# Geotechnical Investigation

## Oxford Highway 104 Sinkhole Investigation
## Cumberland County, NS

**File No: 193111**

Prepared for:
Nova Scotia Transportation
and Infrastructure Renewal
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# 1.0 INTRODUCTION

Acting on the request and authorization of Nova Scotia Transportation and Infrastructure Renewal (NSTIR), Harbourside Geotechnical Consultants (HGC) have completed a geotechnical investigation for Highway 104 near Oxford in Cumberland County, Nova Scotia.

Nearby sinkhole activity at 4627 Main Street in Oxford has prompted both the Town of Oxford and NSTIR to organize investigations to better understand the subsurface conditions at these sites.

The purpose of this geotechnical investigation was to determine the subsurface soil and rock conditions adjacent to the westbound lanes covering a 500 m length of Highway 104 west of Exit 6. This report does not attempt to delineate individual karst features or zones of influence, but rather assess the likely behaviour of the overburden material under karst influences based on strata thickness and material properties. Geotechnical recommendations to address these findings include various types of monitoring systems as well as potential modifications to the highway to manage karst-related risk to Highway 104 at Oxford.

The scope of work completed for this project includes the following:

- Collection and review of existing information including:
    - LIDAR, topographic, and geological mapping
    - Air photos
    - Existing reports
- Completion of a geotechnical field investigation including six boreholes,
- A laboratory testing program; and
- Preparation of this report presenting the findings of the field investigation and laboratory analyses, as well as comments and recommendations to support NSTIR in managing karst-related risk to the highway.

This report has been prepared specifically and solely for the project described herein and contains all of the findings of this investigation.

# 2.0 SITE DESCRIPTION AND GEOLOGY

The investigation area includes a 500 m stretch of highway immediately west of where the on-ramp meets the westbound lanes of Highway 104 at Exit 6, just south of the Town of Oxford in Cumberland County, Nova Scotia.

In this area, the highway consists of two westbound and two eastbound lanes, divided by a grassy median. Highway grades increase across the investigation area as the westbound lanes climb a slight hill. Ground elevations increase north of the site, and lands are forested and include a salt lake and a number of small ponds. Ground elevations decrease to the south, with forested lands and a few additional small ponds. Vickery Lake can be seen from the highway, southwest of the investigation area. Embankment fills were used to account for these changes in elevation, the slopes of which can be seen tapering towards the edges of the right of way in some areas. There is evidence of karst activity in the investigation area and adjacent to the highway, including minor surface depressions near ditches and a patched depression in the right-most westbound lane of the highway. Sinkholes are known to be present in the region. In the summer of 2018, a sinkhole formed in the parking lot of the Oxford Lion’s Club, at 4627 Main Street, approximately 700 m northeast of the investigation area.

Based on available information from geological mapping along the alignment, the native overburden material consists of a combination of glacifluvial deposits, as well as ground moraine glacial till consisting of a mixture of sand, clay, and gravel.  Bedrock geology mapping indicates that the site overlies the Windsor Group consisting of Early Carboniferous rocks including, anhydrite, gypsum, dolostone, limestone, siltstone, and minor salt.

# 3.0 INVESTIGATIVE PROCEDURES

## 3.1 *GENERAL*

The geotechnical investigation, which included drilling six boreholes, was conducted between October 7 and 30, 2019. Samples of the soil and bedrock were recovered from the boreholes, classified in the field, and taken to our laboratory for final classification and testing. A detailed summary of the soil and bedrock conditions encountered, as well as the sampling and testing carried out, is presented on the Borehole Records in Appendix A. A document entitled “Symbols and Terms used on Borehole and Test Pit Records”, which clarifies terms used through this report, as well as symbols and terms used on the borehole and test pit records is also included in Appendix A for reference. Locations of the boreholes put down for this investigation are provided on Drawing G01 in Appendix C.

## 3.2 *BOREHOLES*

To collect information regarding karst-related risk, six boreholes were advanced adjacent to the existing highway. Boreholes were positioned in proximity to areas of potential karst activity following review of LIDAR, historical air photos, and site visits. The borehole locations are described as follows:

- Four boreholes were advanced through the north shoulder of the westbound lanes, including:
    - Borehole BH06, positioned midway along the merging lane of the Exit 6 on-ramp.
    - Borehole BH02 and BH03, positioned near observed surface depression in ditch and previously infilled pond noted in historical air photos.
    - Borehole BH01, positioned near area of previous highway repairs.
- Two boreholes (BH04 and BH05) were advanced through the centre of the median

Conditions at each location were observed and logged by geotechnical personnel.

The boreholes were put down using a track-mounted CME55 drill equipped for geotechnical sampling and testing. Boreholes were drilled to depths ranging from 18.2 to 76.5 m below the ground surface. The boreholes were advanced through the overburden using a combination of HW- and NW-sized casing. Soil sampling was carried out at regular intervals using conventional split-spoon samplers.

Split-spoon samples were obtained while performing standard penetration testing (SPT) as described in *ASTM D1586 Standard Test Method for Standard Penetration Test and Split-Barrel Sampling of Soils*. The standard penetration test (SPT) “N-value” is the number of blows required to advance a 50-mm outer-diameter split-spoon sampler a distance of 300 mm into the soil using a standardized drop height and weight. N-values generally provide an indication of soil consistency or compactness and may also be used to aid in estimation of other soil parameters.

Bedrock, where encountered, was proven by coring in either HQ or NQ size. The recovery and rock quality designation (RQD) of each run of core were recorded.

In select boreholes, water levels were measured through the casing upon removal of the drill rods. Standpipe piezometers were not installed in order to limit groundwater flow pathways to the bedrock surface.

Boreholes which encountered gypsum bedrock were subsequently grouted to above the bedrock surface in order to minimize the effects of groundwater flow on the gypsum. The upper portions of the boreholes were backfilled with bentonite to limit the ingress of surface water.

## 3.3 *LABORATORY TESTING*

Samples recovered from the boreholes were taken to our geotechnical laboratory in Dartmouth, Nova Scotia for final classification and testing. Testing on select soil samples included:

- Water content determinations (*ASTM D2216 Standard Test Methods for Laboratory Determination of Water Content of Soil and Rock by Mass*),
- Particle-size analyses (*ASTM D6913 Standard Test Method for Particle-Size Distribution of Soils Using Sieve Analysis*), and
- Atterberg Limits (*ASTM D4318 Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils*); and,

A summary of the testing performed is presented on the borehole records in Appendix A and separate figures in Appendix B. Soil descriptions used throughout this report are in general accordance with the Unified Soil Classification System (*ASTM D2487 Standard Practice for Classification of Soils for Engineering purposes / ASTM D2488 Standard Practice for Description and Identification of Soils*).

## 3.4 *SURVEYING*

Final locations and elevations of boreholes were surveyed by Harbourside personnel using a construction-grade GPS unit. Borehole coordinates are provided in MTM Zone 5 NAD83 CSRS (2010). Elevations of the test locations are referenced to the Canadian Geodetic Vertical Datum of 2013 (CGVD2013).

# 4.0 SUBSURFACE CONDITIONS

The subsurface conditions at the boreholes generally comprised the following sequence:

- Asphalt
- Rootmat
- Fill
- Lean Clay
- Glacial Till
- Bedrock

Not all strata were encountered at all test locations. The subsurface conditions observed in the boreholes and test pits are summarized in Table 1, and the subsequent paragraphs. The subsurface conditions are described in additional detail on the Borehole Records provided in Appendix A.

**Table 1 Summary of Subsurface Conditions**

| Location | Ground Elevation[(a)] (m) | Layer Thickness (m) | | | | | Bedrock | |
|---|---|---|---|---|---|---|---|---|
| | | Asphalt | Rootmat | Fill | Lean Clay | Glacial Till | Depth to Surface (m) | Surface Elevation (a) (m) |
| BH01 | 26.83 | 0.46 | - | 3.35 | - | 1.24 | 5.05 | 21.78 |
| BH02 | 23.93 | - | - | 8.79 | 19.91(b) | 30.23(c) | 58.93 | -35.00 |
| BH03 | 23.40 | - | 0.08 | 6.07 | 16.46(d) | - | 22.61 | 0.79 |
| BH04 | 26.12 | - | 0.02 | 5.87 | - | 13.79 | 19.68 | 6.44 |
| BH05 | 22.59 | - | 0.05 | 6.15 | 5.76(e) | 3.43(f) | 15.39 | 7.20 |
| BH06 | 19.55 | - | - | 12.60 | - | 17.14 | 29.74 | -10.19 |

(a) Elevations are referenced to CGVD2013.
(b) Includes 0.66 m of grey original sandy topsoil at top of layer.
(c) Includes 0.41 m of brown lean clay at bottom of layer.
(d) Includes 1.11 m of brown silty sand at top of layer.
(e) Includes 0.99 m of brown silty sand in upper portion of layer.
(f) Includes 1.70 m of grey lean clay with sand at bottom of layer.

## 4.1 *ASPHALT*

Borehole BH01 was advanced through the asphalt highway surface near the white line of the north shoulder. The thickness of this layer was 0.46 m at this test location.

## 4.2 *ROOTMAT*

A surficial layer of rootmat was encountered at boreholes BH03, BH04, and BH05. The layer ranged in thickness from 20 mm to 80 mm.

## 4.3 *FILL*

Fill was encountered at all test locations. The layer typically consisted of common borrow, which ranged from sandy lean clay to silty sand with varying amounts of gravel. Where encountered the fills varied in thickness from 3.35 to 12.60 m. Trace organic matter, trace rootlets, and occasional cobbles were typically noted within these layers. A sandstone boulder, 0.60 m in diameter, was encountered within the fill layer in borehole BH01 at a depth of 1.80 m.

The results of five particle-size analyses on the fill materials are presented in Table 2.

**Table 2 Particle Size Analyses – Fill**

| Location | Sample No. | Sample Depth (m) | ASTM Soil Classification[a] | Material Composition by Weight (%) | | |
|---|---|---|---|---|---|---|
| | | | | Gravel | Sand | Fines[b] |
| BH03 | SS6 | 3.25 to 3.86 | Sandy lean CLAY with gravel | 18 | 27 | 55 |
| BH03 | SS7 | 3.86 to 4.47 | Silty SAND with gravel | 18 | 49 | 33 |
| BH04 | SS6 | 3.81 to 4.42 | Sandy lean CLAY with gravel | 20 | 29 | 51 |
| BH06 | SS6 | 3.22 to 3.83 | Sandy lean CLAY | 14 | 29 | 57 |
| BH06 | SS11 | 7.72 to 8.33 | Clayey GRAVEL with sand | 49 | 35 | 16 |

(a) See ASTM D2487, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System).

(b) For particle size analyses performed by sieve, the percent of silt- and clay-sized particles are reported collectively as the percent fines.

The water contents of 16 samples of fill ranged from 10 to 17 percent, with an average of 13 percent. Atterberg limit testing conducted on two fill samples indicated that this material has a plastic limit of 14 to 15 and a liquid limit of 28.

Standard Penetration Test (SPT) N-values obtained within the fill layer ranged from 2 to 53, with most values below 30. Refusal occurred three times within this layer, suggesting the presence of occasional cobbles.

Based on the sampling and testing carried out, the fill can generally be described as reddish-brown sandy lean clay with gravel.

## 4.4 *LEAN CLAY*

A layer of lean clay was encountered below the fill layer in boreholes BH02, BH03, and BH05. Where encountered, this layer varied in thickness from 5.76 to 19.91 m. The layer typically consisted of lean clay to lean clay with sand, often exhibiting a varved structure of alternating layers of clays, silts, and fine sands. This structure suggests the deposit may be glaciolacustrine in nature. Trace black organic matter, as well as trace white vivianite inclusions were noted within this layer. Occasional gravel was observed throughout, with gypsum gravel content increasing below 19.6 m with proximity to the bedrock surface in borehole BH03. Layers of silty sand were observed in the upper portion of this layer and can be summarized as follows:

- A 0.66 m layer of original topsoil consisting of grey silty sand with organics was observed at the top of this layer in borehole BH02.
- A 1.11 m layer of brown silty sand was observed at the top of this layer in borehole BH03.
- A 0.99 m layer of brown silty sand was observed in the upper portion of this layer in borehole BH05.

The results of seven particle-size analyses conducted on samples recovered from this layer are presented in Table 3. The water contents of 15 samples from this layer ranged from 11 to 30 percent, with an average of 22 percent. Atterberg limit testing conducted on three lean clay samples indicated that this material has a plastic limit of 17 to 19 and a liquid limit of 23 to 38.

Standard Penetration Test (SPT) N-values obtained within this layer ranged from 3 to 36. Refusal occurred once in borehole BH03 at a depth of 21.10 m, where gypsum gravel content increased with proximity to the bedrock surface. Pocket penetrometer tests conducted in the field on recovered samples from this layer indicated undrained shear strengths ranging from 100 to 175 kPa.

**Table 3 Particle Size Analyses – Lean Clay**

| Location | Sample No. | Sample Depth (m) | ASTM Soil Classification[(a)] | Material Composition by Weight (%) | | |
|---|---|---|---|---|---|---|
| | | | | Gravel | Sand | Fines[(b)] |
| BH02 | SS15 | 10.82 to 11.43 | Lean CLAY with sand | 3 | 16 | 81 |
| BH02 | SS17 | 12.17 to 12.78 | Lean CLAY | 0 | 15 | 85 |
| BH02 | SS29 | 25.65 to 26.26 | Lean CLAY with sand | 0 | 23 | 77 |
| BH03 | SS10 | 6.15 to 6.76 | Silty SAND | 12 | 75 | 13 |
| BH03 | SS12 | 7.64 to 8.25 | Lean CLAY with sand | 4 | 18 | 78 |
| BH03 | GB30 | 20.24 to 21.13 | Silty, clayey GRAVEL with sand | 44 | 20 | 36 |
| BH05 | SS13 | 9.20 to 9.81 | Lean CLAY with sand | 3 | 13 | 84 |

(a) See ASTM D2487, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System).

(b) For particle size analyses performed by sieve, the percent of silt- and clay-sized particles are reported collectively as the percent fines.

Based on the sampling and testing carried out, the layer can generally be described as soft to hard reddish-brown to brown lean clay with sand.

## 4.5 *GLACIAL TILL*

A layer of glacial till was encountered in all boreholes except for BH03. Where encountered, this layer varied in thickness from 1.24 to 30.23 m. In the western test locations, the layer typically consisted of sandy lean clay to clayey sand with gravel. At the easternmost test location (BH06) the composition of the till varied between a sandy silt and silty, clayey sand. Occasional gravel, blackened wood fragments, and frequent cobbles were observed within the till layer. Conglomerate and sandstone boulders as large as 2.26 m were observed in the upper portion of the till layer in borehole BH04. A layer of brown lean clay, 0.41 m in thickness, was observed at the bottom of the till layer in borehole BH02. A layer of grey lean clay with sand, 1.70 m in thickness, was observed at the bottom of the till layer in borehole BH05.

The results of eight particle-size analyses conducted on samples recovered from this layer are presented in Table 4. The water contents of 19 samples from this layer ranged from 9 to 19 percent, with an average of 14 percent. Atterberg limit testing conducted on three glacial till samples indicated that this material has a plastic limit of 11 to 14 and a liquid limit of 22 to 26.

Standard Penetration Test (SPT) N-values obtained within this layer were as low as 11, where till was encountered closer to surface (BH01), and as high as 158 where till was tested at depth (BH02). Refusal occurred seven times within this layer, suggesting the presence of frequent cobbles. The lower 6.42 m of silty, clayey sand till in borehole BH06 was significantly less dense than the material above, with N-values between 2 and 11. Pocket penetrometer tests conducted in the field on recovered samples from the till indicated undrained shear strengths equal to or greater than 200 kPa.

**Table 4 Particle Size Analyses – Glacial Till**

| Location | Sample No. | Sample Depth (m) | ASTM Soil Classification[(a)] | Material Composition by Weight (%) | | |
|---|---|---|---|---|---|---|
| | | | | Gravel | Sand | Fines[(b)] |
| BH02 | SS35 | 34.65 to 35.26 | Clayey SAND | 13 | 49 | 38 |
| BH02 | SS41 | 42.14 to 42.75 | Sandy lean CLAY | 12 | 35 | 53 |
| BH04 | SS9 | 6.20 to 6.81 | Lean CLAY | 1 | 10 | 89 |
| BH04 | SS18 | 13.69 to 14.30 | Clayey SAND with gravel | 24 | 50 | 26 |
| BH05 | SS17 | 12.19 to 12.80 | Sandy lean CLAY | 15 | 30 | 55 |
| BH05 | GB21 | 14.68 to 15.19 | Lean CLAY with sand | 5 | 13 | 82 |
| BH06 | SS19 | 13.72 to 14.33 | Sandy SILT | 3 | 36 | 61 |
| BH06 | SS34 | 27.20 to 27.81 | Silty, clayey SAND | 5 | 55 | 40 |

(a) See ASTM D2487, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System).

(b) For particle size analyses performed by sieve, the percent of silt- and clay-sized particles are reported collectively as the percent fines.

Based on the sampling and testing carried out, the layer can generally be described as stiff to hard reddish-brown clayey sand to sandy lean clay.

## 4.6 *BEDROCK*

Bedrock was cored in all six boreholes put down as part of the investigation. The depth to the bedrock surface ranged from 5.05 m at BH01 to 58.93 m at BH02.

### *4.6.1 Conglomerate*

A layer of very poor quality reddish-brown conglomerate, 2.70 m in thickness, was encountered in borehole BH01 at a depth of 5.05 m. This conglomerate was underlain by a layer of very soft brown lean clay, approximately 2.00 m in thickness, followed by very poor quality white gypsum as seen at other test locations in the investigation area.

### *4.6.2 Gypsum*

Bedrock typically consisted of weak, grey and white gypsum.

In boreholes BH01, BH04, and BH06, the upper 1.50 to 3.99 m of gypsum was of very poor to fair quality, showing increased signs of weathering. The rock quality then improved significantly as fresh rock was encountered at greater depths, with better recovery of good to excellent quality samples of gypsum.

In boreholes BH02, BH03, and BH05, the gypsum was of very poor to poor quality, moderately to highly weathered, with occasional brown clay infilling of fractures. Rock quality and degree of weathering did not appear to improve with depth, despite coring with 8.79 to 17.57 m of penetration into this layer. Core recovery within the gypsum at these test locations was poor, with an average of 37%.

## 4.7 *GROUNDWATER*

In select boreholes, water levels were measured through the casing upon removal of the drill rods. Standpipe piezometers were not installed in order to limit groundwater flow pathways to the bedrock surface. Details of all water level measurements and observations are shown on the appended Borehole Records.

Due to the relatively low hydraulic conductivity of the native soils (and some of the fills) the groundwater level is difficult to establish when measured through the casing over a relatively short interval. Water levels can be very complex in karst terrain, often having significantly different elevations when measured in the glacial till and bedrock separately.

Water levels may fluctuate with precipitation events, climatic and seasonal weather trends and in response to construction activity.

# 5.0 DISCUSSION AND RECOMMENDATIONS

The purpose of this geotechnical investigation was to determine the subsurface soil and rock conditions adjacent to the westbound lanes covering a 500 m length of Highway 104 west of Exit 6, with particular attention paid to how the findings relate to both immediate and future sinkhole risk.

Based on our geotechnical investigation, we are providing discussion and recommendations to address these findings, including monitoring system options as well as potential modifications to the highway to manage karst-related risk.

## 5.1 *KARST TOPOGRAPHY AND GEOLOGY*

Karst is a distinctive landscape topography typically formed by dissolving carbonate rocks such as limestone, dolomite and marble, or other highly soluble evaporite rocks such as halite, gypsum and anhydrite. The geological process involved can result in unusual surface and subsurface features ranging from sinkholes, irregular surface topography, vertical shafts, disappearing and reappearing springs as well as complex underground drainage systems and caves.

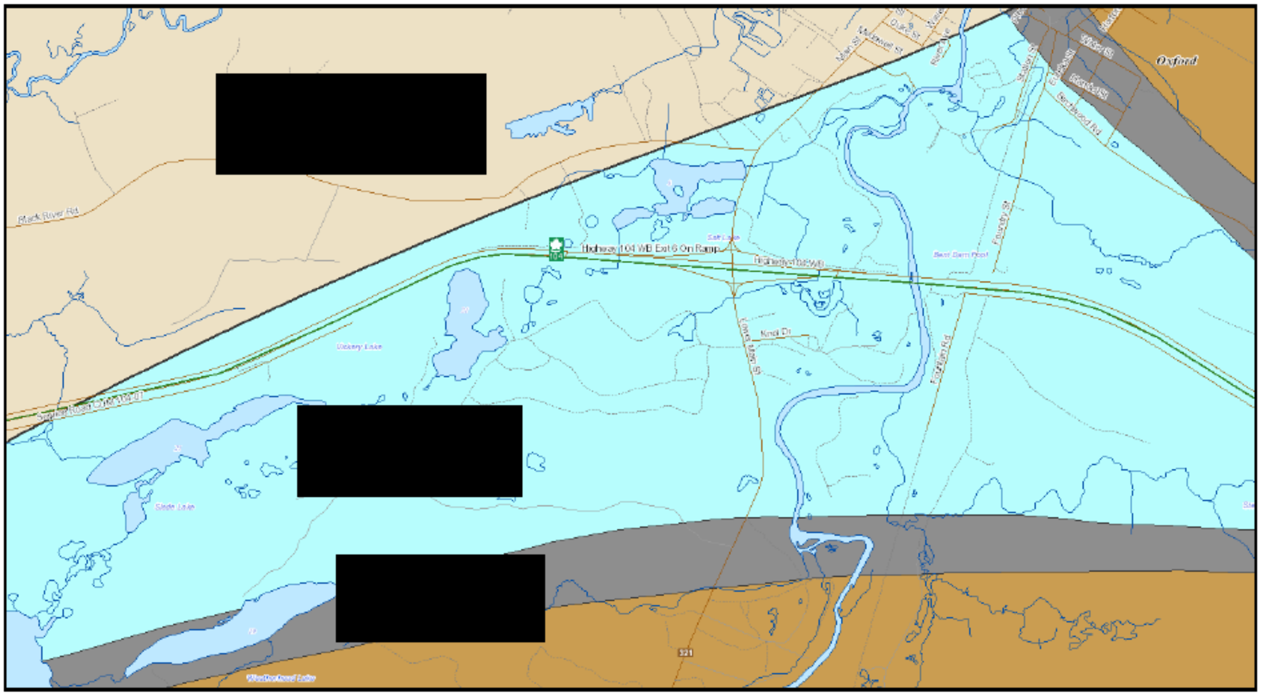
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**Figure 1 Local Bedrock Geology**

Bedrock comprised of rock types such as limestone or gypsum may have a network of drainage pathways which transmit both groundwater and surface water. Some of these drainage pathways can open directly to the surface to form sinkholes while others may undergo a slow process of ground subsidence due to loss of overburden into one of the channels. The key contributor to the formation of sinkholes or subsidence is the movement of water. Areas where little change of drainage patterns or surface features have occurred will tend to reach a relatively stable configuration. Any significant change in conditions can initiate or accelerate the formation of karst type features.

Throughout Nova Scotia, the formation of karst topography is typically associated with areas underlain by Carboniferous rocks of the Windsor Group which contain the rock types noted above. As detailed in Section 2, the highway in the investigation area overlies various formations of the Windsor Group. Bedrock mapping of the investigation area can be found in Figure 1, on the previous page.

Karst topography is known to occur throughout this area of Cumberland County. Following two months of subsidence, a sinkhole formed in the parking lot of the Oxford Lion's Club at 4627 Main Street in August, 2018, widening to approximately 40 m over the next year or so (Tizzard, Demont, & Brushett, 2019). The undeveloped lands west of Main Street and north of Highway 104 are marked by a number of small ponds and lakes which may be water-filled sinkholes.

An anticline runs east and west across this region, the crest of which can be traced from Malagash Point to past Oxford (Roland, 1982). The crest of this anticline has been eroded away to expose the Windsor Group evaporites described above (Roland, 1982). LIDAR imagery of the investigation area shows evidence of karst activity in the form of a pockmarked landscape of surface depressions which overlaps the area of the eroded anticline crest (Figure 2).

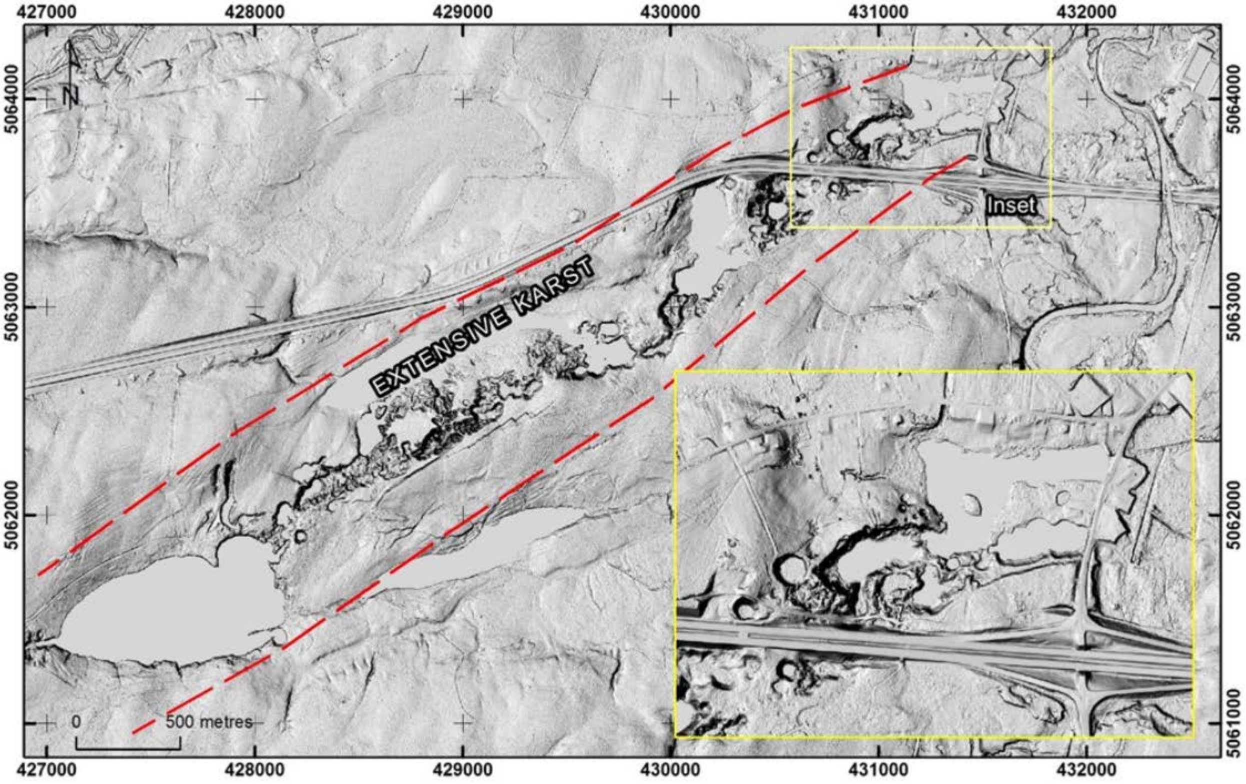

**Figure 2** **LIDAR Survey Flown in 2018. From Tizzard, Demont, & Brushett, 2019, p. 67.**

## 5.2 *KARST-RELATED FINDINGS*

Results of the investigation indicate that the highway near Exit 6 is underlain by rock types that have potential to create karst type features. Towards the north of the westbound lanes, occasional small depressions were observed in the ditch, within the backslope, and at the top of the slope along the existing highway. Furthermore, it is understood that a repair in the centre of the northern westbound travelling lane of Highway 104 was needed due to the formation of a small depression in the past. This repair has consisted of infilling the void and patching with asphalt. Control points have been placed in the asphalt surface in the vicinity of this repair for surveying and subsidence monitoring by NSTIR.

Review of historical air photos (Figure 3) revealed that a pond had been infilled over various phases of highway construction. Boreholes BH02, BH03, and BH05 were placed in proximity to this infilled area in order to gain subsurface information near a potential area of previous karst activity. Sampling of the overburden at these locations indicated a deposit of lean clay with sand underlying the common borrow fill materials. This deposit exhibited a varved structure of alternating layers of clays, silts, and fine sands. This structure suggests the deposit may be glaciolacustrine in nature and not related to karst activity.

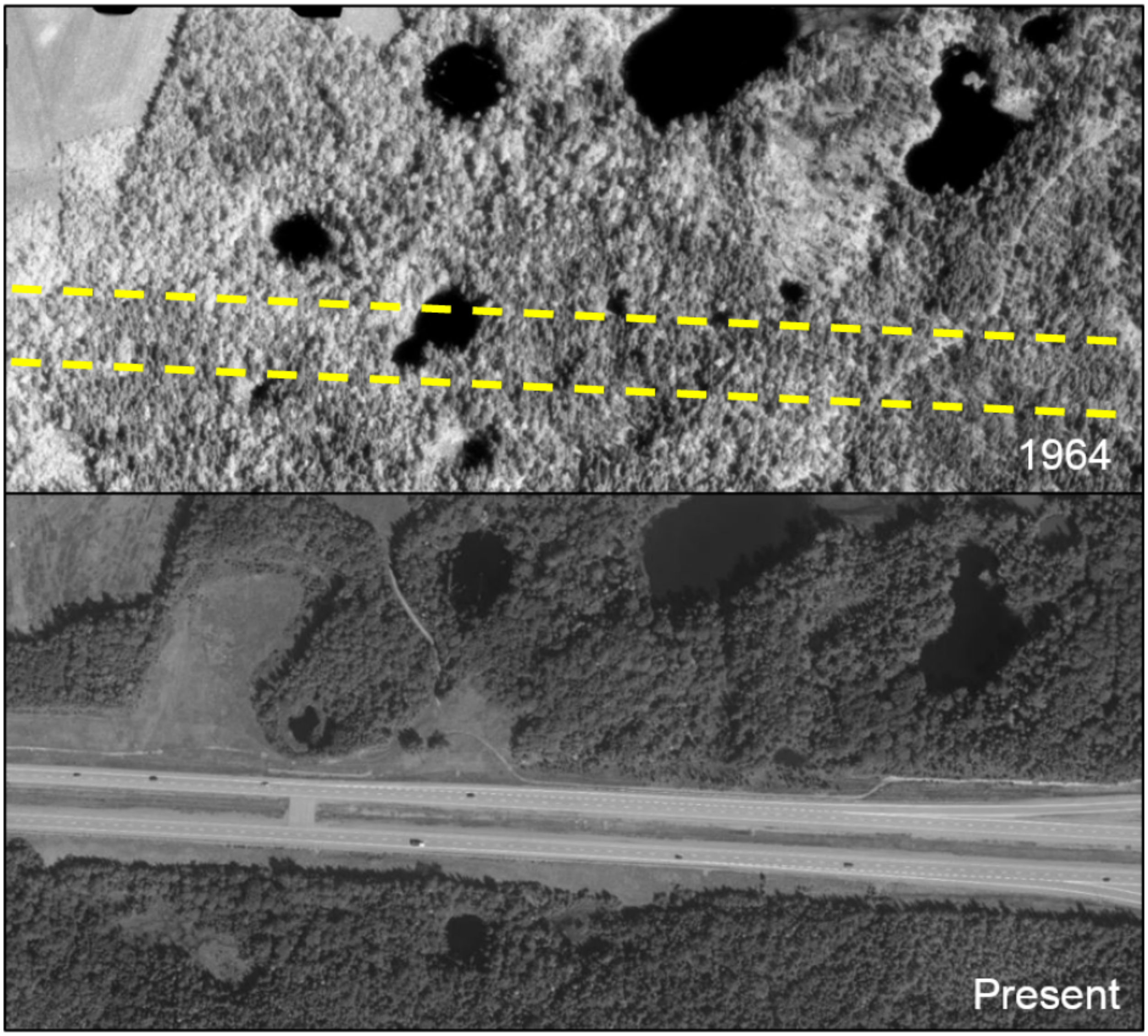

**Figure 3** **Comparison of 1964 air photo with current satellite imagery. Scales are matched in order to demonstrate old topography that was infilled during highway construction.**

The majority of the investigation area consists of gently rolling terrain comprised of relatively thick overburden. The glacial till and glaciolacustrine deposits encountered are fine-grained and cohesive which will help to limit significant movement of surface water and groundwater to the bedrock. Glacial tills encountered in borehole BH06 were generally coarser and less cohesive.

The total depth to karst-risk bedrock varied from 9.75 m at borehole BH01 to 58.93 m at borehole BH02. Where encountered, the elevation of the karst-risk bedrock surface ranged from 17.08 m to -35.00 m CGVD2013. A noticeable softening of overburden materials with proximity to the bedrock surface was noted in boreholes BH04 and BH06. An increase in clay content was noted in other locations. Penetration of the bedrock surface was often accompanied by a loss of drilling fluid. This observation, in combination with grout takes significantly higher than theoretical volumes when filling the boreholes, may indicate a fractured, weathered bedrock surface.

## 5.3 *SUBSIDENCE SINKHOLES*

According to Waltham, Bell, & Culshaw (2005) the chances are orders of magnitude greater for an engineered structure, such as a road, to be damaged during its design lifetime by a sinkhole which develops due to soil failure instead of bedrock collapse. This is due to the difference in timescales required for material removal of bedrock versus soil. The removal of sufficient material to create an unstable cave in karst-prone bedrock can require tens of thousands of years. In the case of the conditions underlying the investigation area, a subsidence sinkhole is the more likely method of formation. This would involve the progressive removal of unconsolidated soil into fissures and voids in the bedrock, where percolation water (often from rainfall) acts as the transport agent through preferential flow pathways in the overburden.

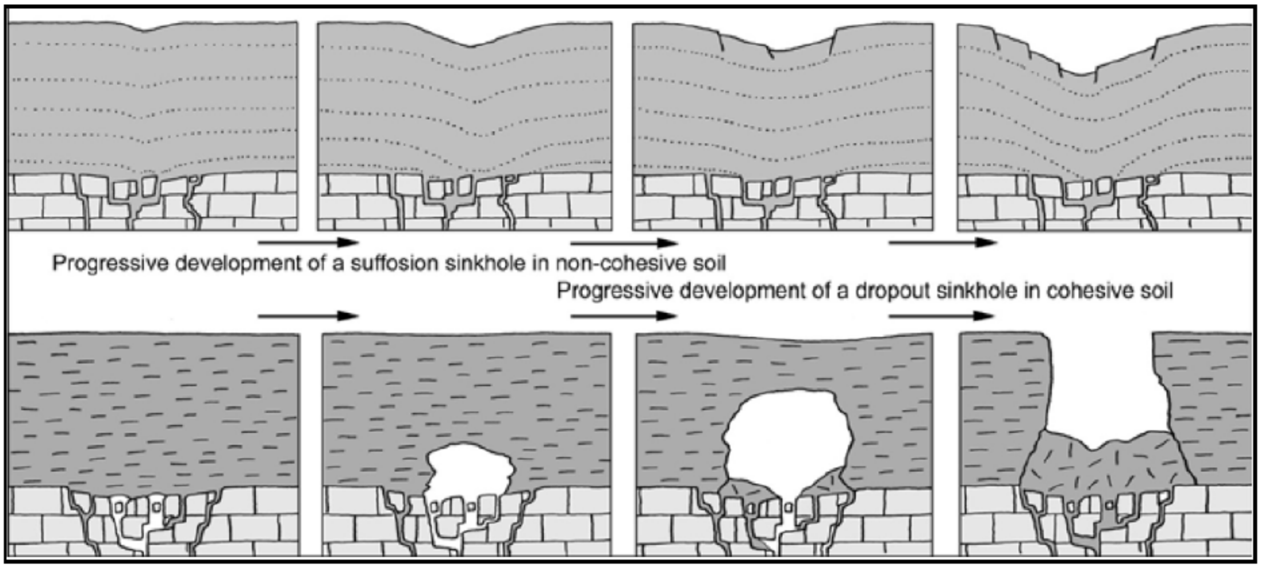

**Figure 4 Progressive Development of Suffosion and Dropout Sinkholes. From Waltham, Bell, & Culshaw, 2005, p. 94.**

Subsidence sinkholes can be further divided into two types depending on the composition of the overburden material (Figure 4). Cohesionless soils result in *suffosion sinkholes*, in which slow, steady deformations may be observed at the ground surface as material is removed. Where the soil is cohesive enough to form an arching void over an open fissure or cave, a *dropout sinkhole* may form as the shear strength of this arch is exceeded, causing upwards cavity migration until relatively rapid surface failure is induced. Seepage flow rates are an important factor in the rate of soil removal in subsidence sinkhole-prone karst areas. Thicker soil covers tend to develop fewer subsidence sinkholes as they provide a greater barrier to prevent groundwater from reaching the bedrock surface.

The overburden material underlying the investigation area falls somewhere between the two behaviours mentioned above. This is common, as it is rare for overburden overlying karst to consist of a completely non-cohesive soil profile. Waltham, Bell, & Culshaw (2005) state that the most common type of subsidence sinkholes “occupy a spectrum of morphologies”, and “start with some slow surface settlement, followed by an intermittent sequence of short but rapid soil failures and collapses” (p. 101). This period of slow initial subsidence can act as a valuable warning signal to larger scale failures. Previously observed ground movements near the area of highway repair, in combination with our understanding of the overburden material, suggest that karst activity within the investigation area will likely initially manifest itself in the form of relatively slow surface settlements. A monitoring system to catch ground deformations accompanied by a contingency plan may assist in managing karst-related risk at the site.

## 5.4 *RECOMMENDATIONS*

Construction and operation of linear corridors throughout the province requires that in many instances the corridors will have to cross areas which are susceptible to karst formation. Several of the province’s existing highways, railways, gas lines and other utilities cross these areas. Owners typically understand the inherent risk of this type of construction and where possible will attempt to avoid the most active areas. Karst-driven subsidence does occur occasionally and repairs are carried out to keep the utilities serviceable. Knowing when and where such features may appear is virtually impossible; however, measures can be taken to reduce risk, where necessary.

In light of the findings described above, it is our opinion that the following measures should be considered for implementation within the investigation area.

### *5.4.1 Ditch Improvements*

Control of road surface runoff is critical in limiting the effects of surface water on karst activity. Existing ditch and culvert configurations and performance should be assessed and optimized where deficiencies are identified.

Ditches should have sufficient slopes to efficiently remove any water from the area. Impermeable, surface linings should be considered in ditches near karst-prone areas. Another option for post-construction improvement would be the installation of a low-permeable HDPE, PVC geomembrane, geosynthetic clay liner (GCL), or low-permeability clay in high-risk ditches. Membranes/liners would serve to further limit infiltration of runoff into areas with observed cavities and subsidence.

Culverts should be designed to remove water from the ditches and discharge well away from the edge of the highway. Culverts should be configured to prevent ponding of water at the inlet. Limiting the use of granular bedding material around the culvert where possible, should be used to prevent movement of water along the bedding or from ponding within the bedding.

### 5.4.2 Monitoring and Contingency Planning

Prediction of the precise location and timing of subsidence sinkholes in karst-prone terrain is nearly impossible due to the heterogeneous nature of the overburden material, in combination with the irregular profile, weathering, and fracturing of the bedrock surface. However, water-driven transport of overburden materials into fractures and caves can induce observable subsidence at surface before failures occur on a larger scale. Consideration and development should be made in the following areas in order to enable NSTIR to catch and respond to such ground movements:

- Design and implementation of a **monitoring system** capable of detecting road surface subsidence to a high degree of accuracy, and
- Creation of a **contingency plan** which will allow NSTIR to respond appropriately and efficiently to a number of karst-related outcomes.

Dunnicliff (1982) outlines the following systematic approach to planning a monitoring program using geotechnical instrumentation:

1. Define the project conditions and purpose of instrumentation, including variables to be monitored (groundwater level, porewater pressure, earth pressure, vertical/horizontal deformation, tilt, load, and strain).
2. Make predictions of behaviour in order to select appropriate instrument ranges and accuracies.
3. Devise solutions and course of action to address problems identified by instrumentation.
4. Assign tasks and responsibility to personnel.
5. Select instruments.
6. Plan the recording of other data that may influence measurements, such as visual observations, temperature, precipitation, etc.
7. Establish procedures for measurements in order to ensure reading correctness.
8. Select instrument locations to suit project conditions and predicted behaviour.
9. Write instrument procurement specifications.
10. Write contractual arrangements for field instrumentation services.
11. Plan installation of instrumentation.
12. Outline guidelines for routine maintenance and instrument calibration.

Several potential monitoring methods have been used for measurement of road subsidence and may be explored, including simple field observations, traditional optical levelling-based surveying of road-mounted control points and reflectors, time domain reflectometry (TDR) measurements of coaxial cables installed in trenches below travelling lanes, and interferometric synthetic aperture radar (InSAR). Whichever method or combination of methods is chosen, it is important that the data is collected and reviewed regularly, and paired with an appropriate contingency plan.

An effective contingency plan will be a necessary accompaniment to the proactive measures described above. This plan will likely establish warning thresholds for monitoring data and an appropriate chain of communication and responsibility in the event of observed subsidence. Movements will be categorized by area of influence and severity, each with a corresponding plan of action for both immediate and long-term remediation.

# 6.0 CLOSURE

This report has been prepared to assess the subsurface soil and rock conditions adjacent to Highway 104, west of Exit 6, with a focus on the likely behaviour of the overburden material under karst influences. This report has been prepared for the sole benefit of NSTIR and their agents. Any use which a third party makes of this report is the responsibility of such third party.

This report is based on the site conditions encountered by Harbourside Geotechnical Consultants at the time of the work at the specific sampling locations and can only be extrapolated to a limited extent around these locations. Should any conditions differ from those detailed on the borehole records, the engineer should be notified to allow reassessment of any design assumptions.

If you have any questions or require any additional information, please do not hesitate to contact the undersigned at your convenience.

Harbourside
Geotechnical Consultants

Kind Regards,

[redacted]

[redacted]

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# 7.0 REFERENCES

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# APPENDIX A

Symbols and Terms Used on Borehole and Test Pit Records

Borehole Records BH01 to BH06

# SYMBOLS AND TERMS USED ON BOREHOLE AND TEST PIT RECORDS

## STRATA PLOT

Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols:

### USCS SOIL CLASSIFICATION SYMBOLS

| MAJOR DIVISIONS | | | SYMBOLS | | TYPICAL DESCRIPTIONS |
|---|---|---|---|---|---|
| | | | GRAPH | LETTER | |
| COARSE GRAINED SOILS<br>MORE THAN 50% OF MATERIAL IS LARGER THAN 75 µm SIEVE SIZE | GRAVELS MORE THAN 50% OF COARSE FRACTION RETAINED ON 4.75 mm SIEVE | CLEAN GRAVELS | ▨ | GW | WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES |
| | | | ▨ | GP | POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES. LITTLE OR NO FINES |
| | | GRAVELS WITH FINES | ▨ | GM | SILTY GRAVELS, GRAVEL – SAND – SILT MIXTURES |
| | | | ▨ | GC | CLAYEY GRAVELS, GRAVEL – SAND – CLAY MIXTURES |
| | SANDS MORE THAN 50% OF COARSE FRACTION PASSING THE 4.75 mm SIEVE | CLEAN SANDS | ▨ | SW | WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES |
| | | | ▨ | SP | POORLY-GRADED SANDS, GRAVELLY SAND, LITTLE OR NO FINES |
| | | SANDS WITH FINES | ▨ | SM | SILTY SANDS, SAND – SILT MIXTURES |
| | | | ▨ | SC | CLAYEY SANDS, SAND – CLAY MIXTURES |
| FINE GRAINED SOILS<br>MORE THAN 50% OF MATERIAL IS SMALLER THAN 75 µm SIEZE SIZE | SILTS AND CLAYS | LIQUID LIMIT LESS THAN 50 | ▥ | ML | INORGANIC SILTS |
| | | | ▧ | CL | INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY |
| | | | ▤ | OL | ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY |
| | SILTS AND CLAYS | LIQUID LIMIT GREATER THAN 50 | ▥ | MH | INORGANIC SILTS |
| | | | ▧ | CH | INORGANIC CLAYS OF HIGH PLASTICITY |
| | | | ▨ | OH | ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS |
| HIGHLY ORGANIC SOILS | | | ▨ | PT | PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS |

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

### OTHER COMMONLY USED SYMBOLS

| | | |
|---|---|---|
| GLACIAL TILL | ▨ | UNSTRATIFIED GLACIAL DEPOSIT RANGING FROM CLAY TO BOULDERS |
| BEDROCK | ▨ | IGNEOUS BEDROCK |
| | ▨ | METAMORPHIC BEDROCK |
| | ▦ | SEDIMENTARY BEDROCK |
| MATERIALS PLACED BY HUMANS | ▩ | FILL: SUBSURFACE MATERIALS IDENTIFIED AS PLACED BY HUMANS |
| | ■ | ASPHALT |
| | ▨ | CONCRETE |

## SAMPLE TYPE

| | |
|---|---|
| SS | Split Spoon (obtained by performing SPT) |
| ST | Shelby Tube (Thin-Walled Tube) |
| GB | Grab Sample |
| PS | Piston Sample |
| WS | Wash Sample |
| HQ, NQ, AQ, BQ, etc. | Rock Core Samples Obtained Using Standard Size Diamond Bits |

## SPT N-VALUE (N-INDEX)

The standard penetration test (SPT) provides a qualitative evaluation of compactness and a qualitative comparison of subsoil stratification. The SPT is performed in in the bottom of a borehole where a split-barrel sampler having an outside diameter of 50.8 mm is impacted using a hammer weighing 623 N falling 0.76 m for each hammer blow. The SPT N-value is the blow count representation of the penetration resistance of the soil. In accordance with ASTM D1586, the N-value, reported in blows per 300 mm, equals the sum of the number of blows (N) required to drive the sampler over the depth interval of 150 to 450 mm. However, when a 600 mm sampler is used the number of blows (N) required to drive the sampler over the interval of 300 to 600 mm may be reported if this value is lower. For samples where insufficient penetration was achieved and N-Values cannot be presented, the number of blows are reported over sampler penetration in mm (e.g. 50/120). Although some methods make use of N-values corrected for various factors (for equipment used, overburden stress, length of drill rod, etc.) no corrections have been applied to the N-values presented on the logs.

### DYNAMIC CONE PENETRATION TEST (DCPT)

Dynamic cone penetration tests (DCPT) are performed using a standard 60-degree apex cone connected to ‘A’ size drill rods with the same standard fall height and weight as the SPT test. The DCPT value is the number of blows of the hammer required to drive the cone 300 mm. The DCPT provides a qualitative evaluation of compactness and allows for a qualitative comparison of subsurface stratification.

## RECOVERY

For soil samples, recovery is recorded as the total length of the soil sample recovered. For rock core, recovery is expressed as a percentage of the total length drilled on a per run basis.

## OTHER TESTS

| | | | | | |
|---|---|---|---|---|---|
| S | Sieve Analysis | CD | Consolidated-Drained Triaxial | C | Consolidation |
| H | Hydrometer Analysis | CU | Consolidated-Undrained Triaxial | $Q_u$ | Unconfined Compression |
| γ | Unit Weight | UU | Unconsolidated Undrained Triaxial | $I_p$ | Point Load Index, Ip(50) |
| $G_s$ | Specific Gravity of Soil Particles | DS | Direct Shear | k | Laboratory Permeability |

## SOIL DESCRIPTION

**Terminology describing common soil genesis:**

| | |
|---|---|
| Rootmat | Vegetation, roots, and moss with organic matter and topsoil typically forming a mattress at the ground surface. |
| Topsoil | Mixture of soil and humus capable of supporting vegetative growth. |
| Peat | A soil composed of vegetable tissue in various stages of decomposition usually with an organic odor, a dark-brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous. |
| Till | Non-stratified glacial deposit which may range from clay to boulders |
| Fill | Artificial (man-made) deposits transported and placed on the natural surface of soil or rock. |

**Terminology describing soil structure:**

| | |
|---|---|
| Homogeneous | The lack of visible bedding and the same appearance and colour throughout |
| Desiccated | Having visible signs of weathering by oxidation of clay minerals, shrinking cracks, etc. |
| Fissured | Having cracks and hence a blocky structure |
| Stratified | Composed of regular alternating successions of different soil types |
| Varved | Comprised of regular alternating successions of silt and clay which were transported into freshwater lakes by melt water |
| Layer | > 75 mm |
| Seam | 2 mm to 75 mm |
| Parting | < 2 mm |
| Pocket | Small erratic deposit, usually less than 300 mm |
| Lens | Lenticular deposit |

**Terminology describing soil types:**
Soils are described in accordance with the Unified Soil Classification System (USCS) as described in ASTM D2487 and ASTM D2488. This system classifies soil into categories representing the results of laboratory tests to determine the particle-size characteristics, the liquid limit, and the plasticity index. Using this system, soils are assigned a group name (e.g. silty sand) and symbol (e.g. SM). The various groupings of this classification system have been devised to correlate in a general way with the engineering behavior of soils. Laboratory tests are performed on the portion of the sample passing the 75 mm sieve.

When laboratory test results indicate that that the soil is close to another classification group, the borderline condition can be indicated with two symbols separated by a slash (e.g. CL/CH).

**Terminology describing cobbles, boulders, and non-matrix materials:**
Materials outside of the USCS (e.g. particles larger than 75 mm, organic matter, construction debris) are described based on the proportion of these materials by weight using the following terminology:

| | |
|---|---|
| Trace, or occasional | < 10% |
| Some | 10% to 20% |
| Frequent | > 20% |

**Terminology describing the compactness condition of cohesionless soils:**
A qualitative term describing the compactness condition of a cohesionless soil is interpreted from the SPT N-value (also known as the N-index). The relationship between the SPT N-value and the compactness condition is shown in the following table.

| **Compactness Condition** | **SPT N-Value (blows per 0.3 m)** |
|---|---|
| Very Loose | 0 to 4 |
| Loose | 4 to 10 |
| Compact | 10 to 30 |
| Dense | 30 to 50 |
| Very Dense | Over 50 |

**Terminology describing the compactness condition of cohesive soils:**
Cohesive soils can be classified in relation to undrained strength. Undrained strength can be determined by a number of tests including: unconfined compression tests, field and laboratory vane tests, laboratory fall-cone tests, shear-box tests, and triaxial tests. The consistency and undrained shear strength may also be approximately related the SPT N-Value. The relationship between the consistency and the undrained shear strength, as well as a rough correlation with SPT N-Value as shown in the following table.

| Consistency | Undrained Shear Strength (kPa) | SPT N-Value (blows per 0.3 m) |
|---|---|---|
| Very Soft | < 12 | < 2 |
| Soft | 12 to 25 | 2 to 4 |
| Firm | 25 to 50 | 4 to 8 |
| Stiff | 50 to 100 | 8 to 15 |
| Very Stiff | 100 to 200 | 15 to 30 |
| Hard | > 200 | > 30 |

## ROCK DESCRIPTION

Rock is a natural aggregate of minerals that cannot be readily broken by hand and that will not disintegrate on a first wetting and drying cycle. A rockmass comprises blocks of intact rock that are separated by discontinuities such as cleavage, bedding planes, joints, shears and faults.

### Terminology Describing Geological Classification of Rock:

Rock is classified with respect to its geological origin or lithology as follows:

| | |
|---|---|
| Igneous Rocks | Rocks such as granite, diorite, and basalt, which are formed by the solidification of molten material. |
| Sedimentary Rocks | Rocks such as sandstone, limestone and shale, which are formed by the lithification of sedimentary soils. |
| Metamorphic Rocks | Rocks such as quartzite, schist, and gneiss, which have been altered by the application of intense heat and/or pressure. |

### Terminology Describing the Strength of Intact Rock:

Strength is the maximum stress level that can be carried by a specimen. Rocks may be classified based on their intact strength as shown in the following table.

| Term | Unconfined Compressive Strength (MPa) |
|---|---|
| Extremely Weak | 0.25 to 1 |
| Very Weak | 1 to 5 |
| Weak | 5 to 25 |
| Medium Strong | 25 to 50 |
| Strong | 50 to 100 |
| Very Strong | 100 to 250 |
| Extremely Strong | > 250 |

### Terminology Describing Discontinuity Spacing

The structural integrity of a rockmass will be affected by the presence of discontinuities. The spacing of discontinuities can vary from extremely wide to extremely close as indicated in the table below.

| Term | Spacing Width (m) |
|---|---|
| Extremely Close | < 0.02 |
| Very Close | 0.02 to 0.06 |
| Close | 0.06 to 0.20 |
| Moderately Close | 0.20 to 0.6 |
| Wide | 0.6 to 2.0 |
| Very Wide | 2.0 to 6.0 |
| Extremely Wide | > 6.0 |

**Rock Quality Designation (RQD)**

RQD is an indirect measure of the number of fractures within a rockmass. The method provides a quick and objective technique to estimate rockmass quality during diamond drill core logging. All pieces of intact and sound rock greater than 100 mm long are summed and divided by the total length of the core run in accordance with ASTM D6032.

| RQD Classification | RQD (%) |
|---|---|
| Very Poor Quality | 0 to 25 |
| Poor Quality | 25 to 50 |
| Fair Quality | 50 to 75 |
| Good Quality | 75 to 90 |
| Excellent Quality | 90 to 100 |

**Terminology to Describe Rock Weathering**

The state of weathering significantly alters the geotechnical behaviour of rocks and rockmasses. Weathering of the rockmass may be classified as shown in the following table.

| Term | Description |
|---|---|
| Fresh | No visible sign of rock material weathering; perhaps slight discolouration on major discontinuity surfaces. |
| Slightly Weathered | Discolouration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discoloured by weathering and may be somewhat weaker than its fresh condition. |
| Moderately Weathered | Less than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones |
| Highly Weathered | More than a half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones. |
| Completely Weathered | All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact. |

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# BOREHOLE RECORD

## BH01

N: 5064990.1 E: 25547406.51

**CLIENT** NOVA SCOTIA TRANSPORTATION AND INFRASTRUCTURE RENEWAL

**LOCATION** HIGHWAY 104, OXFORD, CUMBERLAND COUNTY, NOVA SCOTIA

**DATES: BORING** 21/10/2019 TO 22/10/2019

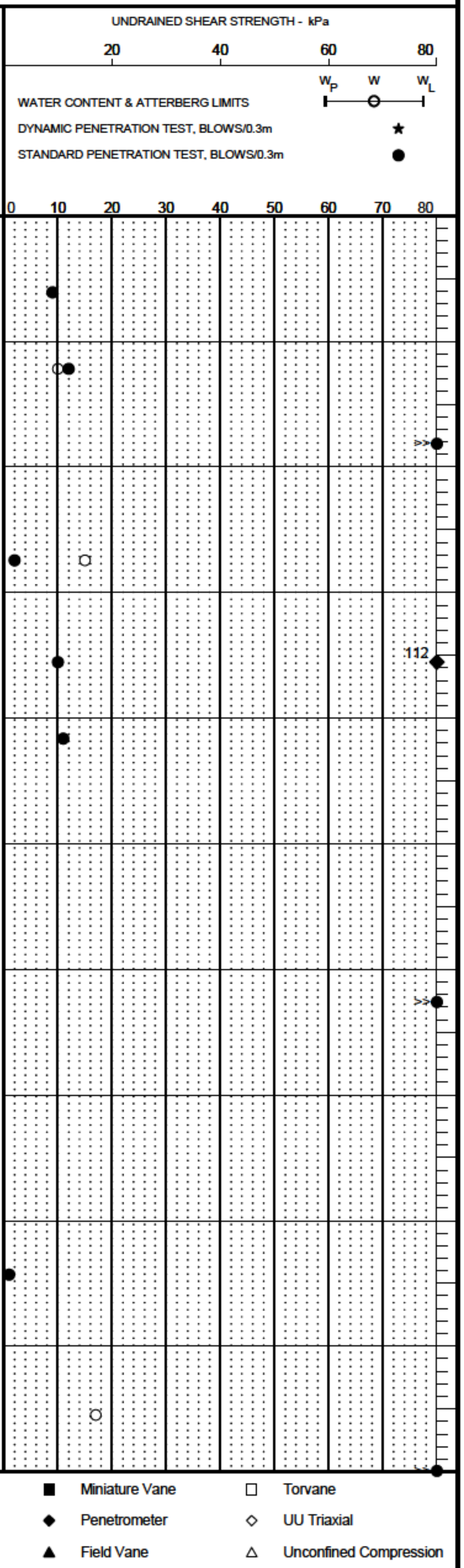
**WATER LEVEL** 22/10/2019

**PROJECT No.** 193111

**DATUM** CGVD2013

**BH SIZE** HW/HQ

| DEPTH (m) | ELEVATION (m) | SOIL/BEDROCK DESCRIPTION | GRAPHIC LOG | WATER LEVEL | TYPE | NUMBER | REC. SOIL (mm) REC. ROCK (%) | BLOWS / 150 mm (N VALUE) RQD % | OTHER TESTS |
|---|---|---|---|---|---|---|---|---|---|
| | 26.83 | ASPHALT | | | | | | | |
| | 26.37 | FILL: reddish-brown sandy lean clay<br>- with trace gravel | | | SS | 1 | 150 | 46-5-5-4 (9) | |
| 1 | | | | | SS | 2 | 200 | 3-3-9-7 (12) | |
| 2 | | - with 0.6 m sandstone boulder at 1.8 m | | | SS | 3 | 75 | 60 / 75 mm | |
| | | | | | SS | 4 | 100 | 2-1-1-1 (2) | |
| 3 | | | | | SS | 5 | 125 | 1-4-6-5 (10) | |
| | 23.02 | Stiff reddish-brown clayey sand with gravel TILL<br>- with grey mottling | | | SS | 6 | 175 | 9-4-7-11 (11) | |
| 4 | | | | | SS | 7 | 200 | 44-50 | |
| 5 | 21.78 | Very poor quality grey to reddish-brown CONGLOMERATE<br>- moderately to slightly weathered | | | HQ | 8 | 62% | 19% | |
| 6 | | | | | SS | 9 | 0 | 50 / 25 mm | |
| 7 | | | | | HQ | 10 | 49% | 7% | |
| | 19.08 | Very soft brown lean CLAY | | | | | | | |
| 8 | | | | | SS | 11 | 0 | 1-0-1-2 (1) | |
| 9 | | | | | SS | 12 | 150 | WT. OF HAMMER | |
| | 17.08 | | | | | | | 9-50 / 125 | |



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**HARBOURSIDE**
Geotechnical Consultants

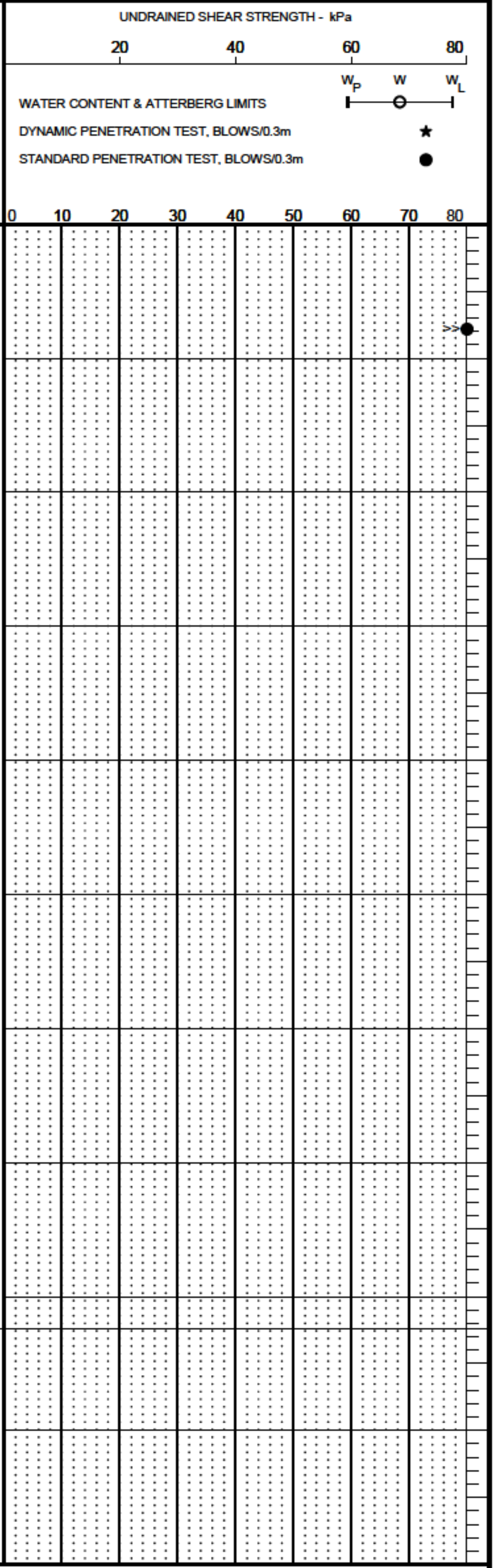
# BOREHOLE RECORD

**BH01**

**N: 5064990.1 E: 25547406.51**

| | | | |
|---|---|---|---|
| **CLIENT** | NOVA SCOTIA TRANSPORTATION AND INFRASTRUCTURE RENEWAL | **PROJECT No.** | 193111 |
| **LOCATION** | HIGHWAY 104, OXFORD, CUMBERLAND COUNTY, NOVA SCOTIA | **DATUM** | CGVD2013 |
| **DATES: BORING** | 21/10/2019 TO 22/10/2019 **WATER LEVEL** 22/10/2019 | **BH SIZE** | HW/HQ |

| DEPTH (m) | ELEVATION (m) | SOIL/BEDROCK DESCRIPTION | GRAPHIC LOG | WATER LEVEL | TYPE | NUMBER | REC. SOIL (mm) REC. ROCK (%) | BLOWS / 150 mm (N VALUE) RQD % | OTHER TESTS |
|---|---|---|---|---|---|---|---|---|---|
| | | Very poor quailty white GYPSUM<br>- moderately to slightly weathered<br>*(continued)* | | | SS | 13 | 225 | mm | |
| | | | | | HQ | 14 | 25% | 0% | |
| | | | | | SS | 15 | 75 | 50 / 75 mm | |
| 11 | | | | | HQ | 16 | 36% | 11% | |
| 12 | | | | | | | | | |
| 13 | | | | | HQ | 17 | 44% | 0% | |
| | 13.09 | Good quality grey and white GYPSUM<br>- slightly weathered to fresh | | | | | | | |
| 14 | | | | ∇ | HQ | 18 | 100% | 76% | |
| | | | | | HQ | 19 | 93% | 93% | |
| 15 | | | | | | | | | |
| 16 | | | | | HQ | 20 | 100% | 85% | |
| 17 | | | | | HQ | 21 | 100% | 90% | |
| 18 | 8.59 | | | | | | | | |
| | | End of borehole | | | | | | | |
| 19 | | | | | | | | | |



| | | | |
|---|---|---|---|
| ■ | Miniature Vane | □ | Torvane |
| ◆ | Penetrometer | ◇ | UU Triaxial |
| ▲ | Field Vane | △ | Unconfined Compression |

**HARBOURSIDE**
Geotechnical Consultants

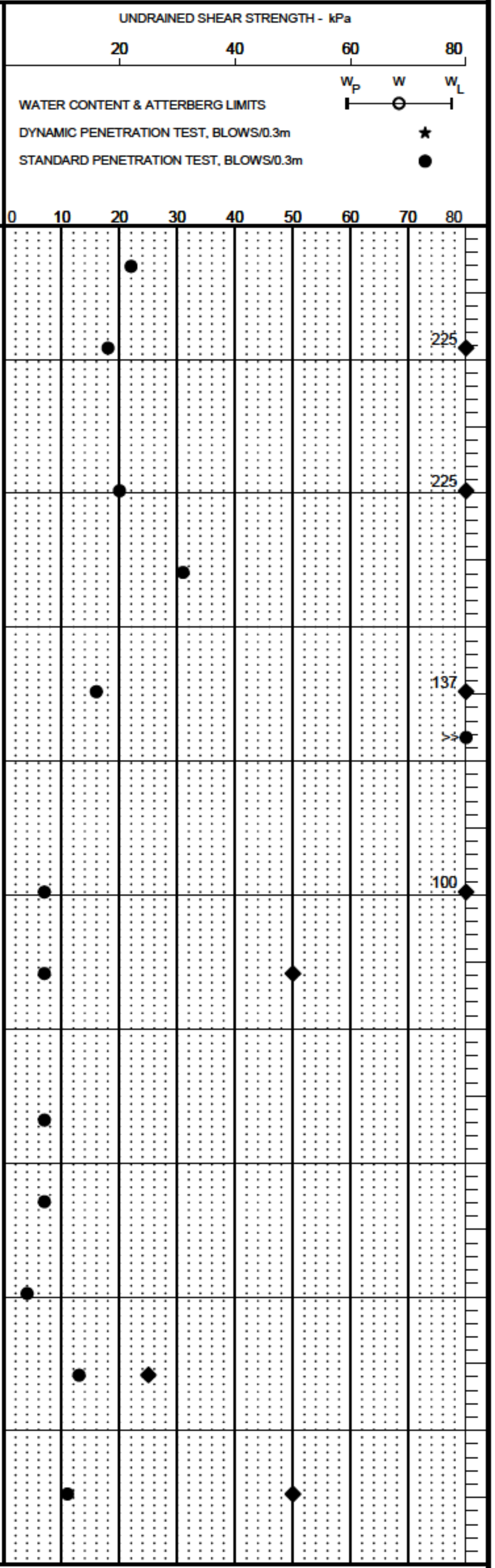
# BOREHOLE RECORD

# BH02

N: 5064989.04 E: 25547522.33

| | | | |
|---|---|---|---|
| **CLIENT** | NOVA SCOTIA TRANSPORTATION AND INFRASTRUCTURE RENEWAL | **PROJECT No.** | 193111 |
| **LOCATION** | HIGHWAY 104, OXFORD, CUMBERLAND COUNTY, NOVA SCOTIA | **DATUM** | CGVD2013 |
| **DATES: BORING** | 09/10/2019 TO 18/10/2019 **WATER LEVEL** 18/10/2019 | **BH SIZE** | HW/HQ, NW/NQ |

| DEPTH (m) | ELEVATION (m) | SOIL/BEDROCK DESCRIPTION | GRAPHIC LOG | WATER LEVEL | TYPE | NUMBER | REC. SOIL (mm) REC. ROCK (%) | BLOWS / 150 mm (N VALUE) RQD % | OTHER TESTS |
|---|---|---|---|---|---|---|---|---|---|
| | 23.93 | FILL: brown silty sand with gravel | | | | | | | |
| | 23.63 | FILL: reddish-brown sandy lean clay with gravel<br>- with occasional cobbles | | | SS | 1 | 325 | 13-12-10-14 (22) | |
| 1 | | | | | SS | 2 | 250 | 10-7-11-12 (18) | |
| 2 | | | | | SS | 3 | 375 | 5-8-12-16 (20) | |
| | | - with trace rootlets at 2.6 m | | | SS | 4 | 350 | 14-14-17-18 (31) | |
| 3 | | | | | SS | 5 | 225 | 6-7-9-11 (16) | |
| | | | | | SS | 6 | 75 | 50 / 75 mm | |
| 4 | | | | | | | | | |
| 5 | | | | | SS | 7 | 250 | 4-4-3-4 (7) | |
| | | | | | SS | 8 | 300 | 2-3-4-4 (7) | |
| 6 | | | | | SS | 9 | 75 | 5-4-3-6 (7) | |
| 7 | | | | | SS | 10 | 0 | 4-4-3-4 (7) | |
| 8 | | | | | SS | 11 | 0 | 3-1-3-5 (4) | |
| | | | | | SS | 12 | 450 | 4-4-9-7 (13) | |
| | 15.14 | ORIGINAL TOPSOIL: grey silty sand with organics | | | | | | | |
| 9 | 14.48 | | | | SS | 13 | 500 | 5-6-5-6 (11) | |



■ Miniature Vane
□ Torvane
◆ Penetrometer
◇ UU Triaxial
▲ Field Vane
△ Unconfined Compression

(Continued Next Page)

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Geotechnical Consultants

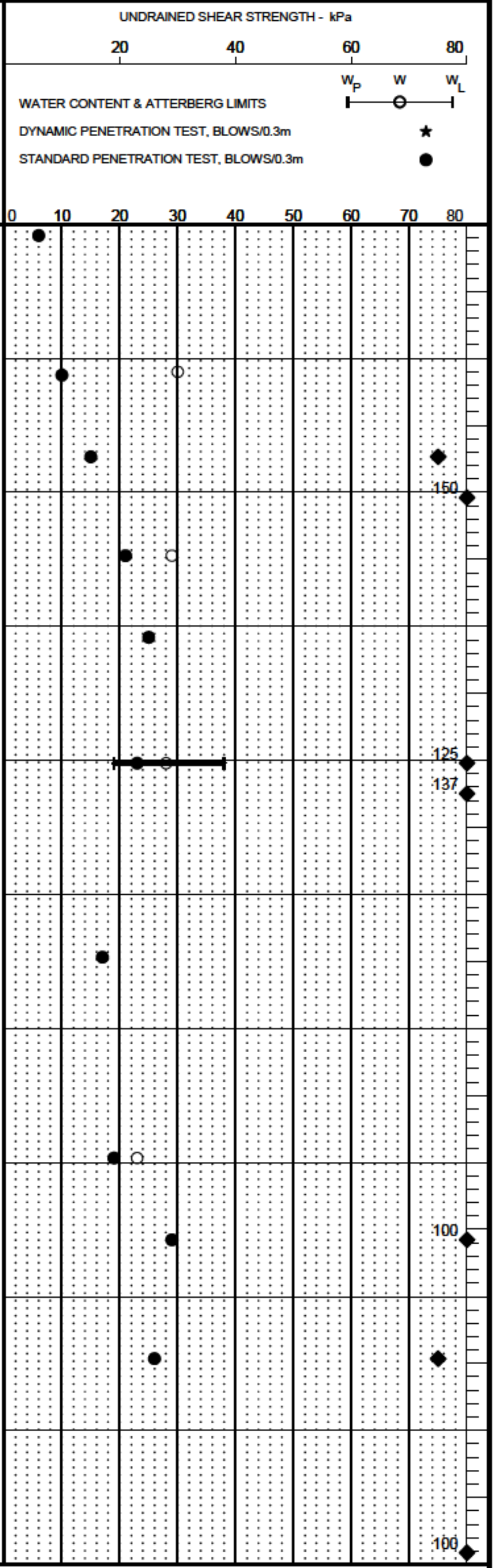
# BOREHOLE RECORD

## BH02

N: 5064989.04 E: 25547522.33

**CLIENT** NOVA SCOTIA TRANSPORTATION AND INFRASTRUCTURE RENEWAL
**PROJECT No.** 193111
**LOCATION** HIGHWAY 104, OXFORD, CUMBERLAND COUNTY, NOVA SCOTIA
**DATUM** CGVD2013
**DATES: BORING** 09/10/2019 TO 18/10/2019 **WATER LEVEL** 18/10/2019
**BH SIZE** HW/HQ, NW/NQ

| DEPTH (m) | ELEVATION (m) | SOIL/BEDROCK DESCRIPTION | GRAPHIC LOG | WATER LEVEL | TYPE | NUMBER | REC. SOIL (mm) REC. ROCK (%) | BLOWS / 150 mm (N VALUE) RQD % | OTHER TESTS |
|---|---|---|---|---|---|---|---|---|---|
| | | Firm to very stiff reddish-brown to brown lean CLAY to lean CLAY with sand<br>- with trace gravel<br>- with trace blackened organics<br>- with trace white vivianite inclusions<br>- varved, with sand partings *(continued)* | | | SS | 14 | 175 | 2-1-5-6 (6) | |
| | | | | | | | | | |
| 11 | | | | | SS | 15 | 425 | 5-4-6-12 (10) | S |
| | | | | | SS | 16 | 500 | 6-6-9-13 (15) | |
| 12 | | | | | | | | | |
| | | | | | SS | 17 | 450 | 7-9-12-16 (21) | S |
| 13 | | | | | SS | 18 | 325 | 12-12-13-14 (25) | |
| | | | | | | | | | |
| 14 | | | | | SS | 19 | 550 | 6-10-13-14 (23) | |
| | | | | ∇ | | | | | |
| 15 | | | | | SS | 20 | 725 | 5-7-10-13 (17) | |
| 16 | | | | | | | | | |
| 17 | | | | | SS | 21 | 200 | 6-8-11-12 (19) | |
| | | | | | SS | 22 | 450 | 12-14-15-15 (29) | |
| 18 | | | | | | | | | |
| | | - with pockets of reddish-brown clayey sand with gravel from 18.1 m to 21.8 m | | | SS | 23 | 500 | 7-13-13-16 (26) | |
| 19 | | | | | | | | | |
| | | | | | | | | | |



■ Miniature Vane □ Torvane
◆ Penetrometer ◇ UU Triaxial
▲ Field Vane △ Unconfined Compression

(Continued Next Page)

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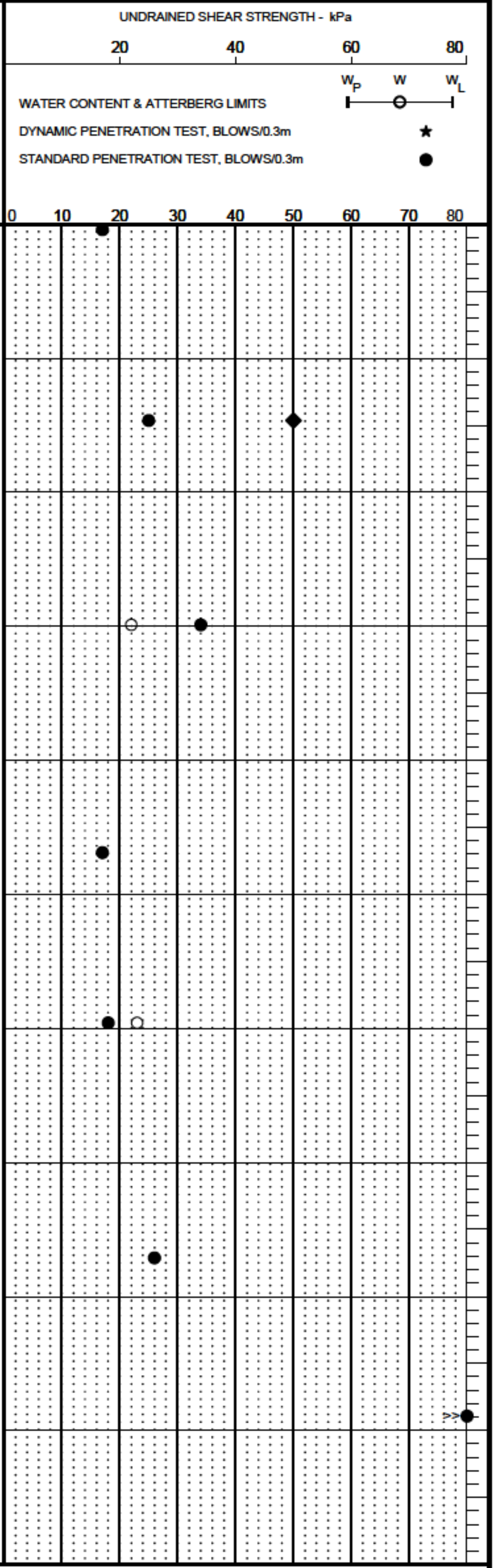
# BOREHOLE RECORD

**BH02**

N: 5064989.04 E: 25547522.33

**CLIENT** NOVA SCOTIA TRANSPORTATION AND INFRASTRUCTURE RENEWAL
**PROJECT No.** 193111
**LOCATION** HIGHWAY 104, OXFORD, CUMBERLAND COUNTY, NOVA SCOTIA
**DATUM** CGVD2013
**DATES: BORING** 09/10/2019 TO 18/10/2019 **WATER LEVEL** 18/10/2019
**BH SIZE** HW/HQ, NW/NQ

| DEPTH (m) | ELEVATION (m) | SOIL/BEDROCK DESCRIPTION | GRAPHIC LOG | WATER LEVEL | TYPE | NUMBER | REC. SOIL (mm) REC. ROCK (%) | BLOWS / 150 mm (N VALUE) RQD % | OTHER TESTS |
|---|---|---|---|---|---|---|---|---|---|
| | | Firm to very stiff reddish-brown to brown lean CLAY to lean CLAY with sand<br>- with trace gravel<br>- with trace blackened organics<br>- with trace white vivianite inclusions<br>- varved, with sand partings *(continued)* | | | SS | 24 | 450 | 5-8-9-13 (17) | |
| 21 | | | | | | | | | |
| | | | | | SS | 25 | 475 | 12-12-13-18 (25) | |
| 22 | | | | | | | | | |
| 23 | | | | | SS | 26 | 550 | 8-12-22-29 (34) | |
| 24 | | | | | | | | | |
| | | | | | SS | 27 | 0 | 9-8-9-19 (17) | |
| 25 | | | | | GB | 28 | 0 | - | |
| 26 | | | | | SS | 29 | 550 | 6-6-12-8 (18) | S |
| 27 | | | | | | | | | |
| | | | | | SS | 30 | 450 | 8-11-15-18 (26) | |
| 28 | | | | | | | | | |
| 29 | -4.77 | Hard reddish-brown clayey sand to sandy lean clay TILL<br>- with frequent cobbles | | | SS | 31 | 200 | 43-53-50 / 75 mm | |



■ Miniature Vane
□ Torvane
◆ Penetrometer
◇ UU Triaxial
▲ Field Vane
△ Unconfined Compression

*(Continued Next Page)*

HARBOURSIDE
Geotechnical Consultants

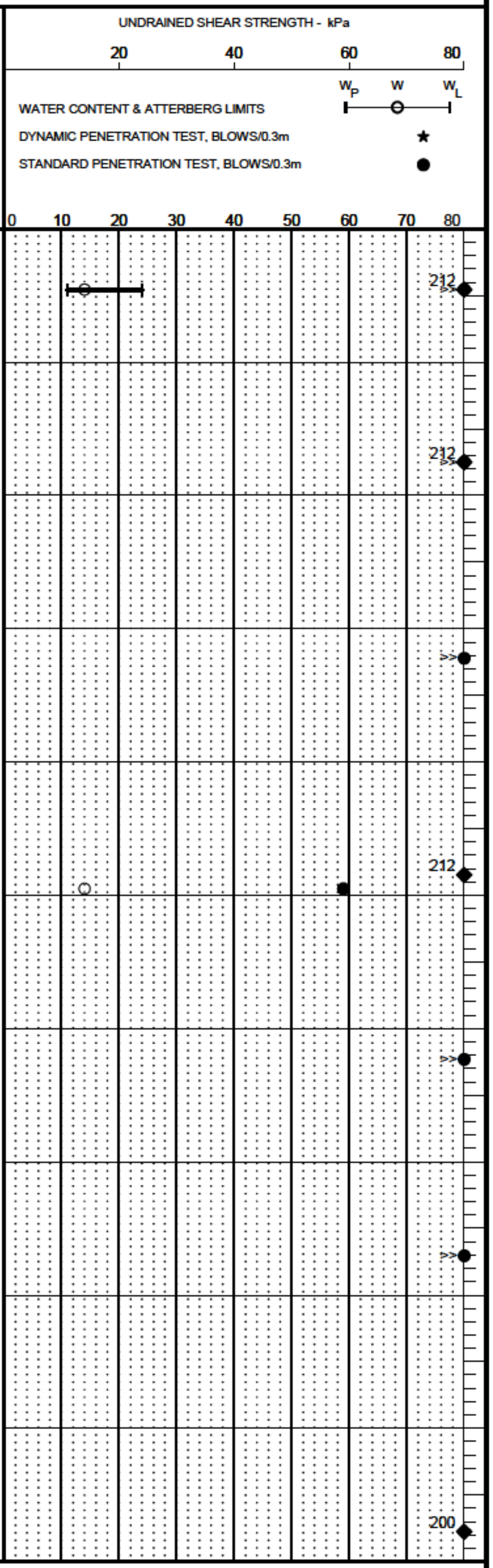
# BOREHOLE RECORD

**BH02**

N: 5064989.04 E: 25547522.33

| | | | |
|---|---|---|---|
| **CLIENT** | NOVA SCOTIA TRANSPORTATION AND INFRASTRUCTURE RENEWAL | **PROJECT No.** | 193111 |
| **LOCATION** | HIGHWAY 104, OXFORD, CUMBERLAND COUNTY, NOVA SCOTIA | **DATUM** | CGVD2013 |
| **DATES: BORING** | 09/10/2019 TO 18/10/2019 **WATER LEVEL** 18/10/2019 | **BH SIZE** | HW/HQ, NW/NQ |

| DEPTH (m) | ELEVATION (m) | SOIL/BEDROCK DESCRIPTION | GRAPHIC LOG | WATER LEVEL | TYPE | NUMBER | REC. SOIL (mm) REC. ROCK (%) | BLOWS / 150 mm (N VALUE) RQD % | OTHER TESTS |
|---|---|---|---|---|---|---|---|---|---|
| | | Hard reddish-brown clayey sand to sandy lean clay TILL<br>- with frequent cobbles *(continued)* | | | SS | 32 | 375 | 21-33-49-70 (82) | |
| 31 | | | | | | | | | |
| | | | | | SS | 33 | 200 | 140-80 / 50 mm | |
| 32 | | | | | | | | | |
| 33 | | | | | SS | 34 | 250 | 35-37-50 / 100 mm | |
| 34 | | | | | | | | | |
| 35 | | | | | SS | 35 | 400 | 20-25-34-64 (59) | S |
| | | | | | GB | 36 | 300 | - | |
| 36 | | | | | SS | 37 | 175 | 82-50 / 25 mm | |
| 37 | | - 0.8 m gypsum boulder at 37.2 m | | | | | | | |
| | | | | | SS | 38 | 125 | 110 / 125 mm | |
| 38 | | - with gypsum and conglomerate cobbles at 38.3 m | | | | | | | |
| 39 | | | | | | | | | |
| | | | | | GB | 39 | 600 | - | |



| | | | |
|---|---|---|---|
| ■ | Miniature Vane | □ | Torvane |
| ◆ | Penetrometer | ◇ | UU Triaxial |
| ▲ | Field Vane | △ | Unconfined Compression |

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HARBOURSIDE
Geotechnical Consultants

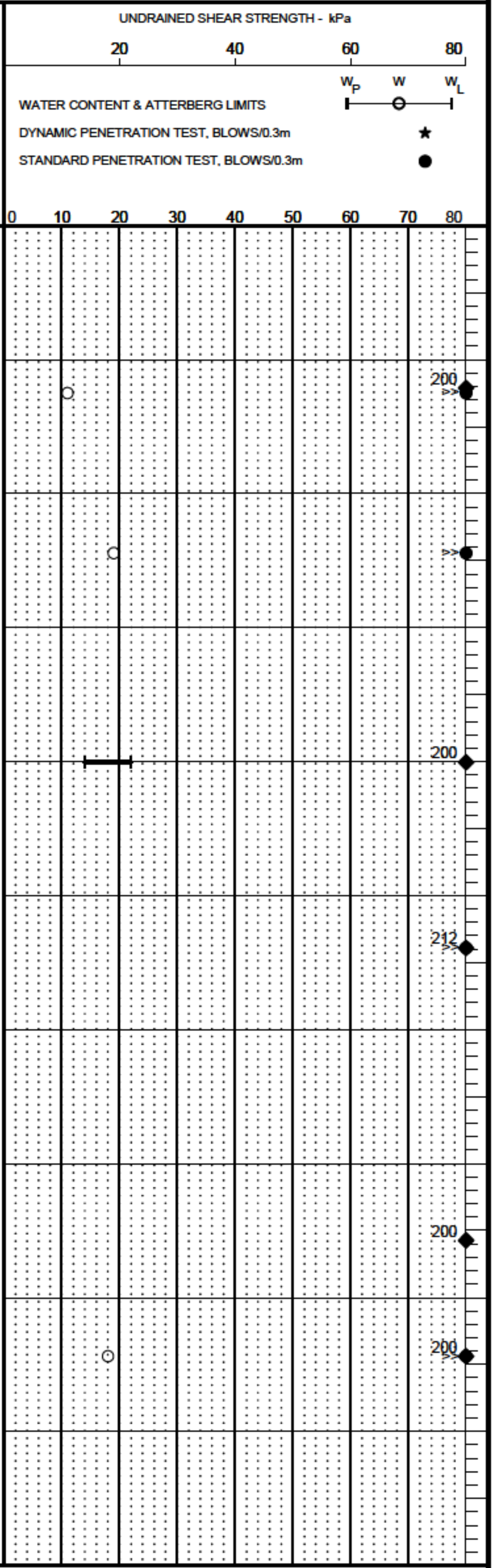
# BOREHOLE RECORD

**BH02**

N: 5064989.04 E: 25547522.33

**CLIENT** NOVA SCOTIA TRANSPORTATION AND INFRASTRUCTURE RENEWAL
**LOCATION** HIGHWAY 104, OXFORD, CUMBERLAND COUNTY, NOVA SCOTIA
**DATES: BORING** 09/10/2019 TO 18/10/2019 **WATER LEVEL** 18/10/2019
**PROJECT No.** 193111
**DATUM** CGVD2013
**BH SIZE** HW/HQ, NW/NQ

| DEPTH (m) | ELEVATION (m) | SOIL/BEDROCK DESCRIPTION | TYPE | NUMBER | REC. SOIL (mm) REC. ROCK (%) | BLOWS / 150 mm (N VALUE) RQD % | OTHER TESTS |
|---|---|---|---|---|---|---|---|
| | | Hard reddish-brown clayey sand to sandy lean clay TILL<br>- with frequent cobbles *(continued)* | | | | | |
| | | - with sand seams at 40.8 m | | | | | |
| 41 | | | SS | 40 | 475 | 57-64-44-59 (103) | |
| 42 | | | SS | 41 | 550 | 33-60-40-51 (91) | S |
| 43 | | | | | | | |
| 44 | | - with trace wood fragments at 44.5 m | GB | 42 | 600 | - | |
| 45 | | | SS | 43 | 500 | 20-36-40-50 / 50 mm | |
| 46 | | | | | | | |
| 47 | | | GB | 44 | 250 | - | |
| 48 | | | SS | 45 | 575 | 11-19-99-75 (118) | |
| 49 | | | | | | | |



■ Miniature Vane
□ Torvane
◆ Penetrometer
◇ UU Triaxial
▲ Field Vane
△ Unconfined Compression

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**HARBOURSIDE**
Geotechnical Consultants

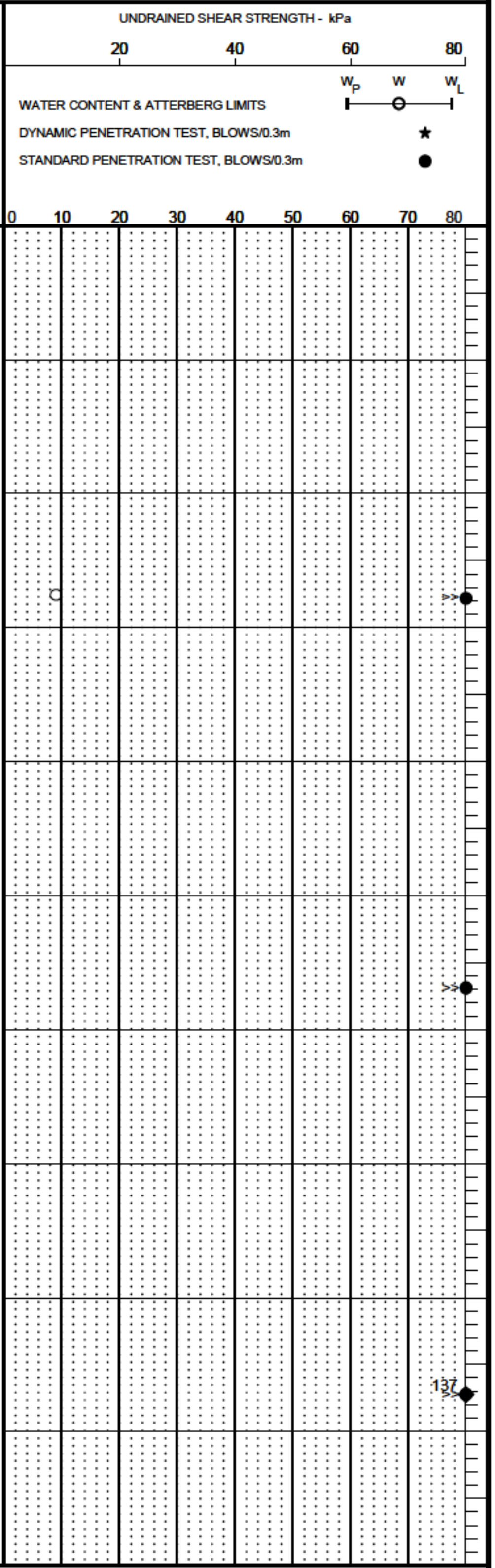
# BOREHOLE RECORD

**BH02**

**N: 5064989.04 E: 25547522.33**

**CLIENT** NOVA SCOTIA TRANSPORTATION AND INFRASTRUCTURE RENEWAL
**LOCATION** HIGHWAY 104, OXFORD, CUMBERLAND COUNTY, NOVA SCOTIA
**DATES: BORING** 09/10/2019 TO 18/10/2019 **WATER LEVEL** 18/10/2019
**PROJECT No.** 193111
**DATUM** CGVD2013
**BH SIZE** HW/HQ, NW/NQ

| DEPTH (m) | ELEVATION (m) | SOIL/BEDROCK DESCRIPTION | GRAPHIC LOG | WATER LEVEL | TYPE | NUMBER | REC. SOIL (mm) REC. ROCK (%) | BLOWS / 150 mm (N VALUE) RQD % | OTHER TESTS |
|---|---|---|---|---|---|---|---|---|---|
|  |  | Hard reddish-brown clayey sand to sandy lean clay TILL<br>- with frequent cobbles *(continued)* |  |  |  |  |  |  |  |
| 51 |  |  |  |  |  |  |  |  |  |
| 52 |  |  |  |  | SS | 46 | 350 | 52-93-65-50 / 50 mm |  |
| 53 |  |  |  |  |  |  |  |  |  |
| 54 |  |  |  |  |  |  |  |  |  |
| 55 |  |  |  |  | SS | 47 | 100 | 32-135-50 / 25 mm |  |
| 56 |  |  |  |  |  |  |  |  |  |
| 57 |  |  |  |  |  |  |  |  |  |
| 58 | -34.59 | Brown lean CLAY |  |  | SS | 48 | 400 | 12-20-100 / 100 mm |  |
|  | -35.00 | Very poor to poor quality white GYPSUM<br>- moderately to highly weathered<br>- with occasional brown clay infilling |  |  |  |  |  |  |  |
| 59 |  |  |  |  | NQ | 49 | 63% | 12% |  |



■ Miniature Vane
◆ Penetrometer
▲ Field Vane
□ Torvane
◇ UU Triaxial
△ Unconfined Compression

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HARBOURSIDE
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# BOREHOLE RECORD

**BH02**

N: 5064989.04 E: 25547522.33

**CLIENT** NOVA SCOTIA TRANSPORTATION AND INFRASTRUCTURE RENEWAL
**PROJECT No.** 193111
**LOCATION** HIGHWAY 104, OXFORD, CUMBERLAND COUNTY, NOVA SCOTIA
**DATUM** CGVD2013
**DATES: BORING** 09/10/2019 TO 18/10/2019 **WATER LEVEL** 18/10/2019
**BH SIZE** HW/HQ, NW/NQ

| DEPTH (m) | ELEVATION (m) | SOIL/BEDROCK DESCRIPTION | GRAPHIC LOG | WATER LEVEL | TYPE | NUMBER | REC. SOIL (mm) REC. ROCK (%) | BLOWS / 150 mm (N VALUE) RQD % | OTHER TESTS |
|---|---|---|---|---|---|---|---|---|---|
| 61 | | Very poor to poor quality white GYPSUM<br>- moderately to highly weathered<br>- with occasional brown clay infilling<br>*(continued)* | | | NQ | 50 | 32% | 7% | |
| 62 | | | | | NQ | 51 | 72% | 0% | |
| 63 | | | | | NQ | 52 | 23% | 0% | |
| | | | | | NQ | 53 | 21% | 0% | |
| 64 | | | | | NQ | 54 | 67% | 0% | |
| 65 | | | | | NQ | 55 | 31% | 0% | |
| 66 | | | | | NQ | 56 | 0% | 0% | |
| | | | | | NQ | 57 | 41% | 21% | |
| 67 | | | | | NQ | 58 | 17% | 0% | |
| 68 | | | | | NQ | 59 | 17% | 0% | |
| 69 | | | | | NQ | 60 | 40% | 17% | |
| | | | | | NQ | 61 | 90% | 0% | |

UNDRAINED SHEAR STRENGTH - kPa
20 40 60 80

WATER CONTENT & ATTERBERG LIMITS $W_P$ W $W_L$
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●

0 10 20 30 40 50 60 70 80

■ Miniature Vane □ Torvane
◆ Penetrometer ◇ UU Triaxial
▲ Field Vane △ Unconfined Compression

*(Continued Next Page)*

**HARBOURSIDE**
Geotechnical Consultants

# BOREHOLE RECORD

## BH02

N: 5064989.04 E: 25547522.33

**CLIENT** NOVA SCOTIA TRANSPORTATION AND INFRASTRUCTURE RENEWAL
**PROJECT No.** 193111
**LOCATION** HIGHWAY 104, OXFORD, CUMBERLAND COUNTY, NOVA SCOTIA
**DATUM** CGVD2013
**DATES: BORING** 09/10/2019 TO 18/10/2019
**WATER LEVEL** 18/10/2019
**BH SIZE** HW/HQ, NW/NQ

| DEPTH (m) | ELEVATION (m) | SOIL/BEDROCK DESCRIPTION | GRAPHIC LOG | WATER LEVEL | TYPE | NUMBER | REC. SOIL (mm) REC. ROCK (%) | BLOWS / 150 mm (N VALUE) RQD % | OTHER TESTS |
|---|---|---|---|---|---|---|---|---|---|
| | | Very poor to poor quality white GYPSUM<br>- moderately to highly weathered<br>- with occasional brown clay infilling<br>*(continued)* | | | NQ | 62 | 20% | 0% | |
| 71 | | | | | NQ | 63 | 17% | 0% | |
| | | | | | NQ | 64 | 7% | 0% | |
| 72 | | - 0.3 m clay seam at 72.3 m | | | NQ | 65 | 34% | 0% | |
| 73 | | | | | NQ | 66 | 33% | 0% | |
| | | | | | NQ | 67 | 24% | 0% | |
| 74 | | | | | NQ | 68 | 13% | 0% | |
| 75 | | - 0.6 m clay seam at 75.0 m | | | NQ | 69 | 34% | 0% | |
| 76 | -52.57 | | | | NQ | 70 | 20% | 0% | |
| | | End of borehole | | | | | | | |
| 77 | | | | | | | | | |
| 78 | | | | | | | | | |
| 79 | | | | | | | | | |

UNDRAINED SHEAR STRENGTH - kPa: 20 40 60 80

WATER CONTENT & ATTERBERG LIMITS: $W_P$ W $W_L$

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

0 10 20 30 40 50 60 70 80

■ Miniature Vane
□ Torvane
◆ Penetrometer
◇ UU Triaxial
▲ Field Vane
△ Unconfined Compression

HARBOURSIDE
Geotechnical Consultants

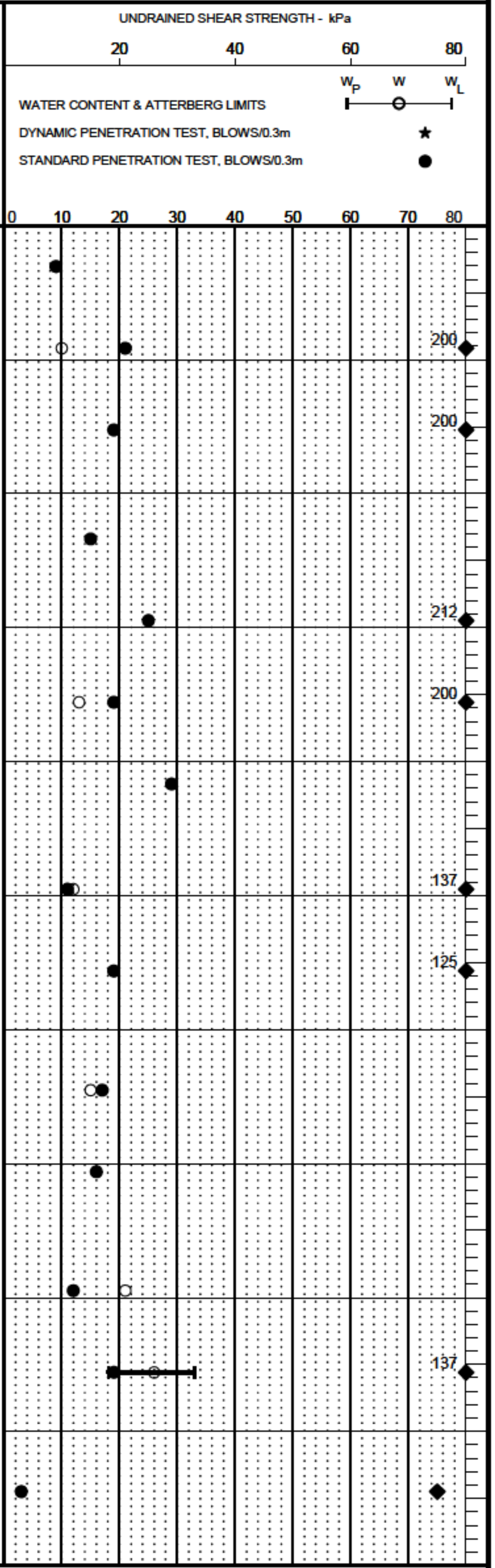
# BOREHOLE RECORD

## BH03

N: 5064988.79 E: 25547554.73

| | | | |
|---|---|---|---|
| **CLIENT** | NOVA SCOTIA TRANSPORTATION AND INFRASTRUCTURE RENEWAL | **PROJECT No.** | 193111 |
| **LOCATION** | HIGHWAY 104, OXFORD, CUMBERLAND COUNTY, NOVA SCOTIA | **DATUM** | CGVD2013 |
| **DATES: BORING** | 07/10/2019 TO 08/10/2019 — **WATER LEVEL** 08/10/2019 | **BH SIZE** | HW/HQ |

| DEPTH (m) | ELEVATION (m) | SOIL/BEDROCK DESCRIPTION | GRAPHIC LOG | WATER LEVEL | TYPE | NUMBER | REC. SOIL (mm) REC. ROCK (%) | BLOWS / 150 mm (N VALUE) RQD % | OTHER TESTS |
|---|---|---|---|---|---|---|---|---|---|
| | 23.40 | | | | | | | | |
| | 23.32 | ROOTMAT | | | | | | | |
| | 23.22 | FILL: grey silty sand with gravel | | | SS | 1 | 350 | 5-6-4-5<br>(9) | |
| | | FILL: reddish-brown sandy lean clay with gravel | | | SS | 2 | 175 | 3-11-10-12<br>(21) | |
| 1 | | | | | SS | 3 | 100 | 6-10-9-13<br>(19) | |
| 2 | | | | | SS | 4 | 0 | 6-7-8-9<br>(15) | |
| 3 | | | | | SS | 5 | 150 | 11-12-13-20<br>(25) | |
| | | | | | SS | 6 | 350 | 8-9-10-13<br>(19) | S |
| 4 | 19.54 | FILL: reddish-brown silty sand with gravel to silty, clayey sand with gravel | | | SS | 7 | 325 | 16-17-15-14<br>(29) | S |
| 5 | | | | | SS | 8 | 350 | 4-5-6-9<br>(11) | |
| | | | | | SS | 9 | 375 | 10-10-9-11<br>(19) | |
| 6 | 17.25 | Compact brown silty SAND<br>- with trace gravel | | | SS | 10 | 475 | 10-8-9-11<br>(17) | S |
| 7 | | | | | SS | 11 | 350 | 12-7-9-10<br>(16) | |
| | 16.14 | Soft to very stiff reddish-brown to brown lean clay with sand to clayey sand<br>- with trace gravel | | | SS | 12 | 475 | 4-4-8-9<br>(12) | S |
| 8 | | | | | SS | 13 | 425 | 6-7-12-14<br>(19) | |
| 9 | | | | | SS | 14 | 225 | 2-1-2-2<br>(3) | |



| | | | |
|---|---|---|---|
| ■ | Miniature Vane | □ | Torvane |
| ◆ | Penetrometer | ◇ | UU Triaxial |
| ▲ | Field Vane | △ | Unconfined Compression |

(Continued Next Page)

HARBOURSIDE
Geotechnical Consultants

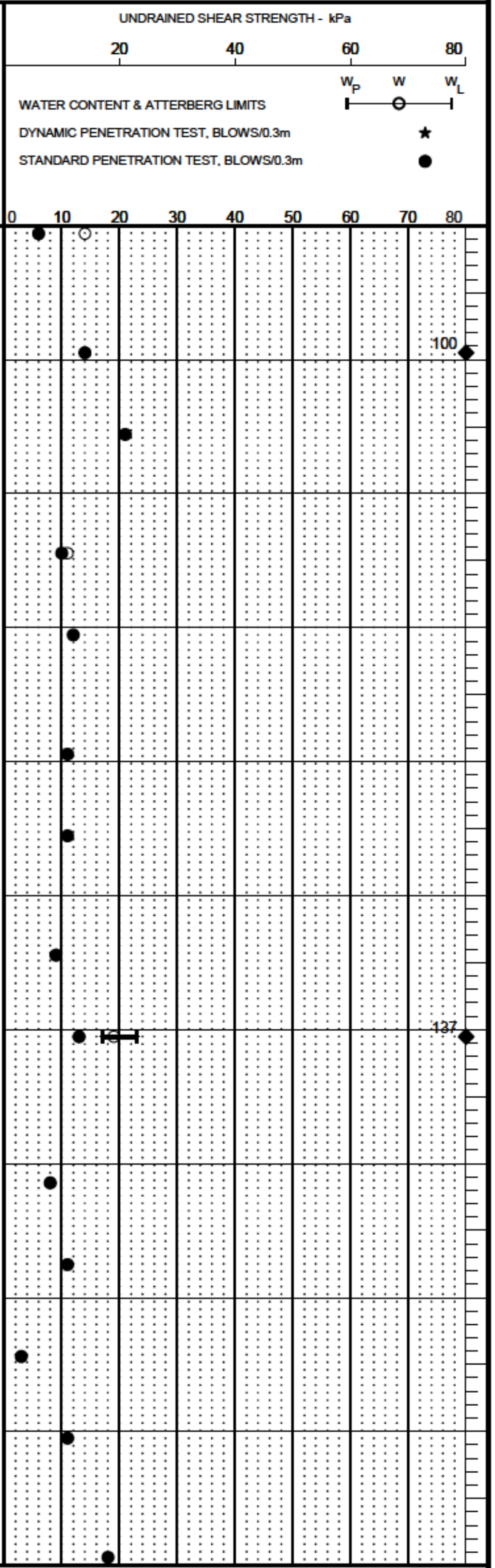
# BOREHOLE RECORD

## BH03

N: 5064988.79 E: 25547554.73

| | | | |
|---|---|---|---|
| **CLIENT** | NOVA SCOTIA TRANSPORTATION AND INFRASTRUCTURE RENEWAL | **PROJECT No.** | 193111 |
| **LOCATION** | HIGHWAY 104, OXFORD, CUMBERLAND COUNTY, NOVA SCOTIA | **DATUM** | CGVD2013 |
| **DATES: BORING** | 07/10/2019 TO 08/10/2019 **WATER LEVEL** 08/10/2019 | **BH SIZE** | HW/HQ |

| DEPTH (m) | ELEVATION (m) | SOIL/BEDROCK DESCRIPTION | GRAPHIC LOG | WATER LEVEL | TYPE | NUMBER | REC. SOIL (mm) REC. ROCK (%) | BLOWS / 150 mm (N VALUE) RQD % | OTHER TESTS |
|---|---|---|---|---|---|---|---|---|---|
| | | Soft to very stiff reddish-brown to brown lean clay with sand to clayey sand<br>- with trace gravel *(continued)* | | | SS | 15 | 125 | 3-3-3-4 (6) | |
| | | | | | | | | | |
| 11 | | | | ▽ | SS | 16 | 425 | 9-6-8-11 (14) | |
| | | | | | SS | 17 | 200 | 10-12-9-15 (21) | |
| 12 | | | | | | | | | |
| | | | | | SS | 18 | 175 | 8-7-4-6 (10) | |
| 13 | | | | | SS | 19 | 250 | 5-4-8-10 (12) | |
| | | | | | | | | | |
| 14 | | | | | SS | 20 | 0 | 3-4-7-8 (11) | |
| | | | | | SS | 21 | 0 | 6-7-6-5 (11) | |
| 15 | | | | | GB | 22 | 150 | - | |
| | | | | | SS | 23 | 0 | 4-5-4-5 (9) | |
| 16 | | | | | SS | 24 | 300 | 5-5-8-11 (13) | |
| | | | | | | | | | |
| 17 | | | | | SS | 25 | 275 | 5-2-6-8 (8) | |
| 18 | | | | | SS | 26 | 0 | 2-5-6-8 (11) | |
| | | | | | SS | 27 | 0 | 2-2-1-4 (3) | |
| 19 | | | | | SS | 28 | 0 | 7-5-6-5 (11) | |
| | | | | | | | | | |
| | | - with gypsum gravel below 19.6 m | | | SS | 29 | 200 | 23-13-9-9 | |



| | | | |
|---|---|---|---|
| ■ | Miniature Vane | □ | Torvane |
| ◆ | Penetrometer | ◇ | UU Triaxial |
| ▲ | Field Vane | △ | Unconfined Compression |

*(Continued Next Page)*

HARBOURSIDE
Geotechnical Consultants

# BOREHOLE RECORD

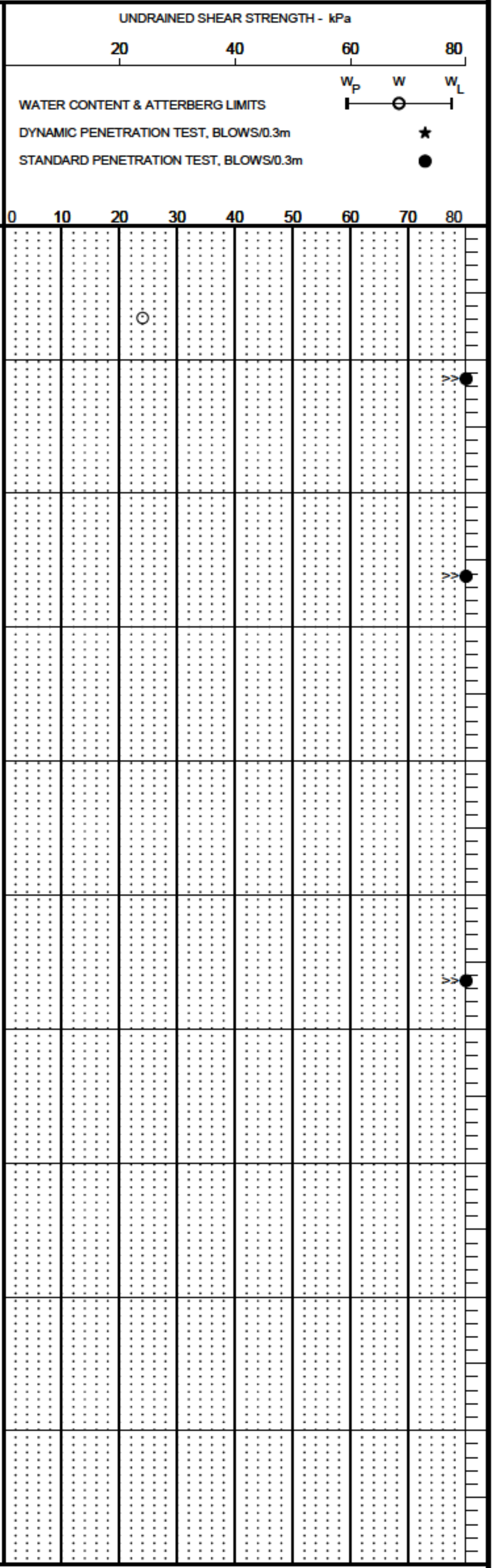
**BH03**

**N: 5064988.79 E: 25547554.73**

**CLIENT** NOVA SCOTIA TRANSPORTATION AND INFRASTRUCTURE RENEWAL
**PROJECT No.** 193111
**LOCATION** HIGHWAY 104, OXFORD, CUMBERLAND COUNTY, NOVA SCOTIA
**DATUM** CGVD2013
**DATES: BORING** 07/10/2019 TO 08/10/2019
**WATER LEVEL** 08/10/2019
**BH SIZE** HW/HQ

| DEPTH (m) | ELEVATION (m) | SOIL/BEDROCK DESCRIPTION | GRAPHIC LOG | WATER LEVEL | TYPE | NUMBER | REC. SOIL (mm) REC. ROCK (%) | BLOWS / 150 mm (N VALUE) RQD % | OTHER TESTS |
|---|---|---|---|---|---|---|---|---|---|
|  |  | Soft to very stiff reddish-brown to brown lean clay with sand to clayey sand<br>- with trace gravel *(continued)* | ▨ |  |  |  |  | (18) |  |
|  |  |  |  |  | GB | 30 | 300 | - | S |
|  |  |  |  |  | SS | 31 | 175 | 50 / 25 mm |  |
|  | 0.79 | Very poor to poor quality white GYPSUM<br>- with occasional brown clay infilling<br>- moderately to highly weathered |  |  | SS | 32 | 25 | 50 / 25 mm |  |
|  |  |  |  |  | HQ | 33 | 41% | 0% |  |
|  |  |  |  |  | HQ | 34 | 30% | 0% |  |
|  |  |  |  |  | SS | 35 | 75 | 50 / 75 mm |  |
|  |  |  |  |  | HQ | 36 | 79% | 21% |  |
|  |  |  |  |  | HQ | 37 | 97% | 39% |  |
|  |  |  |  |  | HQ | 38 | 25% | 0% |  |

Depth scale: 21, 22, 23, 24, 25, 26, 27, 28, 29



■ Miniature Vane
□ Torvane
◆ Penetrometer
◇ UU Triaxial
▲ Field Vane
△ Unconfined Compression

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HARBOURSIDE
Geotechnical Consultants

# BOREHOLE RECORD

## BH03

N: 5064988.79 E: 25547554.73

| | | | |
|---|---|---|---|
| **CLIENT** | **NOVA SCOTIA TRANSPORTATION AND INFRASTRUCTURE RENEWAL** | **PROJECT No.** | **193111** |
| **LOCATION** | **HIGHWAY 104, OXFORD, CUMBERLAND COUNTY, NOVA SCOTIA** | **DATUM** | **CGVD2013** |
| **DATES: BORING** | **07/10/2019 TO 08/10/2019** WATER LEVEL **08/10/2019** | **BH SIZE** | **HW/HQ** |

| DEPTH (m) | ELEVATION (m) | SOIL/BEDROCK DESCRIPTION | GRAPHIC LOG | WATER LEVEL | TYPE | NUMBER | REC. SOIL (mm) REC. ROCK (%) | BLOWS / 150 mm (N VALUE) RQD % | OTHER TESTS |
|---|---|---|---|---|---|---|---|---|---|
| | | Very poor to poor quality white GYPSUM<br>- with occasional brown clay infilling<br>- moderately to highly weathered<br>*(continued)* | | | | | | | |
| 31 | | | | | HQ | 39 | 42% | 0% | |
| 32 | | | | | HQ | 40 | 34% | 0% | |
| 33 | | | | | | | | | |
| 34 | | | | | HQ | 41 | 51% | 7% | |
| 35 | | | | | HQ | 42 | 12% | 0% | |
| 36 | -12.69 | | | | | | | | |
| | | End of borehole | | | | | | | |
| 37 | | | | | | | | | |
| 38 | | | | | | | | | |
| 39 | | | | | | | | | |

UNDRAINED SHEAR STRENGTH - kPa

20 40 60 80

WATER CONTENT & ATTERBERG LIMITS $W_P$ W $W_L$

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

0 10 20 30 40 50 60 70 80

| | | | |
|---|---|---|---|
| ■ | Miniature Vane | □ | Torvane |
| ◆ | Penetrometer | ◇ | UU Triaxial |
| ▲ | Field Vane | △ | Unconfined Compression |

HARBOURSIDE
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# BOREHOLE RECORD

## BH04

N: 5064976.68 E: 25547363.61

**CLIENT** NOVA SCOTIA TRANSPORTATION AND INFRASTRUCTURE RENEWAL

**PROJECT No.** 193111

**LOCATION** HIGHWAY 104, OXFORD, CUMBERLAND COUNTY, NOVA SCOTIA

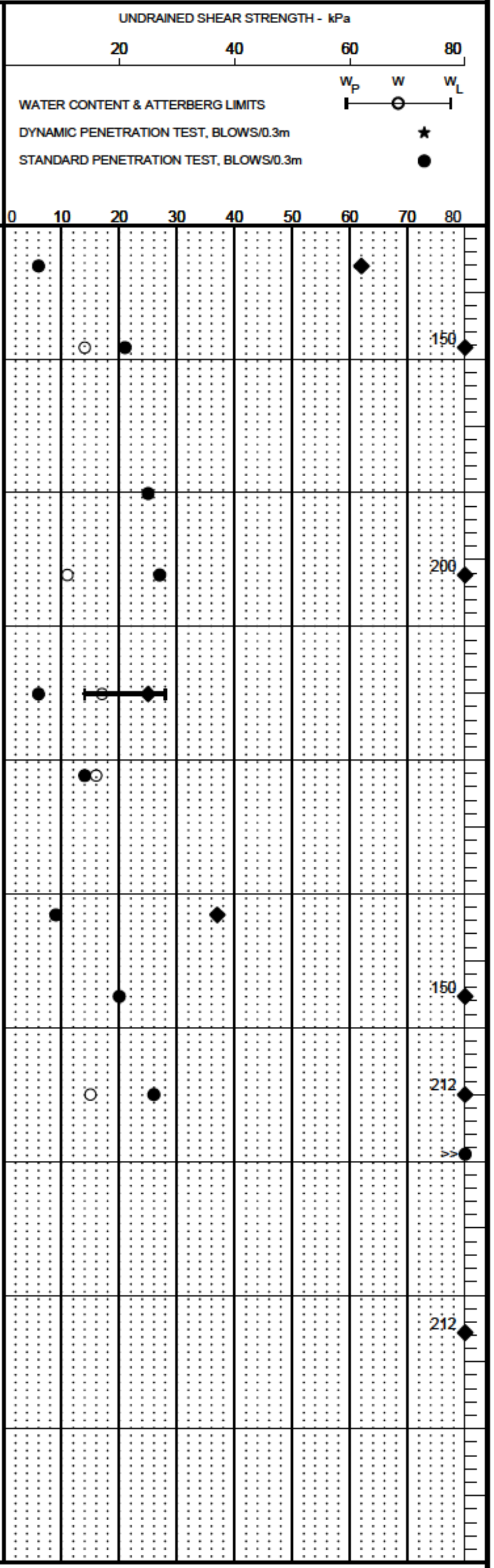
**DATUM** CGVD2013

**DATES: BORING** 23/10/2019 TO 25/10/2019

**WATER LEVEL** 25/10/2019

**BH SIZE** HW/HQ

| ELEVATION (m) | SOIL/BEDROCK DESCRIPTION | GRAPHIC LOG | WATER LEVEL | TYPE | NUMBER | REC. SOIL (mm) REC. ROCK (%) | BLOWS / 150 mm (N VALUE) RQD % | OTHER TESTS |
|---|---|---|---|---|---|---|---|---|
| 26.12 | | | | | | | | |
| 26.10 | ROOTMAT | | | | | | | |
| | FILL: reddish-brown to brown sandy lean clay with gravel<br>- with occasional cobbles<br>- with rootlets to 1.2 m | | | SS | 1 | 300 | 1-3-3-5 (6) | |
| | | | | SS | 2 | 250 | 3-8-13-10 (21) | |
| | | | | SS | 3 | 100 | 70-16-12-13 (25) | |
| | | | | SS | 4 | 200 | 10-13-14-13 (27) | |
| | | | | SS | 5 | 325 | 2-2-4-5 (6) | |
| | | | | SS | 6 | 300 | 5-8-6-20 (14) | S |
| | | | | SS | 7 | 275 | 2-4-5-6 (9) | |
| | | | | SS | 8 | 150 | 5-7-13-14 (20) | |
| 20.23 | Very stiff to hard reddish-brown lean clay TILL<br>- with grey mottling<br>- with trace gravel | | | SS | 9 | 300 | 7-10-16-25 (26) | S |
| | | | | SS | 10 | 125 | 7-5 / 125 mm | |
| 19.03 | Fair quality grey to reddish-brown conglomerate<br>- slightly to highly weathered | | | HQ | 11 | 610 | - | |
| 18.42 | Hard reddish-brown lean clay TILL<br>- with grey mottling<br>- with trace gravel | | | HQ | 12 | 1120 | - | |
| 17.69 | Very poor to fair quality reddish-brown SANDSTONE<br>- slightly to moderately weathered | | | | | | | |



■ Miniature Vane
□ Torvane
◆ Penetrometer
◇ UU Triaxial
▲ Field Vane
△ Unconfined Compression

(Continued Next Page)

HARBOURSIDE
Geotechnical Consultants

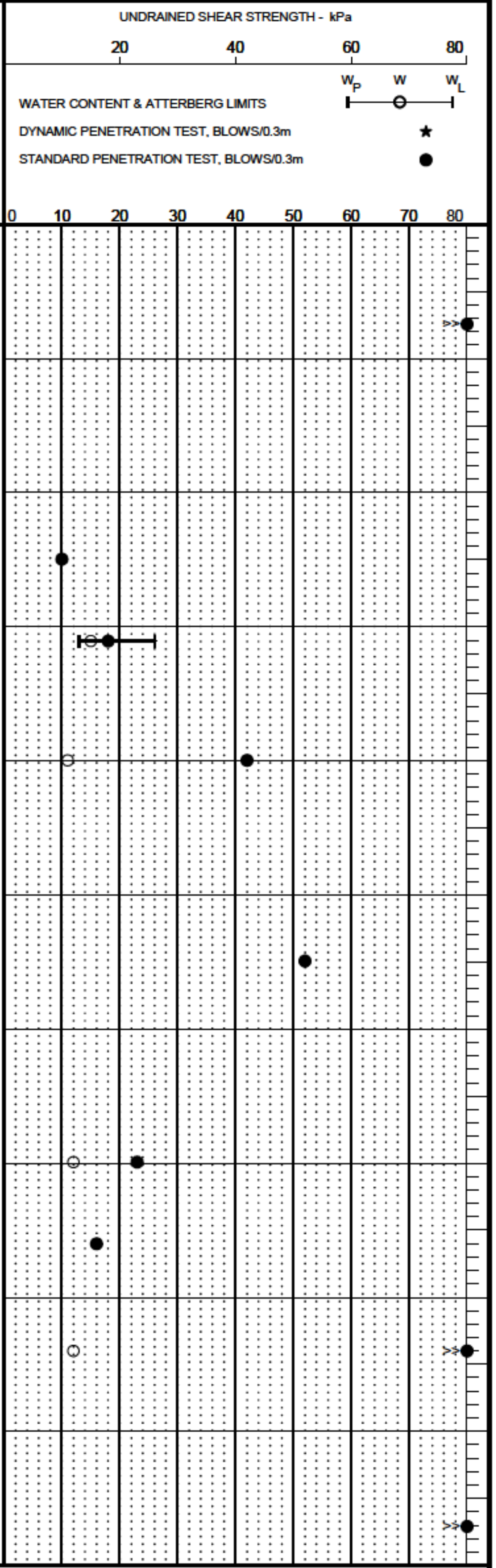
# BOREHOLE RECORD

## BH04

N: 5064976.68 E: 25547363.61

**CLIENT** NOVA SCOTIA TRANSPORTATION AND INFRASTRUCTURE RENEWAL
**PROJECT No.** 193111
**LOCATION** HIGHWAY 104, OXFORD, CUMBERLAND COUNTY, NOVA SCOTIA
**DATUM** CGVD2013
**DATES: BORING** 23/10/2019 TO 25/10/2019 **WATER LEVEL** 25/10/2019
**BH SIZE** HW/HQ

| DEPTH (m) | ELEVATION (m) | SOIL/BEDROCK DESCRIPTION | WATER LEVEL | TYPE | NUMBER | REC. SOIL (mm) REC. ROCK (%) | BLOWS / 150 mm (N VALUE) RQD % | OTHER TESTS |
|---|---|---|---|---|---|---|---|---|
| | 15.43 | Very poor to fair quality reddish-brown SANDSTONE<br>- slightly to moderately weathered<br>*(continued)* | | HQ | 13 | 610 | - | |
| | | Stiff to hard reddish-brown to brown clayey sand with gravel TILL<br>- with occasional conglomerate and sandstone cobbles | | SS | 14 | 0 | 50 / 100 mm | |
| 11<br>12 | | | | HQ | 15 | 990 | - | |
| | | | | SS | 16 | 75 | 7-4-6-15 (10) | |
| 13 | | | | SS | 17 | 350 | 11-9-9-15 (18) | |
| 14 | | | | SS | 18 | 375 | 10-17-25-30 (42) | S |
| 15 | | | | | | | | |
| | | | | SS | 19 | 300 | 22-21-31-37 (52) | |
| 16 | | | | | | | | |
| 17 | | | ∇ | SS | 20 | 475 | 8-8-15-10 (23) | |
| | | | | SS | 21 | 275 | 6-9-7-16 (16) | |
| 18 | | | | | | | | |
| | | | | SS | 22 | 150 | 11-15-50 / 125 mm | |
| 19 | 6.44 | | | | | | | |
| | | | | SS | 23 | 50 | 50 / 50 mm | |



■ Miniature Vane
□ Torvane
◆ Penetrometer
◇ UU Triaxial
▲ Field Vane
△ Unconfined Compression

*(Continued Next Page)*

**HARBOURSIDE**
Geotechnical Consultants

# BOREHOLE RECORD

## BH04

N: 5064976.68 E: 25547363.61

**CLIENT** NOVA SCOTIA TRANSPORTATION AND INFRASTRUCTURE RENEWAL
**LOCATION** HIGHWAY 104, OXFORD, CUMBERLAND COUNTY, NOVA SCOTIA
**DATES: BORING** 23/10/2019 TO 25/10/2019 **WATER LEVEL** 25/10/2019
**PROJECT No.** 193111
**DATUM** CGVD2013
**BH SIZE** HW/HQ

| DEPTH (m) | ELEVATION (m) | SOIL/BEDROCK DESCRIPTION | GRAPHIC LOG | WATER LEVEL | TYPE | NUMBER | REC. SOIL (mm) REC. ROCK (%) | BLOWS / 150 mm (N VALUE) RQD % | OTHER TESTS |
|---|---|---|---|---|---|---|---|---|---|
| | | Fair to excellent quality white GYPSUM - slightly weathered to fresh *(continued)* | | | HQ | 24 | 100% | 70% | |
| 21 | | | | | | | | | |
| 22 | | | | | HQ | 25 | 100% | 100% | |
| 23 | | | | | HQ | 26 | 93% | 89% | |
| 24 | 2.04 | End of borehole | | | | | | | |
| 25 | | | | | | | | | |
| 26 | | | | | | | | | |
| 27 | | | | | | | | | |
| 28 | | | | | | | | | |
| 29 | | | | | | | | | |

UNDRAINED SHEAR STRENGTH - kPa
20 40 60 80

WATER CONTENT & ATTERBERG LIMITS $W_P$ W $W_L$
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●

0 10 20 30 40 50 60 70 80

| | | | |
|---|---|---|---|
| ■ | Miniature Vane | □ | Torvane |
| ◆ | Penetrometer | ◇ | UU Triaxial |
| ▲ | Field Vane | △ | Unconfined Compression |

**HARBOURSIDE**
Geotechnical Consultants

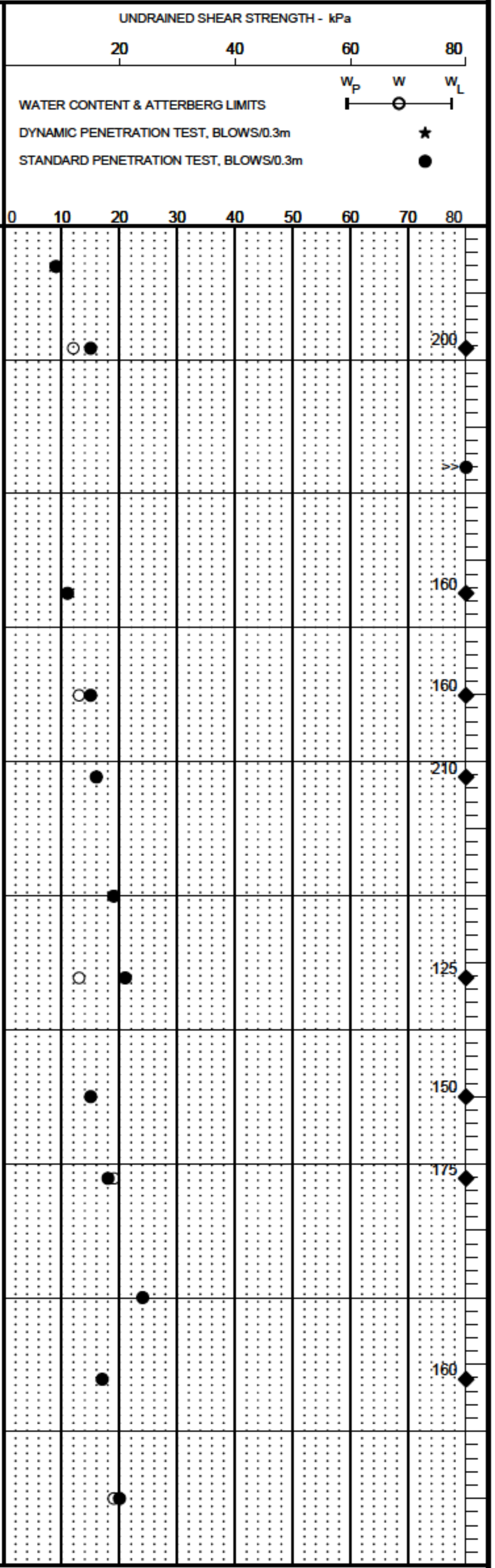
# BOREHOLE RECORD

## BH05

N: 5064965.77 E: 25547547.35

**CLIENT** NOVA SCOTIA TRANSPORTATION AND INFRASTRUCTURE RENEWAL
**PROJECT No.** 193111
**LOCATION** HIGHWAY 104, OXFORD, CUMBERLAND COUNTY, NOVA SCOTIA
**DATUM** CGVD2013
**DATES: BORING** 25/10/2019 TO 28/10/2019
**WATER LEVEL** 28/10/2019
**BH SIZE** HW/HQ

| DEPTH (m) | ELEVATION (m) | SOIL/BEDROCK DESCRIPTION | GRAPHIC LOG | WATER LEVEL | TYPE | NUMBER | REC. SOIL (mm) REC. ROCK (%) | BLOWS / 150 mm (N VALUE) RQD % | OTHER TESTS |
|---|---|---|---|---|---|---|---|---|---|
| | 22.59 | | | | | | | | |
| | 22.54 | ROOTMAT | | | | | | | |
| | | FILL: reddish-brown sandy lean clay with gravel<br>- with occasional cobbles<br>- with trace organics | | | SS | 1 | 175 | 3-5-4-5 (9) | |
| | | | | | SS | 2 | 350 | 6-7-8-10 (15) | |
| | | | | | SS | 3 | 75 | 40-50 / 50 mm | |
| | | | | | SS | 4 | 175 | 5-5-6-14 (11) | |
| | | | | | SS | 5 | 275 | 5-6-9-11 (15) | |
| | | | | | SS | 6 | 275 | 2-6-10-15 (16) | |
| | | | | | SS | 7 | 0 | 7-8-11-12 (19) | |
| | | | | | SS | 8 | 525 | 5-12-9-14 (21) | |
| | 16.39 | Very stiff reddish-brown lean CLAY with sand<br>- with trace white vivianite inclusions<br>- with trace sand partings<br>- with trace gravel | | | SS | 9 | 350 | 5-6-9-10 (15) | |
| | | | | | SS | 10 | 300 | 6-8-10-10 (18) | |
| | 14.89 | Compact brown silty SAND | | | SS | 11 | 400 | 10-10-14-13 (24) | |
| | | | | | SS | 12 | 350 | 9-7-10-12 (17) | |
| | 13.90 | Very stiff to hard brown lean CLAY with sand<br>- varved, with trace black sand partings<br>- with trace organics at 8.9 m | | | | | | | |
| | | | | | SS | 13 | 475 | 7-9-11-15 (20) | S |
| | | | | | | | | 8-14-15- | |



■ Miniature Vane
□ Torvane
◆ Penetrometer
◇ UU Triaxial
▲ Field Vane
△ Unconfined Compression

(Continued Next Page)

HARBOURSIDE
Geotechnical Consultants

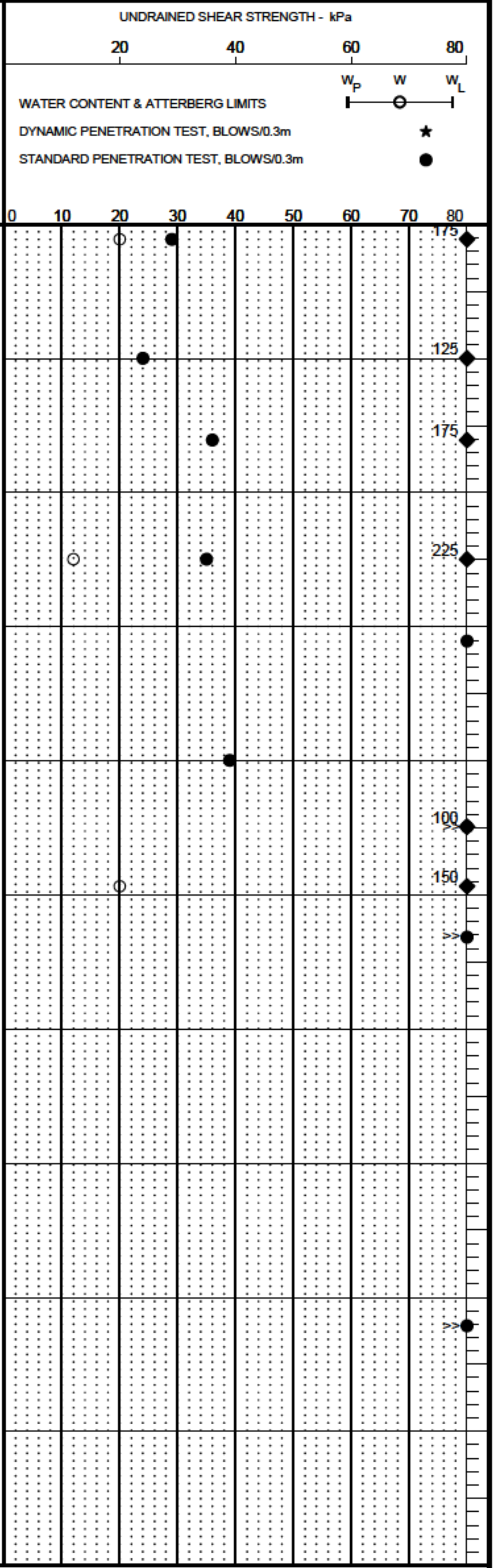
# BOREHOLE RECORD

**BH05**

N: 5064965.77 E: 25547547.35

| | | | |
|---|---|---|---|
| **CLIENT** | NOVA SCOTIA TRANSPORTATION AND INFRASTRUCTURE RENEWAL | **PROJECT No.** | 193111 |
| **LOCATION** | HIGHWAY 104, OXFORD, CUMBERLAND COUNTY, NOVA SCOTIA | **DATUM** | CGVD2013 |
| **DATES: BORING** | 25/10/2019 TO 28/10/2019 — **WATER LEVEL** 28/10/2019 | **BH SIZE** | HW/HQ |

| DEPTH (m) | ELEVATION (m) | SOIL/BEDROCK DESCRIPTION | GRAPHIC LOG | WATER LEVEL | TYPE | NUMBER | REC. SOIL (mm) REC. ROCK (%) | BLOWS / 150 mm (N VALUE) RQD % | OTHER TESTS |
|---|---|---|---|---|---|---|---|---|---|
| | | Very stiff to hard brown lean CLAY with sand<br>- varved, with trace black sand partings<br>- with trace organics at 8.9 m<br>*(continued)* | | | SS | 14 | 350 | 16<br>(29) | |
| 11 | | | | | SS | 15 | 600 | 5-9-15-15<br>(24) | |
| | | - with trace white vivianite inclusions from 10.7 m to 11.9 m | | ∇ | SS | 16 | 375 | 10-16-20-23<br>(36) | |
| 12 | 10.63 | Hard dark reddish-brown sandy lean clay TILL | | | | | | | |
| | | | | | SS | 17 | 525 | 13-15-20-39<br>(35) | S |
| 13 | | - with blackened wood fragments at 13.1 m | | | SS | 18 | 550 | 28-38-42-47<br>(80) | |
| | 8.90 | Hard grey lean CLAY with sand<br>- with trace gravel<br>- with trace sand partings | | | | | | | |
| 14 | | | | | SS | 19 | 25 | 20-18-21-28<br>(39) | |
| | | | | | SS | 20 | 225 | 20-27-50 / 75 mm | |
| 15 | | | | | GB | 21 | 300 | - | S |
| | 7.20 | | | | SS | 22 | 225 | 28-54 / 100 mm | |
| 16 | | Very poor quality grey and white GYPSUM<br>- moderately to highly weathered<br>- with occasional brown clay infilling | | | HQ | 23 | 57% | 20% | |
| 17<br>18 | | | | | HQ | 24 | 27% | 0% | |
| | | | | | SS | 25 | 75 | 50 / 50 mm | |
| | | | | | HQ | 26 | 70% | 0% | |
| 19 | | | | | HQ | 27 | 63% | 0% | |



| | |
|---|---|
| ■ Miniature Vane | □ Torvane |
| ◆ Penetrometer | ◇ UU Triaxial |
| ▲ Field Vane | △ Unconfined Compression |

*(Continued Next Page)*

HARBOURSIDE
Geotechnical Consultants

# BOREHOLE RECORD

**BH05**

N: 5064965.77 E: 25547547.35

**CLIENT** NOVA SCOTIA TRANSPORTATION AND INFRASTRUCTURE RENEWAL
**PROJECT No.** 193111
**LOCATION** HIGHWAY 104, OXFORD, CUMBERLAND COUNTY, NOVA SCOTIA
**DATUM** CGVD2013
**DATES: BORING** 25/10/2019 TO 28/10/2019 **WATER LEVEL** 28/10/2019
**BH SIZE** HW/HQ

| DEPTH (m) | ELEVATION (m) | SOIL/BEDROCK DESCRIPTION | GRAPHIC LOG | WATER LEVEL | TYPE | NUMBER | REC. SOIL (mm) REC. ROCK (%) | BLOWS / 150 mm (N VALUE) RQD % | OTHER TESTS |
|---|---|---|---|---|---|---|---|---|---|
| | | Very poor quality grey and white GYPSUM<br>- moderately to highly weathered<br>- with occasional brown clay infilling<br>*(continued)* | | | HQ | 28 | 24% | 0% | |
| | | | | | HQ | 29 | 40% | 0% | |
| 21 | | | | | HQ | 30 | 52% | 0% | |
| 22 | | | | | HQ | 31 | 20% | 0% | |
| 23 | | | | | HQ | 32 | 14% | 0% | |
| | | | | | HQ | 33 | 40% | 0% | |
| 24 | -1.59 | End of borehole | | | | | | | |
| 25 | | | | | | | | | |
| 26 | | | | | | | | | |
| 27 | | | | | | | | | |
| 28 | | | | | | | | | |
| 29 | | | | | | | | | |

UNDRAINED SHEAR STRENGTH - kPa
20 40 60 80

WATER CONTENT & ATTERBERG LIMITS $W_P$ W $W_L$
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●

0 10 20 30 40 50 60 70 80

■ Miniature Vane
□ Torvane
◆ Penetrometer
◇ UU Triaxial
▲ Field Vane
△ Unconfined Compression

HARBOURSIDE
Geotechnical Consultants

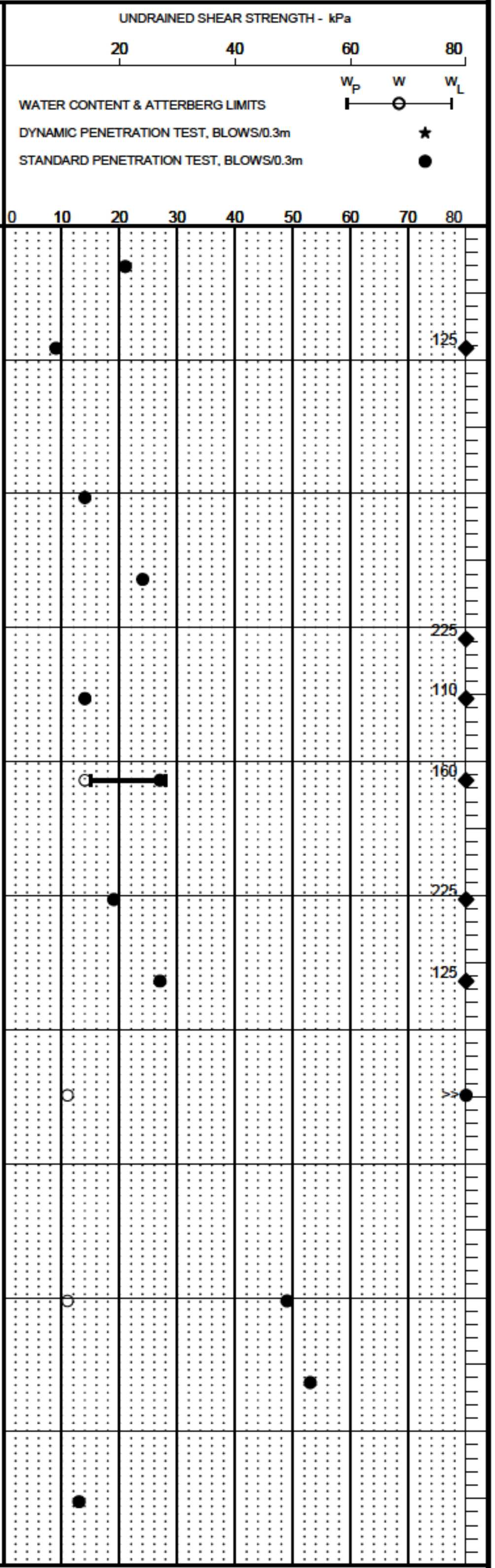
# BOREHOLE RECORD

**BH06**

N: 5064978.11 E: 25547734.72

| | | | |
|---|---|---|---|
| CLIENT | NOVA SCOTIA TRANSPORTATION AND INFRASTRUCTURE RENEWAL | PROJECT No. | 193111 |
| LOCATION | HIGHWAY 104, OXFORD, CUMBERLAND COUNTY, NOVA SCOTIA | DATUM | CGVD2013 |
| DATES: BORING | 28/10/2019 TO 30/10/2019   WATER LEVEL 30/10/2019 | BH SIZE | HW/HQ |

| DEPTH (m) | ELEVATION (m) | SOIL/BEDROCK DESCRIPTION | GRAPHIC LOG | WATER LEVEL | TYPE | NUMBER | REC. SOIL (mm) REC. ROCK (%) | BLOWS / 150 mm (N VALUE) RQD % | OTHER TESTS |
|---|---|---|---|---|---|---|---|---|---|
| | 19.55 | FILL: brown silty sand with gravel | | | SS | 1 | 350 | 13-14-12-9 (21) | |
| 1 | 18.94 | FILL: reddish-brown sandy lean clay with gravel<br>- with occasional cobbles | | | SS | 2 | 250 | 6-3-6-9 (9) | |
| | | | | | | | | | |
| 2 | | | | | SS | 3 | 0 | 5-4-10-9 (14) | |
| | | | | | SS | 4 | 100 | 7-11-13-15 (24) | |
| 3 | | | | | GB | 5 | 250 | - | |
| | | | | | SS | 6 | 350 | 3-6-8-9 (14) | S |
| 4 | | | | | SS | 7 | 325 | 10-12-15-16 (27) | |
| | | | | | | | | | |
| 5 | | | | | SS | 8 | 200 | 9-9-10-15 (19) | |
| | | | | | SS | 9 | 275 | 14-15-14-13 (27) | |
| 6 | | | | | | | | | |
| | | | | | SS | 10 | 200 | 7-8-13-50 / 75 mm | |
| 7 | | | | | | | | | |
| 8 | 11.63 | FILL: brownish-red clayey gravel with sand | | | SS | 11 | 425 | 8-22-28-21 (49) | S |
| | | | | | SS | 12 | 125 | 29-40-32-21 (53) | |
| 9 | | | | | | | | | |
| | | | | | SS | 13 | 0 | 11-9-5-8 (13) | |



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**HARBOURSIDE**
Geotechnical Consultants

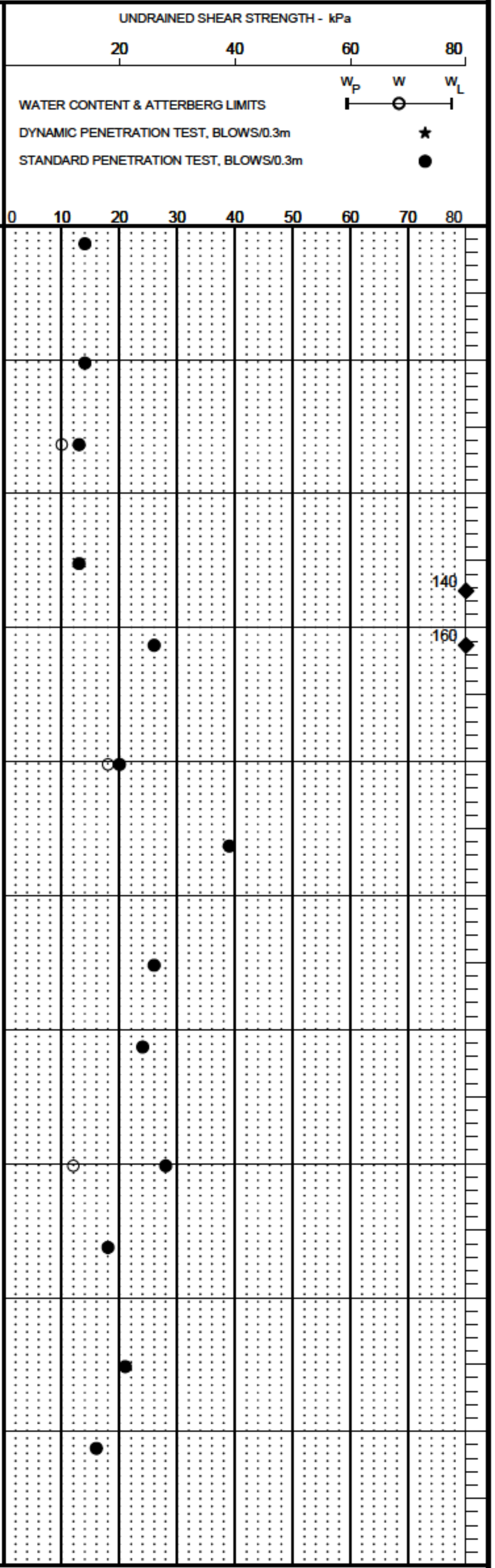
# BOREHOLE RECORD

## BH06

N: 5064978.11 E: 25547734.72

|  |  |  |  |
|---|---|---|---|
| **CLIENT** | NOVA SCOTIA TRANSPORTATION AND INFRASTRUCTURE RENEWAL | **PROJECT No.** | 193111 |
| **LOCATION** | HIGHWAY 104, OXFORD, CUMBERLAND COUNTY, NOVA SCOTIA | **DATUM** | CGVD2013 |
| **DATES: BORING** | 28/10/2019 TO 30/10/2019 **WATER LEVEL** 30/10/2019 | **BH SIZE** | HW/HQ |

| DEPTH (m) | ELEVATION (m) | SOIL/BEDROCK DESCRIPTION | WATER LEVEL | TYPE | NUMBER | REC. SOIL (mm) REC. ROCK (%) | BLOWS / 150 mm (N VALUE) RQD % | OTHER TESTS |
|---|---|---|---|---|---|---|---|---|
|  |  | FILL: brownish-red clayey gravel with sand *(continued)* |  | SS | 14 | 200 | 5-7-8-6<br>(14) |  |
|  |  |  | ∇ |  |  |  |  |  |
| 11 |  |  |  | SS | 15 | 50 | 7-6-8-10<br>(14) |  |
|  |  |  |  | SS | 16 | 175 | 7-7-6-11<br>(13) |  |
| 12 |  |  |  |  |  |  |  |  |
|  |  |  |  | SS | 17 | 325 | 2-7-6-10<br>(13) |  |
|  | 6.95 | Compact to dense reddish-brown sandy silt to silty, clayey sand TILL<br>- with trace gravel |  |  |  |  |  |  |
| 13 |  |  |  | SS | 18 | 325 | 7-13-14-12<br>(26) |  |
| 14 |  |  |  | SS | 19 | 350 | 14-10-10-11<br>(20) | S |
|  |  |  |  | SS | 20 | 275 | 8-9-30-22<br>(39) |  |
| 15 |  |  |  |  |  |  |  |  |
|  |  |  |  | SS | 21 | 175 | 20-13-13-14<br>(26) |  |
| 16 |  |  |  | SS | 22 | 250 | 11-12-12-16<br>(24) |  |
| 17 |  |  |  | SS | 23 | 275 | 15-13-15-18<br>(28) |  |
|  |  |  |  | SS | 24 | 200 | 9-8-10-11<br>(18) |  |
| 18 |  |  |  | SS | 25 | 350 | 11-9-12-9<br>(21) |  |
| 19 |  |  |  | SS | 26 | 275 | 11-10-8-8<br>(16) |  |
|  |  |  |  |  |  |  | 9-7-10-12 |  |



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HARBOURSIDE
Geotechnical Consultants

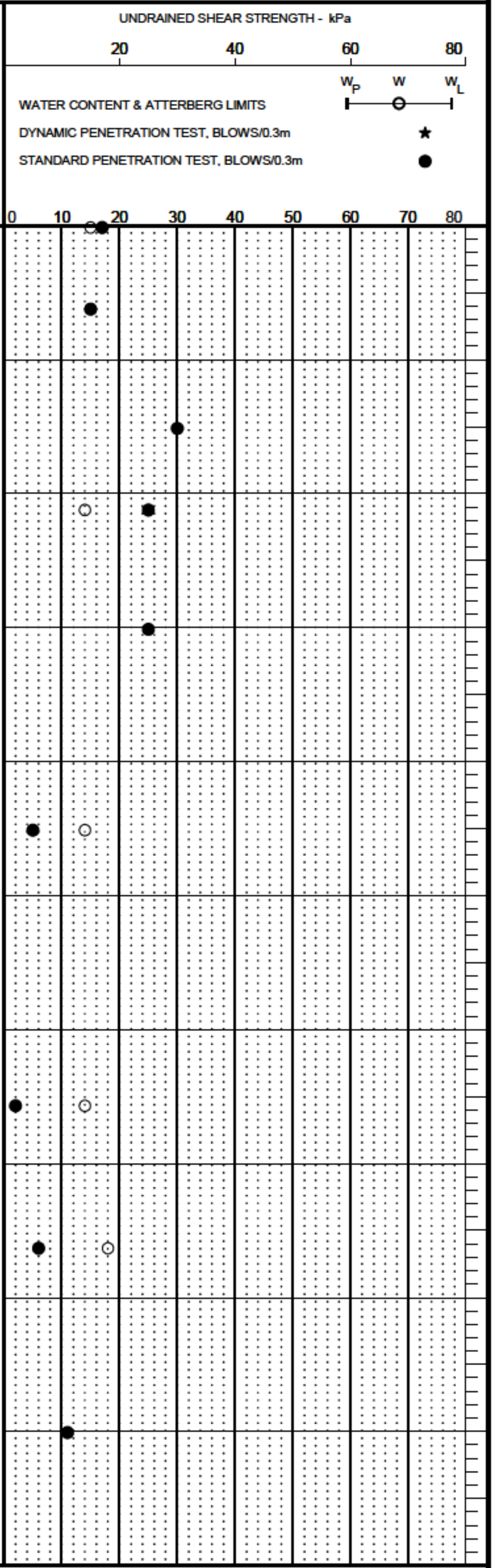
# BOREHOLE RECORD

**BH06**

N: 5064978.11 E: 25547734.72

| | | | |
|---|---|---|---|
| **CLIENT** | NOVA SCOTIA TRANSPORTATION AND INFRASTRUCTURE RENEWAL | **PROJECT No.** | 193111 |
| **LOCATION** | HIGHWAY 104, OXFORD, CUMBERLAND COUNTY, NOVA SCOTIA | **DATUM** | CGVD2013 |
| **DATES: BORING** | 28/10/2019 TO 30/10/2019 **WATER LEVEL** 30/10/2019 | **BH SIZE** | HW/HQ |

| DEPTH (m) | ELEVATION (m) | SOIL/BEDROCK DESCRIPTION | TYPE | NUMBER | REC. SOIL (mm) REC. ROCK (%) | BLOWS / 150 mm (N VALUE) RQD % | OTHER TESTS |
|---|---|---|---|---|---|---|---|
| | | Compact to dense reddish-brown sandy silt to silty, clayey sand TILL<br>- with trace gravel *(continued)* | SS | 27 | 300 | (17) | |
| | | | SS | 28 | 325 | 11-8-7-9 (15) | |
| 21 | | | | | | | |
| | | | SS | 29 | 275 | 8-29-18-12 (30) | |
| 22 | | | SS | 30 | 300 | 9-19-14-11 (25) | |
| 23 | | | SS | 31 | 75 | 19-11-14-25 (25) | |
| | -3.77 | Very loose to loose silty, clayey sand TILL<br>- with trace gravel | | | | | |
| 24 | | | SS | 32 | 100 | 15-7-2-3 (5) | |
| 25 | | | | | | | |
| 26 | | | SS | 33 | 275 | 0-0-2-2 (2) | |
| 27 | | | SS | 34 | 300 | 2-3-3-3 (6) | S |
| 28 | | | | | | | |
| 29 | | | SS | 35 | 0 | 6-6-5-7 (11) | |
| | | | SS | 36 | 250 | 11-50 | |
| | -10.19 | | | | | | |



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HARBOURSIDE
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# BOREHOLE RECORD

**BH06**

N: 5064978.11 E: 25547734.72

| | | | |
|---|---|---|---|
| **CLIENT** | NOVA SCOTIA TRANSPORTATION AND INFRASTRUCTURE RENEWAL | **PROJECT No.** | 193111 |
| **LOCATION** | HIGHWAY 104, OXFORD, CUMBERLAND COUNTY, NOVA SCOTIA | **DATUM** | CGVD2013 |
| **DATES: BORING** | 28/10/2019 TO 30/10/2019 | **WATER LEVEL** 30/10/2019 | **BH SIZE** HW/HQ |

| DEPTH (m) | ELEVATION (m) | SOIL/BEDROCK DESCRIPTION | GRAPHIC LOG | WATER LEVEL | TYPE | NUMBER | REC. SOIL (mm) REC. ROCK (%) | BLOWS / 150 mm (N VALUE) RQD % | OTHER TESTS |
|---|---|---|---|---|---|---|---|---|---|
| | | Very poor to excellent quality grey and white GYPSUM<br>- slightly weathered to fresh *(continued)* | | | HQ | 37 | 100% | 0% | |
| 31 | | | | | HQ | 38 | 95% | 37% | |
| 32<br>33 | | | | | HQ | 39 | 51% | 17% | |
| 34 | -15.15 | | | | HQ | 40 | 100% | 95% | |
| 35<br>36<br>37<br>38<br>39 | | End of borehole | | | | | | | |

UNDRAINED SHEAR STRENGTH - kPa: 20 40 60 80

WATER CONTENT & ATTERBERG LIMITS: $W_P$ W $W_L$

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

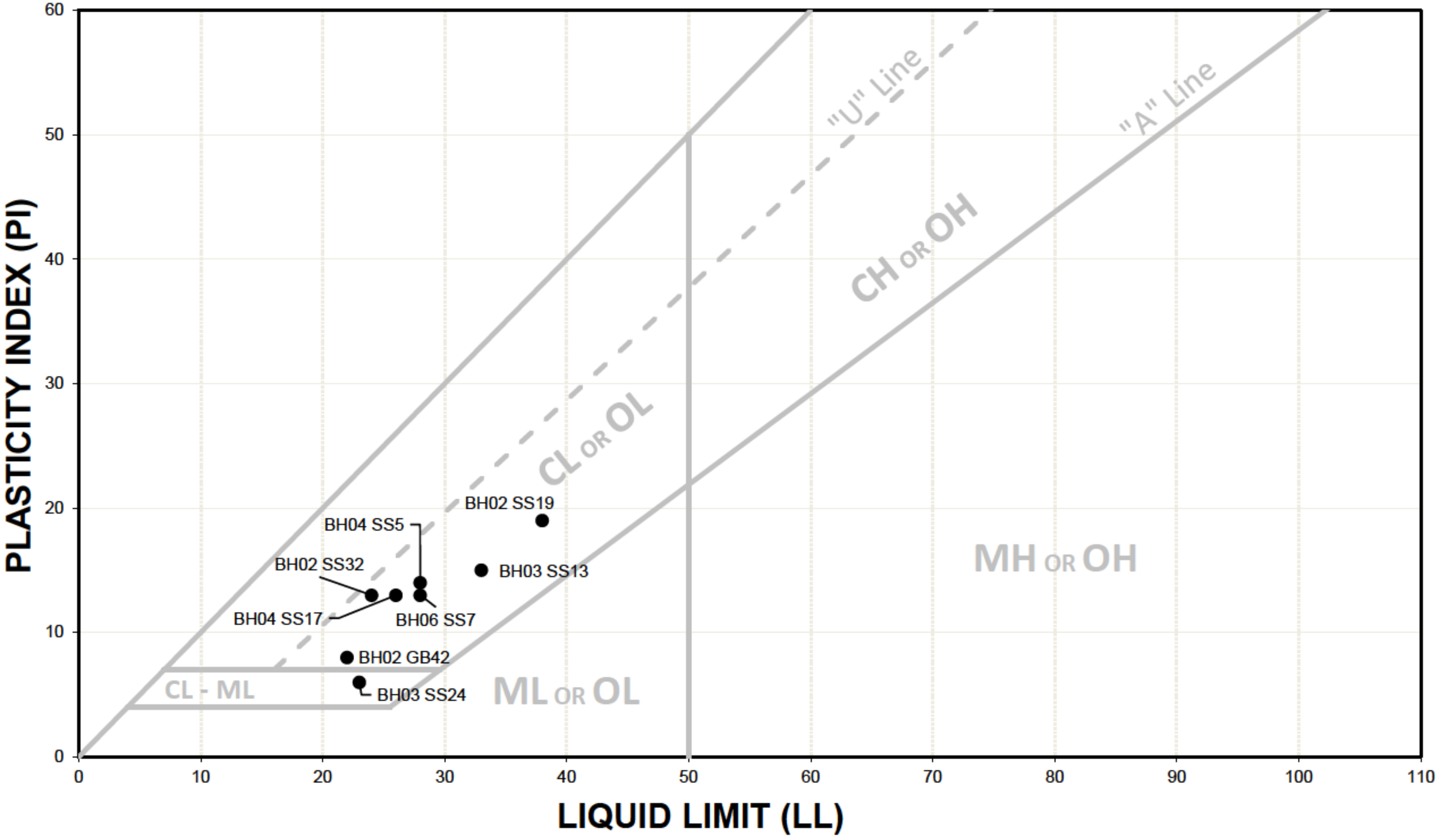
0 10 20 30 40 50 60 70 80

# APPENDIX B

## Laboratory Testing Results

Checked: DJW

# ATTERBERG LIMITS



PROJECT No.: 193111

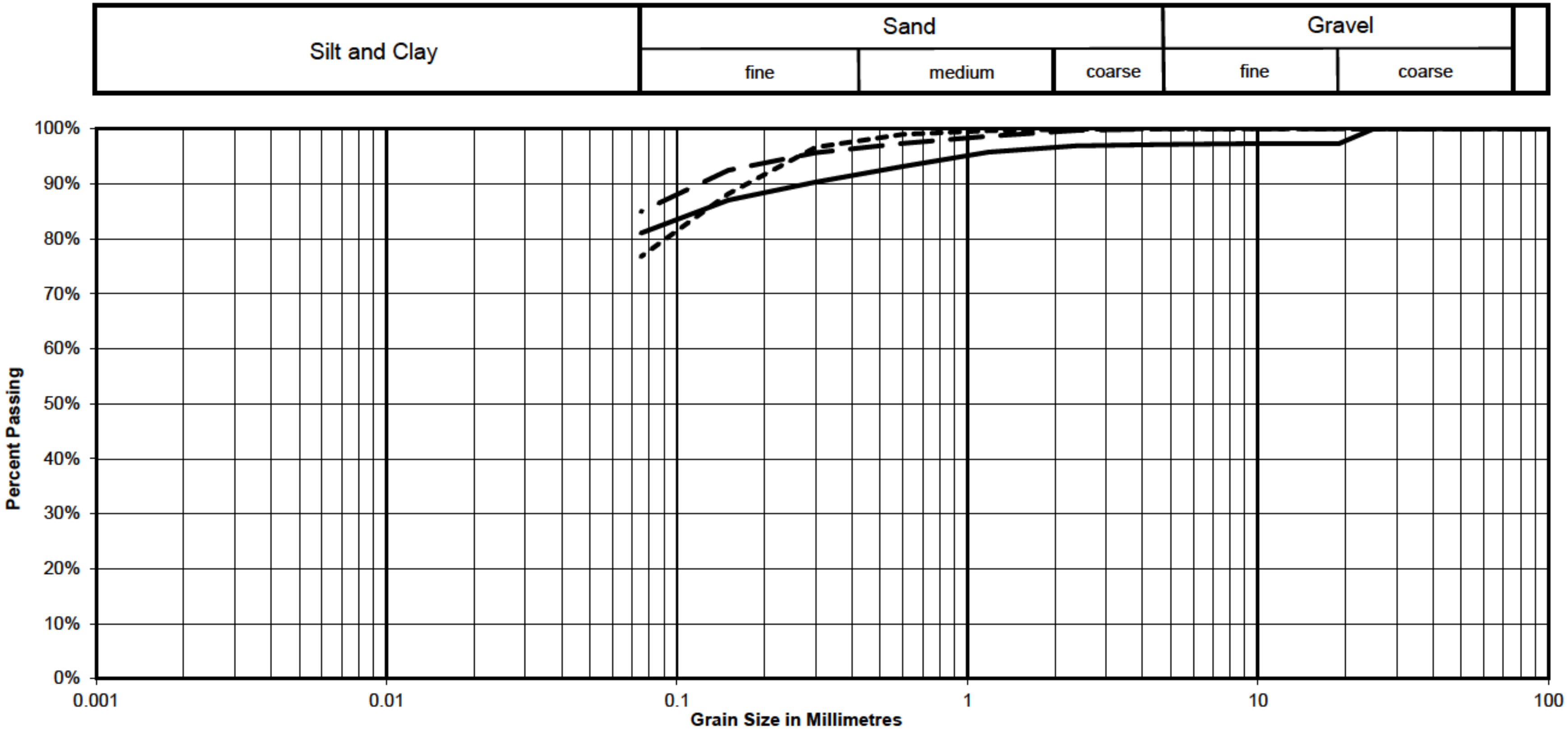
HGC

t: 1.902.405.4696 | f: 1.902.405.4693
219 Waverley Road, Suite 200
Dartmouth, NS B2X 2C3
http://harboursideengineering.ca

| | |
|---|---|
| CLIENT | NSTIR |
| PROJECT | Oxford Highway 104 Investigation |
| LOCATION | Cumberland County, NS |

Checked: **DJW**

# GRAIN SIZE DISTRIBUTION



| CURVE | BOREHOLE / TESTPIT | SAMPLE | DEPTH (m) | SOIL FRACTION | | | SOIL DESCRIPITION |
|---|---|---|---|---|---|---|---|
| | | | | GRAVEL | SAND | SILT/CLAY | |
| ——— | BH02 | SS15 | 10.82 to 11.43 | 3% | 16% | 81% | Lean CLAY with sand |
| — — - | BH02 | SS17 | 12.17 to 12.78 | 0% | 15% | 85% | Lean CLAY |
| - - - - | BH02 | SS29 | 25.65 to 26.26 | 0% | 23% | 77% | Lean CLAY with sand |

H
G
C

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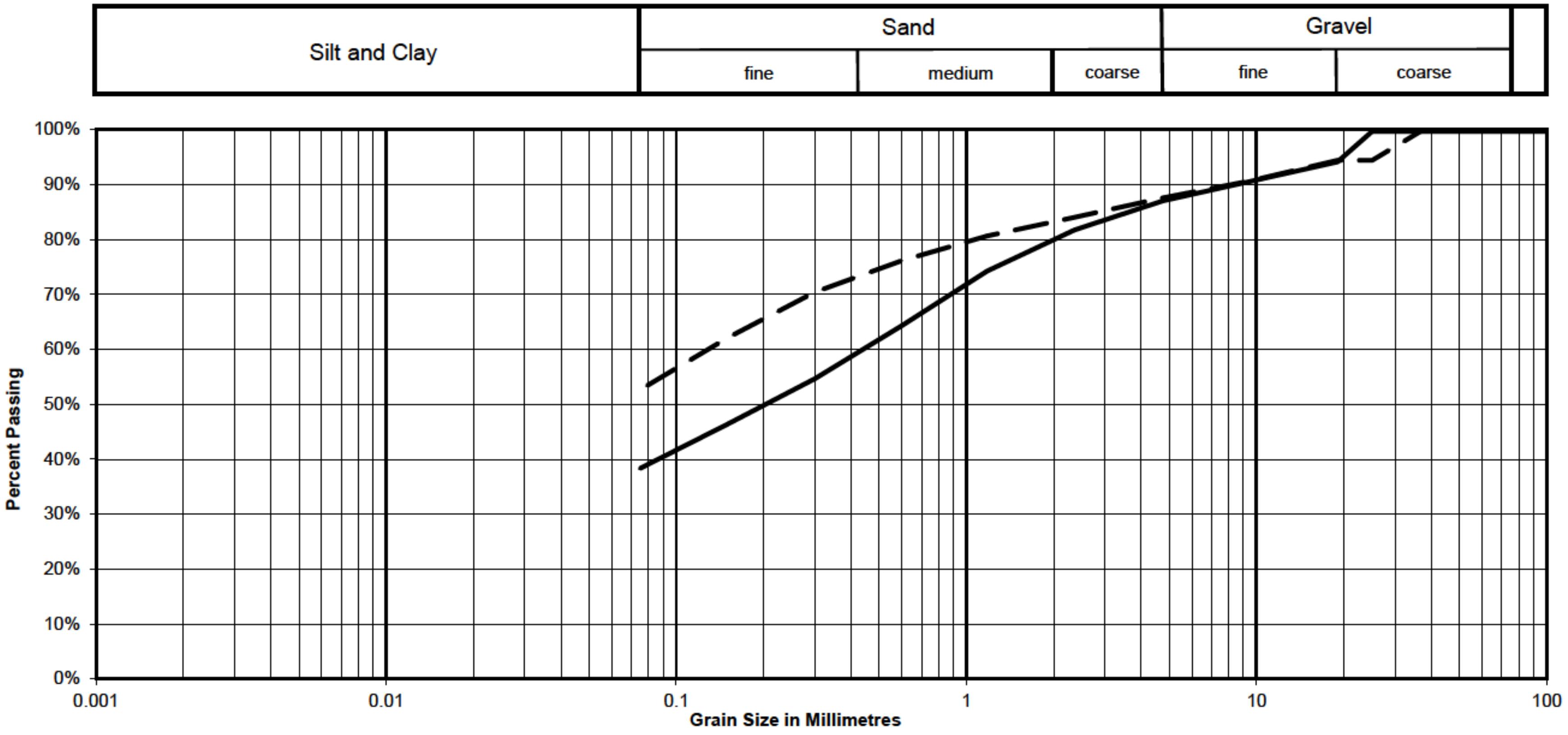
Dartmouth, NS B2X 2C3
http://harboursideengineering.ca

CLIENT NSTIR
PROJECT Oxford Highway 104 Investigation
LOCATION Cumberland County, NS

PROJECT No.: 193111

Checked: **DJW**

# GRAIN SIZE DISTRIBUTION



| CURVE | BOREHOLE / TESTPIT | SAMPLE | DEPTH (m) | SOIL FRACTION | | | SOIL DESCRIPITION |
|---|---|---|---|---|---|---|---|
| | | | | GRAVEL | SAND | SILT/CLAY | |
| —— | BH02 | SS35 | 34.65 to 35.26 | 13% | 49% | 38% | Clayey SAND |
| — — - | BH02 | SS41 | 42.14 to 42.75 | 12% | 35% | 53% | Sandy lean CLAY |

PROJECT No.: 193111

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G
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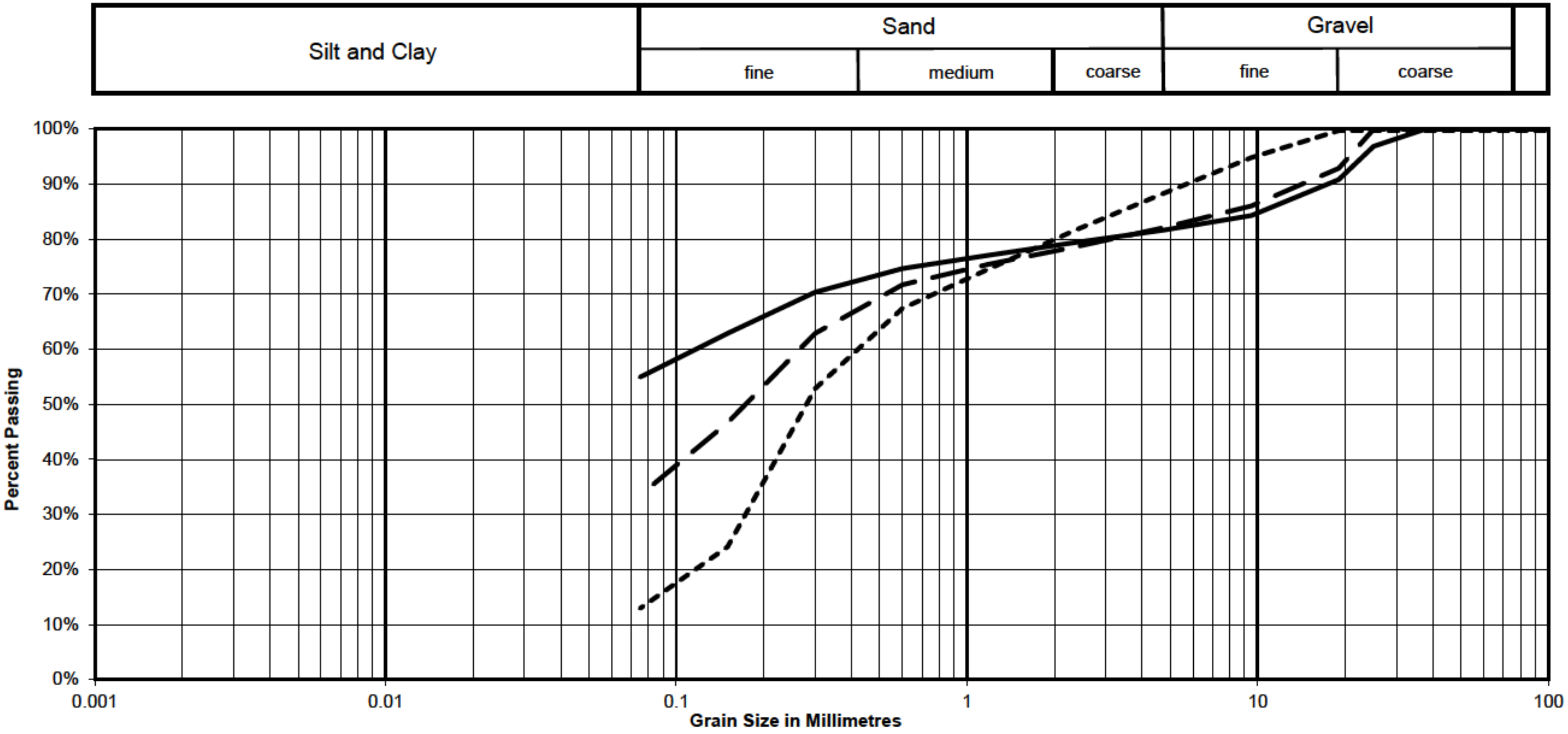
| | |
|---|---|
| CLIENT | NSTIR |
| PROJECT | Oxford Highway 104 Investigation |
| LOCATION | Cumberland County, NS |

Checked: **DJW**

# GRAIN SIZE DISTRIBUTION



| CURVE | BOREHOLE / TESTPIT | SAMPLE | DEPTH (m) | SOIL FRACTION | | | SOIL DESCRIPITION |
|---|---|---|---|---|---|---|---|
| | | | | GRAVEL | SAND | SILT/CLAY | |
| ——— | BH03 | SS6 | 3.25 to 3.86 | 18% | 27% | 55% | Sandy lean CLAY with gravel |
| — — - | BH03 | SS7 | 3.86 to 4.47 | 18% | 49% | 33% | Silty SAND with gravel |
| - - - - | BH03 | SS10 | 6.15 to 6.76 | 12% | 75% | 13% | Silty SAND |

PROJECT No.: 193111

HGC

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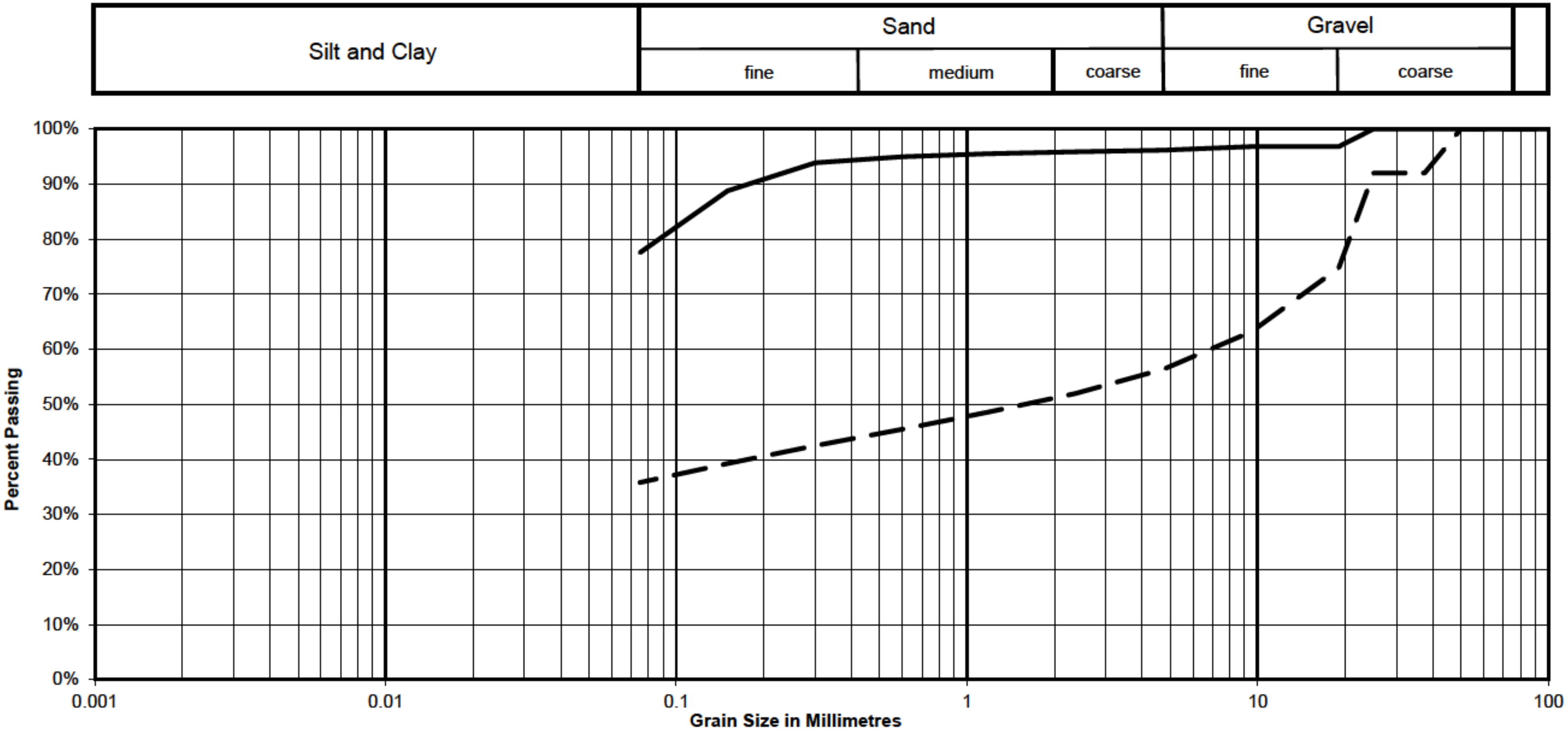

| CURVE | BOREHOLE / TESTPIT | SAMPLE | DEPTH (m) | SOIL FRACTION | | | SOIL DESCRIPITION |
|---|---|---|---|---|---|---|---|
| | | | | GRAVEL | SAND | SILT/CLAY | |
| ─── | BH03 | SS12 | 7.64 to 8.25 | 4% | 18% | 78% | Lean CLAY with sand |
| – – - | BH03 | GB30 | 20.24 to 21.13 | 44% | 20% | 36% | Silty, clayey GRAVEL with sand |

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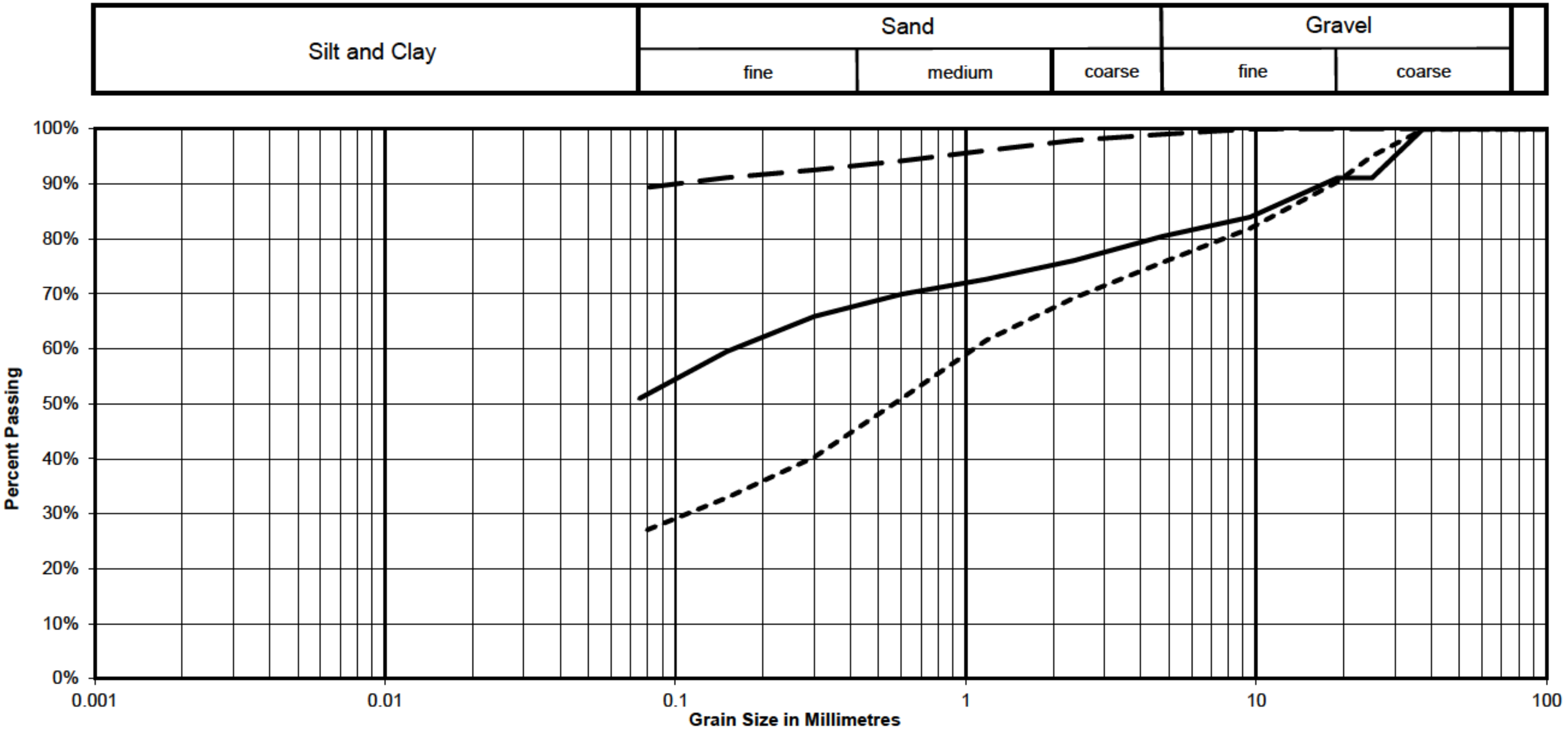

| CURVE | BOREHOLE / TESTPIT | SAMPLE | DEPTH (m) | SOIL FRACTION | | | SOIL DESCRIPITION |
|---|---|---|---|---|---|---|---|
| | | | | GRAVEL | SAND | SILT/CLAY | |
| ——— | BH04 | SS6 | 3.81 to 4.42 | 20% | 29% | 51% | Sandy lean CLAY with gravel |
| — — - | BH04 | SS9 | 6.20 to 6.81 | 1% | 10% | 89% | Lean CLAY |
| - - - - | BH04 | SS18 | 13.69 to 14.30 | 24% | 50% | 26% | Clayey SAND with gravel |

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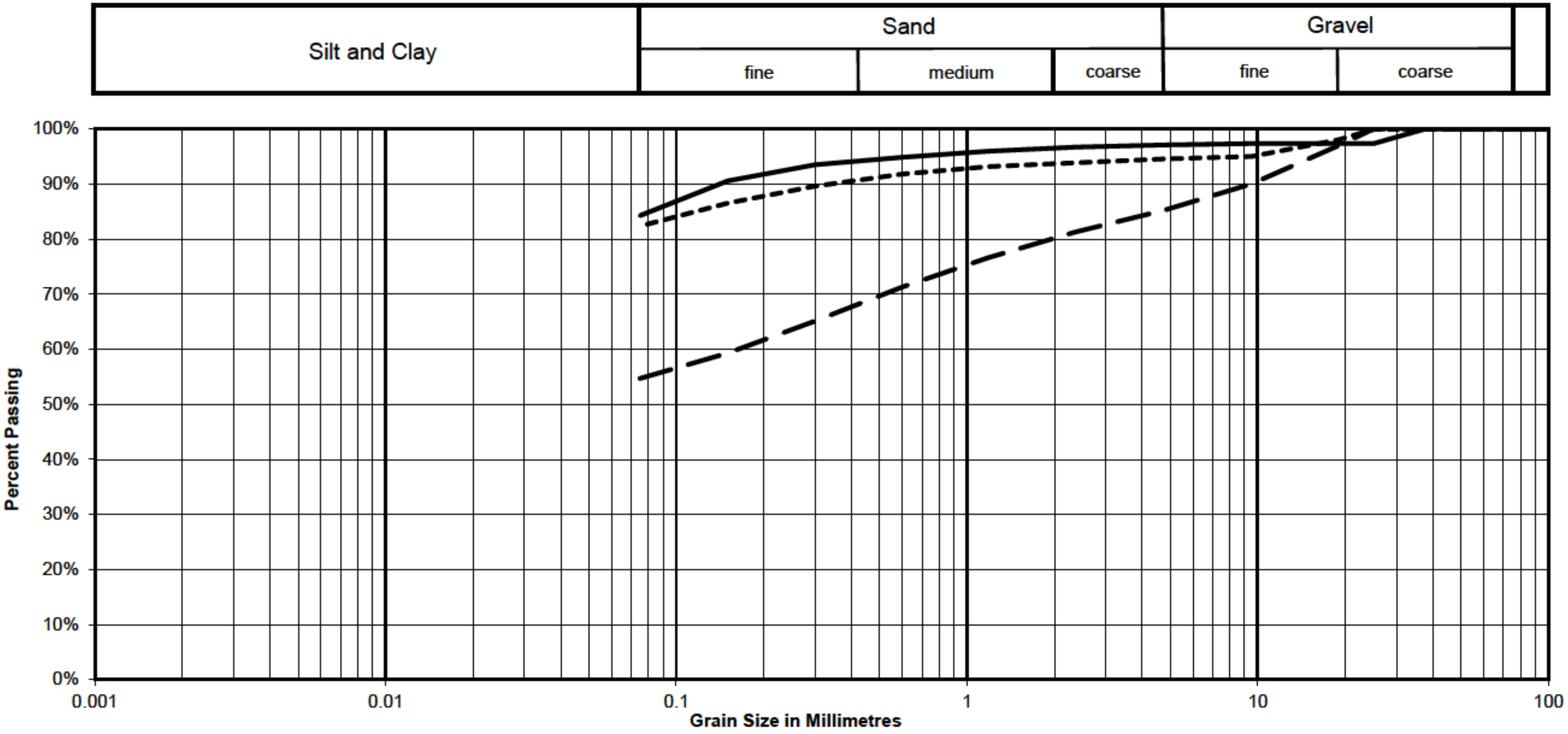
# GRAIN SIZE DISTRIBUTION



| CURVE | BOREHOLE / TESTPIT | SAMPLE | DEPTH (m) | SOIL FRACTION | | | SOIL DESCRIPITION |
|---|---|---|---|---|---|---|---|
| | | | | GRAVEL | SAND | SILT/CLAY | |
| ——— | BH05 | SS13 | 9.20 to 9.81 | 3% | 13% | 84% | Lean CLAY with sand |
| — — | BH05 | SS17 | 12.19 to 12.80 | 15% | 30% | 55% | Sandy lean CLAY |
| - - - - | BH05 | GB21 | 14.68 to 15.19 | 5% | 13% | 82% | Lean CLAY with sand |

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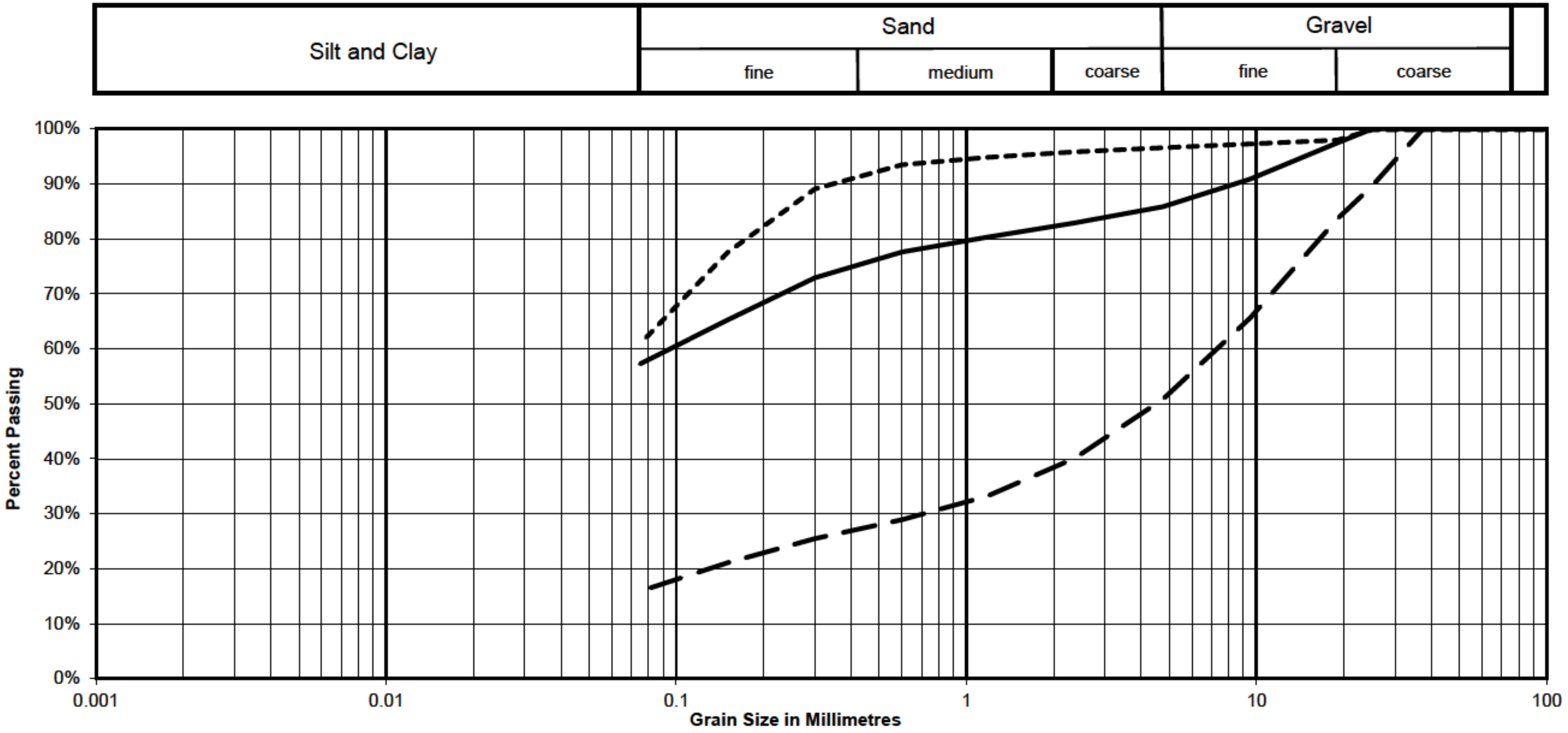

| CURVE | BOREHOLE / TESTPIT | SAMPLE | DEPTH (m) | SOIL FRACTION | | | SOIL DESCRIPITION |
|---|---|---|---|---|---|---|---|
| | | | | GRAVEL | SAND | SILT/CLAY | |
| ——— | BH06 | SS6 | 3.22 to 3.83 | 14% | 29% | 57% | Sandy lean CLAY |
| — — | BH06 | SS11 | 7.72 to 8.33 | 49% | 35% | 16% | Clayey GRAVEL with sand |
| - - - - | BH06 | SS19 | 13.72 to 14.33 | 3% | 36% | 61% | Sandy SILT |

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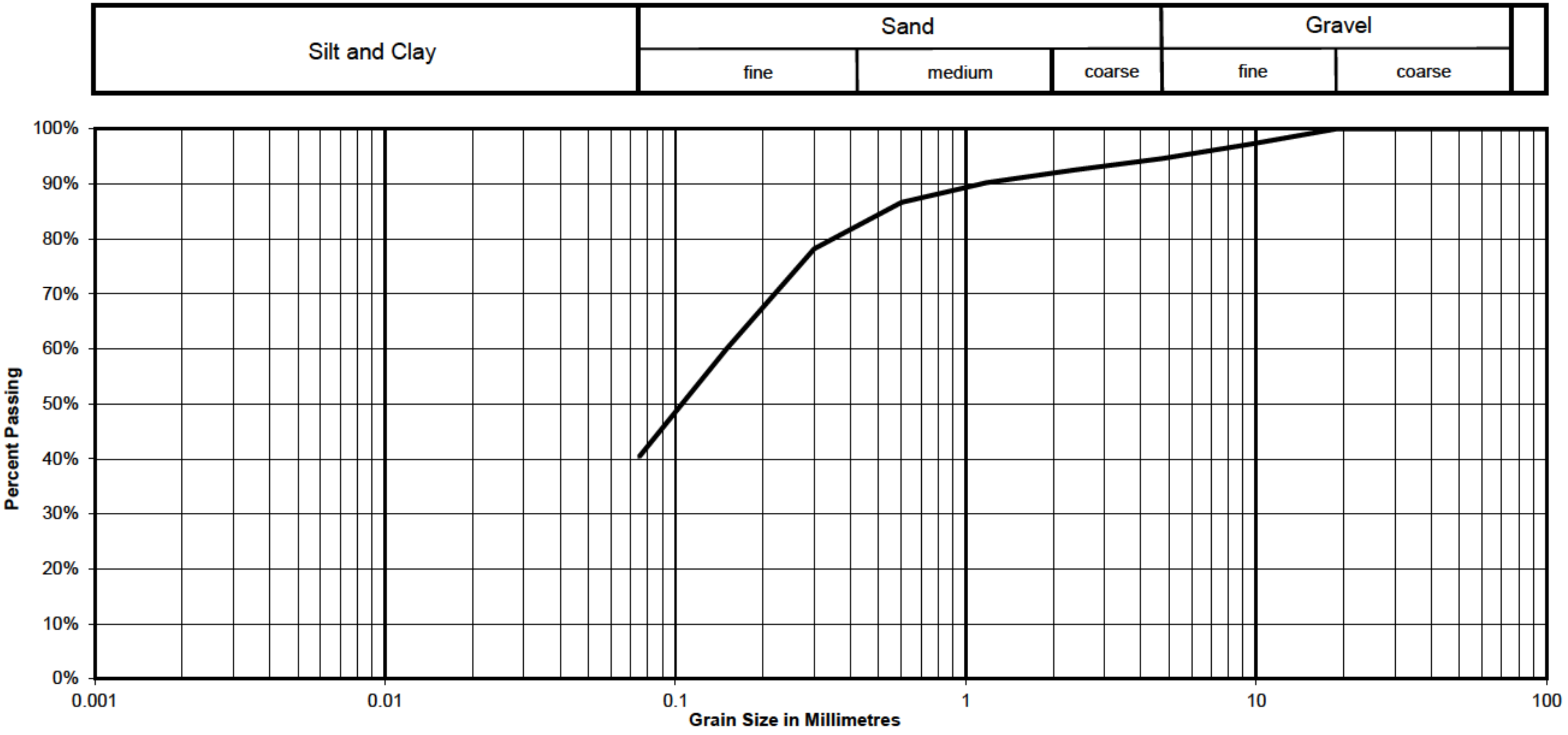

| CURVE | BOREHOLE / TESTPIT | SAMPLE | DEPTH (m) | SOIL FRACTION | | | SOIL DESCRIPITION |
|---|---|---|---|---|---|---|---|
| | | | | GRAVEL | SAND | SILT/CLAY | |
| — | BH06 | SS34 | 27.20 to 27.81 | 5% | 55% | 40% | Silty, clayey SAND |

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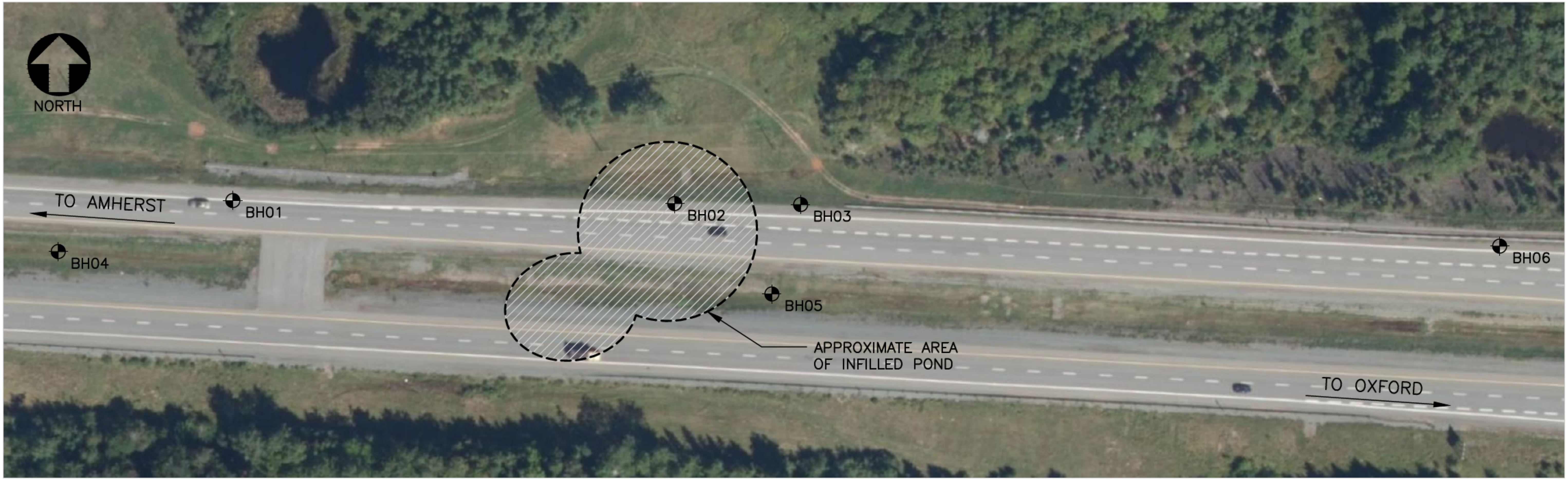
PROJECT No.: 193111

# APPENDIX C

Drawing G-01 Borehole Location Plan



# BOREHOLE LOCATION PLAN

N.T.S.

## BOREHOLE COORDINATES

| BOREHOLE # | NORTHING | EASTING | ELEVATION (m) |
|---|---|---|---|
| BH01 | 5064990.10 | 25547406.51 | 26.83 |
| BH02 | 5064989.04 | 25547522.33 | 23.93 |
| BH03 | 5064988.79 | 25547554.73 | 23.40 |
| BH04 | 5064976.68 | 25547363.61 | 26.12 |
| BH05 | 5064965.77 | 25547547.35 | 22.59 |
| BH06 | 5064978.11 | 25547734.72 | 19.55 |

**NOTE:**
ALL COORDINATES ARE MTM 5
NAD 83 CSRS (2010)

| Scale | Date | Drawn | Designed | Checked | Approved | Contract |
|---|---|---|---|---|---|---|
| AS NOTED | NOVEMBER 2019 | D. LARADE | D. WHEELER | V. GOREHAM | V. GOREHAM | 193111 |

HARBOURSIDE
Geotechnical Consultants

OXFORD, HWY. 104 SINKHOLE
CUMBERLAND COUNTY

BOREHOLE LOCATION PLAN

SKETCH No.
G-01

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