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ELANDSFONTEIN COLLIERY HYDROGEOLOGICAL BASELINE ASSESSMENT: EIA SCOPING STUDY

July 2020

Conducted on behalf of:
Environmental Impact Management Services (Pty) Ltd

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Executive summary

Gradient Consulting (Pty) Ltd was appointed by Environmental Impact Management Services (Pty) Ltd to conduct a hydrogeological specialist investigation and groundwater impact assessment in support of an Environmental Authorisation (EA) and amendment process to be followed for Anker Coal and Mineral Holdings SA (Pty) Ltd Elandsfontein Colliery.

The objective of this investigation is to assess the potential impact of the proposed activities and associated facilities on the local and regional groundwater regime.

The project extent and greater mine lease area is located on a portion of the remaining extent of portion 8; remaining extent of portion 1; a portion of the remaining extent of portion 6; portion 44; portion 14 and the remaining extent of portion 7 of the Farm Elandsfontein 309 JS, situated approximately 4.0 km south of Kwa-Guqa and about 16.0 km west of Emalahleni, Mpumalanga Province, South Africa

The topography of the greater study area is characterised by moderately undulating plains and pans. The north-eastern perimeter is shaped by a topographical high at 1565 mamsl and forms the watershed between quaternary catchments B20G and B11K. The lowest on-site elevation is situated towards the southwest and is recorded at 1476 mamsl. On-site gradients are relatively gentle to moderate with the average slope calculated at 2.30% and –2.20% respectively.

The resource management of the greater study area falls under the Olifants WMA and quaternary catchment B20G.

Although local surface water drainage on site is inferred to be in a general southwestern direction, the regional drainage occurs in a general north to north-western direction. The Grootspruit drainage transects the project area to the southwestern perimeter.

The calculated mean annual precipitation (MAP) for this rainfall zone is 530.76 mm/a, while the mean annual evaporation accounts to 1689.0 mm/a.

The study area is underlain by the Ecca Group of the Karoo Supergroup and fall within the Madzaringwe Formation, consisting mainly of arenaceous strata. On a regional scale, two geological lineaments (potentially faults zones) exist in close proximity to the greater study area, striking in a general north-south and southwest-northeast orientation respectively.

The site is predominantly underlain by an intergranular and fractured aquifer system (d3) comprising mostly fractured and weathered compact sedimentary/ arenaceous rocks.

Two main hydrostratigraphic units can be inferred in the saturated zone:

i. A shallow, weathered zone aquifer occurring in the transitional soil and weathered bedrock formations underlain by more consolidated bedrock.

ii. An intermediate/deeper fractured aquifer where groundwater flow will be dictated by transmissive fracture zones that occur in the relatively competent host rock.

The hydraulic conductivity of sandstone formations can range from $9e^{-05}$ – $9e^{-01}$ m/d whereas the hydraulic conductivity of denser shale formations is lower and estimated at $9e^{-09}$ – $9e^{-05}$ m/d. It should also be noted that mined out and back-filled areas may have different hydraulic properties as the inherent values have been altered and modified.

An approximation of recharge for the study area is estimated at ~6.21 % of MAP i.e. ~32.93 mm/a.

Off the boreholes visited during the hydrocensus user survey, the majority is in use (>73.0%)) with the groundwater application mostly for monitoring purposes as well as domestic and livestock purposes. It should be noted that there is various neighbouring boreholes in close proximity (< 1.0 km) to the mining operations.

The unsaturated zone within the study area is in the order of ~2.85 to ~17.34 m with a mean thickness of approximately 7.84 m.

Analysed water level data for the shallow aquifer indicate that the majority of levels correlate very well to the topographical elevation and it can be assumed that the regional groundwater flow direction of the shallow aquifer is dictated by topography. Accordingly, the inferred groundwater flow direction will be in a general southwestern direction towards the lower laying drainage system of the Grootspruit drainage system.

The average groundwater gradient (i) of the shallow, weathered aquifer in the vicinity of the potential high-risk seepage areas i.e. mine discard dump and/or slurry ponds is moderately flat and calculated at approximately 0.004 with gradients increasing towards the southwestern perimeter of the mine lease area.

The expected seepage rate from contamination originating at the mine discard dump is estimated at an average of 0.96 m/a and will be dependent on local groundwater gradients.

The overall ambient groundwater quality of the shallow aquifer is good with the majority of macro and micro determinants below the SANS 241:2015 limits. Isolated sampling localities indicate above limits ammonium (NH_4) concentrations which can may suggest nearby anthropogenic activities.

The local groundwater quality is indicative of an impacted groundwater system and suggest coal mine pollution and acid mine drainage (AMD) conditions present. The latter is characterised by a low pH environment increasing the solubility and concentrations of metals i.e. usually aluminum, iron and manganese.

The overall water quality of the upstream surface water samples is poor due to elevated levels of sulphate as well as heavy metals (Fe, Al and Mn). The downstream water quality is unacceptable due to highly elevated levels of sulphate as well as heavy metals (Fe, Al and Mn) causing high salt loads. There is a definite deterioration of water quality evident in a downstream direction and suggest contaminated water ingress from potentially mine decant and interflow zones or seepage from mine discard dumps.

The majority of regional/ neighbouring boreholes suggest either a recently recharged and unimpacted water environment (Calsium-Bi-carbonate dominance), and/or area of dissolution and mixing, whereas current monitoring boreholes on site indicate a static and disordinate environment (Sulphate dominance suggesting impacts from coal mine pollution).

Furthermore, groundwater sampling localities ECBH03, ELNBH03 correlate well to the hydrochemical signature of surface water sampling locality ASW01 and suggest similar water environments and potential origins.

A **GQM Index = 4** was estimated for the aquifer system and according to this estimate, a "**Medium**" level groundwater protection is required for this aquifer system. According to the DRASTIC index methodology applied, this mining activities and associated infrastructure's risk to groundwater pollution is rated as "**Moderate**", Di = 102.

The main impacts and activities associated with the operational phase activities include the following:

i. Impact on the groundwater quantity and change in the regional phreatic/ piezometric levels due to mine dewatering.
ii. A depletion in aquifer storage and formation of a depression zone may potentially lead to a reduction in groundwater contribution to baseflow of local drainages and/or groundwater supported wetlands.
iii. Impact on groundwater quality due to leachate of contaminants from waste facilities i.e. mine discard dump, slurry ponds, coal stockpiles, unlined pollution control dams (PCD) as well as carbonaceous overburden dumps.
iv. Impact on groundwater quality due to hydrocarbon contamination caused by mine heavy vehicles and machinery.

The main impacts and activities associated with post -operational phase activities include the following:

i. Post-operational water level rebound and flooding of mine voids.
ii. Decanting of poor water quality caused by leachate of sulphide bearing minerals such as pyrite in the presence of oxygen and water to create an acidic environment (i.e. acid rock drainage).
iii. Seepage of poor water quality from waste facilities i.e. mine discard dump, slurry ponds, coal stockpiles, unlined pollution control dams (PCD) as well as carbonaceous overburden dumps

The following recommendations are proposed following this investigation:

1. It is recommended that this hydrogeological baseline assessment report be reviewed and distributed as part of the public participation and scoping phases. Relevant input and/or comments received from I&AP's should be addressed as part of the EIA phase to follow.
2. It is suggested that all hydrocensus and monitoring localities be revisited in order to gather wet-season data and information for comparison and time series trend analysis.
3. A spatial distribution of mine discard dumps, overburden as well as waste material samples should be analysed to determine the risk for acid rock drainage potential as well as a source term for the mass transport model.
4. A numerical groundwater flow model should be developed based on the hydrogeological conceptual model defined from site characetrisation data and information gathered. The groundwater flow model should be calibrated with applicable groundwater data to an acceptable level. The latter should be used

to simulate estimated mine inflow and dewatering volumes, groundwater capture zones and water level drawdown, contamination plume migration curves. Accordingly, the model output should be used to qualify and quantify preliminary groundwater impacts as stated in this report.

List of Abbreviations

ASTM	**=**	**American Society for Testing Materials**
Avg	**=**	**Average**
BH	**=**	**Borehole**
CMB	**=**	**Chloride Mass Balance**
D	**=**	**Saturated Thickness**
DEM	**=**	**Digital Elevation Model**
DRASTIC	**=**	**DI Index**
DWS	**=**	**Department of Water Affairs and Sanitation (formerly DWA or DWAF)**
EC	**=**	**Electrical Conductivity (mS/m)**
EIA	**=**	**Environmental Impact Assessment**
EIMS	**=**	**Environmental Impact Management Services**
E.N.	**=**	**Electro Neutrality**
EPA	**=**	**United States Environmental Protection Agency**
ha	**=**	**Hectares**
GIS	**=**	**Geographic Information Systems**
GN 704	**=**	**Government Notice 704**
GQM	**=**	**Groundwater Quality Management**
i	**=**	**Hydraulic gradient (dimensionless)**
IWULA	**=**	**Integrated Water Use License Application**
ISP	**=**	**Internal Strategic Perspective**
K	**=**	**Hydraulic Conductivity (m/d)**
l/s	**=**	**Litre per second**
LoM	**=**	**Life of Mine**
m^3/d	**=**	**Cubic meters per day**
MAE	**=**	**Mean Annual Evaporation**
mamsl	**=**	**Metres Above Mean Sea Level**
MAR	**=**	**Mean Annual Runoff**
mbgl	**=**	**Metres Below Ground Level**
mcm	**=**	**Million Cubic Metres**
meq/L	**=**	**Mili-equivalents per litre**
mg/l	**=**	**Milligrams per litre**
mm/a	**=**	**Millimetre per annum**
MPRDA	**=**	**Minerals and Petroleum Resources Development Act (Act 28 of 2002)**
n	**=**	**Porosity**
NGA	**=**	**National Groundwater Archive**
NGDB	**=**	**National Groundwater Database**
NWA	**=**	**National Water Act (Act 36 of 1998)**
REV	**=**	**Representative Elementary Value**
S	**=**	**Storage coefficient**
Sc	**=**	**Specific Storage**
SoW	**=**	**Scope of Work**
SANAS	**=**	**South African National Accreditation System**
SANS	**=**	**South African National Standards**
T	**=**	**Transmissivity (m^2/d)**

TDS	**=**	**Total Dissolved Solids**
UNESCO	**=**	**The United Nations Educational, Scientific and Cultural Organisation**
USGS	**=**	**United States Geological Survey**
WGS	**=**	**World Geodetic System**
WM	**=**	**With Mitigation**
WOM	**=**	**Without Mitigation**
WUL	**=**	**Water Use Licence**

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1. INTRODUCTION

1.1. Project background

Gradient Consulting (Pty) Ltd was appointed by Environmental Impact Management Services (Pty) Ltd (hereafter referred to as EIMS) to conduct a hydrogeological specialist investigation and groundwater impact assessment in support of an Environmental Authorisation (EA) and amendment process to be followed for Anker Coal and Mineral Holdings SA (Pty) Ltd Elandsfontein Colliery.

Elandsfontein Colliery is an existing colliery which was approved in terms the Minerals Act (1999) and currently holds two mining rights (MP 314 MR as well as MP63 MR). The applicant plans to consolidate the two mining right areas into a single mining right with associated consolidated EMPR. Furthermore, the applicant proposes to expand the existing mining operations to include additional mineral resource areas within the consolidated mining right boundary. This report serves as a scoping level study and focuses on the status quo of the regional groundwater system and aim to quantify and qualify potential impacts on sensitive environmental receptors.

1.2. Objectives

The objective of this investigation is to:

i. Establish site baseline and background conditions and identify sensitive environmental receptors.

ii. Determine the current status quo of the regional groundwater system including aquifer classification, aquifer unit delineation and vulnerability.

iii. Geochemical assessment and first order assessment on the long-term potential for the occurrence of Acid Mine (Rock) Drainage (AMD).

iv. Waste classification in accordance with Regulation GNR 635 of the National Waste Act (Act 59 of 2008).

v. Development of a numerical groundwater flow model.

vi. Development of a contaminant transport model with of a source term derived from the geochemical assessment.

vii. Hydrogeological impact assessment and risk matrix.

viii. Recommendations on best practise mitigation and management measures to be implemented.

ix. Compilation of an integrated groundwater monitoring network and protocol.

1.3. Terms of reference

The investigation is based on the terms of reference and scope of work (SoW) as detailed in proposal ref.no. HG-P-19-050-V1, submitted in September 2019. This project plan and scope of work (SoW) was compiled in accordance with the Environmental Impact Assessment (EIA) Regulations, Government Notice (GN) R982 (NEMA 2014). The scope of work is summarised below.

1.3.1. Phase A: Desk study and gap analysis

Phase A will entail the following activities:

i. Information gathering and data acquisition.

ii. Desk study and review of existing specialist reports as well as newly gathered monitoring data for hydrochemical and water level trend analysis.

iii. Fatal flaw and gap analysis.

1.3.2. Phase B: Update the existing hydrogeological baseline assessment - hydrocensus user survey, hydrochemical analysis and aquifer classification

Phase B will entail the following activities:

i. Hydrocensus user survey to evaluate and verify existing surface and groundwater uses, local and neighbouring borehole locations and depths, spring localities and seepage zones, regional water levels, abstraction volumes, groundwater application as well as environmental receptors in the vicinity of the mining footprints.

ii. Sampling of existing boreholes and surface water bodies according to best practise guidelines and analyses of six (6) water samples to determine the macro and micro inorganic chemistry and hydraulic connections based on hydrochemistry (analyses at SANAS accredited laboratory).

iii. Assess the structural geology and geometry of the aquifer systems with respect to hydraulic interactions and compartmentalisation.

iv. Data interpretation aiding in aquifer classification, delineation and vulnerability ratings. Development of a scientifically defendable hydrogeological baseline.

v. Compilation of geological, hydrogeological and hydrochemical thematic maps summarising the aquifer system(s), indicating aquifer delineation, groundwater piezometric map, depth to groundwater, groundwater flow directions as well as regional geology.

1.3.3. Phase C: Geochemical assessment and source term determination

Phase C will entail the following activities:

i. Review and analysis of existing information.

ii. Laboratory analysis and geochemical assessment of composite waste samples of strategically placed sampling localities (Static leach testing (TCLP), AMD generation, NAG Potential and sulphide speciation (2 samples)).

iii. Processing of geochemical data.

iv. Geochemical interpretation of laboratory results and source term determination.

v. Formulation of a geochemical conceptual model.

vi. Report writing and AMD strategy.

1.3.4. Phase D: Update the existing numerical groundwater flow and mass transport model

Phase D will entail the following activities:

i. Update the existing conceptual hydrogeological model in conjunction with newly gathered site characterisation information as well as monitoring data.

ii. Update the existing numerical groundwater flow model by applying the Finite Element Flow (FEFLOW) modelling software. Model domain to include proposed infrastructure and mine extension footprint as well as associated activities.

iii. Calibration of groundwater flow model using site specific data including hydrocensus geosites as well as existing time-series monitoring data.

iv. Development of a numerical mass transport model utilizing the calibrated groundwater flow model as basis.

v. The calibrated model will be used to simulate management scenario's as follows:

a. Steady state groundwater flow directions, hydraulic gradient and flow velocities.

b. Potential groundwater inflow volumes and mine dewatering rates.

c. Seepage potential from wastewater facilities and mass transport plume migration with time.

d. Mine post-closure decant positions and volumes with time.

e. Water management alternatives and best practice mitigation measures.

1.3.5. Phase E: Hydrogeological impact assessment and reporting

Phase E will entail the following activities:

i. Compilation of a detailed hydrogeological specialist investigation report with conclusions and recommendations on the following aspects:

a. Fatal flaw and gap analyses.

b. Site baseline characterisation.

c. Field work summary and interpretation.

d. Aquifer classification and vulnerability.

e. Geochemical source term determination.

f. Numerical groundwater flow and mass transport model development, calibration and simulations.

g. Formulation of an impact assessment and risk matrix of proposed activities.

h. Recommendation on best practise mitigation and management measures to be implemented.

ii. Update the current groundwater monitoring network and protocol.

1.4. Project assumptions and limitations

Data limitations were addressed by following a conservative approach and assumptions include the following:

i. The scale of the investigation was set at 1:50 000 resolutions in terms of topographic and spatial data, a lower resolution of 1:250 000 scale for geological data and a 1: 500 000 scale resolution for hydrogeological information.
ii. The Digital Elevation Model (DEM) data was interpolated with a USGS grid spacing of 25 m intervals.
iii. Rainfall data and other climatic data was sourced from the WR2012 database.
iv. Water management and catchment-based information was sourced from the GRDM and Aquiworx databases.
v. The concept of representative elementary volumes (REV) have been applied i.e. a scale has been assumed so that heterogeneity within a system becomes negligible and thus can then be treated as a homogeneous system. The accuracy and scale of the assessment will result in deviations at point e.g. individual boreholes.
vi. No site characterisation boreholes were drilled as part of this investigation and aquifer parameters as well as hydrostratigraphic units were assumed based on historical investigation and similar studies conducted.
vii. The investigation relied on data collected as a snapshot of field surveys and existing monitoring data. Further trends should be verified by continued monitoring as set out in the monitoring program.
viii. Groundwater divides have been assumed to align with surface water divides and it is assumed that groundwater cannot flow across this type of boundaries.
ix. Where data was absent or insufficient, values were assumed based on literature studies and referenced accordingly[1].

[1] Where model assumptions were made or reference values used, a conservative approach was followed. Data gaps identified should be addressed as part of the model update.

2. METHODOLOGY

The groundwater impact assessment was undertaken by applying the methodologies as summarised below.

2.1. Desk study and review

This task entails the review of available geological and hydrogeological information including DWS supported groundwater databases (NGA/ Aquiworx), existing specialist reports, mine plans as well as climatic and other relevant groundwater data. Data collected was used to delineate various aquifer and hydrostratigraphic units, establish the vulnerability of local aquifers, aquifer classification as well as aquifer susceptibility.

2.2. Hydrocensus user survey

A hydrocensus user survey was undertaken in August 2019 (representing dry-season contribution) in order to confirm the presence of potential sensitive environmental receptors in the vicinity of the project area, determine the surrounding groundwater application and piezometric water levels and collect water samples for analysis. Furthermore, a site visit and terrain walk-over were conducted in order to formulate and define the hydrogeological conceptual model.

2.3. Hydrochemical analysis

Water samples collected were submitted at a SANAS accredited laboratory to determine the macro and micro inorganic chemistry and potential hydraulic connections present. SANS 241:2015 Drinking Water Standards was applied and used a guideline for all water quality analysis.

2.4. Groundwater impact assessment

Identification of preliminary and potential impacts and ratings related to new developments and/or listed activities are defined based on outcomes of the investigation. An impact can be defined as any change in the physical-chemical, biological, cultural and/or socio-economic environmental system that can be attributed to human and/or other related activities. The broad approach to the significance rating methodology is to determine the environmental risk (ER) by considering the consequence (C) of each impact (comprising Nature, Extent, Duration, Magnitude, and Reversibility) and relate this to the probability/likelihood (P) of the impact occurring. This determines the environmental risk. In addition, other factors including cumulative impacts, public concern, and potential for irreplaceable loss of resources, are used to determine a prioritisation factor (PF) which is applied to the ER to determine the overall significance (S). Mitigation measures were recommended in order to render the significance of impacts identified.

3. LEGAL FRAMEWORK AND REGULATORY REQUIREMENTS

The following water management legislation should be adhered to:

3.1. The National Water Act (Act 36 of 1998)

The purpose of the National Water Act, 36 of 1998 ("NWA") as set out in Section 2, is to ensure that the country's water resources are protected, used, developed, conserved, managed and controlled, in a way which inter alia considers the reduction, prevention and degradation of water resources. The NWA states in Section 3 that the National Government is the public trustee of the Nation's water resources. The National Government must ensure that water is protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner for the benefit of all persons and in accordance with its constitutional mandate. Section 22 of the NWA states that a person may only use water without a license if such water use is: permissible under Schedule 1, if that water use constitutes as a continuation of an existing lawful water use, or if that water use is permissible in terms of a general authorization issued under Section 39. Permissible water use furthermore includes water use authorised by a license issued in terms of the NWA or alternatively without a license if the responsible authority dispensed with a license requirement under subsection 3.

3.1.1. Section 21 water use activities

Section 21 of the National Water Act indicates that water use includes the following:

a. taking water from a water resource (section 21(a));
b. storing water (section 21(b));
c. impeding or diverting the flow of water in a water course (section 21(c));
d. engaging in a stream flow reduction activity contemplated in section 3649 (section 21(d));
e. engaging in a controlled activity which has either been declared as such or is identified in section 37(1)50 (section 21(e));
f. discharging waste or water containing waste into a water resource through a pipe, canal, sewer, sea outfall or other conduit (section 21(f));
g. disposing of waste in a manner which may detrimentally impact on a water resource (section 21(g);
h. disposing in any manner of water which contains waste from, or which has heated in, any industrial or power generation process (section 21 (h));
i. altering the bed, banks, course or characteristics of a water course (section 21(i));
j. removing, discharging or disposing of water found underground if it is necessary for the efficient continuation of an activity or for the safety of people (section 21(j)); and
k. using water for recreational purposes (section 21(k)).

3.1.2. GN 704 Regulations on the use of water for mining and related activities aimed at the protection of water resources (1999)

It is important that integrated water management should be conducted in accordance with Government Notice (GN) 704. The following regulations were referenced from the GN 704 document published.

Section 4: Restriction of Locality

"No person in control of a mine or activity may-

i. Locate or place any residue deposit, dam, reservoir, together with any associated structure or any other facility within the 1:100 year flood-line or within a horizontal distance of 100 metres from any watercourse or estuary, borehole or well, excluding boreholes or wells drilled specifically to monitor the pollution of groundwater, or on waterlogged ground, or on the ground likely to become waterlogged, undermined, unstable or cracked;
ii. Except in relation to a matter contemplated in regulation 10, carry on any underground or opencast mining, prospecting or any other operation or activity under or within the 1:50 year flood-line or within a horizontal distance of 100 metres from any watercourse or estuary, whichever is the greatest;
iii. Place or dispose of any residue or substance which causes or is likely to cause pollution of a water resource, in the workings of any underground or open cast mine excavation, prospecting diggings, pit or any other excavation; or
iv. Use any area or locate any sanitary convenience, fuel depots, reservoir or depots for any substance which causes or is likely to cause pollution of a water resource within the 1:50 year flood-line of any watercourse or estuary."

Section 6: Capacity requirements of clean and dirty water systems

"Every person in control of a mine or activity must-

i. Confine any unpolluted water to a clean water system, away from any dirty area;
ii. Design, construct, maintain and operate any clean water system at the mine or activity so that it is not likely to spill into any dirty water system more than once in 50 years;
iii. Collect the water arising within any dirty area, including water seeping from mining operations, outcrops or any other activity, into a dirty water system;
iv. Design, construct, maintain and operate any dirty water system at the mine or activity so that it is not likely to spill into any clean water system more than once in 50 years; and
v. Design, construct, maintain and operate any dam or tailings dam that forms part of a dirty water system to have a minimum freeboard of 0.8 metres above full supply level, unless otherwise specified in terms of Chapter 12 of the Act.
vi. Design, construct and maintain all water systems in such a manner as to guarantee the serviceability of such conveyances for flows up to and including those arising as a result of the maximum flood with an average period of recurrence of once in 50 years."

Section 7: Protection of water resources

"Every person in control of a mine or activity must take reasonable measures-

i. Prevent water containing waste or any substance which causes or is likely to cause pollution of a water resource from entering any water resource, either by natural flow or by seepage, and must retain or collect such substance or water containing waste for use, re-use, evaporation or for purification and disposal in terms of the Act;
ii. Design, modify, locate, construct and maintain all water systems, including residue deposits, in any area so as to prevent the pollution of any water resource through the operation or use thereof and to restrict the possibility of damage to the riparian or in-stream habitat through erosion or sedimentation, or the disturbance of vegetation, or the alteration of flow characteristics;
iii. Cause effective measures to be taken to minimise the flow of any surface water or floodwater into mine workings, opencast workings, other workings or subterranean caverns, through cracked or fissured formations, subsided ground, sinkholes, outcrop excavations, adits, entrances or any other openings;
iv. Design, modify, construct, maintain and use any dam or any residue deposit or stockpile used for the disposal or storage of mineral tailings, slimes, ash or other hydraulic transported substances, so that the water or waste therein, or falling therein, will not result in the failure thereof or impair the stability thereof;
v. Prevent the erosion or leaching of materials from any residue deposit or stockpile from any area and contain material or substances so eroded or leached in such area by providing suitable barrier dams, evaporation dams or any other effective measures to prevent this material or substance from entering and polluting any water resources;
vi. ensure that water used in any process at a mine or activity is recycled as far as practicable, and any facility, sump, pumping installation, catchment dam or other impoundment used for recycling water, is of adequate design and capacity to prevent the spillage, seepage or release of water containing waste at any time;
vii. At all times keep any water system free from any matter or obstruction which may affect the efficiency thereof; and
viii. Cause all domestic waste, including wash-water, which cannot be disposed of in a municipal sewage system, to be disposed of in terms of an authorisation under the Act.

3.2. Mineral and Petroleum Resources Development Act (Act 28 of 2002)

The establishment, reclamation, expansion or decommissioning of residue stockpiles or residue deposits must be authorised in terms of the Mineral and Petroleum Resources Development Act (MPRDA) (Act 28 of 2002). Section 42 of the MPRDA states that:

i. Residue stockpiles and residue deposits must be managed in the prescribed manner on any site demarcated for that purpose in the environmental management plan or environmental management programme in question.

ii. No person may temporarily or permanently deposit any residue stockpile or residue deposit on any site other than on a site contemplated in subsection.

3.3. National Environmental Management: Waste Act (Act 59 of 2008)

Furthermore, the establishment, reclamation, expansion or decommissioning of residue stockpiles or residue deposits must also be authorised through a waste management licence issued in terms of the National Environmental Management Waste Act 59 of 2008.

The classification and definitions herein considered the following documents[2]:

i. Government Notice 635, National Environmental Management: Waste Act 59 of 2008: National Norms and Standards for the Assessment of Waste for Landfill Disposal (hereafter referred to as GNR 635).
ii. Government Notice 636, National Environmental Management: Waste Act 59 of 2008: National Norms and Standards for Disposal of Waste to Landfill (hereafter referred to as GNR 636).

It should be noted that Government Notice GN 990 published in September 2018 serve to amend the regulations regarding the planning and management of residue stockpiles and residue deposits (2015). The main aim is to allow for the pollution control measures required for residue stockpiles and residue deposits, to be determined on a case by case basis, based on a risk analysis conducted by a competent person. Accordingly, a risk analysis must be conducted to determine the pollution control measures suitable for a specific residue stockpile or residue deposit as part of an application for a waste management licence.

[2] It should be noted that, although a pollution control barrier system designed in terms of the National Norms and Standards for the Assessment of Waste for Landfill Disposal (GN R635 and the National Norms and Standards for the Disposal of Waste to Landfill (GN R636) is no longer applicable and/or enforceable, the Total Concentration (TC) and Leachable Concentration (LC) thresholds as stipulated in GNR635 standards are still applied as part of the waste assessment because guidelines and limits are based on Environmental Protection Agency (EPA) of the Australian State of Victoria and still bears reference.

4. STUDY AREA AND LISTED ACTIVITIES

4.1. Regional setting and site locality

The project extent and greater mine lease area is located on a portion of the remaining extent of portion 8; remaining extent of portion 1; a portion of the remaining extent of portion 6; portion 44; portion 14 and the remaining extent of portion 7 of the Farm Elandsfontein 309 JS, situated approximately 4.0 km south of Kwa-Guqa and about 16.0 km west of Emalahleni, Mpumalanga Province, South Africa. The site is accessible from the N4 national route and N104 to the north as well as route R547 to the east. General site coordinates are listed in Table 4-1 with the site locality and layout depicted in Figure 4-2.

Table 4-1 General site coordinates (Coordinate System: Geographic, Datum: WGS84).

Latitude	-25.904
Longitude	29.092

4.2. Mining infrastructure and schedule

Elandsfontein Colliery holds two mining right areas i.e. MP 314 MR (593 ha) as well as MP63 MR (237 ha). The roll over strip mining method is utilised to extract coal from the shallower No.2 coal seam. The existing opencast operations has an approximate extend of 257 ha while the applicant wishes to authorise an additional 69.47 ha. Deeper coal is extracted by underground bord and pillar mining using decline shafts to access No. 1 coal seam. The historical underground footprint covers an approximate area of 182 ha, while the applicant wishes to authorise an additional 379 ha. Associated infrastructure consists of a discard dump, coal ROM stockpiles, overburden stockpiles, pollution control dams (PCD) and slurry dam. Refer to Figure 4-2 for a summary of existing/ proposed mining zones and infrastructure map.

Figure 4-1 **Aerial extent and greater study area.**

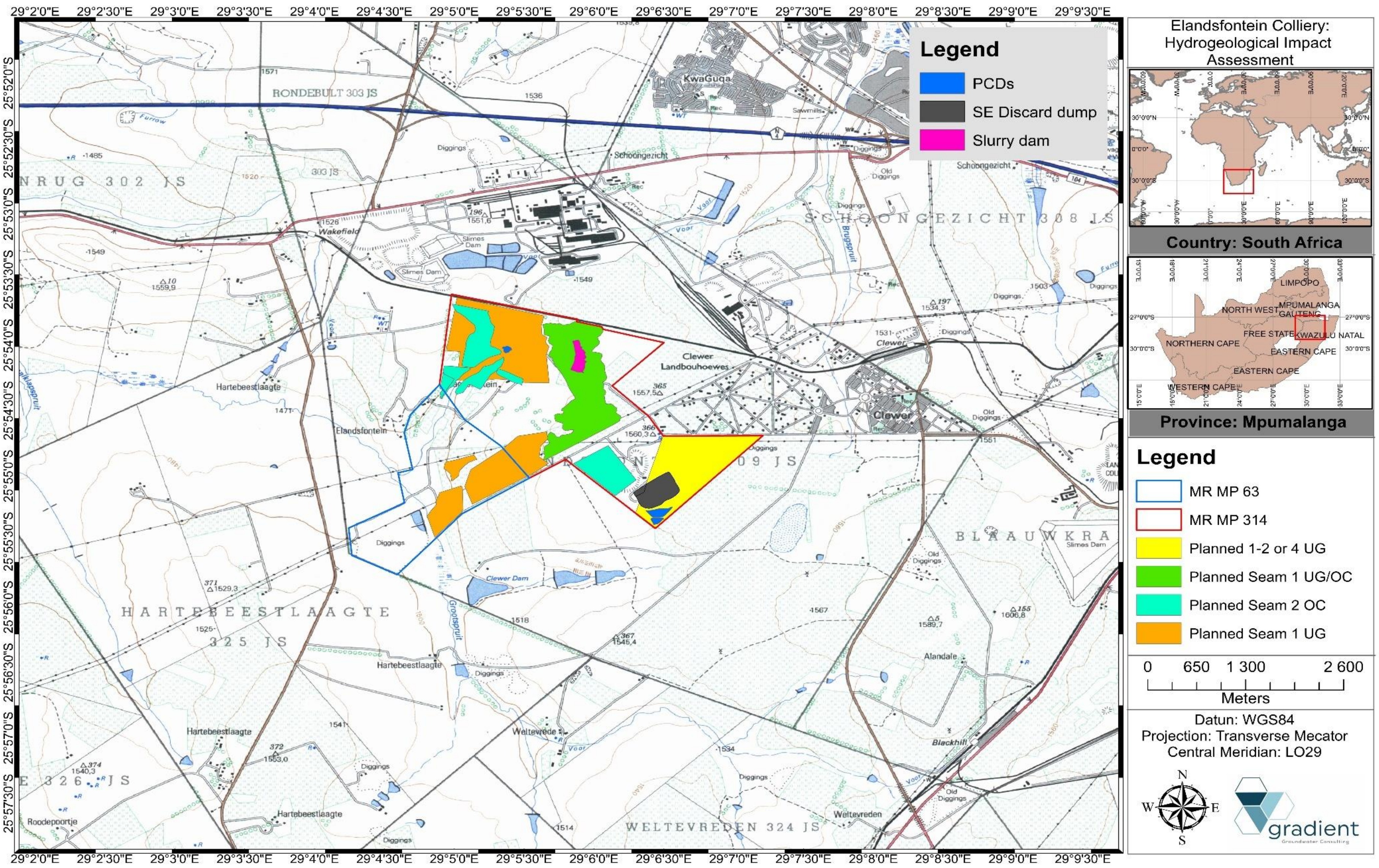


Figure 4-2 **Greater study area and mine infrastructure (1:50 000 topographical mapsheet 2529CC).**

5. PHYSIOGRAPHY

5.1. Topography

The topography of the greater study area is characterised by moderately undulating plains and pans. The north-eastern perimeter is shaped by a topographical high at 1565 meters above mean sea level (mamsl) and forms the watershed between quaternary catchments B20G and B11K. To the south and southeast, the landscape gradually flattens out towards the lower laying drainage system with the lowest on-site elevation recorded as 1476 mamsl.

On-site gradients are relatively gentle to moderate with the average slope calculated at 2.30% and –2.20% respectively with an elevation loss of ~30.0 m over a lateral distance of ~3.50 km. Figure 5-1 depicts a northsouth-eastwest topographical cross-section of the greater study area while Figure 5-2 shows the regional topographical contours and setting.

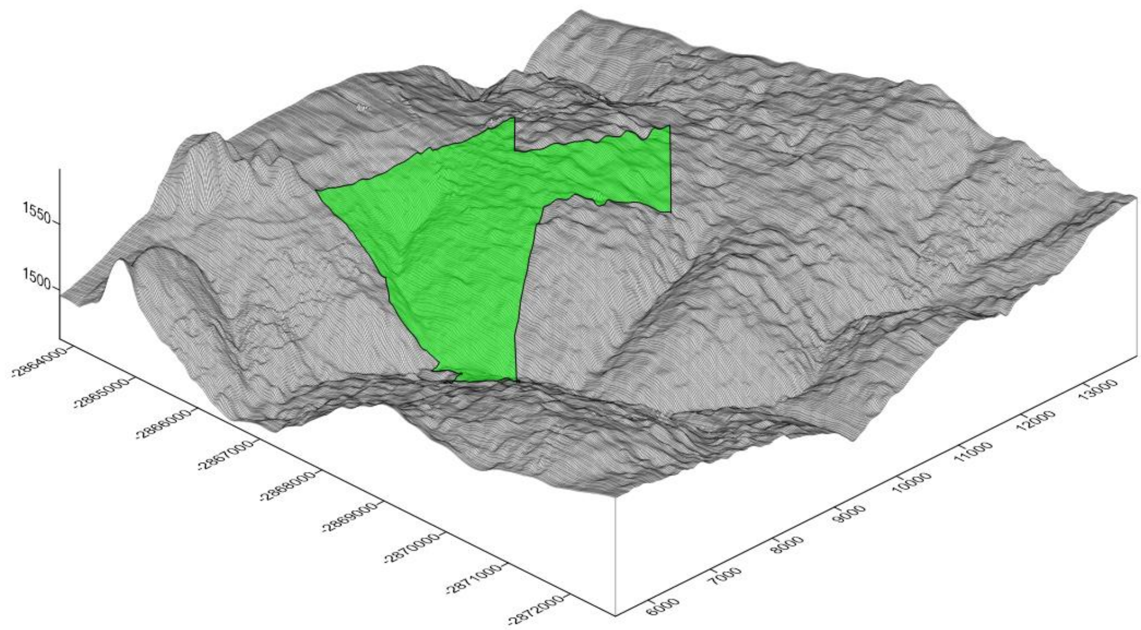


Figure 5-1 Topographical cross-sections of the greater study area.

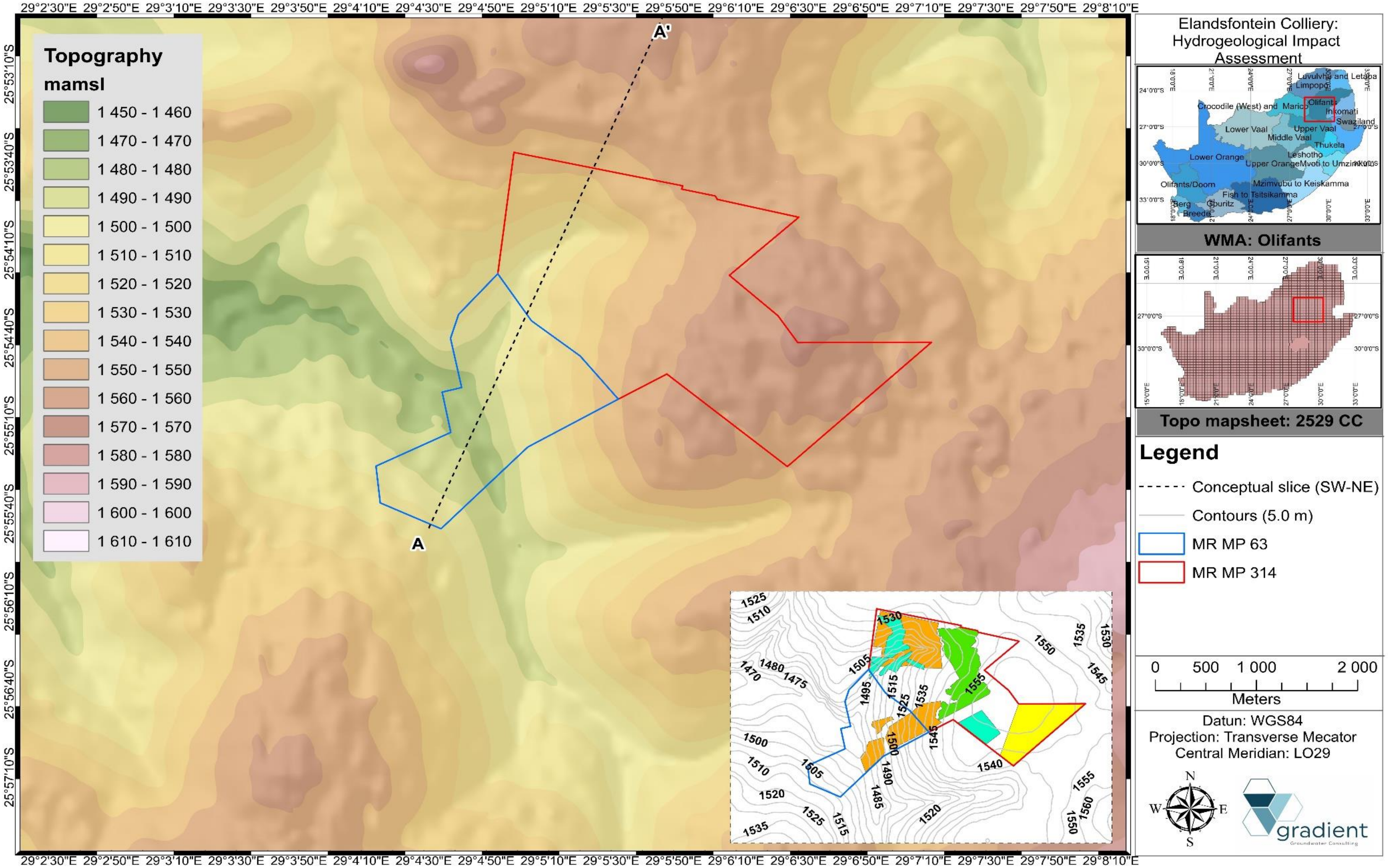


Figure 5-2 **Regional topography (Figure 10-2).**

5.2. Drainage and catchment

The project area is situated in primary catchment (B) of the Elands, Wilge, Steelpoort and Olifants River drainage systems. The resource management falls under the Olifants Water Management Area (WMA) (54 550 km^2) which spans portions of the Limpopo, Mpumalanga as well as Gauteng. The study area is situated within quaternary catchment B20G (nett surface area of 519.4 km^2), falls within hydrological zone J and has an estimated mean annual runoff (MAR) of 44.1 mcm (million cubic metres) (WR 2012).

Although local surface water drainage on site is inferred to be in a general southwestern direction, the regional drainage occurs in a general north to north-western direction. The Grootspruit, transecting the project area to the southwest, convergences with the Saalboomspruit approximately 5.0 km to the northwest of the mine lease area from where it flows in a general northern direction before joining the Kromdraaispruit and Wilge Rivier ~ 20.0 km to the north. Major surface water features within this quaternary catchment include the Clewer dam < 1.0 km up-gradient of the mine lease boundary.

Refer to Figure 5-3 for a spatial layout of the project area in relation the water management area, quaternary catchments as well as regional drainage patterns. Table 5-1 provides a summary of relevant climatological and hydrogeological information for quaternary catchment B20G.

Table 5-1 Quaternary catchment information: CB20G.

Attribute	Catchment information
Water Management Area (WMA)	Olifants
Primary catchment	B
Secondary catchment	B2
Tertiary catchment	B20
Quaternary catchment	B20G
Major rivers	Elands,Wilge,Steelpoort and Olifants
Hydro-zone	J
Rainfall zone	B2C
Area (km^2)	522.0
Mean annual rainfall (mm)	669.0
Mean annual evaporation (mm)	1700.0
Mean annual runoff (mm)	44.1
Baseflow	10.8
Population	34279.0
Total groundwater use (l/s)	5.2
Present Eco Status Category	Category E/F
Recharge	7.0
Average water level (mbgl)	13.4
Soil type	SaClLm
Groundwater General Authorization	0 m^3/ha/a

Note: Catchment based information sourced from Aquiworx 2014

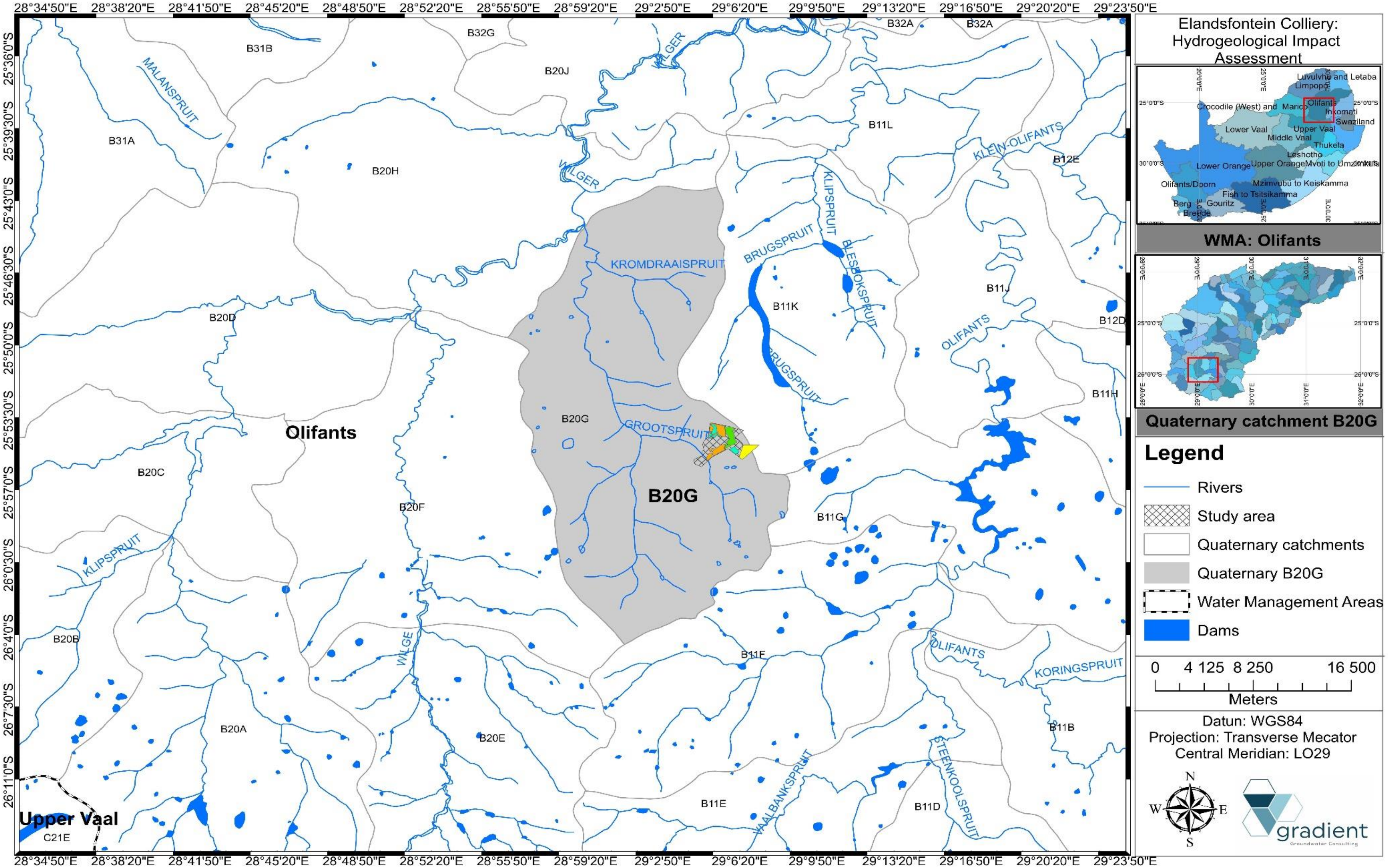


Figure 5-3 **Quaternary catchments and water management area.**

5.3. Climate

The study area's weather pattern reflects a typical summer rainfall region, with > 85.0% of precipitation occurring as high-intensity thunderstorms from October to March. Patched rainfall and evaporation data were sourced from the WR2012 database (Rainfall zone B2C) and span a period of some 90 years (1920 – 2009). The calculated mean annual precipitation (MAP) for this rainfall zone is 530.76 mm/a, with the 5th percentile of the data set (roughly equivalent to a 1:20 year drought period) calculated at 342.74 mm/a and the 95th percentile (representing a ~1:20 flood period) 717.84 mm/a. The highest MAP for the 90 years of rainfall data was recorded as of 940.85 mm (1995) while the lowest MAP of 291.38 mm was recorded during 1965. This quaternary catchment is categorised under evaporation zone 4A which have a mean annual evaporation (s-pan) of 1689.0 mm/a, more than double the annual precipitation for the greater study area. Figure 5-4 depicts a bar chart of the yearly rainfall distributions with Figure 5-5 indicating monthly rainfall patterns. Figure 5-6 provides a comparison of monthly precipitation and evaporation volumes. A summary of rainfall data used as part of this statistical analysis is summarised in Appendix A: Rainfall data.

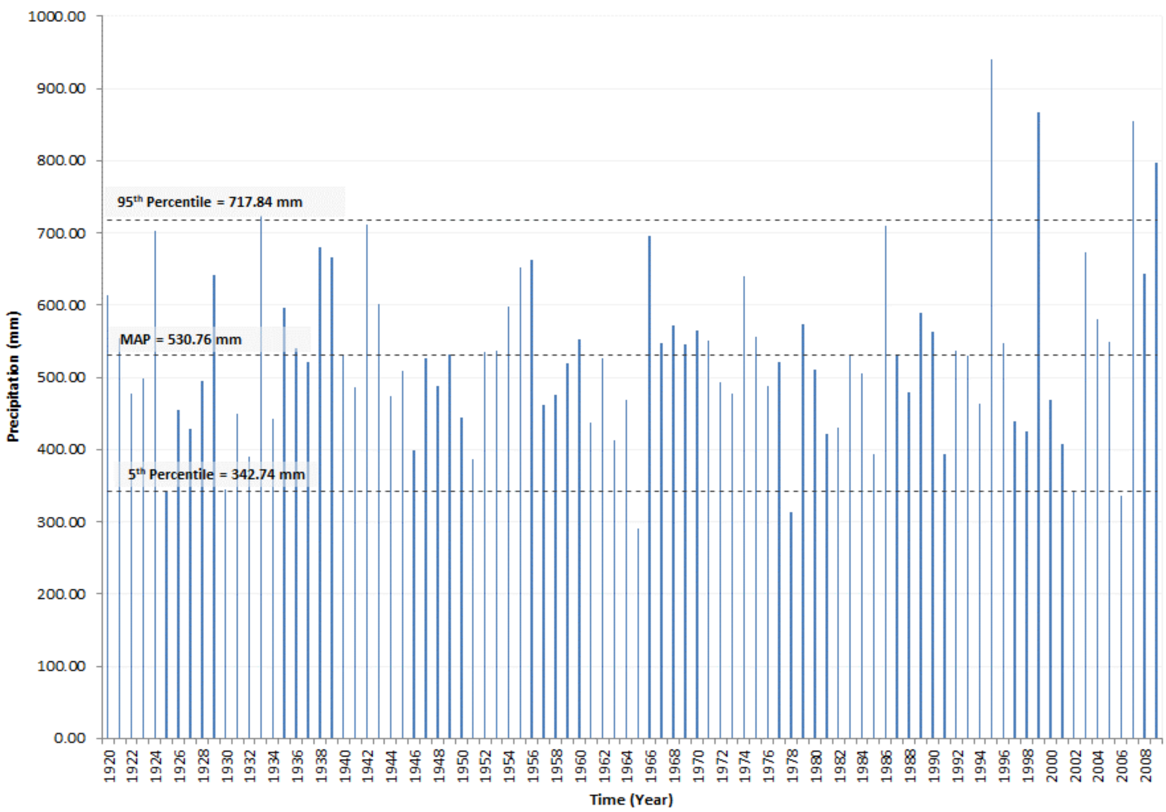


Figure 5-4 **Bar chart indicating yearly rainfall distribution for rainfall zone B2C (WR2012).**

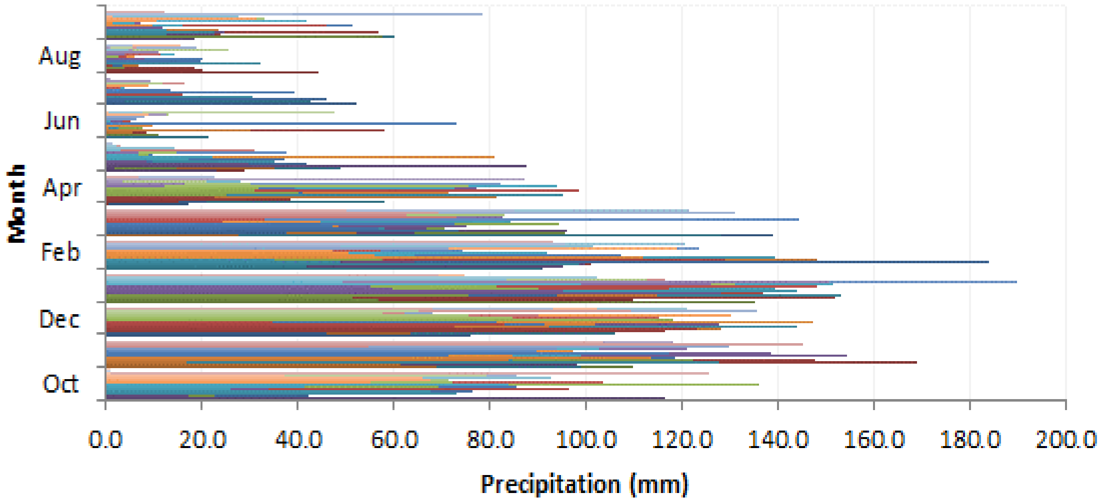


Figure 5-5 Bar chart indicating monthly rainfall distribution for rainfall zone B2C (WR2012).

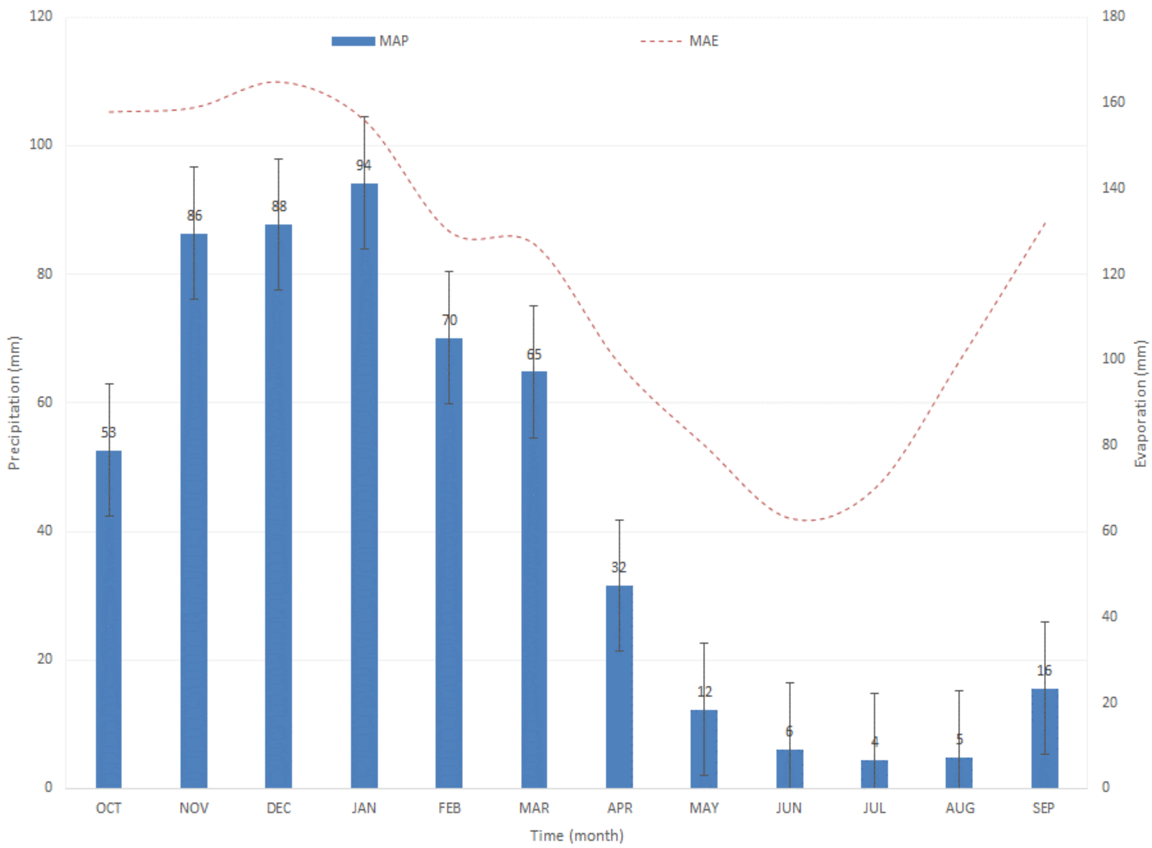


Figure 5-6 Bar chart and curve comparing monthly rainfall and evaporation distribution (WR2012).

5.4. Geological setting

5.4.1. Regional geology

The greater study area falls within the Ecca Group of the Karoo Supergroup, which consists of a sequence of units, mostly of nonmarine origin, deposited between the Late Carboniferous and Early Jurassic (Schlüter and Thomas, 2008). The Permian Ecca Group follows conformably after the Dwyka Group in certain sections, however in some localities overlies unconformably over older basement rocks. The Ecca Group underlies the Beaufort Group in all known outcrops and exposures and comprises a total of 16 formations consisting largely of shales and sandstones (Figure 5-7).

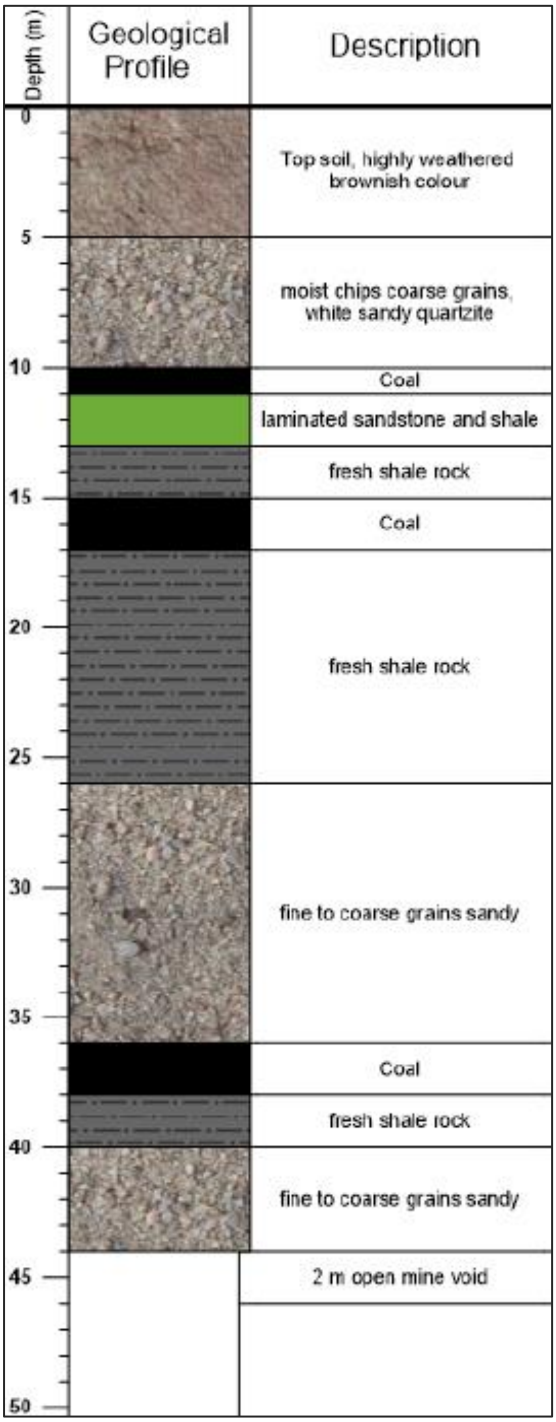
5.4.2. Local geology

According to the 1:250 000 geological mapsheet (2528, Pretoria) the study area falls within the Madzaringwe formation with surficial geology consisting mainly of shale, shaly sandstone, grit, sandstone, conglomerate as well as interlaminated coal layers and entail predominantly arenaceous formations. Refer to Table 5-2 for a simplified stratigraphic column of the study area.

5.4.3. Structural geology

On a regional scale, two geological lineaments (potentially faults zones) exist in close proximity to the greater study area, striking in a general north-south and southwest-northeast orientation respectively. Faults zones may have an impact on the local hydrogeological regime as it can serve as potential preferred pathways for groundwater flow and contaminant transport.

Table 5-2 Simplified stratigraphic column of the greater study area (after Digby Wells, 2018).



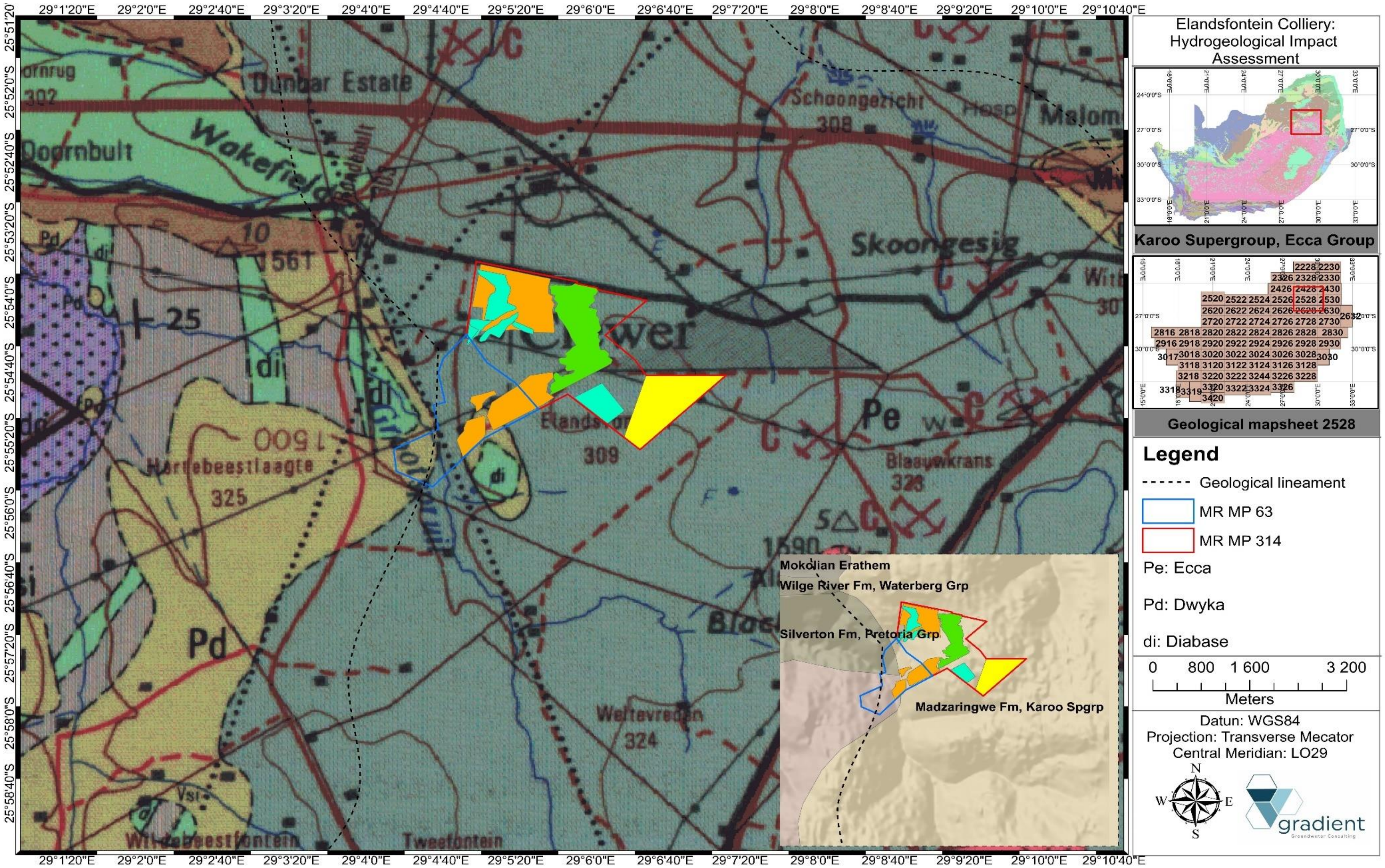


Figure 5-7 **Regional geology and stratigraphy (Geological mapsheets 2630).**

6. HYDROGEOLOGICAL BASELINE ASSESSMENT

6.1. Regional hydrogeology

The Department have characterised South African aquifers based on host-rock formations in which it occurs together with its capacity to transmit water to boreholes drilled into relative formations. The water bearing properties of respective formations can be classified into four aquifer classes defined as:

a. **Class A:** Intergranular o Aquifers associated either with loose and unconsolidated formations such as sands and gravels or with rock that has weathered to only partially consolidated material.
b. **Class B:** Fractured o Aquifers associated with hard and compact rock formations in which fractures, fissures and/or joints occur that are capable of both storing and transmitting water in useful quantities.
c. **Class C:** Karst o Aquifers associated with carbonate rocks such as limestone and dolomite in which groundwater is predominantly stored in and transmitted through cavities that can develop in these rocks.
d. **Class D:** Intergranular and fractured o Aquifers that represent a combination of Class A and B aquifer types. This is a common characteristic of South African aquifers. Substantial quantities of water are stored in the intergranular voids of weathered rock but can only be tapped via fractures penetrated by boreholes drilled into it. Each of these classes is further subdivided into groups relating to the capacity of an aquifer to transmit water to boreholes, typically measured in l/s. The groups therefore represent various ranges of borehole yields.

According to the DWS Hydrogeological map (DWS Hydrogeological map series 2526 Johannesburg) the site is predominantly underlain by an intergranular and fractured aquifer system (d3) comprising mostly fractured and weathered compact sedimentary/ arenaceous rocks (Figure 6-1). The Ecca Group consists mainly of shales and sandstones that are very dense with permeability usually very low due to poorly sorted matrices. Water is stored mainly in decomposed/partly decomposed rock and water bearing fractures are principally restricted to a shallow zone below the static groundwater level. Sustainable borehole yields are limited to < 0.5 l/s, while higher yielding boreholes (> 3.0 l/s) may occur along structural features i.e. fault and fracture zones (Barnard, 2000). Water levels are variable and controlled by topography, ranging from 10.0 mbgl (in low laying areas) to > 40.0 mbgl in higher elevated areas (Olifants ISP DWS, 2004). The maximum aquifer depth fluctuates between 30.0 – 50.0 mbgl. depicted in Figure 6-2.

6.2. Local hydrostratigraphic units

For the purposes of this investigation, two main hydrostratigraphic units can be inferred in the saturated zone[3]:

i. A shallow, weathered zone aquifer occurring in the transitional soil and weathered bedrock formations underlain by more consolidated bedrock. Ecca sediments are weathered to depths between 5.0 – 15.0 mbgl (Digby Wells, 2018). Groundwater flow patterns usually follow the topography, discharging as natural springs and/or baseflow at topographic low-laying areas. Usually this aquifer can be classified as a secondary porosity aquifer and is generally unconfined with phreatic water levels. Due to higher effective porosity (*n*) this aquifer is most susceptible to impacts from contaminant sources.

ii. An intermediate/deeper fractured aquifer where groundwater flow will be dictated by transmissive fracture zones that occur in the relatively competent host rock. Fractured sandstones and shales sequences are considered as hard-rock aquifers holding water in storage in both pore spaces and fractures. Groundwater yields, although more heterogeneous, can be expected to be higher than the weathered zone aquifer. This aquifer system usually displays semi-confined or confined characteristics with piezometric heads often significantly higher than the water-bearing fracture position.

[3] it should be noted that no site characterisation boreholes have been drilled to confirm this assumption and this is based on historical hydrogeological investigation in this area and/or similar environments.

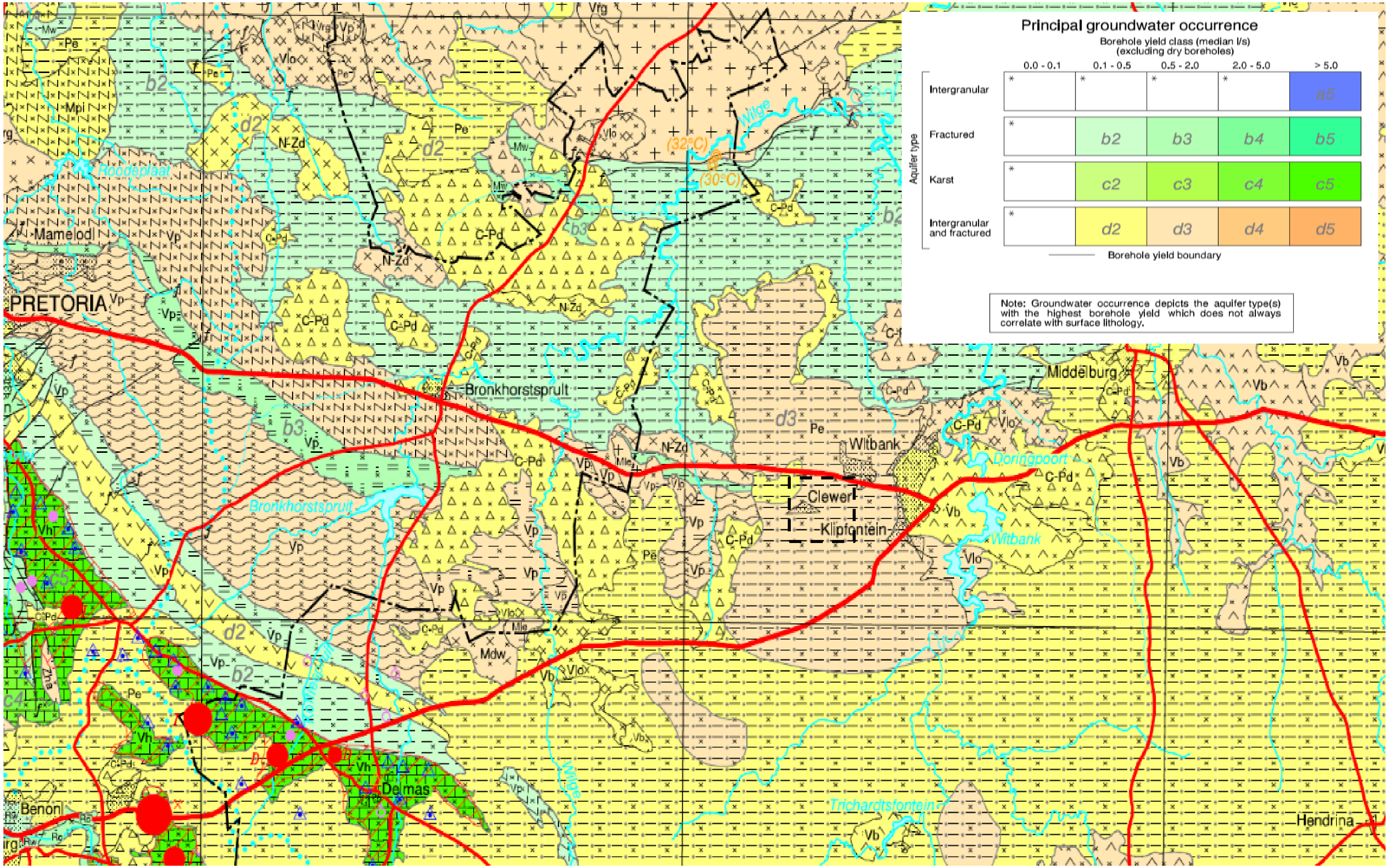


Figure 6-1 **Hydrogeological map illustrating the typical groundwater occurrence for the study region.**

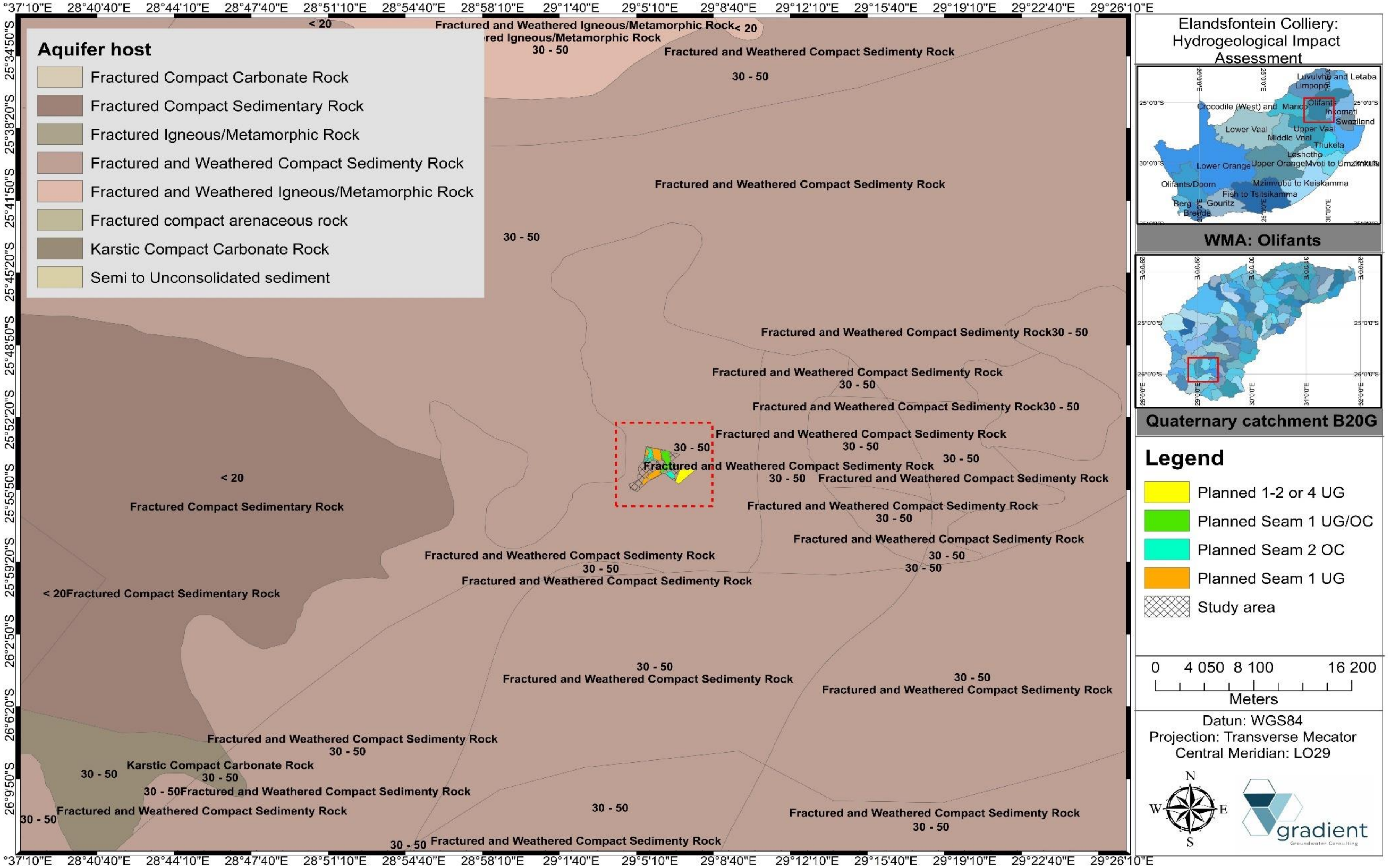


Figure 6-2 **Hydrostratigrpahical units.**

6.3. Hydraulic parameters

To follow is a brief overview of aquifer hydraulic parameters based on published literature for similar hydrogeological conditions as well as historical reports.

6.3.1. Hydraulic conductivity and Transmissivity

Hydraulic conductivity is the constant of proportionality in Darcy's Law which states that the rate of flow through a porous medium is proportional to the loss of head, and inversely proportional to the length of the flow path as indicated in the following equation:

Equation 6-1 Hydraulic Conductivity (Darcy's Law).

$$\boldsymbol{K} = \frac{\boldsymbol{Q}}{\boldsymbol{A}\left(\frac{dh}{dl}\right)}$$

where:

K = Hydraulic Conductivity (m/d).

Q = Flow of water per unit of time (m^3/d).

dh/dl = Hydraulic gradient.

A = is the cross-sectional area, at a right angle to the flow direction, through which the flow occurs (m^2)

The hydraulic conductivity of sandstone formations can range from $9e^{-05}$ – $9e^{-01}$ m/d whereas the hydraulic conductivity of denser shale formations is lower and estimated at $9e^{-09}$ – $9e^{-05}$ m/d. The conductivity of the weathered aquifer, including brittle coal seams, may be orders of magnitude higher and is estimated at $5e^{-02}$ m/d. It should also be noted that mined out and back-filled areas may have different hydraulic properties as the inherent values have been altered and modified (Freeze and Cherry, 1979).

Transmissivity can be expressed as the product of the average hydraulic conductivity (K) and thickness (b) of the saturated portion of an aquifer and expressed by:

Equation 6-2 Transmissivity.

$$\boldsymbol{T} = \boldsymbol{Kb}$$

where:

T = Transmissivity (m^2/d).

K = Hydraulic Conductivity (m/d).

b = Saturated aquifer thickness.

The average transmissivity for the shallow, weathered aquifer is estimated at 1.0 m^2/d.

6.3.2. Storativity

Storativity refers to the volume of water per volume of aquifer released as a result of a change in head. For a confined aquifer, the storage coefficient is equal to the product of the specific storage and aquifer thickness. Typical storativity values for dense sedimentary formations is in the order of 10^{-5} – 10^{-3} while storativity values of the shallow, weathered aquifer can be slightly higher at 10^{-2} (Freeze and Cherry, 1979).

6.3.3. Porosity

Porosity is an intrinsic value of seepage velocity and hence contamination migration. The porosity of sandstone formations ranges between 0.05 – 0.30, while porosity of shale formations varies from 0 – 0.10. Porosity of the weathered aquifer and unconsolidated formations can be as high as 0.25 – 0.40 depending on the nature and state of weathering as well as sorting (Freeze and Cherry, 1979).

6.3.4. Recharge

An approximation of recharge for the study area is estimated at ~6.21 % of MAP i.e. ~32.93 mm/a as summarised in Table 6-1. Groundwater recharge was calculated using the RECHARGE Program1 (van Tonder and Xu, 2000), which includes using qualified guesses as guided by various schematic maps. The following methods/sources were used to estimate the recharge: (i) Chloride Mass Balance (CMB) method (ii) Geology (iii) Vegter Groundwater Recharge Map (Figure 6-3) (iv) Harvest Potential Map; (v) Baseflow as a minimum recharge value (Figure 6-4) (vi) Literature and (vi) Qualified opinion. It should be noted that due to the modified mining environment, recharge values may differ at certain zones i.e. backfilled areas, discard dumps etc. Using the simplified CMB method as proposed by Bean (2003), the following equation applies to calculating recharge.

Equation 6-3 Chloride Mass Balance formula.

$$R = \frac{Cl_{p+D}}{Cl_g}$$

where:

R = Recharge (mm/a)

Cl_p = Representative mean chloride concentration in rainwater including contributions from dry deposition

Cl_g = Chloride concentration in groundwater resulting from diffuse recharge

Table 6-1 Recharge estimation (after van Tonder and Xu, 2000).

Recharge method/ Reference	Recharge (mm/a)	Recharge (% of MAP)	Weighted Average (High = 5; Low = 1)
Chloride	28.89	5.44	3.00
Geology	28.25	5.32	3.00
Vegter	32.00	6.03	4.00
Harvest Potential	25.00	4.71	4.00
Baseflow	37.50	7.07	3.00
Literature	40.00	7.54	5.00
Qualified Opinion	37.15	7.00	3.00
Weighted average	**32.93**	**6.21**	**25.00**

Notes: Recharge per annum were calculated using a MAP of 531 mm/a.

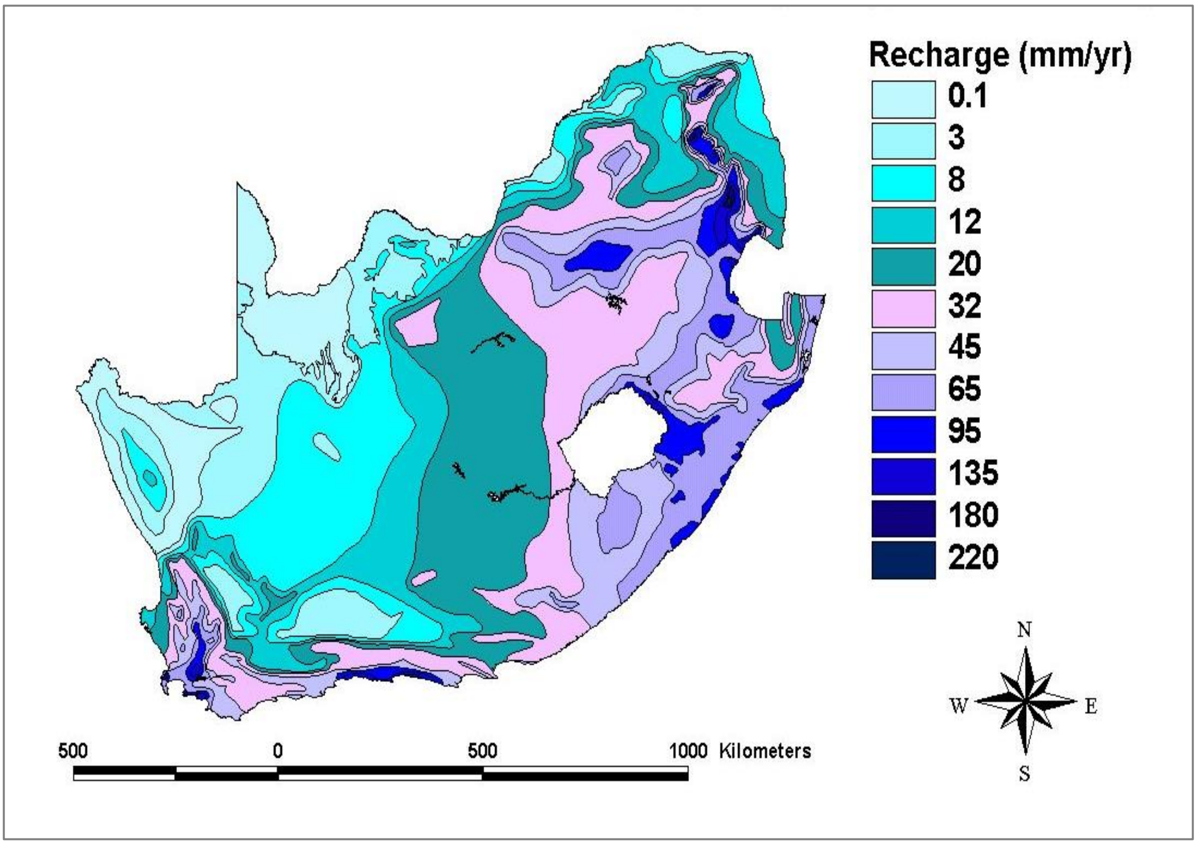


Figure 6-3 **Groundwater recharge distribution in South Africa (After Vegter, 1995).**

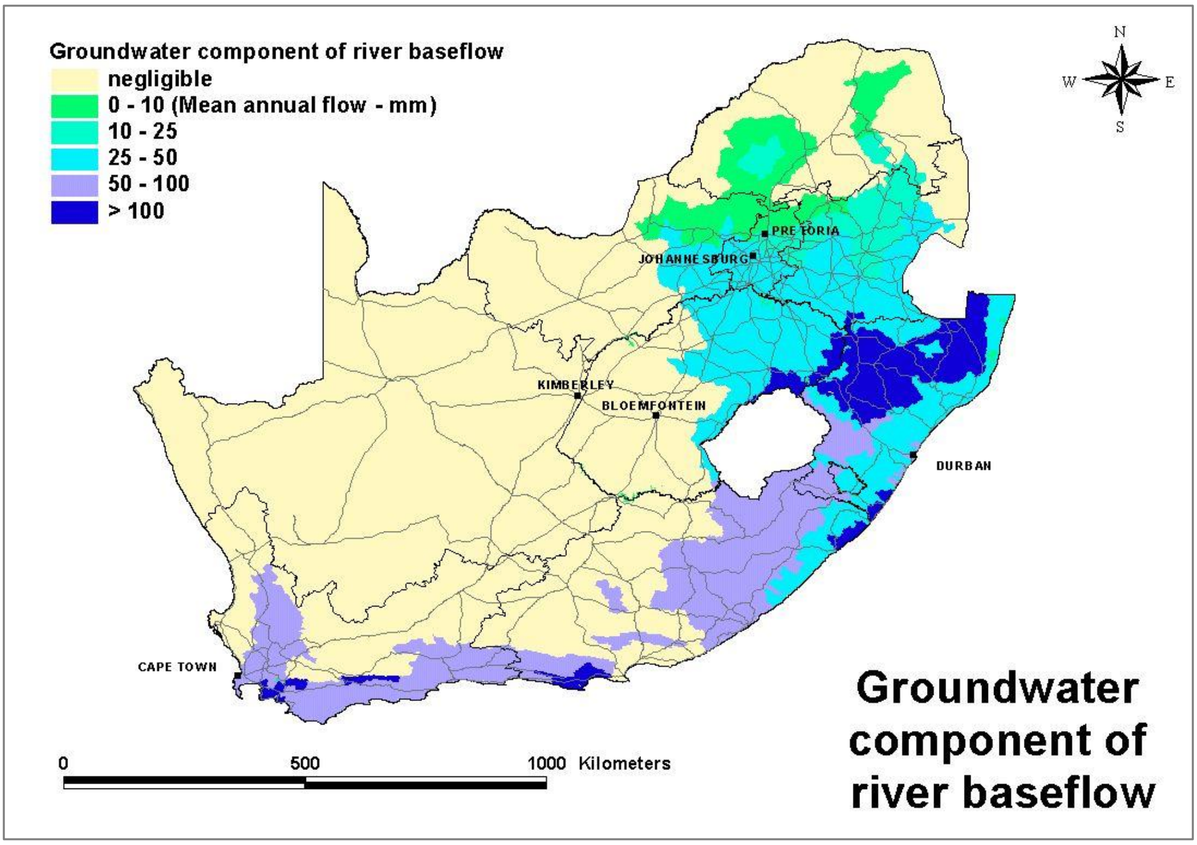


Figure 6-4 **Groundwater component of river baseflow in South Africa (DWS, 2013).**

6.4. Site investigation

A hydrocensus user survey within the greater study area was conducted during August 2019[4] where relevant hydrogeological baseline information was gathered. The aim of the hydrocensus survey is to determine the ambient and background groundwater conditions and applications prior to the proposed activities and to identify potential sensitive environmental receptors i.e. groundwater users in the direct vicinity of the operations. Geosites visited include 21 boreholes as well as two (2) surface water features i.e. drainages. Relevant hydrocensus information is summarised in Table 6-2 with a spatial distribution map shown in Figure 6-5.

6.4.1. Groundwater status

Of the boreholes recorded, the majority are in use (>73.0%) with only two boreholes are not currently utilised Refer to Figure 6-7.

6.4.2. Groundwater application

According to the Olifants Internal Strategic Perspective (ISP) (2004), the greater study area is charatcerised by agricultural activities, mostly stock farming, but with maize and other arable crops grown in flat areas. Most boreholes recorded are being applied for monitoring purposes (> 70.0 %) while groundwater application recorded for domestic and livestock purposes is ~17.0% and domestic and household purposes accounts for ~11.0% as summarised in Figure 6-8.

6.4.3. Borehole equipment

Most boreholes visited are not equipped (>70.0 %) while the remaining boreholes are equipped with submersible pumps (~28.0%) as indicated in Figure 6-9.

[4] It should be noted that relevant site information gathered will be representative of dry season contribution.

Table 6-2 Hydrocensus user survey: relevant geosite information.

Site ID	Latitude	Longitude	Water level (mbgl)	Water level status	Site type	Site status	Equipment	Water application	Owner	Contact details	Comments
ASW 01	-25.90871	29.06532	0.00		River	Not in use		Not in use		Witbank Anker Mine	
AHBH01	-25.91653	29.06203	4.85	Static	Borehole	Domestic	Submersible	Water supply	0724114242	Witbank Anker Mine	Pump 1x per week for 20 min
AHBH02	-25.91809	29.04529	10.29	Static	Borehole	Domestic & Livestock	Submersible	Water supply	0728984173	Witbank Anker Mine	Pump 4X per week for 1Hour
AHBH03	-25.92835	29.07116	8.18	Static	Borehole	Domestic	Submersible	Water supply	0715370381	Witbank Anker Mine	Pump 1x evey 2 weeks for 1,5 Hours
ELNBH1	-25.91337	29.10857	36.31	Static	Borehole	Monitoring	Not Equipped	Monitoring		Witbank Anker Mine	
ECBH05	-25.90390	29.09791	39.07	Static	Borehole	Monitoring	Not Equipped	Monitoring		Witbank Anker Mine	
ELNBH 07 S	-25.90810	29.09977	13.98	Static	Borehole	Monitoring	Not Equipped	Monitoring		Witbank Anker Mine	
ELNBH 06 D	-25.90823	29.09978	0.00		Borehole	Not in use	Not equipped	Not in use		Witbank Anker Mine	Ants closed borehole
ECBH 02	-25.90317	29.09656	7.56	Static	Borehole	Monitoring	Not equipped	Monitoring		Witbank Anker Mine	
ECBH 03	-25.90300	29.09633	7.57	Static	Borehole	Monitoring	Not equipped	Monitoring		Witbank Anker Mine	
ECBH 04	-25.90200	29.09721	9.55	Static	Borehole	Monitoring	Not equipped	Monitoring		Witbank Anker Mine	
ELNBH 02	-25.91422	29.10172	49.69	Static	Borehole	Monitoring	Not equipped	Monitoring		Witbank Anker Mine	Not allot of water to take sample
GW 02	-25.91337	29.09551	23.19	Static	Borehole	Monitoring	Not equipped	Monitoring		Witbank Anker Mine	
ELNBH 03	-25.91994	29.08637	17.34	Static	Borehole	Monitoring	Not equipped	Monitoring		Witbank Anker Mine	
ASW 02	-25.91884	29.07801	0.00		River	Not in use		Not in use		Witbank Anker Mine	
BH 173	-25.92416	29.07895	4.02	Static	Borehole	Monitoring	Not equipped	Monitoring		Witbank Anker Mine	
BH 172	-25.92389	29.07795	5.78	Static	Borehole	Monitoring	Not equipped	Monitoring		Witbank Anker Mine	
FFBH 11	-25.98498	29.08882	6.81	Static	Borehole	Monitoring	Not equipped	Monitoring		Witbank Anker Mine	
AHBH04	-25.91113	29.11185	7.18	Static	Borehole	Not in use	Not equipped	Not in use	0826263161	Witbank Anker Mine	
AHBH05	-25.90756	29.11130	38.68	Recovering	Borehole	Domestic & Livestock	Submersible	Water supply	0727833920	Witbank Anker Mine	Timer pump 1every hour foe 5min
AHBH06	-25.90661	29.11516	19.89	Recovering	Borehole	Domestic & Irrigation	Submersible	Water supply	0836607410	Witbank Anker Mine	Pump 1x pd for 9h
AHBH07	-25.90243	29.11997	7.54	Static	Borehole	Not in use	Not equipped	Not in use	0790532976	Witbank Anker Mine	
AHBH08	-25.90627	29.12654	4.28	Static	Borehole	Not in use	Submersible	Not in use	0790782209	Witbank Anker Mine	

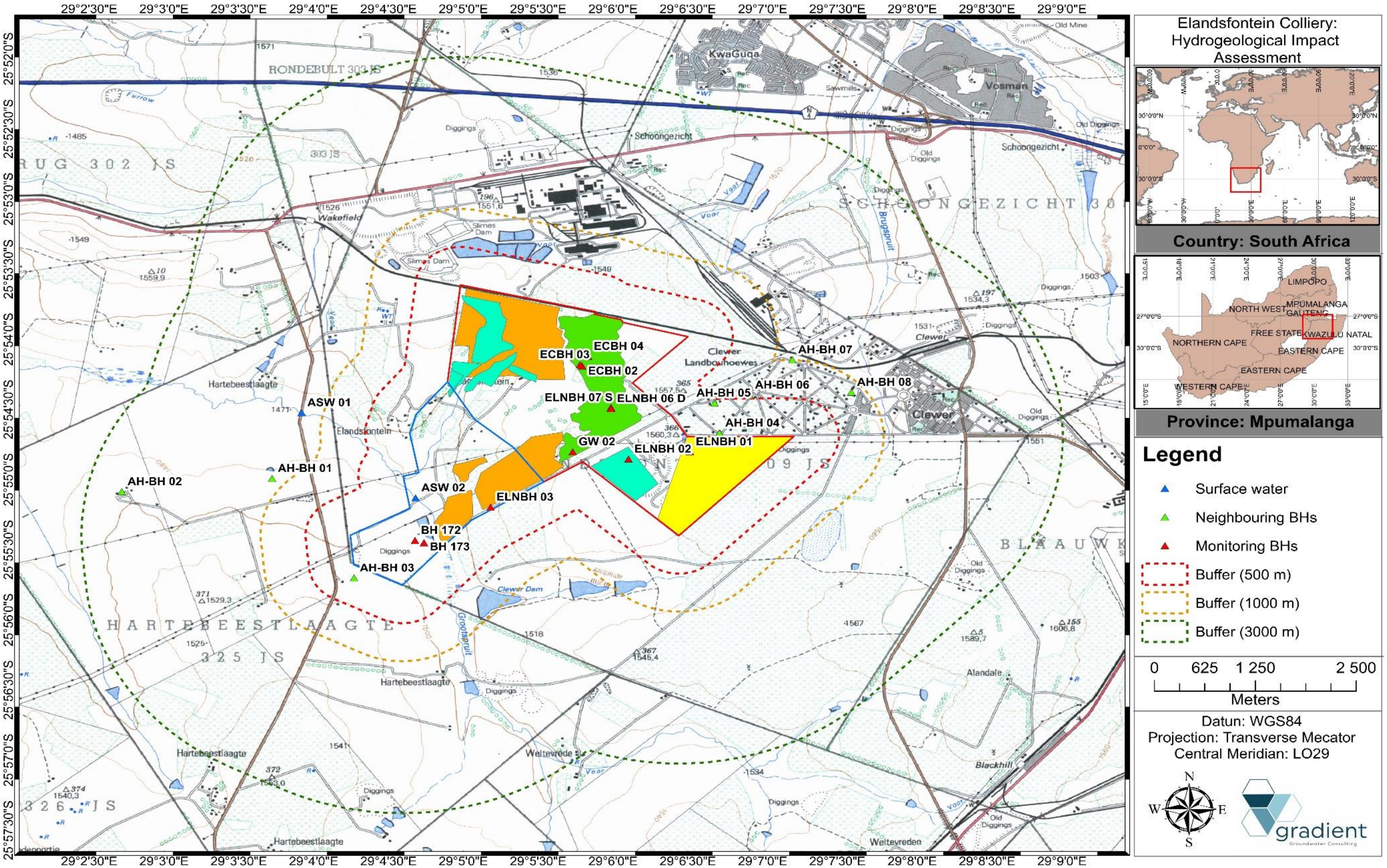


Figure 6-5 **Spatial distribution of hydrocensus user survey geosites.**

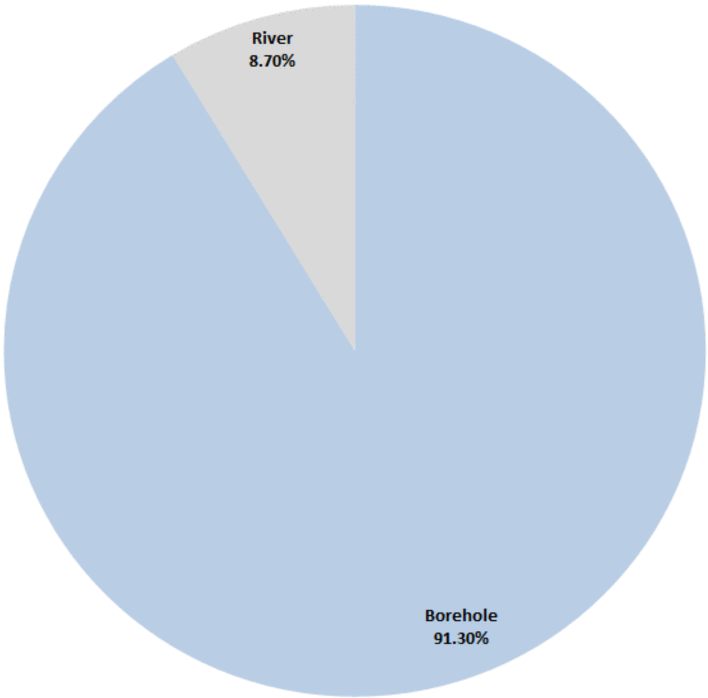


Figure 6-6 Hydrocensus user survey: Geosite recorded.

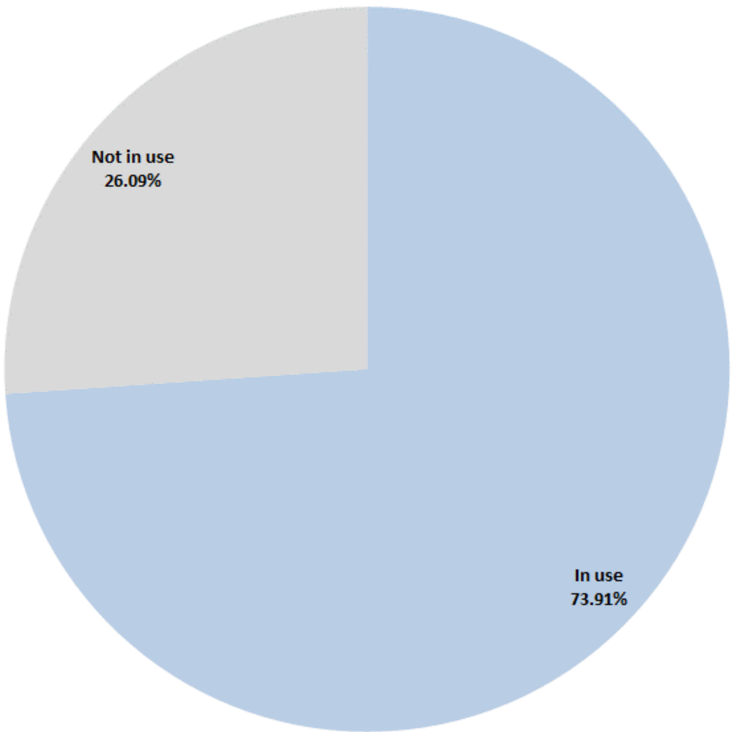


Figure 6-7 Hydrocensus user survey: Groundwater status.

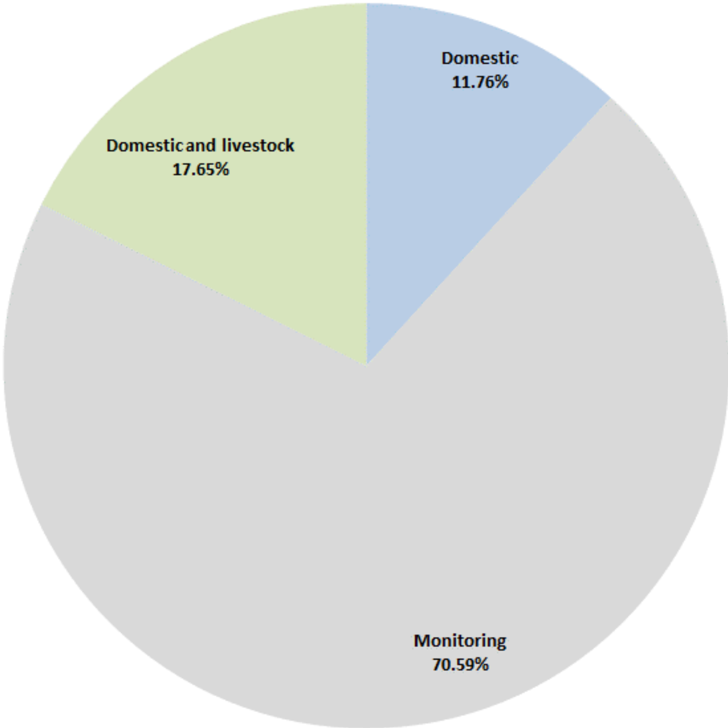


Figure 6-8 **Hydrocensus user survey: Groundwater application.**

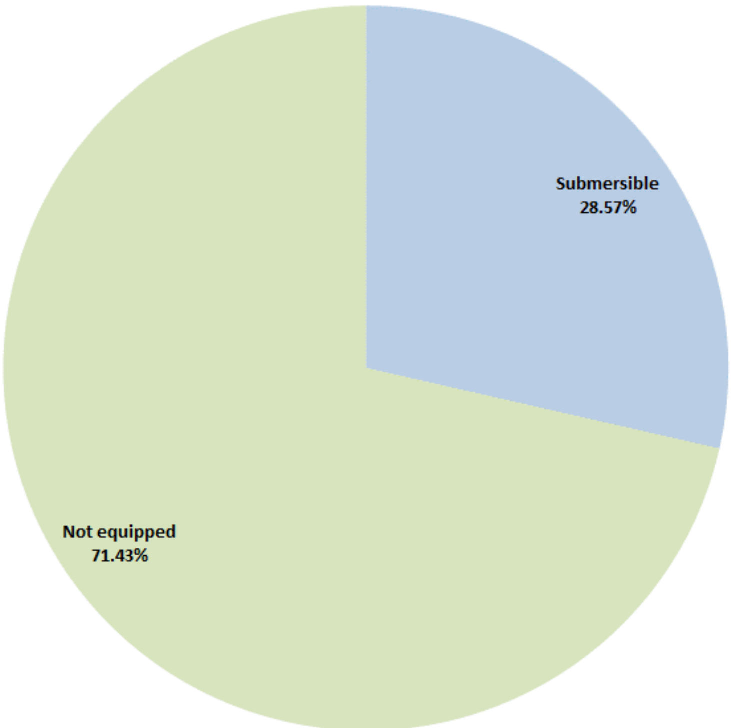


Figure 6-9 **Hydrocensus user survey: Equipment type.**

7. GROUNDWATER FLOW EVALUATION

The following sub-sections outline the site-specific hydrogeology of the study area.

7.1. Unsaturated zone

The thickness of the unsaturated or vadose zone was determined by subtracting the undisturbed static water level elevation from corresponding surface topography. The latter will govern the infiltration rate, as well as effective recharge of rainfall to the aquifer. Furthermore, the nature of the formation(s) forming the unsaturated zone will significantly influence the mass transport of surface contamination to the underlying aquifer(s). The unsaturated zone[5] within the study area is in the order of ~2.85 to ~17.34 m with a mean thickness of approximately 7.84 m.

7.2. Depth to groundwater

A distribution of borehole water levels recorded as part of the hydrocensus user survey as well as boreholes forming part of the existing groundwater monitoring network were considered and used to interpolate local groundwater elevation and hydraulic head contours. The groundwater levels available from the hydrocensus survey and monitoring boreholes in and around the mining areas are summarized in Table 7-1 and depicted in Figure 7-1.The minimum water level was recorded at on-site borehole GW05 (2.85 mbgl), while the deepest water level measured was at borehole locality ELNBH02, 49.69 mbgl[6].

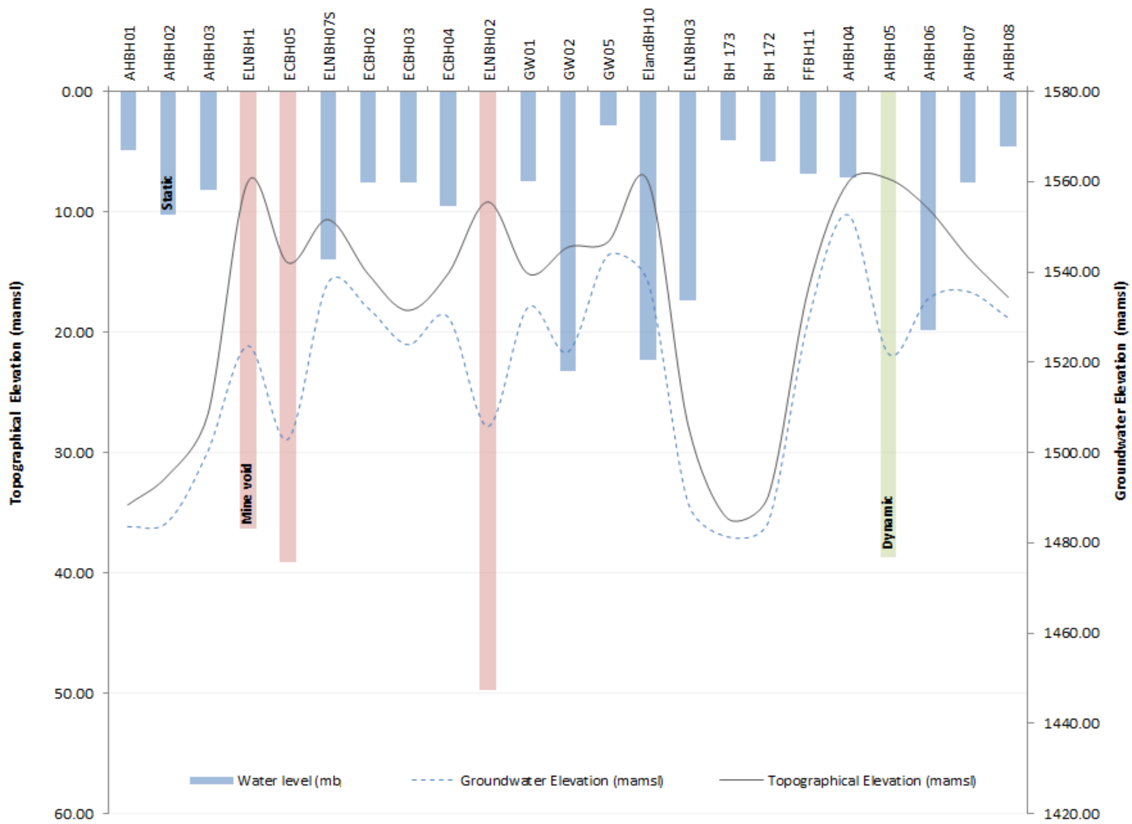


Figure 7-1 **Topographical elevation vs. groundwater elevation correlation graph.**

[5] This is based on all static groundwater levels measured at surveyed boreholes.

[6] It should be noted that static water levels in excess of ~35.0 mbgl measured within the mining footprints are assumed to enter historical mine voids. Hydrochemistry analysis also confirm this assumption.

Table 7-1 Regional water level summary[7].

Site ID	Topographical Elevation (mamsl)	Water level (mbgl)	Groundwater Elevation (mamsl)	Water level status
AHBH01	1488.41	4.85	1483.56	Static
AHBH02	1494.94	10.29	1484.65	Static
AHBH03	1508.46	8.18	1500.28	Static
ELNBH1	1559.92	36.31	1523.61	Shaft
ECBH05	1541.99	39.07	1502.92	Shaft
ELNBH07S	1551.57	13.98	1537.59	Static
ECBH02	1539.57	7.56	1532.01	Static
ECBH03	1531.45	7.57	1523.88	Static
ECBH04	1539.57	9.55	1530.02	Static
ELNBH02	1555.47	49.69	1505.78	Dynamic
GW01	1539.58	7.43	1532.15	Static
GW02	1545.46	23.19	1522.27	Dynamic
GW05	1546.62	2.85	1543.77	Static
ElandBH10	1559.99	22.33	1537.66	Static
ELNBH03	1506.10	17.34	1488.76	Static
BH 173	1485.29	4.02	1481.27	Static
BH 172	1490.29	5.78	1484.51	Static
FFBH11	1536.04	6.81	1529.23	Static
AHBH04	1559.84	7.18	1552.66	Static
AHBH05	1560.58	38.68	1521.90	Dynamic
AHBH06	1553.95	19.89	1534.06	Dynamic
AHBH07	1543.18	7.54	1535.64	Static
AHBH08	1534.39	4.58	1529.81	Static
Harmonic mean	**1533.20**	**4.98**	**1517.87**	
Minimum	**1485.29**	**2.85**	**1481.27**	
Maximum	**1560.58**	**49.69**	**1552.66**	
Standard deviation	**24.45**	**13.12**	**21.29**	
Correlation		**0.84**		

[7] Correlation factor calculated by accounting for all water levels measured on-site (static, dynamic and mine void water levels).

7.3. Groundwater flow direction and hydraulic gradients

Analysed data indicate that the regional groundwater elevation correlates moderately to the topographical elevation (R^2 ~ 0.84) suggesting a dynamic environment. However, water level data for the shallow aquifer indicate that the majority of levels correlate very well to the topographical elevation (R^2 > 0.93) (Figure 7-1). Accordingly, it can be assumed that the regional groundwater flow direction of the shallow aquifer is dictated by topography. Accordingly, the inferred groundwater flow direction of the shallow aquifer will be in a general southwestern direction towards the lower laying drainage system of the Grootspruit transecting the project area from where it will discharge as baseflow. On-site water levels of the underground mine void do not correlate well to topography and is a function of the coal seam floor contours historically mined.

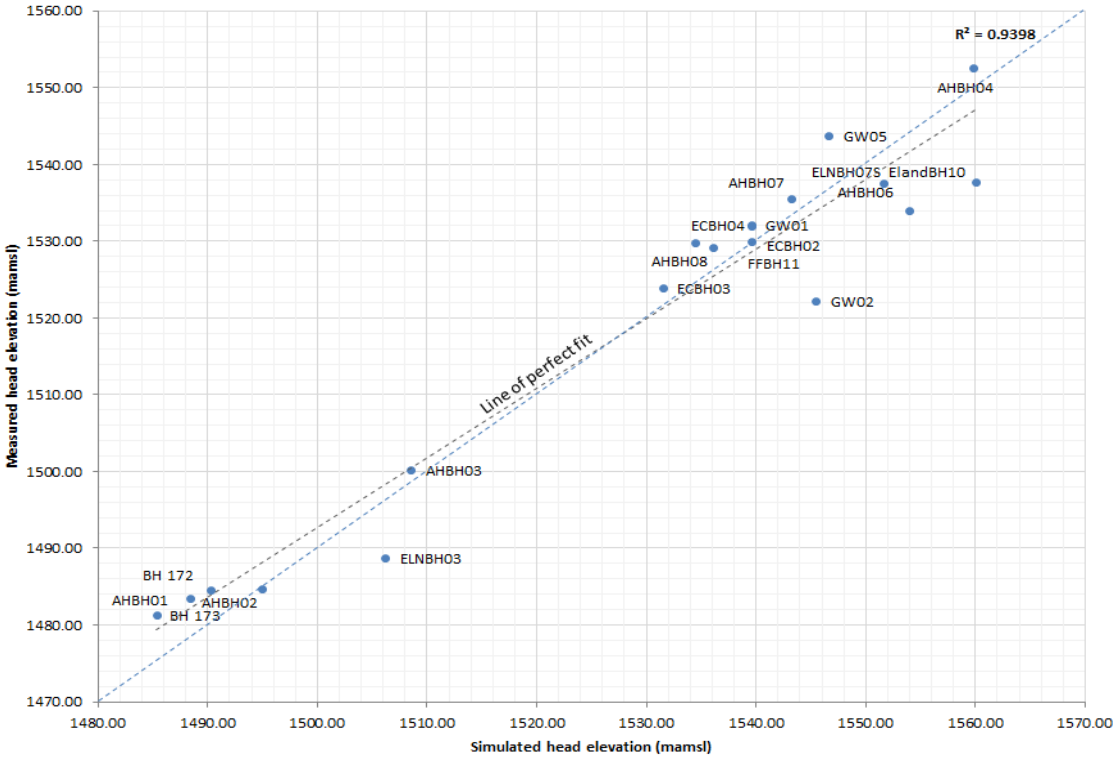


Figure 7-2 Correlation between topography and groundwater elevation in the shallow aquifer (static WL).

Groundwater flow path lines are lines perpendicular to groundwater contours, flow generally occurs faster where contours are closer together and gradients are thus steeper as depicted in Figure 7-3.The groundwater or hydraulic gradient is the change in the hydraulic head over a certain distance, mathematically it is the difference in hydraulic head over a distance along the flow path between two points. The latter provides an indication of the direction of groundwater flow. The following equation can be applied:

Equation 7-1 Hydraulic gradient.

$$i = \frac{dh}{dl}$$

where:

i = Hydraulic gradient (dimensionless).

dh = Is the head loss between two observation wells.

dL = Horizontal distance between two observation points.

The average groundwater gradient (i) of the shallow, weathered aquifer in the vicinity of the potential high-risk seepage areas i.e. mine discard dump and/or slurry ponds is moderately flat and calculated at approximately 0.004, with a maximum of 0.013 towards the west and southwest while a gentler gradient of -0.003 exists to the north as summarised in Table 7-2.

Table 7-2 Inferred groundwater gradient and seepage direction.

Inferred seepage direction	Hydraulic gradient (i)
South	0.013
East	-0.005
West	0.011
North	-0.003
Minimum	**-0.005**
Maximum	**0.013**
Standard deviation	**0.008**
Geometric Mean	**0.004**

7.4. Darcy flux and groundwater flow velocity

The Darcy flux (or velocity) is a function of the hydraulic conductivity (K) and the hydraulic gradient as suggested by Equation 7-2 whereas the seepage velocity can be defined as the Darcy flux divided by the effective porosity[8] (Equation 7-3). This is also referred to as the average linear velocity and can be calculated by applying the following equations (Fetter 1994).

Equation 7-2 Darcy flux.

$$v = Ki$$

Equation 7-3 Seepage velocity.

$$v = \frac{Ki}{\emptyset}$$

where:

v = flow velocity (m/d).

K = hydraulic conductivity (m/d).

i = hydraulic gradient (dimensionless).

ø = effective porosity.

[8] It should be noted that effective porosity percentages have been assumed and in situ tests have not been conducted to confirm these ratios.

The expected seepage rate from contamination originating at the discard dump is estimated at an average of 0.48 m/a, with a maximum distance of 2.37 m/a in a southern to southwestern direction as summarized in Table 7-3[9].

Table 7-3 Darcy flux and seepage rates.

Shallow, weathered aquifer	Hydraulic gradient (i)	Hydraulic conductivity (K)	Darcy flux (m/d)	Effective porosity	Seepage velocity (m/d)	Seepage velocity (m/a)
South	0.013	0.050	0.001	0.100	0.007	2.373
East	0.005	0.050	0.000	0.100	0.002	0.890
West	0.011	0.050	0.001	0.100	0.005	1.986
North	0.003	0.050	0.000	0.100	0.001	0.476
Minimum	**0.003**	**0.050**	**0.000**	**0.100**	**0.001**	**0.476**
Maximum	**0.013**	**0.050**	**0.001**	**0.100**	**0.007**	**2.373**
Standard deviation	**0.004**	**0.000**	**0.000**	**0.000**	**0.002**	**0.774**
Harmonic Mean	**0.005**	**0.050**	**0.000**	**0.100**	**0.003**	**0.964**

[9] This estimate does however not take into account all known or suspected zones in the aquifer like preferential flow paths formed by faults and fracture zones or igneous contact zones like the intrusive dykes that have higher transmissivities than the general aquifer matrix. Such structures may cause flow velocities to 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.

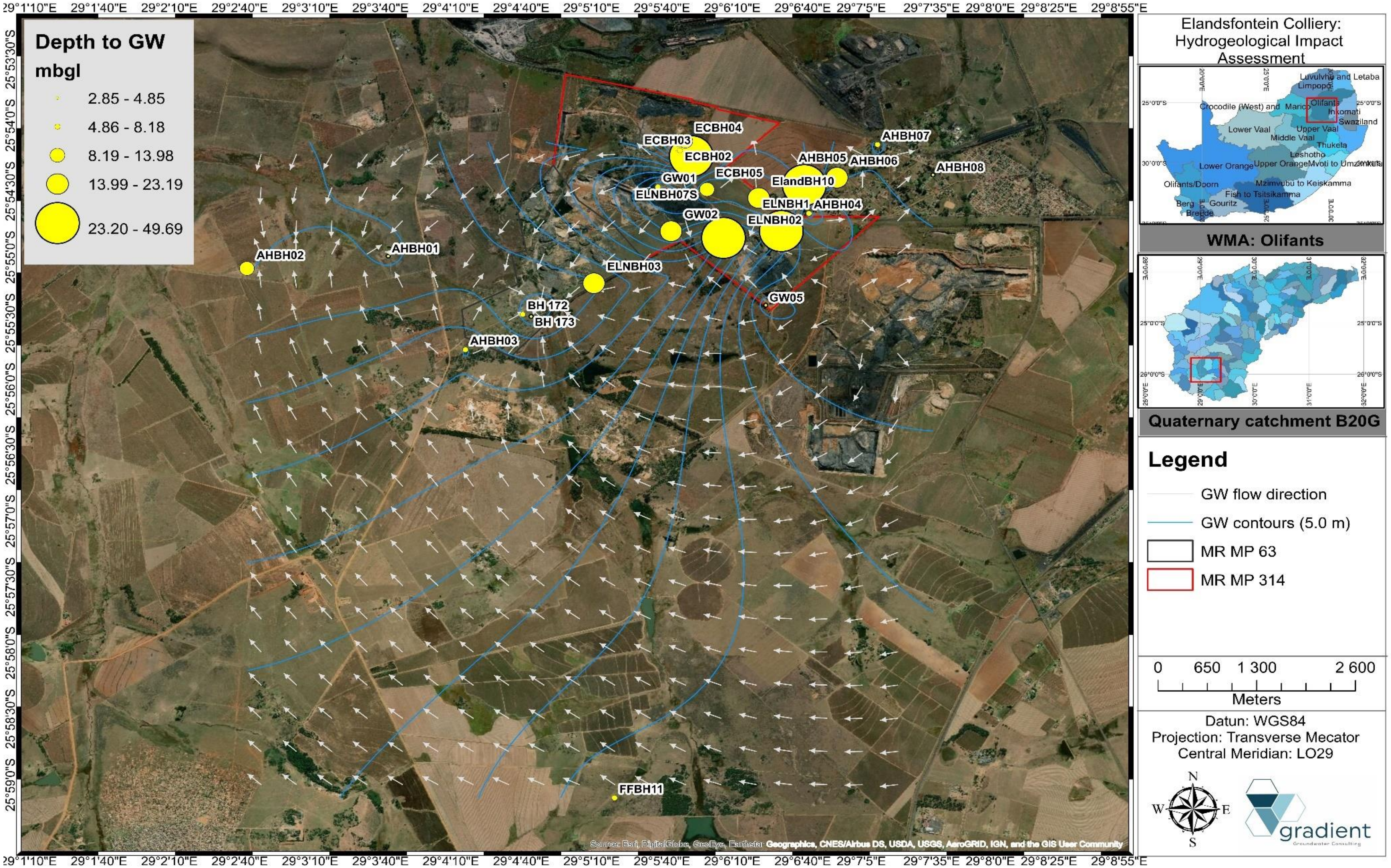


Figure 7-3 **Regional groundwater flow direction and depth to groundwater.**

8. HYDROCHEMISTRY

8.1. Water quality analysis

The South African National Standards (SANS 241: 2015) have been applied to assess the water quality within the project area. The standards specify a maximum limit based on associated risks for constituents (Refer to Table 8-1). Water samples were submitted for analysis at a SANAS accredited laboratory for inorganic analysis. Parameters exceeding the stipulated SANS 241:2015 thresholds are highlighted in red (acute health), elemental concentrations above this range are classed as unsuitable for domestic consumption without treatment whereas yellow highlighted cells indicate parameters above aesthetic limits. These standards were selected for use as the current and future water uses in the area are primarily domestic application and/or livestock watering. Refer to Appendix B for laboratory analysis certificates.

Table 8-1 SANS 241:2015 risks associated with constituents occurring in water.

Risk	Effect
Aesthetic	Determinant that taints water with respect to taste, odour and colour and that does not pose an unacceptable health risk if present at concentration values exceeding the numerical limits specified.
Operational	Determinant that is essential for assessing the efficient operation of treatment systems and risks to infrastructure.
Acute Health – 1	Routinely quantifiable determinant that poses an immediate health risk if consumed with water at concentration values exceeding the numerical limits specified.
Acute Health – 2	Determinant that is presently not easily quantifiable and lacks information pertaining to viability and human infectivity which, however, does pose immediate unacceptable health risks if consumed with water at concentration values exceeding the numerical limits specified.
Chronic Health	Determinant that poses an unacceptable health risk if ingested over an extended period if present at concentration values exceeding the numerical limits specified.

Table 8-2 SANS 241:2015 physical aesthetic, operational and chemical parameters.

Parameter	Risk	Unit	Standard limits [a]
Physical and aesthetic determinants			
Electrical conductivity (EC)	Aesthetic	mS/m	≤170
Total Dissolved Solids (TDS)	Aesthetic	mg/l	≤1200
Turbidity [b]	Operational	NTU	≤1
	Aesthetic	NTU	≤5
pH [c]	Operational	pH units	≥5 to ≤9,7
Chemical determinants – macro			
Nitrate as N[d]	Acute health	mg/l	≤11
Sulphate as SO_4^{-2}	Acute health	mg/l	≤500
	Aesthetic	mg/l	≤250
Fluoride as F	Chronic health	mg/l	≤1.5
Ammonia as N	Aesthetic	mg/l	≤1.5
Chloride as Cl^-	Aesthetic	mg/l	≤300
Sodium as Na	Aesthetic	mg/l	≤200
Zinc as Zn	Aesthetic	mg/l	≤5
Chemical determinants – micro			
Antimony as Sb	Chronic health	mg/l	≤0.02
Arsenic as As	Chronic health	mg/l	≤0.010
Cadmium as Cd	Chronic health	mg/l	≤0.003
Total chromium as Cr	Chronic health	mg/l	≤0.050
Copper as Cu	Chronic health	mg/l	≤2.0
Iron as Fe	Chronic health	mg/l	≤2.0

Parameter	Risk	Unit	Standard limits [a]
	Aesthetic	mg/l	≤0.30
Lead as Pb	Chronic health	mg/l	≤0.010
Manganese as Mn	Chronic health	mg/l	≤0.50
	Aesthetic	mg/l	≤0.10
Mercury as Hg	Chronic health	mg/l	≤0.006
Nickel as Ni	Chronic health	mg/l	≤0.07
Selenium as Se	Chronic health	mg/l	≤0.010
Uranium as U	Chronic health	mg/l	≤0.015
Vanadium as V	Chronic health	mg/l	≤0.2
Aluminium as Al	Operational	mg/l	≤0.3

a The health-related standards are based on the consumption of 2 L of water per day by a person of a mass of 60 kg over a period of 70 years.

b Values in excess of those given in column 4 may negatively impact disinfection.

c Low pH values can result in structural problems in the distribution system.

d This is equivalent to nitrate at 50 mg/l NO_3^-.

8.2. Data validation

The laboratory precision was validated by employing the plausibility of the chemical analysis, electro neutrality (E.N.) which is determined according to Equation 8-1, below. An error of less than 5% is an indication that the analysis results are of suitable precision for further evaluation. All samples analysed indicate a good plausibility and data can be considered as accurate and correct (Table 8-3).

Equation 8-1 Electro-neutrality.

$$E.N. = \frac{\sum cations\left[\frac{meq}{L}\right] + \sum anions\left[\frac{meq}{L}\right]}{\sum cations\left[\frac{meq}{L}\right] - \sum anions\left[\frac{meq}{L}\right]} .100\% < 5.0\%$$

Table 8-3 Laboratory precision and data validity.

Sample Localities	Σ Major cations (meq/l)	Σ Major anions (meq/l)	Electro-Neutrality [E.N.] %
ASW 01	32.70	32.96	-0.40%
AHBH 01	1.23	1.28	-2.02%
AHBH 02	4.71	4.79	-0.85%
AHBH 03	2.07	2.17	-2.52%
AHBH 04	2.00	2.00	0.09%
AHBH 05	0.84	0.84	-0.11%
AHBH 06	0.49	0.50	-0.96%
AHBH 07	0.84	0.86	-0.89%
ELN BH 01	1.03	1.09	-2.87%
ELN BH 03	28.68	29.05	-0.64%
ELN BH 07	0.46	0.48	-2.11%
ECBH 02	4.97	5.15	-1.75%
ECBH 03	30.38	32.47	-3.31%
ECBH 04	7.99	8.12	-0.80%
ECBH 05	1.52	1.61	-2.97%
BH172	16.09	15.97	0.36%
BH173	1.29	1.23	2.23%
ASW 02	7.40	7.46	-0.40%
FFBH 11	11.01	11.06	-0.20%

Note: E.N. < 5.0% generally reflect an accurate laboratory analysis.

In order to assess future impacts of the proposed mining expansion activities on the groundwater regime, it is necessary to develop a baseline for groundwater prior to onset. The following section serves to characterise ambient groundwater conditions and develop a relevant baseline for future reference. Table 8-4, Table 8-5 as well as Table 8-6 below classify water quality according to pH, Total Dissolved Solids (TDS) as well as total hardness.

Table 8-4 Hydrochemical classification according to pH-values.

pH Values used to indicate alkalinity or acidity of water	
pH: > 8.5	Alkaline/Basic
pH: 6.0- 8.5	Neutral
pH: < 6	Acidic

Table 8-5 Hydrochemical classification according to salinity.

TDS Concentrations to indicate the salinity of water	
TDS < 450 mg/l	Non-saline
TDS 450 - 1 000 mg/l	Saline
TDS 1 000 - 2 400 mg/l	Very saline
TDS 2 400 - 3 400 mg/l	Extremely saline

Table 8-6 Hydrochemical classification according to hardness.

Hardness concentrations to indicate softness or hardness of water	
Hardness < 50 mg/l	Soft
Hardness 50 – 100 mg/l	Moderately soft
Hardness 100 – 150 mg/l	Slightly hard
Hardness 150 – 200 mg/l	Moderately hard
Hardness 200 – 300 mg/l	Hard
Hardness 300 – 600 mg/l	Very hard
Hardness > 600mg/l	Extremely hard

8.3. Groundwater quality

The overall ambient groundwater quality of the shallow aquifer is good with the majority of macro and micro determinants below the SANS 241:2015 limits. Isolated sampling localities indicate above limits ammonium (NH4) concentrations which can may suggest nearby anthropogenic activities.

The local groundwater quality is indicative of an impacted groundwater system and suggest coal mine pollution and acid mine drainage (AMD) conditions present. The latter is characterised by a low pH environment increasing the solubility and concentrations of metals i.e. usually aluminum, iron and manganese. Leaching from mined out faces as well as other waste facilities i.e. discard dumps containing carbonaceous material and sulphides will allow for oxidation and hydration resulting in the generation of acidity (H^+), sulphates (SO_4^{2-}) and ferric (Fe^{3+}) and ferrous (Fe^{2+}) iron species and the movement of other conservative contaminants with groundwater in a downgradient direction from the source.

8.4. Surface water quality

Only two surface water samples were collected and analysed i.e. upstream and downstream of the Grootspruit. The overall water quality of the upstream surface water samples is poor due to elevated levels of sulphate as well as heavy metals (Fe, Al and Mn). The downstream water quality is unacceptable due to highly elevated levels of sulphate as well as heavy metals (Fe, Al and Mn) causing high salt loads. There is a definite deterioration of water quality evident in a downstream direction and suggest contaminated water ingress from potentially mine decant and interflow zones. Figure 8-1 depicts a bar-chart of major anion and cation composition while Figure 8-2 indicate a spatial distribution map of major anion and cation composition per sample. To follow is a brief description of the water quality for each sample analysed as summarised in Table 8-7.

8.4.1. Surface water sampling locality ASW01

Water quality can be described as neutral, very saline and extremely hard:

- pH of 7.16.
- TDS of 2150.86 mg/l.
- Total Hardness ($CaCO_3$/l) of 1500.02 mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- EC of 239.0 mS/m.
- TDS of 2150.86 mg/l.
- SO_4 of 1529.17 mg/l.
- Al of 6.60 mg/l.
- Mn of 8.14 mg/l.

8.4.2. Surface water sampling locality ASW02

Water quality can be described as neutral, saline and very hard:

- pH of 7.09.
- TDS of 487.86 mg/l.
- Total Hardness ($CaCO_3$/l) of 327.74 mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- SO_4 of 349.0 mg/l.
- Al of 1.52 mg/l.
- Fe of 0.80 mg/l.
- Mn of 4.52 mg/l.

8.4.3. Groundwater sampling locality ABHB01

Water quality can be described as neutral, non-saline and soft:

- pH of 7.09.
- TDS of 487.86 mg/l.
- Total Hardness ($CaCO_3$/l) of 327.74 mg/l.

None of the chemical variable concentrations exceeded SANS 241-1: 2015.

8.4.4. Groundwater sampling locality ABHB02

Water quality can be described as neutral, non-saline and slightly hard:

- pH of 7.44.
- TDS of 248.46 mg/l.
- Total Hardness ($CaCO_3$/l) of 119.43 mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- F of 1.91 mg/l.

8.4.5. Groundwater sampling locality ABHB03

Water quality can be described as acidic, non-saline and moderately soft:

- pH of 5.71.

- TDS of 108.69 mg/l.
- Total Hardness ($CaCO_3$/l) of 73.95 mg/l.

None of the chemical variable concentrations exceeded SANS 241-1: 2015.

8.4.6. Groundwater sampling locality ABHB04

Water quality can be described as acidic, non-saline and soft:

- pH of 5.68.
- TDS of 137.83 mg/l.
- Total Hardness ($CaCO_3$/l) of 48.79 mg/l.

None of the chemical variable concentrations exceeded SANS 241-1: 2015.

8.4.7. Groundwater sampling locality ABHB05

Water quality can be described as acidic, non-saline and soft:

- pH of 5.45.
- TDS of 58.86 mg/l.
- Total Hardness ($CaCO_3$/l) of 24.83 mg/l.

None of the chemical variable concentrations exceeded SANS 241-1: 2015.

8.4.8. Groundwater sampling locality ABHB06

Water quality can be described as acidic, non-saline and soft:

- pH of 5.90.
- TDS of 34.62 mg/l.
- Total Hardness ($CaCO_3$/l) of 14.66 mg/l.

None of the chemical variable concentrations exceeded SANS 241-1: 2015.

8.4.9. Groundwater sampling locality AHBH07

Water quality can be described as neutral, non-saline and soft:

- pH of 6.49.
- TDS of 48.94 mg/l.
- Total Hardness (CaCO3/l) of 17.94 mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- Mn of 0.14 mg/l.

8.4.10. Groundwater sampling locality ELNBH01

Water quality can be described as acidic, non-saline and soft:

- pH of 2.90.
- TDS of 59.73 mg/l.
- Total Hardness (CaCO3/l) of 36.99 mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- pH of 2.90.

8.4.11. Groundwater sampling locality ELNBH03

Water quality can be described as acidic, very saline and extremely hard:

- pH of 5.17.
- TDS of 1832.71 mg/l.
- Total Hardness (CaCO3/l) of 899.00 mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- EC of 254.00 mS/m.
- TDS of 1832.71 mg/l.
- SO_4 of 1306.71 mg/l.
- F of 32.18 mg/l.
- Al of 31.20 mg/l.
- Fe of 8.11 mg/l.
- Mn of 105.00 mg/l.

8.4.12. Groundwater sampling locality ELNBH07

Water quality can be described as neutral, non-saline and soft:

- pH of 6.50.
- TDS of 33.96 mg/l.
- Total Hardness ($CaCO_3$/l) of 17.56 mg/l.

None of the chemical variable concentrations exceeded SANS 241-1: 2015.

8.4.13. Groundwater sampling locality ECBH02

Water quality can be described as neutral, non-saline and moderately hard:

- pH of 5.98.
- TDS of 333.37 mg/l.
- Total Hardness (CaCO3/l) of 174.80 mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- NH_4 of 44.40 mg/l.

8.4.14. Groundwater sampling locality ECBH03

Water quality can be described as acidic, very saline and extremely hard:

- pH of 4.83.
- TDS of 2091.54 mg/l.
- Total Hardness (CaCO3/l) of 1469.39 mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- pH 4.83.
- EC of 218.00 mS/m.
- TDS of 2091.54 mg/l.
- SO_4 of 1461.00 mg/l.
- Fe of 1.54 mg/l.
- Mn of 0.37 mg/l.

8.4.15. Groundwater sampling locality ECBH04

Water quality can be described as neutral, non-saline and very hard:

- pH of 5.06.
- TDS of 524.92 mg/l.
- Total Hardness (CaCO3/l) of 359.12 mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- SO_4 of 371.74 mg/l.
- Al of 1.07 mg/l.
- Fe of 1.16 mg/l.
- Mn of 2.02 mg/l.

8.4.16. Groundwater sampling locality ECBH05

Water quality can be described as acidic, non-saline and moderately soft:

- pH of 3.07
- TDS of 105.62 mg/l.
- Total Hardness (CaCO3/l) of 70.39 mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- pH of 3.07

8.4.17. Groundwater sampling locality BH172

Water quality can be described as neutral, very saline and very hard:

- pH of 6.39.
- TDS of 1023.88 mg/l.
- Total Hardness (CaCO3/l) of 529.39 mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- SO_4 of 733.86 mg/l.
- F of 12.31 mg/l.
- Al of 20.10 mg/l.
- Fe of 43.40 mg/l.
- Mn of 13.00 mg/l.

8.4.18. Groundwater sampling locality BH173

Water quality can be described as acidic, non-saline and soft:

- pH of 3.25.
- TDS of 76.49 mg/l.
- Total Hardness (CaCO3/l) of 48.54 mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- pH of 3.25.
- F of 2.91 mg/l.

8.4.19. Groundwater sampling locality FFBH11

Water quality can be described as alkaline, saline and moderately hard:

- pH of 8.75.
- TDS of 741.57 mg/l.
- Total Hardness (CaCO3/l) of 152.19 mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- SO_4 of 362.00 mg/l.
- Mn of 0.15 mg/l.

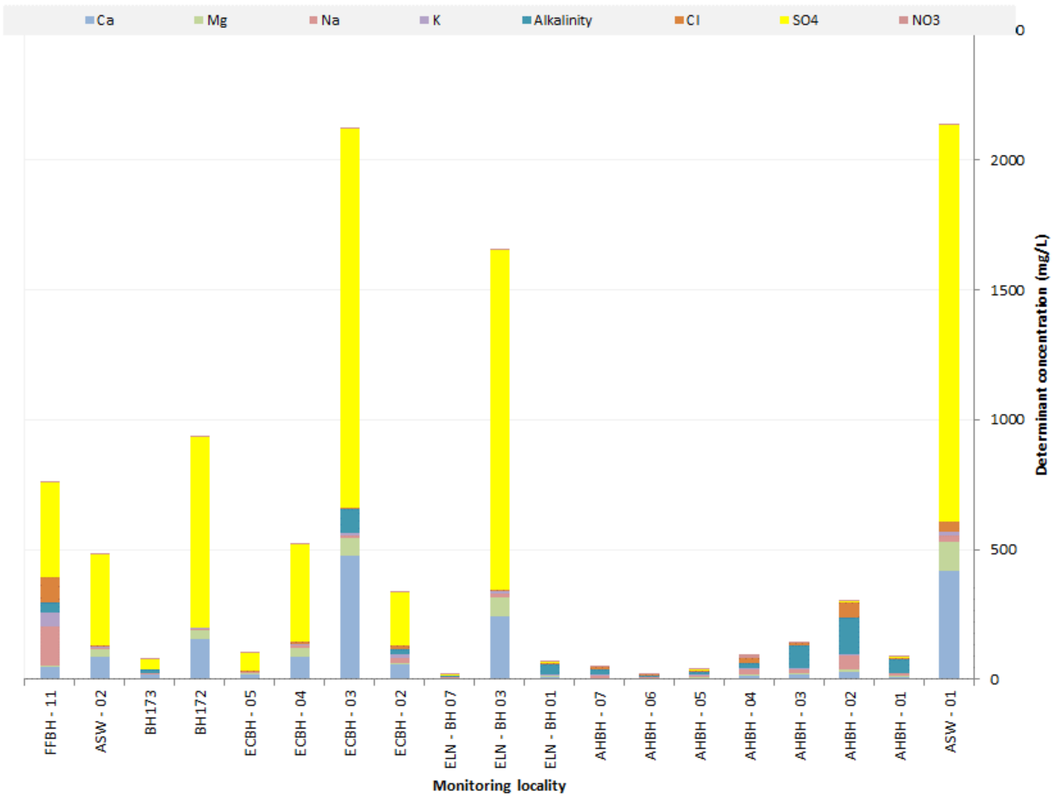


Figure 8-1 **Hydrochemistry: Composite bar-chart indicating sample major anion cation composition (mg/l).**

Table 8-7 Hydrochemistry: Hydroccensus user survey geosite water quality evaluation (SANS 241:2015).

Determinant	Unit	Risk	SANS 241:2015 limits	ASW 01	ASW 02	AHBH 01	AHBH 02	AHBH 03	AHBH 04	AHBH 05	AHBH 06	AHBH 07	ELN BH01	ELN BH03	ELN BH07	ECBH 02	ECBH 03	ECBH 04	ECBH 05	BH172	BH173	FFBH 11
General parameters																						
pH	-	Operational	≥5.0 ≤ 9.5	7.16	7.09	7.57	7.44	5.71	5.68	5.45	5.90	6.49	2.90	5.17	6.50	5.98	4.83	5.06	3.07	6.39	3.25	8.75
EC	mS/m	Aesthetic	≤170.0	239.00	91.40	12.76	47.80	21.40	22.10	10.90	6.46	10.40	12.10	254.00	5.56	52.20	218.00	80.00	18.00	169.00	14.70	119.00
TDS		Aesthetic	≤ 1 200.0	2150.86	487.86	63.01	248.46	108.69	137.83	58.86	34.62	48.94	59.73	1832.71	33.96	333.37	2091.54	524.92	105.62	1023.88	76.49	741.57
Total Alkalinity	CaCO3/l	-	-	0.00	0.00	55.60	141.00	91.80	18.00	7.60	5.80	20.60	38.00	0.00	3.20	19.80	90.20	2.60	2.80	0.00	11.20	38.20
Total Hardness	mg/l	-	-	1500.02	327.74	36.71	119.43	73.95	48.79	24.83	14.66	17.94	36.99	899.00	17.56	174.80	1469.39	359.12	70.39	529.39	48.54	152.19
Anions																						
Cl	mg/l	Aesthetic	≤300.0	38.65	5.42	3.60	59.90	6.90	20.94	8.09	3.09	10.63	2.97	4.49	2.24	14.13	5.83	8.85	1.10	1.16	1.55	96.30
SO_4	mg/l	Acute health	≤250.0	1529.17	349.00	2.49	7.63	2.78	1.85	2.43	0.68	1.16	5.95	1306.71	3.05	205.00	1461.00	371.74	68.10	733.86	38.90	362.00
F	mg/l	Acute health	≤1.50	<0.09	0.58	0.21	1.91	1.03	0.09	<0.09	0.10	<0.09	0.18	32.18	0.11	1.47	0.52	0.51	0.09	12.31	2.91	<0.09
NO_3< N	mg/l	Acute health	≤11.0	<0.35	<0.35	<0.35	<0.35	0.40	13.91	5.65	3.80	1.59	1.51	<0.35	3.93	<0.35	0.46	0.66	1.44	<0.35	<0.35	<0.35
PO_4	mg/l	-	-	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.05	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Cations and metals																						
NH_4	mg/l	Aesthetic	≤1.50	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	3.05	<0.45	4.44	0.82	<0.45	<0.45	0.63	<0.45	0.62
Na	mg/l	Aesthetic	≤200.0	28.00	8.13	10.41	51.60	10.60	19.92	3.83	2.92	9.93	3.17	17.07	1.58	20.04	11.30	8.92	1.50	6.06	5.30	150.00
K	mg/l	-	-	12.10	3.21	1.08	2.52	4.63	5.81	6.61	2.49	1.76	5.52	9.74	1.36	10.50	9.96	5.07	1.34	4.18	2.45	54.10
Ca	mg/l	-	-	416.26	89.15	7.13	28.70	20.10	12.40	5.77	3.71	3.59	8.73	243.78	5.12	56.10	475.00	86.10	20.90	153.54	16.76	46.60
Mg	mg/l	-	-	111.86	25.53	4.59	11.60	5.77	4.33	2.53	1.31	2.18	3.69	70.49	1.16	8.43	68.80	35.00	4.42	35.45	1.63	8.70
Al	mg/l	Operational	0.3	6.60	1.52	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	31.20	0.01	0.02	<0.01	1.07	0.05	20.10	0.14	<0.01
Fe	mg/l	Aesthetic	0.3	0.09	0.80	0.13	<0.01	0.03	<0.01	<0.01	<0.01	<0.01	0.02	105.00	<0.01	<0.01	1.54	1.16	<0.01	43.40	0.06	<0.01
Mn	mg/l	Aesthetic	0.1	8.14	4.52	<0.01	<0.01	<0.01	0.09	0.01	0.01	0.14	<0.01	8.11	0.02	0.07	0.37	2.02	0.06	13.00	0.09	0.15

Note: "- " indicate that no limits have been provided by the SANS 2015:241 guidelines.
"< " indicate that results analysed are below the detection limits.
Shaded cells exceed SANS 241:2015 drinking water guidelines.

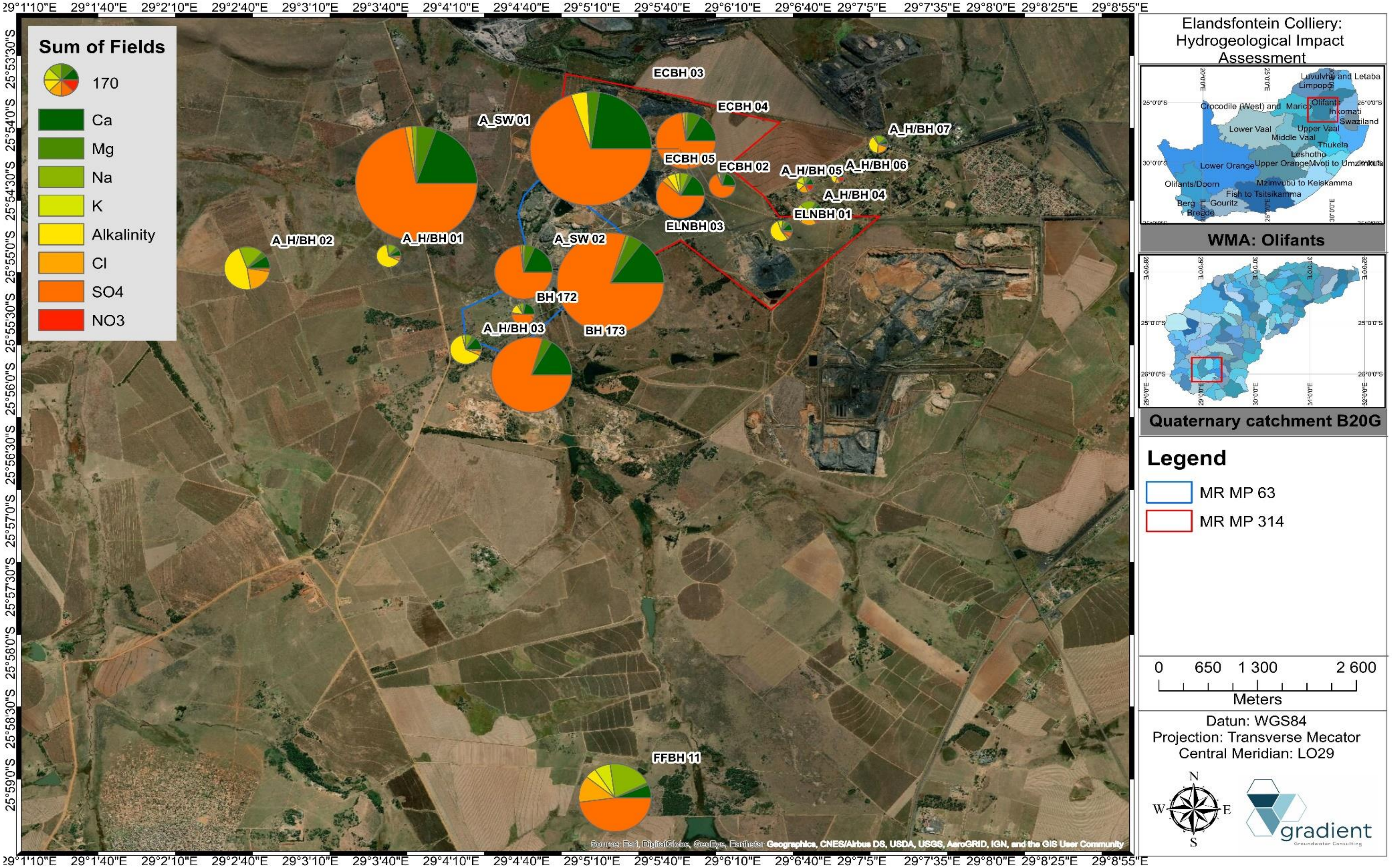


Figure 8-2 **Hydrochemical analysis spatial distribution (mg/l).**

8.5. Hydrochemical signature

The hydrochemical signature of the samples analysed were evaluated by means of diagnostic plots. The latter aid to get an understanding of various environments and sources from where groundwater and surface water originates. Three types of diagnostic plots were used to characterise analysed water samples based on hydrochemistry.

8.5.1. Piper diagrams

A piper diagram is a diagnostic representation of major anions and cations as separate ternary plots (Figure 8-3). Different water types derived from different environments plot in diagnostic areas. The upper half of the diamond normally contains water of static and disordinate regimes, while the middle area generally indicates an area of dissolution and mixing. The lower triangle of this diamond shape indicates an area of dynamic and coordinated regimes. Figure 8-4 depicts a piper diagram developed from the hydrocensus water quality analysis results. The majority of regional/ neighbouring boreholes suggest either a recently recharged and unimpacted water environment (Calsium-Bi-carbonate dominance), and/or area of dissolution and mixing, whereas current monitoring boreholes on site indicate a static and disordinate environment (Sulphate dominance suggesting impacts from coal mine pollution). Sampling locality FFBH11 indicate a Sodium-Chloride dominance suggesting brine waters.

8.5.2. Stiff diagrams

A Stiff diagram, or Stiff pattern, is a graphical representation of chemical analyses and major anions and cations, first developed by H.A. Stiff in 1951. STIFF diagrams plot the equivalent concentrations of major anions and cations on a horizontal scale on opposite sides of a vertical axis. The plot point of each parameter is linked to the adjacent point creating a polygon around the vertical axis. Water with similar major ion ratios will show similar geometries.

Figure 8-5 depicts Stiff diagrams compiled from the hydrocensus user survey sampling analysis. Groundwater sampling localities ECBH03, ELNBH03 correlate well to the hydrochemical signature of surface water sampling locality ASW01 and suggest similar water environments and potential origins.

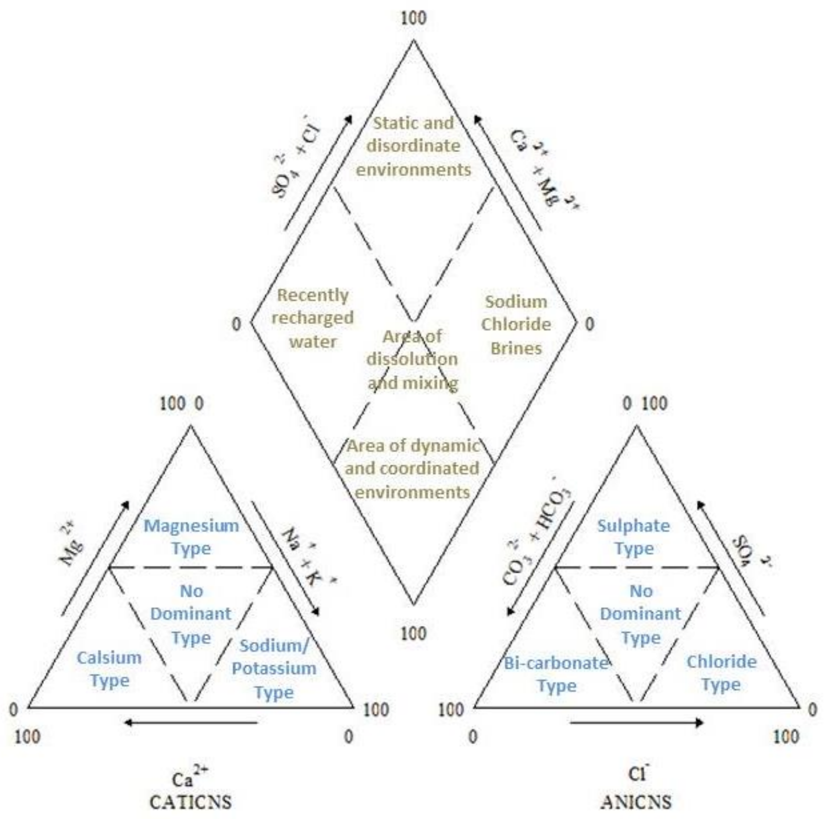


Figure 8-3 **Piper diagram indicating classification for anion and cation facies in terms of ion percentages.**

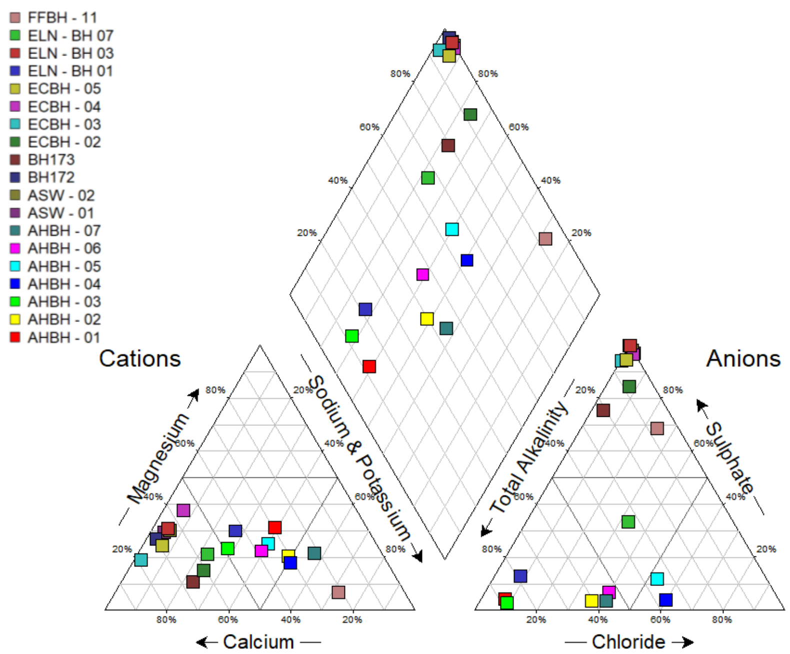


Figure 8-4 **Piper diagram indicating major anions and cations of hydrocnesus water samples.**

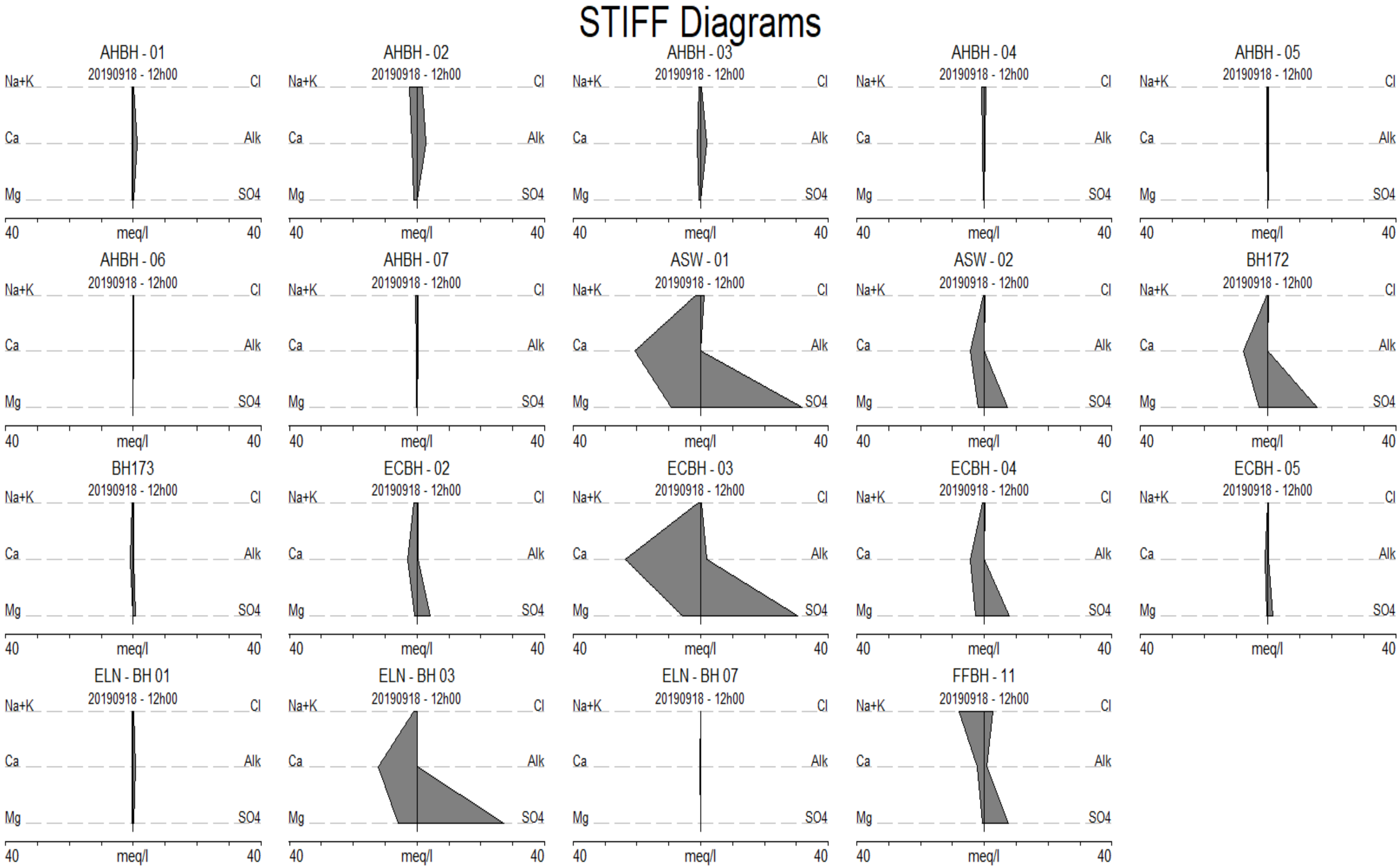


Figure 8-5 **Stiff diagrams representing hydrocenus sampling localities analysed.**

8.6. Expanded Durov diagram

The expanded Durov diagram is used to show hydrochemical processes occurring within different hydrogeological systems. Different fields of the diagram could be summarized as follows:

Field 01: Water (mostly fresh, clean and recently recharged) with HCO_3- and CO_3 as dominant anion and Ca as dominant cation.

Field 02: Water (mostly fresh, clean, and relatively young) that also has an Mg signature, often found in dolomitic terrain.

Field 03: Often associated with Na ion exchange between groundwater and aquifer material (sometimes in Na-enriched granites or other felsic rocks) or because of contamination effects from a source rich in Na.

Field 04: Often associated with mining related SO_4 contamination.

Field 05: 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 06: Groundwater from field 5 that has been contact with a source rich in Na or old stagnant NaCl dominated water that resides in Na rich host rock/material.

Field 07: Water rarely plots in this field that indicates NO_3 or Cl enrichment or dissolution.

Field 08: Groundwater that is usually a mix of different type, for example water from 2 that has undergone Cl mixing/contamination or old stagnant NaCl-dominated water that has mixed with water richer in Mg.

Field 09: Seawater or very old stagnant water that has reached the end of the geohydrological cycle (deserts, salty pans etc.), or water that has moved a long time and/or distance through the aquifer and has undergone significant ion exchange.

The majority of regional/ neighbouring groundwater samples can be classified as Field 02 i.e. mostly fresh, clean and relatively young with HCO_3- and CO_3 dominance evident, whereas most of the on-site monitoring boreholes can be classified as Field 04 which can often be associated with mining related SO_4 contamination.

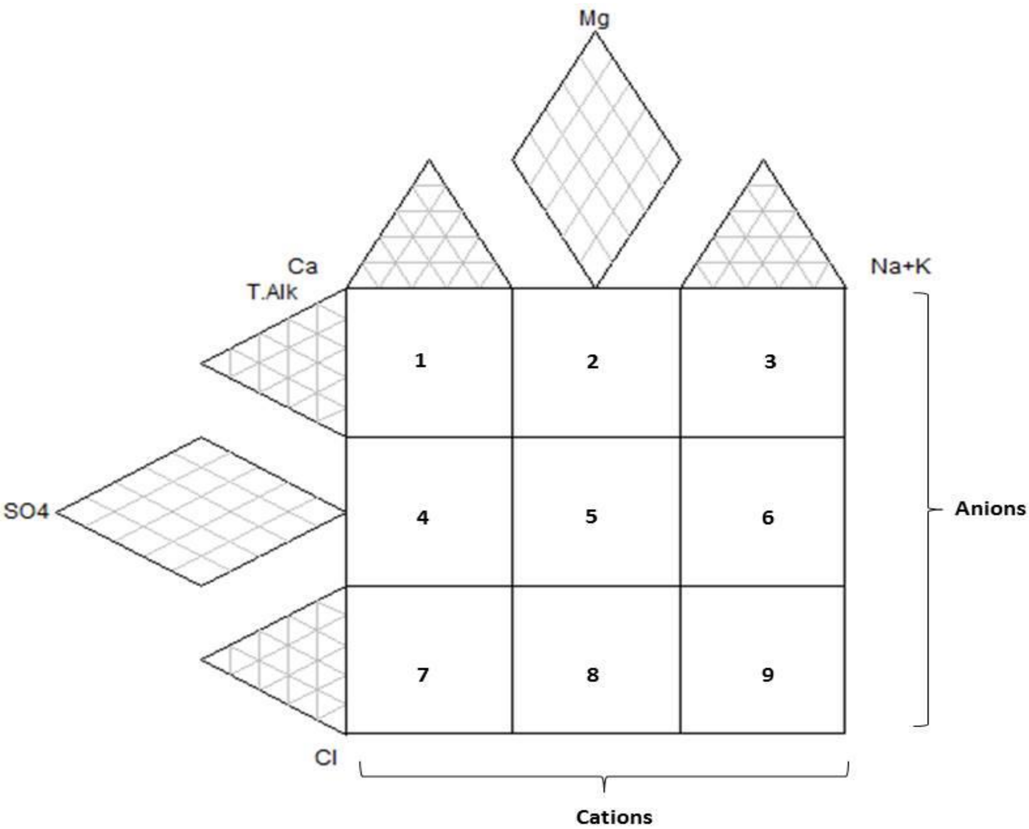


Figure 8-6 Extended Durov diagram indicating major anions and cations.

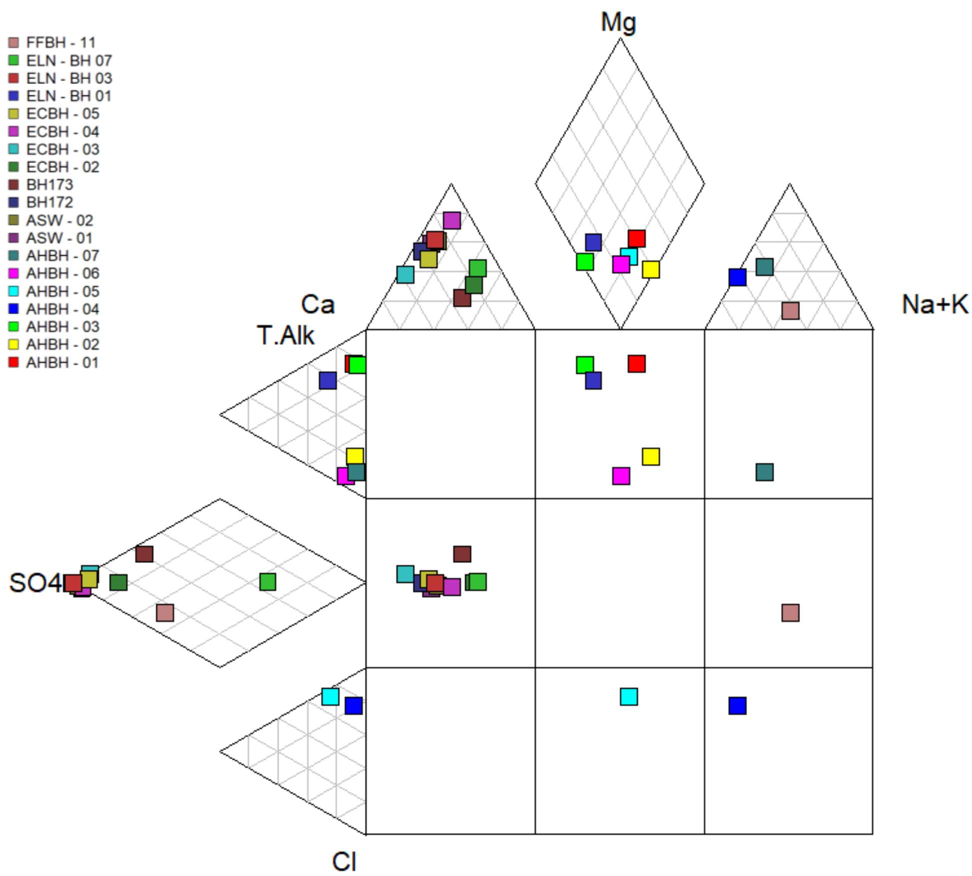


Figure 8-7 Extended Durov diagram of surface water monitoring points.

9. AQUIFER CLASSIFICATION AND GROUNDWATER MANAGEMENT INDEX

The most widely accepted definition of groundwater contamination is defined as the introduction into water of any substance in undesirable concentration not normally present in water e.g. microorganisms, chemicals, waste or sewerage, which renders the water unfit for its intended use (UNESCO, 1992). The objective is to formulate a risk-based framework from geological and hydrogeological information obtained as part of this investigation. Two approaches were followed in an estimation of the risk of groundwater contamination as discussed below. As part of the aquifer classification, a Groundwater Quality Management (GQM) Index is used to define the level of groundwater protection required. The GQM Index is obtained by multiplying the rating of the aquifer system management and the aquifer vulnerability. A summary of the GQM index for the greater study area is presented in Table 9-2 with cells shaded in blue indicating the rating of the aquifer. A **GQM Index = 4** was estimated for the aquifer system and according to this estimate, a "**Medium**" level groundwater protection is required for this aquifer system.

Equation 9-1 GMQ Index.

$$\textbf{\textit{GQM Index}} = \boldsymbol{Aquifer\ system\ management\ x\ Aquifer\ vulnerability}$$

9.1. Aquifer classification

The aquifer classification was guided by the principles set out in South African Aquifer System Management Classification (Parsons, 1995). Aquifer classification forms a very useful planning tool which can be applied to guide the management of groundwater systems. According to the aquifer classification map of South Africa the project area is underlain by a poor to "**Minor aquifer**" (DWS, 2013). The classifications and definitions for each aquifer system are summarised in Table 9-1 cells shaded in blue indicate the classification of the aquifer.

Table 9-1 Aquifer System Management Classes (After Parsons , 1995).

Sole source aquifer	An aquifer which is used to supply 50% or more of domestic water for a given area, and for which there are no reasonable available alternative sources should the aquifer be impacted upon or depleted. Aquifer yields and natural water quality are immaterial.
Major aquifer system	Highly permeable formations, usually with a known 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, which do not have a high primary permeability, or other formations of variable permeability. Although these aquifers seldom produce large quantities of water, they are important both for local supplies and supplying base flow to 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 as unusable. However, groundwater flow through such rocks, although imperceptible, 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.

9.2. Aquifer vulnerability

Aquifer vulnerability can be defined as the tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer. According to the aquifer vulnerability map of South Africa the project area is underlain by an aquifer system with a "**Moderate**" vulnerability rating (DWS, 2013).

9.3. Aquifer susceptibility

Aquifer susceptibility is a qualitative measure of the relative ease with which a groundwater body can be potentially contaminated by anthropogenic activities. According to the Aquifer susceptibility map of South Africa the project area is underlain by an aquifer system with a "**Medium**" susceptibility rating (DWS, 2013).

Table 9-2 Groundwater Quality Management Index.

Aquifer system Management qualification		Aquifer vulnerability Classification	
Class	**Points**	**Class**	**Points**
Sole Source Aquifer System	6	High	3
Major Aquifer System	4	**Moderate**	**2**
Minor Aquifer System	**2**	Low	1
Non-Aquifer System	0		
Special Aquifer System	0-6		

GQM INDEX	Level of protection
<1	Limited Protection
1 to 3	Low Level Protection
3 to 6	**Medium Level Protection**
6 to 10	High Level Protection
>10	Strictly Non- Degradation

9.4. Groundwater contamination risk assessment

The concept of groundwater vulnerability to contamination by applying the DRASTIC methodology was introduced by Aller et al. (1987) and refined by the US EPA (United States Environmental Protection Agency). DRASTIC is an acronym for a set of parameters that characterise the hydrogeological setting and combined evaluated vulnerability: Depth to water level, Nett Recharge, Aquifer media, Soil media, Topography, Impact of the vadose zone and Hydraulic Conductivity. This method provides a basis for evaluating the vulnerability to pollution of groundwater resources based on hydrogeological parameters.

Lynch *et al* (1994) suggests a considerable variation in terms of hydraulic conductivity in hard rock aquifers and revised this methodology to accommodate local aquifer conditions accordingly. Parameters used as part of the index are summarised in Table 9-4 while the aquifer risk matrix is summarised in Table 9-4 below. The DRASTIC index (DI) can be computed using the following formula.

Equation 9-2 DRASTIC Index (Di).

$$\text{Di} = DrD\lambda + RrR\lambda + ArA\lambda + Sr\,S\lambda + TrT\lambda + IrI\lambda$$

where:

D = Depth to Water Table

R = Recharge

A = Aquifer media.

S = Soil media.

T = Topographic aspect.

I = Impact of vadose zone media.

C = Conductivity.

Where **D, R, A, S, T, I**, and **C** are the parameters, r is the rating value, and λ the constant weight assigned to each parameter as summarised in Table 9-3 below (Lynch et al, 1994).

Table 9-3 Ratings assigned to groundwater vulnerability parameters (Lynch et al, 1994).

Depth to groundwater (D_R)

Range (m)	Rating
0 – 5	10
5 – 15	7
15 – 30	3
> 30	1

Net Recharge (R_R)

Range (mm)	Rating
0 – 5	1
5 – 10	3
10 – 50	6
50 – 100	8
> 100	9

Aquifer Media (A_R)

Range	Rating
Dolomite	10
Intergranular	8
Fractured	6
Fractured and weathered	3

Soil Media (S_R)

Range	Rating
Sand	8 – 10
Shrinking and/or aggregated clay	7 - 8
Loamy sand	6 - 7
Sandy loam	5 - 6
Sandy clay loam and loam	4 - 5
Silty clay loam, sandy clay and silty loam	3 - 4
Clay loam and silty clay	2 – 3

Topography (T_R)

Range (% slope)	Rating
0 – 2	10
2 – 6	9
6 – 12	5
12 – 18	3
> 18	1

Impact of the vadose zone (I_R)

Range	Rating
Gneiss,Namaqua metamorphic rocks	3
Ventersdorp, Pretoria, Griqualand West, Malmesbury, Van Rhynsdorp, Uitenhage, Bokkeveld, Basalt, Waterberg, Soutspansberg, Karoo (northern), Bushveld, Olifantshoek	4
Karoo (southern)	5
Table Mountain, Witteberg, Granite, Natal, Witwatersrand, Rooiberg, Greenstone, Dominion, Jozini	6
Dolomite	9
Beach sands and Kalahari	10

Table 9-4 DRASTIC Index.

Risk/ Vulnerability	DRASTIC Index (Di)
Low	50-87
Moderate	87-109
High	109-183

According to the DRASTIC index methodology applied, this mining activities and associated infrastructure's risk to groundwater pollution is rated as "**Medium**", **Di** = 102 due to the relatively shallow groundwater table/ piezometric head as well as fairly flat topographical slopes within the greater study area (Table 9-5).

Table 9-5 DRASTIC weighting factors.

Parameter	Range	Rating	Description	Relative weighting
Depth to water (D) (mbgl)	0 - 5	10	Refers to the depth to the water surface in an unconfined aquifer. Deeper water table levels imply lesser chance for contamination to occur. Depth to water is used to delineate the depth to the top of a confined aquifer.	5
	5 -15	**7**		
	15 - 30	3		
	> 30	1		
Net recharge (R) (mm/a)	0-5	1	Indicates the amount of water per unit area of land which penetrates the ground surface and reaches the water table. Recharge water is available to transport a contaminant vertically to the water table, horizontal with in an aquifer.	3
	5-10	3		
	10-50	**6**		
	50-100	8		
	> 100	9		
Aquifer media (A)	Dolomite	10	Refers to the consolidated or unconsolidated medium which serves as an aquifer. The larger the grain size and more fractures or openings within an aquifer, leads to higher permeability and lower attenuation capacity, hence greater the pollution potential.	4
	Intergranular	8		
	Fractured	6		
	Fractured and weathered	**3**		
Soil media (S)	Sand	10	Refers to the uppermost weathered portion of the vadose zone characterised by significant biological activity. Soil has a significant impact on the amount of recharge.	2
	Shrinking and/or aggregated clay	8		
	Loamy sand	6		
	Sandy loam	5		
	Sandy clay	**4**		
	Silty loam	3		
	Silty clay and clay loam	2		
Topography (T) (Slope %)	0 - 2	10	Refers to the slope of the land surface. It helps a pollutant to runoff or remain on the surface in an area long enough to infiltrate it.	1
	2 - 6	**9**		
	6 - 12	5		
	12 - 18	3		
	> 18	1		
Impact of vadose zone (I)	Gneiss, Namaqua metamorphic rocks	3	Is defined as unsaturated zone material. The significantly restrictive zone above an aquifer forming the confining layers is used in a confined aquifer, as the type of media having the most significant impact.	5
	Ventersdorp, Pretoria, Griekwaland West, Malmesbury, Van Rhynsdorp, Uitenhage, Bokkeveld, Basalt, Waterberg, Soutpansberg, Karoo (Northern), Bushveld, Olifantshoek	**4**		
	Karoo (Southern)	5		
	Table Mountain, Witteberg Granite, Natal, Witwatersrand, Rooiberg, Greenstone, Dominion, Jozini	6		
	Dolomite	9		
	Beach sands and Kalahari	10		
DRASTIC Index (Di) = 102				

10. HYDROGEOLOGICAL CONCEPTUAL MODEL

The hydrogeological conceptual model consists of a set of assumptions, which will aid in reducing the problem statement to a simplified and acceptable version. Data gathered during the desk study and site investigation has been incorporated to develop a conceptual understanding of the regional hydrogeological system. Figure 10-1 depicts a generalised hydrogeological conceptual model for similar environments and illustrate the concept of primary porous media aquifers and secondary fractured rock media aquifers. In porous aquifers, flow occurs through voids between unconsolidated rock particles whereas in double porosity aquifers, the host rock is partially consolidated, and flow occurs through the pores as well as fractures in the rock. In secondary aquifers the host rock is consolidated, and porosity is generally restricted to fractures that have formed after consolidation of the rock. The weathered zone aquifer and secondary rock aquifer in the area could be classified as double porosity aquifers. Figure 10-2 depicts a southwest-northeast cross section of the study area with relevant data and information included (refer to Figure 5-2 for spatial reference).

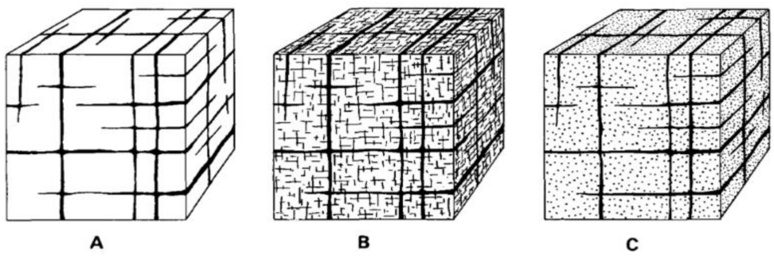


Figure 10-1 Generalised conceptual hydrogeological model (after Kruseman and de Ridder, 1994).

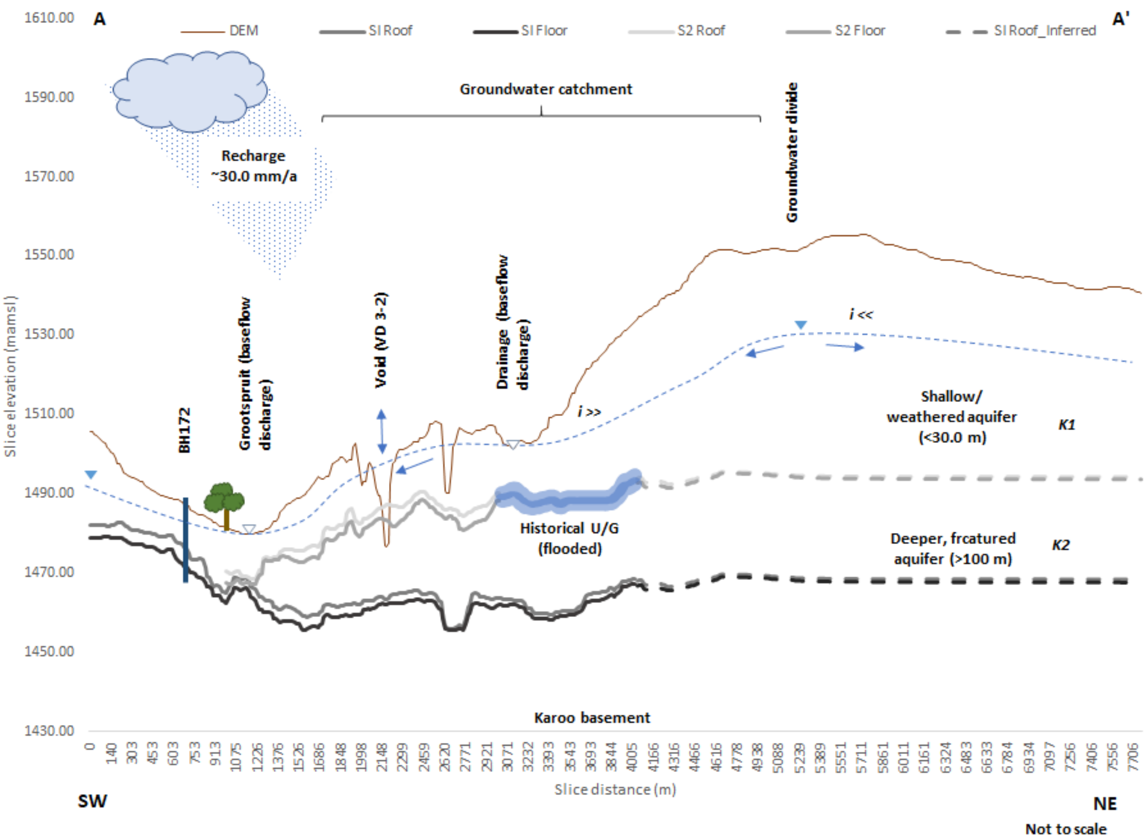


Figure 10-2 lHydrogeological conceptual model: Southwest-Northeast cross section (Figure 5-2).

11. ENVIRONMENTAL IMPACT ASSESSMENT

Identification of potential impacts and ratings related to the proposed activities are briefly discussed below.

11.1. Methodology

An impact can be defined as any change in the physical-chemical, biological, cultural and/or socio-economic environmental system that can be attributed to human and/or other related activities. The impact significance rating methodology is guided by the requirements of the NEMA EIA Regulations 2014 (as amended). The broad approach to the significance rating methodology is to determine the environmental risk (ER) by considering the consequence (C) of each impact (comprising Nature, Extent, Duration, Magnitude, and Reversibility) and relate this to the probability/ likelihood (P) of the impact occurring. This determines the environmental risk. In addition, other factors, including cumulative impacts and potential for irreplaceable loss of resources, are used to determine a prioritisation factor (PF) which is applied to the ER to determine the overall significance (S). The impact assessment will be applied to all identified alternatives. Where possible, mitigation measures will be recommended for impacts identified.

11.2. Determination of Environmental Risk

The significance (S) of an impact is determined by applying a prioritisation factor (PF) to the environmental risk (ER). The environmental risk is dependent on the consequence (C) of the particular impact and the probability (P) of the impact occurring. Consequence is determined through the consideration of the Nature (N), Extent (E), Duration (D), Magnitude (M), and reversibility (R) applicable to the specific impact. For the purpose of this methodology the consequence of the impact is represented by the following equation:

Equation 11-1 Impact Consequence.

$$\mathbf{C} = (\boldsymbol{E} + \boldsymbol{D} + \boldsymbol{M} + +\boldsymbol{R})(\boldsymbol{N4})$$

Each individual aspect in the determination of the consequence is represented by a rating scale as defined in Table 11-1 below.

Table 11-1 Criteria for Determining Impact Consequence.

Aspect	Description	Weight
Nature	Likely to result in a negative/ detrimental impact.	-1
	Likely to result in a positive/ beneficial impact.	1
Extend	Activity (i.e. limited to the area applicable to the specific activity)	1
	Site (i.e. within the development property boundary)	2
	Local (i.e. the area within 5 km of the site)	3
	Regional (i.e. extends between 5 and 50 km from the site)	4
	Provincial/ National (i.e. extends beyond 50 km from the site)	5
Duration	Immediate (< 1 year)	1
	Short term (1 – 5 years)	2

Aspect	Description	Weight
	Medium term (6 – 15 years)	3
	Long term (the impact will cease after the operational life span of the project)	4
	Permanent (no mitigation measure of natural process will reduce the impact after construction).	5
Magnitude	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected)	1
	Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected)	2
	Moderate (where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way)	3
	High (where natural, cultural or social functions or processes are altered to the extent that it will temporarily cease), or	4
	Very high / don't know (where natural, cultural or social functions or processes are altered to the extent that it will permanently cease).	5
Reversibility	Impact is reversible without any time and cost	1
	Impact is reversible without incurring significant time and cost	2
	Impact is reversible only by incurring significant time and cost	3
	Prohibitively high time and cost	4
	Irreversible	5

Table 11-2 Probability scoring.

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

The result is a qualitative representation of relative ER associated with the impact. ER is therefore calculated by applying the following equation:

Equation 11-2 Impact Consequence.

$$\text{ER} = C\,.\,P$$

Table 11-3 Determination of Environmental Risk.

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

The outcome of the environmental risk assessment will result in a range of scores, ranging from 1 through to 25. These ER scores are then grouped into respective classes as described in Table 11-4.

Table 11-4 Significance classes.

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

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

11.3. Impact prioritization

Further to the assessment criteria presented in the section above, it is necessary to assess each potentially significant impact in terms of:

i. Cumulative impacts; and

ii. The degree to which the impact may cause irreplaceable loss of resources.

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

Table 11-5 Criteria for Determining Prioritisation.

Cumulative Impact (C)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change	Low (1)
	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change	Medium (2)
	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/ definite that the impact will result in spatial and temporal cumulative change	High (3)
Irreplaceable loss of Resource (LR)	Where the impact is unlikely to result in irreplaceable loss of resources	Low (1)
	Where the impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited	Medium (2)
	Where the impact may result in the irreplaceable loss of resources of high value (services and/or functions)	High (3)

The value for the final impact priority is represented as a single consolidated priority, determined as the sum of each individual criteria represented in Table 11-5 . The impact priority is therefore determined as follows:

Equation 11-3 Impact Consequence.

$$\text{Priority} = CI + LR$$

The result is a priority score which ranges from 3 to 9 and a consequent PF ranging from 1 to 2 (Refer to Table 11-6 below).

Table 11-6 Determination of Prioritisation Factor.

Priority	Ranking	Prioritisation factor
2	Low	1
3	Medium	1.125
4	Medium	1.25
5	Medium	1.375
6	High	1.5

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

Table 11-7 Final Environmental Significance Rating.

Value	Description
≤ -20	High negative (i.e. where the impact must have an influence on the decision process to develop in the area).
> -20 ≤ -10	Medium negative (i.e. where the impact could influence the decision to develop in the area).
> -10	Low negative (i.e. where this impact would not have a direct influence on the decision to develop in the area).
0	No impact
< 10	Low positive (i.e. where this impact would not have a direct influence on the decision to develop in the area).
≥ 10 < 20	Medium positive (i.e. where the impact could influence the decision to develop in the area).
≥ 20	High positive (i.e. where the impact must have an influence on the decision process to develop in the area).

The significance ratings and additional considerations applied to each impact will be used to provide a quantitative comparative assessment of the alternatives being considered. In addition, professional expertise and opinion of the specialists and the environmental consultants will be applied to provide a qualitative comparison of the alternatives under consideration. This process will identify the best alternative for the proposed project.

11.4. Impact Identification and significance ratings

Impacts and significant ratings associated different project phases are briefly discussed below and summarised in Table 11-8 and Table 11-9.

11.4.1. Construction phase: Associated activities and impacts

As Elandsfontein Colliery is an existing operational mine with infrastructure already established and utilised, this phase is not relevant.

11.4.2. Operational phase: Associated activities and impacts

The main impacts associated with operational phase activities include the following:

1. Impact on the groundwater quantity and change in the regional phreatic/ piezometric levels due to mine dewatering.
2. A depletion in aquifer storage and formation of a depression zone may potentially lead to a reduction in groundwater contribution to baseflow of local drainages and/or groundwater supported wetlands.
3. Impact on groundwater quality due to leachate of contaminants from waste facilities i.e. mine discard dump, slurry ponds, coal stockpiles, unlined pollution control dams (PCD) as well as carbonaceous overburden dumps.
4. Impact on groundwater quality due to hydrocarbon contamination caused by mine heavy vehicles and machinery.

11.4.3. Operational phase: Management and mitigation measures

Mitigation and management measures associated with the operational phase activities include the following:

i. Development and implementation of an integrated groundwater monitoring program to assess regional groundwater levels will serve as early warning mechanism to implement mitigation measures. Lowering of regional piezometric levels is inevitable and cannot be mitigated, however it is recommended that alternative water supply sources or compensation measures should be investigated for nearby users impacted on.

ii. The existing groundwater flow model should be recalibrated with time-series monitoring data in order to be applied as water management tool for scenario predictions.

iii. Development and implementation of an integrated groundwater monitoring program evaluating the regional water quality will serve as early warning mechanism to implement mitigation measures. Effectiveness of alternative barrier systems such as seepage capturing/ scavenger boreholes and/or cut-off trenches down-gradient of waste facilities should be evaluated in order to constrain the migration of contaminants from site. it is recommended that alternative water supply sources or compensation measures should be investigated for nearby users impacted on.

iv. Monitoring should be conducted by suitably qualified and experienced persons according to an approved water monitoring program. Water samples should be analysed by an accredited laboratory. The monitoring network should be refined and updated based on hydrochemical results obtained to ensure optimisation and adequacy of the proposed localities.

v. Mine heavy vehicles and machinery must be serviced and maintained regularly in order to ensure that oil spillages are limited. Spill trays must be provided if refuelling of construction vehicles is done on site. Further to this spill kits must be readily available in case of accidental spillages.

vi. The applicant shall appoint a suitably qualified and responsible person to give effect to all recommendations as stipulated in specialist reports to ensure compliance to licence conditions pertaining to activities in order to ensure that potential impact(s) are minimised and mitigation measures proposed are functioning effectively.

11.4.4. Post-operational phase: Associated activities and impacts

The main impacts associated with mine post-operational phase activities include the following:

1. Post-operational water level rebound and flooding of mine voids.
2. Decanting of poor water quality caused by leachate of sulphide bearing minerals such as pyrite in the presence of oxygen and water to create an acidic environment (i.e. acid rock drainage).
3. Seepage of poor water quality from waste facilities i.e. mine discard dump, slurry ponds, coal stockpiles, unlined pollution control dams (PCD) as well as carbonaceous overburden dumps

11.4.5. Post-operational phase: Management and mitigation measures

Mitigation and management measures associated with the post-operational phase activities include the following:

i. Monitoring of surface water and groundwater in accordance with the implemented monitoring network and protocol should be continued throughout the post operational phase.

ii. Ensure that rehabilitation is properly conducted and in accordance with best practise guidelines as well as the approved mine closure and rehabilitation plan.

iii. The groundwater capture zone should return back to the pre-mining equilibrium after cessation of mine dewatering and replenishment of groundwater in storage, however the lasting effect and subsequent impact on neighbouring borehole water levels and yields should be monitored with alternative water supply sources or compensation measures available for nearby users if impacted on.

Table 11-8 Impact assessment significant rating: Operational phase.

IMPACT DESCRIPTION				Pre-Mitigation							Post Mitigation								Priority Factor			
Identifier	Impact	Alternative	Phase	Nature	Extent	Duration	Magnitude	Reversibility	Probability	Pre-mitigation ER	Nature	Extent	Duration	Magnitude	Reversibility	Probability	Post-mitigation ER	Confidence	Cumulative Impact	Irreplaceable loss	Priority Factor	Final score
1.1.1	Impact on the groundwater quantity and change	Alternative 1	Operation	-1	3	3	2	2	4	-10	-1	3	2	1	2	4	-8	Medium	2	2	1.25	-10.00
1.1.2	A depletion in aquifer storage and formation of a	Alternative 1	Operation	-1	3	3	4	2	4	-12	-1	3	3	4	2	4	-12	Medium	2	2	1.25	-15.00
1.1.3	Impact on groundwater quality due to leachate of	Alternative 1	Operation	-1	3	4	4	3	4	-14	-1	2	4	3	2	3	-8.25	Medium	2	2	1.25	-10.31
1.1.4	Impact on groundwater quality due to hydrocarbo	Alternative 1	Operation	-1	2	4	4	4	3	-10.5	-1	2	4	2	2	2	-5	Medium	2	2	1.25	-6.25

Table 11-9 Impact assessment significant rating: Post-closure phase.

IMPACT DESCRIPTION				Pre-Mitigation							Post Mitigation								Priority Factor			
Identifier	Impact	Alternative	Phase	Nature	Extent	Duration	Magnitude	Reversibility	Probability	Pre-mitigation ER	Nature	Extent	Duration	Magnitude	Reversibility	Probability	Post-mitigation ER	Confidence	Cumulative Impact	Irreplaceable loss	Priority Factor	Final score
1.1.5	Post-operational water level rebound and floodin	Alternative 1	Rehab and closure	1	3	3	2	1	4	9	1	3	2	1	2	4	8	Medium	2	1	1.13	9.00
1.1.6	Decanting of poor water quality caused by leach	Alternative 1	Rehab and closure	-1	3	4	4	3	4	-14	-1	2	3	3	3	3	-8.25	Medium	2	2	1.25	-10.31
1.1.7	Seepage of poor water quality from waste faciliti	Alternative 1	Rehab and closure	-1	3	4	4	3	4	-14	-1	2	2	3	3	3	-7.5	Medium	2	2	1.25	-9.38

12. CONCLUSIONS

The following conclusions were derived from the outcomes of this investigation:

1. The site is predominantly underlain by an intergranular and fractured aquifer system comprising mostly fractured and weathered compact sedimentary/ arenaceous rocks. It should be noted that the Ecca Group consists mainly of shales and sandstones that are very dense with permeability usually very low due to poorly sorted matrices.
2. On a local scale, two aquifer units can be inferred in the saturated zone:
    i. A shallow, weathered zone aquifer occurring in the transitional soil and weathered bedrock formations underlain by more consolidated bedrock. Due to higher effective porosity (*n*) this aquifer is most susceptible to impacts from contaminant sources.
    ii. An intermediate/deeper fractured where the underground mine void is situated.
3. Various neighbouring boreholes in close proximity (< 1.0 km) to the mining operations are utilized for domestic and livestock watering.
4. The unsaturated/ vadose zone within the study area is limited (< 8.0 mbgl) with shallow water levels of the weathered aquifer posing a risk to groundwater contamination.
5. Analysed data indicate that the regional groundwater elevation correlates moderately to the topographical elevation suggesting a dynamic environment. The inferred groundwater flow direction of the shallow aquifer mimics topography and is expected to be in a general southwestern direction towards the lower laying drainage system of the Grootspruit from where it will discharge as baseflow.
6. The groundwater gradient increases towards the west and southwest while a gentler gradient exists to the north. The latter will influence seepage rates from mine waste facilities and should be noted.
7. The regional ambient groundwater quality of the shallow aquifer is good and suggest an unimpacted groundwater system, however isolated monitoring localities within site boundary is indicative of an impacted groundwater system and shows signs of coal mine pollution and acid mine drainage (AMD).
8. The mine void water quality is acidic and extremely saline with pH < 3.0 and sulphate concentration > 1400 mg/l.
9. The hydrochemical signature of surface water locality ASW01, downstream sampling locality of the Grootspruit, suggest similar water environments to the mine void water which is potentially decanting as either interflow or baseflow at the lower laying zones or seepage from unrehabilitated discard dumps and other waste facilities.

13. RECCOMMENDATIONS

The following recommendations are proposed following this investigation:

1. It is recommended that this hydrogeological baseline assessment report be reviewed and distributed as part of the public participation and scoping phases. Relevant input and/or comments received from I&AP's should be addressed as part of the EIA phase to follow.
2. It is suggested that all hydrocensus and monitoring localities be revisited in order to gather wet-season data and information for comparison and time series trend analysis.
3. A spatial distribution of mine discard dumps, overburden as well as waste material samples should be analysed to determine the risk for acid rock drainage potential as well as a source term for the mass transport model.
4. A numerical groundwater flow model should be developed based on the hydrogeological conceptual model defined from site characetrisation data and information gathered. The groundwater flow model should be calibrated with applicable groundwater data to an acceptable level. The latter should be used to simulate estimated mine inflow and dewatering volumes, groundwater capture zones and water level drawdown, contamination plume migration curves. Accordingly, the model output should be used to qualify and quantify preliminary groundwater impacts as stated in this report.

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15. APPENDIX A: RAINFALL DATA (RAINFALL ZONE B2C)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1920	125.2	61.1	76.2	74.0	91.2	138.9	17.4	11.6	0.0	0.0	0.0	17.5	613.1
1921	58.0	107.9	74.1	51.5	69.1	90.7	0.6	29.0	13.7	0.0	44.6	15.0	554.3
1922	58.9	109.7	80.8	135.2	46.1	20.9	18.7	0.1	2.2	1.1	0.0	4.4	478.3
1923	18.0	84.7	78.4	56.9	60.4	124.3	30.7	23.4	0.0	0.0	2.2	18.7	497.7
1924	39.3	98.9	106.0	50.9	90.7	127.9	58.2	48.9	21.6	0.3	0.3	60.3	703.3
1925	20.6	69.2	63.5	50.0	40.8	27.9	5.6	35.1	1.8	12.9	0.0	13.4	340.8
1926	16.0	74.1	45.9	83.2	77.0	64.3	21.1	0.8	0.0	52.5	9.7	9.6	454.0
1927	100.2	32.9	55.7	110.0	45.5	40.5	15.4	0.9	0.0	0.0	20.1	8.0	429.1
1928	15.9	85.9	85.9	57.0	50.4	95.5	20.1	14.7	11.1	0.0	0.1	57.7	494.2
1929	116.3	98.3	113.0	96.8	95.3	64.4	24.0	1.9	0.0	21.2	10.7	0.2	642.1
1930	12.0	31.9	59.8	70.4	41.9	46.5	38.6	0.0	0.3	42.9	0.0	0.0	344.2
1931	39.3	61.5	57.7	135.4	60.4	52.5	7.7	11.9	0.1	0.0	0.0	23.5	450.0
1932	42.3	96.5	66.5	50.7	62.5	37.8	13.4	0.1	3.0	3.9	0.0	13.3	390.0
1933	4.6	169.0	116.6	151.8	100.9	56.5	38.5	19.7	8.6	14.1	18.4	24.1	722.9
1934	22.7	106.3	103.8	51.6	74.1	73.2	5.0	1.1	0.0	0.0	3.9	1.6	443.3
1935	17.4	32.9	75.2	122.9	99.7	96.3	41.4	87.9	0.0	0.1	0.0	22.9	596.8
1936	51.6	127.6	53.9	153.2	98.4	26.9	15.3	1.4	0.0	0.1	0.0	12.6	541.1
1937	59.8	17.0	127.9	114.9	39.8	42.8	81.5	3.2	5.9	9.6	7.0	11.7	521.1
1938	42.4	46.0	114.4	94.0	183.8	73.5	15.0	42.1	0.0	46.0	3.7	19.4	680.4
1939	47.5	147.8	123.3	60.3	63.1	58.9	22.8	26.3	58.2	0.0	1.4	57.1	666.6
1940	13.8	122.4	92.4	75.8	61.3	70.5	76.3	0.0	0.0	0.2	0.2	18.0	530.9
1941	36.7	20.1	87.9	107.4	64.5	67.0	17.7	29.9	17.7	0.0	12.1	25.0	485.9
1942	73.1	84.7	144.0	85.7	49.2	58.2	95.2	35.4	0.2	30.8	32.4	22.8	711.6
1943	55.6	84.2	92.2	107.4	148.2	51.9	5.0	3.7	30.2	0.0	0.0	23.8	602.2
1944	76.4	118.4	30.4	94.4	66.8	56.9	20.2	10.0	0.0	0.0	0.0	0.6	474.1
1945	32.7	48.9	72.6	136.7	128.8	71.5	12.0	5.8	0.0	0.0	0.0	0.2	509.2
1946	19.7	76.9	83.6	70.9	57.7	49.8	25.4	0.1	7.8	1.7	0.0	4.6	398.2
1947	26.5	101.6	127.6	128.2	31.7	75.3	14.5	8.5	0.0	0.1	0.0	11.8	525.7
1948	67.8	111.5	32.6	143.8	35.1	33.1	36.7	12.1	2.6	0.0	0.0	12.8	488.2
1949	51.2	113.4	101.8	74.1	51.1	48.5	71.6	14.3	0.6	0.4	0.0	4.9	531.9
1950	15.8	52.9	91.6	73.9	59.4	47.3	41.0	37.5	1.3	0.8	19.9	3.5	444.8
1951	96.5	10.1	83.3	53.5	76.6	23.0	17.4	6.3	2.5	16.2	0.2	0.6	386.1
1952	26.7	83.1	114.0	66.0	96.5	94.3	40.2	8.1	0.2	0.0	0.3	6.1	535.3
1953	34.1	154.5	73.2	95.1	76.8	45.7	35.4	9.0	0.0	0.0	0.3	12.0	536.0
1954	26.2	99.2	68.6	139.3	139.4	50.3	50.3	17.5	5.8	0.2	0.6	0.0	597.3
1955	52.0	84.8	147.2	55.2	111.9	60.6	0.1	81.3	9.9	2.8	0.0	45.8	651.5
1956	85.8	71.6	81.5	68.7	107.2	72.9	20.3	15.7	27.2	39.6	20.5	51.5	662.6
1957	52.9	31.6	34.8	117.1	34.5	42.2	98.4	3.8	0.1	0.0	0.0	46.1	461.5
1958	69.5	60.1	118.2	90.0	56.2	28.5	31.1	13.7	0.7	4.6	0.0	2.6	475.2
1959	20.4	138.7	95.7	59.9	49.3	54.5	77.3	7.3	2.1	0.5	8.1	5.1	518.9
1960	41.3	86.5	87.6	68.0	64.3	84.6	72.9	22.3	7.8	1.7	0.1	16.1	553.3
1961	51.8	63.9	88.6	73.8	56.3	44.7	38.0	0.7	2.8	0.0	6.2	9.8	436.5
1962	43.2	117.3	76.7	103.6	24.2	24.3	39.6	9.8	73.2	13.4	0.0	1.7	527.0
1963	50.3	78.0	40.5	148.3	43.3	24.6	12.7	3.0	5.2	0.0	4.3	2.3	412.6
1964	136.2	38.3	113.6	81.4	40.4	8.2	31.8	9.2	0.0	3.8	2.7	3.1	468.8
1965	10.5	76.1	65.5	55.2	46.9	5.8	13.7	6.3	3.5	0.0	0.4	7.3	291.4
1966	83.9	86.8	107.9	151.3	91.7	46.8	94.1	6.8	1.2	3.9	14.3	6.3	695.0
1967	75.3	97.4	79.4	84.4	50.7	97.5	37.2	13.8	0.2	2.2	7.0	1.6	546.7
1968	29.9	89.8	80.0	65.2	74.6	144.4	36.9	37.7	0.0	0.1	0.9	12.8	572.3
1969	103.5	98.1	115.4	75.7	57.3	33.0	31.9	6.7	0.7	3.1	11.6	8.4	545.5
1970	72.5	72.5	84.9	131.2	33.3	41.6	75.8	14.8	1.9	0.0	0.1	36.8	565.3
1971	35.7	121.1	100.8	126.1	37.8	82.8	12.2	6.8	0.4	0.0	4.2	23.1	551.0
1972	33.4	102.7	48.8	98.8	43.2	66.6	54.2	0.0	0.0	0.0	2.9	41.8	492.4
1973	55.4	61.1	130.2	95.1	47.5	20.0	45.0	2.1	0.9	9.0	0.8	10.9	478.0
1974	19.3	94.0	81.3	189.8	123.8	34.0	82.5	6.7	6.4	0.2	0.1	1.1	639.2
1975	30.8	123.8	90.4	95.8	72.7	73.2	28.9	31.2	0.0	0.0	0.0	8.5	555.4
1976	71.5	83.9	75.6	96.5	8.8	83.1	30.1	1.4	0.0	0.0	3.2	33.0	487.2
1977	40.4	76.8	49.3	150.8	90.0	60.2	16.3	1.1	0.0	0.5	11.1	24.4	521.0
1978	51.3	49.0	39.1	49.6	28.2	32.7	28.3	3.4	1.7	7.6	12.7	10.1	313.7
1979	67.7	116.4	58.6	115.9	119.1	52.9	11.1	0.8	0.0	0.0	0.1	31.4	573.9
1980	12.6	129.8	68.1	110.3	71.7	58.4	15.8	0.0	8.3	0.0	9.2	26.2	510.3
1981	56.6	54.9	62.2	116.7	38.3	62.7	9.1	0.6	0.7	16.3	0.0	3.6	421.8
1982	58.7	24.6	57.9	112.6	31.1	53.3	21.0	13.7	13.3	12.1	25.8	5.8	430.0
1983	76.5	135.5	89.1	70.1	29.9	93.0	3.5	0.1	12.9	9.3	5.8	4.0	529.7
1984	92.7	60.9	51.5	83.4	101.3	67.3	0.5	14.4	0.0	0.2	4.9	28.0	505.0
1985	65.9	31.5	102.8	70.0	43.6	42.4	25.9	0.0	9.2	0.0	0.5	1.5	393.4
1986	85.8	116.8	135.7	82.5	49.1	131.1	9.7	1.2	0.0	0.0	19.2	78.5	709.4
1987	48.3	145.1	109.5	68.4	32.0	69.4	16.0	3.2	9.6	0.5	6.4	21.1	529.6
1988	79.4	39.1	65.3	71.6	102.9	31.5	32.9	1.3	48.0	0.0	5.8	0.8	478.7
1989	33.0	118.0	112.0	45.4	92.4	94.1	87.2	2.0	0.0	1.0	0.9	2.9	588.9
1990	32.9	49.7	121.1	102.2	120.6	121.4	0.8	2.4	7.7	0.0	0.0	3.8	562.6
1991	37.5	48.8	102.3	74.6	62.2	35.6	9.5	0.0	0.5	0.0	15.8	6.3	393.1
1992	66.3	79.9	93.1	47.0	95.8	85.3	22.6	1.6	0.0	0.0	5.6	39.0	536.3
1993	125.5	103.6	68.1	69.6	93.1	50.4	6.8	0.0	0.0	0.0	0.0	12.3	529.4
1994	46.6	61.9	62.4	62.2	36.2	113.9	56.8	6.8	0.0	0.0	6.7	9.6	463.3
1995	66.7	140.9	174.1	166.2	238.9	84.8	54.8	6.8	0.0	0.3	5.8	1.6	940.9
1996	78.6	35.3	67.1	68.3	4.2	172.7	33.5	58.0	2.3	2.7	3.0	21.7	547.4
1997	57.6	111.0	49.9	80.9	43.8	42.2	4.6	0.0	0.0	0.0	0.0	48.9	438.7
1998	41.2	133.3	101.7	68.3	8.7	23.2	14.7	13.9	5.8	0.0	0.0	13.9	424.8
1999	34.7	144.9	161.0	174.2	140.1	129.1	51.5	14.1	1.7	0.4	0.0	14.9	866.5
2000	99.1	78.7	103.6	29.9	61.9	22.2	8.4	40.4	14.6	0.0	0.0	10.6	469.2
2001	72.2	109.4	61.1	39.9	47.1	13.4	23.5	14.2	7.8	0.0	6.5	12.1	407.3
2002	38.4	32.1	92.2	52.6	71.4	44.1	6.0	0.0	1.2	0.0	0.7	3.0	341.5
2003	61.6	51.1	93.2	80.1	153.6	189.5	21.9	4.4	4.5	12.2	0.7	0.0	672.9
2004	0.0	119.2	115.2	161.0	45.2	62.5	78.1	0.0	0.0	0.0	0.0	0.0	581.1
2005	24.1	85.0	59.3	191.0	135.1	55.0	0.0	0.0	0.0	0.0	0.0	0.0	549.6
2006	0.0	96.5	115.5	36.3	7.2	12.9	18.7	0.0	20.5	0.0	0.0	29.2	336.7
2007	162.3	95.8	131.7	215.5	22.8	195.3	0.0	30.9	0.0	0.0	0.0	0.0	854.3
2008	45.5	130.3	85.9	118.3	80.8	83.2	5.8	13.0	39.7	0.0	14.9	25.1	642.6
2009	89.7	149.2	117.4	134.0	102.2	73.7	130.1	0.0	0.0	0.0	0.0	0.0	796.3
Geometric mean	**52.6**	**86.4**	**87.7**	**94.1**	**70.1**	**64.9**	**31.6**	**12.3**	**6.1**	**4.5**	**4.9**	**15.6**	**530.8**
Minimum	**0.0**	**10.1**	**30.4**	**29.9**	**4.2**	**5.8**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**291.4**
Maximum	**162.3**	**169.0**	**174.1**	**215.5**	**238.9**	**195.3**	**130.1**	**87.9**	**73.2**	**52.5**	**44.6**	**78.5**	**940.9**
Standard deviation	**31.5**	**36.1**	**29.3**	**38.9**	**39.7**	**37.9**	**27.1**	**16.7**	**12.4**	**10.4**	**7.9**	**16.3**	**119.5**

16. APPENDIX B: WATER QUALITY ANALYSIS LABORATORY CERTIFICATES

18. APPENDIX C: SPECIALIST CURICULUM VITAE