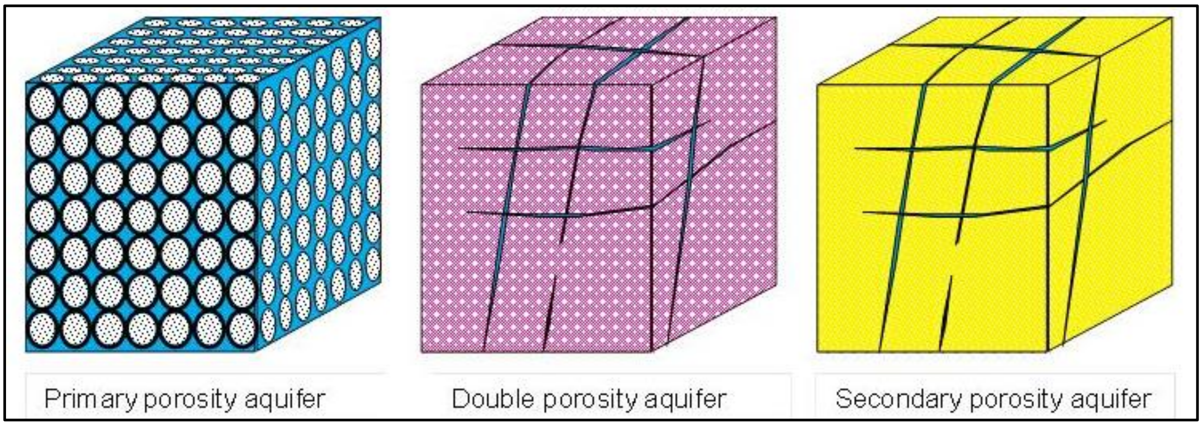

Figure 3.8: Types of aquifers based on porosity

3.6 Aquifer Transmissivity and Storativity

No aquifer testing was performed for the purpose of this investigation. All previously conducted groundwater related studies were consulted in order to obtain a better indication of the average hydraulic properties of the aquifer underlying the mining area.

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

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

The fractured rock aquifer underlying the mining area is known for being highly heterogeneous, which may result in significant variations in aquifer transmissivity/storativity over relatively short distances.

The average hydraulic conductivity (permeability) of the shallow weathered zone aquifer is 0.14 m/d, which based on an average aquifer thickness of approximately 12 meters, translates to a transmissivity of around 1.7 m^2/d *(GCS, 1998)*.

Pumping tests that were performed on the deeper fractured rock aquifer revealed transmissivity values of between 0.1 m^2/d and 7 m^2/d *(GCS, 1998)*, confirming the aquifer to be highly heterogeneous.

3.7 Aquifer Recharge and Discharge Rates

According to Figure 3.9 the mean annual recharge to the aquifer underlying the Matla mine lease area is in the region of 32 mm, which based on an average rainfall of approximately 754 mm/a (Figure 2.3) translates to a recharge percentage of just over 4%. During the model calibration process, changes are made to the aquifer recharge (among other model input parameters) until an acceptable correlation is achieved between the model simulated and measured/actual groundwater elevations. During this calibration process for the Matla Stooping Project, a much lower recharge of between 0.6% and 1.2% was eventually assigned to the aquifer regime underlying the mine lease area **(Section 4)**.

Where outcrop occurs, the effective recharge percentage can be slightly higher while in low-lying topographies where discharge generally occurs and thicker sediment deposits, the effective recharge will be lower or even zero. Based on this estimate, the mean annual recharge to the aquifer regime as defined in Figure 3.2 should be ± 34.6 Mm^3.

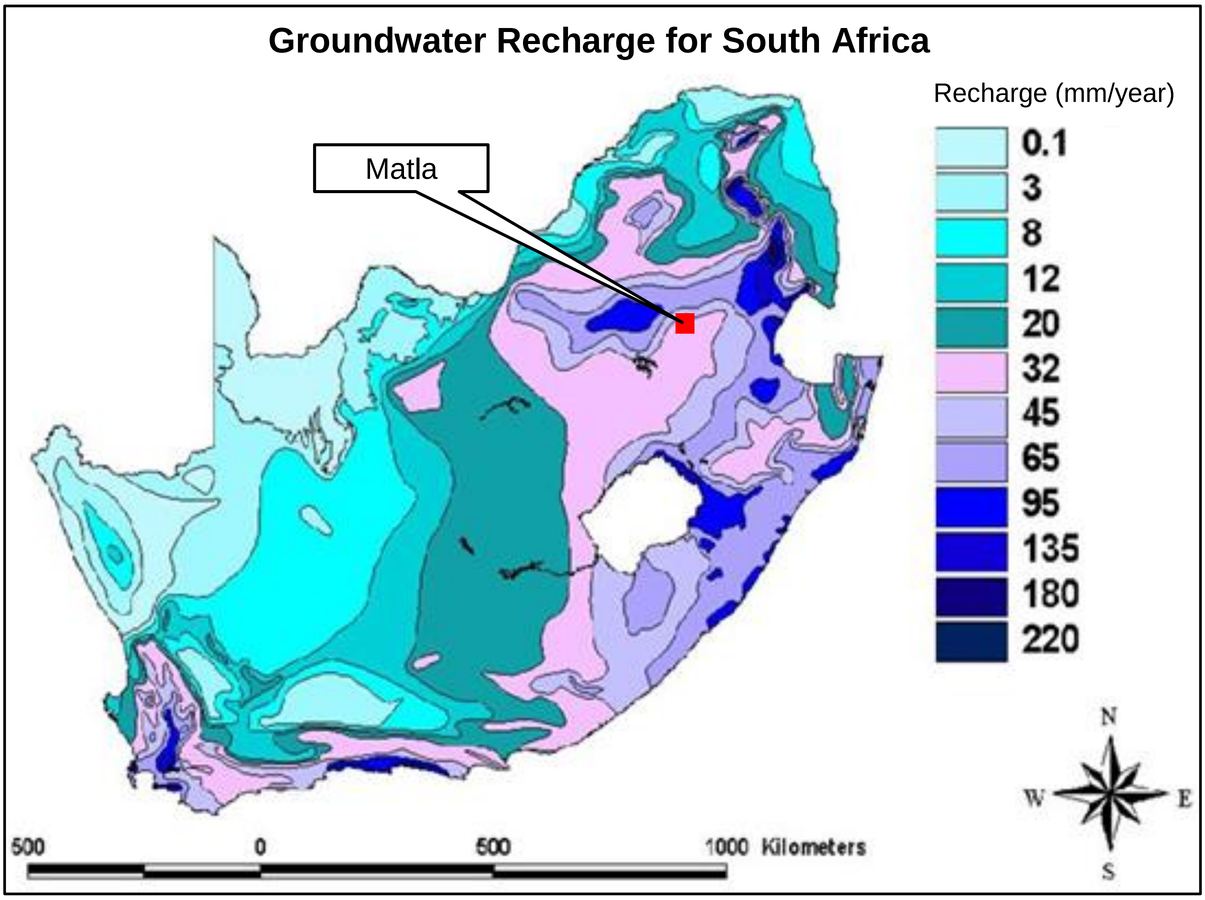

Figure 3.9: Mean annual aquifer recharge for South Africa *(Vegter, 1995)*

3.8 Groundwater Quality Characteristics

Please note that data collected during the GCS hydrocensus/user survey of 2014 (Appendix A) were used to characterise the groundwater quality conditions.

Aquatico Laboratory (a South African National Accreditation System (SANAS) accredited laboratory according to ISO/IEC 17025:2005 standards No: T0374) in Pretoria, South Africa, was commissioned to undertake the analytical testing for the collected groundwater samples. Samples were collected from six boreholes located during the GCS hydrocensus/user survey of 2014 and their positions are indicated in Figure 3.11. The results of the groundwater analyses are provided Table 3.3 together with the guidelines used in the assessment.

Groundwater quality data was evaluated with the aid of diagnostic chemical diagrams and by comparing the inorganic concentrations to the:

- Department of Water Affairs'(DWA) South African Water Quality Guidelines (SAWQG) target range, Volume 1, Domestic Use (1996), and
- SABS South African National Standards for Drinking Water (SANS 241:2011).

The four main factors usually influencing groundwater quality are:

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

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

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

Although never clear-cut, the general characteristics of the different fields of the diagram could be summarized as follows:

<u>Field 1:</u>

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

<u>Field 2:</u>

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

<u>Field 3:</u>

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

<u>Field 4:</u>

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

Field 5:

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

Field 6:

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

Field 7:

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

Field 8:

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

Field 9:

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

The layout of the fields of the Expanded Durov diagram (EDD) is shown in Figure 3.10.

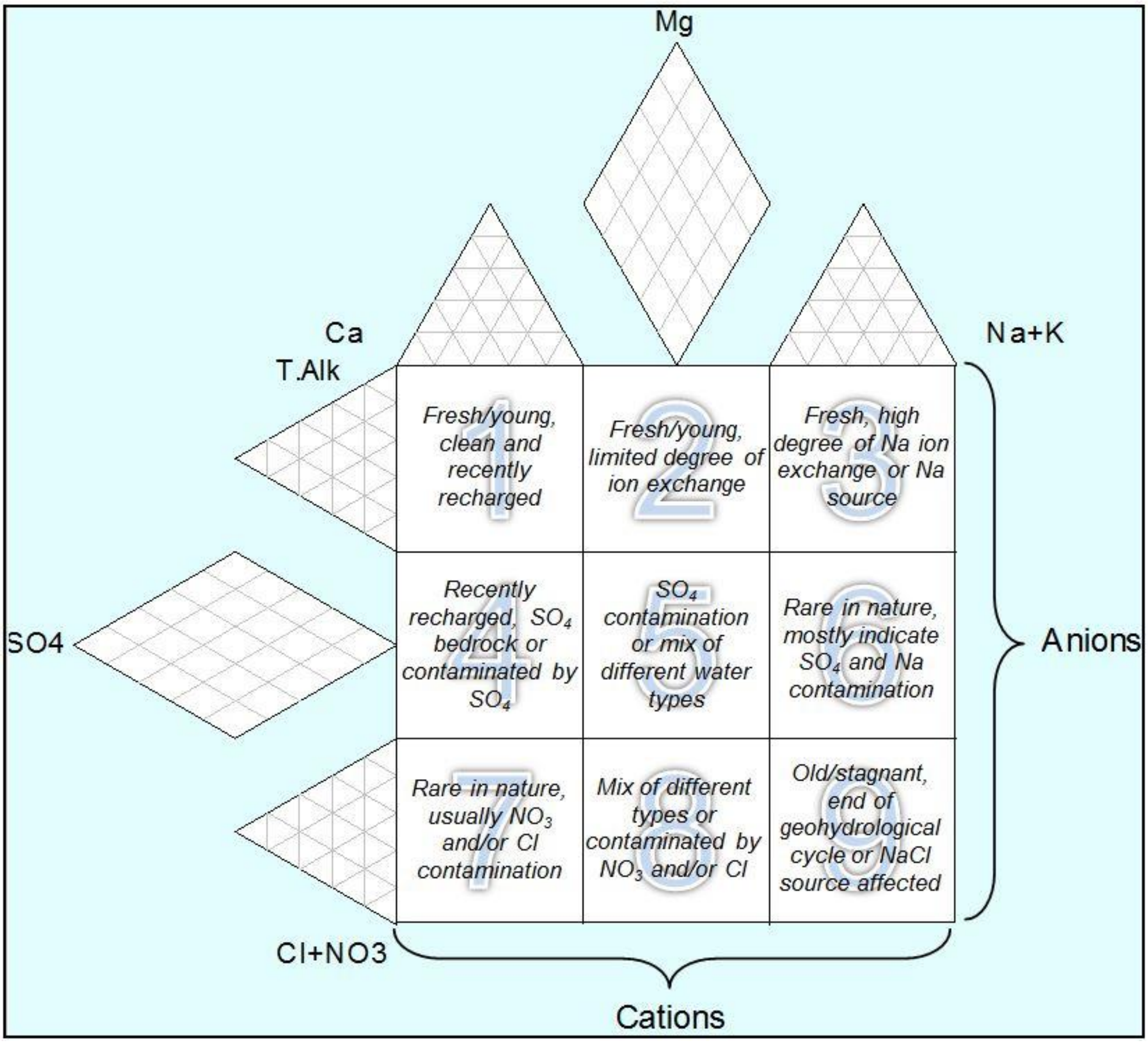

Figure 3.10: Layout of fields of the Expanded Durov diagram

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

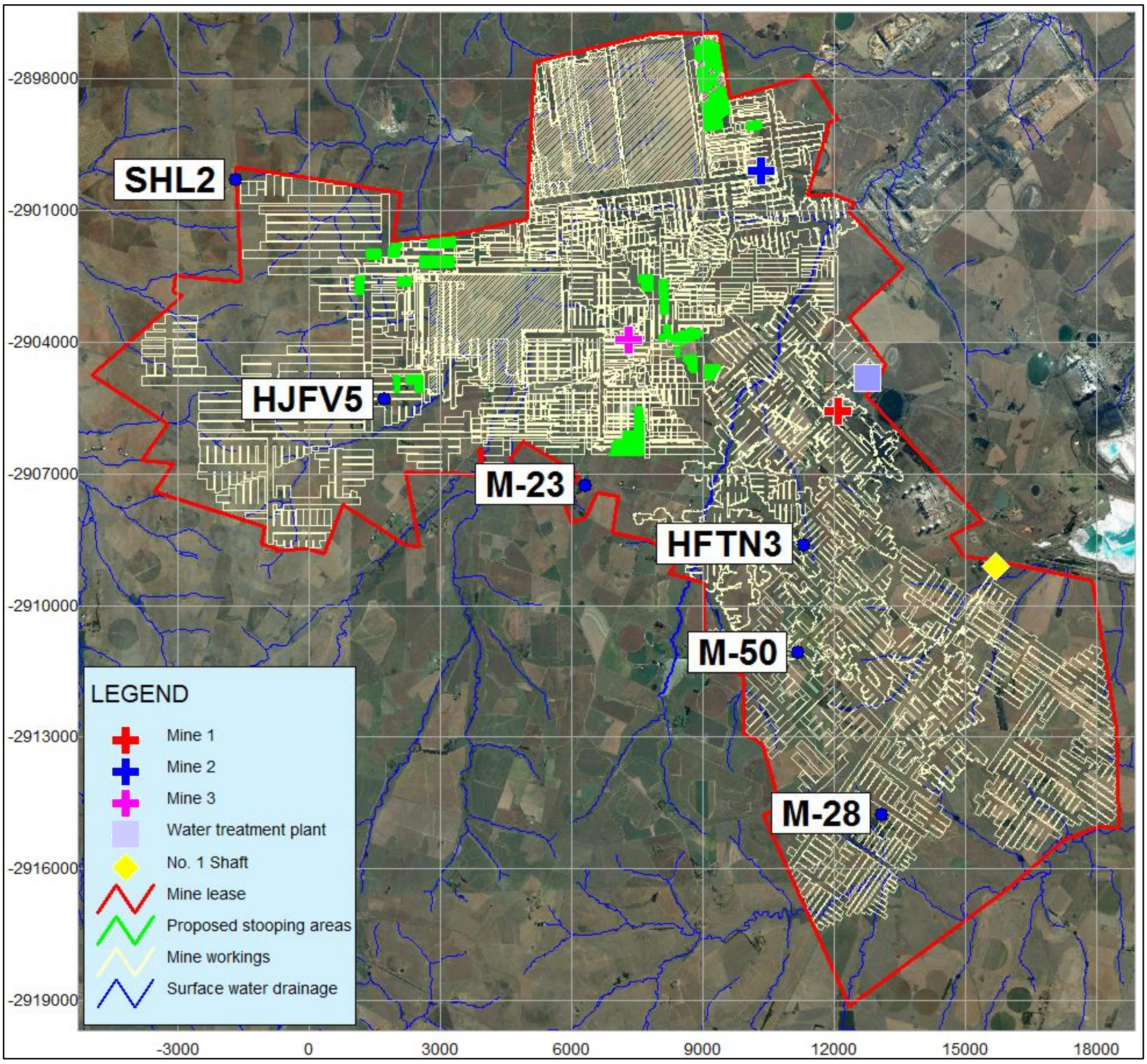

Figure 3.11: Positions of boreholes sampled

The electrical conductivity (EC) of the groundwater varies between 24 mS/m and 66 mS/m. Groundwater pH varies between 7.4 and 8.1 (pH unit), indicating neutral to slightly alkaline conditions. The elevated electrical conductivity and subsequent total dissolved solids (TDS) readings observed in borehole SHL2 can be attributed to the elevated calcium concentrations.

An analysis of the major ionic constituents was undertaken using Expanded Durov (Figure 3.12) and Stiff (Figure 3.13) diagrams to assess the proportions of these constituents and broadly characterise the aquifer water type/s. Groundwater is mainly dominated by calcium and magnesium cations, while bicarbonate alkalinity dominates the anion content. The dominant plot positions of groundwater in fields one and two of the EDD are indications of fresh, clean, relatively young groundwater that has undergone natural magnesium and sodium ion exchange.

In general, the water from the sampled boreholes is considered to be of good quality. Comparison with relevant guidelines/standards is summarized in the following bullet points:

Major Ionic Constituents Parameters:

- The concentrations of cations and anions reported from the various sample locations are below the relevant DWA SAWQG and SANS 241-1 water quality criteria for domestic/drinking water use, except for calcium.
- Calcium exceeded the DWA SAWQG quality tolerance level of 32 mg/L at M50, SHL2, HJFV5, M28 and HFTN3. Although, no health effect is associated with the elevated calcium concentrations, potential scaling and lathering of soap impairments are expected.

Metals/Metalloids Constituents:

- All metals/metalloids reported from the various sample locations are below the relevant DWA SAWQG and SANS 241-1 water quality criteria for domestic/drinking water use.

Nitrogen-species parameters:

- Nitrate (NO_3 as N) concentrations at M28 and M23 exceed the DWA SAWQG quality tolerance level of 6 mg/L, while concentrations at SHL2 also exceed the SANS 241-1 quality tolerance level of 11 mg/L.
- Accordingly to the relevant guidelines, the potential health effects associated with the elevated nitrate concentrations include methaemoglobinaemia in infants and/or mucous membrane irritation in adults.

Key Issues:

- *Groundwater is considered to be of good quality according to the two sets of guidelines used in the assessment.*
- *Boreholes are situated in the open field and far away from potential surface sources of groundwater contamination.*
- *Typical impacts associated with coal mining related activities include elevated groundwater salinity (TDS/EC), elevated concentrations of sulphate and iron and a decrease in groundwater pH conditions. Groundwater from all six boreholes displays no such signs of coal mining related impacts.*
- *Please note that the underground workings will continue to act as a sink for both groundwater and any potential contamination that may originate from the Matla mining activities for as long as it takes groundwater levels to recover from the impacts of mine dewatering.*
- *Groundwater from the sampled boreholes is considered to be representative of the ambient/unaffected groundwater quality conditions. This information can therefore be used quite effectively to assess groundwater quality impacts that may potentially originate from the coal mining and/or related activities at Matla.*

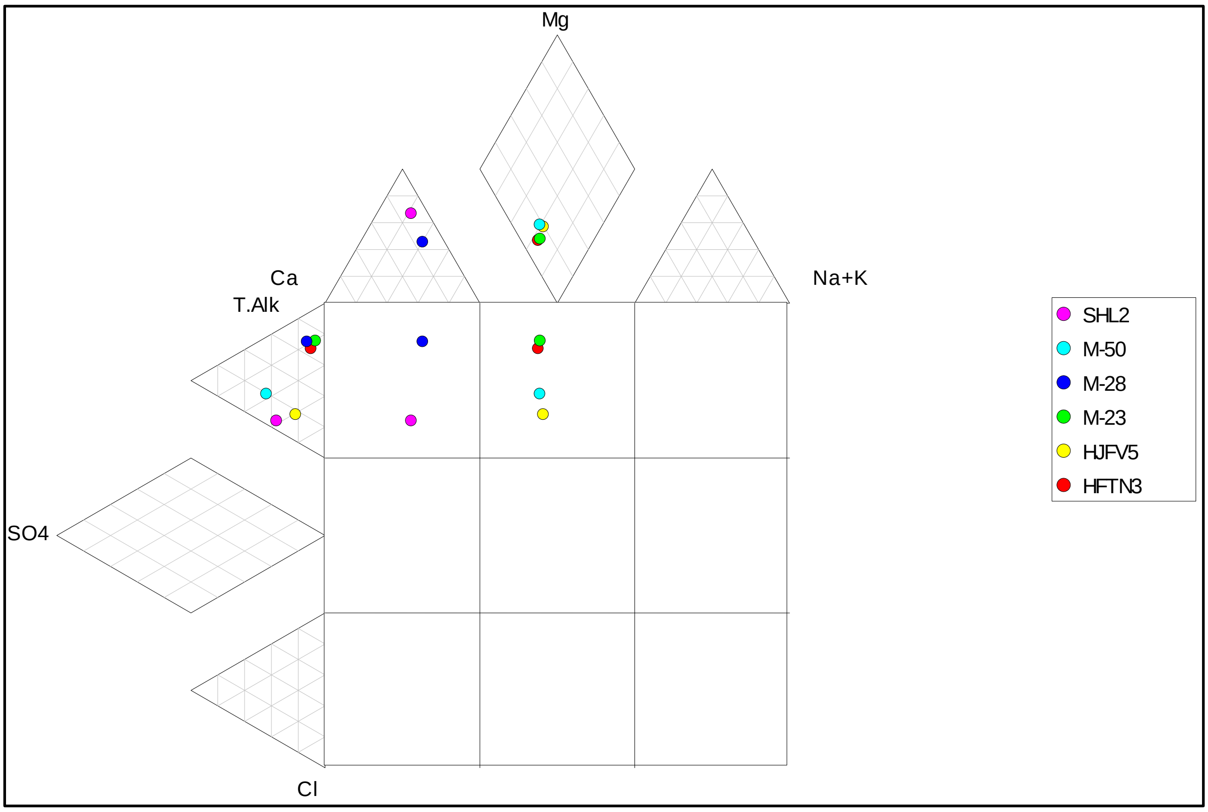

Figure 3.12: Expanded Durov diagram of groundwater chemistries

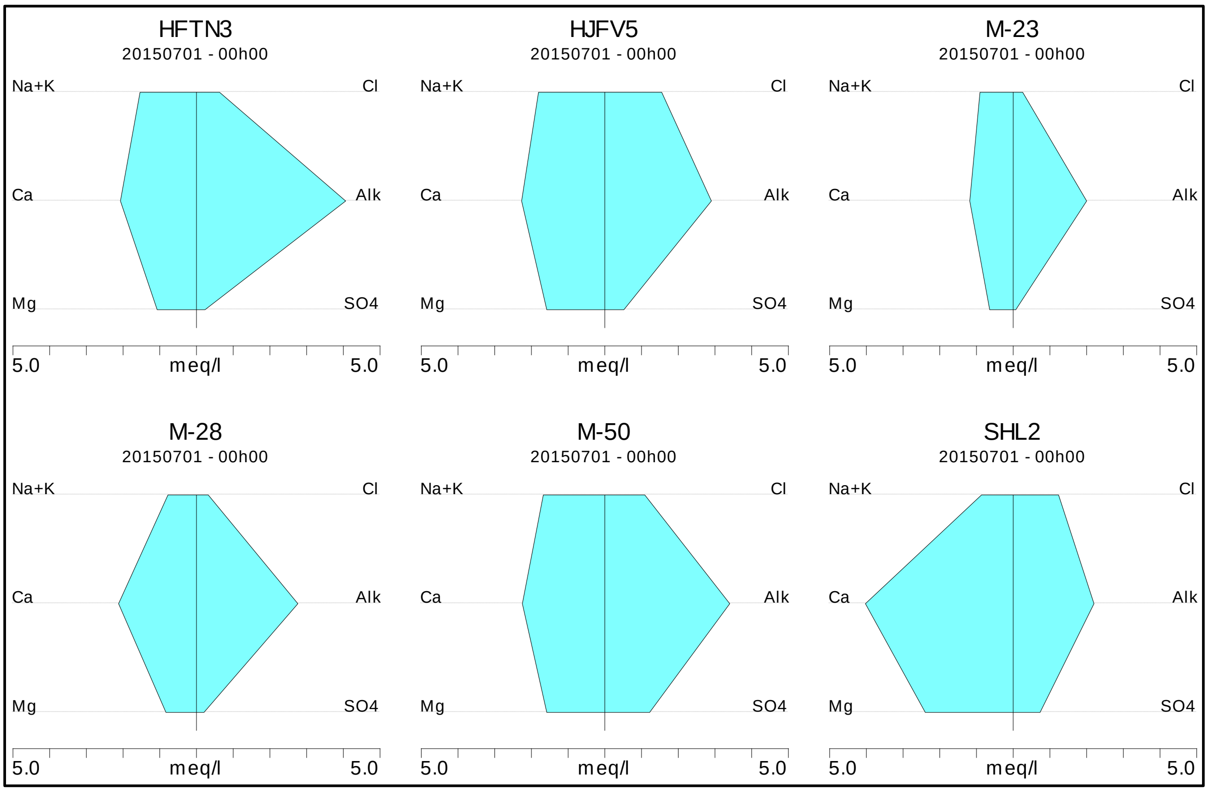

Figure 3.13: Stiff diagrams of groundwater chemistries

Table 3.3: Results of physical and chemical analyses of groundwater samples

Analyses	Unit	Detection Limit	DWA SAWQTV	SANS 241-1	M50	SHL2	HJFV5	M28	HFTN3	M23	*Minimum*	*Maximum*	*Mean*	*Geomean*
Physio-Chemical Parameters														
pH	pH unit	n/a	6 - 9	5 - 9.7	7.99	7.7	7.35	7.68	8.13	7.43	*7.35*	*8.13*	*7.71*	*7.71*
Electrical Conductivity	mS/m	0.1	<70	<170	48.3	66.1	49.6	33.3	41.6	24	*24*	*66.1*	*43.8*	*41.7*
Total Dissolved Solids	mg/L	10	<450	<1200	310	452	299	222	253	160	*160*	*452*	*283*	*269*
Total Alkalinity	mg $CaCO_3$/L	2.477	NS	NS	170	110	145	138	203	100	*100*	*203*	*144*	*140*
Total Hardness	mg $CaCO_3$/L	n/a	NS	NS	191	321	192	148	157	91	*91*	*321*	*183*	*171*
Inorganic and Metal Parameters														
Major Ionic Constituents														
Calcium	mg/L	0.0259	<32	NS	45	80.6	45.4	42.5	41.5	23.7	*23.7*	*80.6*	*46.5*	*43.6*
Magnesium	mg/L	0.009	<30	NS	19.2	29.1	19.2	10.1	13	7.77	*7.77*	*29.1*	*16.4*	*14.9*
Potassium	mg/L	0.018	<50	NS	5.98	4.46	8.69	4.01	9.06	8	*4.01*	*9.06*	*6.7*	*6.38*
Sodium	mg/L	0.013	<100	<200	35	17.2	36.4	15.5	30	16.1	*15.5*	*36.4*	*25.03*	*23.4*
Sulphate	mg/L	0.04	<200	<500	58.6	35.2	24.9	9.83	11.2	3.42	*3.42*	*58.6*	*23.86*	*16.38*
Chloride	mg/L	0.423	<100	<300	38.6	43.8	54.9	11.4	22.3	9.17	*9.17*	*54.9*	*30.03*	*24.5*
Fluoride and Phosphorus Constituents														
Fluoride	mg/L	0.055	<1	<1.5	0.132	0.128	0.172	0.132	0.218	0.17	*0.128*	*0.218*	*0.159*	*0.156*
Orthophosphate	mg/L	0.008	NS	NS	0.009	0.013	0.014	0.027	0.012	0.02	*0.009*	*0.027*	*0.016*	*0.015*
Metals/Metalloids Constituents														
Aluminium	mg/L	0.003	<0.15	NS	BDL	BDL	BDL	BDL	BDL	BDL	*na*	*na*	*na*	*na*
Cadmium	mg/L	0.001	<0.005	<0.003	BDL	BDL	BDL	BDL	BDL	BDL	*na*	*na*	*na*	*na*
Cobalt	mg/L	0.001	NS	<0.5	BDL	BDL	BDL	BDL	BDL	BDL	*na*	*na*	*na*	*na*
Copper	mg/L	0.001	<1	2	BDL	BDL	BDL	BDL	BDL	BDL	*na*	*na*	*na*	*na*

Analyses	Unit	Detection Limit	DWA SAWQTV	SANS 241-1	M50	SHL2	HJFV5	M28	HFTN3	M23	*Minimum*	*Maximum*	*Mean*	*Geomean*
Chromium (total)	mg/L	0.001	NS	0.05	BDL	BDL	BDL	BDL	BDL	BDL	*na*	*na*	*na*	*na*
Iron	mg/L	0.003	<0.1	2	BDL	BDL	BDL	BDL	BDL	BDL	*na*	*na*	*na*	*na*
Manganese	mg/L	0.001	<0.05	0.5	BDL	BDL	BDL	BDL	BDL	BDL	*na*	*na*	*na*	*na*
Nickel	mg/L	0.001	NS	<0.15	BDL	BDL	BDL	BDL	BDL	BDL	*na*	*na*	*na*	*na*
Lead	mg/L	0.004	<0.01	0.01	BDL	BDL	BDL	BDL	BDL	BDL	*na*	*na*	*na*	*na*
Zinc	mg/L	0.002	<3	5	BDL	0.035	0.063	0.05	BDL	0.021	*0.021*	*0.063*	*0.042*	*0.039*
Nitrogen-Species Parameters														
Ammonia	mg/L	0.005	<1	<1.5	0.083	0.089	0.091	0.098	0.092	0.224	*0.083*	*0.224*	*0.113*	*0.105*
Nitrate	mg/L	0.017	<6	<11	0.935	39.3	4.71	9.87	0.293	6.77	*0.29*	*39.3*	*10.31*	*3.88*

Note/s:
- mS/m - milli Siemens per metre,
- mg/L - milli grams per Litre,
- mg $CaCO_3$/L - milli grams calcium carbonate per Litre,
- NS - no standards/guideline trigger values,
- BDL - below detection limit,
- na - not applicable.

3.9 Potential for Acid Mine Drainage

Metal sulphides, of which pyrite is the most common, are very prone to oxidation when brought into contact with water and oxygen. The chemical reactions are collectively referred to as acid mine drainage (AMD). The root of the problem lies in the chemical and bacteriological oxidation of the metal sulphides, which is explained/illustrated with the following reaction train:

$2FeS_2 + 7O_2 + 2H_2 – 2FeSO_4 + H_2SO_4$ .... (1)

$4FeSO_4 + 2H_2SO_4 + O2 – 2Fe_2 (SO_4)_3 + 2H_2O$ .... (2)

$3Fe_2 (SO_4)_3 + 12H2O – 2HFe_3(SO_4)_2 (OH)_6 + 5H_2SO_4$ .... (3)

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

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

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

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

No acid base accounting was performed for the purpose of this investigation, however the surrounding mines are known to generate acid *(GCS, 1998)*. The weathered sandstone, shale, and the 5 seam roof and floor all have the potential for acidification. Groundwater flowing through these areas is likely to generate acid when exposed to oxygen and water. The coarse sandstone, on the other hand, has a very large neutralising potential and will give groundwater flowing through it an alkaline character *(GCS, 2006)*.

3.10 Potential Sources of Contamination

A source area is defined as an area in which groundwater contamination is generated or released from as seepage or leachate. Source areas are subdivided into two main groups:

Point sources:

The contamination can easily be traced back to the source and typically includes mine infrastructure such as a processing plant, overburden/waste rock dump, pollution control dam, underground workings, ROM stockpile, etc.

Diffuse sources:

Diffuse sources of groundwater contamination are typically associated with poor quality leachate formation through numerous surface sources.

An evaluation of the mining area and related activities revealed numerous potential source areas, which are listed and briefly discussed below in Table 3.4.

Table 3.4: Potential sources of groundwater contamination

Source	Contamination risk	Comments
1) Plant area	High	- Impact on the groundwater only occurs through leachate formation from surface. Impacts thus only occur as a result of rainfall recharge or when water is introduced in some form where leachate can form that seeps to the groundwater.
2) Waste rock dumps and stockpiles	High	- Effective recharge through waste rock dumps and stockpiles is much higher than the natural recharge of the area due to lower evaporation rates. - Surface water run-off originating from these source areas, toe-seeps and seepage through the base may potentially be of poor quality and could cause adverse groundwater quality impacts should it enter the aquifer. - Seepage from waste rock dumps and stockpiles is likely to be affected by acid mine/rock drainage and therefore high in iron and sulphate content.
3) Underground mining areas	High	- Contamination will only leave these areas after groundwater levels have recovered from the impacts of mine dewatering. - Water collecting in these areas is usually characterised by high concentrations of iron and sulphate and low pH due to acid mine drainage.
4) Dirty water retaining facilities (water treatment plant, pollution control dam, sewage, etc.)	Low/Medium	- These facilities are developed and constructed for the sole purpose of containing dirty/affected water and therefore minimising the risk of it contaminating the groundwater. Mismanagement of these facilities may

Source	Contamination risk	Comments
		however lead to spills and/or leakages that have the potential to contaminate the underlying groundwater.
5) Workshops and washing/cleaning bays	Low/Medium	- Impact on the groundwater only occurs through leachate formation from surface. Impacts thus only occur as a result of rainfall recharge or when water is introduced in some form where leachate can form that seeps to the groundwater. - Organic contaminants are usually the main pollutants of concern (e.g. oil, grease, diesel, petrol, hydraulic fluid, solvents, etc.).

Key Issues:

- *The coal and overburden material have the potential to generate an acidic leachate high in sulphate and iron content due to acid mine/rock drainage. This characteristic behaviour of material containing metal sulphide minerals (usually pyrite), significantly increases a source's potential to adversely affect the quality of groundwater.*
- *Water collecting in the mine workings will stratify with time, i.e. the "heavier" polluted water will sink to the bottom or floor of the mine leaving the "lighter" water of better quality to occupy the upper parts of the water column. The water that will eventually decant should therefore be of a better quality than that in the reactive coal horizon.*
- *This stratified system may however be disturbed in areas experiencing high water ingress and consequent mixing of the water columns, thus adversely affecting the quality of the decanting water.*
- *High extraction mining has led to surface subsidence (especially above shortwall panels) in the Matla mine lease area. Wherever subsidence has occurred, recharge to the underground workings is expected to have increased significantly. If the Matla underground workings are to decant, the water is expected to be of poor quality.*

3.11 Potential Pathways for Contamination

In order for contamination to reach and eventually affect a receptor/s, it needs to travel along a preferred pathway. The effectiveness of a pathway to conduit contamination is determined by three main factors, namely:

- Hydraulic conductivity of pathway,
- Groundwater hydraulic gradient, and
- Area through which flow occurs.

All three abovementioned factors have a linear relationship with the flow of contamination through a preferred pathway, meaning an increase in any one of the three will lead to an increase in flow.

The following potential pathways were identified in the mine lease area:

3.11.1 Saturated weathered zone (weathered zone aquifer)

As discussed in **Section 3.5** of the report, the weathered zone aquifer is composed of soil and weathered bedrock, which depending on the weathering depth and depth to groundwater level may be between 0 and 12 meters thick.

The rate of flow depends on the hydraulic conductivity of the aquifer and groundwater hydraulic gradient that were already discussed in **Section 3.4**. Groundwater/contaminant flux in this aquifer is expected to be in the order of 6 m/y, which is considered to be relatively slow. Please note that the weathered zone aquifer system is undeveloped in areas where the groundwater level is deeper than the contact between the weathered zone and fresh bedrock.

3.11.2 Geological structures

Dykes and faults are known to occur throughout the mine lease area, which may act as sufficient pathways for contamination. The crystalline nature of an igneous dyke is characteristic of an aquiclude, however rapid cooling during intrusion caused highly transmissive fracture zones to form along the contact between the intrusive and surrounding rock.

The flow rates provided in **Section 3.4** may increase by several orders of magnitude should a transmissive geological structure be located in the down gradient groundwater flow direction and if it is also orientated parallel to the local flow direction.

3.12 Potential Receptors of Contamination

A receptor of groundwater contamination usually occurs in the form of a groundwater user that relies on groundwater for domestic, irrigation or livestock watering purposes. Surface water features (stream, river, dam, etc.) that rely on groundwater base flow for the sustainment of the aquatic environment are also considered to be important receptors.

Numerous groundwater users were located during the user surveys and their positions are indicated in Figure 3.1. Numerous perennial surface water streams cut through the mine lease area, which are also considered to be potential receptors (Figure 2.1).

Key Issues:

For a negative groundwater quality impact to be registered the following three components should be present:

- *A source to generate and release the contamination,*
- *A pathway along which the contamination may migrate, and*
- *A receptor to receive the contamination.*

All three these components are present within the Matla mine lease area, which stresses the importance of a comprehensive early detection groundwater monitoring program (source monitoring) and ongoing water management and containment of source effects.

3.13 Mine Water Balance and Post Closure Decant

Numerous water balance models have been done for Matla throughout the years, of which the most recent one was completed in June 2015 by Mine Water Consultants.

3.13.1 Water currently residing in the workings

The proposed stooping areas are located within existing underground mining areas:

- 1 Mine – 4 seam mining (bord- and pillar only),
- 2 Mine – 2 seam mining (bord- and pillar and longwall),
- 2 Mine – 5 seam mining (bord- and pillar and longwall),
- 3 Mine – 2 seam mining (bord- and pillar only), and
- 3 Mine – 4 seam mining (bord- and pillar and longwall).

These areas are either partially or completely flooded and would require dewatering before Matla can safely commence with their planned stooping activities. For this reason it is important to have a good understanding of the dewatering requirements. The bulk water volumes that are currently (June 2015) present in the underground workings was calculated by Mine Water Consultants and are indicated in Figure 3.14 and Figure 3.15.

The labels shown in the two abovementioned figures indicate the water level elevation and the volume of water in the compartments. Only the major compartments are labelled. The indicated volumes represent the maximum amount of water currently residing in the underground workings. The current presence of water in the underground workings may (and should) differ from the calculated results as the latter indicates maximum rather than measured values.

Most of the areas outside the service lines (main development) are closed off with walls to improve ventilation of the workings. Although these ventilation walls are not designed to be watertight they will have a restraining effect on the water bodies. This may result into sections with more water or sections with less water than calculated. Confirmation of water levels inside these sections is needed to accurately calculate the volumes of water inside the various compartments of the workings.

Old Anglo opencast workings are located directly adjacent and north of Matla's Mine 3, which depending on the structural integrity of the barrier or boundary pillars, could affect water balance calculations due to intermine flow. Future water balance calculations should therefore take into consideration this possible scenario, which could either cause an increase or decrease in the total volume of water residing in Matla's underground workings depending on flow directions.

3.13.2 Recharge calculations – Lateral recharge component (groundwater)

When a mine cavity is abandoned water will enter the void. The time it takes to fill the void is dependent on numerous factors like type of mining, depth of mining, type of overlaying strata, water level in the direct surroundings and the amount of annual rainfall. The mining void will slowly be filled by water from a lateral source (groundwater) and by recharge water from above. Unless mining goes through major faults and/or sheer zones the recharge from groundwater will be very small in comparison with recharge from rainfall.

Darcy's Law is used to calculate the recharge from groundwater flow (lateral recharge). The average lateral recharge value for all the workings combined is 12.9 m^3/d. The recharge per working is expected to be below 3 m^3/d *(Mine Water Consultants, 2015)*.

3.13.3 Recharge calculations – Vertical recharge component (rainfall)

The projections are made under average annual rainfall conditions of 678 mm/a as measured at Kriel weather station. As long as there is enough space in the mine to accommodate excess recharge during excessively wet years, this prediction is valid. Over a period of 10 years or more, predictions average out and average rainfall may be used in the model. The combined daily recharge for all five underground workings (lateral and recharge from rainfall which take place from the top) varies from a low recharge range value of 8 800 m^3/d to a high range of 17 000 m^3/d, with an average of approximately 12 900 m^3/d *(Mine Water Consultants, 2015)*.

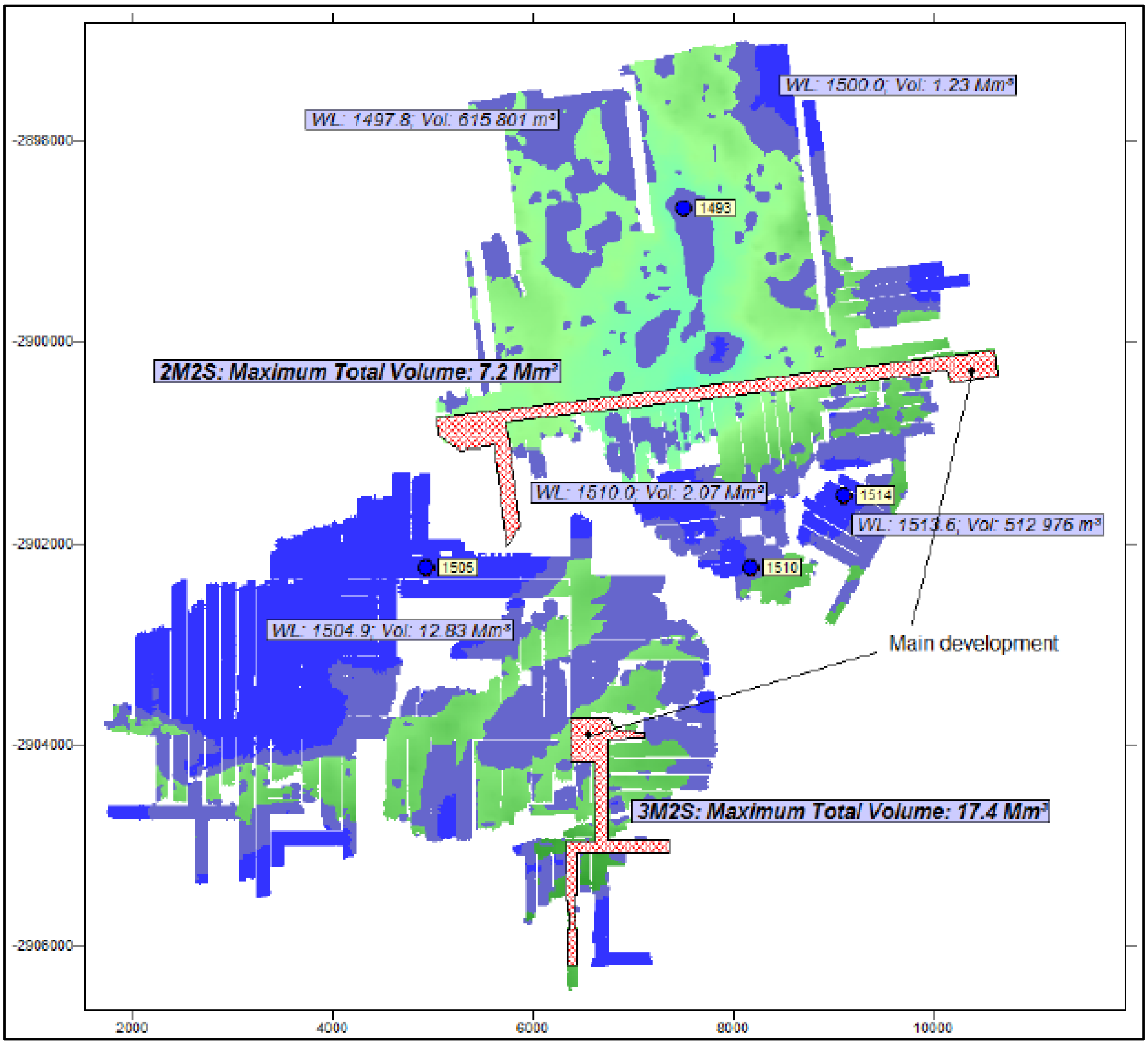

Figure 3.14: Potential water in the 2 seam mines *(Mine Water Consultants, 2015)*

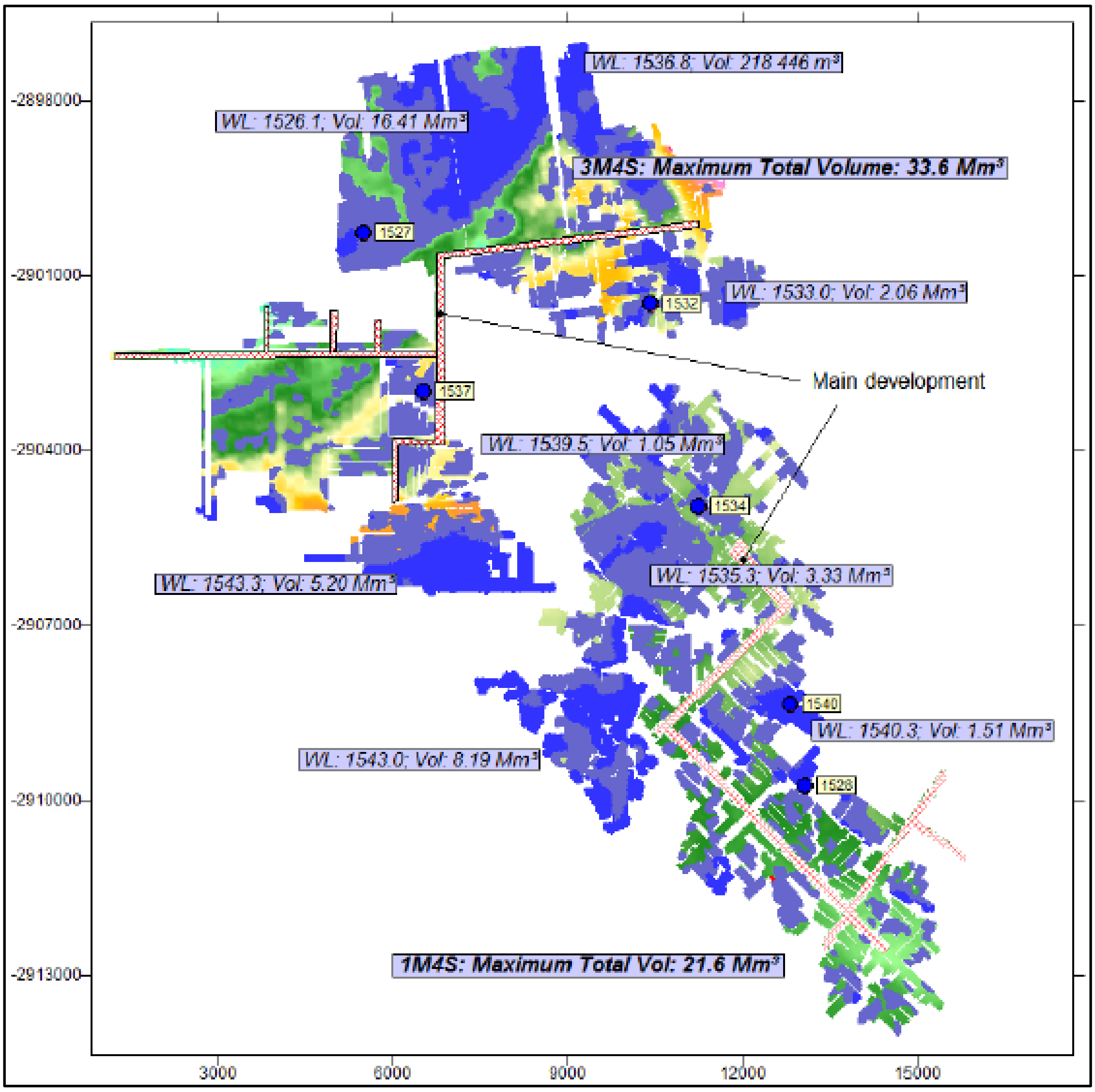

Figure 3.15: Potential water in the 4 seam mines *(Mine Water Consultants, 2015)*

3.13.4 Post closure decant

Decanting of a mine void generally occurs as a result of an excess volume of water that cannot be "absorbed" by the aquifer system. This excess water is generated by the increased recharge from surface (vertical recharge component) due to roof collapse and ensuing surface subsidence. Decanting is expected to occur at the lowest undermined surface elevation/s, provided that it is hydraulically connected to the underground void by means of a transmissive geological structure (fracture/fault), exploration borehole, shaft, etc.

The average vertical recharge to the underground workings was estimated by Mine Water Consultants (2014) to be in the order of 12 900 m^3/d. Once the entire underground void has been flooded, this is the same volume of water expected to decant. Potential decant positions/areas are indicated in Figure 3.16

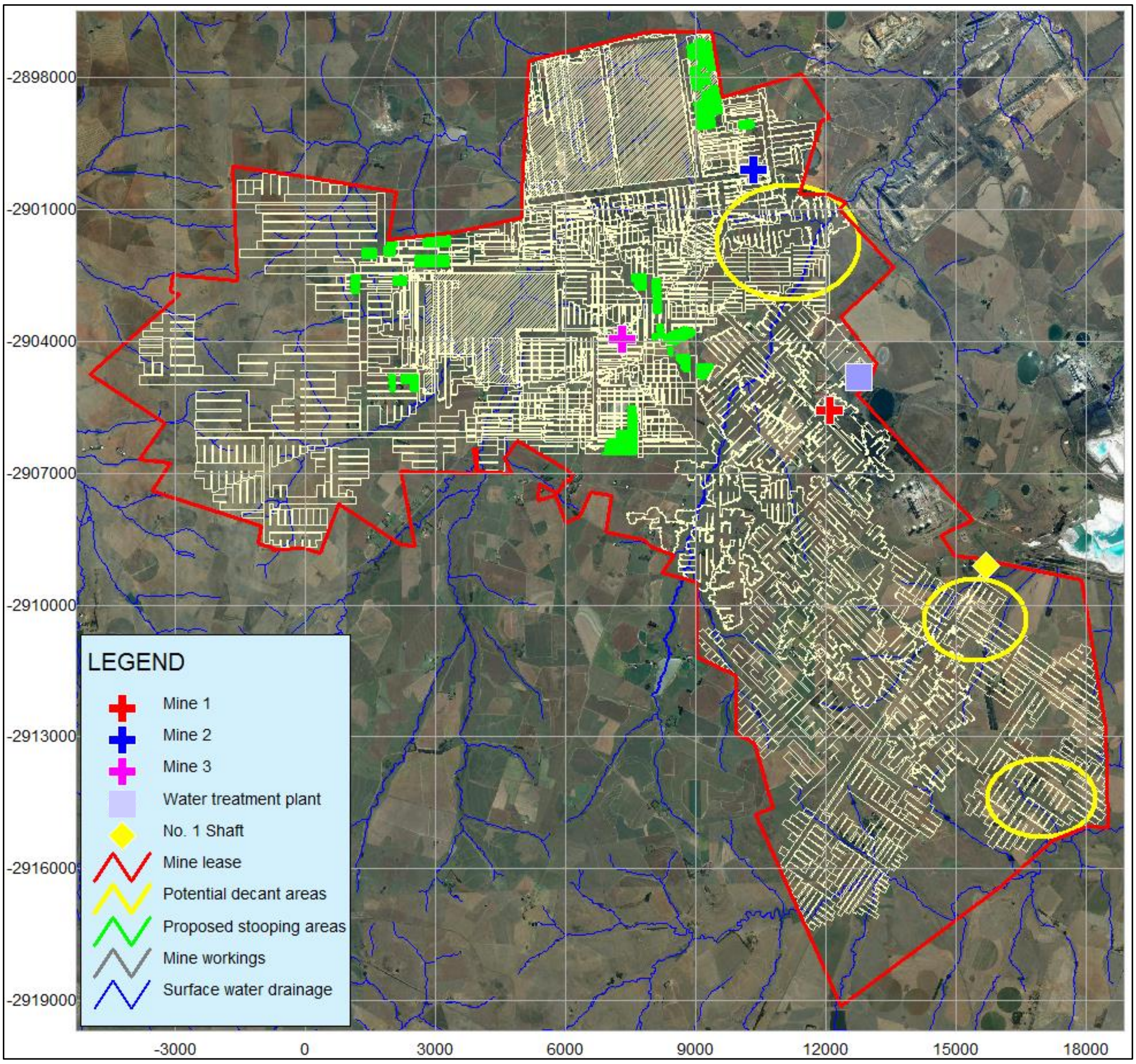

Figure 3.16: Potential decant areas

Key Issues:

- *The planned stooping areas are either partially or completely flooded and would require dewatering before Matla can safely commence with mining.*
- *The planned stooping activities are expected to cause an increase in the vertical recharge component. The areas earmarked for stooping are however small in comparison with the larger mining area and their effect/impact on the water balance is therefore expected to be small.*
- *The average vertical recharge to the underground workings of approximately 12 900 m3/d is also the average expected decant volume once the entire underground void has been flooded.*

3.14 Summary of Conceptual Model

A vertical cross section of the mine lease area is provided in Figure 3.17. Based on our assessment of all groundwater related aspects and previous groundwater studies, we conceptualize the hydrogeological system underlying the Matla mine lease area as follows:

- The mine lease area is underlain by sedimentary rocks (mainly sandstone, siltstone, shale and coal) of the Ecca Group, Karoo Supergroup.
- Two aquifer systems are present, namely a shallow aquifer composed of soil and weathered bedrock and a deeper fractured rock aquifer hosted within the solid/unweathered bedrock.
- The average transmissivity of the weathered zone aquifer is approximately 1.7 m^2/d, while the transmissivity of the more heterogeneous fractured rock aquifer generally varies between 0.1 m^2/d and 7 m^2/d.
- Approximately 4% of the mean annual rainfall reaches the groundwater table to recharge the aquifer.
- Natural groundwater drainage from the Matla mine lease area is towards the west/north-west and north-east.
- The average hydraulic gradient was calculated to be in the order of 0.7%, resulting in a groundwater seepage velocity/flux of approximately 5.8 m/y.
- Groundwater levels around the mining area generally vary between ± 2 and 22 meters below surface (mbs).
- Groundwater levels in excess of ten meters deep are considered to be affected (be it from groundwater abstraction for domestic/other purposes or mine dewatering), however impacts are largely restricted due to the generally low hydraulic properties of the aquifer host rock.
- Groundwater is considered to be of good quality according to the two sets of guidelines used in the assessment of the chemical and physical groundwater analyses.
- Numerous potential sources of groundwater contamination occur within the mine lease area. Studies have shown that the coal and waste material have the potential to generate acidic leachate due to acid mine/rock drainage, significantly increasing the source’s potential to adversely affect groundwater quality.
- The saturated weathered zone and geological structures (dykes and faults) within the mine lease area were identified as possible pathways along which groundwater and potential contamination may migrate at accelerated rates.
- Numerous groundwater users and perennial surface water streams occur throughout the mine lease area, which are considered to be important receptors of contamination that may potentially originate from the coal mining and related activities.
- The planned stooping areas are either partially or completely flooded and would require dewatering before Matla can safely commence with their stooping activities.

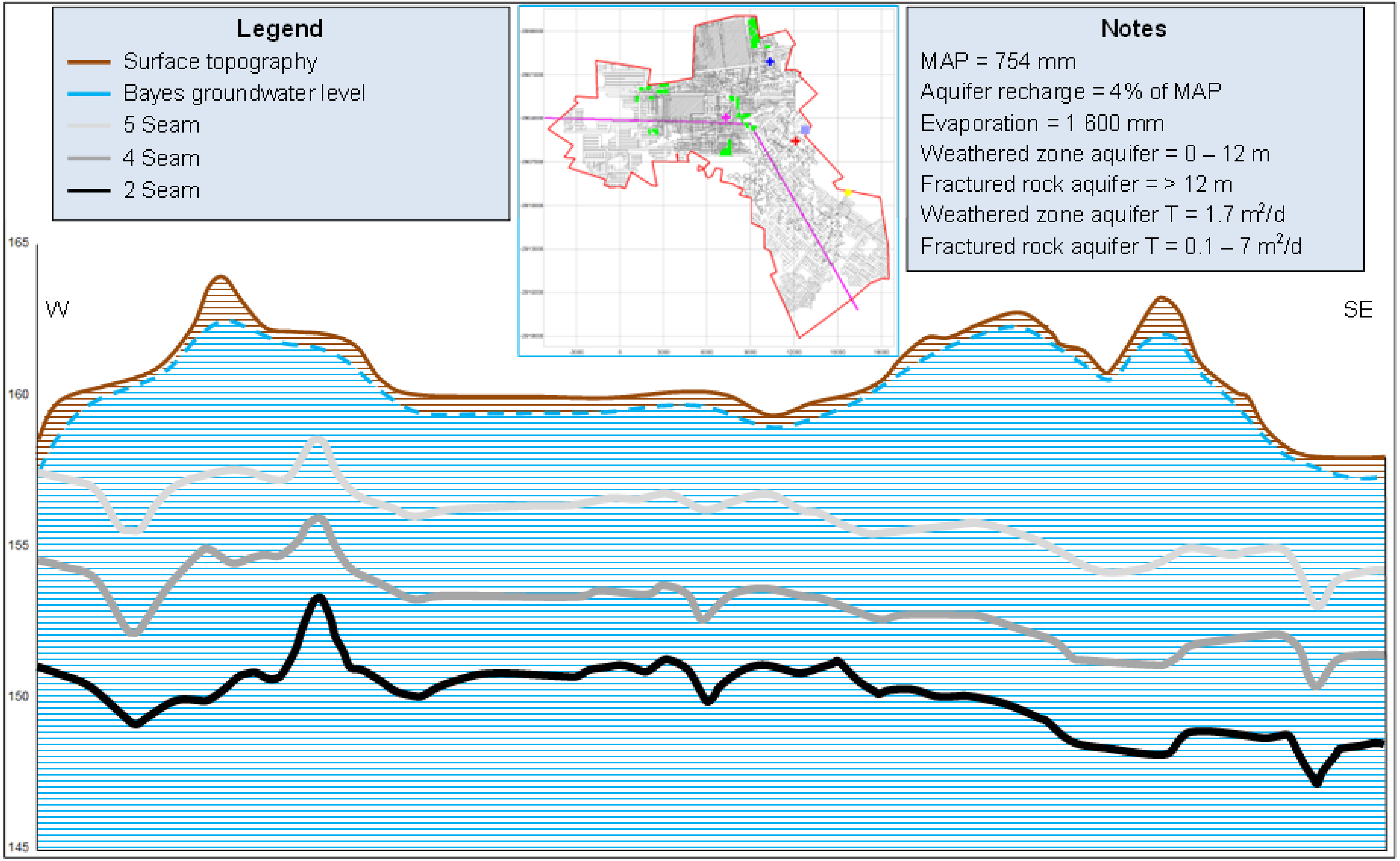

Figure 3.17: Vertical cross section through mine lease area

4 NUMERICAL GROUNDWATER MODEL

Numerical groundwater modelling was done for the following studies:

- New access shaft and overland conveyor for Mine 1 *(Groundwater Square, 2008)*,
- Water treatment plant *(Golder Associates Africa, 2012), and*
- The stooping of existing underground mining areas located on Eskom and Exxaro owned land surface areas *(GCS, 2016)*.

The main findings of the three individual modelling exercises are summarised in the following subsections. Please note that the model constructed for the Stooping Project (*GCS, 2016)* was also used to simulate the combined impact of all potential surface source areas within the Matla mine lease area **(Section 4.4)** and is therefore discussed in more detail **(Section 4.3)**.

4.1 Modelling Results for the New Access Shaft at Mine 1 *(Groundwater Square, 2008)*

At the request of *Exxaro* the MODFLOW and MT3D numerical flow and transport model codes were used. The maximum expected extent of the zones within which groundwater quality and water levels will be impacted at any time post-mining (10 years to 30 years after closure), as a result of the planned activities, are likely to be smaller than those depicted in Figure 4.1 (red and blue dotted lines respectively).

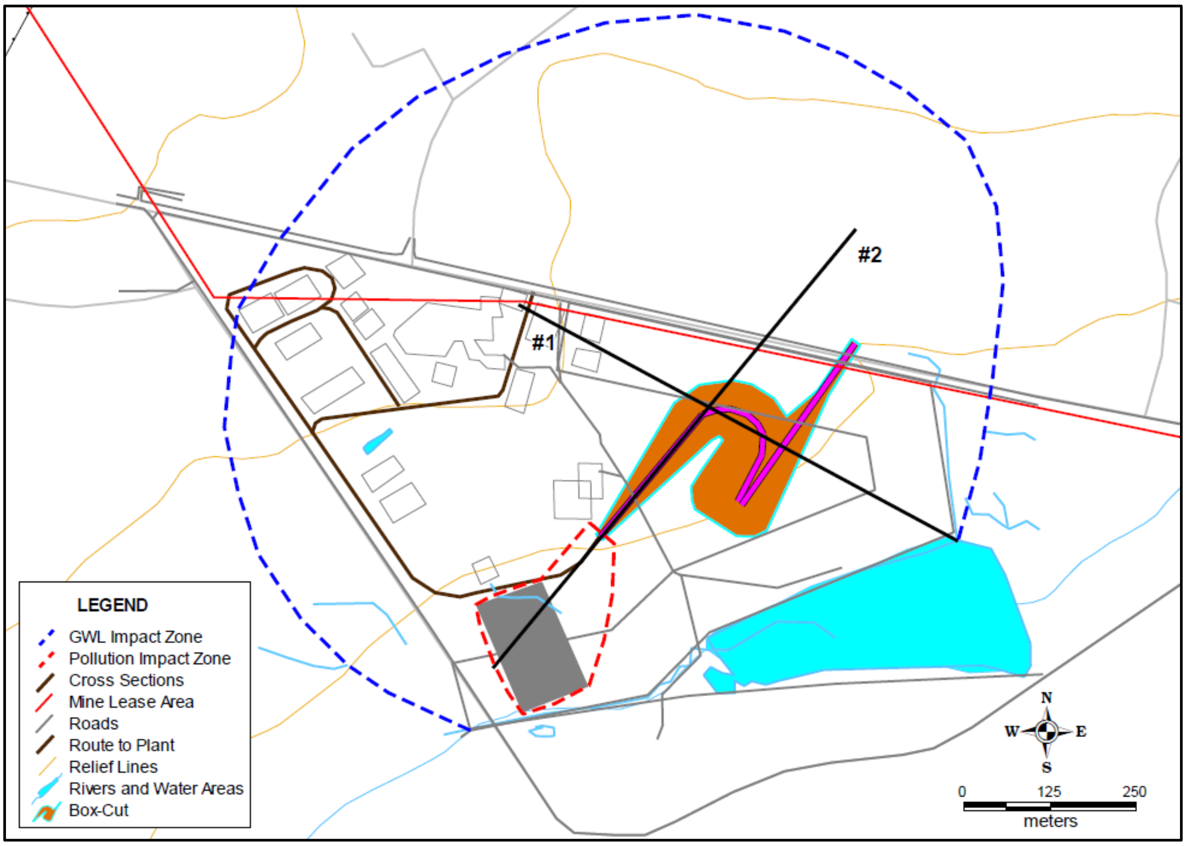

Figure 4.1: Maximum extent of 1) groundwater quality and 2) groundwater level impact zones

Due to the slope of the coal seam, excess water generated during the first years of mining will most likely have to be pumped to surface, or stored in well-planned underground shallow dams.

Whilst the mine might impact on groundwater levels in its immediate vicinity, the potential also exists that the mine will decant after closure. A deteriorating quality might also be observed in the local groundwater system and the Bakenlaagte Spruit.

Impacts were also simulated for the underground mining areas and the results of the model simulations are summarised below.

4.1.1 Operational phase

<u>*Mine water balance:*</u>

- Figure 4.2 depicts the volume of water expected to flow into the mine on an annual basis as mining progresses:
    - The green solid line indicates the water-make on an annual basis;
    - The orange line indicates the cumulative volumes of all water over time (i.e. storage space required);
- Assuming a mining height of 3.5m-4m, at 60%-70% extraction and recharge of between 1.5% and 2% of MAP to the underground mine:
    - After mining, the available void space was estimated at $1.6x10^6m^3$ to $2.1x10^6m^3$, compared to the total volume of water generated of $1x10^6m^3$;
    - The total volume of water generated during mining would therefore only fill the available void space between 50% and 60%;
    - The above calculations do not provide for water usage during the operational phase;
- It is therefore possible in principle (may not always be practical) that if a certain area/size of the deepest lying areas is mined first, enough void space will be available to store water for the remainder of the life of mine:
    - The area required to be mined first, and made available for water storage, was conservatively estimated at between 25% and 30% of the total mine.
    - Such an area is the deepest lying 4 Seam, to be mined during the 5 years of 2025 to 2029.

<u>*Impact on groundwater levels:*</u>

- During mining, groundwater levels in the immediate vicinity of the No.1 Shaft mine will be influenced;
- Groundwater levels in the shallow weathered zone aquifer and immediately above the 4 Seam workings will be affected (aquifer is <30m deep):
    - All mining above 60m deep was identified. These are predominantly to the east and south;

  - Given the depth to groundwater table in high lying areas, near the quaternary catchment divide, such areas bordering shallow 4 seam elevations were identified;
  - Water levels in the natural pans along the south-eastern mine lease boundary might be impacted;
- Even in areas where the coal seam was found to be relatively deep, the groundwater levels immediately above (10m to 30m) the 4 Seam may potentially be impacted:
  - As a result of the groundwater flow directions, dewatering should not extend beyond the surrounding rivers and streams or Pit-23.

Impact on groundwater quality:

- Groundwater flow into the underground workings is expected to be of similar quality to the background groundwater quality;
- The aquifers surrounding un-flooded mining sections are not expected to be impacted in terms of groundwater quality during the mining phase. This is due to groundwater flowing toward the dewatered mining area;
- However, flooded sections may potentially have a deteriorating groundwater quality impact on surrounding aquifers:
  - This is a very slow process as indicated for the “Post-Mining-Phase”;
- No hydro-geochemical evaluation was performed on the water quality trends that will develop on the 4 seam during mining.

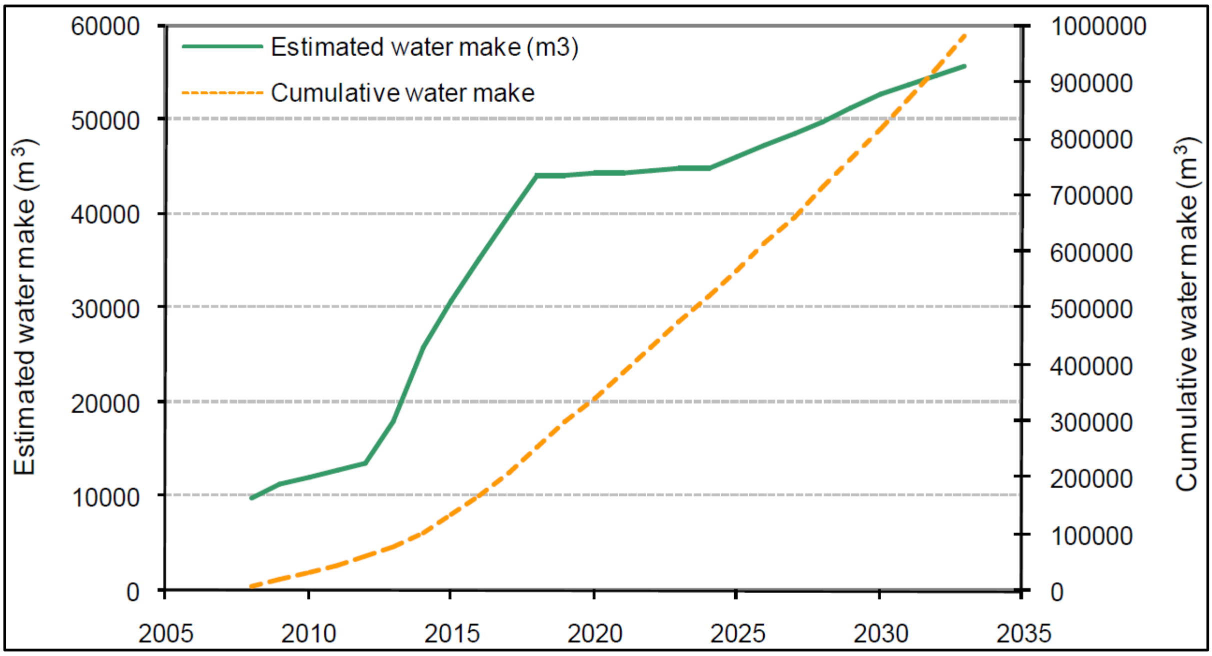

Figure 4.2: Expected mine water balance

4.1.2 Post-mining phase

Mine water balance:

- The post-mining water balance will depend on:
  - The final mine plan, including provision for an additional mine Shaft;
  - Water management strategies for the *Matla Coal* mining complex;
- Assuming the mine is 50% flooded after mining ceased, it is expected to take approximately 40 years to 50 years to completely flood.

Impact on groundwater levels:

- With reference to the steady state regional groundwater flow model for the post-mining situation, i.e. flooded underground workings in all *Matla Coal* mines:
  - None of the deeper model layers indicated the potential for groundwater and mine water to flow "across" the Riet Spruit;
  - In future assessments, the Riet Spruit may therefore be interpreted as the northern aquifer boundary of 1-Mine and the No.1 Shaft mine;
- The groundwater level distribution in the shallow weathered zone aquifer is expected to be almost identical to the pre-mining situation:
- After flooding, groundwater levels in the influenced areas of the weathered zone aquifer are expected to recover within a few years;
  - Groundwater levels around the natural pans to the southeast should not be impacted once the mine has flooded.

Impact on groundwater quality:

- As no hydro-geochemical assessment was performed, no predictions could be made on the long-term mine water quality trends;
- However, the zone of impact was determined through numerical transport modelling at a constant "unit concentration" of 2000mg/L on the 4 Seam:
  - The results depict the worst-case scenario where the whole mine is flooded;
  - It is evident that the impact is restricted to the immediate vicinity of mining at these depths;
- A clear distinction can be seen between the water qualities on the coal seam horizon and the top-most shallow weathered zone aquifer, which interacts with the Bakenlaagte Spruit in the east as well as the Dwars-in-die-weg Spruit in the south.

Please refer to the original report for more detailed discussions on the model simulated groundwater quality and water level impacts.

4.2 Modelling Results for the Water Treatment Plant *(Golder Associates Africa, 2012)*

The numerical model for the project was constructed using Processing MODFLOW Pro, a pre- and post-processing package for MODFLOW and MT3D. A total of twelve different model scenarios were run, however only those concerning the “two brine ponds layout” are summarised shortly in the following paragraphs.

The four scenarios run with two brine ponds under anticipated seepage rates, the sulphate concentrations are expected to increase to around 1400 mg/l in the weathered aquifer in the immediate vicinity within the 6 years that the two ponds will be operational. Simulations indicate that sulphate concentrations will probably not increase to above 200 mg/l if the brine ponds are removed after 6 years and rehabilitated.

In the long term sulphate concentrations are not expected to increase above 200 mg/l in the weathered or fractured rock aquifers. Contamination will therefore be restricted to the immediate vicinity of the WTP and the brine ponds under anticipated seepage conditions.

If maximum seepage rates take place from the two brine ponds, sulphate concentrations may increase to around 4000 mg/l in the 6 years that the ponds will be operational. Contamination is not expected to migrate from the brine ponds in this period. In the long-term, sulphate concentrations are not expected to exceed 200 mg/l in the weathered or fractured rock aquifers, due to the effect of dilution from rainfall with time.

If the two brine ponds are not removed and rehabilitated after 6 years, sulphate concentrations may increase to around 4000 mg/l in the weathered aquifer and to 1200 mg/l in the fractured rock aquifer. Contamination is expected to migrate in a northerly and easterly direction towards the pans. Under anticipated seepage conditions, the plume is not expected to reach the pans within 100 years, but will come very close.

Under maximum seepage rates, sulphate concentrations are expected to increase to around 6200 mg/l in the weathered aquifer in the immediate vicinity of the brine ponds and to around 1700 mg/l in the fractured rock aquifer. Sulphate concentrations exceeding 200 mg/l will reach the pans to the north of the WTP in both the weathered and fractured rock aquifers under these conditions.

No private boreholes are located within the affected zone.

Please refer to the original report for more detailed discussions on the model simulated groundwater quality and water level impacts.

4.3 Modelling Results for the Planned Stooping of Underground Mining Areas *(GCS, 2016)*

4.3.1 Model restrictions and limitations

The numerical groundwater model, despite all efforts and advances in software and algorithms, remains a very simplified representation of the very complex and heterogeneous interacting aquifer systems underlying the site.

The integrity of a numerical model depends strongly on the formulation of a sound conceptual model and the quality and quantity (distribution, length of records etc.) of input data:

Garbage In = Garbage Out

Where accurate long term monitoring and test data over the entire project area is not available the model results should therefore be regarded as providing qualitative rather than quantitative results and also need to be verified and updated regularly by means of a comprehensive groundwater monitoring program. Nonetheless, a numerical model can be used quite successfully to assess the effectiveness of various management and remediation options/techniques, especially if the shortcomings in information and assumptions made in the construction and calibration of the model are clearly listed and kept in mind during modelling.

All available information regarding the geological makeup (especially geological structures) of the mining area was considered in the construction of the numerical model. Geological structures such as dykes and faults, because the aquifer is of a secondary fractured nature, usually have higher transmissivities in comparison to the host rock and serve as preferred flow paths or conduits for groundwater movement. These structures therefore have the ability to significantly affect the outcome of a model. Areas still exist where such structural geological information is not available, therefore modelling (i.e. updating of the model) should be an ongoing process as new information becomes available with time.

No stooping schedules were available for the Phase 1 areas, therefore a worst case approach was followed whereby all the areas were simulated to be stooped during the same period.

4.3.2 Model domain and boundary conditions

The Processing Modflow 8 modelling package was used for the model simulations. The finite difference model grid constructed to include the entire Matla mine lease area is indicated in Figure 4.3. Model dimensions and aquifer parameters used in the construction and calibration of the model are provided in Table 4.1.

The following model boundaries were used to define the model area and are also indicated in Figure 4.3:

- **No-flow boundaries** in a model, as in nature, are groundwater divides (topographic high or low areas/lines) and geological structures (dykes) across which no groundwater flow is possible.

- **General head boundaries** are boundaries through which groundwater movement is possible. The rate at which the groundwater moves through the boundary depends on the groundwater gradients as well as the hydraulic conductivities on opposite sides of the boundary position.

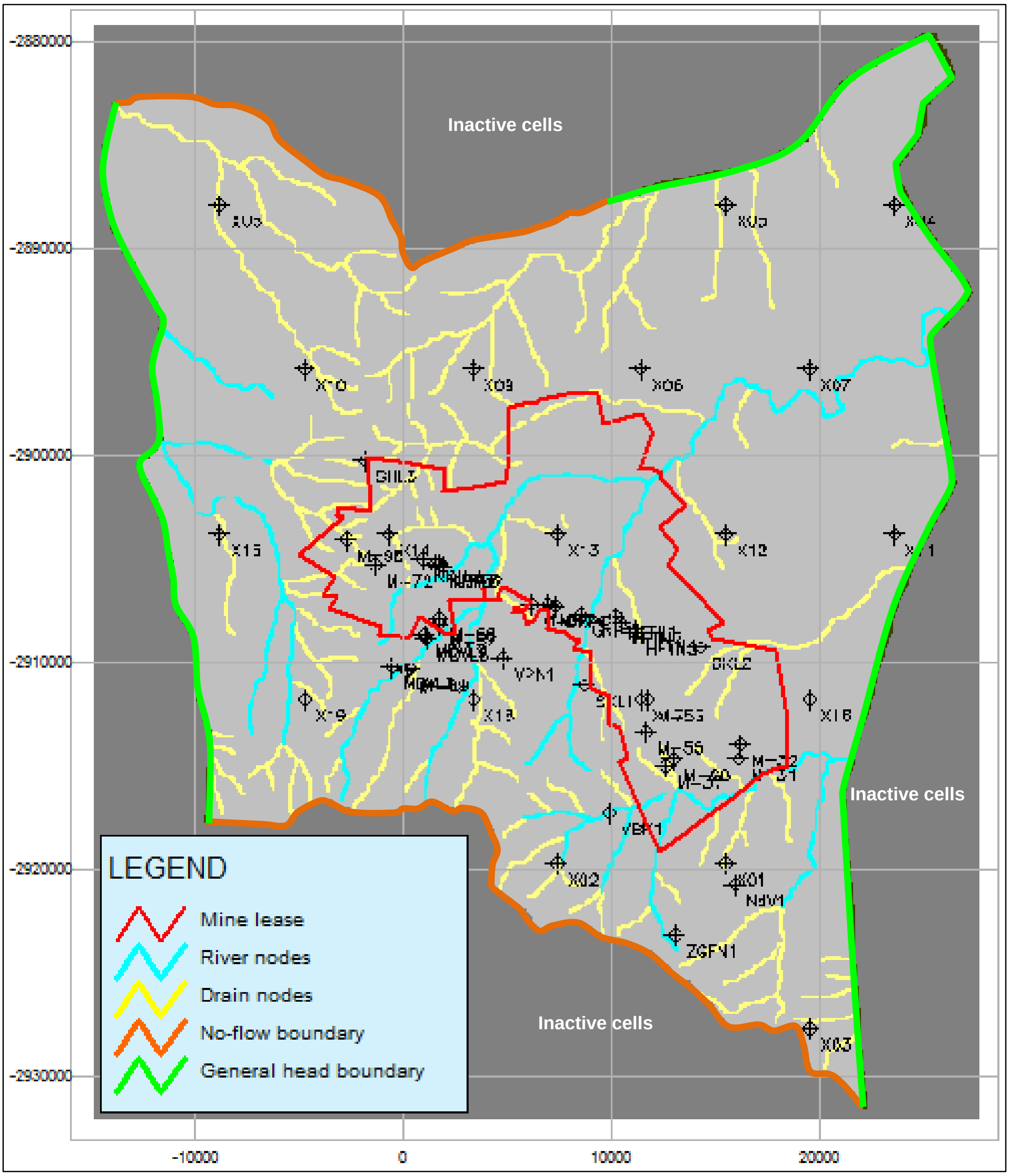

Figure 4.3: Numerical model grid

Table 4.1: Model dimensions and aquifer parameters

Grid size	Easting = 42 210m Northing = 52 640m
Rows and Columns	Rows = 752, Columns = 603
Cell size	70m by 70m
Transmissivity: Shallow aquifer	1.8 m^2/day
Transmissivity: Deeper aquifer	0.35 m^2/day
Specific yield: Shallow aquifer	0.06
Storage coefficient: Deeper aquifer	0.001
Effective porosity: Shallow aquifer	6%
Effective porosity: Deeper aquifer	2%
Recharge	0.6% - 1.2 % of MAP

4.3.3 Model calibration results

During the steady state calibration of the flow model changes were made to mainly the hydraulic properties (transmissivity) of the aquifer host rock and effective recharge (Table 4.1) until an acceptable correlation was achieved between the measured/observed groundwater elevations and those simulated by the model. Groundwater level information from user boreholes was used in the calibration process. A correlation of ± 97% was achieved with the calibration of the flow model and the results are provided in Figure 4.4

The calibrated groundwater elevations were exported from the flow model and used to construct a contour map of the steady state groundwater elevations (Figure 4.5). The lowest groundwater elevations were simulated to occur in the north-western and north-eastern down gradient directions. Groundwater elevations follow the surface topography and increase towards the south.

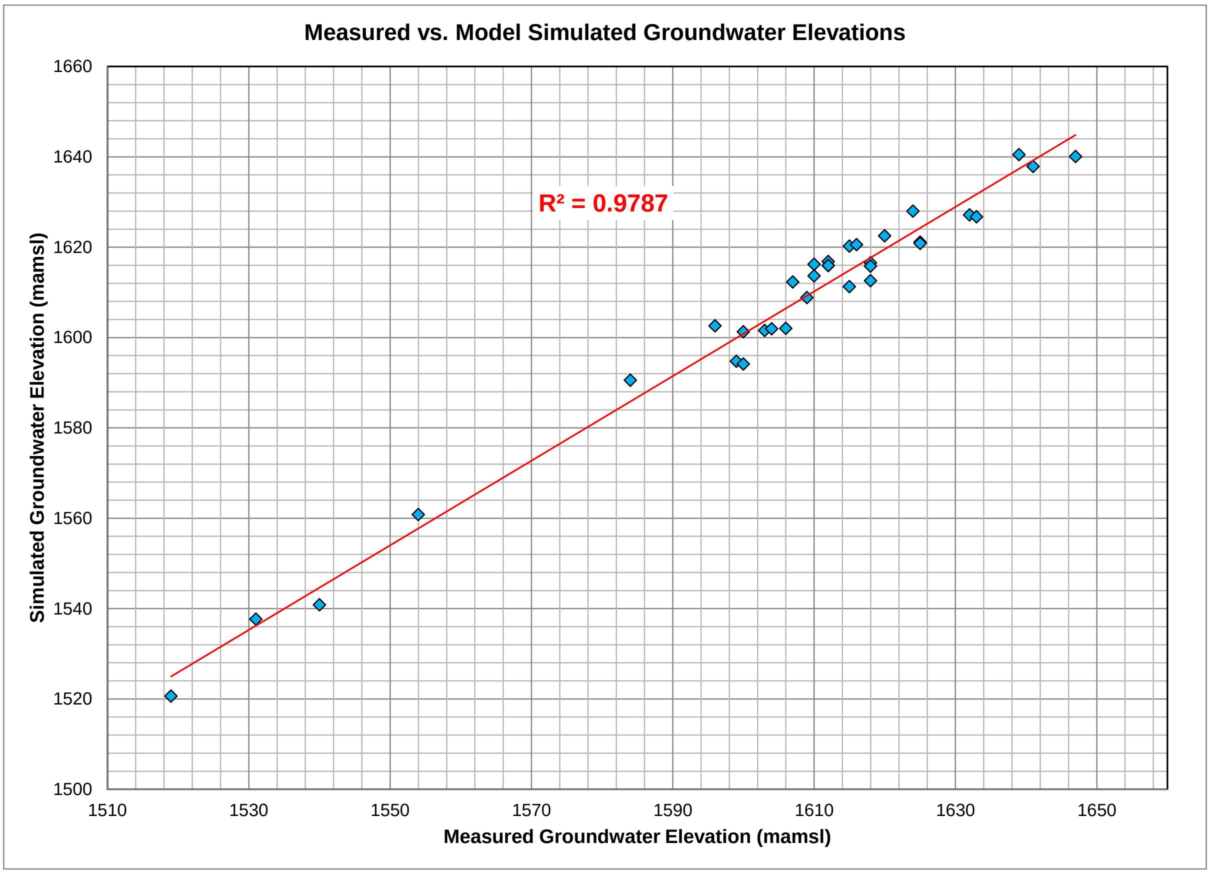

Figure 4.4: Numerical flow model calibration results

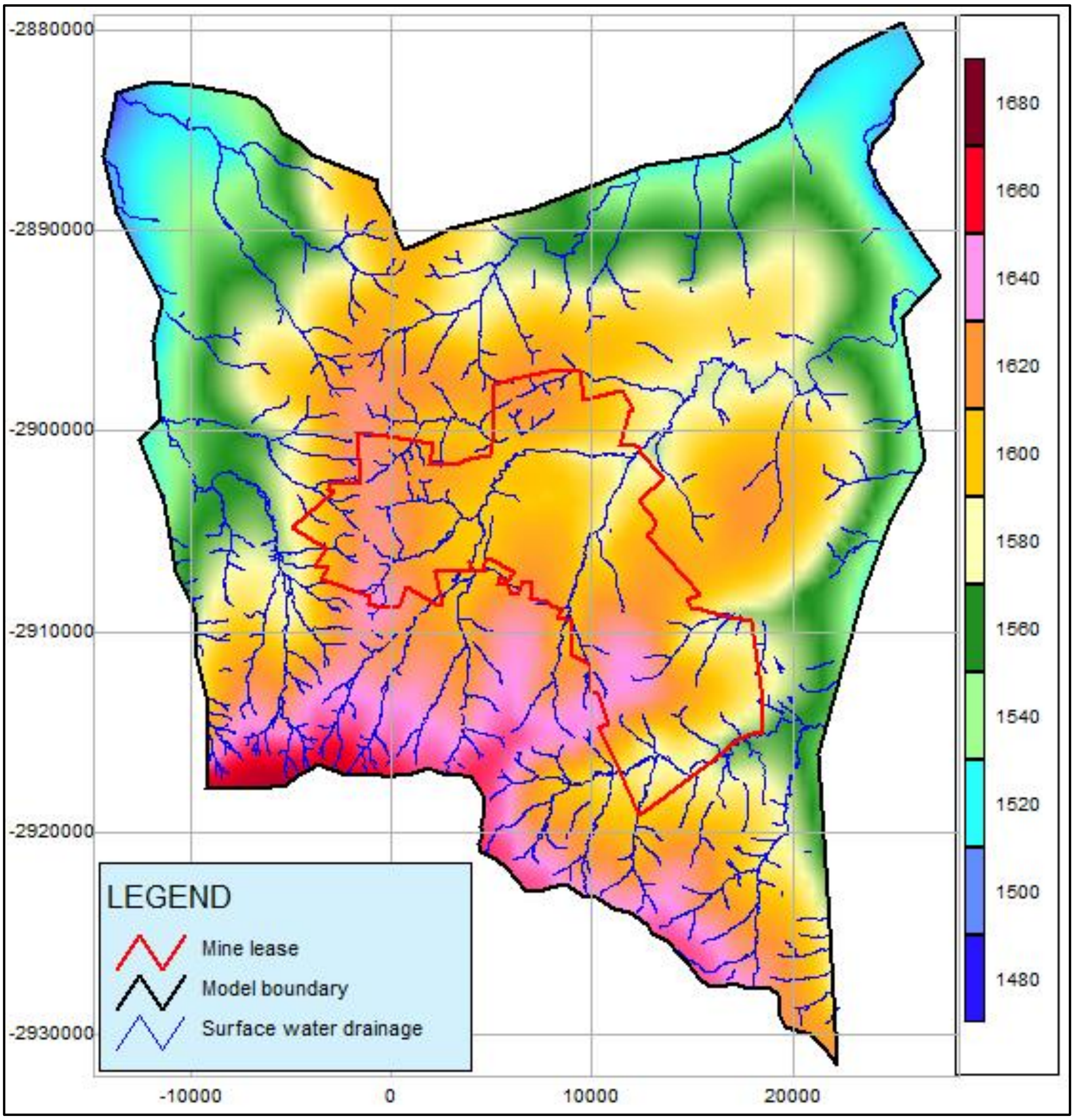

Figure 4.5: Model simulated steady state groundwater elevations (mamsl)

4.3.4 Flow model

Impacts on groundwater levels are expected to occur as a result of roof collapse followed by surface subsidence. The flow model was therefore used to simulate this potential impact. A mine plan and schedule are yet to be finalised for the planned stooping areas, which is considered to be a serious shortcoming in the model simulations.

The extent of the groundwater level impacts is governed by the hydraulic properties of the aquifer host rock and time. The influence of time on the radius/extent of the cone of depression (water level impact) is explained by means of the following equation *(Bear, 1979)*:

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

Where R = *Radius (m),*

T = *Aquifer transmissivity* (m^2/d),

t = *Time (days),*

S = *Storativity.*

The equation shows that an increase in time will lead to an increase in the radius of influence (extent of depression cone), which is why the mine plan/schedule plays such an important role in the model simulations. The same holds true for aquifer transmissivity, i.e. impacts on groundwater levels are expected to extend along transmissive geological structures. Such structures may also greatly increase groundwater discharge into the active mine workings.

The planned stooping was simulated to occur over an assumed time period of five years. We strongly recommend an update of the model simulations once the mine plan/schedule has been finalised.

In order to better indicate the impact of the planned stooping activities on the surrounding groundwater levels, initial groundwater elevations were subtracted from the simulated groundwater elevations at the end of year five. The difference between these two data sets therefore represents the total decrease in water level experienced over the simulation time. This data was used to construct a contour map of the model simulated groundwater depression cones, which are indicated in Figure 4.6. Groundwater user boreholes located within the mine lease area are indicated in the abovementioned figure with the use of blue place marks.

Summary of simulations:

A maximum groundwater level drawdown/decrease of 11 meters was simulated to occur in an area bordered by low transmissivity dykes (green lines in Figure 4.6). On average, drawdown was simulated to vary between approximately four and nine meters. A total area of ± 25 km^2 was simulated to experience decreases in water levels. Ten groundwater user boreholes are located within this affected area, namely:

Table 4.2: Potentially affected groundwater user boreholes

BH	Model simulated drawdown (m)
HJFV2	5
HJFV5	3
KRTL1	3
KRTL6	5
KRTL8	6
KRTL9	6
KRTL10	6
KRTL11	6
M-19	3
VFN1	2

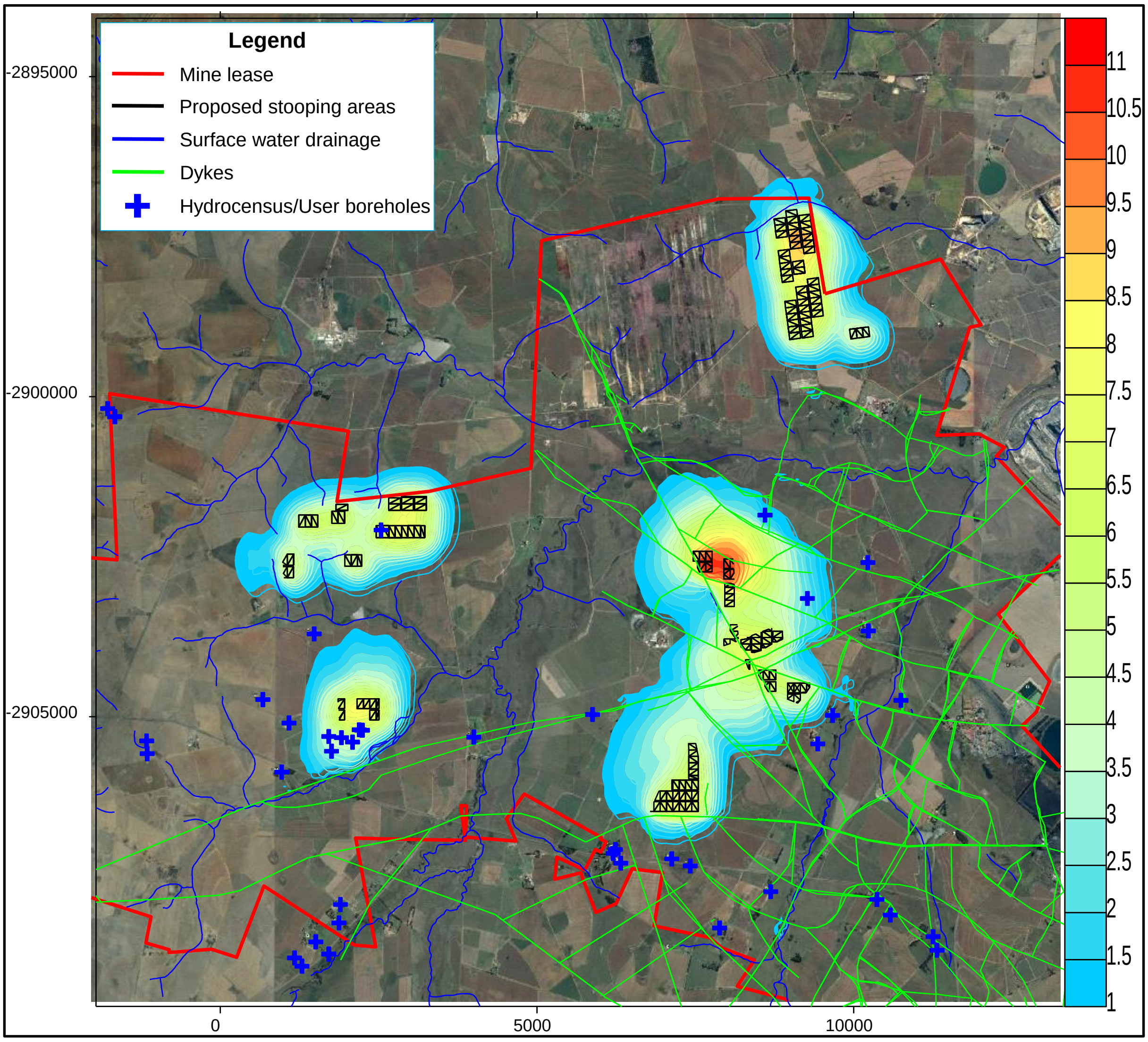

Figure 4.6: Model simulated groundwater depression cones (meters)

Key Issues:

- *Ten groundwater user boreholes were simulated to be affected by the planned stooping activities.*
- *These boreholes were simulated to experience water level decreases of between two and six meters.*
- *We therefore recommend quarterly monitoring (at least) of groundwater levels in the model simulated affected areas.*
- *Monitoring data should be assessed on a regular basis to determine/quantify the impact (if any) on groundwater levels.*
- *Groundwater users should be compensated for their loss should the monitoring program indicate adverse groundwater level impacts.*

4.4 Results of Mass Transport Model Simulation to Include all Major Potential Surface Source Areas

The mass transport model was constructed to simulate pollution migration in the aquifer system underlying the mine lease area. Five main source areas were identified and included in the model simulations:

- Pollution control dams at No 1 Shaft, Mine 1, Mine 2 and Mine 3,
- Water treatment plant and associated brine ponds.

In order to better indicate the impact of the potential sources on the surrounding groundwater quality conditions, contamination contours were exported from the mass transport model after a 25 and 50 years simulation runtime and used to construct the simulated contamination plumes, which are provided in Figure 4.7 and Figure 4.8 respectively.

The contamination was simulated by applying contaminated recharge to the entire surface areas of the potential sources listed above. The source areas were assigned a theoretical concentrations of 100%, therefore the results of the model simulations should be regarded as qualitative rather than quantitative.

Summary of simulations:

As mentioned earlier in the report **(Section 3.3/3.4)**, impacts on groundwater levels are restricted and groundwater migration on a regional scale still follows the natural/pre-mining flow patterns/directions. Plumes were consequently simulated to follow the groundwater flow directions as indicated in Figure 3.7.

Plume migration is however quite slow as a result of the relatively low hydraulic properties of the aquifer host rock and low groundwater hydraulic gradients. Plumes were simulated to have migrated an average distance of ± 400 meters after a model runtime of 50 years, which translates to 8 meters per year. This is slightly higher than the 6 meters per year calculated in **Section 3.4** of the report with the *Fetter (1994)* equation.

User boreholes located during the *GCS 2014* hydrocensus/user survey are indicated in Figure 4.7 and Figure 4.8 with the use of yellow place marks. Please note that none of these boreholes are located within the areas simulated to be affected by the contamination plumes.

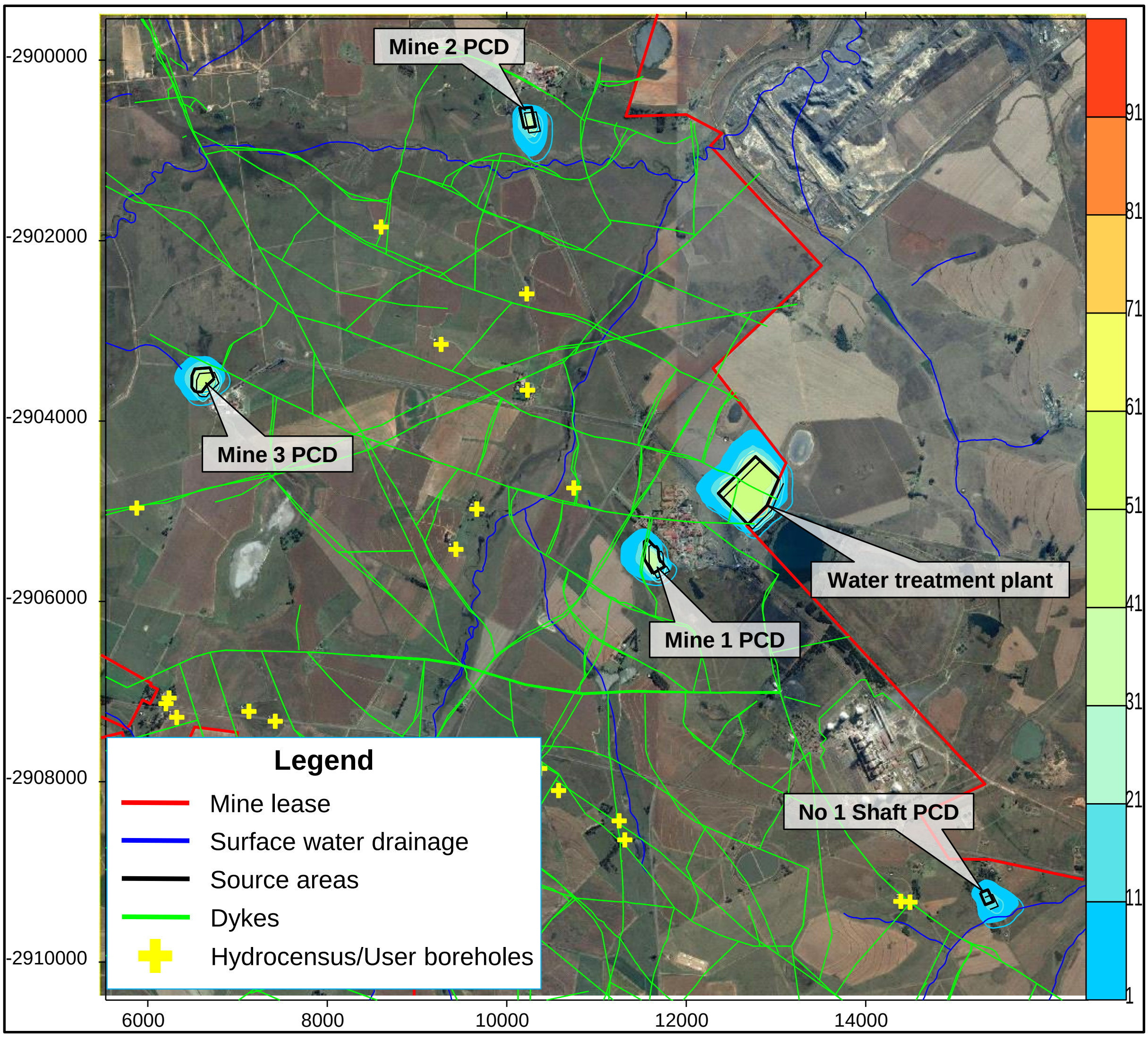

Figure 4.7: Simulated plume migration after 25 years (%)

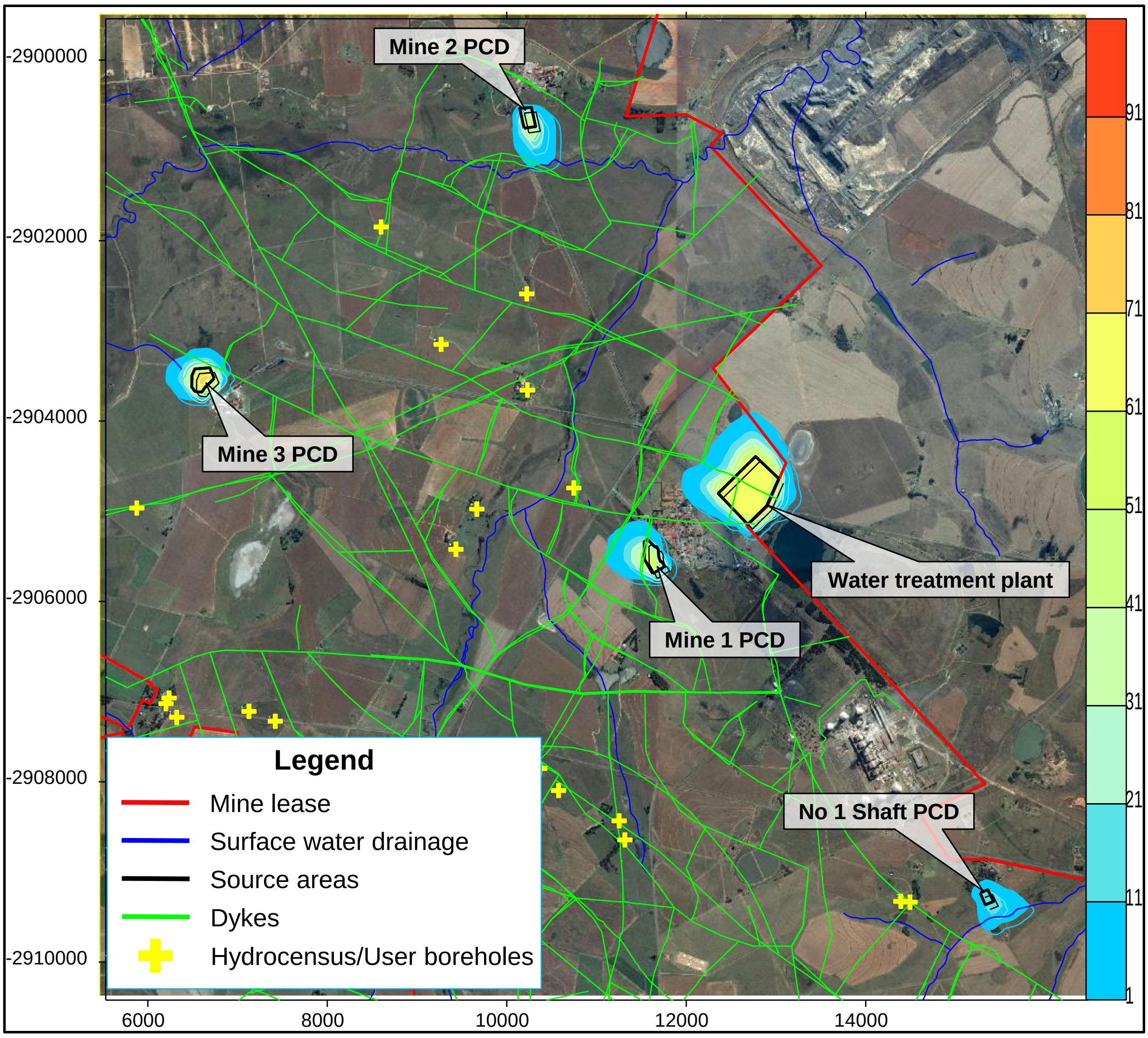

Figure 4.8: Simulated plume migration after 50 years (%)

5 ENVIRONMENTAL IMPACT ASSESSMENT AND MITIGATION MEASURES

This part of the hydrogeological input to the EMP report describes and evaluates the potential impacts associated with the following activities within the Matla mine lease area:

- Underground mining operations at Mine 1, Mine 2 and Mine 3,
- Stooping of existing underground mining areas located on Eskom and Exxaro owned land surface areas,
- Re-routing of the Riet Spruit at Mine 3,
- Construction and operation of a new access shaft and overland conveyor at Mine 1,
- Construction and operation of a water treatment plant.

These five activities are discussed and evaluated individually in the following subsections. The criteria used for the risk evaluation are provided in **Table 5.1**

According to the Information Series 5: Impact Significance of the Integrated Environmental Management Information Series *(Department of Environmental Affairs and Tourism, 2002)*:

'The concept of significance is at the core of impact identification, prediction, evaluation and decision-making. Deciding whether a project is likely to cause significant environmental effects is central to the practice of EIA.'

Impact assessment is therefore based on the description of an impact, the significance of this impact, and how the impact can be managed. Impact assessment and management measures must be based on the requirements as set out in the relevant Regulations and guidelines of the National Environmental Management Act No 107 of 1998 (as amended), the Minerals and Petroleum Resources Development Act No 28 of 2002 (as amended) and the National Water Act No 36 of 1998 (as amended).

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

Table 5.1: Impact assessment criteria

Description		Rating
Magnitude		
Not applicable/none/negligible		0
Minor		2
Low		4
Moderate		6
High		8
Very high/don't know		10
Duration		
Not applicable/none/negligible		0
Immediate		1
Short-term (0-5 years)		2
Medium-term (5-15 years)		3
Long-term (ceases with the operational life)		4
Permanent		5
Scale		
Not applicable/none/negligible		0
Site only		1
Local		2
Regional		3
National		4
International		5
Probability		
Not applicable/none/negligible		0
Improbable		1
Low probability		2
Medium probability		3
Highly probable		4
Definite/don't know		5
Significance		
High (positive)	>60	H
Medium (positive)	30 to 60	M
Low (positive)	<30	L
Neutral	0	N
Low (negative)	>-30	L
Medium (negative)	-30 to -60	M
High (negative)	<-60	H

***Note:** The maximum value that can be achieved is 100 Significance Points (SP).*

Please note that only the operational and decommissioning/closure phases will be evaluated where applicable, seeing that all construction activities have already been completed.

5.1 Groundwater Impacts Associated with the Access and Ventilation Shafts

The following aspects were considered during the assessment:

- Groundwater levels are expected to be affected by the shafts.
- In the extreme case, large water makes (>2L/s) may be encountered between 5m and 30m below surface.
- Large water makes are normally associated with structural features such as dykes, sills and fault zones, most of which have been pinpointed by geophysical surveys, extensive exploration drilling as well as mining advancement. These have been factored into the placement of the shafts.
- However, insignificant inflows into the mine have been observed to date at the numerous conventionally drilled rescue bays, which are typically sleeved (upper 30m) and plugged through the upper unconsolidated rock.

5.1.1 Operational phase

Potential environmental impact:

Due to the depth of the shafts below the local groundwater level, they are expected to cause a lowering (decrease) in the local groundwater levels. Impacts are however expected to be negligible due to the small size of the shafts in relation to the larger Matla mine lease area. Plugging together with the low hydraulic properties of the aquifer host rock will also greatly restrict the area affected.

Table 5.2: Impact rating construction/operational phase - Groundwater level

Status of impact	Magnitude	Duration	Scale	Probability	Significance
Before mitigation					
-	Low	Permanent	Site only	Definite	Medium (50)
After mitigation					
-	Minor	Permanent	Site only	Low probability	Low (16)

Recommended mitigation measures:

Transmissive geological structures were identified prior to construction and avoided as far as practically possible. The shafts were lined (upper 30m) and plugged through the upper unconsolidated rock to minimise the influx of groundwater (i.e. minimise aquifer dewatering). Water yielding fractures in the fresh rock at depth were grouted with cement.

Although not a mitigation measure, a comprehensive groundwater monitoring program should be put in place to monitor the impact (if any) on local groundwater levels.

5.1.2 Decommissioning and closure phase

Potential environmental impact:

The impacts discussed for the operational phase will continue throughout the decommissioning and closure phase for as long as it takes groundwater levels to recover from the impacts of mine dewatering.

Table 5.3: Impact rating construction/operational phase - Groundwater level

Status of impact	Magnitude	Duration	Scale	Probability	Significance
Before mitigation					
-	Low	Permanent	Site only	Definite	Medium (50)
After mitigation					
-	Minor	Permanent	Site only	Low probability	Low (16)

Recommended mitigation measures:

Shafts will be sealed off from the surface in an effort to minimise the risk of future decant. Decanting is however still expected, especially in areas affected (i.e. surface subsidence) by the high extraction mining. Although not a mitigation measure, a comprehensive groundwater monitoring program should be put in place to monitor the impact (if any) on local groundwater levels.

5.2 Groundwater Impacts Associated with the Underground Mining Activities at Mine 1, Mine 2 and Mine 3

The following aspects were considered during the assessment:

- During the operation phase of mining and for as long as it takes groundwater levels to recover from the impacts of mine dewatering, impacts on groundwater are expected to be quantitative by nature, rather than qualitative.
- Only after groundwater levels have recovered, will contamination migrate in the down gradient groundwater flow direction to potentially affect the surrounding groundwater users. Impacts on groundwater quality are therefore expected to be negligible during the operational phase.
- The generally low hydraulic properties of the aquifer host rock will greatly restrict the area affected by mine dewatering and the rate at which potential contamination migrates (please refer to **Section 3.4** for the groundwater flow velocity).

5.2.1 Operational phase

Potential environmental impact:

Groundwater levels within the mining areas are expected be lowered as a result of the dewatering activities. High extraction mining followed by roof collapse and surface subsidence will greatly increase the impact on groundwater levels.

Table 5.4: Impact rating operational phase - Groundwater level

Status of impact	Magnitude	Duration	Scale	Probability	Significance
Before mitigation					
-	High	Permanent	Local	Definite	High (75)
After mitigation					
-	Minor	Long term	Site only	Medium	Low (21)

Recommended mitigation measures:

No mitigation measures can prevent the aquifer from being dewatered. High extraction mining and roof instability should however be avoided if possible, especially below surface water courses, wetlands or any other surface water features. Water yielding fractures should also be sealed off to minimise aquifer dewatering and subsequent lowering of groundwater levels.

Although not a mitigation measure, a comprehensive groundwater monitoring program should be put in place to monitor the impact of mine dewatering on local groundwater levels.

5.2.2 Decommissioning and closure phase

Potential environmental impact:

During the decommissioning and closure phase, mining activities will gradually come to an end and all mining equipment and remaining infrastructure will be removed and cleared. Mine dewatering/pumping will also cease, allowing groundwater levels to slowly recover. Only after the entire underground void has been flooded, will groundwater levels recover to establish a new equilibrium. The decommissioning and closure phase activities are therefore expected to have a positive effect/impact on surrounding groundwater levels.

The coal and overburden material have the potential to generate acidic leachate high in sulphate and iron content due to acid mine/rock drainage **(Section 3.9)**. Any potential decant from the underground void is therefore expected to be of poor quality and has the potential to contaminate the groundwater.

Table 5.5: Impact rating decommissioning and closure phase - Groundwater level

Status of impact	Magnitude	Duration	Scale	Probability	Significance
Before mitigation					
+	Moderate	Permanent	Local	Definite	High (65)
After mitigation					
+	Moderate	Permanent	Local	Definite	High (65)

Table 5.6: Impact rating decommissioning and closure phase - Groundwater quality

Status of impact	Magnitude	Duration	Scale	Probability	Significance
Before mitigation					

-	High	Permanent	Regional	Definite	High (80)
After mitigation					
-	Low	Permanent	Local	Medium	Medium (33)

Recommended mitigation measures:

The water level within the mine void should be kept below the decant elevation and the contact between the weathered zone and fresh bedrock to minimise/restrict the down gradient movement of a pollution plume.

Although not a mitigation measure, a comprehensive groundwater monitoring program should be put in place to monitor the impact (if any) on local groundwater quality conditions. Monitoring of water levels in the underground void also plays a crucial role in volume calculations and the effective management of the mine water.

5.3 Groundwater Impacts Associated with the Stooping of Existing Underground Mine Workings

The following aspects were considered during the assessment:

- The proposed stooping areas are located within and are surrounded by existing mine workings.
- Six groundwater samples were collected within the mine lease area and the results of their chemical and physical analyses revealed overall good groundwater quality conditions.
- Impacts associated with the planned stooping activities are therefore expected to be related to groundwater levels (quantitative), rather than groundwater quality (qualitative).
- Given Matla's long and extensive mining history, the impact of the proposed stooping activities (over and above the already existing groundwater level impacts) is expected to be low in the context of the existing operation.

5.3.1 Operational phase

Potential environmental impact:

Impacts are expected to be quantitative by nature, rather than qualitative. Impacts on groundwater levels already occur as a result of groundwater abstraction for domestic/other purposes or mine dewatering.

Most of the existing mine workings occur at depths of between ±75 and 120 meters below surface. At these depths the mine's impact on groundwater levels in the shallower overlying aquifer/s is low. High extraction mining has however caused the roof to collapse in some areas, which ultimately led to subsidence of the surface.

In such an event a hydraulic connection is created between the deep mine workings and overlying aquifer/s. Water from the aquifer is now free to drain into the mine workings, ultimately causing water levels to decrease.

The proposed stooping is expected to have such an impact as all supporting pillars will be mined out, thus causing the roof to collapse followed by surface subsidence.

The recharge to the stooping areas will increase once roof collapse and surface subsidence start to occur. The overall groundwater make in the catchment will thus increase, however slightly due to the limited size of the areas proposed for stooping. At an increase in effective recharge of approximately 5% of MAP, the average increase will be approximately 220 m^3/d. This increase is but 2% of the current estimated recharge of 12 900 m^3/d to the Matla workings *(Mine Water Consultants, 2015)*.

Table 5.7: Impact rating decommissioning and closure phase - Groundwater level

Status of impact	Magnitude	Duration	Scale	Probability	Significance
Before mitigation					
-	Moderate	Long term	Local	Highly probable	Medium (48)
After mitigation					
-	Moderate	Long term	Local	Highly probable	Medium (48)

As stated previously, the medium impact of the proposed stooping will be very small in the context of the existing larger Matla operation footprint.

Recommended mitigation measures:

Stooping should not be conducted below surface water courses, wetlands or any other surface water features.

Other than the comprehensive monitoring of groundwater levels and early detection of impacts, no mitigation measures are available for the stooping, roof collapse and shallow aquifer dewatering. No other impacts from the proposed stooping operation are discussed because the water and waste management, processing, storm water will be incorporated in the existing infrastructure.

Key Issues:

- *The planned stooping activities are expected to cause a lowering of the local groundwater levels, for which no mitigation measures are available.*
- *The effective recharge will increase to the mine workings, but the increase is very small in the larger Matla groundwater make.*
- *The generally low hydraulic properties of the aquifer host rock are however expected to significantly restrict the extent of the affected areas.*
- *Residual impacts will remain for as long as it takes groundwater levels to recover and establish a new equilibrium.*

5.3.2 Decommissioning and closure phase

Potential environmental impact:

During the decommissioning and closure phase, mining activities will gradually come to an end and all mining equipment and remaining infrastructure will be removed and cleared. Mine dewatering/pumping will also cease, allowing groundwater levels to slowly recover. Only after the entire underground void has been flooded, will groundwater levels recover to establish a new equilibrium. The decommissioning and closure phase activities are therefore expected to have a positive effect/impact on surrounding groundwater levels.

Table 5.8: Impact rating decommissioning and closure phase - Groundwater level

Status of impact	Magnitude	Duration	Scale	Probability	Significance
Before mitigation					
+	Moderate	Long term	Local	Definite	Medium (60)
After mitigation					
+	Moderate	Long term	Local	Definite	Medium (60)

Key Issues:

- *The decommissioning and closure phase activities are expected to have a positive effect/impact on the surrounding groundwater levels.*
- *Once groundwater levels have recovered from the impacts of mine dewatering, groundwater flow patterns will return to normal/pre-mining – allowing any potential contamination to migrate in the down gradient groundwater flow directions. The residual impacts are therefore expected to change from being quantitative by nature to now being qualitative.*

5.4 Groundwater Impacts Associated with the Crushing and Screening Plant

The following aspects were considered during the assessment:

- The coal and interburden contain metal sulphides (usually pyrite), which in the presence of oxygen and water will oxidise to produce an acidic leachate.
- Coal stockpiles and/or dirty surface areas contaminated with coal therefore have the potential to produce acidic leachate.
- Other than a very small reduction in aquifer recharge directly underneath compacted and covered surface areas, groundwater levels are expected to remain unaffected.

5.4.1 Operational phase

Potential environmental impact:

Impacts on the groundwater quality only occur through leachate formation from dirty/contaminated surface areas. Impacts thus only occur as a result of rainfall recharge or when water is introduced in some form where leachate can form that seeps to the groundwater.

Table 5.9: Impact rating operational phase - Groundwater quality

Status of impact	Magnitude	Duration	Scale	Probability	Significance
Before mitigation					

-	High	Long term	Local	Definite	High (70)
After mitigation					
-	Low	Long term	Local	Low	Low (20)

Recommended mitigation measures:

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

Clean surface water should not come into contact with dirty water or coal contaminated material. The surface area should be lined to prevent the ingress of poor quality seepage.

Dedicated source monitoring boreholes should be in place to timeously detect any contamination breakthroughs.

5.4.2 Decommissioning and closure phase

Potential environmental impact:

During the decommissioning and closure phase all surface infrastructure will be removed and contaminated surface areas rehabilitated. These activities are therefore expected to have a positive impact on the quality of the underlying groundwater (i.e. recharge will no longer get contaminated).

Table 5.10: Impact rating decommissioning and closure phase - Groundwater quality

Status of impact	Magnitude	Duration	Scale	Probability	Significance
Before mitigation					
+	Low	Permanent	Local	Definite	Medium (55)
After mitigation					
+	Low	Permanent	Local	Definite	Medium (55)

Recommended mitigation measures:

All mining and related infrastructure should be removed from the disturbed land use areas together with potentially hazardous material. Final rehabilitation, including the placement of topsoil and establishment of vegetation on rehabilitated areas should aim to re-establish ambient recharge to the underlying aquifer.

5.5 Groundwater Impacts Associated with the Water Treatment Plant and Associated Brine Ponds

The following aspects were considered during the assessment:

- The water treatment plant has the potential to affect both groundwater quality and water levels.
- The plant was developed to separate mine water into a low salinity product stream and a high salinity brine waste by means of reverse osmosis (RO).

- The concentrated brine is considered to be hazardous and a potential source of groundwater contamination.
- The brine is disposed of in brine ponds constructed of multiple HDPE liners and leakage detection layers.

5.5.1 Operational phase

Potential environmental impact:

Please note that impacts on groundwater quality and water levels are not expected to occur as long as the plant and brine ponds are managed according to best practice guidelines and regularly inspected for leakages.

In the unlikely event of mismanagement, continuous leakages will artificially recharge the underlying aquifer, causing groundwater levels directly underneath the facility to increase/rise. This process is better known as groundwater mounding and has the potential to affect groundwater flow directions and velocities.

Minor spills and/or leakages will migrate downwards and contaminate the unsaturated zone. This contamination will again mobilise during and directly after rainfall events to eventually enter the underlying aquifer and contaminate the groundwater. Once in the groundwater, contamination will migrate laterally in the direction of groundwater flow. Flow velocities for the Matla mine lease area were calculated and discussed in **Section 3.4**. More significant and/or prolonged spills/leakages will follow the route of least resistance downwards through the unsaturated zone and contaminate the underlying groundwater.

Table 5.11: Impact rating decommissioning and closure phase - Groundwater level

Status of impact	Magnitude	Duration	Scale	Probability	Significance
Before mitigation					
-	Minor	Long term	Site only	Definite	Medium (35)
After mitigation					
-	None	None	None	None	Neutral

Table 5.12: Impact rating decommissioning and closure phase - Groundwater quality

Status of impact	Magnitude	Duration	Scale	Probability	Significance
Before mitigation					
-	High	Long term	Local	Definite	High (70)
After mitigation					
-	None	None	None	None	Neutral

Recommended mitigation measures:

Brine ponds should be lined with appropriate liners to prevent any seepage from entering the underlying aquifer and contaminating the groundwater. Dedicated source monitoring boreholes should be in place to timeously detect any contamination breakthroughs.

Appropriate maintenance and regular inspections should keep leakages to a minimum. Clean surface water should not come into contact with dirty water or surface areas contaminated with the brine. Accidental contaminant spills should immediately be cleaned up with the appropriated absorbent substances/materials.

A dedicated geophysical survey should be carried out to confirm the orientation and magnitude of any dykes and fault zones that might occur in the down gradient groundwater flow direction. These geological structures have the potential to act as preferred pathways for any potential contamination.

5.5.2 Decommissioning and closure phase

Potential environmental impact:

During the decommissioning and closure phase all surface infrastructure will be removed and contaminated surface areas rehabilitated. These activities are therefore expected to have a positive impact on groundwater quality and water level conditions.

Table 5.13: Impact rating decommissioning and closure phase - Groundwater level

Status of impact	Magnitude	Duration	Scale	Probability	Significance
Before mitigation					
+	Low	Permanent	Local	Definite	Medium (55)
After mitigation					
+	Low	Permanent	Local	Definite	Medium (55)

Table 5.14: Impact rating decommissioning and closure phase - Groundwater quality

Status of impact	Magnitude	Duration	Scale	Probability	Significance
Before mitigation					
+	Moderate	Permanent	Local	Definite	High (65)
After mitigation					
+	Moderate	Permanent	Local	Definite	High (65)

Recommended mitigation measures:

All infrastructure should be removed from the disturbed land use areas together with potentially hazardous material. Final rehabilitation, including the placement of topsoil and establishment of vegetation on rehabilitated areas should aim to re-establish ambient recharge to the underlying aquifer.

5.6 Groundwater Impacts Associated with the Dirty Water Retaining Facilities

The following aspects were considered during the assessment:

- Dirty water retaining facilities include all pollution control dams, sewage treatment facilities, return water dam, etc.
- These facilities have the potential to affect both groundwater quality and water levels.

5.6.1 Operational phase

Potential environmental impact:

Please note that impacts on groundwater quality and water levels are not expected to occur as long as the facilities are managed according to best practice guidelines and regularly inspected for leakages.

In the unlikely event of mismanagement, continuous leakages will artificially recharge the underlying aquifer, causing groundwater levels directly underneath the facility to increase/rise. This process is better known as groundwater mounding and has the potential to affect groundwater flow directions and velocities.

Minor spills and/or leakages will migrate downwards and contaminate the unsaturated zone. This contamination will again mobilise during and directly after rainfall events to eventually enter the underlying aquifer and contaminate the groundwater. Once in the groundwater, contamination will migrate laterally in the direction of groundwater flow. Flow velocities for the Matla mine lease area were calculated and discussed in **Section 3.4**. More significant and/or prolonged spills/leakages will follow the route of least resistance downwards through the unsaturated zone and contaminate the underlying groundwater.

Table 5.15: Impact rating decommissioning and closure phase - Groundwater level

Status of impact	Magnitude	Duration	Scale	Probability	Significance
Before mitigation					
-	Minor	Long term	Site only	Definite	Medium (35)
After mitigation					
-	None	None	None	None	Neutral

Table 5.16: Impact rating decommissioning and closure phase - Groundwater quality

Status of impact	Magnitude	Duration	Scale	Probability	Significance
Before mitigation					
-	High	Long term	Local	Definite	High (70)
After mitigation					
-	None	None	None	None	Neutral

Recommended mitigation measures:

All water retaining facilities should be lined with appropriate liners to prevent any seepage from entering the underlying aquifer and contaminating the groundwater. Dedicated source monitoring boreholes should be in place to timeously detect any contamination breakthroughs.

Appropriate maintenance and regular inspections should keep leakages to a minimum. Clean surface water should not come into contact with dirty water or contaminated surface areas. Accidental contaminant spills should immediately be cleaned up with the appropriated absorbent substances/materials.

A dedicated geophysical survey should be carried out to confirm the orientation and magnitude of any dykes and fault zones that might occur in the down gradient groundwater flow direction. These geological structures have the potential to act as preferred pathways for any potential contamination.

5.6.2 Decommissioning and closure phase

Potential environmental impact:

During the decommissioning and closure phase all surface infrastructure will be removed and contaminated surface areas rehabilitated. These activities are therefore expected to have a positive impact on groundwater quality and water level conditions.

Table 5.17: Impact rating decommissioning and closure phase - Groundwater level

Status of impact	Magnitude	Duration	Scale	Probability	Significance
Before mitigation					
+	Low	Permanent	Local	Definite	Medium (55)
After mitigation					
+	Low	Permanent	Local	Definite	Medium (55)

Table 5.18: Impact rating decommissioning and closure phase - Groundwater quality

Status of impact	Magnitude	Duration	Scale	Probability	Significance
Before mitigation					
+	Moderate	Permanent	Local	Definite	High (65)
After mitigation					
+	Moderate	Permanent	Local	Definite	High (65)

Recommended mitigation measures:

All infrastructure should be removed from the disturbed land use areas together with potentially hazardous material. Final rehabilitation, including the placement of topsoil and establishment of vegetation on rehabilitated areas should aim to re-establish ambient recharge to the underlying aquifer.

5.7 Groundwater Impacts Associated with the Stockpiling of Coal, Topsoil and Overburden Material

The following aspects were considered during the assessment:

- Stockpiles are dry source areas and leachate formation will only occur during/following a rainfall event.
- The topsoil is relatively inert and any potential leachate is expected to be of reasonably good quality.
- The coal and overburden on the other hand contain metal sulphides (usually pyrite), which in the presence of oxygen and water will oxidise to produce an acidic leachate.
- Stockpiles are not expected to have any adverse impacts on groundwater levels.

5.7.1 Operational phase

Potential environmental impact:

As mentioned above, leachate generated by coal and overburden stockpiles is expected to be acidic and high in sulphate and iron content. Surface water run-off originating from these source areas, toe-seeps and seepage through the base have the potential to contaminate the underlying groundwater should it enter the aquifer.

Table 5.19: Impact rating decommissioning and closure phase - Groundwater quality

Status of impact	Magnitude	Duration	Scale	Probability	Significance
Before mitigation					
-	High	Long term	Local	Definite	High (70)
After mitigation					
-	None	None	None	None	Neutral

Recommended mitigation measures:

Stockpile areas should be lined with the appropriate liners to prevent poor quality leachate from entering the aquifer and contaminating the groundwater. Clean surface water should not come into contact with dirty water or contaminated surface areas.

Dedicated source monitoring boreholes should be in place to timeously detect any contamination breakthroughs.

A dedicated geophysical survey should be carried out to confirm the orientation and magnitude of any dykes and fault zones that might occur in the down gradient groundwater flow direction. These geological structures have the potential to act as preferred pathways for any potential contamination.

5.7.2 Decommissioning and closure phase

Potential environmental impact:

During the decommissioning and closure phase all stockpiles will be removed and contaminated surface areas rehabilitated. These activities are therefore expected to have a positive impact on groundwater quality.

Table 5.20: Impact rating decommissioning and closure phase - Groundwater quality

Status of impact	Magnitude	Duration	Scale	Probability	Significance
Before mitigation					
+	Moderate	Permanent	Local	Definite	High (65)
After mitigation					
+	Moderate	Permanent	Local	Definite	High (65)

Recommended mitigation measures:

All stockpiles should be removed from the disturbed land use areas and contaminated surface areas rehabilitated. Final rehabilitation, including the placement of topsoil and establishment of vegetation on rehabilitated areas should aim to re-establish ambient recharge to the underlying aquifer.

5.8 Groundwater Impacts Associated with the Re-Routing of the Riet Spruit at Mine 3

The following aspects were considered during the assessment:

- Most of the upper reaches of the Riet Spruit are non-perennial and can be classified as a losing stream *(Golder Associates, 2006)*.

Potential environmental impact:

The re-routing of the Rietspruit is expected to have a minor impact on the groundwater levels. Because the Riet Spruit is a losing stream and discharges water into the underlying aquifer (whenever water is present), groundwater levels along the old/original drainage channel can be expected to decrease slightly. On the other hand, groundwater levels are expected to increase along the new drainage channel. The re-routing of the Rietspruit is however not expected to have any impact on the nett groundwater balance.

Table 5.21: Impact rating - Groundwater level

Status of impact	Magnitude	Duration	Scale	Probability	Significance
Before mitigation					
-	Minor	Permanent	Site only	Low	Low (16)
After mitigation					
-	Minor	Permanent	Site only	Low	Low (16)

Recommended mitigation measures:

No mitigation measures are available to prevent/minimise the impact (even though low) on groundwater levels.

6 GROUNDWATER MONITORING PROTOCOL

A total of 42 boreholes are currently included in Matla's groundwater monitoring program and their positions are indicated below in Figure 6.1. The monitoring program does have room for improvement, especially in terms of source monitoring. The conceptual positions of additional monitoring boreholes are also indicated in the abovementioned figure. Short motivations for each of the proposed boreholes are provided in Table 6.1.

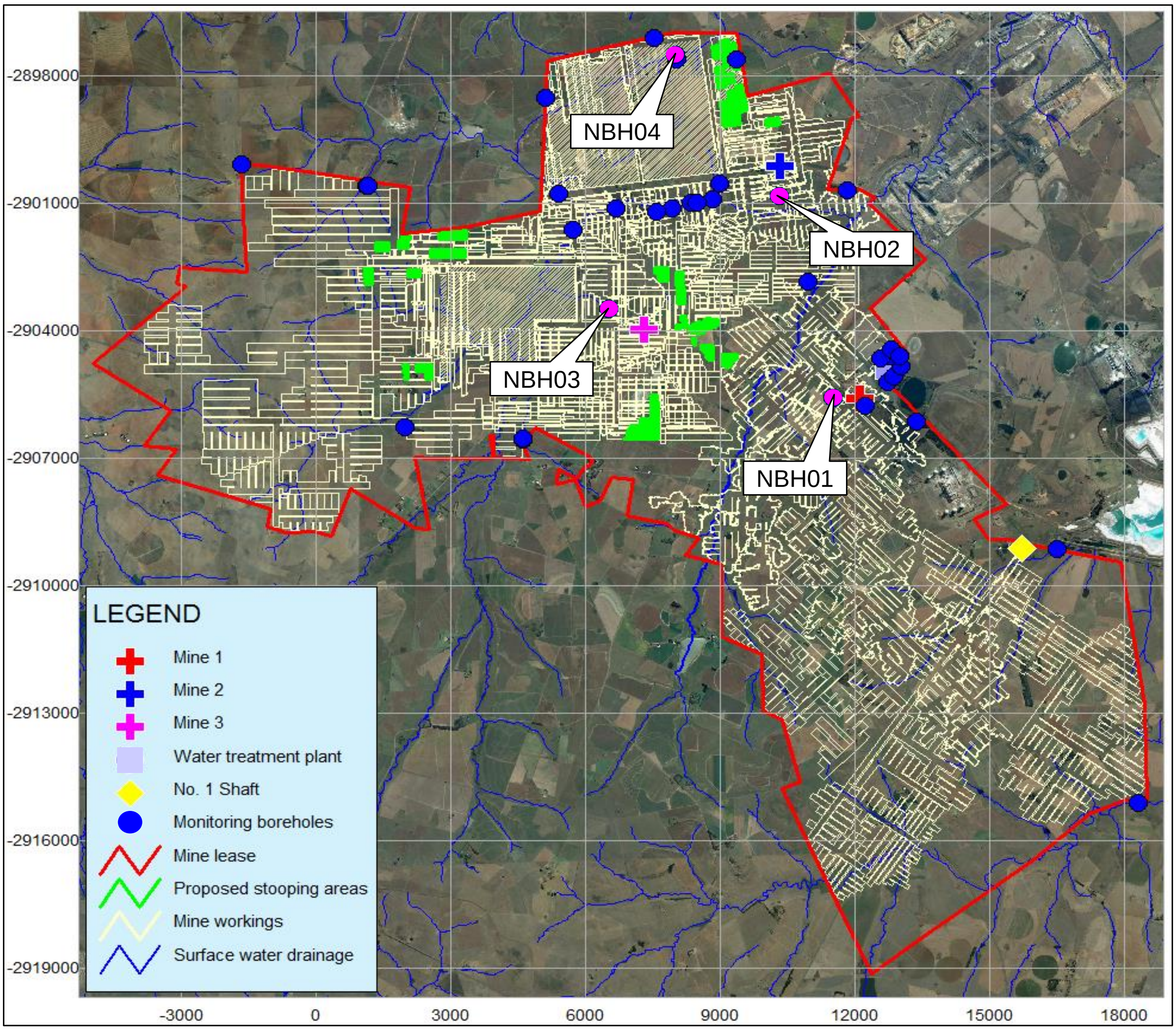

Figure 6.1: Positions of existing and proposed additional groundwater monitoring boreholes

Table 6.1: Motivations for additional source monitoring boreholes

Borehole	Motivation
NBH01	Down gradient from the Mine 1 pollution control dam
NBH02	Down gradient from the Mine 2 pollution control dam
NBH03	Down gradient from the Mine 3 pollution control dam
NBH04	Down gradient from old opencast workings/To replace borehole MGWGF

Groundwater samples are collected at quarterly intervals and analysed for a wide range of chemical and physical parameters, which are considered to be more than sufficient to adequately assess the groundwater quality conditions over the wet and dry seasons. Groundwater levels are measured on a monthly basis, which is also considered to be sufficient (especially since groundwater level monitoring should take priority over groundwater quality monitoring during the operational phase).

Regular revision of the efficiency of the monitoring program by a qualified geohydrologist is recommended. Should the sampling program be changed, it should be done in consultation with the Department of Water and Sanitation (DWS).

The following maintenance activities should be adhered to:

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

The quarterly report should be an update of the database with time-series graphs and statistical analysis (average, maximum, minimum, 5 -, 50 – and 95 percentile values as well as linear performance). Data should also be presented in a map format to present a clear picture of the water quality situation. Laboratory results should be analysed against the target water quality guidelines for domestic use (South African National Standards for drinking water; *SANS 241:2015*).

In terms of flow, all water uses and discharges should be measured on an ongoing basis.

An annual detailed evaluation report on the surface and groundwater quality should be prepared that will analyse the water quality situation in detail to investigate trends and non-compliance.

Monitoring results should be entered into an electronic database as soon as results are available, and at no less than one quarterly interval, allowing:

- Data presentation in tabular format,
- Time-series graphs with comparison abilities,
- Statistical analysis (minimum, maximum, average, percentile values) in tabular format,
- Graphical presentation of statistics,
- Linear trend determination,
- Performance analysis in tabular format,
- Presentation of data, statistics and performance on diagrams and maps, and
- Comparison and compliance to the South African National Standards for drinking water *(SANS 241:2015)*.

As far as possible, the same monitoring points should be used to develop a long data record and enable trend analysis and recognition of progressive impacts with time.

Key Issues:

- *The current sampling frequency and range of chemical and physical parameters are considered to be sufficient.*
- *There are however room for improvement, especially in terms of source monitoring. At least four additional source monitoring boreholes are recommended down gradient from pollution control dams and the old opencast workings.*
- *For as long as the underground mine workings remain sinks, groundwater level monitoring should take priority over groundwater quality monitoring.*
- *Dedicated monitoring of water levels in the abandoned underground mine workings plays a crucial role in the development of an accurate water balance model.*
- *See previous: Diligent water level monitoring at nearest users to proposed stooping areas to detect impacts timeously.*

7 RECOMMENDATIONS

The following recommendations are made:

- The mine should conduct a feasibility study detailing the required dewatering before stooping can commence.
- The monitoring program should be expanded and adhered to.
- Additional work is required to assess the impact of mining on the quality and quantity of base flow to streams.
- A mine wide geochemical assessment and geochemical model should be conducted to guide mine water operational philosophies and closure assessments.
- All the monitoring and hydrocensus information should be compiled into a database and updated as new monitoring information becomes available.
- •A closure water management plan should be developed. This should assess the managed of decant via channelled decant or the management of a critical water level to minimise contamination of the shallow weathered aquifer. The co disposal facility should also be assessed in terms of a remediation action plan should the risk for contaminating on the stream be high. This should all be analysed in a financial model to further inform the most effective closure water management options. The groundwater model should be used as a management tool to inform this process.
- A mine wide numerical flow and contaminant transport should be constructed to assess the cumulative impacts of all the activities on the mine which could impact on groundwater. The Matla Stooping model can be used as a basis. The model should be updated every 2 years.

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9 APPENDIX A: RESULTS OF HYDROCENSUS/USER SURVEYS

Results of hydrocensus/user survey *(GCS, 2006)*

BH	South	East	Elevation (mamsl)	SWL (mbs)	Abstraction (m^3/d)	Comments	Owner
GCSBH01	-26.25976	29.03977	1606	-	Not in use	Water supplied by mine pipeline.	P. Streicher 0825661374
GCSBH02	-26.24791	29.04354	1596	6.9	0.2	Garden use.	C. Erasmus 0828567163
GCSBH03	-26.31995	29.16427	1620	-	5.0	Submersible pump. Livestock watering.	H. Jacobs 0823882207
GCSBH04	-26.32013	29.16554	1583	5.6	Not in use	Not in use.	H. Jacobs 0823882207
GCSBH05	-26.32649	29.16208	1635	-	-	Wind pump.	H. Jacobs 0823882207
GCSBH06	-26.31962	29.15236	1596	-	1.0	Submersible pump. Domestic and livestock watering.	H. Jacobs 0823882207
GCSBH07	-26.31952	29.15170	1598	3.8	Not in use	Replacement for borehole 6. Not in use.	H. Jacobs 0823882207
GCSBH08	-26.31365	29.14893	1609	-	-	Wind pump.	H. Jacobs 0823882207
GCSBH09	-26.31209	29.14460	1608	-	-	Mono pump.	H. Jacobs 0823882207
GCSBH10	-26.20214	29.11383	1591	-	Not in use	Water supplied by Matla Mine. Blocked wind pump.	T. Swartz 0136431807
GCSBH11	-26.19948	29.11280	1586	-	-	Minimal use, periodically dries up.	T. Swartz 0136431807
GCSBH12	-26.29266	29.14649	1612	1.8	-	Rarely used.	N. Boshoff 0835644205
GCSBH13	-26.29362	29.14311	1615	6.1	5.0	Domestic and livestock watering.	N. Boshoff 0835644205
GCSBH14	-26.27620	29.06042	1650	7.0	Not in use	Not in use. Dry. Water for domestic use from mine.	N. de Vos 0823880106
GCSBH15	-26.27510	29.06149	1615	-	Not in use	Not in use. Dry. Old mono pump.	N. de Vos 0823880106
GCSBH16	-26.27796	29.07397	1621	-	Not in use	Wind pump. Not in use.	N. de Vos 0823880106
GCSBH17	-26.27762	29.05976	1615	-	Not in use	Borehole never used.	N. de Vos 0823880106
GCSBH18	-26.27765	29.05998	1611	-	-	Garden use.	N. de Vos 0823880106
GCSBH19	-26.29415	29.15514	1598	-	-	Submersible pump. Domestic and livestock watering.	H. Jacobs 0823882207
GCSBH20	-26.28150	29.08670	1613	-	5.0	Submersible pump.	Robertson 0176484012
GCSBH21	-26.28972	29.07111	1605	-	Not in use	Borehole blocked.	Booysen
GCSBH22	-26.31472	29.07583	1627	-	-	Wind pump.	J.C. Bezuidenhout
GCSBH23	-26.31380	29.07961	1614	-	-	Wind pump. Livestock watering.	J.C. Bezuidenhout
GCSBH24	-26.31287	29.08821	1617	18.0	-	Submersible pump.	J.C. Bezuidenhout
GCSBH25	-26.32277	29.07472	1615	2.4	-	Submersible pump.	Unknown

BH	South	East	Elevation (mamsl)	SWL (mbs)	Abstraction (m^3/d)	Comments	Owner
GCSBH26	-26.28005	29.04879	1607	29	-	Submersible pump.	J.C. Bezuidenhout
GCSBH27	-26.25015	29.12470	1610	-	-	Old wind pump.	A.J. Cronje 0176484235
GCSBH28	-26.25010	29.12478	1612	9	-	Not in use.	A.J. Cronje 0176484235
GCSBH29	-26.30592	28.94783	1588	-	-	Mono pump. Bad taste to water. Domestic and livestock watering.	JBR Cameron 0828247684
GCSBH30	-26.30410	28.94768	1587	-	-	Mono pump. Bad taste to water. Domestic and livestock watering.	JBR Cameron 0828247684
GCSBH31	-26.25526	29.15108	1592	1.6	72	Domestic and livestock watering.	A. Cronje 0824571875
GCSBH32	-26.25319	29.12773	1627	-	-	Used for crop spraying.	A. Cronje 0824571875
GCSBH33	-26.27118	28.95761	1585	16	-	Submersible pump. Irrigation and livestock watering.	F.C Truter 0176831602
GCSBH34	-26.27054	28.95699	1588	-	5	Mono pump.	F.C Truter 0176831602
GCSBH35	-26.27009	28.95622	1615	-	-	Mono pump.	F.C Truter 0176831602
GCSBH36	-26.26962	28.95256	1592	-	-	Wind pump. Domestic use.	F.C Truter 0176831602
GCSBH37	-26.27019	28.94840	1562	-	-	Wind pump. Domestic use.	F.C Truter 0176831602
GCSBH38	-26.26975	28.95012	1580	-	-	Wind pump. Domestic use.	F.C Truter 0176831602
GCSBH39	-26.25933	29.01609	1617	23	-	Wind pump. Domestic use and garden.	J.J Venter 0824439284
GCSBH40	-26.26178	29.01731	1614	-	-	Submersible pump. Livestock watering.	J.J Venter 0824439284
GCSBH41	-26.01686	29.01686	1619	-	-	Submersible pump. Livestock watering.	J.J Venter 0824439284
GCSBH42	-26.26049	29.02060	1606	31	-	Submersible pump. Livestock watering.	J.J Venter 0824439284
GCSBH43	-26.24525	29.01450	1620	-	-	Wind pump. Livestock watering.	J.J Venter 0824439284
GCSBH44	-26.25444	29.00618	1622	-	-	Wind pump.	J.J Venter 0824439284
GCSBH45	-26.26474	29.00945	1618	-	-	Wind pump.	J.J Venter 0824439284

Note: *mamsl - Meters above mean sea level,*

mbs - Meters below surface,

SWL - Static water level.

Results of hydrocensus/user survey *(Groundwater Square, 2008)*

BH	X	Y	Elevation (mamsl)	Owner	Depth (m)	SWL (mbs)	Yield (l/s)	Comments
MF-01	15 183	-2 909 400	1590	Mr JH Jacobs	6	-	-	Bricked-up fountain.
M-01	16 401	-2 912 288	1611	Mr JH Jacobs	120	8.2	0.6	Large stock = 250, G = 1, drilled 1993-1994, Yield summer 1.11 l/s, winter 0.14 l/s, reservoir 10 x 1.8m.
M-02	16 543	-2 912 318	1611	Mr JH Jacobs	80	9.1	0.2	Large stock = 250, G = 1, drilled 2003, yield summer 1.11 l/s, winter 0.14 l/s.
M-03	16 770	-2 912 596	1615	Mr JH Jacobs	-	19	-	Will install windmill at later stage.
M-04	17 908	-2 912 476	1603	Mr JH Jacobs	-	4.1	-	Windmill broken.
M-05	16 200	-2 913 026	1624	Mr JH Jacobs	-	-	-	More than 12 years old, reservoir 6 x 1.5m.
M-06	15 282	-2 912 389	1599	Mr JH Jacobs	120	7.8	0.4	M-06 & M-07 are connected pump into same tank, use 5000l/day.
M-07	15 217	-2 912 249	1599	Mr JH Jacobs	41	3	0.6	2 Years old, two 5000l tanks.
M-08	15 152	-2 912 253	1600	Mr JH Jacobs	41	3.5	0.6	Backup borehole, older than 12 years.
M-09	15 977	-2 912 078	1604	Mr JH Jacobs	120	10	0.4	Backup borehole, drilled 1993-1994.
M-10	15 856	-2 911 948	1601	Mr JH Jacobs	100	5.5	0.1	Backup borehole.
M-11	14 877	-2 911 586	1598	Mr JH Jacobs	70	-	0.2	3 x 5000l tanks + cement irrigation dam 10 x 1.6m.
M-12	14 442	-2 911 413	1596	Mr JH Jacobs	120	8.3	0.5	Not in use.
M-13	13 666	-2 912 197	1602	Mr JH Jacobs	25	8.1	2.2	Mined drilled rescue bay, too much water intersected to commission.
M-14	15 564	-2 910 055	1578	Mr JH Jacobs	-	3.2	-	Broken hand pump.
M-15	15 495	-2 909 436	1585	Mr JH Jacobs	120	24	0.1	Potability deteriorated to undrinkable.
M-16	15 409	-2 909 343	1599	Mr JH Jacobs	60	-	0.2	Not in use.
M-17	10 210	-2 903 955	1585	Mr E Muller	-	-	-	Not in use.
M-18	10 197	-2 902 887	1586	Mr E Muller	-	-	-	Area undermined, dewatered, mine supplies farm with water.
M-19	9 238	-2 903 448	1590	Mr E Muller	-	2.1	-	Windmill broken.
M-20	11 607	-2 907 173	1602	Mr E Muller	-	6.1	-	Broken, water supplied by mine.
M-21	14 362	-2 909 620	1600	Mr E Muller	-	1	-	5000l tank.
M-22	6 207	-2 907 373	1616	Mr F de Vos	35	5.3	-	Not in use since last year, less than 0.14 l/s, 5000l reservoir, pipeline from mine.
M-23	6 293	-2 907 584	1618	Mr F de Vos	20	3.3	0.1	Weak pump 5 minutes then dry.
M-24	7 098	-2 907 514	1628	Mr F de Vos	-	1.7	-	Broken
M-25	7 914	-2 908 662	1618	Mr F de Vos	40	27	0.2	Pumping water level, 5000l tank.
M-26	9 399	-2 905 717	1600	Mr F de Vos	20	9.6	-	5000l tank.
M-27	9 640	-2 905 274	1590	Mr F de Vos	-	46	-	Not in use.
M-28	13 059	-2 915 053	1606	Mr F de Vos	-	8	0.6	5000l tank + 2 cement dams 1.6 x 9m.
M-29	13 265	-2 916 660	1575	Mr F de Vos	30	-	0.4	5000l tank, sample taken at 13:45, pumped.
M-30	14 091	-2 915 393	1605	Mr F de Vos	-	-	0.4	2 x 5000l tanks, 0.75 Kw Franklin motor.
M-31	16 248	-2 915 020	1602	Mr F de Vos	-	5.8	-	Broken windmill.
M-32	16 322	-2 914 336	1605	Mr F de Vos	40	1.7	0.7	5000l tank, 0.75 Kw Franklin motor.

BH	X	Y	Elevation (mamsl)	Owner	Depth (m)	SWL (mbs)	Yield (l/s)	Comments
M-33	16 561	-2 914 203	1607	Mr F de Vos	20	4.8	0.3	5000l tank, 0.75 Kw Franklin motor.
M-34	17 469	-2 914 167	1605	Mr F de Vos	-	5.4	-	Broken hand pump, drilled 19690321.
M-35	18 039	-2 913 900	1693	Mr F de Vos	-	6.4	-	Sample taken at 14:25, pumped.
M-36	18 452	-2 913 609	1593	Mr F de Vos	50	36	0.3	Backup for cattle, 10 x 1.6m cement reservoir.
M-37	12 744	-2 915 380	1597	Mr Barnard	25	8.6	1.4	Use 10000 l/day, borehole registered, 5000l tank, 12 years old.
M-38	12 731	-2 915 343	1597	Mr Barnard	25	12	1.4	Use 5000 l/day, borehole registered, 5000l tank, 12 years old.
M-39	7 582	-2 911 700	1618	Mr J Bezuidenhout	120	23	3.3	Borehole registered, small earth dam, pumping water level.
M-40	4 073	-2 905 677	1605	Mr CJH Erasmus	-	6.8	-	Poor potability, undrinkable 5 years ago, are undermined, water supply by mine.
M-41	7 942	-2 911 620	1610	Mr J Bezuidenhout	120	-	3.3	Unable to measure water level, borehole closed, in cattle kraal.
M-42	8 571	-2 911 218	1604	Mr J Bezuidenhout	120	12	12.8	Use 15000l/day, irrigate 1400 hectares, pivot run on water from registered dam.
M-43	8 809	-2 911 491	1609	Mr J Bezuidenhout	55	-	10.0	Sample taken at 11:20, pumped.
M-44	4 849	-2 902 649	1600	Mr FC Truter	-	-	-	Dry, dewatered, undermined, water supply by mine.
M-50	11 150	-2 911 372	1641	Mr B Roux	-	-	-	Other contact numbers 0860109116, 011 539 2686.
M-51	11 240	-2 911 450	1640	Mr B Roux	-	21	-	-
M-52	11 823	-2 910 983	1642	Mr B Roux	-	-	-	-
M-53	11 830	-2 912 186	1643	Mr B Roux	-	-	-	-
M-54	11 977	-2 911 505	1642	Mr B Roux	-	-	-	-
M-55	11 801	-2 913 687	1645	Mr B Roux	-	14	-	-
M-56	1 848	-2 908 510	1620	Mr M Erasmus	-	18	-	-
M-57	1 874	-2 908 235	1623	Mr M Erasmus	-	14	-	-
M-58	1 439	-2 908 762	1621	Mr M Erasmus	-	-	-	-
M-59	21 311	-2 915 400	1561	Mr F de Vos	60	23	0.8	10 People
M-60	20 797	-2 914 305	1559	Mr F de Vos	70	-	0.1	10 People
M-61	21 681	-2 913 908	1560	Mr F de Vos	-	-	0.3	Broken windmill.
M-62	19 230	-2 913 267	1584	Mr F de Vos	-	6.9	0.2	Broken windmill.
M-63	20 694	-2 911 152	1587	ESCOM	8	-	0.2	Borehole blocked.
M-64	20 682	-2 911 770	1598	ESCOM	32	14	0.1	-
M-65	20 631	-2 912 094	1598	ESCOM	35	3.6	0.2	Between two dams.
M-66	20 644	-2 912 181	1598	ESCOM	-	-	0.3	-
M-67	20 612	-2 911 863	1598	ESCOM	60	16	0.1	5 People and 1 garden.
M-68	18 905	-2 911 160	1585	ESCOM	-	-	0.5	500 Large stock.

Note: *mamsl - Meters above mean sea level,*

mbs - Meters below surface,

SWL - Static water level.

Results of hydrocensus/user survey *(Golder, 2011)*

BH	Coordinates		Elevation	SWL	BH depth	Pump type	Yield	Use	Owner
	X	Y	(mamsl)	(mbs)	(m)		(l/h)		
ERAS3	4096	-2905383	1612	6.3	8	No Pump	Not known	Not in use	Mr C Erasmus
HJFV11	-972	-2905863	1613	3.8	100	Wind Pump	Not known	Domestic and Cattle	Mr H Venter
HJFV2	2089	-2905394		5.5	100	Submersible	Not known	Not in use	Mr H Venter
HJFV4	-1734	-2905214		13.2	100	Wind Pump	Not known	Not in use	Mr H Venter
HJFV5	1709	-2905310	1626	8.6	100	Submersible	3000	Domestic and Cattle	Mr H Venter
HJFV8	-1085	-2905095		0.9	100	Wind Pump	Not known	Not in use	Mr H Venter
M-01	16427	-2911995	1614	7.7	120	Submersible	Not known	Domestic, Cattle, Sheep	Mr H Jacobs
M-02	16568	-2912022	1615	6.2	120	Submersible	Not known	Domestic, Cattle, Sheep	Mr H Jacobs
M-03	16328	-2912160	1627	3.4	120	No Pump	Not known	Not in use	Mr H Jacobs
M-05	16228	-2912730	1639		Not known	Wind Pump	Not known	Cattle	Mr H Jacobs
M-06	15333	-2912070	1608	8.4	60	Submersible	Not known	Domestic, Cattle, Sheep	Mr H Jacobs
M-07	15239	-2911956	1605	3.1	30	Submersible	Not known	Domestic, Cattle, Sheep	Mr H Jacobs
M-100	-4408	-2908857	1620	3.0	30	Submersible	6500	Domestic	Mr A De Villiers
M-101	-4385	-2908918	1618	4.1	30	Submersible	10000	Cattle in Winter and mixing of poison for Crops	Mr A De Villiers
M-102	-4403	-2908942	1621		20	Both Wind pump and Submersible	5000	Cattle in Winter and mixing of poison for Crops	Mr A De Villiers
M-103	4656	-2908513	1621		45	Submersible	5000	Domestic	Mr A De Villiers
M-104	4968	-2909893	1637	2.8	Not known	Submersible	10000	Domestic and Piggery	Mr P Streicher
M-105	-4195	-2906592	1593	13.8	Not known	Submersible	Not known	Not in use	Mr C Nel
M-106	-4346	-2906472	1598	17.2	32	Submersible	Not known	Domestic	Mr C Nel
M-107	-4274	-2906518	1605		Not known	Mono pump	Not known	Domestic	Mr C Nel
M-108	15120	-2904826	1597	1.4	Not known	Submersible	Not known	Domestic	Mr D Cronje
M-109	12479	-2904247	1622		Not known	Wind Pump	Not known	Not in use	Mr D Cronje
M-11	14902	-2911294	1609	2.8	10	Both Wind pump and Submersible	Not known	Domestic and Cattle	Mr H Jacobs
M-110	9936	-2897080	1613		Not known	Wind Pump	Not known	Not in use	Mr A van Niekerk
M-110	13209	-2902802	1599	0.5	100	Submersible	Not known	Not in use	Mr A van Niekerk

BH	Coordinates		Elevation	SWL	BH depth	Pump type	Yield	Use	Owner
	X	Y	(mamsl)	(mbs)	(m)		(l/h)		
M-111	9541	-2895953	1629		Not known	Wind Pump	Not known	Not in use	Mr A van Niekerk
M-112	-3304	-2908348	1606	5.6	50	Wind Pump	Not known	Cattle	Mr J Cameron
M-113	-2089	-2907400	1645	49.7	100	Submersible	1500	Domestic and Cattle	Mr J Cameron
M-114	-178	-2908444	1634	7.4	50	Submersible	2000	Domestic	Mr J Cameron
M-115	18	-2908585	1646	6.6	50	Submersible	2000	Not in use	Mr J Cameron
M-116	-769	-2908707	1651	9.0	50	Submersible	2000	Domestic	Mr J Cameron
M-117	-1004	-2908708	1647	5.7	50	Submersible	1500	Not in use	Mr J Cameron
M-118	-493	-2907420	1622	0.4	50	Submersible	2000	Domestic and Cattle	Mr J Cameron
M-119	-600	-2907424	1631	4.1	50	Submersible	2000	Domestic and Cattle	Mr J Cameron
M-12	14469	-2911114	1605	7.2	20	Wind Pump	Not known	Not in use	Mr H Jacobs
M-120	-681	-2907379	1634	2.8	50	Submersible	2000	Not in use	Mr J Cameron
M-121	-1093	-2900056	1613	3.5	25	No Pump	Not known	Not in use	Mr J Cameron
M-122	-41	-2901838	1628	4.7	50	Wind Pump	2000	Not in use	Mr J Cameron
M-123	-1067	-2901541	1637	5.4	50	Submersible	2000	Domestic	Mr J Cameron
M-124	-400	-2900400	1626			Wind Pump	Not known	Cattle	Mr J Cameron
M-125	-927	-2899520	1628			Wind Pump	Not known	Cattle	Mr J Cameron
M-126	-4585	-2911076	1612	6.9	50	Submersible	2000	Poultry farm	Mr J Cameron
M-127	-4709	-2911093	1611	6.9	50	Submersible	2000	Poultry farm	Mr J Cameron
M-128	-4625	-2911025	1615		50	Wind Pump	1500	Domestic	Mr J Cameron
M-129	-4004	-2912375			50	Wind Pump	1500	Domestic	Mr J Cameron
M-130	-3739	-2912638	1660		50	Wind Pump	1500	Cattle	Mr J Cameron
M-131	-4564	-2912559	1625		50	Mono pump	2000	Poultry farm	Mr J Cameron
M-132	-4258	-2907886	1587	1.6	50	Wind Pump	1500	Cattle	Mr J Cameron
M-133	-3124	-2907518			50	Wind Pump	1500	Cattle	Mr J Cameron
M-134	-5200	-2910239	1598	20.4	50	Mono pump	2000	Domestic	Mr J Cameron
M-135	-5186	-2910430	1601	7.2	50	Submersible	2000	Domestic	Mr J Cameron

BH	Coordinates		Elevation	SWL	BH depth	Pump type	Yield	Use	Owner
	X	Y	(mamsl)	(mbs)	(m)		(l/h)		
M-136	-3646	-2910406	1605		50	Wind Pump	Not known	Cattle	Mr J Cameron
M-137	-2137	-2906559	1631		50	No Pump	Not known	Not in use	Mr J Cameron
M-138	-317	-2906426	1632		50	Mono pump	Not known	Not in use	Mr J Cameron
M-15	15523	-2909141	1600	5.9	60	No Pump	Not known	Not in use	Mr H Jacobs
M-16	15344	-2908964							Mr H Jacobs
M-17	10231	-2903657	1596		Not known	Mono pump	Not known	Not in use	Mr E Muller
M-18	10213	-2902590	1590		Not known	Mono pump	Not known	Not in use	Mr E Muller
M-19	9270	-2903143	1598	0.9	Not known	Wind Pump	Not known	Not in use	Mr E Muller
M-21	14320	-2909077	1626	2.6	Not known	Submersible	Not known	Domestic and Cattle	Mr N Boshoff
M-22	6234	-2907071	1615	2.2	Not known	Submersible	Not known	Cattle	Mr N De Vos
M-23	6311	-2907286	1627	2.5	Not known	Submersible	Not known	Domestic	Mr N De Vos
M-24	7124	-2907222	1641	1.9	20	No Pump	Not known	Not in use	Mr N De Vos
M-25	7947	-2908361	1628	30.9	Not known	Submersible	Not known	Domestic	Mr N De Vos
M-26	9432	-2905423	1608	4.1	Not known	Submersible	Not known	Domestic	Mr N De Vos
M-27	9665	-2904959	1611	16.1	35	No Pump	Not known	Not in use	Mr N De Vos
M-28	13085	-2914757	1628	6.8	30	Submersible	Not known	Domestic	Mr N De Vos
M-29	13297	-2916361	1582	4.9	Not known	Submersible	Not known	Domestic	Mr N De Vos
M-30	14113	-2915079	1619	7.1	Not known	Submersible	Not known	Domestic	Mr N De Vos
M-31	16271	-2914722	1621	3.8	Not known	Wind Pump	Not known	Not in use	Mr N De Vos
M-32	16347	-2914034	1613	11.8	Not known	Submersible	Not known	Domestic	Mr N De Vos
M-33	16599	-2913902	1624	2.7	Not known	Submersible	Not known	Domestic	Mr N De Vos
M-36	18481	-2913321	1600	26.0	35	Wind Pump	Not known	Not in use	Mr N De Vos
M-37	12771	-2915084	1606	6.8	Not known	Mono Pump	12000	Domestic, Sheep	Mr Barnard
M-38	12759	-2915035	1601	9.7	Not known	Submersible	1200	Domestic, Sheep	Mr Barnard
M-42	86065	-2910910		1.4	120	Submersible	40000		Mr J Bezuidenhout
M-43	8831	-2911194	1597	38.8	50	Submersible	36000	Domestic, Cattle	Mr J Bezuidenhout

BH	Coordinates		Elevation	SWL	BH depth	Pump type	Yield	Use	Owner
	X	Y	(mamsl)	(mbs)	(m)		(l/h)		
M-45	10115	-2913590	1590	3.6	Not known	Submersible	6000	Domestic, Sheep	Mr Barnard
M-50	11171	-2911077	1688	6.1	80	Submersible	Not known	Domestic and Cattle	Mr B Roux
M-51	11263	-2911149	1663	4.9	80	Submersible	Not known	Domestic and Cattle	Mr B Roux
M-52	11856	-2910678			20	Hand Pump	Not known	Domestic	Mr B Roux
M-53	11864	-2911886			20	Hand Pump	Not known	Domestic	Mr B Roux
M-54	12016	-2911337	1659	3.9	12	Wind Pump	Not known	Cattle	Mr B Roux
M-55	11831	-2913373	1666	11.6	20	Submersible	Not known	Domestic and Cattle	Mr B Roux
M-56	1900	-2907936	1627	19.2	Not known	Submersible	Not known	Domestic	Mr M Erasmus
M-57	1874	-2908216	1622	0.0	Not known	Submersible	Not known	Domestic	Mr M Erasmus
M-58	1506	-2895170	1618	15.1	100	Submersible	Not known	Domestic	Mr M Erasmus
M-59	21310	-2915161	1567	10.4	40	No Pump	Not known	Not in use	Mr N De Vos
M-61	21676	-2913670	1578	9.2	20	Wind Pump	Not known	Not in use	Mr N De Vos
M-69	545	-2910405	1618	7.4	100.00	Submersible	Not known	Domestic and Horses	Mr P Streicher
M-70	375	-2910441	1618	8.2	Not known	Submersible	Not known	Domestic and Horses	Mr P Streicher
M-71	-785	-2910591			Not known	Submersible	Not known	Domestic	Mr P Streicher
M-72	-1162	-2905373	1635	1.1	40	Submersible	2000	Domestic	Mr H Venter
M-73	4027	-2901101	1613	18.5	60	No Pump	Not known	Not in use	Mr C Erasmus
M-74	4234	-2900154	1605	7.8	30	Submersible	1500	Domestic	Mr C Erasmus
M-74B	3896	-2899856			30	Wind Pump	Not known	Cattle	Mr C Erasmus
M-74C	3666	-2899840			30	Submersible	Not known	Domestic	Mr C Erasmus
M-75	3131	-2908354	1615	3.8	10	No Pump	Not known	Not in use	Mr C Erasmus
M-76	3239	-2907722	1610	2.6	14	No Pump	10000	Not in use	Mr C Erasmus
M-77	2573	-2907738	1611	0.0	80	No Pump	Not known	Not in use	Mr C Erasmus
M-78	12026	-2913541	1659	9.1	30	Submersible	Not known	Not in use	Mr B Roux
M-79	11697	-2913398	1665	4.7	12	No Pump	Not known	Not in use	Mr B Roux
M-80	383	-2910934		2.5	5	No Pump	Not known	Not in use	Mr P Streicher

BH	Coordinates		Elevation	SWL	BH depth	Pump type	Yield	Use	Owner
	X	Y	(mamsl)	(mbs)	(m)		(l/h)		
M-81	10786	-2911668	1651		Not known	Wind Pump	Not known	Not in use	Mr B Roux
M-81B	10769	-2911779	1649	1.1	5	No Pump	Not known	Not in use	Mr B Roux
M-82	11311	-2896884	1610	16.6	85	Submersible	4500	Domestic, Cattle and Sheep	Mr C Boshoff
M-83	11327	-2896843	1612	4.4	85	No Pump	Not known	Not in use	Mr C Boshoff
M-84	11216	-2897020	1603	6.5	45	Submersible	Not known	Garden and Earthworm Farm	Mr C Boshoff
M-85	11108	-2897251	1594	15.4	78	No Pump	Not known	Not in use	Mr C Boshoff
M-86	20290	-2917075	1585	2.6	Not known	Hand Pump	Not known	Not in use	Mr N De Vos
M-87	20614	-2917006	1581	3.1	6	No Pump	Not known	Not in use	Mr N De Vos
M-88	18906	-2910924	1593	3.4	30	Wind Pump	Not known	Not in use	Mr N De Vos
M-89	19401	-2911961	1614	1.7	2.5	No Pump	Not known	Not in use	Mr N De Vos
M-91	11877	-2900550	1612	19.4	35	Submersible	Not known	Domestic	Mr A van Niekerk
M-92	12089	-2900372	1614	6.3	30	Wind Pump	Not known	Not in use	Mr A van Niekerk
M-93	15250	-2914253	1612	1.1	Not known	Wind Pump	Not known	Not in use	Mr N De Vos
M-94	7887	-2908297	1626	3.3	Not known	Hand Pump	Not known	Not in use	Mr N De Vos
M-95	10032	-2897773	1603	2.4	Not known	Submersible	Not known	Domestic	Mr A van Niekerk
M-96	11303	-2898633	1598	0.2	Not known	Wind Pump	Not known	Not in use	Mr T Swartz
M-97	11420	-2898931	1595		Not known	Wind Pump	Not known	Not in use	Mr T Swartz
M-98	-2532	-2904112	1608	0.0	Not known	Submersible	Not known	Domestic, Cattle & Horses	Mr P Streicher
M-99	-2174	-2903797	1621	12.2	Not known	Submersible	Not known	Domestic, Cattle & Horses	Mr P Streicher
ZDF-10	3913	-2901419	1616	95.0	115	No Pump	Not known	Not in use	Anglo
ZDF-10B	3907	-2901421			Not known	No Pump	Not known	Not in use	Anglo
ZDF-12	9211	-2896802	1607		85	No Pump	Not known	Not in use	

Note: *mamsl - Meters above mean sea level,*

mbs - Meters below surface,

SWL - Static water level.

Results of hydrocensus/user survey *(GCS, 2014)*

BH ID	Coordinates & Elevation			Borehole Construction Information				Static Water Level		Borehole Status & Water Application Information					Owner / Village
	Coordinates		Elevation	Borehole Depth	Casing Diameter	Screen/Perforated Casing Length	Reference Level Height	Static Water Level		Status	Water Application				
	Easting	Northing									Domestic	Livestock	Irrigation	None	
	[m]	[m]	[m aMSL]	[m]	[m]	[m]	[m aGL]	[m bGL]	[m aMSL]						
BKL2	14390	-2909326	1602	Unknown	Unknown	Unknown	0.12	1.63	1600.37	Submersible	x	x	-	-	Bakenlaagte: Mr. E. Muller
M-24	7127	-2907219	1632	3	Unknown	Unknown	0.22	1.72	1630.28	Open	-	-	-	x	Grootpan: Me. N. de Vos
MDVL8	1290	-2908894	1619	Unknown	Unknown	Unknown	0.7	2.03	1616.97	Handpump	x	-	-	-	Moedverloren: Mr. M. Erasmus
KRTL3	1087	-2905096	1628	Unknown	Unknown	Unknown	0.04	2.43	1625.57	Open	-	-	-	x	Kortlaagte
ZGFN1	13189	-2923237	1644	Unknown	Unknown	Unknown	0.25	2.48	1641.52	Submersible	x	x	x	-	Kruisementfontein: Me. N. de Vos
HFTN2	10576	-2908097	1615	5	Unknown	Unknown	0.14	2.66	1612.34	Open	-	-	-	x	Haasfontein
KRTL6	1913	-2905326	1619	50	Unknown	Unknown	0.52	3.1	1615.9	Windmill	-	x	-	-	Kortlaagte
HFTN1	10367	-2907852	1611	Unknown	Unknown	Unknown	Surface	3.17	1607.83	Submersible	x	-	-		Haasfontein
MDVL9	1173	-2908765	1624	Unknown	Unknown	Unknown	0.13	3.78	1620.35	Submersible	x	-	-	-	Moedverloren: Mr. M. Erasmus
NdV1	16057	-2920835	1622	12	Unknown	Unknown	0.3	3.98	1618.02	Submersible	x	x	x	-	Onverwacht: Me. N. de Vos
VPN1	4967	-2909893	1637	Unknown	Unknown	Unknown	0.27	4.17	1632.83	Submersible	x	x	-	-	Vlakpan: Mr. P. Streicher
M-31	16277	-2914721	1611	Unknown	Unknown	Unknown	0.38	4.25	1606.75	Windmill	-	-	-	x	Kruisementfontein: Me. N. de Vos
HFTN4	11252	-2908433	1615	10	Unknown	Unknown	0.21	4.46	1610.54	Open	-	-	-	x	Haasfontein: Mr. J. Bezuidenhout
M-23	6322	-2907286	1623	6	Unknown	Unknown	0.22	4.72	1618.28	Submersible	x	x	-	-	Grootpan: Me. N. de Vos
VBK1	10112	-2917357	1589	Unknown	Unknown	Unknown	0.6	4.9	1584.1	Submersible	x	-	-	-	Vaalbank: Mr. J. Barnard
GRP1	8688	-2907731	1607	8	Unknown	Unknown	0.06	5.11	1601.89	Open	-	-	-	x	Grootpan
HJFV2	2090	-2905395	1615	80	Unknown	Unknown	0.38	5.4	1609.6	Submersible	-	-	-	x	Kortlaagte
HFTN3	11314	-2908645	1616	8	Unknown	Unknown	Surface	5.42	1610.58	Open	-	-	-	x	Haasfontein: Mr. J. Bezuidenhout
SHL3	-1663	-2900312	1639	7	Unknown	Unknown	0.23	5.46	1633.54	Open	-	-	-	x	Strehla: Mr. M. Erasmus
M-53	11854	-2911890	1653	Unknown	Unknown	Unknown	0.11	5.96	1647.04	Handpump	x	-	-	-	Nooitgedacht: Mr. B. Roux

BH ID	Coordinates & Elevation			Borehole Construction Information				Static Water Level		Borehole Status & Water Application Information					Owner / Village
	Coordinates		Elevation	Borehole Depth	Casing Diameter	Screen/Perforated Casing Length	Reference Level Height	Static Water Level		Status	Water Application				
	Easting	Northing									Domestic	Livestock	Irrigation	None	
	[m]	[m]	[m aMSL]	[m]	[m]	[m]	[m aGL]	[m bGL]	[m aMSL]						
M-37	12770	-2915080	1606	Unknown	Unknown	Unknown	0.3	6.01	1599.99	Submersible	x	x	-	-	Onverwacht: Mr. J. Barnard
M-32	16348	-2914032	1608	Unknown	Unknown	Unknown	0.26	7.89	1600.11	Submersible	x	x	x	-	Kruisementfontein: Me. N. de Vos
MDVL3	-345	-2910278	1625	Unknown	Unknown	Unknown	0.28	8.03	1616.97	Submersible	x	-	-	-	Moedverloren: Mr. P. Streicher
M-72	-1161	-2905377	1634	24	Unknown	Unknown	0.2	9.18	1624.82	Submersible	x	x	x	-	Kortlaagte
M-28	13089	-2914756	1614	Unknown	Unknown	Unknown	0.06	10.54	1603.46	Submersible	x	x	x	-	Onverwacht: Me. N. de Vos
SKL1	8837	-2911197	1617	Unknown	Unknown	Unknown	0.3	12.18	1604.82	Submersible	x	-	x	-	Schaapkraal: Mr. B. Roux
M-69	544	-2910405	1617	Unknown	Unknown	Unknown	GL	12.3	1604.7	Submersible	x	x	x	-	Moedverloren: Mr. P. Streicher
M-55	11832	-2913376	1656	Unknown	Unknown	Unknown	0.29	13.87	1642.13	Submersible	x	-	x	-	Nooitgedacht: Mr. B. Roux
M-70	373	-2910441	1620	Unknown	Unknown	Unknown	0.21	14.24	1605.76	Submersible	x	-	x	-	Moedverloren: Mr. P. Streicher
HJFV5	1713	-2905307	1621	36	Unknown	Unknown	Surface	14.29	1606.71	Submersible	x	-	x	-	Kortlaagte
M-98	-2528	-2904111	1606	16	Unknown	Unknown	GL	15	1591	Submersible	x	x	-	-	Kortlaagte: Mr. P. Streicher
M-57	1875	-2908218	1623	45	Unknown	Unknown	0.21	15.63	1607.37	Open	-	-	-	x	Moedverloren: Mr. M. Erasmus
M-56	1898	-2907932	1631	Unknown	Unknown	Unknown	0.26	18.77	1612.23	Submersible	-	x	-	-	Moedverloren: Mr. M. Erasmus
GRP4	7419	-2907329	1631	26	Unknown	Unknown	0.58	22.49	1608.51	Open	-	-	-	x	Grootpan: Me. N. de Vos
BKL1	14492	-2909335	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Blocked	-	-	-	x	Bakenlaagte: Mr. E. Muller
GRP2	6201	-2907134	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Open	-	-	-	x	Grootpan: Me. N. de Vos
GRP3	5877	-2904965	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Mono pump	-	-	-	x	Grootpan: Me. N. de Vos
GRP5	10746	-2904743	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Windmill	-	-	-	x	Grootpan: Me. N. de Vos
KRTL1	1757	-2905537	Unknown	Unknown	Unknown	Unknown	0.19	NM	NM	Blocked	-	-	-	x	Kortlaagte
KRTL10	2246	-2905210	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Blocked	-	-	-	-	Kortlaagte: Mr. J. Venter

BH ID	Coordinates & Elevation			Borehole Construction Information				Static Water Level		Borehole Status & Water Application Information					Owner / Village
	Coordinates		Elevation	Borehole Depth	Casing Diameter	Screen/Perforated Casing Length	Reference Level Height	Static Water Level		Status	Water Application				
	Easting	Northing									Domestic	Livestock	Irrigation	None	
	[m]	[m]	[m aMSL]	[m]	[m]	[m]	[m aGL]	[m bGL]	[m aMSL]						
KRTL11	2539	-2902082	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Open	-	-	-	-	Kortlaagte: Mr. J. Venter
KRTL2	1485	-2903706	Unknown	Unknown	Unknown	Unknown	0.07	NM	NM	Windmill	-	x	x	-	Kortlaagte
KRTL4	675	-2904730	Unknown	Unknown	Unknown	Unknown	0.33	NM	NM	Windmill	-	x	-		Kortlaagte
KRTL5	674	-2904730	Unknown	Unknown	Unknown	Unknown	Surface	NM	NM	Blocked	-	-	-	x	Kortlaagte
KRTL7	-1151	-2905576	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Windmill	-	-	-	x	Kortlaagte
KRTL8	2196	-2905202	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Blocked	-	-	-	-	Kortlaagte: Mr. J. Venter
KRTL9	2236	-2905210	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Blocked	-	-	-	-	Kortlaagte: Mr. J. Venter
KTFN1	15983	-2914844	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Windmill	-	-	-	x	Kruisementfontein: Me. N. de Vos
M-17	10230	-2903657	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Mono pump	-	-	-	x	Vierfontein: Mr. E. Muller
M-18	10222	-2902590	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Mono pump	-	-	-	x	Vierfontein: Mr. E. Muller
M-19	9268	-2903152	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Windmill	-	x	-	-	Vierfontein: Mr. E. Muller
M-22	6237	-2907072	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Submersible	-	-	-	x	Grootpan: Me. N. de Vos
M-26	9433	-2905423	Unknown	Unknown	Unknown	Unknown	0.27	NM	NM	Submersible	x	-	-	-	Grootpan: Me. N. de Vos
M-27	9666	-2904977	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Submersible	-	-	-	x	Grootpan: Me. N. de Vos
M-29	13292	-2916362	Unknown	Unknown	Unknown	Unknown	0.04	NM	NM	Submersible	x	x	-	-	Onverwacht: Me. N. de Vos
M30	14113	-2915076	Unknown	Unknown	Unknown	Unknown	0.1	NM	NM	Submersible	x	x	-		Onverwacht: Me. N. de Vos
M-50	11175	-2911074	Unknown	100	Unknown	Unknown	0.33	NM	NM	Submersible	x	x	x	-	Nooitgedacht: Mr. B. Roux
M-51	11266	-2911150	Unknown	100	Unknown	Unknown	Surface	NM	NM	Submersible	X	-	x	-	Nooitgedacht: Mr. B. Roux
M-52	11853	-2910678	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Handpump	x	-	-	-	Nooitgedacht: Mr. B. Roux
M-54	12016	-2911334	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Windmill	-	x	-	-	Nooitgedacht: Mr. B. Roux
M-71	-790	-2910594	Unknown	Unknown	Unknown	Unknown	0.17	NM	NM	Submersible	-	-	-	x	Moedverloren: Mr. P. Streicher

BH ID	Coordinates & Elevation			Borehole Construction Information				Static Water Level		Borehole Status & Water Application Information					Owner / Village
	Coordinates		Elevation	Borehole Depth	Casing Diameter	Screen/Perforated Casing Length	Reference Level Height	Static Water Level		Status	Water Application				
	Easting	Northing									Domestic	Livestock	Irrigation	None	
	[m]	[m]	[m aMSL]	[m]	[m]	[m]	[m aGL]	[m bGL]	[m aMSL]						
M-81	10789	-2911667	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Windmill	-	-	-	x	Schaapkraal: Mr. B. Roux
M-94	7883	-2908299	Unknown	Unknown	Unknown	Unknown	Surface	NM	NM	Submersible	x	x	-	-	Grootpan: Me. N. de Vos
M-99	-2176	-2903801	Unknown	98	Unknown	Unknown	NM	NM	NM	Submersible	x	x	-	-	Kortlaagte: Mr. P. Streicher
MDVL1	972	-2905863	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Windmill	x	x	-		Moedverloren
MDVL2	-311	-2911211	Unknown	6	Unknown	Unknown	0.28	NM	NM	Windmill	-	-	-	x	Moedverloren: Mr. P. Streicher
MDVL4	4002	-2905317	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Mono pump	-	-	-	-	Moedverloren: Mr. P. Streicher
MDVL5	1510	-2908515	Unknown	Unknown	Unknown	Unknown	0.33	NM	NM	Submersible	-	x	-	-	Moedverloren: Mr. M. Erasmus
MDVL6	1715	-2908708	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Blocked	-	-	-	x	Moedverloren: Mr. M. Erasmus
MDVL7	1714	-2908705	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Blocked	-	-	-	x	Moedverloren: Mr. M. Erasmus
OVWT1	14157	-2915163	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Blocked	-	-	-	x	Onverwacht: Me. N. de Vos
OVWT2	14319	-2915386	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Blocked	-	-	-	x	Onverwacht: Me. N. de Vos
SFNBH2	10247	-2917892	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Open	-	-	-	-	Vaalbank: Mr. J. Barnard
SHL1	-2064	-2900619	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Mono pump	-	-	-	x	Strehla: Mr. M. Erasmus
SHL2	-1662	-2900312	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Mono pump	x	-	-	-	Strehla: Mr. M. Erasmus
SHL4	-1777	-2900186	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Windmill	x	-	-	-	Strehla: Mr. M. Erasmus
SKL2	7969	-2911300	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Windmill	x	x	-	-	Schaapkraal: Mr. B. Roux
SKL3	7596	-2911408	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Windmill	-	x	-	-	Schaapkraal: Mr. B. Roux
VFN1	8599	-2901849	Unknown	Unknown	Unknown	Unknown	NM	NM	NM	Mono pump	-	-	-	x	Vierfontein: Mr. E. Muller

Note/s:

- Coordinates = Projection: *Universal Transverse Mercator*, Datum: *WGS84;* m = metres; m aMSL = metres above Mean Sea Level; m bGL - metres below Ground Level; NM = not measured (either blocked/vandalised/collapsed/not accessible).