**GEOTECHNICAL REVIEW**

**PROPOSED BREAKWATER RECONSTRUCTION (STRUCTURE 305)**

**NORTH LAKE SMALL CRAFT HARBOUR, KINGS COUNTY, PRINCE EDWARD ISLAND**

**JOOSE ENVIRONMENTAL PROJECT NO. JE0160-C**

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March 29, 2016

Joose Environmental Project No. JE0160-C

Ms. Brenda Victor, P. Eng., Project Manager
Public Works and Government Services Canada
3 Queen Street (Cambridge Building)
PO Box 1268
Charlottetown PE C1A 8R4

Dear Ms. Victor:

**Reference: Geotechnical Review - Proposed Breakwater Reconstruction (Structure 305) North Lake Small Craft Harbour, Kings County, Prince Edward Island**

## Introduction

This report presents the results of the geotechnical review carried out for the above-noted project, in accordance with your request. The purpose of the review was to assess all available geotechnical information for the specified area of the subject site and to compile all of the pertinent data into this summary report.

For the purposes of our review, we have assumed that that the existing geotechnical information serves as a good representation of the present conditions, and we have provided our comments and preliminary recommendations accordingly.

## Methodology

The available information reviewed for this project consisted of:

- Golder Associates, Geotechnical Investigation, Report No. 831-6025, issued August 1983.

A total of five (5) boreholes, BH 203, BH 204, BH 211, BH 212, and BH 213, were drilled in close proximity to Structure 305 during the above noted investigation. A sixth borehole (BH 209) was drilled to the south of the structure and is included in this report for reference purposes.

The above boreholes were drilled at the site in June of 1983 using land based equipment. The boreholes were either drilled over the edge of the existing wharf (BH 203 and 204), through the existing wharf deck (BH 209, BH 211, and BH 212), or at ground surface near the wharf (BH 213). The boreholes were advanced to depths ranging from 8.8 to 15.8 m below harbour bottom, the wharf deck, or ground surface. The borehole locations are shown in relation to Structure 305 on the appended Drawing No. 1.

Samples of the overburden soils encountered were taken at regular intervals by means of a conventional split spoon sampler during the performance of Standard Penetration Tests (SPT). Bedrock was proven at each borehole location by rotary core drilling in BXL-size (40 mm core diameter).

The original Golder Borehole Records, showing the conditions encountered at the site and the sampling and testing carried out, are included in the Appendix.

The Golder report references all elevations to LWOST (low water of ordinary spring tides) based on the benchmark shown on the appended drawing. LWOST datum is essentially synonymous to Low Normal Tide (LNT) Datum and Chart Datum, which are more commonly used today, and are therefore used within this report.

**Subsurface Conditions**

The subsurface conditions encountered at the boreholes are shown in detail on the appended Borehole Records, are summarized on Table 1 (also appended) and are described below. The subsurface conditions encountered at the site are also depicted on the Stratigraphic Section included on Drawing No. 1 in the Appendix.

Marine Deposit

A layer of red sand to silty sand was encountered at the surface of BH 213 and found to extend to a depth of 6.7 m. This layer was not encountered at the other boreholes locations and has been designated as a marine deposit for the purposes of this report. A similar sand deposit was encountered along the east side of the run, in the vicinity of Structure 306.

Standard Penetration Test N-values within the sand/silty sand were found to range from 2 to 18 with an average of 11 indicating a variable, but generally compact, relative density.

The moisture content of selected samples of the sand/silty sand was found to range from 8 to 24 percent with an average of 17 percent.

The following parameters may be assigned to the sand/silty sand:

| | |
|---|---|
| Total Unit Weight | 19 kN/m$^3$ |
| Submerged Unit Weight | 9 kN/m$^3$ |
| Effective Friction Angle | 32 degrees |

Fill Materials

A layer of fill materials, described as a “boulder fill” was encountered below the wharf deck and void at BH 209, BH 211, and BH 212. The thickness of the fill was found to range from 0.3 m at BH 209 to 4.8 m at BH 211. Since split spoon sampling was undertaken within this layer with the samples recovered being described as silty sand/sand/sandstone, it may be assumed that the boulder fill is likely a local sandstone fill. N-values within the boulder/sandstone fill were found to range from 38 to in excess of 50. Although the higher N-values may be attributed to the presence of larger sandstone fragments, it is expected that the boulder/sandstone fill is likely in a compact state.

The following parameters may be assigned to the boulder/sandstone fill:

| | |
|---|---|
| Total Unit Weight | 20 kN/$m^3$ |
| Submerged Unit Weight | 10 kN/$m^3$ |
| Effective Friction Angle | 34 degrees |

Glacial Till

Alternating layers of red silty sand, sandy silt, and clayey silt were encountered directly below the fill at BH 209, BH 211, and BH 212, below the marine sand at BH 213, and at harbour bottom at BH 203 and BH 204. The Golder report indicates that the silty sand layers dominate this stratum. The silty sand, sandy silt, and clayey silt layers have been classified as glacial till for the purposes of this report. The thickness of the till stratum was found to range from 4.2 m at BH 212 and BH 213 to 7.9 m at BH 211, and to average 5.4 m at the boreholes. The elevation of the till surface was found to range from a low of el. -4.60 m at BH 213 to a high of el. 1.00 m at BH 209. The till surface profile is depicted on the appended stratigraphic section.

The N-values obtained within the till were found to range from 4 to in excess of 50 with an overall average of 18 (excluding the >50 values) indicating a variable, but predominantly compact, relative density. The greater than 50 N-values may be attributed to the presence of sandstone gravel, and possibly some sandstone cobbles, within the till.

The natural moisture content of multiple till samples was found to range from 14 to 26 percent with an average of 18 percent. Grain size analyses performed on split spoon samples of the till recovered from the inner harbour and from the vicinity of the east breakwater (i.e., Structure 306) show it to contain 6 percent gravel, 24 to 53 percent sand, 28 to 50 percent silt, and 13 to 20 percent clay (< 0.002 mm) sizes. An Atterberg Limit determination shows the till to contain fines of low plasticity based on liquid and plastic limits of 17 percent and 13 percent, respectively.

The following parameters may be assigned to the till stratum for design purposes:

| | |
|---|---|
| Total Unit Weight | 20 kN/$m^3$ |
| Submerged Unit Weight | 10 kN/$m^3$ |
| Effective Friction Angle | 32 degrees |

 

Bedrock

Sedimentary bedrock was encountered directly below the till stratum at each borehole location, at depths ranging from 5.1 to 12.7 m below harbour bottom, the wharf deck, or ground surface. The elevation of the bedrock surface was found to range from a high of el. -3.90 m at BH 209 to a low of el. –10.90 m at BH 211. The bedrock surface profile is depicted on the appended stratigraphic section.

The rock core recovered consisted predominantly of sandstone with occasional mudstone layers. The upper portion of the bedrock is weathered to a soli-like character. As would be expected, the degree of weathering decreases with increasing depth. The weathered rock was sufficiently “soft” such that Standard Penetration Testing could be occasionally carried out in this material. The SPT results obtained for 17 of 20 such tests yielded N-values greater than 100 indicating that the weathered bedrock zone would be considered a very dense soil.

The bedrock is considered to be very poor quality and very severely fractured based on an average core recovery value of 44 percent, and RQD (Rock Quality Designation) values ranging from 0 to 32 percent.

The following parameters may be assigned to the bedrock for design purposes:

| | |
|---|---|
| Total Unit Weight | 22 $kNm^3$ |
| Submerged Unit Weight | 12 $kN/m^3$ |
| Effective Friction Angle | 35 degrees |

**Discussion and Recommendations**

It is understood that the existing breakwater consists of a timber pile wharf with timber and concrete deck sections and that the proposed reconstruction will predominantly occur within the footprint of the existing structure. It is assumed that the proposed reconstruction will likely involve a similar pile-supported structure with armour protection to be provided, as required, along the seaward side.

The subsurface conditions encountered at the site are considered to be generally favorable for this type of construction. No compressible marine soils were encountered and the thickness of the competent till stratum was found to range from 4.2 to 7.9 m across the site. The bedrock surface profile is quite variable, however, ranging from el -3.90 m to el. -10.90 m at the boreholes.

Preliminary recommendations are provided below for the design and construction of a pile-supported wharf structure based on the available subsurface information. More specific geotechnical design input can be provided, if requested, during the design stage for this project.

Pile-Supported Structure

For the conditions encountered, steel piles (H or pipe) or timber piles could be considered for use at the site. It is expected that piles would be driven to/into the underlying sandstone bedrock to develop the required capacity.

Steel piles should be driven using a hammer with a rated energy of at least 350 J/cm$^2$ of net steel cross sectional area. Previous experience has shown that an actual delivered energy in the order of 200 J/cm$^2$ is required to attain the allowable contact stress/bearing pressures given below. Refusal may be taken as 10 blows for the last 25 mm of pile penetration.

Actual penetration depths of steel piles into the sandstone bedrock will depend on the driving energy delivered and the bedrock condition/strength at the pile locations. Previous experience has shown that penetration depths can vary significantly from site to site or within the same site, depending on the rock quality and strength, and can range from less than 1 m to 2 m or more.

The vertical capacity of steel piles driven to refusal, as defined above, may be determined using an allowable contact stress of 50 MPa (based on net steel area) for steel H and open end pipe piles. An allowable bearing pressure of 7 MPa may be used for design of closed end pipe piles (based on gross end area).

The capacity of timber piles driven to refusal on the bedrock surface would be governed by the allowable fiber stress of the pile. For timber piles driven to bedrock, refusal is typically taken as 4 blows per 25 mm of pile penetration using a hammer energy in the order of 750 joules times the pile tip diameter in centimeters. The use of a protective shoe is recommended to prevent damage to the pile tip during driving. Some limited penetration of timber piles into weathered sandstone bedrock may be possible.

Re-tapping of some piles (e.g., 20 percent) within a 48-hour period is recommended to assess relaxation effects, and the requirement to re-tap additional piles.

The settlement of piles installed as outlined above and proportioned for the expected loads would be negligible. For the analysis of lateral resistance, an effective pile width of two times the pile diameter may be used.

For driven piles, some uplift resistance will be obtained through shaft friction (typically 50 percent of the shaft friction available in compression is assumed for uplift). The actual magnitude of the uplift resistance would depend on the type/size of the pile selected for use and the depth driven. Additional uplift resistance, if required, could be obtained through the use of socketed piles and/or rock anchors.

Other Considerations

As noted previously, no compressible marine soils were encountered at the subject site. Consequently, there should be no long-term settlement concerns associated with placing new fill materials/armour protection at the site.

Since some new fill materials/armour protection may be placed along the seaward side of the wharf, design of the structure would have to take the corresponding lateral forces into consideration. The following parameters may be assigned to the various strata encountered for design purposes:

| Parameter/Soli Type | Marine (compact sand) | Sandstone Fill (compacted) | Glacial Till | Bedrock (Sandstone) |
|---|---|---|---|---|
| Total Unit Weight, $kN/m^3$ | 19 | 20 | 20 | 22 |
| Submerged Unit Weight, $kN/m^3$ | 9 | 10 | 10 | 12 |
| Effective Friction Angle, degrees | 32 | 34 | 32 | 35[2] |
| Active Earth Pressure Coefficient, Ka | 0.31 | 0.28 | 0.31 | 0.27 |
| Passive Earth Pressure Coefficient, Kp[1] | 3.25 | 3.54 | 3.25 | 3.70 |

Notes:
[1] neglecting the effects of wall friction
[2] based on bedrock zone fragmented by pile penetration
Ka and Kp values provided are based on a vertical wall and horizontal backfill

**Closing Comments**

It is important to note that, although the available information was obtained by a reputable geotechnical firm and the boreholes provide good coverage across the site, the previous investigation was undertaken over 30 years ago. It is possible that some conditions may have changed at the site as a result of natural processes such as sedimentation or scour, or human activities such as infilling or dredging. It is recommended that the Department's records be reviewed to determine if any such activities may have occurred, or are suspected to have occurred. Unless there is a reason to suspect that the site conditions may have changed, no further boreholes at this site should be required provided that no significant changes to the structure footprint are planned. It is important to note, however, that we cannot attest to the correctness or present day relevance of the existing geotechnical information.

We trust this letter contains all of the information required at this time, and we are available at your convenience should you have any questions. We would be pleased to provide further geotechnical input for this project on an as required, as requested basis.

Sincerely,

**JOOSE ENVIRONMENTAL CONSULTING INC.**

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GWZ/g

# APPENDIX

Table 1 - Borehole Summary - North Lake (Structure 305)

| | Borehole Number | | | | | |
|---|---|---|---|---|---|---|
| | < South End | | | | North End > | |
| | BH 209 | BH 204 | BH 203 | BH 213 | BH 212 | BH 211 |
| **Wharf Deck el., m** | 3.44 | - | - | - | 3.76 | 3.73 |
| **Void Thickness, m** | 2.13 | - | - | - | 0.61 | 1.93 |
| **Ground Surface el., m** | 1.31 | - | - | 2.07 | 3.15 | 1.80 |
| **Harbour Bottom el., m** | - | -0.17 | -0.71 | - | - | - |
| **Fill Thickness, m** | 0.31 | 0.00 | 0.00 | 0.00 | 4.25 | 4.80 |
| **Marine Soil Thickness, m** | 0.00 | 0.00 | 0.00 | 6.67 | 0.00 | 0.00 |
| **Depth to Till Surface, m** | 0.31 | 0.00 | 0.00 | 6.67 | 4.25 | 4.80 |
| **Till Surface el., m** | 1.00 | -0.17 | -0.71 | -4.60 | -1.10 | -3.00 |
| **Till Thickness, m** | 4.90 | 5.09 | 5.89 | 4.20 | 4.20 | 7.90 |
| **Depth to Bedrock, m** | 5.21 | 5.09 | 5.89 | 10.87 | 8.45 | 12.70 |
| **Bedrock Surface el., m** | -3.90 | -5.26 | -6.60 | -8.80 | -5.30 | -10.90 |
| **Depth of Borehole, m** | 12.89 | 8.90 | 8.81 | 12.25 | 12.34 | 15.82 |

NOTES:

- the borehole information was obtained from Golder Associates Report No. 831-6025, issued August 1983
- elevations are referenced to Low Normal Tide (LNT) Datum

The following information is intended to assist in the interpretation of terms and symbols used on the borehole logs, test pit logs and reports.

**Soils Description**

Terminology describing common soil genesis:

| | |
|---|---|
| *Topsoil* | - mixture of soil and humus capable of supporting vegetative growth |
| *Peat* | - mixture of visible and invisible fragments of decayed organic matter |
| *Till* | - unstratified glacial deposit which may range from clay to boulders |
| *Fill* | - material below the surface identified as placed by humans (excluding buried services) |

Terminology describing soil structure:

| | |
|---|---|
| *Desiccated* | - having visible signs of weathering by oxidization of clay minerals, shrinkage cracks, etc. |
| *Fissured* | - having cracks, and hence a blocky structure |
| *Varved* | - composed of regular alternating layers of silt and clay |
| *Stratified* | - composed of alternating successions of different soil types, e.g. silt and sand |
| *Layer* | - > 75 mm in thickness |
| *Seam* | - 2 mm to 75 mm in thickness |
| *Parting* | - < 2 mm in thickness |

Terminology describing soil types:

The classification of soil types are made on the basis of grain size and plasticity in accordance with the Modified Unified Soil Classification System (MUSCS) and in accordance with the Canadian Foundation Engineering Manual Fourth Edition (Canadian Geotechnical Society, 2006). The classification excludes particles larger than 75 mm (3 inches). The MUSCS provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification.

Terminology describing cobbles, boulders, and non-matrix materials (organic matter or debris):

Terminology describing materials outside the USCS, (e.g. particles larger than 76 mm, visible organic matter and construction debris) is based upon the proportion of these materials present:

| | |
|---|---|
| *Trace, or occasional* | Less than 10% |
| *Some* | 10-20% |
| *Frequent* | > 20% |

**Consistency of Cohesive Soils**: May be estimated using simple field tests, or described in terms of a strength scale. In the field, the undrained shear strength ($s_u$) can be assessed using a simple field tool appropriate for cohesive soils, in conjunction with the relevant calibration. Refer to AS 1726-1993, Table A4.

| Consistency - Essentially Cohesive Soils | | | | | |
|---|---|---|---|---|---|
| **Term** | **Field Guide** | **Symbol** | **SPT "N" Value** | **Undrained Shear Strength $s_u$ (kPa)** | **Unconfined Compressive Strength $q_u$ (kPa)** |
| Very soft | Oozes between fingers when | VS | 0-2 | <12 | <25 |
| Soft | Easily moulded with fingers. | S | 2-4 | 12-25 | 25-50 |
| Firm | Can be moulded by strong pressure of fingers. | F | 4-8 | 25-50 | 50-100 |
| Stiff | Not possible to mould with fingers. | St | 8-15 | 50-100 | 100-200 |
| Very stiff | | VSt | 15-30 | 100-200 | 200-400 |
| Hard | Can be indented with difficulty by thumb nail. | H | >30 | >200 | >400 |

**Note:** SPT - N to $q_u$ correlation from Terzaghi and Peck, 1967. (General guide only).

| Soil Particle Sizes | |
|---|---|
| **Term** | **Size Range** |
| BOULDERS | >200 mm |
| COBBLES | 63-200 mm |
| Coarse GRAVEL | 20-63 mm |
| Medium GRAVEL | 6-20 mm |
| Fine GRAVEL | 2.36-6 mm |
| Coarse SAND | 0.6-2.36 mm |
| Medium SAND | 0.2-0.6 mm |
| Fine SAND | 0.075-0.2 mm |
| SILT | 0.002-0.075 mm |
| CLAY | <0.002 mm |

**Consistency of Non-Cohesive Soils**: Is described in terms of the density index, as defined in AS 1289.0-2000. This can be assessed using a field tool appropriate for non-cohesive soils, in conjunction with the relevant calibration. Refer to AS 1726-1993, Table A5; BS5930-1999, p117.

| Consistency - Essentially Non-Cohesive Soils | | | | |
|---|---|---|---|---|
| **Term** | **Symbol** | **SPT N Value** | **Field Guide** | **Density Index (%)** |
| Very loose | VL | 0-4 | Foot imprints readily | 0-15 |
| Loose | L | 4-10 | Shovels Easily | 15-35 |
| Medium dense | MD | 10-30 | Shovelling difficult | 35-65 |
| Dense | D | 30-50 | Pick required | 65-85 |
| Very dense | VD | >50 | Picking difficult | 85-100 |

**Standard Penetration Test (SPT)**: Refer to. AS 1289.6.3.1-2004. Example report formats for SPT results are shown below:

| Test Report | Penetration Resistance (N) | Explanation / Comment |
|---|---|---|
| 4, 7, 11 | N=18 | Full penetration; N is reported on engineering borehole log |
| 18, 27, 32 | N=59 | Full penetration; N is reported on engineering borehole log |
| 4, 18, 30/15 mm | N is not reported | 30 blows causes less than 100 mm penetration (3rd interval) - test discontinued |
| 30/80 mm | N is not reported | 30 blows causes less than 100 mm penetration (1st interval) - test discontinued |
| rw | N<1 | Rod weight only causes full penetration |
| hw | N<1 | Hammer and rod weight only causes full penetration |
| hb | N is not reported | Hammer bouncing for 5 consecutive blows with no measurable penetration - test discontinued |

Rock Description

Except where specified below, terminology for describing rock is as defined by the International Society for Rock Mechanics (ISRM) 2007 publication “The Complete ISRM Suggested Methods for Rock Characterization, Testing and Monitoring: 1974-2006”

Terminology Describing Rock Quality:

| RQD | Rock Mass Quality |
|---|---|
| *0 - 25* | *Very Poor Quality* |
| *25 - 50* | *Poor Quality* |
| *50 - 75* | *Fair Quality* |
| *75 - 90* | *Good Quality* |
| *90 - 100* | *Excellent Quality* |

| Alternate (Colloquial) Rock Mass Quality | |
|---|---|
| *Very Severely Fractured* | *Crushed* |
| *Severely Fractured* | *Shattered or Very Blocky* |
| *Fractured* | *Blocky* |
| *Moderately Jointed* | *Sound* |
| *Intact* | *Very Sound* |

**RQD (Rock Quality Designation)** denotes the percentage of intact and sound rock retrieved from a borehole of any orientation. All pieces of intact and sound rock core equal to or greater than 100 mm (4 inches) long are summed up and divided by the total length of the core run. RQD is determined in accordance with ASTM D6032.

**SCR (Solid Core Recovery)** denotes the percentage of solid core (cylindrical) retrieved forma borehole of any orientation. All pieces of the solid (cylindrical) core are summed and divided by the total length of the core run (It excludes all portions of core pieces that are not fully cylindrical as well as crushed or rubble zones).

**Fracture Index (FI)** is defined as the number of naturally occurring fractures within a given length of core. The Fracture Index is reported as a simple count of the natural occurring fractures.

Refer to AS 1726-1993 (Appendix A3.3) for the description and classification of rock material composition, including:

(a) Rock type (Table A6, (a) and (b))
(b) Grain size
(c) Texture and fabric
(d) Colour (describe as per soil).

The condition of a rock material refers to its weathering characteristics, strength characteristics and rock mass properties. Refer to AS 1726-1993 (Appendix A3 Tables A8, A9 and A10).

**Weathering Condition (Degree of Weathering):**

The degree of weathering is a continuum from fresh rock to soil. Boundaries between weathering grades may be abrupt or gradational.

| Rock Material Weathering | | |
|---|---|---|
| **Weathering Grade** | **Symbol** | **Definitio** |
| Residual Soil | RS | Soil-like material developed on extremely weathered rock; the mass structure and substance fabric are no longer evident; there is a large change in volume but the material has not been significantly transported. |
| Extremely Weathered Rock | XW | Rock is weathered to such an extent that it has 'soil' properties, i.e. it either disintegrates or can be remoulded in water, but substance fabric and rock structure still recognizable. |
| Highly Weathered Rock | HW | Strong discolouration is evident throughout the rock mass, often with significant change in the constituent minerals. The intact rock strength is generally much weaker than that of the fresh rock. |
| Moderately Weathered Rock | MW | Modest discolouration is evident throughout the rock fabric, often with some change in the constituent minerals. The intact rock strength is usually noticeably weaker than that of the fresh rock. |
| Slightly Weathered | SW | Rock is slightly discoloured but shows little or no change of strength from fresh rock. |
| Fresh Rock | FR | Rock shows no sign of decomposition or staining. |

Notes:

1. Minor variations within broader weathering grade zones will be noted on the engineering borehole logs.
2. Extremely weathered rock is described in terms of soil engineering properties.
3. Weathering may be pervasive throughout the rock mass, or may penetrate inwards from discontinuities to some extent.
4. The ‘Distinctly Weathered (DW)’ class as defined in AS 1726-1993 is divided to incorporate HW and MW in the above table. The symbol DW should not be used.

**Strength Condition (Intact Rock Strength):**

Terminology Describing Rock Strength

| Strength Classification | Grade | Unconfined Compressive Strength (MPa) |
|---|---|---|
| Extremely Weak | R0 | < 1 |
| Very Weak | R1 | 1 - 5 |
| Weak | R2 | 5 - 25 |
| Medium Strong | R3 | 25 - 50 |
| Strong Very | R4 | 50 - 100 |
| Strong Extremely | R5 | 100 - 250 |
| Strong | R6 | > 250 |

**Discontinuity Spacing**: On the geotechnical borehole log, a graphical representation of defect spacing vs depth is shown. This representation takes into account all the natural rock defects occurring within a given depth interval, excluding breaks induced by the drilling / handling of core. Refer to AS 1726-1993, BS5930-1999.

| Defect Spacing | | | Bedding Thickness (Sedimentary Rock Stratification) | |
|---|---|---|---|---|
| **Spacing/Width (mm)** | **Descriptor** | **Symbol** | **Descriptor** | **Spacing /Width (mm)** |
| | | | Thinly Laminated | <6 |
| <20 | Extremely Close | EC | Thickly Laminated | 6 - 20 |
| 20 - 60 | Very Close | VC | Very Thinly Bedded | 20 - 60 |
| 60 - 200 | Close | C | Thinly Bedded | 60 -200 |
| 200 - 600 | Medium | M | Medium Bedded | 200 - 600 |
| 600 - 2000 | Wide | W | Thickly Bedded | 600 - 2000 |
| 2000 - 6000 | Very Wide | VW | Very Thickly Bedded | >2000 |
| >6000 | Extremely Wide | EW | | |

| Defect Spacing in 3D | |
|---|---|
| **Term** | **Description** |
| Blocky | Equidimensional |
| Tabular | Thickness much less than length or width |
| Columnar | Height much greater than cross section |

| Direct Persistence (areal extent) |
|---|
| Trace length of defect given in metres |

The list on the following table provides an explanation of terms and symbols used on the geotechnical borehole, test pit and penetrometer logs.

| Test Results | | | | Test Symbols | |
|---|---|---|---|---|---|
| PI | Plasticity Index | $c'$ | Effective Cohesion | DCP | Dynamic Cone Penetrometer |
| LL | Liquid Limit | $c_u$ | Undrained Cohesion | SPT | Standard Penetration Test |
| LI | Liquidity Index | $c'_R$ | Residual Cohesion | CPTu | Cone Penetrometer (Piezocone) Test |
| DD | Dry Density | $\varphi'$ | Effective Angle of Internal Friction | PANDA | Variable Energy DCP |
| WD | Wet Density | $\varphi_u$ | Undrained Angle of Internal Friction | PP | Pocket Penetrometer Test |
| LS | Linear Shrinkage | $\varphi'_R$ | Residual Angle of Internal Friction | U50 | Undisturbed Sample 50 mm (nominal diameter) |
| MC | Moisture Content | $c_v$ | Coefficient of Consolidation | U100 | Undisturbed Sample 100mm (nominal diameter) |
| OC | Organic Content | $m_v$ | Coefficient of Volume Compressibility | UCS | Uniaxial Compressive Strength |
| WPI | Weighted Plasticity Index | $c_{\alpha\varepsilon}$ | Coefficient of Secondary Compression | Pm | Pressuremeter |

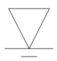
| Test Results | | | | Test Symbols | |
|---|---|---|---|---|---|
| WLS | Weighted Linear Shrinkage | e | Voids Ratio | FSV | Field Shear Vane |
| DoS | Degree of Saturation | $\varphi'_{cv}$ | Constant Volume Friction Angle | DST | Direct Shear Test |
| APD | Apparent Particle Density | $q_t$ / $q_c$ | Piezocone Tip Resistance (corrected / uncorrected) | PR | Penetration Rate |
| $s_u$ | Undrained Shear Strength | $q_d$ | PANDA Cone Resistance | A | Point Load Test (axial) |
| $q_u$ | Unconfined Compressive Strength | $I_{s(50)}$ | Point Load Strength Index | D | Point Load Test (diametral) |
| *R* | Total Core Recovery | *RQD* | Rock Quality Designation | L | Point Load Test (irregular lump) |

Sample Type

| | |
|---|---|
| SS | Split spoon sample (obtained by performing the Standard Penetration Test) |
| ST | Shelby tube or thin wall tube |
| DP | Direct-Push sample (small diameters tube sampler hydraulically advanced) |
| PS | Piston sample |
| BS | Bulk sample |
| WS | Wash sample |
| HQ,NQ, BQ, etc | Rock core samples obtained with the use of standard size diamond coring bits. |

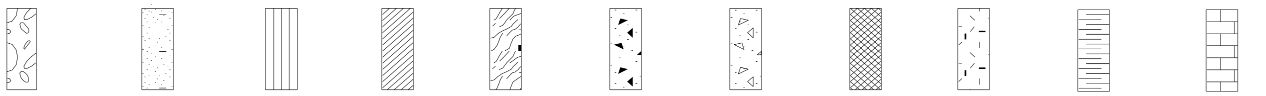
Water Level Measurement


Measurement in standpipe, piezometer, or well


Inferred

Strata Plot

Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



Boulders Cobbles Gravel | Sand | Silt | Clay | Organics | Asphalt | Concrete | Fill | Igneous Bedrock | Meta-morphic Bedrock | Sedi-mentary Bedrock

Form G.A.-D-I.

Project No. 831-6025

# RECORD OF BOREHOLE 209

LOCATION See Figure 3 BORING DATE June 24, 1983 DATUM LWOST

SAMPLER HAMMER WEIGHT 622N DROP 0.76 m PENETRATION TEST HAMMER WEIGHT DROP

| BORING METHOD | ELEV'N. DEPTH | DESCRIPTION |
|---|---|---|
| | 3.44 | Top of Wharf |
| WASH DRILLING, BW CASING | | Air Gap |
| | 1.31 / 1.0 | Boulder Fill |
| | 2.4 | Alternative layers of compact to dense red SILTY SAND to SANDY SILT trace gravel & firm red CLAYEY SILT, trace sand & gravel |
| | -3.9 / 7.3 | Weathered layered SANDSTONE and MUDSTONE (BEDROCK) |
| DIAMOND DRILLING, UNCASED | -9.45 / 12.89 | End of Borehole |

| SAMPLE NUMBER | TYPE | BLOWS/0.3m | REMARKS |
|---|---|---|---|
| 1 | 50 mm OD | 43 | |
| 2 | " | 6 | |
| 3 | " | 4 | |
| 4 | " | 15 | |
| 5 | " | 50/0.125 m | |
| 6 | " | 23/0.15 m<br>50/0.75 m | |
| 7 | BXL RC | | RQD=0%<br>SCR=27%<br>TCR=58% |
| 8 | 50 mm OD | 58 | |

ELEVATION SCALE: 4, 3, 2, 1, 0, -1, -2, -3, -4, -5, -6, -7, -8, -9, -10

DYNAMIC PENETRATION RESISTANCE, BLOWS/

SHEAR STRENGTH Cu. NAT. V. - + Q. - ● REM.V. - ⊕ U. - O

COEFFICIENT OF PERMEABILITY, k., CM./SEC. 1x10 1x10 1x10 1x10

WATER CONTENT, PERCENT $W_P$ W $W_L$ 5 10 15 20

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

15 0 5 10 Percent axial strain at failure

VERTICAL SCALE 1:75

**Golder Associates**

DRAWN [illegible]

CHECKED [illegible]

Form G.A.-D-I. Project No. 831-6025

# RECORD OF BOREHOLE 204

LOCATION See Figure 3 BORING DATE June 22, 1983 DATUM LWOST

SAMPLER HAMMER WEIGHT 622N DROP 0.76 m PENETRATION TEST HAMMER WEIGHT DROP

| BORING METHOD | ELEV'N. / DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | BLOWS/0.3m |
|---|---|---|---|---|---|
| | 4.04 | Drilling Platform | | | |
| WASH DRILLING, BW CASING | 0.0 | Air Gap | | | |
| WASH DRILLING, BW CASING | -0.17 / 4.21 | Harbour Bottom | | | |
| WASH DRILLING, BW CASING | | Alternating layers of compact red SILTY SAND & stiff red CLAYEY SILT trace gravel | 1 | 50 mm DO | 28 |
| | | | 2 | 50 mm DO | 10 |
| | | | 3 | 50 mm DO | 11 |
| | -5.3 / 9.3 | | | | |
| WASH DRILLING, BW CASING | | Weathered red SANDSTONE (BEDROCK) | 4 | 50 mm DO | 30 |
| | | | 5 | 50 mm DO | 20 |
| DIAMOND DRILLING, UNCASED | | | 6 | BXL RC | |
| DIAMOND DRILLING, UNCASED | | | 7 | 50 mm DO | 58 |
| | -9.07 / 13.11 | End of Borehole | | | |

ELEVATION SCALE: 4, 3, 2, 1, 0, -1, -2, -3, -4, -5, -6, -7, -8, -9

DYNAMIC PENETRATION RESISTANCE, BLOWS/

SHEAR STRENGTH Cu. NAT. V. - + Q. - ● REM.V. - ⊕ U. - O

RQD=7%
SCR=10%
TCR=30%

COEFFICIENT OF PERMEABILITY, k, CM./SEC. 1x10 1x10 1x10 1x10

WATER CONTENT, PERCENT $W_P$ W $W_L$ 5 10 15 20

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

15 0 5 10 Percent axial strain at failure

VERTICAL SCALE 1:75

**Golder Associates**

DRAWN ____ CHECKED ____

Form G.A.-D-1. Project No. 831-6025

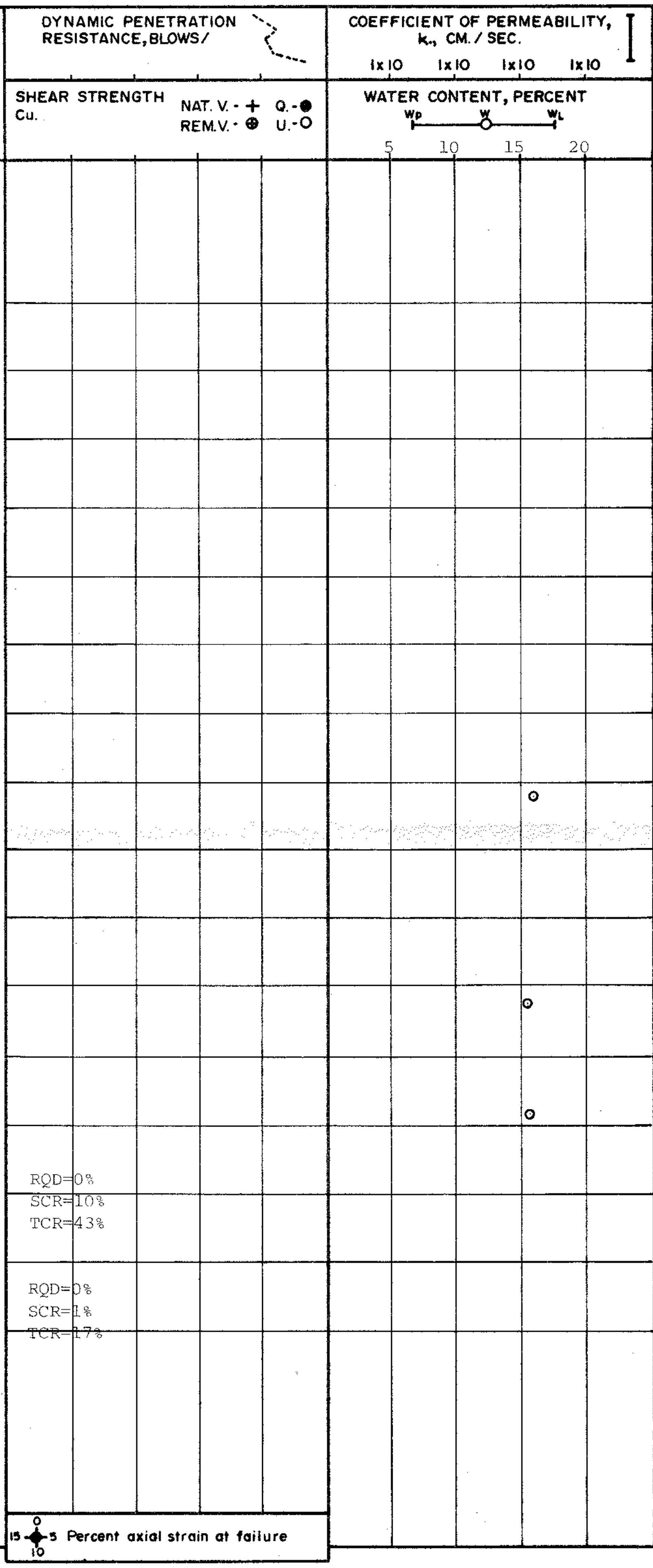
# RECORD OF BOREHOLE 203

LOCATION See Figure 3 | BORING DATE June 21, 1983 | DATUM LWOST

SAMPLER HAMMER WEIGHT 622N | DROP 0.76 m | PENETRATION TEST HAMMER WEIGHT | DROP

| BORING METHOD | ELEV'N. / DEPTH | DESCRIPTION | SAMPLE NUMBER | TYPE | BLOWS/0.3m |
|---|---|---|---|---|---|
| | 4.20 | Drilling Platform | | | |
| WASH DRILLING, BW CASING | 0.0 | | | | |
| | -0.71 | Harbour Bottom | | | |
| | 4.91 | Alternating layers of compact red SAND some silt and stiff to very stiff red CLAYEY SILT | 1 | 50 mm DO | 18 |
| | | | 2 | " | 13 |
| | | | 3 | " | 19 |
| | | | 4 | " | 8 |
| | -6.60 | | | | |
| | 10.8 | Weathered red SANDSTONE (BEDROCK) | 5 | " | 59 |
| DIAMOND DRILLING, UNCASED | | | 6 | BXL RC | |
| | | | 7 | 50 mm DO | 68 |
| | -9.52 | | 8 | BXL RC | |
| | 13.72 | End of Borehole | | | |

ELEVATION SCALE: 5, 4, 3, 2, 1, 0, -1, -2, -3, -4, -5, -6, -7, -8, -9, -10




ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION

VERTICAL SCALE 1:75

**Golder Associates**

DRAWN GGW

CHECKED MM

Form G.A.-D-I. Project No. 831-6025

# RECORD OF BOREHOLE 213

LOCATION See Figure 3 BORING DATE June 30, 1983 DATUM LWOST

SAMPLER HAMMER WEIGHT 622N DROP 0.76 m PENETRATION TEST HAMMER WEIGHT DROP

| BORING METHOD | ELEV'N. DEPTH | DESCRIPTION | STRAT. PLOT |
|---|---|---|---|
| WASH DRILLING, BW CASING | 2.07 / 0.00 | Very loose to compact red SAND some silt to SILT SAND | |
| | -4.6 / 6.7 | Alternating layers of compact red SILTY SAND & stiff red CLAYEY SILT, trace sand and gravel | |
| DIAMOND DRILLING, UNCASED | -8.8 / 10.9 | Faintly weathered red SANDSTONE (BEDROCK) | |
| | -10.18 / 12.25 | | |

| SAMPLE NUMBER | TYPE | BLOWS/0.3m | Notes |
|---|---|---|---|
| 1 | 50 mm OD | 2/0.30 m, 2/0.15 m | |
| 2 | " | 18 | |
| 3 | " | 4 | |
| 4 | " | 16 | |
| 5 | " | 16 | |
| 6 | " | 14 | |
| 7 | " | 26 | |
| 8 | " | 19/0.15 m, 50/0.10 m | |
| 9 | BXL RC | | RQD=0%, SCR=0%, TCR=57% |

ELEVATION SCALE: 3, 2, 1, 0, -1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11

DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m

SHEAR STRENGTH Cu. NAT. V. - + Q. - ● REM.V. - ⊕ U. - O

COEFFICIENT OF PERMEABILITY, k, CM./SEC. 1x10 1x10 1x10 1x10

WATER CONTENT, PERCENT Wp W WL 5 10 15 20

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

15 0 5 10 Percent axial strain at failure

VERTICAL SCALE 1:75

**Golder Associates**

DRAWN W.G.W. CHECKED [illegible]

Form G.A.-D-I.

Project No. 831-6025

# RECORD OF BOREHOLE 212

LOCATION See Figure ?

BORING DATE June 30, 1983

DATUM LWOST

SAMPLER HAMMER WEIGHT 622N DROP 0.76 m

PENETRATION TEST HAMMER WEIGHT DROP

| BORING METHOD | ELEV'N. DEPTH | DESCRIPTION | NUMBER | TYPE | BLOWS/0.3m | ELEVATION SCALE | SHEAR STRENGTH / WATER CONTENT, PERCENT | ADDITIONAL LAB. TESTING |
|---|---|---|---|---|---|---|---|---|
| | 3.76 | Top of wharf | | | | 4 | | |
| WASH DRILLING BW CASING | 0.0 / 3.15 | Air Gap | | | | 3 | | |
| | 0.61 | BOULDER FILL | | | | 2 | | |
| | | | 1 | 50 mm OD | 50/0.05 m | 1 / 0 | | |
| | -1.1 | | 2 | " | 44 | -1 | w ≈ 17 | |
| | 4.9 | Alternating layers of compact red SILTY SAND and stiff red CLAYEY SILT | 3 | " | 9 | -2 / -3 | | |
| | | | 4 | " | 19 | -4 | → 26 | |
| | -5.3 / 9.1 | Weathered red SANDSTONE (BEDROCK) | 5 | " | 54 | -5 / -6 | | |
| | | | 6 | " | 86 | -7 | | |
| DIAMOND DRILLING UNCASED | -8.58 | | 7 | BXL RC | | -8 | RQD=0% SCR=0% TCR=10% | |
| | 12.34 | End of Borehole | | | | -9 / -10 | | |

DYNAMIC PENETRATION RESISTANCE, BLOWS/

COEFFICIENT OF PERMEABILITY, k., CM./SEC. 1x10 1x10 1x10 1x10

SHEAR STRENGTH Cu. NAT. V. - + Q. - ● REM.V. - ⊕ U. - O

WATER CONTENT, PERCENT Wp W WL 5 10 15 20

PIEZOMETER OR STANDPIPE INSTALLATION

15 0 5 10 Percent axial strain at failure

VERTICAL SCALE 1:75

**Golder Associates**

DRAWN WGH

CHECKED [signature]

Form G.A.-D-1.

Project No. 831-6025

# RECORD OF BOREHOLE 211

LOCATION See Figure 3 BORING DATE June 29, 1983 DATUM LWOST

SAMPLER HAMMER WEIGHT 622N DROP 0.76 m PENETRATION TEST HAMMER WEIGHT DROP

| BORING METHOD | ELEV'N. / DEPTH | SOIL PROFILE DESCRIPTION | SAMPLE NUMBER | TYPE | BLOWS/0.3m | WATER CONTENT / REMARKS |
|---|---|---|---|---|---|---|
| | 3.73 | Top of wharf | | | | |
| WASH DRILLING, BW CASING | 0.0 | AIR GAP | | | | |
| | 1.8 / 1.9 | BOULDER FILL | 1 | 50 mm OD | 64 | |
| | | | 2 | " | 38 | |
| | | | 3 | " | 50/0.762 m | |
| | -3.0 / 6.7 | Alternating layers of compact red SILTY SAND trace to some gravel & red CLAYEY SILT trace to some sand & gravel | 4 | BXL RC | | |
| | | | 5 | 50 mm OD | 13 | |
| | | | 6 | " | 27 | |
| | | | 7 | " | 50/0.15 m | |
| DIAMOND DRILLING | | | 8 | BXL RC | | RQD=0% SCR=0% TCR=0% |
| | | | 9 | 50 mm OD | 59 | |
| | | | 10 | BXL RC | | RQD=0% SCR=0% TCR=0% |
| | | | 11 | 50 mm OD | 50/0.127 m | |
| UNCASED | -10.9 / 14.6 | Faintly weathered red SANDSTONE (BEDROCK) | 12 | BXL RC | | RQD=32% SCR=65% TCR=82% |
| | -12.09 / 15.82 | End of Borehole | | | | |

DYNAMIC PENETRATION RESISTANCE, BLOWS/

SHEAR STRENGTH Cu. NAT. V. - + Q. - ● REM.V. - ⊕ U. - O

COEFFICIENT OF PERMEABILITY, k., CM./SEC. 1x10 1x10 1x10 1x10

WATER CONTENT, PERCENT $W_P$ W $W_L$ 5 10 15 20

ELEVATION SCALE: 2, 3, 2, 1, 0, -1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11, -12

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

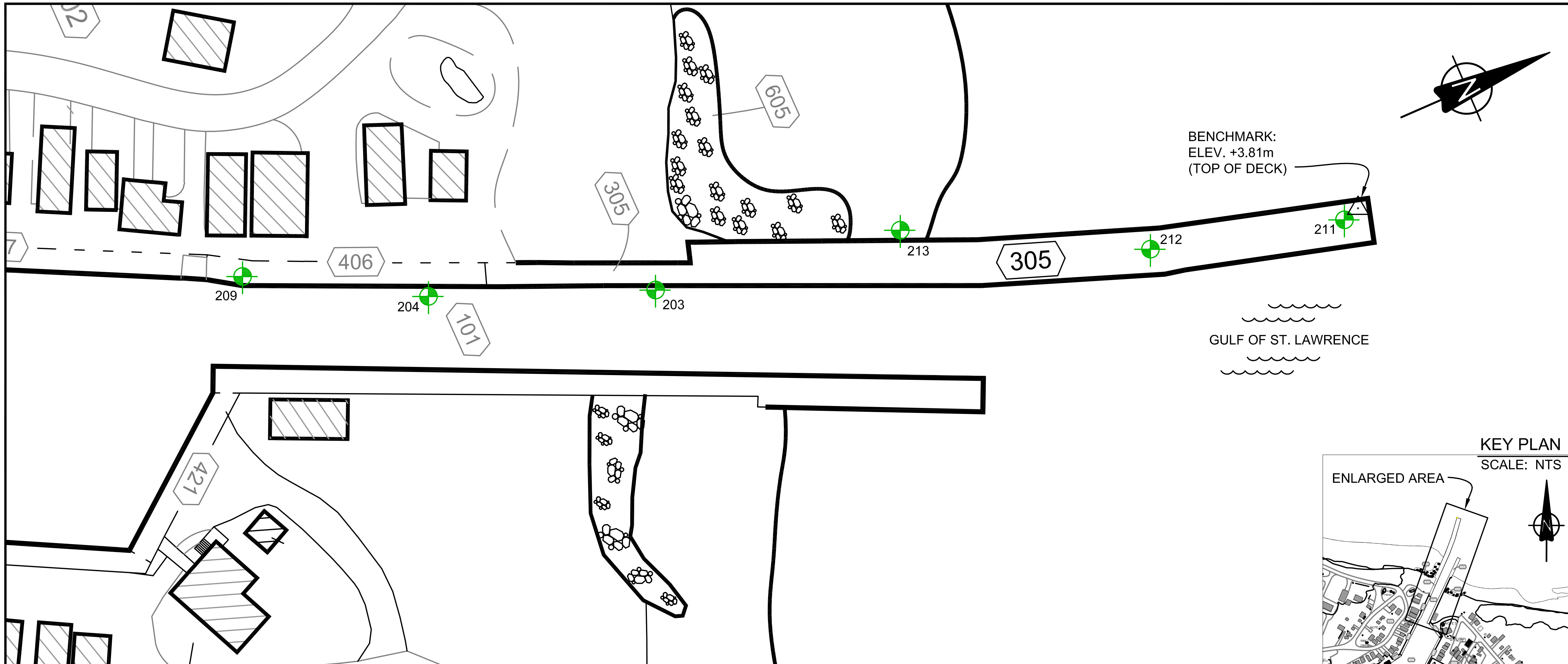
15 0 5 10 Percent axial strain at failure

VERTICAL SCALE 1:75

Golder Associates

DRAWN WGW

CHECKED MJ

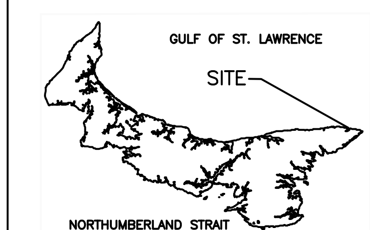


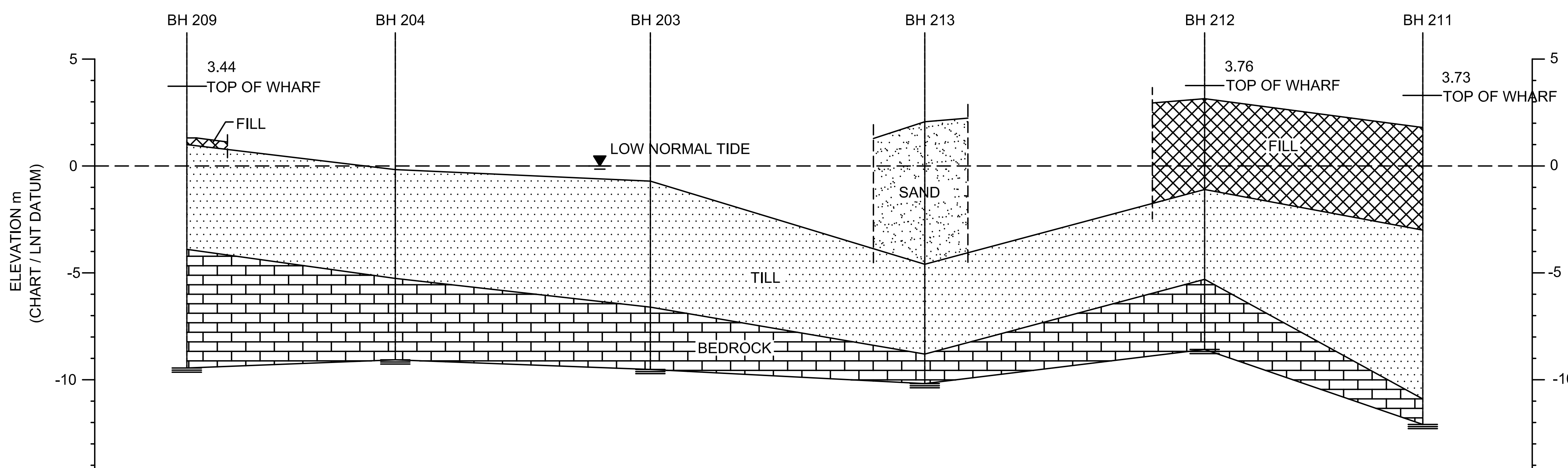

PLAN VIEW
SCALE: 1 : 750

# LEGEND

BOREHOLE LOCATION; GOLDER ASSOCIATES REPORT NO. 831-6025, ISSUED AUGUST, 1983

BENCHMARK: CHART (LOW NORMAL TIDE) DATUM




STRATIGRAPHIC SECTION
SCALE: 1 : 750 (HORIZONTAL)
1 : 250 (VERTICAL)

JOOSE ENVIRONMENTAL

# BOREHOLE LOCATION PLAN AND STRATIGRAPHIC SECTION

STRUCTURE 305

NORTH LAKE SMALL CRAFT HARBOUR, KINGS COUNTY, PEI

**CLIENT:** PUBLIC WORKS AND GOVERNMENT SERVICES CANADA

**SCALE:** AS SHOWN

| DWN BY: | APPD BY: |
|---|---|
| MLJ | GWZ |
| **JOB NO.:** JE0160C | **DWG NO.:** 1 |
| **DATE:** 2016/03/24 | |

**SUPPLEMENTAL GEOTECHNICAL INVESTIGATION**
**PROPOSED BREAKWATER**
**NORTH LAKE, KINGS COUNTY, PE**

**JOOSE ENVIRONMENTAL PROJECT NO. JE0160**

Joose Environmental Consulting Inc.
P.O. Box 19
North Wiltshire PE C0A 1Y0

August 18, 2017

Joose Environmental Project No. JE0160

Ms. Brenda Victor, P. Eng., Project Manager
Public Works and Government Services Canada
3 Queen Street (Cambridge Building)
P.O. Box 1268
Charlottetown PE C1A 8R4

Dear Ms. Victor:

**Reference: Supplemental Geotechnical Investigation**
**Proposed Breakwater Reconstruction (Structure 305)**
**North Lake Small Craft Harbour, Kings County, Prince Edward Island**

## Introduction

Further to your request and our previous geotechnical review, this report presents the findings of the supplemental geotechnical investigation carried out for the above-noted project. Since the alignment of the proposed breakwater has been shifted approximately 12 m to the west of the existing breakwater, the primary purpose of the present investigation was to assess the subsurface conditions along the new alignment and to confirm that the overall favorable conditions encountered during the previous investigation (Golder Associates, Geotechnical Investigation, Report No. 831-6025, issued August 1983) are still applicable. This report should be read in conjunction with our previous Geotechnical Review Report issued to PWGSC on March 29, 2016.

## Methodology

The field work for the present investigation was undertaken on two separate dates, during low tide periods, as follows:

- August 2, 2017 - initial probe and manual sampling program; and
- August 8, 2017 - borehole program.

### Probe/Sampling Program

A 12-mm diameter fiberglass rod was used to probe the centerline of the proposed breakwater to check for the presence of very soft/very loose soils. A total of eight (8) probes were undertaken along the centerline at the following locations:

- Probe 1 (P1) - Station 0+013
- Probe 2 (P2) - Station 0+020
- Probe 3 (P3) - Station 0+028
- Probe 4 (P4) - Station 0+040
- Probe 5 (P5) - Station 0+050
- Probe 6 (P6) - Station 0+060
- Probe 7 (P7) - Station 0+070
- Probe 8 (P8) - Station 0+080

The probe locations are shown in relation to the proposed breakwater on Drawing No. 1R (appended).

Soil samples were recovered from the three (3) probe locations located above the tide level (i.e., P1, P2 and P3) for visual classification and laboratory testing. The probe locations and surface elevations were established in the field by CBCL Limited personnel; elevations are referenced to Low Normal Tide (Chart) Datum. The conditions encountered at the probe locations are summarized on Table 1 (appended).

Borehole Program

The borehole program consisted of drilling two (2) boreholes at the site with a track-mounted CME 55 auger drill rig. The boreholes were advanced to an average depth of 8.5 m below the ground surface. The boreholes were located along the proposed breakwater centerline as follows:

- BH 101 - Station 0+015
- BH 102 - Station 0+033

The borehole locations are shown in relation to the previous boreholes on Drawing No. 1R (appended).

Samples of the overburden soils encountered were taken at regular intervals by means of a conventional split spoon sampler during the performance of Standard Penetration Tests.

All soil samples recovered were placed in moisture-proof containers and were delivered to our office for classification and testing. All soil samples remaining after testing will be stored for a period of 60 days from the date of issue of this report after which they will be discarded unless directions to the contrary are received.

Detailed logs of the strata encountered at the site and of the sampling/testing carried out are shown on the appended Borehole Records.

The borehole locations were established relative to the existing breakwater by our personnel. Surface elevations at the boreholes were interpolated from the survey information provided and are referenced to Low Normal Tide (Chart) Datum.

**Subsurface Conditions**

The subsurface conditions encountered at the probe and borehole locations are shown in detail on appended Table 1 - Probe Summary, on the Borehole Records (also appended) and are described below.

The subsurface conditions encountered at the site are also depicted on the Stratigraphic Section included on Drawing No. 1R (appended). As noted on the drawing, the conditions at previous BH 213 have been replaced with the sand-till profile encountered at BH 101 and BH 102.

Marine Deposit

A layer of brown to greyish brown sand was encountered at the surface of the probe and borehole locations. The thickness of the sand deposit was fond to range from 1.5 to 2.1 m at the boreholes; all of the probes were terminated within the sand. Traces of organic matter were encountered within the sand at P2; no evidence of organics was observed at the other test locations.

Although it was generally possible to push, with some resistance, the probe rod a depth of 100 to 450 mm into the sand, no apparent very loose/soft soils were identified at the probe locations.

Standard Penetration Test N-values of 1 and 2 were obtained within the upper 600 mm of the sand deposit at the borehole locations indicating a very loose relative density. The N-values below this upper very loose layer were found to range from 14 to 27 indicating a compact relative density.

Grain size testing (curves appended) was performed on selected sand samples recovered from the probe and borehole locations. The results of the grain size tests are presented in the following table and show the sand deposit to be comprised of a fine to medium grained sand with traces of fines (i.e., silt and clay sizes) and gravel. The testing shows the sand deposit to contain an average of 3 percent gravel, 94 percent sand, and 3 percent fines. The natural moisture content of the sand (11 samples) was found to range from 3 to 34 percent with an overall average of 22 percent.

**Grain Size and Moisture Content Test Summary - Sand Deposit**

| Location | Sample No. | Depth, mm | Gravel, % | Sand, % | Silt/Clay, % | Moisture Content, % |
|---|---|---|---|---|---|---|
| P1 | 1 | 0 to 150 | - | - | - | 3 |
| P1 | 2 | 450 to 600 | - | - | - | 18 |
| P2 | 1 | 0 to 150 | 0 | 99 | 1 | 5 |
| P2 | 2 | 450 | 1 | 98 | 1 | 34 |
| P3 | 1 | 0 to 150 | 3 | 96 | 1 | 26 |
| P3 | 2 | 150 to 300 | 1 | 98 | 1 | 31 |
| BH 101 | SS 1 | 0 to 600 | - | - | - | 14 |
| BH 101 | SS 2 | 600 to 1,200 | 7 | 88 | 5 | 23 |
| BH 101 | SS 3 | 1,500 to 2,100 | - | - | - | 22 |
| BH 102 | SS 1 | 0 to 600 | - | - | - | 29 |
| BH 102 | SS 2 | 600 to 1,200 | 8 | 85 | 7 | 22 |

<u>Glacial Till</u>

A glacially derived till stratum was encountered directly below the sand deposit at both borehole locations. The till consists predominantly of a reddish brown clayey silt and sand with trace to some gravel size particles. The till surface elevation was found to range from el. -0.03 m at BH 101 to el. -0.42 m at BH 102. Both boreholes were terminated within the till stratum.

The N-values obtained within the till were found to range from 5 to 18 with an overall average of 12 generally indicating a firm to stiff consistency. Pocket penetrometer testing carried out on selected till samples also indicates a firm to stiff consistency.

Grain size analyses (curves appended) performed on split spoon samples of the till show it to contain an average of 6 percent gravel, 52 percent sand, and 42 percent fines. Atterberg Limit determinations show the till to contain fines of low plasticity based on average liquid and plastic limits of 19 percent and 16 percent, respectively. The natural moisture content of multiple till samples was found to range from 15 to 21 percent with an average of 17 percent.

**Discussion and Recommendations**

It is understood that the proposed new breakwater is to consist of a rubble mound structure with armored slopes. The subsurface conditions encountered at the site, during the present and previous investigations, are considered to be favorable for this type of construction. No significant layers of compressible marine soils were encountered at the test locations.

The breakwater may be constructed directly over the sand deposit. Most of the settlement of the breakwater associated with compression of the sand should occur during fill placement. It is recommended that the breakwater be constructed in relatively uniform lifts across the site to avoid non-uniform loading of the sand and to ensure stable conditions during fil placement.

Excavated sand recovered from above the water level would be suitable for reuse as core material provided it is free of debris and organic matter. Excavated sand recovered from below the water level would be too wet for reuse unless it is stockpiled and permitted to dry.

Since the sand deposit, due to its uniform gradation and lack of fines, would be highly susceptible to erosion and scour, it is understood that a geotextile is to be utilized to be protect the sand against wave and current action. It may also be necessary, depending on the overall design of the breakwater, to key the west toe of slope into the sand to ensure that no undermining can occur.

We would be pleased to provide further geotechnical input for this project on an as required, as requested basis.

**Closing Comments**

A subsurface investigation is a limited sampling of a site. In the event that any conditions are encountered that differ from those encountered at the test locations, we request that we be notified immediately to permit a reassessment of our design assumptions. We trust this report contains all of the information required at this time, and we are available at your convenience should you have any questions.

Sincerely,

**JOOSE ENVIRONMENTAL CONSULTING INC.**

*George Zafiris*

George W. Zafiris, P. Eng.
Geotechnical Engineer
georgez@bellaliant.net

GWZ/gz

# APPENDIX

**Table 1 - Probe Summary**

| Probe No. | Location | Surface Elevation (m) | Comments |
|---|---|---|---|
| P1 | Sta. 0+13 | 2.15 | Above tide level; excavate 600 mm into sand; recover two samples; able to push probe an additional 100 mm |
| P2 | Sta. 0+20 | 1.84 | Above tide level; excavate 450 mm into sand; recover two samples; black sand encountered at 450 mm depth containing trace to some organic matter; able to push rod an additional 100 mm |
| P3 | Sta. 0+28 | 1.10 | Above tide level; excavate 300 mm into sand; recover two samples; able to push rod an additional 100 mm |
| P4 | Sta. 0+40 | 0.81 | Below tide level; able to push rod 450 mm into bottom |
| P5 | Sta. 0+50 | 0.65 | Below tide level; able to push rod 450 mm into bottom |
| P6 | Sta. 0+60 | 0.35 | Below tide level; able to push rod 250 mm into bottom |
| P7 | Sta. 0+70 | 0.17 | Below tide level; able to push rod 250 mm into bottom |
| P8 | Sta. 0+80 | -0.20 | Below tide level; able to push rod 100 mm into bottom |

NOTES:

- probes were undertaken on 02 August 2017
- probe locations are along proposed breakwater centerline; Sta. 0+00 is at south end of proposed breakwater
- the probe consisted of a 12 mm diameter fiberglass rod
- probe locations and surface elevations were provided by CBCL Limited; elevations are referenced to Low Normal Tide (Chart) Datum
- the sand samples recovered were found to consist of a brown to greyish brown, fine to medium grained sand, with trace silt, gravel

JOOSE ENVIRONMENTAL

The following information is intended to assist in the interpretation of terms and symbols used on the borehole logs, test pit logs and reports.

**Soils Description**

Terminology describing common soil genesis:

| | |
|---|---|
| *Topsoil* | - mixture of soil and humus capable of supporting vegetative growth |
| *Peat* | - mixture of visible and invisible fragments of decayed organic matter |
| *Till* | - unstratified glacial deposit which may range from clay to boulders |
| *Fill* | - material below the surface identified as placed by humans (excluding buried services) |

Terminology describing soil structure:

| | |
|---|---|
| *Desiccated* | - having visible signs of weathering by oxidization of clay minerals, shrinkage cracks, etc. |
| *Fissured* | - having cracks, and hence a blocky structure |
| *Varved* | - composed of regular alternating layers of silt and clay |
| *Stratified* | - composed of alternating successions of different soil types, e.g. silt and sand |
| *Layer* | - > 75 mm in thickness |
| *Seam* | - 2 mm to 75 mm in thickness |
| *Parting* | - < 2 mm in thickness |

Terminology describing soil types:

The classification of soil types are made on the basis of grain size and plasticity in accordance with the Modified Unified Soil Classification System (MUSCS) and in accordance with the Canadian Foundation Engineering Manual Fourth Edition (Canadian Geotechnical Society, 2006). The classification excludes particles larger than 75 mm (3 inches). The MUSCS provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification.

Terminology describing cobbles, boulders, and non-matrix materials (organic matter or debris):

Terminology describing materials outside the USCS, (e.g. particles larger than 76 mm, visible organic matter and construction debris) is based upon the proportion of these materials present:

| | |
|---|---|
| *Trace, or occasional* | Less than 10% |
| *Some* | 10-20% |
| *Frequent* | > 20% |

**Consistency of Cohesive Soils**: May be estimated using simple field tests, or described in terms of a strength scale. In the field, the undrained shear strength ($s_u$) can be assessed using a simple field tool appropriate for cohesive soils, in conjunction with the relevant calibration. Refer to AS 1726-1993, Table A4.

| Consistency - Essentially Cohesive Soils | | | | | |
|---|---|---|---|---|---|
| **Term** | **Field Guide** | **Symbol** | **SPT "N" Value** | **Undrained Shear Strength $s_u$ (kPa)** | **Unconfined Compressive Strength $q_u$ (kPa)** |
| Very soft | Oozes between fingers when | VS | 0-2 | <12 | <25 |
| Soft | Easily moulded with fingers. | S | 2-4 | 12-25 | 25-50 |
| Firm | Can be moulded by strong pressure of fingers. | F | 4-8 | 25-50 | 50-100 |
| Stiff | Not possible to mould with fingers. | St | 8-15 | 50-100 | 100-200 |
| Very stiff | | VSt | 15-30 | 100-200 | 200-400 |
| Hard | Can be indented with difficulty by thumb nail. | H | >30 | >200 | >400 |

**Note:** SPT - N to $q_u$ correlation from Terzaghi and Peck, 1967. (General guide only).

| Soil Particle Sizes | |
|---|---|
| **Term** | **Size Range** |
| BOULDERS | >200 mm |
| COBBLES | 63-200 mm |
| Coarse GRAVEL | 20-63 mm |
| Medium GRAVEL | 6-20 mm |
| Fine GRAVEL | 2.36-6 mm |
| Coarse SAND | 0.6-2.36 mm |
| Medium SAND | 0.2-0.6 mm |
| Fine SAND | 0.075-0.2 mm |
| SILT | 0.002-0.075 mm |
| CLAY | <0.002 mm |

**Consistency of Non-Cohesive Soils**: Is described in terms of the density index, as defined in AS 1289.0-2000. This can be assessed using a field tool appropriate for non-cohesive soils, in conjunction with the relevant calibration. Refer to AS 1726-1993, Table A5; BS5930-1999, p117.

| Consistency - Essentially Non-Cohesive Soils | | | | |
|---|---|---|---|---|
| **Term** | **Symbol** | **SPT N Value** | **Field Guide** | **Density Index (%)** |
| Very loose | VL | 0-4 | Foot imprints readily | 0-15 |
| Loose | L | 4-10 | Shovels Easily | 15-35 |
| Medium dense | MD | 10-30 | Shovelling difficult | 35-65 |
| Dense | D | 30-50 | Pick required | 65-85 |
| Very dense | VD | >50 | Picking difficult | 85-100 |

**Standard Penetration Test (SPT)**: Refer to. AS 1289.6.3.1-2004. Example report formats for SPT results are shown below:

| Test Report | Penetration Resistance (N) | Explanation / Comment |
|---|---|---|
| 4, 7, 11 | N=18 | Full penetration; N is reported on engineering borehole log |
| 18, 27, 32 | N=59 | Full penetration; N is reported on engineering borehole log |
| 4, 18, 30/15 mm | N is not reported | 30 blows causes less than 100 mm penetration (3rd interval) - test discontinued |
| 30/80 mm | N is not reported | 30 blows causes less than 100 mm penetration (1st interval) - test discontinued |
| rw | N<1 | Rod weight only causes full penetration |
| hw | N<1 | Hammer and rod weight only causes full penetration |
| hb | N is not reported | Hammer bouncing for 5 consecutive blows with no measurable penetration - test discontinued |

Rock Description

Except where specified below, terminology for describing rock is as defined by the International Society for Rock Mechanics (ISRM) 2007 publication "The Complete ISRM Suggested Methods for Rock Characterization, Testing and Monitoring: 1974-2006"

Terminology Describing Rock Quality:

| RQD | Rock Mass Quality |
|---|---|
| *0 - 25* | *Very Poor Quality* |
| *25 - 50* | *Poor Quality* |
| *50 - 75* | *Fair Quality* |
| *75 - 90* | *Good Quality* |
| *90 - 100* | *Excellent Quality* |

| Alternate (Colloquial) Rock Mass Quality | |
|---|---|
| *Very Severely Fractured* | *Crushed* |
| *Severely Fractured* | *Shattered or Very Blocky* |
| *Fractured* | *Blocky* |
| *Moderately Jointed* | *Sound* |
| *Intact* | *Very Sound* |

**RQD (Rock Quality Designation)** denotes the percentage of intact and sound rock retrieved from a borehole of any orientation. All pieces of intact and sound rock core equal to or greater than 100 mm (4 inches) long are summed up and divided by the total length of the core run. RQD is determined in accordance with ASTM D6032.

**SCR (Solid Core Recovery)** denotes the percentage of solid core (cylindrical) retrieved forma borehole of any orientation. All pieces of the solid (cylindrical) core are summed and divided by the total length of the core run (It excludes all portions of core pieces that are not fully cylindrical as well as crushed or rubble zones).

**Fracture Index (FI)** is defined as the number of naturally occurring fractures within a given length of core. The Fracture Index is reported as a simple count of the natural occurring fractures.

Refer to AS 1726-1993 (Appendix A3.3) for the description and classification of rock material composition, including:

(a) Rock type (Table A6, (a) and (b))
(b) Grain size
(c) Texture and fabric
(d) Colour (describe as per soil).

The condition of a rock material refers to its weathering characteristics, strength characteristics and rock mass properties. Refer to AS 1726-1993 (Appendix A3 Tables A8, A9 and A10).

**Weathering Condition (Degree of Weathering):**

The degree of weathering is a continuum from fresh rock to soil. Boundaries between weathering grades may be abrupt or gradational.

| Rock Material Weathering | | |
|---|---|---|
| **Weathering Grade** | **Symbol** | **Definitio** |
| Residual Soil | RS | Soil-like material developed on extremely weathered rock; the mass structure and substance fabric are no longer evident; there is a large change in volume but the material has not been significantly transported. |
| Extremely Weathered Rock | XW | Rock is weathered to such an extent that it has 'soil' properties, i.e. it either disintegrates or can be remoulded in water, but substance fabric and rock structure still recognizable. |
| Highly Weathered Rock | HW | Strong discolouration is evident throughout the rock mass, often with significant change in the constituent minerals. The intact rock strength is generally much weaker than that of the fresh rock. |
| Moderately Weathered Rock | MW | Modest discolouration is evident throughout the rock fabric, often with some change in the constituent minerals. The intact rock strength is usually noticeably weaker than that of the fresh rock. |
| Slightly Weathered | SW | Rock is slightly discoloured but shows little or no change of strength from fresh rock. |
| Fresh Rock | FR | Rock shows no sign of decomposition or staining. |

Notes:

1. Minor variations within broader weathering grade zones will be noted on the engineering borehole logs.
2. Extremely weathered rock is described in terms of soil engineering properties.
3. Weathering may be pervasive throughout the rock mass, or may penetrate inwards from discontinuities to some extent.
4. The 'Distinctly Weathered (DW)' class as defined in AS 1726-1993 is divided to incorporate HW and MW in the above table. The symbol DW should not be used.

**Strength Condition (Intact Rock Strength):**

Terminology Describing Rock Strength

| Strength Classification | Grade | Unconfined Compressive Strength (MPa) |
|---|---|---|
| Extremely Weak | R0 | < 1 |
| Very Weak | R1 | 1 - 5 |
| Weak | R2 | 5 - 25 |
| Medium Strong | R3 | 25 - 50 |
| Strong Very | R4 | 50 - 100 |
| Strong Extremely | R5 | 100 - 250 |
| Strong | R6 | > 250 |

**Discontinuity Spacing**: On the geotechnical borehole log, a graphical representation of defect spacing vs depth is shown. This representation takes into account all the natural rock defects occurring within a given depth interval, excluding breaks induced by the drilling / handling of core. Refer to AS 1726-1993, BS5930-1999.

| Defect Spacing | | | Bedding Thickness (Sedimentary Rock Stratification) | |
|---|---|---|---|---|
| **Spacing/Width (mm)** | **Descriptor** | **Symbol** | **Descriptor** | **Spacing /Width (mm)** |
| | | | Thinly Laminated | <6 |
| <20 | Extremely Close | EC | Thickly Laminated | 6 - 20 |
| 20 - 60 | Very Close | VC | Very Thinly Bedded | 20 - 60 |
| 60 - 200 | Close | C | Thinly Bedded | 60 -200 |
| 200 - 600 | Medium | M | Medium Bedded | 200 - 600 |
| 600 - 2000 | Wide | W | Thickly Bedded | 600 - 2000 |
| 2000 - 6000 | Very Wide | VW | Very Thickly Bedded | >2000 |
| >6000 | Extremely Wide | EW | | |

| Defect Spacing in 3D | |
|---|---|
| **Term** | **Description** |
| Blocky | Equidimensional |
| Tabular | Thickness much less than length or width |
| Columnar | Height much greater than cross section |

| Direct Persistence (areal extent) |
|---|
| Trace length of defect given in metres |

The list on the following table provides an explanation of terms and symbols used on the geotechnical borehole, test pit and penetrometer logs.

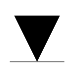
| Test Results | | | | Test Symbols | |
|---|---|---|---|---|---|
| PI | Plasticity Index | $c'$ | Effective Cohesion | DCP | Dynamic Cone Penetrometer |
| LL | Liquid Limit | $c_u$ | Undrained Cohesion | SPT | Standard Penetration Test |
| LI | Liquidity Index | $c'_R$ | Residual Cohesion | CPTu | Cone Penetrometer (Piezocone) Test |
| DD | Dry Density | $\varphi'$ | Effective Angle of Internal Friction | PANDA | Variable Energy DCP |
| WD | Wet Density | $\varphi_u$ | Undrained Angle of Internal Friction | PP | Pocket Penetrometer Test |
| LS | Linear Shrinkage | $\varphi'_R$ | Residual Angle of Internal Friction | U50 | Undisturbed Sample 50 mm (nominal diameter) |
| MC | Moisture Content | $c_v$ | Coefficient of Consolidation | U100 | Undisturbed Sample 100mm (nominal diameter) |
| OC | Organic Content | $m_v$ | Coefficient of Volume Compressibility | UCS | Uniaxial Compressive Strength |
| WPI | Weighted Plasticity Index | $c_{\alpha\varepsilon}$ | Coefficient of Secondary Compression | Pm | Pressuremeter |

| Test Results | | | | Test Symbols | |
|---|---|---|---|---|---|
| WLS | Weighted Linear Shrinkage | $e$ | Voids Ratio | FSV | Field Shear Vane |
| DoS | Degree of Saturation | $\varphi'_{cv}$ | Constant Volume Friction Angle | DST | Direct Shear Test |
| APD | Apparent Particle Density | $q_t$ / $q_c$ | Piezocone Tip Resistance (corrected / uncorrected) | PR | Penetration Rate |
| $s_u$ | Undrained Shear Strength | $q_d$ | PANDA Cone Resistance | A | Point Load Test (axial) |
| $q_u$ | Unconfined Compressive Strength | $I_{s(50)}$ | Point Load Strength Index | D | Point Load Test (diametral) |
| *R* | Total Core Recovery | *RQD* | Rock Quality Designation | L | Point Load Test (irregular lump) |

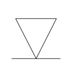
## Sample Type

| | |
|---|---|
| SS | Split spoon sample (obtained by performing the Standard Penetration Test) |
| ST | Shelby tube or thin wall tube |
| DP | Direct-Push sample (small diameters tube sampler hydraulically advanced) |
| PS | Piston sample |
| BS | Bulk sample |
| WS | Wash sample |
| HQ,NQ, BQ, etc | Rock core samples obtained with the use of standard size diamond coring bits. |

## Water Level Measurement



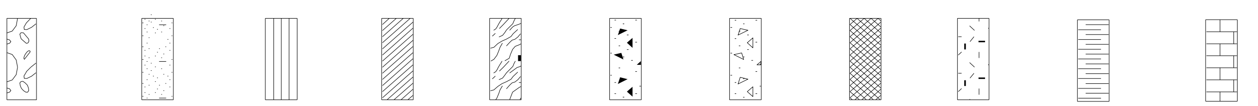
Measurement in standpipe, piezometer, or well



Inferred

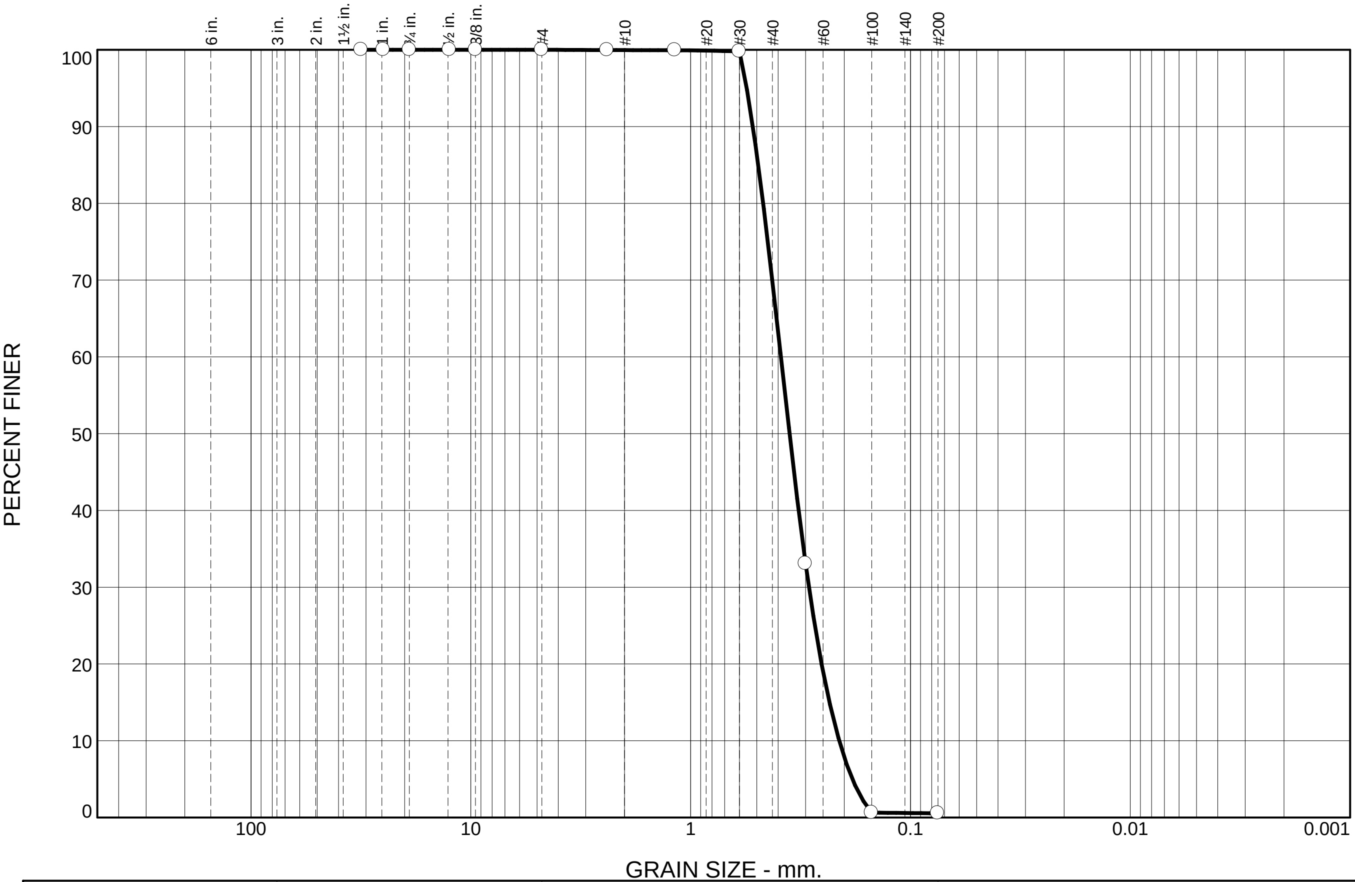
## Strata Plot

Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



Boulders Cobbles Gravel | Sand | Silt | Clay | Organics | Asphalt | Concrete | Fill | Igneous Bedrock | Metamorphic Bedrock | Sedimentary Bedrock

# Particle Size Distribution Report




| | % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|---|
| | | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| ○ | 0.0 | 0.0 | 0.0 | 0.0 | 30.1 | 69.4 | 0.5 | |
| | | | | | | | | |
| | | | | | | | | |

| | LL | PL | $D_{85}$ | $D_{60}$ | $D_{50}$ | $D_{30}$ | $D_{15}$ | $D_{10}$ | $C_c$ | $C_u$ |
|---|---|---|---|---|---|---|---|---|---|---|
| ○ | | | 0.4927 | 0.3885 | 0.3548 | 0.2897 | 0.2335 | 0.2109 | 1.02 | 1.84 |
| | | | | | | | | | | |
| | | | | | | | | | | |

| | Material Description | USCS | AASHTO |
|---|---|---|---|
| ○ | Sand | SP | |

**Project No.** 17-12608 **Client:** Joose Environmental

**Project:** QC- Soils Analysis JE-0160 NorthLake

○ **Location:** P2-S1 - Station 0+20 **Depth:** 0-6" **Sample Number:** 1

FUNDY Engineering

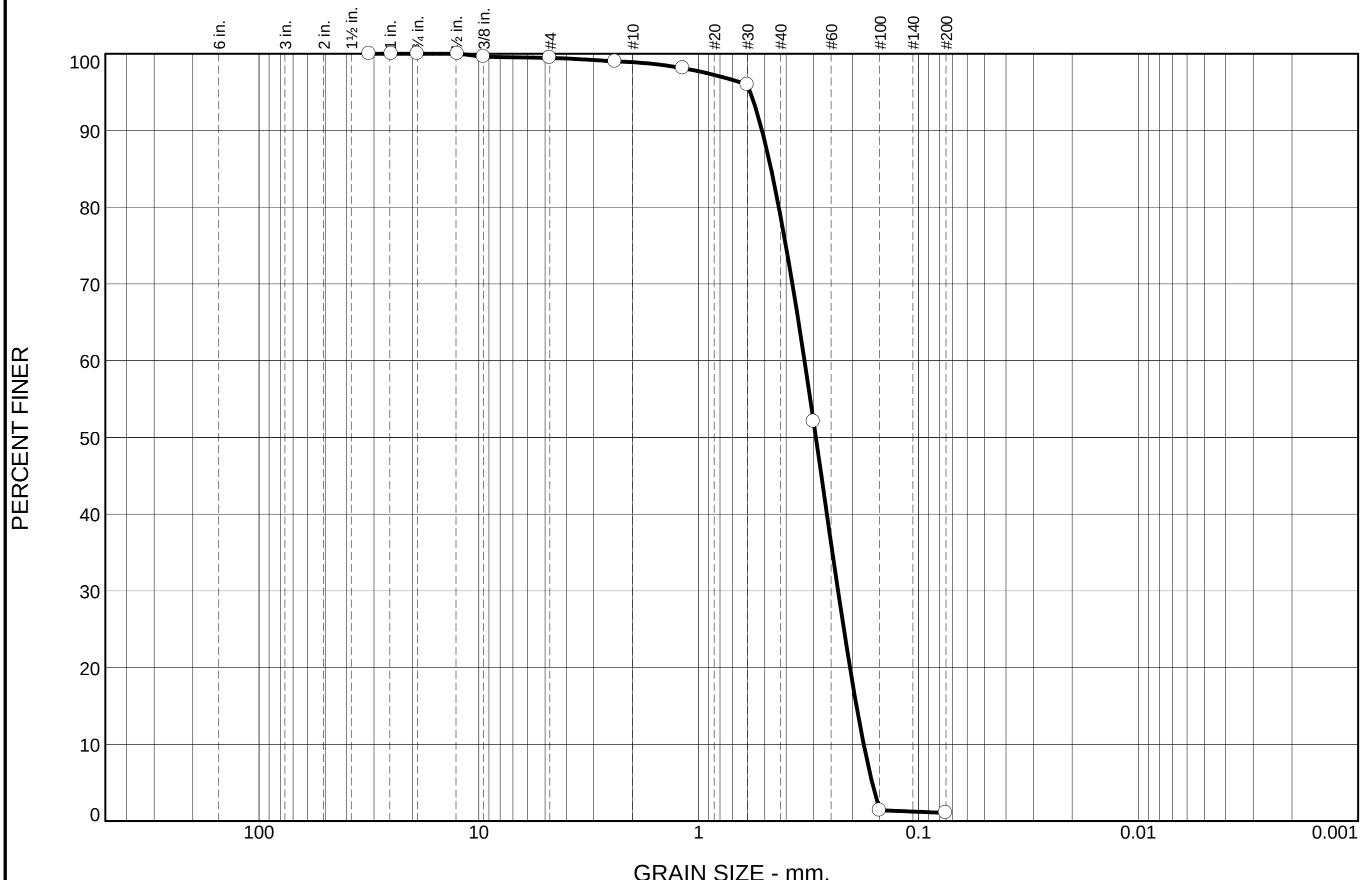
**Remarks:**

○Moisture Content of the sample was 4.7%

**Figure**

**Tested By:** B.Brennan **Checked By:** D.Taweel

# Particle Size Distribution Report




| % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|
| | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| 0.0 | 0.0 | 0.5 | 0.6 | 19.9 | 77.9 | 1.1 | |

| LL | PL | $D_{85}$ | $D_{60}$ | $D_{50}$ | $D_{30}$ | $D_{15}$ | $D_{10}$ | $C_c$ | $C_u$ |
|---|---|---|---|---|---|---|---|---|---|
| | | 0.4684 | 0.3299 | 0.2929 | 0.2322 | 0.1914 | 0.1775 | 0.92 | 1.86 |

| Material Description | USCS | AASHTO |
|---|---|---|
| Sand | SP | |

**Project No.** 17-12608 **Client:** Joose Environmental

**Project:** QC- Soils Analysis JE-0160 North Lake

**Location:** P2-S2 - 20 m **Depth:** 18" **Sample Number:** 2

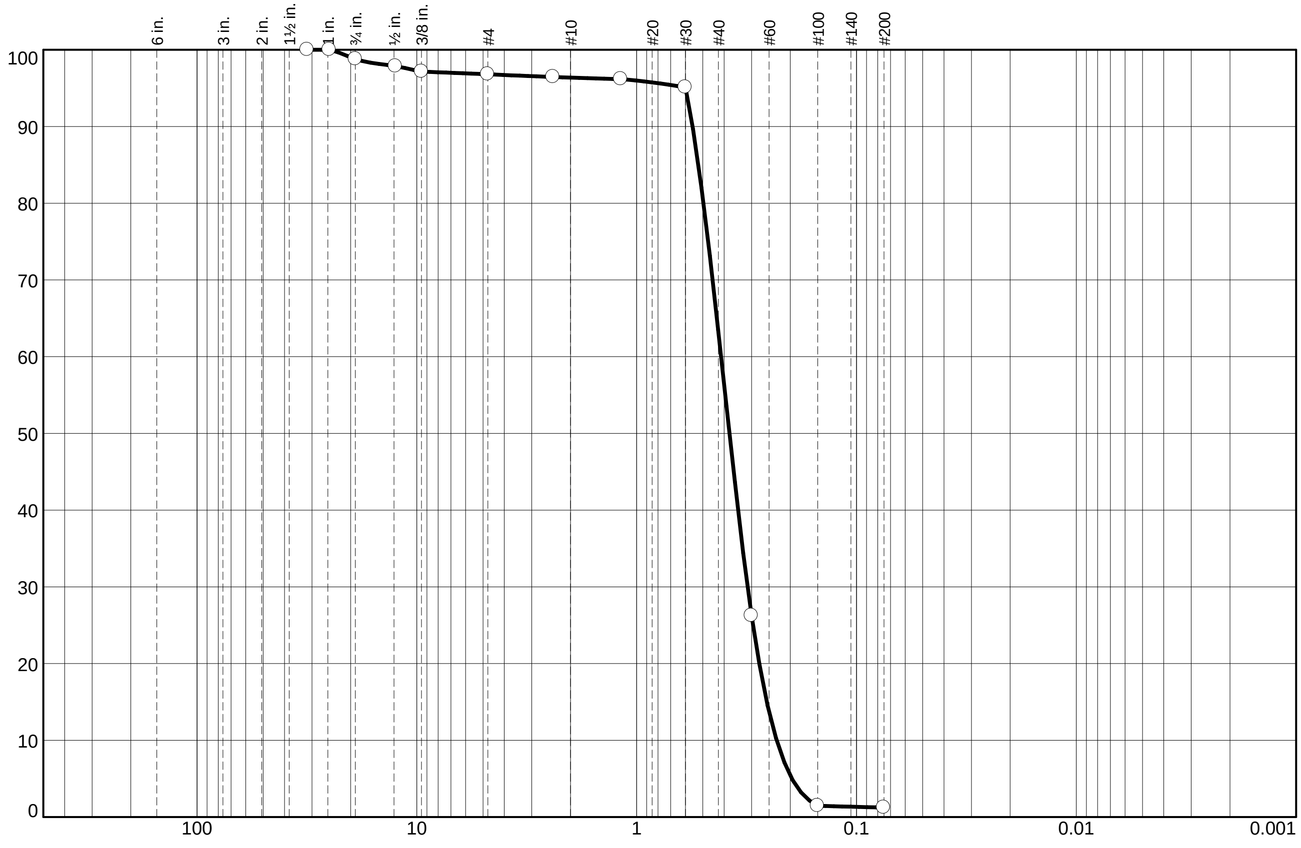
FUNDY Engineering

**Remarks:**
Moisture Content on the sample was 33.7%

**Figure**

**Tested By:** B.Brennan **Checked By:** D.Taweel

# Particle Size Distribution Report




| | % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|---|
| | | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| ○ | 0.0 | 1.2 | 2.0 | 0.4 | 33.1 | 62.1 | 1.2 | |
| | | | | | | | | |
| | | | | | | | | |

| | LL | PL | $D_{85}$ | $D_{60}$ | $D_{50}$ | $D_{30}$ | $D_{15}$ | $D_{10}$ | $C_c$ | $C_u$ |
|---|---|---|---|---|---|---|---|---|---|---|
| ○ | | | 0.5238 | 0.4129 | 0.3782 | 0.3129 | 0.2557 | 0.2306 | 1.03 | 1.79 |
| | | | | | | | | | | |
| | | | | | | | | | | |

| Material Description | USCS | AASHTO |
|---|---|---|
| ○ Sand | SP | |

**Project No.** 17-12608 **Client:** Joose Environmental

**Project:** QC- Soils Analyusis JE-0160 North Lake

○ **Location:** P3-S1 Station 0+28 **Depth:** 0-6" **Sample Number:** 3

FUNDY Engineering

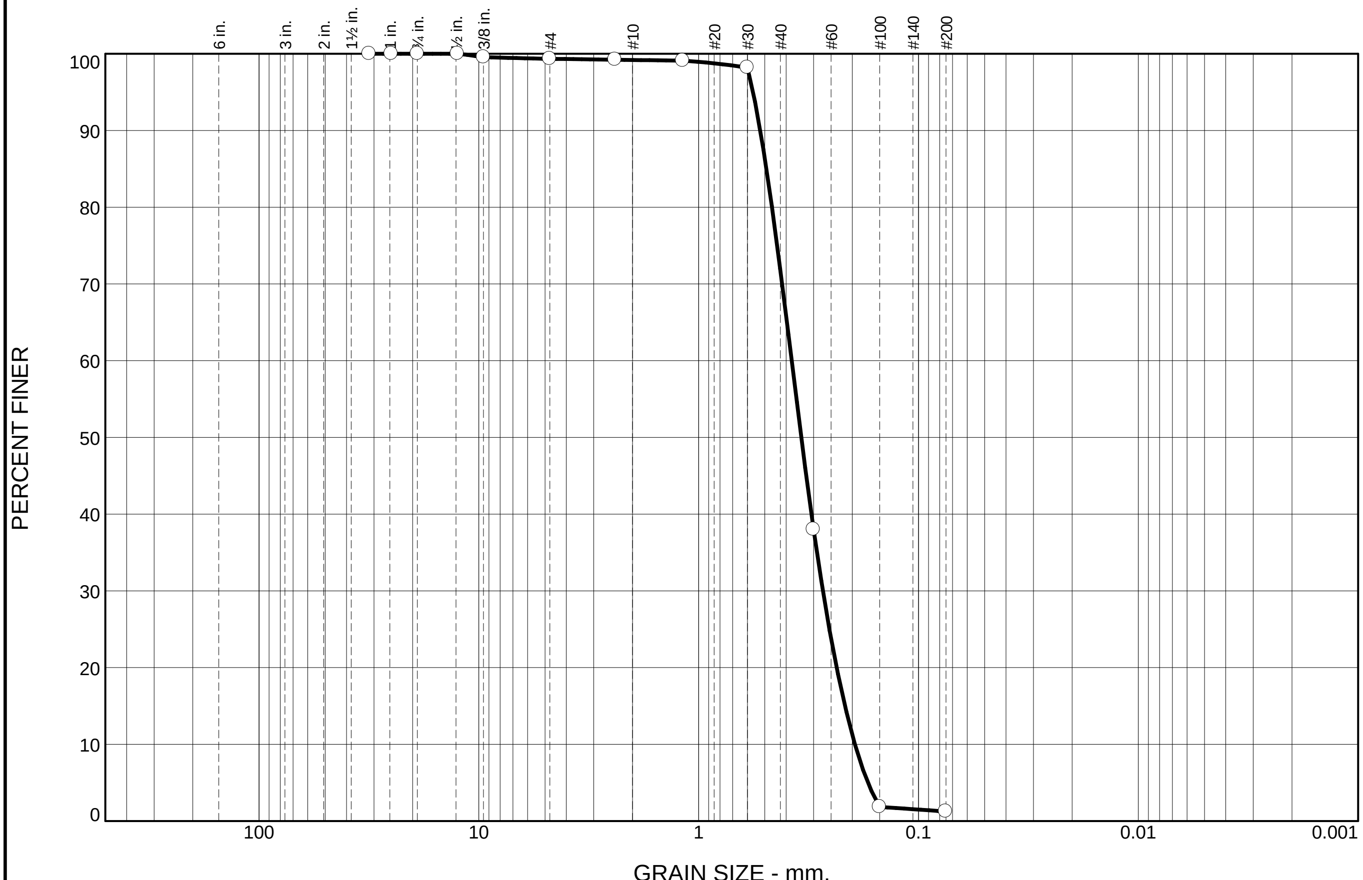
**Remarks:**

○Moisture Content of the sample was 26.5%

**Figure**

**Tested By:** B.Brennan **Checked By:** D.Taweel

# Particle Size Distribution Report




| | % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|---|
| | | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| ○ | 0.0 | 0.0 | 0.7 | 0.1 | 27.4 | 70.6 | 1.2 | |
| | | | | | | | | |
| | | | | | | | | |

| | LL | PL | $D_{85}$ | $D_{60}$ | $D_{50}$ | $D_{30}$ | $D_{15}$ | $D_{10}$ | $C_c$ | $C_u$ |
|---|---|---|---|---|---|---|---|---|---|---|
| ○ | | | 0.4917 | 0.3772 | 0.3411 | 0.2722 | 0.2159 | 0.1946 | 1.01 | 1.94 |
| | | | | | | | | | | |
| | | | | | | | | | | |

| Material Description | USCS | AASHTO |
|---|---|---|
| ○ Sand | SP | |

**Project No.** 17-12608 **Client:** Joose Environmental

**Project:** QC- Soils Analysis JE-0160 North Lake

○ **Location:** P3-S2 Station 0+28 **Depth:** 6"- 12" **Sample Number:** 4

FUNDY Engineering

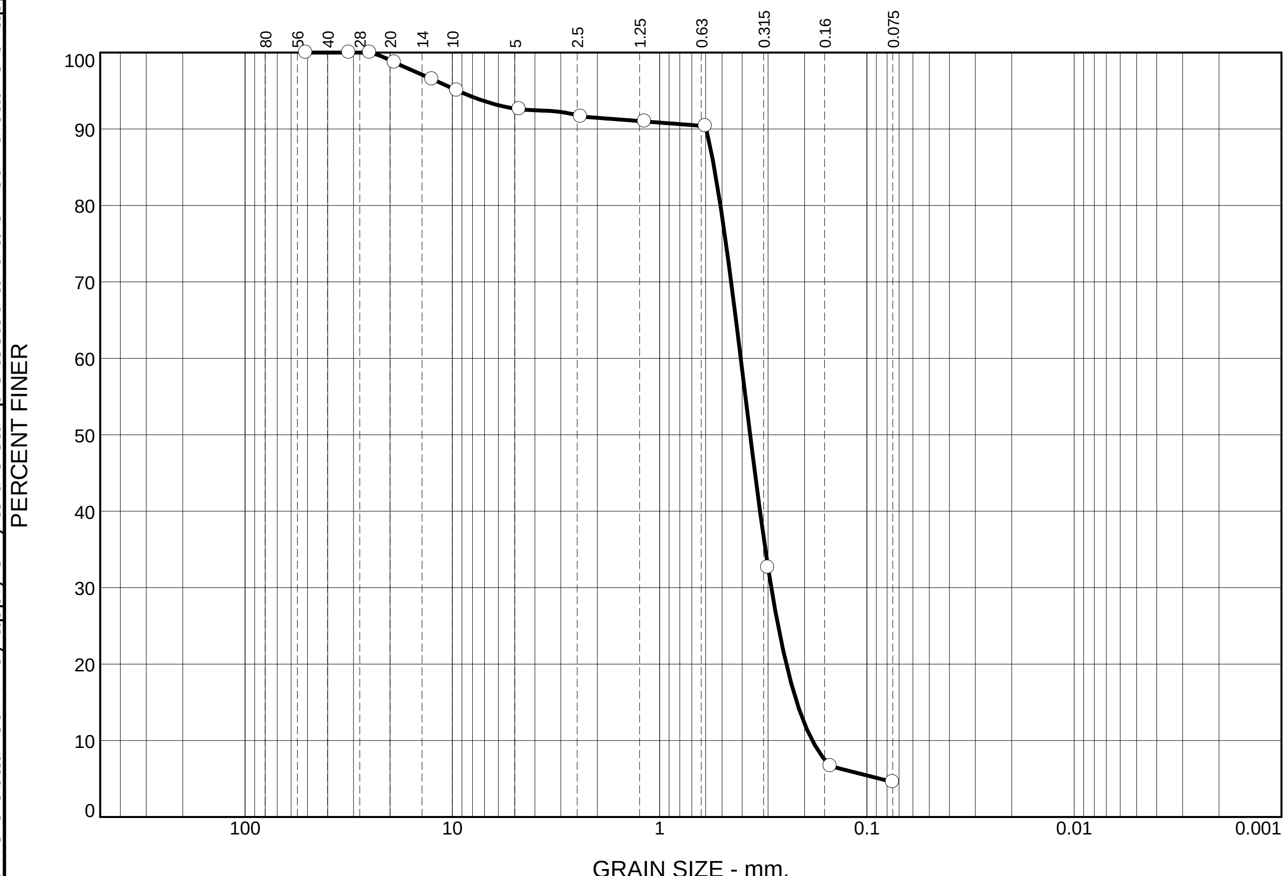
**Remarks:**

○Moisture Content of the sample was 31.1%

**Figure**

**Tested By:** B.Brennan **Checked By:** D.Taweel

# Particle Size Distribution Report




| % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|
| | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| 0 | 1 | 6 | 2 | 27 | 59 | 5 | |

| LL | PL | $D_{85}$ | $D_{60}$ | $D_{50}$ | $D_{30}$ | $D_{15}$ | $D_{10}$ | $C_c$ | $C_u$ |
|---|---|---|---|---|---|---|---|---|---|
| | | 0.5457 | 0.4065 | 0.3661 | 0.2894 | 0.2177 | 0.1835 | 1.12 | 2.21 |

| Material Description | USCS | AASHTO |
|---|---|---|
| Aug 10 2017 | SP | |

**Project No.** 17-12608 **Client:** Joose Environmental

**Project:** NorthLake Breakwater

**Location:** BH - 101 SS#2

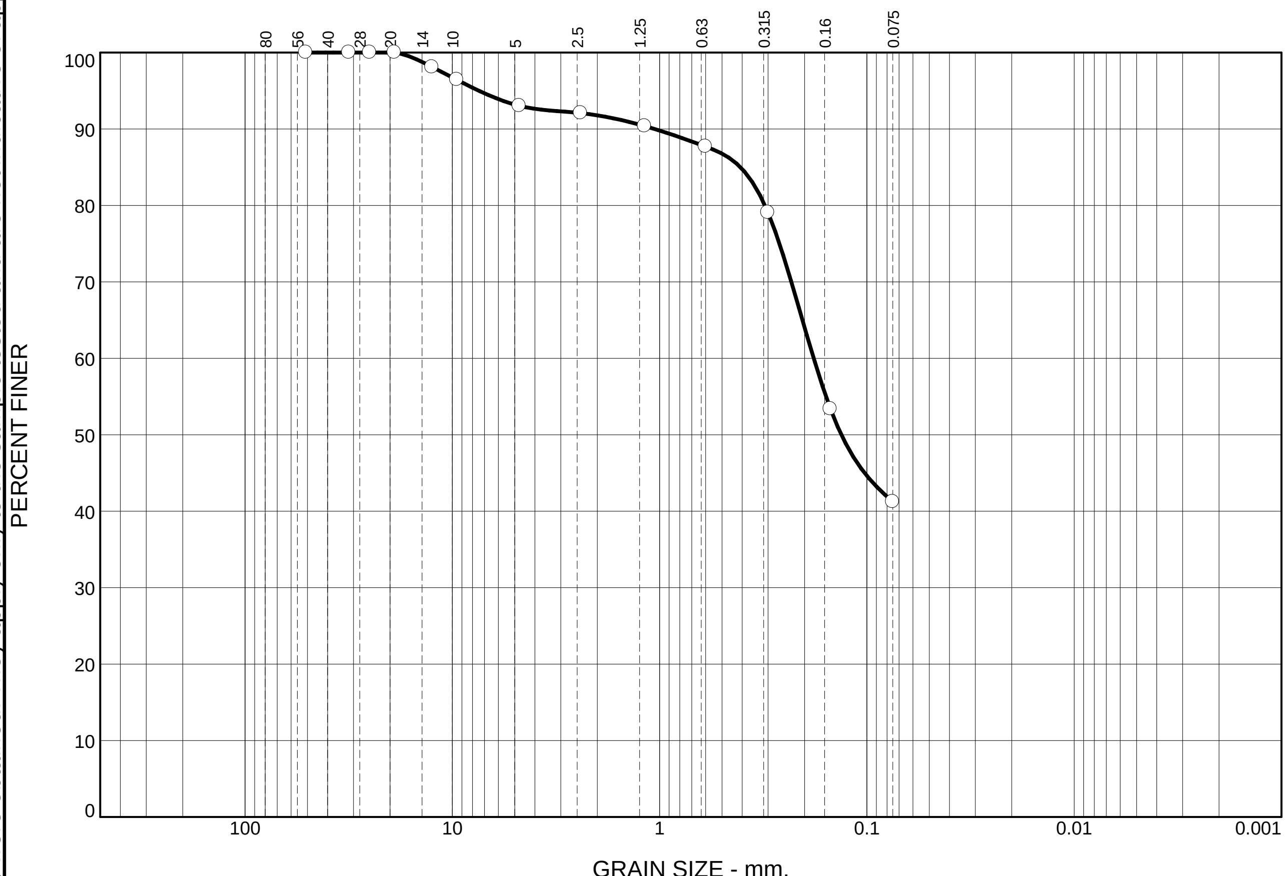
**Remarks:**

FUNDY Engineering

**Figure**

**Tested By:** R.Wakelin **Checked By:** D.Taweel

# Particle Size Distribution Report




| | % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|---|
| | | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| ○ | 0 | 0 | 7 | 1 | 7 | 44 | 41 | |
| | | | | | | | | |
| | | | | | | | | |

| | LL | PL | $D_{85}$ | $D_{60}$ | $D_{50}$ | $D_{30}$ | $D_{15}$ | $D_{10}$ | $C_c$ | $C_u$ |
|---|---|---|---|---|---|---|---|---|---|---|
| ○ | 19 | 17 | 0.4077 | 0.1806 | 0.1328 | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

| Material Description | USCS | AASHTO |
|---|---|---|
| ○ Aug 10 2017 | SM | A-4(0) |

**Project No.** 17-12608 **Client:** Joose Environmental

**Project:** North Lake Breakwater

○ **Location:** BH 101 SS#5

FUNDY Engineering

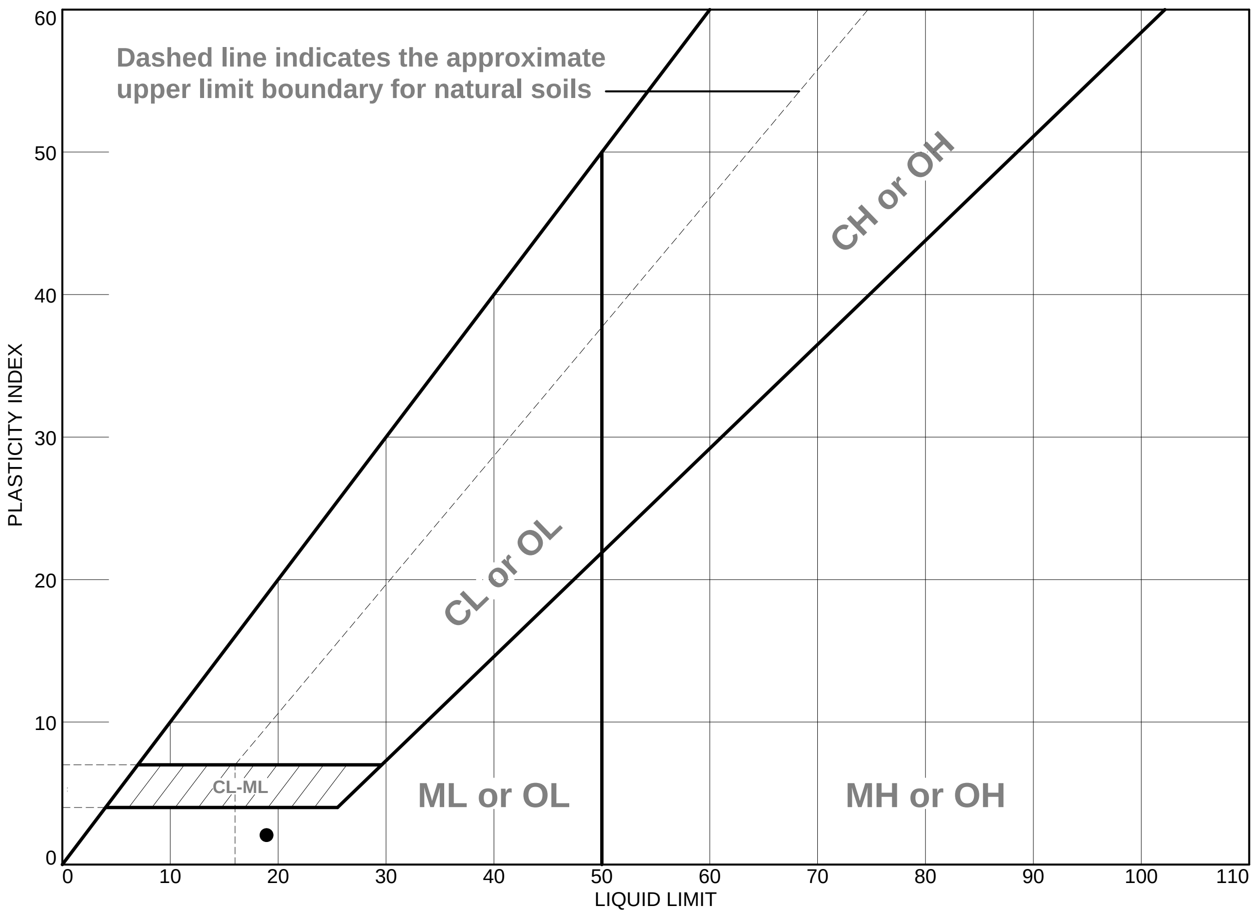
**Remarks:**

**Figure**

**Tested By:** R.Wakelin **Checked By:** D.Taweel

These results are for the exclusive use of the client for whom they were obtained. They apply only to the sample tested and are not indicative of apparently identical samples

# LIQUID AND PLASTIC LIMITS TEST REPORT




| | MATERIAL DESCRIPTION | LL | PL | PI | %<#40 | %<#200 | USCS |
|---|---|---|---|---|---|---|---|
| ● | Aug 10 2017 | 19 | 17 | 2 | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

**Project No.** 17-12608 **Client:** Joose Environmental

**Project:** North Lake Breakwater

● **Location:** BH 101 SS#5

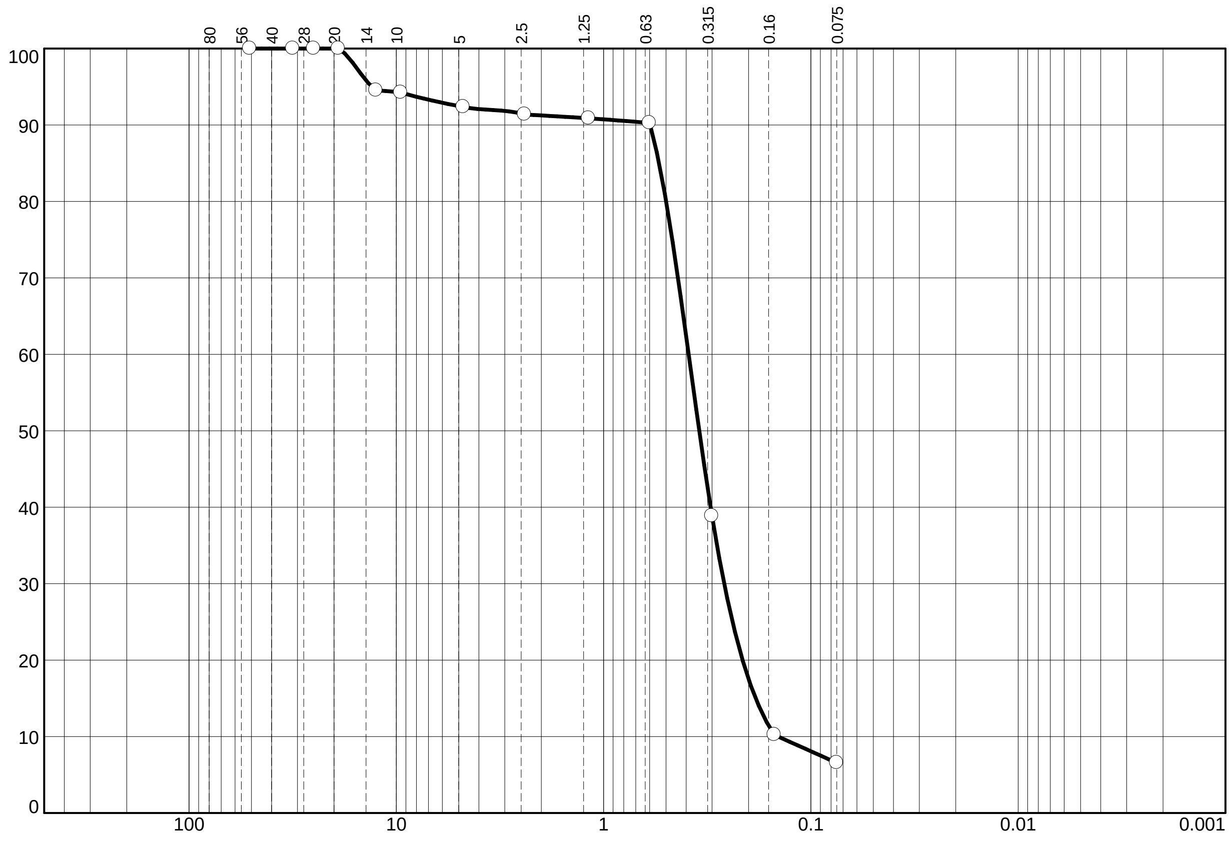
**Remarks:**

FUNDY Engineering

**Figure**

**Tested By:** R.Wakelin **Checked By:** D.Taweel

# Particle Size Distribution Report




| | % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|---|
| | | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| ○ | 0 | 0 | 8 | 1 | 24 | 60 | 7 | |

| | LL | PL | $D_{85}$ | $D_{60}$ | $D_{50}$ | $D_{30}$ | $D_{15}$ | $D_{10}$ | $C_c$ | $C_u$ |
|---|---|---|---|---|---|---|---|---|---|---|
| ○ | | | 0.5400 | 0.3891 | 0.3458 | 0.2620 | 0.1848 | 0.1440 | 1.23 | 2.70 |

| Material Description | USCS | AASHTO |
|---|---|---|
| ○ Aug 10 2017 | | |

**Project No.** 17-12608 **Client:** Joose Environmental

**Project:** North Lake Breakwater

○ **Location:** BH 102 SS#2

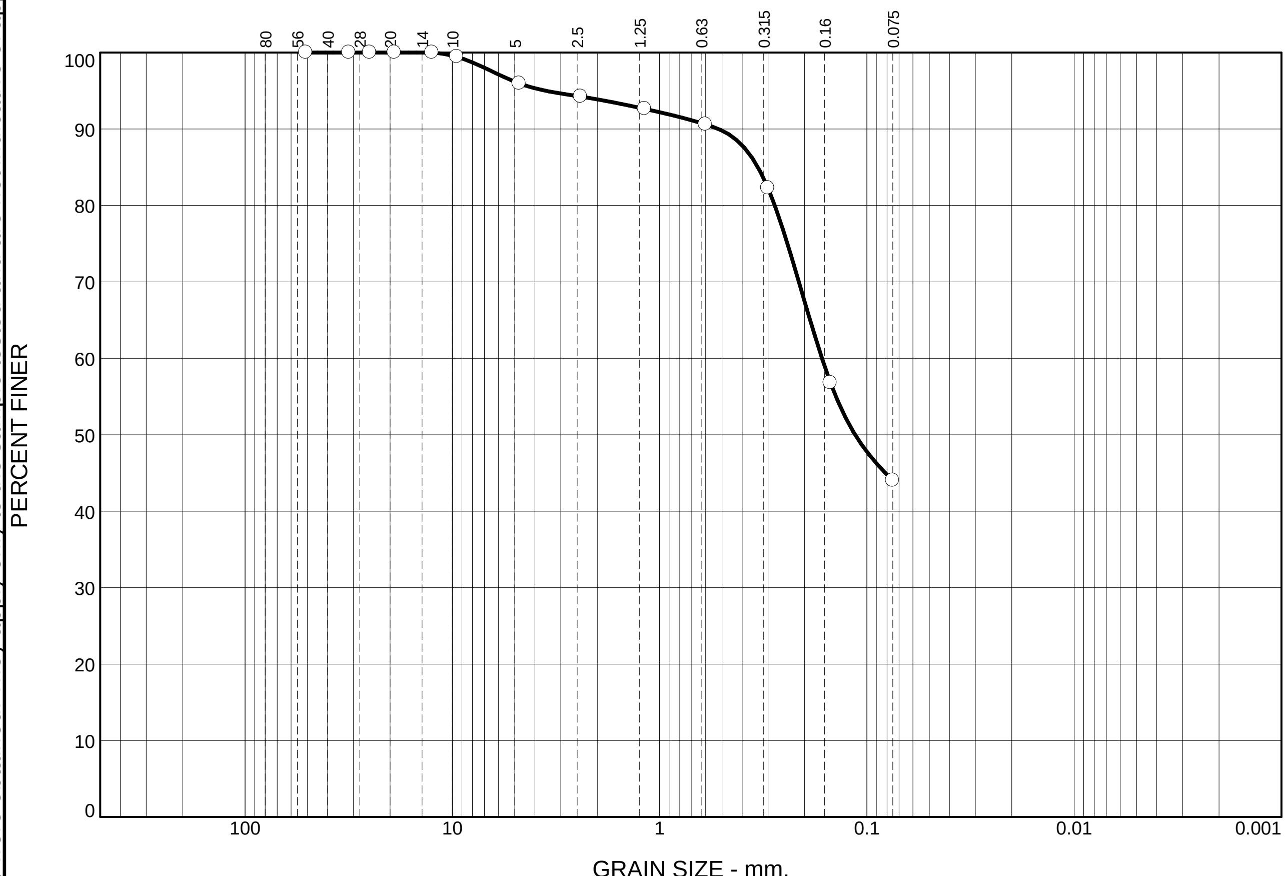
FUNDY Engineering

**Remarks:**

**Figure**

**Tested By:** R.Wakelin **Checked By:** D.Taweel

# Particle Size Distribution Report




| % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|
| | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| 0 | 0 | 4 | 2 | 5 | 45 | 44 | |

| LL | PL | $D_{85}$ | $D_{60}$ | $D_{50}$ | $D_{30}$ | $D_{15}$ | $D_{10}$ | $C_c$ | $C_u$ |
|---|---|---|---|---|---|---|---|---|---|
| 19 | 16 | 0.3358 | 0.1649 | 0.1139 | | | | | |

| Material Description | USCS | AASHTO |
|---|---|---|
| Aug 10 2017 | SM | A-4(0) |

**Project No.** 17-12608 **Client:** Joose Environmental

**Project:** North Lake Breakwater

**Location:** BH 102 SS#6

FUNDY Engineering

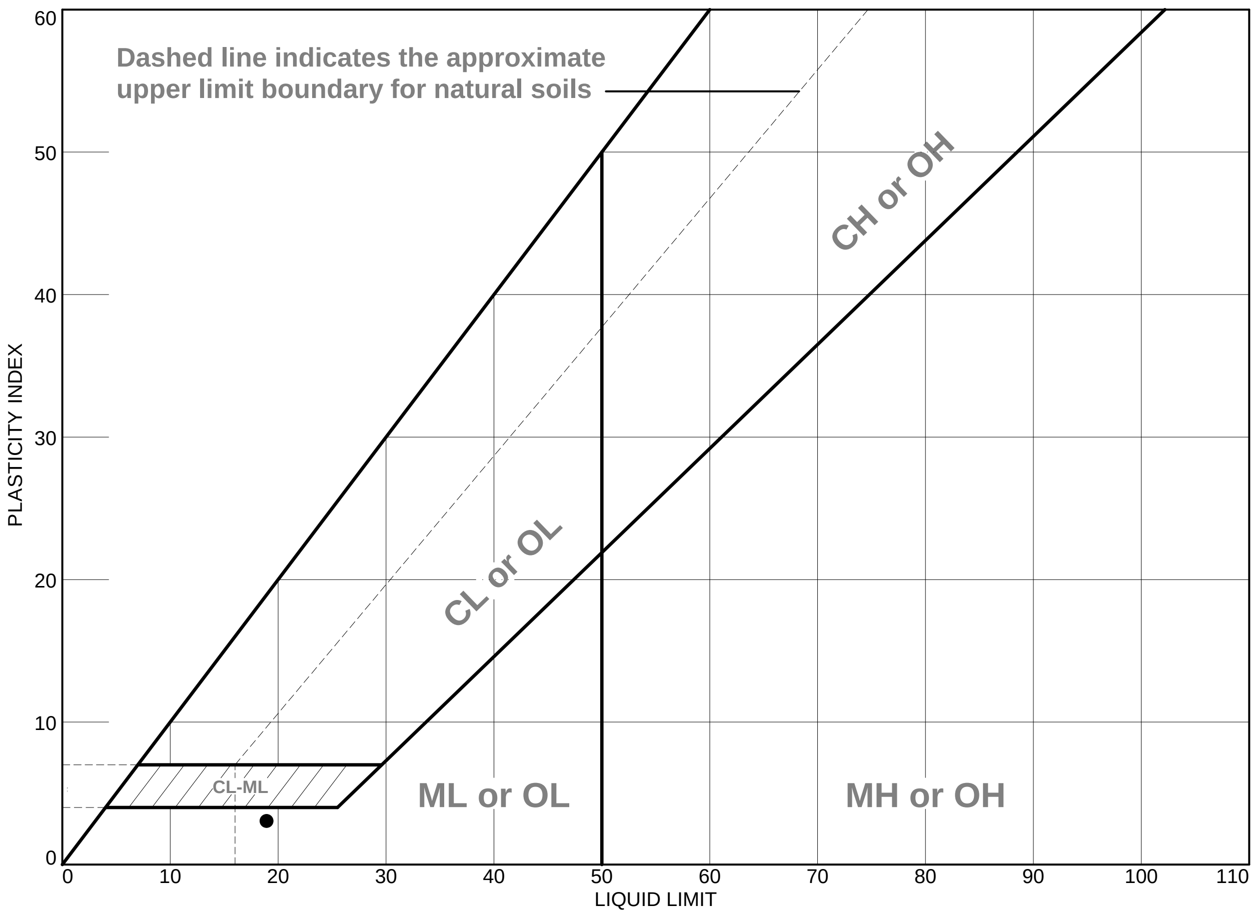
**Remarks:**

**Figure**

**Tested By:** R.Wakelin **Checked By:** D.Taweel

These results are for the exclusive use of the client for whom they were obtained. They apply only to the sample tested and are not indicative of apparently identical samples

# LIQUID AND PLASTIC LIMITS TEST REPORT




| | MATERIAL DESCRIPTION | LL | PL | PI | %<#40 | %<#200 | USCS |
|---|---|---|---|---|---|---|---|
| ● | Aug 10 2017 | 19 | 16 | 3 | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

**Project No.** 17-12608 **Client:** Joose Environmental

**Project:** North Lake Breakwater

●**Location:** BH 102 SS#6

**Remarks:**

FUNDY Engineering

**Figure**

**Tested By:** R.Wakelin **Checked By:** D.Taweel

# BOREHOLE No. BH 101



**Date Drilled:** 08 AUG 2017
**Contractor:** Logan Drilling Group
**Equipment:** Track-mounted auger (CME 55)

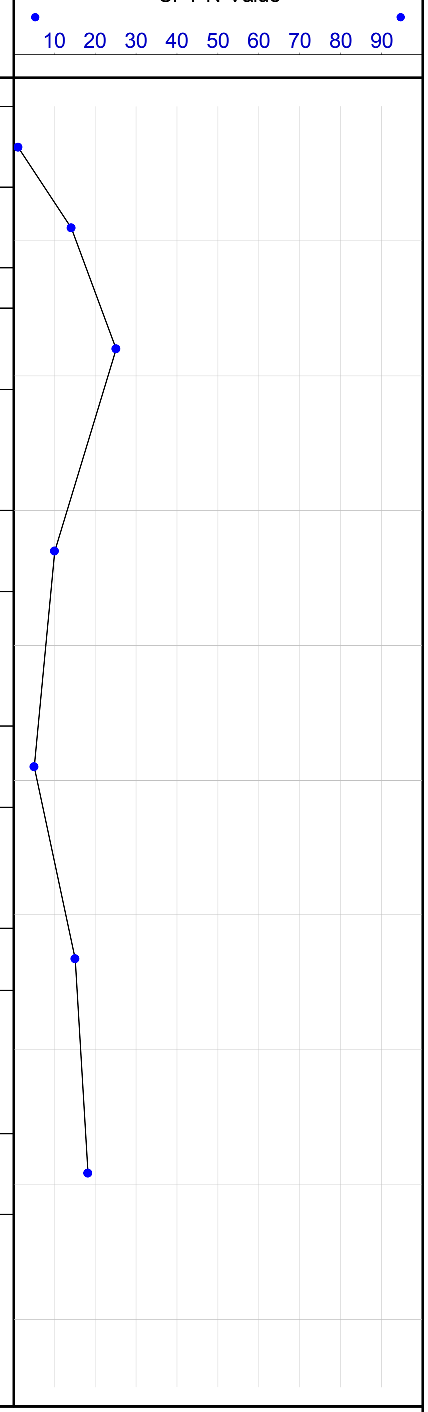
**Location:** Proposed Breakwater, Sta. 0+015
**Elevation:** 2.1
**Datum:** Low Normal Tide (Chart)

**Project No.** JE0160
**Project:** North Lake Harbour
**Client:** PWGSC

| Elevation, m / Depth, m | SOIL DESCRIPTION | Sample Type | Sample Number | Recovery, mm | SPT N-Value | Moisture Content, % | Other Tests |
|---|---|---|---|---|---|---|---|
| 2.10 | Ground Surface | | | | | | |
| 2.10 / 0.00 | Very loose to compact, fine to medium grained, brown sand, trace silt, gravel: **Marine Deposit** | SS | 1 | 500 | 1 | 14 | |
| | | SS | 2 | 550 | 14 | 22 | S |
| | | SS | 3 | 300 | 25 | 22 | |
| -0.03 / 2.13 | Firm to stiff, reddish brown clayey silt and sand, trace to some gravel: **Till** | SS | 4 | 200 | 10 | 20 | |
| | | SS | 5 | 350 | 5 | 18 | S/L |
| | | SS | 6 | 300 | 15 | 18 | |
| | | SS | 7 | 150 | 18 | 21 | |
| -6.13 / 8.23 | End of Borehole | | | | | | |

Depth scale: ft 0–31; m 0–9

SPT N-Value

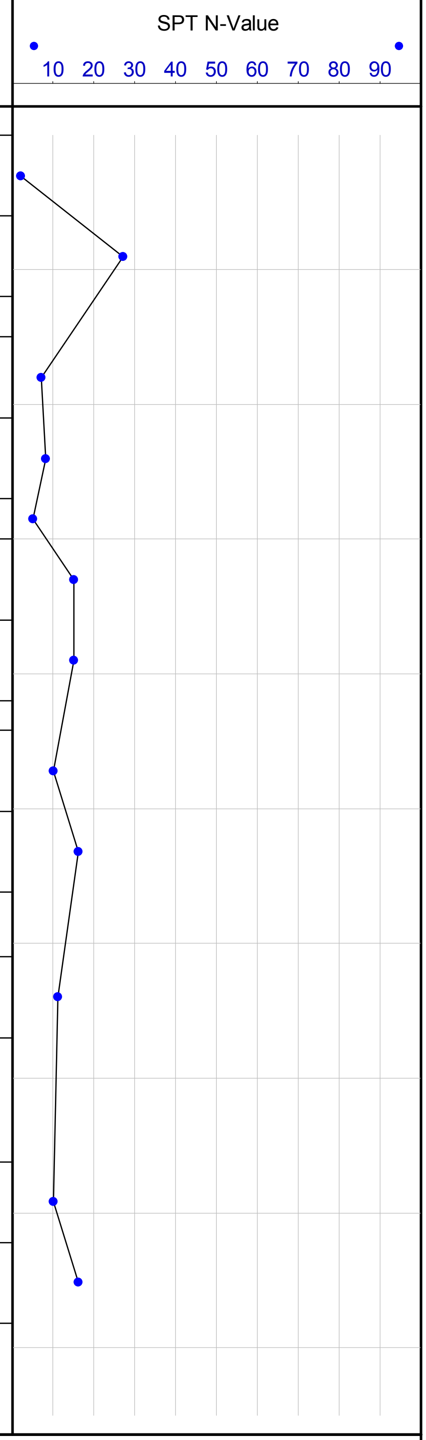


# BOREHOLE No. BH 102

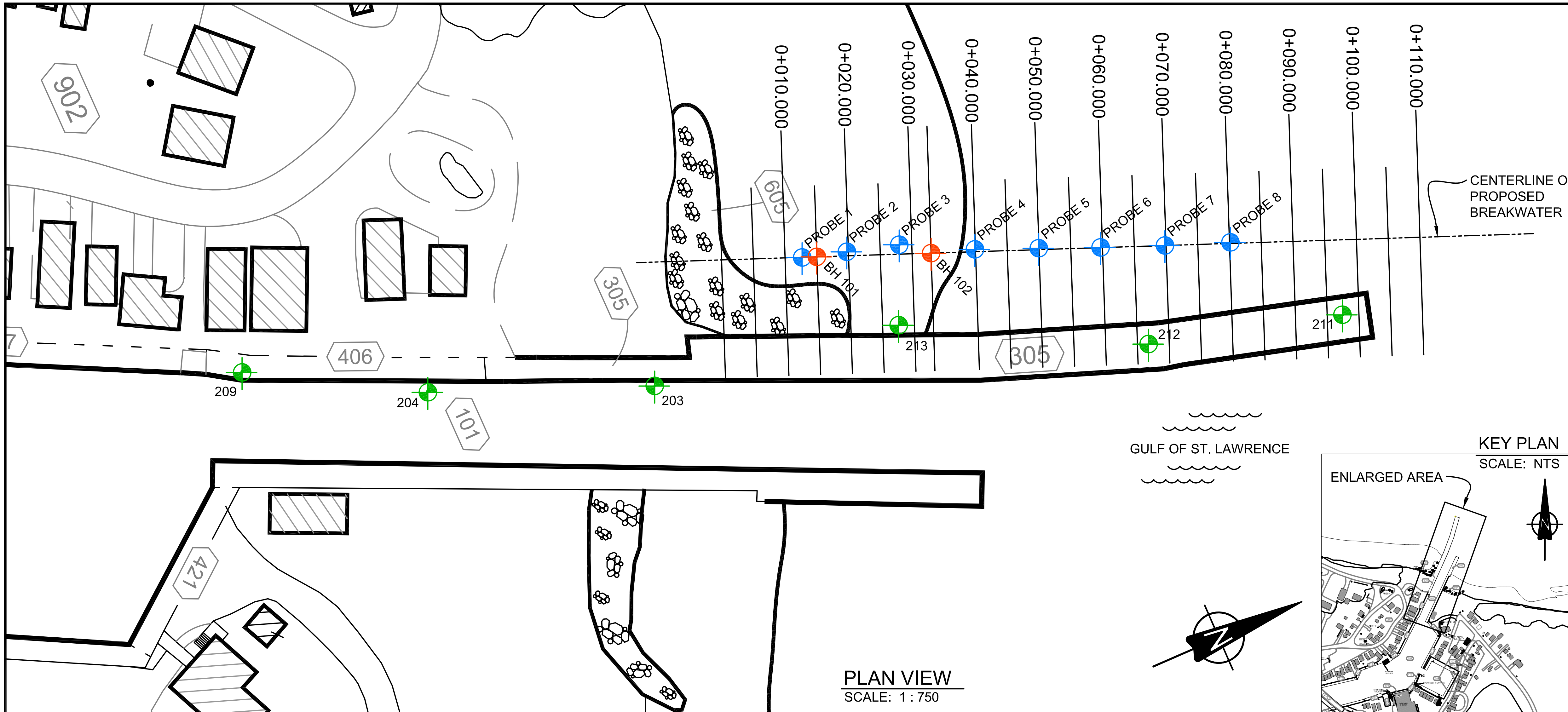


| | | |
|---|---|---|
| **Date Drilled:** 08 AUG 2017<br>**Contractor:** Logan Drilling Group<br>**Equipment:** Track-mounted auger (CME 55) | **Location:** Proposed Breakwater, Sta. 0+033<br>**Elevation:** 1.1<br>**Datum:** Low Normal Tide (Chart) | **Project No.** JE0160<br>**Project:** North Lake Harbour<br>**Client:** PWGSC |

| Depth (ft / m) | Elevation, m | SOIL DESCRIPTION | Strata Plot | Water Level | Sample Type | Sample Number | Recovery, mm | SPT N-Value | Moisture Content, % | Other Tests |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 / 0 | 1.10<br>0.00 | Ground Surface | | | | | | | | |
| 0–5 ft | | Very loose to compact, fine to medium grained, brown to greyish brown sand, trace silt, gravel: **Marine Deposit** | | | SS | 1 | 500 | 2 | 29 | |
| | | | | | SS | 2 | 550 | 27 | 22 | S |
| 5 ft | -0.42<br>1.52 | | | | | | | | | |
| 5–29 ft | | Firm to stiff, reddish brown clayey silt and sand, trace to some gravel: **Till** | | | SS | 3 | 300 | 7 | 18 | |
| | | | | | SS | 4 | 450 | 8 | 17 | |
| | | | | | SS | 5 | 0 | 5 | | |
| | | | | | SS | 6 | 450 | 15 | 15 | S/A |
| | | | | | SS | 7 | 0 | 15 | | |
| | | | | | SS | 8 | 450 | 10 | 16 | |
| | | | | | SS | 9 | 550 | 16 | 15 | |
| | | | | | SS | 10 | 450 | 11 | 16 | |
| | | | | | SS | 11 | 550 | 10 | 16 | |
| | | | | | SS | 12 | 450 | 16 | 15 | |
| 29 ft | -7.74<br>8.84 | End of Borehole | | | | | | | | |



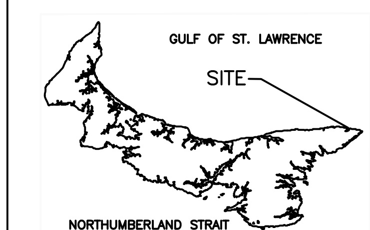

Joose Environmental

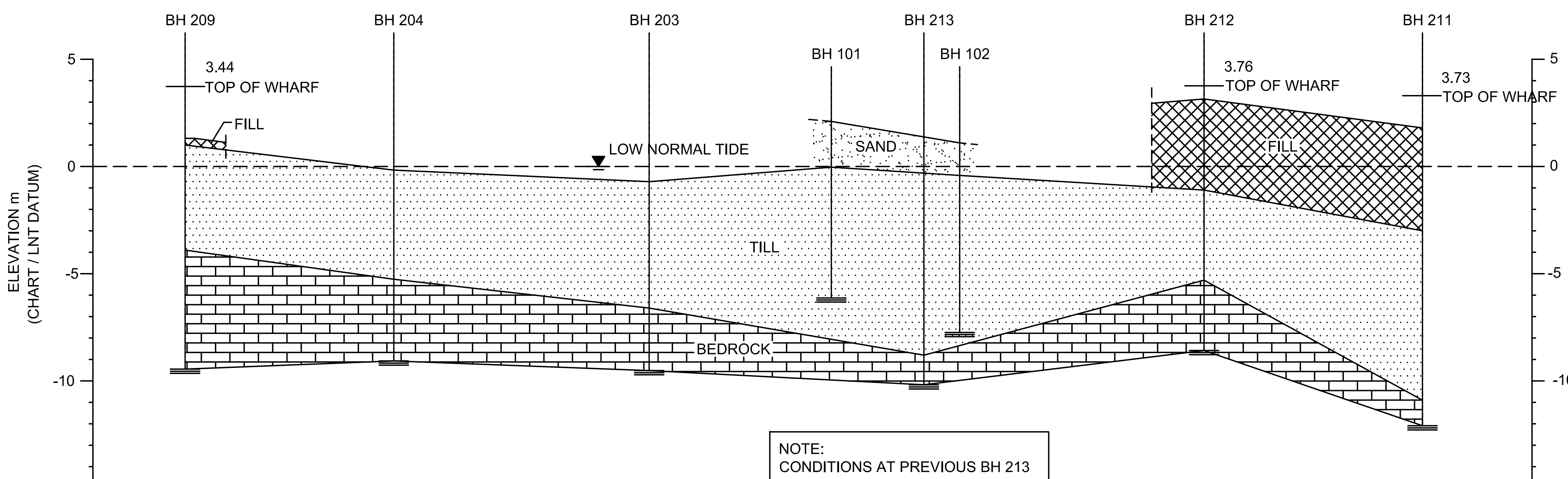



PLAN VIEW
SCALE: 1 : 750

# LEGEND

- PROBE LOCATION, PRESENT INVESTIGATION
- BOREHOLE LOCATION, PRESENT INVESTIGATION
- BOREHOLE LOCATION; GOLDER ASSOCIATES REPORT NO. 831-6025, ISSUED AUGUST, 1983




NOTE:
CONDITIONS AT PREVIOUS BH 213 HAVE BEEN REPLACED WITH SAND-TILL PROFILE ENCOUNTERED AT BH 101 AND BH 102

STRATIGRAPHIC SECTION
SCALE: 1 : 750 (HORIZONTAL)
1 : 250 (VERTICAL)

# BOREHOLE LOCATION PLAN AND STRATIGRAPHIC SECTION

STRUCTURE 305

NORTH LAKE SMALL CRAFT HARBOUR, KINGS COUNTY, PEI

**CLIENT:** PUBLIC WORKS AND GOVERNMENT SERVICES CANADA

**SCALE:** AS SHOWN

| DWN BY: | APPD BY: |
| --- | --- |
| MLJ | GWZ |
| **JOB NO.:** JE0160 | **DWG NO.:** 1R |
| **DATE:** 2017/08/18 | |