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Hydrogeological Study

for

Ekandustria Operations

Compiled for:

Sasol Dyno Nobel (Pty) Ltd

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- I have no bias with regard to this project or towards the various stakeholders involved in this project.
- I have not received, nor have I been offered, any significant form of inappropriate reward for compiling this report.

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Customer Satisfaction:

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EXECUTIVE SUMMARY

Geo Pollution Technologies - Gauteng (Pty) Ltd (GPT) was appointed by Sasol Dyno Nobel (Pty) Ltd to conduct a hydrogeological impact study for the current development. The current development is in the process of applying for an integrated Water Use License (iWUL).

The site is located in Ekandustria, 14 km north of Bronkhorstspruit, Gauteng Province. The topography is gently undulating and the slope is more or less in the order of 1:15 (6%).Locally drainage is towards the tributary of the Masokololo River that flows from south east to north west to the south west of the site. On a larger scale, drainage occurs towards the generalised flow of the Elands River which flows from south to north, approximately 10km west of the site.

The geology underlying the property consists of the Wilgerivier Formation of the Waterberg Group while the geology to the south side of the property consists of intrusive diabase. The Wilgerivier Formation consists of a thick, continuous sequence of red to red-brown sediments, including quartzite, grit and sandstone. The diabase located in the centre as a ring structure, is intruded into the central portion of the basin.

According to Barnard (2000)[1], groundwater occurrence within the Wilgerivier Formation is associated with fault and fracture zones and with bedding planes. The groundwater potential is classed as low to moderate on the basis that 80% of boreholes on record produce less than 2l/s.

A geophysical survey was conducted on site to identify drilling targets. Therefore, three (3) resistivity traverses were completed using the Lund Imaging System with a Wenner-Schlumberger geometry and a unit electrode spacing of 10 m, over a period of two (2) days. From these results three (3) drilling targets were selected along anomalies identified and drilled via percussion drilling. Two of the three boreholes encountered water while the third was dry. A pumping test was conducted on SSBH2 as this borehole had the highest blow yield. The results indicated that for a 24 hour pump cycle, the borehole can be pumped at 3 l/s and for a pumping cycle of 8 hours with a recovery period of 16 hours, the borehole can be pumped at a rate of 5 l/s or 1800 l/hour.

A hydrocensus was conducted and a total of seven properties were visited but only one property could be accessed. Two boreholes were identified and the groundwater level could only be measured in one (1). None of the properties visited were within 1 km of the Ekandustria site. In addition to the hydrocensus, water level information was obtained from the monitoring network provided by the Client for the February 2023 monitoring event. Monitoring takes place on a quarterly basis. The groundwater levels varied between a minimum of 0.5 m and a maximum of 7.73 m below ground level.

Monitoring results were supplied by the client for the site and indicated groundwater exceedances above the SANS recommended limit of EC, TDS, NO_3 and N, NO_2 as N, F and NH_3. Surface water qualities showed that only iron concentrations were above the SANS recommended limit.

Using the GDT tool the vulnerability of the aquifer below the site was calculated as medium. Using the “South African Aquifer System Management Classification, December 1995” the aquifer was classified as a “Minor Aquifer System”. Therefore, measures must be taken to limit the risk to the underlying aquifer and the Masokolo River and its tributaries.

[1] An Explanation of the 1:500 000 General Hydrogeological Map: Johannesburg 2526. Barnard H.C, October 2000. Department of Water Affairs & Sanitation. ISBN 0-621-29914-6

A Reserve Determination was done for the Ekandustria site. The assessment was done on a "rapid" level using the software GRDM version 4.0.0.0. The data used for the calculation was derived from the WRC90 dataset contained in the "GRDM" software driven by the Resource Directed Measures from the Department of Water Affairs and FET water. A maximum projection of the planned water demand from the borehole is 447m^3/day (13 429 m^3/month) or 161 150 m^3/annum.

A general authorization allows a total of 0 m^3/ to be abstracted, thus it is concluded that General Authorization **cannot** be applied for. It is evident that local recharge in the quaternary catchment B31A (18.25 Mm^3/annum) will be able to supply in the demand of the site. The recharge on the property will allow for abstraction of ~ 201226.8 m^3/annum, without making provision for current abstraction & the baseflow requirement.

An impact quantification was done using the procedures for the assessment and minimum criteria for reporting aquatic biodiversity in terms of sections 24(5)(a) and (h) and 44 of the National Environmental Management Act, 1998. The impacts quantification produced the following significance ratings:

- Dewatering on private boreholes – very low
- Water quality deterioration – very high
- Baseflow/wetland impacts – very low

Recommendations

- Water quantity and quality data should continue to be collected on a regular, ongoing basis during operations. This includes abstraction volume monitoring.
- The hydrocensus and risk assessment should at least be repeated once before closure to evaluate any impacts.

TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

LIST OF APPENDICES

LIST OF ABBREVIATIONS

Abbreviation	Explanation
ARD	Acid Rock Drainage
BPG	Best Practice Guidelines
CMS	Catchment Management Strategy
CSM	Conceptual Site Model
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
IWRMP	Integrated Water Resources Management Plan
IWRM	Integrated Water Resources Management
km^2	Square kilometre
L/s	Litres per second
mamsl	Metres above mean sea level
Ml/d	Megalitres per day
m	metre
mm	Millimetre
mm/a	Millimetres per annum
mS/m	Millisiemens per metre
m^3	Cubic metre
MAP	Mean Annual Precipitation
MPRDA	Mining and Petroleum Resources Development Act (Act No. 73 of 2002) 1989)
NEMA	National Environmental Management Act (Act No. 107 of 1998)
NWA	National Water Act (Act No. 36 of 1998)
ppm	Parts per million
RDM	Resource Directed Measures
RQO	Resource Quality Objective
RWQO	Resource Water Quality Objective
TDS	Total Dissolved Solids
WMA	Water Management Area
WMP	Water Management Plan

DEFINITIONS

Definition	Explanation
Aquiclude	A geologic formation, group of formations, or part of formation through which virtually no water moves
Aquifer	A geological formation which has structures or textures that hold water or permit appreciable water movement through them. Source: National Water Act (Act No. 36 of 1998).
Borehole	Includes a well, excavation, or any other artificially constructed or improved underground cavity which can be used for the purpose of intercepting, collecting or storing water in or removing water from an aquifer; observing and collecting data and information on water in an aquifer; or recharging an aquifer. Source: National Water Act (Act No. 36 of 1998).
Boundary	An aquifer-system boundary represented by a rock mass (e.g. an intruding dolerite dyke) that is not a source of water, and resulting in the formation of compartments in aquifers.
Cone of Depression	The depression of hydraulic head around a pumping borehole caused by the withdrawal of water.
Confining Layer	A body of material of low hydraulic conductivity that is stratigraphically adjacent to one or more aquifers; it may lie above or below the aquifer.
Dolomite Aquifer	See “Karst” Aquifer
Drawdown	The distance between the static water level and the surface of the cone of depression.
Fractured Aquifer	An aquifer that owes its water-bearing properties to fracturing.
Groundwater	Water found in the subsurface in the saturated zone below the water table.
Groundwater Divide or Groundwater Watershed	The boundary between two groundwater basins which is represented by a high point in the water table or piezometric surface.
Groundwater Flow	The movement of water through openings in sediment and rock; occurs in the zone of saturation in the direction of the hydraulic gradient.
Hydraulic Conductivity	Measure of the ease with which water will pass through the earth's material; defined as the rate of flow through a cross-section of one square metre under a unit hydraulic gradient at right angles to the direction of flow (m/d).
Hydraulic Gradient	The rate of change in the total hydraulic head per unit distance of flow in a given direction.
Infiltration	The downward movement of water from the atmosphere into the ground.
Intergranular Aquifer	A term used in the South African map series referring to aquifers in which groundwater flows in openings and void spaces between grains and weathered rock.
Karst (Karstic)	The type of geomorphological terrain underlain by carbonate rocks where significant solution of the rock has occurred due to flowing groundwater.

Definition	**Explanation**
Karst (Karstic) Aquifer	A body of soluble rock that conducts water principally via enhanced (conduit or tertiary) porosity formed by the dissolution of the rock. The aquifers are commonly structured as a branching network of tributary conduits, which connect together to drain a groundwater basin and discharge to a perennial spring.
Monitoring	The regular or routine collection of groundwater data (e.g. water levels, water quality and water use) to provide a record of the aquifer response over time.
Observation Borehole	A borehole used to measure the response of the groundwater system to an aquifer test.
Phreatic Surface	The surface at which the water level is in contact with the atmosphere: the water table.
Piezometric Surface	An imaginary or hypothetical surface of the piezometric pressure or hydraulic head throughout all or part of a confined or semi-confined aquifer; analogous to the water table of an unconfined aquifer.
Porosity	Porosity is the ratio of the volume of void space to the total volume of the rock or earth material.
Production Borehole	A borehole specifically designed to be pumped as a source of water supply.
Recharge	The addition of water to the saturated zone, either by the downward percolation of precipitation or surface water and/or the lateral migration of groundwater from adjacent aquifers.
Recharge Borehole	A borehole specifically designed so that water can be pumped into an aquifer in order to recharge the ground-water reservoir.
Saturated Zone	The subsurface zone below the water table where interstices are filled with water under pressure greater than that of the atmosphere.
Specific Capacity	The rate of discharge from a borehole per unit of drawdown, usually expressed as m3/d•m.
Specific Yield	The ratio of the volume of water that drains by gravity to that of the total volume of the saturated porous medium.
Storativity	The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.
Transmissivity	Transmissivity is the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. It is expressed as the product of the average hydraulic conductivity and thickness of the saturated portion of an aquifer.
Unsaturated Zone (Also Termed Vadose Zone)	That part of the geological stratum above the water table where interstices and voids contain a combination of air and water.
Watershed (Also Termed Catchment)	Catchment in relation to watercourse or watercourses or part of a watercourse means the area from which any rainfall will drain into the watercourses or part of a watercourse through surface flow to a common point or points. Source: National Water Act (Act No. 36 of 1998).
Water Table	The upper surface of the saturated zone of an unconfined aquifer at which pore pressure is equal to that of the atmosphere.

HYDROGEOLOGICAL STUDY

EKANDUSTRIA OPERATIONS

1 INTRODUCTION

Geo Pollution Technologies - Gauteng (Pty) Ltd (GPT) was appointed by Sasol Dyno Nobel (Pty) Ltd to conduct a hydrogeological impact study for the current development. The current development is in the process of applying for an integrated Water Use License (iWUL).

The report is structured according to the requirements of the National Water Act, 1998 Regulations regarding the procedural requirements for water use licence applications and appeals 24 March 2017, Act N0. R. 267.

2 GEOGRAPHICAL SETTING

2.1 Site Location, Topography and Drainage

The site is located in Ekandustria, 14 km north of Bronkhorstspruit, Gauteng Province (Figure 1).

The topography (shown in Figure 2) can normally be used as a good first approximation of the hydraulic gradient in the unconfined aquifer. This discussion will focus on the slope and direction of fall of the area under investigation, features that are important from a groundwater point of view.

The area is characterised by a gently undulating topography and in the area of the site the slope is more or less in the order of 1:15 (6%).

Locally drainage is towards the tributary of the Masokololo River that flows from south east to north west to the south west of the site. On a larger scale, drainage occurs towards the generalised flow of the Elands River which flows from south to north, approximately 10km west of the site.

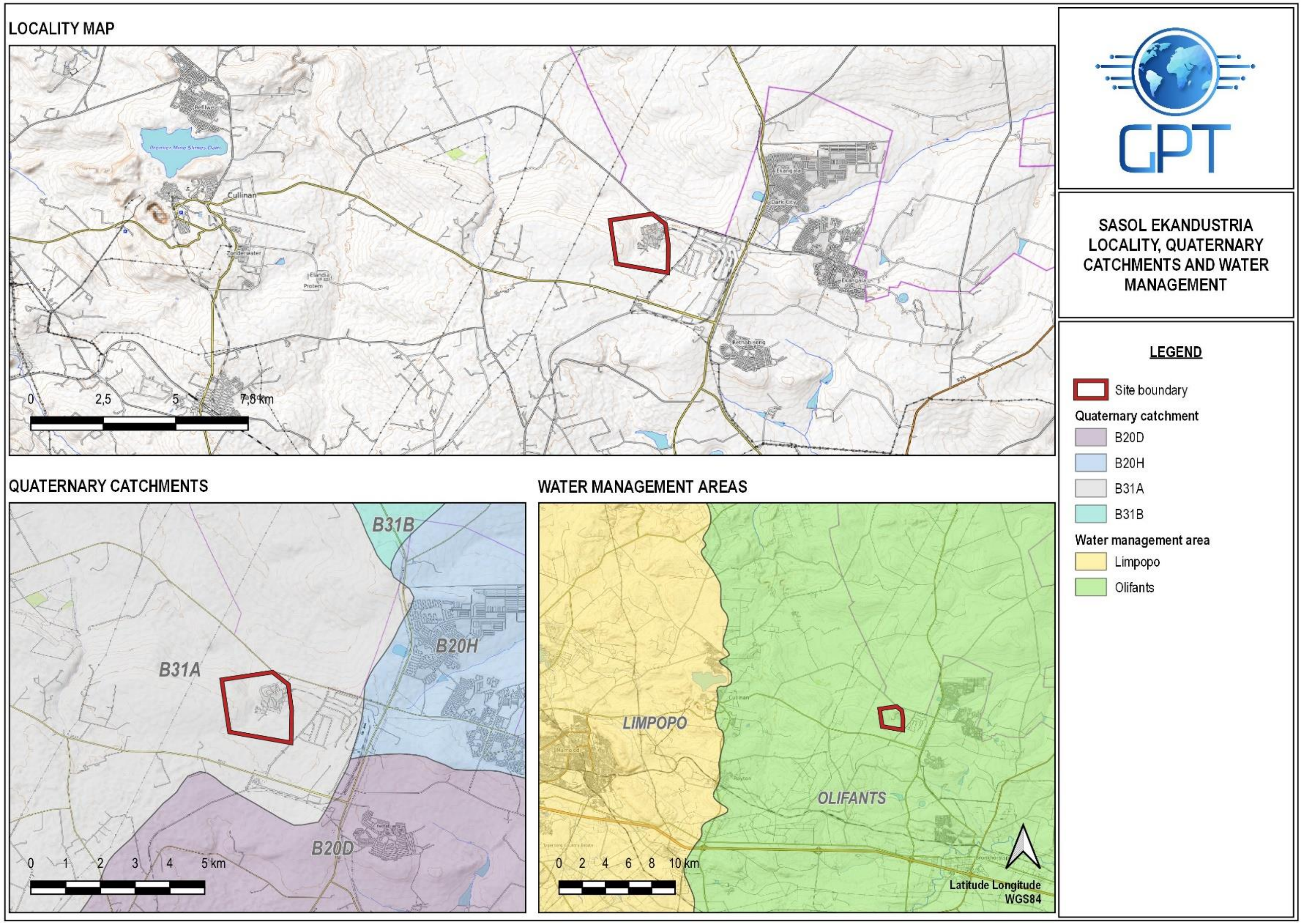

Figure 1: Site Location and Quaternary Catchment Boundaries

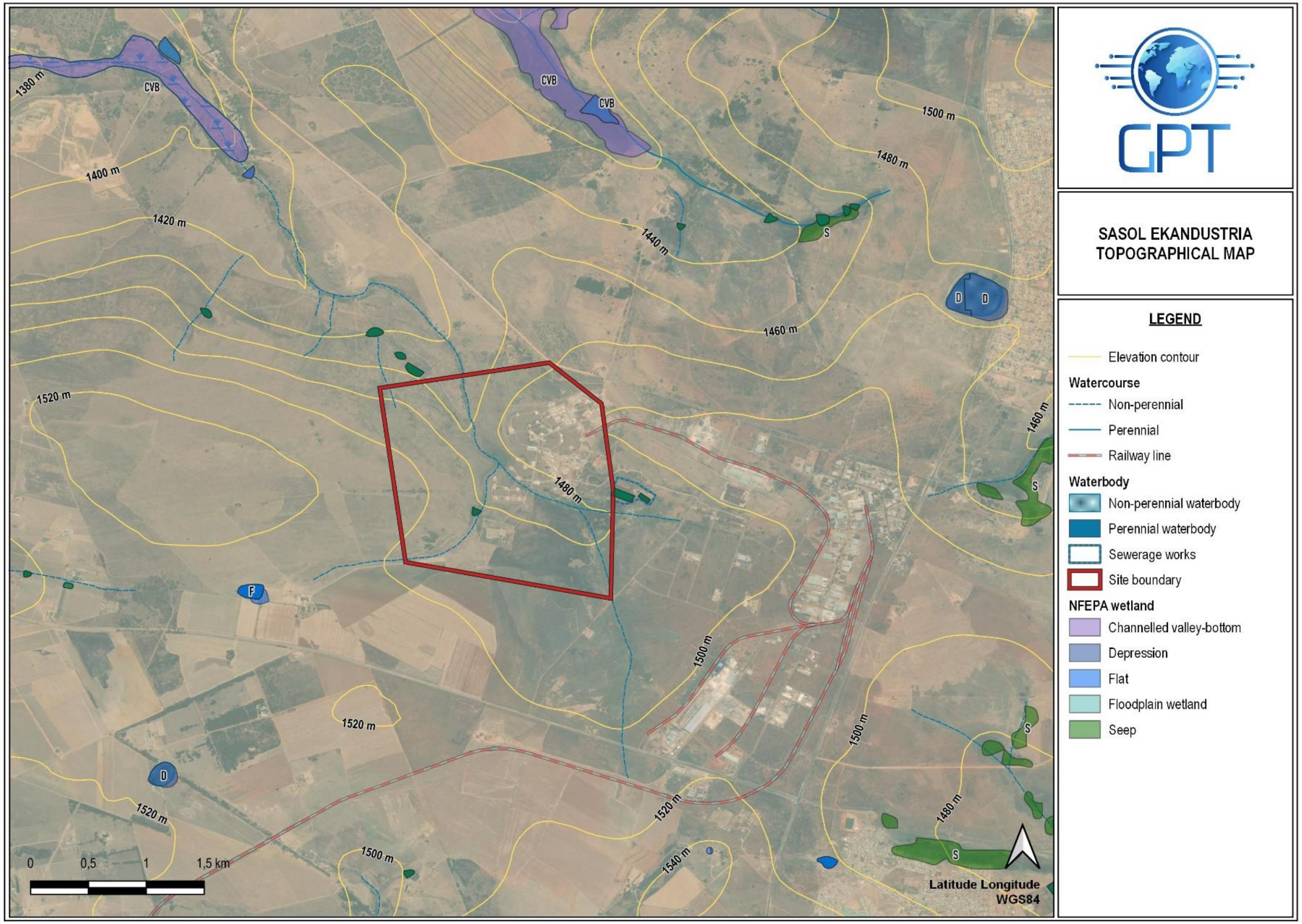

Figure 2: Site Topography

2.2 Climate

Climatic data was obtained from the DWS weather station Groenfontein at Bronkhorstspruit Dam (Station B2E001) (rainfall data and evaporation data) for the Bronkhorstspruit area (Table 1)[2]. The site is located in the summer rainfall region of Southern Africa with precipitation usually occurring in the form of convectional thunderstorms. The average annual rainfall (measured over a period of 56 years) is approximately 683.2mm/a with the high rainfall months between November and April.

Table 1: Climatic Data

Month	Average Monthly Rainfall (mm)	Mean Monthly Evaporation (mm)
January	134.4	165.1
February	79.4	143.3
March	86.2	135.1
April	44.2	105.3
May	14	85.7
June	6.6	67.9
July	2.5	74.7
August	6.4	102.5
September	19.3	138.7
October	68.8	163.5
November	104.5	159.4
December	115	174.4
Annual	683.2	1517.6

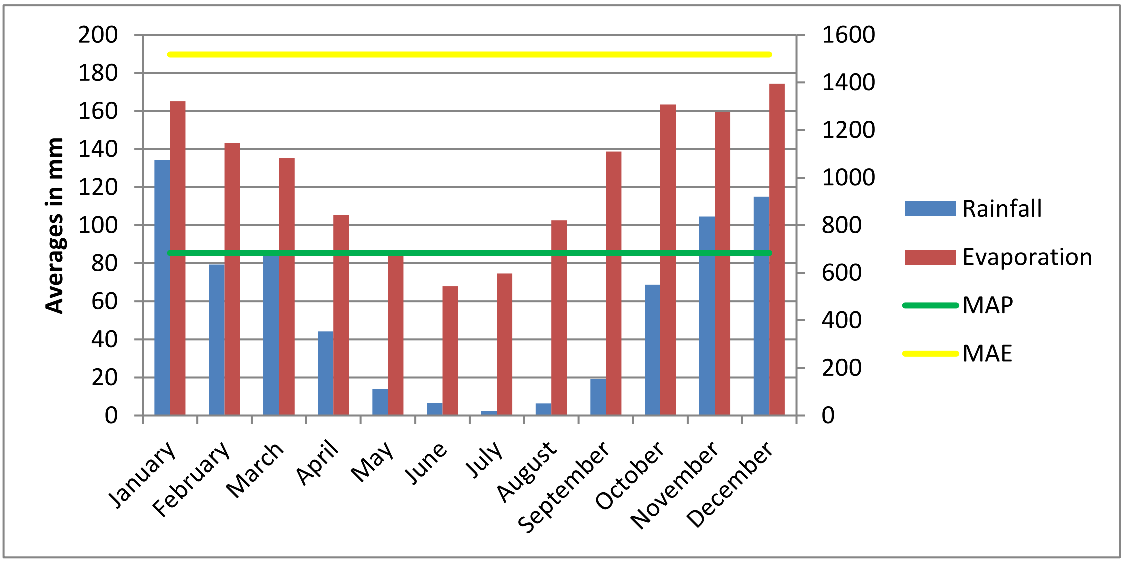

Figure 3: Climatic data representation

2 Department of Water Affairs (DWA): www.dwa.gov.za

3 SCOPE OF WORK

The following scope of work was supplied by the client:

Regional Reserve Determination

- Delineate resource units (default quaternary, unless geologically different)
- Delineate response units (same as resource unless existing information shows otherwise)
- Drainage (rivers and gauging stations in the resource unit area)
- Climate (average rainfall, reference source)
- Vegter regions (hydrological regions and recharge)
- Geo-hydrology - wq, wl, aquifer tests, main fracture zones – storage, sustainable yield, assurance of supply?
- Aquifer status: Local expert consideration (reference source), natural /impacted (mapping these areas in the resource unit), importance (both socioeconomic and strategic), vulnerability, dependent ecosystems, total current use, classification (Parsons and current resource classification system).
- Licensing conditions - wl, wq, level of acceptable degradation?
- Monitoring requirements - according to the Category (Appendix A).

Borehole hydrocensus survey

- Detail borehole census within at least 1km width zone around the area of recharge as well as on the area itself. Information to be collected for each borehole should at least include pump installation depth, borehole depth, depth of water level, yield of the borehole, depth of water strike(s), volume abstracted (daily, weekly, monthly) and water quality (one macro analysis per property in the zone).
- Contact details of relevant parties in the hydro census area.

Impact study – Numerical model

- Impact the abstraction will have on existing users and surrounding properties. This should be short- and long-term impact. This might have to be supported by a numerical model.
- Proximity to and potential impact of the abstraction on surface water discharges and groundwater dependent terrestrial ecosystems.
- Potential impact of abstraction on groundwater and surface water quality.

Additional information

Geohydrological report

- A geo-hydrological report compiled by an acceptable and qualified geohydrological consultant. Report should include appropriate maps, tables and figures to support the conclusions and recommendations.
- Aquifer description and characteristics including extent of the aquifer and hydraulic properties (storativity and transmissivity). This would require testing. Drilling might or might

not be required. Groundwater piezometric contour map showing flow direction and a depth to water level contour map.

Other:

- Effective annual recharge on this property and the safe yield of the aquifer.
- Volume and purpose of the water required and the volume available for abstraction. A water balance that at least cover the aquifer unit in which the property is located should, in other words, is done that includes all gains and losses.
- Detail geology of the area, including structures, maps etc.
- Geo-referenced map of the property in question, with boreholes, surface water features, geological features, physical structures (houses, stores, irrigation equipment) and current pollution sources (septic tanks, pit latrines, petrol/ diesel tanks, irrigation areas) depicted.

Monitoring programme - weekly water levels, weekly rainfall, 3 monthly macro analysis and surface water discharges and 6 monthly qualities in the 1km width zone..

3.1 Project Objectives

Within the scope of work the groundwater study aimed to address the following:

- Quantify the current groundwater status quo
- Impact Predictions
- Groundwater Risk Assessment
- Groundwater Management Options and Mitigation Measures

4 METHODOLOGY

4.1 Desk Study

This entailed the gathering of information through the collation, scrutiny and evaluation of available and relevant meteorological, geographical, geological, hydrogeological and water quality data.

4.2 Hydrocensus

The hydrocensus was done as a site familiarisation exercise and the collection of data from the study area and surrounding environments. It comprised a census of key boreholes, wells, springs and any other groundwater related information.

4.3 Geophysics

Electrical Resistivity Tomography (ERT) was used to map preferential flow paths due to the presence of interference causing infrastructure on the site which prevents the use of other methods such as the electromagnetic and magnetic methods. The geophysical survey was conducted by a reputable subcontractor and the data supplied to GPT.

4.4 Borehole Drilling and Siting

Borehole drilling was required to obtain detailed knowledge of the following site-specific groundwater characteristics amongst others:

- The geological units responsible for the geophysical anomalies
- The hydraulic properties of the aquifer systems by means of hydraulic tests
- Boreholes can also be used as part of monitoring networks or for abstraction purposes.

The percussion drilling was guided by the South African National Standard, SANS 10299-4:2003. Development, Maintenance and Management of Groundwater Resources. Part 4: Design construction and drilling of water boreholes.

4.5 Aquifer Tests

Test-pumping was conducted to achieve the following results:

- Groundwater resource evaluation, the aquifer characteristics, i.e. the ability of the aquifer to store and transmit groundwater
- Existence of barriers or recharge boundaries
- Borehole construction performance or borehole efficiency
- Design of the production system, i.e. the pump size and the reticulation system; and
- Information regarding the boreholes sustainable yield.

The test-pumping was guided by the South African National Standard, SANS 10299-4:2003. Development, Maintenance and Management of Groundwater Resources. Part 4: Test-pumping of water boreholes.

4.6 Sampling and Chemical Analyses

The sampling and analyses conducted for the study are discussed in the following paragraphs.

4.6.1 Groundwater sampling

Groundwater was sampled in accordance with the GPT's Standard Operating Procedure for groundwater sampling[3] by bailing. Before the bailed sample is collected an electrical conductivity (EC) profile down the hole is considered to detect changes in EC. EC profiles, compared with the construction logs of monitoring wells are then used to determine the optimum sampling depth of each hole. The sample was taken at a depth where the EC reaches a maximum. The bailer is then lowered to the prescribed depth and the sample taken.

4.7 Groundwater Recharge Calculations

Recharge to the shallow, unconfined aquifer was calculated using the RECHARGE program developed by the Institute for Groundwater Studies at the University of the Free State, South Africa. The calculated recharge percentage equates to approximately 5%.

[3] Available on request from marius@gptglobal.com

Table 2: Recharge calculation for the shallow unconfined aquifer

Recharge Estimation			
Various schematic maps			
	Recharge (mm)	Recharge %	Certainty
Soil	20.2	3.0	3
Geology	36.2	5.3	5
Vegter	65.0	9.5	1
Acru	10.0	1.5	2
Harvest Potential	10.0	1.5	2

4.8 Groundwater Availability Assessment

According to Barnard (2000)[4], groundwater occurrence within the Wilgerivier Formation is associated with fault and fracture zones and with bedding planes. The groundwater potential is classed as low to moderate on the basis that 80% of boreholes on record produce less than 2l/s.

5 PREVAILING GROUNDWATER CONDITIONS

5.1 Geology

5.1.1 Regional Geology

The published 1: 250 000 Geological Series 2528 Pretoria indicates that the geology underlying the property consists of the Wilgerivier Formation of the Waterberg Group (Figure 4). The geology to the south side of the property consists of intrusive diabase.

The Wilgerivier Formation consists of a thick, continuous sequence of red to red-brown sediments, including quartzite, grit and sandstone. The regional geology of the sandstone of the Waterberg Group can be understood as sand, deposited in layers, in a huge basin, stretching from south of Cullinan, Bronkhorstspruit, Witbank and Middelburg, with the Loskop dam as the northern boundary.

The diabase located in the centre as a ring structure, is intruded into the central portion of the basin. The dip of these layers is to the middle of this huge basin and varies from 2 degrees to 60 degrees.

5.1.2 Local Geology

On site, the sandstone layers of the Waterberg Group dip towards the north at an angle of 10 degrees. The Diabase sill like structure, located to the south of the site was intruded between the layered Waterberg Group.

[4] An Explanation of the 1:500 000 General Hydrogeological Map: Johannesburg 2526. Barnard H.C, October 2000. Department of Water Affairs & Sanitation. ISBN 0-621-29914-6

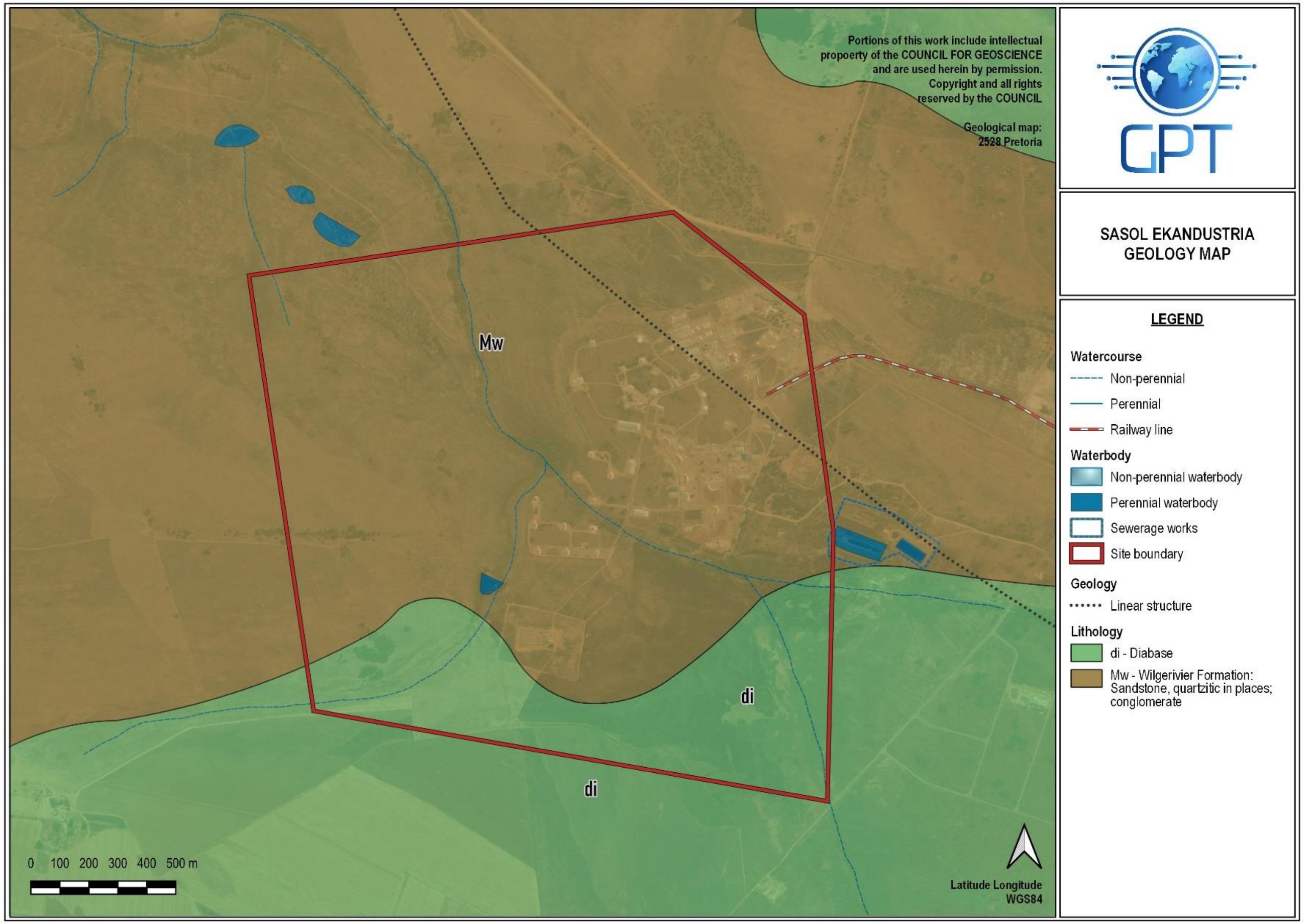

Figure 4: Regional Geology Map (1:250 000 geology series map)

5.2 Hydrogeology

According to the Johannesburg 2526 1:500 000 General Hydrogeological Map[5] the Wilgerivier rocks typically act as fractured rock aquifers and have expected yields in the range of 0.1-0.5 l/s. According to the geohydrological map the diabase to the south of the site are predominantly intergranular and fractured secondary aquifers with average yields expected in the range of 0.5-2.0.

However, the multi-layered weathering system present on these rocks could prove to have up to two aquifer systems present in the form of a shallow, saprolitic aquifer with a weathered, intergranular soft rock base associated with the contact of fresh bedrock and the weathering zone; and a fractured bedrock aquifer. These aquifer systems are discussed below.

5.2.1 Unsaturated zone - Shallow, saprolitic aquifer

The main source of recharge into the shallow aquifer is rainfall that infiltrates the aquifer through the unsaturated (vadose) zone. Vertical movement of water is faster than lateral movement in this system as water moves predominantly under the influence of gravity.

5.2.2 Saturated zone - Fractured, bedrock aquifer

Groundwater movement is predominantly associated with secondary structures in this aquifer (fractures, faults, dykes, etc.). Hydraulic conductivity

The commonly expected values of porosity and permeability for sedimentary rock types, similar to those present in the Wilgerivier Formation of the Waterberg Group, are 0.05 – 0.3 (porosity) and 10^{-3} $m.d^{-1}$ (hydraulic conductivity) respectively (Kruseman & de Ridder, 1994). Movement of groundwater in this aquifer will be preferential in secondary structures such as joints, faults and fractures.

5.3 Geophysical Survey

The resistivity method is a non-invasive geophysical tool that can provide cost-effective answers to geological questions. The method is based on the fact that different geological units are more or less resistive to electrical current flow. A DC or slowly varying AC current is injected into the earth by means of pairs of grounded current electrodes. The voltage drops between pairs of grounded potential electrodes is then measured at selected positions. These voltage drops are dependent on the resistivities of the materials through which the electrical currents are flowing.

By assuming that the earth is homogeneous and isotropic, measurements of the injected electrical current and measured voltage drops, as well as the distances between the different electrodes, may be used to calculate an apparent resistivity for the earth at a specific position and (pseudo-)depth. The apparent resistivities recorded during a survey may be inverted to obtain a model of the resistivity distribution within the subsurface. The model resistivity distribution may now be interpreted in terms of the local geological conditions by incorporating known information on the geology of the site.

The resistivity was conducted using the Lund Imaging System with a Wenner-Schlumberger geometry and a unit electrode spacing of 10 m.

Three (3) resistivity traverses were completed over a period of two (2) days. The traverses were chosen based on the following information:

- Site boundaries

[5] Haupt, C.J., (1995). An explanation of the 1:500 000 General Hydrogeological Map. Rustenburg 2526. DWAF.

- Structures such as houses & fences
- Geological information
- Topography and drainage

It should be noted that geophysics does not provide an indication of water but rather geological features such as dykes, fractures and weathering zones which are potential water bearing features. The traverses are shown in Figure 5 below.

- Traverse 1 was done in a south to north direction and stretched a distance of 400m along the eastern boundary fence of the site, close to the water reservoir.
- Traverse 2 was done in an east to west direction and stretched a distance of 400m crossing traverse 1 at station 29.
- Traverse 3 was done in an east to west direction and stretched 300m stopping at the eastern boundary of the site.

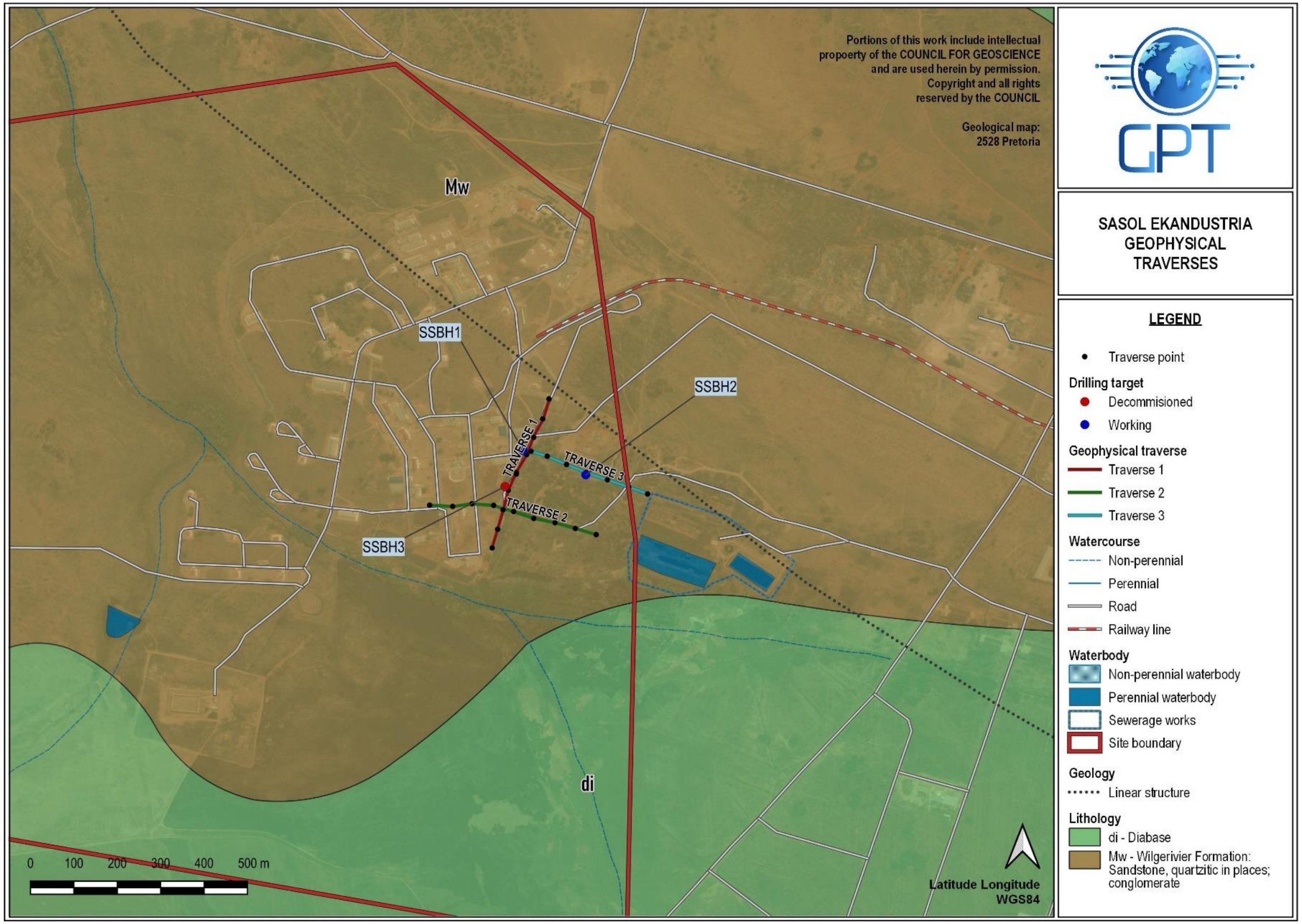

Figure 5: Resistivity Traverse Locality Map

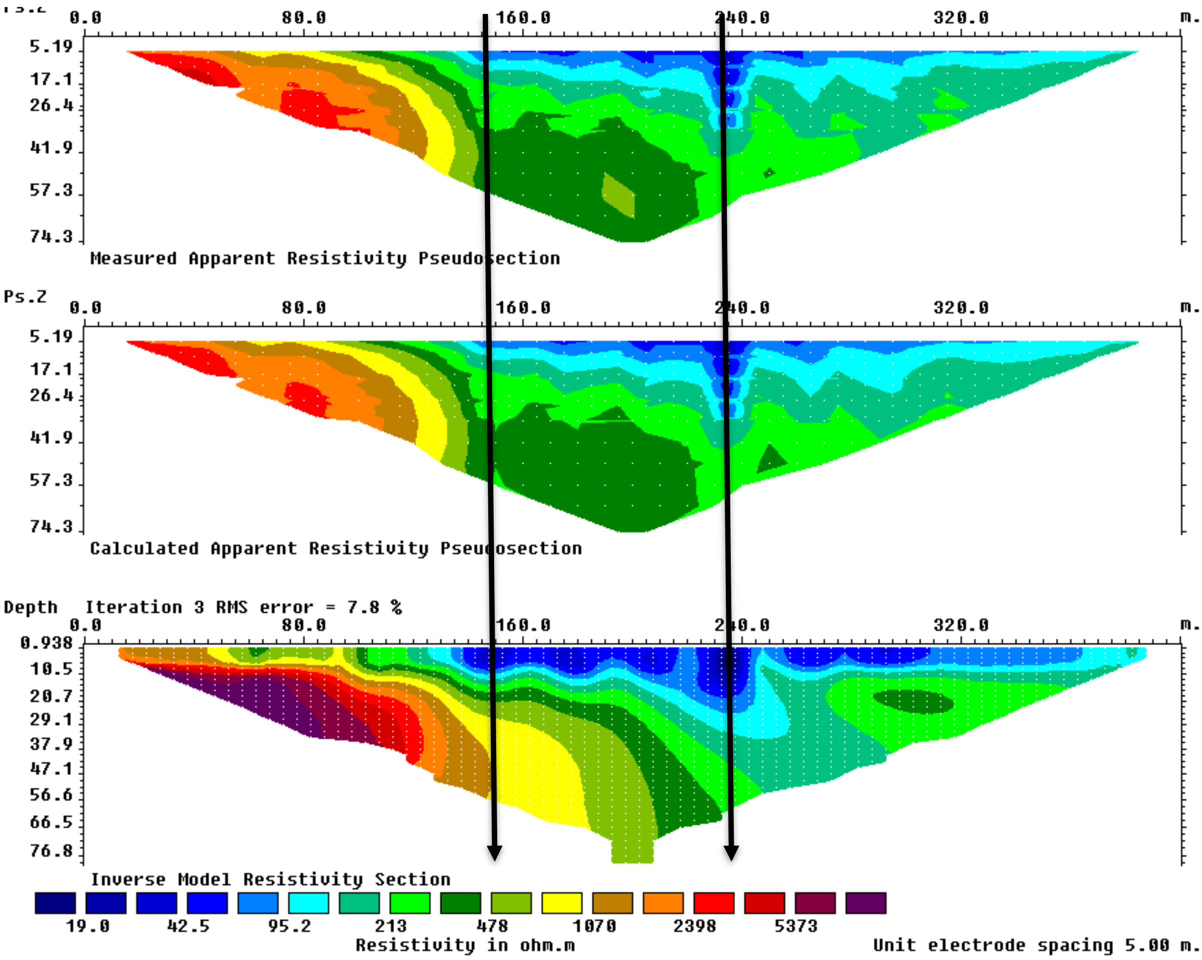

Figure 6: Traverse 1 (400 m in an north to south direction)

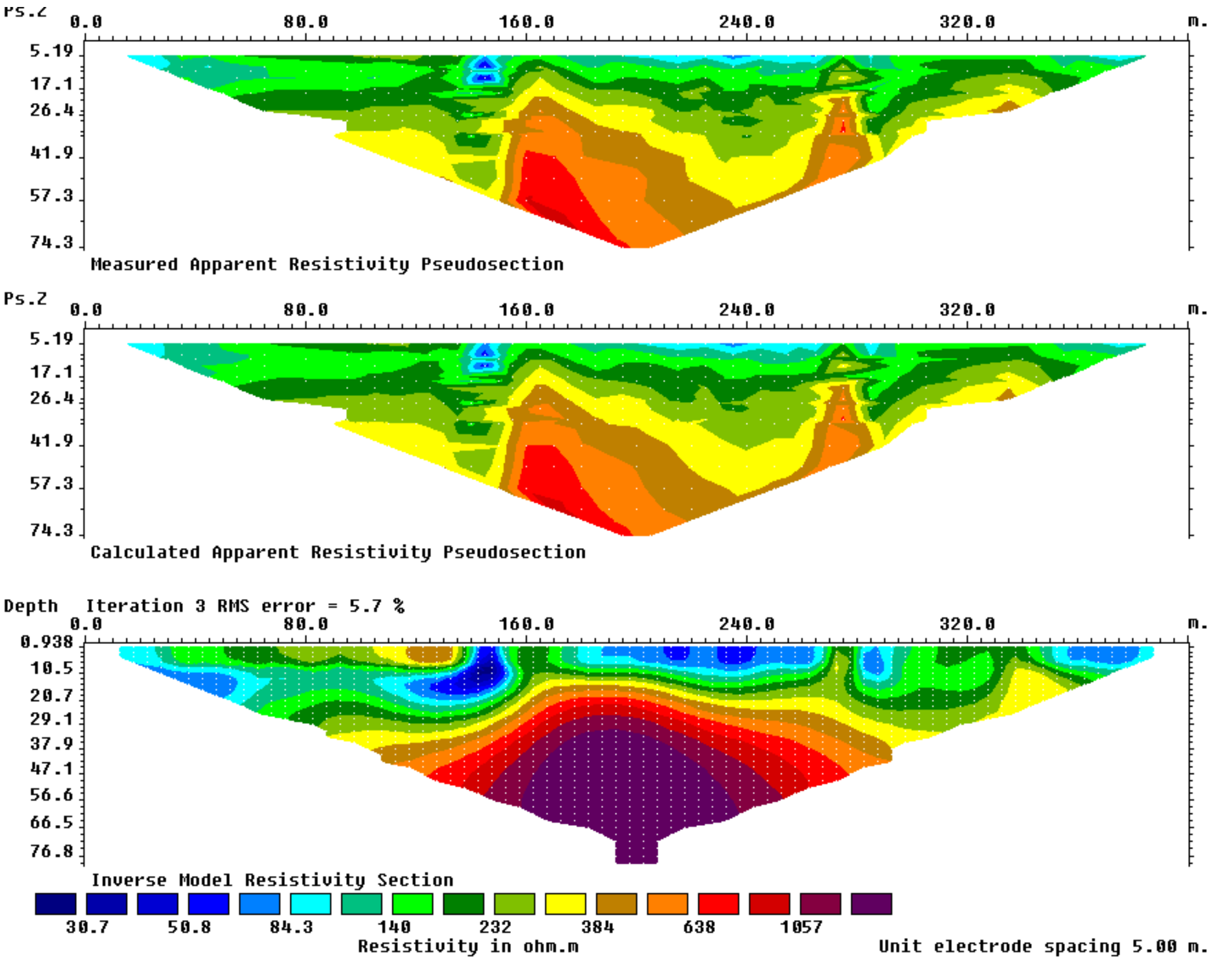

Figure 7: Traverse 2 (400 m in an eastern to western direction)

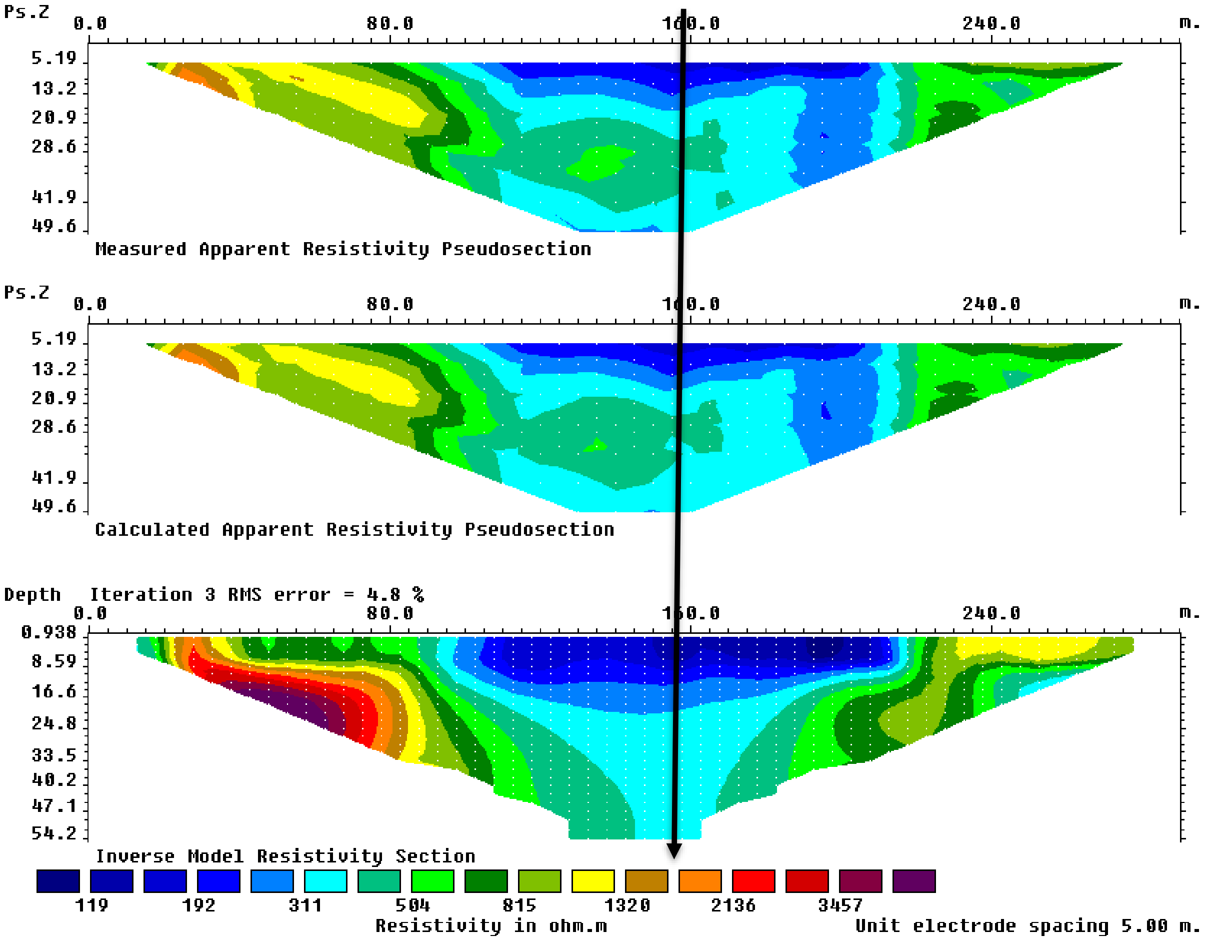

Figure 8: Traverse 3 (300 m in an eastern to western direction)

5.3.1 Proposed drilling targets

From the results of the geophysical investigations, three (3) drilling targets were selected. The drilling targets are explained below (see Figure 6 to Figure 8 above):

- Drilling target 1 (T1A) – The resistivity data of Traverse 1 indicates an area of low apparent resistivity possibly indicating an area of deeper weathering up to 30 m deep at a distance of 255 m. This could possibly indicate the presence of a paleo channel.
- Drilling target 2 (T1B) – This drilling target was also sited on Traverse 1 at a distance of 150 m where the resistivity data indicates a zone between a rock with a higher apparent resistivity and a rock with a lower apparent resistivity. This could indicate the presence of a possible contact between the Waterberg sandstones and a dolerite dyke.
- Drilling target 3 (T3A) – The resistivity data of Traverse 3 indicated an area of low apparent resistivity at a distance of 150 m possibly indicating an area of deeper weathering.
- Traverse 2 did not indicate any possible drilling targets as no clear anomalies are indicated.
- Based on experience and knowledge of the geohydrological environment that the intended target is the shallow weathered aquifer. This upper aquifer is associated with this weathered zone and water is often found within a few meters below surface.
- It is recommended that target 1, be drilled first then target 2 and target 3 should only be considered if targets 1 and 2 are unsuccessful.

Table 3: Borehole coordinates and proposed drilling depths

Name	X coordinate (East)	Y coordinate (South)	Borehole termination depth (m)
Target 1 (T1A)	28.68628	-25.685267	50
Target 2 (T1B)	28.686696	-25.68444	80
Target 3 (T3A)	28.688135	-25.684999	50

5.4 Percussion drilling

Three (3) percussion boreholes were drilled along anomalies identified during the geophysical survey (see **Error! Reference source not found.**).

The lithology encountered is typical of Wilgerivier Formation sediments:

- Borehole 1 (SSBH1) had a weathering depth of 12 m and fresh moderately to unweathered sandstone up to a depth of 50 m.
- Borehole 2 (SSBH2) – The borehole had a weathering depth of roughly 12 m with moderately weathered to fresh sandstone to a depth of 120 m.
- Borehole 3 (SSBH3) –The borehole had a weathering depth of 17 m with moderately weathered to fresh sandstone to a depth of 50 m.

5.5 Drilling results

Three percussion boreholes were drilled on the drilling targets identified based on the geophysical survey. A summary of the borehole parameters can be seen in Table 4 . The boreholes can be described as follows:

- Borehole 1 (SSBH1) – The borehole had a weathering depth of 12 m and fresh moderately to unweathered sandstone up to a depth of 50 m. Seepage was encountered at a depth of 11 m. The main water strikes were encountered at a depth of 25 m and 28 m respectively resulting in a blow yield of 0.6 l/s. The borehole was cased with steel casing from the top of the borehole to the bottom of the borehole with screened casing at a depth of 24 m to 50 m.
- Borehole 2 (SSBH2) – The borehole had a weathering depth of roughly 12 m with moderately weathered to fresh sandstone to a depth of 120 m. Seepage was encountered at a depth of 13 m The main water strike was encountered at a depth of 95 m and a secondary strike was encountered at 102 m resulting in a blow yield of 4.4 l/s. The borehole was cased with solid casing from the top of the borehole to a depth of 18 m.
- Borehole 3 (SSBH3) – The borehole was drilled on drilling target 3 (T3A). The borehole had a weathering depth of 17 m with moderately weathered to fresh sandstone to a depth of 50 m. The borehole did not produce any water strikes and was decommissioned immediately after drilling ceased at a depth of 50 m.
- The borehole logs can be seen in APPENDIX 2.

Table 4: Borehole information

Borehole	Date Drilled	Latitude	Longitude	Drilled depth (m)	Casing Depth (m)	Borehole diameter (mm)	Blow Yield (l/s)
SSBH1	12-Apr-22	-25.68526	28.68628	50	50	177	0.6
SSBH2	14-Apr-22	-25.68444	28.686696	120	18	165	4.4
SSBH3	19-Apr-22	-25.68499	28.688135	50	-	165	-

5.6 Aquifer Test Analysis

A pumping test was conducted on the newly drilled SSBH2 as it was the borehole with the highest blow yield. An eight hour constant discharge test was conducted on the borehole followed by recovery monitoring. The FC-Program (Flow Characteristic) 2014 version developed by the University of the Free State was used to calculate the sustainable yields for the respective boreholes.

Based on the blow yield of 4.4 l/s, the borehole was tested at a constant rate of 4 l/s for a period of eight hours. The borehole recovery was measured after the constant rate test stopped. Table 4 below depicts the sustainable yield calculated from the 4 l/s discharge rate using the Cooper-Jacob method. For a 24 hour pump cycle, the borehole can be pumped at 3 l/s and for a pumping cycle of 8 hours with a recovery period of 16 hours, the borehole can be pumped at a rate of 5 l/s or 1800 l/hour.

Table 5: Pump test summary

Borehole ID	Q (test) l/s	Borehole depth (m)	Pump Time (min)	Recovery Time (min)	Sustainable yield (l/s) - Cooper-Jacob	Sustainable yield (l/s) per 8-hour pumping cycle	Available Drawdown (m)	Total volume of water pumped during an 8 hour pumping cycle (kl)
SSBH1	4	120	360	10	3	5	90	144

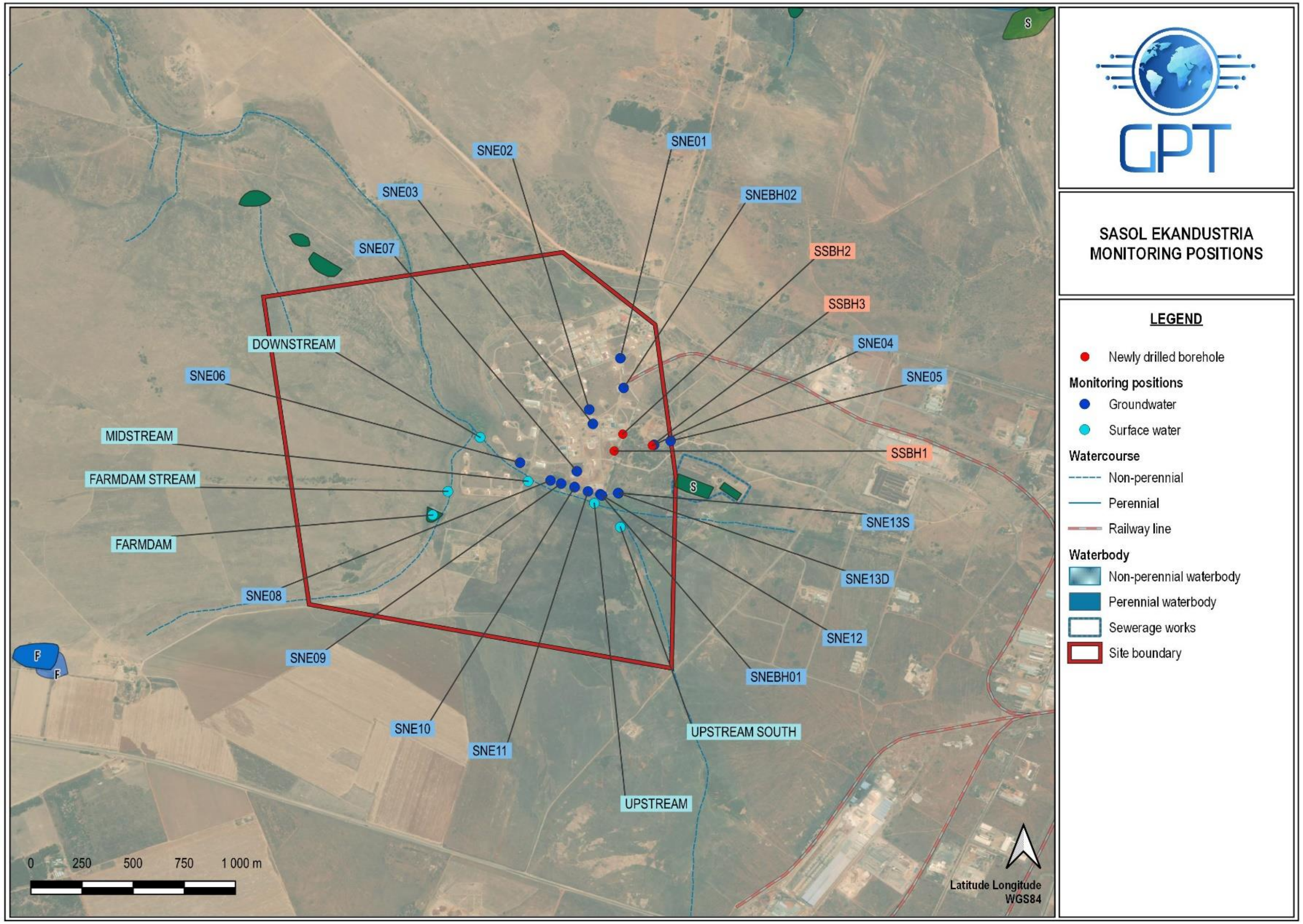

Figure 9: Drilled positions

5.7 Groundwater Levels

During the hydrocensus, a total of seven properties were visited but only one property could be accessed. Two boreholes were identified and the groundwater level could only be measured in one (1). None of the properties visited were within 1 km of the Ekandustria site. In addition to the hydrocensus, water level information was obtained from the monitoring network provided by the Client for the February 2023 monitoring event. Monitoring takes place on a quarterly basis. Seven water levels were available, while eight of the water levels could not be measured (Table 6).

The groundwater levels varied between a minimum of 0.5 m and a maximum of 7.73 m below ground level (Table 6). The relationship, using the boreholes from the hydrocensus, is shown in Figure 10 below.

This general relationship is useful to make a quick calculation of expected groundwater levels at selected elevations, or to calculate the depth of to the groundwater level (unsaturated zone):

Groundwater level = Elevation x gradient + intercept

Groundwater depth = Elevation – Calculated Groundwater Level

In general a good relationship should exist between topography and static groundwater level. This relationship can be used to distinguish between boreholes with water levels at rest, and boreholes with anomalous groundwater levels due to disturbances such as pumping or local hydrogeological heterogeneities.

However, due to the heterogeneity of the subsurface, these relationships should not be expected to hold everywhere under all circumstances, and deviations could thus be expected.

Table 6: Available groundwater level statistics

BH ID	13 February 2023
SNEBH01	Pump in-situ
SNE07	0.55
SNE05	8.79
SNE04	7.73
SNE13D	Inaccessible
SNE13S	Inaccessible
SNE11	Bees inside
SNE10	1.19
SNE06	3.27
SNE12	Bees inside
SNE09	Artesian
SNE01	Pump in-situ
SNE02	Bees inside
SNE03	3.07
Average	4.10

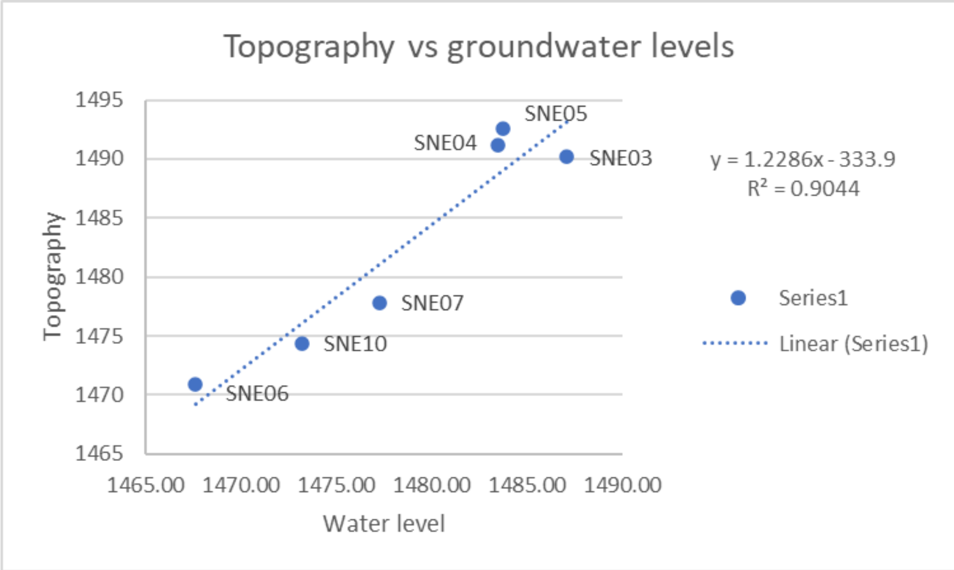

Figure 10: Correlation Graph of topography vs available groundwater levels

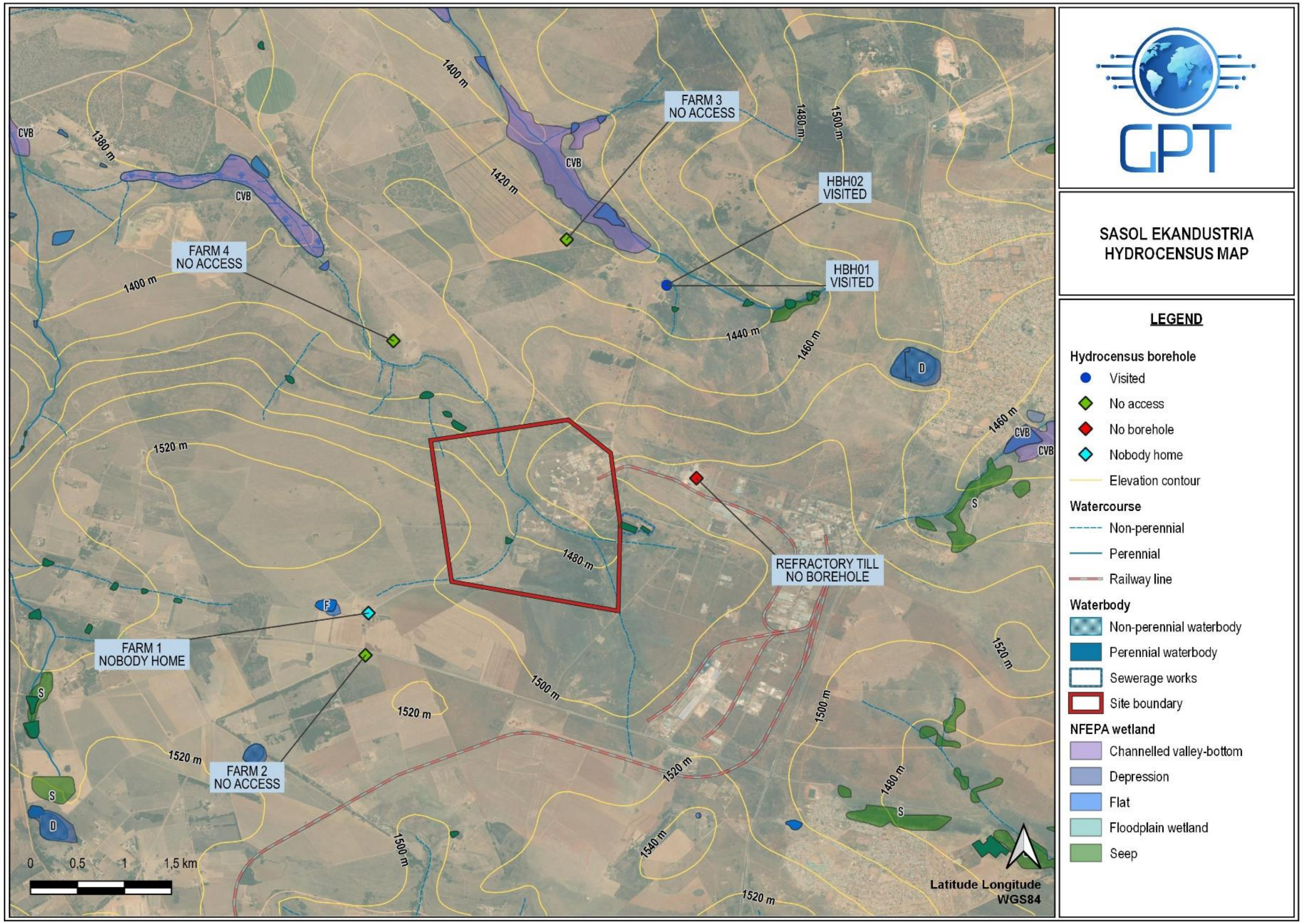

Figure 11: Map indicating hydrocensus area.

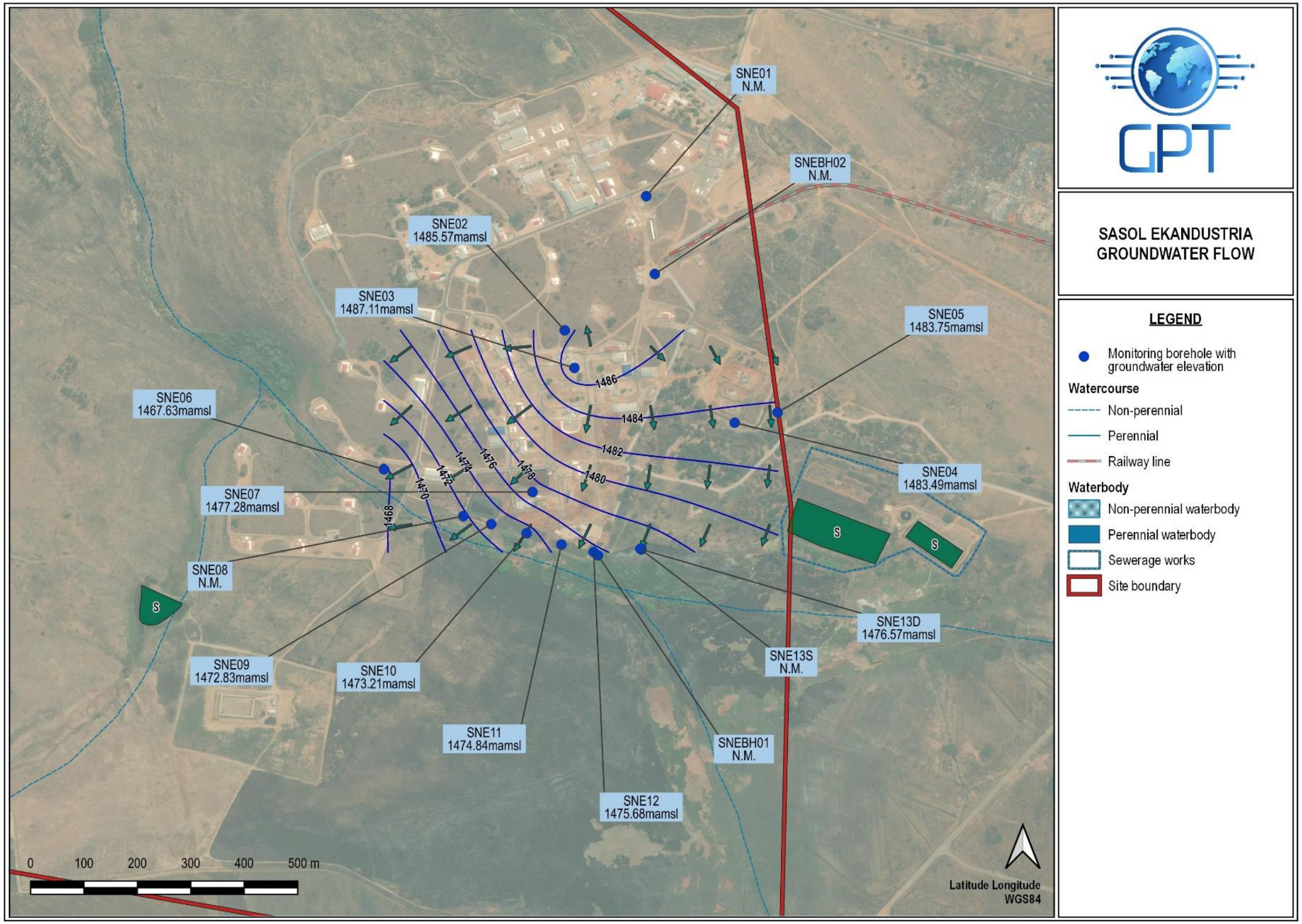

Figure 12: Map showing the groundwater flow direction.

5.8 Groundwater and Surface Water Quality

Water qualities were supplied by the client for the site, this included 10 groundwater samples and 3 surface water samples.

The water results are compared with the maximum recommended concentrations for domestic use as defined by the SANS 241-1: 2015 target water quality limits. The SANS 241-1: 2015 standard is applicable to all water services institutions and sets numerical limits for specific determinants to provide the minimum assurance necessary that the drinking water is deemed to present an acceptable health risk for lifetime consumption. The results of the screening for groundwater are presented in Table 7 and Table 8 and discussed in the sections below:

5.8.1 Groundwater quality vs SANS standards

- Conductivity exceeded the recommended limit in SNE01.
- TDS exceeded the recommended limit in SNE01.
- Nitrate as N exceeded the recommended limit in SNE01, SNE03, SNE04, SNE05, SNE07, SNE09 and SNE10.
- Nitrite as N exceeded the recommended limit in SNE01, SNE06, SNE07, SNE10, SNE11 and SNEBH01.
- Fluoride exceeded the recommended limit in SNE01.
- Ammonia exceeded the recommended limit in SNE03, SNE05, SNE07, SNE09 and SNE10.
- The surface water point Farm Dam exceeded the recommended limit for Fe.

5.8.2 Spatial analysis of groundwater quality

The pie diagrams (Figure 13) show both the individual ions present in a water sample and the total ion concentrations in meq/l or mg/l. The scale for the radius of the circle represents the total ion concentrations, while the subdivisions represent the individual ions. It is very useful in making quick comparisons between waters from different sources and presents the data in a convenient manner for visual inspection. From the tables and figures the following can be deduced:

- The majority of the boreholes have high proportions of nitrate as N.
- The boreholes SNE11, SNE06 and SNEBH01 have high proportions of sulphate.
- The surface water monitoring position Farmdam as well as the borehole SNE03 have a high proportion of Ca.

Table 7: Water qualities compared to SANS 241-1:2015 guidelines for human consumption

Determinant	Risk	Unit	Standard limits	SNE01	SNE03	SNE04	SNE05	SNE06	SNE07	SNE09
Physical and aesthetic determinants										
Conductivity at 25 °C	Aesthetic	mS/m	170	2278	55	124	41	13.2	102.7	97.7
Total dissolved solids	Aesthetic	mg/L	1200	11409	120	632	220	80	530	504
pH at 25 °C [b]	Operational	pH units	5 to 9.7	8.2	6.6	5.5	5	6.8	6.5	6.5
Chemical determinants — macro-determinants										
Nitrate as N (NO_3 - N)	Acute health	mg/L	11	3369.81	58	486.65	180.95	3.93	400.07	352.07
Nitrite as N (NO_2 - N)	Acute health	mg/L	0.9	132.33	0.27	BDL	BDL	3.13	2.98	0.42
Combined nitrate plus nitrite (NO_3+NO_2)	Acute health		1	3502.14	58.27	486.65	180.95	7.06	403.05	352.49
Sulfate as SO_4^{2-}	Acute health	mg/L	500	34.12	27.00	24.21	8.90	20.93	12.06	5.41
Fluoride as F^-	Chronic health	mg/L	1.5	1.82	0.12	BDL	BDL	0.25	1.06	0.16
Ammonia as N	Aesthetic	mg/L	1.5	BDL	3.30	0.71	2.14	0.62	19.44	60.18
Chloride as Cl^-	Aesthetic	mg/L	300	BDL	6.38	74.18	11.66	8.07	10.5	15.67
Sodium as Na	Aesthetic	mg/L	200	11.54	1.58	93.96	53.22	6.42	13.97	16.53
Chemical determinants — micro-determinants										
Potassium as K		mg/L	-	6.37	1.81	6.663	4.74	4	8.89	5.89
Phosphate as PO4	Acute health	mg/L	0.2	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Iron as Fe	Aesthetic	mg/L	0.3	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Magnesium as Mg		mg/L	-	9.48	6.12	35.96	2.9	2.28	19.35	5.5
Calcium as Ca		mg/L	-	16.01	75	79.62	5.36	7.62	87.98	32.36
Microbiological determinants										
Total coliforms [d]	Operational	cfu/100 mL	10	NA	NA	NA	NA	NA	NA	NA
BDL = Below Detection Limit										
NA = Not Analysed										

Table 8: Water qualities compared to SANS 241-1:2015 guidelines for human consumption (continued)

Determinant	Risk	Unit	Standard limits	SNE09	SNE10	SNE11	SNEBH01	Farm Dam	Surface Down Stream	Surface Up Stream
Physical and aesthetic determinants										
Conductivity at 25 °C	Aesthetic	mS/m	170	97.7	84.3	15.7	20.1	5.97	160	149
Total dissolved solids	Aesthetic	mg/L	1200	504	436	95	113	25.3	817	762
pH at 25 °C [b]	Operational	pH units	5 to 9.7	6.5	6.3	7	6.7	6.39	7.53	7.59
Chemical determinants — macro-determinants										
Nitrate as N (NO_3 - N)	Acute health	mg/L	11	352.07	403.21	7.82	3.1	NA	NA	NA
Nitrite as N (NO_2 - N)	Acute health	mg/L	0.9	0.42	3.27	3.04	2.91	NA	NA	NA
Combined nitrate plus nitrite (NO_3+NO_2)	Acute health		1	352.49	406.48	10.86	6.01	BDL	NA	NA
Sulfate as SO_4^{2-}	Acute health	mg/L	500	5.41	14.96	21.82	14.60	NA	NA	NA
Fluoride as F^-	Chronic health	mg/L	1.5	0.16	0.41	0.24	0.13	BDL	NA	NA
Ammonia as N	Aesthetic	mg/L	1.5	60.18	28.35	0.71	0.36	1.06	NA	NA
Chloride as Cl^-	Aesthetic	mg/L	300	15.67	6.13	9.83	12.87	0.88	NA	NA
Sodium as Na	Aesthetic	mg/L	200	16.53	12.86	9.37	10.19	1.19	NA	NA
Chemical determinants — micro-determinants										
Potassium as K		mg/L	-	5.89	22.54	4.04	3.47	NA	NA	NA
Phosphate as PO4	Acute health	mg/L	0.2	BDL	BDL	BDL	BDL	NA	NA	NA
Iron as Fe	Aesthetic	mg/L	0.3	BDL	BDL	BDL	BDL	1.74	NA	NA
Magnesium as Mg		mg/L	-	5.5	10.87	2.11	4.46	1.49	NA	NA
Calcium as Ca		mg/L	-	32.36	96.64	9.41	11.71	3.65	NA	NA
Microbiological determinants										
Total coliforms [d]	Operational	cfu/100 mL	10	NA	NA	NA	NA	NA	BDL	BDL
BDL = Below Detection Limit										
NA = Not Analysed										

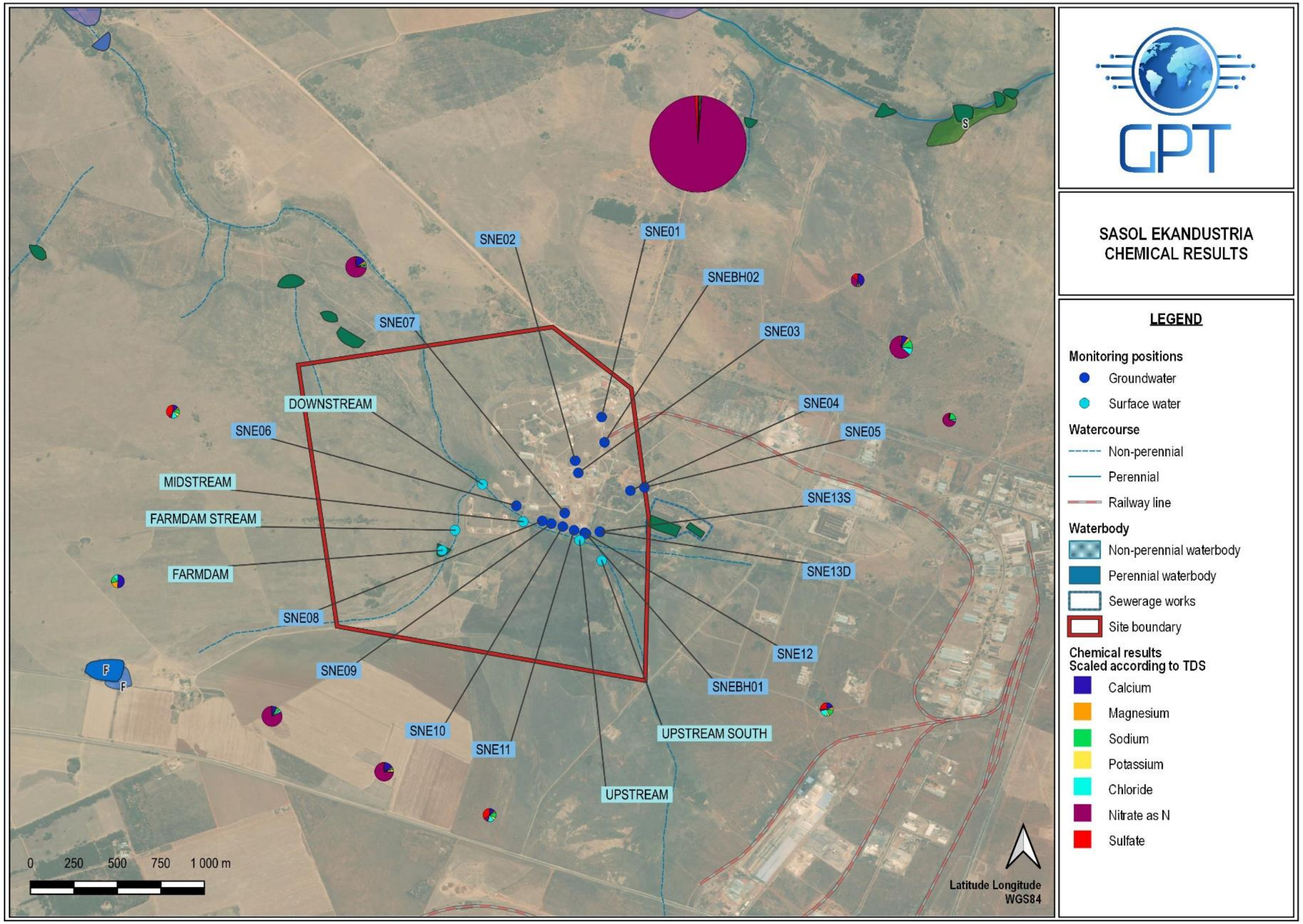

Figure 13: Pie diagrams for groundwater samples

6 AQUIFER CHARACTERISATION

The term aquifer refers to a strata or group of interconnected strata comprising of saturated earth material capable of conducting groundwater and of yielding usable quantities of groundwater to boreholes and /or springs (Vegter, 1994). In the light of South Africa's limited water resources, it is important to discuss the aquifer sensitivity in terms of the boundaries of the aquifer, its vulnerability, classification and finally protection classification, as this will help to provide a framework in the groundwater management process.

6.1 Aquifer Vulnerability

Aquifer vulnerability assessment indicates the tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer. Stated in another way, it is a measure of the degree of insulation that the natural and manmade factors provide to keep contamination away from groundwater.

- Vulnerability is high if natural factors provide little protection to shield groundwater from contaminating activities at the land surface.
- Vulnerability is low if natural factors provide relatively good protection and if there is little likelihood that contaminating activities will result in groundwater degradation.

The following factors have an effect on groundwater vulnerability:

- Depth to groundwater: Indicates the distance and time required for pollutants to move through the unsaturated zone to the aquifer.
- Recharge: The primary source of groundwater is precipitation, which aids the movement of a pollutant to the aquifer.
- Aquifer media: The rock matrices and fractures which serve as water bearing units.
- Soil media: The soil media (consisting of the upper portion of the vadose zone) affects the rate at which the pollutants migrate to groundwater.
- Topography: Indicates whether pollutants will run off or remain on the surface allowing for infiltration to groundwater to occur.
- Impact of the vadose zone: The part of the geological profile beneath the earth's surface and above the first principal water-bearing aquifer. The vadose zone can retard the progress of the contaminants.

The Groundwater Decision Tool (GDT) was used to quantify the vulnerability of the aquifer underlying the site using the below assumptions.

- Depth to groundwater below the site was estimated from water levels measured during the hydrocensus inferred to be at mean of ~10 mbgl.
- Groundwater recharge of ~32 mm/a (~4.7% recharge),
- Sandy clay soil vadose zone
- Gradient of 3% were assumed and used in the estimation.

The aquifer vulnerability for a contaminant released from surface to a specified position in the groundwater system after introduction at some location above the uppermost aquifer was determined using the criteria described below and assuming a worst-case scenario:

- Highly vulnerable (> 60), the natural factors provide little protection to shield groundwater from contaminating activities at the land surface.
- Medium Vulnerable = 30 to 60%, the natural factors provide some protection to shield groundwater from contaminating activities at the land surface, however based on the contaminant toxicity mitigation measures will be required to prevent any surface contamination from reaching the groundwater table.
- Low Vulnerability (< 30 %), natural factors provide relatively good protection and if there is little likelihood that contaminating activities will result in groundwater degradation.
- The GDT calculated a vulnerability value of 54%, which is medium.

6.2 Aquifer Classification

The aquifer(s) underlying the subject area were classified in accordance with "A South African Aquifer System Management Classification, December 1995."

The main aquifers underlying the area were classified in accordance with the Aquifer System Management Classification document[6]. The aquifers were classified by using the following definitions:

- Sole Aquifer System: An aquifer which is used to supply 50% or more of domestic water for a given area, and for which there is no reasonably available alternative sources should the aquifer be impacted upon or depleted. Aquifer yields and natural water quality are immaterial.
- Major Aquifer System: Highly permeable formations, usually with a known or probable presence of significant fracturing. They may be highly productive and able to support large abstractions for public supply and other purposes. Water quality is generally very good (Electrical Conductivity of 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. Aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large quantities of water, they are important for local supplies and in supplying base flow for rivers.
- Non-Aquifer System: These are formations with negligible permeability that are regarded as not containing groundwater in exploitable quantities. Water quality may also be such that it renders the aquifer unusable. However, groundwater flow through such rocks, although imperceptible, does take place, and needs to be considered when assessing the risk associated with persistent pollutants.

Based on information collected during the hydrocensus it can be concluded that the aquifer system in the study area can be classified as a "Minor Aquifer System", based on the fact that the local population is not dependent on groundwater.

In order to achieve the Aquifer System Management and Second Variable Classifications, as well as the Groundwater Quality Management Index, a points scoring system as presented in Table 9 and Table 10 was used.

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[6] Department of Water Affairs and Forestry & Water Research Commission (1995). A South African Aquifer System Management Classification. WRC Report No. KV77/95.

Table 9: Ratings - Aquifer System Management and Second Variable Classifications

Aquifer System Management Classification		
Class	Points	Study area
Sole Source Aquifer System:	6	
Major Aquifer System:	4	
Minor Aquifer System:	2	2
Non-Aquifer System:	0	
Special Aquifer System:	0 – 6	
Second Variable Classification (Weathering/Fracturing)		
Class	Points	Study area
High:	3	
Medium:	2	2
Low:	1	

Table 10: Ratings - Groundwater Quality Management (GQM) Classification System

Aquifer System Management Classification		
Class	Points	Study area
Sole Source Aquifer System:	6	
Major Aquifer System:	4	
Minor Aquifer System:	2	2
Non-Aquifer System:	0	
Special Aquifer System:	0 – 6	
Aquifer Vulnerability Classification		
Class	Points	Study area
High:	3	
Medium:	2	2
Low:	1	

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. The GQM index for the study area is presented in Table 11.

The vulnerability, or the tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer, in terms of the above, is classified as **medium.**

The level of groundwater protection based on the Groundwater Quality Management Classification:

GQM Index = Aquifer System Management x Aquifer Vulnerability

=2 x 2 = 4

Table 11: GQM Index for the Study Area

GQM Index	Level of Protection	Study Area
<1	Limited	
1 – 3	Low Level	
3 - 6	Medium Level	4
6 – 10	High Level	
>10	Strictly Non-Degradation	

6.3 Aquifer Protection Classification

A Groundwater Quality Management Index of 4 was estimated for the study area from the ratings for the Aquifer System Management Classification. According to this estimate a **medium level of groundwater protection** is required for the aquifer. Reasonable and sound groundwater protection measures based on the modelling will therefore be recommended to ensure that no cumulative pollution affects the aquifer, even in the long term.

DWA's water quality management objectives are to protect human health and the environment. Therefore, the significance of this aquifer classification is that measures must be taken to limit the risk to the following environments.

- The protection of the underlying aquifer.
- The Masokololo and its tributaries.

7 RESERVE DETERMINATION

7.1 Introduction

***Definition of Reserve**: "The quantity and quality of water required to supply basic needs of people to be supplied with water from that resource and to protect aquatic ecosystems in order to secure ecologically sustainable development and use of water resources".*

To be able to quantify the groundwater component of the Reserve, the following relationship has to be solved:

$$\mathbf{GW_{allocate} = (Re + GW_{in} - GW_{out}) - BHN - GW_{Bf}}$$

where:

$GW_{allocate}$	=	groundwater allocation
Re	=	recharge
GW_{in}	=	groundwater inflow
GW_{out}		groundwater outflow
BHN	=	basic human needs
GW_{Bf}	=	groundwater contribution to baseflow

Under the National Water Act (Act No. 36 of 1998) the bulk water uses at Sasol Dyno Nobel (Pty) Ltd must be authorised. The water will be abstracted from boreholes and used for irrigation purposes. Under these circumstances, the following (ground) water use is recognised as being relevant to the licence application:

- Section 21 (a) – taking water from a resource.

7.2 Approach

The assessment was done on a "rapid" level using the software GRDM version 4.0.0.0. The data used for the calculation was derived from the WRC90 dataset contained in the "GRDM" software driven by the Resource Directed Measures from the Department of Water Affairs and FET water. The local catchment falls within the B31A quaternary catchment as shown in Figure 1. The default values were used in the assessment in order to develop some guidance on the potential impact of the proposed abstraction on the overall groundwater use in the catchment.

7.3 Description of the Study Area

The property, hereafter referred to as Ekandustria, has a total area of 366ha. The local catchment within which the site is located falls within the B31A quaternary catchment. The quaternary catchment has a total area of 386.6 km^2 and the catchment falls within the Olifants Water Management Area.

The dominant vegetation type is mixed bushveld savannah in the northern section and rocky highveld grassland in the south. Locally drainage is towards the tributary of the Masokololo River that flows from southeast to north west to the south west of the site. On a larger scale, drainage occurs towards the generalised flow of the Elands River which flows from south to north, approximately 10km west of the site Present Water Demand

A maximum projection of the planned water demand from the borehole is 10m^3/day (30 m^3/month) or 3650 m^3/annum.

The Department of Water and Sanitation (DWS) categorises the water use licence applications in 3 categories based on the amount of recharge that is used by the applicant in relation to the specified property:

- Category A: Small scale abstraction (<60% recharge on property)
- Category B: Medium scale abstraction (60-100% recharge on property)
- Category C: Large scale abstraction (>100% recharge on property)

7.4 Reserve Directed Measures Assessment

7.4.1 Classification

Groundwater classification is currently based on a Stress Index which relates water use to recharge. The quaternary catchments in which the study area falls is classified as category B which indicates low levels of stress in terms of abstraction/recharge (respectively). The resource is not stressed. At this stage Classification is not directly linked to potential abstraction but is only indicative of the current situation.

7.4.2 Reserve

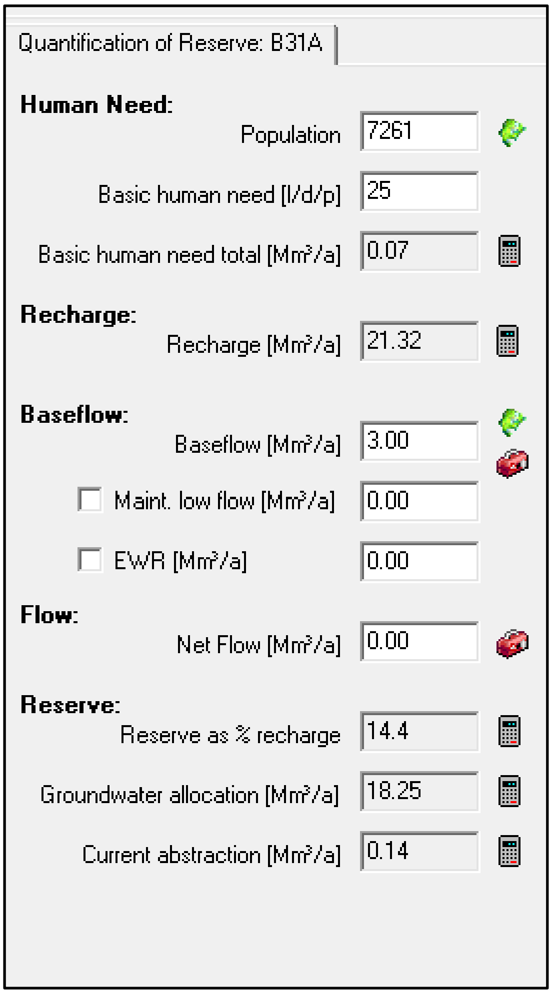
The following table summarises the most salient parameters relevant to this catchment:

Table 12: Most salient parameters relevant to the catchment.

Quaternary Catchment	Area km^2	Population (2010)	General Authorisation (m^3/ha/a)	Rainfall (mm/a)	Recharge (mm/a)	Current Use (2010) (Mm^3/a)
B31A	**386.6**	**7261**	**0**	**677**	**54.98**	**0.14**

If general authorization is considered, a total of 0 m^3/a can be abstracted. It can thus be concluded that General Authorization **cannot** be applied for. The following tables summarizes the Reserve for the catchment.

Table 13: A summary of the Reserve for the quaternary catchment B31A



If this calculation is done based on the actual area of the local catchment within the affected quaternary catchments, the following emerges:

Table 14: Recharge to the property

Catchment	Actual area (ha) of property	Recharge in Quartenary Catchment (mm/a)	Recharge on property	
Local	366	54.98	201226.8	m^3/a
Total	*366*		*201226.8*	m^3/a
			0.201	Mm^3/a
			551	m^3/day
			6.38	l/second

There will be applied for an abstraction volume of 161150 m^3/annum which is >60% of the recharge on the property. This places the catchment in Category B (medium scale abstraction >60% of the recharge on the property) (see section 6.4).

Furthermore, it is evident that local recharge in the quaternary catchment B31A (18.25 Mm^3/annum) will be able to supply in the demand of the site. The recharge on the property will allow for abstraction of ~ 201226.8 m^3/annum, without making provision for current abstraction & the baseflow requirement.

7.4.3 Resource Quality Objectives

Maintain regional groundwater table to:

- Ensure that schedule 1 water users adjacent to the site have adequate water supply to basic human need.
- Ensure that adequate water is available to maintain base flow in the tributaries of the Masokololo River.

8 GROUNDWATER MONITORING SYSTEM

8.1 Groundwater Monitoring Network

A groundwater monitoring system has to adhere to the criteria mentioned below. As a result the system should be developed accordingly.

8.1.1 Source, plume, impact and background monitoring

A groundwater monitoring network should contain monitoring positions which can assess the groundwater status at certain areas. The boreholes can be grouped classification according to the following purposes:

- **Source monitoring:** Monitoring boreholes are placed close to or in the source of contamination to evaluate the impact thereof on the groundwater chemistry.
- **Plume monitoring:** Monitoring boreholes are placed in the primary groundwater plume’s migration path to evaluate the migration rates and chemical changes along the pathway.
- **Impact monitoring:** Monitoring of possible impacts of contaminated groundwater on sensitive ecosystems or other receptors. These monitoring points are also installed as early warning systems for contamination break-through at areas of concern.
- **Background monitoring:** Background groundwater quality is essential to evaluate the impact of a specific action/pollution source on the groundwater chemistry.

8.1.2 System response monitoring network

Groundwater levels: The response of water levels to abstraction is monitored. Static water levels are also used to determine the flow direction and hydraulic gradient within an aquifer. Where possible all of the above mentioned borehole’s water levels need to be recorded during each monitoring event.

8.1.3 Monitoring frequency

In the operational phase and closure phase, quarterly monitoring of groundwater quality and groundwater levels is recommended. Quality monitoring should take place before after and during the wet season, i.e. during September and March. It is important to note that a groundwater-monitoring network should also be dynamic. This means that the network should be extended over time to accommodate the migration of potential contaminants through the aquifer as well as the expansion of infrastructure and/or addition of possible pollution sources.

8.2 Monitoring Parameters

The identification of the monitoring parameters is crucial and depends on the chemistry of possible pollution sources. They comprise a set of physical and/or chemical parameters (e.g. groundwater levels and predetermined organic and inorganic chemical constituents). Once a pollution indicator has been identified it can be used as a substitute to full analysis and therefore save costs. The use of pollution indicators should be validated on a regular basis in the different sampling positions. The parameters should be revised after each sampling event; some metals may be added to the analyses during the operational phase, especially if the pH drops.

8.2.1 Abbreviated analysis (pollution indicators)

Physical Parameters:

- Groundwater levels

Chemical Parameters:

- Field measurements:
  - pH, EC
- Laboratory analyses:
  - Major anions and cations (Ca, Na, Cl, SO4)
  - Other parameters (EC)

8.2.2 Full analysis

Physical Parameters:

- Groundwater levels

Chemical Parameters:

- Field measurements:
  - pH, EC
- Laboratory analyses:
  - Anions and cations (Ca, Mg, Na, K, NO3, Cl, SO4, F, Fe, Mn, Al, & Alkalinity)
  - Other parameters (pH, EC, TDS)
  - Petroleum hydrocarbon contaminants (where applicable, near workshops and petroleum handling facilities)
  - Sewage related contaminants (E.Coli, faecal coliforms) in borehole in proximity to septic tanks or sewage plants.

8.3 Monitoring Boreholes

DWAF (1998) states that "A monitoring hole must be such that the section of the groundwater most likely to be polluted first, is suitably penetrated to ensure the most realistic monitoring result."[7]

Currently a monitoring network does exist for the current development. The monitoring positions are shown in Figure 14 below. Monitoring reports are compile and submitted to the Department of Water and Sanitation on a regular basis.

A monitoring network should be dynamic. This means that the network should be extended over time to accommodate the migration of contaminants through the aquifer as well as the expansion of infrastructure and/or addition of possible pollution sources. An audit on the monitoring network should be conducted annually.

[7] Department of Water Affairs and Forestry (DWAF). (1998). Minimum Requirements for the Water Monitoring at Waste Management Facilities. CTP Book Printers. Cape Town.

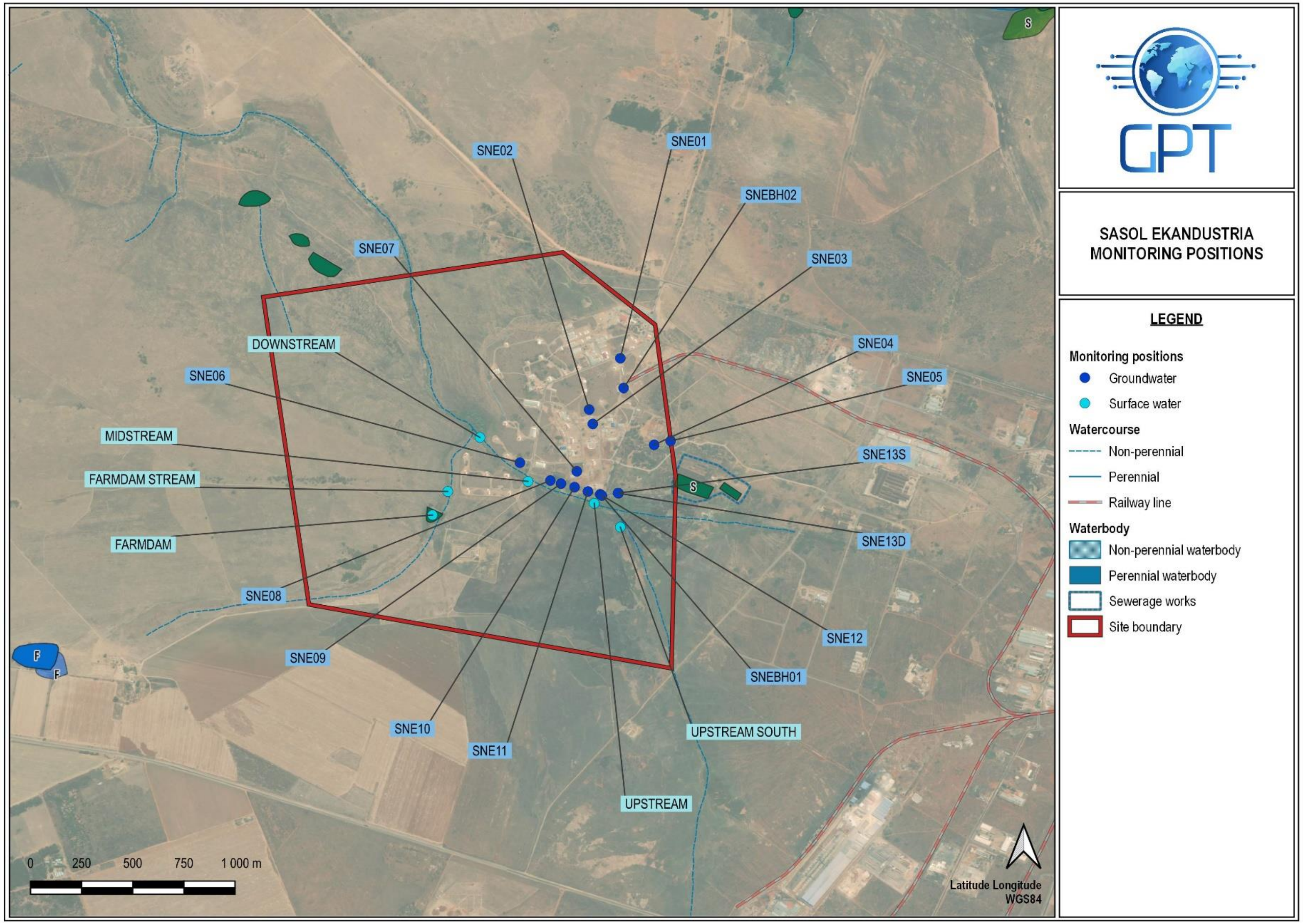


Figure 14: Existing Monitoring Network

9 IMPACTS QUANTIFICATION

The impact quantification was done using the procedures for the assessment and minimum criteria for reporting aquatic biodiversity in terms of sections 24(5)(a) and (h) and 44 of the National Environmental Management Act, 1998. In terms of groundwater the proposed development impact on the functioning of the aquatic feature in terms of:

- base flows;
- quantity of water including change in the hydrological regime or hydroperiod of the aquatic ecosystem;
- quality of water;
- the location of areas not suitable for development, which are to be avoided during construction and operation, where relevant;
- additional environmental impacts expected from the proposed development
- the degree to which impacts and risks can be mitigated;
- the degree to which the impacts and risks can be reversed;
- the degree to which the impacts and risks can cause loss of irreplaceable resources;
- a suitable construction and operational buffer for the aquatic ecosystem, using the accepted methodologies;

9.1 Environmental Impact Assessment (EIA) Regulations, 2017

The Environmental Impact Assessment (EIA) 2014 Regulations [as amended] promulgated in terms of Sections 24 (5), 24M and 44 of the National Environmental Management Act, 1998 (Act No. 107 of 1998) [as amended] (NEMA), requires that all identified potential impacts associated with the proposed project be assessed in terms of their overall potential significance on the natural, social and economic environments. The criteria identified in the EIA Regulations (2014) include the following:

- Nature of the impact;
- Extent of the impact;
- Duration of the impact
- Probability of the impact occurring;
- Degree to which impact can be reversed;
- Degree to which impact may cause irreplaceable loss of resources;
- Degree to which the impact can be mitigated; and
- Cumulative impacts.

The impact assessment methodology (as defined below) whereby the Significance of a potential impact is determined through the assessment of the relevant temporal and spatial scales determined of the Extent, Magnitude and Duration criteria associated with a particular impact. This method does not explicitly define each of the criteria but rather combines them and results in an indication of the overall significance.

Table 15: Significance Rating of Impact(s)

Impacts	Extent	Duration	Intensity	Reversibility	Probability	Significance = Irreplaceability (Reversibility + Intensity + Duration + Extent) X Probability		Mitigation Efficiency (ME)	Significance Rating (WM) = Significance Rating (WOM) x Mitigation Efficiency	
Dewatering on private boreholes	1	1	1	1	1	4	Very low	0.2	0.8	Very low
Water quality deterioration	5	5	5	5	5	100	Very High	0.2	20	Low
Baseflow/wetland impacts	1	2	3	2	1	8	Very low	1	8	Very low

10 CONCLUSIONS AND RECOMMENDATIONS

Geo Pollution Technologies - Gauteng (Pty) Ltd (GPT) was appointed by Sasol Dyno Nobel (Pty) Ltd to conduct a hydrogeological impact study for the current development. The current development is in the process of applying for an integrated Water Use License (iWUL).

The site is located in Ekandustria, 14 km north of Bronkhorstspruit, Gauteng Province. The topography is gently undulating and the slope is more or less in the order of 1:15 (6%).Locally drainage is towards the tributary of the Masokololo River that flows from south east to north west to the south west of the site. On a larger scale, drainage occurs towards the generalised flow of the Elands River which flows from south to north, approximately 10km west of the site.

The geology underlying the property consists of the Wilgerivier Formation of the Waterberg Group while the geology to the south side of the property consists of intrusive diabase. The Wilgerivier Formation consists of a thick, continuous sequence of red to red-brown sediments, including quartzite, grit and sandstone. The diabase located in the centre as a ring structure, is intruded into the central portion of the basin.

According to Barnard (2000)[8], groundwater occurrence within the Wilgerivier Formation is associated with fault and fracture zones and with bedding planes. The groundwater potential is classed as low to moderate on the basis that 80% of boreholes on record produce less than 2l/s.

A geophysical survey was conducted on site to identify drilling targets. Therefore, three (3) resistivity traverses were completed using the Lund Imaging System with a Wenner-Schlumberger geometry and a unit electrode spacing of 10 m, over a period of two (2) days. From these results three (3) drilling targets were selected along anomalies identified and drilled via percussion drilling. Two of the three boreholes encountered water while the third was dry. A pumping test was conducted on SSBH2 as this borehole had the highest blow yield. The results indicated that for a 24 hour pump cycle, the borehole can be pumped at 3 l/s and for a pumping cycle of 8 hours with a recovery period of 16 hours, the borehole can be pumped at a rate of 5 l/s or 1800 l/hour.

A hydrocensus was conducted and a total of seven properties were visited but only one property could be accessed. Two boreholes were identified and the groundwater level could only be measured in one (1). None of the properties visited were within 1 km of the Ekandustria site. In addition to the hydrocensus, water level information was obtained from the monitoring network provided by the Client for the February 2023 monitoring event. Monitoring takes place on a quarterly basis. The groundwater levels varied between a minimum of 0.5 m and a maximum of 7.73 m below ground level.

Monitoring results were supplied by the client for the site and indicated groundwater exceedances above the SANS recommended limit of EC, TDS, NO_3 and N, NO_2 as N, F and NH_3. Surface water qualities showed that only iron concentrations were above the SANS recommended limit.

Using the GDT tool the vulnerability of the aquifer below the site was calculated as medium. Using the “South African Aquifer System Management Classification, December 1995” the aquifer was classified as a “Minor Aquifer System”. Therefore, measures must be taken to limit the risk to the underlying aquifer and the Masokolo River and its tributaries.

[8] An Explanation of the 1:500 000 General Hydrogeological Map: Johannesburg 2526. Barnard H.C, October 2000. Department of Water Affairs & Sanitation. ISBN 0-621-29914-6

A Reserve Determination was done for the Ekandustria site. The assessment was done on a “rapid” level using the software GRDM version 4.0.0.0. The data used for the calculation was derived from the WRC90 dataset contained in the “GRDM” software driven by the Resource Directed Measures from the Department of Water Affairs and FET water. A maximum projection of the planned water demand from the borehole is 447m3/day (13 429 m3/month) or 161 150 m3/annum.

A general authorization allows a total of 0 m^3/ to be abstracted, thus it is concluded that General Authorization **cannot** be applied for. It is evident that local recharge in the quaternary catchment B31A (18.25 Mm^3/annum) will be able to supply in the demand of the site. The recharge on the property will allow for abstraction of ~ 201226.8 m^3/annum, without making provision for current abstraction & the baseflow requirement.

An impact quantification was done using the procedures for the assessment and minimum criteria for reporting aquatic biodiversity in terms of sections 24(5)(a) and (h) and 44 of the National Environmental Management Act, 1998. The impacts quantification produced the following significance ratings:

- Dewatering on private boreholes – very low
- Water quality deterioration – very high
- Baseflow/wetland impacts – very low

Recommendations

- Water quantity and quality data should continue to be collected on a regular, ongoing basis during operations. This includes abstraction volume monitoring.
- The hydrocensus and risk assessment should at least be repeated once before closure to evaluate any impacts.

APPENDIX I: HYDROCENSUS INFORMATION

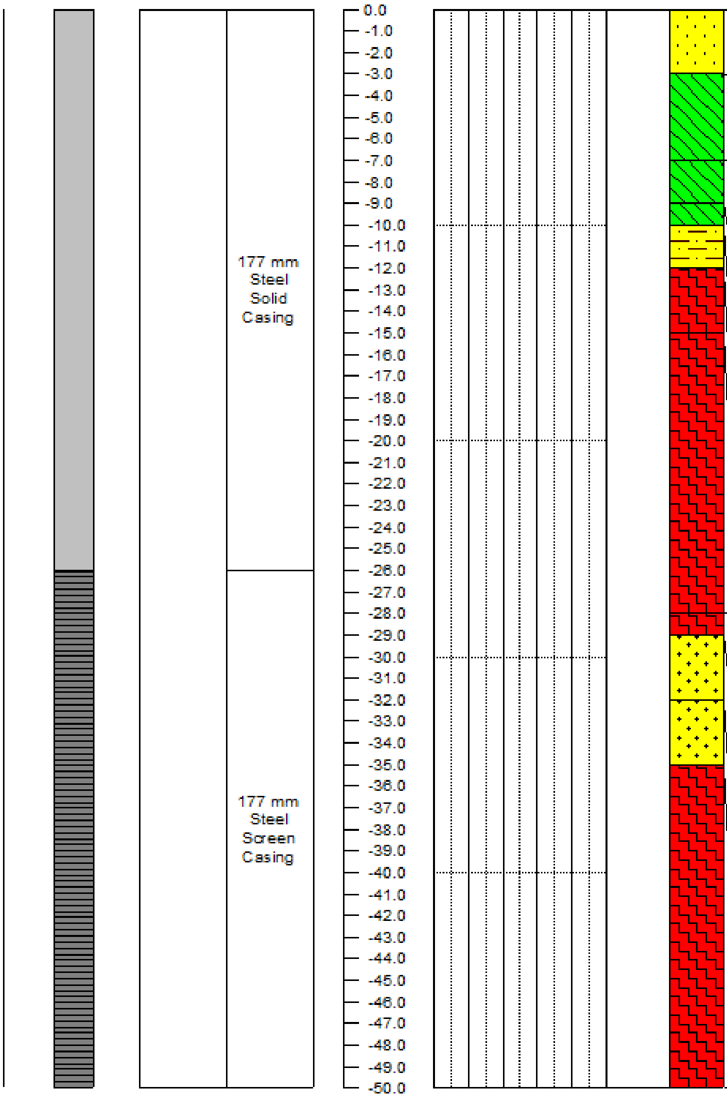
APPENDIX II: LABORATORY CERTIFICATE OF ANALYSIS

APPENDIX 2: BOREHOLE LOGS

Geo Pollution Technologies Gauteng (Pty) Ltd

PROJECT NO:	BISEP-22-6761	**DRILL EQUIP:**	Percussion
PROJECT NAME:	Sasol Ekandustria Water	**DRILLING METHOD:**	Air Percussion
BOREHOLE NO:	SSBH1	**CONTRACTOR:**	Georoc
LOGGED BY:	C Gouws	**SWL:**	
CLIENT:	Sasol	**CHECKED BY:**	
DATE DRILLED:	2022-04-12		

BOREHOLE CONSTRUCTION	DEPTH (M)	PENETRATION RATE (sec)	PROFILE	DESCRIPTION	PID



Sand: Moist, red brown, loose, fine and medium grained, loamy, sand.

Clay: Moist, red brown, firm, fine and medium grained sandy, clay.

Clay: Moist, brown, firm to stiff, fine and medium grained, sandy, clay with some rounded larger grains.

Clay: Moist, red brown, stiff, fine and medium grained, sandy, clay with some rounded larger grains.

Silt: Wet, brown, fine grained, clayey, silt.

Quartzite: Wet, brown, medium and coarse grained, iron rich, quartzite.

Quartzite: Wet, brown, medium and coarse grained, quartzite with some larger rounded cobbles.

Quartzite: Wet, dark brown, fine and medium grained, quartzite going into sandstone.

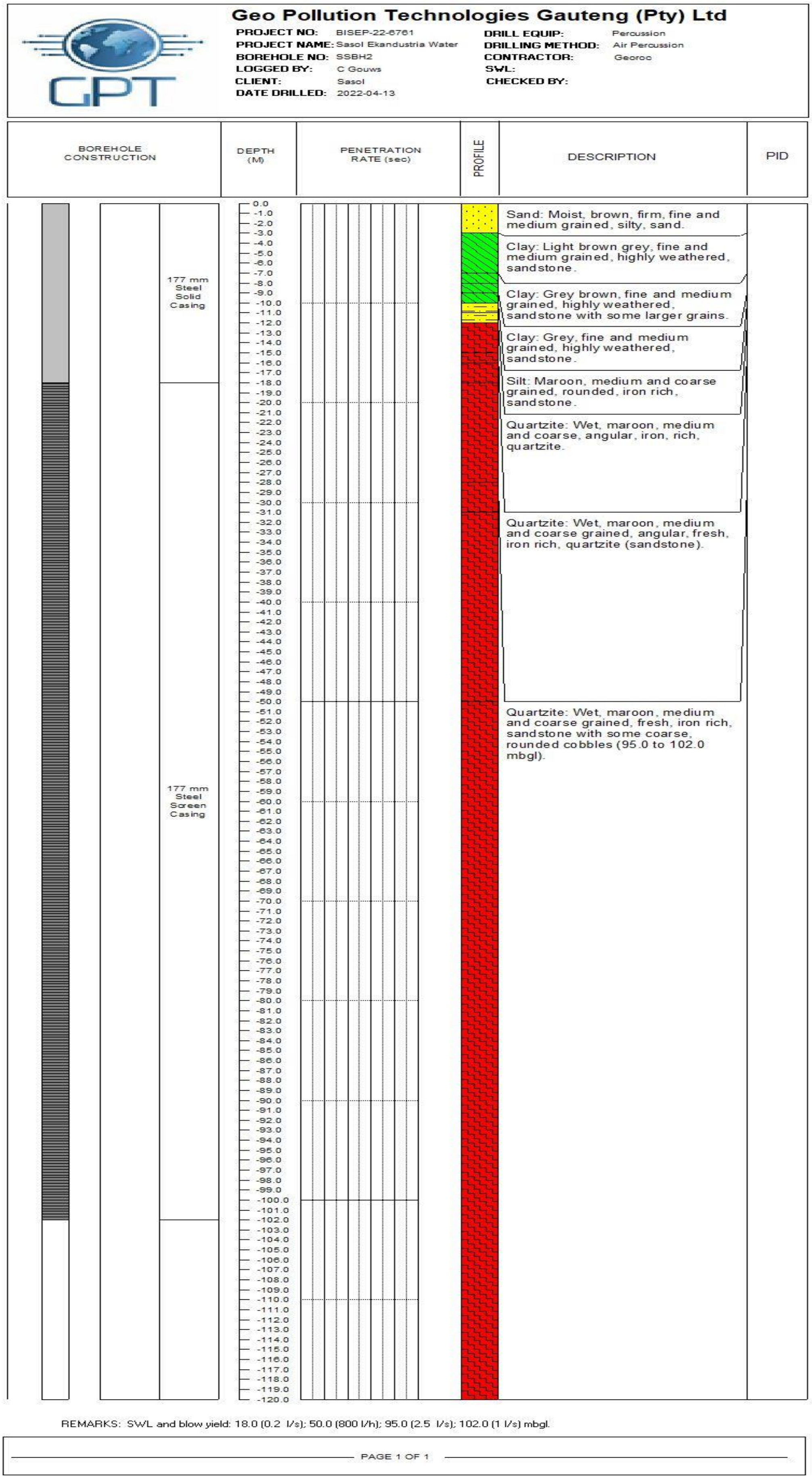
Sandstone: Wet, maroon brown, fine and medium grained, iron rich, sandstone with some larger quarts, grains.

Sandstone: Maroon brown, loose, fine and medium grained, weathered, sandstone.

Quartzite: Wet, maroon, medium and coarse grained, angular, fresh, quartzite (iron rich).

REMARKS: Groundwater seepage observed: 11.0; 13.0 (1 l/s); 25.0 (0.5 l/s); 28.0 (1 l/s) mbgl.

PAGE 1 OF 1


Geo Pollution Technologies Gauteng (Pty) Ltd
GPT
PROJECT NO: BISEP-22-6761
PROJECT NAME: Sasol Ekandustria Water
BOREHOLE NO: SSBH2
LOGGED BY: C Gouws
CLIENT: Sasol
DATE DRILLED: 2022-04-13
DRILL EQUIP: Percussion
DRILLING METHOD: Air Percussion
CONTRACTOR: Georoc
SWL:
CHECKED BY:
BOREHOLE CONSTRUCTION
DEPTH (M)
PENETRATION RATE (sec)
PROFILE
DESCRIPTION
PID
177 mm Steel Solid Casing
177 mm Steel Screen Casing
Sand: Moist, brown, firm, fine and medium grained, silty, sand.
Clay: Light brown grey, fine and medium grained, highly weathered, sandstone.
Clay: Grey brown, fine and medium grained, highly weathered, sandstone with some larger grains.
Clay: Grey, fine and medium grained, highly weathered, sandstone.
Silt: Maroon, medium and coarse grained, rounded, iron rich, sandstone.
Quartzite: Wet, maroon, medium and coarse, angular, iron, rich, quartzite.
Quartzite: Wet, maroon, medium and coarse grained, angular, fresh, iron rich, quartzite (sandstone).
Quartzite: Wet, maroon, medium and coarse grained, fresh, iron rich, sandstone with some coarse, rounded cobbles (95.0 to 102.0 mbgl).
REMARKS: SWL and blow yield: 18.0 (0.2 l/s); 50.0 (800 l/h); 95.0 (2.5 l/s); 102.0 (1 l/s) mbgl.
PAGE 1 OF 1

Geo Pollution Technologies Gauteng (Pty) Ltd

PROJECT NO:	BISEP-22-6761	**DRILL EQUIP:**	Percussion
PROJECT NAME:	Sasol Ekandustria Water	**DRILLING METHOD:**	Air Percussion
BOREHOLE NO:	SSBH3	**CONTRACTOR:**	Georoc
LOGGED BY:	C Gouws	**SWL:**	
CLIENT:	Sasol	**CHECKED BY:**	
DATE DRILLED:	2022-04-14		

BOREHOLE CONSTRUCTION	DEPTH (M)	PENETRATION RATE (sec)	PROFILE	DESCRIPTION	PID
	0.0 – -3.0			Loam: Moist, red brown, firm, fine and medium grained, clayey, loam.	
	-3.0 – -17.0			Sand: Grey, loose, fine and medium grained, sand (highly weathered, sandstone).	
	-17.0 – -28.0			Sandstone: Grey, medium coarse grained, weathered, rounded, sandstone.	
	-28.0 – -40.0			Sandstone: Wet, maroon, medum and coarse grained, angular, iron rich, sandstone.	

REMARKS: Groundwater seepage observed: 35.0 mbgl. Decomissioned

PAGE 1 OF 1