CITY OF TSHWANE METROPOLITAN MUNICIPALITY

BASIC ASESSMENT:

HYDROGEOLOGICAL INVESTIGATION

AT THE

GA RANKUWA CEMETERY

APRIL 2015

DOCUMENT NUMBER

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Project Title: Hydrogeological Investigation at the Ga Rankuwa Cemetery

Location: Ga Rankuwa, Gauteng Province

Co-ordinates (WGS84):
S 25.56742^{0}
E 27.97073^{0}

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EXECUTIVE SUMMARY

The Environmental & Advisory Unit of Aurecon SA (Pty Ltd) was appointed by the City of Tshwane Metropolitan Municipality to conduct a Basic Assessment for the Ga Rankuwa Cemetery. A hydrogeological investigation was conducted as part of Assessment requirements.

The investigation consisted of the following:

1. *Desk study & Hydrocensus.*
2. *Borehole siting by means of a ground geophysical survey.*
3. *Appointment of a drilling contractor and supervising the drilling of a monitoring borehole.*
4. *Hydraulic testing & chemical analysis of the newly drilled borehole.*
5. *Report on the findings of the investigation.*

Based on the existing data and newly acquired data, the following can be concluded:

- The Ga Rankuwa Cemetery is underlain by ferro-gabbro and ferro-diorite with some magnetite bands and inclusions of the Ferro-Gabbro Unit of the Bushveld Complex. No linear structures or faults in close proximity to the cemetery are shown on the published geological map.
- The groundwater yield potential is classed as poor since 81% of boreholes on record produce less than 2 l/s. This was confirmed during the drilling phase with the major water strikes intercepted in the newly drilled borehole having a blow yield of 3000l/h (0.83 l/s).
- The water level at the site was measured to be 6.3 mbgl.
- A single resistivity traverse was performed and the geophysical profiles did not show any significant linear geological structure. Some deep weathering was observed at 80m on the traverse and a downstream monitoring borehole (GA-BH1) was drilled at this location.
- Localised groundwater flow in the vicinity of the Ga-Rankuwa Cemetery will be in a south westerly direction towards the local drainage. Based on the results of the falling head tests, potential pollutants originating from the cemetery and seeping to the groundwater would migrate at a rate of ~0.013 m/d towards the man-made drainage.
- The hydrocensus revealed no existing boreholes. The residential areas as well as the cemetery are dependent on municipal water supply.
- A bailed groundwater sample was collected for chemical analysis from the newly drilled borehole. The water quality in the borehole exceeds the Standard Limits for drinking water due to the elevated manganese concentration. The manganese concentration may be attributed to the geology that underlies the site.
- From the groundwater chemistry, the sampled borehole does not show any sign of contamination as a result of the activities at the cemetery.

Based on the above conclusions, the following recommendations are made:

- A groundwater monitoring program should be implemented to monitor the impact of the cemtery on the hydrogeological environment. Should it become evident from the monitoring program that pollution of the groundwater occurs, corrective and remedial actions should be implemented.

- It is recommended that an upstream borehole, as well as two more downstream boreholes are drilled as an expansion of the monitoring network as stated in Section 11.

1 INTRODUCTION

The *Environmental & Advisory Unit of Aurecon SA (Pty Ltd)* was appointed by the City of Tshwane Metropolitan Municipality to conduct a Basic Assessment for the Ga Rankuwa Cemetery. A hydrogeological investigation was conducted as part of Assessment requirements.

The investigation consisted of the following:

1. Desk study & Hydrocensus.
2. Borehole siting by means of a ground geophysical survey.
3. Appointment of a drilling contractor and supervising the drilling of a monitoring borehole.
4. Hydraulic testing & chemical analysis of the newly drilled borehole.
5. Report on the findings of the investigation.

This report is not intended to be an exhaustive description of the investigation at the Ga Rankuwa Cemetery, but rather as a specialist hydrogeological study to evaluate the overall hydrogeological character of the site, as well as recommendations on a groundwater monitoring program.

2 METHODOLOGY

The work completed for the purposes of compiling a hydrogeological report comprised the following:

2.1 Desk Study

The collating of all existing published data. Aerial photos and geological maps were studied to identify possible structural features. This data was used to familiarise ourselves with the site conditions and project objectives. Target areas for the geophysical traverses were identified.

2.2 Site Visit

A site visit was conducted to familiarise ourselves with the site and to evaluate the geology, hydrogeology and potential receptors of pollution emanating from the cemetery.

2.3 Hydrocensus

A hydrocensus was carried out on the property of the cemetery as well as the adjacent area to identify legitimate groundwater users, the groundwater potential and quality. Where possible, groundwater levels were also measured to assist in the understanding of groundwater flow at the site.

2.4 Geophysical Survey

A geophysical survey was performed in pre-determined areas of the site to identify possible dykes, faults and/or fracture zones which may act as groundwater flow barriers or preferential pathways. Due to the close proximity of existing infrastructure (overhead power lines, piping, fences, etc.) which would interfere with the majority of the geophysical techniques, the options were limited and the resistivity technique had to be used. The data was used to assist in the placement of the downstream monitoring borehole.

2.5 Borehole Drilling

After interpretation of the geophysical data, a drilling target was selected. The borehole was drilled using an air percussion rig and the borehole will act a fourfold purpose: (1) verification of the geology; (2) determine aquifer parameters through hydraulic testing; (3) determine groundwater quality and (4) serve as a future monitoring borehole.

2.6 Hydraulic Testing

Hydraulic testing of the newly drilled borehole was done to determine aquifer parameters (hydraulic conductivity) which will give an indication of the rate at which groundwater flows in the investigated area. Falling head tests (“slug tests”) were carried out.

2.7 Groundwater Sampling

Groundwater samples were collected for a major inorganic analysis in the newly drilled borehole, as well as boreholes identified during the hydrocensus.

2.8 Reporting

Upon completion of the desk study and field work, a document was compiled summarising the findings of the investigation.

3 AVAILABLE INFORMATION

The following information was available and was used in the investigation:

- 1:50 000 Geological Map (2527DB Brits).
- 1:500 000 Hydrogeological Map (Johannesburg 2526)
- An Explanation of the 1:500 000 General Hydrogeological Map – Johannesburg 2526. HC Barnard, October 2000.

4 PHYSIOGRAPHY

4.1 Site Location

The site is located in the suburb of Ga Rankuwa Unit 25 on the northern outskirts of Pretoria. It is accessible from Lucas Mangope Road (M21) via two unmarked roads (Map 1, Appendix A). The adjacent land-use mainly comprise of a number of residential areas, light industrial areas and smallholdings where small scale agricultural activities are practised.

4.2 Topography & Drainage

Local drainage from the cemetery will be in a southerly direction at a slope of 0.8% towards the stormwater drainage that flows a westerly direction. The drainage flows into the Rosespruit which eventually flows into the Crocodile River.

4.3 Geology & Hydrogeology

According to the published 1:50 000 geological map (2527DB Brits) the cemetery is underlain by ferro-gabbro and ferro-diorite with some magnetite bands and inclusions of the Ferro-Gabbro Unit (Bierkraal Magnetit Gabbro Unit, Rustenburg Layered Suite), Bushveld Complex (Map 2, Appendix

A). According to the published geological map no linear structures or faults in close proximity to the cemetery are shown.

According to Barnard (2000), groundwater occurrence within the granite of the Rustenburg Layered Suite is associated with deeply weathered and fractured mafic rocks. The groundwater yield potential is classed as poor since 81% of boreholes on record produce less than 2 l/s. The mafic rocks tend to weather to a clay-rich soil that is represented by the well-known black turf (black cotton soil). The very low permeability of this soil is considered to impede recharge to underlying aquifers.

The depth to groundwater level typically occurs between 5 and 40m below surface. This was confirmed by the measured water level (6.36 mbgl).

The marginally questionable groundwater quality is associated with the average EC value of 105mS/m. Caution is required when considering this water for human consumption.

It can be assumed that the regional groundwater flow direction will emulate to local topography. Groundwater flow will thus be in a westerly direction towards the man-made drainage.

5 GROUNDWATER USE

A hydrocensus was carried out on the 11th of March 2015 on the property of the cemetery as well as the adjacent area to identify legitimate groundwater users, the groundwater potential and quality. The hydrocensus extended to a distance of ~1km from the cemetery, except where a river or a surface water body exists. The hydrocensus did not extend past such a feature as surface water bodies are usually hydraulically connected to an aquifer, acts as a constant-head boundary and a groundwater pollution plume would theoretically not extend past a constant head boundary.

No boreholes were found during the hydrocensus on and around the property of the cemetery. The residential area in which the cemetery is located as well as the cemetery itself is dependent on municipal water supply.

6 GEOPHYSICAL SURVEY

No linear structures traversing the site were identified on the regional geological map. However, geological maps are not intended to delineate structures on small scale, and thus geophysical methods had to be used to identify such structures, if present.

The objective of the field survey was to investigate possible geological lineaments or weathering to determine the location of possible water bearing structures which could act as preferred groundwater pathways. The ground geophysical survey would also aid to select suitable targets for the placement of the up- and downstream monitoring boreholes.

Keeping the occurring geological formations and infrastructure (piping, & overhead power lines, fences, etc.) which may create “background noise” in mind, an electrical resistivity survey was done.

6.1 Resistivity Technique

Applying this method, the earth’s electrical resistivity is measured. Electrical current is driven through one pair of electrodes and the potential established in the earth by this current is measured with a second pair of electrodes. For this survey, the ABEM “LUND” resistivity imaging system was used. The instrument measures bulk resistivity from the surface as apparent resistivity (∆) vs. a geometric factor which is converted to true resistivity vs. depth during the interpretation process. The direct current resistivity profiling method was applied for the determination of the shallow geo-electrical section using the Schlumberger protocol.

The resistivity data were processed using the RES-2DINV version 3.52-inversion package from GEOTOMO Inc. The processing sequence consisted of converting the LUND data files into an appropriate format, de-spiking of the raw data and finally inverting the data using appropriate inversion parameters.

6.2 Discussion of Results

One resistivity traverse was performed with a total length of 200m. The geophysical profile did not show any significant linear geological structure. Some deep weathering was observed at 80m on Line 1 and a monitoring borehole was drilled at this location. Coordinates of the resistivity traverse and position of the drilling target are presented in Table 1. The geophysical profiles are presented in Appendix B.

Table 1. Coordinates of the geophysical traverses and drilling targets

Traverse nr.	Start Coordinates (WGS84)	End Coordinates (WGS84)	Drilling Target (Borehole nr)
GA-T1	S 25.56907^{o} E 27.96958^{o}	S 25.56976^{o} E 27.97137^{o}	GA-BH1 (80m)

7 BOREHOLE DRILLING

One downstream monitoring borehole was drilled on the 3rd of March 2015. The borehole was drilled down to a depth of 25m and delivered with 125 mm PVC casing, gravel pack, bentonite seal, concrete plinth, marker plate and lockable cap (Figure 1). Solid casing was installed in the upper 3m, as well as a bentonite sanitary seal. Perforated (slotted) casing and a gravel pack was installed in the remainder of the borehole in order to allow seepage into the borehole.

Drilling of the boreholes was supervised by a qualified geotechnician/hydrogeologist and necessary information (geological profile, weathered zones, water strikes, borehole depth, casing installation, etc.) was recorded. The location of the monitoring boreholes is presented in Map 3 in Appendix A. Details of the boreholes are presented in Table 2 and borehole and construction logs in Appendix C.

Table 2. Details of the monitoring boreholes drilled at Ga Rankuwa Cemetery

BH nr.	Coordinates (WGS84)	Depth (m)	Static water level (mbgl)	Water Strikes (mbgl)	Blow Yield (l/hour)
GA-BH2	S 25.56934° E 27.97032°	25	6.35	20, 24	3000

Figure 1. Borehole GA-BH1

8 HYDRAULIC TESTING

A falling head test (“slug test”) was carried out on the newly drilled borehole. The test involves continues measuring of the water level response in a borehole to the rapid displacement of water therein. This displacement or rise in water level is caused as a result from the introduction of a slug below the rest water level. “Slug tests” were carried out using a “Solinst Levelogger” recording water levels at very short intervals (3 seconds). Data acquired from the “slug tests” was used to calculate the hydraulic conductivity (K) used in the calculation of the flow velocity of groundwater on-site. Hydraulic conductivity provides an indication of the ease with which water moves through the subsurface and is used to calculate rates of groundwater movement.

The slug test analysis is presented in Appendix D and the results of the analysis are shown in Table 3.

Table 3. Calculated hydraulic conductivity as derived from the slug test data

BH nr.	K (m/d)
GA-BH2	4.88×10^{-2}

Hydraulic conductivity (K) measured in m/d can be defined as: *“the volume of a fluid passing through a porous medium in a unit time under a specific hydraulic gradient and moving through a unit area perpendicular to the flow direction.”* Darcy’s flow equation was used to calculate the groundwater flow velocity on-site. Darcy’s Law states that the rate of flow through a porous medium is proportional to the loss of head, and inversely proportional to the length of the flow path. Alternatively Darcy’s Law can be rewritten to be defined by the following equation:

$V = (K\ i)/n_e$

Where:

V = Flow velocity

K = Hydraulic Conductivity

i = Groundwater gradient/surface slope

n_e = Effective porosity

Applying the values calculated for the site and using a porosity of 3% (0.03), the groundwater flow velocity on-site was calculated to be:

$V = (0.05 \times 0.008)/0.03$

$= 0.013$ m/d

Based on Darcy’s flow equation potential pollutants originating from the cemetry and seeping to the groundwater would thus migrate at an estimated rate of ~0.013 m/d towards the man-made drainage located to the south west of the site.

9 GROUNDWATER CHEMISTRY

A bailed groundwater samples was collected for chemical analysis from the newly drilled borehole (GA-BH1) on the 11th of March 2015. The groundwater samples were submitted to an accredited laboratory (*Aquatico Scientific in Pretoria*) for a major cation/anion analysis, as well as selected trace metals. The laboratory reports are attached in Appendix E.

The analytical results were compared with the SABS drinking water standards (SANS 241-1:2011, edition 1) (Table 4). Water is classified unfit for human consumption if the Standard Limits are exceeded.

Table 4. Chemical parameters compared to SANS 241-1:2011 (edition 1) drinking water standards

Sample Nr.	GA-BH1						Standard Limits
Ca	93.70						~
Mg	44.90						~
Na	51.60						200
K	1.49						~
Mn	0.71						0.1
Fe	0						0.3
F	0.18						1.5
NO_3-N	6.49						11
NH_4-N	0.12						1.5
PO_4	0.068						-
Cl	22.8						300
SO_4	22.8						250
TDS	513						1200
T-Alk	404						~
pH	7.63						5.0 - 9.7
EC	83						170

Notes

Yellow = Acceptable

Exceeds standard limits

0 = below detection limit of analytical technique

EC measurements in mS/m, other parameters in mg/ℓ

From Table 4 it can be concluded that the water quality in boreholes GA-BH1 exceeds the Standard Limits due to the elevated manganese concentration. The elevated manganese concentration may be attributed to the geology in which the borehole is drilled and does not pose a health risk. The sampled borehole does not show any sign of contamination as a result of the activities at the cemetery.

10 AQUIFER CLASSIFICATION

The aquifer(s) underlying the project area were classified in accordance *with "A South African Aquifer System Management Classification, December 1995."*

Classification has been done in accordance with the following definitions for Aquifer System Management Classes:

- Sole Aquifer System: An aquifer which is used to supply 50% or more of domestic water for a given area, and for which there is no reasonably available alternative sources should the aquifer be impacted upon or depleted. Aquifer yields and natural water quality are immaterial.
- Major Aquifer System: Highly permeable formations, usually with a known or probable presence of significant fracturing. They may be highly productive and able to support large abstractions for public supply and other purposes. Water quality is generally very good (Electrical Conductivity of less than 150 mS/m).
- Minor Aquifer System: These can be fractured or potentially fractured rocks which do not have a high primary permeability, or other formations of variable permeability. Aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large quantities of water, they are important for local supplies and in supplying base flow for rivers.
- Non-Aquifer System: These are formations with negligible permeability that are regarded as not containing groundwater in exploitable quantities. Water quality may also be such that it renders the aquifer unusable. However, groundwater flow through such rocks, although imperceptible, does take place, and needs to be considered when assessing the risk associated with persistent pollutants.

Based on information collected during the hydrocensus it can be concluded that aquifer system in the study area can be classified as a "Minor Aquifer System". Groundwater is not a sole source of water. The aquifer is however important for supplying baseflow to the Rosespruit.

In order to achieve the Groundwater Quality Management Index a points scoring system as presented in Table 5, Table 6 and Table 7 was used.

Table 5. Ratings for the Aquifer System Management and Second Variable Classifications:

Aquifer System Management Classification		
Class	Points	Study area
Sole Source Aquifer System:	6	
Major Aquifer System:	4	
Minor Aquifer System:	2	2
Non-Aquifer System:	0	
Special Aquifer System:	0 – 6	
Second Variable Classification (Weathering/Fracturing)		
Class	Points	Study area
High:	3	
Medium:	2	
Low:	1	1

Table 6. Ratings for the Groundwater Quality Management (GQM) Classification System:

Aquifer System Management Classification		
Class	Points	Study area
Sole Source Aquifer System: Major Aquifer System: Minor Aquifer System: Non-Aquifer System: Special Aquifer System:	6 4 2 0 0 - 6	2
Aquifer Vulnerability Classification		
Class	Points	Study area
High:	3	
Medium:	2	
Low:	1	1

The occurring aquifer(s), in terms of the above definitions, is classified as a "minor aquifer system".

The vulnerability, or the tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer, in terms of the above, is classified as **low**. Although a shallow water table (<

The level of groundwater protection based on the Groundwater Quality Management Classification:

GQM Index = Aquifer System Management x Aquifer Vulnerability

= 2 X 1 = 2

Table 7. GQM index for the study area

GQM Index	Level of Protection	Study Area
<1	Limited	
1 - 3	Low Level	2
3 - 6	Medium Level	
6 - 10	High Level	
>10	Strictly Non-Degradation	

Aquifer Susceptibility

Aquifer susceptibility, a qualitative measure of the relative ease with which a groundwater body can be potentially contaminated by anthropogenic activities and which includes both aquifer vulnerability and the relative importance of the aquifer in terms of its classification, in terms of the above, is classified as **low**.

Aquifer Protection Classification

The ratings for the Aquifer System Management Classification and Aquifer Vulnerability Classification yield a Groundwater Quality Management Index of 6 for the study area, indicating that **low level groundwater protection** may be required.

Due to the low GQM index calculated for this area, a low level of protection is needed to adhere to DWS's water quality objectives. Reasonable and sound groundwater protection measures are recommended to ensure that no cumulative pollution affects the aquifer, even in the long term.

In terms of DWS's overarching water quality management objectives which is (1) protection of human health and (2) the protection of the environment, the significance of this aquifer classification is that if any potential risk exist, measures must be triggered to limit the risk to the environment, which in this case is the (1) protection of the Secondary Underlying Aquifer and (2) the Rosespruit which drains the subject.

11 MONITORING PROGRAM

A groundwater monitoring network has been developed for the Ga-Rankuwa Cemetery incorporating the newly drilled borehole (Table 8). It is important to note that a groundwater-monitoring network should be dynamic. This means that the network should be extended over time to accommodate the migration of contaminants through the aquifer as well as the expansion of infrastructure and/or addition of possible pollution sources. At the time of writing of this report, no other boreholes with the exception of the newly drilled borehole (GA-BH1) existed at the site. It is recommended that an upstream borehole, as well as two more downstream boreholes are drilled as an expansion of the monitoring network.

Table 8. Monitoring boreholes to be included into the monitoring program

Borehole	Objective
GA-BH1	Downstream from the Cemetery. Impact monitoring.

Water samples must be taken from the monitoring boreholes by using approved sampling techniques and adhering to recognised sampling procedures. Table 9 below presents the parameters and frequency that should form part of the groundwater monitoring program. The results should be recorded on a data base and reported annually to the Department of Water and Sanitation.

Table 9. Proposed monitoring requirements

Class	Parameter	Frequency	Motivation
Physical	Static groundwater levels	Monthly	Time dependant data is required to understand the groundwater flow dynamics of the site. An anomaly in static water levels caused by mounding below the drainage field may give early warning to spillages or leakages from lined/unlined facilities.
	Rainfall	Daily	Recharge to the saturated zone is an important parameter in assessing groundwater vulnerability. Time dependant data is required to understand the groundwater flow dynamics of the site.
	Groundwater abstraction rates (if present)	Monthly	Response of groundwater levels to abstraction rates could be useful to calculate aquifer storativity – important for groundwater management. Could also explain anomalous groundwater level measurements.
Chemical	Major chemical parameters: Ca, Mg, Na, K, NO_3, NH_4, SO_4, Cl, Fe, Mn, F, Alkalinity, pH, EC, TDS.	Quarterly (Jan., Apr., Jul., Sept) May be reduced to bi-annual (April & Sept.) as more data becomes available)	Background information is crucial to assess impacts during operation and thereafter. Changes in chemical composition may indicate areas of groundwater contamination and be used as an early warning system to implement management/remedial actions. Legal requirement.
	Minor chemical constituents Cr & Cr^6, Ni, As, Cu, Pb, Cd, Zn Stable isotopes	Ad hoc Basis.	Changes in chemical composition may indicate areas of groundwater contamination and be used as an early warning system to implement management/remedial actions. The monitoring program should allow for research and refinement of the conceptual hydrogeological model. This may, from time to time, require special analyses like stable isotopes.

12 CONCLUSIONS & RECOMMENDATIONS

Based on the existing data and newly acquired data, the following can be concluded:

- The Ga Rankuwa Cemetery is underlain by ferro-gabbro and ferro-diorite with some magnetite bands and inclusions of the Ferro-Gabbro Unit of the Bushveld Complex. No linear structures or faults in close proximity to the cemetery are shown on the published geological map.
- The groundwater yield potential is classed as poor since 81% of boreholes on record produce less than 2 l/s. This was confirmed during the drilling phase with the major water strikes intercepted in the newly drilled borehole having a blow yield of 3000l/h (0.83 l/s).
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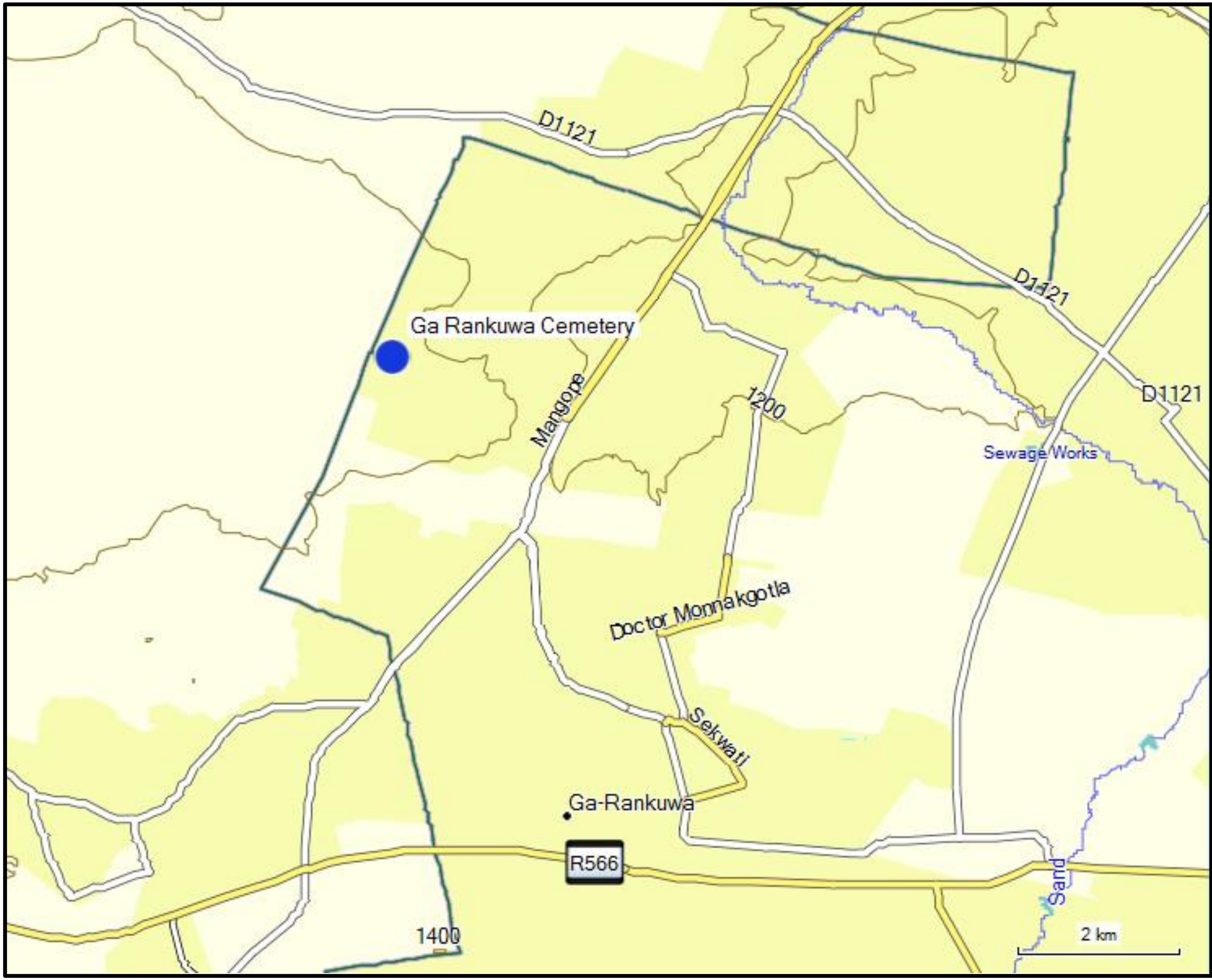
- From the groundwater chemistry, the sampled borehole does not show any sign of contamination as a result of the activities at the cemetery.

Based on the above conclusions, the following recommendations are made:

- ➢ A groundwater monitoring program should be implemented to monitor the impact of the cemtery on the hydrogeological environment. Should it become evident from the monitoring program that pollution of the groundwater occurs, corrective and remedial actions should be implemented.
- ➢ It is recommended that an upstream borehole, as well as two more downstream boreholes are drilled as an expansion of the monitoring network as stated in Section 11.

APPENDIX A

MAPS



Project Title:

HYDROGEOLOGICAL INVESTIGATION AT THE GA RANKUWA CEMETERY

Map Title:

GA RANKUWA CEMETERY: Locality Map

Map Number:

Map 1

LEGEND

● Cemetery

Project nr: 111378

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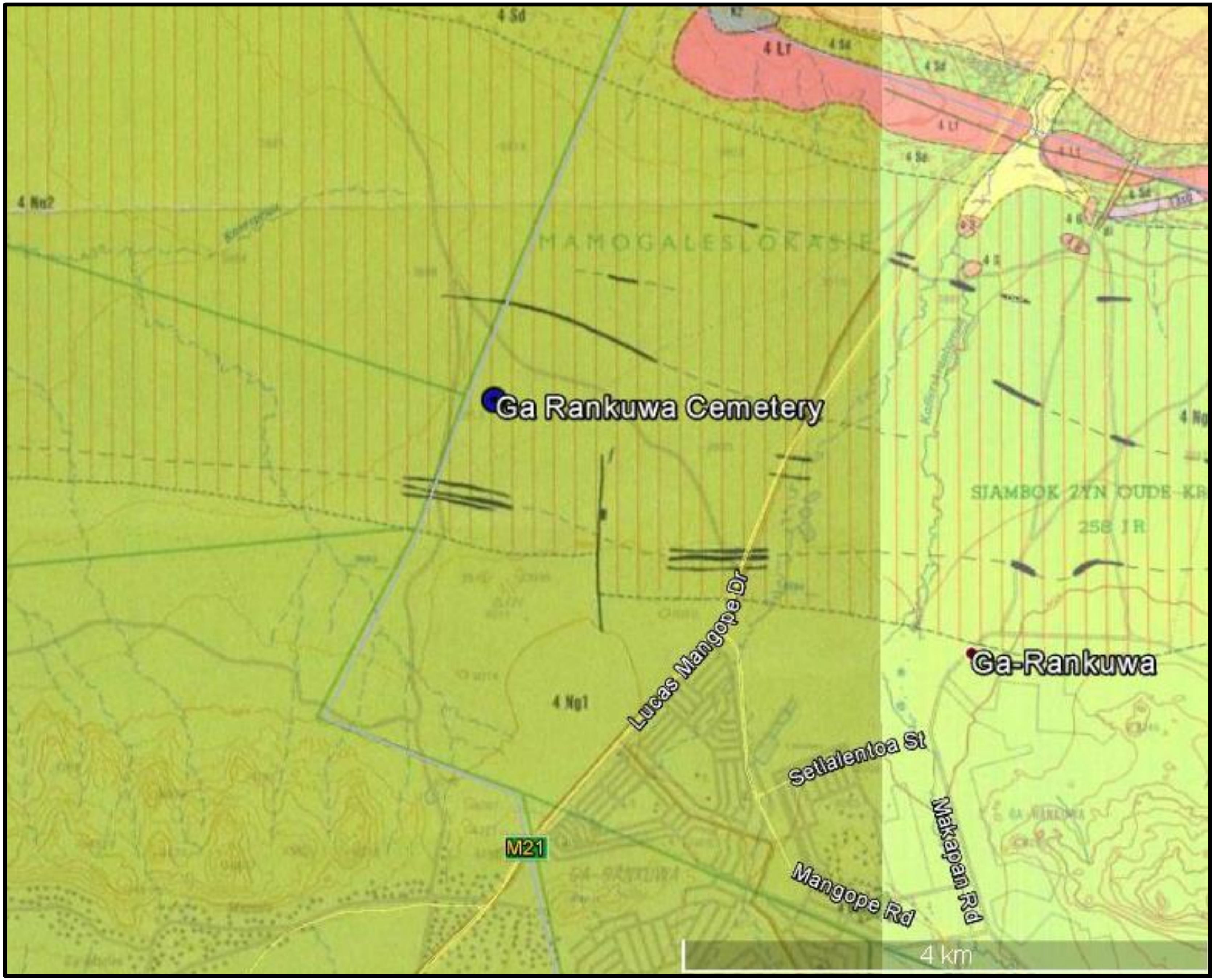
Lynnwood Bridge Office Park
4 Daventry Street
Lynwood Manor 0040
www.aurecongroup.com



Project Title:

HYDROGEOLOGICAL INVESTIGATION AT THE GA RANKUWA CEMETERY

Map Title:

GA RANKUWA CEMETERY: Geological Setting

Map Number:

Map 2

LEGEND

4Ng2: Ferro-Gabbro Unit, Bushveld Complex

4Ng1: Gabbro Unit, Bushveld Complex

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Project nr: 111378

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Lynwood Bridge Office Park
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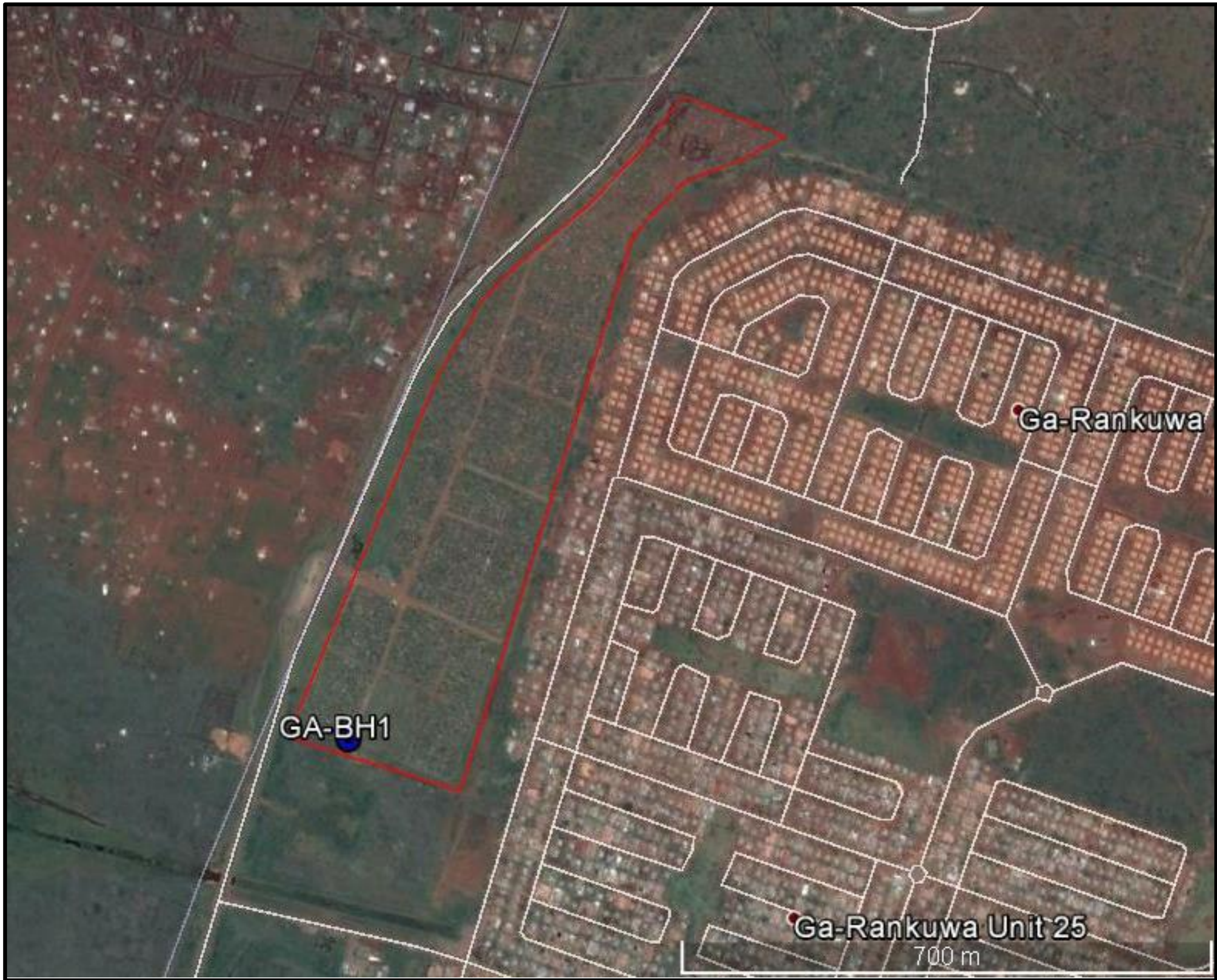

Project Title:

HYDROGEOLOGICAL INVESTIGATION AT THE GA RANKUWA CEMETERY

Map Title:

Ga Rankuwa Cemetery: Borehole Locations

Map Number:

Map 3

LEGEND

◉ Borehole

Project nr: 111378

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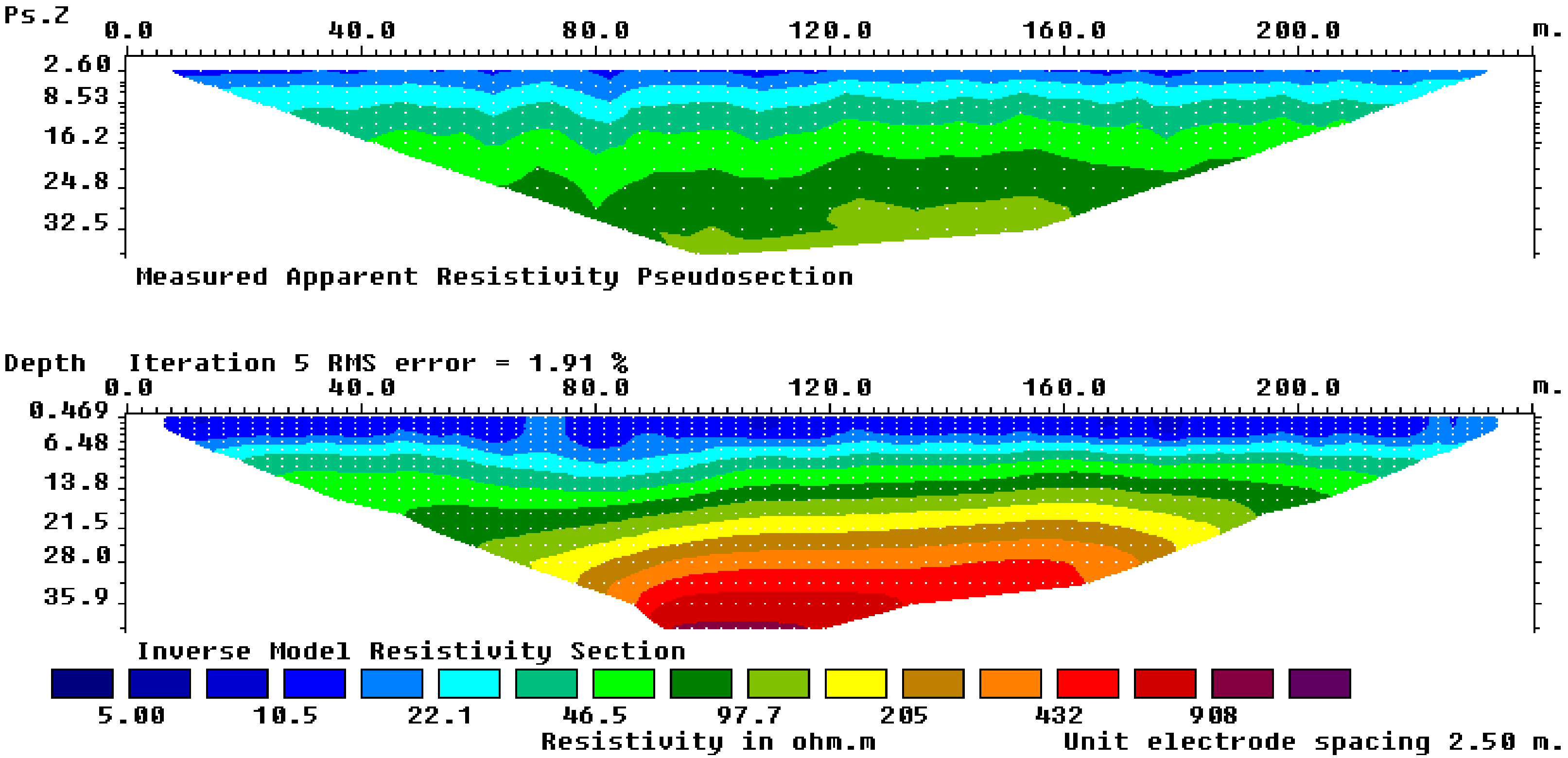
APPENDIX B

GROUND GEOPHYSICAL PROFILES

Garankuwa Resistivity Traverse   Field Survey: R Jonker / M Terblanche - 24 Feb 2015



Coords	WGS84		GPS ~ Elev
0	S25.56907	E27.96958	1185
50	S25.56924	E27.97003	1182
100	S25.56941	E27.97048	1190
150	S25.56958	E27.97092	1191
200	S25.56976	E27.97137	1191

Data of high quality

No obvious drill site

Best option around 80 m (possible minor fractures)

APPENDIX C

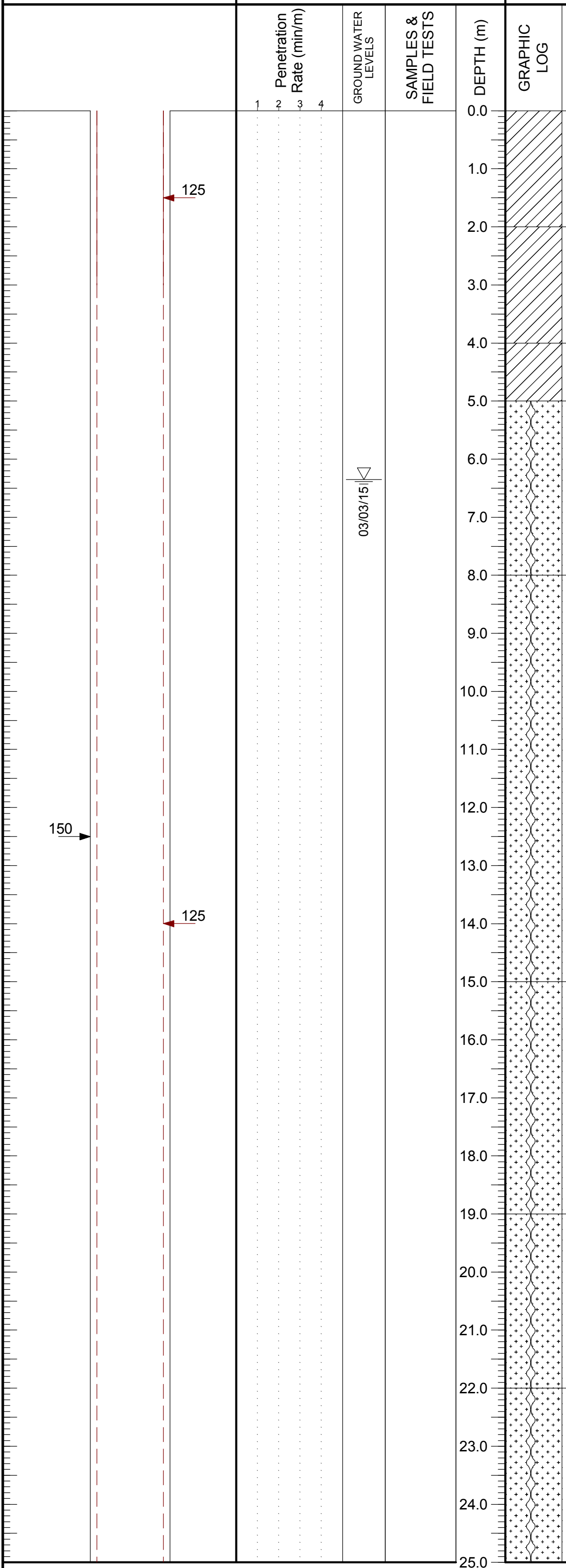
BOREHOLE LOGS

PROJECT : Ga Rankuwa Cemetery
LOCATION : Ga Rankuwa
CLIENT : City of Tshwane MM

HOLE NO : GA-BH1
FILE / JOB NO : 111378
SHEET : 1 OF 1

CONTRACTOR : SGRS	RIG TYPE : Audie Eng Spider	ANGLE FROM HORIZONTAL : 90°	LATITUDE : 25.56934°
DRILLER : Andries	LOGGED BY : MT	HOLE DIA : 150 mm	LONGITUDE : 27.97032°
DATE STARTED : 15/3/3	DATE LOGGED : 15/3/3	HOLE DEPTH : 25 m	ELEVATION : 1190.000 (MSL)
DATE COMPLETED : 15/3/3	CHECKED BY : MT	COLLAR HEIGHT : 0.3 m	GRID & DATUM : WGS84

CONSTRUCTION | DRILLING | MATERIAL



Depth	MATERIAL DESCRIPTION
	CLAY: Black Turf
2.00m	CLAY: Reddish brown clayey soil
4.00m	CLAY: Yelloish brown
5.00m	GABBRO: Yellowish brown - Highly weathered
8.00m	GABBRO: Yellowish grey - Moderately weathered
15.00m	GABBRO: Yellowish grey - Highly weathered
19.00m	GABBRO: Yellowish grey - Moderately weathered. Seepage @ 20m
22.00m	GABBRO: Dark grey - Slightly Weathered and fractured @ 24m. Waterstrike at 24m - 3000l/h
25.00m	BOREHOLE GA-BH1 TERMINATED AT 25.00 m

— Hole
— — Casing (plain / perforated)
→ Hole diameter (mm)
← Casing diamater (mm)

APPENDIX D

SLUG TEST ANALYSIS

Lynwood Bridge Office Park
4 Daventry Street
Lynwood Manor

Slug test analysis

No:

Project: Garankuwa Cemetery

Client:

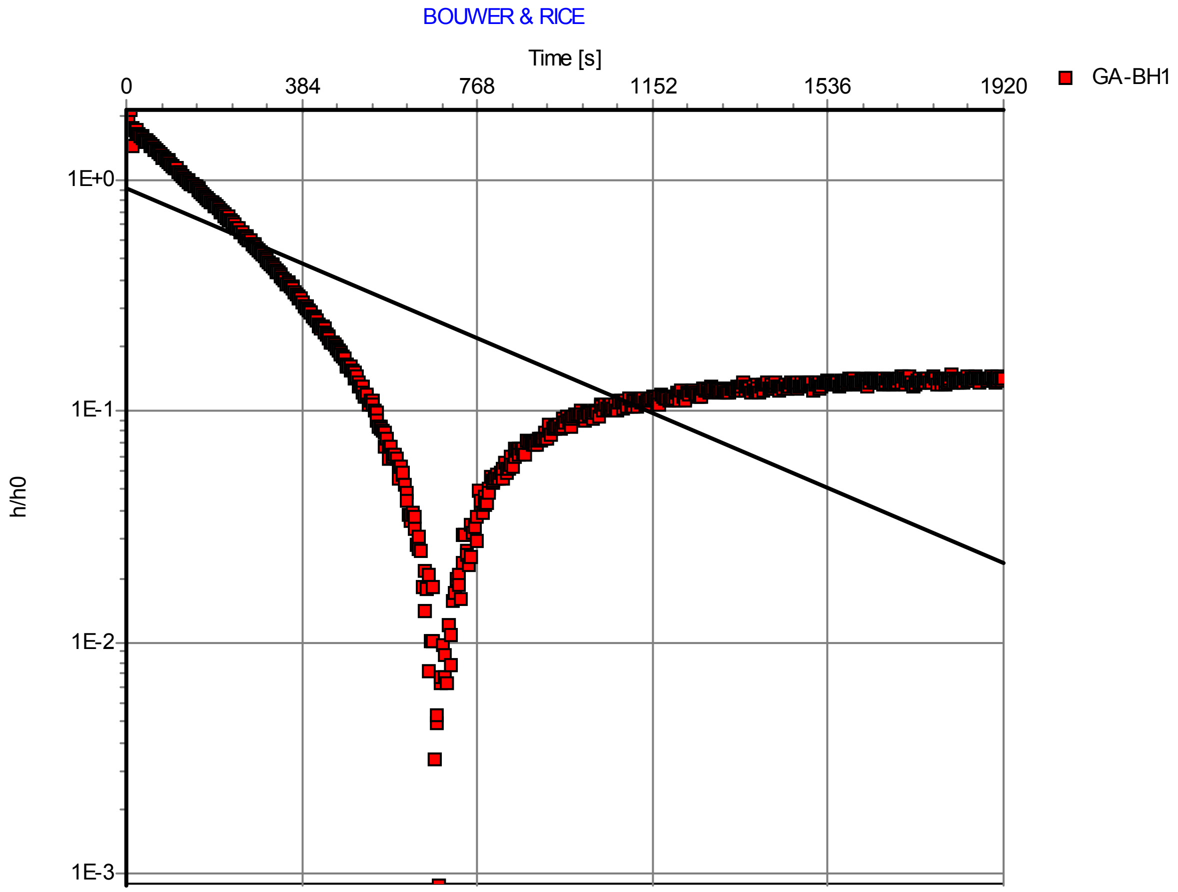
Location:		Slug test:	GA-BH1	Test well:	GA-BH1

Test performed by: M Terblanche
Test date: 2015/03/16

Evaluated by: M Terblanche
Evaluation date: 2015/03/17

Analysis method: BOUWER & RICE

Aquifer thickness: 18.65 [m]



Conductivity: 4.88×10^-2 [m/d]

APPENDIX E

LABORATORY REPORTS

Test Report

Client: Aurecon
Address: Lynwood Bridge Office Park, No. 4 Daventry str., Pretoria, 0081
Report no: 23504
Project: Aurecon

Date of certificate: 18 March 2015
Date accepted: 13 March 2015
Date completed: 18 March 2015
Revision: 0

Lab no:				206256
Date sampled:				12-Mar-15
Sample type:				Water
Locality description:				GA-BH1
	Analyses	**Unit**	**Method**	
A	pH @ 25°C	pH	ALM 20	7.63
A	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	82.7
A	Total dissolved solids (TDS)	mg/l	ALM 26	513
A	Total alkalinity	mg $CaCO_3$/l	ALM 01	404
A	Chloride (Cl)	mg/l	ALM 02	22.8
A	Sulphate (SO_4)	mg/l	ALM 03	22.8
A	Nitrate (NO_3) as N	mg/l	ALM 06	6.49
A	Ammonium (NH_4) as N	mg/l	ALM 05	0.115
A	Orthophosphate (PO_4) as P	mg/l	ALM 04	0.068
A	Fluoride (F)	mg/l	ALM 08	0.181
A	Calcium (Ca)	mg/l	ALM 30	93.7
A	Magnesium (Mg)	mg/l	ALM 30	44.9
A	Sodium (Na)	mg/l	ALM 30	51.6
A	Potassium (K)	mg/l	ALM 30	1.49
A	Aluminium (Al)	mg/l	ALM 31	<0.003
A	Iron (Fe)	mg/l	ALM 31	<0.003
A	Manganese (Mn)	mg/l	ALM 31	0.707
A	Total hardness	mg $CaCO_3$/l	ALM 26	419

A = Accredited N = Non accredited O = Outsourced S = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine
The results relates only to the test item tested.
Results reported against the limit of detection.
Results marked 'Not SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory.
Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation.

M. Swanepoel
Technical Signatory