GEOHYDROLOGICAL AND RISK ASSESSMENT STUDY FOR PORTION 62 OF THE FARM COMMISIEDRIFT 327 JQ, RUSTENBURG, NORTH WEST PROVINCE

Prepared for

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EXECUTIVE SUMMARY

This document presents the results of a Hydrogeological Assessment study which aim at establishing a baseline reference of hydrogeological data to form part of a WULA (Water Use Licence Application).

A school is planned for Portion 62 of the farm Commissiesdrift 327 JQ. The school is planned to be located on the western side of the Olifantsnek village which is located on the bank of the Olifantsnek Dam.

Olifantsnek village is located 15 km south of Rustenburg on the R24 provincial road. Portion 62 is 28.9193 ha in surface area. No services such as water and sanitation are available in the Olifantsnek village. The water demand for the school will be 56.1m^3/d. This water demand will be satisfied by three groundwater production boreholes located on the land portion. These three boreholes had to be tested to be able to calculate the recommended yield from these boreholes.

HK Geohydrological Services (Pty) Ltd was appointed by Hydro Science to submit these boreholes to yield testing procedures and to do a geohydrological assessment study for the proposed school development.

A desk study was performed to gather relevant geological and hydrogeological information. A hydro-census followed the desk study to establish borehole information in the region of the site. The purpose of this survey was to gather relevant hydrogeological information to study the groundwater regime, current groundwater use and borehole coordinates in the area. Twenty four boreholes were visited on and around the proposed development site.

During the study three groundwater production boreholes BH 1, BH 2, and BH 3 was submitted to borehole yield testing procedures to be able to calculate the aquifer parameters Transmisivity and Storativity. Groundwater abstraction volumes were calculated from the aquifer parameters and the sustainability of the abstraction was measured against the groundwater recharge volumes of the development portion. A geological walk over study was done of the site to study the in-situ geology. The groundwater recharge volumes were calculated to be able to verify the sustainability of the planned water abstraction.

During the hydrogeological study the following conclusions could be made:

- During the hydro-census twenty four boreholes were visited. The hydro-census data gives a broad picture that north of the planned development area low groundwater abstraction figures is prevailing.
- The water level depth as measured in the boreholes visited on site during the hydro-

census range from 7.03 meters below ground level to 36.05 meters below ground level.

- Three boreholes were submitted to borehole yield testing procedures.
- The three boreholes can be recommended to serve as water abstraction boreholes.
- The water that can be taken from these three boreholes is 56.1m^3/d.
- The water from the three boreholes tested shows good quality water. The chemical parameters analysed for is below the standard limits specified. The water does not need to be treated chemically to enhance the quality.
- The Total Faecal Coliform count for borehole BH 1 is 2CFU/100ml which means that the water needs to be treated prior to human consumption. Chlorination of the water from borehole BH 1 is recommended prior to human consumption. Water from borehole BH 2 and BH 3 do not need to be bacteriologically treated prior to human consumption.
- The mean groundwater recharge on the specific proposed development portion is calculated to be in the order of 46.6mm/a or 6.6% of MAP or 36.92m^3/d.
- For all practical reasoning will groundwater recharged to the north and west of the site eventually flow towards Portion 62. The three boreholes BH 1 to BH 3 are located topographically low and can make use of the groundwater recharge that is generated up the valley which is located to the west of the proposed development area. The valley stretch for 7km to the west of the site. This valley is also 5.2km in width which generate 1 696 240m^3 in groundwater recharge per day.
- The vulnerability of the Groundwater Aquifer due to the Hydrogeological Conditions at Portion 62 can be rated as medium risk.
- The soil and silty sand are permeable and will act as a filter system. The vertical travel of contaminated water will be at a rate of 0.25m/d. The risk of organic or microbiological contaminants is negligible.
- The sand and silt that is found on site has a minimal to medium capacity to absorb contaminants and a medium to high capacity to create an effective barrier to the movement of biological contaminants.
- A high reduction of bacteria and viruses will be evident in the unsaturated aquifer if a leak does happen. Nitrates, phosphates and chlorides will be minimally reduced. The top layer will form a good barrier to the movement of biological contaminants but will have little reduction in chemical contaminants.
- The aquifer is only vulnerable to the most persistent pollutants in the very long term.
- The significance of the potential impacts in the operational phase is rated as “Negligible”.
- With mitigation, the significance of these activities is rated as “Negligible”.

The following recommendations are made:

- The groundwater abstraction boreholes must be utilized at the recommended rates and duty cycles.

- The groundwater monitoring network as stipulated in Section 9 must be implemented as recommended. Detail recommendations regarding the groundwater monitoring is stipulated in this section.

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1. INTRODUCTION

1.1 Background

This document presents the results of a Hydrogeological Assessment study which aim at establishing a baseline reference of hydrogeological data to form part of a WULA (Water Use Licence Application).

A school is planned for Portion 62 of the farm Commissiesdrift 327 JQ. The school is planned to be located on the western side of the Olifantsnek village which is located on the bank of the Olifantsnek Dam.

Olifantsnek village is located 15 km south of Rustenburg on the R24 provincial road. Portion 62 is 28.9193 ha in surface area. No services such as water and sanitation are available in the Olifantsnek village. The water demand for the school will be 54.2m^3/d. This water demand will be satisfied by three groundwater production boreholes located on the land portion. These three boreholes had to be tested to be able to calculate the recommended yield from these boreholes.

HK Geohydrological Services (Pty) Ltd was appointed by Hydro Science to submit these boreholes to yield testing procedures and to do a geohydrological assessment study for the proposed school development.

1.2 Scope of Investigation

1) Desk study to study the geology and groundwater regime.
2) Studying of existing hydrological, geotechnical and environmental reports.
3) Site visit and Hydro-census of existing boreholes in at least a 1km radius from the planned development area.
4) Submit the three boreholes to borehole yield testing procedures according DWS standards.
5) Taking of water samples for water quality analyses.
6) Creation of geological, hydrogeological and hydrochemical GIS maps of the aquifer system.
7) Do a category C geohydrological study and a groundwater risk assessment report for the site.

1.3 Water use licence application information

To abstract water from an aquifer on a large scale for commercial activities, a water use license will be needed. A Regional - Initial calculation is done to determine the amount of information necessary for each new Water Use license application for groundwater abstraction.

The calculations are based on the following:

- Size of the property ($Area_{prop}$). Surface area of Portion 62 of the farm Commissiesdrift 327 JQ is 28.9193 ha or 0.289193Km^2
- Recharge – HP (RE). Preliminary groundwater recharge taken as 46.6mm per annum. (Calculated in Section 6.3)
- Existing use volumes (ABS_{ex}). 4m^3/d.
- New use volumes (ABS_{new}). Provision is made for 19 800m^3/a or 52.1m^3/d which is 1.21ℓ/s for 12h/d.
- Scale of abstractions (ABS_{scale})

Calculations: -

Groundwater Recharge

$Area_{prop}$ x RE			=	RE_{area} (m^3/a)
$Area_{prop}$	=	0.289193Km^2	=	289 193m^2
RE			=	46.6mm/annum
289 193m^2 x (0.0466m)			=	**13 476.4 m^3/a or 36.92m^3/d**

Groundwater Demand

ABS_{ex} + ABS_{new}	=	ABS total (m^3/a)
4 m^3/day + 52.1m^3/d	=	**20 476.5m^3/a or 56.1m^3/a**

Scale of Abstraction

ABS_{scale}	=	(ABS_{total} / RE_{Area}) x 100
	=	(20 476.5 m^3/a / 13 476.4 m^3/a) x 100
	=	**152 %**

Based on the calculations for the property size only (ignoring water use considerations) the abstraction is classified as Category C – Large Scale Abstraction (>100%) of recharge on property. The proposal set out below is therefore to complete a Category C study. The Category C study requirements are taken from the Water Use License Application Requirements of the Department of Water Affairs and Forestry:

Category C

- A geo-hydrological report compiled by an acceptable and qualified geo-hydrological consultant. Report should include appropriate maps, tables and figures to support the conclusions and recommendations.
- Detail geology of the area, including structures, maps etc.
- Detail borehole census within at least 1km (Recommend **2km**) width zone around the area of recharge as well as on the area itself. Information to be collected for each borehole should at least include pump installation depth, borehole depth, depth of water level, yield of the borehole, depth of water strike(s), volume abstracted (daily, weekly, monthly) and water quality (one macro analysis per property in the zone).
- Aquifer description and characteristics including extent of the aquifer and hydraulic properties (storativity and transmissivity). This would require testing. Drilling might or might not be required. Groundwater piezometric contour map showing flow direction and a depth to water level contour map.
- Effective annual recharge on this property and the safe yield of the aquifer.
- Volume and purpose of the water required and the volume available for abstraction. A water balance that at least cover the aquifer unit in which the property is located should, in other words be done that includes all gains and losses.
- Contact details of relevant parties in the hydro census area.
- Impact the abstraction will have on existing users and surrounding properties. This should be short- and long-term impact. This might have to be supported by a numerical model.
- Proximity to and potential impact of the abstraction on surface water discharges and groundwater dependent terrestrial ecosystems.
- Potential impact of potential use on groundwater and surface water quality.
- Geo-referenced map of the property in question, with boreholes, surface water features, geological features, physical structures (houses, stores, irrigation equipment) and current pollution sources (septic tanks, pit latrines, petrol/ diesel tanks, irrigation areas) depicted.
- Monitoring programme - weekly water levels, weekly rainfall, 3 monthly macro analysis and surface water discharges and 6 monthly qualities in the 1km width zone.

The Department of Water Affairs and Forestry recommends that the following measures be taken when testing boreholes for sustainable yields and to provide the following information:

- Refer to test procedures in the South African National Standards Code No.: SANS 10299.

- Perform a three (3) hour stepped draw down test to determine the discharge rate of the intended constant rate test OR;
- The constant discharge test should be done at approximately $^{2}/_{3}$ of the blow yield of the bore hole.
- For **HOUSEHOLD** use it is recommended that a 8 hour constant rate test be performed with the draw down and the recovery measured.
- For **IRRIGATION** it as recommended that a 24 constant rate test should be performed while the draw down and the recovery is measured. This test could also be performed for intended **BULK WATER SUPPLY** for a volume of up to 150 000 m^3 per annum.
- For **BULK WATER SUPPLY** in excess of 150 000 m^3 per annum it as recommended that a 72 hour constant rate test should be performed while the draw down and the recovery of the bore hole is measured.
- All data as obtained above should be attached to the relevant Water Use License Application forms, together with an analysis of the data (including draw down curves) and recommendation for the sustainable yield of the borehole(s), by a qualified Geo-hydrologist.

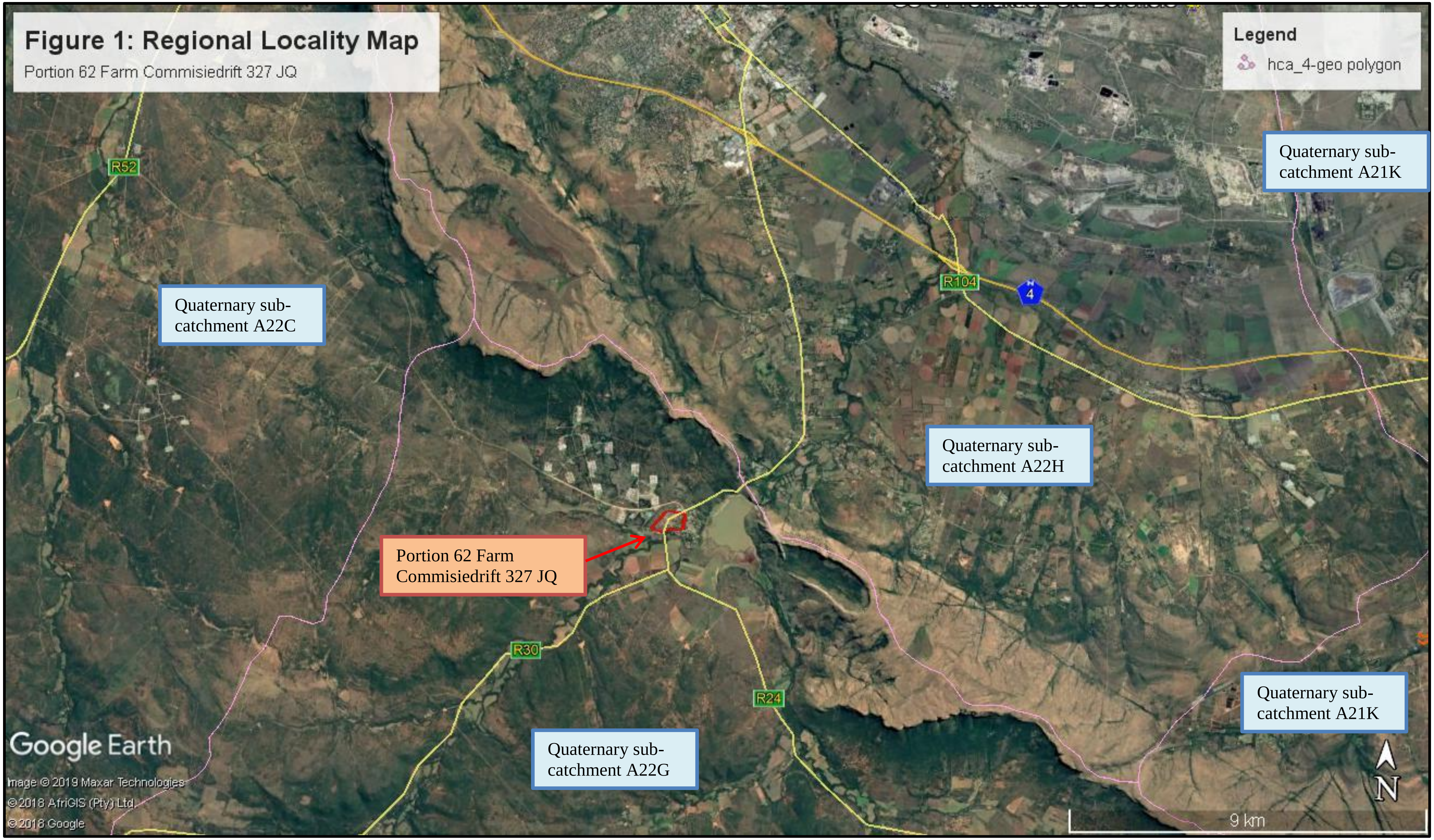


Figure 1: Regional locality map.

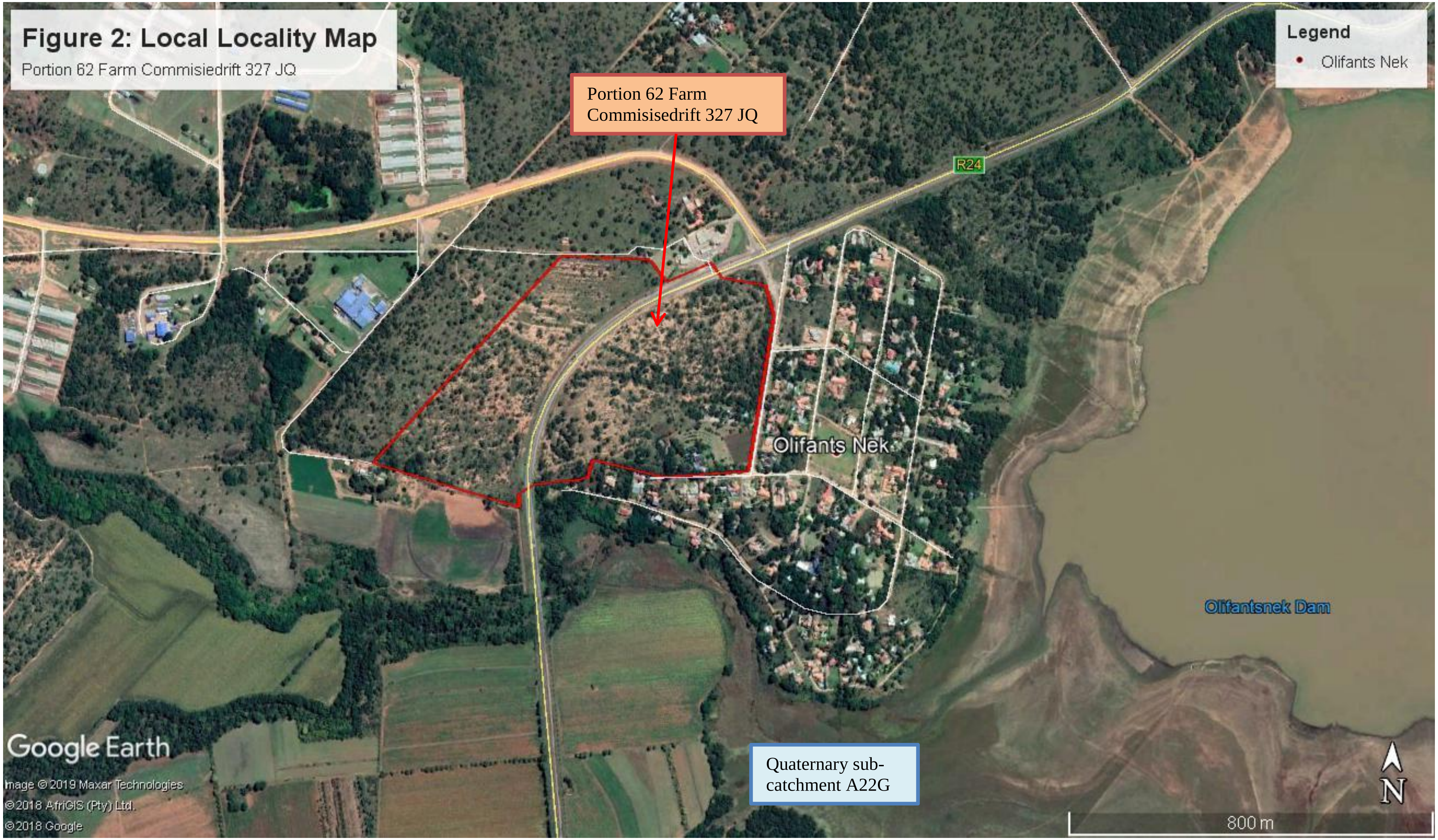


Figure 2: Local locality map of the region.

2. CLIMATE AND REGIONAL SETTING

2.1 Catchment area

Portion 62 is located in quaternary sub-catchment A22G. Refer to figure 1. The site area of this study is located in the upper Hex River which is one of the tributaries of the Crocodile River.

2.2 Climate

The climate at the proposed development area is warm and wet summers with cold and dry winters.

2.3 Rainfall

The site is located in Weather Bureau section number 0511 and in rainfall zone A2F. The closest rainfall station still in use is 0511467. This weather station is located approximately 2km east of the development portion. The rainfall period for this station covers the years from 1924 to 1989. The Mean Annual Precipitation (MAP) for the period is 711mm/a. Rainfall occurs as typical summer thunderstorms with lightning and fairly strong winds. Summer rainfall is typically from October to April, in which approximately 90.75% of rainfall normally occurs. The typical dry period is between May and September each year, covering the winter months.

2.4 Evaporation

The proposed development portion is located in Evaporation Zone 3B. The closest Evaporation station A2E008, the Rustenburg station which is located approximately 15km north of the proposed development, gives a mean annual evaporation (MAE) of 1645 mm for the S-Pan and 2054 mm A-Pan value. The evaporation measurements cover the years 1957 to 1979.

2.5 Drainage area

The site is located in Hydro Zone N with a Mean Annual Runoff (MAR) of 20 to 50mm per annum.

3. METHODOLOGY

A desk study was performed to gather relevant geological and hydrogeological information. A hydro-census followed the desk study to establish borehole information in the region of the site. The purpose of this survey was to gather relevant hydrogeological information to study the groundwater regime, current groundwater use and borehole coordinates in the area. Twenty four boreholes were visited on and around the proposed development site.

During the study three groundwater production boreholes BH 1, BH 2, and BH 3 was submitted to borehole yield testing procedures to be able to calculate the aquifer parameters Transmisivity and Storativity. Groundwater abstraction volumes were calculated from the aquifer parameters and the sustainability of the abstraction was measured against the groundwater recharge volumes of the development portion as well as the regional groundwater catchment area. A geological walk over study was done of the site to study the in-situ geology. The groundwater recharge volumes were calculated to be able to verify the sustainability of the planned water abstraction.

4. GEOLOGICAL SETTING

The 1:250 000 Geological Series map no 2526 Rustenburg indicates that the area of interest lies on Slate shale and hornfels of the Pretoria Group. The stale and shale forms a low yielding aquifer. Diabase on the other hand intruded the slate and shale layers which can form a medium yielding aquifer. A number of diabase sills penetrated the shale layers in the region. The contact zones of the shale and diabase intrusions normally weather to a productive aquifer.

Quaternary deposits were laid down in the valleys which normally form a Primary aquifer which normally have a good storage capacity. The three proposed production boreholes are located on the contact zone of the Silverton Formation which is the slate and shale host rock and the quaternary deposits. The quaternary deposits are expected to form a productive storage of water which replenish fast after and during the rainy season.

The geology map is below on Figure 4 which shows the regional geology. The position of the development site is marked in red.

Era	Group	Formation	Lithology	Colour
QUATERNARY			Surface deposits	Q
MOKOLIAN			Diabase	di
VAALIAN	Pretoria Group	Silverton	Slate, shale, hornfels	Vsi

Figure 3: Geological Legend (Condensed)

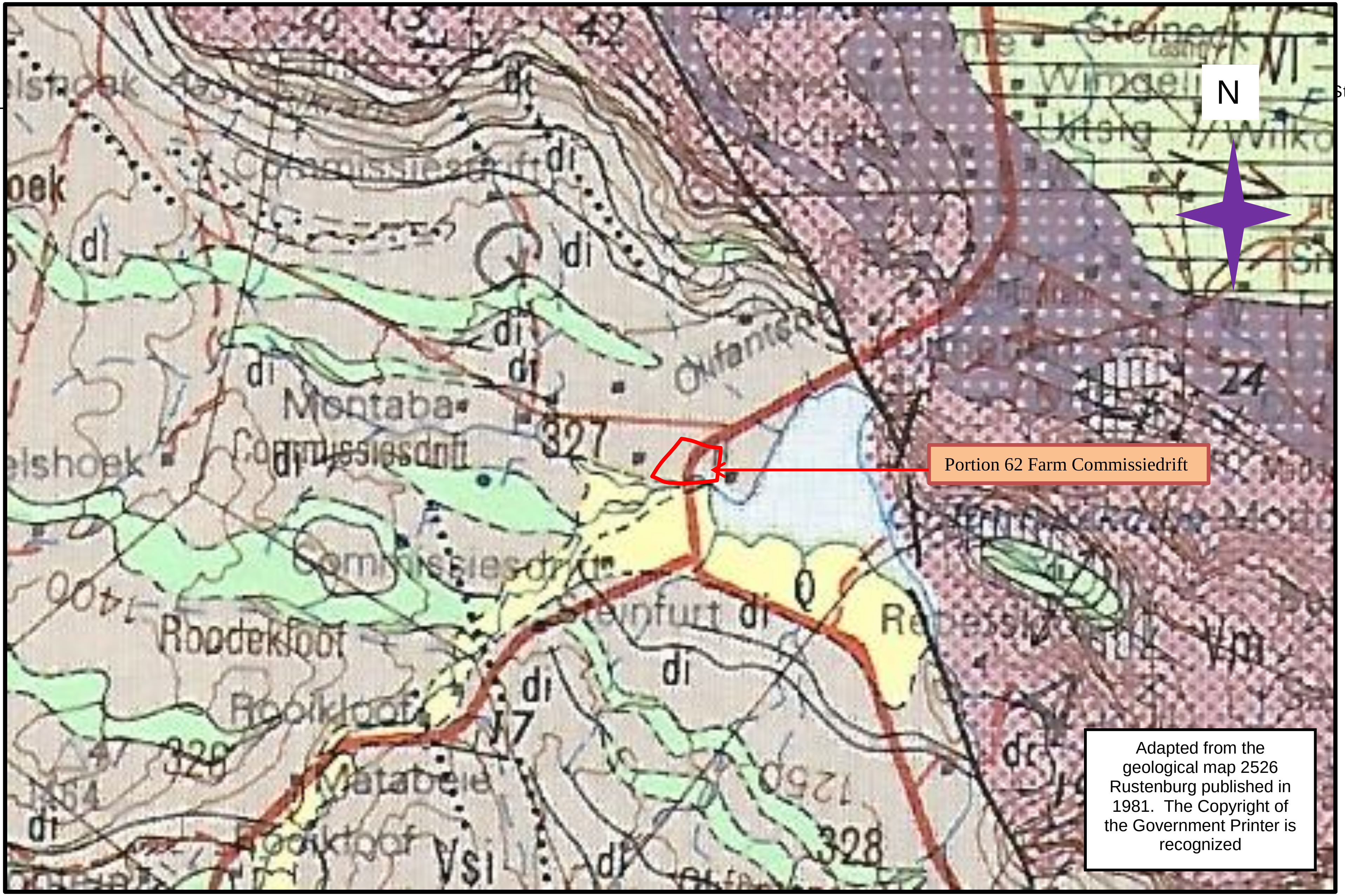


Figure 4: Regional 1: 250 000 geological map 2526 Rustenburg.

5. FIELD WORK

5.1 Desk study and Hydro-Census Data

A desk study was performed to gather relevant geological and hydrogeological information. A hydro-census followed the desk study to establish borehole information in the region of the site. The purpose of this survey was to gather relevant hydrogeological information to study the groundwater regime, current groundwater use and borehole coordinates in the area. Twenty four boreholes were visited on and around the site.

Six boreholes could be found on the development portion, Portion 62. Two of these boreholes are equipped and in use. The other four boreholes are not quipped. Seventeen water level depths could be measured in the twenty three boreholes visited. The static water level depths range from 7.03mbgl to 36.05mbgl. Two boreholes visited were pumping recently. These water level measurements of the two boreholes are dynamic water level depths. They measured 62.47 and 73.02 meters below ground level. Sixteen of the twenty three boreholes are in use. The rest of the boreholes are not equipped.

Figure 5 below gives the positions of the groundwater hydro-census study information of the twenty four boreholes visited.

TABLE 1: Borehole Hydro-Census Details

Borehole number	Co- ordinates		Water level (mbgl)	Groundwater Elevation (mamsl)	Remarks
	Latitude And Longitude	Ground Elevation (mamsl)			
Boreholes located on Portion 62 Commissiesdrift					
BH 1	25.79188° 027.23427°	1220	14.80	1205	Borehole equipped with submersible pump. Water used for household and flats. Only used for REC school in emergency situations.
BH 2	25.79161° 027.23424°	1222	15.20	1207	Borehole equipped with submersible pump. Water used for household and flats. Only used for REC school in emergency situations.
BH 3	25.79228° 027.23572°	1214	10.00	1204	Casing was equipped earlier and then stolen in 1996. Broken pump house. Tested for 2000 liters. Not equipped now.
BH 4	25.79216° 027.23547°	1215	11.23	1204	Borehole not tested. Borehole depth ± 35m BH not equipped.
H/BH 1	25.79011° 027.23811°	1234	32.93	1201	Borehole in field, low yielding. Casing only. Never been equipped.
H/BH 2	25.78893° 027.23971°	1234	Dry	---	Borehole in field, low yielding. Casing only. Borehole depth ± 25m
Boreholes providing water to REC Schools and Academies, 184 Machol Street, Olifantsnek.					
BH 1 REC	25.793222° 027.244278°	1229	33.42	1196	Submersible pump. Domestic use. Abstract 21 600 ℓ/d
BH 2 REC	25.791558° 027.243556°	1227	62.47 Dynamic	---	Submersible pump. Domestic use. Abstract 22 400 ℓ/d
BH 3 REC	25.793119° 027.243072°	1239	73.02 Dynamic	---	Submersible pump. Water not fit for human consumption.
Boreholes located around the Comisiesdrift site					
H/BH 3	25.79212° 027.23952°	1224	12.96	1211	Owner: Engelbrecht: 072 360 5002. Borehole used for household, no municipal water. Borehole depth ± 65m
H/BH 4	25.79196° 027.24076°	1232	34.83	1198	Owner: Oliver Page: 082 410 7870. Borehole used for household, no municipal water. Use water every day.
H/BH 5	25.792115° 027.239058°	1220	---	---	Owner, Dirk Hurn. 073 591 4804. Submersible pump. Located on porch. Cannot measure WL.
H/BH 6	25.78246° 027.23988°	1236	31.17	1205	Owner. Piet Dreyer. 082 719 7440. Submersible pump. Used for farming and houses.
H/BH 7	25.78124° 027.24024°	1236	36.05	1205	Owner. Piet Dreyer. 082 719 7440. Submersible pump. Used for farming and houses.
H/BH 8	25.78706° 027.24101°	1227	---	---	Owner. Hannie Pretorius. 072 533 1177. Submersible pump. Used for Filling station.
H/BH 9	25.78684° 027.24101°	1226	27.43	1199	Owner. Hannie Pretorius. 072 533 1177. Submersible pump. Used for Filling station.
H/BH 10	25.79236° 027.23710°	1213	---	---	Owner. Olifantsnek Municipal. Submersible pump. Used to supply Olifantsnek Village.
H/BH 11	25.791816° 027.242480°	1233	---	---	Owner. Japie Minnie. Submersible pump. Used for house and garden.

H/BH 12	25.79268^o 027.23486^o	1212	7.03	1205	Owner. Morne Graham. Submersible pump. Used for irrigation.
Borehole located on Rainbow chicken premises					
BH01	25.791816^o 027.242480^o	1232	13	1219	Owner: Rainbow Chicken, Elvin Johnsen 083 724 7498. Submersible pump. In use.
BH02	25.791816^o 027.242480^o	1233	13.5	1219	Owner: Rainbow Chicken, Elvin Johnsen 083 724 7498. Submersible pump. Not use.
BH03	25.791816^o 027.242480^o	1232	10.24	1222	Owner: Rainbow Chicken, Elvin Johnsen 083 724 7498. Not equipped. Not use.
BH04	25.791816^o 027.242480^o	1227	8.36	1219	Owner: Rainbow Chicken, Elvin Johnsen 083 724 7498. Submersible pump. In use for game watering.
BH05	25.791816^o 027.242480^o	1223	---	---	Owner: Rainbow Chicken, Elvin Johnsen 083 724 7498. Not in use.

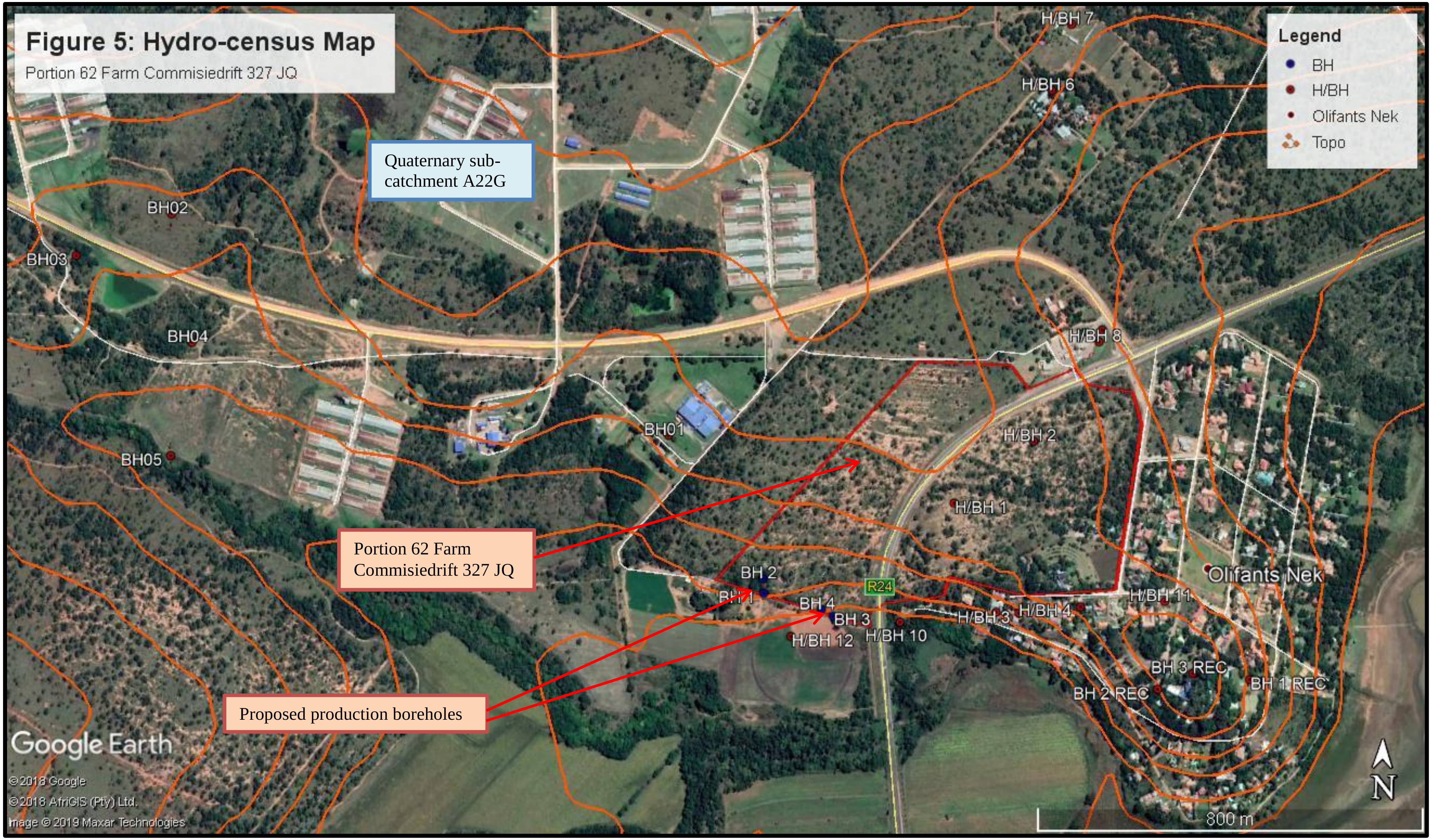


Figure 5: Hydro-census map.

5.2 Test pumping of existing production borehole

The Three boreholes namely BH 1, BH 2 and BH 3 were submitted to borehole yield testing procedures during the study. The boreholes were submitted to a Step Test and a Constant Discharge Test with a recovery test to follow the constant yield test. The borehole yield tests were conducted according to the standards laid down in the publication of the Department of Water Affairs and Forestry, ***"Minimum Standards and guidelines for Groundwater Resource Development for the Community Water Supply and Sanitation Programme".***

A **Step Test** or calibration test consists of pumping a borehole at different rates for sixty minutes per step, until the maximum rate the borehole can deliver. The water level is constantly monitored and noted during each step. This gives an indication of the possible yield the borehole can sustain for a Constant Discharged Test. A step test also gives an indication of the potential of the aquifer in the immediate area around the borehole.

The **Constant Discharge Test** consist of pumping a borehole at a specific rate for a duration of 6 to 24 or 48 hours, with a sudden switch off of the pump after the pump cycle, with a recovery test following immediately afterwards. The Constant Discharge Curves was analysed by using the Basic FC, FC inflection point, Cooper-Jacob and Barker/Bangoy methods, to give an indication of Transmisivity and Storativity values.

Borehole **BH 1** has a static water level at 14.80 metres below ground level. The blow out yield was reported as 1.40ℓ/s. The borehole was pumped for two steps of 30 minutes at rates of 1.40 and 2.01 ℓ/s. The water level draw down was measured constantly during these steps. The water level draw down after each step measured 1.97 and 16.12 metres below the original static water level. The water level did not reach pump inlet during the step test. A maximum inflow rate could therefore not be measured.

The pump was switched of and the water level allowed recovering for 15 minutes. The water level recovered back to 0.35 meters below the original water table in the allowed 15 minutes

The borehole was then submitted to a constant discharge test with duration of 1800 minutes at a rate of 1.40ℓ/s. The pump was switched off after 1800 minutes or 30 hours. The water level draw down was measured at 27.80 metres below the original static water level. The borehole was allowed to recover for 30 minutes or 0.5 hours. The water level recovered back to 0.44 metres below the original water table. This can be regarded as a very fast recovery rate.

Borehole **BH 2** has a static water level at 15.20 metres below ground level. The borehole was pumped for two steps of 30 minutes at rates of 0.60 and 1.25 ℓ/s. The water level draw down was measured constantly during these steps. The water level draw down after each step measured 12.22 and 28.42 metres below the original static water level. The water level did not reach pump inlet during the step test. A maximum inflow rate could therefore not be measured.

The borehole was allowed to recover for 30 minutes or 0.5 hours. The water level recovered back to 0.22 metres below the original water table. This can be regarded as a very fast recovery rate.

The borehole was then submitted to a constant discharge test with duration of 24 hours at a rate of 0.75ℓ/s. The pump was switched off after 1440 minutes or 24 hours. The water level draw down was measured at 14.07 metres below the original static water level. The borehole was allowed to recover for 90 minutes or 1.5 hours. The water level recovered back to the original water level in the allowed 90 minutes. This can be regarded as a fast recovery rate.

Borehole **BH 3** has a static water level at 9.8 metres below ground level. The borehole was pumped for two steps of 30 minutes at rates of 0.75 and 1.1 ℓ/s. The water level draw down was measured constantly during these steps. The water level draw down after each step measured 0.80 and 11.77 metres below the original static water level. The water level did not reach pump inlet during the step test. A maximum inflow rate could therefore not be measured. The pump was switched of and the water level allowed recovering for 20 minutes. The water level did recovered back to the original water table in the allowed 20 minutes.

The borehole was then submitted to a constant discharge test with duration of 360 minutes at a rate of 0.70ℓ/s. The pump was switched off after 360 minutes or 6 hours. The water level draw down was measured at 14.80 metres below the original static water level. The borehole was allowed to recover for 60 minutes or 1 hour. The water level recovered back to the original water table in the allowed 60 minutes. This can be regarded as a fast recovery rate.

Detail information is listed below in Table 2 regarding the borehole yield tests.

TABLE 2: Test pumping results

BH No.1 BH Depth & Static Water Level	Step Test				Constant Discharge Test			Comment on the Water Level Recovery Rate of the Constant Discharge Test
	Step No.	Rate (l/s)	Dur. (min)	D/D (m)	Rate (l/s)	Dur. (min)	D/D (m)	
BH 1 Depth: 55m Static water level:14.80m Date tested: 18 July 2019	1 2	1.40 2.01	30 30	1.97 16.12	1.40	1800	27.80	100% in 40 min. Very fast recovery.
BH 2 Depth: 56m Static water level:15.20m Date tested: 12 July 2019	1 2	0.60 1.25	30 30	12.22 28.42	0.75	1440	14.07	100% in 90 min. Very fast recovery.
BH Backup Depth: 49.5m Static water level:9.8m Date tested: 19 July 2019	1 2	0.75 1.10	10 30	0.80 11.77	0.70	360	14.80	100% in 60 min Very fast recovery.

ST - Step Test
CDT - Constant Discharge Test
SWL - Static Water Level in metres below ground level
Dur. – Duration
D/D – Draw down

5.3 Borehole abstraction figures

The Constant Discharge Curves of the tests were analysed by utilizing the Basic FC, FC inflection point, Cooper-Jacob, Theis and Barker/Bangoy methods, to give an indication of Transmisivity and Storativity values. Refer to Figure 6 to Figure 11. The average abstraction rate (based on a 24 hour duty cycle) of these methods were taken to calculate the yield for 12 hours per day. Please refer to the summary sheet for more detailed borehole recommendations. Refer to Figure 7, 9 and 11.

The abstraction rates for the boreholes are given for each individual method described above. The average recommended (Interpreted from all data available) abstraction rate for the borehole is given in Table 3 below. It is important to understand that the abstraction figure given below in Table 3 only make provision for the aquifer parameters of the borehole tested. The recommended abstraction figures were scaled down to make provision for borehole interference with other boreholes in the area.

A summary of the methods used for the abstraction rates and the Graphical presentations of the draw down curves and recovery curves can be found in Figure 6 to Figure 11 below. Table

2 listed above, gives a summary of the pump test data.

TABLE 3: Recommended abstraction schedule for production boreholes (FC method)

Borehole No.	Recommended Abstraction Rate		Dynamic water Level (mbcl)	Comments
	For 12h/d	in m^3/d		
BH 1	0.5	21.6	±40	Water level depth is 14.80 (mbgl) (18/07/2019)
BH 2	0.6	25.9	±16	Water level depth is 15.20 (mbgl) (12/07/2019)
BH 3	0.2	8.6	±12	Water level depth is 9.8 (mbgl) (19/07/2019)
Total volume recommended		**56.1**		

Cooper-Jacob method

Main | Theis | Cooper-Jacob 2

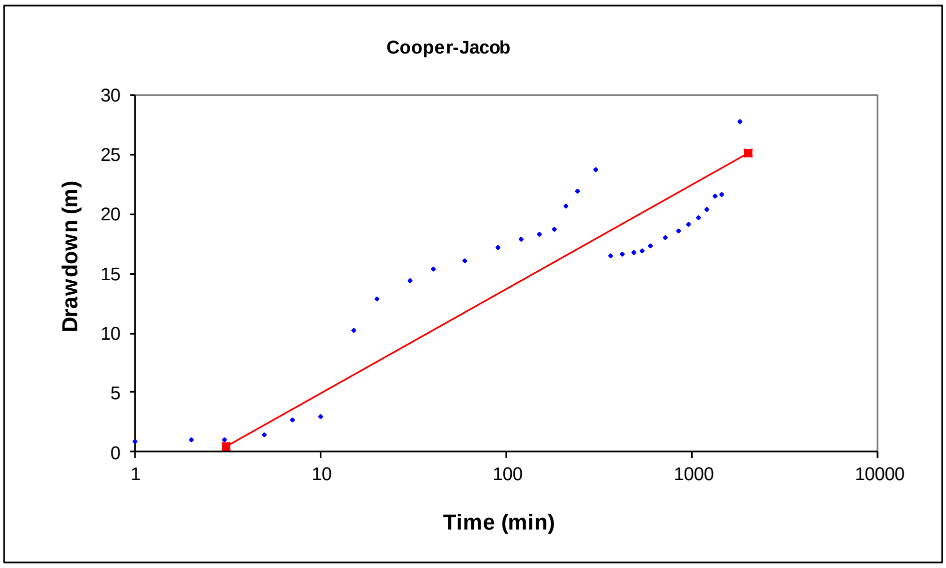
BH 1

$T(m^2/d)$ =	2,5	r_e (m)=	1,52
S =	4,65E-03	Q (l/s) =	1,4

1,52

	No boundaries	1 no-flow	2 no-flow	Closed
Q_sust	0,86	0,43	0,28	0,21
Avg. Q_sust =	0,45	std. dev =	0,29	

including influence of bh's



x0	y0	x1	y1
3,1	0,5	2011	25,1

Theis

T (m2/d)	S	r
3	2,80E-04	5,00

Top

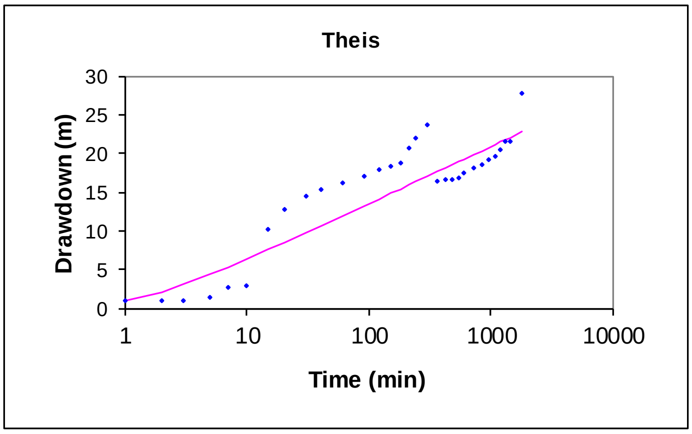


Figure 6: Cooper Jacob and Theis methods BH 1

Summary	Main	BH 1							
Applicable	**Method**	**Sustainable yield (l/s)**	**Std. Dev**	**Early T (m^2/d)**		**Late T (m^2/d)**		**S**	**AD used**
☑	**Basic FC**	0,27	0,18	3		1,2		1,65E-03	30,0
☐	**Advanced FC**			3		1,2		1,00E-03	30,0
☐	**FC inflection point**	0,00	0,00						11,4
☑	**Cooper-Jacob**	0,45	0,29			2,5		4,65E-03	30,0
☐	**FC Non-Linear**	2,49	2,20			34,0		5,06E-03	30,0
☑	**Barker**	0,43	0,40	K_f =	2235		S_s =	1,00E-07	30,0
	Average Q_sust (l/s)	**0,38**	**0,10**	b =	0,05	Fractal dimension n =		1,80	

Recommended abstraction rate (L/s)		**0,40**	for 24 hours per day
Hours per day of pumping	**12**	**0,57**	L/s for 12 hours per day

Amount of water allowed to be abstracted per month	**1036,8**	m^3
Borehole could satisfy the basic human need of	**1382**	persons
Is the water suitable for domestic use (Yes/No)	**Y**	

Figure 7: Summary Sheet BH 1

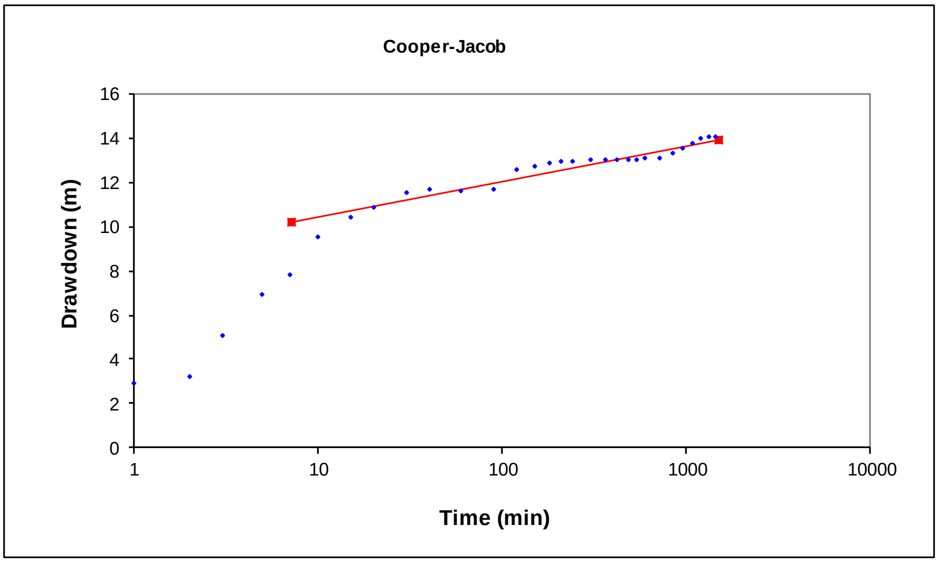
Cooper-Jacob method

Main | Theis | Cooper-Jacob 2

BH 2

$T(m^2/d)$ =	7,5	r_e (m)=	1,52	1,52
S =	1,37E-08	Q (l/s) =	0,75	

	No boundaries	1 no-flow	2 no-flow	Closed	
Q_sust	1,22	0,61	0,40	0,31	including influence of bh's
Avg. Q_sust =	0,64	std. dev =	0,41		



x0	y0	x1	y1
7,1	10,2	1511	13,9

Theis

T (m2/d)	S	r
4	1,00E-05	5,00

Top

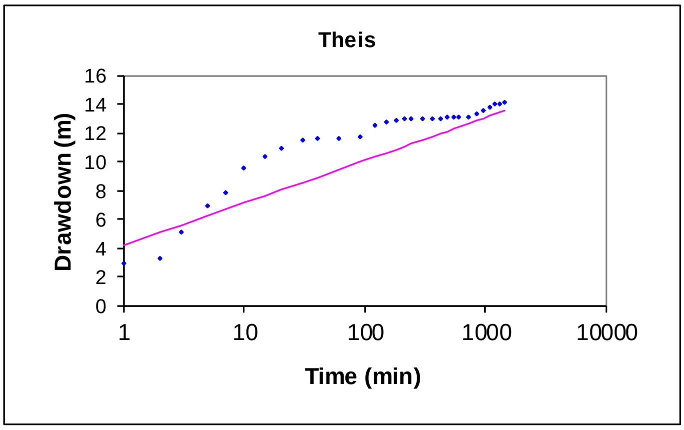


Figure 8: Cooper Jacob and Theis methods BH 2

Summary	Main	BH 2

Applicable	Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)	Late T (m^2/d)	S	AD used
☑	Basic FC	0,54	0,26	4	3,3	1,65E-03	30,0
☐	Advanced FC			4	3,3	1,00E-03	30,0
☐	FC inflection point	0,00	0,00				11,4
☑	Cooper-Jacob	0,64	0,41		7,5	1,37E-08	30,0
☐	FC Non-Linear	2,49	2,20		34,0	5,06E-03	30,0
☑	Barker	0,48	0,20	K_f = 1190	S_s =	2,00E-07	30,0
	Average Q_sust (l/s)	0,55	0,08	b = 0,06	Fractal dimension n =	1,80	

Recommended abstraction rate (L/s)		0,55	for 24 hours per day
Hours per day of pumping	12	0,78	L/s for 12 hours per day

Amount of water allowed to be abstracted per month	1425,6	m^3
Borehole could satisfy the basic human need of	1901	persons
Is the water suitable for domestic use (Yes/No)	Y	

Figure 9: Summary Sheet BH 2

Cooper-Jacob method

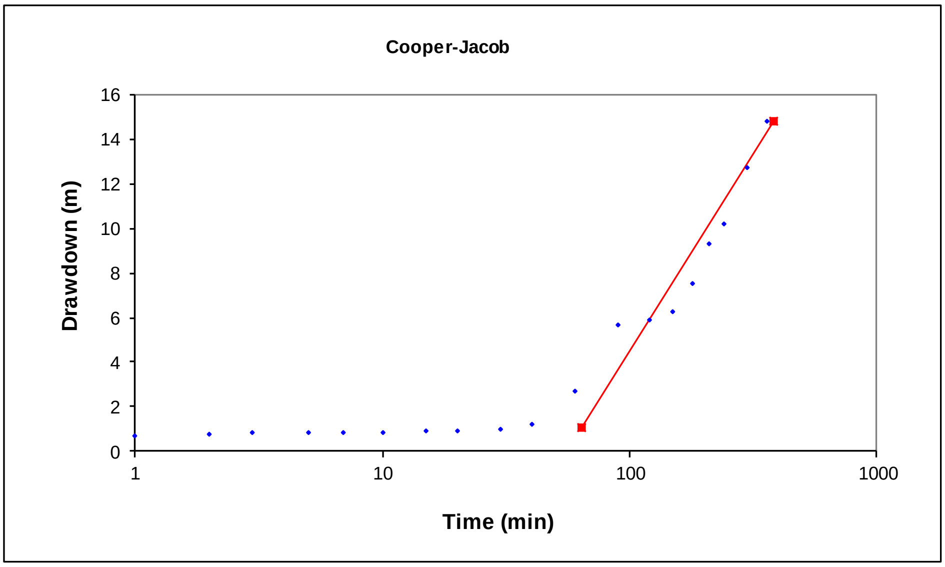
Main | Theis | Cooper-Jacob 2

BH 3

$T(m^2/d)$ =	0,6	r_e (m)=	1,52	1,52
S =	2,35E-02	Q (l/s) =	0,7	

	No boundaries	1 no-flow	2 no-flow	Closed
Q_sust	0,28	0,14	0,09	0,07
Avg. Q_sust =	0,14	std. dev =	0,09	

including influence of bh's



x0	y0	x1	y1
64,1	1,1	381	14,8

Theis

T (m2/d)	S	r
3	3,90E-04	5,00

Top

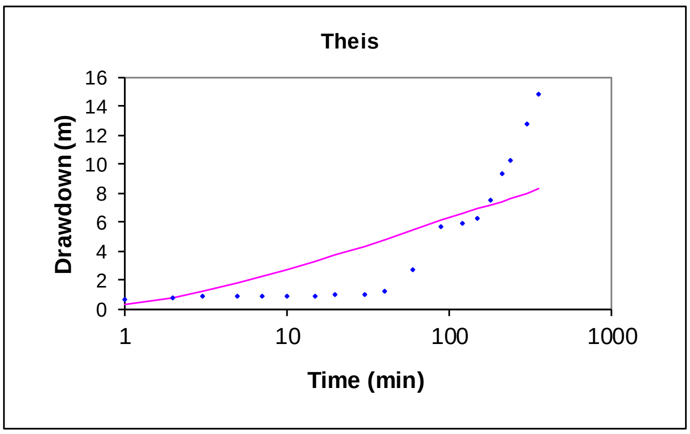


Figure 10: Cooper Jacob and Theis methods BH 3

Summary	Main	BH 3						
Applicable	Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)		Late T (m^2/d)	S	AD used
☑	Basic FC	0,11	0,09	8		0,5	1,65E-03	30,0
☐	Advanced FC			8		0,5	1,00E-03	30,0
☐	FC inflection point	0,00	0,00					11,4
☑	Cooper-Jacob	0,14	0,09			0,6	2,35E-02	30,0
☐	FC Non-Linear	2,49	2,20			34,0	5,06E-03	30,0
☑	Barker	0,21	0,25	K_f =	1190	S_s =	1,00E-07	30,0
	Average Q_sust (l/s)	0,16	0,05	b =	0,05	Fractal dimension n =	1,80	

Recommended abstraction rate (L/s)		0,16	for 24 hours per day
Hours per day of pumping	12	0,23	L/s for 12 hours per day

Amount of water allowed to be abstracted per month	414,72	m^3
Borehole could satisfy the basic human need of	553	persons
Is the water suitable for domestic use (Yes/No)	Y	

Figure 11: Summary Sheet BH 3.

5.4 Water quality

Water samples were retrieved from borehole BH 1, BH 2 and BH 3 for water quality analyses. The three water samples were preserved and delivered to Aquatico, an accredited water laboratory, to be analysed for water quality purposes. The analyses include the major cat and an-ions as listed in Table 5, The Total Coliform Bacteria count and E. Coli count were also analysed for. The results of the chemical and bacteriological analyses performed on the groundwater sample are presented in Table 6. The quality of water is classified according to the SANS 241-1 and 2: 2011 as in the Publication “South African National Standard” Part 1 and Part 2, SABS. Please refer to Figure 8 for the original analyses from SABS. Table 4 below gives the Risk guideline involved for using the surface water for domestic purposes.

Table 4: Risk guideline legend

Aesthetic	Determinand that taints water with respect to taste, odour and colour and that does not pose an unacceptable health risk if present at concentration values exceeding the numerical limits specified.
Operational	Determinand that is essential for assessing the efficient operation of treatment systems and risks to infrastructure.
Acute Health - 1	Routinely quantifiable determinand that poses an immediate health risk if consumed with water at concentration values exceeding the numerical limits specified.
Acute Health - 2	Determinand that is presently not easily quantifiable and lacks infomration pertaining to viability and human infectivity which, however, does pose immediate unacceptable health risks if consumed with water at concentration values exceeding the numerical limits specified.
Chronic Health	Determinand that poses an unacceptable health risk if ingested over an extended period if present at concentration values exceeding the numerical limits specified.
(orange)	Exceeds Acute health - 1, Acute health - 2 and Chronic health guideline values
(yellow)	Exceeds only Operational and Aesthetic guideline values

Chemical Water Quality

The water from the three boreholes tested shows good quality water. The chemical parameters analysed for is below the standard limits specified for SANS 241: 2015 Drinking Water. The water does not need to be treated chemically to enhance the quality.

Bacteriological Water Quality

The Total Faecal Coliform count for borehole BH 1 is 2CFU/100ml which means that the water needs to be treated prior to human consumption. Chlorination of the water from borehole BH 1 is recommended prior to human consumption. Borehole BH 2 and BH 3 do not need to be bacteriologically treated prior to human consumption.

Table 5: Water quality of borehole BH 1, BH 2 and BH 3.

Determinant	**Unit**	**Risk**	**Standard limits**	BH 1	BH 2	BH 3
pH value	pH units	Operational	6.0 to 9.0	7.44	7.13	7.49
Electric Conductivity	mS/m	Aesthetic	<2000	58.6	72.2	55.3
Total Dissolved Solids (TDS @105˚C)	mg/ℓ	Aesthetic	<1500	432	447	379
Total alkalinity	Mg CaCO3/l			366	383	291
Chloride as Cl	mg/ℓ	Aesthetic	<400	24.1	20.5	30.4
Sulphate as SO4	mg/ℓ	Acute health - 1	≤ 500	26.3	33.7	27.7
Nitrate (NO3) mg/ℓ N	mg/ℓ	Acute health - 1	<10	3.99	4.03	3.08
Ammonia as N	mg/ℓ	Aesthetic	≤ 1.5	0.032	0.039	0.112
Orthophosphate (PO4) as P	mg/ℓ			0.014	0.005	0.013
Fluoride as F	mg/ℓ	Chronic health	≤ 1.5	0.316	0.352	0.327
Calcium as Ca	mg/ℓ			57.1	55.9	52.2
Magnesium as Mg	mg/ℓ			56.6	57.1	50.9
Sodium as Na	mg/ℓ	Aesthetic	<300	24.9	26.5	24.2
Potassium as K	mg/ℓ		<20	1.21	1.34	1.35
Aluminium as Al	mg/ℓ	Operational	≤ 0.3	0.002	0.003	0.003
Iron as Fe	mg/ℓ	Chronic health	<2000(Target <200)	0.004	0.004	0.004
Manganese as Mn	mg/ℓ	Chronic health	<50 (Target <10)	0.001	0.001	0.105
Total Faecal Coliforms	CFU/100mℓ	Acute health – 1	Not detected	2	0	0
Total coliform	CFU/100mℓ	Acute health - 2	<100 (Target <20)	3	3	4
Total hardness	mgCaCO$_3$/ℓ			375	375	340

The water quality analyses done by Aquatico for borehole BH 1 BH 2 and BH 3 can be seen below in Figure 12A and 12B.

aquatico Laboratories (Pty). Ltd.

ilac-MRA sanas Testing Laboratory T0685

Test Report

Client: HK Geohydrological Services
Address: 25ste laan, 327, Villieria, Pretoria,
Report no: 71941
Project: HK Geohydrological Services

Date of certificate: 26 July 2019
Date accepted: 23 July 2019
Date completed: 26 July 2019
Date received: 23 July 2019

Lab no:			29708	29709
Date sampled:			23-Jul-19	23-Jul-19
Aquatico sampled:			No	No
Sample type:			Water	Water
Locality description:			BH3	BH1
Analyses	**Unit**	**Method**		
A pH @ 25°C	pH	ALM 20	7.49	7.44
A Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	55.3	58.6
A Total dissolved solids (TDS)	mg/l	ALM 26	379	432
A Total alkalinity	mg CaCO3/l	ALM 01	291	366
A Chloride (Cl)	mg/l	ALM 02	30.4	24.1
A Sulphate (SO_4)	mg/l	ALM 03	27.7	26.3
A Nitrate (NO_3) as N	mg/l	ALM 06	3.08	3.99
A Ammonium (NH_4) as N	mg/l	ALM 05	0.112	0.032
A Orthophosphate (PO_4) as P	mg/l	ALM 04	0.013	0.014
A Fluoride (F)	mg/l	ALM 08	0.327	0.316
A Calcium (Ca)	mg/l	ALM 30	52.2	57.1
A Magnesium (Mg)	mg/l	ALM 30	50.9	56.6
A Sodium (Na)	mg/l	ALM 30	24.2	24.9
A Potassium (K)	mg/l	ALM 30	1.35	1.21
A Aluminium (Al)	mg/l	ALM 31	0.003	<0.002
A Iron (Fe)	mg/l	ALM 31	<0.004	<0.004
A Manganese (Mn)	mg/l	ALM 31	0.105	<0.001
A E.coli	CFU/100ml	ALM 40	<1	2
A Total coliform	CFU/100ml	ALM 40	4	3
A Total hardness	mg CaCO3/l	ALM 26	340	375

A = Accredited N = Non accredited Out = Outsourced Sub = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine ATR = Alternative test report ; The results relates only to the test item tested; Results reported against the limit of detection; Results marked 'Non SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory; Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation; The report shall not be reproduced except in full without approval of the laboratory
The results apply to the sample received.

H. Holtzhausen
Technical Signatory

Figure 12A: Water quality analyses from borehole BH 1 and BH 3 aquatico Laboratories (Pty). Ltd.

ilac-MRA sanas Testing Laboratory T0685

Test Report

Page 1 of 1

Client:	HK Geohydrological Services	**Date of certificate:**	18 July 2019
Address:	25ste laan, 327, Villieria, Pretoria,	**Date accepted:**	15 July 2019
Report no:	70756	**Date completed:**	18 July 2019
Project:	HK Geohydrological Services	**Date received:**	15 July 2019

Lab no:			27329
Date sampled:			13-Jul-19
Aquatico sampled:			No
Sample type:			Water
Locality description:			Commisiedrift BH2
Analyses	**Unit**	**Method**	
A pH @ 25°C	pH	ALM 20	7.13
A Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	72.2
A Total dissolved solids (TDS)	mg/l	ALM 26	447
A Total alkalinity	mg CaCO3/l	ALM 01	383
A Chloride (Cl)	mg/l	ALM 02	20.5
A Sulphate (SO_4)	mg/l	ALM 03	33.7
A Nitrate (NO_3) as N	mg/l	ALM 06	4.03
A Ammonium (NH_4) as N	mg/l	ALM 05	0.039
A Orthophosphate (PO_4) as P	mg/l	ALM 04	<0.005
A Fluoride (F)	mg/l	ALM 08	0.352
A Calcium (Ca)	mg/l	ALM 30	55.9
A Magnesium (Mg)	mg/l	ALM 30	57.1
A Sodium (Na)	mg/l	ALM 30	26.5
A Potassium (K)	mg/l	ALM 30	1.34
A Aluminium (Al)	mg/l	ALM 31	0.003
A Iron (Fe)	mg/l	ALM 31	<0.004
A Manganese (Mn)	mg/l	ALM 31	<0.001
A E.coli	CFU/100ml	ALM 40	<1
A Total coliform	CFU/100ml	ALM 40	3
A Total hardness	mg CaCO3/l	ALM 26	375

A = Accredited N = Non accredited Out = Outsourced Sub = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine ATR = Alternative test report ; The results relates only to the test item tested; Results reported against the limit of detection; Results marked 'Non SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory; Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation; The report shall not be reproduced except in full without approval of the laboratory
The results apply to the sample received.

M. Swanepoel
Technical Signatory

Figure 12B: Water quality analyses from borehole BH 2

6. HYDROGEOLOGICAL ASSESSMENT

6.1 Groundwater Level Depth

The water level depth information of sixteen boreholes is available in the area. The density of data of the sixteen data points are not enough to construct complete groundwater level contours for the area. Three groundwater contours namely 1200, 1205 and 1220 however could be partially constructed. These groundwater contours show that the groundwater contours to a large degree follows the surface contours.

Due to the uniform geology the water level elevation should to a large degree mimic the surface contours. This can also be seen from the water level measurements taken in the existing boreholes on site. The groundwater flow direction should also to a large degree follow the surface water flow directions.

The water level depth in the area range between 7.03 and 36.05 metres below ground level.

6.2 On Site Surface Water Drainage and Groundwater Movement

The groundwater contours, groundwater elevations and surface contours were used to guide the construction of the groundwater flow directions. As expected, groundwater from the mountainous north which is 2.5 to 3 kilometres away flow towards the site to be developed. Refer to Figures 1, 4 and 13.

Surface water and groundwater flow is in a south eastern direction towards the Olifantsnek Dam. The groundwater flow directions is shown as light blue arrows on Figure 13 which show the groundwater and surface water flow directions in the area on and around the proposed development site.

6.3 Groundwater recharge area

The scale of abstraction, calculated in Section 1; the introduction, is a function of the volume of the groundwater demand set by the plant development versus the volume of groundwater recharged on the proposed development property per annum.

For a water use licence application (WULA), the Department of Water Affairs requires that the surface area of the proposed development be used to calculate the groundwater recharge volume. This will ensure that at 100% abstraction of groundwater recharge, each owner will, theoretically, abstract only the volume of water recharged on his own property. In practice the flow of groundwater is not bound by man-made borders, but rather by the surface topography and the geology.

The groundwater recharge program from Gerrit van Tonder and Yongzin Xu, to estimate groundwater recharge and groundwater reserve, was used to estimate a mean groundwater recharge figure. This was done for the groundwater catchment area delineated by the boundary calculated above. The mean value of the soil, geology, Vegter, Acru, Harvest Potential and Chloride methods were used, together with a weighting ratio, to estimate the groundwater recharge figure for the specific site.

Table 6, listed below, gives the mean groundwater recharge figure, calculated by the six methods mentioned, on the development area defined by the property boundary. The Table summarizes all the methods used, as well as the weighting ratios used. For instance, a weighting ratio of 1 was given for the Acru, which normally seems to be a very conservative value and 5 for the Vegter method and chloride method, which is normally considered to give a more representative groundwater recharge value. The mean groundwater recharge on the specific proposed development portion is calculated to be in the order of 46.6mm/a or 6.6% of MAP or 36.92m^3/d. This figure of 46.6mm/a calculated by the program can be regarded as a fairly representative value.

If a more practical approach is taken it is also important to note that a large groundwater catchment area is to the north of the proposed site. For all practical reasoning will groundwater recharged to the north and west of the site eventually flow towards the Portion 62. The three boreholes BH 1 to BH 3 are located topographically low and can make use of the groundwater recharge that is generated up the valley which is located to the west of the proposed development area. The valley stretch for 7km to the west of the site. This valley is also 5.2km in width which generate 1 696 240m^3 in groundwater recharge per day.

TABLE 6: Groundwater recharge figures and percentages

Summary of Recharge MAIN

Olifantsnek Dam

Method	mm/a	% of rainfall	Certainty (Very High=5 ; Low=1)		
Cl	65.6	9.2	5		
SVF: Equal Volume		#DIV/0!	4		
SVF: Fit			4		
CRD			4		
Qualified Guesses :					
Soil	46.6	6.6	5		
Geology	43.4	6.1	5		
Vegter	45.0	6.3	5		
Acru	20.0	2.8	1		
Harvest Potential	25.0	3.5	2		
Expert's guesses			3		
Base Flow (minimum Re)			1		
^{2}H displacement method			1		
Carbon 14 method			1		
EARTH Model			1		
Groundwater Flow Model			1		
Average recharge	46.6	6.6			
Recharge =	46.6	6.6	=	0.013476	Mm^3/a
			=	36.92	m^3/d
Area (Km^2) =	0.289193		=	0.43	L/s
Annual Rainfall (mm) =	711				

Figure 13: Contour map showing 5 meter interval surface contours with 5 meter groundwater contours with groundwater flow directions (blue arrows

6.4. Available groundwater resources

From the groundwater recharge figures calculated for Portion 62 a volume of 36.92m^3/d is recharged on this land portion. The water demand for the three production boreholes is 56.1m^3/d. Borehole BH 1 to BH 3 can deliver 56.1m^3/d which can be used for the proposed development site. Practically the large groundwater recharge area to the north of the site will ensure enough groundwater recharge for the three boreholes to be used for the proposed development. The large farming activities of Rainbow Chicken used a bulk water supply pipe line to supply in the daily water demand for the farming activities. Groundwater use to the north of the proposed development site is therefore minimal.

7. AQUIFER RISK ASSESSMENT

7.1 Parsons Rating System

The “Parsons Rating System” is an aquifer classification system developed to implement a strategy for managing groundwater quality in South Africa. Classification, vulnerability and susceptibility are rated for a specific aquifer to be studied. This system gives a classification on a regional scale which normally is seen as such.

a) Aquifer Classification

The aquifer at Portion 62 is classed as a **minor** aquifer region and can be described as a moderate yielding aquifer system of variable water quality.

b) Aquifer vulnerability

A **least** tendency or likelihood does exist for contamination to reach a specific position in the groundwater system after introduction continuously at some location above the uppermost aquifer.

c) Aquifer susceptibility

The aquifer is rated to have a **Low** susceptibility. Susceptibility is a qualitative measure of the relative ease with which a groundwater body can be potentially contaminated by anthropogenic activities and includes both aquifer vulnerability and the relative importance of the aquifer in terms of its classification.

d) Groundwater Quality Management Classification

The **GQM index of this option is rated at 2**, with a **Low** protection level needed.

7.2 Water Resources

Borehole BH 1, BH 2 and BH 3 are located on Portion 62. These boreholes will be used for the school development. Two boreholes are currently equipped and the third borehole needs to be equipped. Boreholes in the region are used for farming activities and domestic use.

7.3 Assessment of the Vulnerability of the Underground Water Resources

The vulnerability of the underground water sources is related to the distance that water must flow to reach the water table and the ease with which it can flow through the soil and rock layers above the water table. An assessment of the soil and rock types and the distance to the water table can be used to obtain a vulnerability class. (Groundwater Protocol document, Version 2, dated March 2003). Five broad classes of aquifer vulnerability are defined in Table 7 below:

Table 7: Vulnerability of groundwater aquifer due to hydrological conditions

Vulnerability Class	Measurements	Definition
Extreme (Usually highly fractured rock and/or high groundwater table).	High risk and short distance (<2m) to water table.	Vulnerable to most pollutants with relatively rapid impact from most contamination disposed of at or close to the surface.
High (Usually gravely or fractured rock, and/or high water table).	High risk and medium distance (2-5m) to water table.	Vulnerable to many pollutants except those highly absorbed, filtered and/or readily transformed.
Medium (Usually fine sand, deep loam soils with semi-solid rock and average water table > 10m).	Low risk and medium to long distance to water table.	Vulnerable to inorganic pollutants but with negligible risk of organic or microbiological contaminants.
Low (Usually clay or loam soils with semi-solid rock and deep water table >20m).	Minimal and low risk and long to very long distance to water table.	Only vulnerable to the most persistent pollutants in the very long term.
Negligible (Usually dense clay and/or solid impervious rock with deep water table).	Minimal risk with confining layers.	Confined beds present with no significant infiltration from surface areas above aquifer.

In Table 7 above, according to the Groundwater Protocol document, Version 2, dated March 2003 in Table A, the vulnerability of the groundwater aquifer due to the hydrogeological conditions at the Portion 62 development area can be rated as medium risk. The distance from the surface to the aquifer at borehole BH 1 to BH 3 is in the region of 10 to 15 metres.

For surface spills on the proposed development area, the travel distance vertically will be in the region of 10 to 15 metres. The shale, slate and hornfels weathers to a clayey matrix with low permeability which will act as a filter system. The vertical travel of water will be at a rate of 0.25m/d. The permeability of shale and slate is regularly measured on nearby sites on the same geology during previous studies. The risk of organic or microbiological contaminants is negligible. The aquifer is only vulnerable to the most persistent pollutants in the very long term. Refer to table 7 above. Table 8 below shows that the soil and silt that is found on site have a minimal to medium capacity to absorb contaminants and a medium to high capacity to create an effective barrier to the movement of biological contaminants.

Table 8: Assessment of the reduction of risk in the unsaturated zone

Unsaturated Zone Conditions	Factor Effecting Reduction			Contamination Reduction			Comments
	Rate of flow in unsaturated zone	Capacity of the media to absorb contaminants	Capacity to create an effective barrier to contaminants	Bacteria and Viruses	Nitrates and Phosphates	Chlorides	
Clay	Very slow <10mm/d	High	High	Very high reduction	High Reduction	High Reduction	Very Good barrier to movement of contaminants. May have problems with water retention in pit
Silt	Slow 10-100mm/d	Medium	High	High Reduction	Some Reduction	Minimal Reduction	Good barrier to movement of biological contaminants, but little reduction in chemical contaminants.
Sandy loam	Slow 10-100mm/d	Medium	High	High Reduction	Some Reduction	Minimal Reduction	Good barrier to movement of biological contaminants, but little reduction in chemical contaminants.
Fractured or weathered sandstone	Medium 0.1 - 10m/d	Medium	Medium	High Reduction	Minimal Reduction	Minimal Reduction	Fair barrier to movement of biological contaminants, but little reduction in chemical contaminants.
Fine sand	Medium 0.1 - 10m/d	Minimal	High	High Reduction	Minimal Reduction	Minimal Reduction	Good barrier to movement of biological contaminants, but little reduction in chemical contaminants.

A high reduction of bacteria and viruses will be evident in the unsaturated aquifer if a sanitation leak does happen. Nitrates, phosphates and chlorides will be minimally reduced. The top layer will form a good barrier to the movement of biological contaminants but will have little reduction in chemical contaminants.

7.4 Existing threats to groundwater quality

The Olifantsnek Village residence use French drains as a sanitation option. These systems however pose a small to negligible risk to the aquifer system.

7.5 Risk from an on-surface risk source

As far as the risk from the Portion 62 development is concerned, the assessment is based on the level of risk of the source. Risk levels are based on three factors: 1) attenuation ability in unconsolidated materials; 2) contamination load and travel time of degradable pollutants, in aquifer systems and 3) vulnerability of the aquifer and behavior of interstitial water regimes. Soil or unconsolidated material may provide a very effective attenuation buffer for certain contaminants and may have a very low attenuation on other contaminants. The nature of the soil materials and the thickness of this zone, are key issues in determining attenuation capacity. The sand and silt layer on surface and the silt content of the sand will sufficiently protect the aquifer below from on surface leaks.

The upper soil's hydraulic conductivity measured in the same geology nearby is 0.25m/d measured at its slowest rate. The hydraulic flow time to the water table = depth to water table ÷ permeability. On this site, the hydraulic flow time will be in the order of 40 days at its slowest rate if a water level depth of 10mbgl is used for the site.

7.6 Position in respect of domestic water sources

The location of a possible risk source, in relation to water sources utilised for human consumption, is of primary concern. In most of rural Southern Africa and at many farming communities around our cities, the only domestic water supplies are obtained from boreholes.

It is therefore essential that minimum distances between possible risk sources and the nearest domestic water resource that is in use, be prescribed. These safe distances depend on many factors due to the highly variable and uncertain nature of the factors that control the dispersion of pathogenic organisms from a risk source. The criteria for determining the distance of a risk source from water resources must therefore be conservative.

The recommended safe distances are based on the acceptable soil's permeability range, in conjunction with the maximum survival times of bacteria, viruses and the breakdown of chemical components. Conservatism has been achieved through the effects of the harsh environmental conditions prevalent in most of Southern Africa, which lowers maximum pathogen survival periods, and by adding a moderate safety factor of 150m to the calculated distances (This ensures a minimum safe distance of 150m at all times). Due to the importance of ensuring pollution free domestic water resources, lowering of the recommend distances has not been considered for the more arid regions of the sub-continent.

The package sewerage treatment plant option that we recommend for the school development will be far enough away from the other groundwater users to pose a risk the existing water boreholes.

7.7 Position in respect of drainage features

The positioning of a risk source, in relation to a drainage feature of any description, is of cardinal importance. Drainage features, including lakes, dams, rivers, streams, gullies, gulley heads and marshes should not be affected in any way by pollutants emanating from a possible risk source. These drainage features must also not pose a flood hazard to any risk source (risk sources must be located above the 1 in 100 year flood level). These limitations necessitate the prescription of minimum distances between risk sources and the nearest drainage feature.

The approach taken is virtually the same as for domestic water sources, the only difference being the reduction of the safety factor to 100 metres, and a further decrease of the recommended distances for arid regions (rainfall < 500mm). If the recommended safe distances prescribed are applied, surface water contamination will be negligible.

No drainage features are located on the proposed development site. The risk to drainage features, from the proposed school development, in the region is negligible.

8. ENVIRONMENTAL IMPACT ASSESSMENT

8.1 Assessment methodology

An impact can be defined as any change in the physical-chemical, biological, cultural and/or socio-economic environmental system that can be attributed to human activities related to alternatives under investigation for meeting a project need. Assessment of impacts will be based on the Department of Environmental Affairs (DEA) (1998) Guideline Document: EIA Regulations. The significance of the aspects/impacts of the process is rated by using a matrix derived from Plomp (2004) and adapted to some extent to fit this process. This matrix uses the consequence and the likelihood of the different aspects and associated impacts to determine the significance of the impacts.

The **significance** of the impacts will be determined through a synthesis of the criteria below:

Probability This describes the likelihood of the impact actually occurring.

Improbable: The possibility of the impact occurring is very low, due to the circumstances, design or experience.

Probable: There is a probability that the impact will occur to the extent that provision must be made therefore.

Highly Probable: It is most likely that the impact will occur at some stage of the development.

Definite: The impact will take place regardless of any prevention plans, and there can only be relied on mitigatory actions or contingency plans to contain the effect.

Duration: The lifetime of the impact

Short term: The impact will either disappear with mitigation or will be mitigated through natural processes in a time span shorter than any of the phases of the project.

Medium term: The impact will last up to the end of the phases of the project, where after it will be negated.

Long term: The impact will last for the entire operational phase of the project but will be mitigated by direct human action or by natural processes thereafter.

Permanent: Impact that will be non-transitory. Mitigation either by man or natural processes will not occur in such a way or in such a time span that the impact can be considered transient.

Scale: The physical and spatial size of the impact

Local: The impacted area extends only as far as the activity, e.g. footprint of the project.

Site: The impact could influence the whole, or a measurable portion of the affected properties.

Regional: The impact could affect the area including the neighbouring areas.

Magnitude/ Severity: Does the impact destroy the environment, or alter its function.

Low: The impact alters the affected environment in such a way that natural processes are not affected.

Medium: The affected environment is altered, but functions and processes continue in a modified way.

High: Function or process of the affected environment is disturbed to the extent where it temporarily or permanently ceases.

Significance: This is an indication of the importance of the impact in terms of both physical extent and time scale, and therefore indicates the level of mitigation required.

Negligible: The impact is non-existent or unsubstantial and is of no or little importance to any stakeholder and can be ignored.

Low: The impact is limited in extent, has low to medium intensity; whatever its probability of occurrence is, the impact will not have a material effect on the decision and is likely to require management intervention with increased costs.

Moderate: The impact is of importance to one or more stakeholders, and its intensity will be medium or high; therefore, the impact may materially affect the decision, and management intervention will be required.

High: The impact could render development options controversial or the project unacceptable if it cannot be reduced to acceptable levels; and/or the cost of management intervention will be a significant factor in mitigation.

A matrix rating and assigning weights for the impacts is shown in Table 9 below.

Table 9: Rating matrix legend for groundwater impacts

Aspect	Description	Weight
Probability	Improbable	1
	Probable	2
	Highly Probable	4
	Definite	5
Duration	Short term	1
	Medium term	3
	Long term	4
	Permanent	5
Scale	Local	1
	Site	2
	Regional	3
Magnitude/Severity	Low	2
	Medium	6
	High	8
Significance	**Sum (Duration, Scale, Magnitude) x Probability**	
	Negligible	<20
	Low	<40
	Moderate	<60
	High	>60

8.2 Impact identification and significance ratings

The impact matrix is listed below to show detailed activities and the related impacts of each individual activity. The potential impact identification is for the Operational phase of the school on Portion 62. The management and mitigation measures are discussed.

8.2.1 Potential impact during operational phase

The significance of the potential impacts during the operational phase is "Low". The probable impacts are:

- Contamination of groundwater from spills at the sanitation option.

With mitigation, the significance of these activities is rate as "Negligible".

- Contamination of surface water from the sanitation option.

With mitigation, the significance of these activities is rate as "Negligible".

- Impact on groundwater levels on other boreholes due to water abstraction

With mitigation measures the significance of these impacts can be rated as "low".

8.2.2 Management and mitigation measures

The following mitigation measures are recommended in the operational phase:

- The boreholes must be used at or below the recommended rates.
- The three production boreholes BH 1, BH 2 and BH 3 must be used for domestic use

purposes at the correct recommended rates.

- The three boreholes BH 1, BH 2 and BH 3 must be used as groundwater monitoring boreholes to monitor the water level depth on a monthly basis and water quality on a bi-annual basis.
- The three monitoring boreholes must be monitored for bacteriological parameters and for major cations and anions on a bi-annual basis.

Table 10: Significance Rating

No	Activity	Without or With Mitigation	Probability		Duration		Scale		Magnitude/ Severity		Significance	
			Score	**Magnitude**	**Score**	**Magnitude**	**Score**	**Magnitude**	**Score**	**Magnitude**	**Score**	**Magnitude**
Operational Phase												
1	Contamination of groundwater from sanitation options of the development.	**WOM**	2	Probable	3	Medium Term	1	Local	2	Low	12	Negligible
		WM	1	Improbable	1	Short Term	1	Local	2	Low	4	Negligible
2	Contamination of surface water from sanitation options.	**WOM**	2	Probable	3	Medium Term	1	Local	2	Low	12	Negligible
		WM	1	Improbable	1	Short Term	1	Local	2	Low	4	Negligible
3	Lowering of regional water level	**WOM**	4	Highly Probable	4	Long Term	2	Site	6	Medium	48	Moderate
		WM	2	Probable	3	Medium Term	2	Site	6	Medium	22	Low

9. MONITORING PROTOCOL

It is important to have a monitoring system in place to monitor the potential impacts on the environment such as surface and groundwater quality in the area around the proposed school project.

The main focus of a monitoring system must be to monitor and detect possible elevated nutrients before the environment is damaged. A groundwater monitoring borehole can detect nutrients before environmental damage is done.

The three groundwater production boreholes BH 1, BH 2 and BH 3 are proposed to serve as groundwater monitoring boreholes for the school project on Portion 62. Refer to Table 5, 11, 12 and Figure 11A and 12B for the monitoring frequency and sampling parameters. Monitoring programmes are site-specific and need to be tailored to meet a specific set of needs or expectations (DWA 1998). The approach followed in developing this monitoring protocol was taken from the DWS (formerly DWAF) Best Practice Guideline – G3: Water Monitoring Systems (DWA, 2006b).

9.1 Monitoring Objectives

Monitoring, measuring, evaluating and reporting are key activities of the monitoring programme. These actions are designed to evaluate possible changes in the physical and chemical nature of the aquifer and geo-sphere and to predict/detect potential impacts on the groundwater.

The key objectives of the monitoring of groundwater changes are:

1. To provide reliable groundwater data that can be used for management purposes.
2. The early detection of changes in groundwater quality and quantity.
3. Provide an on-going performance record on the efficiency of the Water Management Plan.
4. Obtain information that can be used to redirect and refocus the Water Management Plan.
5. Determine compliance with environmental laws, standards and the water use licence and other environmental authorizations.
6. Refine the conceptual and numerical (management) models.

This will ensure that management is timely warned of problems and unexpected impacts that might occur, and can be positioned to implement mitigation measures at an early stage.

9.2 Possible risk sources

Potential risk sources include the following:

1. Possible leaks or outflows at the sanitation system.

9.3 Receiving environment

The following hydrological units may be impacted by the project and related activities:

- The surface water below the school site.
- The aquifer below the school site and the regional aquifer downstream of the site.

9.4 Monitoring Network

The three existing water production boreholes BH 1, BH 2 and BH 3 must be sampled. The positions of the three boreholes are given on Figure 5. The water monitoring frequency for groundwater samples are given in Table 11 below.

9.5 Monitoring Frequency

The three (3) sample points given above must be sampled bi-annually and analysed for micro and macro chemical parameters and bacteriological parameters. Refer to Table 5 and Figure 12 for the detailed parameters to be analysed for. The water level must be taken at the three proposed monitoring boreholes as stipulated in Table 11 and 12.

Table 11: Water monitoring Frequency

Site name	Chemistry Sampling	Water Level Measurements
Production borehole BH 1, BH 2 and BH 3	Bi-annually	Monthly

9.6 Sampling parameters

An accredited laboratory, with the necessary quality assurance, must carry out analysis of key samples. Quality control measures should be in place and may include blanks, standards, duplicates, cation-anion balances etc. This will ensure consistency in monitoring and the verification and validation of water quality data. Data from groundwater and surface water quality monitoring must be stored together electronically to enable trend analysis and waste load calculations to be carried out.

Table 12 Sampling parameters

Sample Type	Field Measurement	Laboratory analysis: Chemical and bacteriological
Groundwater	Monthly water level depth measurements	Bi-annually

9.7 Sampling Procedures

The sampling procedure for groundwater should be done according to the protocol by Weaver, 1992. The actions can be summarised as follows:

1. Calibrate the field instruments before every sampling run. Read the manufacturers manual and instructions carefully before calibrating and using the instrument.
2. Purging a borehole can be done in the following ways:
   a. With a portable pump
   b. With an already installed submersible pump
   c. By lowering a bailer into the hole
3. Prior to sampling, measure the water level and record.
4. Install the pump (If not equipped) with the inlet close to the static water level.
5. Set up the EC, pH and temperature meter.
6. Start pumping and record the pumping rate in ℓ/s.
7. Continuously measure the pH and EC values.
8. If the field chemistry stabilizes the borehole is purged. Note that approximately one column of water should be removed. The volume of water to be removed is calculated using the following formula:

   Volume of standing water = $\pi r^2 \times h \times 1000$, where

   R = radius of borehole in meter

   H = height of water column in meter
9. Some boreholes are low yielding and go dry when purging. Leave the borehole to recover for a few hours. When returning, install the pump with the inlet close to the static water level and continue with the next step. Alternatively, bail the borehole.
10. Sample for chemical constituents – remove the cap of the plastic 1 litre sample bottle, but do not contaminate inner surface of cap and neck of sample bottle with hands. Fill the sample bottle without rising.
11. Leave sample air space in the bottle (at least 2.5 cm) to facilitate mixing by shaking before examination.
12. Replace the cap immediately.
13. Complete the sample label with a water resistant marker and tie the label to the neck of the sample bottle with a string or rubber band. The following information should be written on the label
    a. An unique sample number and description
    b. The date and time of sampling
    c. The name of the sampler
15. Place sample in a cooled container (e.g. cool box) directly after collection. Try and keep the container dust-free and out of any direct sunlight. Do not freeze samples.
16. Complete the data sheet for the borehole
17. See to it that the sample gets to the appropriate laboratory as soon as possible. Samples for chemical analysis should reach the laboratory preferably within seven days.

10. CONCLUSIONS

During the hydrogeological study the following conclusions could be made:

- During the hydro-census twenty four boreholes were visited. The hydro-census data gives a broad picture that north of the planned development area low groundwater abstraction figures is prevailing.
- The water level depth as measured in the boreholes visited on site during the hydro-census range from 7.03 meters below ground level to 36.05 meters below ground level.
- Three boreholes were submitted to borehole yield testing procedures.
- The three boreholes can be recommended to serve as water abstraction boreholes.
- The water that can be taken from these three boreholes is 56.1m^3/d.
- The water from the three boreholes tested shows good quality water. The chemical parameters analysed for is below the standard limits specified. The water does not need to be treated chemically to enhance the quality.
- The Total Faecal Coliform count for borehole BH 1 is 2CFU/100ml which means that the water needs to be treated prior to human consumption. Chlorination of the water from borehole BH 1 is recommended prior to human consumption. Water from borehole BH 2 and BH 3 do not need to be bacteriologically treated prior to human consumption.
- The mean groundwater recharge on the specific proposed development portion is calculated to be in the order of 46.6mm/a or 6.6% of MAP or 36.92m^3/d.
- For all practical reasoning will groundwater recharged to the north and west of the site eventually flow towards the Portion 62. The three boreholes BH 1 to BH 3 are located topographically low and can make use of the groundwater recharge that is generated up the valley which is located to the west of the proposed development area. The valley stretch for 7km to the west of the site. This valley is also 5.2km in width which generate 1 696 240m^3 in groundwater recharge per day.
- The vulnerability of the Groundwater Aquifer due to the Hydrogeological Conditions at Portion 62 can be rated as medium risk.
- The soil and silty sand are permeable and will act as a filter system. The vertical travel of contaminated water will be at a rate of 0.25m/d. The risk of organic or microbiological contaminants is negligible.
- The sand and silt that is found on site has a minimal to medium capacity to absorb contaminants and a medium to high capacity to create an effective barrier to the movement of biological contaminants.
- A high reduction of bacteria and viruses will be evident in the unsaturated aquifer if a leak does happen. Nitrates, phosphates and chlorides will be minimally reduced. The top layer will form a good barrier to the movement of biological contaminants but will

have little reduction in chemical contaminants.

- The aquifer is only vulnerable to the most persistent pollutants in the very long term.
- The significance of the potential impacts in the operational phase is rated as "Negligible".
- With mitigation, the significance of these activities is rated as "Negligible".

11. RECOMENDATIONS

The following recommendations are made:

- The groundwater abstraction boreholes must be utilized at the recommended rates and duty cycles.
- The groundwater monitoring network as stipulated in Section 9 must be implemented as recommended. Detail recommendations regarding the groundwater monitoring is stipulated in this section.

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