

**FINAL  
FOUNDATION INVESTIGATION AND DESIGN REPORT  
REPLACEMENT OF THE HIGHWAY 401 OVERPASS AT  
CHOATE ROAD  
NORTHUMBERLAND COUNTY – PORT HOPE, ONTARIO  
ASSIGNMENT NO.: 4019-E-0021  
GWP 4068-14-00**



**THURBER ENGINEERING LTD.**



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**SITE NO. 21X-0230/B0  
GEOCRES NO.: 30M16-075**

**Report  
to  
MCINTOSH PERRY | LEA JOINT VENTURE**

Latitude: 43.969303°  
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August 2023  
Thurber File No.: 33099



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**PART 1. FACTUAL INFORMATION**

**1. INTRODUCTION**

This section of the report presents the factual findings obtained from a preliminary and two detailed foundation investigations conducted by Thurber Engineering Ltd. (Thurber) for the replacement of the Highway 401 overpass structure located at Choate Road in Port Hope, Ontario. Thurber carried out the preliminary foundation investigation as a subconsultant to WSP Canada (WSP) under Agreement No. 4014-E-0014 and the detailed foundation investigations as a subconsultant to a LEA Consulting (LEA) and McIntosh Perry Consulting Engineers (MPCE) joint venture under Agreement No. 4016-E-0014 and Agreement No. 4019-E-0021, Assignment No. 18.

A Preliminary General Arrangement (GA) drawing and base plan mapping were provided by LEA for the preparation of this report.

The purpose of these investigations was to explore the subsurface conditions at the site and, based on this data, provide a borehole location plan, record of boreholes, stratigraphic profile, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions influencing design and construction of a replacement structure was developed in the course of the current investigation.

**2. SITE DESCRIPTION**

**2.1 General**

Site 21X-0230/B0 is located on Highway 401, approximately 550 m west of the Highway 401 County Road 28 underpass in Port Hope, Ontario. The location of the structure is shown on the inset Key Plan on Drawing No. 1 in Appendix A.



Highway 401 at the location of the overpass has three through lanes in each direction. The traffic volume on this section of Highway 401 is understood to be 50,000 AADT (2016). It is noted that for project orientation purposes, Highway 401 will be assumed to be oriented east-west. The eastbound and westbound lanes are separated by a median concrete barrier wall. There are steel beam guide rails located along the outside lanes east of the bridge in both directions and west of the bridge in the westbound direction. A noise barrier wall is located west of the bridge along the outside lane in the eastbound direction.

Choate Road at the overpass location is oriented north-south, has one lane in each direction.

Based on the historical contract documents, the existing three-span, continuous reinforced, concrete T-beam structure, is approximately 58.2 m long, and 28.7 m wide.

The lands surrounding the site consist of agriculture fields and the Port Hope Conservation Area to the north of Highway 401. A church and residential properties are located south of Highway 401 on the west side of Choate Road. Corbitt's Dam is located to the southeast of the site. Storm water drainage in the area is to existing catch basins and the Ganaraska River located approximately 140 m to the east of the site. Site photographs showing the general conditions at the site are presented in Appendix D.

The approach embankments range in height from approximately 10.7 m to 12.1 m. The embankment side slopes are inclined at approximately 2H:1V. The slopes are vegetated with a combination of long grass and brush. A section of the north slope west of Choate Road has rip-rap at surface and a mid-slope plateau.

## **2.2 Site Geology**

The site is located within a physiographic region known as the Iroquois Plain. This area was formed by a body of water known as Lake Iroquois and is characterized by lacustrine deposits of sand, silts and clays. Along Highway 401, within the project limits, the principal overburden consists of till and clay with occasional drumlins (Chapman and Putnam, 1984).

## **3. EXISTING INFORMATION**

The GEOCRE Reports, 30M16-7 and 30M16-27, present the results of the investigations carried out for the design and construction of the existing bridge structure and approach embankments respectively. The investigations included six boreholes for the structure and four for the approach embankments. Three of the structure boreholes were advanced approximately 3.0 m into the limestone bedrock while all approaches boreholes were advanced to refusal on inferred bedrock.



The stratigraphy in the area of the bridge is generally described as loose to compact silty sand to sandy silt, over clayey silt at the east abutment and firm to stiff silty clay overlying a compact fine sand at the west abutment. The site is underlain by sound limestone bedrock based on AXT rock coring. The Borehole Logs indicated the bedrock surface elevation ranges from 306.8 ft. (93.4 m) to 304.2 ft. (92.6 m); the converted elevations within brackets have been shifted from NGVD29 to NAVD88.

It should be noted that settlement issues at the west abutment were noted in the original Foundation Investigation Report and it was recommended to construct the approach embankments well in advance of the actual bridge construction.

A Preliminary Foundation Investigation for replacement of this structure was carried out by Thurber in 2016 under Assignment No. 4014-E-0014. The preliminary site investigation and field-testing program was carried out between May 30<sup>th</sup> and June 1<sup>st</sup>, 2016, and included advancing four boreholes labelled 301 through 304. A Detailed Foundation Investigation for replacement of this structure was carried out by Thurber in 2019 under agreement 4016-E-0014. The detailed site investigation and field-testing program was carried out between February 19<sup>th</sup> and 26<sup>th</sup>, 2019, and included advancing thirteen boreholes labelled 19-01 through 19-13. The results of these preliminary and detailed investigation boreholes have been included in the description of subsurface conditions that follows.

#### **4. SITE INVESTIGATION AND FIELD TESTING**

An additional detailed site investigation and field-testing program was carried out between April 18<sup>th</sup> and May 7<sup>th</sup>, 2022, to supplement the 2016 preliminary and 2019 detailed investigations and included advancing four boreholes labelled CR22-01 through CR22-04. The northing, easting and elevation of the boreholes are shown on the Borehole Location and Soil Strata Drawings in Appendix A and are summarized in Table 4-1. The site is within MTM Zone 10. The site is within MTM Zone 10. The as-drilled locations of the boreholes below the existing bridge were measured relative to existing site features to decimeter accuracy; the elevations of the boreholes below the existing bridge were surveyed to centimeter accuracy using a Nikon AP-8 Auto-Level. The as-drilled locations and elevations of all other boreholes were surveyed using a Trimble Catalyst DA2 global positioning system antenna with centimeter accuracy. The elevations were surveyed relative to the first order vertical benchmark tablet number PBM 61-69 set in the south face of the west abutment of the Choate Road Overpass which has a geodetic elevation of 109.880 m.

**Table 4-1: Borehole Summary**

Borehole No.	Drilled Location	Northing (m)	Easting (m)	Ground Surface Elevation (m)	Termination Depth (m)
301	West approach – Hwy 401 WB L3	4 870 634.9	401 378.1	110.2	17.2
302	West abutment – Hwy 401 EB L3	4 870 611.1	401 381.9	110.2	21.5
303	East abutment – Hwy 401 WB L3	4 870 647.2	401 463.0	107.7	20.0
304	East approach – Hwy 401 EB L3	4 870 624.8	401 472.5	107.6	15.4
19-01	Side Slope – N/W Corner	4 870 653.6	401 402.3	102.7	12.5
19-02	Choate Road – West Shoulder	4 870 646.0	401 423.2	97.5	8.5
19-03	Choate Road – East Shoulder	4 870 650.0	401 430.9	97.9	8.1
19-04	East Foreslope – North Side	4 870 653.2	401 446.2	101.6	12.0
19-05	Side Slope – N/E Corner	4 870 668.9	401 469.0	100.0	10.4
19-06	Choate Road – West Shoulder	4 870 628.0	401 422.2	97.0	8.5
19-07	Choate Road – East Shoulder	4 870 631.0	401 428.4	97.2	7.2
19-08	East Foreslope – Hwy 401 C/L	4 870 632.4	401 444.0	102.2	12.1
19-09	Side Slope – S/W Corner	4 870 596.5	401 390.8	104.0	14.7
19-10	Choate Road – West Shoulder	4 870 613.2	401 421.5	96.7	8.6
19-11A	Choate Road – East Shoulder	4 870 612.4	401 425.6	96.5	8.0
19-11B	Choate Road – East Shoulder	4 870 613.6	401 426.1	96.6	3.4
19-12	East Foreslope – South Side	4 870 610.6	401 441.1	100.5	11.1
19-13	Side Slope – S/E Corner	4 870 603.3	401 472.8	98.7	10.3

Borehole No.	Drilled Location	Northing (m)	Easting (m)	Ground Surface Elevation (m)	Termination Depth (m)
CR22-01	West abutment – North end	4 870 664.4	401 407.4	99.3	9.3
CR22-02	East abutment – North end	4 870 666.4	401 450.9	99.9	9.7
CR22-03	West abutment – Below EB	4 870 641.9	401 404.3	104.0	14.4
CR22-04	West abutment – Below WB	4 870 623.4	401 401.9	104.0	14.4

Thurber contacted Ontario One Call in advance of the field investigation to obtain utility locates/clearances in the vicinity of the intended borehole locations. In addition, MTO traffic operations was contacted to obtain ATMS Fibre utility locates and RW Electric was contacted to obtain MTO electric locates for the project limits.

Boreholes 301 through 304, 19-02, 19-03, 19-06, 19-07, 19-10, 19-11A and 19-11B were advanced with truck mounted CME drill rigs equipped with hollow stem augers. Borehole CR22-01 was advanced with a track mounted D50 drill rig equipped with NW size casing and wash boring. Boreholes 19-01, 19-04, 19-05, 19-08, 19-09, 19-12, 19-13, CR22-02, CR22-03 and CR22-04 were advanced with portable drilling techniques utilizing a half-weight hammer and NW size casing and wash boring. The subsurface stratigraphy encountered in the boreholes was recorded in the field by Thurber personnel. Split spoon samples were collected at regular depth intervals in the boreholes via the completion of Standard Penetration Tests (SPT), following the methods described in ASTM Standard D1586-11. In-situ shear vane testing was carried out within the cohesive strata where possible using an MTO 'N' sized vane following the methods described in ASTM Standard D2573-18. Two thin-wall (Shelby) Tube samples of the cohesive soil were retrieved to obtain relatively undisturbed soil samples for further laboratory testing. All soil samples recovered from split spoons were placed in moisture-proof containers and the samples were transported to Thurber's Ottawa or Pickering geotechnical laboratory for further examination and testing. Bedrock was cored in all boreholes following ASTM Standard D6032-08 except Boreholes 301 and 304, where bedrock was inferred by auger or SPT refusal. HQ size coring equipment was used in Boreholes 302 and 303 and NQ size coring equipment was used in all other cored boreholes. Bedrock core samples were stored in core boxes for transport.



A 25 mm diameter standpipe piezometer was installed in Borehole 303, a 38 mm diameter standpipe was installed in Borehole CR22-04 and 19 mm diameter standpipes were installed in Boreholes 19-01, 19-03, 19-10 and 19-13 to allow for measurement of the groundwater level at the site. Piezometer construction details are illustrated on the corresponding Record of Borehole sheets, provided in Appendix B. The piezometer in Borehole 303 was decommissioned in accordance with Ontario MOE Regulation 903 on May 31, 2016. The standpipes in Boreholes 19-01, 19-03, 19-10 and 19-13 were decommissioned in accordance with Ontario MOE Regulation 903 on August 20, 2020. The piezometer in Borehole CR22-04 was decommissioned in accordance with Ontario MOE Regulation 903 on August 23, 2023.

The boreholes without piezometer installations were backfilled with a low-permeability combination of soil cuttings and bentonite pellets in accordance with Ontario MOE Regulation 903 as amended. All on-road boreholes were capped with 150 mm of cold patch asphalt and, in the boreholes through Highway 401, the cold patch was underlain by 150 mm layer of concrete.

Shear wave velocity profiles were measured using Multi-Channel Analysis of Surface Waves (MASW) techniques. The Testing was carried out by Geophysics GPR International Inc. on February 26<sup>th</sup>, 2019. The results from the field investigation are provided in Appendix B. The MASW testing was completed on the east and west sides of Choate Road approximately parallel to the road alignment.

## **5. LABORATORY TESTING**

Geotechnical laboratory testing consisted of natural moisture content determination and visual identification of all retained soil samples. More than 25% of the recovered soil samples were tested for grain size distribution and, where appropriate, Organic Content, Atterberg Limits and Consolidation in accordance with MTO and ASTM standards. All rock cores were photographed and their total core recovery (TCR), solid core recovery (SCR) and rock quality designation (RQD) were measured. Selected samples of the rock core were submitted for unconfined compressive strength (UCS) testing. Chemical analysis for determination of pH, conductivity, resistivity, soluble sulphate, sulphide and chloride concentrations was carried out on seven soil samples.

The results of geotechnical tests are summarized on the Record of Borehole sheets included in Appendix B and laboratory results are presented on the figures included in Appendix C.

## **6. DESCRIPTION OF SUBSURFACE CONDITIONS**

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix B and the Borehole Location and Soil Strata Drawing included in Appendix



A. Soil classification for the 2022 investigation is in accordance with ASTM D2487 with cohesive soils described as per current MTO Guidelines for Foundation Engineering Services. An overall description of the stratigraphy is given in the following sections, however, the factual data presented in the Record of Boreholes governs any interpretation of the site conditions. It must be recognized that soil and groundwater conditions may vary between and beyond sampled locations.

In general, the stratigraphy in the area of the boreholes through the embankments is generally characterized by an asphalt pavement, overlying sand and gravel fill, overlying granular and cohesive embankment fill, overlying native clay and silty sand to silt, overlying glacial till, and underlain by limestone bedrock.

More detailed descriptions of the individual strata are presented below.

## **6.1 Fill**

A fill layer was encountered from surface in Boreholes 19-01, 19-04, 19-05, 19-09, 19-12 and 19-13; below the topsoil in Boreholes CR22-01, CR22-02 and CR22-03; below the asphalt in Boreholes 301, 302, 303, 304, 19 02, 19 03, 19 06, 19 07, 19 10 and 19 11A; below the armor stone in Borehole 19-08 and below a layer of concrete and boulders in Borehole CR22-04. The top of fill ranges in elevation from 110.0 m to 96.4 m and the thickness of this layer ranged from 0.6 m to 14.5 m.

The fill encountered at this site is highly variable between boreholes and does not display uniform layering. For the purposes of this report the fill has been described above as a single unit and the following sections providing details of field and lab testing based on the type of fill.

### Asphalt

The thickness of the asphalt on Highway 401 ranged from 180 mm to 290 mm in Boreholes 301, 302, 303 and 304 which were drilled through the driving lanes of the highway.

The thickness of asphalt was found to be 75 mm in Boreholes 19-02, 19-03, 19-06, 19-07, 19-10 and 19-11A located near the edge of pavement on Choate Road.

### Armor Stone

Armor stone was encountered from the surface in Borehole 19-08 located on the east abutment foreslope. The thickness of the armor stone was approximately 0.8 m. Coring was required to get through the armor stone.





### Concrete and Boulders

A layer consisting of boulders and concrete was encountered from the surface in Borehole CR22-04 located on the west abutment foreslope. The thickness of the concrete and boulders was approximately 3.7 m but is expected to be highly variable as it is understood to have been placed to repair a foreslope washout shortly after construction. Coring was required to get through the concrete and boulders.

### Topsoil

Topsoil was encountered at surface in three boreholes, labelled CR22-01 through CR22-03, and had a thickness of 150 mm.

### Sand Fill

Sand fill was generally encountered directly below the asphalt surface and within the foreslopes at this site. The SPT 'N' values ranged from weight of hammer to 100 blows for 75 mm of penetration indicating a very loose to very dense condition; but typically, loose to compact. It should be noted that silt and clay fill (described below) was found to be interlayered within the granular fill at several borehole locations.

The moisture content of the samples tested ranged from 1% to 28%. A single moisture content of 56% was noted in the surficial granular fill in Borehole 19-05; organics were noted within this sample. The results of grain size analysis conducted on selected samples of this material are summarized in Table 6-1 and are illustrated on Figures C1 to C5 in Appendix C.

**Table 6-1: Gradation Results for Sand Fill**

Soil Particle	Percentage (%)	
Gravel	0 – 35	
Sand	21 – 96	
Silt	1 - 49	9 – 57
Clay		6 – 19

Atterberg Limits testing was completed on eight samples of the sand fill (minus the gravel and coarse sand fraction). Five samples were found to be non-plastic, the remaining three samples were found to be of low plasticity and are illustrated on Figure C16 in Appendix C.

### Silt and Clay Fill

Fill consisting predominantly of silt and clay with varying amounts of sand and gravel and possible cobbles was encountered below and/or interbedded with the sand fill in most boreholes. The SPT 'N' values ranged from weight of hammer for 300 mm of penetration to 100 blows for 125 mm of penetration. The clay fill material was not conducive to shear vane testing due to the generally high sand and gravel content but is estimated to have a generally very stiff consistency.

The moisture content of the samples tested ranged from 8% to 32%. The results of grain size analysis conducted on selected samples of this material are summarized in Table 6-2 and are illustrated in Figures C6 to C8 in Appendix C.

**Table 6-2: Gradation Results for the Silt and Clay Fill**

Soil Particle	Percentage (%)
Gravel	0 – 21
Sand	10 – 41
Silt	34 – 50
Clay	14 – 40

Atterberg Limits testing was completed on selected samples of the silt and clay fill (minus the gravel and coarse sand fraction). Six of the samples were found to be non-plastic, the remaining twelve samples were found to range from low to intermediate plasticity (ML to CI), the results are summarized in Table 6-3 and are illustrated on Figures C17 and C18 in Appendix C.

**Table 6-3: Atterberg Limit Results for the Silt and Clay Fill**

Parameter	Moisture Content (%)
Liquid Limit	14 – 42
Plastic Limit	10 – 23
Plasticity Index	3 – 23

### Wood Fill

A fill layer consisting predominantly of wood, some sand and other organics was encountered below the granular fill in Borehole 19-10. The top of this layer was 95.4 m in elevation and the thickness was 2.2 m. The SPT 'N' values ranged from 26 to 50, recognizing that the correlation between 'N' values and relative density are not intended for wood.

The moisture content of the samples tested ranged from 26% to 118%. The results of two organics content tests performed on this material indicated the organic content to range from 2.2 to 9.9% and are presented in Appendix C.

## 6.2 Clayey Silt (CL-ML to CL) to Silty Clay (CI)

A deposit ranging from clayey silt to silty clay with varying amounts of silt, sand and gravel was encountered below the fill materials in Boreholes 301, 302, 19-01, 19-02, 19-05, 19-06, 19-07, 19-09, 19-11A and CR22-01; and below the silty sand in Borehole 19-08. It is noted that the 300 and 19 series Borehole logs utilize a previous naming convention. This layer has a top elevation ranging from 100.4 m to 94.6 m. The thickness of this layer ranged from 0.8 m to 5.3 m. In-situ shear vane testing could not be performed in much of the deposit as the vane could not penetrate the clay which is estimated to be very stiff. Where shear vane testing could be performed, the undrained shear strengths ranged from 32 to 88 kPa; indicating a firm to stiff consistency.

The moisture content of the samples tested ranged from 14% to 39%. The results of grain size analysis testing conducted on selected samples of this material are summarized in Table 6-4 and are illustrated on Figures C9 to C11 in Appendix C.

**Table 6-4: Gradation Results for Clayey Silt (CL-ML to CL) to Silty Clay (CI)**

Soil Particle	Percentage (%)	
	Clayey Silt (CL-ML to CL)	Silty Clay (CI)
Gravel	1 – 13	0 – 2
Sand	1 – 34	4 – 16
Silt	37 – 62	43 – 50
Clay	17 – 49	40 – 50

The results of Atterberg Limits testing completed on selected samples of this material are summarized in Table 6-5 and are illustrated on Figures C19 through C21 in Appendix C. The test results indicate the clay to be of low to intermediate plasticity (CL-ML to CI).

**Table 6-5: Atterberg Limit Results for Clayey Silt (CL-ML to CL) to Silty Clay (CI)**

Parameter	Moisture Content (%)	
	Clayey Silt (CL-ML to CL)	Silty Clay (CI)
Liquid Limit	17 – 33	35 – 50
Plastic Limit	13 – 19	17 – 22
Plasticity Index	4 – 17	18 – 28

Consolidation tests were carried out on clay samples retrieved from Boreholes 19-01 and 19-11B at elevations of 96.3 m and 93.5 m respectively. The results are summarized below in Table 6-6 and presented in Appendix C.

**Table 6-6: Consolidation Testing Results**

Parameter	BH19-01 ST1	BH19-11B ST1
Elevation	96.3 m	93.5 m
w	24.6%	39.5%
e <sub>o</sub>	0.661	1.083
p <sub>o</sub> '	65 kPa	42 kPa
p <sub>c</sub> '	180 kPa	220 kPa
C <sub>c</sub>	0.243	0.369
C <sub>r</sub>	0.039	0.102
C <sub>v</sub>	0.105 mm <sup>2</sup> /s	0.046 mm <sup>2</sup> /s
C <sub>vr</sub>	0.422 mm <sup>2</sup> /s	0.166 mm <sup>2</sup> /s

### 6.3 Silty Sand (SM)

A layer consisting predominantly of silty sand with varying amounts of gravel and clay was encountered below the fill in Boreholes 19-08 and 19-13. The top of this layer ranges in elevation from 95.3 m to 94.9 m. The thickness of this layer ranged from 0.7 m to 2.0 m. The SPT 'N' values ranged from 21 blows for 300 mm of penetration to 100 blows for 225 mm of penetration a compact to very dense condition.

The moisture content of the samples tested ranged from 11% to 15%. The results of grain size analysis conducted on one sample of this material indicates a gravel content of 11%, a sand content of 77%, and a silt and clay content of 12%. The grain size analysis results are illustrated on Figure C12 in Appendix C.

### 6.4 Sandy Silt (ML)

A stratum of sandy silt was encountered beneath the clay layer in Borehole 301; beneath the fill layers in Boreholes 303 and 304; and beneath the silty sand some gravel in Borehole 19-13. Trace to some organics were noted within this layer in Boreholes 303, 304 and 19-13. The top of this layer had an elevation ranging from 95.5 m to 92.9 m. The thickness of this layer ranged from 1.1 m to 2.3 m. The SPT 'N' values ranged from 6 to 10 indicating a loose to compact condition. A strong hydrocarbon odour was noted from samples of this material obtained from Borehole 303.



The moisture content of the samples tested ranged from 13% to 25%. The result of an organic content test on material from Borehole 19-13 indicated an organic content of 7.2% and is provided in Appendix C. The results of a grain size analysis test conducted on a sample of this material indicates a gravel content of 6%, a sand content of 27%, a silt content of 52% and clay content of 15%. The grain size analysis results are illustrated on Figure C13 in Appendix C.

The results of Atterberg Limits testing indicate a liquid limit of 14, a plastic limit of 11 and plasticity index of 3, indicating a low plastic silt (ML). Atterberg Limits analysis results are illustrated on Figure C22 in Appendix C.

## 6.5 Glacial Till

A stratum of glacial till consisting predominantly of silty sand with gravel was encountered beneath the clayey silt to silty clay stratum in Boreholes 302, 19-01, 19-02, 19-05, 19-06, 19-07, 19-08, 19-09, 19-11A and CR22-01; beneath the sandy silt stratum in Boreholes 301, 303, 304 and 19-13; and beneath fill layers in Boreholes 19-03, 19-04, 19-10, 19-12, CR22-02, CR22-03 and CR22-04. Cobbles and boulders were noted within this layer in several boreholes. This layer has a top elevation ranging from 95.9 m to 91.8 m. The thickness of this layer ranged from 0.1 m to 2.8 m. The SPT 'N' values ranged from 9 to greater than 100 blows for 300 mm of penetration indicating a loose to very dense condition, but typically compact to very dense. A hydrocarbon odour was noted from samples of this material obtain from Boreholes 301, 302 and 303.

The moisture contents of the samples tested ranged from 4% to 29%. The results of grain size analysis conducted on selected samples of this material are summarized in Table 6-7 and are illustrated on Figures C14 and C15 in Appendix C.

**Table 6-7: Gradation Results for Glacial Till**

Soil Particle	Percentage (%)	
Gravel	9 – 59	
Sand	31 – 79	
Silt	10 – 25	21 – 25
Clay		6 – 8

Based on the results of two Atterberg Limits tests the fines portion is classified as non-plastic. Glacial till is noted to inherently contain cobbles and boulders.

## 6.6 Bedrock

The overburden materials were underlain by a grey, fine grained limestone bedrock. The bedrock surface ranges from elevation 91.7 m to 93.4 m in the boreholes where rock was cored. Photographs of the bedrock core are provided in Appendix C. Table 6-8 summarizes the depths and elevations of the bedrock surface.

**Table 6-8: Summary of Bedrock Depth/Elevation**

Borehole No.	Depth to Bedrock Surface (mbgs)	Bedrock Surface Elevation (m)
301	17.2	93.1*
302	18.5	91.8
303	15.3	92.4
19-01	9.3	93.4
19-02	4.7	92.8
19-03	4.7	93.2
19-04	8.7	92.9
19-05	7.2	92.8
19-06	4.5	92.5
19-07	4.2	93.0
19-08	9.1	93.1
19-09	11.4	92.6
19-10	4.1	92.6
19-11A	4.6	91.9
19-12	7.9	92.6
19-13	7.0	91.7
CR22-01	6.2	93.1
CR22-02	6.5	93.4
CR22-03	11.5	92.5
CR22-04	11.4	92.6

\* Inferred Bedrock by SPT/auger refusal

Boreholes 302 and 303 were advanced into the bedrock by coring with HQ-size coring equipment and Boreholes 19-01 through 19-13 and CR22-01 through CR22-04 were advanced into the bedrock with NQ-size coring equipment. The bedrock within the top 1.6 m in Borehole 303 and



within the top 2.4 m in Borehole 19-10 was moderately weathered. The top 0.9 m of the moderately weathered layer in Borehole 303 could be penetrated with the drill rig augers.

Within the moderately weathered bedrock that was cored in Boreholes 302 and 19-10, the total core recovery (TCR) ranged from 91 to 100%, the solid core recovery (SCR) ranged from 39 to 73% and the Rock Quality Designation (RQD) ranged from 8 to 37%. Based on the RQD values the weathered bedrock is classified as very poor to poor quality.

Outside of the moderately weathered limestone bedrock layer the TCR ranged from 91 to 100% with an average of 99%, the SCR ranged from 39 to 100% with an average of 90% and the RQD ranged from 0 to 100% with an average of 63%. Based on the RQD values the bedrock is classified as very poor to excellent, but typically fair based on the average RQD.

The unconfined compressive strength of the Limestone Bedrock was measured to range from 86.1 to 106.4 MPa from six core sample from Boreholes 19-03, 19-06, 19-08, 19-11A, CR22-02 and CR22-03 indicating strong to very strong bedrock. The results are included in Appendix C.

## **6.7 Groundwater**

The groundwater levels were measured in five standpipe piezometers installed in Boreholes 303, 19-01, 19-03, 19-10, 19-13 and CR22-04. The measurements are presented in the Record of Borehole sheets in Appendix B and in Table 6-9 below:

**Table 6-9: Groundwater Level Observations**

Borehole	Groundwater Level		Date of Measurement
	Depth (mbgs)	Elevation (m)	
303	10.9	96.8	May 31, 2016
19-01	5.2	97.5	Feb. 24, 2019
	5.2	97.5	Feb. 25, 2019
	5.2	97.5	Mar. 16, 2019
19-03	1.5	96.4	Feb. 21, 2019
	1.6	96.3	Feb. 23, 2019
	1.5	96.4	Feb. 24, 2019
	1.5	96.4	Feb. 25, 2019
19-10	1.0	95.7	Feb. 21, 2019
	1.1	95.6	Feb. 23, 2019
	1.1	95.6	Feb. 24, 2019
	1.1	95.6	Feb. 25, 2019
19-13	4.6	94.1	Feb. 23, 2019
	4.7	94.0	Feb. 24, 2019
	4.7	94.0	Feb. 25, 2019
	4.7	94.0	Mar. 16, 2019
CR22-04	6.3	97.7	May 9, 2022
	7.3	96.7	Sept. 26, 2022
	7.3	96.7	Sept. 30, 2022

These observations are considered short term and it should be noted that fluctuations of the groundwater level are to be expected. In particular, the groundwater levels may be at a higher elevation after periods of significant and/or prolonged precipitation.

The piezometer in Borehole 303 was decommissioned in accordance with Ontario MOE Regulation 903 on May 31, 2016. The standpipes in Boreholes 19-01, 19-03, 19-10 and 19-13 were decommissioned in accordance with Ontario MOE Regulation 903 on August 20, 2020. The piezometer in Borehole CR22-04 was decommissioned in accordance with Ontario MOE Regulation 903 on August 23, 2023.





## 6.8 Analytical Testing

Six samples of soil were submitted to Paracel Laboratories in Ottawa, Ontario and one sample was submitted to SGS Canada Inc. in Lakefield, Ontario for analysis of pH, water soluble sulphate and chloride concentrations, resistivity and conductivity. Five of the submitted samples was also tested for sulphide. The analysis results are provided in Appendix C and are summarized in Table 6-10 below:

**Table 6-10: Results of Chemical Analysis**

Borehole	301	304	19-02	19-05	19-08	19-09	CR22-01
Sample	SS3	SS4	SS4B	SS7	SS7	SS10	SS3
Depth (m)	1.5 – 2.1	2.3 – 2.9	2.6 – 2.9	4.6 – 5.2	5.3 – 5.9	6.9 – 7.5	1.5 – 2.1
Chloride (µg/g)	650	670	161	21	263	315	340
Sulphate (µg/g)	27	48	35	24	53	28	17
Sulphide (%)	-	-	< 0.02	0.02	< 0.02	< 0.02	< 0.04
pH (-)	8.2	8.4	8.1	7.9	7.9	7.9	8.5
Resistivity (Ohm-cm)	817	796	2,300	5,030	1,680	1,700	1,150
Conductivity (µS/cm)	1,220	1,260	434	199	595	587	867

## 6.9 MASW Testing

The shear wave velocities measured by the MASW testing generally increased with depth from about 300 m/s to 900 m/s on the east side and 1,000 m/s on the west side. The harmonic mean of the shear wave velocities within the upper 30 m ( $V_{s30}$ ) was 599 m/s on the west side and 588 m/s on the east side. The test results are provided in Appendix B.

## 7. MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling. The as-drilled locations and ground surface elevation were measured by Thurber following completion of the field program.

Terex Drilling Solutions of Concord, Ontario and George Downing Estate Drilling Ltd. of Hawkesbury, Ontario supplied and operated the truck mounted CME drill rigs to carry out the drilling, sampling, and in-situ testing, standpipe piezometer installation and borehole decommissioning of the on-road boreholes. M3 Drilling of Hawkesbury, Ontario and Marathon Drilling of Ottawa, Ontario supplied and operated the portable and track mounted drilling equipment to carry out the drilling, sampling, and in-situ testing, standpipe piezometer installation and borehole decommissioning of the off-road boreholes. Traffic control was performed in



accordance with Ontario Book 7 for short duration closures; all signs, barrels, cones and traffic control personnel were provided by Direct Traffic Management of Mississauga, Ontario, On Track Safety Ltd. of Thornhill, Ontario and Beacon Lite Ltd. of Kingston, Ontario. The field investigations were supervised on a full-time basis by Mr. Justin Gray, P.Eng., Mr. Christopher Murray, P.Eng., Miss Allison Chow, EIT, Mr. Sean O'Bryan CET, Mr. Nick Weil and Mr. Joe Lin. Overall supervision of the field investigation program was provided by Mr. Christopher Murray, P.Eng. MASW testing was completed by Geophysics GPR International Inc. of Mississauga, Ontario.

Routine geotechnical laboratory testing was completed by Thurber's laboratories in Ottawa and Pickering, Ontario. Analytical testing was completed by Paracel Laboratories in Ottawa, Ontario and SGS Canada Inc. in Lakefield, Ontario. Unconfined compressive strength testing was carried out by Thurber's laboratory in Oakville, Ontario and Stantec laboratories in Ottawa, Ontario. Organic content and consolidation testing were carried out by Stantec laboratories in Ottawa, Ontario. Interpretation of the factual data and preparation of this report was completed by Mr. Christopher Murray, P.Eng. The report was reviewed by Mr. Paul Carnaffan, P.Eng. and Dr. P.K. Chatterji, P.Eng., the Designated Principal Contact for MTO Foundation Projects.



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**FINAL  
FOUNDATION INVESTIGATION AND DESIGN REPORT  
REPLACEMENT OF THE HIGHWAY 401 OVERPASS AT CHOATE ROAD  
NORTHUMBERLAND COUNTY – PORT HOPE, ONTARIO  
ASSIGNMENT NO.: 4019-E-0021  
GWP 4068-14-00**

**GEOCRES NO.: 30M16-075**

**PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS**

**8. GENERAL**

This section of the report provides an interpretation of the factual data from Part 1 of this report and presents foundation design recommendations to assist the project team in the design of the replacement of the Highway 401 overpass structure located at Choate Road in Port Hope, Ontario. The discussion and recommendations presented in this report are based on the information provided by LEA Consulting (LEA), McIntosh Perry Consulting Engineers (MPCE) and the factual data obtained during the current field investigation. Thurber Engineering Limited (Thurber) carried out the assignment as a sub-consultant to MPCE under Agreement No. 4019-E-0021.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation, LEA Consulting and McIntosh Perry Consulting Engineers and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. The construction or design-build contractor must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

**8.1 Existing Foundations**

Based on the historical contract documents, the abutments and piers of the existing three span bridge were designed to be supported by steel 14 HP73 (HP 360x108) piles driven into bedrock. All piles supporting the piers are indicated to be battered at 1H:6V with an approximate length of 3 m, while the piles supporting the abutments are shown to include a back row of vertical piles and a front row of piles battered at 1H:12V with approximate pile lengths of 12 m. The design load

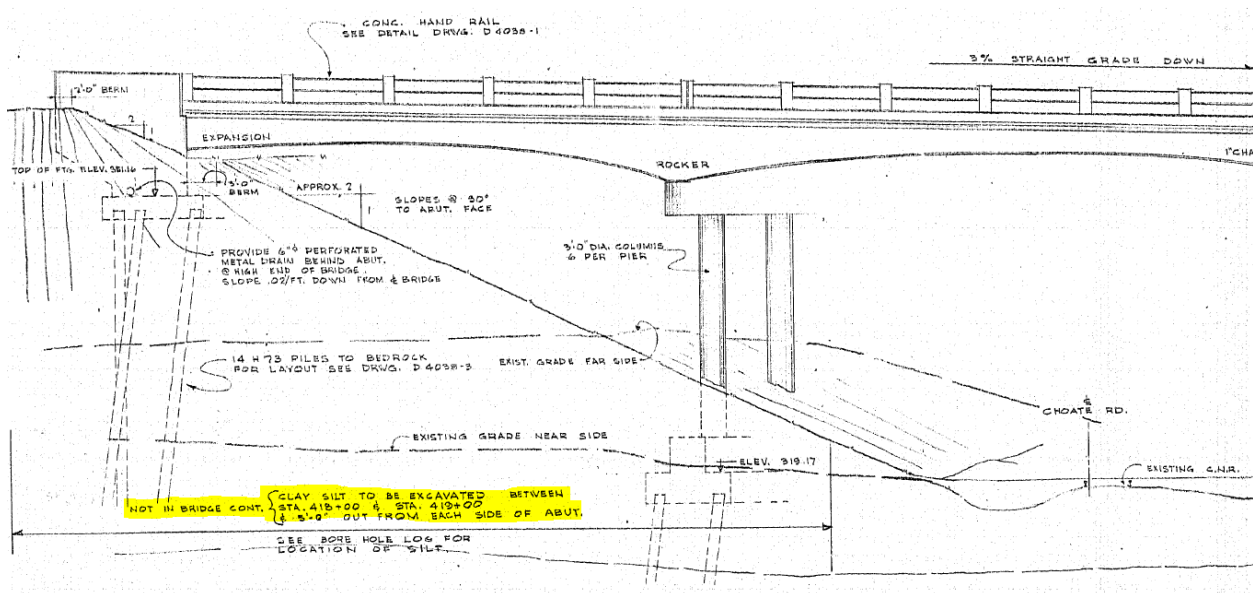


for the piles was noted as 150 kips (667 kN) on the contract drawings. The abutment foreslopes are identified as being sloped at 2H:1V.

A letter within the GEOCRE file for this site, dated December 24, 1957, summarizing the findings of the investigation for the bridge structure indicated that the soft silty clay stratum on the west side of the bridge would cause an approach failure under the superimposed load of the approach embankment (in the order of 30 to 35 feet (10 to 12 m) in height). Keying the foundations into the bedrock to resist the lateral thrust from movement of the embankment or removing the poor subsoil were presented as options.

The GEOCRE file also includes a report dated January 23, 1958, presenting the findings and recommendations for the bridge approaches. It confirmed the presence of poor soils at the west approach but indicated that removal may not be economical and recommending that the embankment be constructed in three stages with suitable time intervals between each stage to permit natural drainage and consolidation of the foundation material.

The 1958 Elevation & Pier Detail Drawing includes a note (see image below) indicating that the clay and silt should be removed from beneath the west embankment from in front of the west pier to behind the west abutment. The note also indicates "Not in Bridge Contract". The historical documents are not conclusive regarding whether the poor soil was removed from beneath the west approach or whether the embankment was constructed in stages over an extended period of time.



Historical documents have also been provided that indicate that a heavy rainfall resulted in undermining of the slope paving at the west abutment, followed by movement of the deck into

contact with the ballast wall and damage to the bearings. Photographs documenting these distresses range from 1978 to 1984. Limited details regarding investigations into the events and remedial measures undertaken were available. It is noted that undermining of the slope paving was extensive enough for a person to stand beneath the slope pavement. If the undermining was reinstated with concrete or grout, it could present an obstruction for excavation or installation of deep foundations for the new structure or retaining walls.

## 8.2 Proposed Structure

It is understood that the existing bridge structure will be replaced using staged construction with a structure widened to the north as shown in the General Arrangement (GA) provided by LEA and dated January 2023 and included in Appendix A. The proposed integral abutment bridge structure is on a 17° skew to Highway 401, 47 m wide, and consists of a single 45 m span. The abutments are founded on vertical 450 MPa grade steel H-piles driven to bedrock.

## 8.3 Applicable Codes and Design Considerations

The geotechnical assessment presented below has been prepared based on the available data regarding the proposed foundations, existing ground surface conditions and in accordance with the Canadian Highway Bridge Design Code (CHBDC) version CSA S6-19.

In accordance with the CHBDC, the analysis and design of the structure takes into consideration the importance of the structure and the consequence associated with exceeding limit states. The importance category and consequence classification are defined by the Regulatory Authority, which, in this case, is the Ministry of Transportation, Ontario (MTO).

**Table 8-1: Bridge Structure Classification**

Criteria	Classification	CHBDC Section
Importance Category	Major Route Bridge	4.4.2
Consequence Classification	Typical Consequence	6.5.1

Accordingly, a consequence factor ( $\Psi$ ) of 1.0, as per Table 6.1 of the CHBDC, has been used in assessing factored geotechnical resistances. If the consequence classification changes, the geotechnical assessment and recommendations provided within this report will need to be reviewed and revised.

As per Section 6.5.3 of the CHBDC, the degree of site prediction model understanding is considered to be *Typical* based on the current information.

The frost penetration depth and associated recommendations are provided in Section 12.5.



## 9. SEISMIC CONSIDERATIONS

### 9.1 Spectral and peak Acceleration Hazard Values

The seismic hazard data for the CHBDC is based on the fifth-generation seismic model developed by the Geological Survey of Canada (GSC)<sup>1</sup>. The GSC seismic hazard calculation data sheet for this site for the *reference* ground condition (Site Class C) is presented in Appendix H. The site coefficients used to determine the design spectral acceleration values are a function of the Site Class, PGA and  $S_a(0.2)$ . The PGA value at this site provided by GSC for a *reference* Site Class C with a 2% probability of exceedance in 50 years (2475-year event) is 0.112 g. This value is to be scaled by the  $F(PGA)$  based on the *site-specific* Site Class, as discussed in Section 9.2.

### 9.2 CHBDC Seismic Site Classification and Performance Category

In accordance with Section 4.4.3.2 of the CHBDC, the selection of the seismic site classification is based on the nature of soil deposit within the upper 30 m of the stratigraphy. As per Table 4.1 of the CHBDC, the Site Class has been classified as a Seismic Site Class C based on the harmonic mean of the shear wave velocity within the upper 30 m,  $V_{s30}$ , measured during the geophysical investigation using Multi-Channel Analysis of Surface Waves (MASW). The results of the seismic testing conducted in the vicinity of the east and west abutments indicate that the average  $V_{s30}$  of the site ranges from 588 to 599 m/s which meets the Seismic Site Class C criteria of  $(360 \text{ m/s} \leq V_s \leq 760 \text{ m/s})$ ; a copy of the results is provided in Appendix B).

### 9.3 Liquefaction Potential

The susceptibility of the cohesionless soils at the site to experience liquefaction was assessed using the SPT data following the simplified method for cohesionless soil as outlined in Boulanger and Idriss (2014)<sup>2</sup>. A single SPT 'N' value of 2 was obtained at a depth of 7.6 m in Borehole CR22-04 which is marginally susceptible to liquefaction under the 2475-year event and not susceptible to the 975-year event. This was not observed elsewhere on site and therefore the cohesionless foundation soils at this site are not considered to be susceptible to liquefaction under the design earthquake.

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<sup>1</sup> <https://earthquakescanada.nrcan.gc.ca/hazard-alea/interpolat/calc-en.php>

<sup>2</sup> Boulanger, R. W., and Idriss, I. M. (2014). CPT and SPT based liquefaction triggering procedures, Report No. UCD/CGM-14/01, Center for Geotechnical Modeling, Department of Civil and Environmental Engineering, University of California, Davis, CA, 134 pp.



The cohesive clayey silt to silty clay deposit at this site is classified as not susceptible to cyclic mobility during a seismic event when assessed using the Boulanger & Idriss (2007)<sup>3</sup> method.

## **10. GEOTECHNICAL ASSESSMENT / CONSIDERATIONS**

Based on the results of the field and laboratory investigation, the review of historical information, and the information provided by MPCE & LEA with regards to the proposed project requirements, the geotechnical foundation design considerations include:

- The existing fill and native soils will not offer sufficient bearing resistance to support bridge abutments on shallow foundations; deep foundations will be required to provide the required geotechnical resistance.
- Wood fill with some sand and organic matter was encountered in Borehole 19-10 at the southwest corner of the existing foreslope. This fill extended to a depth of 3.5 m below the surface of Choate Rd (elev. 93.2 m). The extent of the wood fill is not fully known.
- Clayey silt and silty clay were encountered in the boreholes on the west side of Choate Rd. New loading imposed by shallow foundations or embankment fill will result in both short-term and long-term settlement of these deposits. It is noted that the settlement will be differential as the magnitude of settlement will depend on the thickness of the clayey/silty clay deposits and the thickness of new fill placed above it.
- Both approaches include a high fill (approximately 10 m to 12 m) constructed above organic silt. Historical documents indicate a concern regarding settlement and stability of the approach embankments during construction; and
- The limits of excavation for the new structure needs to consider potential conflict with existing structure and may require temporary protection systems to limit the extents of the excavations and/or to ensure stability of the existing structures and roadways.

## **11. EVALUATION OF DESIGN OPTIONS**

The results of the field and laboratory investigation and historical data indicate that the site soil stratigraphy consists of fill materials overlying native silts and clays overlying glacial till, underlain by limestone bedrock.

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<sup>3</sup> Boulanger, R. W., & Idriss, I. M. (2007). Evaluation of cyclic softening in silts and clays. Journal of geotechnical and geoenvironmental engineering, 133(6), 641-652.





Approximate key elevations are as follows:

▪ Hwy 401 asphalt surface at the existing abutments	110.2 m West side 107.6 m East side
• Existing top of pavement on Choate Rd beneath bridge	97.9 m to 96.5 m
• Top of glacial till deposit	95.9 m to 91.8 m
• Top of bedrock	91.7 m to 93.4 m

The following foundation alternatives were considered for the bridge replacement:

- Shallow Foundations
- Caissons (drilled shaft piles)
- Driven Steel Piles (H-piles and pipe piles)
- Drilled-in Pipe Piles (down-the-hole hammer)
- Micropiles

These foundation alternatives are discussed in the following sections and evaluated from a geotechnical perspective in terms of their respective advantages, disadvantages, risks and consequences for the three main structural elements. The evaluation is summarized in the tables provided in Appendix E. A preferred replacement alternative from a geotechnical engineering perspective is recommended.

- Shallow Foundations

The existing fill, native clayey silt, silty clay, and sandy silt will not offer sufficient bearing resistance to support bridge piers on shallow foundations and would require deep excavations at the abutment locations. Shallow foundations bearing on native soils might be feasible if retaining walls are required near the toe of the embankment slopes.

- Caissons

Caisson foundations can offer high axial and lateral geotechnical resistance, particularly, when they are socketed into bedrock but are not compatible with an integral abutment approach. If Integral abutments are not required at this site, caissons are considered feasible, however, restrictions or special measures would be required for caissons that require rock sockets if they are located too close to existing deep foundations end-bearing on the bedrock during staged construction. These measures may include extending a steel casing down into the socket, limiting the number of caissons that can be left open at any given time, and monitoring of the existing structure.



- Driven Steel Piles

Steel piles driven to refusal on or within the bedrock are considered feasible for the bridge abutments. The use of either steel H-piles or pipe piles could be considered at this site, however, pipe piles fitted with a driving shoe to help seat the piles into the rock cause greater soil displacement than steel piles increasing the potential for disturbance of adjacent piles.

- Drilled in Pipe Piles

Drilled-in pipe piles are feasible from a foundations perspective at this site and would offer moderate to high geotechnical axial and lateral resistance. Drilled in pipe piles may be preferable over driven steel piles at the abutments if large lateral resistance is required.

- Micropiles

Micropiles would provide low to moderate axial compression loads. A larger number is required to achieve the same overall resistance as driven steel piles or caissons. In addition, they provide low lateral resistance for an individual micro-pile. Lateral resistance is often achieved by installing groups of micro-piles at different inclinations. The cost for micropiles is typically higher than for driven steel piles or caissons in order to achieve similar geotechnical resistance. Micropiles can offer an advantage where installation is required in areas with limited vertical clearance or for applications that also require significant uplift resistance.

## **12. FOUNDATION DESIGN RECOMMENDATIONS**

Based on an evaluation of foundation alternatives presented above and the geometry of the proposed Choate Road Overpass structure, the recommended foundation approach from a geotechnical perspective is to support the abutments on steel H-piles driven to bedrock.

Foundation recommendations and considerations are presented in the following sections.

### **12.1 Driven Steel H-Piles**

The abutments may be founded on steel HP 310x132 piles end-bearing on the bedrock.

The estimated pile tip elevations based on piles reaching refusal at the bedrock surface are summarized in Table 12-1.

**Table 12-1: Estimated Pile Tip Elevations**

Foundation Element	Approximate Underside of Pile Cap Elevation (m)	Estimated Pile Tip Elevation (top of bedrock) (m)	Estimated Pile Length (m)
East Abutment	103.5	92.6	10.9
West Abutment	104.5	92.5	12.0

The design parameters for axial resistance of Grade 450W HP 310x132 steel piles driven to refusal on or in the limestone bedrock can be taken as:

- Factored axial geotechnical resistances at ULS 2,500 kN
- The SLS condition will not govern for piles founded on the bedrock

The factored geotechnical resistances provided include the following factors:

- Consequence factor ( $\Psi$ ) of 1.0
- Geotechnical resistance factors (CHBDC Table 6.2):
  - $\phi_{gu} = 0.4$ , ULS (static analysis; typical degree of understanding)

*The structural resistance of the pile must be checked by the structural engineer which may govern the design.*

Driven piles must be installed in accordance with OPSS.PROV 903. The potential for conflict with the existing steel piles must be checked.

As the piles are to be driven to bedrock the pile tips of the new piles at the site should be protected from damage during driving with pile tip protection from an approved manufacturer such as Titus Steel (standard H-Point) or approved equivalent.

The appropriate pile driving note is “Piles to be driven to bedrock.”.

## **12.2 Deep Foundations – Lateral Resistance**

The lateral resistance for the soil adjacent to a vertical pile or caisson is developed on the face of the deep foundation element embedded in the foundation soils and estimated using P-y curves.

The P-y curves representing the response of the soil under static loading conditions are shown in Appendix F to allow for calculation of the *ultimate* lateral capacity of an individual pile. Calculation of the P-y curves considered the ground surface elevation and the underside elevations of the pile caps at the abutments as outlined above in Section 12.1. The values provided in Appendix F were calculated for a single, vertical HP 310x132 pile at the abutments considering the soil parameters summarized in Table 12-2, below. It is noted that P-y curves have been provided

separately for the eastbound and westbound lanes at the west abutment due to the different soil conditions encountered.

**Table 12-2: L-Pile Analysis – Soil Stratigraphy**

Soil Stratum	Bulk Unit Weight (kN/m <sup>3</sup> )	Friction Angle (°)	Undrained Shear Strength (kPa)
Existing Fill	20.0	30	-
Silty Clay (CI)	17.0	-	110
Clayey Silt (CL)	17.0	-	35
Glacial Till	21.0	35	-

A geotechnical resistance factor of 0.5 ( $\phi_{gu}$ ) and 0.8 ( $\phi_{gs}$ ) as per Table 6.2 of the CHBDC (static analysis – typical understanding) should be applied to the *ultimate* ULS and SLS values, respectively.

Where lateral spacing between an adjacent pile is less than four equivalent pile diameters, the lateral resistance will also need to be further reduced based on the center-to-center spacing. The reduction factors to be used can be obtained from Figures C6.22, C6.23, and C6.24 of the Commentary to the CHBDC.

The lateral resistance of the soil acting against the deep foundations is dependent on several factors including the effective overburden stress and is therefore directly dependent on the proposed geometry of the proposed bridge and retaining walls. If there are any changes to the proposed structure, the soil response to lateral loading from the deep foundations in the form of p-y curves should be reevaluated.

### 12.3 Deep Foundations - Downdrag

No significant cohesive soil deposits were encountered in the area of the east abutment and downdrag loading on the existing and proposed east abutment piles is considered negligible.

Cohesive soils were encountered at the proposed west abutment to the north of the existing Highway 401 alignment. Based on borehole data it appears that the majority of the native clay was sub excavated and replaced with fill material below the existing Highway 401 west bridge abutment. Given that the cohesive soils have been removed below the existing west abutment, downdrag loading on the existing west abutment piles is considered negligible.

Time dependent settlement of the cohesive foundation soils will occur north of the existing bridge alignment in the area of the west abutment due to the proposed high fill embankment widening. As a result, deep foundations at the proposed west abutment north of the existing highway bridge



will need to be designed to carry the additional static downdrag loads developed along the length of the piles embedded in the cohesive layers and overlying materials. Provided that the deep foundations are installed following the recommended preload period of six months, the *unfactored* static downdrag load for HP 310x132 is estimated to be up to 300 kN.

This downdrag load should be factored in accordance with the CHBDC. In accordance with Section 6.11.4.10 of the CHBDC and Clause C6.11.4.10 of the Commentary, in the structural design of a pile, the factored downdrag load should be added to the factored permanent loads to assess the effects of downdrag. In geotechnical analysis of downdrag, live load effects should not be considered.

The neutral plane for static downdrag calculations can be taken as the base of the cohesive deposits.

## **12.4 Backfill and Lateral Earth Pressure**

### **12.4.1 Backfill**

Structural backfill material should consist of Granular A or Granular B Type II meeting the OPSS.PROV 1010 specifications and SP110S06. The backfill must be in accordance with OPSS.PROV 902 and placed and compacted in accordance with OPSS.PROV 501 to the extents shown on OPSD 3101.150. The backfill should be compacted and compaction equipment to be used adjacent to the structure must be restricted in accordance with OPSS.PROV 501.07.02.

### **12.4.2 Static Lateral Earth Pressure**

Lateral earth pressure provided in the equations in the sections below are based on the assumption that the backfill is fully drained so that there are no unbalanced hydrostatic pressures. If adequate drainage cannot be confirmed, the potential for buildup of hydrostatic pressures should be considered in the design.

Lateral earth pressures acting on vertical structures should be computed in accordance with the Section 6.12 of the CHBDC but under fully drained conditions, the lateral pressures are generally given by the following expression:

$$\sigma_h = K * (\gamma d + q)$$

where:

$$\begin{aligned}\sigma_h &= \text{static lateral earth pressure on the wall at depth } d \text{ (kPa)} \\ K &= \text{static earth pressure coefficient (see table below)}\end{aligned}$$

- $\gamma$  = unit weight of retained soil (see table below) adjusted below water level  
 $d$  = depth below top of fill where pressure is computed (m)  
 $q$  = value of any surcharge (kPa)

A lateral earth pressure due to backfill compaction should be added to the calculated lateral earth pressure in accordance with Clause 6.12.3 of the CHBDC. Typical earth pressure coefficients for use in design of vertical walls for a horizontal backslope are shown in Table 12-3.

**Table 12-3: Static Earth Pressure Coefficients**

Material	Unit Weight (kN/m <sup>3</sup> )	K <sub>A</sub> (yielding wall)	K <sub>0</sub> (non-yielding wall)
OPSS Granular A	22.8	0.27	0.43
OPSS Granular B Type II	22	0.27	0.43
Existing Embankment Fill	20.5	0.33	0.50

For rigid structures, it is recommended that at-rest horizontal lateral earth pressures be used for design. Active pressures should be used for the design of unrestrained walls. The ratio of wall movement to wall height required to mobilize the active condition would be approximately 0.002.

For static analysis, passive earth resistance in front of the abutments should be ignored, and therefore has not been provided.

#### **12.4.3 Combined Static and Seismic Lateral Earth Pressure**

In accordance with Clause 6.14 of the CHBDC, structures should be designed using dynamic earth pressure coefficients that incorporate the effects of earthquake loading. The following recommendations are per Section C6.14.7.2 of the Commentary of the CHBDC which states that seismically induced lateral soil pressures may be calculated using Mononobe Okabe Method with:

- $k_h = \frac{1}{2} * F(PGA) * PGA$ , for structures that allow 25 to 50 mm of movement, and
- $k_h = F(PGA) * PGA$ , for non-yielding walls

The coefficients of horizontal earth pressure for seismic loading presented in Table 12-4 may be used for vertical walls. The provided earth pressure coefficients are based on a 1 in 2475yr seismic event and a Seismic Site Class C.

**Table 12-4: Combined Static and Seismic Earth Pressure Coefficients**

Material	Unit Weight (kN/m <sup>3</sup> )	K <sub>AE</sub> (yielding wall)	K <sub>AE</sub> (non-yielding wall)
OPSS Granular A	22.8	0.30	0.34
OPSS Granular B Type II	22	0.30	0.34

The total pressure due to combined static and seismic loads acting at a specific depth below the top of the wall/soil may be determined using the following equation that includes consideration of material properties and the soils profile.

$$\sigma_{hAE} = K * \gamma * d + (K_{AE} - K_A) * \gamma * (H - d)$$

where:

$\sigma_{hAE}$	=	combined static and seismic lateral earth pressure on wall at depth d (kPa)
d	=	depth below the top of the wall where pressure is computed (m)
K	=	static earth pressure coefficient (K <sub>A</sub> for yielding walls, K <sub>o</sub> for non-yielding walls)
$\gamma$	=	unit weight of retained soil (kN/m <sup>3</sup> ), adjusted below water level
K <sub>AE</sub>	=	combined static and seismic earth pressure coefficient
H	=	total height of the wall (m)

## 12.5 Frost Depth

The frost penetration depth at this site is 1.4 m as per OPSD 3090.101. Accordingly, a minimum of 1.4 m of earth cover, or equivalent insulation, must be provided above the base of the pile caps to serve as frost protection.

## 12.6 Cement Type and Corrosion Potential

Analytical tests were completed to determine the potential for degradation of concrete in the presence of soluble sulphates and the potential for corrosion of exposed steel used in buried infrastructure. The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. Soluble sulphate concentrations less than 1000 µg/g generally indicate that a low degree of sulphate attack is expected for concrete in contact with soil and groundwater. The sulphate content in the soils is low ranging from 17 to 53 µg/g, see Section 6.8. The selection for class of concrete should include consideration of the effects of road de-icing salts.



The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The tests results provided in Section 6.8 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects. The corrosive effects of road de-icing salts should also be considered.

## **12.7 Embankment Settlement**

Detailed settlement calculations resulting from the embankment widening to the north have been provided in the Highway 401 High Fill Widening Report (Geocres: 30M16-079). At the east approach, provided the organic silt outside of the existing embankment footprint below the new retaining structure is sub excavated, the results indicated that a maximum settlement of 50 mm can be expected at the east approach embankment with 30 mm occurring within the 1 month. At the west abutment, a maximum of 85 mm of settlement can be expected with 80 mm occurring within 6 months of fill placement; a 6-month preload period is recommended. These settlements are expected to be at a maximum value at the new north crest of embankment slope and linearly reduces to approximately 10 mm at the existing edge of pavement for both approaches.

The magnitude of the embankment self-compression constructed with granular materials is in the order of 0.5% of the newly reconstructed embankment height and is expected to occur during fill placement.

## **12.8 Embankment Stability**

The existing high embankments are sloped at approximately 2H:1V. No evidence of global slope instability was noted during the field investigations. A previous washout of the west abutment is understood to have occurred and where it was repaired the surface of the foreslope was observed to be concrete.

Slope stability of the high fill widening to the north has been addressed in the Highway 401 High Fill Widening Report (Geocres: 30M16-079). Stability analysis results for the existing south embankment side slopes and proposed bridge foreslopes are summarized in the below table and provided in Appendix G.



**Table 12-5. Summary of Embankment Slope Stability Analysis Results**

Location	Slope Inclination	Factor of Safety	
		Static Drained Conditions	Seismic Loading
South Embankment Slope East of Choate Road	2H:1V	1.3 (Figure G1)	1.1 (Figure G2)
Proposed East Foreslope	2H:1V	1.5 (Figure G3)	1.2 (Figure G4)
South Embankment Slope West of Choate Road	2H:1V	1.4 (Figure G5)	1.2 (Figure G6)
Proposed West Foreslope	2H:1V	1.5 (Figure G7)	1.2 (Figure G8)

The seismic analyses in Table 12-5 have been carried out using a horizontal ground acceleration of 0.056g, equal to ½ of the site adjusted PGA value (0.112g) corresponding to a 2% probability of occurrence in 50 years for a seismic Site Class C.

Based on this global stability assessment, the existing embankment south side slopes at the east and west approaches were found to be stable under both static and seismic conditions with 1.3 and 1.4 factors of safety, respectively, under static conditions. The proposed east and west foreslopes were also found to be stable under both static and seismic conditions. It is noted that the east foreslope contains the end of an RSS wall that is required for embankment widening to the north of the existing Highway alignment; the base elevation of the RSS wall constructed on a thick granular pad is at elevation 96.0 m. Further design recommendations for this RSS wall are provided in the Highway 401 High Fill Widening Report (Geocres: 30M16-079).

Embankment reinstatement after construction of the bridge structure and associated widening to the north should be carried out in accordance with OPSS.PROV 206. The south embankment around the new bridge structure should be locally reconstructed with side slopes to match existing which are inclined at approximately 2H:1V using Granular A or Granular B Type II. The fill should be placed and compacted in accordance with OPSS.PROV 501.

Where newly placed embankment fill is placed against existing embankment slopes or on a sloping ground surface steeper than 3H:1V, benching of the existing slope should be carried out in accordance with OPSD 208.010. Fill should be placed started at the toe of the embankment and working upwards.

Slope protection and drainage measures will be required to ensure the long-term surficial stability of the embankment slopes. Normal slope vegetation should be established as soon as possible



after completion of the embankment fills to control surficial erosion in general accordance with OPSS.PROV 804.

### **13. CONSTRUCTION CONSIDERATIONS**

#### **13.1 Excavation**

All excavation must be conducted in accordance with the requirements of the Occupational Health & Safety Act & Regulations (OHSA) for Construction Projects. The fills and native materials at the site should be classified as Type 3 in accordance with OHSA where excavations are above the groundwater level. Where excavations extend below the groundwater level, the soils should be classified as Type 4 due to the loose silt and sandy silt materials.

Excavation should occur in a dewatered environment (see Section 13.3). Excavations must be planned and carried out in a manner that does not impact on the stability of the existing highway and bridge. The temporary cut slopes may have to be protected from precipitation and runoff to avoid surficial instabilities. The duration of temporary open excavations and cut slopes should be minimized to reduce the likelihood of causing instability concerns. Embankment and cut slope stability is the responsibility of the Contractor.

Excavation for the structure must be carried out in accordance with OPSS.PROV 902 as amended by SP109S12 and NSSP FOUN0003 and will be carried out through the existing fill and/or into the underlying native deposits. Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor.

Material stockpiling is a temporary construction measure and the associated stability implications are the responsibility of the Contractor. The selection and placement of construction equipment (such as cranes) and the construction of temporary construction access roads are also the Contractor's responsibility. Placement of the crane or temporary stockpiling must not destabilize the embankment or excavations.

At locations where there are space restrictions or where a slope has to be retained, the excavations will need to be carried out within a protection system. Further discussion on temporary protection systems (TPS) is presented in Section 13.2.

#### **13.2 Temporary Protection Systems**

Temporary Protection Systems will be required during staged construction of the new bridge structure and may be required for the wingwalls and for various stages of construction; temporary construction systems must be implemented in accordance with OPSS.PROV 539 as amended by



SP105S09. Performance Level 2 (maximum 25 mm horizontal deflection) is considered appropriate where the protection supports the existing highway. More stringent performance levels may be required if the protection system is intended to support existing structures or utilities. The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall and these factors must be considered when designing the shoring system. It is noted that mass concrete, concrete and boulders were encountered in the west foreslope and may interfere with excavations and installation of temporary protection systems. The Contractor must be prepared to dislodge or penetrate such obstructions. An NSSP has been provided in Appendix I alerting the contractor of these obstructions.

The design of roadway protection is the responsibility of the Contractor. All protection systems should be designed by a licensed Professional Engineer experienced in such designs and retained by the Contractor. The design of the roadway protection system must incorporate traffic loading and surcharge loading due to construction equipment and operations. A suitable anchoring and/or bracing system may need to be incorporated into the temporary protection design to resist lateral earth pressure loadings. The Contractor should select the wall type and design taking into account the soil conditions encountered in the boreholes.

The following parameters apply for design of the temporary shoring system:

$\gamma$	=	21 kN/m <sup>3</sup>	(bulk unit weight for fill)
	=	20 kN/m <sup>3</sup>	(bulk unit weight for native sand/silt)
$\gamma'$	=	11 kN/m <sup>3</sup>	(submerged unit weight for fill)
	=	10 kN/m <sup>3</sup>	(submerged unit weight for native sand/silt)
$K_a$	=	0.31	(active pressure coefficient for fill)
	=	0.35	(active earth pressure coefficient for native sand/silt)
$K_p$	=	3.3	(passive pressure coefficient for fill)
	=	2.9	(passive earth pressure coefficient for native sand/silt)

For free draining shoring systems, the short-term groundwater level should be assumed at the base of excavation both in front of and behind the wall.



The actual pressure distribution acting on the shoring system is a function of construction sequence and the relative flexibility of the wall and these factors must be considered when designing the shoring system.

### **13.3 Surface and Groundwater Control**

Subgrade preparation and construction of foundations must be carried out in the dry. All excavations for foundation construction must be dewatered prior to the placement of concrete, as per OPSS.PROV 902 and NSSP FOUN0003.

The Contractor must be prepared to control the groundwater and surface water flow at the site to permit construction in a dry and stable excavation. Water from either surface flow and/or groundwater must be diverted away from the excavation at all times. Groundwater perched within the embankment fill and surface runoff will tend to seep into and accumulate in open excavations.

Dewatering design and decisions regarding dewatering, must be carried out by the Contractor. Due to the shallow excavation depths being considered and the depth to groundwater at the site it is anticipated that conventional sump and pump techniques should be sufficient.

### **13.4 Erosion Protection**

The Contractor should provide silt fences and erosion control blankets as per OPSS.PROV 805 and OPSD 219.110 throughout the duration of construction to prevent transport of silt/sediment.

Slope protection and drainage measures will be required to ensure the long-term surficial stability of the embankment slopes. A vegetation cover should be established on all exposed earth surfaces to protect against surficial erosion in general accordance with OPSS.PROV 803 OPSS.PROV 804. Slope vegetation should be established as soon as possible after completion of construction in order to limit surficial erosion and water should be prevented from running down an unprotected slope.

## **14. CONSTRUCTION CONCERNS**

Potential construction concerns include, but are not necessarily limited to:

- Existing Foundations

It is noted that the proposed abutment and pier locations are in close proximity to the existing deep foundations. The layout of the new piles must avoid conflicts with existing piles.



- Obstructions (ie: boulders, buried debris)

Buried obstructions (e.g. mass concrete or grout placed to backfill the washout that occurred in the early 1980's) may be encountered during construction and interfere with excavations and installation of deep foundations and temporary protection/dewatering systems. The Contractor must be prepared to dislodge or penetrate such obstructions. Where obstructions are encountered near the surface, the Contractor may choose to remove such obstructions, provided it does not destabilize the existing embankment or foundation elements. A NSSP alerting bidders to the potential of encountering obstructions has been provided in Appendix I.

- Slope Stability

Care must be taken during construction to ensure the stability of the high fill slopes during construction of the widening.

- Protection Systems

The potential for movements of the existing structure and/or highway embankment during excavation for new foundations. Given that the existing structure is to remain in service during construction, appropriate temporary protection systems must be provided a monitoring plan should be developed and implemented during construction.

- Vibration Monitoring

Vibrations in the existing structure should be monitored during pile or caisson installation during staged construction to ensure stability. Suggested text for a vibration monitoring NSSP has been included in Appendix I.

- Equipment Selection

The Contractor's selection of construction equipment and methodology must include assessment of the capability of the existing soils to support the proposed construction equipment and supplies.

The successful performance of the project will depend largely upon good workmanship and quality control during construction. Observation of the excavation, foundation construction and backfilling operations by qualified geotechnical personnel will be required during construction to confirm that the foundation recommendations are correctly implemented and material specifications are met.



## 15. CLOSURE

Engineering analysis and preparation of this report were carried out by Mr. Christopher Murray, P.Eng. The report was reviewed Mr. Paul Carnaffan, P.Eng. and Dr. P.K. Chatterji, P.Eng., the Designated Principal Contact for MTO Foundation Projects.

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## STATEMENT OF LIMITATIONS AND CONDITIONS

### 1. STANDARD OF CARE

This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or made.

### 2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report, which is of a summary nature and is not intended to stand alone without reference to the instructions given to Thurber by the Client, communications between Thurber and the Client, and any other reports, proposals or documents prepared by Thurber for the Client relative to the specific site described herein, all of which together constitute the Report.

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### 3. BASIS OF REPORT

The Report has been prepared for the specific site, development, design objectives and purposes that were described to Thurber by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the Report, subject to the limitations provided herein, are only valid to the extent that the Report expressly addresses proposed development, design objectives and purposes, and then only to the extent that there has been no material alteration to or variation from any of the said descriptions provided to Thurber, unless Thurber is specifically requested by the Client to review and revise the Report in light of such alteration or variation.

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### 5. INTERPRETATION OF THE REPORT

- a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and the Report is delivered subject to the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. If special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.
- b) Reliance on Provided Information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to Thurber. Thurber has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Thurber does not accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by Thurber. Thurber is entitled to rely on such representations, information and instructions and is not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.
- c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.
- d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

### 6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

### 7. INDEPENDENT JUDGEMENTS OF CLIENT

The information, interpretations and conclusions in the Report are based on Thurber's interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Thurber does not accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.

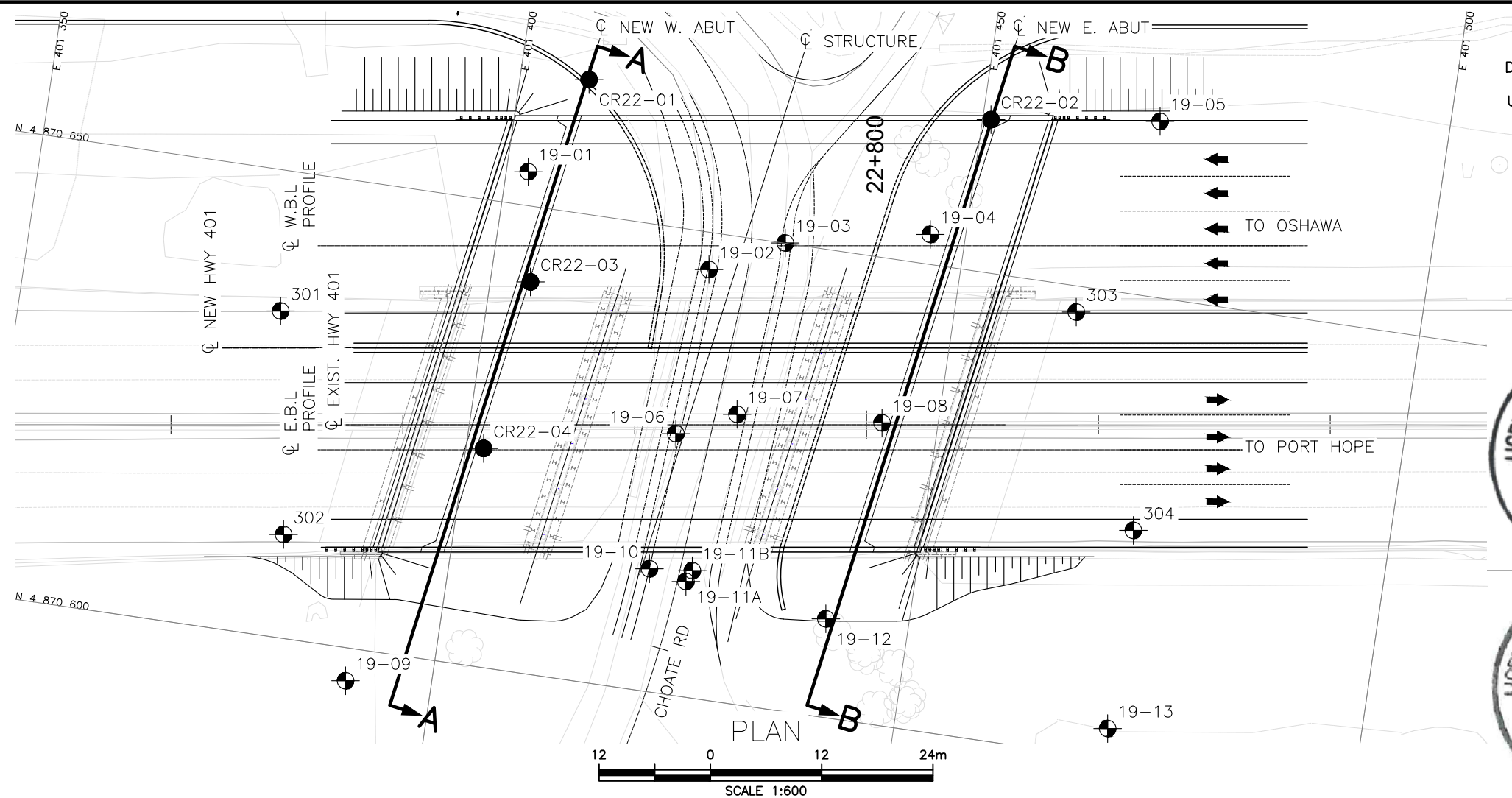


## **Appendix A Drawings**

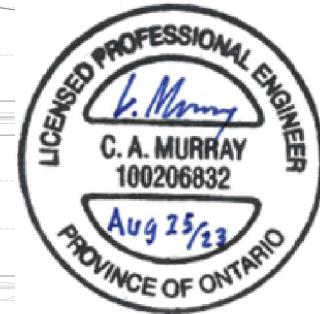
General Arrangement Drawing  
Borehole Locations and Stratra Drawing







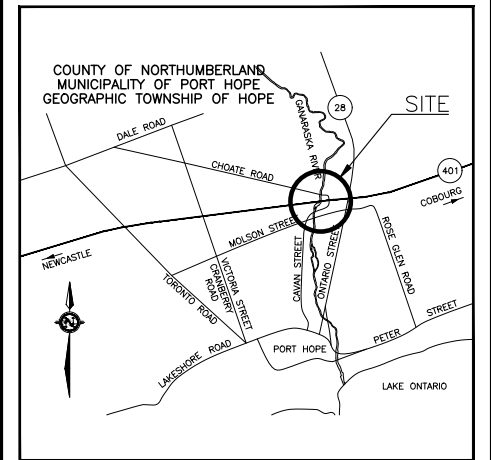
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AND/OR MILLIMETRES  
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HIGHWAY 401  
CHOATE ROAD OVERPASS  
BRIDGE REPLACEMENT  
BOREHOLE LOCATIONS AND SOIL STRATA

Ontario



KEYPLAN

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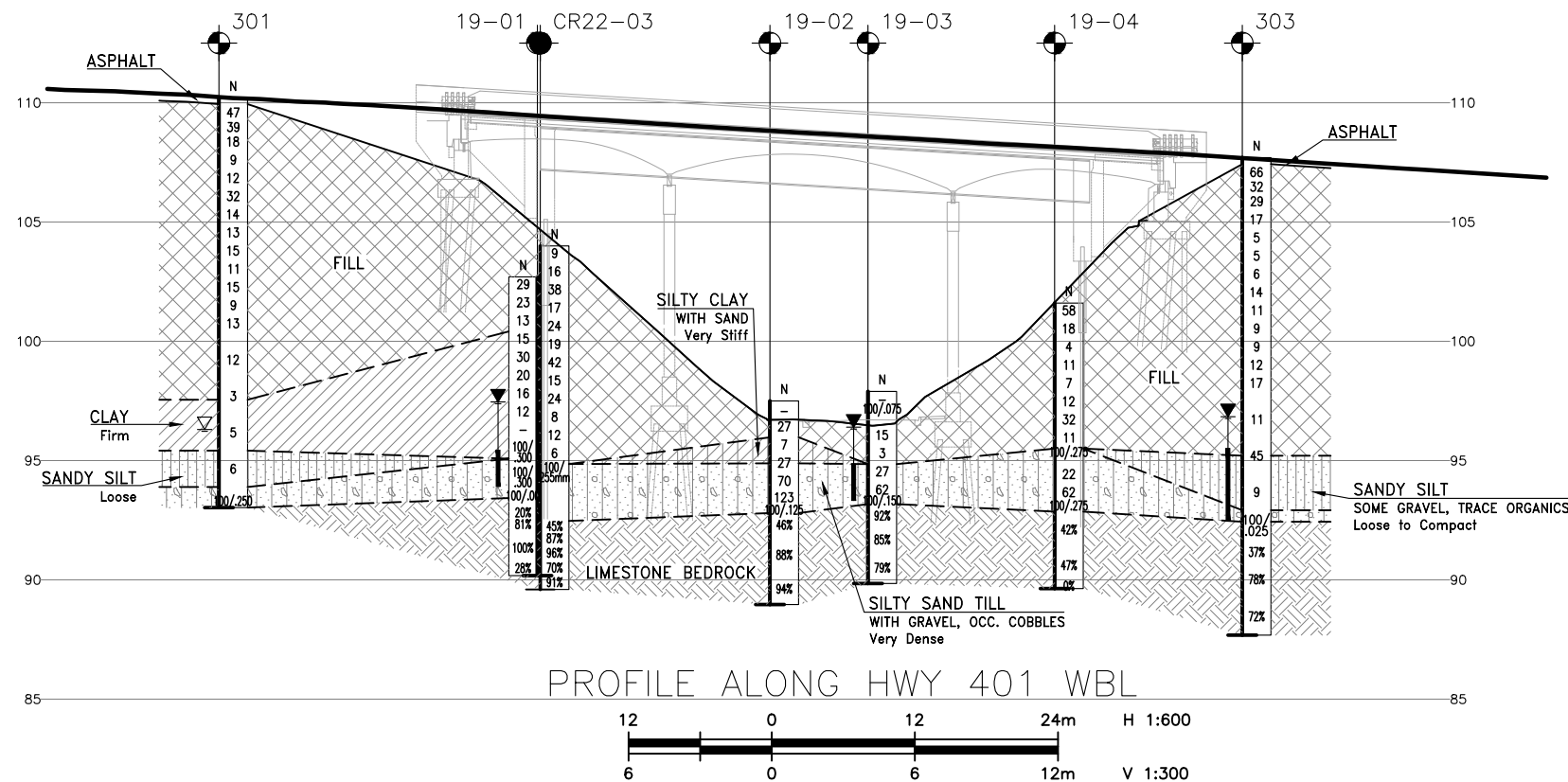
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⊙	Borehole (Previous Investigation)
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CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
≡	Water Level
≡	Head Artesian Water
≡	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
19-12	100.5	4 870 610.6	401 441.1
19-13	98.7	4 870 603.3	401 472.8
301	110.2	4 870 634.9	401 378.1
302	110.2	4 870 611.1	401 381.9
303	107.7	4 870 647.2	401 463.0
304	107.6	4 870 624.8	401 472.5
CR22-01	99.3	4 870 664.4	401 407.4
CR22-02	99.9	4 870 666.4	401 450.9
CR22-03	104.0	4 870 641.9	401 404.3
CR22-04	104.0	4 870 623.4	401 401.9
19-01	102.7	4 870 653.6	401 402.3
19-02	97.5	4 870 646.0	401 423.2
19-03	97.9	4 870 650.0	401 430.9
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19-06	97.0	4 870 628.0	401 422.2
19-07	97.2	4 870 631.0	401 428.4
19-08	102.2	4 870 632.4	401 444.0
19-09	104.0	4 870 596.5	401 390.8
19-10	96.7	4 870 613.2	401 421.5
19-11A	96.5	4 870 612.4	401 425.6
19-11B	96.6	4 870 613.6	401 426.1

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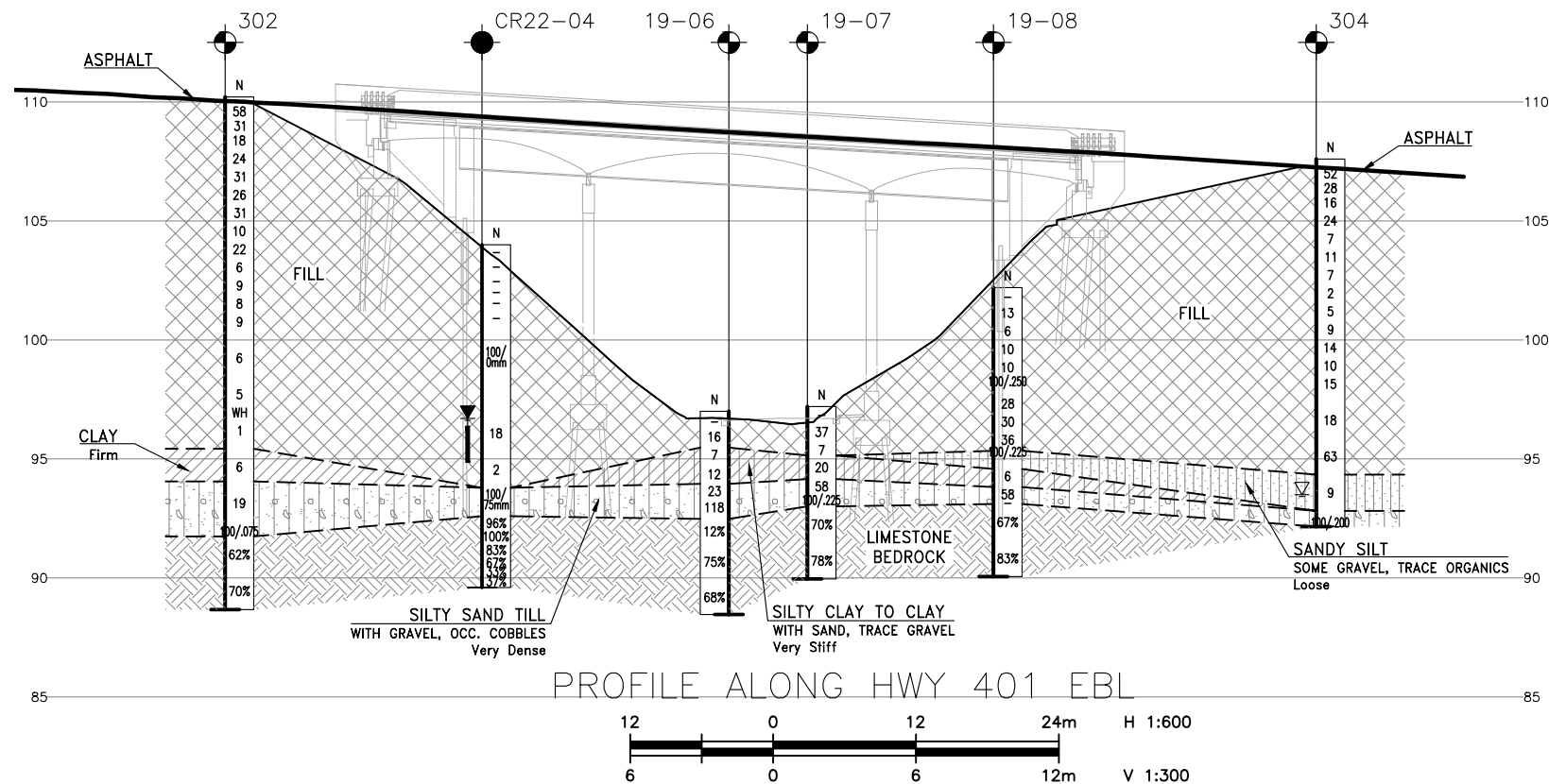
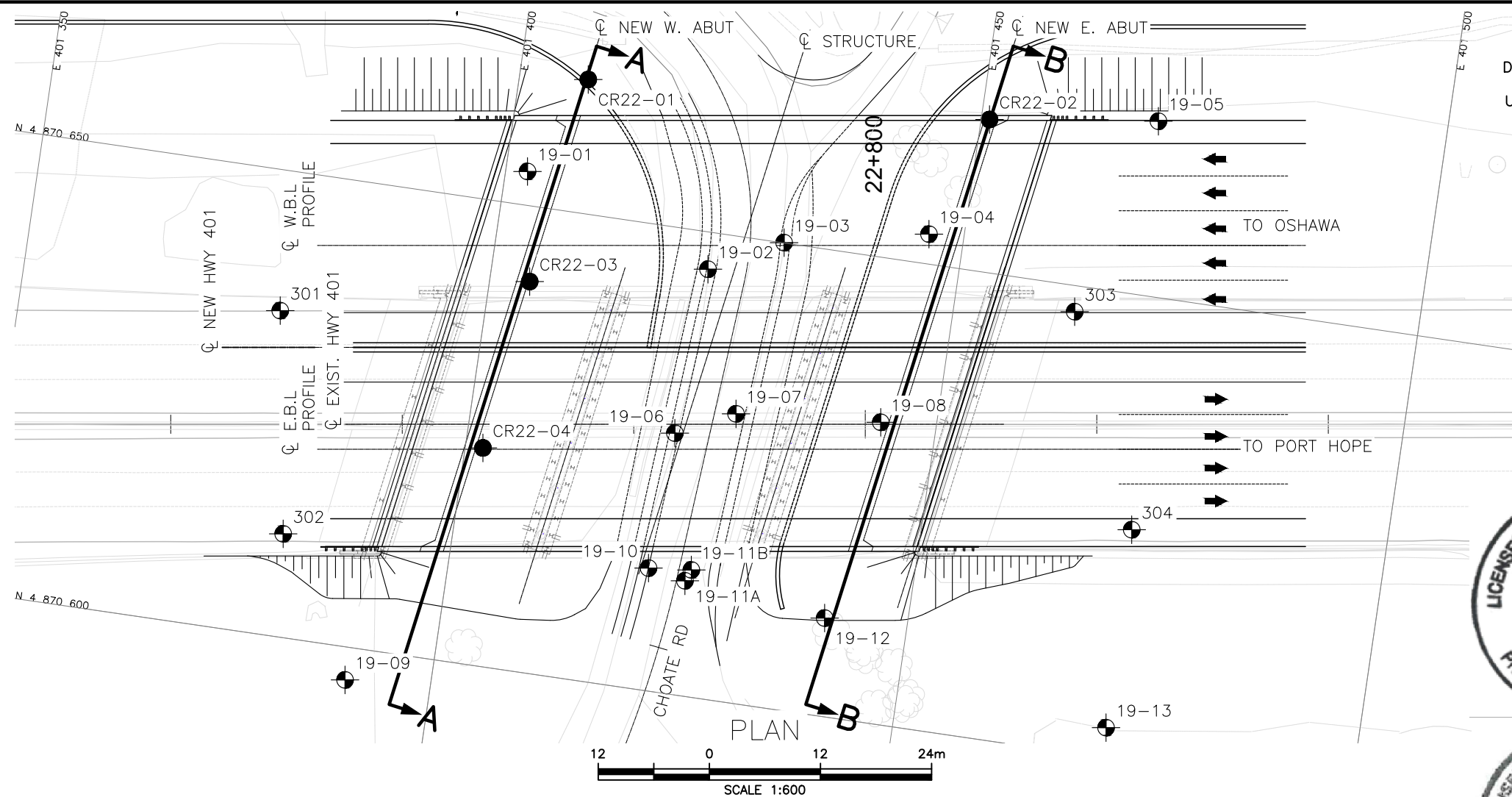
- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Coordinate system is MTM NAD 83 Zone 10.

GEOCRES No. 30M16-075



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LOAD	DATE	OCT 2022	
STRUCT	DWG	1	





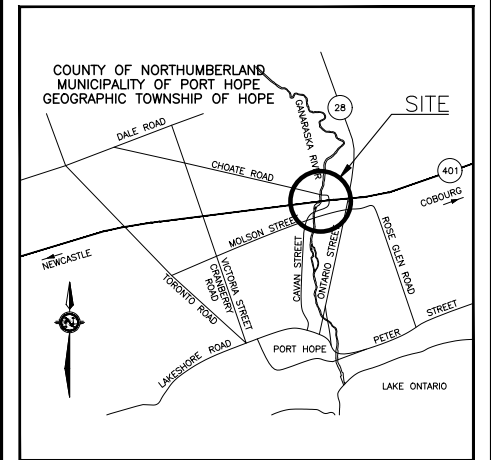
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WP No

HIGHWAY 401  
CHOATE ROAD OVERPASS  
BRIDGE REPLACEMENT  
BOREHOLE LOCATIONS AND SOIL STRATA

Ontario



KEYPLAN

LEGEND

●	Borehole (Current Investigation)
⊙	Borehole (Previous Investigation)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
W	Water Level
HA	Head Artesian Water
P	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
19-12	100.5	4 870 610.6	401 441.1
19-13	98.7	4 870 603.3	401 472.8
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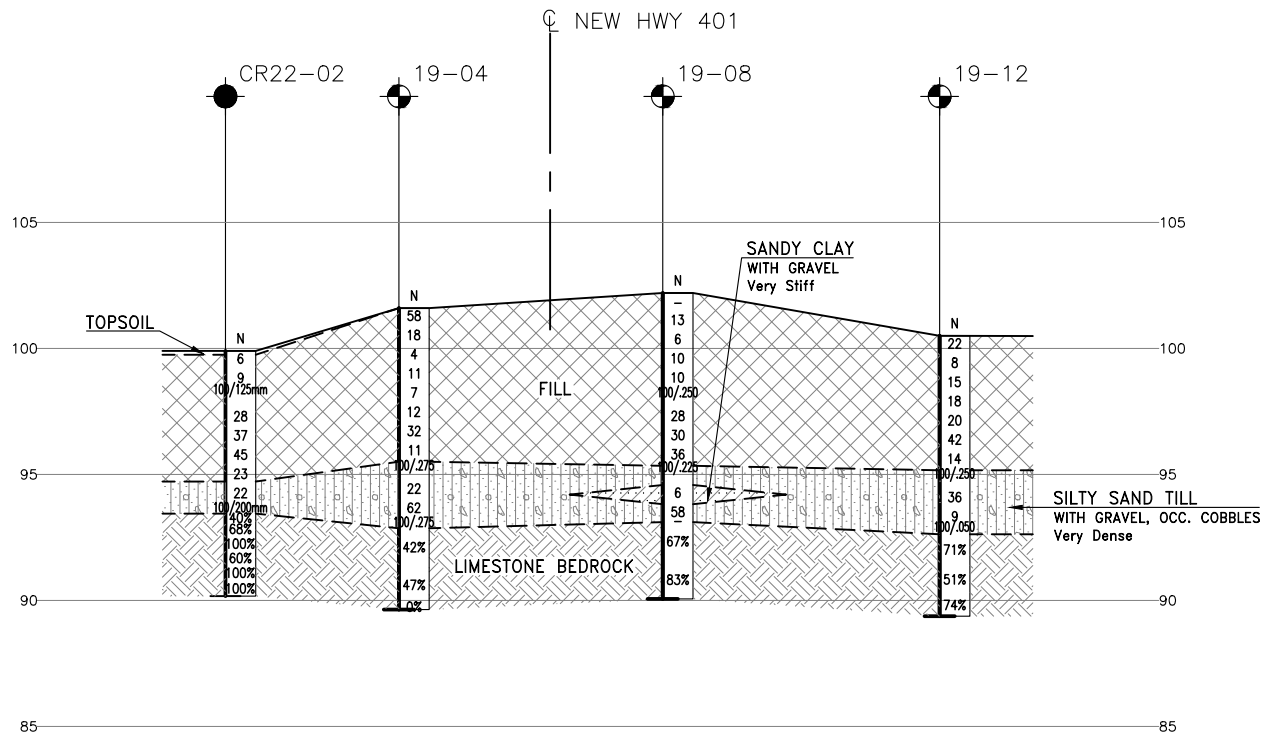
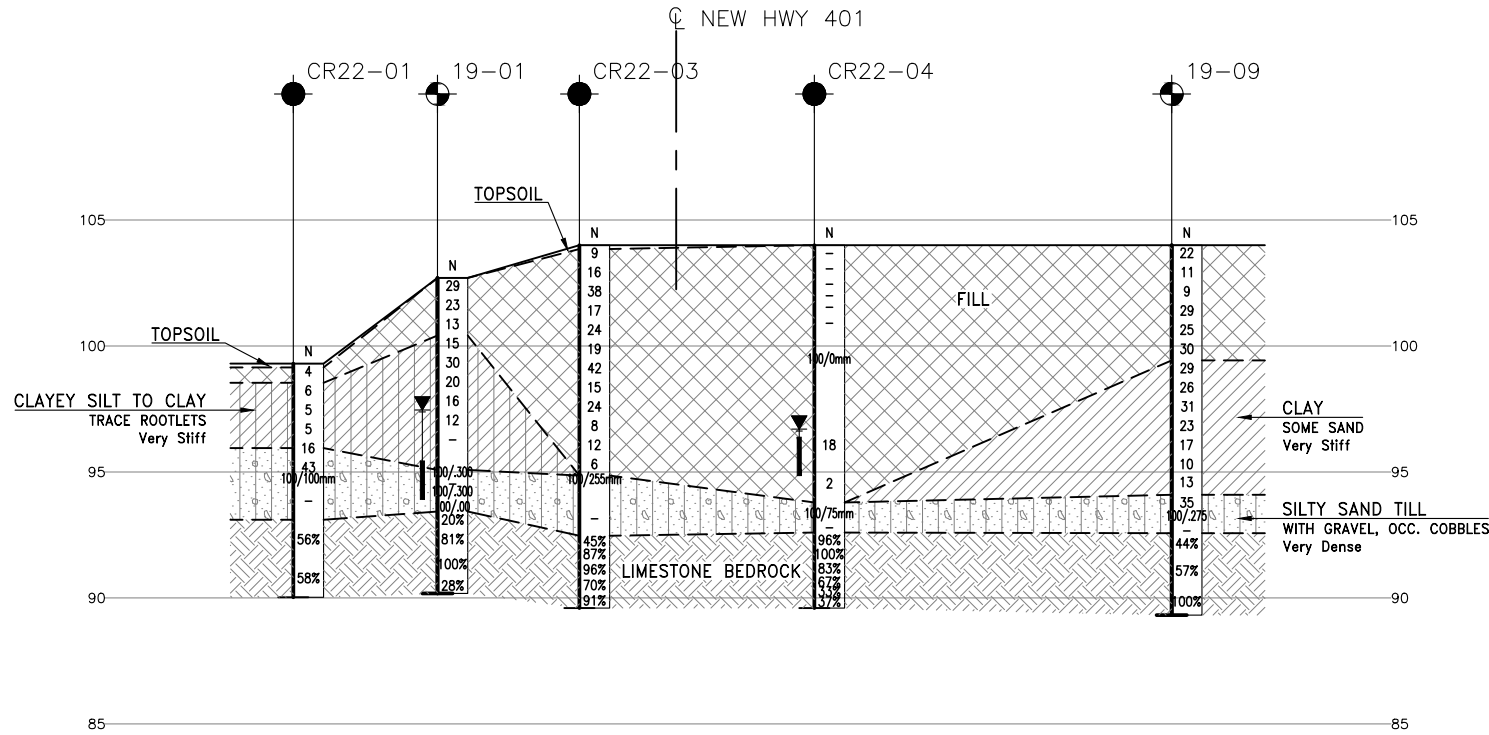
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GEORES No. 30M16-075

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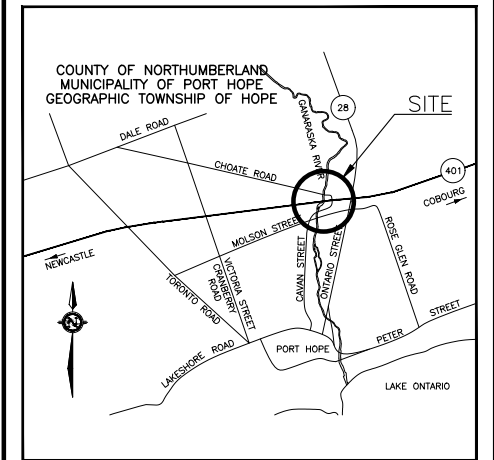


CONT No  
WP No

HIGHWAY 401  
CHOATE ROAD OVERPASS  
BRIDGE REPLACEMENT  
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

Ontario



KEYPLAN

LEGEND

●	Borehole (Current Investigation)
⊙	Borehole (Previous Investigation)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
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⌵	Piezometer
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NO	ELEVATION	NORTHING	EASTING
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GEOCRES No. 30M16-075

REVISIONS	DATE	BY	DESCRIPTION
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LOAD	DATE	OCT 2022	
STRUCT	DWG	3	



## **Appendix B   Field Investigation and Testing**

Symbols and Terms  
Record of Boreholes Sheets  
MASW Testing Report



## SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS

### TERMINOLOGY DESCRIBING COMMON SOIL GENESIS

Topsoil	mixture of soil and humus capable of supporting vegetative growth
Peat	mixture of fragments of decayed organic matter
Till	unstratified glacial deposit which may include particles ranging in sizes from clay to boulder
Fill	material below the surface identified as placed by humans (excluding buried services)

### TERMINOLOGY DESCRIBING SOIL STRUCTURE:

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

### RECOVERY:

For soil samples, the recovery is recorded as the length of the soil sample recovered.

### N-VALUE:

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 63.5 kg hammer falling 0.76 m, required to drive a 50 mm O.D. split spoon sampler 0.3 m into undisturbed soil. For samples where insufficient penetration was achieved and N-value cannot be presented, the number of blows are reported over the sampler penetration in millimetres (e.g. 50/75).

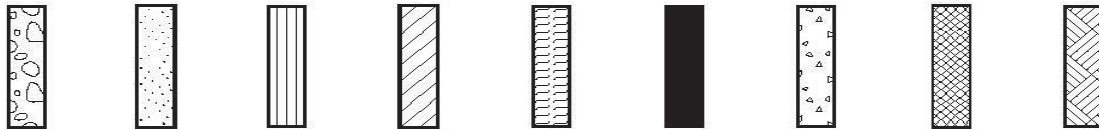
### DYNAMIC CONE PENETRATION TEST (DCPT):

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to an "A" size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone 0.3 m into the soil. The DCPT is used as a probe to assess soil variability.



### STRATA PLOT:

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



Boulders  
Cobbles  
Gravel      Sand      Silt      Clay      Organics      Asphalt      Concrete      Fill      Bedrock

### TEXTURING CLASSIFICATION OF SOILS

Classification	Particle Size
Boulders	Greater than 200 mm
Cobbles	75 – 200 mm
Gravel	4.75 – 75 mm
Sand	0.075 – 4.75 mm
Silt	0.002 – 0.075 mm
Clay	Less than 0.002 mm

### TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

Descriptive Term	Undrained Shear Strength (kPa)
Very Soft	12 or less
Soft	12 – 25
Firm	25 – 50
Stiff	50 – 100
Very Stiff	100 – 200
Hard	Greater than 200

NOTE: Clay sensitivity is defined as the ratio of the undisturbed strength over the remolded strength.

### SAMPLE TYPES

SS	Split spoon samples
ST	Shelby tube or thin wall tube
DP	Direct push sample
PS	Piston sample
BS	Bulk sample
WS	Wash sample
HQ, NQ, BQ etc.	Rock core sample obtained with the use of standard size diamond coring equipment

### TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

Descriptive Term	SPT “N” Value
Very Loose	Less than 4
Loose	4 – 10
Compact	10 – 30
Dense	30 – 50
Very Dense	Greater than 50

### MODIFIED UNIFIED SOIL CLASSIFICATION

Major Divisions		Group Symbol	Typical Description
COARSE GRAINED SOIL	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILT AND CLAY SOILS $W_L < 35\%$	ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		OL	Organic silts and organic silty-clays of low plasticity.
	SILT AND CLAY SOILS $35\% < W_L < 50\%$	MI	Inorganic compressible fine sandy silt with clay of medium plasticity, clayey silts.
		CI	Inorganic clays of medium plasticity, silty clays.
		OI	Organic silty clays of medium plasticity.
	SILT AND CLAY SOILS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy of silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other organic soils.

Note -  $W_L$  = Liquid Limit





## EXPLANATION OF ROCK LOGGING TERMS

### ROCK WEATHERING CLASSIFICATION

Fresh (FR)	No visible signs of weathering.
Fresh Jointed (FJ)	Weathering limited to surface of major discontinuities.
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock materials.
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structures are preserved.

### TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.
Solid Core Recovery: (SCR)	Percent ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1 m in length or larger, as a percentage of total core length
Unconfined Compressive Strength: (UCS)	Axial stress required to break the specimen.
Fracture Index: (FI)	Frequency of natural fractures per 0.3 m of core run.

### DISCONTINUITY SPACING

Bedding	Bedding Plane Spacing
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 to 2 m
Medium bedded	0.2 to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 to 60 mm
Laminated	6 to 20 mm
Thinly laminated	Less than 6 mm

### STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength (MPa)
Extremely Strong	Greater than 250
Very Strong	100 – 250
Strong	50 – 100
Medium Strong	25 – 50
Weak	5 – 25
Very Weak	1 – 5
Extremely Weak	0.25 – 1

# RECORD OF BOREHOLE No 301

1 OF 2

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.969357°, Long: -78.29638°  
Site 21-230, MTM Zone 10: N 4 870 634.9 E 401 378.1 ORIGINATED BY CM  
HWY 401 BOREHOLE TYPE HSA COMPILED BY CM  
DATUM Geodetic DATE 2016.05.31 - 2016.05.31 CHECKED BY KCP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								20 40 60 80 100				w <sub>p</sub> w w <sub>L</sub>				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE								
110.2																
0.0 110.0	260 mm ASPHALT															
0.3	SILTY SAND with gravel dense brown FILL		1	SS	47											
			2	SS	39											
108.7																
1.5	SILTY SAND, some gravel compact brown FILL		3	SS	18											
108.0																
2.3	SILTY SAND, clayey, trace gravel loose to dense brown FILL		4	SS	9										7 45 34 14	
			5	SS	12											
			6	SS	32											
			7	SS	14										7 53 40 (SI+CL)	
104.9																
5.3	SILTY SAND loose to compact brown FILL		8	SS	13											
			9	SS	15											
			10	SS	11										1 77 22 (SI+CL)	
			11	SS	15											
			12	SS	9											
			13	SS	13											

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+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity 20  
15 10 5 10 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 301

2 OF 2

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.969357°, Long: -78.29638° Site 21-230, MTM Zone 10: N 4 870 634.9 E 401 378.1 ORIGINATED BY CM  
 HWY 401 BOREHOLE TYPE HSA COMPILED BY CM  
 DATUM Geodetic DATE 2016.05.31 - 2016.05.31 CHECKED BY KCP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								○ UNCONFINED      + FIELD VANE						
								● QUICK TRIAXIAL      × LAB VANE						
							WATER CONTENT (%)							
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# RECORD OF BOREHOLE No 302

1 OF 3

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.969143°, Long: -78.296337° Site 21-230, MTM Zone 10: N 4 870 611.1 E 401 381.9 ORIGINATED BY CM  
 HWY 401 BOREHOLE TYPE HSA / HQ Coring COMPILED BY CM  
 DATUM Geodetic DATE 2016.06.01 - 2016.06.01 CHECKED BY KCP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								20 40 60 80 100					
								20 40 60 80 100					
110.2													
0.0													
109.9													
0.3	SILTY SAND with gravel dense brown		1	SS	58								33 53 14 (SI+CL)
109.3	FILL												
0.9	SILTY SAND, some gravel compact to dense brown		2	SS	31								
	FILL												
			3	SS	18								
			4	SS	24								
			5	SS	31								
			6	SS	26								
			7	SS	31								
			8	SS	10								
			9	SS	22								
103.4													
6.9	SILTY SAND loose brown		10	SS	6								2 72 26 (SI+CL)
	FILL												
			11	SS	9								
			12	SS	8								1 84 15 (SI+CL)
			13	SS	9								

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+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity








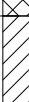
20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 302

2 OF 3

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.969143°, Long: -78.296337° Site 21-230, MTM Zone 10: N 4 870 611.1 E 401 381.9 ORIGINATED BY CM  
 HWY 401 BOREHOLE TYPE HSA / HQ Coring COMPILED BY CM  
 DATUM Geodetic DATE 2016.06.01 - 2016.06.01 CHECKED BY KCP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				W P      W      W L				GR   SA   SI   CL				
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE				WATER CONTENT (%)								
	Continued From Previous Page						20	40	60	80	100									
97.3	SILTY SAND loose brown FILL																			
			14	SS	6															
13.0	SILTY SAND to sandy SILT very loose brown FILL																			
			15	SS	5															
95.4	CLAY (CL) firm grey																			
			16	SS	WH															
14.8	CLAY (CL) firm grey																			
			17	SS	1															
94.1	CLAY (CL) firm grey																			
			18	SS	6															
16.2	SILTY SAND (SM) with gravel TILL compact to very dense grey slight hydrocarbon odour																			
			19	SS	19															
91.8	BEDROCK limestone faintly weathered to fresh fair quality moderately bedded grey																			
			20	SS	100/															
18.5	BEDROCK limestone faintly weathered to fresh fair quality moderately bedded grey																			
			1	RUN	75mm															

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+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 302

3 OF 3

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.969143°, Long: -78.296337°  
 HWY 401 BOREHOLE TYPE HSA / HQ Coring Site 21-230, MTM Zone 10: N 4 870 611.1 E 401 381.9  
 DATUM Geodetic DATE 2016.06.01 - 2016.06.01  
 ORIGINATED BY CM  
 COMPILED BY CM  
 CHECKED BY KCP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE				WATER CONTENT (%) w <sub>P</sub> w      w <sub>L</sub>				
	Continued From Previous Page						20	40	60	80	100					
	<b>BEDROCK</b> limestone faintly weathered to fresh fair quality moderately bedded grey		2	RUN												
88.7																
21.5	End of Borehole Borehole dry on completion of drilling prior to coring															

**METRIC**

Lat: 43.969457°, Long: -78.295319°  
Site 21-230, MTM Zone 10: N 4 870 647.2 E 401 463.0

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+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

**METRIC**[illegible]

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# RECORD OF BOREHOLE No 303

3 OF 3

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.969457°, Long: -78.295319°  
 Site 21-230, MTM Zone 10: N 4 870 647.2 E 401 463.0 ORIGINATED BY CM  
 HWY 401 BOREHOLE TYPE HSA / HQ Coring COMPILED BY CM  
 DATUM Geodetic DATE 2016.05.30 - 2016.05.30 CHECKED BY KCP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
20.0	End of Borehole  Standpipe Readings: Date      Depth (m)      Elev. (m) 05/31/2016      10.9      96.8													

DOUBLE LINE 22645 CHOATE RD.GPJ 2012TEMPLATE(MTO).GDT 10/2/20

# RECORD OF BOREHOLE No 304

1 OF 2

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.969254°, Long: -78.295205° Site 21-230, MTM Zone 10: N 4 870 624.8 E 401 472.5 ORIGINATED BY CM  
 HWY 401 BOREHOLE TYPE HSA COMPILED BY CM  
 DATUM Geodetic DATE 2016.06.01 - 2016.06.01 CHECKED BY KCP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
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107.6								<div><div>20406080100</div><div>○ UNCONFINED      + FIELD VANE</div><div>● QUICK TRIAXIAL    × LAB VANE</div></div>																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						

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+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 304

2 OF 2

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.969254°, Long: -78.295205° Site 21-230, MTM Zone 10: N 4 870 624.8 E 401 472.5 ORIGINATED BY CM  
 HWY 401 BOREHOLE TYPE HSA COMPILED BY CM  
 DATUM Geodetic DATE 2016.06.01 - 2016.06.01 CHECKED BY KCP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)  w <sub>p</sub> w      w <sub>L</sub>		
								20   40   60   80   100									
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE									
	Continued From Previous Page																
	SILTY SAND compact brown FILL						97										
			14	SS	18												
95.9							96										
11.7	SAND some gravel very dense grey																
			15	SS	63		95										
94.4																	
13.3	Sandy SILT (ML) some gravel, trace organics loose brown						94										
			16	SS	9												
92.8							93										
14.8	GRAVEL (GM), Silty with Sand TILL very dense brown																
92.2			17	SS	100/												
15.4	End of Borehole Groundwater level was measured in the open borehole at 14.1 m BGS (elev. 93.5 m) on 2016/06/01				200mm									49 34 17 (SI+CL)			

DOUBLE LINE 22645 CHOATE RD.GPJ 2012TEMPLATE(MTO).GDT 10/2/20

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 19-01

1 OF 2

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.969523°, Long: -78.296074°  
 HWY 401 BOREHOLE TYPE Portable / NW casing / NQ coring ORIGINATED BY NW  
 DATUM Geodetic DATE 2019.02.23 - 2019.02.24 COMPILED BY AC  
 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)					
102.7								20	40	60	80	100						
0.0	Clayey SILT some sand and organic matter compact brown		1	SS	29									○				
102.1	FILL																	
0.6	CLAY with sand very stiff brown			2	SS	23								○				
	FILL																	
			3	SS	13									├─○─┤			2 27 47 24	
100.4																		
2.3	CLAY (CI) very stiff brown		4	SS	15									○				
				5	SS	30								├─○─┤			2 6 50 42	
				6	SS	20								○				
				7	SS	16								├─○─┤			0 4 46 50	
				8	SS	12								├─○─┤				
	- Unable to turn vane, >106 kPa												>>├─┤	○				
96.7																		
6.0	CLAY (CL) firm grey		1	ST	-									├─○─┤			0 1 52 47 OED: e <sub>s</sub> =0.661 C <sub>c</sub> =0.188 C <sub>r</sub> =0.039	
95.1																		
7.6	SILTY SAND (SM) with gravel, occasional cobbles TILL very dense grey - 110 mm cobble at 7.9 m		9	SS	100/300 mm									○				
				1	GS	-									○			
				10	SS	100/300 mm									○			24 56 20 (SI+CL)
93.4			11	SS	100/0 mm													
9.3	BEDROCK limestone		1	RUN	-												RUN #1 TCR=100% SCR=100% RQD=20%	

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

DOUBLE LINE 22645 CHOATE RD.GPJ 2012TEMPLATE(MTO).GDT 10/2/20

## METRIC

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

# RECORD OF BOREHOLE No 19-02

1 OF 1

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.969451°, Long: -78.295816° Site 21-230, MTM Zone 10: N 4 870 646.0 E 401 423.2 ORIGINATED BY AC  
 HWY 401 BOREHOLE TYPE HSA / NQ coring COMPILED BY AC  
 DATUM Geodetic DATE 2019.02.21 - 2019.02.21 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
								20	40	60	80	100	W <sub>P</sub>	W	W <sub>L</sub>		
97.5																	
0.0																	
0.1	ASPHALT (75 mm)																
	SAND with silt and gravel compact dark brown to brown FILL		1	GS	-							o					
			2	SS	27							o				31 59 10 (SI+CL)	
96.0																	
1.5	SILTY CLAY (CL-ML) with sand very stiff grey-brown		3	SS	7							o				1 15 62 22	
94.9			4	SS	27							o					
2.6	SILTY SAND (SM) with gravel, occasional cobbles TILL very dense grey-brown to grey											o					
			5	SS	70							o				30 43 21 6 non-plastic	
			6	SS	123							o					
92.8			7	SS	100/							o					
4.7	BEDROCK limestone with silt seams slightly weathered fine grained thinly bedded grey		1	RUN	-	125 mm										RUN #1 TCR=97% SCR=69% RQD=46%	
			2	RUN	-											RUN #2 TCR=100% SCR=88% RQD=88%	
			3	RUN	-											RUN #3 TCR=100% SCR=94% RQD=94%	
89.0																	
8.5	End of Borehole																

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 19-03

1 OF 1

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.969487°, Long: -78.295719° Site 21-230, MTM Zone 10: N 4 870 650.0 E 401 430.9 ORIGINATED BY SOB  
 HWY 401 BOREHOLE TYPE HSA / NQ coring COMPILED BY AC  
 DATUM Geodetic DATE 2019.02.19 - 2019.02.19 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
97.9								20	40	60	80	100				
0.0																
0.1	ASPHALT (75 mm)															
	SILTY SAND with gravel very dense brown FILL		1	GS	-									o		25 60 15 (SI+CL)
			2	SS	100/ 75 mm									o		
96.4																
1.5	SILTY SAND with gravel compact brown FILL		3	SS	15									o		27 43 30 (SI+CL)
95.6														o		
2.3	SILTY SAND very loose grey FILL		4	SS	3									o		1 59 32 8 non-plastic
94.9														o		
3.0	SILTY SAND (SM) with gravel TILL compact to very dense brown		5	SS	27									o		
			6	SS	62									o		20 55 25 (SI+CL)
93.2			7	SS	100/ 150 mm									o		
4.7	BEDROCK limestone fresh fine grained thinly bedded grey		1	RUN	-										FI 2	RUN #1 TCR=100% SCR=100% RQD=92% UCS=106.4MPa
			2	RUN	-										2	RUN #2 TCR=100% SCR=93% RQD=85%
			3	RUN	-										1	RUN #3 TCR=100% SCR=92% RQD=79%
89.8															3	
															2	
															6	
8.1	End of Borehole														2	
Standpipe Readings:																
Date		Depth (m)	Elev. (m)													
02/21/2019		1.5	96.4													
02/23/2019		1.6	96.3													
02/24/2019		1.5	96.4													
02/25/2019		1.5	96.4													

DOUBLE LINE 22645 CHOATE RD.GPJ 2012TEMPLATE(MTO).GDT 10/2/20

# RECORD OF BOREHOLE No 19-04

1 OF 2

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.969513°, Long: -78.295527° Site 21-230, MTM Zone 10: N 4 870 653.2 E 401 446.2 ORIGINATED BY NW  
 HWY 401 BOREHOLE TYPE Portable / NW casing / NQ coring COMPILED BY AC  
 DATUM Geodetic DATE 2019.02.25 - 2019.02.26 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)					
								20	40	60	80	100	W <sub>P</sub>	W	W <sub>L</sub>			
101.6	0.0	SILT with sand some organics frozen brown FILL	1	SS	58													
101.0	0.6	SILTY CLAYEY SAND, trace gravel compact brown FILL	2	SS	18													8 43 33 16
100.1	1.5	CLAY with sand very stiff brown FILL	3	SS	4													
			4	SS	11													
			5	SS	7													1 14 47 38
97.8	3.8	SILTY SAND with gravel compact to dense grey FILL	6	SS	12													
			7	SS	32													
			8	SS	11													17 48 28 7 non-plastic
95.5	6.1	SAND (SP-SM) with silt some gravel TILL compact to very dense grey	9	SS	100/ 275 mm													
			10	SS	22													10 79 11 (SI+CL)
			11	SS	62													
			12	SS	100/ 275 mm													
92.9	8.7	BEDROCK limestone fresh fine grained thinly bedded grey	1	RUN	-													RUN #1 TCR=97% SCR=97% RQD=42%

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity 20  
15 10 5 10 (%) STRAIN AT FAILURE

DOUBLE LINE 22645 CHOATE RD.GPJ 2012TEMPLATE(MTO).GDT 10/2/20




# RECORD OF BOREHOLE No 19-04

2 OF 2

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.969513°, Long: -78.295527°  
 HWY 401 BOREHOLE TYPE Portable / NW casing / NQ coring ORIGINATED BY NW  
 DATUM Geodetic DATE 2019.02.25 - 2019.02.26 COMPILED BY AC  
 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)						
								20   40   60   80   100	○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE			W <sub>P</sub> W      W <sub>L</sub>						
	Continued From Previous Page							20	40	60	80	100	20	40	60			
	<b>BEDROCK</b> limestone fresh fine grained thinly bedded grey						91										3  1  3  2  3  9  2	RUN #2 TCR=100% SCR=95% RQD=47%  RUN #3 TCR=100% SCR=100% RQD=0%
			2	RUN	-													
89.6			3	RUN	-		90											
12.0	End of Borehole  A half-weight (32 kg) drop hammer was used to advance the split-spoon sampler. The "N" values above have been corrected to estimate the "N" value that would have been obtained with a standard 64 kg hammer.																	

# RECORD OF BOREHOLE No 19-05

1 OF 2

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.969651°, Long: -78.295241°  
Site 21-230, MTM Zone 10: N 4 870 668.9 E 401 469.0 ORIGINATED BY NW  
HWY 401 BOREHOLE TYPE Portable / NW casing / NQ coring COMPILED BY AC  
DATUM Geodetic DATE 2019.02.21 - 2019.02.22 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC      NATURAL      LIQUID LIMIT      MOISTURE      LIMIT CONTENT		
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Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

DOUBLE LINE 22645 CHOATE RD.GPJ 2012TEMPLATE(MTO).GDT 10/2/20

# RECORD OF BOREHOLE No 19-05

2 OF 2

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.969651°, Long: -78.295241°  
 HWY 401 BOREHOLE TYPE Portable / NW casing / NQ coring Site 21-230, MTM Zone 10: N 4 870 668.9 E 401 469.0  
 DATUM Geodetic DATE 2019.02.21 - 2019.02.22 ORIGINATED BY NW  
 COMPILED BY AC  
 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page																
89.6	<b>BEDROCK</b> limestone																
10.4	slightly weathered to fresh fine grained thinly bedded grey																
	End of Borehole																
	A half-weight (32 kg) drop hammer was used to advance the split-spoon sampler. The "N" values above have been corrected to estimate the "N" value that would have been obtained with a standard 64 kg hammer.																

# RECORD OF BOREHOLE No 19-06

1 OF 1

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.969289°, Long: -78.295832° Site 21-230, MTM Zone 10: N 4 870 628.0 E 401 422.2 ORIGINATED BY AC  
 HWY 401 BOREHOLE TYPE HSA / NQ coring COMPILED BY AC  
 DATUM Geodetic DATE 2019.02.21 - 2019.02.21 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT				UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)						
								20    40    60    80    100					W P                      W                      W L						
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE											
97.0							20	40	60	80	100								
0.0 0.1		ASPHALT (75 mm)																	
		SAND with silt and gravel compact grey-brown FILL		1	GS	-													
				2	SS	16													
95.5																			
1.5		CLAY (CL) trace sand very stiff brown		3	SS	7													
				4	SS	12													
94.0																			
3.0		SILTY SAND (SM) with gravel TILL compact to very dense grey-brown		5	SS	23													
				6	SS	118													
92.5																			
4.5		BEDROCK limestone with silt seams slightly weathered fine grained thinly bedded grey		1	RUN	-													
				2	RUN	-													
				3	RUN	-													
88.5																			
8.5		End of Borehole																	

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20  
15 10 5 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 19-07

1 OF 1

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.969316°, Long: -78.295753° Site 21-230, MTM Zone 10: N 4 870 631.0 E 401 428.4 ORIGINATED BY SOB  
HWY 401 BOREHOLE TYPE HSA / NQ coring COMPILED BY AC  
DATUM Geodetic DATE 2019.02.19 - 2019.02.19 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
97.2														
0.0	ASPHALT (75 mm)													
0.1	SILTY SAND with gravel dense brown FILL		1	GS	-									
			2	SS	37									
95.7														
1.5	SILTY CLAYEY SAND loose brown FILL		3	SS	7									1 51 33 15
95.1														
2.1	SILTY CLAY (CL-ML) with sand trace gravel very stiff brown													
			4	SS	20									9 15 46 30
94.2														
3.0	SILTY SAND with gravel, occasional cobbles and boulders TILL very dense brown		5	SS	58									
			6	SS	100/ 225 mm									
93.0														
4.2	BEDROCK limestone with silt seams slightly weathered fine grained thinly bedded grey													
			1	RUN	-									RUN #1 TCR=100% SCR=90% RQD=70%
			2	RUN	-									RUN #2 TCR=100% SCR=90% RQD=78%
90.0														
7.2	End of Borehole													

DOUBLE LINE 22645 CHOATE RD.GPJ 2012TEMPLATE(MTO).GDT 10/2/20

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 19-08

1 OF 2

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.969326°, Long: -78.295559° Site 21-230, MTM Zone 10: N 4 870 632.4 E 401 444.0 ORIGINATED BY SOB  
 HWY 401 BOREHOLE TYPE Portable / NW casing / NQ coring COMPILED BY AC  
 DATUM Geodetic DATE 2019.02.21 - 2019.02.22 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>P</sub>			NATURAL MOISTURE CONTENT W			LIQUID LIMIT W <sub>L</sub>			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
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+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

DOUBLE LINE 22645 CHOATE RD.GPJ 2012TEMPLATE(MTO).GDT 10/2/20

# RECORD OF BOREHOLE No 19-08

2 OF 2

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.969326°, Long: -78.295559° Site 21-230, MTM Zone 10: N 4 870 632.4 E 401 444.0 ORIGINATED BY SOB  
 HWY 401 BOREHOLE TYPE Portable / NW casing / NQ coring COMPILED BY AC  
 DATUM Geodetic DATE 2019.02.21 - 2019.02.22 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT  $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
								20 40 60 80 100					
Continued From Previous Page							<div><div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></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+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 19-09

1 OF 2

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.96901°, Long: -78.296228° Site 21-230, MTM Zone 10: N 4 870 596.5 E 401 390.8 ORIGINATED BY SOB  
 HWY 401 BOREHOLE TYPE Portable / NW casing / NQ coring COMPILED BY AC  
 DATUM Geodetic DATE 2019.02.23 - 2019.02.25 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
								20	40	60	80	100	W <sub>P</sub>	W	W <sub>L</sub>		
104.0																	
0.0	SILTY SAND some gravel loose to compact brown FILL		1	SS	22												
			2	SS	11												
			3	SS	9												
			4	SS	29												
			5	SS	25												
100.2																	
3.8	SAND with silt some gravel dense brown FILL		6	SS	30												
99.4																	
4.6	CLAY (CL) some sand very stiff brown to tan		7	SS	29												
			8	SS	26												

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE



# RECORD OF BOREHOLE No 19-09

2 OF 2

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.96901°, Long: -78.296228° Site 21-230, MTM Zone 10: N 4 870 596.5 E 401 390.8 ORIGINATED BY SOB  
 HWY 401 BOREHOLE TYPE Portable / NW casing / NQ coring COMPILED BY AC  
 DATUM Geodetic DATE 2019.02.23 - 2019.02.25 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)								
								20   40   60   80   100	○ UNCONFINED      + FIELD VANE			w <sub>p</sub> w      w <sub>L</sub>								
Continued From Previous Page																				
9.9	<b>SILTY SAND</b> trace gravel, occasional cobbles and boulders <b>TILL</b> dense to very dense brown		15	SS	35		93										9   78   13 (SI+CL)			
			16	SS	100/ 275 mm															
92.6			17	NQ	-															
11.4	<b>BEDROCK</b> limestone with silt seams slightly weathered fine grained thinly bedded grey		1	RUN	-		92										RUN #1 TCR=94% SCR=75% RQD=44%			
			2	RUN	-															RUN #2 TCR=91% SCR=77% RQD=57%
			3	RUN	-															
89.3							90										RUN #3 TCR=100% SCR=100% RQD=100%			
14.7	End of Borehole																			
	A half-weight (32 kg) drop hammer was used to advance the split-spoon sampler. The "N" values above have been corrected to estimate the "N" value that would have been obtained with a standard 64 kg hammer.																			

# RECORD OF BOREHOLE No 19-10

1 OF 1

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.969156°, Long: -78.295843° Site 21-230, MTM Zone 10: N 4 870 613.2 E 401 421.5 ORIGINATED BY AC  
 HWY 401 BOREHOLE TYPE HSA / NQ coring COMPILED BY AC  
 DATUM Geodetic DATE 2019.02.20 - 2019.02.20 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W P W W L				GR	SA	SI	CL
96.7								20	40	60	80	100								
0.0								20	40	60	80	100								
0.1	ASPHALT (75 mm)																			
	SAND with silt and gravel compact brown to grey-brown FILL		1	GS	-															35 54 11 (SI+CL)
95.4			2	SS	21															
1.3	WOOD some sand and organic matter black FILL																			Organic Content 2.0%
			3	SS	26															
			4	SS	50															
			5	SS	40															Organic Content 9.9%
93.2																				
3.5	GRAVEL (GW-GM) with silt and sand TILL dense to very dense grey																			59 31 10 (SI+CL)
92.6			6	SS	100/ 275 mm															
4.1	BEDROCK limestone with silt seams moderately weathered to fresh fine grained thinly bedded grey																			
			1	RUN	-															RUN #1 TCR=96% SCR=38% RQD=8%
			2	RUN	-															RUN #2 TCR=91% SCR=48% RQD=33%
			3	RUN	-															RUN #3 TCR=100% SCR=97% RQD=88%
88.1																				
8.6	End of Borehole																			
	Standpipe Readings:																			
	Date Depth (m) Elev. (m)																			
	02/21/2019 1.0 95.7																			
	02/23/2019 1.1 95.6																			
	02/24/2019 1.1 95.6																			
	02/25/2019 1.1 95.6																			

DOUBLE LINE 22645 CHOATE RD.GPJ 2012TEMPLATE(MTO).GDT 10/2/20

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 19-11A

1 OF 1

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.969148°, Long: -78.295792° Site 21-230, MTM Zone 10: N 4 870 612.4 E 401 425.6 ORIGINATED BY AC  
 HWY 401 BOREHOLE TYPE HSA / NQ coring COMPILED BY AC  
 DATUM Geodetic DATE 2019.02.20 - 2019.02.20 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT				UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)					
								20	40	60	80	100	W <sub>P</sub>	W	W <sub>L</sub>		
96.5																	
0.0																	
0.1	ASPHALT (75 mm)																
	SILTY SAND some gravel compact to dense brown to black FILL		1	GS	-		96										
			2	SS	43												
							95										
	- some organics at 1.7 m		3	SS	10												
94.4																	
2.1	CLAY (Cl) with sand stiff grey to grey-brown		4	SS	4		94										
			5	SS	18												
93.0							93										
3.5	GRAVEL (GM), silty with sand, occasional cobbles TILL very dense brown to grey-brown		6	SS	100/ 300 mm												
91.9							92										
4.6	BEDROCK limestone with silt seams slightly weathered fine grained thinly bedded grey		1	RUN	-												
							91										
			2	RUN	-		90										
			3	RUN	-		89										
88.5																	
8.0	End of Borehole																



+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 19-11B

1 OF 1

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.96916°, Long: -78.295786° Site 21-230, MTM Zone 10: N 4 870 613.6 E 401 426.1 ORIGINATED BY AC  
 HWY 401 BOREHOLE TYPE HSA / NQ coring COMPILED BY AC  
 DATUM Geodetic DATE 2019.02.21 - 2019.02.21 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
96.6								20	40	60	80	100		
0.0	Augered to 2.7 m													
93.9														
2.7	CLAY (Cl), some sand stiff brown		1	ST	-									0 10 47 43
93.2														
3.4	End of Borehole													OED: e <sub>0</sub> =1.083 C <sub>c</sub> =0.265 C <sub>r</sub> =0.102

# RECORD OF BOREHOLE No 19-12

1 OF 2

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.96913°, Long: -78.295599° Site 21-230, MTM Zone 10: N 4 870 610.6 E 401 441.1 ORIGINATED BY AC/SOB  
 HWY 401 BOREHOLE TYPE Portable / NW casing / NQ coring COMPILED BY AC  
 DATUM Geodetic DATE 2019.02.19 - 2019.02.20 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)						
								20	40	60	80	100	W <sub>P</sub>	W			W <sub>L</sub>	
100.5																		
0.0	Silty, Clayey SAND with organics compact dark brown FILL		1	SS	22													
99.9																		
0.6	SANDY CLAY some organics and wood very stiff grey to brown FILL		2	SS	8												3 31 42 24	
			3	SS	15													
98.2																		
2.3	SILTY SAND with gravel compact brown FILL		4	SS	18												16 40 31 13 non-plastic	
97.5																		
3.0	Sandy SILT trace gravel, some wood compact to dense grey-brown FILL		5	SS	20												7 41 38 14 non-plastic	
			6	SS	42													
			7	SS	14													
95.2																		
5.3	SILTY SAND with gravel TILL loose to very dense grey-brown		8	SS	100/ 250 mm													
			9	SS	36													
			10	SS	9													
			11	SS	100/ 50 mm													
92.6																		
7.9	BEDROCK limestone with silt seams slightly weathered fine grained thinly bedded grey		1	RUN	-												RUN #1 TCR=98% SCR=88% RQD=71%	
			2	RUN	-												RUN #2 TCR=100% SCR=100% RQD=51%	

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

## METRIC

[illegible]

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

## METRIC

Lat: 43.96906°, Long: -78.295205°  
Site 21-230, MTM Zone 10: N 4 870 603.3 E 401 472.8

DOUBLE LINE 22645 CHOATERD.GPJ 2012TEMPLATE(MTO).GDT 10/2/20

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

# RECORD OF BOREHOLE No 19-13

2 OF 2

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.96906°, Long: -78.295205°  
Site 21-230, MTM Zone 10: N 4 870 603.3 E 401 472.8 ORIGINATED BY NW  
HWY 401 BOREHOLE TYPE Portable / NW casing / NQ coring COMPILED BY AC  
DATUM Geodetic DATE 2019.02.19 - 2019.02.21 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page																
88.4	<b>BEDROCK</b> limestone with silt seams slightly weathered fine grained thinly bedded grey														2		
10.3	End of Borehole  A half-weight (32 kg) drop hammer was used to advance the split-spoon sampler. The "N" values above have been corrected to estimate the "N" value that would have been obtained with a standard 64 kg hammer.  Standpipe Readings: Date      Depth (m)      Elev. (m) 02/23/2019      4.6      94.1 02/24/2019      4.7      94.0 02/25/2019      4.7      94.0 03/16/2019      4.7      94.0																



# RECORD OF BOREHOLE No CR22-01

1 OF 1

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.969619°, Long: -78.296009° Highway 401/ Choate Road, MTM z10: N 4 870 664.4 E 401 407.4 ORIGINATED BY JZL  
 HWY 401 BOREHOLE TYPE D50 Track Mount/ NW Casing / NQ Coring COMPILED BY AO  
 DATUM Geodetic DATE 2022.05.07 - 2022.05.07 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
99.3	Ground Surface							20	40	60	80	100					GR SA SI CL
0.0	TOPSOIL (150 mm)																
0.2	SANDY SILT some Gravel Trace Clay and Organics Loose		1	SS	4		99										10 28 48 14
98.5	Dark brown																
0.8	FILL																
	CLAYEY SILT (CL) trace rootlets Very stiff Brown to light brown		2	SS	6		98										
			3	SS	5												
			4	SS	5		97										0 1 50 49
95.9	-S <sub>u</sub> > 106 kPa		5	SS	16		96										
3.4	SILTY SAND with Gravel Occasional cobbles Dense to very dense Light brown GLACIAL TILL		6	SS	43		95										17 52 25 6
			7	SS	100/												
	-Frequent Cobbles and Boulders below 4.7 m				100mm												
			1	NQ	-		94										
93.1																	
6.2	LIMESTONE BEDROCK Slightly weathered to Fresh Grey Fine grained Thinly to medium bedded Strong to very strong		1	RUN	-		93										

DOUBLE LINE 33089 - HWY 401 CHOATE AND GANARASKA DD.GPJ 2012TEMPLATE(MTO).GDT 22-9-29

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10





(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No CR22-02

1 OF 2

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.969631°, Long: -78.295467° Highway 401/ Choate Road, MTM z10: N 4 870 666.4 E 401 450.9 ORIGINATED BY JZL  
 HWY 401 BOREHOLE TYPE Portable / NW Casing / NQ Coring COMPILED BY AO  
 DATUM Geodetic DATE 2022.04.18 - 2022.04.19 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)
99.9	Ground Surface							20	40	60	80	100						
0.0	TOPSOIL (150 mm)							20	40	60	80	100						
0.2	SANDY CLAYEY SILT trace Gravel and Organics Occasional cobbles Loose to Very Dense Brownish grey FILL		1	SS	6													
			2	SS	9													
			3	SS	100/ 125mm													
97.6																		
2.3	SILTY CLAYEY SAND with Gravel Compact to Dense Dark grey FILL		4	SS	28													
			5	SS	37													
			6	SS	45													
			7	SS	23													
94.7																		
5.2	SANDY SILT with Gravel Occasional Cobbles and Boulders Compact to Very Dense Grey GLACIAL TILL		8	SS	22													
			9	SS	100/ 200mm													
93.4																		
6.5	LIMESTONE BEDROCK Slightly weathered to Fresh Grey Fine grained Thinly to medium bedded Strong to very strong		1	RUN	-													
			2	RUN	-													
			3	RUN	-													
			4	RUN	-													
			5	RUN	-													
			6	RUN	-													
90.2																		
9.7	End of Borehole																	

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
 20  
 15  
 10  
 (%) STRAIN AT FAILURE

## METRIC

[illegible]




+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

# RECORD OF BOREHOLE No CR22-03

1 OF 2

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.969417°, Long: -78.296052° Highway 401/ Choate Road, MTM z10: N 4 870 641.9 E 401 404.3 ORIGINATED BY JZL/AO  
 HWY 401 BOREHOLE TYPE Portable / NW Casing / NQ Coring COMPILED BY AO  
 DATUM Geodetic DATE 2022.04.20 - 2022.04.26 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE										WATER CONTENT (%)
104.0	Ground Surface							20	40	60	80	100		20	40	60		GR SA SI CL
0.0	TOPSOIL (150 mm)																	
0.2	SILTY SAND trace Gravel, trace Clay Occasional Cobbles and Boulders Loose to dense Brown FILL		1	SS	9									○				0 70 30 (SI+CL)
			2	SS	16		103						●					
			3	SS	38		102						○					
			4	SS	17								○					0 70 24 6
			5	SS	24		101						○					
			6	SS	19		100						○					
			7	SS	42		99						○					
			8	SS	15		98						○					15 74 11 (SI+CL)
			9	SS	24		97						○					
			10	SS	8		96						○					1 77 9 13
			11	SS	12													
			12	SS	6								○					
94.9																		
9.1	SILTY SAND with Gravel Frequent Cobbles and Boulders Very Dense Grey GLACIAL TILL		13	SS	100/ 255mm									○				

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 (%) STRAIN AT FAILURE

DOUBLE LINE 33059 - HWY 401 CHOATE AND GANARASKA DD.GPJ 2012TEMPLATE(MTO).GDT 22-9-29

## METRIC

[illegible]

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity

# RECORD OF BOREHOLE No CR22-04

1 OF 2

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.969251°, Long: -78.296086° Highway 401/ Choate Road, MTM z10: N 4 870 623.4 E 401 401.9 ORIGINATED BY JZL/AO  
 HWY 401 BOREHOLE TYPE Portable / NW Casing / NQ Coring COMPILED BY AO  
 DATUM Geodetic DATE 2022.04.28 - 2022.05.05 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w <sub>P</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)
104.0	Ground Surface							20	40	60	80	100					GR SA SI CL
0.0	CONCRETE and BOULDERS FILL		1	NQ	-												
			2	NQ	-												
			3	NQ	-												
			4	NQ	-												
			5	NQ	-												
			6	NQ	-												
100.3	INFERRED COBBLES with Sand Infill FILL																
3.7	Note: Portable NW Casing became blocked within Cobbles at 4.6 m. Unable to clear blockage to conduct splitspoon samples until 7.6 m		1	SS	100/0mm												
96.4																	
7.6	SAND (SP) some to trace Silt Compact to Very Loose Brown FILL		2	SS	18												1 92 7 (SI+CL)
			3	SS	2												3 96 1 (SI+CL)

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No CR22-04

2 OF 2

METRIC

GWP# 4068-14-00 LOCATION Lat: 43.969251°, Long: -78.296086° Highway 401/ Choate Road, MTM z10: N 4 870 623.4 E 401 401.9 ORIGINATED BY JZL/AO  
 HWY 401 BOREHOLE TYPE Portable / NW Casing / NQ Coring COMPILED BY AO  
 DATUM Geodetic DATE 2022.04.28 - 2022.05.05 CHECKED BY CM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page							20	40	60	80	100					GR SA SI CL
93.8																	
10.2	SILTY SAND with Gravel Frequent Cobbles and Boulders Very Dense Grey GLACIAL TILL		4	SS	100/ 75mm		93									FI	
92.6			1	NQ	-											2	
11.4	LIMESTONE BEDROCK Fresh Grey Fine grained Thinly to medium bedded Strong to very strong		2	RUN	-		92									0	RUN #2 TCR=100% SCR=96% RQD=96%
			3	RUN	-											2	RUN #3 TCR=100% SCR=100% RQD=100%
			4	RUN	-		91									3	RUN #4 TCR=93% SCR=93% RQD=83%
			5	RUN	-											1	RUN #5 TCR=97% SCR=94% RQD=67%
			6	RUN	-											3	RUN #6 TCR=95% SCR=83% RQD=33%
			7	RUN	-		90									2	RUN #7 TCR=95% SCR=65% RQD=37%
89.6																6	
14.4	End of Borehole Monitoring well installed consists of 38-mm diameter Schedule 40 PVC pipe with a 1.5-m slotted screen. Water level readings: DATE      DEPTH (m)      ELEV. (m) 2022.05.09      6.3      97.7 2022.09.26      7.3      96.7 2022.09.30      7.3      96.7  Note: A half-weight hammer was used to advance the split-spoon sampler. The "N" values presented above have been adjusted to provide an estimate of the "N" value that would have been obtained with a standard hammer.																

DOUBLE LINE 33059 - HWY 401 CHOATE AND GANARASKA DD.GPJ 2012TEMPLATE(MTO).GDT 22-9-29



**GEOPHYSICS GPR INTERNATIONAL INC.**

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gprtor@gprtor.com  
www.geophysicsgpr.com

March 7, 2019

GPR file: T191229

Christopher Murray, M.A.Sc., P.Eng.  
Geotechnical Engineer  
**Thurber Engineering Ltd.**  
2460 Lancaster, Suite 104  
Ottawa, Ontario  
K1B 4S5

**RE: Shear-wave velocity sounding at Highway 401 & Choate Road, Port Hope, Ontario**

Dear Mr. Murray:

Geophysics GPR International Inc. has been requested by Thurber to carry out a shear-wave velocity sounding at the above site in Port Hope. Figure 1 shows the location of the test profile.

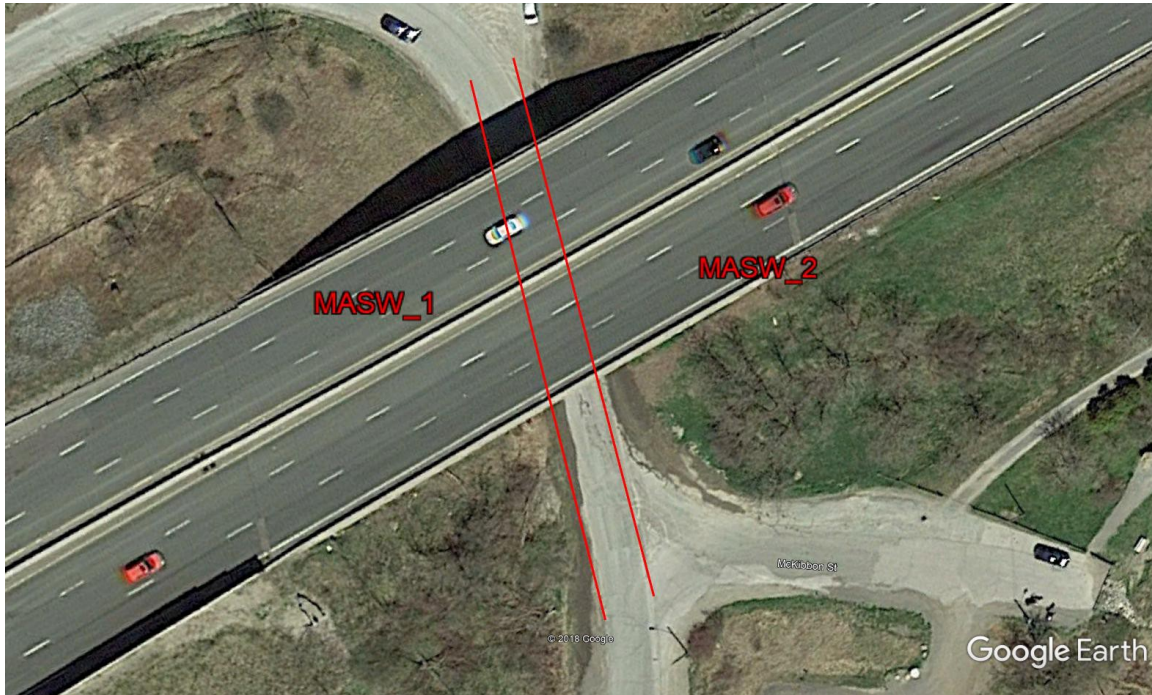
The survey was performed on February 26<sup>th</sup>, 2019.

The investigation included the multi-channel analysis of surface waves (MASW), the micro-tremor array measurements (MAM) and the refraction methods to generate a shear-wave velocity model (Figures 4 & 5).

The following paragraphs describe the survey design, the principles of the test method, the methodology for interpreting the data, and provide a culmination of the results in table format.







**Figure 1:** Approximate location of the shear-wave velocity soundings

## **MASW and MAM Surveys**

### ***Basic Theory***

The Multi-channel Analysis of Surface Waves (MASW) and the Micro-tremor Array Measurements (MAM) are seismic methods used to evaluate the shear-wave velocities of subsurface materials through the analysis of the dispersion properties of Rayleigh surface waves (“ground roll”). The dispersion properties are measured as a change in phase velocity with frequency. Surface wave energy will decay exponentially with depth. Lower frequency surface waves will travel deeper and thus be more influenced by deeper velocity layering than the shallow higher frequency waves. Inversion of the Rayleigh wave dispersion curve yields a shear-wave ( $V_s$ ) velocity depth profile (sounding). Figure 2 outlines the basic operating procedure for the MASW method. Figure 3 is an example image of a typical MASW record and resulting 1D  $V_s$  model. A more detailed description of the method can be found in the paper *Multi-channel Analysis of Surface Waves*, Park, C.B., Miller, R.D. and Xia, J. *Geophysics*, Vol. 64, No. 3 (May-June 1999); P. 800–808.

### ***Survey Design***

The geometry of an MASW survey is similar to that of a seismic refraction investigation (i.e. 24 geophones in a linear array). The fundamental principle involves intentionally generating an acoustic wave at the surface and digitally recording the surface waves from the moment of source impact with a linear series of geophones on the surface. This is referred to as an “active source” method. An elastic-wave hammer was used as the primary energy source with traces being recorded at 6 locations: approximately 6 m off both ends, 25 to 30 m



off both ends, and in the middle of the spread. Data were collected with geophones spacing of 3m and 1m for a total of 10 shot records per sounding.

Unlike the refraction method, which produces a data point beneath each geophone, the shear-wave depth profile is the average of the bulk area within the middle third of the geophone spread.

The theoretical maximum depth of penetration (34.5m) is half of the maximum seismic array length (69 m), in practice the maximum depth of penetration is often influenced by the geology.

The MAM/passive survey used the same geophone array set up as for the MASW survey. Unlike the MASW survey, the MAM method is considered a “passive source” method in that there is no time break and the motions recorded are from ambient energy generated by cultural noise such as traffic, wind, wave motion, etc. Data collection for the passive method involves recording approximately 10 minutes of background “noise.” The records generated by the MAM method contain lower frequency data, thus increasing the data resolution at greater depths of investigation. Typically the MAM results aid in clarifying the MASW results for depths greater than 20 m; however, the direction of noise propagation relative to the spread orientation can influence the results.

### ***Interpretation Method and Accuracy of Results***

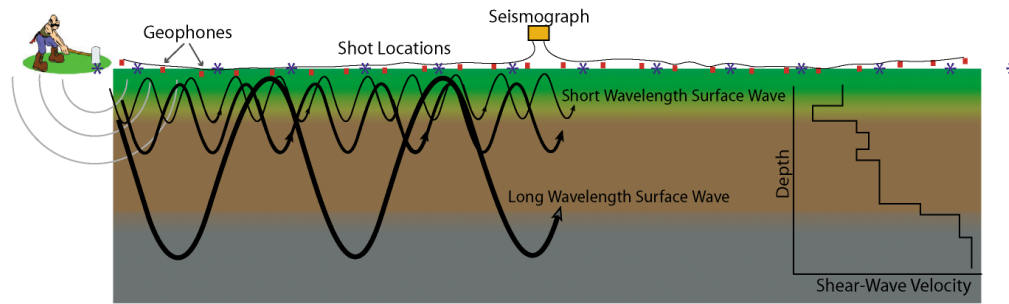
The main processing sequence involved plotting, picking, and 1-D inversion of the MASW/MAM shot records using the SeisimagerSW™ software package. In theory, all MASW shot records should produce a similar shear-wave velocity profile. In practice, however, differences can arise due to energy dissipation and localized surface variations. The results of the inversion process are inherently non-unique and the final model must be judged to be geologically realistic. The inversion modelling also assumes that all layering is flat/horizontal and laterally uniform.

The results of the MASW/MAM tests are presented in chart format as Figures 4 & 5. The chart presents the 1-D shear wave velocity values from the inversion models of the passive and active seismic records.

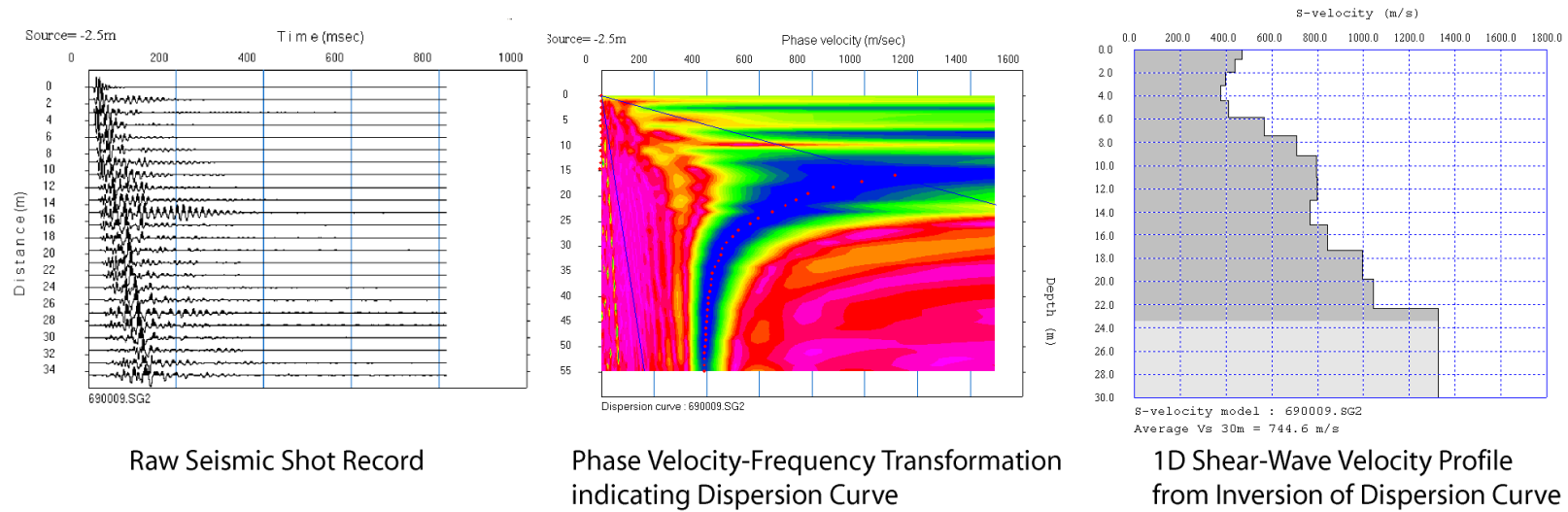
The  $V_{s30}$  values for the sounding are presented in Table 1. The  $V_{s30}$  values are based on the harmonic mean of the shear wave velocities over the upper 30 m. The  $V_{s30}$  value is calculated by dividing the total depth of interest (e.g. 30 m) by the sum of the time spent in each velocity layer up to that depth. This harmonic mean value reflects the equivalent single layer response.

The estimated error in the average  $V_{s30}$  value determined through MASW tests is typically +/-10 to 15% for overburden sites. The shear-wave velocities modelled through the MASW method within bedrock have a higher estimated error.



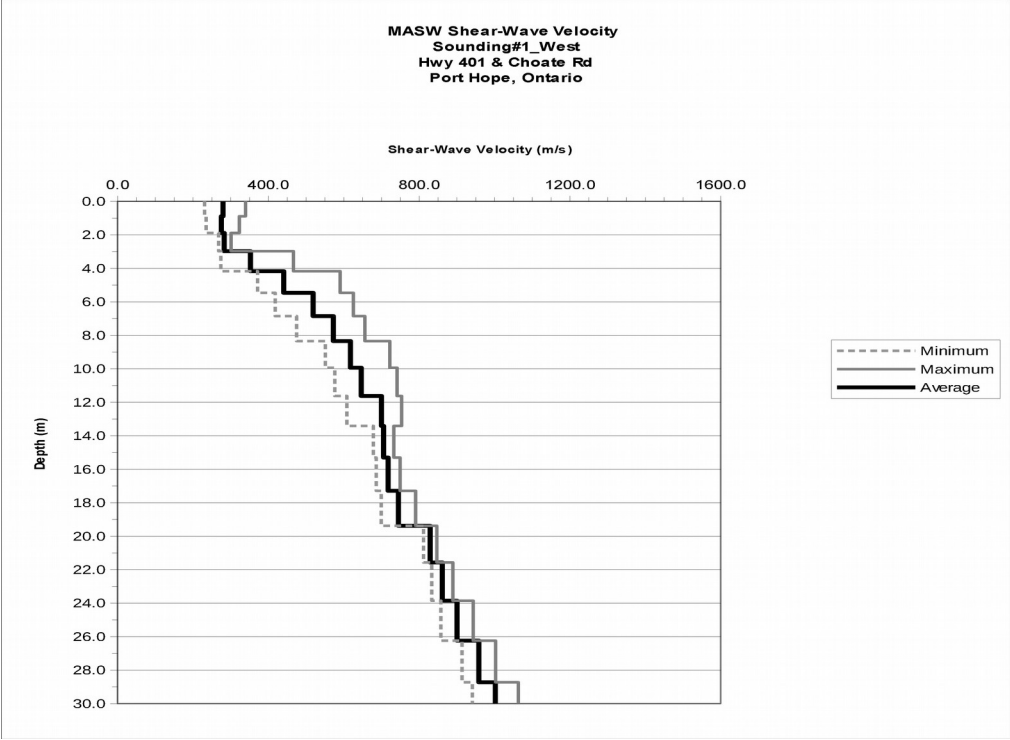


**Figure 2: MASW Operating Principle**

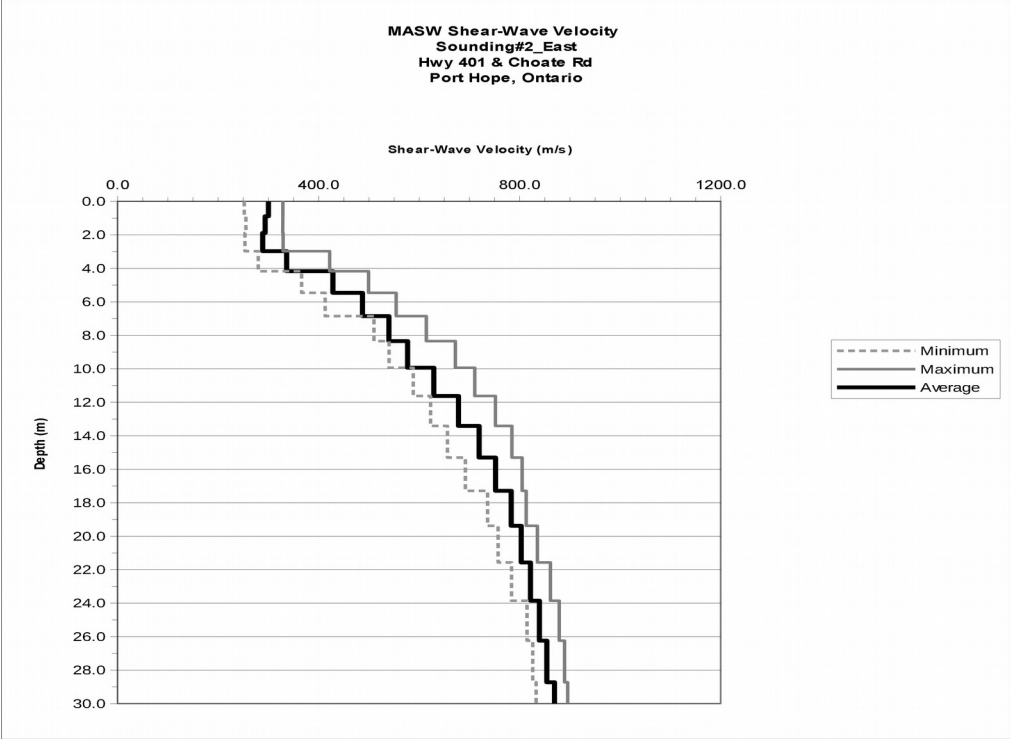


**Figure 3: Example of a typical MASW shot record, phase velocity/frequency curve and resulting 1D shear-wave velocity model.**





**Figure 4: MASW Shear-wave Velocity Sounding**



**Figure 5: MASW Shear-wave Velocity Sounding**



## CONCLUSIONS

The approximate location of the shear-wave sounding is indicated in Figure 1.

The MASW shear-wave models are presented in Figures 4 and 5. The results are summarized in Table 1. The background seismic noise levels at this site were high. The quality of the seismic records and the resulting dispersion were good.

Simple critical distance calculations from refracted P-waves show that the bedrock could be at 4.5m deep. MASW models were not constrained with refraction results.

No boreholes or geotechnical data were available at the time of this report.

**Table 1: Calculated  $V_s30$  values (m/s) from the MASW data (0 to 30m)**

Sounding	Minimum	Average	Maximum	Site Class
1 - West	534	<b>599</b>	672	<b>C</b>
2 - East	532	<b>588</b>	650	<b>C</b>

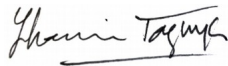
The calculated average  $V_s30$  values from the 1D MASW soundings collected was 599 and 588m/s +/-15% to 20% respectively for soundings 1 and 2.

The  $V_s30$  values calculated for the minimum and the maximum envelopes ranged from 532 to 672m/s.

Based on the average  $V_s30$  values (as determined through the MASW method) and table 4.1.8.4.A of the National Building Code of Canada, 2015 Edition, the investigated area is site class "C" ( $360 < V_s30 \leq 760$  m/s).

It must be noted that the site classification provided in this report is based solely on the  $V_s30$  value as derived from the MASW method and that it can be superseded by other geotechnical information. This geotechnical information includes, but is not limited to, the presence of sensitive and/or liquefiable soils, more than 3m of soft clays, high moisture content, etc. The reader is referred to section 4.1.8.4 of the National Building Code of Canada, 2015 Edition for more information on the requirements for site classification.

This report has been written by Lhoucin Taghya, P.Geo.



Lhoucin Taghya, P.Geo.  
Geophysicist





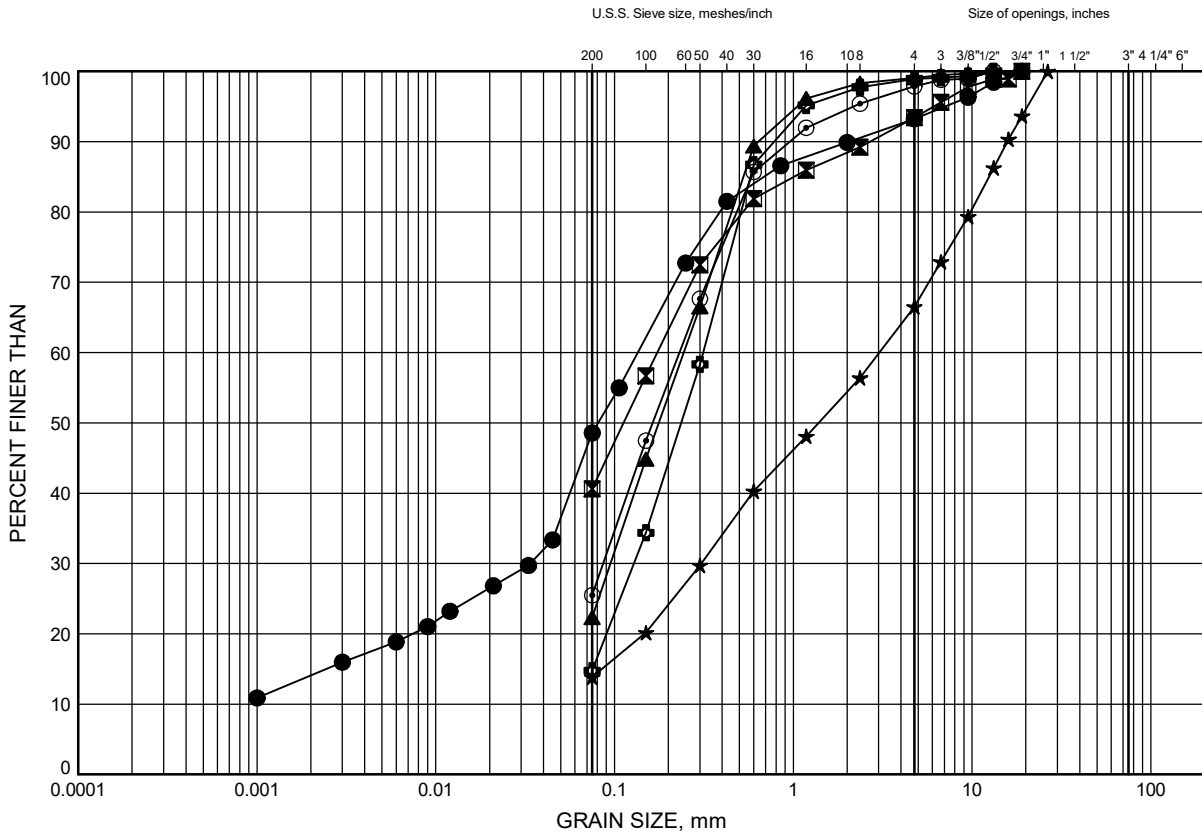
## **Appendix C   Laboratory Testing**

Particle Size Analysis Figures  
Atterberg Limits Figures  
Unconfined Compressive Strength Testing Results  
Analytical Testing Results  
Bedrock Core Photographs



# GRAIN SIZE DISTRIBUTION

## Granular Fill - Sand



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	301	2.5	107.7
⊠	301	4.9	105.4
▲	301	7.2	103.1
★	302	0.6	109.6
⊙	302	7.2	103.1
⊕	302	8.7	101.5

Date September 2022

GWP# 4068-14-00

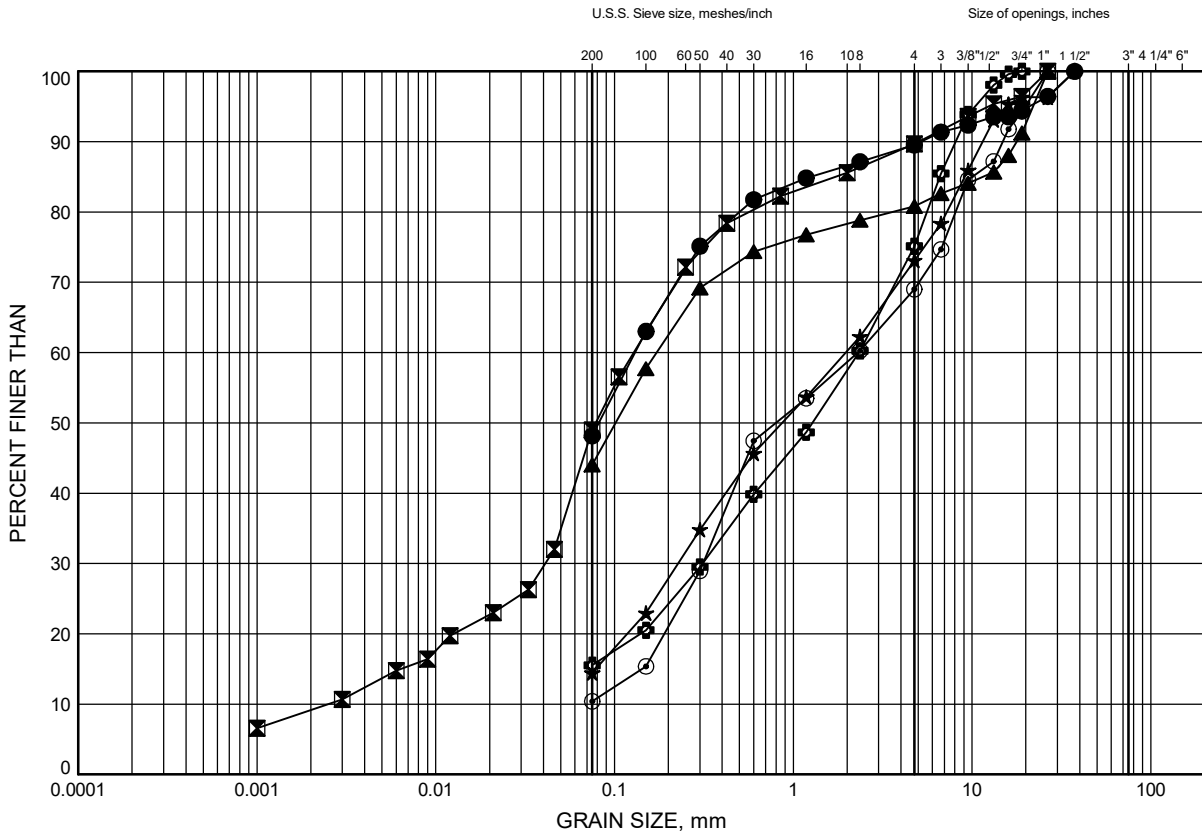


Prep'd CM

Chkd. PC

# GRAIN SIZE DISTRIBUTION

## Granular Fill - Sand



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	303	2.6	105.1
⊠	303	5.6	102.1
▲	303	11.0	96.7
★	304	0.6	107.0
⊙	19-02	1.1	96.4
⊕	19-03	0.3	97.6

Date September 2022

GWP# 4068-14-00



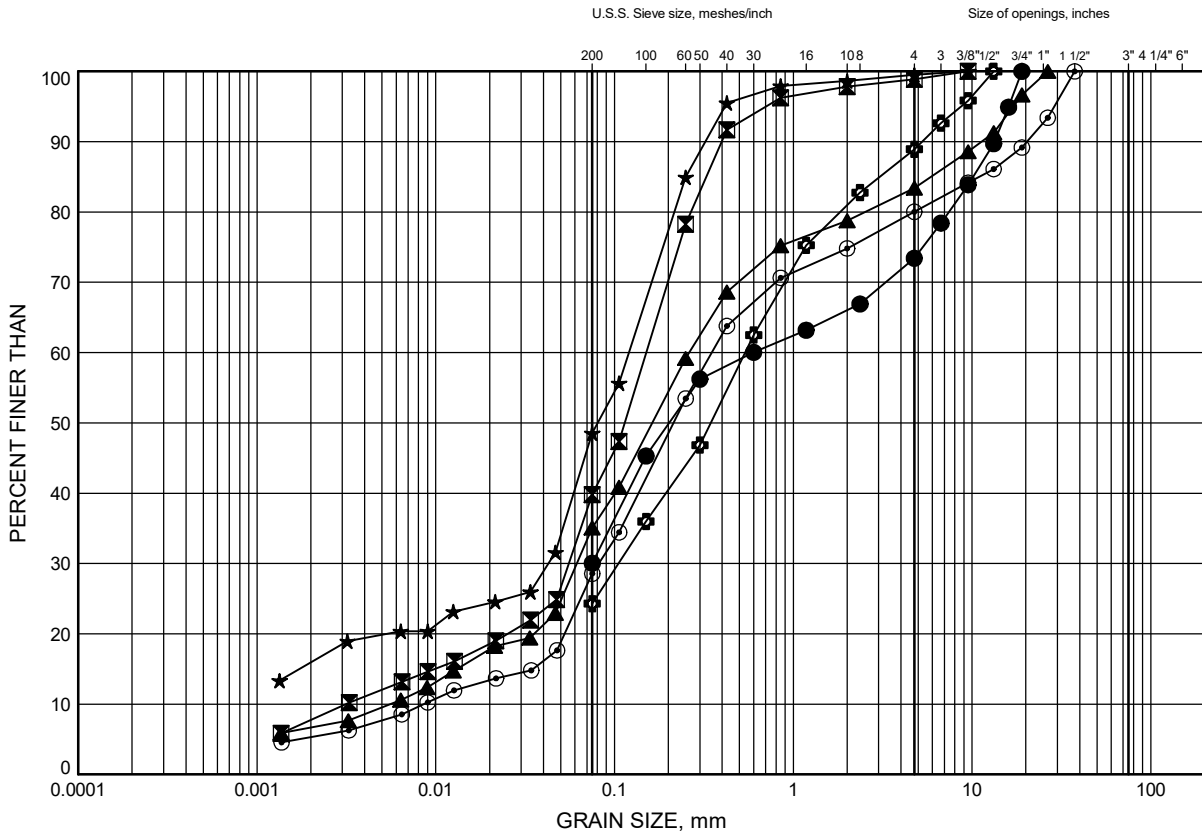
Prep'd CM

Chkd. PC



# GRAIN SIZE DISTRIBUTION

## Granular Fill - Sand



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	19-03	1.9	96.0
⊠	19-03	2.5	95.4
▲	19-04	5.6	96.0
★	19-07	1.8	95.4
⊙	19-08	6.4	95.8
⊕	19-09	1.8	102.2

Date September 2022

GWP# 4068-14-00

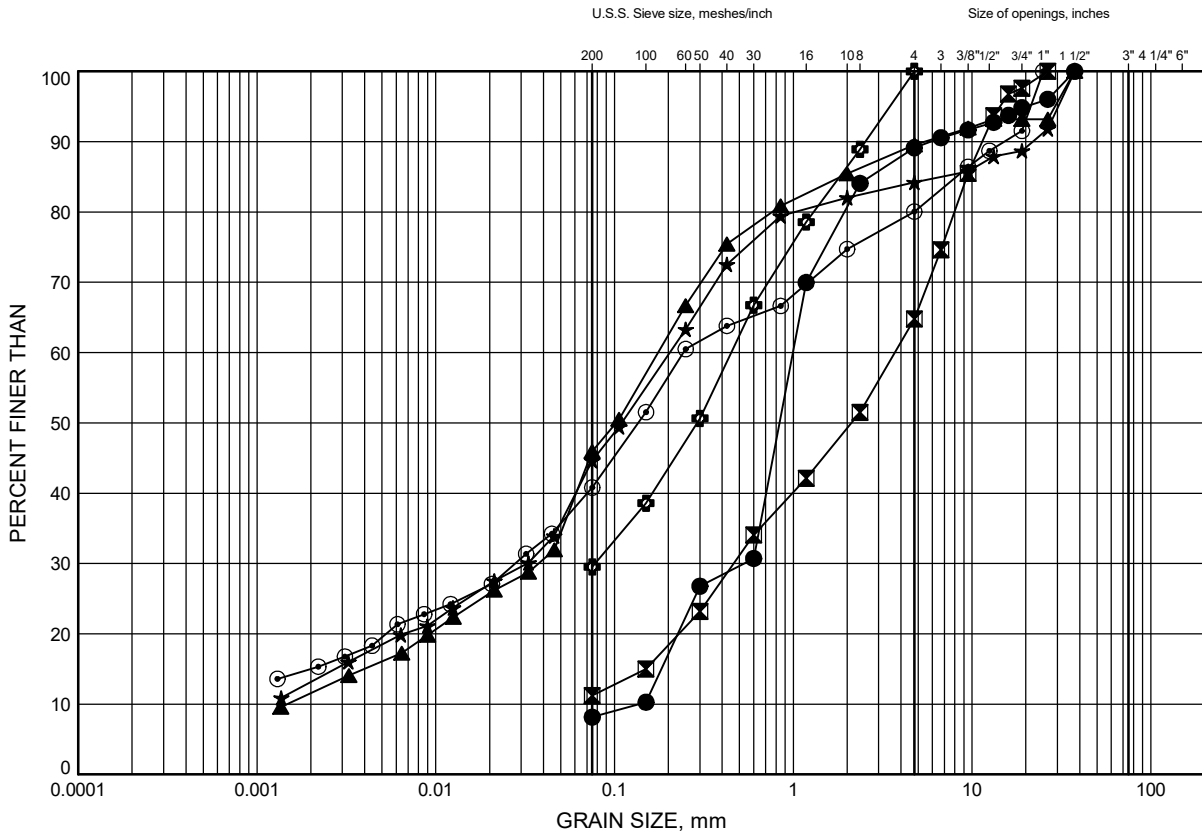


Prep'd CM

Chkd. PC

# GRAIN SIZE DISTRIBUTION

## Granular Fill - Sand



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	19-09	4.1	99.9
⊠	19-10	0.4	96.3
▲	19-11A	1.8	94.7
★	19-12	2.6	97.9
⊙	CR22-02	2.6	97.3
⊕	CR22-03	0.3	103.7

Date September 2022

GWP# 4068-14-00

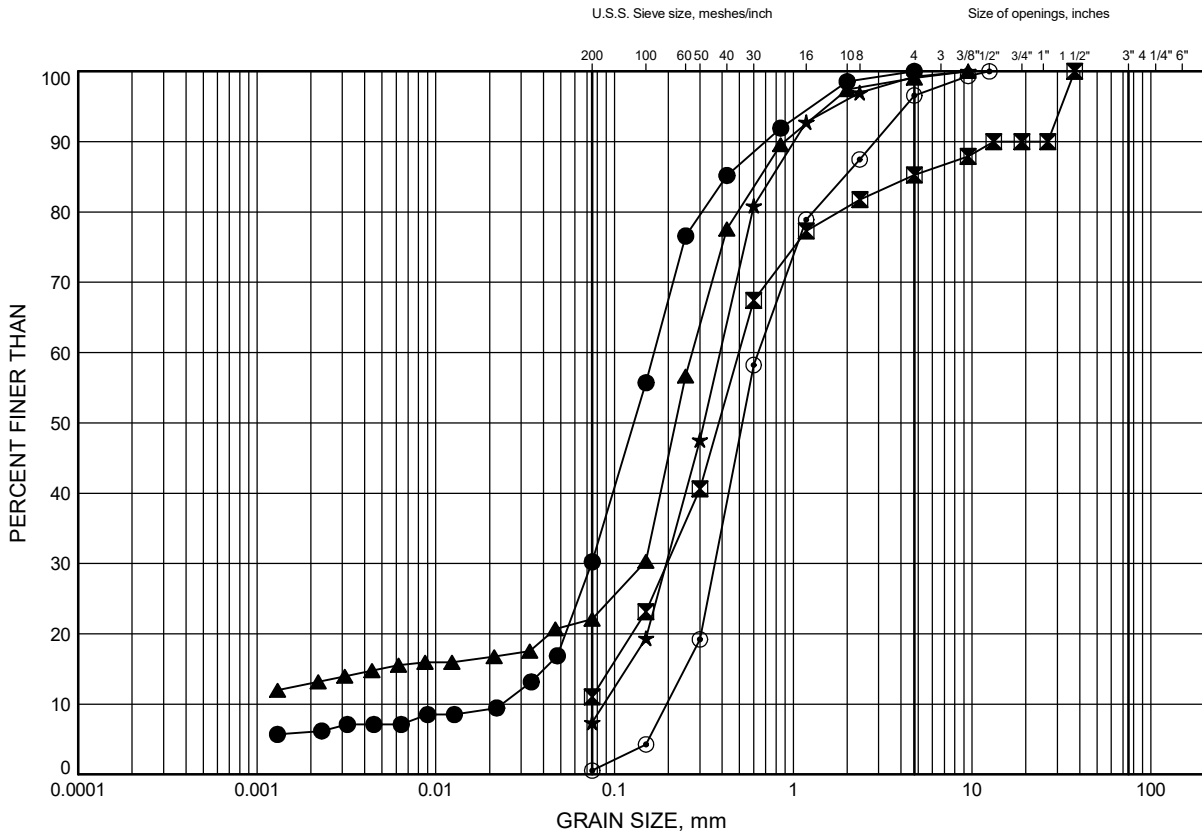


Prep'd CM

Chkd. PC

# GRAIN SIZE DISTRIBUTION

## Granular Fill - Sand



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	CR22-03	2.6	101.4
⊠	CR22-03	5.6	98.4
▲	CR22-03	7.9	96.1
★	CR22-04	7.9	96.1
⊙	CR22-04	9.4	94.6

Date September 2022

GWP# 4068-14-00

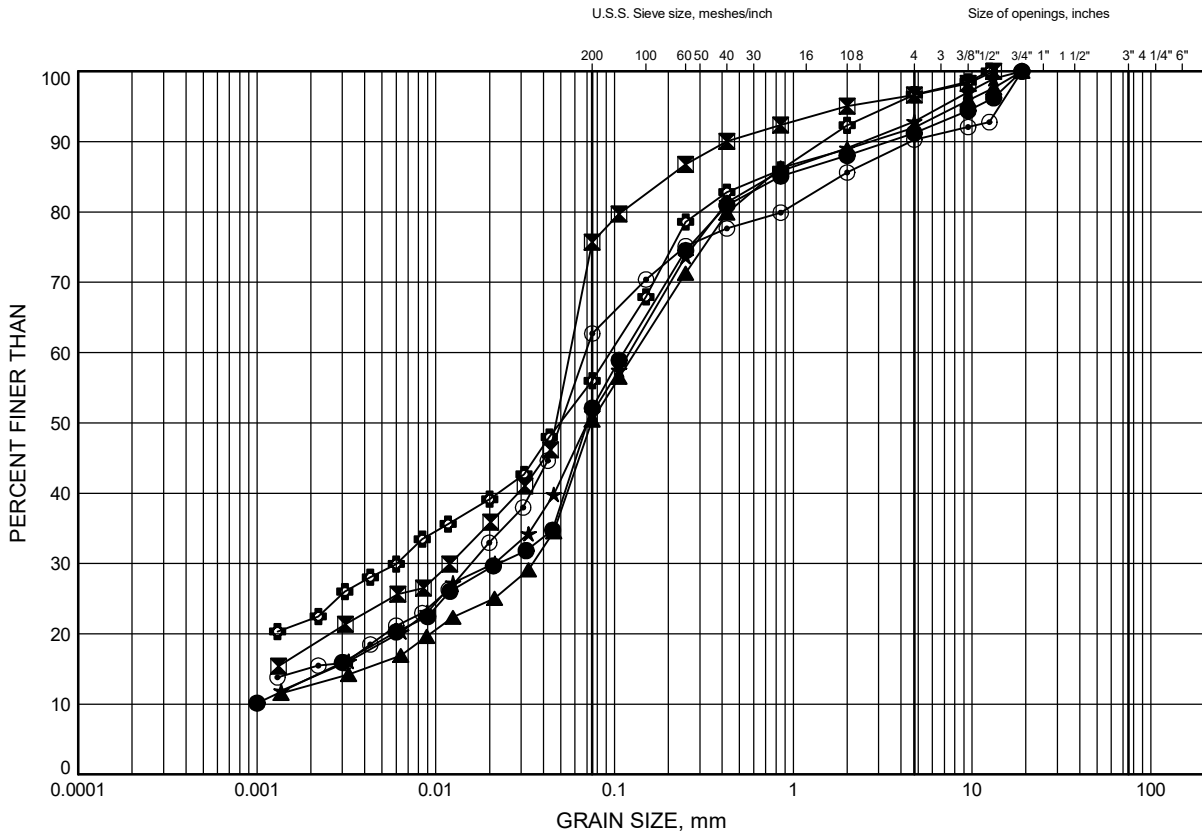


Prep'd CM

Chkd. PC

# GRAIN SIZE DISTRIBUTION

## Granular Fill - Silt



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	304	3.4	104.3
⊠	19-05	0.3	99.7
▲	19-05	4.1	95.9
★	19-12	3.4	97.1
⊙	CR22-01	0.3	99.0
⊕	CR22-02	0.4	99.5

Date September 2022

GWP# 4068-14-00

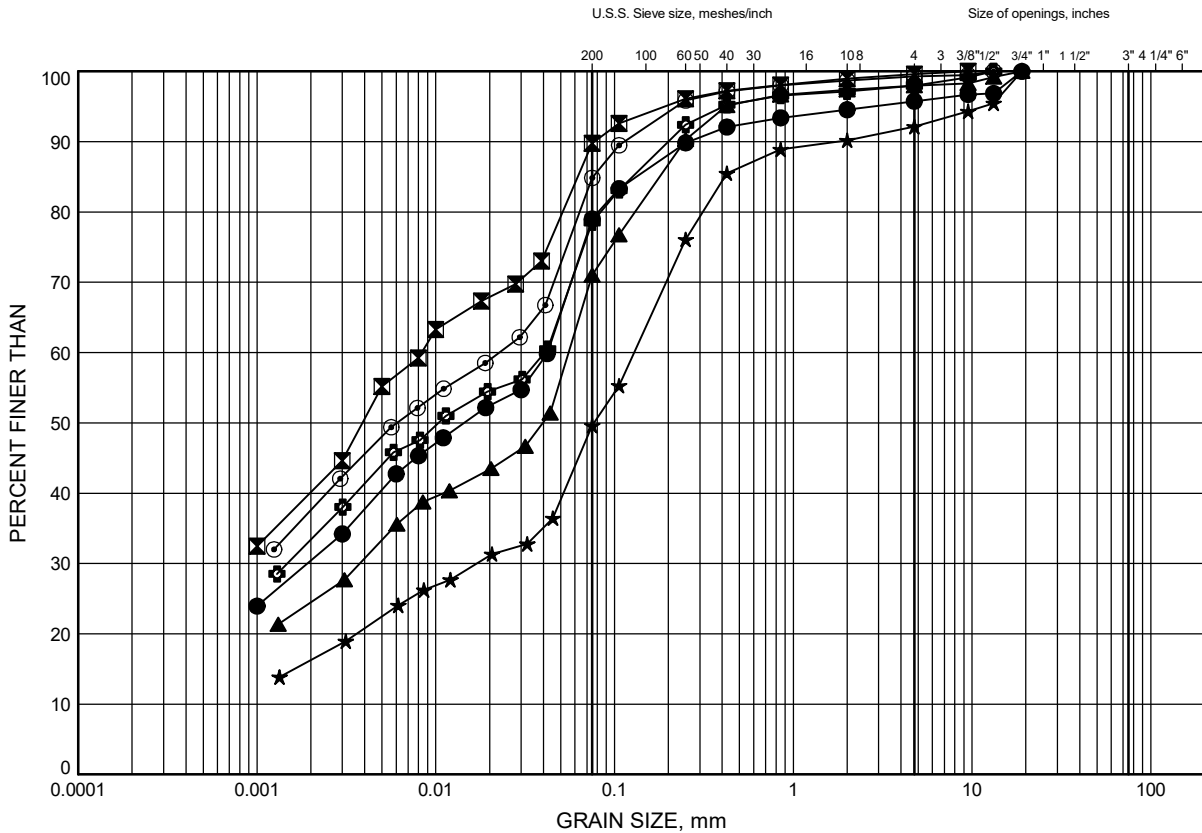


Prep'd CM

Chkd. PC

# GRAIN SIZE DISTRIBUTION

## Cohesive Fill



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	303	7.9	99.8
⊠	304	7.2	100.5
▲	19-01	1.8	100.9
★	19-04	1.1	100.5
⊙	19-04	3.4	98.2
⊕	19-05	1.8	98.2

Date September 2022

GWP# 4068-14-00

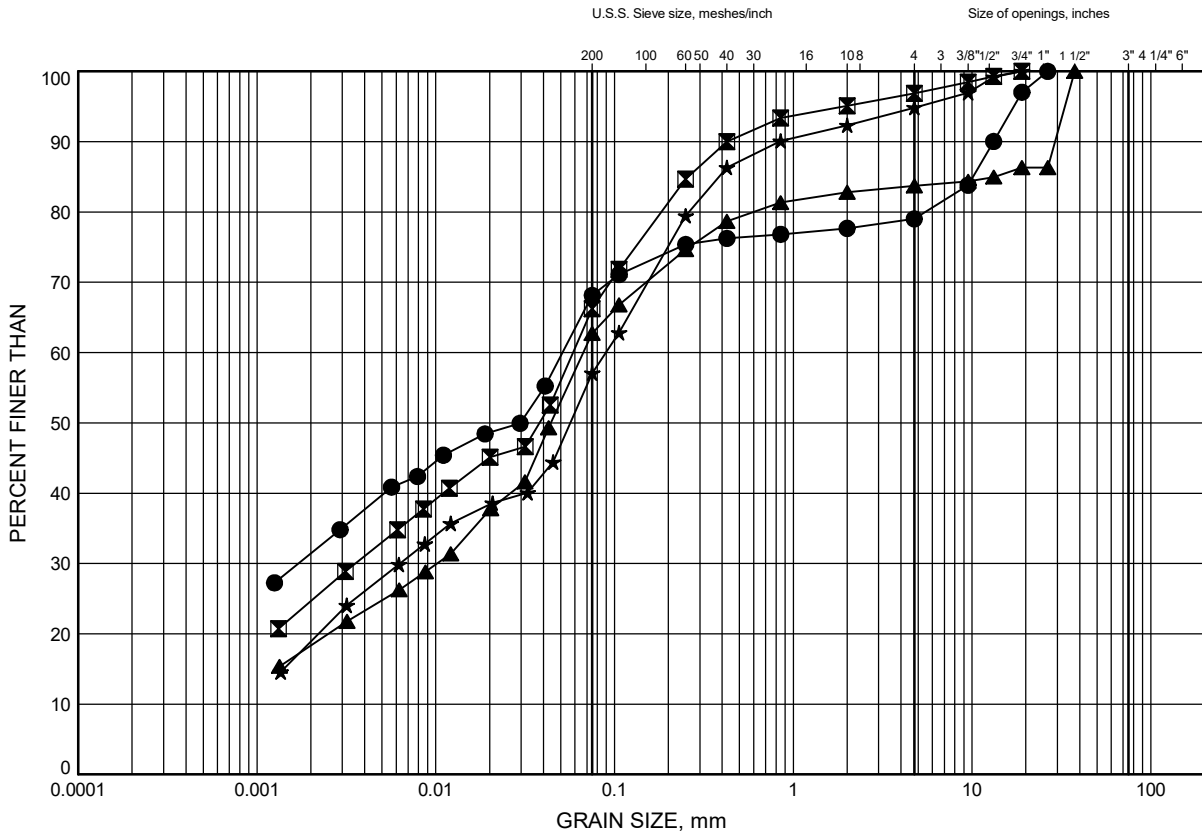


Prep'd CM

Chkd. PC

# GRAIN SIZE DISTRIBUTION

## Cohesive Fill



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	19-08	3.4	98.8
⊠	19-12	1.1	99.4
▲	19-13	0.3	98.4
★	19-13	1.1	97.6

Date September 2022

GWP# 4068-14-00

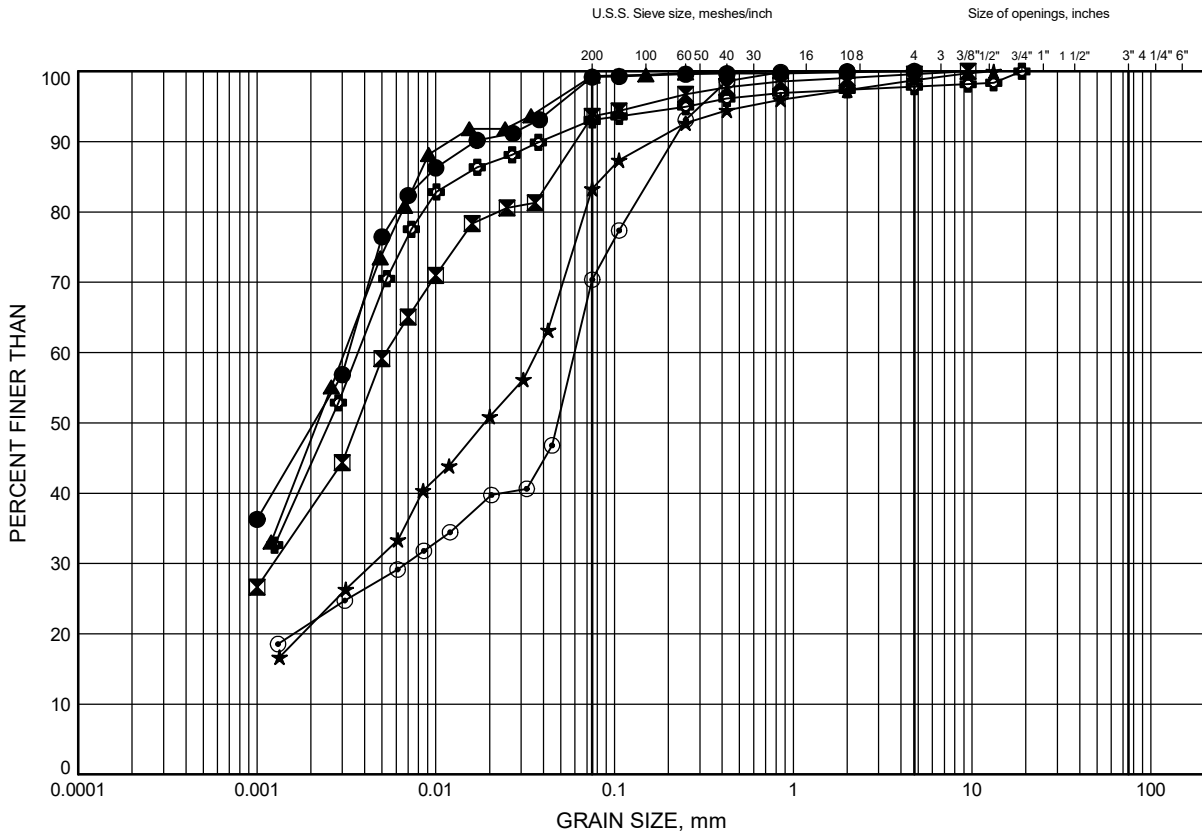


Prep'd CM

Chkd. PC

# GRAIN SIZE DISTRIBUTION

Clayey Silt (CL-ML to CL)



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	301	14.0	96.2
⊠	302	15.5	94.7
▲	19-01	6.4	96.3
★	19-02	1.9	95.6
⊙	19-05	5.6	94.4
⊕	19-06	1.8	95.2

Date September 2022

GWP# 4068-14-00

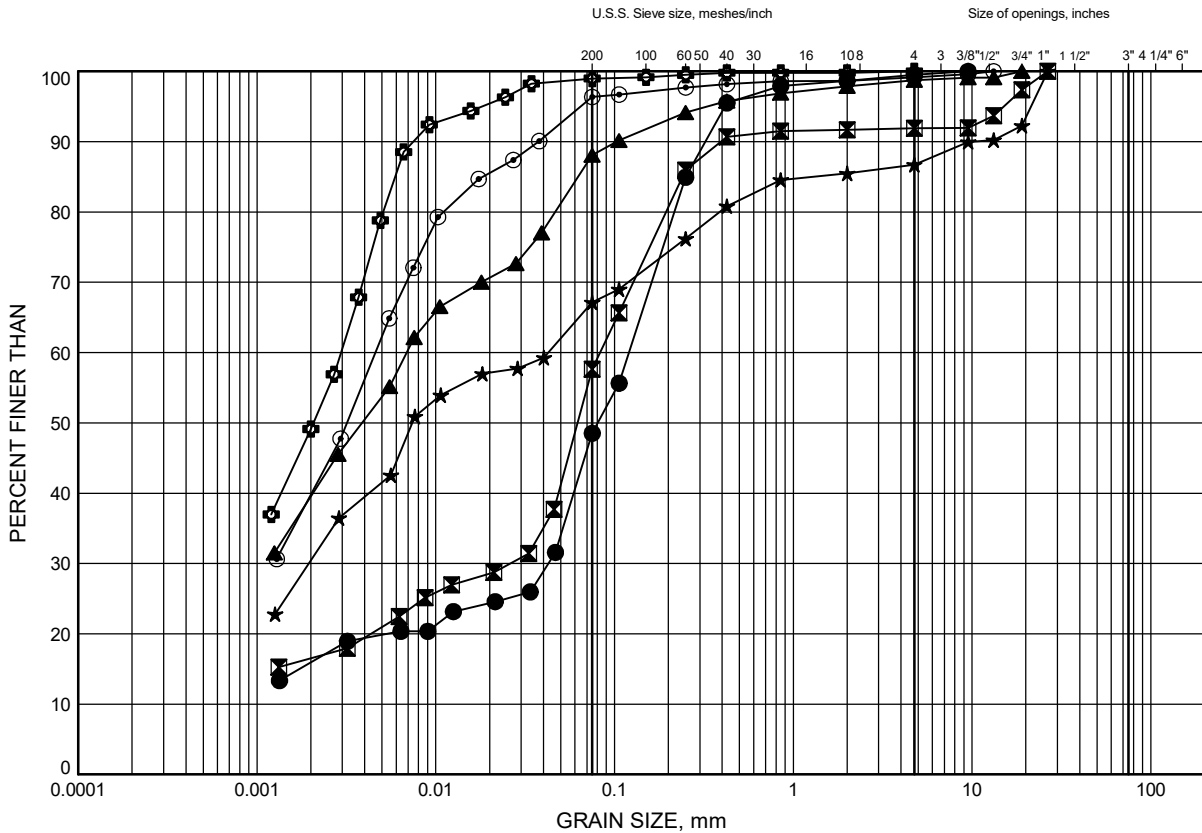


Prep'd CM

Chkd. PC

## GRAIN SIZE DISTRIBUTION

Clayey Silt (CL-ML to CL)



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	19-07	1.8	95.4
⊠	19-08	7.9	94.3
▲	19-09	5.6	98.4
★	19-09	7.9	96.1
⊙	19-09	9.4	94.6
⊕	CR22-01	2.6	96.7

Date September 2022

GWP# 4068-14-00



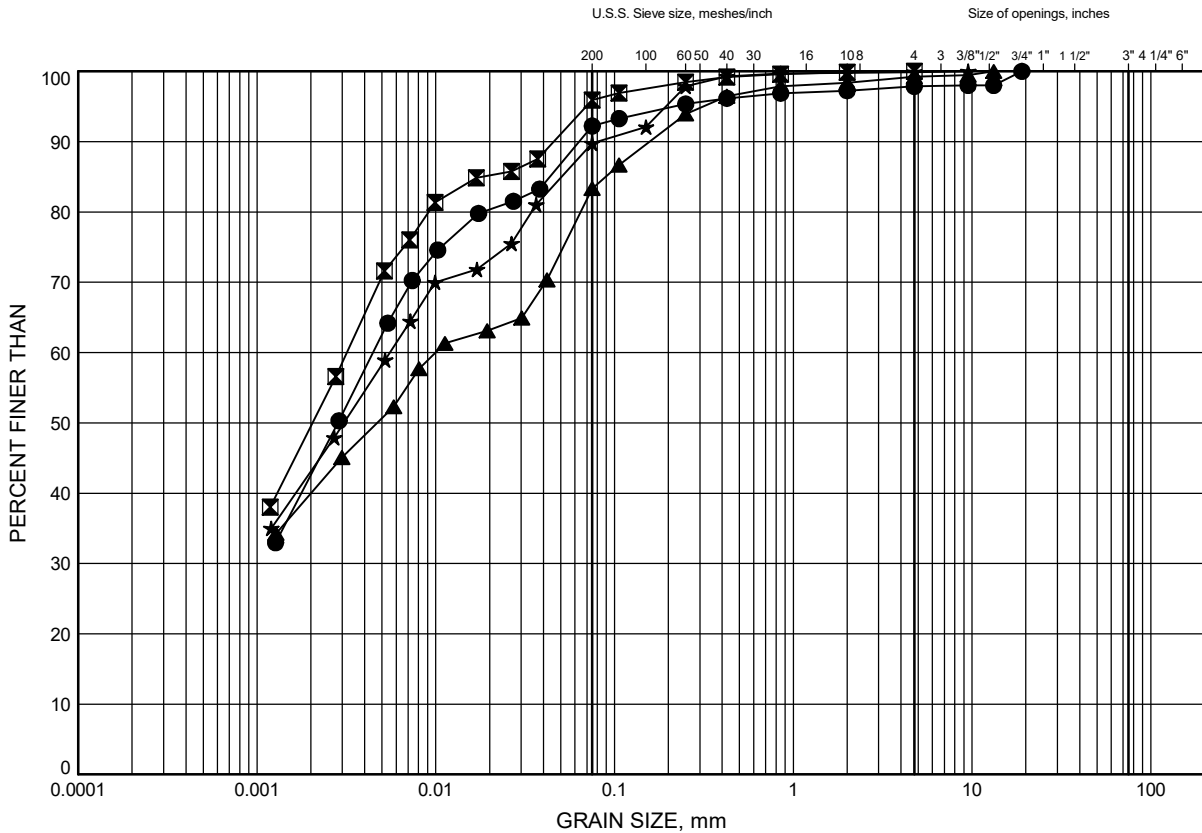
Prep'd CM

Chkd. PC



# GRAIN SIZE DISTRIBUTION

## Silty Clay (CI)



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	19-01	3.4	99.3
⊠	19-01	4.9	97.8
▲	19-11A	3.3	93.2
★	19-11B	3.0	93.6

Date September 2022

GWP# 4068-14-00

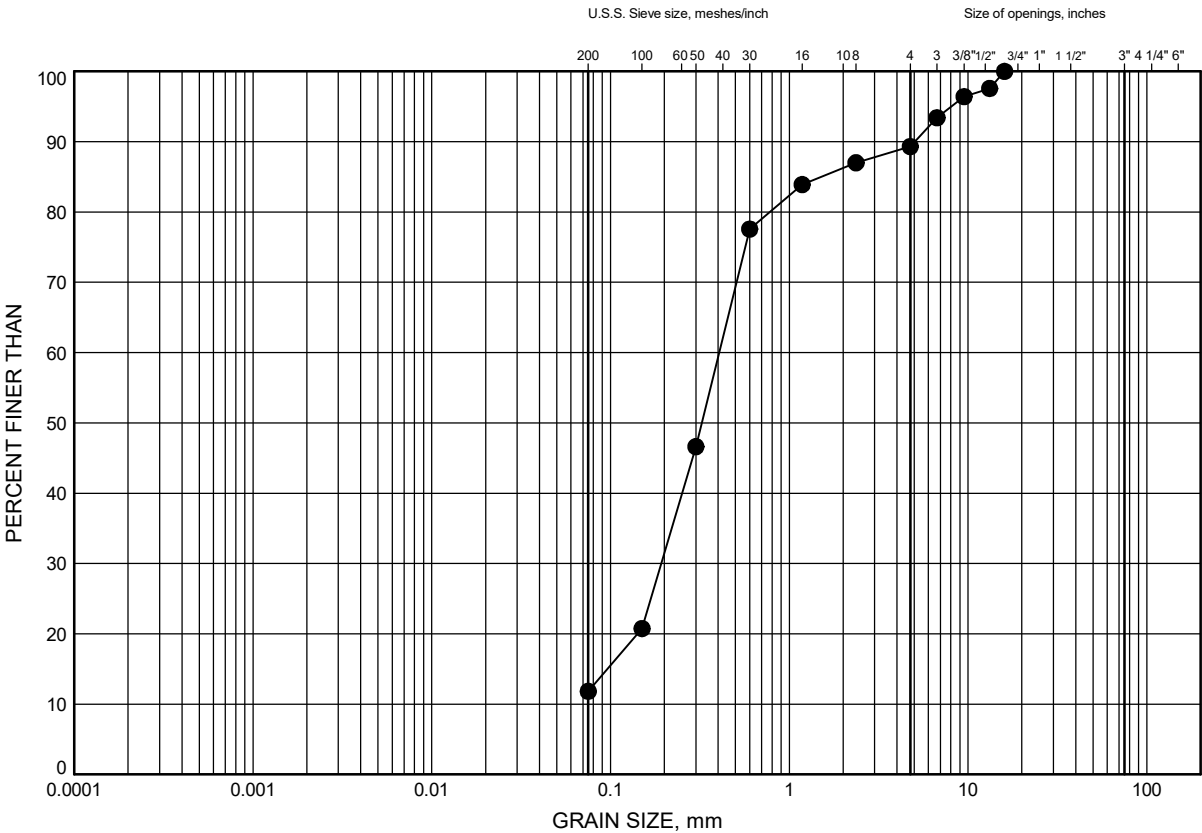


Prep'd CM

Chkd. PC

GRAIN SIZE DISTRIBUTION

Silty Sand (SM)



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

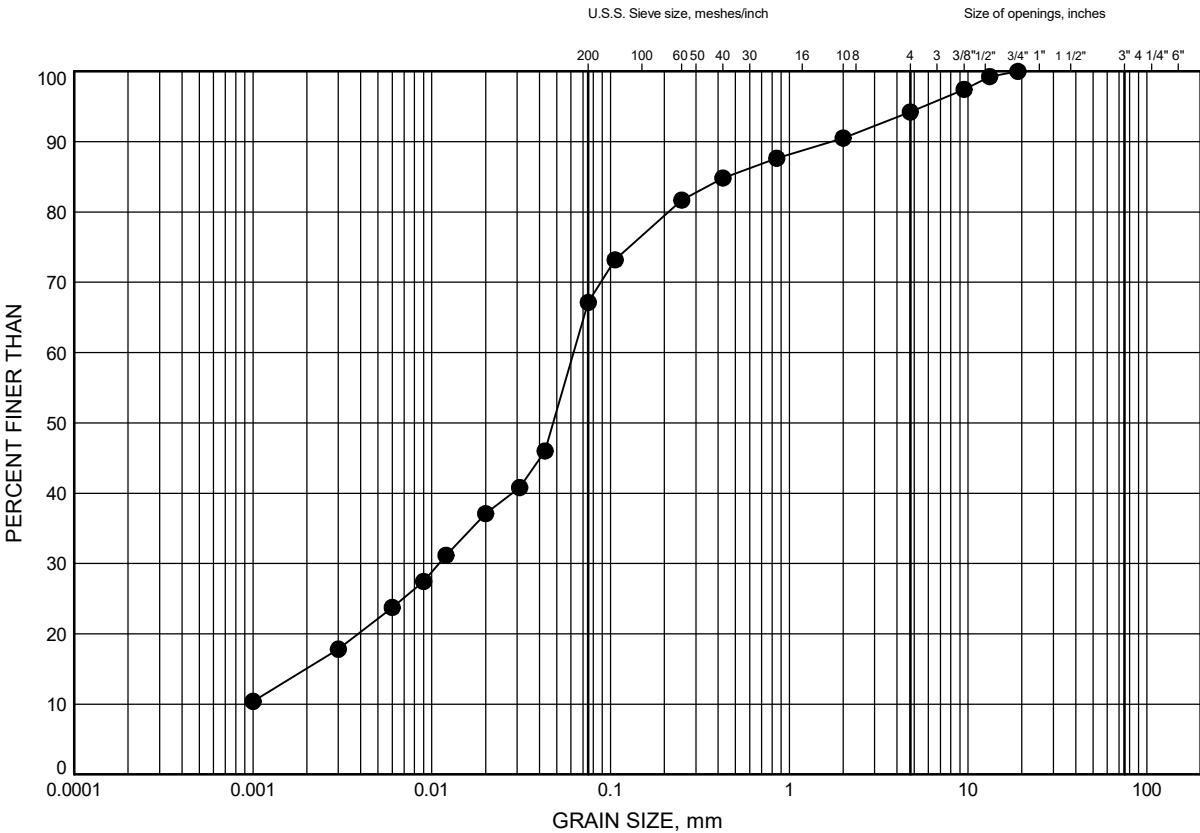
SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	19-13	4.9	93.8

GRAIN SIZE DISTRIBUTION - THURBER 33099 - HWY 401 CHOATE AND GANARASKA DD.GPJ 9-30-22



GRAIN SIZE DISTRIBUTION

Sandy Silt (ML)



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

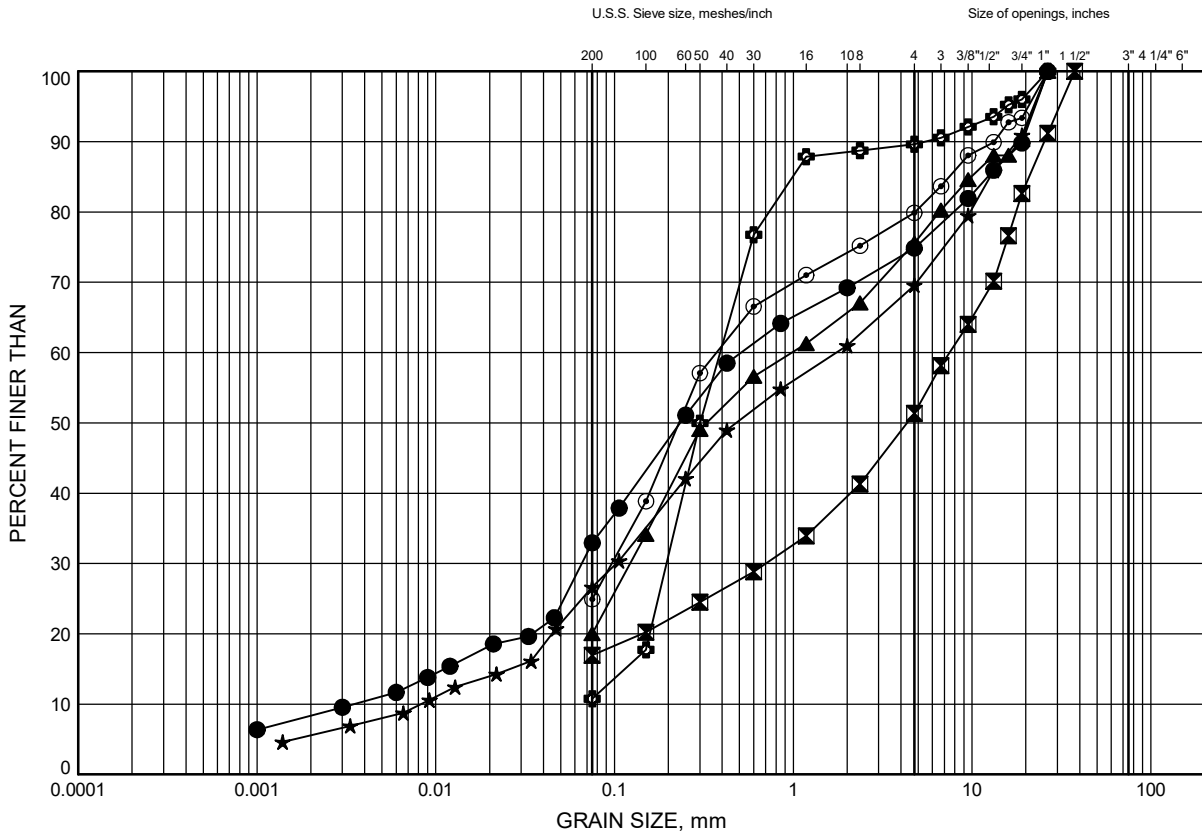
SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	301	15.5	94.7

GRAIN SIZE DISTRIBUTION - THURBER 33099 - HWY 401 CHOATE AND GANARASKA DD.GPJ 9-30-22



# GRAIN SIZE DISTRIBUTION

## Glacial Till



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	302	17.1	93.2
⊠	304	15.3	92.3
▲	19-01	8.5	94.2
★	19-02	3.3	94.2
⊙	19-03	4.1	93.8
⊕	19-04	7.1	94.5

Date September 2022

GWP# 4068-14-00

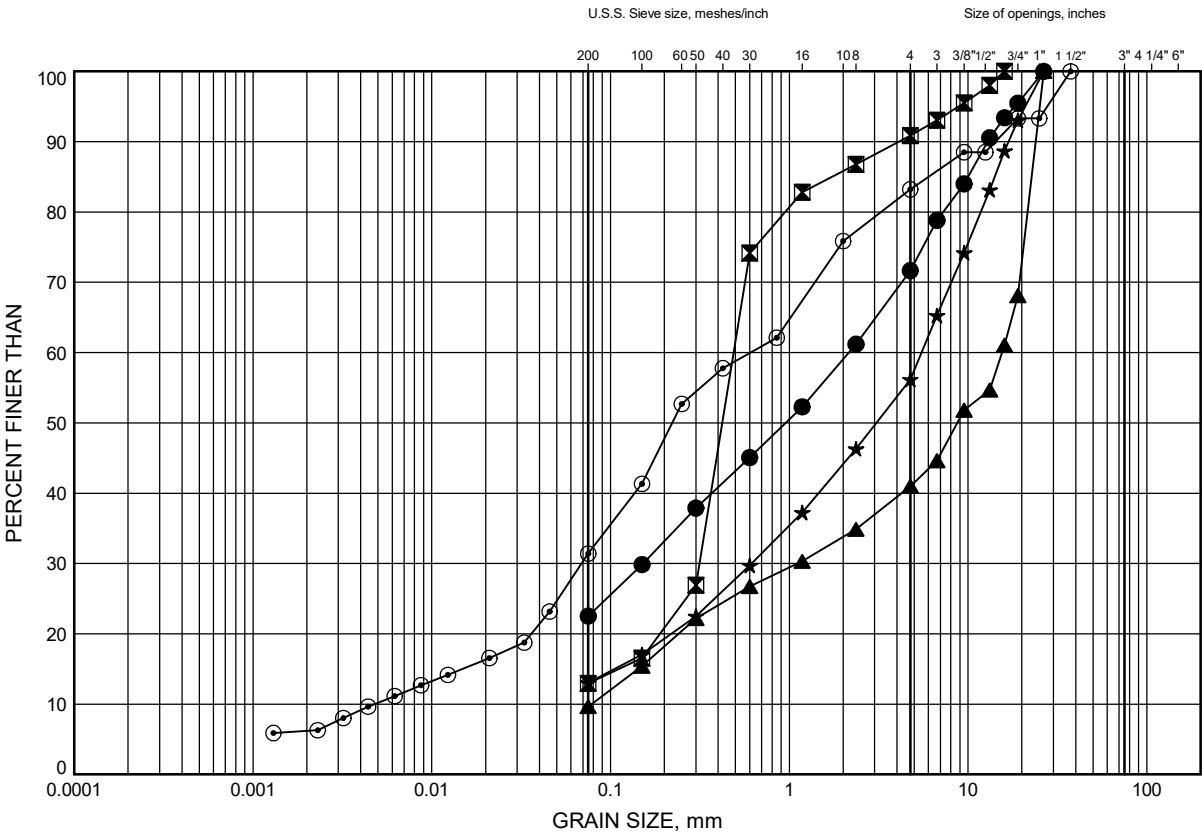


Prep'd CM

Chkd. PC

GRAIN SIZE DISTRIBUTION

Glacial Till



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

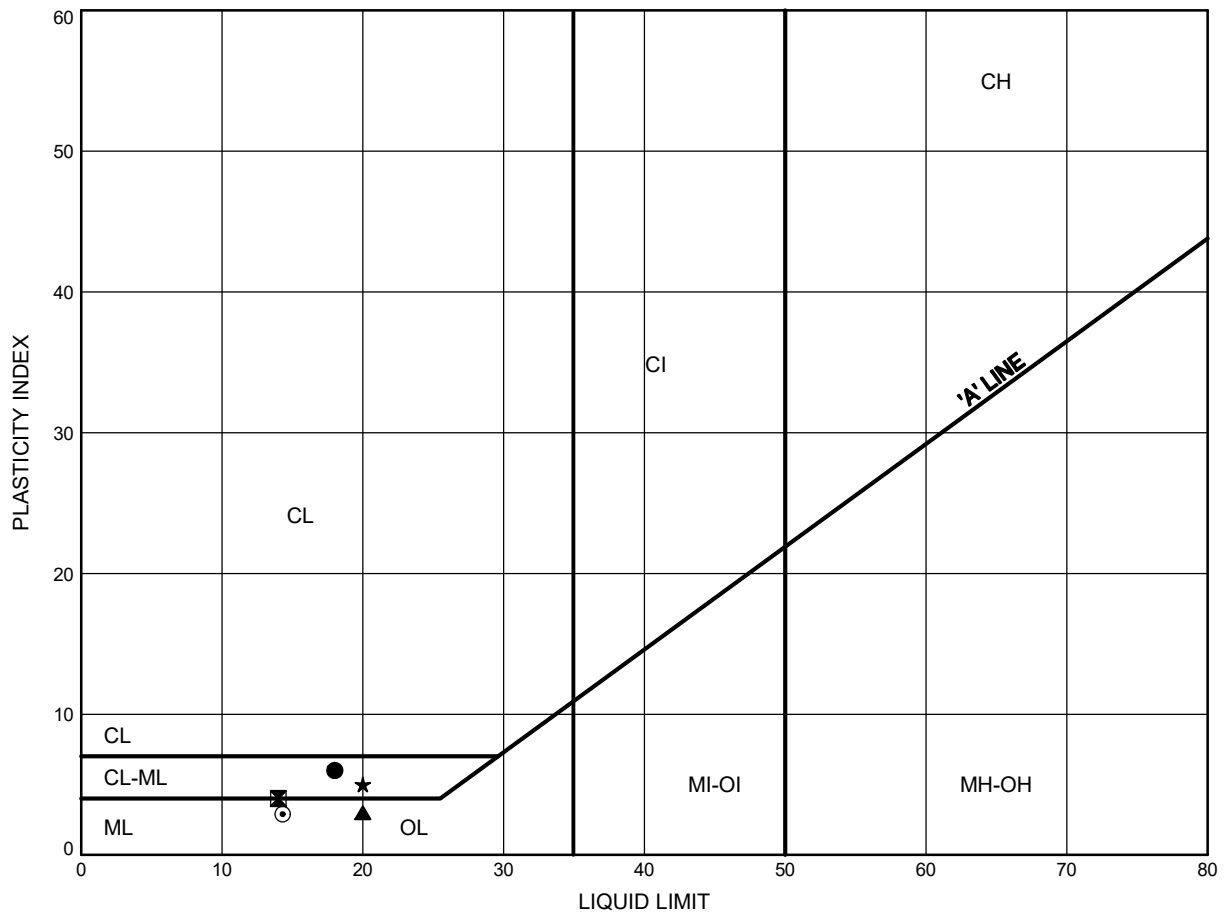
SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	19-06	4.0	93.0
⊠	19-09	10.8	93.2
▲	19-10	3.6	93.1
★	19-11A	4.0	92.5
⊙	CR22-01	4.1	95.2

GRAIN SIZE DISTRIBUTION - THURBER 33099 - HWY 401 CHOATE AND GANARASKA DD.GPJ 9-30-22

# Highway 401 Choate and Ganaraska Detailed Design ATTERBERG LIMITS TEST RESULTS

FIGURE C16

## Granular Fill



## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	301	2.5	107.7
⊠	304	3.4	104.3
▲	19-05	4.1	95.9
★	19-07	1.8	95.4
⊙	CR22-02	2.6	97.3

Date September 2022

GWP# 4068-14-00



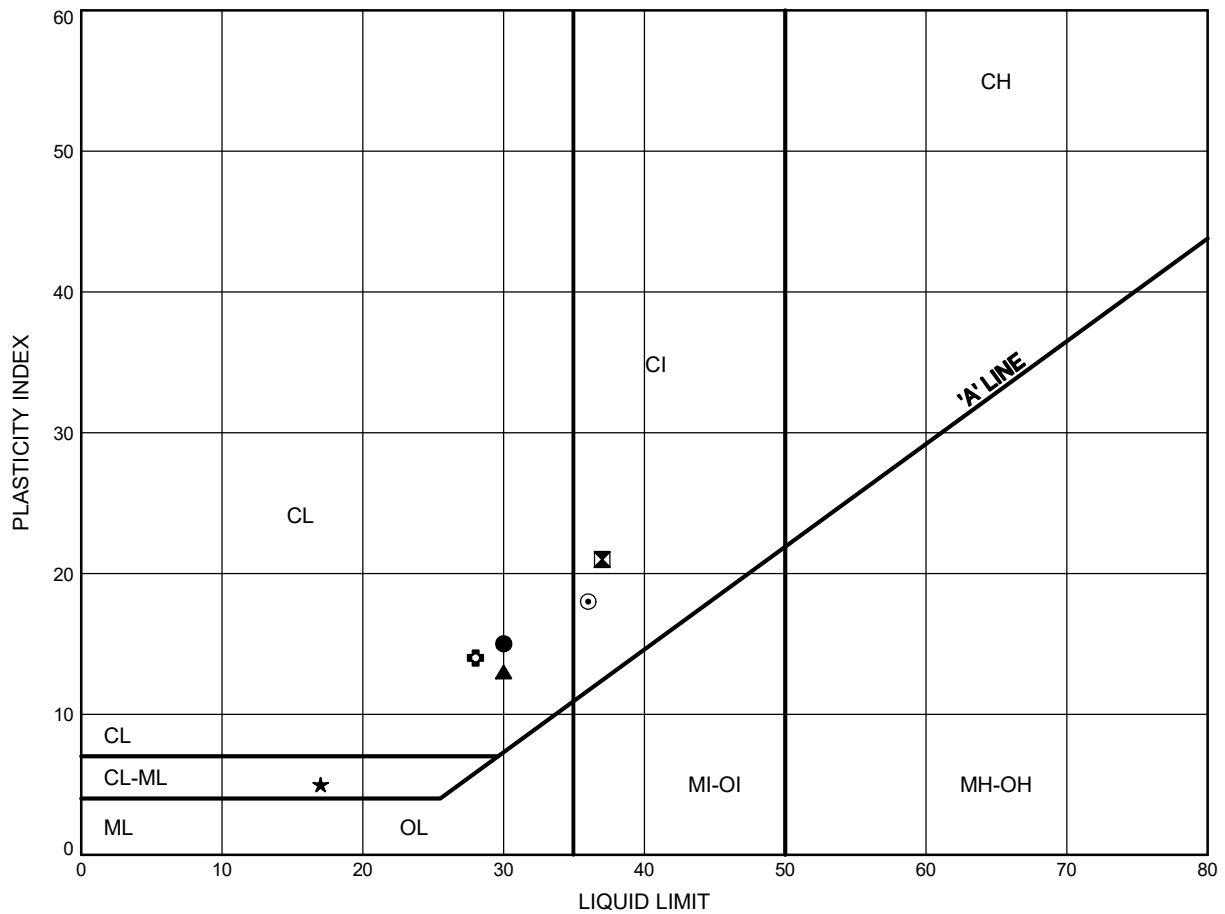
Prep'd CM

Chkd. PC

Highway 401 Choate and Ganaraska Detailed Design  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE C17

**Cohesive Fill**



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	303	7.9	99.8
⊠	304	7.2	100.5
▲	19-01	1.8	100.9
★	19-04	1.1	100.5
⊙	19-04	3.4	98.2
⊕	19-05	1.8	98.2

Date September 2022

GWP# 4068-14-00



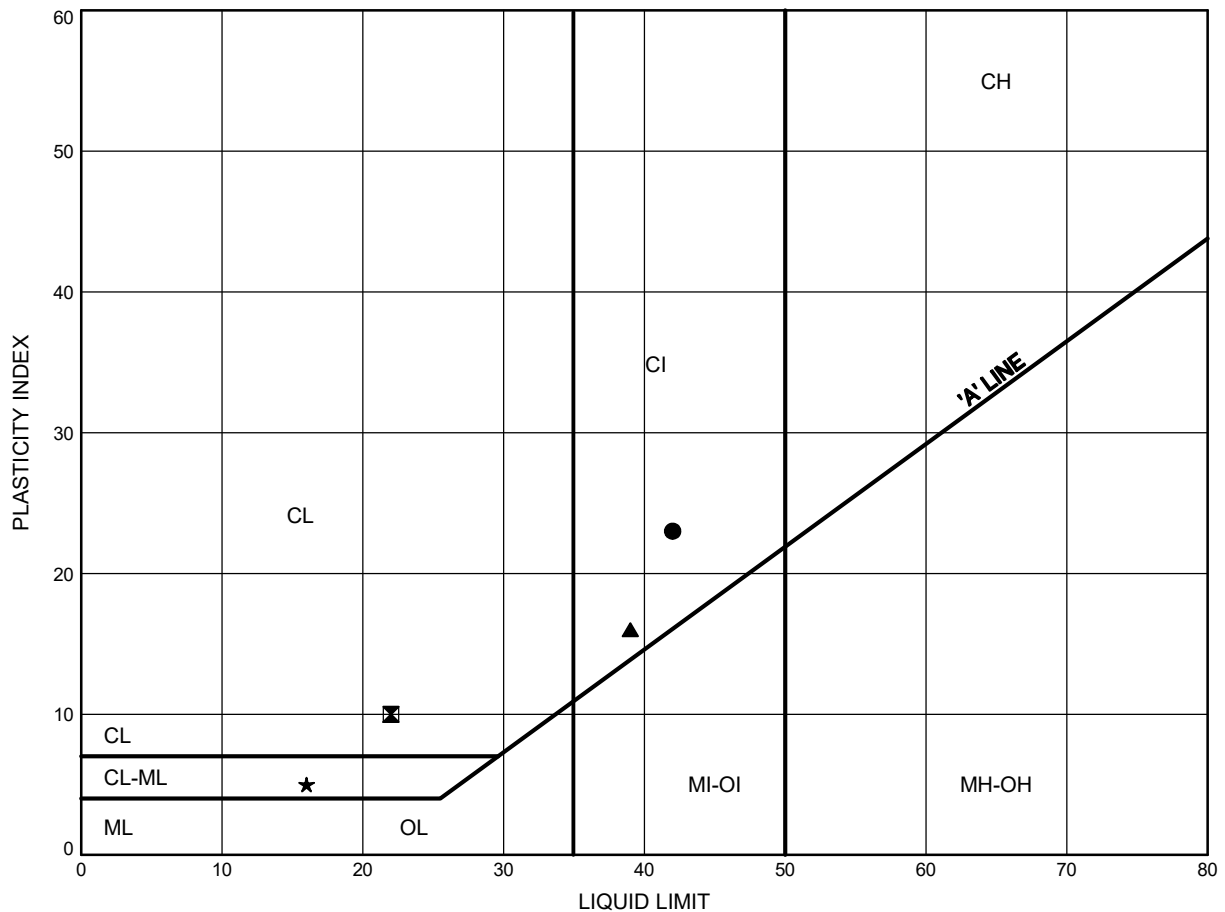
Prep'd CM

Chkd. PC

Highway 401 Choate and Ganaraska Detailed Design  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE C18

**Cohesive Fill**



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	19-08	3.4	98.8
⊠	19-12	1.1	99.4
▲	19-13	0.3	98.4
★	19-13	1.1	97.6

Date September 2022

GWP# 4068-14-00



Prep'd CM

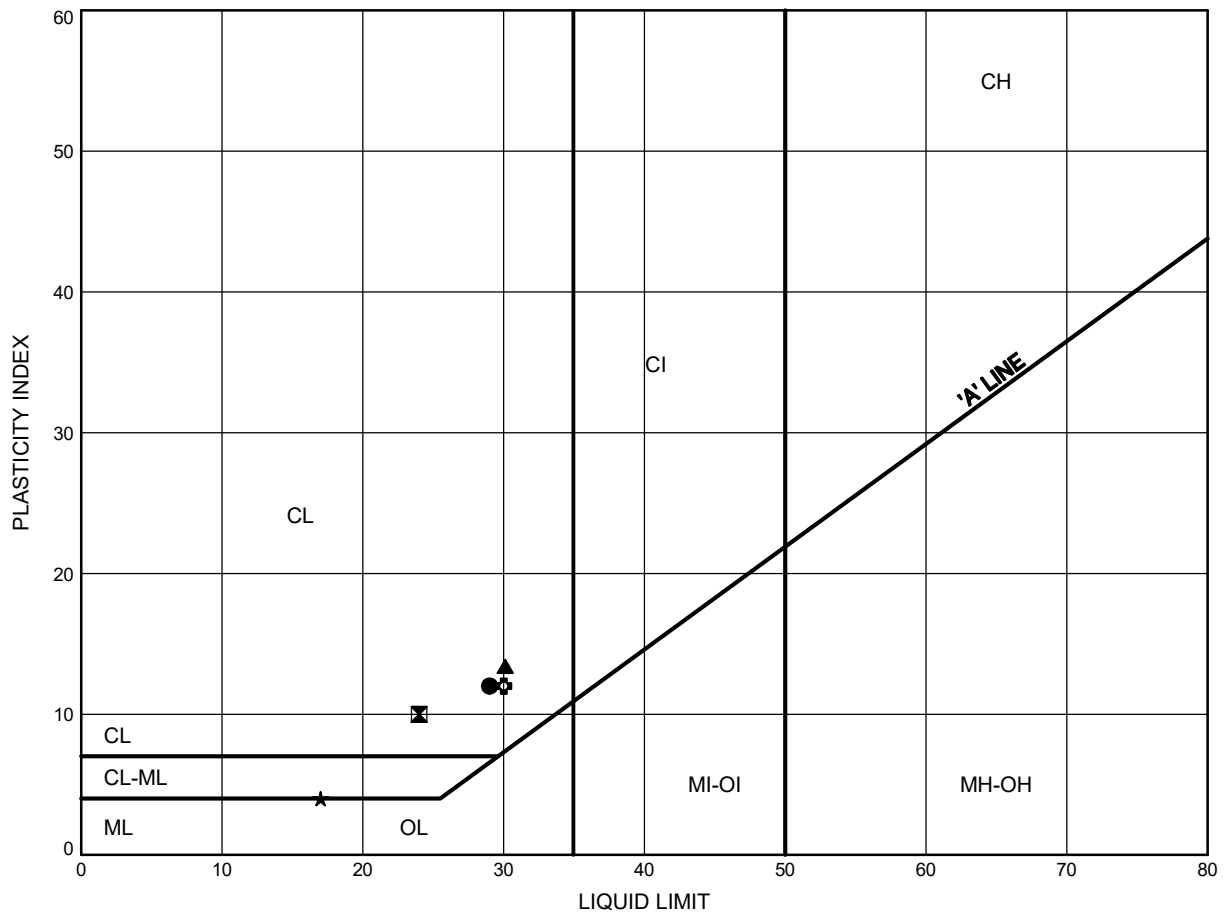
Chkd. PC



Highway 401 Choate and Ganaraska Detailed Design  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE C19

Clayey Silt (CL-ML to CL)



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	301	14.0	96.2
⊠	302	15.5	94.7
▲	19-01	6.4	96.3
★	19-02	1.9	95.6
⊙	19-05	5.6	94.4
⊕	19-06	1.8	95.2

Date September 2022

GWP# 4068-14-00



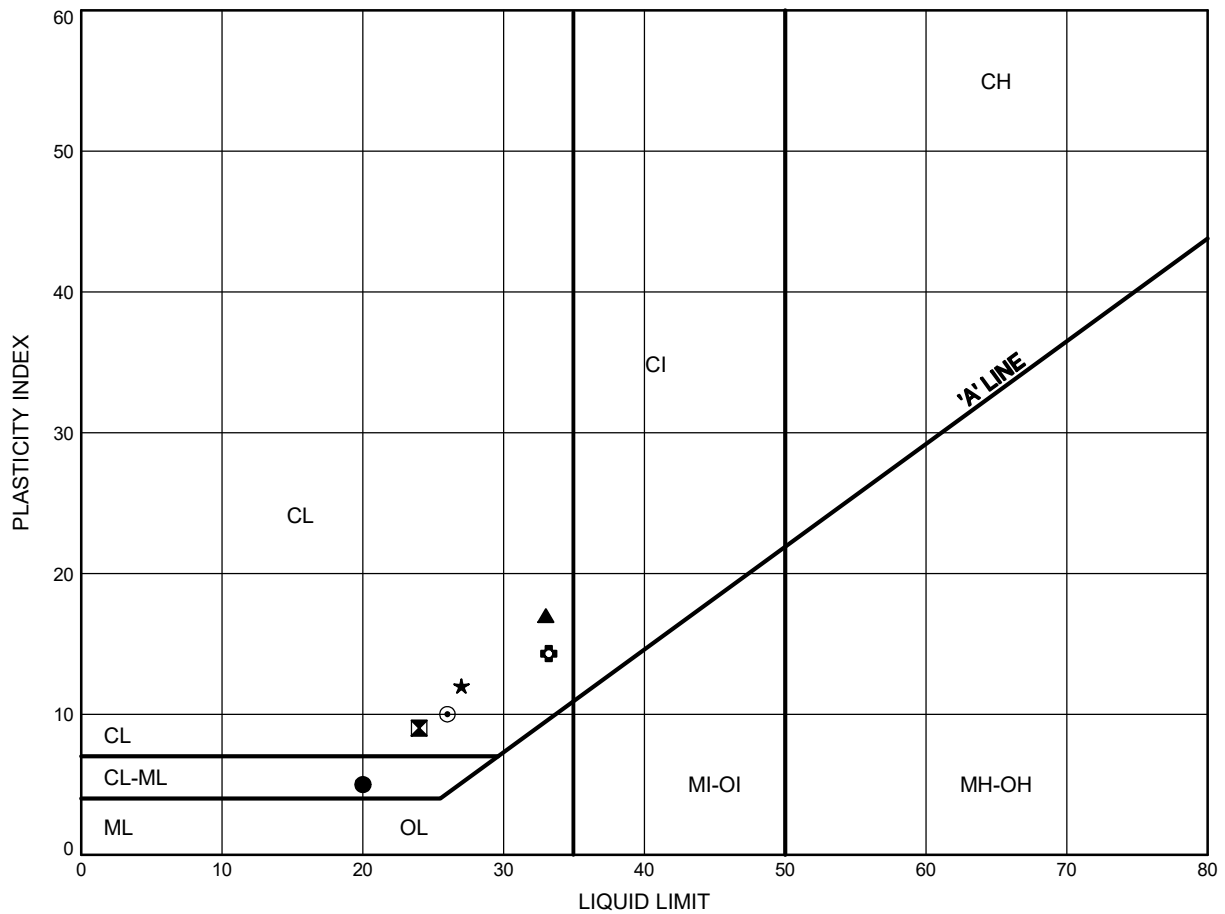
Prep'd CM

Chkd. PC

# Highway 401 Choate and Ganaraska Detailed Design ATTERBERG LIMITS TEST RESULTS

FIGURE C20

Clayey Silt (CL-ML to CL)



## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	19-07	1.8	95.4
⊠	19-08	7.9	94.3
▲	19-09	5.6	98.4
★	19-09	7.9	96.1
⊙	19-09	9.4	94.6
⊕	CR22-01	2.6	96.7

Date September 2022

GWP# 4068-14-00



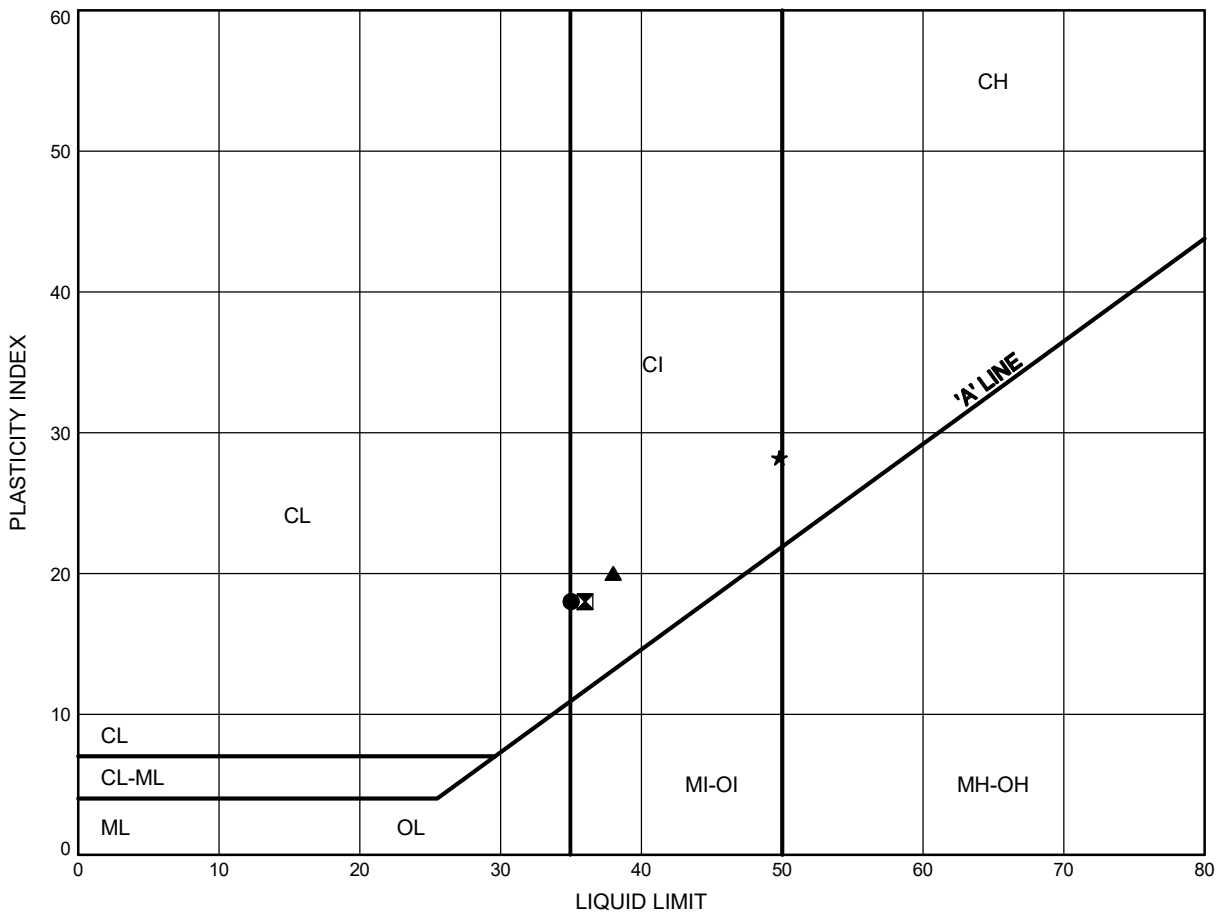
Prep'd CM

Chkd. PC

Highway 401 Choate and Ganaraska Detailed Design  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE C21

Silty Clay (CI)



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	19-01	3.4	99.3
⊠	19-01	4.9	97.8
▲	19-11A	3.3	93.2
★	19-11B	3.0	93.6

Date September 2022

GWP# 4068-14-00



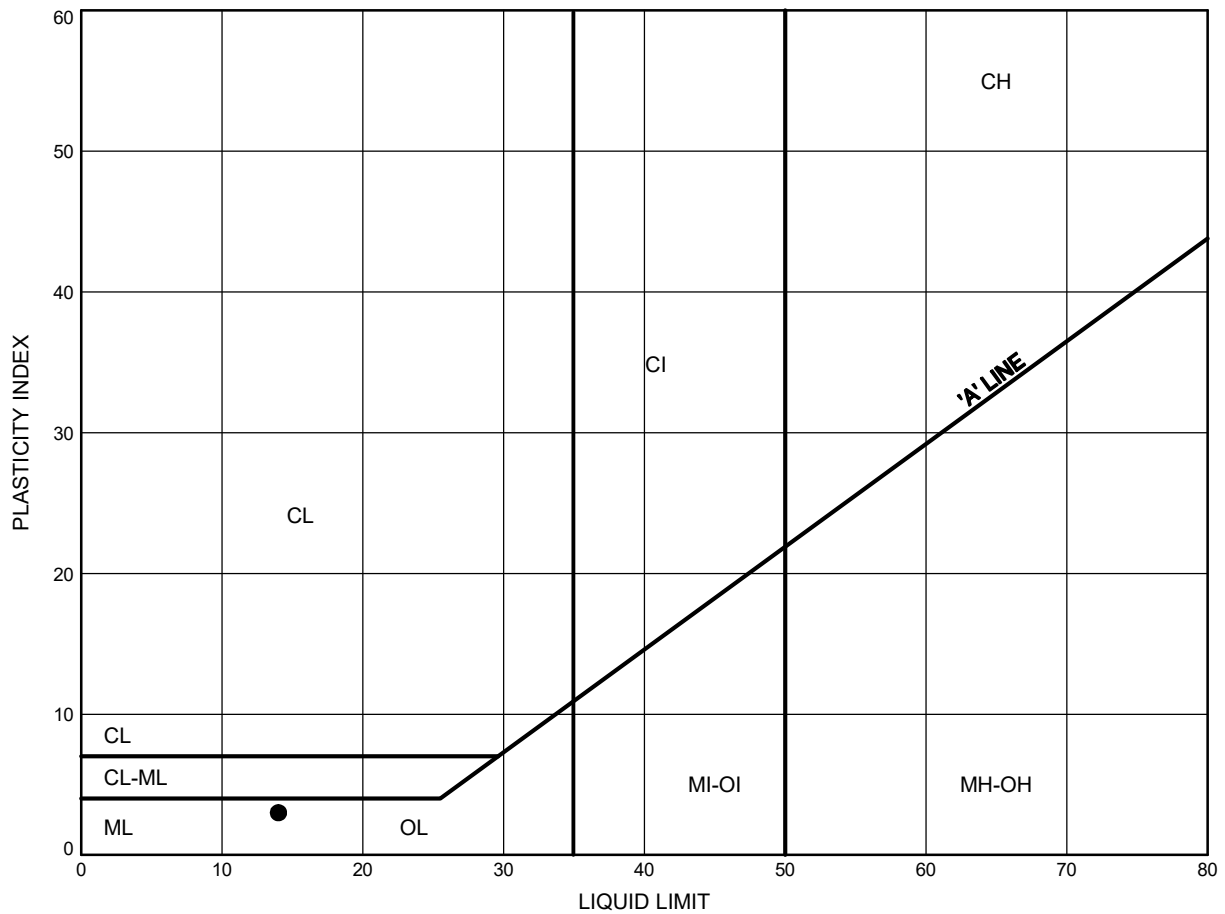
Prep'd CM

Chkd. PC

Highway 401 Choate and Ganaraska Detailed Design  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE C22

Sandy Silt (ML)



**LEGEND**

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	301	15.5	94.7

Date September 2022

GWP# 4068-14-00



Prep'd CM

Chkd. PC

Certificate of Analysis  
**Client: Thurber Engineering Ltd.**  
**Client PO:**

Report Date: 15-Jun-2016  
Order Date: 13-Jun-2016  
**Project Description: 19-5161-263**

		<b>Client ID:</b>	301 SS3 (5'-7')	304 SS4 (7'6"-9'6")	401 SS4 (7'6"-9'6")	403 SS3 (5'-7')
		<b>Sample Date:</b>	31-May-16	01-Jun-16	31-May-16	30-May-16
		<b>Sample ID:</b>	1625054-01	1625054-02	1625054-03	1625054-04
		<b>MDL/Units</b>	Soil	Soil	Soil	Soil
<b>Physical Characteristics</b>						
% Solids	0.1 % by Wt.		90.5	91.9	95.2	97.5
<b>General Inorganics</b>						
Conductivity	5 uS/cm		1220	1260	782	1210
pH	0.05 pH Units		8.21	8.35	8.44	8.31
Resistivity	0.10 Ohm.m		8.17	7.96	12.8	8.26
<b>Anions</b>						
Chloride	5 ug/g dry		650	670	365	758
Sulphate	5 ug/g dry		27	48	21	76

Certificate of Analysis  
**Client: Thurber Engineering Ltd.**  
**Client PO:**

Report Date: 12-Mar-2019

Order Date: 1-Mar-2019

**Project Description: 22645**

<b>Client ID:</b>	19-2, SS4B, 8'7"-9'6"	19-5, SS7, 15'-17'	19-8, SS7, 17'6"-19'6"	19-9, SS10, 22'6"-24'6"
<b>Sample Date:</b>	02/21/2019 09:00	02/21/2019 09:00	02/21/2019 09:00	02/21/2019 09:00
<b>Sample ID:</b>	1909473-01	1909473-02	1909473-03	1909473-04
<b>MDL/Units</b>	Soil	Soil	Soil	Soil

#### Physical Characteristics

% Solids	0.1 % by Wt.	92.8	83.9	91.2	80.3
----------	--------------	------	------	------	------

#### General Inorganics

Conductivity	5 uS/cm	434	199	595	587
pH	0.05 pH Units	8.05	7.85	7.91	7.91
Resistivity	0.10 Ohm.m	23.0	50.3	16.8	17.0

#### Anions

Chloride	5 ug/g dry	161	21	263	315
Sulphate	5 ug/g dry	35	24	53	28

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.  
Lakefield - Ontario - K0L 2H0  
Phone: 705-652-2000 FAX: 705-652-6365

**Paracel Laboratories**

Attn : Dale Robertson

300-2319 St.Laurent Blvd.  
Ottawa, ON  
K1G 4K6, Canada

Phone: 613-731-9577  
Fax:613-731-9064

13-March-2019

**Date Rec. :** 05 March 2019  
**LR Report:** CA12115-MAR19  
**Reference:** Project#:1909473

**Copy:** #1

## CERTIFICATE OF ANALYSIS

### Final Report

Sample ID	Sample Date & Time	Sulphide %
1: Analysis Start Date		13-Mar-19
2: Analysis Start Time		13:56
3: Analysis Completed Date		13-Mar-19
4: Analysis Completed Time		14:34
5: QC - Blank		< 0.02
6: QC - STD % Recovery		118%
7: QC - DUP % RPD		2%
8: RL		0.02
9: 19-2, SS4B, 8'7"-9'6"	21-Feb-19	< 0.02
10: 19-5, SS7, 15'-17'	21-Feb-19	0.02
11: 19-8, SS7, 17'6"-19'6"	21-Feb-19	< 0.02
12: 19-9, SS10, 22'6"-24'6"	21-Feb-19	< 0.02

RL - SGS Reporting Limit

Kimberley Didsbury  
Project Specialist,  
Environment, Health & Safety



# FINAL REPORT

CA40225-JUL22 R1

**Client:** Thurber Engineering Ltd.

**Project:** 33099, Hwy 401 Choate and Ganaraska DD

**Project Manager:** Chris Murray

**Samplers:** Joe Lin

MATRIX: SOIL

Sample Number	5	6	7	8	9	10	11	12
Sample Name	CR22-01 SS3	GR22-02 SS6	GR22-03 SS5	GR22-07 SS5	GR22-08 SS5	DC22-05 SS10	DC22-07 SS3	DC22-11 SS10
Sample Matrix	5'-7'	12'6"-14'6"	10'-12'	10'-12'	10'-12'	30'-23'	5'-7'	25'-27'
Sample Date	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
Sample Date	17/05/2022	12/04/2022	28/03/2022	06/04/2022	11/04/2022	02/06/2022	19/05/2022	25/05/2022

Parameter	Units	RL	Result	Result	Result	Result	Result	Result	Result	Result
<b>Corrosivity Index</b>										
Corrosivity Index	none	1	14	6	9	14	9	6	4	4
Soil Redox Potential	mV	no	314	279	191	272	237	234	279	227
Sulphide (Na2CO3)	%	0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
pH	pH Units	0.05	8.54	7.37	8.10	8.17	8.15	8.11	8.34	8.17
Resistivity (calculated)	ohms.cm	-9999	1150	1320	1510	1119	2090	2470	7530	4500
<b>General Chemistry</b>										
Conductivity	uS/cm	2	867	550	622	1390	479	405	131	222
<b>Metals and Inorganics</b>										
Moisture Content	%	0.1	22.6	30.5	20.6	9.7	12.2	17.0	8.4	10.2
Sulphate	µg/g	0.4	17	46	66	11	16	5.4	12	67
<b>Other (ORP)</b>										
Chloride	µg/g	0.4	340	170	160	330	89	5.4	13	8.4





**Stantec Consulting Ltd.**  
400 - 1331 Clyde Avenue, Ottawa ON K2C 3G4

March 22, 2019  
File: 122410864

**Attention: Christopher Murray, M.A.Sc., P.Eng.**

Thurber Engineering Ltd.  
104 – 2460 Lancaster Road  
Ottawa, Ontario, Canada, K1B 4S5  
Tel: 613-274-2121 ext. 104  
E-mail: CMurray@thurber.ca

Dear Mr. Murray,

**Reference: Consolidation Test Results for HWY 401, Choate Road Project, Thurber Consulting Ltd.,  
File #22645: BH 19-01, ST 1, & BH 19-11B, ST 1, sampled on February 24 & 21, 2019**

This letter presents the results of one-dimensional consolidation tests carried out on the above referenced samples in accordance with ASTM D2435/D2435M - 11. The test results are provided in the attached tables and figures.

This letter provides test results only and does not constitute any interpretation or engineering recommendations with respect to material suitability or specification compliance.

We trust the information presented herein meets your present requirements. Should you have any questions or require additional information, please do not hesitate to contact us.

Regards,

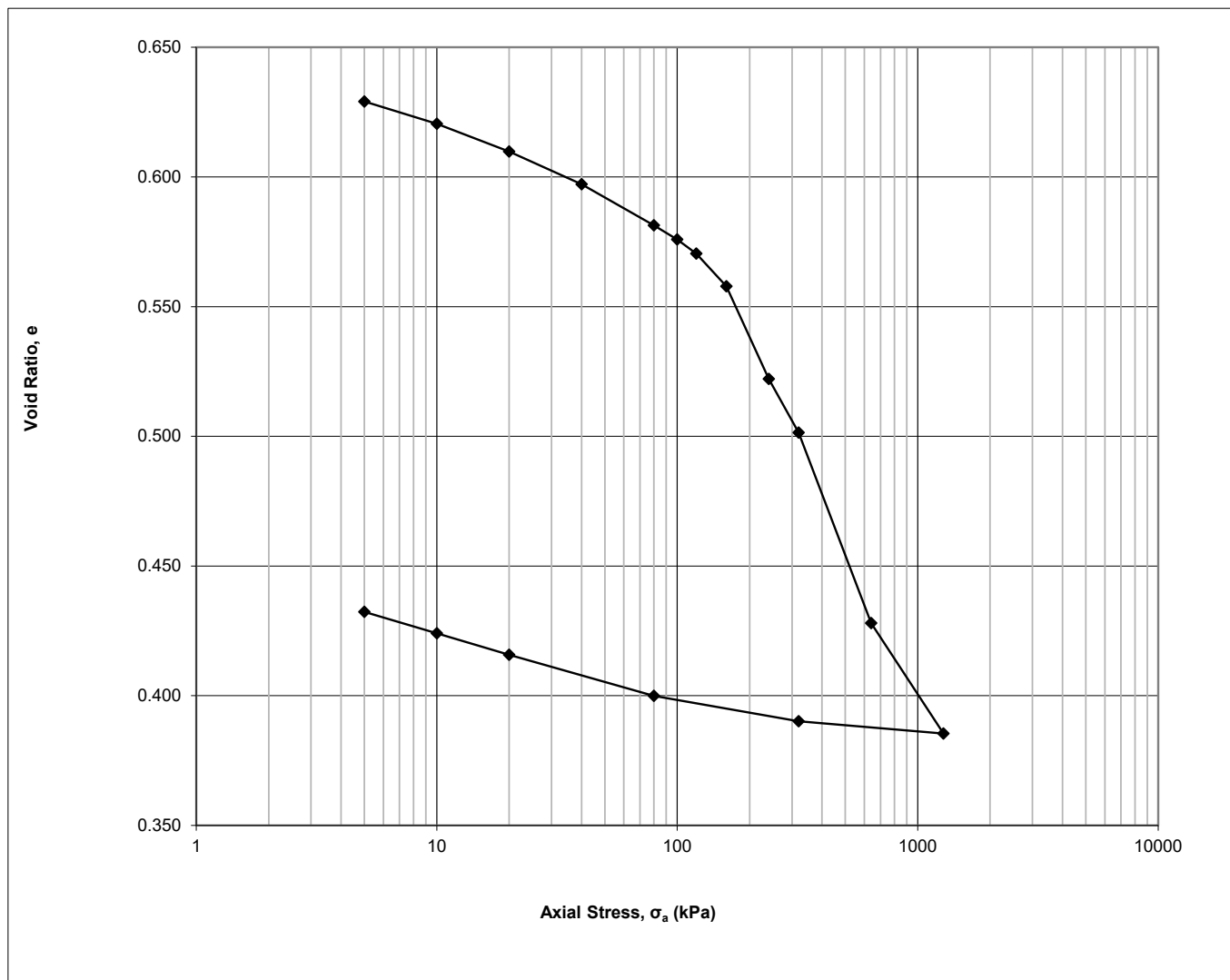
**STANTEC CONSULTING LTD.**

A handwritten signature in blue ink, appearing to read "Ramy Saadeldin", written over a horizontal line.

Ramy Saadeldin, Ph.D., P.Eng.  
Geotechnical Engineering  
Phone: (613) 738-6047  
Fax: (613) 722-2799  
Ramy.Saadeldin@stantec.com

**Project**  
**Project No.**  
**Borehole No.**  
**Sample No.**  
**Sample Depth**

**Thurber Engineering, File# 22645**  
**122410864**  
**BH 19-01**  
**ST 1**  
**20-22 ft.**



**One-Dimensional Consolidation Test using Incremental Loading**  
**ASTM D2435/D2435M - 11**

**Specimen Details**

Project Name	Thurber Engineering, File# 22645
Project Location	HWY 401-Choate Road
Borehole	BH 19-01
Sample No.	ST 1
Depth	20-22 ft.
Sample Date	February 24, 2019
Test Number	One
Technician Name	Daniel Boateng

**Soil Description & Classification**

Silt and Clay, Grey, Varved, Moist- CL	
Specific Gravity of Solids	2.720
Liquid Limit %	30
Plastic Limit %	17
Plasticity Index %	13
Average water content of trimmings %	25
<b>Additional Notes (information source, occurrence and size of large isolated particles etc.)</b>	

**Initial Specimen Conditions**

Height	mm	20.00
Diameter	mm	50.00
Area	mm <sup>2</sup>	1963
Volume	mm <sup>3</sup>	39270
Mass	g	80.09
Dry Mass	g	64.30
Density	Mg/m <sup>3</sup>	2.039
Dry Density	Mg/m <sup>3</sup>	1.637
Water Content	%	24.56
Degree of Saturation	%	100.0
Height of Solids	mm	12.04
Initial Void Ratio		0.661

**Final Specimen Conditions**

Water Content	%	20.83
Final Void Ratio		0.432

22-Mar-19  
22-Mar-19

Date: Date:

D. Boateng  
R. Saadeldin

Checked by:  
Approved by:

V:\01216\active\laboratory\_standing\_offers\2019 L  
22-Mar-19

Filename:  
Date:

## One-Dimensional Consolidation Test using Incremental Loading

### ASTM D2435/D2435M - 11

**Specimen Details**

Project Name	Thurber Engineering, File# 22645
Project Location	HWY 401-Choate Road
Borehole	BH 19-01
Sample No.	ST 1
Depth	20-22 ft.
Sample Date	February 24, 2019
Test Number	One
Technician Name	Daniel Boateng

**Test Procedure**

Date Started	March 14, 2019
Date Finished	March 20, 2019
Machine Number	Frame A
Cell Number	C1
Ring Number	R1
Trimming Procedure	Turntable
Moisture Condition	Inundated
Axial Stress at Inundation kPa	5
Water Used	Distilled
Test Method	A and B
Interpretation Procedure for $c_v$	2

**All Departures from Outlined ASTM D2435/D2435M-11 Procedure**

--

**Calculations**

Load Increment	Increment Duration min	Axial Stress $\sigma_a$ kPa	Corrected Deformation $\Delta H$ mm	Specimen Height H mm	Axial Strain $\epsilon_a$ %	Void Ratio e
Seating	0.0	0	0.0000		0.00	0.661
1	21.7	5	0.3864		1.93	0.629
2	21.7	10	0.4901		2.45	0.620
3	23.3	20	0.6189		3.09	0.610
4	25.0	40	0.7708		3.85	0.597
5	30.0	80	0.9612		4.81	0.581
6	29.9	100	1.0268		5.13	0.576
7	33.3	120	1.0931		5.47	0.570
8	45.0	160	1.2438		6.22	0.558
9	1440.0	240	1.6741		8.37	0.522
10	1440.0	320	1.9232		9.62	0.501
11	1440.0	640	2.8077		14.04	0.428
12	192.8	1280	3.3202		16.60	0.385
13	10.1	320	3.2627		16.31	0.390
14	16.8	80	3.1452		15.73	0.400
15	33.4	20	2.9547		14.77	0.416
16	38.5	10	2.8550		14.28	0.424
17	41.8	5	2.7557		13.78	0.432

## One-Dimensional Consolidation Test using Incremental Loading

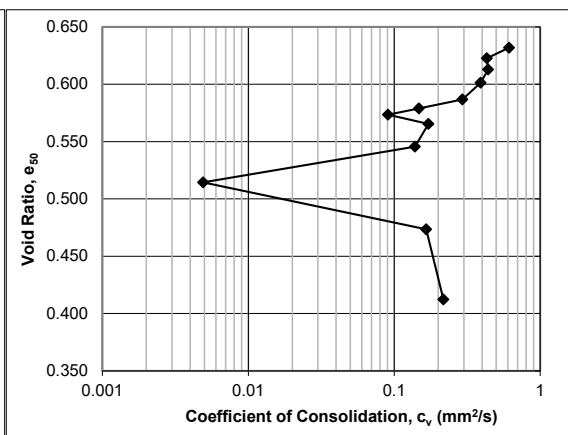
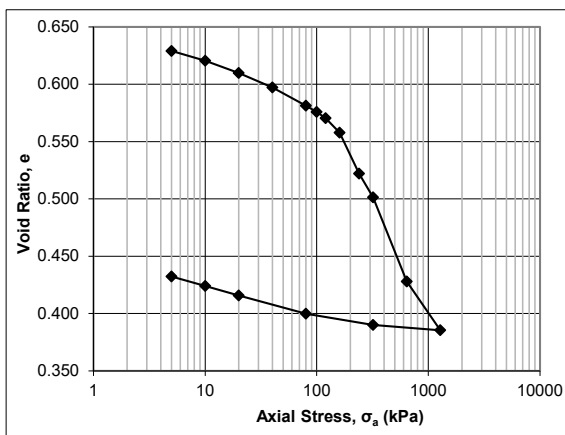
### ASTM D2435/D2435M - 11

**Specimen Details**

Project Name	Thurber Engineering, File# 22645
Project Location	HWY 401-Choate Road
Borehole	BH 19-01
Sample No.	ST 1
Depth	20-22 ft.
Sample Date	February 24, 2019
Test Number	One
Technician Name	Daniel Boateng

**Calculations**

Load Increment	Axial Stress $\sigma_a$ , average kPa	Calculated using Interpretation Procedure 2				Interpretation Procedure 1		Interpretation Procedure 2	
		Corrected Deformation $\Delta H_{50}$ mm	Specimen Height $H_{50}$ mm	Axial Strain $\epsilon_{a,50}$ %	Void Ratio $e_{50}$	Time $t_{50}$ sec	Coeff. Consol. $c_v$ mm <sup>2</sup> /s	Time $t_{90}$ sec	Coeff. Consol. $c_v$ mm <sup>2</sup> /s
Seating	0								
1	3	0.3524	19.6476	1.76	0.632			134	6.13E-01
2	8	0.4642	19.5358	2.32	0.623			188	4.31E-01
3	15	0.5811	19.4189	2.91	0.613			181	4.41E-01
4	30	0.7217	19.2783	3.61	0.601			202	3.91E-01
5	60	0.8957	19.1043	4.48	0.587			264	2.93E-01
6	90	0.9902	19.0098	4.95	0.579			518	1.48E-01
7	110	1.0570	18.9430	5.29	0.573			839	9.07E-02
8	140	1.1529	18.8471	5.76	0.565			439	1.71E-01
9	200	1.3906	18.6094	6.95	0.546			530	1.39E-01
10	280	1.7672	18.2328	8.84	0.514			14387	4.90E-03
11	480	2.2590	17.7410	11.29	0.474			402	1.66E-01
12	960	2.9972	17.0028	14.99	0.412			282	2.17E-01
13	800	3.2774	16.7226	16.39	0.389				
14	200	3.1932	16.8068	15.97	0.396				
15	50	3.0445	16.9555	15.22	0.408				
16	15	2.9386	17.0614	14.69	0.417				
17	8	2.8352	17.1648	14.18	0.426				





Project No.: 122410864

Project Name: Thurber Eng., File# 22645

Photo Log

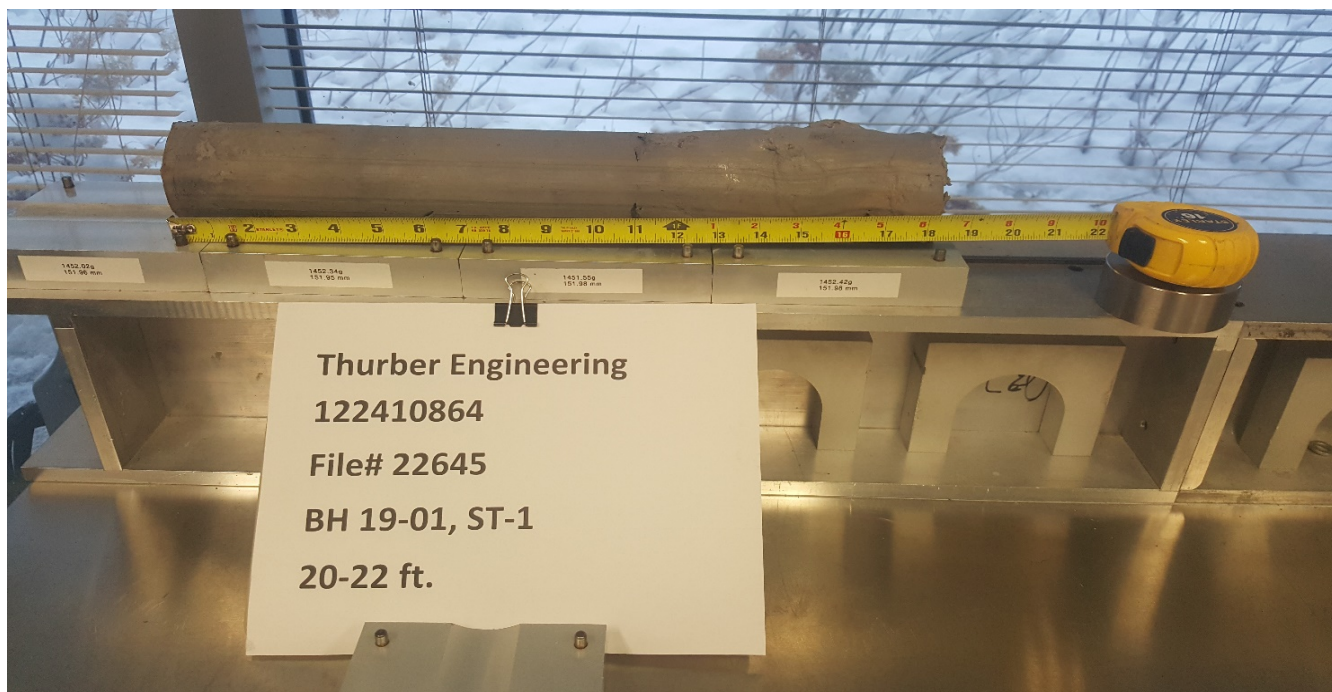


Photo No.: 1

Borehole: BH19-01, ST 1

Depth: 20 – 22 ft

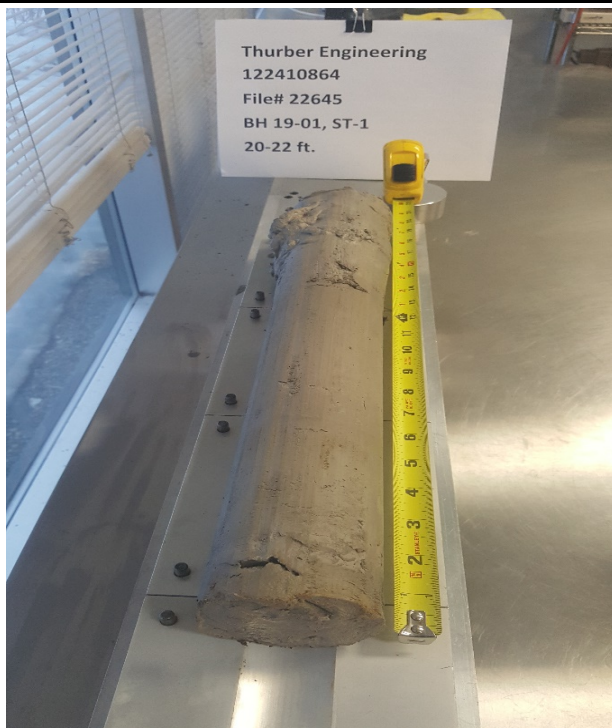


Photo No.: 2

Borehole: BH19-01, ST 1

Depth: 20 – 22 ft





Project No.: 122410864

Project Name: Thurber Eng., File# 22645

Photo Log

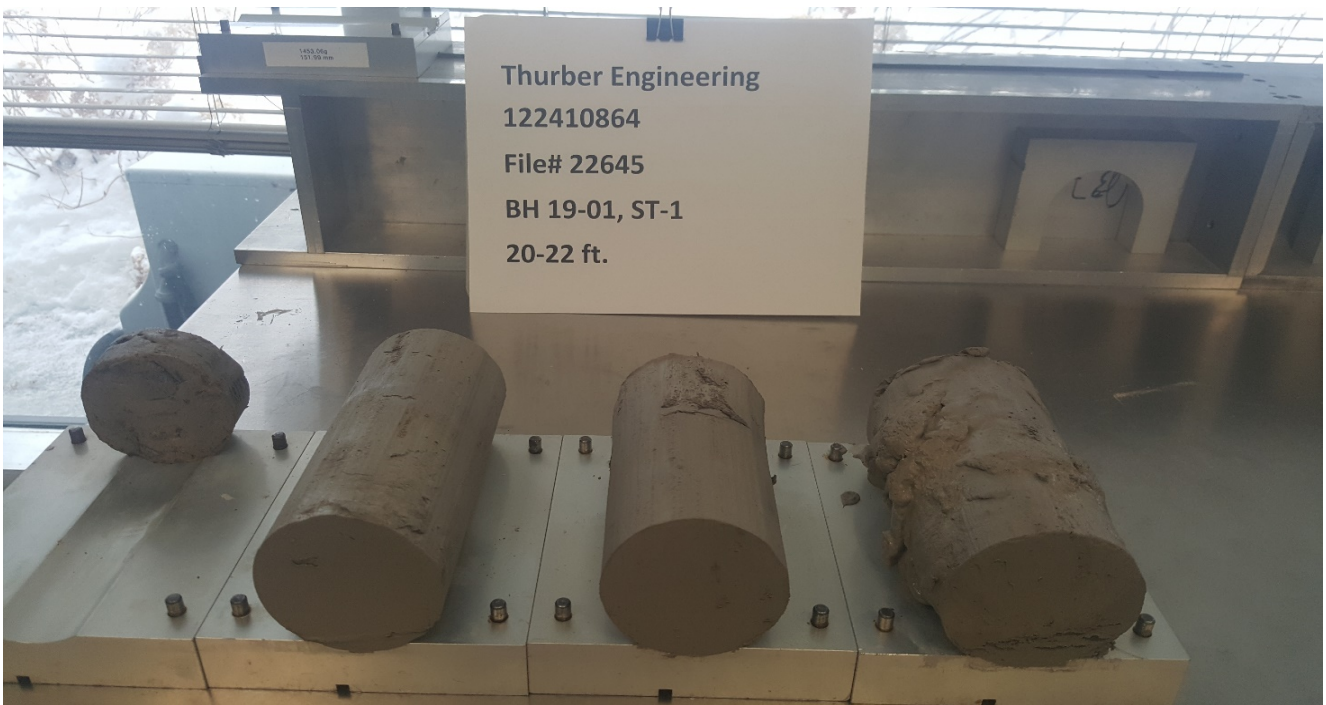


Photo No.: 3

Borehole: BH19-01, ST 1

Depth: 20 – 22 ft

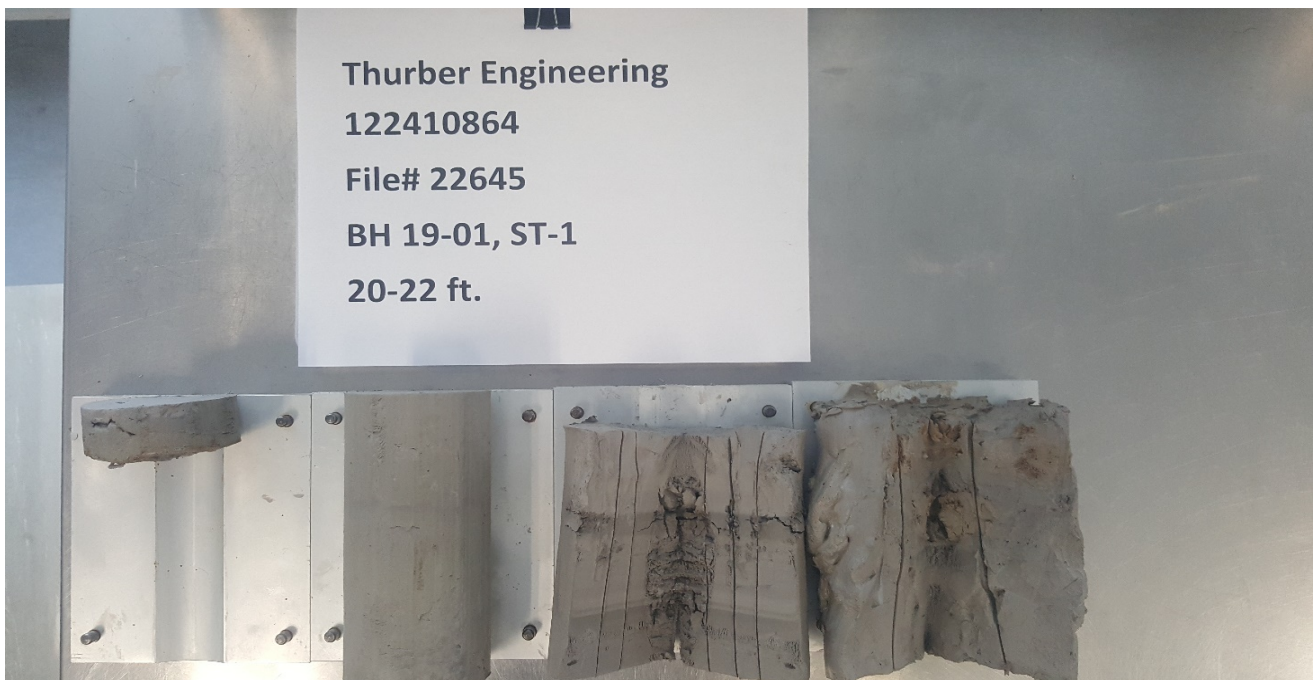


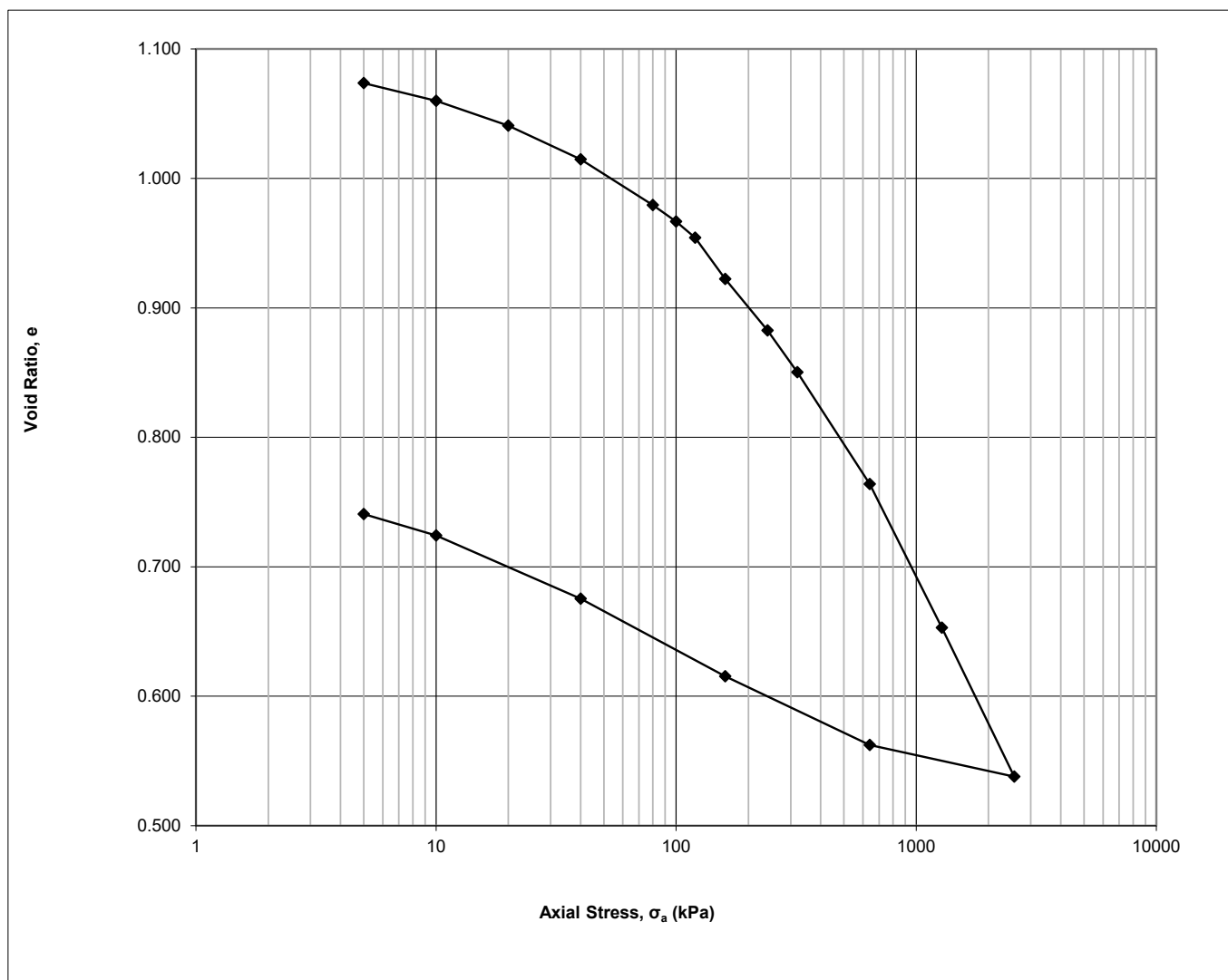
Photo No.: 4

Borehole: BH19-01, ST 1

Depth: 20 – 22 ft

**Project**  
**Project No.**  
**Borehole No.**  
**Sample No.**  
**Sample Depth**

**Thurber Engineering, File# 22645**  
**122410864**  
**BH 19-11B**  
**ST 1**  
**9-11 ft.**





**One-Dimensional Consolidation Test using Incremental Loading**  
**ASTM D2435/D2435M - 11**

**Specimen Details**

Project Name	Thurber Engineering, File# 22645
Project Location	HWY 401-Choate Road
Borehole	BH 19-11B
Sample No.	ST 1
Depth	9-11 ft.
Sample Date	February 21, 2019
Test Number	Two
Technician Name	Daniel Boateng

**Soil Description & Classification**

Silt and Clay, Trace Sand, Brown, Desiccated, Moist-CI	
Specific Gravity of Solids	2.729
Liquid Limit %	50
Plastic Limit %	22
Plasticity Index %	28
Average water content of trimmings %	39
<b>Additional Notes (information source, occurrence and size of large isolated particles etc.)</b>	
Six inches of fine sand at bottom of Shelby	

**Initial Specimen Conditions**

Height	mm	20.00
Diameter	mm	50.00
Area	mm <sup>2</sup>	1963
Volume	mm <sup>3</sup>	39270
Mass	g	71.76
Dry Mass	g	51.45
Density	Mg/m <sup>3</sup>	1.827
Dry Density	Mg/m <sup>3</sup>	1.310
Water Content	%	39.48
Degree of Saturation	%	99.5
Height of Solids	mm	9.60
Initial Void Ratio		1.083

**Final Specimen Conditions**

Water Content	%	33.00
Final Void Ratio		0.741

22-Mar-19  
22-Mar-19

Date: Date:

D. Boateng  
R. Saadeldin

Checked by:  
Approved by:

V:\01216\active\laboratory\_standing\_offers\2019 L  
22-Mar-19

Filename:  
Date:

## One-Dimensional Consolidation Test using Incremental Loading

### ASTM D2435/D2435M - 11

**Specimen Details**

Project Name	Thurber Engineering, File# 22645
Project Location	HWY 401-Choate Road
Borehole	BH 19-11B
Sample No.	ST 1
Depth	9-11 ft.
Sample Date	February 21, 2019
Test Number	Two
Technician Name	Daniel Boateng

**Test Procedure**

Date Started	March 14, 2019
Date Finished	March 20, 2019
Machine Number	Frame B
Cell Number	C2
Ring Number	R2
Trimming Procedure	Turntable
Moisture Condition	Inundated
Axial Stress at Inundation kPa	5
Water Used	Distilled
Test Method	A and B
Interpretation Procedure for $c_v$	2

**All Departures from Outlined ASTM D2435/D2435M-11 Procedure**

--

**Calculations**

Load Increment	Increment Duration min	Axial Stress $\sigma_a$ kPa	Corrected Deformation $\Delta H$ mm	Specimen Height H mm	Axial Strain $\epsilon_a$ %	Void Ratio e
Seating	0.0	0	0.0000		0.00	1.083
1	25.0	5	0.0900		0.45	1.074
2	30.0	10	0.2208		1.10	1.060
3	35.0	20	0.4050		2.03	1.041
4	38.4	40	0.6545		3.27	1.015
5	48.4	80	0.9944		4.97	0.979
6	41.7	100	1.1159		5.58	0.967
7	50.1	120	1.2360		6.18	0.954
8	1440.0	160	1.5430		7.72	0.922
9	1440.0	240	1.9241		9.62	0.883
10	1440.0	320	2.2348		11.17	0.850
11	86.9	640	3.0638		15.32	0.764
12	100.0	1280	4.1295		20.65	0.653
13	98.3	2560	5.2334		26.17	0.538
14	31.6	640	4.9987		24.99	0.562
15	80.0	160	4.4897		22.45	0.615
16	161.8	40	3.9139		19.57	0.675
17	200.2	10	3.4445		17.22	0.724
18	113.3	5	3.2853		16.43	0.741

## One-Dimensional Consolidation Test using Incremental Loading

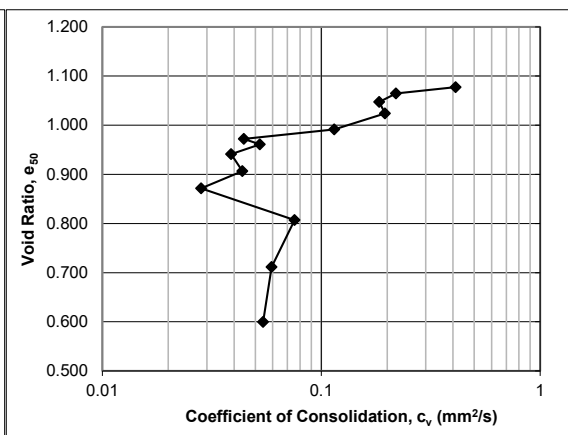
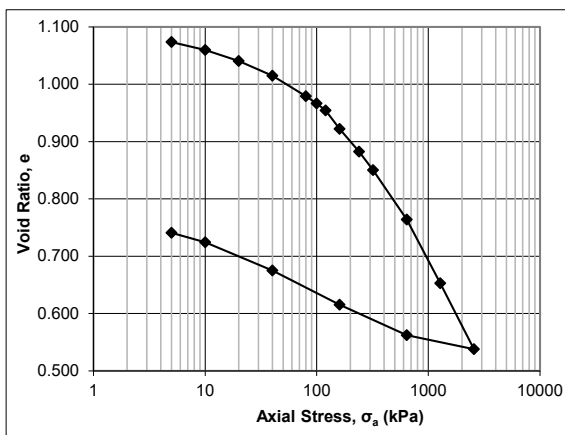
### ASTM D2435/D2435M - 11

**Specimen Details**

Project Name	Thurber Engineering, File# 22645
Project Location	HWY 401-Choate Road
Borehole	BH 19-11B
Sample No.	ST 1
Depth	9-11 ft.
Sample Date	February 21, 2019
Test Number	Two
Technician Name	Daniel Boateng

**Calculations**

Load Increment	Axial Stress $\sigma_a$ , average kPa	Calculated using Interpretation Procedure 2				Interpretation Procedure 1		Interpretation Procedure 2	
		Corrected Deformation $\Delta H_{50}$ mm	Specimen Height $H_{50}$ mm	Axial Strain $\epsilon_{a,50}$ %	Void Ratio $e_{50}$	Time $t_{50}$ sec	Coeff. Consol. $c_v$ mm <sup>2</sup> /s	Time $t_{90}$ sec	Coeff. Consol. $c_v$ mm <sup>2</sup> /s
Seating	0								
1	3	0.0524	19.9476	0.26	1.077			205	4.11E-01
2	8	0.1752	19.8248	0.88	1.065			380	2.19E-01
3	15	0.3425	19.6575	1.71	1.047			445	1.84E-01
4	30	0.5648	19.4352	2.82	1.024			409	1.96E-01
5	60	0.8780	19.1220	4.39	0.992			675	1.15E-01
6	90	1.0630	18.9370	5.32	0.972			1715	4.43E-02
7	110	1.1723	18.8277	5.86	0.961			1434	5.24E-02
8	140	1.3624	18.6376	6.81	0.941			1898	3.88E-02
9	200	1.6917	18.3083	8.46	0.907			1628	4.36E-02
10	280	2.0310	17.9690	10.15	0.871			2423	2.83E-02
11	480	2.6502	17.3498	13.25	0.807			845	7.55E-02
12	960	3.5676	16.4324	17.84	0.711			964	5.94E-02
13	1920	4.6394	15.3606	23.20	0.600			922	5.43E-02
14	1600	5.0967	14.9033	25.48	0.552				
15	400	4.7343	15.2657	23.67	0.590				
16	100	4.1822	15.8178	20.91	0.647				
17	25	3.8703	16.1297	19.35	0.680				
18	8	3.4288	16.5712	17.14	0.726				





Project No.: 122410864

Project Name: Thurber Eng., File# 22645

Photo Log

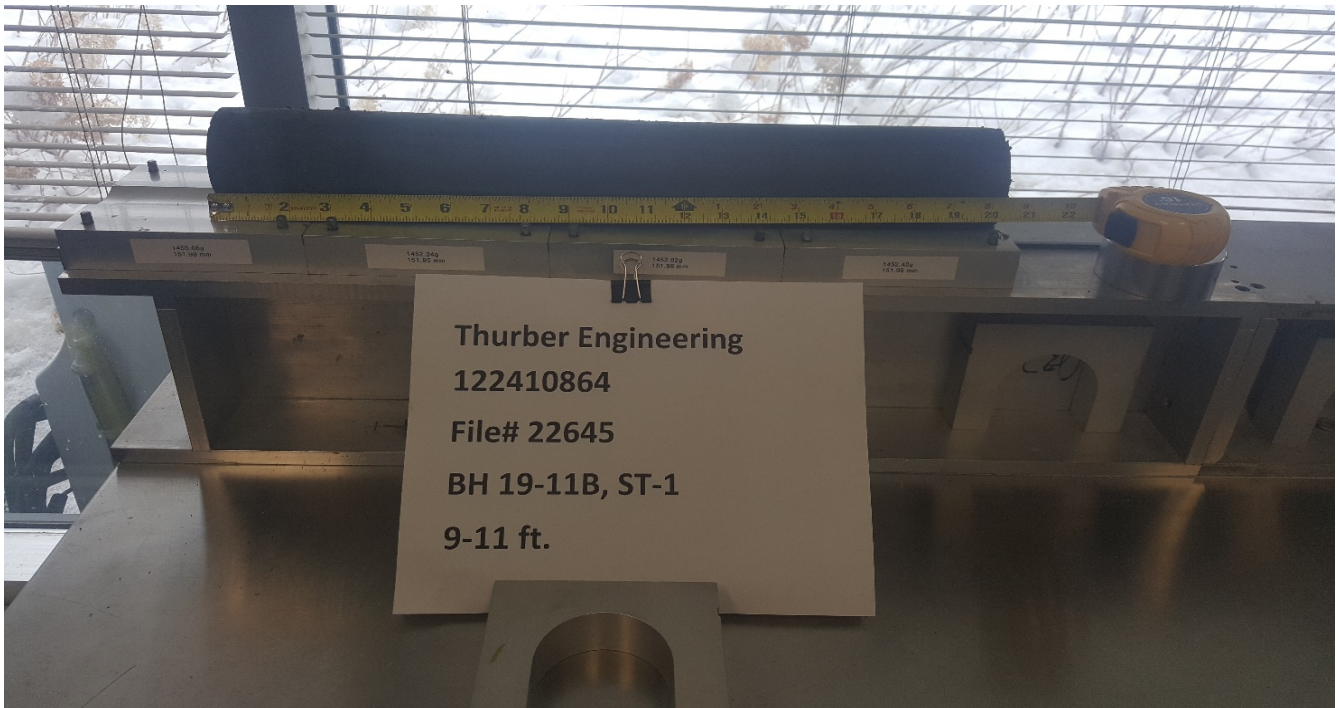


Photo No.:

1

Borehole: BH19-11B, ST 1

Depth: 9 – 11 ft.



Photo No.:

2

Borehole: BH19-11B, ST 1

Depth: 9 – 11 ft.





Project No.: 122410864

Project Name: Thurber Eng., File# 22645

Photo Log

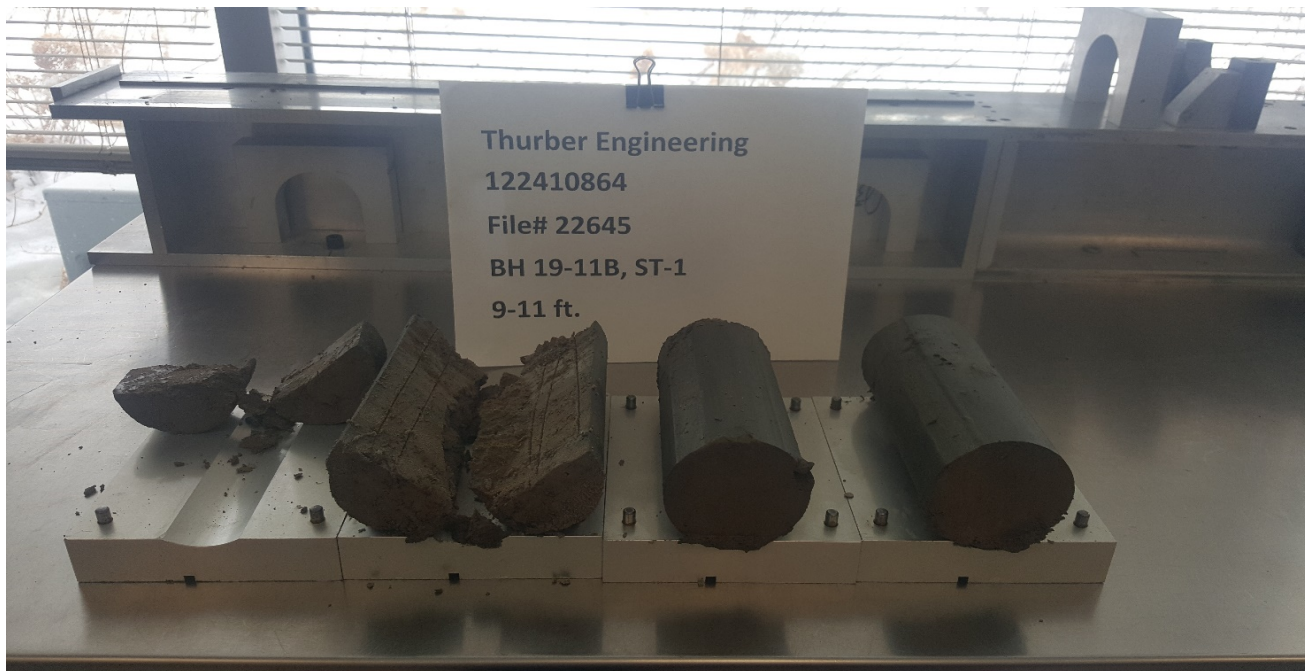


Photo No.:

3

Borehole: BH19-11B, ST 1

Depth: 9 – 11 ft.

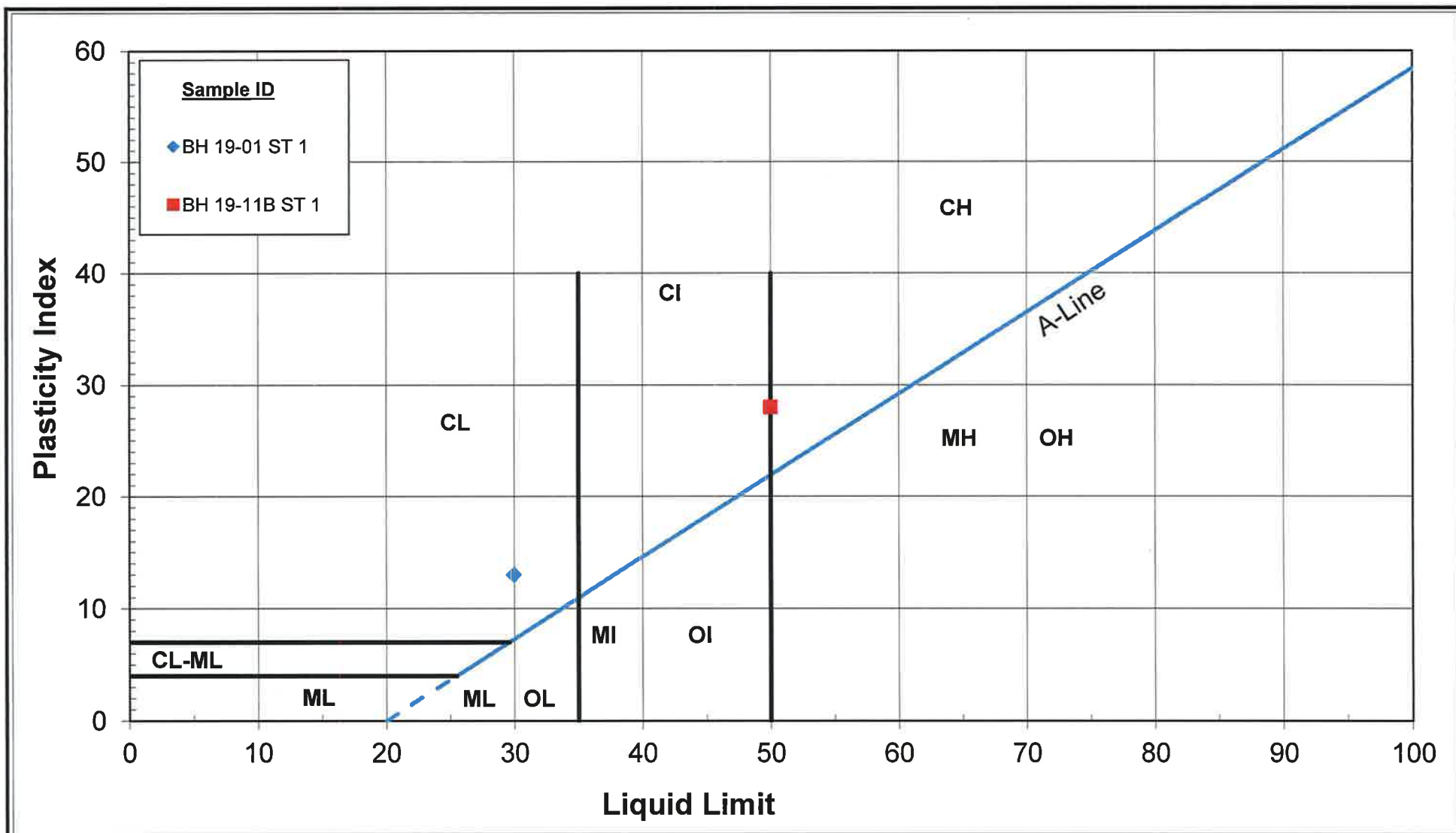


Photo No.:

4

Borehole: BH19-11B, ST 1

Depth: 9 – 11 ft.

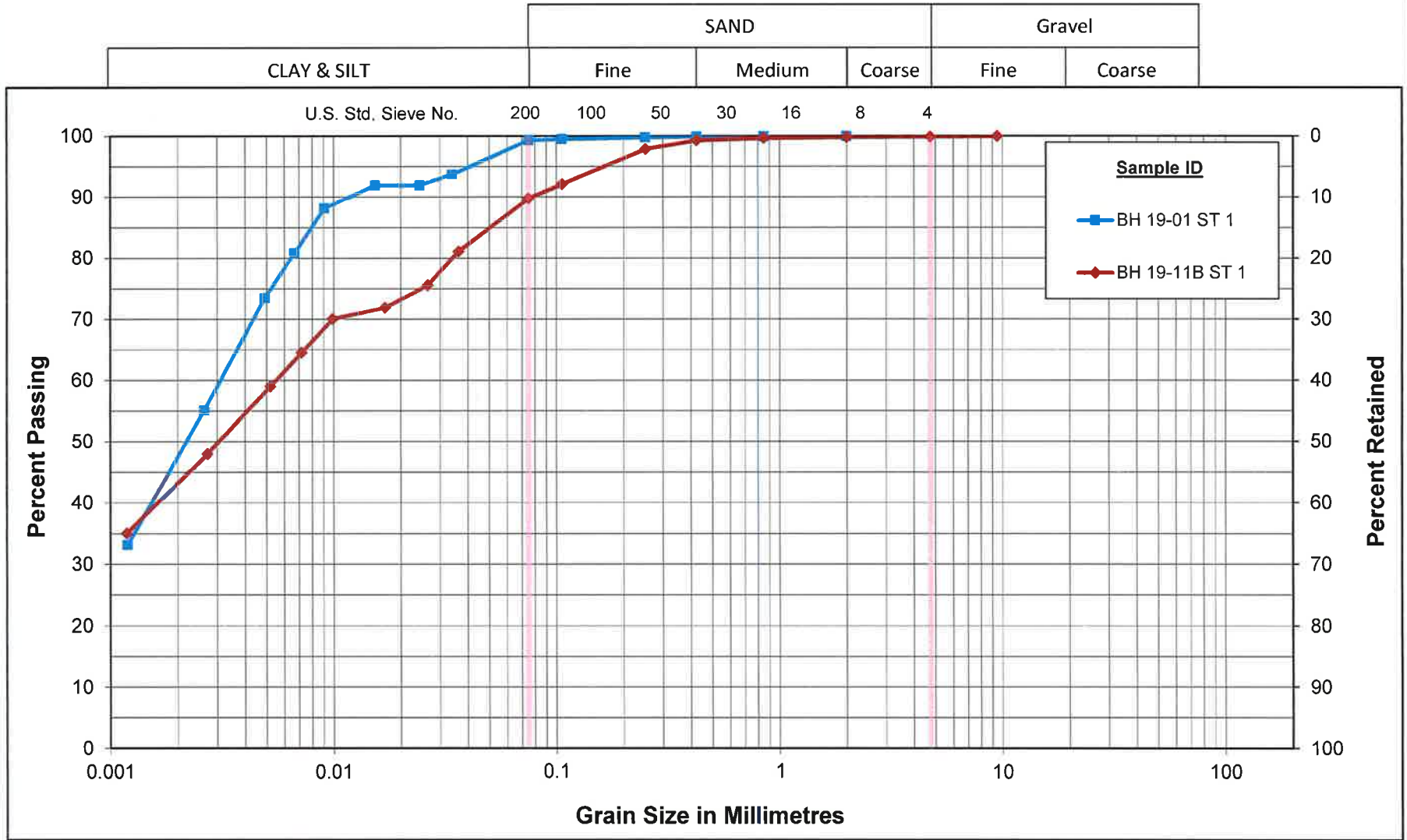


Thurber Engineering, File #22645  
HWY 401-Choate Road  
**PLASTICITY CHART**

Figure No.

Project No. 122410864

# Unified Soil Classification System



## GRAIN SIZE DISTRIBUTION

Thurber Engineering, File# 22645  
HWY 401, Choate Road

Figure No.

Project No. 122410864



**Stantec**

**Stantec Consulting Ltd**  
2781 Lancaster Rd, Suite 100 A&B  
Ottawa, ON K1B 1A7  
Tel: (613) 738-6075  
Fax: (613) 722-2799

March 25, 2019  
File: 122410864

**Attention:** Thurber Engineering Ltd., File #22645

**Reference:** ASTM D7012, Method C, Unconfined Compressive Strength of Intact Rock Core

The table below summarizes four (4) Rock Core compressive strength results.

Location	Sample Depth	Compressive Strength (MPa)	Description of Break
BH19-03 Run-1	18'2"-18'8"	106.4	Columnar vertical cracking through both ends
BH19-6 Run-3	23'7"-24'1"	86.1	Columnar vertical cracking through both ends
BH19-8 Run-2	36'9"-37'7"	88.1	Diagonal fracture with no cracking through ends
BH19-11A Run-1	18'2"-18'8"	91.8	Columnar vertical cracking through both ends

Sincerely,

**Stantec Consulting Ltd**

Brian Prevost  
Laboratory Supervisor  
Tel: 613-738-6075  
[brian.prevost@stantec.com](mailto:brian.prevost@stantec.com)



## UNCONFINED COMPRESSION TEST REPORT

### ASTM D7012-14

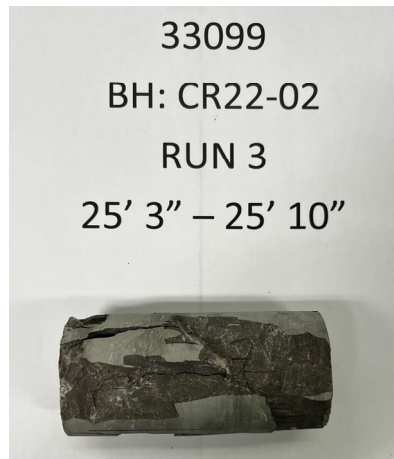
CLIENT:	McIntosh Perry	FILE NUMBER:	33099
PROJECT NAME:	Hwy 401 Choate & Ganaraska	REPORT DATE:	29-Aug-22
BOREHOLE No.:	CR22-02	TEST DATE:	16-Aug-22
SAMPLE No.:	Run 3		
SAMPLE DEPTH:	25' 3" - 25' 10"		
DESCRIPTION:	Limestone		

Avg. Height (cm):	10.7	Weight (g):	545.2
Avg. Diameter (cm):	5.0	Wet Density (kg/m <sup>3</sup> ):	2,574
H. to Dia. Ratio**:	2.1:1	Dry Density (kg/m <sup>3</sup> ):	2,564
Cross Sectional Area (cm <sup>2</sup> ):	19.79	Moisture Content* (%):	0.4
Sample Volume (cm <sup>3</sup> ):	211.78		

ORIGINAL SPECIMEN



FRACTURED SPECIMEN



AVG. RATE OF STRAIN TO FAILURE:	0.250 MPa/s
MAXIMUM COMPRESSIVE LOAD:	204.0 kN
UNCONFINED COMPRESSIVE STRENGTH:	103.1 MPa

Note: \* The moisture content was obtained before the test.  
 \*\* Dimensions of Specimen conform to ASTM D 4543-04.

TEST DONE BY: GF  
 REVIEWED BY: WM

33099 - UCS - CR22-02 Run 3 - August 17, 2022

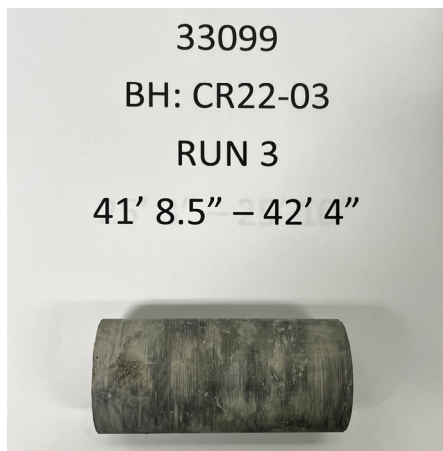
## UNCONFINED COMPRESSION TEST REPORT

### ASTM D7012-14

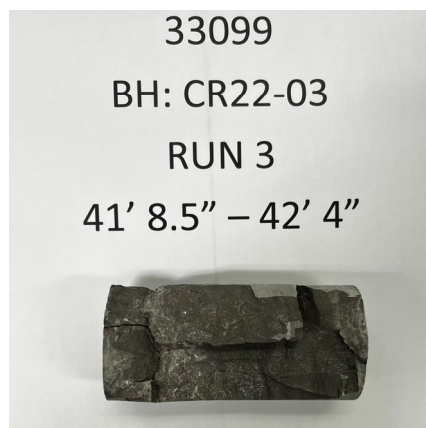
CLIENT:	McIntosh Perry	FILE NUMBER:	33099
PROJECT NAME:	Hwy 401 Choate & Ganaraska	REPORT DATE:	29-Aug-22
BOREHOLE No.:	CR22-03	TEST DATE:	16-Aug-22
SAMPLE No.:	Run 3		
SAMPLE DEPTH:	41' 8.5" - 42' 4"		
DESCRIPTION:	Limestone		

Avg. Height (cm):	10.6	Weight (g):	549.5
Avg. Diameter (cm):	5.0	Wet Density (kg/m <sup>3</sup> ):	2,598
H. to Dia. Ratio**:	2.1:1	Dry Density (kg/m <sup>3</sup> ):	2,586
Cross Sectional Area (cm <sup>2</sup> ):	19.95	Moisture Content* (%):	0.5
Sample Volume (cm <sup>3</sup> ):	211.47		

ORIGINAL SPECIMEN



FRACTURED SPECIMEN



AVG. RATE OF STRAIN TO FAILURE:	0.250 MPa/s
MAXIMUM COMPRESSIVE LOAD:	185.6 kN
UNCONFINED COMPRESSIVE STRENGTH:	93.0 MPa

Note: \* The moisture content was obtained before the test.  
 \*\* Dimensions of Specimen conform to ASTM D 4543-04.

TEST DONE BY: GF  
 REVIEWED BY: WM

33099 - UCS - CR22-03 Run 3 - August 17, 2022



**Stantec**

**Stantec Consulting Ltd**  
100 A&B – 2781 Lancaster Rd  
Ottawa, ON K1B 1A7  
Tel: (613) 738-6075  
Fax: (613) 738-6067

March 25, 2019  
File: 122410864

**Attention:** Chris Murray, Thurber Engineering, File #17848

**Reference:** ASTM D2974 Organic Matter of Peat & Other Soils

The table below summarizes test results for Organic Matter of Peat and Other Soils.

Source	Depth	Location	Organic Content
BH19-10 SS-2B	4'2"-4'6"	Highway 401-Choate Road	2.0%
BH19-10 SS-5A	10'-11'4"	Highway 401-Choate Road	9.9%
BH19-13 SS-9	20'-22'	Highway 401-Choate Road	7.2%

Sincerely,

**Stantec Consulting Ltd.**

*Brian Prevost*

Brian Prevost  
Laboratory Supervisor  
Tel: 613-738-6075  
Fax: 613-738-6067  
[brian.prevost@stantec.com](mailto:brian.prevost@stantec.com)

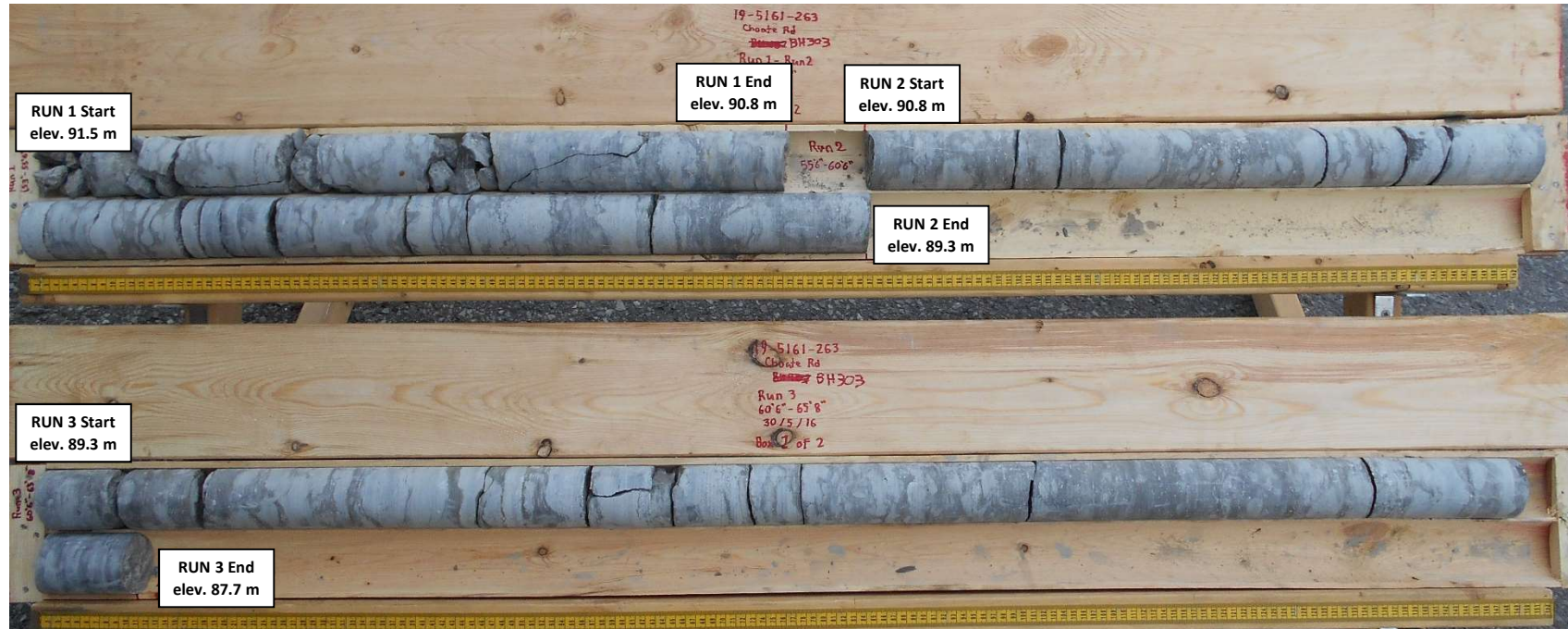
**Borehole 302**  
**RUN 1 to 2 (of 2)**  
**Elevation 91.7 m to 88.7 m**



**Foundation Investigation**  
**Highway 401 overpass at Choate Road**  
**Site 21-230**  
**Township of Hope, Ontario**

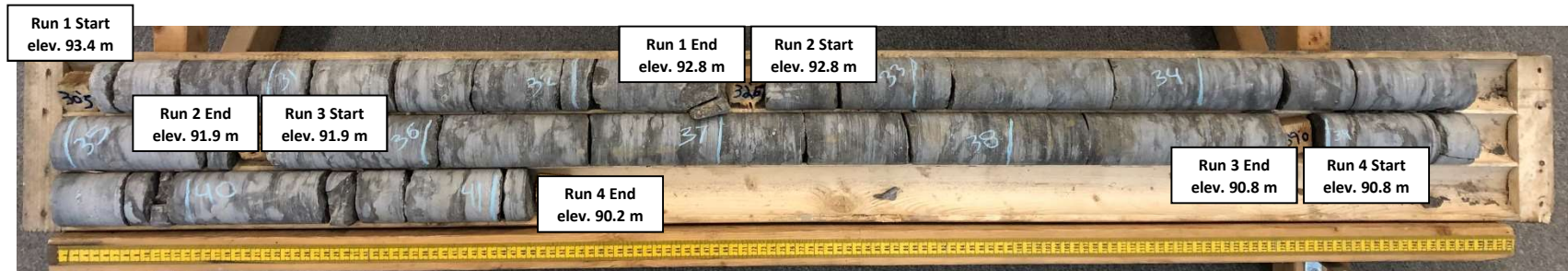
**GWP: 4068-14-00**  
**Project No.: 22645**

**Borehole 303**  
**RUN 1 to 3 (of 3)**  
**Elevation 91.5 m to 87.7 m**

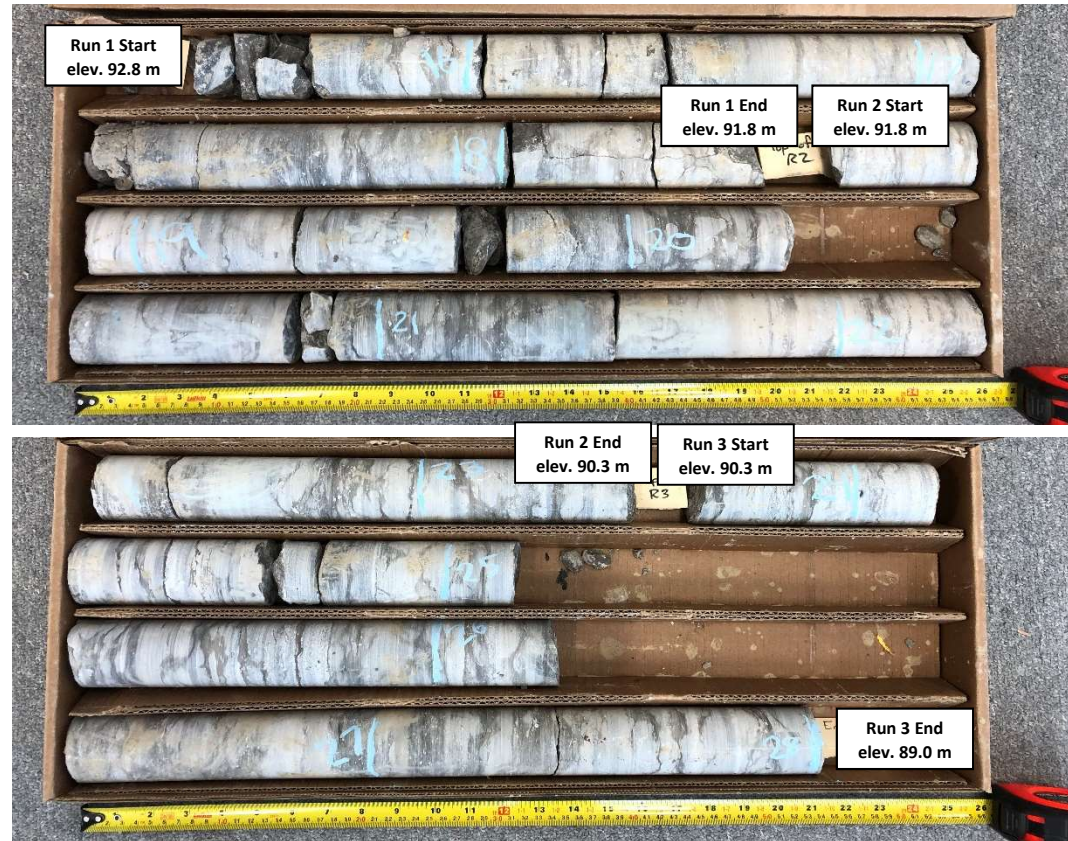




**Borehole 19-01**  
**Run 1 to 4 (of 4)**  
**Elevation 93.4 m to 90.2 m**



**Borehole 19-02**  
**Run 1 to 3 (of 3)**  
**Elevation 92.8 m to 89.0 m**



**THURBER** ENGINEERING LTD.

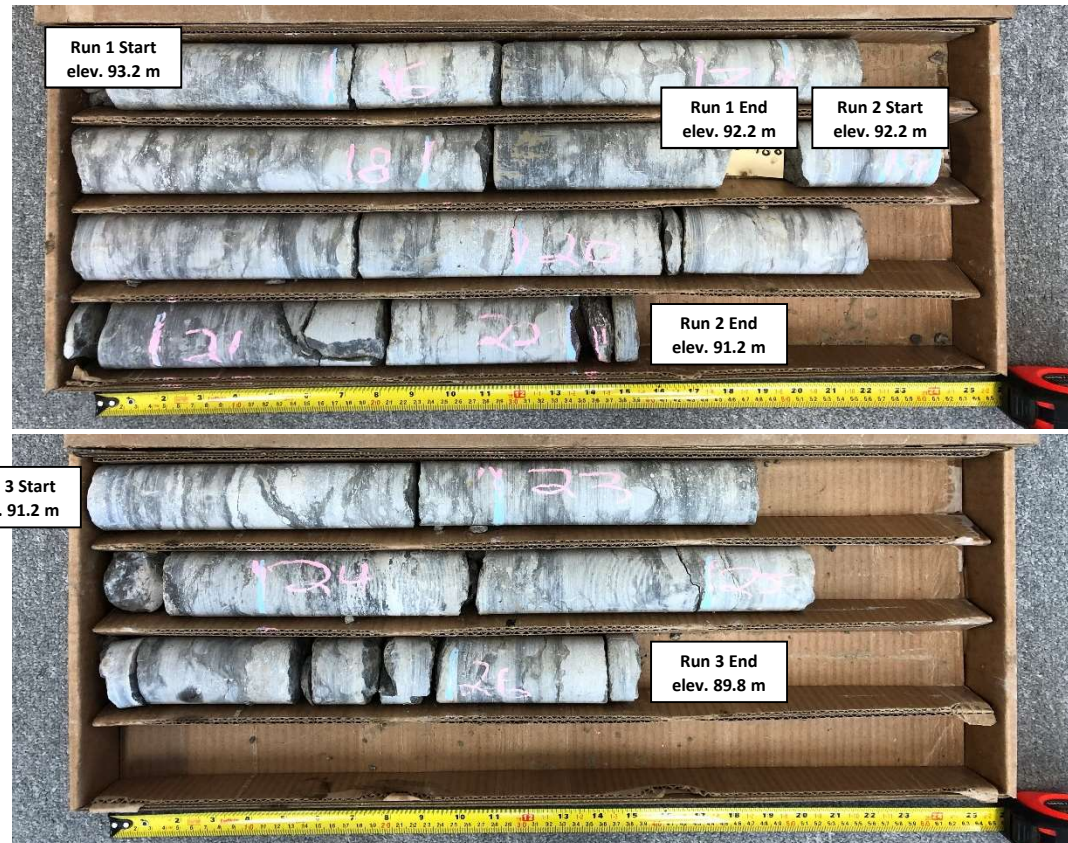
**Foundation Investigation**  
**Highway 401 overpass at Choate Road**  
**Site 21-230**  
**Township of Hope, Ontario**

**GWP: 4068-14-00**

**Project No.: 22645**



**Borehole 19-03**  
**Run 1 to 3 (of 3)**  
**Elevation 93.2 m to 89.8 m**

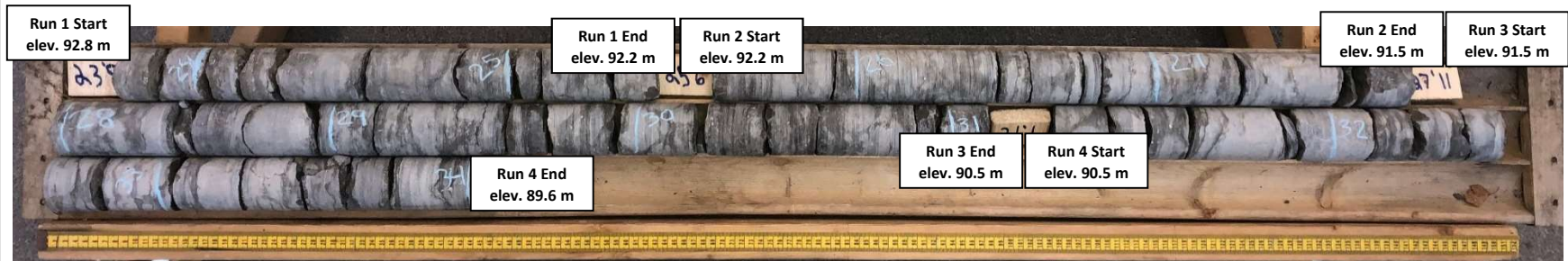




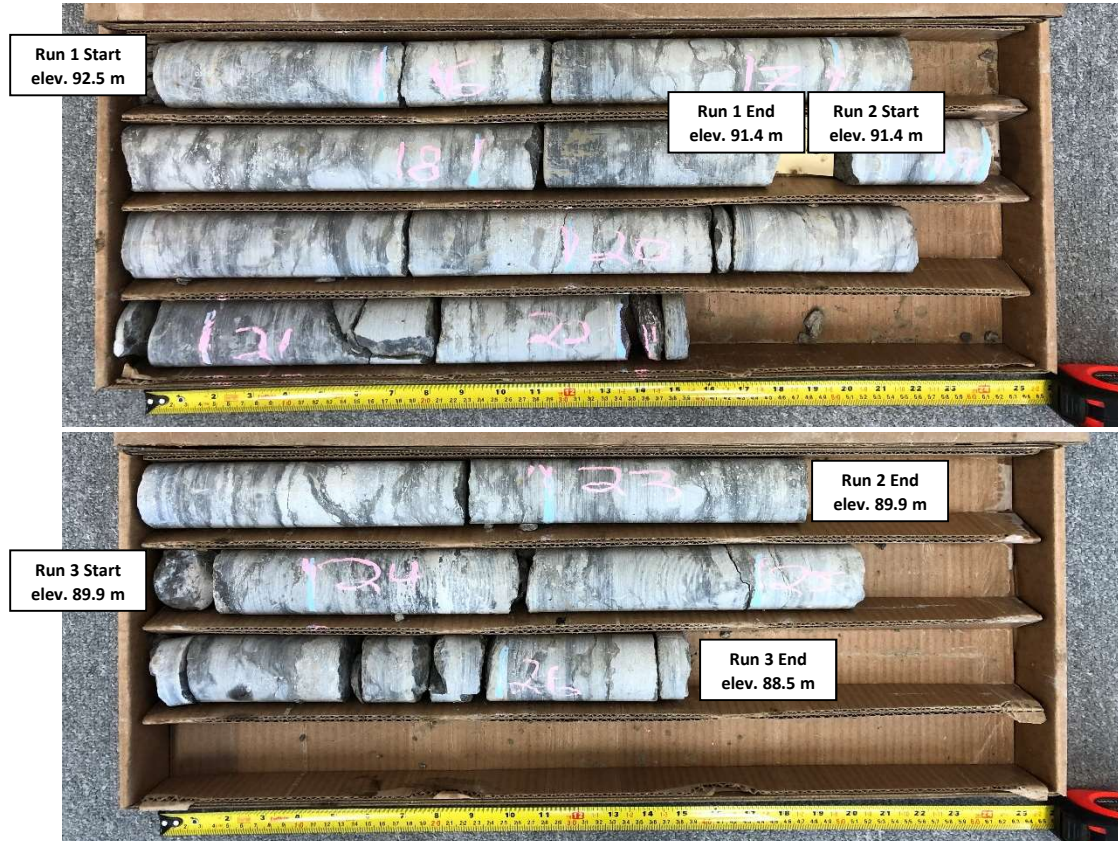
**Borehole 19-04**  
**Run 1 to 3 (of 3)**  
**Elevation 92.9 m to 89.6 m**



**Borehole 19-05**  
**Run 1 to 4 (of 4)**  
**Elevation 92.8 m to 89.6 m**



**Borehole 19-06**  
**Run 1 to 3 (of 3)**  
**Elevation 92.5 m to 88.5 m**



**THURBER** ENGINEERING LTD.

**Foundation Investigation**  
**Highway 401 overpass at Choate Road**  
**Site 21-230**  
**Township of Hope, Ontario**

**GWP: 4068-14-00**

**Project No.: 22645**



**Borehole 19-07**  
**Run 1 to 2 (of 2)**  
**Elevation 93.0 m to 90.0 m**



**Borehole 19-08**  
**Run 1 to 2 (of 2)**  
**Elevation 93.1 m to 90.1 m**



**THURBER** ENGINEERING LTD.

**Foundation Investigation**  
**Highway 401 overpass at Choate Road**  
**Site 21-230**  
**Township of Hope, Ontario**

**GWP: 4068-14-00**

**Project No.: 22645**

**Borehole 19-09**  
**Run 1 to 3 (of 3)**  
**Elevation 92.6 m to 89.3 m**



**Foundation Investigation**  
**Highway 401 overpass at Choate Road**  
**Site 21-230**  
**Township of Hope, Ontario**

**GWP: 4068-14-00**  
**Project No.: 22645**



**Borehole 19-10**  
**Run 1 to 3 (of 3)**  
**Elevation 92.6 m to 88.1 m**



**THURBER** ENGINEERING LTD.

**Foundation Investigation**  
**Highway 401 overpass at Choate Road**  
**Site 21-230**  
**Township of Hope, Ontario**

**GWP: 4068-14-00**

**Project No.: 22645**

**Borehole 19-11A**  
**Run 1 to 3 (of 3)**  
**Elevation 91.9 m to 88.5 m**



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**Foundation Investigation**  
**Highway 401 overpass at Choate Road**  
**Site 21-230**  
**Township of Hope, Ontario**

**GWP: 4068-14-00**

**Project No.: 22645**



**Borehole 19-12**  
**Run 1 to 3 (of 3)**  
**Elevation 92.6 m to 89.4 m**



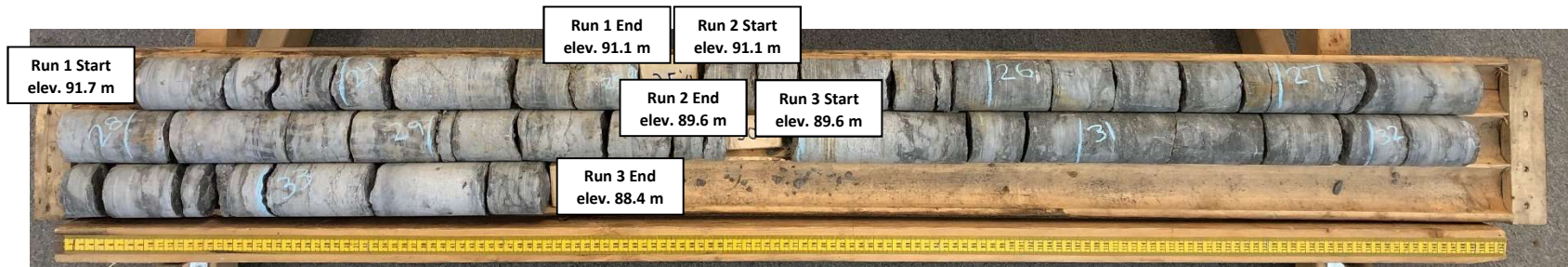
**THURBER** ENGINEERING LTD.

**Foundation Investigation**  
**Highway 401 overpass at Choate Road**  
**Site 21-230**  
**Township of Hope, Ontario**

**GWP: 4068-14-00**

**Project No.: 22645**

**Borehole 19-13**  
**Run 1 to 3 (of 3)**  
**Elevation 91.7 m to 88.4 m**



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**Foundation Investigation**  
**Highway 401 overpass at Choate Road**  
**Site 21-230**  
**Township of Hope, Ontario**

**GWP: 4068-14-00**

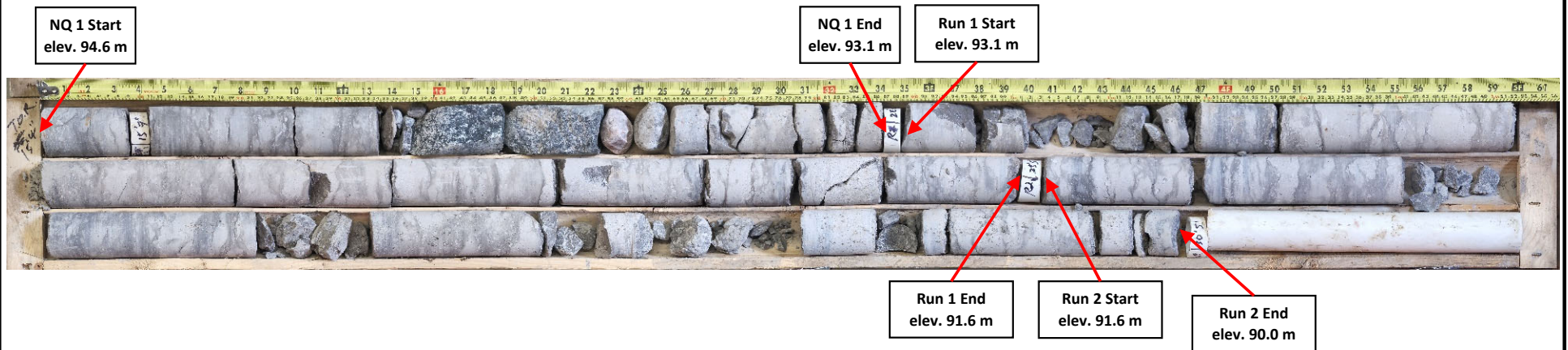
**Project No.: 22645**

# Borehole CR22-01

Runs 1 to 2

Depth 6.2 to 9.3 m

Elevation 93.1 to 90.0 m

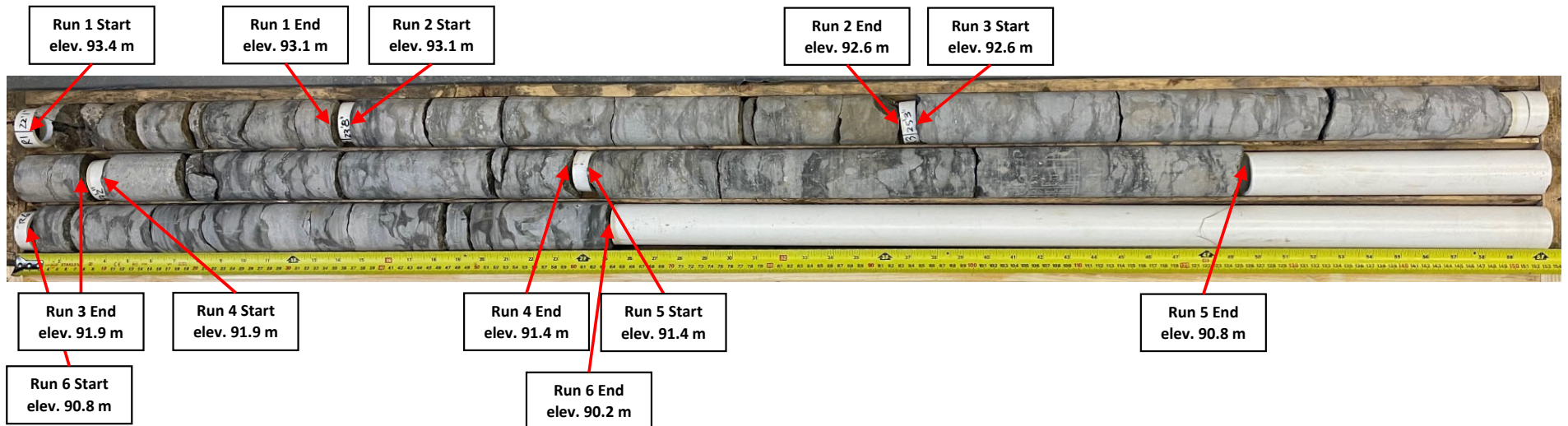


## Borehole CR22-02

Runs 1 to 6

Depth 6.7 to 9.7 m

Elevation 93.4 to 90.2 m



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**Geotechnical Investigation  
Highway 401 – Choate Road Bridge  
Site 21X-0230/B0  
Port Hope, Ontario**

**GWP: 4068-14-00  
BH CR22-02  
Project No.: 33099**

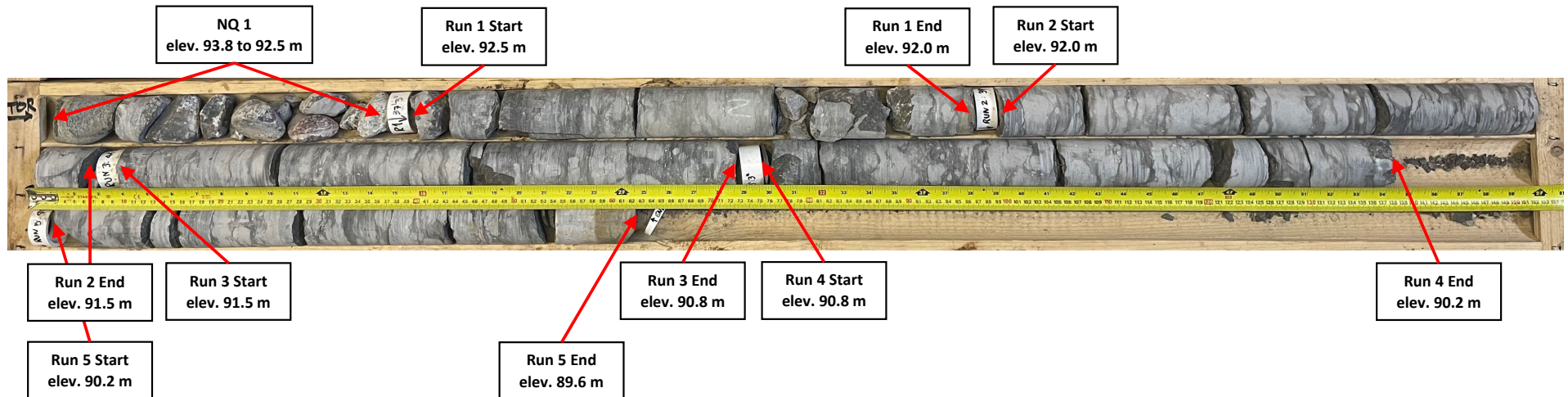


# Borehole CR22-03

Runs 1 to 5

Depth 11.5 to 14.4 m

Elevation 92.5 to 89.6 m

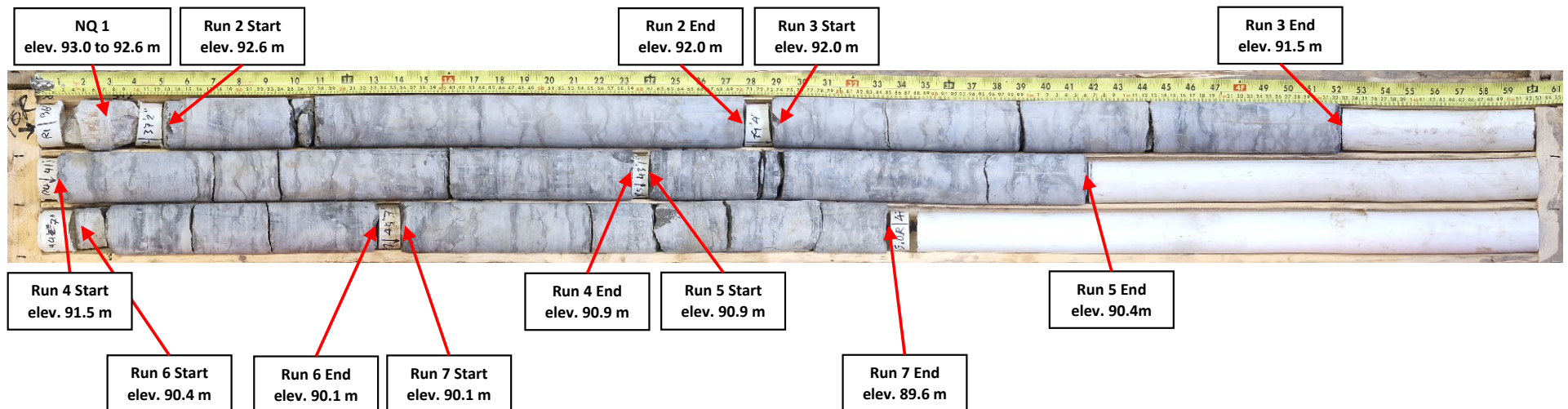


# Borehole CR22-04

Runs 2 to 7

Depth 11.4 to 14.4 m

Elevation 92.6 to 89.6 m



**THURBER** ENGINEERING LTD.

Geotechnical Investigation  
Highway 401 – Choate Road Bridge  
Site 21X-0230/B0  
Port Hope, Ontario

GWP: 4068-14-00  
BH CR22-04  
Project No.: 33099



## **Appendix D   Site Photographs**



Photo 1: North side of Hwy 401 Overpass at Choate Road looking East from the West embankment



Photo 2: West bridge abutment looking west from the entrance to the conservation area





Photo 3: Highway 401 Overpass at Choate Road West foreslope looking West from Choate Road



Photo 4: Highway 401 Overpass at Choate Road West foreslope looking South along Choate Road



## **Appendix E   Comparison of Foundation Alternatives**



### Comparison of Foundation Alternatives

Comment	Drilled-in Pipe Piles	Driven Steel H-Piles	Caissons	Micropiles	Spread Footings on Native Soils
<b>Advantages:</b>	<p>Moderate to high geotechnical resistance</p> <p>Better alignment control than caissons</p> <p>Higher lateral resistance than driven piles can be achieved with a sufficiently long rock socket</p>	<p>High axial resistance</p> <p>Relatively quick installation</p> <p>Readily available equipment</p>	<p>High axial geotechnical resistance.</p> <p>Readily available equipment</p> <p>Higher lateral resistance can be achieved with a sufficient rock socket length</p>	<p>Provide resistance in both tension and compression</p> <p>Easily installed in areas with limited headroom</p>	<p>Quicker installation and lower costs than deep foundations.</p>
<b>Disadvantages:</b>	<p>Higher cost than driven piles</p> <p>Fewer contractors with appropriate equipment</p> <p>Slower installation than driven piles</p>	<p>Low lateral resistance for short piles</p>	<p>Can be difficult to clean and inspect the base.</p> <p>Temporary steel liners and/or synthetic slurry may be required for excavation.</p> <p>Likely requires concrete to be placed using tremie techniques.</p>	<p>Low resistance to lateral load</p> <p>Lower axial compression resistance than other deep foundation options</p> <p>Higher cost than other alternatives for similar resistance</p>	<p>Provide a lower geotechnical resistance than deep foundations</p> <p>Native soils providing acceptable bearing resistance are too deep to be practical for abutments</p> <p>Significant dewatering would be required at the piers</p>
<b>Risks / Consequences</b>	Potential impact on adjacent driven piles	Piles are damaged during driving / add additional piles to pile group	Potential impact on adjacent driven piles		
<b>Relative Cost:</b>	<b>Moderate</b>	<b>Moderate</b>	<b>High</b>	<b>High</b>	<b>Low to Moderate</b>
<b>Conclusion:</b>	<b>FEASIBLE</b>	<b>RECOMMENDED</b>	<b>FEASIBLE</b>	<b>FEASIBLE</b>	<b>NOT RECOMMENDED</b>



## Appendix F P-y Curves

SOIL P-Y CURVES  
Choate Road Overpass

HP310x132: East Abutment, Underside Elev. 103.5m

Elev. (m)	102.5		101.5		100.5		99.5		98.5		97.5		96.5		95.5		94.5		93.5							
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)						
Static	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000						
	0.0019	16.0218	0.0020	43.6336	0.0049	188.8311	0.0093	483.0299	0.0108	701.9137	0.0108	842.2965	0.0099	897.3061	0.0085	878.2787	0.0023	794.1594	0.0021	804.9194						
	0.0022	17.0791	0.0023	47.3428	0.0049	189.5917	0.0095	492.6302	0.0109	706.3659	0.0109	847.6391	0.0100	910.1063	0.0087	904.2317	0.0025	849.4328	0.0024	870.2883						
	0.0025	18.0529	0.0026	50.8732	0.0049	190.3505	0.0097	502.2304	0.0110	710.8181	0.0110	852.9817	0.0102	922.9065	0.0090	930.1846	0.0028	902.4775	0.0027	932.6321						
	0.0028	18.9588	0.0029	54.2523	0.0050	191.1072	0.0099	511.8307	0.0111	715.2702	0.0111	858.3243	0.0103	935.7067	0.0092	956.1376	0.0031	953.5831	0.0029	992.3962						
	0.0031	19.8085	0.0032	57.5007	0.0050	191.8621	0.0101	521.4310	0.0111	719.7224	0.0111	863.6669	0.0105	948.5069	0.0095	978.6126	0.0033	1002.9800	0.0032	1049.9240						
	0.0034	20.6106	0.0035	60.6348	0.0050	192.6150	0.0103	531.0313	0.0112	724.1745	0.0112	869.0094	0.0106	961.3071	0.0097	997.7025	0.0036	1050.8560	0.0035	1105.4860						
	0.0037	21.3716	0.0038	63.6678	0.0051	193.3660	0.0104	540.6315	0.0113	728.6267	0.0113	874.3520	0.0107	974.1073	0.0100	1016.7920	0.0039	1097.3640	0.0038	1159.3040						
	0.0040	22.0968	0.0041	66.6103	0.0051	194.1152	0.0106	550.2318	0.0113	733.0789	0.0113	879.6946	0.0109	986.9074	0.0102	1035.8820	0.0041	1142.6350	0.0041	1211.5560						
	0.0043	22.7905	0.0043	69.4713	0.0051	194.8625	0.0108	559.8321	0.0114	737.5310	0.0114	885.0372	0.0110	999.7076	0.0105	1054.9720	0.0044	1186.7770	0.0044	1262.3930						
	0.0046	23.4562	0.0046	72.2582	0.0052	195.6080	0.0110	567.7757	0.0115	741.9832	0.0115	890.3798	0.0112	1012.5080	0.0107	1074.0620	0.0047	1229.8850	0.0046	1311.9440						
	0.0049	24.0967	0.0049	74.9775	0.0052	196.3516	0.0112	575.1059	0.0115	746.4354	0.0115	895.7224	0.0113	1025.3080	0.0110	1093.1520	0.0050	1272.0410	0.0049	1360.3150						
	0.0052	24.7144	0.0052	77.6346	0.0052	197.0934	0.0114	582.4361	0.0116	750.8875	0.0116	901.0650	0.0115	1038.1080	0.0112	1112.2420	0.0052	1313.3130	0.0052	1407.6030						
	0.0085	31.1940	0.0085	107.1357	0.0085	271.9889	0.0116	589.7663	0.0117	755.3397	0.0117	906.4076	0.0116	1050.9080	0.0115	1131.3310	0.0085	1812.3720	0.0085	1942.4920						
	0.0117	37.6736	0.0117	136.6369	0.0117	346.8844	0.0117	597.0965	0.0117	759.7918	0.0117	911.7502	0.0117	1063.7090	0.0117	1150.4210	0.0117	2311.4320	0.0117	2477.3810						
	0.0141	37.6736	0.0141	136.6369	0.0141	346.8844	0.0141	597.0965	0.0141	791.7558	0.0141	950.1070	0.0141	1069.6620	0.0141	1150.4210	0.0141	2311.4320	0.0141	2477.3810						
	0.0164	37.6736	0.0164	136.6369	0.0164	346.8844	0.0164	597.0965	0.0164	791.7558	0.0164	950.1070	0.0164	1069.6620	0.0164	1150.4210	0.0164	2311.4320	0.0164	2477.3810						

HP310x132: West Abutment WBL, Underside Elev. 104.5m

Elev. (m)	103.5		102.5		101.5		100.5		99.5		98.5		97.5		96.5		95.5		94.5		93.5		92.5				
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)					
Static	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000					
	0.0019	16.0218	0.0020	43.6336	0.0049	188.8311	0.0000	20.6580	0.0000	20.6580	0.0000	20.6580	0.0000	20.6580	0.0005	103.7195	0.0000	6.5730	0.0005	207.1751	0.0009	372.4498	0.0013	613.5271			
	0.0022	17.0791	0.0023	47.3428	0.0049	189.5917	0.0000	41.3160	0.0000	41.3160	0.0000	41.3160	0.0000	41.3160	0.0009	146.6815	0.0001	13.1460	0.0010	295.6416	0.0013	467.0435	0.0017	708.7955			
	0.0025	18.0529	0.0026	50.8732	0.0049	190.3505	0.0001	61.9740	0.0001	61.9740	0.0001	61.9740	0.0001	61.9740	0.0014	170.8894	0.0005	19.7190	0.0014	369.4570	0.0017	550.5811	0.0020	796.4238			
	0.0028	18.9588	0.0029	54.2523	0.0050	191.1072	0.0003	82.6320	0.0003	82.6320	0.0003	82.6320	0.0003	82.6320	0.0019	186.6088	0.0012	26.2920	0.0018	434.7509	0.0021	626.6226	0.0024	878.2253			
	0.0031	19.8085	0.0032	57.5007	0.0050	191.8621	0.0008	103.2900	0.0008	103.2900	0.0008	103.2900	0.0008	103.2900	0.0023	197.3453	0.0023	32.8650	0.0022	494.2407	0.0025	697.1207	0.0027	955.3795			
	0.0034	20.6106	0.0035	60.6348	0.0050	192.6150	0.0016	123.9480	0.0016	123.9480	0.0016	123.9480	0.0016	123.9480	0.0028	204.5171	0.0040	39.4380	0.0027	549.4268	0.0028	763.2895	0.0031	1028.7070			
	0.0037	21.3716	0.0038	63.6678	0.0051	193.3660	0.0030	144.6060	0.0030	144.6060	0.0030	144.6060	0.0030	144.6060	0.0033	208.9346	0.0064	46.0110	0.0031	601.2455	0.0032	825.9472	0.0034	1098.8070			
	0.0040	22.0968	0.0041	66.6103	0.0051	194.1152	0.0051	165.2640	0.0051	165.2640	0.0051	165.2640	0.0051	165.2640	0.0038	211.1209	0.0095	52.5840	0.0035	650.3297	0.0036	885.6776	0.0038	1166.1350			
	0.0043	22.7905	0.0043	69.4713	0.0051	194.8625	0.0081	185.9220	0.0081	185.9220	0.0081	185.9220	0.0081	185.9220	0.0042	211.4396	0.0135	59.1570	0.0039	697.1319	0.0040	942.9152	0.0042	1231.0430			
	0.0046	23.4562	0.0046	72.2582	0.0052	195.6080	0.0124	206.5800	0.0124	206.5800	0.0124	206.5800	0.0124	206.5800	0.0047	210.1567	0.0185	65.7300	0.0044	741.9895	0.0044	997.9945	0.0045	1293.8150			
	0.0049	24.0967	0.0049	74.9775	0.0052	196.3516	0.0181	227.2380	0.0181	227.2380	0.0181	227.2380	0.0181	227.2380	0.0052	207.4749	0.0247	72.3030	0.0048	785.1621	0.0048	1051.1790	0.0049	1354.6810			
	0.0052	24.7144	0.0052	77.6346	0.0052	197.0934	0.0256	247.8960	0.0256	247.8960	0.0256	247.8960	0.0256	247.8960	0.0056	203.6368	0.0321	78.8760	0.0052	826.8551	0.0052	1102.6820	0.0052	1413.8330			
	0.0085	31.1940	0.0085	107.1357	0.0085	271.9889	0.0353	268.5540	0.0353	268.5540	0.0353	268.5540	0.0353	268.5540	0.0094	146.8273	0.0408	85.4490	0.0085	1141.0600	0.0085	1521.7020	0.0085	1951.0900			
	0.0117	37.6736	0.0117	136.6369	0.0117	346.8844	0.0475	289.2120	0.0475	289.2120	0.0475	289.2120	0.0475	289.2120	0.0131	90.0178	0.0509	92.0220	0.0117	1455.2650	0.0117	1940.7210	0.0117	2488.3460			
	0.0141	37.6736	0.0141	136.6369	0.0141	346.8844	0.0626	309.8700	0.0626	309.8700	0.0626	309.8700	0.0626	309.8700	0.0169	33.2083	0.0626	98.5950	0.0141	1455.2650	0.0141	1940.7210	0.0141	2488.3460			
	0.0164	37.6736	0.0164	136.6369	0.0164	346.8844	0.0783	309.8700	0.0783	309.8700	0.0783	309.8700	0.0783	309.8700	0.0178	33.2083	0.0665	98.5950	0.0164	1455.2650	0.0164	1940.7210	0.0164	2488.3460			

SOIL P-Y CURVES  
Choate Road Overpass

HP310x132: West Abutment EBL, Underside Elev. 104.5m

Elev. (m)	103.5		102.5		101.5		100.5		99.5		98.5		97.5		96.5		95.5		94.5		93.5		92.5					
P-y Curves	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)	y (m)	P (kN/m)				
Static	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000				
	0.0019	16.0218	0.0020	43.6336	0.0049	188.8311	0.0093	483.0299	0.0108	701.9137	0.0108	842.2965	0.0108	982.6792	0.0100	1037.3950	0.0087	1016.6450	0.0078	1005.8560	0.0021	913.6816	0.0020	926.6100				
	0.0022	17.0791	0.0023	47.3428	0.0049	189.5917	0.0095	492.6302	0.0109	706.3659	0.0109	847.6391	0.0109	988.9122	0.0101	1051.1080	0.0090	1043.6440	0.0081	1045.3740	0.0024	984.1531	0.0023	1007.0310				
	0.0025	18.0529	0.0026	50.8732	0.0049	190.3505	0.0097	502.2304	0.0110	710.8181	0.0110	852.9817	0.0110	995.1453	0.0103	1064.8210	0.0092	1070.6420	0.0084	1080.5740	0.0027	1051.5090	0.0026	1083.5060				
	0.0028	18.9588	0.0029	54.2523	0.0050	191.1072	0.0099	511.8307	0.0111	715.2702	0.0111	858.3243	0.0111	1001.3780	0.0104	1078.5350	0.0094	1097.6410	0.0087	1108.6610	0.0030	1116.1910	0.0029	1156.6470				
	0.0031	19.8085	0.0032	57.5007	0.0050	191.8621	0.0101	521.4310	0.0111	719.7224	0.0111	863.6669	0.0111	1007.6110	0.0105	1092.2480	0.0097	1124.6390	0.0090	1136.7480	0.0033	1178.5390	0.0032	1226.9190				
	0.0034	20.6106	0.0035	60.6348	0.0050	192.6150	0.0103	531.0313	0.0112	724.1745	0.0112	869.0094	0.0112	1013.8440	0.0107	1105.9610	0.0099	1148.1150	0.0093	1164.8350	0.0035	1238.8300	0.0035	1294.6860				
	0.0037	21.3716	0.0038	63.6678	0.0051	193.3660	0.0104	540.6315	0.0113	728.6267	0.0113	874.3520	0.0113	1020.0770	0.0108	1119.6740	0.0101	1168.1980	0.0096	1192.9220	0.0038	1297.2850	0.0038	1360.2380				
	0.0040	22.0968	0.0041	66.6103	0.0051	194.1152	0.0106	550.2318	0.0113	733.0789	0.0113	879.6946	0.0113	1026.3100	0.0109	1133.3880	0.0103	1188.2800	0.0099	1221.0090	0.0041	1354.0880	0.0040	1423.8130				
	0.0043	22.7905	0.0043	69.4713	0.0051	194.8625	0.0108	559.8321	0.0114	737.5310	0.0114	885.0372	0.0114	1032.5430	0.0111	1147.1010	0.0106	1208.3620	0.0102	1249.0960	0.0044	1409.3950	0.0043	1485.6080				
	0.0046	23.4562	0.0046	72.2582	0.0052	195.6080	0.0110	567.7757	0.0115	741.9832	0.0115	890.3798	0.0115	1038.7770	0.0112	1160.8140	0.0108	1228.4440	0.0105	1277.1830	0.0047	1463.3360	0.0046	1545.7890				
	0.0049	24.0967	0.0049	74.9775	0.0052	196.3516	0.0112	575.1059	0.0115	746.4354	0.0115	895.7224	0.0115	1045.0100	0.0113	1174.5270	0.0110	1248.5260	0.0108	1305.2700	0.0049	1516.0240	0.0049	1604.4940				
	0.0052	24.7144	0.0052	77.6346	0.0052	197.0934	0.0114	582.4361	0.0116	750.8875	0.0116	901.0650	0.0116	1051.2430	0.0115	1188.2410	0.0113	1268.6080	0.0111	1333.3570	0.0052	1567.5570	0.0052	1661.8470				
	0.0085	31.1940	0.0085	107.1357	0.0085	271.9889	0.0116	589.7663	0.0117	755.3397	0.0117	906.4076	0.0117	1057.4760	0.0116	1201.9540	0.0115	1288.6900	0.0114	1361.4440	0.0085	2163.2290	0.0085	2293.3480				
	0.0117	37.6736	0.0117	136.6369	0.0117	346.8844	0.0117	597.0965	0.0117	759.7918	0.0117	911.7502	0.0117	1063.7090	0.0117	1215.6670	0.0117	1308.7720	0.0117	1389.5310	0.0117	2758.9010	0.0117	2924.8500				
	0.0141	37.6736	0.0141	136.6369	0.0141	346.8844	0.0141	597.0965	0.0141	791.7558	0.0141	950.1070	0.0141	1108.4580	0.0141	1228.0130	0.0141	1308.7720	0.0141	1389.5310	0.0141	2758.9010	0.0141	2924.8500				
	0.0164	37.6736	0.0164	136.6369	0.0164	346.8844	0.0164	597.0965	0.0164	791.7558	0.0164	950.1070	0.0164	1108.4580	0.0164	1228.0130	0.0164	1308.7720	0.0164	1389.5310	0.0164	2758.9010	0.0164	2924.8500				





- The following assumptions were made in the analysis:
1. The analysis was completed for a vertical element (i.e. no inclination) and flat ground
  2. These curves are for static loading. Seismic effects have not been included.
  3. The effects of construction disturbance is not considered.
  4. Depth above frost should be ignored in design

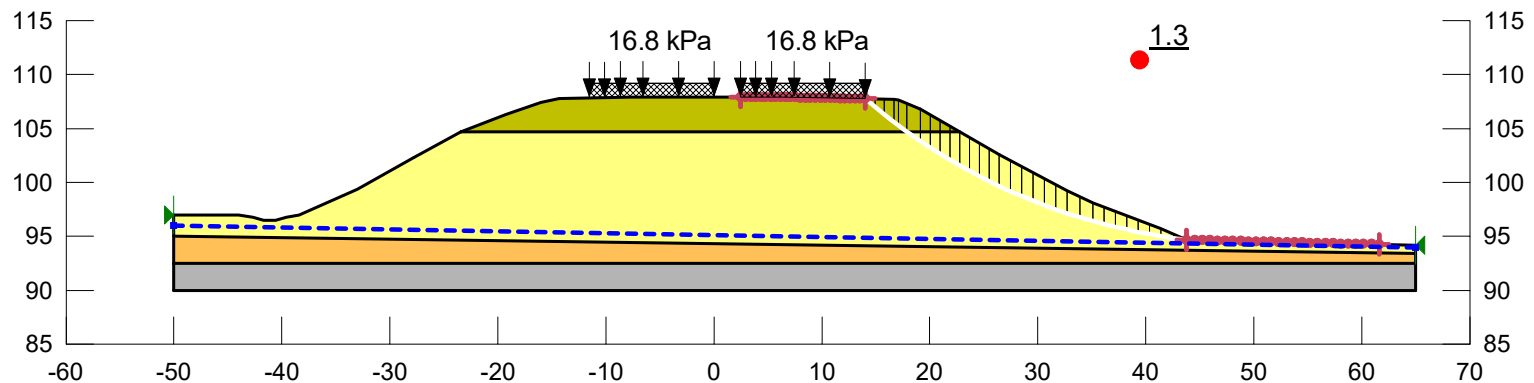
- NOTES:
1. **The p-y data provided is unfactored.** Lateral resistance or deflection calculated based on these parameters should be factored using the geotechnical resistance factors ( $\phi_{gu}$  and  $\phi_{gs}$ ) provided in the CHBDC
  2. If lateral spacing between an adjacent structural element is less than four equivalent diameters, suitable reduction factors based on center to center spacing should be applied based on tables of the CHBDC



## **Appendix G Slope Stability Analysis Figures**







Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	1A) Upper Embankment Fill	Mohr-Coulomb	21	0	32	1
	1B) Lower Embankment Fill	Mohr-Coulomb	20	0	30	1
	6) Glacial Till	Mohr-Coulomb	21	0	35	1
	7) Bedrock	Bedrock (Impenetrable)				1

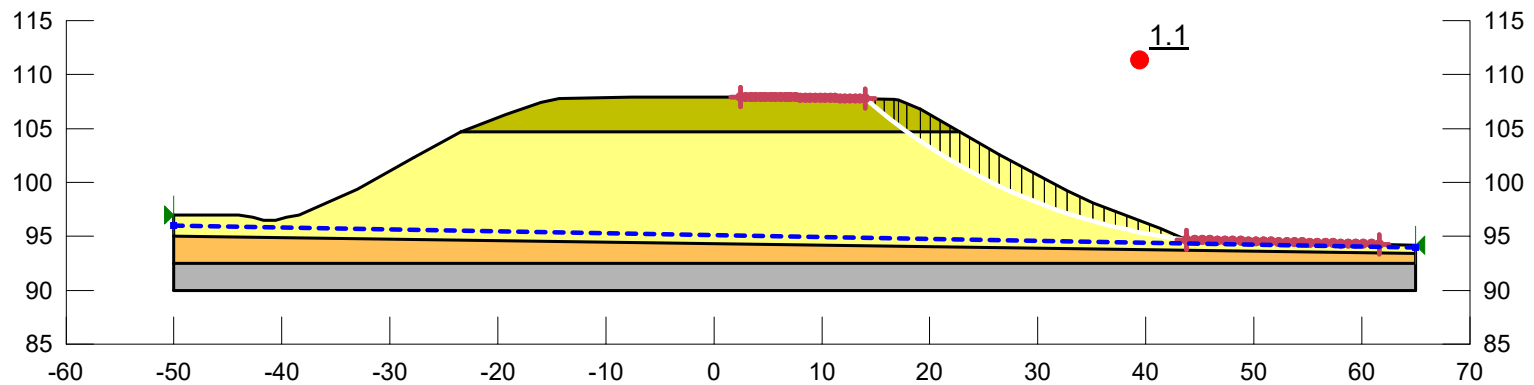


Project Choate Road Overpass		
Analysis East Approach Drained Static		
Seismic Coefficient H: g, V: g	Last Run 08/23/2023, 04:25:38 PM	Scale 1:700

Additional Details  
 Name: East Approach  
 Comments: Global Slope Stability  
 Method: Morgenstern-Price, Half-Sine  
 Minimum Slip Surface Depth: 3 m  
 Entry: (14, 107.75243) m, Exit: (43.8, 94.7) m  
 Center: (50.112121, 149.65561) m, Radius: 55.316925 m

**Figure G1**









Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	1A) Upper Embankment Fill	Mohr-Coulomb	21	0	32	1
	1B) Lower Embankment Fill	Mohr-Coulomb	20	0	30	1
	6) Glacial Till	Mohr-Coulomb	21	0	35	1
	7) Bedrock	Bedrock (Impenetrable)				1

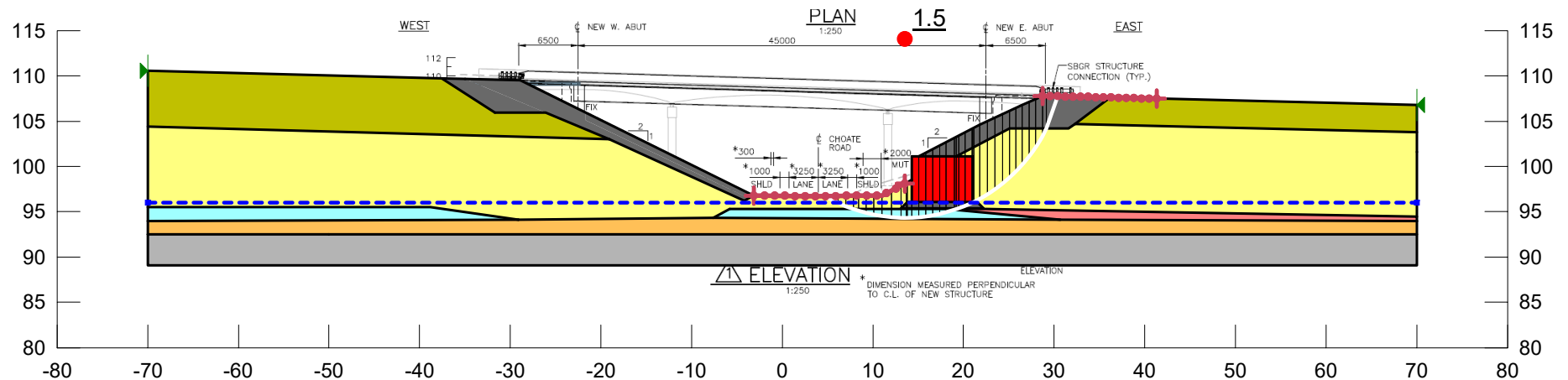


Project Choate Road Overpass		
Analysis East Approach Seismic		
Seismic Coefficient H: 0.056g, V: g	Last Run 08/23/2023, 04:25:52 PM	Scale 1:700

Additional Details  
 Name: East Approach  
 Comments: Global Slope Stability  
 Method: Morgenstern-Price, Half-Sine  
 Minimum Slip Surface Depth: 3 m  
 Entry: (14, 107.75243) m, Exit: (43.8, 94.7) m  
 Center: (50.112121, 149.65561) m, Radius: 55.316925 m

**Figure G2**









Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	1A) Upper Embankment Fill	Mohr-Coulomb	21	0	32	1
	1B) Lower Embankment Fill	Mohr-Coulomb	20	0	30	1
	2) RSS Wall	High Strength	22.8			1
	3) Granular A or B Type II	Mohr-Coulomb	22.8	0	35	1
	4) Drained Clayey Silt to Silty Clay	Mohr-Coulomb	18	1	29	1
	5) Sandy Silt	Mohr-Coulomb	20	0	30	1
	6) Glacial Till	Mohr-Coulomb	21	0	35	1
	7) Bedrock	Bedrock (Impenetrable)				1

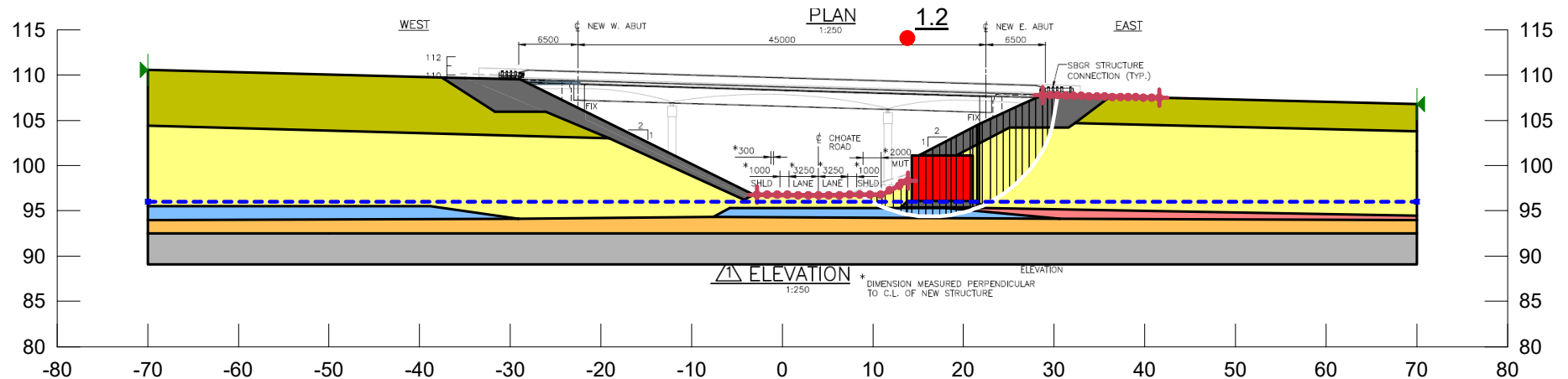



Project Choate Road Overpass		
Analysis East Foreslope Drained Static		
Seismic Coefficient H: g, V: g	Last Run 08/23/2023, 04:25:30 PM	Scale 1:700

Additional Details	
Name: Choate Road Overpass	
Comments: Global Slope Stability	
Method: Morgenstern-Price, Half-Sine	
Minimum Slip Surface Depth: 3 m	
Entry: (4.8045483, 96.713952) m, Exit: (30.379934, 107.7552) m	
Center: (13.537471, 111.62684) m, Radius: 17.281729 m	

**Figure G3**

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	1A) Upper Embankment Fill	Mohr-Coulomb	21	0	32	1
	1B) Lower Embankment Fill	Mohr-Coulomb	20	0	30	1
	2) RSS Wall	High Strength	22.8			1
	3) Granular A or B Type II	Mohr-Coulomb	22.8	0	35	1
	4) Undrained Clayey Silt to Silty Clay	Mohr-Coulomb	18	50	0	1
	5) Sandy Silt	Mohr-Coulomb	20	0	30	1
	6) Glacial Till	Mohr-Coulomb	21	0	35	1
	7) Bedrock	Bedrock (Impenetrable)				1








 <b>THURBER</b>	Project			Additional Details	
	Choate Road Overpass			Name: Choate Road Overpass	
	Analysis			Comments: Global Slope Stability	
	East Foreslope Seismic			Method: Morgenstern-Price, Half-Sine	
	Seismic Coefficient			Minimum Slip Surface Depth: 3 m	
H: 0.056g, V: 0g		Last Run		Entry: (8.5705102, 96.766258) m, Exit: (30.419897, 107.75414) m	
		08/23/2023, 04:25:32 PM		Center: (16.413143, 108.38887) m, Radius: 14.021128 m	
		Scale			
		1:700			

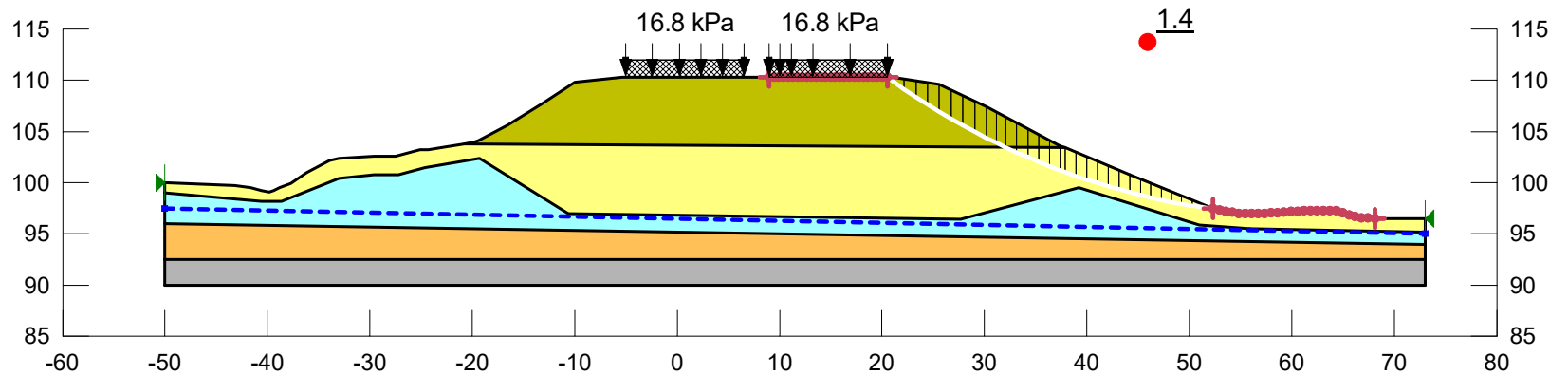
H:\Projects\30001 to 40000\33099 - Hwy 401 Choate and Ganaraska DD\Analysis\2 - Choate Road Bridge\Slope Stability 20230823.qsz

Figure G4

Tool Version: 11.4.0.18

**Figure G4**






Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	1A) Upper Embankment Fill	Mohr-Coulomb	21	0	32	1
	1B) Lower Embankment Fill	Mohr-Coulomb	20	0	30	1
	4) Drained Clayey Silt to Silty Clay	Mohr-Coulomb	18	1	29	1
	6) Glacial Till	Mohr-Coulomb	21	0	35	1
	7) Bedrock	Bedrock (Impenetrable)				1

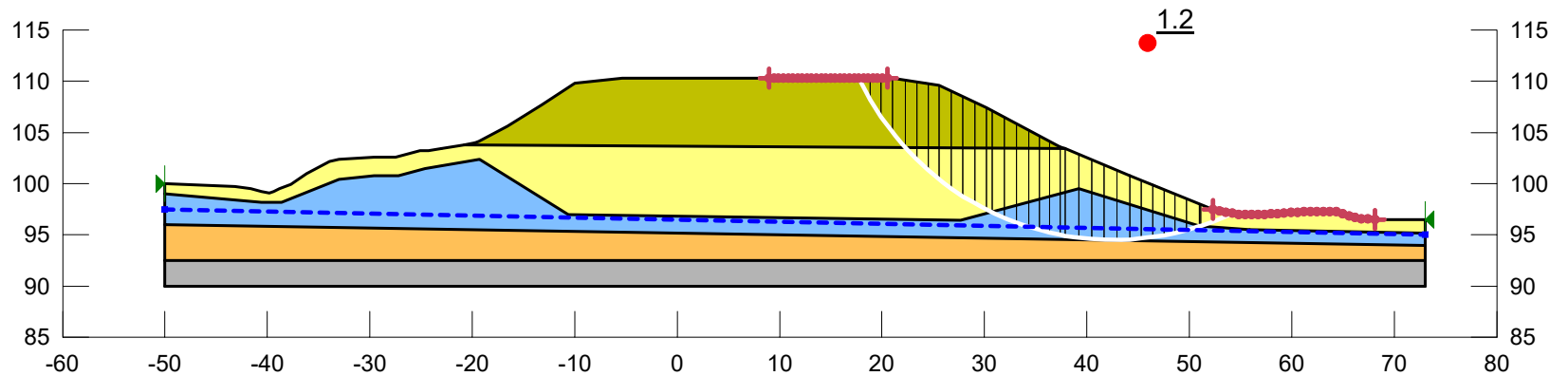


Project Choate Road Overpass		
Analysis West Approach Drained Static		
Seismic Coefficient H: g, V: g	Last Run 08/23/2023, 04:25:46 PM	Scale 1:700

Additional Details  
Name: West Approach  
Comments: Global Slope Stability  
Method: Morgenstern-Price, Half-Sine  
Minimum Slip Surface Depth: 3 m  
Entry: (20.5, 110.3) m, Exit: (52.806791, 97.373302) m  
Center: (62.084895, 167.39582) m, Radius: 70.634523 m

**Figure G5**









Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	1A) Upper Embankment Fill	Mohr-Coulomb	21	0	32	1
	1B) Lower Embankment Fill	Mohr-Coulomb	20	0	30	1
	4) Undrained Clayey Silt to Silty Clay	Mohr-Coulomb	18	50	0	1
	6) Glacial Till	Mohr-Coulomb	21	0	35	1
	7) Bedrock	Bedrock (Impenetrable)				1

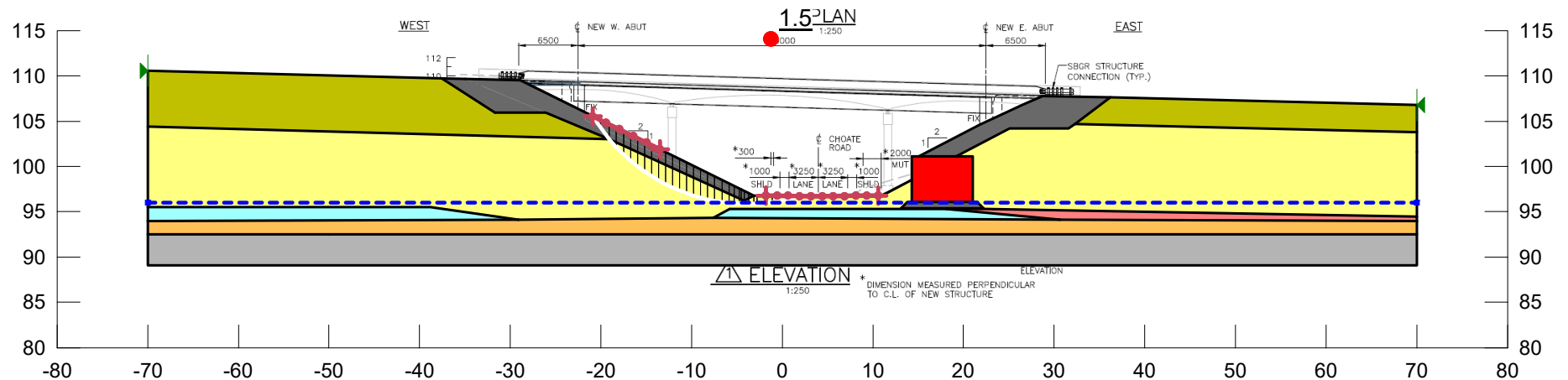


Project		
Choate Road Overpass		
Analysis		
West Approach Seismic		
Seismic Coefficient	Last Run	Scale
H: 0.056g, V: g	08/23/2023, 04:25:58 PM	1:700

Additional Details  
 Name: West Approach  
 Comments: Global Slope Stability  
 Method: Morgenstern-Price, Half-Sine  
 Minimum Slip Surface Depth: 3 m  
 Entry: (17.74, 110.3) m, Exit: (54.172637, 97.096517) m  
 Center: (42.568982, 121.94471) m, Radius: 27.424035 m

**Figure G6**

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	1A) Upper Embankment Fill	Mohr-Coulomb	21	0	32	1
	1B) Lower Embankment Fill	Mohr-Coulomb	20	0	30	1
	2) RSS Wall	High Strength	22.8			1
	3) Granular A or B Type II	Mohr-Coulomb	22.8	0	35	1
	4) Drained Clayey Silt to Silty Clay	Mohr-Coulomb	18	1	29	1
	5) Sandy Silt	Mohr-Coulomb	20	0	30	1
	6) Glacial Till	Mohr-Coulomb	21	0	35	1
	7) Bedrock	Bedrock (Impenetrable)				1











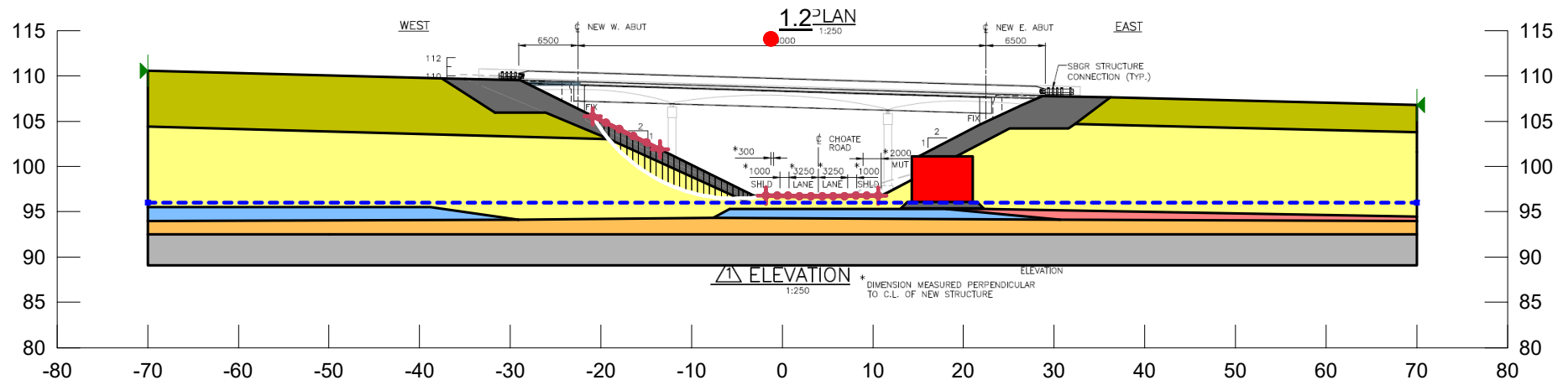
Project Choate Road Overpass		
Analysis West Foreslope Drained Static		
Seismic Coefficient H: g, V: g	Last Run 08/23/2023, 04:25:32 PM	Scale 1:700

Additional Details  
 Name: Choate Road Overpass  
 Comments: Global Slope Stability  
 Method: Morgenstern-Price, Half-Sine  
 Minimum Slip Surface Depth: 3.5 m  
 Entry: (-20.899997, 105.56201) m, Exit: (1.9199626, 96.728485) m  
 Center: (-3.8007791, 115.84246) m, Radius: 19.951712 m

**Figure G7**



Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
	1A) Upper Embankment Fill	Mohr-Coulomb	21	0	32	1
	1B) Lower Embankment Fill	Mohr-Coulomb	20	0	30	1
	2) RSS Wall	High Strength	22.8			1
	3) Granular A or B Type II	Mohr-Coulomb	22.8	0	35	1
	4) Undrained Clayey Silt to Silty Clay	Mohr-Coulomb	18	50	0	1
	5) Sandy Silt	Mohr-Coulomb	20	0	30	1
	6) Glacial Till	Mohr-Coulomb	21	0	35	1
	7) Bedrock	Bedrock (Impenetrable)				1



Project Choate Road Overpass		
Analysis West Foreslope Seismic		
Seismic Coefficient H: 0.056g, V: 0g	Last Run 08/23/2023, 04:25:32 PM	Scale 1:700

Additional Details  
Name: Choate Road Overpass  
Comments: Global Slope Stability  
Method: Morgenstern-Price, Half-Sine  
Minimum Slip Surface Depth: 3 m  
Entry: (-20.899997, 105.56201) m, Exit: (-1.8, 96.784848) m  
Center: (-5.2067654, 114.54173) m, Radius: 18.080731 m

**Figure G8**



## **Appendix H GSC Seismic Hazard**

# 2015 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836  
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

April 02, 2018

Site: 43.9692 N, 78.2957 W User File Reference: Choate Road Overpass

Requested by: C. Murray, Thurber Engineering

**National Building Code ground motions: 2% probability of exceedance in 50 years (0.000404 per annum)**

Sa(0.05)	Sa(0.1)	<b>Sa(0.2)</b>	Sa(0.3)	<b>Sa(0.5)</b>	<b>Sa(1.0)</b>	<b>Sa(2.0)</b>	<b>Sa(5.0)</b>	<b>Sa(10.0)</b>	<b>PGA (g)</b>	<b>PGV (m/s)</b>
0.163	0.204	<b>0.178</b>	0.140	<b>0.105</b>	<b>0.059</b>	<b>0.029</b>	<b>0.0074</b>	<b>0.0031</b>	<b>0.112</b>	<b>0.087</b>

**Notes.** Spectral ( $S_a(T)$ , where  $T$  is the period in seconds) and peak ground acceleration (PGA) values are given in units of  $g$  ( $9.81 \text{ m/s}^2$ ). Peak ground velocity is given in  $\text{m/s}$ . Values are for "firm ground" (NBCC 2015 Site Class C, average shear wave velocity  $450 \text{ m/s}$ ). NBCC2015 and CSAS6-14 values are specified in **bold** font. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. *These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.*

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.05)	0.014	0.049	0.086
Sa(0.1)	0.021	0.069	0.114
Sa(0.2)	0.023	0.066	0.104
Sa(0.3)	0.020	0.056	0.085
Sa(0.5)	0.016	0.044	0.066
Sa(1.0)	0.0080	0.025	0.038
Sa(2.0)	0.0034	0.012	0.019
Sa(5.0)	0.0007	0.0027	0.0044
Sa(10.0)	0.0005	0.0012	0.0018
PGA	0.012	0.038	0.063
PGV	0.0100	0.033	0.052

## References

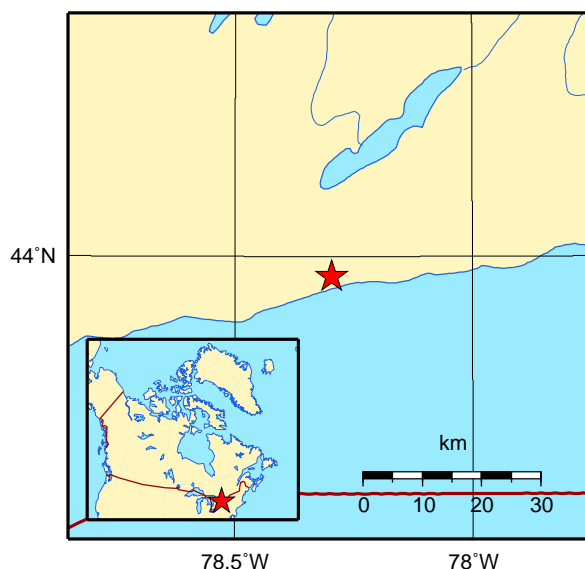
**National Building Code of Canada 2015 NRCC no. 56190;**  
**Appendix C:** Table C-3, Seismic Design Data for Selected Locations in Canada

**User's Guide - NBC 2015, Structural Commentaries NRCC no. xxxxxx** (in preparation)  
**Commentary J:** Design for Seismic Effects

**Geological Survey of Canada Open File 7893** Fifth Generation Seismic Hazard Model for Canada: Grid values of mean hazard to be used with the 2015 National Building Code of Canada

See the websites [www.EarthquakesCanada.ca](http://www.EarthquakesCanada.ca) and [www.nationalcodes.ca](http://www.nationalcodes.ca) for more information

Aussi disponible en français



Natural Resources  
Canada

Ressources naturelles  
Canada

Canada



## **Appendix I   List of Referenced Specifications and Contract Provisions**



1. The following Special Provisions and OPSS Documents referenced in this report:

- OPSS.PROV 206
- OPSS.PROV 501
- OPSS.PROV 539
- OPSS.PROV 803
- OPSS.PROV 804
- OPSS.PROV 805
- OPSS.PROV 902
- OPSS.PROV 903
- OPSS.PROV 1010
- OPSD 208.010
- OPSD 219.110
- OPSD 3090.101
- OPSD 3101.150
- SP105S09
- SP109S12
- SP110S06
- FOUN0003

2. Contract Provision – Presence of Existing Piles

“The proposed piles are to be advanced in close proximity to the piles supporting the existing piers and abutments. Although the pile layout on the structural drawings has been selected to avoid conflict with piles supporting the existing bridge piers and abutments the potential for conflict still exists.

Should the new piles encounter the existing piles the Contractor shall report the conflict to Contract Administrator to determine if adjustment to the pile driving program is required.”

3. Contract Provision – Obstructions

“Obstructions (e.g. mass concrete or grout placed to backfill the washout that occurred in the early 1980’s) should be expected within the existing fill. The obstructions may interfere with pile installation and the installation of roadway protection. The Contractor should be prepared to remove, dislodge or otherwise penetrate these obstructions to advance the piles or install the roadway protection systems to the specified tip elevation/resistance while meeting the specified deflection tolerances.”

## **VIBRATION MONITORING**

Item No.

---

Special Provision

---

### **1.0 SCOPE**

This special provision describes requirements to carry out vibration monitoring on both the existing bridges and newly constructed bridges during the staged construction of deep foundations for the Highway 401 Choate Road and Ganaraska River Bridge replacements.

### **2.0 REFERENCES – Not Used**

### **3.0 DEFINITIONS**

For the purpose of this specification, the following definitions apply:

**Peak Particle Velocity (PPV)** means the maximum component velocity in millimetres per second that ground particles move as a result of energy released from explosive detonations.

**Preconstruction Survey** means a detailed record, accompanied by film or video, as necessary, of the condition of private or public property including bridges, prior to the commencement of construction activities that may cause undue ground vibrations.

### **4.0 DESIGN AND SUBMISSION REQUIREMENTS**

#### **4.1 Vibration Monitoring Plan Submission**

The Contractor shall submit details of the vibration monitoring plan to the Contract Administrator for review at least three (3) weeks prior to the start of rock excavation or construction of deep foundations. All submissions shall bear the signature and seal of Professional Engineer licensed to practice in the Province of Ontario. The submittals shall satisfy the specifications and at a minimum contain the following specific information:

- a) Equipment and methods used by the Contractor to perform the work that may cause undue vibration
- b) Qualifications of the vibration monitoring specialist.
- c) Details regarding the proposed instrumentation.
- d) Proposed location of instruments on the existing Highway 401 Choate Road Bridge, Highway 401 Ganaraska River Bridge, nearby dam, Hope Street Sanitary Pump Station, utilities and building structures.
- e) Method of monitoring, proposed frequency of readings and proposed frequency of submission of readings to Contract Administrator.
- f) Proposed methods for adjusting deep foundation construction methods if readings show vibrations exceeding the specified limits.

## **4.2 Preconstruction Survey**

When construction activities such as rock excavation or installation of deep foundations that may cause significant ground vibrations will be carried out, a condition survey of property and structures that may be affected by the work shall be carried out.

The condition survey shall include the location and condition of adjacent properties, buildings, underground structures, dams, utilities, and structures, within a distance of 100 metres from the construction activity.

Copies of the condition survey and water quality test results shall be submitted to the Contract Administrator prior to the operation of the groundwater control system.

## **5.0 MATERIALS – Not Used**

## **6.0 EQUIPMENT**

### **7.2 Monitoring Equipment**

All monitoring equipment shall be capable of measuring and recording ground vibration (PPV) up to 200 mm/s in the vertical, transverse, and radial directions. The equipment shall have been calibrated within the last 12 months either by the manufacturer or other qualified agent. Proof of calibration shall be submitted to the Contract Administrator prior to commencement of any monitoring operations.

## **7.0 CONSTRUCTION**

### **7.1 Monitoring**

#### **7.1.1 General**

The Contractor shall employ a vibration monitoring consultant to carry out monitoring for PPV. During rock excavation, deep foundation construction or other construction activities that may cause undue ground vibration. Ground vibration (PPV) shall be monitored at the closest portion of any utility, residence, structure, or facility. The monitoring equipment shall be repositioned as required.

#### **7.1.2 Ground Vibration**

Ground vibration as measured by PPV shall be limited to the maximum levels shown in Table 1.

**TABLE 1**  
**Maximum Peak Particle Velocity (PPV) Values**

<b>Element</b>	<b>Frequency (Hz)</b>	<b>PPV (mm/s)</b>
Structures and Pipelines	$\leq 40$	20
	$> 40$	50
Concrete and Grout < 72 hours from placement	N/A	10

If the vibration readings are not within the limits stated above, the Contractor must alter the deep foundation installation procedures until the vibrations at the existing bridge structure, residential/commercial/industrial buildings and/or utilities, as applicable, are within acceptable levels.

## **7.2 Records**

The results of ground vibration monitoring shall be made available to the Contract Administrator for site review at the end of each working day that rock excavation, deep foundation construction or other construction activities that may cause undue ground vibration was carried out.

## **7.3 Damage**

Upon completion of installation or deep foundations or immediately following the receipt of a complaint, a site condition survey shall be performed to determine if any damage has resulted. The Contractor shall record all incidents of any damage, which shall be reported immediately in writing to the Contract Administrator. All other complaints shall be reported to the Contract Administrator in writing within 24 hours of receipt. Each complaint report shall include the name and address of the complainant, time received, and description of the circumstances that led to the complaint.

## **8.0 QUALITY ASSURANCE – Not Used**

## **9.0 MEASUREMENT FOR PAYMENT – Not Used**

## **10.0 BASIS OF PAYMENT**

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.