Proposed Wincanton 472 Solar Energy Power Plant: Assessment of the Groundwater Resources

Report Prepared for

VentuSA Energy (Pty) Ltd

Report Number SRK 452538/Final

Report Prepared by

srk consulting

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Proposed Wincanton 472 Solar Energy Power Plant: Assessment of the Groundwater Resources

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Table of Contents

List of Tables

List of Figures

List of Appendixes

Disclaimer

The opinions expressed in this Report have been based on the information supplied to SRK Consulting (South Africa) (Pty) Ltd (SRK) by VentuSA Energy (Pty) Ltd, the borehole yield testing contractor AB Pumps and the local land owner as well as NGA data from the Department of Water Affairs. SRK has exercised due care in reviewing the supplied information. Whilst SRK has compared the available data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the available data. SRK does not accept responsibility for any errors or omissions in the supplied information and does not accept any consequential liability arising from commercial decisions or actions resulting from them. Opinions presented in this report apply to the site conditions and features as they existed at the time of SRK's investigations, and those reasonably foreseeable. These opinions do not necessarily apply to conditions and features that may arise after the date of this Report, about which SRK had no prior knowledge nor had the opportunity to evaluate.

Glossary of Terms

Aquifer: A water-bearing geological formation capable of supplying economic quantities of groundwater to wells, boreholes and springs.

Aquitard: A saturated geological unit with a relatively low permeability that retards, but does not prevent the movement of water; while it may not readily yield water to boreholes and springs, it may act as a storage unit.

Aquiclude: A geological unit with a very low permeability that severely restricts groundwater movement. GRU boundaries are commonly formed by aquicludes, e.g. dykes.

Contamination: The introduction of any substance into the environment by the action of man.

Fractured-rock Aquifer: Aquifers where groundwater occurs within fractures and fissures in hard-rock formations.

Groundwater: Refers to the water filling the pores and voids in geological formations below the water table.

Groundwater Flow: The movement of water through openings and pore spaces in rocks below the water table i.e. in the saturated zone. Groundwater naturally drains from higher lying areas to low lying areas such as rivers, lakes and the oceans. The rate of flow depends on the slope of the water table and the transmissivity of the geological formations.

Groundwater Recharge: Refers to the portion of rainfall that actually infiltrates the soil, percolates under gravity through the unsaturated zone (also called the Vadose Zone) down to the saturated zone below the water table (also called the Phreatic Zone).

Groundwater Resource: All groundwater available for beneficial use, including by man, aquatic ecosystems and the greater environment.

Groundwater Resource Units: (GRU's) Represent provisional zones defined for the purposes of assessing and managing the groundwater resources of a region, in terms of large-scale abstraction from relatively shallow (depth < 300m) production boreholes. They represent areas where the broad geohydrological characteristics (i.e. water occurrence and quality, hydraulic properties, flow regime, aquifer boundary conditions etc.) are anticipated to be similar. Sometimes also called Groundwater Management Units (GMU's).

Intergranular Aquifer: Aquifers where groundwater is contained in original intergranular interstices of sedimentary and weathered formations.

Major Aquifer System: Highly permeable formations, usually with a known or probable presence of significant fracturing and/or intergranular porosity; may be highly productive and able to support large abstractions for public supply and other purposes; water quality is generally very good.

Minor Aquifer System: Fractured or potentially fractured rocks that do not have a high primary permeability, or other formations of variable permeability; aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large quantities of water, they are important both for local supplies and in supplying base flow for rivers.

Non-Aquifer: A groundwater body that is essentially impermeable, does not readily transmit water and/or has a water quality that renders it unfit for use.

Non-Aquifer Systems: formations with negligible permeability that are generally regarded as not containing groundwater in exploitable quantities; water quality may also be such that it renders the aquifer unusable; groundwater flow through such rocks does take place and needs to be considered when assessing the risk associated with persistent pollutants.

Permeability: The ease with which a fluid can pass through a porous medium and is defined as the volume of fluid discharged from a unit area of an aquifer under unit hydraulic gradient in unit time (expressed as $m^3/m^2 \cdot d$ or m/d). It is an intrinsic property of the porous medium and is independent of the properties of the saturating fluid; not to be confused with *hydraulic conductivity*, which relates specifically to the movement of water.

Pollution: The introduction into the environment of any substance by the action of man that is, or results in, significant harmful effects to man or the environment.

Recharge: The addition of water to the zone of saturation, either by the downward percolation of precipitation or surface water and/or the lateral migration of groundwater from adjacent aquifers.

Saline Water: Water that is generally considered unsuitable for human consumption or for irrigation because of its high content of dissolved solids.

Saturated Zone: The subsurface zone below the water table where interstices are filled with water under pressure greater than that of the atmosphere

Specific Yield: Ratio of the volume of water that a given mass of saturated rock or soil will yield by gravity from that mass.

Storativity (S): The volume of water released from storage per unit of aquifer storage area per unit change in head.

Unconfined Aquifer: An aquifer with no confining layer between the water table and the ground surface where the water table is free to fluctuate.

Unsaturated Zone: That part of the geological stratum above the water table where interstices and voids contain a combination of air and water; synonymous with *zone of aeration* or *vadose zone*.

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.

List of Abbreviations

DWA	Department of Water Affairs (previously DWAF)
DWAF	Department of Water Affairs and Forestry
EC	Electrical Conductivity (Salinity of water)
GA	General Authorisation
GRA2	Groundwater Resource Assessment Phase 2
ℓ/s	litres per second
m	metres
m amsl	metres above mean sea level
MAP	Mean Annual Precipitation
mbc	metres below collar
m bgl	metres below ground level
mg/ℓ	milligrams per litre
mm	millimetres
mS/m	milli-Siemens per metre
MW	Mega Watt
m^3/a	cubic metres per annum
m^3/ha/a	cubic metres per hectare per annum
m^3/m	cubic metres per month
NGIS	National Groundwater Information System
PV	Photovoltaic
PVSEP Plant	Photovoltaic Solar Energy Power Plant
SD	Standard Deviation
SRK	SRK Consulting (South Africa) Pty Ltd

1 Introduction

During August 2012 SRK Consulting (SRK) was requested by Mr Riccardo Panzeri of VentuSA Energy (Pty) Ltd (VentuSA) to submit a cost proposal for a detailed groundwater resource assessment and provide specialist input to the Water Use Licence required for a proposed Photovoltaic Solar Energy Power Plant (PVSEP Plant) on the farm Wincanton 472, Portion 0 (the site) which is located immediately east of Dibeng in the Northern Cape Province. SRK was subsequently appointed on 15 August 2012 to carry out the assessment as proposed.

The proposed development is adjacent to portion 4 of the farm Wincanton 472 for which SRK has conducted a groundwater resource assessment during 2012 (**Figure 1**). All farms in the area are totally dependent on groundwater for domestic use, stock watering and some small scale irrigation.

1.1 Scope of Work

The following scope of work and deliverables were proposed by SRK and accepted by VentuSA:

1. Obtain all hydrogeological data for this area from the Department of Water Affairs' (DWA) National Groundwater Archive (NGA) and other sources.

2. Conduct a hydrocensus on the property and its surrounds. During this exercise all relevant hydrogeological information (e.g. borehole depth, yield, groundwater strikes, etc.) is to be collected from the owners. Groundwater levels, field measured Electrical Conductivity (EC) and pH values of the groundwater are to be collected during this visit.

3. Of the existing boreholes on the property, identify one suitable for yield testing.

4. Complete the required DWA forms for a groundwater license application.

5. Compile a final report in which the results and recommendations are summarized. The report is to specifically include a groundwater monitoring scheme and programme and identify suitable monitoring boreholes.

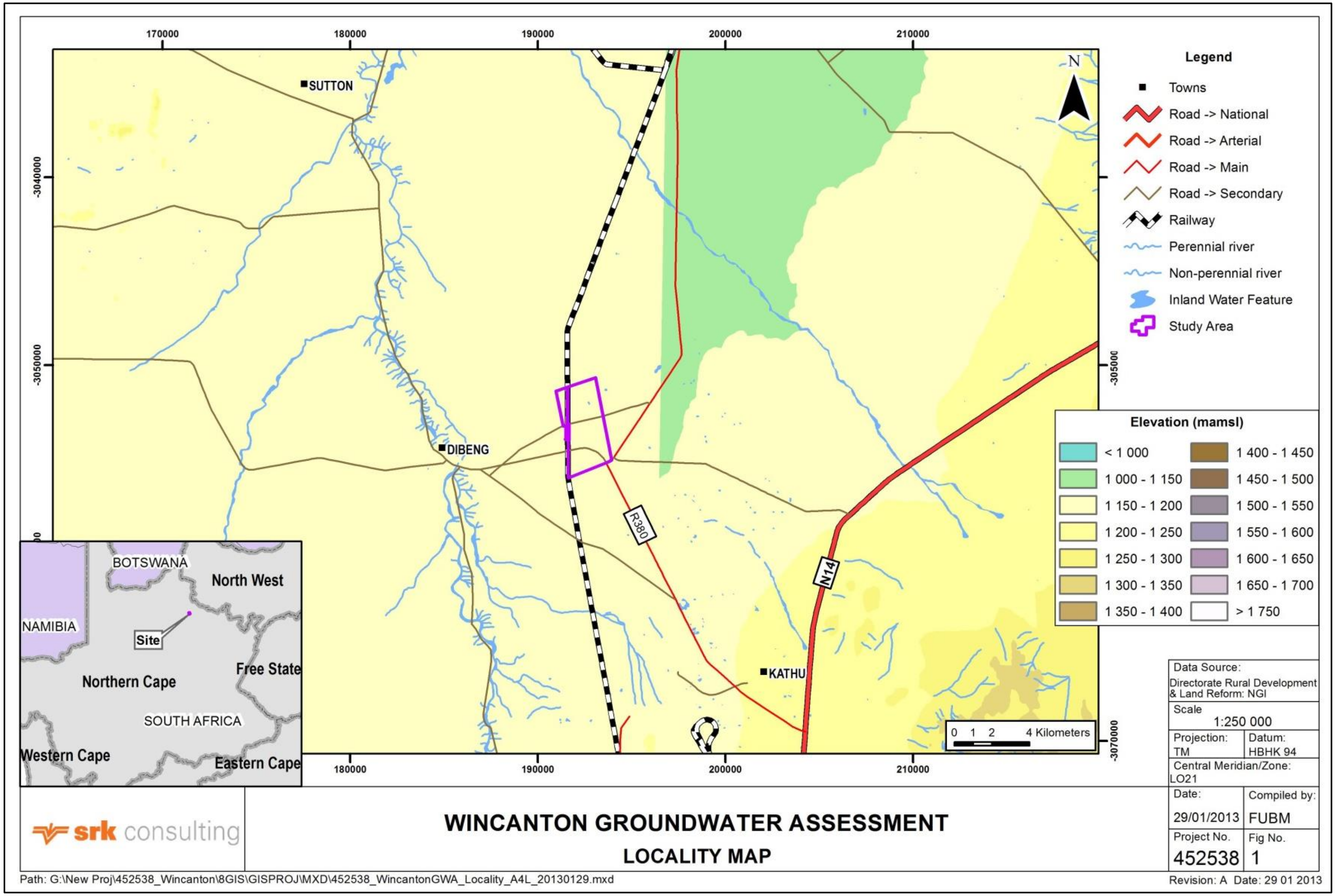


Figure 1: Locality of the Proposed Wincanton 472 Photovoltaic Solar Power Plant Site

1.2 Work Programme

After appointment on 15 August 2012, a hydrocensus of the boreholes in the area was conducted on 21 August 2012. No suitable borehole for yield testing could be identified and a new borehole, WNE1, had to be constructed. This borehole was subsequently yield tested during the period 19 - 24 June 2013.

2 Project Description

A 75 MW Photovoltaic Solar Energy Power Plant (here after referred to as a PVSEP Plant) is proposed by VentuSA for the site. The PVSEP Plant consists of large arrays of photovoltaic (PV) cells. The sun emits photons (light), which generate electricity when they collide with a photovoltaic cell. This is known as the photovoltaic effect. PV cells are made from a semi-conducting material. Thus the PVSEP Plant generates power by converting sunlight, the most abundant energy source on the planet, directly into electricity. PV cells generate direct current (DC) electricity whilst the ESCOM grid distributes alternating current (AC) electricity. Therefore, feeding of PV generated electricity into the grid requires the transformation of DC into AC by a special, grid-controlled solar inverter.

3 Water Demand

VentuSA calculated the maximum water demand as c.135 m^3/d and 39 m^3/d for the construction and operational phases respectively. On an annual basis these average demands will amount to 49 353 and 14 235 m^3, respectively. The water demand calculations for these phases as provided by the client are indicated in **APPENDIX 1** at the end of this report.

4 Baseline Data

4.1 Physiography and Climate

The site is located c.6 km east of Dibeng in the Northern Cape Province and along the R380 route to Kathu. Drainage is in a north-westerly direction along the Ga Mogara River, which joins the Kuruman River further downstream. The terrain in the study area is very flat with a general slope of c.1:140 or 0.7% to the north-west. A small valley with local steeper slopes is formed by the Ga Mogara River.

The elevation of the study area varies between c.1 134 mamsl in the far north-western part and 1 142 mamsl in the south-eastern part thereof. Generally the area is covered with a thin layer of windblown sand, which absorbs most of the precipitation and therefore the absence of drainage channels other than the Ga Mogara River.

The climate of the area is typical of a semi-desert with very hot summers and cold winters. Temperature data for Upington, c.200 km west of the site (as supplied by the South African Weather Service), for the period 1961-2000 is summarized in **Table 1**. The data indicate that January is the hottest month with an average maximum daily temperature of 36 ^{o}C and June and July the coldest with an average maximum daily temperature of 21 ^{o}C for both months. During July the average minimum daily temperature drops to only 4 ^{o}C. The table also indicates that the absolute maximum temperature recorded during the period 1960-2000 was 43 ^{o}C and the lowest -7 ^{o}C.

Table 1: Temperature Data for Upington (South African Weather Service)

Month	Temperature (° C)				Precipitation		
	Highest Recorded	Average Daily Maximum	Average Daily Minimum	Lowest Recorded	Average Monthly (mm)	Average Number of days with >= 1mm	Highest 24 Hour Rainfall (mm)
January	42	36	20	10	24	4	33
February	42	34	20	9	35	6	59
March	41	32	18	5	37	6	46
April	38	28	13	2	26	5	52
May	34	24	8	-2	10	2	26
June	29	21	5	-5	4	2	13
July	29	21	4	-6	2	1	7
August	33	23	6	-7	4	1	40
September	39	27	9	-2	4	2	19
October	40	30	13	2	9	3	22
November	41	33	16	5	17	3	51
December	43	35	19	6	17	4	42
Year	**43**	**29**	**13**	**-7**	**189**	**37**	**59**

The average monthly precipitation and standard deviation (SD) values for the study area, as provided by the South African Weather Service, are summarized in **Table 2** below. The area falls within the summer rainfall area with a mean annual precipitation (MAP) of c.340 mm.

Table 2: Monthly Precipitation Statistics for Wincanton Farm (Source: South African Rain Atlas)

	Station S27° 35' E022° 57'												
Month	***Jan***	***Feb***	***Mar***	***Apr***	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***	***Annual***
Mean (mm):	*58.6*	*62.6*	*61.9*	*32.5*	*13.0*	*5.0*	*3.4*	*5.4*	*10.3*	*19.0*	*29.6*	*42.4*	***343.7***
SD (mm):	*44.4*	*47.3*	*45.3*	*31.8*	*19.1*	*10.8*	*8.9*	*11.9*	*16.2*	*21.8*	*28.2*	*35.1*	***103.3***
SD = Standard Deviation													

The data indicate that approximately 83% of the precipitation occurs during the months November to April, which is characteristic of a summer rainfall area. March is the wettest month with an average precipitation of >60 mm, whilst July is the driest with <4 mm.

The rainfall distribution of the area, as obtained from the DWA's National Groundwater Resource Assessment Phase 2 (GRA2) dataset, is indicated in **Figure 2** over page. The figure clearly indicates that the rainfall decreases from east to west with the highest precipitation in the hilly areas of the Kuruman Hills to the east of the site where the MAP is >500 mm/a. West and north of Dibeng the MAP decreases to <400 mm/a. For unknown reasons these values are significantly higher than the values obtained from the South African Rain Atlas.

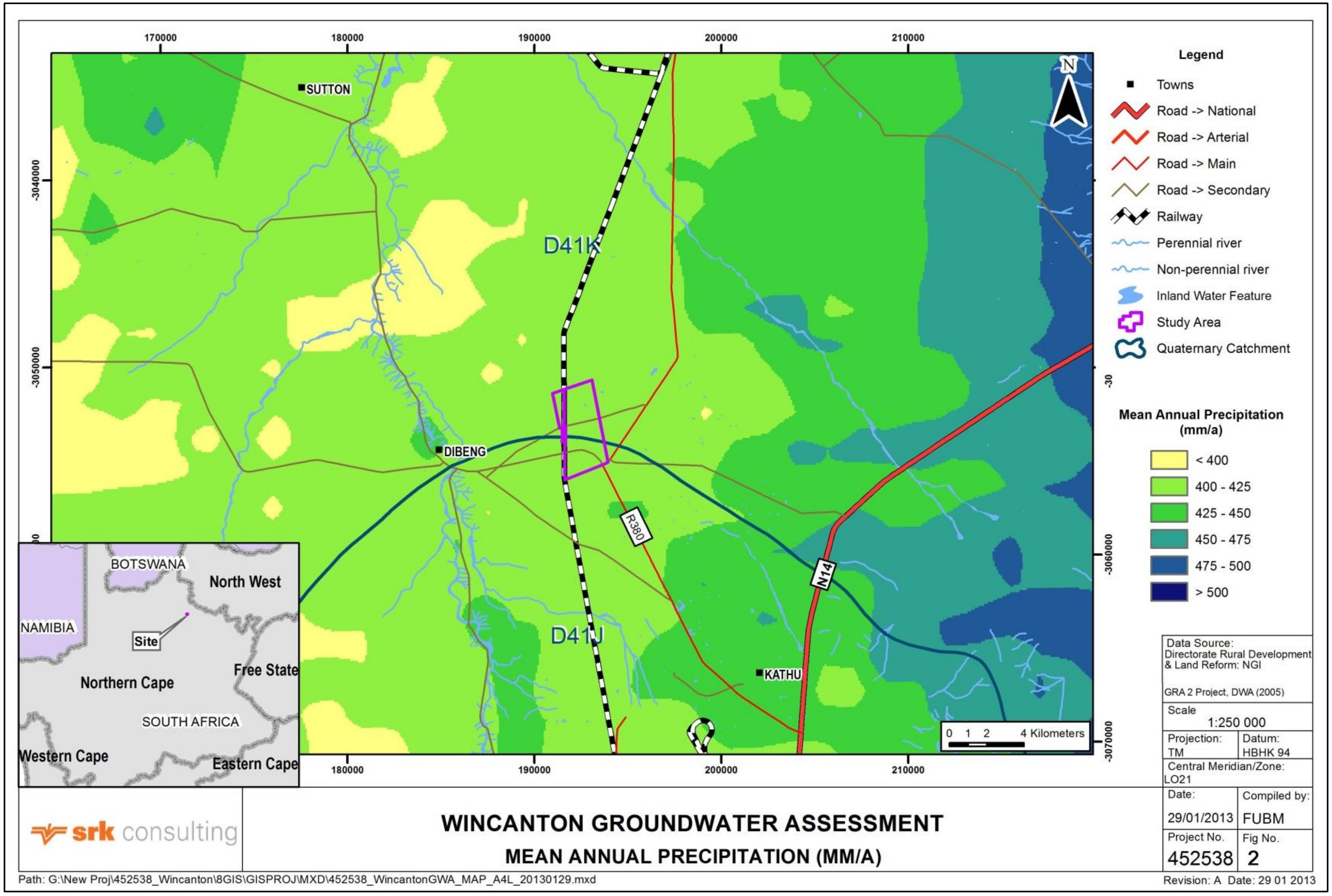


Figure 2: mean Annual Precipitation of the Wincanton Area

4.2 Geology

The geology of the study area is depicted in **Figure 3** with the geological legend indicated in **Figure 4**. The geological map indicates that the site is exclusively underlain by Recent Age deposits of the Kalahari Group. These consist of surface limestone and windblown sand. The latter is exposed to the south-east of the study area and along the Ga Mogara River. Boreholes drilled in the area indicate that the surface limestone generally extends to 20-30 m bgl whereafter argillaceous material is normally intersected. Coarser material occurs normally near the base of the Kalahari Group which consists of coarse sand, fine gravel, coarse gravel and in palaeo channels, boulders at the base before bedrock is intersected. These sediments form a well-defined high yielding aquifer when intersected below the groundwater table. Dibeng is located along a regional SW-NE striking palaeo river channel, which has been infilled with Karoo sediments (tillites of the Dwyka Group). These sediments are covered by saturated younger Kalahari sediments to form a high yielding primary aquifer in this area. In the Dibeng area these sediments reach a vertical thickness of >40 m (Borehole G45383).

Sediments of the Asbestos Hills Formation outcrop c.18 km south-east of the study area near Kathu. These sediments consist of jaspilite, crocidolite, minor shale and mudstone of the Daniëlskuil Member and banded ironstone of the underlying Kuruman Member.

A few isolated outcrops of amygdaloidal lava of the Ongeluk Formation occur c.17 km east of the site along the Vlermuisleegte. This Formation is separated from the underlying Daniëlskuil Member by the thin Makganyane diamictite Formation. Although this Formation is completely covered in the Wincanton area, it forms an important aquifer, which can yield significant volumes of groundwater.

4.3 Hydrogeology

4.3.1 Aquifer Type

Groundwater in this area occurs in both unconfined intergranular and semi-confined fractured-rock aquifers (**Figure 5** on page 9). These aquifers are also known as primary and secondary aquifers, respectively. Secondary aquifers are formed by jointing and fracturing of the otherwise solid bedrock by compressional and tensional forces that operates in the Earth’s crust from time to time. The fractures are formed by faulting, folding, intrusion of dolerite dykes and kimberlite fissures, cooling of massive lava outflows and other geological forces. Generally the fractured, groundwater bearing zones are narrow and steep dipping. Therefore the correct location of successful boreholes relative to these structures is of crucial importance. On the other hand primary aquifers occur over relative large areas and do not change significantly over short distances. Therefore the siting of production boreholes in these aquifers is normally less challenging.

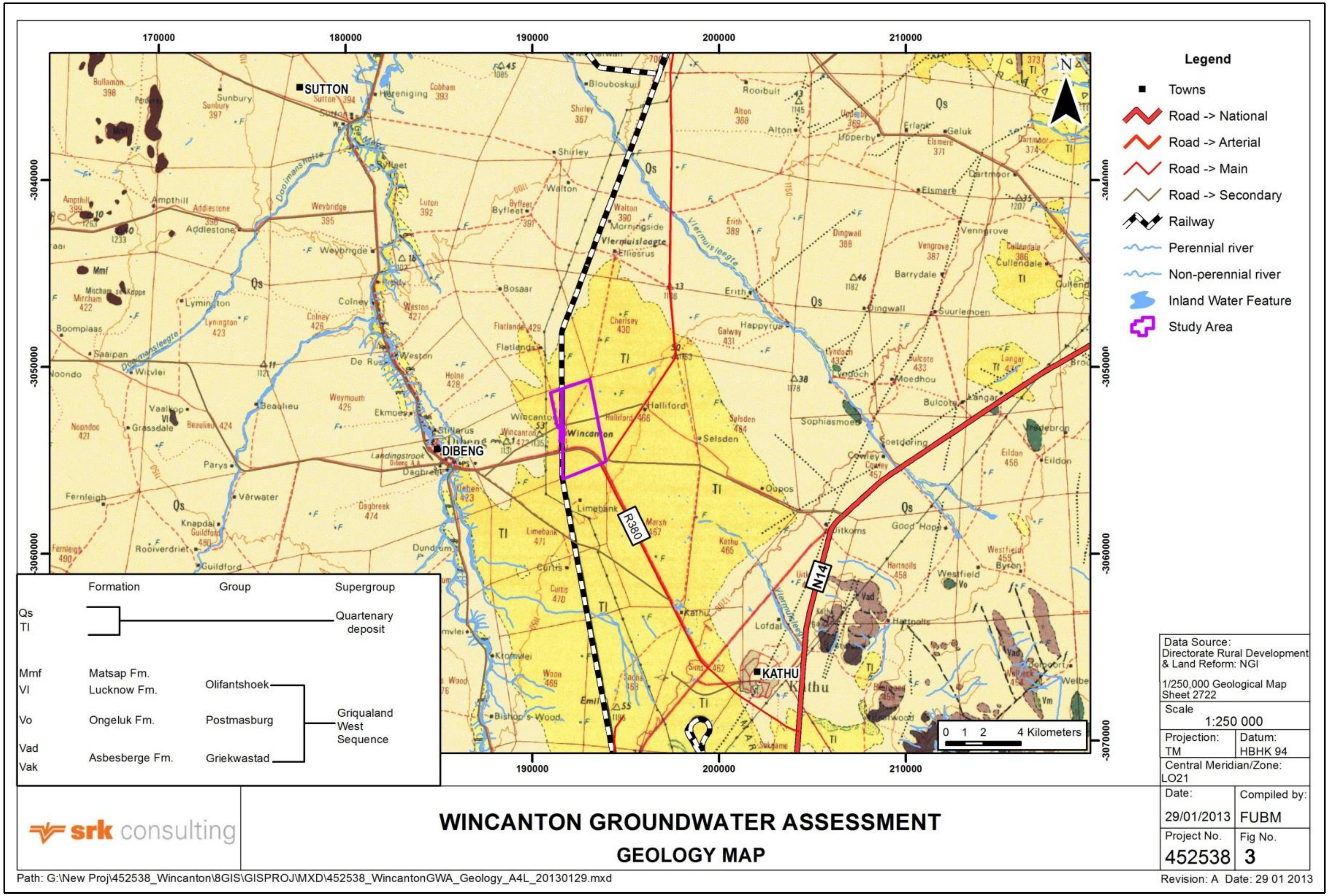


Figure 3: Geology of the Wincanton Area (after Council for Geoscience)

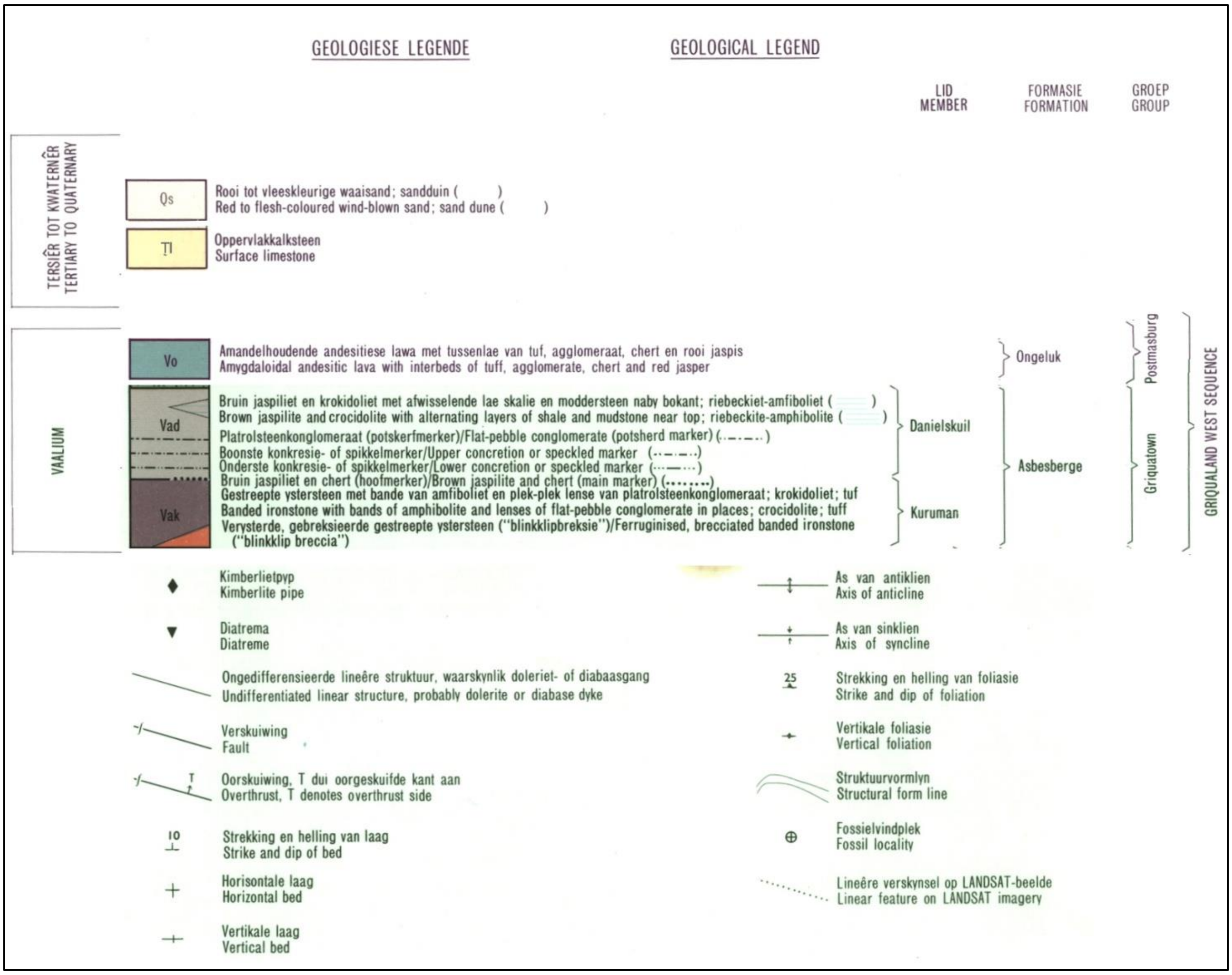


Figure 4: Geological Legend for Figure 3

Unconfined interganular aquifers occur where the groundwater level is intersected in loose unconsolidated material like silt, sand, gravel and boulders. In the study area these sediments are linked to palaeo drainage channels. The unconsolidated deposits and weathered zones are well developed to relative great depths in several localities in this area, which forms a prominent, high yielding primary aquifer with significant groundwater exploitation potential.

Figure 5 indicates that the eastern part of site is underlain by an intergranular and fractured rock aquifer with an average yield of 0.1 to 0.5 ℓ/s. The area immediately west of the site is underlain by an intergranular primary aquifer. Average borehole yields of successful boreholes drilled in this area vary between 0.1 and 0.5 ℓ/s.

4.3.2 NGA Data

The geohydrological information for this area was retrieved from the NGA and is summarized in **APPENDIX 2** at the back of this report. **Figure 6** on page 10 indicates the localities of the NGA boreholes.

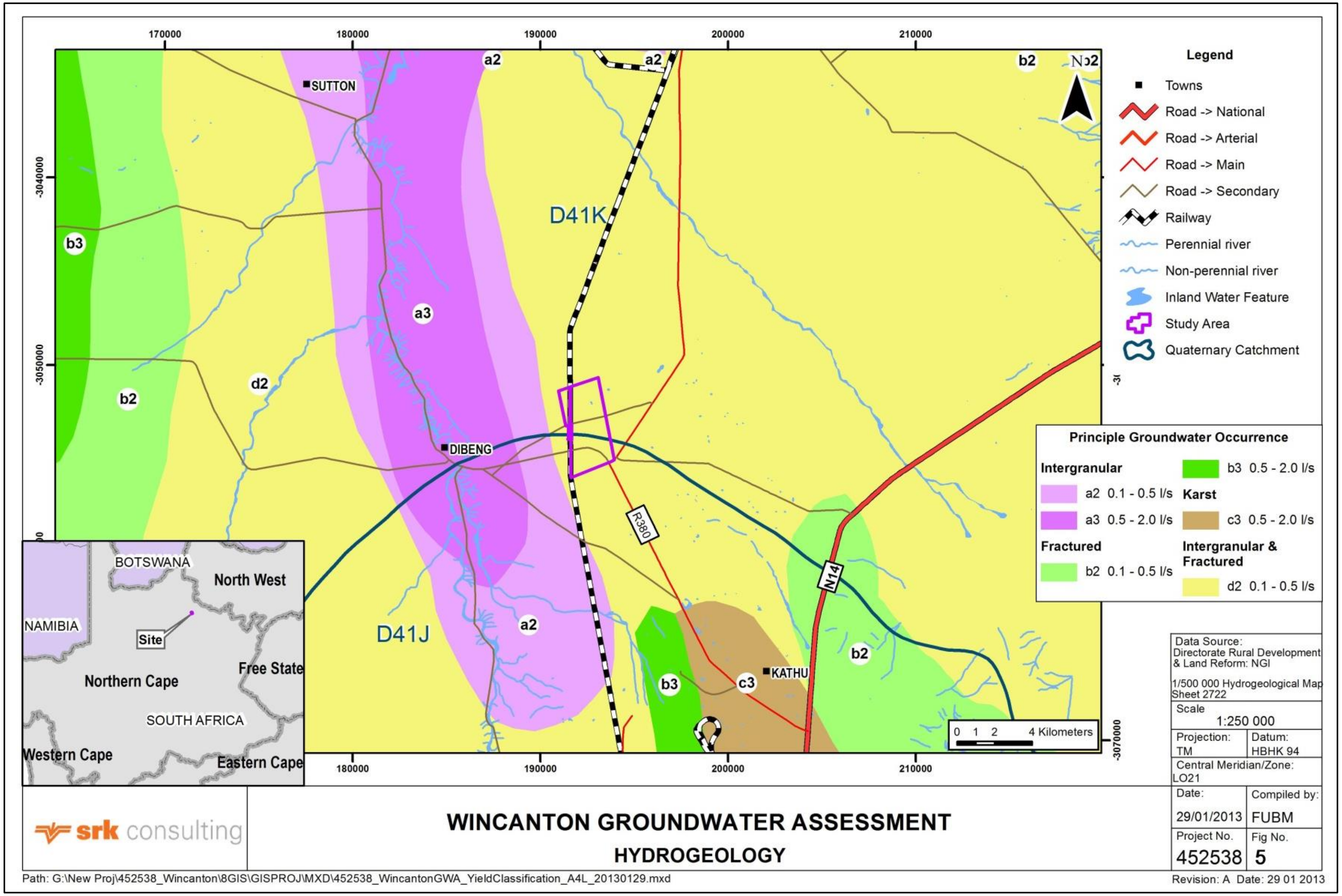


Figure 5: Aquifer Type and Yield Potential in the Wincanton Area (after the DWA 1:500 000 scale Hydrogeological Map Series Data)

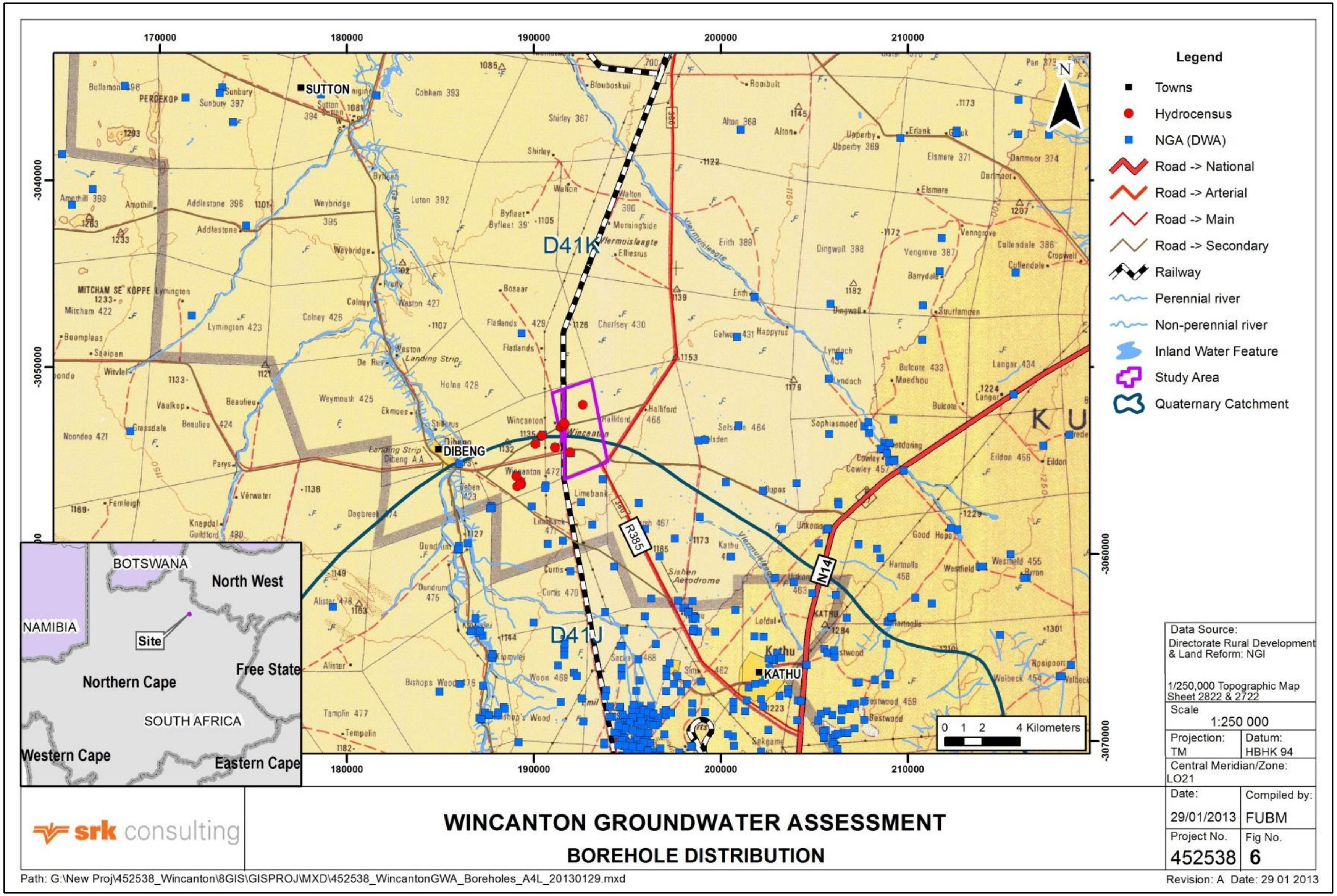


Figure 6: Borehole Localities in the Wincanton Area

Appendix 2 indicates that the average borehole depth for this area is c.128 m bgl and the median borehole depth is 100 m bgl. The average yield of successful boreholes is c.9 ℓ/s compared to the median yield of 0.47 ℓ/s. This emphasizes the fact that the average borehole yield is largely skewed by a few extraordinary high yielding boreholes. Therefore, the median yield is a much better indication of the yield that can be expected from a successful borehole drilled in this area.

No field measured EC's and pH's were recorded in the NGA data, but EC's are expected to be <150 mS/m throughout this area unless the groundwater is locality polluted by surface sources like kraals, soak away pits, etc.

4.3.3 Hydrocensus Results

The hydrocensus results are summarized in **Table 3** over page with the localities of these boreholes indicated in **Figure 6** on the previous page. Sixteen boreholes were surveyed on the property and surrounding area. Some NGA boreholes indicated on the map could not be located during the hydrocensus. These boreholes have likely collapsed or their coordinates are incorrect. Of the surveyed boreholes, nine were equipped – one with a mono pump, four with electrical submersible pumps and four with windpumps. All equipped boreholes are used for stock watering and/or domestic purposes.

During the hydrocensus survey very little geohydrological data such as borehole depths, yields, groundwater strikes and depth of pump intakes could be obtained from the owners. Other relevant geohydrological data such as groundwater levels, quality, equipment, etc. were measured and recorded. Simultaneously, the local geology and positions of possible groundwater bearing structures were noted to identify possible vulnerable areas.

Borehole WIN1 is 49 m deep and has a maximum immediate yield of >20 ℓ/s, although the installed mono pump yields only c.8 ℓ/s. The yield of the submersible pump installed in borehole WIN2 is lower at 1.4 ℓ/s, and the reported blow out yield is 4.2 ℓ/s. This significant difference in borehole yield over a short distance in a primary aquifer can only be explained by poor borehole construction or blow out yields that were affected by air loss. All the surveyed boreholes are believed to abstract groundwater from gravel in the Kalahari sediments and therefore borehole yields will not differ significantly over relative short distances and assuming that all the boreholes have been optimally constructed.

With the hydrocensus information on hands, four suitable boreholes were identified to yield test. However, on closer inspection all these boreholes were invaded by roots or had collapsed. Therefore a new production borehole, WNE1, had to be constructed.

Field measured EC's are in the order of 70 mS/m and thus, based on the EC measurements groundwater can be classified as fit for human consumption.

Table 3: Summary of Hydrocensus Results in Study Area.

Bh Number	Equipment	Depth (m bgl)	Latitude	Longitude	Water Level (m bgl)	EC in mS/m	pH	Use	Estim. Abstrac-tion (m^3/a)	Comments
139	Windpump		-27.58664	22.92488	15.03			Stock	1,135	
WIN4	Windpump		-27.58275	22.92818				None		40m from Bh 140. Collapsed
140	Submersible pump		-27.58249	22.92845	Closed	66	7.55	Domestic, Stock	5,475	
141	Submersible pump		-27.58812	22.93552	Closed	68	7.9	Domestic, Stock	7,300	Guesthouse
WIN1	Mono Pump	49	-27.60622	22.91776	15.16	66	7.77	Solar Farm	6,753	Wincanton Solar Farm, Yield >20 ℓ/s
WIN2	Submersible pump	42	-27.60715	22.91546	15.89	54	7.69	Domestic, Stock	3,650	Borehole yield 15m^3/h, Pumps @ 5 m^3/h
WIN3	Open		-27.60494	22.91728	16.21					
142	None		-27.60234	22.91487				None		Dry
143	Windpump	71	-27.59037	22.94383	15.67	68	7.78	Stock	1,135	
WIN5	Windpump		-27.56733	22.95032	Closed	70	7.81	Stock	1,135	
WIN6			-27.57846	22.93840	Closed				2,271	
WIN7	Submersible Pump		-27.57784	22.93930	Closed	71	7.62	Domestic, Stock	5,256	
WIN8			-27.57746	22.94033						
WIN9			-27.57684	22.94062						
WIN10			-27.57631	22.94038						
138	None		-27.60630	22.91694				None		Collapsed
Hydrocensus conducted on 21-Aug-2012								**TOTAL ABSTRACTION**	**34,110**	**m^3/a**

4.3.4 Drilling Results

A new production borehole was drilled during the period 11 to 12 June 2013 by Radisson Drilling on request of the client. The drill site was selected near current collapsed and blocked boreholes and close to the proposed solar farm. **Table 4** below summarizes the drilling results.

Table 4: Drilling results obtained at Wincanton

Bh No:	**WNE1**	**Lat**	**Long**			
	Start: 11/06/2013 Stop: 12/06/2013	**-27.57623**	**22.94028**			
Depth (m bgl)	**Geology**	**Water Strike (m bgl)**	**Blow Yield (ℓ/s)**	**EC (mS/m)**	**pH**	**Comments**
0 - 3	White to yellow-brown weathered calcrete					
-4	Fine unconsolidated gravel					
-20	Calcified sand and fine gravel - weathers brown	15 - 18				Mudflow
-30	Fine to medium gravel	20 - 32	9.50	70	7.55	
-36	Very coarse gravel and cobblestone	32 - 36	40.00	68	7.50	Borehole collapses, cannot penetrate deeper
	Water Level = 12.69 m bgl (12/06/2013 11h30)					
	Construction					
0 - 36	254mm Air Percussion drilling 36m x203mm ID x 4.5mm Wall thickness steel casing, Perforated 18-36 m bgl.					

A small volume of groundwater was intersected in calcified gravel from 15 to 18 m bgl. However, significant volumes of groundwater were intersected in unconsolidated gravel from 20 to 36 m bgl, with the main water strike occurring in very coarse gravel from 32 to 36 m bgl (see **Figure 7**). At 36 m bgl the blow yield was approximately 40 ℓ/s and no further penetration by means of air percussion drilling was possible at this level. The borehole was cased all the way with 203 mm steel casing which had been perforated from 18 to 36m bgl. Directly after completion the groundwater level was measured at 12.69 m below the borehole collar.

Figure 7: Coarse Gravel Intersected In Borehole WNE1

4.3.5 Current Abstraction

The current abstraction from the site and surrounding areas is estimated as 34 110 m^3/a. For the site the estimated current abstraction is 9 797 m^3/a. These estimates are based on pump yields and reported pumping schedules. No significant irrigation takes place on the site or the surrounding areas.

4.3.6 Aquifer Vulnerability

Figure 8 on page 14 shows aquifer vulnerability as determined by evaluating seven parameters, namely:

- Depth to groundwater;
- Recharge;
- Aquifer media;
- Soil media;
- Topography;
- Impact on vadose zone; and
- Hydraulic conductivity.

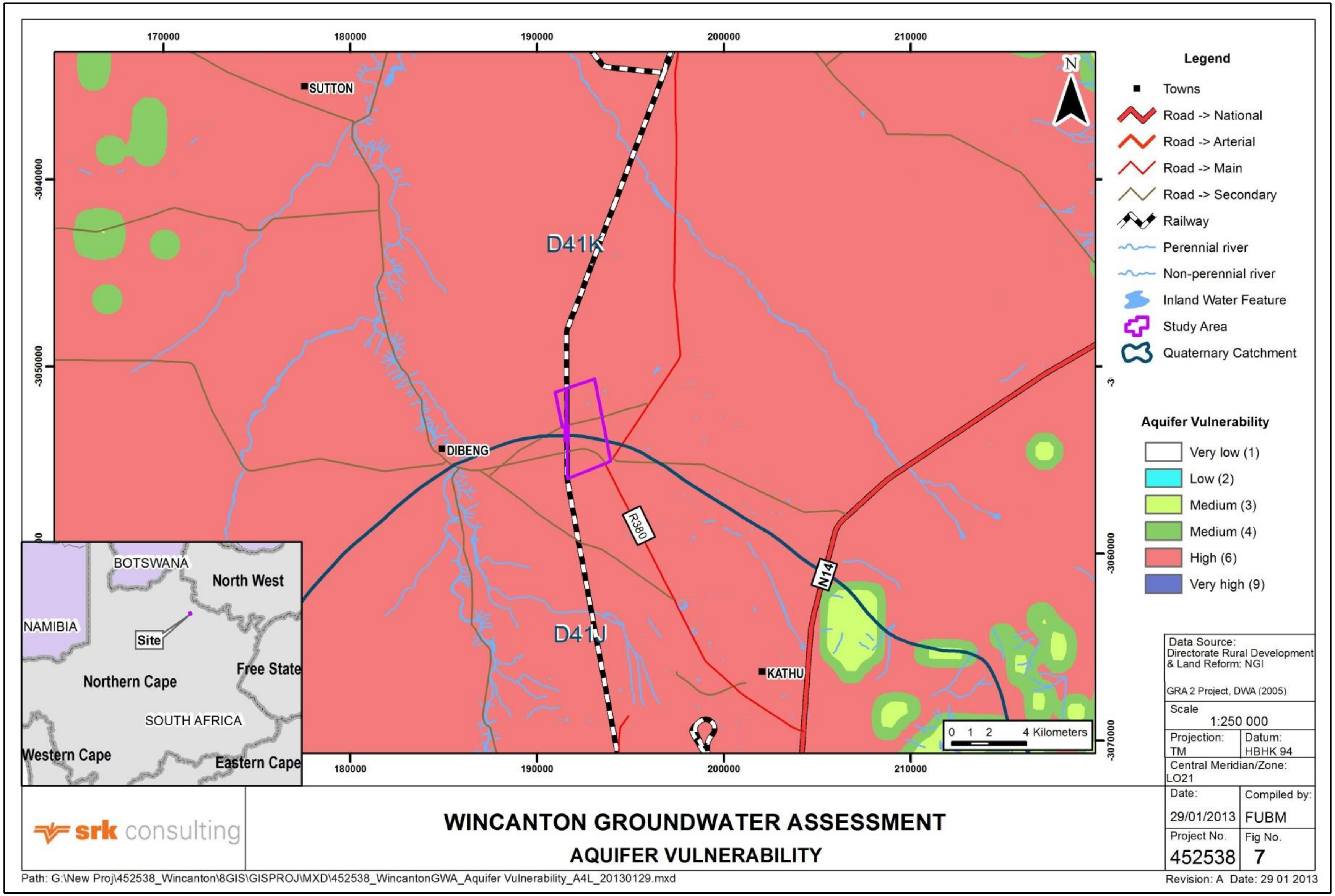


Figure 8: Aquifer Vulnerability Map of Wincanton Area

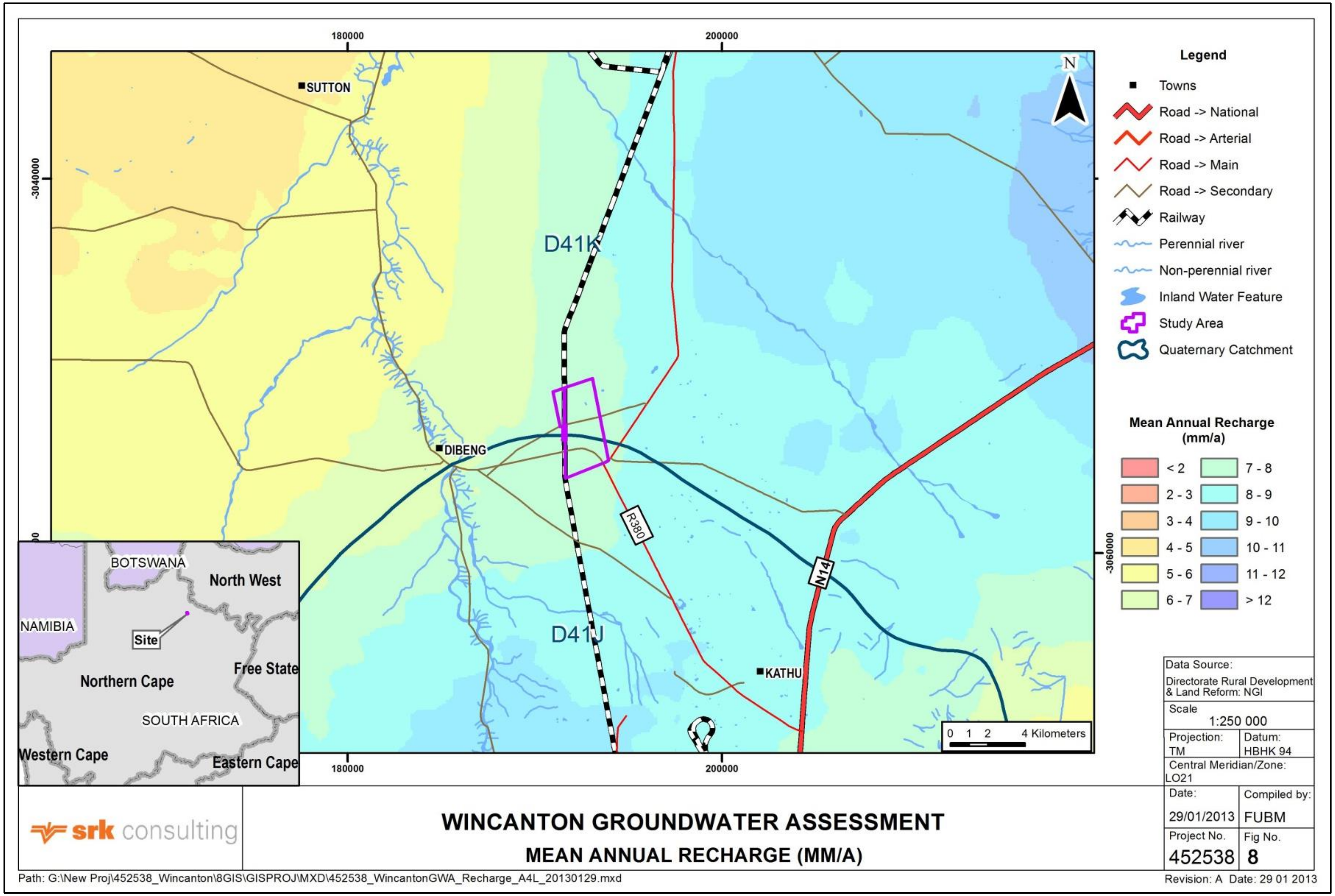


Figure 9: Groundwater recharge in the Wincanton area

Aquifer vulnerability is defined as the likelihood for contamination to reach a specified position in the groundwater system after being introduced at some point above the uppermost aquifer. The aquifers at Wincanton are classified as having high vulnerability to contamination mainly due to the relative shallow depth to the water table and transmissive, calcareous material on top of the main aquifer. The closest areas with medium groundwater vulnerability occur approximately 9 km southeast and 14 km northwest of the property, respectively.

4.3.7 Recharge

Groundwater recharge is defined as the addition of water to the zone of saturation, either by the downward percolation of precipitation or surface water and/or the lateral migration of groundwater from adjacent aquifers. The average annual recharge in mm of the area is represented in **Figure 9** on page 15. Recharge is reliant on rainfall and therefore it follows a similar distribution to rainfall with the highest recharge of 10-11 mm/a occurring in the hilly areas east of the site and the lowest recharge of 4-5 mm/a occurring in the area northwest of Dibeng. At Wincanton the average recharge is 7-8 mm/a, which equates to c.2.2% of the MAP value obtained from the GRA2 data.

4.3.8 Groundwater Resource Potential

The site straddles both Quaternary Drainage Regions D41J and D41K (see **Figure 8**). For both regions the amount of water available under General Authorisation is listed under Zone A of the Groundwater Taking Zones, where no water may be taken from these drainage regions except as set out under Schedule 1[1] and small industrial users[2] (DWAF, 2004). Small industrial use allows for a maximum groundwater abstraction of 20 m^3/d.

One Groundwater Resource Unit (GRU), based on the D41J Quaternary Catchment, was defined for this area (see **Figure 8**). The GRA2 grid datasets (DWAF, 2005) were used to derive the MAP, effective recharge and groundwater resource potential for this GRU. As boreholes cannot intersect all the available recharge in an area, an exploitability factor (DWAF, 2005) was used to calculate the volume of groundwater that can actually be abstracted through boreholes. Current abstraction based on the hydrocensus data was subtracted from this value to determine the current Groundwater Exploitation Potential (GEP). The GEP for the area covered by the site (9.86 km^2) was also calculated. These calculated values are summarised in **Table 5** over page.

[1] Not taking more than 10 cubic metres from groundwater on any given day.

[2] •"Small industrial users" mean water users who qualify as work creating enterprises that do not use more than twenty cubic metres per day (i.e. 20 000 litres/day) and identified in the Standard Industrial Classification of All Economic Activities (5th edition), published by the Central Statistics Service, 1993, as amended and supplemented, under the following categories:-

a) 1: food processing;
b) 2: prospecting, mining and quarrying;
c) 3: manufacturing;
d) 4: construction

Table 5: Groundwater Exploitation Potential of Wincanton Area

Quaternary Catchment	Area (km^2)	Exploi-tability Factor	Pota-bility Factor	Drought Index years	Annual Abstraction (m^3/a/catch-ment)	Annual Potential Recharge (m^3/a/catchment)		Groundwater Resource Potential based on Recharge (m^3/a/catchment)		Groundwater Exploitation Potential based on Recharge (m^3/a/catchment)	
						Normal (Mean)	Dry	Normal (Mean)	Dry	Normal (Mean)	Dry
		Ef	Pf	Di	At	Re	Re (dry)	AGRP	AGRP (dry)	GEP	GEP (dry)
D41J	3873.63	0.4084	0.9569	36.95	1,924,240	27,606,700	18,295,600	25,682,460	16,371,360	10,488,717	6,686,063
D41K	4212.77	0.3516	0.8077	264.89	294,854	29,135,400	19,203,500	28,840,546	18,908,646	10,140,336	6,648,280
Wincanton	9.86	0.8500	1.0000	36.95	9,797	70,297	46,587	60,500	36,790	51,425	31,272

The GRA2 data indicate that the site has an estimated average mean recharge of approximately 70 300 m^3/a. Once the proposed PVSEP Plant is operative, less groundwater will be abstracted for other purposes on this property. Therefore, the current calculated abstraction of 9 797 m^3/a will decrease significantly. The calculated water demand for the plant will be maximum c.49 353 m^3/a during the construction phase, which is c.70% of the mean annual recharge on this property. If this demand is added to the current abstraction the total future abstraction on the property will be c.84% of the mean potential recharge. This can be regarded as a worst case scenario as the current abstraction will decrease significantly once the PVSEP is in operation. Therefore, supplying the water demand of the PVSEP Plant from groundwater should not have any significant effects on the groundwater resources of the site and those of the neighbouring properties. The water demand during operation will be c.20% of the mean potential recharge.

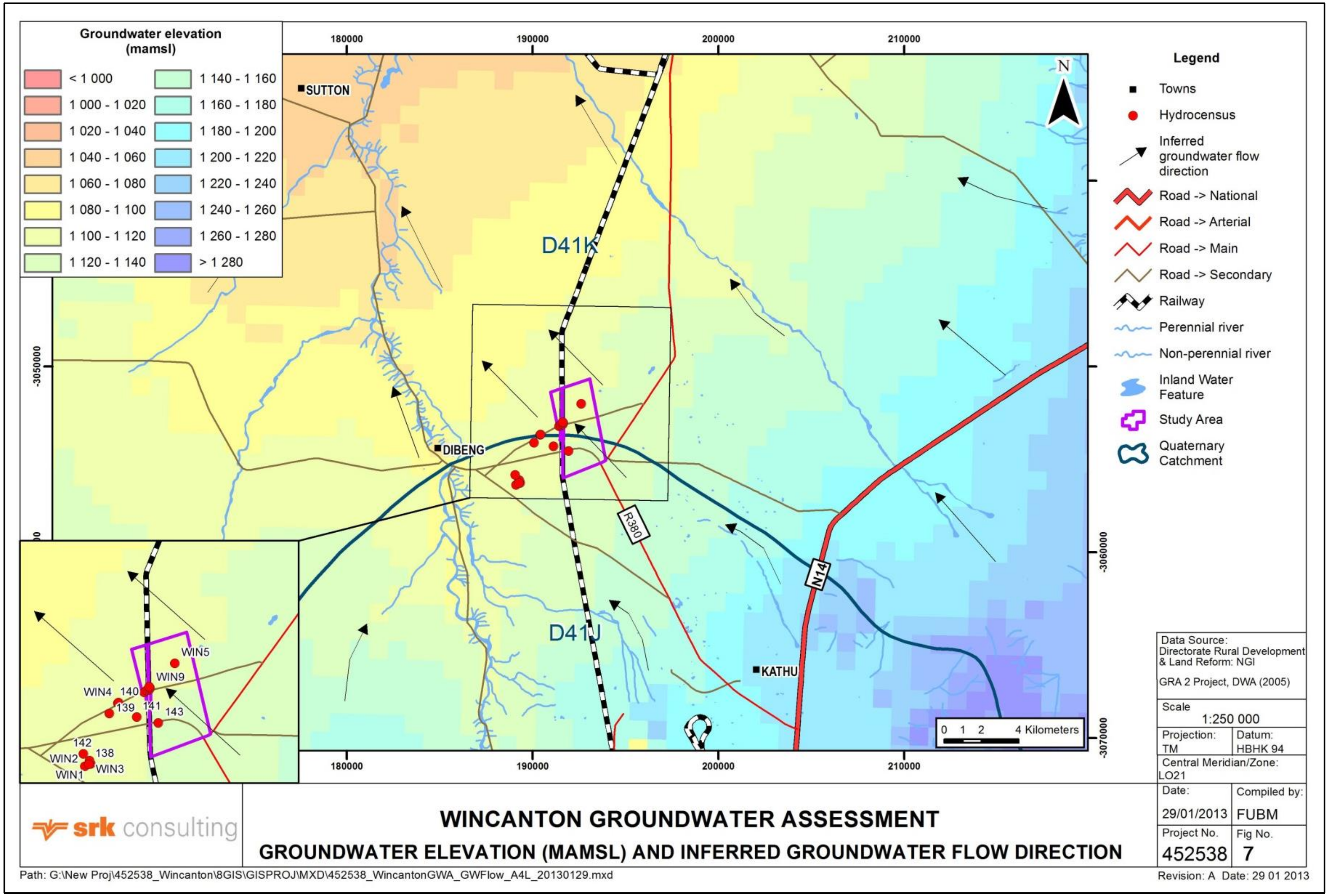


Figure 10: Inferred Groundwater Flow Directions in the Wincanton Area

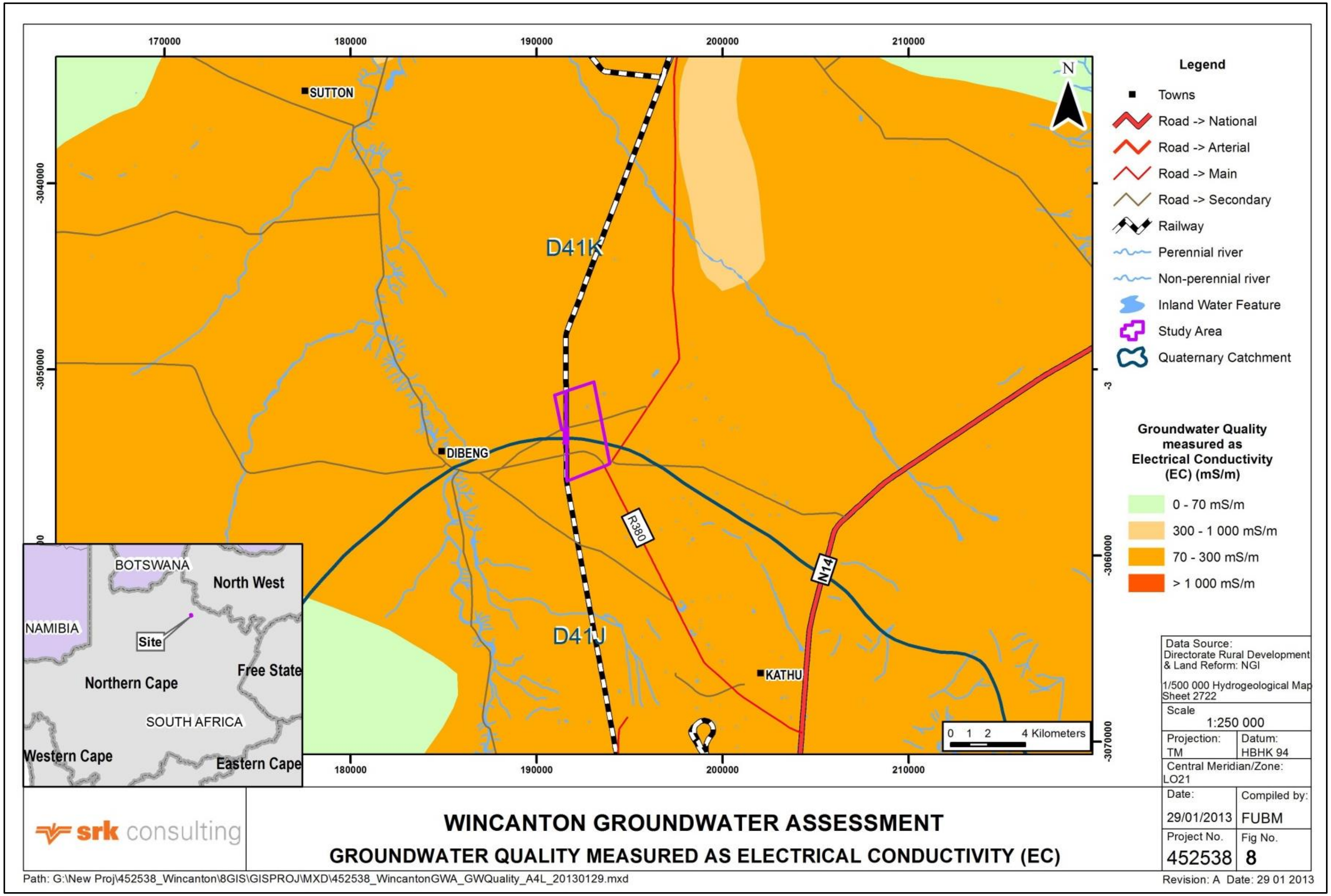


Figure 11: Groundwater Salinity in Wincanton Area

4.3.9 Depth to Water Table and Inferred Groundwater Flow Directions

The hydrocensus data indicate that the depth to water table in the study area is c.15 m bgl. These data and data from the NGA were used to plot the groundwater elevations on the topographical map, from which the groundwater flow directions were inferred (**Figure 10**). The groundwater elevations generally mimics the surface elevation contours and generally flows in a north-westerly direction from higher lying to lower lying areas. Locally the inferred flow at the site is westwards towards the Ga Mogara River.

4.3.10 Groundwater Quality

The groundwater salinity, expressed as Electrical Conductivity (EC) in mS/m of the site is graphically depicted in **Figure 11**. The map, which is based on the DWA hydrogeological map series, indicates that the groundwater quality throughout the area falls in the range of 70-300 mS/m. Field measured EC's of groundwater from equipped boreholes in the area are in the order of 70 mS/m, which correlates well with the map's suggested range of values.

Based on field measured EC's the groundwater throughout the study area is suitable for long term human consumption[3]. Slight variations in groundwater quality are expected in areas where the groundwater is polluted by over flowing dams and kraals.

4.3.11 Lineament Mapping

The study area is totally covered by relatively thick Kalahari sediments, which conceal all geological lineaments in the bedrocks. Therefore, no lineament mapping was conducted for this area as groundwater occurs in a primary, intergranulated aquifer and the occurrence thereof in the primary aquifer is not linked to secondary geological structures.

4.3.12 Yield Testing

The newly drilled borehole WNE1 was yield tested by Welltek Services during the period 19 – 23 June 2013. The initial water level was 15.51 mbc and the measured borehole depth is 35 m bgl. The borehole was submitted to a step drawdown test (SDT) consisting of four one hour steps at discharge rates of 2.13, 4.10, 6.22 and 8.26 ℓ/s, respectively. The final drawdown at the end of the last step was only 3.96 m. As the proposed PVSEP will not use large volumes of water, it was decided to use a small pump (maximum yield of 8 ℓ/s) for the yield testing in order to save cost. Water level recovery after pump switch-off was rapid with full recovery occurring after 40 minutes. Subsequently, a 72-hour constant discharge test (CDT) at an average discharge rate of 7.26 ℓ/s was carried out. The final water level drawdown at the end of this test was 4.03 m. A distinctive increase in the drawdown rate, similar to a boundary effect, is noticed after approximately 850 minutes of pumping. However, the gradient of the drawdown graph again flattens towards the end of the test. The reason for this behaviour is yet unknown. Water level recovery after pump shutdown was again rapid with full recovery occurring after 720 minutes (12 hours), which is significantly less than the pumping time. The yield test data were analysed by means of the FC-method (Van Tonder & Xu, 1999) programme to determine the long term sustainable yield of the borehole. In the FC analyses a recharge of 2.2% of the MAP, or 7.5 mm/a, was allowed for. An available drawdown of 7.5 m (the distance between the rest water level and first significant water strike) was used in the calculations and the drawdown was extrapolated for two years. The data were also analysed by means of the Recovery Method where the rate of recovery after completion of the yield test is used to determine the long term sustainable yield. This method normally

[3] $\leq$150 mS/m is acceptable for long term human consumption (SANS, 241-2006)

calculates conservative yields. The yield test data and diagnostic plots are included in **APPENDIX 3** at the back of this report. The log derivative value of 0.10 indicates a very good fracture network.

Table 6: Sustainable Yield of Borehole WNE1 as Calculated by the FC-method

Summary		Main		WNE1			
Applicable	Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)	Late T (m^2/d)	S	AD used
☑	Basic FC	4.09	2.51	485	45.7	2.20E-03	7.5
☐	Advanced FC			485	45.7	2.20E-03	7.5
☑	FC inflection point	2.52	1.20				3.0
☑	Cooper-Jacob	5.23	3.39		197.0	1.45E-04	7.5
☑	FC Non-Linear	3.31	2.92	145.0		1.00E-03	7.5
☑	Barker	4.73	4.47	K_f = 27	S_s =	2.00E-03	7.5
	Average Q_sust (l/s)	3.98	1.09	b = 3.02	Fractal dimension n =	2.23	
						1.34E-03	
	Recommended abstraction rate (L/s)		4.00	for 24 hours per day			
	Hours per day of pumping	12	5.66	L/s for 12	hours per day		
	Amount of water allowed to be abstracted per month		10368	m^3 or 340.9	m^3/day		

Table 6 above summarizes the calculated sustainable yield obtained by the FC and other methods. These methods indicate a long term sustainable yield of 4 ℓ/s at continuous pumping, i.e. 345.6 m^3/d. The calculated fractal dimension of 2.23 indicates radial flow which suggests that groundwater does not flow in a preferred direction during pumping. This is to be expected given that the borehole penetrates an intergranular aquifer. **Table 7** below summarizes the calculations of the Recovery method.

Table 7: Sustainable Yield of Borehole WIN1 As Calculated by the Recovery Method

Borehole WNE1 - Recovery Analysis	
Duration of test (min)	4320
Duration for full recovery (min)	720
Average yield (ℓ/s)	7.26
Sustainable yield based on recovery (m^3/d)	537.7
Sustainable yield (ℓ/s @ 24h/d pumping)	6.2

The recovery method yields normally conservative values, but in this case the sustainable yield calculated by this method is significantly more than that calculated by the FC and other methods. However, the more conservative value of the FC-method is recommended which is >11 times the estimated peak water demand. Therefore it is safe to predict that this borehole can easily satisfy the required demand.

5 Possible Impacts and Mitigation Measures

Table 8 over page indicates possible groundwater impacts during the construction, operation and decommission phases of the PVSEP Plant without any mitigation measures taken. Mitigation measures need to be implemented to minimise identified impacts during all phases of the project life-cycle (construction, operation and decommissioning). These measures are also indicated in this table. **Table**

9 indicates the severity of the impacts with the proposed mitigation measures applied. It is clear that these measures significantly reduce the risk of groundwater contamination. Therefore it is essential that these measures be implemented as part of the normal plant operation.

Table 8: Possible Groundwater Impacts Without Mitigation Measures

Construction Phase: Groundwater impacts

	Status of Impacts		Spatial Scale of Impacts		Temporal scale of impacts		Probability of Impacts		Severity of Impacts		Significance of impacts	
Impact description	Rating	Quan-tative Rating	Rating	Quan-tative Rating	Rating	Quan-tative Rating	Rating	Quan-tative Rating	Rating	Quan-tative Rating	Rating	Quan-tative Rating
Groundwater abstraction	Negative	-	Low	1	Low	1	Improbable	1	Minor	1	Low	4
Oil and Fuel spills	Negative	-	Low	1	Low	1	Probable	2	Average	2	Medium	6
Groundwater contamination from on site sanitation	Negative	-	Medium	2	Medium	2	Probable	2	Average	2	Medium	8

Essential mitigation measures:

- Place oil traps under stationary machinery, Only re-fuel machines at fuelling station, Construct structures to trap fuel spills at fuelling station, Immediately clean oil and fuel spills and dispose contaminated material (soil, etc.) at licensed sites only
- Place plastic sheets on surface where salt is up- or unloaded to collect spilled salt
- A procedure for the storage, handling and transport of different hazardous materials must be drawn up and strictly enforced.
- A groundwater monitoring system must be implemented to monitor groundwater quality and water levels.
- Ensure vehicles and equipment are in good working order and drivers and operators are trained.
- Make use of sewage tanks for sanitation purposes and remove sewage to municipal sewage works.
- Ensure that good housekeeping rules are applied.

Operational Phase: Groundwater impacts

	Status of Impacts		Spatial Scale of Impacts		Temporal scale of impacts		Probability of Impacts		Severity of Impacts		Significance of impacts	
Impact description	Rating	Quan-tative Rating	Rating	Quan-tative Rating	Rating	Quan-tative Rating	Rating	Quan-tative Rating	Rating	Quan-tative Rating	Rating	Quan-tative Rating
Groundwater abstraction	Negative	-	Low	1	Low	1	Improbable	1	Minor	1	Low	4
Oil and Fuel spills	Negative	-	Low	1	Low	1	Probable	2	Average	2	Medium	6
Groundwater contamination from on site sanitation	Negative	-	Medium	2	Medium	2	Probable	2	Average	2	Medium	8

Essential mitigation measures:

- Minimise waste water by the appropriate engineering design and re-use for other purposes where possible.
- A procedure for the storage, handling and transport of different hazardous materials must be drawn up and strictly enforced.
- Ensure vehicles and equipment are in good working order and drivers and operators are trained.
- Place oil traps under stationary machinery, Only re-fuel machines at fuelling station, Construct structures to trap fuel spills at fuelling station, Immediately clean oil and fuel spills and dispose contaminated material (soil, etc.) at licensed sites only
- Place plastic sheets on surface where salt is up- or unloaded to collect spilled salt
- A groundwater monitoring system must be implemented to monitor groundwater quality and water levels.
- Sewage tanks must be constructed and sewage removed to municipal treatment works.
- Ensure that good housekeeping rules are applied.

Decommisioning Phase: Groundwater impacts

	Status of Impacts		Spatial Scale of Impacts		Temporal scale of impacts		Probability of Impacts		Severity of Impacts		Significance of impacts	
Impact description	Rating	Quan-tative Rating	Rating	Quan-tative Rating	Rating	Quan-tative Rating	Rating	Quan-tative Rating	Rating	Quan-tative Rating	Rating	Quan-tative Rating
Oil and Fuel spills	Negative	-	Low	1	Low	1	Probable	2	Average	2	Medium	6
Groundwater contamination from on site sanitation	Negative	-	Low	1	Low	1	Probable	2	Average	2	Low	6

Essential mitigation measures:

- A procedure for the storage, handling and transport of different hazardous materials must be drawn up and strictly enforced.
- Ensure vehicles and equipment are in good working order and drivers and operators are trained.
- Place oil traps under stationary machinery, Only re-fuel machines at selected re-fuelling points, construct structures to trap fuel spills at re-fuelling points, Immediately clean oil and fuel spills and dispose contaminated material (soil, etc.) at licensed sites only
- Place plastic sheets on surface where salt is uploaded to collect spilled salt
- Sewerage tanks must be rehabilitated.
- Ensure that good housekeeping rules are applied.

Table 9: Possible Groundwater Impacts With Mitigation Measures

Construction Phase: Groundwater impacts												
	Status of Impacts		Spatial Scale of Impacts		Temporal scale of impacts		Probability of Impacts		Severity of Impacts		Significance of impacts	
Impact description	Rating	Quan-tative Rating	Rating	Quan-tative Rating	Rating	Quan-tative Rating	Rating	Quan-tative Rating	Rating	Quan-tative Rating	Rating	Quan-tative Rating
Oil and Fuel spills	Negative	-	None	0	None	0	Improbable	1	Minor	1	Low	2
Groundwater abstraction	Negative	-	None	0	None	0	Improbable	1	Minor	1	Low	2
Groundwater contamination from on site sanitation	Negative	-	None	0	None	0	Improbable	1	Minor	1	Low	2
Operational Phase: Groundwater impacts												
	Status of Impacts		Spatial Scale of Impacts		Temporal scale of impacts		Probability of Impacts		Severity of Impacts		Significance of impacts	
Impact description	Rating	Quan-tative Rating	Rating	Quan-tative Rating	Rating	Quan-tative Rating	Rating	Quan-tative Rating	Rating	Quan-tative Rating	Rating	Quan-tative Rating
Groundwater abstraction	Negative	-	None	0	None	0	Improbable	1	Minor	1	Low	2
Oil and Fuel spills	Negative	-	None	0	None	0	Improbable	1	Minor	1	Low	2
Groundwater contamination from on site sanitation	Negative	-	None	0	None	0	Improbable	1	Minor	1	Low	2
Decommisioning Phase: Groundwater impacts												
	Status of Impacts		Spatial Scale of Impacts		Temporal scale of impacts		Probability of Impacts		Severity of Impacts		Significance of impacts	
Impact description	Rating	Quan-tative Rating	Rating	Quan-tative Rating	Rating	Quan-tative Rating	Rating	Quan-tative Rating	Rating	Quan-tative Rating	Rating	Quan-tative Rating
Oil and Fuel spills	Negative	-	None	0	None	0	Improbable	1	Minor	1	Low	2
Spills when rehabilitating sewage tanks	Negative	-	None	0	None	0	Improbable	1	Minor	1	Low	2

6 Conclusions

Based on the information discussed in this report the following can be concluded regarding the groundwater conditions at the site:

- The proposed PVSEP Plant has calculated peak water demands of 135 m^3/d and 39 m^3/d during the construction and operational phases respectively. These equate to 49 353 m^3/a and 14 235 m^3/a, respectively;
- The mean annual recharge for the site and surrounding area is 7-8 mm/a or c.2.2% of the MAP (obtained from GRA2 data)
- Mean annual recharge for the site is estimated at 70 300 m^3, which is c.5 times the anticipated demand during operation and therefore this proposed abstraction will unlikely have a negative effect on surrounding groundwater users;
- Groundwater in this area occurs mainly in an intergranular, primary aquifer associated with gravel beds at the base of the Kalahari Group;

- Average yield of successful boreholes is 9.0 ℓ/s compared to the median yield of 0.47 ℓ/s, which emphasizes the fact that the average borehole yield is skewed by a few extraordinary high yielding boreholes;
- Maximum immediate yields of boreholes drilled in this area vary largely between 0.0 (dry) and 44.4 ℓ/s;
- Sixteen boreholes were identified on the site and surrounding area during the hydrocensus of which nine are operative and equipped with a Mono pump (1), windpumps (4) and electrical submersible pumps (4). Groundwater levels obtained at these boreholes are relative shallow at 15 - 16 m bgl;
- An estimated 9 797 m^3 of groundwater is abstracted per annum from these boreholes;
- No large scale irrigation occurs in the area and groundwater abstracted from boreholes is mainly used for stock watering and some domestic purposes;
- Groundwater quality, measured as salinity (EC), in the study area is generally good and in the order of 70 mS/m, which is from a salinity perspective fit for long term human consumption;
- The General Authorisation for taking of groundwater from Drainage Region D41J and D41K, in which the site is located, is zero, except for schedule one and small scale industrial purposes;
- The predicted water demands of 135 m^3/d during construction and 39 m^3/d during the operational phase are both more than the maximum volume allowed for small scale industrial use under Schedule 1;
- The aquifer vulnerability at the proposed site and surrounding areas is high.
- Results obtained during the construction of new production borehole WNE1 were positive and the borehole had a blow yield of c. 40 ℓ/s.
- Yield tests conducted on borehole WNE1 indicate a long term sustainable yield of 4 ℓ/s at continuous pumping, i.e. 345.6 m^3/d, which is more than adequate to supply the anticipated demand of the proposed facility.
- With mitigation measures imposed, the impact of the PVSEP Plant on groundwater resources will be negligible.

7 Recommendations

Based on the conclusion of this report the following is recommended:

1. Potential sources of groundwater pollution such as on-site sanitation facilities required for the PVSEP Plant must be assessed and properly managed to prevent groundwater pollution;
2. Solar panels can be placed all over the area as these do not pose a groundwater pollution hazard;
3. All existing boreholes (used and unused) must be properly sealed at the surface to prevent surface pollution of the groundwater. This measure will also prevent bees from invading the boreholes;
4. The newly drilled borehole WNE1 can be operated as indicated in **Table 10**.

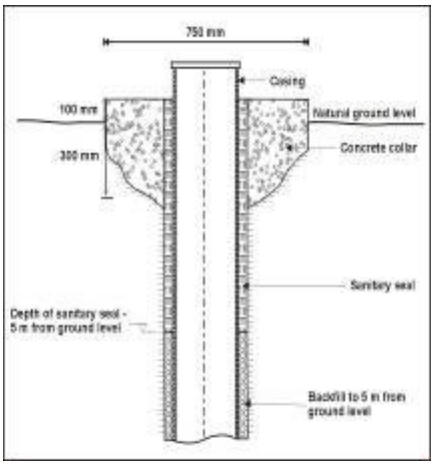
Table 10: Recommended operation for borehole WNE1

Bh No	Latitude (DD)	Longitude (DD)	Depth (m bgl)	Rest Water Level (m bgl)	Recom. Pump Intake (m bgl)	Max. Pump Water Level (m bgl)	Sustainable Yield		
							ℓ/s @ 24h/d pumping	m^3/day	m^3/a
WNE1	-27.57623	22.94028	35	12.51	25	20	4.0	345.6	126,144

5. Only borehole WIN9 is suitable as a monitoring borehole for production borehole WNE1 as all the other nearby boreholes are blocked or has partially collapsed;
6. Abstracted volumes and groundwater levels must be measured at production and monitoring boreholes preferably on a weekly basis, but at least monthly;
7. Rainfall must be recorded on a daily basis at the site;
8. Groundwater samples must be collected bi-annually and analysed by a SANAS accredited laboratory for macro-chemical and micro-biological constituents;
9. These data must be analysed by a qualified hydrogeologist at least on a yearly basis in order to identify red flag situations timeously and take the necessary preventative measures;
10. In order to safeguard the groundwater supplies from contamination and equipment from theft and damage, a zone of protection must be established around each production borehole.

The protection zone is an area of at least 50 m x 50 m, centred on the actual borehole. The following measures must be applied in this protection zone:

- No pit latrines, VIP's, soak-aways or septic tanks – to prevent effluent from percolating into the aquifer and borehole;
- No storage of fuel, lubricants or other hazardous substances without a leak prove;
- Production boreholes for domestic use must be equipped with a sanitary seal – to prevent contaminated surface water and spilled fuel from percolating down the casing into the borehole;
- The concrete collar around borehole casing must be at least 100 mm higher than the floor or surface level to prevent spilled fuel, water from leakages, wash water, etc. to enter the borehole;
- No ponding of surface water must be allowed, i.e. the area must be sloped for surface water to drain away from this zone;
- Vegetation, other than trees and large bushes, should be maintained in this zone – Note: Roots of bushes and trees growing near boreholes often grows into the borehole where it can cause considerable problems;
- The borehole and pumping equipment must be housed in a lockable pump house. For this purpose a removable cage



manufactured out of galvanised steel mesh and corrugated steel sheets is recommended. This cage, rather than a brick building, is recommended as it can be readily removed in case the borehole is damaged or if it needs to be re-developed and cleaned.

- The production boreholes, as well as other monitoring boreholes in the area, must be properly sealed to prevent entry of reptiles, insects, birds and small rodents.
- The entire area should be properly fenced with a lockable gate to prevent unauthorised entry and to exclude animals. The gate must be positioned and of such a type that allows easy vehicle access.
- A signboard must be erected on the gate warning people of the dangers and that unauthorised entry is not allowed.

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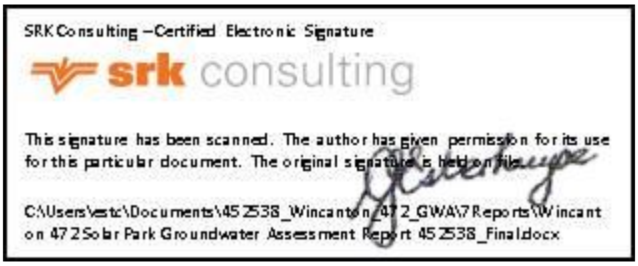

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All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted hydrogeological and environmental practices.

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APPENDIX 1: Calculations of Maximum Water Demands

Water demand for the construction phase was calculated as follows by VentuSA Energy (Pty) Ltd:

1. Average water demand for labour during the construction phase is 1 280 m^3/a or 3.5 m^3/d

2. For construction purposes another 48 047 m^3/a is needed over the 18 months period. This equals an average water consumption of 4 004 m^3/m or 131.5 m^3/day.

   Thus the average water demand during construction will be 135 m^3/d.

The water demand during the operational phase is as follows:

WATER USE FOR PLANT MAINTENANCE

Washing of photovoltaic modules.

1. Quantity: 3 ℓ/m^2 twice a year for each m^2 of PV.

   Total for the 75 MW Plant: 3 363 m^3/year (13 m^3/work day)

WATER USE FOR PLANT PERSONNEL & GENERAL SERVICES

2. Hygienic use for Personnel and Employees

   A maximum of 50 people will work daily for 8 hours in the PVSEP Plant during working days.

   Quantity: 50 x 50 ℓ/day = 2.5 m^3/day

   Total for the 75 MW Plant: 6 500 m^3/year

3. Inner roads maintenance
   Quantity: 80 m^3/week for 50 weeks/a = 16 m^3/work day
   Total for the 75 MW Plant: 4 000 m^3/year

4. Building cleaning and general use
   Quantity: 7 m^3/day during working days
   Total for the 75 MW Plant: 1 750 m^3/year

   Thus the average water demand during operation will be 39 m^3/d.

Therefore the average daily water demand for the construction phase will be 135 m^3/d. For the operational phase the average water demand will be 39 m^3/d. A groundwater license authorizing 140 m^3/d will cover unforeseen peak demands during construction and operational phases.

APPENDIX 2: NGA Data for Wincanton Study Area

Bh_No	Latitude	Longitude	Accuracy (m)	Water Level (m bgl)	Depth (m bgl)	Diameter	Depth Top	Depth Bottom	Yield (l/s)
2722DB00102	-27.75038	22.99749	1	9.49	46.33	152 mm (6.0)"			
2722DB00071	-27.75032	22.98084	1	17.80	235.5	152 mm (6.0)"			
2722DB00075	-27.75031	22.98224	100	78.84	150.23	152 mm (6.0)"			
2722DB00188	-27.75031	22.98643	1	43.80	119.36	152 mm (6.0)"			
2722DB00112	-27.75031	22.98921	1		84.76	152 mm (6.0)"			
2722DB00253	-27.75031	22.99338	1	29.07	104.5	152 mm (6.0)"			
2722DB00254	-27.75031	22.99615	1	4.76	70	152 mm (6.0)"			
2722DB00189	-27.7503	22.98364	1	41.23	97.6	152 mm (6.0)"			
2722DB00160	-27.75021	22.9054	100						
47592	-27.75017	22.90734	10	31.93	100	165 mm (6.5)"	58		1.00
2722DB00162	-27.75016	22.90557	100						
2722DB00250	-27.75008	22.98408	1						
2722DB00251	-27.75008	22.98408	1	47.05	70	152 mm (6.0)"			
2722DB00161	-27.75005	22.90552	100						
2722DB00157	-27.74996	22.90585	100						
2722DB00197	-27.74956	22.99114	1	6.41	30	152 mm (6.0)"			
2722DB00200	-27.74954	22.9988	1	29.85	100	152 mm (6.0)"			
2722DB00196	-27.7492	22.99219	1	6.10	42	152 mm (6.0)"			
2722DB00195	-27.7492	22.99455	1	7.90	30	152 mm (6.0)"			
2722DB00170	-27.74908	22.98439	1	78.50	200	152 mm (6.0)"			
2722DB00106	-27.74907	22.98504	1						
2722DB00187	-27.74907	22.98782	1	46.78	70	152 mm (6.0)"			
2722DB00117	-27.74907	22.9906	1						
2722DB00104	-27.74907	22.99477	1						
2722DB00101	-27.74905	22.99612	1	7.19	30	152 mm (6.0)"			
2722DB00017	-27.74846	22.99659	1						
2722DB00171	-27.74845	22.99238	1	25.45	130	152 mm (6.0)"			
2722DB00103	-27.74786	22.99748	1	23.36	47.6	152 mm (6.0)"			
2722DB00031	-27.74783	22.97252	1	88.77	408.86	152 mm (6.0)"			
2722DB00109	-27.74783	22.98642	1						
2722DB00105	-27.74783	22.98921	1						
2722DB00113	-27.74783	22.99199	1		48.2	152 mm (6.0)"			
2722DB00172	-27.74722	22.98713	1	67.96	106.49	152 mm (6.0)"			
2722DB00248	-27.74664	22.97919	100		109.06	152 mm (6.0)"			
2722DB00110	-27.74659	22.98782	1		58	152 mm (6.0)"			
2722DB00108	-27.74659	22.9906	1		58.7	152 mm (6.0)"			
2722DB00227	-27.74657	22.99612	1		70	152 mm (6.0)"			
2722DB00194	-27.74656	22.99618	1	36.00	60	152 mm (6.0)"			
2722DB00198	-27.74654	22.9892	1	18.01	123	152 mm (6.0)"	116		
2722CB00091	-27.74622	22.96806	100	175.14		152 mm (6.0)"			
2722DB00074	-27.74597	22.98295	100	73.80	122.4	152 mm (6.0)"			
2722DB00097	-27.74536	22.97947	1	69.91	178	152 mm (6.0)"			
2722DB00186	-27.74536	22.98643	1	46.67	70	152 mm (6.0)"			
2722DB00111	-27.74536	22.98921	1		57	152 mm (6.0)"			

Bh_No	Latitude	Longitude	Accuracy (m)	Water Level (m bgl)	Depth (m bgl)	Diameter	Depth Top	Depth Bottom	Yield (l/s)
2722DB00077	-27.74535	22.97112	100	56.40	196	152 mm (6.0)"			
2722DB00076	-27.74535	22.97669	100	84.13	110	152 mm (6.0)"			
2722DB00098	-27.74535	22.97669	100	72.18	95	152 mm (6.0)"			
2722DB00072	-27.74535	22.98087	1	21.97	187.17	152 mm (6.0)"			
2722DB00044	-27.74534	22.96418	1	78.75	90	152 mm (6.0)"			
2722DB00226	-27.7453	22.99747	1		61	152 mm (6.0)"			
2722DB00019	-27.74482	22.99751	1	145.51	190	152 mm (6.0)"			
2722DB00199	-27.7448	22.99127	1	19.26	196	152 mm (6.0)"			
2722DB00121	-27.74474	22.98851	1	52.61	75	152 mm (6.0)"			
2722DB00173	-27.74473	22.98434	1	65.63	117.6	152 mm (6.0)"			
2722DB00191	-27.74412	22.9906	1		46	152 mm (6.0)"			
2722DB00190	-27.74411	22.99338	1	46.43	70	152 mm (6.0)"			
2722DB00223	-27.74356	22.97839	100	8.29	73.15	152 mm (6.0)"			
2722DB00070	-27.74349	22.97834	1	16.55	162.07	152 mm (6.0)"			
2722DB00122	-27.74288	22.98782	1	63.73	85	152 mm (6.0)"			
2722DB00261	-27.74261	22.94612							
2722DB00163	-27.74259	22.94617	100						
2722DB00022	-27.74205	22.97529	1	102.16	120.7	152 mm (6.0)"	31.09		
2722DB00124	-27.74164	22.98225	100		126.2	152 mm (6.0)"			
2722DB00020	-27.74116	22.99926	1						
2722DB00225	-27.74099	22.97555	1		99.97	152 mm (6.0)"	60.96		0.00
2722DB00225	-27.74099	22.97555	1	72.97	99.97	152 mm (6.0)"	70.1		0.00
2722DB00043	-27.74095	22.97559	1	15.10	40	152 mm (6.0)"			
2722DB00249	-27.74063	22.98383	100						
2722DB00181	-27.7404	22.98643	1	51.50	70	152 mm (6.0)"			
2722DB00224	-27.73986	22.97382	100	29.80	353	152 mm (6.0)"			
2722DB00164	-27.7397	22.95794	100		42	152 mm (6.0)"			
2722DB00222	-27.7397	22.95795	100	4.00	14	152 mm (6.0)"			
2722DB00094	-27.7392	22.98221	100	94.17	238.98	152 mm (6.0)"			
2722DB00073	-27.73916	22.98086	1	81.20	167.3	152 mm (6.0)"			
2722DB00237	-27.73915	22.97246	1	20.45	90	152 mm (6.0)"			
2722DB00078	-27.73878	22.97213	100	3.26	82	152 mm (6.0)"			
2722DB00247	-27.73878	22.97213	100		119.93	152 mm (6.0)"			
2722DB00252	-27.73855	22.98991	1	49.65	70	152 mm (6.0)"			
2722DB00107	-27.73794	22.99474	1		178	127 mm (5.0)"	54.25		
2722DB00246	-27.73715	22.98313	100		126.43	152 mm (6.0)"			
2722DB00095	-27.73669	22.98225	100	68.18	108.7	152 mm (6.0)"			
2722DB00115	-27.73668	22.99059	1						
2722DB00096	-27.73667	22.97391	100	65.43	154.39	152 mm (6.0)"			
2722DB00219	-27.73483	22.98156	1	66.76	111	152 mm (6.0)"			
2722DB00015	-27.73455	22.99056	100	99.95	120	152 mm (6.0)"			
2722DB00201	-27.73421	22.97669	1		223.8	152 mm (6.0)"			
2722DB00132	-27.73421	22.97947	1		96.43	152 mm (6.0)"			
2722DB00082	-27.73421	22.98535	1	69.50	103.62	152 mm (6.0)"			
2722DB00192	-27.73421	22.98782	1		73.85	152 mm (6.0)"			

Bh_No	Latitude	Longitude	Accuracy (m)	Water Level (m bgl)	Depth (m bgl)	Diameter	Depth Top	Depth Bottom	Yield (l/s)
2722DB00081	-27.73298	22.98504	1	59.81	108.05	152 mm (6.0)"			
2722DB00080	-27.73298	22.99477	1	5.08	76	152 mm (6.0)"			
2722DB00262	-27.73261	22.98389							
2722DB00228	-27.73243	22.98426	1		85.3	152 mm (6.0)"			
2722DB00239	-27.73209	22.97951	1		143.05	152 mm (6.0)"			
2722DB00093	-27.73205	22.97495	1						
2722DB00207	-27.73191	22.9755	1	3.88	104.33	152 mm (6.0)"			
2722DB00233	-27.73191	22.9755	1		94.33	152 mm (6.0)"			
2722DB00209	-27.73174	22.98226		59.02	172	152 mm (6.0)"			
2722DB00130	-27.73174	22.98503	1		80	152 mm (6.0)"			
2722DB00243	-27.73166	22.97177	1		98.15	152 mm (6.0)"			
2722DB00016	-27.73156	22.96432							
2722DB00260	-27.73122	22.91778							
2722DB00218	-27.73112	22.98434	1	105.05	160	152 mm (6.0)"			
2722DB00063	-27.73111	22.91795	1		16.9	152 mm (6.0)"			
2722DB00221	-27.73064	22.96427	100		13.58	152 mm (6.0)"			
2722DB00211	-27.7305	22.97808	1	89.04	130.9	152 mm (6.0)"			
2722DB00193	-27.7305	22.98922	1		41	152 mm (6.0)"			
2722DB00240	-27.73021	22.98572	1		169.11	152 mm (6.0)"			
2722DB00215	-27.72927	22.97391	1	84.87	131	152 mm (6.0)"			
2722DB00180	-27.72925	22.98652	1	77.48	96.1	152 mm (6.0)"			
2722DB00210	-27.72884	22.98086	1	85.57	95	152 mm (6.0)"	24		
2722DB00046	-27.72802	22.9753	1	87.42	131.05	152 mm (6.0)"			
2722DB00216	-27.72801	22.98227	1	91.56	134	152 mm (6.0)"			
2722DB00133	-27.72679	22.98503	1		91.59	152 mm (6.0)"			
2722DB00091	-27.72678	22.97111	1		307	152 mm (6.0)"			
2722DB00125	-27.72658	22.98719	1		59.38	152 mm (6.0)"			
26705	-27.72614	22.99681	1	49.98	135	165 mm (6.5)"	30		
2722DB00231	-27.72559	22.98338	1		109.67	152 mm (6.0)"			
2722DB00217	-27.72555	22.96974	1	80.78	105	152 mm (6.0)"			
2722DB00214	-27.72555	22.98822	1	84.15	149.89	152 mm (6.0)"	32		
2722DB00208	-27.72554	22.98642	1	3.86	45.5	152 mm (6.0)"			
2722DB00213	-27.72471	22.98086	1	84.99	124.52	152 mm (6.0)"			
2722DB00229	-27.72465	22.97967	1		157.67	152 mm (6.0)"			
2722DB00242	-27.72454	22.97951	1						
2722DB00045	-27.72433	22.97393	1	87.93	141	152 mm (6.0)"			
2722DB00230	-27.72366	22.97594	1		156.3	152 mm (6.0)"			
2722DB00205	-27.72313	22.98547	1						
2722DB00203	-27.72307	22.97531	1		105	152 mm (6.0)"			
2722DB00232	-27.72254	22.97184	1		94.48	152 mm (6.0)"			
2722DB00033	-27.72246	22.98296	1	107.47	123	152 mm (6.0)"			
2722DB00179	-27.72184	22.9906	1	50.09	265	152 mm (6.0)"			
2722DB00178	-27.72184	22.99199	1	45.11	241	152 mm (6.0)"			
2722DB00212	-27.72183	22.98226	1	88.58	121	152 mm (6.0)"			
2722DB00088	-27.72183	22.98504	1		90	152 mm (6.0)"			

Bh_No	Latitude	Longitude	Accuracy (m)	Water Level (m bgl)	Depth (m bgl)	Diameter	Depth Top	Depth Bottom	Yield (l/s)
2722DB00083	-27.72128	22.9889	1		77.97	152 mm (6.0)"			
2722DB00085	-27.72087	22.97228	1		142.1	152 mm (6.0)"			
2722DB00049	-27.72065	22.95282	1	4.47	25	152 mm (6.0)"			
2722DB00220	-27.7206	22.9781			162.67	152 mm (6.0)"			
2722DB00034	-27.7206	22.97949	1	99.48	324	152 mm (6.0)"			
2722DB00047	-27.7206	22.98366	1	32.87	130	152 mm (6.0)"			
2722DB00087	-27.72059	22.9753	1		154	152 mm (6.0)"			
2722DB00177	-27.72059	22.99338	1	63.03	217	152 mm (6.0)"			
2722DB00021	-27.7204	22.99287	1						
2722DB00155	-27.72037	22.89754	100						
2722DB00156	-27.72033	22.89764	100						
2722DB00241	-27.72016	22.98422	1		92.34	152 mm (6.0)"			
2722DB00154	-27.7196	22.89642	100						
2722DB00084	-27.71939	22.98058	1		88.94	152 mm (6.0)"			
2722DB00090	-27.71936	22.97669	1		109	152 mm (6.0)"			
2722DB00089	-27.71935	22.97947	1		188.39	152 mm (6.0)"			
2722DB00126	-27.71845	22.97648	1		74.92	152 mm (6.0)"			
2722DB00064	-27.71828	22.90628	1	10.00	63	152 mm (6.0)"			
2722DB00158	-27.71827	22.90175	100						
2722DB00128	-27.71813	22.98367	1		227.7	152 mm (6.0)"			
2722DB00086	-27.71812	22.96695	1	44.40	227.76	152 mm (6.0)"			
2722DB00030	-27.71812	22.96835	1	103.44	259	152 mm (6.0)"			
2722DB00165	-27.71812	22.97947	1		371	152 mm (6.0)"			
2722DB00092	-27.71812	22.98226	1		90	152 mm (6.0)"			
2722DB00028	-27.71812	22.98504	1	3.81	206	152 mm (6.0)"			
2722DB00176	-27.71812	22.99338	1	46.20	310	152 mm (6.0)"			
2722DB00167	-27.71798	22.98921	1		268	152 mm (6.0)"			
2722DB00014	-27.71706	22.76612		44.20	108.81	152 mm (6.0)"	62.48		0.16
2722DB00005	-27.71706	22.89945		30.00	79	152 mm (6.0)"	42.8		0.41
2722DB00006	-27.71706	22.89945		43.00	80	152 mm (6.0)"	73		0.71
2722DB00007	-27.71706	22.89945		16.46	78.64	152 mm (6.0)"	16.46		0.01
2722DB00008	-27.71706	22.89945		18.29	77.11	152 mm (6.0)"	25.3		0.01
2722DB00009	-27.71706	22.89945		22.86	53.65	152 mm (6.0)"	29.57		0.08
2722DB00010	-27.71706	22.89945		17.07	41.45	152 mm (6.0)"	24.99		0.12
2722DB00159	-27.71693	22.90648	100		18.7	152 mm (6.0)"			
2722DB00166	-27.71688	22.97391	1		97	152 mm (6.0)"			
2722DB00168	-27.71688	22.99061	1		255	152 mm (6.0)"			
2722DB00175	-27.71684	22.99754	1	37.76	259	152 mm (6.0)"			
2722DB00206	-27.71625	22.99065	1	4.45	43.28	152 mm (6.0)"			
2722DB00027	-27.71564	22.98227	1	23.90	228	152 mm (6.0)"			
2722DB00169	-27.71563	22.98782	1		250	152 mm (6.0)"			
2722DB00174	-27.71563	22.99617	1	47.14	306	152 mm (6.0)"			
2722DB00018	-27.71503	22.99777	100						
2722DB00066	-27.71492	22.90999	1	4.59	25	152 mm (6.0)"			
26756	-27.71459	22.98535	100	20.55	135	152 mm (6.0)"	7.5		0.00

Bh_No	Latitude	Longitude	Accuracy (m)	Water Level (m bgl)	Depth (m bgl)	Diameter	Depth Top	Depth Bottom	Yield (l/s)
26756	-27.71459	22.98535	100		135	152 mm (6.0)"	60		0.00
26755	-27.71445	22.98484	100	46.40	105	152 mm (6.0)"	6		
2722DB00236	-27.71438	22.99743		35.74	47.36	152 mm (6.0)"			
30490	-27.71436	22.98515	100	3.49	38	152 mm (6.0)"	35		
2722DB00029	-27.71435	22.97912	1	61.07	120	152 mm (6.0)"			
2722DB00065	-27.7142	22.90949	1	4.81	25	152 mm (6.0)"			
2722DB00055	-27.71366	22.97255	100	17.65					
2722DB00202	-27.71316	22.96696	1		113.55	152 mm (6.0)"			
2722DB00255	-27.71316	22.96696	1		40	152 mm (6.0)"			
2722DB00129	-27.71316	22.97252	1		84	152 mm (6.0)"			
2722DB00026	-27.7127	22.98323	1	24.21	259	152 mm (6.0)"			
2722DB00036	-27.71257	22.98931	1	40.36	306.08	152 mm (6.0)"			
2722DB00264	-27.71233	22.78639			137.46	152 mm (6.0)"	64.01		1.00
2722DB00264	-27.71233	22.78639		51.82	137.46	152 mm (6.0)"	82.3		1.00
2722DB00204	-27.71214	22.97988	1						
2722DB00238	-27.71133	22.94033	100		294.38	152 mm (6.0)"			
2722DB00037	-27.70945	22.95166	1	90.14	460.7	152 mm (6.0)"			
13942	-27.70815	22.96451	100						
2722DB00263	-27.70733	22.87445			123	152 mm (6.0)"	122		
2722DB00244	-27.70535	22.98119	1						
2722DB00039	-27.70534	22.96498	1	54.05	110	152 mm (6.0)"			
2722DB00042	-27.70534	22.99742	1	3.46	62.51	152 mm (6.0)"			
2722DB00153	-27.70404	22.89806	100						
2722DB00234	-27.70345	22.88556		22.49	45	152 mm (6.0)"			
2722DB00011	-27.70039	22.98278		110.00	125	152 mm (6.0)"	120		0.01
2722DB00013	-27.70039	22.98278			95	152 mm (6.0)"			
2722DB00235	-27.70039	22.98278		4.49	25	152 mm (6.0)"			
2722DB00267	-27.69872	22.94883	100		75	406 mm (16.0)"	37	40	44.40
2722DB00267	-27.69872	22.94883	100		75	406 mm (16.0)"	50	75	44.40
2722DB00271	-27.69872	22.94883			75	152 mm (6.0)"	37	40	44.40
2722DB00271	-27.69872	22.94883			75	152 mm (6.0)"	50	75	44.40
2722DB00041	-27.69812	22.97309	1	39.31	70	152 mm (6.0)"			
2722DB00099	-27.69812	22.99742	1	4.17	140	152 mm (6.0)"			
2722DB00266	-27.69716	22.94717	100		100	406 mm (16.0)"	38.4		25.00
2722DB00266	-27.69716	22.94717	100		100	406 mm (16.0)"	55.91		25.00
2722DB00270	-27.69716	22.94717			100	152 mm (6.0)"	38	40	25.00
2722DB00270	-27.69716	22.94717			100	152 mm (6.0)"	55	91	25.00
47589	-27.69483	22.90389	10		102	165 mm (6.5)"			
2722DB00035	-27.69451	22.97309	1	36.79	373.98	152 mm (6.0)"			
2722DB00048	-27.69451	22.99742	1	9.75	347.72	152 mm (6.0)"			
2722DB00135	-27.69376	22.93848	100	42.84	611	152 mm (6.0)"	217		
2722DB00278	-27.69205	22.91195	100						
2722DB00100	-27.69174	22.99915	1	48.06	406	152 mm (6.0)"			

Bh_No	Latitude	Longitude	Accuracy (m)	Water Level (m bgl)	Depth (m bgl)	Diameter	Depth Top	Depth Bottom	Yield (l/s)
2722DB00067	-27.69056	22.90289	1	9.61	35	152 mm (6.0)"			
2722DB00068	-27.69045	22.90296		8.13	35	152 mm (6.0)"			
2722DB00256	-27.69039	22.90251							
2722DB00069	-27.69039	22.90277	1	5.00	25	152 mm (6.0)"			
2722DB00024	-27.69011	22.98195		88.32	102.68	152 mm (6.0)"			
2722DB00268	-27.68872	22.90306			132	165 mm (6.5)"	132		
2722DB00269	-27.68872	22.90306			138	165 mm (6.5)"	21		0.22
2722DB00038	-27.68861	22.94192	1	4.92	27	152 mm (6.0)"			
047591A	-27.68618	22.9096	10						
2722DB00032	-27.68589	22.94194	1	34.87	432	152 mm (6.0)"			
47590	-27.68523	22.90059	10		999.99	152 mm (6.0)"			
2722DB00054	-27.68392	22.97227	100						
2722DB00040	-27.68368	22.9731	1	9.63	60	152 mm (6.0)"			
2722DB00123	-27.68345	22.94194	100		376.04	152 mm (6.0)"			
2722DB00123	-27.68345	22.94194	100		6.5	165 mm (6.5)"			
2722DB00052	-27.68263	22.99143	100						
2722DB00023	-27.68096	22.94193	100	34.55	260.3	152 mm (6.0)"			
2722DB00150	-27.6799	22.89747	1		64	152 mm (6.0)"			
2722DB00149	-27.6785	22.89535	100		18.3	152 mm (6.0)"			
2722DB00151	-27.67804	22.89099	100		33.5	152 mm (6.0)"			
2722DB00152	-27.67759	22.89616	100						
2722DB00148	-27.67714	22.89352	100		22.9	152 mm (6.0)"			
2722DB00245	-27.67646	22.97411	1						
2722DB00059	-27.67328	22.925	100						
2722DB00147	-27.67164	22.89333	100		21.3	152 mm (6.0)"			
2722DB00053	-27.66934	22.98522	100						
2722DB00060	-27.66772	22.96352	100						
2722DB00002	-27.66706	22.81612			122.83	152 mm (6.0)"			
2722DB00003	-27.66706	22.81612			71.02	152 mm (6.0)"			
2722DB00004	-27.66706	22.81612			64.01	152 mm (6.0)"			
2722DB00025	-27.66067	22.98834		14.12	112.6	152 mm (6.0)"			
2722DB00058	-27.64813	22.94442	100		25	152 mm (6.0)"			
2722DB00057	-27.64557	22.96813	100		29.2	152 mm (6.0)"			
2722DB00144	-27.64038	22.99251	1						
2722DB00119	-27.63869	22.88322	100	88.79	100	152 mm (6.0)"			
2722DB00116	-27.63842	22.88388	100		11.6	152 mm (6.0)"			
2722DB00120	-27.63815	22.88373	100						
2722DB00118	-27.63661	22.88389	100						
2722DB00114	-27.63553	22.88855	100						
2722DB00061	-27.63518	22.93198	100						
2722DB00127	-27.6334	22.94017	100						
2722DB00145	-27.62727	22.98442	1						
2722DB00062	-27.62551	22.95593	100						
2722DB00258	-27.61845	22.90028							
2722DB00259	-27.61845	22.90084							

Bh_No	Latitude	Longitude	Accuracy (m)	Water Level (m bgl)	Depth (m bgl)	Diameter	Depth Top	Depth Bottom	Yield (l/s)
2722DB00051	-27.61807	22.90162	100						
2722DB00050	-27.61722	22.90098	100		43	152 mm (6.0)"			
2722DB00182	-27.61719	22.92301	100	8.33	20.5	152 mm (6.0)"			
2722DB00146	-27.61471	22.98081	1						
2722DB00134	-27.61465	22.94965	100						
2722DB00184	-27.60804	22.93011	100	10.23	20.23	152 mm (6.0)"			
2722DB00183	-27.60689	22.93036	100	5.02	145	152 mm (6.0)"			
2722DB00138	-27.6063	22.91694	100	25.95	50	152 mm (6.0)"			
2722DB00185	-27.60353	22.96116	100	7.13	17.13	152 mm (6.0)"			
2722DB00142	-27.60234	22.91487	100	10.30	35	152 mm (6.0)"			
2722DB00257	-27.59705	22.88361		6.01	20	152 mm (6.0)"			
2722DB00143	-27.59126	22.94384	100	7.64	71	152 mm (6.0)"			
2722DB00265	-27.59039	22.88639	100		43	203 mm (8.0)"			
45383	-27.59039	22.88695	100	15.93	40	305 mm (12.0)"	25		0.10
2722DB00141	-27.58836	22.93523		7.72	30	152 mm (6.0)"			
2722DB00139	-27.58664	22.92488	100	11.95	35	152 mm (6.0)"			
2722DB00140	-27.58249	22.92845	100	8.30	50	152 mm (6.0)"			
2722DB00001	-27.53372	22.91612		11.28	29.57	152 mm (6.0)"	27.43		0.53

APPENDIX 3: Yield Test Data and Diagnostic Plots for Borehole WNE1

BOREHOLE NO:	DEBEN	WATER LEVEL [mbdl]:	12.63	WATER DEPTH [mbgl]:	12.42	AVAILABLE DRAWDOWN [m]:	14.49

STEPPED DISCHARGE TEST & RECOVERY

DISCHARGE RATE 1		RPM			DISCHARGE RATE 2		RPM			DISCHARGE RATE 3		RPM		
DATE & TIME		06/19/2013 12:00			DATE & TIME		06/19/2013 13:00			DATE & TIME		06/19/2013 14:00		
TIME (min)	DRAWDOWN (m)	YIELD (l/s)	TIME (min)	RECOVERY (m)	TIME (min)	DRAWDOWN (m)	YIELD (l/s)	TIME (min)	RECOVERY (m)	TIME (min)	DRAWDOWN (m)	YIELD (l/s)	TIME (min)	RECOVERY (m)
1	0.85		1		1	1.49		1		1	2.40		1	
2	0.90	2.03	2		2	1.60		2		2	2.75		2	
3	0.96	2.03	3		3	1.63		3		3	2.80	6.22	3	
5	1.03		5		5	1.67		5		5	2.83		5	
7	1.05		7		7	1.83	4.10	7		7	3.01	6.22	7	
10	1.07		10		10	2.03		10		10	3.10		10	
15	1.09		15		15	2.08		15		15	3.16		15	
20	1.11		20		20	2.09	4.10	20		20	3.18		20	
30	1.13	2.03	30		30	2.10		30		30	3.20		30	
40	1.14		40		40	2.14		40		40	3.21	6.22	40	
50	1.15		50		50	2.19	4.10	50		50	3.23		50	
60	1.16		60		60	2.21		60		60	3.23		60	
			70					70					70	
			80					80					80	
			90					90					90	
			100					100					100	
			110					110					110	
			120					120					120	
			150					150					150	
	Average Yield (l/s):	2.03	180			Average Yield (l/s):	4.10	180			Average Yield (l/s):	6.22	180	
	Drawdown (%):	8.01	210			Drawdown (%):	15.25	210			Drawdown (%):	22.29	210	

DISCHARGE RATE 4		RPM			DISCHARGE RATE 5		RPM			DISCHARGE RATE 6		RPM		
DATE & TIME		06/19/2013 15:00			DATE & TIME		06/19/2013 15:00			DATE & TIME		06/19/2013 15:00		
TIME (min)	DRAWDOWN (m)	YIELD (l/s)	TIME (min)	RECOVERY (m)	TIME (min)	DRAWDOWN (m)	YIELD (l/s)	TIME (min)	RECOVERY (m)	TIME (min)	DRAWDOWN (m)	YIELD (l/s)	TIME (min)	RECOVERY (m)
1	3.26		1		1			1		1			1	1.00
2	3.27		2		2			2		2			2	0.54
3	3.30	8.25	3		3			3		3			3	0.40
5	3.37		5		5			5		5			5	0.30
7	3.43		7		7			7		7			7	0.24
10	3.54	8.27	10		10			10		10			10	0.20
15	3.67		15		15			15		15			15	0.14
20	3.75		20		20			20		20			20	0.08
30	3.82	8.26	30		30			30		30			30	0.04
40	3.88		40		40			40		40			40	0.00
50	3.93		50		50			50		50			50	
60	3.96	8.28	60		60			60		60			60	
			70					70					70	
			80					80					80	
			90					90					90	
			100					100					100	
			110					110					110	
			120					120					120	
			150					150					150	
			180					180					180	
			210					210					210	
			240					240					240	
	Average Yield (l/s):	8.27	300			Average Yield (l/s):	0.00	300			Average Yield (l/s):	0.00	300	
	Drawdown (%):	27.33	360			Drawdown (%):		360			Drawdown (%):		360	

DATUM LEVEL ABOVE GROUND [m]:	0.21	WAS SAND PUMPED ?	NO
STATIC WATER LEVEL AFTER STEPPED DISCHARGE TEST [mbdl]:	12.63	WAS THE WATER CLEAN?	YES

BOREHOLE NO:		DEBEN			WATER LEVEL [mbdl]:		12.63				WATER LEVEL [mbgl]:		12.42
CONSTANT DISCHARGE TEST & RECOVERY													
DISCHARGE BOREHOLE					OBSERVATION HOLE 1			OBSERVATION HOLE 2			OBSERVATION HOLE 3		
TEST STARTED					WATER LEVEL [mbcl]:		N/A	WATER LEVEL [mbcl]:		N/A	WATER LEVEL [mbcl]:		N/A
DATE & TIME:		06/20/2013 7:00			CASING HEIGHT [m]:		N/A	CASING HEIGHT [m]:		N/A	CASING HEIGHT [m]:		N/A
TEST COMPLETED					CASING DIAMETER [m]:		N/A	CASING DIAMETER [m]:		N/A	CASING DIAMETER [m]:		N/A
DATE & TIME:		06/23/2013 19:00			DISTANCE [m]:		N/A	DISTANCE [m]:		N/A	DISTANCE [m]:		N/A
TIME [min]	DRAWDOWN [m]	YIELD [l/s]	TIME [min]	RECOVERY [m]	TIME: [min]	DRAWDOWN [m]	RECOVERY [m]	TIME: [min]	DRAWDOWN [m]	RECOVERY [m]	TIME: [min]	DRAWDOWN [m]	RECOVERY [m]
1	1.86		1	2.24	1			1			1		
2	2.12		2	1.42	2			2			2		
3	2.21	7.05	3	1.14	3			3			3		
5	2.33		5	0.97	5			5			5		
7	2.47		7	0.93	7			7			7		
10	2.60		10	0.88	10			10			10		
15	2.72	7.23	15	0.85	15			15			15		
20	2.76		20	0.82	20			20			20		
30	2.80		30	0.78	30			30			30		
40	2.83		40	0.73	40			40			40		
60	2.84	7.23	60	0.66	60			60			60		
90	2.85		90	0.60	90			90			90		
120	2.86		120	0.57	120			120			120		
150	2.87		150	0.53	150			150			150		
180	2.87		180	0.48	180			180			180		
210	2.88		210	0.40	210			210			210		
240	2.89	7.25	240	0.33	240			240			240		
300	2.89		300	0.26	300			300			300		
360	2.92		360	0.20	360			360			360		
420	2.93		420	0.14	420			420			420		
480	2.94	7.27	480	0.09	480			480			480		
540	2.95		540	0.05	540			540			540		
600	2.96		600	0.02	600			600			600		
720	2.97		720	0.00	720			720			720		
840	3.00	7.25			840			840			840		
960	3.24				960			960			960		
1080	3.40				1080			1080			1080		
1200	3.48	7.25			1200			1200			1200		
1320	3.56				1320			1320			1320		
1440	3.63	7.24			1440			1440			1440		
1560	3.70				1560			1560			1560		
1680	3.76				1680			1680			1680		
1800	3.81	7.26			1800			1800			1800		
1920	3.84				1920			1920			1920		
2040	3.86				2040			2040			2040		
2160	3.88	7.27			2160			2160			2160		
2280	3.89				2280			2280			2280		
2400	3.91				2400			2400			2400		
2520	3.92	7.26			2520			2520			2520		
2640	3.93				2640			2640			2640		
2760	3.93				2760			2760			2760		
2880	3.94	7.27			2880			2880			2880		
3000	3.95				3000			3000			3000		
3120	3.96				3120			3120			3120		
3240	3.96	7.25			3240			3240			3240		
3360	3.97				3360			3360			3360		
3480	3.98				3480			3480			3480		
3600	3.99				3600			3600			3600		
3720	3.99	7.27			3720			3720			3720		
3840	4.00				3840			3840			3840		
3960	4.01				3960			3960			3960		
4080	4.01	7.24			4080			4080			4080		
4200	4.02				4200			4200			4200		
4320	4.03				4320			4320			4320		

FC-METHOD : Estimation of the sustainable yield of a borehole

WNE1 | Main | Deriv | Inflection point method

Extrapolation time in years = (enter)	2	1051200	Extrapol.time in minutes
Effective borehole radius (r_e) = (enter)	1.08	1.08	Est. r_e / From r(e) sheet
Q (l/s) from pumping test =	7.26	2.20E-03	S-late / Change r_e
s_a (available drawdown), sigma_s = (enter)	7.5	0.000	Sigma_s from risk / Down
Annual effective recharge (mm) =	7.5	10.91	s_available working drawdown(m)
t(end) and s(end) of pumping test =	4320	4.03	End time and drawdown of test
Average maximum derivative = (enter)	2.5	2.5	Estimate of average of max deriv
Average second derivative = (enter)	0.0	0.0	Estimate of average second deriv
Derivative at radial flow period = (enter)	0.24	0.24	Read from derivative graph
	T-early[m^2/d] =	484.76	Aqui. thick (m) 20
T and S estimates from derivatives	T-late [m^2/d] =	45.71	Est. S-late = 1.10E-03
(To obtain correct S-value, use program RPTSOLV)	S-late =	2.20E-03	S-estimate could be wrong

BASIC SOLUTION

(Using derivatives + subjective information about boundaries) — Maximum influence of boundaries at long time

(No values of T and S are necessary)	No boundaries	1 no-flow	2 no-flow	Closed no-flow
sWell (Extrapol.time) =	10.00	16.00	21.99	39.97
Q_sust (l/s) =	7.92	4.95	3.60	1.98
	Best case	→		Worst case

Average Q_sust (l/s) = 4.09

with standard deviation= 2.51

(If no information exists about boundaries skip advanced solution and go to final recommendation)

ADVANCED SOLUTION

(Using derivatives+ knowledge on boundaries and other boreholes)

(Late T-and S-values a priori + distance to boundary)

T-late [m^2/d] = (enter) → 45.71

S-late = (enter) → 2.20E-03

1. BOUNDARY INFORMATION (choose a or b)	(Code =9999 = dummy value if not applicable)			
(a) Barrier (no-flow) boundaries →	Closed Square	Single Barrier	Intersect. 90°	2 Parallel Barriers
Bound. distance a[meter] : (enter)	9999	9999	9999	9999
Bound. distance b[meter] : (enter)			9999	9999
s_Bound(t = Extrapol.time) [m] =	0.00	0.00	0.00	0.00
(b) Fix head boundary + no-flow →	Closed Fix	Single Fix	90°Fix+no-flow	// Fix+no-flow
Bound. distance to fix head a[meter] : (enter)	9999	9999	9999	9999
Bound. distance to no-flow b[meter] : (enter)			9999	9999
s_Bound(t = Extrapol.time) [m] =	0.00	0.00	0.00	0.00
2. INFLUENCE OF OTHER BOREHOLES →	Q (l/s)	r (m)	u_r	W(u,r)
	0	9999	1.65E+00	0.08
	0	9999	1.65E+00	0.08
s_(influence of BH1,BH2) =	0.00	0.00	1.92E-08	17.19
SOLUTION INCLUDING BOUNDS AND BH's				
Fix head + No-flow : Q_sust (l/s) =	9999.00	9999.00	9999.00	9999.00
No-flow : Q_sust (l/s) =	9999.00	9999.00	9999.00	9999.00
Enter selected Q for risk analysis = (enter) →	4.00	Sigma_s =	0.000	Up / Risk

(Go to Risk sheet and perform risk analysis from which sigma_s will be estimated : only for barrier boundaries)

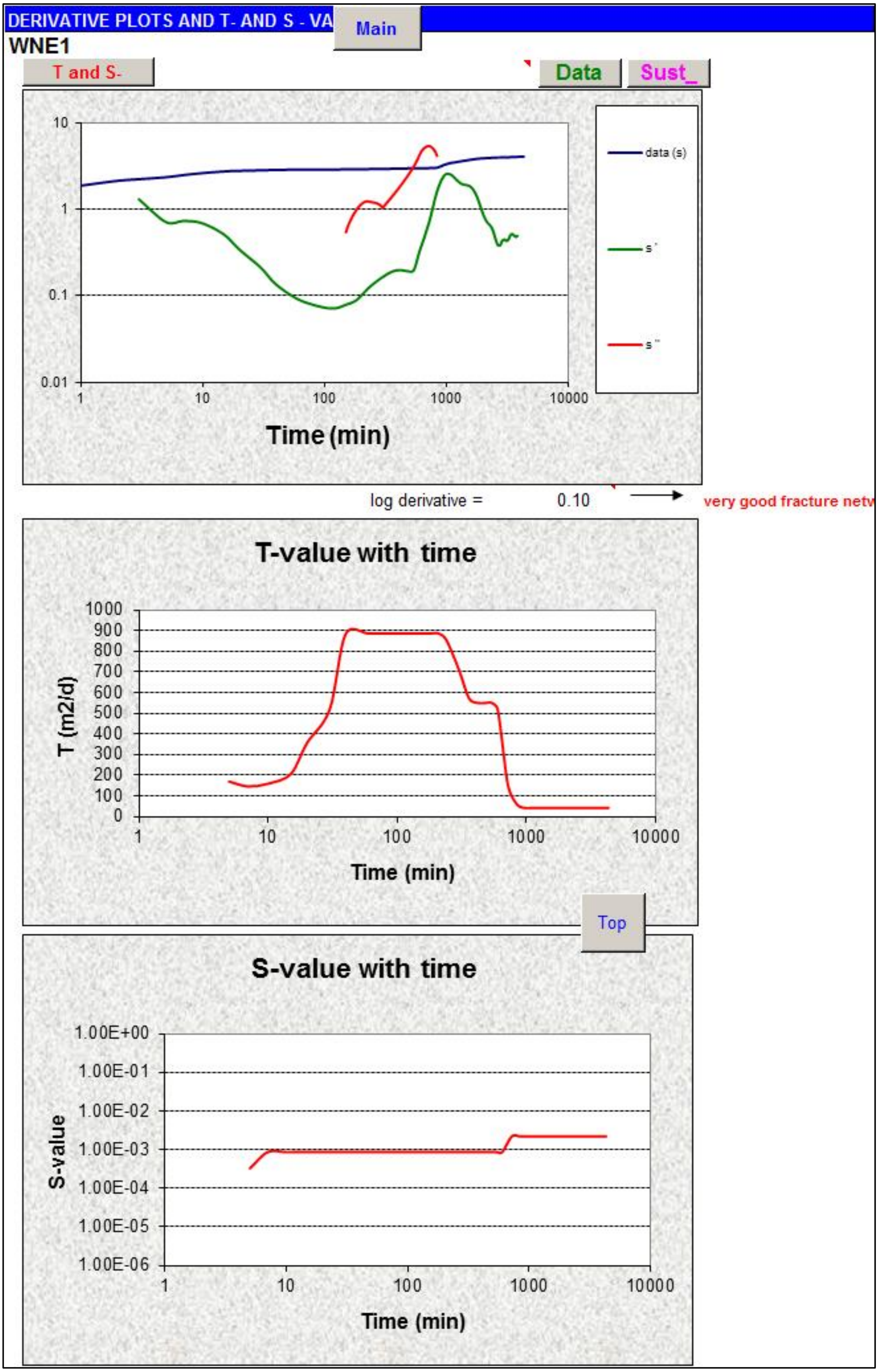
FINAL RECOMMENDED ABSTRACTION RATE

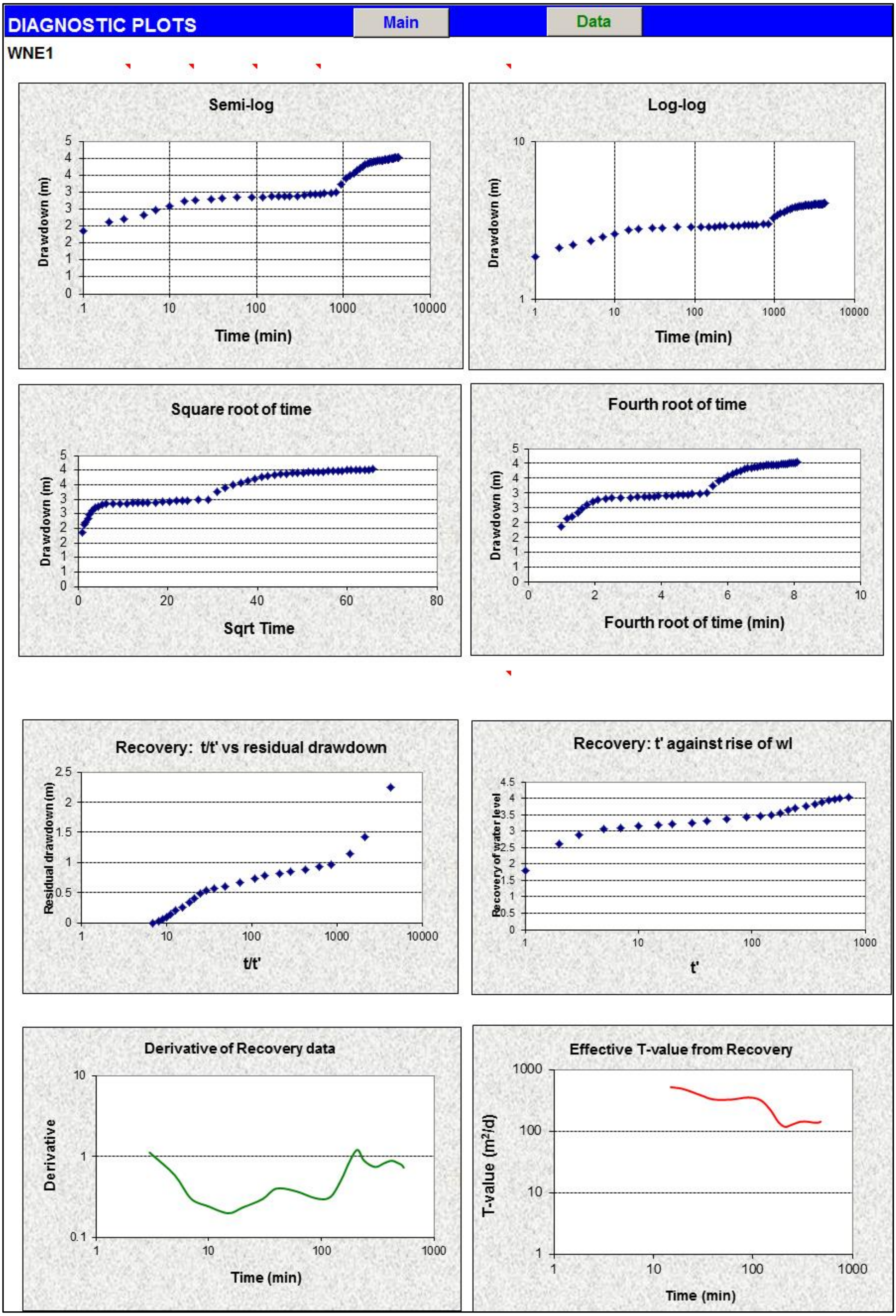
Abstraction rate (l/s) for 24 hr/d = (enter)	4.00
Total amount of water allowed to be abstracted per month (m^3) =	10368

COMMENTS

Q_sust with 68% safety =

Q_sust with 95% safety =


DERIVATIVE PLOTS AND T- AND S - VA
Main
WNE1
T and S-
Data
Sust_
10
1
0.1
0.01
1
10
100
1000
10000
Time (min)
data (s)
s'
s''
log derivative =
0.10
very good fracture netw
T-value with time
1000
900
800
700
600
500
400
300
200
100
0
T (m2/d)
1
10
100
1000
10000
Time (min)
Top
S-value with time
1.00E+00
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
S-value
1
10
100
1000
10000
Time (min)


DIAGNOSTIC PLOTS
Main
Data
WNE1
Semi-log
Drawdown (m)
Time (min)
Log-log
Drawdown (m)
Time (min)
Square root of time
Drawdown (m)
Sqrt Time
Fourth root of time
Drawdown (m)
Fourth root of time (min)
Recovery: t/t' vs residual drawdown
Residual drawdown (m)
t/t'
Recovery: t' against rise of wl
Recovery of water level
t'
Derivative of Recovery data
Derivative
Time (min)
Effective T-value from Recovery
T-value (m²/d)
Time (min)

SRK Report Distribution Record

Report No.	452538_Draft
Copy No.	1

Name/Title	Company	Copy	Date	Authorised by
Mr Dave Peinke	VentuSA Energy (Pty) Ltd 7 West Quay Road 1st floor, block 106 A Cape Town 8001 South Africa	1	26 June 2013	
DWA	Kimberley	2	26 June 2013	
Project file	SRK, Cape Town, G-Drive	3	26 June 2013	
Library	SRK, Cape Town	4	26 June 2013	

Approval Signature: