SanMari GeoHydro Consulting

GEOHYDROLOGICAL SERVICES

Water Use Licence Application Geohydrological Assessment:

Kaaldraai KQ 321 (Portion 6)

Limpopo Water Management area

Makoppa Dome Groundwater Region

November 2023

CLIENT: Aart van den Brink

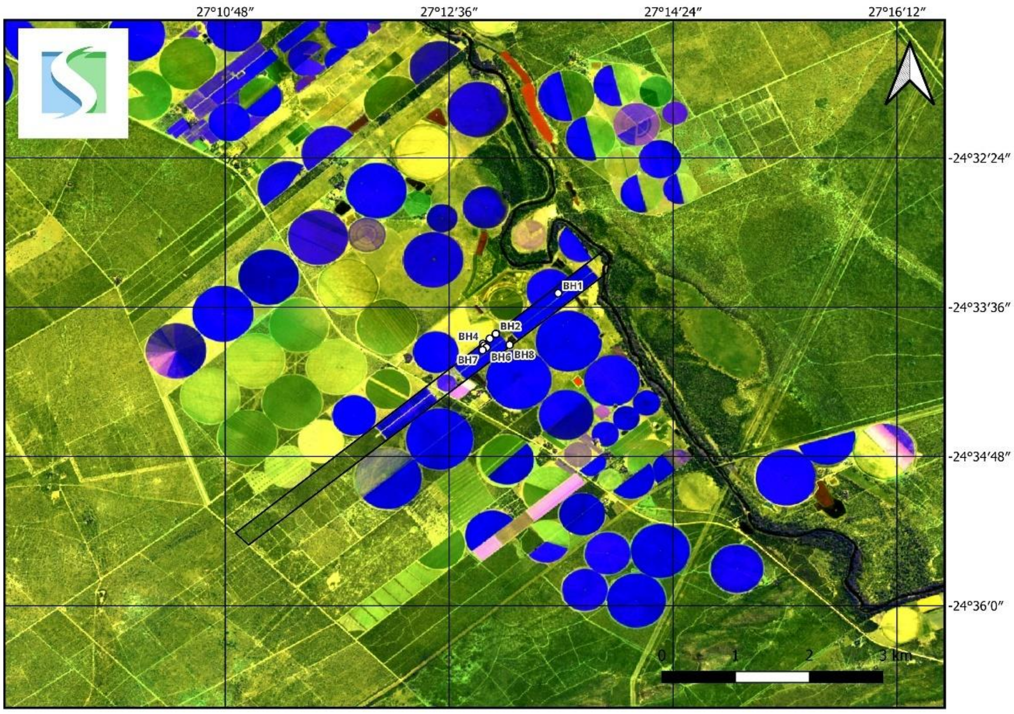
WATERBERG DISTRICT MUNICIPALITY

THABAZIMBI LOCAL MUNICIPALITY

LIMPOPO PROVINCE

GEOHYDROLOGICAL REPORT IN SUPPORT OF WATER USE LICENCE

November 2023



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EXECUTIVE SUMMARY:

SanMari Geohydro Consulting was appointed by JVR Water Consultants in October 2023, for the Geohydrological Services and compiling of the geohydrological report in support of the Water Use Licence Application on the farm Kaaldraai KQ 321 (Portion 6); Thabazimbi Local Municipality, Limpopo Province.

Groundwater will be abstracted from boreholes within the Kaaldraai 321 KQ (Portion 6) property boundary for the irrigation of a total of 134ha of wheat and soya bean crops. Groundwater will be abstracted from six boreholes.

Geohydrological Characteristics	Kaaldraai KQ 321 Portion 6
Geology:	Complex lithology. Thin overlying alluvial deposits. Possible combination of granite, conglomerates, quartzites and dolomites.
Aquifer Types:	Karst aquifer characteristics
Aquifer classification:	Major aquifer system
Long term recommended Yields:	Average 5.8L/s yields
Depth to Water table:	7-10mgbl
Groundwater Quality:	Marginal to very poor quality (Cl & N)
Regional Groundwater Use:	Agriculture and domestic
Main Annual Rainfall:	564mm
Recharge:	3-4%
Groundwater available for abstraction from GRU (Reserve):	13.744Mm3/annum
Water Demand:	Total 1 405 660m^3/annum (1 171 385m^3/annum from groundwater) Existing Validated and Verified surface water volume of 234 275m^3/annum
Cumulative Sustainable Yield from tested borehole (s):	1 450 656m^3/annum
Volume to be applied for:	1 171 385m^3/annum (81% of total sustainable yield

The main objective of this investigation was to estimate the long-term sustainability of the planned groundwater abstraction and resulting impacts on the catchment area.

All geohydrological activities were undertaken according to the minimum Standards and Guidelines for Groundwater Resource Development document of DWS.

TO SUMMARIZE:

- **The eight production boreholes relevant to the groundwater application are situated on Farm Kaaldraai KQ 321 (Portion 6), which lies within the A24J quaternary catchment area.** The listed title deed under this application cover a total area of 172.934ha (1.72934km^2).
- According to the Catchment classification based on General Authorisations (GA) under the **National Water Act** (Act No 36 of 1998) quaternary catchment region A24J, is allowed a volume of 45m^3/ha/annum. (*Refer Appendix A: Map 1).*
- **The total annual water demand for the 134ha crop development, considering the drought conditions, is calculated at an approximate figure of 1 405 660m^3/annum according to the SAPWAT analysis.** *The application volume therefor constitutes a licence application.*
- After analysis of the results of the pump tests at all eight production boreholes, and calculating the influence of these boreholes on each other, it was concluded that a total sustainable volume 1 450 656m3/annum could be abstracted from the eight production boreholes. However, only a volume of **1 171 385m3/annum** will be relevant to this application. **It is recommended that only Boreholes 2; 3; 4; 5; 7; & 8 be used as production boreholes to fulfil the application demand.** Boreholes 1 and 6 will be implemented as monitoring boreholes.
- Considering the water demand and existing verified and lawful use from the Crocodile River, the groundwater abstraction volume relevant to this **application accounts to 1 171 385m^3/annum. The application volume pertains only 80% of the total calculated sustainable abstraction volume of the tested aquifer.**
- To help ensure continuity of water supply, the groundwater will be pumped into a holding/balancing dam for storage.
- **Vegetation** in terms of simplified Acocks Veld Types can be classified as Savanna types (Sour Bushveld). Landcover is mainly agricultural land with vast mountain areas.
- It will further be motivated in this report that all production boreholes within the title dead property under investigation, are abstracting water from a potentially good yielding, chert-rich karst aquifer, with very good storage capacity. A very

conservative approach was used to calculate the recharge value, firm yield calculation and the optimum, sustainable groundwater abstraction volumes.

- According to the GRAII project (2005) dataset compiled by DWS, the **utilisable groundwater exploitation potential (UGEP)** during the dry season for quaternary catchment area A24J, approximates a volume of 8 182 300m^3/km^2/annum. For the total area of the title deed of 172.934ha (1.729km^2), an approximate volume of 14.147Mm^3/annum is therefore exploitable during the dry season. The application abstraction volume from groundwater of 1.171Mm^3/annum, therefore comfortably falls within this exploitable figure.
- The **regional topography** of the site is undulating with a maximum slope of 27%. The elevation in the regional study area ranges between 850 and 1300 mamsl, gently sloping in a north-eastern direction towards the perennial Crocodile River. The regional topography and drainage are demonstrated in Figure 2.
- The average depth of the weathered zone within the quaternary catchment area A24J according to the GRAII project (2005) dataset compiled by DWS is 60.8mbgl and that of the fractured zone is 185.67mbgl.
- During the pump test in June 2023, the **static water level** within all tested boreholes varied from 7.07mbgl up to 10.09mbgl, which are considered to be representative of the ambient or unaffected water level conditions.
- According to the 1: 500 000 Hydrogeological Map, Polokwane; 2326, the underlying aquifer is classified as a fractured and intergranular aquifer with **groundwater yield potential in the range of 0.5 to 2l/s**. The report will provide evidence supporting the high likelihood that the underlying aquifer is composed of the dolomites found within the Malmani Subgroup and that groundwater is mainly abstracted from a karst aquifer. The results of the pump test characterised the underlying aquifer as a karst aquifer with good potential storage and transmissivity.
- An average **groundwater recharge** of 4% (21-25mm/annum) of the MAP (Mean Annual Precipitation) was estimated according to the Harvest potential maps (Vegter). The MAP is estimated at a figure of 564mm/annum (Vegter) (A24J Quaternary catchment area).
- The results of the **water quality** analysis will be discussed in detail in this report (Heading 12). The results were assessed against the SANS241 (2011) standards and exhibited a range from moderate to dangerous water quality levels. In terms of the Irrigation Classification, the Sodium Adsorption Ratio (SAR) at all the tested

boreholes classified as medium to very high-salinity water (C2-C4), and generally low-sodium hazard (S1/S2).

- The Crocodile River subterranean control area, established in October 1981 south of Thabazimbi, was created to manage extraction from the alluvial aquifer and maintain stability in the river's flow. An imaginary red line delineates the area along the river, roughly corresponding to the extent of the alluvial deposit. Groundwater within this red line boundary is categorized and managed as river or surface water. However, pump test results contradict this categorization for all eight tested boreholes situated within the alluvial deposits according to the geological map. These boreholes, crucial to the application, are believed to be drawing water from the dolomitic aquifer characterized by high storage capacity and significant Transmissivity-values

1. Introduction and Scope of Work

SanMari Geohydro Consulting was appointed by JVR Water Consultants in October 2023, for the Geohydrological Services and compiling of the geohydrological report in support of the Water Use Licence Application for Aart van den Brink, farm Kaaldraai KQ 321 (Portion 6); Thabazimbi Local Municipality, Limpopo Province.

Groundwater will be abstracted from six (6) boreholes within the boundaries of the farm Kaaldraai KQ 321 (Portion 6). Two boreholes will be implemented as monitoring boreholes. The planned abstracted groundwater will be utilized for 134ha grain crops. Wheat will be harvested during the winter months and soya will be harvested during the summer months.

Under the National Water Act (Act No 36 of 1998); the Department of Water and Sanitation (DWS) requires a hydrogeological assessment of the relevant production boreholes to determine the long term, sustainable yield of the aquifer. Combined data from the Groundwater Resource Assessment Phase II project (GR II), Harvest Potential maps (Vegter;1997), results of the pump test data as well as the results of a borehole census in a 2km radius of the study area were used to evaluate the potential of groundwater within the study area.

The following activities were completed:

- Desk study, Borehole census and geology maps of the study area;
- Evaluation of groundwater exploitation potential and limitations in the study area;
- Testing of eight existing boreholes (The testing procedures followed DWS Guidelines and Standards).
- Evaluation of aquifer potential feasibility study, relating to pump test analysis for the purpose of recommending a long-term yield for a sustainable water source
- An attempt to registration of tested boreholes on National Groundwater Archive/database.
- Compilation of the geohydrological assessment in support of the WULA.

2. Geographical Setting, Climate and Topography

The study area of farm Kaaldraai KQ 321 (Portion 6) is located approximately 20km west of the town Thabazimbi, Waterberg District, Limpopo Province. (*Refer Appendix A: Map 2 - Regional map of study area).*

The Crocodile-West catchment spans over part of the North West, Limpopo and Gauteng provinces (DWAF, 2004b) and was further divided into four tertiary-catchment areas the Upper Crocodile (A21), Elands River (A22), Apies-Pienaars River (A23) and Lower Crocodile River (A24). Our study area is located within the quaternary catchment area A24J, within the Lower Crocodile River catchment.

The Crocodile River Control Area, situated south of Thabazimbi, was proclaimed in October 1981 in order to control abstraction from the alluvial aquifer and to stabilize flow in the river. An imaginary red line-bounded area has been established along the river, which coincides more or less with the extent of the alluvial deposit. Groundwater occurring within this red line-bounded area is regarded and treated as river or surface water.

The meteoblue **climate** diagrams are based on 30 years of hourly weather model simulations. Figure 1 gives a good indication of typical climate patterns and expected conditions (temperature, precipitation, sunshine and wind) in the project area.

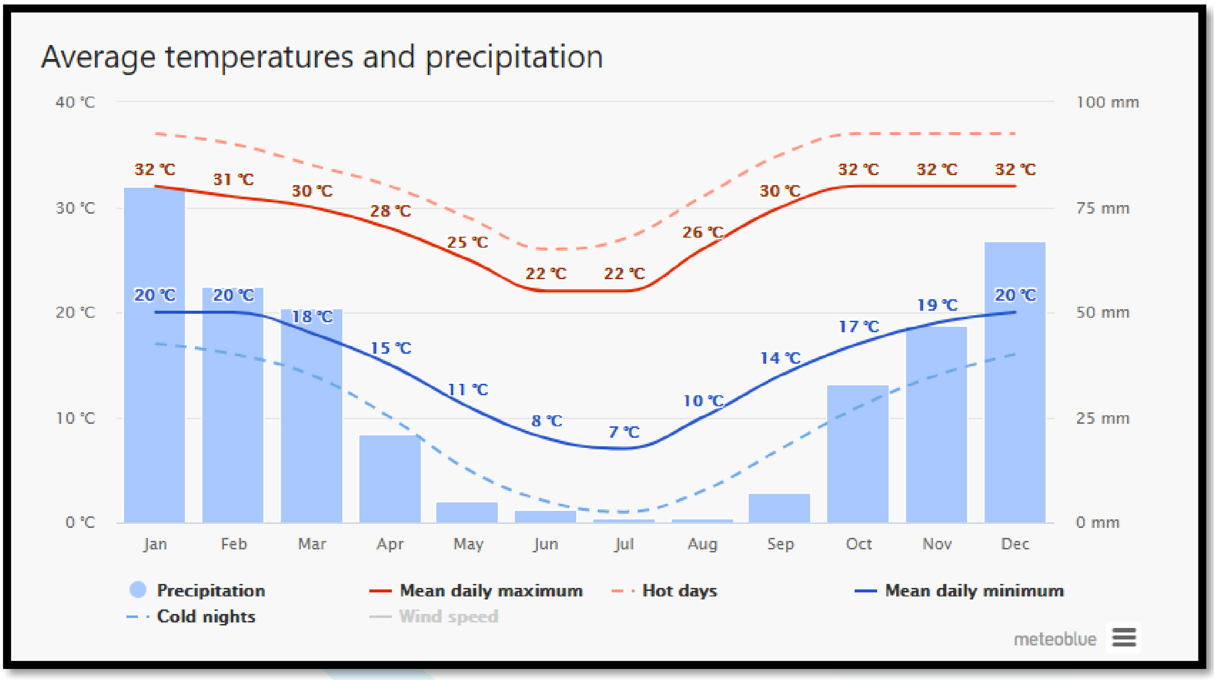
The average annual rainfall (1970-2000) for the study area location is 569 mm per year (SamSamWeather Tool; Open source info).

The rainfall and evaporation distribution are based on weather station data for Quaternary catchment A24J (DWS, 2020a). The distributions show that most rainfall occurs from October to April, i.e. summer rainfall. The catchment has a MAP of 564 mm/a and a MAE of 2 449 mm/a.

This climate is classified as BSh according to the Köppen-Geiger climate classification (CSIR). This implies a hot warm semi-arid climate (Bsh). Thabazimbi experiences significant seasonal variation in monthly rainfall.

The study area's **vegetation** consists of tropical bushveld and savannah north of the Magaliesberg. Much of the vegetation in the study area had been modified due to agricultural activities.

FIGURE 1: AVERAGE TEMPERATURES AND PRECIPITATION OF THE THABAZIMBI AREA

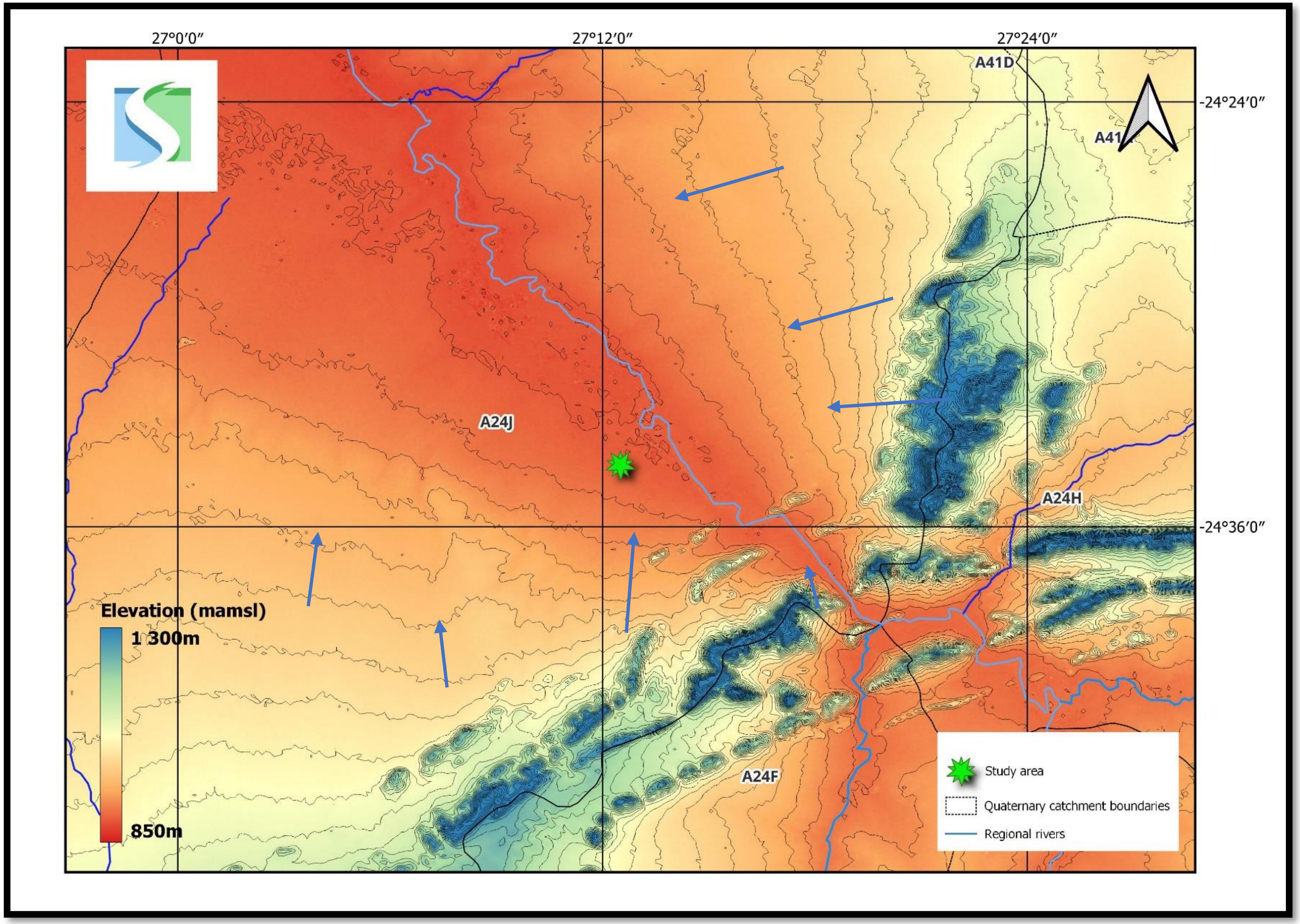


Large scale irrigation takes place in the Lower Crocodile River tertiary-catchment area (Refer Appendix A, Map 13, Sentinel satellite image Aug 2023). Other major activities include game and cattle farming along with a few mining activities.

The **topography** in the study area is characterized by a valley rising from west to east and bounded in the north and south by Vliegepoort mountain ranges. The non-perennial Crocodile River traverses a flood plain that forms the western portion of the valley (Refer: Figure 2).

The Crocodile River has its source in the Witwatersrand mountain range. This river fills several dams before it passes the town of Thabazimbi and meanders for many kilometers through a sparsely inhabited area before joing the Marico River just west of Rooibokkraal at the boundary of the North West Province to form the start of the Limpopo River.

FIGURE 2: REGIONAL ELEVATION MAP AND SURFACE DRAINING DIRECTION



3. Hydrocensus results

According to the NGA (National Groundwater Archive) and WARMS (Water use Authorization & Registration Management System) records, the highest borehole density distribution for the quaternary catchment area A24J, occur along the alluvial aquifer as depicted on MAP 9, Appendix A. From this map and the listed WARMS data it is clear that large scale groundwater abstractions, as well as surface water abstractions from the Crocodile River, are taken place in the regional study area for agricultural use (MAP 9; MAP 13; Appendix A).

According to the NGA (DWS 2010, the regional borehole data within a 10-km radius of our study area, showed an average borehole depth of 104 m ranging between 48 m and 156 m. The Water Strike distribution based on the available groundwater data showed that the main water strike zone is found at depths between 31 and 60 m. Another water strike zone was also noted at depths between 91 and 100 m.

Although neighbouring farmers are abstracting water from the Crocodile River, groundwater is also utilized for irrigation purposes.

From the production borehole test data as well as the 2km borehole census data of groundwater under application data, borehole yields are all high yielding boreholes. Sustainable yields can vary from 5 up to 15l/s. Borehole depths vary from 50m up to 110m, with static water levels averaging at 9mbgl.

According to the GRA II data set, the average water level within the A24J quaternary catchment area is 35.01m.

All groundwater abstractions within a 2km radius from our study area will be considered in terms of resource directed measures and calculations.

All NGA listed boreholes and information available within a 2km radius from the farm Kaaldraai KQ 302, are presented in Table 1 and Table 2 and displayed in Figure 3.

TABLE 1: NGA LISTED DATA WITHIN A 2KM RADIUS FROM THE CENTRE OF KAALDRAAI FARM

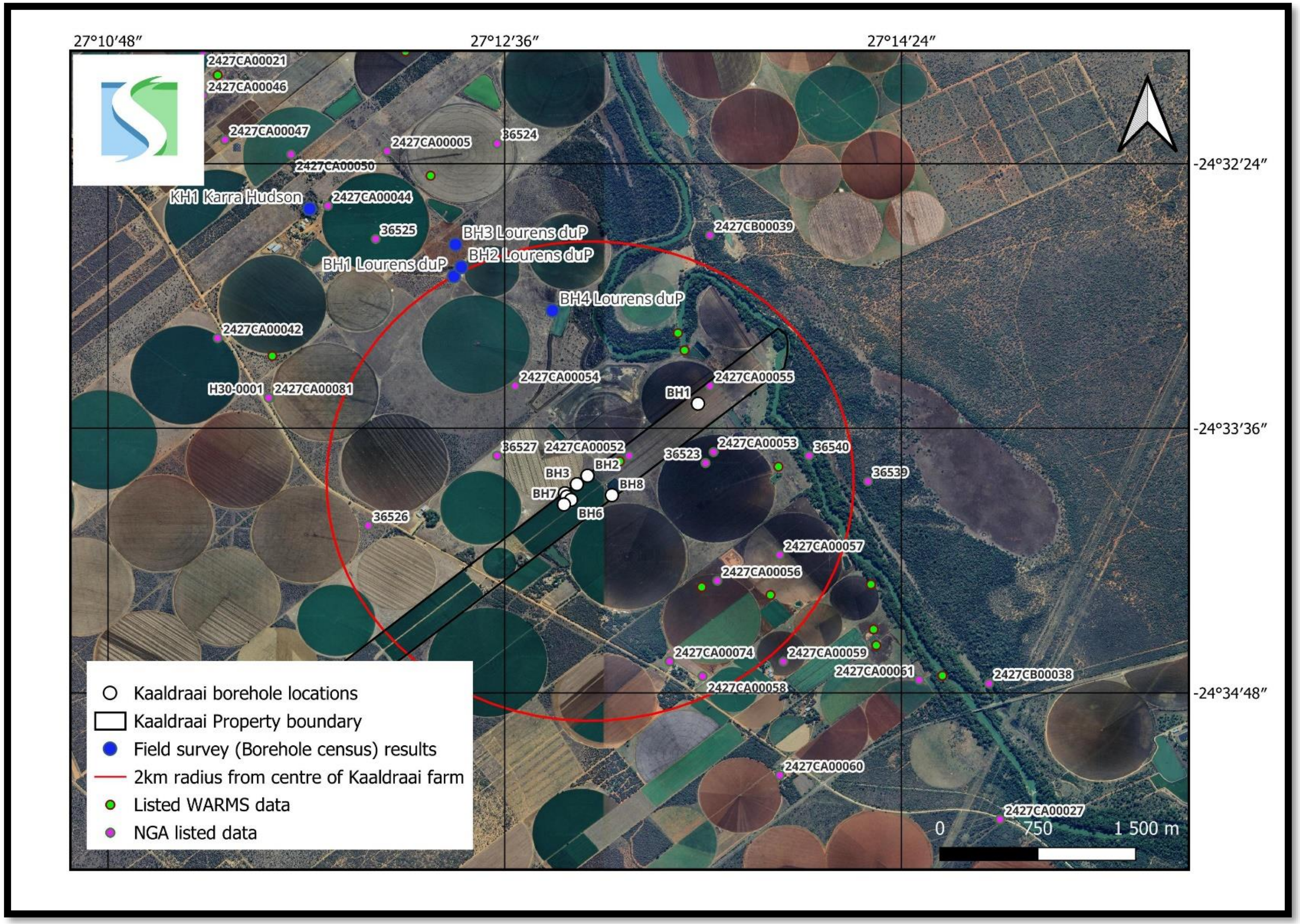
NGA BH nr	Latitude	Longitude	Depth (m)	EC (mS/m)	Yield (l/s)	Static water level (mbgl)	Lithology	Waterstrike (m)
2427CA00052	-24.56207	27.21942		82.1				
2427CA00053	-24.56179	27.22580		44.7				
2427CA00054	-24.55679	27.21080		129.0				
2427CA00055	-24.55679	27.22553		75.0				
2427CA00056	-24.57152	27.22608		107.5				
2427CA00057	-24.56957	27.23080		67.0				
2427CA00058	-24.57874	27.22497		152.8				
2427CA00059	-24.57763	27.23108		134.7				
36523	-24.56262	27.22519	92		8	10.04		
36525	-24.54568	27.20025	54,8					
36526	-24.56735	27.19969	78		1			
36527	-24.56207	27.20943	78		15	10.15		
36539	-24.56401	27.23747	36		3			
36540	-24.56207	27.23302	59,7		21	13.26		
2427CA00074	-24.57762	27.22247	102			26.00	Soil	42

The available hydro census information is shown in Table 2. This information is comprised of the boreholes found located on neighbouring farms.

TABLE 2: BOREHOLE CENSUS RESULTS

User	Latitude	Longitude	Depth (m)	SWL (mbgl)	Use	Equiptment
BH1 L du Plessis	-24,5485	27,20616	50	11,1	Irrigation	Submersible
BH2 L du Plessis	-24,5478	27,20672	50	11	Irrigation	Submersible
BH3 L du Plessis	-24,5461	27,20628	50	11,3	Irrigation	Submersible
BH4 L du Plessis	-24,5511	27,21361	50	6,9	Irrigation	Submersible
Kara Hudson	-24,543484	27,195252	50	unknown	Domestic	Submersible

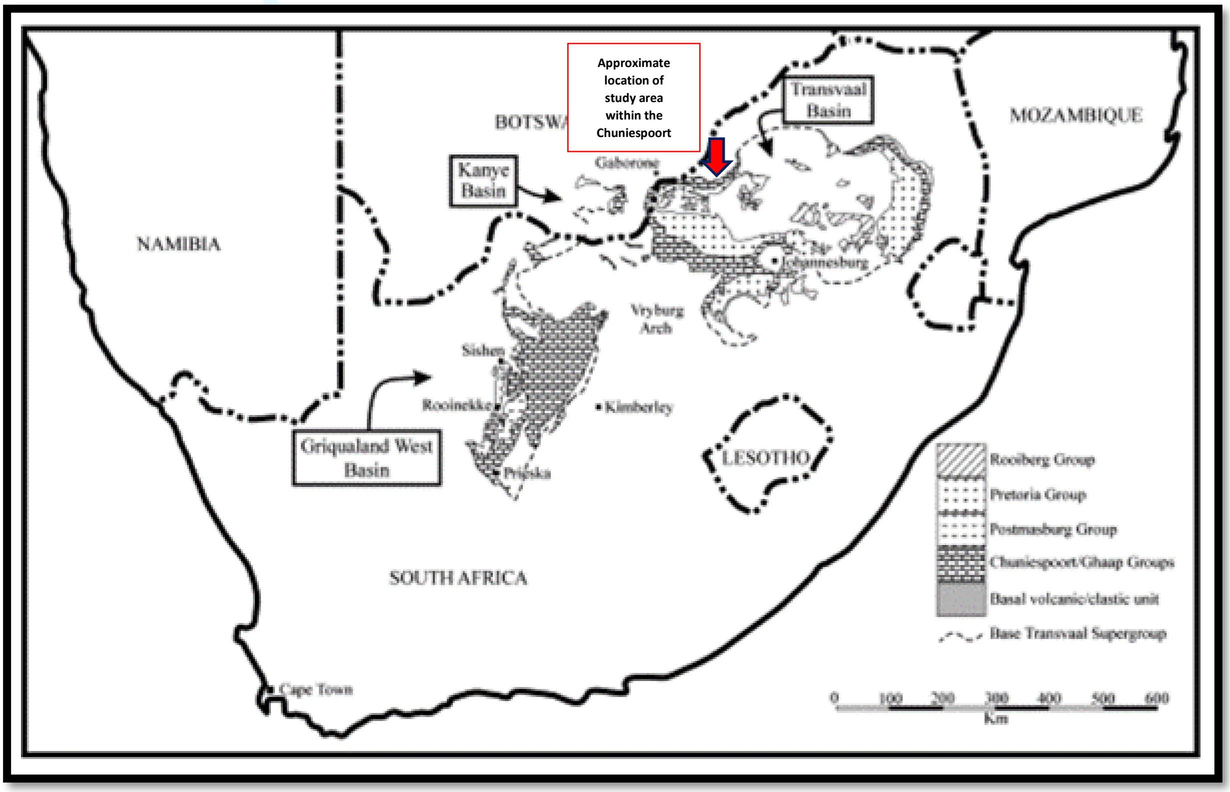
FIGURE 3: BH LOCATIONS WITHIN A 2KM RADIUS FROM FARM KAALDRAAI



4. Geology of Regional study Area

The regional geology is comprised of Formations from the Bushveld Complex, Transvaal Supergroup, Ventersdorp Supergroup and the Olifantshoek Supergroup. The undifferentiated Tonalite, Granite and Gneiss is overlain by the Ventersdorp Supergroup, which is comprised of basalt, andesite, quartz/feldspar porphyry, tuff and agglomerate conglomerate, shale, sandstone (de Beer, 2019). Formation of the Chuniespoort Goup are also found in the regional area and consists of the Malmani Subgroup and the Penge Formation. The Malmani Subgroup is comprised of dolomite, stromatolitic chert, minor carbonaceous shale, limestone, and quartzite (de Beer, 2019). The Penge Formation is comprised of an iron-formation (de Beer, 2019).

FIGURE 4: LOCALITY MAP, SHOWING THE DISTRIBUTION OF THE MAJOR SUBDIVISIONS OF THE TRANSVAAL SUPERGROUP (REFERENCE MOORE, TSIKOS & POLTEAU)



Towards the southern Vliegepoort mountain range, the sub-surface lithology contains predominantly carbonate rocks of the Transvaal System.

Our local study area geology is comprised predominantly of the Quaternary outcrops of unconsolidated weathered material which includes alluvium, colluvium, eluvium, gravel, scree, sand, soil and debris (de Beer, 2019).

FIGURE 5: GEOLOGICAL FORMATIONS WITHIN THE REGIONAL STUDY AREA (REFER: GEOSS 2022/03-23)

Code	Formation/ Group/System/		Description
⌒⌒	Tertiary to Quaternary		Alluvial material
			Kalahari sand
	***		
T3dQ/T3ds/T3dQ	Daspoort Stage	Transvaal System	Quartzite partly ferruginous, mainly at bas with locally interbedded shale
T3ds			Shale (partly micaceous and ferruginous) and hornfels
T3dQ			Ferruginous quartzite with locally developed ferruginous conglomerate
T3dL			Andesitic lava, locally with quartzite and conglomerate at base
T3dS	Timeball Hill Stage		Ferrugineous shale and hornfels
T3tQ			Quartzite
T3tS			Shale and hornfels-locally with conglomerate and quartzite near the base and higher up
T2I	Dolomite Series and Malmani Subgroup		Banded ironstone, locally with shaly dolomitic limestone at the top
T2			Dolomite, chert, shale, locally with interbedded quartzite
T1	Black Reef Series and Malmani Subgroup		Quartzite, grit, conglomerate, shale
Vds	Ventersdorp System		Shale
Vr			Conglomerate, grit quartzite, sandstone, greywacke, breccia, shale, agglomerate, tuff
Vlf			Acidic lave (quartz porphyry, felsite and rhyolite) agglomerate, tuff with interbedded quartzite, grit, conglomerate, breccia and shale
Vla			Andesitic lava with acidic lave, quartzite
VQ			Quartzite, arkose, conglomerate
Di	Archean Complex		Diabase
1G			Granite and granite-gneiss including small scattered occurrences of Swaziland System; largely covered
S	Swaziland System and Jamestown Igneous Suite		Gneiss, granulite schist; quartzite, arkose, banded ironstone, diorite, norite, amphibolite, serpentinite; lava (S) undifferentiated lava

*** younger lithostratigraphic units applicable to larger study are indicated in legend of geology map.

According to the 1: 250 000 Geology map (2426 Thabazimbi), underlying the Quaternary deposits, and directly underlying our study area, can be found the oldest lithology of the regional area i.e. the Undifferentiated Tonalite, Granite and Gneiss (Refer Map 5). These rocks are comprised of potassic gneiss and migmatite and is strongly porphyroblastic (de Beer, 2019). Du Toit (June 2010) describes these regional rocks as **"Intrusive in the Swazian** stratified rocks, is the unnamed granite body of granitic to granodioritic composition. It has a gneissose structure in many places with migmatitic phases developed around inclusions of primitive rock."

The sub-surface lithology of our bigger regional study area contains predominantly carbonate rocks of the Transvaal System.

4.1 Aquifer geohydrology and geology of study area

"The regional setting comprises of numerous aquifer systems, comprising of the Crocodile River primary aquifer; quartzite, shale and andesite aquifer; Penge banded iron formation aquifer, Malmani Subgroup dolomite aquifer, Breccia Basin aquifer, Bushveld Igneous Complex aquifer and structures associated with diabase intrusions. The southern mountainous area is characterized by extensive faulting and numerous diabase intrusions. There is a major northeast - southwest trending fault structure towards the south of the study area and several minor north-west south east trending faults crosscutting several geological formations. The study area's aquifer characteristics are mostly associated with fault structures and fractured zones associated with intrusives in the parent bedrock.

The intergranular aquifer associated with the Crocodile River, deeper weathered zones in the granite bedrock and fractured zones within the quartzitic bedrock underlie the Kaaldraai property. These fracture zones are associated with mapped faults which may well facilitate greater than average recharge in the area. The geological conceptualisation enables the definition of more local aquifers (i.e. Groundwater Resource Units (GRUs))" (Quote Geoss report 2022/03-23).

In the "Explanation of the Hydrogeological Map; Polokwane 2326", our study area is described as being underlain by intergranular and fractured aquifers of an unnamed granite body of granitic to granodioritic composition. This granite body is believed to be intrusive in the Swazian stratified rocks. The groundwater potential of these rocks is described as low potential. The latter does not correlate with the aquifer potential evident in the eight tested production boreholes on the farm Kaaldraai.

Since there is no drill log information available for our production boreholes, which were drilled by previous farm owners, we must depend on the results of the pump test data to gain insights into the underlying rock formation.

Typical of a karst aquifer, the response to pumping was rapid, with water levels declining quickly due to the presence of conduits and fractures that provide high-conductivity pathways for groundwater flow. This make it challenging to estimate aquifer parameters accurately. In alluvial aquifers, the water level drawdown during pumping are typically more gradual.

In all the tested boreholes, the drawdown in water levels stabilized after a short period during the constant test, indicating a consistent hydraulic pressure within each borehole. This stabilization of the water level was interpreted as reaching the karst aquifer or fracture network, establishing the critical level within each production borehole.

The Karst aquifers of the Carbonate rocks of the Chuniespoort Group unit which covers the southern and south-eastern mountainous areas of our regional study area, consists of an alteration of chert-bearing and chert-free dolomite with the Duitschland Formation consisting of dolomite, shale and limestone at the base with an increase of clastic material towards the top. The Malmani and Duitschland Formation have been grouped together to represent the carbonate rocks of the Chuniespoort Group. These formations strike in a general east-west direction. Tectonic activity in the form of thrust faulting and folding has resulted in these formations dipping steeply to the south. (Reference Moore, Tshikos, Polteau).

Additionally, a prominent linear structure, extending in a north-westerly direction along the Crocodile River, was identified from ERTS images and are presented on the 1:250,000 Thabazimbi (2426) geological map (Refer MAP 6 & MAP 8).

Considering the available information:

- The 1:250,000 Geology map (2426 Thabazimbi) shows numerous geological faults originating in the carbonate rock formations of the Vliegepoort mountain, striking towards the alluvial deposits and Undifferentiated rocks forming the Crocodile River valley.
- Carbonate rocks of the Chuniespoort Group unit, covering the south-eastern Vliegepoort mountain, drain towards the north-westerly meandering Crocodile River.
- Structurally the study area is characterised by a northwest-southeast trending linear feature inferred from aeromagnetic and photogeological data most likely representing a dyke partly controlled by faulting (Council for Geoscience, 1974)

Based on these findings, the author speculates that our study area is underlain by a karst aquifer and recharged from the dolomites of the Vliegepoort mountains. This speculation could account for the high-yielding boreholes within the boundaries of the farm Kaaldraai KQ 321.

- **Groundwater flow direction**

In our larger regional study area, it is suspected that groundwater static water levels mirror the topography. The higher lying southern and south-eastern mountainous area naturally drains towards the north north-western draining Crocodile River. The flow gradient in the higher lying areas is steep, in the range of 1:20 and becoming a lot more gradual towards the north in the range of 1:400.

Insufficient recent static water level data was available to create a groundwater contour flow map. Accurate groundwater flow direction depiction on a contour map necessitates precise and updated data for interpolation.

In a previous study (Refer: Tricon Agric Services Pty; Farm Van Wykskraal 116, Portion 3 (March 2022)), good correlation between surface elevations and the groundwater levels, suggests that groundwater flow takes place under semi-confined conditions and generally mimics the surface topography.

5. Surface Groundwater Interaction

Colvin et al. (2003) classified the hydrogeological terrains and their influence on the nature of groundwater discharge to rivers (Kirchner et al. 2001; Vegter, 1995, Kelbe et al., 2001; Rosewarne 2002; Chevalier et al., 2004; Net et al., 2003) of South Africa in 6 principal aquifer types. One of the principal aquifer types is listed as the Carbonates, in which our study area lies. The properties of the Carbonates are listed in the following table:

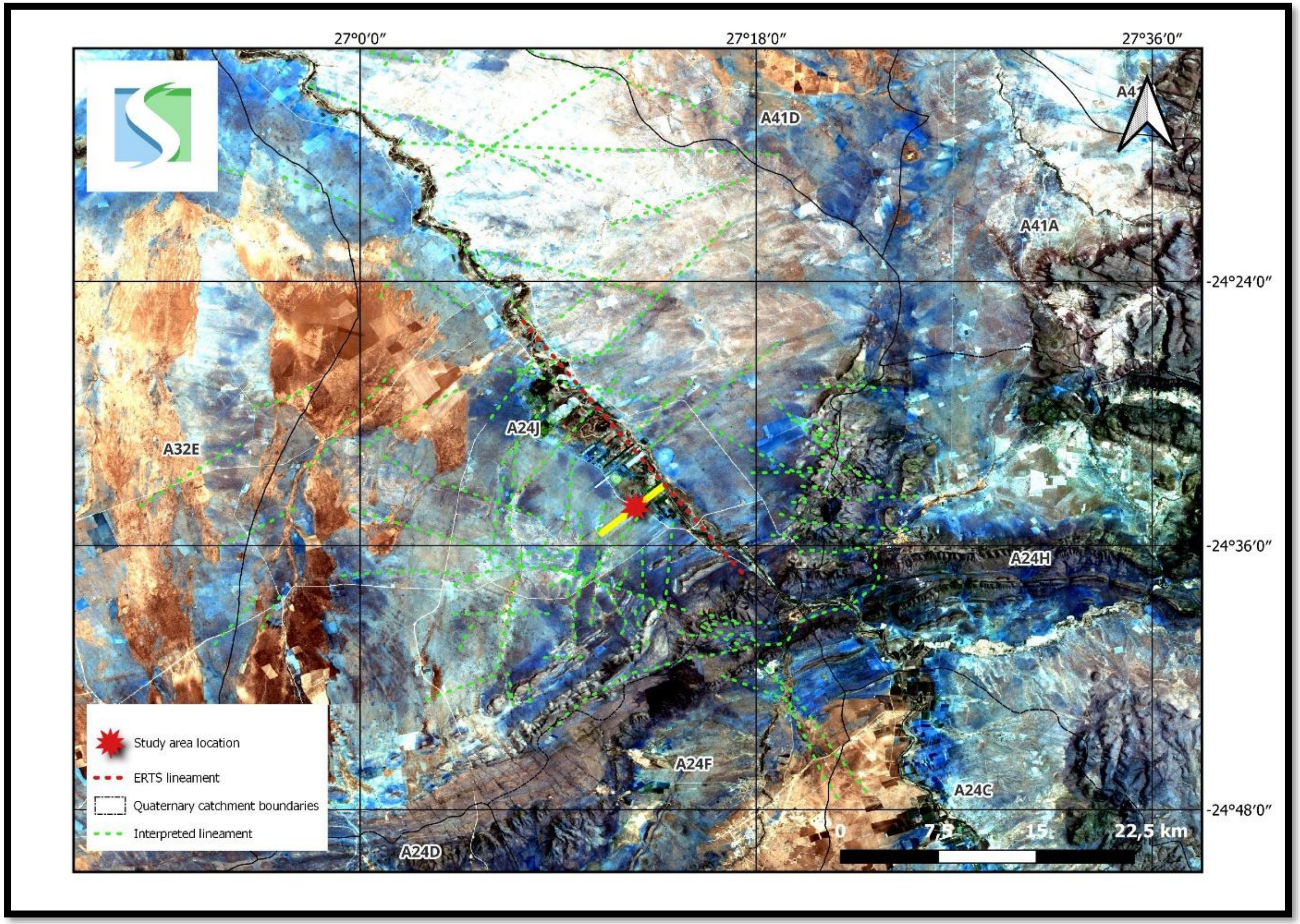
Aquifer type	Carbonates
Rock types	Dolomites and limestones
Aquifer characteristics	Secondary aquifer; water storage is in the solution cavities created by dissolving the carbonates (high permeability and storativity); often compartmentalised by impermeable dykes
Nature of discharge to rivers	Large volumes of water and sustained flows in the dolomites and in some situations in the limestones; typically discharged through eyes, springs and wetlands

The water storage in the secondary aquifers within the dolomites, are therefore expected to contribute to the flow of the Crocodile River within our study area. Numerous seasonal and in many cases perennial springs occurring in the carbonates contribute significantly to the base flow component in major rivers.

This theory finds support in the interpreted lineament observed in ERTS images (Earth Resources Technology Satellite), which runs in a southeast to northwest direction from the Malmani Subgroup dolomites in the southern Vliegepoort mountain range along the entire length of the Crocodile River. This interpreted lineament could serve as a potential source for multiple aquifers along the river (Refer Figure 6.**Error! Reference source not found.**)

The contribution of the carbonates to the base flow is further motivated by the author to contribute to the groundwater source of the production boreholes relevant to this application.

FIGURE 6: INTERPRETED LINEAR STRUCTURES (LANDSAT 4 SATELLITE IMAGE, OCT 1984)



6. Aquifer Characteristics

Regional and local thrust faulting duplicated the Subgroup in the Thabazimbi occurrence, rendering it a very complicated local hydrogeological system (Refer Appendix A: MAP 6 & MAP 10).

Based on the above statement the author motivates that the thin layer of quaternary deposits underlying the farm Kaaldraai are mostly utilized in conjunction with the underlying bedrock. This theory was also motivated in report SMGC0062 (farm Diepwater KQ 302), where the driller reported and was able to present photos of the chert-rich dolomitic formation drilled in boreholes on the Diepwater farm, approximately 9km further along the Crocodile River.

Despite the absence of drilling or borehole construction data for the boreholes under investigation, the discussion of test data characteristics will be presented. This analysis aims to reinforce the notion that the groundwater resource might originate from the carbonate rocks of the Chuniespoort Group unit, which constitute the dolomitic Vliegepoort mountains to the southeast of the study area.

It is speculated by the author that groundwater in our study area occurs in two different aquifers, mainly:

A **primary aquifer** consisting of alluvial sediments having inherent porosity and restricted to a zone all along the Crocodile River and

A **secondary aquifer** in which groundwater occurs along fault and shear zones associated with intense deformation resulting in the occurrence of fractures, joints, and cavities subsequently enlarged by dissolution processes in the dolomites.

Dolomitic rock generally exhibits moderate to high porosity, allowing it to retain a substantial amount of water within its pore spaces. The presence of interconnected pore spaces and fractures often leads to moderate to high permeability, providing these aquifers with significant storage capacity. These features were evident in the results obtained from the pump test data conducted at the boreholes relevant to this application.

Furthermore, the water quality analysis revealed elevated levels of dissolved minerals, such as calcium and magnesium, which are commonly found in dolomitic groundwater.

7. Aquifer Vulnerability

DRASTIC is a model that considers the main hydrological and geological factors with a potential impact on aquifer pollution. The aquifer vulnerability method makes use of seven (7) factors to calculate the vulnerability index value (Aller et al.,1987). The number indicated in parenthesis at the end of each factor description is the weighting or relative importance of that factor:

- Depth to groundwater (D) – determines the maximum distance contaminants travel before reaching the aquifer (3)
- Net recharge (R) – amount of water that can travel from ground surface to the water table; (1)
- Aquifer (A) – the composition of the aquifer material; (10)
- Soil media (S) – the uppermost portion of the unsaturated zone; (6)
- Topography (T) – the slope of the groundwater surface; (10)
- Impact of the vadose zone (I) – the type of material present between the bottom of the soil zone and water table; and (5)
- Hydraulic conductivity of the aquifer (C) – indicates the aquifer’s ability to allow for the flow of water to occur. (10)

The DRASTIC map for the study area is shown in MAP 12, Appendix A. When compared to the simplified geology map (Appendix 1; MAP 7), the dolomitic areas are rated a high vulnerability as compared to the surrounding geologies. It is further noted that the dolomitic areas are also associated with high yielding aquifers.

The groundwater in the study area is classified as having an "extreme" vulnerability rating to surface-based contaminants, primarily due to the shallow static water level and the direct overlay of Quaternary outcrops. As detailed in the Geology section, the clayey and sandy alluvial layer within our study area is likely underlain by the karst aquifer, a component of the Transvaal geological system. The high permeability of the overlying sediments and shallow static water level in the immediate study area, significantly amplifies the risk of surface-based contaminants infiltrating the deeper groundwater system.

8. Recharge to Groundwater Response Unit

The geohydrological response unit (GRU) and recharge area has been defined as an area of 1312km^2 (See MAP 9 , Appendix A). Within this GRU area, 1.72934km^2 (172.934ha) of the total area of the GRU are registered title deeds under Kaaldraai KQ 321(Portion 6), relevant to the WUL application under investigation.

The boundaries of the groundwater response/recharge unit/area are defined on the northern, eastern and southern boundaries by the quaternary catchment area boundary. The western boundary is defined by the harvest potential areas defined by Vegter as well as the lithology of the regional area. Vegter's boundaries are based on lithology, recharge figures, rock formation as well as aquifer characteristics.

Rainfall data are based on weather station data for Quaternary catchment A24J (DWS, 2020a). The catchment has a MAP of 564 mm/a and a MAE of 2 449 mm/a.
Rainfall data from the Surface Water Resources of South Africa 2005 project estimate the average for this catchment A24J as 586mm/a.
According to the map of the Groundwater Resources of the Republic of South Africa by Vegter (1995), this area has a recharge value of 5 – 15 mm/a; i.e., 3-4% of Mean Annual Precipitation (MAP). The GRA II (DWAF, 2006) recharge map for the study area shows the estimated recharge average as 3% of the MAP. In a more recent project, in a combined effort of DWS, ESRI, Earthstar Geographic groundwater recharge values were evaluated and depicted in Appendix A: MAP 11(Farm Mapper).

According to Cape FarmMapper Ver 2.7 (Spatial Information & Mapping Services unit at the Western Cape Department of Agriculture), recharge values within the Groundwater Response/Recharge Unit (GRU) vary from 12mm on the flat flood plain area, up to 32-48mm in the southern and south-eastern mountainous area. The map of the Groundwater Resources of the Republic of South Africa by Vegter (1995), therefor correlates with the more recent information, depicting a recharge value of 8-12mm/a, i.e. 2% to 3% of Mean Annual Precipitation (MAP).

A conservative recharge figure of 3% was used in our calculations for our relevant study area.

Steyn (1969) investigated springs and boreholes in the dolomite formation, forming the mountainous regions towards south-east of our study area. Spring flow was reported to be dependent on rainfall i.e. decreasing/ceasing during periods of low/no rainfall, and increasing/resuming after periods of high rainfall. These conditions indicate significant recharge to the dolomite from precipitation, and emphasize the role of the dolomite as a secondary aquifer (Reference: P.J. Hobbs (Oct 1983)).

For the purpose of this study the modelled values within the A24J quaternary catchment area, of 0.1Mm^3/annum is considered to represent the groundwater contribution to baseflow (GRDM database, DWS 2013).

9. Groundwater Resource Directed Measures

In the study, Quaternary catchment boundaries and geohydrological response units served as the primary delineation criteria for groundwater resource units, crucial for determining aquifer reserves and exploitation potential. To evaluate the current status of groundwater resources in our study area, the concept of sustainable use was employed, applying the notion of water stress in terms of water quantity, as outlined by Parsons and Wentzel (2007).

9.1 Reserve determination

According to the WARMS (Water Use Authorization and Registration Management System; November 2023), applications listed as a registered Water use status in regulation with the National Water Act, calculates to a **total volume of 34 153 944m^3/annum**, **within the A24J quaternary catchment (this total includes the status "lawful" as well as "lawfulness still to be determined" for both surface and groundwater).**

The total volume of **groundwater applications (lawful) within the A24J quaternary catchment area, accounts to 12 900 611.01m3/annum. A total volume of river/surface applications (lawful) accounts to 13 892 416m3/annum.**

Registered applications (status "lawful" & "lawfulness still to be determined") within the **GRU were calculated to a total volume of 18.2Mm^3/annum (groundwater and river/stream water allocations**). Registrations of rivers/streams accounts to a total volume of 10.266Mm^3/annum (status "lawful" & "lawfulness still to be determined"). **Registered groundwater applications** (status "lawful" & "lawfulness still to be determined") **within the GRU account to 7 933 313m^3/annum**.

Table 3: Summary of WARMS registered groundwater application data (Jan 2023)

Area	Lawful Water use (Mm^3) (Groundwater)	Lawfulness still to be determined (Mm^3) (Groundwater)	Total volume of registered applications (Mm^3)
A24J	12.9	2.644	15.545
GRU	7.156	0.78	7.933

Desktop study results indicates the quaternary catchment within which the study area falls (A24J quaternary catchment), comprises 2 516km^2 with an estimated mean annual precipitation of 564mm/annum, an estimated baseflow of 0.1Mm^3/annum (GRDM database 2013) and a recharge of 3% of MAP.

- ✓ ***Total recharge value*** **calculation for A24J catchment area:**

Area x rainfall x recharge value

2 516km^2 x 564mm x 3% = **42.57Mm^3/annum**

- ✓ ***Total recharge value*** **calculation for the GRU (Geohydrological response unit,** Appendix 1; MAP 9)**:**

Area x rainfall x recharge value

1312km^2 x 564mm x 3% **= 22.199Mm^3/annum**

Considering the application volume of 1 171 385m^3/annum, this volume entails 5.3% of the total recharge to the GRU.

- ✓ To *determine **the reserve*** **in the GRU:**

Recharge - (Baseflow + Current registered abstraction (Groundwater WARMS - Lawfull as well as unverified registrations)

22.199Mm^3 - (0.0521Mm^3/annum + 7.933Mm^3) = **13.744Mm^3/annum)**

- ✓ To *determine **the reserve*** **in the A24J quaternary catchment area:**

Recharge - (Baseflow + Current registered abstraction (Groundwater WARMS Lawfull as well as unverified registrations)

42.57Mm^3 - (0.1Mm^3/annum + 15.545Mm^3) = **26.925Mm^3/annum)**

Resulting in a total remaining groundwater reserve volume of 13.744Mm^3/annum within the boundaries of the GRU (Geohydrological response unit) and a total remaining

groundwater reserve volume of 26.925Mm^3/annum within the A24J quaternary catchment area.

The client's application volume of 1 171 408m^3/annum therefore constitutes 8.5% of the remaining reserve volume within the GRU.

TABLE 4: SUMMARY OF RECHARGE AND RESERVE CALCULATIONS

Groundwater UNIT	Area (km^2)	Average Annual rainfall (mm)	Baseflow (Mm^3/annum)	WARMS registrations total (Gwater) (Mm^3)	Calculated Recharge (Mm^3/annum)	Calculated Reserve (Mm^3/annum)
A24J quaternary catchment	2516	564	0.1	15.545	42.57	26.925
GRU	1312	564	0.0521	7.933	22.199	13.744

9.2 Safe yield calculation

Quoting J.L. Jolly (GH3495; Dec 1986); “The safe yield of an aquifer is defined as the maximum continuous supply which can be obtaind from an aquifer without causing any undesirable effects.”

For our GRU the safe yield would be the yield resulting for conditions when the abstraction equals the recharge. For MAP conditions (564m) and a 3% rainfall recharge. The total recharge volume to the GRU would be 22.199Mm^3/annum. If a 5% irrigation return flow is taken into account the volume of groundwater abstaction could be increased to a safe yield of 23.35Mm^3/annum for the Groundwater Recharge Unit (GRU).

Considering the total volume of registered groundwater applications of the WARMS data within our GRU (7.933Mm^3/annum; “Lawful use” as well as “Lawfulness still to be determined”), adding our application volume of 1.171Mm^3/annum, the total volume accounts to 9.104Mm^3/annum. Considering the safe yield calculation of 23.35Mm^3/annum, the total registered groundwater abstraction volume of 9.104Mm^3/annum falls well within the safe yield calculations.

This volume represents a firm yield calculation of 740L/s, which closely aligns with the Aquifer firm yield calculation reported for the A24J quaternary catchment area in the WRC (2012) study, which was calculated at 788L/s.

Emphasis will still be on detailed aquifer management and monitoring to prevent long term dewatering of the GRU.

9.3 Aquifer management classification

The aquifer(s) underlying the project area were classified in accordance with "A South African Aquifer System Management Classification, December 1995" by Parsons. Classification has been done in accordance with the definitions for Aquifer System Management Classes defined Table 5:

TABLE 5: DEFINITIONS OF AQUIFER SYSTEM MANAGEMENT CLASSES (PARSONS, WRC REPORT KV117/98)

Definitions of Aquifer System Management classes	
Sole Source Aquifer System	An aquifer which is used to supply 50% of more of domestic water for a given area, and for which there are no reasonably available alternative sources should the aquifer be impacted upon or deplete. 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 (less than 150mS/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 both for local supplies and in supplying base flow for rivers.
Non-Aquifer System	These are formations with negligible permeability that are generally regarded as not containing groundwater in exploitable quantities. Water quality may also be such that it renders the aquifer as unusable. However, groundwater flow through such rocks, although imperceptible, does take place and needs to be considered when assessing the risk associated with persistent pollutants.
Special Aquifer System	An aquifer designated as such by the Minister of Water Affairs, after due process

Due to the significant role that agriculture plays in the socio-economic development of the Limpopo Province, ensuring the sustainability of the groundwater source is crucial for the province's future. Based on the available information it can be concluded that the aquifer system in the study area can be classified as a "Major Aquifer System".

In order to achieve the **Groundwater Quality Management Index (GQM)**; a point scoring system, making use of the Aquifer Management Classification as well as the Aquifer Vulnerability (Heading 7) was used. The level of groundwater protection based on the Groundwater Quality Management Classification calculates to a "High level" of protection.

GQM Index = Aquifer System Management X Aquifer Vulnerability

These results emphasize the importance of safeguarding of the dolomitic aquifer system and limiting the risk to the environment, in terms of both available abstraction volumes and water quality.

9.4 Aquifer Exploitation Potential

To effectively manage the groundwater resource, especially within the context of this specific groundwater project, it is crucial to quantify the resource by determining the storage capacity, recharge rates, as well as allocated and actual abstraction from the groundwater aquifer.

The GRII dataset of 2005 will enable us to calculate an additional estimated **aquifer exploitation potential** volume. Quaternary catchment boundaries were used as the primary delineation of groundwater resource units in our study area.

The mean annual precipitation and annual recharge figures of quaternary catchment area A24J are presented in Table 6 as derived from the GRII dataset (2005).

TABLE 6: RAINFALL AND ANNUAL RECHARGE FIGURES FOR THE QUATERNARY CATCHMENT AREA (GRII)

Area of Quaternary catchment A24J	2 516km^2
Mean Annual Rainfall	564mm
Annual Recharge	10-25mm
Annual Recharge (%)	3%
Utilisable groundwater exploitation potential (dry season)	8 182 300m^3/km^2/annum
Utilisable groundwater exploitation potential (wet season)	11 322 200m^3/km^2/annum
UGEP for GRU 1312km^2 (dry season) **UGEP for GRU 1312km^2 (wet season)**	10 735Mm^3/annum 14 854Mm^3/annum
UGEP for 1.34km^2 crop development (dry season) **UGEP for 1.34km^2 crop development (wet season)**	10.964Mm^3/annum 15.171Mm^3/annum

For the 134 hectares (1.34km^2) of the total planned grain crop development, relevant to this application, a **volume of 10.964Mm^3/annum is exploitable during the dry season. The applicable volume of 1 171 385m^3/annum therefore pertain 10.7% of the total utilisable groundwater exploitation potential set out for the planned crop development area (134ha) under the GRAII dataset (2005), during the dry season.**

Note should be taken that the total area of the full title deed pertains an area of 172.9ha (1.73km^2**).**

9.5 Stress Index Classification

The abstraction volumes of other users and already allocated water use licences within the quaternary catchment area, will determine the final volume of abstraction allocated to the client.

For the purpose of the stress index, the study classification will focus on the 1312km^2 Geohydrological Response/Resource Unit (GRU) outlined in Appendix A: MAP 9. Additionally, the total abstraction volume from boreholes within a 2km radius area detailed in Appendix A: Map 4, pertinent to this application, will also be considered.

The total volume of groundwater abstraction within these two areas was calculated from the existing, listed and registered WARMS records (status “lawful” as well as “lawfulness still to be determined”).

The stress index reads:

$$\text{Stress Index} = \frac{\text{Groundwater Abstraction}}{\text{Recharge} - \text{Baseflow}}$$

The figures used for determining the level of stress within the GRU, are represented in the following table.

Quantification	1312km^2(area of GRU)
Mean Annual Precipitation	564mm (GRII value)
Total recharge to GRU	22.199Mm^3 (GRII value)
Baseflow*	0.0521Mm^3/annum
Approx total abstraction	7.933Mm^3/annum+ 1.171Mm^3(application volume)

*Estimated using GRDM (DWS 2013)

The present status category was then assigned according to the stress-index and categories described in Figure 7.

Table 4-1 Guide for determining the level of stress of a groundwater resource unit, based on abstraction, baseflow and recharge (modified after Parsons and Wentzel, 2007).

PRESENT STATUS CATEGORY	DESCRIPTION	STRESS INDEX (groundwater abstraction / recharge – baseflow)
A	Unstressed or low levels of stress	< 0.05
B		0.05-0.20
C	Moderate levels of stress	0.20-0.50
D		0.50-0.75
E	Stressed	0.75-0.95
F	Critically stressed	> 0.95

FIGURE 7: REFERENCE WRC REPORT KV/236/10

With a result of 0.4, assuming all existing WARMS groundwater application abstraction volumes are verified and allocated, the GRU will be under a "moderate level of stress". (Category C/D).

*Considering the total planned groundwater abstraction volume (1 552 611m^3/annum) within the 2km radius area around our study area, the stress index classification will be in a **critically stressed** category.*

*However, considering the possibility earlier discussed in this report of **very good potential recharge from the karst aquifers** and the results of the aquifer testing, these high-yielding boreholes could be justified.*

Implementing a borehole management and monitoring plan at all eight tested boreholes as outlined in Heading 14 in this report as well as implementing further detailed actions described in Appendix C, will be critical in managing the sustainability of the regional groundwater resource.

9.6 Radius of influence

Recent SENTINEL satellite images (Dated Aug 2023) (See Appendix A: MAP 13), confirm large scale agricultural development currently taking place in the regional study area, specifically along the banks of the Crocodile River, upstream as well as downstream from our study area.

The eight boreholes relevant to this application are located within an approximate 800m radius from each other.

The eight production boreholes were tested for a duration of 24 hours. Over the duration of 24 hours constant test, no influence could be detected in any of the monitoring boreholes, other than very little response (10cm) at BH5, during the constant test at BH6.

Influences over long-term periods were however considered in the final optimum recommended yields.

Only six of the eight boreholes will be relevant to this application volume abstraction.

Furthermore, the transmissivity and abstraction yield at the closest two production boreholes were taken into account during the calculation of each production borehole's optimum yield calculation. Aquifer characteristics of monitoring boreholes were therefore taken into consideration in the final calculations. Optimum initial long-term yields were adapted, and more conservative abstraction yields were recommended.

9.7 Delineation of Borehole protection zone

To estimate the zone of influence or zone of contribution of the planned abstraction volume from the production boreholes, on any nearby groundwater source, or the potential of a pollution source influencing the production boreholes, a modified version of the Cooper-Jacob method will be used to determine the protection zone and extent of the fracture. (Refer: *Manual on pumping test analysis in fractured-rock aquifers, van Tonder. 2001)* Although we are abstracting water from a karst aquifer, these calculations could still be relevant making use of the correct estimated aquifer characteristic.

Modified Cooper-Jacob Equation:

Set s = 0

$$r = 1.5\left(\frac{\sqrt{Tt}}{S}\right)$$

Where: s - final drawdown during the pump testing (m)

Q - pumping rate (m^3/day)

T - Transmissivity (m^2/day)

t – time(day)

r – radial distance from the pumping borehole (m)

S – Storitivity (-)

To calculate a qualified estimation of the extent of the fracture/cavity, the Transmissivity and Storage values of the fracture are required. Making use of the early time pump test data, an estimation of the horizontal or vertical extent of the weathered/broken/fractured compact carbonate aquifer, was calculated at all tested boreholes (Refer Table 7).

TABLE 7: SUMMARY OF BOREHOLE PROTECTION ZONE CALCULATIONS

Borehole nr	Average radius of (m) fracture/cavity/aquifer	Standard deviation (m)	Estimated borehole catchment area (m)
BH1	614	302	1677
BH2	507	222	1793
BH3	241	95	1793
BH4	217	85	1677
BH5	296	119	1553
BH6	333	136	1268
BH7	205	80	1677
BH8	202	79	1553
Median	269m	107m	1 677m

Results of these calculations revealed the extent of the aquifer within the complicated hydrogeological system, as an area around all boreholes of standard deviation of 107m and a median value of 269m. It will therefore be encouraged that an area of radius of 300m around each production borehole be protected and any further drilling within this radius should be discouraged. *Where existing boreholes are already within this calculated radius, a strict management and monitoring plan with very conservative sustainable yields, as has already been in cooperated in the optimum sustainable yield calculations, are to be implemented.*

Other than the relevant production boreholes, no other neighbouring boreholes are located within the radius of influence of the production boreholes as depicted in Figure 8.

Van Tonder also suggested using the recharge and abstraction rate, to estimate the borehole catchment area. The results of these calculations revealed the borehole catchment area around all boreholes with median radius 1 677m. Therefor protecting an area of radius 2km around each borehole from any hazardous chemical elements or any other pollution source is further recommended.

From Figure 9 depicting all lawful users within a 2km radius from the relevant production boreholes, four other lawful users were identified.

Ensuring no further groundwater source development, other than the existing resources already in place, as well as preventing any pollution source within a radius of 2km, will assist in preventing pollution and dewatering of the relevant aquifer system. This further emphasises the importance of a well-managed groundwater monitoring system.

By implementing **a borehole management plan** as described in paragraph 14 in this report, it can be assumed with a reasonable degree of certainty that the conservative, recommended sustainable abstraction volumes derived from the pump test data, when managed correctly, will have little to no effect on the groundwater levels.

FIGURE 8: RADIUS OF INFLUENCE RELEVANT TO PRODUCTION BOREHOLES

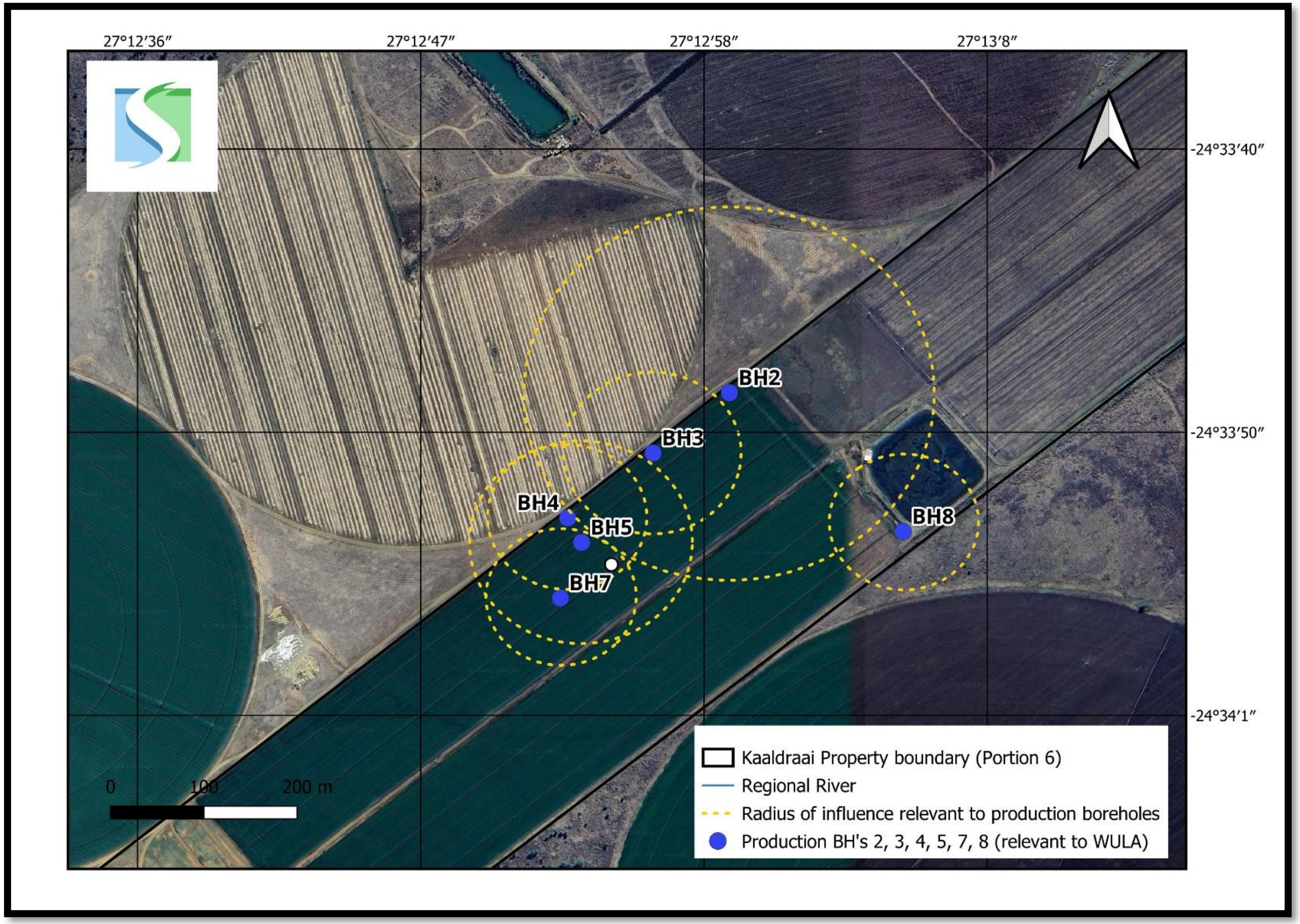
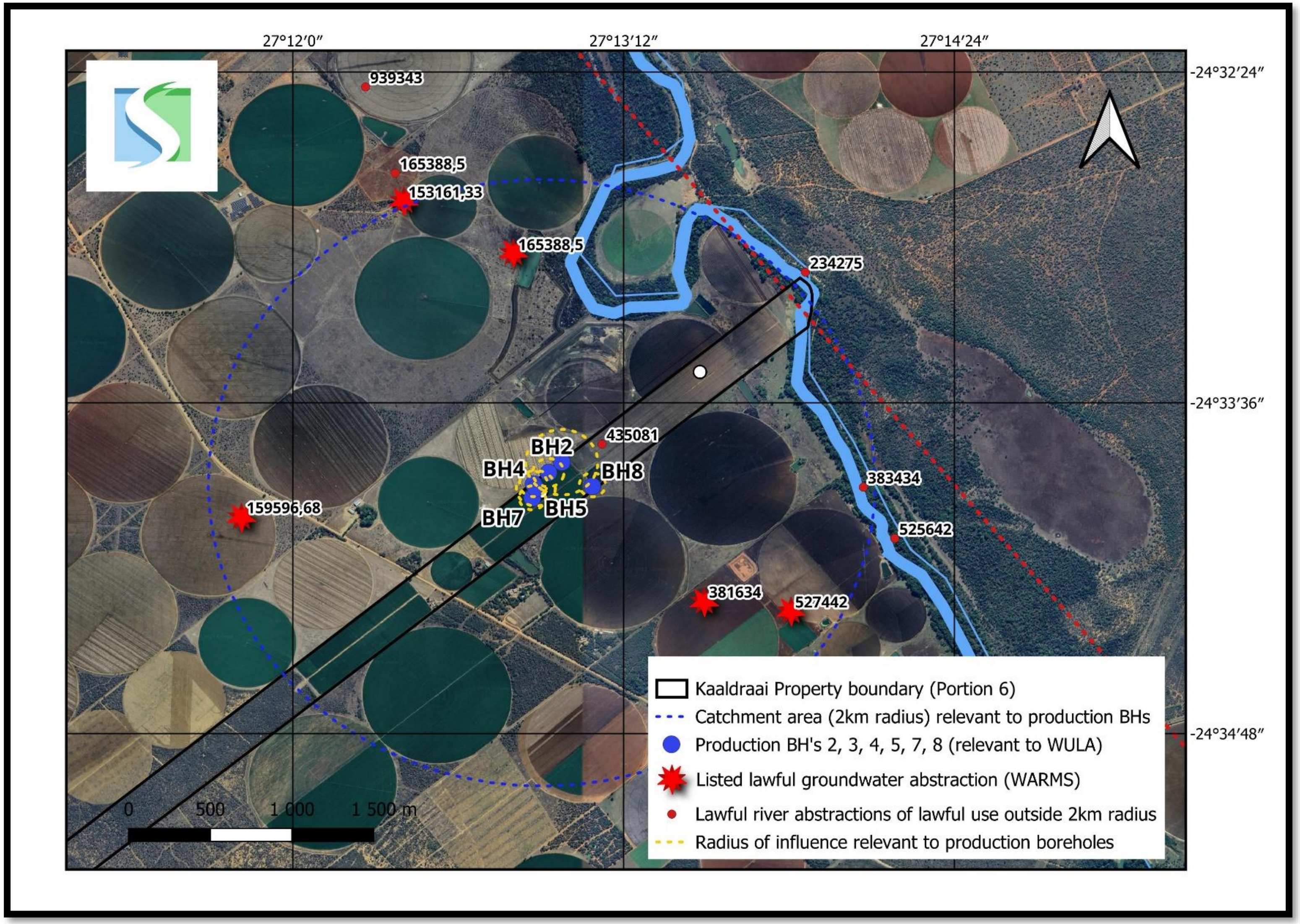


FIGURE 9: CATCHMENT AREA (2KM) RELEVANT TO PRODUCTION BOREHOLES



10. Drilling Summary

A summary of all available borehole information is provided in Table 8.

TABLE 8: BOREHOLE INFORMATION

Borehole number	Latitude	Longitude	Depth (mbgl)	SWL (mbgl)	Casing diameter (mm)	Casing estimated depth(m)
BH1	24°33'29.27"S	27°13'28.63"E	110	7.07	254	18 (4mm)
BH2	24°33'48.90"S	27°12'58.55"E	110	8.18	254	18 (4mm)
BH3	24°33'51.20"S	27°12'55.66"E	110	9.5	254	18 (4mm)
BH4	24°33'53.67"S	27°12'52.41"E	110	9	254	18 (4mm)
BH5	24°33'54.60"S	27°12'52.93"E	110	8.54	254	18 (4mm)
BH6	24°33'55.44"S	27°12'54.07"E	110	9.1	254	18 (4mm)
BH7	24°33'56.72"S	27°12'52.13"E	110	8.67	254	18 (4mm)
BH8	24°33'54.18"S	27°13'5.20"E	110	10.09	254	18 (4mm)

All the production boreholes were drilled by previous farm owners, and no information could be found to shed light on the underlying rock formation.

11. Pump test methodology

Testing was completed to the specifications of the Department of Water and Sanitation as described in the document, the Minimum Standards and Guidelines for Groundwater Resource Development for the Community Water Supply and Sanitation Programme. (1997).

Twenty-four-hour constant discharge tests were undertaken at all relevant boreholes making use of the farmer’s existing pump in each borehole, as to save costs to the farmer. Eight (8) boreholes in total were tested.

11.1 Aquifer characteristics calculated from pump test results

Although the 1: 250 000 Thabazimbi 2426 Geology map depicts the geology of this area as quaternary alluvial deposits, the author suspects that the groundwater sources in the tested aquifers, could be from a dual source, i.e. alluvial deposits and karst aquifers. The complexity of the underlying aquifers was discussed previously under Heading 4.1 in this report.

The response in all drawdown levels at the start of the tests, were rapid with stabilizing of the drawdown levels, indicating a consistent hydraulic pressure within the boreholes. In contrast, in alluvial aquifers, water level drawdown during pumping is usually more gradual.

Rapid declining at the start of the test, is typical of a karst aquifer due to the presence of conduits and fractures that provide high-conductivity pathways for groundwater flow, establishing the critical level within each production borehole. This make it challenging to estimate aquifer parameters accurately.

It is recommended that Borehole 1 (550m from the Crocodile river) not be implemented as a production borehole relevant to the WULA application due to its proximity to the river.

During the constant testing at all relevant boreholes water was abstracted from the production boreholes at constant abstraction yields varying from 19.5l/s up to 25.4l/s for a duration of 24hours.

In all eight tested boreholes, an almost immediate full recovery of drawdown levels was observed after the 24-hour pump period.

Influence in drawdown levels of monitoring boreholes during the constant test was minimal. Borehole 5 experienced a total drop of 10cm in static water level during the constant test at Borehole 6, only 40m away.

TABLE 9: TRANSMISSIVITY VALUES OF TESTED BOREHOLES

Borehole number	Transmissivity interpreted from pumptest data
BH1	In the order of 1000
BH2	In the order of 1000
BH3	In the order of 1000
BH4	In the order of 500
BH5	In the order of 800
BH6	In the order of 1000
BH7	In the order of 1000
BH8	In the order of 1000

11.2 Optimum yield calculation and parameters used

To estimate optimum pumping rates, pumping schedules and aquifer parameters, the pump test data were analysed by means of the FC method. From the constant discharge test, aquifer characteristics (Transmissivity and Storage) were calculated from the results of the drawdown and recovery levels during the testing process. These characteristics, as well as the close proximity of the boreholes from each other were also taken into consideration in the final optimum yield recommendation of each tested borehole. The FC method was approved by DWS and developed by the Institute for Groundwater Studies to calculate a sustainable abstraction yield.

Although the software is primarily designed for fractured aquifers, these calculations could still be relevant making use of the correct estimated aquifer characteristic.

The following parameters were implemented for all eight tested boreholes within the FC-analysis:

- Zero annual effective recharge
- Data was extrapolated over a period of two years
- One no-flow boundary at 200m
- the Transmissivity, distance from the production borehole as well as abstraction yield from the closest two nearby boreholes were taken into consideration in the calculation of the final optimum yield of each tested borehole

TABLE 10: RESULTS OF MONITORING BOREHOLES DURING TESTING

Tested borehole	Monitoring	Monitoring	Results
BH1	No monitoring		
BH2	BH3		No influence
BH3	BH2		No influence
BH4	BH3	BH5	No influence
BH5	BH3	BH4	No influence
BH6	BH5	BH7	BH5 10cm
BH7	BH5	BH6	No influence
BH8	BH2	BH3	No influence

It is important to note that a very conservative approach was followed to calculate the recharge and firm yield volumes; the actual volumes are believed to be much higher than the calculated volumes.

The aim of the recommended maximum safe yield is to prevent the waterlevel from drawing down more than 2-3m and potentially dewatering the cavity at approximately 11m depth.

11.3 Summary of sustainable long term recommended yields

According to the results of the pump tests, the following long-term optimum yields are recommended for the six production boreholes (BH 2,3,4,5,7 and 8) relevant to this groundwater application (Table 11).

In recommending safe long-term yields within karst aquifers, utmost caution is exercised to avoid excessive dewatering of the cavities, which could lead to the potential collapse of the aquifer. Therefore, in all the boreholes tested, the primary objective of the recommended maximum safe yields was to ensure that water levels did not drop down by more than 2-3 meters. Critical levels within these tested boreholes were identified at depths ranging from 11 to 14 meters below ground level.

The recommended long-term yields represent the scenario where the six boreholes are in production for 24 hours per day and the influence of the nearby boreholes were considered.

It is recommended to designate BH1 and BH6 as permanent monitoring boreholes as they will constitute an integral part of the groundwater monitoring program.

The total sustainable yield from the six relevant boreholes calculates to 1 103 760m^3/annum. The application volume relevant to this application is 1 171 385m^3/annum.

TABLE 11: OPTIMUM LONG-TERM RECOMMENDATIONS AFTER ANALYSIS OF TEST RESULTS

Borehole nr	BH1 (Monitoring bh)	BH2
Recommended pumping rate (l/s)	7L/s (25 200L/h)	6L/s (21 600L/h)
Pumping duration (Duty cycle) (hrs)	24 hrs	24 hrs
Critical Water level (mgbl)	11m	11m
Dynamic water level (mbgl)	8m	9.5m
Volume per day (m^3)	604.8m^3/day (220 752m^3/annum)	518.4m^3/day (189 216m^3/annum)
Rest water level (mbgl)	7.07m	8.18m
Borehole depth (mbgl)	110m	110m
Recommended pump depth (mbgl)	12m	12m
Available drawdown used (m)	4m	4m

Borehole nr	BH3	BH4
Recommended pumping rate (l/s)	7L/s (25 200L/h)	6L/s (21 600L/h)
Pumping duration (Duty cycle) (hrs)	24 hrs	24 hrs
Critical Water level (mgbl)	12m	13m
Dynamic water level (mbgl)	11m	11m
Volume per day (m^3)	604.8m^3/day (220 752m^3/annum)	518.4m^3/day (189 216m^3/annum)
Rest water level (mbgl)	9.5m	9m
Borehole depth (mbgl)	110m	110m
Recommended pump depth (mbgl)	16m	16m
Available drawdown used (m)	7m	7m

Borehole nr	BH5	BH6 (Monitoring bh)
Recommended pumping rate (l/s)	5L/s (18 000L/h)	4 L/s (14 400L/h)
Pumping duration (Duty cycle) (hrs)	24 hrs	24 hrs
Critical Water level (mgbl)	12m	12m
Dynamic water level (mbgl)	10m	10m
Volume per day (m^3)	432m^3/day (157.7m^3/annum)	345.6m^3/day (126 144m^3/annum)
Rest water level (mbgl)	8.54m	9.1m
Borehole depth (mbgl)	110m	110m
Recommended pump depth (mbgl)	16m	16m
Available drawdown used (m)	7.5m	7m

Borehole nr	BH7	BH8
Recommended pumping rate (l/s)	6L/s (21 600L/h)	5 L/s (18 000L/h)
Pumping duration (Duty cycle) (hrs)	24 hrs	24 hrs
Critical Water level (mgbl)	12m	14m
Dynamic water level (mbgl)	10m	10m
Volume per day (m^3)	518.4m^3/day (189 216m^3/annum)	432m^3/day (157.7m^3/annum)
Rest water level (mbgl)	8.67m	10.09
Borehole depth (mbgl)	110m	110m
Recommended pump depth (mbgl)	16m	16m
Available drawdown used (m)	7m	6m

The following table is a summary of recommended 8-hour, 12-hour and 24-hour duty cycles for the production boreholes relevant to the application:

TABLE 12: RECOMMENDED PUMP DUTY CYCLE VARIATIONS

Borehole nr	BH2	BH3	BH4	BH5	BH7	BH8
24-hour duty cycle	6	7	6	5	6	5
12-hour duty cycle	9	10	9	7	9	7
8-hour duty cycle	11	12	11	9	11	9

12. Groundwater Quality

Water samples were collected by the testing contractor at each borehole during the late stages of the constant discharge test. The aim of sampling at this late stage of the test, will ensure a good representation of the quality of the deeper aquifer system.

These samples were analysed by Magalies Water Labs accredited testing Laboratories in Brits. The results of analysis (27 November 2023) have been compared to screening guidelines to assess the suitability for human consumption and agricultural use.

The chemistry results obtained have been classified according to the DWAF (1998) standards for domestic water. Table 13 enables an evaluation of the water quality with regards to the various parameters measured (DWAF, 1998). Table 14 presents the water quality results of each tested borehole, colour coded according to the DWAF drinking water assessment standards.

TABLE 13: WATER QUALITY ACCORDING TO DWS DRINKING WATER ASSESSMENT STANDARDS

Class	PH	EC mS/m	TDS mg/l	TH as CaCo3 mg/l	Ca mg/l	Fe mg/l	K mg/l	Mg mg/l	Mn mg/l	Na mg/l	F mg/l	Cl mg/l	N mg/l	SO_4 mg/l
Class 0	5-9.5	<70	<450	0-200	0-80	<0.5	<25	<30-70	<0.05	<100	<0.7	<100	<6	<100-200
Class 1	4.5-5 9.5-10	70-150	450-1000	200-300	80-150	0.5-1.0	25-50	70-100	0.05-0.1	100-200	0.7-1	100-200	6-10	200-400
Class 2	4-4.5 10-10.5	150-370	1000-2400	300-600	150-300	1.0-5.0	50-100	100-200	0.1-1	200-400	1-1.5	200-600	10-20	400-600
Class 3	3-4 10.5-11	370-520	2400-3400	>600	>300	5.0-10.0	100-500	200-400	1-5	400-1000	1.5-3.5	600-1200	20-40	600-1000
Class 4	<3 or >11	>520	>3400			>10	>500	>400	>5	>1000	>3.5	>1200	>40	>1000

Class 0: Ideal water quality. Suitable for lifetime use.

Class 1: Good water quality. Suitable for use, rare instances of negative effects.

Class 2: Marginal water quality-conditionally acceptable. Neg. effects may occur in some sensitive groups.

Class 3: Poor water quality. Unsuitable for use without treatment. Chronic effects may occur.

Class 4: Dangerous water quality, totally unsuitable for use. Acute effects may occur.

[Refer to Water quality analysis on the following page:

*** LSI – Langelier Saturation Index**

****SAR – Sodium Adsorption Ratio**

***** TCC – Total Coliforms Colilert]**

TABLE 14: WATER QUALITY RESULTS (MAGALIES WATER LABORATORY)

Parameter	**Units**	**RESULTS BH1**	**RESULTS BH2**	**RESULTS BH3**	**RESULTS BH4**	**RESULTS BH5**	**RESULTS BH6**	**RESULTS BH7**	**RESULTS BH8**	**SANS 241:2015**
pH	pH unit	6.98	7.06	6.91	7.04	6.88	7.26	6.95	7.16	5.0 – 9.7
Electrical Conductivity	mS/m	304	219	208	166	526	119	253	112	<=170
TDS	mg/l	1981	1421	1351	1080	3419	776	1641	728	<=1200
Total Alkalinity	mg $CaCO_3$/l	470	402	259	276	629	221	308	208	Not specified
HCO3	mg/l	573	490	315	336	767	270	375	250	Not specified
CO3	mg/l	282	241	155	165	377	132	184	123	Not specified
Chloride as Cl	mg/l Cl	715	371	421	299	1503	189	637	176	<150
Fluoride as F	mg F/l	0.34	0.08	0.4	0.32	0.59	0.59	0.56	0.47	<=1.5
Nitrate as N	mg N/l	30	26	21	16	46	12	25	18	10
Sulphate as SO_4	mg SO_4/l	148	114	88	78	222	86	91	95	<=250
Total Cadmium	µg Cd/l	0.94	1.1	0.91	0.61	1.6	0.66	0.29	0.98	<=3
Iron as Fe	µg Fe/l	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	<=300
Total Aluminium	µg Al/l	3.5	4.3	4	3.5	6.8	2.8	3.4	2.8	<=300
Manganese as Mn	µg Mn/l	1.9	<0.09	<0.09	<0.09	<0.09	<0.09	0.99	<0.09	<=100
Total Zinc	mg/l	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<=5
Calcium as Ca	mg Ca/l	187	142	124	107	279	61	149	59	Not specified
Total Cobalt	µg Co/l	12	8.0	9.7	6.9	11	7.5	11	5.7	<=500
Total Chromium	µg Cr/l	**49**	**60**	23	21	**55**	5.9	28	5.9	<=50
Total Copper	µg Cu/l	5.0	1.7	0.36	<0.01	3.6	0.88	0.85	<0.01	<=2000
Total Magnesium	mg/l Mg	95	79	80	67	122	55	89	52	Not specified
Total Nickel	µg Ni/l	<0.09	2.3	1.7	1.7	3.8	<0.09	0.15	<0.09	<=50
Potassium as K	mg K/l	2.6	2.4	1.7	1.9	2.9	2.1	1.9	2.0	No specified
Sodium as Na	mg Na/l	210	153	119	108	317	64	153	59	<=200
Total hardness	mg/l CaCO3	**857**	**681**	**638**	**542**	**1197**	**378**	739	361	Not specified
LSI*		**0.25**	**0.15**	**-0.2**	**-0.1**	**0.42**	**-0.3**	-0.06	-0.4	
SAR**	**Mg/L**	**S1:C4**	**S1:C4**	**S1:C4**	**S1:C3**	**S2:C4**	**S1:C3**	**S1:C4**	**S1:C3**	
E coli	colonies per 100ml	ND	ND	ND	ND	ND	ND	ND	ND	ND
TCC***	colonies per 100ml	**155**	ND	**1**	**114**	**1**	**6**	ND	5	<=10

12.1 Irrigation water classification

Irrigation water quality refers to the kind and number of salts present in the water and their effects on crop growth and development.

The **Langelier Saturation Index** was calculated for all the production boreholes.

- **Boreholes 3, 4, 6, 7 & 8** accounted for water that is undersaturated with respect to calcium carbonate. Undersaturated water tends to remove existing calcium carbonate protective coatings in pipelines and equipment. **Slightly corrosive but non-scale forming.**
- **Boreholes 1, 2 & 5** is considered balanced but pitting corrosion possible. The water is **slightly scale forming and corrosive.**
- Consideration of these factors is crucial in designing the irrigation system's infrastructure and selecting appropriate materials.

Sodium Adsorption Ratio results

The Sodium Adsorption Ratio (SAR) at all the tested boreholes classified as low to medium sodium hazard water (S1/S2), and high to very high salinity water hazard (C3/C4).

- **Salinity hazard**

Salinity within all boreholes was classified as either high (C3) or very high-salinity water (C4). This water can not be used on soils with restricted drainage and in general not suitable for irrigation under ordinary conditions.

- **Sodium hazard**

In all tested boreholes, the sodium hazard was classified as a low-medium sodium water (S1/S2). This water can be used for irrigation on almost all soils with little danger of developing harmful levels of sodium.

Within **Borehole 5,** the groundwater classified as a medium-sodium water (S2). This water may cause an alkalinity problem in fine-textured soils under low-leaching conditions. It can be used on coarse textured soils with good permeability.

12.2 Chemical diagrams

The Piper chemical diagram was used to represent the chemical characterisation of the tested boreholes.

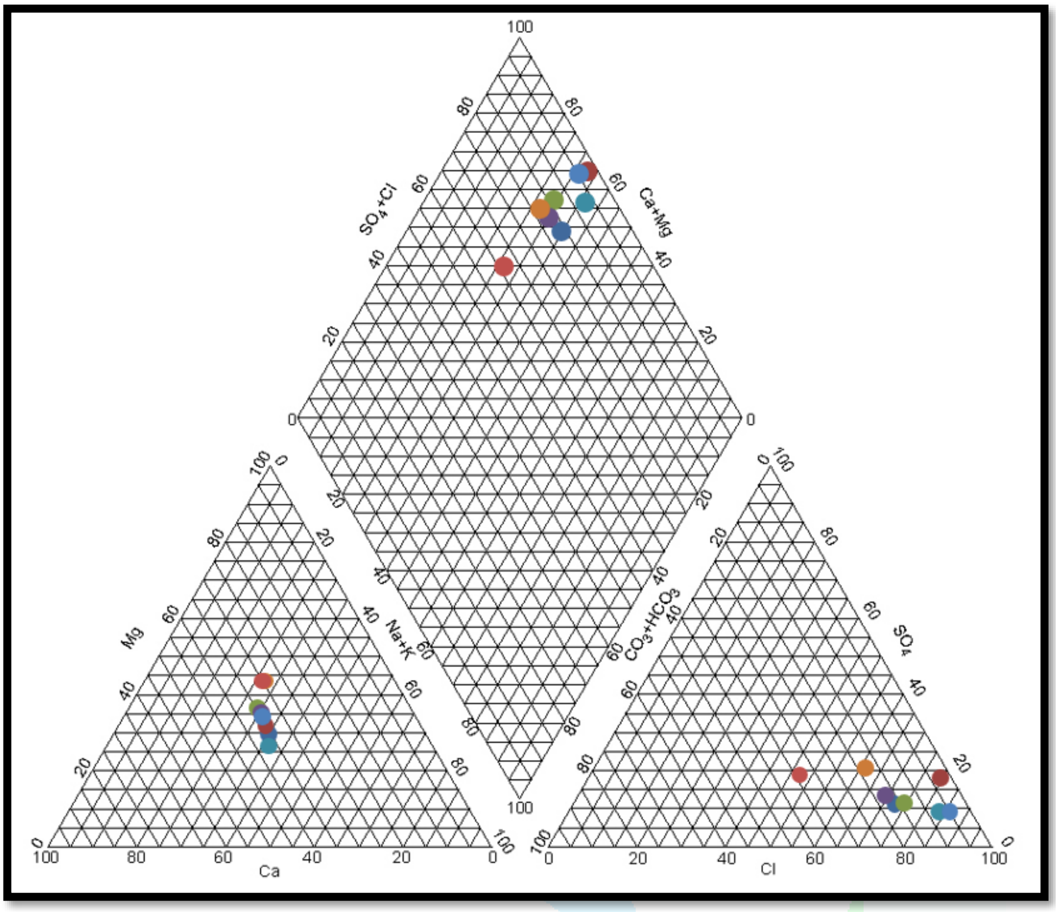


FIGURE 10: PIPER DIAGRAM REPRESENTING THE CHEMICAL RESULT OF ALL EIGHT BOREHOLES

- In Figure 10 the chemistry of all eight samples have been plotted on a tri-linear diagram known as a **Piper diagram.** This diagram indicates the distribution of cations and anions in separate triangles and then a combination of the chemistry in the central diamond. **Groundwater classified as a dominantly calcium-magnesium-chloride water type** (Classified Type A - Dominant cations Ca^{2+} and or Mg^{2+}, dominant anions Cl_2^- and or SO_4^{-2}). The water seems to be of an unpolluted, chloride enriched groundwater resource.

- The **Stiff Diagram** (Figure 11) is a graphical representation of the relative concentrations of the cations (positive ions) and anions (negative ions). This diagram shows concentrations of cations and anions relative to each other (not as a percentage as with Piper) and direct reference can be made to specific salts in the water.
- From the shape of the Stiff diagram the major ions present in the water can be compared. It's evident that the groundwater pertaining to our aquifer is predominantly influenced by Chloride and Nitrate anions, exhibiting a well-balanced concentration of cations.
- The original Magalies Water Labs results for all eight boreholes are attached in Appendix D.

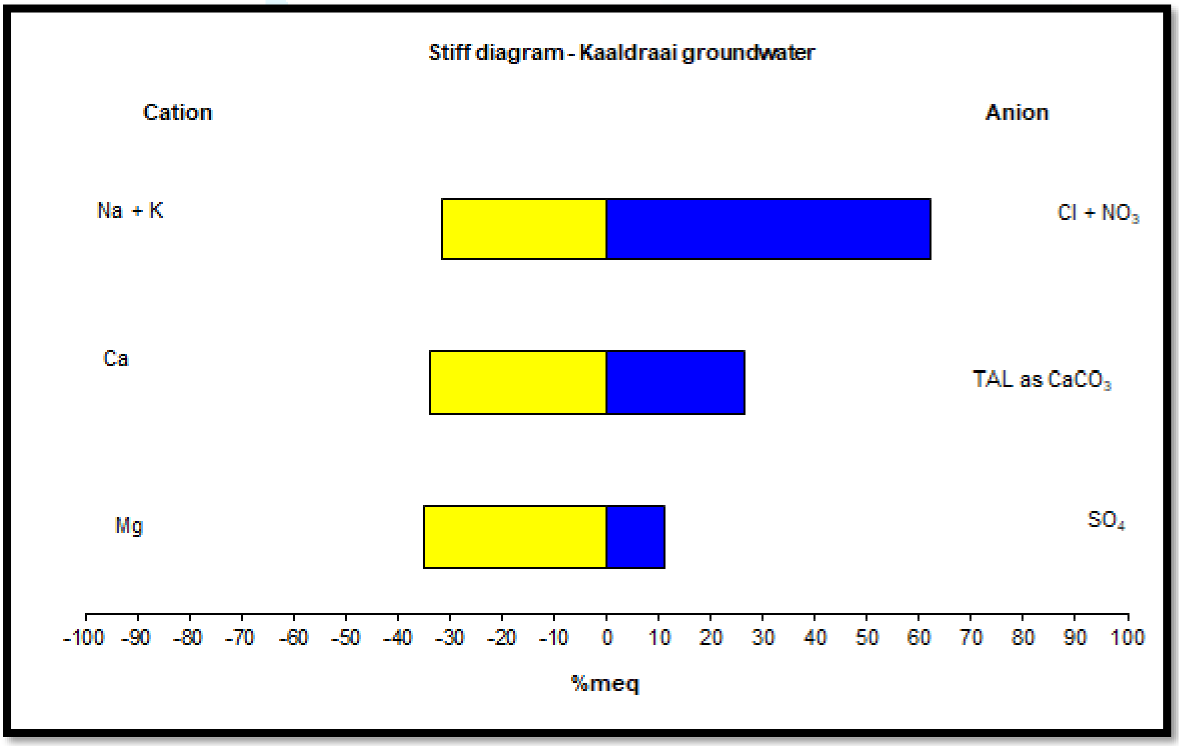


FIGURE 11: STIFF DIAGRAM

12.3 Conclusion of the chemical results

All determinants are compared according to SANS241 (2011) Drinking Water Standards for the domestic:

- **The water quality analysis within the Kaaldraai farm boundary is dominated by elevated Chloride (Cl) and Nitrate (as N) and slightly elevated calcium (Ca), magnesium (Mg) and sodium (Na) values in boreholes 1,2,5 & 7.**
- In terms of water quality for domestic use, boreholes 3, 4, 6 & 8 classify as **good to marginal water quality** relevant to all constituents.
- **Boreholes 1, 2, & 7** are classified as poor water quality, unsuitable for domestic use without treatment (Class 3) due to the high elevated Chloride (Cl) and Nitrate (N) constituents.
- Borehole 5 classify as, dangerous water quality, **totally unsuitable for domestic use** due to the Chloride (Cl) and Nitrate (as N) parameters classified as a Class 4, as well as dangerously high EC values.
- Elevated Nitrate as N values correlates with the elevated nitrate(N) values found in the Swazian Rock formation.
- **The elevated levels of Chloride and Nitrate could serve as indications of diverse groundwater resources recharging these aquifers.**
- **The Piper diagram categorizes all groundwater as calcium-magnesium-chloride water type (Type A), potentially supporting the theory of the groundwater originating from the dolomites in the mountainous regions. This inference aligns with the depiction of numerous fault structures on the 1:250,000 geological map (2426 Thabazimbi) showcased in MAP 6 of Appendix A.**
- **Elevated Chromium (Cr)** values in boreholes 1, 2 and could only be explained by the Chrome rich ore deposits found in the regional area. This could further motivate the complexity of the underlying rock formations. The source of the elevate Cr value needs further detailed study which this report does not cover.
- **The bacterial count** (TCC) within production boreholes 1 & 4 exceed recommended domestic standards. Contamination during the sampling process, could explain these results. Because of the results of the bacterial count, this water is not suitable for

domestic use before treatment. A retest will have to confirm the bacterial count results.

- In **terms of agricultural use, Boreholes 3, 4, 6, 7, and 8 are anticipated to exhibit slight corrosiveness without scale formation. Conversely, Boreholes 1, 2, and 5 are expected to be slightly scale-forming and corrosive.** These factors need to be considered in the infrastructure design and layout.
- The SAR results reveal a very high salinity and low-sodium hazard.

13. Risk Assessment

The risk assessment includes the identification and rating of the potential risks associated with the groundwater abstraction at Kaaldraai KQ 321 (Portion 6) and any proposed mitigation measures where possible.

The activity related to the WULA relates to the abstraction of groundwater from six (6) boreholes for agricultural use on this property. There are two potential impacts associated with the groundwater abstraction: the risk of depletion of the groundwater due to *over-abstraction* and the risk of *groundwater quality deterioration* as a result of over-abstraction. These will be discussed separately below.

13.1 Depletion of the Groundwater Resource

Over-abstraction of groundwater from these boreholes is likely to lead to depletion of the water levels in the area over time. This can cause damage to the aquifer and might impact on neighbouring groundwater users that are reliant on the same source of water. All six (6) boreholes have been tested according to SANS 10299_4-2003 and the total sustainable volume of abstraction has been determined to 1 103 760m^3/annum.

Groundwater monitoring is recommended to ensure that groundwater abstraction is sustainable. The monitoring programme will indicate whether the groundwater resource is impacted and mitigation measures can be instituted before long term impacts occur.

Groundwater abstraction from the six (6) production boreholes should take place according to the **borehole management plan** (Paragraph 14), with weekly groundwater level and flow meter readings taken at the boreholes and stored in central database for analysis and interpretation.

It is recommended to designate BH1 and BH6 as permanent monitoring boreholes as they will constitute an integral part of the groundwater monitoring program.

Mitigation for over-abstraction would be reduction in abstraction.

Following the recommended monitoring and managing plan as explained in Paragraph 14 as well as laid out in Appendix C, the depletion of the groundwater resource as a result of over-abstraction is highly unlikely.

To ensure continuity of water supply, it is recommended that water tanks/surface dams/balancing dams be used for storage of groundwater.

13.2 Groundwater Quality Deterioration

Over-abstraction of groundwater from the boreholes can potentially draw poorer water quality from the nearby environment into the borehole. This is likely to affect the groundwater quality in the area in general and might affect the supply in other boreholes within the interconnected aquifers.

Groundwater quality monitoring at regular periods is recommended to ensure that groundwater abstraction is sustainable. The quality monitoring will be a direct indication whether the groundwater resource is impacted by a surface contamination source. Mitigation for over-abstraction would be reduction in abstraction.

As proven in this report, the groundwater abstraction required is well within the sustainable supply of the aquifer and reserve resources within the GRU as well as quaternary catchment area. Negative quality impact is therefore expected to be highly unlikely.

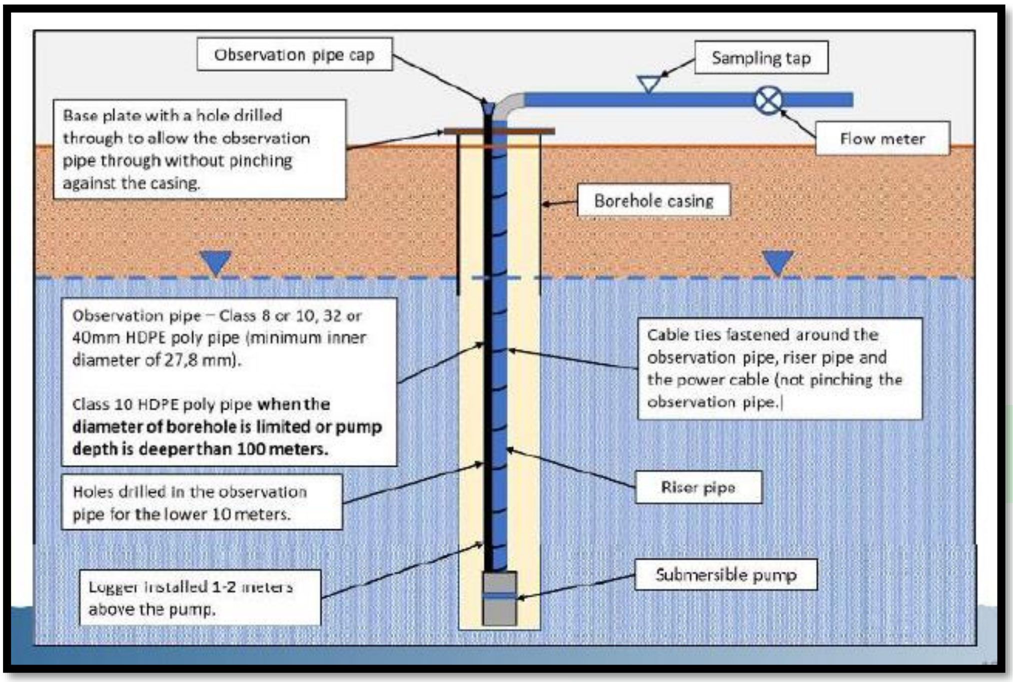


FIGURE 12: MONITORING COMPLIANCE

14. Environmental Management and Groundwater Monitoring Plan

The management of the above potential impacts will include monitoring and recommending the following actions:

- The production boreholes should be installed with piezometer (dipper tube), flow meter and take off tap in the riser pipe for groundwater sampling (See Figure 12).
- *Groundwater levels* can be measured within the well, and the pump programmed to shut off automatically if the water goes below the critical level (Table 15).
- **The two boreholes not relevant to this application (BH 1 & BH6) is recommended to form part of the groundwater monitoring plan.**

TABLE 15: SUMMARY OF CRITICAL WATER LEVELS IN ALL TESTED BOREHOLES

Borehole nr	Critical level (mbgl)	Recommended pump installation depth (m)
BH2	11m	12m
BH3	12m	16m
BH4	13m	16m
BH5	12m	16m
BH7	12m	16m
BH8	12m	16m

- *In-line meters:* Specific conductivity can be monitored using an in-line conductivity meter installed in the discharge line, including features like an automated shut off if the electrical conductivity goes above 200-250mS/m.
- The daily quantity of water taken from all production boreholes must be metered or gauged and the total recorded at the last day of each month.
- Water samples must be collected at both production boreholes on a quarterly basis and submitted to a SANAS accredited laboratory for analysis. The data, times, and monitoring point in respect of each sample taken shall be recorded together with the results of the analysis.

- Dedicated monitoring personnel need to ensure that all monitoring equipment are in working order and maintained to ensure the consistency of data collection which ultimately enables the efficient management of the groundwater resource.
- Record and track the water quality changes and water level data over time. It is recommended that a geohydrologist review the above information to ensure optimal groundwater abstraction and management control (See example of monitoring sheet in Appendix E).
- *Water metering* is recommended to be installed to assists with detecting uncontrolled leaks.
- Should it become evident from the monitoring program that pollution of the groundwater or anomalous lowering in static water level occur, *corrective and remedial actions* should be implemented immediately.

TABLE 16: SUMMARY OF MONITORING PROGRAMME REQUIREMENTS

Class	Parameter	Frequency	Motivation
Physical	Static groundwater levels	Weekly	*Time dependant data is required to understand the regional groundwater flow dynamics. *A lowering in the static water levels may indicate that the aquifer is utilised in an unsustainable way and abstraction rates need to be decreased. *Conditions of the Water Use Licence
	Groundwater abstraction volumes	Weekly	*Calculate monthly & annual abstraction volumes. *Conditions of the Water Use Licence.
Chemical	Major ions and trace elements: SA Water quality guideline	Bi-annually	*Changes in chemical composition may indicate areas of groundwater contamination and be used as an early warning system to implement management/remedial actions. *To determine whether the water is fit for the intended use. *Conditions of the Water Use Licence

Monitoring parameters

Physical Parameters:

- Groundwater levels (static water levels); and
- Groundwater Abstraction volumes (from flow meter).

Chemical parameters:

- Field measurements:
  - pH, EC;
- Laboratory analyses:
  - Anions and cations (Ca, Mg, Na, K, NO3, Cl, SO4, F, Fe, Mn, Al, Hardness and Bicarbonate, Carbonate and Total Alkalinity);
  - Other parameters (pH, EC, TDS)

TABLE 17: RECOMMENDED CORRECTIVE AND REMEDIAL ACTIONS

Mitigation measurements	Remedial actions
Pump depth	Reduce the pump depth
Low-volume, high-frequency pumping	Increase the frequency and reduce the duration of pumping to minimize drawdown in the well and the surrounding aquifer
Increase storage	Increase water storage and pump in wet season for use in drier periods. Augment the water supplies using water from other sources such as rainwater harvesting. Ensure water in storage tanks is kept free from contaminants by following health guidelines for water storage and disinfection.
Prevent leaks	Install water meters or other alarms/indicators so that leaks can be detected and fixed quickly

15. Conclusion

Based on existing and newly acquired data, the following can be concluded:

- **The application volume, relevant to this WULA, constitutes a total groundwater volume of 1 171 385m^3/annum.** Based on the results of the pump tests from all tested boreholes, a **total abstraction volume of 1 450 656m^3/annum** can safely be abstracted from the aquifer resource. The application volume therefor constitutes 80% of the total sustainable abstraction volume calculated from the pump test data at all tested boreholes.
- A very conservative approach was followed in calculating the long term, sustainable yields of these aquifers and the influences of all monitoring boreholes were considered during the final optimum abstraction volumes.
- The **total water demand for the 134ha agricultural farming** accounts to 1 405 660m^3/annum according to the SAPWAT analysis. The additional 234 275m^3/annum will be supported by the existing verified and validated lawful use from the Crocodile River.
- A favourable **recharge volume to the GRU** (Geohydrological response unit) within the study area was calculated to **22.19Mm^3/annum** with a total **remaining reserve volume of 13.744Mm^3/annum.**
- Considering the application volume of the WULA of 1 171 385m^{3,} this volume therefore constitutes **to 8.5% of the total reserve of the GRU and 4.3% of the total reserve of the quaternary catchment area.**
- Considering the **safe yield calculation** within the GRU of 23.35Mm^3/annum, the total registered abstraction volume (WARMS plus the application volume) of 9.104Mm^3/annum falls well within the safe yield calculations.
- The applicable volume of 1 171 385m^3/annum pertain 10.7% of the total utilisable groundwater exploitation potential set out for the planned crop development area (134ha) under the GRAII dataset (2005), during the dry season.
- In terms of potential impact on aquifer pollution the Kaaldraai study area rated as **extremely vulnerable to surface pollution**. The dominant factor contributing to this rating is the high permeability of the Quaternary alluvial sands and the shallow high yielding aquifer conditions

- The prevailing conditions within the shallow dolomitic aquifer might suggest substantial recharge to the dolomite from precipitation, a point previously highlighted by Steyn (1969) and further supported by Hobbs (1983).
- The present status category according to the **stress-index within the GRU is categorized as a "moderate level" of stress. The large-scale agricultural industry in the regional area, contributes to this level.** Conservative pump test analysis, as well as recharge and reserve calculations however confirmed that the application volume relevant to this application, falls well within the limits of the sustainable abstraction volumes.
- The stress-index however in the **2km radius area** of our study area is **critically stressed.** Large-scale irrigation is planned within a 2-5km radius. It is however emphasized that the recharge and reserve volume calculated, making use of very **conservative figures**, as well as the motivation of the underlying karst aquifer, are still indicating that the application volume relevant to this application falls well within the limits of the sustainable abstraction volumes.

- According **to Parson's Aquifer System Management classification**, the aquifer system could be classified as a **Major Aquifer System**. The protection of the aquifer system in terms of available abstraction volumes as well as water quality, is therefore of extreme importance.
- The **Piper diagram** categorizes all groundwater **as calcium-magnesium-chloride water type (Type A),** potentially supporting the theory of the groundwater originating from the dolomites in the mountainous regions.
- Boreholes 1, 2, 5 & 7 is dominated by elevated Chloride (Cl) and Nitrate (as N) values, classifying these boreholes unsuitable for domestic use.
- In terms of agricultural use, Boreholes 3, 4, 6, 7, and 8 are anticipated to exhibit slight corrosiveness without scale formation. Conversely, Boreholes 1, 2, and 5 are expected to be slightly scale-forming and corrosive.
- The SAR results reveal a very high salinity and low-sodium hazard.

- **Microbial counts** in boreholes 1 & 4 exceed domestic use standards and not suitable for domestic use before treatment.
- To ensure **continuity of water supply,** a holding/balancing dam will be utilized for the storage of groundwater.

16. Final recommendations

Considering the aquifer characteristics derived from the pump tests, recharge figures of the aquifer within the GRU, as well as the available exploitation volume within the geohydrological resource unit (GRU), it is recommended that the Water Use Licence be approved for the groundwater application volume of 1 171 385m^3/annum. It is however imperative that the applicant implements the proposed "Environmental Management & Groundwater Monitoring Program". Production boreholes should be equipped as follow:

- Installation of a 32 mm LDPE observation pipe from the pump depth to the surface, open at the bottom. This allows for a 'window' of access down the borehole which enables manual water level monitoring and can house an electronic water level logger if required.
- Installation of a sampling tap (to monitor water quality).
- Installation of a flow volume meter (to monitor abstraction rates and volumes).
- The appropriate borehole pump must be installed, i.e. not an over-sized pump that is choked with a gate valve. If the monitoring shows that more water can be abstracted, then duty cycles (i.e. the duration of pumping time) may be increased, and not the flow rate.
- After pump installation at all the tested boreholes, it is strongly recommended that a strict **groundwater management and monitoring plan** will be put into place. This will involve regular measuring and documenting the static water level as well as water quality of the production borehole (See example of monitoring sheet Appendix E). This will form part of the borehole management plan. This precautional plan will enable the client to detect early dewatering of the aquifer as well as detecting pollution plumes and make provision to prevent any further spread of pollution.

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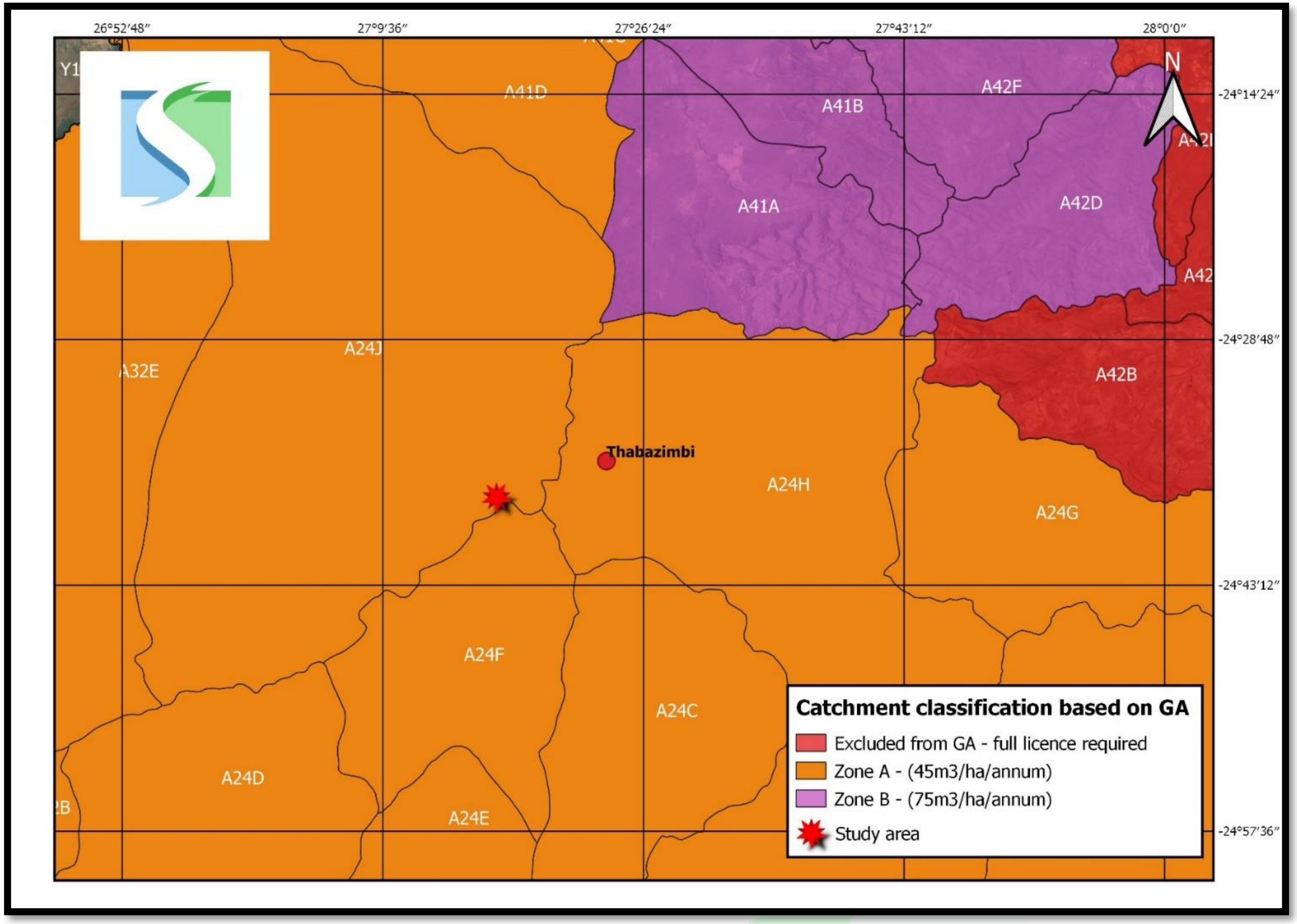
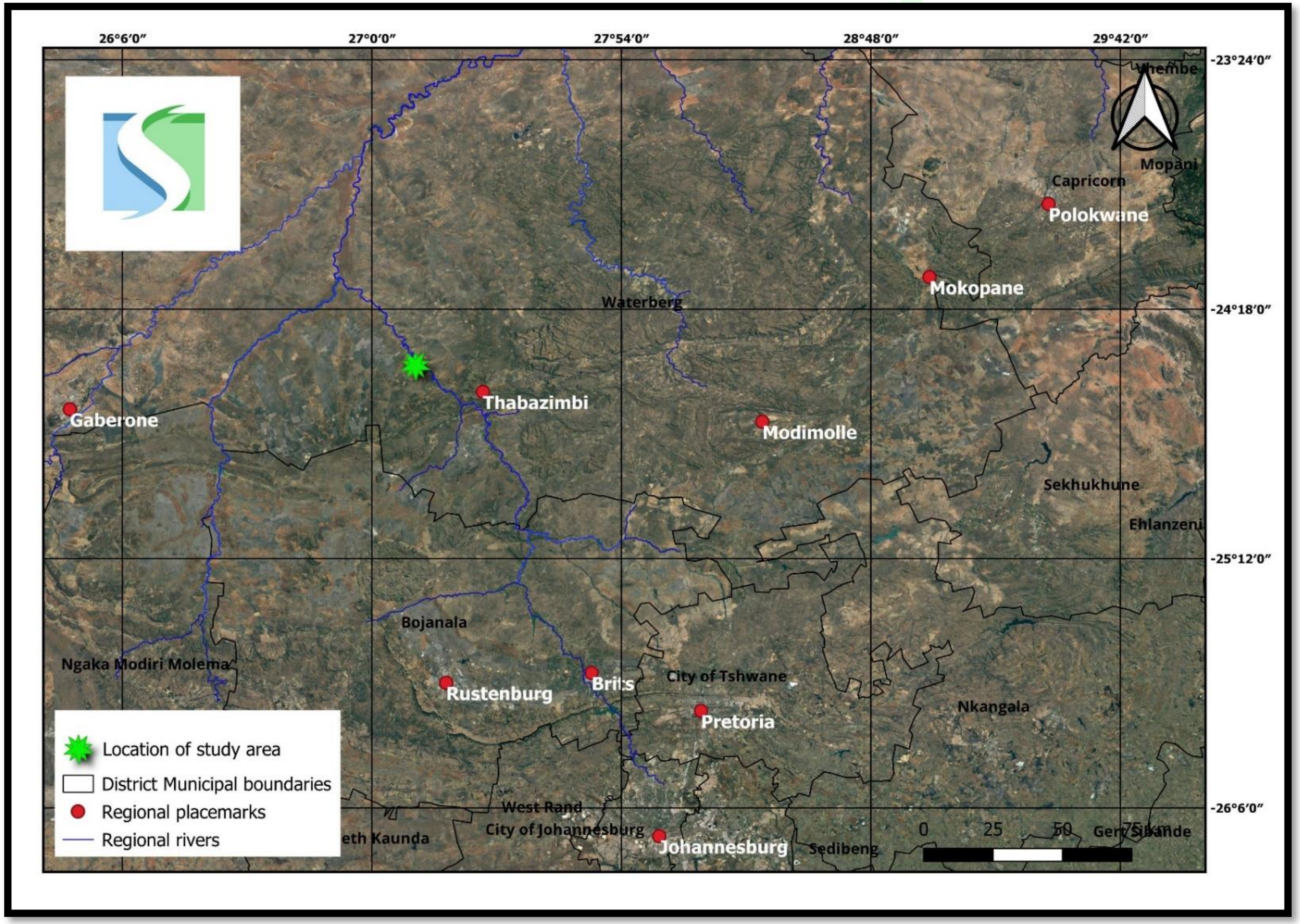
Appendix A

Maps

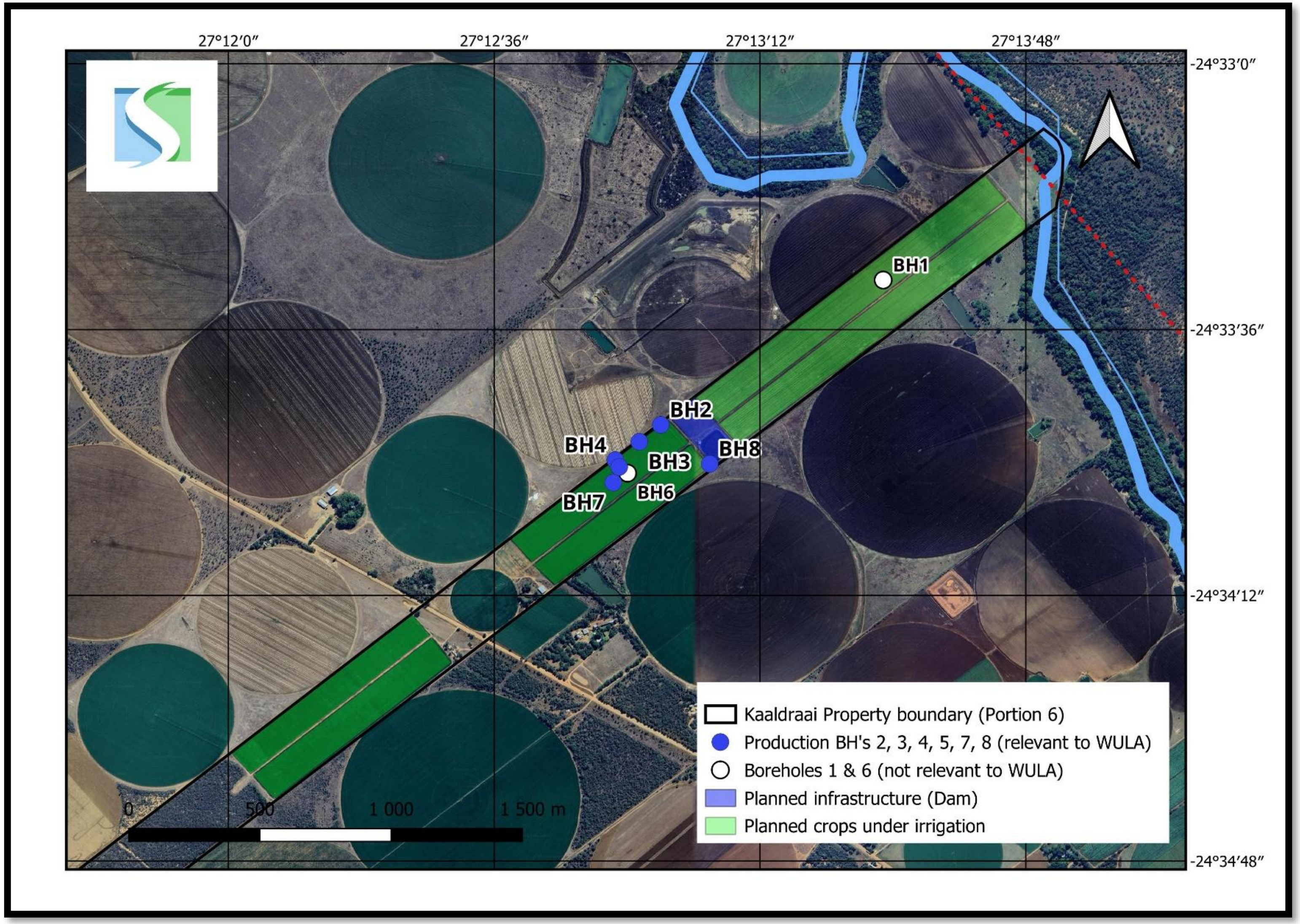
List of Maps



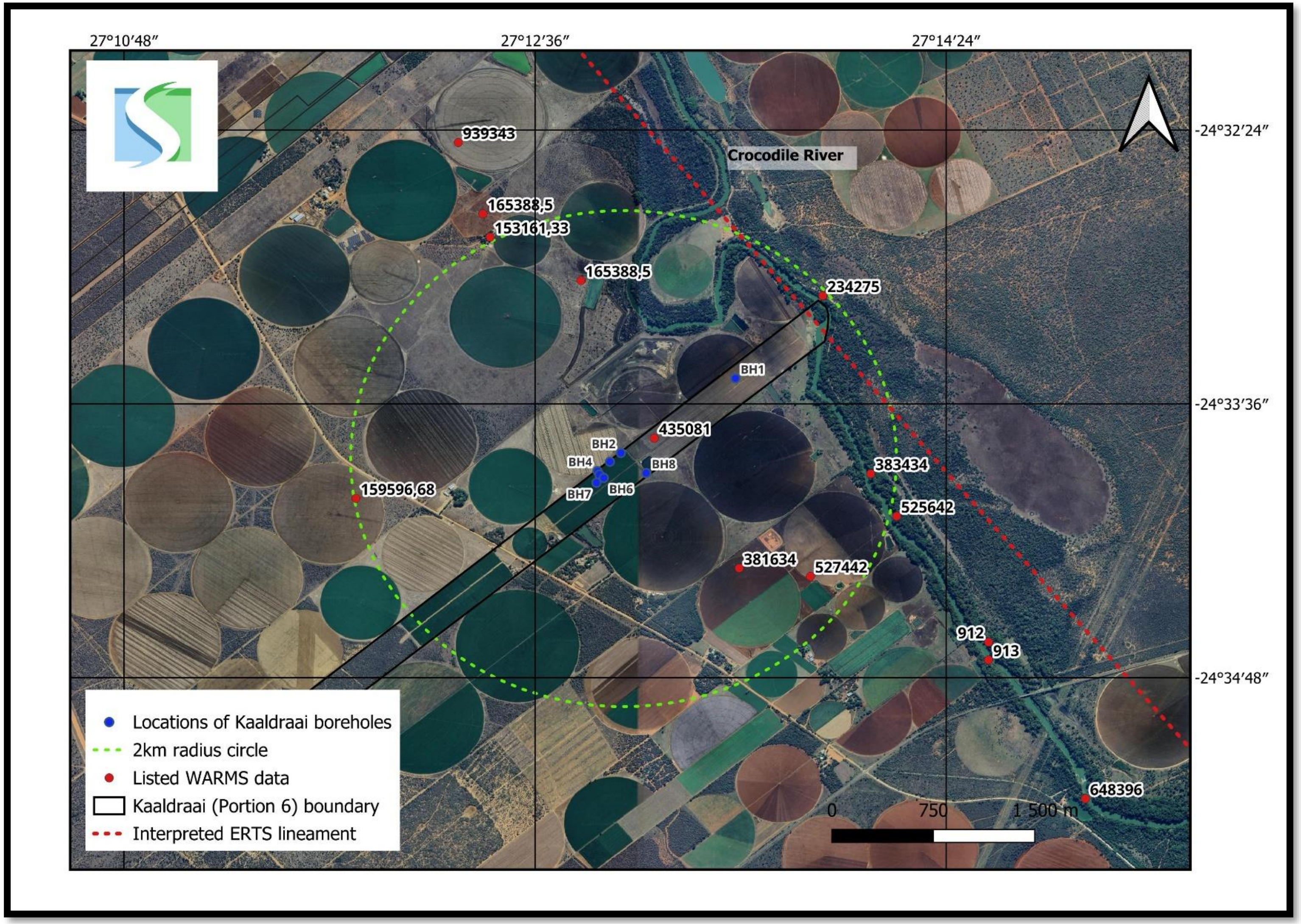
MAP 1: CATCHMENT CLASSIFICATION BASED ON THE GA ACCORDING TO THE NATIONAL WATER ACT



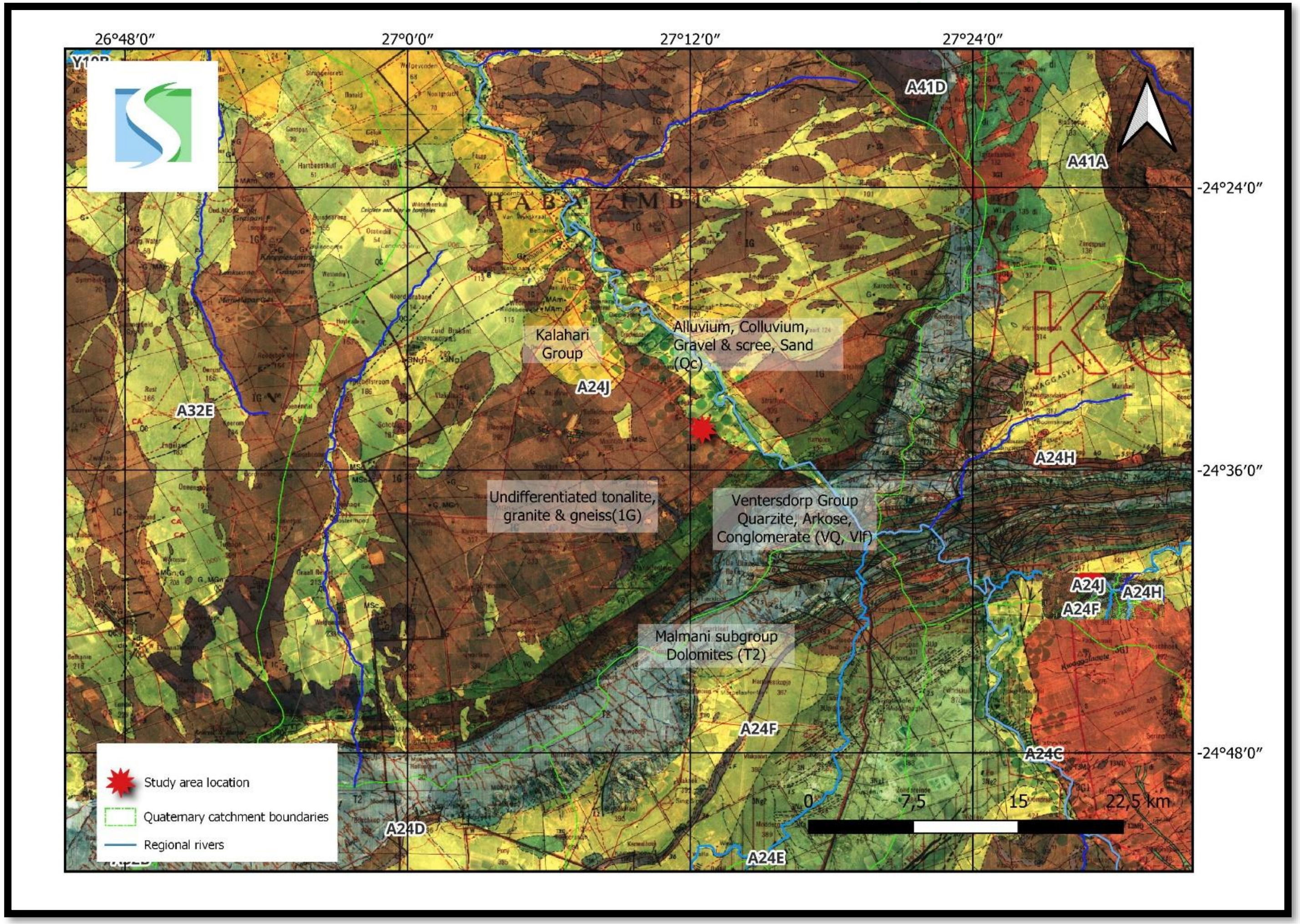
MAP 2: REGIONAL MAP OF STUDY AREA



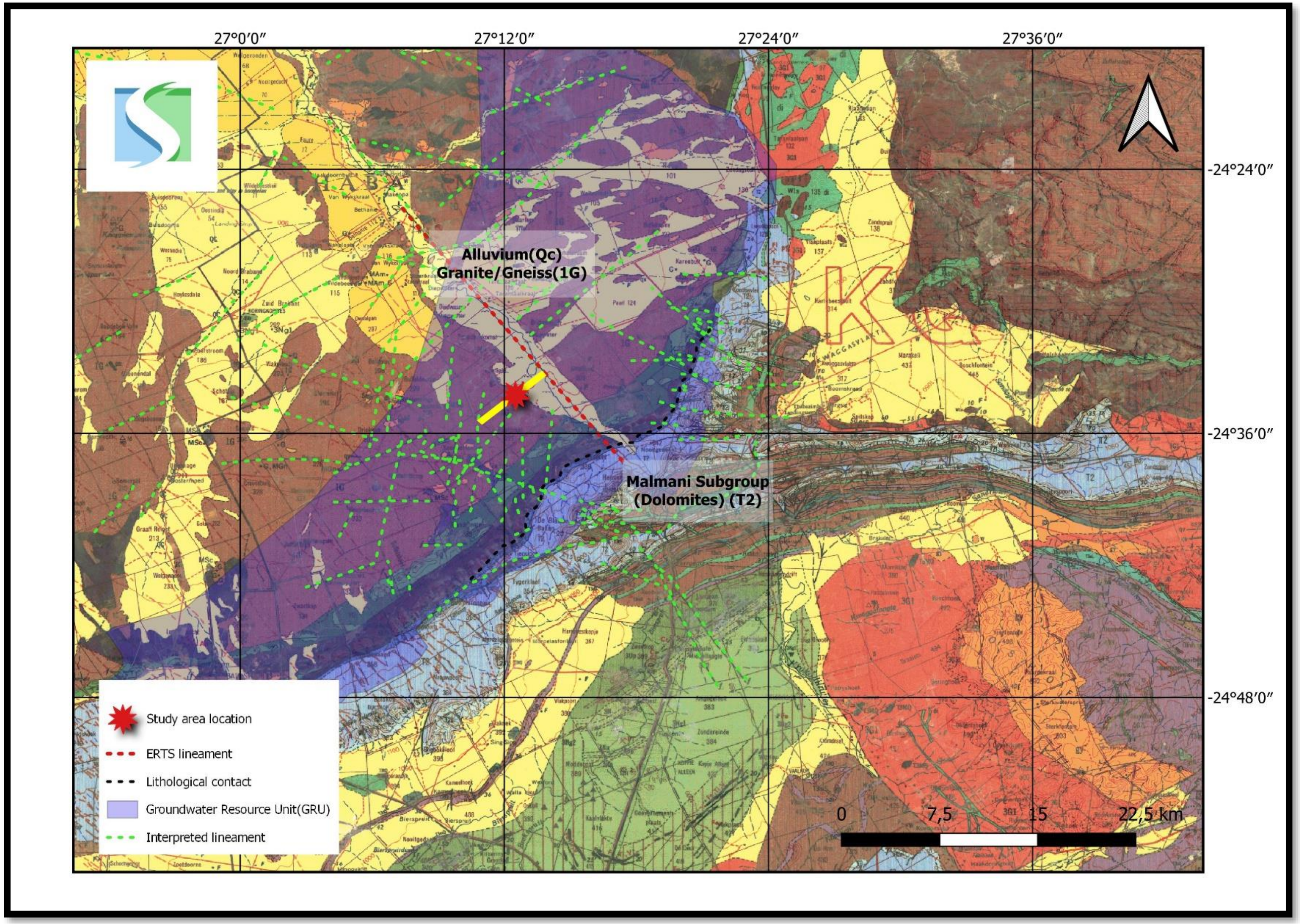
MAP 3: LOCATION OF PRODUCTION BOREHOLES AND PLANNED INFRASTRUCTURE RELEVANT TO THIS APPLICATION ON THE FARM KAALDRAAI KQ 321 (PORTION 6)



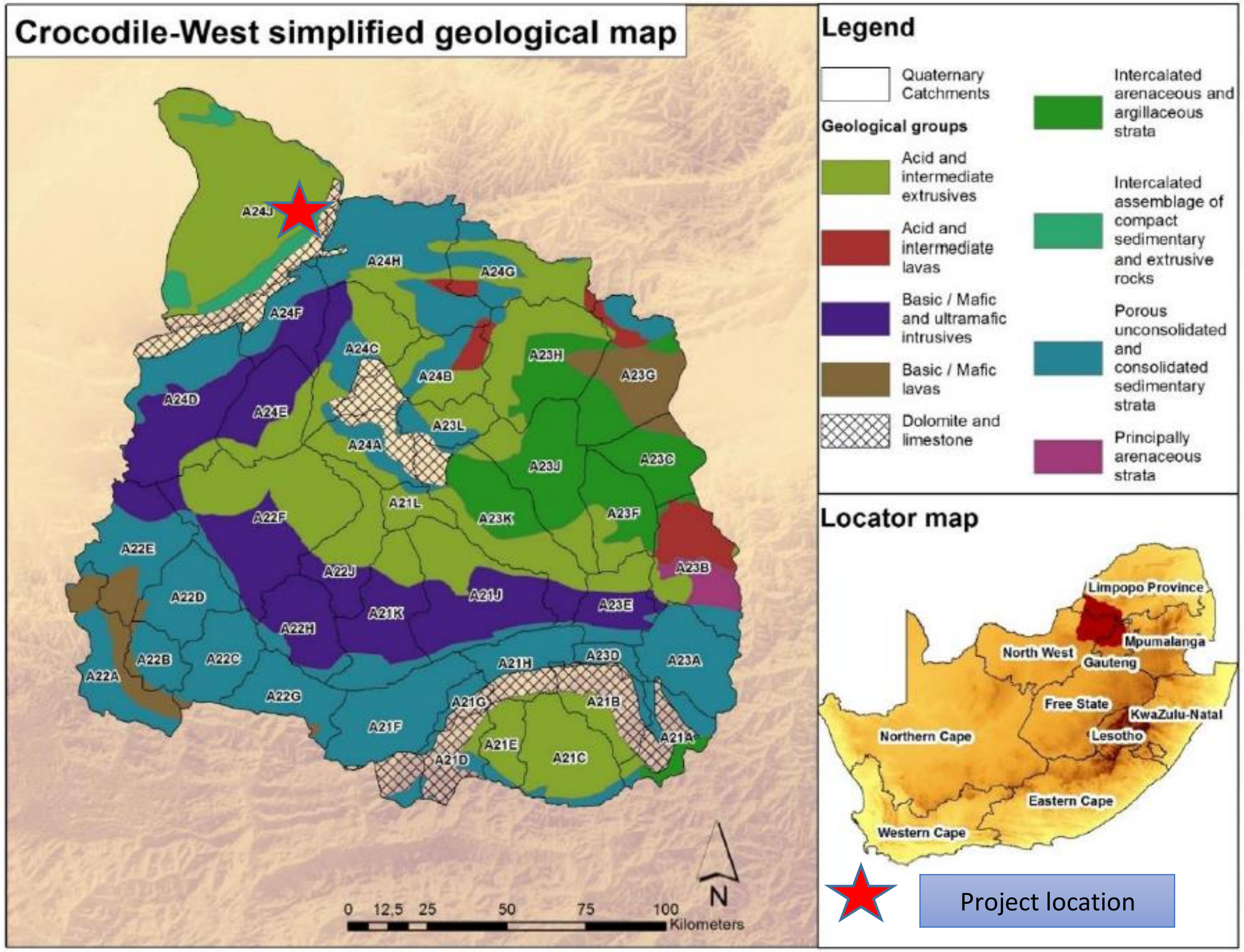
MAP 4: WUL APPLICATIONS WITHIN A 2KM RADIUS FROM FARM KAALDRAAI KQ321 (PORTION 6)



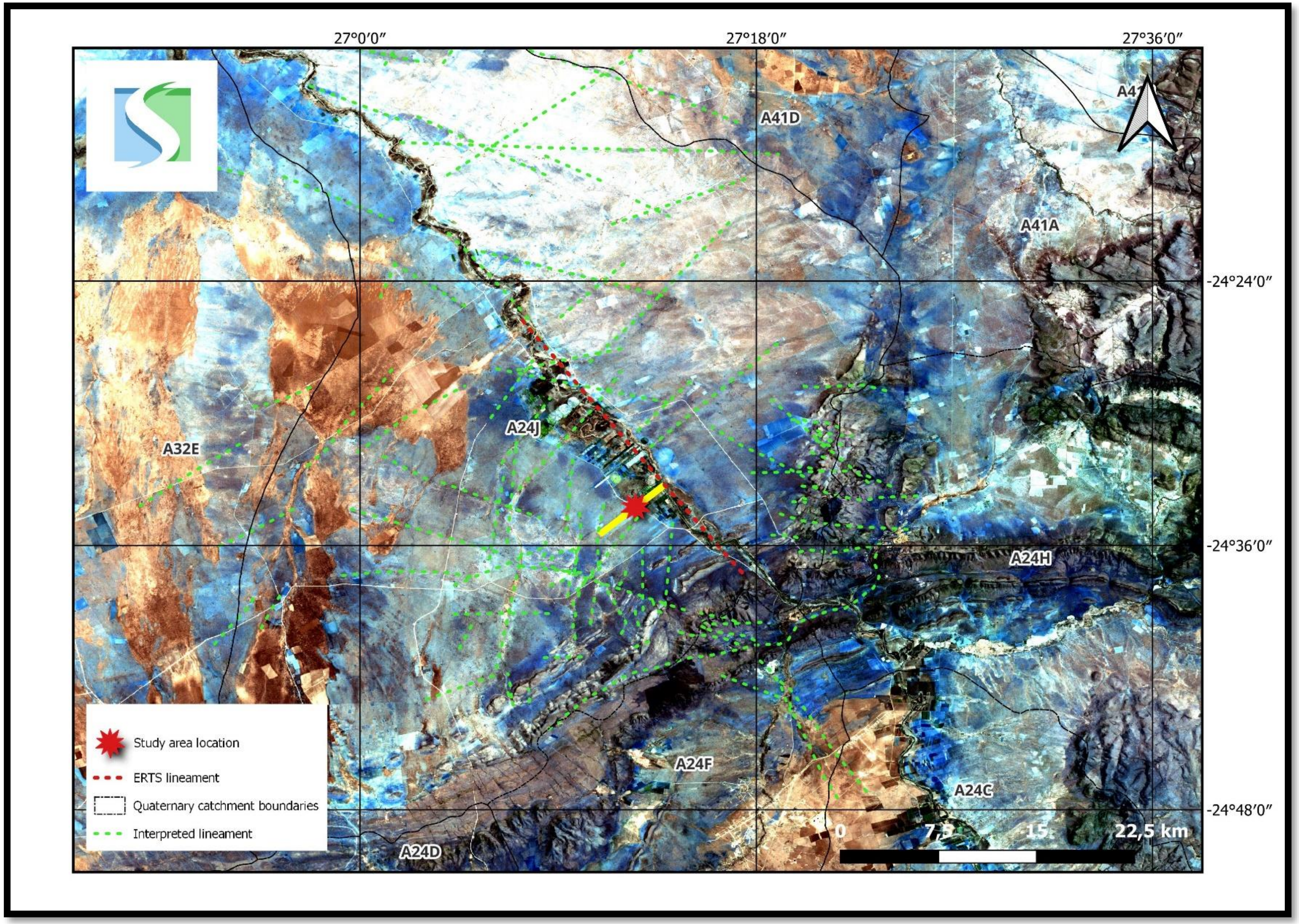
MAP 5: GEOLOGY OF STUDY AREA (1:250 000; GEOLOGICAL SERIES; 2426 THABAZIMBI)



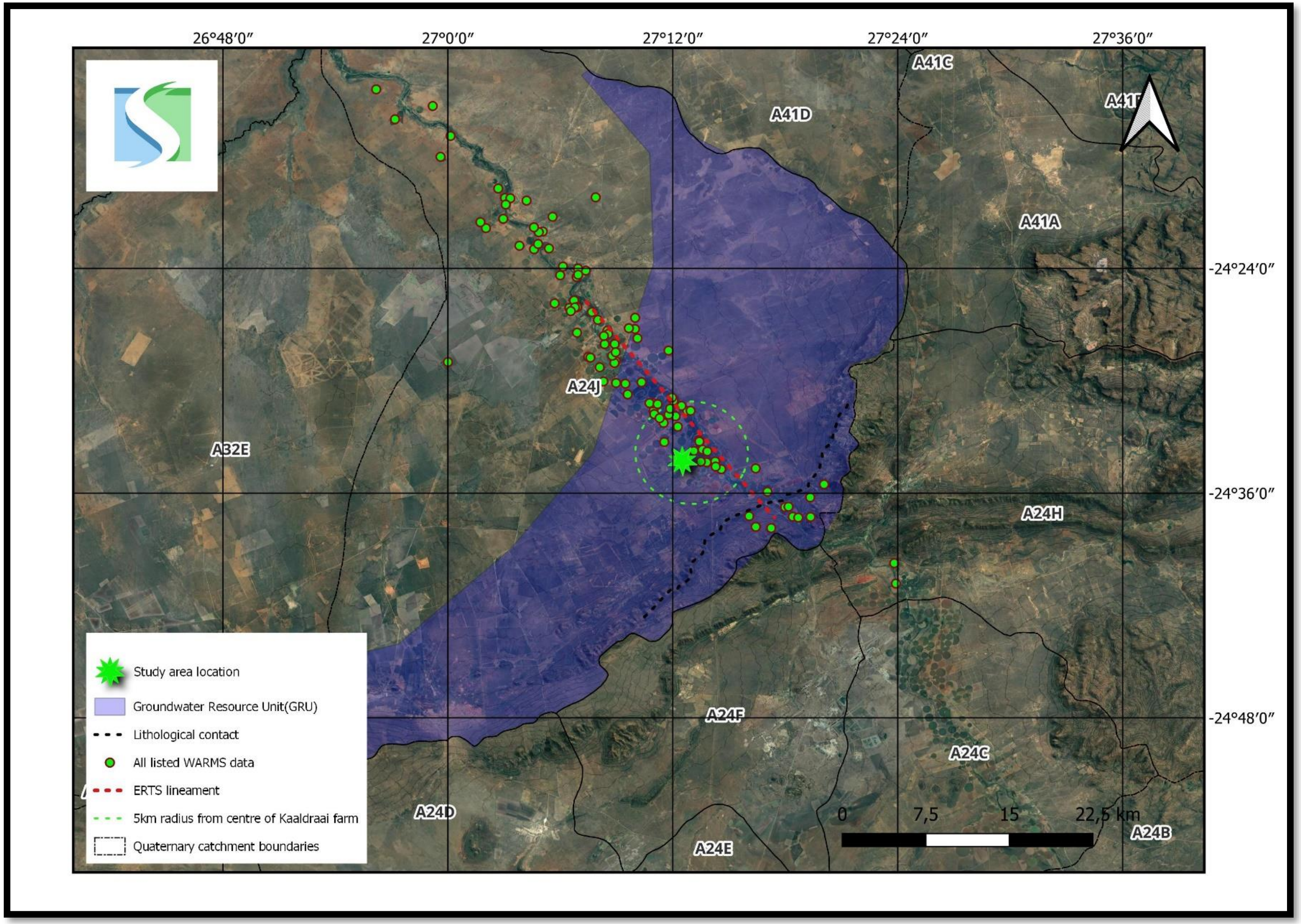
MAP 6: GROUNDWATER RECHARGE FROM DOLOMITIC VLIEGEPOORT MOUNTAINS



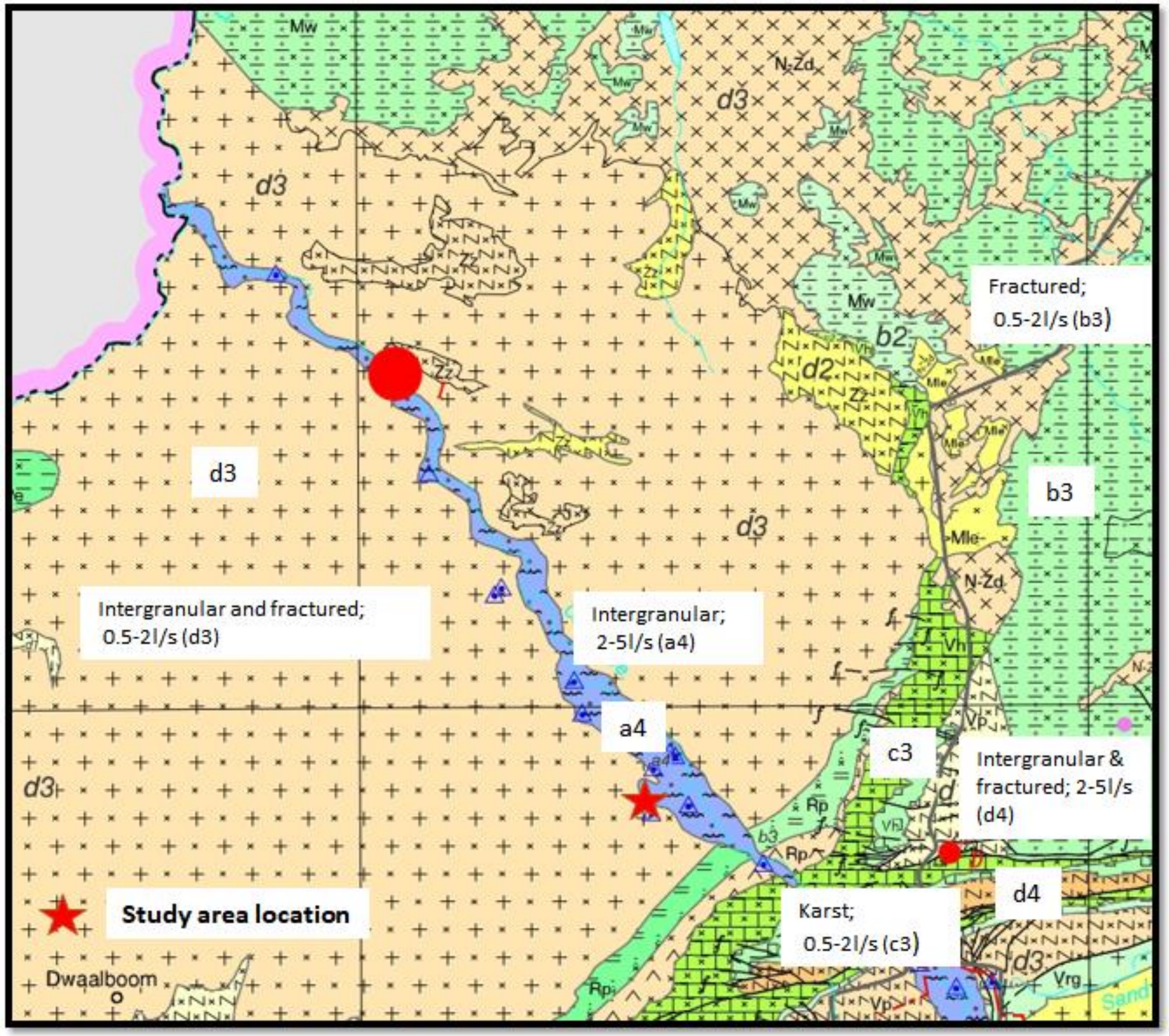
MAP 7: SIMPLIFIED GEOLOGY (REFERENCE HOLZHAUZEN PH; MAY 2018)



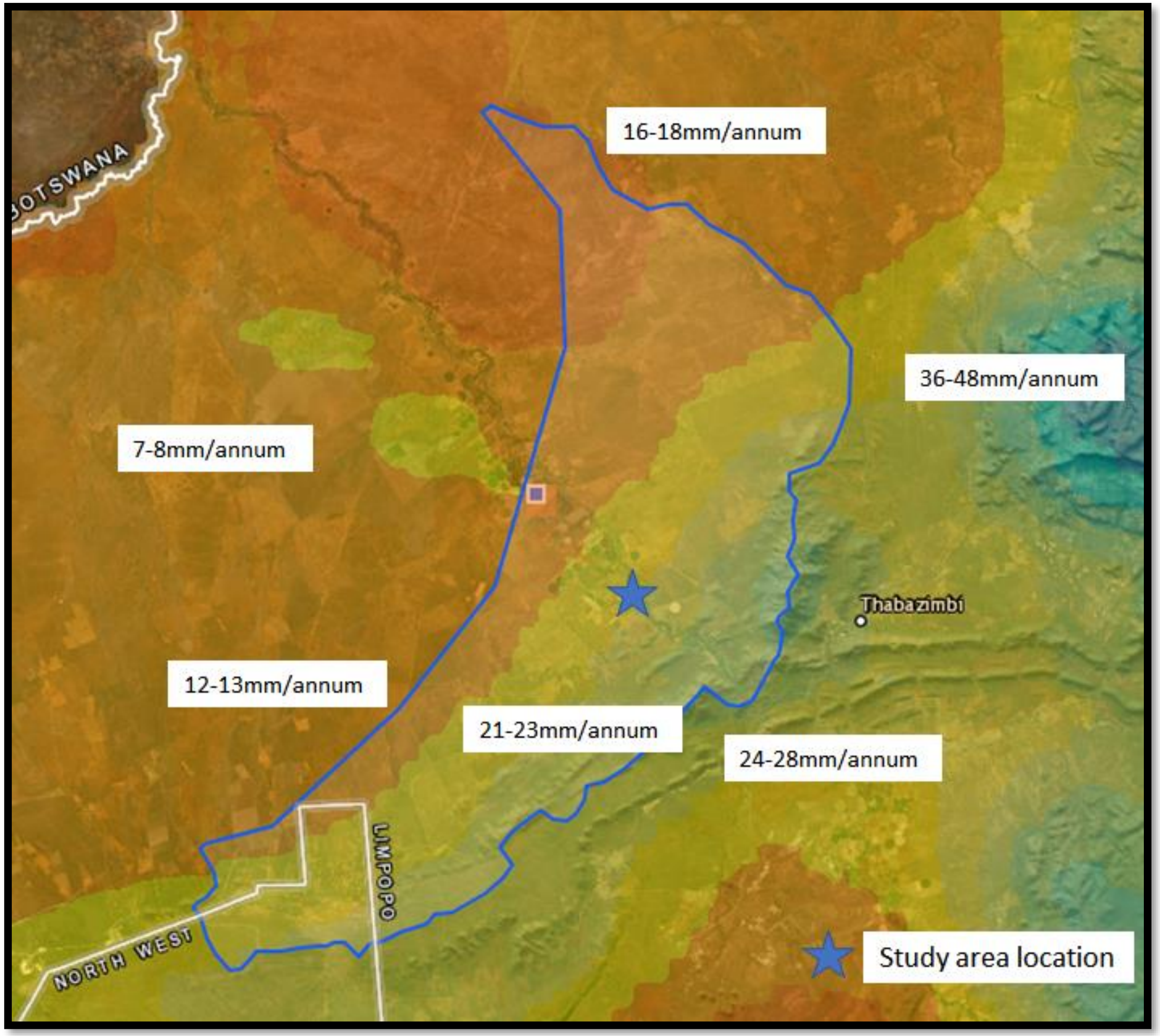
MAP 8: FALSE COLOUR LANDSAT 5 SATELLITE IMAGE OF STUDY AREA (DATE OF IMAGE OCTOBER 1984) DEPICTING INTERPRETED LINEAR STRUCTURES



MAP 9: GEOHYDROLOGICAL RESPONSE UNIT (GRU)



MAP 10: AQUIFER CLASSIFICATION (HYDROLOGY MAP SERIES OF SA; 2326 POLOKWANE; 1:500 000)



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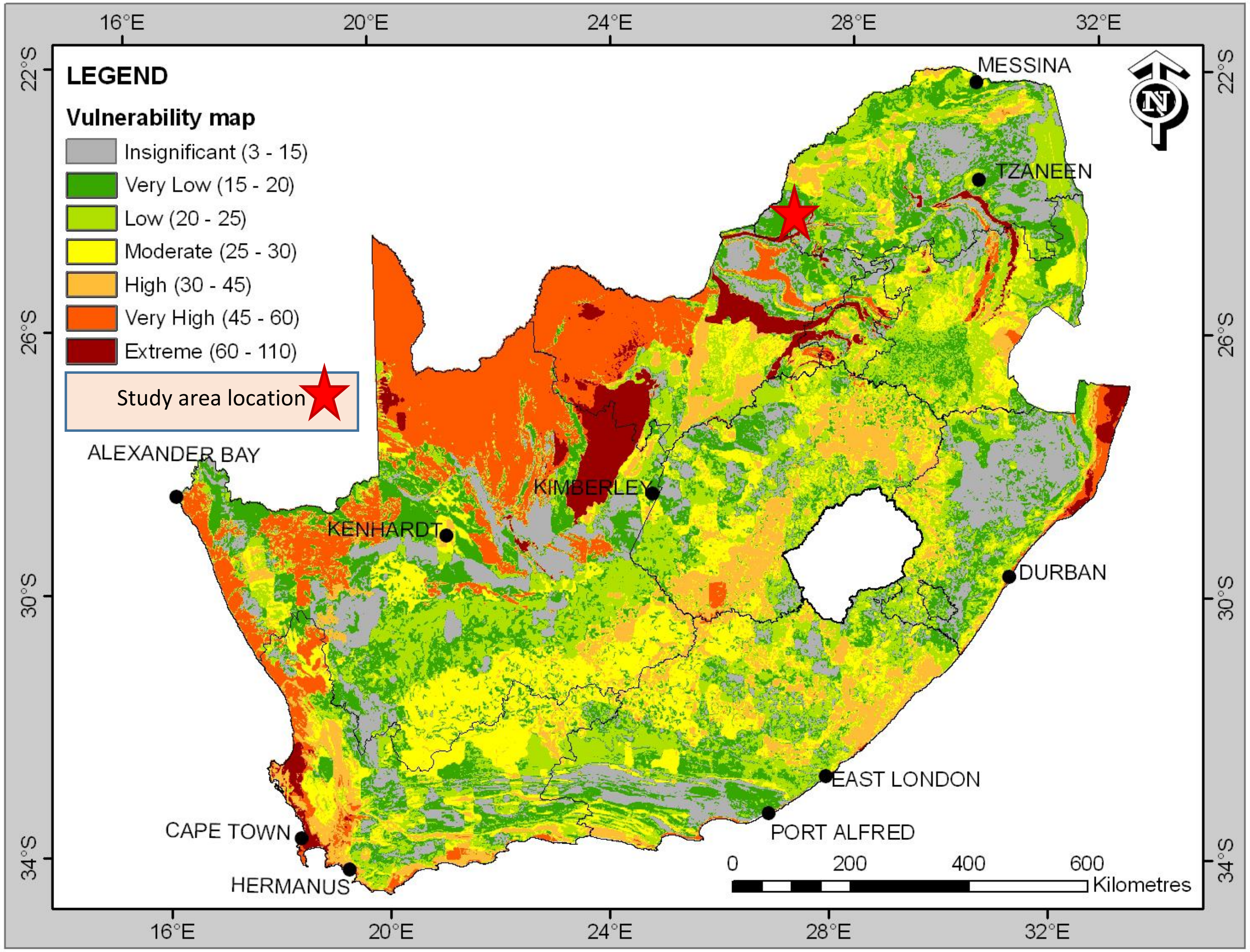
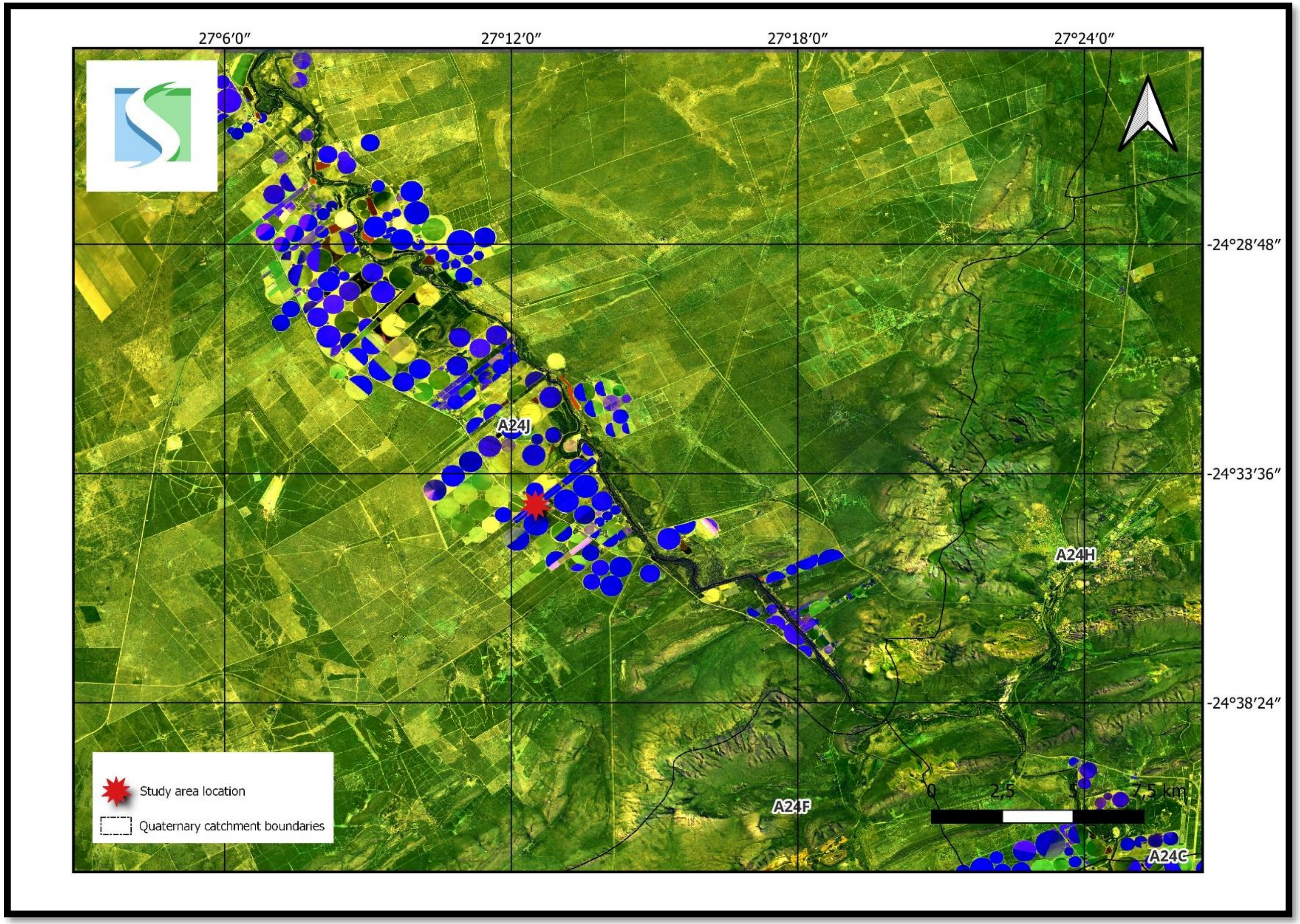
MAP 11: GROUNDWATER RECHARGE ESTIMATIONS WITHIN THE REGIONAL STUDY AREA



MAP 12: VULNERABILITY MAP OF SA (SA JOURNAL OF GEOMATICS; VOL 2; NO 2; APRIL 2013)



MAP 13: FALSE COLOUR SENTINEL SATELLITE IMAGE OF STUDY AREA (DATE OF IMAGE AUG 2023)

Appendix B

Pump test Analysis Summary and Test Data

TABLE 18: OPTIMUM LONG-TERM SUSTAINABLE RECOMMENDED YIELDS

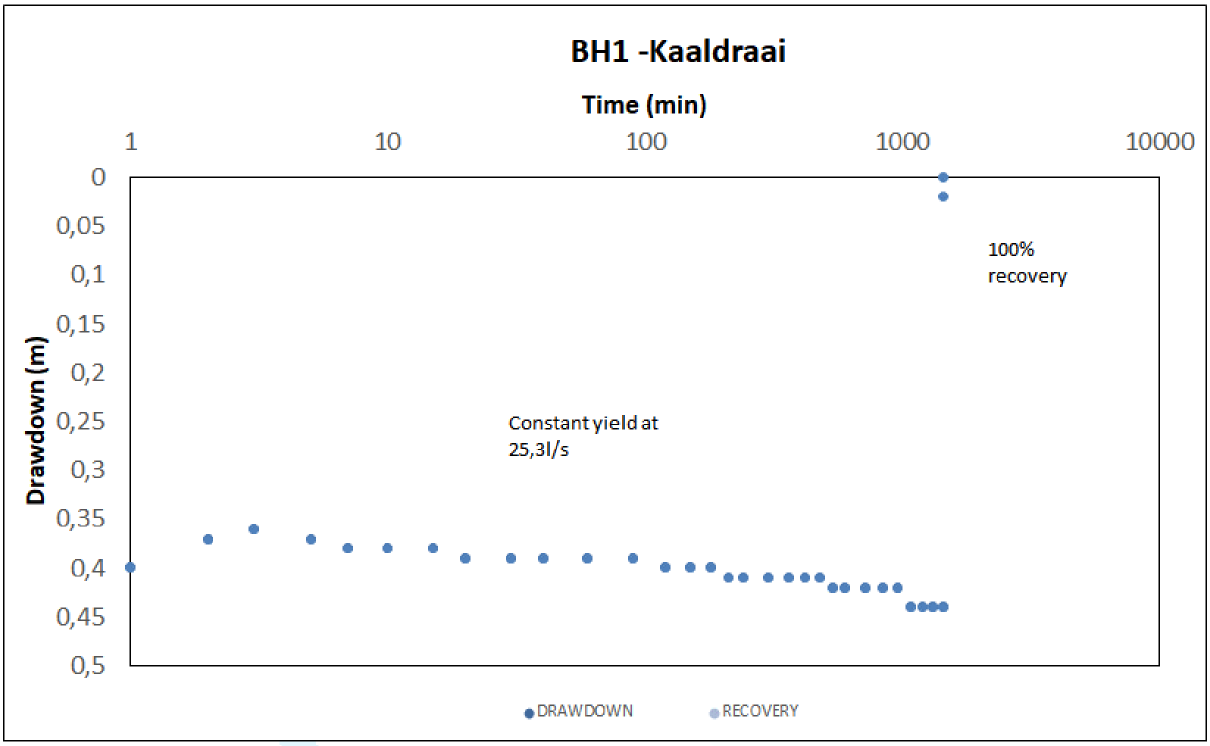
Borehole nr	BH1 (Monitoring bh)	**BH2**
Recommended pumping rate (l/s)	7L/s (25 200L/h)	6L/s (21 600L/h)
Pumping duration (Duty cycle) (hrs)	24 hrs	24 hrs
Critical Water level (mgbl)	11m	11m
Dynamic water level (mbgl)	8m	9.5m
Volume per day (m^3)	604.8m^3/day (220 752m^3/annum)	518.4m^3/day (189 216m^3/annum)
Rest water level (mbgl)	7.07m	8.18m
Borehole depth (mbgl)	110m	110m
Recommended pump depth (mbgl)	12m	12m
Available drawdown used (m)	4m	4m

Borehole nr	**BH3**	**BH4**
Recommended pumping rate (l/s)	7L/s (25 200L/h)	6L/s (21 600L/h)
Pumping duration (Duty cycle) (hrs)	24 hrs	24 hrs
Critical Water level (mgbl)	12m	13m
Dynamic water level (mbgl)	11m	11m
Volume per day (m^3)	604.8m^3/day (220 752m^3/annum)	518.4m^3/day (189 216m^3/annum)
Rest water level (mbgl)	9.5m	9m
Borehole depth (mbgl)	110m	110m
Recommended pump depth (mbgl)	16m	16m
Available drawdown used (m)	7m	7m

Borehole nr	BH5	BH6 (Monitoring bh)
Recommended pumping rate (l/s)	5L/s (18 000L/h)	4 L/s (14 400L/h)
Pumping duration (Duty cycle) (hrs)	24 hrs	24 hrs
Critical Water level (mgbl)	12m	12m
Dynamic water level (mbgl)	10m	10m
Volume per day (m^3)	432m^3/day (157.7m^3/annum)	345.6m^3/day (126 144m^3/annum)
Rest water level (mbgl)	8.54m	9.1m
Borehole depth (mbgl)	110m	110m
Recommended pump depth (mbgl)	16m	16m
Available drawdown used (m)	7.5m	7m

Borehole nr	BH7	BH8
Recommended pumping rate (l/s)	6L/s (21 600L/h)	5 L/s (18 000L/h)
Pumping duration (Duty cycle) (hrs)	24 hrs	24 hrs
Critical Water level (mgbl)	12m	14m
Dynamic water level (mbgl)	10m	10m
Volume per day (m^3)	518.4m^3/day (189 216m^3/annum)	432m^3/day (157.7m^3/annum)
Rest water level (mbgl)	8.67m	10.09
Borehole depth (mbgl)	110m	110m
Recommended pump depth (mbgl)	16m	16m
Available drawdown used (m)	7m	6m

GRAPH 1: RESULTS OF CONSTANT TEST DATA AT BOREHOLE 1 (LIN-LOG)



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Summary	Main	BH 1 Kaaldraai

Applicable	Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)		Late T (m^2/d)		S	AD used
☑	Basic FC	9,47	6,10	#NUM!		1333,4		2,20E-03	1,0
☑	Advanced FC	6,01		#NUM!		1000,0		1,00E-03	1,0
☐	FC inflection point	na	#NUM!						0,0
☐	Cooper-Jacob	18,09	11,71			5180,1		3,43E-03	1,0
☐	FC Non-Linear	na	0,04			4,0		3,75E-03	1,0
☐	Barker	na	0,00	K_f =	301		S_s =	1,19E-03	1,0
	Average Q_sust (l/s)	7,74	2,44	b =	0,20	Fractal dimension n =		0,22	

Recommended abstraction rate (L/s)		7,00	for 24 hours per day		
Hours per day of pumping	12	9,90	L/s for	12	hours per day

Amount of water allowed to be abstracted per month	18144	m^3
Borehole could satisfy the basic human need of	24192	persons
Is the water suitable for domestic use (Yes/No)	?	

12l/s for 8 hours/day(345,6m^3/day)
10l/s for 12 hours/day(432m^3/day)
7l/s for 24 hours/day (604,8m^3/day)

Recommended pump depth (mbgl)	12m
Total Casing length	Steel
Critical depth, water level should not exceed	11m
Dynamic water level (m)	8m
Depth of bh	110m
Static water level	7,07m

Management recommendations

KARST AQUIFER
This borehole exhibited characteristics typical of a karst aquifer
The response in drawdown at the start of the constant test was rapid with stabilizing of the drawdown levels, indicating a consistent hydraulic pressure within the borehole.
This was interpreted as reaching the karst aquifer.
Groundwater occurs along fault and shear zones associated with intense deformation resulting in the occurrence of fractures, joints and cavaties subsequently enlarged by dissolution processes in the dolomites.
In recommending safe long term yields, care is taken not to dewater the cavaties, causing dewatering of the aquifer, causing collapsing, and consequently destroying the aquifer.
During the constant test, water was abstracted from this borehole at a constant abstraction yield of 25,3l/s for a duration of 24 hours.
Water was abstracted from the karst aquifer at a depth of approximately 7,5m for a period of 24 hours.
Water was drawn still drawn from this cavity when the test was terminated after 24 hours with almost immediate recovery in drawdown levels.

The T-value of the formation is in the order of 1000.

The aim of the recommended maximum safe yield is to prevent the waterlevel from drawing down more than 2-3m and potentially dewatering the cavity at approximately 8m depth.

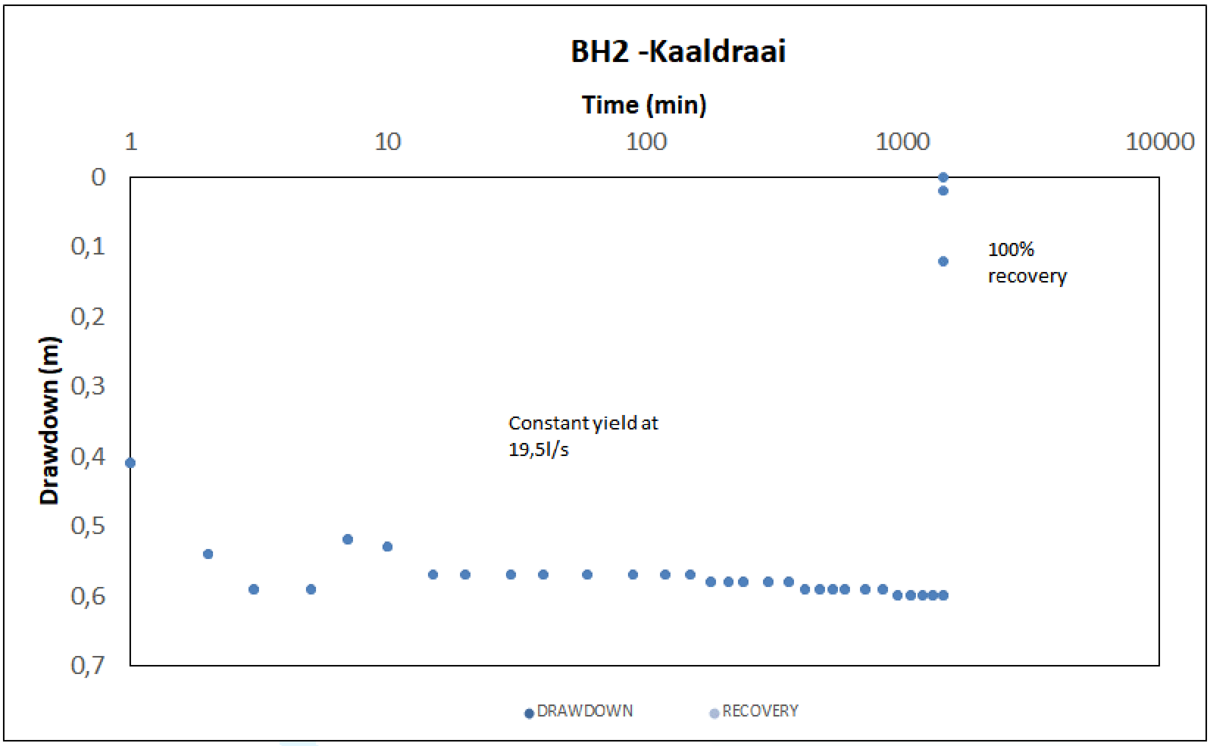
Recommended depth of pump = not exceeding 12m depth
Critical depth = 11m
Static water level = 7,07m

Assumptions
One no-flow boundary at 200m
No rainfall recharge

Date of test: November 2023

Further comments:
It is strongly recommended that a borehole management plan is put into place to secure the sustainability of the source.
It is absolutely critical that the depth of the waterlevel never exceeds the depth of 11m.
Change in pressure within the cavity will cause collapsing of the aquifer and will destroy the borehole as well as surrounding aquifer.

GRAPH 2: RESULTS OF CONSTANT TEST DATA AT BOREHOLE 2 (LIN-LOG)



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Summary

Main

BH 2 Kaaldraai

Applicable	Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)	Late T (m^2/d)	S	AD used
☑	Basic FC	6,72	1,30	#NUM!	3083,2	2,20E-03	1,0
☑	Advanced FC	4,39		#NUM!	1000,0	1,00E-03	1,0
☐	FC inflection point	na	0,00				0,0
☐	Cooper-Jacob	-0,81	0,52		3016,6	1,90E-01	1,0
☐	FC Non-Linear	na	0,04		4,0	3,75E-03	1,0
☐	Barker	na	0,00	K_f = 301	S_s =	1,19E-03	1,0
	Average Q_sust (l/s)	5,55	1,65	b = 0,20	Fractal dimension n =	0,22	

Recommended abstraction rate (L/s)	6,00	for 24 hours per day
Hours per day of pumping 8	10,39	L/s for 8 hours per day

Amount of water allowed to be abstracted per month	15552	m^3
Borehole could satisfy the basic human need of	20736	persons
Is the water suitable for domestic use (Yes/No)	?	

11l/s for 8 hours/day(316,8m³/day)
9l/s for 12 hours/day(388,8m³/day)
6l/s for 24 hours/day (518,4m³/day)

Recommended pump depth (mbgl)	12m
Total Casing length	Steel
Critical depth, water level should not exceed	11m
Dynamic water level (m)	9,5m
Depth of bh	110m
Static water level	8,18m

Management recommendations

KARST AQUIFER
This borehole exhibited characteristics typical of a karst aquifer
The response in drawdown at the start of the constant test was rapid with stabilizing of the drawdown levels, indicating a consistent hydraulic pressure within the borehole.
This was interpreted as reaching the karst aquifer.
Groundwater occurs along fault and shear zones associated with intense deformation resulting in the occurrence of fractures, joints and cavaties subsequently enlarged by dissolution processes in the dolomites.
In recommending safe long term yields, care is taken not to dewater the cavaties, causing dewatering of the aquifer, causing collapsing, and consequently destroying the aquifer.
During the constant test, water was abstracted from this borehole at a constant abstraction yield of 19,5l/s for a duration of 24 hours.
Water was abstracted from the karst aquifer at a depth of approximately 9m for a period of 24 hours.
Water was drawn still drawn from this cavity when the test was terminated after 24 hours with almost immediate recovery in drawdown levels.

The T-value of the formation is in the order of 1000.

The aim of the recommended maximum safe yield is to prevent the waterlevel from drawing down more than 2-3m and potentially dewatering the cavity at approximately 9m depth.

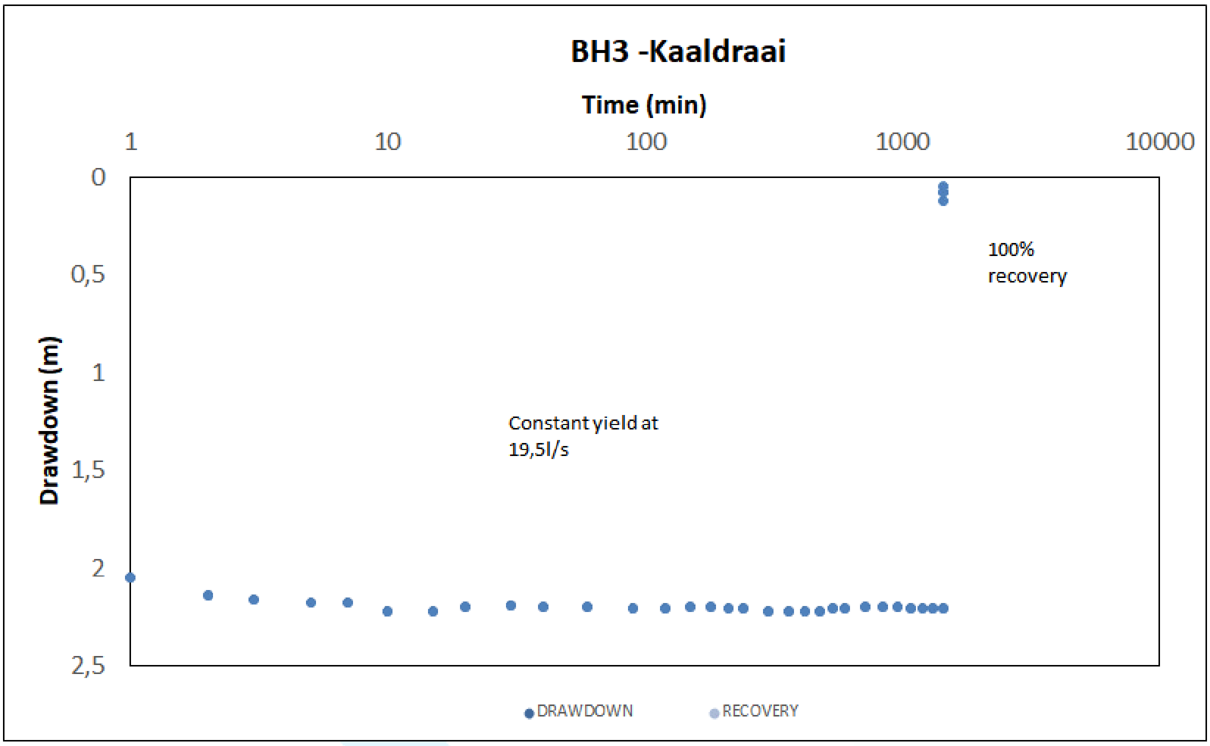
Recommended depth of pump = not exceeding 12m depth
Critical depth = 11m
Static water level = 8,18m

Assumptions
One no-flow boundary at 200m
No rainfall recharge

Date of test: November 2023

Further comments:
It is strongly recommended that a borehole management plan is put into place to secure the sustainability of the source.
It is absolutely critical that the depth of the waterlevel never exceeds the depth of 11m.
Change in pressure within the cavity will cause collapsing of the aquifer and will destroy the borehole as well as surrounding aquifer.

GRAPH 3: RESULTS OF CONSTANT TEST DATA AT BOREHOLE 3 (LIN-LOG)



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Summary

Main

BH 3 Kaaldraai

Applicable	Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)	Late T (m^2/d)	S	AD used
☑	**Basic FC**	6,71	1,91	#NUM!	1027,7	2,20E-03	2,0
☑	**Advanced FC**	6,19		#NUM!	1000,0	1,00E-03	2,0
☐	**FC inflection point**	na	#NUM!				0,0
☐	**Cooper-Jacob**	2,84	1,84		2594,8	2,90E-15	2,0
☐	**FC Non-Linear**	na	0,04		4,0	3,75E-03	2,0
☐	**Barker**	na	0,00	K_f = 301	S_s =	1,19E-03	2,0
	Average Q_sust (l/s)	**6,50**	**0,36**	b = 0,20	Fractal dimension n =	0,22	

Recommended abstraction rate (L/s)	**7,00**	for 24 hours per day
Hours per day of pumping 12	**9,90**	L/s for 12 hours per day

Amount of water allowed to be abstracted per month	**18144**	m^3
Borehole could satisfy the basic human need of	**24192**	persons
Is the water suitable for domestic use (Yes/No)	**?**	

12l/s for 8 hours/day(345,6m3/day)
10l/s for 12 hours/day(432m3/day)
7l/s for 24 hours/day (604,8m3/day)

Recommended pump depth (mbgl)	**16m**
Total Casing length	**Steel**
Critical depth, water level should not exceed	**12m**
Dynamic water level (m)	**11m**
Depth of bh	**110m**
Static water level	**9,5m**

Management recommendations

KARST AQUIFER

This borehole exhibited characteristics typical of a karst aquifer
The response in drawdown at the start of the constant test was rapid with stabilizing of the drawdown levels, indicating a consistent hydraulic pressure within the borehole.
This was interpreted as reaching the karst aquifer.
Groundwater occurs along fault and shear zones associated with intense deformation resulting in the occurrence of fractures, joints and cavaties subsequently enlarged by dissolution processes in the dolomites.
In recommending safe long term yields, care is taken not to dewater the cavaties, causing dewatering of the aquifer, causing collapsing, and consequently destroying the aquifer.
During the constant test, water was abstracted from this borehole at a constant abstraction yield of 19,5l/s for a duration of 24 hours.
Water was abstracted from the karst aquifer at a depth of approximately 12m for a period of 24 hours.
Water was drawn still drawn from this cavity when the test was terminated after 24 hours with almost immediate recovery in drawdown levels.

The T-value of the formation is in the order of 1000.

The aim of the recommended maximum safe yield is to prevent the waterlevel from drawing down more than 2-3m and potentially dewatering the cavity at approximately 12m depth.

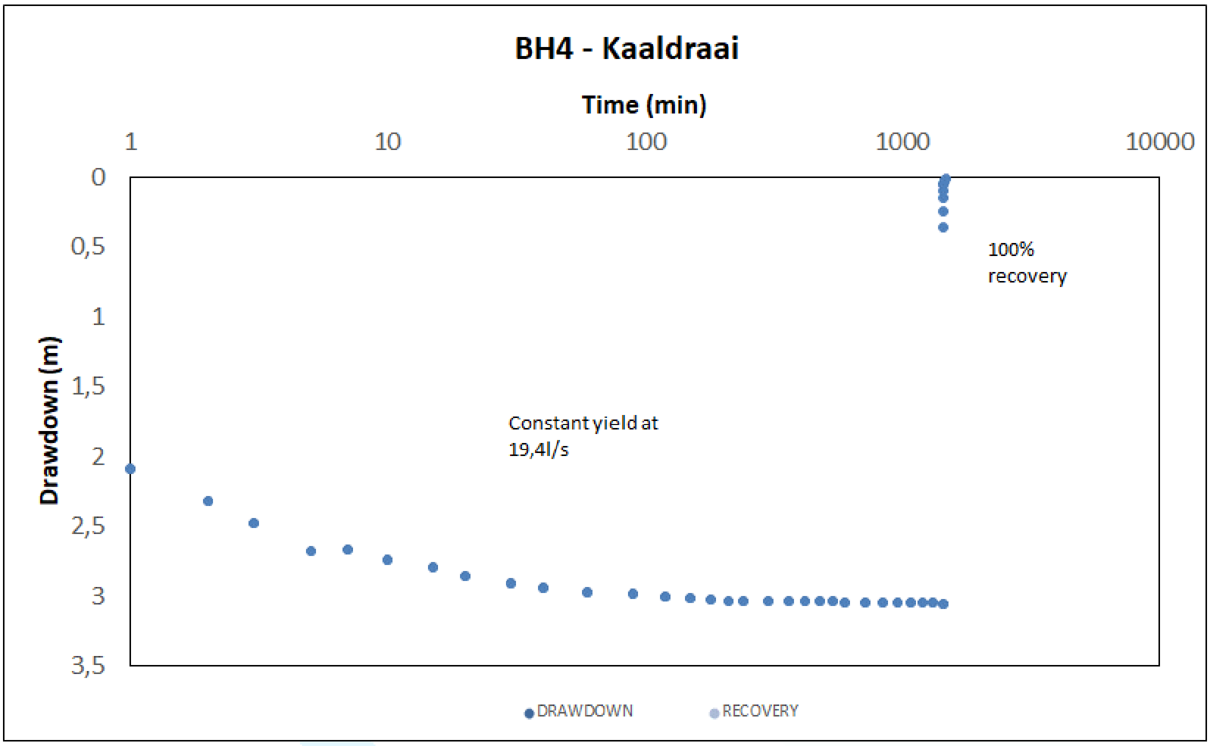
Recommended depth of pump = not exceeding 16m depth
Critical depth = 12m
Static water level = 9,5m

Assumptions
One no-flow boundary at 200m
No rainfall recharge

Date of test: November 2023

Further comments:
It is strongly recommended that a borehole management plan is put into place to secure the sustainability of the source.
It is absolutely critical that the depth of the waterlevel never exceeds the depth of 12m.
Change in pressure within the cavity will cause collapsing of the aquifer and will destroy the borehole as well as surrounding aquifer.

GRAPH 4: RESULTS OF CONSTANT TEST DATA AT BOREHOLE 4 (LIN-LOG)



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Summary

BH 4 Kaaldraai

Applicable	Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)		Late T (m^2/d)		S	AD used
☑	Basic FC	5,78	1,89	1169		511,2		2,20E-03	3,0
☑	Advanced FC	5,30		1169		500,0		1,00E-03	3,0
☐	FC inflection point	na	#NUM!						0,0
☐	Cooper-Jacob	1,16	0,75			464,9		3,66E-02	3,0
☐	FC Non-Linear	na	0,04			4,0		3,75E-03	3,0
☐	Barker	na	0,00	K_f =	301		S_s =	1,19E-03	3,0
	Average Q_sust (l/s)	5,54	0,34	b =	0,20	Fractal dimension n =		0,22	

Recommended abstraction rate (L/s)	**6,00**	for 24 hours per day	
Hours per day of pumping 8	**10,39**	L/s for 8	hours per day

Amount of water allowed to be abstracted per month	**15552**	m^3
Borehole could satisfy the basic human need of	**20736**	persons
Is the water suitable for domestic use (Yes/No)	**?**	

11l/s for 8 hours/day(316,8m^3/day)
9l/s for 12 hours/day(388,8m^3/day)
6l/s for 24 hours/day (518,4m^3/day)

Recommended pump depth (mbgl)	**16m**
Total Casing length	**18m Steel (254mm)**
Critical depth, water level should not exceed	**13m**
Dynamic water level (m)	**11m**
Depth of bh	**110m**
Static water level	**9m**

Management recommendations

KARST AQUIFER
This borehole exhibited characteristics typical of a karst aquifer
The response in drawdown at the start of the constant test was rapid with stabilizing of the drawdown levels,
indicating a consistent hydraulic pressure within the borehole.
This was interpreted as reaching the karst aquifer.
Groundwater occurs along fault and shear zones associated with intense deformation resulting
in the occurrence of fractures, joints and cavaties subsequently enlarged by dissolution processes in the
dolomites.
In recommending safe long term yields, care is taken not to dewater the cavaties, causing dewatering of the
aquifer, causing collapsing, and consequently destroying the aquifer.
During the constant test, water was abstracted from this borehole at a constant abstraction yield of 19,4l/s for a duration of 24 hours.
Water was abstracted from the karst aquifer at a depth of approximately 12m for a period of 24 hours.
Water was drawn still drawn from this cavity when the test was terminated after 24 hours with almost immediate recovery in drawdown levels.

The T-value of the formation is in the order of 800.

The aim of the recommended maximum safe yield is to prevent the waterlevel from drawing down more than 2-3m and potentially dewatering the cavity at approximately 11m depth.

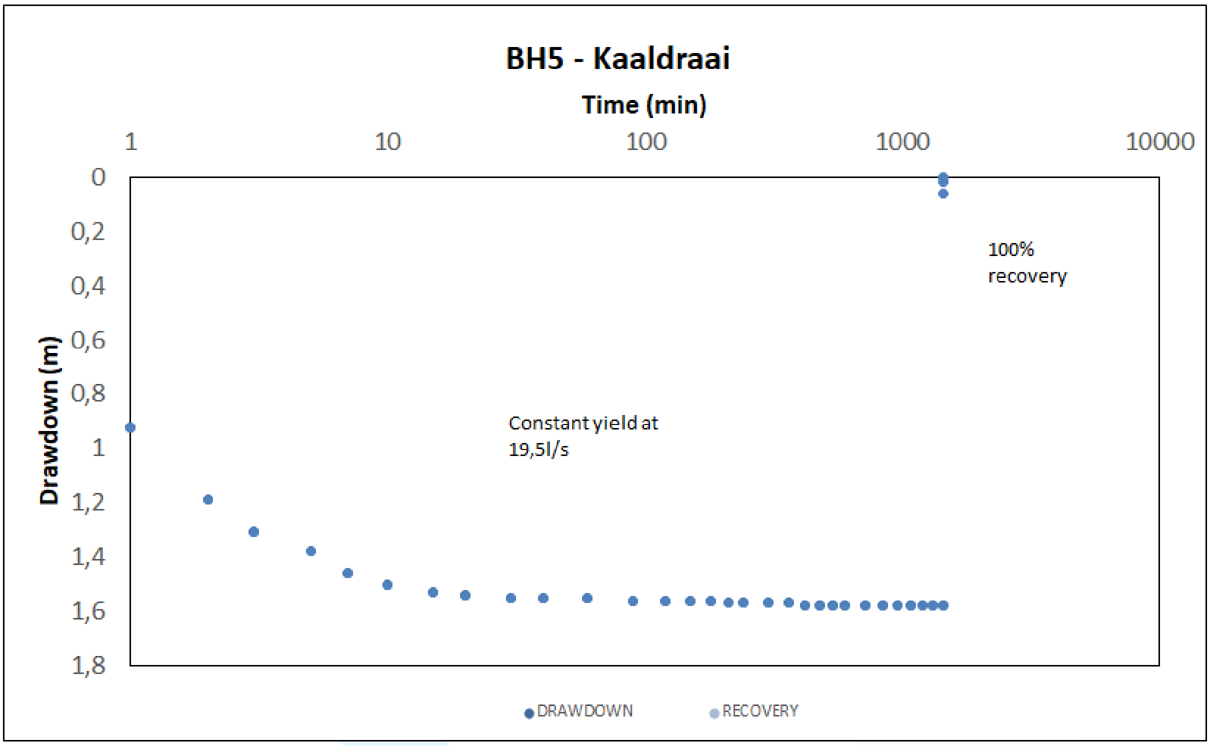
Recommended depth of pump = not exceeding 16m depth
Critical depth = 13m
Static water level = 9m

Assumptions
One no-flow boundary at 200m
No rainfall recharge

Date of test: November 2023

Further comments:
It is strongly recommended that a borehole management plan is put into place to secure the sustainability
of the source.
It is absolutely critical that the depth of the waterlevel never exceeds the depth of 12m.
Change in pressure within the cavity will cause collapsing of the aquifer and will destroy the borehole as well as surrounding aquifer.

GRAPH 5: RESULTS OF CONSTANT TEST DATA AT BOREHOLE 5 (LIN-LOG)



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Summary

Main

BH 5 Kaaldraai

Applicable	Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)		Late T (m^2/d)		S	AD used
☑	Basic FC	4,83	1,75	4244		770,8		2,20E-03	1,5
☑	Advanced FC	4,76		4244		800,0		1,00E-03	1,5
☐	FC inflection point	na	#NUM!						0,0
☐	Cooper-Jacob	0,38	0,24			771,3		1,64E-01	1,5
☐	FC Non-Linear	na	0,04			4,0		3,75E-03	1,5
☐	Barker	na	0,00	K_f =	301		S_s =	1,19E-03	1,5
	Average Q_sust (l/s)	4,80	0,05	b =	0,20	Fractional dimension n =		0,22	

Recommended abstraction rate (L/s)		5,00	for 24 hours per day		
Hours per day of pumping	12	7,07	L/s	for 12	hours per day

Amount of water allowed to be abstracted per month	12960	m^3
Borehole could satisfy the basic human need of	17280	persons
Is the water suitable for domestic use (Yes/No)	?	

9l/s for 8 hours/day(259,2m^3/day)
7l/s for 12 hours/day(302,4m^3/day)
5l/s for 24 hours/day (432m^3/day)

Recommended pump depth (mbgl)	16m
Total Casing length	18m Steel (254mm)
Critical depth, water level should not exceed	12m
Dynamic water level (m)	10m
Depth of bh	110m
Static water level	8,54m

Management recommendations

KARST AQUIFER
This borehole exhibited characteristics typical of a karst aquifer
The response in drawdown at the start of the constant test was rapid with stabilizing of the drawdown levels, indicating a consistent hydraulic pressure within the borehole.
This was interpreted as reaching the karst aquifer.
Groundwater occurs along fault and shear zones associated with intense deformation resulting in the occurrence of fractures, joints and cavaties subsequently enlarged by dissolution processes in the dolomites.
In recommending safe long term yields, care is taken not to dewater the cavaties, causing dewatering of the aquifer, causing collapsing, and consequently destroying the aquifer.
During the constant test, water was abstracted from this borehole at a constant abstraction yield of 19,5l/s for a duration of 24 hours.
Water was abstracted from the karst aquifer at a depth of approximately 10,1m for a period of 24 hours.
Water was drawn still drawn from this cavity when the test was terminated after 24 hours with almost immediate recovery in drawdown levels.

The T-value of the formation is in the order of 800.

The aim of the recommended maximum safe yield is to prevent the waterlevel from drawing down more than 2-3m and potentially dewatering the cavity at approximately 11m depth.

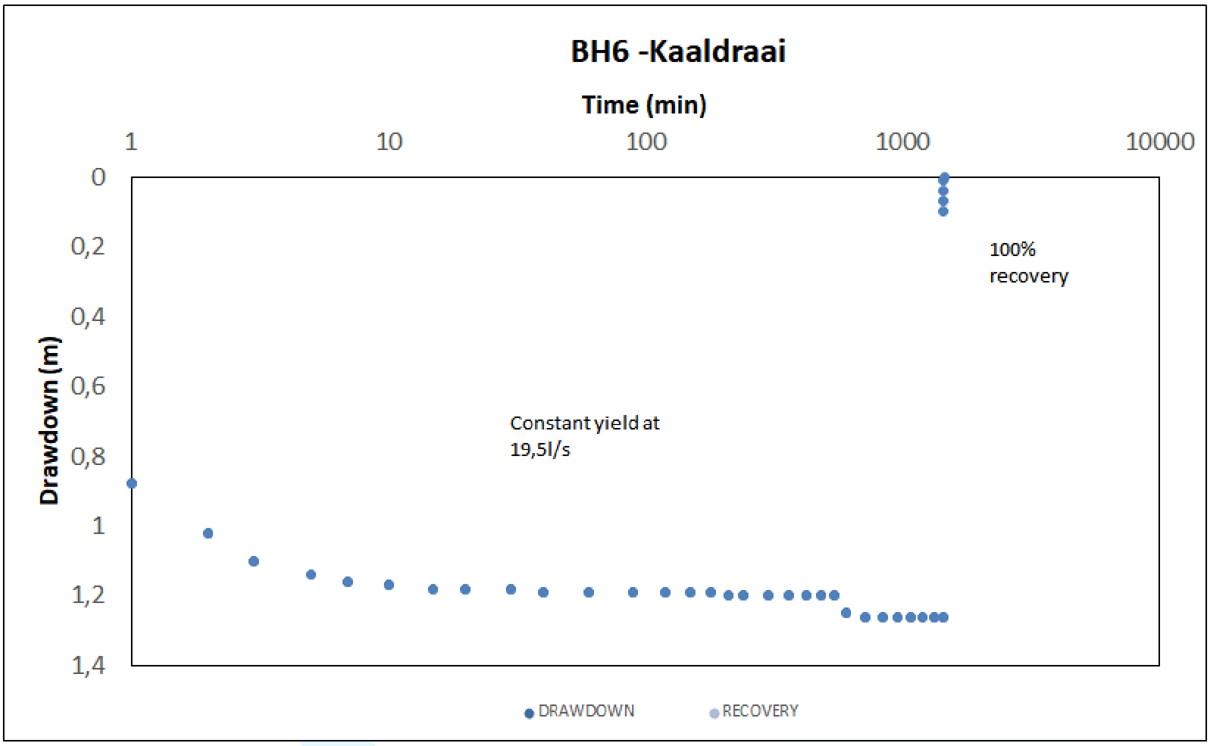
Recommended depth of pump = not exceeding 16m depth
Critical depth = 12m
Static water level = 8,54m

Assumptions
One no-flow boundary at 200m
No rainfall recharge

Date of test: November 2023

Further comments:
It is strongly recommended that a borehole management plan is put into place to secure the sustainability of the source.
It is absolutely critical that the depth of the waterlevel never exceeds the depth of 12m.
Change in pressure within the cavity will cause collapsing of the aquifer and will destroy the borehole as well as surrounding aquifer.

GRAPH 6: RESULTS OF CONSTANT TEST DATA AT BOREHOLE 6 (LIN-LOG)



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Summary	Main	BH 6 Kaaldraai

Applicable	Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)		Late T (m^2/d)		S	AD used
☑	**Basic FC**	4,43	1,65	#NUM!		1027,7		2,20E-03	1,0
☑	**Advanced FC**	4,05		#NUM!		1000,0		1,00E-03	1,0
☐	**FC inflection point**	na	#NUM!						0,0
☐	**Cooper-Jacob**	5,70	3,69			2594,8		7,45E-07	1,0
☐	**FC Non-Linear**	na	0,04			4,0		3,75E-03	1,0
☐	**Barker**	na	0,00	K_f =	301		S_s =	1,19E-03	1,0
	Average Q_sust (l/s)	**4,24**	**0,26**	b =	0,20	Fractal dimension n =		0,22	

Recommended abstraction rate (L/s)	**4,00**	for 24 hours per day
Hours per day of pumping 12	**5,66**	L/s for 12 hours per day

Amount of water allowed to be abstracted per month	**10368**	m^3
Borehole could satisfy the basic human need of	**13824**	persons
Is the water suitable for domestic use (Yes/No)	**?**	

7l/s for 8 hours/day(201,6m³/day)
6l/s for 12 hours/day(259,2m³/day)
4l/s for 24 hours/day (345,6m³/day)

Recommended pump depth (mbgl)	**16m**
Total Casing length	**Steel**
Critical depth, water level should not exceed	**12m**
Dynamic water level (m)	**10m**
Depth of bh	**110m**
Static water level	**9,1m**

Management recommendations

KARST AQUIFER
This borehole exhibited characteristics typical of a karst aquifer
The response in drawdown at the start of the constant test was rapid with stabilizing of the drawdown levels, indicating a consistent hydraulic pressure within the borehole.
This was interpreted as reaching the karst aquifer.
Groundwater occurs along fault and shear zones associated with intense deformation resulting in the occurrence of fractures, joints and cavaties subsequently enlarged by dissolution processes in the dolomites.
In recommending safe long term yields, care is taken not to dewater the cavaties, causing dewatering of the aquifer, causing collapsing, and consequently destroying the aquifer.
During the constant test, water was abstracted from this borehole at a constant abstraction yield of 19,5l/s for a duration of 24 hours.
Water was abstracted from the karst aquifer at a depth of approximately 10,4m for a period of 24 hours.
Water was drawn still drawn from this cavity when the test was terminated after 24 hours with almost immediate recovery in drawdown levels.

The T-value of the formation is in the order of 1000.

The aim of the recommended maximum safe yield is to prevent the waterlevel from drawing down more than 2-3m and potentially dewatering the cavity at approximately 11m depth.

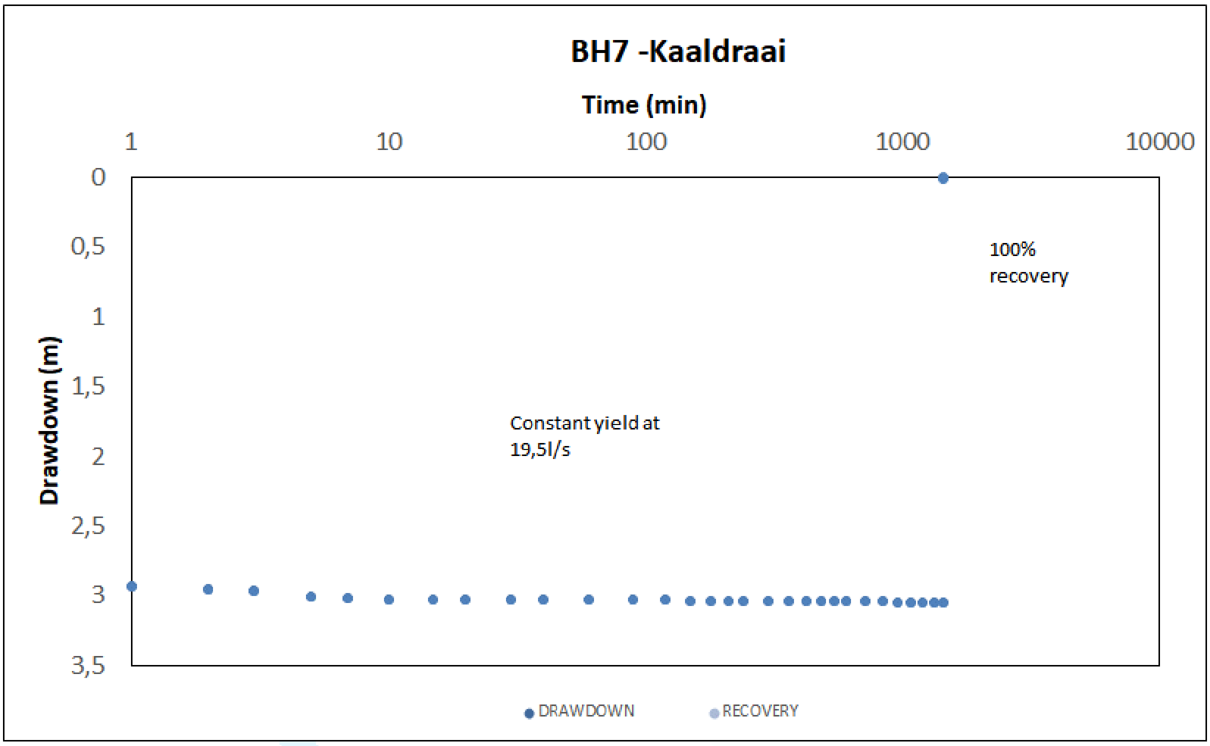
Recommended depth of pump = not exceeding 16m depth
Critical depth = 12m
Static water level = 9,1m

Assumptions
One no-flow boundary at 200m
No rainfall recharge

Date of test: November 2023

Further comments:
It is strongly recommended that a borehole management plan is put into place to secure the sustainability of the source.
It is absolutely critical that the depth of the waterlevel never exceeds the depth of 12m.
Change in pressure within the cavity will cause collapsing of the aquifer and will destroy the borehole as well as surrounding aquifer.

GRAPH 7: RESULTS OF CONSTANT TEST DATA AT BOREHOLE 7 (LIN-LOG)



SanMari GeoHydro Consulting

Summary — BH 7 Kaaldraai

Main

Applicable	Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)		Late T (m^2/d)		S	AD used
☑	**Basic FC**	5,99	1,53	#NUM!		1027,7		2,20E-03	2,0
☑	**Advanced FC**	5,65		#NUM!		1000,0		1,00E-03	2,0
☐	**FC inflection point**	na	0,00						0,0
☐	**Cooper-Jacob**	2,92	1,89			2594,8		1,50E-23	2,0
☐	**FC Non-Linear**	na	0,04			4,0		3,75E-03	2,0
☐	**Barker**	na	0,00	K_f =	301		S_s =	1,19E-03	2,0
	Average Q_sust (l/s)	**5,82**	**0,24**	b =	0,20	Fractal dimension n =		0,22	

Recommended abstraction rate (L/s)	**6,00**	for 24 hours per day	
Hours per day of pumping 12	**8,49**	L/s for 12	hours per day

Amount of water allowed to be abstracted per month	15552	m^3	**11l/s for 8 hours/day(316,8m^3/day)**
Borehole could satisfy the basic human need of	20736	persons	**9l/s for 12 hours/day(388,8m^3/day)**
Is the water suitable for domestic use (Yes/No)	?		**6l/s for 24 hours/day (518,4m^3/day)**

Recommended pump depth (mbgl)	**16m**
Total Casing length	**Steel**
Critical depth, water level should not exceed	**12m**
Dynamic water level (m)	**10m**
Depth of bh	**110m**
Static water level	**8,67m**

Management recommendations

KARST AQUIFER

This borehole exhibited characteristics typical of a karst aquifer
The response in drawdown at the start of the constant test was rapid with stabilizing of the drawdown levels, indicating a consistent hydraulic pressure within the borehole.
This was interpreted as reaching the karst aquifer.
Groundwater occurs along fault and shear zones associated with intense deformation resulting in the occurrence of fractures, joints and cavaties subsequently enlarged by dissolution processes in the dolomites.
In recommending safe long term yields, care is taken not to dewater the cavaties, causing dewatering of the aquifer, causing collapsing, and consequently destroying the aquifer.
During the constant test, water was abstracted from this borehole at a constant abstraction yield of 19,5l/s for a duration of 24 hours.
Water was abstracted from the karst aquifer at a depth of approximately 12m for a period of 24 hours.
Water was drawn still drawn from this cavity when the test was terminated after 24 hours with almost immediate recovery in drawdown levels.

The T-value of the formation is in the order of 1000.

The aim of the recommended maximum safe yield is to prevent the waterlevel from drawing down more than 2-3m and potentially dewatering the cavity at approximately 12m depth.

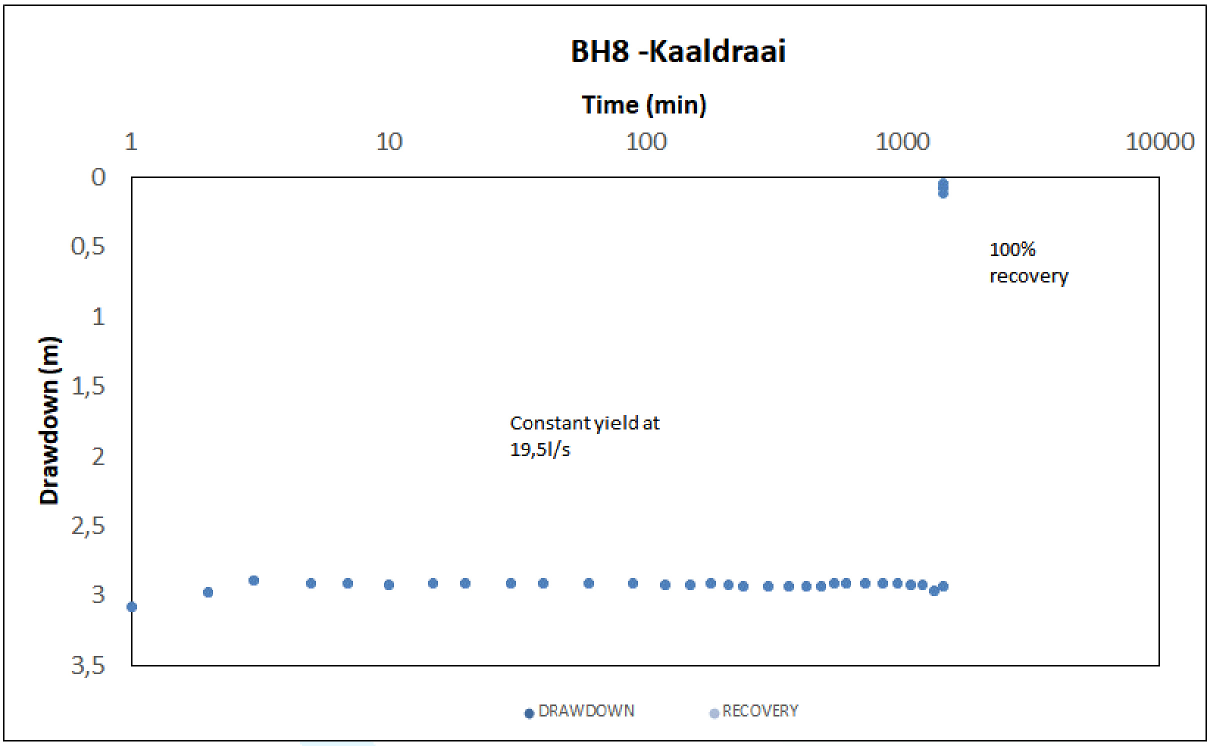
Recommended depth of pump = not exceeding 16m depth
Critical depth = 12m
Static water level = 8,67m

Assumptions
One no-flow boundary at 200m
No rainfall recharge

Date of test: November 2023

Further comments:
It is strongly recommended that a borehole management plan is put into place to secure the sustainability of the source.
It is absolutely critical that the depth of the waterlevel never exceeds the depth of 12m.
Change in pressure within the cavity will cause collapsing of the aquifer and will destroy the borehole as well as surrounding aquifer.

GRAPH 8: RESULTS OF CONSTANT TEST DATA AT BOREHOLE 8 (LIN-LOG)



SanMari GeoHydro Consulting

Summary	Main	BH 8 Kaaldraai

Applicable	Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)	Late T (m^2/d)	S	AD used
☑	Basic FC	5,27	1,20	#NUM!	1027,7	1,10E-03	2,0
☑	Advanced FC	4,58		#NUM!	1000,0	1,00E-03	2,0
☐	FC inflection point	na	0,00				0,0
☐	Cooper-Jacob	2,77	1,79		4667,8	1,78E-41	2,0
☐	FC Non-Linear	na	0,04		4,0	3,75E-03	2,0
☐	Barker	na	0,00	K_f = 301	S_s =	1,19E-03	2,0
	Average Q_sust (l/s)	4,93	0,49	b = 0,20	Fractal dimension n =	0,22	

Recommended abstraction rate (L/s)	5,00	for 24 hours per day	
Hours per day of pumping 12	7,07	L/s for 12	hours per day

Amount of water allowed to be abstracted per month	12960	m^3
Borehole could satisfy the basic human need of	17280	persons
Is the water suitable for domestic use (Yes/No)	?	

9l/s for 8 hours/day(259,2m³/day)
7l/s for 12 hours/day(302,4m³/day)
5l/s for 24 hours/day (432m³/day)

Recommended pump depth (mbgl)	16m
Total Casing length	Steel
Critical depth, water level should not exceed	14m
Dynamic water level (m)	10m
Depth of bh	24m
Static water level	10,09m

Management recommendations

KARST AQUIFER
This borehole exhibited characteristics typical of a karst aquifer
The response in drawdown at the start of the constant test was rapid with stabilizing of the drawdown levels, indicating a consistent hydraulic pressure within the borehole.
This was interpreted as reaching the karst aquifer.
Groundwater occurs along fault and shear zones associated with intense deformation resulting in the occurrence of fractures, joints and cavaties subsequently enlarged by dissolution processes in the dolomites.
In recommending safe long term yields, care is taken not to dewater the cavaties, causing dewatering of the aquifer, causing collapsing, and consequently destroying the aquifer.
During the constant test, water was abstracted from this borehole at a constant abstraction yield of 19,5l/s for a duration of 24 hours.
Water was abstracted from the karst aquifer at a depth of approximately 12,5m for a period of 24 hours.
Water was drawn still drawn from this cavity when the test was terminated after 24 hours with almost immediate recovery in drawdown levels.

The T-value of the formation is in the order of 1000.

The aim of the recommended maximum safe yield is to prevent the waterlevel from drawing down more than 2-3m and potentially dewatering the cavity at approximately 13m depth.

Recommended depth of pump = not exceeding 16m depth
Critical depth = 14m
Static water level = 10,09m

Assumptions
One no-flow boundary at 200m
No rainfall recharge

Date of test: November 2023

Further comments:
It is strongly recommended that a borehole management plan is put into place to secure the sustainability of the source.
It is absolutely critical that the depth of the waterlevel never exceeds the depth of 14m.
Change in pressure within the cavity will cause collapsing of the aquifer and will destroy the borehole as well as surrounding aquifer.

Appendix C

Technical borehole management recommendation options

These include:

- Installation of a 32 mm (inner diameter, class 10) observation pipe from the pump depth to the surface, closed at the bottom and slotted for the bottom 5 – 10 m. This allows for a 'window' of access down the borehole which enables manual water level monitoring and can house an electronic water level logger.
- **Alternatively,** the installation of an electronic water level logger. *Groundwater level* can be measured within the well, and the pump programmed to shut off automatically if the water goes below the *critical depth* as summarized in Table 15 and explained in Paragraph 14 in this report.
- **Alternatively,** *C-T-D transducers:* Specialized pressure transducers, which measure conductivity, temperature and depth (C-T-D), may be installed in an access tube in the well.
- Installation of a sampling tap (to monitor water quality).
- Installation of a flow volume meter (to monitor abstraction rates and volumes).
- The appropriate borehole pump must be installed, i.e. not an over-sized pump that is choked with a gate valve. If the monitoring shows that more water can be abstracted, then the duration of pumping time will be increased (not the flow rate).
- The borehole and pump should be serviced annually.
- *Water metering* is recommended to be installed to assists with detecting uncontrolled leaks

Monitoring parameters and summary of monitoring programme

Physical Parameters:

- Groundwater levels (static water levels where possible); and
- Groundwater Abstraction volumes (from flow meter).

Chemical parameters:

- Field measurements:
  - pH, EC;
- Laboratory analyses:
  - Anions and cations (Ca, Mg, Na, K, NO3, Cl, SO4, F, Fe, Mn, Al, Hardness and Bicarbonate, Carbonate and Total Alkalinity);
  - Other parameters (pH, EC, TDS)

Monitoring boreholes	Sampling interval	Analysis	Standards and Guidelines
All production boreholes	Weekly abstraction volumes should be recorded	n/a	WUL Requirements
All monitoring & production boreholes	Weekly measuring the depth of groundwater levels (static water levels)	n/a	WUL Requirements
All monitoring & production boreholes	Bi-annually: sampling for water quality analysis (Refer: Table 11)	Full analysis	SA Water quality Guidelines: Domestic, Irrigation, livestock watering

It is highly recommended that a geohydrologist review the above information to ensure optimal groundwater abstraction and management control.

Appendix D

Magalies Water

Water Quality Analysis results

BH1 to BH8

Geo Asset
97 Steyn Str
Baillie Park
Potchefstroom

Scientific Services
Brits Laboratory
Erf 3472 (near no. 5 Stoffberg Street), Brits
0250
Tel 012 381 6600
VAT No. 4930111143

T0625

Water Quality Analysis Report

Report date:	**2023-11-27**	**Attention:**	**Pierre Jan Van Vuuren**
Samples received:	**2023-11-10**	**Tel:**	
Certificate Number:	**2023-89514-28302**	**E-mail:**	**pierre19970226@outlook.com**
Order Number:			

Comment: Final report.

Sample matrix				Borehole Water	Borehole Water	Borehole Water	Borehole Water	Borehole Water	Borehole Water
Sample condition				Normal	Normal	Normal	Normal	Normal	Normal
Sample number				89514	89515	89516	89517	89518	89519
Sample date				2023-11-10	2023-11-10	2023-11-10	2023-11-10	2023-11-10	2023-11-10
Analysis start date				2023-11-11	2023-11-11	2023-11-11	2023-11-11	2023-11-11	2023-11-11
Analysis completion date				2023-11-27	2023-11-27	2023-11-27	2023-11-27	2023-11-27	2023-11-27
Identification on container				Kaaldraai Gat 1	Kaaldraai Gat 2	Kaaldraai Gat 3	Kaaldraai Gat 4	Kaaldraai Gat 5	Kaaldraai Gat 6
Determinand	**Unit**	**Method Number**	**SANS 241:2015 Limits**	**Results**	**Results**	**Results**	**Results**	**Results**	**Results**
pH @ 25°C	pH units	CLM001	≥ 5.00 to ≤ 9.70	6.98	7.06	6.91	7.04	6.88	7.20
Electrical Conductivity @ 25°C	mS/m	CLM002	≤ 170.0	304.7	218.6	207.8	166.2	526.0	119.4
Temperature*	°C	CLM001	≤ 30	22	22	22	22	22	22
Turbidity	NTU	CLM003	≤ 1.0	0.29	0.53	0.53	0.51	0.50	0.52
Alkalinity Total	mg/L CaCO3	CLM004	≤ 300	470	402	259	276	629	221
Chloride	mg/L Cl-	CLM005	≤ 300	715	371	421	299	1 503	189
Fluoride	mg/L F-	CLM005	≤ 1.5	0.34	0.080	0.40	0.32	0.59	0.59
Nitrate	mg/L N	CLM005	≤ 11	30	26	21	16	46	12
Sulphate	mg/L SO_4	CLM005	≤ 500	148	114	88	78	222	86
Total Cadmium (ICP-OES)	µg/L Cd	CLM038	≤ 3.0	0.94	1.1	0.91	0.61	1.6	0.66

Sample matrix				Borehole Water	Borehole Water	Borehole Water	Borehole Water	Borehole Water	Borehole Water
Sample condition				Normal	Normal	Normal	Normal	Normal	Normal
Sample number				89514	89515	89516	89517	89518	89519
Sample date				2023-11-10	2023-11-10	2023-11-10	2023-11-10	2023-11-10	2023-11-10
Langelier saturation index*	mL	CLM 055	≥ -1.0 to ≤ 1.00	0.25	0.15	-0.2	-0.1	0.42	-0.3
TDS by calculation	mg/L	CLM056	≤ 1200	1 981	1 421	1 351	1 080	3 419	776
Total Iron (ICP-OES)	µg/L Fe	CLM038	≤ 2000	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37
Total Aluminium (ICP-OES)	µg/L Al	CLM038	≤ 300	3.5	4.3	4.0	3.5	6.8	2.8
Total Manganese (ICP-OES)	µg/L Mn	CLM038	≤ 400	1.9	<0.09	<0.09	<0.09	<0.09	<0.09
Total Zinc (ICP-OES)	mg/L Zn	CLM038	≤ 5.0	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Total Calcium (ICP-OES)	mg/L Ca	CLM039	≤ 300	187	142	124	107	279	61
Total Cobalt (ICP-OES)	µg/L Co	CLM038	≤ 2400	12	8.0	9.7	6.9	11	7.5
Total Chromium (ICP-OES)	µg/L Cr	CLM038	≤ 50	49	60	23	21	55	5.9
Total Copper (ICP-OES)	µg/L Cu	CLM038	≤ 2000	5.0	1.7	0.36	<0.01	3.6	0.88
Total Lead (ICP-OES)	µg/L Pb	CLM038	≤ 10	<0.01	<0.01	<0.01	1.2	<0.01	<0.01
Total Magnesium (ICP-OES)	mg/L Mg	CLM039	≤ 100	95	79	80	67	122	55
Total Nickel (ICP-OES)	µg/L Ni	CLM038	≤ 70	<0.09	2.3	1.7	1.7	3.8	<0.09
Total Potassium (ICP-OES)	mg/L K	CLM039	≤ 100	2.6	2.4	1.7	1.9	2.9	2.1
Total Sodium (ICP-OES)	mg/L Na	CLM039	≤ 200	210	153	119	108	317	64
Hardness Total (ICP-OES)	mg/L CaCO3	CLM018	≤ 300	857	681	638	542	1 197	378

Sample matrix				Borehole Water	Borehole Water	Borehole Water	Borehole Water	Borehole Water	Borehole Water
Sample condition				Normal	Normal	Normal	Normal	Normal	Normal
Sample number				89514	89515	89516	89517	89518	89519
Sample date				2023-11-10	2023-11-10	2023-11-10	2023-11-10	2023-11-10	2023-11-10
E.coli Colilert	MPN/100 ml	MLM 016	≤ 0	ND	ND	ND	ND	ND	ND
Total Coliforms Colilert	MPN/100 ml	MLM 016	≤ 10	155	ND	1	114	1	6
Sodium Adsorption Ratio (ICP-OES)	mg/L	CLM024		18	15	12	12	22	8.5

ND = Not detected

Technical Signatory(Chemistry):___Paki Dikobe___ Technical Signatory (Micro):___n/a___

Signature:___P.Dikobe___ Date: 27/11/2023 Signature:___n/a___ Date:___n/a___

Disclaimer: The information contained in this report is relevant only to the sample (s) tested by Magalies Water Laboratory and the results apply to the sample as received. Any further use of the above information is not the responsibility of Magalies Water Laboratory. Except for the full report, part of this report may not be reproduced without written approval of Magalies Water Laboratory. "Method numbers" refers to our internal methods. Standard methods are available on request. Only chemistry samples will be kept for one month after date of reporting. Tests marked with * in this report are not included in the SANAS Schedule of Accreditation for this laboratory. Test marked with ^ is information that is provided by the customer. The validity of results can be affected when the information is supplied by the customer. Tests marked with # in this report are subcontracted and not included in the SANAS Schedule of Accreditation for this laboratory. Opinions and interpretations expressed herein are outside the scope of SANAS accreditation for this laboratory. When sampling is done by the laboratory it will be done according to P010, which will be made available upon request. When a statement of conformity to a specification or standard is provided, the laboratory shall document the decision rule employed, taking into account the level of risk associated with the decision rule employed, and apply the decision rule. Decision rule will only be applied upon request by the customer. Results contained in this report were performed at the laboratory's permanent facilities. Any deviations, additions to, or exclusions from the method will be noted under remarks in this report.

Page 3 of 3 Certificate number: 2023-89514-28302

Appendix E

Aquifer monitoring data sheet (example)

Borehole water level monitoring						
Initial static water level =					To be calculated	
Date	**Water level (mbgl)**	**Static/Dynamic**	**Pressure (bar)**	**Flow meter reading (m^3/Liters)**	**Abstraction volume**	**Date (Water sample taken)**