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TECHNICAL REPORT

Upgrading of the Paballelo Jupiter Cemetery

Dawid Kruiper Municipality- ZF Mgcawu District Municipality

Phase 1 Engineering Geological Site Investigation

Prepared for
EnviroAfrica

Date
31/03/2023

Compiled by
Kevin Coertzen (Pr.Sci.Nat)

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Technical Report

GC22/109A

31 March 2023

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Project Details

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GeoCalibre Geotechnical Consultancy (Pty) Ltd.

Kevin Coertzen
Professional Natural Scientist (400011/17) NHBRC
Competent Person (Barcode 3000179078)
kevin@geocalibre.co.za

33 Denne Avenue
Bainsvlei
Bloemfontein
9301

Approved by:

Kevin Coertzen	Digitally signed: 31/03/2023	31/03/2023
Name	Signature	Date

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1. Project Introduction

1.1. Background

This report describes the results of the Phase 1 Engineering Geological Site Investigation conducted in support of the proposed upgrading- and associated expansion- of the existing Jupiter Cemetery in the Paballelo Settlement. The planned extension traverses the undeveloped north eastern portion of the Remaining Extent of ERF 5530 (RE/5530), situated along the south western perimeter of Paballelo. The site exhibits a rectangular shaped parcel of land with a combined total extent of approximately 3.3 Ha.

The cemetery falls in the boundaries of the Dawid Kruiper Municipality of the greater ZF Mgcawu District Municipality- Northern Cape Province of South Africa.

The detailed investigation was undertaken in order to assess the engineering geological character of the site; primarily focussing on its suitability for the use as a cemetery. The site suitability for use as a cemetery is determined according to the broad criteria as suggested by Fisher (1994) and Hall & Hanbury (1990).

1.2. Terms of Appointment

GeoCalibre Geotechnical Consultancy was appointed by *EnviroAfrica* to compile an in depth professional geotechnical report for the development and its associated attributes.

Procurement Authority: Dawid Kruiper Municipality

Tender reference: TN029/2022 Upgrading Cemeteries at Rietfontein, Askham and Paballelo Jupiter cemetery (Impact study).

The information presented in this document is based on the information supplied by the Client prior to the commencement of the compilation of this technical report; therefore, GeoCalibre Geotechnical Consultancy (Pty) Ltd- shall not be held liable for, and is indemnified against all actions, claims, demands, losses, liabilities, costs, damages and expenses prompted by, or in connection with, inaccurately relayed information pertaining to the site and/or the development.

1.3. GeoCalibre- Company Background and Information

GeoCalibre is a specialist geotechnical consulting firm made up of a team of qualified professional geo-practitioners. The firm was established out of a love for the industry and an urge to define a new calibre of professional consulting.

GeoCalibre uses advanced scientific methods to create accurate and reproducible geotechnical models; successfully guiding the implementation of site-specific design precautionary measures/engineering solutions.

The methodology followed throughout the investigative process accounts for the nature and location of the development as well as adhering to the standards of our practice (SANS and SAICE). Investigations undertaken by GeoCalibre are overseen by suitably qualified Engineering Geologists *professionally registered* (Pr.Sci.Nat) with the South African Council of Natural Scientific Professions (SACNASP)- in accordance with all the relevant and required procedures and legislations. GeoCalibres employees are also members of the South African Institute for Engineering and Environmental Geologists (SAIEG).

1.4. Limitations of the Geotechnical Assessment

The presented geotechnical model is based on a data base of available information, on-site soil profiles and the results from soil laboratory tests. Parcels of land within the developmental area which are free of excavations are modelled through interpolation and extrapolation of known testing locations, to identify problem issues of a geotechnical nature on which this report is based. Variances in soil and rock quality and quantity from those predicted may be encountered during construction and these should be recorded.

The contents of this report are valid as of the date of preparation. However, changes in the condition of the site can occur over time as a result of either natural processes or human activity. If a substantial lapse of time occurs between the submission of our report and the start of work at the site, or if conditions have changed due to natural causes or construction operations at or adjacent to the site, we urge that our report be reviewed to determine the applicability of the conclusions and recommendations considering the changed conditions.

In addition, advancements in the practice of geotechnical engineering and engineering geology and changes in applicable practice codes may affect the validity of this report. Our investigation did not include the evaluation or assessment of any potential environmental hazards or groundwater contamination that may be present.

1.5. Information Sources

- **Geological Map:**
  - Geological Series Map 2820 Upington; scale 1: 250 000 (digital format)
- **Hydrogeological Map:**
  - Hydrogeological Series Map 2718 Upington, scale 1: 500 000 (2001)
  - SADC Groundwater Information Portal (SADC GIP)
  - Electronic Maps of the Water Management Areas and Drainage Regions in South Africa- DWAF [Department of Water Affairs and Forestry]- 1996 and 1999 (www.dwa.gov.za).
- **Topocadastral maps:**
  - 2821 Ac; scale 1:50 000 (digital format)
- **Provided by the Client:**
  - Site boundary
- **Remote Sensing Information:**
  - Google Earth Pro ™
  - Planet GIS
  - Elevation Models
  - Northern Cape Cadastral Land Layer (2022)

- **Cemetery Site Reference Documents**
  - Groundwater resources of the Republic of South Africa (1995, WRC).
  - Guidelines for cemetery site evaluation (Fisher 1994; Hall & Hanbury 1990).
  - WRC Report No. 2449/1/18- Environmental Risk Assessment, Monitoring and Management of Cemeteries (2018).
- **Available geotechnical reports:**
  - Numerous reports from the region compiled by Kevin Coertzen (Pri.Sci.Nat and MSAIEG) and Matthys Dippenaar (PhD).

SANS 10400 and the guideline and specification documents by the South African Institute of Engineering and Environmental Geologists (SAIEG) and South African Institution for Civil Engineers (1997), AEG/SAIEG/SAICE (2002) were consulted.

1.6. Scope of the Investigation

An engineering geological site investigation was be carried out across the site in question in order to assess the nature of the underlying strata as well as model the geomorphological nature of the area as a whole; primarily focussing on its **suitability for the use as a cemetery**.

The site suitability for use as a cemetery is determined according to the broad criteria as suggested by Fisher (1994) and Hall & Hanbury (1990).

The aim of the overall site investigation can be summarised as follows:

- Establishment of a **regional geological**, **geomorphological** and **geo-technical** model for the site.
- To delineate the **succession of strata** (soil and rock) underlying the site; with the identification of problematic **physical, chemical** and **mechanical** characteristics which may influence the development.
- Identify **shallow ground water** features.
- Comment on the **soil permeability** and groundwater vulnerability to pollution.
- To compute the **excavatability properties** of the materials underlying the site.
- Determine the **sidewall stability** and **workability** of the site soils.
- To aid the development moving forward through the formulation of an **accurate geotechnical model** for the site under investigation.

The investigation <u>excludes</u> the following aspects, where applicable:

- Detailed hydrological, hydropedological, hydrogeological, pedological, flood line, or wetland delineation studies.
- Ground and/or surface water sampling/testing
- Undermining investigations
- Geophysical, resistivity, or corrosion studies
- Geo-environmental assessments.
- Township establishment/land rezoning (SANS 634)

1.7. Investigative Methodology

The investigation is undertaken in a number of phases in order to achieve the aims discussed above. The investigative phases are as follows:

- **Phase 1:** Introduction and Regional Assessment of the Site
- **Phase 2:** Geotechnical Analysis
- **Phase 3:** Data Assessment and Report Compilation

1.7.1. Phase 1: Introduction and Regional Assessment of the Site

The collation and evaluation of all the available topographic, geo-morphological and geological data across the investigated site and its' surroundings. This assessment is done through the use of available regional maps and remote sensing images.

This section of the report will include a description and summary of the site's nature, based on existing literature, and is supplemented with the compilation of a series of base maps.

1.7.2. Phase 2: Geotechnical Analysis

Trenching and Sampling

The field work phase of the investigation was conducted by GeoCalibre in February 2023. Test pits were excavated through the use of a TLB-type light mechanical excavator (Bell 315 SK) to a depth of approximately 2.5 m or refusal.

A total of SIX (6) test pits (TP1 to TP6) were excavated during the trenching phase of the investigation. The succession of soil layers exposed within the test pits were logged and a series of detailed photographs were taken of the different layers.

Disturbed and bulk samples were taken of the material deemed to be important to the proposed development. The quantity and locations of samples were governed by the in-situ characteristics of the excavated material.

Laboratory Testing

Standard foundation tests were conducted by Letaba Lab (**SANAS Accredited**) on disturbed soil samples. These tests were undertaken in order to determine the composition of the underlying soils (i.e.: the relative percentages of gravel, sand, silt and clay) and to evaluate the suitability of the materials for the re-use in the proposed construction.

The following tests were conducted:

I. Atterberg limits (Liquid Limit, Plasticity Index and Linear Shrinkage)- (SANS 3001: GR10/11)

II. Particle-size Distribution (SANS 3001: GR1)

III. Maximum Dry Density vs. Optimum Moisture Content (SANS 3001: GR30)

IV. Californian Bearing Ratio versus Compaction Effort (MOD AASHTO method) (SANS 3001: GR40)

V. pH and EC analysis (chemical analysis)

VI. Double hydrometer as an indication of material dispersivity.

1.7.3. Phase 3: Data Assessment and Report Compilation

The investigation concluded with the compilation of a technical report detailing the methodology utilised during the study and the summarised results obtained.

This includes a potential geotechnical evaluation of the site as well as the recommendations with regards to site-specific engineering solutions.

1.8. Development within 1 : 100 year-flood lines

It must be noted that the National Water Act (Act 36 of 1998) states the following regarding development within the 1 : 100 year-flood lines of any stream or river (Thompson, 2006):

- **Section 21(c):** Impeding or diverting the flow of water in watercourses (including alteration of the hydraulic characteristics of flood events) requires licensing according to the Act.
- **Section 21(i):** Any action that may alter the bed, banks, courses or characteristics of watercourses (including flood events) requires licensing according to the Act, including: widening or straightening of the bed or banks of a river to allow for the construction the housing development and altering the course of a river partially or completely (i.e.: river diversion) to be able to use or develop the area where the watercourse originally was.

The National Water Act does not prohibit development within 1 : 100 year-flood lines; however, the Act requires detailed analysis of the effects of the proposed development on the surrounding environment, with special reference to surface and sub-surface water flow.

The Act requires that suitable precautionary measures be implemented to limit the effect within and downstream from the proposed development.

2. Description of the Environment

2.1. Site Location and Description

The **study area** for this investigation is seen to fall within the central portions of the Northern Cape Province of South Africa; situated within the western extent of Upington. Upington is located within the jurisdictive boundary of the Dawid Kruiper Municipality of the greater ZF Mgcawu District Municipality. On a more localised scale, the **study area** in question is situated along the south western perimeter of the **Paballelo Settlement**.

This report describes the results of the Phase 1 Engineering Geological Site Investigation conducted in support of the proposed upgrading- and associated expansion- of the existing **Jupiter Cemetery.** The boundary (red polygon on Image 1 below) of the existing cemetery spans a surface area of approximately **7.2 Ha** and was seen to host numerous surficial and subsurface structures- all of which form part of its daily operations.

The **primary site** for this investigation encompasses the undeveloped parcel of land seen to fall immediately south west of the existing cemetery. This area has been earmarked for the **planned extension** of the existing cemetery, exhibiting a rectangular shaped parcel of land with a combined total extent of approximately **3.3 Ha** (green polygon on Image 1 below). This planned extension traverses the north eastern portion of the Remaining Extent of ERF 5530 (RE/5530), access to which is aided by a network of both gravel and sealed roads across Paballelo- with the condition expected to fluctuate seasonally.

The site for this investigation is located at the following coordinates:

Latitude: 28.435448° S **Longitude:** 21.201747° E

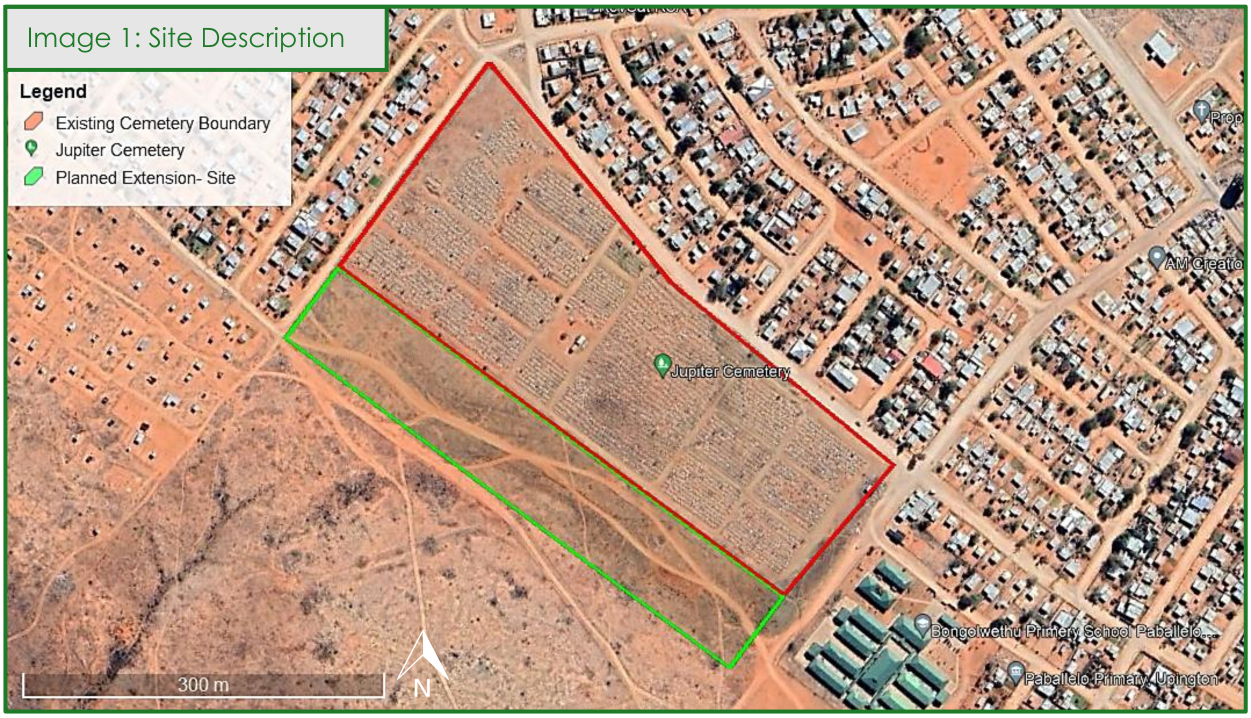


Image 1: Site Description

This parcel of land was investigated to assess its' **suitability** for the use as a cemetery site according to the broad criteria as suggested by Fisher (1994) and Hall & Hanbury (1990). Future developments will encompass the subdivision of this area into various land-use zones i.e., drainage features, infrastructural units, roadways, and services etc. Each of these zones may require their own set of geotechnical assessments and associated engineering solutions.

The surface across most of the planned extension/site was seen to display a **reworked nature** attributed to past and ongoing **human activities** in the region. This reworking was predominantly related to the **township establishment** undertaken in the region, including **anthropogenic** features such as services, roadways/pathways, minor sand mines, scattered heaps of dumped fill, basic earthworks and vegetation depletion/degradation. The exact extent of the existing surface and subsurface infrastructure in this region is not known. These combined actions have not only artificially diversified the topographical nature of the investigated area, but also its geotechnical character.

The photo series below graphically depicts the surficial nature of the site at the time of this study.

2.2. Regional Topography

Topography is based on elevation profiles from the available remote sensing information and basic field observations. This does not substitute land survey data. Topography and regional hydrology (e.g., steep slopes, very flat slopes, defined drainage features, and rapid changes in slope) affect the distribution of ground as it affects the weathering, erosion, transport, and deposition of materials. As such, it provides a valuable indication of possible changes in subsurface ground and water conditions, but also affects the stability of slopes and the direction of surface runoff.

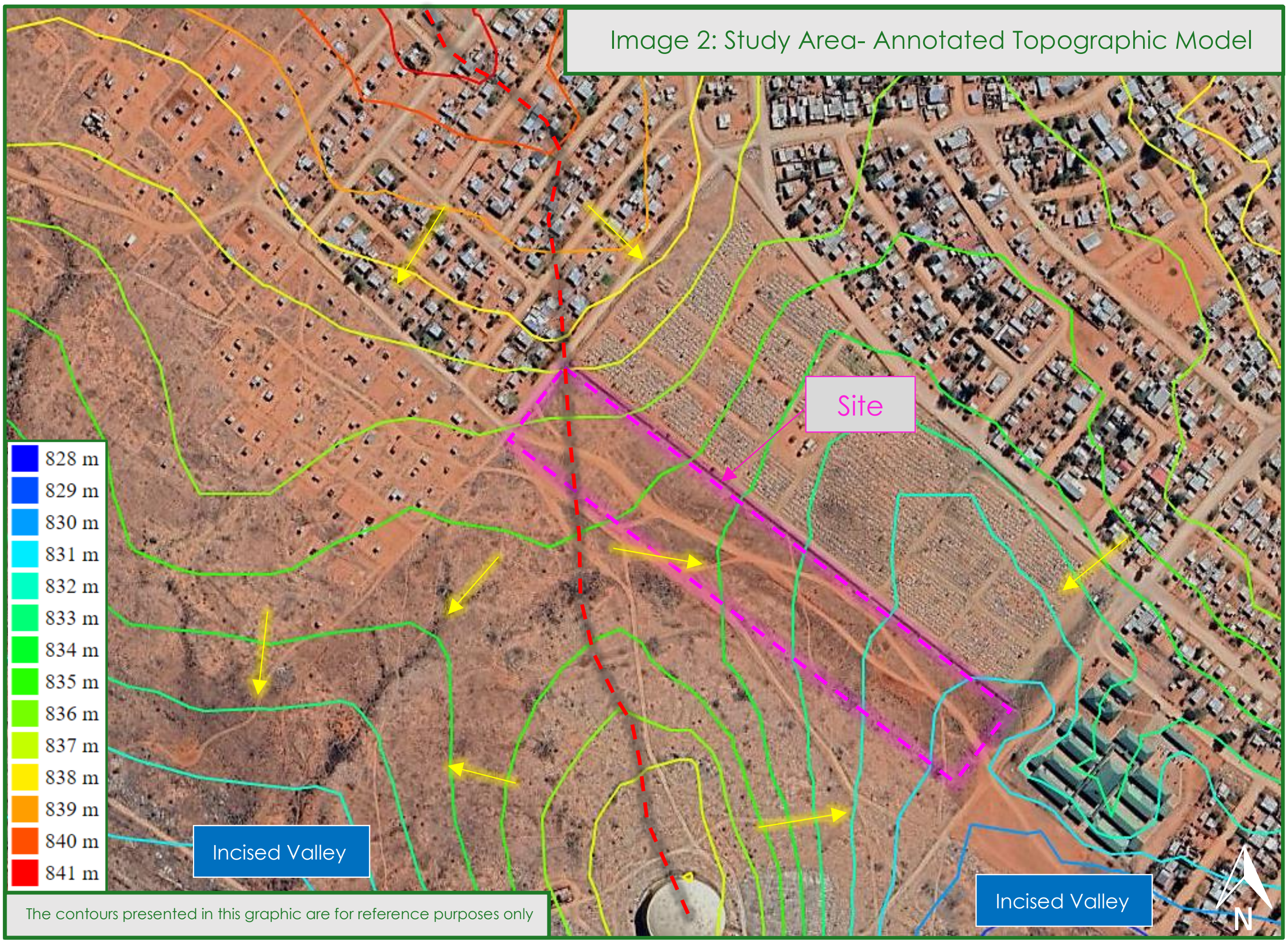
The regional setting is seen to display an **undulating surface morphology** with irregular shaped intermittent ridges separated by low lying incised valley landforms- typical to that of regional gneissic terrains. These rocks form part of an ancient batholithic intrusion which have subsequently been disturbed by various geological processes, resulting in a discontinuous underlying rock mass.

Moreover, this **inherent variability** is exposed through **erosional processes**; with alternating water ways following zones of weakness in the rock mass. The low-lying areas- between alternating ridges- are frequently filled over time with transported sediments of varying shapes and sizes (quaternary aged sediments).

As seen in the topographic model below (Image 2); a **ridge** landform (red/yellow colours) is seen to bisect the study area- with its predicted **crest** annotated as the **red dashed line** on the image. The shape of the crest was seen to fluctuate across the study areas' footprint; however, it generally followed a **N/S orientation**.

Furthermore, this ridge landform forms the **primary watershed feature** for the area, with the natural slopes **diverging** from its central axes (yellow arrows on the image)- **converging** upon the low-lying south eastern and south western portions of the study area. Through the process of **headward erosion**, numerous valley structures have **incised** their way into the high-lying terrain; examples of which are pointed out on the image. Refer to Image 2 below which depicts the topographic nature of the region.

Image 2: Study Area- Annotated Topographic Model



The contours presented in this graphic are for reference purposes only

Although the image depicts a fluctuating geomorphological environment (constant changes in colour), the contours exhibit an irregular shape and the range in elevation is notably low. This serves as evidence for a uniform and continuous surficial morphology.

With reference to Image 2; site is seen to fall primarily along the south eastern side slope of the high-lying terrain. Consequently, the **natural** topographic nature of the site can be characterised by **very gentle slopes** (natural) typically extending from the higher lying areas to the north and north west- towards the low-lying southern to south eastern portions of the site.

Localised slope variances were encountered due to the occurrence of small-scale anomalies- both natural and anthropogenic.

As a whole, the site is seen to host a **very gentle sloping surface morphology**, with average measured slopes of **less than 2 degrees**. The north western portions of the site were seen to display the highest measured elevations of approximately 838 meters above mean sea level (MAMSL); decreasing to an elevation of approximately 831 MAMSL in the far south eastern portions (calculated using Google Earth PRO tm).

Additional to the natural slopes, the area was seen to display an **artificially reworked surficial nature** leading to topographic variability across its extent. In some areas, the reworking of the surface though ongoing human activities has affected the continuity and degree of natural slopes in the area, impacting its' natural drainage character and resulting in the formation of **small-scale topographic anomalies.**

Based on the available information, the development will entail the rehabilitation of the site's surface.

2.3. Regional Drainage

The drainage nature of the study area will mirror its' topographic nature as described in Section 2.3 of this report.

The ridge structure annotated on Image 2 will serve as the primary watershed feature for the region, with the secondary occurrence of minor local divides. The developments orientation in relation to the natural slopes will impact the rate and associated energy of the overland flow. This orientation is expected to fluctuate across the footprint of the contract and will need to be addressed in the design to ensure appropriate fluid dynamics.

Due to the sites' **very gentle sloping nature**, it will drain mainly by means of **low energy surface run-off (sheet-flow);** with storm water flowing from the high lying northern to north western portions of the site, in a southerly to south easterly direction. The very gentle sloping portions of the site will be subjected to elevated degrees of **surface water infiltration** into the underlying soils, rather than rapid surface water flow, accentuating **surface water ponding** and **fluctuating moisture conditions** after prolonged precipitation events.

Surface water ponding- and associated temporary perched water tables- is exacerbated through the occurrence of compacted surfaces and localised depressions (artificial).

The land surface located upslope of the site is seen to exhibit a similar topographic nature. Should excessive infiltration take place across this area; it is predicted that elevated volumes of **shallow ground water throughflow** may occur across the investigated site.

Natural slopes **converge** upon the low-lying south eastern portions of the site. Across these areas, the rate of surface water flow is expected to **increase**- with medium energy surface water flow. **Channelized/converging surface water flow** elevates the risk for **erosion** in these areas.

The **anthropogenic reworking** of the surface will result in **local variations** of surface water flow- both rate and direction. The continuity and manipulation of the topography and associated drainage plays a pivotal role in the longevity and sustainability of the development. Topographic anomalies identified/ measured during the professional survey can be addressed individually in the design, and in so doing eliminating their localised effects.

According to the available information (Topocadastral Map 2821 Ac- Figure 3), there are no **natural** drainage structures traversing the investigated site. There is a non-perennial stream channel mapped to the south west of the site but due to the watershed it is envisaged that the site will drain to the south east rather than the south west. For this reason, the surface runoff will be channelled away artificially due to the presence of infrastructure between the site and major natural drainage systems in the area.

2.4. Regional Climate

The greater Upington area is considered an **arid desert climate** and is classified as **BWh** by the Köppen and Geiger system and **Arid Interior** (SANS 204-2). The area has an average annual temperature of 21.6 °C and an average annual rainfall of **219 mm** with both temperature and rainfall being highest during the summer months.

Climate determines the mode and rate of **weathering**. The effect of climate on the weathering process (i.e., soil formation) is determined by the climatic N value defined by Weinert, 1980. The N-value is calculated as 12 times the January evaporation divided by the annual precipitation and indicates whether an area is predominantly moisture-surplus ($N < 5$) or moisture-deficit ($N > 5$).

The climatic N-value (Weinert, 1980) of the area is deemed to be **more than 20**; therefore, **physical/mechanical disintegration** of the parent rocks in the regional setting is deemed the principal mode of weathering. This mode of weathering favours the formation of an abundance of rocky fragments occurring within the soil matrix. Chemical decomposition will take place but on a lower scale.

2.5. Regional Vegetation and Biotic Activity

The area is within the Nama-Karoo Biome very near to the northern border of the Bushmanland Arid Grassland (NKb) comprising intermingling units of Lower Gariep Broken Veld, Kalahari Karroid Shrubland and Gordonia Duneveld.

At the time of this investigation, the vegetation across the site was comprised predominately of a sparse grass cover with scattered small shrubs/bushes. The natural vegetation had been denuded to varying degrees with areas subject to high foot/traffic volumes being scarred- leaving behind bare topsoils.

The degree of organic material and biotic activity was seen to decrease with an increase in depth. Traces of fine roots were encountered in the site’s subsoils at depth. Additional sub-surface vegetation is predicted to occur in areas hosting shrubs/bushes; however, the extent of these root zones is predicted to diminish with an increased distance from the trunk.

The site was seen to host **biological activity** is the form of localised biological tunnels and nests. The exact depth of the biological tunnelling is not known- with individual tunnels varying in sizes from 5 to 250 mm.

3. Regional Geological and Hydrogeological Setting

3.1. Introduction

The regional geology provides geological context to the anticipated distribution of geological material and how these can affect the distribution of lithologies (rock types) with different chemical, mineralogical, structural, and mechanical properties. Bedrock refers to the rock directly underlying the site and, when exposed to surface, is referred to as outcrop. Bedrock can be underlain by other rock types at shallow depths, and it is usually overlain by residual soils derived of its in-situ weathering and transported soils deposited from other positions.

3.2. Regional Stratigraphic Setting

According to the available geological information (geological series map: 2820 Upington); the study area is underlain by the following geological units (Figure 2):

“Qg”- Gordonia Formation of the Kalahari Group (Qg); red-brown, wind-blown sand and dunes.

“Mj”- Amphibolite; amphibole gneiss; hornblende-biotite, biotite and quartzo-feldspathic gneiss with lenses of calc-silicate rocks from the Jannelspan Formation (previously the Donkieboud Granite Gneiss).

The site is generally blanketed by varying thicknesses of quaternary sediments. Historical development, excavation and/ or levelling practices may have disrupted the surficial materials and variations in soil properties should be accounted for. The likelihood of imported fill and building rubble should also be accounted for in shallow horizons- requiring the rehabilitation of the sites surface prior to the establishment of the cemetery.

Bedrock is confirmed to be highly variable, comprising amphibolite gneiss and calc-silicates of the Jannelspan Formation. Residual and completely weathered horizons are calcified, with layers or zones of hardpan calcrete on the bedrock interface in most of the profiles. The bedrock surface is highly variable across the area. Hardpan calcrete forming on the bedrock also varies greatly in thickness, extent, and continuity, but generally seems to form above the less-weathered bedrock. Variable bedrock topography and lithology (rock type) may influence excavatability and residual soil properties over small distances.

3.2.1. Quaternary Sediments

The vast majority of the site was seen to be blanketed by **alternating sequences** of transported sediments. These young deposits consist of **multiple cycles** of deposition resulting from varying transport mechanisms (a combination of both **aeolian** and **colluvial** deposits).

Based on the available exposures, the site was seen to be blanketed by a fine sediment deposit deemed to be of an aeolian origin. The primary make-up of the **aeolian sediment deposits** include resistant quartz particles along with less resistant micas and feldspars (clays). The less resistant minerals typically weather to a clay which bridges the gaps between the more resistant minerals. These **clay bridges** give high strength to the aeolian soils under dry conditions, however very low strength under wet conditions. As such, these soils frequently undergo **collapse settlement** under an **increase in moisture conditions**.

Transported sediments deemed to be of a **colluvial origin** were seen to generally underly the above-described sands. **Colluvium** is a general name for unconsolidated sediments that have been deposited along or at the base of slopes by either rain wash, sheetwash and/or slow continuous downslope creep.

These combined transported materials have been transported by a natural agent during relatively recent geological times and has not undergone lithification into a sedimentary rock. Furthermore, due to their age and shallow occurrence- these deposits may **lack essential pre-consolidation characteristics**. This may result in additional **movement** upon saturation and loading.

3.2.2. Calcrete

Calcrete may develop as a **groundwater** or **pedogenic** types depending on whether precipitation occurred above a shallow groundwater table or if the carbonate has been carried downwards through the soil by rainwater. Calcretes also typically form in areas with rainfall below 550 mm/y. In some instances, the groundwater table occurs directly below the hardpan horizon.

Calcrete **outcrops/boulders** were scattered across the site- more prolific in areas which have undergone erosion- with the shape, consistency and composition to fluctuate intermittently. The pedogenic layer is in the process of decomposing; for this reason, it was excavatable to a degree- with alternating hard and soft zones. The excavated material was notably **gravelly/cobbly/bouldery** with a fine-grained powdery matrix.

Due to the implemented mode of excavation, the exact thickness and extent of the hardpan calcrete underlying the site is not known, including the material immediately below it.

3.2.3. Gneiss- Jannelspan Formation

Following geological field mapping and the assessment of the exposed soil profiles- the site is modelled to be underlain by bedrock which resembles the physical and geotechnical characteristics of **gneiss**.

The ancient age of the bedrock indicates the likelihood of highly disturbed bedrock including the presence of extensive jointing, hydrothermal veins, and a large degree of weathering. As such, it is predicted that highly variable bedrock, ranging from undisturbed competent rock to highly fractured and weathered incompetent rock, could be encountered.

The **banded character** of the gneiss leads to a variable weathering profile, where less weathered, moderately hard core-stones or bands may occur within a soil-like material. Quartz-rich zones will also undergo less weathering than its mica-rich counterpart. The orientation of these bands (i.e.: vertical or horizontal) may also lead to the occurrence of deeply weathered zones within generally less weathered material.

This undulating weathering profile results in a **variable bedrock topography,** which in turn will negatively affect both the **continuity of excavatability** and the **movement of fluids** across the site.

Furthermore, the mineralogy of granitic/gneissic rocks comprises of more resistant quartz along with less resistant micas and feldspars. The less resistant minerals typically weather to a clay which bridges the gaps between the more resistant minerals. These **clay bridges** give high strength to the residual soils under dry conditions, however low strength under wet conditions. As such, these soils frequently undergo **collapse settlement** under an **increase in moisture.**

3.3. Dolomitic Land

The study area does not reflect any risk for the formation of sinkholes or subsidence's caused by the presence of water-soluble rocks (dolomite or limestone), and as such is **not deemed "*dolomitic land*".**

3.4. Prominent Geological Structures

According to the available information, there are no prominent geological structures traversing the investigated site.

Geological mapping is based on surficial outcrops and aeromagnetic data (regional geophysical data), either of which are not feasible in a geological setting of this nature. The thick sediment deposits blanket geological structures, with their extensive nature and thickness obscuring traceable geophysical patterns. It is recommended that the nature, stability, and extent of these geological structures be investigated for larger more sensitive structures.

3.5. Mineral Deposits

According to the geological maps and accompanied explanation no specific mineral deposits are present on the site. A quarry is visible approximately 600 m north east of the site- the exact extent of mining in this area is not know but seems to be limited to surface operations.

3.6. Seismic Risk

According to **Kijko et al (2003)** the regional seismic hazard in the project area can be defined as **LOW**, exhibiting a 10% probability of a seismic event with a peak ground acceleration of **less than 100 cm/s^2** within a period of 50 years.

3.7. Hydrogeological Setting

It is envisaged that the future development across the site will be serviced by local municipal services, for this reason, no site-specific hydraulic conductivity tests or borehole searches were undertaken.

The findings of a detailed hydrological survey- conducted by a competent specialist- overwrites the information presented below (where applicable).

Based on the SADC Groundwater Information Portal; there are no recent boreholes drilled across or within close proximity to the study area in question. For this reason, the static rest level and chemistry of the ground water cannot be discussed.

The site falls within the Quaternary Catchment Areas D73F, within the greater Orange River Water Management Area.

According to the available hydrogeological information (hydrogeological series map: 2718 Upington, scale 1: 500 000 (2001); the study area is mainly underlain by **Fractured Aquifers** of medium yield with **limited potential (b3)-** an average borehole yield class of between **0.5 to 2.0 median l/s** can be expected**.**

The groundwater quality is deemed to be between 70 and 300 mS/m (electrical conductivity range).

The groundwater is of the $(Ca,Mg)Cl_2$ - $(Ca,Mg)SO_4$ - $(Na,K)Cl$ - $(Na,K)_2SO_4$ hydrochemical types. Total dissolved solids are 500- 1500 mg/l.

Groundwater levels are estimated between 30-50 m with recharge rates of ~1-10 mm per year. Enhanced groundwater recharge, and related localized seepage, may occur within the bedrock surrounding geological features.

The bedrock may act as a lower-permeability material with an irregular bedrock interface causing limited deep percolation or infiltrated water and upward perching. This is a function of the material distribution and, although not inferred to occur given the climatic conditions of the area, it is implied to be more likely to evaporation and lateral movement of moisture in the very shallow horizons, very low local deep percolation and groundwater recharge, and induced surface runoff in intensive rainfall events.

According to the available information, large scale groundwater abstraction does not take place within close proximity to the site.

4. Geotechnical Setting

4.1. Slope Stability and Erosion

Developments of this nature typically include the rehabilitation/remoulding of the site's surface. Emphasis should be placed on surface drainage and storm water control measures to avoid instabilities, focused infiltration, surface water ponding and erosion.

No natural slope instabilities were visible in these areas at the time of the investigation (basic visual inspection). The final layout of the development is not known but based on the natural slopes prior to modification, specialised methods for the stabilisation of cuts into the existing slopes are not deemed necessary. Due to the gradient- cut to fill site preparation is also not expected for structures constructed parallel to the natural slopes.

Addressing the concerns surrounding the **convergence** of surface water upon the low-lying portions of the site- is key to the stability and longevity of the development as a whole (Section 2.2/2.3). Convergent high-energy flow upon the low-lying areas from the surrounding high-lying terrain elevates both the rate and volume of both surface and sub-surface water flow.

The overall **very gentle sloping nature** of the site will aid surface **water infiltration** into the underlying soils, rather than rapid surface water flow, accentuating **surface water ponding** and **fluctuating moisture conditions** after prolonged precipitation events.

Surface water ponding is aggravated through the reworked nature of the surface and low permeability subsoils upon compaction. Infiltrating water then moves laterally through the soft zone of the sub-terrain, converging upon the low-lying areas and associated incised valley landforms.

Surficial stormwater control measures should be implemented across the site to limit the volume of infiltrating fluids. Furthermore, attention must be given to **site contouring** in these areas to ensure an effective gradient is achieved so that ponding does not occur, and the draining of water is efficient to minimise erosion and damage to the construction downslope.

The modification of the sites' surface and the compaction of the topsoil through vehicle and/or foot traffic will result in poor drainage characteristics and the possibility of **high energy** channelized/concentrated surface water flow. This high energy/concentrated runoff will cause **erosion** and appropriate measures must be taken to prevent this from occurring.

The blanketing soils are deemed to be **erodible** classifying as a **SM/SC** type material according to the USCS and tested to be potentially dispersive. **Erosion** was prolific across most of the site- amplified along roads which have been constructed parallel to natural slopes. The shape and extent of the erosional landforms across the site were seen to fluctuate. Should development take place in these areas, zones hosting existing erosional landforms should be treated as areas of concern and dealt with accordingly in the design.

The anthropogenic reworking of the sites surface will result in local variations of surface water flow- both rate and direction. The continuity and manipulation of the topography and associated drainage plays a pivotal role in the longevity and sustainability of the development.

4.2. Trenching

The field work phase of the investigation was conducted by GeoCalibre in February 2023. Test pits were excavated through the use of a TLB-type light mechanical excavator (Bell 315 SK) to a depth of approximately 2.5 m or refusal.

A total of **SIX (6) test pits** (TP1 to TP6) were excavated across the site, at locations chosen on merit to map and model variances in the underlying strata. Test pits were distributed across the designated development area (Figure 5), in accessible locations deemed safe for excavations and free of subsurface infrastructure. The succession of soil layers exposed within the test pits were logged and a series of detailed photographs were taken.

An Engineering Geologist supervised the excavation of the trial pits. The description of soil profiles is done according to SANS 633:2012 and describes the moisture, colour, consistency, structure, (soil) texture and origin. The soil profile is described according to the following parameters:

- **Moisture** dictates the colour and consistency of soils and indicates how and where water moves and the depth to perched water systems.
- **Colour** indicates the oxidizing or reducing state of soils and assist in the identification of minerals in completely weathered to fresh rock.
- **Consistency** is separated between cohesive and granular as the drainage and permeability affects the soil's shear strength.
- **Structure** describes any relict features from rock or soil and those that form through packing, soil and rock structures, seepage, reworking/biotic action.
- **Texture** is the abundance of different grain sizes in soils and is described by means of field test.
- **Origin** is the formation of the soil by means of transport of weathering.

4.3. Generalized Ground Profile

Note: this description is based on field observations and does **not** reflect the results of any laboratory tests.

4.3.1. Introduction

Based on the results from the trenching phase of the investigation; most of the site is blanketed by a variable succession of **aeolian sand**, typically interacted with rounded **calcrete cobbles** and **boulders**. This sandy material was generally underlain by a **variable granular succession** of material deemed to be a **pebble marker**. This intercalated succession of sediments has a **heterogenous composition** and **loosely packed nature**- the variability of which impacts the continuity of the site's geotechnical nature.

Across the majority of the site, the transported materials were typically underlain by an **intercalated successions** of both **calcrete** and **weathered rock**. Bedrock is confirmed to be highly variable, comprising amphibolite gneiss and calc-silicates of the Jannelspan Formation.

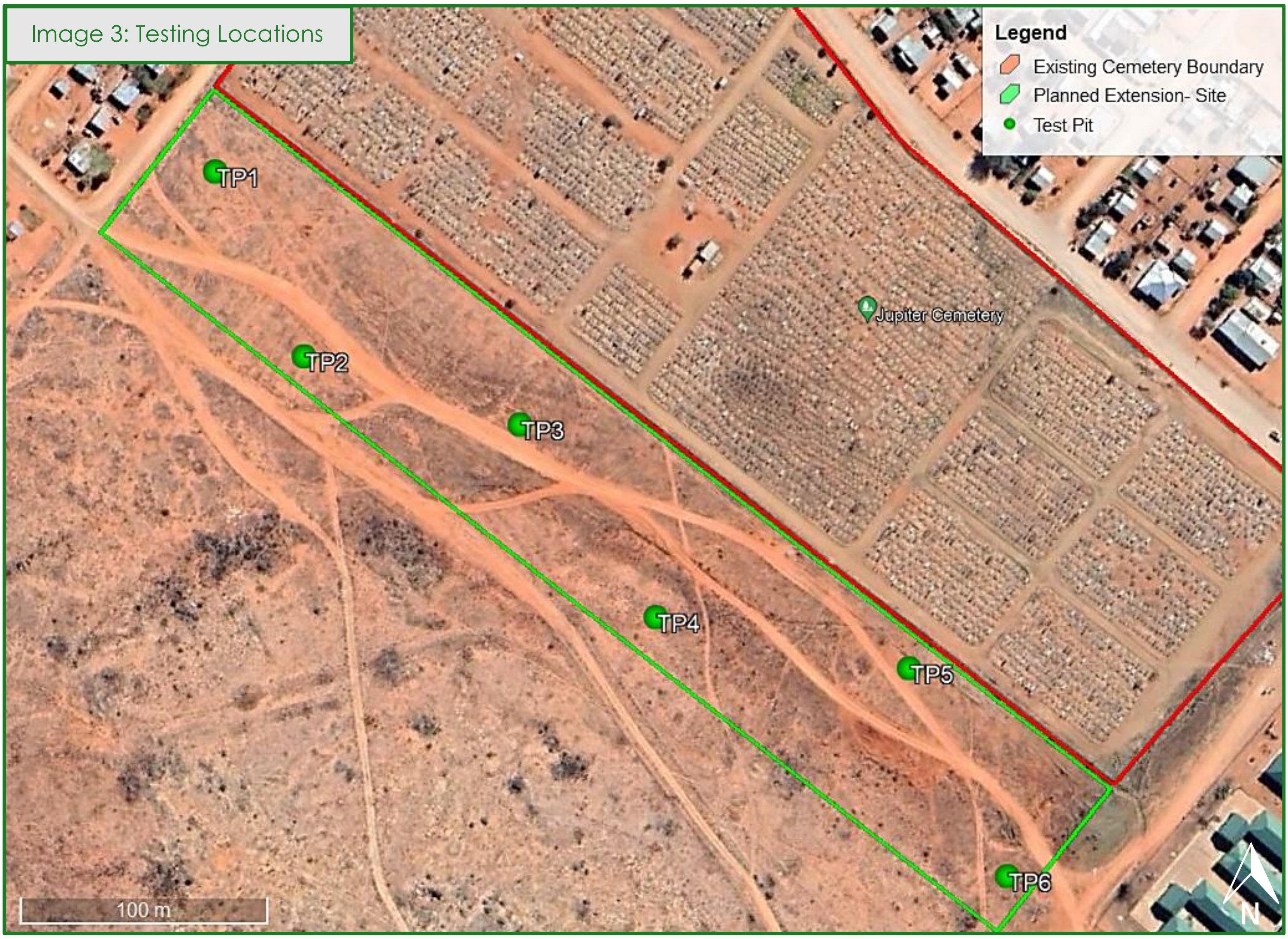
Detailed soil profile logs are included in **Appendix A.**

Refer to **Table 1** overleaf which depicts the summarised ground profile of the site. Following this table, **Image 3** depicts the testing locations across the site.

Table 1: Summarised Ground Profile for the Site

Summarised Ground Profile															
Test Pit	Aeolian Sand			Pebble Marker			Hardpan Calcrete			Completely Weathered Gneiss Bedrock			Excavation Character		
	From	To	Thickness (m)	From	To	Thickness (m)	From	To	Thickness (m)	From	To	Thickness (m)	Test pit depth (m)	Termination Conditions	Termination Material
TP1	0,00	0,18	0,18	0,18	0,37	0,19	0,37	0,94	0,57	-	-	-	0,94	**R**	HC
TP2	0,00	0,17	0,17	0,17	0,51	0,34	-	-	-	0,51	1,15	0,64	1,15	**R**	WGB
TP3	0,00	0,30	0,30	0,30	0,52	0,22	-	-	-	0,52	1,18	0,66	1,18	**R**	WGB
TP4	0,00	0,20	0,20	-	-	-	-	-	-	-	-	-	0,20	**R**	HC
TP5	0,00	0,49	0,49	0,49	0,75	0,26	-	-	-	0,75	1,30	0,55	1,30	**R**	WGB
TP6	0,00	0,42	0,42	0,42	0,90	0,48	-	-	-	-	-	-	0,90	**R**	HC
Data Summary	**Minimum**		0,17	0,17	0,37	0,19	0,37	0,94	0,57	0,51	1,15	0,55	0,20		
	Max		0,49	0,49	0,90	0,48	0,37	0,94	0,57	0,75	1,30	0,66	1,30		
	Average		**0,29**	0,31	0,61	**0,30**	0,37	0,94	**0,57**	0,59	1,21	**0,62**	**0,95**		
Notes:	Thickness refers to the exposed thickness of each soil horizon (meters)														
	All depths displayed in meters (m)														
	Horizon depths displayed in the table are average measured values														
	Excavation conditions: R-Refusal; DE - Difficult Excavation; ES- Excavation Stopped														
	Materials: HC- Hardpan Calcrete; WGB- Weathered Gneissic Bedrock														

Image 3: Testing Locations



Although the section below presents a summary of the generalised soil profile exposed across the site- it should be noted that variability was encountered in numerous individual excavations, amplifying geotechnical variability.

The information presented below is based on point data. Every effort was made during the site investigation to ensure that generally accepted practices of our profession were used in the sub-surface evaluation of the site, and that the sampling and testing was representative of the soil/rock conditions observed on-site. Variances in soil quality and quantity from those predicted may be encountered during construction and these should be recorded.

The ground profiles across the site can be **generally summarised** as follows:

4.3.2. Surficial Uncontrolled Fill- Human Origin

Based on visual inspection, fill materials were seen to blanket the site intermittently. **Uncontrolled fill** was not exposed in any of the excavated test pits (surficial anomalies avoided). This attribute is **expected** to occur numerous times across the site due to the extent of previous and ongoing human activities in the area (i.e., between known testing locations).

These combined successions of fill material were dumped/reworked across the area in an **uncontrolled manner** during past **anthropogenic activities**. Based on exposures, this material displayed a variable composition, thickness and consistency, with the occurrence of **anthropogenic contamination**. The **mechanics** of these deposits are predicted to be **highly variable** as a result of both the variable nature of the particles (both natural and anthropogenic) and the variable interaction between them.

Based on the available information, fill is limited to surficial occurrences and was not encountered in any of the excavated test pits.

As for the removal of relict infrastructure, it is strongly recommended that this material be selectively mined and removed from within the footprint of the proposed development (extent determined by the design engineer).

Due to the localised occurrence and planned rehabilitation of the area, uncontrolled fill materials will not form a dominant part in the site classification.

4.3.3. Transported Sediments

Aeolian Sand- Gordonia Formation

The investigated site was seen to be blanketed by transported material deemed to be of **aeolian origin** (windblown sand), reworked and/or contaminated to varying degrees through past **anthropogenic processes**.

The exposed successions of aeolian sand were seen to be slightly variable, with fluctuations in moisture content, consistency, and colour across the site. Furthermore, due to its age and shallow occurrence- this sandy deposit may **lack** essential pre-consolidation characteristics. This will result in additional consolidation settlement upon saturation and loading.

In general, the aeolian sand was seen to display a low in-situ density, fine-grained nature and a voided fabric; attributes typically associated with **potentially collapsible soils**.

The exposed aeolian sands were generally described as a: *slightly moist; light orangey or light brown, mottled white;* ***loose; pinholed; silty sand*** *with* ***traces*** *of* ***gravel, cobbles*** *and roots; aeolian sand; abundant fine roots; biological activity; minor anthropogenic reworking in the upper extent; traces of calcrete nodules.*

This sediment was present from the **surface** extending to average depths of between **0.17 and 0.49 m** below the existing ground level (E.G.L.)- displaying an **average exposed thickness of 0.29 m**.

The aeolian sand was generally intercalated with the decomposed hardpan calcrete at depth; for this reason, the thickness and composition of the material was seen to fluctuate sporadically across the site.

Pebble Marker

A well-defined **heterogenous deposit** of granular material was generally encountered from below the topsoil. This variable transported material was deemed to be a **pebble marker**. The pebble marker was generally intercalated with nodular calcrete- due to their similar characteristics, these materials have been combined into a single discussion.

A pebble marker is defined as a conglomerate of loose rock and soil material and defines the boundary between transported and residual soil horizons within a natural setting.

This material horizon consisted of a random orientation, shape and size of clasts (heterogeneous composition) with an overall **loosely packed** and **poorly sorted nature**. As a whole, the pebble marker was made up of hard quartz particles- ranging from gravel to cobble sized- **supported by a fine-grained matrix**. It should be noted that the geotechnical nature of this horizon will be a function of the properties of the matrix rather than individual hard particles.

The pebble marker was generally described as a: *slightly moist; light orangey brown, mottled white;* ***loose; matrix supported; sub-angular gravels and cobbles in a matrix of silty sand****; pebble marker; traces of fine roots, traces of* ***calcrete nodules/boulders****;* ***heterogenous composition*** *and* ***poorly sorted nature***.

The pebble marker horizon was encountered from below the aeolian sand extending to depths of between **0.37 and 0.90 m** below E.G.L.- displaying an **average exposed thickness** of **0.30 m.**

The pebble marker was typically seen to share an undulating contact with the underlying rock/pedocrete. As such, the final **thickness** of the pebble marker horizon was seen to **fluctuate sporadically.**

4.3.4. Pedogenic Material- Hardpan Calcrete

The above-described materials were seen to be underlain by a **pedogenic material** deemed to be decomposed **hardpan calcrete.**

Although not profiled as a dominant succession in all the test pits, calcrete was generally present along the **bedrock interface** in most of the excavations, to the point that the exposed extent of the rock mass was deemed to be calcified. Hardpan calcrete forming on the bedrock varies greatly in thickness, extent, and continuity, but generally seems to form above the less-weathered bedrock.

Due to the very gentle sloping nature of the area, the processes of water infiltration and surface water ponding are favoured over surface water run-off (sheet flow). In this case, **pedogenic materials** are predicted to have formed due to **fluctuating moisture conditions-** with the perching of water upon the less permeable rock mass at depth.

The calcrete was variable across the site and present at varying degrees of induration- with single test pits hosting intercalated concretionary and hardpan calcrete. Furthermore, hardpan calcrete outcrops and boulders were present across most of the site- exhibiting a highly undulating g morphology.

Where exposed the **hardpan calcrete** was profiled as; *slightly moist; light greyish brown, **medium dense to dense at base**; **cemented**; **silty calcrete powder** with **abundant calcrete gravel, cobbles and boulder-sized calcrete concretions**; decomposed hardpan calcrete; traces of fine roots; infiltration zones; host material predicted to be residual gneiss.*

The calcrete was made up of hard particles- ranging from gravel/ **cobble** to **boulder sized concretions**- **with a fine-grained matrix**. It should be noted that the geotechnical nature of this horizon will be a function of the properties of both the **matrix** and the **individual hard clasts**.

In test pit TP1, a distinct succession of hardpan calcrete was exposed immediately below the pebble marker- extending to a depth of **0.94 m** below the existing ground level.

With depth, induration increases due to the calcification of the profile, with the in-situ materials becoming harder with depth. The hardpan calcrete was seen to display an undulating nature with a variable composition. **Difficult excavation conditions** were experienced within this horizon- through the use of a TLB-type light mechanical excavator- with ranges in final excavation depths as a result of its undulating nature.

4.3.5. Weathered Gneiss Bedrock- Jannelsepan Formation

Weathered gneissic bedrock was generally encountered below the calcrete.

Notably thin exposures of **weathered bedrock** were encountered across the site. The bedrock displayed a variable depth of occurrence (intercalated with its' pedocrete counterpart)- resulting in the formation of an **undulating bedrock topography-** which in turn will negatively affect both the **continuity of excavatability** and the **movement of fluids** across the site. Due to the limited exposures of the rock mass, coupled with its weathered state, the exact composition of the gneiss could not be defined (i.e., amphibolite, calc-silicates).

Where exposed, the **completely weathered bedrock** was generally described as a: *slightly moist, light greyish brown, blotched white; **dense; coarse grained**; **closely jointed; completely weathered; medium hard rock**; calcified gneiss of the Jannelsepan Formation; infiltration zones; bands of residuum; **gradual transition to less weathered bedrock at the base; calcification on rock faces** and along joints; traces of **cobbles and boulder-sized calcrete concretions;** extensively calcified rock mass.*

The weathered bedrock was encountered from below the pebble marker and/or calcrete, extending to the **final excavation depth** of between **1.15** and **1.30 m** below the E.G.L, with an **average exposed thickness of 0.62 m**.

Due to the hard nature of the bedrock- and in some cases hardpan calcrete- the TLB could only partially rip the intact rock/ pedocrete before undergoing refusal at depths of between **0.20 and 1.30 m E.G.L**; **average excavation depth of ~0.95 m**.

Limited exposures of the rock mass were possible in the excavations undertaken by TLB. Excavations within the weathered rock mass were notably challenging; with exposed material displaying a very dense nature at depth. The rock masses and hardpan pedocrete at depth will require hard rock excavation to unearth. Its' inherent excavatability predicted to fluctuate over short distances because of varying degrees of weathering and spacing of discontinuities. The undulating bedrock topography impacts the continuity of **excavatability** across the site.

4.4. Groundwater and Shallow Seepage

The natural seepage and ground water flow characteristics of the area have been modified/altered to varying degrees during and following township establishment across the region.

This investigation was undertaken in the summer months of the year (summer rainfall region)- with rainfall occurring immediately before the field work phase of the investigation.

Although shallow seepage was not encountered across the site, all of the excavations in natural materials were seen to host discolouration (speckles, mottles and/ or patches) and **pedogenic materials at depth** (varying degrees of calcification). These pedogenic inclusions indicate the periodic occurrence of **fluctuating moisture conditions** after prolonged precipitation events. The evidence for fluctuating moisture conditions was encountered within the **upper 1.0 meter** of the profile. These systems result from soils periodically reaching saturation from infiltrating water, shallow interflow or rising subsurface waters.

The predominant runoff will occur as **sheet wash** following the topography. Waterlogged conditions and/or surface water ponding following prolonged and intense precipitation events are anticipated across the site due to its very gentle sloping nature and anthropogenically induced undulating topography.

During rainfall events the upper granular materials will allow **infiltration** and **lateral** ground water movement. Should infiltration take place, it is predicted that **elevated volumes** of **shallow ground water throughflow** may occur- converging upon the mapped low-lying terrain to the south east.

Infiltrating water is predicted to flow/perch along the **rock-soil interface** at depth, with its flow dynamics dependant on the topography of the rock mass at that point. It is predicted that the rock mass at depth is **practically impervious**. Localised infiltration may take place along extensive joint sets or fractures. Furthermore, the predicted undulating topography of the underlying lithology affects the continuity of the shallow water flow dynamics of the site.

Good site drainage measures, on surface and subsurface, must be implemented to prevent moisture changes, which may add to the development of perched groundwater tables. Drainage precautions are required to minimise infiltration that may lead to perching on the underlying bedrock.

For light structures, damp proofing of floors and foundation walls will be necessary to prevent rising damp due to possible surface water accumulation and life cycle changes. Additional precautions should be implemented for deep structures such as sumps, subsoil tanks, deep pipelines etc.

Grave excavations, foundations and installed services will cause soil density and texture changes which may lead to variations in soil moisture across the site with flow changes and build-up of moisture that may differ from the natural conditions.

Excavations may need to be dewatered following prolonged precipitation events- to be undertaken in line with the prescribed HSE protocols of the development. Furthermore, the influx of water- both surface and sub-surface- into the trenches may drastically impact their stability.

If the site or a portion thereof is situated within the 1:100-year flood lines, or have been delineated as a wetland, it is the prerogative of the Civil Engineer or other suitably experienced specialist to overwrite the geotechnical recommendations for such portions.

4.5. Rock- and/or Pedocrete Outcrops

The site was seen to host scattered and somewhat variable occurrences of **hardpan calcrete outcrops**- coupled with visible **surficial boulders**.

These features are expected to have an impact on the overall **continuity of the excavatability** across the site, with pockets of deeper soils being present between the outcrops (as seen in the local test pits). This variability can take place over a very short distance. Additional shallow anomalies may be masked by blanketing fills.

It is recommended that the exact location and extent of these anomalies be modelled by the surveyor for the amalgamation into the site's earthworks model.

Uncontrolled fill and relict infrastructure may hamper the continuity- similar to that of localised outcrops/boulders.

4.6. Site Excavatability

4.6.1. Introduction and Description

Excavatability is a measure of material to be excavated/dug/mined with conventional excavation equipment such as a bulldozer with rippers, mechanical excavator or other grading equipment.

In rock masses, this characteristic is governed by the shear strength of both the intact rock and the discontinuities separating them. Fluctuating excavation conditions correlate to the depth, spacing and degree of fracturing of the underlying rock mass.

The **average** excavation depth across the site was approximately **0.95 m.**

Profiles were described in trenches excavated by means of TLB-type light mechanical excavator. End of hole conditions were typically due to refusal on either hardpan calcrete or weathered bedrock at depth. The majority of the test pits displayed a **range of excavation depths** linking to the **undulating topography of the hardpan calcrete/weathered bedrock at depth**.

Test pit TP4 was the **shallowest test pit**, excavated to a depth of **0.20 m** below E.G.L before undergoing refusal in hardpan calcrete. Both test pits TP1 and TP6 refused at depths of ~0.9 m- with the remaining test pits excavated across the site reaching final depths exceeding 1.0 m, but less than 1.4m.

Boulders and undulating gneissic bedrock can be expected in bulk excavations, as encountered prolifically in sites in the region.

4.6.2. Excavation Notes- Weathered Gneissic Bedrock and Hardpan Calcrete

Where deep excavations are undertaken for graves, services, foundations or to modify the sites surface- the excavation properties of the hardpan calcrete and gneissic rock mass need to be considered.

Fluctuating excavation conditions correlate to the depth, spacing and degree of fracturing of the underlying rock masses.

The physical and mineralogical nature of **gneiss-** coupled with the varying degrees of induration- has led to the formation of a **highly undulating bedrock topography**. These sub-surface features are expected to have an impact on the overall **continuity of the excavatability** across the site, with pockets of deeper soils being present between the shallow pinnacles of rock. In a gneissic terrain, this variability can take place over a **very short distance**.

Furthermore, excavations within the hardpan pedocrete and weathered rock mass were notably challenging; with exposed material displaying a dense/very dense nature at depth.

The rock masses and hardpan pedocrete at depth will require **hard rock excavation** to unearth.

The final layout of the development is not known (including associated earthworks); however, allowance should be made for HARD Excavation, typically requiring blasting, wedge and split, chemical fracturing and/or heavy pecking -the exact method of which is dependent on the required final working levels, available equipment and the local environment.

Blasting shallow holes in bedrock or other hard material with no overburden to act as a damping blanket will create fly rock which could be problematic. If blasting is to be undertaken, it should be designed by and conducted under the supervision of a blasting specialist and advice should be sought as to whether or not it is best to drill and blast through the overburden or whether small areas of this rock can be blasted post-stripping of the overburden provided that appropriate measures such as the use of blast mats are adopted.

A provisional volume of material can be determined using the information from the trial pits and the final earthworks model. The calculated volume should also include excavation for sumps and deep services.

4.7. Cutting/Trench Stability

Across most of the site, excavations generally remained **stable** for a period of at least 1 hour with little or no over break or collapse occurring. Localised sidewall instabilities are predicted in areas hosting thick fills and/or relict infrastructure. Should bulk excavations be conducted in these portions they will need to be shored or adequately sloped/modified to limit failure.

It is envisaged that temporary shallow trenches and/or cuttings to depths of up to 1.5 m will remain stable (where dry)- the stability of which can be assessed periodically. No loading of the temporary slopes by machinery, equipment, excavated soil or materials shall be allowed. Any excavation deeper than 1,5 mbgl must be stabilised as prescribed in the relevant act.

Should the sites surface need to be extensively modified for the development, permanent cut slopes should be stabilised, or the geometry adequately modified to ensure long-term stability.

Although it is predicted that fresh exposures in bedrock/pedocrete exhibit stable conditions in near vertical cuts (depending on orientation), it is recommended that excavations be adequately sloped (approximately 60 to 75 degrees) or stabilised to reduce the risk of instabilities. Instability is predicted to be in the form of localised rock block failure, necessitating the removal or stabilisation of unstable rock blocks.

The following attributes should be considered when formulating the construction documentation:

- All excavations should be inspected by a competent person (engineer or geo-professional with relevant training and experience) at least once a day and following any periods of rain or any long periods where no work has taken place.
- The provisions of the Occupational Health and Safety Act of 1993 and Construction Regulations of 2014 must be followed in the excavations and workings therein. In terms of Section 11 of the Construction Regulations the contractor must appoint an excavation supervisor.
- Sheet wash from stormwater or other waters shall be prevented from running over the trench/pit flanks.
- Instability problems may be particularly problematic where the following ground conditions are encountered.
    - Thick occurrences of uncontrolled fill and relict infrastructure.
    - Perched water tables/seepage and moist to wet material (during rainy season).
- Trenches/box-cuts may need to be dewatered between and following prolonged precipitation events because of water temporarily perching upon the underlaying less permeable materials at depth.
- Existing Services: damages to existing wet services and/or existing leaking services will result in surface water ponding and unstable trench sidewall conditions; drastically hampering safety, terrain mobility and site excavatability.

4.8. Erodibility of Material- Backfilled Excavations

The following are findings on the relationships between different properties and erodibility parameters of soil:

- An increase in **percentage clay** leads to an **increase** in **erosion resistance**.
- An increase in **PI** in general leads to an **increase** in **erosion resistance** (there are few exceptions).
- Increase in **Plastic Limit** leads to an **increase** in **erosion resistance** in fine grained soils.
- **Steep slopes** increase flow velocities/volumes and as such **decrease erosion resistance**.
- **Dispersive** soils (typical to those of regional colluviums) tend to be less erosion resistant.

Inadequate temporary erosion and drainage control measures can result in severe damage to backfilled excavations. Recently backfilled excavations are especially vulnerable to both surface and sub-surface (tunnel) erosion because of the low shear strength of the recently disturbed soil, even if some degree of compaction has been applied to the backfill.

Based on the above considerations combined with the presence of erosion gullies etc. it can be noted that the soils blanketing the site are prone to erosion. The following can be done to **minimize erosion** of problematic soils during and following grave excavations.

- Minimise surface wash towards the /excavations graves from upslope areas.
- Drainage measures along constructed internal roads.
- Ensure that trenches are backfilled to the equivalent level of the surrounding terrain.
- The predicted collapsible and compressible natural materials will reduce in volume following over-excavation and backfilling.
- A maintenance regime should be put in place to periodically assess the nature of the grave sites for a set period following their establishment. Areas showing visible deformation should be modified accordingly, in order to avoid further deformation and/or permanent damage.

4.9. Engineering and Material Characteristics

4.9.1. Introduction and Sampling

The engineering material properties of the various sampled soil horizons were measured in laboratory conditions as per accredited testing procedures.

Standard foundation indicator, compaction tests and soil chemistry tests were conducted by Letaba Lab Bloemfontein (**SANAS Accredited**) on disturbed and bulk soil samples. These tests were undertaken in order to determine the composition of the underlying soils (i.e.: the relative percentages of gravel, sand, silt and clay) and to evaluate the suitability of the materials for the re-use in the proposed construction.

Full laboratory test results are included in **Appendix B**.

The sampling which took place during this investigation was based on both the in-situ geotechnical properties of the exposed soil horizons as well as the nature of the development. Problem soil horizons were accurately sampled where encountered (i.e., collapsible/expansive soils).

This section focuses on the identification and assessment of the soil properties which will have an effect on the proposed construction.

The sampling process **excluded** the following inclusions:

- Oversized particles
- Organic materials
- Anthropogenic contamination

This section focuses on the identification and assessment of the soil properties which will have an effect on the **establishment of a cemetery site.** Attributes such as material re-usability, stabilisation properties, pipeline bedding/ backfill, and specialist soil mechanics did not form part of the scope of this investigation.

4.9.2. Bulk and Disturbed Samples- Laboratory Test Results

The soil testing which was conducted across the site can be subdivided into three broad categories, as follows:

- **Foundation Indictor Tests**

  Atterberg limits (Liquid Limit, Plasticity Index and Linear Shrinkage) and Particle-size Distribution

- **Compaction Tests**

  Maximum Dry Density versus Optimum Moisture Content and Californian Bearing Ratio versus Compaction Effort (MOD AASHTO method)

- **Soil Chemistry Tests**

  pH and EC analysis (corrosivity) as well as double hydrometers as an indication of material dispersivity.

The results presented in the summaries to follow are as received from the accredited testing facility. Although the summaries have been annotated **no** amendments have been made to the results themselves.

The tables to follow summarise the results of the soil tests conducted on the various sampled materials.

Table 2: Foundation Indictor Test Results

Foundation Indictor Test Results																				
				Particle Size Distribution								Atterberg Limits			Grading Characteristics		Material Classification		
				Standard Sieves Cumulative percentage passing				Hydrometer Result Soil Mortar Analysis % of material <0,425 mm											
Sample Number	Test Pit	Depth (m)	Sampled Material	37,5 mm	20 mm	2,00 mm	0,425 mm	% Coarse Sand	% Fine Sand	% Silt	% Clay	LL	PI	LS	Grading Modulus	Effective Size (D_{10})	TRB	USC	Heave
9655/1	TP 1	0.37-0.94	Hardpan Calcrete	100	100	38	29	23,4	46,3	10,1	8,8	36	11	5,3	2,2	0,066	A-2-6	SM/SC	**LOW**
9655/2	TP 2	0.17-0.51	Pebble Marker	100	100	88	69	20,9	58,3	8,1	4,5	-	SP	0,8	1,2	0,036	A-2-4	SM	**LOW**
9655/3	TP 3	0.00-0.30	Aeolain Sand	100	100	89	71	20,0	61,5	4,9	2,6	-	NP	0,0	1,2	0,058	A-2-4	SM	**LOW**
9655/4	TP 5	0.00-0.75	Mixed Sample: Aeolain Sand and Pebble Marker	100	100	58	48	18,5	60,1	7,1	3,0	-	SP	1,1	1,8	0,064	A-1-b	SM	**LOW**
9655/5	TP 6	0.00-0.42	Aeolain Sand	100	98	77	70	8,3	12,5	31,0	34,0	35	18	9,0	0,9	0,002	A-6	CL	**MEDIUM**
9655/6	TP 6	0.42-0.90	Pebble Marker	100	96	57	44	22,5	55,1	6,0	6,7	21	4	2,0	1,9	0,061	A-1-b	SM/SC	**LOW**
Notes	1. Hydrometer test and Atterberg Limits undertaken on material passing the <0,425 mm sieve 2. Atterberg Limits: Liquid Limit (LL), Plasticity Index weighted (PI), Linear Shrinkage (LS). 3. Heave: Potential expansiveness (acc. Van Der Merwe, 1964). 4. Effective Size (D10) values presented as received from Letaba Lab. Where D10 values are lower than the measured 2 micron reading an inferred value of 0,002 is used for reference purposes.																		

Table 3: Compaction Test Results

Compaction Test Results										
Sample Number	Test Pit	Depth (m)	Sampled Material	Compaction Test Results		Measured CBR Values			Material Classification	
				MDD (kg/m^3)	OMC (%)	90%	93%	100%	COLTO	Material re-usage potential
9655/1	TP 1	0.37-0.94	Hardpan Calcrete	1921	10,2	14	21	54	G6	GOOD
9655/4	TP 5	0.00-0.75	Mixed Sample: Aeolain Sand and Pebble Marker	2120	8,1	20	24	38	G6	GOOD

Notes:
1. Compaction Test Results; percentage compaction of MDD (MOD AASTHO Method); CBR of 13.344 kN
2. MDD- Maximum Dry Density; OMC- Optimum Moisture Content
3. Material classification and re-usage potential based on the COLTO classification system

Table 4: Soil Chemistry Test Results

Soil Chemistry Test Results								
Sample Number	Test Pit	Depth (m)	Sampled Material	Corrosivity Indicators				Dispersivity Indicators
				Profiled In-Situ Moisture	% Clay	pH	EC (S/m)	Double Hydrometer Results (%)
9655/3	TP 3	0.00-0.30	Aeolain Sand	Slightly Moist	2,6	7	0,016	67
9655/4	TP 5	0.00-0.75	Mixed Sample: Aeolain Sand and Pebble Marker	Slightly Moist	3,0	7,2	0,017	68

Notes:
1. Material as per soil profile description.
2. Moisture as per soil profile description or natural moisture content.
3. Percentage clay, pH, EC (electrical Conductivity) and double hydrometer as per laboratory results.

4.9.3. Laboratory Test Results- Summary and Discussion

The results from the **laboratory testing phase** indicate the following:

- The sampled materials grade as **fine/coarse sand** with a **grading modulus** ranging between **0.9 and 2.2**.
  - Hardpan calcrete sampled in test pit TP1 display the highest GM of 2.2, with the lowest GM of 0.9 measured for the aeolian sand sampled from test pit TP6.
- The soils exhibit a **low to medium plasticity**, low to medium linear shrinkage values and an overall **LOW to MEDIUM potential for heave** (acc. Van Der Merwe, 1964).
  - The measured **PI values** range between **NP and 18**.
  - The highest PI of 18 and associated "MEDIUM" heave classification was recorded in the aeolian sand sampled in test pit TP6.
  - The majority of the on-site materials exhibit a low plasticity.
- Clay percentages are low to moderate in the sites subsoil, which may be sufficient to form clay bridges between grains that are typical of a **collapsible grain structure**.

- Typical Unified Soil Classes (USC) is **SM** (silty sand) and **SC** (clayey sand), with the localised occurrence of **CL** (low plasticity clay).
- Typical TRB Class is **A-1-b, A-6, A-2-4 and A-2-6.**
- Drainage will be fair to practically impervious and a low compressibility can be expected once compacted.
- The samples reacted **WELL** to compaction**:**
    - These materials classified as a **G6- type** material according to the COLTO classification system.
    - The compacted samples displayed a calculated **remoulded bearing capacity** of between approximately **145 and 160 kPa** @ 93 % MOD AASHTO with a Factor of Safety of 1.5.
    - As such, these granular materials are deemed suitable for the use in the proposed construction and associated engineered fill and road layer works (suitability based on the engineer's design).
    - The material should provide good fill for use as selected layers and even subbase layers in road construction.
    - Basecourse materials for roads and concrete gravels will have to be imported for construction purposes.
- Some of the soil samples were tested for pH and electrical conductivity. These results and other indicators of aggressiveness to steel and concrete (corrosivity) are shown in Table 4.
    - EC values are moderate to high coupled with slightly alkaline pH values, low clay contents, and evidence of fluctuating moisture conditions throughout the entire profiles.
    - Based on the measured **EC results**; the granular material underlying the site is deemed to be **mildly corrosive** to steel and concrete.
- Based on the double hydrometer results the material underlying the site is deemed to be **dispersive**.

4.9.4. Inferred Material Properties- Unified Soil Classification System

The Unified Soil Classification System (USCS) is a soil classification system used in engineering and geology to describe the texture and grain size of a soil. The classification system can be applied to most unconsolidated materials and is represented by a two-letter symbol. The demarcated result can be used to infer a wide range of soil properties and characteristics.

As part of this assessment a number of engineering material properties can be **inferred** utilising the databank of geo-parameters aligned with the calculated USC of any give material- to be measured in follow-up studies where required.

Although the various samples were extracted from materials of different origins (i.e., alluvium, colluvium, residuum)- they can all be grouped together into a **single summary** due to their similar USC classifications.

The materials sampled across the most of the site classified as **SM** and **SC**.

The following inferred paraments/attributes can be used in **preliminary designs**:

- Fine-grained SM and SC soils are deemed to be erodible.
- Typical CBR values range between 10 and 20 % and can go up to 40% in SM materials.
- Generally regarded as average fill material.
- Average/fair road subgrade.
- Poor (SM) and good (SC) for the use in untreated roads.
- Good and mostly good for trenching (may require shoring).
- Drainage will be fair to practically impervious once compacted.
- Low compressibility once compacted.
- Reasonably stable embankment material.
- Typical values of soil friction angle (degrees):
    - SC Soils: 30 to 40
    - SM Soils: 27 to 34
- Typical values of soil cohesion (kPa)
    - SC Soils: 5
    - SM Soil: 20 to 50
- Typical values of soil permeability (m/s)
    - SC Soils: 5.5x10-9 to 5.5x10-6
    - SM Soils: 1x10-8 to 5x10-6

4.10. Permeability Analysis

4.10.1. Introduction

The permeability of a soil and/or rock is the capacity of the body to allow water to pass through it. Soil permeability is usually represented by the coefficient of permeability (k), where k is the rate of flow of water per unit area of soil when under a unit hydraulic gradient. Hydraulic conductivity defines how easily pore fluid escapes from the compacted pore space.

Soil is a very complex medium. To assess the permeability/hydraulic conductivity of such a composite material various assumptions are made. Fundamentally, soil permeability can be visualized as a skeleton of practically impermeable soil grains in contact with each other, leaving a complex network of mostly interconnected pore space between them. The notion of soils being a "porous medium" is the core concept in the assessment of soil permeability.

A detailed study regarding the permeability of the site was not conducted (i.e., pump tests, lugeon tests in the rock mass, piezometers and large scale infiltrometer testing). The presented results should therefore only be used as estimates of permeability.

Undisturbed sample extraction was not possible/feasible across the site due to the shallow occurrence of granular materials, pedocretes and weathered rock. For this reason, the hydraulic conductivity measured from falling/constant head permeability tests has been omitted from this analysis.

Various methods can be used to estimated soil permeability, including laboratory tests and numerous empirical correlations.

In this report, the following versions of permeability estimates are discussed:

- **Calculated Values**- calculated permeability estimates encompass results derived from **empirical formulae** and make use of attributes calculated during the testing of disturbed soil samples.
- **Inferred Values-** inferred permeability data is acquired from geotechnical **literature** and available **databases.**

The presented *Permeability Description/Classification* is extracted from the graphic included in the Appendix C- Site Classification Reference Tables.

4.10.2. Soil Permeability

1. **Calculated Permeability Values**

Calculated permeability estimates can be derived using **Hazen's rule.** This **empirical formula** correlates the **hydraulic conductivity** of the soil with its **particle size distribution** (measured in the lab during disturbed soil testing). The original correlation was not intended to be used for soil but has since been adopted by geotechnical practitioners. The relationship is only applicable to granular soils but can be used on cohesive soils as a basic estimate of permeability.

Calculated effective diameter- referred to as the "D10 value"- is calculated assuming a linear soil size relationship from the 2-micron sieve, as depicted on the soil test results obtained from Letaba Lab.

From there, due to the nature of this assessment, the **Hazen's correlation factor (C)** is assumed to be an **average of 1,0**- rather than using a range of possible factors. This can be modified where required by the design team.

The **calculated** permeability estimates are presented in **Table 5** overleaf.

2. **Inferred Permeability Values**

Inferred permeability data for the soils underlying the site can be acquired from geotechnical literature and available databases. The following permeability data is available on geotechdata.info:

Typical values of **soil permeability (m/s):** SC Soils: 5.5×10^{-9} to 5.5×10^{-6} and SM Soils: 1×10^{-8} to 5×10^{-6}

The combined **INFERRED** and **CALCULATED** permeability values are presented in **Table 5** overleaf, followed by **Table 6** which models the **average combined permeability description/classification** for the sites' sub-soils.

Table 5: Hydraulic Conductivity Analysis- Inferred and Calculated Attributes

Hydraulic Conductivity Analysis- Inferred and Calculated Attributes									
Sample Details				Inferred Permeability Unified Soil Classification System			Calculated Permeability Hazen's Correlation Rule		
Sample Number	Test Pit	Sample Depth (m)	Sampled Material	Unified Soil Classification (USC)	Inferred Permeability (m/s) Lower	Inferred Permeability (m/s) Upper	Calculated effective size (mm) "D10 value"	Calculated Average Permeability (m/s)	Calculated Average Permeability (m/day)
9655/1	TP 1	0.37-0.94	Hardpan Calcrete	SM/SC	5,50E-09	5,00E-06	6,6E-02	4,36E-05	3,76E+00
9655/2	TP 2	0.17-0.51	Pebble Marker	SM	1,00E-08	5,00E-06	3,6E-02	1,30E-05	1,12E+00
9655/3	TP 3	0.00-0.30	Aeolain Sand	SM	1,00E-08	5,00E-06	5,8E-02	3,36E-05	2,91E+00
9655/4	TP 5	0.00-0.75	Mixed Sample: Aeolain Sand and Pebble Marker	SM	1,00E-08	5,00E-06	6,4E-02	4,10E-05	3,54E+00
9655/5	TP 6	0.00-0.42	Aeolain Sand	CL	5,00E-10	5,00E-08	2,0E-03	4,00E-08	3,46E-03
9655/6	TP 6	0.42-0.90	Pebble Marker	SM/SC	5,50E-09	5,00E-06	6,1E-02	3,72E-05	3,21E+00
Data Summary			**Minimum**	**Generally SM**	5,00E-10	5,00E-08	2,00E-03	4,00E-08	3,46E-03
			Maximum		1,00E-08	5,00E-06	6,60E-02	4,36E-05	3,76E+00
			Average		**6,92E-09**	**4,18E-06**	4,78E-02	**2,81E-05**	2,42E+00

Table 6: Combined Permeability Description/Classification

Combined Permeability Description/Classification					
Attribute		**Combined Average Value**	**Classification of Permeability** (Terzaghi, Peck 1967)	**Characteristics of Flow** (Head, 1985)	**Character of Permeability** (Pazdro, Kozerski 1990)
Inferred Permeability (m/s)	Lower	**6,92E-09**	Very small to practically impermeable	Practically impermeable	Impermeable
	Upper	**4,18E-06**	Small	Good to weak	Weak to semi-permeable
Calculated Permeability (m/s)		**2,81E-05**	Average to small	Good	Average to weak

4.10.3. Inferred Rock Mass Permeability

The mechanical properties of a rock mass are dependant not only on the properties of the intact rock (Uniaxial Compressive Strength etc.) but also on the properties of the discontinuities (spacing, orientation, continuity, etc.).

The various intact rock and discontinuity properties will each have their own impact on the overall geotechnical properties of the rock mass, such as the permeability and strength.

Rock permeability can be described as the ability for water to flow through the interconnected pores (primary permeability) and fractures (secondary permeability) of the rock medium. Water may flow through the interconnected pores of the rock medium or/and along discontinuities in the rock such as joints and faults. Primary permeability is negligible compared to secondary permeability in a highly fractured rock.

The secondary permeability is governed by the number and aperture of discontinuities. These properties are further depended on other factors such as the vertical stress applied with depth and the interconnectivity of the fractures. As vertical stress increases with depth, fractures are theoretically sealed resulting in only primary permeability.

Within jointed rock masses, permeability is typical dominated by the secondary permeability, with the majority of flow occurring along discontinuities (joints, shear zones, etc). As such, the properties of the discontinuities (aperture, spacing, persistence, etc) have a significant impact on the associated permeability of the rock mass.

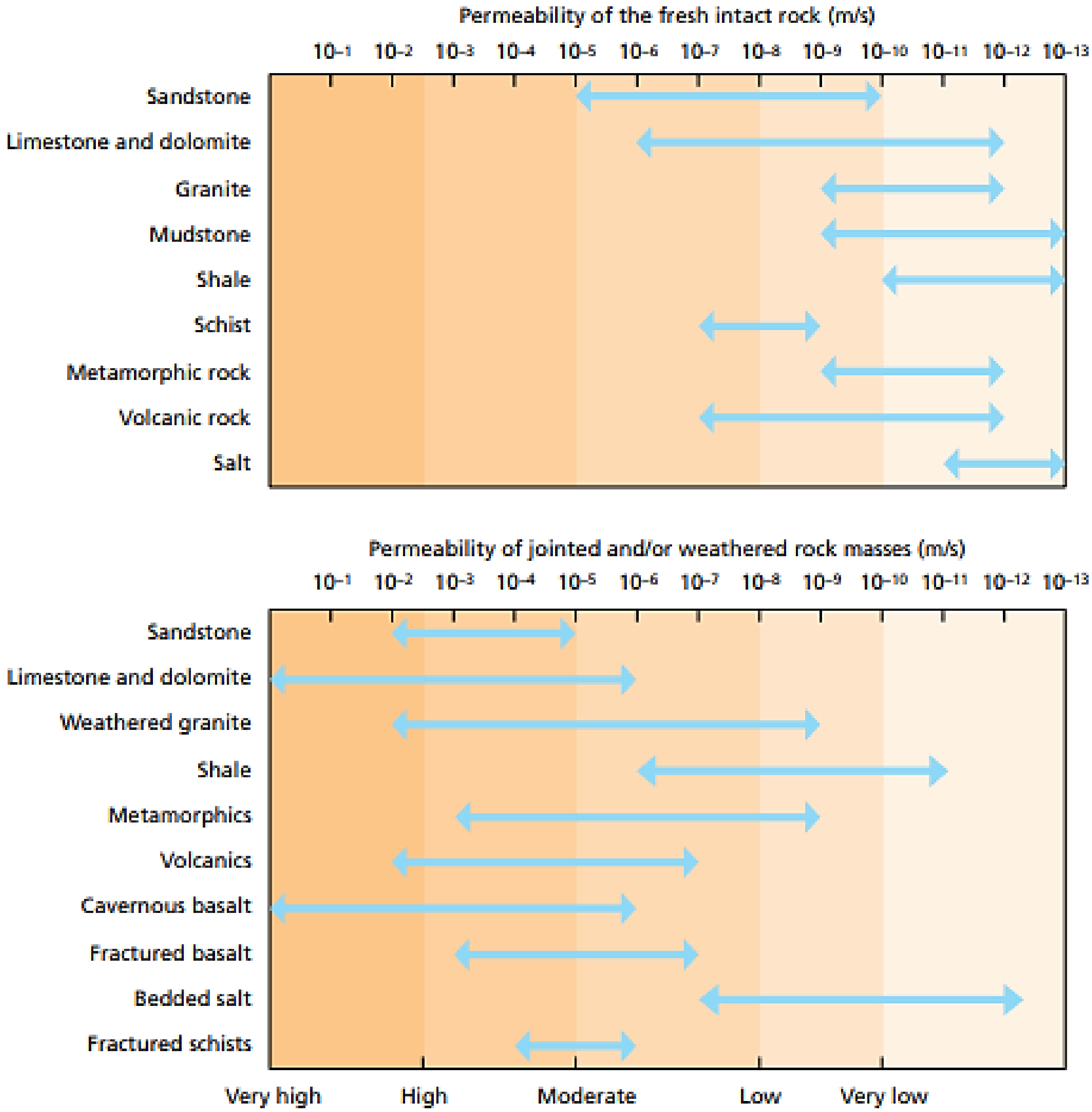
Terzaghi and Peck (1967) incorporated the relationship between the degree of jointing of a rock mass and its' associated permeability. This relationship allows for an initial estimate for rock mass permeability based on visual exposures.

Table 7: Rock Mass Permeability Classification

Permeability Rating	Rock Mass Degree of Jointing	Permeability range (m/s)
Highly Permeable	Very closely spaced joints	1 to 10^{-2}
Medium Permeable	Closely to moderately spaced joints	10^{-2} to 10^{-5}
Slightly Permeable	Widely to very widely spaced joints	10^{-5} to 10^{-9}
Impermeable	Unjointed, massive	< 10^{-9}

Based on on-site exposures from this and the neighbouring sites, the rock mass encountered at the base of excavations was seen to display closely spaced joints. As such, in accordance with the table above, the rock mass is anticipated to display a medium permeable nature. Only thin exposures of the weathered rock mass were possible through the use of a TLB- with the natural of the rock mass at depth unknown.

Furthermore, the graphic below is presented by Gonzalez de Vallejo, 2011 for the inferred permeability of rock. The data ranges presented for **metamorphic rock** can be used in initial designs. As depicted in the graphic, the permeability of the fresh intact rock is notably poor, with the permeability range drastically increasing where weathered rock is encountered.



Based on the cumulative results of this study and the limited exposures of the rock mass- due to its low degree of weathering and closely to moderately spaced joints- it is envisaged that the rock mass at depth is semi/slightly permeable to impermeable, with a weak to practically impermeable characteristic of flow.

This attribute, coupled with its **undulating topography**, aids in the formation of **temporary perched ground water tables,** as exposed across vast extent of the site. Infiltrating water is predicted to flow/perch along the rock-soil interface at depth, with its flow dynamics dependant on the topography of the rock mass at that point.

5. Cemetery Site Suitability and Discussion

5.1. Introduction

This report describes the results of the Phase 1 Engineering Geological Site Investigation conducted in support of the proposed upgrading- and associated expansion- of the existing Jupiter Cemetery in the Paballelo Settlement. The cemetery falls in the boundaries of the Dawid Kruiper Municipality of the greater ZF Mgcawu District Municipality- Northern Cape Province of South Africa.

The **primary site** for this investigation encompasses the undeveloped parcel of land seen to fall immediately south west of the existing cemetery. This area has been earmarked for the **planned extension** of the existing cemetery, exhibiting a rectangular shaped parcel of land with a total extent of approximately **3.3 Ha**.

This parcel of land was investigated to assess its' **suitability** for the use as a cemetery site according to the broad criteria as suggested by Fisher (1994) and Hall & Hanbury (1990). Future developments will encompass the subdivision of this area into various land-use zones i.e., drainage features, infrastructural units, roadways, and services etc. Each of these zones may require their own set of geotechnical assessments and associated engineering solutions.

The surface across most of the planned extension/site was seen to display a reworked nature attributed to past and ongoing human activities in the region. This reworking was predominantly related to the township establishment undertaken in the region, including anthropogenic features such as services, roadways/pathways, minor sand mines, scattered heaps of dumped fill, basic earthworks and vegetation depletion/degradation.

The geotechnical attributes of the site with regards to the establishment of a cemetery site have been discussed at length in the preceding sections of this report. Attributes such as exact material re-usability, stabilisation properties, pipeline bedding/ backfill, and specialist soil mechanics did not form part of the scope of this investigation.

There are geotechnical attributes of the site which are not ideally suited for the planned development (delineated in this report)- for this reason, **advanced engineering solutions** will be required to ensure the stability and longevity of the development. The following **concerns** have been highlighted in this report:

- Rehabilitation of the sites surface- including earthworks to create stable working levels, removal of fills, relict infrastructure and vegetation.
- Site topography/drainage- attributes discussed in Section 2.2/2.3 and 4.1.
- Generalised ground profile depicting the variability of the underlying materials across the site- discussed in Section 4.3.
- Shallow seepage and fluctuating/temporary perched ground water tables- discussed in Section 4.4.
- Pedocrete/bedrock outcrops and poor site excavatability- discussed in Section 4.5 and 4.6.
- Trench/cutting stability and erodibility of backfilled excavations- discussed in Sections 4.7 and 4.8.
- Summarised engineering material characteristics- discussed in Section 4.9.
- Permeability assessment- discussed in Section 4.10.

5.2. General Discussion

The following requirements are deemed essential for a site to be acceptable as a cemetery site:

- Surface gradient between 2 and 6 degrees is ideal to prevent ponding and excessive surface erosion due to runoff.
- Hand excavatability to at least 1,8 m but preferably deeper.
- Soil consistency that allows for stable sidewalls for at least 48 hours.
- Low permeabilities of between 10^{-4} to 10^{-6} cm/s for underlying soil to prevent contamination of groundwater.
- Located above the 1:50 year flood line and at safe distances from drainage features with an accepted safety factor of 100 m.
- A buffer zone of at least 2,5 m between base of grave and groundwater table.

The minimum safe horizontal distance between domestic water supply sources and a cemetery is taken as roughly 150 m. The sensitivity of the of the water sources in the area will need to be addressed in a follow up hydrogeological investigation.

Developments of this nature typically include the rehabilitation/remoulding of the site's surface- within and immediately surrounding the planned structures.

The low gradient will need to be remedied by good site water management to prevent the local saturation of parts.

Perched groundwater tables may occur on the unweathered bedrock. Good surface water management can reduce this possibility.

Surface water bodies/inferred drainage channels are present within 1.0 km of the site. The possibility of surface water pollution may therefore be low, depending on water management measures implemented on site.

The depth to bedrock is shallow across the majority of the site. The bedrock may act as a lower-permeability material with an irregular bedrock interface causing limited deep percolation or infiltrated water and upward perching. This is a function of the material distribution and, although not inferred to occur given the climatic conditions of the area, it is implied to be more likely to evaporation and lateral movement of moisture in the very shallow horizons, very low local deep percolation and groundwater recharge, and induced surface runoff in intensive rainfall events.

No evidence is available of any boreholes being utilized for domestic water supply to the surrounding communities within an approximately 1,5 km radius of the proposed site- to be confirmed during the hydrocensus.

The present groundwater quality is generally good.

There are no visible man-made features or boreholes within the site boundaries.

The study area does not reflect any risk for the formation of sinkholes or subsidence's caused by the presence of water-soluble rocks (dolomite), and as such is not deemed "*dolomitic land*".

5.3. Site Suitability Parameters and Scoring

The following parameters are evaluated to assess the general suitability of the site for use as a small cemetery:

- **Excavatability-** extent of soft material across the site.
- **Stability-** sidewall/trench stability following excavation and exposure.
- **Workability of soil-** refers to the ease with which the soil can be excavated from the grave and re-compacted back into the grave.
- **Water table depth-** the so-called basal buffer zone, or the vertical soil succession between the base of the deepest grave and the permanent or perched groundwater table is crucial regarding possible groundwater contamination. A minimum depth to the shallowest groundwater of 2,5 m is usually regarded as suitable for natural attenuation purposes.
- **Subsoil permeability-** The permeability of a soil and/or rock is the capacity of the body to allow water to pass through it. A reduced permeability in the underlying strata is regarded as being favourable.
- **Backfill permeability**- same as above just relating to the back filled materials.

The graphic below depicts the evaluation parameters and associated scoring system to assess the general suitability of the site for use as a small cemetery (Hall and Hanbury 1990):

Engineering Geological/ Geotechnical
Excavatability ease to 1.80m
Stability sidewalls stable for prolonged periods
Workability material to be used as compacted backfill

Excavatability	Assessment	Score
Easy spade	Geological pick pushed in 50 mm with ease	15
Pick and spade	Geological pick causes slight indentation	10
Machine	Firm blows with pick cause 1 – 3 mm indentations	5
Blasting	Backactor refusal	0

Stability	Assessment	Score
Stable	Little overbreak with safe excavation profiling	20
Overbreak	Overbreak between 1.3 and 1.8 m	15
Slightly unstable	Minor falls of material	8
Unstable	Collapse of excavation likely	1

Workability	Unified	MOD AASHTO	Score
Excellent to good	GW. SW, GP	> 1 800 kg/m^3	10
Fair	SP, SM	< 1 800 kg/m^3	5
Poor	OL, CL, ML	< 1 700 kg/m^3	2
Very poor	OH. CH, MH	< 1 500 kg/m^3	0

Sanitary/ Environmental/ Hydrogeological
Water table thickness of protective vadose zone
Subsoil permeability preventing ponding and rapid infiltration
Backfill permeability preventing ponding and rapid infiltration

Water Table	Water Table Depth (m)	Score
Deep water table	> 8	25
Intermediate water table	4 – 8	5
Possible perched water	0 – 4	5
Waterlogged soil	0 – 4	Fail

Subsoil Permeability	Percolation Rate	Approx. Permeability	Score
Impermeable	Not measurable	< 10^{-7} m/s	15
Relatively impermeable	10 – 15 mm/h	$10^{-6} – 10^{-7}$ m/s	20
Relatively permeable	15 – 50 mm/h	$10^{-5} – 10^{-6}$ m/s	10
Permeable	50 – 1 000 mm/h	< 10^{-5} m/s	0

Backfill Permeability	Unified Class	Score
Impermeable	OH, CL, CH	5
Relatively impermeable	GC, SC, MH	10
Relatively permeable	GP, SP, GW	7
Very permeable	SW, SP	0

Final Ranking	Suitability
> 90	Very good
75 – 90	Satisfactory
60 – 75	Poor
< 60	Unacceptable

The table overleaf summarises the evaluation parameters and associated scores to assess the general suitability of the site for use as a small cemetery.

Table 8: Combined Cemetery Site Evaluation- Paballelo

Parameter	Geotechnical Discussion	Assigned Score	Comments
Excavatability	The average excavation depth across the site was approximately 0.95 m. Profiles were described in trenches excavated by means of TLB-type light mechanical excavator. End of hole conditions were typically due to refusal on either hardpan calcrete or weathered bedrock at depth. The majority of the test pits displayed a range of excavation depths linking to the undulating topography of the hardpan calcrete/ weathered bedrock at depth. The site was seen to host scattered and somewhat variable occurrences of hardpan calcrete outcrops- coupled with visible surficial boulders. Shallow excavations by hand may not be possibly due to rock and/or boulders.	**0** Hard rock excavation methods required to reach target depths of at least 1.8 m.	The rock masses and hardpan pedocrete at depth will require hard rock excavation to unearth. Limited site excavatability may require the implementation of shallow graves with heaped stones (as seen across the existing Jupiter Cemetery).
Stability Rating	Excavations generally remained stable for a period of at least 1 hour with little or no over break or collapse occurring. Localised sidewall instabilities are predicted in areas hosting thick fills and/or relict infrastructure. Sheet wash from stormwater or other waters shall be prevented from running over the trench/pit flanks.	**20**	Box-cuts may need to be dewatered between and following prolonged precipitation events because of water temporarily perching upon the underlaying bedrock.
Workability Rating	Typical Unified Soil Classes (USC) is SM (silty sand) and SC (clayey sand), with the localised occurrence of CL (low plasticity clay). Measured Mod AASTHO MDD for the on-site materials range between 1921 and 2120 kg/m^3	**10**	Boulders and/or cobbles will reduce workability to a degree. Oversized particles may need to be broken down or removed prior to backfilling of graves.
Water Table Rating	Groundwater rest levels are estimated to be in excess of 10 m, with recharge rates of ~1-10 mm per year. Infiltrating water is predicted to flow/perch along the rock-soil interface at depth, with its flow dynamics dependant on the topography of the rock mass at that point. Shallow perching of percolating groundwater upon the bedrock at depth is predicted across the site. The low gradient of less than 2° will also need some stormwater precautionary measures to prevent ponding and infiltration. There is therefore a slight possibility of pollution of the groundwater, and especially the perched groundwater table, from the cemetery.	**5** Possible perched water table Increased to **25** Following site modification practises which limit the formation of perched ground water tables.	Good site drainage measures, on surface and subsurface, must be implemented to minimise infiltration that may lead to perching and prevent moisture changes, which may add to the development of perched groundwater tables.
Permeability Rating	As a whole the permeability of the on-site materials is expected to drastically decrease with depth. The soft materials sampled across the site have a calculated average permeability of ~2.81x10^{-5} – generally classifying as *relatively permeable*. Due to its low degree of weathering and closely to moderately spaced joints- it is envisaged that the rock mass at depth is semi/slightly permeable to impermeable, with a weak to practically impermeable characteristic of flow.	**10**	The permeability of the subsoil below burial depth will vary depending on the material type at this depth.
Backfill Permeability	Typical Unified Soil Classes (USC) is SM (silty sand) and SC (clayey sand), with the localised occurrence of CL (low plasticity clay). It is predicted that the backfilled material will be relatively permeable to relatively impermeable.	**7** to **10**	Variable rating due to the heterogenous composition/ nature of the sites' subsoils. Permeability of the backfilled materials is predicted to increase with an increase in excavation depth.

5.4. Final Rating

Using the assigned scoring presented in Table 8- the final rating is as follows:

1. **Option 1- Final rating 52**- site suitability deemed to be "***unacceptable***".
    a. This suitability rating is applicable to the development should **no** surface/subsurface drainage measures be implemented during its establishment to reduce the formation of perched ground wate tables.
    b. In its current state, the site has a water table score of "5" due to the predicted occurrence of seasonal perched water tables.
2. **Option 2- Final rating 75**- site suitability deemed to be "***poor***" but may still be feasible following the implementation of site-specific precautionary measures.
    a. This suitability rating is applicable to the development should surface/ subsurface drainage measures be implemented during its establishment to reduce the formation of perched ground wate tables.
    b. The permanent ground water rest level is predicted to exceed 10 m below the egl.- for this reason, once perched ground water tables are mitigated the water table score will increase to "25".

5.5. Conclusion and Summarised Design Considerations

Based on the information gained from published maps and other literature as well as the field investigations the proposed site seems to conform to most of the accepted criteria for a suitable cemetery site.

The following **three (3) major attributes** limit the success of the development:

1. **Very gentle slopes of less than 2 degrees:**
    a. The site will be subjected to elevated degrees of surface water infiltration into the underlying soils, rather than rapid surface water flow, accentuating surface water ponding and fluctuating moisture conditions after prolonged precipitation events.
    b. Waterlogged conditions and/or surface water ponding following prolonged and intense precipitation events are anticipated across the site due to its very gentle sloping nature and anthropogenically induced undulating topography.
    c. Localised slope variances were encountered due to the occurrence of small-scale anomalies- both natural and anthropogenic.
2. **Poor site excavatability conditions:**
    a. The average excavation depth across the site was ~0.95 m.
    b. Profiles were described in trenches excavated by means of TLB-type light mechanical excavator. End of hole conditions were typically due to refusal on either hardpan calcrete or weathered bedrock at depth.
    c. The majority of the test pits displayed a range of excavation depths linking to the undulating topography of the hardpan calcrete/ weathered bedrock at depth.
    d. The site was seen to host scattered and somewhat variable occurrences of hardpan calcrete outcrops- coupled with visible surficial boulders.

e. The rock masses and hardpan pedocrete at depth will require hard rock excavation methods to unearth.

f. Limited site excavatability may require the implementation of shallow graves with a tumulus/cairn/burial mound (as seen across the existing Jupiter Cemetery).

3. Shallow perched ground water tables:

a. The sensitivity of the of the water sources in the area will need to be addressed in the follow up hydrogeological investigation.

b. Infiltrating water is predicted to flow/perch along the rock-soil interface at depth, with its flow dynamics dependant on the topography of the rock mass at that point. This attribute, coupled with its undulating topography, aids in the formation of temporary perched ground water tables.

c. Grave excavations, foundations and installed services will cause soil density and texture changes which may lead to variations in soil moisture across the site with flow changes and build-up of moisture that may differ from the natural conditions.

The three major site constraints high-lighted above require the implementation of site-specific design considerations to ensure the suitability and longevity of the cemetery site development.

As for the removal of relict infrastructure, it is strongly recommended that the uncontrolled fills/land fill materials be selectively mined and removed from within the footprint of the proposed development (extent determined by the design engineer)- in line with the HSE protocols of the development.

Organic materials should be removed from all backfill prior to placement. The decomposition of organic material in the fill over time can lead to the formation of voids followed by subsurface piping.

Lump formation and cobbles in the clayey and/or silty transported and cemented soils will be a problem during dry periods. It will be good practice to break down the excavated soil into smaller lumps while the machine is on site. Soil lumping will cause settlement over time and it may be useful to control settlement during routine maintenance.

The anthropogenic reworking of the surface will result in local variations of surface water flow- both rate and direction.

The continuity and manipulation of the topography and associated drainage plays a pivotal role in the longevity and sustainability of the development. Topographic anomalies identified during the survey can be addressed individually in the design, and in so doing eliminating their localised effects.

Surficial stormwater control measures should be implemented across the site to limit the volume of infiltrating fluids which may add to the development of perched groundwater tables. Furthermore, attention must be given to site contouring in these areas to ensure an effective gradient is achieved so that ponding does not occur, and the draining of water is efficient to minimise erosion and damage to the development downslope.

The modification of the sites' surface and the compaction of the topsoil through vehicle and/or foot traffic will result in poor drainage characteristics and the possibility of high energy channelized/concentrated surface water flow. This high energy/concentrated runoff will cause erosion and appropriate measures must be taken to prevent this from occurring.

It is envisaged that temporary shallow trenches and/or cuttings to depths of up to 1.5 m will remain stable (where dry)- the stability of which can be assessed periodically. No loading of the temporary slopes by machinery, equipment, excavated soil or materials shall be allowed. Sheet wash from stormwater or other waters shall be prevented from running over the trench/pit flanks.

All excavations should be inspected by a competent person (engineer or geo-professional with relevant training and experience) at least once a day and following any periods of rain or any long periods where no work has taken place.

The pH and conductivity in the subsoils are generally mildly corrosive.

The site conditions with regards the geotechnical considerations are such that any light structure placed on the materials occurring on site will need special precautionary measures to prevent serious damage to the structure. Additional foundation modifications to prevent damage to single-storey structures due to differential settlements are deemed necessary. In the light of the variable site conditions, it is recommended that further geotechnical studies be undertaken within the footprints of future structures- specifically for large/ sensitive structures.

Special attention must be given to the selection of the correct material to be used for the bedding, fill material and the general backfill in the construction.

All earthworks should be carried out in a manner to promote stable development of the site. It is recommended that earthworks be carried out along the guidelines given in SABS 1200/SANS 10400 (current version). Placement of fill layers should be undertaken in layers not exceeding 200mm thick when placed loose and compacted using suitable compaction plant to achieve 93% Modified AASHTO maximum dry density at ±2% optimum moisture content.

The pits were backfilled without proper compaction in layers. If structures are to be positioned over or across this pit, proper compaction will be necessary to prevent additional settlements from taking place. If development takes place across previous infrastructure such as foundations, septic tank excavations or previous waste dumps, additional foundation measures will be needed to prevent damage to structures due to differential settlements.

Quality control testing should be undertaken by an accredited laboratory where possible.

It is assumed that the development will be serviced by the usual municipal services or specific environmentally acceptable measures.

Additional to the considerations listed above, a **maintenance regime** should be put in place to periodically assess the nature of the grave sites for a set period following their establishment. Areas showing visible deformation should be modified accordingly, in order to avoid further deformation and/or permanent damage.

6. Report Provisions

This report has sought to highlight areas of potential critical issues related to the establishment of a cemetery site such as groundwater, excavation and soil property problems, to provide the client with the necessary information. It is highly recommended that the suggested precautionary measures be implemented to prevent contamination of surface and groundwater sources.

The investigation was conducted according to the accepted proposal and the scope of works and literature references provided in this document. Field work and reporting were conducted and/ or overseen by professionally registered scientists with the South African Council for Natural Scientific Professions. Furthermore, GeoCalibre has have employed accepted engineering geologic procedures, and our opinions and conclusions are made in accordance with generally accepted principles and practices in engineering geology.

The presented geotechnical model is based on a data base of available information and available on-site exposures. Parcels of land within the developmental area which are free of excavations are modelled using on-site observations and surrounding exposures.

While every effort is made during the fieldwork phase to identify the different soil horizons, areas subject to a perched water table, areas of poor drainage, areas underlain by hard rock and to estimate their distribution, it is impossible to guarantee that variations are excluded over the extent of the site which are the subject of this report.

Infrastructure will need to be constructed in the problem areas to mitigate the effects of the presented geotechnical characteristics. Specialist follow-up studies for structures can be undertaken by GeoCalibre.

In view of the variability inherent in natural materials, a competent person must inspect all future excavations at the time of construction to ensure that the materials are adequate for the proposed structure and that they are in accordance with the recommendations stated in this report.

The design and implementation of the planned engineering fills remains the responsibility of the consulting engineers/competent person- with GeoCalibre and its' employees carrying no liability in this regard. The placement of engineered fill must be controlled with suitable field tests to ensure that the required densities are achieved during compaction, and that the quality of the fill material is within specification to ensure the longevity of the development.

The determination of flood lines and delineation of wetland areas were not part of this investigation scope and should be addressed by suitably competent professionals prior to the final site development plan is compiled, if deemed necessary. If the site or a portion thereof is situated within the 1:100-year flood line, or has been delineated as a wetland, it is the prerogative of the Civil Engineer or other suitably experienced specialist to overwrite the recommendations for such portions.

This investigation did not include the assessment of any potential environmental hazards, or groundwater impacts that may be present, or ensue from the construction of the proposed structures.

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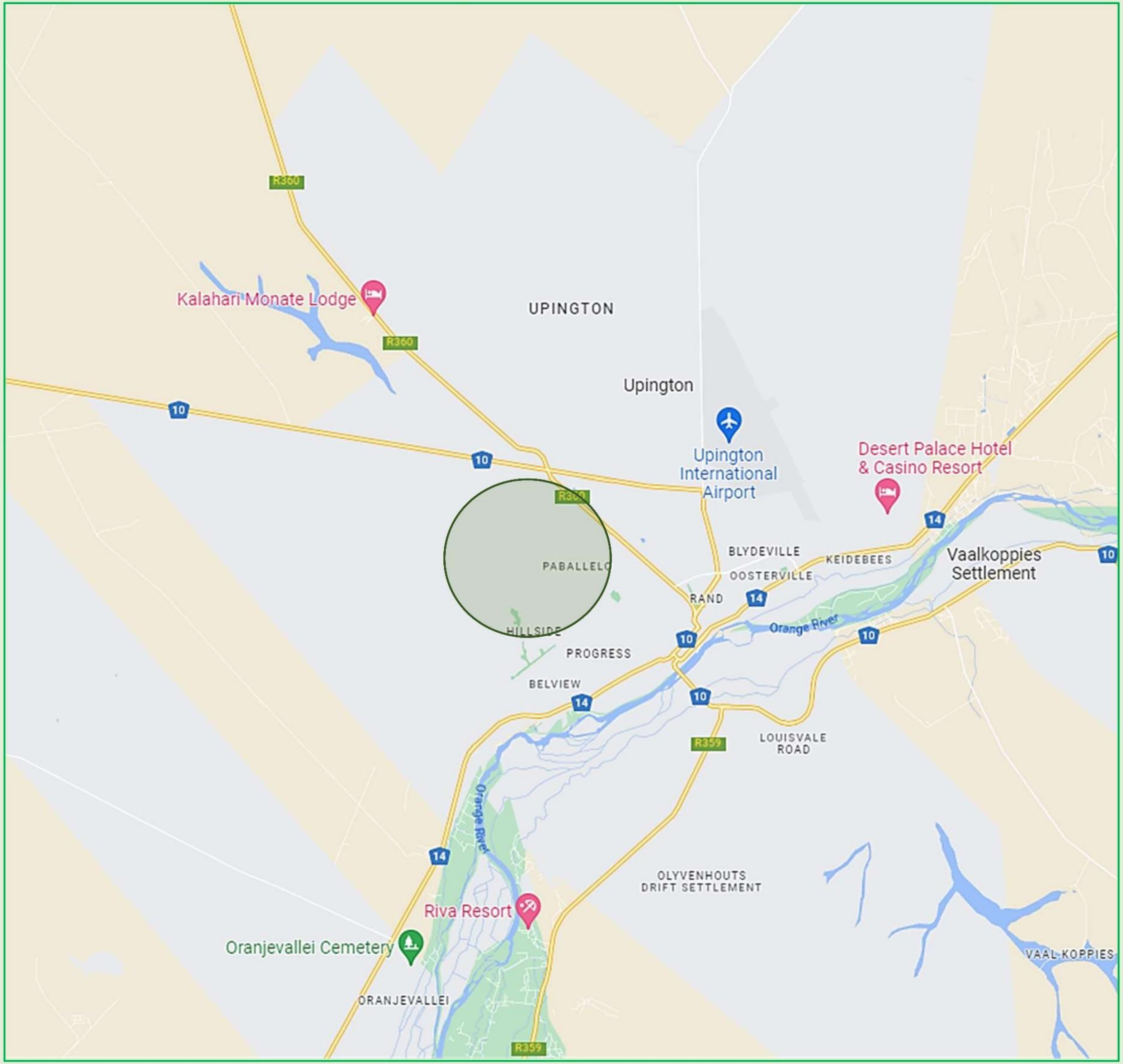
LAYOUT MAPS



GEOCALIBRE
GEOTECHNICAL CONSULTANCY

Figure 1

Study Area Location

LEGEND

Study Area

N

GeoCalibre Geotechnical Consultancy (PTY) LTD

Kevin Coertzen Pri.Sci.Nat and MSAIEG	33 Denne Avenue Bainsvlei Bloemfontein

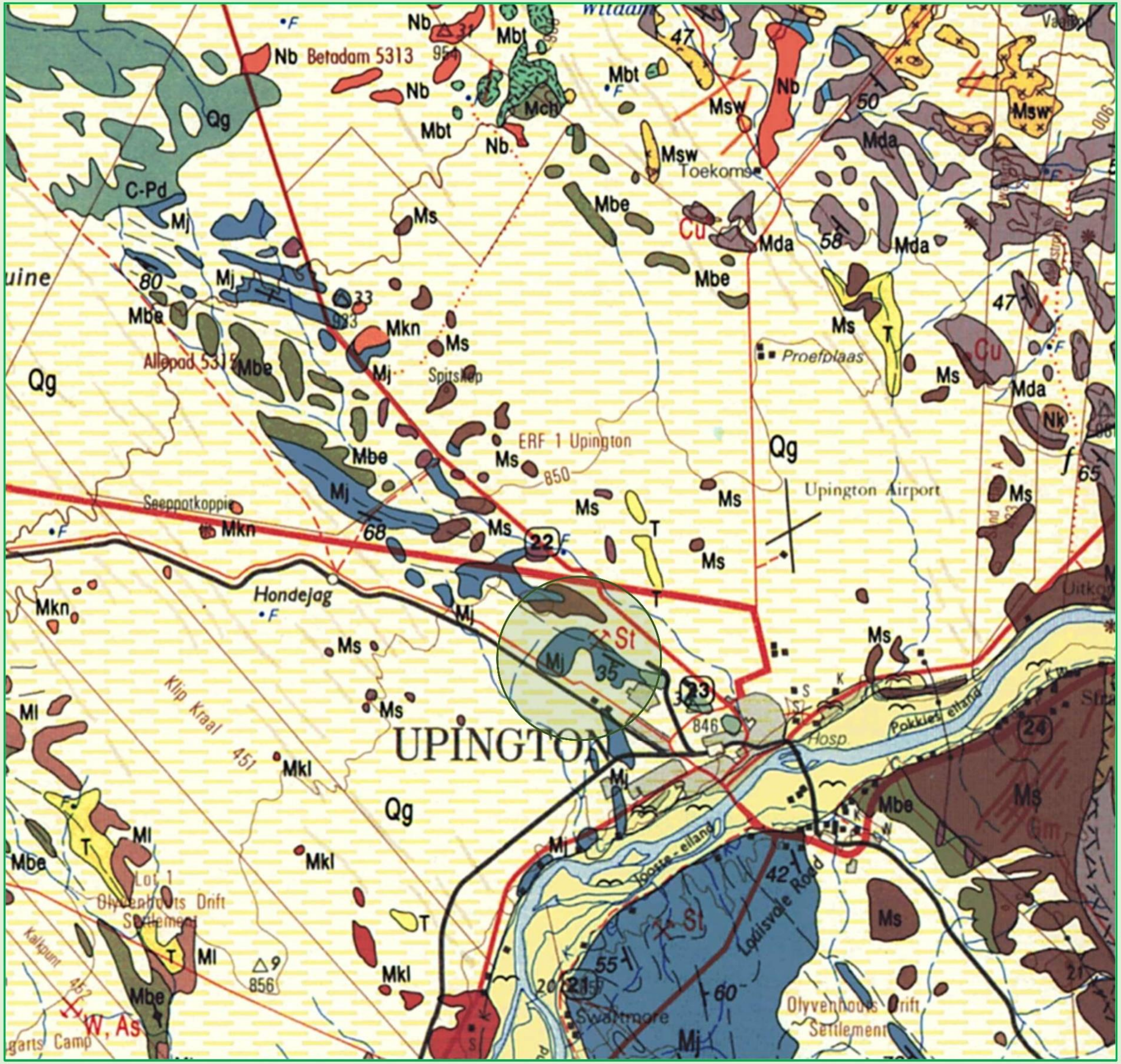


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Figure 2

Regional Geology Map

LEGEND

Qg	Red-brown wind-blown sand and dunes- Gordonia Formation
Mj	Amphibolite, amphibolite gneiss, biotite gneiss, pelitic gneisses, lenses of calc– silicate rocks
Mbe	Migmatic, biotite rich and alminous gneisses- Bethesda Formation
Ms	Weakly foliated biotite granite

Geological Series Map:
2820 Upington; Scale 1 : 250 000

N

GeoCalibre Geotechnical Consultancy (PTY) LTD

Kevin Coertzen
Pri.Sci.Nat and MSAIEG

33 Denne Avenue
Bainsvlei
Bloemfontein

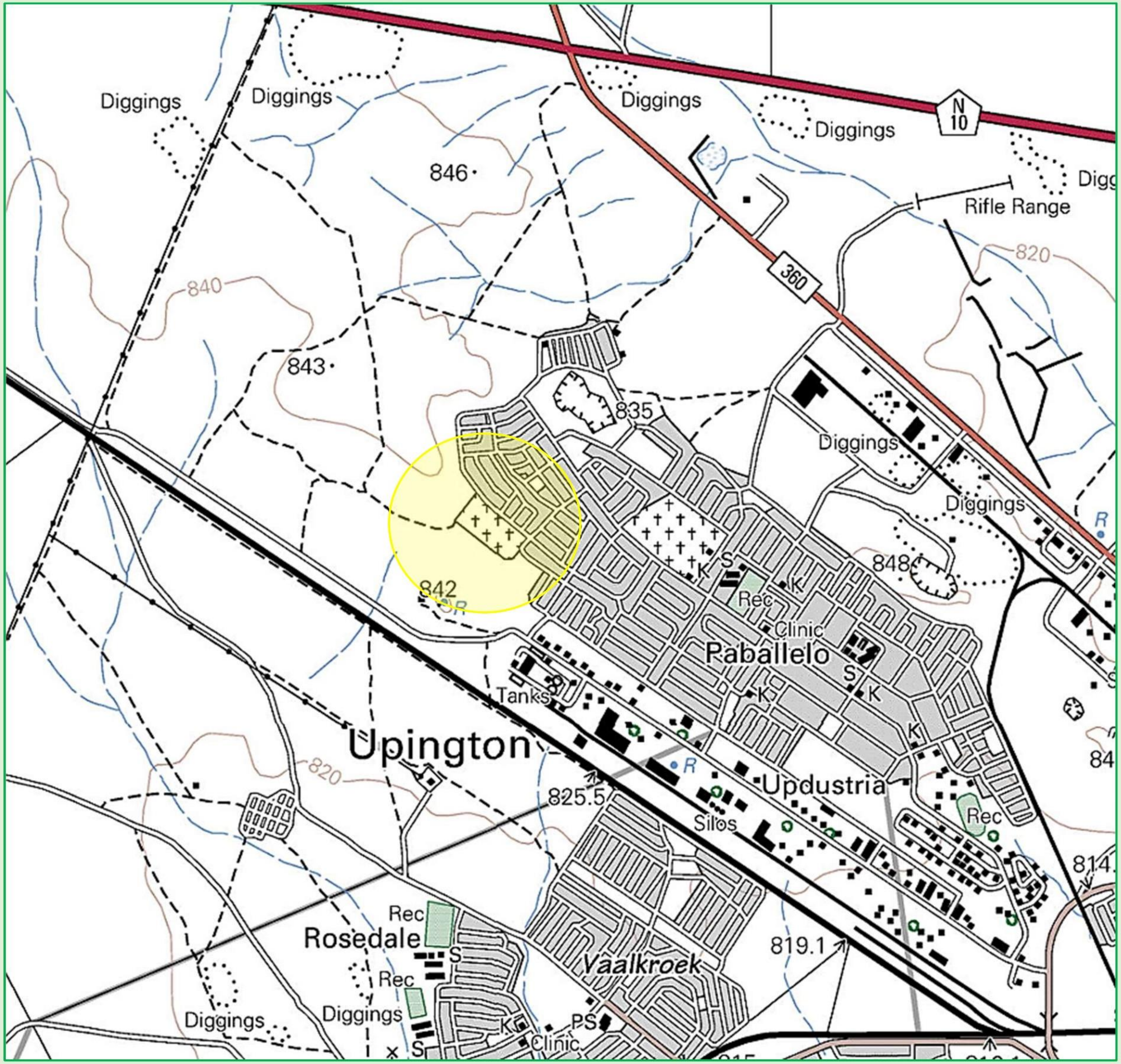

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Figure 3

Topocadastral Map

LEGEND

Study Area

Topocadastral Maps:
2821 Ac; Scale 1 : 20 000

N

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Pri.Sci.Nat and MSAIEG

33 Denne Avenue
Bainsvlei
Bloemfontein

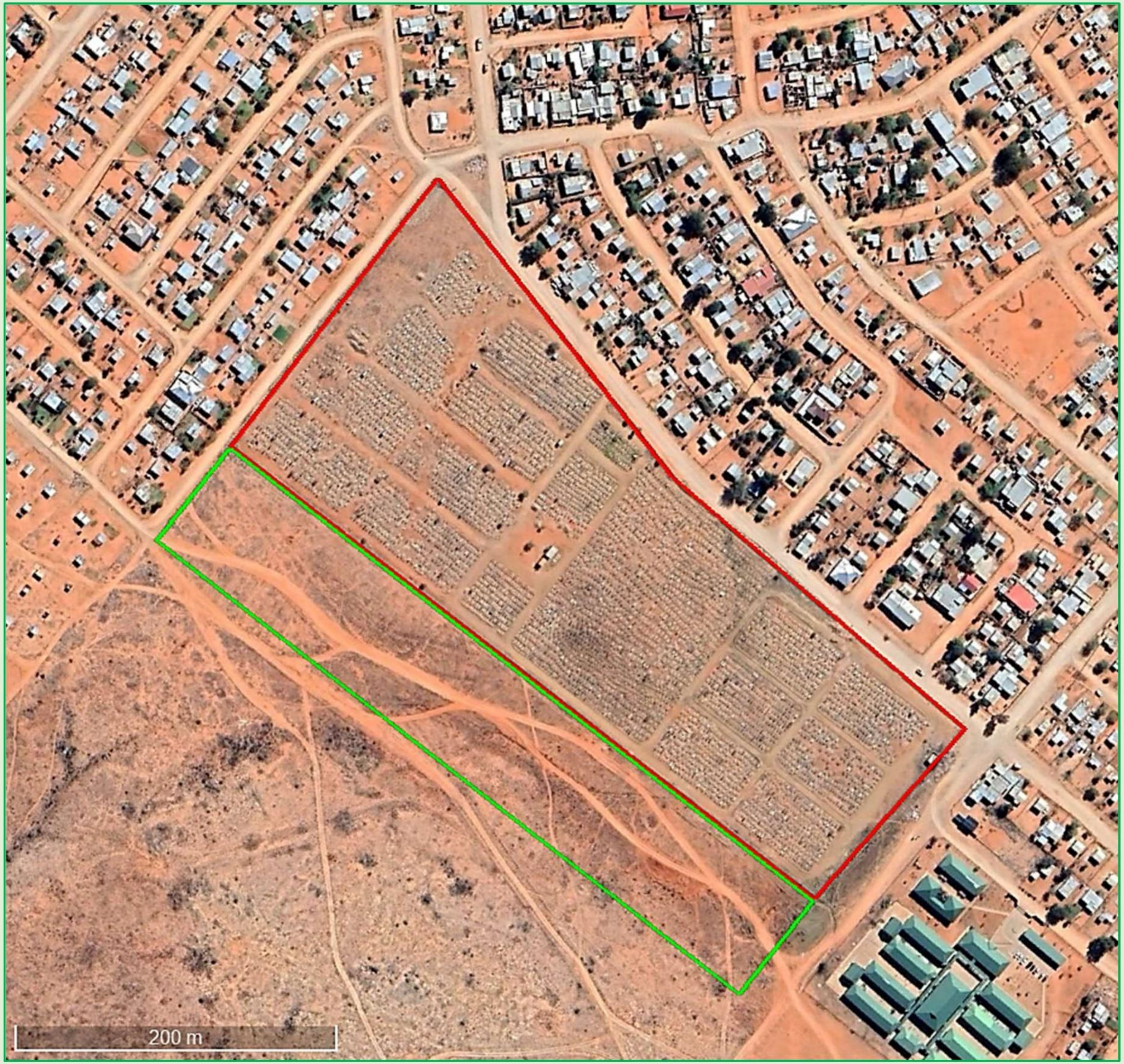

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Figure 4

Site Location- Aerial View

LEGEND

- Existing Cemetery Boundary
- Planned Extension- Site

N

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Pri.Sci.Nat and MSAIEG

33 Denne Avenue
Bainsvlei
Bloemfontein

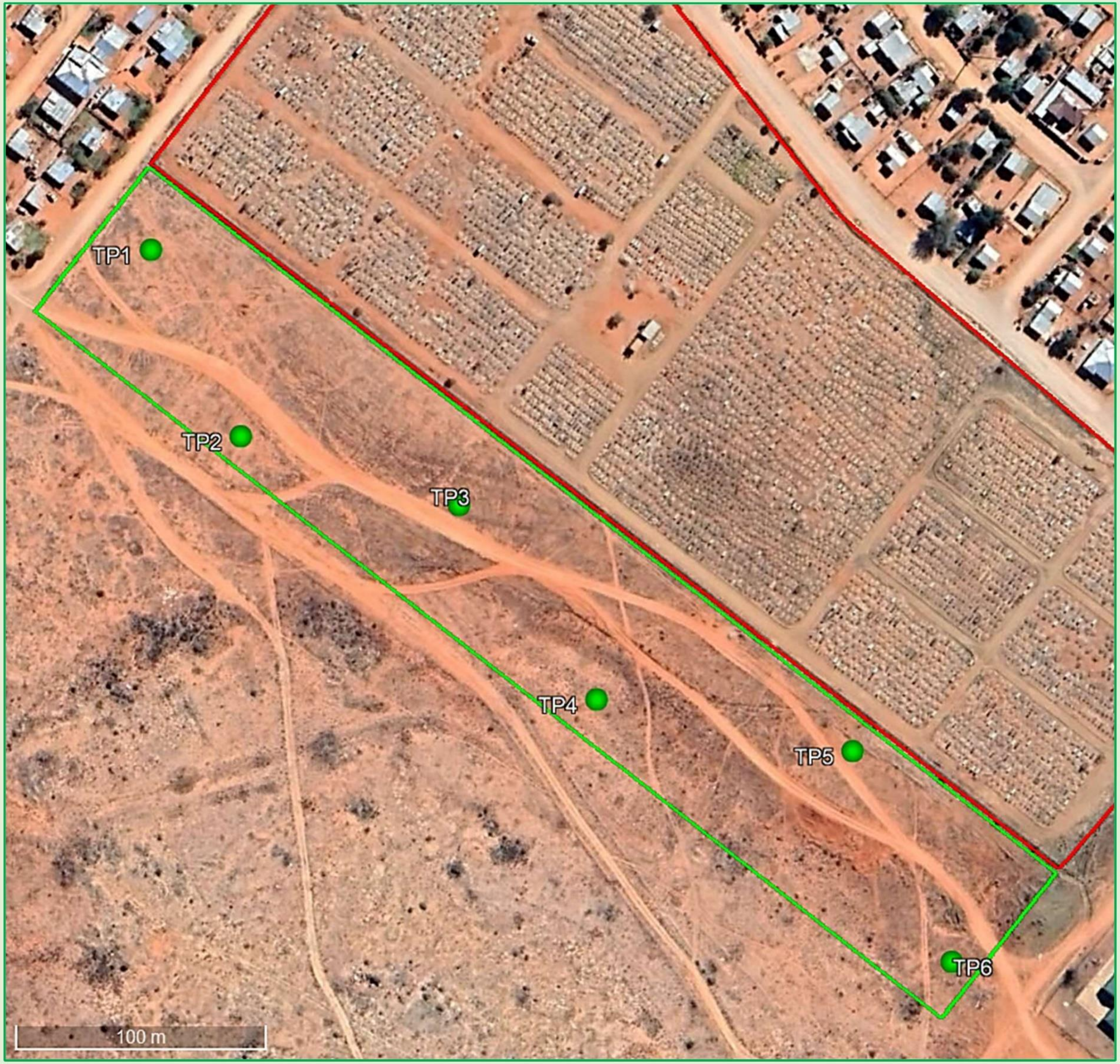

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Figure 5

Testing Locations

LEGEND

Test Pit

Site Boundary

N

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Testing Locations

GC-23-109 A

Paballelo Cemetery- Upington

EnviroAfrica

Test Pit Locations

Test Pit Number	Location		Elevation (meters above mean sea level)	Final Excavation Depth with TLB (m)
	Latitude (South)	Longitude (East)		
TP1	28.43382	21.19980	837	0,37 - 0,94
TP2	28.43448	21.20017	836	0,30 - 1,15
TP3	28.43472	21.20105	835	0,91 - 1,18
TP4	28.43542	21.20160	834	0,20
TP5	28.43560	21.20265	832	1,30
TP6	28.43636	21.20306	831	0,90

Please note that all GPS co-ordinates are extracted from Garmin Oregon 600 tm and elevation data from Google Earth PRO

Appendix Index

Upgrading of the Paballelo Jupiter Cemetery

Index:

Appendix A

Soil Profiles

GEOCALIBRE GEOTECHNICAL CONSULTANCY

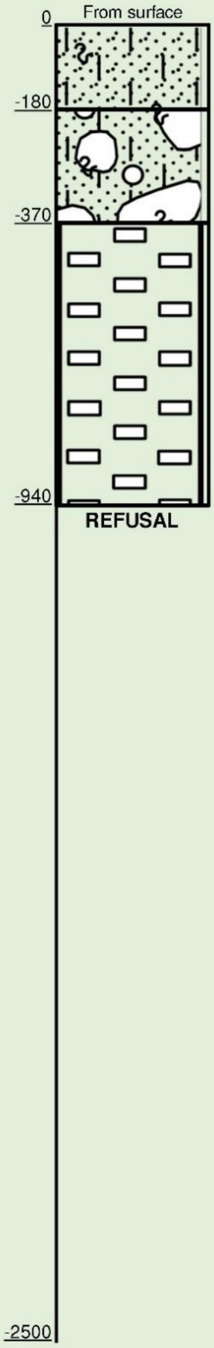
Test Pit TP1

GC-23-109 A

Paballelo Cemetery- Upington

EnviroAfrica

Soil Profile for Test Pit TP1



slightly MOIST; light orangey BROWN; LOOSE; PINHOLED; silty SAND with traces of gravel; Aeolian Sand; abundant fine roots; biological activity; minor anthropogenic reworking in the upper extent; Not Sampled.

slightly MOIST; light orangey BROWN; LOOSE; MATRIX SUPPORTED; sub-angular gravels and cobbles in a matrix of silty SAND; PEBBLE MARKER; traces of fine roots; heterogeneous composition and poorly sorted nature; Not Sampled.

~Undulating contact

slightly MOIST; light greyish BROWN; medium DENSE to dense at base; CEMENTED; silty calcrete powder with abundant calcrete gravel, cobble, and boulder-sized calcrete concretions; decomposed HARDPAN CALCRETE; traces of fine roots; infiltration zones; Bulk Sample No. U1.

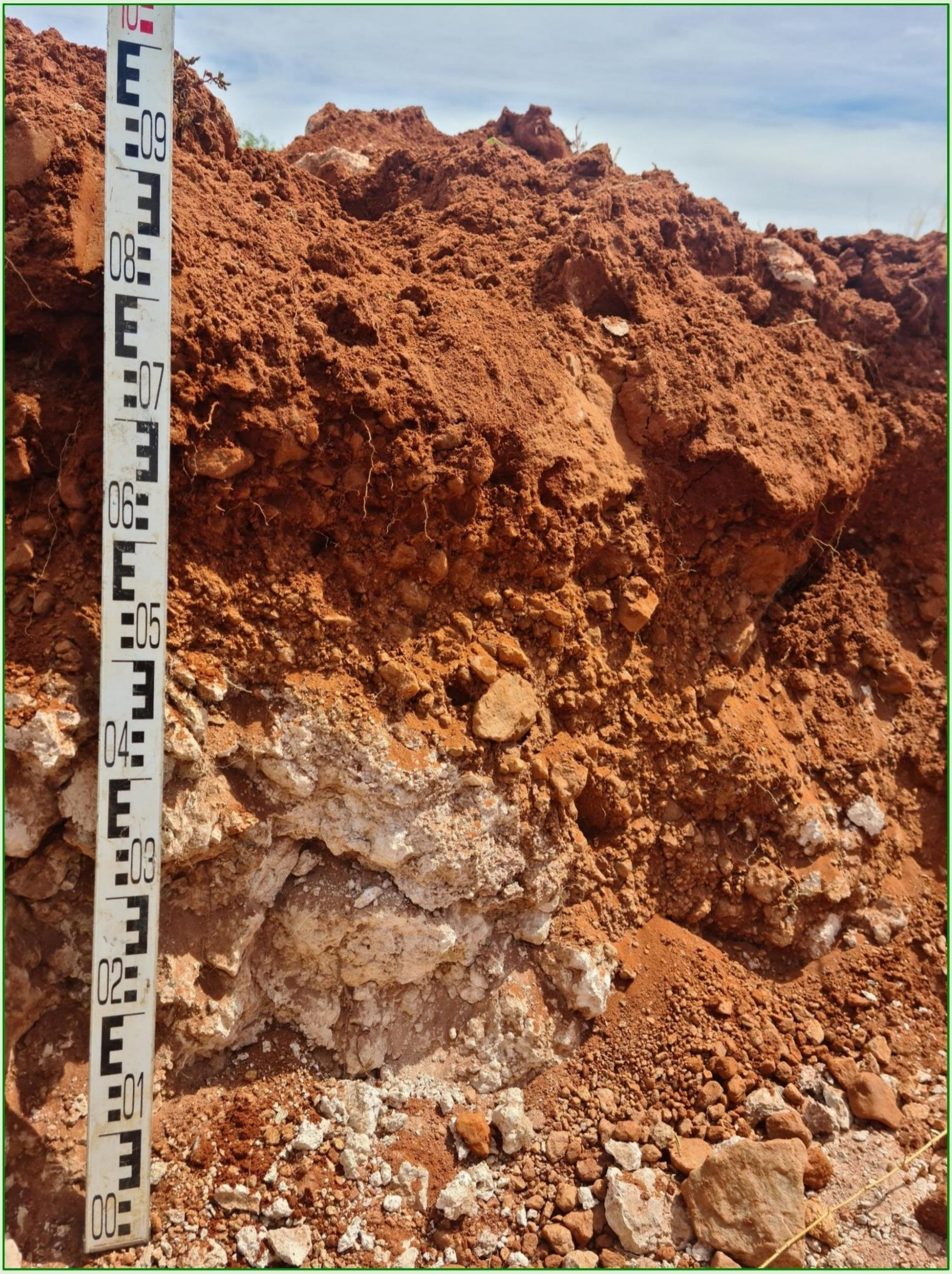
~Undulating excavation depth (420 to 940)

Profile Notes		Excavation Description	
Profiled by:	Cole Herbig (Engineering Geologist)	Contractor:	ALS Rentals
Groundwater Seepage:	N/A	Machine:	Bell 315 SK- TLB-type Light Mechanical Excavator
Excavation Stability:	Sidewalls stable	Excavation Character:	Refusal on hardpan calcrete
Samples Extracted:	1 Bulk Sample	Date Profiled:	06/02/2023
Elevation (MAMSL):	837	Coordinates:	28.43382°S 21.19980°E

GEOCALIBRE
GEOTECHNICAL CONSULTANCY

GC-23-109 A
Paballelo Cemetery- Upington

Profile Photo: TP1



GEOCALIBRE GEOTECHNICAL CONSULTANCY

Material Present in Test Pit: TP1

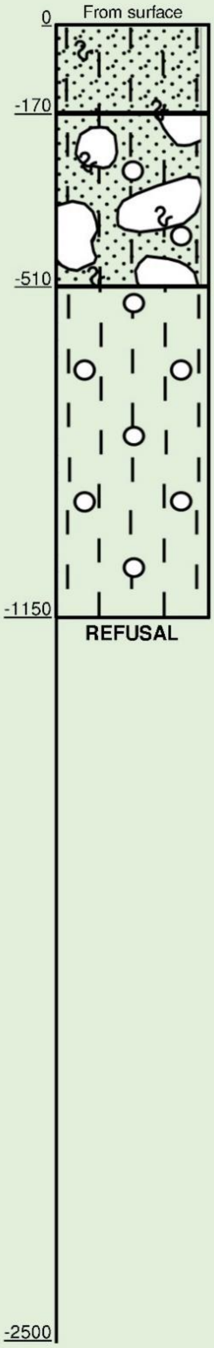
Surroundings of Test Pit: TP1

Facing North

Facing East

GEOCALIBRE GEOTECHNICAL CONSULTANCY	**Test Pit TP2** GC-23-109 A Paballelo Cemetery- Upington EnviroAfrica

Soil Profile for Test Pit TP2



slightly MOIST; light orangey BROWN; LOOSE; PINHOLED; silty SAND with traces of gravel; AEOLIAN SAND; abundant fine roots; Not Sampled.

slightly MOIST; light orangey BROWN; LOOSE; MATRIX SUPPORTED; sub-angular gravels and cobbles in a matrix of silty SAND; PEBBLE MARKER; traces of fine roots; heterogeneous composition and poorly sorted nature; Disturbed Sample No. U2.

slightly MOIST, light greyish BROWN; DENSE; coarse grained; closely JOINTED; COMPLETELY weathered; MEDIUM HARD ROCK; calcified GNEISS of the Jannelsepan Formation; infiltration zones; bands of residuum; gradual transition to less weathered bedrock at the base; calcification on rock faces and along joints; Not Sampled.

Profile Notes		Excavation Description	
Profiled by:	Cole Herbig (Engineering Geologist)	**Contractor:**	ALS Rentals
Groundwater Seepage:	N/A	**Machine:**	Bell 315 SK- TLB-type Light Mechanical Excavato
Excavation Stability:	Sidewalls stable	**Excavation Character:**	Refusal on less weathered calcified gneissic bedrock
Samples Extracted:	1 Disturbed Sample	**Date Profiled:**	06/02/2023
Elevation (MAMSL):	836	**Coordinates:**	28.43448°S 21.20017°E

GC-23-109 A
Paballelo Cemetery- Upington

Profile Photo: TP2

Material Present in Test Pit: TP2

Surroundings of Test Pit: TP2

Facing North

Facing South

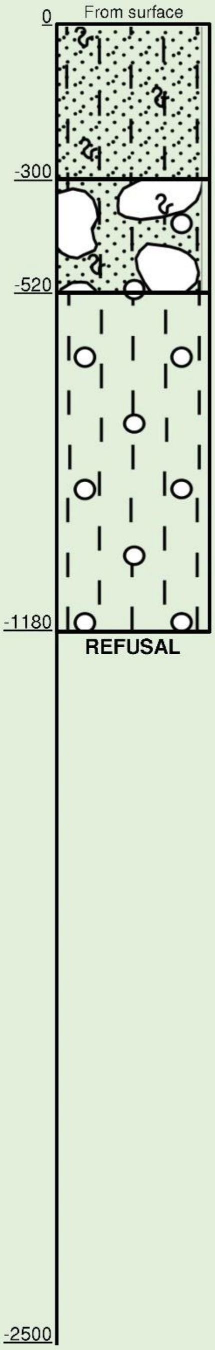
Test Pit TP3

GC-23-109 A

Paballelo Cemetery- Upington

EnviroAfrica

Soil Profile for Test Pit TP3



0 – 300: slightly MOIST; light BROWN; LOOSE; PINHOLED; silty SAND with traces of fine roots; Aeolian Sand; abundant fine roots; minor anthropogenic reworking in the upper extent; Disturbed Sample No. U3.

300 – 520: slightly MOIST; light orangey BROWN; LOOSE; MATRIX SUPPORTED; sub-angular gravels and cobbles in silty SAND matrix; PEBBLE MARKER; heterogeneous composition and poorly sorted nature; traces of roots; Not Sampled.

~Undulating contact

520 – 1180: slightly MOIST, light greyish BROWN; blotched white; DENSE; coarse grained; closely JOINTED; COMPLETELY weathered; MEDIUM HARD ROCK; calcified GNEISS of the Jannelsepan Formation; bands of residuum; gradual transition to less weathered bedrock at the base; calcification on rock faces and along joints; traces of cobbles and boulder-sized calcrete concretions; Not Sampled.

~Undulating excavation depth

Profile Notes		Excavation Description	
Profiled by:	Cole Herbig (Engineering Geologist)	**Contractor:**	ALS Rentals
Groundwater Seepage:	N/A	**Machine:**	Bell 315 SK- TLB-type Light Mechanical Excava
Excavation Stability:	Sidewalls stable	**Excavation Character:**	Refusal on less weathered calcified gneissic bedrock
Samples Extracted:	1 Disturbed Sample	**Date Profiled:**	06/02/2023
Elevation (MAMSL):	835	**Coordinates:**	28.43472°S 21.20105°E

GEOCALIBRE
GEOTECHNICAL CONSULTANCY

GC-23-109 A
Paballelo Cemetery- Upington

Profile Photo: TP3

Material Present in Test Pit: TP3

Surroundings of Test Pit: TP3

Facing West

Facing South

GEOCALIBRE
GEOTECHNICAL CONSULTANCY

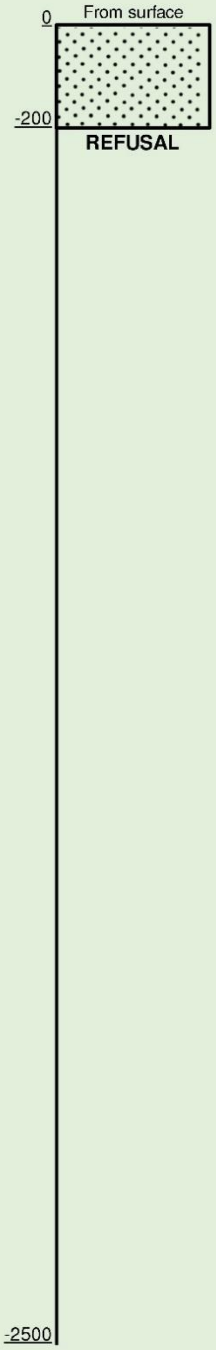
Test Pit TP4

GC-23-109 A

Paballelo Cemetery- Upington

EnviroAfrica

Soil Profile for Test Pit TP4



slightly MOIST; light orangey BROWN, mottled white; LOOSE; PINHOLED; silty SAND with traces of fine gravel and cobbles; AEOLIAN SAND; traces of calcrete nodules; minor fine roots; rapid transition to hardpan calcrete at the base; Not Sampled.

Profile Notes		Excavation Description	
Profiled by:	Cole Herbig (Engineering Geologist)	Contractor:	ALS Rentals
Groundwater Seepage:	N/A	Machine:	Bell 315 SK- TLB-type Light Mechanical Excavator
Excavation Stability:	Sidewalls stable	Excavation Character:	Refusal on hardpan calcrete
Samples Extracted:	N/A	Date Profiled:	06/02/2023
Elevation (MAMSL):	834	Coordinates:	28.43542°S 21.20160°E

GC-23-109 A
Paballelo Cemetery- Upington

Profile Photo: TP4

GC-23-109 A

Paballelo Cemetery- Upington

Material Present in Test Pit: TP4

Surroundings of Test Pit: TP4

Facing East

Facing South West

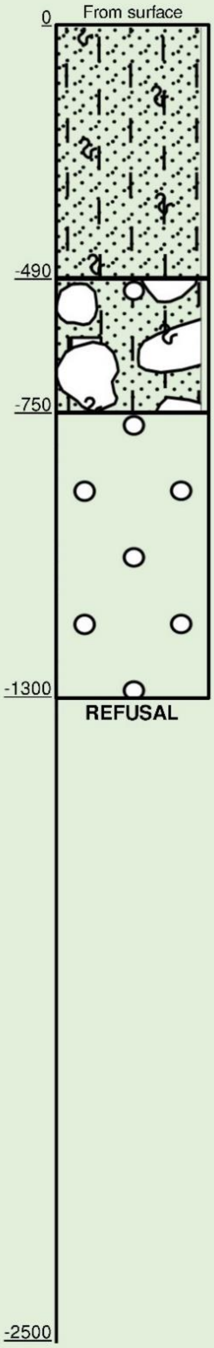
GEOCALIBRE
GEOTECHNICAL CONSULTANCY

Test Pit TP5

GC-23-109 A
Paballelo Cemetery- Upington

EnviroAfrica

Soil Profile for Test Pit TP5



slightly MOIST; light orangey BROWN, mottled white; LOOSE; PINHOLED; clayey SAND with traces of fine gravel; AEOLIAN SAND; minor fine roots; minor anthropogenic reworking in the upper extent; Bulk Sample No. U4.

Gradual contact

slightly MOIST; light orangey BROWN, mottled white; LOOSE; MATRIX SUPPORTED;; fine gravel and cobbles in a matrix of silty SAND; PEBBLE MARKER; heterogeneous composition and poorly sorted nature; traces of roots; traces of calcrete nodules; Bulk Sample No. U4.

slightly MOIST, dark greyish BROWN, blotched white; DENSE; coarse grained; closely JOINTED; COMPLETELY weathered; MEDIUM HARD ROCK; calcified GNEISS of the Jannelsepan Formation; infiltration zones; gradual transition to less weathered bedrock at the base; calcification on rock faces and along joints; pockets of powdery calcrete and gravel-sized calcrete concretions; highly calcified; Not Sampled.

Profile Notes		Excavation Description	
Profiled by:	Cole Herbig (Engineering Geologist)	**Contractor:**	ALS Rentals
Groundwater Seepage:	N/A	**Machine:**	Bell 315 SK- TLB-type Light Mechanical Excavator
Excavation Stability:	Sidewalls stable	**Excavation Character:**	Refusal on less weathered gneissic bedrock
Samples Extracted:	1 Bulk Sample	**Date Profiled:**	06/02/2023
Elevation (MAMSL):	832	**Coordinates:**	28.43560°S 21.20265°E

GC-23-109 A
Paballelo Cemetery- Upington

Profile Photo: TP5

GEOCALIBRE
GEOTECHNICAL CONSULTANCY

GC-23-109 A
Paballelo Cemetery- Upington

Material Present in Test Pit: TP5

Surroundings of Test Pit: TP5

Facing South West

Facing North

Test Pit TP6

GC-23-109 A

Paballelo Cemetery- Upington

EnviroAfrica

Soil Profile for Test Pit TP6

slightly MOIST; light orangey BROWN; LOOSE; PINHOLED; silty SAND with traces of fine gravel; AEOLIAN SAND; abundant fine roots; Disturbed Sample No. U5.

slightly MOIST; light orangey BROWN, mottled white; LOOSE; MATRIX SUPPORTED; sub-rounded gravel and cobbles in a silty SAND matrix; PEBBLE MARKER; heterogeneous composition and poorly sorted nature; traces of roots; traces of calcrete boulders; Disturbed Sample No. U6.

Profile Notes		Excavation Description	
Profiled by:	Cole Herbig (Engineering Geologist)	**Contractor:**	ALS Rentals
Groundwater Seepage:	N/A	**Machine:**	Bell 315 SK- TLB-type Light Mechanical Excavator
Excavation Stability:	Sidewalls stable	**Excavation Character:**	Refusal on hardpan calcrete
Samples Extracted:	2 Disturbed Samples	**Date Profiled:**	06/02/2023
Elevation (MAMSL):	831	**Coordinates:**	28.43636°S 21.20306°E

GEOCALIBRE
GEOTECHNICAL CONSULTANCY

GC-23-109 A
Paballelo Cemetery- Upington

Profile Photo: TP6

Material Present in Test Pit: TP6

Surroundings of Test Pit: TP6

Facing South West

Facing South

Appendix B

Laboratory Test Results

Disturbed and Bulk Samples

LETABA LABORATORIES AND SURVEYORS (Pty) Ltd

CIVIL ENGINEERING MATERIALS LABORATORY

6 Gruis Street, Hilton
Bloemfontein, 9301
P.O Box 22874,
Exton Road, 9313

T0864

Tel. No: 087 285 0816 e-mail : letaba@letabalab.co.za www.letabalab.co.za

GRAVEL, SOIL AND SAND ANALYSIS : FOUNDATION INDICATOR TEST REPORT

SANS 3001 Methods GR1, GR3, GR5, GR10, GR20, GR30 & GR40

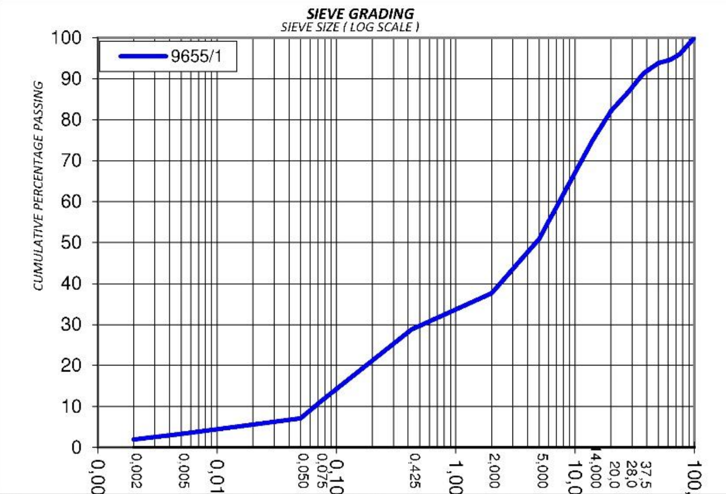
Client : **Geocalibre (Pty) Ltd** Address: 33 Denne Avenue, Donegal SH, Bainsvlei, Bloemfontein, 9301

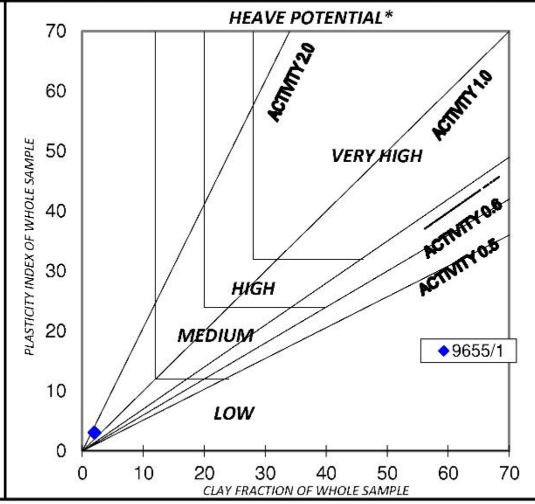
Contract : **Phase 1 Investigation - Paballelo Cemetery - Upington**

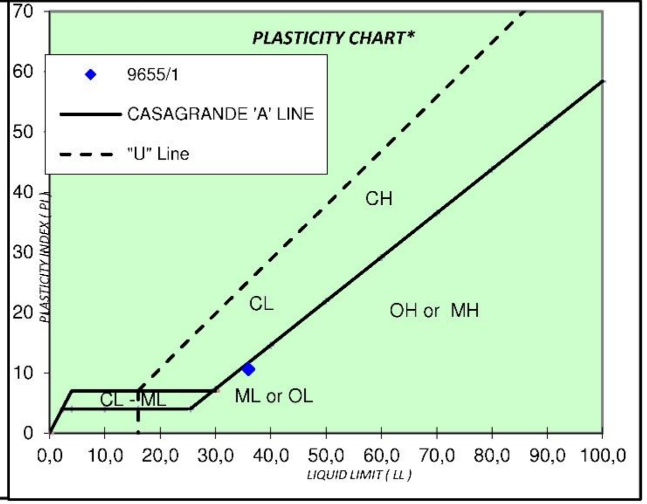
Description : **TP 1 (U1) from 0.37-0.94 m below existing ground level - uncrushed material**

Date Sampled: 06-Feb-23
Doc No: 9655/1(i)
Date Tested: 25-Feb-23

Depth (m)	Sample No.	Description (Unified Soil Classification - ASTM D2487*)	Sieve analysis Cumulative percentage passing												Soil Mortar Analysis % of mat. <2,00 mm*				Effective size*	Uniformity - coef.*	Curvature coef.*	Grading modulus*	Atterberg Limits			Classifications*			
			50,0 mm	37,5 mm	28.0 mm	20,0 mm	14.0 mm	5.0 mm	2,00 mm	0,425 mm	0,075 mm	0,05 mm*	0.005 mm*	0.002 mm*	Coarse sand <2,0 >0,425mm	Fine sand <0,425 >0,075mm	Silt <0,05 >0,005mm	Clay <0,005 mm					Liquid Limit	Plasticity Index	Linear Shrinkage	Unified Soil	COLTO	US.Highway	Group Index
0.37-0.94	9655/1	drk Red Well graded Clayey sand	94	91	87	82	75	51	38	29	11	7,1	3,3	2,0	23,4	46,3	10,1	8,8	0,066	112	0,6	2,2	36	11	5,3	sw/sc	G6	A-2-6	0







Remarks: ** tests done at Bloemfontein branch

The Shrinkage Product of this material was 153

Date Issued: 13/Mar/23 Technical signatory (Name) : **J.Wingrove** Signature:

Digitally signed by Jayson Wingrove
Date: 2023.03.13 10:47:30 +02'00'

LETABA LABORATORIES AND SURVEYORS (Pty) Ltd
CIVIL ENGINEERING MATERIALS LABORATORY

6 Gruis Street, Hilton
Bloemfontein, 9301
P.O Box 22874,
Exton Road, 9313

T0864

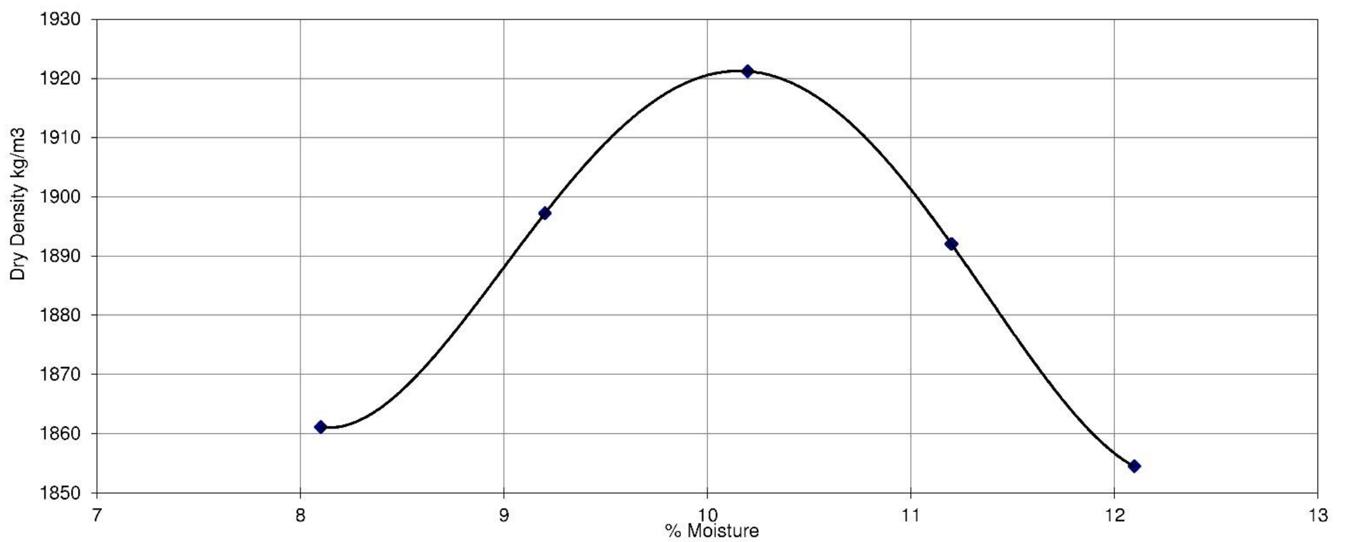
Tel. No: 087 285 0816 e-mail : letaba@letabalab.co.za www.letabalab.co.za

CBR and Maximum Dry Density Test Report

SANS 3001 Methods GR20, GR30 & GR40

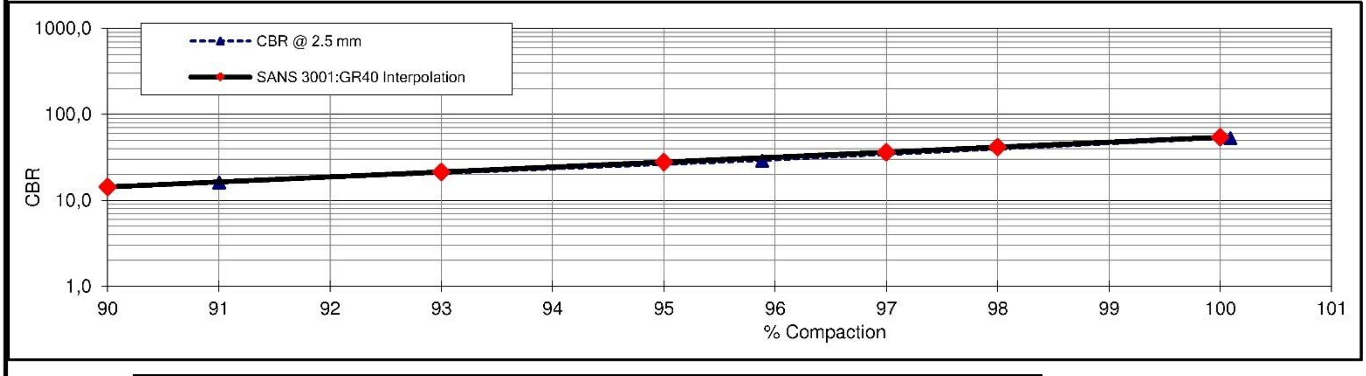
Client:	Geocalibre (Pty) Ltd	Date tested:	25-Feb-23
Contract :	Phase 1 Investigation - Paballelo Cemetery - Upington	Date Sampled:	06-Feb-23
Description:	TP 1 (U1) from 0.37-0.94 m below existing ground level - uncrushed material	Sample No.	9655/1
		Doc no:	9655/1(II)

*Maximum Dry Density =	1921	kg/m³
Optimum moisture content =	10,2	%



California Bearing Ratio

* This sample was prepared for compaction by using the Scalping method



% Compaction	100	98	97	95	93	90
CBR of 13.3 kN	54	42	36	28	21	14

** tests done at Bloemfontein branch

REMARKS

Briquette Information			
Compaction (%)	100,1	95,9	91,0
Dry Density (kg/m³)	1923	1842	1748
Compaction Moisture (%)	10,1	10,1	10,0
% Swell	0,11	0,27	0,55

Date Issued: 13-Mar-23 Technical signatory (Name) : J.Wingrove Signature:

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Date: 2023.03.13 10:47:41 +02'00'

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6 Gruis Street, Hilton
Bloemfontein, 9301
P.O Box 22874,
Exton Road, 9313

T0864

Tel. No: 087 285 0816   e-mail : letaba@letabalab.co.za   www.letabalab.co.za

GRAVEL, SOIL AND SAND ANALYSIS : FOUNDATION INDICATOR TEST REPORT

SANS 3001 Methods GR1, GR3, GR5, GR10, GR20, GR30 & GR40

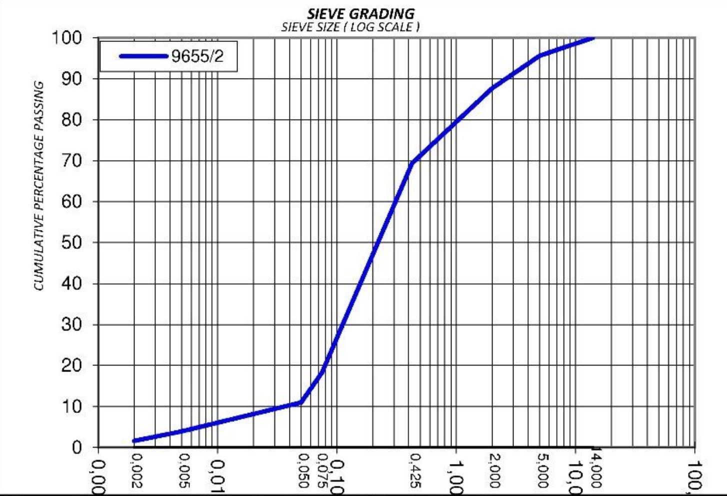
Client : **Geocalibre (Pty) Ltd**   Address: 33 Denne Avenue, Donegal SH, Bainsvlei, Bloemfontein, 9301

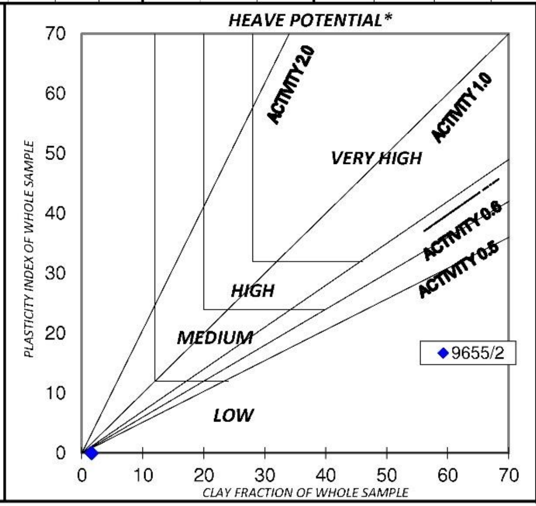
Contract : **Phase 1 Investigation - Paballelo Cemetery - Upington**

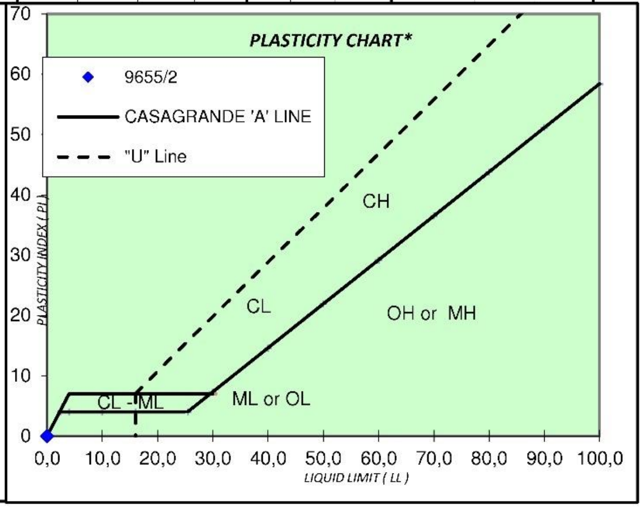
Description : **TP 2 (U2) from 0.17-0.51 m below existing ground level - uncrushed material**

Date Sampled: 06-Feb-23
Doc No: 9655/2(i)
Date Tested: 25-Feb-23

Depth (m)	Sample No.	Description (Unified Soil Classification - ASTM D2487*)	Sieve analysis – Cumulative percentage passing: 50,0 mm	37,5 mm	28.0 mm	20,0 mm	14.0 mm	5.0 mm	2,00 mm	0,425 mm	0,075 mm	0,05 mm*	0.005 mm*	0.002 mm*	Soil Mortar Analysis % of mat. <2,00 mm*: Coarse sand <2,0 >0,425mm	Fine sand <0,425 >0,075mm	Silt <0,05 >0,005mm	Clay <0,005 mm	Effective size*	Uniformity - coef.*	Curvature coef.*	Grading modulus*	Atterberg Limits: Liquid Limit	Plasticity Index	Linear Shrinkage	Classifications*: Unified Soil	COLTO	US.Highway	Group Index
0.17-0.51	9655/2	drk Red Silty sand					100	96	88	69	18	11,0	3,9	1,6	20,9	58,3	8,1	4,5	0,036	9	1,1	1,2		SP	0,8	SM(d)	N/A	A-2-4	0







Remarks: ** tests done at Bloemfontein branch

The Shrinkage Product of this material was 56

Date Issued: 13/Mar/23   Technical signatory (Name) : **J.Wingrove**   Signature:

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Date: 2023.03.13 10:47:59 +02'00'

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CIVIL ENGINEERING MATERIALS LABORATORY

6 Gruis Street, Hilton
Bloemfontein, 9301
P.O Box 22874,
Exton Road, 9313

T0864

Tel. No: 087 285 0816 e-mail : letaba@letabalab.co.za www.letabalab.co.za

GRAVEL, SOIL AND SAND ANALYSIS : FOUNDATION INDICATOR TEST REPORT

SANS 3001 Methods GR1, GR3, GR5, GR10, GR20, GR30 & GR40

Client : **Geocalibre (Pty) Ltd** Address: 33 Denne Avenue, Donegal SH, Bainsvlei, Bloemfontein, 9301

Contract : **Phase 1 Investigation - Paballelo Cemetery - Upington**

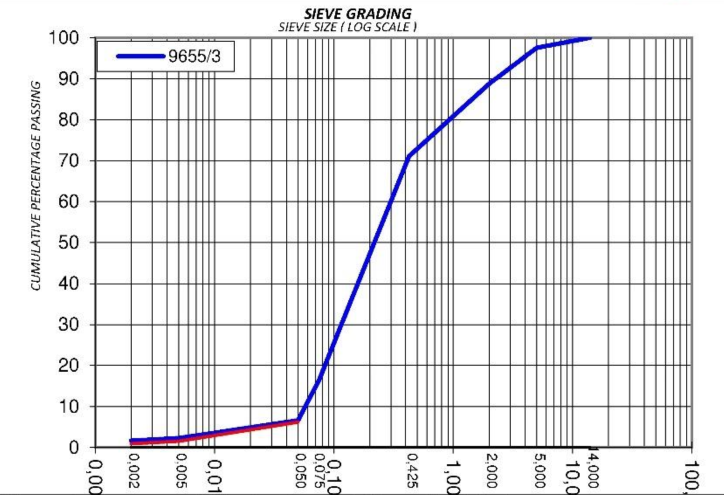
Description : **TP 3 (U3) from 0.0-0.30 m below existing ground level - uncrushed material**

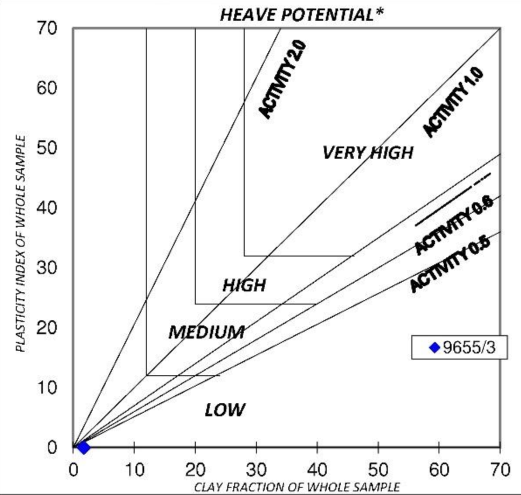
Date Sampled: 06-Feb-23

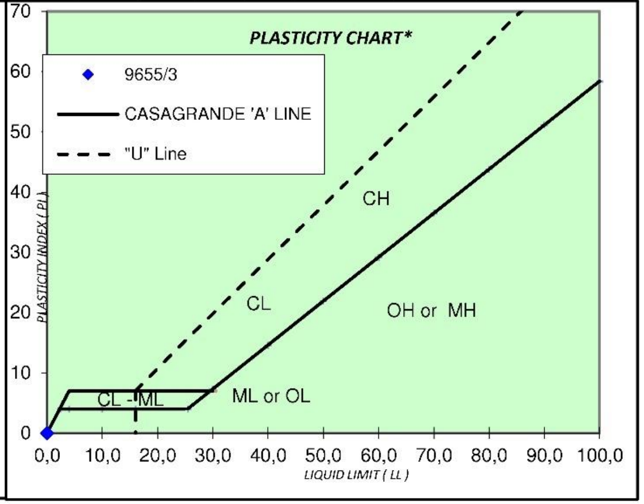
Doc No: 9655/3(i)

Date Tested: 25-Feb-23

Depth (m)	Sample No.	Description (Unified Soil Classification - ASTM D2487*)	Sieve analysis Cumulative percentage passing: 50,0 mm	37,5 mm	28,0 mm	20,0 mm	14,0 mm	5,0 mm	2,00 mm	0,425 mm	0,075 mm	0,05 mm*	0.005 mm*	0.002 mm*	Soil Mortar Analysis % of mat. <2,00 mm*: Coarse sand <2,0 >0,425mm	Fine sand <0,425 >0,075mm	Silt <0,05 >0,005mm	Clay <0,005 mm	Effective size*	Uniformity - coef.*	Curvature coef.*	Grading modulus*	Atterberg Limits: Liquid Limit	Plasticity Index	Linear Shrinkage	Classifications*: Unified Soil	COLTO	US.Highway	Group Index
0.0-0.30	9655/3	drk Red Silty sand					100	98	89	71	16	6,6	2,3	1,7	20,0	61,5	4,9	2,6	0,058	5	0,8	1,2		NP	0,0	SM(d)	N/A	A-2-4	0
											*Double Hydrometer Values:	6,2	1,5	0,9															







Remarks: ** tests done at Bloemfontein branch

The Shrinkage Product of this material was 0

***DOUBLE HYDROMETER RESULT : 67 %** If Double Hydrometer result is above 40%, the material is considered to be dispersive.

***pH =7 , *Electrical Conductivity =0,016 S/m, tested on the whole sample**

Date Issued: 13/Mar/23 Technical signatory (Name) : **J.Wingrove** Signature:

Digitally signed by Jayson Wingrove
Date: 2023.03.13 10:48:12 +02'00'

SF 7.8-104_F-ind_CBR_EC_pH_disp Colto_Rev 43_Eff Date: 2023-01-20

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CIVIL ENGINEERING MATERIALS LABORATORY

6 Gruis Street, Hilton
Bloemfontein, 9301
P.O Box 22874,
Exton Road, 9313

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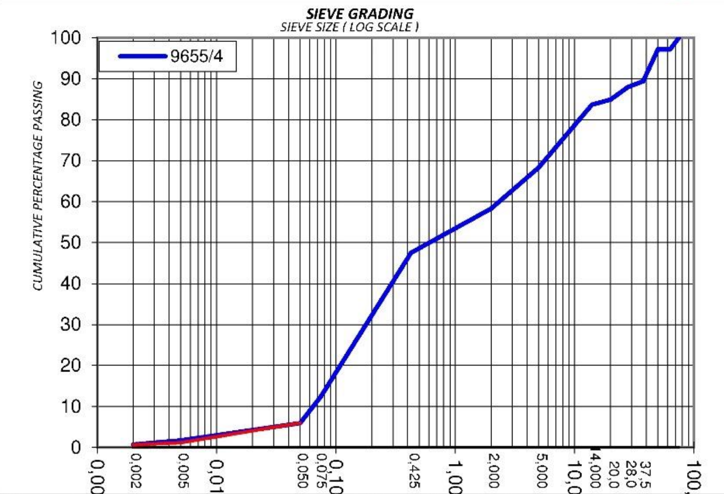
Tel. No: 087 285 0816 **e-mail :** letaba@letabalab.co.za www.letabalab.co.za

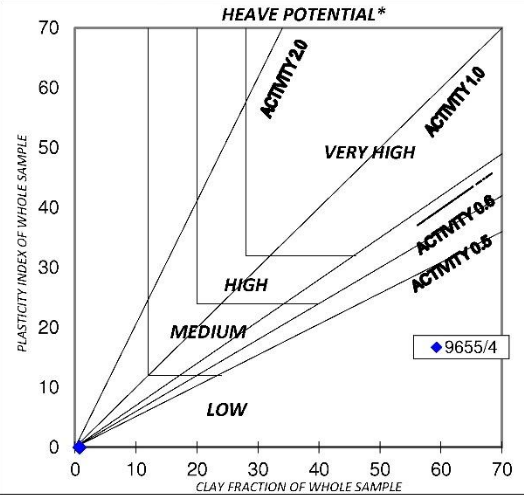
GRAVEL, SOIL AND SAND ANALYSIS : FOUNDATION INDICATOR TEST REPORT

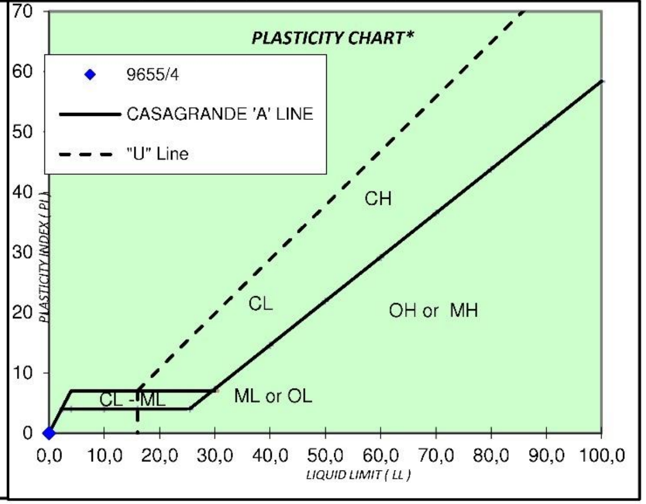
SANS 3001 Methods GR1, GR3, GR5, GR10, GR20, GR30 & GR40

Client :	**Geocalibre (Pty) Ltd**	Address: 33 Denne Avenue, Donegal SH, Bainsvlei, Bloemfontein, 9301	**Date Sampled: 06-Feb-23**
Contract :	**Phase 1 Investigation - Paballelo Cemetery - Upington**		**Doc No:** 9655/4(i)
Description :	**TP 5 (U4) from 0.00-0.75 m below existing ground level - uncrushed material**		**Date Tested: 25-Feb-23**

Depth (m)	Sample No.	Description (Unified Soil Classification - ASTM D2487*)	Sieve analysis Cumulative percentage passing: 50,0 mm	37,5 mm	28,0 mm	20,0 mm	14,0 mm	5,0 mm	2,00 mm	0,425 mm	0,075 mm	0,05 mm*	0.005 mm*	0.002 mm*	Soil Mortar Analysis % of mat. <2,00 mm*: Coarse sand <2,0 >0,425mm	Fine sand <0,425 >0,075mm	Silt <0,05 >0,005mm	Clay <0,005 mm	Effective size*	Uniformity - coef.*	Curvature coef.*	Grading modulus*	Atterberg Limits: Liquid Limit	Plasticity Index	Linear Shrinkage	Classifications*: Unified Soil	COLTO	US.Highway	Group Index
0.00-0.75	9655/4	drk Red Silty sand	97	89	88	85	84	68	58	48	13	5,9	1,8	0,7	18,5	60,1	7,1	3,0	0,064	36	0,2	1,8		SP	1,1	SM(d)	G6	A-1-b	0
											*Double Hydrometer Values:	6,0	1,2	0,6															







Remarks: ** tests done at Bloemfontein branch

The Shrinkage Product of this material was 52

***DOUBLE HYDROMETER RESULT : 68 %** If Double Hydrometer result is above 40%, the material is considered to be dispersive.

***pH =7,2 , *Electrical Conductivity =0,017 S/m, tested on the -5mm fraction**

Date Issued: 13/Mar/23 Technical signatory (Name) : **J.Wingrove** Signature:

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Date: 2023.03.13 10:36:15 +02'00'

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6 Gruis Street, Hilton
Bloemfontein, 9301
P.O Box 22874,
Exton Road, 9313

T0864

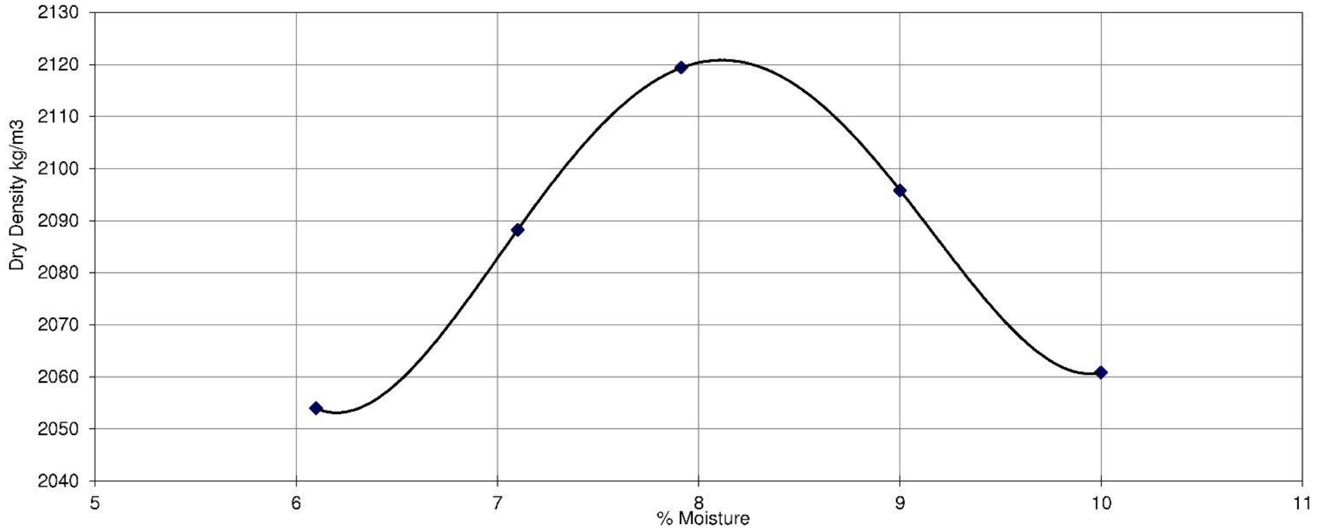
Tel. No: 087 285 0816 e-mail : letaba@letabalab.co.za www.letabalab.co.za

CBR and Maximum Dry Density Test Report

SANS 3001 Methods GR20, GR30 & GR40

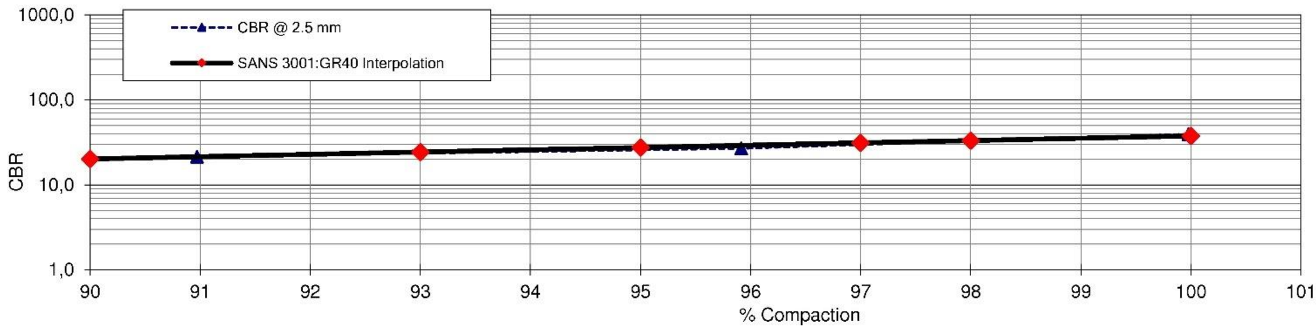
Client:	Geocalibre (Pty) Ltd	Date tested:	25-Feb-23
Contract :	Phase 1 Investigation - Paballelo Cemetery - Upington	Date Sampled:	06-Feb-23
Description:	TP 5 (U4) from 0.00-0.75 m below existing ground level - uncrushed material	Sample No.	9655/4
		Doc no:	9655/4(ii)

*Maximum Dry Density =	2120	kg/m³
Optimum moisture content =	8,1	%



California Bearing Ratio

* This sample was prepared for compaction by using the Scalping method



% Compaction	100	98	97	95	93	90
CBR of 13.3 kN	38	33	31	28	24	20

** tests done at Bloemfontein branch

REMARKS

Briquette Information			
Compaction (%)	100,0	95,9	91,0
Dry Density (kg/m³)	2120	2033	1929
Compaction Moisture (%)	7,9	7,8	7,8
% Swell	0,06	0,17	0,26

Date Issued: 13-Mar-23 Technical signatory (Name) : J.Wingrove Signature:

Digitally signed by Jayson Wingrove
Date: 2023.03.13
10:36:31 +02'00'

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GRAVEL, SOIL AND SAND ANALYSIS : FOUNDATION INDICATOR TEST REPORT

SANS 3001 Methods GR1, GR3, GR5, GR10, GR20, GR30 & GR40

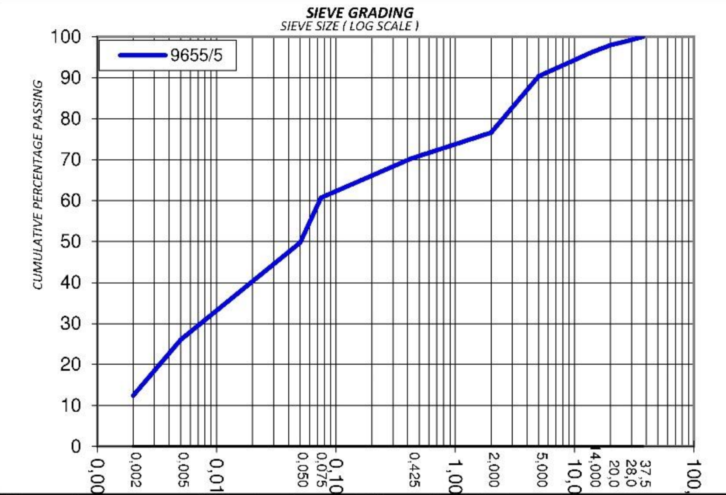
Client : **Geocalibre (Pty) Ltd** Address: 33 Denne Avenue, Donegal SH, Bainsvlei, Bloemfontein, 9301

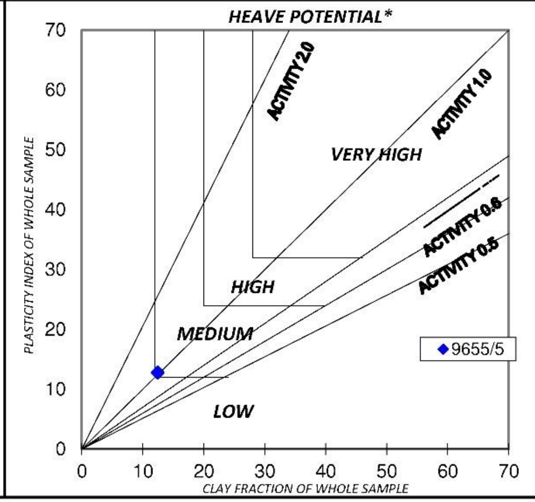
Contract : **Phase 1 Investigation - Paballelo Cemetery - Upington**

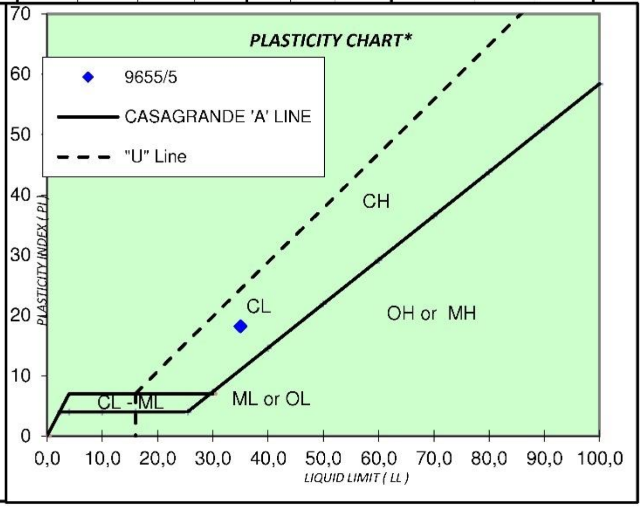
Description : **TP 6 (U5) from 0.0-0.42 m below existing ground level - uncrushed material**

Date Sampled: 06-Feb-23
Doc No: 9655/5(i)
Date Tested: 25-Feb-23

Depth (m)	Sample No.	Description (Unified Soil Classification - ASTM D2487*)	Sieve analysis Cumulative percentage passing												Soil Mortar Analysis % of mat. <2,00 mm*				Effective size*	Uniformity - coef.*	Curvature coef.*	Grading modulus*	Atterberg Limits			Classifications*			
			50,0 mm	37,5 mm	28.0 mm	20,0 mm	14.0 mm	5.0 mm	2,00 mm	0,425 mm	0,075 mm	0,05 mm*	0.005 mm*	0.002 mm*	Coarse sand <2,0 >0,425mm	Fine sand <0,425 >0,075mm	Silt <0,05 >0,005mm	Clay <0,005 mm					Liquid Limit	Plasticity Index	Linear Shrinkage	Unified Soil	COLTO	US.Highway	Group Index
0.0-0.42	9655/5	lt Brown Inorganic clay		100	99	98	96	90	77	70	61	49,8	26,0	12,4	8,3	12,5	31,0	34,0	<0.002	73	0,7	0,9	35	18	9,0	CL	N/A	A-6	8







Remarks: ** tests done at Bloemfontein branch

THIS MATERIAL IS NOT SUITABLE FOR WEARING COARSE AS THE SHRINKAGE PRODUCT IS GREATER THAN 550

Date Issued: 13/Mar/23 Technical signatory (Name) : **J.Wingrove** Signature:

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Date: 2023.03.13 10:48:36 +02'00'

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T0864

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SANS 3001 Methods GR1, GR3, GR5, GR10, GR20, GR30 & GR40

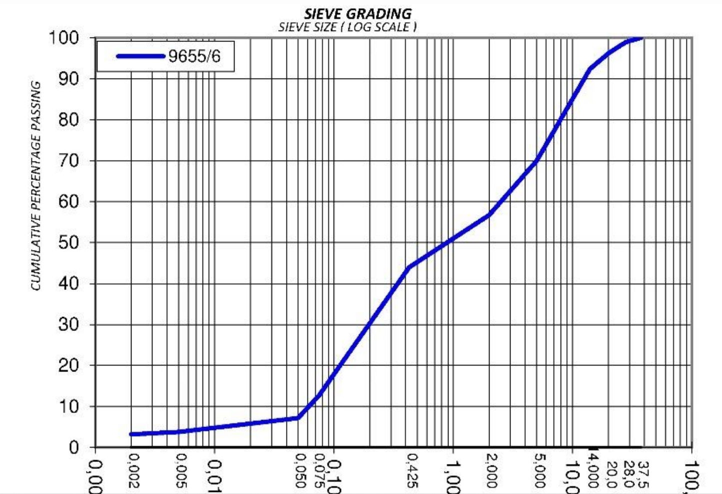
Client : **Geocalibre (Pty) Ltd** Address: 33 Denne Avenue, Donegal SH, Bainsvlei, Bloemfontein, 9301

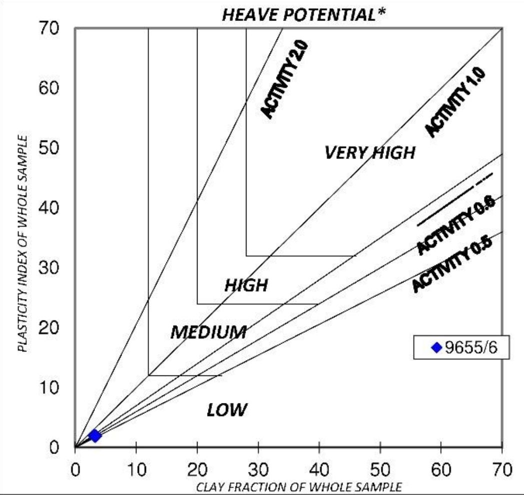
Contract : **Phase 1 Investigation - Paballelo Cemetery - Upington**

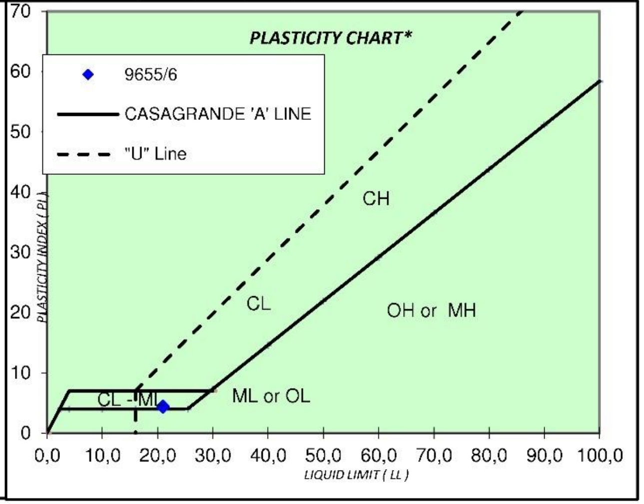
Description : **TP 6 (U6) from 0.42-0.90 m below existing ground level - uncrushed material**

Date Sampled: 06-Feb-23
Doc No: 9655/6(i)
Date Tested: 25-Feb-23

Depth (m)	Sample No.	Description (Unified Soil Classification - ASTM D2487*)	Sieve analysis Cumulative percentage passing: 50,0 mm	37,5 mm	28,0 mm	20,0 mm	14,0 mm	5,0 mm	2,00 mm	0,425 mm	0,075 mm	0,05 mm*	0.005 mm*	0.002 mm*	Soil Mortar Analysis % of mat. <2,00 mm*: Coarse sand <2,0 >0,425mm	Fine sand <0,425 >0,075mm	Silt <0,05 >0,005mm	Clay <0,005 mm	Effective size*	Uniformity - coef.*	Curvature coef.*	Grading modulus*	Atterberg Limits: Liquid Limit	Plasticity Index	Linear Shrinkage	Classifications*: Unified Soil	COLTO	US.Highway	Group Index
0.42-0.90	9655/6	drk Red Silty/clayey sand		100	99	96	92	70	57	44	13	7,2	3,8	3,2	22,5	55,1	6,0	6,7	0,061	41	0,2	1,9	21	4	2,0	sm/sc	N/A	A-1-b	0







Remarks: ** tests done at Bloemfontein branch

The Shrinkage Product of this material was 88

Date Issued: 13/Mar/23 Technical signatory (Name) : J.Wingrove Signature:

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Date: 2023.03.13 10:48:53 +02'00'

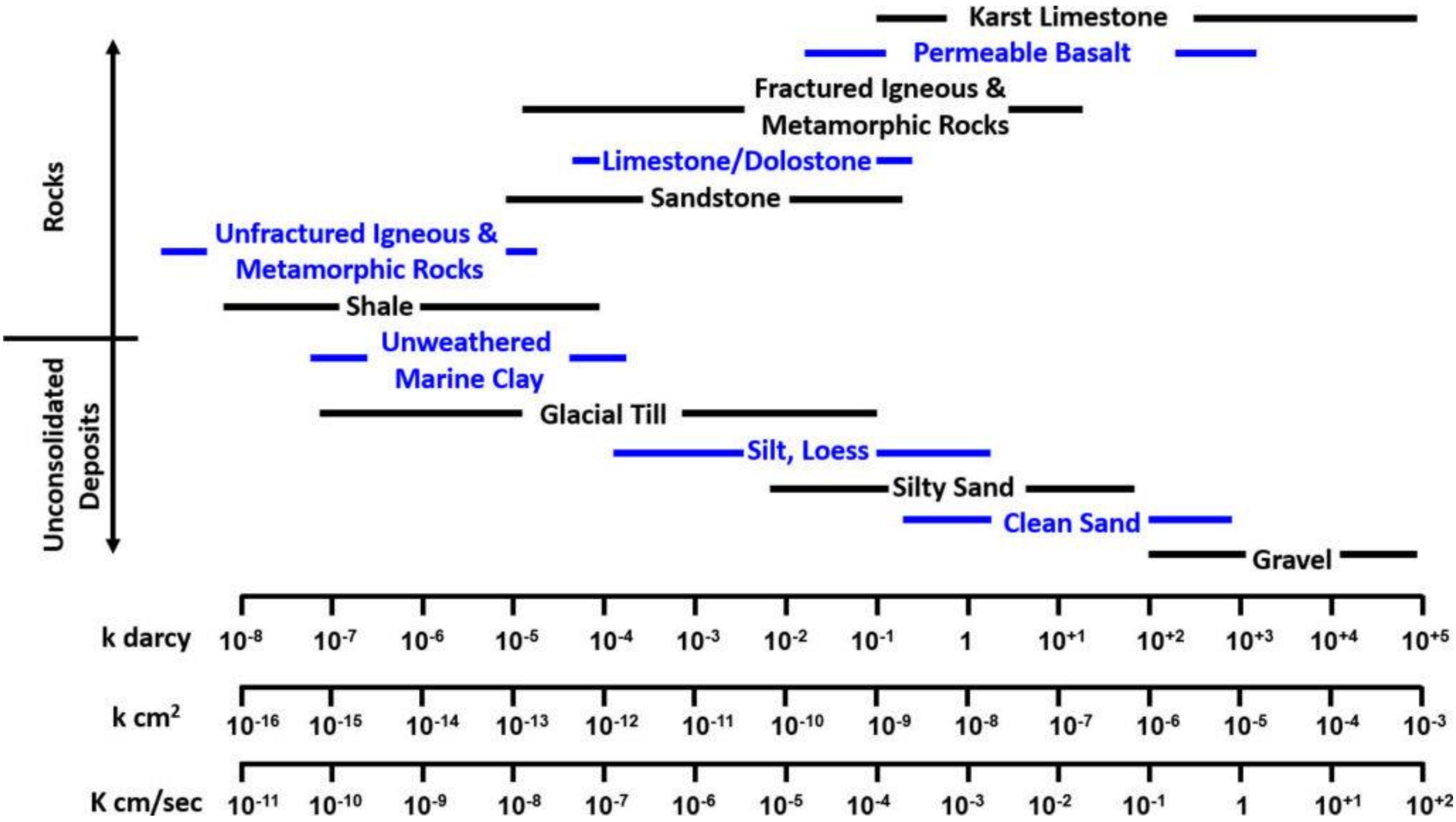
Appendix C

Site Classification Reference Tables

Geotechnical Constraints in Urban Development (SANS 634:2012)

CONSTRAINT		DESCRIPTOR		
DESCRIPTION		1 (most favourable)	2 (intermediate)	3 (least favourable)
A	Collapsible soil	Any collapsible horizon or consecutive horizons totalling depth of less than 750 mm in thickness	Any collapsible horizon or consecutive horizons totalling depth of more than 750 mm in thickness	n/a
B	Seepage	Permanent or perched water table more than 1.5 m below ground surface	Permanent or perched water table less than 1.5 m below ground surface	Swamps and marshes
C	Active soil	Low soil-heave potential anticipated	Moderate soil-heave potential anticipated	High soil-heave potential anticipated
D	Highly compressible soil	Low soil compressibility anticipated	Moderate soil compressibility anticipated	High soil compressibility anticipated
E	Erodibility of soil	Low	Intermediate	High
F	Difficulty of excavation to 1.5 m depth	Scattered or occasional boulders less than 10% of total volume	Rock or hardpan pedocretes between 10% and 40% of total volume	Rock or hardpan pedocretes more than 40% of total volume
G	Undermined ground	Undermining at a depth greater than 200 m below surface	Old, undermined areas to a depth of 200 m below surface	Mining within less than 200 m of surface with total extraction
H	Stability (dolomite land)	Possibly stable	Potentially instable	Known sinkholes and dolines
I	Steep slopes	2-6 degrees	< 2 degrees or 6-18 degrees	> 18 degrees
J	Unstable natural slopes	Low risk	Intermediate risk	High risk
K	Seismic activity	10% probability of an event less than 100 cm/s^2 in 50 years	Mining-induced seismicity > 100 cm/s^2	Natural seismicity > 100 cm/s^2
L	Flooding	n/a	Adjacent to known drainage or channel with slope < 1%	Areas within drainage channel or floodplain

(After Partridge, Wood & Brink)



Karst Limestone
Permeable Basalt
Fractured Igneous &
Metamorphic Rocks
Limestone/Dolostone
Sandstone
Unfractured Igneous &
Metamorphic Rocks
Shale
Unweathered
Marine Clay
Glacial Till
Silt, Loess
Silty Sand
Clean Sand
Gravel
Rocks
Unconsolidated
Deposits
k darcy
10-8 10-7 10-6 10-5 10-4 10-3 10-2 10-1 1 10+1 10+2 10+3 10+4 10+5
k cm2
10-16 10-15 10-14 10-13 10-12 10-11 10-10 10-9 10-8 10-7 10-6 10-5 10-4 10-3
K cm/sec
10-11 10-10 10-9 10-8 10-7 10-6 10-5 10-4 10-3 10-2 10-1 1 10+1 10+2

Character of permeability (Pazdro, Kozerski 1990)	very good	good	average	weak	semi-permeable	impermeable
Classification of permeability (Terzaghi, Peck 1967)	large	average	small	very small	practically impermeable	
(Head, 1985)	high	average	low	very low	practically impermeable	
Characteristic of flow water (Head, 1985)	good	weak	practically impermeable			
Soil	stones and gravels	sands	cracked and stale clays	boulder clays	silts	high plasticity clays
						clays with microcracks and noncracked hard clays

coef. of permeability k [m/s]: 1, 10^{-1}, 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6}, 10^{-7}, 10^{-8}, 10^{-9}, 10^{-10}, 10^{-11}, 10^{-12}

Direct investigations	*in situ*	pumping, water take off or water-injection of boreholes, pits, wells	investigation in different type piezometers: by falling-head test or pressure piezometers, self boring pressuremeter SBP
		open infiltrometers (single and double)	BAT probe, double-sealed infiltrometer
	labora-tory	constant-head permeability tests	falling-head permeability tests, Rowe's cell
			constant-flow rate permeability tests (Flow Pump)
Indirect Investigations	*in situ*	indicatory investigatins: (chemical, colorimetric, isotopic)	static penetration tests CPTU, SCPTU
			DMTA, DMTC tests
		geophisical researches	
	labora-tory	computational methods from empirical and analitical formulas, investigations on physical models	on the basis consolidation theory, investigations quantitative microstructure SEM
	theore-tical	analog modelling, numerical models calibration, solution of inverse problems and others	

Box 9. **Geotechnical Considerations.**

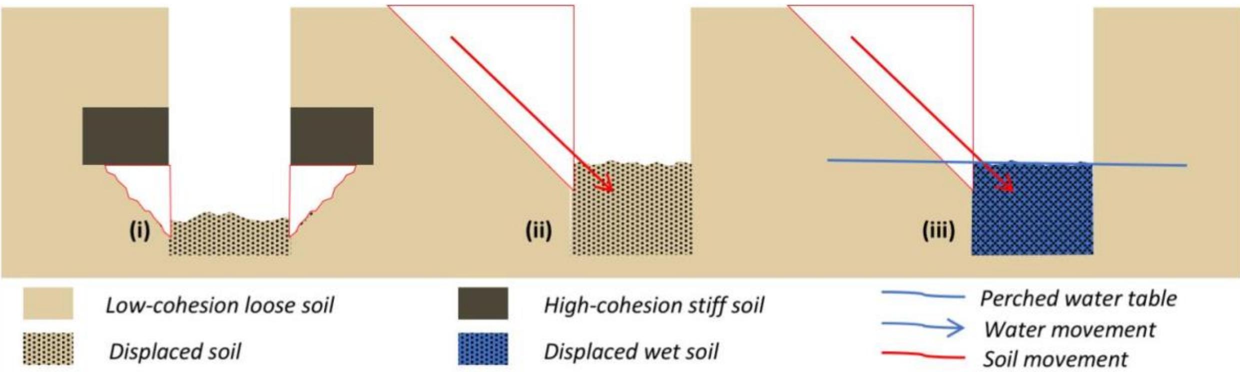
BOX 9. GEOTECHNICAL CONSIDERATIONS

(a) Excavation (In-)stability

Cenozoic sand deposits (Welmoed Western Cape 2017):

(left) Collapse of weak loose sands

(right) Orange layer: indurated by iron; possible zone of periodic wetting



(b) Karst/ Dolomite Instability

(left) Dolomite in the Irene Cemetery (2012): a leaking water pipe mobilised overburden into a sinkhole through the ingress scenario. Landscaping and irrigation were the anthropogenic causes of the sinkhole.

(right) Dolomite and calcrete in the vicinity of Taung (2005): difficult excavation in shallow bedrock and hard calcretes result in shallow graves and the need to create rock mounds over coffins.

(c) Excavatability/ Backfill Materials

(d) Perched Water and Flooded Graves

(left) Near wetland conditions and flooded grave excavations in a cemetery underlain by Hammanskraal Formation Sandstone (Pretoria, 2012). A leaking underground pipeline apparently contributed to the flooding of newly excavated graves.

READ MORE:
ADAPTED FROM: This document; Dippenaar 2014; Dippenaar et al. 2014; Dippenaar and Van Rooy 2018

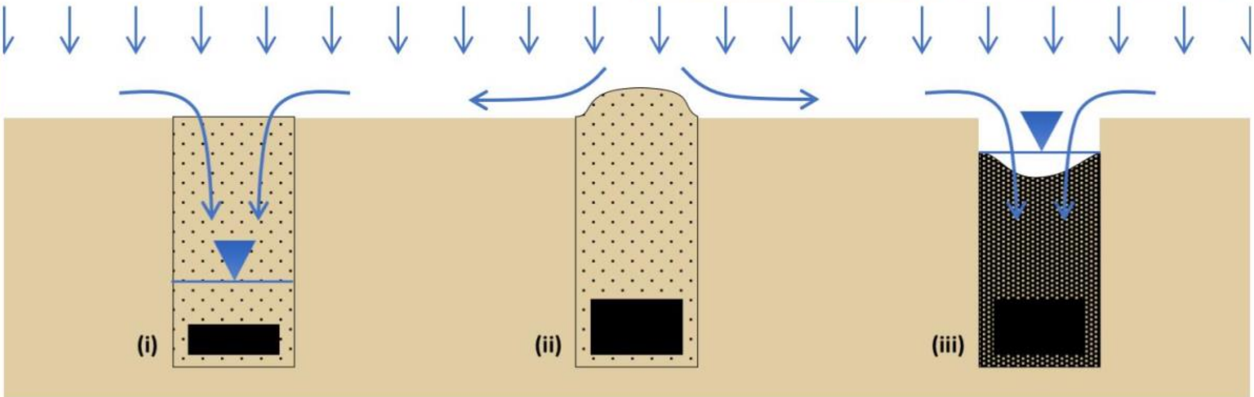
Box 10. **Engineering Hydrogeological Considerations.**

BOX 10. ENGINEERING HYDROGEOLOGICAL CONSIDERATIONS

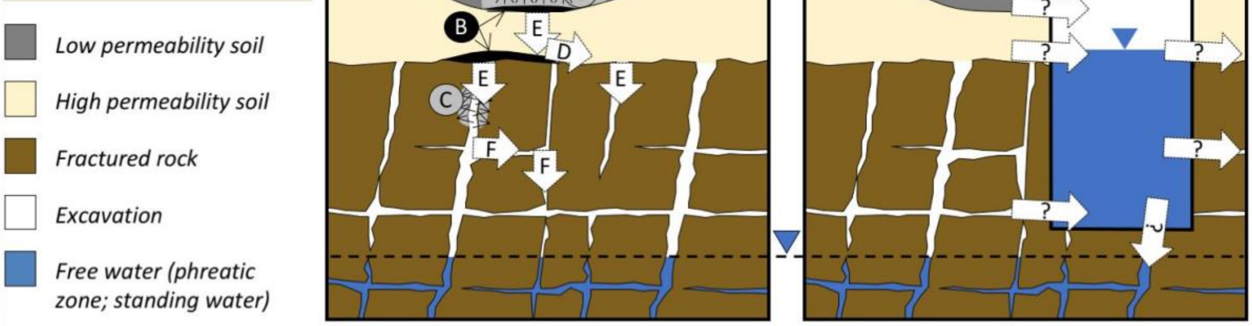
(a) Grave Backfill and Flow

(left) Karoo Mudrocks (Middelburg Mpumalanga, 2016); mounded backfill

(right) Cenozoic Sands (Delft Western Cape, 2016); depressed backfill



(b) Complex Subsurface Flow Systems



Different flow scenarios co-occur in the subsurface, all contributing to the complex subsurface system. Excavation through these intercept numerous flow scenarios and affect future subsurface flow systems. Proposed scenarios include:

A) **Normal perching**: moisture can perch and disperse on lower permeability horizons due to the high suctions in small void spaces and the effort required to breach those suctions for water entry.

B) **Capillary-barriered** perching: moisture can perch and disperse on higher permeability horizons due to excessive adhesion and suction in fine-grained materials retaining moisture above larger voids or fractures, thus not allowing water entry.

C) **Imbibition**: moisture can imbibe laterally or vertically into finer-grained lower-permeability materials (soil or primary porosity of rock) due to suction, especially at fairly low moisture contents.

D) **Shallow interflow**: perched water can be mobilised as cohesion (water-water attraction) dominates and interflow ensues on lower permeability materials.

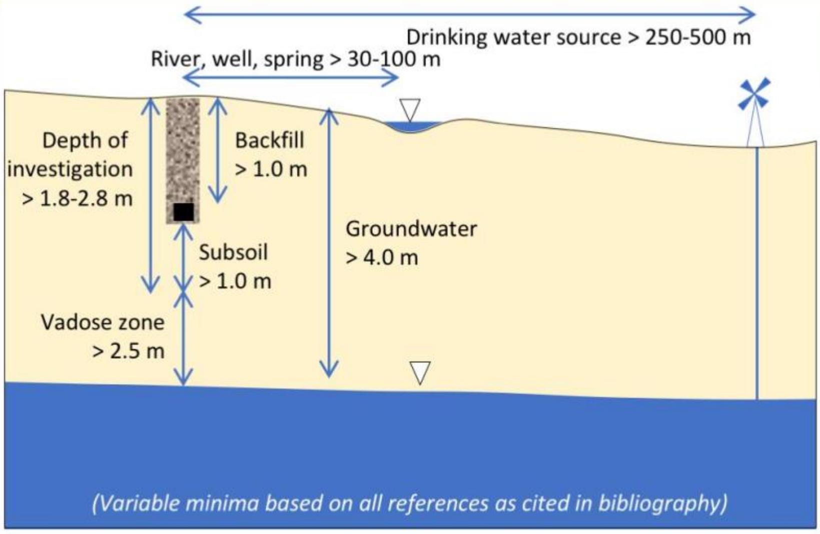
E) **Deep percolation**: perched water at high or total saturation in the vadose zone can mobilise as cohesion dominates, and gravity-driven percolation or drainage results.

F) **Unsaturated fracture flow**: seepage at partial saturation through fracture intersections and networks.

READ MORE: ADAPTED FROM: This document; (b) Dippenaar and Van Rooy 2018

Box 11. **Generic Minimum Requirements for Investigation.**

BOX 11. GENERIC MINIMUM REQUIREMENTS FOR CEMETERIES



(a) Generic Requirements for Siting and Investigations

Additional Specifications

Numerous dated other approaches require proving, by any means, the following:

- Deep water table
- Absence of perched water tables
- Soil conductivity 1 x 10^{-7} - 5 x 10^{-5} cm/s
- Thick excavatable soils
- No proximate water supply or drainage features
- Stability of sidewalls
- Surface gradient 2-6° (9° in exceptional cases)
- Space for adequate future expansion

(b) Standard Rating Scores (Hall and Hanbury 1990)

Engineering Geological/ Geotechnical

- **Excavatability** ease to 1.80 m
- **Stability** sidewalls stable for prolonged periods
- **Workability** material to be used as compacted backfill

Excavatability	Assessment	Score
Easy spade	Geological pick pushed in 50 mm with ease	15
Pick and spade	Geological pick causes slight indentation	10
Machine	Firm blows with pick cause 1 - 3 mm indentations	5
Blasting	Backactor refusal	0

Stability	Assessment	Score
Stable	Little overbreak with safe excavation profiling	20
Overbreak	Overbreak between 1.3 and 1.8 m	15
Slightly unstable	Minor falls of material	8
Unstable	Collapse of excavation likely	1

Workability	Unified	MOD AASHTO	Score
Excellent to good	GW. SW, GP	> 1 800 kg/m³	10
Fair	SP, SM	< 1 800 kg/m³	5
Poor	OL, CL, ML	< 1 700 kg/m³	2
Very poor	OH. CH, MH	< 1 500 kg/m³	0

Sanitary/ Environmental/ Hydrogeological

- **Water table** thickness of protective vadose zone
- **Subsoil permeability** preventing ponding and rapid infiltration
- **Backfill permeability** preventing ponding and rapid infiltration

Water Table	Water Table Depth (m)	Score
Deep water table	> 8	25
Intermediate water table	4 - 8	5
Possible perched water	0 - 4	5
Waterlogged soil	0 - 4	Fail

Subsoil Permeability	Percolation Rate	Approx. Permeability	Score
Impermeable	Not measurable	< 10^{-7} m/s	15
Relatively impermeable	10 - 15 mm/h	10^{-6} - 10^{-7} m/s	20
Relatively permeable	15 - 50 mm/h	10^{-5} - 10^{-6} m/s	10
Permeable	50 - 1 000 mm/h	< 10^{-5} m/s	0

Backfill Permeability	Unified Class	Score
Impermeable	OH, CL, CH	5
Relatively impermeable	GC, SC, MH	10
Relatively permeable	GP, SP, GW	7
Very permeable	SW, SP	0

Final Ranking	Suitability
> 90	Very good
75 - 90	Satisfactory
60 - 75	Poor
< 60	Unacceptable

READ MORE: ADAPTED FROM: (a) Croucamp and Richards 2002; Dent and Knight 1998; Dippenaar 2014; EA 2004; Engelbrecht 2000; Fisher 1992; Fisher 1994; Fisher and Croucamp 1993; Hall and Hanbury 1990; NIEA 2012; WHO 1996; Young et al. 2002; (b) Hall and Hanbury 1990