



*Geohydrological impact assessment relating
to the proposed new Waste Water Treatment
Works; Postmasburg, Northern Cape.*

REPORT:

GEOSS Report No: 2014/12-11

PREPARED FOR:

Bernard de Witt
EnviroAfrica
P.O. Box 5367
Helderberg
7135
021 851-1616

bernard@enviroafrica.co.za

PREPARED BY:

Charles Peek, Dale Barrow and Julian Conrad
GEOSS - Geohydrological and Spatial
Solutions International (Pty) Ltd
Unit 19, Technostell Building,
9 Quantum Street,
TechnoPark
Stellenbosch 7600
Tel: (021) 880-1079
Email: jconrad@geoss.co.za
(www.geoss.co.za)



06 January 2015

EXECUTIVE SUMMARY

GEOSS - Geohydrological and Spatial Solutions International (Pty) Ltd were appointed to assess the geohydrological impacts of the proposed Waste Water Treatment Works in Postmasburg. Both the Waste Water Treatment Works and the associated discharge of the treated effluent were to be assessed. This project involved assessing groundwater characteristics, quality and flow directions of the area as well as an assessment of the potential groundwater impacts based on the planned quantity and quality of the final effluent to be discharged.

The geology of the area consists predominantly of dolomite which commonly forms solution cavities and karst aquifers. Based on data obtained it is evident that the aquifer is regarded as a “major” aquifer, with high yields and marginal to good quality groundwater. The aquifer is the sole source of water for farmers in the area. The aquifer also supports a number of springs in the area.

The quality of the treated effluent is reasonably good and is in fact comparable, if not better, than ambient groundwater with regard to certain parameters, including the frequently used water quality indicator, Electrical Conductivity. The orthophosphate concentration of the effluent is elevated with regard to groundwater, and at the anticipated discharge volumes, the quality of groundwater may be gradually impacted if the effluent is allowed to infiltrate rapidly and recharge the aquifer(s). Orthophosphate is a compound that is present in most fertilizers and is favourable for plant nourishment. It is therefore anticipated that the concentration can be lowered by means of plant uptake. If irrigation of the effluent on the agricultural lands was implemented (as opposed to disposal in the river) then it would be considerably less of a potential contamination problem. Negotiations should be undertaken with local farmers regarding making use of the effluent for irrigation purposes. This should be further investigated as it would enable the crops to take up the majority of these ions and potential contaminants.

Chlorine is a chemical parameter that is used in the water treatment process and can have a negative effect on crop quality and yield. The concentrations at which free chlorine can be applied to crops (mostly lucerne in this case) is less than 0.25 mg/L. The January 2012 analysis did not detect any free chlorine in the water, and chloride concentrations were comparable to groundwater.

If the treated effluent can be used as irrigation water this will result in a decrease in groundwater abstraction within the area and possibly even enable the development of additional agricultural lands. This option is more favourable than just letting the treated effluent flow out and infiltrate into the groundwater. The possibility of irrigating with the treated effluent was also raised by landowners consulted during the hydrocensus.

It is essential that monitoring of the groundwater quality takes place at and down-gradient of the point of effluent disposal, be it via irrigation or discharge as proposed. The monitoring will serve as an early warning system for groundwater users down-gradient of the site. Existing boreholes can be incorporated into the monitoring network.

TABLE OF CONTENTS

1. INTRODUCTION	1
2. TERMS OF REFERENCE	1
3. METHODOLOGY	1
4. DESCRIPTION OF THE STUDY AREA.....	2
4.1 Topography.....	2
4.2 Climate.....	2
4.3 Geology	4
4.4 Geohydrology.....	4
4.4.1 <i>Aquifers</i>	4
4.4.2 <i>Groundwater Quality</i>	5
4.4.3 <i>Groundwater Abstraction</i>	6
4.4.4 <i>Groundwater Vulnerability</i>	6
4.4.5 <i>Aquifer Classification</i>	6
4.5 Hydrology.....	7
4.6 Hydrocensus	7
5. RESULTS	8
5.1 Groundwater Levels	8
5.2 Groundwater Quality.....	8
5.3 Groundwater Use.....	12
5.4 Treated Effluent Quality.....	12
5.5 Groundwater Dependent Ecosystems.....	15
6. ASSESSMENT OF IMPACTS.....	15
6.1 Contamination source and toxicity assessment	16
6.2 Pathways.....	16
6.3 Receptors.....	16
6.4 Anticipated Impacts.....	17
6.4.1 <i>Surface runoff</i>	17
6.4.2 <i>Aquifer characteristics</i>	17
6.4.3 <i>Groundwater Levels</i>	17
6.4.4 <i>Groundwater Quality</i>	18
6.4.5 <i>Ecosystems</i>	18
7. DISCUSSION.....	18
8. RECOMMENDATIONS	19
9. CONCLUSION.....	19
10. ACKNOWLEDGEMENTS	20
11. REFERENCES	20
12. APPENDIX A: MAPS	22
13. APPENDIX B: HYDROCENSUS FIELD DATA.....	31
14. APPENDIX C: DWAF GUIDELINES FOR DOMESTIC USE.....	35

15. APPENDIX C: LABORATORY ANALYSIS RESULTS	37
16. APPENDIX D: FIELD PHOTOGRAPHS	40

LIST OF FIGURES

Figure 1. Average Rainfall Graph for Postmasburg from World Weather Online (2012)....	3
Figure 2. Average Temperature Graph for Postmasburg from World Weather Online (2012).....	3
Figure 3. Piper diagram of groundwater samples collected in and south west of Postmasburg.....	9
Figure 4. Explanation of Piper groundwater classes.....	9
Figure 5. Stiff diagrams for groundwater samples collected in and south west of Postmasburg.....	10

LIST OF TABLES

Table 1. Borehole Yield Test Results (SRK 2009a and SRK 2009b).	5
Table 2. Groundwater chemistry results colour coded according to the DWAF (1998) guidelines for domestic use (DWA, 1998).....	11
Table 3. Class description from DWA water guidelines for domestic use (DWAF, 1998). ..	11
Table 4. Groundwater quality in comparison to final effluent quality.	13
Table 5. Table showing sites and people visited and associated comments.....	32
Table 6. Borehole position and water level data.....	33
Table 7. Borehole field chemistry, yield and comment.	34

LIST OF MAPS

Map 1. Location of the study area within a regional setting	23
Map 2: The study site and surrounding area (1:50 000, topocadastral map 2823)	24
Map 3: Aerial photo of the study area and relevant points.....	25
Map 4: Geological setting of the study area (2822 Postmasburg, Council for Geoscience).....	26
Map 5. Ground water level elevation contour map (DWA Hydrogeological Series) with inferred groundwater flow directions from manual measurements.....	27
Map 6: Groundwater quality map as a function of EC showing DWAF (2005) data and manual measurements.....	28
Map 7: Regional aquifer yield from the 1:500 000 scale groundwater map (DWAF, 2000). ..	29
Map 8: Regional groundwater vulnerability (calculated according to the DRASTIC methodology) and boreholes (DWAF, 2005).....	30

ABBREVIATIONS

CDT	constant discharge test
ch	collar height
COD	chemical oxygen demand
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	electrical conductivity
GDE	groundwater dependent ecosystems
L/s	litres per second

m	metres
m ² /d	square metres per day
mamsl	metres above mean sea level
MAP	mean annual precipitation
mbch	metres below collar height
mbgl	metres below ground level
mg/L	milligrams per litre
mm/a	millimetres per annum
mS/m	milliSiemens per meter
NGA	National groundwater Archive
NGA	national groundwater archive
ORP	oxygen reduction potential
pH	negative log of hydrogen ion activity
T	transmissivity
TDS	total dissolved solids
WARMS	water authorisation and registration management system
WGS84	Since the 1st January 1999, the official co-ordinate system for South Africa is based on the World Geodetic System 1984 ellipsoid, commonly known as WGS84, with the ITRF91 (epoch 1994.0) co-ordinates of the Hartebeesthoek Radio Astronomy Telescope used as the origin of this system. This new system is known as the Hartebeesthoek94 Datum.
WUA	Water Users Association
WWTW	Waste Water Treatment Works.

GLOSSARY OF TERMS

- Aquifer:** a geological formation, which has structures or textures that hold water or permit appreciable water movement through them [from National Water Act (Act No. 36 of 1998)].
- Borehole:** includes a well, excavation, or any other artificially constructed or improved groundwater cavity which can be used for the purpose of intercepting, collecting or storing water from an aquifer; observing or collecting data and information on water in an aquifer; or recharging an aquifer [from National Water Act (Act No. 36 of 1998)].
- Groundwater Dependant Ecosystem:** Ecosystems dependant on ground water: their structure and function would be fundamentally altered if that ground water were no longer available or was impacted with regards to quality.
- Groundwater:** water found in the subsurface in the saturated zone below the water table or piezometric surface i.e. the water table marks the upper surface of groundwater systems.
- Hydraulic conductivity:** measure of the ease with which water will pass through earth material; defined as the rate of flow through a cross-section of one square metre under a unit hydraulic gradient at right angles to the direction of flow (in m/d)
- Hydraulic gradient:** the slope of the water table or piezometric surface; is a ratio of the change of hydraulic head divided by the distances between the two points of measurement.
- Transmissivity:** the rate at which a volume of water is transmitted through a unit width of aquifer under a unit hydraulic head (m²/d); product of the thickness and average hydraulic conductivity of an aquifer.
- Unconfined aquifer:** also known as water table or phreatic aquifers, because their upper boundary is the water table or phreatic surface. Typically the shallowest aquifer at a given location is unconfined, meaning it does not have a confining layer between it and the surface. Unconfined aquifers usually receive recharge water directly from

the surface, from precipitation or from a body of surface water (e.g., a river, stream, or lake) which is in hydraulic connection with it.

Water Table: the upper surface of the saturated zone of an unconfined aquifer at which pore pressure is at atmospheric pressure, the depth to which may fluctuate seasonally.

Suggested reference for this report:

GEOSS (2014). Geohydrological impact assessment relating to the proposed new Waste Water Treatment Works; Postmasburg, Northern Cape. GEOSS Report Number: 2014/12-11. GEOSS - Geohydrological & Spatial Solutions International (Pty) Ltd. Stellenbosch, South Africa.

Cover photo:

Existing Waste Water Treatment Works - Postmasburg

GEOSS project number:

2013_11-1170

1. INTRODUCTION

EnviroAfrica appointed GEOSS – Geohydrological and Spatial Solutions International (Pty) Ltd to assess the hydrogeological impacts of the proposed new Waste Water Treatment Works (WWTW) at Postmasburg.

The study included a site visit on 5th and 6th November 2014 to assess groundwater characteristics, including groundwater quality and flow directions. In addition the quantity and quality of the final effluent to be discharged was also assessed. The study involved considering the quality of the final effluent and an evaluation of potential contamination sources, pathways and receptors. The study area, within a regional context, is shown in **Map 1 (Appendix A)**. **Map 2 (Appendix A)** shows a more detailed layout of the study area.

2. TERMS OF REFERENCE

The prime objective of this project was to complete a geohydrological impact assessment evaluating the impacts the proposed Postmasburg WWTW may have. A groundwater risk characterization was completed to determine problem identification, receptor characterization, an exposure assessment and a toxicity assessment.

The study involved the following key tasks:

Task 1: Data Collation. Obtain all relevant data to the project (i.e. obtain data from the National Groundwater Archive, Water Quality Management System and Water Information Management System), geological maps and geohydrological maps. This includes reviewing previous relevant reports and studies pertaining to the Postmasburg Waste Water Treatment Works.

Task 2: Hydrocensus and Site Visit. Complete a site visit and complete a hydrocensus (i.e. visit all boreholes in the study area and measure yields and water quality (pH, EC, TDS and ORP) where possible). This will include an evaluation of the water quality of the disposed effluent and an evaluation of contamination sources, pathways and receptors.

Task 3: Data Analysis. Analyze the data using geohydrological methods and evaluate the groundwater risks in relation to the proposed developments.

Task 4: Reporting. The results will then be documented in a report.

All the results and findings from the study are presented within this report.

3. METHODOLOGY

The procedure adopted for this study involved a desktop study followed by the necessary field work. The initial desktop study involved obtaining and reviewing all relevant data to the project. This included data from the NGA, Water Quality Management System, Water Information Management System, and WARMS. Geological maps and hydrogeological maps were also assessed.

On 5th and 6th November 2014 a field trip was completed to conduct the site visit and hydrocensus. The hydrocensus involved measuring groundwater levels, borehole yields, groundwater quality in the field (pH, EC, TDS and ORP) and collecting samples where possible. A 1 km search radius was considered adequate for assessing the possible groundwater impacts of discharging the treated effluent. Numerous farmers were visited and contacted and any relevant information obtained so as to enable a better understanding and conceptualisation of the groundwater in the area. Previous groundwater reports on the area were also obtained for review.

All the data and information obtained was analysed using hydrogeological methods and this baseline study report presents the findings and results.

4. DESCRIPTION OF THE STUDY AREA

Postmasburg is located in the Northern Cape some 180 km east of Upington and 170 km north-west of Kimberley. The locality map is presented in **Map 1 (Appendix A)**. The existing Postmasburg WWTW are located to the south-east of the town, and the proposed new location for the WWTW and discharge point for the treated effluent is presented in **Map 2, (Appendix A)**. It is proposed that a new WWTW be built downstream of Postmasburg which would enable gravity flow from an existing sewer main pump station to the plant in lieu of expanding the existing works located on high ground. The final treated effluent will flow, via gravity feed, to the discharge point after which it will enter the Groenwater Spruit that flows in a south-westerly direction away from Postmasburg. The Groenwater Spruit only flows episodically (once every few years) after significant rainfall events. The Groenwater Spruit is used for agricultural practices and particularly for the cultivation of lucerne.

4.1 Topography

The relief of the area is presented in **Map 2 (Appendix A)** and is largely flat and covered with wind-blown sand and calcrete. The topography increases gradually eastward from the town of Postmasburg to approximately 1 300 mamsl. North of the town are the north-south striking Klipfontein Hills. The drainage is therefore from the east and northeast in a southerly direction towards the Groenwater Spruit.

The proposed new WWTW are located south-west of the town of Postmasburg. The topography slopes down from Postmasburg towards the proposed WWTW and the Groenwater Spruit. (**Map 3, Appendix A**).

4.2 Climate

Postmasburg receives predominantly summer rainfall with 80% of mean annual precipitation (MAP) being received from November to April. The MAP for Postmasburg is ~ 330 mm/a (SRK, 2009a). The rainfall commonly takes place in the form of thunder

showers in summer and the precipitation is often rapid causing an increase in storm water run-off. The monthly rainfall distribution is presented in **Figure 1**.

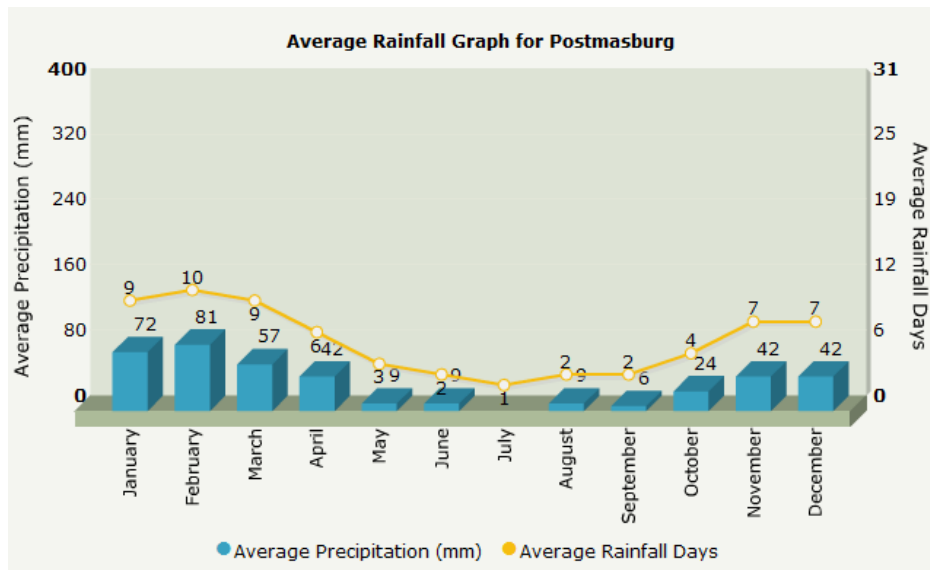


Figure 1. Average Rainfall Graph for Postmasburg from World Weather Online (2012).

During high rainfall periods (as experienced in early 2011) the storm water run-off flows into the maturation/evaporation ponds at the water treatment works. This rapid and high influx of water causes the treated effluent to overflow from the maturation ponds. This uncontrolled discharge flows northwest through residential areas, the Postmasburg CBD and finally into the Groenwater Spruit.

Postmasburg has a semi-desert climate with hot summers and cold winters. The summer day time temperature is around 30 °C, while in winter the temperature can drop to below freezing and frost is common. The average monthly maximum and minimum temperatures are presented in **Figure 2**.

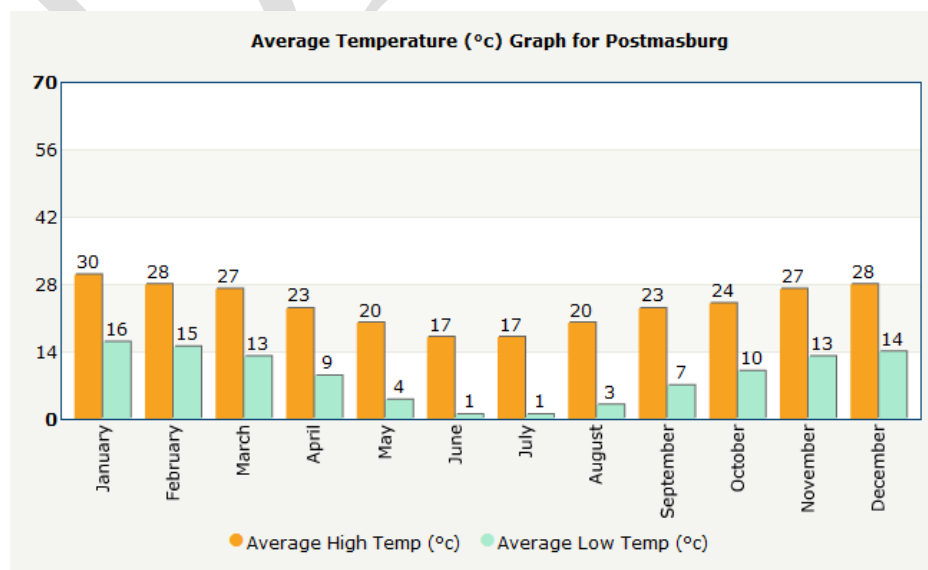


Figure 2. Average Temperature Graph for Postmasburg from World Weather Online (2012).

4.3 Geology

A geology map of the Postmasburg WWTW and environs is presented in **Map 4 (Appendix A)**. The Lime Acres member of the Ghaap Plateau Formation outcrops and extensively underlies the study area. The lithology consists of dolomites, limestone and chert. Postmasburg is located on the axis of the Marimane Anticline, and the Ghaap Plateau Formation outcrops along this fold axis.

The Lime Acres Member is overlain by the Kuruman Member of the Asbestos Hills Formation. Outcrops of the Gamagara Formation occur west of Postmasburg and these consist of shale, flagstone, quartzite and conglomerate.

Large parts of the study area are covered by relatively recent deposits of surface limestone, calcrete and windblown sand. The windblown sand occurs particularly to the east, west and south of the town along the flanks of the Asbestos Hills Formation.

Intrusions in the area consist of dolerite and diabase dykes which are commonly associated with fault zones. Kimberlite pipes also occur which are mined for diamonds in some instances.

4.4 Geohydrology

4.4.1 Aquifers

Secondary aquifers are prevalent in the area (**Map 5, Appendix A**). Fractured (secondary) aquifers are associated with the joints and fractures caused by intrusions (dolerite, diabase and kimberlite), cooling of igneous and volcanic bodies and faulting. The presence of limestones and dolomite means that karst aquifers also prevail. Solution cavities form within these carbonaceous rocks, particularly along fracture zones and geological contacts. These aquifers form a significant source of water for municipal, domestic and agricultural supply. Additionally groundwater is also found in the upper weathered zone which generally extends to a depth of 25 m below ground level (SRK, 2009a).

Several municipal supply boreholes at Postmasburg were yield tested by SRK and the results are presented in SRK (2009a & 2009b). A summary of the testing from some of the relevant boreholes is presented in **Table 1**. It is evident from the constant discharge test (CDT) durations, high abstraction rates and low drawdown of the groundwater levels that the boreholes are high yielding. The fractal dimensions determined from the yield test data analysis indicated radial flow, which suggests the presence of karst structures and solution cavities as would be expected in this geological setting with the prevalence of dolomite.

Table 1. Borehole Yield Test Results (SRK 2009a and SRK 2009b).

Borehole	CDT Duration (hours)	CDT Yield (L/s)	Drawdown (m)	Recommended Yield (L/s)	Average Transmissivity (T) (m²/d)
Hospital	72	15.2	8.84	4.0	50
Fish & chips	72	20.1	1.07	15.0	1 500
Houtstraat	48	16.2	7.25	4.9	150
Honeyball	72	15.1	13.31	3.5	75
Dam	72	12.2	4.31	7.0	300
OF2	72	10.2	4.19	5.3	150
OF3	72	5.5	0.97	3.2	65
OF4	72	20.0	3.85	2.0	300
OF6	68	7.5	0.93	2.9	100
OF8	72	18.2	11.89	14.4	500
SF2	72	8.1	11.77	6.7	80

While groundwater flow is rapid and the aquifer is highly transmissive, recovery at a number of the boreholes was slow. Additionally, the effects of the yield testing were identified in monitoring boreholes located relatively far afield (1.5 km in the case of the Hospital borehole). This indicates the extensive nature and interconnectivity of these karst structures. The slow recovery also indicates that groundwater recharge is a limiting factor, and that while the aquifer has a high hydraulic conductivity it needs to be carefully managed. The groundwater gradient in the area is generally towards the west and south-west, as presented in **Map 5 (Appendix A)**.

4.4.2 Groundwater Quality

Groundwater quality in the area is good and SRK (2009a) reports that all field EC measurements were less than 150 mS/m, making it Class 1 water, suitable for long term human consumption. It was also stated that higher EC values can generally be linked to groundwater pollution from potential sources such as the WWTW, homesteads, kraals, overflowing dams and stock water points and pans (SRK, 2009a). **Map 6 (Appendix A)** presents the EC for the area taken from Department of Water Affairs and Forestry (DWAF; now Department Water and Sanitation (DWS)) Hydrogeological Map Series (DWAF, 2000). This indicates that the regional EC is between 70 and 300 mS/m which is in agreement with previous literature. Chemistry data for municipal supply boreholes and farmer's boreholes was obtained from previous literature, namely Clean Stream Scientific Services (2010) and SRK (2009a). The pH of the groundwater is alkaline (between 7.5 and 8.5) and the EC ranges from a very low 37.5 mS/m at the Soetfontein Spring to 204 mS/m at the Makoudam borehole. All the other boreholes EC values are between 108 mS/m and 153 mS/m.

4.4.3 Groundwater Abstraction

Aquifer type and yields from the DWS Hydrogeological Map Series are presented in **Map 7 (Appendix A)** and indicate that yields in the study area range between 0.5 and 2 L/s and the groundwater is abstracted from a Karst aquifer. From more detailed investigations and pumping tests presented in previous literature it is evident that yields are greater than 2 L/s. Sustainable yields vary between 2 and 15 L/s (pumping 24 hours per day i.e. non-stop) for yield tested boreholes in the study area (see **Table 1**).

4.4.4 Groundwater Vulnerability

The vulnerability rating of the aquifer is presented in **Map 8 (Appendix A)**, and is determined according to the DRASTIC method[§] of Aller et al. (1987). The groundwater in the area has high to very high vulnerability to surface based contamination (DWAF, 2005). This is to be expected as a result of high hydraulic conductivity and the extensive nature of the karst aquifers.

4.4.5 Aquifer Classification

The land proposed for the construction of the new WWTW is located on what is classified as a Major Aquifer (Parsons and Conrad, 1998). The Karst aquifers are highly permeable, are able to support high yielding boreholes and have a good water quality with regard to EC (generally less than 150 mS/m). The aquifer is also believed to be extensive in nature

§

The DRASTIC approach is based on four major assumptions:

- *The contaminant is introduced at ground surface*
- *The contaminant is flushed into the groundwater by precipitation*
- *The contaminant has the mobility of water*
- *The area evaluated using DRASTIC is 40.5 ha or larger*

The DRASTIC method takes into account the following factors:

D	=	depth to groundwater	(5)
R	=	recharge	(4)
A	=	aquifer media	(3)
S	=	soil type	(2)
T	=	topography	(1)
I	=	impact of the vadose zone	(5)
C	=	conductivity (hydraulic)	(3)

The number indicated in parenthesis at the end of each factor description is the weighting or relative importance at that factor. In spite of the widespread use of DRASTIC, the effectiveness of the method has met with mixed success due to hydrogeological heterogeneity and the many assumptions that need to be made in determining groundwater vulnerability. In addition the use of a generic vulnerability map only gives a broad indication of relative vulnerability and in many instances detailed scale, contaminant specific vulnerability assessments are required.

as evidenced from the pumping test results. Farmers in the area are entirely dependent on groundwater for their domestic use and for agricultural purposes.

4.5 Hydrology

The town of Postmasburg is located in and around the Groenwater Spruit (**Map 2, Appendix A**) which flows in a south and south-westerly direction. The topography of the area slopes gradually towards the Groenwater Spruit which is an episodic river fed by numerous small tributaries. Flow only takes place after heavy rainfall events and the flow is of short duration. These events only occur every couple of years and for this reason the fertile soils of the Groenwater Spruit river bed are used for the cultivation of lucerne and for other agricultural purposes.

4.6 Hydrocensus

The hydrocensus was carried out on 5th and 6th November 2014 within an area of 1 km surrounding the proposed WWTW site (**Map 3, Appendix A**). During the hydrocensus municipal and farm boreholes were visited and relevant personnel consulted regarding water supply and the use of groundwater.

Wherever possible a groundwater level was measured and a groundwater sample analysed for field chemistry parameters. The coordinates of borehole positions were measured at the various sites and any historical groundwater information was obtained from the farmers and municipal employees. The main target area of the hydrocensus was surrounding and down-gradient (i.e. south-west) of the proposed treated effluent discharge point.

The Hydrocensus data obtained are all presented in **Appendix B**. All the sites visited and related comments are presented in **Table 5**. The contact details of the various landowners consulted are presented in **Table 5**. All boreholes visited and their groundwater levels are presented in **Table 6**. All field chemistry data is presented in **Table 7**.

Map 3 (Appendix A) shows the borehole distribution and how significant groundwater abstraction occurs along the course of the Groenwater Spruit, both in town and to the south-west on the farm lands. Measured borehole yields were also high (**Map 7, Appendix A**) in agreement with previous literature (presented in **Table 1**).

Collected EC data during the hydrocensus is plotted in **Map 6 (Appendix A)**. All the obtained values were within the expected range from the hydrogeological Map Series (DWAF, 2000) and from previous reports on the area.

Groundwater level measurements were taken wherever possible and these are plotted as an elevation (mamsl) in **Map 5 (Appendix A)**. The groundwater elevation contours are taken from the Hydrogeological Map Series (DWA, 2000) and show groundwater flow to be in a westerly direction. Measured groundwater levels indicate that the hydraulic gradient slopes

towards the south-east along the course of the Groenwater Spruit. It is thought that the groundwater flow follows the surface topography somewhat, flowing towards the Groenwater Spruit and then in a south-westerly direction.

5. RESULTS

Based on the desktop study and hydrocensus the nature of the groundwater in the region is discussed in this chapter. In addition, consideration is given to the nature of the effluent intended for discharge into the Groenwater Spruit from the proposed WWTW.

5.1 Groundwater Levels

The depth to groundwater ranges from 4.21 to 16.1 m below ground level (mbgl) for the 15 sites visited during the hydrocensus. Springs are common in the area as indicated by the farm names (e.g. Olynfontein, Kalkfontein, Soetfontein, Ploegfontein etc.). Springs were visited at the following sites: Soetfontein, Olynfontein and Kalkfontein. All three springs are utilized for irrigation or domestic purposes. The shallow nature of the groundwater increases its vulnerability to surface contamination as well as the occurrence of groundwater dependant ecosystems. The groundwater flow direction is inferred in **Map 5 (Appendix A)**.

5.2 Groundwater Quality

EC measurements from the hydrocensus ranged between 103 and 153 mS/m for the six sites analysed, excluding the EC of 219 mS/m measured at OF2. The reason for this anomalously high EC is that the borehole is located in the Groenwater Spruit and when the river flowed in 2011 and floodwaters flowed into the borehole. The borehole could not be purged prior to sampling.

Five groundwater samples (from boreholes KS_1, KS_2, OF2_BH, KKF_Spring and SF-Spring) were taken and submitted for laboratory analysis, the results of which are presented in the Piper diagram in **Figure 3** (alongside those of various municipal and farm boreholes captured from obtained literature). The final treated effluent quality is plotted as well.

The groundwater in the area has a dominant magnesium cation and has a high alkalinity relative to the sulphate and chloride anions. This is to be expected for the geological setting. The water is classified as being Type B and Type A (as presented in **Figure 4**). Most of the borehole samples are classified as Type B, which is the general groundwater type of the area with the dominating cations being calcium and magnesium and the dominant anion being bicarbonate (alkalinity). This is to be expected for karst aquifers associated with dolomites (general chemical composition $\text{CaMg}(\text{CO}_3)_2$).

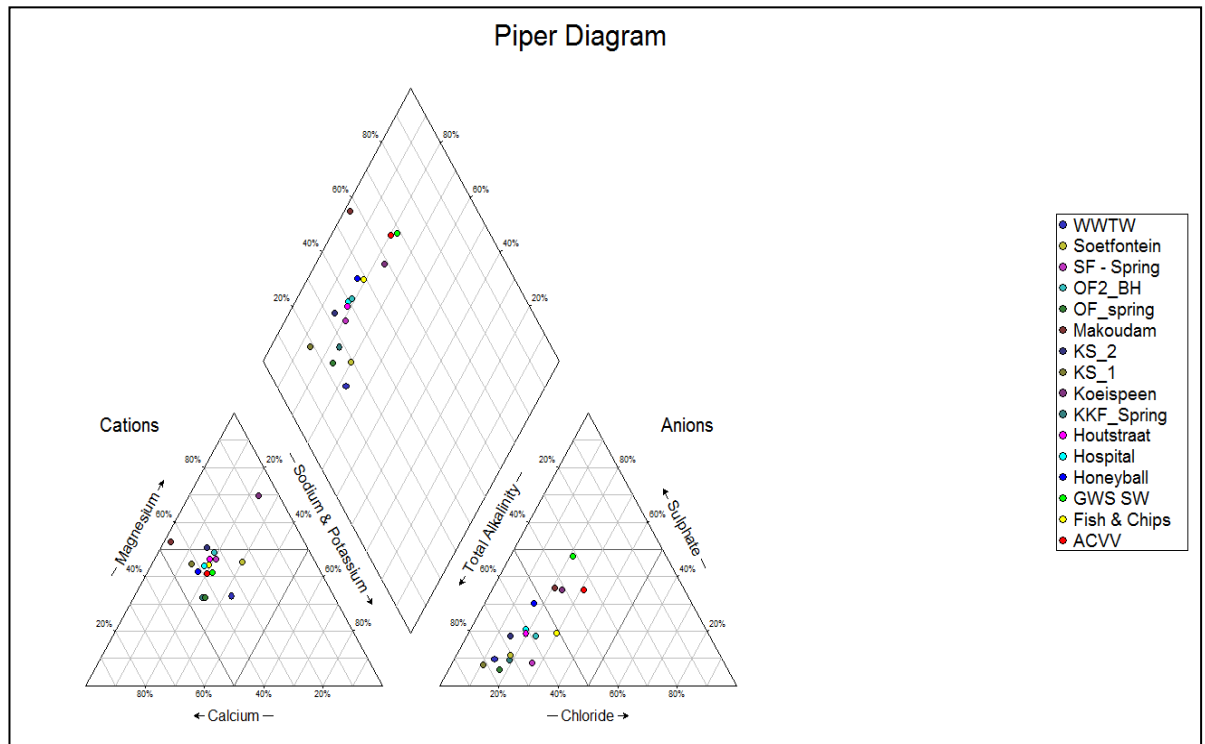


Figure 3. Piper diagram of groundwater samples collected in and south west of Postmasburg.

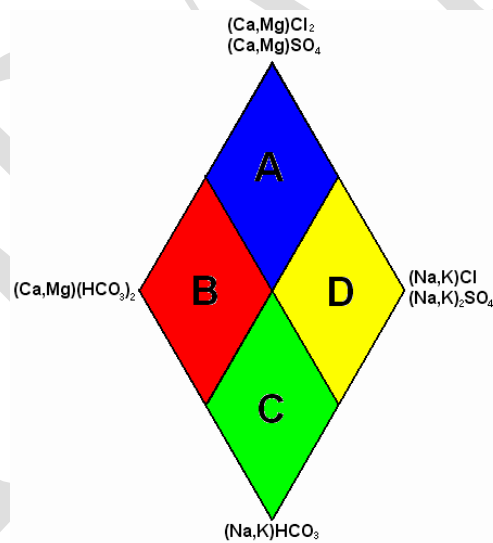


Figure 4. Explanation of Piper groundwater classes.

Stiff diagrams for the boreholes are presented in **Figure 5**. The typical signature indicates the dominant alkalinity and magnesium cation, with the calcium cation varying somewhat for the various boreholes. The high Ca and Mg concentrations mean the hardness of the water ranges from Hard to very Hard (> 600 mg/l). The water chemistry is plotted in **Table 2** and colour coded according to the DWAF (1998) guidelines.

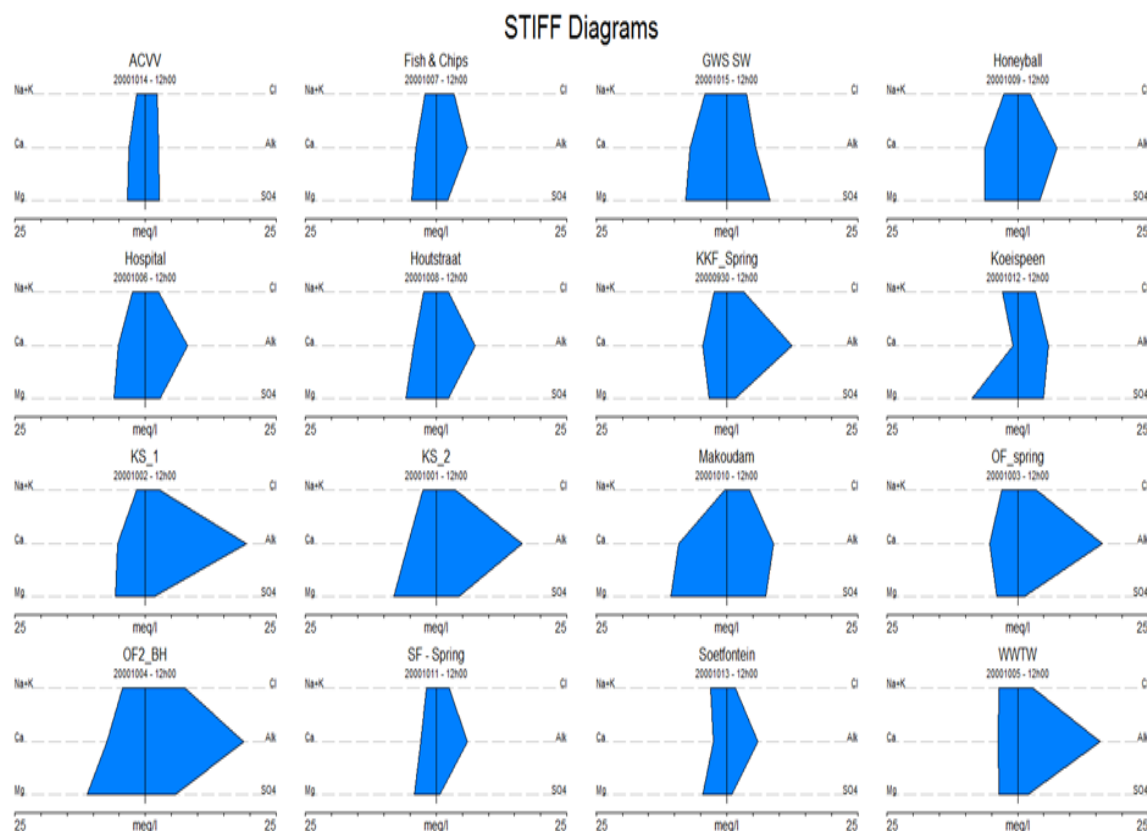


Figure 5. Stiff diagrams for groundwater samples collected in and south-west of Postmasburg.

Table 2. Groundwater chemistry results colour coded according to the DWAF (1998) guidelines for domestic use (DWA, 1998).

SiteName	Date Measured	pH	EC (mS/m)	TDS (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	SO ₄ (mg/L)	N NO ₃ (mg/L)	F (mg/L)	Mn (mg/L)	Hardness (as CaCO ₃) (mg/L)
KKF_Spring	2014/11/05	7.4	104	626	93.69	41.23	56.07	1.49	115.98	78.74	1.554	0.20	-	403.73
KS_2	2014/11/05	7.7	153	914	107.16	98.03	56.39	2.42	129.32	211.84	7.766	0.30	-	671.27
KS_1	2014/11/05	7.6	119	711	107.94	69.34	39.4	1.08	94.12	84.34	5.331	0.10	-	555.07
OF_Spring	2014/11/05	7.4	120	720	107.61	48.62	67.83	1.49	129.32	59.24	4.604	0.30	-	468.92
OF2_BH	2014/11/05	7.2	219	1313	148.65	36.22	97.66	3.83	267.17	277.04	5.854	0.30	-	932.13
	2014/11/05	7.9	108	649	74.52	43.11	78.88	5.41	100.79	95.34	0.947	0.40	-	787.638
Hospital	2009/04/01	7.20	126.00		104.00	73.00	40.00	29.00	90.00	133.00	2.70	0.10	-	559.30
Fish & Chips	2009/04/01	7.50	115		79	58	43	8.7	123	108	0.50	0.10	-	435.30
Houtstraat	2009/04/01	7.4	116.00		87.00	70.00	48	10.3	85	112	3.90	0.10	-	504.50
Honeyball	2009/04/01	7.2	136.00		125.00	77.00	54.00	9.40	84.00	206.00	12.20	0.20	-	628.20
Makoudam	2009/04/01	7.20	204.0		184.0	131.0	4.4	11.50	155.0	355.0	15.6	0.2	-	997.10
SF - Spring	2009/12/10	8.58	37.5	427.0	60.0	51.0	41.0	4.00	88.0	36.0	1.7	0.2	-	359.10
Koeispeen	2009/02/01	8.36	127.0	832.0	17.0	106.0	63.0	8.00	120.0	240.0	1.8		-	477.10
Soetfontein	2010/03/01	7.89	110.0	476.0	51.0	57.0	72.0	1.00	56.0	45.0	14.4	0.4	0.011	361.20
ACVV	2011/12/05	7.72	94.1	432.0	64.4	41.4	35.9	5.07	81.9	124.3	4.5	0.2	0.001	330.74
GWS SW	2011/12/05	8.15	193.9	1032.0	140.5	96.3	92.6	9.2	132.8	396.3	0.1	0.2	0.257	746.18

Table 3. Class description from DWA water guidelines for domestic use (DWAF, 1998).

Blue	(Class 0)	Ideal water quality - suitable for lifetime use.
Green	(Class I)	Good water quality - suitable for use, rare instances of negative effects.
Yellow	(Class II)	Marginal water quality - conditionally acceptable. Negative effects may occur.
Red	(Class III)	Poor water quality - unsuitable for use without treatment. Chronic effects may occur.
Purple	(Class IV)	Dangerous water quality - totally unsuitable for use. Acute effects may occur.

The groundwater chemistry commonly exceeds the domestic use guidelines with regard to hardness, and is sometimes marginal with regards to major cations (Mg and Ca), salinity (EC, TDS) and Nitrates (Clean Stream Scientific Services, 2010). These high concentrations are mostly due to natural conditions relating to geology and the climate. High nitrate levels were detected in certain boreholes in 2009 (> 10 mg/ℓ) and may suggest contamination which can become a problem for both human and stock ingestion. Boreholes and springs sampled in 2014 have nitrate levels that can be classified as Class 0.

The hardness of the water means that it has a marginal water quality, and is classified as poor in some cases. With regard to the other parameters the groundwater quality ranges from marginal to good. Hard water affects its taste, impairs the lathering of soap and causes scaling problems in pipes and hot water appliances. Infants under the age of 1 are sensitive to water where magnesium is the main contributor to hardness (DWAF, 1998) as is the case here.

5.3 Groundwater Use

The hydrocensus revealed that groundwater use is significant in and around Postmasburg. The town itself is supplied by numerous boreholes. The yields of the boreholes are high (**Table 1**) and groundwater is used for both domestic and agricultural purposes. **Map 7 (Appendix A)** shows actual yield measurements obtained at a few of the boreholes, these indicate the high yielding nature of the aquifer. The farmers stated that during dry periods the groundwater level does drop significantly, with certain boreholes and springs becoming unusable. They do however recover rapidly after rainfall events.

Farmers make use of groundwater for their stock watering, irrigation and domestic purposes. Immediately surrounding and down-gradient of the proposed WWTW are numerous boreholes utilised by farmers. Boreholes are the sole source of drinking water for the farms south-west of Postmasburg along the Groenwater Spruit.

5.4 Treated Effluent Quality

The final treated effluent to be discharged into the Groenwater Spruit is of a relatively good quality. The most recent final effluent analysis results are presented in **Table 4** along with the general limit and groundwater values. The final effluent has 0 Faecal coliforms (/100mℓ) and is comparable and even better than the groundwater with regard to certain parameters (namely EC, Nitrate, Nitrite, and COD).

The treated effluent sampled on 6th November 2014 is however elevated with regard to the parameters sodium and orthophosphate. The elevated sodium concentration is not considered a problem and is still classified as a “good” according to the DWAF domestic use guidelines (DWAF, 1998). Orthophosphate is present at concentrations far greater than that of groundwater but is still within the general limit for irrigation (10 mg/ℓ).

Table 4. Groundwater quality in comparison to final effluent quality.

Flag	SiteName	DateTimeMeas	pH	EC mS/m	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Alk mg/l	Cl mg/l	SO4 mg/l	N NO3mg/l	N_Ammonia mg/l	Flouride mg/l
	General Limit		5.5 - 9.5	150.0								15.0	6	1.00
	Final Effluent		7.62	125.0	94.6	70.4	109.0	11.8	268.0	128.0	104.0	6.5	0.48	0.99
	KKF_Spring	2014/11/05	7.4	104	626	93.69	41.23	56.07	1.49	115.98	78.74	1.554	0.247	0.20
	KS_2	2014/11/05	7.7	153	914	107.16	98.03	56.39	2.42	129.32	211.84	7.766	0.248	0.30
	KS_1	2014/11/05	7.6	119	711	107.94	69.34	39.4	1.08	94.12	84.34	5.331	0.243	0.10
	OF_Spring	2014/11/05	7.4	120	720	107.61	48.62	67.83	1.49	129.32	59.24	4.604	0.281	0.30
	OF2_BH	2014/11/05	7.2	219	1313	148.65	36.22	97.66	3.83	267.17	277.04	5.854	0.254	0.30
	WWTW_final effluent	2014/11/05	7.9	108	74.52	43.11	78.88	5.41	787.638	100.79	95.34	0.847	0.43	0.40
	Hospital	2009/04/01	7.20	126.00	104.00	73.00	40.00	29.00	404.00	90.00	133.00	2.70		0.10
	Fish & Chips	2009/04/01	7.50	115	79	58	43	8.7	297	123	108	0.50		0.10
	Houtstraat	2009/04/01	7.4	116.00	87.00	70.00	48	10.3	377	85	112	3.90		0.10
	Honeyball	2009/04/01	7.2	136.00	125.00	77.00	54.00	9.40	377.00	84.00	206.00	12.20		0.20
	Makoudam	2009/04/01	7.20	204.0	184.0	131.0	4.4	11.50	446.0	155.0	355.0	15.6		0.20
	SF - Spring	2009/12/10	8.58	37.5	60.0	51.0	41.0	4.00	296.0	88.0	36.0	1.7		0.18
	Koeispeen	2009/02/01	8.36	127.0	17.0	106.0	63.0	8.00	294.0	120.0	240.0	1.8	0.18	
	Soetfontein	2010/03/01	7.89	110.0	51.0	57.0	72.0	1.00	300.0	56.0	45.0	14.4		0.44
	ACVV	2011/12/05	7.72	94.1	64.4	41.4	35.9	5.07	124.7	81.9	124.3	4.5	0.015	0.18
	GWS SW	2011/12/05	8.15	193.9	140.5	96.3	92.6	9.2	273.2	132.8	396.3	0.1	0.292	0.19
	Final Effluent	2011/12/02		113.0								3.7	7.5	

SiteName	DateTimeMeas	N NO2 mg/l	OrthoPhosphate mg/l	Suspendid_Solids mg/l	coliforms /100ml	Hardness mg/l	COD mg/l	free_chlorine mg/l
General Limit		15.00	10.00	25.00	1000.00		75.00	0.25
Final Effluent		0.08	7.70	4.00	0.00	526.00	8.70	0.00
KKF_Spring	2014/11/05	0	0	42		403.73	18	
KS_2	2014/11/05	0	0	78		671.27	9	
KS_1	2014/11/05	0	0	47		555.07	5	
OF_Spring	2014/11/05	0	0.1	38		468.92	9	
OF2_BH	2014/11/05	0	0	55		932.13	6	
WWTW_final effluent	2014/11/05	0	8.51	40		363.60	25	
Hospital	2009/04/01	0.10				559.30		
Fish & Chips	2009/04/01	0.10				435.30		
Houtstraat	2009/04/01	0.10				504.50		
Honeyball	2009/04/01	0.10				628.20		
Makoudam	2009/04/01	0.10				997.10		
SF - Spring	2009/12/10					359.10		
Koeispeen	2009/02/01					477.10		
Soetfontein	2010/03/01					361.20		
ACVV	2011/12/05		1.95		2300.00	330.74		
GWS SW	2011/12/05		0.03		1300.00	746.18		
Final Effluent	2011/12/02	0.08	5.80		0.00		18.50	

5.5 Groundwater Dependent Ecosystems

Groundwater dependent ecosystems (GDEs) are ecosystems that depend on groundwater and can include wetlands, vegetation, springs, river base flows etc. The groundwater dependence of ecosystems will range from complete reliance to partial reliance on groundwater. Groundwater dependence influences the extent to which an ecosystem is affected by changes in groundwater quantity and quality. The dependency of ecosystems on groundwater is based on one or more of four basic groundwater attributes (SKM, 2001):

- flow or flux - the rate and volume of supply of groundwater;
- level - for unconfined aquifers, the depth below surface of the water table;
- pressure - for confined aquifers, the potentiometric head of the aquifer and its expression in groundwater discharge areas; and
- quality - the chemical quality of groundwater expressed in terms of pH, salinity and/or other potential constituents, including nutrients and contaminants.

The rivers in the area are episodic suggesting that the river is either not groundwater dependant or only partially groundwater dependant (only during high rainfall periods when the groundwater level is at its highest).

There are an abundance of springs within the dolomites as indicated by the farm names. These natural groundwater seepage and discharge points supply flora and fauna with water and therefore supply groundwater dependant ecosystems. While detailed investigations of the flora and fauna was not included in the scope of works for this study it is still important to note their presence and consider potential impacts that the proposed effluent discharge might have.

6. ASSESSMENT OF IMPACTS

In this section the potential impacts related to the WWTW and proposed discharge of the treated effluent are discussed. The current uncontrolled discharge of the effluent towards the town, and ultimately into the Groenwater Spruit, may have had impacts already. As part of the hydrocensus an appointment was made with Albertus Viljoen of the Tshiping Water User Association. He has sampled the ACVV borehole in town as well as the surface water in the Groenwater Spruit and is concerned about historical impacts emanating from the uncontrolled effluent discharge. His investigation does not form part of this study but it is important to note that previous contamination up-stream may have taken place.

6.1 Contamination source and toxicity assessment

The discharge of the effluent is the primary concern with regard to contamination. The effluent will flow from the proposed WWTW directly into the Groenwater Spruit. The proposed pipeline from an existing sewer main runs along the course of the river and any leakages or breakages in the pipeline will also represent secondary sources of potential contamination.

The final effluent chemistry analysis is presented in **Table 4**, and it is evident that the effluent orthophosphate concentrations are greater than that of groundwater. Orthophosphate, although generally not very toxic to human beings, can have adverse effects relating to eutrophication of water bodies and impact the smell and taste of the water. With regard to the other parameters for which analysis data was obtained, it is evident that the final effluent will have a quality comparable and even better than that of the groundwater. A full macro chemical analysis of the final effluent quality was obtained from BVI Consulting.

The current WWTW can treat a maximum of 4 800 m³/day, and over the months of September, October and November the WWTW treated in the region of 3 000 m³/day. This amounts to a discharge rate of 35 L/s, if the rate were to be constant throughout the day. The discharge will be into a small impoundment with an earth embankment and a concrete overflow structure in order to attenuate the flow and to control outflow velocities preventing possible erosion of the river bed.

6.2 Pathways

The discharge of the effluent is expected to seep into alluvium within the Groenwater Spruit and the tributary where it is discharged. It will percolate through the unsaturated zone into the groundwater within the weathered zone as well as the dolomite aquifer(s). These aquifers are laterally extensive and highly conductive due to the presence of solution cavities. The groundwater flow direction is expected to follow topography and the course of the Groenwater Spruit in a south-westerly direction.

6.3 Receptors

At the point of discharge the vegetation will be a receptor of the discharged effluent. Agricultural lands within the Groenwater Spruit may also be receptors of the effluent depending on the time it takes for the discharged effluent to infiltrate into the alluvium.

The effluent will seep into the alluvium and into the groundwater. Groundwater users around and down-gradient of the discharge point are therefore considered receptors despite the fact that the effluent will be diluted. Groundwater is used for domestic purposes, irrigation and stock watering and it will therefore be important that the quality

not be compromised. The closest domestic supply boreholes down-gradient of the proposed discharge point are borehole OF2 (~980 m) and OF6 (1 070 m).

6.4 Anticipated Impacts

Anticipated impacts on groundwater are related to the development of the proposed WWTW and the discharge of the treated effluent. The development of the proposed WWTW should not have an effect on the groundwater if it is properly constructed and managed. Infrastructure will need to be well constructed, monitored and maintained. Assuming this to be the case the investigation will focus on the impacts resulting from the discharging of the treated effluent.

6.4.1 Surface runoff

The Groenwater Spruit is an episodic river and does not flow every year. The effluent discharge will be ongoing but it is anticipated that the discharged effluent will filter into the river alluvium and not result in river flow. The amount of time taken for the flow to take place prior to infiltrating the alluvium is uncertain and detailed hydrological investigation would be able to provide more clarity on this matter.

6.4.2 Aquifer characteristics

The area of choice has a high groundwater vulnerability to surface based contaminants (**Map 8**) and is regarded as a major aquifer. The surface geology consists of unconsolidated sands and river alluvium and it is anticipated that infiltration and mixing will take place between the effluent and the groundwater. The alluvium is underlain by highly transmissive and extensive dolomite aquifers which would support the transport of contaminants. The aquifer is sensitive to contamination sources and as it supplies water for domestic purposes it will be important not to compromise its quality. The anticipated impacts relating to quality will be discussed in Chapter 6.4.4.

6.4.3 Groundwater Levels

The proposed new WWTW effluent discharge is expected to have an effect on groundwater levels. Numerous landowners stated that in dry periods the groundwater levels drop and Albertus Viljoen (Tshiping WUA) asked about the possibility of artificial recharge through the injection of the effluent. While the quality of the effluent is not of suitable quality for injection directly into the aquifer the discharge of the effluent will serve as a form of managed recharge for the aquifers in the vicinity of, and hydraulically linked to, the Groenwater Spruit. The result will be that the groundwater levels are buffered from dropping too significantly during dry periods. This is considered a favourable effect as long as the groundwater quality is not compromised.

6.4.4 Groundwater Quality

The biggest concern regarding the proposed new WWTW is its effluent discharge and the impacts that it may have on groundwater and the down-gradient groundwater users. Groundwater is the sole source of water for a number of farmers in the area and its quality must not be negatively impacted.

That said, it is evident from the effluent analysis results that the quality of the treated effluent is within general standards for treated effluent (National Water Act, 1998) and is generally better than regional groundwater with regard to EC. The effluent also contains 0 faecal coliforms (organisms/100 ml) and is ideal quality with regard to nitrate and nitrite concentrations.

Orthophosphates are elevated with regard to the groundwater concentrations for the area but are still within the discharge and irrigation limits. In September, October and November 2011, January 2012 and November 2014 the ammonia concentration was less than 3 mg/L but it exceeded the general limit of 6 mg/L (National Water Act) in December 2011. This was due to a problem with the aerator at the plant and is therefore not considered of significance.

6.4.5 Ecosystems

The springs and groundwater dependant ecosystems are not expected to be impacted by the effluent discharge. It is anticipated that vegetation will increase around the discharge point, as is evident at the two springs that were visited. The vegetation and foliage will become relatively impenetrable if left for a long period of time, and is expected to result in development of new ecosystems. Constituents such as orthophosphates are plant nutrients that will support the rapid growth.

7. DISCUSSION

From the investigation it is evident that the effluent from the current WWTW is of a reasonably good quality and that it is in fact comparable, if not better, than groundwater with regard to certain parameters. Orthophosphate is present at elevated concentrations with regards to groundwater and at the anticipated volumes of discharge it is expected that the quality of groundwater will be gradually impacted if the water is allowed to infiltrate and recharge the aquifers. The aquifer is major with high yields and marginal to good quality and is the sole source of water for farmers in the area.

Orthophosphate is a parameter that is present in most fertilizers and is favourable for plant nourishment. It is therefore anticipated that the concentration of the groundwater recharging effluent can be lowered by means of plant uptake. If irrigation of the effluent on the agricultural lands was implemented (as opposed to disposal in the river) then it would be considerably less of a contamination threat. Negotiations would be undertaken

with local farms regarding irrigation of the effluent. This should be further investigated as it would enable the crops to take up the majority of these ions.

Chlorine is a chemical parameter that is used in the water treatment process and can possibly have a negative effect on crop quality and yield. The concentrations at which free chlorine can be applied to crops (mostly lucerne in this case) should be investigated but is expected to be less than 0.25 mg/L. In the most recent analysis no free chlorine was detected, and the chloride concentration was comparable to that of groundwater. If irrigation water can be obtained from the treated effluent it will enable a decrease in groundwater abstraction as well the possible development of additional agricultural lands. This will be more favourable than letting the water flow out and infiltrate into the groundwater. The possibility of irrigating the treated effluent was also raised by landowners consulted during the hydrocensus. The water is suitable for irrigation as specified by the National Water Act (1998) for the irrigation of less than 2 000 m³/day.

One valid concern raised during the hydrocensus was regarding the quality control of the discharged effluent. While it is often within the discharge limit, it is important to ensure that the quality remains good and no discharge takes place if the quality is compromised in any way. It will be important to implement quality control and monitoring of the discharged effluent as is currently taking place.

8. RECOMMENDATIONS

Following on from the study the following recommendations are made:

- Ensure that the treated effluent parameters are within the general disposal limits (National Water Act, 1998) and that ammonia is kept below 3 mg/L.
- If chemistry analyses are favourable for irrigation engage farmers regarding the use of the effluent for irrigation. A gravity feed system can be implemented for the irrigation enabling electricity saving and a decrease in the need for fertilizers. This will be the most favourable means of disposal.
- Implement a groundwater monitoring network at and down-gradient of the proposed WWTW. The monitoring should include automated water level measurement and quarterly sampling. These will serve as an early warning system for contamination. Infrastructure must be able to withstand flooding of the river. Existing boreholes can be included in the monitoring network where suitable. Monitoring boreholes should be appropriately designed and constructed.

9. CONCLUSION

The groundwater in the area is a valuable resource and is vulnerable to surface based contamination. While the water quality of the final effluent is good with regard to certain indicator parameters (for November 2014) it has a relatively elevated orthophosphate concentration. As this is considered a plant nutrient it is recommended that the water be

used for crop irrigation as opposed to letting the water flow out in a single stream where infiltration to groundwater will be more rapid. The water quality suitability for irrigation should be considered with special reference to the relevant crops (i.e. lucerne). From existing data this is the most favourable method of disposal.

It is essential that monitoring of the groundwater levels and quality takes place at and down-gradient of the point of effluent disposal, be it via irrigation or discharge as proposed. The monitoring will serve as an early warning system for groundwater users down-gradient of the site. Existing boreholes could be incorporated into the monitoring network.

10. ACKNOWLEDGEMENTS

The following people are gratefully thanked for their input and support into this project:

- Gert Meiring and Xaviar Gray of BVI Consulting Engineers for providing previous reports, relevant information and assisting with site orientation
- Saskia Buning, subcontractor of BVI Consulting Engineers, for providing chemistry data
- Albertus Viljoen of the Tshiping WUA and Charl and Altus Viljoen of Olynfontein farm for their assistance during the hydrocensus and for providing previous reports and data.

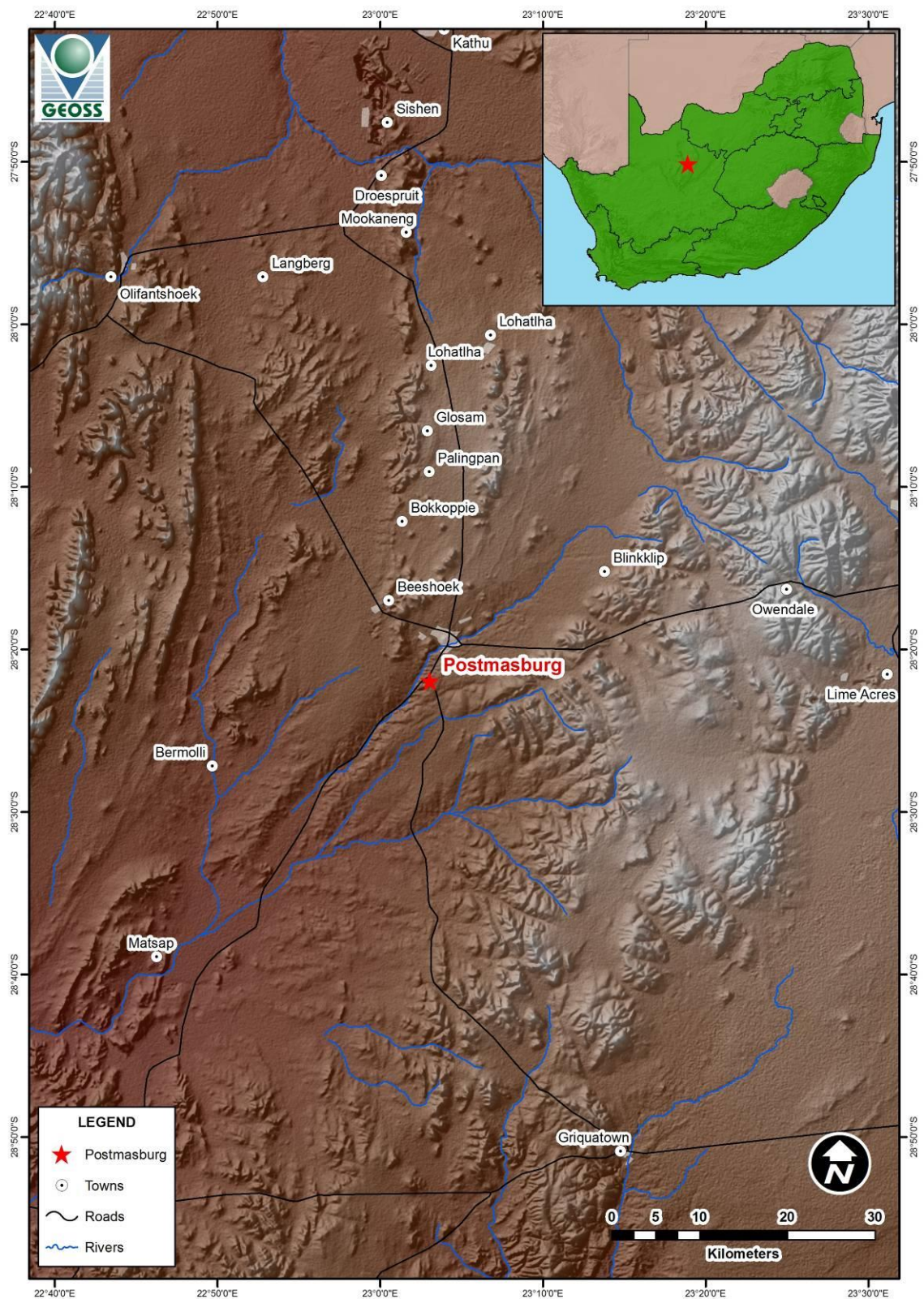
11. REFERENCES

- Clean Stream Scientific Services. 2010. Sishen South Exploration Project. Annual Hydrocensus Report. February/March 2010.
- Council for Geoscience. 1 : 250 000 geological map 2824 Postmasburg
- DWAF, 1998. Quality of domestic water supplies, Volume 1: Assessment guide. Department of Water Affairs and Forestry, Department of Health, Water Research Commission, 1998.
- DWAF, 1998. The National Water Act, No 36. Department of Water Affairs and Forestry. Pretoria.
- DWAF, 2000. Groundwater Resource Assessment – Phase I. 1:500 000 Hydrogeological National Map Series. Department of Water Affairs and Forestry. Pretoria.
- DWAF, 2005. Groundwater Resource Assessment Phase II, (GRAII). Department of Water Affairs and Forestry, Pretoria.
- GEOSS 2012. Geohydrological impact assessment relating to the proposed new treated effluent outfall Pipeline; Postmasburg, Northern Cape. GEOSS Report G2012/01-01. GEOSS - Geohydrological & Spatial Solutions International (Pty) Ltd. Stellenbosch, South Africa.
- Parsons and Conrad, 1998. Explanatory notes for the aquifer classification map of South Africa. WRC Report No. 116/98. Water Research Commission, Pretoria.
- SKM, 2001. Environmental Water Requirements of Groundwater Dependent Ecosystems. Technical Report Number 2, Sinclair Knight Mertz for Environment Australia.

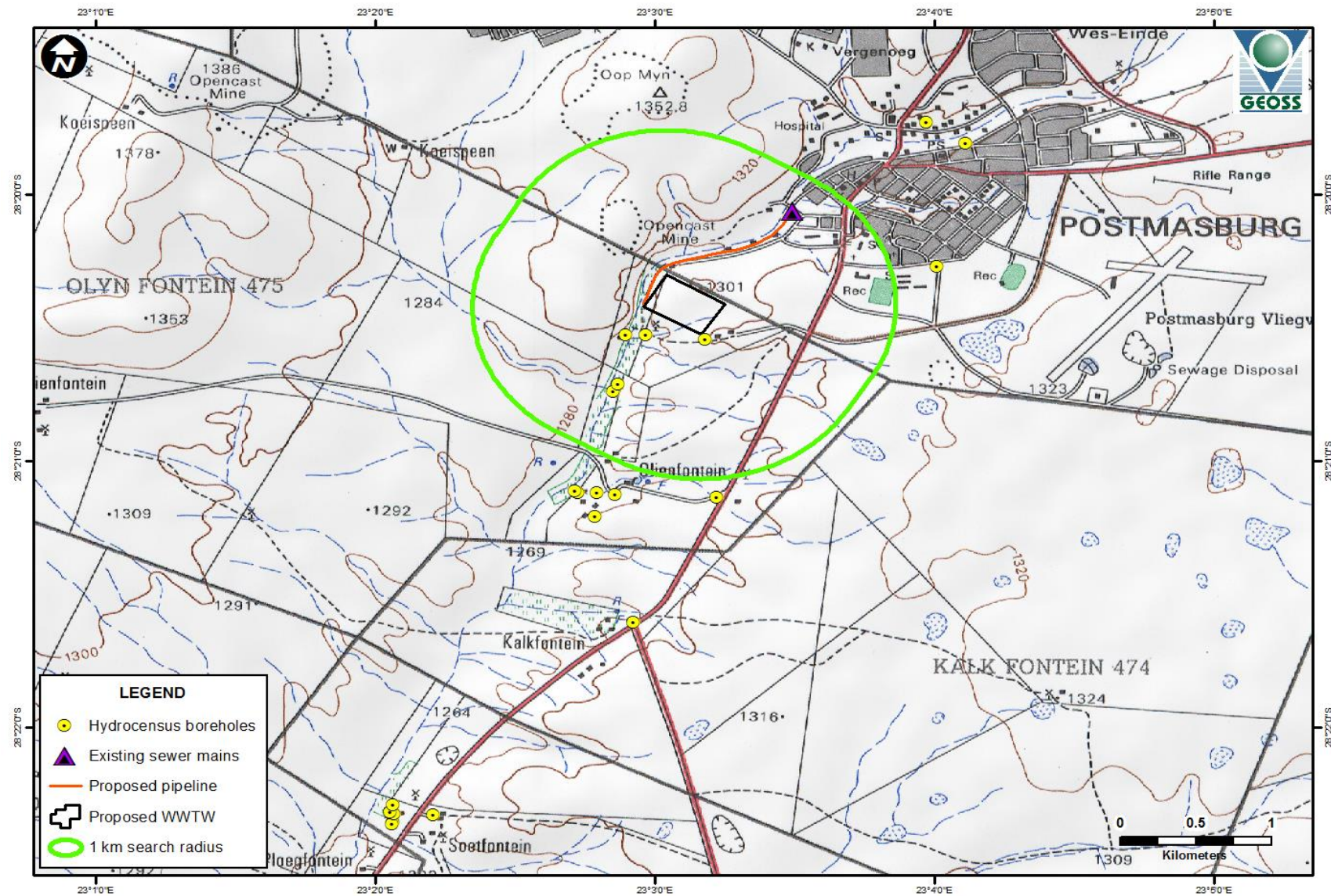
- SRK, 2009a. Yield Testing of Nine Municipal Boreholes at Postmasburg and Groenwater for the Tsantsabane Municipality. Tender No. TM 32/2008. April 2009. SRK consulting engineers and scientists.
- SRK, 2009b. Yield Test analyses of twenty four yield tested boreholes in the Sishen South Area. District Postmasburg, Northern Cape Province. Prepared for AB Pumps. November 2009. SRK consulting engineers and scientists.

DRAFT

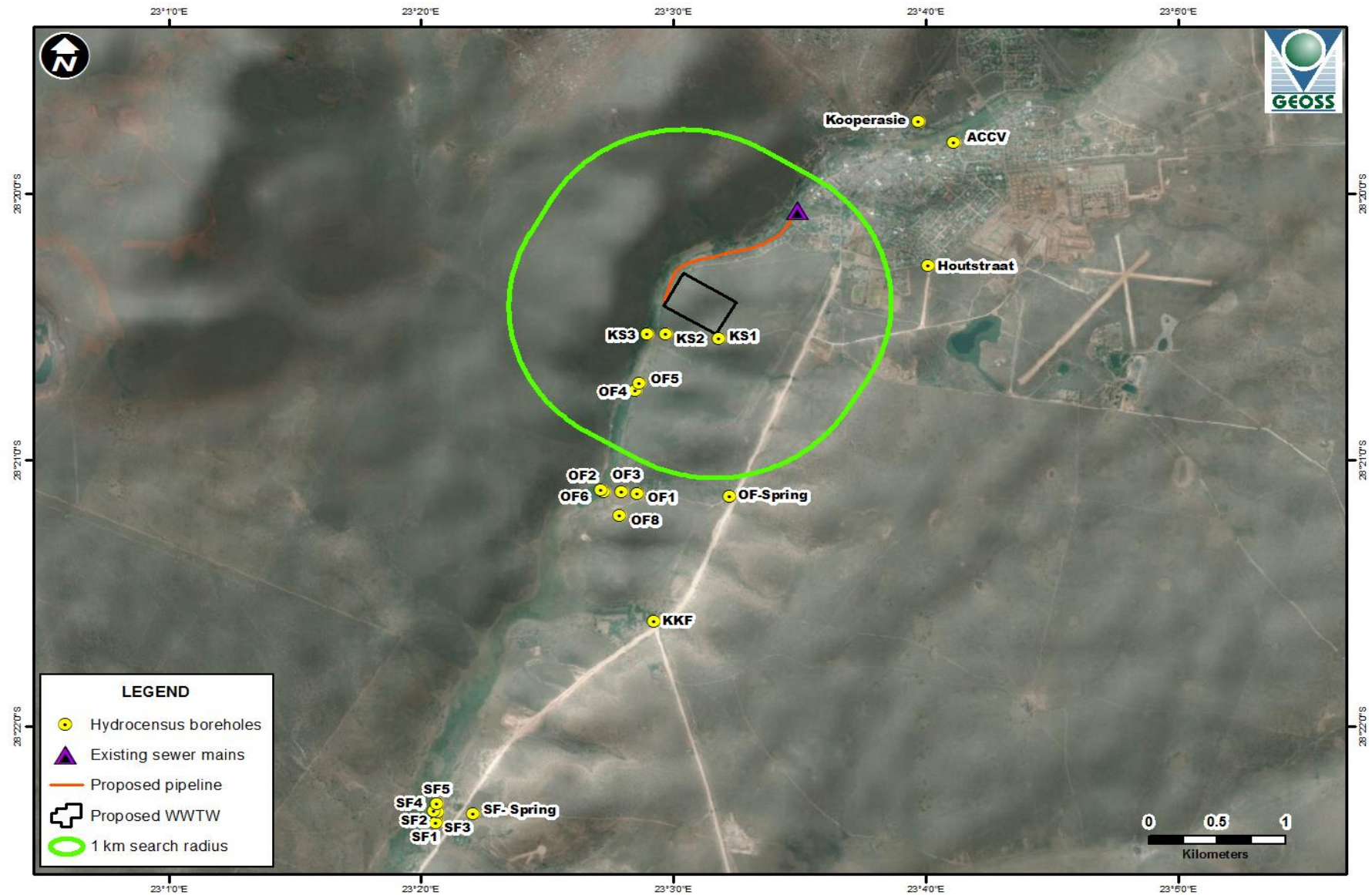
12. APPENDIX A: MAPS



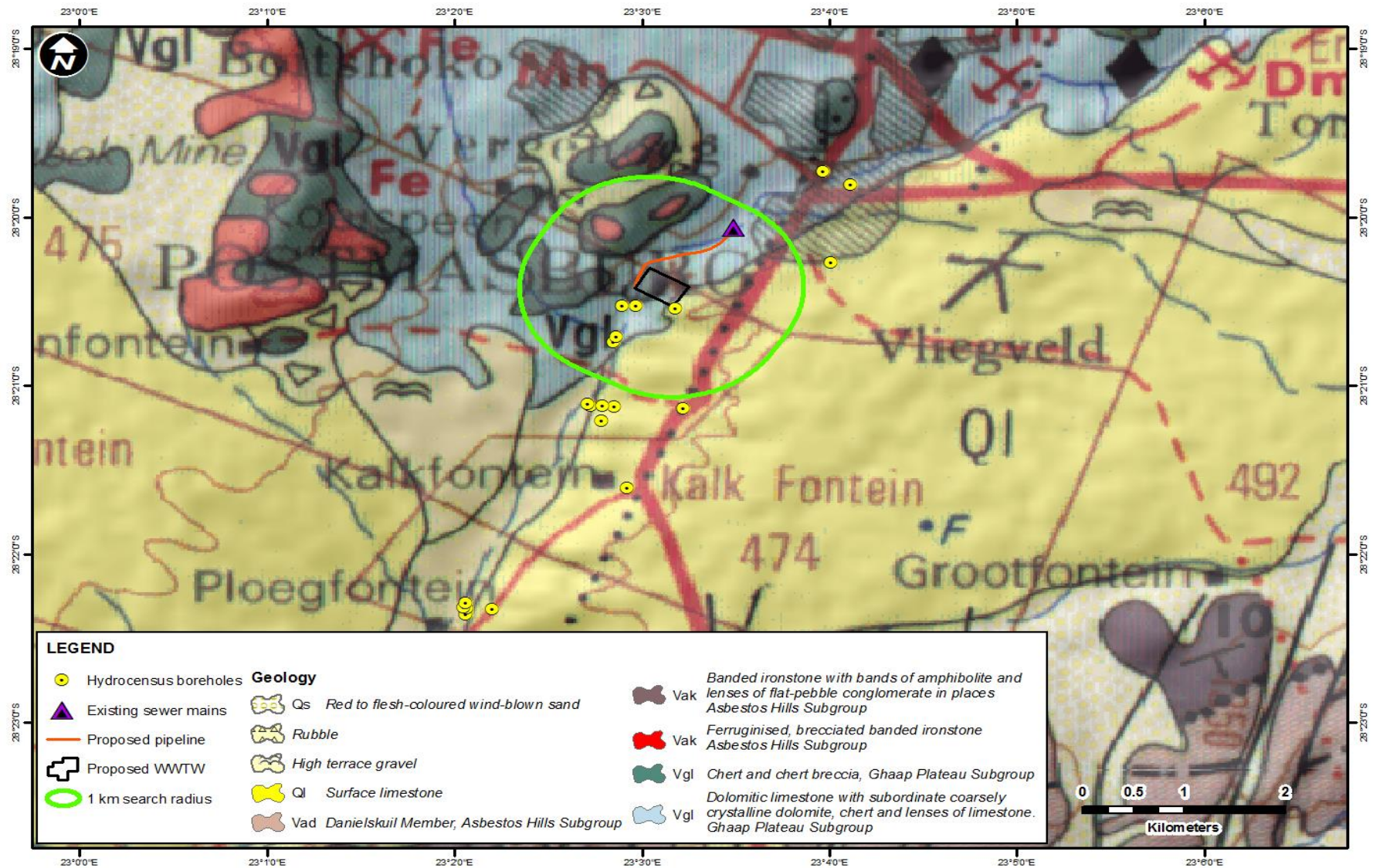
Map 1. Location of the study area within a regional setting



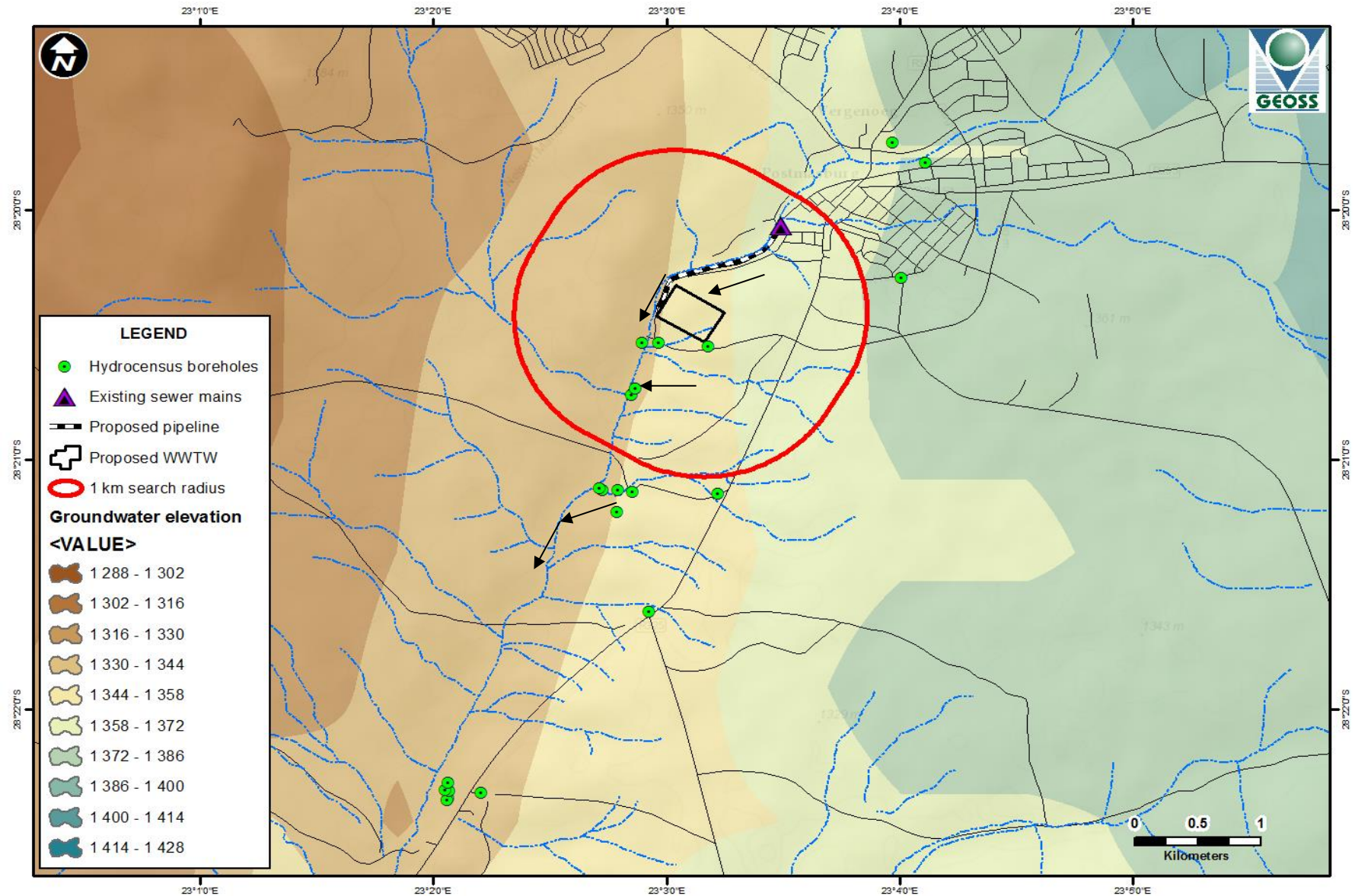
Map 2: The study site and surrounding area (1:50 000, topocadastral map 2823)



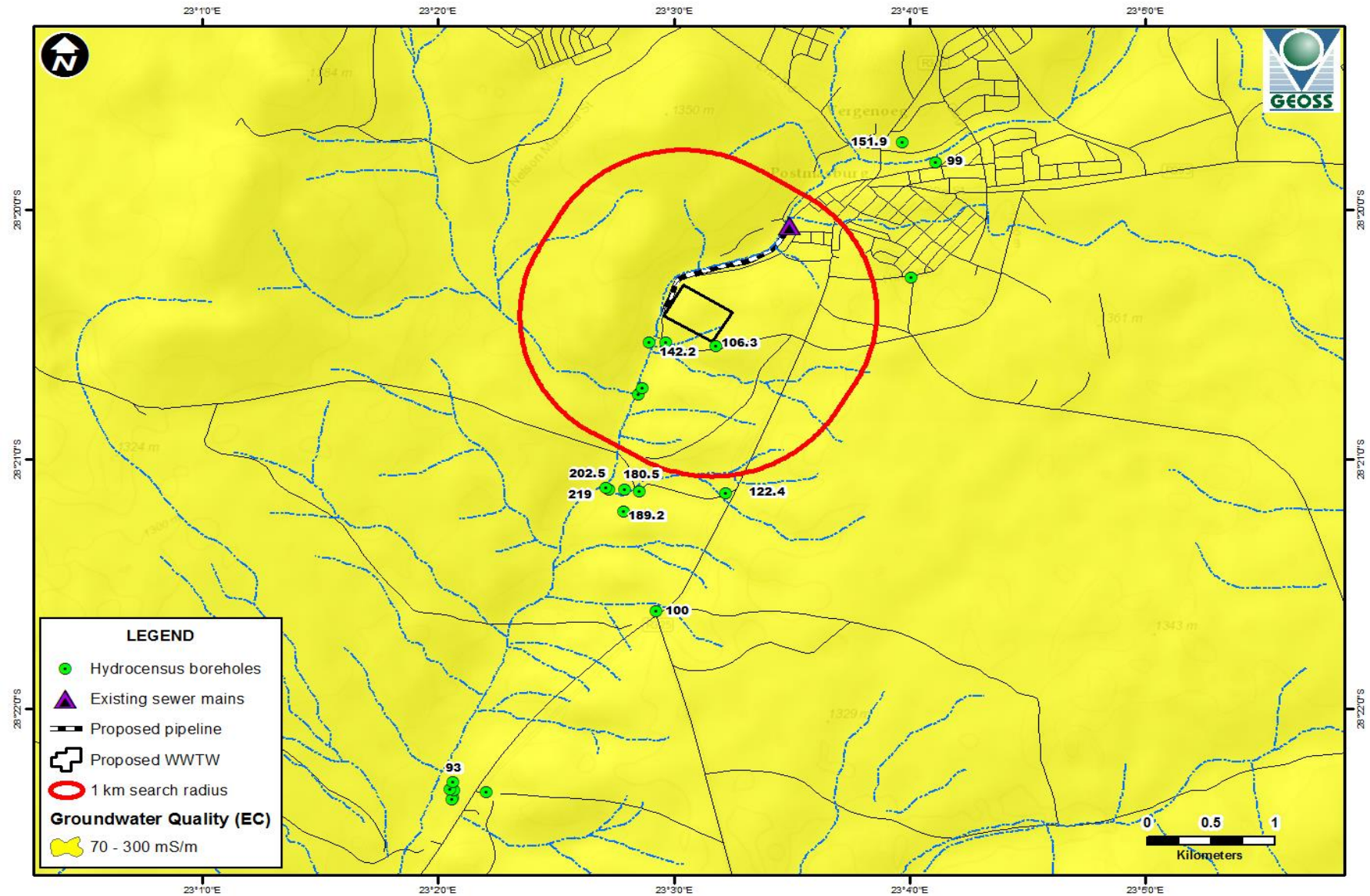
Map 3: Aerial photo of the study area and relevant points



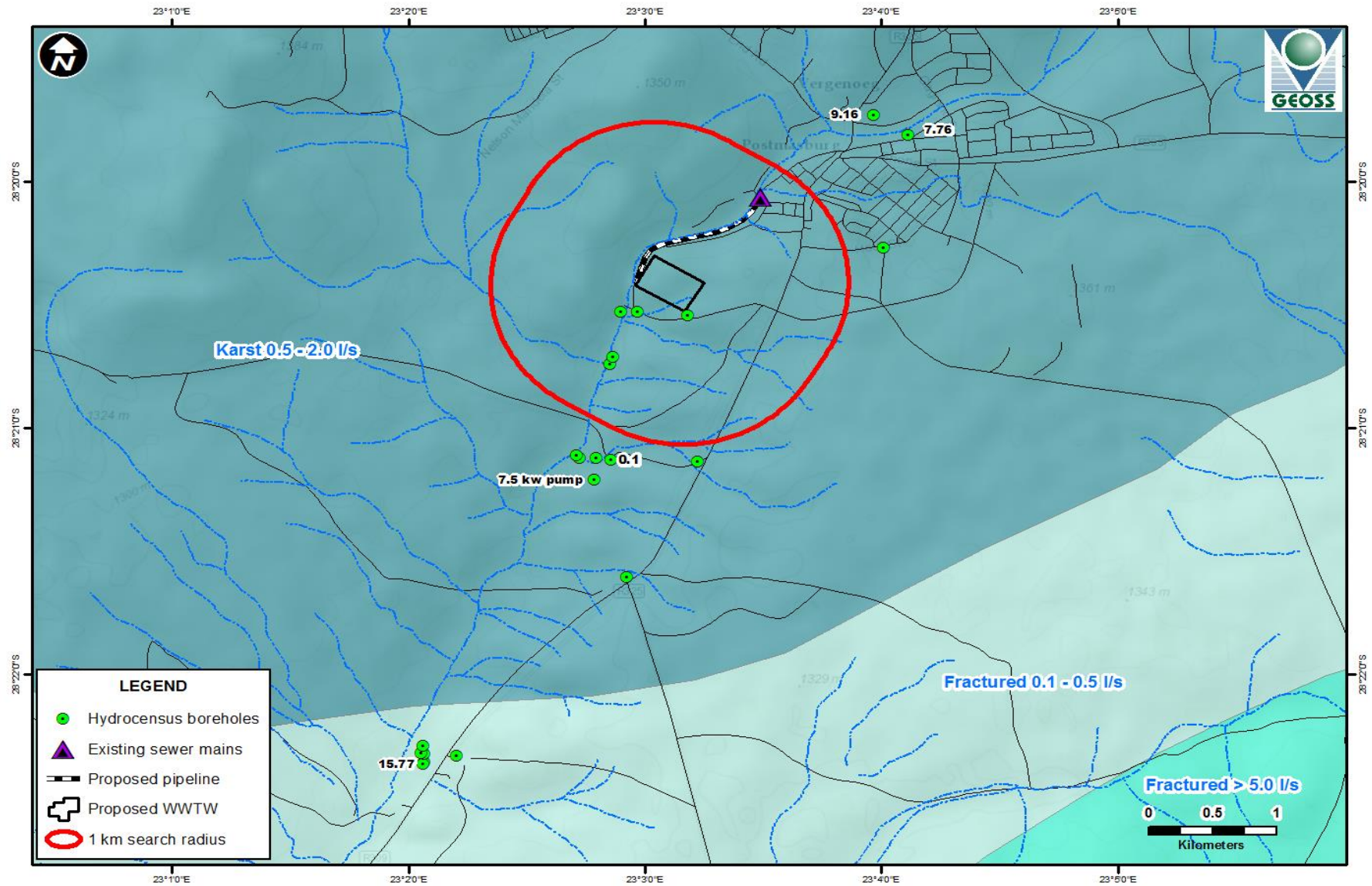
Map 4: Geological setting of the study area (2822 Postmasburg, Council for Geoscience)



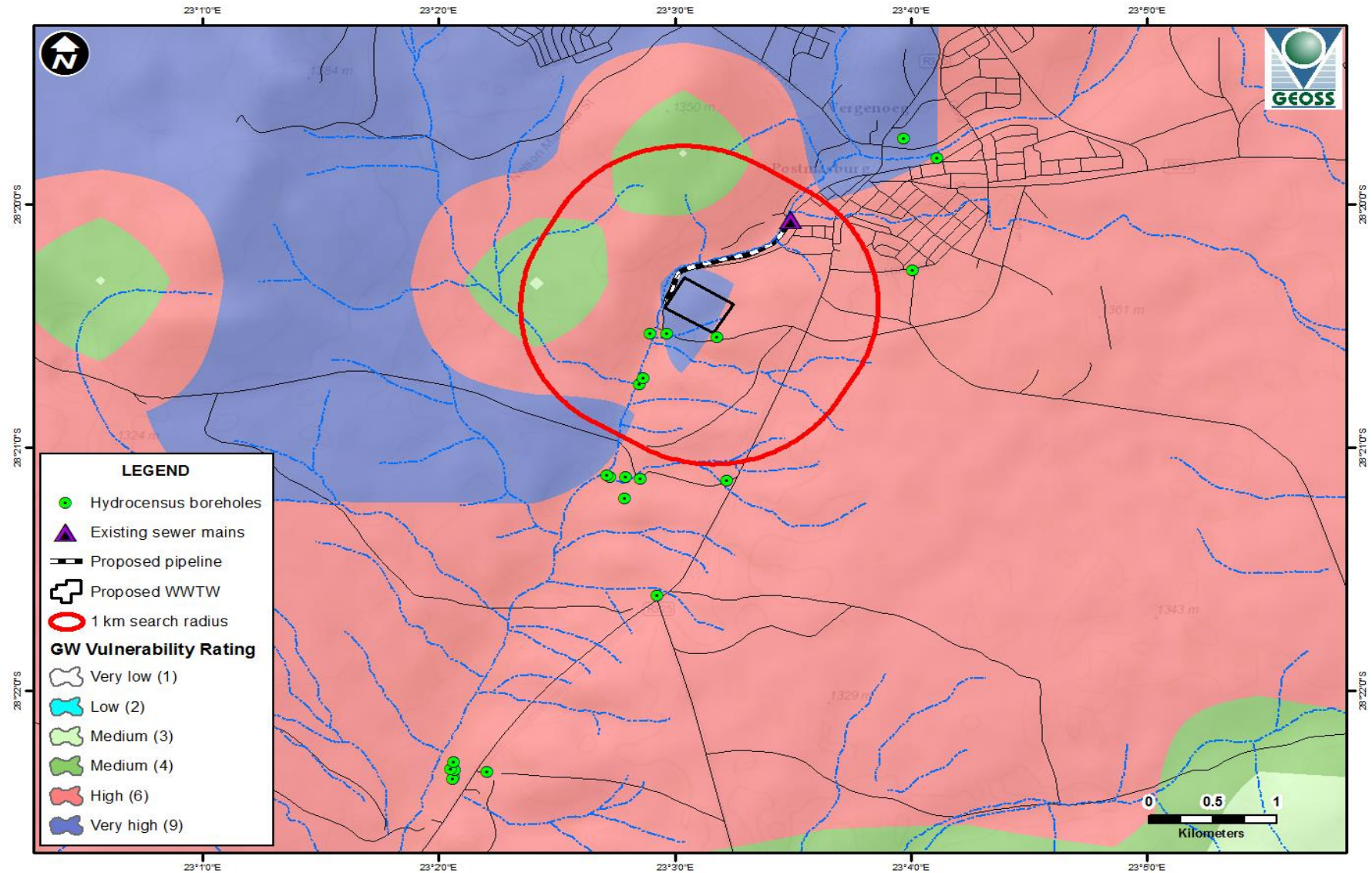
Map 5. Ground water level elevation contour map (DWA Hydrogeological Series) with inferred groundwater flow directions from manual measurements



Map 6: Groundwater quality map as a function of EC showing DWA (2005) data and manual measurements.



Map 7: Regional aquifer yield from the 1:500 000 scale groundwater map (DWAF, 2000).



Map 8: Regional groundwater vulnerability (calculated according to the DRASTIC methodology) and boreholes (DWAF, 2005).

13. APPENDIX B: HYDROCENSUS FIELD DATA

Table 5. Table showing sites and people visited and associated comments.

Site	Contact Person	Contact number	Date	Time	Comment
Water Treatment Works	Xaviar Gray	0848959641	07-Dec-11	10:40	Chem data shows high faecal coliforms - Xaviar says this was from a pipe leakage - wont be in future.
Water Treatment Works	Sakia	0824569955	07-Dec-11	10:40	Need to contact Saskia to obtain up to date chem info. Effluent discharge details from Gert.
Municipality	Pertulia Mabobo	0788932321	07-Dec-11	11:15	Does sampling of municipal supply (boreholes) - supplied chem data
Municipality	Hendrik Ross	0823573480	07-Dec-11	11:15	Municipal manager along with Jacques Majiedt
Municipality	Jacques Majiedt	0824926994	07-Dec-11	11:15	Municipal workshop manager - long experience and knowledge of boreholes etc.
Olyn Fontein	Charl Viljoen	0823714737	07-Dec-11	14:30	What about irrigating the effluent? BH used for domestic supply and irrigation. Part of WUA.
Kalkfontein	Dries van der Walt	-	-	-	Unable to meet with him or obtain a contact number.
Soetfontein	Albertus Viljoen	0836495452	07-Dec-11	16:30	Concerned about quality control of discharged effluent, sewerage already entering Groenwaterspruit, CI hindering plant growth. Will send chem analysis from CVV & river (in village). Managed recharge is a good idea. Lots of Springs in the area.
Olyn Fontein	Altus Viljoen	altus.aj@gmail.com	08-Dec-11	08:00	Son of Charl, to provide rainfall data for the area.
Koeispeen	JJ Schoultz	0722641367	08-Dec-11	10:30	Lives on Jaco Karstens' farm/ Showed BH positions and assisted with sample.
Koeispeen	Jaco Karstens	0731592005	08-Dec-11	10:30	Lives on other land but mother stays on farm. Have not met him - contact details from JJ

Table 6. Borehole position and water level data

Location	Date	Time	Lat	Long	WL	CH	WL mbgl	pH	temp	ORP	EC	TDS	DO Mg/l	DO %
SF1	05/11/2014	09:11	-28.3726	23.03444	4.791	0.15	4.641	7.16	20.4		93.9	610	27.7	2.5
SF2	05/11/2014	09:20	-28.37272	23.03437	0	0	0							
SF3	05/11/2014	09:25	-28.37208	23.03448	4.424	0.2	4.224							
SF4	05/11/2014	09:30	-28.37201	23.03423	4.481	0.17	4.311							
SF5	05/11/2014	09:35	-28.37154	23.03442	4.421	0	4.421	7.19	20.4		93	606	23.8	2.12
SF- Spring	05/11/2014	09:45	-28.37219	23.03679	0	0	0							
OF1	05/11/2014	09:55	-28.35213	23.04764	4.25	0.55	3.7							
OF8	05/11/2014	10:05	-28.35348	23.04648	16.832	0.11	16.722	7.53	20.8		133.9	889	81.4	7.33
OF6	05/11/2014	10:15	-28.35201	23.04546	7.097	0.33	6.767							
OF2	05/11/2014	10:25	-28.35188	23.04525	6.809	0.25	6.559	7.05	19.5		202.5	1317	41.4	3.77
OF3	05/11/2014	10:30	-28.38201	23.04678	6.937	0.215	6.722							
OF4	05/11/2014	10:40	-28.34568	23.04755										
OF5	05/11/2014	10:50	-28.34521	23.04781	9.093	0.552								
OF-Spring	05/11/2014	10:55	-28.35228	23.05373	0	0	0	7.13	23		115.5	752	87.93	4.38
KS1	05/11/2014	11:10	-28.34242	23.05304				7.57	21.8		113.5	738	81.4	7.13
KS2	05/11/2014	11:20	-28.34215	23.0495	13.584	0.42		7.62	24.3		142.2	923	80.4	6.68
KS3	05/11/2014	11:30	-28.34216	23.04831	10.783	1.102								
KKF	05/11/2014	12:30	-28.36012	23.04877	0	0	0	7.19	23.7		100	651	53	4.44
ACCV	06/11/2014	10:00	-28.33015	23.06857										
Houtstraat	06/11/2014	10:15	-28.33784	23.06685										
Kooperasie	06/11/2014	10:25	-28.32882	23.06619										

Table 7. Borehole field chemistry, yield and comment.

Location	Date	Time	Comment
SF1	05/11/2014	09:11	Used as a back up borehole, abstracts groundwater from both the sandy alluvium and karst geology. Depth around 60 m and yeild unknown
SF2	05/11/2014	09:20	Used as a back up borehole, abstracts groundwater from both the sandy alluvium and karst geology. Depth around 60 m and yeild unknown
SF3	05/11/2014	09:25	Main borehole, not pumping borehole, abstracts groundwater from both the sandy alluvium and karst geology. Depth around 60 m and yeild unknown
SF4	05/11/2014	09:30	Main borehole, not pumping borehole, abstracts groundwater from both the sandy alluvium and karst geology. Depth around 60 m and yeild unknown
SF5	05/11/2014	09:35	Not in use or equiped
SF- Spring	05/11/2014	09:45	Drilled into spring and installed pipe line to feed farm dam. Manhole was locked
OF1	05/11/2014	09:55	wind pump, not pumping. No Sample availble.
OF8	05/11/2014	10:05	used to pump water into a reservoir for anmials and irrigation, abstracts groundwater from both the sandy alluvium and karst geology. Depth around 60 m and yeild unknown
OF6	05/11/2014	10:15	used to pump water into a reservoir for anmials and irrigation, abstracts groundwater from both the sandy alluvium and karst geology. Depth around 60 m and yeild unknown
OF2	05/11/2014	10:25	used to pump water into a reservoir for anmials and irrigation, abstracts groundwater from both the sandy alluvium and karst geology. Depth around 60 m. Borehole is located in the river bed. Farm is concerened that effluent water will flood his crops and boreholes
OF3	05/11/2014	10:30	used to pump water into a reservoir for anmials and irrigation, abstracts groundwater from both the sandy alluvium and karst geology. Depth around 60 m. Borehole is located in the river bed. No sample.
OF4	05/11/2014	10:40	No access to water level, borehole located in the river bed.
OF5	05/11/2014	10:50	No sample, borehole located in river bed.
OF-Spring	05/11/2014	10:55	Runs all year round, reported that flow has increased since they built the effluent ponds up gradient. Gravity feed to house and used for irrigation.
KS1	05/11/2014	11:10	Sampled from tap inside the house.
KS2	05/11/2014	11:20	Sampled from tank near borehole. Used for livestock only.
KS3	05/11/2014	11:30	Not in use or equiped. Loacted in river bed and was damaged by a flood.
KKF	05/11/2014	12:30	Used as drinking water and irrigation, sampled at source.
ACCV	06/11/2014	10:00	New borehole house built around location, locked. Data can be requested by BIC enginnering.
Houtstraat	06/11/2014	10:15	New borehole house built around location, locked.
Kooperasie	06/11/2014	10:25	New borehole house built around location, locked.

14. APPENDIX C: DWAF (1998) GUIDELINES FOR DOMESTIC USE

<u>Sample Marked :</u>	DWA (1998) Drinking Water Assessment Guide				
	Class 0	Class I	Class II	Class III	Class IV
pH	5-9.5	4.5-5 & 9.5-10	4-4.5 & 10-10.5	3-4 & 10.5-11	< 3 & >11
Conductivity (mS/m)	<70	70-150	150-370	370-520	>520
Turbidity (NTU)	<0.1	0.1-1	1-20	20-50	>50
Faecal Coliforms (org./100 ml)	0	0-1	1-10	10-100	>100
	<u>mg/l</u>	<u>mg/l</u>	<u>mg/l</u>	<u>mg/l</u>	<u>mg/l</u>
Total Hardness (as CaCO ₃)	0-200-	200-300	300-60	>600	-
Calcium (as Ca)	0-80	80-150	150-300	>300	
Magnesium (as Mg)	<30-70	70-100	100-200	200-400	>400
Sodium (as Na)	<100	100-200	200-400	400-1000	>1000
Potassium (as K)	<25	25-50	50-100	100-500	>500
Zinc (as Zn)	<3-20	>20	Noticeable taste	Astringent taste	Repulsive taste
Chloride (as Cl)	<100	100-200	200-600	600-1200	>1200
Fluoride (as F)	<0.7	0.7-1.0	1.0-1.5	1.5-3.5	>3.5
Sulphate (as SO ₄)	<100-200	200-400	400-600	600-1000	>1000
Total Dissolved Solids	<450	450-1000	1000-2400	2400-3400	>3400
Nitrate& Nitrite (as N)	<6	6-10	10-20	20-40	>40
Iron (as Fe)	<0.01-0.5	0.5-1.0	1.0-5.0	5.0-10.0	>10
Manganese (as Mn)	<0.05-0.1	0.1-0.4	0.4-4	4.0-10.0	>10
Copper (as Cu)	0-1	1-1.3	1.3-2	2-15	>15
Cadmium (as Cd)	<0.003	0.003-0.005	0.005-0.02	0.02-0.05	>0.05
Arsenic (as As)	<0.01	0.01-0.05	0.05-0.2	0.2-2	>2

15. APPENDIX C: LABORATORY ANALYSIS RESULTS



16 Van der Berg Crescent
Gant's Centre
Strand

Tel. (021) 853-1490
Fax (021) 853-1423

E-Mail admin@bemlab.co.za

P O Box 684
Somerset Mall,
7137

Vat Reg. Nr. 4200161414

Report No.: **WT9814**

Julian Conrad
GEOSS (Pty) Ltd
Unit 19, Technostell Building
9 Quantum Street, Technopark
Stellenbosch
7600

Water Analyses Report

Date received: 10/11/2014

Date tested: 12/11/2014

Reference No.	Lab. No.	pH	EC mS/m	Na mg/l	K mg/l	Ca mg/l	Mg mg/l	Cl mg/l	CO ₃ * mg/l	HCO ₃ mg/l	SO ₄ mg/l	P mg/l	NH ₄ -N mg/l	NO ₃ -N mg/l	F mg/l	TDS mg/l	Temperature °C	Date Sampled	Alkalinity mg/l	NO ₂ -N mg/l
KKF_Spring	9814	7.4	104	56.07	1.49	93.69	41.23	115.98		369.08	78.74	0.000	0.247	1.554	0.200	626	9.40	05/11/2014	623.484	0.00
KS_2	9815	7.7	153	56.39	2.42	107.16	98.03	129.32	35.11	454.50	211.84	0.000	0.248	7.766	0.300	914	9.40	05/11/2014	817.758	0.00
KS_1	9816	7.6	119	39.40	1.08	107.94	69.34	94.12		522.07	84.34	0.000	0.243	5.331	0.100	711	11.10	05/11/2014	967.354	0.00
OF_Spring	9817	7.4	120	67.83	1.49	107.61	48.62	129.32		460.88	59.24	0.003	0.281	4.604	0.300	720	10.90	05/11/2014	811.232	0.00
OF2_Bh	9818	7.2	219	97.66	3.83	148.65	136.22	267.17		603.67	277.04	0.000	0.254	5.854	0.300	1313	10.30	05/11/2014	938.238	0.00
WWTW	9819	7.9	108	78.88	5.41	74.52	43.11	100.79	30.10	370.36	95.34	2.781	0.430	0.947	0.400	649	10.30	05/11/2014	787.638	0.00
Method [#]		3136	3135	3132	3132	3132	3132	3138	3137	3137	3132	3132	3133	3134						

Reference No.	Lab. No.	COD mg/l	Suspended Sol mg/l	PO ₄ mg/l	Hardness mg CaCO ₃ /l
KKF_Spring	9814	18.00	42	0.00	403.73
KS_2	9815	9.00	78	0.00	671.27
KS_1	9816	5.00	47	0.00	555.07
OF_Spring	9817	9.00	38	0.01	468.92
OF2_Bh	9818	6.00	55	0.00	932.13
WWTW	9819	25.00	40	8.51	363.60
Method [#]		3140			

[#]Refer to BemLab work instructions

Order no.: #1170

Statement: Samples received in good condition. Sample temperature at reception is stipulated in the results table. Ideally the sample(s) should reach the laboratory within 6 hours, or be kept at <10°C and delivered within 24 hours. If these conditions are not maintained, analysis will proceed but interpretation of the results generated is at the clients own discretion. The reported results may be applied only to samples received. Any recommendations included with this report are based on the assumption that the samples were representative of the block from which they were taken.

DRAFT

16. APPENDIX D: FIELD PHOTOGRAPHS



Postmasburg WWTW treated effluent



Proposed WWTW site



**Dolomites and iron banding outcropping
below proposed WWTW site**



**Groenwater Spruit – agricultural land and
alluvial cover**



Municipal Borehole Houtstraat



Municipal Borehole ACVV



Municipal Borehole Kooperasie



Koeispeen Private borehole – KS1



Koeispeen Private borehole – KS2



Koeispeen Private borehole – KS3



Olynfontein - OF-Spring



Olynfontein OF1– Wind pump



Olynfontein Private Borehole – OF2



Olynfontein Private Borehole – OF3



Olynfontein Private Borehole – OF4



Olynfontein Private Borehole – OF6



Olynfontein Private Borehole – OF8



Soetfontein – SF - Spring



Soetfontein Private Borehole – SF1



Soetfontein Private Borehole – SF2



Soetfontein Private Borehole – SF3



Soetfontein Private Borehole – SF4



Soetfontein Private Borehole – SF5



Kalkfontein private spring – KKF- spring

(last page)