REPORT TO
VELA VKE CONSULTING ENGINEERS
ON THE
GEOTECHNICAL INVESTIGATION
FOR THE
CORNUBIA DEVELOPMENT
EXCLUDING PHASE I

DRENNAN, MAUD AND PARTNERS
CONSULTING CIVIL ENGINEERS AND
ENGINEERING GEOLOGISTS
68 Ridge Road,
Tollgate, Durban, 4001

Ref N° 20157 (II)
OCTOBER 2009
## CONTENTS

1. INTRODUCTION AND SCOPE OF WORK. ........................................ Page -1-

2. SITE DESCRIPTION. .............................................................. Page -2-

3. FIELD WORK. ................................................................. Page -2-
   3.1 Inspection Pits. .......................................................... Page -2-
   3.2 Dynamic Cone Penetrometer Test (DCP). ............................ Page -3-

4. GEOLOGY AND SOILS. ....................................................... Page -3-
   4.1 General. ................................................................. Page -4-
   4.2 Fill. ......................................................................... Page -4-
   4.3 Top Soils and Colluvium. ............................................. Page -4-
   4.4 Alluvium. ............................................................... Page -4-
   4.5 Aeolian Dune Sands. .................................................. Page -5-
   4.6 Berea Formation. ..................................................... Page -5-
   4.7 Dolerite. ................................................................. Page -5-
   4.8 Vryheid Formation. .................................................... Page -5-
   4.9 Structural Features. ................................................... Page -6-

5. LABORATORY TESTING. ...................................................... Page -6-
   5.1 General. ................................................................. Page -6-
   5.2 Grading Analysis. ........................................................ Page -6-
   5.2.1 Aeolian Dune Sands ................................................. Page -8-
   5.2.2 Berea Red Formation ............................................. Page -8-
   5.2.3 Dolerite .............................................................. Page -8-
   5.2.4 Residual Vryheid .................................................. Page -9-
   5.2.5 Weathered Shale (Vryheid Formation) .......................... Page -9-
   5.2.6 Weathered Siltstone (Vryheid Formation) ..................... Page -9-
   5.2.7 Weathered Sandstone (Vryheid Formation) .................... Page -9-

   5.3 Mod AASHTO and CBR Test Results .................................. Page -10-
   5.3.1 Aeolian Dune Sand ................................................. Page -10-
   5.3.2 Berea Formation .................................................. Page -10-
   5.3.3 Dolerite .............................................................. Page -11-
   5.3.4 Residual Vryheid .................................................. Page -11-
   5.3.5 Weathered Shale (Vryheid Formation) ......................... Page -11-
   5.3.6 Weathered Siltstone ............................................. Page -12-
   5.3.7 Weathered Sandstone ............................................ Page -12-
6. GEOTECHNICAL ASSESSMENT. .......................................................... Page -12-
6.1 Development Proposals. .......................................................... Page -13-
6.2 Slope Stability. ......................................................................... Page -13-
6.3 Wetland and Conservation. ....................................................... Page -13-
6.4 Subsoil Activity .......................................................................... Page -14-
  6.4.3 Heave According to Van der Merwe (1964) ......................... Page -14-
  6.4.4 Collapsible Soils .................................................................. Page -15-
6.5 Subsoil Seepage. ......................................................................... Page -15-
6.6 Founding Conditions. ............................................................... Page -15-
6.7 NHBRC Classification. ............................................................. Page -16-
6.8 Construction Material. .............................................................. Page -17-
  6.8.3 Flanders Quarry .................................................................. Page -17-
6.9 Excavatability. ........................................................................... Page -18-

7. DEVELOPMENT RECOMMENDATIONS. ................................. Page -18-
7.1 Earthworks. ............................................................................... Page -19-
  7.1.3 Cuts ................................................................................... Page -19-
  7.1.4 Fills .................................................................................... Page -20-
7.2 Founding .................................................................................. Page -20-
  7.2.1 Shallow Founding ............................................................... Page -20-
  7.2.2 Deep Founding .................................................................. Page -21-
7.3 Drainage and Erosion Control. ................................................. Page -21-
7.4 Sanitation. ................................................................................ Page -22-
7.5 Road Construction. .................................................................. Page -22-
  7.5.6 Concluding Assessment ...................................................... Page -23-

8. CONCLUSIONS .............................................................................. Page -24-

APPENDIX 1 - INSPECTION PIT PROFILES
APPENDIX 2 - DYNAMIC CONE PENETROMETER TEST RESULTS
APPENDIX 3 - LABORATORY TEST RESULTS

FIGURE 1A - GEOLOGICAL PLAN
FIGURE 1B - GEOTECHNICAL PLAN
1. INTRODUCTION AND SCOPE OF WORK

Drennan, Maud and Partners was requested by VELA VKE Consulting Engineers in an email dating the 12th December 2008 to conduct a geotechnical investigation of the southern part of the Blackburn Sugar Estate.

This report presents the geotechnical information and development recommendations for the area excluding “Phase 1” for the proposed Cornubia Development. The “Phase 1” proposed Cornubia development, was reported on separately in our report reference 20157, dated July 2009, titled “Report to Vela VKE Consulting Engineers on the Geotechnical Investigation for the Area for Phase 1 of the Cornubia Development (1).

2. SITE DESCRIPTION

The area stretches from the “Phase 1” area, demarcated to Drennan, Maud and Partners in the west, eastwards to the N2 freeway in the east. The northern boundary is the Umhlanga River and the southern boundary is the Mount Edgecombe Highway.

The site compromises a gentle hill and valley system draining northwards into the Umhlanga River. Furthermore a manmade dam has been established in the south western part of the area reported on here, fed by to valley lines from the north.

The area is presently under sugarcane cultivation of the Blackburn Estate. Very steep slopes and main valley lines are covered by dense partly indigenous bush. Further are various parts under individual use, such as land fills, a resting borrow pit, private farming, informal settlements etc.

3. FIELD WORK

The field work comprised a total of 22 days of field work during the period 8th of January to 24th March 2009. This included the entire area (incl. “Phase 1”) and comprised general geological mapping of the area, excavating and logging of inspection pits, limited sampling of the materials and dynamic cone penetrometers testing.

The access to certain portions of the area was restricted by the present land use such as commercial farming, private fenced of areas, informal settlements and informal land fills.
3.1 Inspection Pits

A total of 267 inspection pits were excavated using a 4X4 TLB, to a maximum depth of 3.10m. Of those, 178 are within the area reported on in this report.

These inspection pits, designated IP 40 to IP 63, IP 65, IP 77 to IP 90, IP 103, IP 104, IP 110, IP 111, IP 113 to IP 188, IP 195 to IP 197, IP 201, IP 202, IP 206 to IP 224, IP 226, IP 227 and IP 244 to IP 278, were excavated in the approximate positions indicated on the site plan Figure 1a and 1b. The subsoils exposed in the inspection pits were examined and logged and the inferred soil profiles are included in Appendix 1 of this report.

3.2 Dynamic Cone Penetrometer Test (DCP)

A total of 283 dynamic cone penetrometer tests were carried out. Of those 162 are within the area reported on in this report. These DCP tests, designated DCP 83, DCP 84, DCP 93 to DCP 181, DCP 189 to DCP 193, DCP 200 - 221, DCP 226, DCP 227, DCP 243 to DCP 283, were carried out in the approximate positions indicated on the site plan Figure 1a and 1b.

The aim of DCP testing was to establish the consistency of the subsoil underlying the site at shallow to moderate depth, as well as to establish the depth to the bedrock if occurring at shallow to moderate depths. The results of the DCP tests are recorded graphically in Figures 2 to 163.

For ease of evaluation, Table 1 below gives a qualitative indication of the consistency of the non-cohesive and cohesive soils based on the DCP results. It should be noted that the results are specific to DMP’s testing equipment and should be used with caution as it is only provided as a guide.

### TABLE 1: Subsoil Consistency inferred from the DCP Test Results

<table>
<thead>
<tr>
<th>Non-Cohesive Soils</th>
<th>Cohesive Soils</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Penetration</strong></td>
<td><strong>Consistency</strong></td>
</tr>
<tr>
<td>1. Non-Cohesive</td>
<td></td>
</tr>
<tr>
<td>&lt;8</td>
<td>Very Loose</td>
</tr>
<tr>
<td>8-18</td>
<td>Loose</td>
</tr>
<tr>
<td>19-54</td>
<td>Medium Dense</td>
</tr>
<tr>
<td>55-90</td>
<td>Dense</td>
</tr>
<tr>
<td>&gt;90</td>
<td>Very Dense</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4. GEOLOGY AND SOILS

4.1 General

4.1.1 The area is predominantly underlain by the micaceous sandstones and siltstones of the Permian Vryheid Formation, containing Jurassic dolerite intrusions. The major valley lines and the flood plains of the Umhlanga River to the north and the dam in the south western area are underlain by Quaternary alluvial sediments. The south eastern corner of the area is underlain by the clays and sands of the Berea Formation, capped by Recent aeolian dune sands.

4.1.2 The budget and time frame of this investigation did not allow to distinguish the scientific correct lithology of the laminated to thinly layered interbedded sedimentary rocks of the Vryheid Formation in detail, eg. separating very thinly bedded fine grained sandstones from siltstone beds is practically impossible with field work methods and require lab analysis.

4.1.3 However, areas with predominantly medium to coarse grained sandstone and sandy siltstone sequences are mapped separately.

4.1.4 Figure 1a shows the geology of the area reported on and is discussed below.

4.2 Fill

4.2.1 Locally fill materials were encountered in areas where previous platforming was carried out to create small structures for farming purposes, such as platforms for cane loading etc. The fill material generally comprises locally derived material from cuts or, imported dolerite type material from the local borrow pit in the area.

4.3 Top Soils and Colluvium

4.3.1 The slopes are generally covered by brown, colluvial sandy clays and clayey sands, containing gravel and pebbles, extending to depths of up to 0,70m below present ground level.

4.4 Alluvium

4.4.1 The major valley lines and low plain areas towards the southern embankment of the Umhlanga River is build up by alluvial sediments both from the drainage lines and from deposits from flood events of the river itself, which comprise alluvial sands in various areas, as well as alluvial clays.
4.5 **Aeolian Dune Sands**

4.5.1 The far south eastern corner, north of the Mt. Edgecombe Highway, comprises Recent aeolian dune sands capping the underlying clayey sands and sandy clays of the Berea Formation.

4.5.2 The dune sands are in general brown loose fine grained sands, which may contain clayey parts of Berea Formation clay, picked up during the sedimentary process, near the contact with the underlying Berea Formation sediments.

4.6 **Berea Formation**

4.6.1 The south eastern elevated areas are underlain by the typical Berea Formation sandy clays and clayey sands of the KZN coastline.

4.6.2 The Berea Formation can be expected to reach depths up to 40 m below present as shown in the boreholes previously drilled for the proposed Cornubia Interchange. The results from this investigation were reported on by Drennan Maud and Partners in our report reference 19221, in March 2008 and is available from Tongaat Hulett Developments if required.

4.7 **Dolerite**

4.7.1 The dolerite intrusions appear in the entire scale of reddish colours from violet over red to orange. The dolerite is locally moderate to completely weathered and covered by residual clays or clayey sandy soils of depth varying from less than 1m to in excess, of 3,00m depending on the mineral composition of the intrusive rock and the exposure to the weathering processes.

4.7.2 However, on the steeper slopes in the area, the residual soils are not present and the weathered bedrock is exposed or covered by shallow colluvial soils.

4.8 **Vryheid Formation**

4.8.1 The micaceous fine grained sandstones, siltstones and shales of the Vryheid Formation are in general grey, laminated to thinly interbedded and highly to medium wide fractured by multiple joint sets. Whereas the medium to coarse sandstone sequences in general are medium to widely bedded
4.8.2 The soils derived from the weathered Vryheid Formation generally comprise yellow brown, grey and orange, sandy silty residual clays and extend in areas to depths beyond the reach of the TLB below the existing ground level. Ferricrete may occur locally in areas where sandstone is the predominant bedrock.

4.8.3 However, on the steepest slopes in the area, the residual soils are not present and the weathered bedrock is exposed or covered by clayey colluvial soils.

4.9 **Structural Features**

4.9.1 The predominant dip direction of the usually moderate to highly jointed sedimentary beds of the Vryheid Formation in the northern and eastern area is in a southerly to south westerly direction, at low angles of 5-10°, whereas this changes to a general dip direction of north to northeast towards the area reported on for “Phase 1”.

4.9.2 The change in predominant dip directions indicates a major tectonic alignment running in a north - south direction throughout the area and correlates with the predominant north - south alignment of most major dolorite intrusions in the area.

4.9.3 However, sedimentary beds might locally dip in a southern or western direction as observed on the Blackburn Estate outside of the Phase 1 area.

5. **LABORATORY TESTING**

5.1 **General**

5.1.1 Selected samples of the subsoils recovered from the IPs excavated on the site were taken to Thekwini Soils Laboratory for testing, for full grading analyses, Mod ASSHTO and CBR purposes and to determine the suitability of the materials for use in road construction.

5.1.2 Table 2 overleaf gives a schedule of the laboratory testing.
### TABLE 2: Schedule of Laboratory Testing

<table>
<thead>
<tr>
<th>IP No</th>
<th>Depth (m)</th>
<th>Description</th>
<th>Full Grading</th>
<th>Mod AASHTO</th>
<th>CBR</th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td>0.80 - 1.00</td>
<td>Dark grey and orange brown, moderately (partly completely) weathered, soft rock Dolerite - (Karoo)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>83</td>
<td>2.00 - 2.30</td>
<td>Orange, red and violet grey, completely weathered, very soft rock DOLERITE - (Karoo)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>86</td>
<td>2.70 - 2.90</td>
<td>Grey brown, shattered, stiff, micaceous very gravelly, slightly sandy silty CLAY - (Residual Vryheid)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>114</td>
<td>1.10 - 1.30</td>
<td>Very dark violet, and red, medium to highly weathered, highly fractured soft to medium hard rock DOLERITE - (Karoo)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>124</td>
<td>0.60 - 0.80</td>
<td>Dark grey, grey and yellow brown, highly to moderately weathered, completely weathered in joints, thinly bedded, closely jointed, micaceous soft to medium hard rock SHALE - (Vryheid Formation)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>162</td>
<td>1.80 - 2.00</td>
<td>Orange, completely weathered, very soft rock DOLERITE - (Karoo)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>187</td>
<td>1.10 - 1.30</td>
<td>Light yellow, orange red and grey, highly weathered, very soft to soft rock SANDSTONE / SILTSTONE - (Vryheid Formation)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>196</td>
<td>1.00 - 1.20</td>
<td>Yellow brown, medium weathered, completely weathered on joints, thinly bedded, closely jointed SANDSTONE - (Vryheid Formation)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>212</td>
<td>2.00 - 2.50</td>
<td>Dark grey brown, moderate to highly weathered, highly fractured, soft rock DOLERITE - (Karoo)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>262</td>
<td>0.20 - 0.50</td>
<td>Brown, loose fine SAND - (Aeolian Dune Sand)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>270</td>
<td>0.60 - 0.80</td>
<td>Red brown, stiff, sandy CLAY - (Berea Red Formation)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
5.1.3  The results of the laboratory testing are summarised in the Laboratory Test Summary Table 3a to 3c, the Materials Analyses Figure’s 164 to 175 in Appendix 3, and are discussed below.

5.2  Grading Analysis

5.2.1  Aeolian Dune Sands

5.2.1.1  The dune sand material encountered in IP 262 classifies as a very clayey fine grained sand with a clay content of 24.1% and a grading modulus of 0.74. The material has a plasticity index of 2.4.

5.2.1.2  In terms of the Revised U.S. Classification this material is A-2-4(0) which is considered excellent to good subgrade material.

5.2.2  Berea Red Formation

5.2.2.1  The Berea Red material encountered in IP 270 classifies as sandy clay with a clay content of 63.4 and a grading modulus of 0.07. The material has a plasticity index of 18.4.

5.2.2.2  In terms of the Revised U.S. Classification this material is A-7-5 (21) which is considered a highly compressible clay and therefore a poor subgrade material.

5.2.3  Dolerite

5.2.3.1  The dolerite materials encountered in IP 79, IP 162 and 212 classifies as slightly clayey sands with a clay contents ranging from 0.6% to 5.8% and a grading modulus between 2.11 to 2.81 The materials have a plasticity index ranging from 6.4 to 9.5.

5.2.3.2  In terms of the Revised U.S. Classification all these materials are classify as A-2-4 (0) materials, which is considered excellent to good subgrade material.

5.2.3.3  The dolerite material encountered in IP 83, however, classifies as a very sandy clay with a clay contents of 27.5% and a grading modulus of 0.53. The material has a plasticity index of 14.

5.2.3.4  In terms of the Revised U.S. Classification this material is A-6 (8) which is considered fair to poor subgrade material.
5.2.4 *Residual Vryheid*

5.2.4.1 The in-situ residual Vryheid material encountered in IP 86 classifies as a very clayey silty sand with a clay content of 21.7% and a grading modulus of 1.39. With a plasticity index of 9.2 this material classifies as low to medium active.

5.2.4.2 In terms of the Revised U.S. Classification this material is A-4 (1) which is considered fair subgrade material.

5.2.5 *Weathered Shale (Vryheid Formation)*

5.2.5.1 The highly weathered shale encountered in IP 124 classifies as slightly clayey fine grained sands with a clay content of 8.1% and a grading modulus between 2.47. The material has a plasticity index of 9.5.

5.2.5.2 In terms of the Revised U.S. Classification these materials are A-2-4(0) which is considered a excellent to good subgrade material.

5.2.6 *Weathered Siltstone (Vryheid Formation)*

5.2.6.1 The material encountered in IP 187 classifies as a very silty clay with a clay content of 57.6% and a grading modulus of 0.12. The material has a plasticity index of 23.9.

5.2.6.2 In terms of the Revised U.S. Classification this material is A-7-5(26), which is considered a highly compressible material and therefore a poor subgrade material.

5.2.7 *Weathered Sandstone (Vryheid Formation)*

5.2.7.1 The sandstone encountered in IP 133 and IP 196 classifies as slightly clayey to clayey sands with a clay content ranging from 6.0% to 15% and a grading modulus between 1.4 and 2.4. The material encountered in IP 133 is non-plastic, whereas the material from IP 196 has a plasticity index of 8.1.

5.2.7.2 In terms of the Revised U.S. Classification these materials are A-2-4, which are considered excellent to good subgrade materials.
5.3 **Mod AASHTO and CBR Test Results**

5.3.1 **Aeolian Dune Sand**

5.3.1.1 The maximum Mod AASHTO density of the Recent dune sand is 1988 kg/m³ at an optimum moisture content of 8.8 %. The material has a CBR of 3 at a compaction of 93% increasing to 5.8 at a compaction of 95% of the materials maximum Mod AASHTO density. The material has a CBR swell of 0.81.

5.3.1.2 As such, in terms of TRH 14 (1985) the material meets the requirements of a G10 and is therefore rated poor as subgrade, but suitable for bulk fill.

5.3.2 **Berea Formation**

5.3.2.1 The maximum Mod AASHTO density of the sandy clay of the Berea Formation is 1604 kg/m³ at an optimum moisture content of 22.4 %. The material has a CBR of 2 at a compaction of 93% increasing to 2.3 at a compaction of 95% of the materials maximum Mod AASHTO density. The CBR swell of the material is 4.

5.3.2.2 As such, in terms of TRH 14 (1985) the material does not meet the requirements of a G10 and is therefore neither suitable as base, subbase or for any selected layers, nor for use as subgrade material in road and pavement construction.

5.3.2.3 It must be noted that although the above results indicate that the Berea Formation material sampled is poor material for use in road and pavement construction, the quality of the Berea Formation materials may vary significantly. In this regard, suitable material meeting the requirements of a G9/G10 soil may occur within the Berea Formation.

5.3.3 **Dolerite**

5.3.3.1 The maximum Mod AASHTO density of the material encountered in IP79 and IP83, ranges from 1735 to 1996 kg/m³ at an optimum moisture contents between 10.1 and 16.9%. The materials have a CBR values ranging from 6 to 28 at a compaction of 93% a increasing to 6.5 to 41 at compaction of 95% of the materials maximum Mod AASHTO density. The maximum CBR swell of the materials are between 0.44% to 1.55%.

5.3.3.2 As such, in terms of TRH 14 (1985) the material generally meets the requirements of a G10 material but selectively, may be as good as a G6 material.
5.3.3.3 The maximum Mod AASHTO density of the materials encountered in IP114 and 212 are ranging between 2115 kg/m³ and 2130 kg/m³ at optimum moisture contents between 8.3% and 8.9%. The materials CBR values range between 21 and 44 at a compaction of 93% as increasing to between 26 and 85 at compaction of 95% of the materials maximum Mod AASHTO density. The material has no CBR swell.

5.3.3.4 As such, in terms of TRH 14 (1985) the material does meet the requirements of G6 (IP 212) and G7 (IP 114) gravel soils and are therefore both considered suitable for the use as subgrade and in lower and upper selected layers in road and pavement construction.

5.3.4 *Residual Vryheid*

5.3.4.1 The maximum Mod AASHTO density of the residual in-situ material is 1936 kg/m³ at an optimum moisture content of 11.9%. The material has a CBR of 4 at a compaction of 93% increasing to 4.9 at a compaction of 95% of the materials maximum Mod AASHTO density. The CBR swell of the material is 1.2%.

5.3.4.2 As such, in terms of TRH 14 (1985) the material does not meet the requirements of a G10 and is therefore suitable as subgrade material and for bulk fill only.

5.3.5 *Weathered Shale (Vryheid Formation)*

5.3.5.1 The maximum Mod AASHTO density of the weathered shale sampled is 1999 kg/m³ at an optimum moisture content of 10.7%. The material has a CBR of 21 at a compaction of 93% increasing to 24 at a compaction of 95% of the materials maximum Mod AASHTO density. The material have no CBR swell.

5.3.5.2 As such, in terms of TRH 14 (1985) the materials do not meet the requirements G7 and are therefore suitable as selected layers and for use as subgrade material in road and pavement construction.

5.3.6 *Weathered Siltstone*

5.3.6.1 The maximum Mod AASHTO density of the weathered material encountered in IP 187, is 1507 kg/m³ at an optimum moisture content of 23.9%. The material has a CBR of 1 at a compaction of 93% increasing to 1.2 at a compaction of 95% of the materials maximum Mod AASHTO density. The material has a CBR swell of 8.74%.

5.3.6.2 As such, in terms of TRH 14 (1985) the material does not meet the requirements of a G10 and is therefore neither suitable as subbase, nor for any selected layers and for use as subgrade material in road and pavement construction.
5.3.7 **Weathered Sandstone**

5.3.7.1 The maximum Mod AASHTO density of the weathered sandstones encountered in IP133 ranges is 1944 kg/m³ at an optimum moisture content of 8.7%. The materials has a CBR values of 3 at a compaction of 93% increasing to 3.6 at a compaction of 95% of the materials maximum Mod AASHTO density. The maximum CBR swell of the material is 1.49%.

5.3.7.2 As such, in terms of TRH 14 (1985) the material classifies as a G10 material and is therefore suitable for use as subgrade material only in road and pavement construction.

5.3.7.3 The maximum Mod AASHTO density of the weathered sandstones encountered in IP196 is 1974 kg/m³ at an optimum moisture content of 10.5%. The materials has a CBR of 3 at a compaction of 93% increasing to 3.6% of the materials maximum Mod AASHTO density. The CBR swell is 2.13%.

5.3.7.4 As such, in terms of TRH 14 (1985) the material does not classify as a G10 material and is therefore not considered suitable in road and pavement construction, but for bulk fill use only.

6. **GEOTECHNICAL ASSESSMENT**

6.1 **Development Proposals**

6.1.1 No details other then general industrial and mixed residential development proposed have been submitted to us.

6.1.2 The results of this investigation indicate that development in general is feasible on the majority of the area reported on here. However, there are some geotechnical constraints to the development which need to be taken into consideration in the planning and implementation of the development. Such geotechnical constraints include, but are not limited to the following;

6.2 **Slope Stability**

6.2.1 The bedrock Vryheid Formation underlying the area is in general laminated to thinly bedded siltstone/shale or thinly bedded sandstone with dolerite intrusions. Predominantly the sedimentary bedrock is closely jointed and inherently unstable, if cut where the bedding plans are dipping out of the slope or embankments are over steepened. No present or past conditions of instability could be observed, but might have been invisible due to the dense cane on the site.
6.2.2 In general the sedimentary bedrock of the Vryheid Formation is found to dip gently in a northern or southern direction. Locally different dip directions can not be excluded.

6.2.3 However, slopes too steep for cane farming, should be considered unstable as significant cutting and filling will be required to developed these areas.

6.3 Wetland and Conservation

6.3.1 Two major features should be considered as mainly wet areas and considered for conservation areas:

- The low flood plains on the southern embankment of the Umhlanga River
- The major valley line systems, draining:
  a) north towards the Umhlanga river
  b) south towards the existing dam

6.3.2 These geomorphological features play important roles in flood protection for the existing and proposed developments in periods of high water levels and floods.

6.3.3 Once sealed by development the absence of the water absorption of those flood plains and major valley systems could cause major problems during periods of heavy rain and unfortunate weather conditions and cause sever damage to existing and proposed development.

6.3.4 We therefore suggest to limit all development to outside of the 100-year-flood-line and initiate a re-naturalization towards the indigenous flora within the 100-year-flood-line to the recreational benefit of the area and to prevent future damages by floods.

6.3.5 Minor wet drainage lines have been engineered on almost all slopes to optimize commercial farming, prior to the present environmental regulations and concerns. Although those drainage lines contains wet soils, no other wetland characteristics have been observed.

6.4 Subsoil Activity

6.4.1 The results from the laboratory tests indicate that the residual material derived from weathered Vryheid Formation bedrock and the Berea Formation clayey soils, generally have a high clay content and are likely to be moderately to highly active. These soils will in general be subjected to volume changes with changes in moisture content.
6.4.2 Furthermore, the colluvial clays and residual clayey soils deriving from dolerite intrusions locally have high clay contents and are also likely to be moderately to highly active, as seen from samples taken within the “Phase 1” area.

6.4.3 **Heave According to Van der Merwe (1964)**

6.4.3.1 The sampled materials within the area reported on here, except some completely to highly weathered sandstones, are in general predicted low in their expansive potential according to Van der Merwe (1964), (< 2%).

6.4.3.2 However, the completely weathered Vryheid Formation and dolerite intrusions as well as the clays of the Berea Formation, may have higher swell potentials depending on composition. These heaving soils may occur locally on a smaller scale where these Formations are predominant.

6.4.3.3 The sample from the completely to highly weathered sandstones of IP 187 of the Vryheid Formation show a linear shrinkage of 12% and a CBR swell of 8.74% and should be considered active.

6.4.4 **Collapsible Soils**

6.4.4.1 The loose collapsible Recent dune sands in the south eastern corner of the area are loose up to depth between 3,90m and 4,20m below EGL (DCPs 267 and DCP 268).

6.4.4.2 Furthermore, will these collapsable sands will be very prone to erosion by wind and water, if exposed during the development over longer periods.

6.5 **Subsoil Seepage**

6.5.1 No subsoil seepage was observed in the inspection pits excavated outside the valley and drainage lines on the site.

6.5.2 However, during periods of high rainfall, seepage may occur at the contact of permeable soils underlain by less or non permeable clays or bedrock formations throughout the area.

6.6 **Founding Conditions**

6.6.1 Founding conditions on the hill tops and slopes are in general moderate to good, depending on the proposed structures and the depth of the active soils underlying the surface.
6.6.2 However, the Recent dune sands in the south east of the area reaching a thicknesses in excess of 4,00m before capping the Berea Formation may require medium deep to deep founding solutions depending on the structures to be founded.

6.6.3 The geotechnical plan (Fig. 1b), should be utilised for a preliminary assessment of founding conditions across the area.

6.6.4 To simplify the map, three areas were designated. These being;

- areas with bedrock within less then 0,5m below EGL,
- areas with bedrock between 0,50m and 1,50m below EGL,
- areas with bedrock below 1,50m of the EGL.

6.7 NHBRC Classification

6.7.1 The Residential Site Class Designations according to NHBRC are shown on the geotechnical plan (Fig 1b.), marked with the site class symbols, within the areas designated above. The broad site class symbols shown on the plan comprise the following;

- R - Rock
- H - Expansive Soils
- C - Collapsible Soils
- S - Compressible Soils

6.7.2 The geotechnical map is not only based on the interpretation of the field work results from this investigation, but also on the results from previous investigations and the interpretation of the geomorphology in relation to the various geological formations. As such the geotechnical map provides a generalised overview of the geotechnical situation to be expected.

6.7.3 It must be noted, that the residential soils character may change locally over short distances depending on the mineral composition of the underlying bedrock, the stage of weathering and the slope characteristic, to such a degree, that it is considered impractical to mark areas for site class designations on the scale map. However, the following should be considered in preliminary assessing development areas;

- R - generally suitable for shallow founding except if blasting is required.
- H - The ‘H’ soils will range from H, through H1 to H3 applicable to the following areas.
• **C** - The 'C' soil will range from C, through C1 to C2 applicable to the following areas.
  > ‘C’, ‘C1’ - Areas underlain by Berea Formation sandy clays and clayey sands.
  > ‘C2’ - Areas underlain by loose Aeolian sands.

• **S** - The ‘S’ soil will range from S, through S1 to S2 applicable to the following areas.
  > ‘S’, ‘S1’ - Areas underlain alluvial sands, clayey sands and clays less than about 1.5 m thick.
  > ‘S2’ - Areas underlain alluvial sands, clayey sands and clays greater than about 1.5 m thick.

6.7.4 Notwithstanding the above, it will be necessary to classify the soils on individual sites or development areas as part of the detailed geotechnical investigation for the proposed structures and or smaller development areas, within the Phase 2 area, as soon as details for the proposed dwellings or structures are available.

6.8 **Construction Material**

6.8.1 Results from the laboratory test indicates that some residual clayey materials and the completely weathered bedrock materials deriving from both Vryheid Formation rocks (IP 196) and the dolerite occurring in the area classify as A-4, A-6 or A-7-5 soils in terms of the Revised U.S. Classification. Furthermore the clayey sands of the Berea Formation encountered classifies as a A-7-5 (21) material.

6.8.2 Locally weathered Vryheid Formation Shale and Dolerite bedrock materials classifies as a G6/7 material, where the sand content is effectively high enough and is therefore considered good for use as subgrade and for selected layers in road and pavement construction.
6.8.3 **Flanders Quarry**

**6.8.3.1** Flanders Quarry is located in the central part of the area reported on here and is at present not operational as a quarry/borrow pit. Drennan, Maud and Partners has been involved in the development, monitoring and the past operation of Flanders Borrow Pit since the early 1980's.

**6.8.3.2** The borrow pit comprises an inclined sheet of dolerite that has intruded into the shale and sandstones of the Vryheid Formation. It is approximately conformable to the bedding of the sedimentary rocks of the Vryheid Formation and strikes north south along the spur.

**6.8.3.3** The type of mineral excavated from the borrow pit comprises weathered dolerite gravel, suitable for the use in construction as G5,G6 and G7 gravel soils. To date, since the monitoring of the borrow pit commenced by Drennan, Maud and Partners, approximately 200,000 m³ of materials has been removed for construction in the area.

This has resulted in a significant cost saving to Tongaat Hulett Developments in the development of the Umhlanga Ridge and Mount Edgecombe areas.

**6.8.3.4** Both an extension of the Quarry to gain suitable construction materials, as well as means to transform the Quarry area into a solid waste deposit have been discussed during the past decade. However, prior to future development in that area, the existing borrow pit needs to be rehabilitated.

**6.8.3.5** For further information, we refer to the present owner Tongaat Hulett Developments (Pty) Ltd.

6.9 **Excavatability**

**6.9.1** The soils and weathered Vryheid Formation bedrock are locally excavatable to a depth up to 3,20m below present ground level. However, the weathered bedrock does get increasingly hard with depth and in places, where the bedrock is shallow, pneumatic tools might be necessary for excavation.

**6.9.2** The soils and weathered bedrock of the dolerite bedrock are locally excavatable to a depth up to 3,20m below present ground level. However, the weathered bedrock does get increasingly hard with depth and in places, where the bedrock is shallow, pneumatic tools might be necessary for excavation.
6.9.3 The Recent dune sands and the Berea Formation will be easy to excavate to depths in excess of 4,00m below present ground level. However, due to the collapsable nature of those materials, the recommendations given below for cut embankments must be considered.

7. DEVELOPMENT RECOMMENDATIONS

7.1 Earthworks

7.1.1 No details of the proposed earthworks have been provided. However, a number of individual building platforms or terraces are likely to be constructed. In this regard, cutting and filling to balance the earthworks of individual platforms is likely to be the most practical and economical earthworks solution. Careful planning of the earthworks will therefore be required. This is not only necessary to ensure stability of cut and fill bank, but also, in that it will be beneficial in that depth to founding below the final ground level may be reduced.

7.1.2 Where possible, individual dwelling plots on the steeper slopes should be designed to have their axes orientated in an up-downslope direction, rather then along the contours. Therewith associated cut and fill slopes can be contained within individual plot boundaries.

7.1.3 Cuts

7.1.3.1 Cut slopes in the colluvial and residual clayey materials, should in general be restricted to a slope angle of 1:2 (26°). Steeper slopes may be created individually, at the discretion of the Engineer. The maximum height of any cut slope should not exceed about 3m without being assessed by the Engineer.

7.1.3.2 In the weathered sandstone and dolerite bedrock, the cut slopes may be increased to 1:1,5 (30°), or even steeper, up to 1:1 (45°) at the discretion of an Engineer.

7.1.3.3 However, it is essential to understand, that the close joint sets in the thinly bedded Vryheid Formation bedrock may cause instability, if cut to unfavourable angles due to adverse dip directions in the bedrock. We therefore recommend that during all cutting of the site, excavations should be continually assessed by a Geotechnical Engineer or Engineering Geologists.
7.1.3.4 The excavation of excessively deep cuts in the Recent dune sands should be avoided during the course of any development. Cut embankments in the loose aeolian sand must be restricted to a slope batter of 1:2 (26°). Where recommended batters cannot be accommodated, a retaining wall should be introduced. It is essential that any wall be properly damp proofed and incorporates suitable surface drainage.

7.1.3.5 Cuts in the more sandy clays of the Berea Formation may be layed back to a slope batter of no more than 1:1.75 (30°) at the discretion of an engineer. Such banks will however fail in time as they lose their temporary cohesive strength, either by drying out or by becoming saturated. As such any excavation deeper than about 1.20 m should therefore be suitably battered back or shored to prevent the collapse of sides under adverse conditions.

7.1.3.6 Cut embankments must be protected against surface erosion by the planting of vegetation immediately after construction.

7.1.4 Fills

7.1.4.1 Prior to the placement of any fill, the in situ subsoil material containing vegetation should be removed. The fills should then be constructed in layers a maximum of 300 mm loose thickness and be compacted to 93% of the materials Max Mod AASHTO Density, prior to the placement of the next layer. The maximum slope angle of any fill should be restricted to 1:1.5 (33°).

7.1.4.2 Where the natural ground slope exceeds a slope angle of 1:6 (10°), the fills should be constructed on surface benched into suitable in-situ material.

7.2 Founding

7.2.1 Shallow Founding

7.2.1.1 Over most of the area outside the 100-year-flood-line concerned building platforms will compromise a composite cut fill platform. Foundation for houses may compromise normal strip footings taken down into competent weathered bedrock in cut, or through fill and residual material into competent weathered bedrock.

7.2.1.2 The maximum allowable bearing pressure of foundations, taken through the residual clayey soils into the weathered bedrock, requiring hard hand picking for excavation, should be restricted to 150 kPa.
7.2.1.3 However, where cut platforms are taken into hard slightly weathered sandstone or dolerite bedrock may be increased to 250kPa, at the discretion of the engineer.

7.2.1.4 Typically, areas where shallow founding will be possible will be areas classified as R, H, H1, C, C1 and S, S1.

7.2.2 Deep Founding

7.2.2.1 Where the depth to suitable founding exceeds the practical and economic depth for normal strip footings, as may occur where deep colluvial and residual soils occur, (H2, H3), the fill portion of the building platforms or alluvial soils (S, S1), as well as in the collapsible loose sands (C2), in the south east, deep founding is required. In this regard, the structures should be supported on ground beams spanning between deep column base foundations, or, piled foundations, taken through all fill, colluvial, alluvial and residual soils, and soft weathered bedrock, to bear into the firmly bedded weathered bedrock at depth below the site.

7.2.2.2 Due to the likely expansive nature of the active clayey colluvial and residual soils occurring in the area, these materials should not be used as fill beneath the surface beds. Imported hard core or suitable in-situ weathered bedrock material is preferred for this purpose.

7.2.2.3 The floor slabs for the structures should be isolated from all walls, ground beams, columns and foundations to allow for any differential movements as may occur in the expensive soils underlying the site. Similarly, all structures should incorporate regularly placed expansion joints.

7.2.2.4 As an alternative founding measure, particularly on the lower portion of the site where the highly active residual clays of the Vryheid Formation bedrock occurs, or where structures span the prick of cut and fill on building platforms, suitably designed reinforced concrete raft foundations are considered the most suitable type of foundation.

7.2.2.5 On cut fill platforms, the raft foundations should be supported on the fill side of the building platform by short auger piles or pads, also taken down through the fill into competent founding material such as weathered bedrock. This may also apply to the dune sands and the Berea Formation materials in the south eastern corner.

7.3 Drainage and Erosion Control

7.3.1 Suitable subsoil drainage, storm water control and preventible solutions to avoid soil erosion will be essential for most developments into the loose sands in the south eastern area.
7.3.2 Although not generally prone to erosion the in-situ soils deriving from the Vryheid Formation and dolerite bedrock as well as weathered bedrock in the northern and eastern parts of the area can nevertheless be gully or donga eroded by concentrated uncontrolled water flow, especially in view of general steepness in some areas. It will therefore be necessary to provide adequate stormwater surface drainage as part of the infrastructural development of the area the discretion of the Engineer.

7.3.3 Due to the clayey nature of most of the subsoils on the site and taking into consideration the environmental aspects of the partly densely developed surroundings, storm water disposal by means of soakpits is in general not considered feasible. Stormwater from all roof and paved areas should be piped or collected in surface drains to discharge into a suitably designed storm water retention system where no efficient storm water system exists.

7.4 Sanitation

7.4.1 The subsoil conditions prevailing in the predominantly clayey areas are such that subsoil percolation disposal of septic tanks and waste water effluent by means of soak pits or French drain trenches cannot be satisfactorily practised therein.

7.4.2 Regional waterborne sewerage should be installed throughout the area as part of its development, also to protect the wetlands and possible recreational areas feeding or surrounding the Umhlanga River from negative environmental impacts.

7.4.3 We also consider this necessary for the south eastern part underlain by the loose Recent dune sands and clayey sands of the Berea Formation. Although percolation will be sufficient, the environmental impact in this area could not be justified.

7.5 Road Construction

7.5.1 The results of the laboratory tests indicate that in general the colluvial and residual clayey material, occurring at a relatively shallow level, on the site is considered poor as a subgrade material in road construction and for use in bulk filling. As such, some subgrade improvement will be required in these areas.

7.5.2 On the other hand, the Vryheid Formation bedrock materials with an effectively high sand content are considered excellent to good as a subgrade material and suitable for use in selected layers in road and pavement construction. The design of the road layer works here should be based on a material classifying as a minimum G8/G9 gravel soil in terms of TRH 14 1985 having a CBR value of about 10.
7.5.3 Furthermore, the dolerite bedrock of most intrusions, including the existing borrow pit, are considered excellent materials for road and pavement construction, if not completely weathered to a silty clay.

7.5.4 The design of the road layer works here should be based on a material classifying as a minimum G8/G9 gravel soil in terms of TRH 14 1985 having a CBR value of about 10.

7.5.5 We recommend that attempts are made to re-establishing and, if needed, extending Flanders Quarry as a source of G5, G6 and G7 gravel soils for the proposed development of the entire Cornubia Development.

7.5.6 Concluding Assessment

7.5.6.1 The above given development recommendations are of a general nature to cover general trends throughout the entire area reported on.

7.5.6.2 The subsoil conditions may change locally and a detailed geotechnical investigation will be required for each smaller units of the development as well as for each single complex structures to establish the specific subsoil conditions to the specific proposed developments or structures, as soon as those details are available and finalized.

8. CONCLUSIONS

8.1 The results of this geotechnical investigation confirm the general geotechnical conditions underlying the areas of the proposed Cornubia Development excluding the “Phase 1” area. In this regard, it is evident that the area is underlain by weathered sandstone, siltstone and shale rocks of the Vryheid Formation intruded by dolerite during the Jurassic. Furthermore, the south eastern slope is capped by the sandy clays and clayey sands of the Berea Formation, which in areas are capped by Recent aeolian dune sands. In addition, on the low plains and major valley lines of the site, alluvial soils overlie the weathered bedrock.

8.2 No details of the proposed layout have been made available. However, the results of the investigation indicate that for most of the area, provided the structures are optimally located on cut and fill platforms, it will likely be feasible to found the structures at a relatively shallow depth, into soft to medium hard bedrock. The maximum allowable bearing pressure of foundations taken into the weathered bedrock, requiring hard hand picking for removal, should be restricted to about 150 kPa. However, where shallow founding is possible into weathered sandstones or dolerite the bearing pressure may be increased to 250kPa at the discretion of an Engineer.
8.3 Where the depth to founding exceeds the practical and economic depth for normal strip footings the structures may be supported on ground beams spanning between piled or deep column base foundations, taken into the weathered bedrock.

8.5 In the south eastern corner of the area loose aeolian dune sands and the sandy clays and clays of the Berea Formation are predominant. Those areas may require deep founding solutions, depending on the development.

8.4 General recommendations with regard to cutting and filling of the site for development have been given. In this regard, permanent cut slopes should be restricted to a batter of 1:2 in the residual and colluvial materials, but may be increased to 1:1 in the weathered sandstone or dolerite bedrock. It is essential to understand that the close joint sets may cause instability, when cut to an unsuitable angles.

8.5 Fills should be restricted to a slope batter of 1:1.5. Cut and fill slopes must be topsoiled and grassed as soon as possible after construction.

8.6 It is evident, that the 100-year-flood-line for the Umhlanga River has been calculated. No construction should take place within this flood line to prevent flood problems for present and future development. The area is suitable for rehabilitation for conservation purposes.

K.M. CHRISTENSEN Dipl.-Geol.

REFERENCE 20157 (II)
OCTOBER 2009
/mh-kc
APPENDIX 1

INSPECTION PIT PROFILES
APPENDIX 2

DYNAMIC CONE PENETROMETER
TEST RESULTS
APPENDIX 3

LABORATORY TEST RESULTS
FIGURE 1A

GEOLOGICAL PLAN
FIGURE 1B

GEOTEchnical PLAN