Geohydrological and geotechnical assessment for the proposed expansion of the Goue Akker Cemetery in Beaufort West.

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GROUNDWATER AND EARTH SCIENCES
GEOSS
SOUTH AFRICA (Pty) Ltd

EXECUTIVE SUMMARY

GEOSS South Africa (Pty) Ltd was appointed by Sharples Environmental Services cc to complete a groundwater and geotechnical impact assessment for the expansion of the existing Goue Akker Cemetery in Beaufort West. The aim of the hydrogeological assessment is to determine the impacts that the proposed expansion may have on groundwater, whereas the geotechnical study is to determine and characterise the engineering properties of the site.

The site is underlain by mudstone and sandstone of the Teekloof Formation which forms part of the Beaufort Group and is locally covered by Quaternary age alluvium deposits towards the south. The area does host a number of dolerite dykes classified as intrusive igneous rocks. The underlying aquifer at the site is classified as a fractured aquifer with an average yield potential of 5.0 L/s. Whereas, mapping of the regional groundwater quality, as indicated by electrical conductivity (EC) the area is in the range of 70 – 300 mS/m. This is considered to be "good to moderate" quality for groundwater, with respect to drinking water standards.

From the hydrocensus, it is clear that the number of groundwater users surrounding the proposed site is limited, however, the water is mainly used for drinking. No groundwater was intersected in any of the ten trial pits. The study area is underlain by very dense silty sand or very dense boulders with a silty matrix. The excavation conditions are expected to be "intermediate" from surface to a depth of 2.0 m below surface and will not require shoring if conditions remain dry. In certain areas the presence of calcrete and/or boulder lenses at depths from 1.6 mbgl may slow excavation rates.

The following recommendations are made:

- The impact of the proposed cemetery expansion on groundwater is considered to be low. Site development can proceed; however, monitoring should be installed on site. Relevant mitigation measures and best practice procedures must be employed to ensure no contamination of the subsurface takes place.
- At least three groundwater monitoring boreholes should be installed in order to detect any potential contamination as quickly as possible.
- The monitoring boreholes should be drilled to a depth of 32 m. Monitoring boreholes should follow the specifications provided in **Section 9.1**.

Note that these recommendations are based on GEOSS's opinion and the final decision of the necessary groundwater monitoring requirements resides with the regulatory authorities.

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TABLE OF CONTENTS

1. INTRODUCTION 1

2. SCOPE OF WORKS 1

3. METHODOLOGY 1

4. SETTING 3

4.1 Topography 3

4.2 Climate 3

4.3 Geology 5

4.1 Hydrogeology 5

4.2 Aquifer vulnerability classification 5

5. DESKTOP ASSESSMENT AND HYDROCENSUS 10

5.1 Desktop Assessment 10

5.2 Hydrocensus (field work) 10

6. GEOTECHNICAL INVESTIGATION 15

6.1 Trial Pits 15

6.2 Laboratory Testing 16

6.3 Geotechnical Assessment 16

6.4 Groundwater flow direction 18

6.5 Water Quality Analysis 19

7. RISK ASSESSMENT 23

8. DISCUSSION 27

9. RECOMMENDATIONS 28

9.1 Proposed groundwater monitoring action plan: 28

9.1.1 Borehole drilling and construction specifications *29*

9.1.2 Groundwater levels *29*

9.1.3 Sampling process *29*

9.1.4 Sample Collection, Preservation and Submission *30*

9.1.5 Sampling frequency and parameter analysis *30*

10. CONCLUSION 30

11. ASSUMPTIONS AND LIMITATIONS 31

12. REFERENCES 32

13. APPENDIX A: TRIAL PIT PHOTOS AND LOGS 33

14. APPENDIX B: DCP TESTING LOGS 47

15. APPENDIX C: LABORATORY ANALYSIS 53

LIST OF MAPS AND FIGURES

Map 1: Locality of the Goue Akker Cemetery, Beaufort West, Western Cape. 2
Map 2: Geological setting of the area (3222, Beaufort West)............ 6
Map 3: Regional aquifer yield (DWAF, 2002) and borehole yields (L/s)............ 7
Map 4: Regional groundwater quality (mS/m) from DWAF (2002) and borehole groundwater quality (EC in mS/m)............ 8
Map 5: Vulnerability rating (DWAF, 2005) and groundwater depths (mbgl)............ 9
Map 6: Hydrocensus boreholes and trial pits. 14
Map 7: Aerial map showing trial pit locations. 17

Figure 1: Monthly average air temperature and rainfall distribution for Beaufort West (Schulze, 2009). 3
Figure 2: Monthly average rainfall and evaporation distribution for Beaufort West (Schulze, 2009). 4
Figure 3: Annual rainfall as measured at De Hoop and Beaufort West weather stations (Beaufort West Area) (De Hoop, 0092369; Beaufort West, 00920815) 4
Figure 4: Correlation between surface topography and groundwater elevation for boreholes proximal to study site. 18
Figure 5: Stiff diagram of the borehole groundwater sample............ 22
Figure 6: Source, Pathway and Receptor assessment. 27
Figure 7: Schematic representation of the proposed general borehole construction. 30

LIST OF TABLES

Table 1: Geological formations within the study area. 5
Table 2: Hydrocensus Site Descriptions............ 11
Table 3: Summary of trial pits. 15
Table 4: Generalised soil profile (note these are disturbed samples). 15
Table 5: Classification table for specific limits............ 19
Table 6: Groundwater quality analysis results............ 20
Table 7: Classification table for the groundwater results (DWAF, 1998) 21
Table 8: Classified production borehole results according to DWAF 1998. 21
Table 9: Impact table for contamination of groundwater as a result of decomposition of human remains. 24
Table 10: Impact table for contamination of groundwater as a result of metal corrosion. 25
Table 11: Impact table for contamination of groundwater as a result of compounds used during embalming............ 26
Table 12: Source-based selection of groundwater quality monitoring variables............ 31

ABBREVIATIONS

BH	Borehole
CGS	Council for Geoscience
DWA	Department of Water Affairs (used to be Department of Water Affairs and Forestry)
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water Affairs and Sanitation
EC	electrical conductivity
L/s	litres per second
m	metres
mbch	meters below collar height
mbgl	metres below ground level
mm	millimetre
mS/m	milli-Siemens per metre
NGA	National Groundwater Archive
WARMS	Water Authorisation and Registration Management System

GLOSSARY OF TERMS

Aquifer: a geological formation, which has structures or textures that hold water or permit appreciable water movement through them [from National Water Act (Act No. 36 of 1998)].

Borehole: includes a well, excavation, or any other artificially constructed or improved groundwater cavity which can be used for the purpose of intercepting, collecting or storing water from an aquifer; observing or collecting data and information on water in an aquifer; or recharging an aquifer [from National Water Act (Act No. 36 of 1998)].

Electrical Conductivity: the ability of groundwater to conduct electrical current, due to the presence of charged ionic species in solution (Freeze and Cherry, 1979).

Fractured aquifer: Fissured and fractured bedrock resulting from decompression and/or tectonic action. Groundwater occurs predominantly within fissures and fractures.

Groundwater: Water found in the subsurface in the saturated zone below the water table or piezometric surface i.e. the water table marks the upper surface of groundwater systems.

Inferred: Where a geological contact or fault is believed to exist however is not confirmed.

DCP: Dynamic Cone Penetrometer

Suggested reference for this report: GEOSS (2020). Geohydrological and geotechnical assessment for the proposed expansion of the Goue Akker Cemetery in Beaufort West. GEOSS Report Number: 2020/03-29. GEOSS South Africa (Pty) Ltd. Stellenbosch, South Africa.

Cover photo: Cover photo taken during site visit.

GEOSS project number: 2019_11-3761

Review by: Julian Conrad (30 March 2020)

GLOSSARY OF TERMS

CURRICULUM VITAE – Dale Barrow

GENERAL

Nationality:	South African
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Specialization:	Groundwater exploration, development, management and monitoring including numerical modeling. Development of the groundwater component of catchment management strategies and other Resource Directed Measures (RDM) activities.
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- Groundwater component of Catchment Management Strategies and other Groundwater Resource Directed Measures.
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- Groundwater development - borehole drilling and test pumping supervision and analysis.
- Groundwater monitoring –development and analysis of groundwater level and quality data.
- Groundwater management – sustainable aquifer development and management.
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EDUCATIONAL AND PROFESSIONAL STATUS

Qualifications

2017	MBA (Cum Laude)	University of Stellenbosch, South Africa
2010	M.Sc. (Geohydrology)	University of the Free State, South Africa
2007	B.Sc (Hons) Structural Geology	University of Stellenbosch, South Africa
2006	B.Sc Geology – Applied Earth Science	University of Stellenbosch, South Africa

Courses

2016	SPRING Software Modelling Course
2013	Aquifer Firm Yield; Wellfield Design; Wellfield costing
2010	Introduction to QGIS (GISSA)
2010	Presentation Skills (Elsabé Daneel productions cc)
2009	Introduction to Isotope Hydrology in Southern Africa (GSSA)
2009	Aquifer Mechanics (IGS-UOFS)
2009	Groundwater Chemistry (IGS-UOFS)
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2009	Groundwater Modelling (IGS-UOFS)
2009	Groundwater Management (IGS-UOFS)

Memberships

- Groundwater Division of the Geological Society of South Africa
- South African Council for National Scientific Professions (SACNASP) Mem. No. 400289/13

EMPLOYMENT RECORD

1 February 2008 to present: GEOSS – Geohydrological and Spatial Solutions International (Pty) Ltd, Stellenbosch

23 July - November 2019 Design and part time lecturing of the Hydrogeology course for 3rd year students at Stellenbosch University.

CURRICULUM VITAE – Charl Muller

GENERAL

Nationality:	South African
Profession:	Geohydrologist
Specialization:	Groundwater exploration, regional development, monitoring and management, geohydrological impact assessment including GIS and Remote Sensing expertise.
Position in firm:	Geohydrologist at GEOSS South Africa (Pty) Ltd
Date commenced:	16th October 2017
Language skills:	English (good – speaking, reading and writing) Afrikaans (good - speaking, reading and writing).

KEY SKILLS

- Groundwater sampling, soil sampling, field measurements, borehole logging, data logging for groundwater monitoring, borehole depth and water level measurements, augering for piezometer installation, groundwater geophysics and conducting hydrocensus studies.

RELEVANT EXPERIENCE

- Numerous groundwater exploration - this includes aerial photo interpretation, resistivity, magnetic and electromagnetic geophysical surveys for borehole siting purposes, data analysis and interpretation and hydrogeological conceptualization, development, monitoring and management projects.
- Extensive satellite image data processing (including geo-referencing) for the Validation and Verification projects within the Breede-Overberg Catchment Management Agency.
- Smaller projects involving borehole siting's (aerial photo interpretation, geological mapping, geophysical profiling).
- Projects involving drilling supervision and pumping test supervision with associated data interpretation (FC Method) and writing of geohydrological reports.
- Groundwater and groundwater quality monitoring projects involving appropriate sampling, measurements, data analysis and reporting.

EDUCATIONAL AND PROFESSIONAL STATUS

Qualifications

2017	MEng (Geotechnical Engineering):	University of Stellenbosch, South Africa
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2014	BSc - Earth Science Degree:	University of Stellenbosch, South Africa

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March 2019 to present	GEOSS SOUTH AFRICA (Pty) Ltd.

SPECIALIST DECLARATION

We, Charl Muller and Dale Barrow, as the appointed independent specialists hereby declare that we:

- act/ed as the independent specialist in this application;
- regard the information contained in this report as it relates to my specialist input/study to be true and correct, and
- do not have and will not have any financial interest in the undertaking of the activity, other than remuneration for work performed in terms of the NEMA, the Environmental Impact Assessment Regulations, 2010 and any specific environmental management Act;
- have and will not have no vested interest in the proposed activity proceeding;
- have disclosed, to the applicant, EAP and competent authority, any material information that have or may have the potential to influence the decision of the competent authority or the objectivity of any report, plan or document required in terms of the NEMA, the Environmental Impact Assessment Regulations, 2010 and any specific environmental management Act;
- are fully aware of and meet the responsibilities in terms of NEMA, the Environmental Impact Assessment Regulations, 2010 (specifically in terms of regulation 17 of GN No. R. 543) and any specific environmental management Act, and that failure to comply with these requirements may constitute and result in disqualification;
- have provided the competent authority with access to all information at my disposal regarding the application, whether such information is favourable to the applicant or not; and
- am aware that a false declaration is an offence in terms of regulation 71 of GN No. R. 543.

Dale Barrow
GEOSS South Africa (Pty) Ltd.
SACNASP - 400289/13
27 March 2020

Charl Muller
GEOSS South Africa (Pty) Ltd.
SACNASP - 123456
27 March 2020

1. INTRODUCTION

GEOSS South Africa (Pty) Ltd was appointed by Sharples Environmental Services cc to complete a geotechnical and groundwater impact assessment for the expanding of the existing Goue Akker Cemetery in Beaufort West (**Map 1**). The aim of the hydrogeological assessment is to determine the impacts the proposed expansion may have on groundwater, whereas the geotechnical study is to determine and characterise the engineering properties of the site.

The study included a site visit, to assess National Groundwater Archive (NGA) borehole data, assess if there are proximal groundwater users such as neighbouring farms and small holdings and to conduct the geotechnical investigation. Ten trial pits were excavated into the subsurface to determine soil characteristics, presence of groundwater, at what depth it occurs as well as the groundwater quality.

2. SCOPE OF WORKS

The scope of work is to provide groundwater and geotechnical specialist services, including the tasks outlined below:

- Assessment of impact on geohydrological resources as a result of the expansion of the existing cemetery.
- Provide recommendations to minimize or mitigate impacts.
- Determine the engineering properties of the in-situ material.

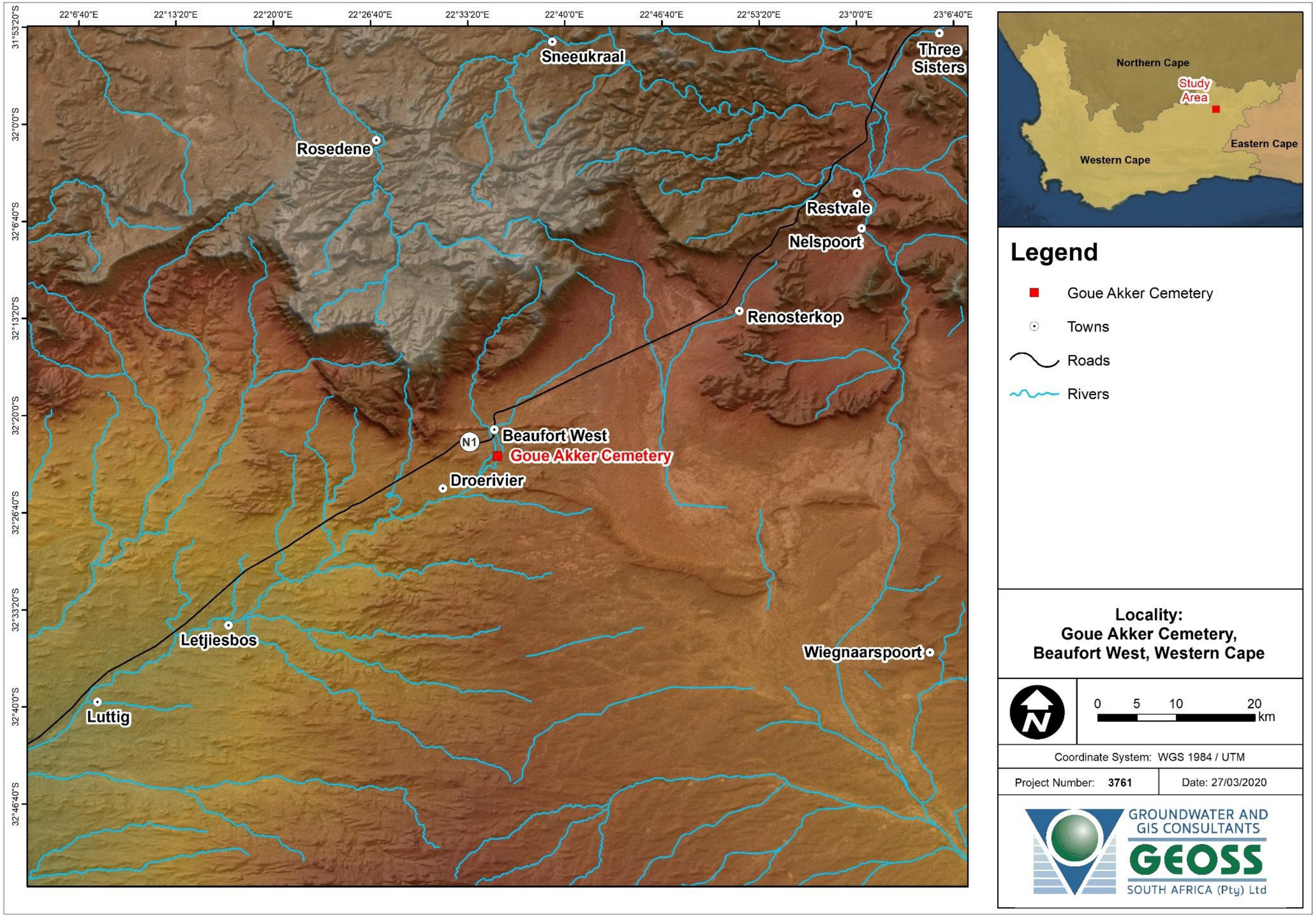
The results of the field investigation are presented in this report along with the data analysis and interpretation.

3. METHODOLOGY

The procedure adopted for this study involved a desktop study followed by the field work. The initial desktop study involved obtaining and reviewing all relevant data to the project. This included analysing data from the NGA, as well as groundwater yield, groundwater chemistry and geological maps of the area.

A site visit was then conducted to verify as much of this data as possible, as well as collect any additional data. This included a hydrocensus of groundwater users in the area, as well as noting any subsurface conditions where possible. Ten trial pits were excavated in open land in an attempt to measure water level depth, water quality and to characterise soil conditions.

All collected data was analysed and interpreted to assess the potential risks associated with the intended site development as they pertain to groundwater; together with classifying soil engineering properties for further expansion.



Map 1: Locality of the Goue Akker Cemetery, Beaufort West, Western Cape.

4. SETTING

4.1 Topography

The study area is situated in the Western Cape on the outskirts of Beaufort West with surrounding topography comprising of low relief, with an average elevation of 830 m above mean sea level (mamsl). The site is situated in the quaternary catchments, J21A, which has a General Authorisation abstraction volume of 0 m^3/ha/yr.

4.2 Climate

The Beaufort West area experiences an Arid Climate with rainfall occurring predominantly during summer months. **Figure 1** shows the monthly average air temperature and rainfall distribution and **Figure** 2 shows the monthly median rainfall and evaporation distribution for the Beaufort West area (Schulze, 2009). Temperatures during the summer months has been known to regularly rise well above 40°C.

The long term mean annual precipitation (1950 - 2000) for the area is 235 mm/a (Schulze et al., 2008). With regard to the rainfall in the Beaufort West region based, **Figure 3** shows the annual rainfall as measured at the De Hoop weather station 0092369 (up until May 2017) and the Beaufort West weather station 00920815 (up until January 2020). The impact of the drought is evident as the annual rainfall has notably decreased over the recent years. The annual rainfall for 2019 was 124.2 mm, 419.8 mm less than the last good rain year in 2012. Rainfall has been below the mean annual precipitation for the last seven years.

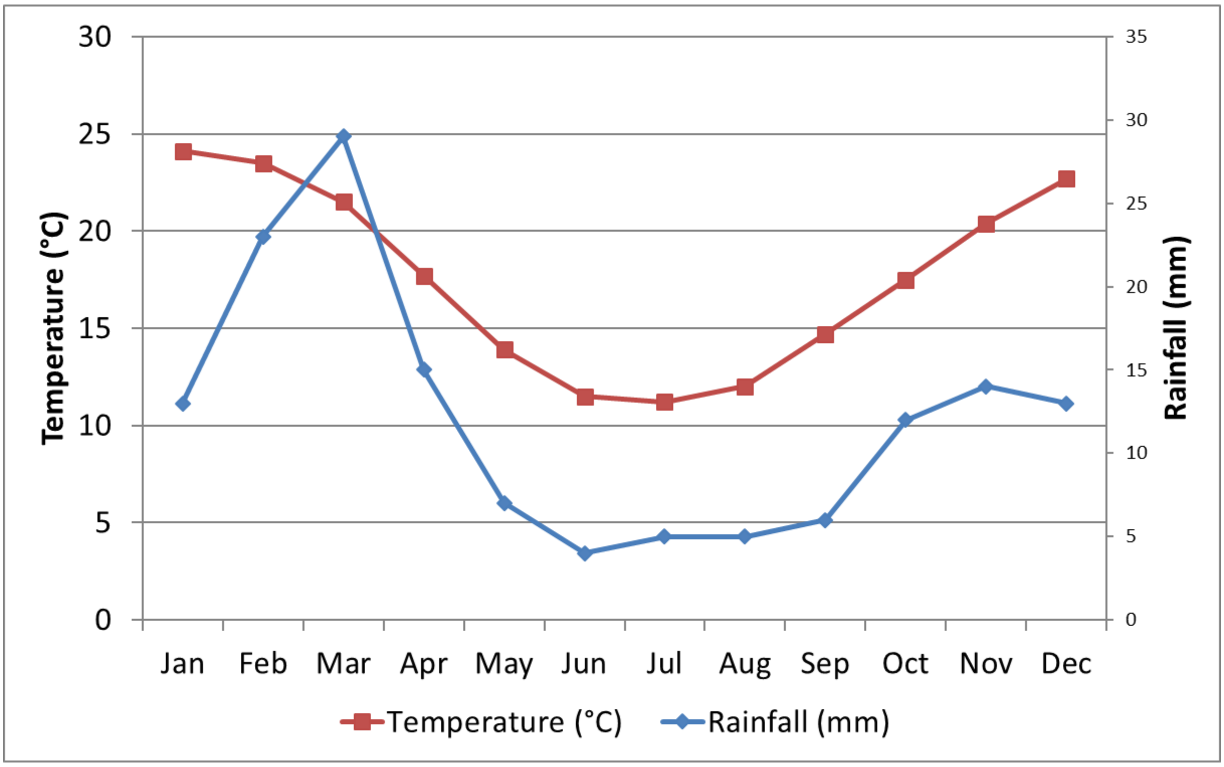


Figure 1: Monthly average air temperature and rainfall distribution for Beaufort West (Schulze, 2009).

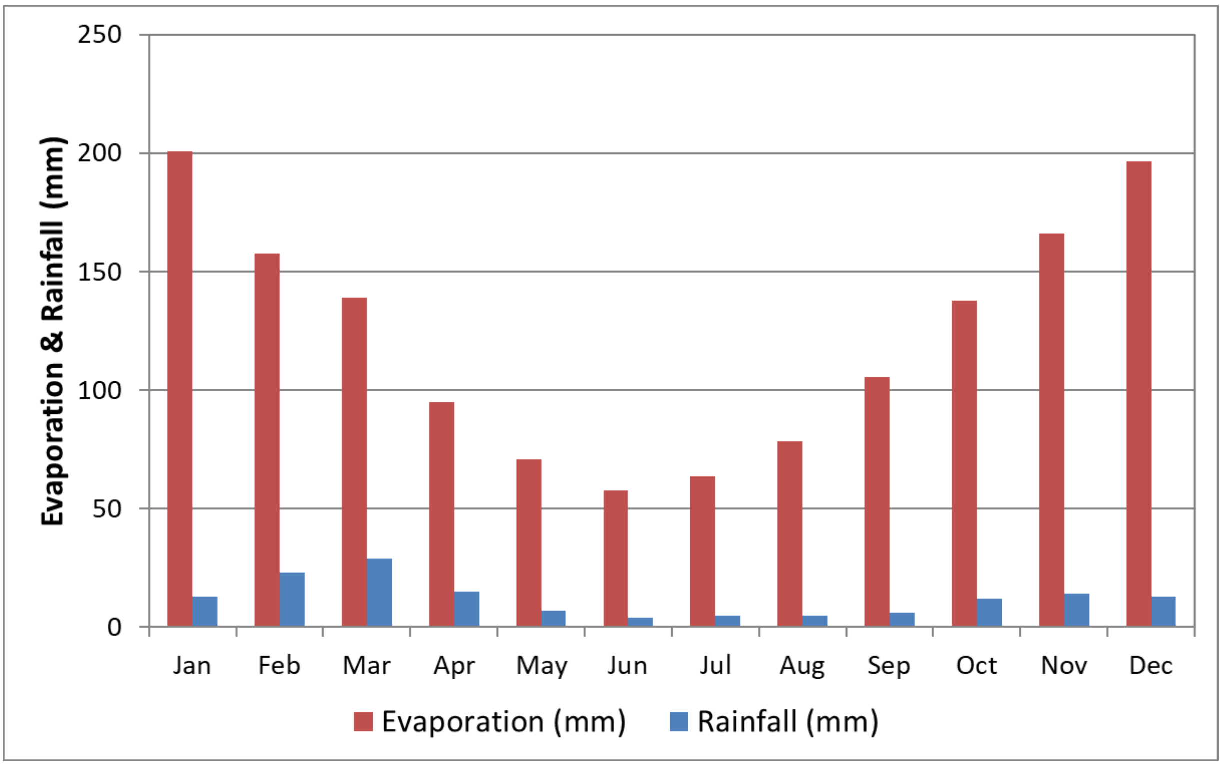


Figure 2: Monthly average rainfall and evaporation distribution for Beaufort West (Schulze, 2009).

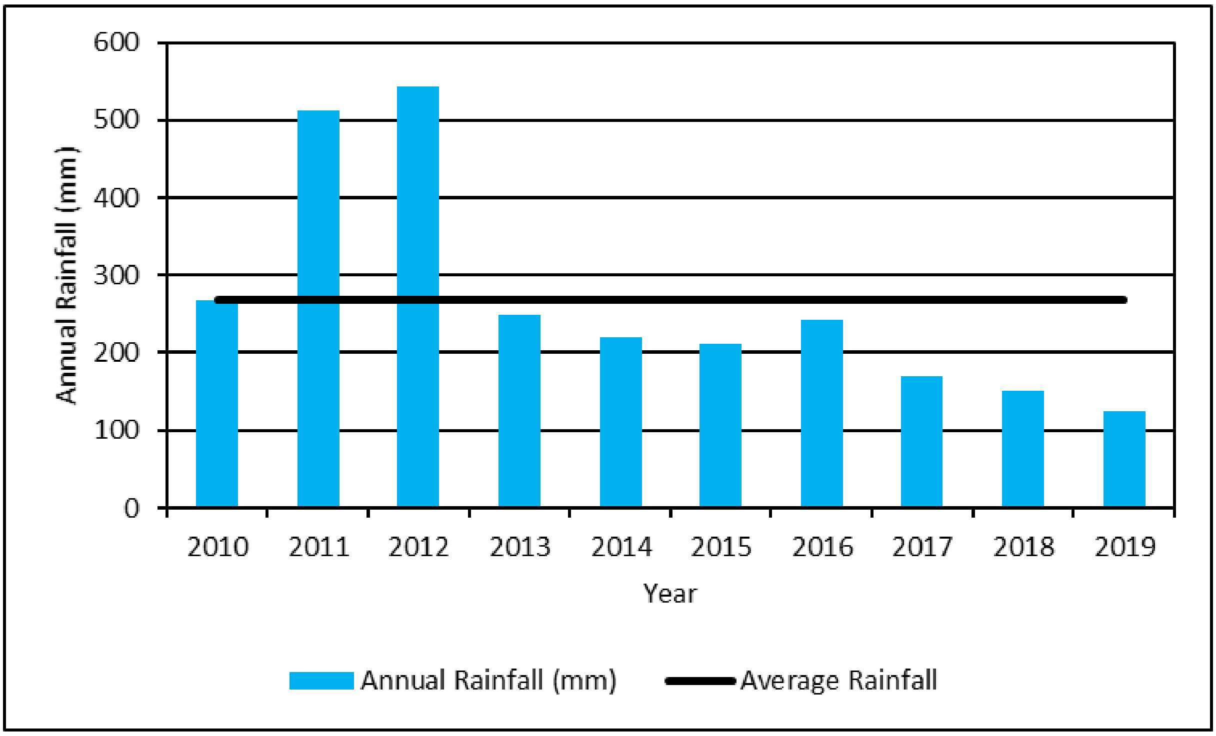


Figure 3: Annual rainfall as measured at De Hoop and Beaufort West weather stations (Beaufort West Area) (De Hoop, 0092369; Beaufort West, 00920815)

4.3 Geology

The Geological Survey of South Africa (now the Council for Geoscience (CGS)) has mapped the area at 1:250 000 scale (3222 Beaufort West). The geological setting is shown in **Map 2** and the main geology of the area is listed in **Table** 1.

Table 1: Geological formations within the study area.

Code	Formation	Group	Lithology
	n/a – Quaternary Age		Alluvium.
Jd	n/a – Intrusion		Dolerite.
Pt	Teekloof Formation	Beaufort West Group	Mudstone, sandstone, thin greenish cherty beds near base and thin pink tuff beds in the northeast.

The site is underlain by mudstone and sandstone of the Teekloof Formation which forms part of the Beaufort Group and is locally covered by Quaternary age alluvium deposits towards the south. The area does host a number of dolerite dykes (intrusive igneous rocks).

4.1 Hydrogeology

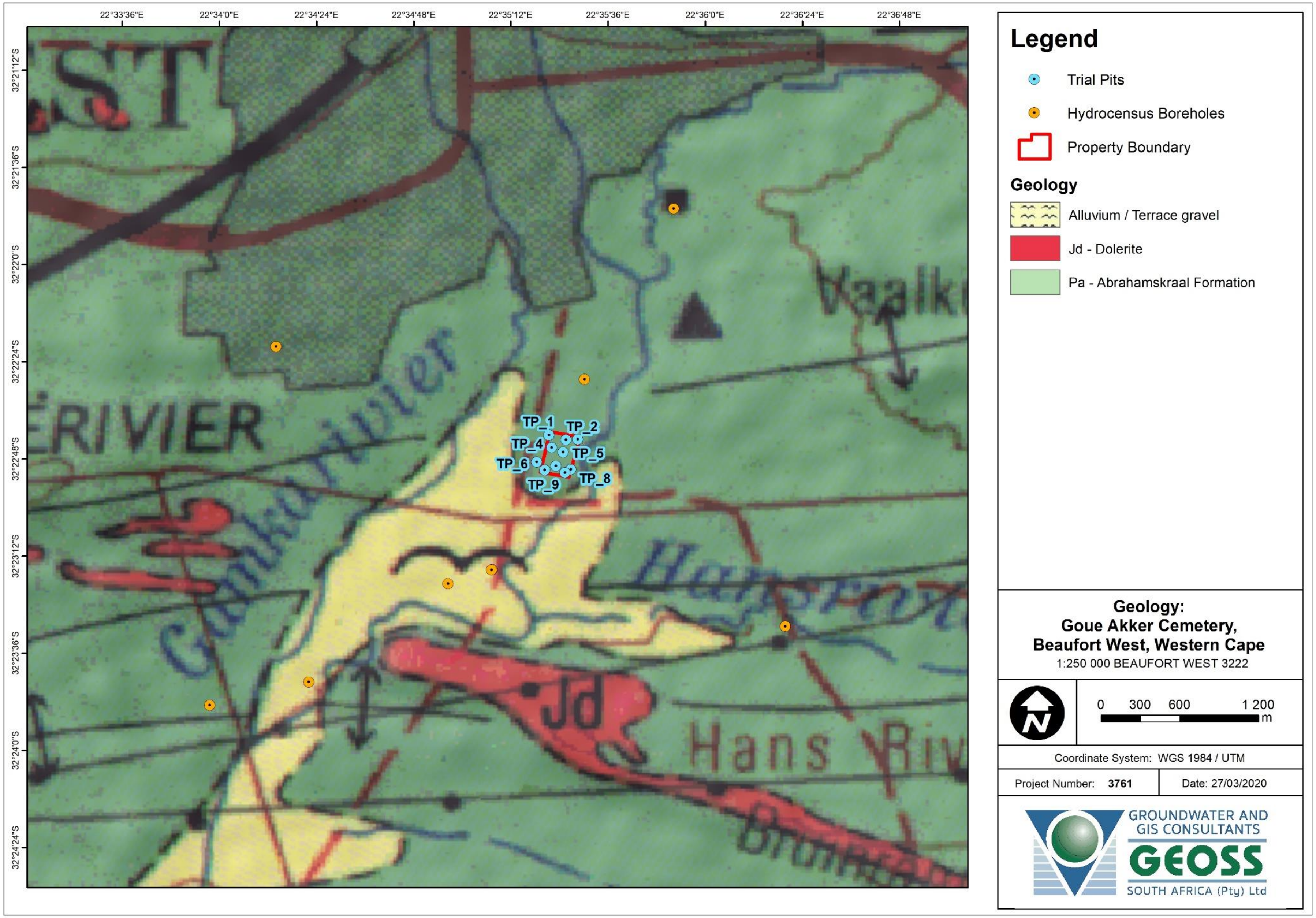
The underlying aquifer at the site is classified by the Department of Water Affairs and Forestry (DWAF, 2002) as a **fractured aquifer** with an average **yield potential of 5.0 L/s** (**Map 3**). A fractured aquifer describes an aquifer where groundwater only occurs in narrow fractures within the bedrock. Based on the DWAF (2002) mapping of the regional **groundwater quality**, as indicated by electrical conductivity (EC) the area is in the range of 70 – 300 mS/m. This is considered to be "**good to moderate**" quality for water (**Map 4**), with respect to drinking water standards. It is important to note that a small stream/drainage channel flows along the eastern boundary of the property and should be considered as a potential receptor for contamination.

4.2 Aquifer vulnerability classification

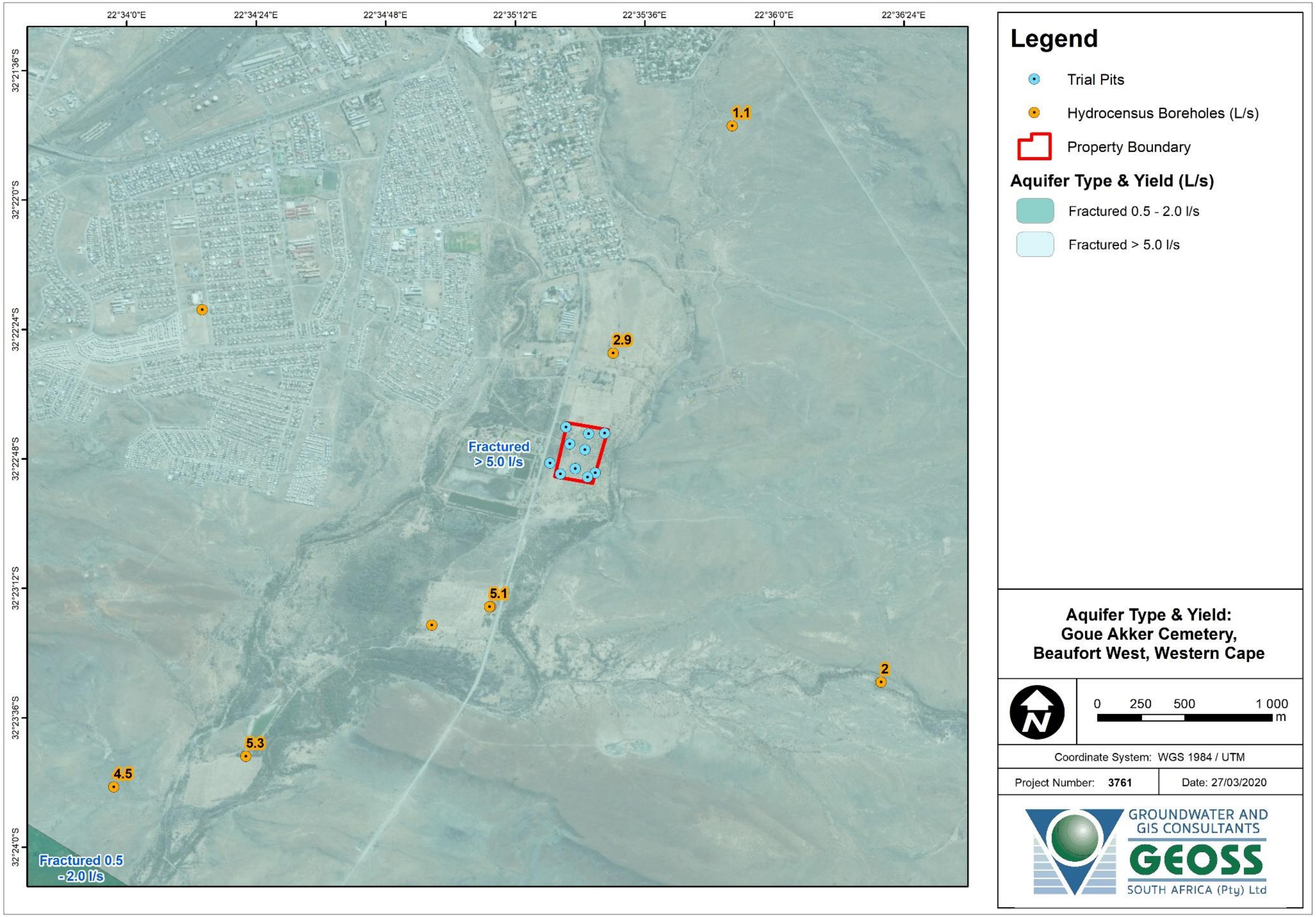
The national scale groundwater vulnerability map, which was developed according to the DRASTIC methodology (DWAF,2005), indicates that the site has a "**low to medium**" **vulnerability** to surface-based contaminants (**Map 5**).

The DRASTIC method considers the following factors:
D = depth to groundwater (5); R = recharge (4); A = aquifer media (3); S = soil type (2); T = topography (1); I = impact of the vadose zone (5); C = conductivity (hydraulic) (3)

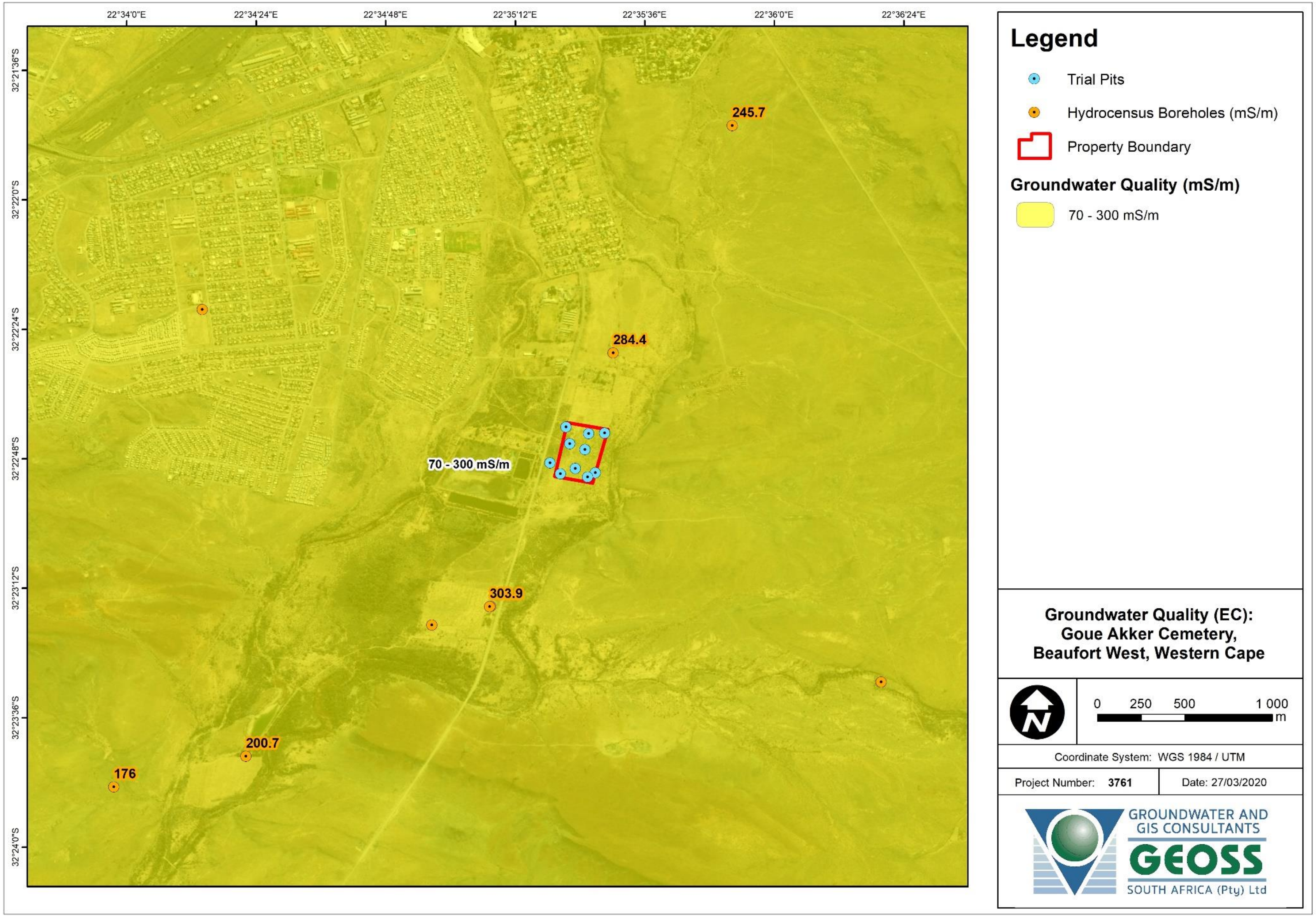
The number indicated in parenthesis at the end of each factor description is the weighting or relative importance of that factor. This "low-medium" rating is associated with the confined nature of the fractured aquifer. The site is underlain by mudstone that weathers to clay forming an impermeable layer above the fractured mudstone and sandstone that likely provide sufficient protection against point and non-point sources of contamination. The depth to groundwater provides further opportunity for natural attenuation in the vadose zone prior to reaching the groundwater.



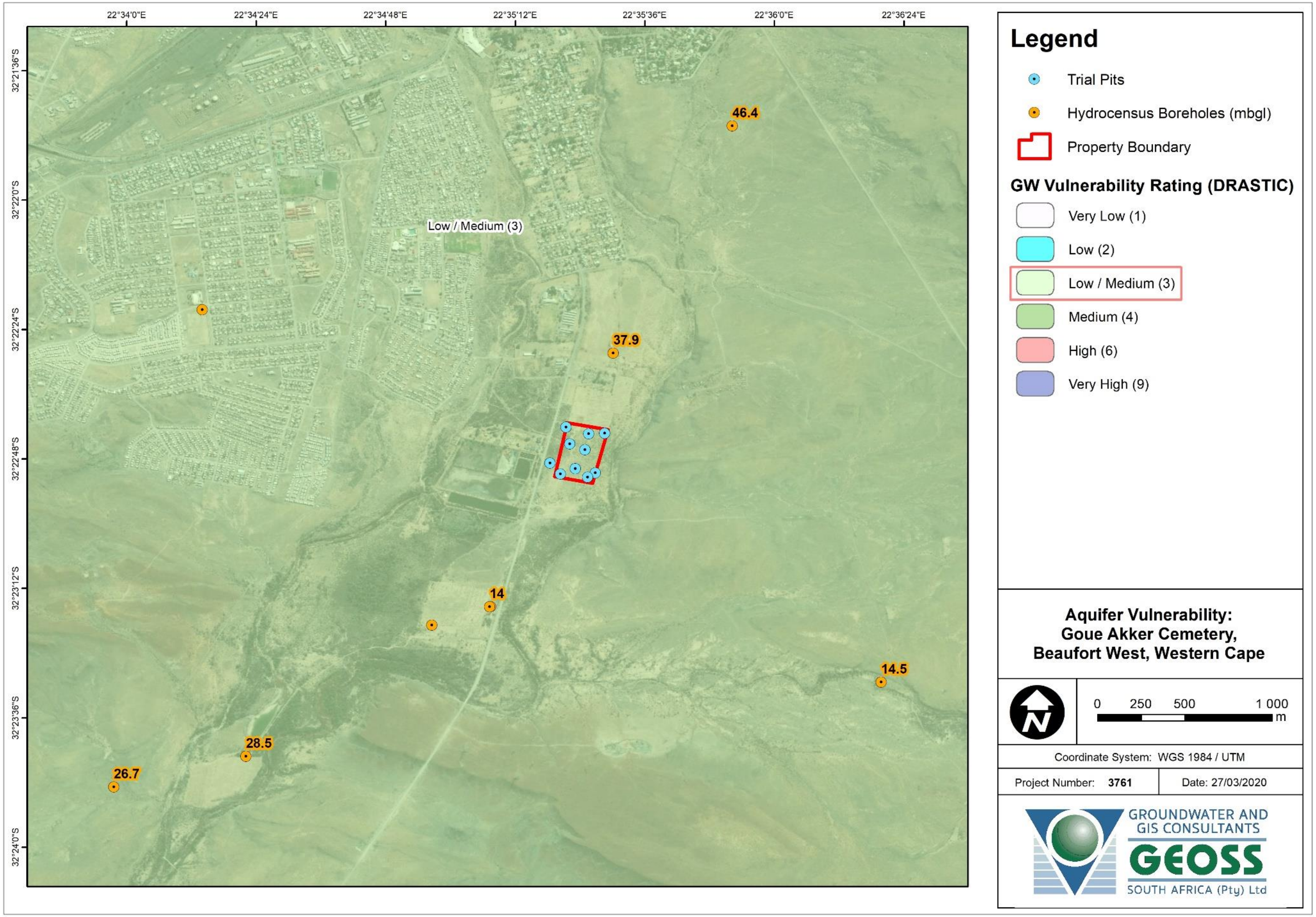
Map 2: Geological setting of the area (3222, Beaufort West).



Map 3: Regional aquifer yield (DWAF, 2002) and borehole yields (L/s).



Map 4: Regional groundwater quality (mS/m) from DWAF (2002) and borehole groundwater quality (EC in mS/m).



Map 5: Vulnerability rating (DWAF, 2005) and groundwater depths (mbgl).

5. DESKTOP ASSESSMENT AND HYDROCENSUS

5.1 Desktop Assessment

A desktop assessment was initially carried out around the property to determine if there were any groundwater users in the area. The National Groundwater Achieve (NGA) database which provides data on borehole positions, groundwater chemistry and yield is currently undergoing maintenance and no information could be retrieved from the database (last date visited 24 March 2020).

5.2 Hydrocensus (field work)

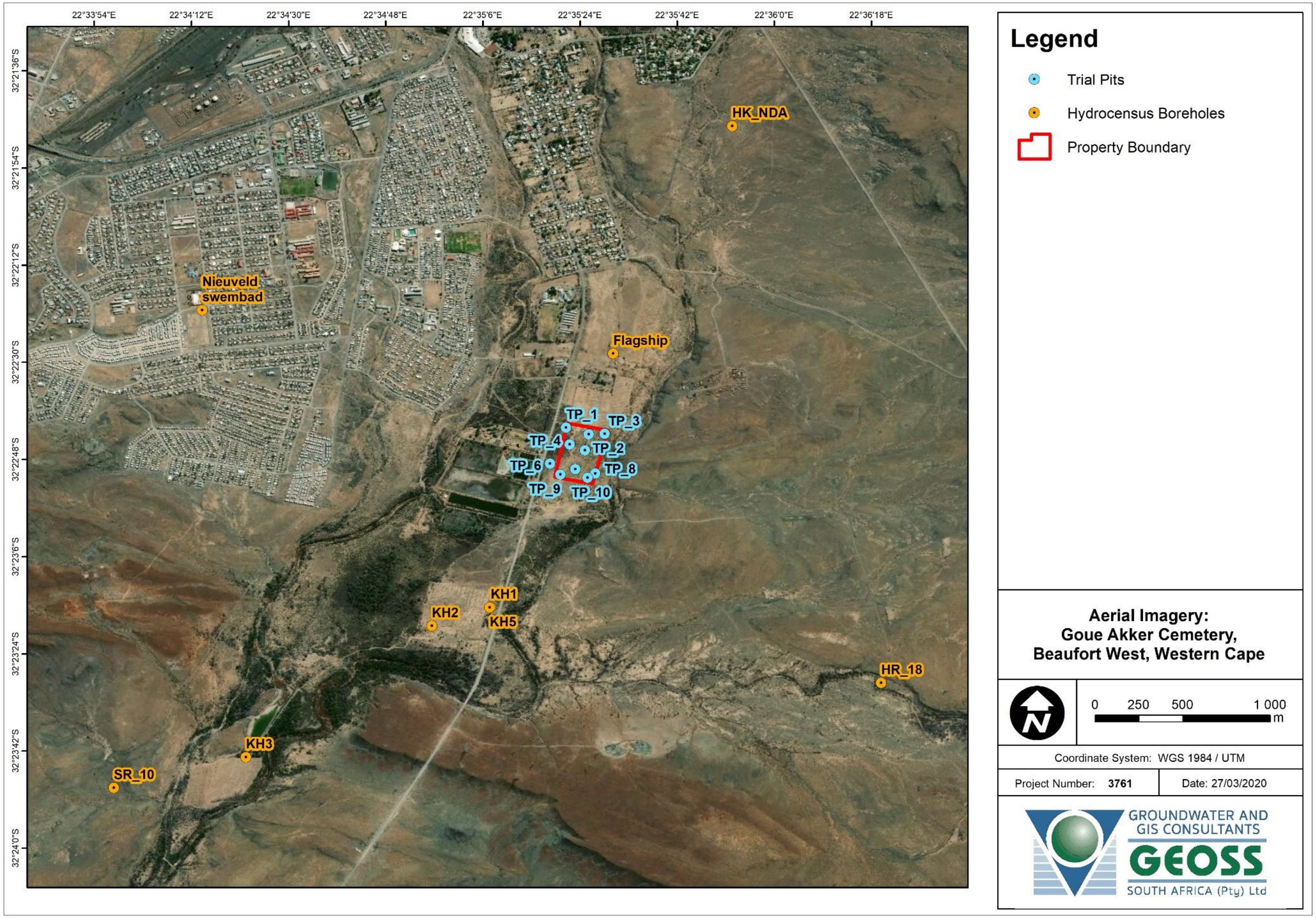
A site visit was conducted on 25 February 2020 to assess groundwater use within the study area (**Map 6**). The results of a field visit investigation are presented in **Table 2**. Based on the hydrocensus data it is evident that there are several groundwater users in the area surrounding the proposed site. The boreholes in the area surrounding the cemetery belong to the Beaufort West Municipality and are used as a source of drinking water for the town's residents. Information within the report for sites is collected from previous GEOSS reports in the area.

Table 2: Hydrocensus Site Descriptions

Site Label	Latitude (DD, WGS84)	Longitude (DD, WGS84)	Dec 2019 WL (mbgl)	Yield (L/s)	EC (mS/m)	TDS (mg/L)	pH	Comments	Photo
SR_10	-32.396904	22.566017	26.735	4.5	176	1124.5	7.31	Borehole working and in use.	
HK_NDA (Hoenderplaas)	-32.362841	22.597848	46.35	1.1	245.7	703	7.75	Borehole working and in use.	
HR_18	-32.391491	22.605513	14.46	2	-	-	-	Borehole working and in use. Solar pump.	

Site Label	Latitude (DD, WGS84)	Longitude (DD, WGS84)	Dec 2019 WL (mbgl)	Yield (L/s)	EC (mS/m)	TDS (mg/L)	pH	Comments	Photo
Nieuveld swembad	-32.372314	22.570565	-	-	-	-	-	Borehole buried. Not in use currently.	
KH1	-32.3876	22.585417	-	-	-	-	-	Borehole not in use.	No photo possible
KH2	-32.388567	22.582383	-	-	-	-	-	Borehole not in use.	No photo possible
KH3	-32.395322	22.572818	28.515	5.3	200.7	1326	7.4	Borehole working and in use.	

Site Label	Latitude (DD, WGS84)	Longitude (DD, WGS84)	Dec 2019 WL (mbgl)	Yield (L/s)	EC (mS/m)	TDS (mg/L)	pH	Comments	Photo
KH5	-32.387615	22.585355	14.035	5.1	303.9	1969.6	7.18	Borehole working and in use.	
Flagship	-32.37455	22.591727	37.905	2.9	284.4	1846	7.31	Borehole working and in use.	



Map 6: Hydrocensus boreholes and trial pits.

6. GEOTECHNICAL INVESTIGATION

6.1 Trial Pits

The site visit involved the excavation of 10 trial pits coupled with DCP testing in an attempt to determine groundwater depth, quality and soil properties. The positions of the trial pits and DCP's were chosen to provide a good spatial coverage of the study area (vegetation permitting). The trial pits were excavated using a tractor loader backhoe (TLB) to a maximum depth of 3 m. Following the excavation, each trial pit was logged and photographed (**Appendix A**). A site walk-over sought to identify and confirm hydrological, hydrogeological and geotechnical features of interest. A total of 10 trial pits were excavated and details are summarised in **Table 3**. None of the trial pits excavated intersected water. The location of the trial pits is shown in **Map 7**.

Table 3: Summary of trial pits.

Label	Latitude (DD, WGS84)	Longitude (DD, WGS84)	Elevation (mamsl)	TP EOH (mbgl)	Sample (S# mbgl)	DCP No.:	DCP EOH (mbgl)
TP01	-32.378370	22.589293	830	2.85	-	DCP01	1.92
TP02	-32.378703	22.590463	830	3.81	-	DCP02	1.92
TP03	-32.378675	22.591284	830	2.82	-	DCP03	0.91
TP04	-32.379231	22.589490	830	2.44	S1 (0.8)	DCP04	Refusal
TP05	-32.379535	22.590268	830	2.85	-	DCP05	Refusal
TP06	-32.380211	22.588466	830	1.85	-	DCP06	Refusal
TP07	-32.380498	22.589771	830	2.90	-	DCP07	Refusal
TP08	-32.380724	22.590804	830	3.10	-	DCP08	1.04
TP09	-32.380772	22.589004	830	2.25	-	DCP09	Refusal
TP10	-32.380945	22.590407	830	2.10	-	DCP10	0.98

Following the execution of trial pits, DCP testing and a site walkover the following generalised soil profile typifies this site and is summarised in **Table 4**:

Table 4: Generalised soil profile (note these are disturbed samples).

Depth (mbgl)	Description
0.00 to 0.30	Dry, pale brown, very dense, weakly cemented, clayey sandy SILT with gravel and cobbles. Transported, alluvial-lacustrine.
0.30 to +3.00	Very slightly moist, orangish pale brown, medium dense becoming very dense with depth, weakly cemented, pin-holed, clayey sandy SILT with some pebbles. Transported, alluvial-lacustrine.
1.60 to +3.00	Very slightly moist, pale brown, very dense, matrix supported, cobbles and BOULDERS with sandy silty matrix. Transported, alluvium. Or Very slightly moist, light brownish white, very dense, cemented, honey combed, CALCRETE. Evaporite.

This site is dominated by clayey sandy SILT to depth. The upper 20 cm is very dense. Just below this, the consistency is loose to medium dense to a depth of about 1.0 mbgl, after which the soil profile becomes very dense to depth. The northern third of the site comprises of SILT to depth while CALCRETE and/or BOULDER lenses that are present within the southern two thirds of the site. These lenses are observed between 1.6 to +3.0 mbgl. No groundwater was intersected in any of the trial pits.

Trial Pit logs and photographs are presented in **Appendix A**., and DCP testing logs are presented in **Appendix B**

Please note, that during the site visit it was found that much of the study area is covered with a piping network that is believed to be an abandoned irrigation system.

6.2 Laboratory Testing

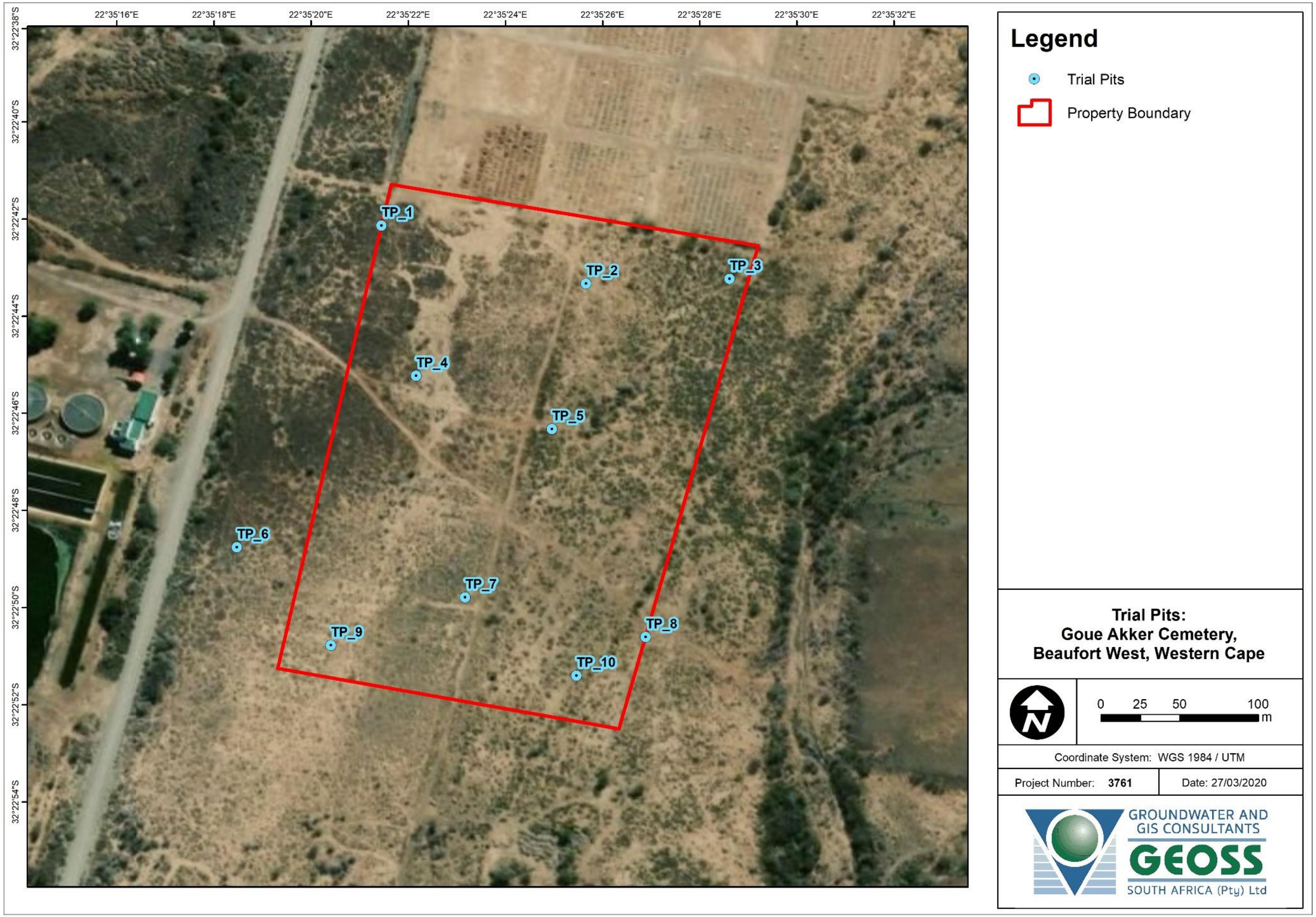
One bulk disturbed soil sample was procured and has been stored should laboratory testing be required at a later stage.

6.3 Geotechnical Assessment

Despite all soil profiles showing dense to very dense soil consistency, the presence of weakly cemented and pinhole soil indicates a potential for collapsible soil and this site is given a preliminary NHBRC classification of C1. This requires single storey masonry constructions to utilise; modified normal footings, compaction of in-situ soils below footings or deep strip foundations. The following procedure is recommended for foundation trenches:

- Foundation trenches to be excavated to 800 mm below surface
- Compaction of excavated surface
- Backfill trench to desired level and compact in 150 mm layers
- For single story buildings utilise conventional reinforced strip footings and design on allowable bearing capacity of 100 kPa

The excavation conditions are expected to be "intermediate to difficult" from surface to a depth of 2.5 m below surface and will not require shoring if conditions remain dry. In certain areas the presence of calcrete and/or boulder lenses at depths from 1.6 mbgl may slow excavation rates and is suggested that a TLB fitted with a hydraulic hammer be made available to the site. The Beaufort West Municipality by-laws pertaining to cemeteries, exhumations and cremations (Notice No. 147/2005), states that standard depths of graves are 1.5 metre for children, 1.8 metre for one adult body and 2.4 metres for two adult bodies. This will be attainable with a TLB excavator fitted with a hydraulic hammer.



Map 7: Aerial map showing trial pit locations.

6.4 Groundwater flow direction

Groundwater level data was obtained from the field hydrocensus in an effort to determine flow direction. The applicability of the Bayesian interpolation technique which correlates the relationship between surface topography and groundwater levels was investigated.

In order to evaluate the relationship between groundwater levels and topography, and the applicability of the interpolation technique, the surface elevations and water table elevations are plotted relative to each other. The data is presented in **Figure 4**, and indicates a 28% correlation between surface topography and water level elevation. This poor relationship can be attributed to the severe drought conditions, and proximal groundwater abstraction. The area also hosts a number of dolerite dykes that affect water level and groundwater flow. Bayesian interpolation is therefore not considered appropriate in the study area based on the available data.

Based on the hydrogeological conceptualisation of the study area, groundwater will flow towards the stream east of the property and south towards the large dyke known as Hansrivier Dyke. The overall groundwater flow direction is thus interpreted as flowing south-east to south.

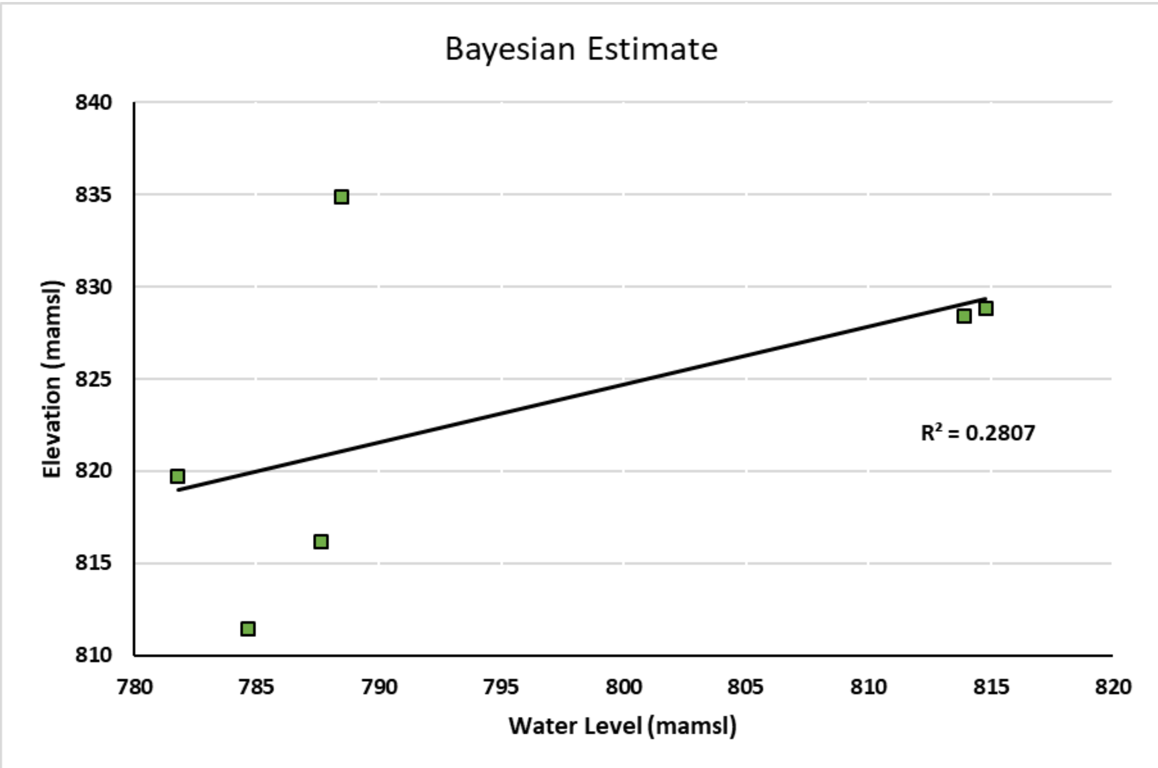


Figure 4: Correlation between surface topography and groundwater elevation for boreholes proximal to study site.

6.5 Water Quality Analysis

A groundwater sample was collected from Flagship Borehole and submitted for inorganic chemistry analysis to a SANAS accredited laboratory (Bemlab) in the Western Cape on 10 March 2017 (GEOSS, 2017). It was selected as a representative sample as it is located upstream to the cemetery. The certificate of analysis for the samples is presented in **Appendix B**. The chemistry results obtained have been classified according to the SANS241-1: 2015 standards for domestic water (**Table 5**). **Table 6** presents the water chemistry analysis results, colour coded according to the SANS241-1: 2015 drinking water assessment standards.

Table 5: Classification table for specific limits

Acute Health
Aesthetic
Chronic health
Operational
Acceptable

Table 6: Groundwater quality analysis results

Analyses	Flagship	SANS 241-1:2015
pH (at 25 °C)	7.2	≥5 - ≤9.7 Operational
Conductivity (mS/m) (at 25 °C)	241.8	≤170 Aesthetic
Total Dissolved Solids (mg/L)	1547	≤1200 Aesthetic
Sodium (mg/L as Na)	267.5	≤200 Aesthetic
Potassium (mg/L as K)	3.7	N/A
Magnesium (mg/L as Mg)	44.6	N/A
Calcium (mg/L as Ca)	195.8	N/A
Chloride (mg/L as Cl)	259.3	≤300 Aesthetic
Sulphate (mg/L as SO_4)	**526**	≤250 Aesthetic ≤500 Acute Health
Nitrate Nitrogen (mg/L as N)	7.38	≤11 Acute Health
Total Alkalinity (mg/L as $CaCO_3$)	391	N/A
Fluoride (mg/L as F)	0.4	≤1.5 Chronic Health
Manganese (mg/L as Mn)	0.05	≤0.1 Aesthetic ≤0.4 Chronic Health
Iron (mg/L as Fe)	0	≤0.3 Aesthetic ≤2 Chronic Health
Copper (mg/L as Cu)	<0.02	≤2 Chronic Health
Zinc (mg/L as Zn)	0.03	≤5 Aesthetic

The chemistry results obtained have been classified according to the DWAF (1998) standards for domestic water. **Table 7** enables an evaluation of the water quality with regards to the various parameters measured (DWAF, 1998). **Table 8** presents the water chemistry analysis results colour coded according to the DWAF drinking water assessment standards.

Table 7: Classification table for the groundwater results (DWAF, 1998)

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

Table 8: Classified production borehole results according to DWAF 1998.

Sample Marked:	**Flagship**	**DWA (1998) Drinking Water Assessment Guide**				
		Class 0	**Class I**	**Class II**	**Class III**	**Class IV**
pH	7.2	5-9.5	4.5-5 & 9.5-10	4-4.5 & 10-10.5	3-4 & 10.5-11	< 3 & >11
Conductivity (mS/m)	241.8	<70	70-150	150-370	370-520	>520
	mg/L					
Total Dissolved Solids	1547	<450	450-1000	1000-2400	2400-3400	>3400
Sodium (as Na)	267.5	<100	100-200	200-400	400-1000	>1000
Potassium (as K)	3.7	<25	25-50	50-100	100-500	>500
Magnesium (as Mg)	44.6	<70	70-100	100-200	200-400	>400
Calcium (as Ca)	195.8	<80	80-150	150-300	>300	
Chloride (as Cl)	259.3	<100	100-200	200-600	600-1200	>1200
Sulphate (as SO4)	526	<200	200-400	400-600	600-1000	>1000
Nitrate& Nitrite (as N)	7.38	<6	6.0-10	10.0-20	20-40	>40
Fluoride (as F)	0.4	<0.7	0.7-1.0	1.0-1.5	1.5-3.5	>3.5
Manganese (as Mn)	0.05	<0.1	0.1-0.4	0.4-4	4.0-10.0	>10
Iron (as Fe)	0.0	<0.5	0.5-1.0	1.0-5.0	5.0-10.0	>10
Copper (as Cu)	<0.02	<1	1-1.3	1.3-2	2.0-15	>15
Zinc (as Zn)	0.03	<20	>20			

From the chemical results presented in **Table 6** and **Table 8**, the groundwater from this borehole is of marginal quality in terms of dissolved minerals and salts.

The Stiff Diagram is a graphical representation of the relative concentrations of the cations (positive ions) and anions (negative ions). This diagram shows concentrations of cations and anions relative to each other and direct reference can be made to specific salts in the water. The Stiff Diagram for the sample from the borehole is shown in **Figure 5**. It is clear that the groundwater sample collected from the Flagship Borehole is dominated by Na+K / Ca and SO43- and that the groundwater has a high dissolved mineral concentration (GEOSS, 2017).

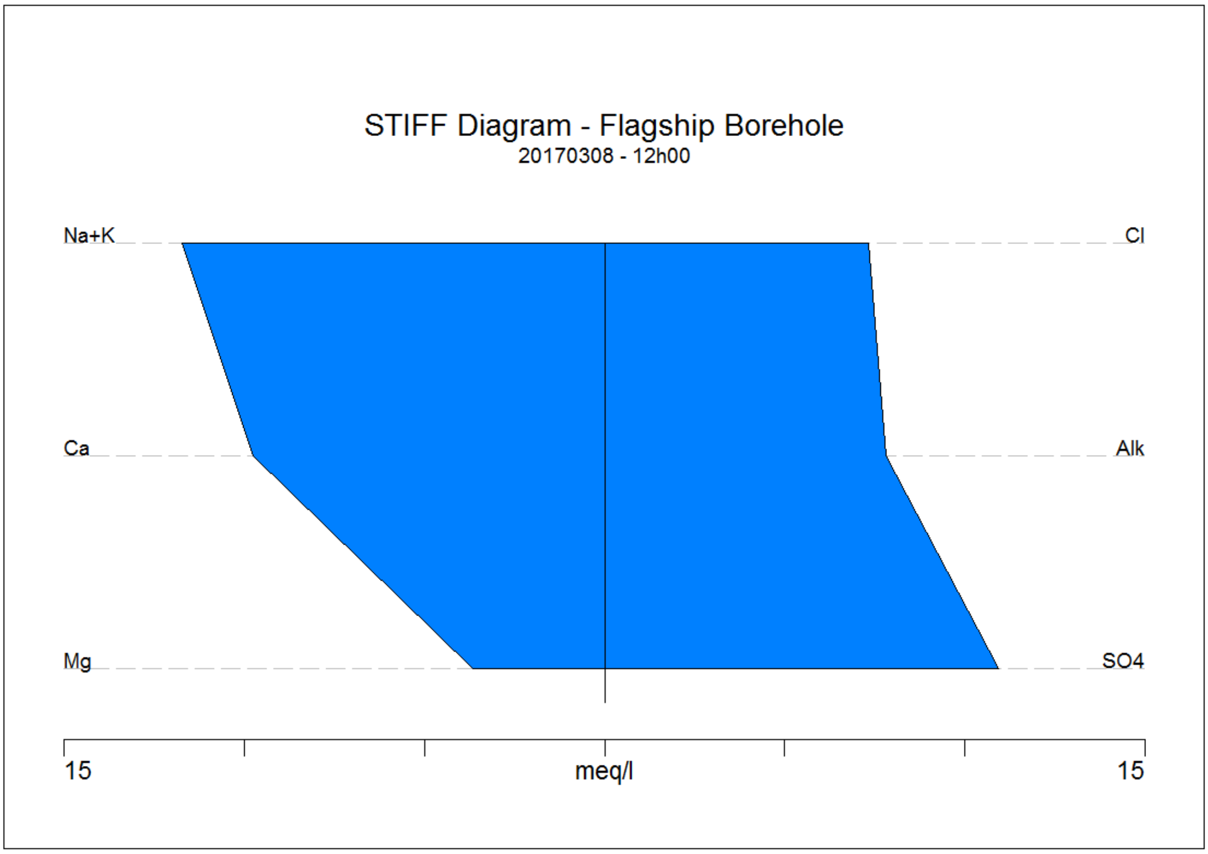


Figure 5: Stiff diagram of the borehole groundwater sample.

7. RISK ASSESSMENT

There are risks associated with the expansion of the Goue Akker Cemetery site. These include decomposition of the bodies producing leachate, chemicals used in the embalming process, metals from the ornamental hinges on coffins, jewellery and other nutrients and pathogens sources from poor sanitary practices or landscaping (Dippenaar, et al., 2018). In the case of the Goue Akker Cemetery, many of these risks already exist due to the exiting cemetery.

The decomposition of human remains result in the formation of leachate which is comprised of 60% water, 30% salts (N, P, Cl, HCO_3, Ca, Na and compounds of metals such as Ti, Cr, Cd, Pb, Fe, Mn and Ni), and 10% organic substances (Żychowski and Bryndal, 2015).

Other contaminants associated with the decomposition of bodies include:

- Chemical substances derived from chemotherapy or the embalming process which could include arsenic, formaldehyde and methanol.
- Makeup such as cosmetics, pigments and other chemical compounds
- Items such as cardiac pacemakers, paints, varnishes, metal hardware, chemicals batteries and dentures.
- Microorganisms such as bacteria, viruses, intestinal fungi, protozoa, and other pathogens.

Exposure to contaminants could be through contact with hazardous substances (contaminants or contaminated groundwater) via ingestion or dermal contact (with both groundwater and soil).

Table 9 summaries possible impacts and proposed mitigation measures associated with the increased decomposition of human remains. **Table 10** presents a summary of possible impacts and proposed mitigation measures associated with the corrosion of metals used as ornaments, plastics, paints and varnishes. **Table 11** summarises the possible impacts and proposed mitigation measures associated with the formation of organics from the embalming process.

Table 9: Impact table for contamination of groundwater as a result of decomposition of human remains.

OPERATIONAL PHASE	
Potential impact and risk:	**Decomposition of Human Remains**
Nature of impact:	Negative
Extent and duration of impact:	Extent is local and duration is short term.
Consequence of impact or risk:	Contaminated groundwater and proximal drainage channel.
Probability of occurrence:	Low probability.
Degree to which the impact may cause irreplaceable loss of resources:	Marginal loss of resource.
Degree to which the impact can be reversed:	Reversible.
Cumulative impact prior to mitigation:	Low
Significance rating of impact prior to mitigation (e.g. Low, Medium, Medium-High, High, or Very-High)	Low
Degree to which the impact can be managed or mitigated:	Low
Proposed mitigation:	Monitoring boreholes are required (minimum of 3) in order to detect any potential contamination as quickly as possible.
Cumulative impact post mitigation:	Low
Significance rating of impact after mitigation (e.g. Low, Medium, Medium-High, High, or Very-High)	Low

Table 10: Impact table for contamination of groundwater as a result of metal corrosion.

OPERATIONAL PHASE	
Potential impact and risk:	**Corrosion of metals**
Nature of impact:	Negative
Extent and duration of impact:	Extent is local and duration is short term.
Consequence of impact or risk:	Contaminated groundwater and proximal drainage channel.
Probability of occurrence:	Low probability.
Degree to which the impact may cause irreplaceable loss of resources:	Marginal loss of resource.
Degree to which the impact can be reversed:	Reversible.
Cumulative impact prior to mitigation:	Low
Significance rating of impact prior to mitigation (e.g. Low, Medium, Medium-High, High, or Very-High)	Medium
Degree to which the impact can be managed or mitigated:	Medium
Proposed mitigation:	Standardise coffin size with ordinary dimensions. Coffin materials should primarily consist of wood or biodegradable materials. Refrain from using excessive ornamental metals, plastics, paints varnishes, etc. All jewellery, dentures, pacemakers, watches, batteries, excessive cosmetics, and other such materials should be removed prior to burial. A coffin interred in a grave should insofar as this is possible be constructed of natural wood or other non-toxic, perishable material as per Provincial Gazette no. 6898.
Cumulative impact post mitigation:	Low
Significance rating of impact after mitigation (e.g. Low, Medium, Medium-High, High, or Very-High)	Low

Table 11: Impact table for contamination of groundwater as a result of compounds used during embalming.

OPERATIONAL PHASE	
Potential impact and risk:	**Embalming process – formaldehyde.**
Nature of impact:	Negative
Extent and duration of impact:	Extent is local and duration is short term.
Consequence of impact or risk:	Contaminated groundwater and proximal drainage channel.
Probability of occurrence:	Low probability.
Degree to which the impact may cause irreplaceable loss of resources:	Minimal loss of resource.
Degree to which the impact can be reversed:	Reversible.
Cumulative impact prior to mitigation:	Low
Significance rating of impact prior to mitigation (e.g. Low, Medium, Medium-High, High, or Very-High)	Low
Degree to which the impact can be managed or mitigated:	Can be mitigated.
Proposed mitigation:	When formaldehyde comes into contact with water it tends to breakdown into methanol, amino acids and several other chemicals and therefore does not persist in the environment. (World Health Organisation, 2002)
Cumulative impact post mitigation:	Low
Significance rating of impact after mitigation (e.g. Low, Medium, Medium-High, High, or Very-High)	Low

8. DISCUSSION

From the hydrocensus, it is clear that the number of groundwater users surrounding the proposed site is limited, however, the water is mainly used for drinking. No groundwater was intersected in any of the ten trial pits. The study area is underlain by very dense silty sand or very dense boulders with silty matrix. The excavation conditions are expected to be intermediate from surface to a depth of 2.0 m below surface and will not require shoring if conditions remain dry. In certain areas the presence of calcrete and/or boulder lenses at depths from 1.6 mbgl may slow excavation rates.

The groundwater quality of the area, based on one laboratory sample and historic monitoring data indicates that the groundwater quality is "moderate "(70 – 300 mS/m) according to the water quality classification.

The aquifer vulnerability to contamination is "low to medium". This rating is associated with the confined nature of the fractured aquifer. The site is underlain by mudstone that weathers to clay forming an impermeable layer above the fractured mudstone and sandstone that likely provide sufficient protection against point and non-point sources of contamination. The excavation of some of the trial pits did indicate the presence of boulders which are likely associated with river deposit caused by the meandering of streams. The groundwater levels measured in the boreholes were found to range between 14 and 46 mbgl. Considering the depth of burials to be 1.4 mbgl, it is deemed that contamination at the site is unlikely to impact greatly on groundwater and proximal drainage channel.

Given the "low to medium" vulnerability of the underlying unconsolidated deposits, the risk of contamination is considered. For a risk to exist there must be a source (s), pathway(s) and receptor(s); these are presented in **Figure 6**. All three are present in this case. The cemetery and proposed expansion represent potential sources of contamination. The underlying aquifer and proximal drainage channel represent both a potential pathway and receptor. Groundwater users represent an additional receptor of potential contamination.

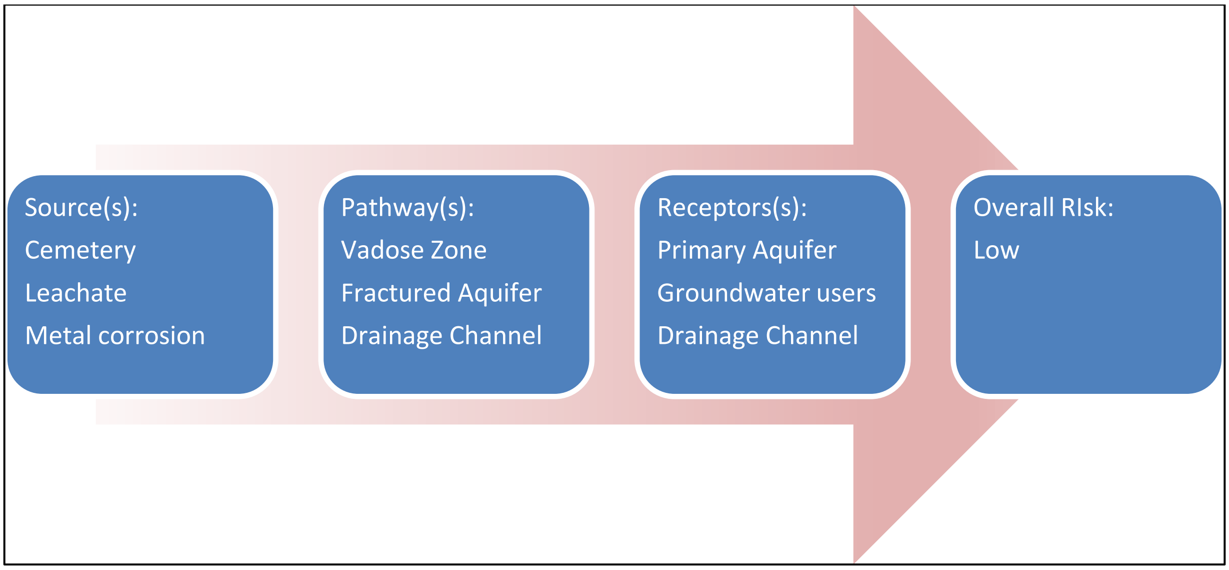


Figure 6: Source, Pathway and Receptor assessment.

Given the vulnerability of the aquifer, the **risk** assigned to potential impacts of contamination is considered to be **Low**. However, good practise dictates no activities should be allowed that are likely to result in contaminants (leachate) to enter into the subsurface. Mitigation is necessary to prevent any potential contamination. Regular groundwater monitoring is recommended to detect potential contamination proximal the cemetery.

The main contaminant risks are not generally associated with the decomposition of the body, and pertain more to the burial process, entombing/encasing and ornaments. While these contaminant risks can strictly speaking be mitigated against, the practicalities of enforcing them are very challenging and unlikely to occur.

9. RECOMMENDATIONS

The following recommendations are made:

- The site development can proceed however, monitoring should be installed on site, with regard to expanding the cemetery. Relevant mitigation measures and best practice procedures must be employed to ensure no contamination of the subsurface takes place (**Table 9**, **10**, **11**, – Proposed Mitigation).
- At least three groundwater monitoring boreholes should be installed in order to detect any potential contamination as early as possible.
- The monitoring boreholes should be drilled to a depth 32 m. Monitoring boreholes should follow the specifications provided in **Section 9.1**.

Note that these recommendations are based on GEOSS's opinion and the final decision on the necessary groundwater monitoring requirements resides with the regulatory authorities.

9.1 Proposed groundwater monitoring action plan:

It is recommended that at least three boreholes should be drilled at the proposed site as part of future site monitoring. This will allow for monitoring of the groundwater quality and groundwater levels across the site. The optimum position of the monitoring boreholes should be based on availability of open space surrounding the planned cemetery expansion, however, generally speaking it is recommended that the boreholes be down-gradient of the cemetery. The down-gradient borehole should be appropriately designed and constructed. The borehole water level and the groundwater quality should be monitored quarterly, so as to determine seasonal fluctuation. The development of a groundwater monitoring programme will be important for assessing any impacts of the site on groundwater and the environment.

It is recommended that groundwater monitoring be undertaken at the proposed site in accordance with guidelines set out in the publication by DWAF (1998). The various aspects of the monitoring are presented in this section, along with relevant recommendations.

9.1.1 Borehole drilling and construction specifications

The drilling will include three boreholes at the proposed site. The drilling should be supervised by a geohydrologist and drill samples should be collected every 1 metre and logged. Additional information should also be collected such as the depth of water strikes, associated water strike yields and groundwater quality. This is crucial information for the optimal design of the boreholes. The driller should be supervised to ensure all site requirements are met. A graphical representation of a proposed borehole construction is presented in **Figure 7**; the exact construction will, however, be unique for the borehole.

The borehole is to be drilled by means of air-percussion. It is not anticipated that multiple aquifers will be present in the bedrock but it will still be important for drilling to be supervised by a geohydrologist. The inner diameter of the uPVC casing must not be less than 110 mm.

A gravel pack should be installed with an annulus of about 2 mm. The boreholes should be developed with compressed air for at least two hours upon completion along with an airlift test to estimate the yield of the borehole. Each borehole must be protected with a concrete block or a flush manhole if there is traffic in the area. Each borehole also needs a permanent plate glued to the lid containing the details pertaining to the borehole. A bentonite plug of at least 500 mm needs to be installed in the annulus at the top of the hole to prevent ingress of surface water.

9.1.2 Groundwater levels

Groundwater level measurements are recommended for the monitoring borehole at the study site. A dip meter can be used to measure the water level below the top of the borehole collar/casing height (mbch). The height of the collar/casing height must then also be measured (m). The water level (metres below ground level (mbgl)) can then be calculated by subtracting the collar/casing height from the water level (mbch). The value must be recorded along with the date and time of measurement.

9.1.3 Sampling process

The monitoring borehole should be assessed to determine whether it is a low or high yielding borehole before sampling. Should the monitoring borehole be of low yield and unable to pump with a conventional pump (until field parameters stabilize and a sample collected), a bailer (grab) sample can be collected. It is preferable to use a low volume sampling pump in most monitoring boreholes (known as a bladder pump).

For a high yielding borehole, it is recommended that the pump be installed either half a meter above the bottom of the borehole or at the highest yielding fracture depth. The groundwater should be pumped into a flow-through cell, an EC and pH probe should be placed into the flow-through cell and be pumped until field chemistry parameters stabilise prior to sampling.

9.1.4 Sample Collection, Preservation and Submission

Sample bottles must be labelled with the borehole name, site name and date. At the time of sampling field, chemistry parameters must be measured and recorded. These include electrical conductivity (EC), oxidation reduction potential (ORP), pH, temperature and dissolved oxygen (DO). Samples must be taken in their correct sampling container and preserved in the correct manner prior to submission to an accredited laboratory for the analysis parameters. The sample method and preservation must be discussed with the laboratory prior to sampling.

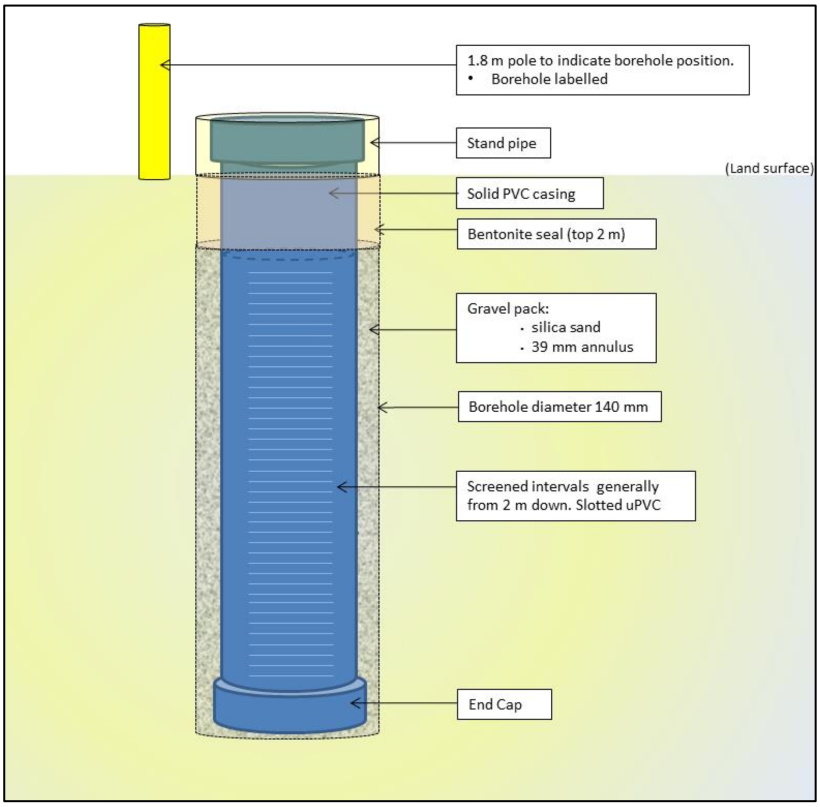


Figure 7: Schematic representation of the proposed general borehole construction.

9.1.5 Sampling frequency and parameter analysis

In order to best understand and monitor the site, it is recommended that quarterly water level measurements be taken (to determine seasonal fluctuation). It is however, considered adequate for boreholes to be sampled bi-annually. **Table 12** indicates the potential parameters for ongoing monitoring.

10. CONCLUSION

The study site has been classified as having a groundwater vulnerability classification of "**low to medium**". And given the relatively deep-water table and shallow burial depths, the extension is deemed to have minimal impact on groundwater and proximal drainage channel.

The proposed expansion will need to conform to the standard industry mitigations measures for developing a cemetery in order to ensure no contamination occurs on site. GEOSS recommends the installation of a groundwater monitoring system on site, as specified in **Section 9.1**.

11. ASSUMPTIONS AND LIMITATIONS

A limitation experienced during this investigation was during the hydrocensus. Not all groundwater users could be located or visited due to a large number of the dwellings, plots and farms being gated. Additionally, not all groundwater users display the relevant signage to indicate groundwater use. It is therefore assumed that the number of groundwater users is in fact greater than are currently represented in this report.

Available data was sourced from relevant groundwater databases and sources. The Aquifer vulnerability, yield and quality data is predominantly accurate albeit mapped at a regional scale.

A further limitation was the temporal nature of the site visit. The field work was undertaken on a single day in February 2020, and does not account for the temporal variability of the water table. While this is not expected to impact the risk assessment for the site, the seasonal fluctuation of water levels will only be known once groundwater monitoring is initiated on the site.

Table 12: Source-based selection of groundwater quality monitoring variables.

Source Activity	Cemetery
Category	**Parameter**
Inorganic	pH
	EC
	K
	Cl
	NO_3
	NH_4
	P
	Na
	Ca
	HCO3
Metals	Fe
	Mn
	Ti
	Cr
	Cd
	Pb
	Ni
Organic (and indicator analysis)	BOD
	COD
	total coliforms
	E coli.

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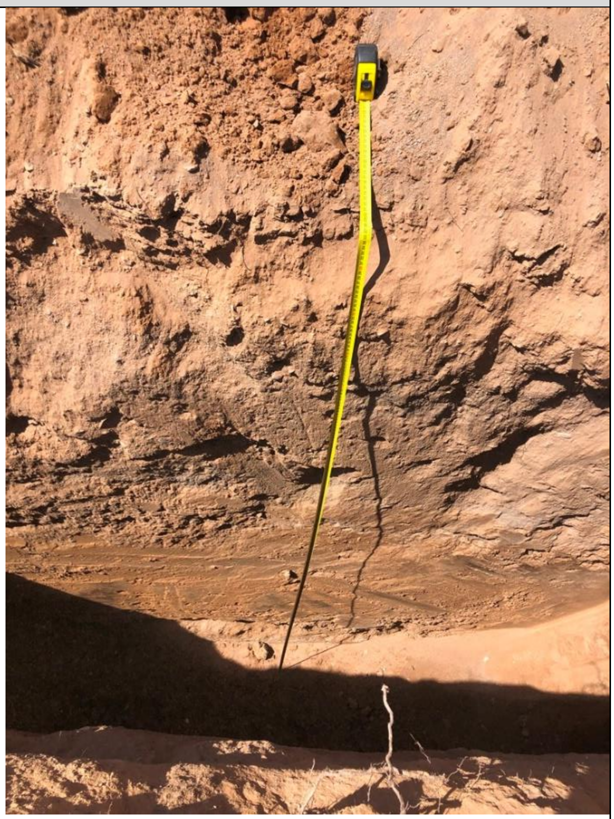
13. APPENDIX A: TRIAL PIT PHOTOS AND LOGS

TP_1	***TP_2***
	
TP_3	***TP_4***
	

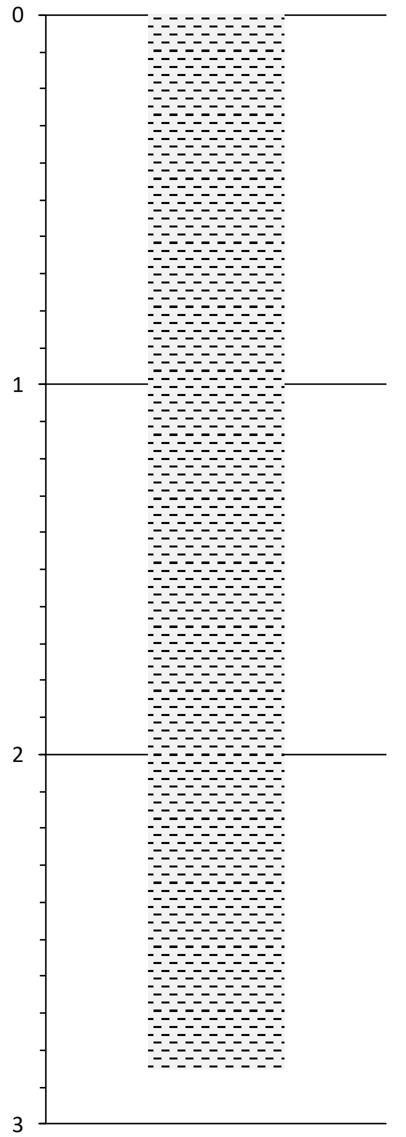
TP_5	TP_6
	
TP_7	**TP_8**
	

TP_9

TP_10

Log of Trial Pit No.: TP01

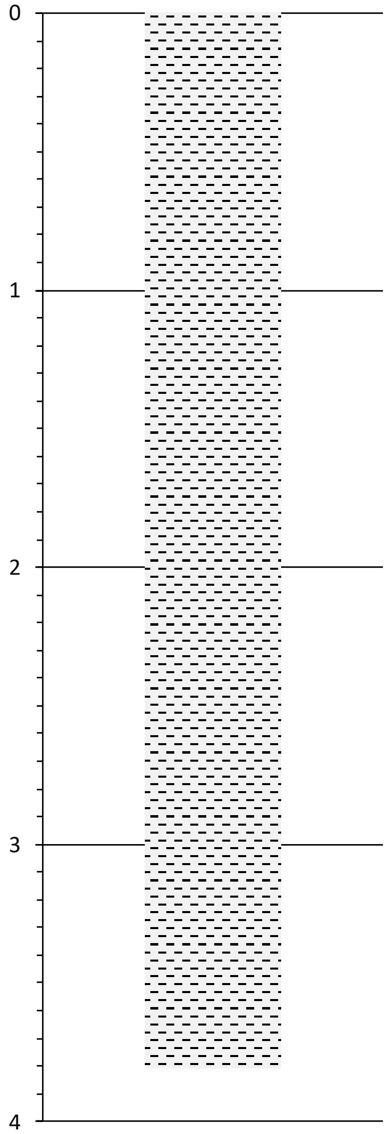
Location:	Beaufort West Cemetary	**Latitude:**	-32.37837036
Date:	11-Mar-20	**Longitude:**	22.589293
Client:	Sharples Environmental Services	**Ground Elevation:**	830

Lithological Description	Lithology (mbgl)	Construction	Comments
Unit 1: 0.00 - 2.85 Dry, pale brown, very dense, weakly cemented, pinholed, clayey sandy SILT. Transported, alluvial-lacustrine.			End of Hole = 2.85 mbgl

Excavated By:	GEOSS	**Remarks:**	
Drill Method:	TLB Excavator		No groundwater
Logged By:	CM/ MB		

Log of Trial Pit No.: TP02

Location:	Beaufort West Cemetary	**Latitude:**	-32.37870304
Date:	11-Mar-20	**Longitude:**	22.59046261
Client:	Sharples Environmental Services	**Ground Elevation:**	830

Lithological Description	Lithology (mbgl)	Construction	Comments
Unit 1: 0.00 - 3.81 Dry becoming very slighty moist, orangish pale brown, Meduim dense becoming very dense, weakly cemented, pinholed, clayey sandy SILT with some pebbles. Transported. alluvial-			End of Hole = 3.81 mbgl

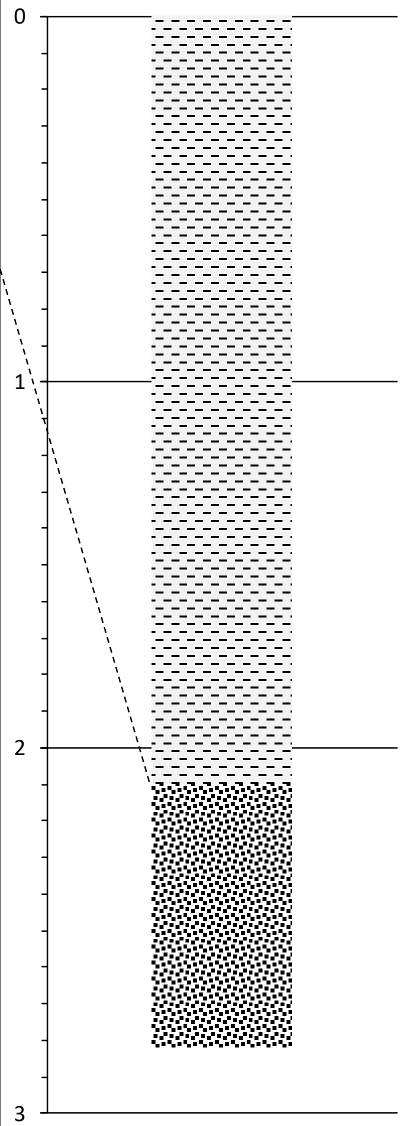
Excavated By:	GEOSS	**Remarks:**	
Drill Method:	TLB Excavator		No groundwater
Logged By:	CM/ MB		

GEOSS SOUTH AFRICA (Pty) Ltd

Log of Trial Pit No.: TP03

Location:	Beaufort West Cemetary	**Latitude:**	-32.37867521
Date:	11-Mar-20	**Longitude:**	22.59128387
Client:	Sharples Environmental Services	**Ground Elevation:**	830

Lithological Description	Lithology (mbgl)	Construction	Comments
Unit 1: 0.00 - 2.10 Dry, pale brown, dense to very dense, weakly cemented, pinholed, clayey sandy SILT with some pebbles. Transported, alluvial-lacustrine.			
Unit 2: 2.10 - 2.82 Very slightly moist, pale brown, clast supported, very dense, coarse GRAVEL with sandy silty matrix. Transported, alluvial-lucustrine.			End of Hole = 2.82 mbgl



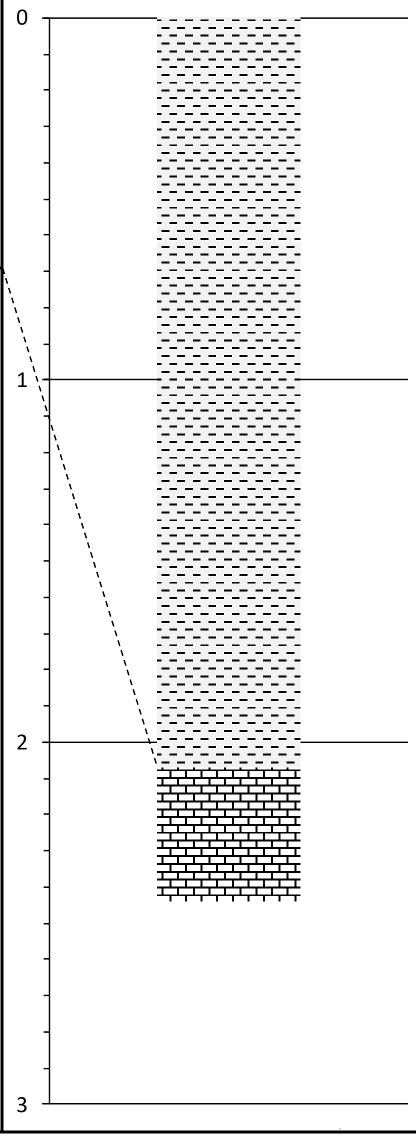
Excavated By:	GEOSS	**Remarks:**	
Drill Method:	TLB Excavator		No groundwater
Logged By:	CM/ MB		

GEOSS SOUTH AFRICA (Pty) Ltd

Log of Trial Pit No.: TP04

Location:	Beaufort West Cemetary	**Latitude:**	-32.37923068
Date:	11-Mar-20	**Longitude:**	22.58949048
Client:	Sharples Environmental Services	**Ground Elevation:**	830

Lithological Description	Lithology (mbgl)	Construction	Comments
Unit 1: 0.00 - 2.07 Dry, pale brown, very dense, weakly cemented, pinholed, clayey sandy SILT with some pebbles. Transported, alluvial-lacustrine.			Sample S1 @ 0.8 mbgl
Unit 2: 2.07 - 2.44 Very slightly moist, light brownish white, very dense, cemented, honey combed in places, CALCRETE. Evaporite.			End of Hole = 2.44 mbgl

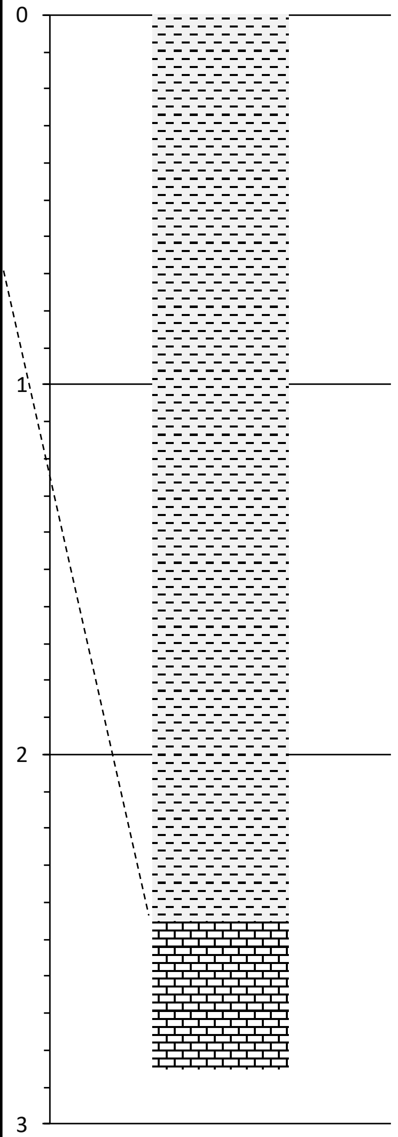


Excavated By:	GEOSS	**Remarks:**	
Drill Method:	TLB Excavator		No groundwater
Logged By:	CM/ MB		

GEOSS SOUTH AFRICA (Pty) Ltd

Log of Trial Pit No.: TP05

Location:	Beaufort West Cemetary	**Latitude:**	-32.37953528
Date:	11-Mar-20	**Longitude:**	22.59026757
Client:	Sharples Environmental Services	**Ground Elevation:**	830

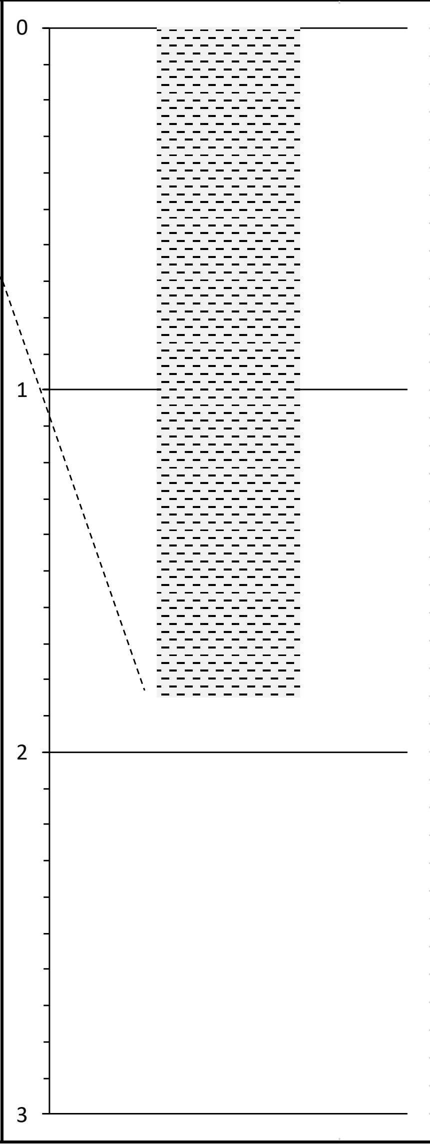
Lithological Description	Lithology (mbgl)	Construction	Comments
Unit 1: 0.00 - 2.45 Dry, pale brown, very dense, weakly cemented, pinholed, clayey sandy SILT with some pebbles. Transported, alluvial-lacustrine.			
Unit 2: 2.45 - 2.85 Very slightly moist, light brownish white, very dense, cemented, honey combed in places, CALCRETE. Evaporite.			End of Hole = 2.85 mbgl

Excavated By:	GEOSS	**Remarks:**	
Drill Method:	TLB Excavator		No groundwater
Logged By:	CM/ MB		

GEOSS SOUTH AFRICA (Pty) Ltd

Log of Trial Pit No.: TP06

Location:	Beaufort West Cemetary	**Latitude:**	-32.38021136
Date:	11-Mar-20	**Longitude:**	22.58846613
Client:	Sharples Environmental Services	**Ground Elevation:**	830

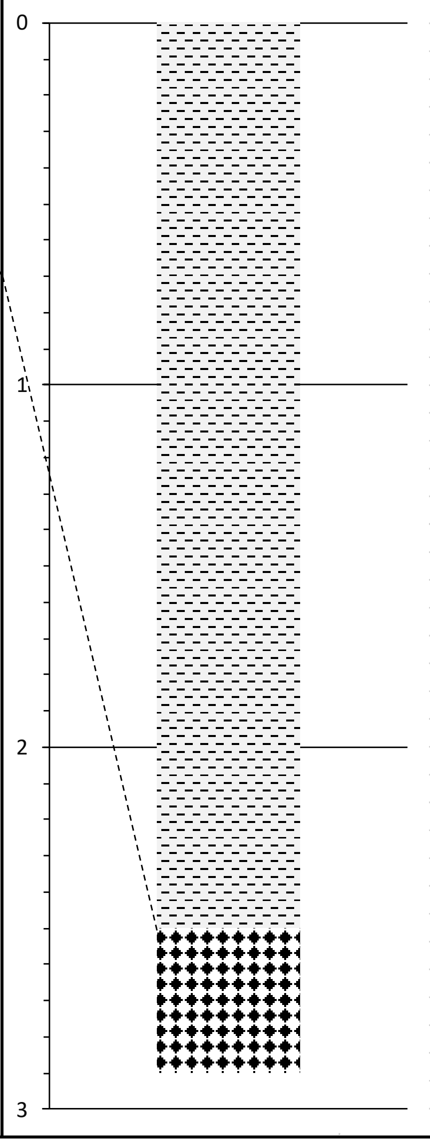
Lithological Description	Lithology (mbgl)	Construction	Comments
Unit 1: 0.00 - 1.85 Dry, pale brown, very dense, weakly cemented, pinholed, clayey sandy SILT with some pebbles. Transported, alluvial-lacustrine.			TLB Refusal on boulders End of Hole = 1.85 mbgl

Excavated By:	GEOSS	**Remarks:**	No groundwater
Drill Method:	TLB Excavator		
Logged By:	CM/ MB		

GEOSS SOUTH AFRICA (Pty) Ltd

Log of Trial Pit No.:	TP07

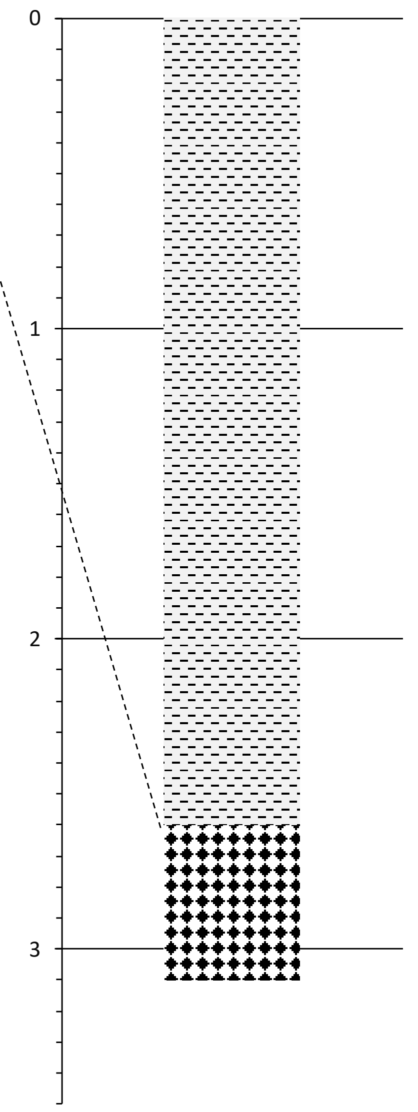
Location:	Beaufort West Cemetary	**Latitude:**	-32.38049802
Date:	11-Mar-20	**Longitude:**	22.5897706
Client:	Sharples Environmental Services	**Ground Elevation:**	830

Lithological Description	Lithology (mbgl)	Construction	Comments
Unit 1: 0.00 - 2.50 Dry, orangish pale brown, very dense, weakly cemented, pinholed, clayey sandy SILT with some pebbles. Transported, alluvial-lacustrine.			
Unit 2: 2.50 - 2.90 Very slightly moist, light brown, very dense, matrix supported, cobbles and BOULDERS with sandy silty matrix. Alluvium			End of Hole = 2.90 mbgl

Excavated By:	GEOSS	**Remarks:**	No groundwater
Drill Method:	TLB Excavator		
Logged By:	CM/ MB		

Log of Trial Pit No.: TP08

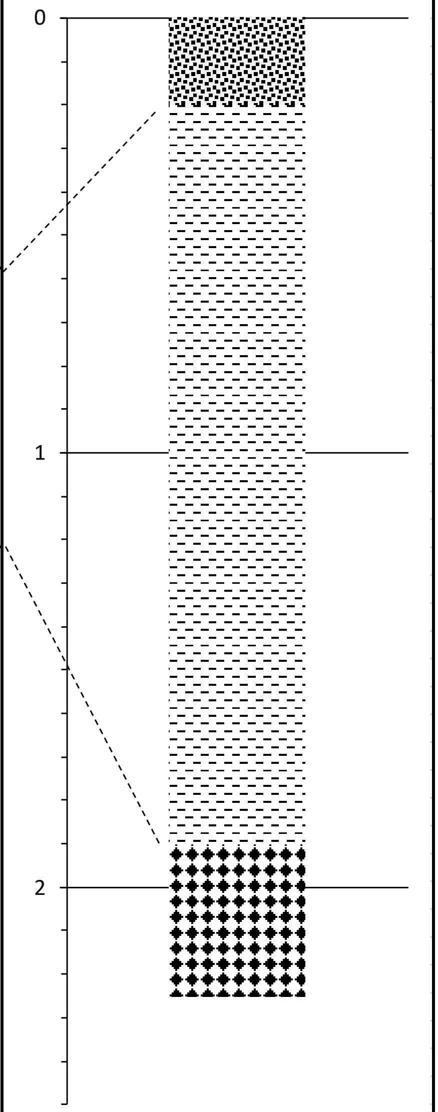
Location:	Beaufort West Cemetary	**Latitude:**	-32.38072425
Date:	11-Mar-20	**Longitude:**	22.59080392
Client:	Sharples Environmental Services	**Ground Elevation:**	830

Lithological Description	Lithology (mbgl)	Construction	Comments
Unit 1: 0.00 - 2.60 Dry, orangish pale brown, very dense, weakly cemented, pinholed, clayey sandy SILT with some pebbles. Transported, alluvial-lacustrine.			
Unit 2: 2.60 - 3.10 Very slightly moist, light brown, very dense, matrix supported, cobbles and BOULDERS with sandy silty matrix. Alluvium			End of Hole = 3.10 mbgl

Excavated By:	GEOSS	**Remarks:**	
Drill Method:	TLB Excavator		No groundwater
Logged By:	CM/ MB		

Log of Trial Pit No.: TP09

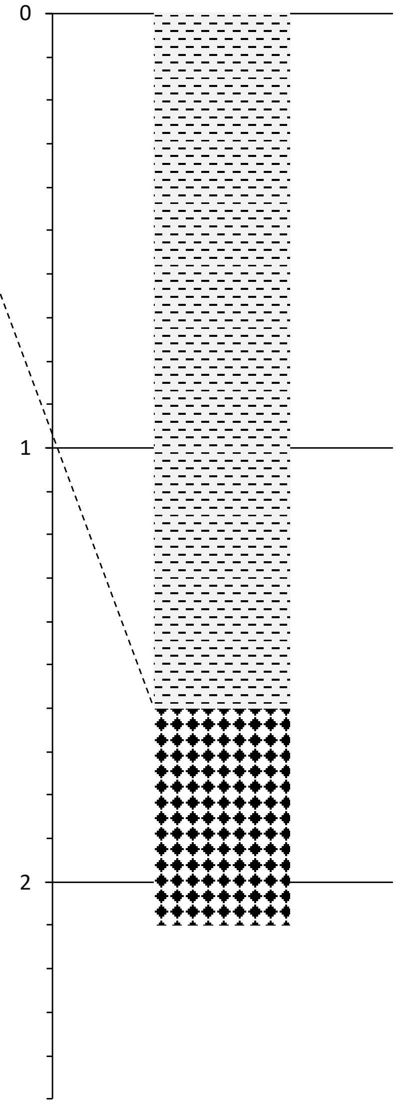
Location:	Beaufort West Cemetary	**Latitude:**	-32.38077228
Date:	11-Mar-20	**Longitude:**	22.58900383
Client:	Sharples Environmental Services	**Ground Elevation:**	830

Lithological Description	Lithology (mbgl)	Construction	Comments
Unit 1: 0.00 - 0.20 Very slightly moist, pale brown, clast supported, very dense, coarse GRAVEL with sandy silty matrix. Transported, alluvial-lucustrine.			TLB Refusal on boulders
Unit 2: 0.20 - 1.90 Very slightly moist, orangish pale brown, very dense, weakly cemented, pinholed, clayey sandy SILT with some pebbles. Transported, alluvial-lacustrine.			
Unit 3: 1.90 to 2.25 Very slightly moist, light brown, very dense, matrix supported, cobbles and BOULDERS with sandy silty matrix. Transported, alluvium			End of Hole = 2.25 mbgl

Excavated By:	GEOSS	**Remarks:**	
Drill Method:	TLB Excavator		No groundwater
Logged By:	CM/ MB		

GEOSS SOUTH AFRICA (Pty) Ltd

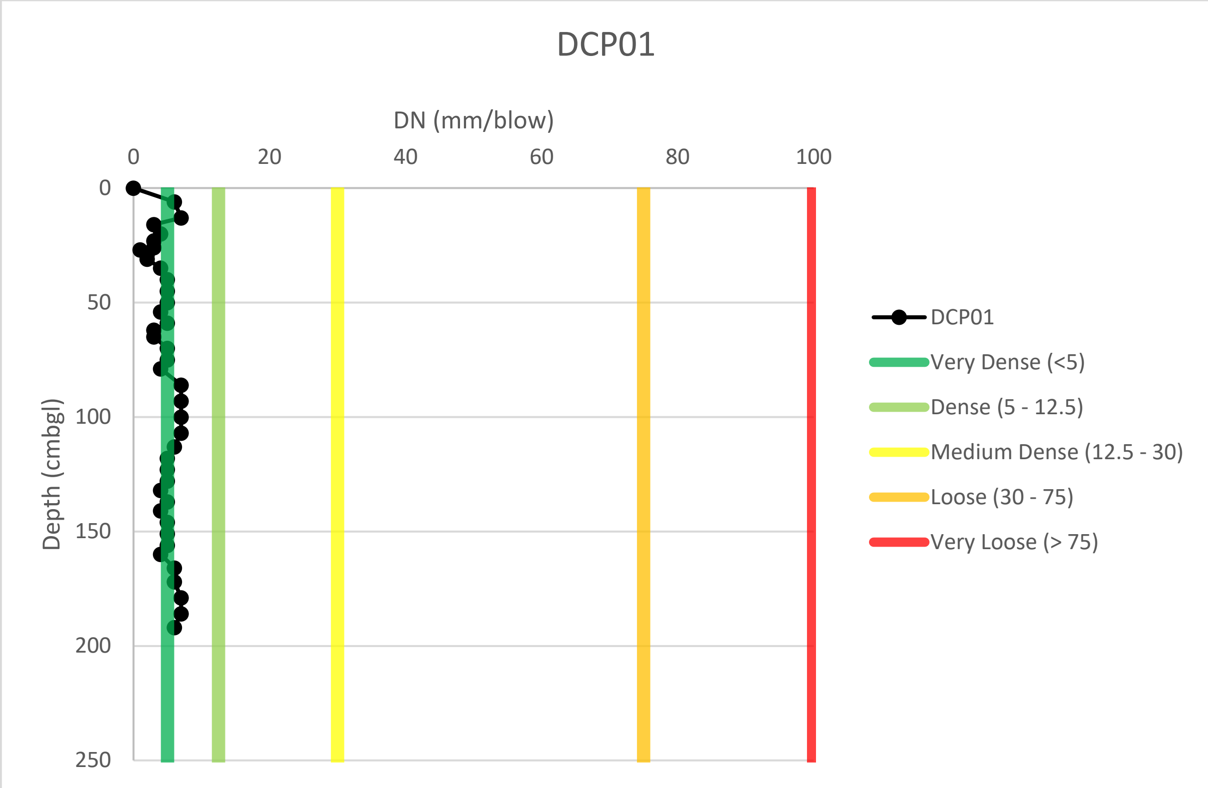
Log of Trial Pit No.:	TP10		
Location:	Beaufort West Cemetary	**Latitude:**	-32.38077228
Date:	11-Mar-20	**Longitude:**	22.58900383
Client:	Sharples Environmental Services	**Ground Elevation:**	830

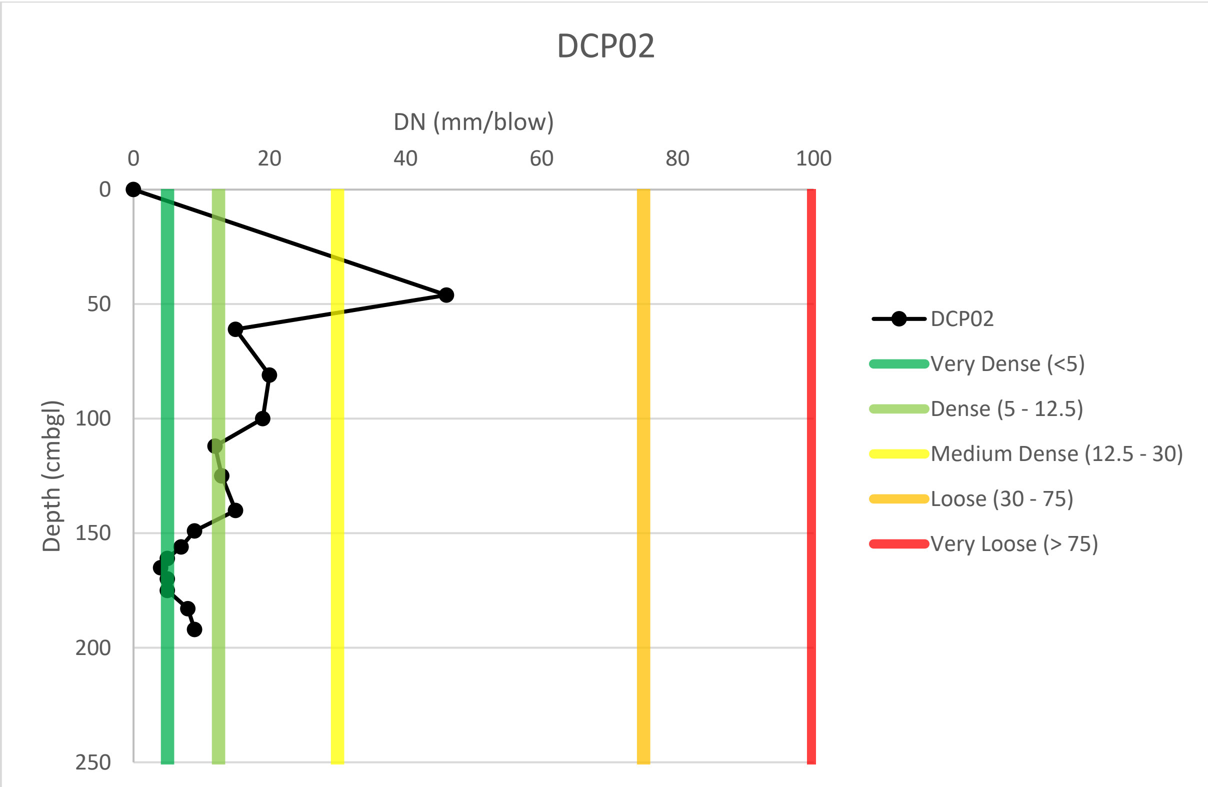
Lithological Description	**Lithology (mbgl)**	**Construction**	**Comments**
Unit 1: 0.00 - 1.60 Very slightly moist, orangish pale brown, very dense, weakly cemented, pinholed, clayey sandy SILT with some pebbles. Transported, alluvial-lacustrine.			TLB Refusal on boulders
Unit 2: 1.60 - 2.10 Very slightly moist, light brown, very dense, matrix supported, cobbles and BOULDERS with sandy silty matrix. Transported, alluvium			End of Hole = 2.10 mbgl

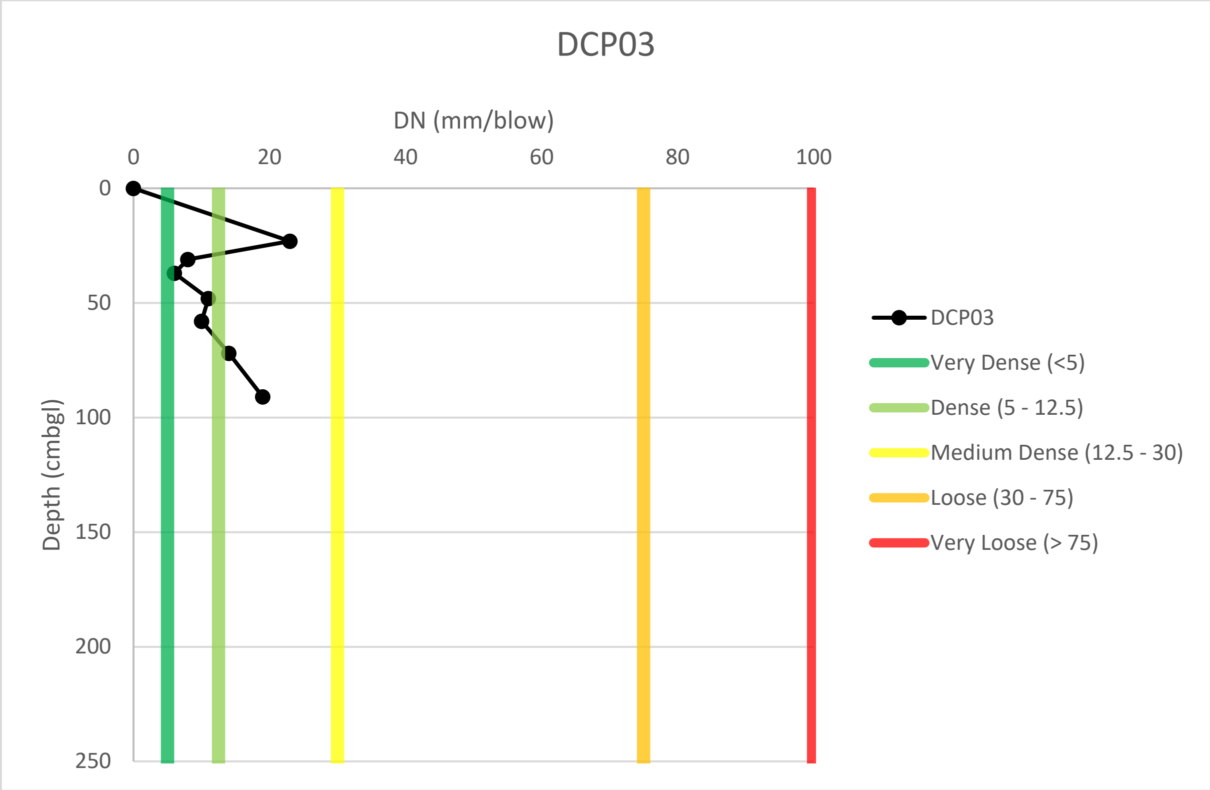
Excavated By:	GEOSS	**Remarks:**	
Drill Method:	TLB Excavator		No groundwater
Logged By:	CM/ MB		

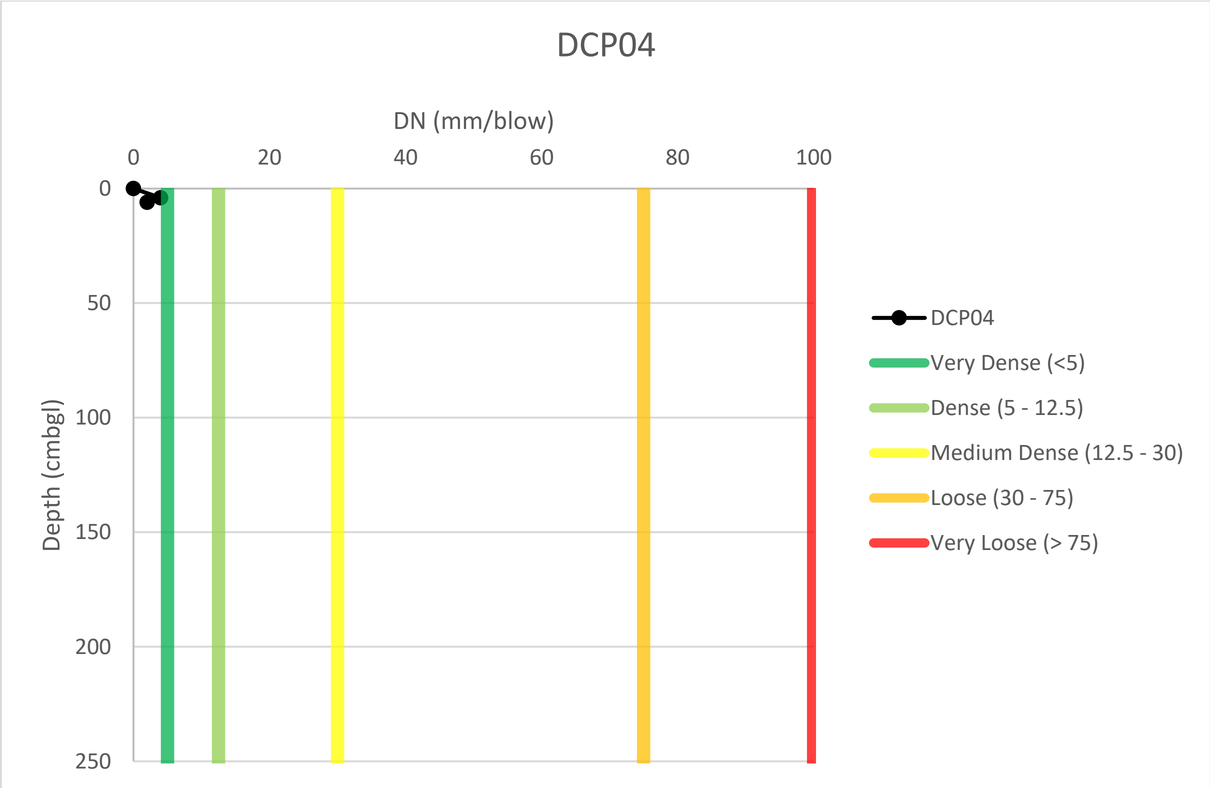
GEOSS SOUTH AFRICA (Pty) Ltd

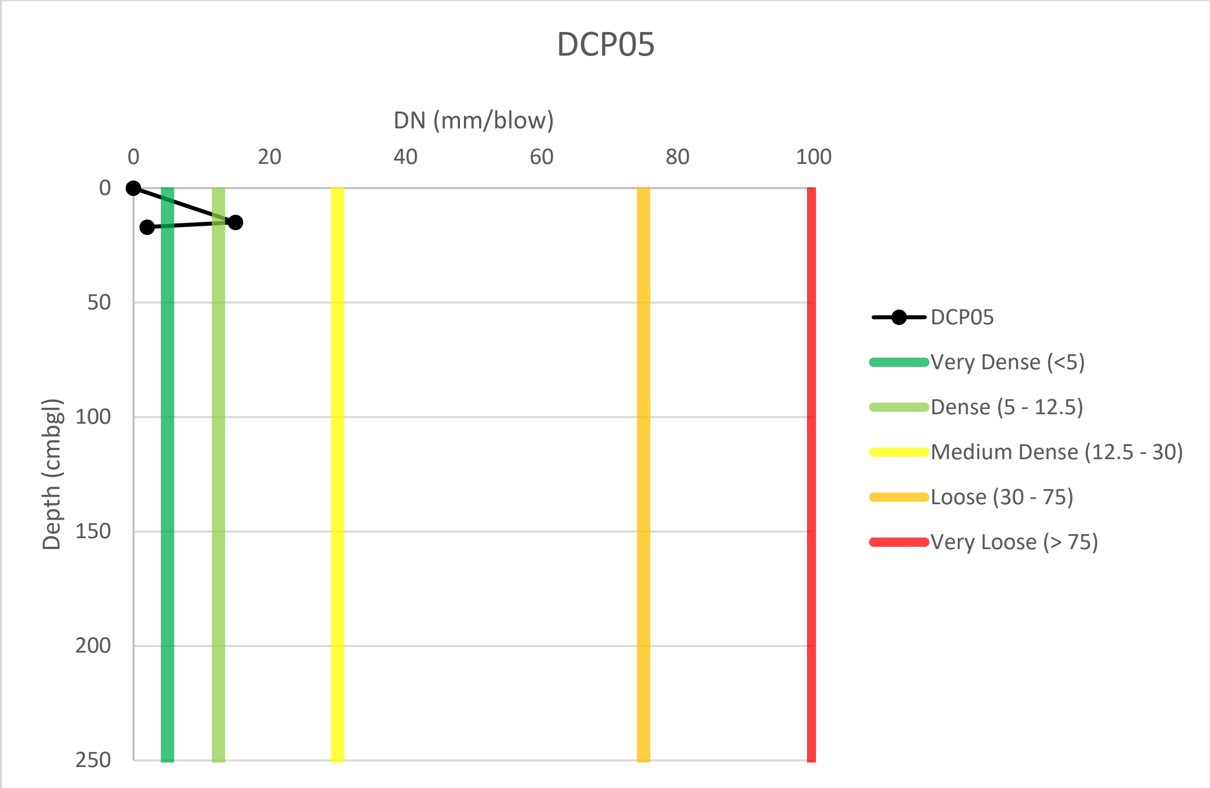
14. APPENDIX B: DCP TESTING LOGS

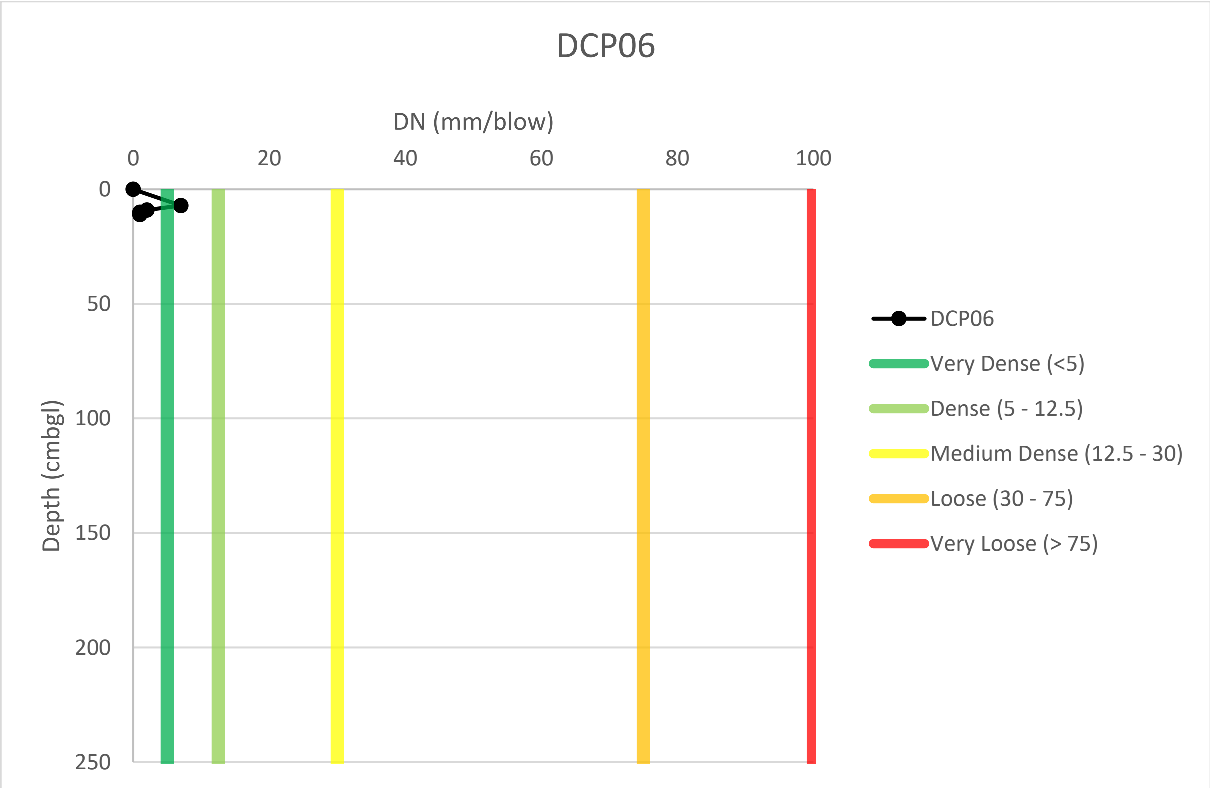

DCP01
DN (mm/blow)
0
20
40
60
80
100
0
50
100
150
200
250
Depth (cmbgl)
DCP01
Very Dense (<5)
Dense (5 - 12.5)
Medium Dense (12.5 - 30)
Loose (30 - 75)
Very Loose (> 75)

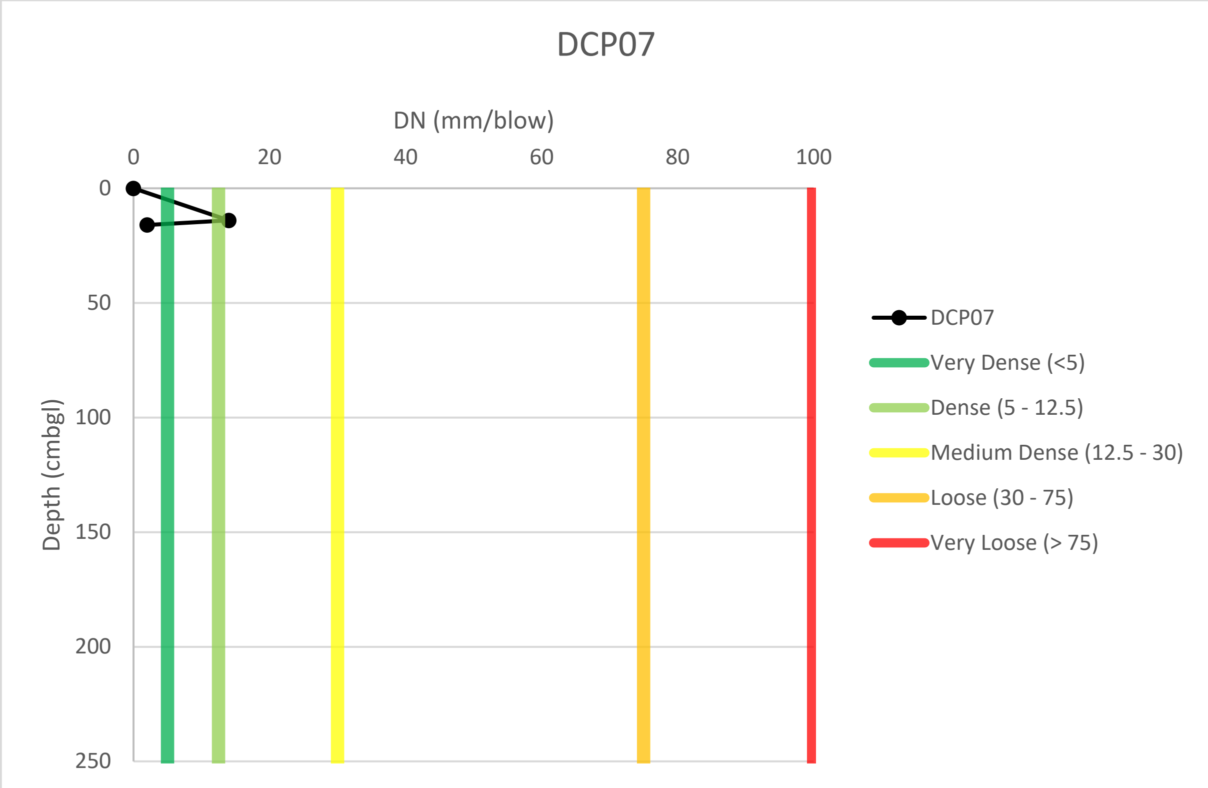

DCP02
DN (mm/blow)
0
20
40
60
80
100
0
50
100
150
200
250
Depth (cmbgl)
DCP02
Very Dense (<5)
Dense (5 - 12.5)
Medium Dense (12.5 - 30)
Loose (30 - 75)
Very Loose (> 75)

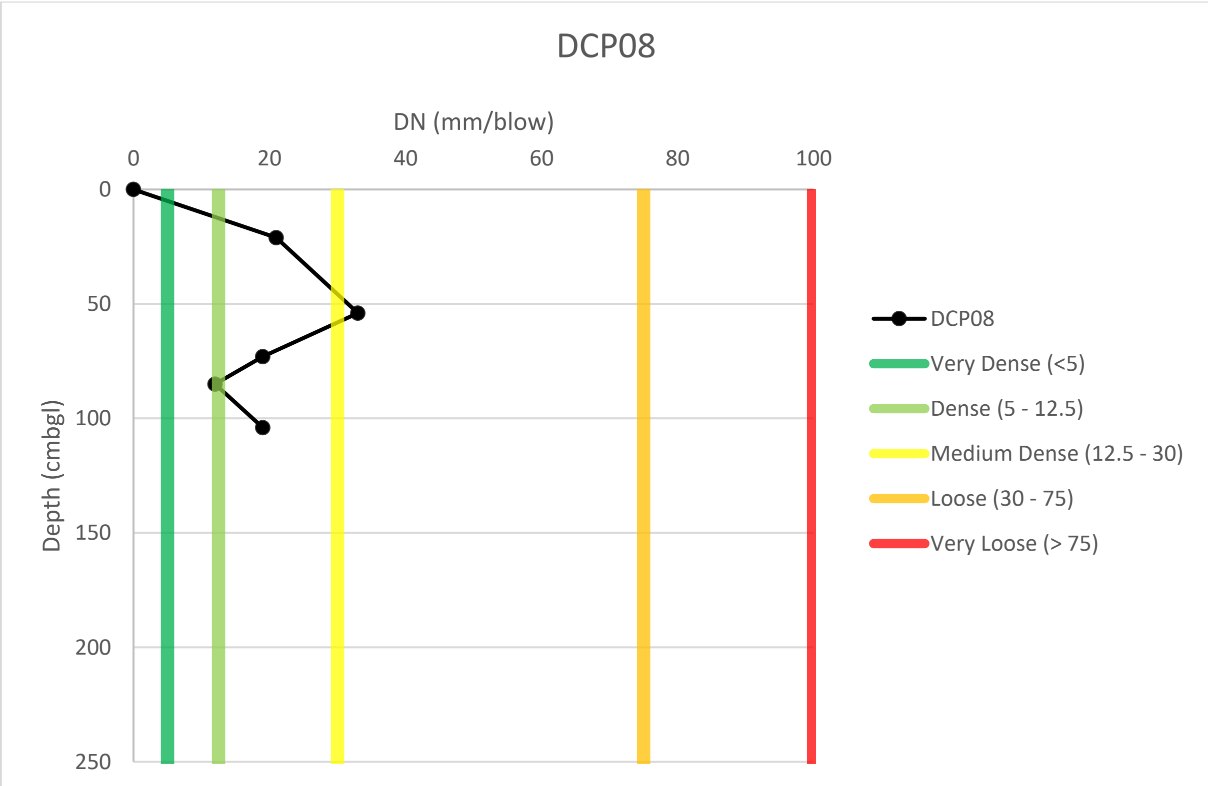

DCP03
DN (mm/blow)
0
20
40
60
80
100
0
50
100
150
200
250
Depth (cmbgl)
DCP03
Very Dense (<5)
Dense (5 - 12.5)
Medium Dense (12.5 - 30)
Loose (30 - 75)
Very Loose (> 75)

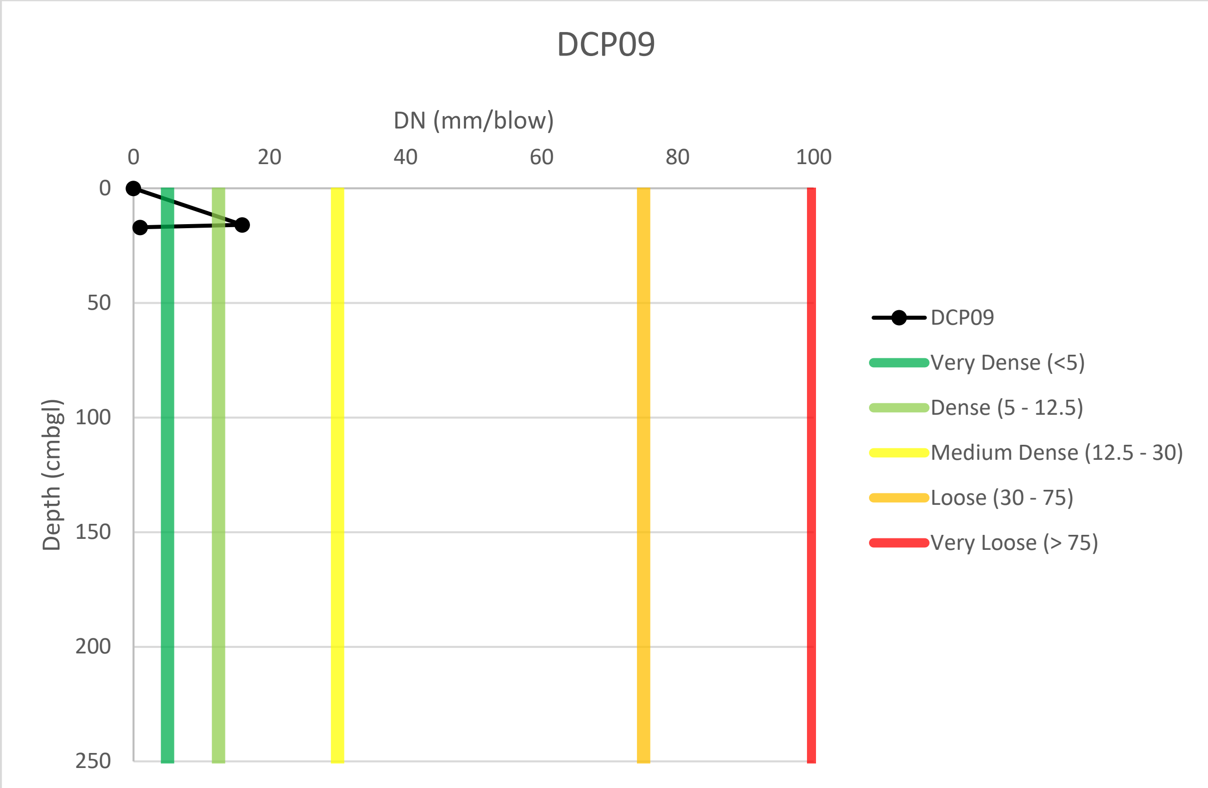

DCP04
DN (mm/blow)
0
20
40
60
80
100
0
50
100
150
200
250
Depth (cmbgl)
DCP04
Very Dense (<5)
Dense (5 - 12.5)
Medium Dense (12.5 - 30)
Loose (30 - 75)
Very Loose (> 75)

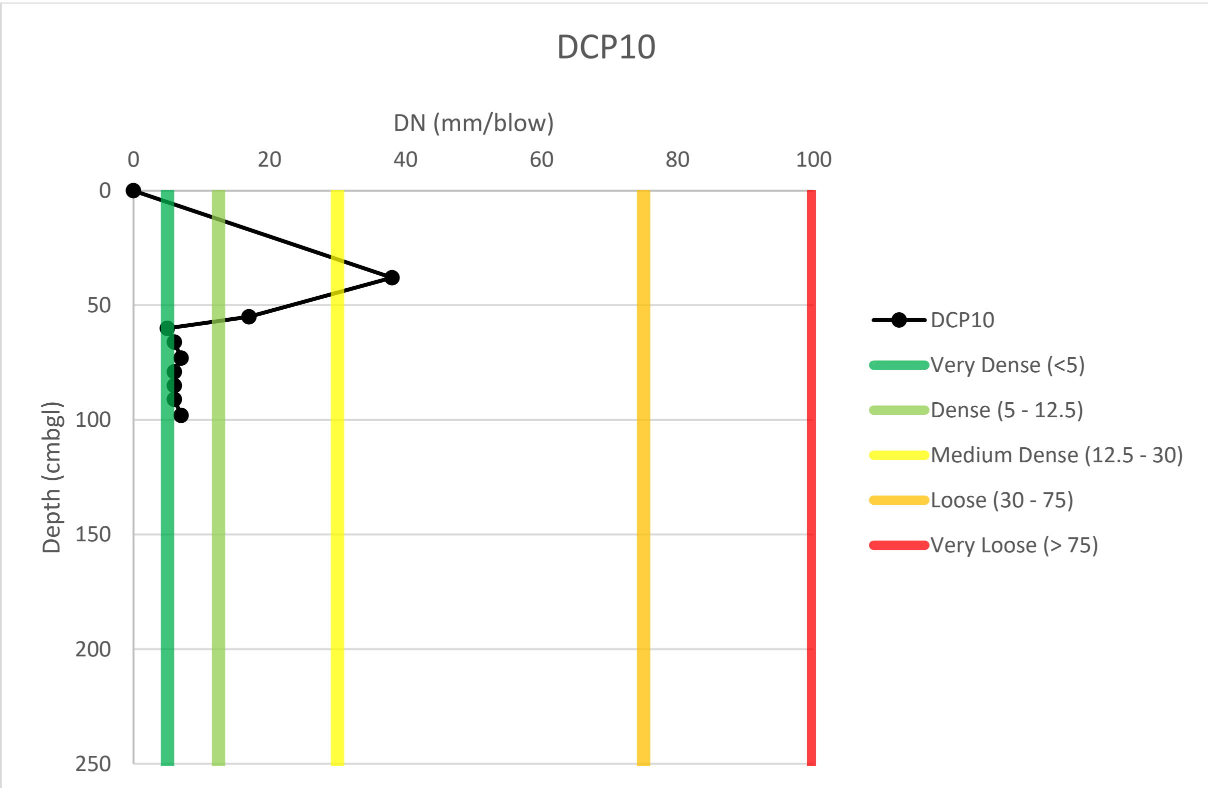

DCP05
DN (mm/blow)
0
20
40
60
80
100
Depth (cmbgl)
0
50
100
150
200
250
DCP05
Very Dense (<5)
Dense (5 - 12.5)
Medium Dense (12.5 - 30)
Loose (30 - 75)
Very Loose (> 75)


DCP06
DN (mm/blow)
0
20
40
60
80
100
Depth (cmbgl)
0
50
100
150
200
250
DCP06
Very Dense (<5)
Dense (5 - 12.5)
Medium Dense (12.5 - 30)
Loose (30 - 75)
Very Loose (> 75)


DCP07
DN (mm/blow)
0
20
40
60
80
100
0
50
100
150
200
250
Depth (cmbgl)
DCP07
Very Dense (<5)
Dense (5 - 12.5)
Medium Dense (12.5 - 30)
Loose (30 - 75)
Very Loose (> 75)


DCP08
DN (mm/blow)
0
20
40
60
80
100
0
50
100
150
200
250
Depth (cmbgl)
DCP08
Very Dense (<5)
Dense (5 - 12.5)
Medium Dense (12.5 - 30)
Loose (30 - 75)
Very Loose (> 75)


DCP09
DN (mm/blow)
0
20
40
60
80
100
0
50
100
150
200
250
Depth (cmbgl)
DCP09
Very Dense (<5)
Dense (5 - 12.5)
Medium Dense (12.5 - 30)
Loose (30 - 75)
Very Loose (> 75)


DCP10
DN (mm/blow)
0
20
40
60
80
100
0
50
100
150
200
250
Depth (cmbgl)
DCP10
Very Dense (<5)
Dense (5 - 12.5)
Medium Dense (12.5 - 30)
Loose (30 - 75)
Very Loose (> 75)

15. APPENDIX C: LABORATORY ANALYSIS

bemlab
www.bemlab.co.za
Part of PathCare

sanas Testing Laboratory T0654

16 Van der Berg Crescent
Gant's Centre
Strand

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

E-Mail admin@bemlab.co.za

P O Box 684
Somerset Mall,
7137

Vat Reg. Nr. 4200161414

CERTIFICATE OF ANALYSES

Report Nr.: **WT003800.DOC**

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

Date received: **10-03-2017**
Order nr.: **1797 A**

Sampled by client

Water Analyses Report

Drinking water evaluation

Origin	Lab. Nr.	pH @ 25°C	EC @ 25°C mS/m	Na mg/l	K mg/l	Ca mg/l	Mg mg/l	Fe mg/l	Cl mg/l	CO_3^{2-} mg/l	HCO_3^- mg/l	SO_4 mg/l	B mg/l	Mn mg/l	Cu mg/l	Zn mg/l	P mg/l	NH_4-N mg/l	NO_3-N mg/l
Flagship Borehole	3800	7.2	241.8	267.5	3.7	195.8	44.6	0.0	259.3		476.0	526	0.52	0.05	<0.02	0.03	0.02	<0.28	7.38
Norm		≥5.0-≤9.7	≤170.0	≤200.0				≤2.0	≤300.0			≤500	≤2.40	≤0.40	≤2.00	≤5.00		≤1.50	≤11.00

Origin	Lab. Nr.	*F mg/l	*TDS mg/l	Alkalinity mg/l	Date Sampled	Temperature at reception (°C)	Date Analysed
Flagship Borehole	3800	0.4	1547.0	391.00	08/03/2017	11.5	13/03/2017
Norm		≤1.5	≤1200.0				

** = Not SANAS Accredited*

Norms according to SANS 241-1:2015.

Statement: The reported results may be applied only to samples received. Any recommendations included with this report are based on the assumption that the samples were representative of the source from which they were taken.

Notes:
To ensure sample integrity, samples are stored only for seven days after release of the report. Thereafter it is disposed of and a fresh sample will be required if additional analyses are requested.
Results marked with "**Not SANAS Accredited**" in this report are not included in the SANAS Schedule of Accreditation for this laboratory. These results relate to the items tested.
This test report shall not be reproduced except in full, without written approval of the laboratory.
CO_3^{2-} analysis only applicable in case of pH > 7.5.
Opinions and interpretations expressed herein are outside the scope of SANAS accreditation.
Refer to website for uncertainty of measurement and referenced methods.
Sample condition: Samples received in good condition.

\\172.17.48.240\bemlab\bemlims\reports\2017\water\word\wt003800.doc **This Laboratory participate in the Agrilasa proficiency and SABS water testing scheme** Page 1 of 2

Dr. Pieter Raath General Manager	**Sandisiwe Mbula** Technical Signatory(Water chemistry)	**16-03-2017** **Date reported**

——————END OF REPORT——————

(last page)

GROUNDWATER AND EARTH SCIENCES
GEOSS
SOUTH AFRICA (Pty) Ltd

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Project no: 2019_11_3761
Phase A
Goue Akker Cemetery Expansion
09 November 2020

Ameesha Sanker
Environmental Assessment Practitioner
Sharples Environmental Services
021 554 5195
ameesha@sescc.net

Vertical burials

Vertical burial would be difficult at this site due to the presence of calcretes and boulders. Vertical holes would most likely be augered to the required depth. In this case the auger will not be able to penetrate the boulders or calcretes.

Yours sincerely,

Charl Muller
Project Hydrogeologist