NOVACRAFF
GROUNDWATER CONSULTANTS

GEOHYDROLOGICAL SITE ASSESSMENT AND REPORTING - LETSEMENG LOCAL MUNICIPALITY LANDFILL SITE DEVELOPMENT

for
NSVT ENVIRONMENTAL CONSULTANTS (PTY) LTD

By

NOVACRAFF GROUNDWATER CONSULTANTS

PROJECT TEAM
D.C. Moolman

NOVACRAFF
GROUNDWATER CONSULTANTS

21 July 2021

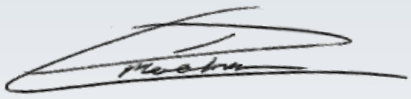
NSVT ENVIRONMENTAL CONSULTANTS (PTY) LTD
P.O Box 42452
1 Fourth Street
Bloemfontein
Free State Province

FOR ATTENTION: LORATO TIGEDI

Dear Miss,

It is our pleasure to enclose one electronic report of: "*GEOHYDROLOGICAL SITE ASSESSMENT AND REPORTING – LETSEMENG LOCAL MUNICIPALITY LANDFILL SITE DEVELOPMENT.*"

Yours sincerely,



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Glossary of Geohydrological Terms

Geohydrological Term	Definition
Aquifer	Aquifer means a geological formation which has structures or textures that hold water or permit appreciable water movement through them,
Aquifer Testing	Aquifer testing involves the withdrawal of measured quantities of water from or the addition of water to, a borehole(s); and the measurement of resulting changes in head in the aquifer both during and after the period of abstraction or addition.
Aquitard	A saturated but poorly permeable bed, formation or group of formations that does not yield water freely to a borehole or spring,
Confined Aquifer	A formation in which the groundwater is isolated from the atmosphere at the point of discharge by impermeable geologic formations; confined groundwater is generally subject to pressure greater than atmospheric.
Contamination	The degradation of natural water quality as a result of man's activities, regardless of whether or not contaminant concentrations reach levels that cause significant degradation of water quality and restrict its use,
Dolerite Dyke	A tabular or sheet-like body of igneous rock that cuts through and across the layering of adjacent rocks.
Drawdown	Drawdown is the lowering of the water table or piezometric surface caused by the extraction of groundwater by pumping a borehole,
Effluent	Liquid waste or sewage discharge, usually discharged in rivers or the sea,
Fractured Water	Is defined as a formation that contains sufficient fractures, cracks and faults that yields economic quantities of water to boreholes and springs.
Groundwater Recharge	The addition of water to the saturated zone, infiltration of surface water and/or the lateral migration of groundwater from adjacent aquifers.
Groundwater Resource	All groundwater available for beneficial use, including man, aquatic ecosystems and greater environment.
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).
Perched Aquifer	Aquifers that contain perched groundwater i.e. bodies of groundwater separated from an underlying body of groundwater by an unsaturated zone.
Porosity	Porosity is the ratio of the volume of void space to the total volume of the rock or earth material.
Preferential Flow	The preferential movement of water through more permeable zones in the subsurface.
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.
Rest/Static Water Level	The groundwater level in a borehole not influenced by abstraction or artificial recharge.
Runoff	All surface and subsurface flow from a catchment, but in practice refers to the flow in a river i.e. excludes groundwater not discharged into a river.
Safe/Sustainable Yield	Safe yield is defined as the maximum rate of withdrawal that can be sustained by an aquifer without causing an unacceptable decline in the hydraulic head or deterioration in water quality in the aquifer.
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.
Unconfined Aquifer	An aquifer without an upper confining layer of impermeable or low permeability soil or rock material. The water table is exposed to the atmosphere through a series of interconnected openings in the overlying soil and/or rock layers and is in equilibrium with atmospheric pressure
Unsaturated Zone	That part of the geological stratum above the water table where interstices and voids contain a combination of air and water.
Vulnerability	This relates to the tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer. Vulnerability gives an indication of how susceptible an aquifer is to contamination.
Wellfield	A group or cluster of boreholes in an area used collectively to supply sufficient groundwater to a user or users.

Table 1. Glossary of Geohydrological terms.

1 INTRODUCTION

Novacraff Groundwater Consultants was appointed by NSVT Environmental Consultants to perform a geohydrological study for the proposed landfill site at Luckhoff. The phases of the project include the following: Desktop Investigation, Site Assessment, Geophysical survey and a Hydrocensus investigation.

2 SITE LOCATION AND DRAINAGE

The study area of the proposed landfill site is located in western part of the Free State Province on the border between the Northern Cape and the Free State Province approximately 150 km to the south west of Bloemfontein. The study area is located in Drainage Area D, Quaternary sub-catchment D33C (Surface Water Resources of South Africa, First Edition, 1994).

The proposed site is situated to the immediate north east of Luckhoff, approximately 1.8 km from the nearest urban areas.

The extent of the investigation is a comprehensive geohydrological study with surface water components included. For this investigation, 1 upstream and 1 downstream surface water site was identified within close proximity of the site, the downstream site was sampled during the hydrocensus investigation.

2.1 TOPOGRAPHY AND SURFACE WATER DRAINAGE

The topographical map can be perused in Figure 2. The surface water drainage direction from the proposed waste site is primarily into a south-western and western direction (refer Figure 2). The south-western drainage direction contributes to the downstream dam (SW01) that was identified and sampled during hydrocensus investigation.

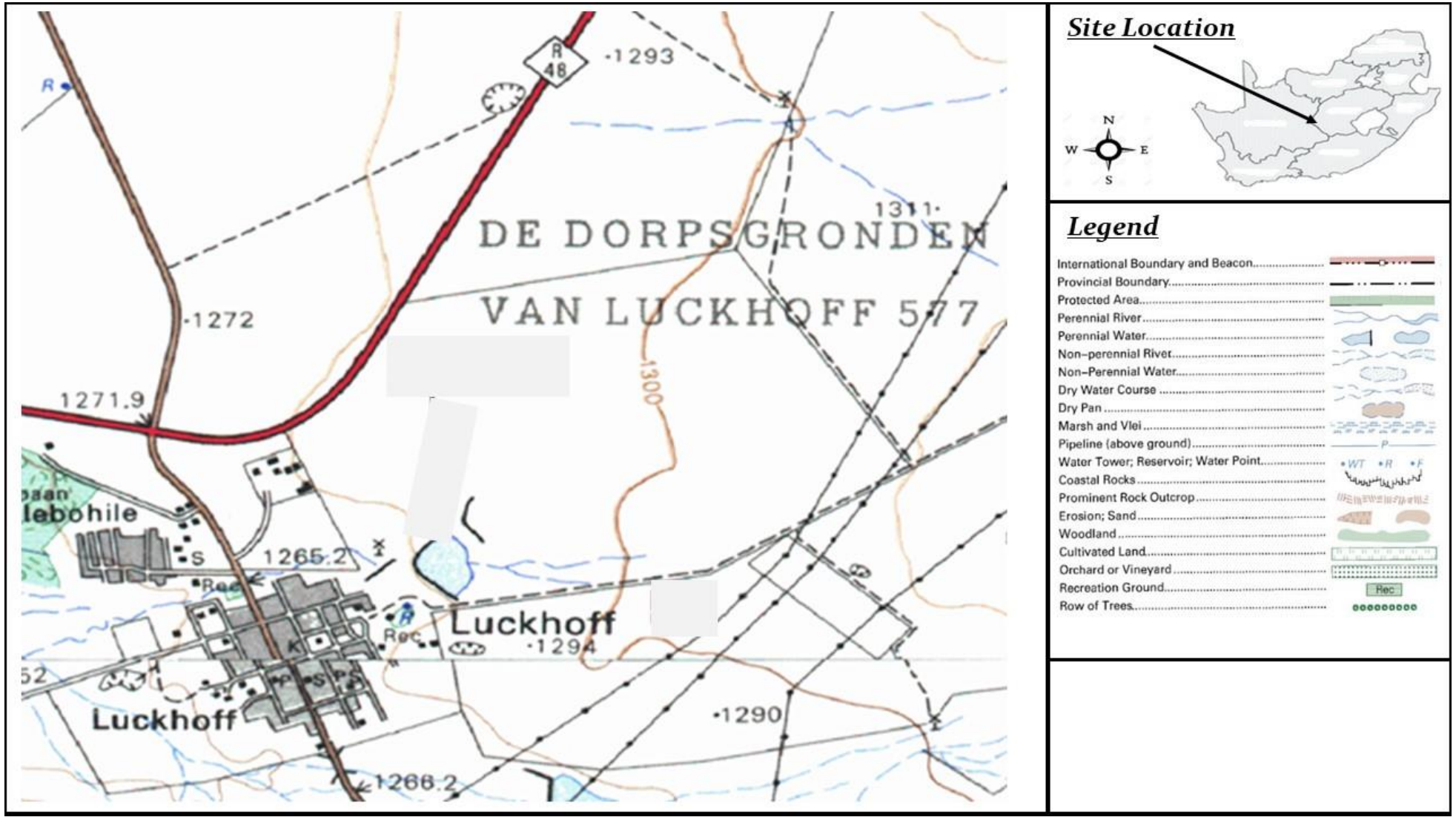


Figure 1. 1:50 000 scale topographic map.

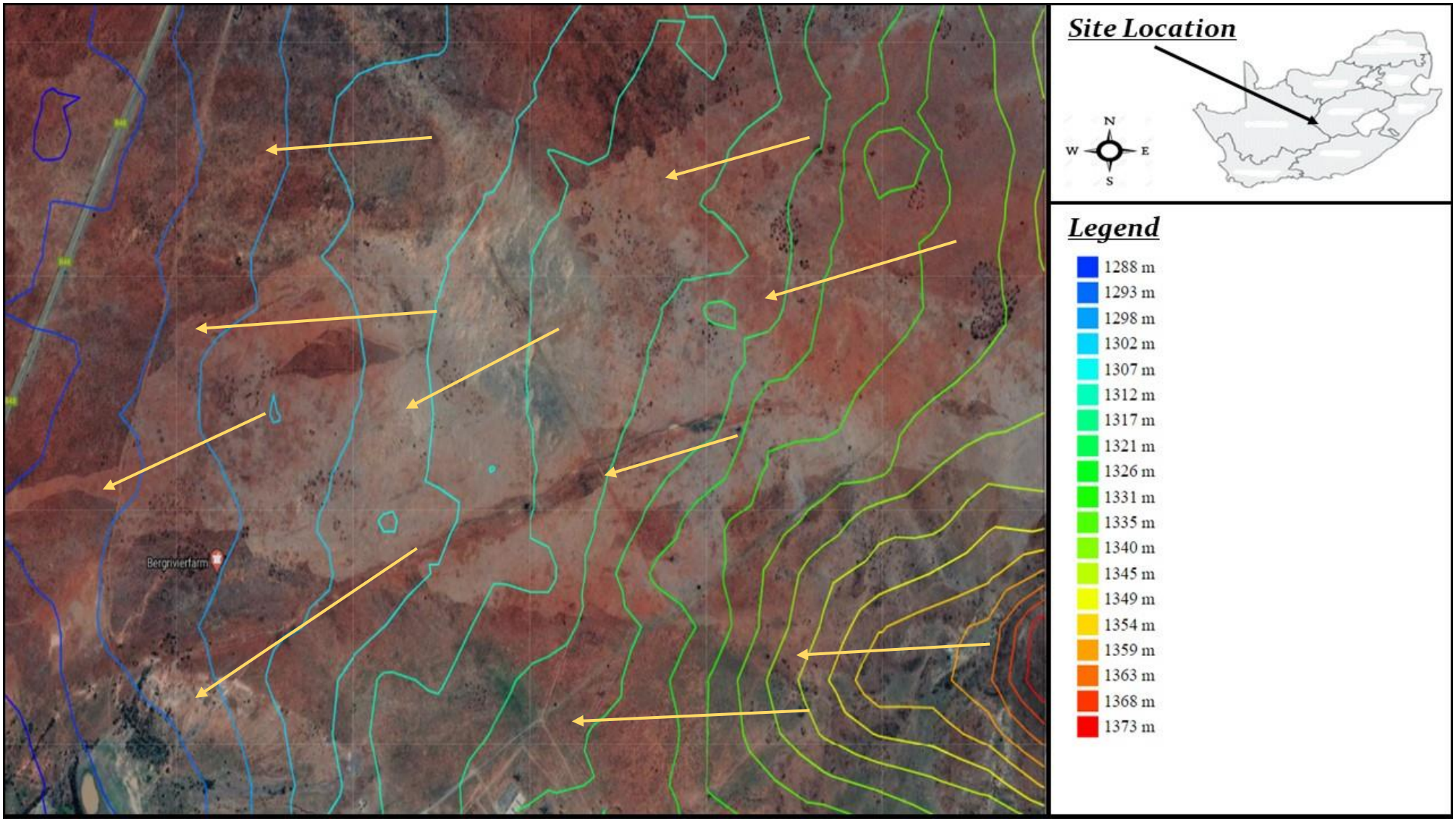
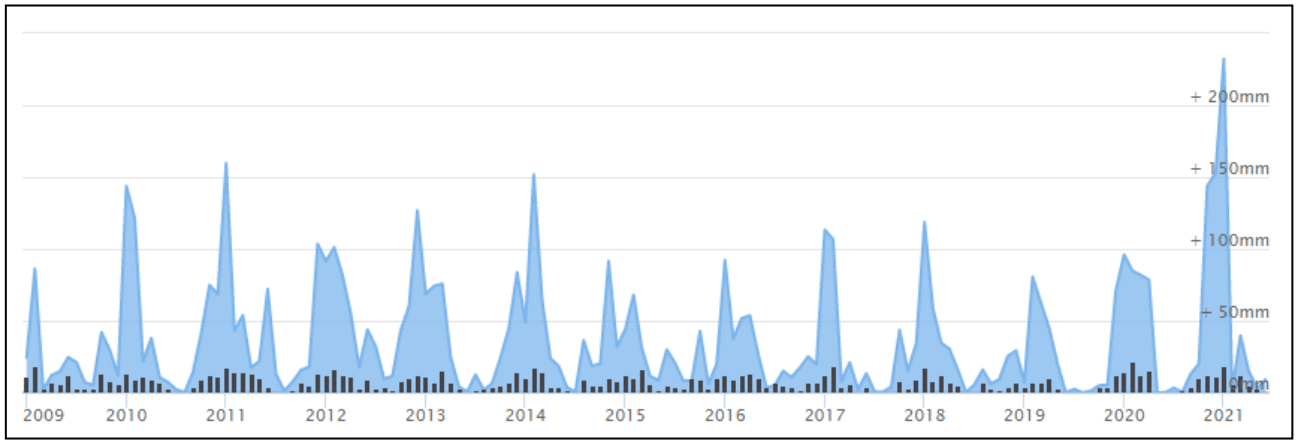


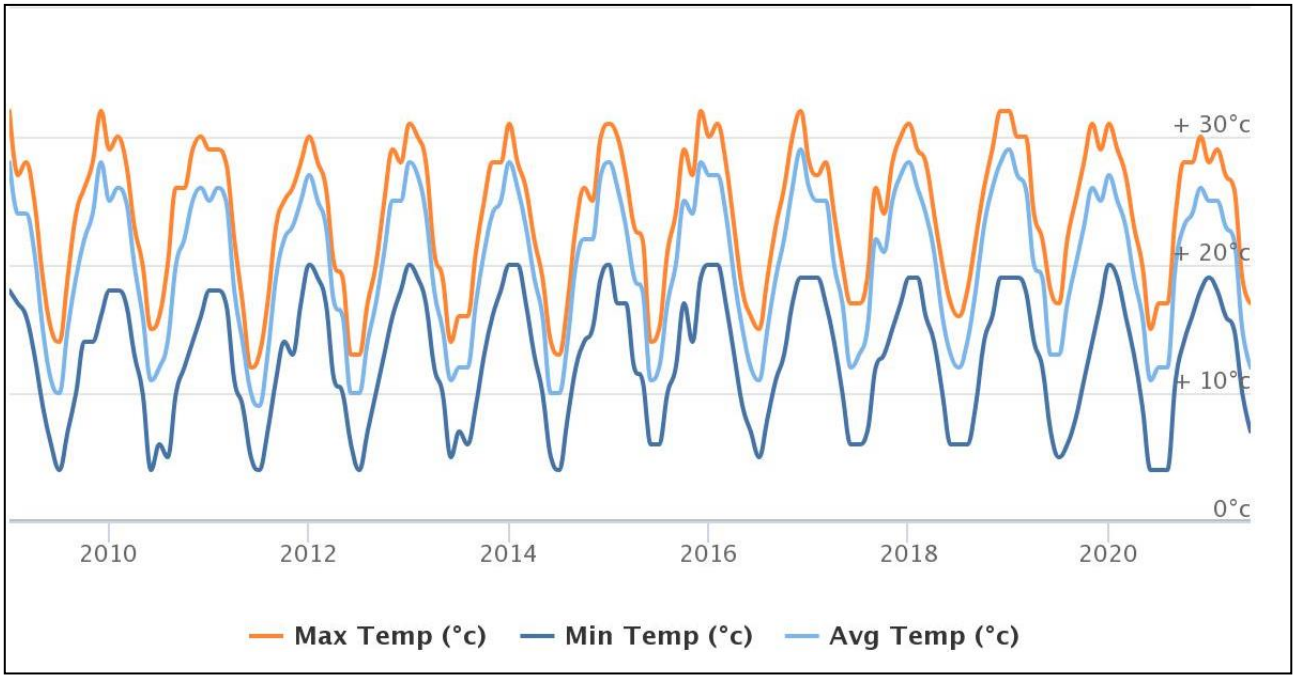
Figure 2. Surface topography and drainage.

3 CLIMATE

The Luckhoff area has a climate characterized by hot summers and cold winters and has a predominantly summer rainfall. Air temperature ranges from a maximum of 34 to 32 °C in January to a minimum of 6 to 4 °C in July. (https://www.worldweatheronline.com).



Average rainfall amount (mm) and rainy days. (https://www.worldweatheronline.com)



Minimum, maximum and Average Temperature (°C). (https://www.worldweatheronline.com)

4 SITE GEOLOGY AND HYDROGEOLOGY

4.1 GEOLOGY

The study area under investigation is predominantly underlying by dolerite sills and overlaying Aeolian sand, legend QS and Jd respectively. Occurrence of calcrete is indicated in the local and regional geology under legend QC.

4.2 GEOHYDROLOGY

The regional hydrogeological map (Bloemfontein 2002 from the department of water affairs and forestry) is utilised to estimate the principal groundwater occurance of the area. The area under investigation is located within zone b3 incicating possible groundwater occurance of 0.5 – 2 l/s supported by section 4.3.1 indicating a minor aquifer in the local area. This was confirmed during the the Hydrocensus field investigation as no major groudwater abstraction was identified within the local area.

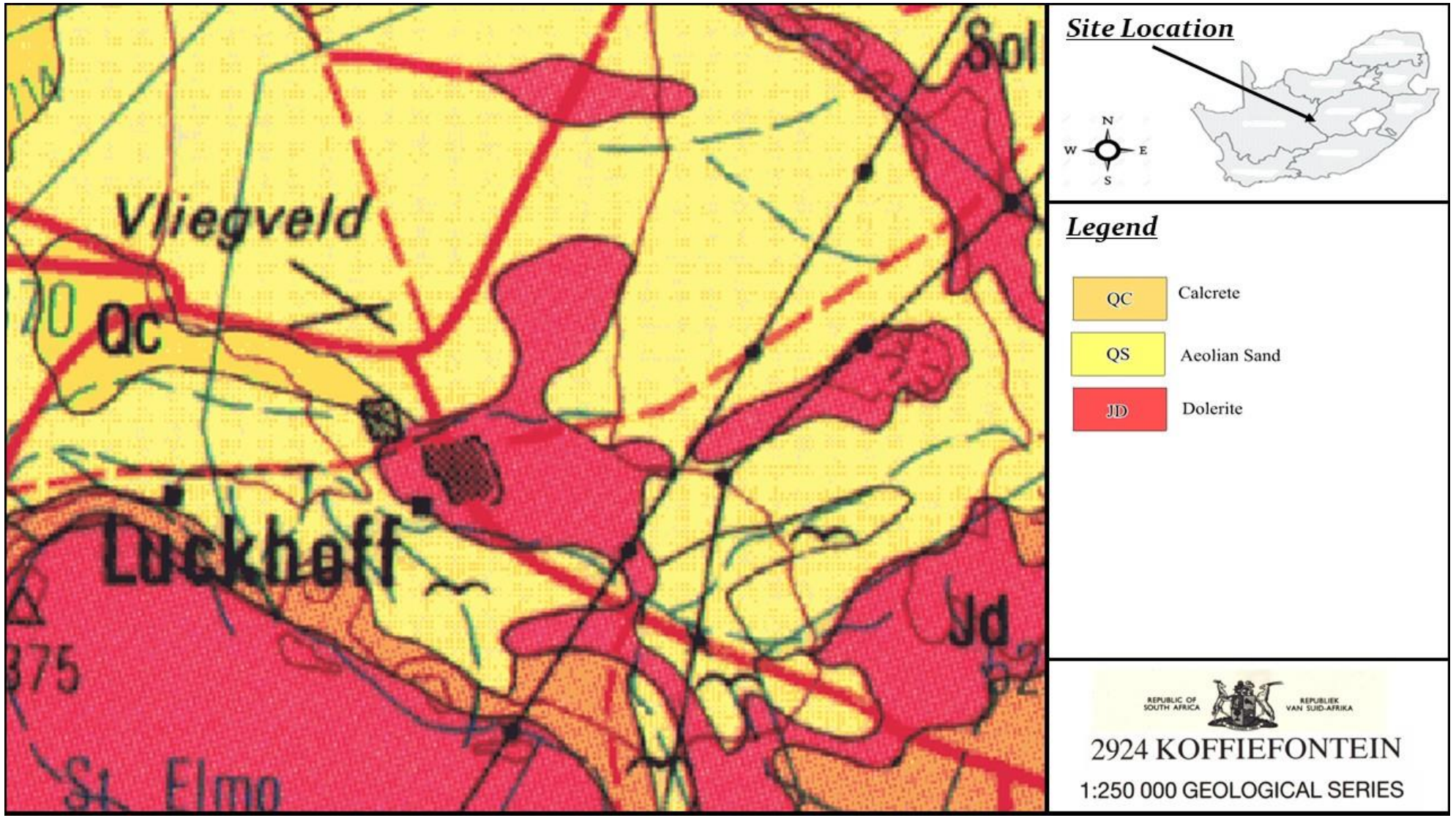


Figure 3. Regional Geology.

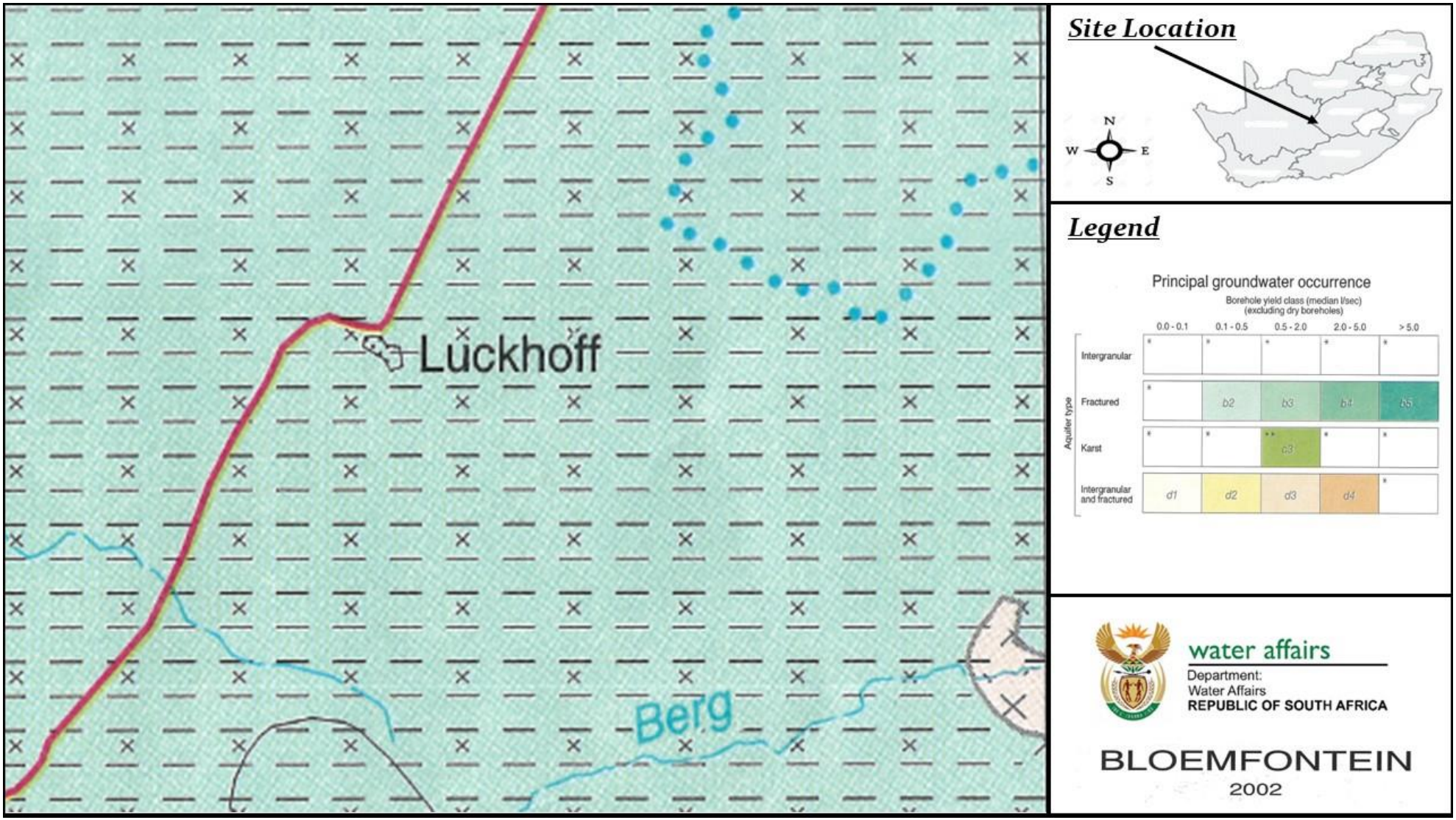


Figure 4. Regional hydrogeological map of potential groundwater in Luckhoff area.

4.3 AQUIFER CLASSIFICATION AND AQUIFER VULNERABILITY

4.3.1 Aquifer Classification

According to the aquifer classification map form the department of water affairs (Figure 5), the aquifer of the area under investigation is classified as a minor aquifer. This is corresponding to the principal groundwater map (Figure 4), indicating possible groundwater occurrence of 0.5 – 2.0L/s for the area under investigation.

4.3.2 Aquifer vulnerability

The objective of defining and mapping aquifer vulnerability is to help planners to protect groundwater as an essential economic resource and to act as a foundation for the designation of protection zones. The concept of aquifer vulnerability derives from the assumption that the physical environment may provide some degree of protection of groundwater against human impacts, especially with regards to pollutants entering the sub surface. Aquifer vulnerability thus combines the hydraulic inaccessibility of the saturated zone to the penetration of pollutants, with the attenuation capacity of the strata overlying the saturated zone (Foster 1998).

The vulnerability of the underground water source is related to the distance that the contaminant must flow to reach the water table, and the ease with which it can flow through the soil and rock layers above the water table. The water level depth map (Figure 7) indicate a water level depth of approximately 10-20 meters below surface.

According to the aquifer vulnerability map form the department of water affairs (Figure 6), the aquifer of the area under investigated is classified as moderately vulnerable.

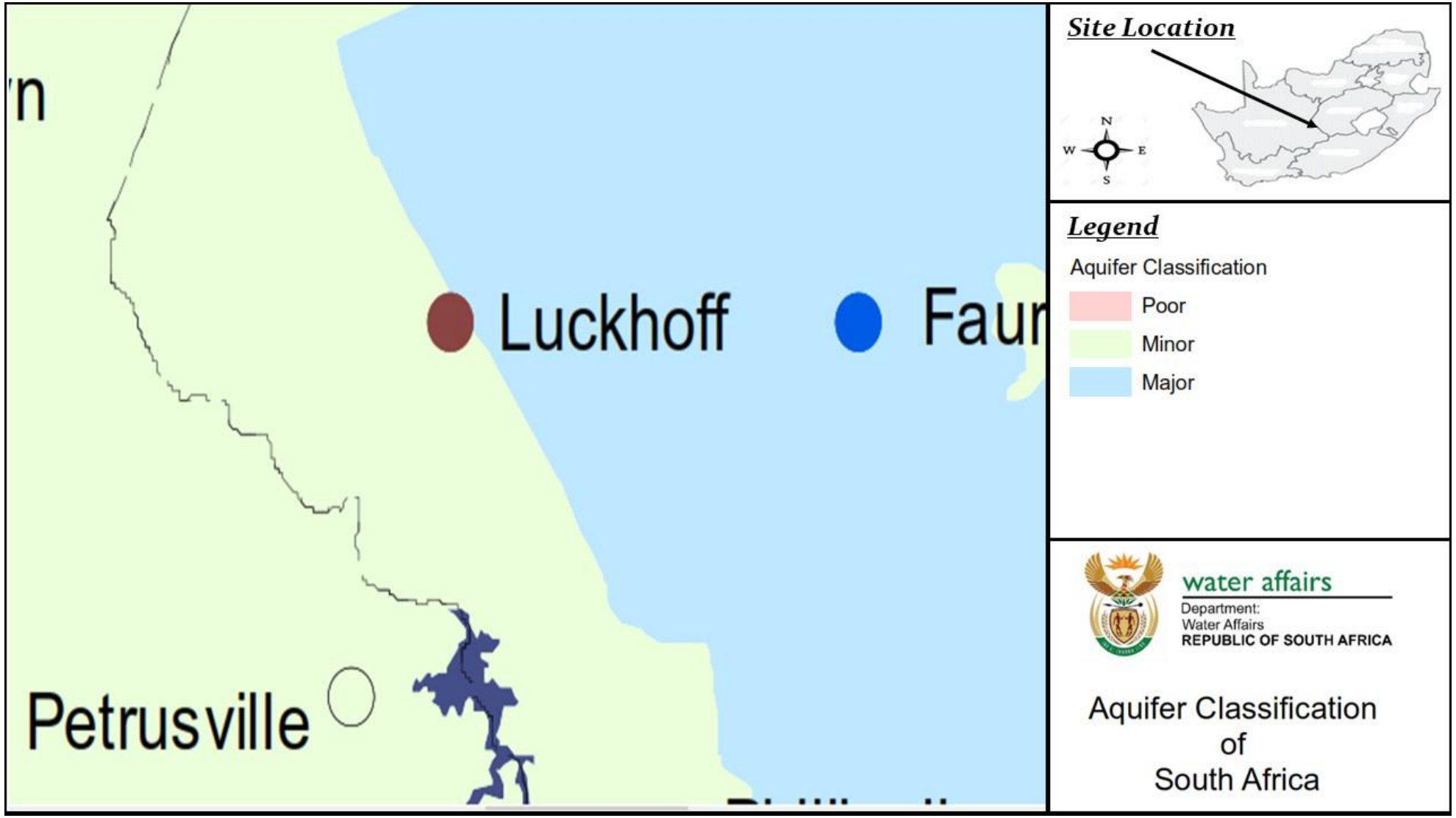


Figure 5. Aquifer classification. Map – Water affairs.

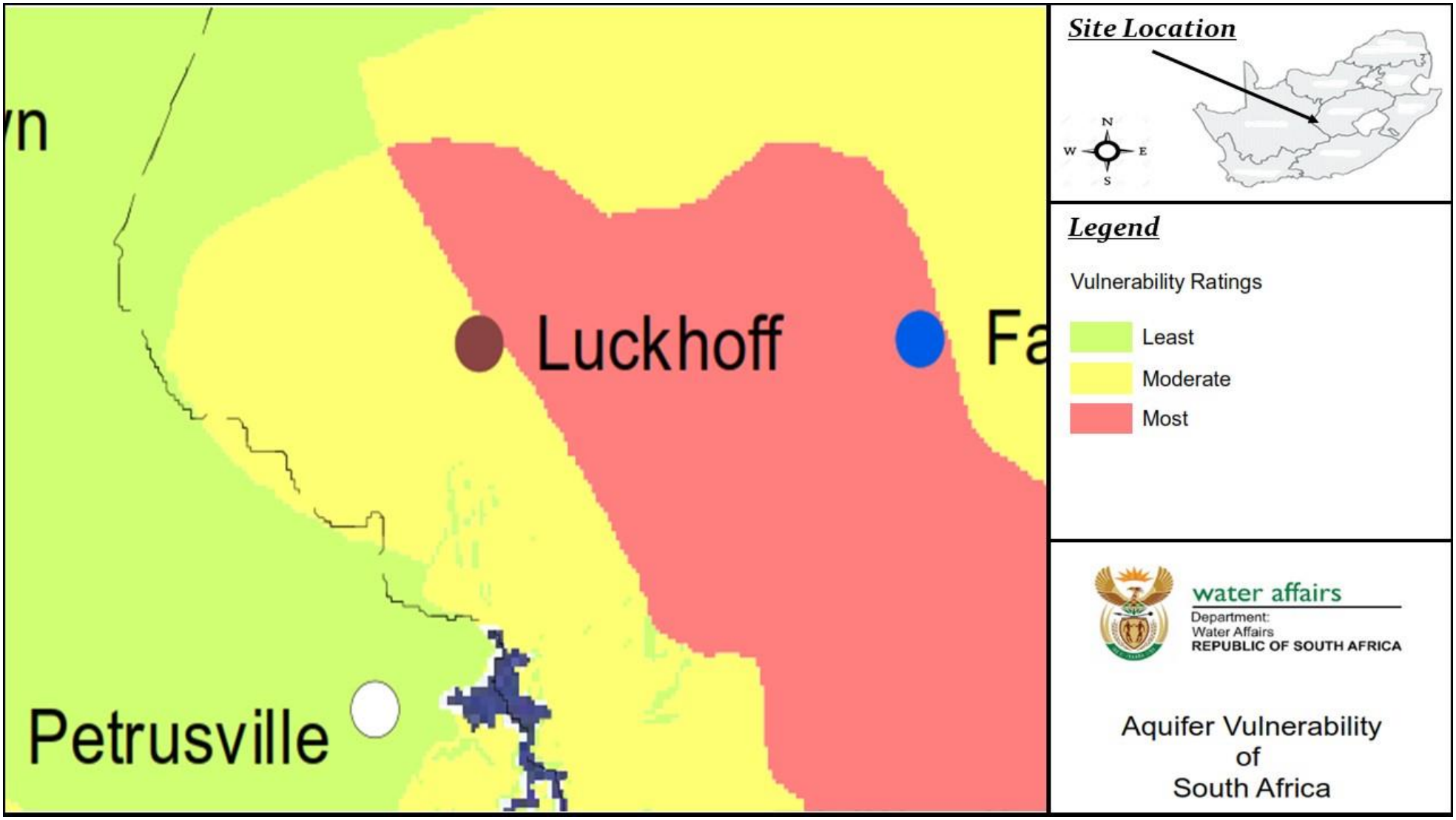


Figure 6. Aquifer vulnerability. Map – Water Affairs.

4.4 WATER LEVELS AND RECHARGE

The groundwater depth in the study area is approximately 10 - 20 mbgl according to the DWA map, refer to Figure 7. During the hydrocensus investigation, no water level could be measured due to a blocked borehole.

The DWA mean annual recharge of the area is between 15 - 25 mm/a and on average 20 mm/a (refer to Figure 8). The Vegter recharge maps estimates the recharge as 20 mm/a (refer to Figure 9). DWA and Vegter data estimates the recharge as 20mm per annum for the area under investigation.

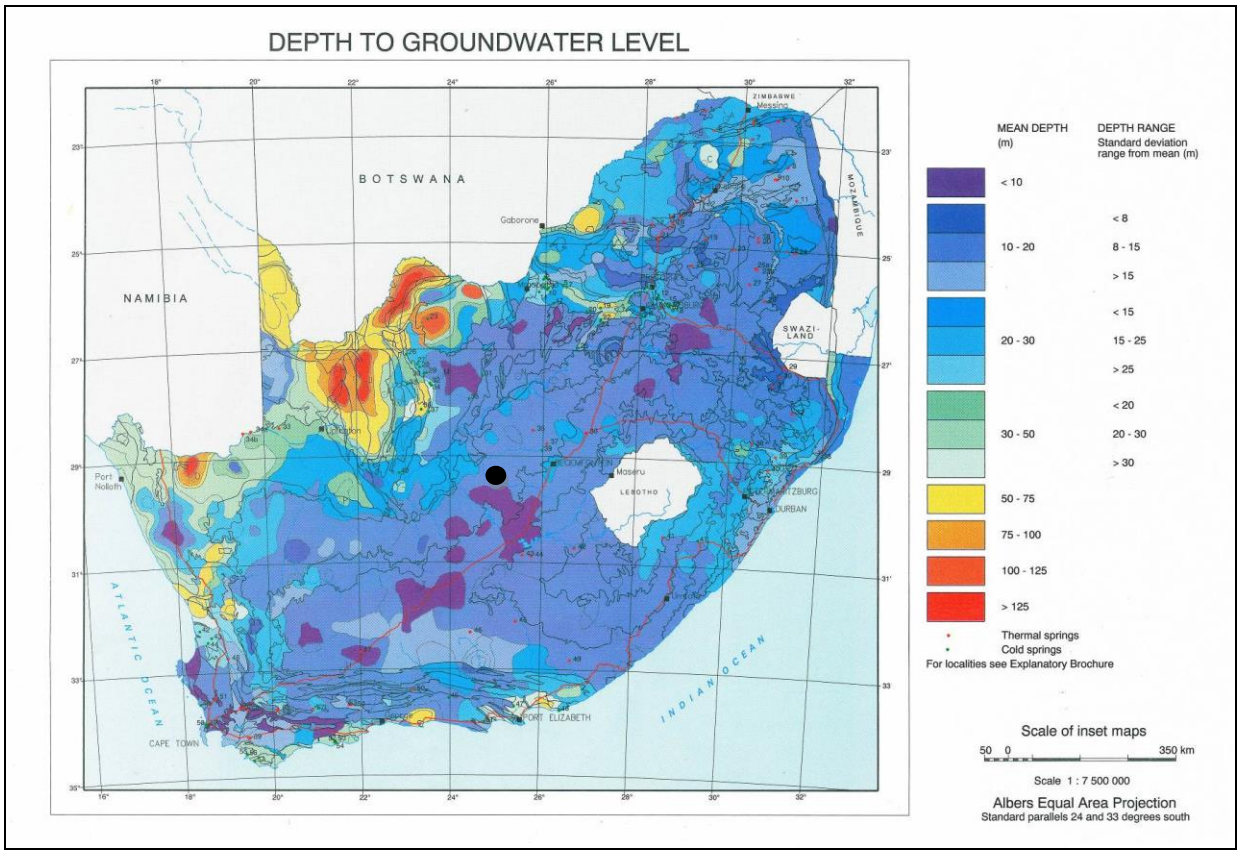


Figure 7. Depth of groundwater level (adapted from the Groundwater Resources of South Africa Map, DWA, 1995). Site location indicated with black circle.

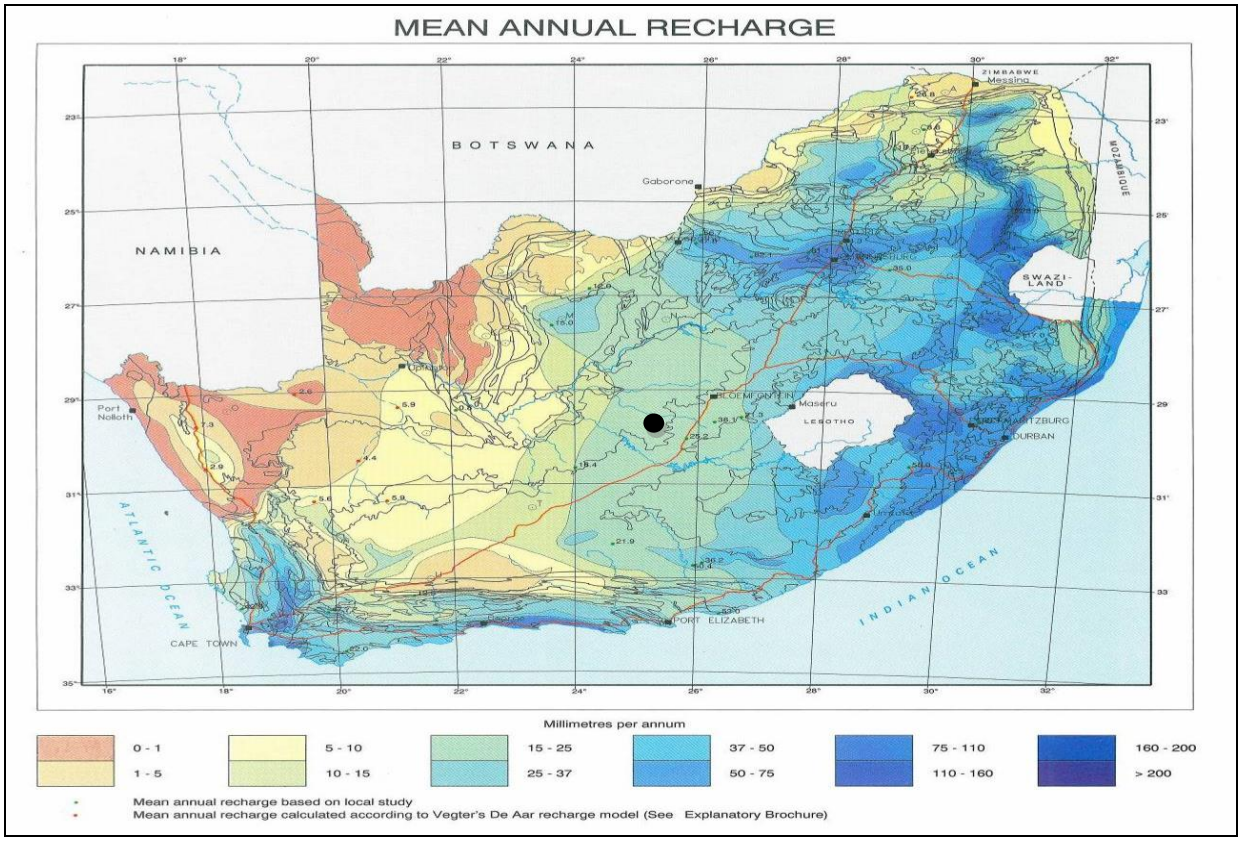


Figure 8. Mean annual recharge (adapted from the Groundwater Resources of South Africa Map, DWA, 1995). Site location indicated with black circle.

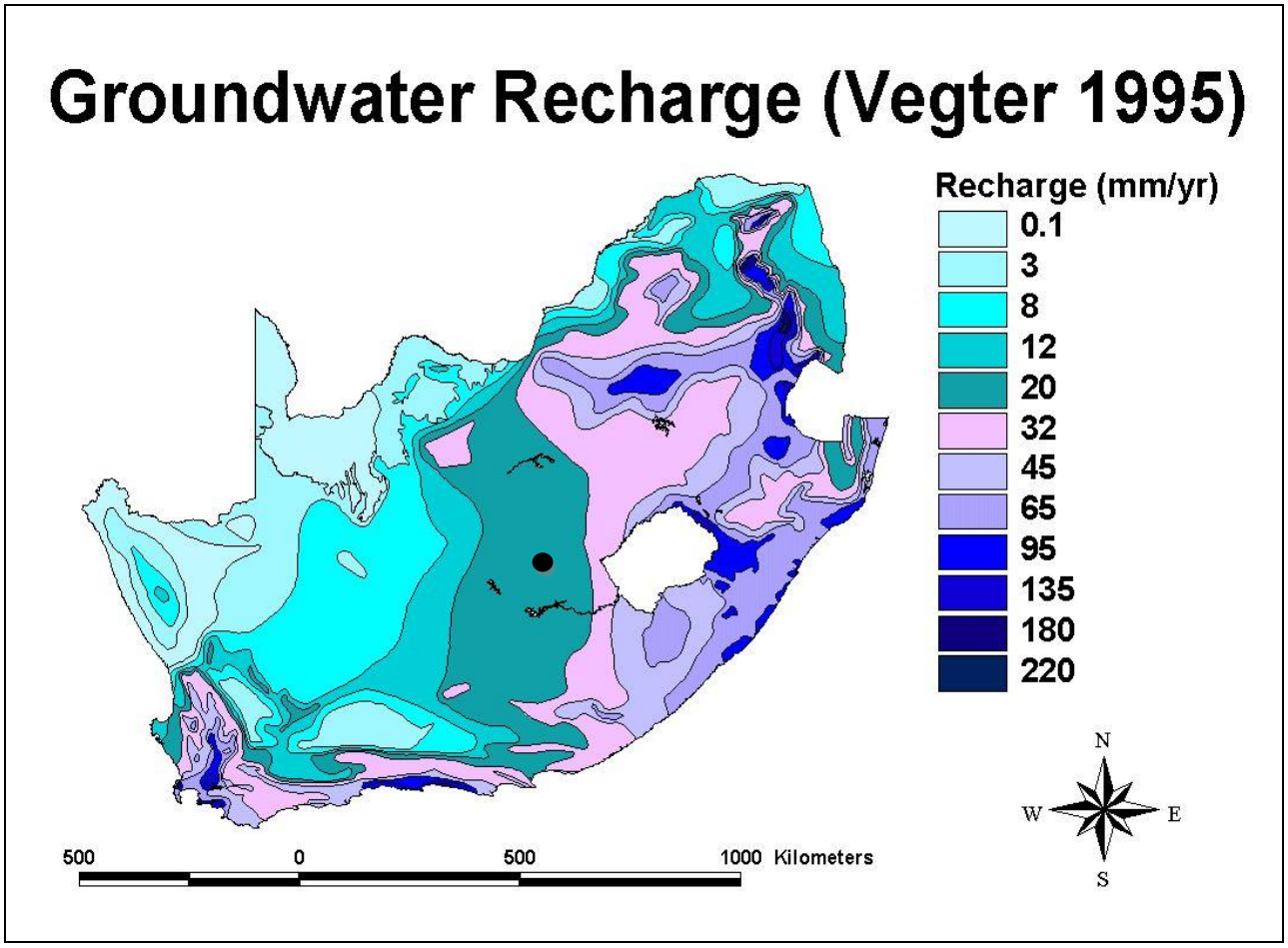


Figure 9. Groundwater recharge estimation map (Vegter, 1995). Site location indicated with black circle.

5 SITE ASSESSMENT

5.1 GEOPHYSICAL INVESTIGATION

The geophysical survey on site was completed with a G5 Proton Magnetometer to determine possible dolerite structures in the local area. The traverse locations can be viewed in Figure 12. According to the data and graphs, a dolerite sill is underlying the the local area. Dolerite outcrops from the dolerite sill was encountered throughout the site under investigation.

These massive sills usually do not contain weathered zones of dimensions significant enough to yield sustainable groundwater in significant or sustainable volumes due to the fact the most weathered zone fractures in these large sills are shallow and do not reach the local water table. Indicating no prominent groundwater flow paths according to the data available.

The following section was abbreviated from “Geophysical field manual for technicians by A.T Roux”

Geophysical techniques rely on the presence of discontinuities or contrasts in the physical properties of materials:

Many geological formations by virtue of their content of magnetic minerals, will behave like large buried magnets and will then have associated with them a magnetic field. This very local magnetic field will be superimposed on the normal magnetic field of the earth

Measurements of the magnetic field taken in the locality of such geological formations will show departures from the undisturbed earth’s magnetic field in the vicinity of these formations. These changes, or anomalies as they are called, could be large or small and cold be either an increase or decrease of the earth’s field and will depend on the depth of burial, degree and direction of magnetization, and the attitude of the formation in relation to the direction of the earth’s field at that locality.

Magnetometers are the instruments used for measuring the magnetic field and by virtue of their sensitivity and range are able to measure not only the changes of field between two rock types with only small differences in magnetic content, but also the prominent anomaly from a dolerite dyke.

- Magnetic surveys are used to locate and delineate:
- Magnetic iron ore deposits,
- Metallic ore deposits which may have either magnetite, pyrrhotite ore ilmenite associated with ore,
- Magnetite-rich zones which may have some indirect or association with a metallic deposit and faults.

It has become apparent in previous section that not only will a magnetic body produce a magnetic effect at the surface, but the amplitude or intensity of the magnetic anomaly and the shape of the anomaly bears some direct relationship to magnetic mineral content, the size, depth and the

shape of the buried body. It then becomes possible to distinguish between these different rocks even if they lie hidden under cover (Figure 10).

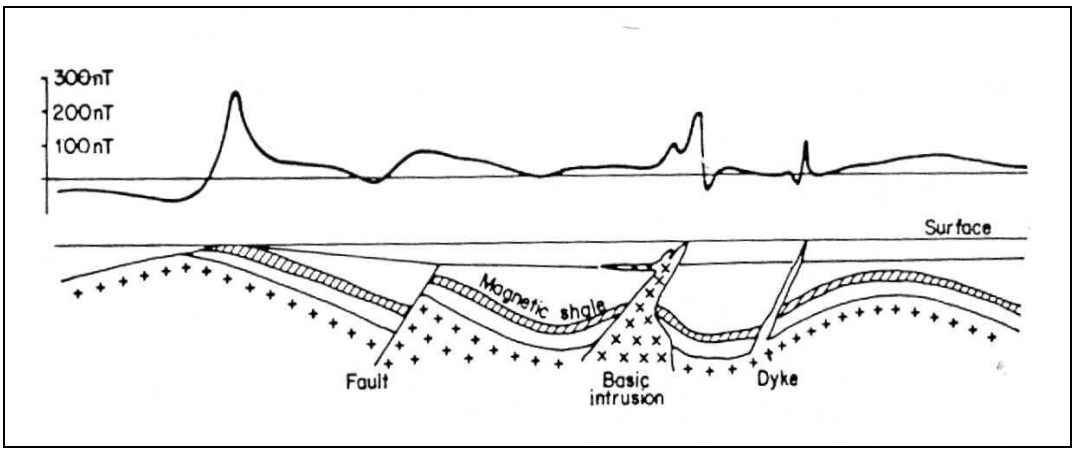


Figure 10. Magnetic profile across a typical geological section. The profile is for the total field inclination 60^0 but would look very similar for the vertical component.

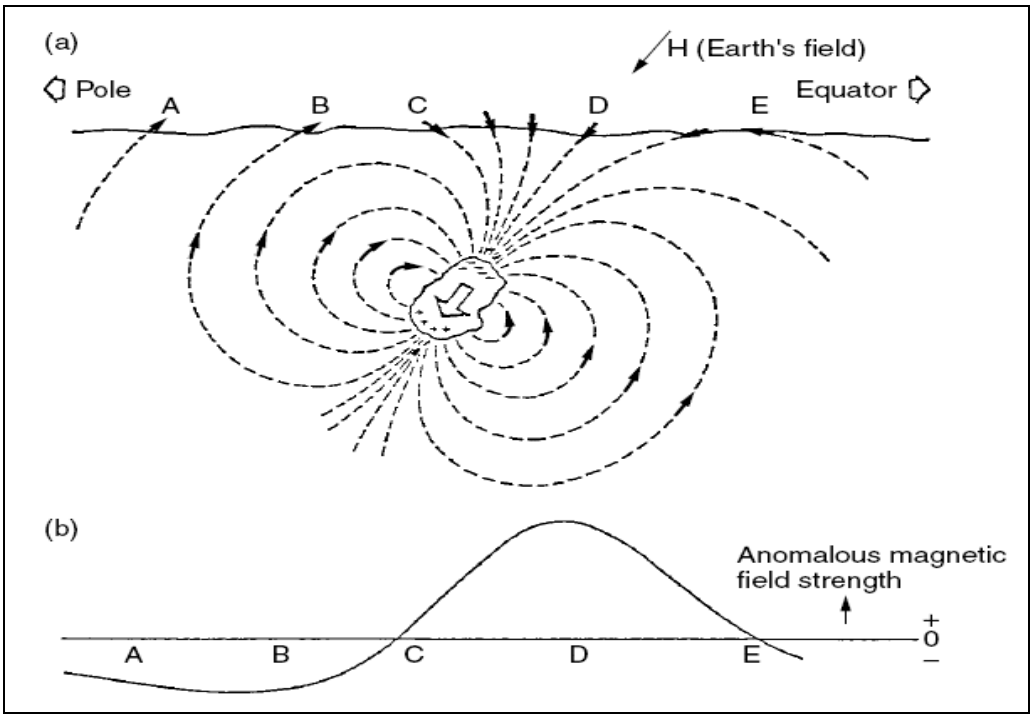


Figure 11. Mid-latitude total field anomaly due to induced magnetization. (a) The induced field. (b) the anomaly profile.

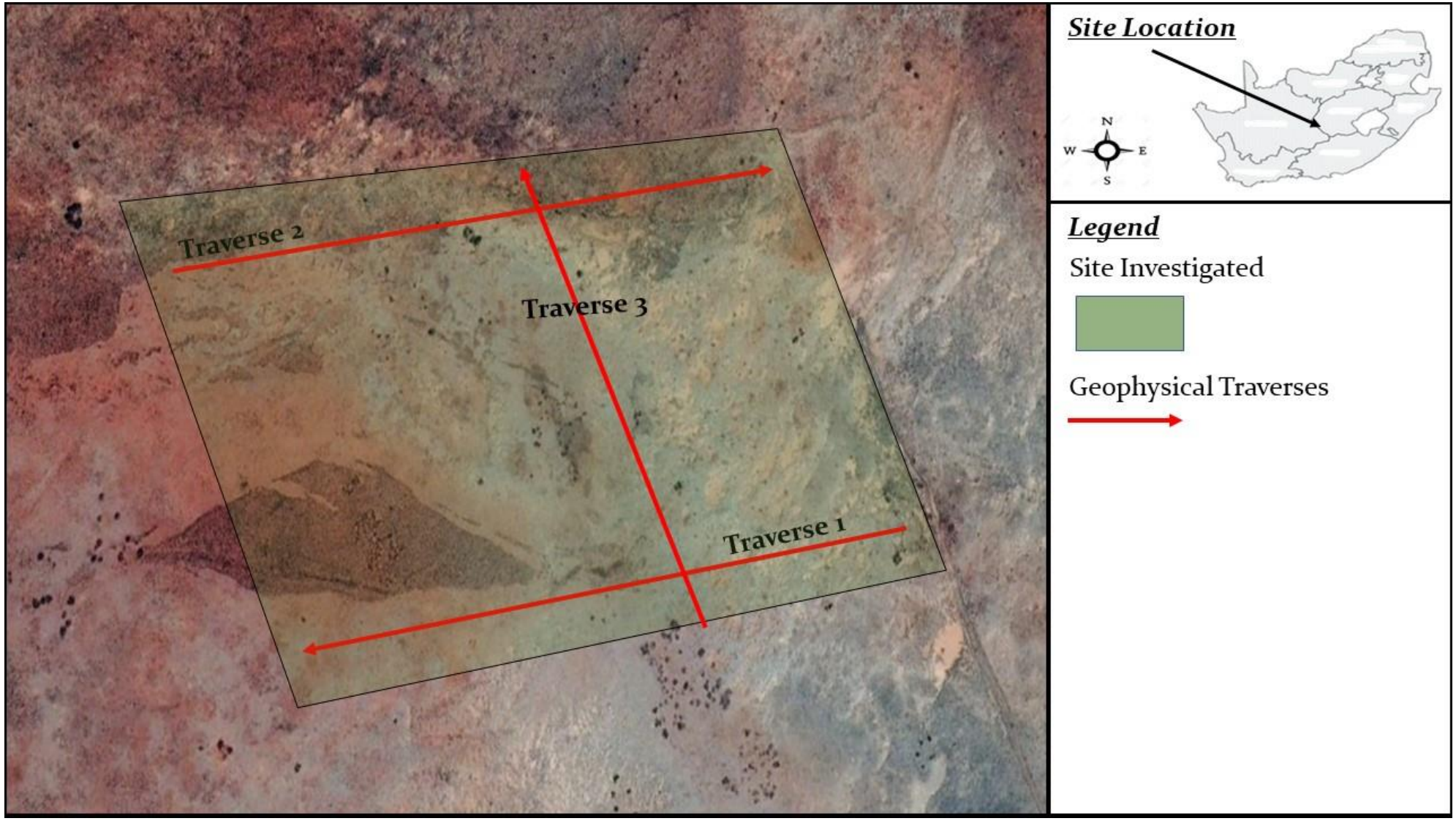


Figure 12. Geophysical Traverses.

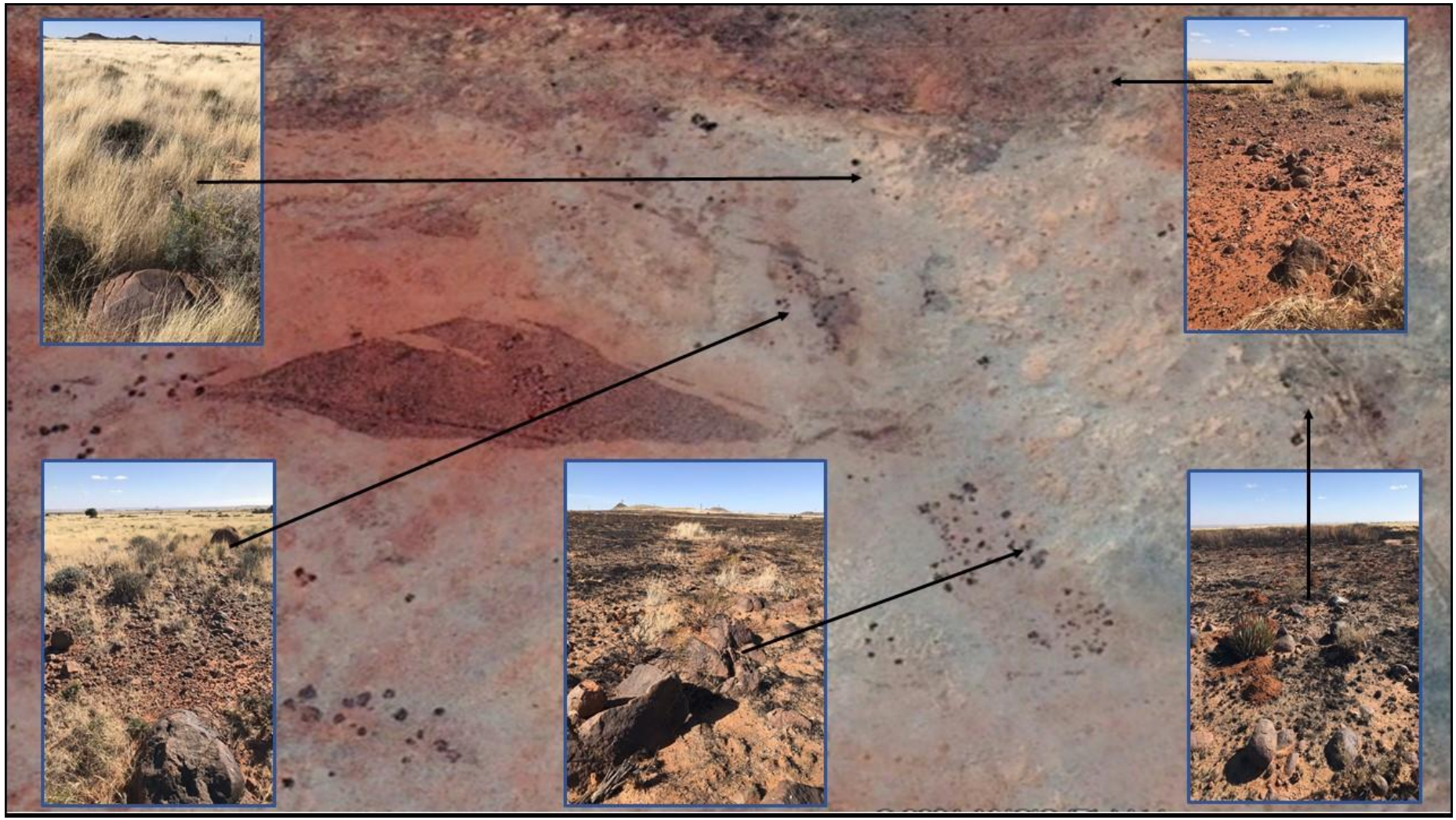


Figure 13. Dolerite outcrops identified during site assessment.

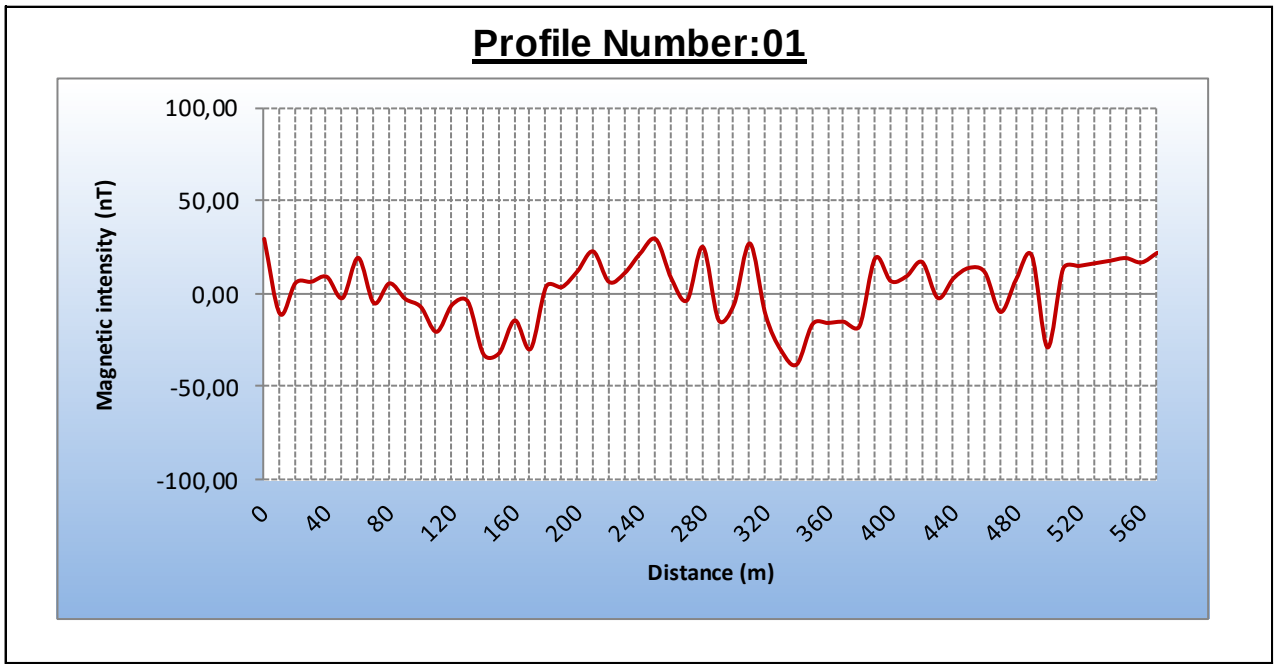


Figure 14. Magnetic profile 01.

Figure 14 is a presentation of the data in a graph format for interpretation. Predominant magnetic anomalies are evident across the entire traverse, indicating a possible underlying dolerite sill. This is verified with outcrops encountered throughout the site under investigation (Figure 13).

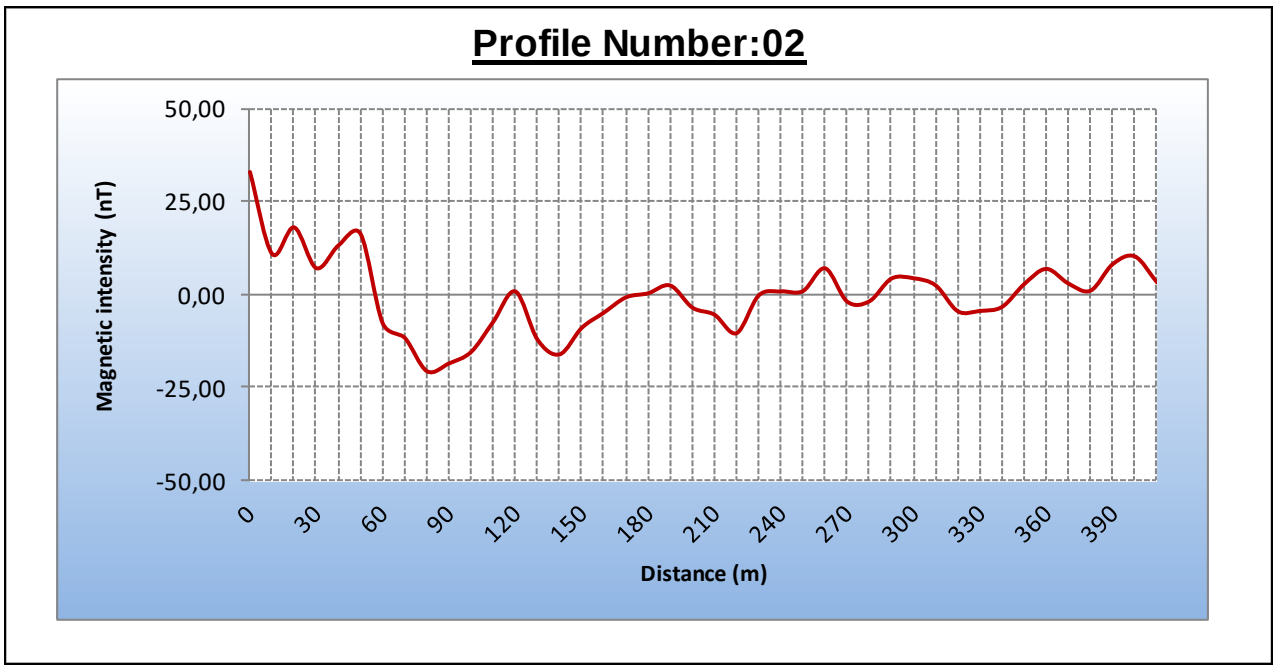


Figure 15. Magnetic profile 02.

Figure 15 is a presentation of the data in a graph format for interpretation. Predominant magnetic anomalies are evident across the entire traverse, indicating a possible underlying dolerite sill. This is verified with outcrops encountered throughout the site under investigation (Figure 13).

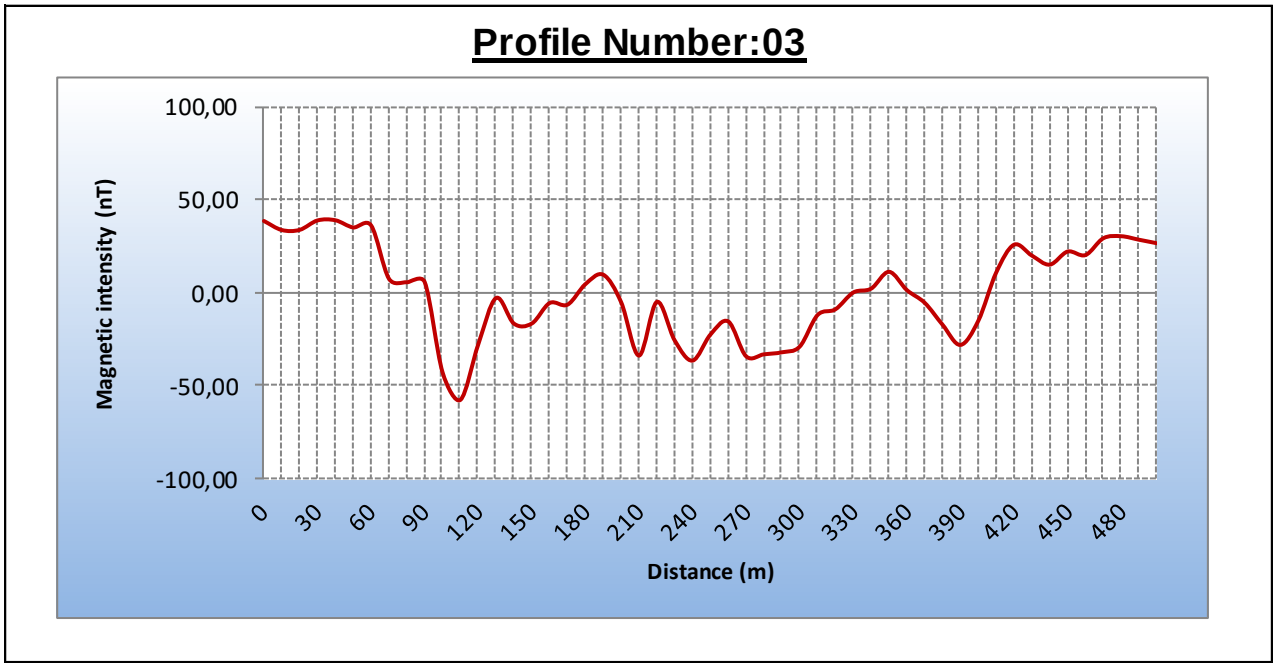


Figure 16. Magnetic profile 03.

Figure 15 is a presentation of the data in a graph format for interpretation. Predominant magnetic anomalies are evident across the entire traverse, indicating a possible underlying dolerite sill. This is verified with outcrops encountered throughout the site under investigation (Figure 13).

5.2 HYDROCENSUS

A hydrocensus survey was done by Novacraff groundwater consultants the 30th of June 2021. The objective of the site assessment was to establish groundwater level depths, existing boreholes and groundwater users on and around the proposed landfill site. Local surface water bodies were evaluated to sample upstream and downstream from the site.

1 borehole and 2 surface water sites were encountered during the hydrocensus survey, 1 sample was collected, and no water level could be verified as the borehole is blocked. Borehole and surface water site locations can be viewed in Figure 17.

Site ID	Site Description	Property	Coordinates		Measured Static Water Level (m)	Equipment	Use	Sampled
			S	E				
BH 01	Borehole downstream from proposed landfill site	Municipal	-29.740903°	24.794205°	Blocked	None	None	No
SW 01	Surface water site downstream from proposed landfill site	Municipal	-29.746250°	24.793426°	~	N/A	Livestock	Yes
SW 02	Surface water site upstream from proposed landfill site	Municipal	-29.739752°	24.809150°	~	N/A	None	No

Table 2. Hydrocensus data.

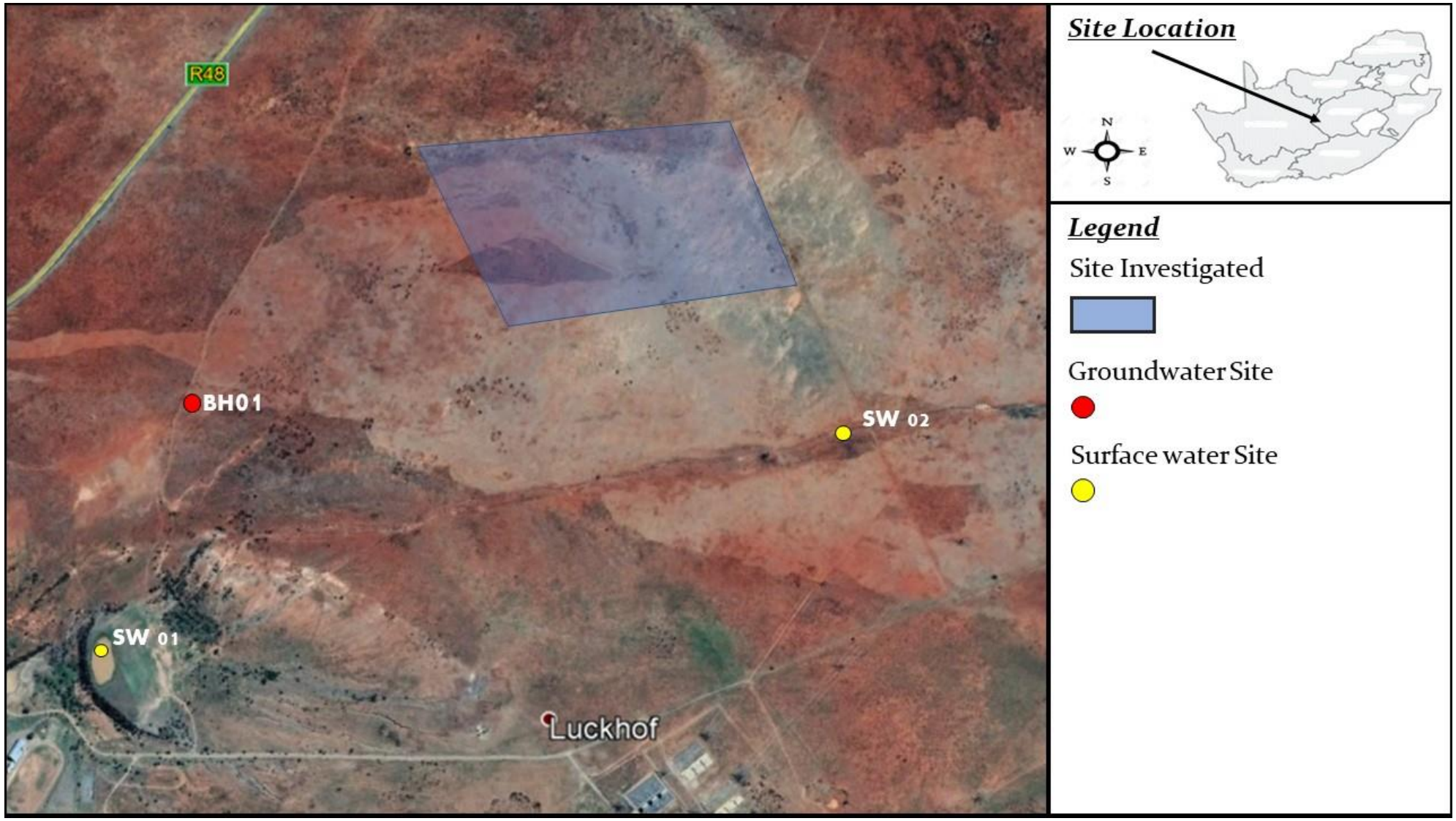


Figure 17. Hydrocensus ground and Surface water site locations.

5.2.1 Hydrocensus Photos

BH01

Surface Water Site Upstream (S02)

Surface Water Site downstream (S01)

5.3 CHEMICAL ANALYSIS

Table 3. Chemistry results.

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Novacraff (Pty) Ltd	Job No:	**E49122 - W21_1761**
Attention: Dirk Moolman	Report Reference:	**ER_NOV_2021-05-18_05384_001**
12 Juta Street	Enquiries:	**Rita Botha**
Heuwelsig	Date:	**2021-05-18**
BLOEMFONTEIN		**RitaB@yanka.co.za**
	Job Reference:	**W21/1761 - Advice Note 2105W192**
	Job Description:	**4 x Routine Analysis**
	Project:	**SPECIAL WATER SAMPLES**

TEST RESULTS FOR — **Novacraff (Pty) Ltd - 18 May 2021**

This report contains results pertaining only to the water/dust samples analysed.

For Standards referenced, and methods base, please see http://www.yanka.co.za/TestsAndStandards.htm

Please contact us if you have any queries concerning the information contained herein. Thank you for your support.

Electronically approved

ANALYSED WITHIN 18 May 2021 - 2021-05-18

RITA BOTHA (Technical Signatory)

SANAS Certificate obtainable from the address below

ENVIRONMENTAL SERVICES http://www.yanka.co.za/Services.htm

*Results not marked with a Test Method YE###***, as well as results marked "Subcontracted" or "Outsourced" , in this report, are not included in the SANAS Schedule of Accreditation for this laboratory. However, outsourced results may be within the Schedule of Accreditation of the source laboratory.*
Opinions and interpretations expressed herein are outside the scope of SANAS accreditation.

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ANALYSTS

Marné, Magda, Venna, Drieka, Sue, Rosemary, Vida, Elize, Charnelle, Petricia, Jeandre, Nadine

Table 7 continues.

YANKA LABORATORIES

CHEMISTRY TEST RESULTS

SAMPLE NUMBER			SW 01	SANS 241:2015 Standard Limits
		Test Method **		
Total Alkalinity (pH>4.5)	mg $CaCO_3$/L	YE010Alk	121	
Conductivity	mS/m	YE020CON	21,5	**< 170**
pH		YE030pH	7,51	**5.0 - 9.7**
Total Hardness	mg $CaCO_3$/L	YE061H	105	
Calcium Hardness	mg $CaCO_3$/L	YE061H	63,9	
Magnesium Hardness	mg $CaCO_3$/L	YE061H	41,0	
Total Dissolved Solids (TDS)	mg/L	Calculation	123	**< 1200**
Calcium	mg Ca/L	YE060ICP	25,6	**< 150**
Chloride	mg Cl/L	YE070AK	3,29	**< 300**
Magnesium	mg Mg/L	YE060ICP	9,95	**< 70**
Nitrate and Nitrite (TON)	mg N/L	YE070AK	<0.35	**< 12**
Potassium	mg K/L	YE060ICP	6,86	**< 50**
Sodium	mg Na/L	YE060ICP	2,60	**< 200**
Silicon	mg Si/L	YE060ICP	1,72	
Sulphate	mg SO_4/L	YE070AK	1,59	**< 500**
Aluminium	mg Al/L	YE060ICP	0,03	**< 0.3**
Arsenic	mg As/L	YE060ICP	<0.009	**<0.01**
Chromium	mg Cr/L	YE060ICP	<0.01	**<0.05**
Copper	mg Cu/L	YE060ICP	<0.01	**< 2**
Fluoride	mg F/L	YE070AK	0,16	**< 1.5**
Iron	mg Fe/L	YE060ICP	0,19	**< 2**
Lead	mg Pb/L	YE060ICP	<0.01	**< 0.01**
Manganese	mg Mn/L	YE060ICP	<0.01	**< 0.4**
Zinc	mg Zn/L	YE060ICP	<0.01	**< 5**
Anion Sum			2,56	
Cation Sum			2,41	
Difference			-0,14	
% Difference			-2,90%	

Methods adapted to accommodate local laboratory conditions. SM refers to the Standard Methods for the Examination of Water and Wastewater.

Unless analysis is indicated as "Total", tests are performed on filtered samples as per ISO 11885.

Ion balance is not used as QC check where pH<3.5.

**** Methods Starting with YE are accredited, and based on ISO, SANS, and/or other national or international standards, please see http://www.yanka.co.za/TestsAndStandards.htm . For ranges, uncertainties, etc., please contact us.**

5.4 CHEMISTRY RESULTS

According to the chemical results in section 5.3, no pollution is detected (this sampling event) for surface water site SW01 downstream for the elements analysed. Indicating no current surface water pollution from the surrounding environment.

6 CONCLUSIONS AND RECOMMENDATIONS

- The surface water drainage direction from the proposed waste site is primarily into a south-western and western direction (refer Figure 2). The south-western drainage direction contributes to the downstream dam (SW01) that was identified and sampled during the hydrocensus investigation. It is recommended to contain run-off water on site, as contaminated runoff water will flow to the downstream dam if not contained.

- The proposed site is predominantly underlying of a dolerite sill, this was verified during the geophysical investigation and the site assessment. Dolerite sills are considered as secondary targets for groundwater resource development as sills can yield feasible groundwater abstraction volumes if it contains weathered zones. Water levels, water strikes and groundwater occurrence can be established during drilling of upstream and downstream monitoring boreholes.

- Monitoring boreholes will be able to give background groundwater quality (upstream) and to identify if any pollution is entering the groundwater system (downstream).

- The Hydrocensus investigation indicate no major groundwater abstraction or groundwater dependence however, borehole BH01 was blocked but is an indication that a feasible groundwater resource is present downstream. Thus, the lining of the site is recommended to ensure no leaching of pollutants into the subsurface.