Hydrogeological Assessment and Aquifer Recharge Potential within the Lephalale (Ellisras) Local Municipality Area

Report Nr: PWMA 01/A42/00/02209_01

Prepared by

VSALEBOA CONSULTING

For the

Directorate: Water Resource Planning Systems (WRPS)

FINAL REPORT

20 January 2010

water affairs
Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

Title:	*Hydrogeological Assessment and Aquifer Recharge Potential within the Lephalale (Ellisras) Local Municipality Area*	
Authors:	*S Veltman*	*Veltwater Groundwater Specialists*
	F Botha	*Praxos*
	RV Weidemann	*VSA Leboa Consulting*
GIS:	*AM Cronje*	*VSA Leboa Consulting*
DWA Report Number	*PWMA 01/A42/00/02209_01*	
Status of Report:	*Final*	

VSA Leboa Consulting (Pty) Ltd
Approved for VSA Leboa Consulting (Pty) Ltd

.....
Director/Project Manager:
VSA Leboa Consulting (Pty) Ltd
Mr RV Weidemann

.....
Project Manager:
Department of Water Affairs
Mr Fanus Fourie

Department of Water Affairs
Water Resources Planning Systems

Approved for the Department of Water Affairs

.....
Director:
Water Resource Planning Systems
Dr Beason Mwaka

.....
Deputy Director:
Water Resource Planning Systems
Mr Elias Nel

Published by
Department of Water Affairs
Private Bag X313
Pretoria
0001
Republic of South Africa
Tel: (012) 336-7500

This report should be cited as:

Department of Water Affairs, 2010. Hydrogeological Assessment and Aquifer Recharge Potential within the Lephalale (Ellisras) Local Municipality Area dated January 2010.

Disclaimer:

Although the information contained in this document is presented in good faith and believed to be correct, the Department of Water Affairs makes no representations or warranties as to the completeness or accuracy of the information, which is only based on actual information received, and makes no commitment to update or correct information.

Professional Service Provider:

VSA Leboa Consulting
VSA Leboa Consulting (Pty) Ltd

Plot 41
Tweefontein
Polokwane
0700

PO Box 222
Polokwane
0700

Tel: 082 315 2977
Fax: 0866857724

ACKNOWLEDGEMENTS

Note on the Department of Water Affairs (DWA)

The Department of Water Affairs (DWA) was until recently known as the Department of Water Affairs and Forestry (DWAF). The Department of Water Affairs is part of the Ministry of Water and Environmental Affairs, under a single Minister. The acronyms "DWA" and "DWAF" both appear in this report, the latter mainly as references to past work done when the Department was known as the Department of Water Affairs and Forestry.

EXECUTIVE SUMMARY

The town of Lephalale is situated in the northern part of South Africa, 200 km north-west of Pretoria in a semi-arid climate zone. The Mokolo River flows through the area, joining up with the Limpopo River in the north. Lephalale is a major role-player in economic development within Limpopo and continual economic development requires development of sustainable water resources. VSA Leboa was appointed by the Department of Water Affairs and Forestry to characterise the aquifers, determine the groundwater potential and the artificial recharge options available to Lephalale.

The Lephalale area lies within the Beit Bridge Complex and is characterised by aquifers of the Karoo Sequence, Waterberg Formation and alluvial aquifers. The Mokolo basin is extremely block faulted with a 250 meter down-throw in the Eenzaamheid fault to the north. In the Lephalale area some major faults, including the Daarby and Eenzaamheid may have changed aquifer properties and these structures where targeted to understand to what extent these changes have occurred.

Groundwater flow around Lephalale takes place in the direction of surface topography and according to structural controls of geology. Semi-confined conditions in the Waterberg occur south of the contact with the Ecca Formation. The fault extends at depth and fractures related to the fault / bedding planes will most likely be encountered at depth anywhere within the fault system.

North of the contact the Ecca overlies the Waterberg and the whole aquifer is confined. The piezometric water level is as a result of the pressure built up in the underlying confined Waterberg which has a hydrostatic connection with the semi-confined Waterberg.

The alluvial aquifer and Waterberg confined aquifer is separated by the impermeable Ecca Formation. The alluvial aquifer in this area does not recharge the Waterberg confined aquifer, since hydrostatic pressure and the confining Ecca layers will not allow for it. The Waterberg semi-confined aquifer discharges in the weathered zone into the alluvial aquifer at the contact of the Eenzaamheid FS with the alluvial aquifer.

Groundwater exploration of the structures found the main water strikes in the Waterberg Group between 120 – 270 mbgl (meters below ground level) with blow yields ranging from 0.2 – >20 L/s. Some of the boreholes drilled through the alluvial deposits into the Waterberg Group encountered alluvial deposits at depth e.g.

conglomerate “pebbles rocks” found at 160 mbgl. This indicates that typical river gravels were deposited within the Waterberg and very high yields can be expected from boreholes intersecting these palæo drainage channels.

Boreholes drilled into the shallow alluvial aquifer had blow yields of 0.7 – 10 L/s. The Ecca Formation only yielded minor water strikes 0.05 – 0.1 L/s and was not considered for further evaluation of the groundwater potential for this area.

Numerical modelling for the Waterberg aquifer was performed to test the recommended yields of the existing exploration boreholes, as well as test different scenarios for utilising the undeveloped groundwater. In the 10 km radius target area 8 existing exploration boreholes, totalling 1.4 Mm^3/a yield, can be equipped and operated as a well field for water supply at Lephalale. Water quality constraints include high concentrations of NaCl and F. No treatment is required for industrial use; however, treatment or blending is required for domestic use of the groundwater.

Planning scenarios for future development options shows that an additional volume of 8000 – 17000 m^3/d can be developed, resulting in 4 – 7.5 Mm^3/a available from the Waterberg aquifer for augmentation. The higher abstraction volume (17000 m^3/d) is not sustainable and can only be accessed for short periods of time.

Impacts to the existing users from the Waterberg aquifer are dependent on the amount of groundwater abstracted, with only minor drops in water levels expected for the Scenarios 1, 2, 3 and 5. Scenario 4 has the highest impact on these users.

The water users from the alluvial aquifer will be affected if the inflows from the river to the aquifer are not augmented with releases from upstream. However, the higher abstraction rate scenarios have a greater benefit when comparing the impact to the volume of water that becomes available from groundwater.

The alluvial aquifer was not adequately explored and it is recommended that this aquifer be drilled further to obtain better estimates for yield potential and artificial recharge potential. First estimates shows alluvial groundwater storage potential at 31 Mm^3/a or 3.8 Mm^3/a for every 1 m drop in water levels within the alluvial.

Various artificial recharge (AR) options looks promising from the aquifer properties, but all the aquifers at Lephalale should be developed and storage created by abstraction from them for any AR scheme to become useful.

TABLE OF CONTENTS

1 INTRODUCTION 1

1.1 OBJECTIVES 1

2 HYDROGEOLOGY 3

2.1 KAROO AQUIFER 3
2.2 WATERBERG AQUIFER 3
2.3 ALLUVIAL AQUIFER 4
2.4 EXISTING DATA 4
2.4.1 Harvest and Exploitation Potential 4
2.4.2 Groundwater Use and Availability 4
2.4.3 Groundwater Flow 5
2.4.4 Water Quality 6

3 GROUNDWATER EXPLORATION 7

3.1 HYDROCENSUS 7
3.2 STRUCTURAL GEOLOGY 8
3.2.1 Target Areas 8
3.3 GEOPHYSICS & DRILLING 9
3.3.1 Results of Targets Drilled 10
3.3.2 Water Strikes 11
3.4 TESTING 12
3.4.1 FC Method 12
3.4.2 Aquifer Characteristics 13
3.5 WATER LEVELS 15
3.5.1 Groundwater Flow 16
3.6 WATER QUALITY 17
3.6.1 Diagnostic Diagrams 17
3.6.2 Drinking Water Standards 21
3.6.3 Stable Isotopes 22
3.6.4 Mixing Ratios and Groundwater Chemistry 24
3.7 CONCEPTUAL MODELS OF LEPHALALE AQUIFERS 25
3.8 AQUIFER POTENTIAL 28
3.8.1 Current Accessible Yield 28
3.8.2 Alluvial Aquifer Development 29
3.8.3 Waterberg Aquifer Development 29
3.9 AUGMENTATION SCHEME VIABILITY FROM THE WATERBERG AQUIFER 31

4 MONITORING 32

4.1 DATA LOGGERS 34

5 ARTIFICIAL RECHARGE AT LEPHALALE 37

5.1 WHAT IS ARTIFICIAL RECHARGE? 37
5.2 AR POTENTIAL AT LEPHALALE 38
5.2.1 Waterberg Aquifer 38
5.2.2 Alluvial Aquifer 39
5.2.3 Default AR in Progress 40

6 NUMERICAL MODELLING 41

6.1 LEPHALALE MODEL ENVIRONMENT 42
6.1.1 Hydrogeological Units and Boundaries 42
6.1.2 Initial Conditions 44
6.2 SENSITIVITY ANALYSES 46
6.3 CALIBRATION AND VERIFICATION 47
6.3.1 Steady State Calibration 48
6.3.2 Transient State Calibration 50
6.3.3 Water Balance 53
6.4 GROUNDWATER DEVELOPMENT & IMPACTS 54
6.4.1 Scenario 1 55
6.4.2 Scenario 2 57
6.4.3 Scenario 3 59
6.4.4 Scenario 4 61
6.4.5 Scenario 5 63
6.4.6 Comparison 65

7 CONCLUSIONS 67

8 RECOMMENDATIONS 68

9 REFERENCES 69

LIST OF APPENDICES

APPENDIX A: LEPHALALE PROJECT MAPS
APPENDIX B: DESKTOP STUDY MAPS
APPENDIX C: GEOPHYSICAL PROFILES
APPENDIX D: DRILLING LOGS
APPENDIX E: MANAGEMENT REPORTS
APPENDIX F: WATER QUALITY
APPENDIX G: DATA LOGGER GRAPHS
APPENDIX H: NUMERICAL MODEL MAPS
APPENDIX I: RPTSOLV DIAGRAMS
APPENDIX J: SCENARIO IMPACT MAPS

LIST OF FIGURES

FIGURE 1: GROUNDWATER RECHARGE, HARVEST POTENTIAL, EXPLOITATION POTENTIAL AND USE FOR THE LEPHALALE AREA 5
FIGURE 2: BAYESIAN WATER LEVEL CORRELATION 15
FIGURE 3: EXPLORATION BOREHOLES' WATER LEVEL COMPARISON 16
FIGURE 4: PIPER DIAGRAM OF LEPHALALE EXPLORATION BOREHOLES 18
FIGURE 5: SAR DIAGRAM OF LEPHALALE EXPLORATION BOREHOLES 18
FIGURE 6: SCHOËLLER DIAGRAM OF WATERBERG EXPLORATION BOREHOLES 19
FIGURE 7: SCHOËLLER DIAGRAM OF MOGOL RIVER AND ALLUVIAL BOREHOLES 19
FIGURE 8: STIFF DIAGRAMS OF WATERBERG EXPLORATION BOREHOLES 20
FIGURE 9: STIFF DIAGRAMS OF MOGOL RIVER AND ALLUVIAL BOREHOLES 20
FIGURE 10: STABLE ISOTOPE DATA IN RELATION TO GLOBAL METEORIC WATER LINE 23
FIGURE 11: NS CROSS-SECTION OF WATERBERG AQUIFER OVER EENZAAMHEID FAULT 26
FIGURE 12: EW CROSS-SECTION OF ALLUVIAL AND WATERBERG CONFINED AQUIFERS NORTH OF EENZAAMHEID FAULT 27
FIGURE 13: COMPARISON BETWEEN MOKOLO RIVER LEVELS AND H21-0703 MONITORING WATER LEVELS 35
FIGURE 14 SCHEMATIC EXAMPLE OF ASR IN A CONFINED AQUIFER 37
FIGURE 15: SCREEN SHOT OF MODEL DOMAIN 44
FIGURE 16: BAYESIAN CORRELATION OF REGIONAL WATER LEVEL DATA SET 45
FIGURE 17: SENSITIVITY ANALYSES AT EENZAAMHEID FAULT STRUCTURE 46
FIGURE 18: SENSITIVITY ANALYSES AT CONFINED AQUIFER 46
FIGURE 19: SENSITIVITY ANALYSES A42G QUATERNARY BOUNDARY 47
FIGURE 20: SENSITIVITY ANALYSES A42H QUATERNARY BOUNDARY 47
FIGURE 21: STEADY STATE OBSERVATION BOREHOLES' TOPOGRAPHY AND WATER LEVELS 49
FIGURE 22: STEADY STATE OBSERVATION BOREHOLES' BAYESIAN CORRELATION 49
FIGURE 23: CONFINED AQUIFER TRANSIENT CALIBRATION RESULTS FOR H21-0681 PUMPING 52
FIGURE 24: EENZAAMHEID FAULT SYSTEM TRANSIENT CALIBRATION RESULTS FOR H21-0665 PUMPING 52
FIGURE 25: EENZAAMHEID FAULT SYSTEM TRANSIENT CALIBRATION RESULTS FOR H21-0700 PUMPING 53
FIGURE 26: GROUNDWATER LEVEL DRAWDOWN (MBGL) FOR H21-0700 PUMPING 56
FIGURE 27: WATER LEVEL DRAWDOWN (M) FOR USERS' BOREHOLES 56
FIGURE 28: GROUNDWATER LEVEL DRAWDOWN (MBGL) FOR CURRENT BOREHOLES PUMPING 57
FIGURE 29: WATER LEVEL DRAWDOWN (M) FOR USERS' BOREHOLES 58
FIGURE 30: GROUNDWATER LEVEL DRAWDOWN (MBGL) FOR CURRENT AND FUTURE BOREHOLES PUMPING 59
FIGURE 31: WATER LEVEL DRAWDOWN (M) FOR USERS' BOREHOLES 60

FIGURE 32: GROUNDWATER LEVEL DRAWDOWN (MBGL) FOR CURRENT AND FUTURE BOREHOLES PUMPING (2 YEAR HIGH ABSTRACTION) 61
FIGURE 33: WATER LEVEL DRAWDOWN (M) FOR USERS' BOREHOLES 62
FIGURE 34: GROUNDWATER LEVEL DRAWDOWN (MBGL) FOR CURRENT AND FUTURE BOREHOLES PUMPING (2 YEAR HIGH ABSTRACTION, 6 MONTH RESTING PERIOD, 2 YEAR HIGH ABSTRACTION) .. 63
FIGURE 35: WATER LEVEL DRAWDOWN (M) FOR USERS' BOREHOLES 64

LIST OF TABLES

TABLE 1: INFORMATION SUMMARY OF AVAILABLE GROUNDWATER – LEPHALALE REGION 5
TABLE 2: SUMMARY OF TARGETS AND EXPLORATION BOREHOLES DRILLED AT LEPHALALE 9
TABLE 3: CONSTANT DISCHARGE TEST RESULTS FOR EXPLORATION BOREHOLES AT LEPHALALE 12
TABLE 4: GROUNDWATER BALANCE FOR QUATERNARY CATCHMENTS AT LEPHALALE 25
TABLE 5: CURRENT ACCESSIBLE GROUNDWATER FROM AQUIFERS AT LEPHALALE 29
TABLE 6: WATER LEVEL MONITORING BOREHOLES AT LEPHALALE 33
TABLE 7: WATER QUALITY MONITORING BOREHOLES AT LEPHALALE 33
TABLE 8: STORATIVITY VALUES FOR THE WATERBERG AQUIFER FROM RPTSOLV RESULTS 51
TABLE 9: CURRENT ACCESSIBLE GROUNDWATER FROM WATERBERG AQUIFER (SINGLE BOREHOLE PUMPING) 54
TABLE 10: WATER USERS SURROUNDING POTENTIAL WELL-FIELD FROM CURRENT EXPLORATION BOREHOLES 55
TABLE 11: WATER BALANCE AND EXPECTED F (MG/L) VALUES FOR DIFFERENT SCENARIOS 65
TABLE 12: MOKOLO RIVER CONTRIBUTION TO GROUNDWATER ABSTRACTION FOR DIFFERENT SCENARIOS 66

1 INTRODUCTION

The town of Lephalale is situated in the northern part of South Africa, some 200 km north west of Pretoria (see Plan 1, Appendix A). The town is situated in a semi-arid climate zone, with an average annual rainfall less than 400 mm and an annual evaporation higher than 2000 mm, making water highly vulnerable to droughts. The Mokolo River is flowing through the study area, joining up with the Limpopo River in the north.

Lephalale is a major role-player in economic development within Limpopo. Local coal deposits are leading to industrial and mining development and this continual economic development requires development of sustainable water resources and therefore the need to investigate every possible water resource option. As a result, Lephalale Local Municipality is constantly investigating new augmentation options, and these options include use of groundwater and aquifer storage and recovery of storm water and/or return flows. VSA Leboa was appointed by the Department of Water Affairs and Forestry to characterise the aquifers, determine the groundwater potential and the artificial recharge options available to Lephalale.

1.1 Objectives

The main objectives of the study are to review the regional hydrogeological conditions at Lephalale, investigate the linear structures within the vicinity of the town, at various depths, to determine the possibility of supplying sufficient potable water from groundwater sources and the possibilities of artificial recharge of the groundwater at Lephalale. The study was divided into four phases and will take two years to complete. The following phases where identified:

- Phase 1 Installation and testing of monitoring wells;
- Phase 2 Detail assessment of local hydrogeology;
- Phase 3 Detail assessment of artificial recharge potential; and
- Phase 4 EIA study.

This report deals with ***Phase 1*** and ***Phase 2***, including a discussion on the options of artificial recharge to assess in detail during Phase 3. The objectives of these two phases were:

- To determine how much water is available through groundwater exploration and testing of the various aquifers at Lephalale;
- Database development to handle and support data acquisition, interpretation and presentation;
- Conceptualise the groundwater systems on site;
- Aquifer yield potential recommendations;
- Installation of piezometric monitoring network, on quality and quantity of groundwater, based on the above;
- To propose artificial recharge systems or methods to increase the yield of the system and enhance water conservation in this area; and
- To give recommendations on typical groundwater exploration methods or techniques that was successful in the Waterberg aquifer, for further use in other areas where this aquifer occurs.

Phase 3 will be covered in a subsequent report:

Report Nr: PWMA 01/A42/00/02209_02

2 HYDROGEOLOGY

The northern section of the Limpopo Province is underlain by the Beit Bridge Complex (Zba) with the Limpopo River as the northern boundary. The Beit Bridge Complex is composed of metamorphic rock (meta-sediments including quartzite, marble, meta-pelites and banded iron formation (Johnson, *et. al.*, 2006)) and is classified as an intergranular or fractured aquifer, having blow yields of 0.5 – 2.0 L/s.

The Lephalale area lies within this Complex and is characterised by aquifers of the Karoo Sequence and Waterberg Formation, with basement and alluvial aquifers also occurring (Titus & Rossouw, 2008), see Plan 2 in Appendix A.

2.1 Karoo Aquifer

The outer rim of the Beit Bridget complex and a greater portion on the western side are formed by the Ecca Group (Pe) of the Karoo Sequence, consisting of mudstone (shale and/or siltstone) and sandstone. The Karoo aquifer is classified as a fractured aquifer, yielding from 2.0 – 5.0 L/s in the siltstone and 0.5 - 2.0 L/s in the shale and sandstone. The central succession of the Ecca Group consists of the Clarens Formation, a predominantly arenaceous rock or feldspathic sandstone. It is classified as an intergranular or fractured aquifer and yields are between 0.1 - 0.5 L/s. The Clarens Formation is underlain by red mudstone and siltstone known as the Lisbon Formation, with limited groundwater potential.

2.2 Waterberg Aquifer

The southern portion is underlain by coarse-grained sandstone forming the Waterberg Group and recently drilled boreholes near the towns of Vaalwater and Alma have recommended yields of more than 2.5 L/s at a 24 hour pump schedule (220 m^3/d). Boreholes drilled at Lephalale into the Waterberg aquifer during this study yielded 4 boreholes with sustainable yields of 2-3 L/s and 5 boreholes with yields higher than 5 L/s at a 24 hour pump schedule (>440 m^3/d).

2.3 Alluvial Aquifer

The basin of the Mokolo River consists of coarse-grained alluvial sand (quartzite) with inter-bedded lenses of finer clay/shale material. The alluvium forms a primary aquifer with thickness in the riverbed varying between 5 m to greater than 25 m.

Alluvial deposits to the south of Lephalale have an average thickness of 9m. In the area to the north the alluvium is generally 4.5 m thick, with the most northern part decreasing to 4m. The alluvium is recharged during periods of high stream-flows (Titus & Rossouw, 2008) and periods of surface water release from the Mokolo dam for irrigation purposes.

2.4 Existing Data

The following sections are included as a summary of the work done by Botha, 2006, at the start of the project and all maps generated are included in Appendix B. The DWAF Hydrological map series for the area was not available at the time and raw borehole data was obtained from the National Groundwater Database (NGDB), with fair borehole coverage over the area (Map 3.1, Appendix B).

2.4.1 Harvest and Exploitation Potential

The Harvest Potential (HP) (Map 3.2) and Exploitation Potential (EP) (Map 3.3) are used as indicators on the groundwater occurrence and the volume of water for each are calculated per quaternary catchments. The Harvest Potential was calculated as $51*10^6 m^3/a$ (quaternary catchments A41E, A42G, H and J) and the Exploitation Potential as $27*10^6 m^3/a$, almost half of the Harvest Potential and the difference between the two as a result of difficult exploration conditions.

2.4.2 Groundwater Use and Availability

The NGDB data and the provincial database were used to calculate annual groundwater volumes available, taking into consideration the Exploration Potential and groundwater already in use.

Table 1 shows the regional assumptions and calculations when the assessment of the available groundwater was done in 2006. The volume of groundwater used was much less than the Exploitation Potential (only 15% of the EP value) and there are still vast exploitable groundwater reserves available, see Figure 1.

Table 1: Information summary of available groundwater – Lephalale Region

Area: **6 060 Km^2**	Use Total / Exploitation Potential: **15.2 %**		Total of Borehole: **2 240**
Boreholes with WL data: 1 285	Boreh. with water WL/ Total Boreh. 57.4 %	Boreholes with Chemical data: 743	Boreh. Chemical/ Total Boreholes: 33.2 %
Fracturation Coefficient	Fracture Depth (m)	Discharge Rate (L/s)	MAP (mm/annuam)
Max: 0.001 Mean: 0.0008 Min: 0.0007	Max: 16 Mean:12.31 Min: 8.0	Max: 50.16 Mean: 1.52 Min: 0.0	Max: 569 Mean: 461 Min: 400
Mean Recharge (mm/annuam)	Harvest Potential (mm/annuam)	Explotation Potential (mm/annuam)	Total Use (mm/annuam)
Max: 32.0 Mean: 16.6 Min: 8.0	Max: 11.18 Mean: 8.46 Min: 6.64	Max: 5.57 Mean: 4.57 Min: 3.32	Max: 1.79 Mean: 0.69 Min: 0.06
Mean Vol: 68 037 273 m^3/a	**Mean Vol.: 51 273 660 m^3/a**	**Mean Vol.: 27 711 168 m^3/a**	**Mean Vol.: 4 212 912 m^3/a**

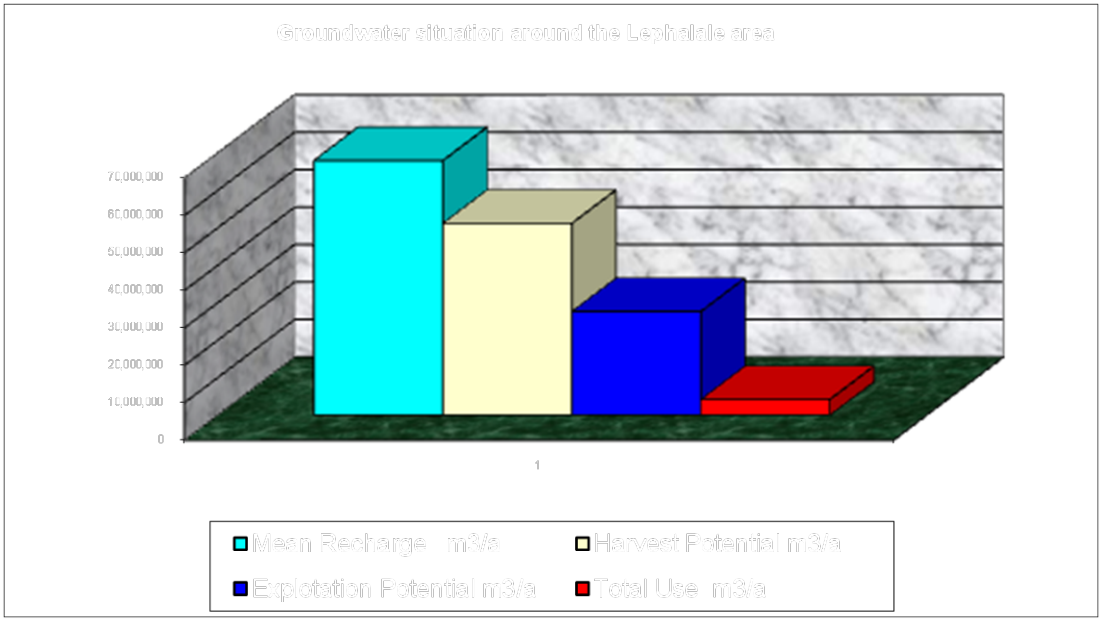


Figure 1: Groundwater Recharge, Harvest Potential, Exploitation Potential and Use for the Lephalale area

Available groundwater reserves are therefore estimated as 23.5 Mm^3/a for the quaternary catchments A41E, A42G, H and J.

2.4.3 Groundwater Flow

Regional groundwater flow paths are in a north-west direction from the higher lying Waterberg mountain range to the lower lying areas in the north, following the general topography (Titus & Rossouw, 2008). Analysis of the borehole data show water levels ranging between 6 – 140 mbgl (Map 3.4), with very low borehole yields

(between 0.5 – 1 l/s for a 24-hour pump cycle (Map 3.5)). This indicates that difficult groundwater exploration conditions can be expected when developing the available groundwater reserves further. (Botha, 2006)

2.4.4 Water Quality

On the commercial farming areas borehole water quality data is limited, with more information available in the communal areas in the northeast of the study area. The data shows elevated EC values with localised highs up to 1000 mS/m (Map 3.6). However, the dataset do not distinguish between layered aquifers having different water quality signatures and most of the area's EC still falls within the "good" drinking water quality. In the northeast the data shows groundwater with marginal elevated nitrate, occurring as a result of poor sanitation and farming practices (Map 3.7). Nitrate values close to Lephalale is still within the "ideal" drinking water quality. (Botha, 2006)

The Waterberg and primary aquifer, however, produce fresh water, with TDS values lower than 500 mg/L, but groundwater from this aquifer is generally classified as a Class 4 drinking water, as a result high fluoride values (see section 3.6 for more on the fluoride concentrations and other parameters).

3 GROUNDWATER EXPLORATION

Groundwater exploration commonly refer to determining physical properties or characteristics of an aquifer system with geophysical surveys, drilling and testing of exploration boreholes, especially where no or limited information is available. Typically an assessment of the exploration data will include determining where water comes from, where it is going, accessible volumes and the quality of the water in a specific aquifer.

Desktop information show vast quantities of groundwater available in and around the Lephalale area. Existing hydrogeological data indicate unfavourable groundwater development potential with poor drilling results. However, the available data is considered of poor scientific content and also suggests limited scientific exploration approaches. (Botha, 2006)

The hydrogeology of the Ecca, Karoo aquifers, indicate poor yields and below average water quality. However, hydrogeological and structural geology in the Waterberg Group showed good groundwater yields and better water quality. The alluvium in the Mokolo River may be a good aquifer but might be limited in recharge and extent. (Botha, 2006)

The groundwater exploration for the Lephalale area focused on identifying the geological structures within the Waterberg Group, with good groundwater potential, and the alluvial aquifers close to Lephalale for hydrogeological characterisation and evaluation of the total exploitable groundwater potential in these systems. The groundwater exploration of the deeper aquifer systems and associated geological structures, was considered of utmost importance to define how water moves, at what rate, how much is available and where it can be intercepted. The following sections describe the various tasks performed in the groundwater exploration of the deeper fractured rock aquifer surrounding the Lephalale area and, to a limited extent, the exploration of the alluvial aquifer.

3.1 Hydrocensus

The Institute for Groundwater Studies, University of the Free State, performed a hydrocensus during 2007 as part of a Water Research Commission study. Data from this hydrocensus was incorporated into the project database and used in the selection

of appropriate drilling targets / sites. Hydrocensus sites are plotted on Plan 2, in Appendix A, and data further discussed as part of the site-specific hydrogeology.

3.2 Structural Geology

Structural geology play a major role in fractured rock aquifers and geological structures can cause improved aquifer conditions or act as hydrogeological barriers or boundaries. The Mokolo basin is extremely block faulted with a 250 meter down-throw in the Eenzaamheid fault to the north. Faults striking SE-NW, SW-NE and ENE orientated faults, subject to the NS tension release stresses, are targeted for the development of groundwater resources (Titus & Rossouw, 2008). In the Lephalale area some major faults, including the Daarby and Eenzaamheid may have changed aquifer properties and it was necessary to target these structures to understand to what extent these changes have occurred.

The structural geology was interpreted taking into account the geological map of 2326 Ellisras (including the Explanation booklet) and the remote sensing (Astersat images) previously done by AGEOTECH.

3.2.1 Target Areas

The interpreted Astersat images, Plan 3 (Appendix A), where used to identify potential high yielding structures. Selecting appropriate target areas and sites was highly dependent on accessibility, since the project team was instructed by Lephalale Local Municipality to keep to public roads and municipal / government property. Keeping these restrictions in mind, the following possible high yielding target areas where identified based on its intersection with publicly accessible areas:

- Dykes, faults and lineaments associated with the Eenzaamheid fault system;
- Dykes, faults and lineaments associated with the Daarby fault system; and
- Deep and shallow boreholes in the alluvial aquifer system.

These areas, the geophysical traverses and drilling targets are indicated on Plan 3, Appendix A.

3.3 Geophysics & Drilling

Geophysical surveys were performed by VSA Leboa and included electro-magnetic, magnetic and multi-resistivity (LUND) ground geophysical surveys. 17 geophysical profiles were completed for the structures identified and the profiles are shown in Appendix C. Table 2 summarises the geological targets, geophysical traverses, stations numbers and the 30 exploration boreholes drilled. Geological logs for the boreholes are included in Appendix D, however H21-0709 (deep core) was still in progress and will be included in the updated report with the numerical modelling.

Table 2: Summary of targets and exploration boreholes drilled at Lephalale

Drill Target	Geophysical Traverse / Station Number	Drill Site ID	Drill Depth (m)
Eenzaamheid Fault (S) Major anomalies in resistivity	Line10/1055	H21-0636	276
	Line10/770	H21-0637	210
	Line10/540	H21-0638	150
	Line10/470	H21-0662	276
	Line10/360	H21-0663	276
	Line10/320	H21-0664	288
	Line10/590	H21-0665	165
	Line 7/185	H21-0669	291
	Line 6/150	H21-0670	211
	Line10/995	H21-0672	128
In between	700m north of Line10	H21-0700	205
	In town - next to Golf	H21-0716	27
Eenzaamheid Fault (N) Anomalies in resistivity	Line 1/245	H21-0666	216
	Line 2/245	H21-0667	300
	Line 3/1120	H21-0668	300
Semi-confined Waterberg	Line 14/566	H21-0707	306
	Line 17/320	H21-0708	308
	Line 14/890	H21-0712	205
	Line 15/260	H21-0713	240
Confined Waterberg	Magnetics - Inside yard	H21-0671	126
	Core drilled appr 40m west 671	H21-0709	162 (in progress)
Confined Waterberg underneath Alluvium	Line 9/480	H21-0701	290
	Next to river in pump yard	H21-0702	250
	Line 16/250	H21-0704	220
Alluvium	Next to river - only alluvium	H21-0703	30
	Line 16/805 - only alluvium	H21-0706	30
	Line 16/910	H21-0714	24
	Alluvium - At bridge	H21-0715	36
Lineaments south of Daarby Fault	Line11B/495	H21-0680	296
	Line11B/640	H21-0681	320

3.3.1 Results of Targets Drilled

The Eenzaamheid Fault system is characterised as two major faults (south and north) and various other associated lineaments.

- The Eenzaamheid Fault S (south) geophysical profiles show two major sub-vertical anomalies in the resistivity data and boreholes H21-0636, H21-0637, H21-0638, H21-0662, H21-0663, H21-0664, H21-0665, H21-0669, H21-0670 and H21-0672 was drilled in and next to these anomalies. All of the boreholes accessed mainly the Waterberg Group sandstone. Minor occurrences of calcrete and diabase were also observed during drilling.
- The Eenzaamheid Fault N (north) geophysical profiles show resistivity anomalies indicating vertical structures. H21-0666 and H21-0668 was drilled to the south of the structure and accessed mainly the Waterberg Group, while H21-0667 was drilled to the north of the structure and accessed Ecca formation as well. This structure is therefore considered the contact zone of the fault between the Waterberg Group and Ecca Formation.

H21-0700 was drilled in between the two faults systems, 700m north of geophysical line 10. This was done to test the concept of the vertical and sub-vertical jointing in the Waterberg continuing at depth.

H21-0716 was drilled next to the golf course in town to establish a reference for the groundwater levels associated with the expected perched water table as a result of irrigating the golf course.

Borehole H21-0671 was drilled inside one of the municipal properties, accessing the confined Waterberg aquifer (artesian borehole) underneath the Ecca Formation. The deep core borehole H21-0709 was sited to the west of H21-0671 to better describe and test the aquifer characteristics of the Waterberg Group.

Boreholes H21-0701, H21-0702 and H21-0704 were drilled through the alluvial aquifer, the Ecca Formation and accessed the confined Waterberg under the alluvium (the confining layer is still the Ecca). H21-0701 and H21-0704 are artesian boreholes.

The alluvial aquifer was accessed with four boreholes, H21-0703, H21-0706, H21-0714 and H21-0715, to evaluate the alluvial aquifer characteristics and the effect of abstraction from the deeper confined Waterberg aquifer on these boreholes.

Lineaments associated with the Daarby Fault system was drilled to the south of the fault on resistivity anomalies indicating resistivity highs and deeper resistivity lows, boreholes H21-0680 and H21-0681. Both boreholes accessed the Ecca Formation and drilled through into the confined Waterberg aquifer. This is emphasized by the artesian borehole H21-0681.

H21-0707 and H21-0708 was drilled 7-8 km to the south of Lephalale, accessing the semi-confined Waterberg aquifer close to the Mokolo River. These sites were drilled in support of the Mokolo Groundwater Reserve study, to determine groundwater / surface water interaction between the Waterberg aquifer and stream flows. Only H21-0708 has a yield that was considered for testing and no major water strikes were recorded during drilling.

H21-0712 and H21-0713 was drilled on weathered profiles close to the Mokolo River in support of the Groundwater Reserve studies under way at the time.

3.3.2 Water Strikes

The main water strikes are found in the Waterberg Group between 120 – 270 mbgl (meters below ground level); see Appendix D for the water strike records in the geological logs. Only two of the boreholes in the Waterberg Group had water strikes yielding more than 1l/s at shallow depths (< 60m). Water strikes in the Waterberg fractured aquifer was not necessarily directly connected with the fault structures, but can be tension release fractures in the host rock or horizontal bedding planes. The water strike yields are described as follows:

- Final blow yields for the Waterberg aquifer ranged from 0.2 – >20 L/s, with an average blow yield of ~6 L/s.
- Six of the boreholes had blow yields higher than 8 L/s.
- All of the artesian boreholes can be linked to the confined Waterberg aquifer (underneath the confining Ecca Formation).

The boreholes drilled into the shallow alluvial aquifer had blow yields of 0.7 – 10 l/s.

The Ecca Formation only yielded minor water strikes 0.05 – 0.1 l/s and was not considered for further evaluation of the groundwater potential for this area.

3.4 Testing

19 boreholes were selected for the 24 hour constant discharge tests and aquifer testing was performed by AB Pumps, with 24 – 48 hour constant discharge tests. Water quality samples were taken during drilling and testing and the chemical analyses results will be discussed in section 3.6.

3.4.1 FC Method

The data was analysed with the Fracture Characterisation (FC) method developed by the Institute for Groundwater Studies, University of the Free State. A summary of the boreholes tested, their blow yields, 24h abstraction rates and individual aquifer parameters (transmissivity as T and storativity as S) are given in Table 3.

Table 3: Constant discharge test results for exploration boreholes at Lephalale

Drill Target	Drill Site ID	Blow Yield (L/s)	24h Yield (L/s)	T_{early} (m/d)	T_{late} (m/d)	S
Semi-confined Waterberg Eenzaamheid Fault (S)	H21-0637	8	4	13.81	6.63	2.2×10^{-3}
	H21-0638	15	7.5	34.7	26.8	2.2×10^{-3}
	H21-0663	8	3	8.9	5.2	1.0×10^{-6}
	H21-0665	>20	14	250	45	2.2×10^{-3}
	H21-0669	0.8	0.12	1	0.5	2.2×10^{-3}
	H21-0670	1.5	0.3	4.5	1.8	2.2×10^{-3}
In between	H21-0700	12	9	13.53	10.54	1.7×10^{-3}
Semi-confined Waterberg Eenzaamheid Fault (N)	H21-0666	8	3	61.9	11.2	8.2×10^{-6}
	H21-0667	3.5	0.8	4.4	2.8	3.5×10^{-6}
Semi-confined Waterberg	H21-0708	2.5	0.7	11.6	7.1	2.2×10^{-3}
	H21-0712	8	2	3.4	3.33	1.17×10^{-3}
Confined Waterberg	H21-0671	>20	9	85	18.6	9.9×10^{-6}
Confined Waterberg underneath Alluvium	H21-0701	3.5	0.7	6.6	2.6	2.0×10^{-3}
	H21-0702	4.2	2	3.3	2.8	2.2×10^{-5}
	H21-0704	2.5	1.4	61.3	2.7	1.4×10^{-3}
Alluvium	H21-0703	0.7	0.15	7	4.7	$*8.8 \times 10^{-4}$
	H21-0715	10	2	370.75	56.59	$*2.2 \times 10^{-3}$
	H21-0706	0.7	*tested but found very weak – no evaluation done*			
Confined Waterberg Daarby Fault	H21-0681	2.2	0.6	1.1	1.1	2.1×10^{-3}

**For the unconfined alluvial aquifer S is measured as S_y or specific yield – the FC calculation is not considered sufficient for this type of aquifer.*

Five exploration boreholes have recommend yields higher than 5 L/s for a 24 hour pump cycle and the highest recommended yield is 14 L/s. Management recommendation reports are included in Appendix E.

Please note: All of these 24h sustainable yields are based on single boreholes pumping and should not be used where boreholes can influence one another. See Plan 4, Appendix A for borehole positions. Optimum pumping rates for boreholes situated close to one another will be obtained during the numerical modelling phase.

3.4.2 Aquifer Characteristics

The following aquifer characteristics were derived from the derivative plot and log-log and semi-log diagnostic diagrams in the FC spreadsheet of the constant discharge test evaluation, for the:

Waterberg semi-confined fractured aquifer;

- H21-0637 shows a confined double porosity aquifer, with the main water strike dewatered at 137.1 mbgl, after which the borehole failed.
- H21-0638 shows a confined double porosity aquifer, with the positions of the main water strikes not reached during the test.
- H21-0663 shows a confined double porosity aquifer, with a major fracture zone reached between 73.91 – 74.34 mbgl.
- H21-0665 shows a confined double porosity aquifer, with a major fracture zone dewatered at 45.97 mbgl. This coincides with the water strikes in the geological log and the diagnostic plots also shows that the borehole is starting to access water only from the fractures below this zone. Therefore the yield of the borehole is declining after this fracture zone is dewatered.
- H21-0666 shows a confined double porosity aquifer, with a fracture dewatered at 73.61 and 77.47 mbgl respectively. This also coincides with the water strikes in the geological log.
- H21-0667 shows a confined double porosity aquifer, with dewatering at 82.08 – 89.91 mbgl respectively. This might be an indication of a flow boundary that was reached, however the first major water strike was at 124 mbgl.

- H21-0669 is pumping from a single vertical fracture plane, but accessing a double porosity system. The first fracture is dewatered at 32.27 mbgl, slightly deeper than the first water strike in the geological log.
- H21-0670 shows a confined double porosity aquifer, with no boundary conditions reached during the test. The first major water strike was at 48 mbgl.
- H21-0671 shows a confined double porosity aquifer, with dewatering at 74.54 – 79.03 mbgl respectively. The first major water strike was at 114 mbgl.
- H21-0700 shows a confined double porosity aquifer, with dewatering at 119.17 mbgl respectively and coincides with the end of the casing.
- H21-0708 shows abstraction from single plane vertical fractures, with dewatering occurring from 17.7 mbgl.
- H21-0712 is pumping from a single vertical fracture plane, but accessing a double porosity system with the main water strike dewatered at 53.41 mbgl, after which the borehole failed.

Waterberg confined fractured aquifer;

- H21-0681 shows a confined double porosity aquifer, with no boundary conditions reached during the test. The first major water strike was at 215 mbgl in the geological log.
- H21-0701 shows a confined double porosity aquifer, but the diagnostics show flow at early time occurs mainly from single plane vertical fractures. No dewatering of structures occurred during the test. The first major water strike was at 122 mbgl in the geological log.
- H21-0702 shows a confined double porosity aquifer, with dewatering between 55.5 – 56.5 mbgl. This occurs at the end of the casing and might be dewatering of the fracture at 44 mbgl, outside the casing.
- H21-0704 shows a confined double porosity aquifer, but the diagnostics show flow at early time occurs mainly from single plane vertical fractures. No dewatering of structures occurred during the test. The first major water strike was at 134 mbgl in the geological log.

Alluvial aquifer;

- H21-0703 shows an unconfined aquifer with delayed yield. The only dewatering or influx point occurred at the end of the casing. The depth where the major water into the borehole occurred during drilling was not reached during the pump test.
- H21-0715 shows an unconfined aquifer with delayed yield and the alluvium dewatered when the water level reaches 8.92 mbgl.

3.5 Water Levels

A strong Bayesian correlation is observed when water level elevations are plotted against surface elevation for the hydrocensus and drilling information, see Figure 2. This indicates that groundwater flow is following the topography in the surrounding aquifer.

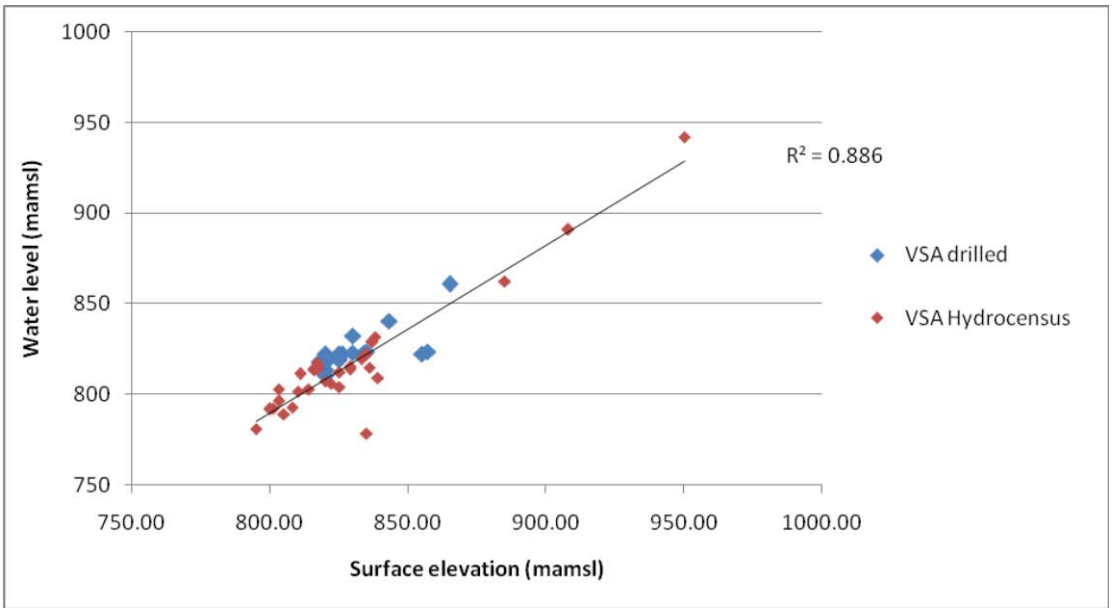


Figure 2: Bayesian water level correlation

However, when comparing the exploration boreholes' water levels, Figure 3, the water levels of the two exploration boreholes drilled in the Eenzaamheid fault system on the contact with the Ecca Formation, H21-0666 and H21-0667, plot below the regional trend and might be linked to dewatering close to these boreholes or within this contact zone. The rest of the boreholes, whether intersecting the confined, semi-confined or alluvial aquifer, all plot relatively close to the regional trend.

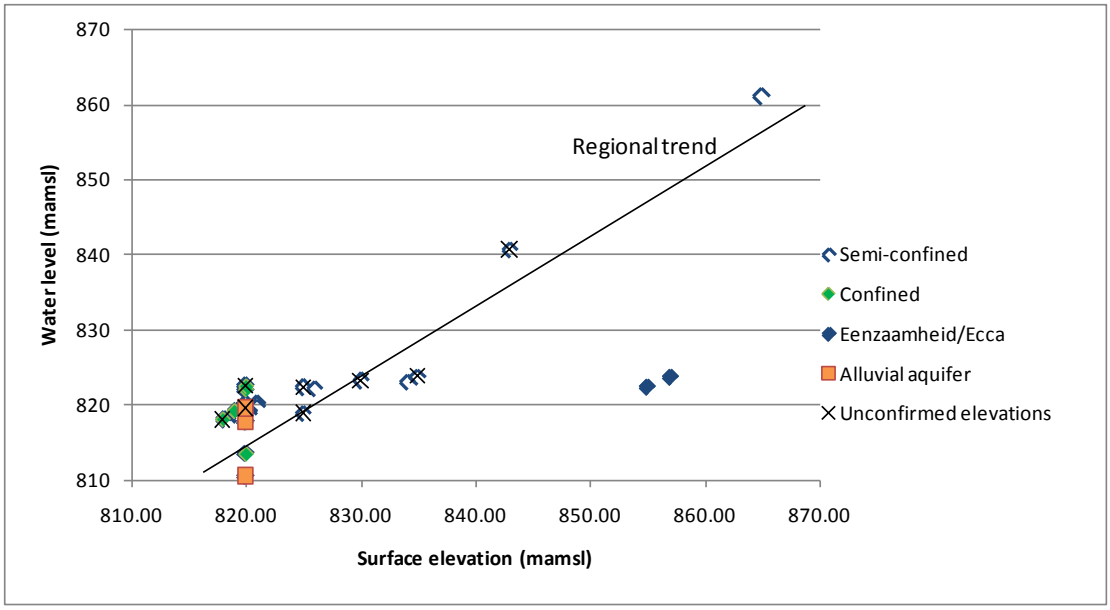


Figure 3: Exploration boreholes' water level comparison

The current information shows that the confined Waterberg aquifer is of local extent and water is under the same pressure head, in the confined aquifer, as in the semi-confined and alluvial aquifers in close proximity to it.

3.5.1 Groundwater Flow

Groundwater flow around Lephalale takes place in the direction of surface topography slope and according to structural controls of geology. Plan 5, Appendix A, shows the piezometric map of the groundwater levels in the quaternary catchments with the groundwater elevations of the exploration boreholes.

3.6 Water Quality

The typical water quality associated with quaternary catchments A42G, H and J varies between a HCO_3^- and Cl dominant water with elevated TDS, with the Cl-dominant boreholes mostly close to river systems. These trends could be due to the influence of evapotranspiration at river systems or the geochemical evolution of water from the recharge area in the south to these "discharge" quaternaries in the north. The rocks associated with the Waterberg aquifers tend to have a lower concentration of TDS. Quaternary catchments A42G and H had TDS values range from 60 – 200 mg/l and A42J (mostly Ecca Formation) TDS values range from 700 – 1100 mg/l. (Titus & Rossouw, 2008)

The evaluation of the water quality was done with WISH (Windows Interpretation System for the Hydrogeologist) developed by the Institute for Groundwater Studies.

3.6.1 Diagnostic Diagrams

Water found in different rock types will typically have different ratios of constituents in solution linked to the chemical nature of the host rock. Therefore diagnostic diagrams, like the Piper or Stiff diagrams, are typically used to distinguish between water in different aquifers, since these use combinations of ratios of anions and cations to plot the water quality relative to one another.

For the Piper diagram, Figure 4, the trapezium is divided into quarters (left, bottom, right and top) and each quarter signifies a typical groundwater type. The following describes the water types found at Lephalale:

- None of the samples falls into the left or bottom quarters, therefore none of them are associated with recently recharged water.
- Most of the samples fall into the sodium chloride dominant (right quarter) is associated with stagnant or slow moving groundwater with little or no recharge.
- The Mogol River, H21-0666 and H21-0667 falls in the middle of the trapezium and is typical of a mixed water type.

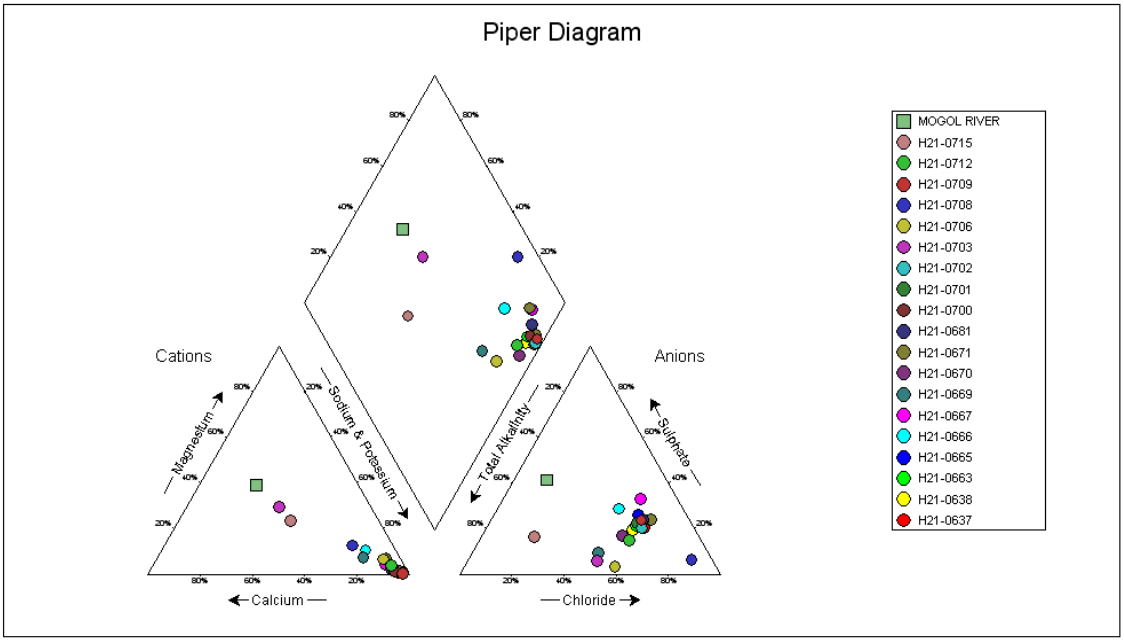


Figure 4: Piper diagram of Lephalale exploration boreholes

The Sodium Absorption Rate (SAR) diagram, Figure 5, shows that the groundwater is unsuitable for irrigation purposes for all of the samples, except for the Mogol River, H21-0715, H21-0703 and H21-0708. Water with a high SAR will lead to the destruction of arable soils due to the ionic exchange of magnesium found in the soils with high levels of sodium in the water.

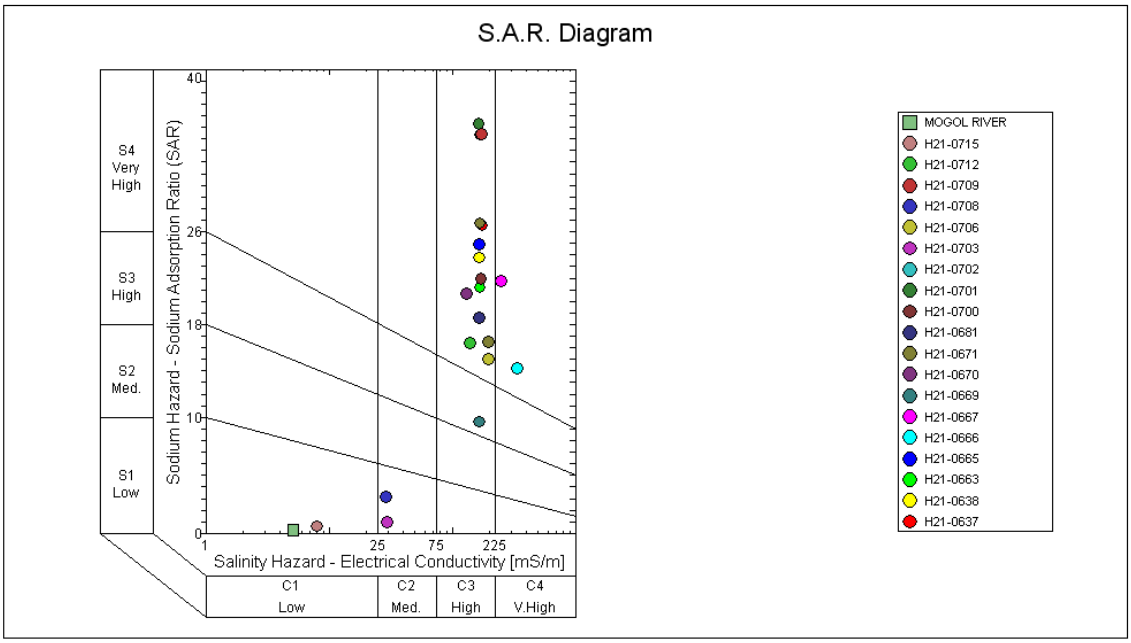


Figure 5: SAR diagram of Lephalale exploration boreholes

The Schoëller diagrams, Figure 6 and Figure 7, shows the chemical differences between the boreholes associated with the Waterberg aquifer and the alluvial aquifer. H21-0637 was included in Figure 7 for reference purposes. It is clear that none of the alluvial boreholes has exactly the same chemical signature and this can be attributed to various ratios of mixing occurring at the different sites.

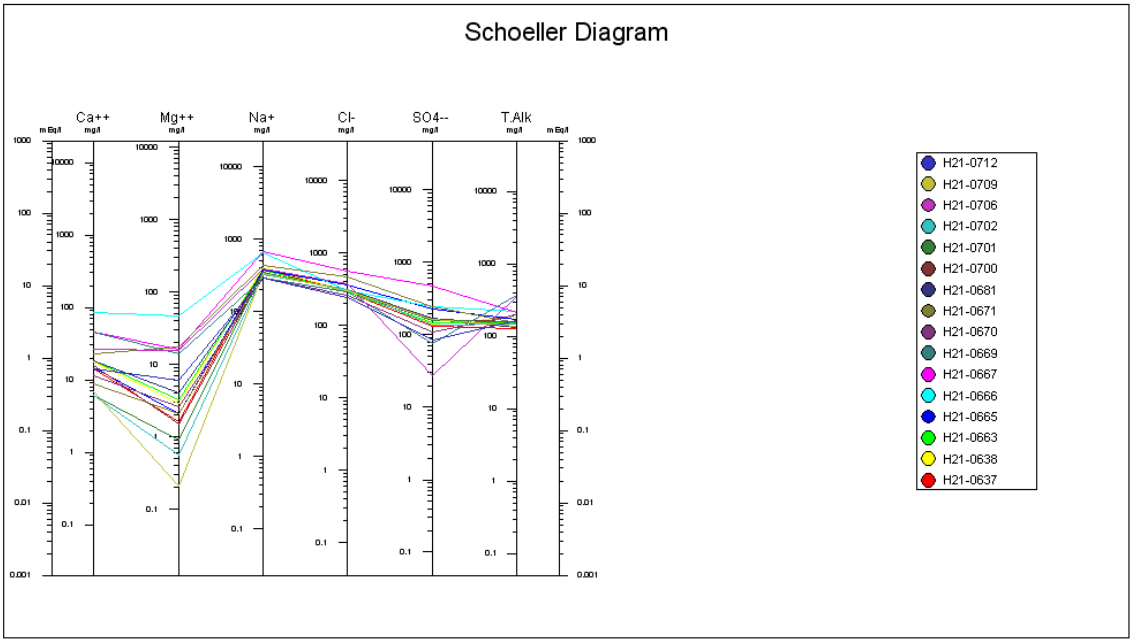


Figure 6: Schoëller diagram of Waterberg exploration boreholes

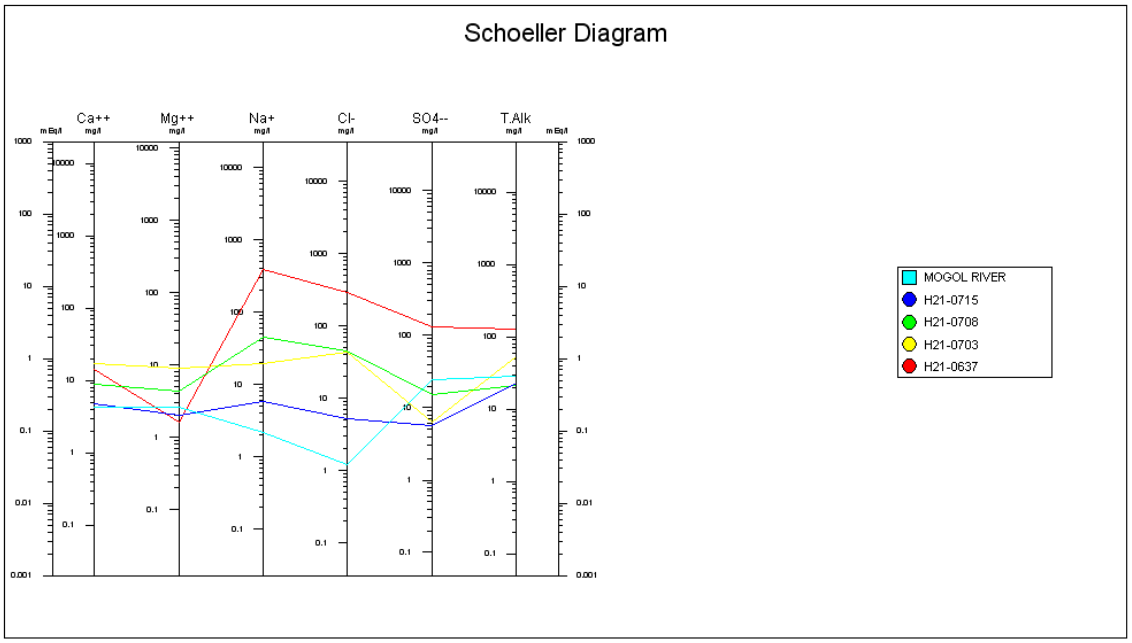


Figure 7: Schoëller diagram of Mogol River and alluvial boreholes

The Stiff diagrams for the Waterberg aquifer are shown in Figure 8. Slight differences are observed for some of the boreholes e.g. H21-0669 and H21-0706 with slightly higher alkalinity (local influences) and higher sodium-chloride and sulphate ratios of H21-0666 and H21-0667. The latter is as a result of the Eenzaamheid fault contact zone and the expected influence of the highly saline and sulphate rich with the Ecca Formation.

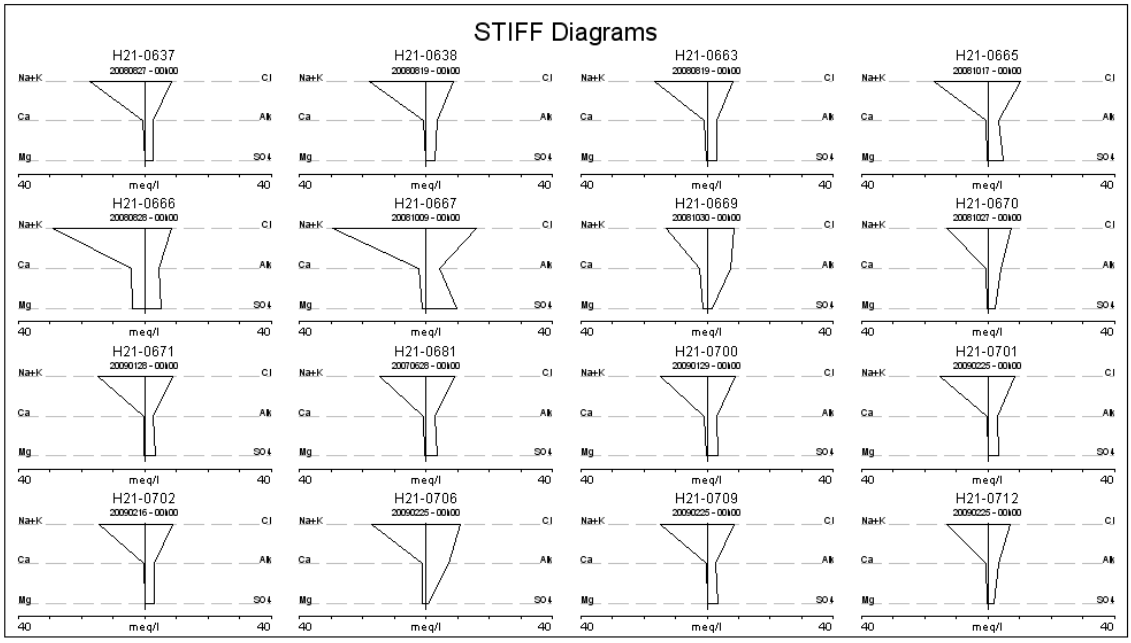


Figure 8: Stiff diagrams of Waterberg exploration boreholes

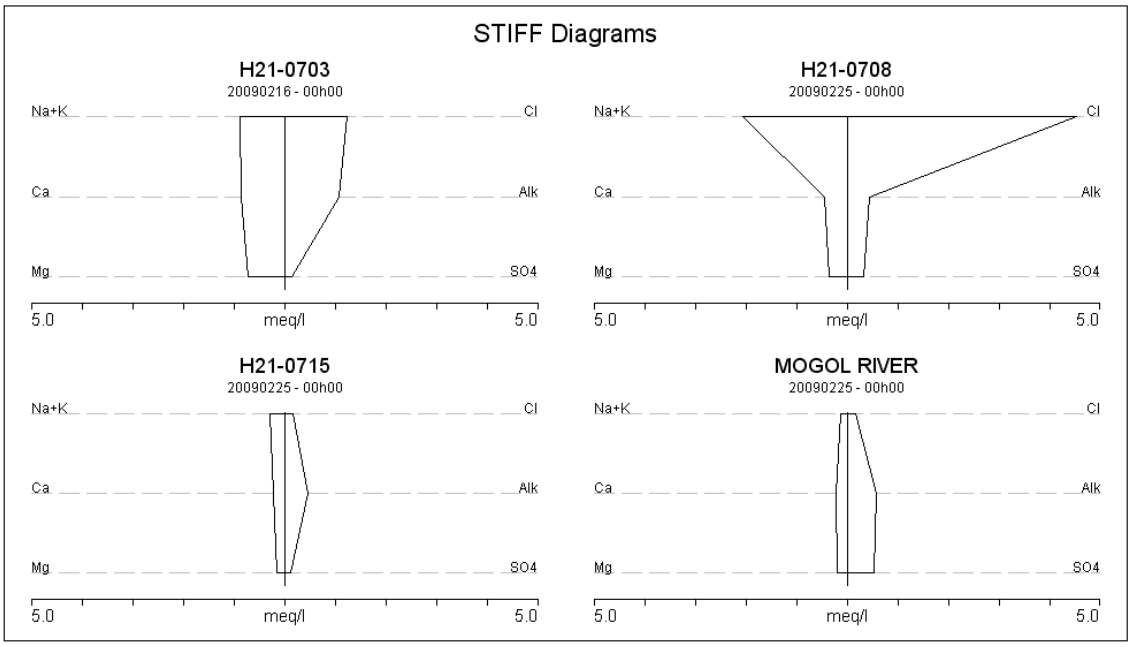


Figure 9: Stiff diagrams of Mogol River and alluvial boreholes

Figure 9 shows the Stiff diagrams of the alluvial boreholes and the Mogol River. H21-0715 is very close to the signature of the river and is most likely because of the direct connection the borehole has with the river through its highly transmissive sandy layers.

H21-0703 tends towards the river water, but some mixing or ion exchange has taken place, most probably as a result of the thick alluvium and lower transmissive sands, more residence time to interact with the alluvial soils, associated with this borehole.

H21-0708 is mixed water between alluvial river water and the deeper Waterberg aquifer. It is most likely that water from the deeper water strikes encountered during drilling, also contributed to the water that was taken during sampling. This implicates a direct connection of the river and the weathered Waterberg sandstones in the upper reaches of the Mokolo River.

3.6.2 Drinking Water Standards

The water quality of the exploration boreholes were plotted against the South African Drinking Water Standards and are shown in Appendix F. The following is concluded for the different boreholes and aquifer types:

- The Waterberg aquifer water quality is good for most of the constituents. However the levels of sodium-chloride (NaCl) are marginal and fluoride (F) is unacceptable for drinking water. The water is classified as CLASS 4 as a result of the fluoride and if considered for domestic use should either be blended to suitable water quality or the fluoride needs to be filtered out.
- H21-0666 and H21-0667 is elevated in sodium-chloride (NaCl) and sulphate (SO4) when compared to the rest of the Waterberg boreholes. This confirms the influence of the contact with the Ecca Formation on these boreholes.
- H21-0703 and H21-0715 has a good water quality, accept for elevated manganese in H21-0703 (possibly due to contact time with thick alluvial sands) and elevated aluminium and iron in H21-0715 and therefore these are classified as marginal – poor water. The latter is highly dependent on pH conditions and could be due to the influence of the river water. The water from the alluvial aquifer is CLASS 3 to CLASS 3 and, for domestic use, would also need to be blended or filtered to suitable standards.

- H21-0708 shows a good water quality in general and is classified as CLASS 3 because of the fluoride concentration just above the 1.5 mg/l limit. Nitrate is also elevated, possibly due to local pollution influences. This water sample is probably what one can expect from a Waterberg aquifer / river water blend, depending on the blending ratio used.

3.6.3 Stable Isotopes

iThemba Labs performed the analyses and preliminary evaluation of the stable isotopes and the report is included in Appendix F. The isotope analyses and interpretation included the stable isotopes D/H (Deuterium (H2)/Hydrogen (H1)) and O18/O16 (Oxygen) , expressed as the relative difference between sampled and Standard Mean Ocean Water (SMOW) or d in permille (‰),to get a baseline of the isotope signature. Plotting d2Ḥ against d18H for rain water (an equilibrium process) produces a straight line called the Global Meteoric Water Line. If such rain water undergoes evaporative losses (a non-equilibrium or kinetic process) at the surface, the resulting d values will plot on a line of lesser slope, an evaporation line, see Figure 10.

Where the evaporation line crosses the GMWL it can be assumed to represent the weighted mean isotopic composition of rain-derived direct recharge in the area. More positive values could imply increasing evaporative moisture losses or mixtures with more isotopically negative ground water.

All the groundwater samples plot on one evaporation line, indicative that only one process is responsible for the enrichment of the stable isotopes i.e. surface evaporation into the air with an average moisture content. Enrichment of isotopes does not occur in groundwater to any degree that is measurable, unless mixing occurs with evaporated surface water sources.

The following is evident from the evaporation line:

1. The Mogol River sample was expected to have a strong surface evaporation signature and therefore be isotopically the heaviest. However it is the lightest sample and high rainfall events in the period preceding the sampling could have caused this sample to be mostly rainfall run-off and as a result be indicative of local rainfall and not river water. It is therefore not indicative of groundwater

discharge, since it is isotopically lighter than the groundwater samples, and these results will have to be confirmed at the end of the dry season, with another river sample.

2. The samples which are isotopically the lightest (H21-0681, H21-0704, H21-0665 and H21-0709) are indicative of deep groundwater and are assumed to be the end member for the Waterberg aquifer. H21-0708 also have an isotopically light signature, but does not only indicate deep groundwater, see section 3.6.1.
3. H21-0702 and H21-0666 is slightly enriched when compared to the end members, but still well within expected ranges of groundwater stable isotopic signatures.
4. H21-0703 and H21-0706 are enriched, with H21-0703 the heaviest isotopic signature. Therefore, these points show enrichment from evaporative surface water sources with H21-0703 having more enrichment than H21-0706.

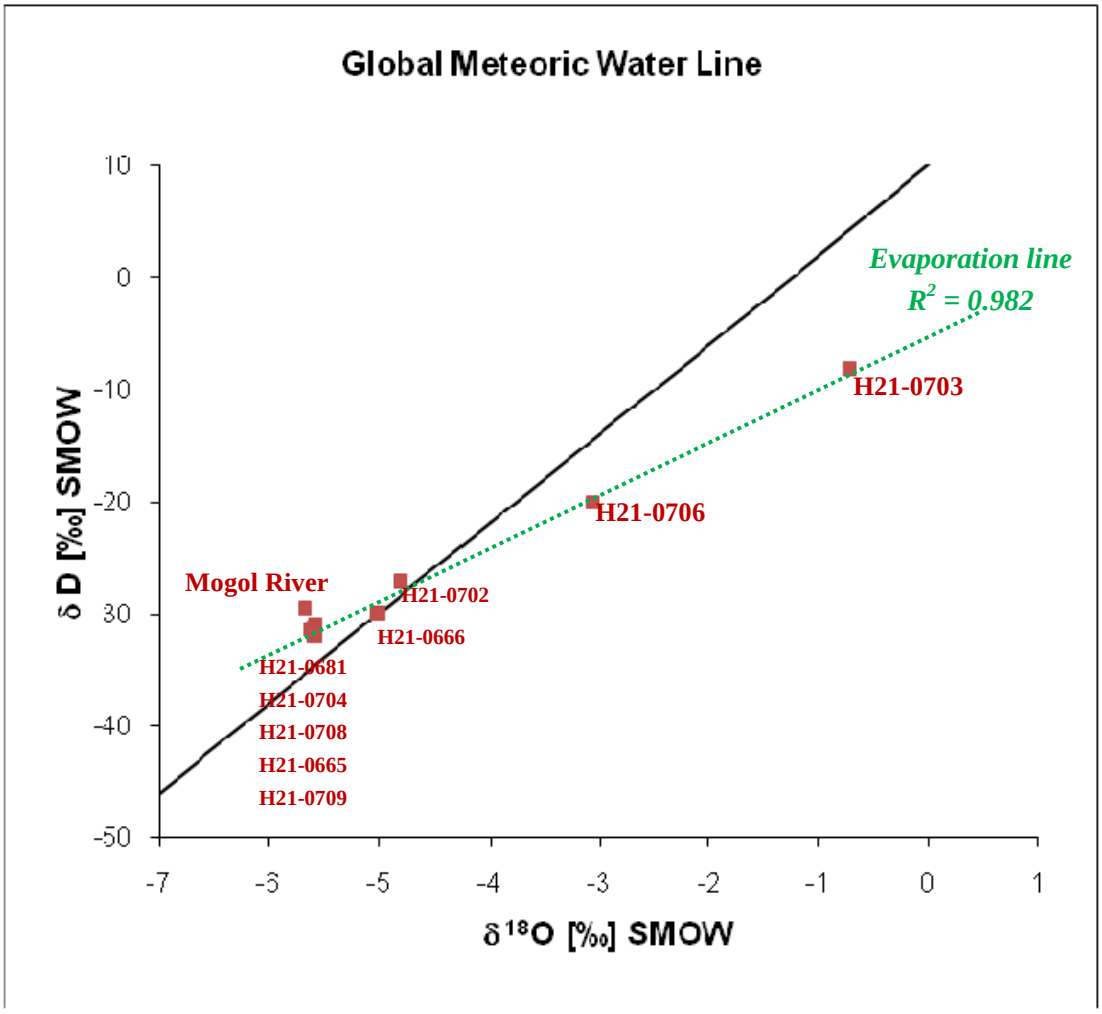


Figure 10: Stable isotope data in relation to Global Meteoric Water Line

3.6.4 Mixing Ratios and Groundwater Chemistry

In order to determine mixing ratios of groundwater and evaporated surface water, different end members for the stable isotopes is needed for the different types of water in a system. For the Lephalale area end members exist for typical rainfall (Mogol River) and deep groundwater (H21-0681, H21-0704, H21-0665 and H21-0709), but none for evaporated surface water.

H21-0703 cannot be assumed an end member for surface water, since the water chemistry indicates mixing of different water has occurred, see section 3.6.1. H21-0715 and a river sample at the end of the dry season are needed to confirm whether an end member for evaporated surface water can be obtained. Mixing ratios for H21-0703 and H21-0706 can then be determined to see whether this water is a mix of Waterberg aquifer and alluvial groundwater or simply evaporated alluvial groundwater.

H21-0708 cannot be only deep groundwater, since the chemistry showed mixing between deep groundwater and river water. However, the isotopic signature falls between the deep groundwater boreholes' and the Mogol River sample. This indicates that mixing of deep groundwater and recent rainfall run-off has occurred in this borehole. Mixing ratios are calculated as a simple linear correlation between end members and for H21-0708 the mixing ratios were calculated as 57% deep groundwater and 43% rain water from river runoff. H21-0708 is therefore also an indication of what diluted Waterberg aquifer water chemistry would consist off.

3.7 Conceptual Models of Lephalale Aquifers

The Lephalale aquifers lie in the drainage area of quaternary catchments A42G, A42H and A42J, where recharge occurs in the higher laying Waterberg Mountains and these quaternary catchments acts as discharge zones for the Waterberg aquifers. A42J also has Karoo and alluvial aquifers associated that can increase the recharge to this quaternary catchment. (Titus & Rossouw, 2008)

Existing groundwater use for these catchments is relatively low due to the low aquifer yields and the abundant surface water available. Volumes for the groundwater balance per quaternary catchment are taken from Titus & Rossouw, 2008, and listed in Table 4.

Table 4: Groundwater balance for quaternary catchments at Lephalale

Quaternary	Area (km^2)	Recharge (mm/a)	Recharge (Mm^3/a)	GW Reserve (Mm^3/a)	GW Abstraction (Mm^3/a)	**Available Groundwater (Mm^3/a)**
A42G	1206	21	25.32	2.70	0.06	**22.56**
A42H	1057	15	15.64	0.87	0.06	**14.71**
A42J	1811	7.25	13.15	0.36	0.19	**12.60**

From the groundwater exploration and testing phase of this project the two viable aquifer systems identified include the Waterberg aquifer and the alluvial aquifer in direct connection with the Mokolo River.

Figure 11 shows a cross-section from south to north of the Waterberg semi-confined and confined aquifers at the Eenzaamheid Fault Structure (FS). The semi-confined conditions in the Waterberg occur south of the contact with the Ecca Formation, as a result of the confined nature of the fractures at depth, although the aquifer is still in contact with atmospheric pressure at the water table. The fault extends at depth and fractures related to the fault / bedding planes will most likely be encountered at depth anywhere within the fault system.

North of the contact the Ecca overlies the Waterberg and the whole aquifer is confined. The piezometric water level is as a result of the pressure built up in the underlying confined Waterberg which has a hydrostatic connection with the semi-confined Waterberg.

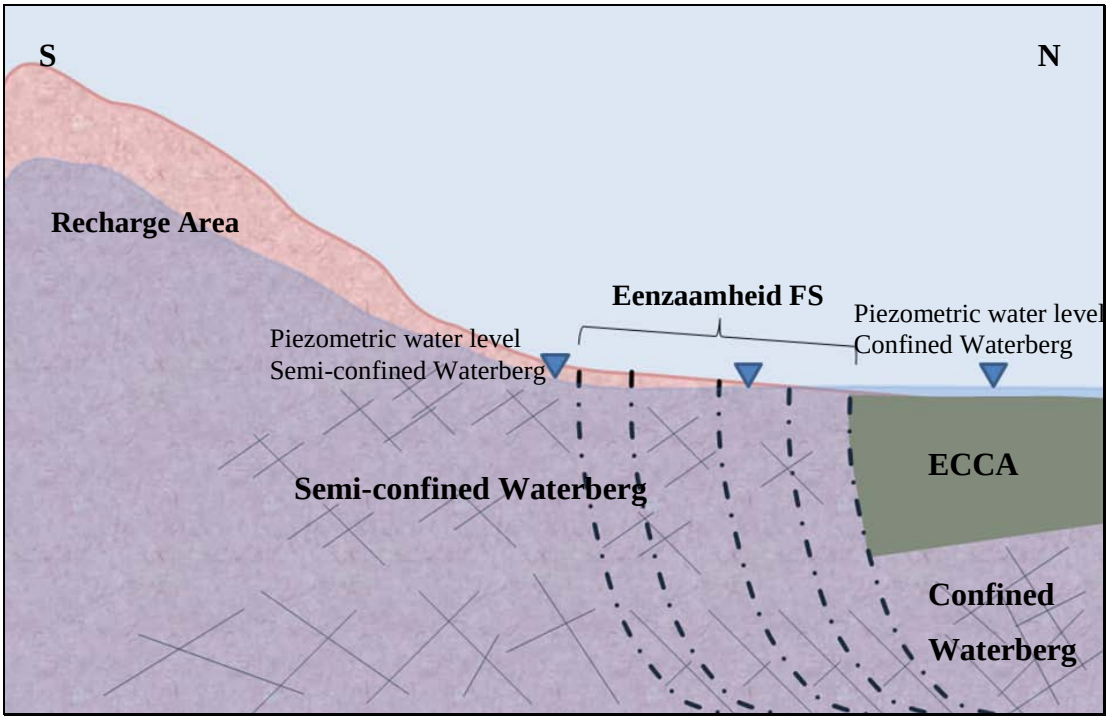


Figure 11: NS cross-section of Waterberg aquifer over Eenzaamheid Fault

Figure 12 shows a cross section of the alluvial and confined Waterberg underneath the Ecca Formation, north of the Eenzaamheid FS, at the river. The alluvial aquifer in this area does not recharge the Waterberg aquifer, since hydrostatic pressure and the confining Ecca layers will not allow for it, and that the Waterberg semi-confined aquifer discharges in the weathered zone into the alluvial aquifer at the contact of the Eenzaamheid FS with the alluvial aquifer. This could also occur higher up in the catchment where the Waterberg semi-confined aquifer is directly linked with the alluvial aquifer through the weathered zone and the river will then act as a discharge area for the Waterberg aquifer.

Two piezometric water levels are observed: one linked to the unconfined alluvial aquifer, linked to the level of the water in the river, and the second piezometric water level linked to the confined Waterberg aquifer. The piezometric level of the water in

the Waterberg is higher than the alluvial because of the hydrostatic pressure of water in the higher lying semi-confined Waterberg.

Some of the boreholes drilled through the alluvial deposits into the Waterberg Group encountered alluvial deposits at depth e.g. conglomerate “pebbles rocks” found at 160 mbgl, after Waterberg sandstone was drilled from 114 mbgl. This indicates that typical river gravels were deposited within the Waterberg and very high yields can be expected from boreholes intersecting these palæo drainage channels.

The alluvial aquifer and Waterberg confined aquifer is separated by the impermeable Ecca Formation. Observation boreholes in the alluvium showed no connection between the two water levels observed, when adjacent boreholes drilled into the Waterberg was tested.

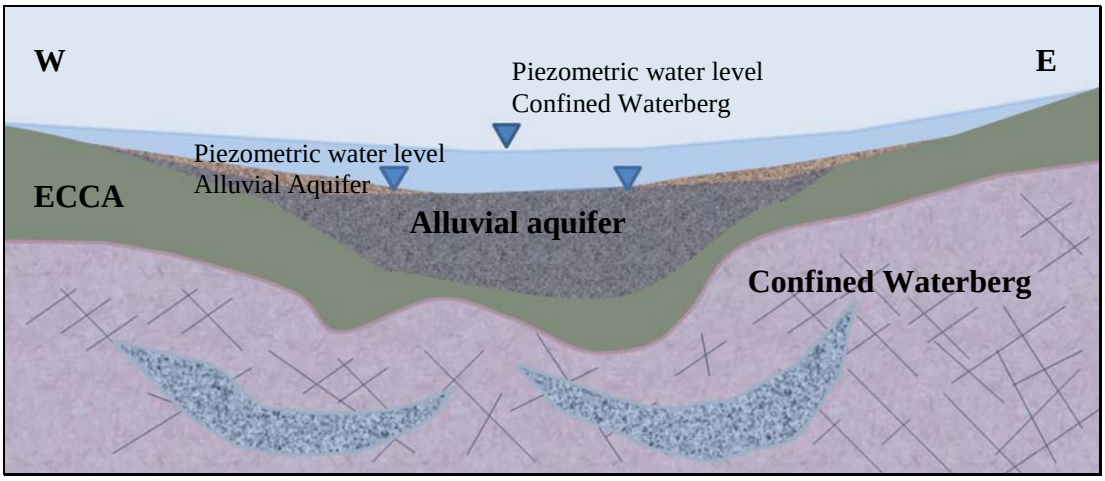


Figure 12: EW cross-section of alluvial and Waterberg confined aquifers north of Eenzaamheid Fault

3.8 Aquifer Potential

Since no major no-flow boundaries were observed during the aquifer testing, the hydrogeological boundaries to groundwater flow at Lephalale are considered to be the quaternary catchment boundaries and the extent of the geological sequence. However, a more practical boundary is needed for the calculation of groundwater resource potential that can be developed in and around Lephalale and a distance of 10km radius, from the town centre, was decided on. Three hydrogeological units are relevant for developing the groundwater potential on site, and are defined as the:

- Waterberg semi-confined fractured rock aquifer;
- Waterberg confined fractured rock aquifer; and
- Alluvial aquifer.

Plan 6, Appendix A, shows the delineation of these hydrogeological units based on geological constraints, aquifer type and piezometric water level elevations. The sections to follow describes the volumes of groundwater already available as a result of the groundwater exploration programme and the volume of water that can be developed in the proposed area, based on recharge and volume of water in storage.

3.8.1 Current Accessible Yield

As a result of the groundwater exploration programme, 10 boreholes can already be equipped and utilised for water supply at Lephalale. Table 5 summarises the yield available for each of the aquifer units from the existing exploration boreholes.

These volumes do need to be verified during the numerical modelling phase to follow, to obtain the optimum abstraction rate for different well fields or boreholes situated close to one another. For instance, boreholes H21-0637 and H21-0638 are too close to other high yielding boreholes in the same hydrogeological structure. During the modelling these boreholes will be pumped at the same time and the effect after a year of pumping will be shown.

Table 5: Current accessible groundwater from aquifers at Lephalale

Aquifer	Drill Site ID	Water Level (mbgl)	Pump Depth (mbgl)	24h Yield (L/s)	Volume (m^3/m)	Volume (m^3/a)	Total (m^3/a)
Semi-confined Waterberg Eenzaamheid Fault System	H21-0637	1.4	120	4	10,368	124,416	**1,322,056**
	H21-0638	0.5	120	7.5	19,440	233,280	
	H21-0663	1.9	120	3	7,776	93,312	
	H21-0665	1.3	119	14	36,288	435,456	
	H21-0700	4.6	119	9	23,328	279,936	
	H21-0666	34.2	102	3	7,776	93,312	
	H21-0712	3.3	76	2	5,184	62,208	
Confined Waterberg	H21-0671	0.3	119	9	23,328	279,936	**342,144**
	H21-0702	2.5	118	2	5,184	62,208	
Alluvium	H21-0703	2.5	28	0.15	388.8	4,665	**62,208**
	H21-0715	1	28	2	5,184	62,208	

3.8.2 Alluvial Aquifer Development

The alluvial aquifer was not adequately explored and it is recommended that this aquifer be drilled further to obtain better estimates for yield potential and artificial recharge potential. According to WSM, 1999, the alluvial aquifer close to Lephalale has a specific yield (S_y) of 0.15 and a thickness of 8-18 m is observed from the current project drilling logs. If a minimum aquifer thickness (D) of 8 m is applied, then the volume of water in storage for the alluvial aquifer is calculated as:

$$Alluvial_{storage} = Area * D * S_y$$

$$= 26\ km^2 * 8\ m * 0.15$$

$$= 31\ Mm^3$$

The S_y value and thickness of the aquifer needs to be confirmed with exploration drilling and testing targeted towards the alluvial aquifer.

3.8.3 Waterberg Aquifer Development

The boreholes accessing the Waterberg aquifer already has a potential yield of 1.66 Mm^3/a. Further groundwater resource development in the Lephalale area is dependent on the water that is recharged from rainfall annually, the water in storage in the aquifer and additional resource e.g. transfers into the aquifer from surface water sources. Water in storage can either be lowered once off, to a level acceptable to all water users / stakeholders of an area, or it can be lowered to increase the volume

available to recharge / artificial recharge of the system. By lowering the piezometric water table in an aquifer system, space is made available for storing additional water in times of excess rainfall and therefore increasing the yield of the system.

Recharge from rainfall

The aquifers at Lephalale will mainly access recharge in the quaternary catchment A42H and recharge was taken as 15 mm/a, see Table 4. Recharge from rainfall to the Waterberg aquifer will only take place over 157 km^2 (half the area), since the confined aquifer is overlaid by the confining Ecca Formation. Therefore recharge to the Waterberg aquifer, accessed by the 10 km radius around Lephalale, is calculated as 2.4 Mm^3/a, not taking into account lateral inflow from the rest of the catchment.

Water in storage

In the 10km radius around Lephalale groundwater can be accessed from both the semi-confined and confined Waterberg Aquifer, with a matrix storativity (S) of 0.0022, Table 3, and an average aquifer thickness 300 m (maximum depth of exploration boreholes). The volume of water in storage for the Waterberg aquifer is calculated as:

$$Waterberg_{storage} = \text{Area} * \text{Aquifer thickness} * S$$
$$= \pi(10{,}000\ m)^2 * 300\ m * 0.0022$$
$$= 208\ Mm^3$$

However, not all of this can be accessed if aquifer integrity is taken into account and for every 1m drop in piezometric water table the following volume is available:

$$Waterberg_{1m\ drop} = \pi(10\ 000m)^2 * 1m * 0.0022$$
$$= 0.7Mm^3$$

The level to which the aquifer should be dropped is dependent on an aquifer management decision in conjunction with artificial recharge options. However a 1m drop in piezometric water level is considered an acceptable impact, since piezometric pressure in the aquifer will be dropped by less than 1% and aquifer integrity will not be compromised. Therefore 0.7Mm^3 is considered the minimum accessible volume of water if storage is utilised.

To be developed further

The existing exploration boreholes in the Waterberg aquifer can already access 1.66 Mm^3/a assuming all boreholes can pump simultaneously. Recharge available amounts to 2.4 Mm^3/a and water in storage to 0.7Mm^3, therefore at least 1.44 Mm^3/a can still be developed without major impacts expected to the Waterberg aquifer.

3.9 Augmentation Scheme Viability from the Waterberg Aquifer

From the information given in this chapter, it was shown that the augmentation scheme of 3*Mm^3/a can be supported by development of the deeper Waterberg aquifer. However certain constraints needs to be taken into account when planning for this development

- Currently, three exploration boreholes were drilled for every successful production borehole.
- The production boreholes yielded 5 L/s on average and therefore 7 production boreholes are needed for every 1 Mm^3/a developed.
- An augmentation scheme for an additional 2 Mm^3/a from the Waterberg aquifer therefore requires 14 production and at least 42 exploration boreholes.
- Each production borehole should be placed at least 2 km apart; the ideal situation will require an area of at least a 100 km^2 well-field, with the 10km^2 radius from town more than sufficient for this development.
- The expected groundwater yield, from the existing exploration boreholes, as different well-fields, will be evaluated during the numerical modelling phase, including the impact abstraction will have on these and other water users in the area.
- Water quality constraints include the high NaCl and F in the water and treatment is not required for industrial use; however treatment for domestic use will be required.

4 MONITORING

According to the Groundwater Reserve study (Titus & Rossouw, 2008) the quaternary catchments A42G, H and J still shows low levels of stress and therefore it was given a category of *Natural*. The following recommendations were made from the Groundwater Reserve study in terms of further aquifer development (Titus & Rossouw, 2008):

- Optimal yields of boreholes and well fields should be determined with appropriate aquifer tests;
- Groundwater levels and gradients should be maintained to river systems, especially where groundwater is contributing to baseflow; and
- Potential impacts of developments should be assessed for both quantity and quality of the groundwater resource.

The monitoring network at Lephalale was designed to meet the first two objectives. The purpose of long term monitoring of water levels is to obtain information on the aquifer response to rainfall, while monitoring during aquifer testing evaluates the response of the groundwater system to stress within structures and is needed for the calculation of aquifer properties, specifically storativity.

Currently the monitoring network consists of 10 continuous monitoring wells equipped with automatic loggers, measuring water levels. The monitoring boreholes are listed in Table 6 and shown on Plan 7, Appendix A. All of the current divers will be used to monitor the aquifer response to rainfall over time; however the purpose of each monitoring borehole during the aquifer testing phase is given in Table 6.

Water quality monitoring is not currently underway and it is recommended that the boreholes listed in Table 7 (see Plan 7, Appendix A) be monitored on a monthly interval for one year, after which the water quality data should be evaluated and the monitoring network adjusted. These boreholes have already one analysis and therefore should continue as soon as possible to have continuity in the data,

Table 6: Water level monitoring boreholes at Lephalale

Aquifer	Monitoring Site ID	Equipment	Purpose
Semi-confined Waterberg	H21-0636	DIVER	Stress response in fault
	H21-0664	DIVER	Stress response in fault
	H21-0667	DIVER	Stress response in fault
	H21-0669	DIVER	Stress response in fault
	H21-0670	DIVER	Stress response in fault
	H21-0700	DIVER	Stress response in aquifer
	H21-0716	DIVER	Stress response in shallow aquifer
Confined Waterberg underneath Alluvium	H21-0702	DIVER	Stress response between aquifers
Alluvium	H21-0703	DIVER	Stress response between aquifers
	H21-0706 moved after initial testing	DIVER	Stress response between aquifers
Confined Waterberg Daarby Fault	H21-0680	DIVER	Aquifer properties

Table 7: Water quality monitoring boreholes at Lephalale

Aquifer	Monitoring Site ID	Equipment	Purpose
Semi-confined Waterberg	H21-0637	NONE	Changes in fault system
	H21-0663	NONE	Changes in fault system
	H21-0667	DIVER	Changes in contact zone
	H21-0670	DIVER	Background water quality
	H21-0700	DIVER	Changes in semi-confined system
	H21-0701	NONE	Changes resulting from river water
	H21-0708	NONE	Upstream water quality
	H21-0712	NONE	Upstream water quality
Confined Waterberg underneath Alluvium	H21-0671	NONE	Changes in confined system
	H21-0702	DIVER	Changes in confined system
Alluvium	H21-0703	DIVER	Alluvial aquifer water quality
	H21-0706	NONE	Alluvial aquifer water quality
	H21-0715	NONE	Alluvial aquifer water quality
Confined Waterberg Daarby Fault	H21-0681	NONE	Changes in confined system

4.1 Data Loggers

Information on the constant rate discharge tests and observation boreholes (tabled) and the time series graphs of the water level data logged (Divers) are included in Appendix G. Continuous water level monitoring started during August 2008 and January 2009 and is ongoing. Distances from the tested boreholes to the observation boreholes are only shown from the dates that the observation boreholes have data. The influence of the constant rate tests on the observation boreholes shows the following:

1. Observation boreholes linked to the Eenzaamheid fault system close to Lephalale (H21-0636, H21-0664, H21-0700) shows a direct and immediate response to constant rate test within the fault less than 1km away (H21-0637, H21-0638, H21-0663, H21-0665 and H21-0700). This confirms the direct connection through fractures with very high hydraulic conductivities. This cannot be explained with a single fracture, since H21-0700 shows the exact same response and has to be a highly fractured fault zone that is intersected with these boreholes.

   Full recovery of the water levels after the initial tests in August 2008 only occurred 2 months after the tests were stopped. Full recovery of water levels has not yet occurred at 1.5 months after the 2nd set of constant rate tests. This indicates slow release of water from the rock matrix and less water is available when this rate is exceeded.

   Testing of the confined aquifer (H21-0701, H21-0702, H21-0704 and H21-0681) shows no effect on the fault zone.

2. Observation boreholes further away from the tested boreholes (H21-0669 and H21-0670) shows very little to no response to the constant rate tests. The water level behaviour in H21-0669 is erratic and cannot be explained. H21-0670 shows no influence and is a good monitoring borehole for assessing the impact on the regional aquifer over time.

3. H21-0706 shows the same trend in water level as H21-0670, except for the recovery of water levels after its own test. This is possibly another borehole that can be used for monitoring aquifer response to rainfall, since it is not hydraulically connected to any of the other boreholes.

4. H21-0667 shows a general decline in water level during the testing period and therefore indicates water from storage is being accessed. This borehole is approximately 5km away and therefore a good monitoring borehole for assessing the impact of abstraction in town on the local aquifer.

5. Observation boreholes in the confined Waterberg aquifer (H21-0702 and H21-0680) show slight changes in water level when H21-0665 was tested. This indicates pressure release in the confined system as a result of the testing. However, when H21-0700 and H21-0637 was tested no response could be observed and is possibly linked to the shorter time (H21-0700) or lower rate (H21-0637) that these boreholes were tested at.

   H21-0702 also shows slow recovery from its own constant rate discharge test and recovery occurred only one month after the test was completed. This is possible due to less hydraulic pressure as a result of this borehole's close proximity to the confined/semi-confined aquifer boundary.

   The drawdown effect in BH21-0680 from the testing of the adjacent borehole H21-0681 is immediate; however recovery is fairly fast due to the hydraulic pressure in the confined aquifer here.

6. H21-0703 does not show any specific response to any of the other pump tests. The fluctuations in water levels are linked to changes in river stage, see Figure 13.

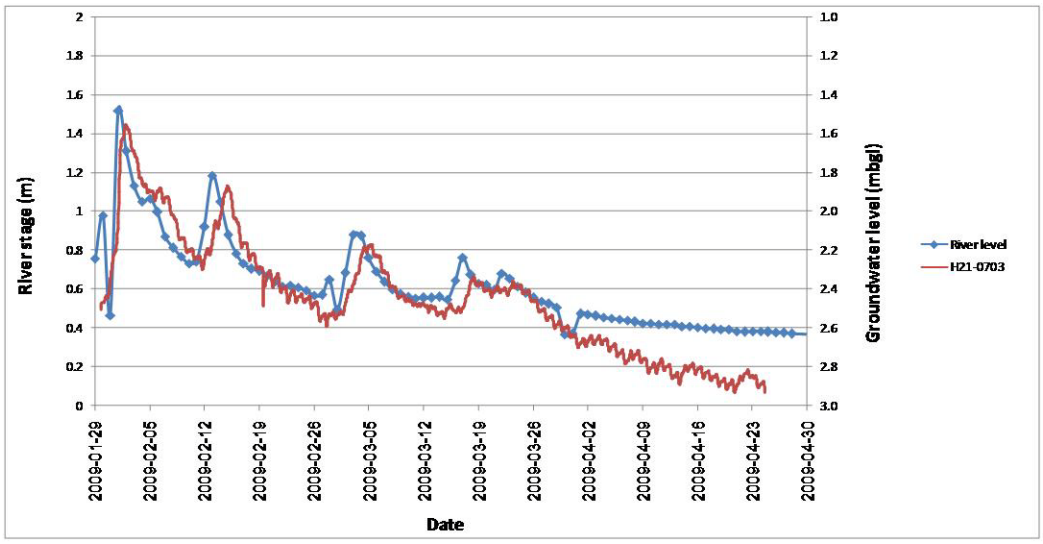


Figure 13: Comparison between Mokolo River levels and H21-0703 monitoring water levels

Two sudden drops in water levels in both H21-0700 and H21-0680 are observed on 26 March 2009 and cannot be explained at this point in time. More detailed analyses of specific observation data will be done during the numerical modelling to determine aquifer parameters e.g. storativity.

5 ARTIFICIAL RECHARGE AT LEPHALALE

5.1 What is Artificial Recharge?

Artificial recharge (AR) or Managed Aquifer Recharge (MAR, the term being promoted internationally), has many approaches. The most common is to store water in the subsurface for later use, this usually being achieved by allowing water to infiltrate the subsurface via infiltration basins or by injecting water via boreholes into the aquifer. In this context, it is a form of water conservation, in that water that would otherwise be lost through evaporation and evapotranspiration from dams, rivers and/or outflows to the sea (fresh or waste water), would be captured and made available for later use. One of most common and studied methods used is Aquifer Storage and Recovery (ASR, Figure 14) and its major advantage is to be able to store good quality water in a generally saline water bearing aquifer, and use the stored water when needed, for example during drought periods. Compared to surface storage, some ASR projects have recovery rates greater than 95%.

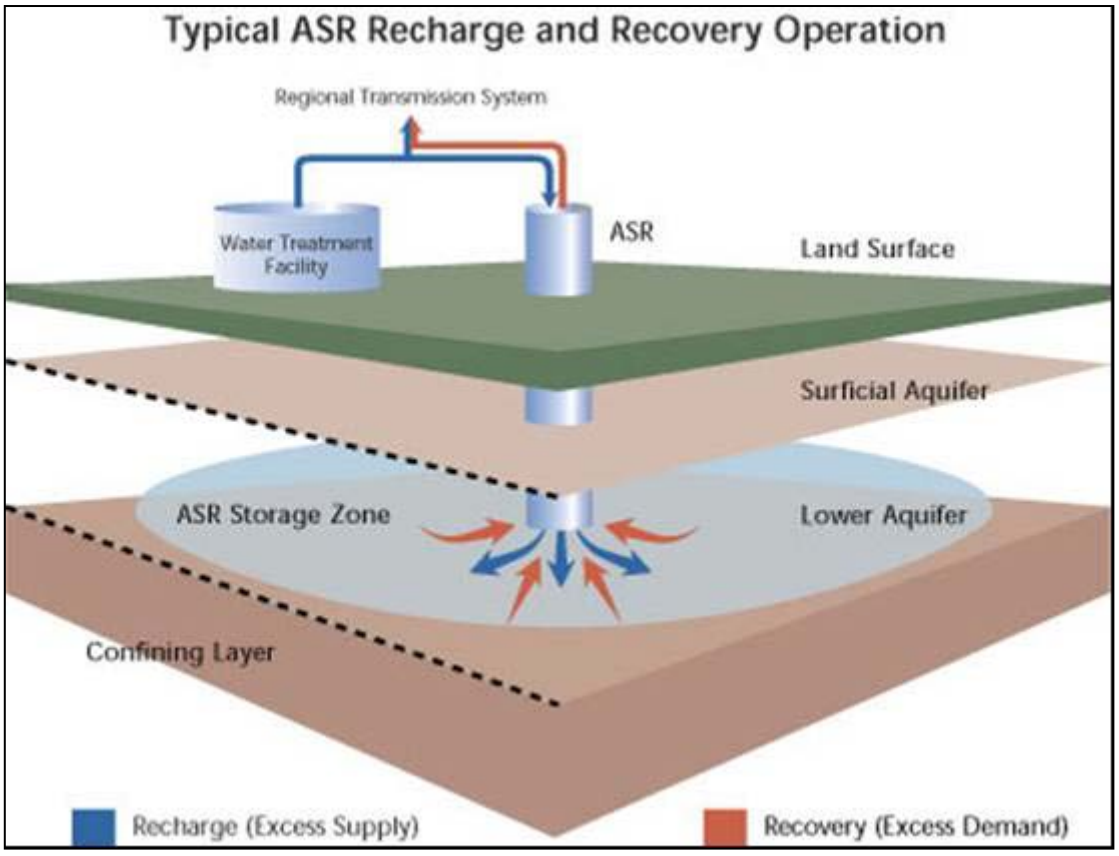


Figure 14 Schematic example of ASR in a confined aquifer

5.2 AR Potential at Lephalale

The desk top hydrogeological assessment showed aquifers within the Lephalale area to generally yield poor quality water, but having reasonable borehole yields (greater than 2 L/s), the limiting factor to be quality rather than quantity, see Plan 8 and 9 in Appendix A for updated maps of the Fluoride and Electrical Conductivity around Lephalale. The poor quality may also be enhanced by low rainfall and high evaporation, making it ideal to investigate ASR as a future augmentation option, storing good quality water in saline aquifers and using it during peak demands.

5.2.1 Waterberg Aquifer

During the exploration phase of this study, the Waterberg semi-confined and confined aquifer was identified as an aquifer that has major yields associated with boreholes drilled on feasible structures and an aquifer that has a vast amount of water in storage. For every 1 m drop in piezometric water level of the aquifer, 0.7Mm^3 of water can be released from storage in a 10 km radius around Lephalale. This is the same amount of water that can be injected for that 1 m drop in water level. Therefore, vast quantities of water can potentially be stored in times of excess rainfall and needs to be used again in times of drought, when water shortages is experienced, to make space for injecting water into the aquifer when excess rain falls again.

Water levels in the Waterberg aquifer is generally not deep, except where dewatering has taken place. Therefore abstraction needs to take place before AR schemes can be implemented. Typical AR schemes that should be considered for the Waterberg aquifer at Lephalale include (Murray, *et. al.*, 2007):

- Aquifer storage recovery (ASR) – water is pumped from a water supply borehole and in times of excess the same borehole is used to inject treated water into the aquifer.
- Aquifer storage transfer & recovery (ASTR) – excess treated water is injected into dedicated injection boreholes and retrieved through dedicated abstraction boreholes. This is considered feasible during the end final stages of development of water resources at Lephalale and should be considered either at the boundary of the abstraction impact or to enhance the water quality of the aquifer.

- Soil aquifer treatment (SAT) – treated sewage effluent or urban storm water is captured and allowed to infiltrate through constructed infiltration ponds and recovered by boreholes after a certain residence time in the aquifer. This method also facilitates nutrient and pathogen removal through filtration at the ponds and can be considered for the area south of the storm water dam. This method is highly dependent on water quality and proper treatment of infiltration water (assumed polluted to an extent) is extremely important.
- Infiltration ponds – ponds are constructed off stream where surface water is diverted to, especially in high run-off events, and allowed to infiltrate into the semi-confined Waterberg aquifer. This is proposed for the linear section along the storm water run-off channel towards the Mokolo River, where high flows are diverted to the Waterberg aquifer. The volume of run-off determines the size of infiltration ponds – infiltration is usually slow and evaporation high, therefore only very good quality water should be used for infiltration.

5.2.2 Alluvial Aquifer

Exploration of the alluvial aquifer was only performed through the drilling of 2 boreholes specifically accessing this resource. However, drilling logs show sands of 10 – 18 m thick and this constitutes a major storage space when accessed. Typical AR schemes that should be considered for the alluvial aquifer at Lephalale include (Murray, *et. al.*, 2007):

- Bank filtration – water is extracted through boreholes along the alluvial sands in the river to induce infiltration from the river, thereby improving and making the quality of the water more consistent.
- Infiltration ponds – ponds are constructed off stream where surface water is diverted to, especially in high run-off events, and allowed to infiltrate into the unconfined alluvial aquifer.

However, this aquifer does not have available storage capacity for excess water and further groundwater exploration needs to focus on the alluvial aquifer in order to find the high yielding areas and to evaluate aquifer characteristics further.

5.2.3 Default AR in Progress

The irrigation of waste water effluent at the Lephalale golf course by default created artificial aquifer to the Waterberg aquifer and should preferably continue.

6 NUMERICAL MODELLING

Numerical modelling is a simplification of the natural environment and cannot simulate the intricacies of the groundwater system in detail. It should be seen as an approximation at best and the quality of the input data will determine the quality of the output information. A numerical model is but 1 of an infinite number of methods that can be applied for the given data, it is a non unique solution. Therefore, groundwater models will always have errors due to the uncertainty in data, the capabilities/limitations of numerical modelling code to describe the natural processes and the factors selected by the modeller to determine the non unique solution.

The conceptual model, section 3.7, describes the hydrogeological environment and is used to design and construct the numerical model to represent simplified but relevant conditions of the groundwater system. The conditions should be chosen in view of the specific objective of the modelling exercise and might not be relevant for other modelling objectives. The following conditions typically need to be described in a model:

1. Known geological and geohydrological features.
2. Boundary conditions of the study area (based on the geology and geohydrology).
3. Static water levels of the study area.
4. The processes governing groundwater flow.
5. Assumptions on which the numerical code selected and development of the model is based on.

Field data is essential in solving conditions 1 – 4 and a model actually develops into a site-specific groundwater model when real data is used. Specific assumptions related to the available field data include:

- The top of the aquifer is represented by the surface topography and available surface elevations are used to construct a representative spatial extent.
- The current geological information is sufficient to describe the extent of the different aquifers.

- The aquifer parameters calculated is representative of the aquifers beyond the area where data is available.

Limitations of models result from generalisations, interpretations and assumptions made in attempting to simulate the natural environment. The following limitations are true for all numerical groundwater models:

- The complexities of fractured rock aquifers imply that the model can only be used as a guide to determine the order of magnitude of the resource, dewatering and contaminant transport.
- The interpretation of modelled results should be based on the assumptions the model was built on and actual results will vary as unknown aquifer conditions and parameters vary in the natural system.

6.1 Lephalale Model Environment

A system is needed that can simulate the behaviour of the groundwater processes in which the most sensitive aspects of the system can be understood and used for further predictions. For the numerical modelling of the Lephalale project area the finite difference method was chosen as a suitable robust numerical solution for simulating the complex natural environment. The finite difference method assumes a homogeneous aquifer and is deemed acceptable for this site, due to the Bayesian correlation of water levels with topography and the level of uncertainty of fracture versus matrix flow and where this would occur. The geological structural information established during the exploration phase is taken into account with the addition of different zones, at these structures' positions, of which the aquifer parameters the model uses differ from the regional aquifer.

6.1.1 Hydrogeological Units and Boundaries

The hydrogeological unit of concern is the Waterberg semi-confined and confined aquifers, since this is where groundwater would be abstracted from until the groundwater level in the aquifer has been lowered to start considering ASR or conjunctive use of the alluvial aquifer with the Waterberg aquifer.

The natural groundwater flow boundaries that exist are limited to the geological faults. The quaternary boundaries of A42G, H and J will have to be considered in combination with the geology and the model domain extent was selected as:

Latitude (decimal degrees): 23.55 to 24.11 (Lo27: -2605866 to -2667292); and

Longitude (decimal degrees): 27.37 to 28.20 (Lo27: 37590 to 122165).

A one-layered two dimensional model, with a mesh size of 434 rows and 567 columns, Figure 15, was constructed, utilising MODFLOW as numerical code and PM WIN 5 as data pre and post processor, to include the following:

- Layer 1: 300 meters thick representing the Waterberg semi-confined and confined aquifer. The single layer represents only the Waterberg aquifer and is deemed acceptable since the influence of abstraction for water supply in this geological layer is tested.
- The boundary condition at the upstream quaternary catchment (mountainous areas of A42G & H) was set as a constant head to fix the groundwater levels at this point. The constant head boundary is considered far enough removed from the abstraction (approximately 50 km) to exclude any potential addition of water from it to the model as a result of the abstraction.
- The boundary conditions for the rest of the quaternary catchments and at the northern contacts of the Daarby and Eenzaamheid Fault Systems (FS) with the Ecca Group was set as no-flow boundaries, since these are geological constraints to groundwater flow in the Waterberg.
- Furthermore, general head cells where introduced to fix the groundwater levels for the upstream catchment boundaries closer to the abstraction (> 20km). However, general head cells allow the decrease in water level as a result of a change in groundwater flux because of the effect of abstraction on the groundwater system. This would therefore allow for a well field to diminish water levels at the model boundary should the impact reach it, although groundwater flow from adjacent catchments is still observed.
- The Mokolo River acts as a drain that takes groundwater that discharges into the river out of the area to the north and this was simulated with 5m deep drains at the position of the river to the north of the confined Waterberg aquifer.

The model boundaries have been moved away as far as data would allow, ensuring that potential dewatering effects do not to reach the boundaries of the model domain.

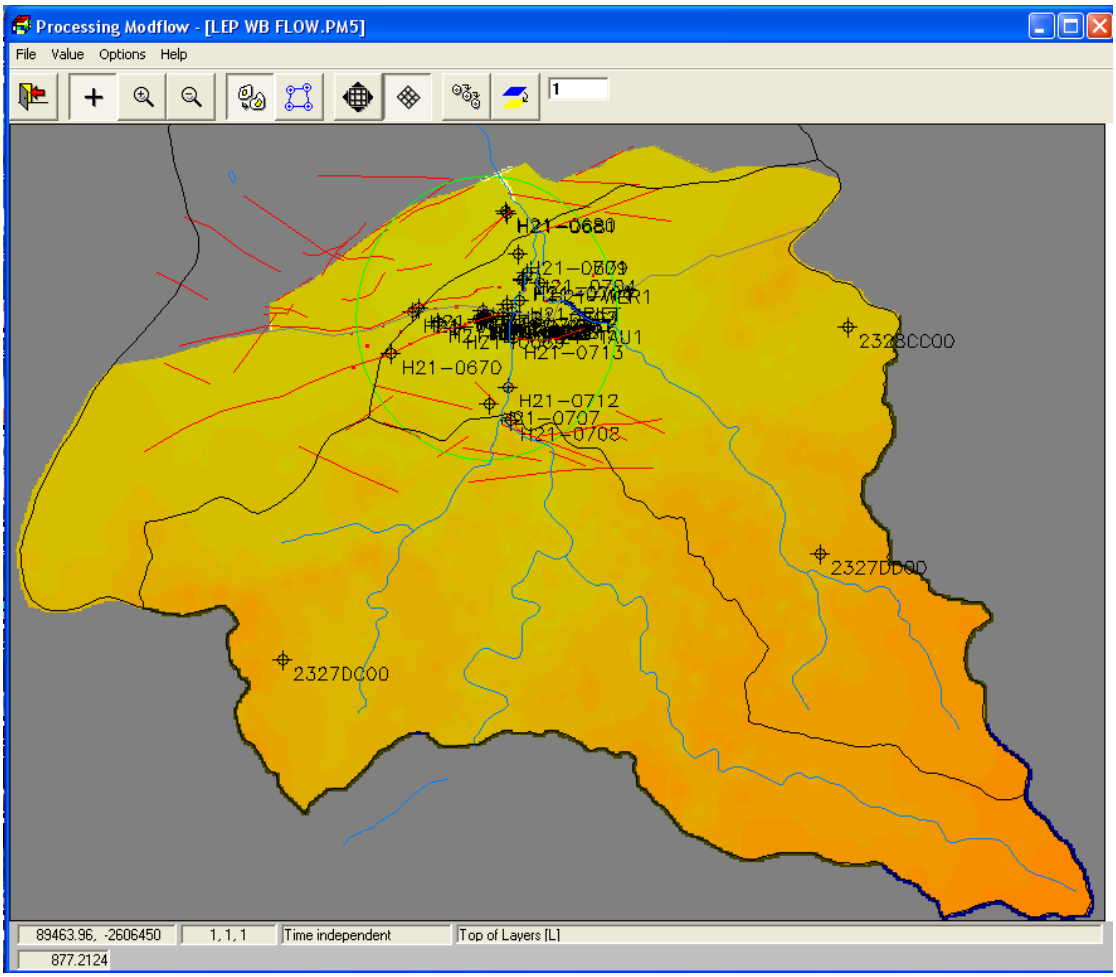


Figure 15: Screen shot of model domain

The numerical model boundaries, observation and abstraction boreholes are indicated on Plan 10 & 11 in Appendix A.

6.1.2 Initial Conditions

Initial groundwater levels were taken as a combination of measured data (section 3.5), NGDB background data and interpolated groundwater levels (especially in the upstream catchments where a lack of data exists). Incorporating the measured water levels and the background data from the NGDB resulted in a dataset of approximately 1300 groundwater levels and the Bayesian correlation is still observed throughout the catchment, Figure 16.

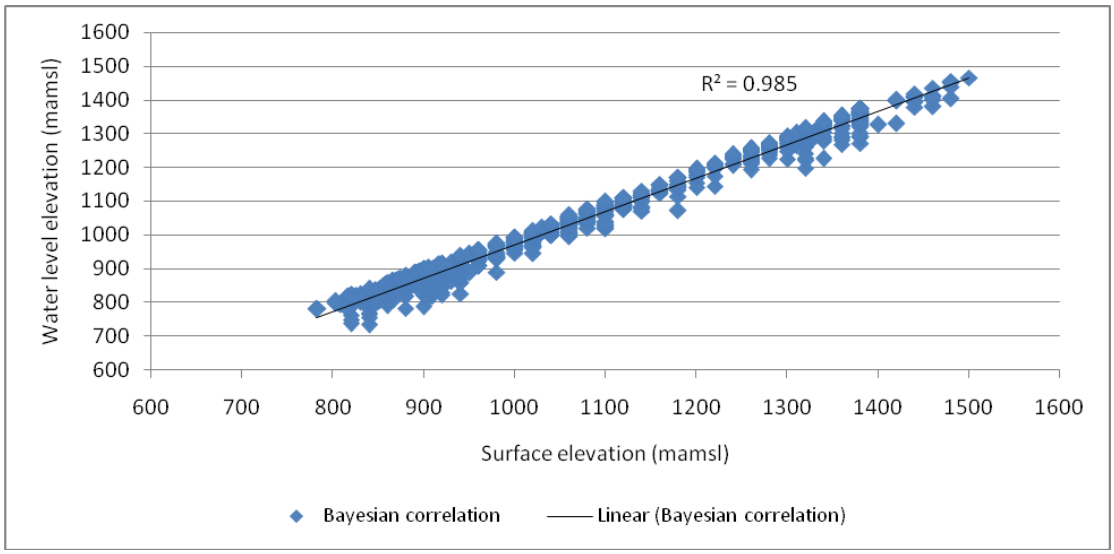


Figure 16: Bayesian correlation of regional water level data set

Interpolation for the data gaps was done with the Bayesian interpolator, Tripol, and the resultant data set was used as starting hydraulic conditions for the numerical model, see Appendix H.

Starting aquifer parameters were set as:

- Transmissivity as T = 10 m/d, and selected as an average of the T_{late} values calculated in Table 3 for the Waterberg aquifers.
- Recharge was set to resemble the same water balance information for the catchments as specified in Table 4 ($3.9x10^{-5}$ m^3/d), except for the confined Waterberg aquifer that was assumed to have zero recharge from rainfall, since the confining Ecca layer will not permit water through at a substantial rate. Recharge into the confined aquifer can therefore only occur through horizontal exchange from the semi-confined Waterberg.
- It was necessary to include the evapotranspiration calculated by Titus & Rossouw, 2008 (two zones of $4x10^{-5}$ m^3/d and $5x10^{-5}$ m^3/d), for the model to stabilise, as soon as recharge to the aquifer is introduced. Evapotranspiration was set at 100% of the calculated values when the groundwater level is at surface, after which it would decline linearly and cease when the groundwater levels were at 5 m below surface.

No structural geology was included at this stage.

6.2 Sensitivity Analyses

A sensitivity analysis of the variation in water levels at specific boreholes, as a result of the variation (up- and downwards 20%) in the different initial hydraulic parameters, section 6.1.2, was done to determine too what degree which parameter controls the flow of groundwater through the area. This gives an indication in which order of priority the parameters will be adjusted to achieve the steady state calibration.

The results of the sensitivity analyses was graphed, Figure 17 to Figure 20, and show in all the boreholes that recharge and evapotranspiration are the governing factors in how the groundwater system reacts, with the transmissivity contributing to changes in water levels to a lesser degree. The constant head was either active in the model or inactive. The effect of the constant head boundary on the borehole depends on the distance from the constant head.

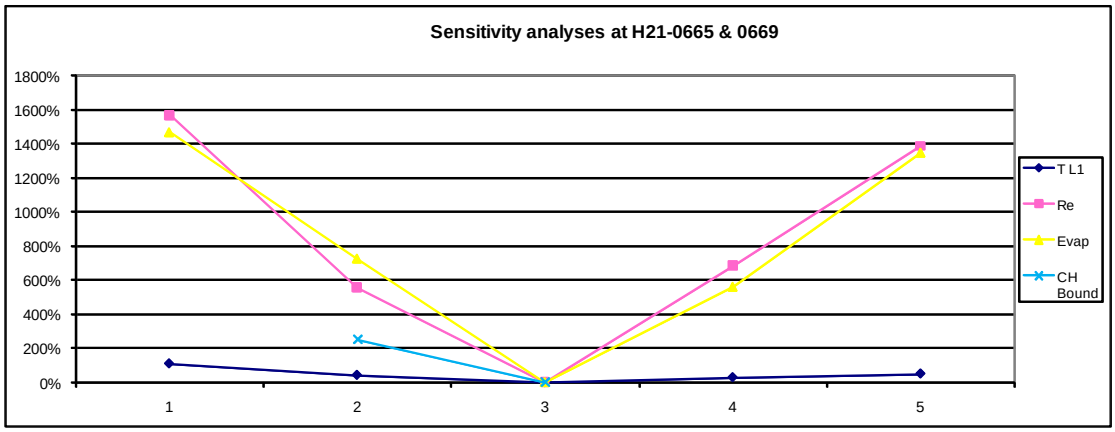


Figure 17: Sensitivity analyses at Eenzaamheid Fault Structure

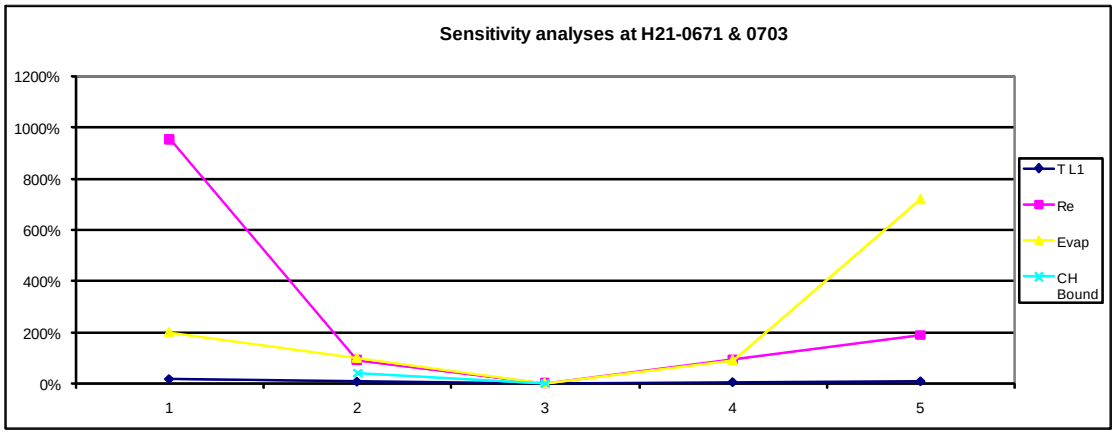


Figure 18: Sensitivity analyses at confined aquifer

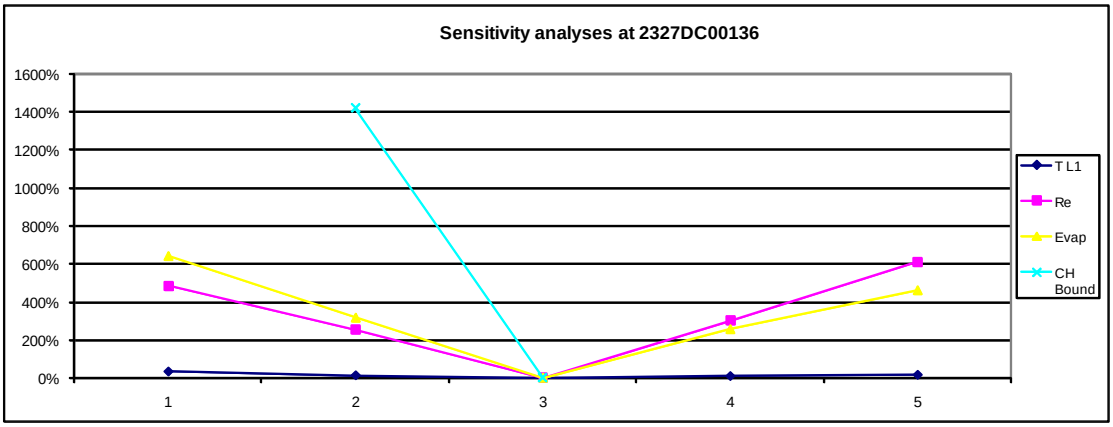


Figure 19: Sensitivity analyses A42G quaternary boundary

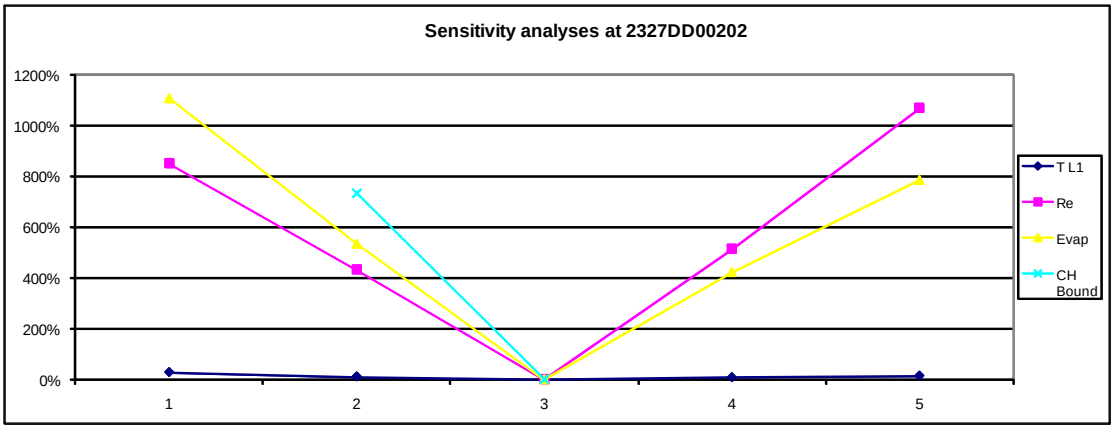


Figure 20: Sensitivity analyses A42H quaternary boundary

6.3 Calibration and Verification

Model calibration and verification are needed to overcome the lack of input data, but also accommodating the simplification of the natural system in the model. In model calibration, model input data is changed after every model run until the simulated values, like groundwater levels, compared with field measurements reaches an acceptable correlation.

Model verification is required to demonstrate that the model can be reliably used to make predictions. A common practice in verification is the comparison of the simulated data with a data set not used in model calibration. Calibration and verification are accomplished if all known and available groundwater scenarios are

reproduced by the model without varying aquifer parameters or characteristics of the model.

6.3.1 Steady State Calibration

Calibration of the Lephalale model was done for steady state conditions and the boreholes indicated in Figure 21 were used as observation boreholes. Water levels at these boreholes were compared to the modelled water levels to check if the simulation of flow through the aquifer occurred as expected, Figure 22.

Recharge zones was included for the upstream quaternary catchments and mainly adjusted as a result of the observed and simulated water level correlations. Evapotranspiration was included at the downstream riverine areas and where very shallow water levels in the Waterberg were observed at the Eenzaamheid FS.

Observed water levels were used as indications of which geological structures influence groundwater levels and the Eenzaamheid FS were included as a specific zone with higher transmissivity (35 m/d) than the rest of the Waterberg aquifer (11 m/d). Transmissivity values at the river systems were also increased to 250 m/d to achieve the same drainage patterns as the observed groundwater levels.

At two sets of boreholes, H21-0666/0667 & H21-0707/0708, calibration could not be achieved and this could be due to a number of reasons:

- H21-0666/0667 is on the contact of the Ecca and Waterberg formations, which also run past the Grootegeluk coal mine. Some degree of dewatering is expected as a result of the cone of depression in the Ecca that could be structurally linked to the fault zone. A drain was added to simulate the dewatering that might occur and although the calibration was closer it was not solved.
- H21-0707/0708 is close to the Mokolo river system and therefore this is a discharge area for the model, resulting in higher water levels than in the actual measurements.

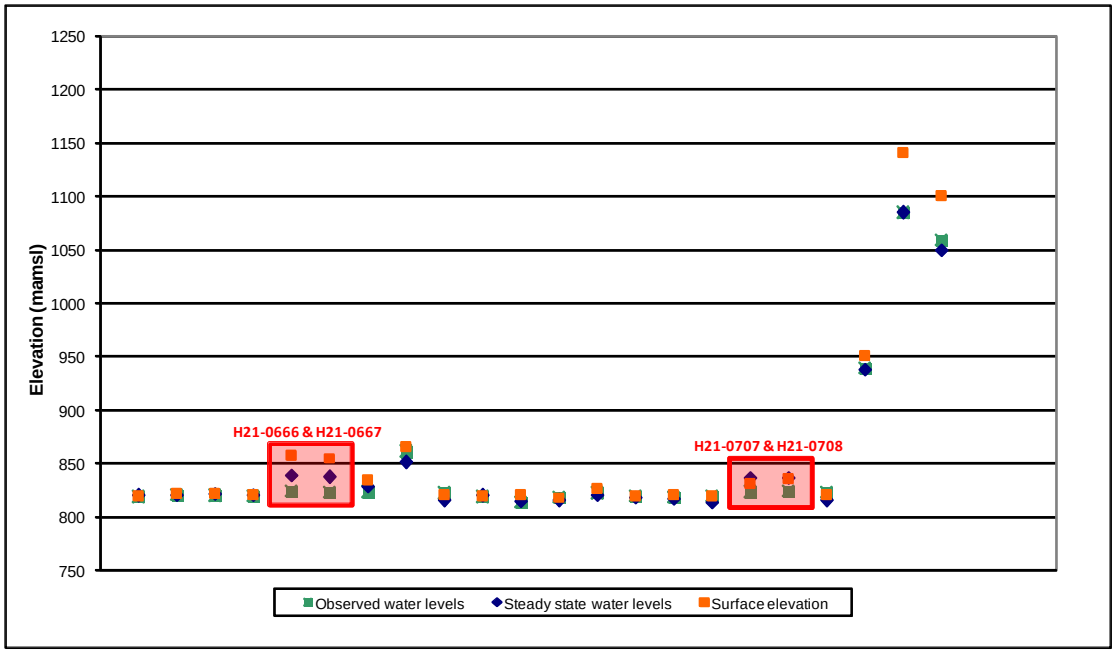


Figure 21: Steady state observation boreholes' topography and water levels

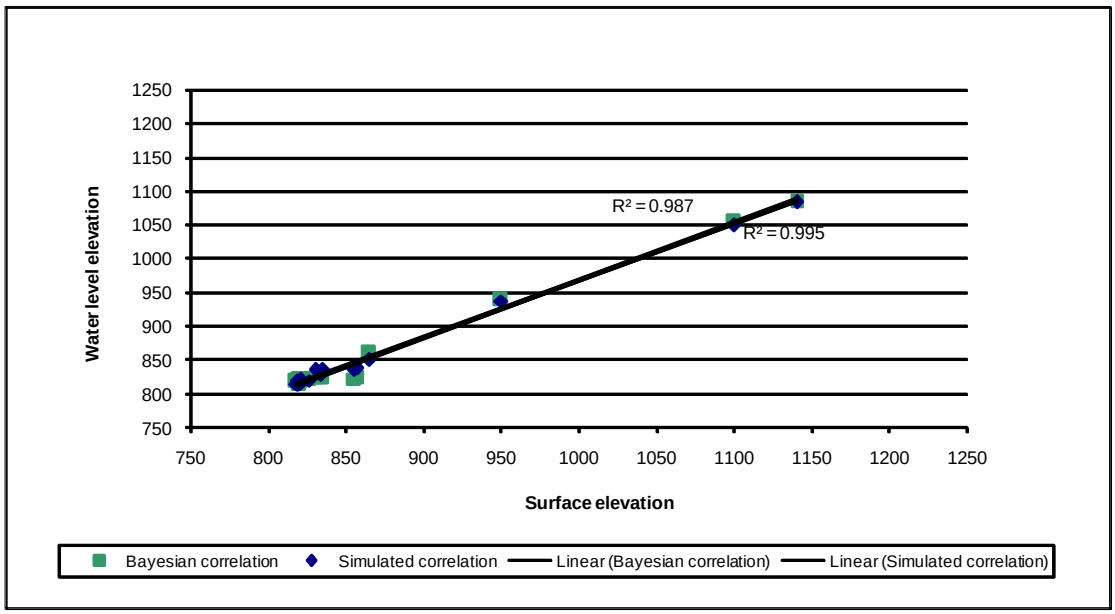


Figure 22: Steady state observation boreholes' Bayesian correlation

The calibrated steady state groundwater level elevations, over the model extent, were used to generate the piezometric groundwater level map for the numerical model, shown in Appendix H. Groundwater flow vectors from the Bayesian piezometric map corresponds well with the piezometric map of the Lephalale numerical model. The

model is viewed as a good representation of the groundwater flow processes, taking place in the Lephalale area.

6.3.2 Transient State Calibration

Transient state calibration is performed for areas where time series data, e.g. aquifer test data or long term monitoring data, is available. This enables the modeller to calibrate for specific parameters that has a low confidence even after the steady state calibration is achieved. Parameters like storativity is not used during steady state and therefore not calibrated for and if transient state calibration can be done the confidence level of the simulations are greatly enhanced.

At Lephalale groundwater monitoring have been taking place with Diver water level data loggers and a good set of data is available to enable transient state calibration. Aquifer responses, during the aquifer testing phase, were observed in the Eenzaamheid Fault System and in the confined aquifer. Useful responses in the observation boreholes H21-0636, H21-0664 and H21-0700 water levels were observed when H21-0665 and H21-0700 were pumping. H21-0280, and to a lesser degree H21-0700, showed a good water level response when H21-0681 was pumping.

H21-0667 shows no direct effect from the constant rate tests and H21-0670 is too far removed. However, the latter can be used for calibration of the rainfall recharge response distant to the well field area.

6.3.2.1 Storativity

RPTSolv was developed by the Institute for Groundwater Studies as a numerical solution for determining storativity (S) of a fractured rock aquifer from single borehole aquifer tests. RPTSolv was used for the estimation of S in the Waterberg semi-confined and confined aquifers from the observation borehole data. Selected aquifer test data from observation boreholes H21-0636, H21-0664, H21-0680 and H21-0700 was used in the simulation for the abstraction boreholes H21-0665, H21-0681 and H21-0700 pumping respectively. The RPTSolv graphs are shown in Appendix I and the results listed in Table 8.

Table 8: Storativity values for the Waterberg aquifer from RPTSolv results

Aquifer	Test borehole	Observation borehole	Storativity (S)	Transmissivity (T)
Semi-confined Waterberg Eenzaamheid Fault System	H21-0665	H21-0636	1.8×10^{-4}	60
	H21-0665	H21-0664	2.1×10^{-4}	129
	H21-0665	H21-0700	4.5×10^{-6}	246
	H21-0700	H21-0636	2.1×10^{-5}	142
	H21-0700	H21-0664	3.2×10^{-5}	164
Confined Waterberg	H21-0681	H21-0700	3.6×10^{-8}	10
	H21-0681	H21-0680	7.6×10^{-5}	7

From these results it is clear that the S is very low, but higher in the fault zone, and the first estimations of T during the steady state calibration might need to be adjusted. The Eenzaamheid Fault System transmissivity ranges between 60 – 246 m/d depending on the fracture distribution and/or connection that the test and observation borehole has. For instance it is clear that although H21-0664 is much closer in proximity to H21-0665, H21-0665 has a more direct fracture connection to H21-0636 and H21-0700. This is also evident from the immediate water level response in H21-0700 when H21-0665 was pumped.

6.3.2.2 Aquifer Response

These RPTSolv results were introduced into the numerical model and the model adjusted for S and T in the vicinity of the boreholes until a fit was achieved. The actual versus simulated drawdown for each of the various test responses are shown in Figure 23to Figure 25.

H21-0681 was assumed to be representative for the confined aquifer and transient calibration results show a good fit for S at 1×10^{-7} and a T value of 11 m/d. However, it is possible that the S value is only indicative of the fracture response and not a matrix S, since the observation boreholes is very close to the abstraction borehole.

H21-0665 and H21-0700 was indicative of the Eenzaamheid Fault Zone response, however initial S and T values had to be adjusted to ensure the observed response was simulated in the observation boreholes. S for the fault zone was calibrated to 4×10^{-6} and high transmissivity values (up to 2500 m/d) had to be included between the boreholes. The observation boreholes react as if pumping from a single fracture with closure of the fracture between H21-0665 and H21-0664. A perfect fit could not be

obtained and can be a result of geological complexities that cannot be accounted for at this stage.

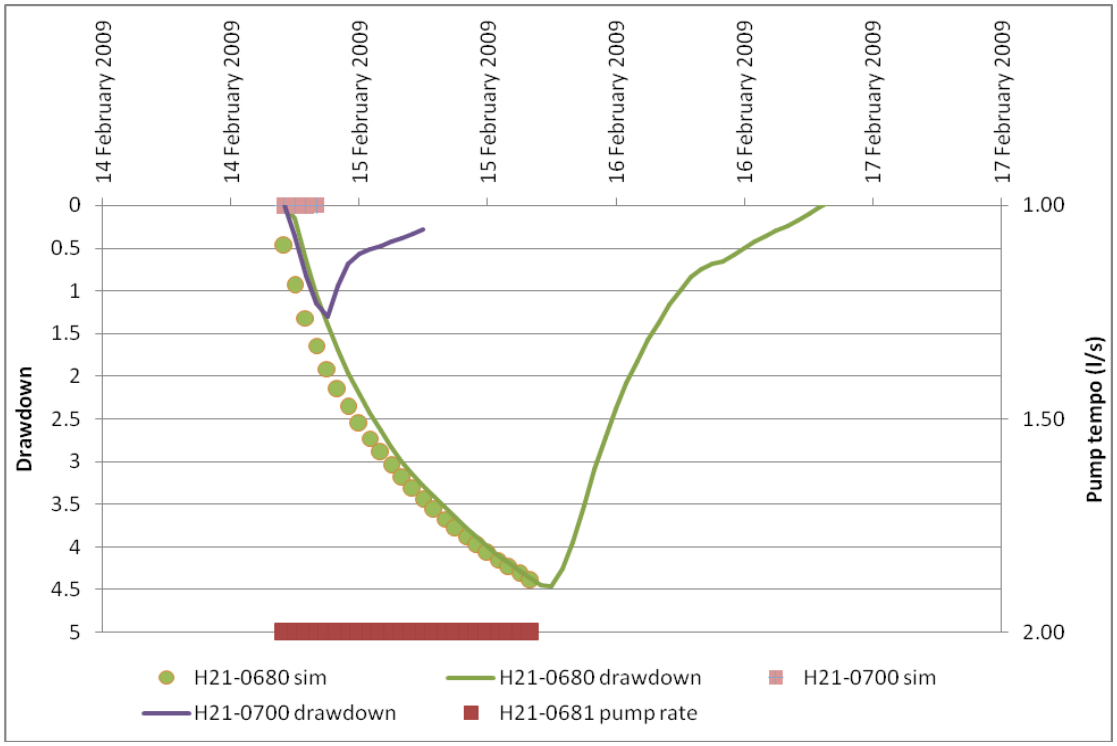


Figure 23: Confined aquifer transient calibration results for H21-0681 pumping

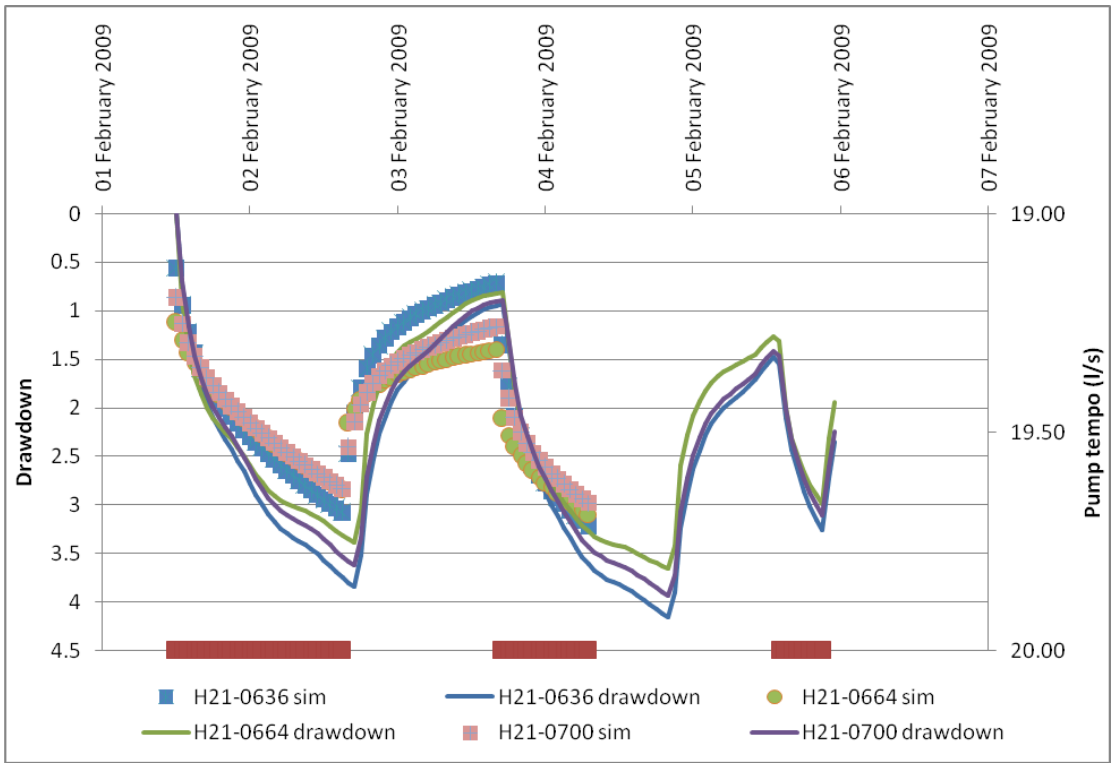


Figure 24: Eenzaamheid Fault System transient calibration results for H21-0665 pumping

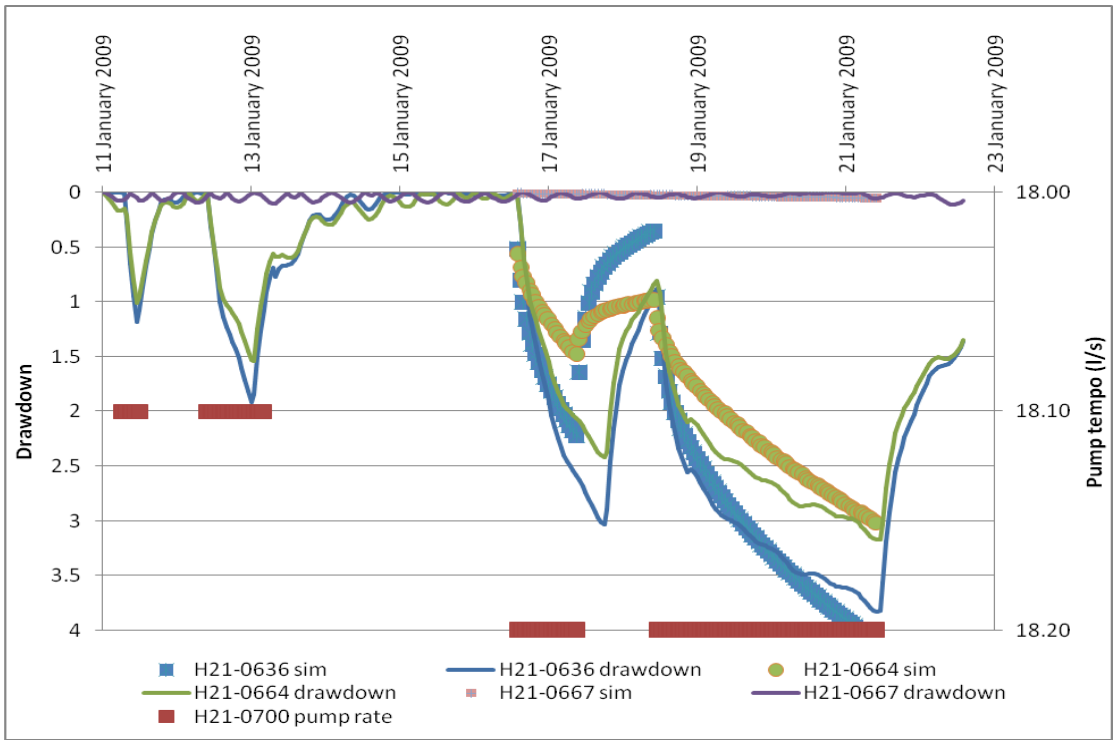


Figure 25: Eenzaamheid Fault System transient calibration results for H21-0700 pumping

6.3.3 Water Balance

Water balance information from the steady state model shows only 2.65Mm^3/a of effective recharge entering the model area. This differs significantly from the estimated recharge in Table 4. When considering potential inflows from the constant head boundary to the north and the flux boundaries at the quaternary catchment boundary, the volume of inflow into the catchment can be up to 5.58Mm^3/a. This amount to 1/10th of the expected recharge and significantly less groundwater are available for sustainable abstraction.

Water released from storage cannot be accounted for in a steady state water balance since this only occurs when abstraction from the aquifer takes place and will be discussed in the sections to follow.

6.4 Groundwater Development & Impacts

From Section 3.8 certain exploration boreholes where identified as possible abstraction boreholes and those accessing the Waterberg aquifer are listed in Table 9. However, these abstraction rates were based on a single borehole pumping and it is necessary to evaluate the sustainability of different well-field options, consisting of these boreholes, during scenario modelling (sections 6.4.1 to 6.4.4) to enable proper groundwater development of the Waterberg aquifer.

Table 9: Current accessible groundwater from Waterberg aquifer (single borehole pumping)

Aquifer	Drill Site ID	Water Level (mbgl)	Pump Depth (mbgl)	24h Yield (L/s)	Volume (m^3/m)	Volume (m^3/a)	Total (m^3/a)
Semi-confined Waterberg Eenzaamheid Fault System	H21-0637	1.4	120	4	10,368	124,416	**1,088,776** **(excl H21-0638)**
	H21-0638	0.5	120	7.5	19,440	233,280	
	H21-0663	1.9	120	3	7,776	93,312	
	H21-0665	1.3	119	14	36,288	435,456	
	H21-0700	4.6	119	9	23,328	279,936	
	H21-0666	34.2	102	3	7,776	93,312	
	H21-0712	3.3	76	2	5,184	62,208	
Confined Waterberg	H21-0671	0.3	119	9	23,328	279,936	**342,144**
	H21-0702	2.5	118	2	5,184	62,208	

The existing users' boreholes in the vicinity of the exploration boreholes were identified from the IGS hydrocensus information, to evaluate the expected impacts at these points. Table 10 shows the users and which aquifer each borehole is likely to access. Whether or not the user will be impacted on is highly dependent on whether or not the borehole is linked to the Waterberg aquifer.

From Table 10 it is clear that only a few boreholes could be impacted by any well field development in the Waterberg aquifer. Boreholes accessing only the aquifer of the Ecca formation will not be impacted on by abstraction form the Waterberg aquifer, since the Ecca formation is very dense and considered to be a confining layer for the Waterberg underneath it.

The boreholes accessing the alluvial aquifer overlaying the Ecca formation will only be impacted if river flows are impacted upon. Impacts on the river system will be discussed in section 6.4.6, but cannot be fully quantified since the alluvial aquifer was not included in the modelling.

The five boreholes linked to the semi-confined Waterberg aquifer will be further evaluated during the numerical modelling scenarios to define the impacts likely to occur.

Table 10: Water users surrounding potential well-field from current exploration boreholes

SiteName	Latitude (DecDeg)	Longitude (DecDeg)	Waterlevel (mbgl)	Aquifer	Impact expected
H21-HORN1	-23.58725	27.73094	8.24	Ecca - outside model	None
H21-HORN2	-23.58756	27.73079	11.09	Ecca - outside model	None
H21-RIET1	-23.67383	27.75417	13.91	Semi-confined Waterberg	Likely
H21-RIET2	-23.68211	27.74831	-0.01	Semi-confined Waterberg	Likely
H21-TAU1	-23.68992	27.76642	20.63	Semi-confined Waterberg	Likely
H21-VOEG1	-23.61314	27.74206	15.18	Ecca	None
H21-VOEG2	-23.63906	27.71928	29.92	Ecca	None
H21-VOEG3	-23.61747	27.75178	0.84	Alluvial on Ecca	River flow related
H21-VOEG4	-23.63028	27.75331	15.14	Ecca	None
H21-VOEG5	-23.62431	27.72617	7.99	Ecca	None
H21-WAT1	-23.68533	27.73400	2.2	Semi-confined Waterberg	Definitely
H21-WER1	-23.66153	27.76939	-0.1	Semi-confined Waterberg	Likely
H21-WER2	-23.65778	27.77143	6.52	Alluvial on Ecca	River flow related
H21-WER3	-23.65339	27.76528	3.03	Alluvial on Ecca	River flow related
H21-WER4	-23.65586	27.76517		Alluvial on Ecca	River flow related

6.4.1 Scenario 1

In this scenario the recommended abstraction of borehole H21-0700 (9 L/s) was simulated to test the borehole's likeliness to fail and to what extent users in the surrounding aquifer will be affected. The scenario was run for 10 years and the development of the drawdown cone over time is shown for year 1, 2 and 10 in Appendix J. Figure 26 and Figure 27 show the drawdown in the abstraction borehole and the impact on the surrounding water users that access the Waterberg aquifer.

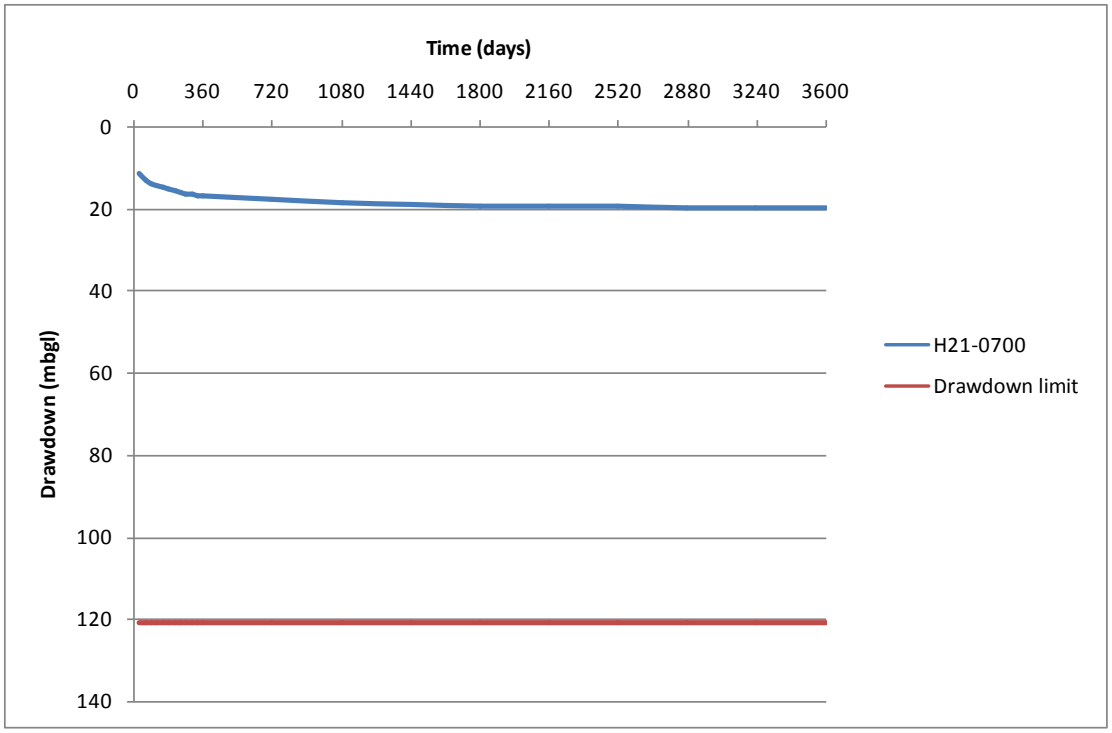


Figure 26: Groundwater level drawdown (mbgl) for H21-0700 pumping

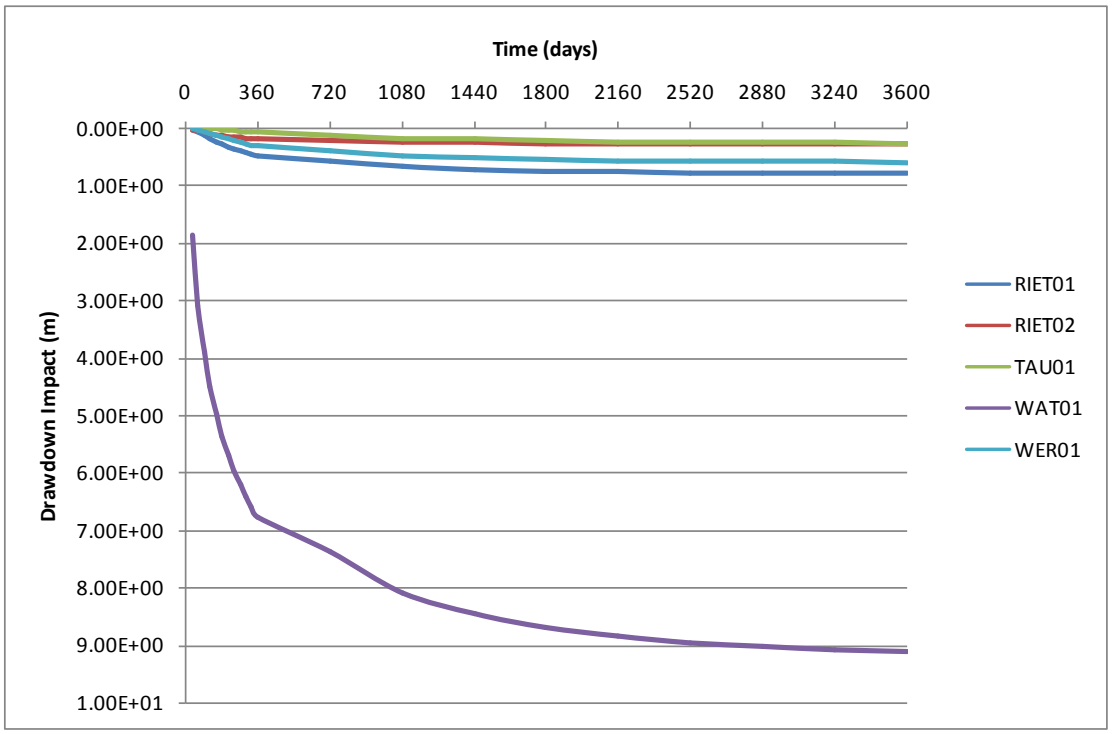


Figure 27: Water level drawdown (m) for users' boreholes

6.4.1.1 Impacts

The extent of the cone of depression is mainly in the 10 km radius area considered for well-field development over the simulation time period. It reaches the river at the end of year 1 and is buffered by inflows from the river throughout the simulation.

The water level drawdown in borehole H21-0700 does not reach the position of the fracture (drawdown limit) and level off at approximately 20 mbgl. Water level drawdown in the users' boreholes as a result of this abstraction is considered minimal (<1m).

6.4.2 Scenario 2

In this scenario the recommended abstractions of all boreholes listed in Table 9 was simulated to test whether the boreholes are likely to fail or not and to what extent users in the surrounding aquifer will be affected. H21-0638 was excluded as part of the well-field because of its proximity to the higher yielding borehole H21-0665.

The scenario was run for 10 years and the development of the drawdown cone over time is shown for year 1, 2 and 10 in Appendix J. Figure 28 and Figure 29 show the drawdown in the abstraction boreholes and the impact on the surrounding water users that access the Waterberg aquifer.

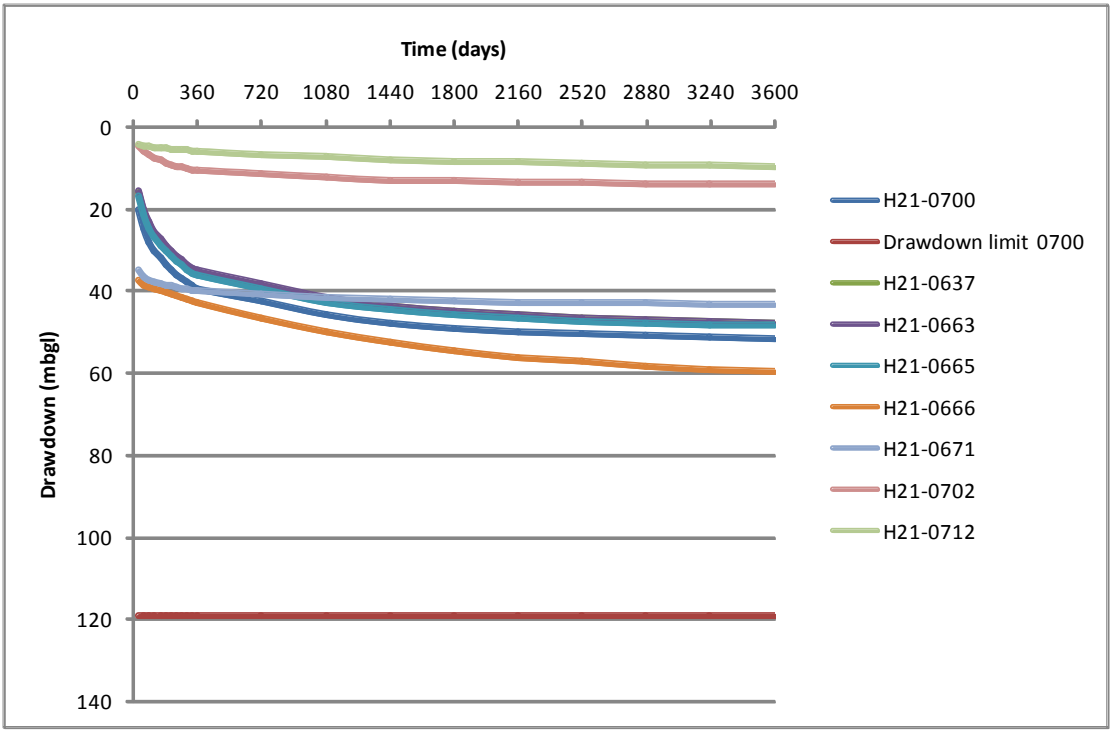


Figure 28: Groundwater level drawdown (mbgl) for current boreholes pumping

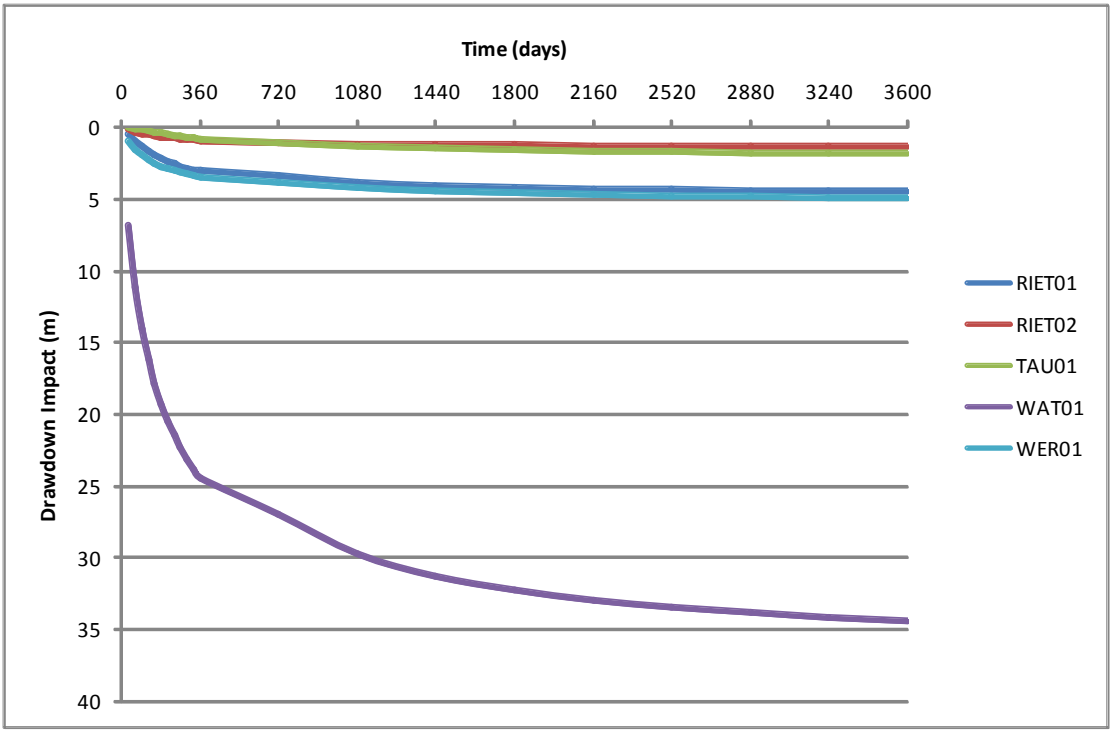


Figure 29: Water level drawdown (m) for users' boreholes

6.4.2.1 Impacts

The extent of the cone of depression is mainly in the 10 km radius area considered for well-field development for the first 2 years. At the end of 10 years the drawdown impact outside of this 10 km radius is limited and reaches 7.5 m close to the no-flow boundary in the northwest. The cone of depression reaches the river very early in the simulation and is buffered by inflows from the river to an extent.

The water level drawdown in none of the boreholes reaches the position of the drawdown limit. Most of the abstraction boreholes level off nearing steady state conditions in the aquifer.

Water level drawdown in the users' boreholes as a result of this abstraction is affected with most of the boreholes water levels impacted 1 – 5m. WAT01 however, is highly impacted and is to be expected since this borehole is in very close to the other high yielding boreholes of the potential well-field.

6.4.3 Scenario 3

In this scenario the boreholes in Scenario 2 was increased with boreholes at a recommended 2 km distance from one another and an average abstraction rate of 5L/s for the 10km radius around Lephalale in the high transmissive Eenzaamheid Fault Zone. This will test the deep aquifers' capability to augment the local water sources in and around the town of Lephalale.

The scenario was run for 10 years and the development of the drawdown cone over time is shown for year 1, 2 and 10 in Appendix J. Figure 30 and Figure 31 show the drawdown in the current abstraction boreholes and the impact on the surrounding water users that access the Waterberg aquifer.

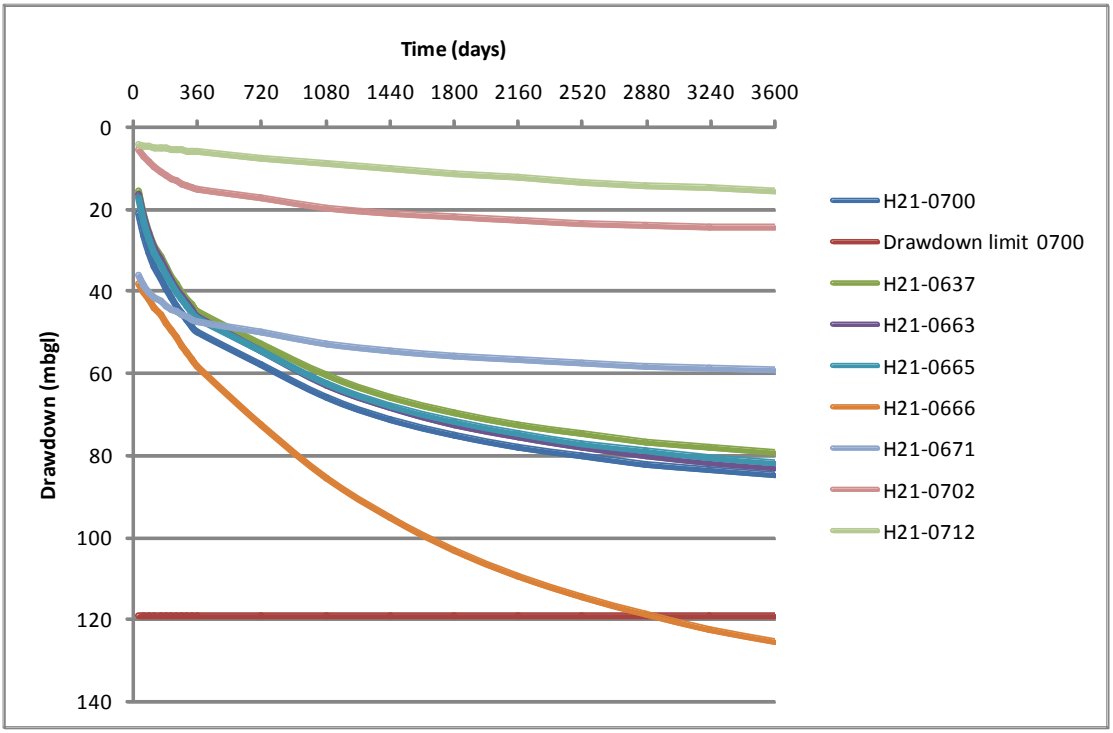


Figure 30: Groundwater level drawdown (mbgl) for current and future boreholes pumping

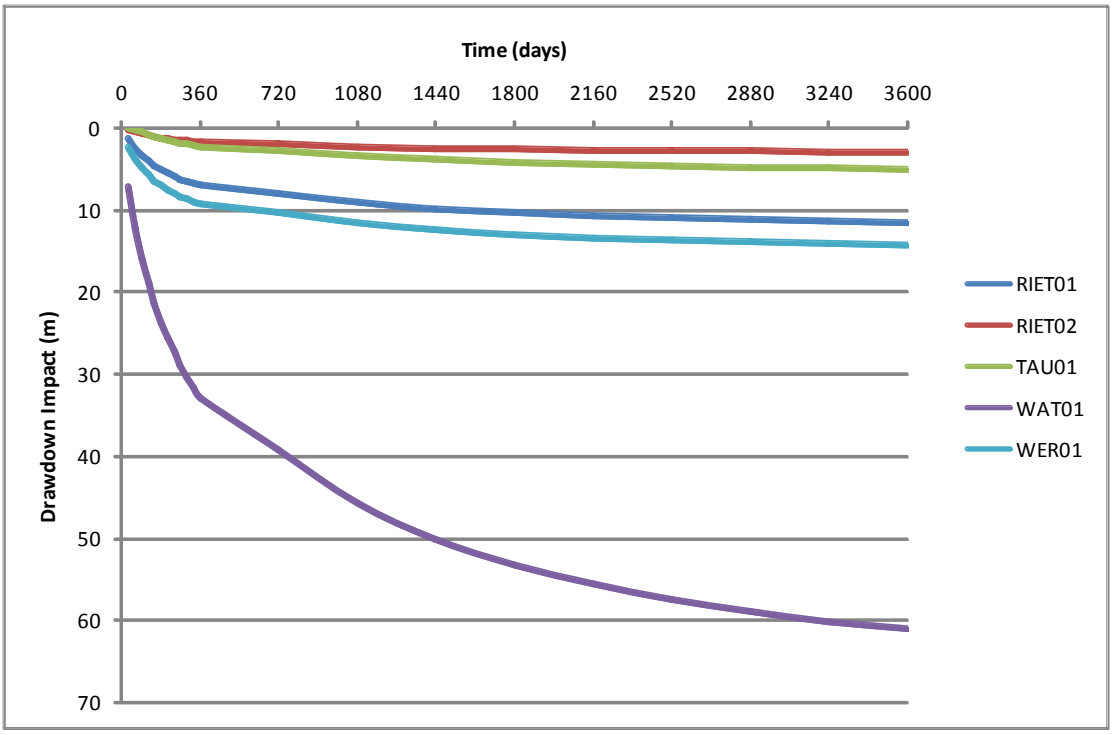


Figure 31: Water level drawdown (m) for users' boreholes

6.4.3.1 Impacts

The extent of the cone of depression exceeds the 10 km radius area considered for well-field development in the first year of the simulation. At the end of 10 years the drawdown impact outside of this 10 km radius is extensive and reaches more than 60 m close to the no-flow boundary in the northwest. The maximum drawdown reached in the aquifer surrounding the abstraction boreholes is 89m.

The cone of depression extends beyond the river in the first year of the simulation and is buffered by inflows from the river.

The water level drawdown in H21-0666 reaches the position of the drawdown limit after eight years and none of the boreholes are nearing steady state conditions e.g. water levels are still dropping and not levelling off.

Water level drawdown in the users' boreholes as a result of this abstraction is affected with most of the boreholes water levels impacted 2.5 – 15m. WAT01 however, is highly impacted and is to be expected since this borehole is in very close to the other high yielding boreholes of the potential well-field.

6.4.4 Scenario 4

In this scenario the boreholes in Scenario 3 was increased with boreholes at a 1 km distance from one another and an average abstraction rate of 5L/s for a 10km radius around Lephalale in the high transmissive zones. This scenario is in support of a short term (2 year maximum) use of storage from the aquifer for the augmentation of water for coal field developments until the pipelines are in place. However, the effect of this scenario is shown for 10 years to illustrate the non-sustainability thereof.

The scenario was run for 10 years and the development of the drawdown cone over time is shown for year 1, 2 and 10 in Appendix J. Figure 32 and Figure 33 show the drawdown in the current abstraction boreholes and the impact on the surrounding water users that access the Waterberg aquifer.

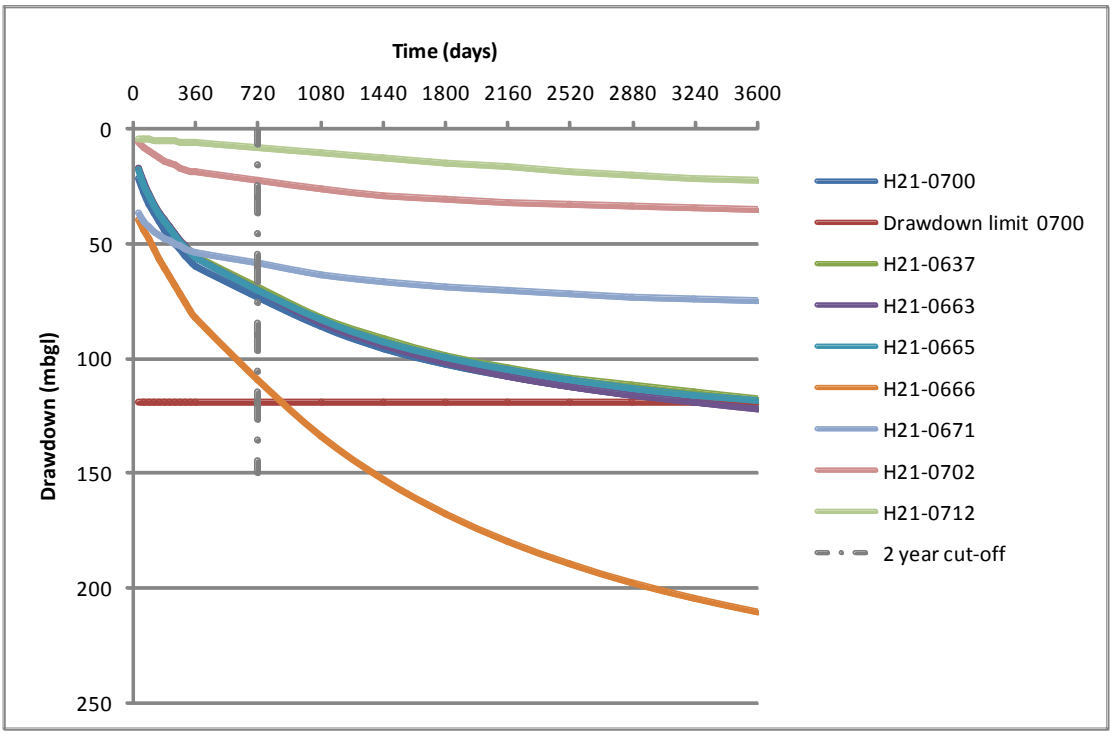


Figure 32: Groundwater level drawdown (mbgl) for current and future boreholes pumping (2 year high abstraction)

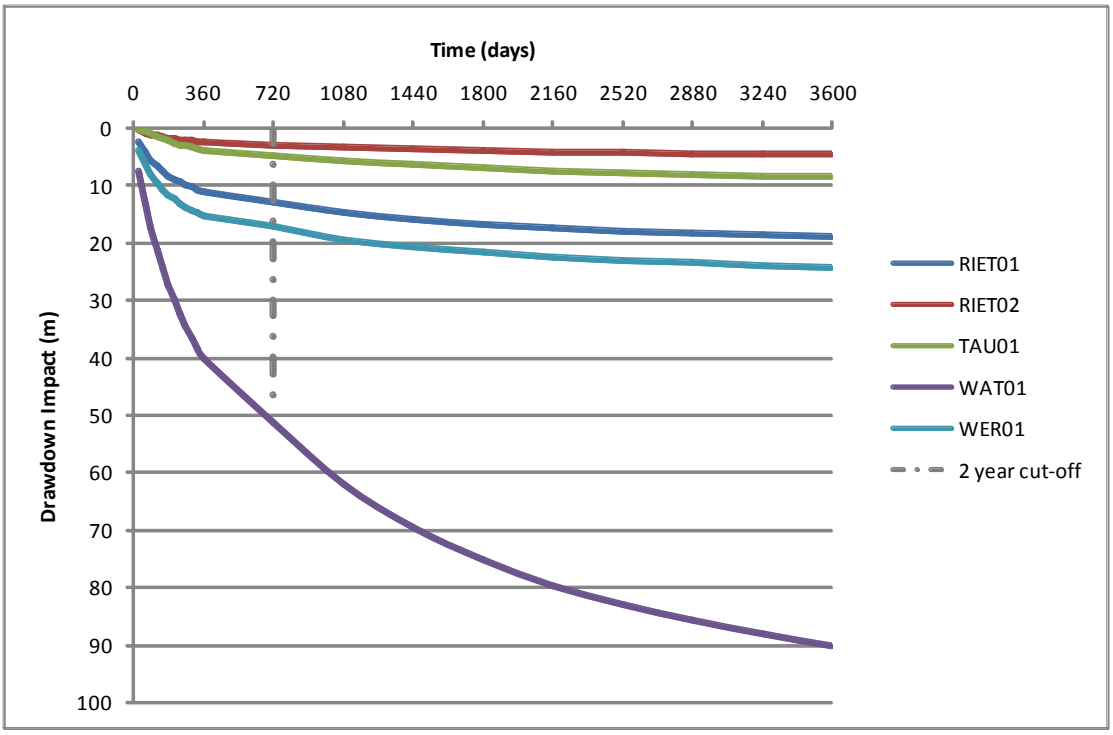


Figure 33: Water level drawdown (m) for users' boreholes

6.4.4.1 Impacts

The extent of the cone of depression exceeds the 10 km radius area considered for well-field development in the first year of the simulation. At the end of 2 years the drawdown impact outside of this 10 km radius is extensive and reaches approximately 50 m close to the no-flow boundary in the northwest. The maximum drawdown reached in the aquifer surrounding the abstraction boreholes is 77 m.

The cone of depression extends well beyond the river in the first year of the simulation and is buffered by inflows from the river.

The water level drawdown in H21-0666 nears the position of the drawdown limit at the end of 2 years. The boreholes are not nearing steady state conditions e.g. water levels are still dropping and not levelling off.

Water level drawdown in the users' boreholes at the end of 2 years is affected with most of the boreholes water levels impacted 3 – 18m. WAT01 however, is highly impacted and is to be expected since this borehole is in very close to the other high yielding boreholes of the potential well-field.

6.4.5 Scenario 5

In this scenario the boreholes in Scenario 4 was moved to a 10km radius around and west–southwest of Lephalale in the high transmissive zone west of the Mokolo river, see Plan 11 in Appendix A. This scenario is in support of a shortfall in supply at the end of 2012 (pumping for 2 year at high abstraction rates) and at the beginning of 2015 (pumping for 2 year at high abstraction rates).

Figure 34 and Figure 35 show the drawdown in the current abstraction boreholes and the impact on the surrounding water users that access the Waterberg aquifer. The scenario was (1) first run for 2 years with a rest period of 2.5 years to observe the expected recovery of the system and thereafter, (2) the abstraction rates of H21-0666 were lowered to 2 l/s and four "future" boreholes adjacent to this borehole were halved (to 2.5 l/s) to reduce the drawdown in this area during the final scenario simulation. The development of the drawdown cone over time is shown for the end of year 2, year 2.5 (after the 6 month rest period) and year 4.5 (at the end of the stress period) in Appendix J.

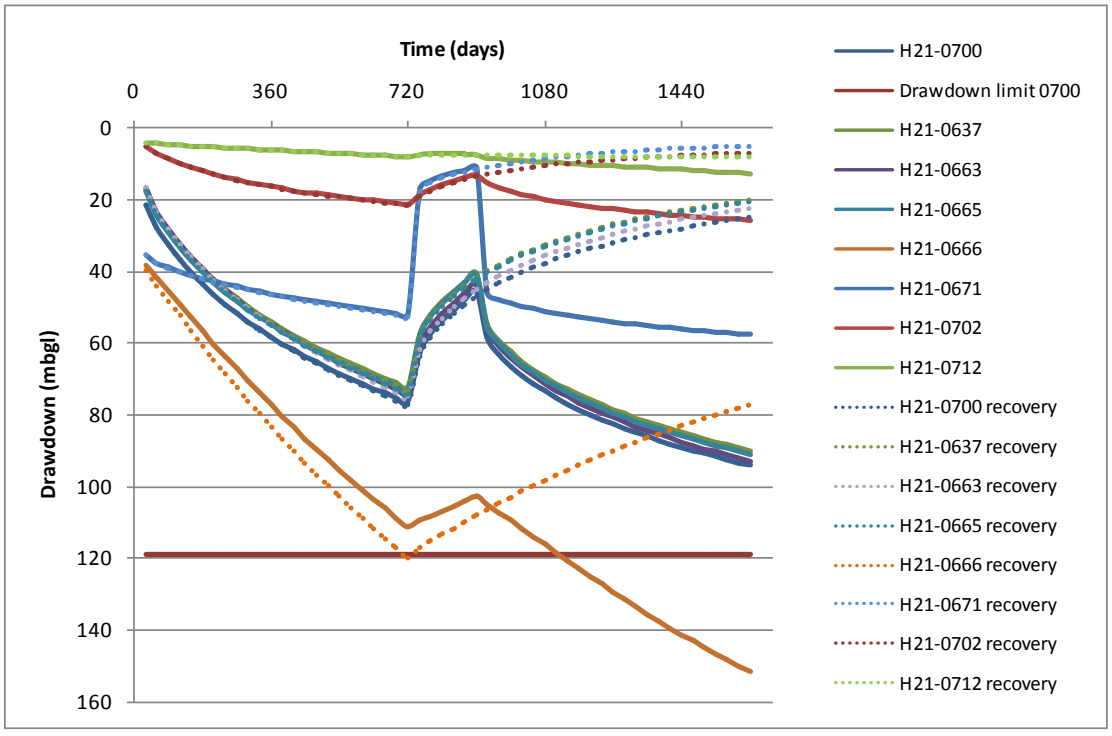


Figure 34: Groundwater level drawdown (mbgl) for current and future boreholes pumping (2 year high abstraction, 6 month resting period, 2 year high abstraction)

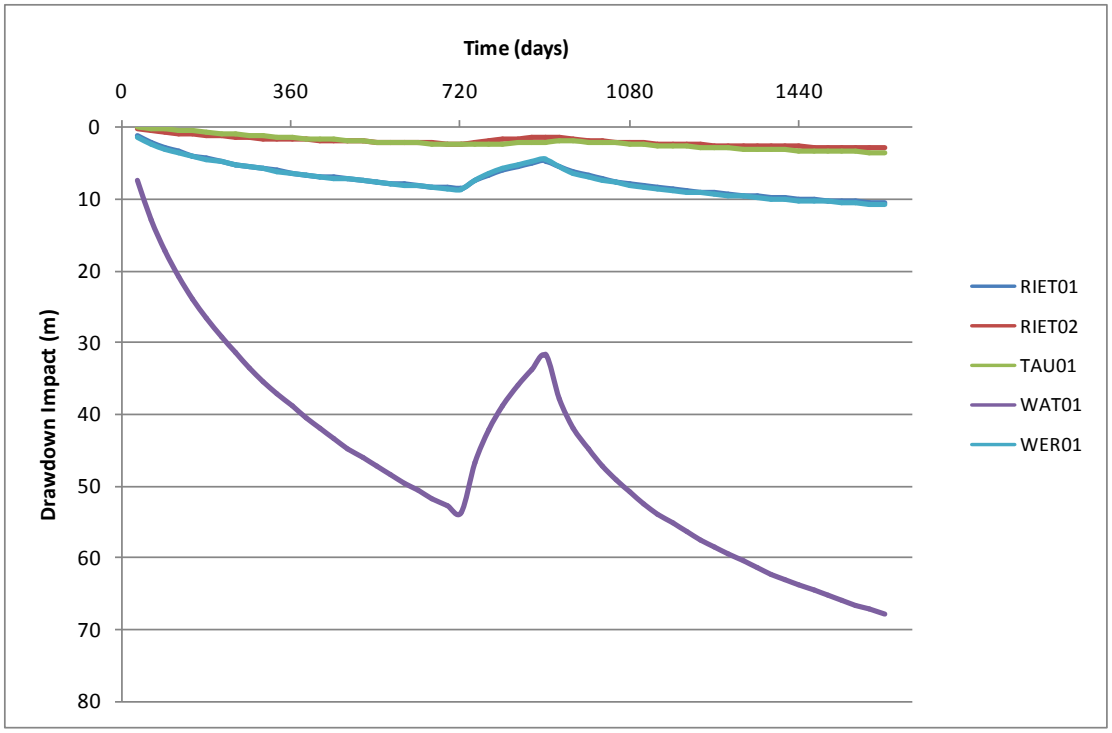


Figure 35: Water level drawdown (m) for users' boreholes

6.4.5.1 Impacts

The extent of the cone of depression exceeds the 10 km radius area considered for well-field development in the first year of the simulation, similar to Scenario 4. Although the cone of depression also extends beyond the river in the first year of the simulation, it is much less pronounced than in Scenario 4 and is also buffered by inflows from the river.

After the first 2 years high abstraction the drawdown impact outside of the 10 km radius is extensive and reaches approximately 30 m close to the no-flow boundary in the northwest. The maximum drawdown reached in the aquifer surrounding the abstraction boreholes is 81 m. After the 6 month recovery period the maximum drawdown impact is reduced to only 61 m, although the extent of the cone of depression stays the same. At the end of 4.5 years the drawdown impact reaches approximately 50 m close to the no-flow boundary in the northwest and the maximum drawdown is 120 m. The aquifer

Even though abstraction rates have been lowered for H21-0666 and surrounding boreholes, the water level drawdown in H21-0666 nears the position of the drawdown

limit in the 3rd year of the simulation. It is likely that this abstraction rate is not sustainable for the entire shortfall period, unless water can be recharged at a higher rate to account for the loss in storage as a result of the first 2 years high abstraction. The current abstraction boreholes are not nearing steady state conditions.

The water level drawdown in Scenario 5 is much less pronounced than in Scenario 4 for the water users' boreholes. This is mainly due to the buffering effect of the river since no abstraction boreholes are located east of the river, where most of the users' boreholes are situated. The boreholes water levels are impacted 3 – 10m at the end of the 4.5 years. WAT01 however, is highly impacted and is to be expected since this borehole is in very close to the other high yielding boreholes of the potential well-field.

6.4.6 Comparison

Table 11 below shows the water balance information for the abstraction boreholes from the various scenarios, as well as the expected Fluoride (F) value as a result of the blended groundwater from the different boreholes.

Table 11: Water balance and expected F (mg/l) values for different scenarios

Drill Site ID	Scenario 1 (m^3/d)	Scenario 2 (m^3/d)	Scenario 3 (m^3/d)	Scenario 4 (m^3/d)	Scenario 5 (m^3/d)
H21-0637		345.6	345.6	345.6	345.6
H21-0638					
H21-0663		259.2	259.2	259.2	259.2
H21-0665		1209.6	1209.6	1209.6	1209.6
H21-0700	777.6	777.6	777.6	777.6	777.6
H21-0666		259.2	259.2	259.2	172.8
H21-0712		172.8	172.8	172.8	172.8
H21-0671		777.6	777.6	777.6	777.6
H21-0702		172.8	172.8	172.8	172.8
Undeveloped			8208	17280	16416
F (blended)	11 mg/l	9 mg/l	9 mg/l	9 mg/l	9 mg/l/
TOTAL VOL (m^3/d)	**778**	**3974**	**12182**	**21254**	**20304**
TOTAL VOL (Mm^3/a)	**0.28**	**1.43**	**4.39**	**7.65**	**7.31**

Table 12 shows the expected inflow from the Mokolo river, if a direct connection exist south of the Eenzaamheid Fault Structure and the river stays at a constant head. If surface flow in the river is reduced, it will result in a reduction of inflow from the river to the groundwater system.

These flow values are approximations at best since the alluvial aquifer was not included in the modelling and no calibration could be done on the interaction between the alluvial and deep aquifers. However, these flow values are expected to be worst case scenarios since a direct interaction was assumed.

Table 12: Mokolo river contribution to groundwater abstraction for different scenarios

	Scenario 1 (m^3/d)	**Scenario 2 (m^3/d)**	**Scenario 3 (m^3/d)**	**Scenario 4 (m^3/d)**	**Scenario 5 (m^3/d)**
Evaluation time	10a	10a	10a	2a	4.5a
Volume of inflow from river (m^3/d)	456	2298	4952	4495	4863
% of groundwater abstraction from Mokolo river	59	58	41	21	24

It is clear that when developing the groundwater system at Lephalale some inflow from the Mokolo River can be expected and the resultant impact on alluvial groundwater users will be a reduction in flow in the river if it cannot be supplemented by upstream releases. However, Scenarios 4 and 5 yields the best impact-to-benefit ratio, when comparing the volume gained from the groundwater system to the expected impact on the Mokolo River.

7 CONCLUSIONS

The following conclusions are based on the groundwater exploration, testing and numerical modelling of the Waterberg and alluvial aquifers at Lephalale:

- Higher yields were drilled than initially expected from background data.
- Test data indicate a confined and semi-confined deep aquifer linked with fracturing, horizontal bedding plains and alluvial deposits associated with the Waterberg Group.
- The Waterberg aquifer can support the augmentation scheme of 3 Mm^3/a and the information shows that:
    - Three exploration boreholes can be drilled and one may result in a production borehole of 6 L/s on average;
    - 7 production boreholes can supply 1 Mm^3/a;
    - The current exploration boreholes can access 1.4 Mm^3/a groundwater from the Waterberg aquifer.
    - The augmentation of an additional 1.6 Mm^3/a requires 12 production and at least 36 exploration boreholes;
    - Each production borehole should be placed at least 2 km apart; the ideal situation requiring an area of at least 100 km^2 well-field;
    - Water quality constraints include high concentrations of NaCl and F – no treatment is required for industrial use; however, treatment or blending is required for domestic use; and
    - The alluvial groundwater users north of the Eenzaamheid Fault will be impacted upon by abstraction from the Waterberg with reduction in surface water flow, if this reduction cannot be supplemented by upstream releases from storage.
    - Continuous development of this aquifer, combined with artificial recharge can increase the capacity further, since artificial recharge can restore groundwater levels and thereby reduce impacts to the river system.

- The evaluation done on the alluvial aquifer was not sufficient since only three boreholes were drilled dedicated to the alluvium.
- The alluvial aquifer potentially shows 31 Mm^3 of water in storage and accessing this resource can increase the yield of the system greatly. For every 1 m drop allowed in the alluvial aquifer 3.8 Mm^3 of water can be released.
- Artificial recharge looks promising from the aquifer properties, but all the aquifers at Lephalale should be developed and storage created by abstraction from them for any AR scheme to become useful.

8 RECOMMENDATIONS

The following recommendations are based on the groundwater exploration, testing and numerical modelling of the Waterberg and alluvial aquifers at Lephalale:

- Lephalale Local Municipality can start abstracting from borehole H21-0700 at 9 L/s (23 000 m^3/m) for a 24 hour pumping schedule or 16 L/s (14 000 m^3/m) for an 8 hour pumping schedule.
- Water quality constraints for this borehole include very high Fluoride and only elevated levels of Sodium-Chloride.
- The exploration boreholes, with the exception of H21-0638, listed in Table 9 can be used as production boreholes for the given yields.
- Groundwater monitoring should continue for both the data loggers and water quality to determine changes induces by the abstraction of the newly drilled exploration boreholes.
- Groundwater resource development (drilling and testing) of Scenario 3 will take approximately 9 months to complete.
- Groundwater resource development (drilling and testing) of Scenario 4 or 5 (Scenario 3 not developed) will take 9 – 18 months to complete, depending on availability of contractors.
- Artificial recharge options should be evaluated for implementation and subsequent optimisation of the water use at Lephalale.

9 REFERENCES

Botha, F.S. (2006). Desktop hydrogeology assessment and aquifer recharge potential at Lephalale Local Municipality. Unpublished report by DWAF.

Johnson, M.R., Anhauesser, C.R. and Thomas, R.J. (2006). The Geology of South Africa. Geological Society of South Africa, Johannesburg, and the Council for Geoscience, Pretoria.

Murray, R., Tredoux, G., Ravenscroft, P and Botha, F. (2007). Artificial Recharge Strategy: Version 1.3. The Department of Water Affairs and Forestry, Pretoria.

Titus, R. & Rossouw, T. (2008). Groundwater reserve determination study for Mokolo (A42) catchment. Water Geosciences Consulting, Pretoria.

WSM. (1999). Alluvial aquifer characterisation for the Limpopo hydrological model. WSM Civil Engineers, Polokwane.

Appendix A: Lephalale Project Maps

Plan 1 – Locality map

Plan 2 – Hydrogeology with hydrocensus boreholes and geological structures.

Plan 3 – Astersat image showing possible dykes (green), faults and contacts in red. Also show positions on geophysical profiles and drilled targets with target ID lables.

Plan 4 – Topo-cadastral background with exploration boreholes and hydrocensus boreholes close to town.

Plan 5 – Water level elevation contours showing exploration borehole water level elevations.

Plan 6: Aquifer units based on geology, structural controls and water levels.

Plan 7: Monitoring network at Lephalale – water quality and water levels.

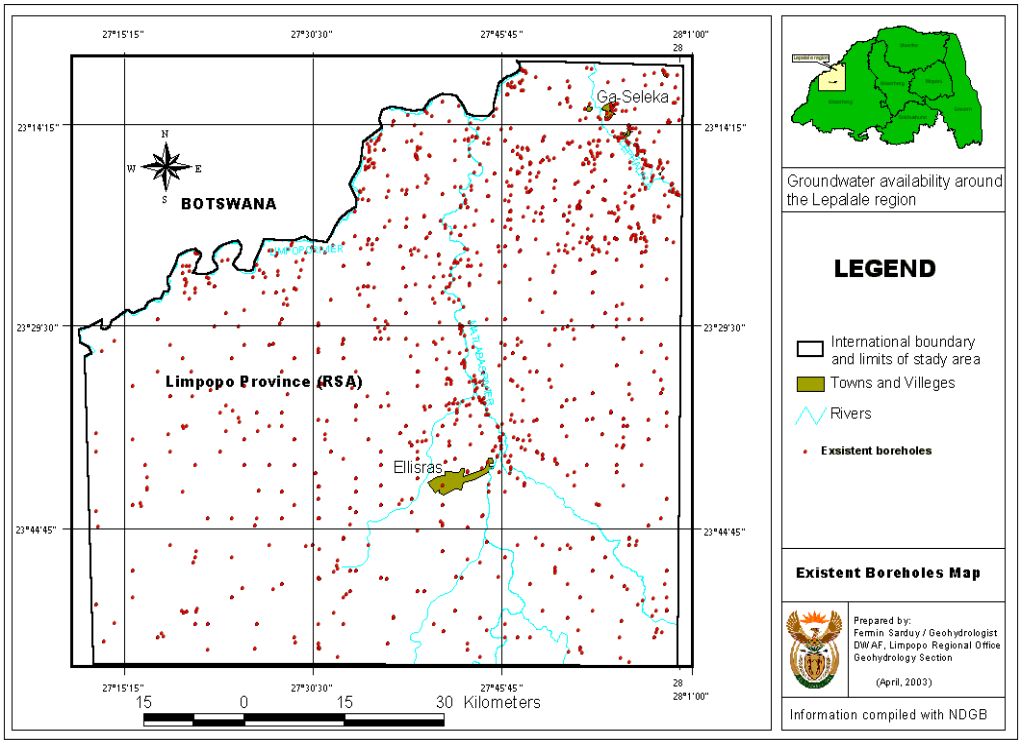
Plan 8: Fluoride (mg/l) distribution at Lephalale.

Plan 9: Electrical Conductivity (mg/l) distribution at Lephalale.

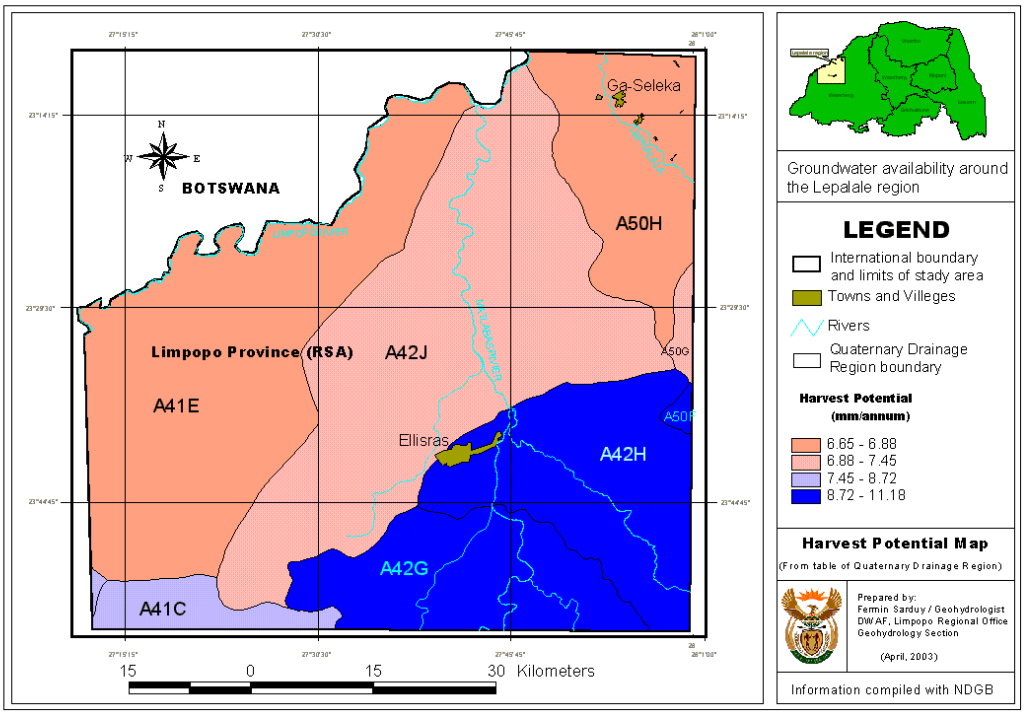
Plan 10 – Lephalale Groundwater Model – numerical model boundary, abstraction and observation boreholes for Scenarios 1 – 4 on the hydrogeology background.

Plan 11 – Lephalale Groundwater Model: Scenario 5.

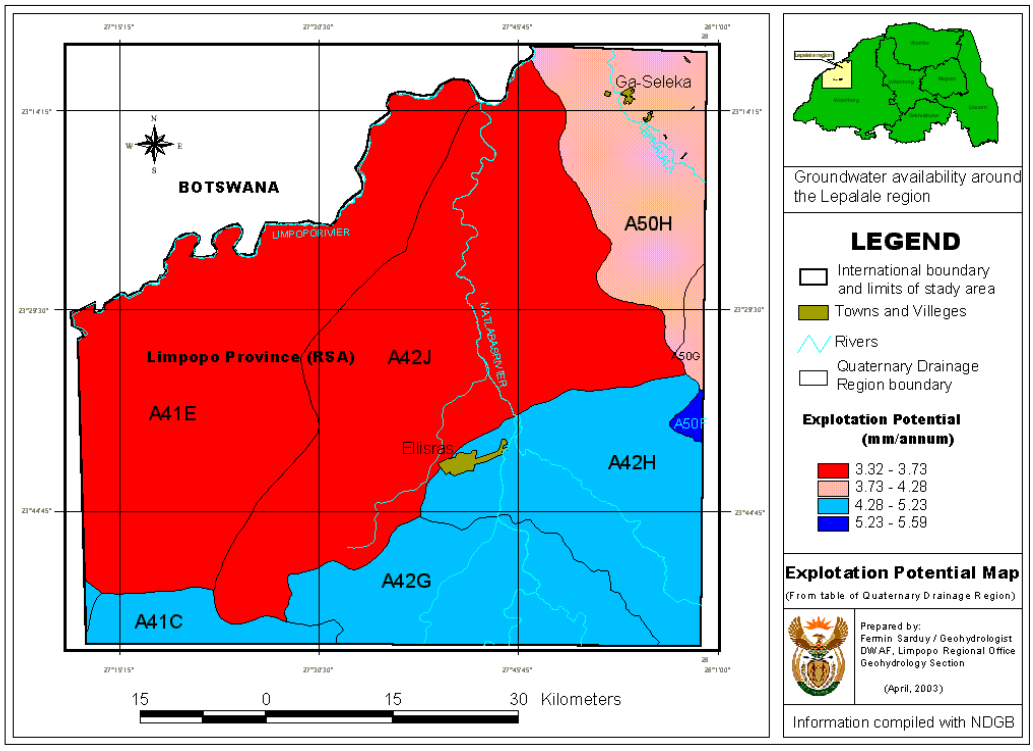
Appendix B: Desktop Study Maps



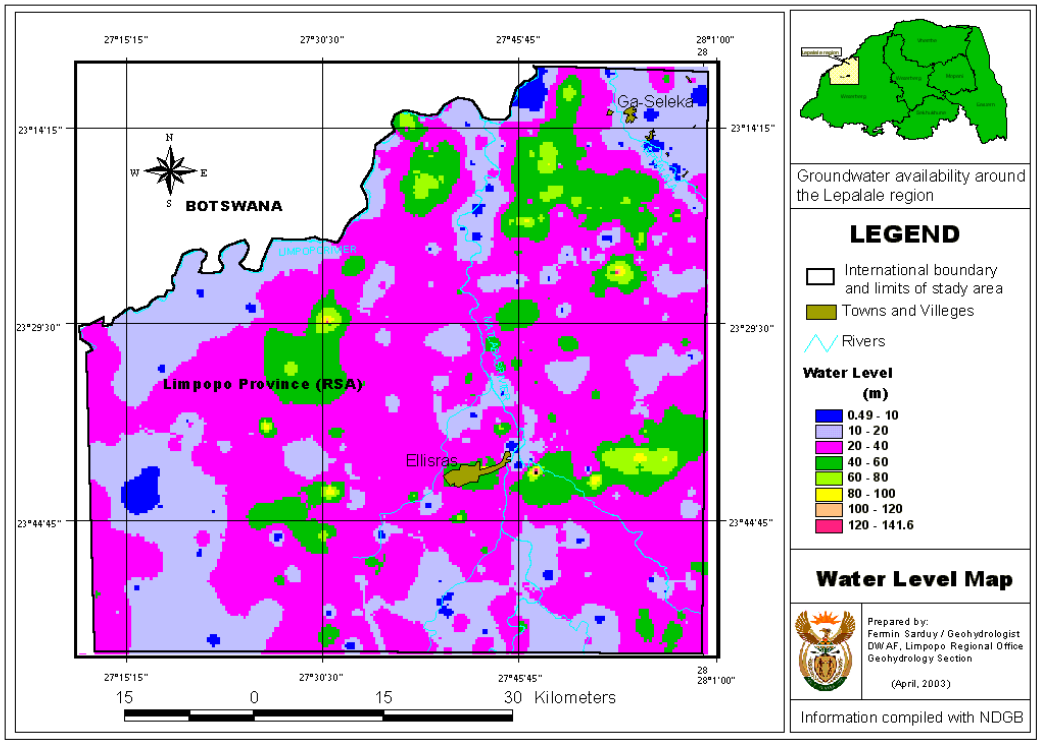
MAP 1.1: Existing data on the NGDB



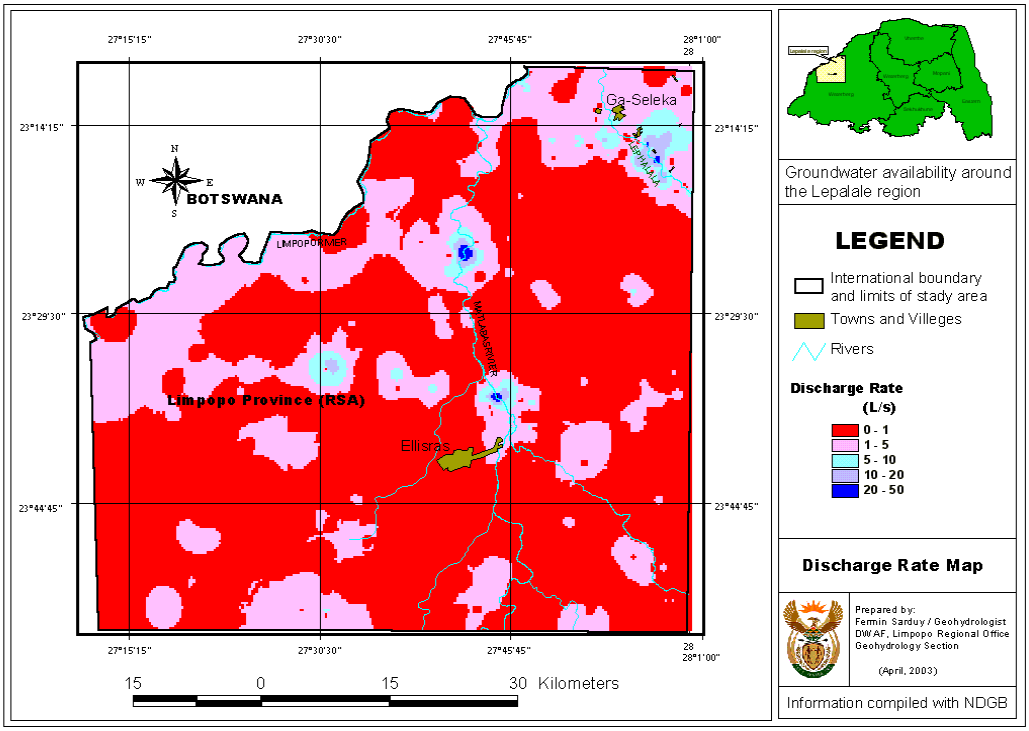
MAP 1.2: Harvest Potential



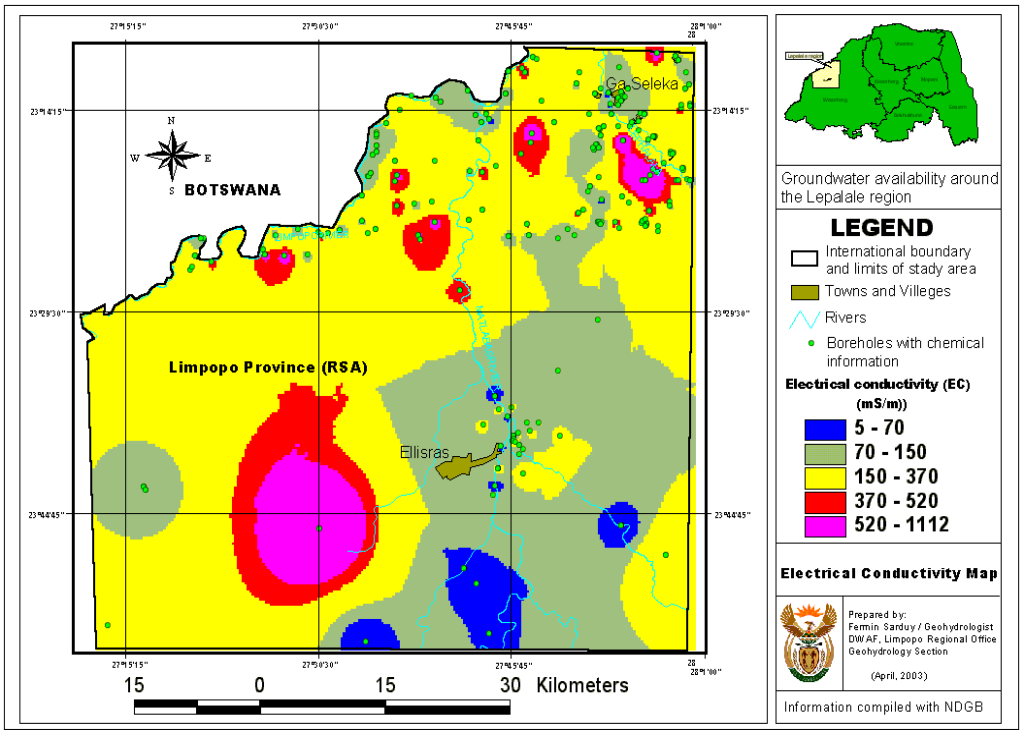
MAP 1.3: Exploitation Potential



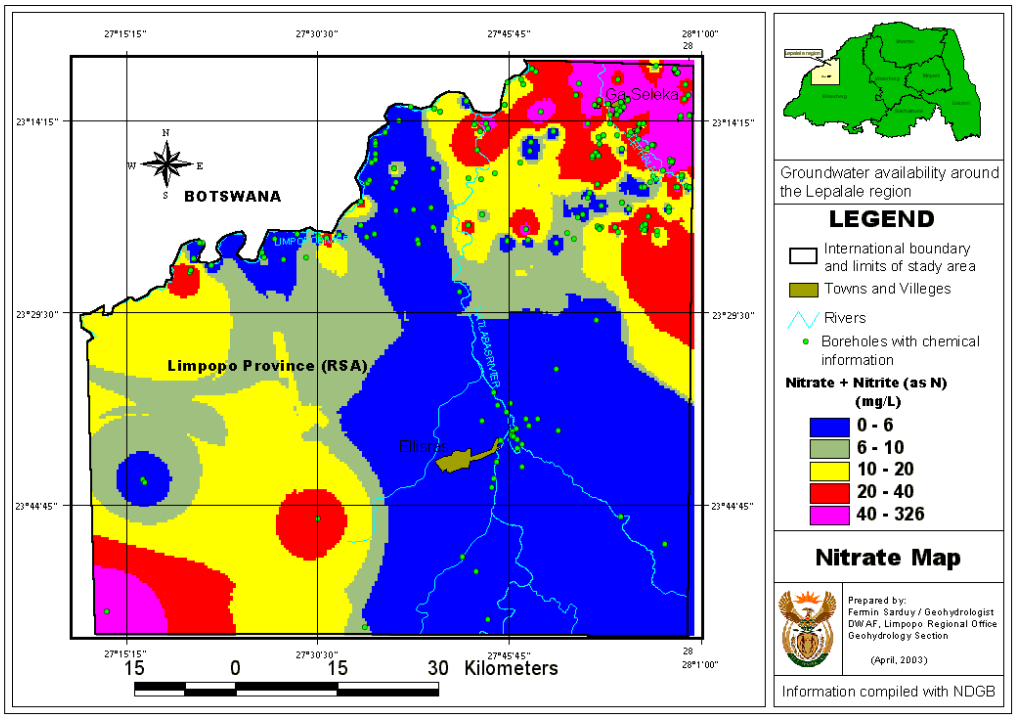
MAP 1.4: Water levels (mbgl)



MAP 1.5: Discharge rates

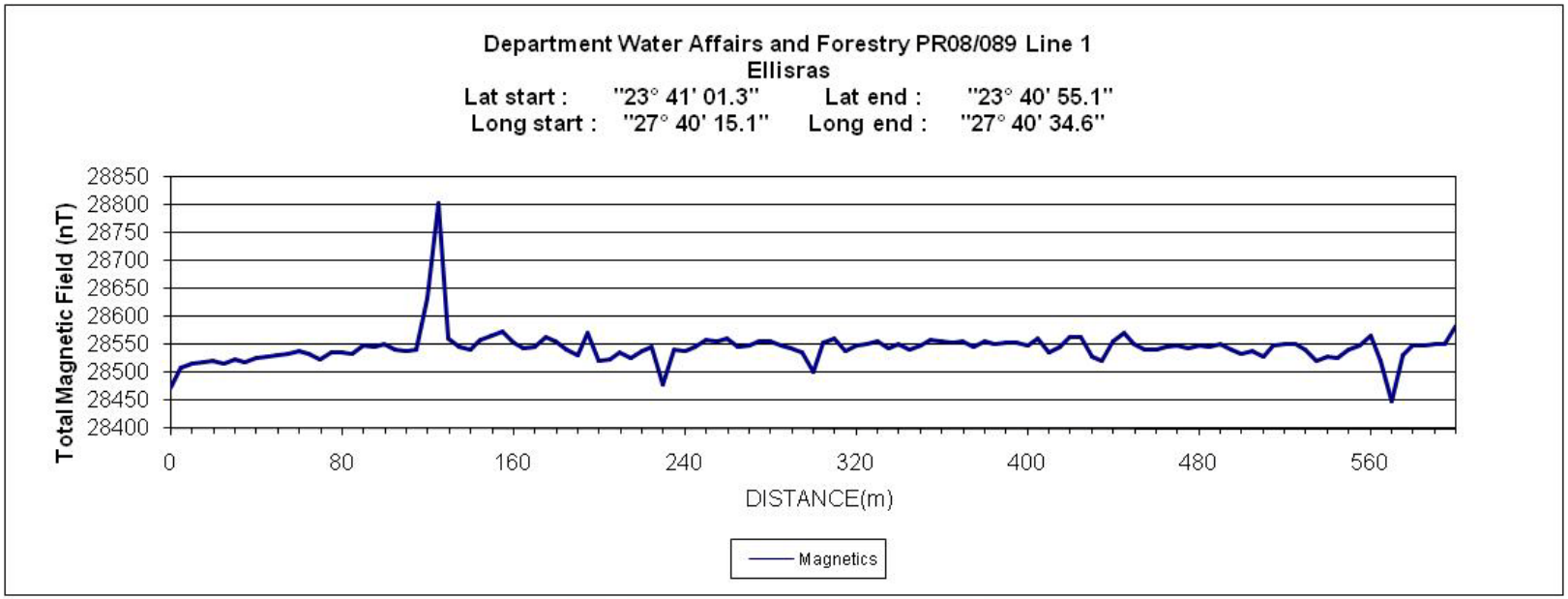


MAP 1.6: Electrical conductivity

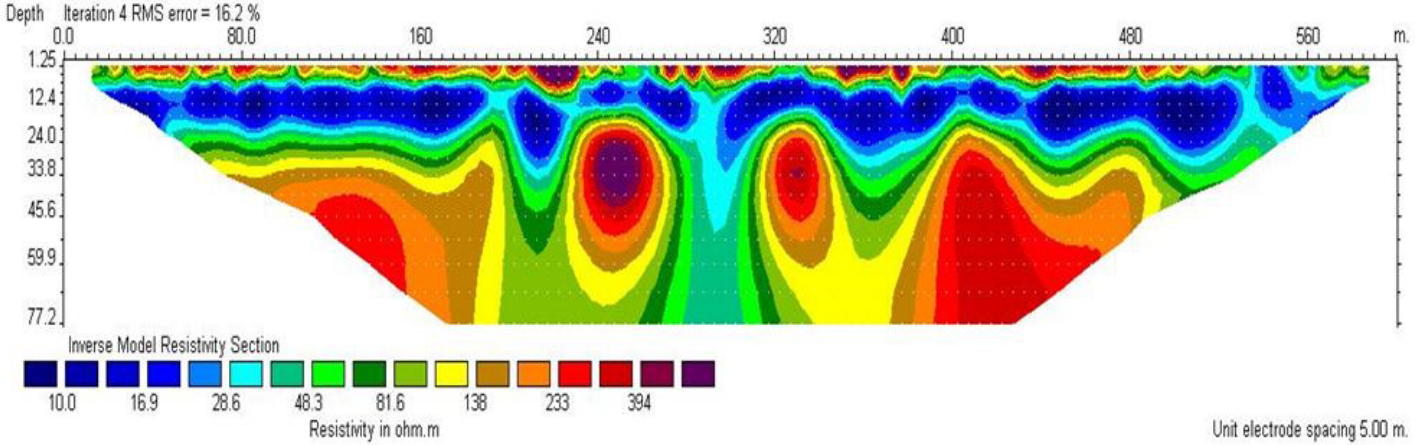


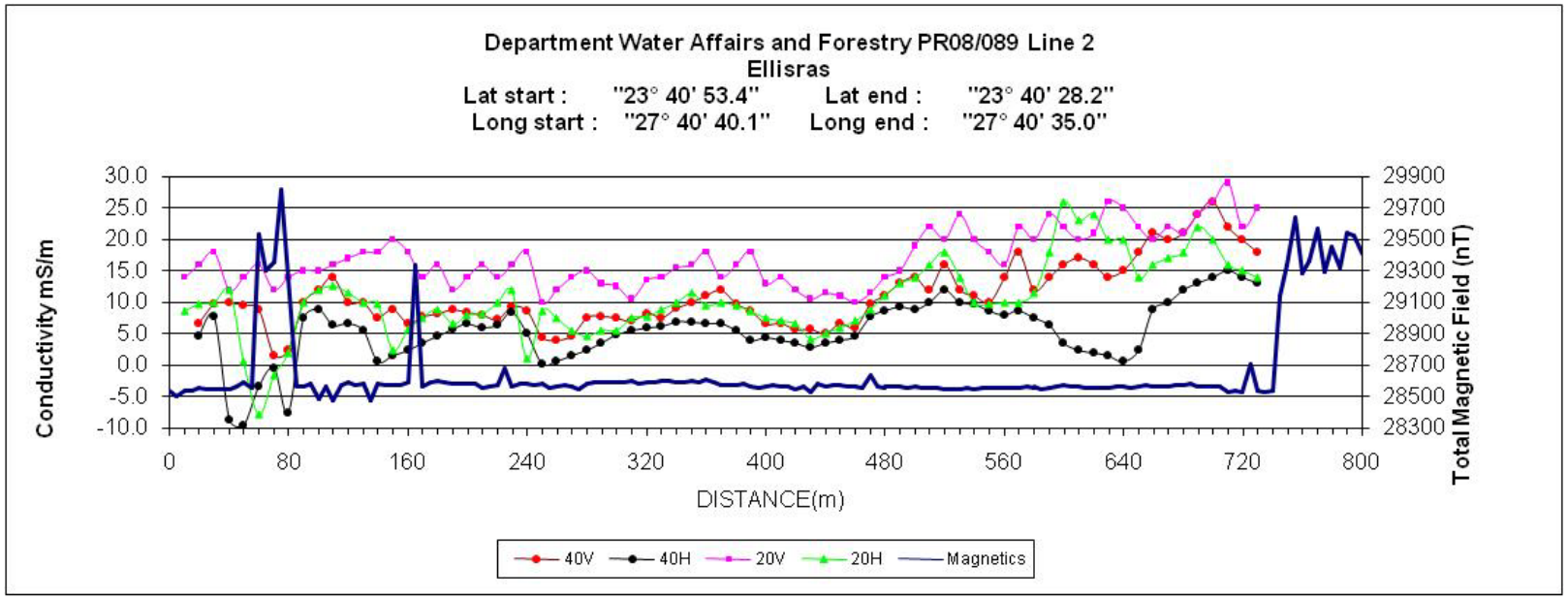
MAP 1.7: Nitrate occurrence

Appendix C: Geophysical Profiles

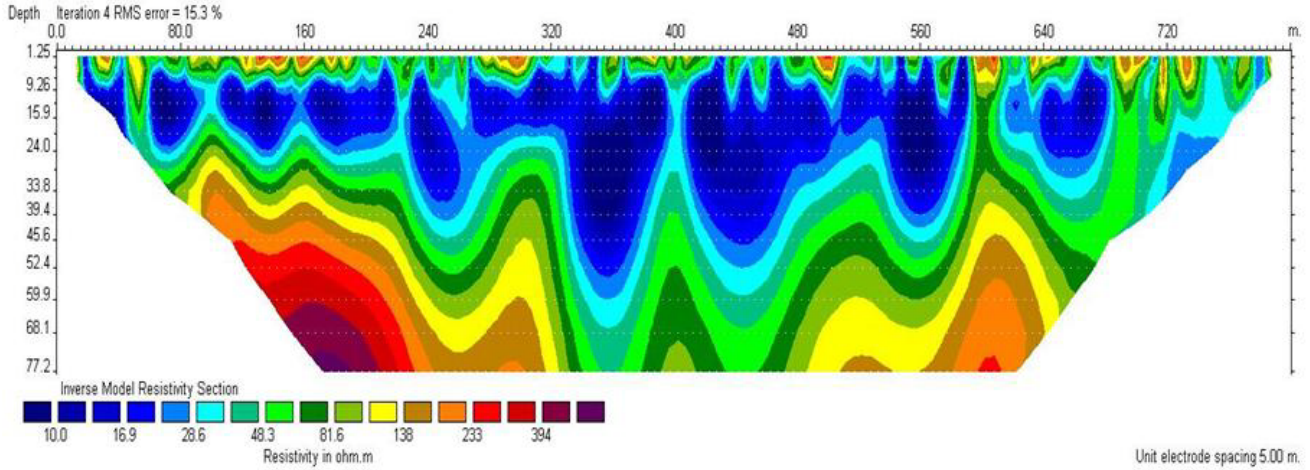


Resistivity imaging section Eras-1, Ellisras. April 2008.

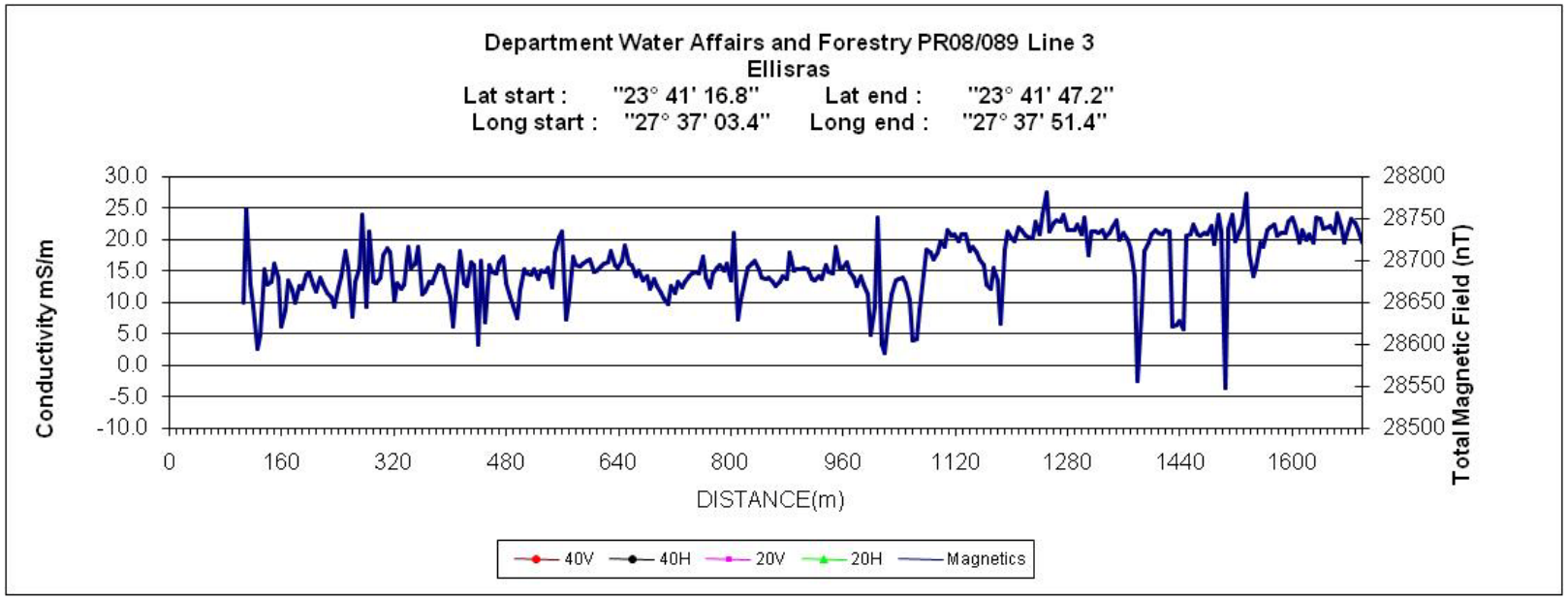




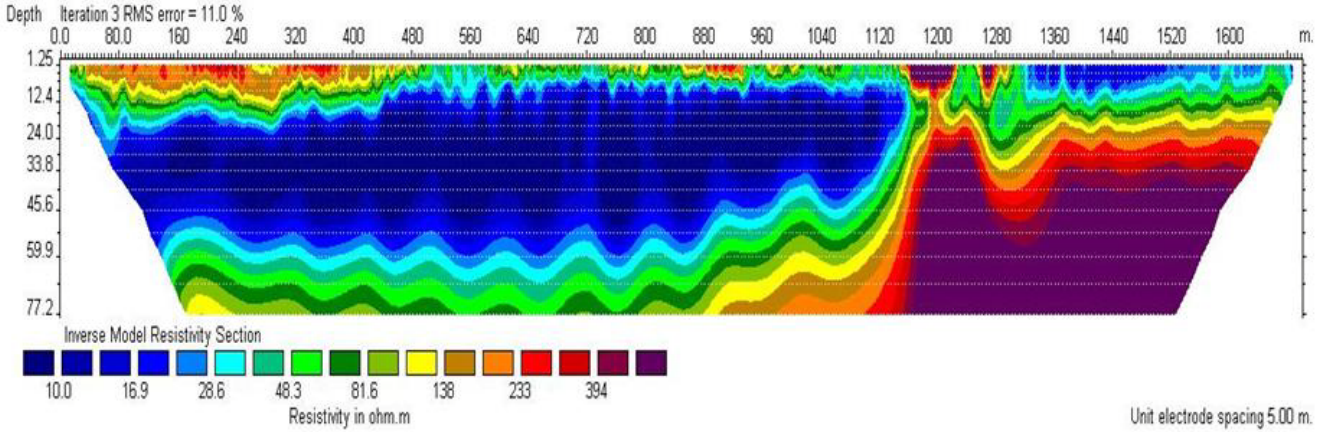
Resistivity imaging section Eras-2, Ellisras. April 2008.

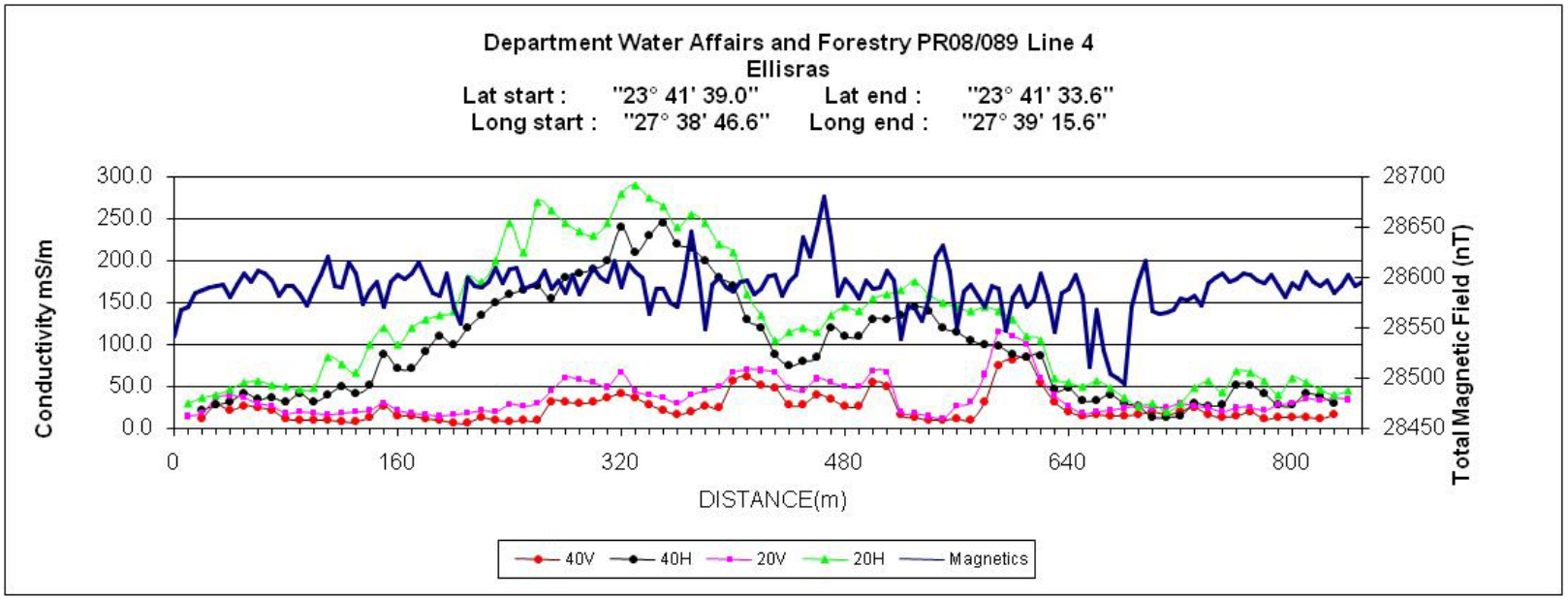


0 = 23 40'53.4"/ 27 40'40.2"
800 = 23 40'28.3" / 27 40'35.1"

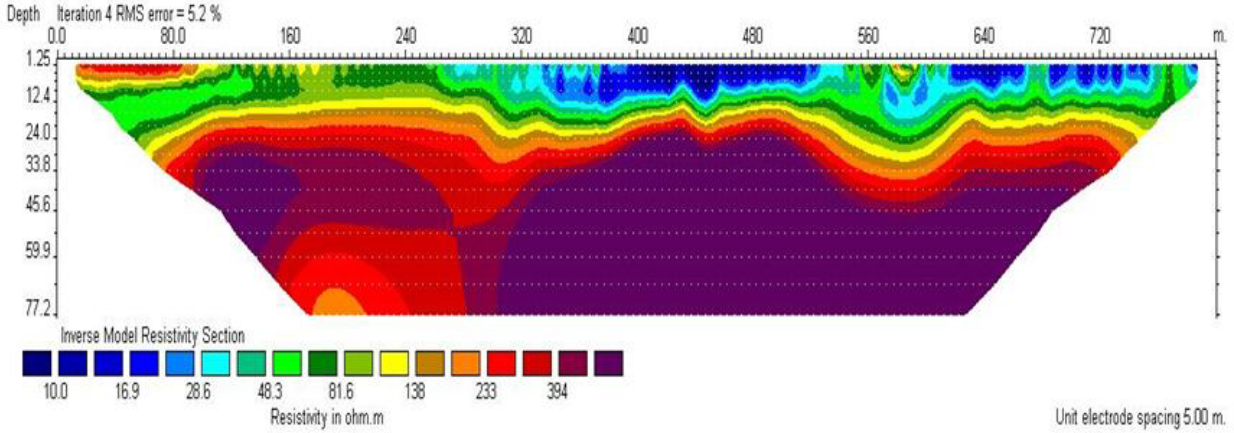


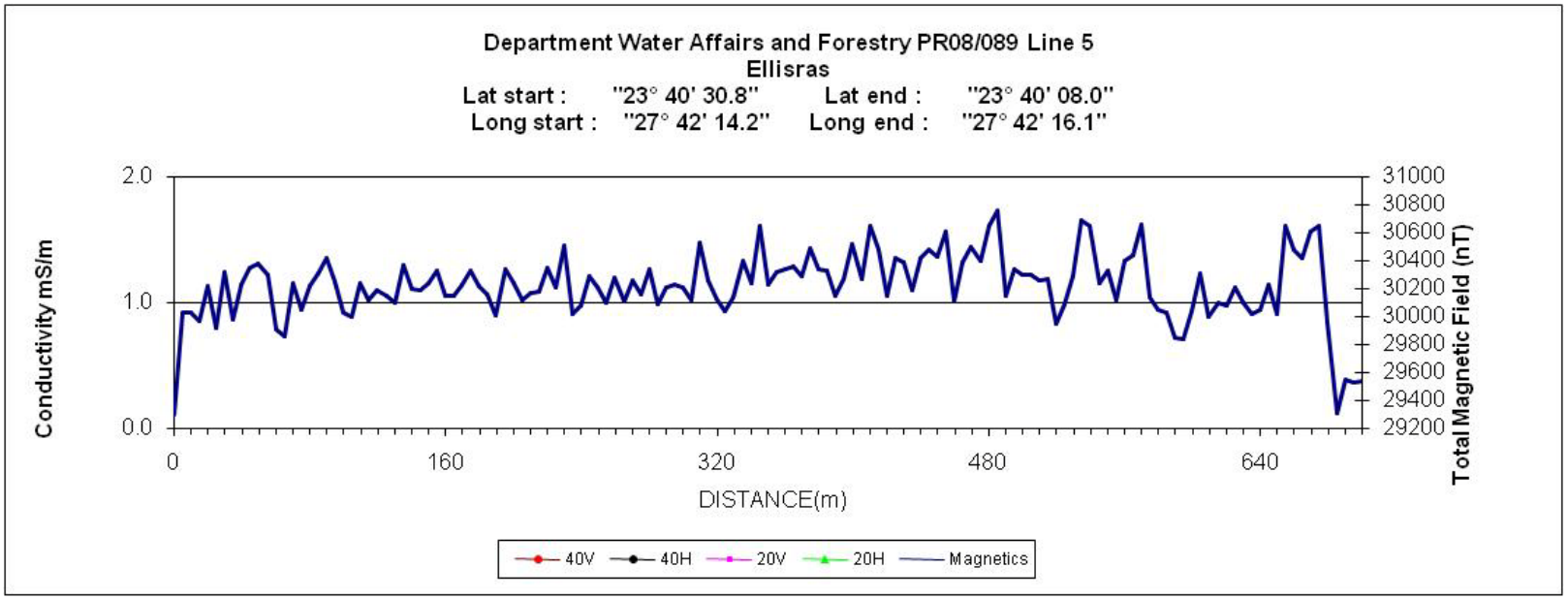
Resistivity imaging section Eras-3, Ellisras. April 2008.

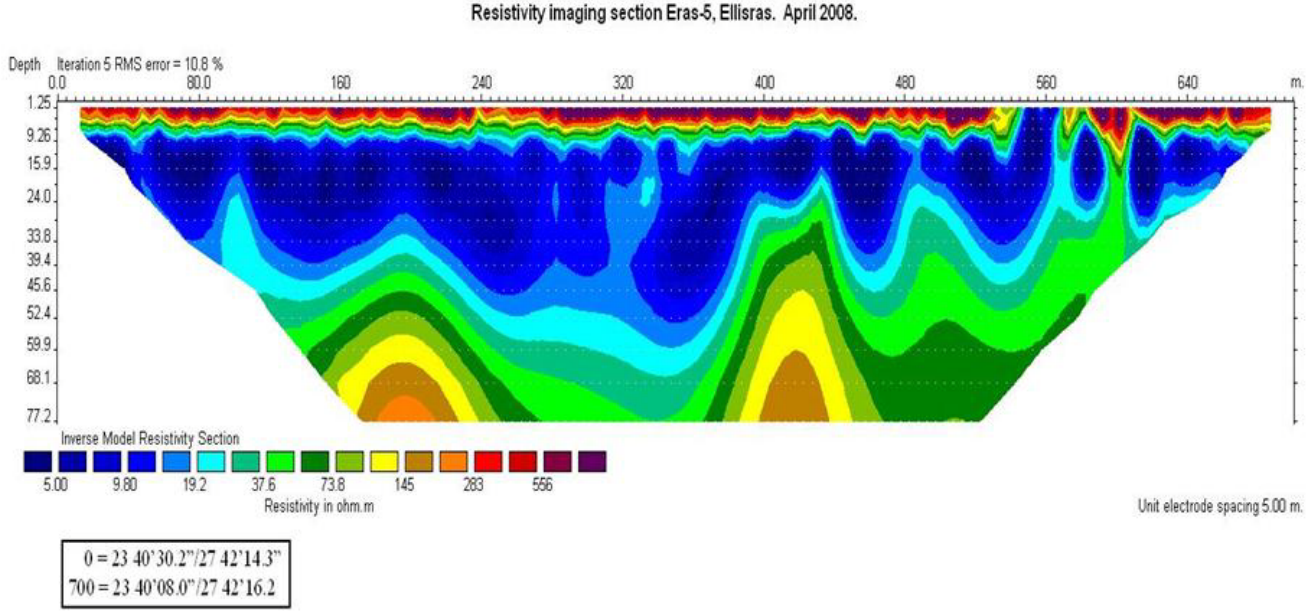


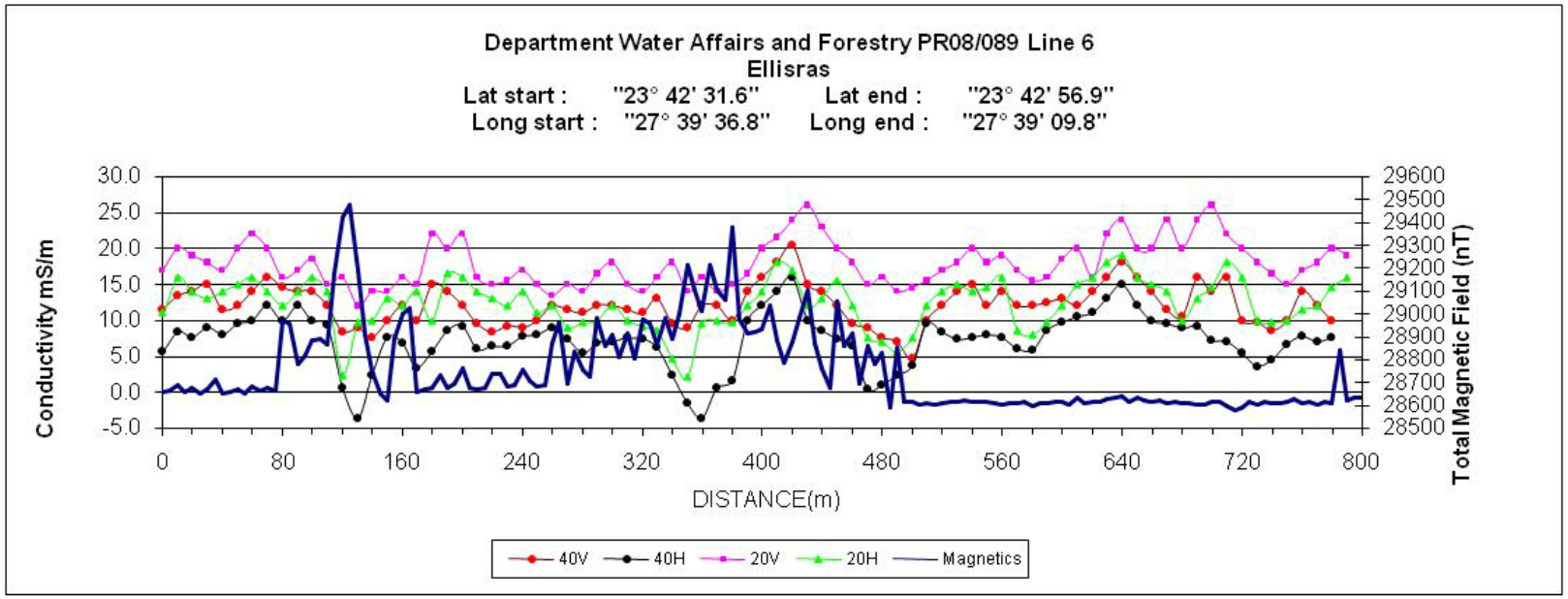


Resistivity imaging section Eras-4, Ellisras. April 2008.

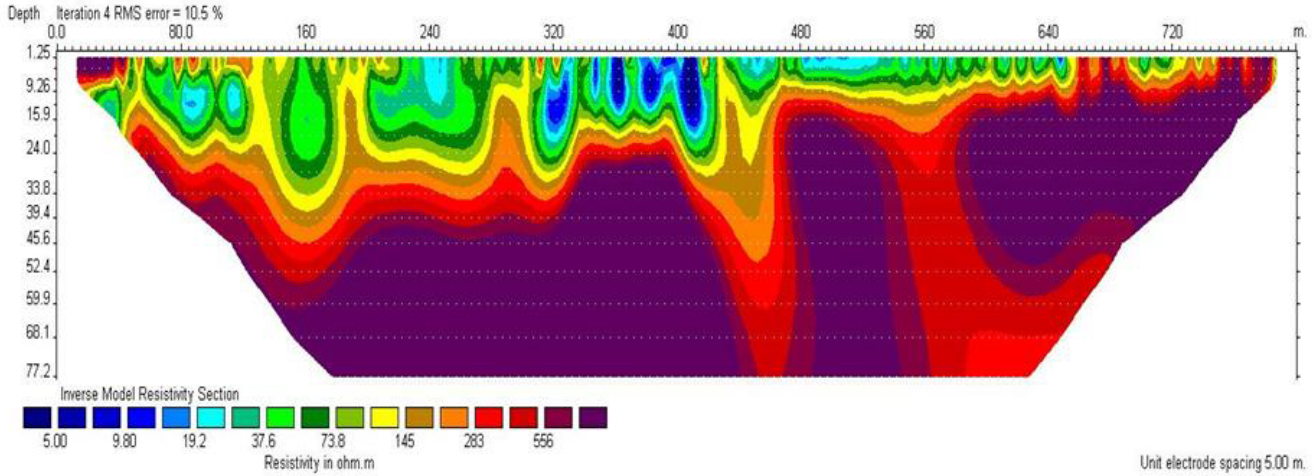



Department Water Affairs and Forestry PR08/089 Line 5
Ellisras
Lat start : "23° 40' 30.8" Lat end : "23° 40' 08.0"
Long start : "27° 42' 14.2" Long end : "27° 42' 16.1"
Conductivity mS/m
2.0
1.0
0.0
0
160
320
480
640
DISTANCE(m)
31000
30800
30600
30400
30200
30000
29800
29600
29400
29200
Total Magnetic Field (nT)
40V
40H
20V
20H
Magnetics

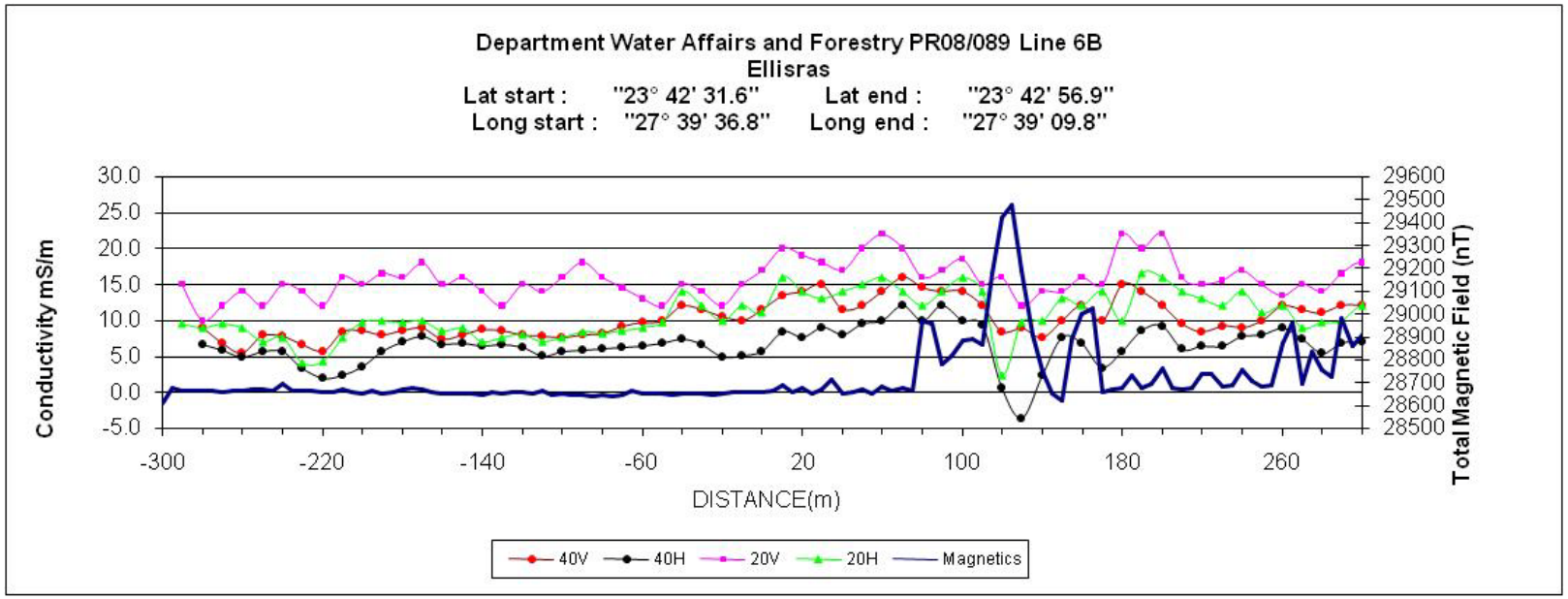

Resistivity imaging section Eras-5, Ellisras. April 2008.
Depth
Iteration 5 RMS error = 10.8 %
0.0
80.0
160
240
320
400
480
560
640
m.
1.25
9.26
15.9
24.0
33.8
39.4
45.6
52.4
59.9
68.1
77.2
Inverse Model Resistivity Section
5.00
9.80
19.2
37.6
73.8
145
283
556
Resistivity in ohm.m
Unit electrode spacing 5.00 m.
0 = 23 40'30.2"/27 42'14.3"
700 = 23 40'08.0"/27 42'16.2



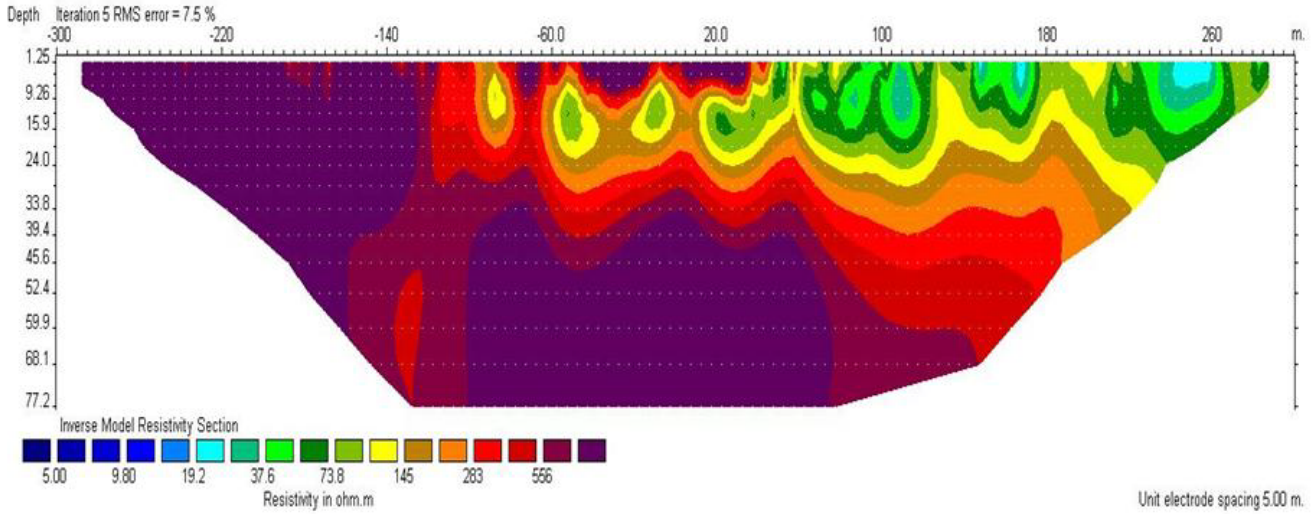
Resistivity imaging section Eras-6, Ellisras. April 2008.

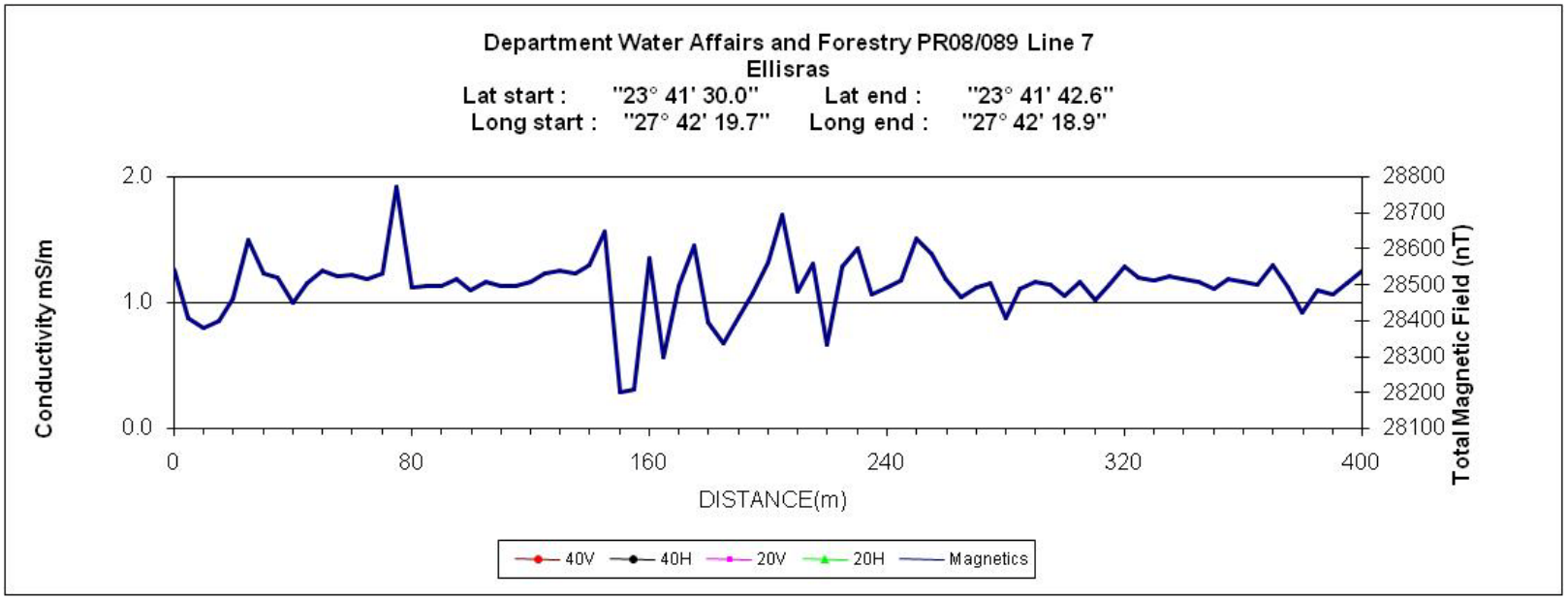


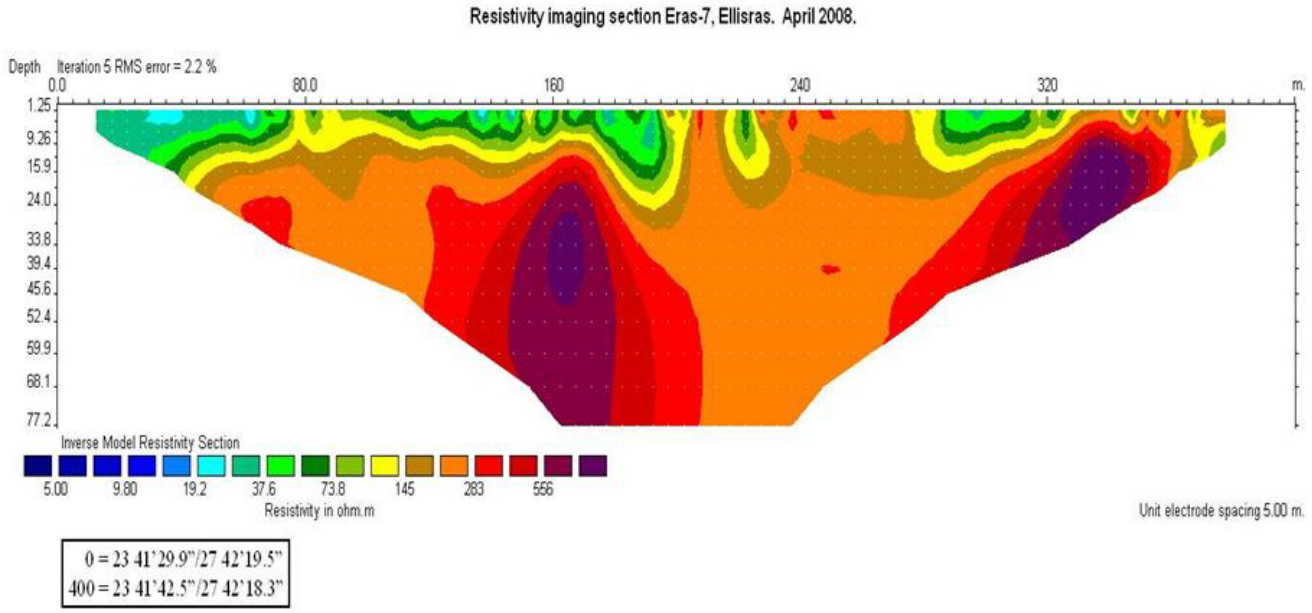
0 = 23 42'38.5"/27 39'29.3"
800 = 23 42'56.8"/27 39'09.0"

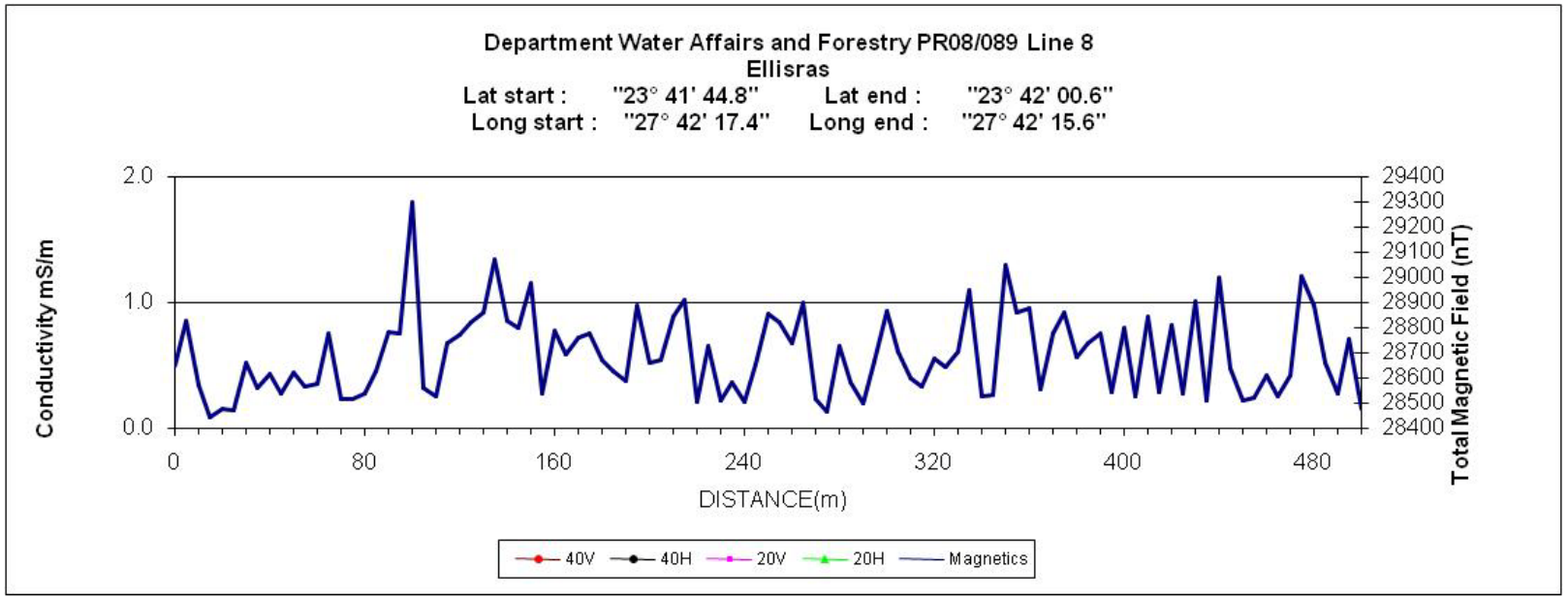


Resistivity imaging section Eras-6(extended), Ellisras. May 2008.

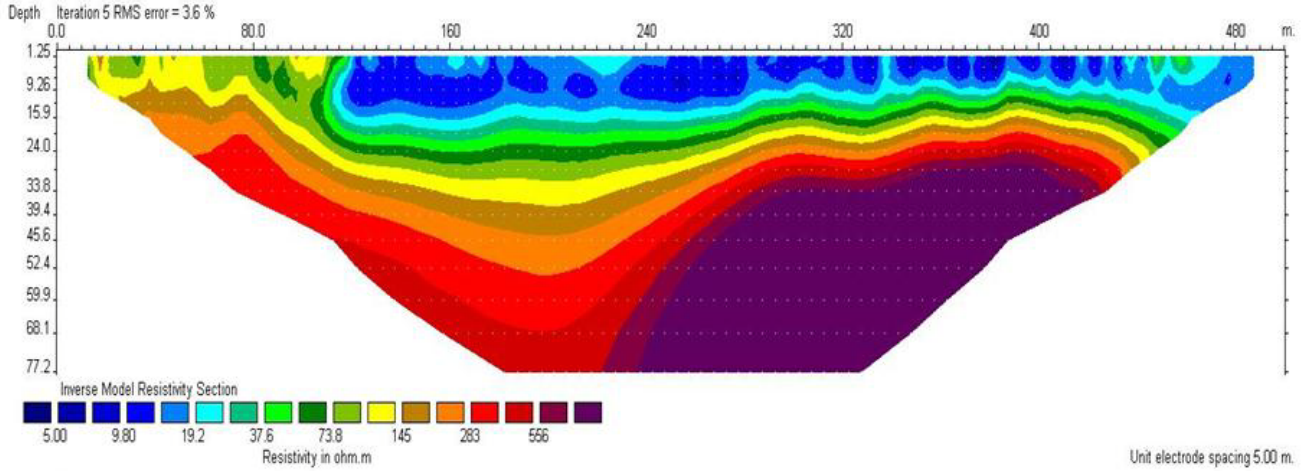



Department Water Affairs and Forestry PR08/089 Line 7
Ellisras
Lat start : "23° 41' 30.0" Lat end : "23° 41' 42.6"
Long start : "27° 42' 19.7" Long end : "27° 42' 18.9"
Conductivity mS/m
2.0
1.0
0.0
0
80
160
240
320
400
DISTANCE(m)
28800
28700
28600
28500
28400
28300
28200
28100
Total Magnetic Field (nT)
40V
40H
20V
20H
Magnetics

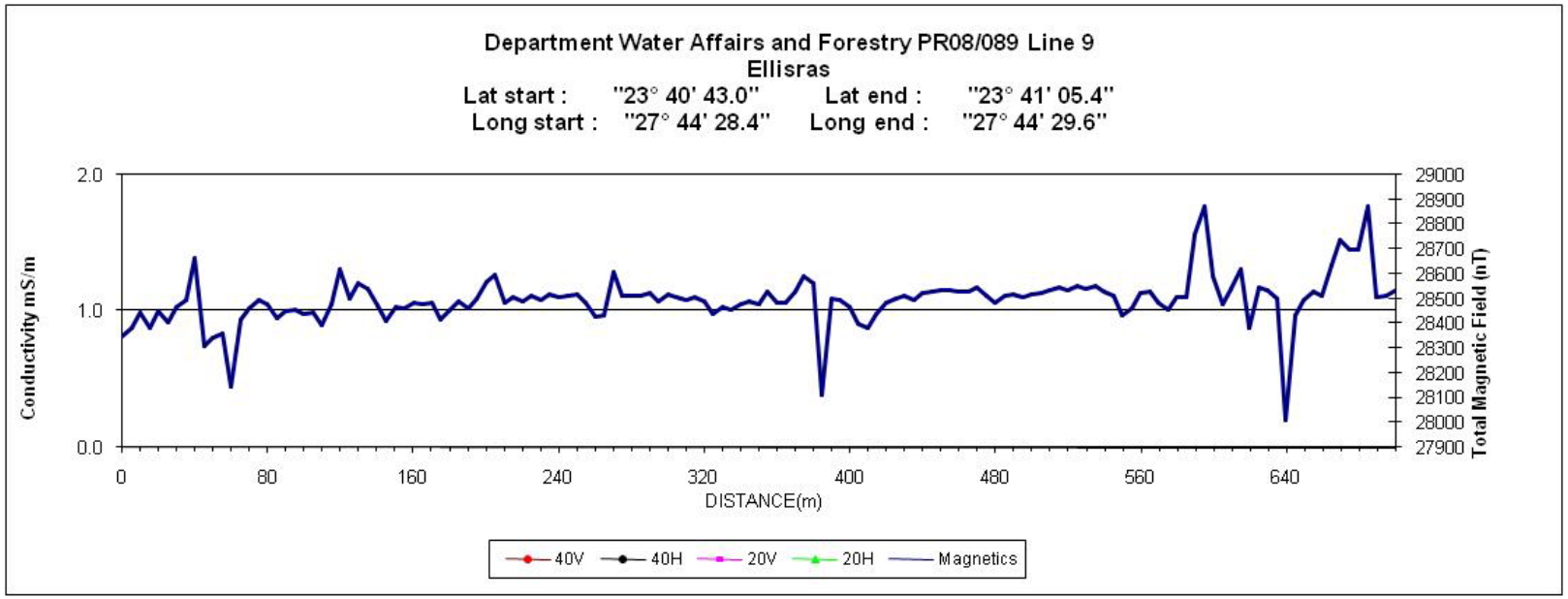

Resistivity imaging section Eras-7, Ellisras. April 2008.
Depth
Iteration 5 RMS error = 2.2 %
0.0
80.0
160
240
320
m.
1.25
9.26
15.9
24.0
33.8
39.4
45.6
52.4
59.9
68.1
77.2
Inverse Model Resistivity Section
5.00
9.80
19.2
37.6
73.8
145
283
556
Resistivity in ohm.m
Unit electrode spacing 5.00 m.
0 = 23 41'29.9"/27 42'19.5"
400 = 23 41'42.5"/27 42'18.3"



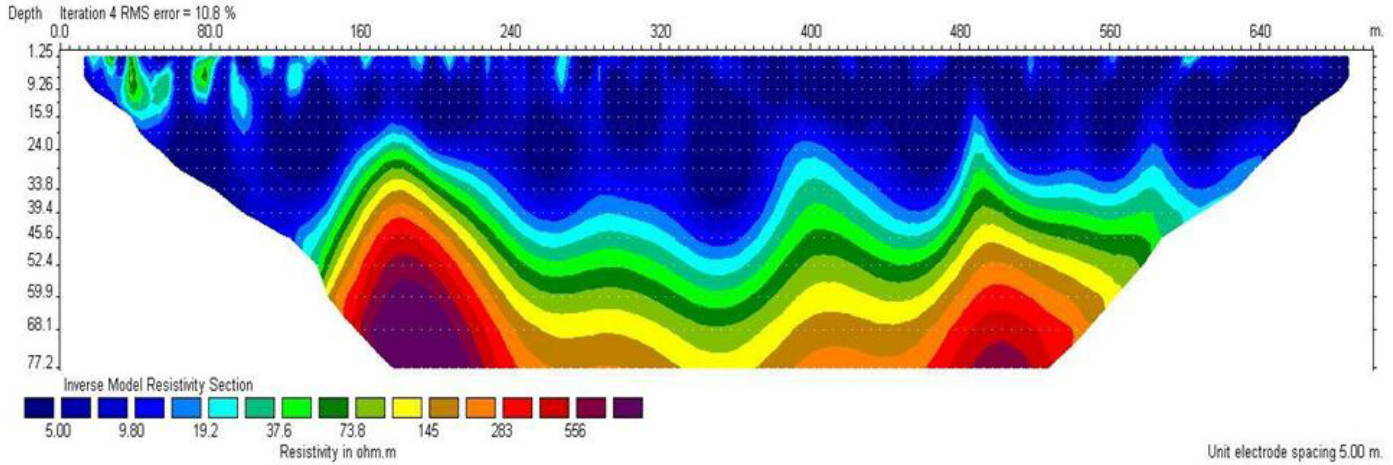
Resistivity imaging section Eras-8, Ellisras. April 2008.



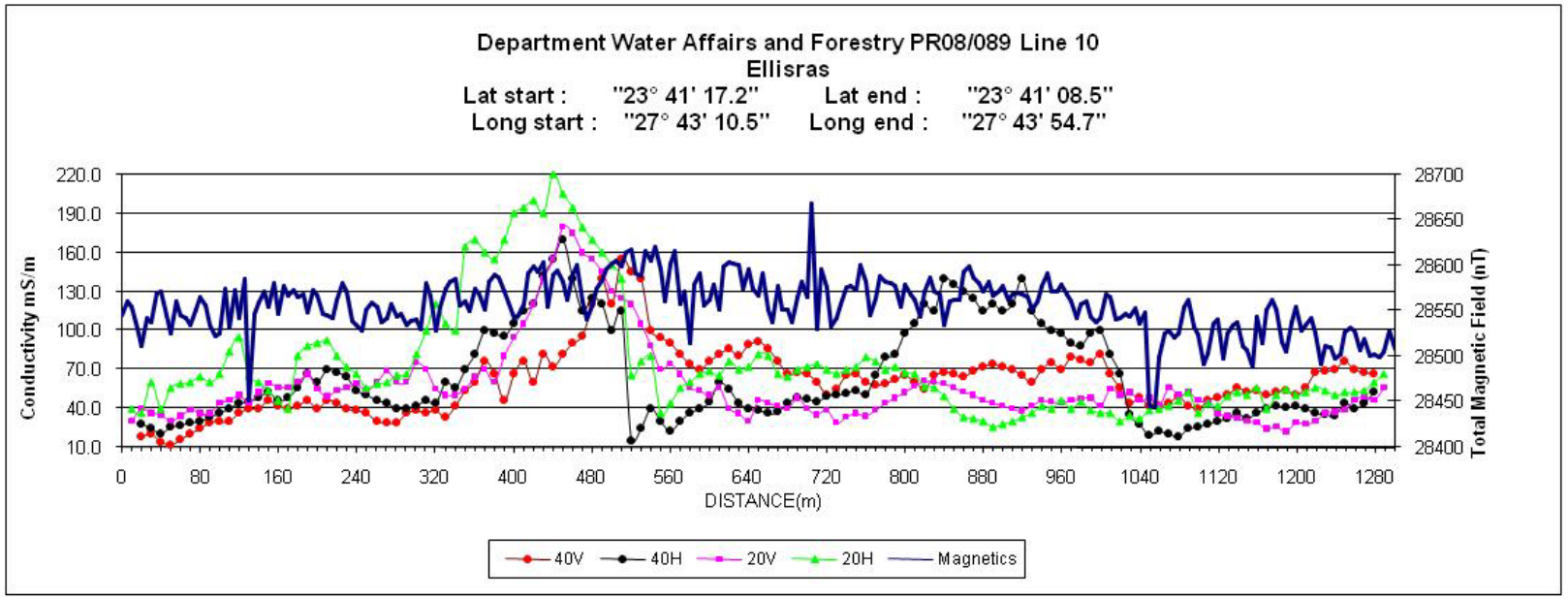
0 = 23 41'44.8"/27 42'17.5"
500 = 23 42'00.8"/27 42'15.9"



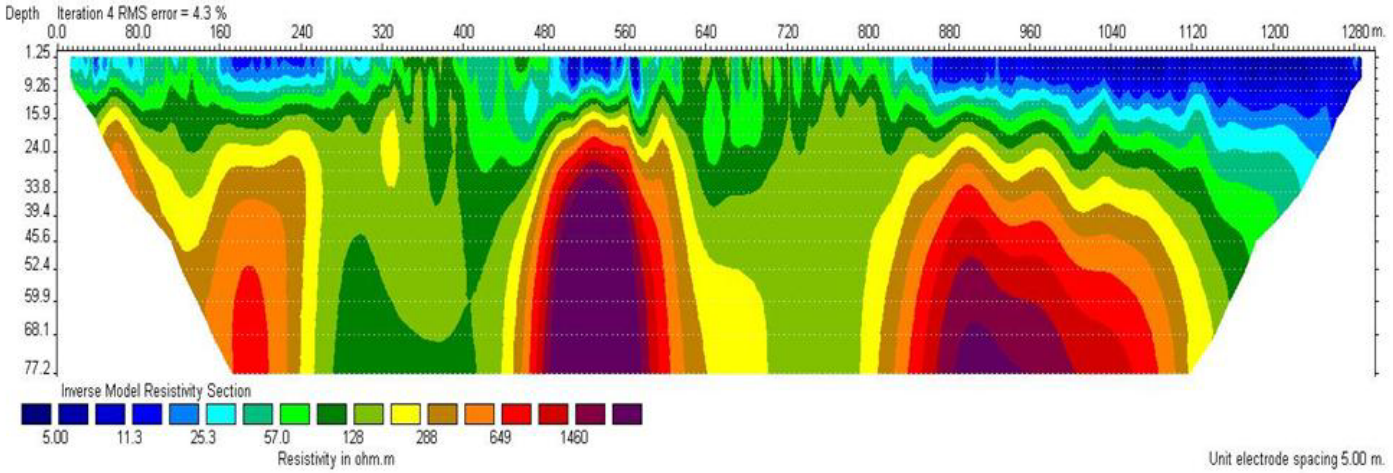
Resistivity imaging section Eras-9, Ellisras. April 2008.



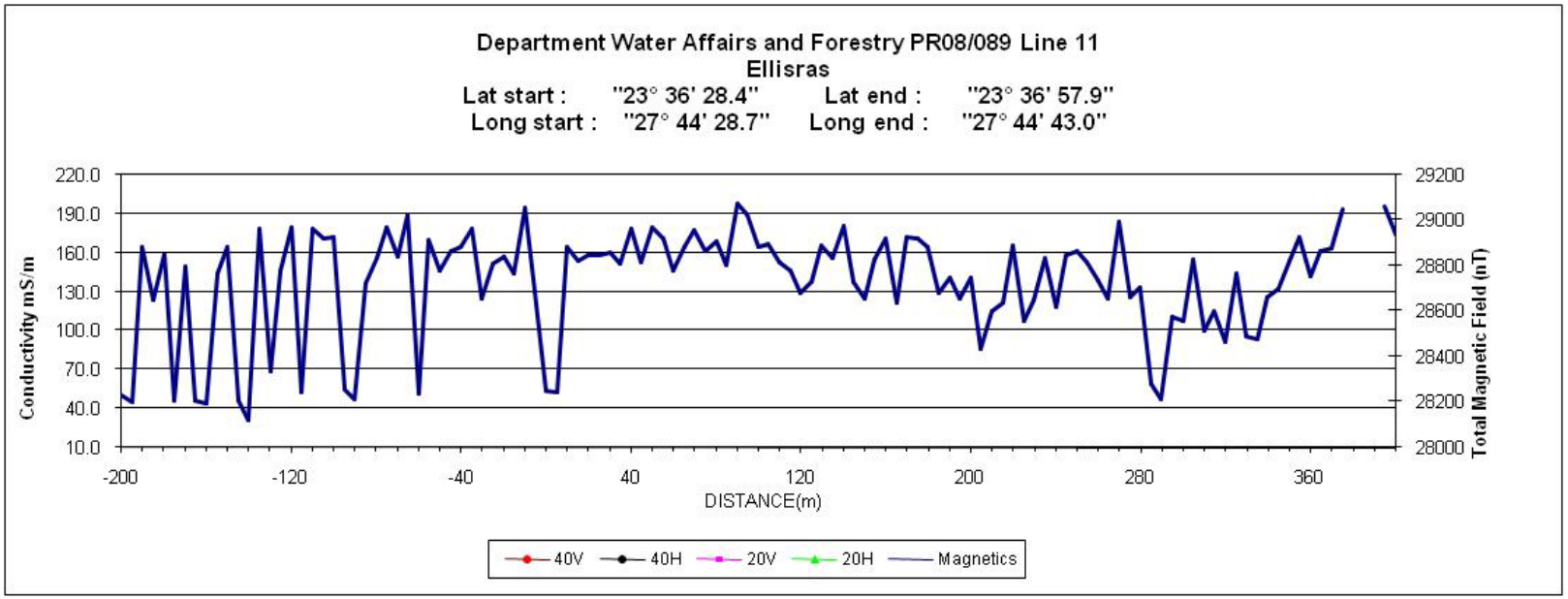
0 = 23 40'43.3"/27 44'28.4"
700 = 23 41'05.1"/27 44'29.6"



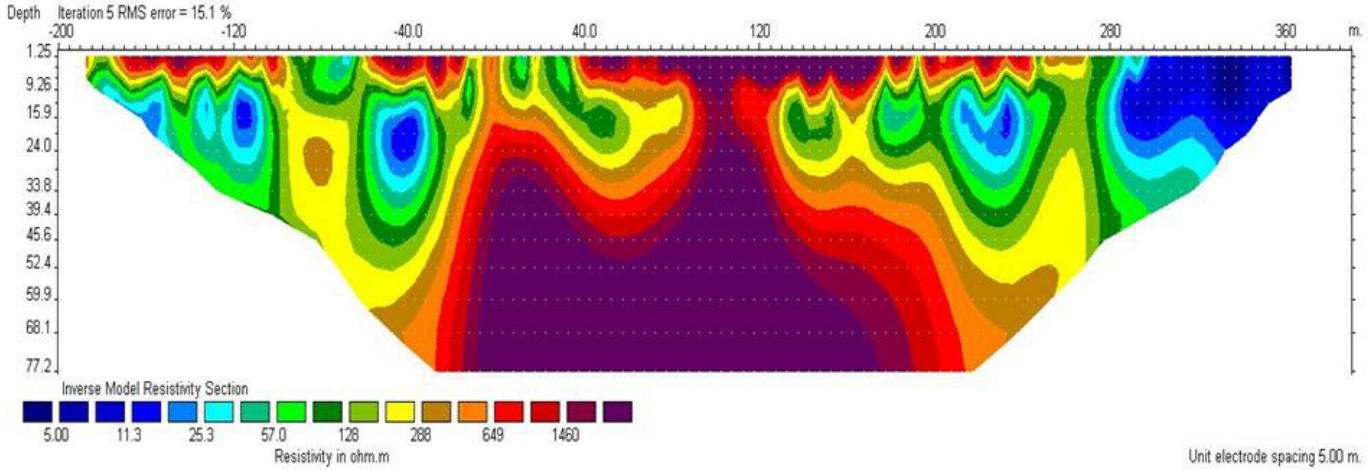
Resistivity imaging section Eras-10, Ellisras. April 2008.



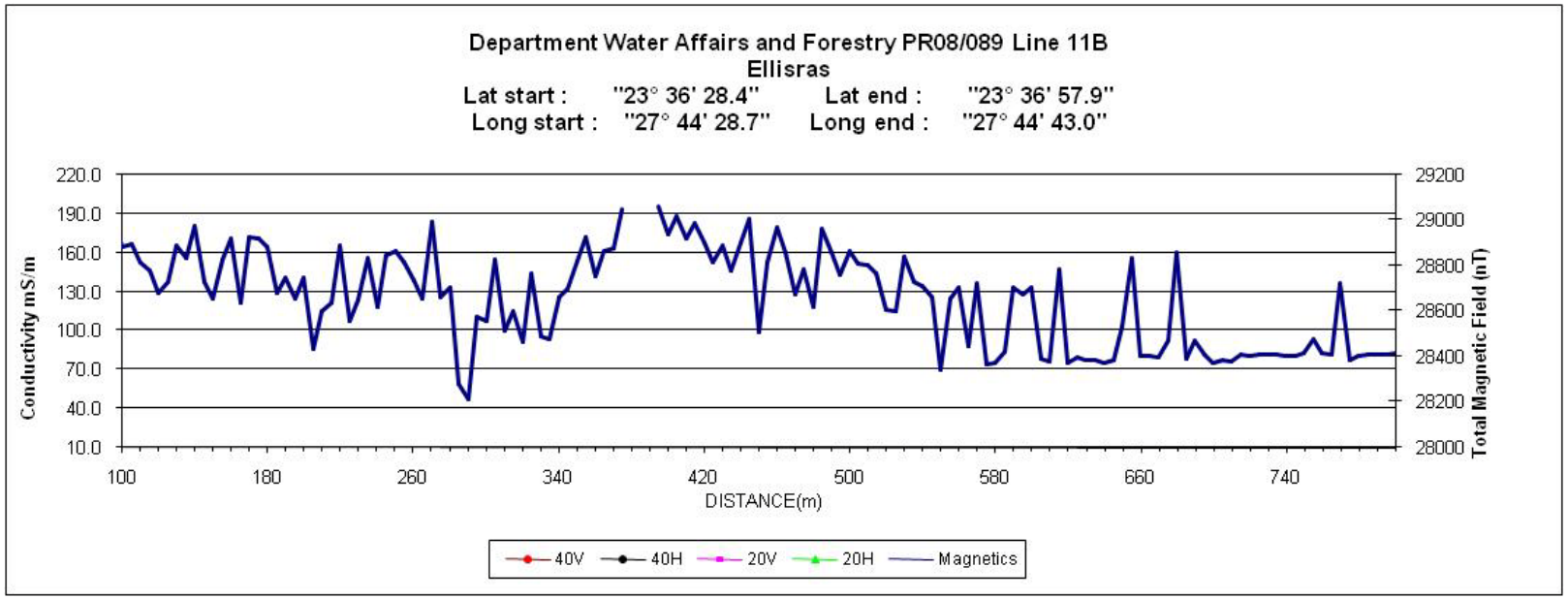
0 = 23 41'17.1"/27 43'10.7"
1300 = 23 41'08.6"/27 43'54.6"



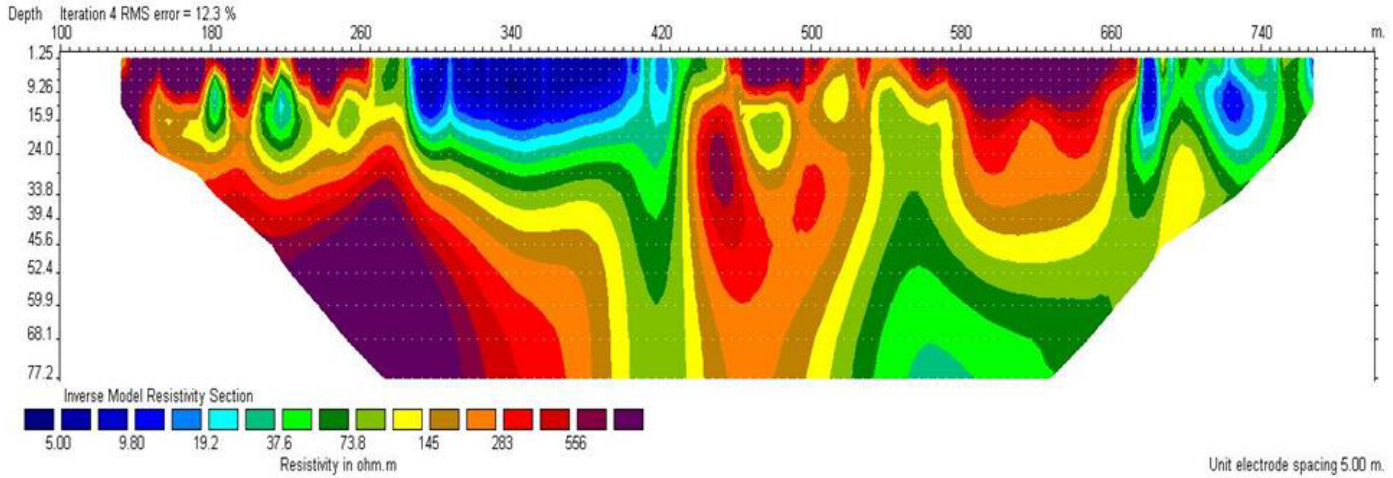
Resistivity imaging section Eras-11, Ellisras. April 2008.

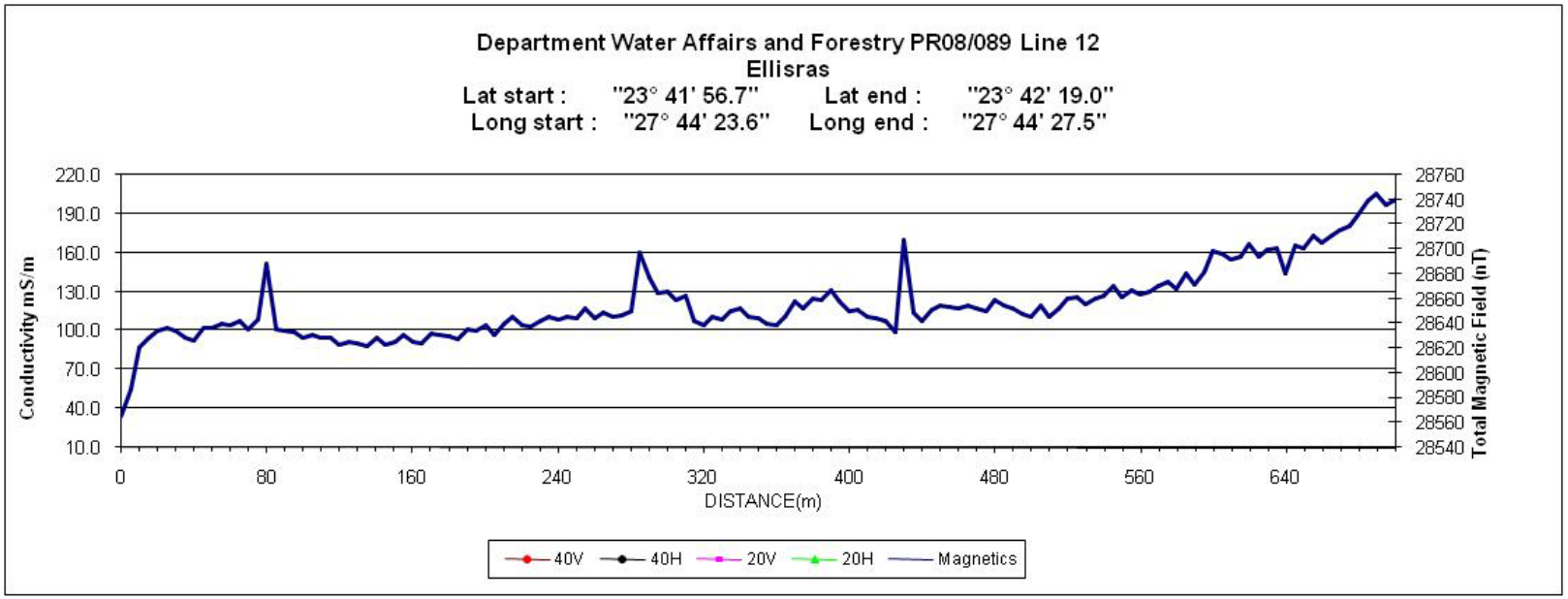


-200 = 23 36'28.5"/27 44'28.7"
400 = 23 36'46.0"/27 44'37.2"

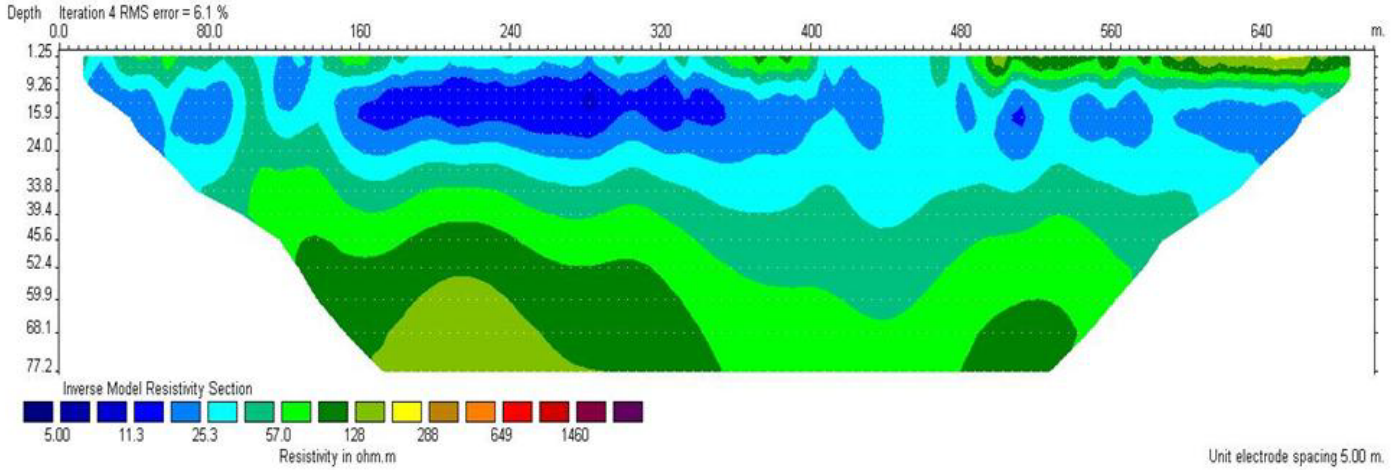


Resistivity imaging section Eras-11(extended), Ellisras. May 2008.

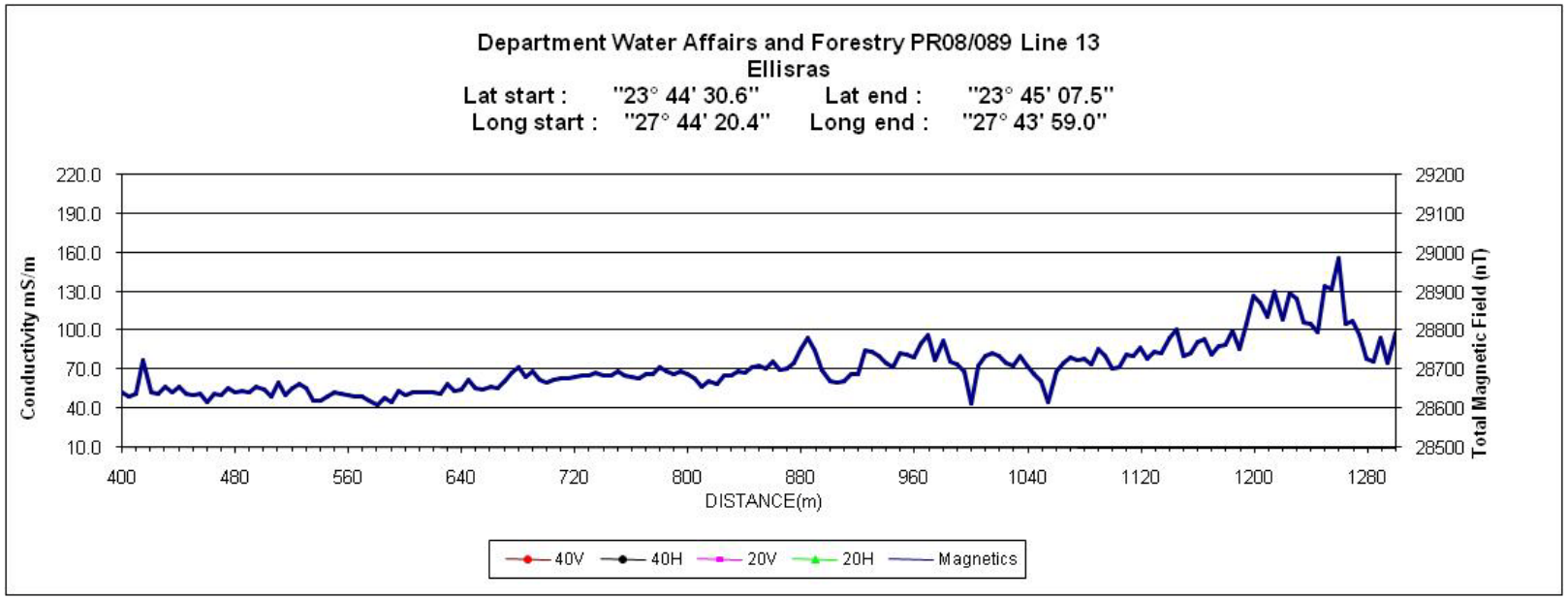




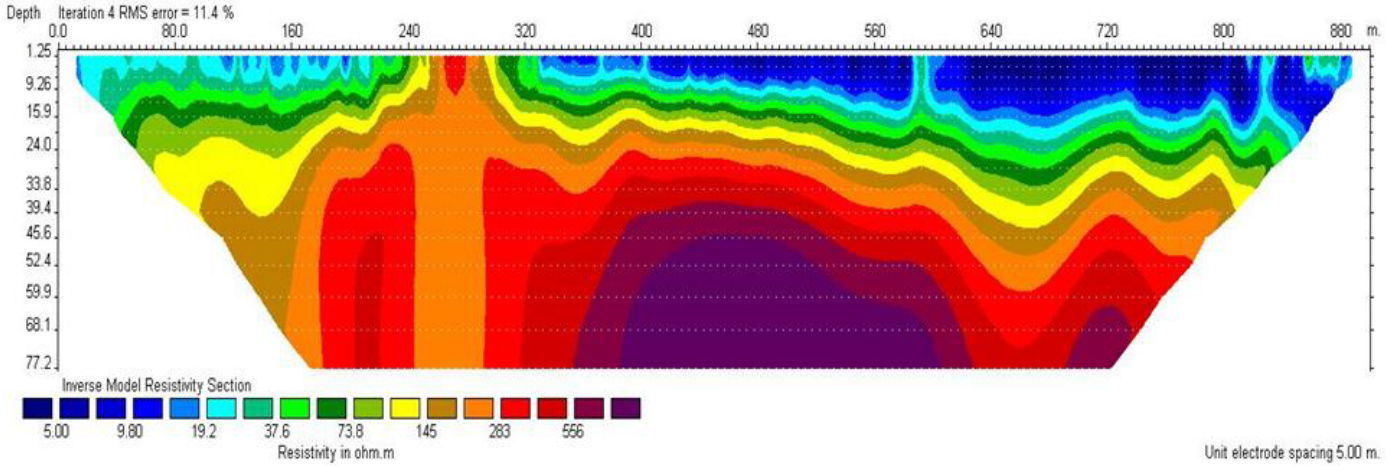
Resistivity imaging section Eras-12, Ellisras. April 2008.



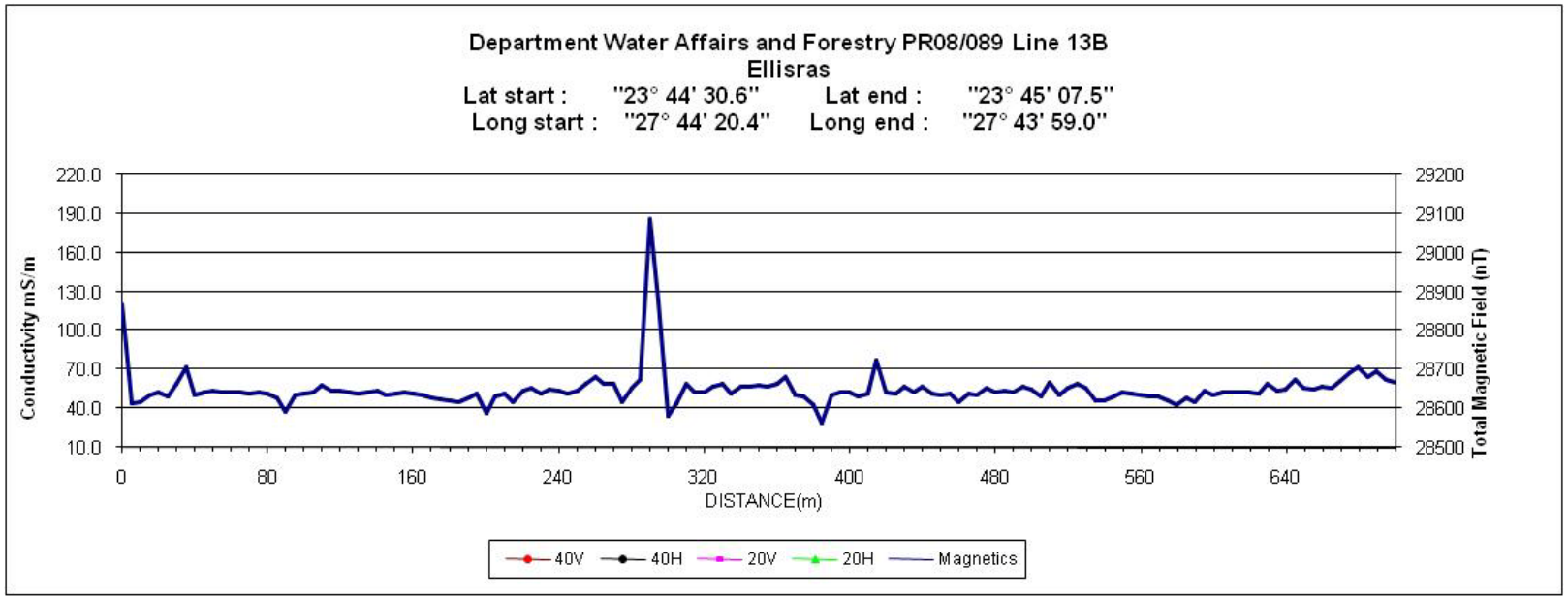
0 = 23 41'56.8"/27 44'23.7"
700 = 23 42'18.8"/27 44'27.5"



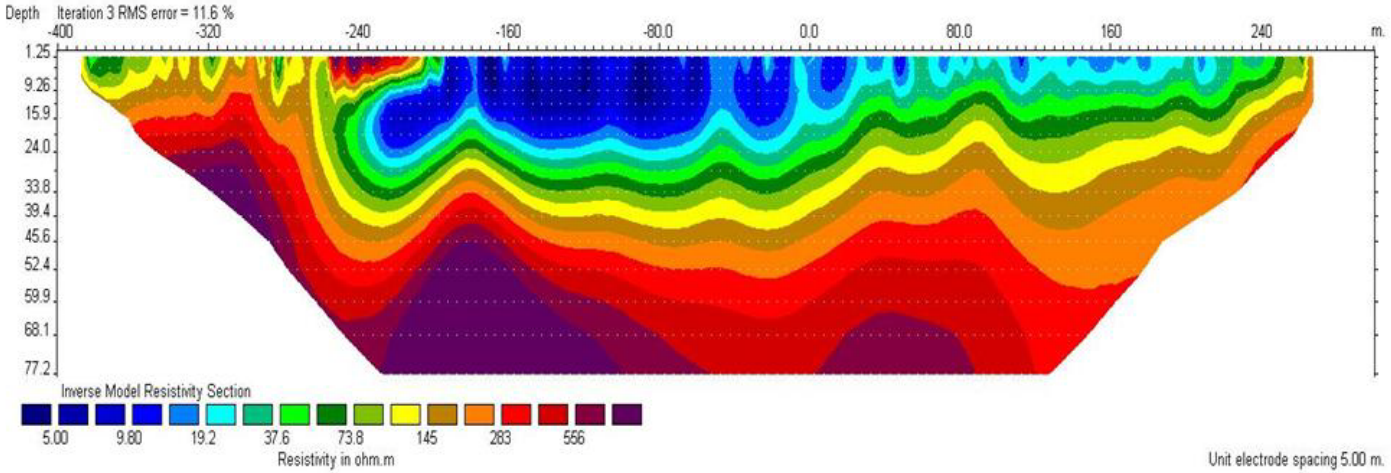
Resistivity imaging section Eras-13, Ellisras. April 2008.

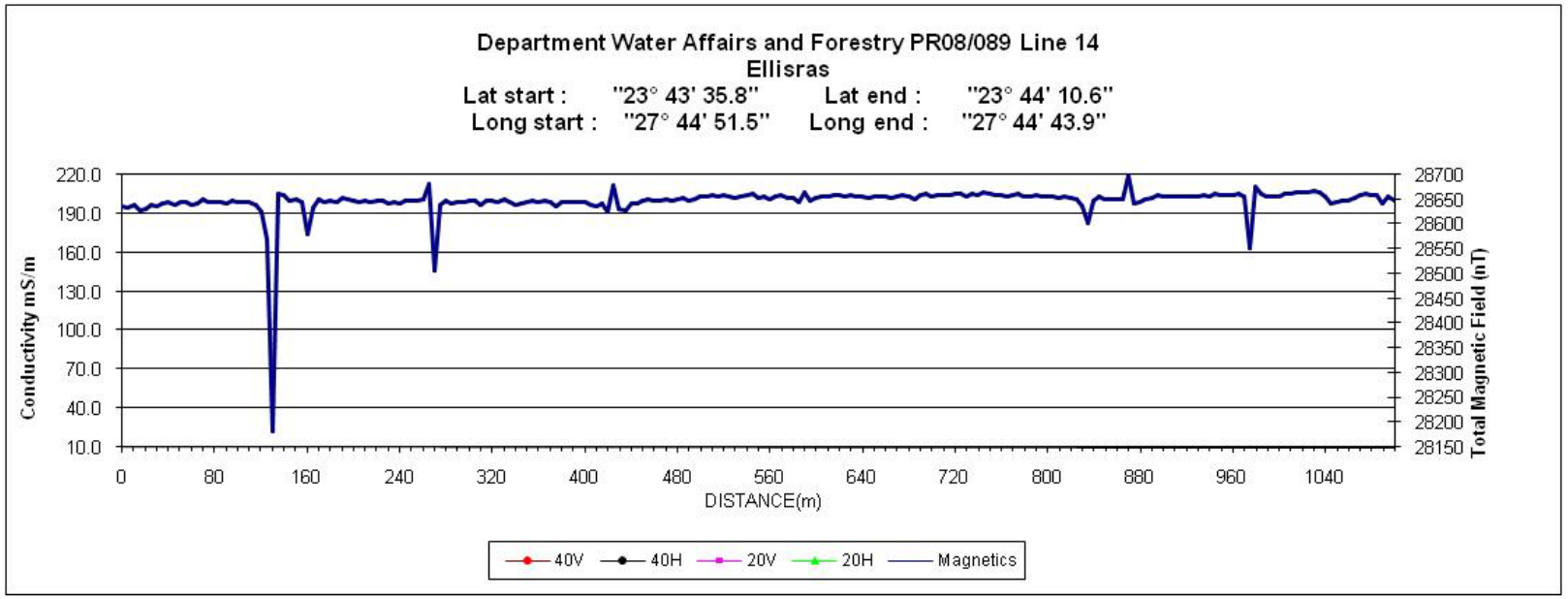


0 = 23 44'42.4"/27 44'14.1"
900 = 23 45'07.5"/27 43'59.1"

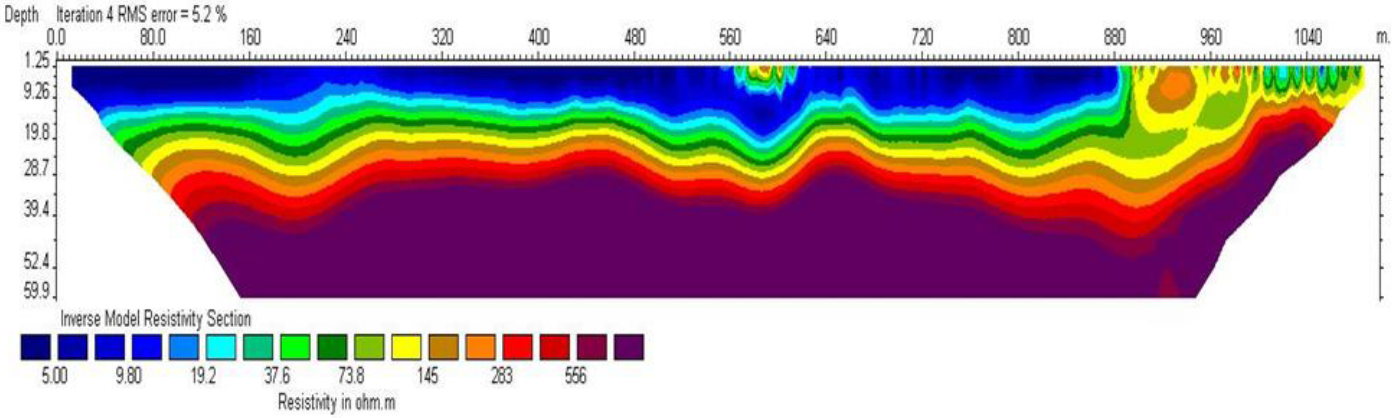


Resistivity imaging section Eras-13(extended), Ellisras. May 2008.

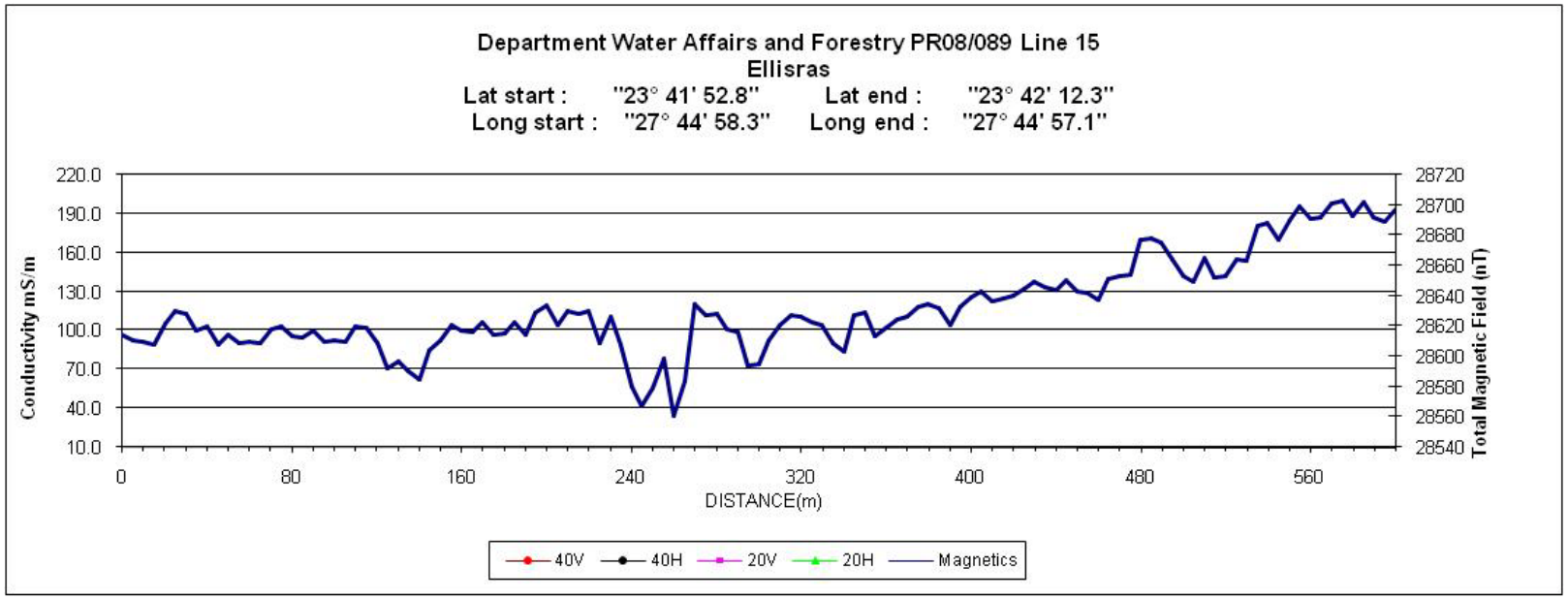




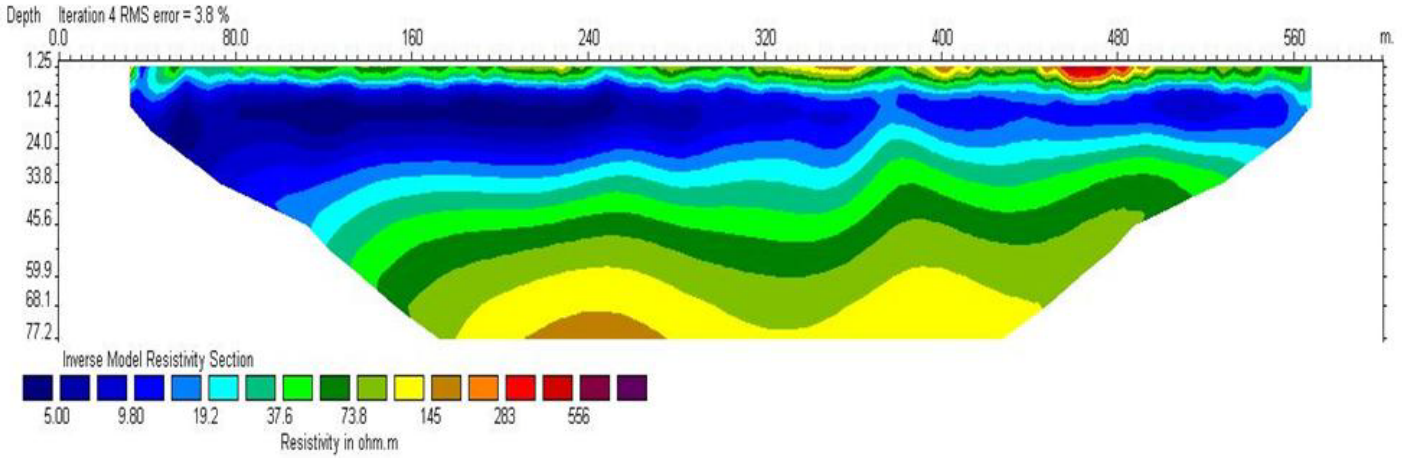
Resistivity imaging section Eras-14, Ellisras. November 2008.



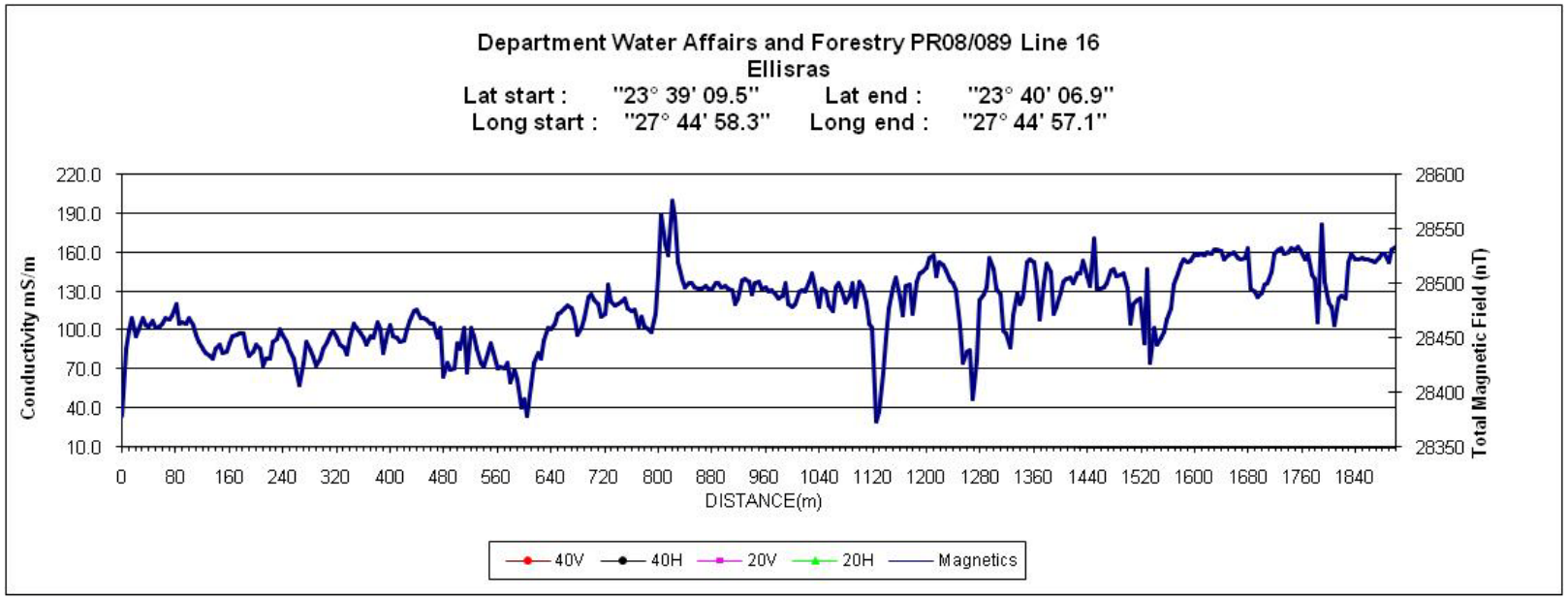
0m: 23 43 35.8 / 27 44 51.5
1100m: 23 44 10.6 / 27 44 43.9



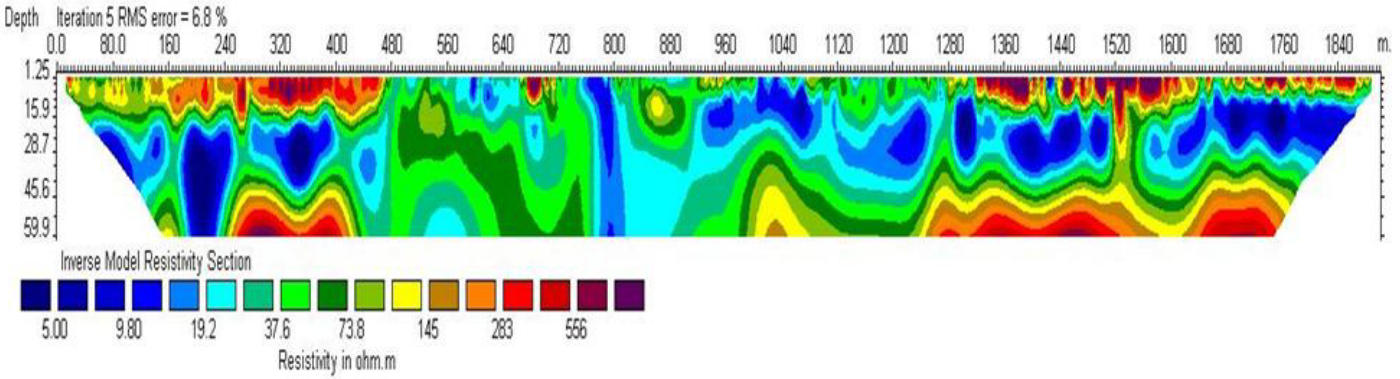
Resistivity imaging section Eras-15, Ellisras. November 2008.



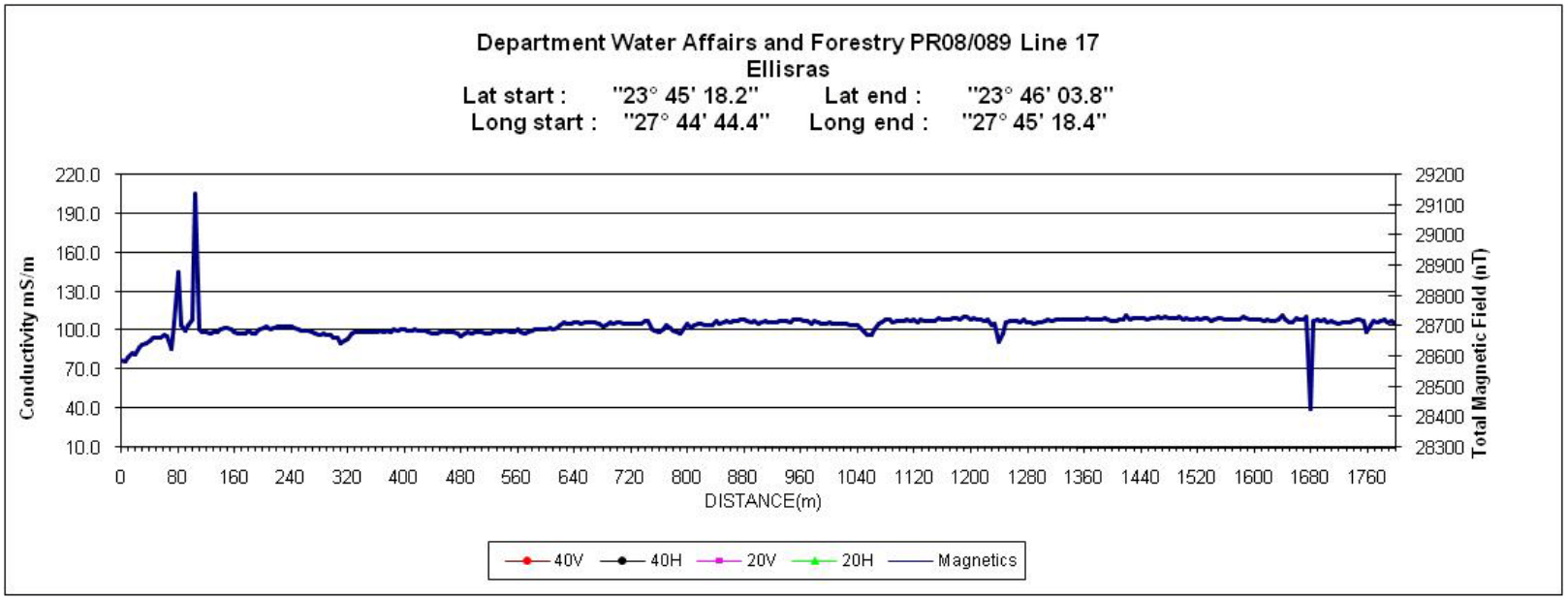
0m: 23 41 52.8 / 27 44 58.3
600m: 23 42 12.3 / 27 44 57.1



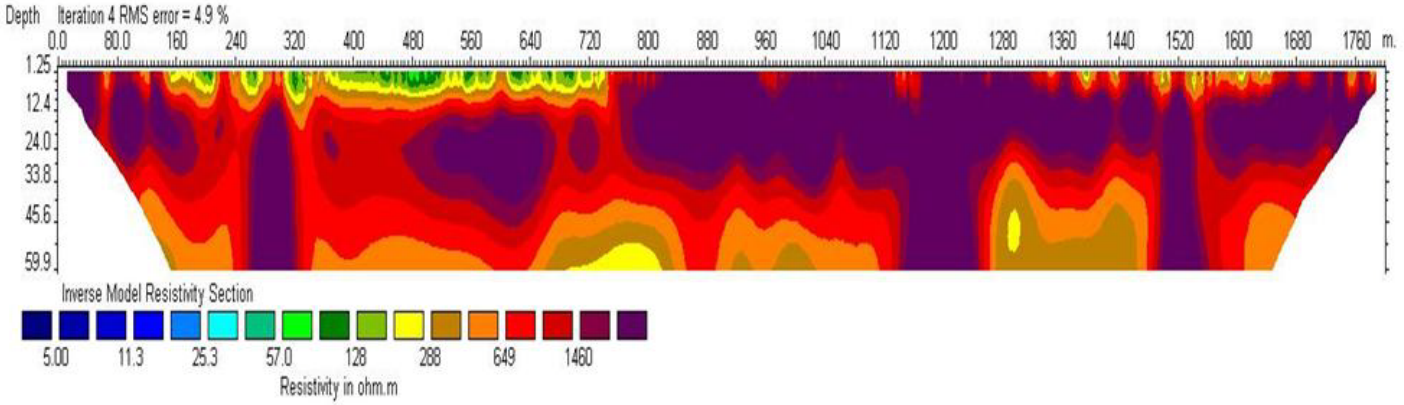
Resistivity imaging section Eras-16, Ellisras. November 2008.



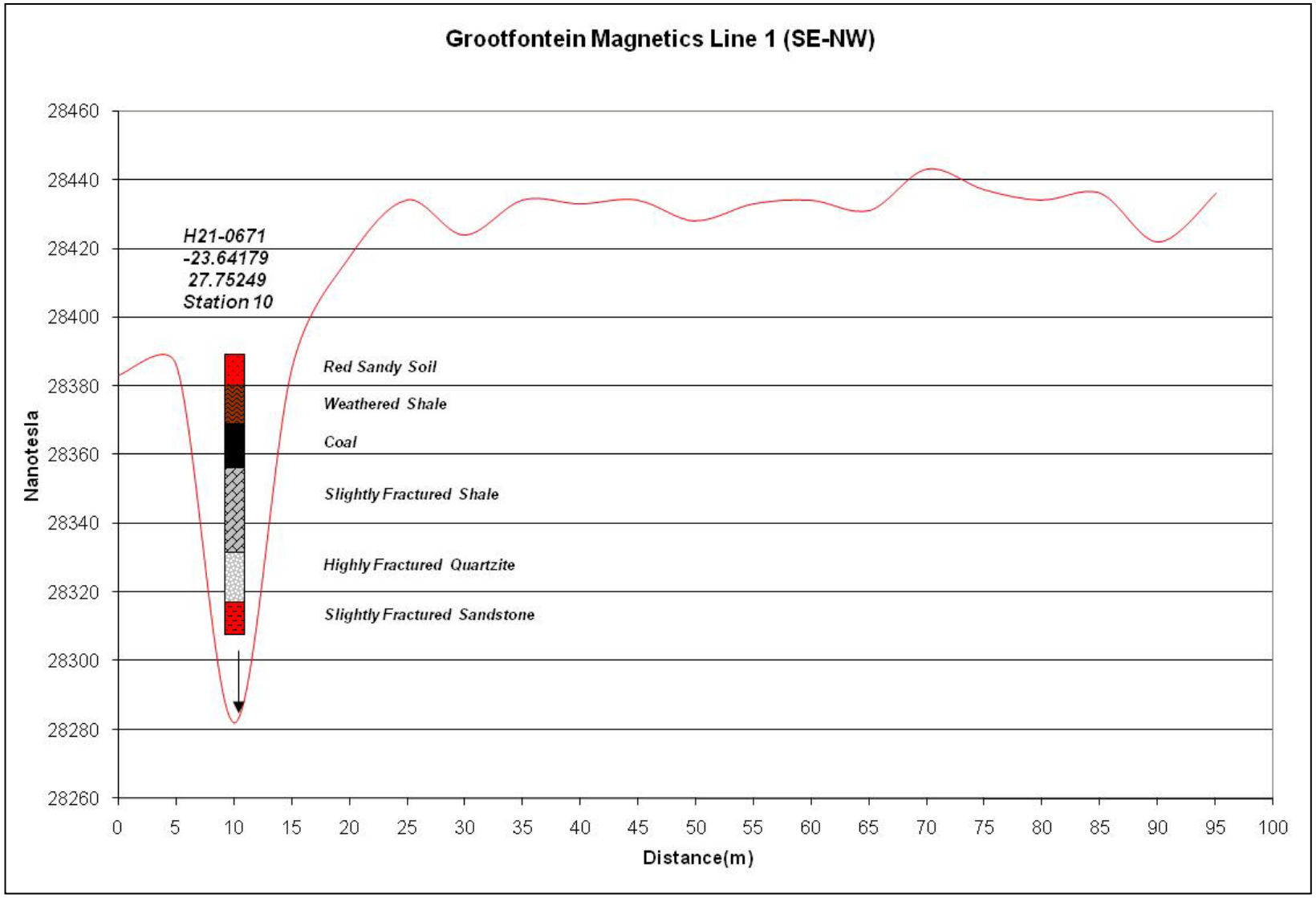
0m: 23 39 09.5 / 27 45 36.5
1900m: 23 40 06.9 / 27 45 29.2



Resistivity imaging section Eras-17, Ellisras. December 2008.



0m: 23 45 18.2 / 27 44 44.4
1800m: 23 46 03.8 / 27 45 18.4


Grootfontein Magnetics Line 1 (SE-NW)
Nanotesla
28460
28440
28420
28400
28380
28360
28340
28320
28300
28280
28260
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Distance(m)
H21-0671
-23.64179
27.75249
Station 10
Red Sandy Soil
Weathered Shale
Coal
Slightly Fractured Shale
Highly Fractured Quartzite
Slightly Fractured Sandstone

Appendix D: Drilling Logs

Borehole Construction and Geological Log

Date compiled: 2008/10/13

BASIC SITE INFORMATION: ***Site Identifier:*** 2327DAV0017 ***Number:*** H21-0636 ***Site type:*** Borehole

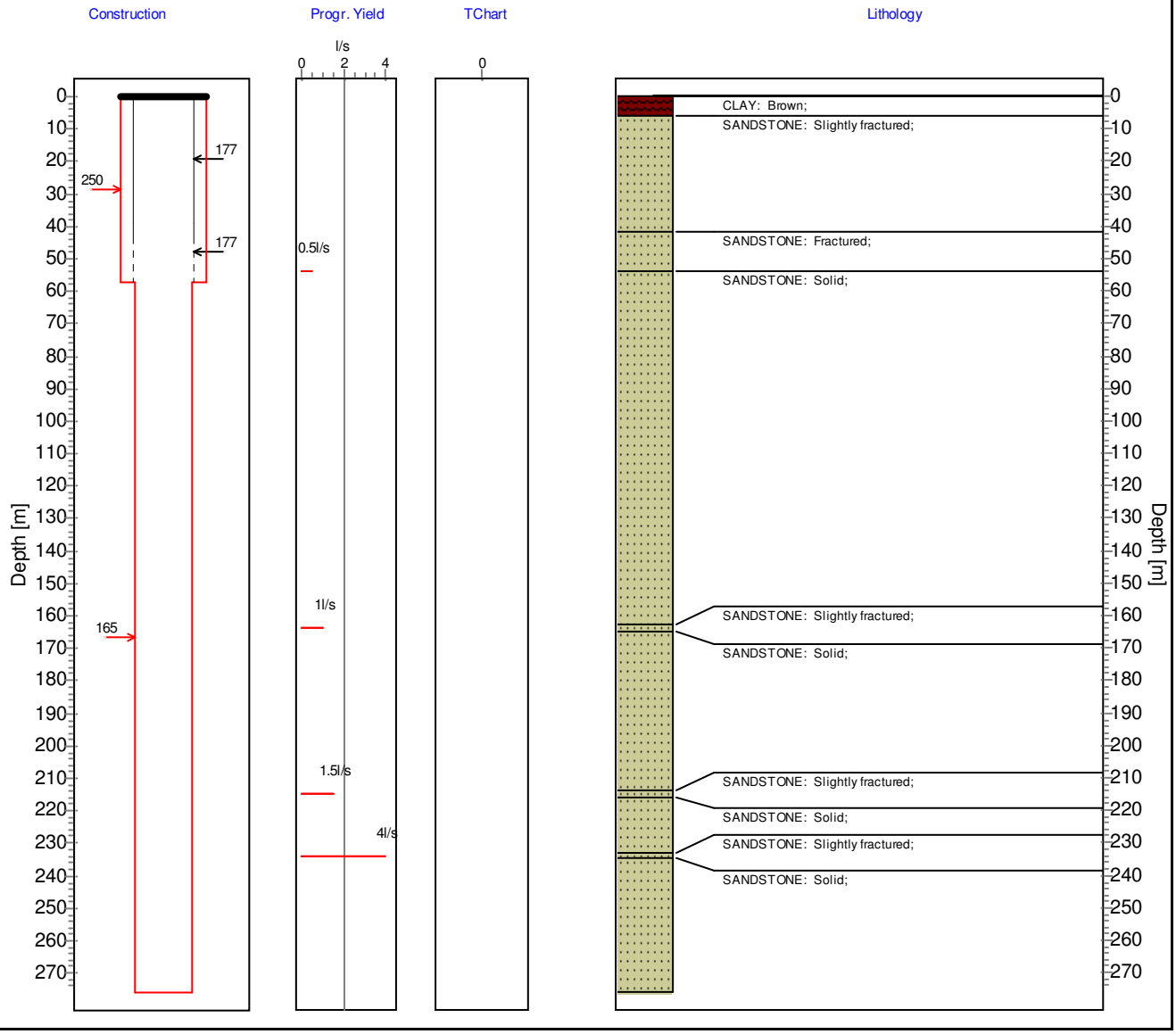
Distr./Farm No.: LPLQ502 ***Site Name/Des.:*** WATERKLOOF PTN. ELLISRAS

Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

Latitude [°]:	23.686220	***Reg./BB.:***	***Topo-set.:***	Flat surface, plain	***Depth [m]:*** 276.00
Longitude [°]:	27.729550	***G-Nr.:***	***Site status:***	Unused	***Col. ht. [m]:*** 0.42
Altitude [m]:	805.00		***Site purp.:***	Exploration	***Diam. [mm]:*** 177
Coord. acc.:	Accurate to within 10 units		***Use applic.:***	Domestic - all purposes	***Drain. reg.:*** A42H
Coord. meth.:	Global Positioning System		***Equipment:***	No equipment	***Rep. inst.:*** DWAF

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend



COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0016 ***Number:*** H21-0637 ***Site type:*** Borehole

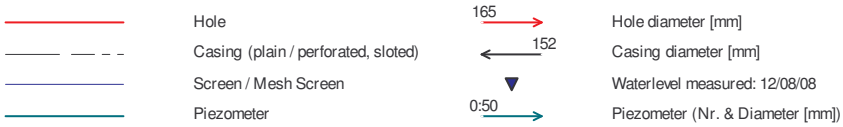
Distr./Farm No.: LPLQ502 ***Site Name/Des.:*** WATERKLOOF PTN. ELLISRAS

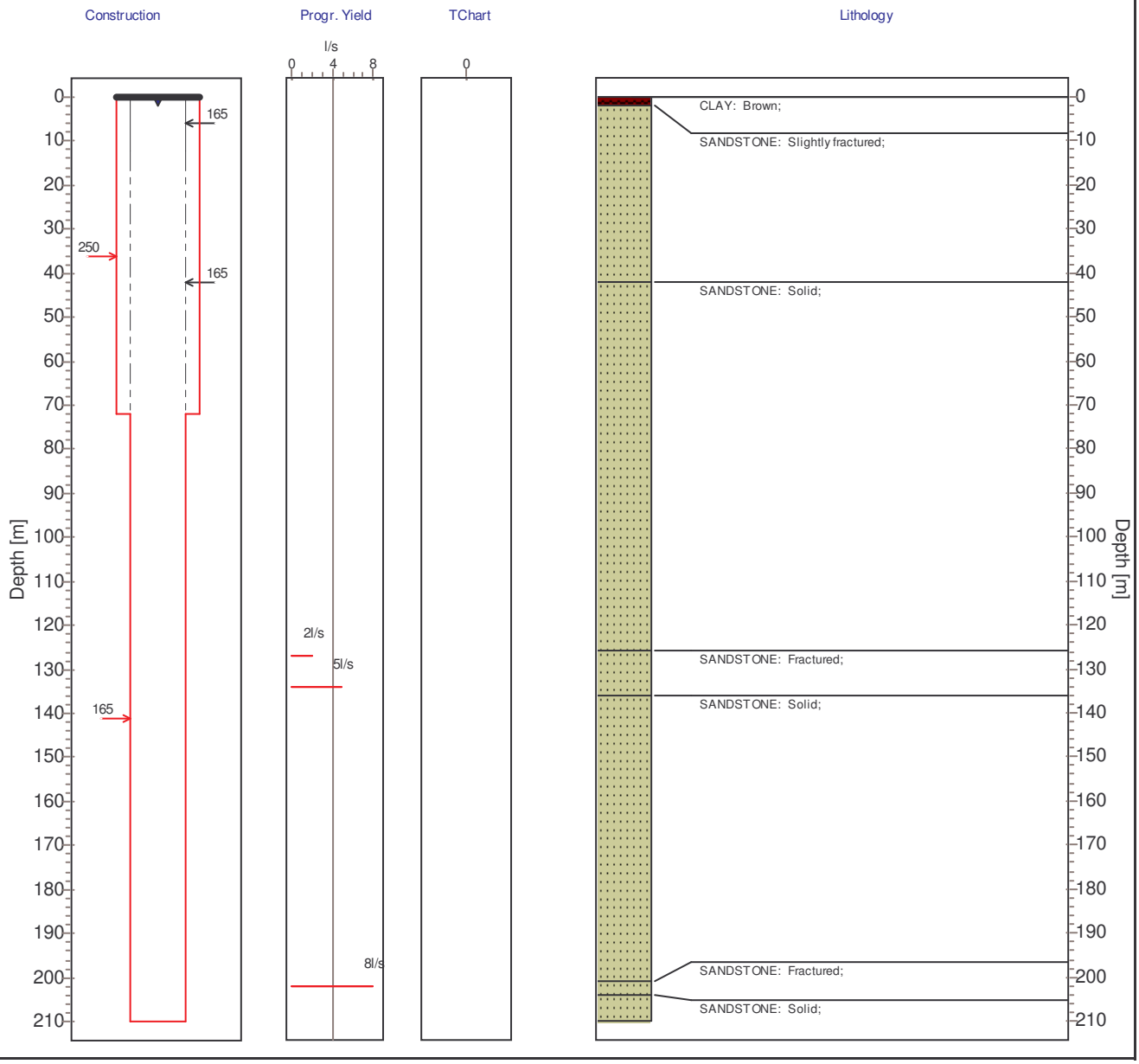
Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

Latitude [°]:	23.686720	***Reg./BB.:***		***Depth [m]:***	210.00
Longitude [°]:	27.726860	***G-Nr.:***		***Col. ht. [m]:***	0.55
Altitude [m]:	806.00	***Topo-set.:***		***Diam. [mm]:***	165
Coord. acc.:	Accurate to within 100 units	***Site status:***	Unused	***Drain. reg.:***	A42H
Coord. meth.:	Interpolated from map	***Site purp.:***	Exploration	***Rep. inst.:***	DWAF
		Use applic.:	Domestic - all purposes		
		Equipment:	No equipment		

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend





COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0019 ***Number:*** H21-0638 ***Site type:*** Borehole

Distr./Farm No.: LPLQ502 ***Site Name/Des.:*** WATERKLOOF PTN. ELLISRAS

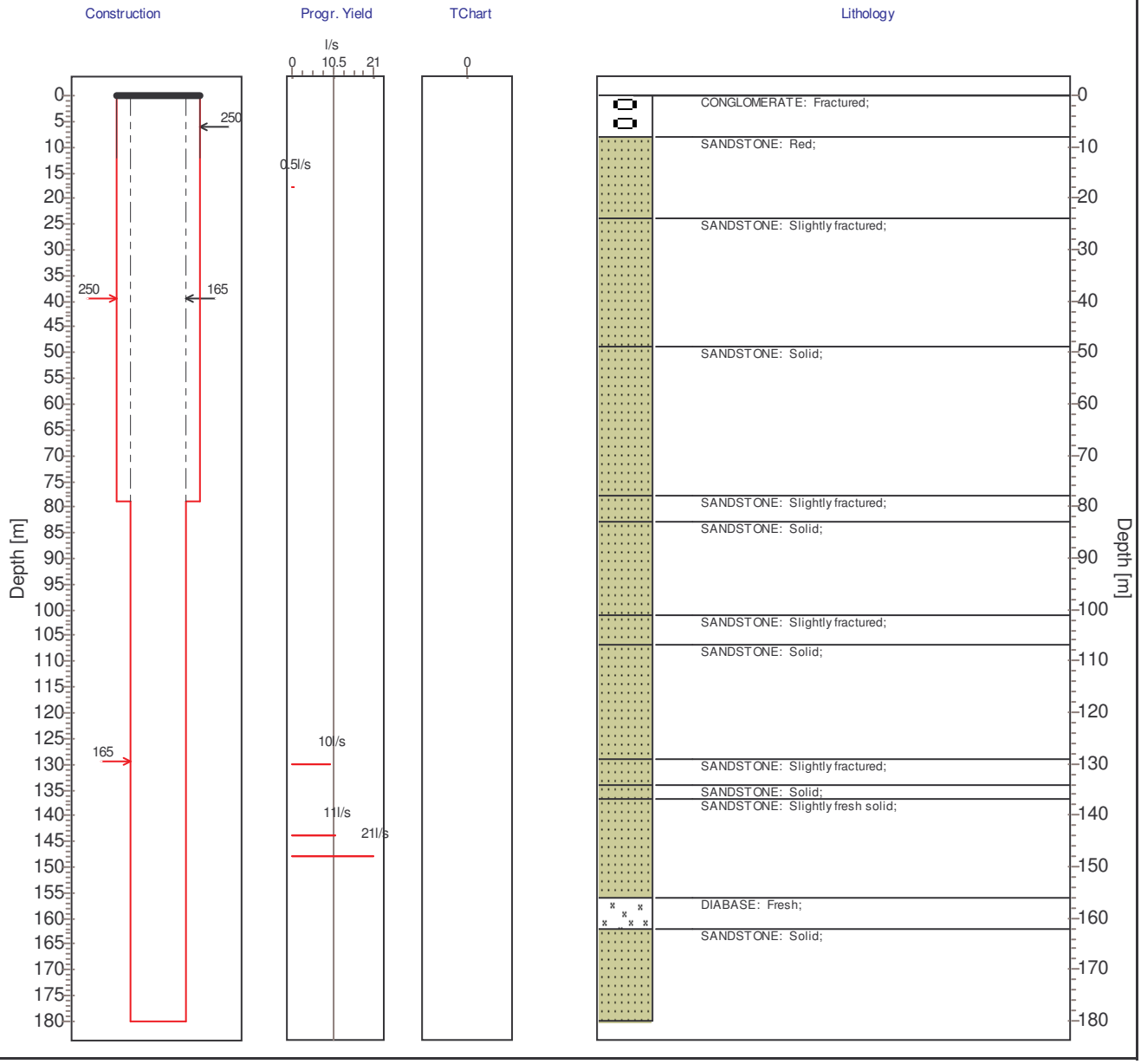
Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

Latitude [°]:	23.687130	***Reg./BB.:***		***Topo-set.:***		***Depth [m]:***	180.00
Longitude [°]:	27.724720	***G-Nr.:***		***Site status:***	Unused	***Col. ht. [m]:***	0.46
Altitude [m]:	807.00			***Site purp.:***	Exploration	***Diam. [mm]:***	165
Coord. acc.:	Accurate to within 100 units			***Use applic.:***	Domestic - all purposes	***Drain. reg.:***	A42H
Coord. meth.:	Interpolated from map			***Equipment:***	No equipment	***Rep. inst.:***	DWAF

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend

Hole
Casing (plain / perforated, sloted)
Screen / Mesh Screen
Piezometer
165 — Hole diameter [mm]
152 — Casing diameter [mm]
Waterlevel with date meas.
0:50 — Piezometer (Nr. & Diameter [mm])



COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2008/10/13

BASIC SITE INFORMATION: ***Site Identifier:*** 2327DAV0020 ***Number:*** H21-0662 ***Site type:*** Borehole

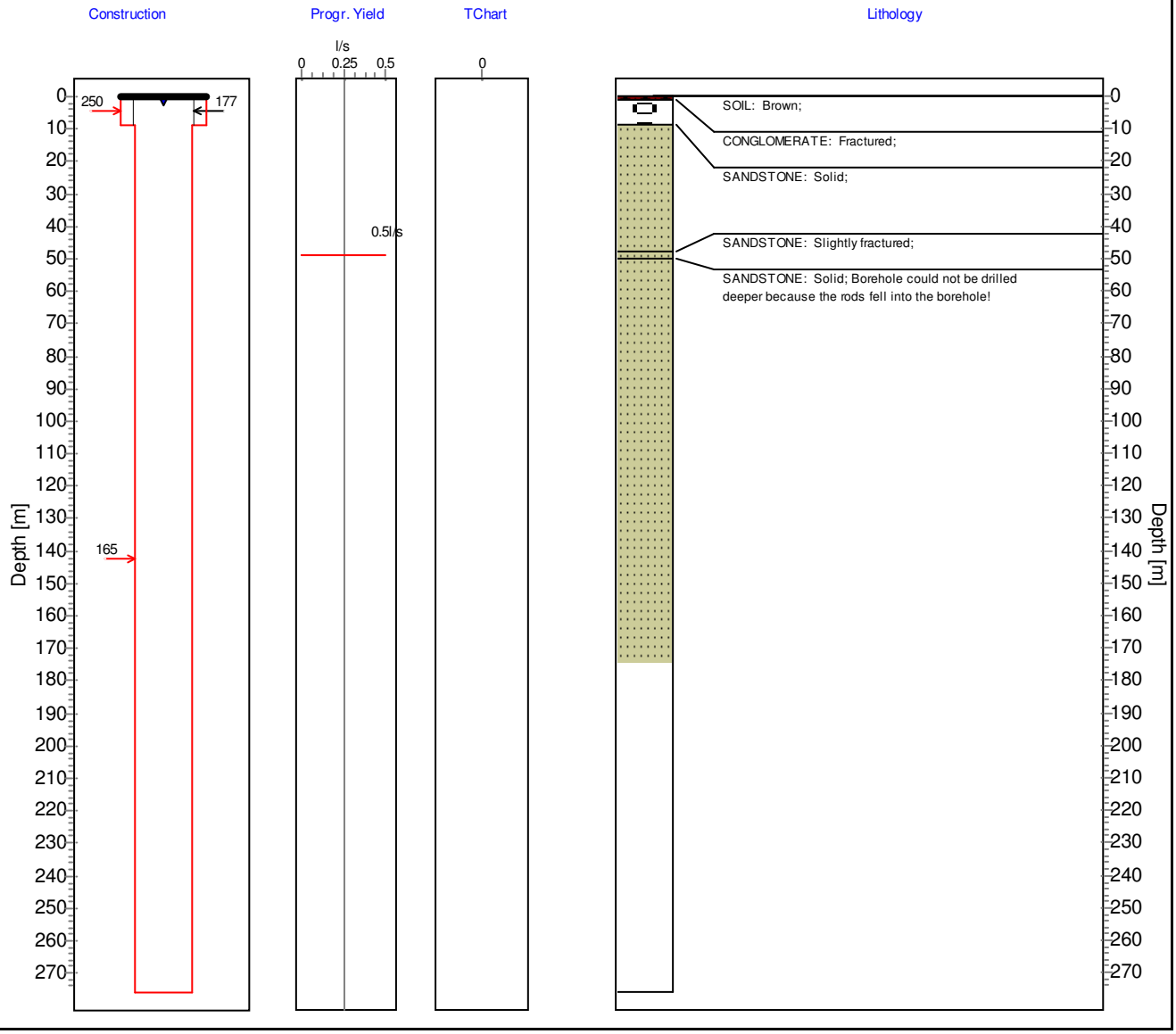
Distr./Farm No.: LPLQ502 ***Site Name/Des.:*** WATERKLOOF PTN. ELLISRAS

Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

Latitude [°]:	23.687270	***Reg./BB.:***	***Topo-set.:***	Flat surface, plain	***Depth [m]:*** 276.00
Longitude [°]:	27.724050	***G-Nr.:***	***Site status:***	Unused	***Col. ht. [m]:*** 0.46
Altitude [m]:	804.00		***Site purp.:***	Exploration	***Diam. [mm]:*** 165
Coord. acc.:	Accurate to within 10 units		***Use applic.:***	Domestic - all purposes	***Drain. reg.:*** A42H
Coord. meth.:	Global Positioning System		***Equipment:***	No equipment	***Rep. inst.:*** DWAF

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend



COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0015 ***Number:*** H21-0663 ***Site type:*** Borehole

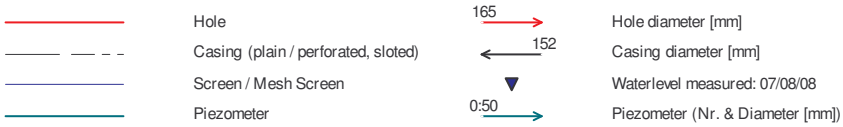
Distr./Farm No.: LPLQ502 ***Site Name/Des.:*** WATERKLOOF PTN. ELLISRAS

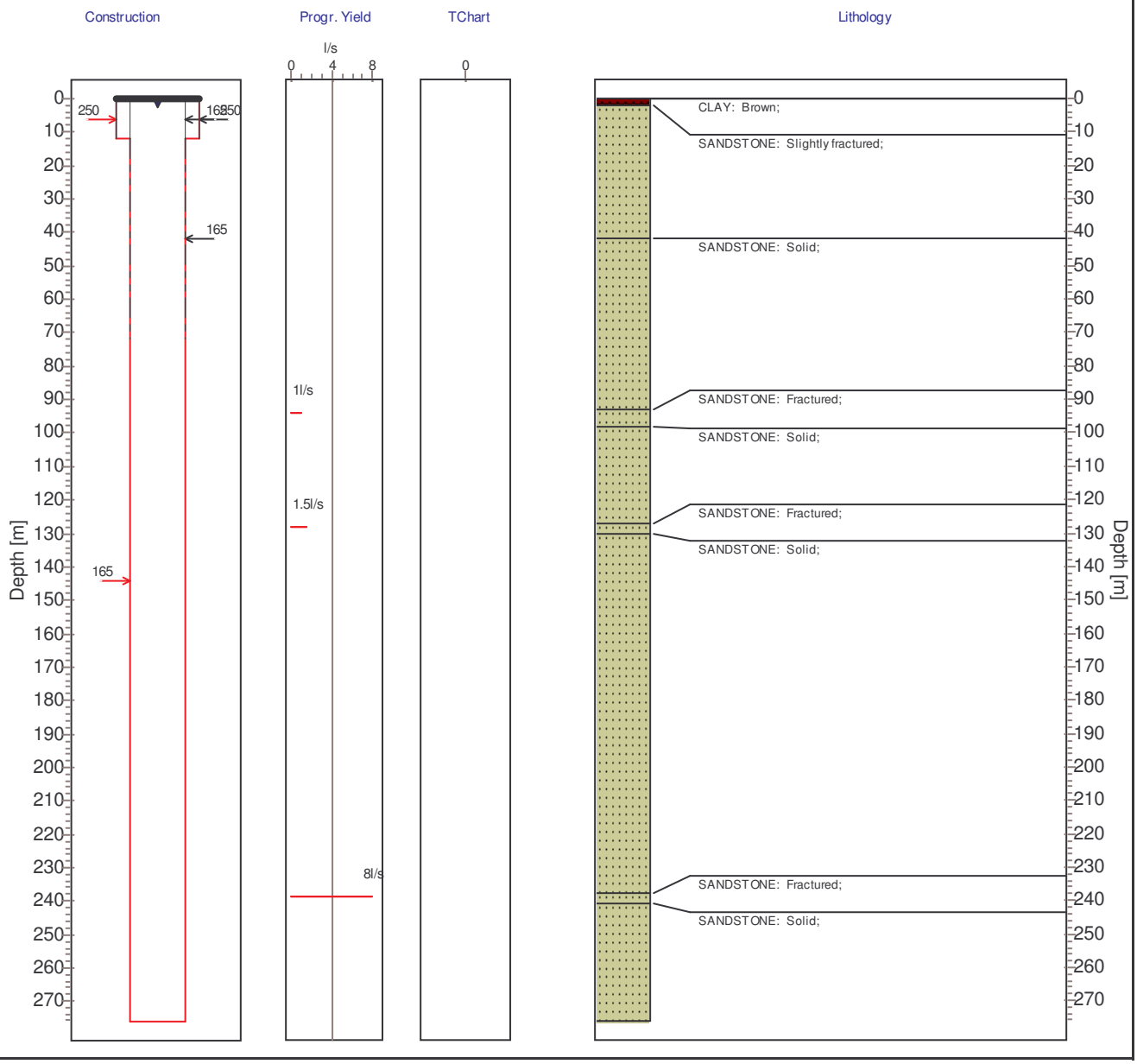
Region Type: District Council ***Region Descr.:*** WATERBERG/ELLISRAS

Latitude [°]:	23.687470	***Reg./BB.:***		***Depth [m]:***	276.00
Longitude [°]:	27.723000	***G-Nr.:***		***Col. ht. [m]:***	0.47
Altitude [m]:	805.00	***Topo-set.:***	Flat surface, plain	***Diam. [mm]:***	165
Coord. acc.:	Accurate to within 10 units	***Site status:***	Unused	***Drain. reg.:***	A41H
Coord. meth.:	Global Positioning System	***Site purp.:***	Exploration	***Rep. inst.:***	DWAF
		Use applic.:	Domestic - all purposes		
		Equipment:	No equipment		

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend





COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0018 ***Number:*** H21-0664 ***Site type:*** Borehole

Distr./Farm No.: LPLQ502 ***Site Name/Des.:*** WATERKLOOF PTN. ELLISRAS

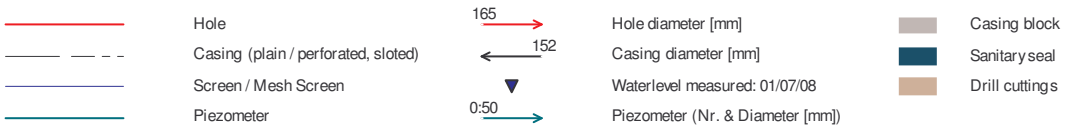
Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

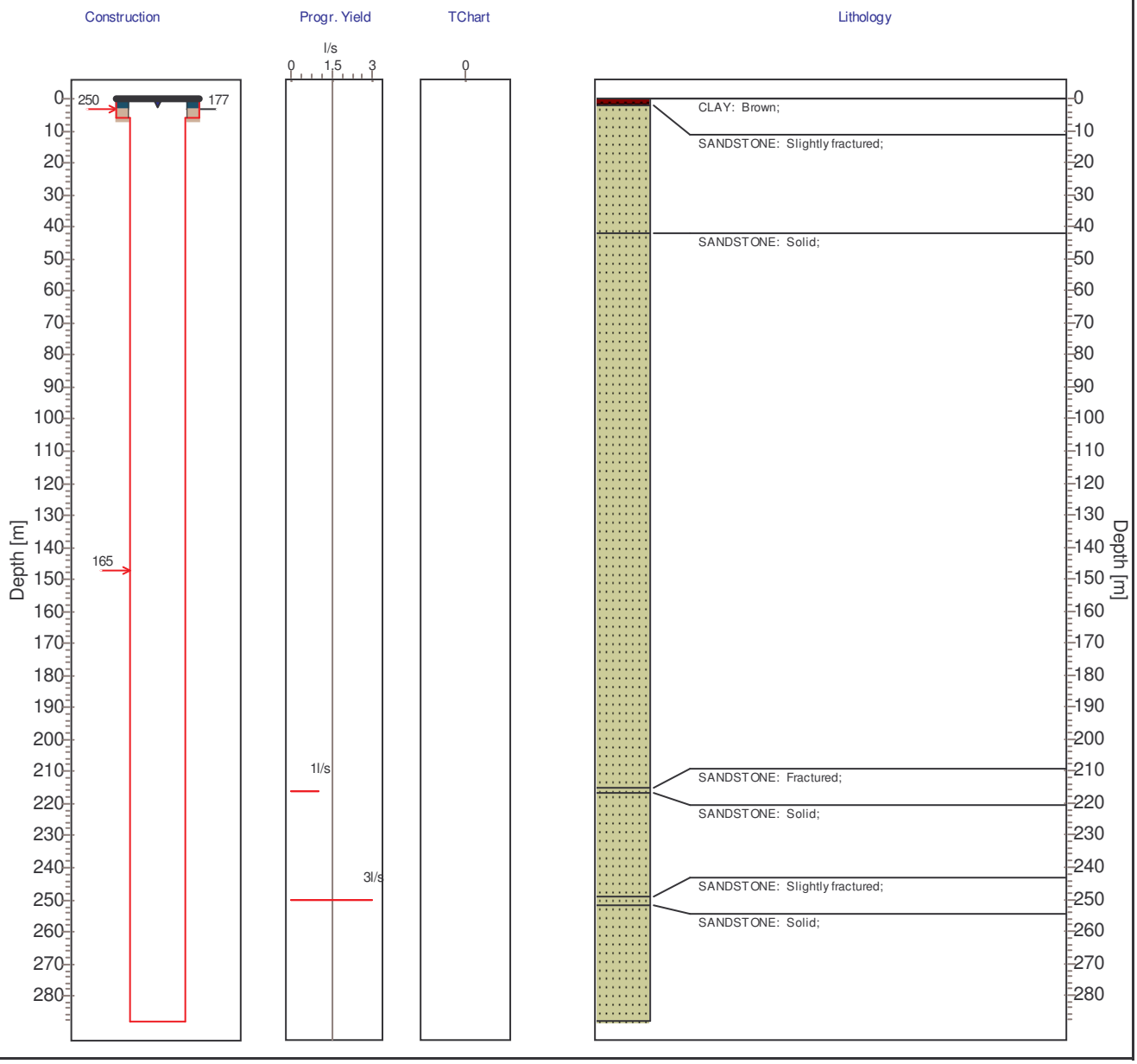
Latitude [°]:	23.687570	***Reg./BB.:***		***Topo-set.:***	Flat surface, plain
Longitude [°]:	27.722620	***G-Nr.:***		***Site status:***	Unused
Altitude [m]:	805.00			***Site purp.:***	Production (water supply)
Coord. acc.:	Accurate to within 10 units			***Use applic.:***	Domestic - all purposes
Coord. meth.:	Global Positioning System			***Equipment:***	No equipment

Depth [m]:	288.00
Col. ht. [m]:	0.21
Diam. [mm]:	165
Drain. reg.:	A42H
Rep. inst.:	DWAF

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend





COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0024 ***Number:*** H21-0665 ***Site type:*** Borehole

Distr./Farm No.: LPLQ502 ***Site Name/Des.:*** WATERKLOOF PTN. ELLISRAS

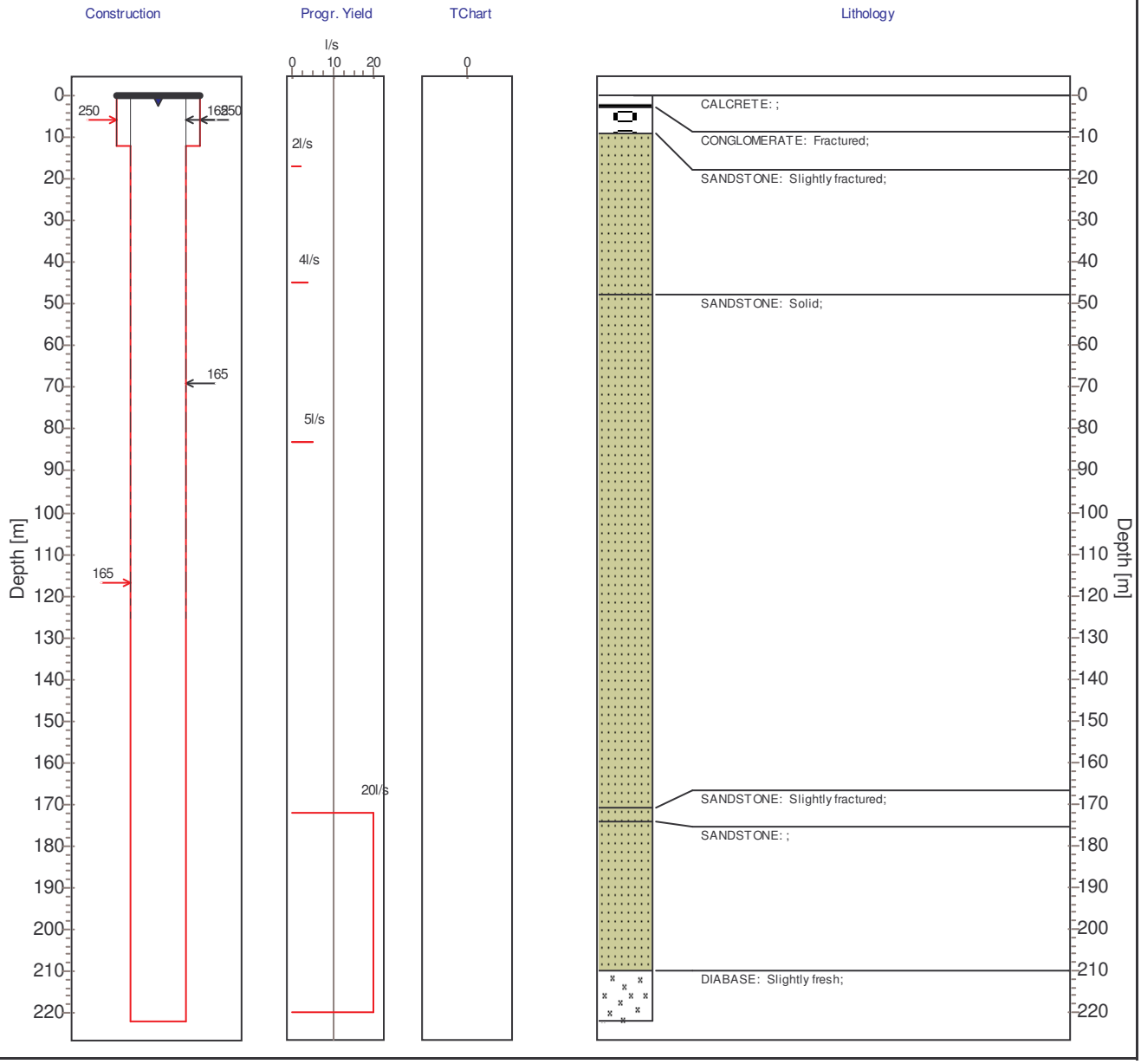
Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

Latitude [°]:	23.687083	***Reg./BB.:***		***Depth [m]:***	218.70
Longitude [°]:	27.725056	***G-Nr.:***		***Col. ht. [m]:***	0.33
Altitude [m]:	805.00	***Topo-set.:***	Flat surface, plain	***Diam. [mm]:***	165
Coord. acc.:	Accurate to within 10 units	***Site status:***	Unused	***Drain. reg.:***	A42H
Coord. meth.:	Global Positioning System	***Site purp.:***	Exploration	***Rep. inst.:***	VSA
		Use applic.:	Domestic - all purposes		
		Equipment:	No equipment		

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend

Hole
Casing (plain / perforated, sloted)
Screen / Mesh Screen
Piezometer
165 Hole diameter [mm]
152 Casing diameter [mm]
Waterlevel measured: 28/01/09
0:50 Piezometer (Nr. & Diameter [mm])



COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0022 ***Number:*** H21-0666 ***Site type:*** Borehole

Distr./Farm No.: LPLQ502 ***Site Name/Des.:*** WATERKLOOF PTN. ELLISRAS

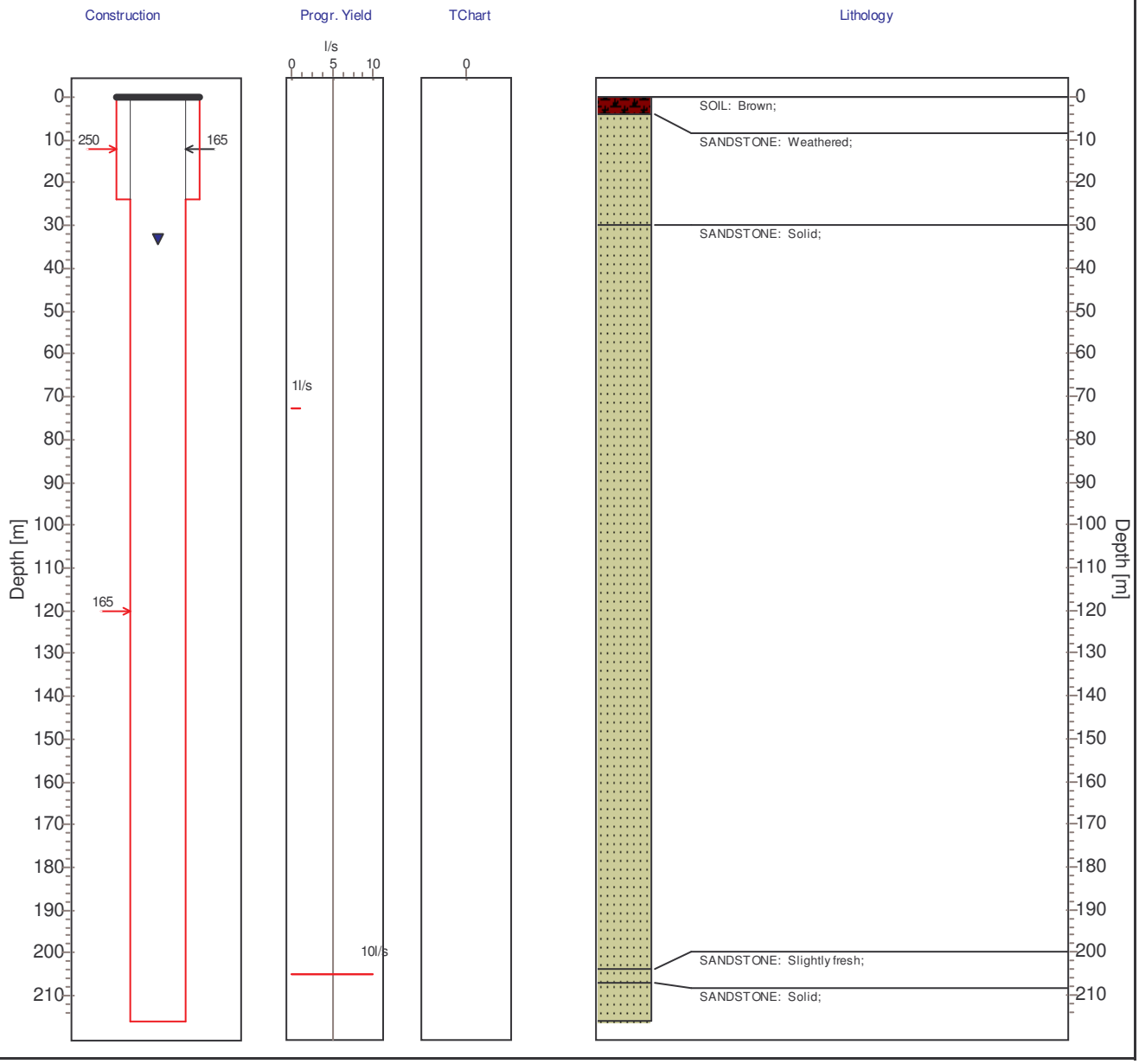
Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

Latitude [°]:	23.682639	***Reg./BB.:***		***Topo-set.:***	Flat surface, plain
Longitude [°]:	27.672917	***G-Nr.:***		***Site status:***	Unused
Altitude [m]:	854.00			***Site purp.:***	Production (water supply)
Coord. acc.:	Accurate to within 10 units			***Use applic.:***	Domestic - all purposes
Coord. meth.:	Global Positioning System			***Equipment:***	No equipment

Depth [m]:	216.00
Col. ht. [m]:	0.36
Diam. [mm]:	165
Drain. reg.:	A42H
Rep. inst.:	VSA

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend



COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0023 ***Number:*** H21-0667 ***Site type:*** Borehole

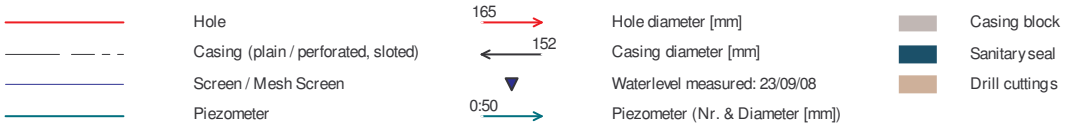
Distr./Farm No.: LPLQ503 ***Site Name/Des.:*** ONVERWACHT PTN. ELLISRAS

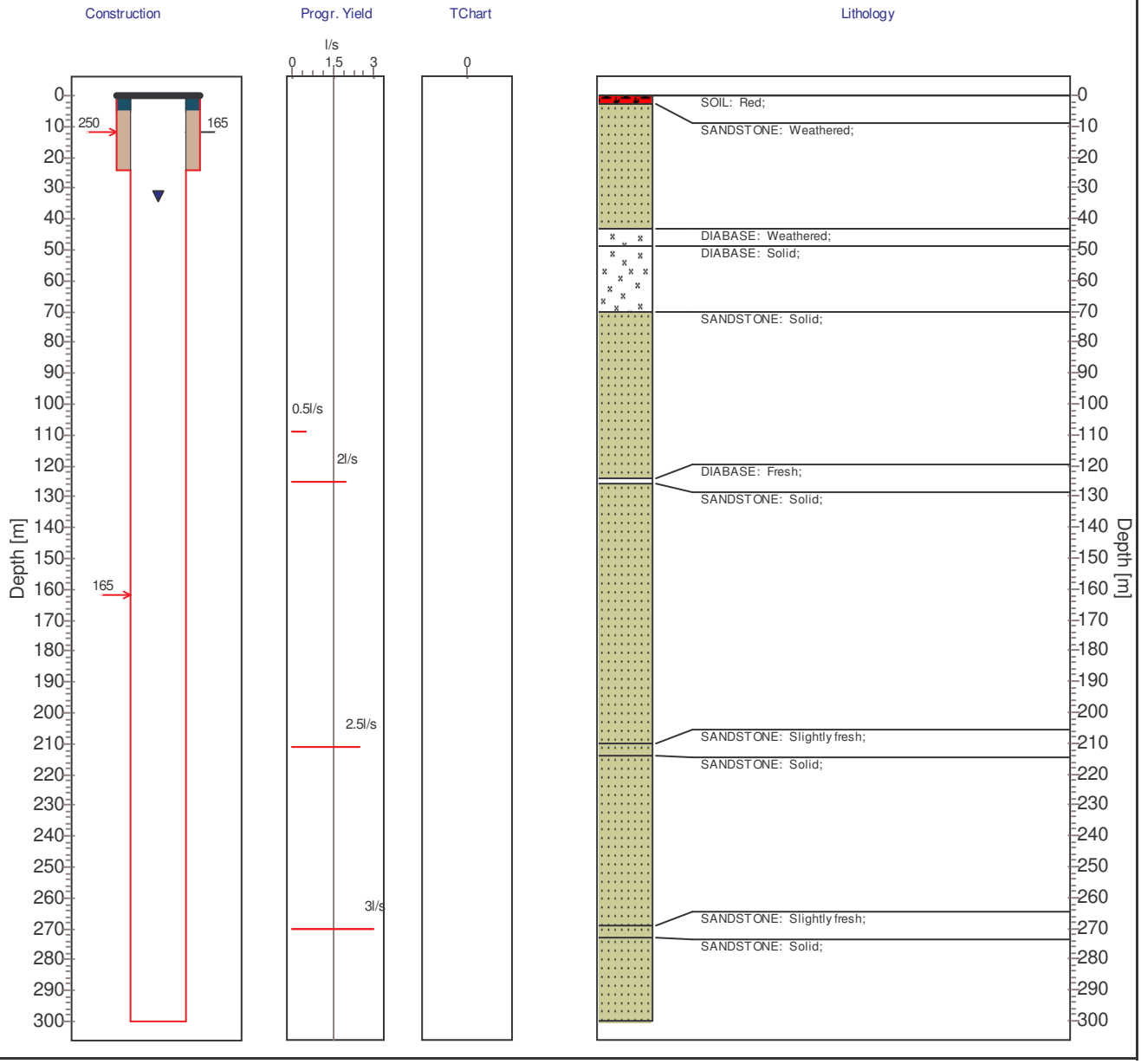
Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

Latitude [°]:	23.679389	***Reg./BB.:***		***Depth [m]:***	300.00
Longitude [°]:	27.677333	***G-Nr.:***		***Col. ht. [m]:***	0.53
Altitude [m]:	852.00	***Topo-set.:***	Flat surface, plain	***Diam. [mm]:***	165
Coord. acc.:	Accurate to within 10 units	***Site status:***	Unused	***Drain. reg.:***	A42H
Coord. meth.:	Global Positioning System	***Site purp.:***	Exploration	***Rep. inst.:***	DWAF
		Use applic.:	Domestic - all purposes		
		Equipment:	No equipment		

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend





COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2008/10/30

BASIC SITE INFORMATION: ***Site Identifier:*** 2327DAV0025 ***Number:*** H21-0668 ***Site type:*** Borehole

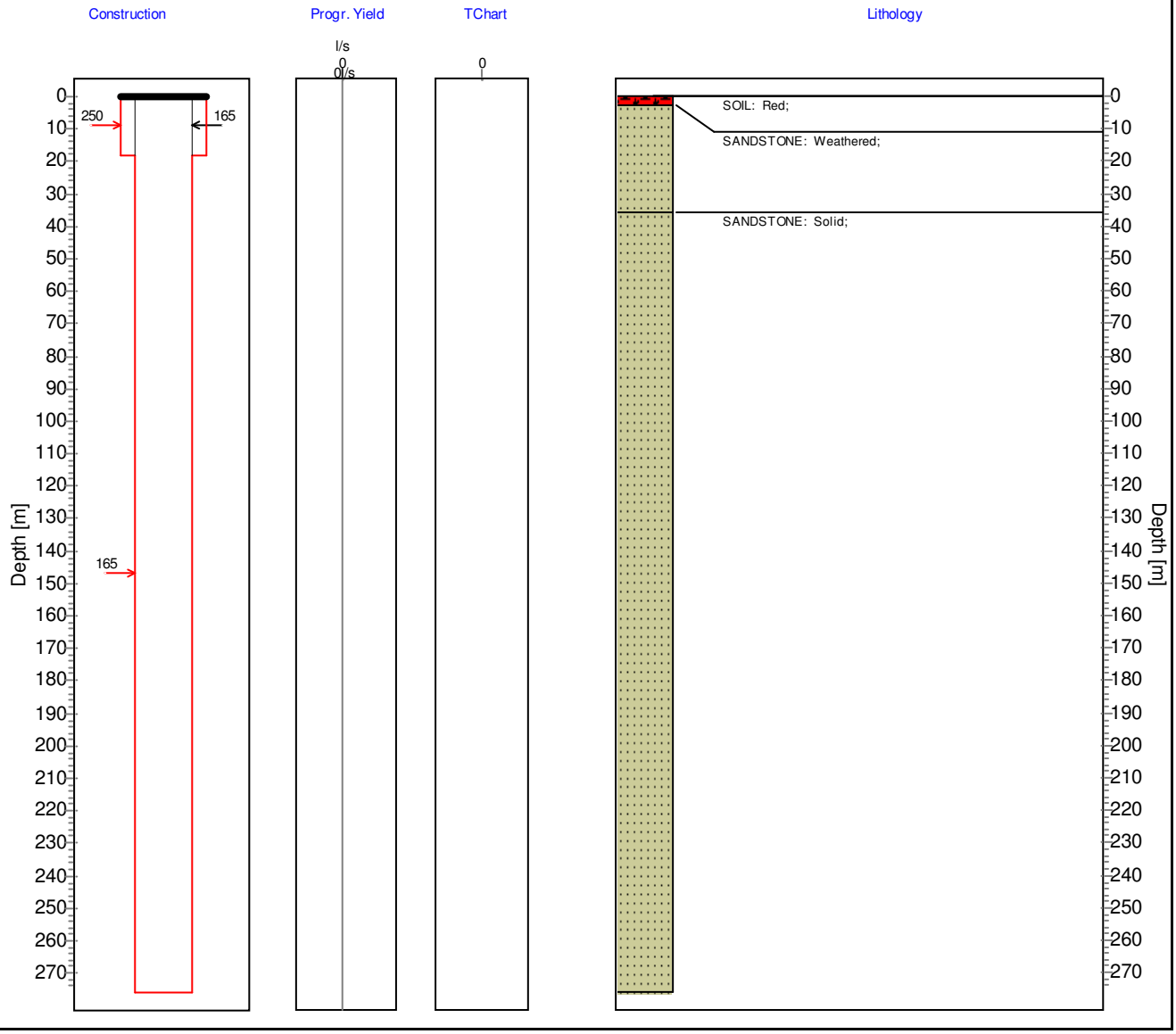
Distr./Farm No.: LPLQ506 ***Site Name/Des.:*** ALTOOSTYD PTN. ELLISRAS

Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

Latitude [°]:	23.694380	***Reg./BB.:***		***Topo-set.:***	Flat surface, plain	***Depth [m]:***	276.00
Longitude [°]:	27.625910	***G-Nr.:***		***Site status:***	Unused	***Col. ht. [m]:***	0.21
Altitude [m]:	862.00			***Site purp.:***	Exploration	***Diam. [mm]:***	165
Coord. acc.:	Accurate to within 10 units			***Use applic.:***	Domestic - all purposes	***Drain. reg.:***	A42H
Coord. meth.:	Global Positioning System			***Equipment:***	No equipment	***Rep. inst.:***	DWAF

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend



COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0026 ***Number:*** H21-0669 ***Site type:*** Borehole

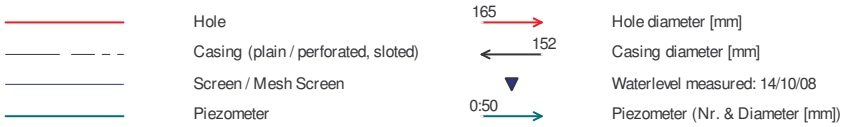
Distr./Farm No.: LPLQ522 ***Site Name/Des.:*** PAARL PTN. ELLISRAS

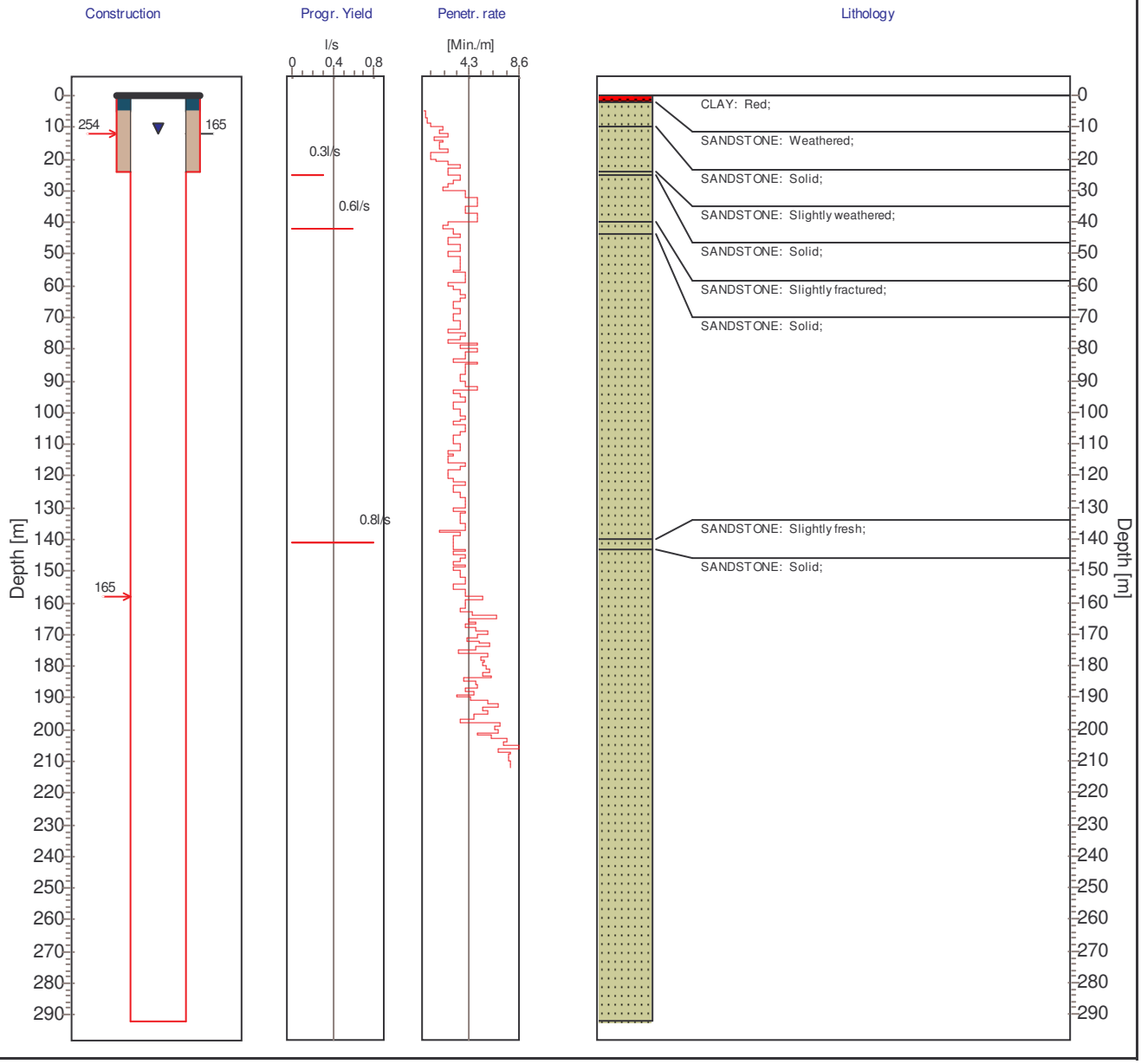
Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

Latitude [°]:	23.693310	***Reg./BB.:***		***Depth [m]:***	291.00
Longitude [°]:	27.705080	***G-Nr.:***		***Col. ht. [m]:***	0.61
Altitude [m]:	833.00	***Topo-set.:***	Flat surface, plain	***Diam. [mm]:***	165
Coord. acc.:	Accurate to within 10 units	***Site status:***	Unused	***Drain. reg.:***	A42H
Coord. meth.:	Global Positioning System	***Site purp.:***	Exploration	***Rep. inst.:***	DWAF
		Use applic.:	Domestic - all purposes		
		Equipment:	No equipment		

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend





COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0027 ***Number:*** H21-0670 ***Site type:*** Borehole

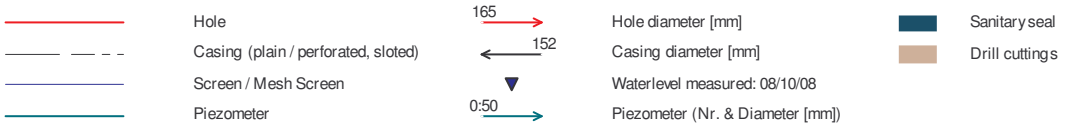
Distr./Farm No.: LPLQ522 ***Site Name/Des.:*** PAARL PTN. ELLISRAS

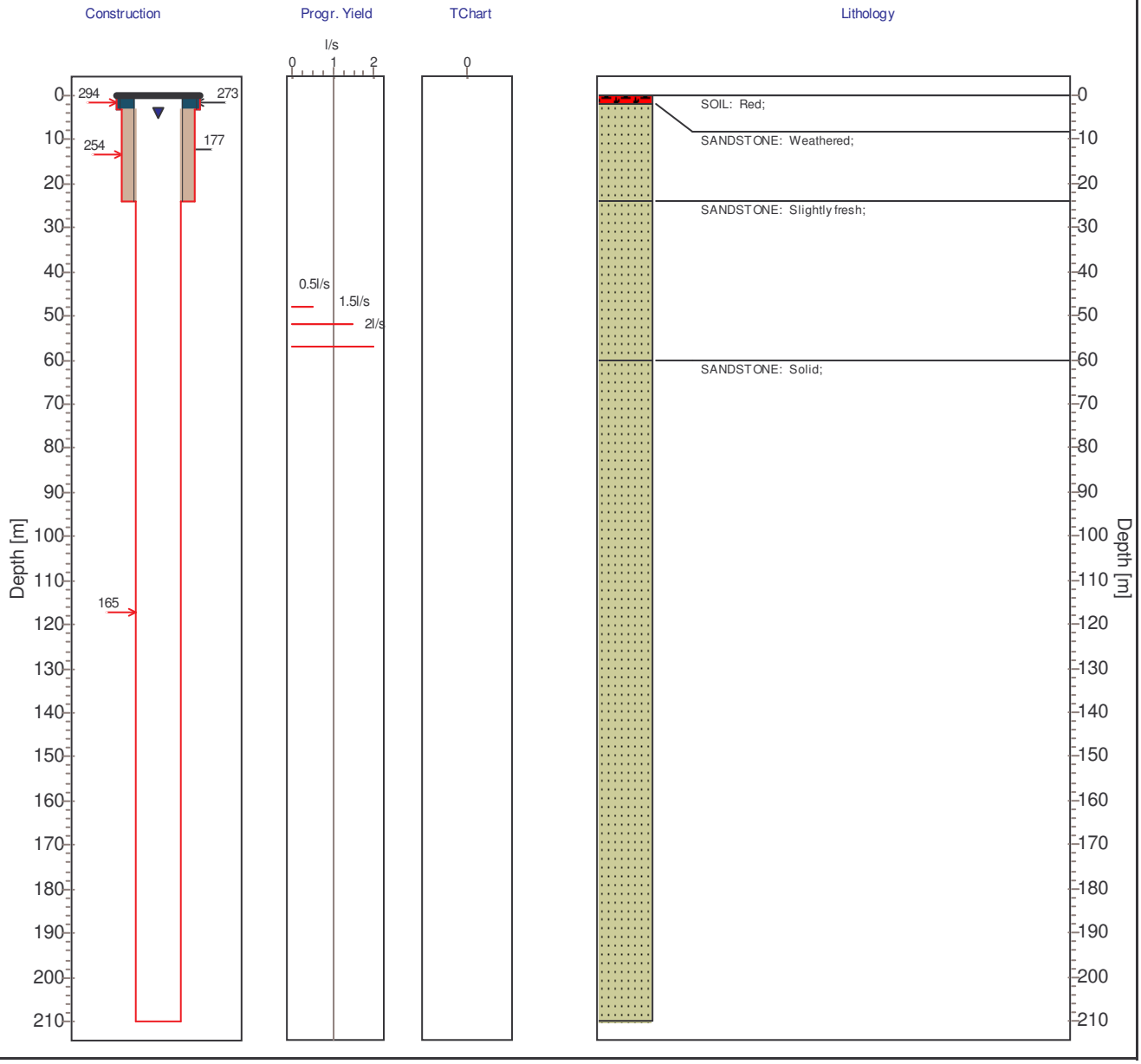
Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

Latitude [°]:	23.711660	***Reg./BB.:***		***Depth [m]:***	213.00
Longitude [°]:	27.657130	***G-Nr.:***		***Col. ht. [m]:***	0.21
Altitude [m]:	860.00	***Topo-set.:***	Flat surface, plain	***Diam. [mm]:***	165
Coord. acc.:	Accurate to within 10 units	***Site status:***	Unused	***Drain. reg.:***	A42H
Coord. meth.:	Global Positioning System	***Site purp.:***	Exploration	***Rep. inst.:***	DWAF
		Use applic.:	Domestic - all purposes		
		Equipment:	No equipment		

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend





COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0028 ***Number:*** H21-0671 ***Site type:*** Borehole

Distr./Farm No.: LPLQ501 ***Site Name/Des.:*** GROOTFONTEIN PTN. ELLISRAS

Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

Latitude [°]:	23.641790	***Reg./BB.:***		***Depth [m]:***	126.00
Longitude [°]:	27.752490	***G-Nr.:***		***Col. ht. [m]:***	0
Altitude [m]:	817.00	***Topo-set.:***	Flat surface, plain	***Diam. [mm]:***	165
Coord. acc.:	Accurate to within 10 units	***Site status:***	Unused	***Drain. reg.:***	A42H
Coord. meth.:	Global Positioning System	***Site purp.:***	Exploration	***Rep. inst.:***	DWAF
		Use applic.:	Domestic - all purposes		
		Equipment:	No equipment		

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

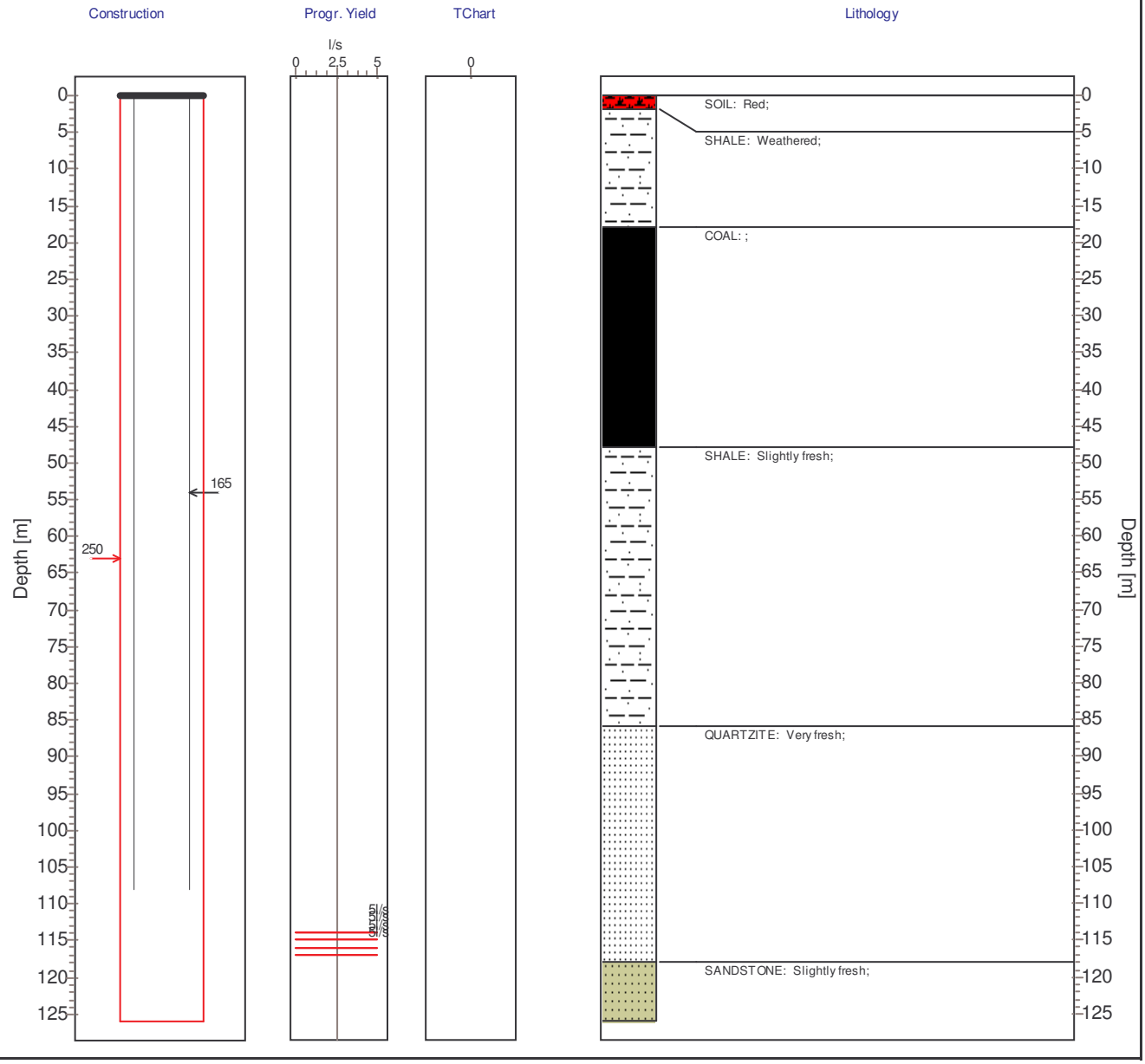
Construction and Geohydrological Legend

Hole — Hole diameter [mm] (165)

Casing (plain / perforated, sloted) — Casing diameter [mm] (152)

Screen / Mesh Screen — Waterlevel with date meas.

Piezometer — Piezometer (Nr. & Diameter [mm]) (0:50)



COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2009/02/26

BASIC SITE INFORMATION: ***Site Identifier:*** 2327DAV0029 ***Number:*** H21-0672 ***Site type:*** Borehole

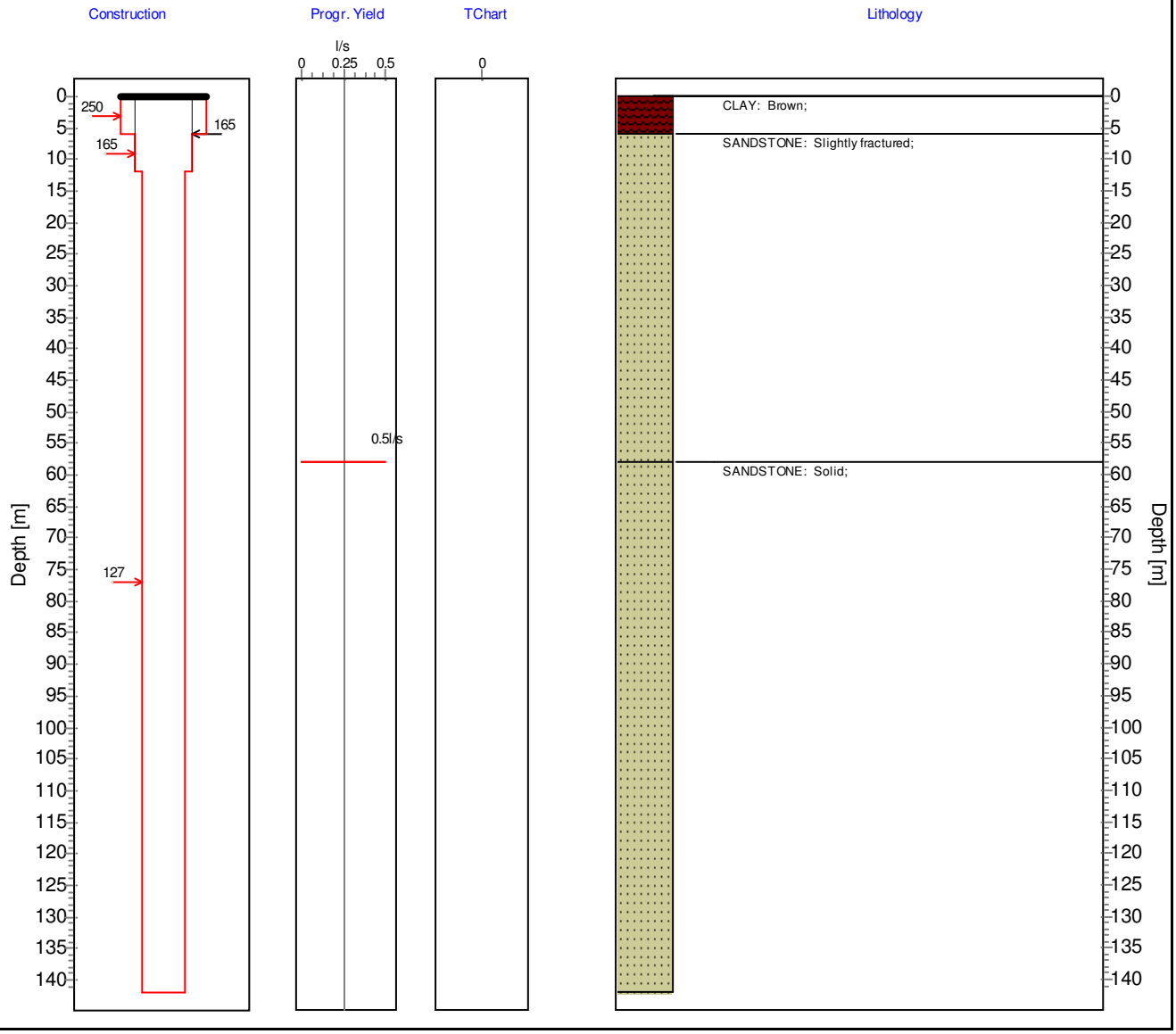
Distr./Farm No.: LPLQ502 ***Site Name/Des.:*** WATERKLOOF PTN. ELLISRAS

Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

Latitude [°]:	23.686260	***Reg./BB.:***	***Topo-set.:***	***Depth [m]:***	142.00
Longitude [°]:	27.729150	***G-Nr.:***	***Site status:*** Unused	***Col. ht. [m]:***	0.42
Altitude [m]:	802.00		***Site purp.:*** Exploration	***Diam. [mm]:***	
Coord. acc.:			***Use applic.:***	***Drain. reg.:***	A42H
Coord. meth.:			***Equipment:*** No equipment	***Rep. inst.:***	DWAF

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend



COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0030 ***Number:*** H21-0680 ***Site type:*** Borehole

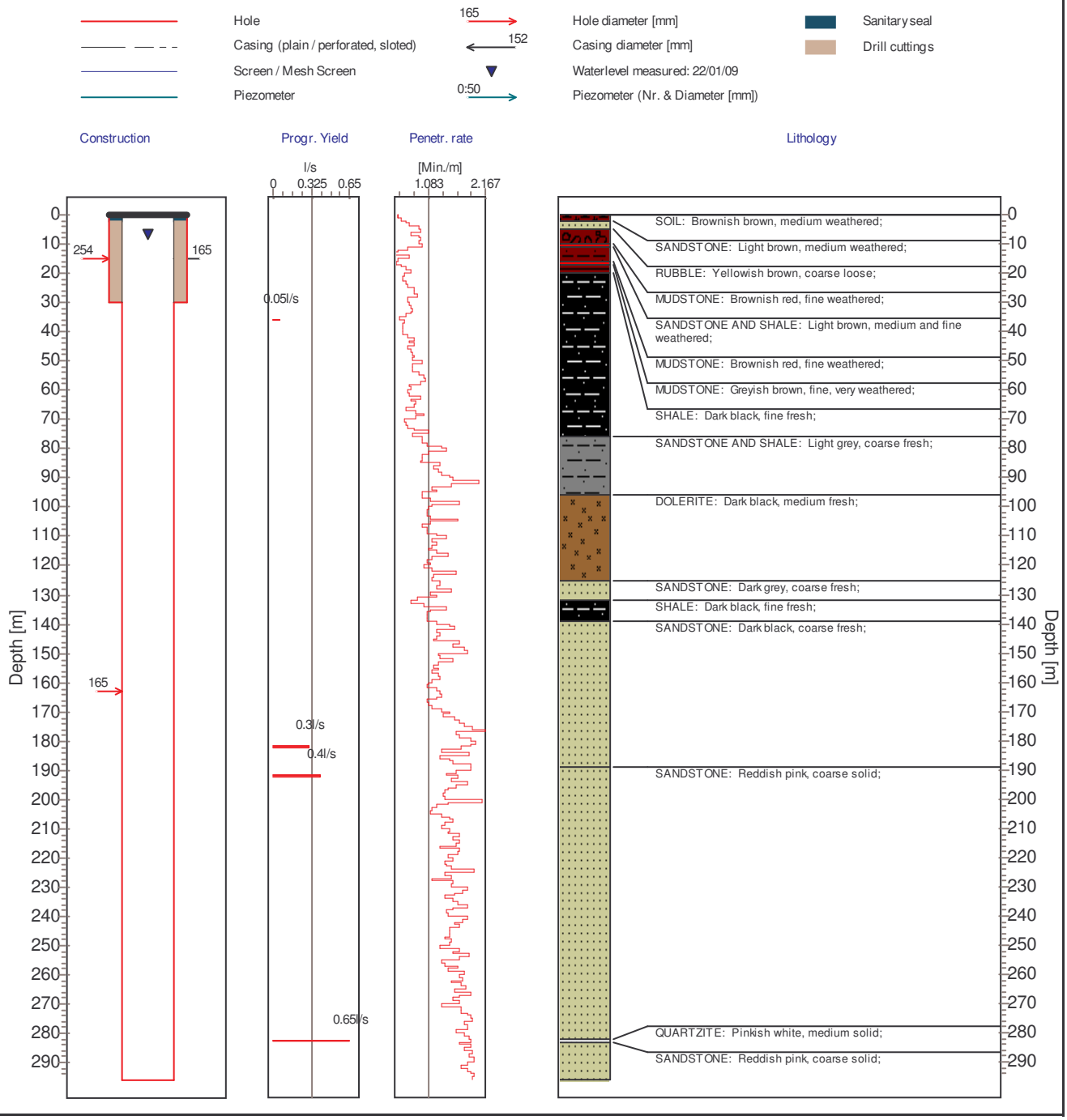
Distr./Farm No.: LPLQ472 ***Site Name/Des.:*** VOGELSTRUISFONTEIN PTN. ELLISRAS

Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

Latitude [°]:	23.611916	***Reg./BB.:***		***Depth [m]:***	296.00
Longitude [°]:	27.743194	***G-Nr.:***		***Col. ht. [m]:***	0.30
Altitude [m]:	820.00	***Topo-set.:***	Hillside (slope)	***Diam. [mm]:***	165
Coord. acc.:	Accurate to within 10 units	***Site status:***	Unused	***Drain. reg.:***	A42H
Coord. meth.:	Global Positioning System	***Site purp.:***	Exploration	***Rep. inst.:***	VSA
		Use applic.:	Domestic - all purposes		
		Equipment:	No equipment		

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend



COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0031 ***Number:*** H21-0681 ***Site type:*** Borehole

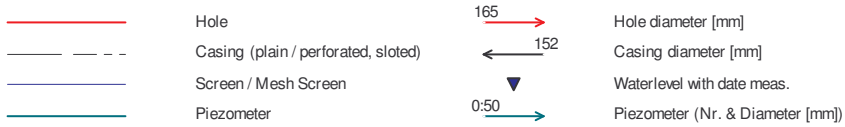
Distr./Farm No.: LPLQ472 ***Site Name/Des.:*** VOGELSTRUISFONTEIN PTN. ELLISRAS

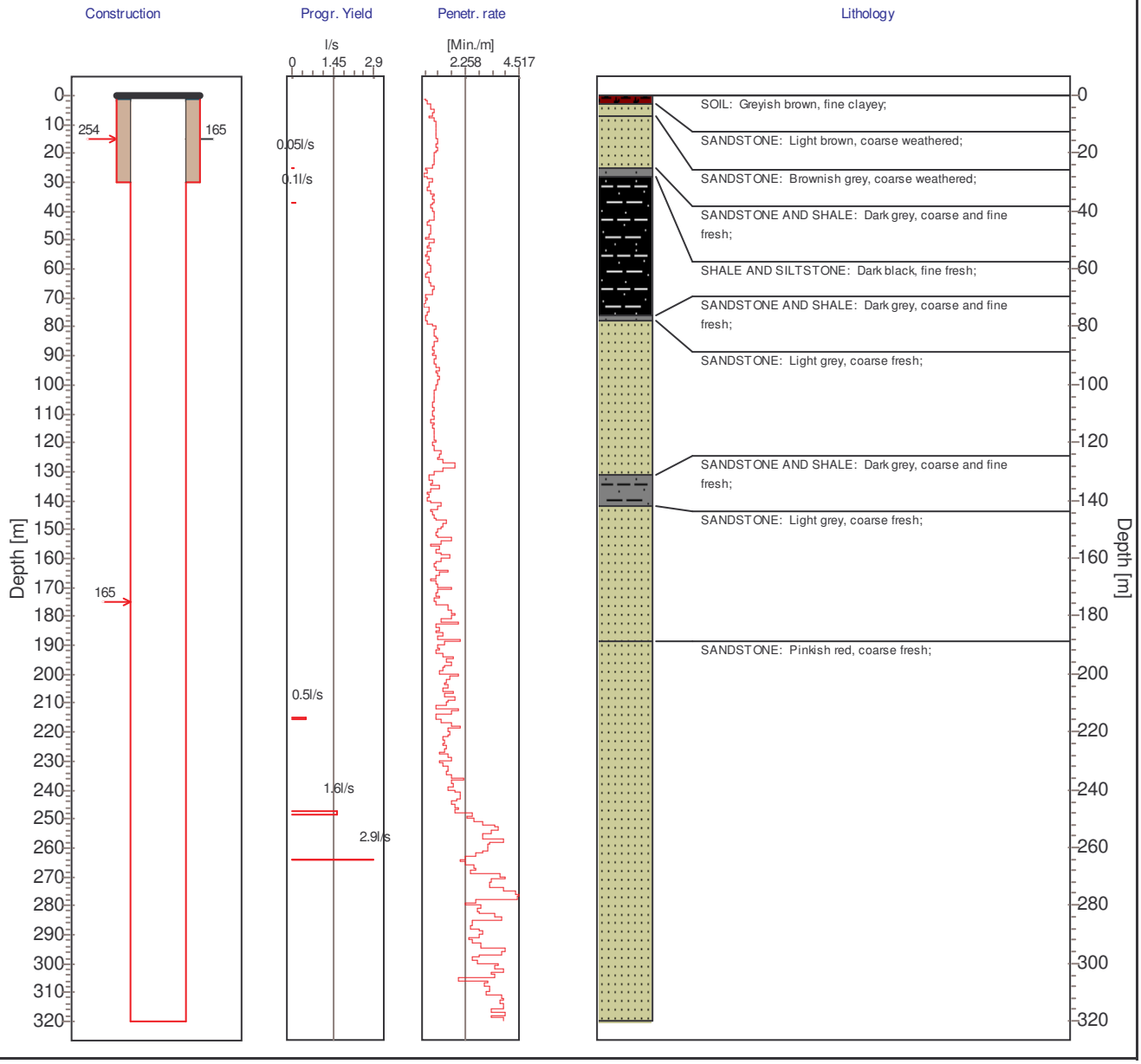
Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

Latitude [°]:	23.613111	***Reg./BB.:***		***Depth [m]:***	291.24
Longitude [°]:	27.743806	***G-Nr.:***		***Col. ht. [m]:***	0.60
Altitude [m]:	815.00	***Topo-set.:***	Ephemeral stream	***Diam. [mm]:***	165
Coord. acc.:	Accurate to within 10 units	***Site status:***	Unused	***Drain. reg.:***	A42H
Coord. meth.:	Global Positioning System	***Site purp.:***	Exploration	***Rep. inst.:***	VSA
		Use applic.:	Domestic - all purposes		
		Equipment:	No equipment		

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend





COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0032 ***Number:*** H21-0700 ***Site type:*** Borehole

Distr./Farm No.: LPLQ502 ***Site Name/Des.:*** WATERKLOOF PTN. ELLISRAS

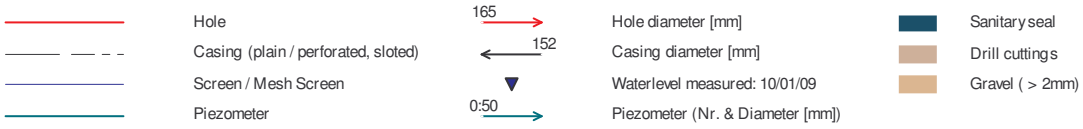
Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

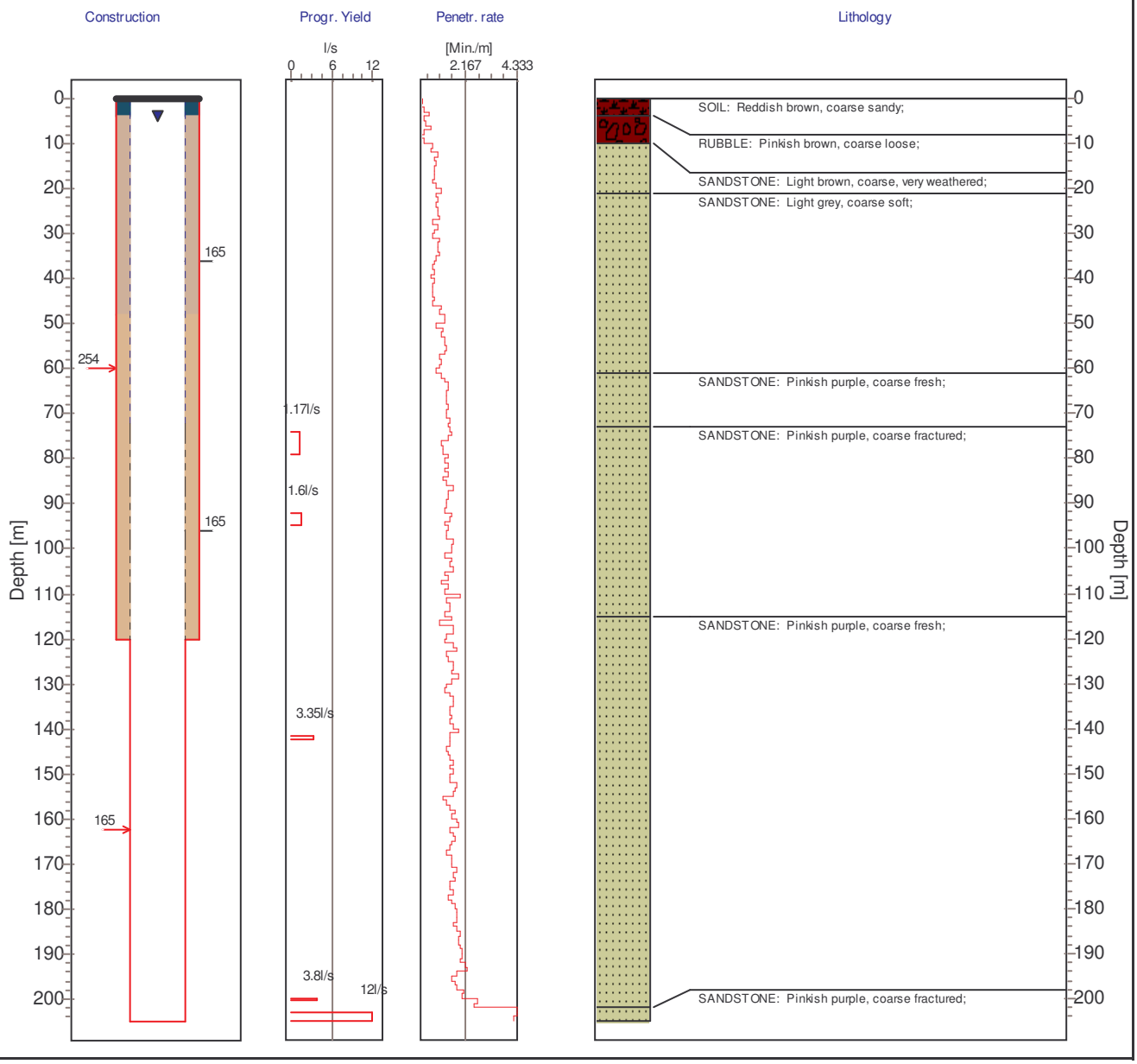
Latitude [°]:	23.681694	***Reg./BB.:***		***Topo-set.:***	Flat surface, plain
Longitude [°]:	27.726361	***G-Nr.:***		***Site status:***	Unused
Altitude [m]:	830.00			***Site purp.:***	Exploration
Coord. acc.:	Accurate to within 100 units			***Use applic.:***	Domestic - all purposes
Coord. meth.:	Global Positioning System			***Equipment:***	No equipment

Depth [m]:	204.82
Col. ht. [m]:	0.50
Diam. [mm]:	165
Drain. reg.:	A42H
Rep. inst.:	VSA

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend





COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0033 ***Number:*** H21-0701 ***Site type:*** Borehole

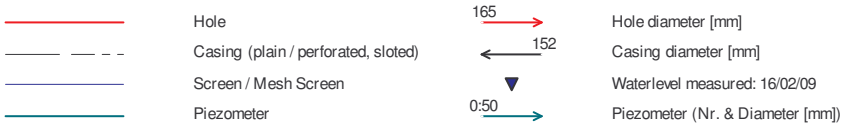
Distr./Farm No.: LPLQ502 ***Site Name/Des.:*** WATERKLOOF PTN. ELLISRAS

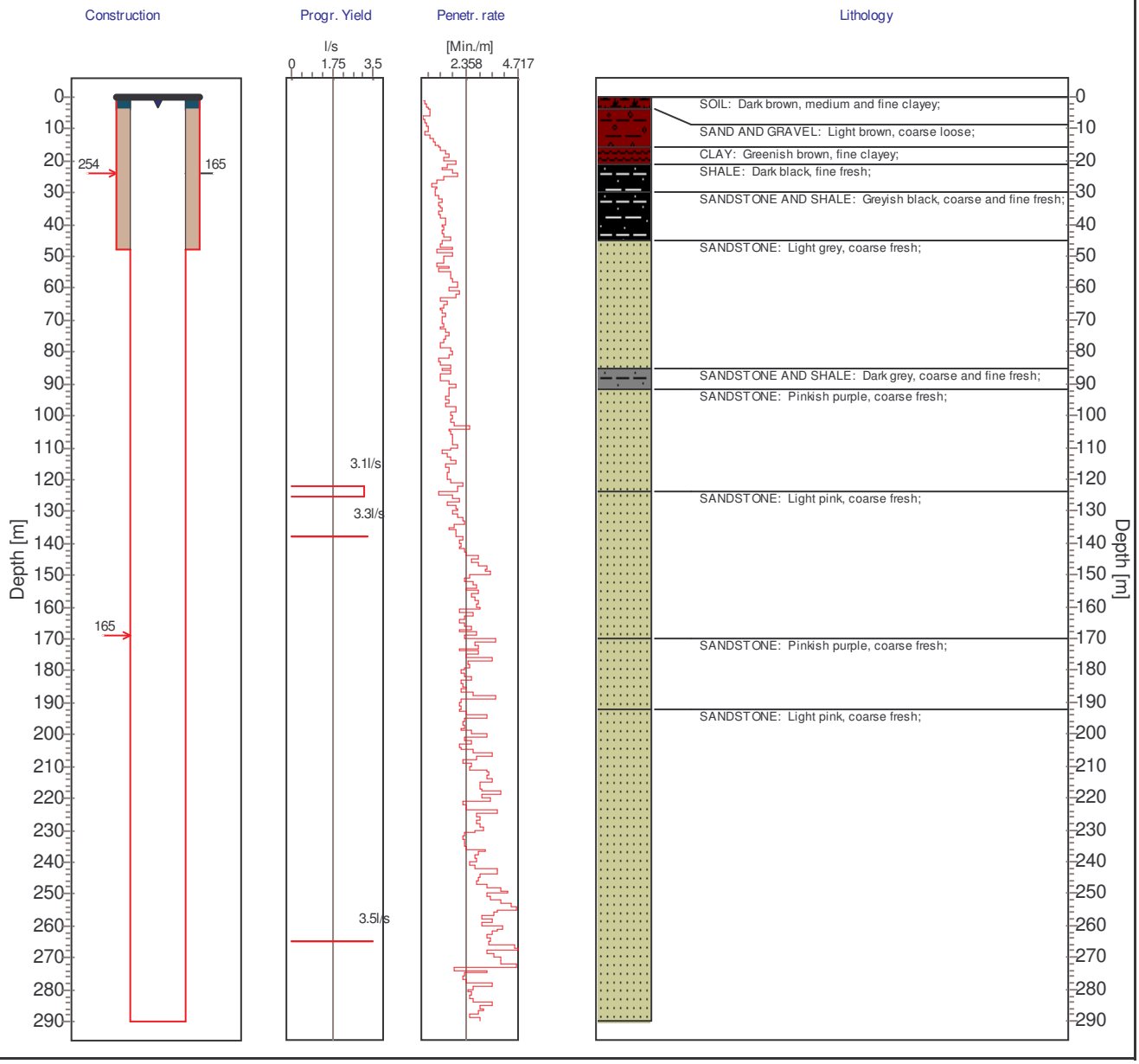
Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

Latitude [°]:	23.682861	***Reg./BB.:***		***Depth [m]:***	248.46
Longitude [°]:	27.741861	***G-Nr.:***		***Col. ht. [m]:***	0.50
Altitude [m]:	815.00	***Topo-set.:***	Flat surface, plain	***Diam. [mm]:***	165
Coord. acc.:	Accurate to within 100 units	***Site status:***	Unused	***Drain. reg.:***	A42H
Coord. meth.:	Global Positioning System	***Site purp.:***	Exploration	***Rep. inst.:***	VSA
		Use applic.:	Domestic - all purposes		
		Equipment:	No equipment		

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend





COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0034 ***Number:*** H21-0702 ***Site type:*** Borehole

Distr./Farm No.: LPLQ502 ***Site Name/Des.:*** WATERKLOOF PTN. ELLISRAS

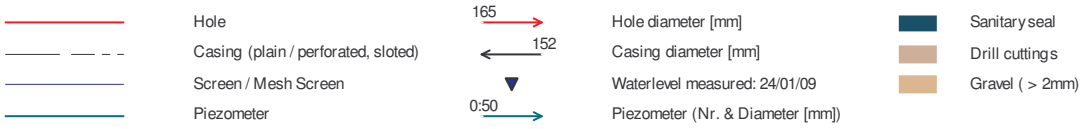
Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

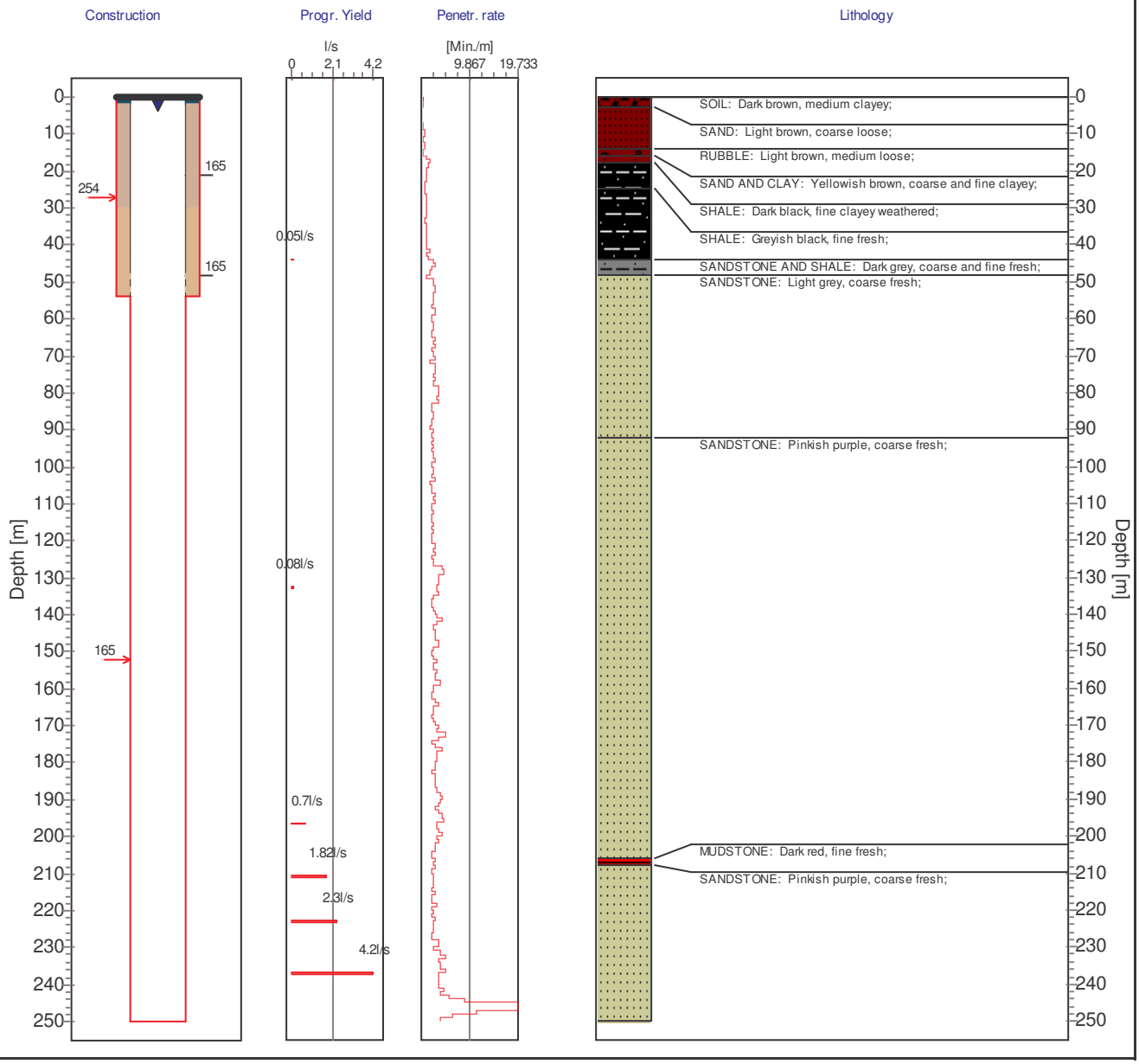
Latitude [°]:	23.676639	***Reg./BB.:***		***Topo-set.:***	In or along river
Longitude [°]:	27.744417	***G-Nr.:***		***Site status:***	Unused
Altitude [m]:	815.00			***Site purp.:***	Exploration
Coord. acc.:	Accurate to within 10 units			***Use applic.:***	Domestic - all purposes
Coord. meth.:	Global Positioning System			***Equipment:***	No equipment

Depth [m]:	250.00
Col. ht. [m]:	0.50
Diam. [mm]:	165
Drain. reg.:	A42H
Rep. inst.:	VSA

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend





COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0035 ***Number:*** H21-0703 ***Site type:*** Borehole

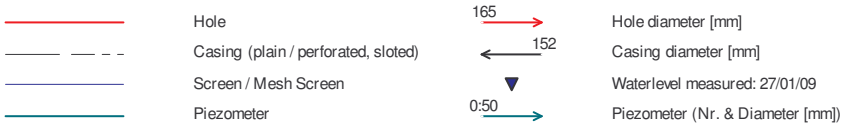
Distr./Farm No.: LPLQ502 ***Site Name/Des.:*** WATERKLOOF PTN. ELLISRAS

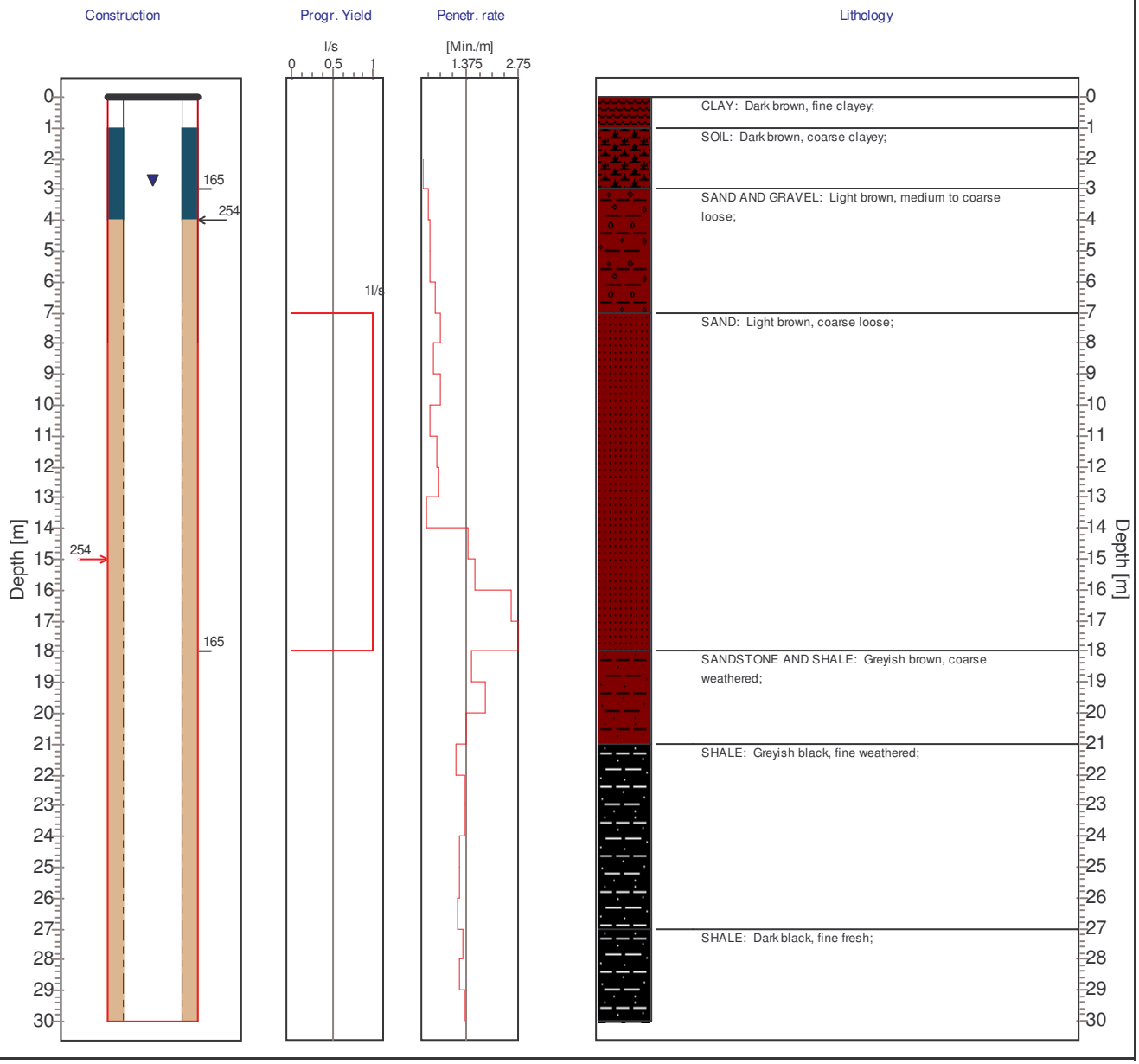
Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

Latitude [°]:	23.676666	***Reg./BB.:***		***Depth [m]:***	30.00
Longitude [°]:	27.744444	***G-Nr.:***		***Col. ht. [m]:***	0.50
Altitude [m]:	815.00	***Topo-set.:***	In or along river	***Diam. [mm]:***	254
Coord. acc.:	Accurate to within 100 units	***Site status:***	Unused	***Drain. reg.:***	A42H
Coord. meth.:	Global Positioning System	***Site purp.:***	Mine drainage	***Rep. inst.:***	VSA
		Use applic.:	Domestic - all purposes		
		Equipment:	No equipment		

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend





COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DBV0012 ***Number:*** H21-0704 ***Site type:*** Borehole

Distr./Farm No.: LPLQ501 ***Site Name/Des.:*** GROOTFONTEIN PTN. ELLISRAS

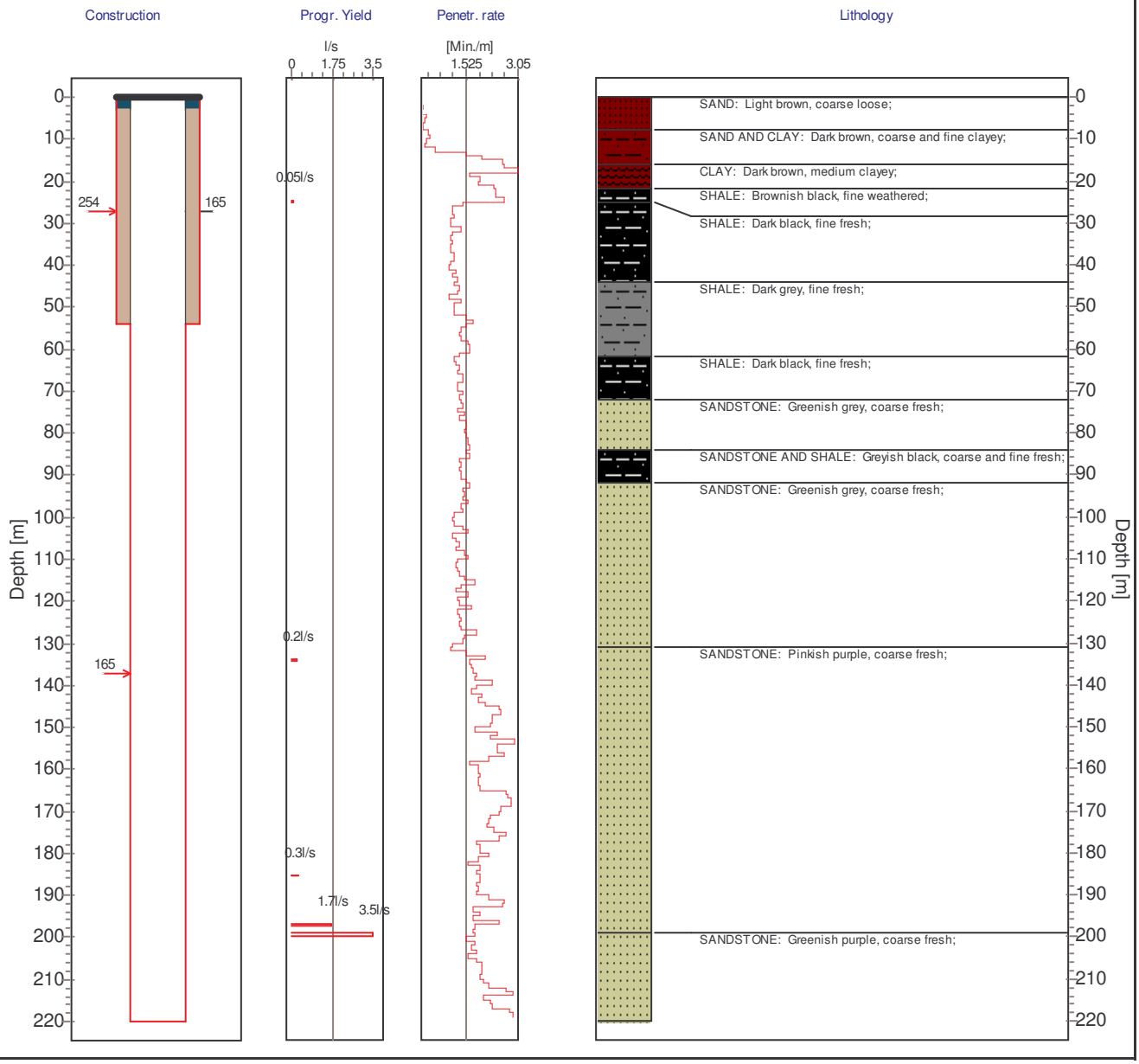
Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

Latitude [°]:	23.654722	***Reg./BB.:***		***Depth [m]:***	220.00
Longitude [°]:	27.759194	***G-Nr.:***		***Col. ht. [m]:***	0.45
Altitude [m]:	820.00	***Topo-set.:***	In or along river	***Diam. [mm]:***	165
Coord. acc.:	Accurate to within 10 units	***Site status:***	Unused	***Drain. reg.:***	A42H
Coord. meth.:	Global Positioning System	***Site purp.:***	Production (water supply)	***Rep. inst.:***	VSA
		Use applic.:	Domestic - all purposes		
		Equipment:	No equipment		

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend

Hole
Casing (plain / perforated, sloted)
Screen / Mesh Screen
Piezometer
165 — Hole diameter [mm]
152 — Casing diameter [mm]
Waterlevel with date meas.
0:50 — Piezometer (Nr. & Diameter [mm])
Casing block
Sanitary seal
Drill cuttings



COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DBV0013 ***Number:*** H21-0706 ***Site type:*** Borehole

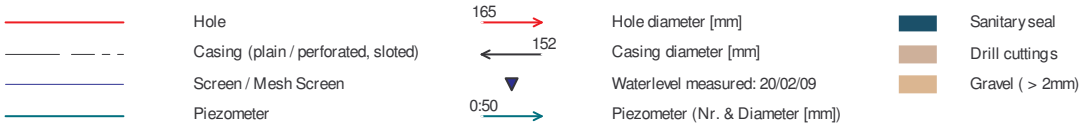
Distr./Farm No.: LPLQ501 ***Site Name/Des.:*** GROOTFONTEIN PTN. ELLISRAS

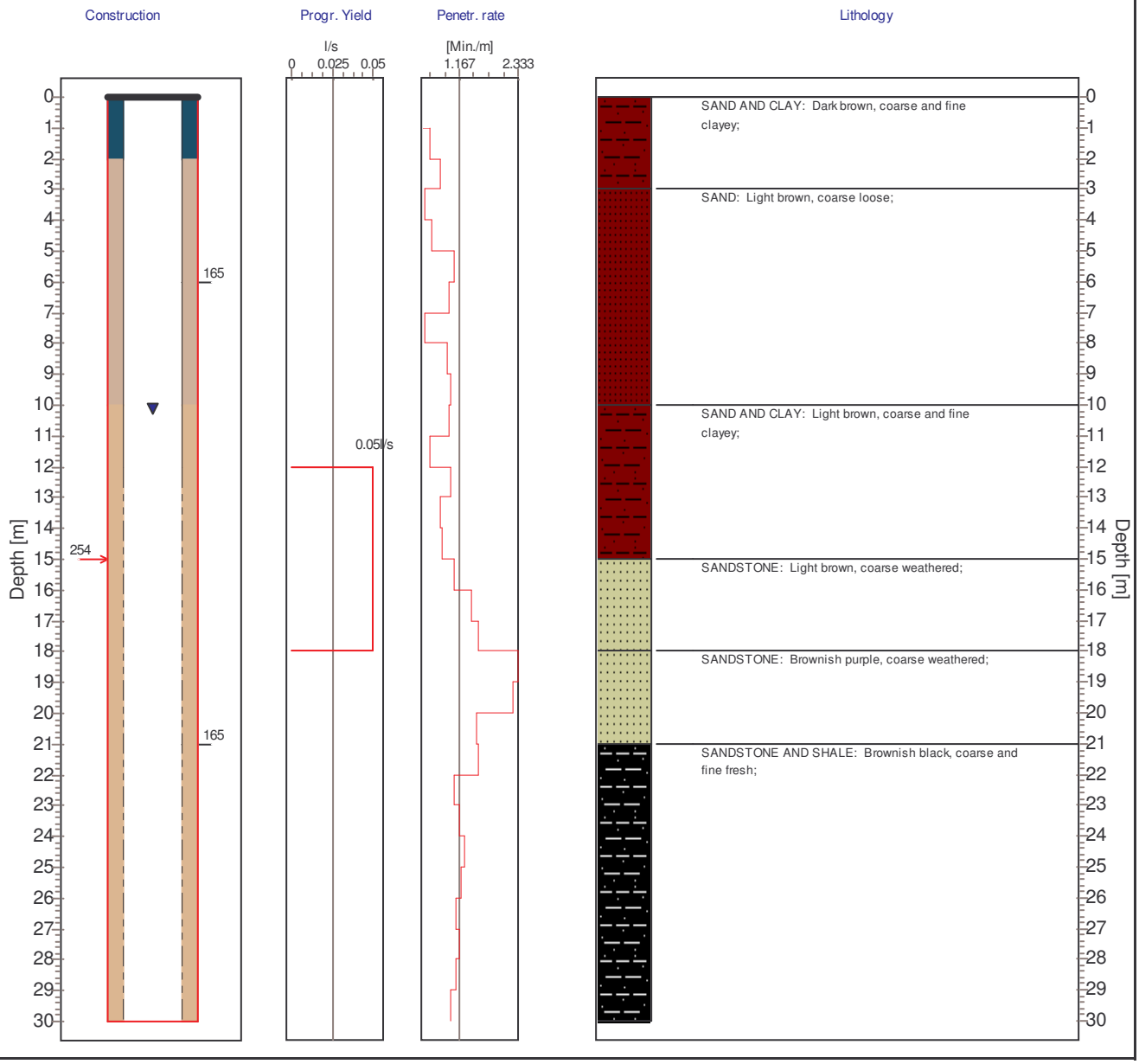
Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

Latitude [°]:	23.659111	***Reg./BB.:***		***Depth [m]:***	30.00
Longitude [°]:	27.756694	***G-Nr.:***		***Col. ht. [m]:***	0.50
Altitude [m]:	820.00	***Topo-set.:***	In or along river	***Diam. [mm]:***	165
Coord. acc.:	Accurate to within 10 units	***Site status:***	Unused	***Drain. reg.:***	A42H
Coord. meth.:	Global Positioning System	***Site purp.:***	Exploration	***Rep. inst.:***	VSA
		Use applic.:	Domestic - all purposes		
		Equipment:	No equipment		

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend





COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0036 ***Number:*** H21-0707 ***Site type:*** Borehole

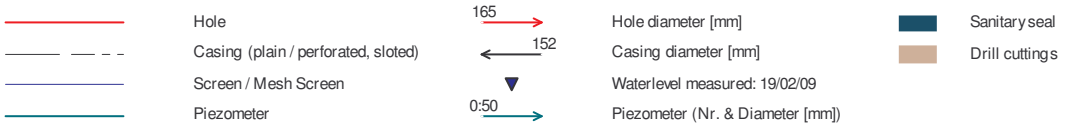
Distr./Farm No.: LPLQ591 ***Site Name/Des.:*** RIVERSBEND PTN. ELLISRAS

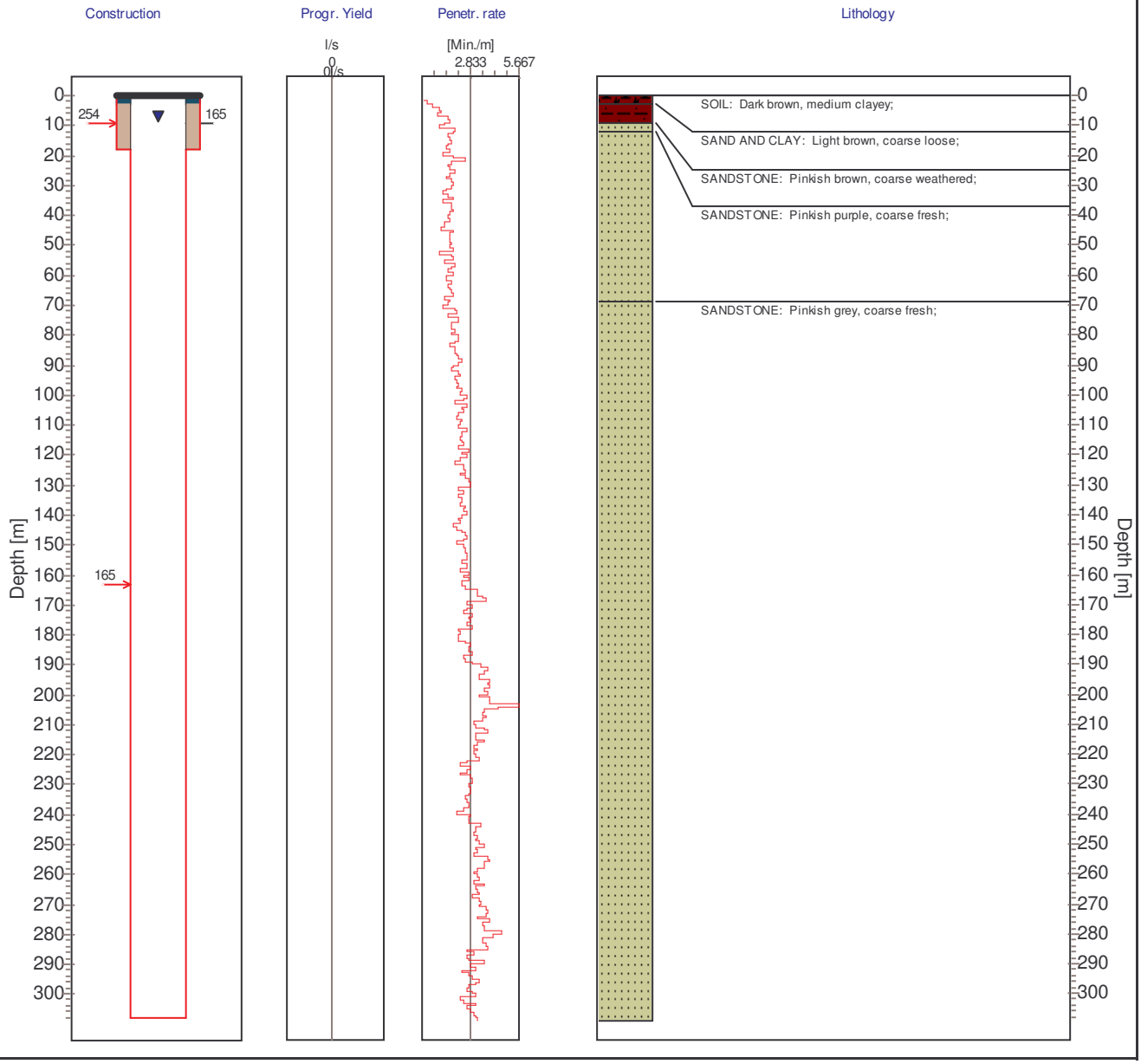
Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

Latitude [°]:	23.731611	***Reg./BB.:***		***Depth [m]:***	305.00
Longitude [°]:	27.746639	***G-Nr.:***		***Col. ht. [m]:***	0.45
Altitude [m]:	825.00	***Topo-set.:***	In or along sinkhole	***Diam. [mm]:***	165
Coord. acc.:	Accurate to within 10 units	***Site status:***	Unused	***Drain. reg.:***	A42H
Coord. meth.:	Global Positioning System	***Site purp.:***	Exploration	***Rep. inst.:***	VSA
		Use applic.:	Domestic - all purposes		
		Equipment:	No equipment		

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend





COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DCV0005 ***Number:*** H21-0708 ***Site type:*** Borehole

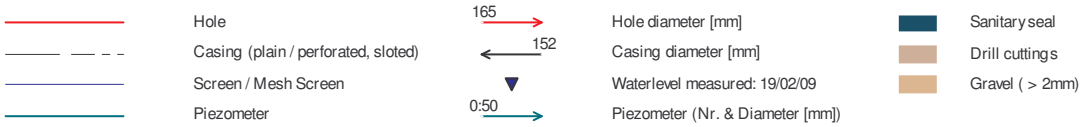
Distr./Farm No.: LPLQ591 ***Site Name/Des.:*** RIVERSBEND PTN. ELLISRAS

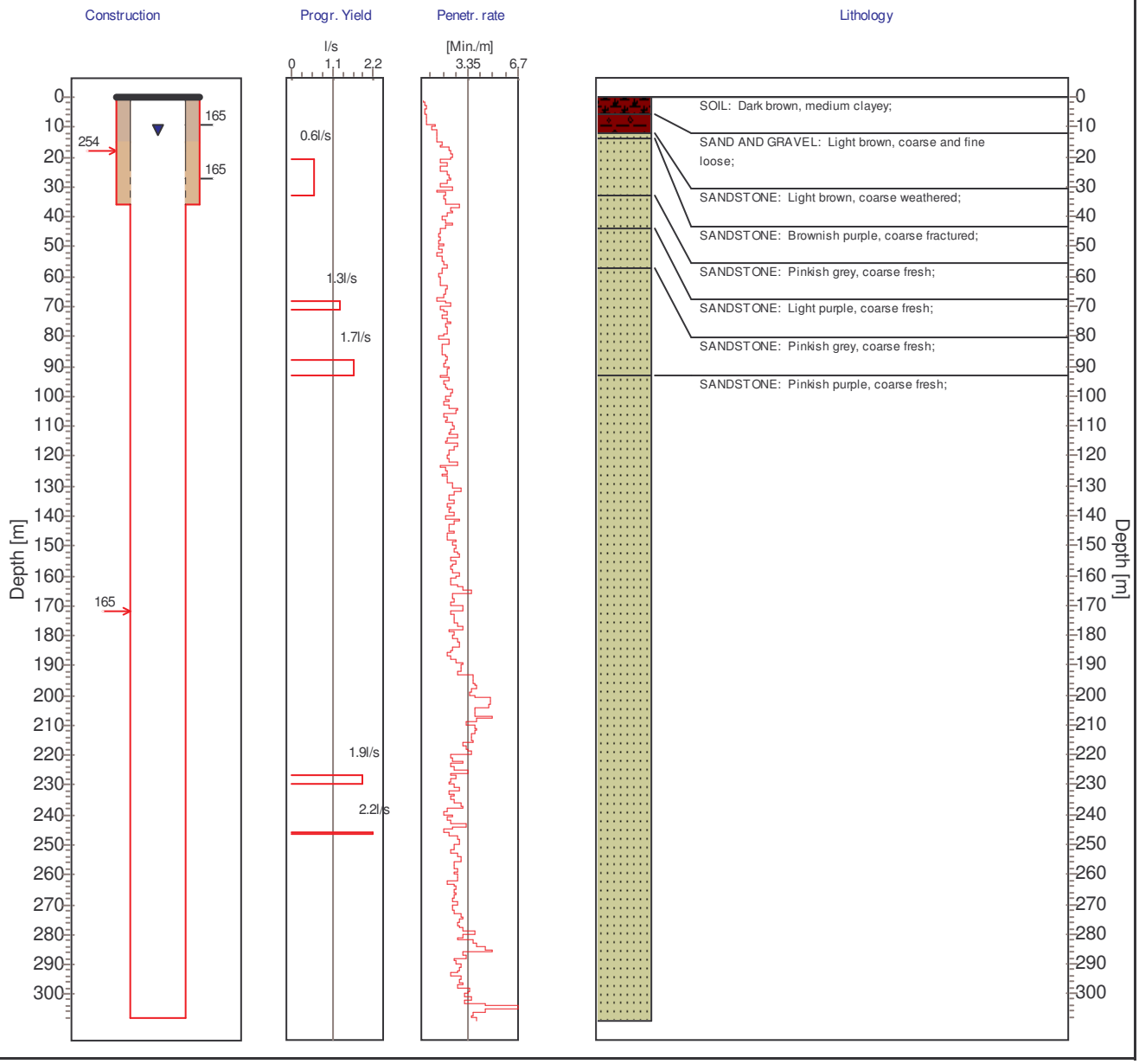
Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

Latitude [°]:	23.757583	***Reg./BB.:***		***Depth [m]:***	307.96
Longitude [°]:	27.747306	***G-Nr.:***		***Col. ht. [m]:***	0.35
Altitude [m]:	835.00	***Topo-set.:***	Hillside (slope)	***Diam. [mm]:***	165
Coord. acc.:	Accurate to within 10 units	***Site status:***	Unused	***Drain. reg.:***	A42G
Coord. meth.:	Global Positioning System	***Site purp.:***	Exploration	***Rep. inst.:***	VSA
		Use applic.:	Domestic - all purposes		
		Equipment:	No equipment		

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend





COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DBV0015 ***Number:*** H21-0709 ***Site type:*** Borehole

Distr./Farm No.: LPLQ501 ***Site Name/Des.:*** GROOTFONTEIN PTN. ELLISRAS

Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

Latitude [°]:	23.641800	***Reg./BB.:***		***Depth [m]:***	163.00
Longitude [°]:	27.752280	***G-Nr.:***		***Col. ht. [m]:***	0.40
Altitude [m]:	830.00	***Topo-set.:***	Flat surface, plain	***Diam. [mm]:***	
Coord. acc.:	Accurate to within 10 units	***Site status:***	Unused	***Drain. reg.:***	A42H
Coord. meth.:	Global Positioning System	***Site purp.:***	Exploration	***Rep. inst.:***	VSA
		Use applic.:	Domestic - all purposes		
		Equipment:	No equipment		

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

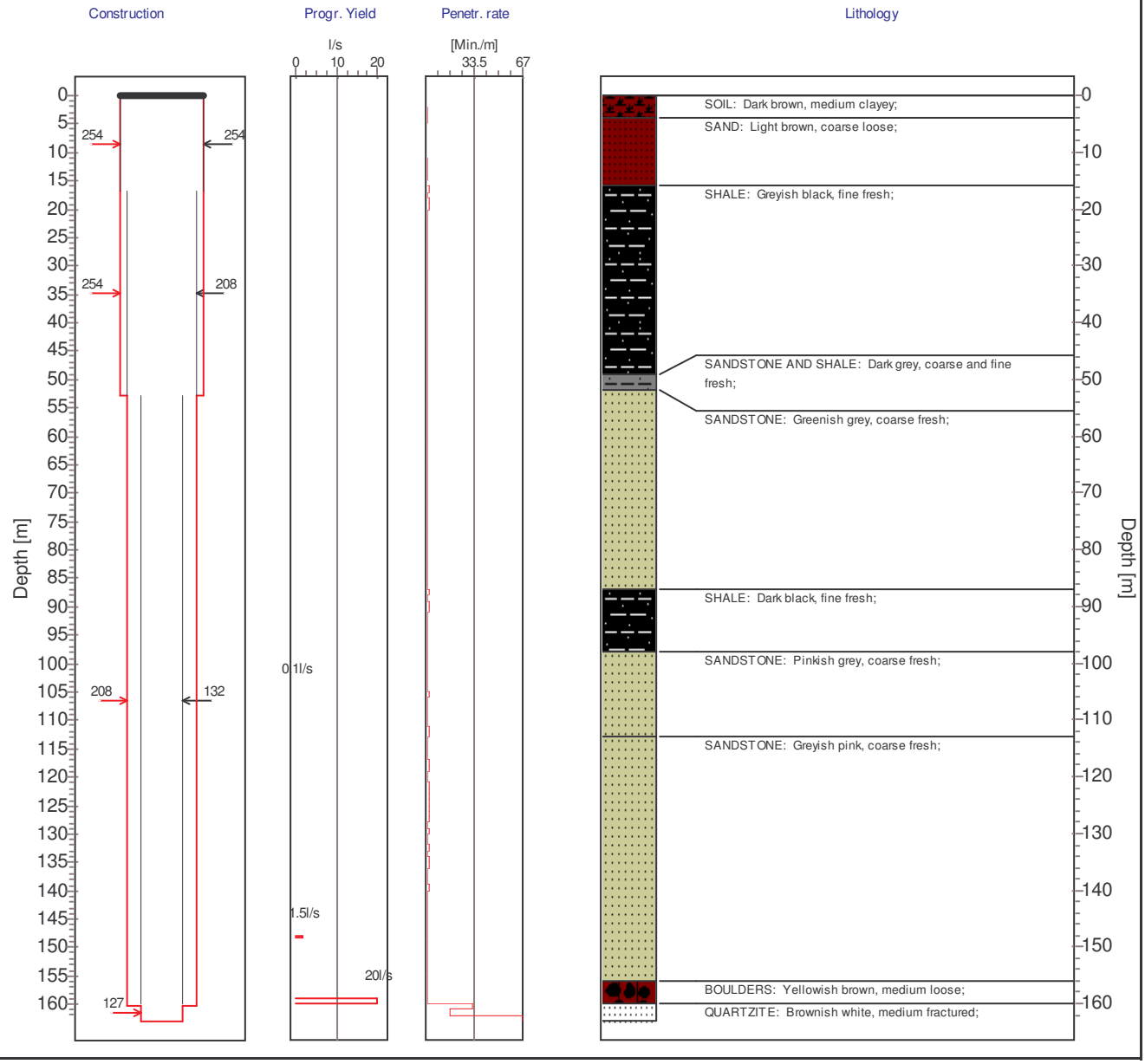
Construction and Geohydrological Legend

Hole — Hole diameter [mm] (165)

Casing (plain / perforated, sloted) — Casing diameter [mm] (152)

Screen / Mesh Screen — Waterlevel with date meas.

Piezometer — Piezometer (Nr. & Diameter [mm]) (0:50)



COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0038 ***Number:*** H21-0712 ***Site type:*** Borehole

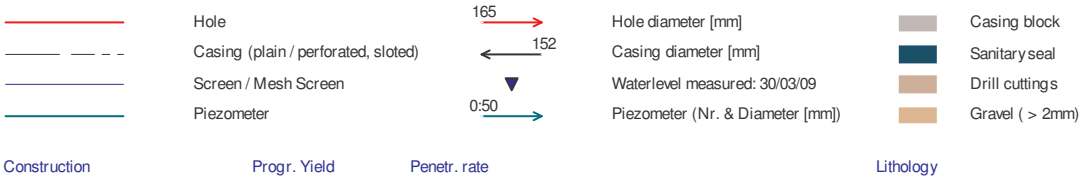
Distr./Farm No.: LPLQ550 ***Site Name/Des.:*** WONDERBOOMHOEK PTN. ELLISRAS

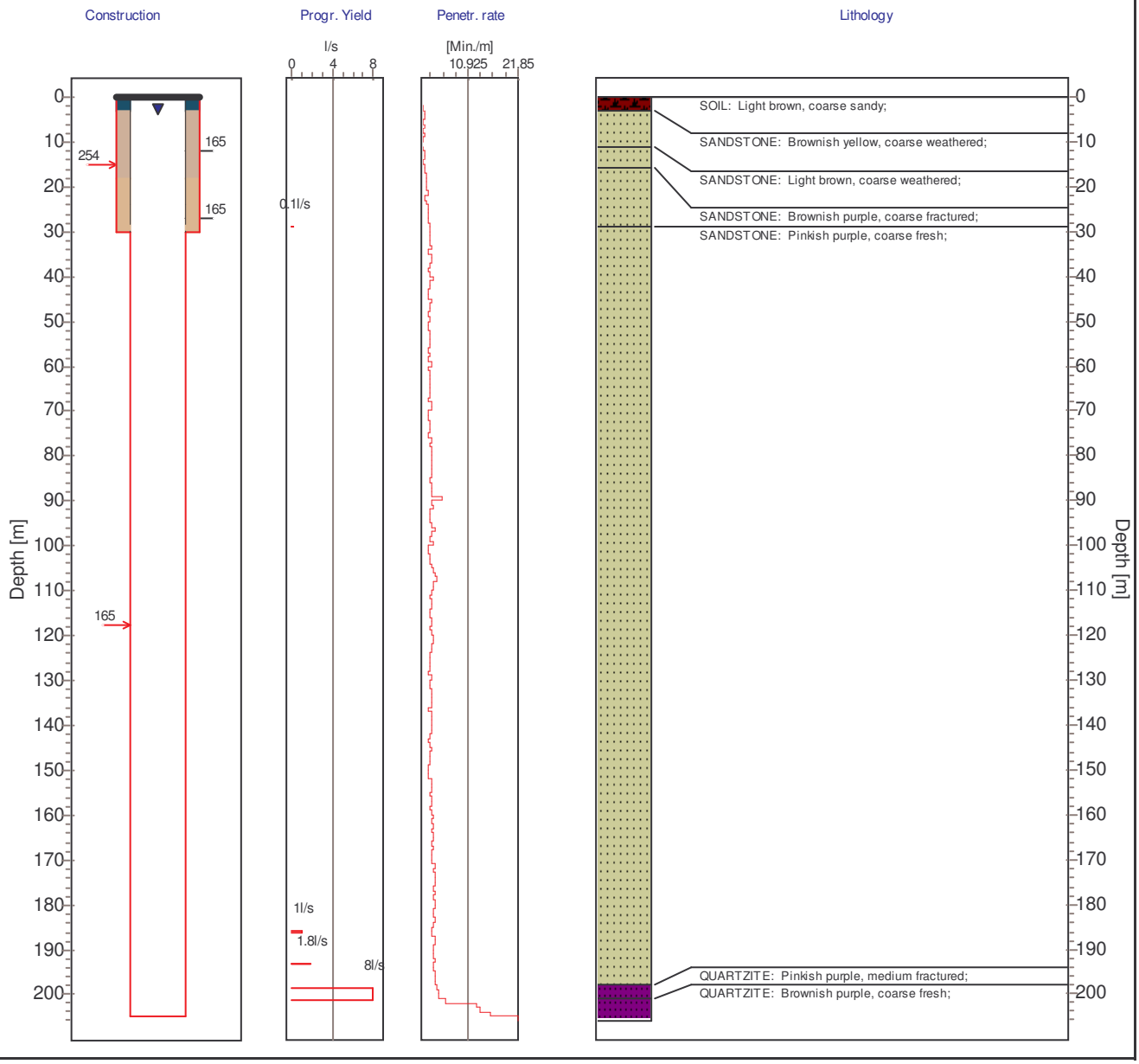
Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

Latitude [°]:	23.734389	***Reg./BB.:***		***Depth [m]:***	204.95
Longitude [°]:	27.745917	***G-Nr.:***		***Col. ht. [m]:***	
Altitude [m]:	825.00	***Topo-set.:***	In or along sinkhole	***Diam. [mm]:***	165
Coord. acc.:	Accurate to within 10 units	***Site status:***	Unused	***Drain. reg.:***	A42H
Coord. meth.:	Global Positioning System	***Site purp.:***	Exploration	***Rep. inst.:***	VSA
		Use applic.:	Domestic - all purposes		
		Equipment:	No equipment		

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend





COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0039 ***Number:*** M21-0713 ***Site type:*** Borehole

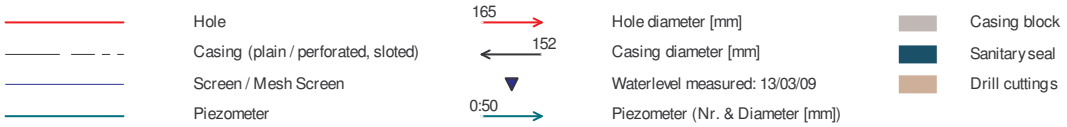
Distr./Farm No.: LPLQ528 ***Site Name/Des.:*** TOUWFONTEIN PTN. ELLISRAS

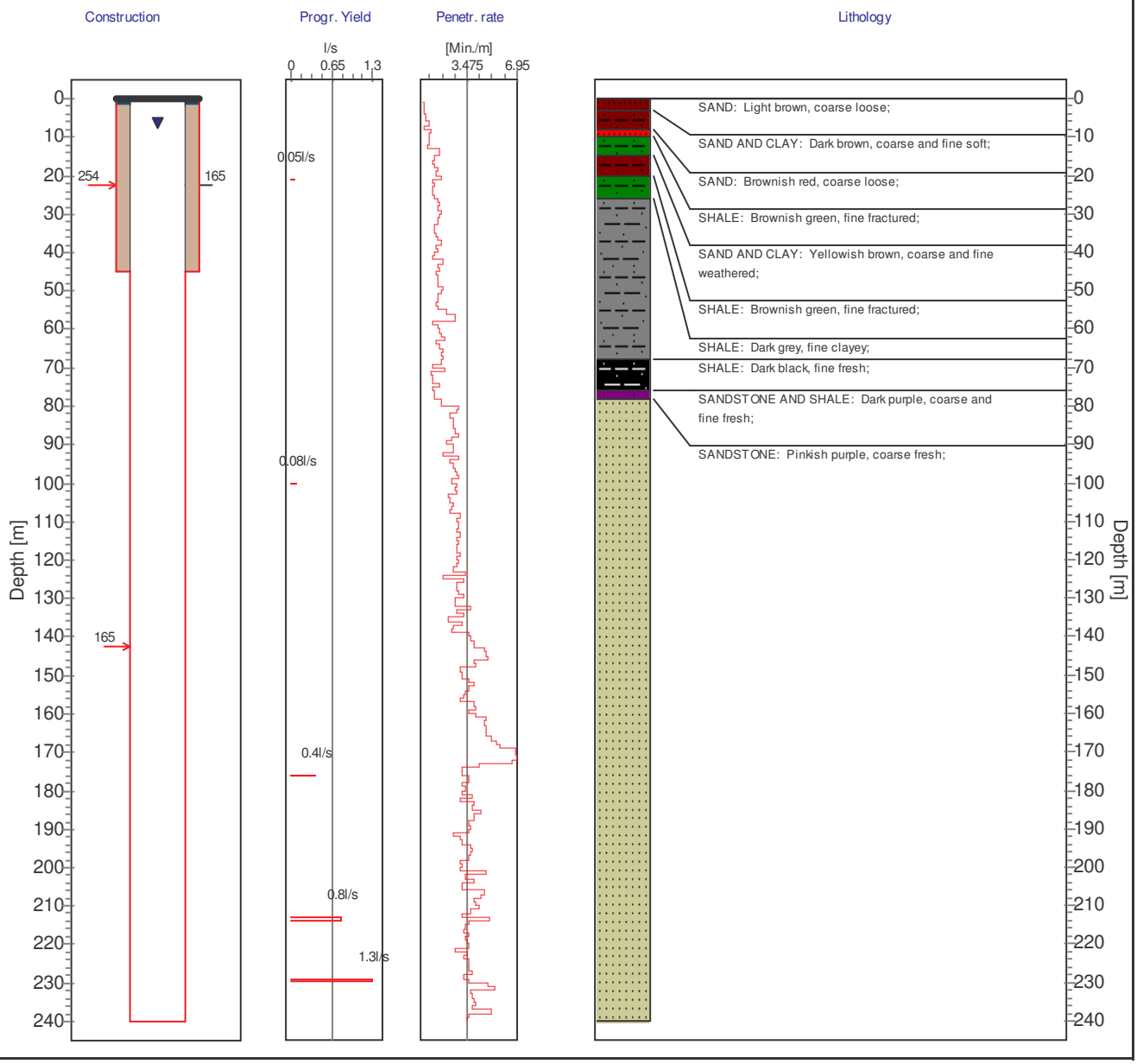
Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

Latitude [°]:	23.700694	***Reg./BB.:***		***Depth [m]:***	240.00
Longitude [°]:	27.749361	***G-Nr.:***		***Col. ht. [m]:***	0.50
Altitude [m]:	825.00	***Topo-set.:***	Flat surface, plain	***Diam. [mm]:***	165
Coord. acc.:	Accurate to within 10 units	***Site status:***	Unused	***Drain. reg.:***	A42H
Coord. meth.:	Global Positioning System	***Site purp.:***	Exploration	***Rep. inst.:***	VSA
		Use applic.:	Domestic - all purposes		
		Equipment:	Recorder		

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend





COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DBV0016 ***Number:*** H21-0714 ***Site type:*** Borehole

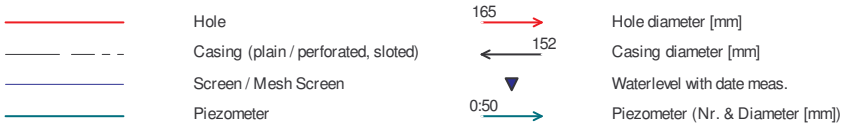
Distr./Farm No.: LPLQ501 ***Site Name/Des.:*** GROOTFONTEIN PTN. ELLISRAS

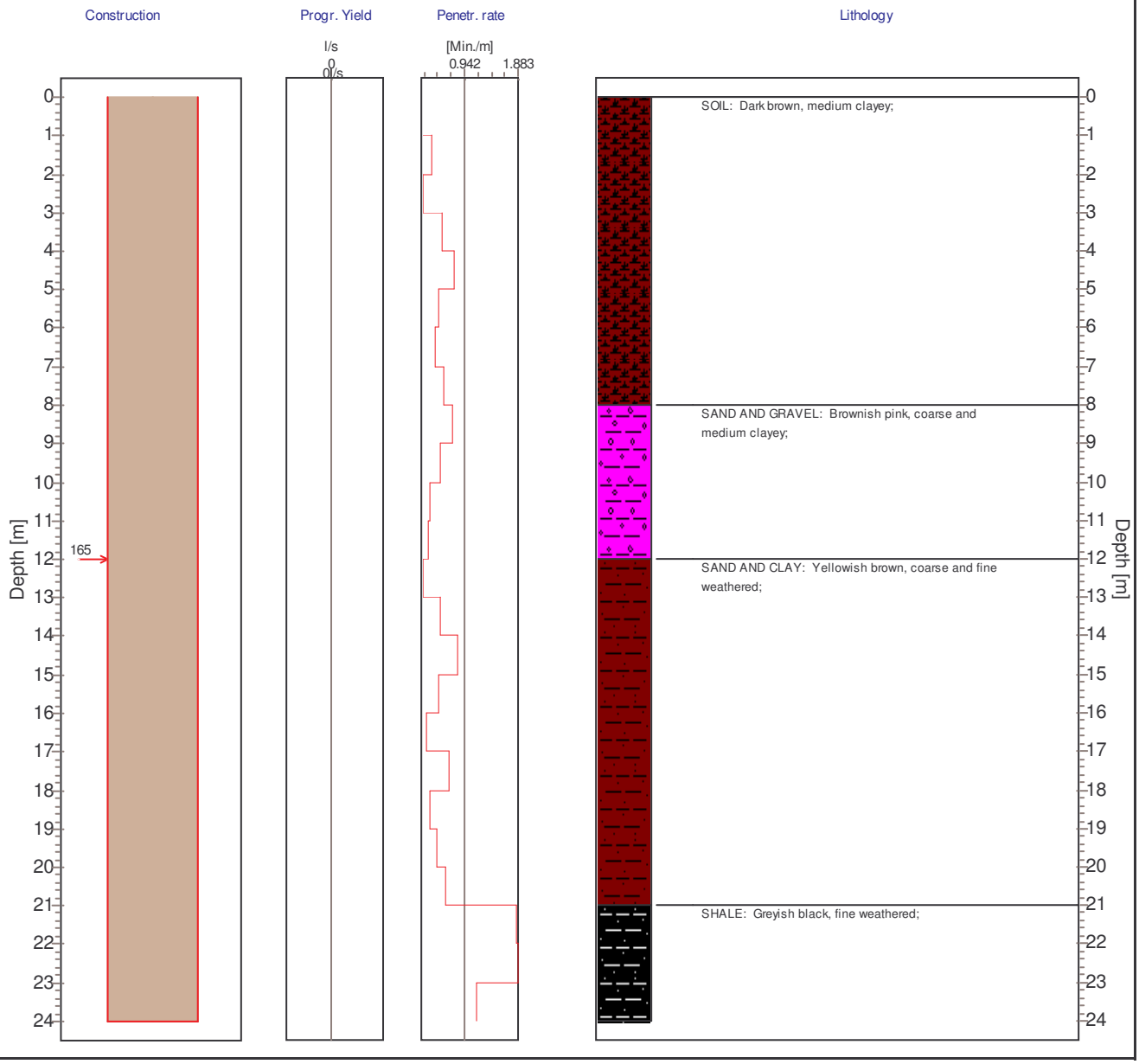
Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

Latitude [°]:	23.660222	***Reg./BB.:***		***Depth [m]:***	24.00
Longitude [°]:	27.756250	***G-Nr.:***		***Col. ht. [m]:***	
Altitude [m]:	820.00	***Topo-set.:***	In or along river	***Diam. [mm]:***	165
Coord. acc.:	Accurate to within 10 units	***Site status:***	Unused	***Drain. reg.:***	A42H
Coord. meth.:	Global Positioning System	***Site purp.:***	Exploration	***Rep. inst.:***	VSA
		Use applic.:	Domestic - all purposes		
		Equipment:	No equipment		

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend





COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0041 ***Number:*** H21-0715 ***Site type:*** Borehole

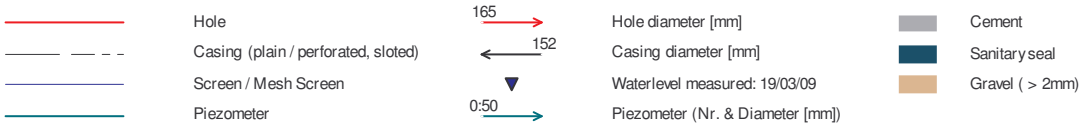
Distr./Farm No.: LPLQ524 ***Site Name/Des.:*** SCHAAPPLAATS PTN. ELLISRAS

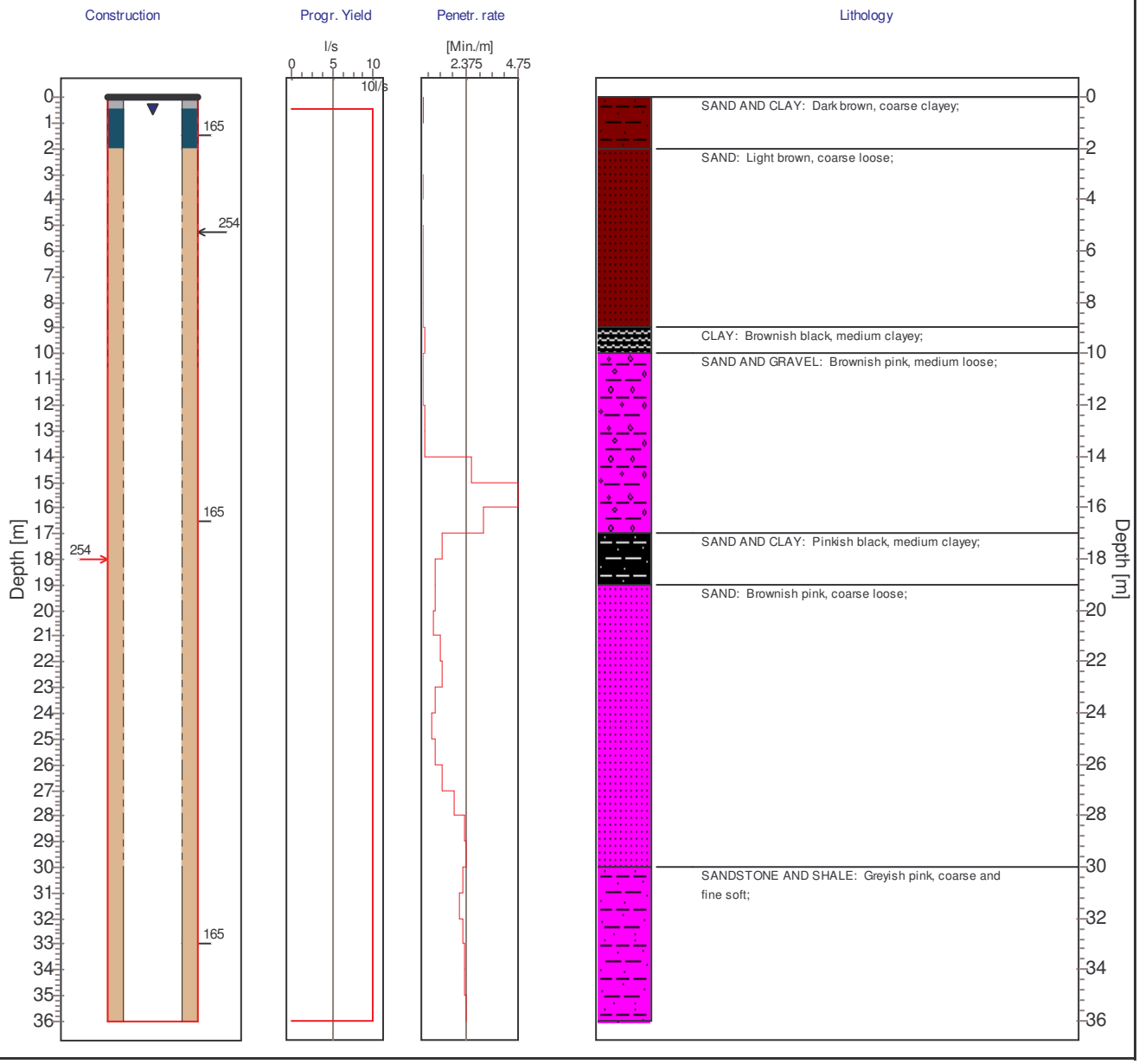
Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

Latitude [°]:	23.687361	***Reg./BB.:***		***Depth [m]:***	32.45
Longitude [°]:	27.745580	***G-Nr.:***		***Col. ht. [m]:***	0.50
Altitude [m]:	820.00	***Topo-set.:***	In or along river	***Diam. [mm]:***	254
Coord. acc.:	Accurate to within 10 units	***Site status:***	Unused	***Drain. reg.:***	A42H
Coord. meth.:	Global Positioning System	***Site purp.:***	Exploration	***Rep. inst.:***	VSA
		Use applic.:	Domestic - all purposes		
		Equipment:	No equipment		

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend





COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Borehole Construction and Geological Log

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0040 ***Number:*** H21-0716 ***Site type:*** Borehole

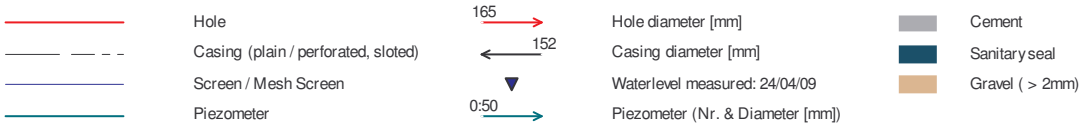
Distr./Farm No.: LPLQ503 ***Site Name/Des.:*** ONVERWACHT PTN. ELLISRAS

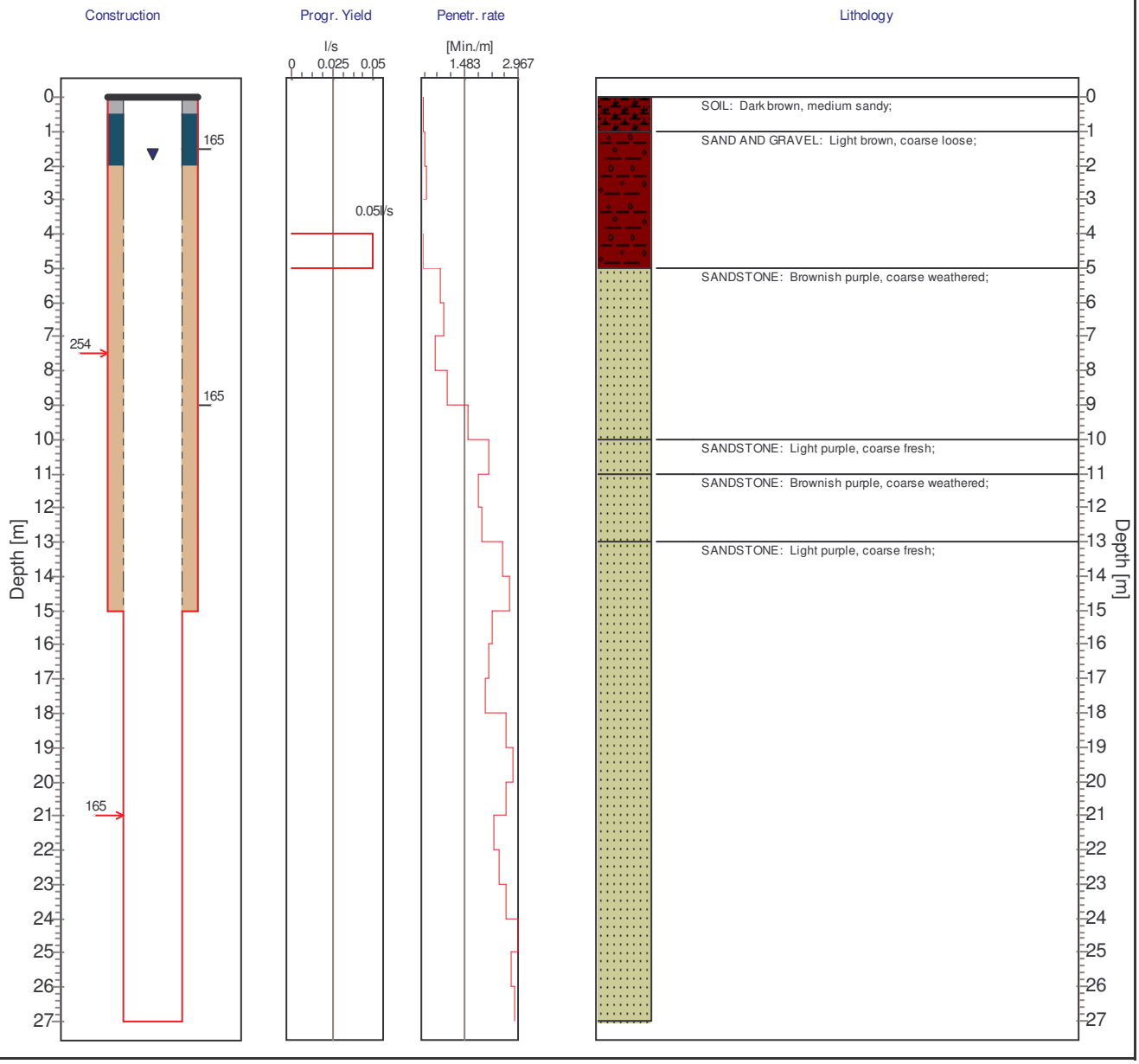
Region Type: District Council ***Region Descr.:*** WATERBERG/LEPHALALE

Latitude [°]:	23.688944	***Reg./BB.:***		***Depth [m]:***	27.00
Longitude [°]:	27.692250	***G-Nr.:***		***Col. ht. [m]:***	0.50
Altitude [m]:	845.00	***Topo-set.:***	Flat surface, plain	***Diam. [mm]:***	165
Coord. acc.:	Accurate to within 10 units	***Site status:***	Unused	***Drain. reg.:***	A42H
Coord. meth.:	Global Positioning System	***Site purp.:***	Exploration	***Rep. inst.:***	VSA
		Use applic.:	Domestic - all purposes		
		Equipment:	No equipment		

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

Construction and Geohydrological Legend





COMMENT:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

Appendix E: Management Reports

MANAGEMENT RECOMMENDATIONS

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0016 **Number:** H21-0637 **Site type:** Borehole

Distr./Farm No.: LPLQ502 **Site Name/Descr.:** WATERKLOOF PTN. ELLISRAS

Latitude [°]:	23.686720	**Alt. No. 1:**		**Diam. [mm]:**	165	**Water lev. [m]:**	3.19
Longitude [°]:	27.726860	**Alt. No. 2:**		**Depth [m]:**	210.00	**WL status:**	Static
Altitude [m]:	806.00	**Rep. inst.:**	DWAF	**Col. ht. [m]:**	0.55	**Date WL meas.:**	20090317

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

EXISTING EQUIPMENT:

Pump:

Type of Inst.: No equipment **Pulley Diam. [mm]:**

Manufacturer: **Depth to Intk. [m]:**

Engine:

Manufacturer: **Power Rating [kW]**

Type of Power: No Equipment **Pulley Diam. [mm]:**

USE APPLICATION:

Site Status: Unused

Purpose: Exploration

Consumer: Urban

Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.: 2008/CS09 **Date sampled:** 20080902 **Depth sampl. [m]:** 0 **Comment:** HIGH F & CADMIUM

Main Parameters:						Calculated Parameters:		Bacteriol. Parameters:
pH:	8.16	**Na:**	395.28 †	**Cl:**	289.9 †	**Langel.:**	-0.30	**E.Coli:**
EC: [mS/m]	176.1 †	**K:**	7.15	**NO3 as N:**	0.6	**Aggr-Ind:**	11.83	**Faec. co:**
TDS:	846 †	**Si:**		**SO4:**	132.1	**Ion-bal:**	13.33 ‡	**Total Co:**
T. Alk.:	130	**Al:**	0.2 †	**F:**	6.87 ‡	**CaCO3:**	42.08	**SPC:**
Ca:	14.26	**Fe:**	0.05					
Mg:	1.58	**Mn:**	0.07 †					

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimim allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
127.00	127.01	2.00	Notch (V- or U-notch)	Fractured	TESTED
134.00	134.01	5.00	Notch (V- or U-notch)	Fractured	TESTED
202.00	202.01	8.00	Notch (V- or U-notch)	Fractured	TESTED

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length	Width	Hor. Dist.	Vert. Dist.
0.00	12.00	165	Steel	4	Plain casing				
12.00	72.00	165	Steel	4	Perforated or slotted				

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m]	%	[min]	T [m²/d]	Storage	Comment
MULTI STEP 1	20080812	120	119.50	5.06	43.55						
MULTI STEP 2	20080812	30	119.50	7.40	116.89	0.22	100	90			
CONSTANT	20080812	2880	119.50	5.75	76.43	0.33	100	1200	16	0.00179	
CONSTANT	20090315	1440	184.50	8.32	103.91	0.37	100	720	8	0.00186	
CONSTANT	20090317	1325	184.50	9.23	181.11	0.57	100	720	6.6	0.00174	
SPECIFIC CAPACITY	20090319	720	0		129.15						0.0666
SPECIFIC CAPACITY	20090319	1325	0		181.11						0.0475

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1		120.00		24	5.00	CLASS 4		127.00

Note: water level measured 11.08.2008 between 13h00 & 16h00 - 1.21m

1		130.00		24	4.00			127.00

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

MANAGEMENT RECOMMENDATIONS

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0019 ***Number:*** H21-0638 ***Site type:*** Borehole

Distr./Farm No.: LPLQ502 ***Site Name/Descr.:*** WATERKLOOF PTN. ELLISRAS

Latitude [°]:	23.687130	***Alt. No. 1:***		***Diam. [mm]:***	165	***Water lev. [m]:***	-0.11000
Longitude [°]:	27.724720	***Alt. No. 2:***		***Depth [m]:***	180.00	***WL status:***	Static
Altitude [m]:	807.00	***Rep. inst.:***	DWAF	***Col. ht. [m]:***	0.46	***Date WL meas.:***	20080801

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

EXISTING EQUIPMENT:

Pump:

Type of Inst.: No equipment ***Pulley Diam. [mm]:***

Manufacturer: ***Depth to Intk. [m]:***

Engine:

Manufacturer: ***Power Rating [kW]***

Type of Power: No Equipment ***Pulley Diam. [mm]:***

USE APPLICATION:

Site Status: Unused

Purpose: Exploration

Consumer: Urban

Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.: H21-0638 ***Date sampled:*** 20080808 ***Depth sampl. [m]:*** 0 ***Comment:***

Main Parameters:						Calculated Parameters:		Bacteriol. Parameters:	
pH:	8.07	***Na:***	407.52 ‡	***Cl:***	304 †	***Langel.:***	-0.16	***E.Coli:***	
EC: [mS/m]	168.3 †	***K:***	8.31	***NO3 as N:***	0.6	***Aggr-Ind:***	11.97	***Faec. co:***	
TDS:	982 †	***Si:***		***SO4:***	140.9	***Ion-bal:***	10.35 ‡	***Total Co:***	
T. Alk.:	181	***Al:***	0.2 †	***F:***	5.85 ‡	***CaCO3:***	55.80	***SPC:***	
Ca:	17.65	***Fe:***	0.03						
Mg:	2.86	***Mn:***	0.07 †						

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimim allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	***Depth to Bot. [m]***	***Yield[l/s]***	***Method meas.***	***Aquifer type***	***Comment***
18.00	18.01	0.50	Notch (V- or U-notch)	Fractured	TESTED
130.00	130.01	10.00	Notch (V- or U-notch)	Fractured	TESTED
144.00	144.01	11.00	Notch (V- or U-notch)	Fractured	TESTED
148.00	148.01	21.00	Notch (V- or U-notch)	Fractured	TESTED

CASING DETAILS:

Depth to Top [m]	***to Bot. [m]***	***Diam. [mm]***	***Material***	***Thickn. [mm]***	***Type of openings***	***Openings [mm]: Length***	***Width***	***Hor. Dist.***	***Vert. Dist.***
0.00	12.00	250	Steel	6	Plain casing				
0.00	79.00	165	Steel	4	Perforated or slotted				

TESTING DETAILS:

Description	***Date***	***Durat. [min]***	***Depth to intk. [m]***	***Disch. rate[l/s]***	***Drawd. [m]***	***Recovery [m]***	***%***	***[min]***	***T [m²/d]***	***Storage***	***Comment***
MULTI STEP 1	20080801	120	119.50	5.09	13.21						
MULTI STEP 2	20080801	120	119.50	10.05	38.85						
MULTI STEP 3	20080801	40	119.50	18.88	119.50	0.17	100	150			
CONSTANT	20080801	4320	119.50	11.18	71.57	0.38	99	2640	13	0.00193	
SPECIFIC CAPACITY	20080805	720	0		60.84						0.1838
SPECIFIC CAPACITY	20080805	1440	0		63.98						0.1747
SPECIFIC CAPACITY	20080805	2880	0		66.87						0.1672
SPECIFIC CAPACITY	20080805	4320	0		71.57						0.1562

RECOMMENDATIONS:

Prior.	***Rec. equipm.***	***Depth to intk. [m]***	***Type of power***	***Duty cyc. [hrs]***	***Disch. rate [l/s]***	***Water quality***	***Dyn. water level [m]***	***Crit. water level [m]***
1		84.00		24	8.50	CLASS 4		130.00

Note:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

MANAGEMENT RECOMMENDATIONS

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0015 ***Number:*** H21-0663 ***Site type:*** Borehole

Distr./Farm No.: LPLQ502 ***Site Name/Descr.:*** WATERKLOOF PTN. ELLISRAS

Latitude [°]:	23.687470	***Alt. No. 1:***		***Diam. [mm]:***	165	***Water lev. [m]:***	6.16
Longitude [°]:	27.723000	***Alt. No. 2:***		***Depth [m]:***	276.00	***WL status:***	Static
Altitude [m]:	805.00	***Rep. inst.:***	DWAF	***Col. ht. [m]:***	0.47	***Date WL meas.:***	20080807

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

EXISTING EQUIPMENT:

Pump:

Type of Inst.: No equipment ***Pulley Diam. [mm]:***

Manufacturer: ***Depth to Intk. [m]:***

Engine:

Manufacturer: ***Power Rating [kW]***

Type of Power: No Equipment ***Pulley Diam. [mm]:***

USE APPLICATION:

Site Status: Unused

Purpose: Exploration

Consumer: Non-urban

Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.: H21-0663 ***Date sampled:*** 20080814 ***Depth sampl. [m]:*** 0 ***Comment:***

Main Parameters:						Calculated Parameters:		Bacteriol. Parameters:	
pH:	8.01	***Na:***	375.85 †	***Cl:***	287.2 †	***Langel.:***	-0.26	***E.Coli:***	
EC: [mS/m]	168.7 †	***K:***	7.06	***NO3 as N:***	0.6	***Aggr-Ind:***	11.87	***Faec. co:***	
TDS:	978 †	***Si:***		***SO4:***	145.7	***Ion-bal:***	9.40 †	***Total Co:***	
T. Alk.:	156	***Al:***	0.2 †	***F:***	7.24 ‡	***CaCO3:***	59.77	***SPC:***	
Ca:	18.63	***Fe:***	0.06						
Mg:	3.23	***Mn:***	0.06 †						

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimim allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
94.00	94.01	1.00	Notch (V- or U-notch)	Fractured	TESTED
128.00	128.01	1.50	Notch (V- or U-notch)	Fractured	TESTED
239.00	239.01	8.00	Notch (V- or U-notch)	Fractured	TESTED

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length	Width	Hor. Dist.	Vert. Dist.
0.00	12.00	165	Steel	4	Plain casing				
0.00	12.00	250	Steel	6	Plain casing				
12.00	72.00	165	Steel	4	Perforated or slotted				

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m]	%	[min]	T [m²/d]	Storage	Comment
MULTI STEP 1	20080807	120	119.50	5.07	44.91						
MULTI STEP 2	20080807	120	119.50	9.80	116.81	0.63	99	120			
CONSTANT	20080807	2880	119.50	5.61	73.28	0.61	99	2160	5.2	0.00184	
SPECIFIC CAPACITY	20080810	720	0		72.71						0.0772
SPECIFIC CAPACITY	20080810	1440	0		72.85						0.0770
SPECIFIC CAPACITY	20080810	2880	0		73.28						0.0766

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1		120.00		24	3.00	CLASS 4		239.00

Note: Water level measured 11.08.2008 between13h00 & 16h00 - 1.45m (fallen in to depth of 14m)

2		120.00		8	6.00	CLASS 4		239.00

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

MANAGEMENT RECOMMENDATIONS

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0018 ***Number:*** H21-0664 ***Site type:*** Borehole

Distr./Farm No.: LPLQ502 ***Site Name/Descr.:*** WATERKLOOF PTN. ELLISRAS

Latitude [°]:	23.687570	***Alt. No. 1:***		***Diam. [mm]:***	165	***Water lev. [m]:***	3.06
Longitude [°]:	27.722620	***Alt. No. 2:***		***Depth [m]:***	288.00	***WL status:***	Static
Altitude [m]:	805.00	***Rep. inst.:***	DWAF	***Col. ht. [m]:***	0.21	***Date WL meas.:***	20090122

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

EXISTING EQUIPMENT:

Pump:

Type of Inst.: No equipment ***Pulley Diam. [mm]:***

Manufacturer: ***Depth to Intk. [m]:***

Engine:

Manufacturer: ***Power Rating [kW]***

Type of Power: No Equipment ***Pulley Diam. [mm]:***

USE APPLICATION:

Site Status: Unused

Purpose: Production (water supply)

Consumer: Urban

Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.: ***Date sampled:*** ***Depth sampl. [m]:*** ***Comment:***

Main Parameters:			**Calculated Parameters:**	**Bacteriol. Parameters:**
pH:	***Na:***	***Cl:***	***Langel.:***	***E.Coli:***
EC: [mS/m]	***K:***	***NO3 as N:***	***Aggr-Ind:***	***Faec. co:***
TDS:	***Si:***	***SO4:***	***Ion-bal:***	***Total Co:***
T. Alk.:	***Al:***	***F:***	***CaCO3:***	***SPC:***
Ca:	***Fe:***			
Mg:	***Mn:***			

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimim allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	*Depth to Bot. [m]*	*Yield[l/s]*	*Method meas.*	*Aquifer type*	*Comment*
216.00	216.01	1.00	Notch (V- or U-notch)	Fractured	TO TEST
250.00	250.01	3.00	Notch (V- or U-notch)	Fractured	TO TEST

CASING DETAILS:

Depth to Top [m]	*to Bot. [m]*	*Diam. [mm]*	*Material*	*Thickn. [mm]*	*Type of openings*	*Openings [mm]: Length*	*Width*	*Hor. Dist.*	*Vert. Dist.*
0.00	6.00	177	Steel	6	Plain casing				

RECOMMENDATIONS:

Prior.	*Rec. equipm.*	*Depth to intk. [m]*	*Type of power*	*Duty cyc. [hrs]*	*Disch. rate [l/s]*	*Water quality*	*Dyn. water level [m]*	*Crit. water level [m]*
1				0	0			

Note: Water level measured 11.08.2008 between 13h00 & 16h00 - 1.49m; 24.04.2009 - 2.86

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

MANAGEMENT RECOMMENDATIONS

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0024 ***Number:*** H21-0665 ***Site type:*** Borehole

Distr./Farm No.: LPLQ502 ***Site Name/Descr.:*** WATERKLOOF PTN. ELLISRAS

Latitude [°]:	23.687083	***Alt. No. 1:***		***Diam. [mm]:***	165	***Water lev. [m]:***	1.11
Longitude [°]:	27.725056	***Alt. No. 2:***		***Depth [m]:***	218.70	***WL status:***	Static
Altitude [m]:	805.00	***Rep. inst.:***	VSA	***Col. ht. [m]:***	0.33	***Date WL meas.:***	20090128

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

EXISTING EQUIPMENT:

Pump:

Type of Inst.: No equipment ***Pulley Diam. [mm]:***

Manufacturer: ***Depth to Intk. [m]:***

Engine:

Manufacturer: ***Power Rating [kW]***

Type of Power: No Equipment ***Pulley Diam. [mm]:***

USE APPLICATION:

Site Status: Unused

Purpose: Exploration

Consumer: Non-urban

Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.: H21-0665 ***Date sampled:*** 20090203 ***Depth sampl. [m]:*** 0 ***Comment:***

Main Parameters:						Calculated Parameters:		Bacteriol. Parameters:
pH:	8.18	***Na:***	367 †	***Cl:***	361 †	***Langel.:***	-0.12	***E.Coli:***
EC: [mS/m]	174 †	***K:***	4.5	***NO3 as N:***	0.3	***Aggr-Ind:***	12.02	***Faec. co:***
TDS:	1180 †	***Si:***	8.64	***SO4:***	165	***Ion-bal:***	-0.88	***Total Co:***
T. Alk.:	164	***Al:***		***F:***	9.44 ‡	***CaCO3:***	51.67	***SPC:***
Ca:	16.9	***Fe:***	0.05					
Mg:	2.31	***Mn:***	0.12 †					

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimim allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	***Depth to Bot. [m]***	***Yield[l/s]***	***Method meas.***	***Aquifer type***	***Comment***
17.00	17.01	2.00	Notch (V- or U-notch)	Fractured	TESTED
45.00	45.01	4.00	Notch (V- or U-notch)	Fractured	TESTED
83.00	83.01	5.00	Notch (V- or U-notch)	Fractured	TESTED
172.00	220.00	20.00	Notch (V- or U-notch)	Fractured	TESTED

CASING DETAILS:

Depth to Top [m]	***to Bot. [m]***	***Diam. [mm]***	***Material***	***Thickn. [mm]***	***Type of openings***	***Openings [mm]: Length***	***Width***	***Hor. Dist.***	***Vert. Dist.***
0.00	12.00	165	Steel	4	Plain casing				
0.00	12.00	250	Steel	6	Plain casing				
12.00	126.00	165	Steel	4	Perforated or slotted				

TESTING DETAILS:

Description	***Date***	***Durat. [min]***	***Depth to intk. [m]***	***Disch. rate[l/s]***	***Drawd. [m]***	***Recovery [m]***	***%***	***[min]***	***T [m²/d]***	***Storage***	***Comment***
CONSTANT	20090215	8640	118.58	20.82	61.52	3.10	95	4320	17	0.00179	
SPECIFIC CAPACITY	20090225	720	0		44.11						0.4559
SPECIFIC CAPACITY	20090225	4320	0		55.94						0.3595
SPECIFIC CAPACITY	20090225	8640	0		61.52						0.3269

RECOMMENDATIONS:

Prior.	***Rec. equipm.***	***Depth to intk. [m]***	***Type of power***	***Duty cyc. [hrs]***	***Disch. rate [l/s]***	***Water quality***	***Dyn. water level [m]***	***Crit. water level [m]***
1		114.00		24	14.00	CLASS 4		172.00

Note:

2		114.00		8	24.00	CLASS 4		172.00

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

MANAGEMENT RECOMMENDATIONS

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0022 ***Number:*** H21-0666 ***Site type:*** Borehole

Distr./Farm No.: LPLQ502 ***Site Name/Descr.:*** WATERKLOOF PTN. ELLISRAS

Latitude [°]:	23.682639	***Alt. No. 1:***		***Diam. [mm]:***	165	***Water lev. [m]:***	33.31
Longitude [°]:	27.672917	***Alt. No. 2:***		***Depth [m]:***	216.00	***WL status:***	Static
Altitude [m]:	854.00	***Rep. inst.:***	VSA	***Col. ht. [m]:***	0.36	***Date WL meas.:***	20080816

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

EXISTING EQUIPMENT:

Pump:

Type of Inst.: No equipment ***Pulley Diam. [mm]:***

Manufacturer: ***Depth to Intk. [m]:***

Engine:

Manufacturer: ***Power Rating [kW]***

Type of Power: No Equipment ***Pulley Diam. [mm]:***

USE APPLICATION:

Site Status: Unused

Purpose: Production (water supply)

Consumer: Non-urban

Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.: 2008/CS10 ***Date sampled:*** 20080902 ***Depth sampl. [m]:*** 0 ***Comment:*** HIGH F & CADMIUM

Main Parameters:						Calculated Parameters:		Bacteriol. Parameters:
pH:	7.42	***Na:***	654.65 ‡	***Cl:***	298.2 †	***Langel.:***	-0.10	***E.Coli:***
EC: [mS/m]	342 ‡	***K:***	20.85	***NO3 as N:***	0.6	***Aggr-Ind:***	12.09	***Faec. co:***
TDS:	1858 †	***Si:***		***SO4:***	247.1 †	***Ion-bal:***	33.91 ‡	***Total Co:***
T. Alk.:	220	***Al:***	0.2 †	***F:***	5.42 ‡	***CaCO3:***	401.92	***SPC:***
Ca:	84.55	***Fe:***	0.01					
Mg:	46.43	***Mn:***	0.01					

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimim allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
73.00	73.00	1.00	Notch (V- or U-notch)	Fractured	TESTED
205.00	205.00	10.00	Notch (V- or U-notch)	Fractured	TESTED

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length	Openings [mm]: Width	Hor. Dist.	Vert. Dist.
0.00	24.00	165	Steel	4	Plain casing				

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m]	Recovery %	Recovery [min]	T [m²/d]	Storage	Comment
MULTI STEP 1	20080816	120	101.50	5.10	23.53						
MULTI STEP 2	20080816	55	101.50	10.02	66.49	1.55	98	180			
CONSTANT	20080816	2880	101.50	6.54	46.41	4.98	90	1200	11.4	0.00191	
SPECIFIC CAPACITY	20080820	720	0		41.14						0.1590
SPECIFIC CAPACITY	20080820	1440	0		43.88						0.1490
SPECIFIC CAPACITY	20080820	2880	0		46.41						0.1409

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1		102.00		24	3.00	CLASS 4		73.00

Note: Borehole is obstructed at ± 102m.

2		102.00		8	6.00	CLASS 4		73.00

Note:

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

MANAGEMENT RECOMMENDATIONS

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0023 ***Number:*** H21-0667 ***Site type:*** Borehole

Distr./Farm No.: LPLQ503 ***Site Name/Descr.:*** ONVERWACHT PTN. ELLISRAS

Latitude [°]:	23.679389	***Alt. No. 1:***		***Diam. [mm]:***	165	***Water lev. [m]:***	32.54
Longitude [°]:	27.677333	***Alt. No. 2:***		***Depth [m]:***	300.00	***WL status:***	Static
Altitude [m]:	852.00	***Rep. inst.:***	DWAF	***Col. ht. [m]:***	0.53	***Date WL meas.:***	20080923

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

EXISTING EQUIPMENT:

Pump:

Type of Inst.: No equipment ***Pulley Diam. [mm]:***

Manufacturer: ***Depth to Intk. [m]:***

Engine:

Manufacturer: ***Power Rating [kW]***

Type of Power: No Equipment ***Pulley Diam. [mm]:***

USE APPLICATION:

Site Status: Unused

Purpose: Exploration

Consumer: Urban

Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.: 2008/CS36 ***Date sampled:*** 20081016 ***Depth sampl. [m]:*** 0 ***Comment:***

Main Parameters:						Calculated Parameters:		Bacteriol. Parameters:	
pH:	7.91	***Na:***	671 ‡	***Cl:***	561 †	***Langel.:***		***E.Coli:***	
EC: [mS/m]	251.7 †	***K:***	16.43	***NO3 as N:***	0.8	***Aggr-Ind:***		***Faec. co:***	
TDS:	1514 †	***Si:***		***SO4:***	468.7 †	***Ion-bal:***	12.28 ‡	***Total Co:***	
T. Alk.:		***Al:***	0.2 †	***F:***	6.04 ‡	***CaCO3:***	180.99	***SPC:***	
Ca:	46.46	***Fe:***	0.02						
Mg:	15.82	***Mn:***	0.1 †						

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimim allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
109.00	109.00	0.50	Notch (V- or U-notch)		TESTED
125.00	125.00	2.00	Notch (V- or U-notch)		TESTED
211.00	211.00	2.50	Notch (V- or U-notch)		TESTED
270.00	270.00	3.00	Notch (V- or U-notch)		TESTED

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length	Width	Hor. Dist.	Vert. Dist.
0.00	24.00	165	Steel	4	Plain casing				

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m]	%	[min]	T [m²/d]	Storage	Comment
MULTI STEP 1	20080923	60	120.00	0.54	11.29						
MULTI STEP 2	20080923	60	120.00	1.02	17.56						
MULTI STEP 3	20080923	60	120.00	2.04	28.01						
MULTI STEP 4	20080923	60	120.00	4.02	80.57						
MULTI STEP 5	20080923	15	120.00	5.50	86.85	0.93	99	240			
CONSTANT	20080924	1440	120.00	3.22	64.48	1.27	98	1440	2.8	0.00176	
SPECIFIC CAPACITY	20080926	720	0		57.46						0.0560
SPECIFIC CAPACITY	20080926	1440	0		64.48						0.0499

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1		102.00		24	0.80	CLASS 4		90.00

Note: Water level: 29.01.209, 14:45 - 32.62m

2		102.00		8	1.50	CLASS 4		90.00

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

MANAGEMENT RECOMMENDATIONS

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0026 ***Number:*** H21-0669 ***Site type:*** Borehole

Distr./Farm No.: LPLQ522 ***Site Name/Descr.:*** PAARL PTN. ELLISRAS

Latitude [°]:	23.693310	***Alt. No. 1:***		***Diam. [mm]:***	165	***Water lev. [m]:***	10.46
Longitude [°]:	27.705080	***Alt. No. 2:***		***Depth [m]:***	291.00	***WL status:***	Static
Altitude [m]:	833.00	***Rep. inst.:***	DWAF	***Col. ht. [m]:***	0.61	***Date WL meas.:***	20081014

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

EXISTING EQUIPMENT:

Pump:

Type of Inst.:	No equipment	***Pulley Diam. [mm]:***	
Manufacturer:		***Depth to Intk. [m]:***	

Engine:

Manufacturer:		***Power Rating [kW]***	
Type of Power:	No Equipment	***Pulley Diam. [mm]:***	

USE APPLICATION:

Site Status:	Unused
Purpose:	Exploration
Consumer:	Urban
Application:	Domestic - all purposes

WATER CHEMISTRY:

Sample No.: 2008/CS43 ***Date sampled:*** 20081105 ***Depth sampl. [m]:*** 0 ***Comment:***

Main Parameters:						**Calculated Parameters:**		**Bacteriol. Parameters:**
pH:	7.57	***Na:***	288.9 †	***Cl:***	293.4 †	***Langel.:***	0.04	***E.Coli:***
EC: [mS/m]	166.9 †	***K:***	15.01	***NO3 as N:***	1.68	***Aggr-Ind:***	12.19	***Faec. co:***
TDS:	976 †	***Si:***		***SO4:***	77.2	***Ion-bal:***	-3.68	***Total Co:***
T. Alk.:	365	***Al:***	0.2 †	***F:***	6.27 ‡	***CaCO3:***	171.49	***SPC:***
Ca:	45.62	***Fe:***	0.04					
Mg:	14.02	***Mn:***	0.28 †					

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimim allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	***Depth to Bot. [m]***	***Yield[l/s]***	***Method meas.***	***Aquifer type***	***Comment***
25.00	25.00	0.30	Notch (V- or U-notch)	Fractured	TESTED
42.00	42.00	0.60	Notch (V- or U-notch)	Fractured	TESTED
141.00	141.00	0.80	Notch (V- or U-notch)	Fractured	TESTED

CASING DETAILS:

Depth to Top [m]	***to Bot. [m]***	***Diam. [mm]***	***Material***	***Thickn. [mm]***	***Type of openings***	***Openings [mm]: Length***	***Width***	***Hor. Dist.***	***Vert. Dist.***
0.00	24.00	165	Steel	4	Plain casing				

TESTING DETAILS:

Description	***Date***	***Durat. [min]***	***Depth to intk. [m]***	***Disch. rate[l/s]***	***Drawd. [m]***	***Recovery [m]***	***%***	***[min]***	***T [m²/d]***	***Storage***	***Comment***
MULTI STEP 1	20081014	60	120.00	0.51	10.75						
MULTI STEP 2	20081014	60	120.00	1.00	45.10						
MULTI STEP 3	20081014	70	120.00	0.70	108.65	10.72	90	120			
CONSTANT	20081014	720	120.00	0.62	46.99	0	100	210	0.5	0.00161	
SPECIFIC CAPACITY	20081015	720	0		46.99						0.0132

RECOMMENDATIONS:

Prior.	***Rec. equipm.***	***Depth to intk. [m]***	***Type of power***	***Duty cyc. [hrs]***	***Disch. rate [l/s]***	***Water quality***	***Dyn. water level [m]***	***Crit. water level [m]***
1		42.00		24	0.12	CLASS 4		41.00

Note:

2		42.00		8	0.21	CLASS 4		41.00

Note: Water level: 14.75 - 24.02.2009

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

MANAGEMENT RECOMMENDATIONS

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0027 **Number:** H21-0670 **Site type:** Borehole

Distr./Farm No.: LPLQ522 **Site Name/Descr.:** PAARL PTN. ELLISRAS

Latitude [°]:	23.711660	**Alt. No. 1:**		**Diam. [mm]:**	165	**Water lev. [m]:**	3.75
Longitude [°]:	27.657130	**Alt. No. 2:**		**Depth [m]:**	213.00	**WL status:**	Static
Altitude [m]:	860.00	**Rep. inst.:**	DWAF	**Col. ht. [m]:**	0.21	**Date WL meas.:**	20090129

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

EXISTING EQUIPMENT:

Pump:

Type of Inst.: No equipment **Pulley Diam. [mm]:**

Manufacturer: **Depth to Intk. [m]:**

Engine:

Manufacturer: **Power Rating [kW]**

Type of Power: No Equipment **Pulley Diam. [mm]:**

USE APPLICATION:

Site Status: Unused

Purpose: Exploration

Consumer: Urban

Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.: 15258 **Date sampled:** 20081017 **Depth sampl. [m]:** 0 **Comment:**

Main Parameters:						Calculated Parameters:		Bacteriol. Parameters:
pH:	8.23	**Na:**	298.6 †	**Cl:**	261.4 †	**Langel.:**	-0.12	**E.Coli:**
EC: [mS/m]	132.5 †	**K:**	9.39	**NO3 as N:**	0.6	**Aggr-Ind:**	11.99	**Faec. co:**
TDS:	770 †	**Si:**		**SO4:**	108.3	**Ion-bal:**	-0.35	**Total Co:**
T. Alk.:	199	**Al:**	0.2 †	**F:**	8.89 ‡	**CaCO3:**	39.61	**SPC:**
Ca:	11.64	**Fe:**	0.09					
Mg:	2.57	**Mn:**	0.07 †					

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimim allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
48.00	48.00	0.50	Notch (V- or U-notch)	Fractured	TESTED
52.00	52.00	1.50	Notch (V- or U-notch)	Fractured	TESTED
57.00	57.00	2.00	Notch (V- or U-notch)	Fractured	TESTED

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length	Width	Hor. Dist.	Vert. Dist.
0.00	3.00	273	Steel	6	Plain casing				
0.00	24.00	177	Steel	4	Plain casing				

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m]	%	[min]	T [m²/d]	Storage	Comment
MULTI STEP 1	20081008	60	120.00	2.00	64.24						
MULTI STEP 2	20081008	15	120.00	4.04	111.14	-	103	90			
CONSTANT	20081009	720	120.00	0.94	20.23	-	119	720	1.8	0.00171	
SPECIFIC CAPACITY	20081011	720	0		20.23						0.0465

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1		48.00		24	0.30	CLASS 4		52.00

Note:

2		48.00		8	0.80	CLASS 4		52.00

Note: Water level: 3.76m - 24.04.2009

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

MANAGEMENT RECOMMENDATIONS

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0028 **Number:** H21-0671 **Site type:** Borehole

Distr./Farm No.: LPLQ501 **Site Name/Descr.:** GROOTFONTEIN PTN. ELLISRAS

Latitude [°]:	23.641790	**Alt. No. 1:**		**Diam. [mm]:**	165	**Water lev. [m]:**	-0.44000
Longitude [°]:	27.752490	**Alt. No. 2:**		**Depth [m]:**	126.00	**WL status:**	Static
Altitude [m]:	817.00	**Rep. inst.:**	DWAF	**Col. ht. [m]:**	0.00	**Date WL meas.:**	20090124

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

EXISTING EQUIPMENT:

Pump:

Type of Inst.: No equipment **Pulley Diam. [mm]:**

Manufacturer: **Depth to Intk. [m]:**

Engine:

Manufacturer: **Power Rating [kW]**

Type of Power: No Equipment **Pulley Diam. [mm]:**

USE APPLICATION:

Site Status: Unused

Purpose: Exploration

Consumer: Urban

Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.: 2009/UIS03 **Date sampled:** 20090128 **Depth sampl. [m]:** 0 **Comment:**

Main Parameters:						Calculated Parameters:		Bacteriol. Parameters:
pH:	8.39	**Na:**	338 †	**Cl:**	307 †	**Langel.:**	-0.27	**E.Coli:**
EC: [mS/m]	169 †	**K:**	2.98	**NO3 as N:**	0.07	**Aggr-Ind:**	11.85	**Faec. co:**
TDS:	1090 †	**Si:**	7.04	**SO4:**	164	**Ion-bal:**	-0.18	**Total Co:**
T. Alk.:	133	**Al:**		**F:**	13.3 ‡	**CaCO3:**	30.33	**SPC:**
Ca:	8.71	**Fe:**	0.05					
Mg:	2.09	**Mn:**	0.05					

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimim allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
114.00	114.00	5.00	Notch (V- or U-notch)	Fractured	TESTED
115.00	115.00	5.00	Notch (V- or U-notch)	Fractured	TESTED
116.00	116.00	5.00	Notch (V- or U-notch)	Fractured	TESTED
117.00	117.00	5.00	Notch (V- or U-notch)	Fractured	TESTED

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length	Width	Hor. Dist.	Vert. Dist.
0.00	108.00	165	Steel	4	Plain casing				

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m]	%	[min]	T [m²/d]	Storage	Comment
MULTI STEP 1	20090124	60	118.58	5.12	10.92						
MULTI STEP 2	20090124	60	118.58	10.21	37.99						
MULTI STEP 3	20090124	60	118.58	19.83	74.53	0	100	3			
CONSTANT	20090124	4320	118.58	18.03	79.82	0	100	5	18	0.00198	
SPECIFIC CAPACITY	20090128	720	0		74.79						0.2411
SPECIFIC CAPACITY	20090128	1440	0		77.16						0.2337
SPECIFIC CAPACITY	20090128	2880	0		78.45						0.2298
SPECIFIC CAPACITY	20090128	4320	0		79.82						0.2259

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1		114.00		24	9.00	CLASS 4		114.00
Note:								
2		114.00		8	16.00	CLASS 4		114.00

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

MANAGEMENT RECOMMENDATIONS

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0030 ***Number:*** H21-0680 ***Site type:*** Borehole

Distr./Farm No.: LPLQ472 ***Site Name/Descr.:*** VOGELSTRUISFONTEIN PTN. ELLISRAS

Latitude [°]:	23.611916	***Alt. No. 1:***		***Diam. [mm]:***	165	***Water lev. [m]:***	7.71
Longitude [°]:	27.743194	***Alt. No. 2:***		***Depth [m]:***	296.00	***WL status:***	Static
Altitude [m]:	820.00	***Rep. inst.:***	VSA	***Col. ht. [m]:***	0.30	***Date WL meas.:***	20090424

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

EXISTING EQUIPMENT:

Pump:

Type of Inst.: No equipment ***Pulley Diam. [mm]:***

Manufacturer: ***Depth to Intk. [m]:***

Engine:

Manufacturer: ***Power Rating [kW]***

Type of Power: No Equipment ***Pulley Diam. [mm]:***

USE APPLICATION:

Site Status: Unused

Purpose: Exploration

Consumer: Urban

Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.: ***Date sampled:*** ***Depth sampl. [m]:*** ***Comment:***

Main Parameters:			**Calculated Parameters:**	**Bacteriol. Parameters:**
pH:	***Na:***	***Cl:***	***Langel.:***	***E.Coli:***
EC: [mS/m]	***K:***	***NO3 as N:***	***Aggr-Ind:***	***Faec. co:***
TDS:	***Si:***	***SO4:***	***Ion-bal:***	***Total Co:***
T. Alk.:	***Al:***	***F:***	***CaCO3:***	***SPC:***
Ca:	***Fe:***			
Mg:	***Mn:***			

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimim allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	***Depth to Bot. [m]***	***Yield[l/s]***	***Method meas.***	***Aquifer type***	***Comment***
35.90	36.00	0.05	Notch (V- or U-notch)	Fractured	TO TEST
182.00	182.20	0.30	Notch (V- or U-notch)	Fractured	TO TEST
192.00	192.10	0.40	Notch (V- or U-notch)	Fractured	TO TEST
282.50	282.80	0.65	Notch (V- or U-notch)	Fractured	TO TEST

CASING DETAILS:

Depth to Top [m]	***to Bot. [m]***	***Diam. [mm]***	***Material***	***Thickn. [mm]***	***Type of openings***	***Openings [mm]: Length***	***Width***	***Hor. Dist.***	***Vert. Dist.***
0.00	30.00	165	Steel	4	Plain casing				

RECOMMENDATIONS:

Prior.	***Rec. equipm.***	***Depth to intk. [m]***	***Type of power***	***Duty cyc. [hrs]***	***Disch. rate [l/s]***	***Water quality***	***Dyn. water level [m]***	***Crit. water level [m]***
1		0		0	0			

Note: Water level: 7.71m - 24.04.2009

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

MANAGEMENT RECOMMENDATIONS

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0031 **Number:** H21-0681 **Site type:** Borehole

Distr./Farm No.: LPLQ472 **Site Name/Descr.:** VOGELSTRUISFONTEIN PTN. ELLISRAS

Latitude [°]:	23.613111	**Alt. No. 1:**		**Diam. [mm]:**	165	**Water lev. [m]:**	-0.56000
Longitude [°]:	27.743806	**Alt. No. 2:**		**Depth [m]:**	291.24	**WL status:**	Static
Altitude [m]:	815.00	**Rep. inst.:**	VSA	**Col. ht. [m]:**	0.60	**Date WL meas.:**	20090214

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

EXISTING EQUIPMENT:

Pump:

Type of Inst.: No equipment **Pulley Diam. [mm]:**

Manufacturer: **Depth to Intk. [m]:**

Engine:

Manufacturer: **Power Rating [kW]**

Type of Power: No Equipment **Pulley Diam. [mm]:**

USE APPLICATION:

Site Status: Unused

Purpose: Exploration

Consumer: Urban

Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.: H21-0681 **Date sampled:** 20090214 **Depth sampl. [m]:** 0 **Comment:**

Main Parameters:						Calculated Parameters:		Bacteriol. Parameters:
pH:	8.12	**Na:**	338 †	**Cl:**	314 †	**Langel.:**	-0.22	**E.Coli:**
EC: [mS/m]	166 †	**K:**	3.42	**NO3 as N:**	0.3	**Aggr-Ind:**	11.90	**Faec. co:**
TDS:	1020 †	**Si:**	6.66	**SO4:**	173	**Ion-bal:**	1.31	**Total Co:**
T. Alk.:	132	**Al:**		**F:**	9.64 ‡	**CaCO3:**	62.73	**SPC:**
Ca:	18.5	**Fe:**	0.05					
Mg:	4.03	**Mn:**	0.05					

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimim allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
24.90	25.00	0.05	Notch (V- or U-notch)	Weathered basin	TESTED
37.00	37.10	0.10	Notch (V- or U-notch)	Fractured	TESTED
215.00	216.00	0.50	Notch (V- or U-notch)	Fractured	TESTED
247.50	248.50	1.60	Notch (V- or U-notch)	Fractured	TESTED
264.00	264.50	2.90	Notch (V- or U-notch)	Fractured	TESTED

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length	Width	Hor. Dist.	Vert. Dist.
0.00	30.00	165	Steel	4	Plain casing				

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m]	%	[min]	T [m²/d]	Storage	Comment
MULTI STEP 1	20090214	60	111.47	1.08	19.06						
MULTI STEP 2	20090214	60	111.47	2.09	55.78						
MULTI STEP 3	20090214	26	111.47	3.88	111.14	1.87	98	180			
CONSTANT	20090214	1440	111.47	2.01	82.38	0	100	720			
SPECIFIC CAPACITY	20090216	720	0		80.57						0.0249
SPECIFIC CAPACITY	20090216	1440	0		82.38						0.0244

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1		90.00		24	0.60	CLASS 4		82.00
Note:								
2		90.00		8	1.50	CLASS 4		82.00

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

MANAGEMENT RECOMMENDATIONS

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0032 ***Number:*** H21-0700 ***Site type:*** Borehole

Distr./Farm No.: LPLQ502 ***Site Name/Descr.:*** WATERKLOOF PTN. ELLISRAS

Latitude [°]:	23.681694	***Alt. No. 1:***		***Diam. [mm]:***	165	***Water lev. [m]:***	6.16
Longitude [°]:	27.726361	***Alt. No. 2:***		***Depth [m]:***	204.82	***WL status:***	Static
Altitude [m]:	830.00	***Rep. inst.:***	VSA	***Col. ht. [m]:***	0.50	***Date WL meas.:***	20090310

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

EXISTING EQUIPMENT:

Pump:

Type of Inst.: No equipment ***Pulley Diam. [mm]:***

Manufacturer: ***Depth to Intk. [m]:***

Engine:

Manufacturer: ***Power Rating [kW]***

Type of Power: No Equipment ***Pulley Diam. [mm]:***

USE APPLICATION:

Site Status: Unused

Purpose: Exploration

Consumer: Non-urban

Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.: 2009/UIS02 ***Date sampled:*** 20090127 ***Depth sampl. [m]:*** 0 ***Comment:***

Main Parameters:						Calculated Parameters:		Bacteriol. Parameters:
pH:	8.05	***Na:***	339 †	***Cl:***	311 †	***Langel.:***	-0.29	***E.Coli:***
EC: [mS/m]	172 †	***K:***	3.76	***NO3 as N:***	0.3	***Aggr-Ind:***	11.84	***Faec. co:***
TDS:	1250 †	***Si:***	6.34	***SO4:***	165	***Ion-bal:***	-0.62	***Total Co:***
T. Alk.:	158	***Al:***		***F:***	10.5 ‡	***CaCO3:***	45.22	***SPC:***
Ca:	15.7	***Fe:***	0.05					
Mg:	1.47	***Mn:***	0.101 †					

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimim allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
74.00	79.00	1.17	Notch (V- or U-notch)	Fractured	TESTED
92.00	95.00	1.60	Notch (V- or U-notch)	Fractured	TESTED
141.50	142.50	3.35	Notch (V- or U-notch)	Fractured	TESTED
200.00	200.50	3.80	Notch (V- or U-notch)	Fractured	TESTED
203.00	205.00	12.00	Notch (V- or U-notch)	Fractured	TESTED

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length	Width	Hor. Dist.	Vert. Dist.
0.00	72.00	165	Steel	4	Screen				
72.00	120.00	165	Steel	4	Perforated or slotted				

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m]	%	[min]	T [m²/d]	Storage	Comment
CONSTANT	20090118	4320	118.58	18.20	70.92	0.21	100	2880	24	0.00192	
CONSTANT	20090310	1920	148.50	20.07	115.48	0.99	99	720	11	0.00193	
SPECIFIC CAPACITY	20090312	720	0		115.10						0.1744
SPECIFIC CAPACITY	20090312	1920	0		115.48						0.1738

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1		144.00		24	11.00	CLASS 4		141.00
Note:								
2		144.00		8	19.00	CLASS 4		141.00

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

MANAGEMENT RECOMMENDATIONS

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0033 **Number:** H21-0701 **Site type:** Borehole

Distr./Farm No.: LPLQ502 **Site Name/Descr.:** WATERKLOOF PTN. ELLISRAS

Latitude [°]:	23.682861	**Alt. No. 1:**		**Diam. [mm]:**	165	**Water lev. [m]:**	1.55
Longitude [°]:	27.741861	**Alt. No. 2:**		**Depth [m]:**	248.46	**WL status:**	Static
Altitude [m]:	815.00	**Rep. inst.:**	VSA	**Col. ht. [m]:**	0.50	**Date WL meas.:**	20090216

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

EXISTING EQUIPMENT:

Pump:

Type of Inst.: No equipment **Pulley Diam. [mm]:**

Manufacturer: **Depth to Intk. [m]:**

Engine:

Manufacturer: **Power Rating [kW]**

Type of Power: No Equipment **Pulley Diam. [mm]:**

USE APPLICATION:

Site Status: Unused

Purpose: Exploration

Consumer: Non-urban

Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.: H21-0701 **Date sampled:** 20090219 **Depth sampl. [m]:** 0 **Comment:**

Main Parameters:						Calculated Parameters:		Bacteriol. Parameters:
pH:	8.34	**Na:**	353 †	**Cl:**	300 †	**Langel.:**	-0.41	**E.Coli:**
EC: [mS/m]	165 †	**K:**	3.01	**NO3 as N:**	0.3	**Aggr-Ind:**	11.72	**Faec. co:**
TDS:	1090 †	**Si:**	5.51	**SO4:**	158	**Ion-bal:**	0.73	**Total Co:**
T. Alk.:	157	**Al:**		**F:**	12.7 ‡	**CaCO3:**	18.96	**SPC:**
Ca:	6.1	**Fe:**	0.05					
Mg:	0.91	**Mn:**	0.05					

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimim allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
122.00	125.50	3.10	Notch (V- or U-notch)	Fractured	TESTED
138.00	138.20	3.30	Notch (V- or U-notch)	Fractured	TESTED
264.80	265.20	3.50	Notch (V- or U-notch)	Fractured	TESTED

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length	Width	Hor. Dist.	Vert. Dist.
0.00	48.00	165	Steel	4	Plain casing				

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m]	%	[min]	T [m²/d]	Storage	Comment
MULTI STEP 1	20090216	60	111.47	1.03	18.00						
MULTI STEP 2	20090216	60	111.47	2.00	39.60						
MULTI STEP 3	20090216	36	111.47	4.06	110.99	0	100	150			
CONSTANT	20090217	1440	111.47	2.21	57.10	1.96	97	1440			
SPECIFIC CAPACITY	20090219	720	0		53.53						0.0413
SPECIFIC CAPACITY	20090219	1440	0		57.10						0.0387

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1		60.00		24	0.70	CLASS 4		55.00
Note:								
2		60.00		8	1.50	CLASS 4		55.00

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

MANAGEMENT RECOMMENDATIONS

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0034 ***Number:*** H21-0702 ***Site type:*** Borehole

Distr./Farm No.: LPLQ502 ***Site Name/Descr.:*** WATERKLOOF PTN. ELLISRAS

Latitude [°]:	23.676639	***Alt. No. 1:***		***Diam. [mm]:***	165	***Water lev. [m]:***	2.44
Longitude [°]:	27.744417	***Alt. No. 2:***		***Depth [m]:***	250.00	***WL status:***	Static
Altitude [m]:	815.00	***Rep. inst.:***	VSA	***Col. ht. [m]:***	0.50	***Date WL meas.:***	20090124

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

EXISTING EQUIPMENT:

Pump:

Type of Inst.: No equipment ***Pulley Diam. [mm]:***

Manufacturer: ***Depth to Intk. [m]:***

Engine:

Manufacturer: ***Power Rating [kW]***

Type of Power: No Equipment ***Pulley Diam. [mm]:***

USE APPLICATION:

Site Status: Unused

Purpose: Exploration

Consumer: Urban

Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.: H21-0702 ***Date sampled:*** 20090125 ***Depth sampl. [m]:*** 0 ***Comment:***

Main Parameters:						Calculated Parameters:		Bacteriol. Parameters:
pH:	7.92	***Na:***	331 †	***Cl:***	309.42 †	***Langel.:***		***E.Coli:***
EC: [mS/m]	164 †	***K:***	3.11	***NO3 as N:***	0.06	***Aggr-Ind:***		***Faec. co:***
TDS:		***Si:***	5.65	***SO4:***	171.67	***Ion-bal:***	6.77 †	***Total Co:***
T. Alk.:		***Al:***	0	***F:***	12.25 ‡	***CaCO3:***	17.73	***SPC:***
Ca:	6.03	***Fe:***	0					
Mg:	0.654	***Mn:***	0.009					

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimim allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
43.80	44.20	0.05	Notch (V- or U-notch)	Fractured	TESTED
132.70	132.80	0.08	Notch (V- or U-notch)	Fractured	TESTED
196.50	196.80	0.70	Notch (V- or U-notch)	Fractured	TESTED
210.90	211.20	1.82	Notch (V- or U-notch)	Fractured	TESTED
222.80	223.20	2.30	Notch (V- or U-notch)	Fractured	TESTED
236.70	237.30	4.20	Notch (V- or U-notch)	Fractured	TESTED

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length	Width	Hor. Dist.	Vert. Dist.
0.00	42.00	165	Steel	4	Plain casing				
42.00	54.00	165	Steel	4	Perforated or slotted				

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m]	%	[min]	T [m²/d]	Storage	Comment
CONSTANT	20090124	1440	117.47	3.04	61.18	3.33	94	1440	2.8	0.00174	
SPECIFIC CAPACITY	20090128	720	0		53.77						0.0565
SPECIFIC CAPACITY	20090128	1440	0		61.18						0.0497

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1		96.00		24	2.00	CLASS 4		197.00
Note:								
2		96.00		8	4.00	CLASS 4		197.00

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

MANAGEMENT RECOMMENDATIONS

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0035 **Number:** H21-0703 **Site type:** Borehole

Distr./Farm No.: LPLQ502 **Site Name/Descr.:** WATERKLOOF PTN. ELLISRAS

Latitude [°]:	23.676666	**Alt. No. 1:**		**Diam. [mm]:**	254	**Water lev. [m]:**	2.70
Longitude [°]:	27.744444	**Alt. No. 2:**		**Depth [m]:**	30.00	**WL status:**	Static
Altitude [m]:	815.00	**Rep. inst.:**	VSA	**Col. ht. [m]:**	0.50	**Date WL meas.:**	20090727

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

EXISTING EQUIPMENT:

Pump:

Type of Inst.: No equipment **Pulley Diam. [mm]:**

Manufacturer: **Depth to Intk. [m]:**

Engine:

Manufacturer: **Power Rating [kW]**

Type of Power: No Equipment **Pulley Diam. [mm]:**

USE APPLICATION:

Site Status: Unused

Purpose: Mine drainage

Consumer: Urban

Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.: 2009/UIS03 **Date sampled:** 20090228 **Depth sampl. [m]:** 0 **Comment:**

Main Parameters:						Calculated Parameters:		Bacteriol. Parameters:
pH:	6.71	**Na:**	19.5	**Cl:**	42.9	**Langel.:**	-1.84	**E.Coli:**
EC: [mS/m]	30	**K:**	1.47	**NO3 as N:**	0.07	**Aggr-Ind:**	10.08	**Faec. co:**
TDS:	182	**Si:**	7.8	**SO4:**	6.45	**Ion-bal:**	1.03	**Total Co:**
T. Alk.:	53.6	**Al:**		**F:**	0.19	**CaCO3:**	79.81	**SPC:**
Ca:	17.4	**Fe:**	0.05					
Mg:	8.85	**Mn:**	1.63 ‡					

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimim allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
7.00	18.00	1.00	Notch (V- or U-notch)	Weathered basin	TESTED

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length	Width	Hor. Dist.	Vert. Dist.
0.00	6.00	165	Steel	4	Plain casing				
0.00	8.00	254	Steel	4	Plain casing				
6.00	30.00	165	Steel	4	Perforated or slotted				

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m]	%	[min]	T [m²/d]	Storage	Comment
MULTI STEP 1	20090127	60	27.47	0.51	4.83						
MULTI STEP 2	20090127	60	27.47	0.82	7.36						
MULTI STEP 3	20090127	60	27.47	0.74	24.97	0.14	99	170			
CONSTANT	20090127	720	27.47	0.52	5.01	0	100	150	4.7	0.00185	
SPECIFIC CAPACITY	20090129	720	0		5.01						0.1055

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1		18.00		24	0.15	CLASS 2		7.00

Note:

2		18.00		6	0.30	CLASS 2		7.00

Note: Water level 24.04.2009 - 2.93m

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

MANAGEMENT RECOMMENDATIONS

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DBV0012 **Number:** H21-0704 **Site type:** Borehole

Distr./Farm No.: LPLQ501 **Site Name/Descr.:** GROOTFONTEIN PTN. ELLISRAS

Latitude [°]:	23.654722	**Alt. No. 1:**		**Diam. [mm]:**	165	**Water lev. [m]:**	-0.45000
Longitude [°]:	27.759194	**Alt. No. 2:**		**Depth [m]:**	220.00	**WL status:**	Static
Altitude [m]:	820.00	**Rep. inst.:**	VSA	**Col. ht. [m]:**	0.45	**Date WL meas.:**	20090207

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

EXISTING EQUIPMENT:

Pump:

Type of Inst.: No equipment **Pulley Diam. [mm]:**

Manufacturer: **Depth to Intk. [m]:**

Engine:

Manufacturer: **Power Rating [kW]**

Type of Power: No Equipment **Pulley Diam. [mm]:**

USE APPLICATION:

Site Status: Unused

Purpose: Production (water supply)

Consumer: Urban

Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.: H21-0704 **Date sampled:** 20090207 **Depth sampl. [m]:** 0 **Comment:**

Main Parameters:						Calculated Parameters:		Bacteriol. Parameters:
pH:	7.33	**Na:**	322 †	**Cl:**	272 †	**Langel.:**	-1.39	**E.Coli:**
EC: [mS/m]	160 †	**K:**	3.23	**NO3 as N:**	0.067	**Aggr-Ind:**	10.70	**Faec. co:**
TDS:	982 †	**Si:**	7.96	**SO4:**		**Ion-bal:**	11.72 ‡	**Total Co:**
T. Alk.:	152	**Al:**		**F:**	12.9 ‡	**CaCO3:**	16.62	**SPC:**
Ca:	6.25	**Fe:**	0.05					
Mg:	0.25	**Mn:**	0.05					

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimim allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
24.90	25.10	0.05	Notch (V- or U-notch)	Weathered basin	TESTED
134.10	134.30	0.20	Notch (V- or U-notch)	Fractured	TESTED
185.20	185.40	0.30	Notch (V- or U-notch)	Fractured	TESTED
196.90	197.20	1.70	Notch (V- or U-notch)	Fractured	TESTED
199.10	200.00	3.50	Notch (V- or U-notch)	Fractured	TESTED

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length	Width	Hor. Dist.	Vert. Dist.
0.00	54.00	165	Steel	4	Plain casing				

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m]	%	[min]	T [m²/d]	Storage	Comment
MULTI STEP 1	20090207	60	118.58	1.36	12.23						
MULTI STEP 2	20090207	60	118.58	2.05	21.62						
MULTI STEP 3	20090207	60	118.58	4.10	70.31						
MULTI STEP 4	20090207	60	118.58	7.79	114.51	0.57	100	90			
CONSTANT	20090207	160	118.58	3.82	42.53	0	100	20			
SPECIFIC CAPACITY	20090208	160	0		42.53						0.0898

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1		78.00		24	1.40	CLASS 4		43.00
Note:								
2		78.00		8	3.00	CLASS 4		43.00

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

MANAGEMENT RECOMMENDATIONS

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DBV0013 **Number:** H21-0706 **Site type:** Borehole

Distr./Farm No.: LPLQ501 **Site Name/Descr.:** GROOTFONTEIN PTN. ELLISRAS

Latitude [°]:	23.659111	**Alt. No. 1:**		**Diam. [mm]:**	165	**Water lev. [m]:**	10.11
Longitude [°]:	27.756694	**Alt. No. 2:**		**Depth [m]:**	30.00	**WL status:**	Static
Altitude [m]:	820.00	**Rep. inst.:**	VSA	**Col. ht. [m]:**	0.50	**Date WL meas.:**	20090220

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

EXISTING EQUIPMENT:

Pump:

Type of Inst.: No equipment **Pulley Diam. [mm]:**

Manufacturer: **Depth to Intk. [m]:**

Engine:

Manufacturer: **Power Rating [kW]**

Type of Power: No Equipment **Pulley Diam. [mm]:**

USE APPLICATION:

Site Status: Unused

Purpose: Exploration

Consumer: Urban

Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.: H21-0706 **Date sampled:** 20090305 **Depth sampl. [m]:** 0 **Comment:**

Main Parameters:						Calculated Parameters:		Bacteriol. Parameters:
pH:	7.78	**Na:**	389 †	**Cl:**	380 †	**Langel.:**	-0.01	**E.Coli:**
EC: [mS/m]	197 †	**K:**	4.81	**NO3 as N:**	0.3	**Aggr-Ind:**	12.15	**Faec. co:**
TDS:	1150 †	**Si:**	6.18	**SO4:**	27.1	**Ion-bal:**	2.69	**Total Co:**
T. Alk.:	359	**Al:**		**F:**	1.77 ‡	**CaCO3:**	128.05	**SPC:**
Ca:	26.1	**Fe:**	0.05					
Mg:	15.3	**Mn:**	1.41 ‡					

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimim allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
12.00	18.00	0.05	Notch (V- or U-notch)	Weathered basin	PUMP SUCTION

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length	Width	Hor. Dist.	Vert. Dist.
0.00	12.00	165	Steel	4	Plain casing				
12.00	30.00	165	Steel	4	Perforated or slotted				

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m]	%	[min]	T [m²/d]	Storage	Comment
MULTI STEP 1	20090220	60	26.80	0.10	19.30						
MULTI STEP 2	20090220	9	26.80	0.20	26.53	24.14	9	120			

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1		27.00		1	0.10	CLASS 3		

Note: Not recommended; water level 24.04.2009 - 9.49m

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

MANAGEMENT RECOMMENDATIONS

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0036 ***Number:*** H21-0707 ***Site type:*** Borehole

Distr./Farm No.: LPLQ591 ***Site Name/Descr.:*** RIVERSBEND PTN. ELLISRAS

Latitude [°]:	23.731611	***Alt. No. 1:***		***Diam. [mm]:***	165	***Water lev. [m]:***	5.61
Longitude [°]:	27.746639	***Alt. No. 2:***		***Depth [m]:***	305.00	***WL status:***	Static
Altitude [m]:	825.00	***Rep. inst.:***	VSA	***Col. ht. [m]:***	0.45	***Date WL meas.:***	20090310

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

EXISTING EQUIPMENT:

Pump:

Type of Inst.:	No equipment	***Pulley Diam. [mm]:***	
Manufacturer:		***Depth to Intk. [m]:***	

Engine:

Manufacturer:		***Power Rating [kW]***	
Type of Power:	No Equipment	***Pulley Diam. [mm]:***	

USE APPLICATION:

Site Status: Unused

Purpose: Exploration

Consumer:

Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.:	***Date sampled:***	***Depth sampl. [m]:***	***Comment:***

Main Parameters:			**Calculated Parameters:**	**Bacteriol. Parameters:**
pH:	***Na:***	***Cl:***	***Langel.:***	***E.Coli:***
EC: [mS/m]	***K:***	***NO3 as N:***	***Aggr-Ind:***	***Faec. co:***
TDS:	***Si:***	***SO4:***	***Ion-bal:***	***Total Co:***
T. Alk.:	***Al:***	***F:***	***CaCO3:***	***SPC:***
Ca:	***Fe:***			
Mg:	***Mn:***			

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimim allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	***Depth to Bot. [m]***	***Yield[l/s]***	***Method meas.***	***Aquifer type***	***Comment***
0.00	0.00	0.00	Notch (V- or U-notch)		DRY-DRILL

CASING DETAILS:

Depth to Top [m]	***to Bot. [m]***	***Diam. [mm]***	***Material***	***Thickn. [mm]***	***Type of openings***	***Openings [mm]: Length***	***Width***	***Hor. Dist.***	***Vert. Dist.***
0.00	18.00	165	Steel	4	Plain casing				

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

MANAGEMENT RECOMMENDATIONS

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DCV0005 **Number:** H21-0708 **Site type:** Borehole

Distr./Farm No.: LPLQ591 **Site Name/Descr.:** RIVERSBEND PTN. ELLISRAS

Latitude [°]:	23.757583	**Alt. No. 1:**		**Diam. [mm]:**	165	**Water lev. [m]:**	10.79
Longitude [°]:	27.747306	**Alt. No. 2:**		**Depth [m]:**	307.96	**WL status:**	Static
Altitude [m]:	835.00	**Rep. inst.:**	VSA	**Col. ht. [m]:**	0.35	**Date WL meas.:**	20090219

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

EXISTING EQUIPMENT:

Pump:

Type of Inst.: No equipment **Pulley Diam. [mm]:**

Manufacturer: **Depth to Intk. [m]:**

Engine:

Manufacturer: **Power Rating [kW]**

Type of Power: No Equipment **Pulley Diam. [mm]:**

USE APPLICATION:

Site Status: Unused

Purpose: Exploration

Consumer:

Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.: H21-0708 **Date sampled:** 20090219 **Depth sampl. [m]:** 0 **Comment:**

Main Parameters:						Calculated Parameters:		Bacteriol. Parameters:
pH:	6.05	**Na:**	45.3	**Cl:**	45.6	**Langel.:**	-3.20	**E.Coli:**
EC: [mS/m]	29	**K:**	3.27	**NO3 as N:**	1.5	**Aggr-Ind:**	8.72	**Faec. co:**
TDS:	198	**Si:**	12.1	**SO4:**	15.2	**Ion-bal:**	12.37 ‡	**Total Co:**
T. Alk.:	21.4	**Al:**		**F:**	1.58 ‡	**CaCO3:**	39.71	**SPC:**
Ca:	8.86	**Fe:**	0.95 †					
Mg:	4.28	**Mn:**	0.05					

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimim allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
21.00	33.00	0.60	Notch (V- or U-notch)	Fractured	TESTED
68.00	71.00	1.30	Notch (V- or U-notch)	Fractured	TESTED
88.00	93.00	1.70	Notch (V- or U-notch)	Fractured	TESTED
227.00	230.00	1.90	Notch (V- or U-notch)	Fractured	TESTED
246.00	246.50	2.20	Notch (V- or U-notch)	Fractured	TESTED

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length	Width	Hor. Dist.	Vert. Dist.
0.00	18.00	165	Steel	4	Plain casing				
18.00	36.00	165	Steel	4	Perforated or slotted				

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m]	%	[min]	T [m²/d]	Storage	Comment
MULTI STEP 1	20090219	60	111.47	1.07	14.23						
MULTI STEP 2	20090219	60	111.47	2.05	19.29						
MULTI STEP 3	20090219	21	111.47	4.07	100.29	12.45	88	180			
CONSTANT	20090220	1440	111.47	1.81	25.79	11.20	57	1440	7.2	0.00189	
SPECIFIC CAPACITY	20090222	720	0		21.72						0.0833
SPECIFIC CAPACITY	20090222	1440	0		25.79						0.0702

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1		42.00		24	0.70	CLASS 3		68.00

Note:

2		42.00		8	1.50	CLASS 3		68.00

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

MANAGEMENT RECOMMENDATIONS

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DBV0015 ***Number:*** H21-0709 ***Site type:*** Borehole

Distr./Farm No.: LPLQ501 ***Site Name/Descr.:*** GROOTFONTEIN PTN. ELLISRAS

Latitude [°]:	23.641800	***Alt. No. 1:***		***Diam. [mm]:***		***Water lev. [m]:***	
Longitude [°]:	27.752280	***Alt. No. 2:***		***Depth [m]:***	163.00	***WL status:***	
Altitude [m]:	830.00	***Rep. inst.:***	VSA	***Col. ht. [m]:***	0.40	***Date WL meas.:***	

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

EXISTING EQUIPMENT:

Pump:

Type of Inst.: No equipment ***Pulley Diam. [mm]:***

Manufacturer: ***Depth to Intk. [m]:***

Engine:

Manufacturer: ***Power Rating [kW]***

Type of Power: No Equipment ***Pulley Diam. [mm]:***

USE APPLICATION:

Site Status: Unused

Purpose: Exploration

Consumer: Non-urban

Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.: H31-0709 ***Date sampled:*** 20090310 ***Depth sampl. [m]:*** 0 ***Comment:***

Main Parameters:						Calculated Parameters:		Bacteriol. Parameters:
pH:	8.45	***Na:***	337 †	***Cl:***	301 †	***Langel.:***		***E.Coli:***
EC: [mS/m]	172 †	***K:***	2.99	***NO3 as N:***	0.3	***Aggr-Ind:***		***Faec. co:***
TDS:	1140 †	***Si:***	7.93	***SO4:***	166	***Ion-bal:***	8.96 †	***Total Co:***
T. Alk.:		***Al:***		***F:***	12.3 ‡	***CaCO3:***	18.18	***SPC:***
Ca:	6.94	***Fe:***	0.06					
Mg:	0.21	***Mn:***	0.05					

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimim allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	***Depth to Bot. [m]***	***Yield[l/s]***	***Method meas.***	***Aquifer type***	***Comment***
104.90	105.10	0.10	Notch (V- or U-notch)	Fractured	TO TEST
148.10	148.20	1.50	Notch (V- or U-notch)	Fractured	TO TEST
159.00	160.00	20.00	Notch (V- or U-notch)	Fractured	TO TEST

CASING DETAILS:

Depth to Top [m]	***to Bot. [m]***	***Diam. [mm]***	***Material***	***Thickn. [mm]***	***Type of openings***	***Openings [mm]: Length***	***Width***	***Hor. Dist.***	***Vert. Dist.***
0.00	16.90	254	Steel	4	Plain casing				
16.90	52.90	208	Steel	4	Plain casing				
52.90	160.00	132	Steel	4	Plain casing				

RECOMMENDATIONS:

Prior.	***Rec. equipm.***	***Depth to intk. [m]***	***Type of power***	***Duty cyc. [hrs]***	***Disch. rate [l/s]***	***Water quality***	***Dyn. water level [m]***	***Crit. water level [m]***
1		0		0	0	CLASS 4		

Note: This borehole will be drilled deeper with core drill (DWAF)

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

MANAGEMENT RECOMMENDATIONS

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0038 **Number:** H21-0712 **Site type:** Borehole

Distr./Farm No.: LPLQ550 **Site Name/Descr.:** WONDERBOOMHOEK PTN. ELLISRAS

Latitude [°]:	23.734389	**Alt. No. 1:**		**Diam. [mm]:**	165	**Water lev. [m]:**	2.71
Longitude [°]:	27.745917	**Alt. No. 2:**		**Depth [m]:**	204.95	**WL status:**	Static
Altitude [m]:	825.00	**Rep. inst.:**	VSA	**Col. ht. [m]:**		**Date WL meas.:**	20090330

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

EXISTING EQUIPMENT:

Pump:

Type of Inst.: No equipment **Pulley Diam. [mm]:**

Manufacturer: **Depth to Intk. [m]:**

Engine:

Manufacturer: **Power Rating [kW]**

Type of Power: No Equipment **Pulley Diam. [mm]:**

USE APPLICATION:

Site Status: Unused

Purpose: Exploration

Consumer: Non-urban

Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.: 2009/CS087 **Date sampled:** 20090330 **Depth sampl. [m]:** 0 **Comment:**

Main Parameters:						Calculated Parameters:		Bacteriol. Parameters:	
pH:	7.74	**Na:**	292.6 †	**Cl:**	246.4	**Langel.:**	-0.59	**E.Coli:**	
EC: [mS/m]	139.7 †	**K:**	8.12	**NO3 as N:**	0.057	**Aggr-Ind:**	11.51	**Faec. co:**	
TDS:	759 †	**Si:**		**SO4:**	83.8	**Ion-bal:**	6.33 †	**Total Co:**	
T. Alk.:	165.6	**Al:**	0.037	**F:**	8.616 ‡	**CaCO3:**	60.71	**SPC:**	
Ca:	14.33	**Fe:**	0.001						
Mg:	6.067	**Mn:**	0.013						

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimim allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
28.90	29.10	0.10	Notch (V- or U-notch)	Fractured	TESTED
186.00	186.20	1.00	Notch (V- or U-notch)	Fractured	TESTED
193.10	193.20	1.80	Notch (V- or U-notch)	Fractured	TESTED
198.50	201.40	8.00	Notch (V- or U-notch)	Fractured	TESTED

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length	Width	Hor. Dist.	Vert. Dist.
0.00	24.00	165	Steel	4	Plain casing				
24.00	30.00	165	Steel	4	Perforated or slotted				

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m]	%	[min]	T [m²/d]	Storage	Comment
MULTI STEP 1	20090330	60	76.40	3.41	29.13						
MULTI STEP 2	20090330	60	76.40	5.03	55.85						
MULTI STEP 3	20090330	25	76.40	8.17	72.57	4.66	94	120			
CONSTANT	20090331	720	76.40	4.04	57.83	0.88	95	720	3.3	0.00179	
SPECIFIC CAPACITY	20090401	720	0		57.83						0.0699

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1		120.00		24	2.00	CLASS 4		186.00

Note:

2		120.00		8	4.00	CLASS 4		186.00

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

MANAGEMENT RECOMMENDATIONS

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0039 ***Number:*** M21-0713 ***Site type:*** Borehole

Distr./Farm No.: LPLQ528 ***Site Name/Descr.:*** TOUWFONTEIN PTN. ELLISRAS

Latitude [°]:	23.700694	***Alt. No. 1:***		***Diam. [mm]:***	165	***Water lev. [m]:***	6.15
Longitude [°]:	27.749361	***Alt. No. 2:***		***Depth [m]:***	240.00	***WL status:***	Static
Altitude [m]:	825.00	***Rep. inst.:***	VSA	***Col. ht. [m]:***	0.50	***Date WL meas.:***	20090313

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

EXISTING EQUIPMENT:

Pump:

Type of Inst.: Recorder ***Pulley Diam. [mm]:***

Manufacturer: ***Depth to Intk. [m]:***

Engine:

Manufacturer: ***Power Rating [kW]***

Type of Power: Other ***Pulley Diam. [mm]:***

USE APPLICATION:

Site Status: Unused

Purpose: Exploration

Consumer: Non-urban

Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.: ***Date sampled:*** ***Depth sampl. [m]:*** ***Comment:***

Main Parameters:			**Calculated Parameters:**	**Bacteriol. Parameters:**
pH:	***Na:***	***Cl:***	***Langel.:***	***E.Coli:***
EC: [mS/m]	***K:***	***NO3 as N:***	***Aggr-Ind:***	***Faec. co:***
TDS:	***Si:***	***SO4:***	***Ion-bal:***	***Total Co:***
T. Alk.:	***Al:***	***F:***	***CaCO3:***	***SPC:***
Ca:	***Fe:***			
Mg:	***Mn:***			

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimim allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	*Depth to Bot. [m]*	*Yield[l/s]*	*Method meas.*	*Aquifer type*	*Comment*
21.10	21.20	0.05	Notch (V- or U-notch)	Weathered basin	MONITORING
100.20	100.30	0.08	Notch (V- or U-notch)	Fractured	MONITORING
176.10	176.30	0.40	Notch (V- or U-notch)	Fractured	MONITORING
213.00	214.00	0.80	Notch (V- or U-notch)	Fractured	MONITORING
229.00	229.50	1.30	Notch (V- or U-notch)	Fractured	MONITORING

CASING DETAILS:

Depth to Top [m]	*to Bot. [m]*	*Diam. [mm]*	*Material*	*Thickn. [mm]*	*Type of openings*	*Openings [mm]: Length*	*Width*	*Hor. Dist.*	*Vert. Dist.*
0.00	45.00	165	Steel	4	Plain casing				

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

MANAGEMENT RECOMMENDATIONS

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DBV0016 ***Number:*** H21-0714 ***Site type:*** Borehole

Distr./Farm No.: LPLQ501 ***Site Name/Descr.:*** GROOTFONTEIN PTN. ELLISRAS

Latitude [°]:	23.660222	***Alt. No. 1:***		***Diam. [mm]:***	165	***Water lev. [m]:***	
Longitude [°]:	27.756250	***Alt. No. 2:***		***Depth [m]:***	24.00	***WL status:***	
Altitude [m]:	820.00	***Rep. inst.:***	VSA	***Col. ht. [m]:***		***Date WL meas.:***	

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

EXISTING EQUIPMENT:

Pump:

Type of Inst.: No equipment ***Pulley Diam. [mm]:***

Manufacturer: ***Depth to Intk. [m]:***

Engine:

Manufacturer: ***Power Rating [kW]***

Type of Power: No Equipment ***Pulley Diam. [mm]:***

USE APPLICATION:

Site Status: Unused

Purpose: Exploration

Consumer:

Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.: ***Date sampled:*** ***Depth sampl. [m]:*** ***Comment:***

Main Parameters:			**Calculated Parameters:**	**Bacteriol. Parameters:**
pH:	***Na:***	***Cl:***	***Langel.:***	***E.Coli:***
EC: [mS/m]	***K:***	***NO3 as N:***	***Aggr-Ind:***	***Faec. co:***
TDS:	***Si:***	***SO4:***	***Ion-bal:***	***Total Co:***
T. Alk.:	***Al:***	***F:***	***CaCO3:***	***SPC:***
Ca:	***Fe:***			
Mg:	***Mn:***			

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimim allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	***Depth to Bot. [m]***	***Yield[l/s]***	***Method meas.***	***Aquifer type***	***Comment***
0.00	0.00	0.00	Notch (V- or U-notch)		DRY-DRILL

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

MANAGEMENT RECOMMENDATIONS

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0041 **Number:** H21-0715 **Site type:** Borehole

Distr./Farm No.: LPLQ524 **Site Name/Descr.:** SCHAAPPLAATS PTN. ELLISRAS

Latitude [°]:	23.687361	**Alt. No. 1:**		**Diam. [mm]:**	254	**Water lev. [m]:**	0.49
Longitude [°]:	27.745580	**Alt. No. 2:**		**Depth [m]:**	32.45	**WL status:**	Static
Altitude [m]:	820.00	**Rep. inst.:**	VSA	**Col. ht. [m]:**	0.50	**Date WL meas.:**	20090319

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

EXISTING EQUIPMENT:

Pump:

Type of Inst.: No equipment **Pulley Diam. [mm]:**

Manufacturer: **Depth to Intk. [m]:**

Engine:

Manufacturer: **Power Rating [kW]**

Type of Power: No Equipment **Pulley Diam. [mm]:**

USE APPLICATION:

Site Status: Unused

Purpose: Exploration

Consumer: Non-urban

Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.: 2009/CS086 **Date sampled:** 20090319 **Depth sampl. [m]:** 0 **Comment:**

Main Parameters:						Calculated Parameters:		Bacteriol. Parameters:
pH:	6.82	**Na:**	5.942	**Cl:**	5.2	**Langel.:**	-2.54	**E.Coli:**
EC: [mS/m]	8.05	**K:**	1.63	**NO3 as N:**	0.057	**Aggr-Ind:**	9.25	**Faec. co:**
TDS:	39	**Si:**		**SO4:**	5.7	**Ion-bal:**	-3.15	**Total Co:**
T. Alk.:	22.9	**Al:**	14.12 ‡	**F:**	0.277	**CaCO3:**	19.82	**SPC:**
Ca:	4.68	**Fe:**	4.58 ‡					
Mg:	1.981	**Mn:**	0.017					

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimim allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	Depth to Bot. [m]	Yield[l/s]	Method meas.	Aquifer type	Comment
0.50	36.00	10.00	Notch (V- or U-notch)		TESTED

CASING DETAILS:

Depth to Top [m]	to Bot. [m]	Diam. [mm]	Material	Thickn. [mm]	Type of openings	Openings [mm]: Length	Width	Hor. Dist.	Vert. Dist.
0.00	3.00	165	Steel	4	Plain casing				
0.00	10.50	254	Steel	4	Perforated or slotted				
3.00	30.00	165	Steel	4	Perforated or slotted				
30.00	36.00	165	Steel	4	Plain casing				

TESTING DETAILS:

Description	Date	Durat. [min]	Depth to intk. [m]	Disch. rate[l/s]	Drawd. [m]	Recovery [m]	%	[min]	T [m²/d]	Storage	Comment
MULTI STEP 1	20090319	60	28.16	5.72	0.80						
MULTI STEP 2	20090319	60	28.16	7.57	1.30						
MULTI STEP 3	20090319	60	28.16	12.70	5.05						
MULTI STEP 4	20090319	60	28.16	20.70	4.92	0	100	80			
CONSTANT	20090322	150	16.16	20.80	15.32	0.11	99	20			
CONSTANT	20090322	20	16.16	14.11	26.62	1.28	95	15			
CONSTANT	20090322	150	27.40	13.60	21.90	0.45	98	150	56	0.00178	

RECOMMENDATIONS:

Prior.	Rec. equipm.	Depth to intk. [m]	Type of power	Duty cyc. [hrs]	Disch. rate [l/s]	Water quality	Dyn. water level [m]	Crit. water level [m]
1		24.00		24	2.00	CLASS 2		

Note:

2		24.00		8	4.00	CLASS 2		

VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

MANAGEMENT RECOMMENDATIONS

Date compiled: 2010/01/18

BASIC SITE INFORMATION:

Site Identifier: 2327DAV0040 ***Number:*** H21-0716 ***Site type:*** Borehole

Distr./Farm No.: LPLQ503 ***Site Name/Descr.:*** ONVERWACHT PTN. ELLISRAS

Latitude [°]:	23.688944	***Alt. No. 1:***		***Diam. [mm]:***	165	***Water lev. [m]:***	1.67
Longitude [°]:	27.692250	***Alt. No. 2:***		***Depth [m]:***	27.00	***WL status:***	Static
Altitude [m]:	845.00	***Rep. inst.:***	VSA	***Col. ht. [m]:***	0.50	***Date WL meas.:***	20090424

Coordinate System: Geographic Decimal Degrees (Longitude/Latitude), WGS 1984

EXISTING EQUIPMENT:

Pump:

Type of Inst.: No equipment ***Pulley Diam. [mm]:***

Manufacturer: ***Depth to Intk. [m]:***

Engine:

Manufacturer: ***Power Rating [kW]***

Type of Power: No Equipment ***Pulley Diam. [mm]:***

USE APPLICATION:

Site Status: Unused

Purpose: Exploration

Consumer: Non-urban

Application: Domestic - all purposes

WATER CHEMISTRY:

Sample No.: ***Date sampled:*** ***Depth sampl. [m]:*** ***Comment:***

Main Parameters:			**Calculated Parameters:**	**Bacteriol. Parameters:**
pH:	***Na:***	***Cl:***	***Langel.:***	***E.Coli:***
EC: [mS/m]	***K:***	***NO3 as N:***	***Aggr-Ind:***	***Faec. co:***
TDS:	***Si:***	***SO4:***	***Ion-bal:***	***Total Co:***
T. Alk.:	***Al:***	***F:***	***CaCO3:***	***SPC:***
Ca:	***Fe:***			
Mg:	***Mn:***			

Concentrations in [mg/l]; Bact. param. in counts/100ml; Chemistry Standard: SABS for human consumption
† Value exceeds recommended maximum limit ‡ Value exceeds maximum allowable limit
! Value exceeds recommended minimum limit ¡ Value exceeds minimim allowable limit

AQUIFER INFORMATION:

Depth to Top [m]	***Depth to Bot. [m]***	***Yield[l/s]***	***Method meas.***	***Aquifer type***	***Comment***
4.00	5.00	0.05	Notch (V- or U-notch)	Weathered basin	DRY-DRILL

CASING DETAILS:

Depth to Top [m]	***to Bot. [m]***	***Diam. [mm]***	***Material***	***Thickn. [mm]***	***Type of openings***	***Openings [mm]: Length***	***Width***	***Hor. Dist.***	***Vert. Dist.***
0.00	3.00	165	Steel	4	Plain casing				
3.00	15.00	165	Steel	4	Perforated or slotted				

RECOMMENDATIONS:

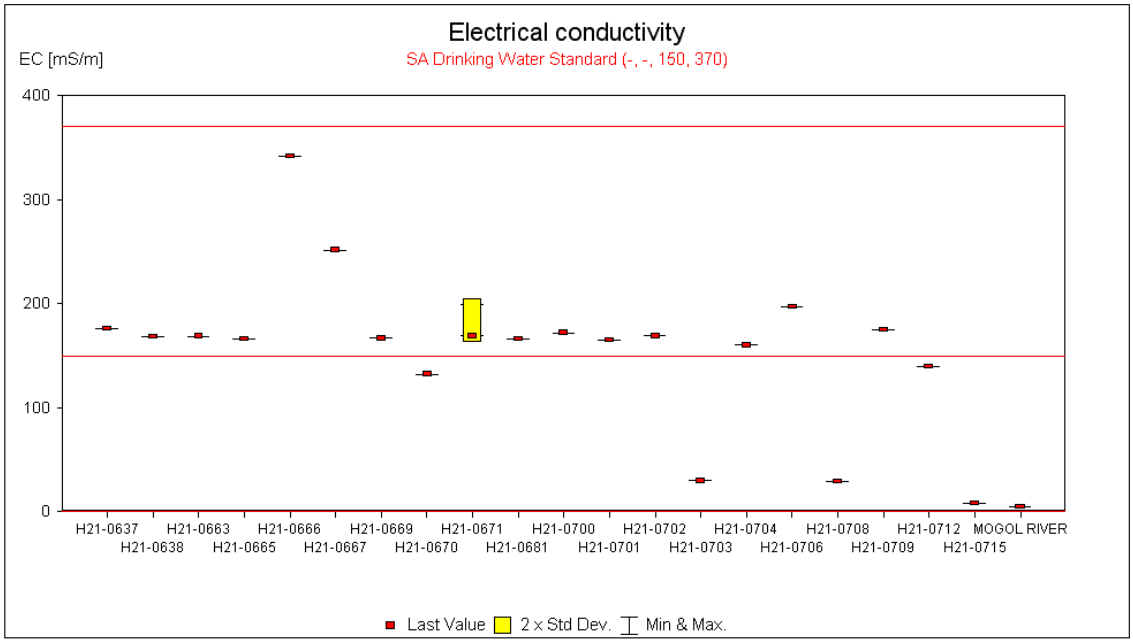
Prior.	***Rec. equipm.***	***Depth to intk. [m]***	***Type of power***	***Duty cyc. [hrs]***	***Disch. rate [l/s]***	***Water quality***	***Dyn. water level [m]***	***Crit. water level [m]***
1		0		0	0			

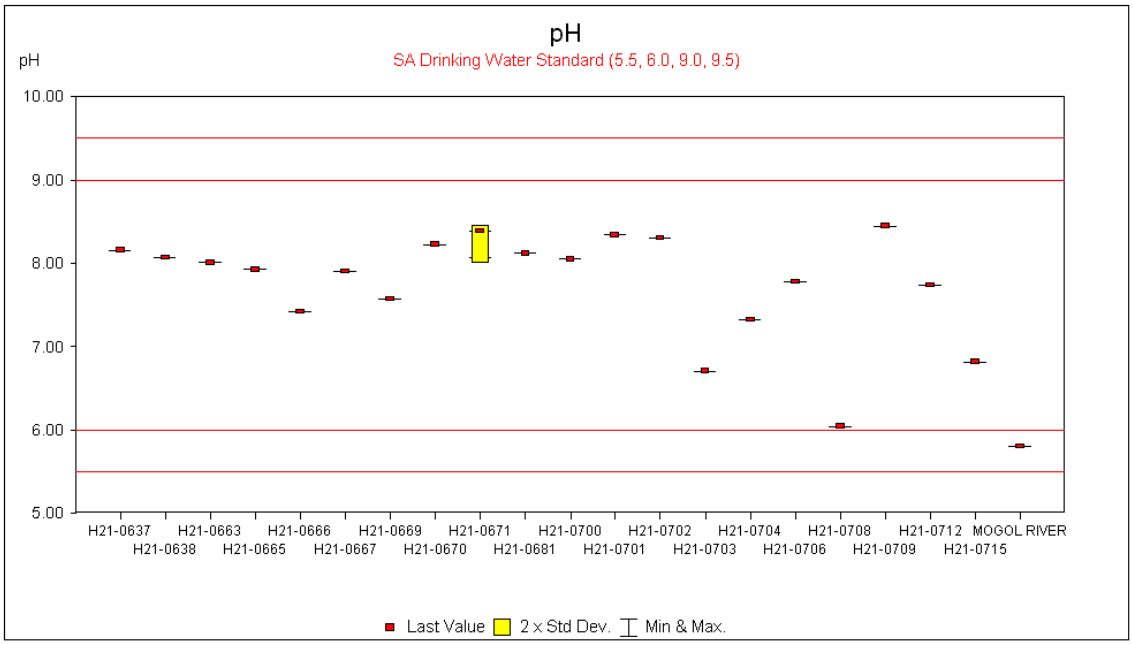
Note: Water level monitoring at golf course; diver removed 24.04.2009; water level 24.04.2009 - 9.49m

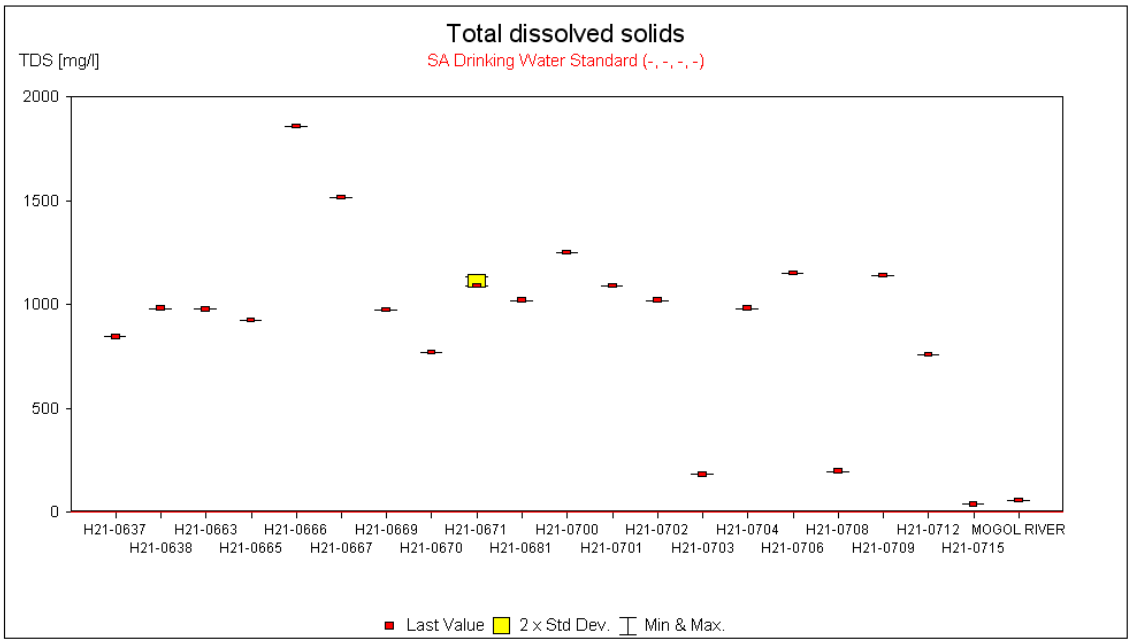
VSA Leboa Consulting (Pty) Ltd.
P.O. Box 222, Pietersburg, 0700
Tel: 082 315 2977/082 315 2978
Fax: 086 685 7724 / 078 890 2585
E-mail: vsaleboanels@mweb.co.za

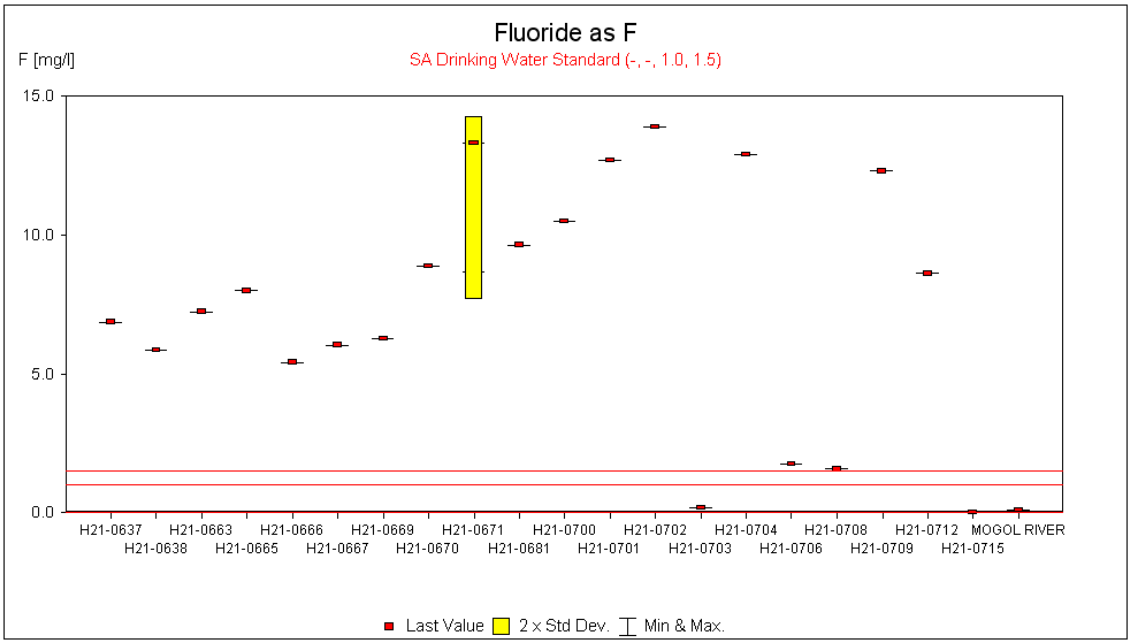
Appendix F: Water Quality

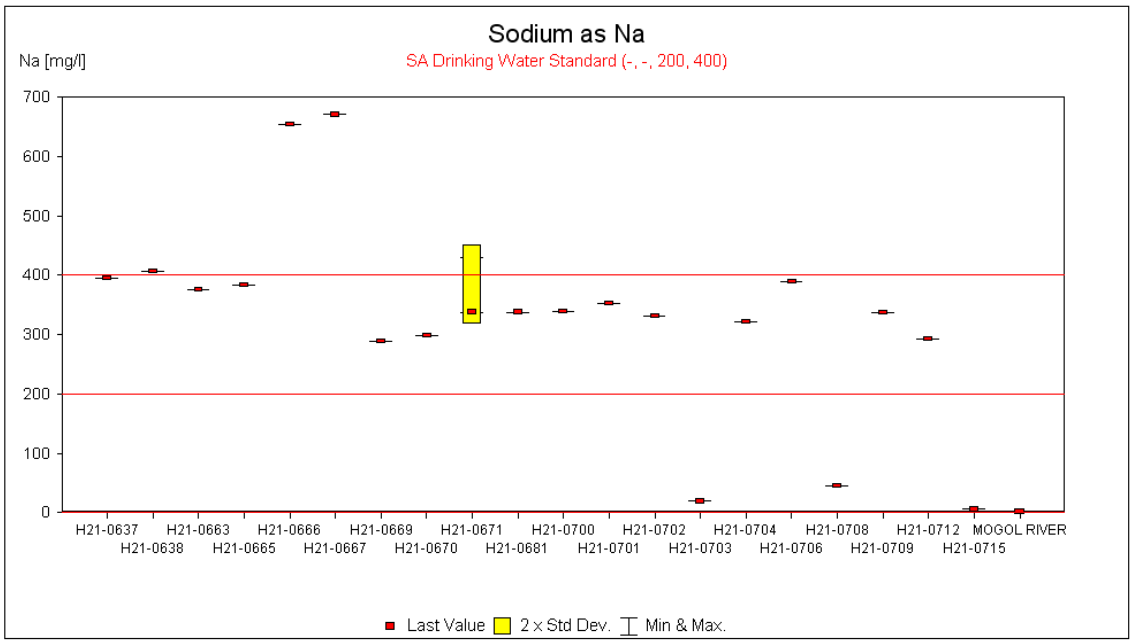
F1: Box-and Whisker plots of available water quality

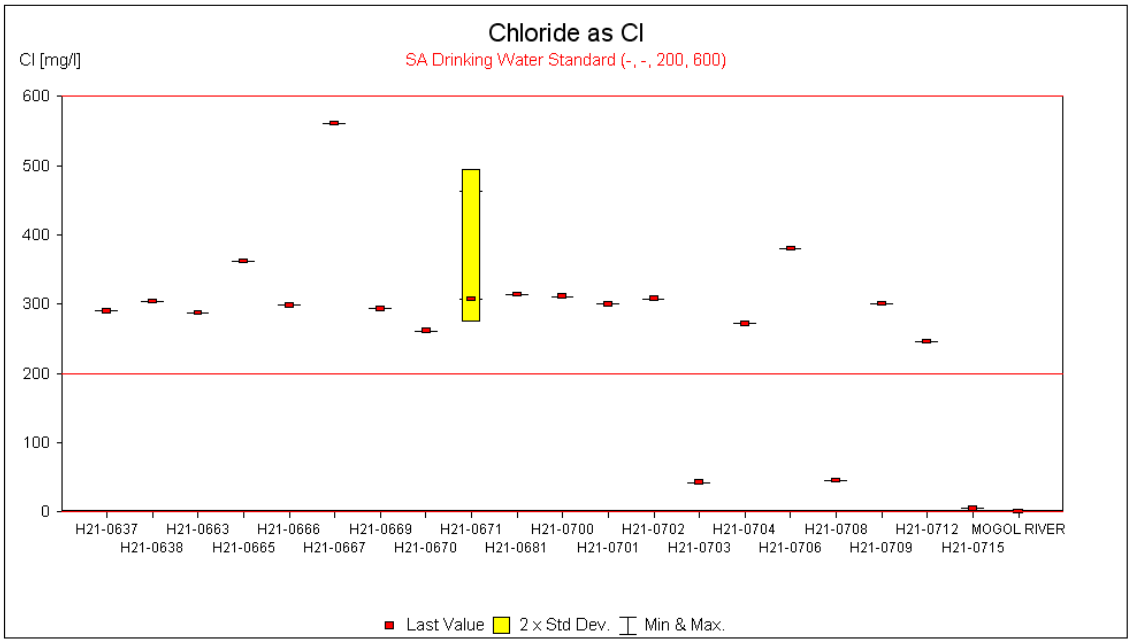


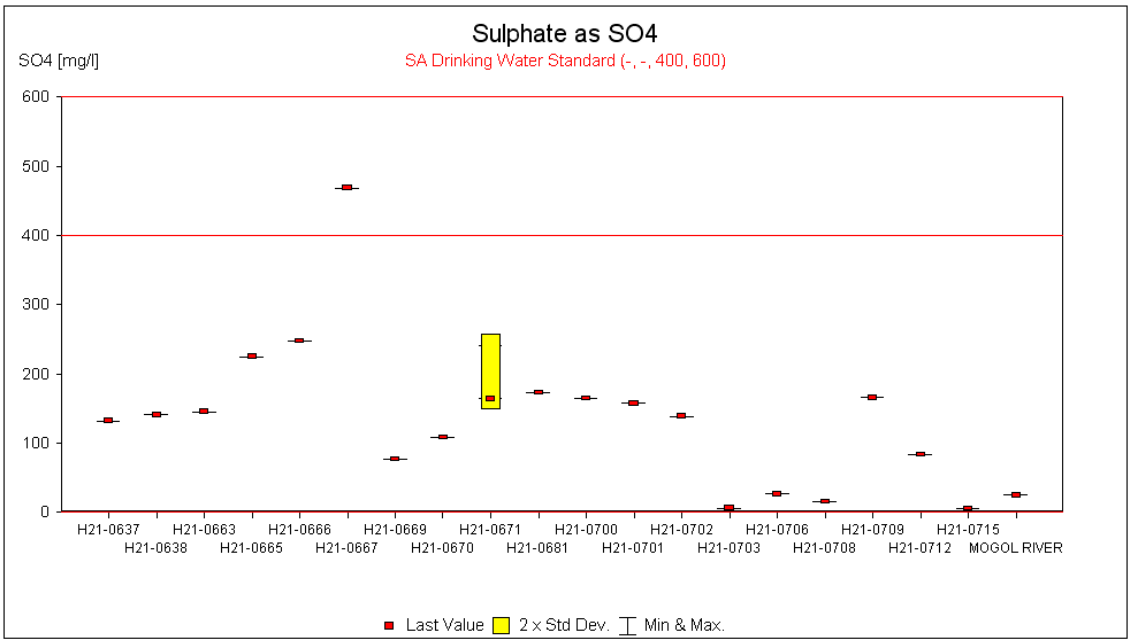


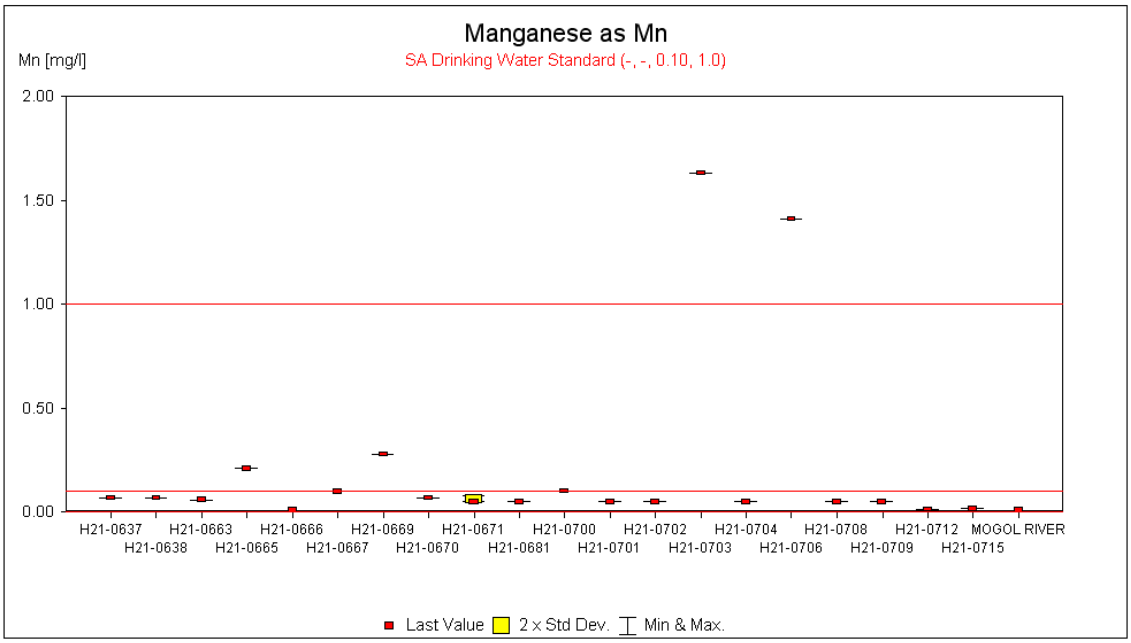

Total dissolved solids
TDS [mg/l]
SA Drinking Water Standard (-, -, -, -)
2000
1500
1000
500
0
H21-0637
H21-0638
H21-0663
H21-0665
H21-0666
H21-0667
H21-0669
H21-0670
H21-0671
H21-0681
H21-0700
H21-0701
H21-0702
H21-0703
H21-0704
H21-0706
H21-0708
H21-0709
H21-0712
H21-0715
MOGOL RIVER
Last Value
2 x Std Dev.
Min & Max.

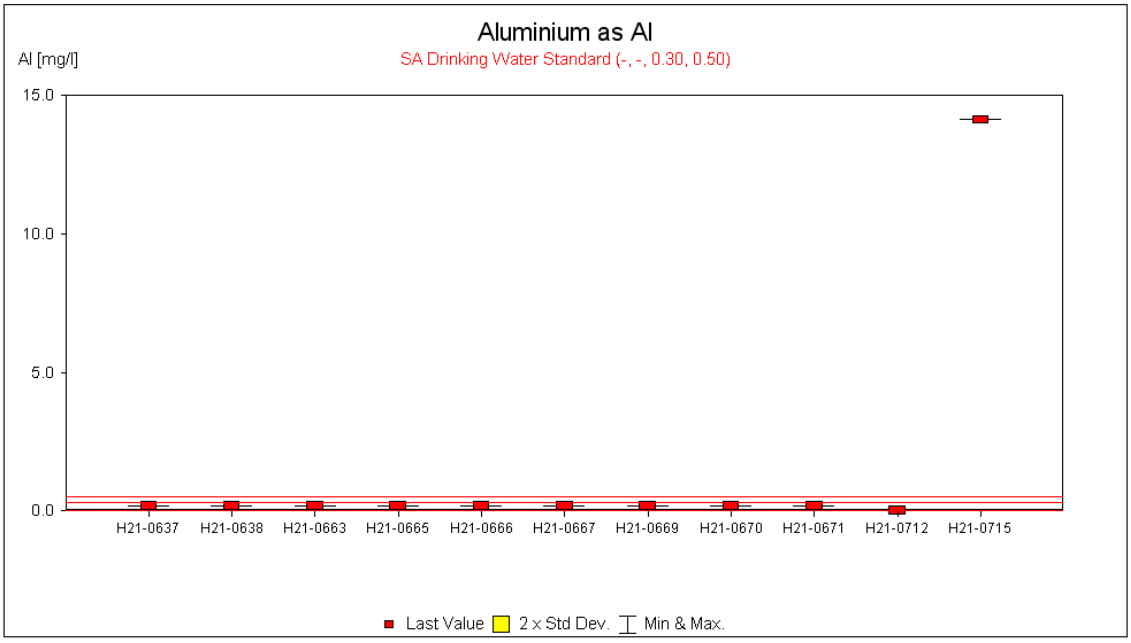

Fluoride as F
F [mg/l]
SA Drinking Water Standard (-, -, 1.0, 1.5)
15.0
10.0
5.0
0.0
H21-0637
H21-0638
H21-0663
H21-0665
H21-0666
H21-0667
H21-0669
H21-0670
H21-0671
H21-0681
H21-0700
H21-0701
H21-0702
H21-0703
H21-0704
H21-0706
H21-0708
H21-0709
H21-0712
H21-0715
MOGOL RIVER
Last Value
2 x Std Dev.
Min & Max.

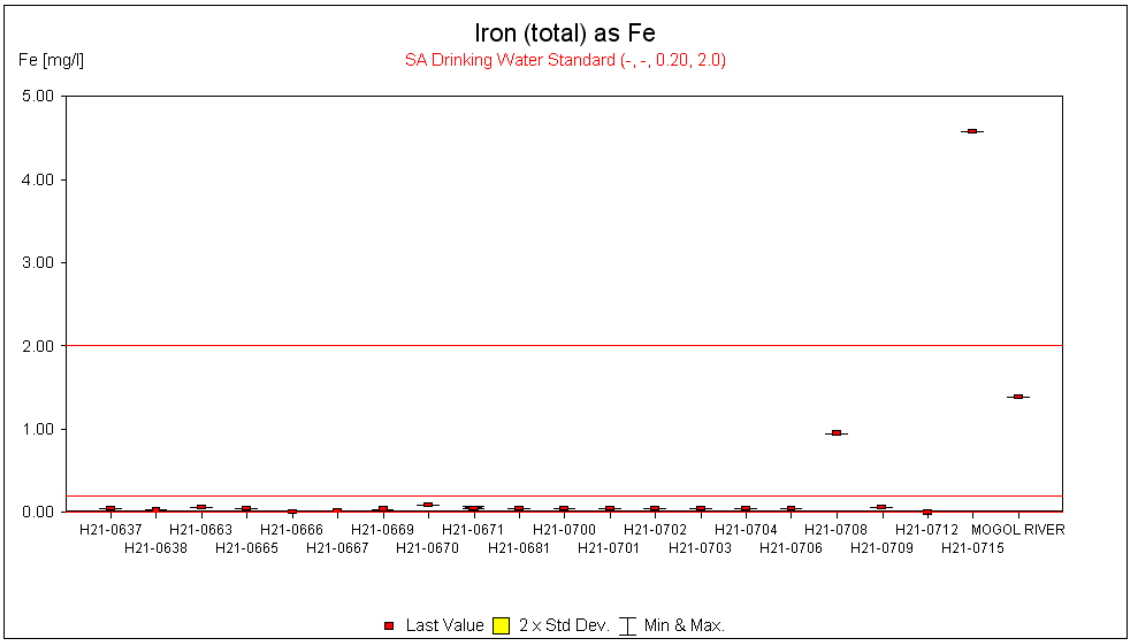

Sodium as Na
Na [mg/l]
SA Drinking Water Standard (-, -, 200, 400)
700
600
500
400
300
200
100
0
H21-0637
H21-0638
H21-0663
H21-0665
H21-0666
H21-0667
H21-0669
H21-0670
H21-0671
H21-0681
H21-0700
H21-0701
H21-0702
H21-0703
H21-0704
H21-0706
H21-0708
H21-0709
H21-0712
H21-0715
MOGOL RIVER
Last Value
2 x Std Dev.
Min & Max.

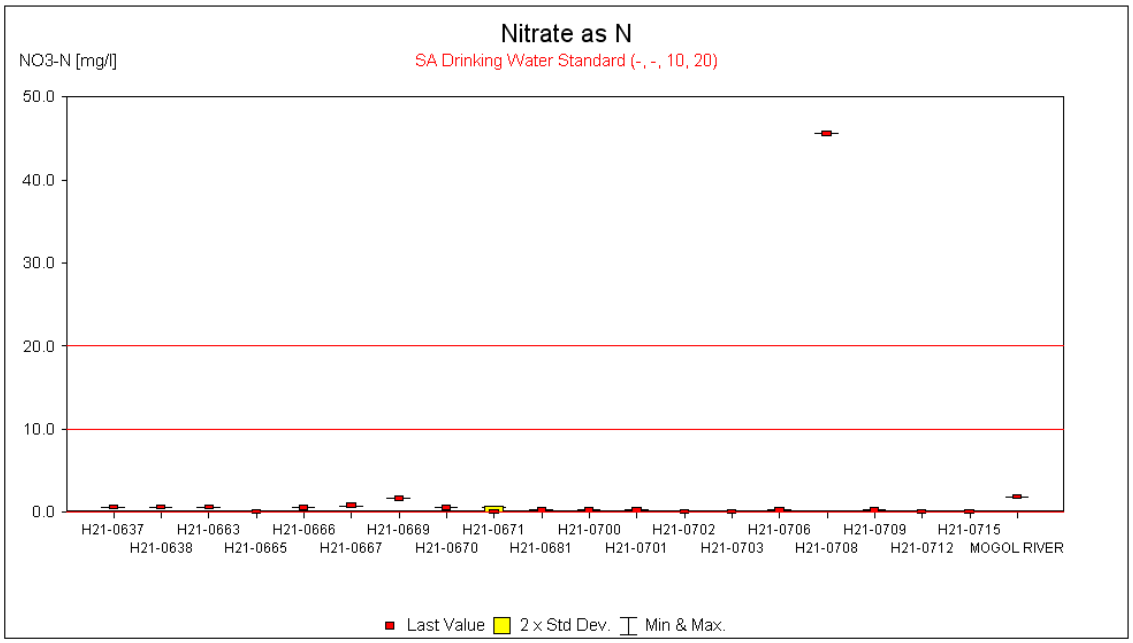

Chloride as Cl
Cl [mg/l]
SA Drinking Water Standard (-, -, 200, 600)
600
500
400
300
200
100
0
H21-0637
H21-0638
H21-0663
H21-0665
H21-0666
H21-0667
H21-0669
H21-0670
H21-0671
H21-0681
H21-0700
H21-0701
H21-0702
H21-0703
H21-0704
H21-0706
H21-0708
H21-0709
H21-0712
H21-0715
MOGOL RIVER
Last Value
2 x Std Dev.
Min & Max.


Sulphate as SO4
SO4 [mg/l]
SA Drinking Water Standard (-, -, 400, 600)
600
500
400
300
200
100
0
H21-0637
H21-0638
H21-0663
H21-0665
H21-0666
H21-0667
H21-0669
H21-0670
H21-0671
H21-0681
H21-0700
H21-0701
H21-0702
H21-0703
H21-0706
H21-0708
H21-0709
H21-0712
H21-0715
MOGOL RIVER
Last Value
2 x Std Dev.
Min & Max.


Manganese as Mn
Mn [mg/l]
SA Drinking Water Standard (-, -, 0.10, 1.0)
2.00
1.50
1.00
0.50
0.00
H21-0637
H21-0638
H21-0663
H21-0665
H21-0666
H21-0667
H21-0669
H21-0670
H21-0671
H21-0681
H21-0700
H21-0701
H21-0702
H21-0703
H21-0704
H21-0706
H21-0708
H21-0709
H21-0712
H21-0715
MOGOL RIVER
Last Value
2 x Std Dev.
Min & Max.


Aluminium as Al
Al [mg/l]
SA Drinking Water Standard (-, -, 0.30, 0.50)
15.0
10.0
5.0
0.0
H21-0637
H21-0638
H21-0663
H21-0665
H21-0666
H21-0667
H21-0669
H21-0670
H21-0671
H21-0712
H21-0715
Last Value
2 x Std Dev.
Min & Max.


Iron (total) as Fe
Fe [mg/l]
SA Drinking Water Standard (-, -, 0.20, 2.0)
5.00
4.00
3.00
2.00
1.00
0.00
H21-0637
H21-0638
H21-0663
H21-0665
H21-0666
H21-0667
H21-0669
H21-0670
H21-0671
H21-0681
H21-0700
H21-0701
H21-0702
H21-0703
H21-0704
H21-0706
H21-0708
H21-0709
H21-0712
MOGOL RIVER
H21-0715
Last Value
2 x Std Dev.
Min & Max.


Nitrate as N
NO3-N [mg/l]
SA Drinking Water Standard (-, -, 10, 20)
50.0
40.0
30.0
20.0
10.0
0.0
H21-0637
H21-0638
H21-0663
H21-0665
H21-0666
H21-0667
H21-0669
H21-0670
H21-0671
H21-0681
H21-0700
H21-0701
H21-0702
H21-0703
H21-0706
H21-0708
H21-0709
H21-0712
H21-0715
MOGOL RIVER
Last Value
2 x Std Dev.
Min & Max.

F2: Stable isotope report – iThemba labs

iThemba LABS GAUTENG

Environmental Isotope Group (EIG)

Postal address: Private Bag 11, Wits, 2050, South Africa.
Physical Address: Empire Road (between Jan Smuts Avenue and Yale Road)
Tel ++27 11 351 7000/1 (switchboard/secretary), Fax ++27 11 351 7053

Report

Reference: VGS001

Date: 4th May 2009

D/H and $^{18}O/^{16}O$ analyses on ten (10) water samples

submitted by Ms. Sonia Veltman
Veltwater

— —

M.J. Butler, O.H.T. Malinga, M. Mabitsela

confidential

1. General

Ten water samples were submitted by Ms. S. Veltman of Veltwater for D/H ($^2H/^1H$) and $^{18}O/^{16}O$ isotope analysis. The samples were received on the 13th of March 2009. As the mass spectrometer had an electronics failure, the analyses took much longer to process than would be customary.

2. Stable Isotope Analysis

Water D/H ($^2H/^1H$) and $^{18}O/^{16}O$ ratios were analysed in the laboratory of the Environmental Isotope Group (EIG) of iThemba Laboratories, Gauteng. The equipment used for stable isotope analysis consists of a PDZ Europa GEO 20-20 gas mass–spectrometer connected to peripheral sample preparation devices. A PDZ water equilibration system (WES), working in dual inlet mode is employed for hydrogen and oxygen isotope analysis of water. Equilibration time for the water sample with hydrogen is about one hour and CO_2 is equilibrated with a water sample in about eight hours. Laboratory standards, calibrated against international reference materials, are analysed with each batch of samples. The analytical precision is estimated at 0.1‰ for O and 0.5‰ for H.

Analytical results are presented in the common delta-notation:

$$\delta^{18}O(‰) = \left[\frac{(^{18}O/^{16}O)_{sample}}{(^{18}O/^{16}O)_{standard}} - 1 \right] \times 1000$$

which applies to D/H ($^2H/^1H$), accordingly. These delta values are expressed as per mil deviation relative to a known standard, in this case standard mean ocean water (SMOW) for $\delta^{18}O$ and δD.

3. Results

The analytical results are presented in Tables 1 and 2 and partially illustrated in Figure 1.

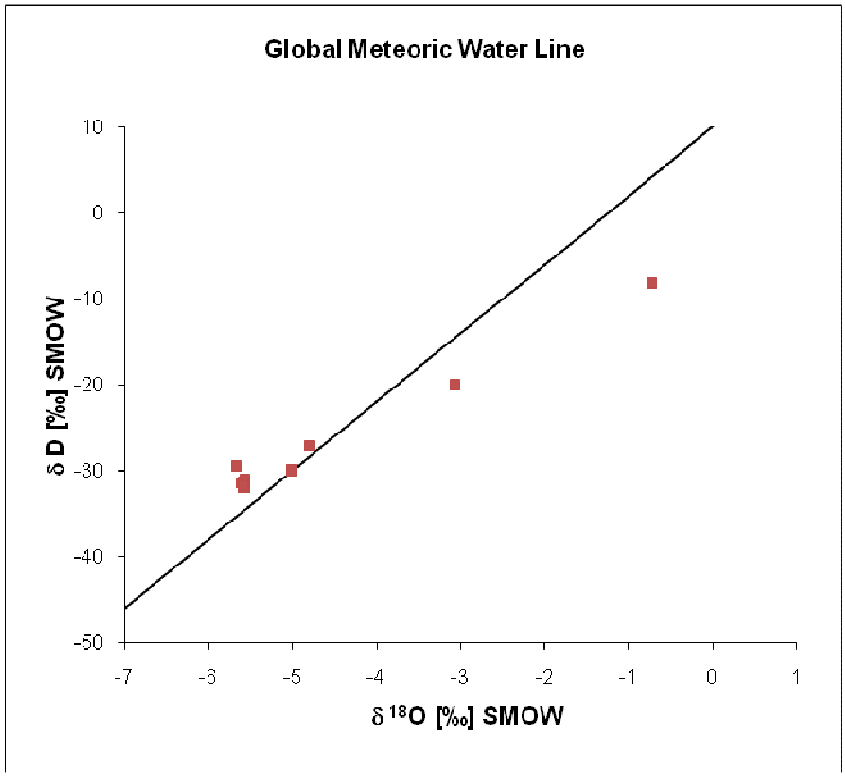


Figure 1: Stable isotope data relative to Global Meteoric Water Line (Craig, 1961).

The stable isotope analyses for all samples data could be well reproduced within the expected analytical error limits. Figure 1 shows these data in a $\delta^{18}O$ vs. δD space relative to the Global Meteoric Water Line (GMWL, Craig, 1961). The isotopically lighter samples plot along and slightly above the GMWL, while the two isotopically heavier samples plot along what is most likely an evaporation slope.

4. References

Craig, H. (1961). Isotopic variations in meteoric waters. *Science*, **133**, 1702–1703.

Table 1: Analytical Results

			Deuterium	Oxygen-18
Lab No	**Field Name**	**Description**	**δD‰ SMOW**	**δ^{18}O‰ SMOW**
VGS 001	H21-0704	2009/02/19	-31.2	-5.58
VGS 002	H21-0706	2009/02/19	-20.0	-3.07
VGS 003	H21-0708	2009/02/19	-31.4	-5.62
VGS 004	H21-0681	2009/02/19	-32.1	-5.57
VGS 005	H21-0702	2009/02/19	-27.1	-4.78
VGS 006	H21-0703	2009/02/19	-8.1	-0.72
VGS 007	H21-0666	2009/02/19	-30.0	-5.00
VGS 008	H21-0665	2009/02/19	-31.5	-5.59
VGS 009	H21-0709	2009/02/19	-31.7	-5.59
VGS 010	Mogol River	Marken Bridge	-29.4	-5.67

Table 2: Stable isotope aliquot determinations

Lab No.	Field Name:	Description	Deuterium analysis	Deuterium Batch	Deuterium δD‰ SMOW	Oxygen-18 analysis	Oxygen-18 Batch	Oxygen-18 $\delta^{18}O$‰ SMOW
VGS 001	H21-0704	2009/02/19 08:46	a	2009/05/02	-31.6	a	2009/04/30	-5.59
			b		-30.9	b		-5.56
					avg.: -31.2			**avg.: -5.58**
					diff.: 0.7			*diff.: 0.03*
VGS 002	H21-0706	2009/02/19 09:18	a	2009/04/18	-20.1	a	2009/04/30	-3.07
			b	2009/05/02	-19.8	b		-3.08
					avg.: -20.0			**avg.: -3.07**
					diff.: 0.2			*diff.: 0.01*
VGS 003	H21-0708	2009/02/19 10:00	a	2009/04/18	-31.4	a	2009/04/30	-5.64
			b		-31.5	b		-5.60
					avg.: -31.4			**avg.: -5.62**
					diff.: 0.1			*diff.: 0.03*
VGS 004	H21-0681	2009/02/19 10:35	a	2009/04/18	-32.1	a	2009/04/30	-5.56
			b		-32.1	b		-5.57
					avg.: -32.1			**avg.: -5.57**
					diff.: 0.1			*diff.: 0.01*
VGS 005	H21-0702	2009/02/19 11:10	a	2009/04/18	-26.8	a	2009/04/30	-4.78
			b		-27.3	b		-4.78
					avg.: -27.1			**avg.: -4.78**
					diff.: 0.4			*diff.: 0.00*
VGS 006	H21-0703	2009/02/19 11:40	a	2009/04/18	-8.4	a	2009/04/30	-0.74
			b		-7.8	b		-0.71
					avg.: -8.1			**avg.: -0.72**
					diff.: 0.6			*diff.: 0.03*
VGS 007	H21-0666	2009/02/19 12:35	a	2009/04/18	-30.4	a	2009/04/30	-4.98
			b		-29.6	b		-5.01
					avg.: -30.0			**avg.: -5.00**
					diff.: 0.8			*diff.: 0.04*
VGS 008	H21-0665	2009/02/19 14:30	a	2009/04/18	-31.4	a	2009/04/30	-5.60
			b		-31.6	b		-5.58
					avg.: -31.5			**avg.: -5.59**
					diff.: 0.2			*diff.: 0.01*
VGS 009	H21-0709	2009/02/19 16:00	a	2009/04/18	-31.9	a	2009/04/30	-5.60
			b		-31.6	b		-5.57
					avg.: -31.7			**avg.: -5.59**
					diff.: 0.2			*diff.: 0.03*
VGS 010	Mogol River	Marken Bridge	a	2009/04/18	-29.5	a	2009/04/30	-5.67
			b		-29.3	b		-5.68
					avg.: -29.4			**avg.: -5.67**
					diff.: 0.1			*diff.: 0.01*

Appendix G: Data Logger Graphs

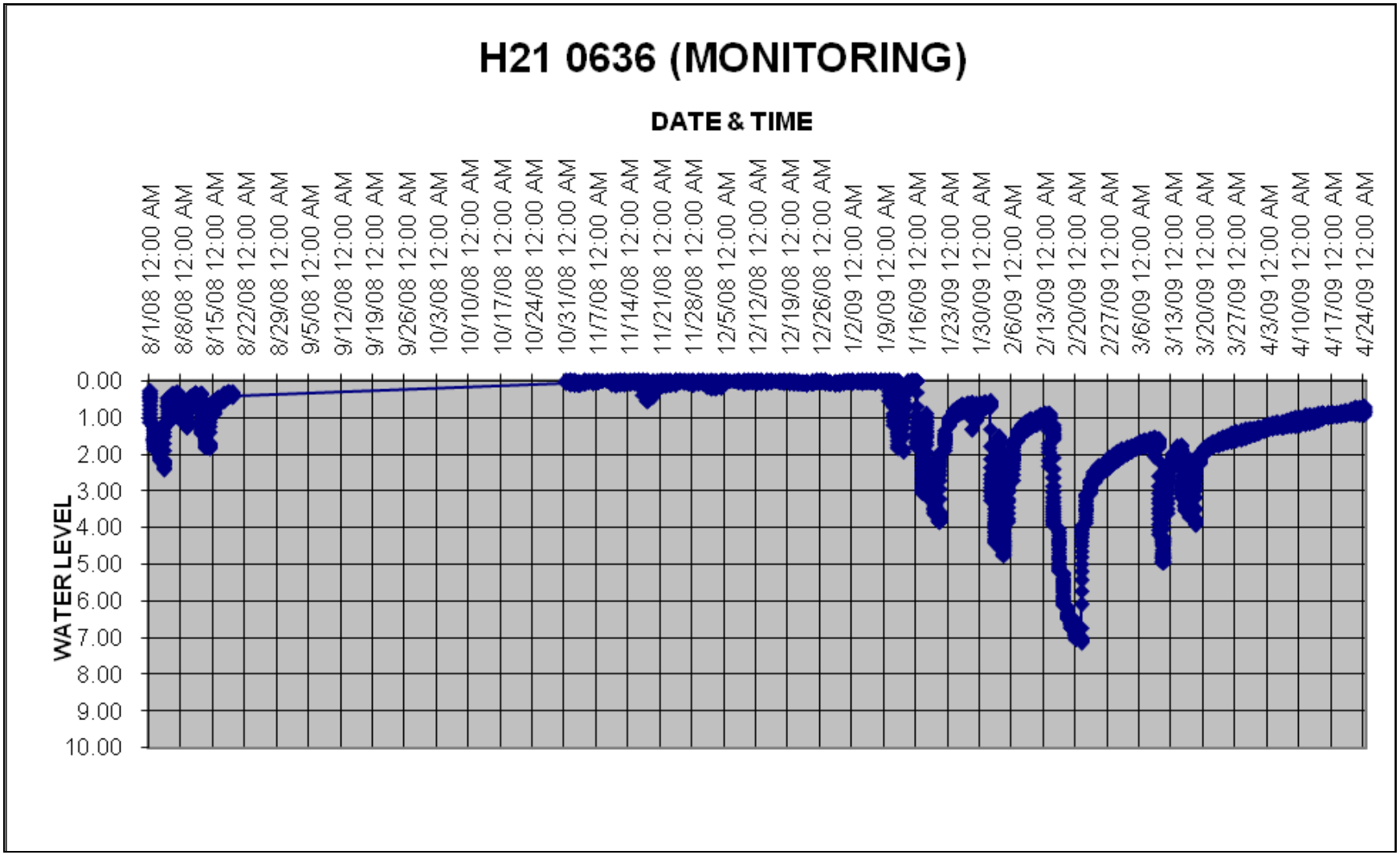
COMPARISON OF CONSTANT RATE DISCHARGE TEST AND OBSERVATION BOREHOLE INFORMATION

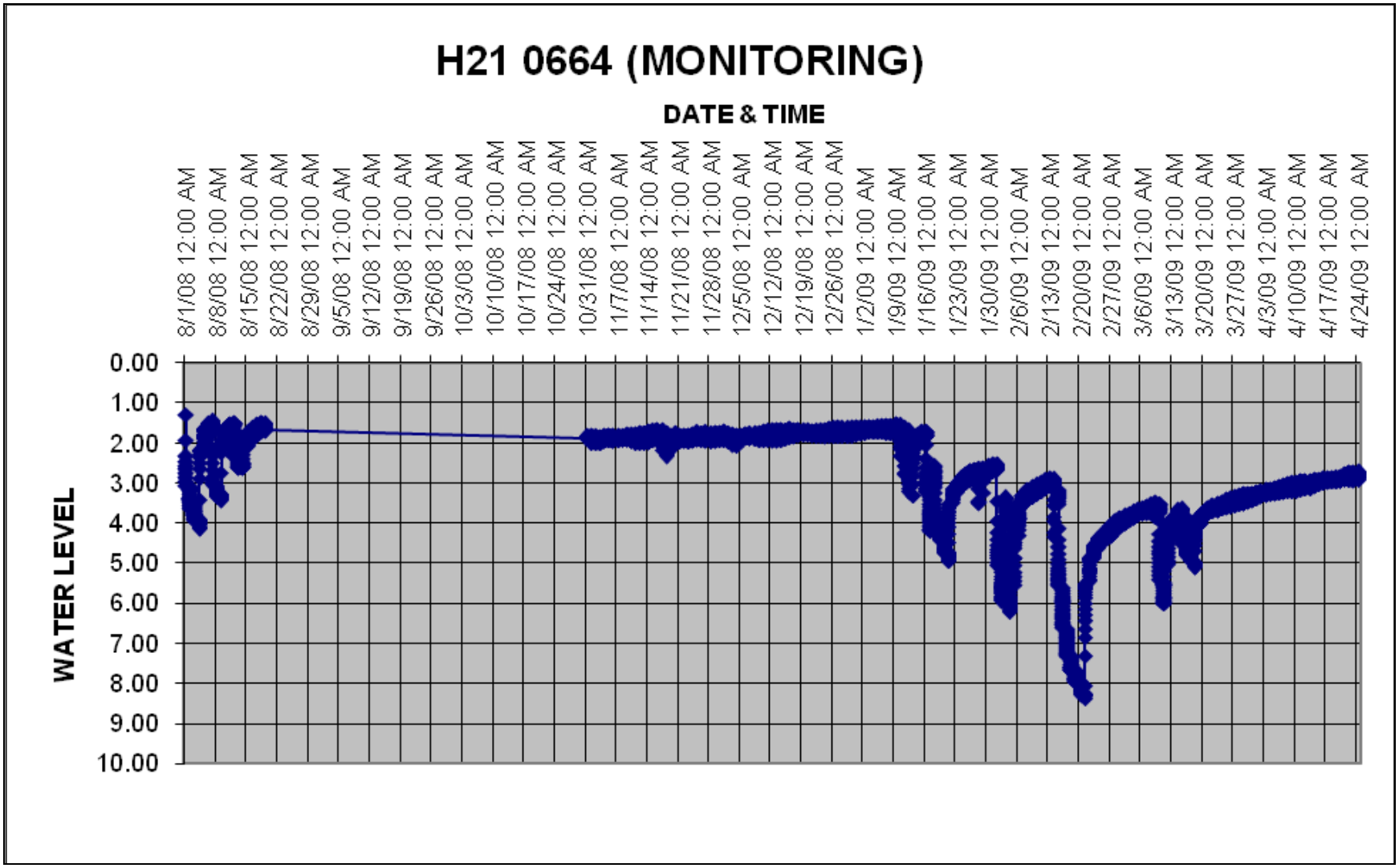
CONSTANT RATE TESTS	DATE	PUMP RATE	CR BOREHOLE DISTANCE FROM									
		(l/s)	H21-0636	H21-0664	H21-0667	H21-0669	H21-0670	H21-0700	H21-0702	H21-0703	H21-0706	H21-0860
START H21-0638	8/1/08 14:00	11.1	515m	220m								
STOP H21-0638	8/4/08 14:00											
START H21-0663	8/7/08 17:00	5.6	695m	40m								
STOP H21-0663	8/9/08 17:00											
START H21-0637	8/12/08 12:00	5.7	285m	450m								
STOP H21-0637	8/14/08 12:00											
START H21-0700	1/11/09 6:00	18.1	700m	800m	5Km	2.5Km	7.8Km					
STOP H21-0700	1/11/09 11:50											
START H21-0700	1/12/09 10:00	18.1	700m	800m	5Km	2.5Km	7.8Km					
STOP H21-0700	1/13/08 4:00											
START H21-0700	1/16/09 14:00	18.2	700m	800m	5Km	2.5Km	7.8Km					
STOP H21-0700	1/17/09 18:00											
START H21-0700	1/18/09 11:00	18.2	700m	800m	5Km	2.5Km	7.8Km	0m	1.9Km	1.9Km	4Km	
STOP H21-0700	1/21/09 11:00											
START H21-0702	1/24/09 18:00	3	1.8Km	2.6Km				1.9Km	0m	10m	2.3Km	
STOP H21-0702	1/25/09 18:00											
START H21-0665	2/1/09 11:50	20	465m	270m	4.9Km	2.1Km	7.4Km	700m	2.3Km	2.3Km	4.5Km	
STOP H21-0665	2/2/09 16:00											
START H21-0665	2/3/09 17:00	20	465m	270m	4.9Km	2.1Km	7.4Km	700m	2.3Km	2.3Km	4.5Km	
STOP H21-0665	2/4/09 7:00											
START H21-0665	2/5/09 14:00	20	465m	270m	4.9Km	2.1Km	7.4Km	700m	2.3Km	2.3Km	4.5Km	
STOP H21-0665	2/5/09 21:00											
START H21-0704	2/11/09 10:00	3.8									500m	
STOP H21-0704	2/12/09 11:00											
START H21-0681	2/14/09 17:00	2										145m
STOP H21-0681	2/15/09 17:00											
START H21-0665	2/15/09 7:00	20	465m	270m	4.9Km	2.1Km	7.4Km	700m	2.3Km	2.3Km	4.5Km	
STOP H21-0665	2/21/09 7:00											
START H21-0701	2/17/09 20:00	2.2	1.3Km	2.1Km				1.6Km	800m	800m	3.1Km	
STOP H21-0701	2/18/09 20:00											
START H21-0700	3/10/09 11:00	18.2	700m	800m	5Km	2.5Km	7.8Km	0m	1.9Km	1.9Km	4Km	
STOP H21-0700	3/11/09 19:00											
START H21-0637	3/15/09 13:00	8.3	285m	450m	5.1Km	2.4Km	7.6Km	600m	2.1Km	2.1Km	4.3Km	
STOP H21-0637	3/16/09 13:00											
START H21-0637	3/17/09 7:00	9.2	285m	450m	5.1Km	2.4Km	7.6Km	600m	2.1Km	2.1Km	4.3Km	
STOP H21-0637	3/18/09 5:00											
TEST H21-0706	2/20/09 12:30	**NO CONSTANT DONE - TEST FAILED**										

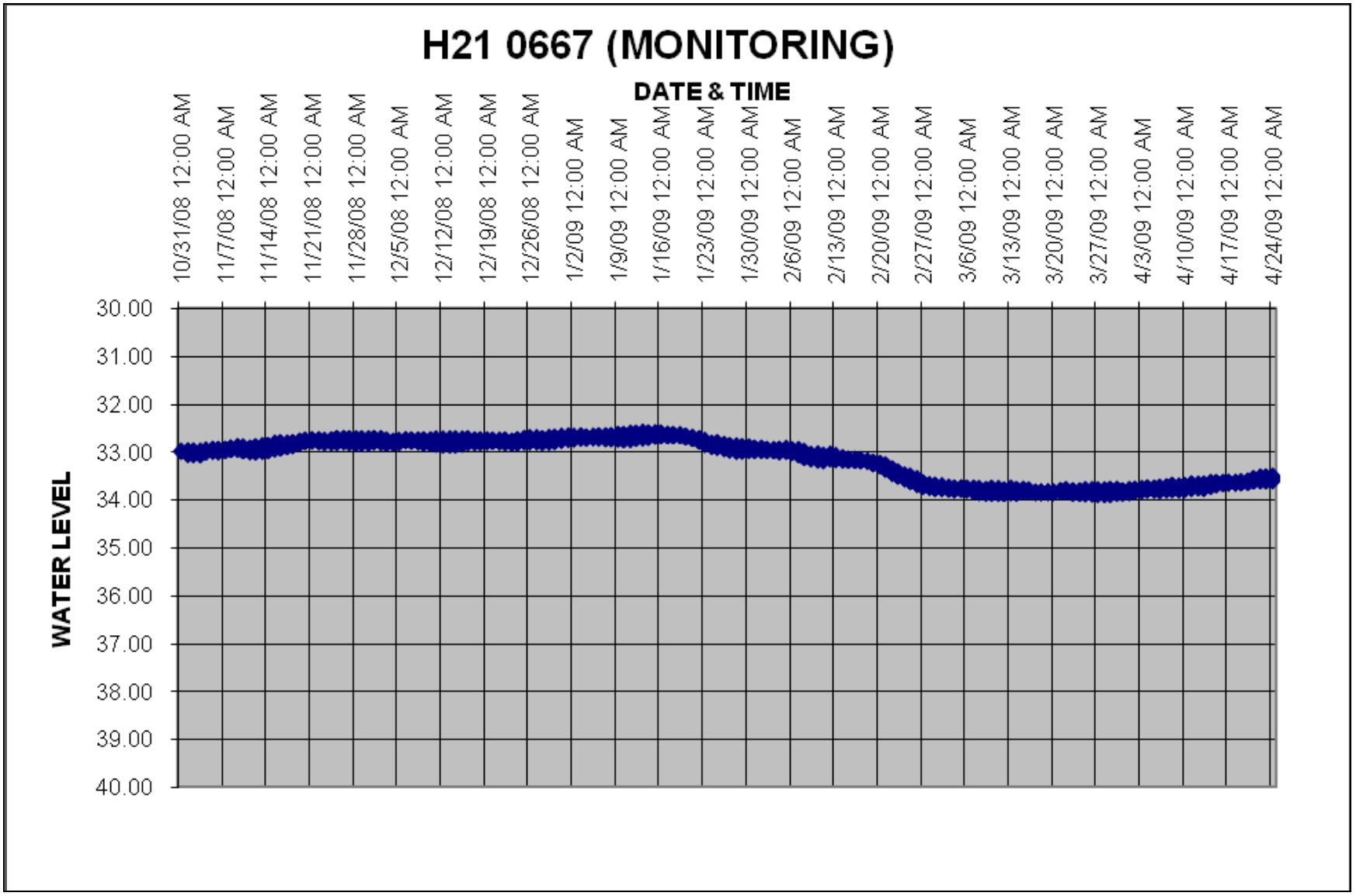
Artesian borehole H21-0709 was drilled on 25/02/2009 flowing at approximately 5l/s - 3.5km from H21-0680

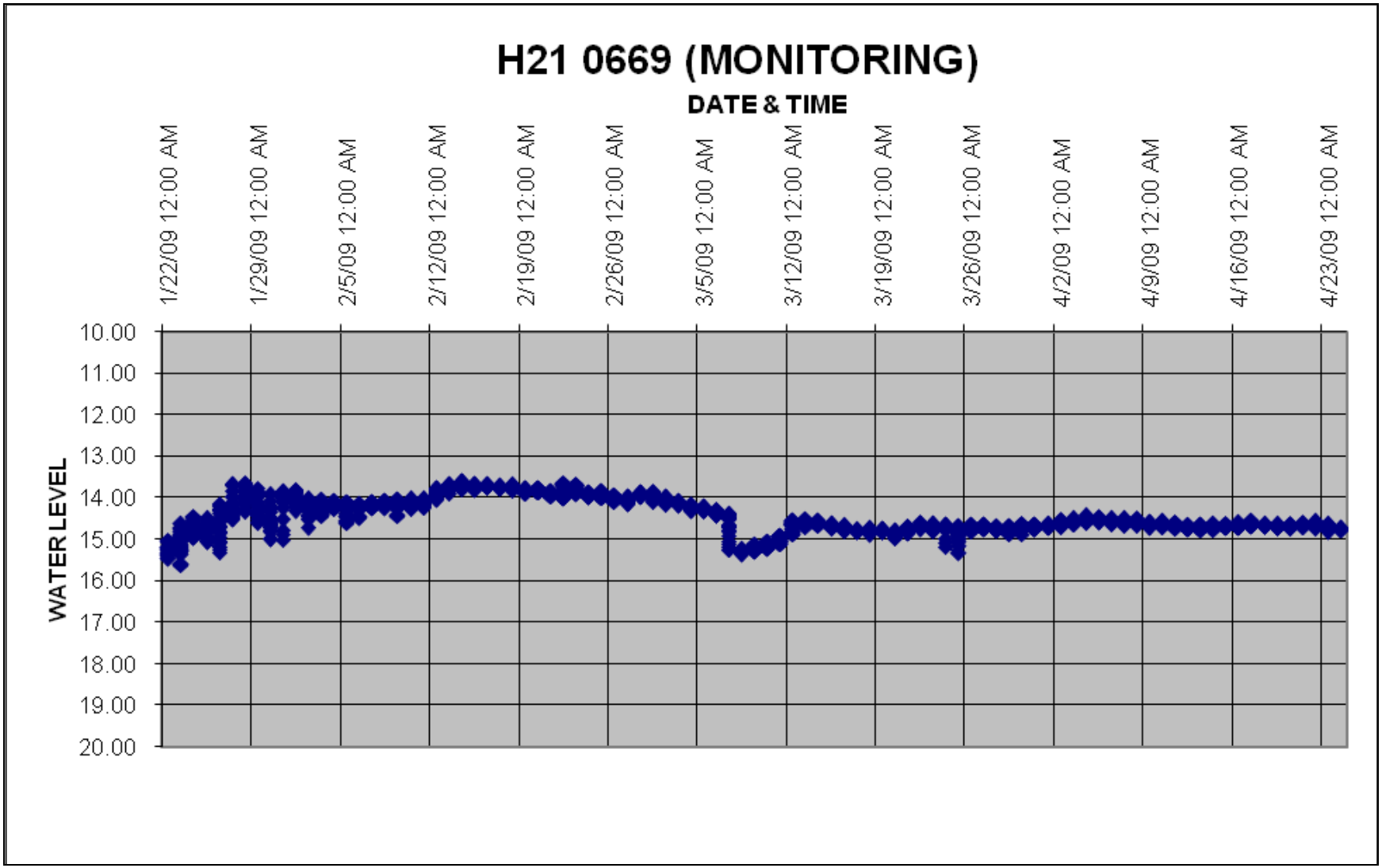
Colour Legend
Semi-confined WB
Confined WB
Alluvium
Daarby fault

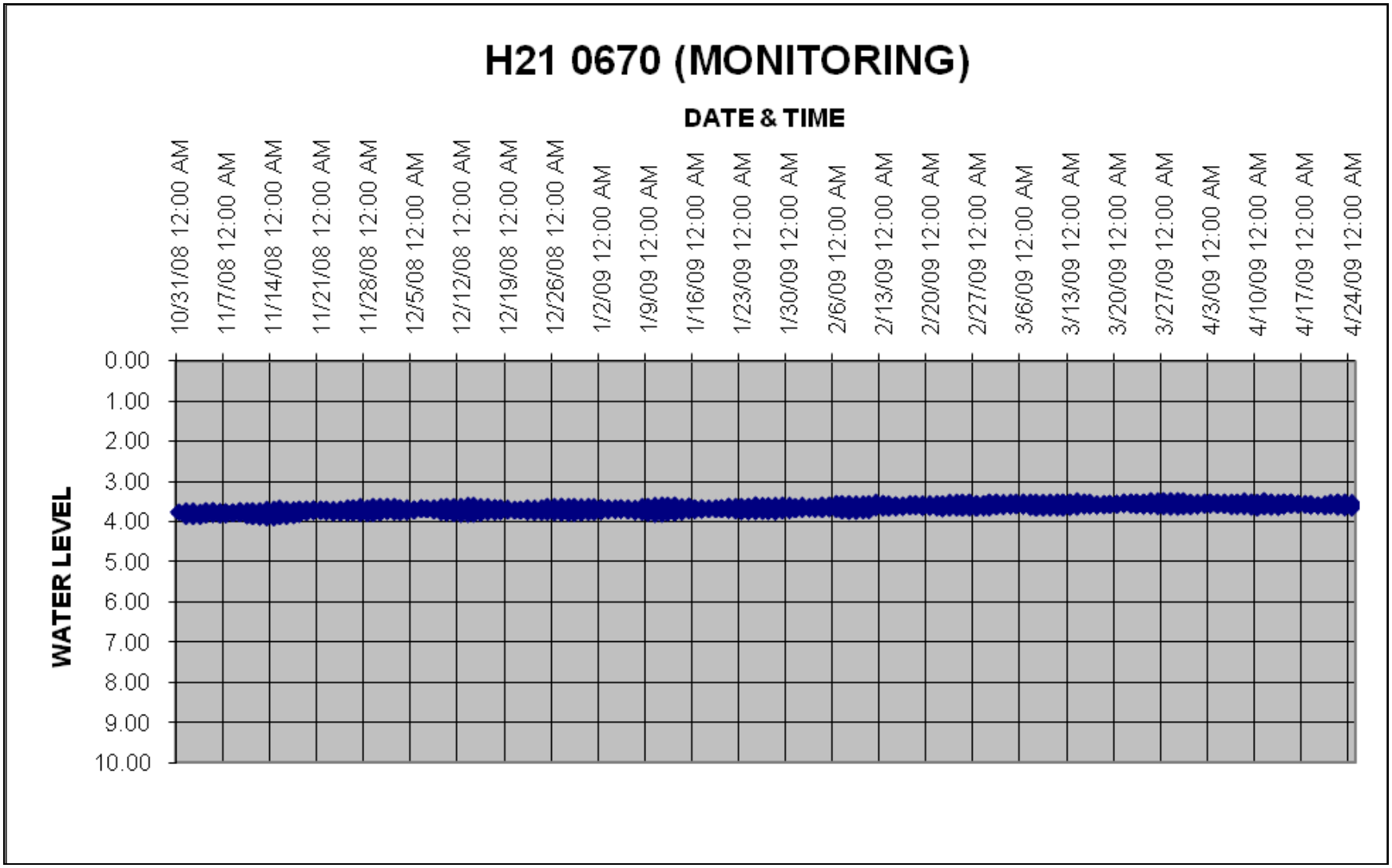
H21 0636 (MONITORING)

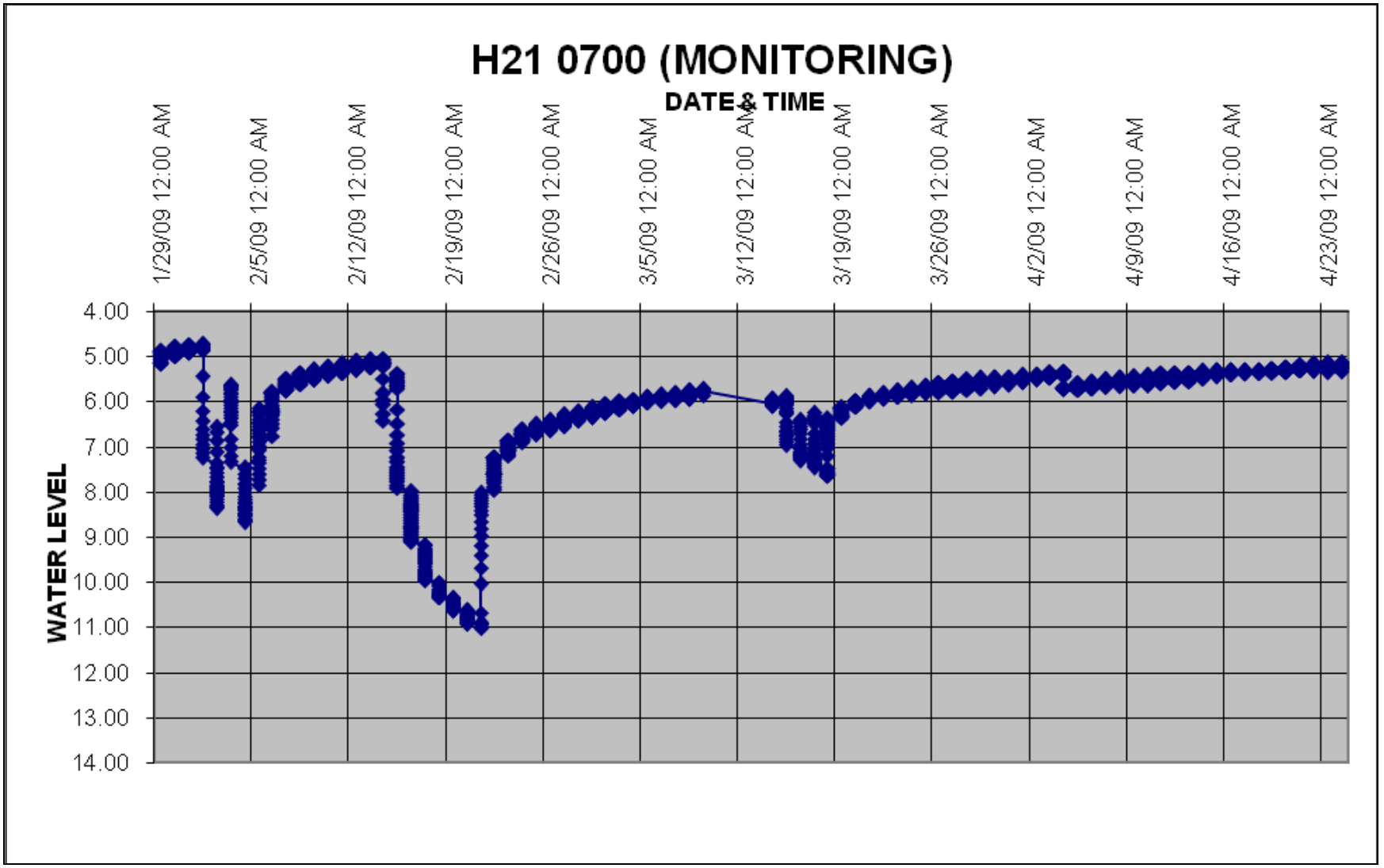


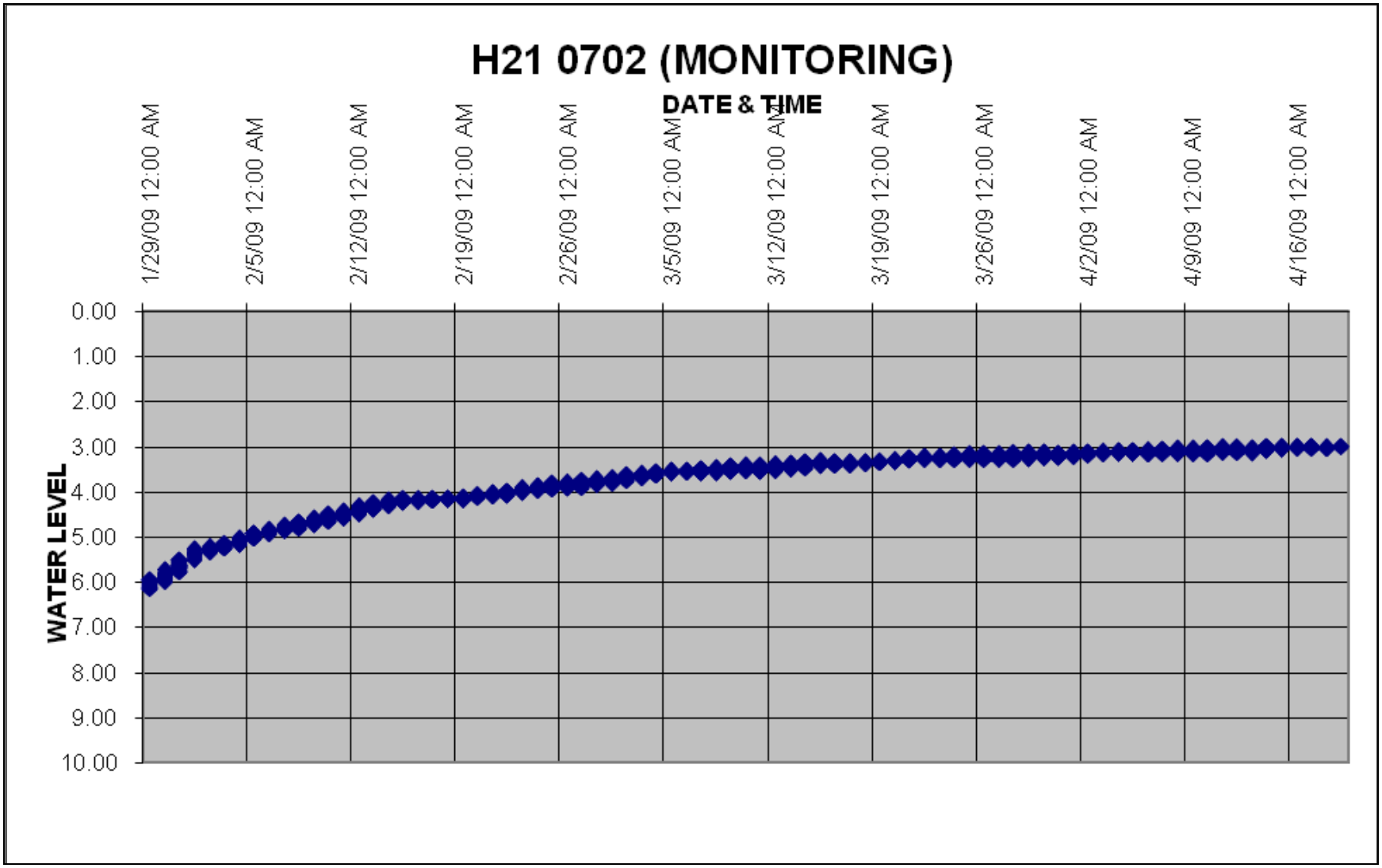

H21 0664 (MONITORING)
DATE & TIME
8/1/08 12:00 AM
8/8/08 12:00 AM
8/15/08 12:00 AM
8/22/08 12:00 AM
8/29/08 12:00 AM
9/5/08 12:00 AM
9/12/08 12:00 AM
9/19/08 12:00 AM
9/26/08 12:00 AM
10/3/08 12:00 AM
10/10/08 12:00 AM
10/17/08 12:00 AM
10/24/08 12:00 AM
10/31/08 12:00 AM
11/7/08 12:00 AM
11/14/08 12:00 AM
11/21/08 12:00 AM
11/28/08 12:00 AM
12/5/08 12:00 AM
12/12/08 12:00 AM
12/19/08 12:00 AM
12/26/08 12:00 AM
1/2/09 12:00 AM
1/9/09 12:00 AM
1/16/09 12:00 AM
1/23/09 12:00 AM
1/30/09 12:00 AM
2/6/09 12:00 AM
2/13/09 12:00 AM
2/20/09 12:00 AM
2/27/09 12:00 AM
3/6/09 12:00 AM
3/13/09 12:00 AM
3/20/09 12:00 AM
3/27/09 12:00 AM
4/3/09 12:00 AM
4/10/09 12:00 AM
4/17/09 12:00 AM
4/24/09 12:00 AM
WATER LEVEL
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00

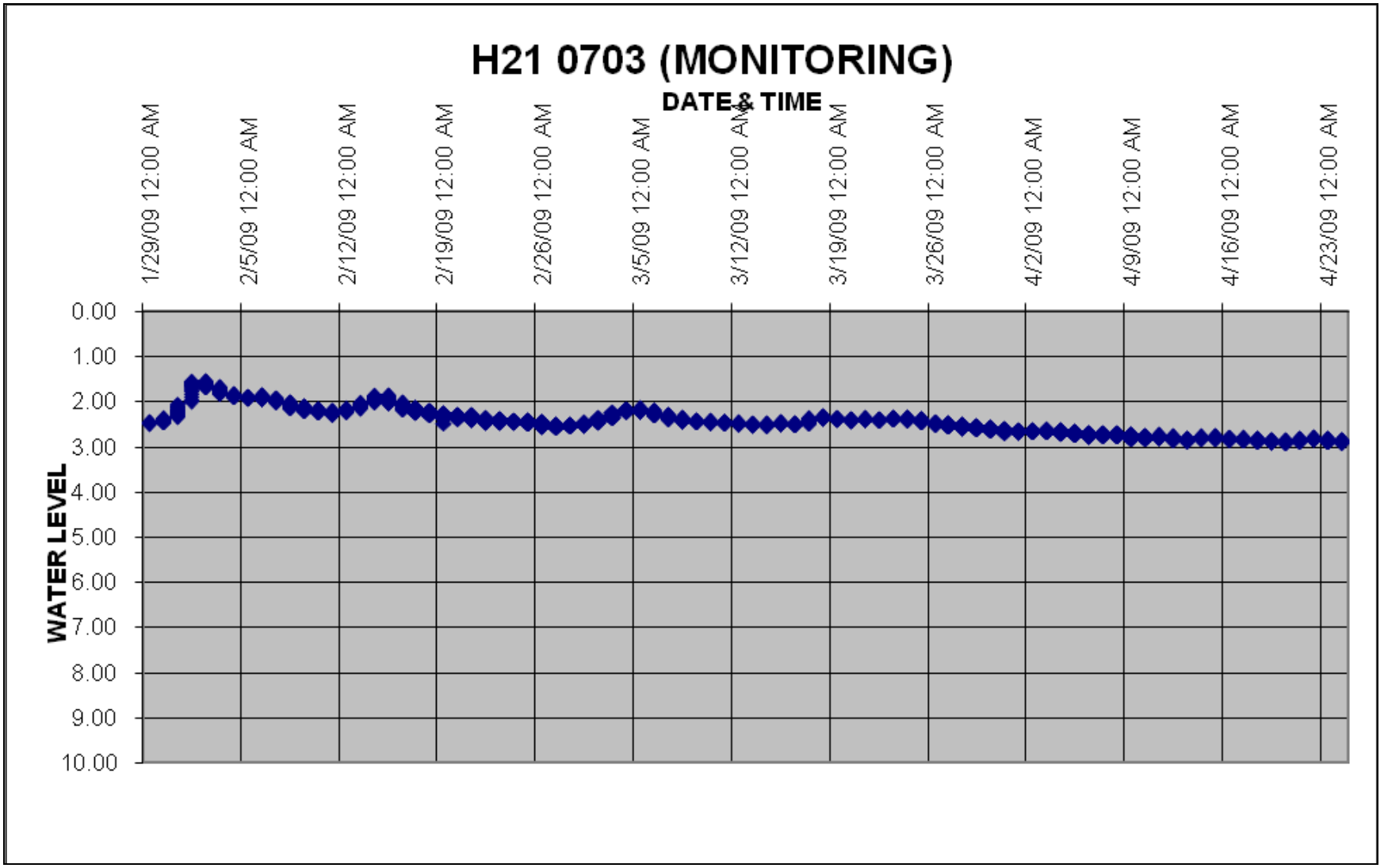

H21 0667 (MONITORING)
DATE & TIME
10/31/08 12:00 AM
11/7/08 12:00 AM
11/14/08 12:00 AM
11/21/08 12:00 AM
11/28/08 12:00 AM
12/5/08 12:00 AM
12/12/08 12:00 AM
12/19/08 12:00 AM
12/26/08 12:00 AM
1/2/09 12:00 AM
1/9/09 12:00 AM
1/16/09 12:00 AM
1/23/09 12:00 AM
1/30/09 12:00 AM
2/6/09 12:00 AM
2/13/09 12:00 AM
2/20/09 12:00 AM
2/27/09 12:00 AM
3/6/09 12:00 AM
3/13/09 12:00 AM
3/20/09 12:00 AM
3/27/09 12:00 AM
4/3/09 12:00 AM
4/10/09 12:00 AM
4/17/09 12:00 AM
4/24/09 12:00 AM
WATER LEVEL
30.00
31.00
32.00
33.00
34.00
35.00
36.00
37.00
38.00
39.00
40.00

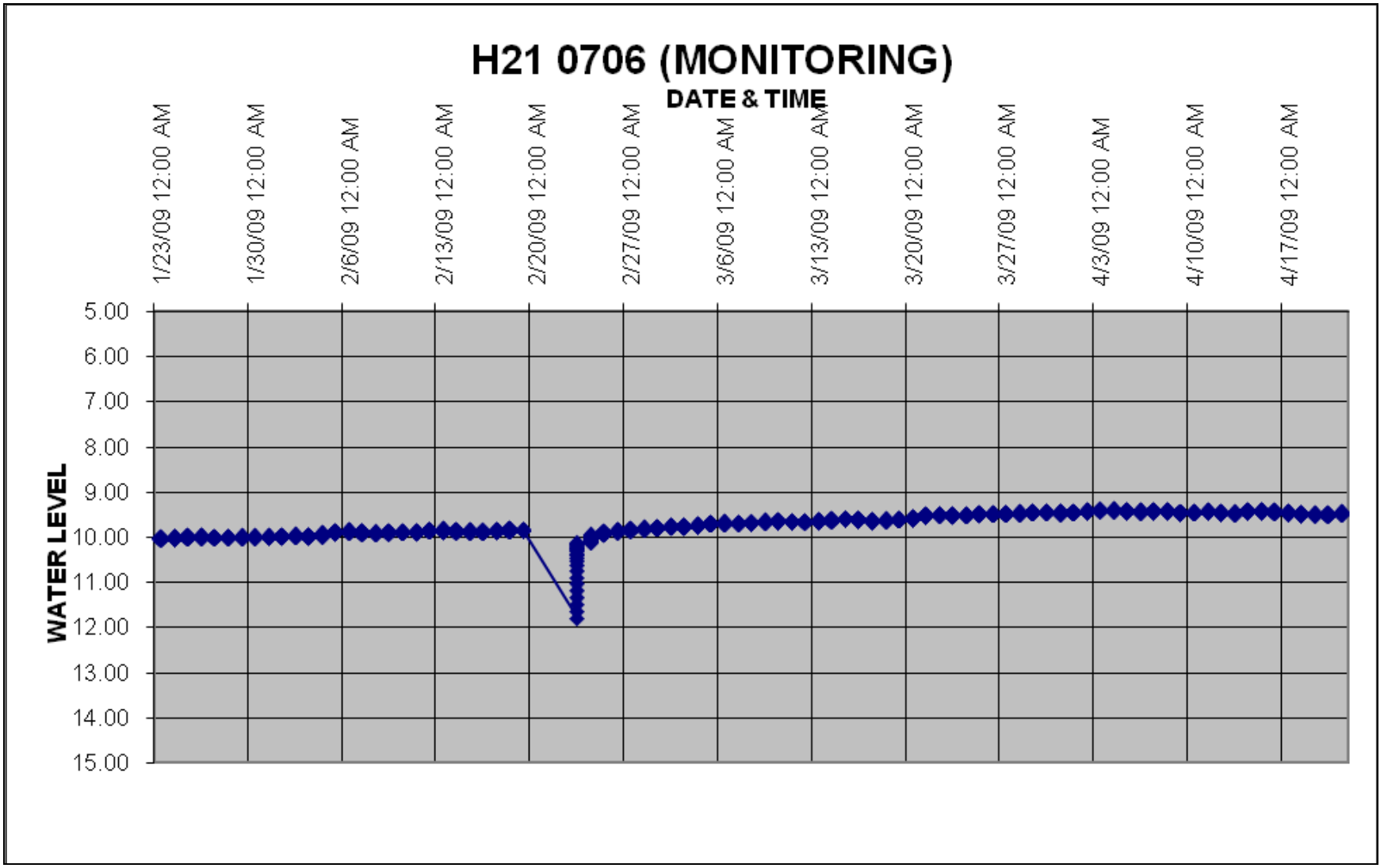

H21 0669 (MONITORING)
DATE & TIME
1/22/09 12:00 AM
1/29/09 12:00 AM
2/5/09 12:00 AM
2/12/09 12:00 AM
2/19/09 12:00 AM
2/26/09 12:00 AM
3/5/09 12:00 AM
3/12/09 12:00 AM
3/19/09 12:00 AM
3/26/09 12:00 AM
4/2/09 12:00 AM
4/9/09 12:00 AM
4/16/09 12:00 AM
4/23/09 12:00 AM
WATER LEVEL
10.00
11.00
12.00
13.00
14.00
15.00
16.00
17.00
18.00
19.00
20.00

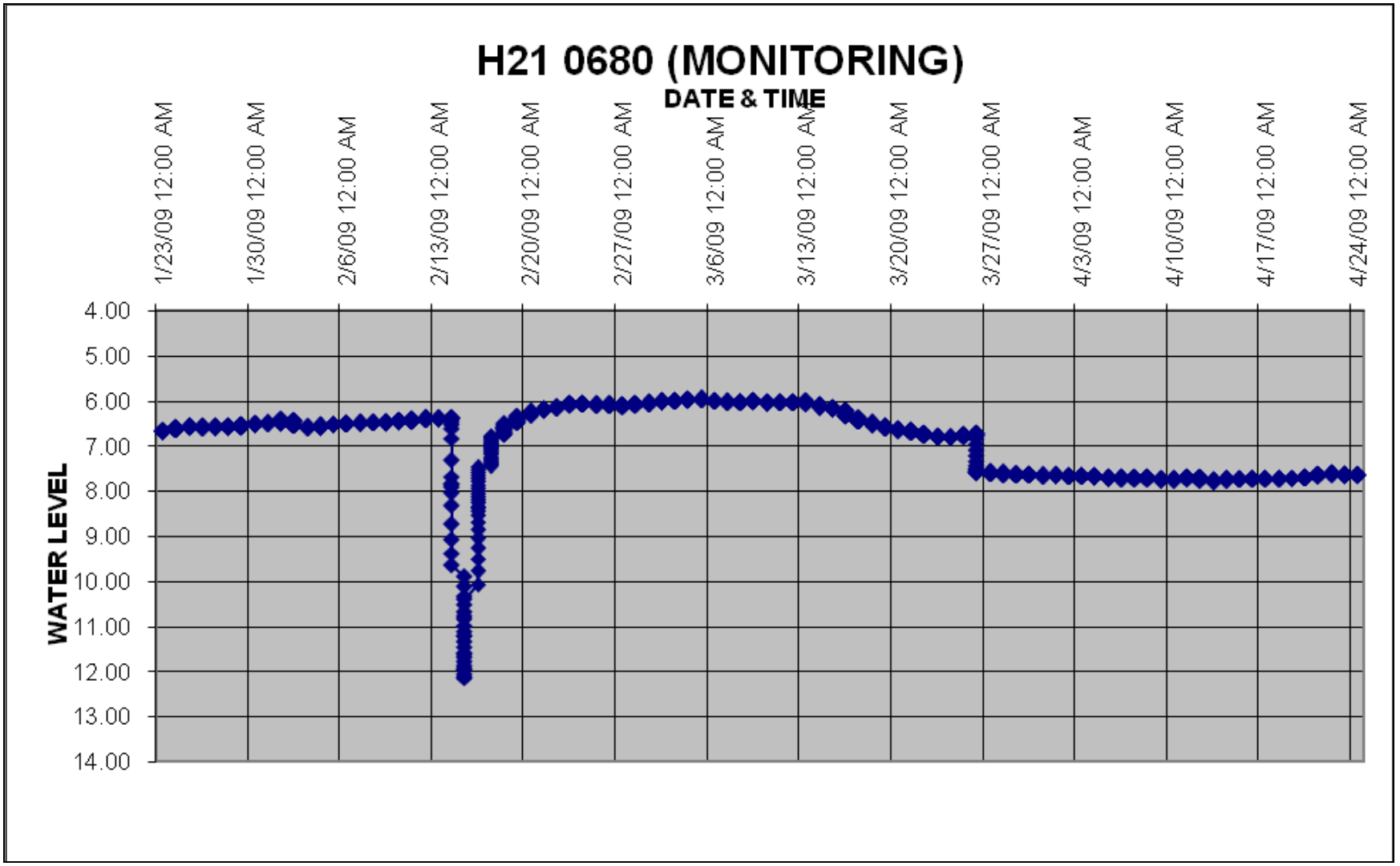

H21 0670 (MONITORING)
DATE & TIME
10/31/08 12:00 AM
11/7/08 12:00 AM
11/14/08 12:00 AM
11/21/08 12:00 AM
11/28/08 12:00 AM
12/5/08 12:00 AM
12/12/08 12:00 AM
12/19/08 12:00 AM
12/26/08 12:00 AM
1/2/09 12:00 AM
1/9/09 12:00 AM
1/16/09 12:00 AM
1/23/09 12:00 AM
1/30/09 12:00 AM
2/6/09 12:00 AM
2/13/09 12:00 AM
2/20/09 12:00 AM
2/27/09 12:00 AM
3/6/09 12:00 AM
3/13/09 12:00 AM
3/20/09 12:00 AM
3/27/09 12:00 AM
4/3/09 12:00 AM
4/10/09 12:00 AM
4/17/09 12:00 AM
4/24/09 12:00 AM
WATER LEVEL
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00


H21 0700 (MONITORING)
DATE & TIME
1/29/09 12:00 AM
2/5/09 12:00 AM
2/12/09 12:00 AM
2/19/09 12:00 AM
2/26/09 12:00 AM
3/5/09 12:00 AM
3/12/09 12:00 AM
3/19/09 12:00 AM
3/26/09 12:00 AM
4/2/09 12:00 AM
4/9/09 12:00 AM
4/16/09 12:00 AM
4/23/09 12:00 AM
WATER LEVEL
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
13.00
14.00


H21 0702 (MONITORING)
DATE & TIME
1/29/09 12:00 AM
2/5/09 12:00 AM
2/12/09 12:00 AM
2/19/09 12:00 AM
2/26/09 12:00 AM
3/5/09 12:00 AM
3/12/09 12:00 AM
3/19/09 12:00 AM
3/26/09 12:00 AM
4/2/09 12:00 AM
4/9/09 12:00 AM
4/16/09 12:00 AM
WATER LEVEL
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00

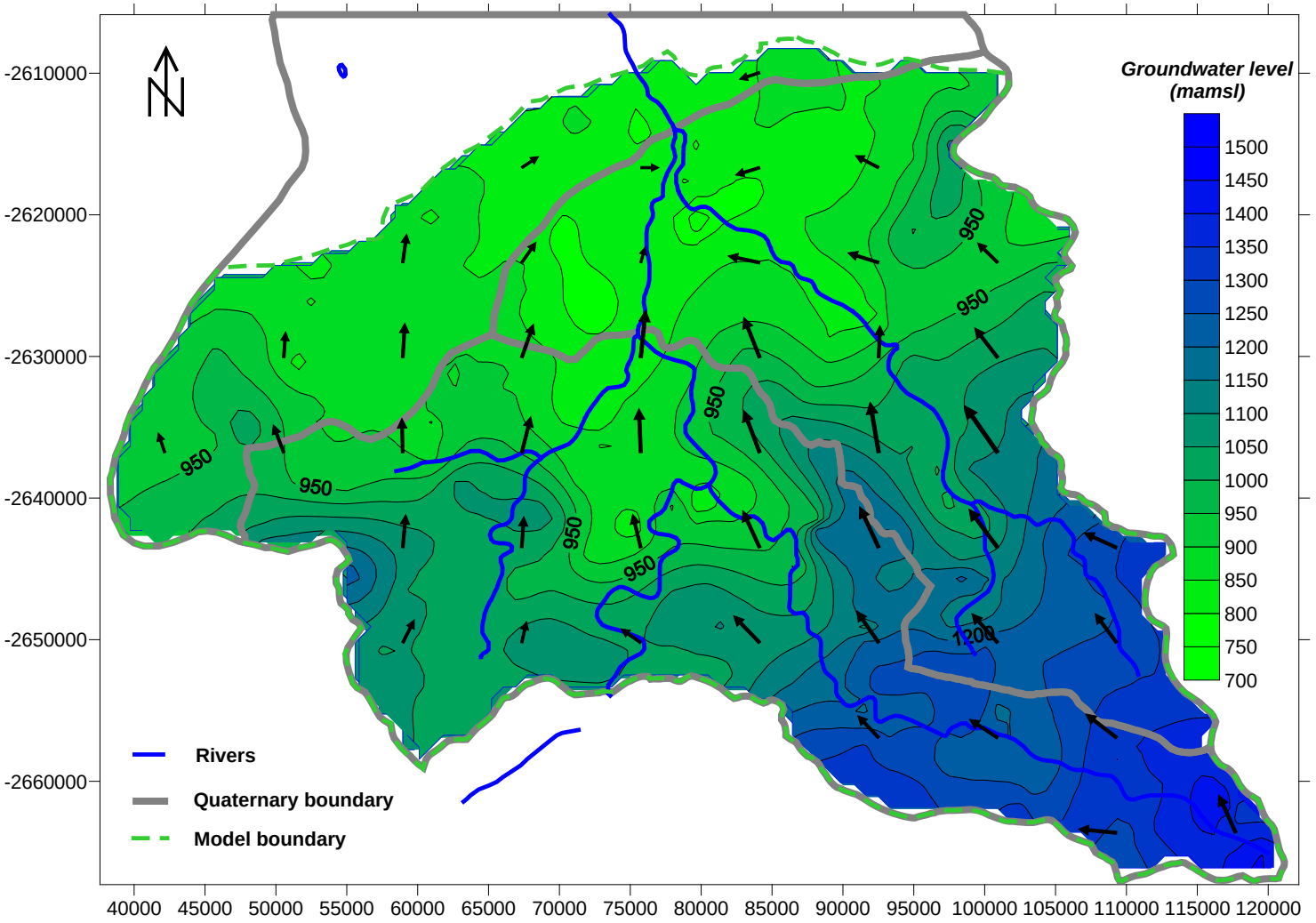

H21 0703 (MONITORING)
DATE & TIME
1/29/09 12:00 AM
2/5/09 12:00 AM
2/12/09 12:00 AM
2/19/09 12:00 AM
2/26/09 12:00 AM
3/5/09 12:00 AM
3/12/09 12:00 AM
3/19/09 12:00 AM
3/26/09 12:00 AM
4/2/09 12:00 AM
4/9/09 12:00 AM
4/16/09 12:00 AM
4/23/09 12:00 AM
WATER LEVEL
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00


H21 0706 (MONITORING)
DATE & TIME
1/23/09 12:00 AM
1/30/09 12:00 AM
2/6/09 12:00 AM
2/13/09 12:00 AM
2/20/09 12:00 AM
2/27/09 12:00 AM
3/6/09 12:00 AM
3/13/09 12:00 AM
3/20/09 12:00 AM
3/27/09 12:00 AM
4/3/09 12:00 AM
4/10/09 12:00 AM
4/17/09 12:00 AM
WATER LEVEL
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
13.00
14.00
15.00

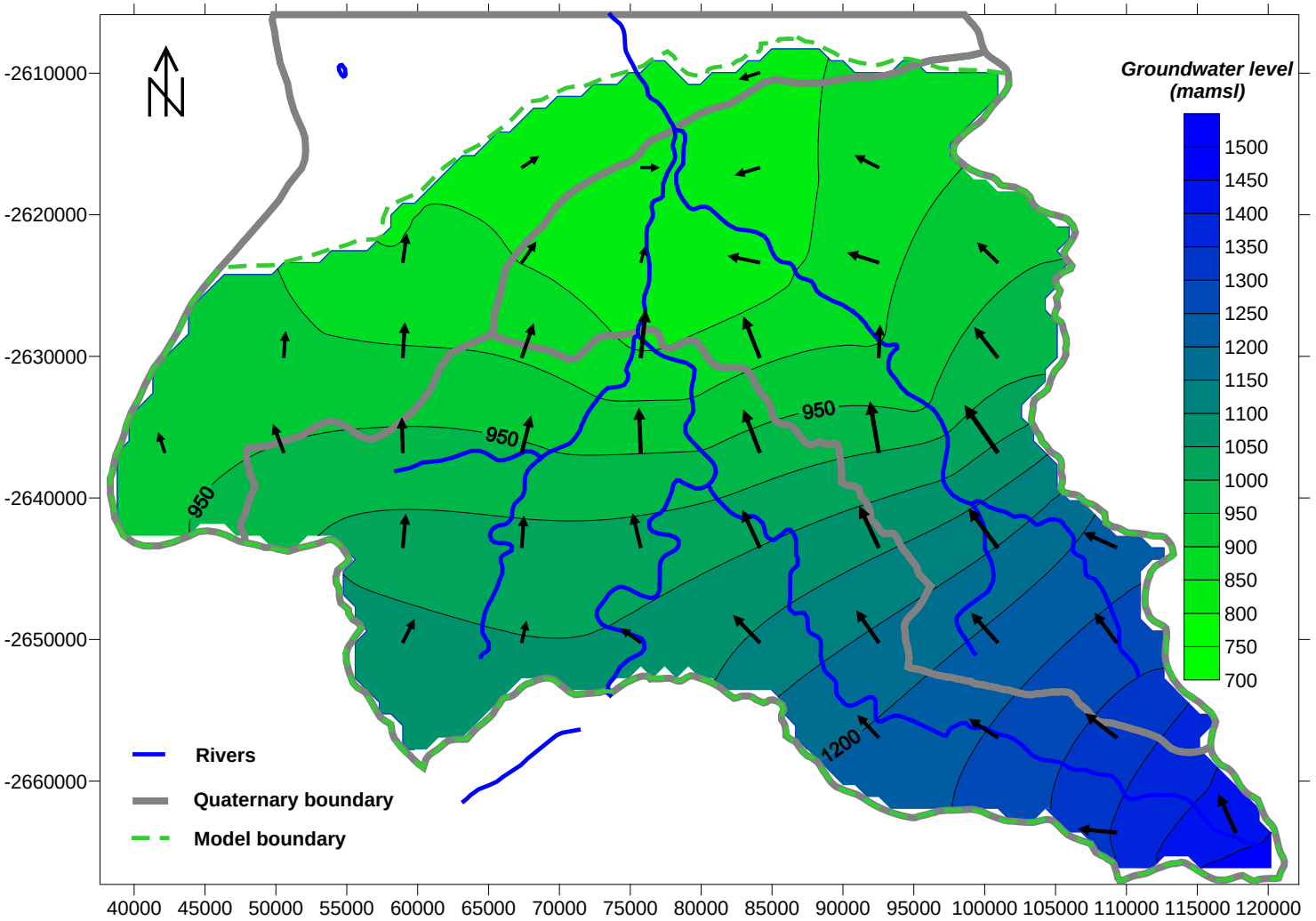

H21 0680 (MONITORING)
DATE & TIME
1/23/09 12:00 AM
1/30/09 12:00 AM
2/6/09 12:00 AM
2/13/09 12:00 AM
2/20/09 12:00 AM
2/27/09 12:00 AM
3/6/09 12:00 AM
3/13/09 12:00 AM
3/20/09 12:00 AM
3/27/09 12:00 AM
4/3/09 12:00 AM
4/10/09 12:00 AM
4/17/09 12:00 AM
4/24/09 12:00 AM
WATER LEVEL
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
13.00
14.00

Appendix H: Numerical Model Maps

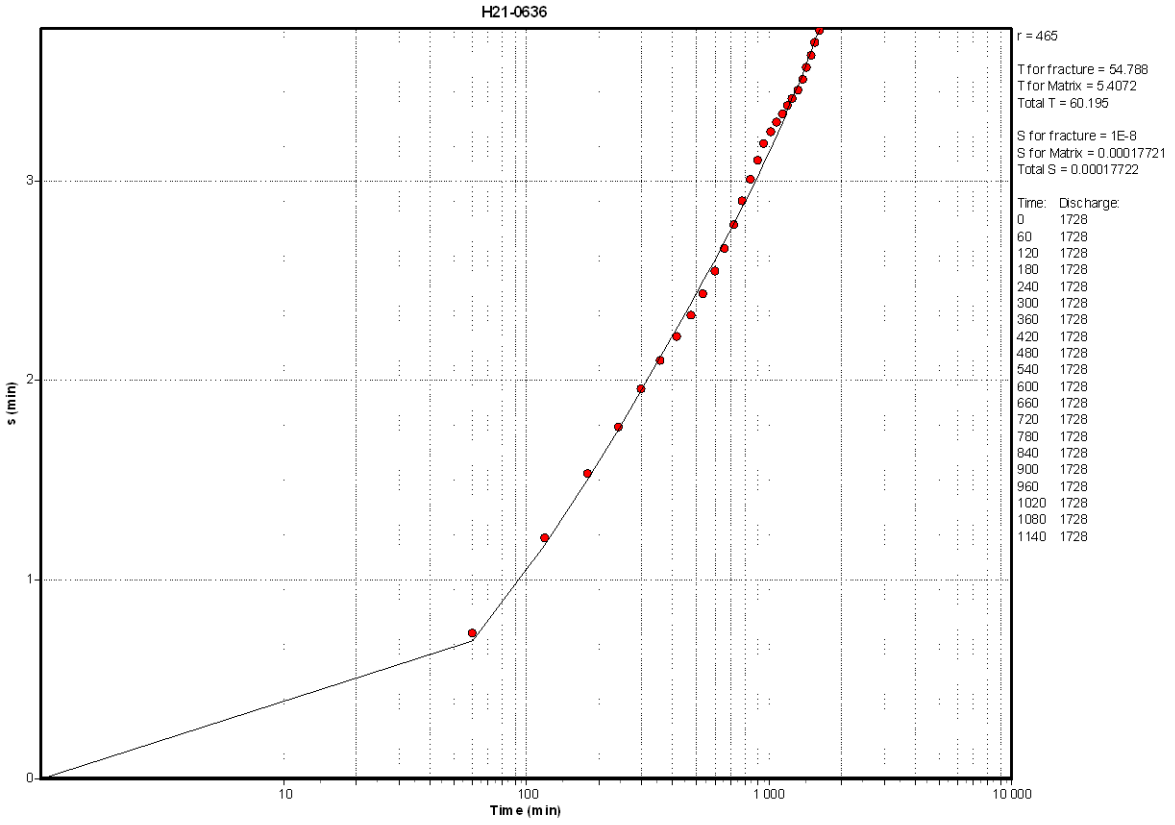
Groundwater piezometric map - Bayesian conditions

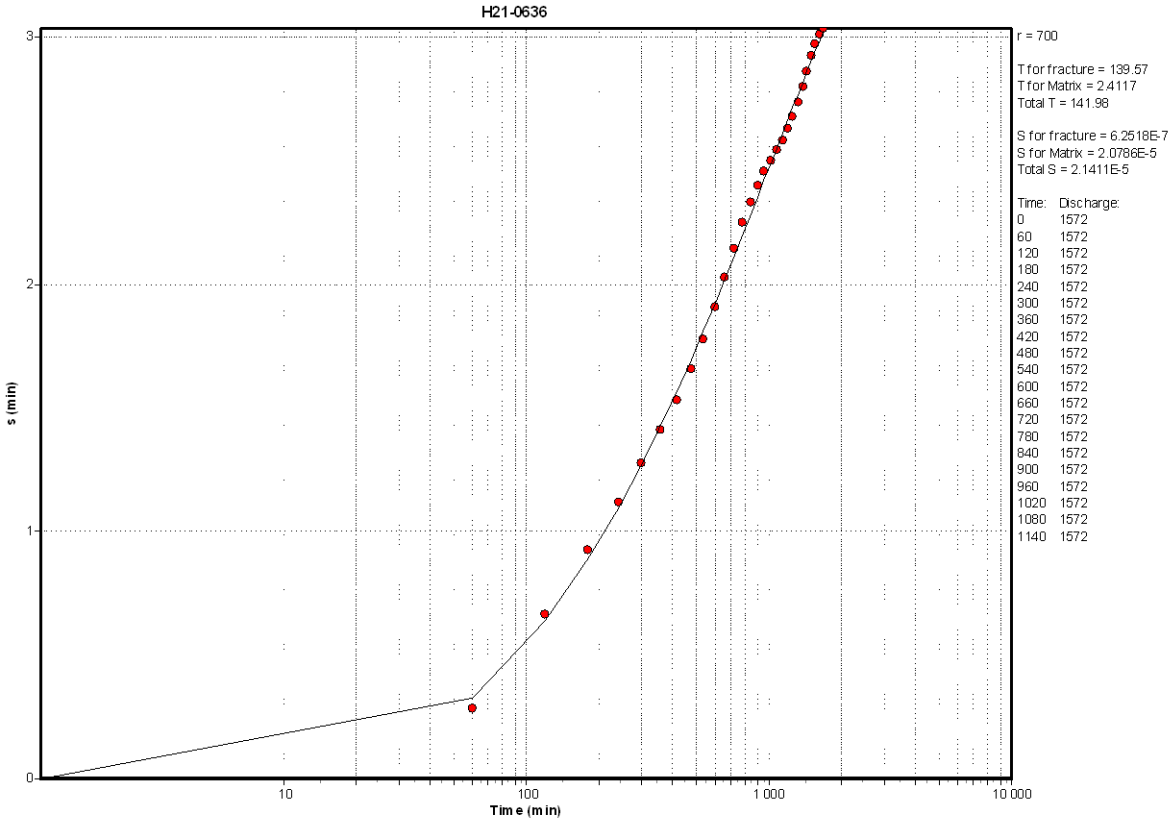


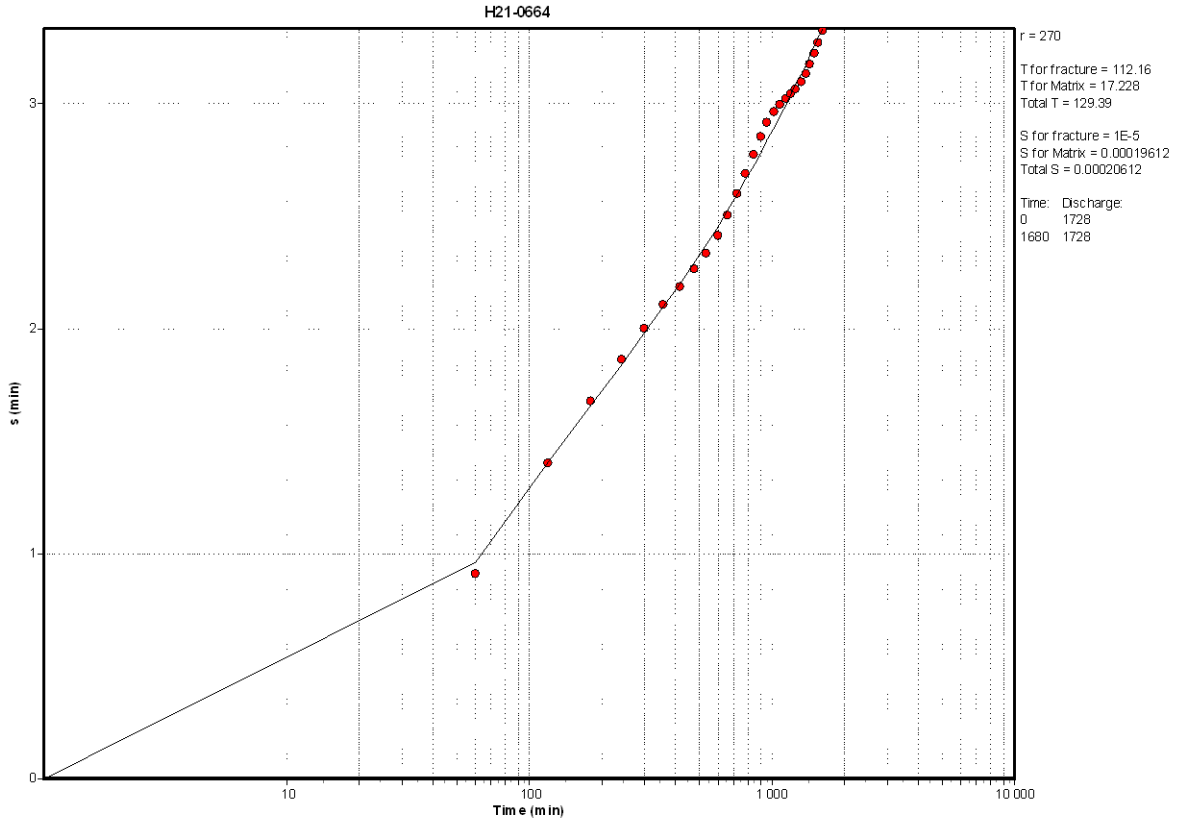
Groundwater piezometric map - Model conditions

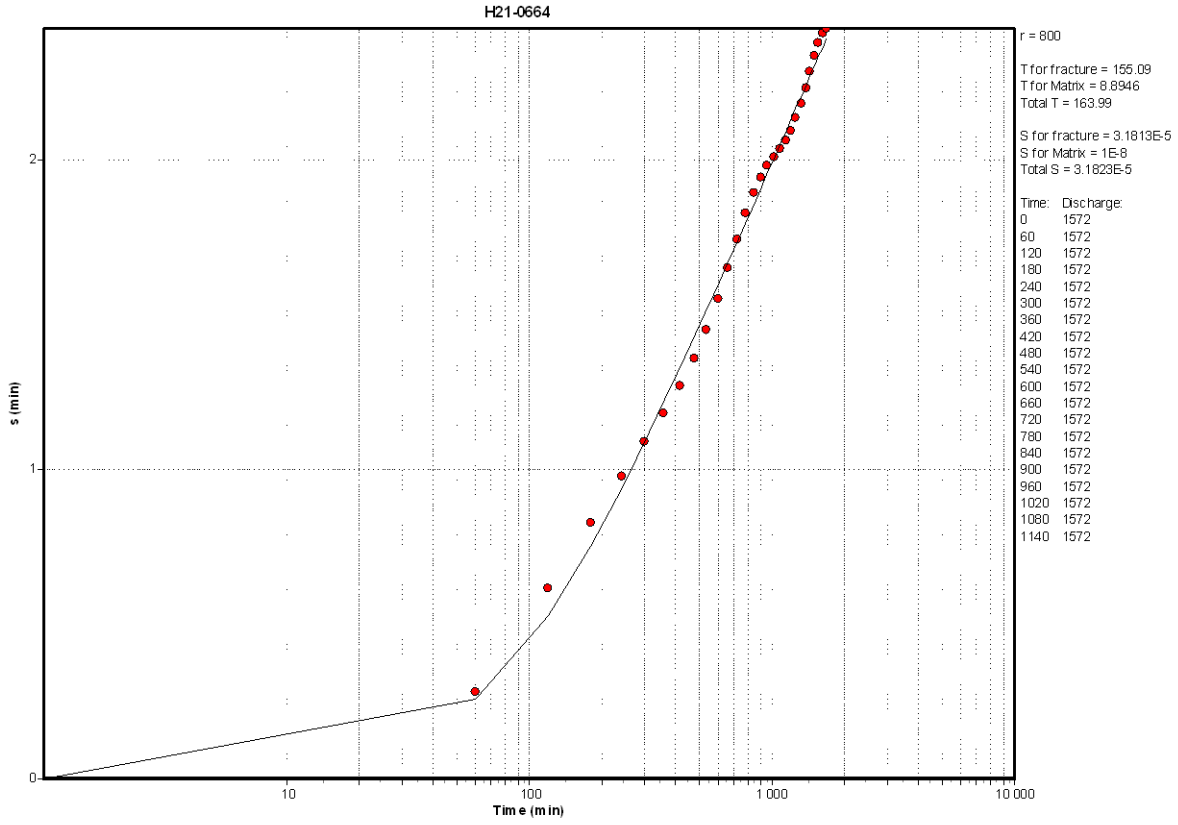


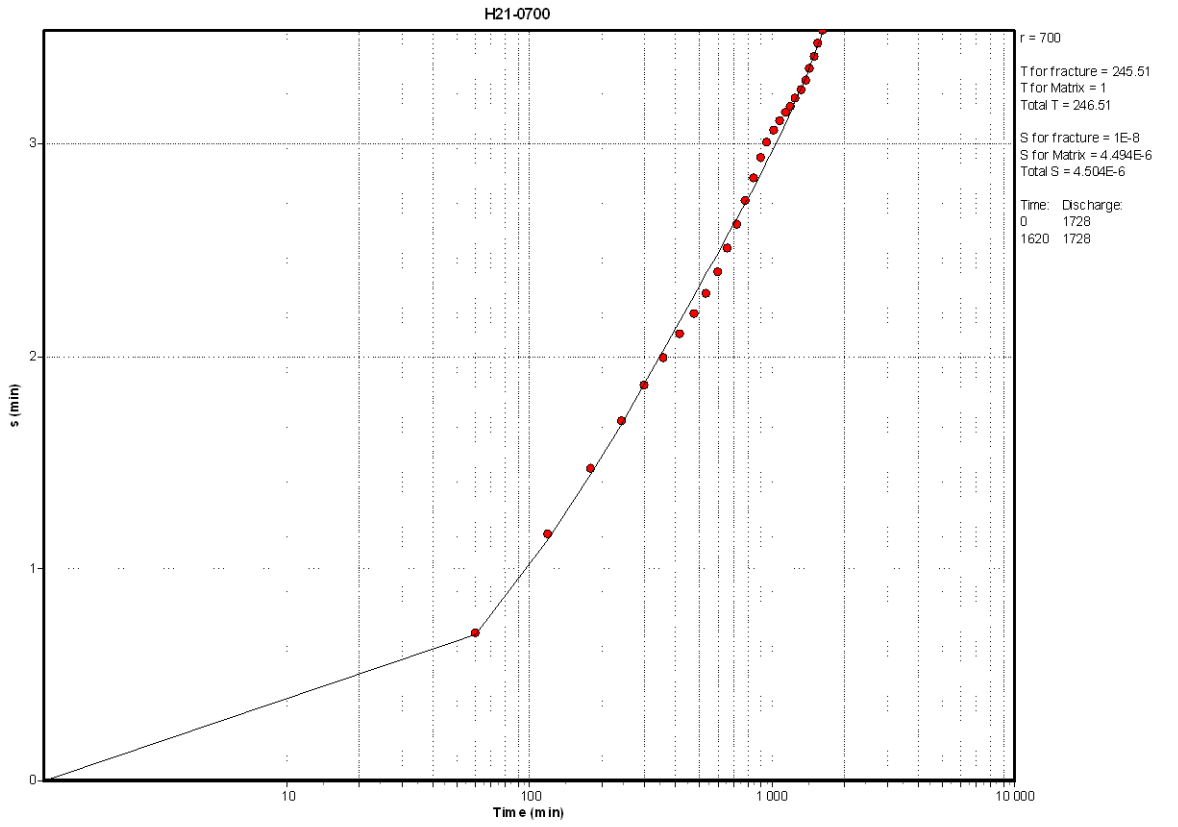
Appendix I: RPTSolv Diagrams

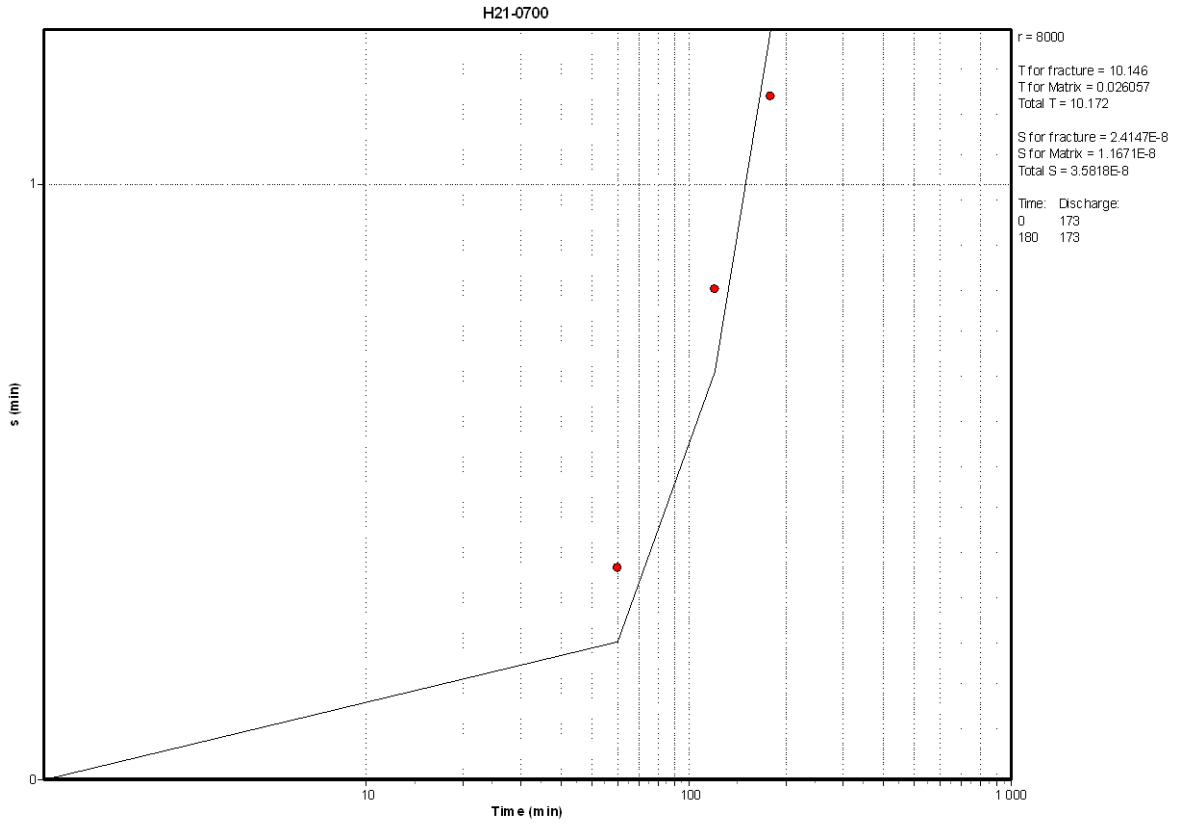

H21-0636
s (min)
Time (min)
0
1
2
3
10
100
1 000
10 000
r = 465
T for fracture = 54.788
T for Matrix = 5.4072
Total T = 60.195
S for fracture = 1E-8
S for Matrix = 0.00017721
Total S = 0.00017722
Time: Discharge:
0 1728
60 1728
120 1728
180 1728
240 1728
300 1728
360 1728
420 1728
480 1728
540 1728
600 1728
660 1728
720 1728
780 1728
840 1728
900 1728
960 1728
1020 1728
1080 1728
1140 1728

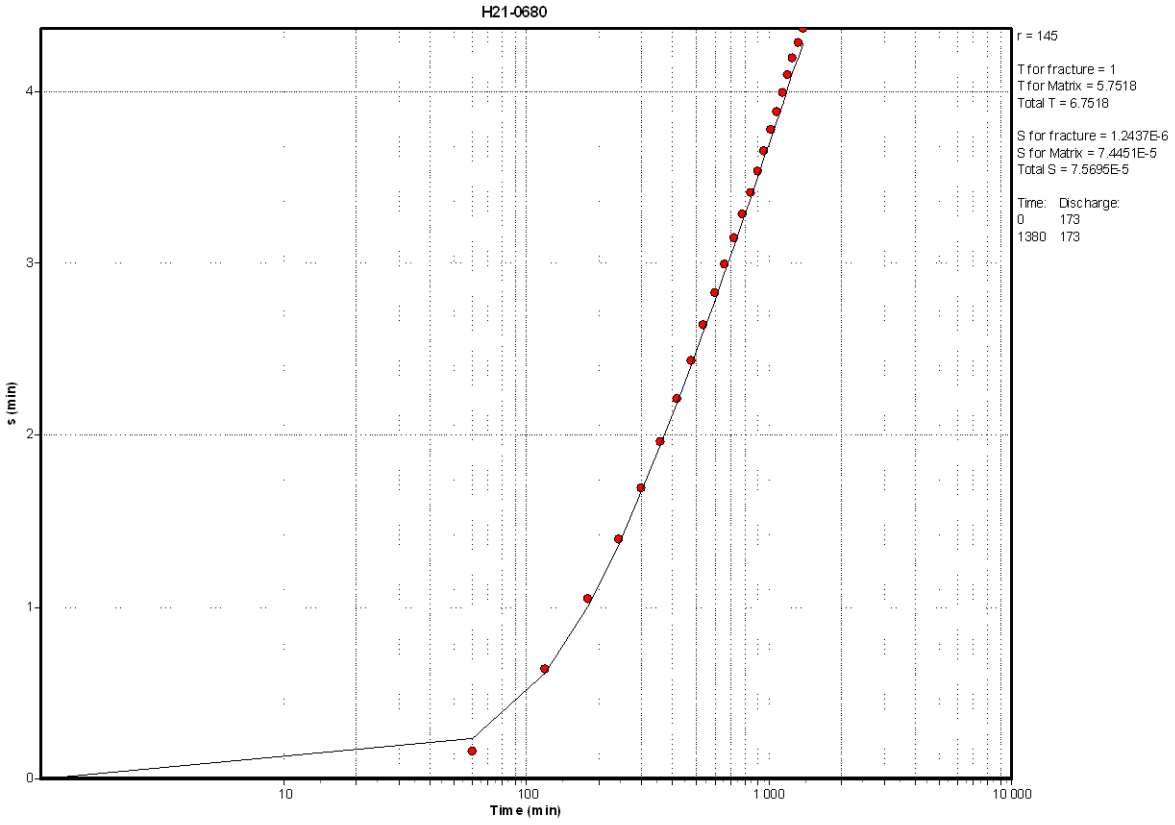

H21-0636
s (min)
Time (min)
0
1
2
3
10
100
1 000
10 000
r = 700
T for fracture = 139.57
T for Matrix = 2.4117
Total T = 141.98
S for fracture = 6.2518E-7
S for Matrix = 2.0786E-5
Total S = 2.1411E-5
Time: Discharge:
0 1572
60 1572
120 1572
180 1572
240 1572
300 1572
360 1572
420 1572
480 1572
540 1572
600 1572
660 1572
720 1572
780 1572
840 1572
900 1572
960 1572
1020 1572
1080 1572
1140 1572


H21-0664
r = 270
T for fracture = 112.16
T for Matrix = 17.228
Total T = 129.39
S for fracture = 1E-5
S for Matrix = 0.00019612
Total S = 0.00020612
Time: Discharge:
0 1728
1680 1728
s (min)
Time (min)
0
1
2
3
10
100
1 000
10 000


H21-0664
r = 800
T for fracture = 155.09
T for Matrix = 8.8946
Total T = 163.99
S for fracture = 3.1813E-5
S for Matrix = 1E-8
Total S = 3.1823E-5
Time: Discharge:
0 1572
60 1572
120 1572
180 1572
240 1572
300 1572
360 1572
420 1572
480 1572
540 1572
600 1572
660 1572
720 1572
780 1572
840 1572
900 1572
960 1572
1020 1572
1080 1572
1140 1572
s (min)
Time (min)
0
1
2
10
100
1 000
10 000

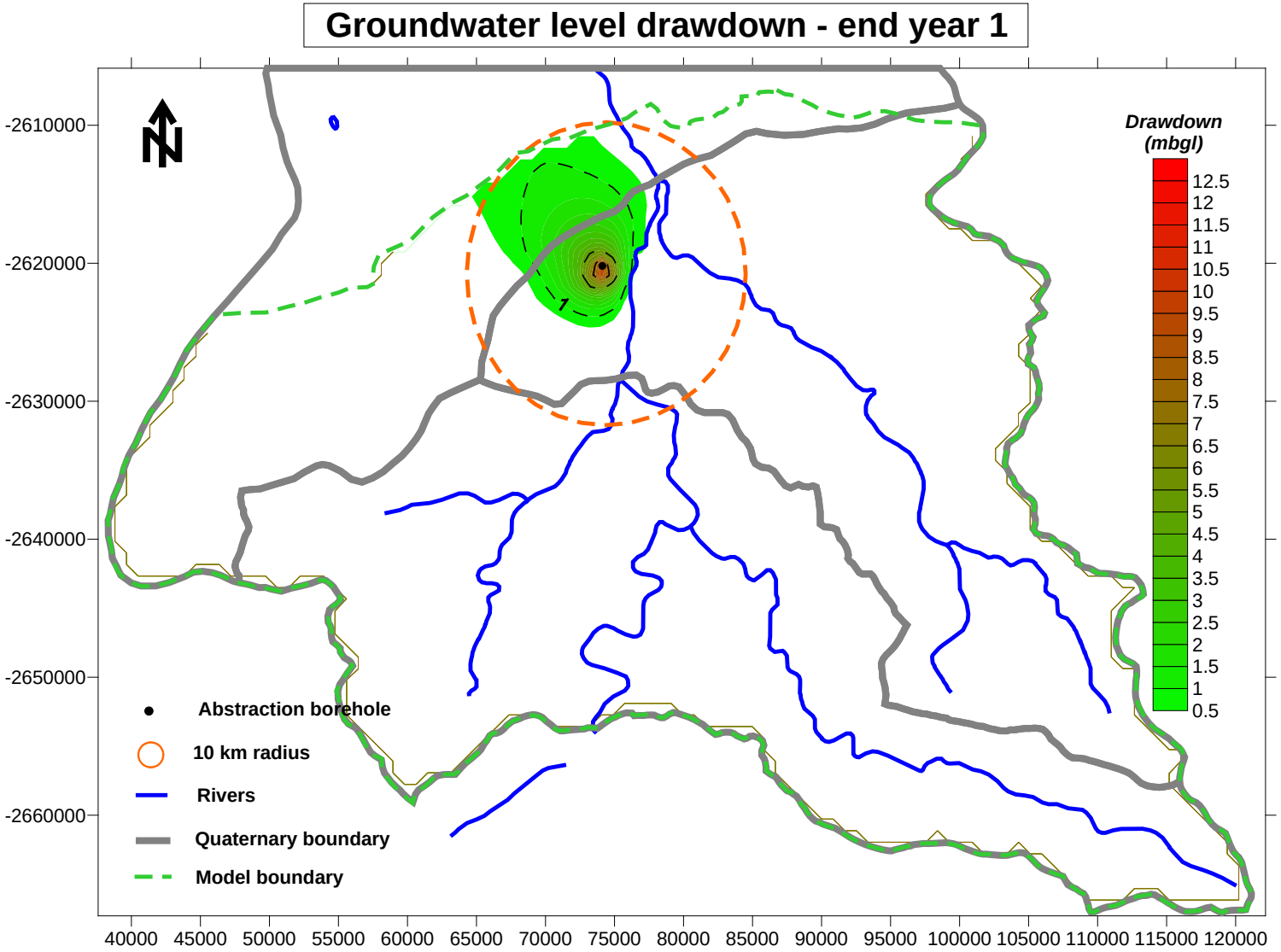

H21-0700
r = 700
T for fracture = 245.51
T for Matrix = 1
Total T = 246.51
S for fracture = 1E-8
S for Matrix = 4.494E-6
Total S = 4.504E-6
Time: Discharge:
0 1728
1620 1728
s (min)
Time (min)
0
1
2
3
10
100
1 000
10 000

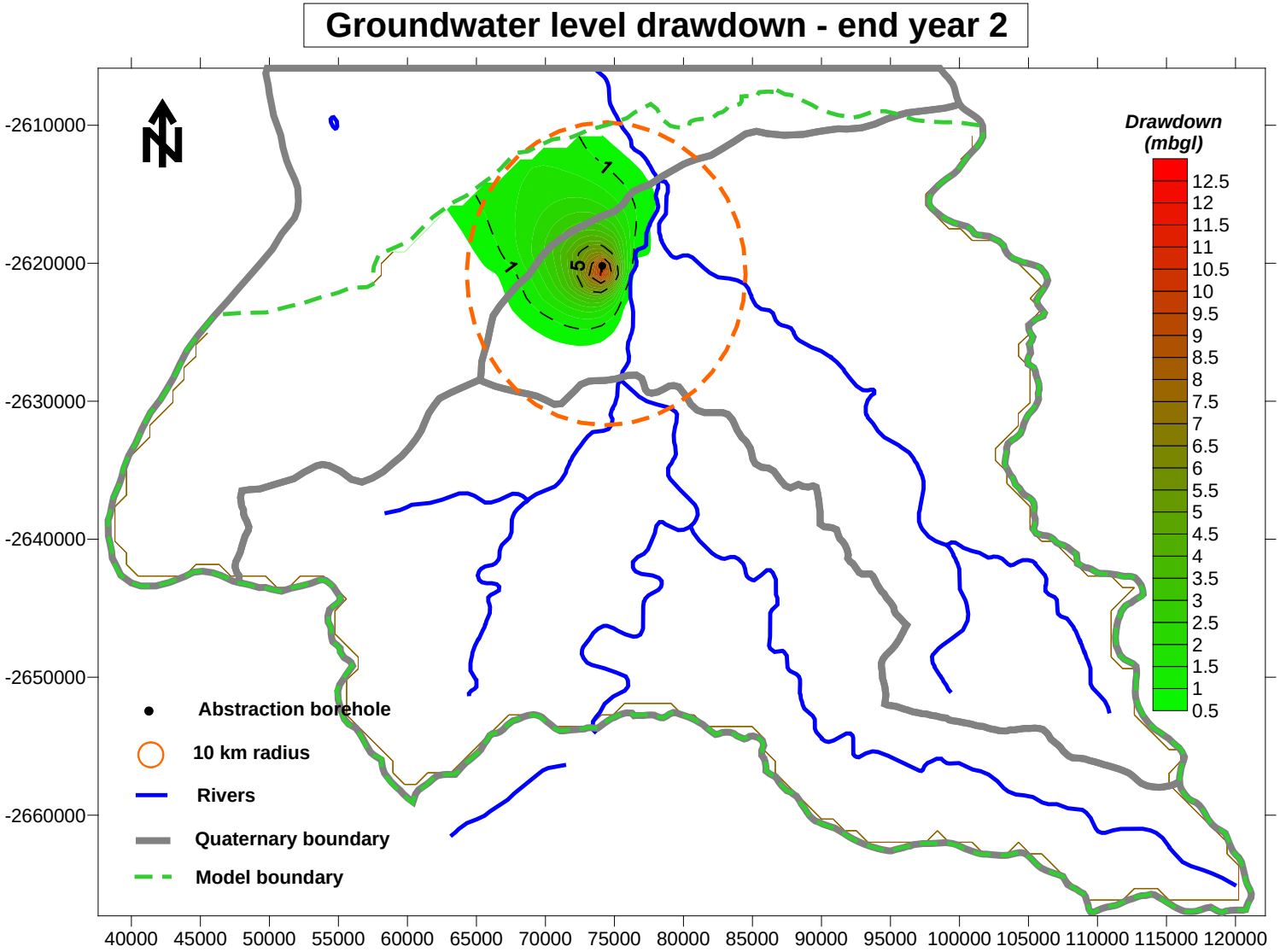

H21-0700
r = 8000
T for fracture = 10.146
T for Matrix = 0.026057
Total T = 10.172
S for fracture = 2.4147E-8
S for Matrix = 1.1671E-8
Total S = 3.5818E-8
Time: Discharge:
0 173
180 173
s (min)
Time (min)
0
1
10
100
1 000

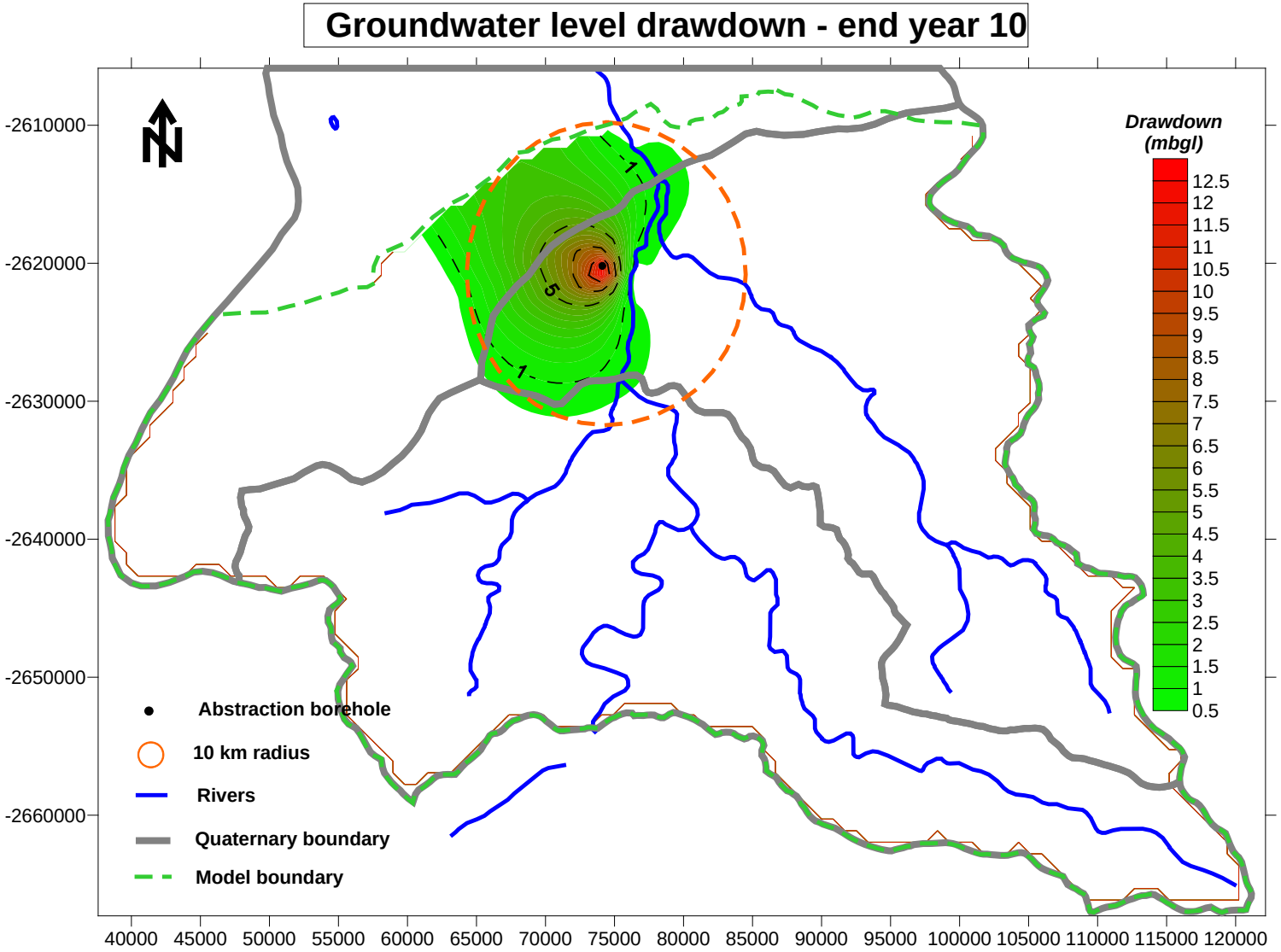

H21-0680
r = 145
T for fracture = 1
T for Matrix = 5.7518
Total T = 6.7518
S for fracture = 1.2437E-6
S for Matrix = 7.4451E-5
Total S = 7.5695E-5
Time: Discharge:
0 173
1380 173
s (min)
Time (min)
0
1
2
3
4
10
100
1 000
10 000

Appendix J: Scenario Impact Maps

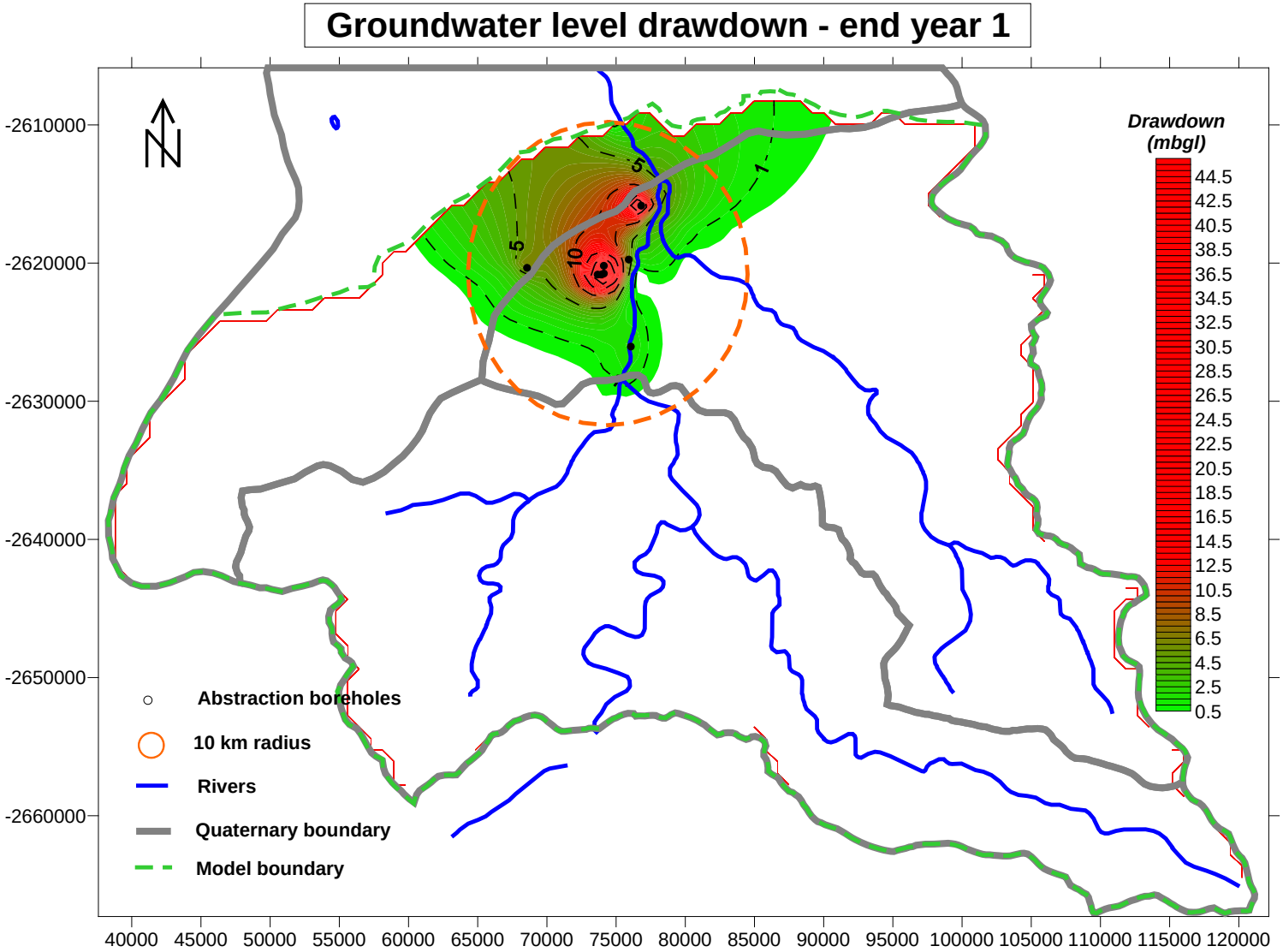
J1: Scenario 1

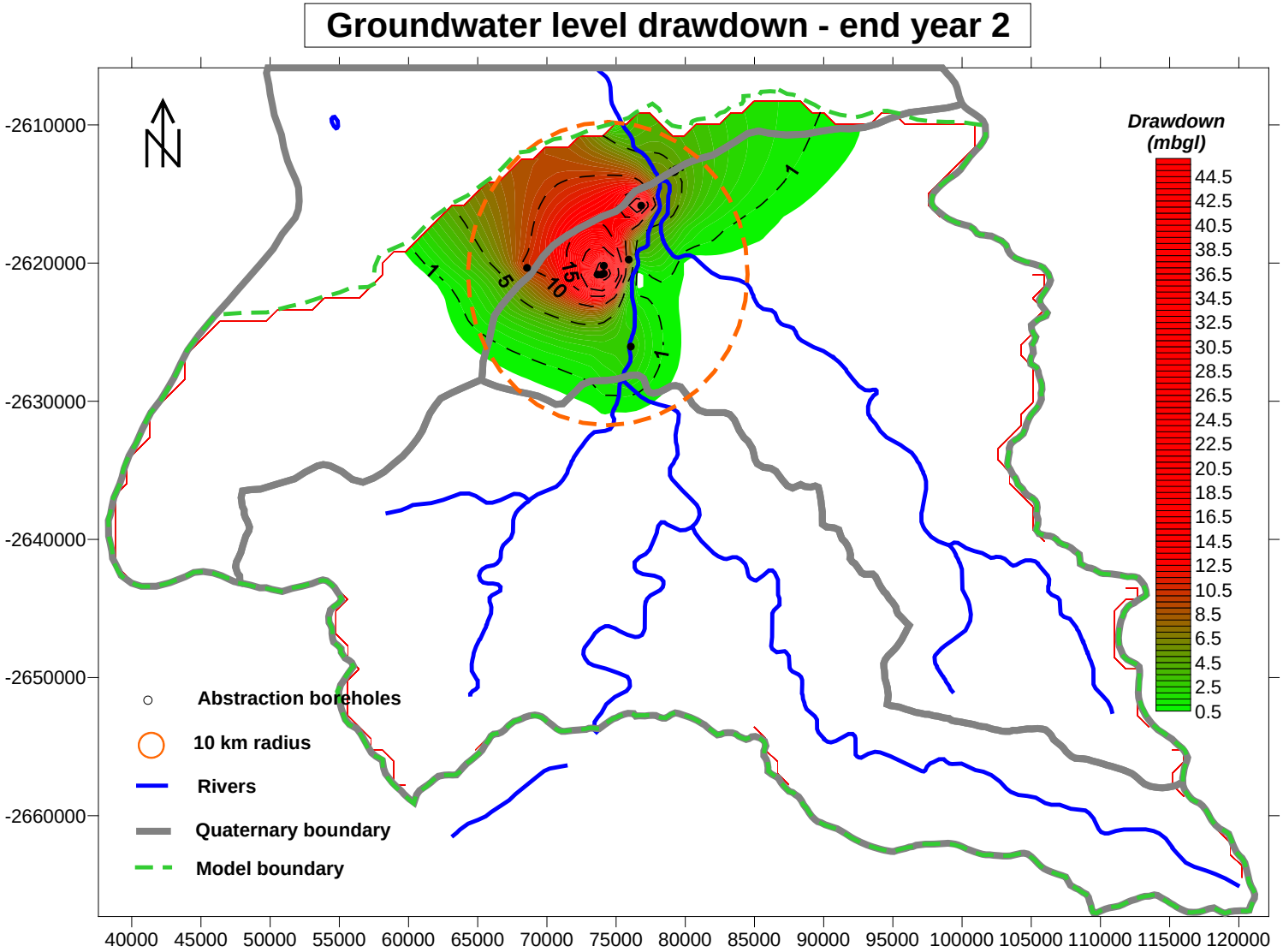

Groundwater level drawdown - end year 1
Drawdown (mbgl)
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
Abstraction borehole
10 km radius
Rivers
Quaternary boundary
Model boundary
-2610000
-2620000
-2630000
-2640000
-2650000
-2660000
40000
45000
50000
55000
60000
65000
70000
75000
80000
85000
90000
95000
100000
105000
110000
115000
120000

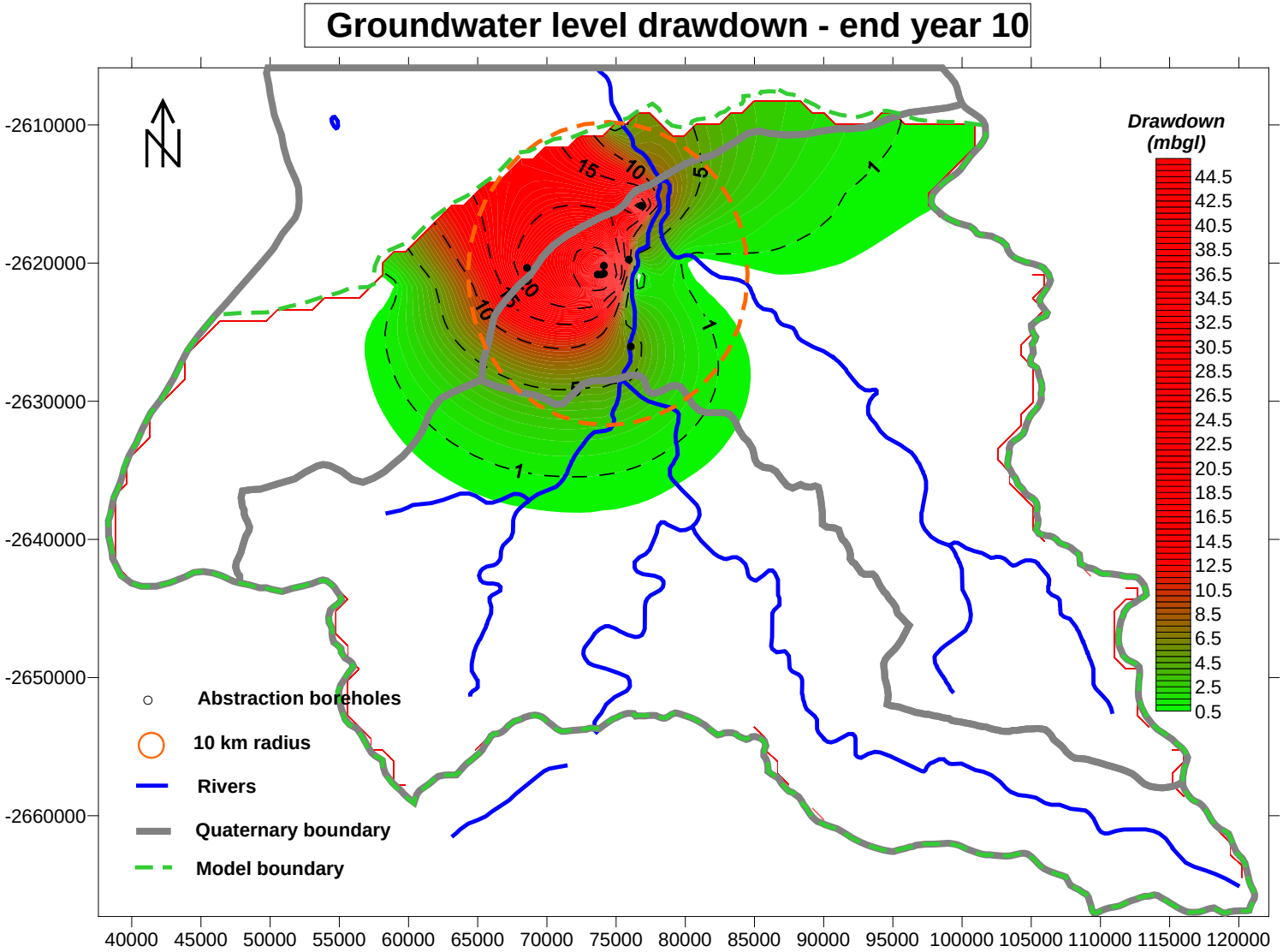

Groundwater level drawdown - end year 2
Drawdown (mbgl)
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
Abstraction borehole
10 km radius
Rivers
Quaternary boundary
Model boundary
-2610000
-2620000
-2630000
-2640000
-2650000
-2660000
40000
45000
50000
55000
60000
65000
70000
75000
80000
85000
90000
95000
100000
105000
110000
115000
120000


Groundwater level drawdown - end year 10
Drawdown (mbgl)
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
Abstraction borehole
10 km radius
Rivers
Quaternary boundary
Model boundary
-2610000
-2620000
-2630000
-2640000
-2650000
-2660000
40000
45000
50000
55000
60000
65000
70000
75000
80000
85000
90000
95000
100000
105000
110000
115000
120000

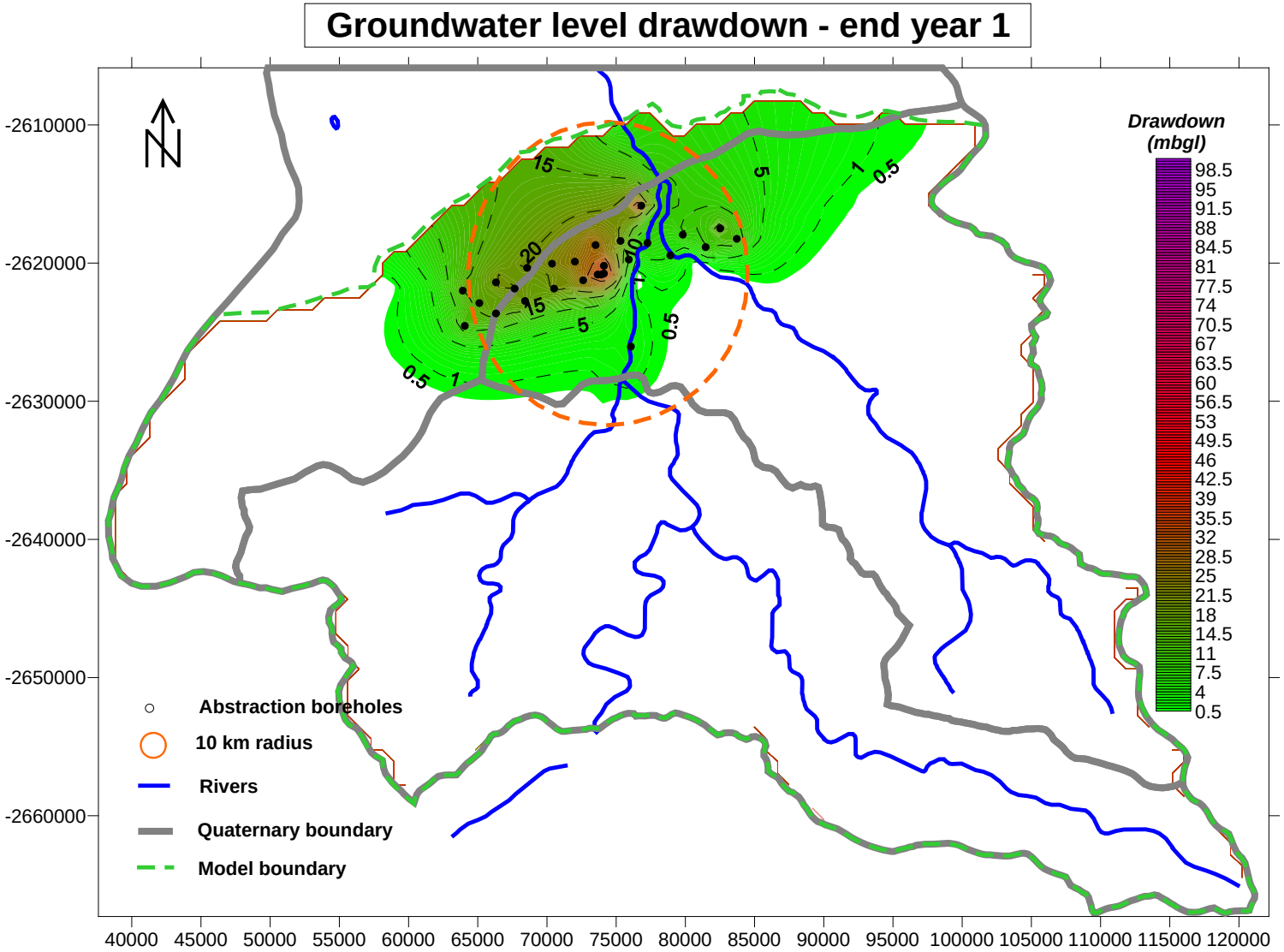
J2: Scenario 2

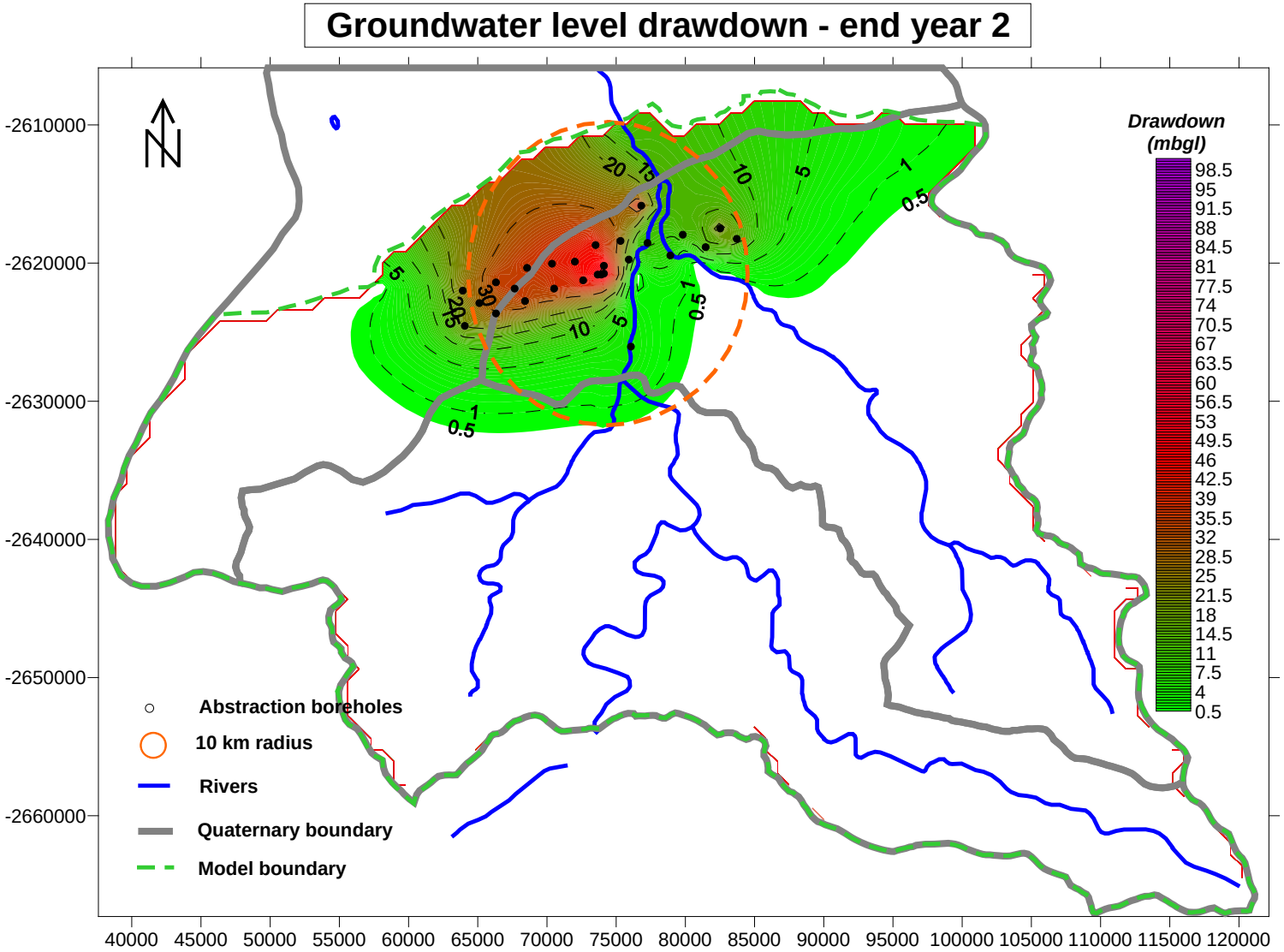

Groundwater level drawdown - end year 1
Drawdown (mbgl)
44.5
42.5
40.5
38.5
36.5
34.5
32.5
30.5
28.5
26.5
24.5
22.5
20.5
18.5
16.5
14.5
12.5
10.5
8.5
6.5
4.5
2.5
0.5
-2610000
-2620000
-2630000
-2640000
-2650000
-2660000
40000
45000
50000
55000
60000
65000
70000
75000
80000
85000
90000
95000
100000
105000
110000
115000
120000
Abstraction boreholes
10 km radius
Rivers
Quaternary boundary
Model boundary

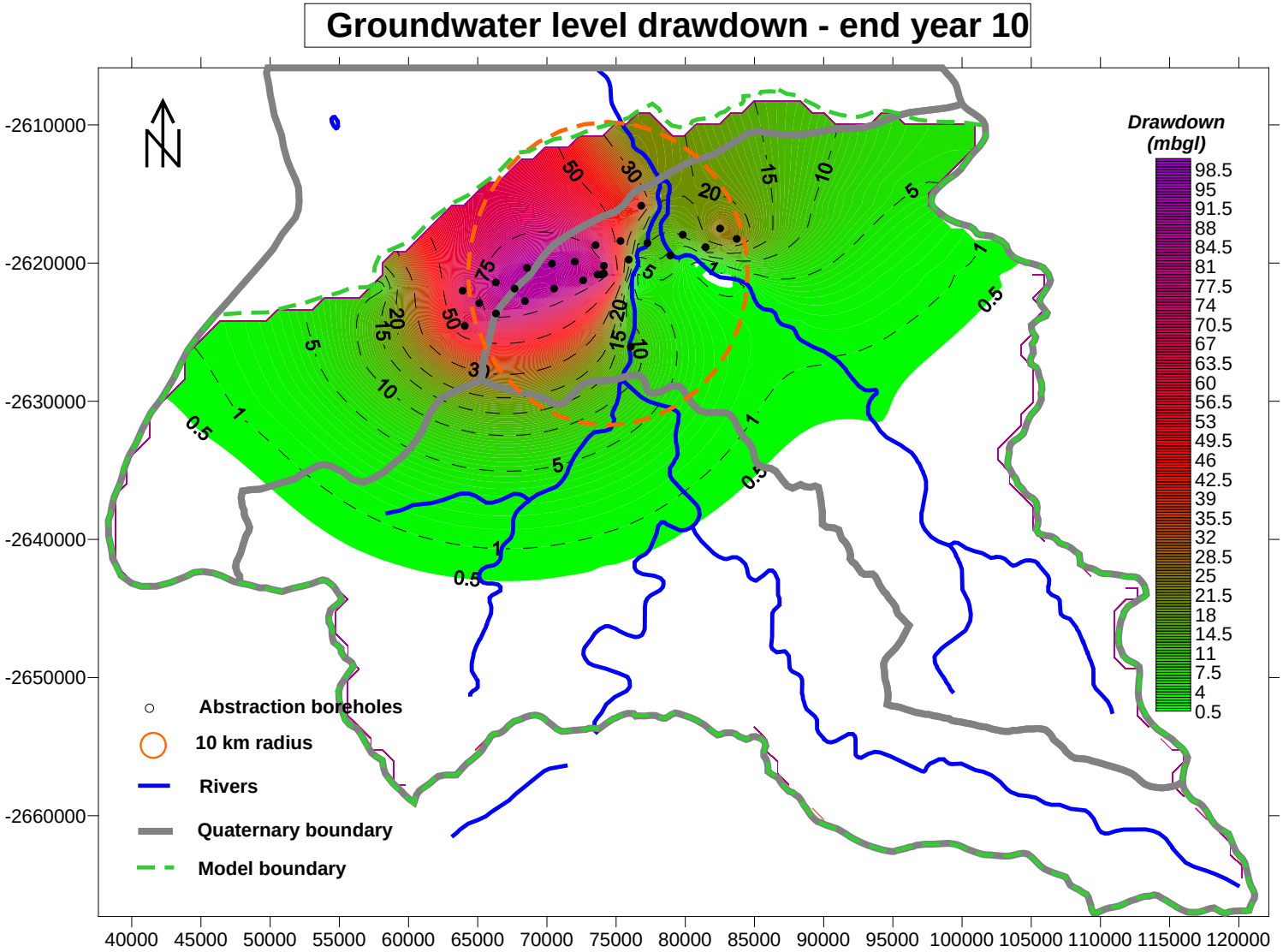

Groundwater level drawdown - end year 2
Drawdown (mbgl)
44.5
42.5
40.5
38.5
36.5
34.5
32.5
30.5
28.5
26.5
24.5
22.5
20.5
18.5
16.5
14.5
12.5
10.5
8.5
6.5
4.5
2.5
0.5
Abstraction boreholes
10 km radius
Rivers
Quaternary boundary
Model boundary
-2610000
-2620000
-2630000
-2640000
-2650000
-2660000
40000
45000
50000
55000
60000
65000
70000
75000
80000
85000
90000
95000
100000
105000
110000
115000
120000


Groundwater level drawdown - end year 10
Drawdown (mbgl)
44.5
42.5
40.5
38.5
36.5
34.5
32.5
30.5
28.5
26.5
24.5
22.5
20.5
18.5
16.5
14.5
12.5
10.5
8.5
6.5
4.5
2.5
0.5
Abstraction boreholes
10 km radius
Rivers
Quaternary boundary
Model boundary
-2610000
-2620000
-2630000
-2640000
-2650000
-2660000
40000
45000
50000
55000
60000
65000
70000
75000
80000
85000
90000
95000
100000
105000
110000
115000
120000

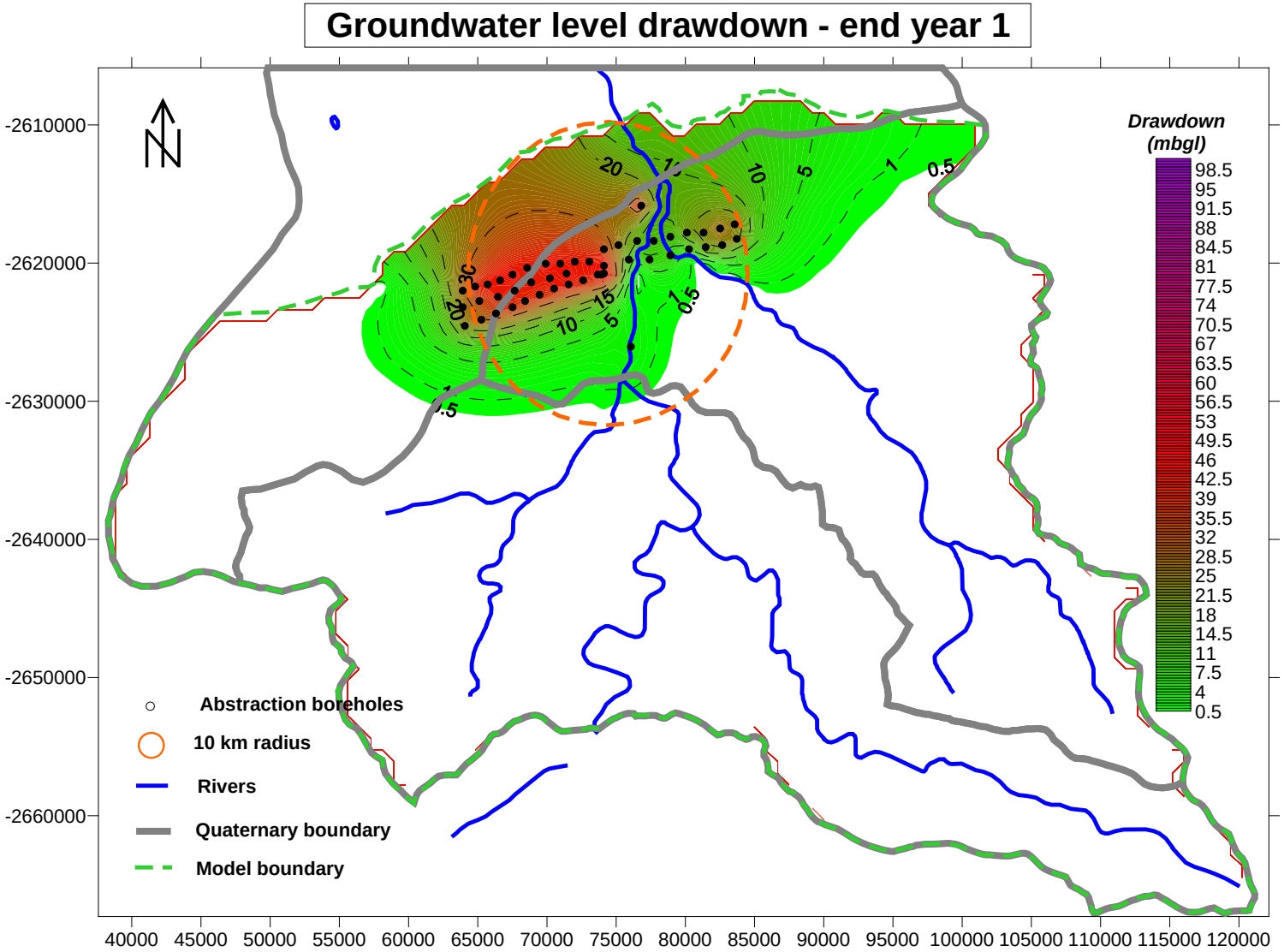
J3: Scenario 3

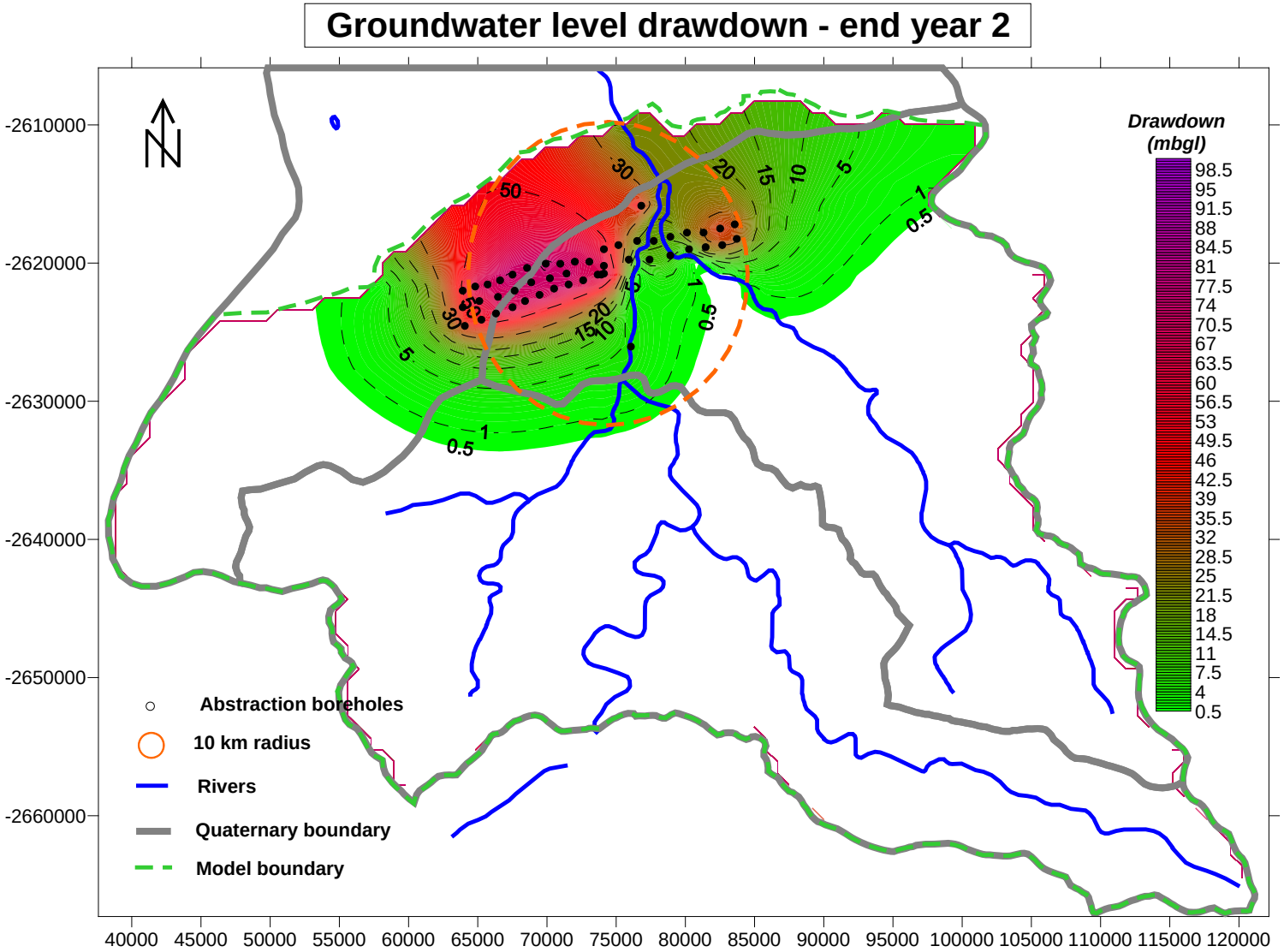

Groundwater level drawdown - end year 1
Drawdown (mbgl)
98.5
95
91.5
88
84.5
81
77.5
74
70.5
67
63.5
60
56.5
53
49.5
46
42.5
39
35.5
32
28.5
25
21.5
18
14.5
11
7.5
4
0.5
Abstraction boreholes
10 km radius
Rivers
Quaternary boundary
Model boundary
-2610000
-2620000
-2630000
-2640000
-2650000
-2660000
40000
45000
50000
55000
60000
65000
70000
75000
80000
85000
90000
95000
100000
105000
110000
115000
120000

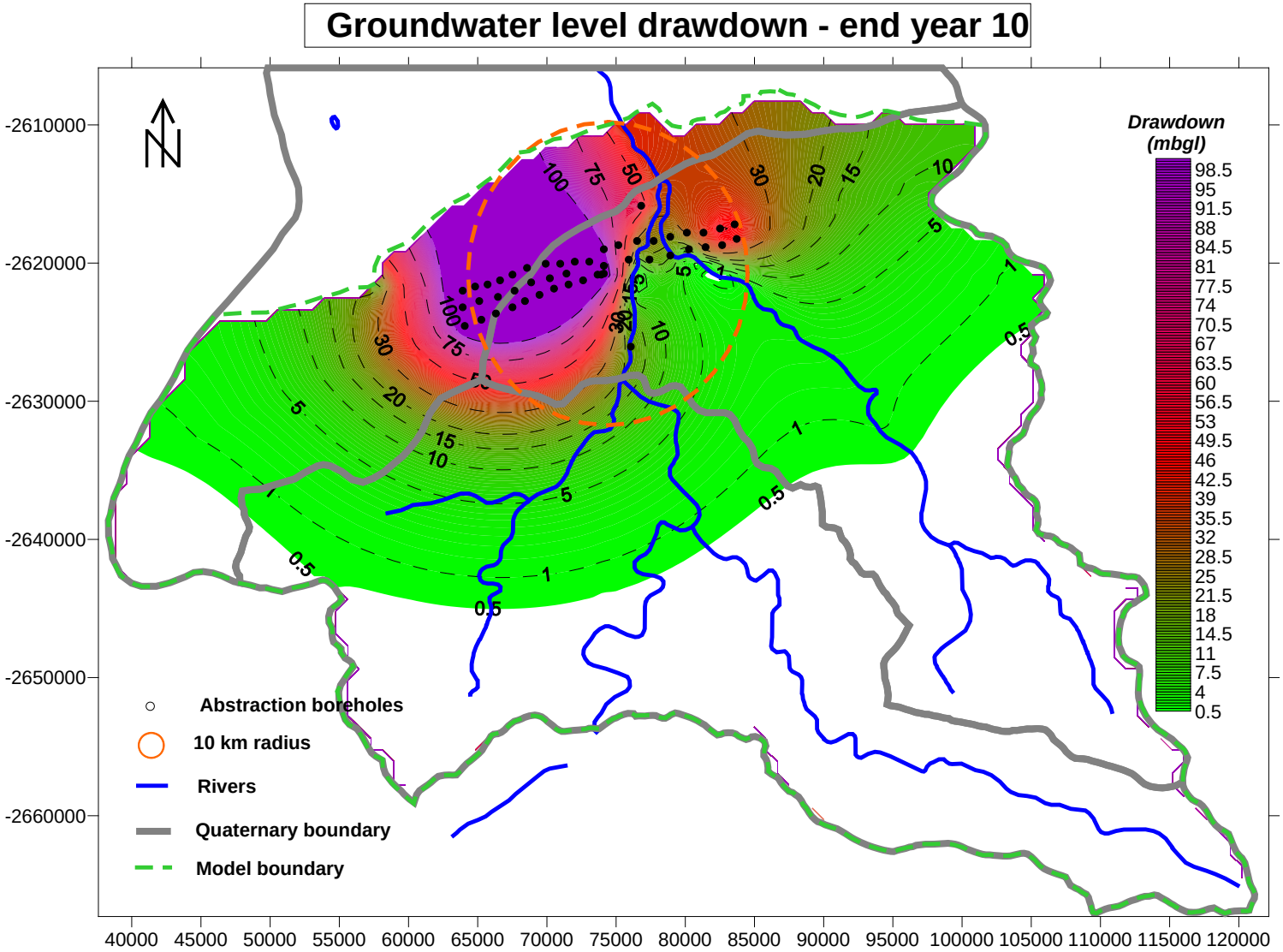

Groundwater level drawdown - end year 2
Drawdown (mbgl)
98.5
95
91.5
88
84.5
81
77.5
74
70.5
67
63.5
60
56.5
53
49.5
46
42.5
39
35.5
32
28.5
25
21.5
18
14.5
11
7.5
4
0.5
Abstraction boreholes
10 km radius
Rivers
Quaternary boundary
Model boundary
-2610000
-2620000
-2630000
-2640000
-2650000
-2660000
40000
45000
50000
55000
60000
65000
70000
75000
80000
85000
90000
95000
100000
105000
110000
115000
120000


Groundwater level drawdown - end year 10
Drawdown (mbgl)
98.5
95
91.5
88
84.5
81
77.5
74
70.5
67
63.5
60
56.5
53
49.5
46
42.5
39
35.5
32
28.5
25
21.5
18
14.5
11
7.5
4
0.5
Abstraction boreholes
10 km radius
Rivers
Quaternary boundary
Model boundary
-2610000
-2620000
-2630000
-2640000
-2650000
-2660000
40000
45000
50000
55000
60000
65000
70000
75000
80000
85000
90000
95000
100000
105000
110000
115000
120000

J4: Scenario 4

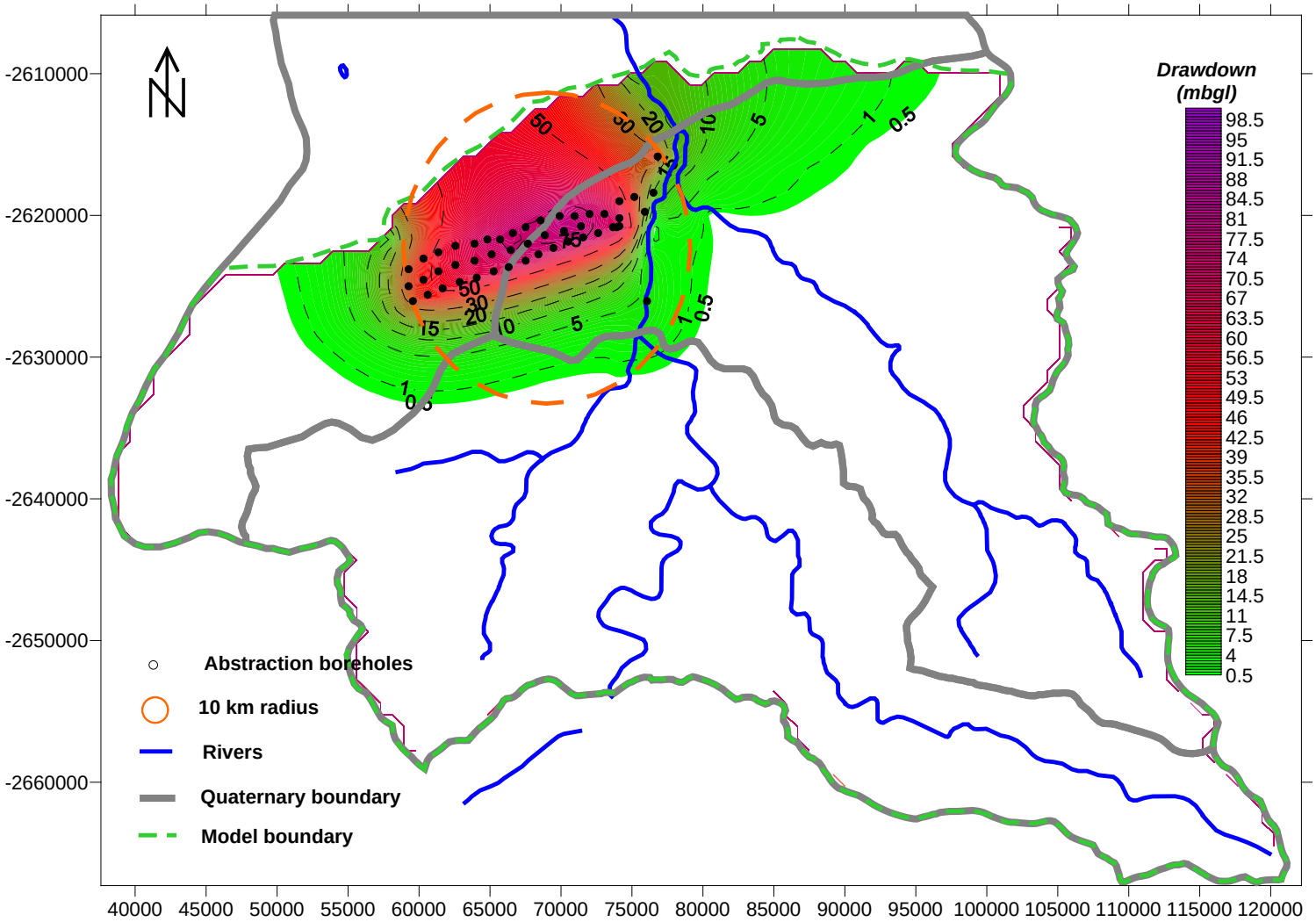

Groundwater level drawdown - end year 1
Drawdown (mbgl)
98.5
95
91.5
88
84.5
81
77.5
74
70.5
67
63.5
60
56.5
53
49.5
46
42.5
39
35.5
32
28.5
25
21.5
18
14.5
11
7.5
4
0.5
Abstraction boreholes
10 km radius
Rivers
Quaternary boundary
Model boundary
-2610000
-2620000
-2630000
-2640000
-2650000
-2660000
40000
45000
50000
55000
60000
65000
70000
75000
80000
85000
90000
95000
100000
105000
110000
115000
120000

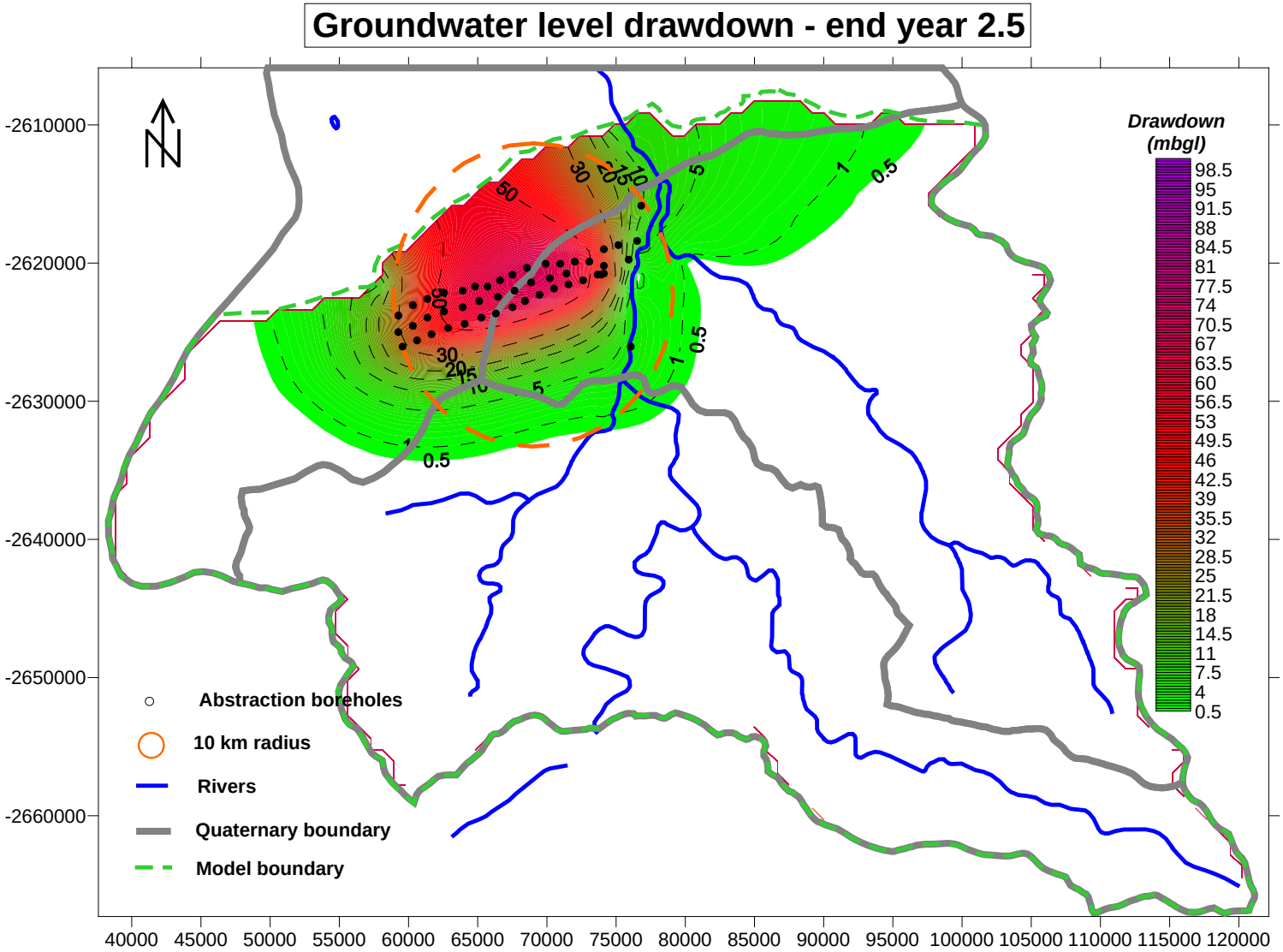

Groundwater level drawdown - end year 2
Drawdown (mbgl)
98.5
95
91.5
88
84.5
81
77.5
74
70.5
67
63.5
60
56.5
53
49.5
46
42.5
39
35.5
32
28.5
25
21.5
18
14.5
11
7.5
4
0.5
Abstraction boreholes
10 km radius
Rivers
Quaternary boundary
Model boundary
-2610000
-2620000
-2630000
-2640000
-2650000
-2660000
40000
45000
50000
55000
60000
65000
70000
75000
80000
85000
90000
95000
100000
105000
110000
115000
120000

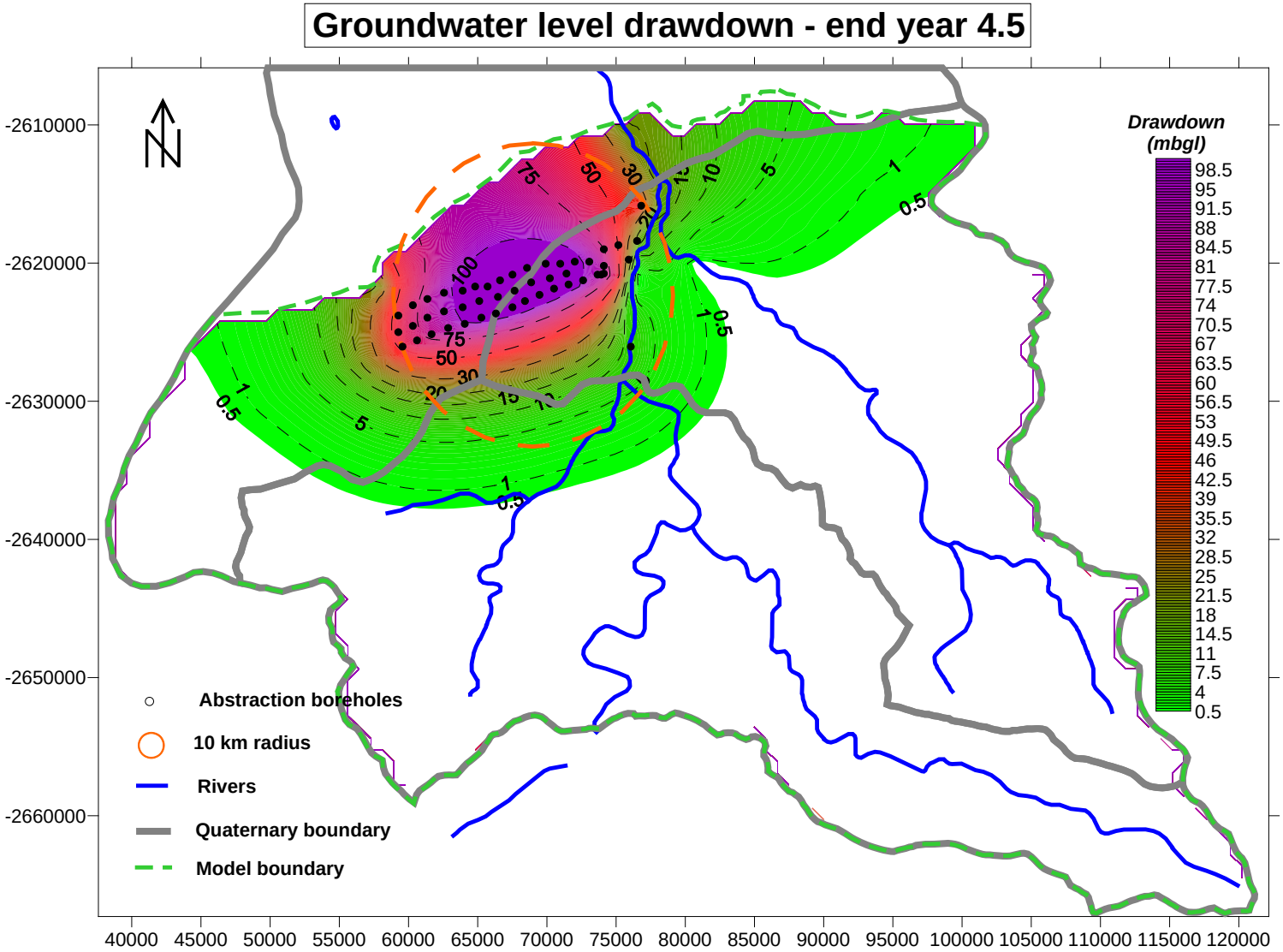

Groundwater level drawdown - end year 10
Drawdown (mbgl)
98.5
95
91.5
88
84.5
81
77.5
74
70.5
67
63.5
60
56.5
53
49.5
46
42.5
39
35.5
32
28.5
25
21.5
18
14.5
11
7.5
4
0.5
Abstraction boreholes
10 km radius
Rivers
Quaternary boundary
Model boundary
-2610000
-2620000
-2630000
-2640000
-2650000
-2660000
40000
45000
50000
55000
60000
65000
70000
75000
80000
85000
90000
95000
100000
105000
110000
115000
120000

J5: Scenario 5

Groundwater level drawdown - end year 2




Groundwater level drawdown - end year 2.5
Drawdown (mbgl)
98.5
95
91.5
88
84.5
81
77.5
74
70.5
67
63.5
60
56.5
53
49.5
46
42.5
39
35.5
32
28.5
25
21.5
18
14.5
11
7.5
4
0.5
Abstraction boreholes
10 km radius
Rivers
Quaternary boundary
Model boundary
-2610000
-2620000
-2630000
-2640000
-2650000
-2660000
40000
45000
50000
55000
60000
65000
70000
75000
80000
85000
90000
95000
100000
105000
110000
115000
120000


Groundwater level drawdown - end year 4.5
Drawdown (mbgl)
98.5
95
91.5
88
84.5
81
77.5
74
70.5
67
63.5
60
56.5
53
49.5
46
42.5
39
35.5
32
28.5
25
21.5
18
14.5
11
7.5
4
0.5
Abstraction boreholes
10 km radius
Rivers
Quaternary boundary
Model boundary
-2610000
-2620000
-2630000
-2640000
-2650000
-2660000
40000
45000
50000
55000
60000
65000
70000
75000
80000
85000
90000
95000
100000
105000
110000
115000
120000

END OF DOCUMENT