REPORT ON A GEOTECHNICAL SHALLOW SOIL INVESTIGATION FOR THE PROPOSED INSTALLATION OF SUBSURFACE FUEL STORAGE TANKS, TZANEEN, SOUTH AFRICA

Shallow Soil Geotechnical Investigation

05 July 2010

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Shallow Soil Geotechnical Investigation

WH10055 – Tzaneen Diesel Depot

COMPILED BY

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REPORT ON A GEOTECHNICAL SHALLOW SOIL INVESTIGATION FOR THE PROPOSED INSTALLATION OF SUBSURFACE FUEL STORAGE TANKS, TZANEEN, SOUTH AFRICA

1. INTRODUCTION

WSM Leshika Consulting (Pty) Ltd. was appointed to conduct a geotechnical investigation for the proposed installation of a subsurface fuel storage tank in Tzaneen, Limpopo Province, South Africa. The fieldwork was conducted on the 11th of May 2010.

The aim of the investigation was to identify the underlying geological formations and their near surface weathered, residual and transported soil cover, evaluate the excavatability of the material on site and identify, if present, potential shallow groundwater and/or seepage conditions.

This report describes the methodology and the findings of the investigation, including the general material characteristics, expected geotechnical constraints and the necessary precautionary measures and recommendations.

2. INFORMATION USED IN THE STUDY

The following available information was used during the course of the investigation:

- 1:250 000-scale 2330 TZANEEN Geological Sheet;
- 1:50 000-scale 2330CC Topographical Sheet;
- Planned site layout;
- Google satellite image.

3. OBJECTIVES OF THE INVESTIGATION

The objectives of this engineering geological investigation were to:

- Identify, where possible, the underlying geological formations and their near surface weathered residual and transported soil cover.
- Delineate the site into geotechnical zones based on the identified geotechnical constraints.
- Obtain the basic data concerning the use of in situ material for guideline purposes.
- To comment on the excavation characteristics of the site soils.
- To comment on potential seasonal shallow seepage water.

4. SITE DESCRIPTION

4.1 Location and size

The proposed site is located in the town of Tzaneen on the corner of Koedoe and Plantasie Avenues. The portion earmarked for the installation of the storage tank is located near the northern boundary of the site next to Koedoe Avenue, and is currently being used as a parking lot. The locality of the site is depicted in Figure 1, Appendix A.

The approximate centre coordinates of the entire site are illustrated in Table 1 (Datum: WGS84):

TABLE 1: APPROXIMATE CENTRE SITE COORDINATES

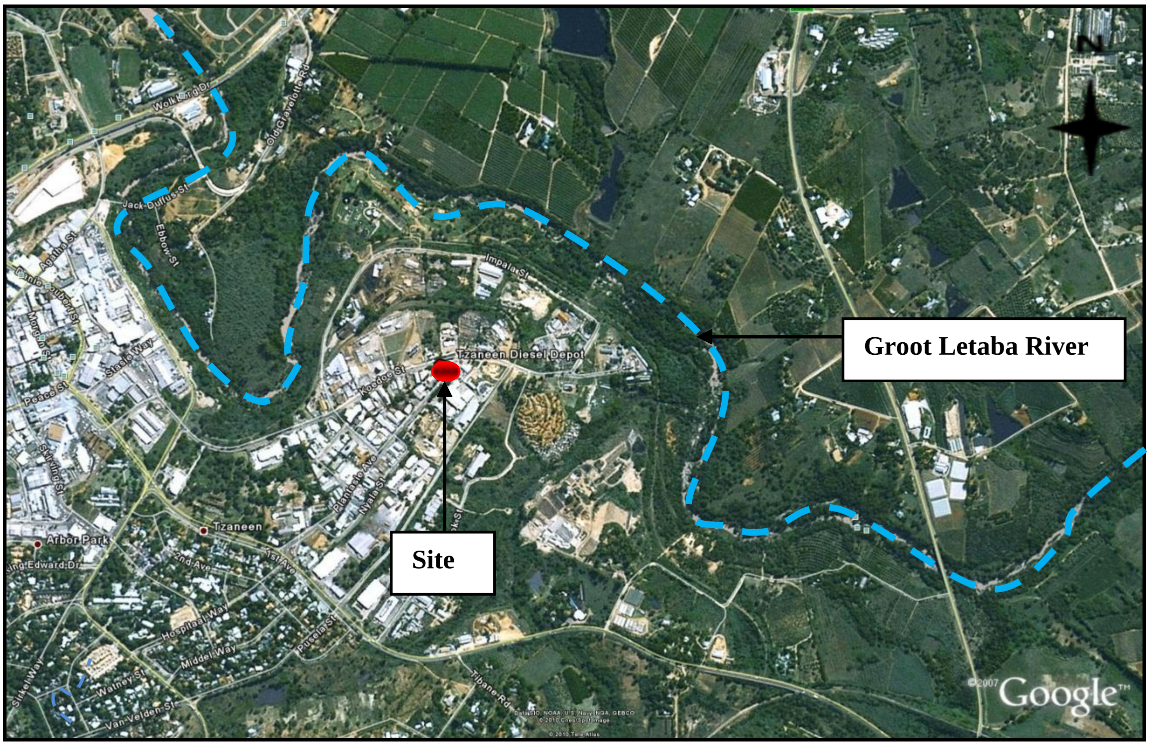
	Investigated area
Latitude	23° 49’ 41.37” S
Longitude	30°10’28.81” E
Elevation (m)	697

4.2 Topography, Drainage and Vegetation

The investigated area gently slopes in a northern direction, with a difference in elevation of 3metres between the highest (698 mamsl.) and lowest (695 mamsl.) points on site.

The site is located in the industrial area of Tzaneen. The majority of the site is currently developed and covered with paving. A couple of large trees (red mahogany and paper bark acacia) are scattered across the site.

As a result of the current extent of development of the site and surrounding area, there are no identified drainage features on, or in the vicinity, of the site. The large Groot Letaba River runs approximately 500-950 meters to east, west and north of the site, with the site being situated in a horseshoe bend of the river (see Satellite Image 1).



Satellite Image 1: Site locality

4.3 Existing services and structures

The site is situated on the corner of Plantasie and Koedoe Avenues and is easily accessible. The site is currently fully developed, with a number of large buildings and structures and the majority of the site covered with paving. The portion of the site earmarked for the installation of the subsurface fuel tanks is currently used as a parking lot, and is covered with paving and a number of small roofing structures (Photograph 1). It is assumed that the site is fully serviced. The planners should refer to services reports and databases of the local authorities to identify any such structures that may affect the suitability of the site or result in costly relocation of services.

Photograph 1: Area of site earmarked for storage tank installation

5. METHOD OF INVESTIGATION

The fieldwork comprised of a field walkover survey and the excavation of one test pit. The test pit was excavated using a Bell 315 S 4x4 TLB (small excavator/backhoe).

The test pit was positioned and excavated in order to successfully identify the geotechnical conditions in the area where the subsurface tanks are to be installed. The test pit position is indicated on in Figure 3, Appendix A. The test pit was excavated down to maximum practical excavation depth (the reach of the TLB).

A suitably qualified Engineering Geologist positioned and inspected the test pit. The soil profile was recorded using the standard procedures as recommended by SAIEG (1997). The soil profile description is included in Appendix B with photographs of the soil profile attached in Appendix C.

A disturbed soil sample was selectively retrieved and submitted to Soillab (Pty) Ltd. of Pretoria for testing. A foundation indicator test was performed on the sample to determine the particle size distribution, potential heave and Atterberg Limits of the soil.

The pH and conductivity of the soil paste was also measured to determine the acidity and potential corrosiveness of the soil.

6. GEOLOGY

6.1 Regional Geology

According to the 1:250 000 TZANEEN geological sheet, the site is underlain by Biotite gneiss and migmatite with anatectic mobilisates (*Zg*) of the Goudplaats-Hout River Gneisses. The geology is depicted in Figure 2, Appendix A.

The formation and typical mineral composition of the underlying rocks is briefly discussed below (B Cairncross, 2004).

Gneiss is a coarse-grained metamorphic rock that is characteristically banded or layered and forms by regional high-grade metamorphism of granite. Large crystals in gneiss are composed of quartz, alkali feldspar, mica and amphiboles. Migmatites refer to gneisses that have undergone intensive metamorphism and deformation, with a toothpaste-like appearance (Cairncross, 2004).

The site is not underlain by potentially soluble rock formations such as dolomite and limestone and no dolomite stability investigation is required.

6.2 Structural Geology

Based on the data obtained from the 1:250 000 TZANEEN geological sheet, a number of diabase dykes are located within a +/- 2 km radius of the site, all generally orientated northeast-southwest. The large Tzaneen Lineament, with a similar orientation to the diabase dykes, runs approximately 4 km to the west of the site.

6.3 Site Specific Geology

No bedrock was encountered during the site investigation and the material encountered in the trial pit was deemed to be transported.

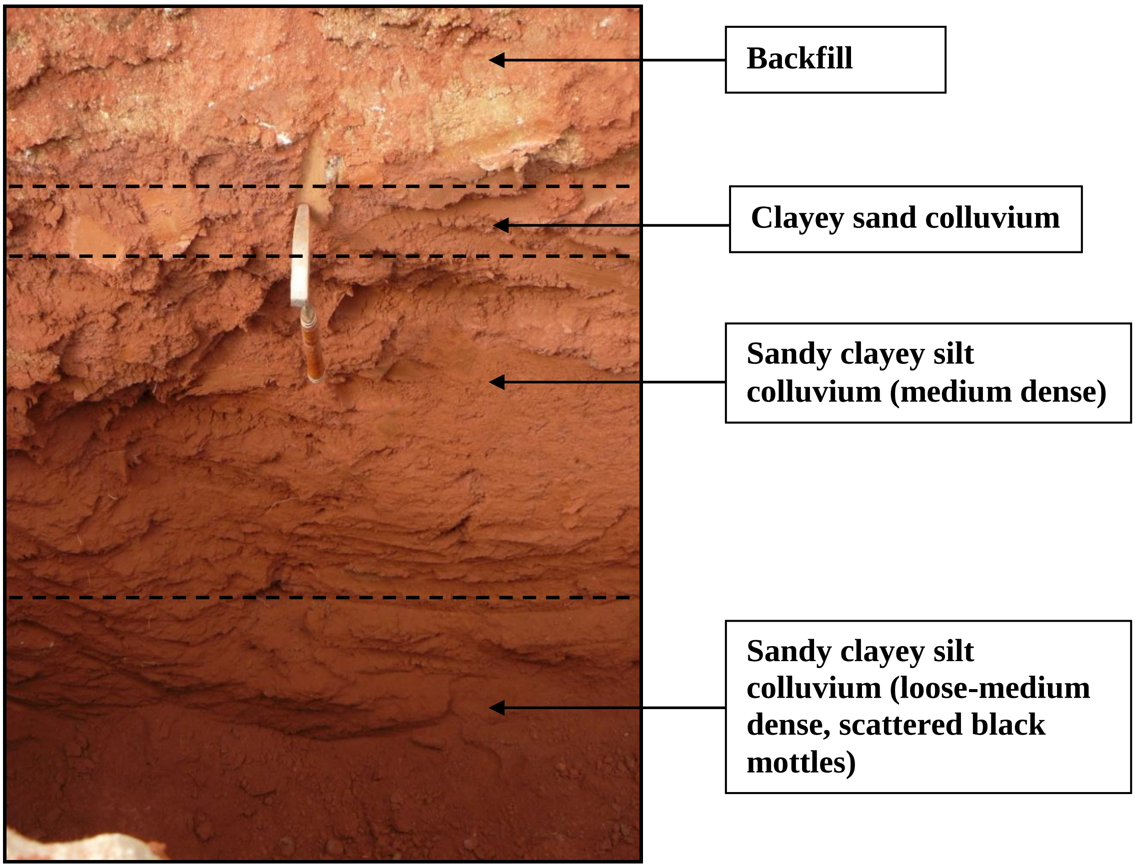
6.4 Typical Soil Profile

The general soil profile is briefly discussed below and summarized in Table 2. The detailed preliminary soil profile description is attached in Appendix B with photographs of the soil profile attached in Appendix C.

The upper soil horizon consisted of intact yellow brown sand, representing the **backfill material** used during the paving of the site.

The backfill material is underlain by a thin dark red **clayey sand colluvium horizon**, with a firm consistency and an intact structure.

The remainder of the profile consists of bright reddish-brown **fine sandy clayey silty colluvial material**. This material is slightly moist and pinholed, with the consistency varying from medium dense to loose, with scattered black mottles deeper down the profile.



Photograph 2: Typical profile

Photograph 3: General nature of the material in the profile

TABLE 2 : SOIL PROFILE SUMMARY

Test pit	Backfill	Clayey sandy colluvium	Sandy clayey silty colluvium	Sandy clayey silty colluvium (mottled)	Depth of test pit	Excavatability down to termination depth TLB	Seepage water encountered
TP01	0.0-0.40	0.40-0.50	0.50-1.40	1.40-2.60	2.60	Soft excavation conditions	None

Rew → Reworked with next horizon; -- horizon not present

7. SHALLOW GROUNDWATER, FLOODING AND SEEPAGE

The material in the excavated trial pit was classified as being only slightly moist, with no water seepage.

The excavated profile contained scattered black mottles from a depth of 1.40 meters, the slight ferruginization indicating the presence of possible fluctuating shallow seasonal water table.

Seasonal shallow groundwater seepage and/or a saturated upper soil profile are thus expected, especially during and towards the end of the raining season and after heavy and/or continuous downpours. The seepage water is expected to occur mainly from 1.40 meters and deeper from where the first indication of mottling was encountered. The seepage water will naturally drain towards the lower slopes.

The design engineer should incorporate the possible waterlogged conditions into the design to prevent possible buoyancy/flotation of the structure.

No drainage features and/or streams run through the site, but the large Groot Letaba River runs approximately 500-950 meters to the east, north and west of the site. ***It is assumed that a floodline investigation has been conducted and that the site is not susceptible to flooding.***

Due to the extent of development of the site minimal infiltration of rainwater is expected, and it is assumed to mainly drain as surface runoff. Proper precautionary measures needs to be taken to ensure sufficient drainage of surface water on the site and to prevent concentrated flow of water that will result in soil erosion, especially after removal of the pavement, during construction and after heavy downpours.

8. MATERIAL PROPERTIES

The evaluation of the material properties is based on the available information, visual observations, soil profile description, field interpretations and laboratory test results. The test results are attached in Appendix D.

A disturbed sample was submitted to Soillab (Pty) Ltd. (Pretoria) for testing. Foundation Indicator, pH and conductivity tests were conducted on this sample.

8.1 pH and Conductivity of the Soils

The pH and conductivity (mS/m^{-1}) of soil pastes of selective samples have been measured to determine the acidity and potential corrosiveness of the soils. The results are indicated in Table 3.

TABLE 3 : SOIL CONDUCTIVITY, PH AND CORROSIVENESS

Sample Position	Sample Depth (m)	pH	Electrical Conductivity of soil paste (mS/m^{-1})	Soil corrosiveness based on the electrical conductivity
TP01	0.50-1.40	6.06	12.0	Mildly corrosive

The results indicate soils that are potentially mildly corrosive to ferrous metals and needs to be taken into consideration by the planners/designers.

8.2 General Engineering and Material Characteristics

The laboratory test results conducted on selectively retrieved samples are summarised in Table 4. The original copies as received from Soillab Pty Ltd. Pretoria are attached in Appendix D.

TABLE 4 : FOUNDATION INDICATOR TEST RESULTS

Test pit no	Depth (m)	Description	Soil composition				Atterberg Limits		LS %	GM	Activity	AASHTO / Unified classification
			Clay %	Silt %	Sand %	Gravel %	LL %	PI %				
TP01	0.50-1.40	Sandy silt	23	37	35	5	45	22	10.0	0.57	Medium	A-7-6 (12) / CL

*NP = Non-plastic

- The **<u>sandy silt colluvium</u>** material classify as “CL” according to the Unified

Soil Classification System, indicating silts and clays with a LL<50 and PI>7. These soils generally contain large amounts of sand, silt and clay, with very little gravel. This material has a medium liquid limit, low grading modulus, a non-critical linear shrinkage, medium expected activity and a low plasticity index.

8.3 Collapse/Consolidation Characteristics of the Soils

Soil compressibility and collapse corresponding to the C2 site class designation of the NHBRC (1999) classification is expected throughout the entire profile due to the pinholed nature of the material and loose to medium dense *in-situ* material consistency. The estimated total settlement for the C2 site class designation is >10 mm, with differential settlement assumed to be equal to 75% of the total settlement.

8.4 Potential Heave of the Soils

The potential expansiveness of the soils were evaluated by Van der Merwes method using the graded PI and clay fraction, potential volume change based on the Atterberg Limits, potential expansiveness by using the Unified Soil Classification and the % swell predicted during the compaction testing (Mod. AASHTO, NRB and Proctor).

Based on the results and interpretations medium potential expansiveness is expected for the majority of the material found in the profile. This is correlated to the H1 site class designation of the NHBRC (1999) classification, with an estimated total settlement of 7.5-15 mm and differential settlement assumed at 75% of the total settlement.

8.5 Slope Stability and Erosion

No steep slopes are present on site and no natural slope instability can occur.

The vertical trench excavated for the purpose of the trial pit was stable for the period investigated with no visual signs of sidewall instability. Instability of trenches or excavations is expected during and after saturation of the soil profile as expected during and after the wet season and after continuous or heavy downpours. Stability will depend on the moisture content of the soils and the slopes of the sidewalls of the excavations and trenches.

The necessary stabilisation techniques and precautionary measures therefore need to be implemented in all trenches deeper than 1.5 meters and that are to be accessed during the construction process. Refer to the SANS specifications for excavations/trenches or to the project specifications as provided by the design engineer.

The upper soil horizons are expected to have an intermediate susceptibility to erosion. Proper water management is recommended if large areas are to be cleared from vegetation. This will limit unwanted erosion, trench flooding and undercutting of structures.

8.6 Permeability

No infiltration tests or laboratory tests were performed to determine the permeability of the upper soils. Using the Fair-Hatch Model, the grading can however be used to give a fair estimation of the permeability of the soils.

The upper soils are expected to have an approximate permeability of 1.13×10^{-3} mm/s, which correlates to the permeability of a typical silty fine sand which is in the region of between approximately $1x10^{-4}$ to $1x10^{-6}$ mm/s (as for silt) and $1x10^{-2}$ to $1x10^{-4}$ mm/s (as for fine sand). This approximate permeability should be used for ***guideline*** purposes only.

9. POTENTIAL OF CONTAMINATION OF SOILS, SURFACE WATER AND GROUNDWATER

9.1 Surface spills

Spillages that occur on surface is expected to either enter the soil profile and percolate vertically down to the groundwater level or run off the sealed surface areas in the direction of slope towards the Groot Letaba River.

Based on the calculated permeability of 1.13 x 10^{-3} using the Fair-Hatch Model, it is assumed that pollutants will travel through the vadose zone to the phreatic surface at a moderate to fairly high rate.

Recommended precautionary measures include:

- Sealing of the areas where fuel products are handled to prevent infiltration of petroleum products into the soil underlying the site.
- Storm water draining from the surfaced areas should ideally be collected in a sealed sump to be treated or removed.
- Preventative measures should be installed to prevent the storm water or other liquids draining into the natural soil.
- The free product and polluted water must be removed from site by a licensed contractor.

9.2 Subsurface spills

Prevention of pollutants reaching the groundwater and soil will be necessary and may include the following:

- Subsurface fuel tanks should be placed in concrete encasements with a sump system to prevent spilled fuel from entering the soil/rock.
- Fuel lines and dispensers should be rendered leak-proof.
- Any boreholes in the vicinity of the site should be properly equipped and sealed and should ideally be monitored on a six-monthly basis for possible hydrocarbon pollution.

10. EXCAVATABILITY

The excavatability of the soil was evaluated by the excavation of a single trial pit in the area identified for the installation of the subsurface tank by means of a Bell 315 S 4x4 TLB (small excavator/backhoe). The excavation conditions encountered in the individual trial pits are summarized in Table 2.

Excavatability of materials can be classified in five different categories according to the SABS 1200 D-1988 standards. Table 5 below is a summary of the SABS standards (refer to SABS 1200D-1988 document for detailed classification):

TABLE 5: EXCAVATION CLASSES (Modified SABS 1200D)

Sample Position	**Simplified description of typical material properties**
Soft excavation	Material that can be efficiently removed or loaded, without prior ripping, by means of a bulldozer, tractor-scraper, track type front-end loader or back-acting excavator without the use of pneumatic tools such as paving breakers
Intermediate excavation	Material that can be efficiently ripped by a bulldozer fitted with a single-tine ripper or with a back-acting excavator of flywheel power exceeding 0,10 kW per mm of tined-bucket width or the use of pneumatic tools before removal by equipment equivalent to that specified above.
Hard rock excavation	Excavation in material that cannot, before removal, be efficiently ripped by a bulldozer. This is material that cannot be efficiently removed without blasting or without wedging and splitting.
Boulder excavation (Class A)	Excavation in material containing more than 40 % by volume boulders of size in the range of 0,03-20m3, in a matrix of soft material or smaller boulders.
Boulder excavation (Class B)	Excavation in material containing 40 % or less by volume boulders of size in the range of 0,03-20m3, in a matrix of soft material or smaller boulders and which require individual drilling and blasting in order to be loaded by a track type front-end loader or back-acting excavator .

The entire profile consisted of fine-grained transported material, with no evidence of bedrock or cobbles/boulders that can result in confined excavation difficulty (“boulder excavation”). The material classifies as “Soft excavation” from surface down to the termination depth of 2.6m below ground level.

11. CONSTRUCTION MATERIALS

The interpretations are based on foundation indicator testing, grading and Atterrberg limits such as PI, LL, grading and Unified Soil Classification alone.

11.1 Fine Aggregates for Mortar and Plaster

It is recommended that fine aggregates be obtained from the nearest source.

The SANS1090 document needs to be consulted for the material specifications and requirements for use as fine aggregates in plaster and mortar.

11.2 Coarse aggregates for Concrete

No suitable source for coarse aggregate for concrete was identified on site.

11.3 Soil Mattresses

The colluvial material covering the site contains 23% clay, 37% silt, 35% sand and 5% gravel. The material has a PI of 22 and a LL of 45 with a medium soil heave potential based on Van der Merwe's indicative "Potential Expansiveness" (PI of whole sample versus clay fraction of whole sample).

The material classifies as "CL" according to the Unified Soil Classification System which indicates material generally with "good to fair" compaction characteristics. The material may be suitable for soil mattress construction if approved by the design engineer. Chemical or physical stabilisation may be required due to the "heave potential".

Material classifying as "CL" typically has a maximum dry density of 1 500 to 1 890 kg/m^3 at an optimum moisture content of 12 to 24%.

11.4 Road Construction

The in situ silty soil is expected to classify as ">G9" according to the TRH14 document, which indicate material only suitable for subgrade construction and not for subbase, base or upper pavement construction

12. CONCLUSIONS AND RECOMMENDATIONS

The proposed site is suitable for the installation of a subsurface fuel storage tank from a geotechnical point of view if the necessary precautionary measures are implemented as outlined within this report.

No potentially soluble rock formations such as dolomite were identified during the investigation and a dolomite stability investigation **will not be** necessary.

The main expected geotechnical constraints on the site are:

- Seasonal shallow groundwater seepage and/or saturated soil profiles;
- High soil collapse/compressibility;
- Medium soil heave (secondary to the compressibility).

Based on the abovementioned constraints the investigated area can be zoned as **C2-H1 / 2ABCDE**, where:

- C and H **before** the / respectively represents collapse (C) and heave (H) and
- A, B, C, D and E **after** the / respectively represents collapse (A), seepage (B), active soils (C), compressibility (D) and erodability (E).

The test pit was positioned so as to directly investigate the proposed area identified for the installation of the subsurface storage tank. The test pit was backfilled by the TLB without proper compaction in layers.

Excavation was stopped at 2.60 meters in loose to medium dense fine-grained material. The assigned excavation class is given as "Soft excavation" conditions.

The material in the excavated trial pit was classified as being only slightly moist, with no water seepage.

Seasonal shallow groundwater seepage and/or a saturated upper soil profile are thus expected, especially during and towards the end of the raining season and after heavy and/or continuous downpours. The seepage water is expected to occur mainly from 1.40 meters and deeper from where the first indication of mottling was first

encountered, and will drain towards the lower slopes.
The design engineer should incorporate the possible waterlogged conditions into the design to prevent possible buoyancy/flotation of the structure.

Proper precautionary measures have to be taken to ensure sufficient drainage of surface water on the site and to prevent concentrated flow of water that will result in soil erosion, especially after removal of the pavement and after heavy downpours.

Based on the calculated results using the grading and the Fair-Hatch Model, the upper soils are expected to have an approximate permeability of 1.13 x 10^{-3} mm/s. It is assumed that pollutants will travel through the vadose zone to the phreatic surface at a moderate to fairly high rate.

13. REPORT PROVISIONS

While every effort is made during the fieldwork phase to identify the various soil horizons, areas subject to perched water table, areas of poor drainage, areas underlain by hard rock, and to estimate their distributions, it is impossible to guarantee that isolated zones of poorer foundation materials or harder rock have not been overlooked.

For this reason, this investigation has sought to highlight areas of potential groundwater and excavation problems, as well as to provide prior warning to the Planners and Consulting Engineers.

A competent engineer should be responsible for the design of the drainage and safety precautionary measures.

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14. REFERENCES

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APPENDIX A

(FIGURES)

Coordinates	Tzaneen Diesel Depot
Latitude	23 49' 41.37"S
Longitude	30 10’ 28.81" E
Elevation (m)	697

Figure 1: Locality map: Tzaneen Diesel Depot

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© Google Earth 2010

Coordinates	Tzaneen Diesel Depot
Latitude	23 49' 41.37"S
Longitude	30 10’ 28.81" E
Elevation (m)	697

†Goudplaats Gneiss Goudplaatsgneis	Zg	Biotite gneiss and migmatite

Figure 2: Geology map: Tzaneen Diesel Depot

WSM LESHIKA
CONSULTING (PTY) LTD

Coordinates	TP01
Latitude	23 49' 41.0"S
Longitude	30 10’ 30.10" E
Elevation (m)	696

Figure 3: Test Pit Position: Tzaneen Diesel Depot

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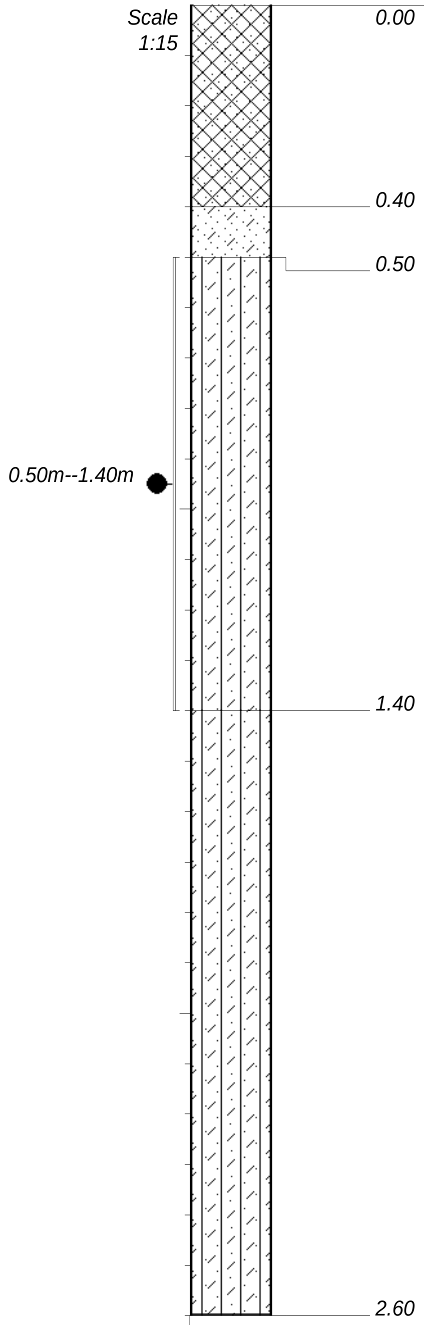
APPENDIX B

(SOIL PROFILE DESCRIPTIONS)

Tekplan
Tzaneen Diesel Depot

HOLE No: TP01
Sheet 1 of 1

JOB NUMBER: WH10055



0.00 Slightly moist, yellow brown speckled white, medium dense, **intact**, SAND. Backfill.

0.40 Slightly moist, dark red brown, firm, **intact** clayey SAND. Colluvium.

0.50 Slightly moist, bright red brown, medium dense, **pinholed** fine sandy clayey SILT. Colluvium.

1.40 Slightly moist, bright red brown with scattered black mottles, loose to medium dense, **pinholed** fine sandy clayey SILT. Colluvium.

2.60

NOTES

1) Hole stopped.

2) No seepage.

3) Disturbed sample from 0.50m--1.40m.

4) Soft excavation conditions.

CONTRACTOR : WSMLeshika Consulting
MACHINE : Bell 315 S 4x4
DRILLED BY :
PROFILED BY : G Brink
TYPE SET BY :
SETUP FILE : STANDARD.SET

INCLINATION :
DIAM :
DATE :
DATE : 2010-06-07
DATE : 01/07/10 13:13
TEXT : ..C:\DOTFILES\10055_DP.TXT

ELEVATION : 697
X-COORD : 2636489
Y-COORD : 0084056

HOLE No: TP01

Tekplan
Tzaneen Diesel Depot

LEGEND
Sheet 1 of 1

JOB NUMBER: WH10055

	░	SAND	{SA04}
	⁘	SANDY	{SA05}
	▥	SILT	{SA06}
	▨	CLAYEY	{SA09}
	▩	FILL	{SA32}
Name ●	☐	DISTURBED SAMPLE	{SA38}

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY :

TYPE SET BY :
SETUP FILE : STANDARD.SET

INCLINATION :
DIAM :
DATE :
DATE :

DATE : 01/07/10 13:13
TEXT : ..C:\DOTFILES\10055_DP.TXT

ELEVATION :
X-COORD :
Y-COORD :

LEGEND
SUMMARY OF SYMBOLS

APPENDIX C

(SOIL PROFILE AND GENERAL PHOTOGRAPHS)

TP01
Photograph

Note: Hole stopped at 2.6m bngl

TP01 (a)
Photograph

Note: Excavation of test pit

TP01 (b)
Photograph

Note: General nature of material

APPENDIX D

(LABORATORY RESULTS)

CLIENT : WSM LESHIKA

PROJECT : TZANEEN DIESEL DEPOT

PROJECT NO. : S10-0618

DATE : 2010-06-01

pH & CONDUCTIVITY

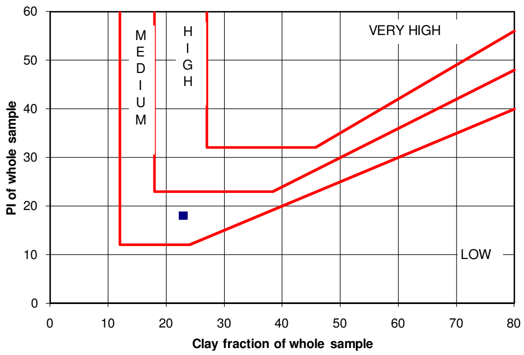
Soillab No	Sample Position	Sample Depth (m)	pH	Electrical Conductivity S/m
S10-0618-01	TP01	0.5-1.4	6.06	0.0120

PARTICLE SIZE ANALYSIS

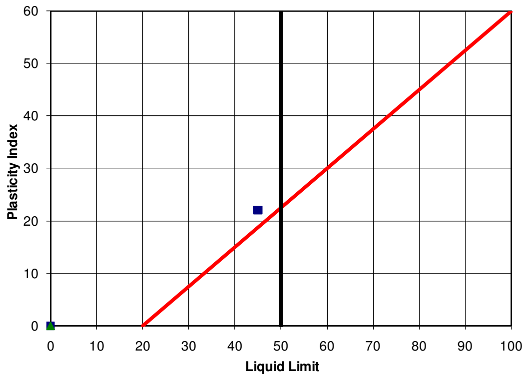
PROJECT : TZANEEN DIESEL DEPOT
JOB No. : S10-0618
DATE : 2010-05-28

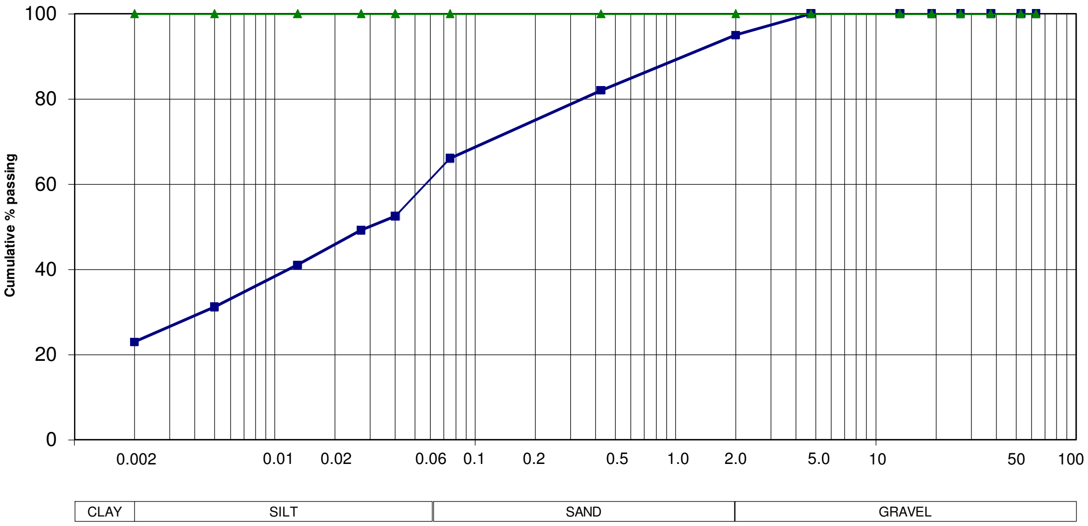
Sample No.	44900	
Soillab sample no.	S10-0618-01	
Depth (m)	0.5-1.4	
Position	TP01	
Material Description	LIGHT RED SANDY SILT	
Moisture (%)		
SG		
SCREEN ANALYSIS (% PASSING) **(TMH 1 A1(a) & A5)**		
63.0 mm	100	
53.0 mm	100	
37.5 mm	100	
26.5 mm	100	
19.0 mm	100	
13.2 mm	100	
4.75 mm	100	
2.00 mm	95	
0.425 mm	82	
0.075 mm	66	
HYDROMETER ANALYSIS (% PASSING) **(TMH 1 A6)**		
0.040 mm	52	
0.027 mm	49	
0.013 mm	41	
0.005 mm	31	
0.002 mm	23	
% Clay	23	
% Silt	37	
% Sand	35	
% Gravel	5	
ATTERBERG LIMITS **(TMH 1 A2 - A4)**		
Liquid Limit	45	
Plasticity Index	22	
Linear Shrinkage (%)	10.0	
Grading Modulus	0.57	
Classification	A-7-6 (12)	
Unified Classification	CL	
Chart Reference	■	▲

POTENTIAL EXPANSIVENESS



PLASTICITY CHART





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