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INITIAL GEOHYDROLOGICAL AND GEOTECHNICAL INVESTIGATION REPORT FOR THE DARVILL CONSTRUCTED WETLAND – PIETERMARITZBURG – KWAZULU-NATAL

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1. INTRODUCTION AND SCOPE OF WORK

Subsequent to the submission of a requested budget proposal, Geomeasure Group (Pty) Ltd. were appointed to undertake an initial geohydrological and geotechnical investigation for the proposed Darvill Constructed Wetland, to be located near the City of Pietermaritzburg within KwaZulu-Natal, in support of documentation that is to be submitted so as to acquire environmental authorization for this project.

It is proposed that the augmented quantity of treated effluent that will arise from an increase in the capacity of the nearby Darvill Sewage Works, will be passed through this constructed wetland, before being discharged into the adjacent Msunduzi River. Four (4) possible sites were initially proposed, with the following scope of work attempted as part of this investigation, undertaken on Site 1:

Phase A – Initial Desktop Assessment

- Identification and delineation of all surface water sources / bodies in proximity to the site.
- Assessment of any applicable existing reports / information pertaining to the project, should they be available.
- Desktop study of, and collation of information pertaining to, the geology and geohydrology of the area.
- Undertaking of a desktop hydrocensus within 2 km of the site, utilising the Department of Water and Sanitation (DWS) KwaZulu-Natal Groundwater Resource Information Database (GRIP) and our in-house (Geom) borehole database.
- Assessment of DWS-mapped structures in proximity to the site, in accordance with the regional geological map.

Phase B – Geohydrological and Geotechnical Investigation

- Preparation of a site-specific safety file.
- Site walkover inspection and reconnaissance of the receiving environment to identify surface and subsurface migration pathways as well as potential receptors located in the vicinity of the site.
- Performance of a basic hydrocensus within a 1 km radius of the site to identify any additional springs and existing boreholes, and where possible:
    - borehole ages, depths, construction types, water strikes, static water levels, equipment and volumes of water currently being abstracted
    - groundwater physical parameters, including temperature, pH, electrical conductivity (EC) levels and total dissolved solids (TDS) concentrations

- Collection of two (2) water samples from boreholes located in close proximity to the site for submission to a SANAS-accredited laboratory for analysis according to the SANS 241: 2015 abbreviated suite of determinants to allow for the assessment of baseline water quality on-site / within the study area.

- Identification and delineation of existing point-source pollution sources within the study area, should any be in evidence.

- Excavation, through the use of a tractor-loaded backhoe (TLB), of a limited number of test pits to the maximum reach of the TLB / refusal for detailed descriptions of soil / weathered rock profile, including assessments of shallow groundwater (if present) and depth to bedrock measurements (if intercepted), and to allow for the collection of selected soil samples.

- Submission of up to three (3) soil samples to a geotechnical laboratory for full indicators analysis, Mod. AASHTO density analysis and falling head permeability analysis.

- Back-filing and part restoration of the excavated test pits.

Phase C – Data Evaluation and Reporting

- Preparation of a geohydrological and geotechnical investigation report, including:
  - field investigation methodologies and applicable principles
  - results of the hydrocensus, including the position of, and distance to, identified groundwater sources as well as the gathered pertinent groundwater field characteristics
  - inferred geology and geohydrology of the area, through the inclusion of gathered field data and the available desktop information, including the preparation of test pit logs though the use of Strater V4.2©; a dedicated subsurface materials logging program
  - evaluation of possible impacts of this project on the water resources in its vicinity, and any existing geohydrological constraints
  - monitoring and sampling recommendations as pertaining to the construction of the wetland, if deemed necessary

Our findings and recommendations, based on this investigation, are contained in this report.

2. SITE INFORMATION

2.1. SITE LOCATION & TOPOGRAPHY

The proposed Darvill Constructed Wetland (hereon also referred to as ‘the site’) is located near the City of Pietermaritzburg, within KwaZulu-Natal, at the co-ordinates 29° 35' 40" S and 30° 26' 10" E, and is accessed off New England Road off the N3 national highway (see attached Locality Plan – Dwg No. 2015/232 Figure 1).

The site is located at an average elevation of approximately 705 m above mean sea level (AMSL). The topography of the study area can be described as gently to moderately undulating, whilst site drainage is in a westerly, northerly and easterly direction towards the Msunduzi River, which directly borders the northern portions of the site (see attached Area Plan – Dwg No. 2015/232 Figure 3). Note that the Bayne's Spruit enters the Msunduzi River just to the north-west of the site, with this tributary itself being fed by another non-perennial tributary away to the east.

2.2. GEOLOGY

The 1 : 250 000 2930 Durban Geological Sheet shows that the site and surrounds are underlain by consolidated sedimentary units of the Dwyka Group and the Pietermaritzburg Formation of the Ecca Group, which both form part of the Karoo Supergroup (see attached Geological Plan – Dwg No. 2015/232 Figure 3). Unconsolidated Quaternary-age alluvium outcrops along the bank of the Msunduzi River, and possibly underlies part of the site at shallow depths.

The Dwyka Group comprises an ancient glacial deposit which consists predominantly of tillite, and includes minor shale, varved shale and subordinate sandstone bands. In this area, the Pietermaritzburg Formation comprises dark silty mudrock, which coarsens upwards, with deformed sandy and silty beds appearing near the top of this unit.

Jurassic-age dolerite of the Karoo Igneous Province intrudes the bedrock of the region in the form of both sub-vertical dykes and sub-horizontal sills, with the latter outcropping to the north of the site.

These sedimentary formations have been subjected to faulting and fracturing associated with the breakup of the ancient Gondwana super-continent, as is illustrated by the sub-regional northeast-southwest trending faults, which pass away to the south and east of the site. These coast-parallel faults likely formed during the shearing off of the Falkland Plateau past the Natal Valley during the mid-Cretaceous period, when east – west extension and movement along the Agulhas Falkland Fracture Zone resulted in east and west Gondwana being separated.

Note that a lineament in this orientation, likely representing a fault, passes just to the west of the site.

2.3. SOILS

The upper (< 0.75 m) soil horizons in this region are partially due to alluvial transportation, as detailed above, with the deeper profiles likely owing their origin to the in situ weathering of the underlying geology.

The overall profile can be characterized as a horizon of dry, light grey-brown, loose, intact (clayey) sand over a layer of slightly moist, yellow-orange to red brown, firm, intact sandy clay. This horizon is typically underlain by a dry to moist, tan-orange to beige-brown, medium dense, intact to laminated silty sand layer with residual weathered tillite.

2.4. GEOHYDROLOGY

The Karoo Supergroup sedimentary units are essentially secondary or fractured rock aquifers with negligible primary storage and permeability. Groundwater storage and movement is generally confined to fractures, joints and bedding planes within the rock mass.

The tillites and shales of the Dwyka Group and Pietermaritzburg Formation respectively are generally classified as moderate-yielding fractured rock aquifers, with borehole yields typically ranging from > 0.5 l/sec – 3.0 l/sec according to the information as contained in the

"*Characterisation and Mapping of the Groundwater Resources KwaZulu-Natal Province Mapping Unit 2*" April 1995, which was prepared for the former Department of Water Affairs and Forestry (DWAF) by Groundwater Consulting Services. Higher yielding boreholes, where yields of > 3.0 l/sec have been recorded, were likely drilled to intersect faults and fracture zones associated with dolerite intrusion emplacement, particularly on the lip of sills and in the contact zones of dykes. The groundwater development potential increases due to the enhancement of the porosity and permeability within these discreet zones.

The Dwyka Group is generally considered to be a poor aquifer due to its massive nature and elevated electrical conductivity (EC) values of the groundwater intersected. This is attributable to high concentrations of dissolved solids, mainly sodium (Na) and chloride (Cl), which frequently renders the water brackish. Groundwater circulating in the shales of the Pietermaritzburg Formation in this area generally has a median EC value of 18 mS/m, whilst the typical hydrochemical facies is said to be $Ca/Na\text{-}HCO_3$.

3. DESKTOP AND FIELD HYDROCENSUS

As detailed above, an initial desktop study was performed for the site, given that this office has undertaken extensive amounts of work in the general area. The desktop study included the following:

- An assessment of investigation reports as prepared for other projects undertaken in proximity (2 km radius) to the site.
- An assessment of the borehole data, within a 2 km radius of the site, as contained within the KZN DWS GRIP database, and our in-house (Geom) database, which together represent the most up-to-date and complete data set for the study area.
- As assessment of other mapped information in proximity (2 km radius) to the site, including the known geology and geohydrology of the region.

From this initial assessment, the following was learnt:

- Numerous shallow and deep monitoring boreholes were installed to the south of the site, which form part of the Darvill Sewage Works monitoring network.
- Three (3) deep monitoring boreholes were installed further to the south of the site, as part of the original development of the Hollingwood Cemetery. However, it has been learnt recently that a housing project may be developed in this area instead.
- Numerous shallow and deep monitoring boreholes were installed to the south-west of the site, which form part of the New England Road Landfill Site monitoring network.
- A limited number of groundwater abstraction boreholes were drilled to the north of the site across the Msunduzi River, however it is expected that said river acts as a geohydrological barrier.
- Elevation increases and rising topography occur to the north and east of the site across the Msunduzi River, and approximately 2 km to the south of the site, which hence acts to 'confine' the site and its immediate surrounds.

The boreholes identified during the desktop and site hydrocensus are shown on the attached Area Plan – Dwg No. 2015/232 Figure 3. As can be seen, there are number of boreholes to the south of the site on the southern side of the Msunduzi River, all of which are monitoring boreholes and the majority of which are either up-gradient or cross-gradient of the site.

The available data and information pertaining to the identified boreholes is shown overleaf in Table 1. It should be noted that whilst many of the boreholes included in the various databases were identified in the field, they were otherwise inaccessible / locked, hence the given information could not necessarily be verified. Regardless, that which is available provides valuable information on the geohydrology of the greater study area.

Note that historic static water levels (SWLs) are included in Table 1, given the drought currently being experienced in the region that has resulted in a drop in SWLs (as detailed further overleaf). Historic SWLs are considered representative of that which is to be expected in the years to come during non-drought times.

Table 1: Darvill Constructed Wetland Hydrocensus Information

Borehole Number	Purpose	Owner	Borehole Age (years)	Borehole Depth (m)	Water Strikes (m bgl[1])	Historic SWL[2] (m bgl)	Yield (l/sec)
P3 (Deep)	Monitoring	New England Road Landfill	21	24.0	3.0 & 12.0	4.9	3.0
P3 (Shallow)	Monitoring	New England Road Landfill	21	8.0	(none)	7.0	-
P2D	Monitoring	New England Road Landfill	16	36.0	36.0	3.5	3.0
P3D	Monitoring	New England Road Landfill	16	24.0	4.9	4.1	-
P2S	Monitoring	New England Road Landfill	16	8.0	6.0	3.6	-
P3S	Monitoring	New England Road Landfill	16	8.0	7.0	4.5	-
NE1	Monitoring	New England Road Landfill	16	13.0	(none)	▨	-
NE 2	Monitoring	New England Road Landfill	16	15.0	(none)	8.8	-
NER 10	Monitoring	New England Road Landfill	16	▨	(none)	5.0	-
NER 11	Monitoring	New England Road Landfill	16	▨	(none)	5.0	-
NER 16	Monitoring	New England Road Landfill	16	▨	(none)	15.0	-
BH A	Monitoring	Hollingwood Cemetery	5	40.0	(none)	39.3	-
BH B	Monitoring	Hollingwood Cemetery	5	40.0	(none)	14.3	-
BH BO	Monitoring	Hollingwood Cemetery	5	25.0	(none)	13.0	-
A 0	Monitoring	Darvill Sewage Works	▨	4.5	▨	(dry)	-
A 1	Monitoring	Darvill Sewage Works	▨	40.0	▨	30	-
A 2	Monitoring	Darvill Sewage Works	▨	3.0	▨	▨	-
A 3	Monitoring	Darvill Sewage Works	▨	2.5	▨	▨	-
A 4	Monitoring	Darvill Sewage Works	▨	24.3	▨	2.0	-
B 0	Monitoring	Darvill Sewage Works	▨	25.0	▨	12.5	-
B 1	Monitoring	Darvill Sewage Works	▨	3.0	▨	(dry)	-
B 3	Monitoring	Darvill Sewage Works	▨	▨	▨	▨	-
B 4	Monitoring	Darvill Sewage Works	▨	15.0	▨	3.2	-

[1] bgl – below ground level

[2] SWL – static water level

▨ Data / information could not be confirmed

Table 1 (Continued): Darvill Constructed Wetland Hydrocensus Information

Borehole Number	Purpose	Owner	Borehole Age (years)	Borehole Depth (m)	Water Strikes (m bgl[1])	Historic SWL[2] (m bgl)	Yield (l/sec)
B 5	Monitoring	Darvill Sewage Works	▨	2.0	▨	▨	-
B 6	Monitoring	Darvill Sewage Works	▨	▨	▨	▨	-
C 1	Monitoring	Darvill Sewage Works	▨	3.5	▨	1.4	-
C 2	Monitoring	Darvill Sewage Works	▨	4.5	▨	2.5	-
C 3	Monitoring	Darvill Sewage Works	▨	25.0	▨	7.5	-
C 4	Monitoring	Darvill Sewage Works	▨	3.0	▨	2.0	-
C 5	Monitoring	Darvill Sewage Works	▨	▨	▨	▨	-
D 1	Monitoring	Darvill Sewage Works	▨	3.8	▨	(dry)	-
F 1	Monitoring	Darvill Sewage Works	▨	21.3	▨	12.0	-
F 2	Monitoring	Darvill Sewage Works	▨	38.0	▨	13.5	-
KZN110026	Production	Sobantu Community	3	114.0	66.0 & 101.0	7.7	0.28
2930CB00069	Production	▨	18	▨	▨	12.76	-

[1] bgl – below ground level

[2] SWL – static water level

▨ Data / information could not be confirmed

From the above table, the following can be determined:

- Boreholes of various depths have been installed in the areas surrounding the proposed Darvill Constructed Wetland.
- During drilling, water strikes were encountered at inconsistent depths, which is typical of a weathered and fractured rock aquifer.
- A shallow / perched (<10 m bgl) and deep (>10 m bgl) aquifer appear to be in existence in the general study area.
- Monitoring boreholes C2, C3 and C4, located closest to the proposed Darvill Constructed Wetland, have a historic SWL averaging 4.0 m bgl.
- Only two (2) of the fifteen (15) boreholes drilled to depth (>10 m) within a 2 km radius of the proposed Darvill Constructed Wetland had measureable groundwater yields, with these averaging 3.0 l/sec.

Photographs of the site and the performed activities are included in Appendix A.

During the hydrocensus, two (2) accessible boreholes, namely BH B and BH B 6, were further assessed. These boreholes were chosen as their locations are spatially diverse around the site in question, and they appear to tap the deep and shallow / perched aquifers respectively.

The data acquired during the field assessment is included in Table 2 below.

Table 2: Darvill Constructed Wetland Field Assessment Information

Borehole Number	Aquifer	SWL[1] (m bgl[2])	pH	EC[3] (mS/cm)	TDS[4] (ppm)	Temp. (°C)
BH B	Deep	27.25	6.7	6.90	441	21.5
BH B6	Shallow / Perched	4.92	5.5	4.92	486	20.1

[1] bgl – below ground level
[2] SWL – static water level
[3] EC – electrical conductivity
[4] TDS – total dissolved solids

As can be seen, when comparing historic and current SWLs in BH B, it is clear that, at least in the deep aquifer in proximity to this borehole, depth to groundwater levels have almost doubled as a result of the current drought conditions.

Groundwater samples were collected from each of these boreholes, and were submitted to the SANAS-accredited Talbot Laboratories for analysis according to the SANS 241: 2015 abbreviated suite of determinants to allow for the assessment of baseline water quality within the study area. The attained results are summarised in Appendix B, where they have been compared to the SANS 241: 2015 Standards for Drinking Water, given that there are groundwater supply boreholes in the general area. Note that the laboratory certificates of analysis are also included in Appendix B.

From the tabulated results, the following can be determined:

- Levels / concentrations of turbidity, iron (Fe), manganese (Mn) and standard plate count in the BH B sample exceed the chosen water quality standards, with the Fe and Mn concentrations, being highly elevated, this is however typical of groundwater quality in the study area.

- Levels / concentrations of turbidity, EC, nitrate (NO_3), sodium (Na), total coliforms and standard plate count in the BH B 6 sample exceed the chosen water quality standards. It is thought that the measured NO_3 concentrations and total coliforms levels in this shallow aquifer are attributable to the fact that processed effluent from the Darvill Sewage Works is land-farmed in the area in proximity to the site, by an independent grass-grower.

- Interestingly, the concentrations of calcium (Ca), Cl, magnesium (Mg), sulphate (SO4), total hardness and lead (Pb) are appreciably higher in the sample collected from BH B 6, which taps the shallow / perched aquifer.

The water quality data, although likely reflecting the impacts of anthropogenic sources, further suggests that there are two (2) distinct aquifers below the area, with the shallow / perched aquifer not necessarily recharging the deep aquifer over a short time scale. The proposed Darvill Constructed Wetland may obviously impact upon the shallow / perched aquifer, but possibly not the deep aquifer, given that which is currently known.

Finally, an existing point-source pollution source assessment was undertaken in proximity to the proposed site, with the findings detailed below (in order of possible severity):

- Darvill Sewage Works:

    - Any uncontained or incorrectly discharged Wastes from the Darvill Sewage Works may impact upon soil and groundwater, with a possible increase in NO_3, ammonia (NH_3), phosphate (PO_4), total coliforms, *E. Coli* and standard plate count occurring.

- Proximal grass-growing operation:

    - The land-farming of sewage from the Darvill Sewage Works, if undertaken incorrectly or in too great a quantity, might result in an increase in NO_3, NH_3 and PO_4 concentrations, and total coliforms, *E. Coli* and standard plate count, in the soil and groundwater environment.

- New England Road Landfill Site:

    - Any uncontained leachate, or other waste streams as resulting from the New England Road Landfill site, would like result in an increase in numerous determinant concentrations in the groundwater environment.

- Hollingwood Cemetery:

    - Should this cemetery site ultimately be utilised, then an increase in various determinant concentrations (as linked to human body decomposition), would possibly be evident in the soil and groundwater environment.

4. GEOTECHNICAL INVESTIGATION

Once the geohydrological investigation had been completed, a geotechnical investigation was undertaken across the area in which the proposed Darvill Constructed Wetland is to be developed.

4.1 SOIL PROFILING

Eleven (11) trial pits were excavated across the site with the assistance of a TLB, at the locations shown in the attached Site Plan – Dwg No. 2015/232 Figure 4. Note that the distribution and location of these trial pits was based upon an initial site plan, with given boundaries, as supplied to this office. The soil profiles exposed in these trial pits were logged in accordance with the Jennings, Brink and Williams Protocol for Geotechnical Profiling. The trial pit logs are included in Appendix C.

From the soil profiling exercise, the following was determined:

- The site is underlain by an upper loose, intact sandy (to clayey, in some areas) topsoil horizon, which generally averages less than 0.50 m in thickness, with varying horizons of medium dense, intact clayey to silty sands and firm, intact sandy clays thereunder.

- Refusal to TLB was encountered at a depth varying between 2.70 m below ground level (bgl) and 3.15 m bgl in the eastern half of the proposed site, whilst in the central areas, refusal had not been encountered down to a depth of 3.60 m.

- Refusal to TLB was encountered at a depth varying between 2.10 m below ground level (bgl) and 3.60 m bgl in the western half of the proposed site, whilst in the central-southern areas, refusal was reached at a depth of < 2.50 m.

- Trial pit TP 10 was excavated alongside a raised access road, and confirmed that said access road was constructed atop ~ 2.00 m of fill material, backfilled atop the previously-detailed loose, intact sandy (to clayey, in some areas) topsoil horizon.

- Finer-grained topsoil was encountered in the vicinity of trial pit TP 11, with clayey sand and sandy clay profiles extending to an appreciable (> 3.00 m) depth.

It should be noted that depth of refusal to TLB does not necessarily correlate with depth to competent bedrock, as the TLB often reached refusal on soft weathered bedrock (tilllite).

4.2 SOIL SAMPLING AND ANALYSIS

Three (3) representative soil samples were collected from across the site and were submitted for various analyses, as shown below in Table 3, to determine the selected physical properties of these materials.

Table 3: Darvill Constructed Wetland Samples Analyses

TP / Sample Number	Depth (m bgl)	Analyses Requirements
TP 6 – Sample 1	1.05 m – 1.85 m	Full Indicator Test + Natural MOD AASHTO + Permeability Test
TP 8 – Sample 2	1.85 m – 2.35 m	Full Indicator Test + Natural MOD AASHTO + Permeability Test
TP 11 – Sample 3	0.00 m – 0.55 m	Full Indicator Test + Natural MOD AASHTO + Permeability Test

[1] bgl – below ground level

The summarised soil parameters are shown in Table 4 overleaf, whilst the Laboratory Certificates are contained in Appendix B.

Table 4: Darvill Constructed Wetland Summarised Soil Parameters

Physical Properties	**TP 6** Sandy Clay	**TP 8** Silty Sand	**TP 11** Clayey Silt
AASHTO Soil Classification	A – 6	A – 6	A – 4
Liquid Limit	38	31.2	25
Plasticity Index	18.1	12.9	7.9
Linear Shrinkage	10.7	10.0	6.7
Potential Expansiveness	Low	Low	Low
Unified Classification	CL or OL	CL or OL	CL or OL
% Gravel	12.4	6.2	0.4
% Sand	29.4	34.8	23.8
% Silt	15.9	29.8	40.2
% Clay	42.3	29.2	35.6
Grading Modulus	0.68	0.59	0.27
D_{10}[#]	<0.002	<0.002	<0.002
MOD AASHTO Density (kg/m^3)	1749	1854	1839
Falling Head Permeability (m/day)	5.66×10^{-4}	5.57×10^{-5}	5.03×10^{-4}
Falling Head Permeability (m/year)	0.2066	0.0203	0.1836

[#] - Diameter (mm) at which 10% of the material passes through the sieve
* - Empirical value

From the above table, the following can be determined:

- The sandy clay and silty sand soils that underlie the site, in which the proposed Darvill Constructed Wetland is likely to be 'founded', are generally of intermediate / moderate plasticity, and are actually fairly similar with regards to texture and grain size, according to the various classifications.

- Soil densities measured across these two (2) soil types were fairly similar, whilst measured permeabilities varied by an order of magnitude. Somewhat surprisingly, the sandy clay soils exhibited the highest permeability, which may attest to secondary porosity.

- Similar dry densities were achieved when these two (2) soil types were re-compacted for the permeability tests, with the ratio thereof similar to that detailed above.

- The sandy to clayey topsoil, as represented by the third sample, is of low plasticity, and is also similar with regards to texture and grain size and density. Measured permeability values likely represent the lower end of the scale, given that sandier topsoil than that sampled was profiled across the site. Re-compaction during this process followed a similar pattern to that detailed above.

5. ANALYSIS OF INFORMATION AND RECOMMENDATIONS FOR DEVELOPMENT

Given the data and information detailed above, further analysis with respects to this project is undertaken below, whilst incorporating certain recommendations for development.

It should be noted that that which is discussed below, is, to a large extent, based upon the client-provided report entitled "*Darvill Wastewater Treatment Works: Wetland Habitat Creation Feasibility Report*" as prepared by GroundTruth and dated August 2014. Two (2) key points were initially noted from this report:

- A surface flow wetland has been proposed, and an initial design has been considered and suggested.

- This initial design shows that the off-take structure, from the existing concrete channel into the proposed constructed wetland, will be located in the vicinity of trial pit TP 9 (as excavated during this investigation), hence data as acquired from trial pit TP 10 and TP 11 only provides additional, possibly confirmatory information.

5.1 ASSESSMENT OF PROPOSED DESIGN

This office cannot comment on the finer details of the design, as proposed in the afore-mentioned report, however the available geohydrological and geotechnical data and information support the proposed design of a surface flow wetland, as is detailed below.

Note though, that if needs be, a subsurface flow design could also be considered, based upon that which is detailed above.

5.2 BULK EARTHWORKS

From the schematic cross-section design made available to this office, it would appear as though three (3) wetland cells have been incorporated into the design, with the base of each 1.5 m lower than that of the previous cell. This suggests that:

- An appreciable volume of soil will have to be removed during the construction of the proposed wetland.

- Depending upon topography, competent bedrock will hopefully not be reached during the excavation of these soils, although soft weathered rock may be. It should be noted though, that depth to refusal (to TLB) varies across the site.

During the geotechnical investigation, it was noted that the soils underlying the site in question were easily excavatable through mechanical means (TLB). Should the base of each cell not extend to competent bedrock, then the bulk earthworks involved as part of the construction of the wetland should progress relatively easily. However, should soft weathered rock (or possibly competent bedrock) be encountered during excavations, then the use of an excavator, or possibly ripping, may be required to reach the required depth. Note that said mechanical means may only be required across part of the site, where shallow depths to refusal were encountered.

When considering the thickness of the soil cover on-site, it becomes apparent that a surface flow wetland is preferable, as subsurface flow wetlands generally extend to greater depths.

5.3 SOIL PERMEABILITIES

As shown in Table 4 above, the permeabilities of the sampled soils are quite low. Note that the permeability of the topsoil may be higher than that shown, given that soil with a greater percentage of fines was sampled, as compared to that which is evident across the site.

The sandy clays and silty sands which occur at depth, and which will probably be found at the base of each cell, have a re-compacted falling head permeability of less than 0.21 m/year, which essentially renders them as impermeable. Of course it must be noted that in-situ permeabilities may be higher, due to 'fracturing' and secondary porosity. Regardless, should the base of each cell be 'founded' on or in these sandy clays or silty sands, then a membrane-type liner should not be required, as the soils will act as an essentially impermeable barrier.

However, should soft weathered rock (or possibly competent bedrock) be reached during excavations, and hence be present at the base of part of the cells, then it is recommended that some form of liner be incorporated. This liner can either take the form of a membrane, or the excavated sandy clays and silty sands can be re-compacted to 95% Mod AASHTO to form a 'clay' liner at least 0.30 m thick, whilst possibly incorporating bentonite into the soils. However, this should all be confirmed by the project civil / design engineer.

At this point it should be noted that although, during non-drought times, the shallow / perched aquifer is likely to be encountered at a depth not too far below the base of each cell, the current water quality thereof is poor (as previously detailed). Furthermore, it does not appear based on the information available that the shallow / perched aquifer and deep aquifer are linked. Hence based on the available information, the proposed constructed wetland does not pose an unacceptable risk to the receiving environment (including the deep aquifer).

5.4 SOIL TYPES

The types of soil, with respects to their possible 'use' on-site, have been partially detailed above, when considering 'clay' liners. The proposed design calls for impermeable berms to be constructed at different points throughout the site, and given the determined permeabilities, it is suggested that the sandy clays and silty sands excavated during the bulk earthworks be considered for use here. They too should be re-compacted to 95% Mod AASHTO, and should likely incorporate bentonite, although this should be confirmed by the project civil / design engineer.

Whilst subsurface flow wetlands typically require large volumes of gravel (which is not available on-site and would otherwise be expensive to import), surface flow wetlands can incorporate a wider variety of soil types. It is hence recommended that advice be sought on whether or not the soils on-site (including the topsoil), that will be excavated during the construction of the wetland, can be used as a medium in which the wetland vegetation can be grown. It is however likely based on the available information that they can be utilised for this purpose.

5.5 DEVELOPMENT AND MONITORING RECOMMENDATIONS

Should environmental authorization be received, and before construction commences, the following should be undertaken:

- A detailed geotechnical investigation should be undertaken across the site, so as to determine and contour depths to bedrock, rock rippability and other parameters / information as required by the project civil / design engineer, so that a full design can be finalised.

- As a form of best practice, it is recommended that the water resources in the vicinity of the Darvill Constructed Wetland be monitored once it is built. As the final design and footprint of the wetland is unknown, it is difficult to delineate monitoring points. However, at this stage, the following can be stated:

    - The Msunduzi River upstream and downstream of the proposed Darvill Constructed Wetland should be sampled regularly, with the collected samples analysed at a SANAS-accredited laboratory according to a suite as determined by a professional hydrologist. Note though, that regular surface water monitoring likely already occurs as part of the operations of the Darvill Sewage Works.

    - A limited number of shallow (< 10 m deep) monitoring wells should be installed around the western, northern and eastern perimeter of the proposed Darvill Constructed Wetland at locations to be based on the final design and footprint of the wetland, and once construction has been completed, so that they are not damaged by construction plant. Further to this, at least one (1) up-gradient and one (1) down-gradient deep (> 30 m deep) monitoring borehole should be installed to monitor the deep aquifer underlying the site. It is imperative that the design and installation of the shallow and deep monitoring boreholes be undertaken by, and supervised by, a qualified and experienced geohydrologist, so that cross-contamination of the shallow and deep aquifers does not occur.

- The installed shallow monitoring wells should be subjected to slug tests, whilst the deep monitoring wells should be subjected to either a slug test or a pump test (depending on their yield) under the supervision of a qualified and experienced geohydrologist. This will allow for the acquisition of hydraulic conductivity values for the shallow and deep aquifers underlying the site, which can in turn be utilised to determine groundwater travel times in shallow and deep aquifers underlying the site.

- Baseline groundwater samples should be collected before the wetland is built, and every six (6) months thereafter, for submission to a SANAS-accredited laboratory for analysis according to the SANS 241: 2015 suite of determinants. This will aid in determining whether or not the shallow aquifer is being impacted upon by the wetland (once built).

- A detailed geohydrological report should then be prepared based on the findings of these investigations, which should include the preparation of a conceptual site model and recommendations for the ongoing management / monitoring of the constructed wetland.

6. CONCLUSIONS

The following can be concluded from the above report:

- Geomeasure Group (Pty) Ltd. were appointed to undertake a geohydrological and geotechnical investigation for the proposed Darvill Constructed Wetland, to be located near the City of Pietermaritzburg.

- The site is located at an average elevation of approximately 705 m AMSL, whilst site drainage is in a westerly, northerly and easterly direction towards the Msunduzi River, which directly borders the northern portions of the site.

- The area is underlain by tillite and shale of the Dwyka Group and the Pietermaritzburg Formation of the Ecca Group respectively, which both form part of the Karoo Supergroup.

- Due to faulting and fracturing associated with the breakup of the ancient Gondwana super-continent, these units are reported to form a moderate potential aquifer with borehole yields in the range of > 0.5 l/sec – 3.0 l/sec, with groundwater reportedly of poor to moderate quality.

- A desktop and field hydrocensus identified a number of monitoring and groundwater supply boreholes within a 2 km radius of the site. The drought conditions currently being experienced has result in a measurable drop in SWLs as compared to historic values.

- Shallow / perched and deep aquifers appear to be in existence in the study area, with the former not necessarily recharging the latter over the short term. Water quality in the former is poor, likely as a result of the effluent land-farming practiced nearby.

- The site is underlain by an upper loose, intact sandy (to clayey, in some areas) topsoil horizon, which generally averages less than 0.50 m in thickness, with varying horizons of medium dense, intact clayey to silty sands and firm, intact sandy clays thereunder.

- Depths to TLB refusal (soft weathered rock) vary across the site, typically between 2.10 m and 3.60 m, whilst laboratory-determined permeabilities are quite low (less than 0.21 m/yr).

- The proposed design of a surface flow wetland is supported by the available data and information.

- Bulk earthworks should progress relatively easily across the site, however if soft weathered rock (or possibly competent bedrock) is encountered during excavations, then the use of an excavator, or possibly ripping, may be required.

- A re-compacted ‘clay’ liner, using material excavated from the site, or a membrane liner, will typically only be required at the base of each cell in the wetland should soft weathered rock (or possibly competent bedrock) be reached during excavations.

- Material excavated from the based on the findings of this investigation appears to be suitable to be re-compacted for use in the berms that are to be constructed as part of the development of the wetland, whilst said material can likely also be used as a medium in which to grow the wetland vegetation.
- A detailed geotechnical investigation should be undertaken once environmental authorization has been received, prior to construction commencing, under the guidance of the project civil / design engineer.

- As a form of best practice, it is recommended that the water resources in the vicinity of the Darvill Constructed Wetland be monitored once it is built. This will include installing and monitoring both shallow (< 10 m deep) and deep (>30 m deep) monitoring boreholes.

We trust that this report meets your immediate requirements in this matter. Please do not hesitate to contact the undersigned if you require any further information.

Yours faithfully,

Blondin

R Sebire
Project Geohydologist

K Gravelét-Blondin
Environmental Geologist

GEOMEASURE GROUP (Pty) Ltd

FIGURES

1 : 250 000 Digital Coverage from Chief Director: Surveys and Mapping

Legend:

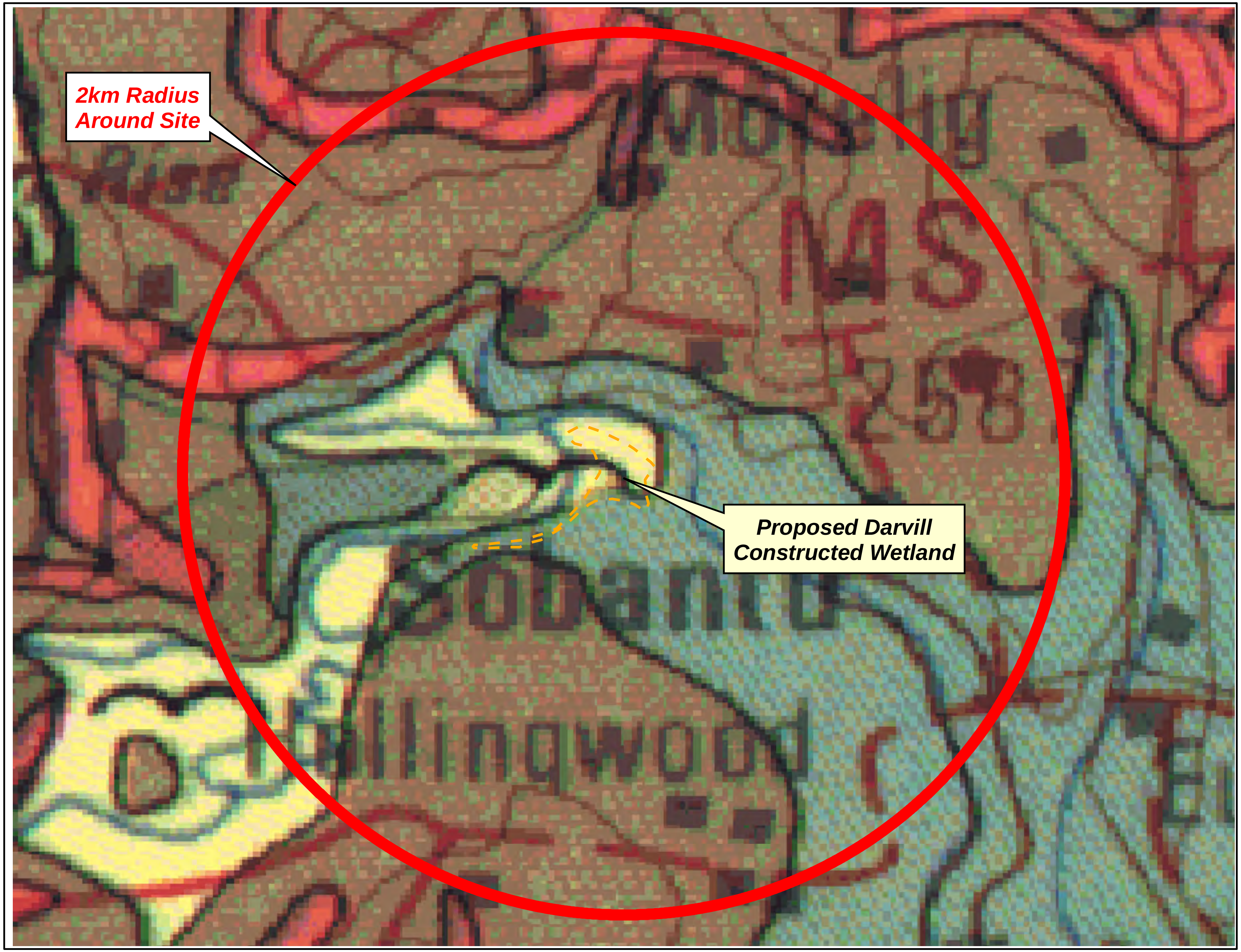
N

GEOMEASURE GROUP
Groundwater & Environmental Consultants

DARVILL CONSTRUCTED WETLAND INVESTIGATION

LOCALITY PLAN

DWG NO. 2015/232
FIGURE 1



Legend:

🟨	Quaternary Alluvium
Jd	Jurassic Dolerite
Pp	Pietermaritzburg Shale
CPd	Dwyka Tillite

1,2 0,6 0 1,2 2,4 3,6 Kilometers

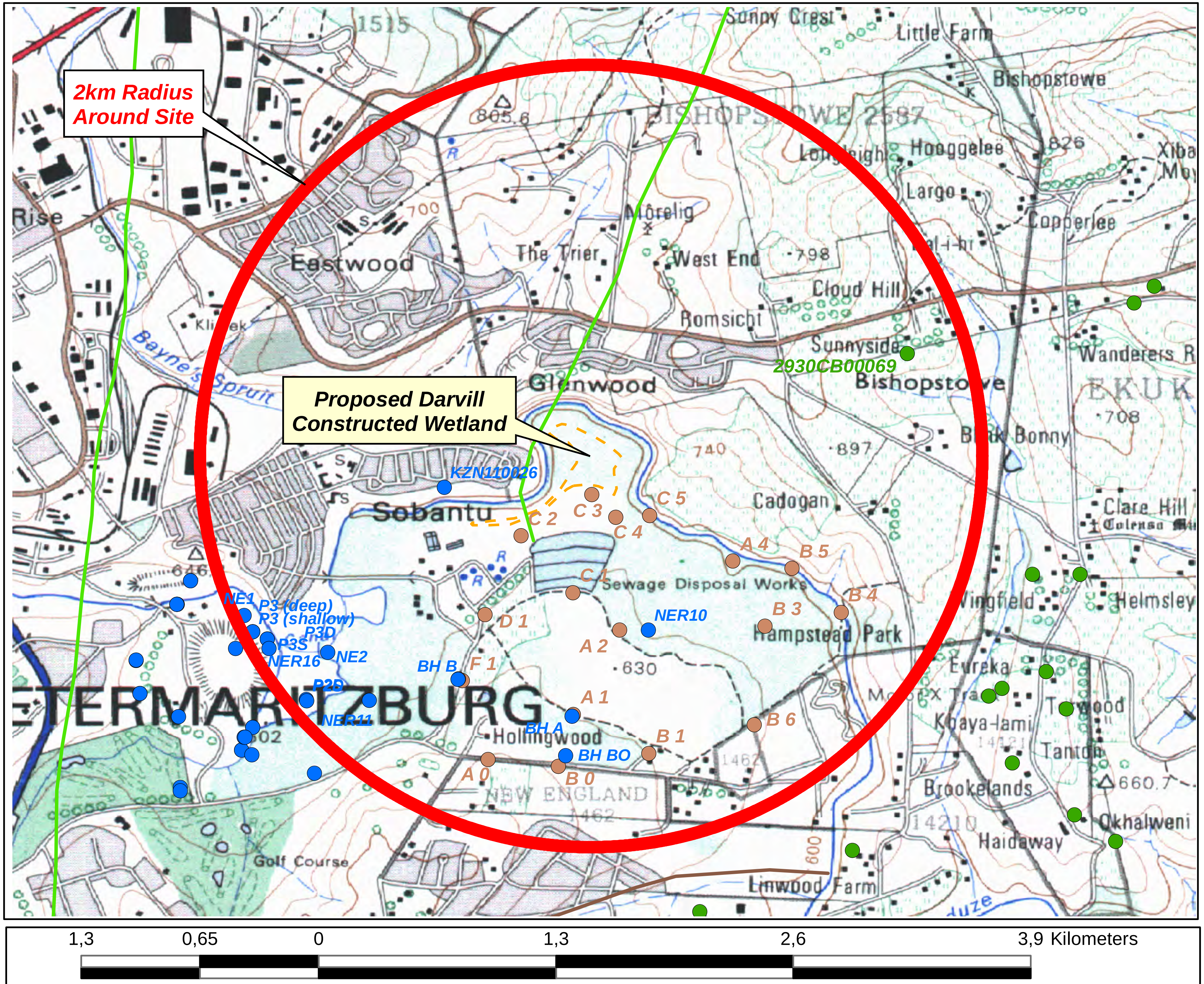
1 : 250 000 Digital Coverage from Chief Director: Surveys and Mapping

GEOMEASURE GROUP
Groundwater & Environmental Consultants

DARVILL CONSTRUCTED WETLAND INVESTIGATION

GEOLOGICAL PLAN

DWG NO. 2015/232
FIGURE 2



1 : 50 000 Digital Coverage from Chief Director: Surveys and Mapping

Legend:

N

- ● Additional BH Data
- ● Geom BH Data
- ● GRIP BH Data
- — Dolerite Dykes
- — Geological Faults
- — Lineaments

GEOMEASURE GROUP
Groundwater & Environmental Consultants

DARVILL CONSTRUCTED WETLAND INVESTIGATION

AREA PLAN SHOWING STRUCTURES & AVAILABLE HYDROCENSUS DATA

DWG NO. 2015/232
FIGURE 3

Legend:

△ Trial Pits

▭ Approximate Site Boundary

GEOMEASURE GROUP
Groundwater & Environmental Consultants

DARVILL CONSTRUCTED WETLAND INVESTIGATION

SITE PLAN

DWG NO. 2015/232
FIGURE 4

Digital Coverage from Google Earth 2015

APPENDIX A

PHOTOGRAPHIC REPORT

DARVILL CONSTRUCTED WETLAND GEOHYDROLOGICAL & GEOTECHNICAL INVESTIGATION PHOTOGRAPHIC REPORT

Plate 1: View of current treated effluent outflow from the Darvill Sewage Works into the Msunduzi River.

Plate 2: View of eastern area where the Darvill Constructed Wetland is to be constructed, beyond the outflow channel.

Plate 3: Existing Darvill Sewage Works monitoring borehole (C 3) just to the south of the site.

Plate 4: Monitoring and sampling of borehole B 6, located away to the south-east of the proposed site.

Plate 5: Treated effluent land-farming practices, to the south of the proposed site.

Plate 6: Excavation of trial pits during the geotechnical investigation, across the site.

APPENDIX B

TABULATED DATA AND LABORATORY CERTIFICATES OF ANALYSIS

ANALYTICAL ANALYSIS IN ACCORDANCE WITH SANS 241: 2015

PROJECT: DARVILL CONSTRUCTED WETLAND

DETERMINANT	**Risk**	**Units**	**Standard Limit**	**BH B**	**BH B 6**
PHYSICAL - WATER QUALITY					
pH	Operational	pH units	≥ 5.0 to ≤ 9.7	6.6	5.5
Colour	Aesthetic	mg/l Pt-Co	≤ 15	<1	7
Turbidity	Aesthetic	NTU	≤ 5	***864***	***49.9***
Conductivity	Aesthetic	mS/m	≤ 170	39	***368***
MACRO CHEMICAL - DETERMINANDS					
Calcium as Ca		mg/l	ns	19	325
Chloride as Cl	Aesthetic	mg/l	≤ 300	23	204
Fluoride as F	Chronic Health	mg/l	≤ 1.5	0.44	0.32
Magnesium as Mg		mg/l	ns	14	330
Nitrate / Nitrite as N	Acute Health - 1	mg/l	≤ 11	<0.1	***35***
Sodium as Na	Aesthetic	mg/l	≤ 200	32	***392***
Sulphate as SO4	Acute Health - 1	mg/l	≤ 500	11.7	218
Total Alkalinity as CaCO3		mg/l	ns	147	30
Total Hardness as CaCO3		mg/l	ns	105	812
MICRO CHEMICAL - DETERMINANDS					
Copper as Cu	Chronic Health	ug/l	≤ 2000	2.06	1.60
Lead as Pb	Chronic Health	ug/l	≤ 10	<1	6.92
Iron as Fe	Chronic Health	ug/l	≤ 2000	***99915***	802
Manganese as Mn	Chronic Health	ug/l	≤ 400	***2535***	161
MICROBIOLOGICAL - DETERMINANDS					
E. Coli	Acute Health - 1	Count / 100 ml	0	0	0
Total Coliforms	Operational	Count / 100 ml	≤ 10	0	***52***
Standard Plate Count	Operational	Count / 100 ml	≤ 1000	***> 10 000***	***1040***

Black - Within Standard Limits

Red - Exceeds Standard Limits

ns - not stated

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2015/11/19

ANALYTICAL REPORT

OUR REF:	**GEOMEASURE GROUP 18815/15** **(O/N: 2015/232)**
COMPANY NAME:	**GEOMEASURE GROUP**
CONTACT ADDRESS:	**P.O. BOX 1194, HILLCREST, 3650**
CONTACT PERSON:	**KENT GRAVELET-BLONDIN**
SAMPLE TYPE:	**BOREHOLE WATER**
DATE SUBMITTED:	**2015/11/09**

Determinand	**Units**	**Method No**	**SANS 241-1:2015 RECOMMENDED LIMITS**	**Results**	
				18815/15	18816/15
				BH B 2015/11/09	BH B6 2015/11/09
Chloride	mg Cl/l	16	< 300	23	204
Colour	mg Pt-Co/l	48	< 15	<1	7
Copper	µg Cu/l	83	< 2000	2.06	1.60
Dissolved calcium	mg Ca/l	8A	Not specified	19	325
Dissolved magnesium	mg Mg/l	9A	Not specified	14	330
E. coli	colonies per 100ml	31	0	0	0
Electrical conductivity at 25°C	mS/m	2	< 170	39	**368**
Fluoride	µg F/l	18A	< 1500	440	320
Iron	µg Fe/l	83	Chronic ≤2000 Aesthetic ≤300	**99 915**	802
Lead	µg Pb/l	83	< 10	<1	6.92
Manganese	µg Mn/l	83	Chronic ≤400 Aesthetic ≤100	**2 535**	161
Nitrate*	mg N/l	Calc.	< 11	0.14	**382**
Nitrite*	mg N/l	65	< 0.9	<0.1	<0.1
Combined Nitrate + Nitrite (sum of Ratios)*	-	-	<1	< 0.1	**35**
pH at 25°C	pH units	1A	5.0 - 9.7	6.6	5.5
Sodium	mg Na/l	6A	< 200	32	**392**
Standard plate count	colonies per ml	31	<1000	**>10 000**	**1 040**
Sulphate	mg SO_4/l	67	Acute Health ≤500 Aesthetic ≤250	11.7	218
Total alkalinity	mg $CaCO_3$/l	10	Not specified	147	30
Total coliforms	colonies per 100ml	31	<10	0	**52**
Total hardness*	mg $CaCO_3$/l	Calc.	Not specified	105	812
Turbidity	NTU	4	Operational ≤1 Aesthetic ≤5	**864**	**49.9**

Comments:
The parameters tested on the sample submitted (lab number 18815/15) conform to the SANS 241:2015 requirements for drinking water, with the exception of iron, manganese, standard plate count, and turbidity.

The iron content of the water is excessive and at this concentration would cause chronic health effects, staining of clothes and objectionable taste and appearance.

At these levels, manganese causes off-putting tastes and brown discolouration of the water. Severe staining of clothes and fixtures can occur.

Due to the absence of organisms of sanitary significance this sample is satisfactory bacteriologically. However, if any form of disinfection is currently being undertaken a standard plate count exceeding 100 counts per ml indicates failure in the system. This should be investigated.

The turbidity of the water exceeds the SANS limit of <5 NTU and is one of the indirect indicators of microbiological water quality and of inefficient water treatment. The presence of turbidity in water results in a cloudy or muddy appearance, and may also affect taste and colour of the water.

The total hardness indicates that this water is slightly hard where lathering of soap would become slightly impaired. Further to this, slight scaling of kettles will also occur at these levels.

The parameters tested on the sample submitted (lab number 18816/15) conform to the SANS 241:2015 requirements for drinking water, with the exception of electrical conductivity, nitrate, combined nitrate + nitrite (sum of ratios), sodium, standard plate count, total coliforms and turbidity.

This nitrate result is excessive and exceeds the SANS 241 specification of 11 mg N/l. This water cannot be recommended for drinking. High nitrate causes methaemoglobanaemia, which reduces the oxygen carrying capacity of the blood. This especially affects young children and the aged.

The sodium content of the water exceeds the SANS limit of 200 mg Na/l but is less than 400 mg Na/l after which a slightly salty taste would be experienced. Excessive intake of sodium salts can cause possible health risks, particularly in sensitive health groups and excessive sodium in the water can impart a salty taste to the water.

The presence of coliforms shows contamination from soil or vegetation which may become more serious after rain. The water is of doubtful quality and cannot be recommended for drinking unless properly disinfected.

The turbidity of the water exceeds the SANS limit of <5 NTU and is one of the indirect indicators of microbiological water quality and of inefficient water treatment. The presence of turbidity in water results in a cloudy or muddy appearance, and may also affect taste and colour of the water.

The total hardness indicates that this water is excessively hard. Excessive total hardness is associated with scaling problems in pipes and hot water appliances, marked effects in taste and lathering very severely impaired.

In order to deem the water suitable for drinking, the complete SANS 241:2015 suite needs to be tested.

Note: All comments were made on the assumption that sampling was performed correctly.

Technical Signatory: Chemistry________________________________ Bacteriology_______________________________

- This report relates only to the samples tested. This report shall not be reproduced, except in full, without the written approval of **TALBOT LABORATORIES.**
- Tests marked with an asterisk (*) in this report are not SANAS accredited and are not included in the Schedule of Accreditation for our laboratory.
- Opinions and interpretations expressed herein are outside the scope of SANAS accreditation.
- Note: Results marked with a double asterisk (**) have been sub-contracted to a peer laboratory.
- Note: Estimates of Uncertainty of Measurement may be obtained from the laboratory if required.

APPENDIX
UNCERTAINTY OF MEASUREMENT

Determinand	Method No	Uncertainty of Measurement (%)	Determinand	Method No	Uncertainty of Measurement (%)
Ammonia	64	± 4.80	Mercury (ICP-MS)	83	± 12.00
Aluminium (ICP-MS)	83	± 13.23	Molybdenum (ICP-MS)	83	± 9.50
Antimony (ICP-MS)	83	± 11.16	Nickel (AAS)	55A	± 3.80
Arsenic (ICP-MS)	83	± 10.56	Nickel (ICP-MS)	83	± 10.63
Barium (ICP-MS)	83	± 9.81	Nitrate/Nitrite	65	± 4.79
Beryllium (ICP-MS)	83	± 9.07	Orthophosphate	66	± 4.80
Boron (ICP-MS)	83	± 12.93	Oxygen Absorbed	39	± 4.40
Cadmium (ICP-MS)	83	± 10.10	Potassium (AAS)	7A	± 5.60
Calcium (AAS)	8A	± 2.56	pH at 25°C (Radiometer)	1	± 1.36
Chromium (ICP-MS)	83	± 8.96	pH Value 25°C (Eutech)	1A	± 1.12
Cobalt (ICP-MS)	83	± 8.91	Selenium (ICP-MS)	83	± 14.60
Copper (AAS)	24A	± 4.20	Silver (ICP-MS)	83	± 18.59
Copper (ICP-MS)	83	± 12.79	Sodium (AAS)	6A	± 5.08
Chemical Oxygen Demand	3	± 3.71	Strontium (ICP-MS)	83	± 8.18
Chloride	16	± 2.80	Sulphate	67	± 3.87
Electrical Conductivity at 25°C	2	± 2.74	Suspended Solids at 105°C	5	± 4.08
Fluoride (Lovibond)	18	± 4.82	Thallium (ICP-MS)	83	± 9.33
Fluoride (MultiDirect)	18A	± 4.10	Tin (ICP-MS)	83	± 10.21
Hexavalent Chromium	68	± 6.67	Titanium (ICP-MS)	83	± 15.52
Iron (AAS)	20A	± 6.20	Total Alkalinity	10	± 2.36
Iron (ICP-MS)	83	± 15.42	Total Dissolved Solids at 180°C	41	± 1.25
Lead (AAS)	26A	± 3.80	Total Solids at 105°C	59	± 0.44
Lead (ICP-MS)	83	± 10.06	Turbidity	4	± 1.70
Lithium (ICP-MS)	83	± 11.86	Uranium (ICP-MS)	83	± 7.95
Magnesium (AAS)	9A	± 5.15	Vanadium (ICP-MS)	83	± 11.15
Manganese (AAS)	19A	± 5.20	Zinc (AAS)	23A	± 4.63
Manganese (ICP-MS)	83	± 9.38	Zinc (ICP-MS)	83	± 15.13

Note: The Uncertainty of Measurement is calculated as a percentage and should be applied to the respective results.

For ICP elements, the UoM applies to total, dissolved and acid soluble metals.

Estimates of Uncertainty of Measurement for microbiological analyses can be provided on request.

Laboratory Test Summary

THEKWINI SOILS LAB. CC

Job Description: Darvill - Ref. 2015/232
Job no.: 7953
Date: 17-12-2015

Lab no.			11145	11146	11147							
Location			TP 6	TP 8	TP 11							
Depth			1.05 - 1.85	1.35 - 1.85	0.0 - 0.55							
Description			-	-	-							
			-	-	-							
Binder Material			-	-	-							
Particle Size (mm)	75	Cumulative % Passing										
	53											
	37.5											
	26.5											
	19		100	100								
	13.2		93	98								
	9.5		89	97								
	4.75		89	96	100							
	2		88	94	100							
	0.425		81	86	96							
	0.25		75	80	91							
	0.15		70	73	86							
	0.075		64	62	77							
Hydrometer	0.05	% Passing	54	57	75							
	0.02		51	46	58							
	0.005		46	36	45							
	0.002		42	29	36							
Soil Mortar	Coarse Sand <2.0 >0.425mm	% Passing	7.9	8.5	3.5							
	Fine Sand <0.425>0.05mm		42.0	39.1	24.3							
	Silt <0.05 >0.005		8.0	19.8	28.4							
	Clay <0.005		42.2	32.6	43.8							
Atterberg Limits	Liquid Limit % (m/m)		38	31.2	25							
	Plasticity Index		18.1	12.9	7.9							
	Linear Shrinkage %		10.7	10	6.7							
	Natural MC %		-	-	-							
Mod AASHTO Density	Dry Density kg/m^3		1749	1854	1839							
	OMC %		16.4	10.9	12							
CBR	100% MDD											
	98%											
	95%											
	93% (Inferred) *											
	90%											
	CBR Swell (%)											
AASHTO Soil Classification *			A - 6 (9)	A - 6 (6)	A - 4 (4)							
Grading Modulus			0.68	0.59	0.27							
TRH 14 (1985) *												

Signature: ....
Title: ....

TEST REPORT

MATERIALS ANALYSIS

THEKWINI SOILS LAB. CC

Project: Darvill - Ref. 2015/232

Ref no.: 7953 **Lab no.:** 11145 **Borehole/Pit no.:** TP 6 **Fig no.:** -

Description: -

Depth: 1.05 - 1.85 -

Test Methods: TMH1 METHOD A1(a), A2, A3 & A4, ASTMD422

Grading Analysis	
Grain Size (mm)	%Passing
75	100.0
53	100.0
37.5	100.0
26.5	100.0
19	100.0
13.2	92.6
9.5	89.5
4.75	88.7
2	87.6
0.425	80.8
0.25	75.2
0.15	70.0
0.075	63.9
0.05	54.4
0.02	50.9
0.005	45.8
0.002	42.3

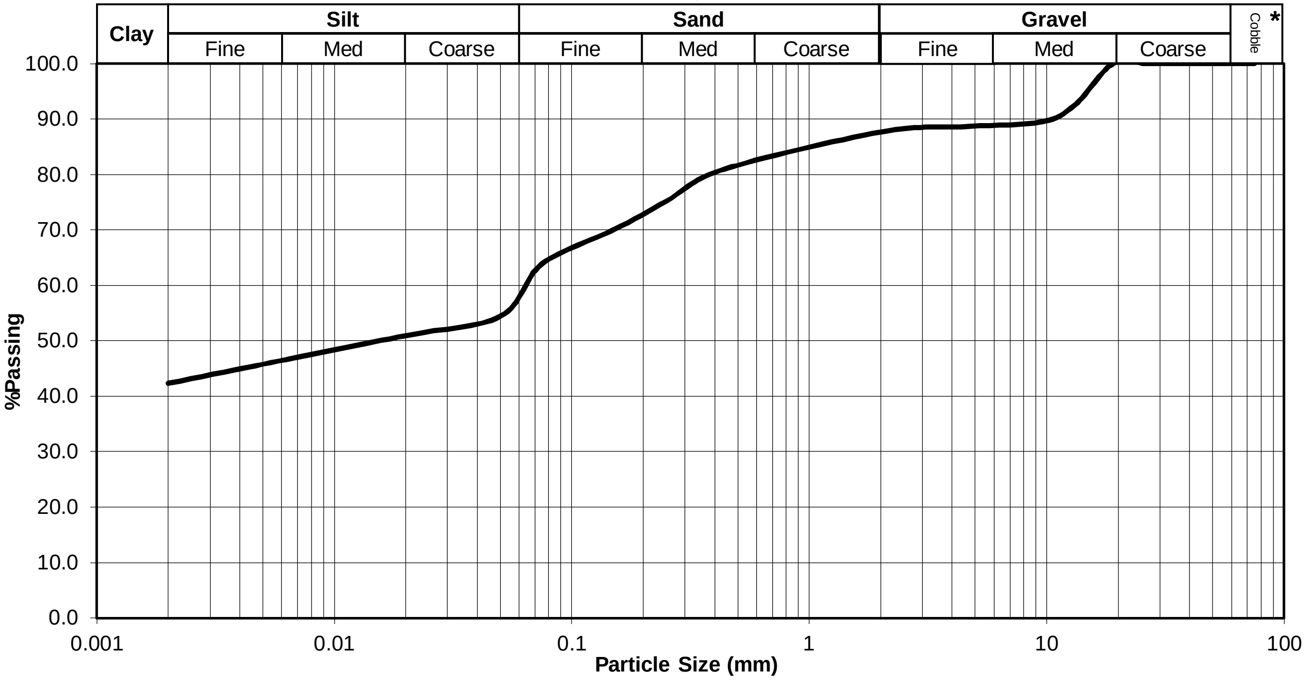
M.I.T SIZE CLASSIFICATION		*
Cobble%		0.0
Gravel%	12.4	
Coarse		0.0
Medium		11.1
Fine		1.3
Sand%	29.4	
Coarse		6.1
Medium		8.9
Fine		14.4
Silt%	15.9	
Coarse		7.3
Medium		4.8
Fine		3.8
Clay%	42.3	

PLASTICITY	
Liquid Limit, %	38
Plasticity Index	18.1
Linear Shrinkage, % (L/L)	10.7

GRADING	
D10 Size (mm)	<0.002
Uniformity Coefficient	*
Grading Modulus	0.68

CLASSIFICATION	*
Potential Expansiveness	Low
Group Index	9
AASHTO Soil Classification	A - 6
Unified Classification	CL or OL

Grading Curve



Ref no.: 7953 Fig no.: -

* Information marked with an asterisk is outside the scope of Accreditation.
The results only relate to the samples tested.
The report may not be reproduced except in full.

TEST REPORT

MATERIALS ANALYSIS

THEKWINI SOILS LAB. CC

Project: Darvill - Ref. 2015/232

Ref no.: 7953 **Lab no.:** 11146 **Borehole/Pit no.:** TP 8 **Fig no.:** -
Description: -
Depth: 1.35 - 1.85 -

Test Methods: TMH1 METHOD A1(a), A2, A3 & A4, ASTMD422

Grading Analysis	
Grain Size (mm)	%Passing
75	100.0
53	100.0
37.5	100.0
26.5	100.0
19	100.0
13.2	97.9
9.5	97.4
4.75	96.4
2	93.8
0.425	85.8
0.25	80.1
0.15	72.9
0.075	61.6
0.05	57.3
0.02	46.5
0.005	35.7
0.002	29.2

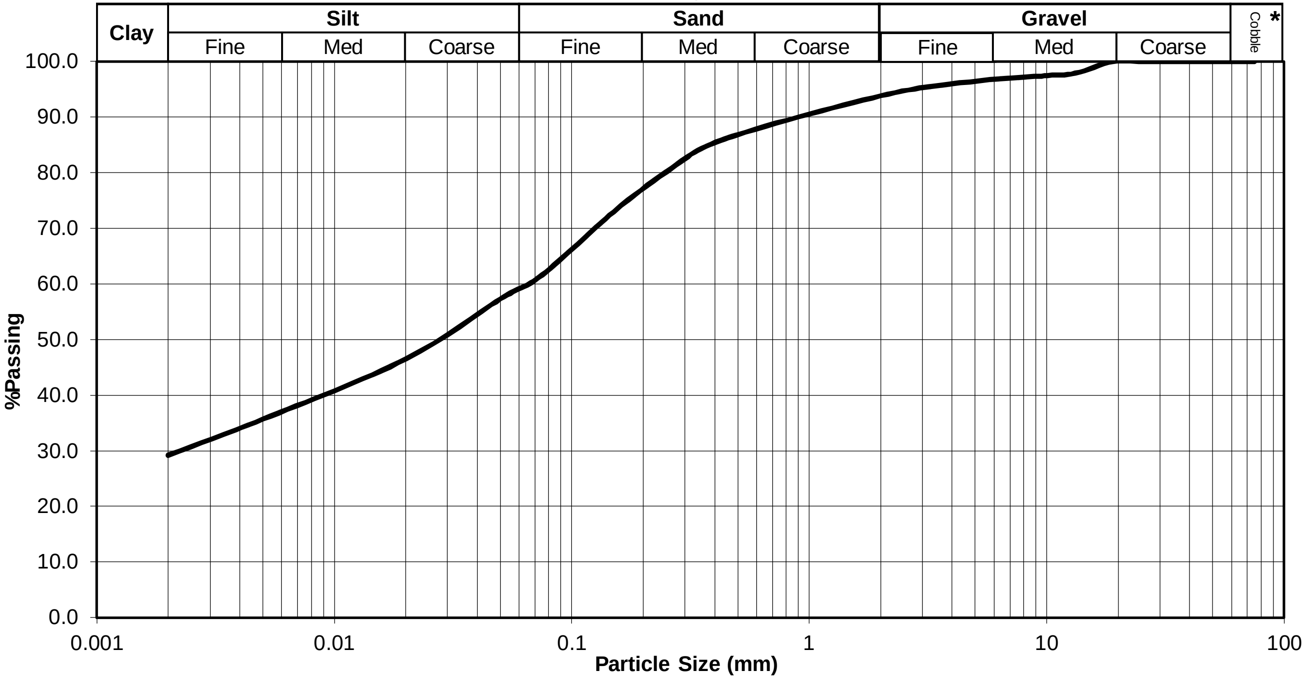
M.I.T SIZE CLASSIFICATION		*
Cobble%		0.0
Gravel%	6.2	
Coarse		0.0
Medium		3.4
Fine		2.8
Sand%	34.8	
Coarse		7.1
Medium		10.2
Fine		17.5
Silt%	29.8	
Coarse		12.5
Medium		10.1
Fine		7.2
Clay%	29.2	

PLASTICITY	
Liquid Limit	31.2
Plasticity Index	12.9
Linear Shrinkage	10

GRADING	
D10 Size (mm)	<0.002
Uniformity Coefficient	NA
Grading Modulus	0.59

CLASSIFICATION	*
Potential Expansiveness	Low
Group Index	6
AASHTO Soil Classification	A - 6
Unified Classification	CL or OL

Grading Curve



Ref no.: 7953 Fig no.: -

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TEST REPORT

MATERIALS ANALYSIS

THEKWINI SOILS LAB. CC

Project: Darvill - Ref. 2015/232

Ref no.: 7953 **Lab no.:** 11147 **Borehole/Pit no.:** TP 11 **Fig no.:** -
Description: -
Depth: 0.0 - 0.55 -

Test Methods: TMH1 METHOD A1(a), A2, A3 & A4, ASTMD422

Grading Analysis	
Grain Size (mm)	%Passing
75	100.0
53	100.0
37.5	100.0
26.5	100.0
19	100.0
13.2	100.0
9.5	100.0
4.75	100.0
2	99.6
0.425	96.1
0.25	91.5
0.15	85.6
0.075	77.3
0.05	74.8
0.02	57.7
0.005	45.4
0.002	35.6

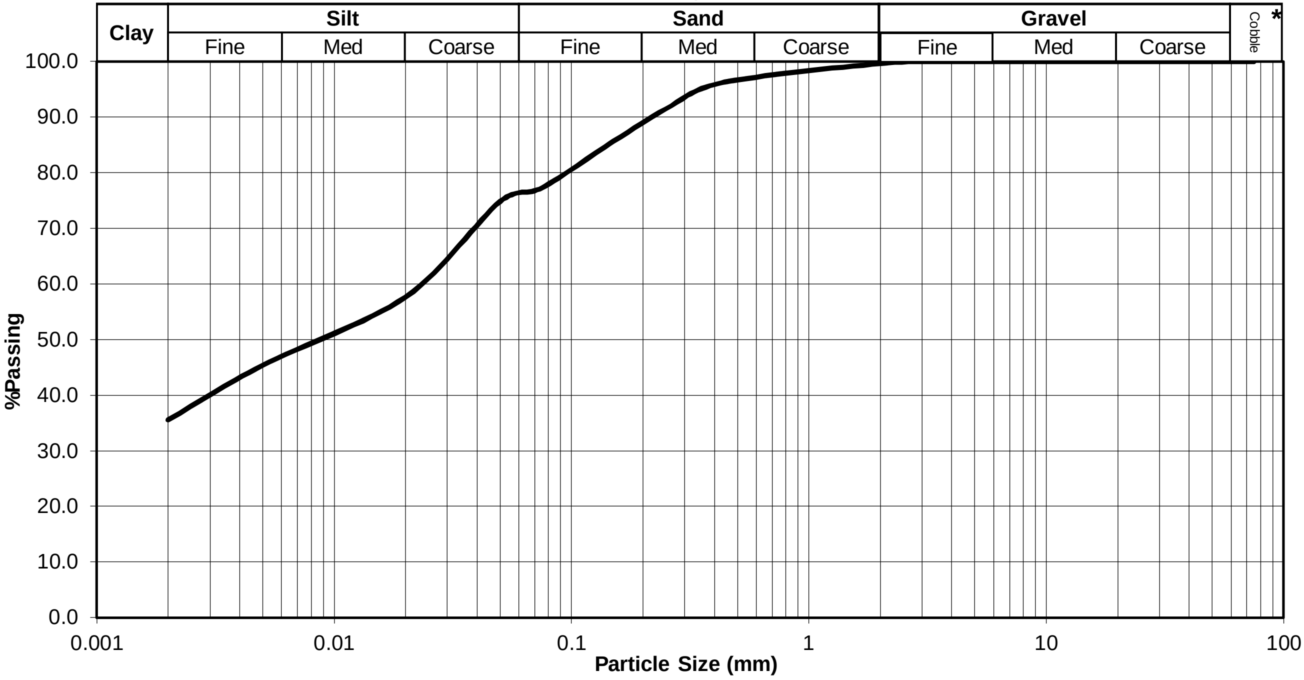
M.I.T SIZE CLASSIFICATION		*
Cobble%		0.0
Gravel%	0.4	
Coarse		0.0
Medium		0.0
Fine		0.4
Sand%	23.8	
Coarse		3.1
Medium		8.0
Fine		12.7
Silt%	40.2	
Coarse		18.2
Medium		11.4
Fine		10.6
Clay%	35.6	

PLASTICITY	
Liquid Limit	25
Plasticity Index	7.9
Linear Shrinkage	6.7

GRADING	
D10 Size (mm)	<0.002
Uniformity Coefficient	NA
Grading Modulus	0.27

CLASSIFICATION	*
Potential Expansiveness	Low
Group Index	4
AASHTO Soil Classification	A - 4
Unified Classification	CL or OL

Grading Curve



Ref no.: 7953 Fig no.: -

* Information marked with an asterisk is outside the scope of Accreditation.
The results only relate to the samples tested.
The report may not be reproduced except in full.

Falling Head Permeability

THEKWINI SOILS LAB. CC
V.A.T REGISTRATION NO. [illegible]

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Tel : (031) 201-8992

P.O. Box 30464,
MAYVILLE, 4058
Fax : (031) 201-7920

Date : 17-12-2015

Ref : 7953

Client : Geomeasure Group

Project : Darvill - Ref. 2015/232

Laboratory Number	Sample Number	Proctor MOD kg/m^3	OMC %	Recompacted Dry Density Kg/m^3	Permeability k = cm/sec
11145	-	1749	16.4	1661	6.556×10^{-7}
11146	-	1854	10.9	1761	6.448×10^{-8}
11147	-	1839	12.0	1747	5.816×10^{-8}

APPENDIX C

TRIAL PIT LOGS

TRIAL PIT LITHOLOGICAL LOG

Depth (m bgl)	Lithology Profile	Lithology Log	GW Seepage (m bgl)	Roots (m bgl)	Termites (m bgl)	Samples (m bgl)	Frontwall Photograph
0 0,3	Soil - Sand	Dry, light brown-grey, loose, intact SAND		*Roots*			(A frontwall photograph of the soil profile was not taken, given that entrance to the trial pit was not allowed)
0,6 0,9 1,2	Soil - Sand	Dry, brown-orange, medium dense, intact clayey SAND with occasional cobbles					
1,5	Soil - Sand	Slightly moist, orange-brown speckled black, medium dense, intact silty SAND					
1,8 2,1 2,4 2,7	Soil - Clay	Slightly moist, tan-orange streaked brown, firm, intact to laminated, sandy CLAY with residual weathered TILLITE					

PROJECT: Darvill Constructed Wetland **JOB NO:** 2015/232

DATE EXCAVATED: 20/11/2015 **TP NO:** TP 1 **LOGGED BY:** Kent Gravelet-Blondin

CONTRACTOR: Scotty's **MACHINE:** New Holland **OPERATOR:** Welcome

TP CO-ORDINATES: 29 35' 45.78'' S / 30 26' 15.75'' E

GEOMEASURE GROUP
Groundwater & Environmental Consultants

NOTE: Trial Pit Reached Refusal

TRIAL PIT LITHOLOGICAL LOG

Depth (m bgl)	Lithology Profile	Lithology Log	GW Seepage (m bgl)	Roots (m bgl)	Termites (m bgl)	Samples (m bgl)	Frontwall Photograph
0	Soil - Sand	Dry, light brown-grey, loose, intact SAND		*Roots*			(A frontwall photograph of the soil profile was not taken, given that entrance to the trial pit was not allowed)
0,3 0,6	Soil - Sand	Slightly moist, dark brown, loose to medium dense, intact SAND					
0,9 1,2	Soil - Sand	Slightly moist, red-brown speckled black, medium dense, intact silty SAND					
1,5 1,8 2,1	Soil - Clay	Dry, tan-beige orange, firm, intact, sandy CLAY with occasional ferricrete					
2,4 2,7	Soil - Clay	Slightly moist, tan-orange streaked brown, firm, intact to laminated, sandy CLAY with residual weathered TILLITE					
3							

PROJECT: Darvill Constructed Wetland

JOB NO: 2015/232

DATE EXCAVATED: 20/11/2015

TP NO: TP 2

LOGGED BY: Kent Gravelet-Blondin

CONTRACTOR: Scotty's

MACHINE: New Holland

OPERATOR: Welcome

TP CO-ORDINATES: 29 35' 43.27" S / 30 26' 15.68" E

GEOMEASURE GROUP
Groundwater & Environmental Consultants

NOTE: Trial Pit Reached Refusal

TRIAL PIT LITHOLOGICAL LOG

Depth (m bgl): 0, 0,3, 0,6, 0,9, 1,2, 1,5, 1,8, 2,1, 2,4, 2,7, 3

Lithology Profile	Lithology Log	GW Seepage (m bgl)	Roots (m bgl)	Termites (m bgl)	Samples (m bgl)
Soil - Sand	Slightly moist, light brown, loose, intact SAND		*Roots*		
Soil - Sand	Slightly moist, red-brown, loose to medium dense, intact silty SAND				
Soil - Sand	Slightly moist,brown blotched beige-grey, medium dense, intact clayey SAND				
Soil - Clay	Slightly moist, orange-beige blotched red-brown, firm, intact to laminated, sandy CLAY with residual weathered TILLITE				

Frontwall Photograph

(A frontwall photograph of the soil profile was not taken, given that entrance to the trial pit was not allowed)

PROJECT: Darvill Constructed Wetland

JOB NO: 2015/232

DATE EXCAVATED: 20/11/2015

TP NO: TP 3

LOGGED BY: Kent Gravelet-Blondin

CONTRACTOR: Scotty's

MACHINE: New Holland

OPERATOR: Welcome

TP CO-ORDINATES: 29 35' 41.82" S / 30 26' 18.93" E

NOTE: Trial Pit Reached Refusal

GEOMEASURE GROUP
Groundwater & Environmental Consultants

TRIAL PIT LITHOLOGICAL LOG

Depth (m bgl)	Lithology Profile	Lithology Log	GW Seepage (m bgl)	Roots (m bgl)	Termites (m bgl)	Samples (m bgl)	Frontwall Photograph
0	Soil - Clay	Dry, light brown-grey, soft, silty CLAY		*Roots*			(A frontwall photograph of the soil profile was not taken, given that entrance to the trial pit was not allowed)
0,3 0,6 0,9 1,2	Soil - Sand	Slightly moist, red-brown, loose to medium dense, intact silty SAND					
1,5 1,8	Soil - Sand	Slightly moist,brown blotched beige-grey, medium dense, intact clayey SAND					
2,1 2,4	Soil - Sand	Dry, red-brown blotched grey-black, medium dense, intact to laminated silty SAND					
2,7 3 3,3 3,6	Soil - Clay	Slightly moist, red-orange brown, firm, intact to laminated, sandy CLAY					

PROJECT: Darvill Constructed Wetland

JOB NO: 2015/232

DATE EXCAVATED: 20/11/2015

TP NO: TP 4

LOGGED BY: Kent Gravelet-Blondin

CONTRACTOR: Scotty's

MACHINE: New Holland

OPERATOR: Welcome

TP CO-ORDINATES: 29 35' 40.56" S / 30 26' 13.61" E

NOTE: Trial Pit Did Not Reach Refusal

GEOMEASURE GROUP
Groundwater & Environmental Consultants

TRIAL PIT LITHOLOGICAL LOG

Depth (m bgl)	Lithology Profile	Lithology Log	GW Seepage (m bgl)	Roots (m bgl)	Termites (m bgl)	Samples (m bgl)	Frontwall Photograph
0 0,3 0,6	Soil - Sand	Dry, grey-brown, loose, intact SAND		*Roots*			
0,9 1,2 1,5	Soil - Clay	Dry, tan-orange beige, firm, intact sandy CLAY					(A frontwall photograph of the soil profile was not taken, given that entrance to the trial pit was not allowed)
1,8 2,1	Soil - Clay	Dry, yellow-orange beige, firm, intact, sandy CLAY with residual weathered TILLITE					

PROJECT: Darvill Constructed Wetland

JOB NO: 2015/232

DATE EXCAVATED: 20/11/2015 **TP NO:** TP 5 **LOGGED BY:** Kent Gravelet-Blondin

CONTRACTOR: Scotty's **MACHINE:** New Holland **OPERATOR:** Welcome

TP CO-ORDINATES: 29 35' 39.66" S / 30 26' 10.64" E

NOTE: Trial Pit Reached Refusal

GEOMEASURE GROUP
Groundwater & Environmental Consultants

TRIAL PIT LITHOLOGICAL LOG

Depth (m bgl)	Lithology Profile	Lithology Log	GW Seepage (m bgl)	Roots (m bgl)	Termites (m bgl)	Samples (m bgl)	Frontwall Photograph
0 0,3 0,6 0,9	Soil - Sand	Dry, grey, very loose to loose, intact SAND		*Roots*			(A frontwall photograph of the soil profile was not taken, given that entrance to the trial pit was not allowed)
1,2 1,5 1,8	Soil - Clay	Slightly moist, red-brown, firm, intact sandy CLAY				*Sample 1*	
2,1 2,4 2,7 3 3,3 3,6	Soil - Clay	Moist, yellow-orange speckled red-black, firm, intact to laminated, sandy CLAY with residual weathered SHALE					

PROJECT: Darvill Constructed Wetland **JOB NO:** 2015/232

DATE EXCAVATED: 20/11/2015 **TP NO:** TP 6 **LOGGED BY:** Kent Gravelet-Blondin

CONTRACTOR: Scotty's **MACHINE:** New Holland **OPERATOR:** Welcome

TP CO-ORDINATES: 29 35' 37.84" S / 30 26' 07.43" E

NOTE: Trial Pit Reached Refusal

GEOMEASURE GROUP
Groundwater & Environmental Consultants

TRIAL PIT LITHOLOGICAL LOG

Depth (m bgl)	Lithology Profile	Lithology Log	GW Seepage (m bgl)	Roots (m bgl)	Termites (m bgl)	Samples (m bgl)	Frontwall Photograph
0 0,3	Soil - Sand	Dry, grey, loose, intact SAND		*Roots*			
0,6	Soil - Sand	Dry, grey, medium dense to dense, intact silty SAND					
0,9 1,2 1,5 1,8	Soil - Clay	Slightly moist, yellow-orange blotched grey-brown, firm, intact sandy CLAY					(A frontwall photograph of the soil profile was not taken, given that entrance to the trial pit was not allowed)
2,1 2,4 2,7	Soil - Clay	Slightly moist, yellow-orange, firm, intact to laminated, silty CLAY with residual weathered TILLITE					
3							

PROJECT: Darvill Constructed Wetland **JOB NO:** 2015/232

DATE EXCAVATED: 20/11/2015 **TP NO:** TP 7 **LOGGED BY:** Kent Gravelet-Blondin

CONTRACTOR: Scotty's **MACHINE:** New Holland **OPERATOR:** Welcome

TP CO-ORDINATES: 29 35' 43.27" S / 30 26' 10.68" E

NOTE: Trial Pit Reached Refusal

GEOMEASURE GROUP
Groundwater & Environmental Consultants

TRIAL PIT LITHOLOGICAL LOG

Depth (m bgl)	Lithology Profile	Lithology Log	GW Seepage (m bgl)	Roots (m bgl)	Termites (m bgl)	Samples (m bgl)	Frontwall Photograph
0 0,3	Soil - Sand	Dry, grey, loose, intact SAND		*Roots*			(A frontwall photograph of the soil profile was not taken, given that entrance to the trial pit was not allowed)
0,6 0,9 1,2	Soil - Sand	Dry, grey, medium dense to dense, intact silty SAND					
1,5 1,8	Soil - Sand	Slightly moist, yellow-orange blotched grey-brown, medium dense, intact clayey SAND					
2,1 2,4	Soil - Sand	Slightly moist, yellow-orange, medium dense, intact to laminated, silty SAND				*Sample 2*	

PROJECT: Darvill Constructed Wetland

JOB NO: 2015/232

DATE EXCAVATED: 20/11/2015

TP NO: TP 8

LOGGED BY: Kent Gravelet-Blondin

CONTRACTOR: Scotty's

MACHINE: New Holland

OPERATOR: Welcome

TP CO-ORDINATES: 29 35' 46.34" S / 30 26' 10.46" E

NOTE: Trial Pit Reached Refusal

GEOMEASURE GROUP
Groundwater & Environmental Consultants

TRIAL PIT LITHOLOGICAL LOG

Depth (m bgl)	Lithology Profile	Lithology Log	GW Seepage (m bgl)	Roots (m bgl)	Termites (m bgl)	Samples (m bgl)	Frontwall Photograph
0	Soil - Sand	Dry, light grey-brown, loose, intact SAND		*Roots*			(A frontwall photograph of the soil profile was not taken, given that entrance to the trial pit was not allowed)
0,3 0,6	Soil - Sand	Dry, brown, medium dense, intact clayey SAND					
0,9 1,2	Soil - Clay	Slightly moist, yellow-orange, firm to laminated, intact silty CLAY with residual weathered TILLITE					

PROJECT: Darvill Constructed Wetland

JOB NO: 2015/232

DATE EXCAVATED: 20/11/2015

TP NO: TP 9

LOGGED BY: Kent Gravelet-Blondin

CONTRACTOR: Scotty's

MACHINE: New Holland

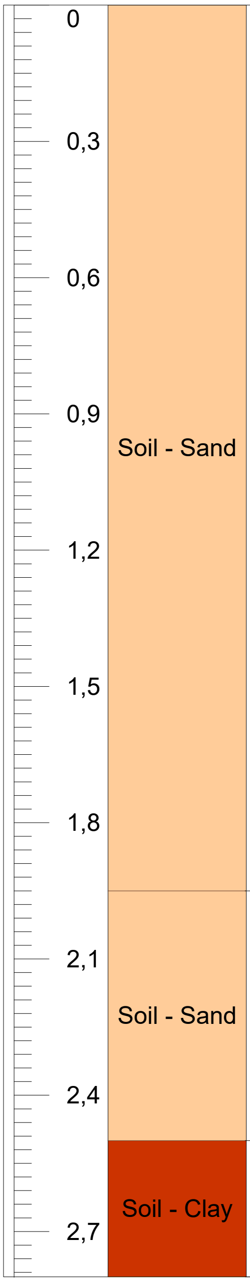
OPERATOR: Welcome

TP CO-ORDINATES: 29 35' 47.62" S / 30 26' 07.43" E

NOTE: Trial Pit Reached Refusal

GEOMEASURE GROUP
Groundwater & Environmental Consultants

TRIAL PIT LITHOLOGICAL LOG



Lithology Profile	Lithology Log	GW Seepage (m bgl)	Roots (m bgl)	Termites (m bgl)	Samples (m bgl)
Soil - Sand	Dry, yellow-orange blotched brown, medium dense, intact clayey SAND (backfill)				
Soil - Sand	Dry, light grey-brown, loose, intact SAND				
Soil - Clay	Moist, yellow-orange brown, firm, intact sandy CLAY				

Frontwall Photograph

(A frontwall photograph of the soil profile was not taken, given that entrance to the trial pit was not allowed)

PROJECT: Darvill Constructed Wetland

JOB NO: 2015/232

DATE EXCAVATED: 20/11/2015

TP NO: TP 10

LOGGED BY: Kent Gravelet-Blondin

CONTRACTOR: Scotty's

MACHINE: New Holland

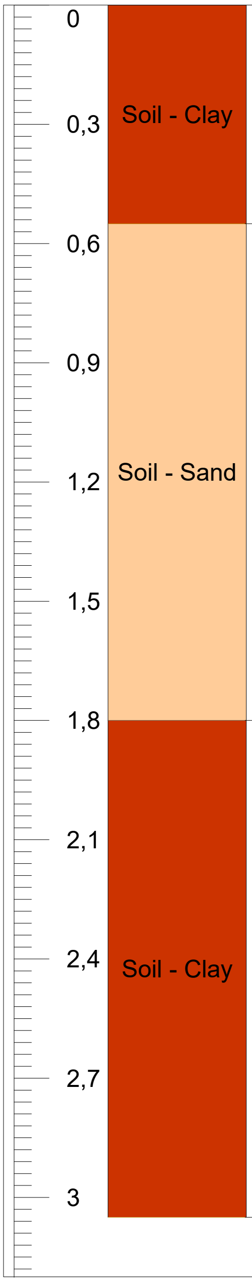
OPERATOR: Welcome

TP CO-ORDINATES: 29 35' 52.88" S / 30 26' 01.32" E

NOTE: Trial Pit Did Not Reach Refusal

GEOMEASURE GROUP
Groundwater & Environmental Consultants

TRIAL PIT LITHOLOGICAL LOG



Lithology Profile	Lithology Log	GW Seepage (m bgl)	Roots (m bgl)	Termites (m bgl)	Samples (m bgl)	Frontwall Photograph
Soil - Clay	Dry, dark brown, soft, intact silty CLAY				*Sample 3*	(A frontwall photograph of the soil profile was not taken, given that entrance to the trial pit was not allowed)
Soil - Sand	Slightly moist, red-brown, medium dense, intact clayey SAND					
Soil - Clay	Slightly moist, red-brown blotched grey, firm to stiff, intact sandy CLAY					

PROJECT: Darvill Constructed Wetland

JOB NO: 2015/232

DATE EXCAVATED: 20/11/2015

TP NO: TP 11

LOGGED BY: Kent Gravelet-Blondin

CONTRACTOR: Scotty's

MACHINE: New Holland

OPERATOR: Welcome

TP CO-ORDINATES: 29 35' 52.35" S / 30 25' 54.04" E

NOTE: Trial Pit Did Not Reach Refusal

GEOMEASURE GROUP
Groundwater & Environmental Consultants