# MARUBENI AND ZINKUMBINI TOWNSHIP DEVELOPMENT

## PRELIMINARY SHALLOW SOIL ENGINEERING GEOLOGICAL INVESTIGATION FOR PLANNING PURPOSES, MARUBENI AND ZINKUMBINI VILLAGE, UMTATA REGION, EASTERN CAPE PROVINCE

Basic Shallow Soil Investigation for Residential Planning

**Project number: WF14066** **17 September 2014**

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# PRELIMINARY SHALLOW SOIL ENGINEERING GEOLOGICAL INVESTIGATION FOR PLANNING PURPOSES, MARUBENI AND ZINKUMBINI VILLAGE, UMTATA REGION, EASTERN CAPE PROVINCE

## 1. INTRODUCTION

WSM Leshika Consulting (Pty) Ltd. was appointed to conduct a basic shallow soil geotechnical assessment for the proposed housing units to be erected in the villages known as Marubeni and Zinkumbini, Umtata Region, Eastern Cape Province.

The area of interest is depicted in Figure 1 and Figure 2, Appendix A.

This report discusses the method of investigation, geotechnical conditions encountered with on-site material characteristics, recommendations and general considerations.

The level of information provided in this report is deemed suitable for planning purposes.

## 2. OBJECTIVES OF THE INVESTIGATION

The main objectives of the investigation were to:

- Identify and discuss the main on-site geotechnical constraints;
- Obtain the basic data concerning the use of in situ material;
- Comment on the excavation characteristics of the site soils;
- Comment on the potential for shallow seepage water conditions;
- Define the general ground conditions and provide site classifications including detailed soil profile and groundwater occurrences within the zone of influence of foundation work;
- Comment on the founding conditions;
- Provide the geotechnical basis for **planning** and **preliminary design** purposes.

## 3. INFORMATION USED DURING THE STUDY

The following information was available at the time of writing this report:

- Locality map;
- Approximate site boundaries;
- 1:50 000-scale 3129AC Topographical map;
- 1:250 000-scale 3128 UMTATA Geological Sheet;
- Existing GoogleEarth images.

Laboratory test results conducted on selectively retrieved soil horizons were also available at the time of writing this report. The laboratory tests consist of basic index tests and compaction tests conducted on a limited number of samples.

Localities for proposed units were not available and no tests for heave and/or collapse or consolidation quantification were conducted for the purposes of this basic investigation.

## 4. METHOD OF INVESTIGATION

The method of investigation can be summarized as:

- Desk study of available databases such as, aerial images and geological sheets;
- Field walkover survey;
- Excavation of a limited number of test pits with a TLB;
- Detailed soil profile descriptions;
- Soil profile photograph recordings;
- Selective soil sampling;
- Basic soil testing;
- Laboratory test results interpretation;
- Compilation of report with findings and recommendations.

20 test pits were excavated by means of a JCB 3CX TLB in the area of interest down to refusal or to near refusal excavation conditions. The test pit positions are depicted in Figure 3, Appendix A.

A suitably qualified engineering geologist positioned and inspected the test pits. The soil profiles were recorded using the standard procedures as per the SANS633:2012 standards. The individual soil profile descriptions are attached as Appendix B with photographs attached as Appendix C.

Disturbed samples were selectively retrieved in order to determine the soil grading, compaction characteristics and general material properties. The samples were submitted to an SANAS accredited laboratory, ControLab South Africa (Pty) Ltd. for testing. The test results are attached as Appendix D.

# 5. GEOLOGY

## 5.1 Regional Geology

According to the 1:250 000-scale geological sheet 3128 Umtata, the area of interest is underlain by:

- “Jd” – Dolerite.
- “Pa” – Grey and brownish-red mudstone, sandstone.

The onsite rock/geology was interpreted as shale/siltstone.

The site is not underlain by potentially soluble dolomitic formations and a specialized dolomite stability investigation **is not required**.

The geology is depicted in Figure 4, Appendix A.

## 5.2 Site Specific Geology

20 Test pits were excavated by means of a TLB and terminated at between 1.05 to 3.1 m bngl (meters below natural ground level) and were terminated in residual to completely to highly weathered shale. Soft excavation conditions were encountered down to termination and refusal depths.

The villages of Marubeni and Zinkumbini is covered with a moderately thick fine sandy silty clayey open structured stiff to very stiff colluvium down to between 0.30 to 1.05 m bngl.

The colluvial layer is underlain in test pits the Zinkumbini village area by a stiff to very stiff open structured silty clayey gravel pebble marker with abundant iron and manganese nodules down to 0.55 m to 0.80 m bngl.

The colluvial layer in the Marubeni village area and pebble marker in the Zinkumbini area is underlain by a medium dense to soft and dense to stiff open and pinholed structured clay silt residual shale down to 0.75 m to 3.10 m bngl. Some of the test pits were terminated in this residual layer. The residual layer is underlain by bedded and jointed very dense completely weathered to highly weathered soft rock shale down to 1.05 m to 3.00 m bngl which generally excavates to silt and rock fragments.

Test pit Zi02 is located on the dolerite and consist of a stiff open structured silty clay/clayey silt colluvium down to 0.45 m bngl. This colluvial layer is underlain by a stiff open structured silty clayey gravelly pebble marker with moderately abundant iron and manganese nodules down to 0.80 m bngl. The pebble marker is underlain by a medium dense to soft pinholed structured clayey silt down to 2.00 m and a clayey silty fine to coarse sand residual dolerite that terminates at 2.70 m bngl.

A summary of the soil profiles are provided in Table 1a and Table 1b. The detailed soil profiles are attached as Appendix B with the relevant profile photographs as Appendix C.

**Table 1a: Soil profiles summary (co-ordinates and soil textures)**

| Test pits | Latitude | Longitude | Elevation | Clay | Silt | Sand | Gravel |
|---|---|---|---|---|---|---|---|
| **Marubeni** | | | | | | | |
| Ma01 | -31.438639° | 29.072416° | 1015 | 0.00-2.60 | 0.00-3.00 | - | 2.60-3.00 |
| Ma02 | -31.447096° | 29.055188° | 1017 | 0.00-2.80 | 0.00-3.10 | 2.80-3.10 | 0.40-0.75 |
| Ma03 | -31.448656° | 29.052850° | 1008 | 0.00-2.80 | 0.60-2.80 | 2.40-2.80 | 0.00-0.60 |
| Ma04 | -31.452662° | 29.054250° | 1008 | 0.00-1.15 | 0.80-2.20 | 1.15-2.20 | 0.00-0.80 |
| Ma05 | -31.455685° | 29.056790° | 999 | 0.00-2.80 | 0.70-2.80 | 0.00-0.70 | - |
| Ma06 | -31.456146° | 29.058848° | 994 | 0.50-1.05 | 1.05-2.80 | 0.00-2.80 | 0.00-0.50 |
| Ma07 | -31.451859° | 29.055635° | 1024 | 0.00-3.10 | 0.00-3.10 | - | - |
| Ma08 | -31.449466° | 29.056728° | 1031 | 0.00-1.20 | 0.00-2.00 | - | - |
| Ma09 | -31.443359° | 29.058843° | 1018 | 0.60-1.90 | 0.00-1.90 | 0.00-0.60 | - |
| Ma10 | -31.440117° | 29.056003° | 1009 | 0.00-3.00 | 0.80-3.00 | 0.00-0.80 | - |
| Ma11 | -31.441761° | 29.053495° | 1014 | 0.00-2.90 | 0.60-2.90 | 0.00-0.60 | - |
| Ma12 | -31.441329° | 29.049545° | 994 | 0.00-2.40 | 0.70-2.80 | - | 0.00-0.70 |
| Ma13 | -31.444196° | 29.046368° | 981 | 0.00-2.80 | 0.00-2.80 | 1.30-2.30 | 0.60-0.90 |
| Ma14 | -31.434663° | 29.051580° | 1005 | 0.00-3.10 | 0.00-3.10 | - | - |
| **Zinkumbini** | | | | | | | |
| Zi01 | -31.429739° | 29.047167° | 1001 | 0.00-1.55 | 0.00-1.55 | - | 0.50-0.80 |
| Zi02 | -31.428835° | 29.052418° | 973 | 0.00-2.70 | 0.00-2.00 | 2.00-2.70 | 0.45-0.80 |
| Zi03 | -31.427408° | 29.042731° | 1014 | 0.00-0.50 | 0.00-2.90 | 0.50-1.50 | - |
| Zi04 | -31.422809° | 29.047095° | 988 | 0.00-0.60 | 0.00-1.15 | - | 0.40-0.60 |
| Zi05 | -31.419199° | 29.050773° | 993 | 0.00-0.75 | 0.00-1.05 | - | 0.30-0.55 |
| Zi06 | -31.427987° | 29.036760° | 1006 | 0.00-0.90 | 0.00-1.30 | - | 0.30-0.55 |

## Table 1b: Soil profiles summary (soil horizons and excavation)

| Test pits | Colluvium | Pebble marker | Residuum | Pedogenic Formations | Completely Weathered Rock | Highly weathered rock | Termination depth | Excavatability up to termination depth | Excavatability at termination depth | Seepage |
|---|---|---|---|---|---|---|---|---|---|---|
| **Marubeni** | | | | | | | | | | |
| Ma01 | 0.00-0.90 | - | 0.90-2.60 | - | 2.60-3.00 | - | 3 | Soft | Soft | No |
| Ma02 | 0.00-0.75 | - | 0.75-3.10 | - | - | - | 3.1 | Soft | Soft | No |
| Ma03 | 0.00-0.60 | - | 0.60-2.40 | - | 2.40-2.80 | 2.40-2.80 | 2.8 | Soft | Intermediate | No |
| Ma04 | 0.00-0.80 | - | 0.80-2.00 | - | 2.00-2.20 | - | 2.2 | Soft | Intermediate | No |
| Ma05 | 0.00-0.70 | - | 0.70-2.40 | - | 1.85-2.80 | - | 2.8 | Soft | Soft | No |
| Ma06 | 0.00-1.05 | - | 1.05-2.80 | - | - | - | 2.8 | Soft | Soft | No |
| Ma07 | 0.00-0.80 | - | 0.80-2.50 | - | 2.50-3.10 | - | 3.1 | Soft | Soft | No |
| Ma08 | 0.00-0.85 | - | 0.85-1.20 | - | 1.20-2.00 | 2.00-2.80 | 2.8 | Soft | Intermediate | No |
| Ma09 | 0.00-0.60 | - | 0.60-1.90 | - | - | 1.90-2.30 | 2.3 | Soft | Intermediate | No |
| Ma10 | 0.00-0.80 | - | 0.80-3.00 | - | - | - | 3 | Soft | Soft | No |
| Ma11 | 0.00-0.60 | - | 0.60-2.90 | - | 2.20-2.90 | - | 2.9 | Soft | Soft | No |
| Ma12 | 0.0-0.70 | - | 0.70-2.40 | - | 2.40-2.80 | - | 2.8 | Soft | Soft | No |
| Ma13 | 0.00-0.90 | - | 0.90-2.80 | - | - | - | 2.8 | Soft | Soft | No |
| Ma14 | 0.00-0.60 | - | 0.60-3.10 | - | - | - | 3.1 | Soft | Soft | No |
| **Zinkumbini** | | | | | | | | | | |
| Zi01 | 0.00-0.50 | 0.50-0.80 | 0.80-1.50 | 0.50-0.80 | - | 1.55-1.90 | 1.9 | Soft | Intermediate to Hard | No |
| Zi02 | 0.00-0.45 | 0.45-0.80 | 0.80-2.70 | 0.45-0.80 | - | - | 2.7 | Soft | Hard | No |
| Zi03 | 0.00-0.50 | - | 0.50-1.50 | - | 1.50-2.90 | - | 2.9 | Soft | Soft | No |
| Zi04 | 0.00-0.40 | 0.40-0.60 | 0.60-1.15 | 0.40-0.60 | - | 1.15-1.20 | 1.2 | Soft | Hard | No |
| Zi05 | 0.00-0.30 | 0.30-0.55 | 0.55-0.75 | 0.30-0.55 | 0.75-1.05 | 0.75-1.05 | 1.05 | Soft | Hard | No |
| Zi06 | 0.00-0.30 | 0.30-0.55 | 0.55-0.90 | 0.30-0.55 | 0.90-1.30 | 0.90-1.30 | 1.3 | Soft | Hard | No |

# 6. SITE DESCRIPTION

## 6.1 Locality and Size

The site is situated approximately 30 km north-east of the town of Umtata and 11 km north north-east from Libode in the villages of Mcwili and Mbomboleni. The approximate size of the investigated area is 420 ha; Marubeni is 200 ha and Zinkumbini is 220 ha.

The approximate centre coordinates of the investigated area is as follows (Decimal Degrees, Datum: WGS84):

| **Marubreni** | **Zinkumbini** |
|---|---|
| Latitude: -31.440061° | Latitude: -31.426277° |
| Longitude: 29.054588° | Longitude: 29.045989° |

The locality is depicted in Figure 1 and Figure 2, Appendix A.

## 6.2 Vegetation, Topography, Drainage and Existing Structures

The site is mainly covered with natural grass, small to medium sized trees and informal mud houses. The remainder of the site is fairly open with steep slopes surrounding the village. No detailed contour map was provided/available at the time of writing this report. The regional topography as per the 1:50 000-scale topographical sheet is attached as Figure 5, Appendix A. The village is located on a large hill, the positive topography of the shale, with steep slopes from the center of the village decreasing to the borders of the site downhill towards the valleys, the negative topography of the shale. The steepest incline is on the south-east side of the village Marubeni outside the village boundaries. Drainage features are located in the low lying valley draining away from the villages. See the elevation profile of the site from north-west to south-east in Figure 1 portraying the positive and negative topography across Zinkumbini and Marubeni and from west to east in Figure 2 and Figure 3 below portraying the slope across the village Zinkumbini and Marubeni respectively. Drainage channels are located in the valleys at the bases of these slopes.

**Figure R1**: Elevation profile from north-west to south-east portraying the positive and negative topography across Zinkumbini and Marubeni.

**Figure R2**: Elevation profile from west to east depicting the slope across the village Zinkumbini.

**Figure R3**: Elevation profile from west to east depicting the slope across the village Marubeni.

## 7. SHALLOW GROUNDWATER OR SEEPAGE WATER

Signs of seasonal shallow seepage water conditions are evident in the soil profiles excavated. Severe shallow seasonal seepage water are expected, water is expected to occur on but not limited to the contact between the upper more permeable soils and the lower completely to highly weathered shale. Seepage water are expected to be mainly perpendicular to the ground contours towards the lower-lying drainage features,

Seasonal seepage water of less than 1.00 m bngl will be a reality throughout the majority of the site as evident by the iron and manganese nodules in the pebble marker and staining throughout the profile. Localised areas of surface ponding conditions can also be expected and should be identified from the detailed ground contour survey data.

Typical seepage areas are generally more prominent in lower-lying areas. The site is situated on a watershed. Seepage is expected to mainly occur for short periods after heavy and/or prolonged rainfall events.

## 8. EXCAVATION CONDITIONS

Excavatability of materials can be classified in five different categories according to the SABS 1200 D-1988 standards. Table 2 below is a summary of the SABS standards (refer to SABS 1200D-1988 document for detailed classification):

**Table 2: 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**<br>**(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. |

| Sample Position | Simplified description of typical material properties |
|---|---|
| **Boulder excavation**<br>**(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 trial pits were excavated by means of a JCB 3CX TLB and the TLB excavatability in the upper excavated material and at termination depths with SABS excavatability correlations are summarized in Table 1b.

The test pits were excavated down to between 1.05 to 3.10 m bngl with an average excavation depth of approximately 2.52 m bngl with a standard deviation of 0.65 m.

Refusal conditions were encountered in the Zinkumbini village in four test pits, Zi02, Zi04, Zi05 and Zi06, within highly weathered shale at 2.70 m, 1.20 m, 1.05 m and 1.30 m bngl respectively. Hard excavation conditions were encountered at these termination depths where refusal conditions were experienced on jointed and layered soft rock shale. Progressive refusal occurred in five tests pits, the majority being in Marubeni, whereby intermediate excavation conditions occurred in residual and highly weathered shale.

Excavation took place with a TLB in a confined trench; deeper excavation could be possible with a TLB in unconfined trenches and there is a possibility that the material may be rippable due to bedding and jointing. The materials are however expected to be excavatable with a larger excavator down to at least 2 m bngl in confined trenches in the highly weathered shale.

Soft excavation was encountered down to termination/refusal depths for all the test pits.

The bedrock conditions are expected to be undulating with depths generally of 1.00 m to 3.00 m bngl over short distances due to the change in slope and location on the slope.

# 9. LABORATORY RESULTS AND GENERAL MATERIAL PROPERTIES

A number of disturbed soil samples were selectively retrieved and submitted to Controlab South Africa (Pty) Ltd. Umtata for testing.

Grading analysis, compaction testing, Atterberg Limit tests were conducted in order to determine the basic material properties for evaluation purposes. The laboratory test results are attached as Appendix D. The USCS (unified soil classification system) was not provided by the laboratory; the classifications used below where interpreted from the results received and should be used with caution as the classification may differ slightly.

## 9.1 Material Classifications and General Material Properties and Ratings

The material encountered and tested generally classifies as "**GC**", "**SP**", "**SM**", "**SC**", "**ML**", "**CL**" and "**MH**" according to the Unified Soil Classification System. The majority of the samples classify as "SM". The Foundation Indicator test results conducted on selectively retrieved samples are summarized in Table 3.

**TABLE 3: Foundation Indicator Test Results**

| Test pit no | Sample depth (m) | Material description | Soil composition | | | | Atterberg Limits | | LS (%) | GM | Class (USCS) | Class (USCS) 2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | LL (%) | PI (%) | | | | |
| Ma01 | 1.00-1.40 | Residual shale | 10 | 52.9 | 33.1 | 4 | 34 | 10 | 4 | 0 | CL | ML |
| Ma01 | 2.40-2.80 | Residual to completely weathered shale | 5 | 31.2 | 47.8 | 16 | 37 | 13 | 7 | 0 | SM | SC |
| Ma02 | 1.00-1.50 | Residual shale | 17 | 43.4 | 39.6 | 0 | 34 | 15 | 6 | 0 | CL | 0 |
| Ma02 | 2.80-3.10 | Residual shale | 4 | 39 | 57 | 0 | 29 | 11 | 4.5 | 0 | SC | SM |
| Ma03 | 1.00-2.00 | Residual shale | 15 | 51 | 32 | 2 | 34 | 12 | 5 | 0.43 | CL | ML |
| Ma03 | 2.40-2.80 | Completely to highly weathered shale | 1 | 11.3 | 74.7 | 13 | 35 | 17 | 7.5 | 0 | SM | SC |
| Ma04 | 1.20-1.80 | Residual shale | 2 | 28.2 | 69.8 | 0 | 25 | 8 | 3 | 0 | SM | SC |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ma06 | 1.50-2.50 | Residual shale | 3 | 23.3 | 71.7 | 2 | 27 | 5 | 3 | 1.05 | SM | SC |
| Ma07 | 2.30-2.80 | Residual to completely weathered shale | 4 | 36.3 | 59.7 | 0 | 31 | 8 | 3 | 0 | SM | SC |
| Ma08 | 1.50-2.80 | Completely to highly weathered shale | 5 | 29.2 | 50.8 | 15 | 29 | 9 | 3.5 | 1.22 | SC | SM |
| Ma09 | 1.00-1.50 | Residual shale | 16 | 33.3 | 50.7 | 0 | 36 | 11 | 6 | 0 | ML | CL |
| Ma12 | 0.20-0.70 | Colluvium | 2 | 20.9 | 55.1 | 22 | cbd | SP | 1 | 0 | SP | 0 |
| Ma12 | 2.00-2.40 | Residual shale | 19 | 50.3 | 28.7 | 2 | 42 | 19 | 9 | 0 | CL | 0 |
| Ma12 | 2.40-2.80 | Completely weathered shale | 17 | 41.7 | 38.3 | 3 | 35 | 7 | 4 | 0 | ML | 0 |
| Ma13 | 1.30-2.30 | Residual shale | 0 | 22.3 | 75.7 | 2 | 24 | 9 | 3.5 | 0.91 | SM | 0 |
| Ma13 | 2.40-2.80 | Residual shale | 8 | 26.2 | 65.8 | 0 | 30 | 11 | 4.5 | 0 | SC | 0 |
| Ma14 | 1.00-1.50 | Residual shale | 20 | 45.3 | 34.7 | 0 | 49 | 16 | 8 | 0 | ML | MH |
| Zi01 | 1.00-1.30 | Residual shale | 8 | 36.4 | 55.6 | 0 | 42 | 16 | 7 | 0 | SM | SC |
| Zi02 | 1.50-2.00 | Residual dolerite | 5 | 37.1 | 57.9 | 0 | 37 | 12 | 6 | 0 | SC | SM |
| Zi03 | 1.80-2.80 | Completely weathered shale | 4 | 49.8 | 46.2 | 0 | 28 | 6 | 3 | 0.55 | ML | 0 |
| Zi04 | 1.00-1.20 | Completely to highly weathered shale | 3 | 10.7 | 42.3 | 44 | 15 | 9 | 3.5 | 0 | GC | SP |
| Zi05 | 0.80-1.00 | Completely to highly weathered shale | 1 | 10.5 | 44.5 | 44 | 24 | 7 | 3.5 | 2.4 | GC | 0 |
| Zi06 | 0.90-1.30 | Completely to highly weathered shale | 6 | 19.1 | 51.9 | 23 | 24 | 9 | 4 | 0 | SC | SM |

The following general descriptions can be assigned to the soil classes:

**GC** → Clayey gravels, poorly graded gravel-sand-clay mixtures.

**SP** → Poorly graded sand.

**SM** → Silty sands, poorly graded silt-sand mixtures.

**SC** → Clayey sands, poorly graded sand-clay mixtures.

**ML** → Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity.

**CL** → Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.

**MH** → Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic soils.

Typical material properties for the above classifications are summarized in Table E1 and Table E2, Appendix F for guideline purposes.

## 10. GEOTECHNICAL EVALUATION

### 10.1 Soil Heave

The potential expansiveness of the material was evaluated based on the indicative laboratory test results and field observations. This included using the Plasticity Index and Linear Shrinkage of the material, Van der Merwe's Method and the material structure to evaluate the potential heave of the material. The potential expansiveness of the materials is visually depicted in Chart 1.

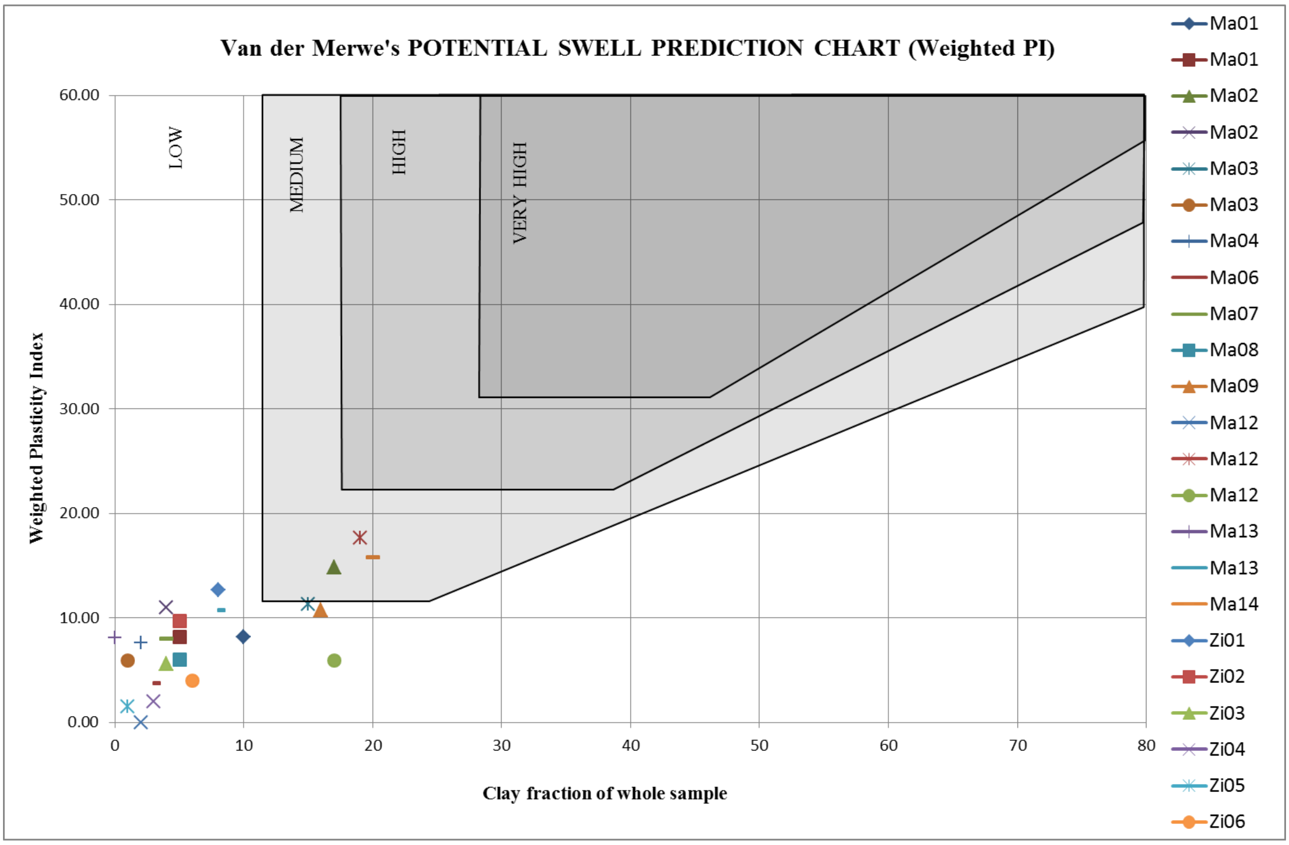


**CHART 1:** Swell Prediction Chart (Weighted PI and Clay Fraction of whole sample)

The indicator test results conducted on all the materials sampled indicate that only the residual shale from Ma02, Ma12 and Zi14 at 1.00-1.50 m, 2.00-2.40 m and 1.00-1.50 respectively has a “Medium” heave potential which confirms the visual interpretations taking into consideration the clay content and soil structure. The test results indicate that the completely to highly weathered shale has a “Low” heave potential with very little amount of clay present as well as the residual shale with low level of fines has a “Low” heave potential.

The residual shale in test pits Ma03, Ma06 and Ma13 had a free swell percentage under 100 % MOD. AASHTO compaction effort of 1.67 %, 1.57 % and 0.91 % respectively. The compacted swell percentage for the completely to highly weathered shale in test pits Ma08, Zi03 and Zi05 is 2.47 %, 3.19 % and 0.81 % respectively. The completely to highly weathered shale of test pits Ma08 and Zi03 has the highest swell percentage of 2.47 % and 3.19 % respectively.
Medium soil heave corresponding to the SAICE (1995) site class designation “**H1**” (7.5 mm to 15 mm total range of expected soil movement, assumed 50% differential movement) is expected in the residual shale and dolerite layer.

Medium soil heave is only expected in the overlying residual that has a high content of fines; the underlying weathered rock and residual shale with low levels of shale are expected to have a low to medium soil heave potential according to the test results received. The residual dolerite from test pit Zi02 also indicates low soil heave potential.

The grading analysis, Atterberg Limits and compaction test results for the materials are attached in Appendix D.

### 10.2 Collapsible and/or Compressible Material

The colluvium layer, pebble marker and the majority of the residual shale consist of medium amounts of fines present that can experience a degree of consolidation. These horizons have an open and pinholed structure that will result in a degree of consolidation corresponding to the SAICE class “C1”.

The layered and jointed completely to highly weathered shale has a slight collapse potential as for SAICE class “C” and “S” consolidation potential.

The lower lying completely to highly weathered shale has a layered and jointed structure which may result in some settlement when loaded.

### 10.3 Erodability

The soils are considered to have a high susceptibility to erosion. Basic erosion protection measures will be recommended such as proper surface drainage in order to avoid concentrated water flow and potential erosion and undercutting of structures/floors and/or unwanted erosion of excavation/foundation/service trenches.

## 11. MAJOR GEOTECHNICAL CONSTRAINTS

Based on the conditions encountered during this investigation the major geotechnical constraints for these sites can be summarized as:

- Medium heave potential in residual shale containing high fines content;
- Low to medium heave potential in compacted weathered shale;
- Severe shallow seasonal seepage water conditions and/or saturated soil profiles;
- Most favorable to intermediate steep slopes surrounding entire village 6 to 12 degrees;
- Excavation difficulty due to shallow bedrock, depending on location on slope.

## 12. SITE CLASSIFICATION

The site is classified based on the different geotechnical and founding conditions as per the SAICE 1995 classification (NHBRC classification as for single story residential/small type structures) and the SANS 634:2012 document of which the applicable tables are attached in Appendix F for reference purposes.

One broad geotechnical zone has been assigned for the site for the purposes of this basic investigation:

**Zone I**: C1-H1 (R) / 2ABCDE (2FI)

**Zone II**: P (Drainage features, seepage areas and steep slopes) / 2BI (Drainage features)

**Where C, S and P before the / refer to:**

C - Collapse settlement;

H - Expansive soils;

(R) - Localised shallow rock.

**The A-B-C-D-E-F-H-I after the / refer to:**

A - Collapsible soils;

B - Seasonal shallow seepage water or saturated soil conditions;

C - Active soils;

D - Consolidation settlement;

E - Erodability of the soil horizons;

F - Excavation difficulty;

I - Steep slopes.

The classification in brackets (2FI) indicates localised occurrences for excavation difficulty and moderately steep slopes which has a highly likelihood.

Refer to Table 1, Table 2, Table 3, Table 4 and Table 5, Appendix F.

## 13. FOUNDATION AND GERNAL RECOMMENDATIONS

For planning purposes the following foundation types/options can be considered for potential small size residential type structures (as for class “H1” and “C1” SAICE 1995 foundation options of which the appropriate tables are attached in Appendix F):

- Modified normal construction (As for class H1).

- Soil raft construction (As for class C1 or H1).

More conservative foundation options may be:

- Stiffened or cellular raft foundations (As for class H2).
- Split construction (As for class H2).

It is recommended that stiffened or cellular raft foundations are considered for planning purposes till more detailed investigations are conducted as required by the SANS634:2012 standards and accommodated with the necessary heave and consolidation quantification tests.

Modified normal construction to even normal construction may be suitable in areas. These foundation options however can only be considered if conditions are proven with more detailed investigations.

## 14. CONSTRUCTION MATERIALS

### 14.1 Soil Mattress and General Backfill

The basic requirements for material to be used for soil mattress construction can be summarized as:

- The material needs to be workable;
- The material needs to have good compaction characteristics;
- The material needs to have a low compressibility once properly compacted;
- The material needs to exhibit a low heave once properly compacted;
- The material needs to have suitable bearing capacity once properly compacted.

The on-site material is generally silty clays in the upper residual shale, residual dolerite and colluvium. The completely to highly weathered shale crumbles to silt and rock fragments when excavated and compacted. The residual shale and completely to highly weathered shale material tested according to the USCS has the following workability rating:

- CL – Good to fair;
- MH – Good workability rating
- ML – Fair workability rating
- SC – Good;
- SM – Fair;
- GC – Fair workability rating

The residual shale material retrieved from test pits Ma03, Ma06 and Ma13 at 1.00-2.00 3m, 1.50-2.50 and 1.30-2.30 has a maximum dry density of 1 630 kg/m$^3$, 1 778 kg/m$^3$ and 1 805 kg/m$^3$ with an optimum moisture content of 16.9 %, 14.3 % and 15.5 % with a measured swell of 1.67 %, 1.57 % and 0.91 % Mod. AASHTO compaction effort respectively. The CBR of the material increases from 1 to 2 to 3; 6 to 11 to 21 and 7 to 13 to 25 at 90%, 95% and 100% Mod. AASHTO compaction efforts respectively. The samples tested classifies as “G10”, “G10” and “G9” according to the TRH/COLTO classification respectively.

The completely weathered shale material retrieved from test pits Zi03 at 1.80-2.80 m has a maximum dry density of 1 554 kg/m$^3$ with an optimum moisture content of 13.2 % with a measured swell of 3.19 % Mod. AASHTO compaction effort. The CBR of the material increases from 1 to 2 to 3 at 90%, 95% and 100% Mod. AASHTO compaction efforts. The samples tested classifies as “G10” according to the TRH/COLTO classification.

The completely to highly weathered shale material retrieved from test pits Ma08 and Zi05 at 1.50-2.80 m and 0.80-1.00 m has a maximum dry density of 1 696 kg/m$^3$ and 1 876 kg/m$^3$ with an optimum moisture content of 16.9 % and 11.2 % with a measured swell of 2.47 % and 0.81 % Mod. AASHTO compaction effort. The CBR of the material increases from 2 to 3 to 5 and 14 to 31 to 66 at 90%, 95% and 100% Mod. AASHTO compaction efforts respectively. The samples tested classifies as “G10” and “G07” according to the TRH/COLTO classification respectively.

The material tested has poor to fair compaction characteristics based on the increase in CBR values, achieved maximum dry densities and relatively low to medium percentage swell measured. The residual shale from test pit Ma06 has fair to good compaction and the completely to highly weathered shale from Zi05 has fair to good compaction based on the CBR values and increase CBR values.

The weathered shale and residual shale with low fines are expected to have a low compressibility once properly compacted. The residual shale with high fines content and upper fines are expected to have a medium to high compressibility even when properly compacted due to the abundance of fines.

The weathered shale and residual shale with low fines are expected to have a low heave potential. The residual shale with high fines content is expected to have a medium heave potential.

The typical fill rating of the material is represented in Table 5 below.

**TABLE 5: Fill and Foundation Material**

| Test pit | Sample depth (m) | Material description | Unified Soil Class | Typical rating for use as general fill material | Typical rating for use as fill for foundation purposes | Expected Dry Density (kg/m3) (PROCTOR) |
|---|---|---|---|---|---|---|
| Ma01 | 1.00-1.40 | Residual shale | CL | Average | Average (Swell?) | 1 730 +/- 20 |
| Ma01 | 2.40-2.80 | Residual to completely weathered shale | SM | Average | Good (density important) | 1 830 +/- 20 |
| Ma02 | 1.00-1.50 | Residual shale | CL | Average | Average (Swell?) | 1 730 +/- 20 |
| Ma02 | 2.80-3.10 | Residual shale | SC | Average | Good (density important) | 1 840 +/- 20 |
| Ma03 | 1.00-2.00 | Residual shale | CL | Average | Average (Swell?) | 1 730 +/- 20 |
| Ma03 | 2.40-2.80 | Completely to highly weathered shale | SM | Average | Good (density important) | 1 830 +/- 20 |
| Ma04 | 1.20-1.80 | Residual shale | SM | Average | Good (density important) | 1 830 +/- 20 |
| Ma06 | 1.50-2.50 | Residual shale | SM | Average | Good (density important) | 1 830 +/- 20 |
| Ma07 | 2.30-2.80 | Residual to completely weathered shale | SM | Average | Good (density important) | 1 830 +/- 20 |
| Ma08 | 1.50-2.80 | Completely to highly weathered shale | SC | Average | Good (density important) | 1 840 +/- 20 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Ma09 | 1.00-1.50 | Residual shale | ML | Average | Good (Liquefaction problem) | 1 650 +/- 20 |
| Ma12 | 0.20-0.70 | Colluvium | SP | Good | Excellent | 1 760 +/- 30 |
| Ma12 | 2.00-2.40 | Residual shale | CL | Average | Average (Swell?) | 1 730 +/- 20 |
| Ma12 | 2.40-2.80 | Completely weathered shale | ML | Average | Good (Liquefaction problem) | 1 650 +/- 20 |
| Ma13 | 1.30-2.30 | Residual shale | SM | Average | Good (density important) | 1 830 +/- 20 |
| Ma13 | 2.40-2.80 | Residual shale | SC | Average | Good (density important) | 1 840 +/- 20 |
| Ma14 | 1.00-1.50 | Residual shale | ML | Average | Good (Liquefaction problem) | 1 650 +/- 20 |
| Zi01 | 1.00-1.30 | Residual shale | SM | Average | Good (density important) | 1 830 +/- 20 |
| Zi02 | 1.50-2.00 | Residual dolerite | SC | Average | Good (density important) | 1 840 +/- 20 |
| Zi03 | 1.80-2.80 | Completely weathered shale | ML | Average | Good (Liquefaction problem) | 1 650 +/- 20 |
| Zi04 | 1.00-1.20 | Completely to highly weathered shale | GC | Good | Excellent | > 1 840 |
| Zi05 | 0.80-1.00 | Completely to highly weathered shale | GC | Good | Excellent | > 1 840 |
| Zi06 | 0.90-1.30 | Completely to highly weathered shale | SC | Average | Good (density important) | 1 840 +/- 20 |

The weathered shale material and residual shale with low fines in general (materials classifying as “SM”, “SC” and “ML”) are considered to have a good rating for typical fill for foundation purposes with “GC” and “SP” as excellent. The materials with an abundance of fines (soils classifying as “CL” and “ML”) are considered to have an average rating for typical fill.

### 14.2 Road Construction

A more detailed investigation should be conducted in order to comment the suitability of the on-site materials for pavement design. The residual shale with low fines and completely weathered shale are expected to have a fair to good rating for subgrade construction and fair for sub-base and not suitable base construction. The residual shale with high fines content is expected to have a fair to poor rating for subgrade construction with a not suitable rating for subbase construction. None of the on-site materials encountered are considered suitable for base construction. It is recommended that borrowpits is identified and that suitable materials are sourced for subbase and base construction.

## 15. CONCLUSIONS

The site is underlain by grey and brownish-red mudstone, sandstone; identified on site to be shale/siltstone.

No potentially soluble dolomitic or limestone formations are present and a dolomite stability investigation is not required.

The area is not undermined and no significant economic mineral deposits are indicated on the relevant geological sheet in the proposed development area that may affect the developability of the site.

One broad geotechnical zone has been assigned for the site for the purposes of this basic investigation:
**Zone I**: C1-H1 (R) / 2ABCDE (2FI)
**Zone II**: P (Drainage features, seepage areas and steep slopes) / 2BI (Drainage features)

For planning purposes one or a combination of the following foundation types/options can be considered:

- Modified normal construction (As for class H1).
- Soil raft construction (As for class C1 or H1).
- Stiffened or cellular raft foundations (As for class H2).
- Split construction (As for class H2).

The stiffened or cellular raft foundations and split construction are considered the more conservative design approach. Proper surface, subsurface drainage and damp proofing will be essential in order to prevent or limit moisture damage to the floors and walls. Corrosion protection is recommended for any ferrous metals or services in contact with the soils. Termite and pesticide control will be recommended below all structures. Basic erosion protection will be highly recommended in order to prevent excessive erosion and potential undercutting of structures.

The report is deemed suitable for basic planning purposes. The standard engineering geological investigations associated with residential development with reference to the minimum requirements as outlined in the SANS634:2012 standards should be conducted for detailed planning, design and enrolment purposes.

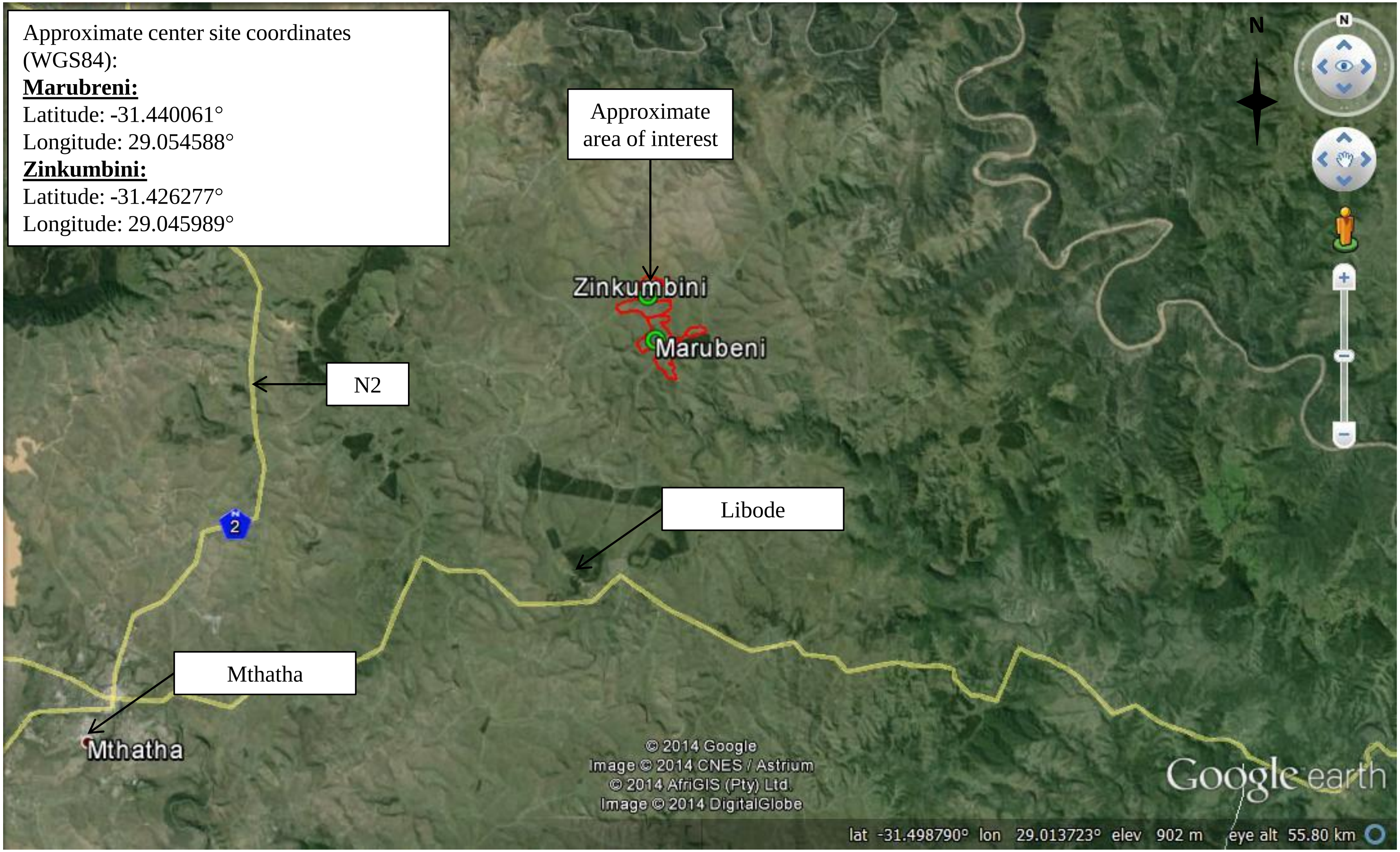
## 16. REPORT PROVISIONS

The report is considered a basic investigation with level of detail considered suitable for basic planning purposes only. The report should be distributed in its full context in order to avoid miss-interpretation that may result from selective data distribution. The engineering geologist assumes no responsibilities for any damages or unforeseen circumstances resulting from any geotechnical hazard if detailed planning and/or design are based on this basic evaluation.

**MICHAEL van RENSBURG**
Engineering Geologist

# APPENDIX A

(Figures)



Approximate center site coordinates (WGS84):

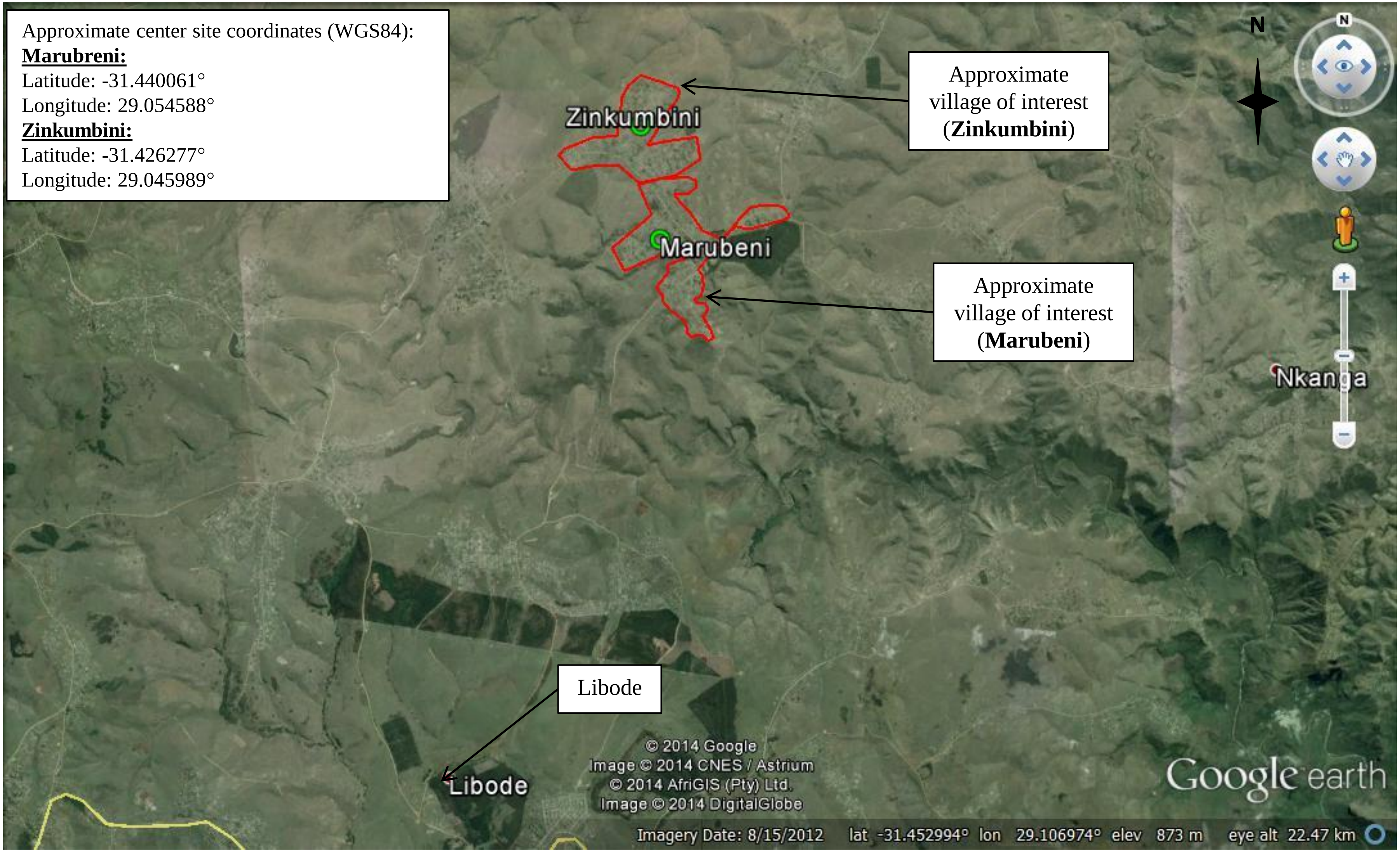
**Marubreni:**
Latitude: -31.440061°
Longitude: 29.054588°

**Zinkumbini:**
Latitude: -31.426277°
Longitude: 29.045989°

**Figure 1:** Locality map 1: Eastern Cape Housing (Marubeni and Zinkumbini)

WSM LESHIKA CONSULTING (PTY) LTD

No: WF14066



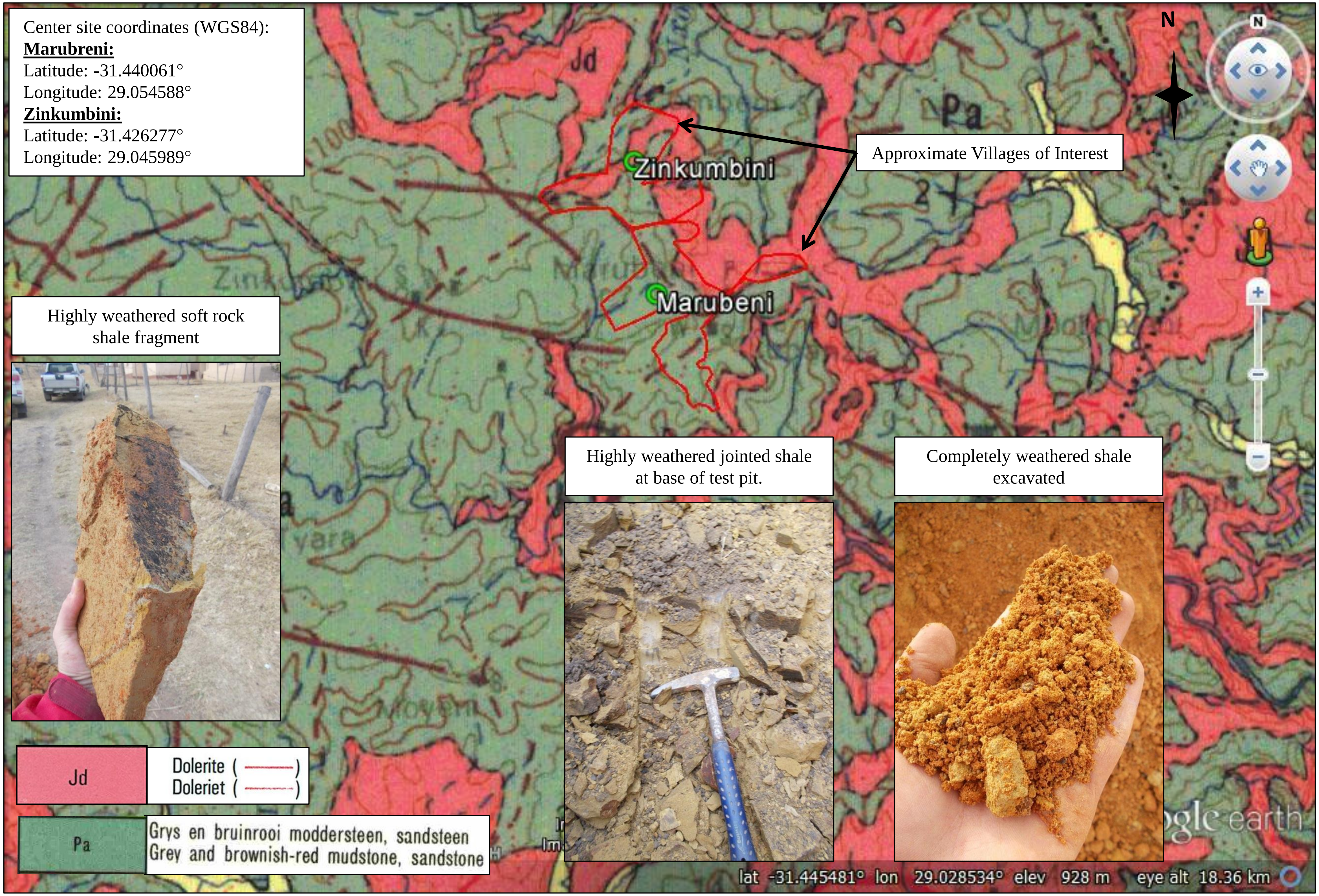
Approximate center site coordinates (WGS84):
**Marubreni:**
Latitude: -31.440061°
Longitude: 29.054588°
**Zinkumbini:**
Latitude: -31.426277°
Longitude: 29.045989°

Approximate village of interest (**Zinkumbini**)

Approximate village of interest (**Marubeni**)

Libode

**Figure 2:** Locality map 2: Eastern Cape Housing (Marubeni and Zinkumbini) WSM LESHIKA CONSULTING (PTY) LTD No: WF14066 © GoogleEarth 2014



Center site coordinates (WGS84):
**Marubreni:**
Latitude: -31.440061°
Longitude: 29.054588°
**Zinkumbini:**
Latitude: -31.426277°
Longitude: 29.045989°

Approximate Villages of Interest

Highly weathered soft rock shale fragment

Highly weathered jointed shale at base of test pit.

Completely weathered shale excavated

**Figure 3:** Geology map: Eastern Cape Housing (Marubeni and Zinkumbini)

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Project No: WH14001

© The Government Printer

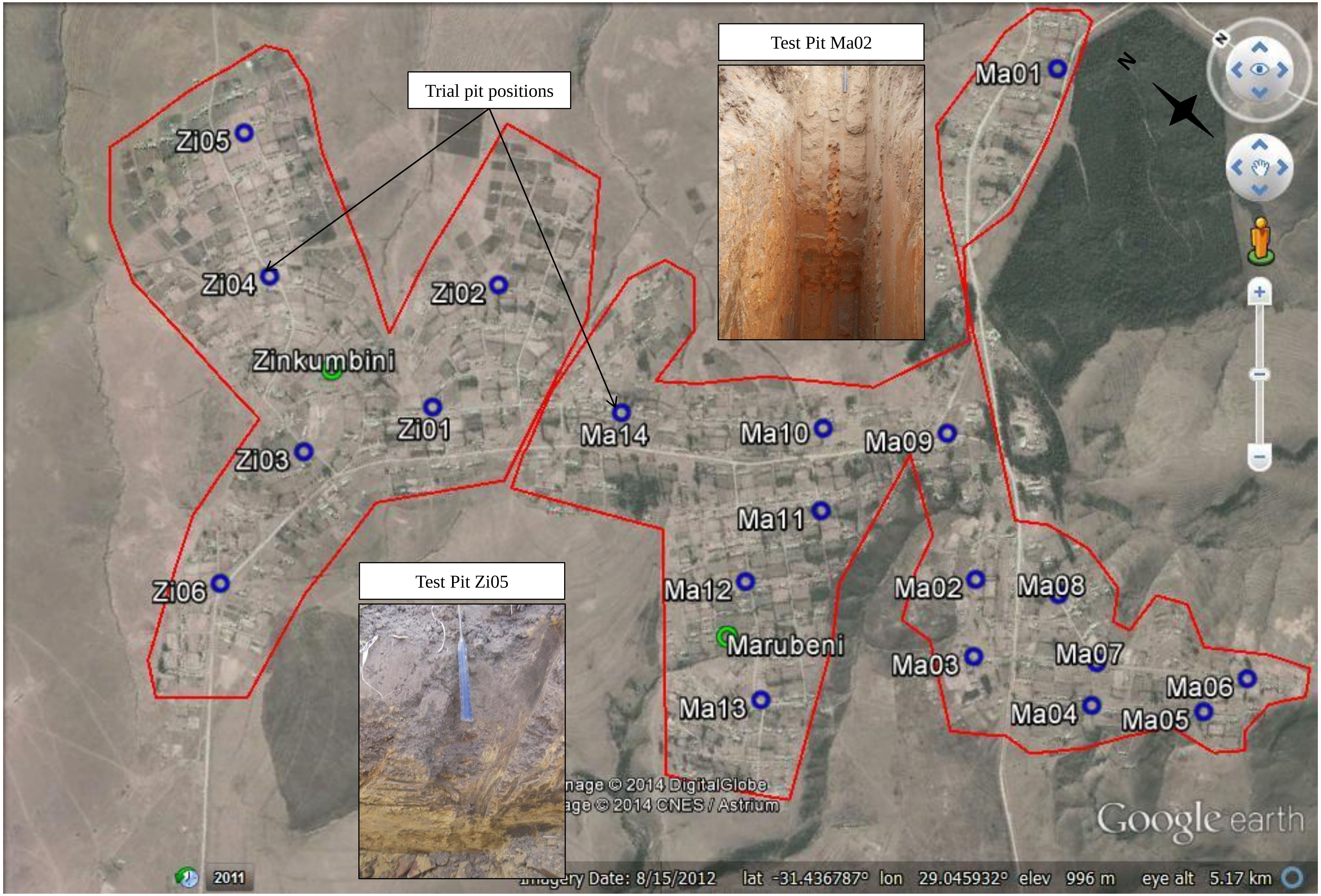
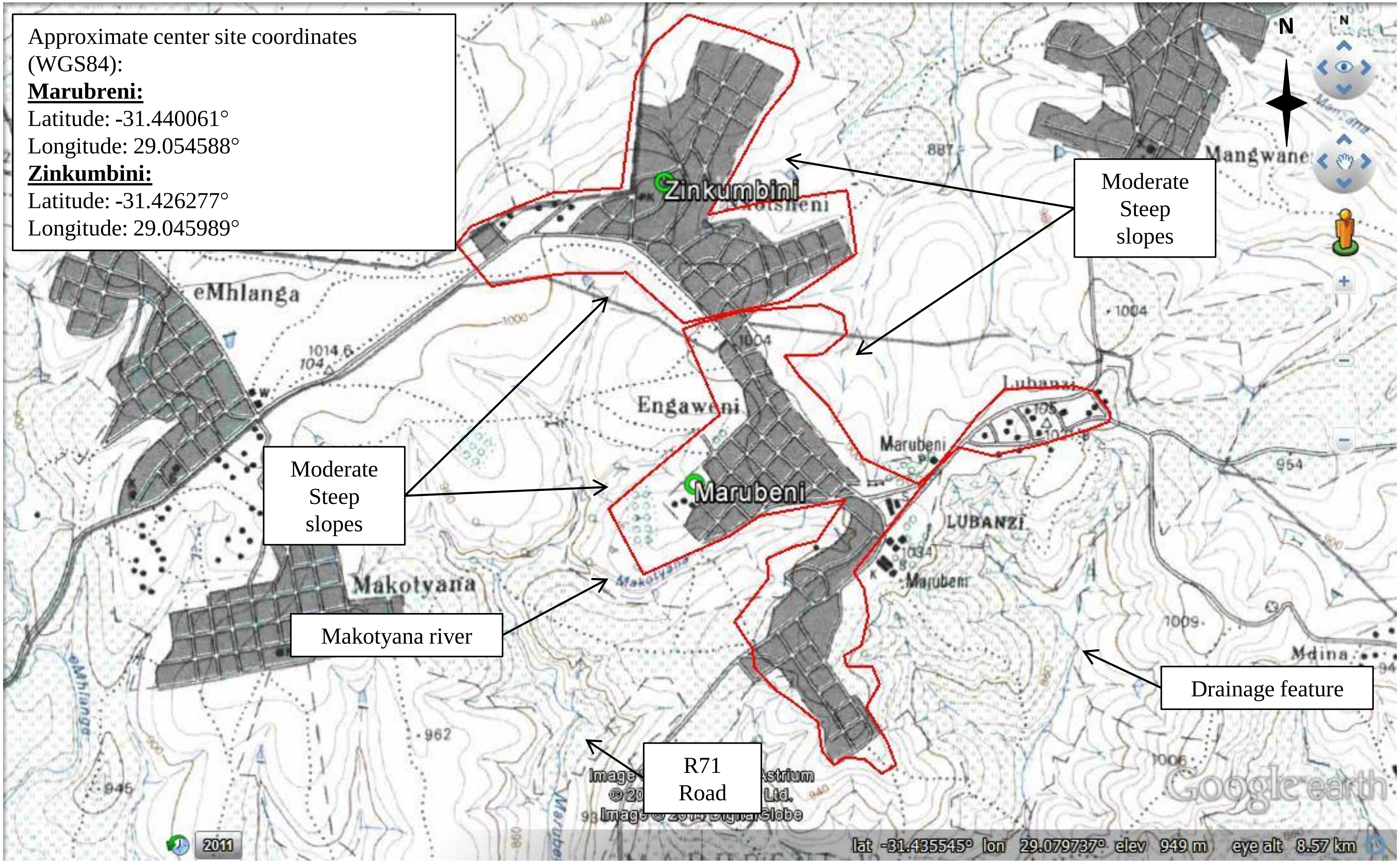


**Figure 4:** Test Pit Positions: Eastern Cape Housing (Marubeni and Zinkumbini)

Project no: WF14066

© GoogleEarth 2014



Approximate center site coordinates (WGS84):

**Marubreni:**

Latitude: -31.440061°

Longitude: 29.054588°

**Zinkumbini:**

Latitude: -31.426277°

Longitude: 29.045989°

Moderate Steep slopes

Moderate Steep slopes

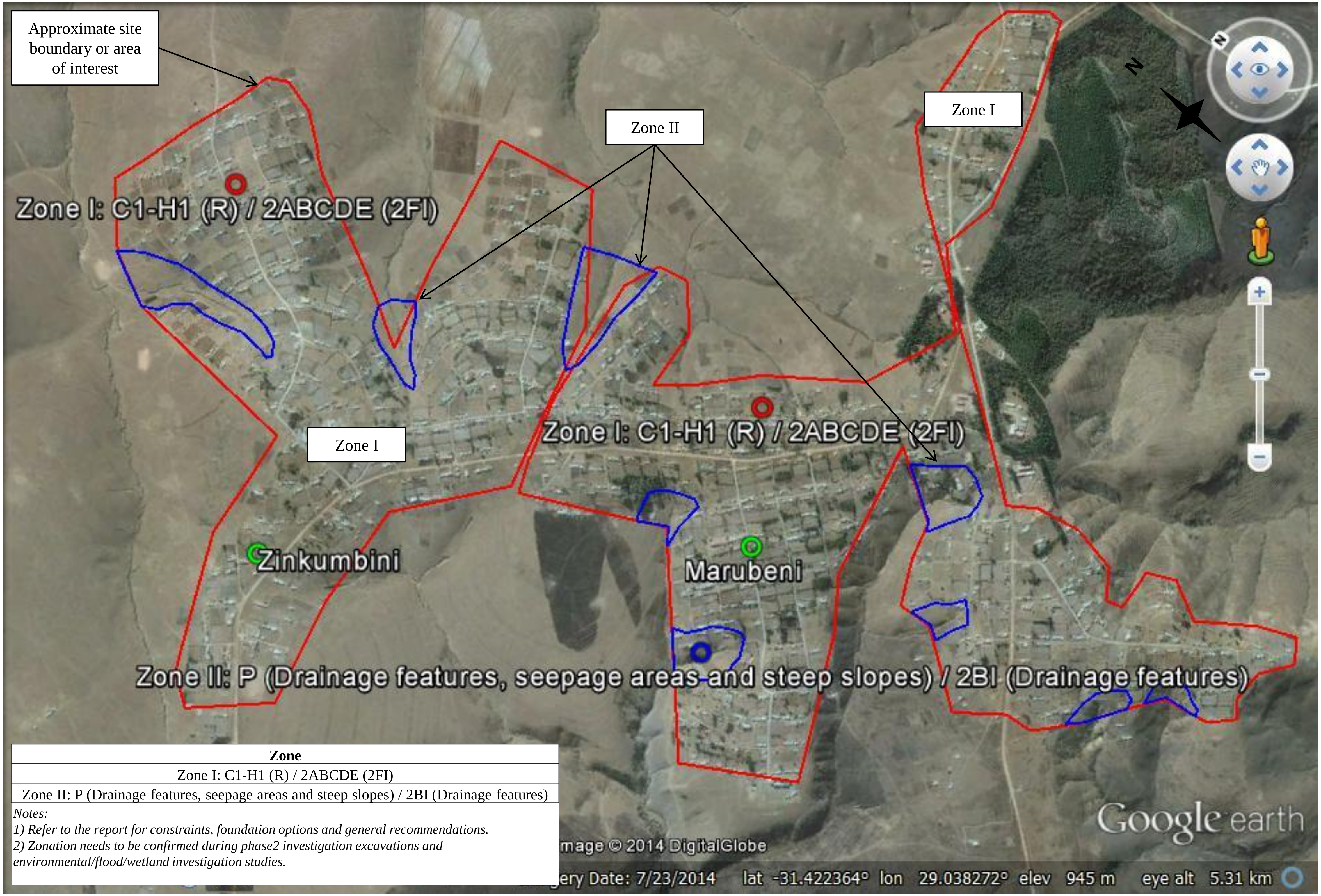
Makotyana river

Drainage feature

R71 Road

**Figure 5:** Topographical map: Eastern Cape Housing (Marubeni and Zinkumbini)

© The Government Printer



| Zone |
|---|
| Zone I: C1-H1 (R) / 2ABCDE (2FI) |
| Zone II: P (Drainage features, seepage areas and steep slopes) / 2BI (Drainage features) |

*Notes:*

*1) Refer to the report for constraints, foundation options and general recommendations.*

*2) Zonation needs to be confirmed during phase2 investigation excavations and environmental/flood/wetland investigation studies.*

**Figure 6:** Geotechnical Zonation: Eastern Cape Housing (Marubeni and Zinkumbini)

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Project no: WF14066

© GoogleEarth 2014

# APPENDIX B

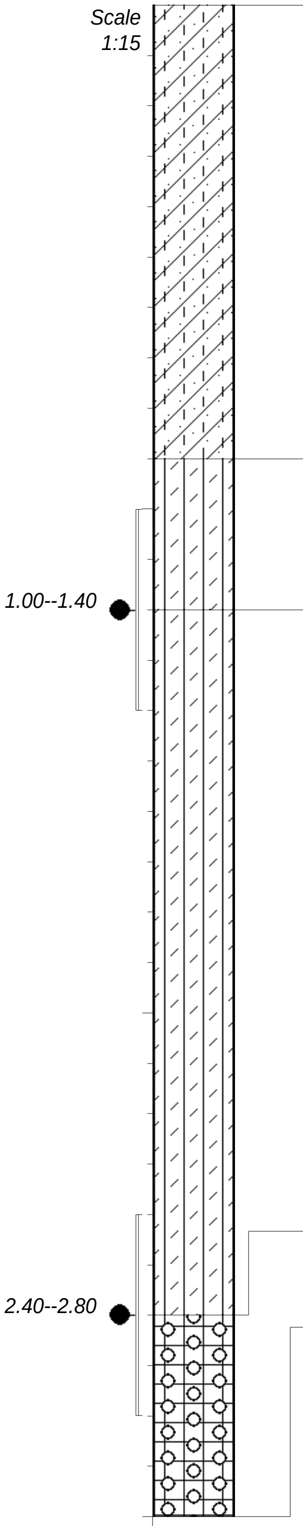
# (Soil Profile Descriptions)

**WSM LESHIKA**
CONSULTING (PTY) LTD

Housing project in Eastern Cape

*HOLE No:* Ma01
*Sheet 1 of 1*

*JOB NUMBER:* WF14066



| | |
|---|---|
| 0.00 | Slightly moist, light grey, very stiff, **open structured**, fine sandy silty CLAY, colluvium. |
| 0.90 | Moist, orange streaked yellow and grey, medium dense to firm, **pinholed**, clayey SILT, residuum. |
| 1.20 | Moist, mustard yellow patched orange and red, dense, **slightly open**, clayey SILT, with completely weathered rock fragments, residual shale. |
| 2.60 | Moist, yellow, dense, **jointed and fractured**, completely weathered shale that excavates to silt and shale gravel fragments. |
| 3.00 | |

NOTES

1) Hole stopped.

2) Sample: 1.00--1.40 m and 2.40--2.80 m.

3) No seepage.

4) Hole stable during investigation.

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*MACHINE :* TLB JCB
*DRILLED BY :*
*PROFILED BY :* HAM van Rensburg
*TYPE SET BY :*
*SETUP FILE : STANDARD.SET*

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*ELEVATION :*
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*Y-COORD :*

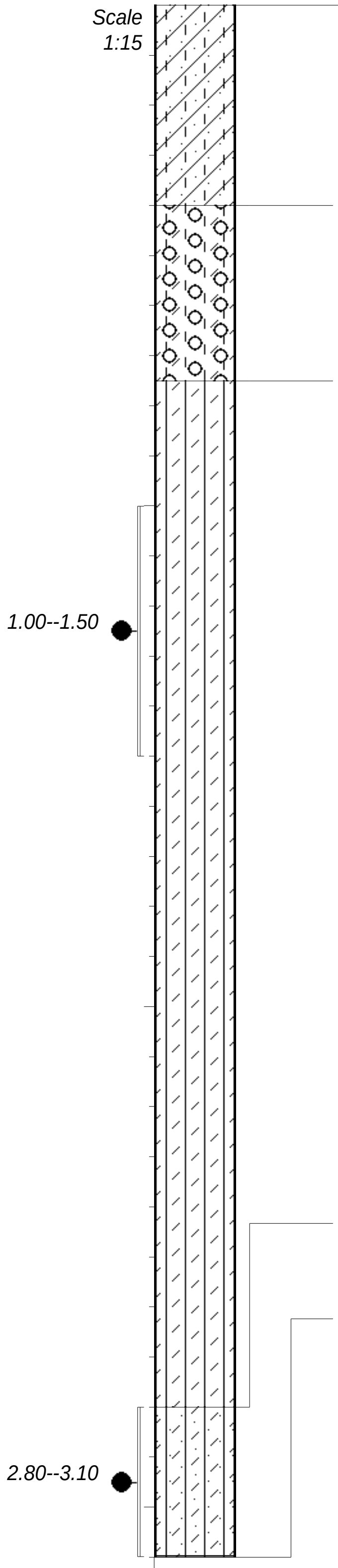
*HOLE No:* Ma01

WSM LESHIKA CONSULTING (PTY) LTD

Housing project in Eastern Cape

*HOLE No:* Ma02
*Sheet 1 of 1*

*JOB NUMBER:* WF14066



| | |
|---|---|
| 0.00 | Slightly moist, grey, very stiff, **open structured**, fine sandy silty CLAY, colluvium. |
| 0.40 | Slightly moist, grey to orange, very stiff, **open structured**, silty clayey fine GRAVEL, colluvium. |
| 0.75 | Moist, orange streaked yellow mottled black, medium dense, **slightly open**, clayey SILT, residual shale. |
| 2.80 | Moist, yellow mottled black, medium dense, **slightly open**, clayey fine sandy SILT, residual shale. |
| 3.10 | |

NOTES

1) Hole stopped.

2) Sample: 1.00--1.50 m and 2.80--3.10 m.

3) No seepage.

4) Hole stable during investigation.

*CONTRACTOR :*
*MACHINE :* TLB JCB
*DRILLED BY :*
*PROFILED BY :* HAM van Rensburg

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*Y-COORD :*

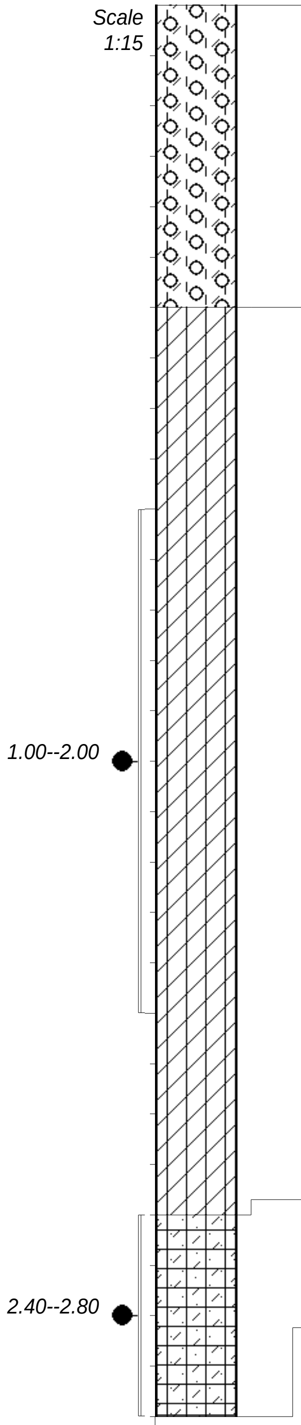
*HOLE No:* Ma02

WSM LESHIKA CONSULTING (PTY) LTD

Housing project in Eastern Cape

*HOLE No:* Ma03
*Sheet 1 of 1*

*JOB NUMBER:* WF14066



*0.00*

Slightly moist, grey to orange, very stiff, **open structured**, silty clayey fine GRAVEL, colluvium.

*0.60*

Moist, maroon red mottled yellow and red, medium dense to firm, **open and pinholed structured**, silty CLAY/ clayey SILT, residual.

*2.40*

Moist, mustard yellow patched red and orange, dense, **slightly layered**, fine sandy clayey SILT/ clayey fine sandy SILT, completely to highly weathered shale becoming harder with depth.

*2.80*

NOTES

1) Progressive Refusal, TLB confined excavation.

2) Sample: 1.00--2.00 m and 2.40--2.80 m.

3) No seepage.

4) Hole stable during investigation.

*CONTRACTOR :*
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*PROFILED BY :* HAM van Rensburg
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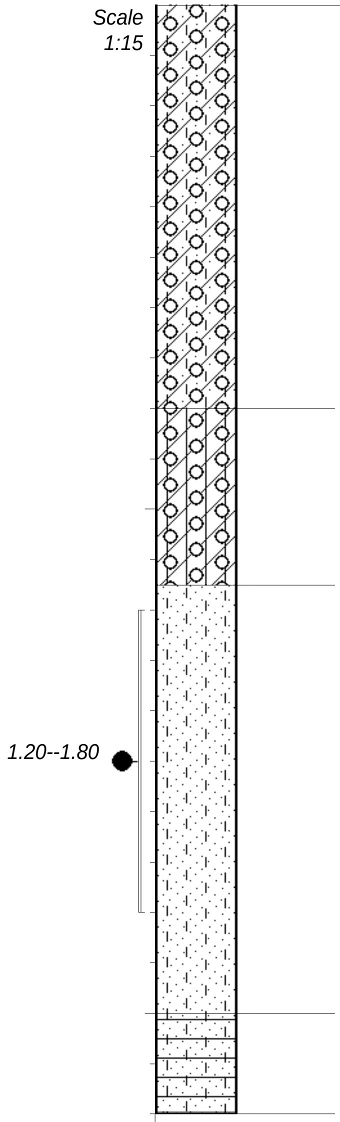
*Y-COORD :*

*HOLE No:* Ma03

Housing project in Eastern Cape

*HOLE No:* Ma04
*Sheet 1 of 1*

*JOB NUMBER:* WF14066



| | |
|---|---|
| 0.00 | Moist, grey black, stiff, **open and shattered**, silty fine sandy CLAY, with moderately abundant gravel, colluvium. |
| 0.80 | Moist, orange mottled yellow and black, medium dense to firm, **slightly open**, clayey SILT with patches and streaked black clay and scattered gravel, residuum. |
| 1.15 | Moist, light yellow orange mottled orange, medium dense, **slightly open**, silty fine SAND, residuum. |
| 2.00 | Moist, light yellow orange mottled orange, very dense, **slightly layered and open**, silty fine SAND, completely weathered shale becoming harder. |
| 2.20 | |

NOTES

1) Progressive Refusal, TLB confined excavation.

2) Sample: 1.20--1.80 m.

3) No seepage.

4) Hole stable during investigation.

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*PROFILED BY :* HAM van Rensburg
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*Y-COORD :*

*HOLE No:* Ma04

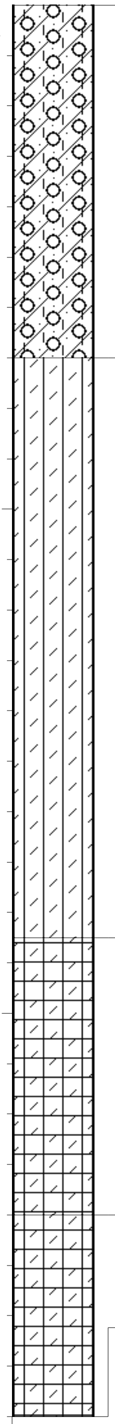
WSM LESHIKA CONSULTING (PTY) LTD

Housing project in Eastern Cape

*HOLE No:* Ma05
*Sheet 1 of 1*

*JOB NUMBER:* WF14066

*Scale 1:15*



| | |
|---|---|
| *0.00* | Slightly moist, grey, stiff, **open and slightly shattered**, silty fine sandy CLAY, with moderately abundant fine gravel, colluvium. |
| *0.70* | Moist, orange mottled red and patched yellow streaked black, medium dense, **pinholed**, clayey SILT, residuum. |
| *1.85* | Moist, grey and maroon brown, medium dense to dense, **slightly layered and jointed**, clayey SILT, residual to completely weathered shale. |
| *2.40* | Moist, light and dark orange streaked yellow and black, medium dense, **pinholed and layered**, clayey SILT, completely weathered shale. |
| *2.80* | |

NOTES

1) Hole stopped.

2) No sample.

3) No seepage.

4) Hole stable during investigation.

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*MACHINE :* TLB JCB
*DRILLED BY :*
*PROFILED BY :* HAM van Rensburg

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*Y-COORD :*

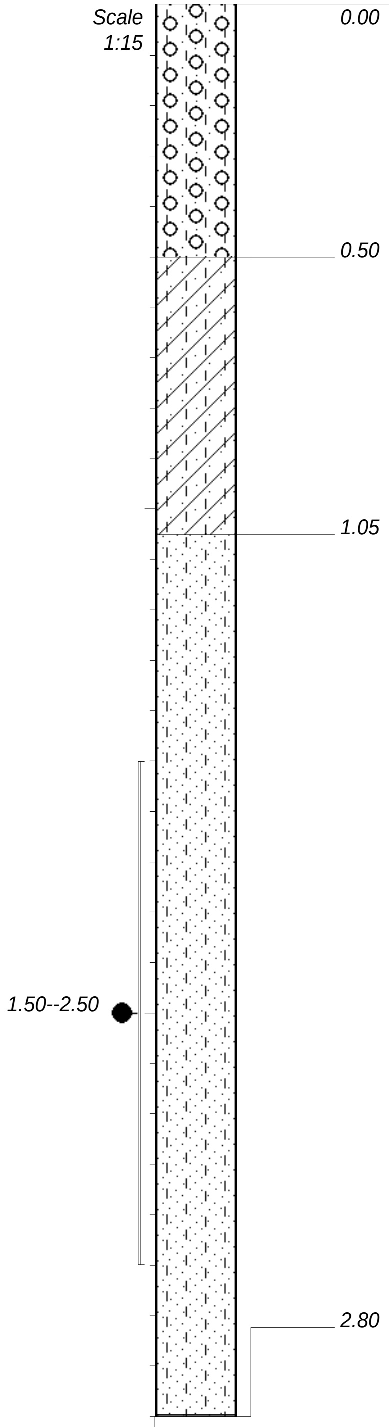
*HOLE No:* Ma05

WSM LESHIKA
CONSULTING (PTY) LTD

Housing project in Eastern Cape

*HOLE No:* Ma06
*Sheet 1 of 1*

*JOB NUMBER:* WF14066



Slightly moist, brown, medium dense to dense, **open structured**, silty sandy GRAVEL, colluvium.

Moist, black, firm, **open structured**, silty sandy CLAY, colluvium.

Moist, light yellow, medium dense, **slightly pinholed**, silty fine SAND, residuum.

NOTES

1) Hole stopped.

2) Sample: 1.50--2.50 m.

3) No seepage.

4) Hole stable during investigation.

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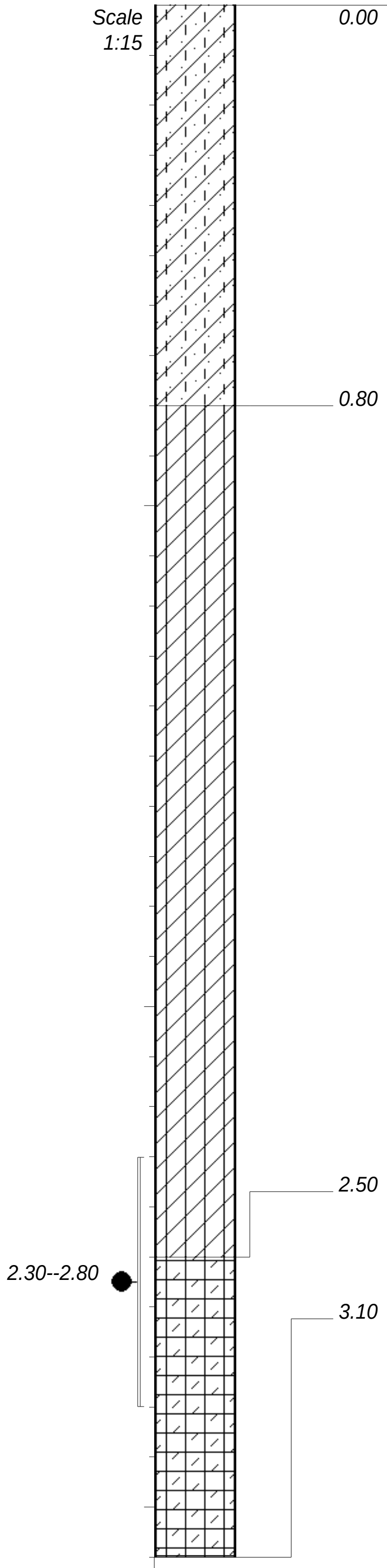
*HOLE No:* Ma06

WSM LESHIKA CONSULTING (PTY) LTD

Housing project in Eastern Cape

*HOLE No:* Ma07
*Sheet 1 of 1*

*JOB NUMBER:* WF14066



Slightly moist, grey, very stiff, **open and slightly shattered**, fine sandy silty CLAY, colluvium.

Moist, orange streaked yellow and black, medium dense to soft, **pinholed**, clayey SILT/ silty CLAY, residuum.

Moist, light and dark orange streaked yellow and black, medium dense, **pinholed jointed and layered**, clayey SILT, completely to highly weathered shale.

NOTES

1) Hole stopped.

2) Sample: 2.30--2.80 m.

3) No seepage.

4) Hole stable during investigation.

*CONTRACTOR :*
*MACHINE :* TLB JCB
*DRILLED BY :*
*PROFILED BY :* HAM van Rensburg
*TYPE SET BY :*
*SETUP FILE : STANDARD.SET*

*INCLINATION :*
*DIAM :*
*DATE :*
*DATE :* 2014/07/16-18
*DATE : 11/09/14 12:04*
*TEXT : ..C:\DOTFILES\SP_DP.TXT*

*ELEVATION :*
*X-COORD :*
*Y-COORD :*

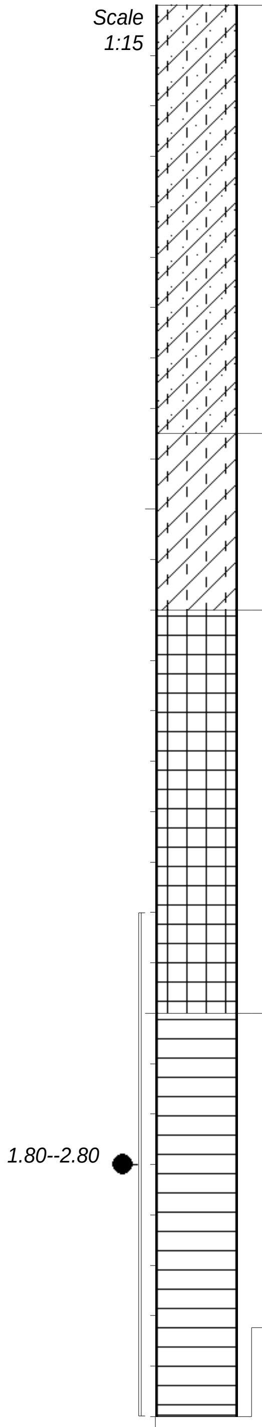
*HOLE No:* Ma07

WSM LESHIKA CONSULTING (PTY) LTD

Housing project in Eastern Cape

*HOLE No:* Ma08
*Sheet 1 of 1*

*JOB NUMBER:* WF14066



*0.00*

Slightly moist, grey, very stiff, **open and slightly shattered**, fine sandy silty CLAY, colluvium.

*0.85*

Moist, orange streaked yellow and black, soft, **pinholed**, silty CLAY, residuum.

*1.20*

Moist, light yellow patched black and orange, medium dense to dense, **slightly layered**, SILT, completely weathered shale. Rock fragments excavated.

*2.00*

Moist, light yellow patched black and orange, dense to very dense, **layered**, highly weathered soft rock shale.

*2.80*

NOTES

1) Progressive Refusal, TLB confined excavation.

2) Sample: 1.80--2.80 m.

3) No seepage.

4) Hole stable during investigation.

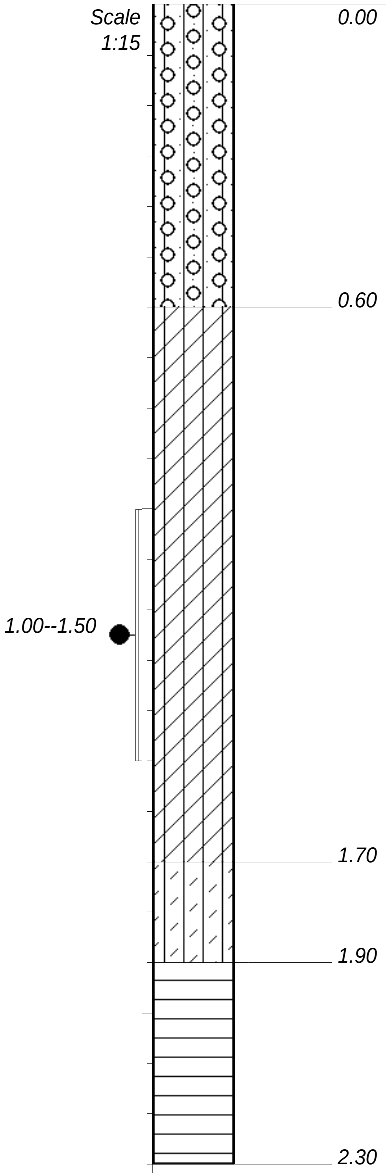
| | | |
|---|---|---|
| *CONTRACTOR :* | *INCLINATION :* | *ELEVATION :* |
| *MACHINE :* TLB JCB | *DIAM :* | *X-COORD :* |
| *DRILLED BY :* | *DATE :* | *Y-COORD :* |
| *PROFILED BY :* HAM van Rensburg | *DATE :* 2014/07/16-18 | *HOLE No:* Ma08 |
| *TYPE SET BY :* | *DATE : 11/09/14 12:04* | |
| *SETUP FILE : STANDARD.SET* | *TEXT : ..C:\DOTFILES\SP_DP.TXT* | |

WSM LESHIKA
CONSULTING (PTY) LTD

Housing project in Eastern Cape

*HOLE No:* Ma09
*Sheet 1 of 1*

*JOB NUMBER:* WF14066



Slightly moist, light grey, stiff, **open and slightly shattered**, silty fine sandy SILT, with abundant fine gravel, colluvium.

Moist, orange streaked yellow red and black, medium dense, **open and pinholed structured**, clayey SILT with black streaks of clay, residuum.

Moist to very moist, maroon red streaked yellow and red, medium dense to soft, **slightly layered**, clayey SILT, residuum.

Moist, dull grey patched black and red, very dense, **layered and joint**, highly weathered soft rock shale.

NOTES

1) Progressive Refusal, TLB confined excavation.

2) Sample: 1.00--1.50 m.

3) No seepage.

4) Hole stable during investigation.

*CONTRACTOR :*
*MACHINE :* TLB JCB
*DRILLED BY :*
*PROFILED BY :* HAM van Rensburg
*TYPE SET BY :*
*SETUP FILE :* STANDARD.SET

*INCLINATION :*
*DIAM :*
*DATE :*
*DATE :* 2014/07/16-18
*DATE :* 11/09/14 12:04
*TEXT :* ..C:\DOTFILES\SP_DP.TXT

*ELEVATION :*
*X-COORD :*
*Y-COORD :*

*HOLE No:* Ma09

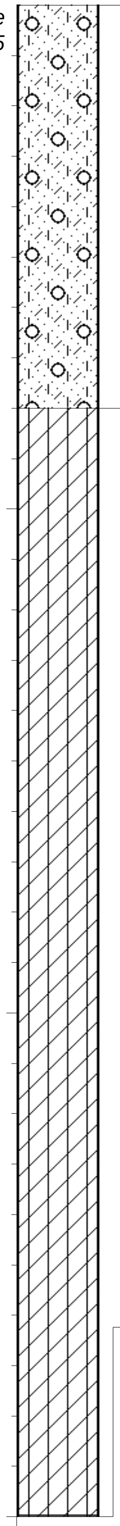
WSM LESHIKA CONSULTING (PTY) LTD

Housing project in Eastern Cape

HOLE No: Ma10
Sheet 1 of 1

JOB NUMBER: WF14066

Scale
1:15



0.00

Slightly moist, brown, medium dense to firm, **open structured**, silty fine gravelly clayey fine to coarse SAND, colluvium.

0.80

Moist, orange maroon speckled black and yellow, medium dense to soft, **pinholed**, CLAY SILT, residuum.

3.00

NOTES

1) Hole stopped.

2) No sample.

3) No seepage.

4) Hole stable during investigation.

CONTRACTOR :
MACHINE : TLB JCB
DRILLED BY :
PROFILED BY : HAM van Rensburg

TYPE SET BY :
SETUP FILE : STANDARD.SET

INCLINATION :
DIAM :
DATE :
DATE : 2014/07/16-18

DATE : 11/09/14 12:04
TEXT : ..C:\DOTFILES\SP_DP.TXT

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: Ma10

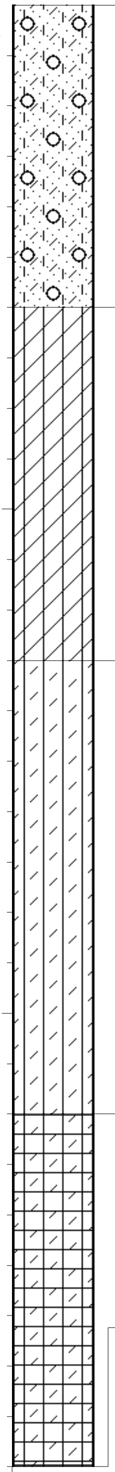
WSM LESHIKA CONSULTING (PTY) LTD

Housing project in Eastern Cape

*HOLE No:* Ma11
*Sheet 1 of 1*

*JOB NUMBER:* WF14066

*Scale 1:15*



*0.00*

Slightly moist, brown, medium dense to firm, **open structured**, silty fine gravelly clayey fine to coarse SAND, colluvium.

*0.60*

Moist, orange maroon speckled black and yellow, medium dense to soft, **slightly pinholed**, CLAY SILT, residuum.

*1.30*

Moist, pinkish and purple mottled white and yellow, medium dense to dense, **slightly layered**, clayey SILT, residuum.

*2.20*

Moist, dull pink brown mottled and streaked yellow, medium dense to soft, **slightly layered**, clayey SILT, residuum to completely weathered shale.

*2.90*

NOTES

1) Hole stopped.

2) No sample.

3) No seepage.

4) Hole stable during investigation.

*CONTRACTOR :*
*MACHINE :* TLB JCB
*DRILLED BY :*
*PROFILED BY :* HAM van Rensburg

*TYPE SET BY :*
*SETUP FILE : STANDARD.SET*

*INCLINATION :*
*DIAM :*
*DATE :*
*DATE :* 2014/07/16-18

*DATE : 11/09/14 12:04*
*TEXT : ..C:\DOTFILES\SP_DP.TXT*

*ELEVATION :*
*X-COORD :*
*Y-COORD :*

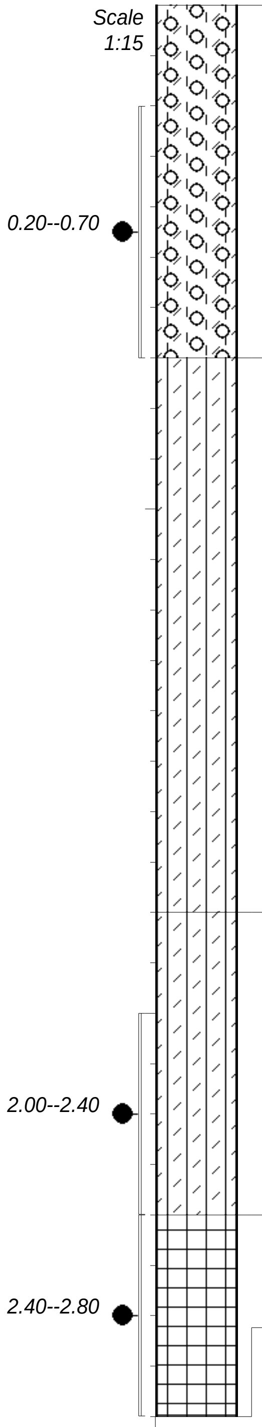
*HOLE No:* Ma11

WSM LESHIKA CONSULTING (PTY) LTD

Housing project in Eastern Cape

*HOLE No:* Ma12
*Sheet 1 of 1*

*JOB NUMBER:* WF14066



| | |
|---|---|
| 0.00 | Slightly moist, brown, medium dense to firm, **open structured**, silty clayey GRAVEL, colluvium. |
| 0.70 | Moist, maroon red streaked light and dark grey speckled yellow, medium dense to soft, **pinholed**, clayey SILT, residuum. |
| 1.80 | Moist, mustard yellow streaked and patched grey, medium dense to soft, **slightly layered**, clayey SILT, residual shale. |
| 2.40 | Moist, dull mustard yellow stained black red and white, dense to very dense, **layered and jointed**, SILT, completely weathered shale. |
| 2.80 | |

NOTES

1) Hole stopped slow excavation.

2) Sample: 0.20--0.70 m; 2.00--2.40 m and 2.40--2.80 m.

3) No seepage.

4) Hole stable during investigation.

*CONTRACTOR :*
*MACHINE :* TLB JCB
*DRILLED BY :*
*PROFILED BY :* HAM van Rensburg
*TYPE SET BY :*
*SETUP FILE : STANDARD.SET*

*INCLINATION :*
*DIAM :*
*DATE :*
*DATE :* 2014/07/16-18
*DATE : 11/09/14 12:04*
*TEXT : ..C:\DOTFILES\SP_DP.TXT*

*ELEVATION :*
*X-COORD :*
*Y-COORD :*

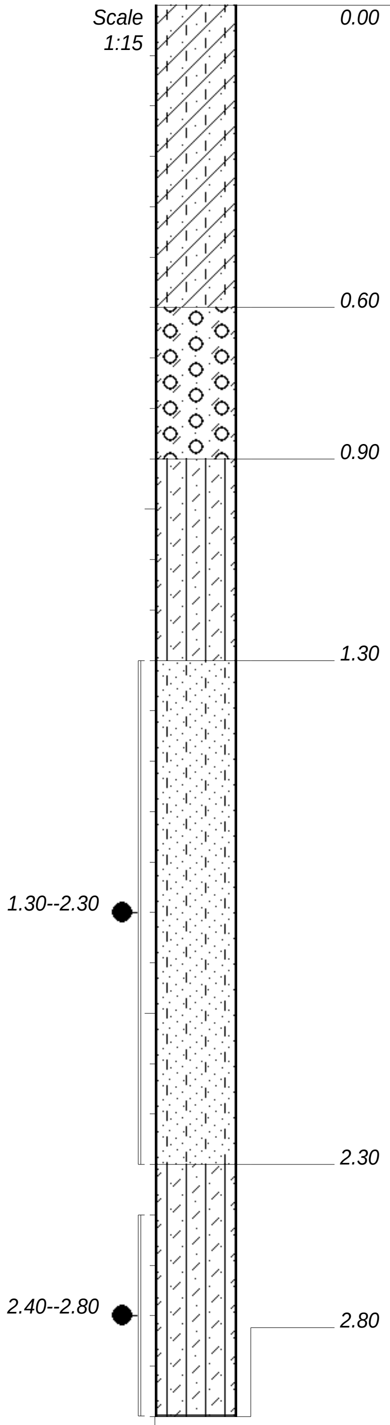
*HOLE No:* Ma12

WSM LESHIKA CONSULTING (PTY) LTD

Housing project in Eastern Cape

*HOLE No:* Ma13
*Sheet 1 of 1*

*JOB NUMBER:* WF14066



Slightly moist, light grey, <u>stiff</u>, **open structured**, fine sandy silty CLAY, colluvium.

Slightly moist, light grey, <u>stiff</u>, **open structured**, fine sandy clayey GRAVEL, colluvium.

Moist, orange streaked and speckled yellow and grey, <u>medium dense</u>, **intact**, fine sandy clayey SILT, residuum.

Moist, dull mustard yellow, <u>dense</u>, **slightly pinholed and layered**, silty fine SAND, residual shale.

Moist, streaked orange and yellow, <u>medium dense to soft</u>, **pinholed**, fine sandy clayey SILT, residual shale.

NOTES

1) Hole stopped.

2) Sample: 1.30--2.30 m and 2.40--2.80 m.

3) No seepage.

4) Hole stable during investigation.

*CONTRACTOR :*
*MACHINE :* TLB JCB
*DRILLED BY :*
*PROFILED BY :* HAM van Rensburg
*TYPE SET BY :*
*SETUP FILE : STANDARD.SET*

*INCLINATION :*
*DIAM :*
*DATE :*
*DATE :* 2014/07/16-18
*DATE : 11/09/14 12:04*
*TEXT : ..C:\DOTFILES\SP_DP.TXT*

*ELEVATION :*
*X-COORD :*
*Y-COORD :*

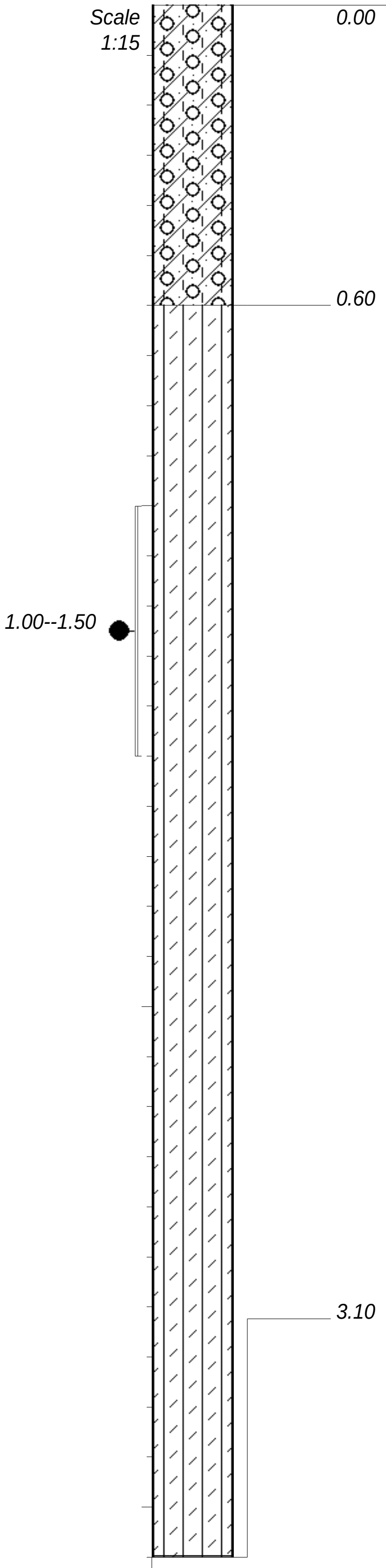
*HOLE No:* Ma13

WSM LESHIKA
CONSULTING (PTY) LTD

Housing project in Eastern Cape

*HOLE No:* Ma14
*Sheet 1 of 1*

*JOB NUMBER:* WF14066



Slightly moist, grey, stiff, **open structured**, fine sandy silty CLAY with scattered gravel, colluvium.

Moist, red speckled yellow and black, medium dense to soft, **pinholed**, clayey SILT, residuum.

NOTES

1) Hole stopped.

2) Sample: 1.00--1.50 m.

3) No seepage.

4) Hole stable during investigation.

*CONTRACTOR :*
*MACHINE :* TLB JCB
*DRILLED BY :*
*PROFILED BY :* HAM van Rensburg
*TYPE SET BY :*
*SETUP FILE : STANDARD.SET*

*INCLINATION :*
*DIAM :*
*DATE :*
*DATE :* 2014/07/16-18
*DATE : 11/09/14 12:04*
*TEXT : ..C:\DOTFILES\SP_DP.TXT*

*ELEVATION :*
*X-COORD :*
*Y-COORD :*

*HOLE No:* Ma14

WSM LESHIKA
CONSULTING (PTY) LTD

Housing project in Eastern Cape

LEGEND
*Sheet 1 of 1*

*JOB NUMBER:* WF14066

| | | |
|---|---|---|
| | GRAVEL | {SA02} |
| | GRAVELLY | {SA03} |
| | SAND | {SA04} |
| | SANDY | {SA05} |
| | SILT | {SA06} |
| | SILTY | {SA07} |
| | CLAY | {SA08} |
| | CLAYEY | {SA09} |
| | SHALE | {SA12} |
| *Name* ● | DISTURBED SAMPLE | {SA38} |

*CONTRACTOR :*
*MACHINE :*
*DRILLED BY :*
*PROFILED BY :*

*TYPE SET BY :*
*SETUP FILE : STANDARD.SET*

*INCLINATION :*
*DIAM :*
*DATE :*
*DATE :*

*DATE : 11/09/14 12:04*
*TEXT : ..C:\DOTFILES\SP_DP.TXT*

*ELEVATION :*
*X-COORD :*
*Y-COORD :*

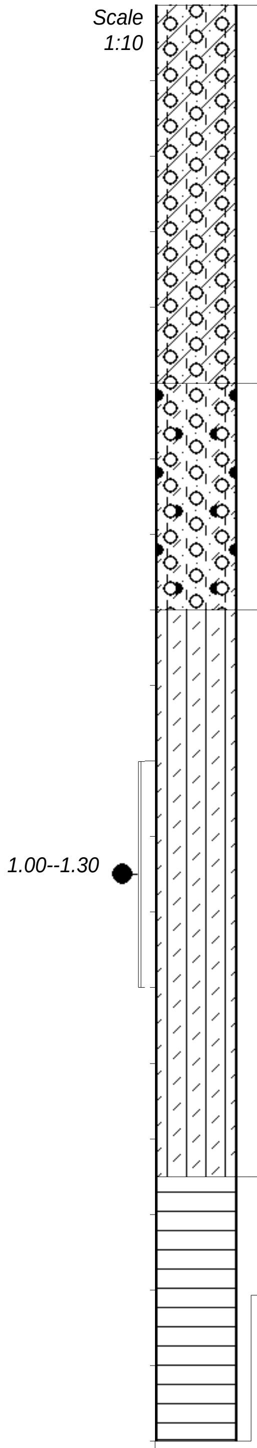
LEGEND
*SUMMARY OF SYMBOLS*

WSM LESHIKA CONSULTING (PTY) LTD

Housing project in Eastern Cape

*HOLE No:* Zi01
*Sheet 1 of 1*

*JOB NUMBER:* WF14066



*0.00*

Slightly moist, grey, <u>stiff</u>, **open structured**, fine sandy silty CLAY scattered gravel, colluvium.

*0.50*

Slightly moist, grey, <u>stiff</u>, **open structured**, fine sandy silty clayey GRAVEL, Fe and Mn nodules as gravel, pebble marker.

*0.80*

Moist, yellow orange streaked light and dark grey, <u>medium dense to dense to soft</u>, clayey SILT, residual shale.

*1.55*

Moist, olive, <u>very dense</u>, **layered**, <u>highly weathered soft rock</u> shale becoming harder with depth.

*1.90*

NOTES

1) Progressive Refusal, TLB confined excavation to Refusal, TLB confined excavation.

2) Sample: 1.00--1.30 m.

3) No seepage.

4) Hole stable during investigation.

*CONTRACTOR :*
*MACHINE :* TLB JCB
*DRILLED BY :*
*PROFILED BY :* HAM van Rensburg
*TYPE SET BY :*
*SETUP FILE : STANDARD.SET*

*INCLINATION :*
*DIAM :*
*DATE :*
*DATE :* 2014/07/16-18
*DATE : 15/09/14 09:20*
*TEXT : ..C:\DOTFILES\SP_DP.TXT*

*ELEVATION :*
*X-COORD :*
*Y-COORD :*

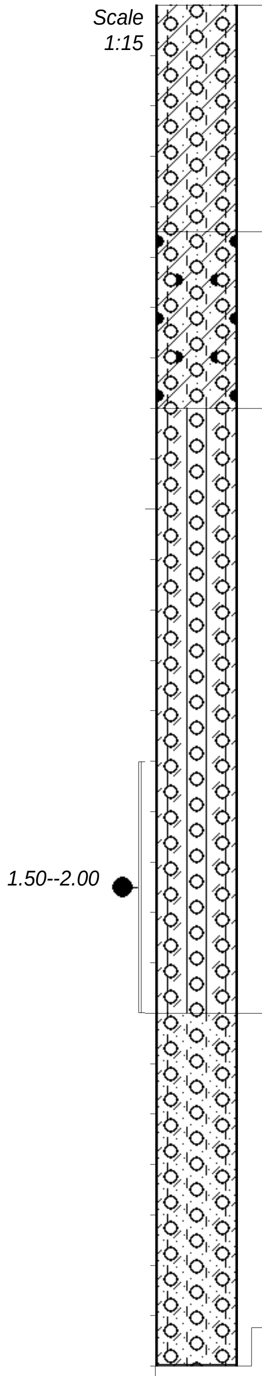
*HOLE No:* Zi01

WSM LESHIKA CONSULTING (PTY) LTD

Housing project in Eastern Cape

*HOLE No:* Zi02
*Sheet 1 of 1*

*JOB NUMBER:* WF14066



| | |
|---|---|
| 0.00 | Slightly moist, grey, <u>stiff</u>, **open structured**, fine sandy silty CLAY scattered gravel, colluvium. |
| 0.45 | Slightly moist, grey, <u>stiff</u>, **open structured**, fine sandy silty CLAY moderately abundant gravel, Fe and Mn nodules as gravel, pebble marker. |
| 0.80 | Moist, dark red patched yellow and black, <u>medium dense to soft,</u> **pinholed**, clayey SILT moderately abundant gravel, residual dolerite. |
| 2.00 | Moist, dark brown, <u>medium dense</u>, **pinholed**, silty clayey fine to coarse SAND with moderately abundant fine gravel, residual dolerite |
| 2.70 | |

NOTES

1) Refusal, TLB confined excavation.

2) Sample: 1.50--2.00 m.

3) No seepage.

4) Hole stable during investigation.

*CONTRACTOR :*
*MACHINE :* TLB JCB
*DRILLED BY :*
*PROFILED BY :* HAM van Rensburg

*TYPE SET BY :*
*SETUP FILE : STANDARD.SET*

*INCLINATION :*
*DIAM :*
*DATE :*
*DATE :* 2014/07/16-18

*DATE : 15/09/14 09:20*
*TEXT : ..C:\DOTFILES\SP_DP.TXT*

*ELEVATION :*
*X-COORD :*
*Y-COORD :*

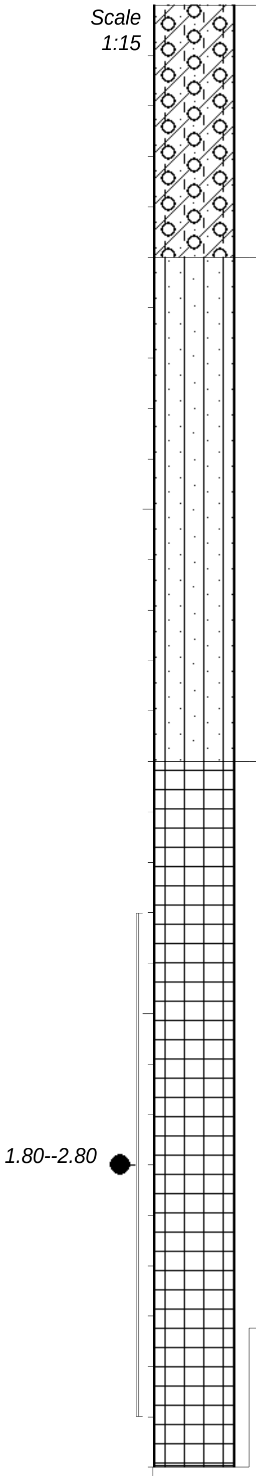
*HOLE No:* Zi02

WSM LESHIKA
CONSULTING (PTY) LTD

# Housing project in Eastern Cape

HOLE No: Zi03
Sheet 1 of 1

JOB NUMBER: WF14066



| | |
|---|---|
| 0.00 | Slightly moist, grey, stiff, **open structured**, fine sandy silty CLAY scattered gravel, colluvium. |
| 0.50 | Moist, orange streaked yellow grey and black, medium dense to soft, **pinholed**, fine sandy SILT, residual shale. |
| 1.50 | Moist, dull mustard yellow streaked orange and red, dense, **slightly layered**, SILT, completely weathered shale. |
| 2.90 | |

NOTES

1) Hole stopped.

2) Sample: 1.80--2.80 m.

3) No seepage.

4) Hole stable during investigation.

CONTRACTOR :
MACHINE : TLB JCB
DRILLED BY :
PROFILED BY : HAM van Rensburg

TYPE SET BY :
SETUP FILE : STANDARD.SET

INCLINATION :
DIAM :
DATE :
DATE : 2014/07/16-18

DATE : 15/09/14 09:20
TEXT : ..C:\DOTFILES\SP_DP.TXT

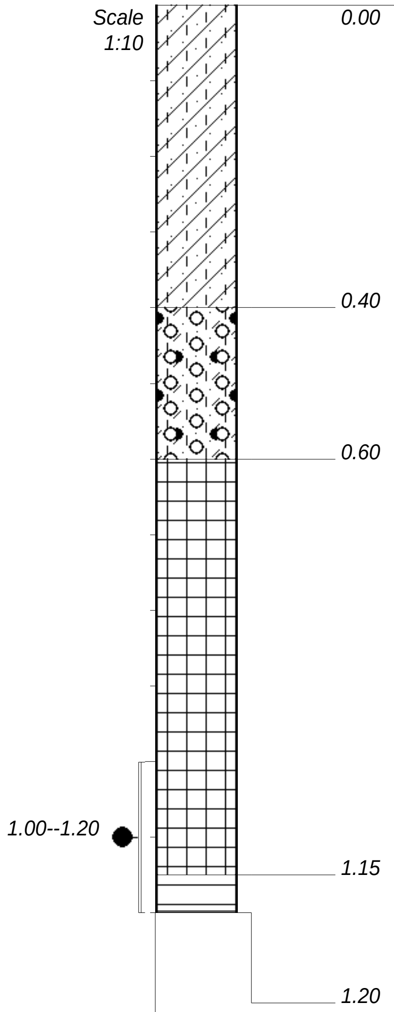
ELEVATION :
X-COORD :
Y-COORD :

HOLE No: Zi03

Housing project in Eastern Cape

*HOLE No:* Zi04
*Sheet 1 of 1*

*JOB NUMBER:* WF14066



| | |
|---|---|
| *0.00* | Slightly moist, grey, very stiff, **open structured**, sandy silty CLAY, colluvium. |
| *0.40* | Slightly moist, grey, very stiff, **open structured**, sandy silty clayey fine GRAVEL, Fe and Mn nodules as gravel, pebble marker. |
| *0.60* | Slightly moist, yellow streaked dark grey orange, very dense, **slightly layered**, SILT, residual to completely weathered shale. |
| *1.15* | Slightly moist, mustard yellow streaked black and red in layers, very dense, **layered and jointed**, highly weathered soft rock shale becoming harder. |
| *1.20* | |

NOTES

1) Refusal, TLB confined excavation.

2) Sample: 1.00--1.20 m.

3) No seepage.

4) Hole stable during investigation.

*CONTRACTOR :*
*MACHINE :* TLB JCB
*DRILLED BY :*
*PROFILED BY :* HAM van Rensburg

*TYPE SET BY :*
*SETUP FILE : STANDARD.SET*

*INCLINATION :*
*DIAM :*
*DATE :*
*DATE :* 2014/07/16-18

*DATE : 15/09/14 09:20*
*TEXT : ..C:\DOTFILES\SP_DP.TXT*

*ELEVATION :*
*X-COORD :*
*Y-COORD :*

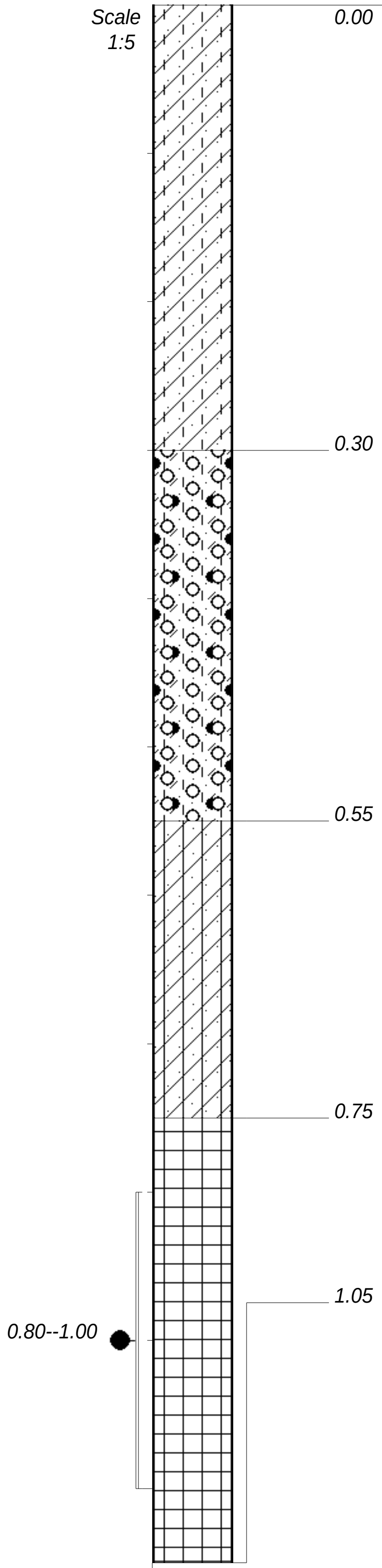
*HOLE No:* Zi04

WSM LESHIKA
CONSULTING (PTY) LTD

Housing project in Eastern Cape

*HOLE No:* Zi05
*Sheet 1 of 1*

*JOB NUMBER:* WF14066



| | |
|---|---|
| *0.00* | Slightly moist, grey, very stiff, **open structured**, sandy silty CLAY, colluvium. |
| *0.30* | Slightly moist, grey, very stiff, **open structured**, sandy silty clayey fine GRAVEL, Fe and Mn nodules as gravel, pebble marker. |
| *0.55* | Slightly moist, mottled black yellow and orange, dense to very stiff, **slightly open**, fine sandy clayey SILT/ silty CLAY, reworked residuum. |
| *0.75* | Mustard yellow stained red and black, **layered and jointed**, SILT, completely to highly weathered soft rock shale becoming harder. |
| *1.05* | |

NOTES

1) Refusal, TLB confined excavation.

2) Sample: 0.80--1.00 m.

3) No seepage.

4) Hole stable during investigation.

*CONTRACTOR :*
*MACHINE :* TLB JCB
*DRILLED BY :*
*PROFILED BY :* HAM van Rensburg
*TYPE SET BY :*
*SETUP FILE : STANDARD.SET*

*INCLINATION :*
*DIAM :*
*DATE :*
*DATE :* 2014/07/16-18
*DATE : 15/09/14 09:20*
*TEXT : ..C:\DOTFILES\SP_DP.TXT*

*ELEVATION :*
*X-COORD :*
*Y-COORD :*

*HOLE No:* Zi05

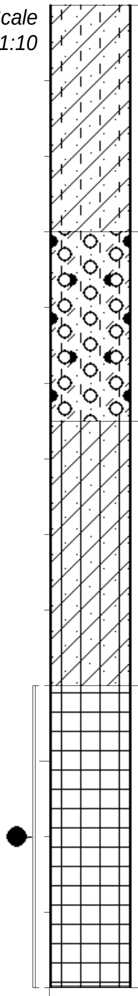
**WSM LESHIKA** CONSULTING (PTY) LTD

Housing project in Eastern Cape

*HOLE No:* Zi06
*Sheet 1 of 1*

*JOB NUMBER:* WF14066

*Scale*
*1:10*



| | |
|---|---|
| *0.00* | Slightly moist, grey, <u>very stiff</u>, **open structured**, sandy silty CLAY, colluvium. |
| *0.30* | Slightly moist, grey mottled black, <u>very stiff</u>, **open structured**, sandy silty clayey fine gravel, Fe and Mn nodules as gravel, pebble marker. |
| *0.55* | Slightly moist, mottled black yellow and orange streaked black, <u>dense to very stiff</u>, **slightly open**, fine sandy clayey SILT/ silty CLAY, reworked residuum. Fe and Mn staining. |
| *0.90* | Dull blue grey stained red and black, **layered and jointed**, SILT, <u>completely</u> to <u>highly weathered soft rock</u> shale becoming harder. |
| *1.30* | |

NOTES

1) Refusal, TLB confined excavation.

2) Sample: 0.90--1.30 m.

3) No seepage.

4) Hole stable during investigation.

*CONTRACTOR :*
*MACHINE :* TLB JCB
*DRILLED BY :*
*PROFILED BY :* HAM van Rensburg
*TYPE SET BY :*
*SETUP FILE : STANDARD.SET*

*INCLINATION :*
*DIAM :*
*DATE :*
*DATE :* 2014/07/16-18
*DATE : 15/09/14 09:20*
*TEXT : ..C:\DOTFILES\SP_DP.TXT*

*ELEVATION :*
*X-COORD :*
*Y-COORD :*

*HOLE No:* Zi06

WSM LESHIKA
CONSULTING (PTY) LTD

Housing project in Eastern Cape

LEGEND
*Sheet 1 of 1*

*JOB NUMBER:* WF14066

| | | |
|---|---|---|
| ○ | GRAVEL | {SA02} |
| ⁚ | SAND | {SA04} |
| · | SANDY | {SA05} |
| ‖ | SILT | {SA06} |
| ¦ | SILTY | {SA07} |
| ▨ | CLAY | {SA08} |
| ⁄ | CLAYEY | {SA09} |
| ☰ | SHALE | {SA12} |
| ● | NODULAR FERRICRETE/ferricrete nodules/honeycomb ferric.... | {SA24} |
| *Name* ● | DISTURBED SAMPLE | {SA38} |

*CONTRACTOR :*
*MACHINE :*
*DRILLED BY :*
*PROFILED BY :*

*TYPE SET BY :*
*SETUP FILE : STANDARD.SET*

*INCLINATION :*
*DIAM :*
*DATE :*
*DATE :*

*DATE : 15/09/14 09:20*
*TEXT : ..C:\DOTFILES\SP_DP.TXT*

*ELEVATION :*
*X-COORD :*
*Y-COORD :*

LEGEND
*SUMMARY OF SYMBOLS*

# APPENDIX C

## (Soil Profile Photographs)

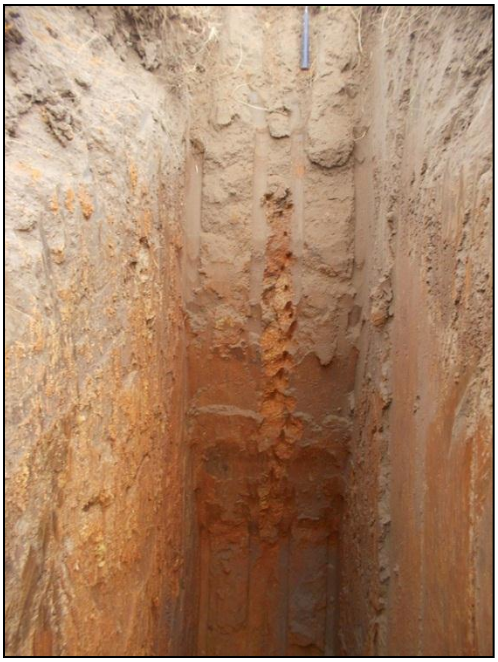
Test Pit number: Ma01

Note: Hole stopped TLB soft excavation.

Test Pit number: Ma01

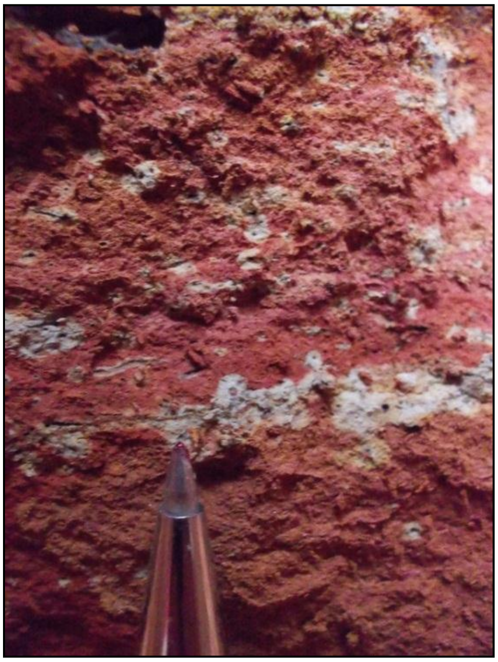
Note: Soft rock shale fragment.

Test Pit number: Ma02



Note: Hole stopped TLB soft excavation.

Test Pit number: Ma02

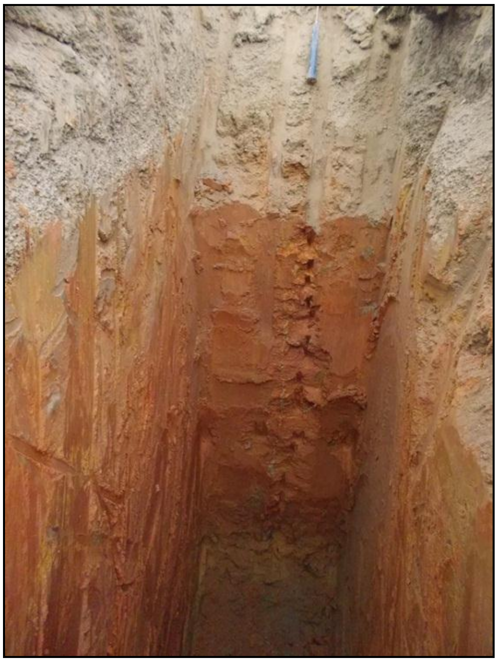


Note: Open structure in profile.

Test Pit number: Ma02

Note: Sandy silty material excavated.

Test Pit number: Ma03



Note: Progressive refusal of TLB.

Test Pit number: Ma03

Note: Highly weathered shale fragment.

Test Pit number: Ma04

Note: Progressive refusal of TLB.

Test Pit number: Ma04

Note: Desiccation cracks in clay horizon.

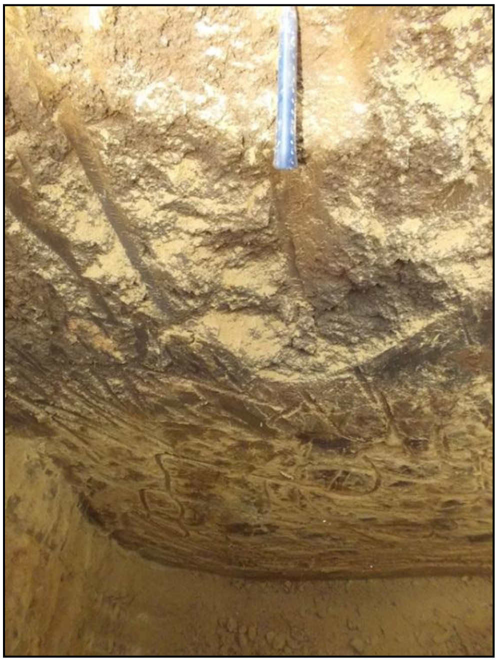
Test Pit number: Ma05

Note: Progressive refusal of TLB.

Test Pit number: Ma05

Note: Jointed structure in completely weathered shale.

Test Pit number: Ma06



Note: Hole stopped TLB soft excavation.

Test Pit number: Ma06

Note: Silty sandy material excavation.

Test Pit number: Ma07

Note: Hole stopped TLB soft excavation.

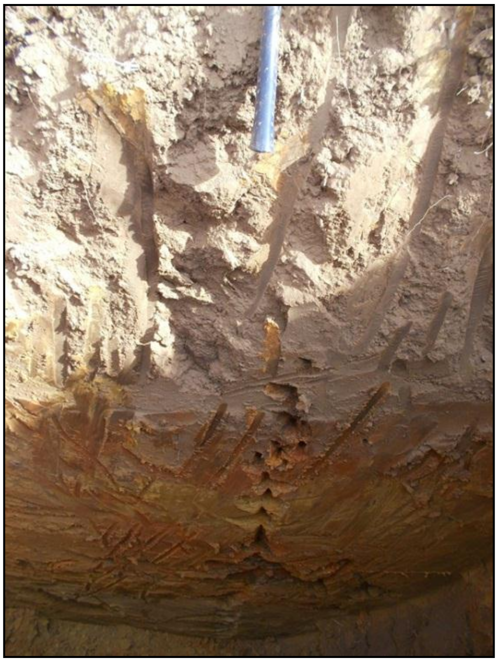
Test Pit number: Ma07

Note: Clayey silty material from excavated weathered shale.

Test Pit number: Ma07

Note: Jointed structure in weathered shale.

Test Pit number: Ma08



Note: Progressive refusal of TLB.

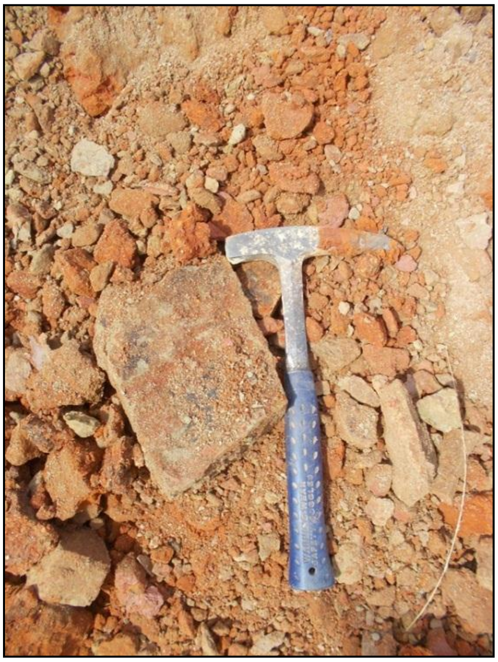
Test Pit number: Ma08

Note: Soft rock shale fragment excavated.

Test Pit number: Ma09

Note: Progressive refusal of TLB.

Test Pit number: Ma09



Note: Highly weathered shale fragment excavated.

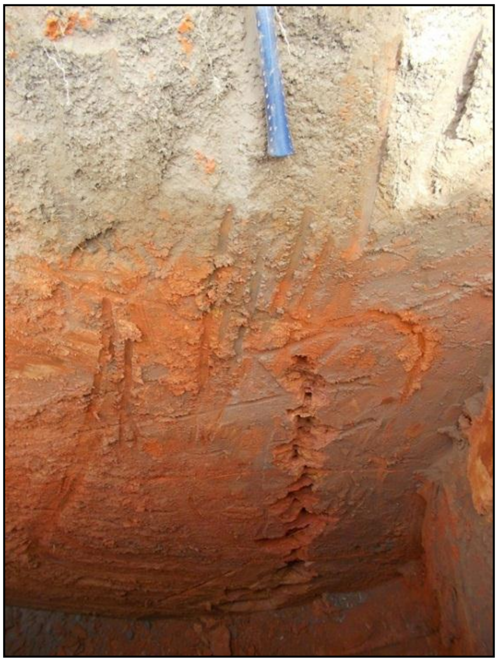
Test Pit number: Ma10

Note: Hole stopped TLB soft excavation.

Test Pit number: Ma10

Note: Pinholed structure in profile.

Test Pit number: Ma11



Note: Hole stopped TLB soft excavation.

Test Pit number: Ma12

Note: Hole stopped TLB soft excavation.

Test Pit number: Ma12

Note: Weathered shale fragment.

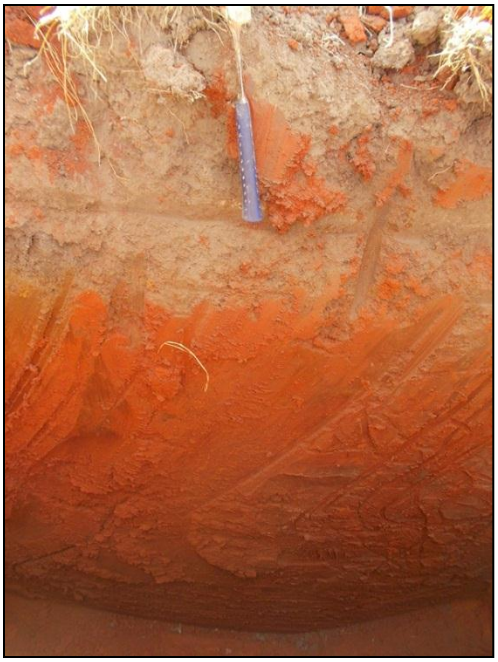
Test Pit number: Ma13

Note: Hole stopped TLB soft excavation.

Test Pit number: Ma13

Note: Silty sandy material excavated.

Test Pit number: Ma14

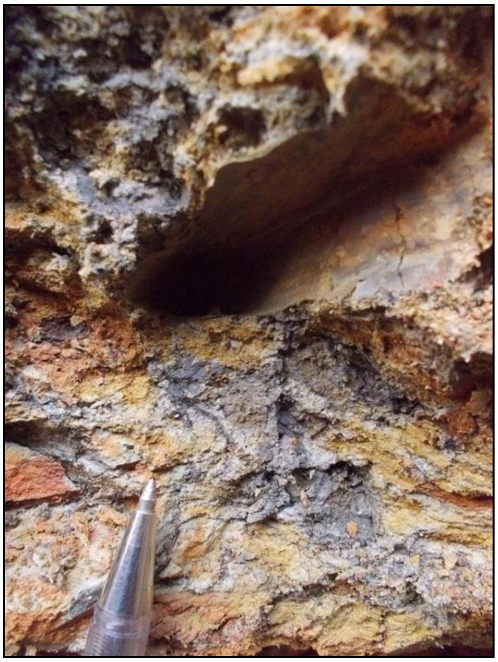


Note: Hole stopped TLB soft excavation.

Test Pit number: Zi01

Note: Progressive refusal to refusal of TLB.

Test Pit number: Zi01



Note: Clayey silty material in profile.

Test Pit number: Zi01

Note: Soft rock shale fragment excavated.

Test Pit number: Zi02

Note: Refusal of TLB.

Test Pit number: Zi02

Note: Iron and manganese nodules.

Test Pit number: Zi03

Note: Hole stopped TLB soft excavation.

Test Pit number: Zi03

Note: Silty material of completely weathered shale.

Test Pit number: Zi04

Note: Refusal of TLB on soft rock shale.

Test Pit number: Zi04

Note: Soft rock shale at base of test pit.

Test Pit number: Zi05

Note: Refusal of TLB on soft rock shale.

Test Pit number: Zi05

Note: Soft rock shale at base of test pit.

Test Pit number: Zi05

Note: View of test pit on site.

Test Pit number: Zi06

Note: Shallow refusal of TLB on soft rock shale.

Test Pit number: Zi06

Note: Refusal of TLB on soft rock shale.

Test Pit number: Zi06

Note: Soft rock shale excavated.

Test Pit number: Zi06

Note: View of test pit on site.

# APPENDIX D

(Laboratory Test Results)

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**CLIENT:** WSM Leshika Consulting (PTY) Ltd
P.O. Box 39942
Moreleta Park
PRETORIA 0044

**ATT :** Mr M. Van Rensburg

**PROJECT:** HOUSING PRJCT IN E.C MARUBENI VILLAGE

**DATE:** 2014.08.13

**REF:** MT 24748

O.N. WF 14066

## FOUNDATION INDICATOR PREDICTION OF HEAVE

| SAMPLE NO | 3146 | 3147 | 3148 | 3149 | 3150 | 3151 |
|---|---|---|---|---|---|---|
| POSITION | Ma 01 | Ma 01 | Ma 02 | Ma 02 | Ma 03 | Ma 03 |
|  | MARUBENI | MARUBENI | MARUBENI | MARUBENI | MARUBENI | MARUBENI |
| DEPTH | 1.00 - 1.40 | 2.40 - 2.80 | 1.00 - 1.50 | 2.80 - 3.10 | 1.00 - 2.00 | 2.40 - 2.80 |
| DESCRIPTION | lt Y Ms | lt Y Br ol | lt R Ms + lt | lt R Ms + lt | lt R Sty s | dk Br dec |
|  |  |  | Y cl Ss | Y cl Ss |  | Dol |

### SIEVE ANALYSIS

| | | | | | | |
|---|---|---|---|---|---|---|
| % PASSING 75 mm |  |  |  |  |  |  |
| 37.5 mm |  |  |  |  |  |  |
| 19 mm | 100 | 100 |  |  | 100 | 100 |
| 9.5 mm | 99 | 92 |  |  | 99 | 96 |
| 4.75 mm | 96 | 84 |  |  | 98 | 87 |
| 2.36 mm | 92 | 76 |  |  | 97 | 70 |
| 1.18 mm | 87 | 69 | 100 |  | 96 | 52 |
| 0.600 mm | 84 | 65 | 99 |  | 95 | 39 |
| 0.425 mm | 82 | 63 | 99 | 100 | 94 | 35 |
| 0.300 mm | 82 | 63 | 99 | 99 | 94 | 32 |
| 0.150 mm | 80 | 62 | 95 | 86 | 91 | 25 |
| 0.075 mm | 62.9 | 36.2 | 60.4 | 43.0 | 66.0 | 12.3 |

### MECHANICAL ANALYSIS

| | | | | | | |
|---|---|---|---|---|---|---|
| 0.06 mm | 56 | 31 | 53 | 37 | 58 | 11 |
| 0.02 mm | 35 | 15 | 31 | 17 | 34 | 6 |
| 0.006 mm | 17 | 8 | 21 | 8 | 19 | 3 |
| 0.002 mm | 10 | 5 | 17 | 4 | 15 | 1 |

### SOIL CONSTANTS

| | | | | | | |
|---|---|---|---|---|---|---|
| LIQUID LIMIT | 34 | 37 | 34 | 29 | 34 | 35 |
| PLASTICITY INDEX | 10 | 13 | 15 | 11 | 12 | 17 |
| LINEAR SHRINKAGE | 4.0 | 7.0 | 6.0 | 4.5 | 5.0 | 7.5 |

### PREDICTION OF HEAVE (VAN DER MERWE METHOD)

| | | | | | | |
|---|---|---|---|---|---|---|
| MOISTURE CONTENT % |  |  |  |  |  |  |
| PI WHOLE SAMPLE | 8.2 | 8.2 | 13.9 | 1.1 | 11.2 | 5.6 |
| ACTIVITY |  |  |  |  |  |  |
| POTENTIAL EXPANSIVENESS | LOW | LOW | MED | LOW | LOW | LOW |

The above test results are pertinent to the samples received and tested only.
While the tests are carried out according to recognized standards Controlab shall not be liable for erroneous testing or reporting thereof. This report may not be reproduced except in full without prior consent of Controlab.
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**ATT :** Mr M. Van Rensburg

**PROJECT:** HOUSING PRJCT IN E.C. MARUBENI VILLAGE

**DATE:** 2014.08.13

**REF:** MT 24748

O.N. WF 14066

# FOUNDATION INDICATOR PREDICTION OF HEAVE

| SAMPLE NO | 3152 | 3153 | 3154 | 3155 | 3156 | 3157 |
|---|---|---|---|---|---|---|
| POSITION | Ma 04 | Ma 06 | Ma 07 | Ma 08 | Ma 09 | Ma 12 |
|  | MARUBENI | MARUBENI | MARUBENI | MARUBENI | MARUBENI | MARUBENI |
| DEPTH | 1.20 - 1.80 | 1.50 - 2.50 | 2.30 - 2.80 | 1.50 - 2.80 | 1.00 - 1.50 | 0.20 - 0.70 |
| DESCRIPTION | lt Y Ss | lt Y + lt G | lt Y + P Sdy | lt Y + P Sdy | dk R Sty s | dk G Ms + |
|  |  | Ss | cl + s | cl + s |  | Sty soil |

## *SIEVE ANALYSIS*

|  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|
| % PASSING 75 mm |  |  |  |  |  |  |
| 37.5 mm |  |  |  |  |  |  |
| 19 mm |  | 100 |  | 100 |  | 100 |
| 9.5 mm |  | 99 |  | 92 |  | 99 |
| 4.75 mm | 100 | 98 |  | 85 | 100 | 78 |
| 2.36 mm | 99 | 95 |  | 78 | 99 | 52 |
| 1.18 mm | 98 | 91 |  | 73 | 99 | 45 |
| 0.600 mm | 97 | 83 |  | 69 | 98 | 44 |
| 0.425 mm | 95 | 75 | 100 | 67 | 98 | 44 |
| 0.300 mm | 89 | 70 | 99 | 66 | 95 | 44 |
| 0.150 mm | 62 | 48 | 80 | 63 | 80 | 43 |
| 0.075 mm | 30.2 | 26.3 | 40.3 | 34.2 | 49.3 | 22.9 |

## *MECHANICAL ANALYSIS*

|  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|
| 0.06 mm | 26 | 23 | 34 | 29 | 44 | 19 |
| 0.02 mm | 13 | 12 | 16 | 14 | 28 | 8 |
| 0.006 mm | 5 | 5 | 8 | 8 | 19 | 3 |
| 0.002 mm | 2 | 3 | 4 | 5 | 16 | 2 |

## *SOIL CONSTANTS*

|  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|
| LIQUID LIMIT | 25 | 27 | 31 | 29 | 36 | CBD |
| PLASTICITY INDEX | 8 | 5 | 8 | 9 | 11 | SP |
| LINEAR SHRINKAGE | 3.0 | 3.0 | 3.0 | 3.5 | 6.0 | 1.0 |

## *PREDICTION OF HEAVE (VAN DER MERWE METHOD)*

|  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|
| MOISTURE CONTENT % |  |  |  |  |  |  |
| PI WHOLE SAMPLE | 7.6 | 3.8 | 0.8 | 6.0 | 10.8 | 1.0 |
| ACTIVITY |  |  |  |  |  |  |
| POTENTIAL EXPANSIVENESS | LOW | LOW | LOW | LOW | LOW |  |

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**ATT :** Mr M. Van Rensburg

**PROJECT:** HOUSING PRJCT IN E.C. MARUBENI VILLAGE

**DATE:** 2014.08.13

**REF:** MT 24748

O.N. 14066

# FOUNDATION INDICATOR PREDICTION OF HEAVE

| SAMPLE NO | 3158 | 3159 | 3160 | 3161 | 3162 | |
|---|---|---|---|---|---|---|
| POSITION | Ma 12 | Ma 12 | Ma 13 | Ma 13 | Ma 14 | |
| | MARUBENI | MARUBENI | MARUBENI | MARUBENI | MARUBENI | |
| DEPTH | 2.00 - 2.40 | 2.40 - 2.80 | 1.30 - 2.30 | 2.40 - 2.80 | 1.00 - 1.50 | |
| DESCRIPTION | P Ms | lt Y + lt R | lt Y + lt R | Blotched Y | lt R Sty soil | |
| | | Sdy cl | Sdy cl | Wth Ms | | |

### SIEVE ANALYSIS

| | | | | | | |
|---|---|---|---|---|---|---|
| % PASSING 75 mm | | | | | | |
| 37.5 mm | | | | | | |
| 19 mm | 100 | | | | | |
| 9.5 mm | 99 | 100 | 100 | | | |
| 4.75 mm | 98 | 97 | 98 | | | |
| 2.36 mm | 96 | 94 | 96 | | 100 | |
| 1.18 mm | 95 | 90 | 94 | 100 | 99 | |
| 0.600 mm | 94 | 87 | 93 | 99 | 99 | |
| 0.425 mm | 93 | 85 | 90 | 98 | 99 | |
| 0.300 mm | 93 | 85 | 86 | 94 | 98 | |
| 0.150 mm | 92 | 83 | 54 | 65 | 91 | |
| 0.075 mm | 69.3 | 58.7 | 22.3 | 34.2 | 65.3 | |

### MECHANICAL ANALYSIS

| | | | | | | |
|---|---|---|---|---|---|---|
| 0.06 mm | 62 | 52 | 19 | 31 | 69 | |
| 0.02 mm | 40 | 31 | 8 | 19 | 38 | |
| 0.006 mm | 25 | 21 | 3 | 11 | 25 | |
| 0.002 mm | 19 | 17 | 0 | 8 | 20 | |

### SOIL CONSTANTS

| | | | | | | |
|---|---|---|---|---|---|---|
| LIQUID LIMIT | 42 | 35 | 24 | 30 | 49 | |
| PLASTICITY INDEX | 19 | 7 | 9 | 11 | 16 | |
| LINEAR SHRINKAGE | 9.0 | 4.0 | 3.5 | 4.5 | 8.0 | |

### PREDICTION OF HEAVE (VAN DER MERWE METHOD)

| | | | | | | |
|---|---|---|---|---|---|---|
| MOISTURE CONTENT % | | | | | | |
| PI WHOLE SAMPLE | 17.7 | 6.1 | 8.1 | 10.8 | 15.9 | |
| ACTIVITY | | | | | | |
| POTENTIAL EXPANSIVENESS | MED | LOW | LOW | LOW | MED | |

The above test results are pertinent to the samples received and tested only.
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**CLIENT:** WSM Leshika Consulting (PTY) Ltd
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PRETORIA, 0044
**ATT:** Mr. M. van Rensburg

**PROJECT:** HOUSING PROJECT IN E.C.
**DATE RECEIVED:** 2014.07.18
**DATE TESTED:** 2014.08.04
**DATE REPORTED:** 2014.08.19
**TEST REPORT NO.:** MT 24748

**O.N.** WF14066

# MATERIALS TEST REPORT

| SAMPLE NO: | 3150 | 3151 | 3152 | 3153 | | |
|---|---|---|---|---|---|---|
| POSITION | Ma 03 | Ma 06 | Ma 08 | Ma 13 | | |
| VILLAGE NAME | MARHUBENI VILLAGE | | | | | |
| DEPTH mm | 1.00 - 2.00 | 1.50 - 2.50 | 1.50 - 2.80 | 1.30 - 2.30 | | |
| DESCRIPTION | lt R sty s | lt Y + lt G Ss | lt Y + P sdy | lt Y + lt R | | |
| | | | cl | sdy cl | | |
| | | | | | | |
| CLASSIFICATION (TRH 14) | G 10 | G 10 | G 10 | G 9 | | |

Sieve Analysis (Wet Preparation) TMH1 - Method A1 (a)

| % PASSING | | | | | | | |
|---|---|---|---|---|---|---|---|
| % PASSING | 75 mm | | | | | | |
| | 63 mm | | | | | | |
| | 53 mm | | | | | | |
| | 37.5 mm | | | | | | |
| | 26.5 mm | | | | | | |
| | 19 mm | 100 | 100 | 100 | | | |
| | 13.2 mm | 99 | 99 | 96 | 100 | | |
| | 4.75 mm | 98 | 98 | 85 | 98 | | |
| | 2.00 mm | 97 | 94 | 77 | 97 | | |
| | 0.425 mm | 94 | 75 | 67 | 90 | | |
| | 0.075 mm | 66.0 | 26.3 | 34.2 | 22.3 | | |

Soil Mortar Analysis - TMH1 - Method A5

| | | | | | | |
|---|---|---|---|---|---|---|
| COURSE SAND (%) | 3 | 20 | 13 | 7 | | |
| FINE SAND (%) | 29 | 52 | 43 | 70 | | |
| SILT / CLAY (%) | 68 | 28 | 44 | 23 | | |
| GRADING MODULUS | 0.43 | 1.05 | 1.22 | 0.91 | | |

Atterberg Limits - TMH1 - Methods A2, A3, A4

| | | | | | | |
|---|---|---|---|---|---|---|
| LIQUID LIMIT (%) | 34 | 27 | 29 | 24 | | |
| PLASTICITY INDEX (%) | 12 | 5 | 9 | 9 | | |
| LINEAR SHRINKAGE (%) | 5.0 | 3 | 3.5 | 3.5 | | |

Maximum Dry Density & Optimum Moisture Content - TMH1 - Method A7 / California Bearing Ratio - TMH1 - Method A8

| | | | | | | |
|---|---|---|---|---|---|---|
| Maximum Dry Density (kg/m$^3$) | 1630 | 1778 | 1696 | 1805 | | |
| Optimum Moisture Content (%) | 16.9 | 14.3 | 16.9 | 15.5 | | |
| C.B.R. @ 100% COMPACTION | 3 | 21 | 5 | 25 | | |
| C.B.R. @ 98 % COMPACTION | 2 | 17 | 4 | 19 | | |
| C.B.R. @ 95 % COMPACTION | 2 | 11 | 3 | 13 | | |
| C.B.R. @ 93 % COMPACTION | 2 | 9 | 3 | 10 | | |
| C.B.R. @ 90 % COMPACTION | 1 | 6 | 2 | 7 | | |
| SWELL @ 100% COMP. (%) | 1.67 | 1.57 | 2.47 | 0.91 | | |

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Lab Manager:

Remarks:
Sample Delivered by Customer ☒
Sampled by Controlab

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**PROJECT:** HOUSING PRJCT IN E.C. ZINKUMBINI VILLAGE

**DATE:** 2014.08.15

**REF:** MT 24752

O.N. WF 14066

# FOUNDATION INDICATOR PREDICTION OF HEAVE

| SAMPLE NO | 3191 | 3192 | 3193 | 3194 | 3195 | 3196 |
|---|---|---|---|---|---|---|
| POSITION | Zi 01 | Zi 01 | Zi 03 | Zi 04 | Zi 05 | Zi 06 |
| | ZINKUMBINI | ZINKUMBINI | ZINKUMBINI | ZINKUMBINI | ZINKUMBINI | ZINKUMBINI |
| DEPTH | 1.00 - 1.30 | 1.50 - 2.00 | 1.80 - 2.80 | 1.00 - 1.20 | 0.80 -1.00 | 0.90 - 1.30 |
| DESCRIPTION | dk Br Sty soil | dk Br Sty soil | dk Br Sty soil | lt G Ms | dk G Ms | dk Br Sdy st + |
| | | | | | | cl |

### SIEVE ANALYSIS

| | | | | | | |
|---|---|---|---|---|---|---|
| % PASSING 75 mm | | | | 77 | 79 | 100 |
| 37.5 mm | | | | 62 | 64 | 84 |
| 19 mm | | | | 56 | 56 | 77 |
| 9.5 mm | | 100 | 100 | 47 | 41 | 69 |
| 4.75 mm | 100 | 98 | 99 | 40 | 33 | 61 |
| 2.36 mm | 98 | 96 | 98 | 32 | 27 | 54 |
| 1.18 mm | 90 | 90 | 96 | 26 | 24 | 49 |
| 0.600 mm | 82 | 84 | 95 | 23 | 23 | 46 |
| 0.425 mm | 79 | 81 | 94 | 22 | 22 | 44 |
| 0.300 mm | 76 | 79 | 94 | 22 | 22 | 44 |
| 0.150 mm | 67 | 69 | 93 | 21 | 21 | 42 |
| 0.075 mm | 44.4 | 42.1 | 53.8 | 13.7 | 11.5 | 25.1 |

### MECHANICAL ANALYSIS

| | | | | | | |
|---|---|---|---|---|---|---|
| 0.05 mm | 39 | 36 | 46 | 12 | 10 | 22 |
| 0.02 mm | 22 | 19 | 23 | 7 | 4 | 11 |
| 0.006 mm | 12 | 9 | 10 | 4 | 2 | 7 |
| 0.002 mm | 8 | 5 | 4 | 3 | 1 | 6 |

### SOIL CONSTANTS

| | | | | | | |
|---|---|---|---|---|---|---|
| LIQUID LIMIT | 42 | 37 | 28 | 15 | 24 | 24 |
| PLASTICITY INDEX | 16 | 12 | 6 | 9 | 7 | 9 |
| LINEAR SHRINKAGE | 7.0 | 6.0 | 3.0 | 3.5 | 3.5 | 4.0 |

### PREDICTION OF HEAVE (VAN DER MERWE METHOD)

| | | | | | | |
|---|---|---|---|---|---|---|
| MOISTURE CONTENT % | | | | | | |
| PI WHOLE SAMPLE | 12.6 | 9.7 | 5.6 | 1.1 | 1.5 | 3.9 |
| ACTIVITY | | | | | | 0.7 |
| POTENTIAL EXPANSIVENESS | LOW | LOW | LOW | LOW | LOW | LOW |

For Controlab:

Remarks:

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PRETORIA, 0044
**ATT:** Mr. M. van Rensburg

**PROJECT:** HOUSING PRJCT IN EC - ZINKUMBINI
**DATE RECEIVED:** 2014.07.18
**DATE TESTED:** 2014.08.06
**DATE REPORTED:** 2014.08.19
**TEST REPORT NO.:** MT 24752

O.N. 14066

## MATERIALS TEST REPORT

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| SAMPLE NO: | 3193 | 3195 | | | | | |
| POSITION | Zi 03 | Zi 05 | | | | | |
| VILLAGE NAME | ZINKUMBINI VILLAGE | | | | | | |
| DEPTH mm | 1.80 - 2.80 | 0.80 - 1.00 | | | | | |
| DESCRIPTION | dk Br sty | lt G Ms | | | | | |
| | soil | | | | | | |
| | | | | | | | |
| CLASSIFICATION (TRH 14) | G 10 | G 7 | | | | | |
| **Sieve Analysis (Wet Preparation) TMH1 - Method A1 (a)** | | | | | | | |
| % PASSING 75 mm | | 79 | | | | | |
| 63 mm | | 76 | | | | | |
| 53 mm | | 72 | | | | | |
| 37.5 mm | | 64 | | | | | |
| 26.5 mm | | 60 | | | | | |
| 19 mm | | 56 | | | | | |
| 13.2 mm | 100 | 48 | | | | | |
| 4.75 mm | 99 | 33 | | | | | |
| 2.00 mm | 97 | 27 | | | | | |
| 0.425 mm | 94 | 22 | | | | | |
| 0.075 mm | 53.8 | 11.5 | | | | | |
| **Soil Mortar Analysis - TMH1 - Method A5** | | | | | | | |
| COURSE SAND (%) | 3 | 19 | | | | | |
| FINE SAND (%) | 41 | 39 | | | | | |
| SILT / CLAY (%) | 55 | 43 | | | | | |
| GRADING MODULUS | 0.55 | 2.40 | | | | | |
| **Atterberg Limits - TMH1 - Methods A2, A3, A4** | | | | | | | |
| LIQUID LIMIT (%) | 28 | 24 | | | | | |
| PLASTICITY INDEX (%) | 6 | 7 | | | | | |
| LINEAR SHRINKAGE (%) | 3.0 | 3.5 | | | | | |
| **Maximum Dry Density & Optimum Moisture Content - TMH1 - Method A7 / California Bearing Ratio - TMH1 - Method A8** | | | | | | | |
| Maximum Dry Density (kg/m$^3$) | 1554 | 1876 | | | | | |
| Optimum Moisture Content (%) | 13.2 | 11.2 | | | | | |
| C.B.R. @ 100% COMPACTION | 3 | 66 | | | | | |
| C.B.R. @ 98 % COMPACTION | 2 | 48 | | | | | |
| C.B.R. @ 95 % COMPACTION | 2 | 31 | | | | | |
| C.B.R. @ 93 % COMPACTION | 2 | 23 | | | | | |
| C.B.R. @ 90 % COMPACTION | 1 | 14 | | | | | |
| SWELL @ 100% COMP. (%) | 3.19 | 0.81 | | | | | |

The above test results are pertinent to the samples tested only. While the tests are carried out according to recognized standards, Controlab shall not be liable for erroneous testing or reporting thereof. This report may not be reproduced except in full withour prior consent of Controlab.

Lab Manager:

Remarks:
Sample Delivered by Customer ☒
Sampled by Controlab ☐

# APPENDIX E

## (Typical Material Properties)

**TABLE E1**: Typical material properties (Unified Soil Classification System)

| Class: | Material description | Subgrade | Subbase | Base | Drainage when compacted | Compaction characteristics | Embankment material | Compressibility when compacted |
|---|---|---|---|---|---|---|---|---|
| GW | Well-graded gravel | Good to Excellent | Good | Fair to good | Excellent | Good | Reasonably stable | Low |
| GP | Poorly grade gravel (<5% fines) | Good to Excellent | Good | Fair to good | Excellent | Good | Reasonably stable | Low |
| GC | Clayey gravel (>12% fines) | Good | Fair | Poor to not suitable | Poor to practically impervious | Good to fair | Reasonably stable | Low |
| SP | Poorly graded sand (<5% fines) | Fair to good | Fair | Poor to not suitable | Excellent | Good | Reasonably stable | Low |
| SM | Silty sand (sand with fines PI<4) | Fair to good | Fair to good | Poor to not suitable | Fair to practically impervious to impervious | Good | Reasonably stable | Low |
| SC | Clayey sand (>12% fines PI>7) | Fair | Poor | Not suitable | Poor, impervious when compacted | Good to fair | Reasonably stable | Low |
| CL | Silts and clays (LL<50 & PI>7) | Fair to poor | Not suitable | Not suitable | Practically impervious | Good to fair | Good stability | Medium |
| ML | Silts and clays (LL<50 & PI<4) | Fair to poor | Not suitable | Not suitable | Semi-pervious to impervious | Good to poor | Poor stability | Medium |
| CH | Silts and clays (LL>50) | Poor to fair | Not suitable | Not suitable | Practically impervious | Fair to poor | Fair stability | Medium to high |
| MH | Silts and clays (LL>50) | Poor | Not suitable | Not suitable | Fair to poor, semi-pervious to pervious | Fair to poor | Poor stability | Medium to high |

**TABLE E2:** Material properties after NAVFAC DM7 (1971)

| Group symbol | Soil type | Max yd | Optimum moisture (%) | Typical strength characteristics | | | |
|---|---|---|---|---|---|---|---|
| | | | | Cu (kPa) | C` (kPa) | ϕ` (deg.) | tan ϕ` |
| GW | Well-graded clean gravels, gravel-sand mixtures | 19.7-21.2 | 11-8 | 0 | 0 | >38 | >0.78 |
| GC | Clayey gravels, poorly graded gravel-sand-clay | 18.1-20.5 | 14-9 | 0 | 0 | >31 | >0.60 |
| SM | Silty sands, poorly graded sand-silt mixtures | 17.3-19.7 | 16-11 | 50 | 5 | 34 | 0.67 |
| SC | Clayey sands poorly graded sand-clays | 16.5-19.7 | 19-11 | 75 | 10 | 31 | 0.60 |
| CL | Inorganic clays of low to medium plasticity | 15.0-18.9 | 24-12 | 85 | 12 | 28 | 0.54 |
| ML | Inorganic silts and clayey silts | 15.0-18.9 | 24-12 | 65 | 10 | 32 | 0.62 |
| CH | Inorganic clays of high plasticity | 11.8-16.5 | 36-19 | 100 | 12 | 19 | 0.35 |

yd – Dry density; Cu – Undrained cohesion; C` - Drained cohesion; ϕ`(deg.) – Shearing resistance

# APPENDIX F

(Classification Tables)

**TABLE C1. GEOTECHNICAL CLASSIFICATION FOR URBAN DEVELOPMENT (after Partridge, Wood and Brink 1993)**

| CONSTRAINT | | Most favourable (1) | Intermediate (2) | Least favourable (3) |
|---|---|---|---|---|
| **A** | Collapsible Soil | Any collapsible horizon or consecutive horizons totalling a depth of less than 750 mm in thickness.* | Any collapsible horizon or consecutive horizons with a depth of more than 750 mm in thickness. | A least favourable situation for this constraint does not occur. |
| **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 predicted. * | Moderate soil heave potential predicted. | High soil-heave potential predicted. |
| **D** | Highly compressible soil | Low soil compressibility expected.* | Moderate soil compressibility expected. | High soil compressibility expected. |
| **E** | Erodability of soil | Low. | Intermediate. | High. |
| **F** | Difficulty of excavation to 1,5 m depth | Scattered or occasional boulders less than 10% of the total volume. | Rock or hardpan pedocretes between 10 and 40 % of the total volume. | Rock or hardpan pedocretes more than 40 % of the total volume. |
| **G** | Undermined ground | Undermining at a depth greater than 100 m below surface (except where total extraction mining has not occurred.) | Old undermined areas to a depth of 100m below surface where stope closure has ceased. | Mining within less than 100 m of surface or where total extraction mining has taken place. |
| **H** | Instability in areas of soluble rock | Possibly unstable. | Probably unstable. | Known sinkholes and dolines |
| **I** | Steep slopes | Between 2 and 6 degrees (all regions). | Slopes between 6 and 18 degrees and less than 2 degrees (Natal and Western Cape).<br>Slopes between 6 and 12 degrees and less than 12 degrees (all other regions). | More than 18 degrees (Natal and Western Cape).<br>More than 12 degrees (all other regions). |
| **J** | Areas of unstable natural slopes | Low risk. | Intermediate risk. | High risk (especially in areas subject to seismic activity). |
| **K** | Areas subject to seismic activity | 10% probability of an event less than 100 $cm/s^2$ within 50 years | Mining-induced seismic activity more 100 $cm/s^2$. | Natural seismic activity more than 100 $cm/s^2$. |
| **L** | Areas subject to flooding | A “most favourable” situation for this constraint does not occur. | Areas adjacent to a known drainage channel or floodplain with slope less than 1%. | Areas within a known drainage channel or floodplain. |

* These areas are designated as 1A, 1C, 1D, or 1F where localised occurrences of the constraint may arise.

**TABLE C2: RESIDENTIAL SITE CLASS DESIGNATIONS** (SAICE, 1995)

| TYPICAL FOUNDATION MATERIAL | CHARACTER OF FOUNDING MATERIAL | EXPECTED RANGE OF TOTAL SOIL MOVEMENTS (mm) | ASSUMED DIFFERENTIA L MOVEMENT (% OF TOTAL) | SITE CLASS |
|---|---|---|---|---|
| Rock (excluding mud rocks which exhibit swelling to some depth) | STABLE | NEGLIGIBLE | - | R |
| Fine-grained soils with moderate to very high plasticity (clays, silty clays, clayey silts and sandy clays) | EXPANSIVE SOILS | < 7,5<br>7,5 – 15<br>15 – 30<br>> 30 | 50%<br>50%<br>50%<br>50% | H<br>H1<br>H2<br>H3 |
| Silty sands, sands, sandy and gravelly soils | COMPRESSIBLE AND POTENTIALLY COLLAPSIBLE SOILS | < 5,0<br>5,0 – 10<br>> 10 | 75%<br>75%<br>75% | C<br>C1<br>C2 |
| Fine-grained soils (clayey silts and clayey sands of low plasticity), sands, sandy and gravelly soils | COMPRESSIBLE SOIL | < 10<br>10 – 20<br>> 20 | 50%<br>50%<br>50% | S<br>S1<br>S2 |
| Contaminated soils<br>Controlled fill<br>Dolomitic areas<br>Land fill<br>Marshy areas<br>Mine waste fill<br>Mining subsidence<br>Reclaimed areas<br>Very soft silt/silty clays<br>Uncontrolled fill | VARIABLE | VARIABLE | | P |

**NOTES:**

1. The classifications C, H, R and S are not intended for dolomitic area sites unless specific investigations are carried out to assess the stability (risk of sinkholes and doline formation) of the dolomites. Where this risk is found to be acceptable, the site shall be designated as Class P (dolomitic areas).
2. Site classes are based on the assumption that differential movements, experienced by single-storey residential buildings, expressed as a percentage of the total movements are equal to about 50% for soils that exhibit expansive or compressive characteristics and 75% for soils that exhibit both compressible and collapse characteristics. Where this assumption is incorrect or inappropriate, the total soil movements must be adjusted so that the resultant different movements implied by the table are equal to that which is expected in the field.
3. In some instances, it may be more appropriate to use a composite description to describe a site mote fully e.g. C1/H2 or S1 and/or H2. Composite Site Classes may lead to higher differential movements and result in design solutions appropriate to a higher range of differential movement e.g. a Class R/C1 site. Alternatively, a further site investigation may be necessary since the final design solution may depend on the location of the building on a particular site.
4. Where it is not possible to provide a single site designation and a composite description is inappropriate, sites may be given multiple descriptions to indicate the range of possible conditions e.g. H-H1-H2 or C1-C2.
5. Soft silts and clays usually exhibit high consolidation and low bearing characteristics. Structures founded on these horizons may experience high settlements and such sites should be designated as being Class S1 or S2 as relevant and appropriate.
6. Sites containing contaminated soils include those associated with reclaimed mine land, land down-slope of mine tailings and old land fills.
7. Where a site is designated as Class P, full particulars relating to the founding conditions on the site must be provided.
8. Where sites are designated as being Class P, the reason for such classification shall be placed in brackets immediately after the suffix – i.e. P(contaminated soils). Under certain circumstances, composite description may be more appropriate – e.g. P(dolomite areas)-C1.
9. Certain fills may contain contaminates which present a health risk. The nature of such fill should be evaluated and should be clearly demarcated as such.

**TABLE C3: FOUNDATION DESIGN, BUILDING PROCEDURES AND PRECAUTIONARY MEASURES FOR SINGLE-STOREY RESIDENTIAL BUILDINGS FOUNDED ON HORIZONS SUBJECT TO CONSOLIDATION SETTLEMENT** (SAICE, 1995)

| SITE CLASS | ESTIMATED TOTAL SETTLEMENT (mm) | CONSTRUCTION TYPE | FOUNDATION DESIGN AND BUILDING PROCEDURES |
|---|---|---|---|
| **S** | **<10** | Normal | - Normal construction (strip footing or slab-on-the-ground foundations)<br>- Good site drainage |
| **S1** | **10-20** | Modified normal | - Reinforced strip footings<br>- Articulation joints at some internal and all external doors<br>- Light reinforcement in masonry<br>- Site drainage and service/plumbing precautions<br>- Foundation pressure not to exceed 50 kPa |
| | | Compaction of in situ soils below individual footings | - Remove in situ material below foundations to a depth and width of 1,5 times the foundation width or to a competent horizon and replace with material compacted to 93% MOD AASHTO density at –1% to +2% of optimum moisture content.<br>- Normal construction with lightly reinforced strip foundations and light reinforcement in masonry. |
| | | Deep strip foundations | - Normal construction with drainage requirements.<br>- Founding on a competent horizon below the problem horizon |
| | | Soil raft | - Remove in situ material to 1,0m beyond perimeter of building to a depth and width of 1,5 times the widest foundation or to a competent horizon and replace with material compacted to 93% MOD AASHTO density at –1% to +2% of optimum moisture content.<br>- Normal construction with lightly reinforced strip footings and light reinforcement in masonry. |
| **S2** | **>20** | Stiffened strip footings, stiffened or cellular raft | - Stiffened strip footing or stiffened or cellular raft with articulation joints or solid lightly reinforced masonry.<br>- Bearing pressure not to exceed 50kPa.<br>- Fabric reinforcement in floor slabs.<br>- Site drainage and service/plumbing precautions. |
| | | Deep strip foundations | - As for S1 but with fabric reinforcement in floor slabs |
| | | Compaction of in-situ soils below individual footings | - As for S1. |
| | | Piled or pier foundations | - Reinforced concrete ground beams or solid slabs on piled or pier foundations.<br>- Ground slabs with fabric reinforcement.<br>- Good site drainage. |
| | | Soil raft | - As for S1. |

**NOTES:**

1. Differential settlement assumed to equal 50% of total settlement.
2. The relaxation of some of these requirements, e.g. the reduction or omission of steel or articulation joints, may result in a Category 2 level of expected damage.
3. Account must be taken on sloping site since differential fill heights may lead to greater differential settlements.
4. Settlements induced by loads imposed by deep filling beneath surface beds may necessitate the adoption of a construction type appropriate to a more severe site class.

## TABLE C4: FOUNDATION DESIGN, BUILDING PROCEDURES AND PRECAUTIONARY MEASURES FOR SINGLE-STOREY RESIDENTIAL BUILDINGS FOUNDED ON HORIZONS SUBJECT TO BOTH CONSOLIDATION AND COLLAPSE SETTLEMENT

(SAICE, 1995)

| SITE CLASS | ESTIMATED TOTAL SETTLEMENT (mm) | CONSTRUCTION TYPE | FOUNDATION DESIGN AND BUILDING PROCEDURES |
|---|---|---|---|
| **C** | **<5** | Normal | - Normal construction (strip footing or slab-on-the-ground foundations)<br>- Good site drainage |
| **C1** | **5 – 10** | Modified normal | - Reinforced strip footings<br>- Articulation joints at some internal and all external doors<br>- Light reinforcement in masonry<br>- Site drainage and service/plumbing precautions<br>- Foundation pressure not to exceed 50 kPa |
| | | Compaction of in situ soils below individual footings | - Remove in situ material below foundations to a depth and width of 1,5 times the foundation width or to a competent horizon and replace with material compacted to 93% MOD AASHTO density at –1% to +2% of optimum moisture content.<br>- Normal construction with lightly reinforced strip foundations and light reinforcement in masonry. |
| | | Deep strip foundations | - Normal construction with drainage requirements.<br>- Founding on a competent horizon below the problem horizon |
| | | Soil raft | - Remove in situ material to 1,0m beyond perimeter of building to a depth and width of 1,5 times the widest foundation or to a competent horizon and replace with material compacted to 93% MOD AASHTO density at –1% to +2% of optimum moisture content.<br>- Normal construction with lightly reinforced strip footings and light reinforcement in masonry. |
| **C2** | **>10** | Stiffened strip footings, stiffened or cellular raft | - Stiffened strip footing or stiffened or cellular raft with articulation joints or solid lightly reinforced masonry.<br>- Bearing pressure not to exceed 50kPa.<br>- Fabric reinforcement in floor slabs.<br>- Site drainage and service/plumbing precautions. |
| | | Deep strip foundations | - As for C1 but with fabric reinforcement in floor slabs |
| | | Compaction of in situ soils below individual footings | - As for C1. |
| | | Piled or pier foundations | - Reinforced concrete ground beams or solid slabs on piled or pier foundations.<br>- Ground slabs with fabric reinforcement.<br>- Good site drainage. |
| | | Soil raft | - As for C1. |

**NOTES:**

1. Differential settlement assumed to equal 75% of total settlement
2. The relaxation of some of these requirements, e.g. the reduction or omission of steel or articulation joints, may result in a Category 2 level of expected damage.

**TABLE C5: FOUNDATION DESIGN, BUILDING PROCEDURES AND PRECAUTIONARY MEASURES FOR SINGLE-STOREY RESIDENTIAL BUILDINGS FOUNDED ON HORIZONS SUBJECT TO HEAVE** (SAICE, 1995)

| SITE CLASS | ESTIMATED TOTAL EXPANSION (mm) | CONSTRUCTION TYPE | FOUNDATION DESIGN AND BUILDING PROCEDURES |
|---|---|---|---|
| **H** | **<7,5** | Normal | - Normal construction (strip footing or slab-on-the-ground foundations)<br>- Good site drainage and service/plumbing precautions recommended. |
| **H1** | **7,5 – 15** | Modified normal | - Lightly reinforced strip footings<br>- Articulation joints at all internal/external doors<br>- Light reinforcement in masonry<br>- Site drainage and service/plumbing precautions |
| | | Soil raft | - Remove in situ material to 1,0m beyond perimeter of the structure and replace with inert backfill, compacted to 93% MOD AASHTO density at –1% to +2% of optimum moisture content.<br>- Normal construction with lightly reinforced strip footings and light reinforcement in masonry if residual movements are <7,5mm, or construction type appropriate to residual movements.<br>- Site drainage and plumbing/service precautions. |
| **H2** | **15-30** | Stiffened or cellular raft | - Stiffened or cellular raft with articulation joints or lightly reinforced masonry.<br>- Site drainage and plumbing/service precautions. |
| | | Piled construction | - Piled foundations with suspended floor slabs with or without ground beams.<br>- Site drainage and plumbing/service precautions. |
| | | Split construction | - Combination of reinforced brickwork/block work and full movement joints.<br>- Suspended floors of fabric-reinforced ground slabs acting independently from the structure.<br>- Site drainage and plumbing/service precautions. |
| | | Soil raft | - As for H1. |
| **H3** | **>30** | Stiffened or cellular raft | - As for H2. |
| | | Piled construction | - As for H2. |
| | | Soil raft | - As for H1. |

**NOTES:**

1. Differential settlement assumed to equal 50% of total settlement
2. The relaxation of some of these requirements, e.g. the reduction or omission of steel or articulation joints, may result in a Category 2 level of expected damage.

# CHART C1: USCS MATERIAL DESIGNATION CHART

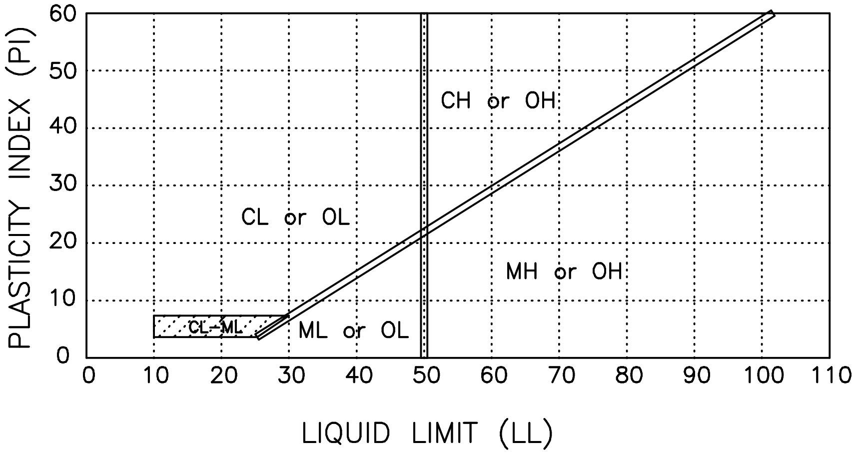
## UNIFIED SOIL CLASSIFICATION SYSTEM

Soils are visually classified by the United Soil Classification System (USCS) on the boring logs presented in this report. Grain size analysis and Atterberg limits tests are often performed on selected samples to aid in classification. The classification system is briefly outlined on this chart. For a more detailed description of the system, see ”The Unified Soil Classification System” Corps of Engineers, US Army Technical Memorandum No. 3–357 (Revised April 1960) or ASTM Designation: D2487–66T.

| MAJOR DIVISIONS | | | | GROUP SYMBOL | TYPICAL NAMES |
|---|---|---|---|---|---|
| COARSE – GRAINED SOILS (Less than 50% passes No. 200 sieve) | GRAVELS (50% or less of coarse fraction passes No. 4 sieve) | CLEAN GRAVELS (Less than 5% passes No. 200 sieve) | | GW | Well graded gravels, gravel–sand mixtures, or sand–gravel–cobble mixtures. |
| | | | | GP | Poorly graded gravels, gravel–sand mixtures, or sand–gravel–cobble mixtures. |
| | | GRAVELS WITH FINES (More than 12% passes No. 200 sieve) | Limits plot below the ”A” line & hatched zone on plasticity chart | GM | Silty gravels, gravel–sand–silt mixtures. |
| | | | Limits plot above the ”A” line & hatched zone on plasticity chart | GC | Clayey gravels, gravel–sand–clay mixtures. |
| | SANDS (More than 50% of coarse fraction passes No. 4 sieve) | CLEAN SANDS (Less than 5% passes No. 200 sieve) | | SW | Well graded sands, gravelly sands. |
| | | | | SP | Poorly graded sands, gravelly sands. |
| | | SANDS WITH FINES (More than 12% passes No. 200 sieve) | Limits plot below the ”A” line & hatched zone on plasticity chart | SM | Silty sands, sand–silt mixtures. |
| | | | Limits plot above the ”A” line & hatched zone on plasticity chart | SC | Clayey sands, sand–clay mixtures. |
| FINE – GRAINED SOILS (50% or more passes No. 200 sieve) | SILTS (Limits Plot Below ”A” Line & hatched Zone on Plasticity Chart) | SILTS OF LOW PLASTICITY (Liquid Limit Less Than 50) | | ML | Inorganic silts, non–plastic or slightly plastic. |
| | | SILTS OF HIGH PLASTICITY (Liquid Limit More Than 50) | | MH | Inorganic silts, micaceous or diatomaceous silty soils, elastic silts. |
| | CLAYS (Limits Plot Above ”A” Line & hatched Zone on Plasticity Chart) | CLAYS OF LOW PLASTICITY (Liquid Limit Less Than 50) | | CL | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. |
| | | CLAYS OF HIGH PLASTICITY (Liquid Limit More Than 50) | | CH | Inorganic clays of high plasticity, fat clays, sandy clays of high plasticity. |

NOTE:
Coarse grained soils with between 5% & 12% passing the No. 200 sieve and fine grained soils with Atterberg limits plotting in the hatched zone on the plasticity chart shall have dual symbol. In Arizona, local streams contain sand, gravel & cobble type material, which are locally known as SGC or riverrun material. The USCS is not used to divide and symbolize this material.

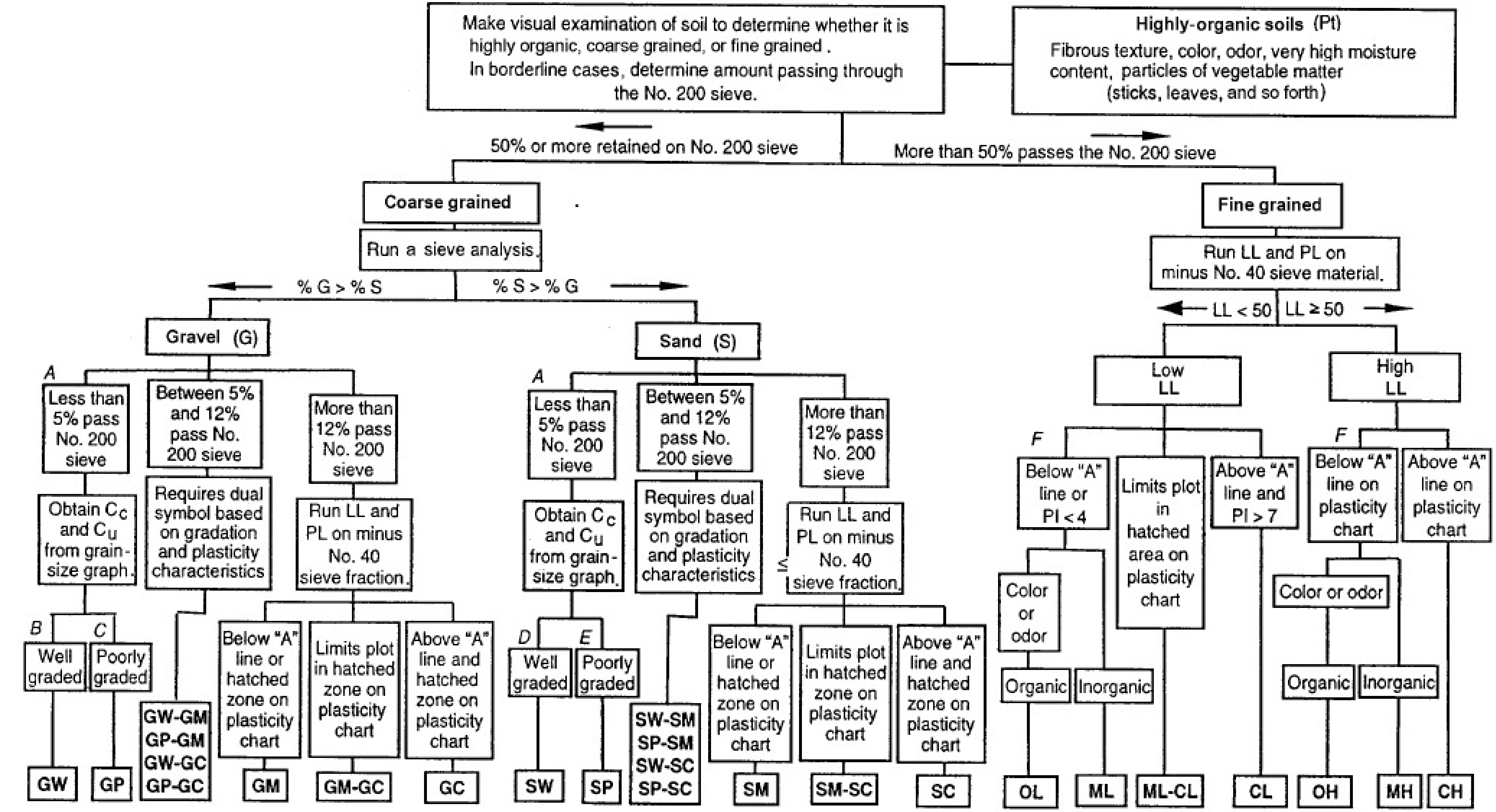
## PLASTICITY CHART



## DEFINITIONS OF SOIL FRACTIONS

| SOIL COMPONENT | PARTICLE SIZE RANGE |
|---|---|
| Cobbles | Above 3 in. |
| Gravel | 3 in. to No. 4 sieve |
| Coarse gravel | 3 in. to 3/4 in. |
| Fine gravel | 3/4 in. to No. 4 sieve |
| Sand | No. 4 to No. 200 |
| Coarse | No. 4 to No. 10 |
| Medium | No. 10 to No. 40 |
| Fine | No. 40 to No. 200 |
| Fines (silt & clay) | Below No. 200 sieve |
| Clay | Smaller than 2 microns |
| Colloid | Smaller than 5 microns |

## CHART C2: USCS DESIGNATION FLOW CHART



*A* If fines interfere with free-draining properties, use a double symbol such as GW-GM.

*B* For well-graded gravel, the $C_u$ must be $> 4$ and the $C_c$ must be $\geq 1$ and $\leq 3$.

*C* For poorly graded gravel, the $C_u$ must be $\leq 4$ and/or the $C_c$ is $< 1$ or $> 3$.

*D* For well graded sand, the $C_u$ must be $> 6$ and the $C_c$ must be $\geq 1$ and $\leq 3$.

*E* For poorly graded sand, the $C_u$ must be $\leq 6$ and/or the $C_c$ is $< 1$ or $> 3$.

*F* In cases where organic material can't be determined by color or odor, a LL and PL test must be conducted on a sample of natural moisture content and a sample that has been oven-dried. Organic soils will show a radical drop in plasticity for the oven-dried sample compared to the retained-moisture sample. Inorganic soils generally fall within ± 1 or 2 percent of each other.