Borehole Yield and Quality Testing at Ackermans, Blackheath.

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GROUNDWATER AND EARTH SCIENCES
GEOSS
SOUTH AFRICA (Pty) Ltd

20 November 2023

EXECUTIVE SUMMARY

GEOSS South Africa (Pty) Ltd was appointed by Johan Roos from KLS Consulting Engineers to conduct yield and groundwater quality testing of one borehole at Ackermans, Blackheath. The yield testing was undertaken by GEOSS SA from 6 to 9 November 2023. This included a Step Test, CDT and Recovery Test at the borehole and sampling of the groundwater for chemical analysis. It is recommended that groundwater abstraction occur within the below-mentioned parameters from the tested borehole. Aquifer over-abstraction is unlikely to occur if these rates are adhered to and if the borehole is managed through long-term monitoring data.

Borehole Details				
Borehole Name	**Latitude (DD)**	**Longitude (DD)**	**Borehole Depth (m)**	**Inner Diameter (mm)**
AB_BH1	-33.95713°	18.67164°	84	135
Abstraction Recommendations				
Borehole Name	**Abstraction rate (L/s)**	**Abstraction Duration (hrs)**	**Recovery Duration (hrs)**	**Possible Volume Abstracted (L/d)**
AB_BH1	2.9	24	0	250 560
Pump Installation Details				
Borehole Name	**Pump Installation Depth (mbgl)**	**Critical Water Level (mbgl)**	**Dynamic Water Level (mbgl)***	**Rest Water Level (mbgl)**
AB_BH1	52	50	30	3.08

* Typical water level expected during long-term production

Through long term water level monitoring data, the abstraction volumes can be optimised by adjusting the abstraction rate if required. It is recommended that the borehole is equipped with a variable frequency drive. This enables adjustments to the flow rate to be made if required, as determined by the hydrogeological analysis of water level and flow rate monitoring data.

From the laboratory results, groundwater from AB_BH1 is of poor quality for potable supply. The primary cause of the poor groundwater quality is the elevated turbidity (22.5 NTU). According to the SANS 241-1:2015 standards the elevated turbidity will have aesthetic effects on the water such as poor colour. Similarly, the iron (1.935 mg/L), manganese (0.114 mg/L) and chloride (328.15 mg/L) will have aesthetic effects on the water such as poor taste and colour. Due to the elevated iron concentration, iron biofouling is likely to occur in the borehole if the borehole is not managed optimally. This will result in the clogging of the borehole as well as abstraction infrastructure. The groundwater from AB_BH1 is currently not suitable for human consumption without treatment. Should the water be used for irrigation, crop selection should take into account the elevated chloride concentration.

To address the potential for iron to clog the borehole and abstraction infrastructure, it is recommended to maintain a constant and continuous pumping schedule as much as possible. Thus, should a daily volume of less than 250 560 L/d be required, it is recommended to decrease the

pumping rate and not the pumping duration. By pumping continuously instead of on a stop-start schedule, iron oxidation in the borehole is minimized, decreasing the amount of iron precipitation inside the boreholes and pumps.

To facilitate monitoring and informed management of the borehole, it is recommended to equip borehole with the following monitoring infrastructure and equipment:

- Installation of a 32 mm (inner diameter, class 10) observation pipe from the pump depth to the surface, closed at the bottom and slotted for the bottom 5 – 10 m. This was done during the testing activities in November 2023.
- Installation of an electronic water level logger (for automated water level monitoring)
- Installation of a sampling tap (to monitor water quality)
- Installation of a flow volume meter (to monitor abstraction rates and volumes)

This report is an important document for obtaining the legal compliance with regard to the use of the groundwater with the Department of Water and Sanitation, but does not constitute a Geohydrological Assessment report in support of a WULA, which would need to incorporate information from this report.

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ABBREVIATIONS

AD	available drawdown
bh	borehole
CDT	constant discharge test
DWA	Department of Water Affairs (pre- 1994)
DWAF	Department of Water Affairs and Forestry (1994 – 2009)
DWS	Department of Water and Sanitation (2009 – ….)
ID	inner diameter
L/s	litres per second
L/d	litres per day
m^2/d	meters squared per day
m	metres
mbgl	metres below ground level
RWL	rest water level below ground level
T	Transmissivity

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)].

Available drawdown: Available drawdown in a borehole is the difference between the rest water level or piezometric surface and the depth that the water level may drop to (typically major water baring unit, boundary inflection or pump depth).

Dynamic water level: the stabilised water level in the borehole during production over long periods of time.

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.

Rest water level: The groundwater level in a borehole not influenced by abstraction or artificial recharge.

Sustainable yield: Sustainable yield is defined as the rate of withdrawal that can be sustained by an aquifer without causing an unacceptable decline in the hydraulic head or deterioration in water quality in the aquifer.

Transmissivity: The rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient.

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AB_BH1 during testing.

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Reviewed by:
Ashleigh Lakshuman (20 November 2023) and Julian Conrad (20 November 2023).

1. INTRODUCTION

GEOSS South Africa (Pty) Ltd was appointed by Johan Roos from KLS Consulting Engineers to conduct yield and water quality testing of one borehole at Ackermans, Blackheath.

The borehole was tested by GEOSS SA from 6 to 9 November 2023, details of this are presented in this report. The borehole's details are presented in **Table 1** below and spatially in **Figure 2.** A borehole drill log is presented in **Appendix A**. The geological setting of the area indicates that the borehole is drilled through the sandy loam of the Springfontyn formation into the underlying greywacke and phyllites of the Tygerberg formation (**Figure 3**).

Table 1: Borehole Details

Borehole	Latitude (DD-WGS84)	Longitude (DD-WGS84)	Depth (m)
AB_BH1	-33.95713°	18.67164°	84

Figure 1: AB_BH1 before (left) and after (right) testing.

2. YIELD TESTING

2.1 Methodology

The yield testing was undertaken by GEOSS SA from 6 to 9 November 2023 and carried out according to the National Standard (SANS 10299-4:2003, Part 4 – Test pumping of water boreholes). This included a Step Test, Constant Discharge Test (CDT) and recovery monitoring of the borehole. For the Step Test, a borehole is pumped at a constant rate for one-hour intervals and the flow rates are incrementally increased for each step. This test is followed by a Constant Discharge Test where the borehole is pumped at a constant rate for an extended period of time, followed by recovery monitoring. The water level drawdown is monitored at pre-determined intervals during these tests (drawdown refers to the difference in water level from the rest water level (RWL) measured before commencement of the yield test). Raw data and measurements taken during the yield tests are presented in **Appendix B.**

Figure 2: Borehole Locality Map

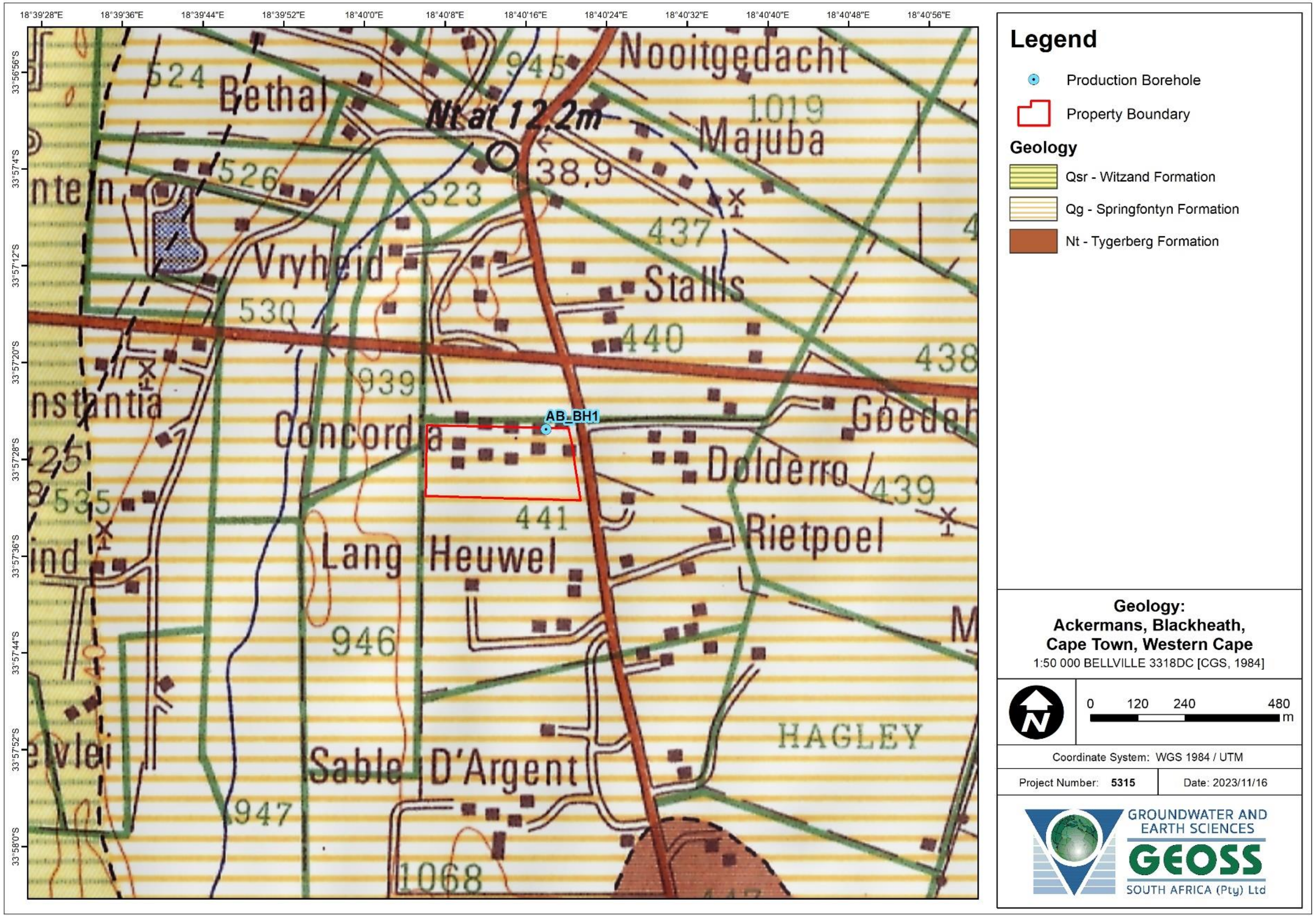

Figure 3: Geological Map with Property Boundary and Tested Borehole Position (1:50 000 Geological Map Series, 3318 DC Bellville)(CGS, 1984).

The yield test data was analysed using the excel-based FC program, developed by the IGS (Institute for Groundwater Studies) in Bloemfontein. The sustainable yield of the borehole was calculated based upon long-term extrapolations of the CDT data according to (1) the Cooper-Jacob approximation of the Theis solution for confined aquifers, (2) the Barker Generalised Radial Flow Model (GRF) for hydraulic tests in fractured rock and (3) the Flow Characteristic (FC) method(s) using first and second derivative calculations. Boundary conditions are accounted for in multiplication factors to the rate of drawdown (derivatives), according to each of the above three methods. These three methods are briefly described below.

1. The Cooper-Jacob approximation of the Theis solution for confined aquifers was designed for porous media aquifers, where infinite acting radial flow (IARF) was observed during the pumping of a borehole. The application of this method to fractured aquifers was discussed by Meier et al (1998), concluding that T estimates using the Cooper-Jacob analysis gave an effective T for the fracture zone. The Cooper-Jacob analysis (and more accurately the Theis method) is therefore viable for analysing pumping test data for fractured aquifers where IARF is observed. The parameters are then used to predict theoretical long-term drawdowns.
2. The Barker GRF Model (Barker, 1988) uses fracture hydraulic conductivity, fracture storativity and flow domain to predict drawdown due to abstraction in a borehole in a fractured medium. By changing these values, a curve of drawdown predictions can be made to fit real-world data and therefore predict theoretical long-term drawdowns.
3. The FC methods are the Basic FC, the FC Inflection Point and the FC Non-Linear. The Basic FC and the FC Inflection Point methods make use of the derivatives of the drawdown data to predict theoretical long-term drawdowns and the scale-back factors are applied to selected available drawdowns. The FC Non-Linear method uses curve fitting of the Step Test data to predict theoretical long-term drawdowns. Due to the short nature of the Step Test, this method is usually not included if the other methods of analysis differ from it.

In all three methods, the available drawdown was carefully selected to ensure that the flow regime described by the analytical solution is not extrapolated beyond its applicable depth, which may easily result in an overuse of the resource. For AB_BH1 this was 50 m (54 mbgl), based on the first fracture intersected in the borehole. A two-year extrapolation time without recharge to the aquifer was selected as per the recommendations within the FC method program.

Water samples were collected at the end of the yield test and submitted for inorganic chemical analyses.

2.2 *Yield Testing at AB_BH1*

The yield testing was conducted between the 6th and the 9th of November 2023. The borehole was measured to a depth of 84 meters below ground level (mbgl). The test pump was installed at a depth of 78.12 mbgl, with the observation pipe ending at 75.32 mbgl. A 7.5 kw submersible pump was used to conduct the testing. The size of the pump was limited by the 135 mm steel casing installed in the borehole. The rest water level (RWL) at the start of the test was 3.08 mbgl.

During the step test, the water level was drawn down 17.08 meters below the rest water level (20.16 mbgl) during the 4th step at a rate of 4.8 L/s (17 280 L/hour, pump max). **Figure 4** shows the time-series drawdown for the Step Test.

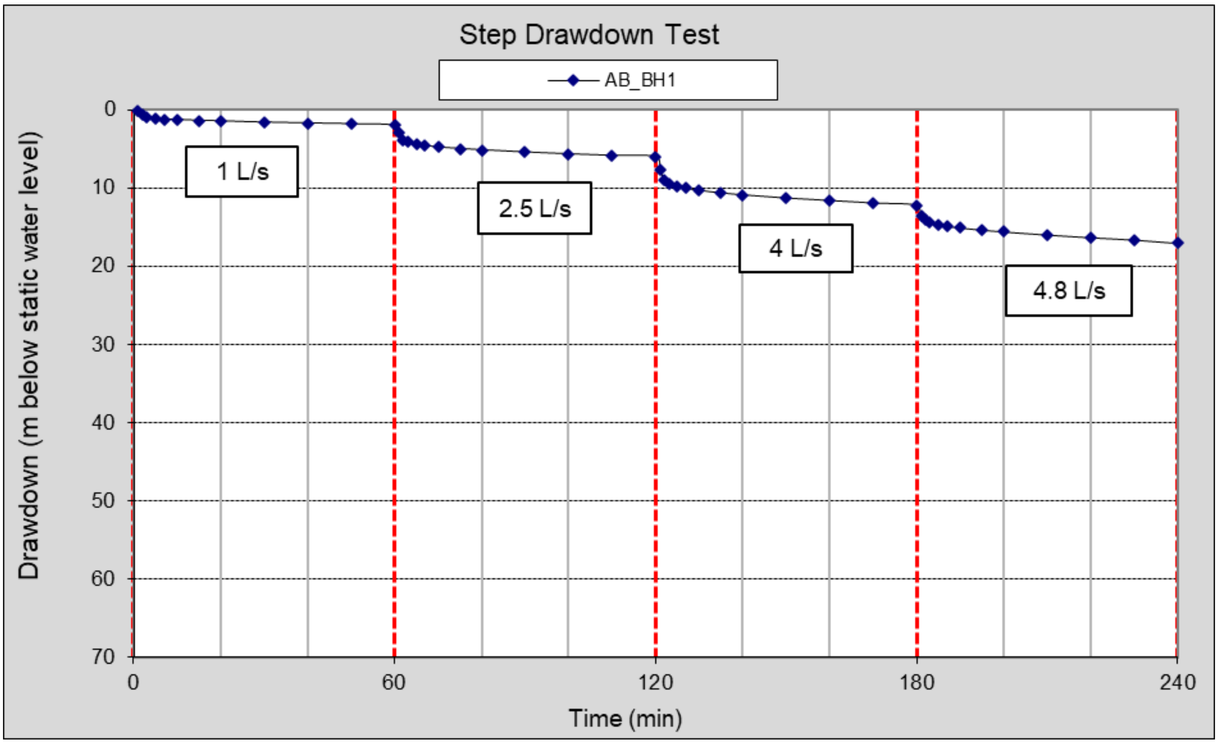

Figure 4: Step Test drawdown data for AB_BH1.

The water level was left to recover overnight. Before starting the CDT, the water level recovered to 3.97 mbgl. Based on the results of the Step Test, the planned 24-hour CDT was conducted at a rate of 4.6 L/s (16 560 L/hour). At the end of the 24-hour period, the water level had drawn down 23.6 meters below the rest water level (27.57 mbgl).

The semi-log plot of the drawdown from the CDT is presented in **Figure 5**. The available drawdown (AD) is indicated with the horizontal red line at 50 m.

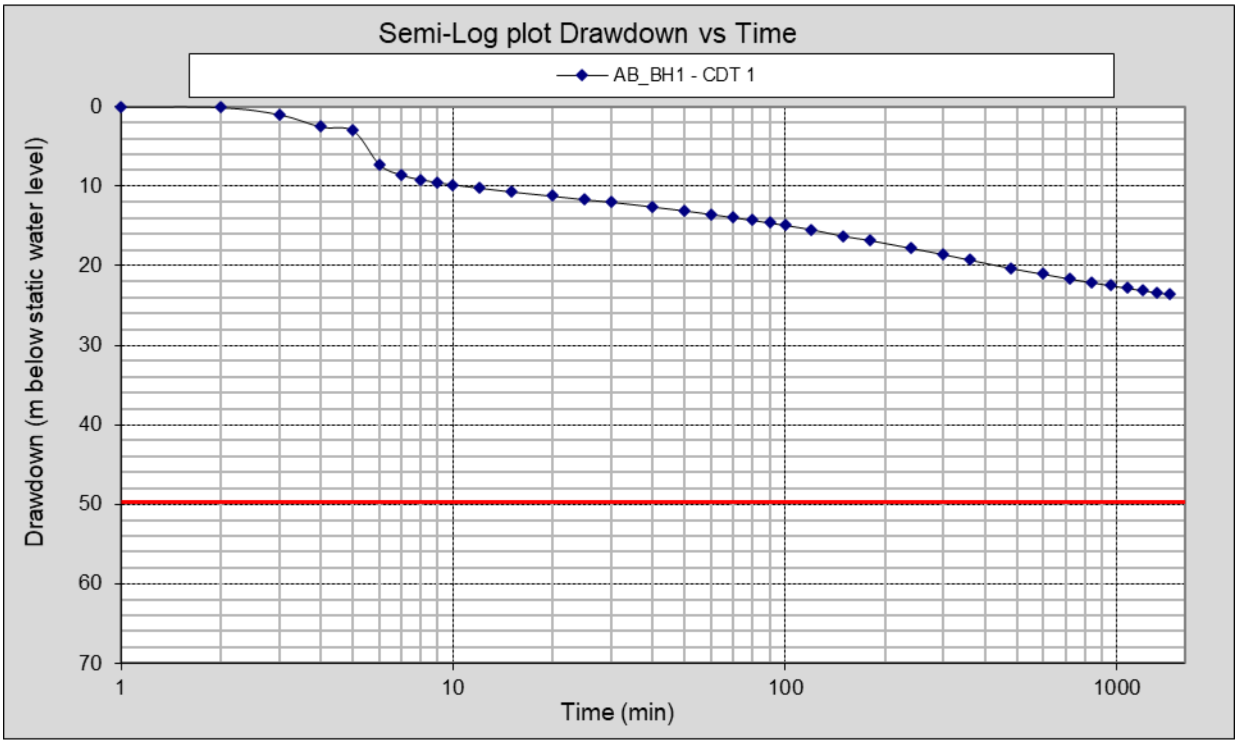

Figure 5: Semi-Log Plot of drawdown during the CDT of AB_BH1 (4.6 L/s).

The recovery of the water level was monitored after the CDT and is presented in **Figure 6**. The recovery was moderate, reaching 95.8% in 24 hours. Monitoring will be essential to determine the long term recovery of the borehole.

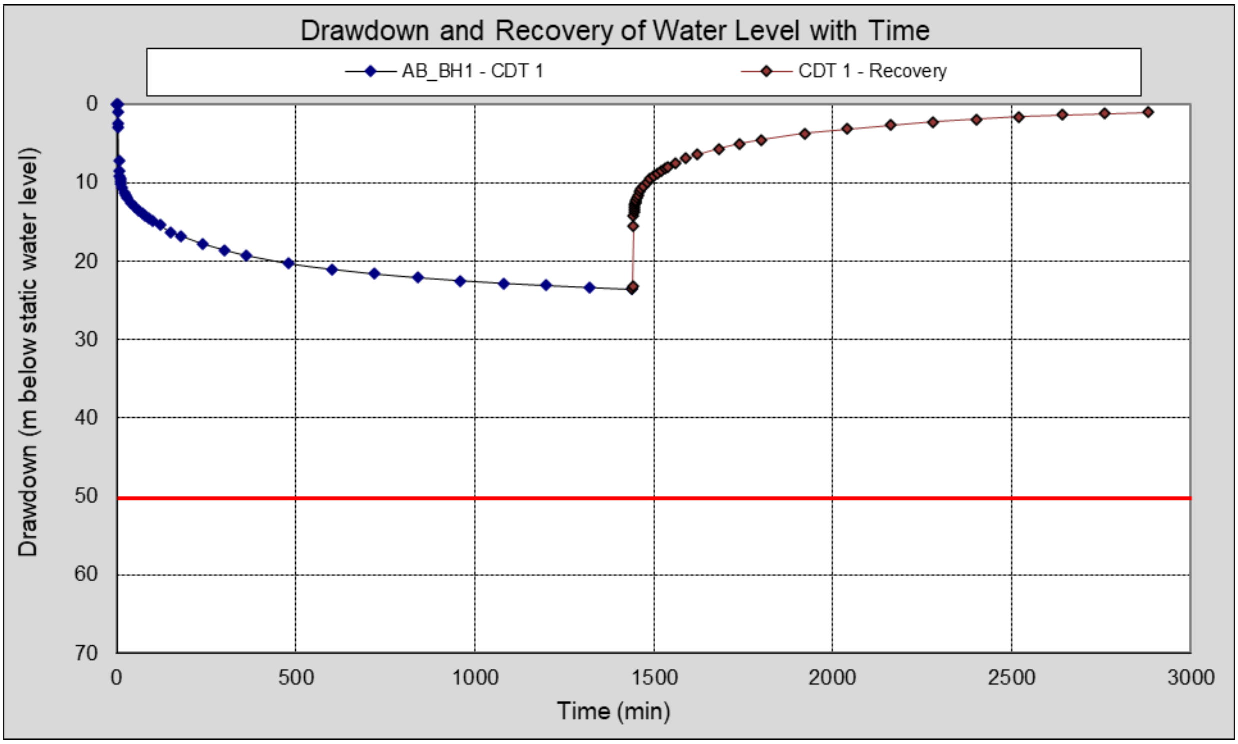

Figure 6: Time-series drawdown and recovery for AB_BH1 (4.6 L/s).

Several methods were used to assess the yield test data as presented in **Table 2.** It is recommended that the borehole can be abstracted from at a rate of up to 2.9 L/s (10 440 L/hour) for up to

24 hours per day. The assessments were based on an available drawdown (AD) of 50 meters below the RWL of the CDT which equates to 54 mbgl.

Table 2: Yield Determination - AB_BH1

AB_BH1			
Method	**Sustainable Yield (L/s)**	**Late *T (m^2/d)**	****AD used (m)**
Basic FC	3.5	11.3	50.0
Cooper-Jacob	2.8	11.4	50.0
FC Non-Linear	2.4	19	50.0
Barker	2.9		50.0
Average Q_sust (L/s)	**2.9**		
Recommended Abstraction			
Abstraction Rate (L/s)	**Abstraction Duration (hours)**		**Recovery Duration (hours)**
2.9	24		0

***AD- Available Drawdown*
** T – Transmissivity*

No boreholes were monitored during the testing of AB_BH1. Transmissivity was calculated through the Theis method using the drawdown response in AB_BH1. The transmissivity of the system was calculated at 11.4 m^2/d. A storativity value of $5x10^{-4}$ was used for the radius of influence calculation based on an average expected value of confined aquifers as report by (Todd, 1980). Based on the aquifer parameters the radius of influence was calculated for the recommended sustainable yield of the borehole. A drawdown of up to 6.3 meters can be expected 1 kilometre away from AB_BH1 at the recommended sustainable rate (2.9 L/s for 24 hours per day) after 2 years of abstraction without recharge (**Figure 7**). It must be noted that the Cooper-Jacob modelling of radius of influence is based on a homogenous, confined aquifer and therefore does not account for the heterogeneity associated with secondary aquifers (fractured rock). Thus, the radius of influence model will only provide an indication of how abstraction at AB_BH1 will impact the water level in the fracture network. This suggests that the cone of depression will not expand equivalently in all directions surrounding the borehole, but will rather propagate along the fracture network within the secondary aquifer.

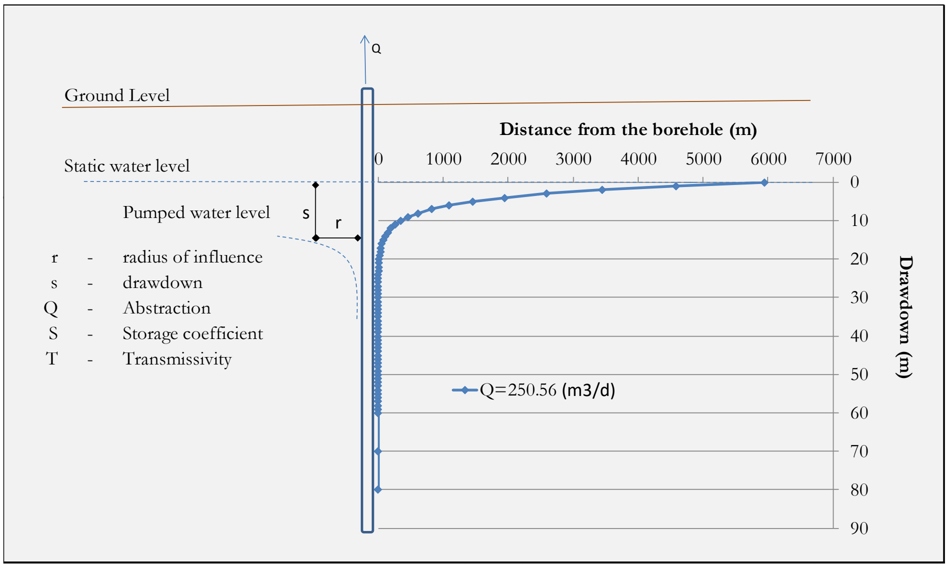

Figure 7: Radius of influence for AB_BH1 at the recommended sustainable yield (2.9 L/s).

3. WATER QUALITY ANALYSIS

Groundwater samples were collected from the borehole at the end of the yield test and submitted for inorganic chemical analyses to a SANAS accredited laboratory (Vinlab) in the Western Cape. The certificate of analysis for the sample is presented in **Appendix C**. The chemistry results obtained for the borehole have been classified according to the SANS241-1: 2015 standards for domestic water **(Table 3). Table 5** presents the water chemistry analysis results, colour coded according to the SANS241-1: 2015 drinking water assessment standards.

Table 3: Classification table for specific limits

Acute Health	**Chronic Health**	**Aesthetic**	**Operational**	**Acceptable**

The limits and associated risks for domestic water as determined by the South African National Standard (SANS) 241:2015 are as follows, where:

- Health risks: parameters falling outside these limits may cause acute or chronic health problems in individuals.
- Aesthetic risks: parameters falling outside these limits indicate that water is visually, aromatically or palatably unacceptable.
- Operational risks: parameters falling outside these limits may indicate that operational procedures to ensure water quality standards are met may have failed.

The chemistry results obtained have also been classified according to the DWAF (1998) standards for domestic water. **Table 4** enables an evaluation of the water quality with regards to the various parameters measured (DWAF, 1998). **Table 6** presents the water chemistry analysis results colour coded according to the DWAF drinking water assessment standards.

Table 4: Classification table for the groundwater results (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.

Table 5: Production borehole results classified according to SANS241-1:2015

Analyses	AB_BH1	SANS 241-1:2015
Date and Time Sampled	08/11/2023 06:30	
pH (at 25 °C)	7.1	5.0 ≤ Operational ≤ 9.7
Conductivity (mS/m) (at 25 °C)	136.1	Aesthetic ≤170
Total Dissolved Solids (mg/L)	922.76	Aesthetic ≤1200
Turbidity (NTU)	22.50	Operational ≤1 Aesthetic ≤5
Colour (mg/L as Pt)	<15	Aesthetic ≤15
Sodium (mg/L as Na)	177	Aesthetic ≤200
Potassium (mg/L as K)	3	N/A
Magnesium (mg/L as Mg)	29	N/A
Calcium (mg/L as Ca)	50	N/A
Chloride (mg/L as Cl)	328.15	Aesthetic ≤300
Sulphate (mg/L as SO_4)	7.66	Aesthetic ≤250 Acute ≤500
Nitrate & Nitrite Nitrogen (mg/L as N)	0.068	≤1 Acute Health
Nitrate Nitrogen (mg/L as N)	<1.00	Acute Health ≤11
Nitrite Nitrogen (mg/L as N)	<0.05	Acute Health ≤0.9
Ammonia Nitrogen (mg/L as N)	0.19	Aesthetic ≤1.5
Total Alkalinity (mg/L as $CaCO_3$)	173.2	N/A
Total Hardness (mg/L as $CaCO_3$)	243.9	N/A
Fluoride (mg/L as F)	<0.15	Chronic Health ≤1.5
Aluminium (mg/L as Al)	<0.008	Operational ≤0.3
Total Chromium (mg/L as Cr)	<0.004	Chronic Health ≤0.05
Manganese (mg/L as Mn)	0.114	Aesthetic ≤0.1 Chronic ≤0.4
Iron (mg/L as Fe)	1.935	Aesthetic ≤0.3 Chronic ≤2
Nickel (mg/L as Ni)	<0.008	Chronic Health ≤0.07
Copper (mg/L as Cu)	0.010	Chronic Health ≤2
Zinc (mg/L as Zn)	<0.008	Aesthetic ≤5
Arsenic (mg/L as As)	<0.010	Chronic Health ≤0.01
Selenium (mg/L as Se)	<0.008	Chronic Health ≤0.04
Cadmium (mg/L as Cd)	0.001	Chronic Health ≤0.003
Antimony (mg/L as Sb)	<0.013	Chronic Health ≤0.02
Mercury (mg/L as Hg)	<0.001	Chronic Health ≤0.006
Lead (mg/L as Pb)	0.009	Chronic Health ≤0.01
Uranium (mg/L as U)	<0.028	Chronic Health ≤0.03
Cyanide (mg/L as CN^-)	<0.01	Acute Health ≤0.2
Total Organic Carbon (mg/L as C)	0.54	N/A
Charge Balance Error %	1.5	≥-5 - ≤5 Acceptable

Table 6: Classified production borehole results according to DWAF 1998.

	AB_BH1	**DWA (1998) Drinking Water Assessment Guide**				
		Class 0	**Class I**	**Class II**	**Class III**	**Class IV**
		Ideal	**Good**	**Marginal**	**Poor**	**Dangerous**
Date and Time Sampled	08/11/2023 06:30					
pH	7.1	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)	136.1	<70	70-150	150-370	370-520	>520
Turbidity (NTU)	22.50	<0.1	0.1-1	1.0-20	20-50	>50
	mg/L					
Total Dissolved Solids	922.76	<450	450-1000	1000-2400	2400-3400	>3400
Sodium (as Na)	177	<100	100-200	200-400	400-1000	>1000
Potassium (as K)	3	<25	25-50	50-100	100-500	>500
Magnesium (as Mg)	29	<70	70-100	100-200	200-400	>400
Calcium (as Ca)	50	<80	80-150	150-300	>300	
Chloride (as Cl)	328.15	<100	100-200	200-600	600-1200	>1200
Sulphate (as SO_4)	7.66	<200	200-400	400-600	600-1000	>1000
Nitrate & Nitrite (as N)	0.068	<6	6.0-10	10.0-20	20-40	>40
Fluoride (as F)	<0.15	<0.7	0.7-1.0	1.0-1.5	1.5-3.5	>3.5
Manganese (as Mn)	0.114	<0.1	0.1-0.4	0.4-4	4.0-10.0	>10
Iron (as Fe)	1.935	<0.5	0.5-1.0	1.0-5.0	5.0-10.0	>10
Copper (as Cu)	0.010	<1	1-1.3	1.3-2	2.0-15	>15
Zinc (as Zn)	<0.008	<20	>20			
Arsenic (as As)	<0.010	<0.010	0.01-0.05	0.05-0.2	0.2-2.0	>2.0
Cadmium (as Cd)	0.001	<0.003	0.003-0.005	0.005-0.020	0.020-0.050	>0.050
Hardness (as $CaCO_3$)	243.900	<200	200-300	300-600	>600	
Charge Balance Error %	1.5	≥-5 - ≤5 Acceptable				

From the chemical results presented in **Table 5** and **Table 6**, groundwater from AB_BH1 is of poor quality for potable supply. The primary cause of the poor groundwater quality is the elevated turbidity (22.5 NTU). According to the SANS 241-1:2015 standards the elevated turbidity will have aesthetic effects on the water such as poor colour. Similarly, the iron (1.935 mg/L), manganese (0.114 mg/L) and chloride (328.15 mg/L) will have aesthetic effects on the water such as poor taste and colour. Due to the elevated iron concentration, iron biofouling is likely to occur in the borehole if the borehole is not managed optimally. This will result in the clogging of the borehole as well as abstraction infrastructure. The groundwater from AB_BH1 is currently not suitable for human consumption without treatment. Should the water be used for irrigation, crop selection should take into account the elevated chloride concentration.

A number of chemical diagrams have been plotted for the groundwater sample and these are useful for chemical characterisation of the water and illustrate the similarities and differences in the water types. The Stiff Diagram is a graphical representation of the equivalent concentrations of the cations (positive ions) and anions (negative ions). This diagram shows concentrations of cations and anions relative to each other and direct reference can be made to specific salts in the water. From **Figure 8**, AB_BH1 is classified as a Sodium & Potassium/Chloride hydrofacies. This is expected of groundwater hosted in the greywacke and phyllites of the Tygerberg formation.

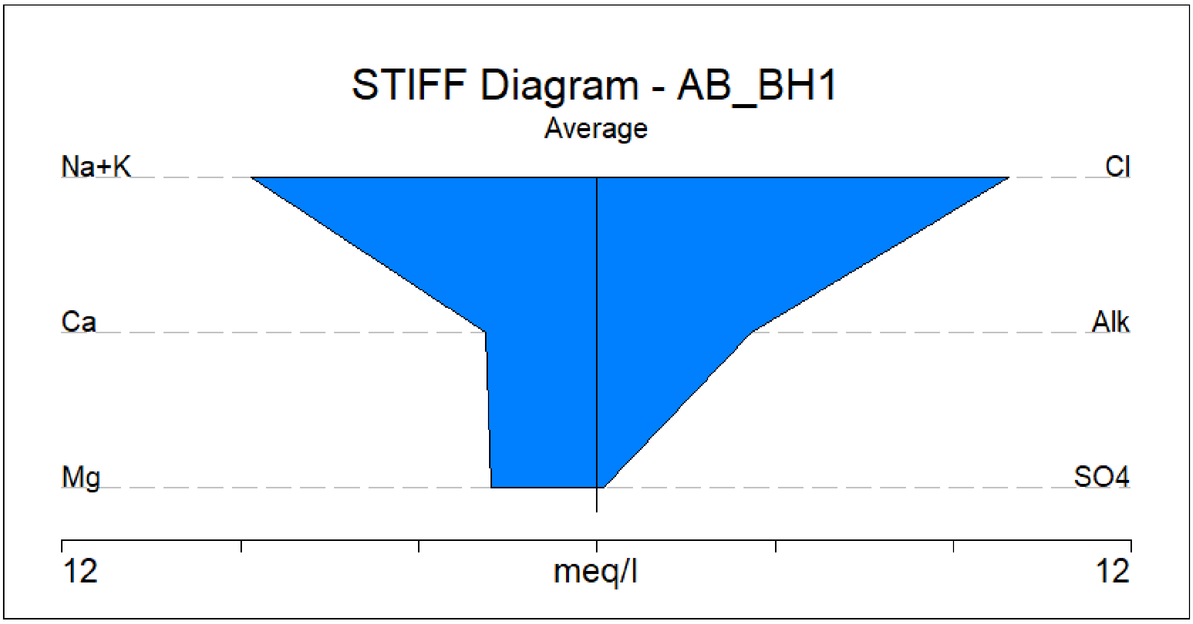

Figure 8: Stiff diagram of the groundwater sample.

The Sodium Adsorption Ratio (SAR) of the groundwater is plotted in **Figure 9**. AB_BH1 plots as S1/C3, thus classified as low risk in terms of sodium adsorption and high risk in terms of salinity hazard. This graph is typically applicable to irrigation, however, is dependent on soil texture and crop type.

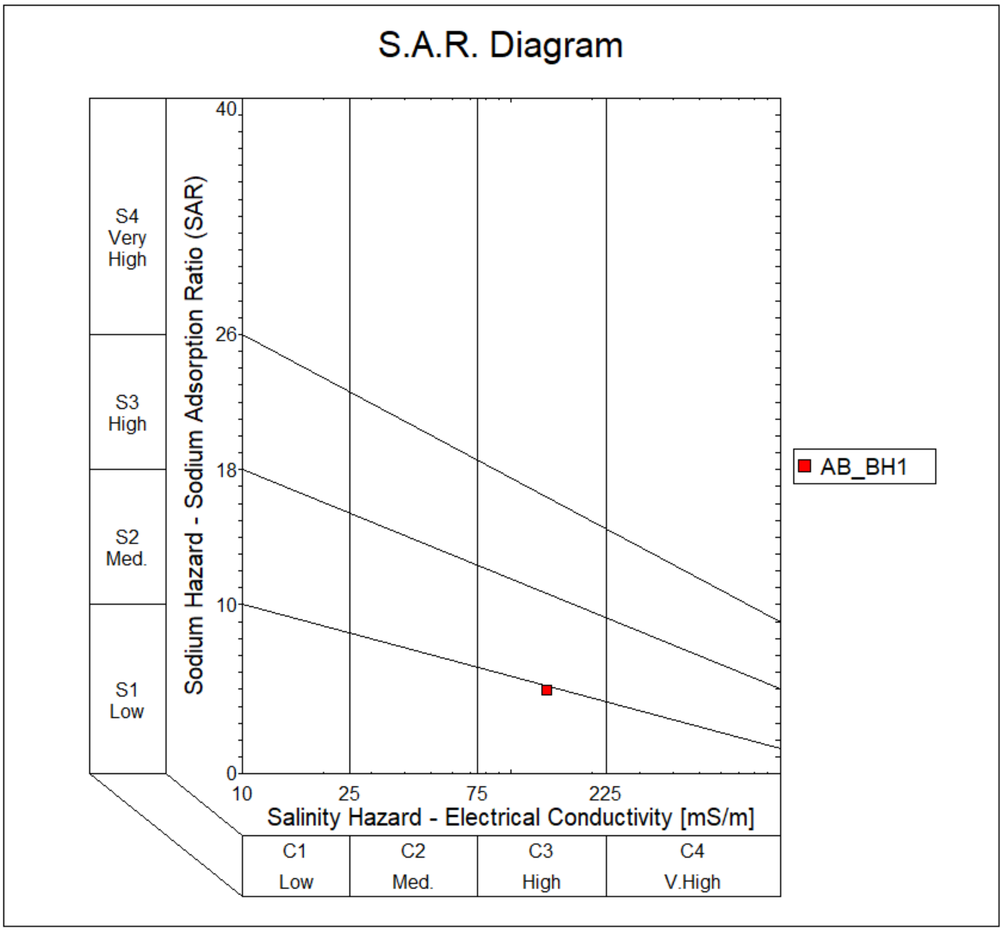

Figure 9: SAR diagram of the groundwater sample.

4. RECOMMENDATIONS

Based on the information obtained from the yield test, the abstraction recommendation for the borehole is presented in **Table 7**. The yield testing was conducted with a Step Test, Constant Discharge Test and Recovery Test and while this data can be analysed to estimate sustainable yields, additional drilling in the area may result in long term cumulative impacts. Optimisation of the resource is also likely through making small changes to the abstraction rate, should the dynamic water level's drawdown be less or more than expected as per **Table 7**. Both of these points are best managed through long term monitoring data.

Table 7: Borehole Abstraction Recommendations

Borehole Details				
Borehole Name	**Latitude (DD)**	**Longitude (DD)**	**Borehole Depth (m)**	**Inner Diameter (mm)**
AB_BH1	-33.95713°	18.67164°	84	135

Abstraction Recommendations				
Borehole Name	**Abstraction rate (L/s)**	**Abstraction Duration (hrs)**	**Recovery Duration (hrs)**	**Possible Volume Abstracted (L/d)**
AB_BH1	2.9	24	0	250 560
Pump Installation Details				
Borehole Name	**Pump Installation Depth (mbgl)**	**Critical Water Level (mbgl)**	**Dynamic Water Level (mbgl)***	**Rest Water Level (mbgl)**
AB_BH1	52	50	30	3.08

* Typical water level expected during long-term production

For borehole AB_BH1 it is recommended that abstraction can occur at a rate of up to 2.9 L/s for 12 hours per day. A pump suitable to deliver the recommended rate should be installed at a depth of 52 mbgl. It is anticipated that abstraction at the recommended rate will cause the water level to drop to a depth of approximately 30 mbgl – this is referred to as the dynamic water level. During abstraction, a maximum level cut off switch should be installed to 50 mbgl to ensure the groundwater level does not drop to the pump inlet.

From the laboratory results, groundwater from AB_BH1 is of poor quality for potable supply. The primary cause of the poor groundwater quality is the elevated turbidity (22.5 NTU). According to the SANS 241-1:2015 standards the elevated turbidity will have aesthetic effects on the water such as poor colour. Similarly, the iron (1.935 mg/L), manganese (0.114 mg/L) and chloride (328.15 mg/L) will have aesthetic effects on the water such as poor taste and colour. Due to the elevated iron concentration, iron biofouling is likely to occur in the borehole if the borehole is not managed optimally. This will result in the clogging of the borehole as well as abstraction infrastructure. The groundwater from AB_BH1 is currently not suitable for human consumption without treatment. Should the water be used for irrigation, crop selection should take into account the elevated chloride concentration.

To address the potential for iron to clog the borehole and abstraction infrastructure, it is recommended to maintain a constant and continuous pumping schedule as much as possible. Thus, should a daily volume of less than 250 560 L/d be required, it is recommended to decrease the pumping rate and not the pumping duration. By pumping continuously instead of on a stop-start schedule, iron oxidation in the borehole is minimized, decreasing the amount of iron precipitation inside the boreholes and pumps.

Through long term water level monitoring data, the abstraction volumes can be optimised by adjusting the abstraction rate if required. It is recommended that the borehole is equipped with a variable frequency drive. This enables adjustments to the flow rate to be made if required, as determined by the hydrogeological analysis of water level and flow rate monitoring data.

As of January 2018 the Department of Water and Sanitation released a Government Gazette stating that: "All water use sector groups and individuals taking water from any water resource (surface or groundwater) regardless of the authorization type, in the Berg, Olifants and Breede Gouritz Water

Management Area, shall install electronic water recording, monitoring or measuring devices to enable monitoring of abstractions, storage and use of water by existing lawful users and establish links with any monitoring or management system as well as keep records of the water used."

Therefore, to facilitate monitoring and informed management of the borehole, it is highly recommended that the borehole be equipped with the following monitoring infrastructure and equipment (diagram included in **Appendix D**):

- Installation of a 32 mm (inner diameter, class 10) observation pipe from the pump depth to the surface, closed at the bottom and slotted for the bottom 5 – 10 m. This was done during the testing activities in November 2023.
- Installation of an electronic water level logger (for automated water level monitoring).
- Installation of a sampling tap (to monitor water quality).
- Installation of a flow volume meter (to monitor abstraction rates and volumes).

This monitoring data should be analysed by a qualified Hydrogeologist to ensure long-term sustainable use from the borehole. The legal compliance with regard to the use of the groundwater also needs to be addressed with the Department of Water and Sanitation.

5. REFERENCES

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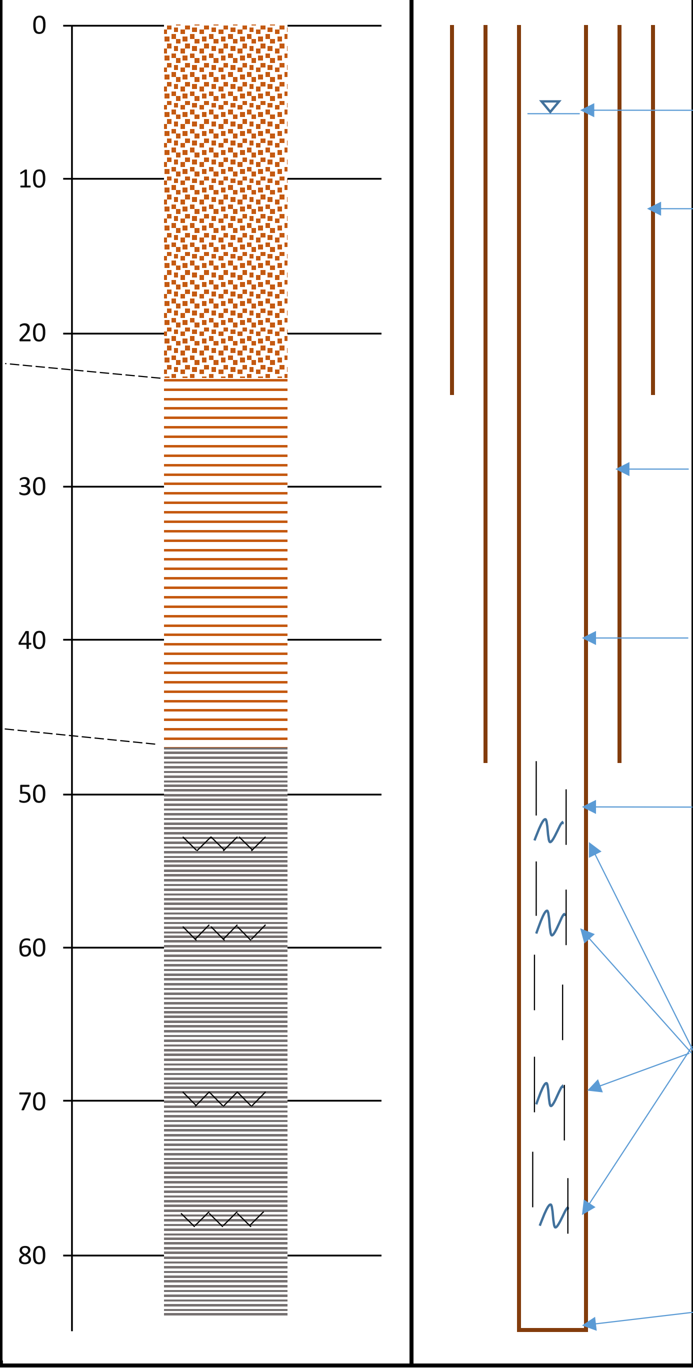
6. APPENDIX A: BOREHOLE LOG

Log of Borehole No.: AB_BH1

Location:	Blackheath	**Latitude:**	-33.95713
Date:	20-Nov-23	**Longitude:**	18.67164
Client:	kls Consulting	**Ground Elevation:**	46 mamsl

Lithological Description	Lithology Symbol & Depth (m)	Borehole Construction	Description & water strike
Springfontyn fm. Sandy loam Tygerberg fm. Clay and weatherd phyllites Tygerberg fm. Phyllites			Water level (3.08 m) 219 mm Solid Steel casing (0 - 24 m) 177 mm Solid Steel casing (0 - 48 m) 139 mm Solid Steel casing (0 - 48 m & 78 - 84 m) 139 mm Perforated Steel casing (48 - 78 m) Water strikes (54, 59, 70 and 77 m) EOH (84 m)

Drilled By:	Gerritsen Drilling SA	**Remarks:**	Blow yield 18 000 L/h
Drill Method:	Air Percussion		
Logged By:	S.Swart		

7. APPENDIX B: YIELD TEST DATA

GROUNDWATER AND EARTH SCIENCES
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Borehole Yield Test Results

Project Name	Ackermans Blackheath
Project Number	5315_A
Borehole Name	AB_BH1

Site Details		
Province	Western Cape	
Area	Blackheath	
Farm/Site Name	Ackermans development	
Rig operator	Lusanda/Nunens	
Pump type	7.5 KW	
Coordinate system	-33.95713	Lat
	18.67164	Long
BoreholeStatus	Newly drilled	
Borehole depth	84	m
Borehole diameter (OD,ID)	135 ID	mm
Dummy pump test	*4	
Casing depth	78	m
Casing height	0.49	m
Datum level above ground	0.98	m
Test pump depth	78.12	m
Observation pipe depth	75.32	m
Logger depth	75.32	m
Available Drawdown	71.26	m
Water level before the test	3.49	mbch
Rest water level before step test	4.06	mbdl
	3.08	mbgl
Rest water level before CDT	4.95	mbdl
	3.97	mbgl
Outlet distance	Stormwater	m
Water sample type	Sans 241	
Comment	Completed	

Test date		
06-Nov-23	-	09-Nov-23

Step test details					
Date	**Step**	**Length**	**Flow rate**		**Comments**
06-Nov-23	1	1 h	1.0	l/s	Completed
06-Nov-23	2	1 h	2.5	l/s	Completed
06-Nov-23	3	1 h	4.0	l/s	Completed
06-Nov-23	4	1 h	4.8	l/s	Completed

Constant discharge test details				
Start Date	**Length**	**Flow rate**		**Comments**
07-Nov-23	24	4.6	l/s	Completed

Recovery details	
Start Date	**Data Capture**
08-Nov-23	Solinst logger

Monitoring boreholes			
Borehole:	**RWL**	**Distance from:**	**AB_BH1**

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DIRECTORS: JE CONRAD, DL BARROW

Step Test	06-Nov-23		5315_A	AB_BH1
Time	14:00		RWL (mbgl)	3.08
Ackermans Blackheath				
Step 1			**Step 2**	
1	l/s		2.5	l/s
Time interval (min)	Water level drawdown (m)		Time interval (min)	Water level drawdown (m)
1	0.16		61	2.96
2	0.72		62	3.86
3	1.05		63	4.17
5	1.20		65	4.46
7	1.23		67	4.60
10	1.30		70	4.80
15	1.41		75	4.99
20	1.49		80	5.16
30	1.64		90	5.44
40	1.75		100	5.68
50	1.85		110	5.87
60	2.04		120	6.03
Step 3			**Step 4**	
4	l/s		4.8	l/s
121	7.61		181	13.52
122	9.02		182	14.15
123	9.44		183	14.43
125	9.82		185	14.72
127	10.06		187	14.91
130	10.32		190	15.12
135	10.64		195	15.39
140	10.89		200	15.62
150	11.29		210	16.01
160	11.62		220	16.36
170	11.93		230	16.66
180	12.22		240	17.08

Constant Discharge Test (CDT) - Raw data			
Ackermans Blackheath			
5315_A	AB_BH1	07-Nov-23	
Time:	06:59	RWL (mbgl)	3.97
	Abstraction rate (L/s)	4.6	
Test Duration: 24 hours			
Hours	Time interval (min)	Water level drawdown (m)	
	0	0.00	
	1	0.00	
	2	0.07	
	3	0.97	
	4	2.51	
	5	3.01	
	6	7.26	
	7	8.57	
	8	9.15	
	9	9.51	
	10	9.78	
	12	10.20	
	15	10.68	
	20	11.22	
	25	11.67	
	30	11.98	
	40	12.58	
	50	13.07	
1	60	13.52	
	70	13.92	
	80	14.27	
	90	14.59	
	100	14.89	
2	120	15.42	
	150	16.26	
3	180	16.79	
4	240	17.78	
5	300	18.55	
6	360	19.25	
8	480	20.31	
10	600	21.04	
12	720	21.63	
14	840	22.10	
16	960	22.49	
18	1080	22.82	
20	1200	23.11	
22	1320	23.35	
24	1440	23.60	

Post CDT Recovery		
Ackermans Blackheath		
5315_A	AB_BH1	08-Nov-23
Hours	Time interval (min)	Water level drawdown (m)
	0	23.60
	1	23.23
	2	15.48
	3	14.29
	4	13.73
	5	13.35
	6	13.06
	7	12.82
	8	12.60
	9	12.42
	10	12.26
	12	11.99
	15	11.64
	20	11.16
	25	10.79
	30	10.46
	40	9.93
	50	9.49
1	60	9.11
	70	8.77
	80	8.46
	90	8.19
	100	7.93
2	120	7.48
	150	6.91
3	180	6.43
4	240	5.66
5	300	5.05
6	360	4.54
8	480	3.73
10	600	3.12
12	720	2.64
14	840	2.24
16	960	1.91
18	1080	1.63
20	1200	1.38
22	1320	1.18
24	1440	0.99

8. APPENDIX C: WATER QUALITY

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2023-11-14

TEST REPORT

Water

Geoss South Africa (Pty) Ltd

Attn: Alison McDuling

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@VinlabSA

Sample Details					
SampleID	W44210				
Water Type	Drinking Water				
Water Source	Borehole				
Sample Temperature					
Description	5315_A_AB_BH1				
Batch Number	5315_A_AB_BH1				
PO Number	5315_A_AB_BH1				
Date Received	2023-11-10				
Condition	Good				

Water - Routine	Unit	Method	Uncertainty	Limit	Results	Results	Results	Results	Results
pH@ 25C (Water)		VIN-05-MW01	^^^	>= 5 to <= 9.7	7.11				
Conductivity@ 25C (Water)	mS/m	VIN-05-MW02	^	<= 170	136.1				
Turbidity (Water)‡	ntu			<= 5	22.5				
Total dissolved solids (Water)‡	mg/L			<= 1200	922.76				
Free Chlorine (Water)‡	mg/L			<= 5	<0.02				
Ammonia (NH4) as N (Water)	mg/L	VIN-05-MW08	8.00%	<= 1.5	0.19				
Nitrate as N (Water)	mg/L	VIN-05-MW08	11.00%	<= 11	<1.00				
Nitrite as N (Water)	mg/L	VIN-05-MW08	4.50%	<= 0.9	<0.05				
Chloride (Cl-) - Water	mg/L	VIN-05-MW08	10.12%	<= 300	328.15				
Sulphates (SO4) - Water	mg/L	VIN-05-MW08	7.56%	<= 500	7.66				
Fluoride (F) - Water	mg/L	VIN-05-MW08	12.30%	<= 1.5	<0.15				
Alkalinity as CaCO3 (Water)‡	mg/L				173.20				
Colour (Water)‡	mg/L Pt-Co			<= 15	<15				
Total Organic Carbon (Water)‡	mg/L			<=10	0.54				
Date Tested					2023-11-10				

Water - Metals	Unit	Method	Uncertainty	Limit	Results	Results	Results	Results	Results
Calcium (Ca) - Water	mg/L	VIN-05-MW43	14.60%		50				

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<35 and a negative result (non-detected) indicates a Cq value of >35.

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^ - Conductivity <1000mS/m = ±1mS/m , >1000mS/m = ±9mS/m
^^ - COD, LR = ±16mg/L, MR = ±40mg/L, HR = ±477mg/L
^^^ - pH ± 0.1

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TEST REPORT

Water

Geoss South Africa (Pty) Ltd

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Magnesium (Mg) - Water	mg/L	VIN-05-MW43	8.40%		29				
Sodium (Na) - Water	mg/L	VIN-05-MW43	11.45%	<= 200	177				
Potassium (K) - Water	mg/L	VIN-05-MW43	9.42%		3				
Zinc (Zn) - Water	mg/L	VIN-05-MW43	19.40%	<= 5	<0.008				
Antimony (Sb) - Water‡	µg/L			<=20	<13.0				
Arsenic (As) - Water‡	µg/L			<= 10	<10.0				
Boron (B) Water	µg/L	VIN-05-MW43	11.79%	<= 2400	54				
Cadmium (Cd) Water	µg/L	VIN-05-MW43	12.26%	<= 3	1				
Chromium (Cr) - Water	µg/L	VIN-05-MW43	13.03%	<= 50	<4				
Copper (Cu) - Water	µg/L	VIN-05-MW43	11.57%	<= 2000	10				
Iron (Fe) - Water	µg/L	VIN-05-MW43	12.49%	<= 2000	1935				
Lead (Pb) - Water	µg/L	VIN-05-MW43	16.32%	<= 10	9				
Manganese (Mn) - Water	µg/L	VIN-05-MW43	12.44%	<= 400	114				
Nickel (Ni) - Water	µg/L	VIN-05-MW43	17.38%	<= 70	<8				
Selenium (Se) - Water‡	µg/L			<= 40	<10.0				
Aluminium (Al) - Water	µg/L	VIN-05-MW43	13.49%	<= 300	<8				
Cyanide (CN) - Water‡	µg/L			<= 200	<10.0				
Mercury (Hg) - Water‡	µg/L			<= 6	<1.0				
Barium (Ba) Water	µg/L	VIN-05-MW43	14.09%	<= 700	78				
Uranium (U) - Water‡	µg/L			<= 30	<28				
Date Tested					2023-11-13				

Comments
W44219 Ion balance = 1.5%

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* - Conductivity <1000mS/m = ±1mS/m , >1000mS/m = ±9mS/m
** - COD, LR = ±16mg/L, MR = ±49mg/L, HR = ±477mg/L
*** - pH ± 0.1

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2023-11-14

TEST REPORT

Water

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Caitlyn McCartney
Laboratory Manager - RP
VIN-05-
M01,M02,M03,M04,M07,M08,M10,M25,
M40,MW07, MW09, MW10, MW12,
MW13, MW14, VIN-05-M42, M44, M45,
MW01, MW02, MW03, MW04, MW06,
MW40, M48, M49, M50, M51, M52, M53,
M54, M55, M46, M56, M57, M58, M58

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* - Conductivity <1000mS/m = ±1mS/m , >1000mS/m = ±9mS/m
** - COD, LR = ±16mg/L, MR = ±48mg/L, HR = ±477mg/L
*** - pH ± 0.1

sanas
Testing Laboratory
T0885

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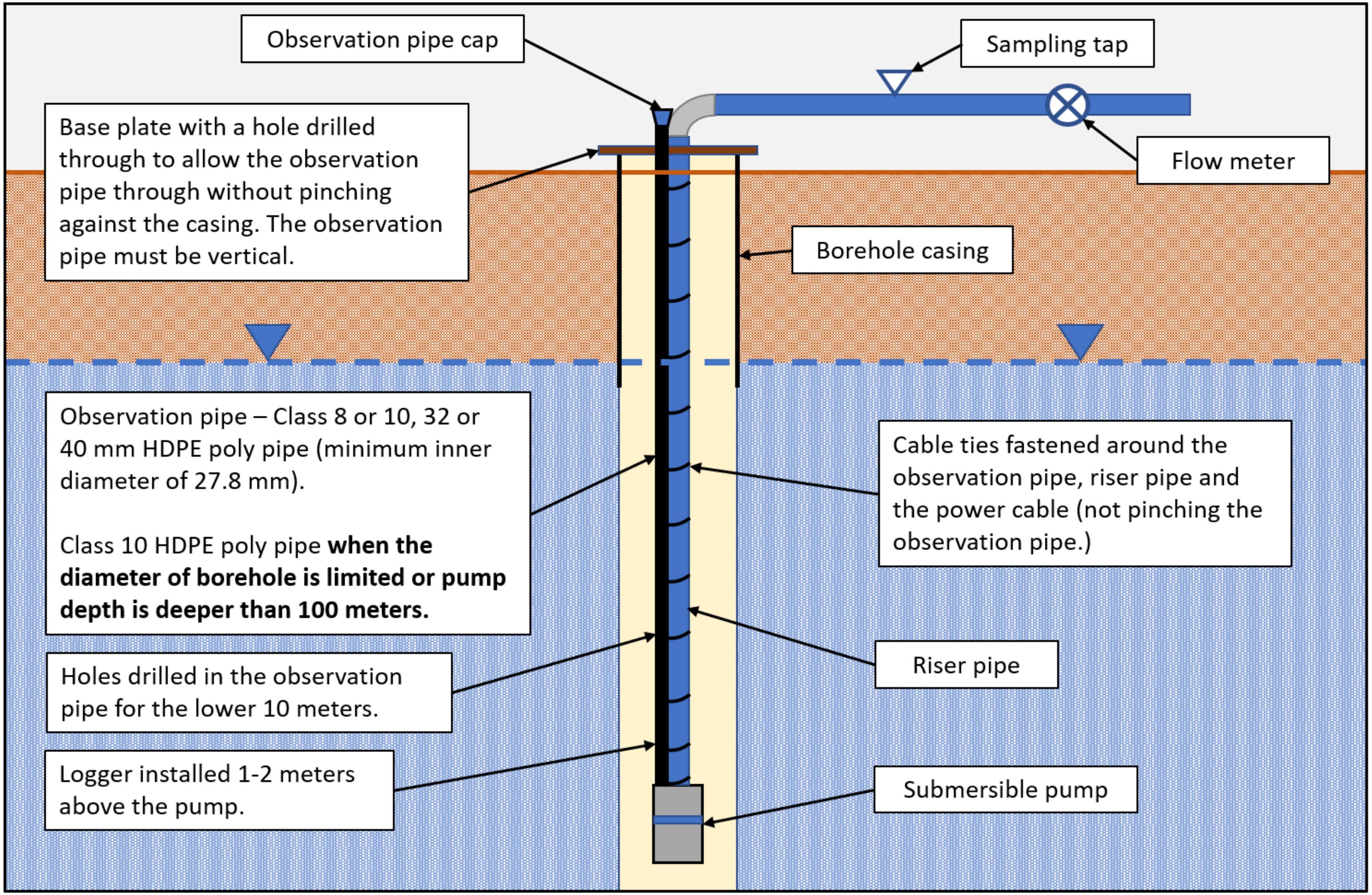
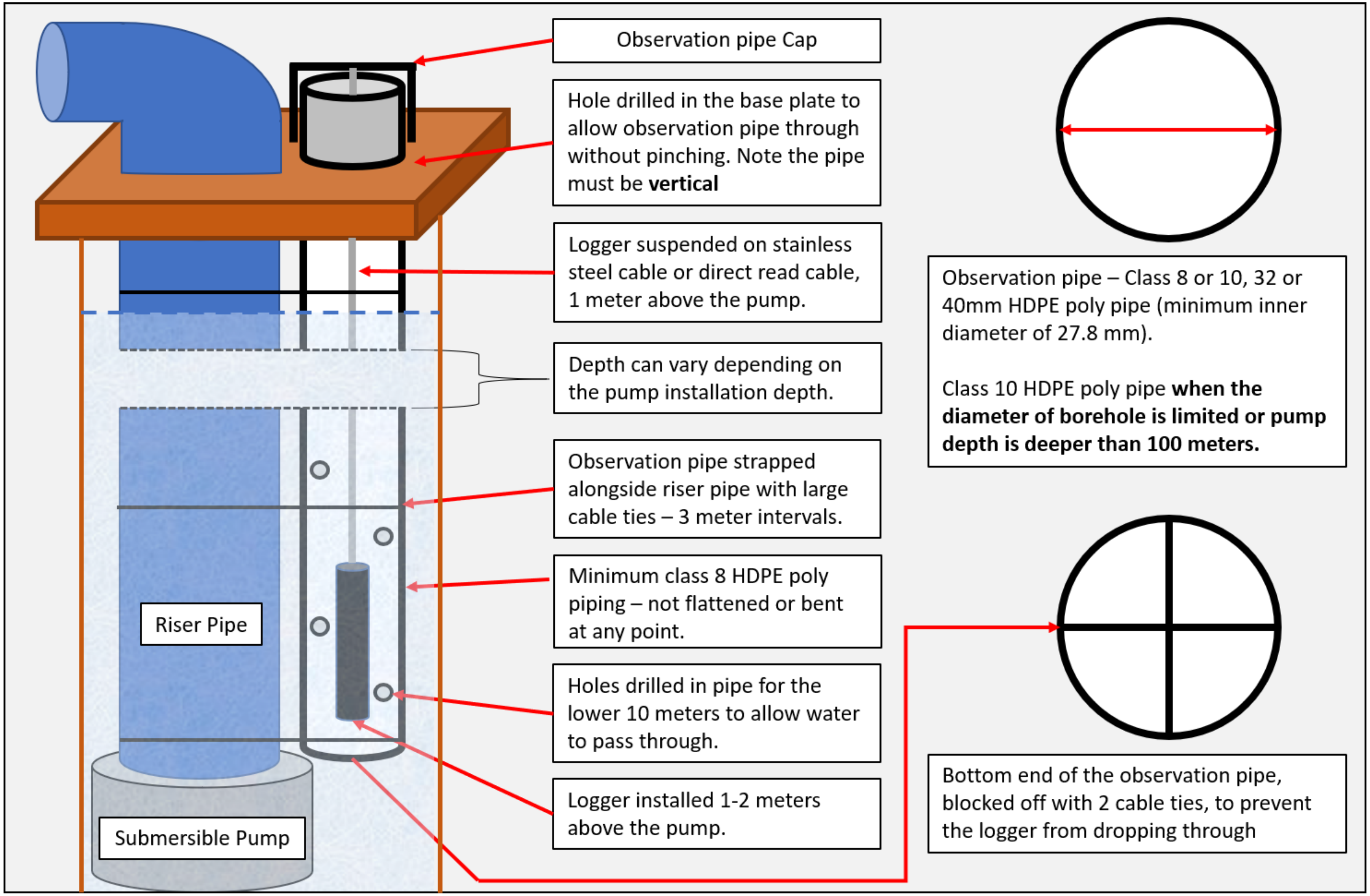
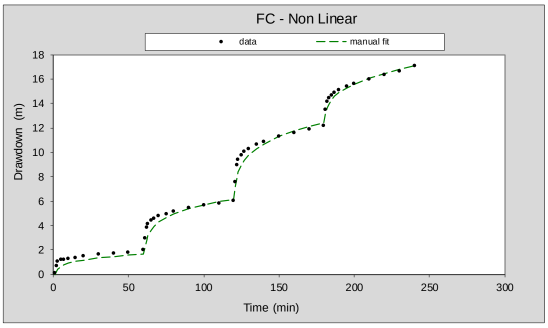
9. APPENDIX D: MONITORING INFRASTRUCTURE DIAGRAM


Observation pipe cap
Sampling tap
Base plate with a hole drilled through to allow the observation pipe through without pinching against the casing. The observation pipe must be vertical.
Flow meter
Borehole casing
Observation pipe – Class 8 or 10, 32 or 40 mm HDPE poly pipe (minimum inner diameter of 27.8 mm).
Class 10 HDPE poly pipe **when the diameter of borehole is limited or pump depth is deeper than 100 meters.**
Cable ties fastened around the observation pipe, riser pipe and the power cable (not pinching the observation pipe.)
Holes drilled in the observation pipe for the lower 10 meters.
Riser pipe
Logger installed 1-2 meters above the pump.
Submersible pump


Observation pipe Cap
Hole drilled in the base plate to allow observation pipe through without pinching. Note the pipe must be **vertical**
Logger suspended on stainless steel cable or direct read cable, 1 meter above the pump.
Depth can vary depending on the pump installation depth.
Observation pipe strapped alongside riser pipe with large cable ties – 3 meter intervals.
Minimum class 8 HDPE poly piping – not flattened or bent at any point.
Holes drilled in pipe for the lower 10 meters to allow water to pass through.
Logger installed 1-2 meters above the pump.
Riser Pipe
Submersible Pump
Observation pipe – Class 8 or 10, 32 or 40mm HDPE poly pipe (minimum inner diameter of 27.8 mm).
Class 10 HDPE poly pipe **when the diameter of borehole is limited or pump depth is deeper than 100 meters.**
Bottom end of the observation pipe, blocked off with 2 cable ties, to prevent the logger from dropping through

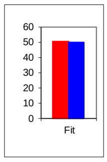
10. APPENDIX E: YIELD TEST DATA ANALYSIS

AB_BH1



FC - Non Linear Method to estimate Q_Sust

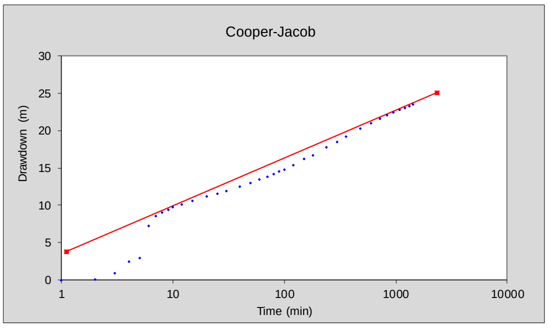
skin effect	Non-Darcian loss		Darcian loss		
A	C	p	B	n	e
7.00E-06	0.00E+00	2.00E+00	2.00E-03	1.87E+00	1.37E+00



Extrapolation	
Ext_pol time (min)	
1051200	
Q (L/s)	Drawdown (m)
4.8	50.10

Available drawdown (m) =		50	
No boundaries	1 no-flow	2 no-flow	Closed
4.8	2.4	1.6	0.8
Q_Sust (L/s)=	2.40	std.dev = 1.73	

Boundaries selected	0 - closed

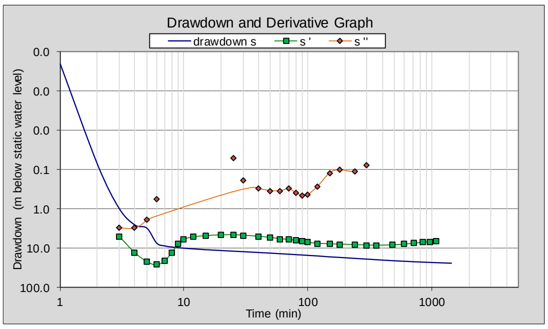


Cooper-Jacob method

$T(m^2/d)$ =	11.4	r_e (m)=	0.1
S =	4.98E-01	Q (l/s) =	4.60

	No boundaries	1 no-flow	2 no-flow	Closed
Q_sust	5.46	2.73	1.80	1.37
Avg. Q_sust =		2.84	std. dev =	1.84

Boundaries selected	0 - closed

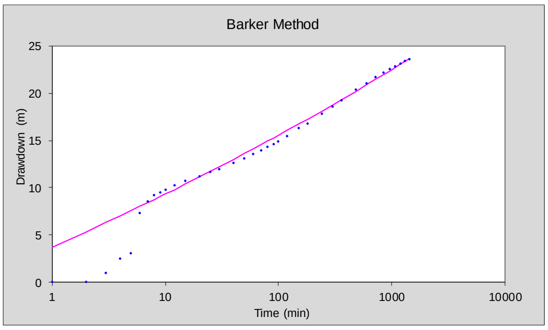


FC method

Extrapolation time in years	2	1051200	Extrapol.time in minutes	
Effective borehole radius (r_e)	0.57280349	0.572803489	Est. r_e	From r(e) sheet
Q (l/s) from pumping test	4.6	0.066104112	S-late	Change r_e
s_a (available drawdown), sigma_s	**50**	0	Sigma_s from risk	
Annual effective recharge (mm)	0	50	s_available working drawdown(m)	
t(end) and s(end) of pumping test	1440	23.6004	End time and drawdown of test	
Average maximum derivative	**6.44**	8.235796315	Estimate of average of max deriv	
Average second derivative	**0.08**	-0.04336762	Estimate of average second deriv	
Derivative at radial flow period	10.7186651	10.71866508	Read from derivative graph	
$T\text{-early}[m^2/d]$		6.785501687	Aqui. thick (m)	60
T and S estimates	**$T\text{-late}\ [m^2/d]$**	**11.29371429**	Est. S-late	0.0033
	S-late	0.066104112		

BASIC SOLUTION

	No boundaries	1 no-flow	2 no-flow	Closed no-flow
sWell (Extrapol.time) =	42.37	60.81	79.25	134.57
Q_sust (l/s) =	5.43	3.78	2.90	1.71
Average Q_sust (l/s) =	**3.46**			
with standard deviation=	1.57			
Boundaries selected	0 - closed			

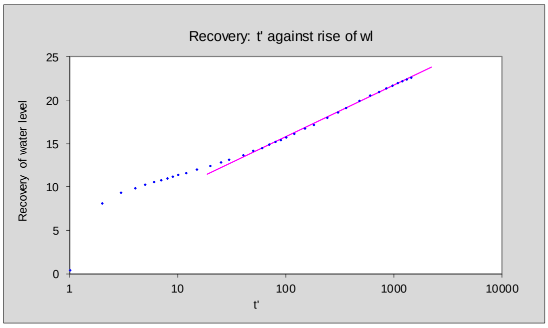


Barker method

	K_f [m/d]	S_f [1/m]	b	n	N
Fit Parameters	0.20	1.41E-03	48.67	1.91	0.0450

	No boundaries	1 no-flow	2 no-flow	Closed
sWell(Extrapol.time)	48.26	85.14	103.58	122.02
Q_sust	4.77	2.70	2.22	1.88

Fractal n = 1.91	Average Q-sust (l/s)=	2.89	std. dev =	1.29
	Boundaries selected	0 - closed		



Recovery

T [m2/d]	12.25523953
CDT Duration	1440
Recovery Duration	1440
Max % Recovery	95.8

(LAST PAGE)