Appendix D

Specialist Input

- Hydrogeological and Contamination Risk Assessment - GEO - LOGIC Hydrogeological Consultants cc, September 2013

HYDROGEOLOGICAL AND CONTAMINATION RISK ASSESSMENT STUDY FOR REMAINING EXTENT OF PORTION 172, PORTION 534, 535, 536 AND 537 OF THE FARM WATERKLOOF 305 JQ, RUSTENBURG, NORTH WEST PROVINCE.

Prepared for

Hydro Science

P.O. Box 1322

RUIMSIG

1732

by

GEO – LOGIC Hydrogeological Consultants cc

Report No: G 2013/044

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EXECUTIVE SUMMARY

HydroScience cc, an independent Environmental Assessment Practitioner (EAP), has been appointed by Mr Alec Brough representing the Brough Family Trust, to apply for a National Environmental Management Act (NEMA) 1998 as amended Section 24G rectification for the unlawful commencement and continuation of listed activities.

The main objective of the project is to establish a formal township. It comprises affordable accommodation facilities for rental to the general public. These facilities have lower rates than surrounding accommodation in Rustenburg and therefore provide assistance to the disadvantaged community who cannot afford to buy property and has limited funds to rent. The facilities include 172 rooms/houses, solar heated water for ablution facilities and a gas geyser and stove inside the units. Generators have been installed for power outages and groundwater from boreholes is used as potable supply and treated sewage water is recycled to water the gardens.

The water demand for the De Brough development is calculated at 60m^3/d. This constitute a water demand of 21 900 m^3/a.

This document presents the results of a hydrogeological - and contamination risk analyses investigation for the development. This groundwater study form part of an EIA process and the report outcome will be used as support document for an Integrated Water Use Licence Application (IWULA) to be launched.

Geo-logic Hydro Geological Consultants cc was appointed by HydroScience cc to do a hydrogeological – and contamination risk assessment study for the housing development.

A desk study was performed to gather relevant geological and geohydrological information. A hydro - census followed the desk study to establish information such as water level depths and borehole depths in the existing boreholes on site. The purpose of this survey was to gather relevant hydrogeological information of current groundwater use on the farm and in the area.

The groundwater regime was studied by utilizing the water level depths in the existing boreholes. An attempt was made to understand the hydrogeology of the site and specifically the potential of groundwater movement in the aquifer. Groundwater movement in the weathered aquifer layers can also be an indicator of the potential groundwater recharge and contamination risk of the site.

Water samples were taken from three boreholes on site and three boreholes topographically below the site, to be analysed for major cat- and an–ions and bacteriological analyses.

Two test pits were dug and prepared for double ring infiltration tests. The aim of these tests

was to establish percolation rates for the relevant soil zones and to facilitate the contamination risk assessment. A contamination risk assessment for the housing development site was done based on the percolation rates measured in the test pits, the hydraulic parameters calculated for the aquifer, the aquifer tests, water level depth and current groundwater quality.

Sustainability of the Groundwater Regime

The sustainability assessment is based on the following information:

- The available water that can be abstracted from the three boreholes calculates to 16.58m^3/d (normal groundwater recharge) plus 0.67m^3/d (induced recharge from treated waste water) = 17.25m^3/d
- The groundwater potential of the three boreholes submitted to borehole yield tests can not be utilized at its full potential due to a limitation on the groundwater recharge area that is 13.8135ha.
- The groundwater contour map indicates to over exploitation of boreholes in the area at un-sustainable rates that led to the depletion of the regional aquifer.
- The chemical water quality from boreholes H/BH 23 and H/BH 5 located outside the development area footprint and borehole BH 1 located on the De Brough property can be categorized as Class 1, recommended water quality.
- The chemical water quality from borehole BH 4 located on the De Brough property can be categorized as Class 2, maximum allowed due to elevated magnesium and nitrate levels.
- The chemical water quality from boreholes BH 2 located on the De Brough property and H/BH 19 can be categorized as above Class 2, due to magnesium and nitrate levels which mean that this water must rather be treated prior to human consumption.
- The water from borehole BH 1 located on the De Brough property and borehole H/BH 5 must be chlorinated prior to human consumption due to elevated E. Coli counts.

On Site Groundwater Contamination Risk Assessment

The vulnerability of the Groundwater Aquifer due to the Hydrogeological conditions at the De Brough development site can be rated as medium to Low. The permeability tests show that the infiltration rates of the subsurface soils are slow. The distance from the surface to the aquifer is a minimum of 17 to 21 metres. Silt and silty sand is found on surface, which acts as filtering system with slow infiltration from surface.

A groundwater flow velocity of 30.6m/year was calculated which suggest that leakage or spillage of effluent or contaminants will have **minimal** impact on the surrounding groundwater resource, assuming no preferential pathways are encountered at or near surface.

The following recommendations are made:

- The recommended abstraction rates of 17.25m^3/d must not be exceed.
- All the boreholes on site must be used for monitoring purposes.
- Water level depths must be measured in all the boreholes on the farm on a monthly basis.
- The boreholes that are used for abstraction purposes must be used as groundwater monitoring facilities for water quality purposes and abstraction volume monitoring.
- Water flow meters must be installed and monitored on a monthly basis for all the boreholes that are used as abstraction boreholes.
- The following parameters must be analysed for: TDS, Turbidity, Nitrate, Faecal Coliform count, Total Plate count, Coliform count, COD, and Phosphate must be analyzed for, on bi-annual intervals, at the four boreholes.
- Rainfall figures must be recorded on a daily basis.
- Water abstraction figures must be noted on a monthly basis for the abstraction boreholes to be used. A flow meter, installed at each abstraction borehole, can be used to facilitate with the abstraction volumes.
- Water level depth must be noted on a monthly basis in all boreholes on the development. A 12 hour rest period must be allowed for, prior to any water level depth measurements.
- A monitoring report must be generated by a qualified geohydrologist on an annual basis to report on water quality and groundwater level responses.
- The recommended abstraction yield should be adhered too to ensure a long term sustainable source.
- The proposed contamination source which is in this case a package plant and irrigation with treated water should preferably be placed away from the boreholes and residents.

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1. INTRODUCTION

1.1 Background

HydroScience cc, an independent Environmental Assessment Practitioner (EAP), has been appointed by Mr Alec Brough representing the Brough Family Trust, to apply for a National Environmental Management Act (NEMA) 1998 as amended Section 24G rectification for the unlawful commencement and continuation of listed activities.

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1.2 Study Area

The proposed development on remaining extent of portion 172, portion 534, 535, 536 and 537 of the farm Waterkloof 305 JQ is located next to the R30 and 12 km south of Rustenburg. The proposed development is located 3km north of the Olifantsnek dam. The proposed development area is located in the North West Province. (Figure 1)

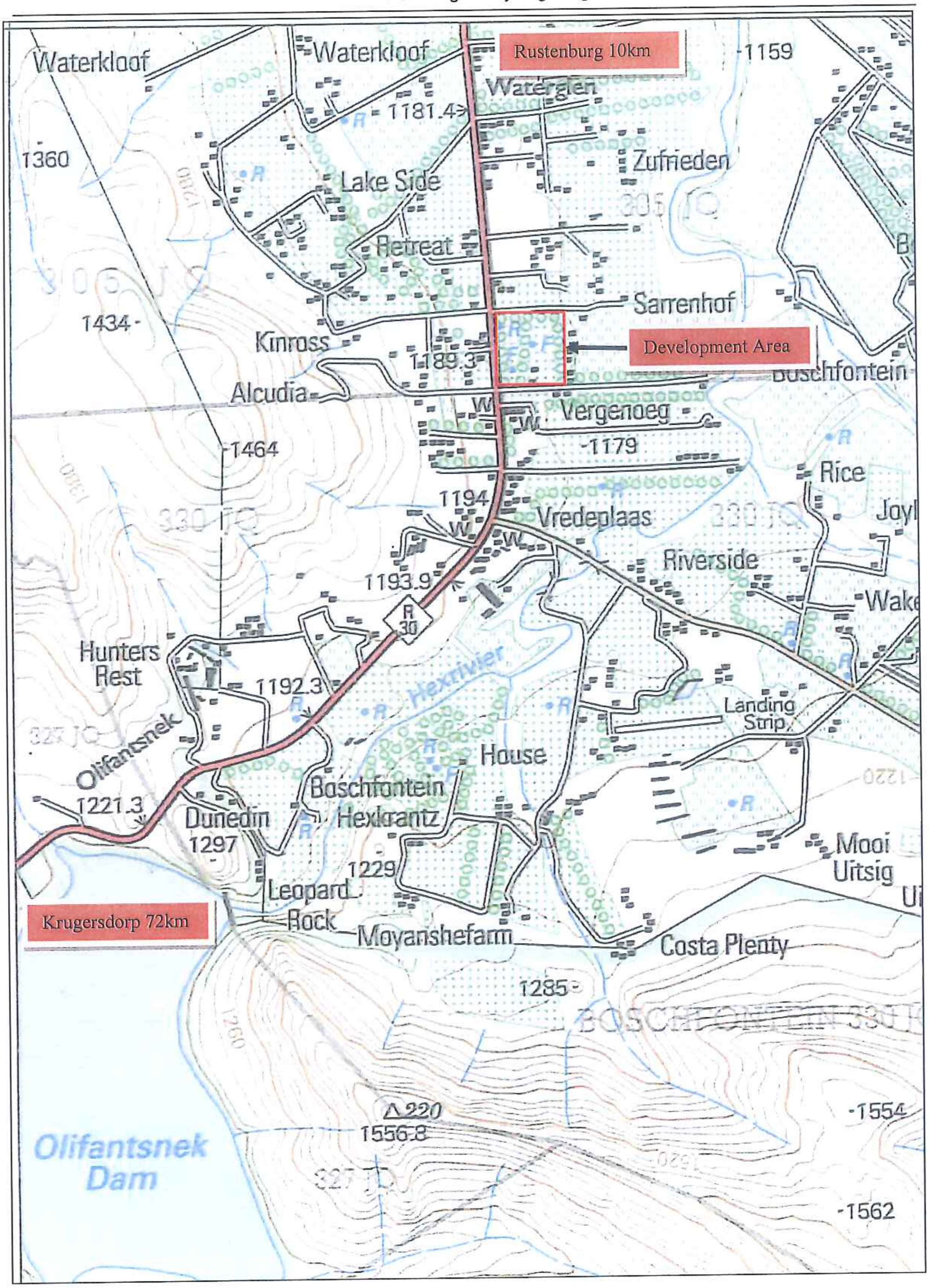

Figure 1: Regional locality map of the development

1.3 Scope of Investigation

The scope of work can be defined as follows:

1) Do a Category C hydrogeological and contamination risk assessment study for the development.

1.4 Existing Information

Maps

Geological Map Series 1: 50 000, 2527 CD Maanhaarrand.

Google Earth Images manipulated and used to show topographical features such as rivers and dams and existing farming practices around the proposed housing development.

1.5 Water Use Licence Application

To abstract water from an aquifer, a water use license is needed. This report will be used during the license application process to support the application with enough information for the DWA representatives to make an informed decision regarding the license application. A Regional - Initial calculation was done to determine the amount of information necessary for the new Integrated Water Use License Application for groundwater abstraction.

The Regional – Initial calculations are based on the following:

- Size of the property ($Area_{prop}$). Surface area of Portions is 13.8135ha or $0.138135km^2$.
- Recharge – HP (RE). Groundwater Recharge taken as 43.8mm per annum or 5.8 % from rainfall. (Refer to Section 8.4 of this report)
- Existing use volumes (ABS_{ex}). Existing use for 600 individuals X 100ℓ per person = 60 000 ℓ per day or $60m^3/d$.
- New use volumes (ABS_{new}). No new use can be accommodated due to high existing use volumes.
- Scale of abstractions (ABS_{scale})

Calculations: -

Groundwater Recharge

$Area_{prop} \times RE = RE_{area} (m^3/a)$

$Area_{prop} = 0.138135km^2 = 138\ 135m^2$

$RE = 43.8mm/annum$

138 135m^2 x (0.0438m) = **6050.3 m^3/a**

Groundwater Demand

$ABS_{ex} + ABS_{new}$ = ABS total (m^3/a)

0 m^3/day + 60 m^3/day = **21 900 m^3/a**

Scale of Abstraction

ABS_{scale} = (ABS_{total} / RE_{Area}) x 100

= (21 900 m^3/a / 6050.3 m^3/a) x 100

= **362 %**

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 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 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 dependant 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 bore holes 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 is 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 is 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.

SCOPE OF WORK

The Category C Geohydrological Study will consist of the following actions:

1) Desk study to study the geology and groundwater regime.
2) Site visit to visit water and sanitation related infrastructure according category C study requirements in a 1km radius. The sanitation infrastructure on the plots next to the development area will be visited and will be surveyed.
3) Hydro census of boreholes in a 1km radius.
4) Establishing of at least 2 test pits for lithological purposes.
5) Conducting of at least 2 soil percolation tests at a depth of 1.5 metres on the site.
6) Calculate the contamination risk involved for the site.
7) Conducting of 3 borehole yield tests by a professional yield testing contractor. Three steps and a constant yield test of 24 hours will be conducted.
8) Taking of water samples for water quality analyses.

9) Categorize the water quality analyses according DWA drinking water standards.
10) Compile a contamination risk for the farm portion.
11) Recommendations on monitoring protocol for long term monitoring purposes
12) Compilation of a Category C groundwater study report and combine the groundwater contamination risk into the report.

2. METHODOLOGY

A desk study was performed to gather relevant geological and geohydrological information. A hydro - census followed the desk study to establish information such as water level depths and borehole depths in the existing boreholes on site. The purpose of this survey was to gather relevant hydrogeological information of current groundwater use on the farm and in the area.

The groundwater regime was studied by utilizing the water level depths in the existing boreholes. An attempt was made to understand the hydrogeology of the site and specifically the potential of groundwater movement in the aquifer. Groundwater movement in the weathered aquifer layers can also be an indicator of the potential groundwater recharge and contamination risk of the site.

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3. CLIMATE AND REGIONAL SETTING

The housing development at De Brough is located in quaternary sub-catchment A22H. 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 4km south of the De Brough development.

The rainfall period for this station covers the years from 1924 to 1989. The Mean Annual Precipitation (MAP) for the period from 1924 to 1989 is 711mm/a. Rainfall occurs as typical summer thunderstorms with heavy lightning and strong winds. Summer rainfall is typically from November to February, in which approximately 65 % of rainfall normally occurs. The typical dry period is between May and September each year, covering the winter months.

The De Brough development is located in Evaporation Zone 3B. The closest Evaporation station A2E008, the Rustenburg station which is located approximately 5km north of the De Brough development gives a mean annual evaporation (MAE) of 1645mm for the S-Pan value and 2054 for the A-pan value. The evaporation measurements cover the years 1957 to 1979.

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

4. TOPOGRAPHY AND SURFACE WATER DRAINAGE

Overall the De Brough development site is relative flat and slightly dipping east to the Hex River which is 820 metres east. The western boundary of the site borders on the R30 road. The site is 14km south of Rustenburg in the North West Province. The area is divided in small agricultural holdings which are mainly used for residential purposes and small scale farming. An irrigation channel receiving water from the Olifantsnek Dam is still in use on the De Brough development. A small number of agricultural holdings receive water from this channel for irrigation purposes.

A small number of drainage features originate in the mountains to the west of the development but vanish when they reach the lower lying areas. No small drainage features are visible on or near the site. The site is drained by sheet wash only. The Hex River drains the regional area and flows in a northern direction.

No earth dams or large water storage facilities are located on the development area. No bulk water line is available near the site.

5. GEOLOGY AND GROUNDWATER DRAINAGE

The 1:250 000 Geological Series map no 2526 Rustenburg indicates that the area of interest lies on Kolobeng Norite, which is part of the Rustenburg Layered Suite. The Kolobeng norite lies on top of the Magaliesburg quartzite which is part of the Pretoria Group and the Transvaal Sequence. The Tweelaagte Bronzitite lies on top of the Lolobeng Norite and is also part of the Rustenburg Layered Suite.

On the site the Kolobeng Norite is not visible. The Magaliesberg quartzite weathers away slowly and normally forms the mountain ranges. The Magalies Mountains to be found in the area is typically representative of the Magaliesberg quartzite. The quartzite rock weathers to fine grained sand which normally migrates down towards the valleys. The site is covered by red fine grained sand that originated from the mountains from the Magaliesberg quartzite which was transported by water towards the site. The thickness of the sand on site may be 10 to 15 metres in depth.

Below the sand the Kolobeng Norite is to be found. Kolobeng Norite is intrusive rocks that is normally blue in colour and weathers to a coarse grained medium yielding aquifer.

Below is a short summary of the lithology of the interested area. The geology map is below on figure 2 which show the regional geology. The development site is marked in red.

Sequence	Group	Formation	Lithology	Color
Rustenburg Layered Suite			Tweelaagte Bronzitite	Vi
			Kolobeng norite	Vn
Transvaal Sequence	Pretoria	Magaliesberg	Quartzite	Vm

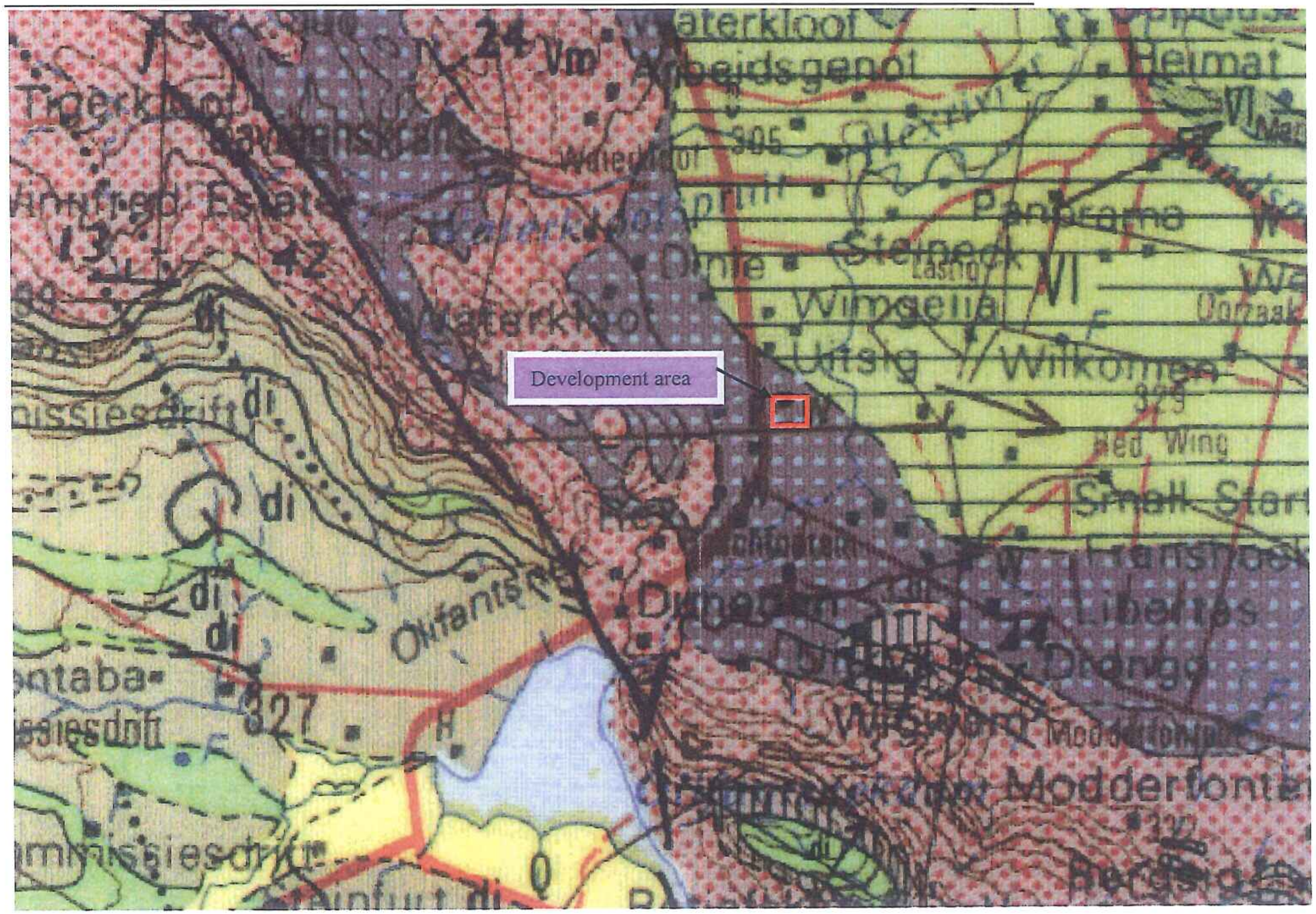

Figure 2: Geology Map Show the development area which is mostly covered by Kolobeng Norite

6. FIELD WORK

6.1 Hydro Census Data

During a desk study and field visits of the De Brough development and plots around the development area, information on four boreholes located inside the development area and thirty boreholes located outside the development area were visited. Sanitation systems were visited to be able to give a regional picture of where boreholes are located and where sanitation systems are located. Information listed below in Table 1 combines all information gathered for the study during the desk study and field work.

The aim of visiting the boreholes was to assess the density of the boreholes, the volumes of water that is taken from the boreholes, the water level depths of the boreholes and to determine the sustainability of the aquifer feeding these boreholes. The water level depths were used to calculate the water level height above mean sea level. This data was used to generate a groundwater contour map to be able to calculate the sustainability of the aquifer.

Groundwater is the only source of domestic water for the residents of the area. Boreholes are the only means of abstracting water for domestic purposes. Two surface water systems are in use for irrigation purposes. A small number of residents are using water from the Olifantsnek Irrigation Canal. Groundwater is also used for irrigation of gardens. During the survey it became evident that the water table in a large number of the boreholes are extremely deep indicating to over exploitation of groundwater in the area.

The aim of visiting the sanitation systems was to get an idea of the density of the sanitation systems and to assess the type and condition of these systems. Most of these systems are septic tank systems that are well functioning. Only two systems are leaking or overflowing to such an extent that contamination is inevitable. The one system is located on the De Brough development at the "Package Plant" position. This Package Plant system is totally inadequate and in a dilapidated state. This system is leaking untreated water into the upper soil layers.

The other system that is not functioning well is located on plot 1 near the position of borehole H/BH 29. This system is leaking untreated water and act as a French drain leaking constantly.

TABLE 1: Borehole Hydro Census Details

Borehole number	Co - ordinates		Water level depth (mbcl)	Ground water Level Elevation (mamsl)	Remarks
	Latitude and Longitude	Elevation (mamsl)			
A Brough: Remaining Extent of Portion 172, Portion 534, 535, 536 and 537 of the farm Waterkloof 305 JQ. Contact Details: Cell: 083 680 0086 Tel: 014 537 2500					
Boreholes on development area					
BH 1	S 25.76291° E 27.27339°	1184	21.60	1162	Borehole depth = 64.70mbcl. Submersible. Are used as main water supply.
BH 2	S 25.76430° E 27.27432°	1180	17.80	1162	Borehole depth = 28.90mbcl. Submersible pump. Are used as standby source.
BH 3	S 25.76419° E 27.27455°	1180	17.35	1163	Borehole depth = 24.40mbcl. Submersible pump. Not in use currently.
BH 4	S 25.76451° E 27.27424°	1180	---	---	Borehole located in servitude. Submersible pump. Deliver water to Portion 247, 181 and 366. Are used once a week.
Sanitation system					
Package Plant	S 25.76452° E 27.27459°	1180	N A	---	Sanitation plant located on De Brough development. Leaking extensively.
Ivor E Davis: Portion 192 of the farm Waterkloof305 JQ. Contact details: ied@telkomsa.net					
Boreholes					
H/BH 1	S 25.76326° E 27.26826°	1207	---	---	Borehole closed up, Can not measure water level depth.
Sanitation system					
Septic Tank	S 25.76309° E 27.26813°	---	N A	---	Approximate position
Ms E. Roselt: (Plot 181) Portion 305 and Portion 366 of the farm Waterkloof. Contact details: 014 537 2521					
Boreholes					
H/BH 2	S 25.76341° E 27.26845°	1206	>41.46	1163	Borehole depth 41.46, Borehole dry.

H/BH 3	S 25.76355° E 27.26858°	1205	49.32	1156	Submersible pump used for a few hours per day.
Sanitation system					
Septic Tank	S 25.76417° E 27.26836°	—	N A	—	Approximate position.
Mr Thabo Moseki: Portion 137 of the farm Waterkloof. Contact details: 083 648 6386					
Boreholes					
H/BH 4	S 25.76521° E 27.27491°	1180	15.44	1165	Submersible pump are used for 25 room Boutique Hotel. Pump to 2 X 5000l tanks.
Sanitation system					
Septic tank	S 25.76529° E 27.27541°	—	—	—	Two stage concrete Septic tank. Very low contamination risk.
Septic tank	S 25.76484° E 27.27558°	—	—	—	Two stage concrete Septic tank. Very low contamination risk.
JJF Brits: Portion 3 of the farm Waterkloof 305 JQ. Contact Details: Cell: 073 150 7824					
Boreholes					
H/BH 5	S 25.76081° E 27.27493°	1178	14.57	1163	Submersible pump are used for domestic use for three houses. Pump to 2 X 10 000l tanks on 12 meter tank stand.
Sanitation system					
Septic tank	S 25.76063° E 27.27515°	—	—	—	Two stage concrete Septic tank. Very low contamination risk.
Septic tank	S 25.76083° E 27.27533°	—	—	—	Two stage concrete Septic tank. Very low contamination risk.
Septic tank	S 25.76156° E 27.27444°	—	—	—	Two stage concrete Septic tank. Very low contamination risk.
W Vos: a Portion of the farm Waterkloof 305 JQ. Contact Details: Cell: 082 777 0240					
Boreholes					
H/BH 6	S 25.76113° E 27.27673°	1172	25.67	1146	Small submersible pump are used for domestic use for one houses.
H/BH 7	S 25.76032° E 27.27680°	1171	26.44	1145	Large irrigation pump. Used for 20 sprinklers. Used 4 hours per day. 6 – 8l/s estimated.

H/BH 8	S 25.76089° E 27.27639°	1174	—	—	Submersible pump 65mm pipe. House and garden use. Located at house. Can not measure water level.
H/BH 9	S 25.76050° E 27.27621°	1175	14.52	1160	Small submersible pump. Not used. Not coupled to pipe.
Sanitation system					
Septic tank	S 25.76060° E 27.27626°	—	NA	--	Concrete septic tank
Charles G Holding: Portion 123 of the farm Waterkloof 305 JQ. Contact Details: Cell: 082 806 3801					
Boreholes					
H/BH 10	S 25.75994° E 27.27119°	1186	—	—	Submersible pump. Borehole sealed and closed up. Located near main road. Domestic and garden use. No water level could be measured.
H/BH 11	S 25.76054° E 27.26956°	1195	25.27	1170	Borehole located inside pump room of rented house. BH not equipped. BH protected. Pump room locked.
Sanitation system					
Septic tank	S 25.76032° E 27.26945°	—	NA	—	Concrete septic tank
Septic tank	S 25.76003° E 27.26923°	—	NA	—	Concrete septic tank
Mr H.W.A Minnaar: Portion 00 of the farm Boschfontein 330 JQ. Jabez Filling Station. Contact Details: Cell: 082 892 0602					
Boreholes					
H/BH 12	S 25.76498° E 27.26963°	1200	29.00	1171	Submersible pump. Steel drum on top. Domestic and garden use.
H/BH 13	S 25.76490° E 27.27052°	1194	21.47	1173	Submersible pump. Steel drum on top. Domestic and garden use.
H/BH 14	S 25.76490° E 27.27145°	1189	—	—	Submersible pump. Brick hut sealed and bolted. Domestic and garden use. No water level could be measured.
Sanitation system					
Septic tank	S 25.76545° E 27.26694°	—	N A	—	Approximate position
Mr J van Dyk: Portion 130 and 247 of the farm Waterkloof 305 JQ. Contact Details: Cell: 082 926 0024					
Boreholes					

H/BH 15	S 25.76238° E 26.27054°	1194	43.83	1150	Submersible pump. Can pump only a few minutes per day. 40mm pipe. Domestic and garden use for 1 house and 8 room guest house.
H/BH 16	S 25.76276° E 27.27130°	1191	---	---	Submersible pump. Located inside abattoir. Borehole never used.
H/BH 17	S 25.76305° E 27.27127°	1191	---	---	Borehole closed up. No equipment. Never used.
H/BH 18	S 25.76310° E 27.27021°	1195	29.32	1166	Portion 247. Submersible pump. 40mm pipe. Domestic and garden use for 2 houses.
Sanitation system					
Septic tank	S 25.76174° E 27.27126°	---	N A	---	Sanitation system for guest house. Four stage pit. Pumped once per annum.
Septic tank	S 25.76305° E 27.27075°	---	N A	---	Sanitation system for private house. Single stage pit.
Septic tank	S 25.76305° E 27.27075°	---	N A	---	Portion 247. Sanitation system for private house. Single stage tank.
Dr Makgoba: Portion 1 of the farm Waterkloof 305 JQ. Contact Details: Cell: 083 627 2851					
Boreholes					
H/BH 19	S 25.76394° E 27.26766°	1181	17.65	1163	Submersible pump. 40mm pipe. Domestic and garden use for 5 to 6 hours per day.
Sanitation system					
Septic tank	S 25.76438° E 27.27601°	---	N A	---	Sanitation system for main house. Three stage concrete tank.
Septic tank	S 25.76389° E 27.27514°	---	N A	---	Sanitation system for worker house. Single stage tank.
Mr C Venter: Portion 201 of the farm Waterkloof 305 JQ. Contact Details: Cell: 082 920 5348					
Boreholes					
H/BH 20	S 25.76294° E 27.26766°	1211	58.21	1153	Submersible pump with 2.2kw motor. Can pump only a few minutes per day. 32mm pipe. Domestic and garden use for 1 house. BH depth 65m.
H/BH 21	S 25.76308° E 27.26777°	1211	Dry	1152	Submersible pump with 1.1kw motor. Currently dry. 32mm pipe. Domestic and garden use for 1 house. BH depth 65m
H/BH 22	S 25.76289° E 27.26705°	1215	59.00	1156	Submersible pump with 2.2kw motor. Can pump only a few minutes per day. 32mm pipe. Domestic and garden use for 1 house
Sanitation system					

Septic tank	S 25.76354° E 27.26713°	—	N A	—	Approximate position
Mr DJJ Ferreira: Portion 2 of the farm Waterkloof 305 JQ. Contact Details: Cell: 082 442 2896 and 083 310 2843					
Boreholes					
H/BH 23	S 25.76166° E 27.27609°	1175	15.03	1160	Submersible pump. 65mm pipe. Domestic, garden and farm use. Daily used.
H/BH 24	S 25.76156° E 27.27569°	1177	15.79	1161	Borehole not equipped. Borehole reported as collapsing.
H/BH 25	S 25.76177° E 27.27676°	1172	9.89	1162	Borehole not equipped and not used.
Sanitation system					
Septic tank	S 25.76205° E 27.27579°	—	—	—	Septic tank constructed from bricks and concrete.
Mr I Bronkhorst: Portion 36 of the farm Boschfontein330 JQ. Contact Details: Cell: 082 444 2195					
Boreholes					
H/BH 26	S 25.76591° E 27.27222°	1188	22.35	1166	Submersible pump. 40mmpipe. Domestic and garden use 1 house and 3 flats. 5h/d
H/BH 27	S 25.76545° E 27.27603°	1174	14.60	1159	Submersible pump. 40mmpipe. Domestic and business use Garden world. 6h/d
Sanitation system					
Septic tank	S 25.76480° E 27.27280°	—	N A	—	2 Stage cement tank
Septic tank	S 25.76565° E 27.27260°	—	N A	—	2 Stage cement tank
Septic tank	S 25.76571° E 27.27262°	—	N A	—	2 Stage cement tank
Mr R Theron: Portion 189 of the farm Waterkloof 305 JQ. Contact Details: Cell: 082 829 4864 or 083 304 7753					
Boreholes					
H/BH 28	S 25.76467° E 27.27143°	1189	26.56	1162	Submersible pump. 50mmpipe. Domestic and business use 2 houses 1 business. 2h/d
Sanitation system					

Septic tank	S 25.76362° E 27.27050°	—	N A	—	Concrete septic tank
Septic tank	S 25.76345° E 27.27067°	—	N A	—	Concrete septic tank
Septic tank	S 25.76391° E 27.27074°	—	N A	—	Concrete septic tank
Septic tank	S 25.76397° E 27.27059°	—	N A	—	Concrete septic tank
Septic tank	S 25.76402° E 27.27055°	—	N A	—	Concrete septic tank
Septic tank	S 25.76429° E 27.27056°	—	N A	—	Concrete septic tank
Septic tank	S 25.76475° E 27.27106°	—	N A	—	Concrete septic tank
Septic tank	S 25.76328° E 27.27142°	—	N A	—	Concrete septic tank
Mr H Muller: Portion 139 of the farm Boschfontein 330 JQ. Contact Details: Cell: 083 234 8941					
Boreholes					
H/BH 29	S 25.76515° E 27.27629°	1173	39.00	1134	Submersible pump. 50mmpipe. Domestic and irrigation use 1 house. 15min 1.5 hours rest.
Sanitation system					
Septic tank	S 25.76496° E 27.27672°	—	N A	—	3 stage tank
Mr A Rouxe: Portion 35 of the farm Boschfontein 330 JQ. Contact Details: Cell: 078 800 8904					
Boreholes					
H/BH 30	S 25.76515° E 27.27836°	1171	—	—	Submersible pump. 40mmpipe. Domestic and irrigation use 8 house. BH locked
Sanitation system					
Septic tank	S 25.76516° E 27.27847°	—	N A	—	2 stage tank + overflow
Septic tank	S 25.76478° E 27.27885°	—	N A	—	2 stage tank + overflow

Figure 3: Hydro-census Information of Boreholes Visited

6.2 Test Pits and Percolation Rate Tests

To be able to calculate the inflow rate of water in the upper layers of soils, double ring inflow meter tests are done on the positions that will be developed for a sanitation site or irrigation with treated water. These tests are done to be able to calculate the contamination risk of the planned irrigation or planned sanitation works.

Infiltration rate of soils is defined as a soil characteristic, determining and describing the maximum rate at which water can enter the soil under specified conditions, including presence of an excess of water. Infiltration rates have application to such problems as erosion rates, leaching and drainage efficiencies, irrigation, water spreading, rainfall runoff, sewerage treatment works and evaluation of potential septic-tank disposal fields, among other applications.

Water inflow rates determined by ponding of large areas are considered the most reliable method of determining infiltration rate, but the high cost makes the infiltrometer-ring method more feasible and economical. The infiltration rate is controlled by the least permeable zone in the subsurface soils. The double-ring infiltrometer is used to help divergent flow in layered soils by providing an outer water barrier to encourage only vertical flow from the inner ring. Many other factors affect the infiltration rate in addition to the soil structure, for example, the condition of the soil surface, the moisture content of the soil, the chemical and physical nature of the soil and the applied water, the head of applied water, and the temperature of the water. The tests done at the same site are not likely to give identical results and the rate measured by the procedure described in this test method is primarily for comparative use. Some aspects of the test, such as the length of time the tests should be conducted and the head of water to applied, must depend upon the experience of the user, the purpose for testing, and the kind of information that is sought.

Two open cylinders, one inside the other, are driven into the ground and partially filled with water which is then maintained at a constant level. The volume of water added to maintain the water level constant is the measure of the volume of water that infiltrated the soil. The volume infiltrated during timed intervals is converted to an infiltration velocity, usually expressed in inches per hour or centimeters per hour. The minimum infiltration velocity is equivalent to the expected infiltration rate.

Two test pits were dug and prepared for double ring inflow meter tests. The infiltration rates of the two test pits done for the study can be found described in Table 2 below. The positions of these test pits can be found on Figure 4.

Test pit 01 is located at the position of the current package plant. The position was chosen to test the soils directly below and at the plant site.

Red sandy, fine grained, loosely compacted soil was found to a depth of 1.6 metres. The test was done in the pit that was constructed for the current sanitation works.

The initial infiltration rate at this test pit measured 7.36 x 10^{-4} cm/s or 2.649cm/h or 0.636m/d which is slow enough to form an active filter to filter out bacteriological matter.

Test pit 02 is located on the grass land that is currently under irrigation with treated sewerage water. The position was chosen due to its central position away from the boreholes where irrigation can take place without possible contamination taking place. The test was done on surface to test the upper sand layers for irrigation purposes.

The hydraulic conductivity rate measured at this pit was constantly measuring 7.36 x 10^{-4} cm/s or 2.649 cm/h or 0.636 m/d, which relates to the hydraulic conductivity of silty sand. The top layer of the sand is compacted and may have enough silt to be responsible for the slow infiltration rate of the water.

Figure 4: Locality Map showing infrastructure, test pits and boreholes on development area.

TABLE 2: Information on Test Pits

Co-ordinates	Elapsed Time	Quantity of water (ml)	Infiltration rate (cm/s)	Infiltration rate (cm/h)	Infiltration rate (m/d)
Pit 1 25.76466° 27.27456°	15 (15min)	2000	2.94×10^{-3}	10.595	2.543
	30 (15min)	1000	1.47×10^{-3}	5.297	1.271
	45 (15min)	500	7.36×10^{-4}	2.649	0.636
	60 (15min)	1000	1.47×10^{-3}	5.297	1.271
	90 (30min)	1000	7.36×10^{-4}	2.649	0.636
	120 (30min)	1000	7.36×10^{-4}	2.649	0.636
	150 (30min)	1000	7.36×10^{-4}	2.649	0.636
Pit 2 26.58375° 27.97218°	15 (15min)	1000	1.47×10^{-3}	5.297	1.271
	30 (15min)	1000	1.47×10^{-3}	5.297	1.271
	45 (15min)	1000	1.47×10^{-3}	5.297	1.271
	60 (15min)	1000	1.47×10^{-3}	5.297	1.271
	90 (30min)	1000	7.36×10^{-4}	2.649	0.636
	120 (30min)	1000	7.36×10^{-4}	2.649	0.636
	150 (30min)	1000	7.36×10^{-4}	2.649	0.636
	180 (30min)	1000	7.36×10^{-4}	2.649	0.636
	210 (30min)	1000	7.36×10^{-4}	2.649	0.636
	240 (30min)	1000	7.36×10^{-4}	2.649	0.636
	270 (30min)	1000	7.36×10^{-4}	2.649	0.636

6.3 Borehole Yield Tests

6.3.1 Test Pumping of Boreholes

The three boreholes that is currently used as production boreholes were submitted to borehole yield tests during the study.

The three 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 24 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 utilising the Basic FC, FC inflection point, Cooper-Jacob and Barker/Bangoy methods, to give an indication of Transmisivity and Storativity values.

Borehole **BH1** is 64.70 metres deep, with a static water level at 21.80 metres below ground level. The borehole was pumped for three steps of 60 minutes at rates of 1.08, 2.05 and 4.15 l/s. The water level draw down was measured constantly during these steps. The water level draw down after each step measured 0.87, 5.63 and 28.40 metres below the original static water level. The water level reached pump inlet after 15 minutes in the third step and a maximum inflow of 3.65 l/s was measured during the step test. The pump was switched of and the water level allowed recovering until it reached the original static water level. The water level was back in 70 minutes to the original water level.

The borehole was then submitted to a constant discharge test with duration of 24 hours at a rate of 2.54 l/s. The pump was switched off after 1440 minutes or 24 hours. The water level draw down was measured at 10.52 metres below the original static water level. The borehole was allowed to recover for 420 minutes or 7 hours. The water level recovered back to the original static water level. This can be regarded as a fast recovery rate.

Borehole **BH2** is 28.9 metres deep, with a static water level at 17.8 metres below ground level. The borehole was pumped for six steps of 60 minutes at rates of 0.35, 0.65, 1.07, 2.06, 4.02 and 7.09 l/s. The water level draw down was measured constantly during these steps. The water level draw down after each step measured 0.44, 0.91, 1.42, 2.05, 4.93 and 7.90 metres below the original static water level. The water level reached pump inlet after 15 minutes in the sixth step. A maximum inflow of 5.66 l/s was measured during the step test. The pump was switched of and the water level allowed recovering for 80 minutes. The water level reached the original static water level in the allowed 80 minutes.

The borehole was then submitted to a constant discharge test with duration of 24 hours at a rate of 3.05 l/s. The pump was switched off after 1440 minutes or 24 hours. The water level draw down was measured at 4.51 metres below the original static water level. The borehole was allowed to recover for 1440 minutes or 24 hours. The water level recovered back to 0.09 metres below the original static water level. This can be regarded as a normal recovery rate.

Borehole **BH3** is 24.4 metres deep, with a static water level at 17.35 metres below ground level. The borehole was pumped for five steps of 60 minutes at rates of 0.33, 0.64, 1.04, 2.07 and 4.03 l/s. The water level draw down was measured constantly during these steps. The water level draw down after each step measured 0.78, 1.34, 2.38, 3.08 and 4.68 metres below the original static water level. The water level reached pump inlet after 15 minutes in the fifth step. A maximum inflow of 3.05 l/s was measured during the step test. The pump was switched off and the water level allowed recovering until it reached the original static water level. The water level reached the original static level in 15 minutes.

The borehole was then submitted to a constant discharge test with duration of 24 hours at a rate of 1.54 l/s. The pump was switched off after 1440 minutes or 24 hours. The water level draw down was measured at 2.59 metres below the original static water level. The borehole was allowed to recover for 300 minutes or 5 hours. The water level recovered back to the original static water level. This can be regarded as a very fast recovery rate.

TABLE 3: Test Pumping Results

BH No. 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)	
BH1	1	1.08	60	0.87	2.54	1440	10.52	100% in 420 min
Depth: 64.70m	2	2.05	60	5.63				
Static water level:21.80m	3	4.15	15	28.40				
Date tested: 23 Sep 2013								
BH2	1	0.35	60	0.44	3.05	1440	4.51	98.0% in 1440 min
Depth: 28.9m	2	0.65	60	0.91				
Static water level:17.80m	3	1.07	60	1.42				
Date tested: 17 Sep 2013	4	2.06	60	2.05				
	5	4.02	60	4.93				
	6	7.09	15	7.90				
BH3	1	0.32	60	0.78	1.54	1440	2.59	100% in 300 min
Depth:24.4m	2	0.64	60	1.34				
Static water level:17.35m	3	1.04	60	2.38				
Date tested: 20 Sep 2013	4	2.06	60	3.08				
	5	4.03	15	4.68				

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

6.3.2 Borehole Abstraction Figures

The Constant Discharge Curves of the three tests were analysed by utilizing the Basic FC, FC inflection point, Cooper-Jacob and Barker/Bangoy methods, to give an indication of Transmisivity and Storativity values. 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 sheets for more detail borehole recommendations in Appendix A at the back of this report.

The abstraction rates for the boreholes are given for each individual method described above. The average abstraction rates for the boreholes are given in Table 4 below. It is important to understand that the abstraction figures given below in Table 4 only make provision for the aquifer parameters of each individual borehole tested. These figures do not make provision for borehole interference with other boreholes in the area, groundwater recharge that may or may not be enough or groundwater catchment size limitations. These abstraction figures below use assumptions such as a limitless catchment area size and no interference or abstraction from 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 Appendix A. Table 3 listed above, gives a summary of the pump test data.

TABLE 4: Abstraction Schedule for Production boreholes (FC method)

Borehole No.	Abstraction Rates		Dynamic water Level (mbcl)	Comments
	For 8h/d	in m^3/d		
BH 1	2.5	72.0	20	Water level 21.6 (mbgl)
BH 2	1.0	28.8	11	Water level 17.8 (mbgl)
BH 3	1.2	34.6	20	Water level 17.4 (mbgl)

Abstraction volumes are given for the three boreholes. Boreholes BH 2 and 3 are located only a few metres apart. Individually these boreholes may be able to sustain 2.7 and 2.0 l/s respectively but with interference on each other the abstraction rates of these two boreholes were scaled down to accommodate each other. Again we must emphasise that in Table 4 the assumption is made that the aquifer size is unlimitled in all directions and that no other boreholes are in use in the area. In Section 8 all factors restricting groundwater use are taken into consideration and final abstraction recommendations are made in Section 8.

7. WATER QUALITY

Water samples were retrieved from three boreholes located on the De Brough development area. These three boreholes represent the water quality of the four boreholes located on the De Brough property. Borehole BH 2 and BH 3 are located 17 metres apart. No water samples were taken from BH 3. Three water samples were also taken from boreholes located topographically down stream of the De Brough development.

The water samples were preserved and delivered to an accredited water laboratory to be analysed for water quality purposes. A full cat - and anion analyses and a Total Coliform Bacteria and E. Coli analyses were done on the samples. The results of the chemical and bacteriological analyses performed on the groundwater samples are presented in Table 5 and Table 6. The quality of water is classified according to the SANS 241: 2006 Drinking Water standard as in the publication "A Drinking Water Quality Framework for South Africa, DWA&F, December 2006". Please refer to Appendix B: Water Quality Analyses Certificate from Aquatico Laboratories (Pty) Ltd.

Chemical Water Quality

The chemical water quality from boreholes H/BH 23 and H/BH 5 located outside the development area footprint and borehole BH 1 located on the De Brough property can be categorized as Class 1, recommended water quality.

The chemical water quality from borehole BH 4 located on the De Brough property can be categorized as Class 2, maximum allowed due to elevated magnesium and nitrate levels.

The chemical water quality from boreholes BH 2 located on the De Brough property and H/BH 19 can be categorized as above Class 2, due to magnesium and nitrate levels which mean that this water must rather be treated prior to human consumption.

Bacteriological Water Quality

The water from borehole BH 1 located on the De Brough property and borehole H/BH 5 must be chlorinated prior to human consumption due to elevated E. Coli counts.

Contaminated boreholes

During the field visits and hydro-census study two sanitation systems were leaking contaminated water into the upper soils. The Sanitation Plant on the De Brough development (Figure 4) is leaking large volumes of water on a continuous basis. The other sanitation system that raised a concern is the Septic tank on Plot 1. This system is located near borehole H/BH 19. This system is continuously leaking water. Three boreholes located near these two sanitation systems show early signs of contamination. The two boreholes BH 2 and BH 4 located on the De Brough property and borehole H/BH 19 show elevated Nitrate, Magnesium, Chemical Oxygen Demand and chloride levels. Table 5 below show the determinants of borehole BH 23 that show un-contaminated baseline values and boreholes BH 2, BH 4 and H/BH 19 that does show elevated levels above the baseline levels of borehole BH 23.

Table 5: Boreholes with elevated determinants versus baseline values represented by BH 23

BH number	Chloride	Nitrate	Magnesium	COD	Potassium
BH 23	21.7	6.2	65	7.43	0.462
BH 2	49.8	13.5	105	25.7	1.82
BH 4	42.4	10.6	85.9	5.15	2.62
BH 19	43	11.2	105	20.6	1.77
(light blue)	Light blue representing base line values				
(orange)	Orange representing elevated values above the baseline values				

TABLE 6: Water Quality of Boreholes located outside the De Brough boundaries

DETERMINANT	UNIT	H/BH 23 Plot 2	H/BH 19 Plot 1	H/BH 5 Plot 3	SOUTH AFRICAN DRINKING WATER STANDARDS SABS 241 : 2006 : ABBREVIATED Class I (Recommended)	Class II (Max. Allowed)	Class II (Water consumption period)
pH	-	8.02	7.84	8.00	5.0 – 9.5	4.0 - 105	No limit
Electric conductivity	mS/m	56.4	88.7	28.1	< 150	150 – 370	7 years
Total dissolved solids	mg/l	291	481	141	< 1 000	1 000 – 2 400	7 years
Turbidity	NTU	--		--	< 1	1 – 5	No limit
Total hardness as CaCO3	mg/l	315	503	152	n.s.	n.s.	n.s.
Calcium hardness as CaCO3	mg/l				n.s.	n.s.	n.s.
Ammonium (NH4) as N	mg/l	0.120	0.150	0.097	<1.0	1.0 – 2.0.	No limit
Total alkalinity as CaCO3	mg/l	236	398	140	n.s.	n.s.	n.s.
Sodium	mg/l	0.593	1.51	0.522	< 200	200 – 400	7 years
Potassium (K)	mg/l	0.462	1.77	0.192	< 50	50 – 100	7 years
Calcium (Ca)	mg/l	18.7	28.7	8.99	< 150	150 – 300	7 years
Magnesium (Mg)	mg/l	65.2	105	31.6	< 70	70 – 100	7 years
Chloride (Cl)	mg/l	21.7	43	1.08	< 200	200 – 600	7 years
Sulphate (SO4)	mg/l	36.1	51.3	12.3	< 400	400 – 600	7 years
Nitrate (NO2)	mg/l	6.2	11.2	1.58	< 10	10 – 20	7 years
Fluoride (F)	mg/l	0.136	0.167	0.174	< 1.0	1.0 – 1.5	1 year
Nickel (Ni)	mg/l				< 150	150 – 350	1 year
Iron (Fe)	mg/l	<3	<3	<3	< 200	200 – 2 000	7 years
Manganese (Mn)	mg/l	<1	<1	<1	< 100	100 – 1000	7 years
Aluminium (Al)	mg/l	<3	<3	<3	< 20	300 – 500	1 year
Chemical oxygen demand (COD)	mg/l	7.43	20.6	19.1			
E Coli bacteria	cfu/100ml	<1	<1	4	Not detected	1	10
Total Coliforms	cfu/100ml	<1	8	47	-	-	-

Green: Class 1, Recommended operational limit.
Yellow: Class 2, Max, allowable for limited duration.

TABLE 7: Water Quality of the De Brough Production Boreholes

DETERMINANT	UNIT	SOUTH AFRICAN DRINKING WATER STANDARDS SABS 241 : 2006 : ABBREVIATED					
		BH 4 De Brough	BH 1 De Brough	BH 2 De Brough	Class I (Recommended)	Class II (Max. Allowed)	Class II (Water consumption period)
pH	-	8.24	8.11	8.76	5.0 – 9.5	4.0 - 105	No limit
Electric conductivity	mS/m	70.0	56.2	90.1	< 150	150 – 370	7 years
Total dissolved solids	mg/l	347	288	430	< 1 000	1 000 – 2 400	7 years
Turbidity	NTU	--		--	< 1	1 – 5	No limit
Total hardness as CaCO3	mg/l	392	319	504	n.s.	n.s.	n.s.
Calcium hardness as CaCO3	mg/l				n.s.	n.s.	n.s.
Ammonium (NH4) as N	mg/l	0.093	0.091	<0.005	<1.0	1.0 – 2.0.	No limit
Total alkalinity as CaCO3	mg/l	276	262	345	n.s.	n.s.	n.s.
Sodium	mg/l	0.539	0.526	<0.013	< 200	200 – 400	7 years
Potassium (K)	mg/l	2.62	1.54	1.82	< 50	50 – 100	7 years
Calcium (Ca)	mg/l	15.4	18.9	28.5	< 150	150 – 300	7 years
Magnesium (Mg)	mg/l	85.9	66.1	105	< 70	70 – 100	7 years
Chloride (Cl)	mg/l	42.4	17.1	49.8	< 200	200 – 600	7 years
Sulphate (SO4)	mg/l	24.1	18.9	24.4	< 400	400 – 600	7 years
Nitrate (NO2)	mg/l	10.6	7.17	13.5	< 10	10 – 20	7 years
Fluoride (F)	mg/l	0.108	0.169	0.143	< 1.0	1.0 – 1.5	1 year
Nickel (Ni)	mg/l				< 150	150 – 350	1 year
Iron (Fe)	mg/l	<3	<3	<3	< 200	200 – 2 000	7 years
Manganese (Mn)	mg/l	<1	<1	<1	< 100	100 – 1000	7 years
Aluminium (Al)	mg/l	<3	<3	<3	< 20	300 – 500	1 year
Chemical oxygen demand (COD)	mg/l	5.15	14.1	25.7			
E Coli bacteria	cfu/100ml	<1	3	<1	Not detected	1	10
Total Coliforms	cfu/100ml	<1	48	16	-	-	-

Green: Class 1, Recommended operational limit.
Yellow: Class 2, Max, allowable for limited duration.

8. GROUNDWATER RESOURCE EVALUATION

8.1 Depth to Groundwater Rest Level

The regional depth to groundwater level on the development site and the boreholes visited during the hydro-census varies between 9.89 mbgl and 59 mbgl in depth. The mean water level depth figure is 27.7 metres below ground level which can be regarded as deep.

The static water rest level does not mimic the surface topography. Four boreholes recently dried up or are in the process of drying up and will not be available as groundwater resource in future. A number of boreholes located west of the development area and located topographically higher up show signs of lowering water tables.

8.2 Groundwater Contour Map

A groundwater level contour map, Figure 5 was generated from the water level depth information. This map shows the water level height in metres above mean sea level (mamsl). The groundwater contours should to a large degree follow the surface level contours which is in a north to south direction. The groundwater level contour map show a large valley forming through the centre of the map forming from west to east according to Figure 5. The forming of this water level contour valley is the result of groundwater that is abstracted at un-sustainable rates from at least 9 boreholes located in the area.

8.3 Groundwater Migration

Even though groundwater over abstraction is taking place in the area groundwater movement to a large degree is still from west to east, from the high topography area to the low topography area.

The groundwater levels was used together with the calculated hydraulic conductivity, average porosity and with Darcy's law, as well as the local topographic gradient and the gradient of the water level to estimate the rate at which groundwater motion and contaminant migration, in the saturated zone, may take place under normal unstressed conditions. (Anderson, 1992)

The groundwater level gradient and flow velocity was calculated by using the water level depths available from Borehole BH 1 (water level height 1162 mamsl) on the De Brough property and borehole H/BH 24 (water level height 1161 mamsl) that is not in use. The gradient of the groundwater level on the site have a gradient of 1:270 in an east north eastern direction.

The groundwater flow velocity or groundwater migration rate was calculated. The groundwater migration rate is the rate at which groundwater will move under steady state conditions which does not make provision for groundwater abstraction. Groundwater abstraction from boreholes may have a negative or positive influence on the groundwater migration rate.

Groundwater Flow Velocity:

Hydraulic conductivity: $K = T/d$

$= 22.7m^2/d / 20m$

$= 1.135m/d$

And:

Groundwater Flow Velocity: $V = Ki/\Phi$

$= 1.135m/d \times 0.0037/0.05$

$= 0.084m/d$

Where:

V = flow velocity (m/d)

K = Hydraulic conductivity (m/d)

i = hydraulic gradient calculated from groundwater contours as 0.0037

T = Late Transmisivity (m^2/d) calculated average of $22.7m^2/d$ from three boreholes yield tests.

d = average thickness of aquifer estimated from the four boreholes yield tests is 25 metres.

Φ = probable average porosity (literature value for fractured aquifers) = 0.05

TABLE 8: Estimated Groundwater Flow Rates

Borehole Number	K (m/d)	Groundwater level gradient	Flow Velocity (m/d)	Flow velocity (m/year)	Comments
From borehole BH 1 to H/BH 24	1.135	0.0037	0.084	30.6	A relative slow groundwater flow velocity of 30.6m/a relate to slow groundwater contamination spreading.

Under normal unstressed conditions, contaminant migration in the saturated zone will be at a rate of 30.6m/year to the east. This means that contamination spreading will be slow in the aquifer conditions prevailing. In the presence of groundwater abstraction at borehole groundwater flow rates may increase.

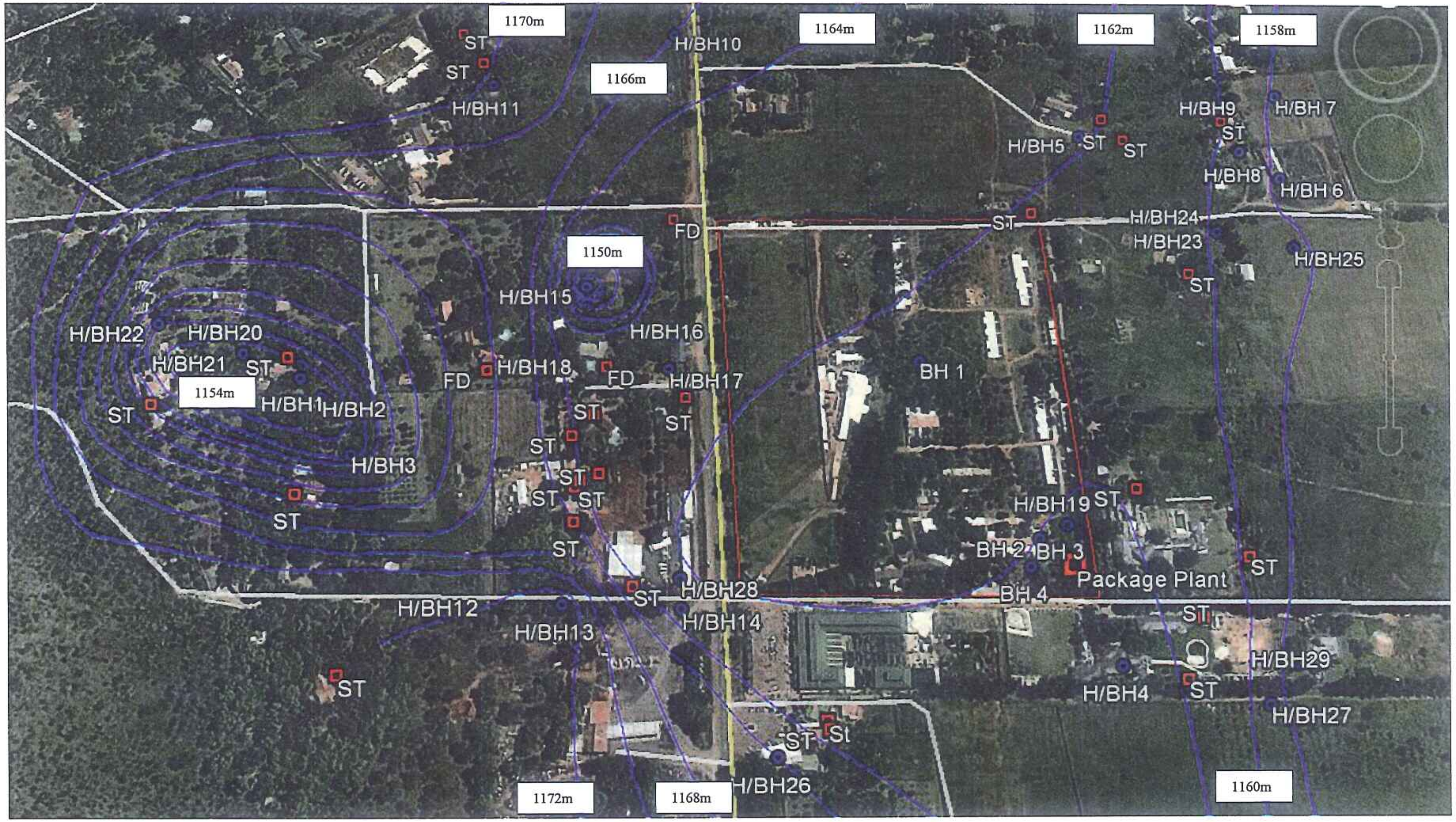

Figure 5: Groundwater contour map

8.4. Groundwater Recharge Figures of Development Portions

The scale of abstraction, calculated in section 1; the introduction, is a function of the volume of the groundwater demand set by the housing development versus the volume of groundwater recharged on the 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 of remaining extent of portion 172, portion 534, 535, 536 and 537 of the farm Waterkloof 305 JQ. 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 9, 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 2 was given for the Harvest Potential method, which in this case seems to be a conservative value and 5 for the Vegter method, which is normally considered to give a more representative groundwater recharge value. The mean groundwater recharge on the specific proposed development portion is in the order of 43.8mm/a or 5.8% of MAP or 16.59m^3/d.

TABLE 9: Groundwater Recharge Figures and Percentages

Method	mm/a	% of rainfall	Certainty (Very High=5 ; Low=1)
CI	45.5	6.1	5
SVF: Equal Volume			4
Qualified Guesses :			
Soil	86.9	11.6	2
Geology	50.9	6.8	4
Vegter	45.0	6.0	5
Acru	10.0	1.3	2
Harvest Potential	12.5	1.7	2
Base Flow (minimum Re)			3
Groundwater Flow Model			1
Average recharge	43.8	5.8	
Recharge =	43.8	5.8	

= 0.0060503 Mm^3/a

= 16.58 m^3/d

= 0.19 L/s

Area (Km^2) =	0.138135
Annual Rainfall (mm) =	748.9

8.5 Sustainable Groundwater Abstraction Recommendation

Groundwater abstraction can only be sustainable when the abstraction rate is the same or less than the replenishment rate. The replenishment rate or groundwater recharge rate in this case is 16.58m^3/d.

The groundwater contour map, Figure 5 shows an alarming picture of a depleting aquifer due to over abstraction of water from a number of boreholes in the region. If un-sustainable abstraction of water will be done in future, the water table will keep on depleting until the aquifer is dry.

The rate of abstraction recommended for the De Brough development can be calculated as follows:

Sustainable abstraction from De Brough development on 13.8135ha = groundwater recharge = 16.58m^3/d

Treated water from sanitation system that is used for irrigation purposes = 70% of 16.58m^3/d X 5.8% which will be replenished as groundwater recharged = 0.67m^3/d.

The available water that can be abstracted from the three boreholes calculates to 16.58m^3/d plus 0.67m^3/d = 17.25m^3/d.

9. CONTAMINATION RISK ASSESSMENT

9.1 Parsons Rating System

The "Parsons Rating System" is an aquifer classification system developed to implement a strategy for managing ground water quality in South Africa. Classification, vulnerability and susceptibility are rated for a specific aquifer to be studied.

a) Aquifer Classification

The aquifer is classed as a **medium yielding** aquifer region with mixed 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 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 the area is rated at 2**, with a **low** protection level needed.

9.2 Assessment of the Vulnerability of the Underground Water Resources

The vulnerability of the underground water sources is related to the distance that the contaminant must flow to reach the water table and the ease with which it can flow trough the soil and rock layers above the water table. An assessment of the soil and rock types, the distance to the water table may be obtained. (Groundwater Protocol document, Version 2, dated March 2003)

Five broad classes of aquifer vulnerability are defined:

Table 10: 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 10 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 De Brough development site can be rated as Medium to low. The distance from the surface to the aquifer is in the region of 17 to 21 metres. Silty fine grained sandy soil originating from the Magaliesberg Quartzite is found on surface, which acts as a filtration system for organic and bacteriological matter. The silty sand layer on surface forms a filtration system that serves as protection for the aquifer below which prevails at a depth of 17 to 21 metres below ground level.

In Table 11 below an assessment is made of the reduction of the contaminants in the unsaturated zone.

Table 11: Assessment of the Reduction of Contaminants 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.

Table 11 above show that the sand and silt layers that is found on the surface of the site have a medium to high capacity to absorb contaminants and a high capacity to create an effective barrier to contaminants. Nitrates and phosphates will also be reduced to some extent. Where clay may be present it will have a high reduction capacity on nitrates and phosphates.

The soils on site have a tendency to restrict groundwater movement that will have a reduction in biological contamination spreading. Chemical contamination reduction may be a problem in zones with limited clay content in the soil.

9.3 Existing Threat to Groundwater Quality

The existing "package plant" on site is leaking water that is not treated to standard. Irrigation of treated waste water may not be done near residents and boreholes. It is recommended that no irrigation with treated water be done closer than 200 metres from residents and boreholes. Canal water must be used for irrigation near the boreholes and residents houses.

9.4 Position in Respect of Domestic Water Sources such as boreholes

The location of a possible contamination source such as a package plant, 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 contamination sources and the nearest domestic water resource be prescribed. These safe distances depend on the many factors due to the highly variable and uncertain nature of the factors that control the dispersion of pathogenic organisms from a contamination source. The criteria for determining the distance of a contamination 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 and viruses. 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 150 m to the calculated distances (This ensures a minimum safe distance of 150 m 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 proposed contamination source which is in this case a package plant development should preferably be placed on the northern side of the development where no boreholes are situated.

10. CONCLUSIONS

Sustainability of the Groundwater Regime

The sustainability assessment is based on the following information:

- The available water that can be abstracted from the three boreholes on the De Brough development calculates to 16.58m^3/d (normal groundwater recharge) plus 0.67m^3/d (induced recharge from treated waste water) = 17.25m^3/d
- The groundwater potential of the three boreholes submitted to borehole yield tests on the De Brough development can not be utilized at its full potential due to a limitation on the groundwater recharge area that is 13.8135ha.
- The groundwater contour map indicates to over exploitation of boreholes in the area at un-sustainable rates that led to the depletion of the regional aquifer.
- The chemical water quality from boreholes H/BH 23 and H/BH 5 located outside the development area footprint and borehole BH 1 located on the De Brough property can be categorized as Class 1, recommended water quality.
- The chemical water quality from borehole BH 4 located on the De Brough property can be categorized as Class 2, maximum allowed due to elevated magnesium and nitrate levels.
- The chemical water quality from boreholes BH 2 located on the De Brough property and H/BH 19 can be categorized as above Class 2, due to magnesium and nitrate levels which mean that this water must rather be treated prior to human consumption.
- The water from borehole BH 1 located on the De Brough property and borehole H/BH 5 must be chlorinated prior to human consumption due to elevated E. Coli counts.

On Site Groundwater Contamination Risk Assessment

The vulnerability of the Groundwater Aquifer due to the Hydrogeological conditions at the De Brough development site can be rated as medium to Low. The permeability tests show that the infiltration rates of the subsurface soils are slow. The distance from the surface to the aquifer is a minimum of 17 to 21 metres. Silt and silty sand is found on surface, which acts as filtering system with slow infiltration from surface.

A groundwater flow velocity of 30.6m/year was calculated which suggest that leakage or spillage of effluent or contaminants will have **minimal** impact on the surrounding groundwater resource, assuming no preferential pathways are encountered at or near surface.

11. RECOMENDATIONS

The following recommendations are made:

- The recommended abstraction rates of 17.25m^3/d must not be exceed.
- All the boreholes on site must be used for monitoring purposes.
- Water level depths must be measured in all the boreholes on the farm on a monthly basis.
- The boreholes that are used for abstraction purposes must be used as groundwater monitoring facilities for water quality purposes and abstraction volume monitoring.
- Water flow meters must be installed and monitored on a monthly basis for all the boreholes that are used as abstraction boreholes.
- The following parameters must be analysed for: TDS, Turbidity, Nitrate, Faecal Coliform count, Total Plate count, Coliform count, COD, and Phosphate must be analyzed for, on bi-annual intervals, at the four boreholes.
- Rainfall figures must be recorded on a daily basis.
- Water abstraction figures must be noted on a monthly basis for the abstraction boreholes to be used. A flow meter, installed at each abstraction borehole, can be used to facilitate with the abstraction volumes.
- Water level depth must be noted on a monthly basis in all boreholes on the development. A 12 hour rest period must be allowed for, prior to any water level depth measurements.
- A monitoring report must be generated by a qualified geohydrologist on an annual basis to report on water quality and groundwater level responses.
- The recommended abstraction yield should be adhered too to ensure a long term sustainable source.
- The proposed contamination source which is in this case a package plant and irrigation with treated water should preferably be placed away from the boreholes and residents.

REFERENCES

1. Department of Water Affairs and Forestry, **SOUTH AFRICAN WATER QUALITY GUIDELINES** - Volume 1 DOMESTIC USE, Second Edition 1996.
2. Department of Water Affairs and Forestry, "**A Drinking Water Quality Framework for South Africa**" December 2005
3. Johnson MR, Anhaeusser CR and Thomas RJ, **The Geology of South Africa**, 2006.
4. SABS, **Specification for water for domestic supplies**. 241 - 1999.

APPENDIX A

Summary of Methods used for Yield Recommendations and Diagnostic Plots of Boreholes, Test Pumping Results and Recovery Rates

Summary — 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	1.72	1.11	19		6.1		2.20E-03	40.0
☑	Advanced FC			19		6.1		1.00E-03	40.0
☑	FC inflection point	0.66	0.37						8.8
☑	Cooper-Jacob	2.86	1.85			14.1		7.21E-03	40.0
☑	FC Non-Linear	2.49	2.20			34.0		5.06E-03	40.0
☐	Barker	3.27	3.45	K_f =	2300		S_s =	1.60E-04	40.0
	Average Q_sust (l/s)	1.93	0.97	b =	0.20	Fractal dimension n =		1.74	

Recommended abstraction rate (L/s)		1.93	for 24 hours per day
Hours per day of pumping	12	2.73	L/s for 12 hours per day

Amount of water allowed to be abstracted per month	5002.56	m^3
Borehole could satisfy the basic human need of	6670	persons
Is the water suitable for domestic use (Yes/No)	Y	

Summary 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	1.93	1.01	51		32.7		8.25E-04	10.0
☑	Advanced FC			51		32.7		1.00E-03	10.0
☑	FC inflection point	1.37	0.54						8.8
☑	Cooper-Jacob	1.99	1.29			39.7		1.81E-02	10.0
☑	FC Non-Linear	2.49	2.20			34.0		5.06E-03	10.0
☐	Barker	1.46	0.57	K_f =	2300		S_s =	1.60E-04	10.0
	Average Q_sust (l/s)	1.95	0.46	b =	0.20	Fractal dimension n =		1.74	

Recommended abstraction rate (L/s)		1.93	for 24 hours per day
Hours per day of pumping	12	2.73	L/s for 12 hours per day

Amount of water allowed to be abstracted per month	5002.56	m^3
Borehole could satisfy the basic human need of	6670	persons
Is the water suitable for domestic use (Yes/No)	Y	

Summary — 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	1.21	0.63	44	29.3	8.25E-04	7.0
☑	Advanced FC			44	29.3	1.00E-03	7.0
☑	FC inflection point	0.94	0.25				8.8
☑	Cooper-Jacob	1.23	0.80		35.9	1.13E-02	7.0
☑	FC Non-Linear	2.49	2.20		34.0	5.06E-03	7.0
☐	Barker	0.97	0.40	K_f = 2300	S_s =	1.60E-04	7.0
	Average Q_sust (l/s)	1.47	0.69	b = 0.20	Fractal dimension n =	1.74	

Recommended abstraction rate (L/s)		1.47	for 24 hours per day
Hours per day of pumping	12	2.08	L/s for 12 hours per day

Amount of water allowed to be abstracted per month	3810.24	m^3
Borehole could satisfy the basic human need of	5080	persons
Is the water suitable for domestic use (Yes/No)	Y	

APPENDIX B

Water Quality Analyses

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ilac-MRA

sanas
T0374

Test Report

Client: Henk Kruidenier
Address: 25ste laan, 327, Villieria, Pretoria, 0186
Report no: 15059
Project: Geo-Logic

Date of certificate: 03 October 2013
Date accepted: 30 September 2013
Date completed: 02 October 2013
Revision: 0

Lab no:			145882	145883	145884	145885	145886
Date sampled:			29-Sep-13	29-Sep-13	29-Sep-13	29-Sep-13	29-Sep-13
Sample type:			Water	Water	Water	Water	Water
Locality description:			H/BH 23 - Plot 2	H/BH 19 - Plot 1	H/BH 5 - Plot 3	BH4 J145 - De Brough	BH 1 - De Brough
Analyses	**Unit**	**Method**					
A pH	pH	ALM 20	8.02	7.84	8.00	8.24	8.11
A Electrical conductivity (EC)	mS/m	ALM 20	56.4	88.7	28.1	70.0	56.2
A Total dissolved solids (TDS)	mg/l	ALM 26	291	481	141	347	288
A Total alkalinity	mg $CaCO_3$/l	ALM 01	236	398	140	276	262
A Chloride (Cl)	mg/l	ALM 02	21.7	43.0	1.08	42.4	17.1
A Sulphate (SO_4)	mg/l	ALM 03	36.1	51.3	12.3	24.1	18.9
A Nitrate (NO_3) as N	mg/l	ALM 06	6.20	11.2	1.58	10.6	7.17
A Nitrite (NO_2) as N	mg/l	ALM 07	0.108	0.115	0.103	0.099	0.100
A Ammonium (NH_4) as N	mg/l	ALM 05	0.120	0.150	0.097	0.093	0.091
A Orthophosphate (PO4) as P	mg/l	ALM 04	0.021	0.021	0.023	0.019	0.020
A Fluoride (F)	mg/l	ALM 08	0.136	0.167	0.174	0.108	0.169
A Calcium (Ca)	mg/l	ALM 30	18.7	28.7	8.99	15.4	18.9
A Magnesium (Mg)	mg/l	ALM 30	65.2	105	31.6	85.9	66.1
A Sodium (Na)	mg/l	ALM 30	0.593	1.51	0.522	0.539	0.526
A Potassium (K)	mg/l	ALM 30	0.462	1.77	0.192	2.62	1.54
A Aluminium (Al)	mg/l	ALM 31	<0.003	<0.003	<0.003	<0.003	<0.003
A Iron (Fe)	mg/l	ALM 31	<0.003	<0.003	<0.003	<0.003	<0.003
A Manganese (Mn)	mg/l	ALM 31	<0.001	<0.001	<0.001	<0.001	<0.001
A E.coli	CFU/100ml	ALM 40	<1	<1	4	<1	3
A Total coliform	CFU/100ml	ALM 40	<1	8	47	<1	48
A Total hardness	mg $CaCO_3$/l	ALM 26	315	503	152	392	319
A Chemical oxygen demand (COD)	mg/l	ALM 10	7.43	20.6	19.1	5.15	14.1

A = Accredited N= Not accredited O = Outsourced S = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine
Results marked 'Not SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory.
This test report shall not be reproduced except in full, without written approval of the laboratory.
Measurement of uncertainty available on request for all methods included in the SANAS Schedule of Accreditation.
Results reported against the limit of detection.

HHausen

Laboratory Manager: H. Holtzhausen

aquatico
Laboratories (Pty). Ltd.

T0374

Test Report

Client: Henk Kruidenier
Address: 25ste laan, 327, Villieria, Pretoria, 0186
Report no: 15239
Project: Geo-Logic

Date of certificate: 17 October 2013
Date accepted: 11 October 2013
Date completed: 16 October 2013
Revision: 0

Lab no: 147645
Date sampled: 11-Oct-13
Sample type: Water

Locality description: BH2 - De Brough

	Analyses	Unit	Method	
A	pH	pH	ALM 20	8.76
A	Electrical conductivity (EC)	mS/m	ALM 20	90.1
A	Total dissolved solids (TDS)	mg/l	ALM 26	430
A	Total alkalinity	mg $CaCO_3$/l	ALM 01	345
A	Chloride (Cl)	mg/l	ALM 02	49.8
A	Sulphate (SO_4)	mg/l	ALM 03	24.4
A	Nitrate (NO_3) as N	mg/l	ALM 06	13.5
A	Nitrite (NO_2) as N	mg/l	ALM 07	0.070
A	Ammonium (NH_4) as N	mg/l	ALM 05	<0.005
A	Ortophosphate (PO_4) as P	mg/l	ALM 04	0.017
A	Fluoride (F)	mg/l	ALM 08	0.143
A	Calcium (Ca)	mg/l	ALM 30	28.5
A	Magnesium (Mg)	mg/l	ALM 30	105
A	Sodium (Na)	mg/l	ALM 30	<0.013
A	Potassium (K)	mg/l	ALM 30	1.82
A	Aluminium (Al)	mg/l	ALM 31	<0.003
A	Iron (Fe)	mg/l	ALM 31	<0.003
A	Manganese (Mn)	mg/l	ALM 31	<0.001
A	E.coli	CFU/100ml	ALM 40	<1
A	Total coliform	CFU/100ml	ALM 40	16
A	Total hardness	mg $CaCO_3$/l	ALM 26	504
A	Chemical oxygen demand (COD)	mg/l	ALM 10	25.7

A = Accredited N= Not accredited O = Outsourced S = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine
Results marked 'Not SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory.

Measurement of uncertainty available on request for all methods included in the SANAS Schedule of Accreditation.
Results reported against the limit of detection.

HHausen
Laboratory Manager: H. Holtzhausen