DRAFT
FOUNDATION INVESTIGATION AND DESIGN REPORT
COUNTY ROAD 28 - HWY 401 N/S-W RAMP RETAINING WALL
NORTHUMBERLAND COUNTY – PORT HOPE, ONTARIO
ASSIGNMENT NO.: 4019-E-0021
GWP 4068-14-00

THURBER ENGINEERING LTD.

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SITE NO. 21X-0232/B0

GEOCRES NO.:

Report

to

MCINTOSH PERRY | LEA JOINT VENTURE

Latitude: 43.969985°
Longitude: -78.288830°

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THURBER

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PART 1. FACTUAL INFORMATION

1. INTRODUCTION

This section of the report presents the factual findings obtained from a detailed foundation investigation conducted by Thurber Engineering Ltd. (Thurber) at Highway 401 Underpass of Ontario Street / County Road 28, Site 21X-0232/B0, located within the geographic township of Hope in the County of Northumberland. For the purposes of this report, the street will be referred to as County Road 28 (CR 28). The purpose of this investigation was to support the detailed design of a retaining wall to allow for the realignment of the County Road 28 – Highway 401 N/S-W Ramp below the northern span of the existing bridge structure. Thurber carried out the detailed foundation investigation as a subconsultant to the McIntosh Perry | LEA joint venture (MPLJV), under MTO Agreement No. 4019-E-0021, Assignment No. 18.

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

The purpose of this investigation 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 the retaining structure was developed in the course of the current investigation.

2. SITE DESCRIPTION

2.1 General

Site 21X-0232/B0 is located on Highway 401, approximately 2.2 km east of Cranberry Road / Victoria Street North and 1.2 km west of Hamilton Road. The location of the structure is shown on the inset Key Plan on Drawing No. 1 in Appendix A.

The current structure carries five lanes of CR 28 traffic over Highway 401. The Ontario Structure Inspection Manual (OSIM) report prepared by MTO on August 8th, 2018 indicates that the existing structure is a three-span structure with reinforced cast-in-place concrete multi-cell box beams and was constructed in 1958. The inspection report indicates that the bridge deck is approximately 79.2 m long and 20.25 m wide, with an approximate 21-degree skew to the highway. There is a retaining wall below the southern span of the bridge retaining the fore slope of the south abutment along the south shoulder of the W-N/S ramp. It is noted that for project orientation purposes, Highway 401 will be assumed to be oriented east-west and CR 28 to be oriented north-south.

Highway 401 at the location of the CR 28 Underpass has three through lanes and the W-N/S ramp in the westbound direction and three through lanes and the N/S-W ramp in the eastbound direction. The outside and median shoulders are paved, and the eastbound and westbound lanes are separated by a concrete barrier wall.

Within the project limits, CR 28 has two lanes in the northbound direction and three lanes in the southbound direction. On the approaches, concrete curb and gutter are present in both directions. Steel beam guiderail systems are also present on the approaches. The existing approach embankments are up to approximately 5.5 m high with slopes that extend down at approximately 2H:1V (Horizontal:Vertical). The embankment slopes are vegetated with long grasses, shrubs, and occasional conifers. No visible signs of slope instability were noted.

The lands surrounding the site are typically commercial with some residential properties to the southwest and Ganaraska Region Conservation Authority (GRCA) conservation lands to the northwest. Storm water drainage in the area is to existing ditches.

Site photographs showing the structure and approach embankments are presented in Appendix D.

2.2 Site Geology

The site is located within the physiographic region of Southern Ontario known as the Iroquois Plain which in this area is characterized as a group of drumlinized uplands, with steep shorecliffs cut into them by deep stream valleys. The soils in the area of this structure are classified as a clay plain which are primarily silt and clay with minor sand and gravel fractions (Chapman and Putnam, 1984).

3. EXISTING INFORMATION

Three foundation investigation reports for the existing Highway 401 – County Road 28 interchange structures were obtained from the online Geocres library:

- Geocres Report No. 30M16-008 (MTO, 1957) presents the results of the foundation investigations carried out for the design and construction of the existing bridge structure. This investigation included 4 boreholes: 2 on the north side and 2 on the south side of the proposed Highway 401 alignment. All 4 boreholes indicated the presence of topsoil underlain by approximately 3 to 4 m of grey clay, underlain by sandy clay loam. The boreholes were terminated within the sandy clay loam deposit at depths ranging from 15.7 to 23.2 m (approx. elev. 90.9 to 84.0 m).
- Geocres Report No. 30M16-032 (Golder, 2001) presents the results of an investigation for a retaining wall through the foreslope of the south abutment. The investigation included one borehole to supplement the borehole data from the 1957 investigation. The soil stratigraphy identified in this borehole was topsoil underlain by clayey silt till. The borehole was terminated upon SPT refusal in the till at a depth of 18.4 m (elev. 86.2 m).
- Geocres Report No. 30M16-071 (Thurber, 2020) presents the results of a preliminary foundation investigation for identifying interim and long-term interchange improvements at County Road 28. The investigation included advancing one borehole near each abutment of the existing County Road 28 / Hwy 401 bridge structure. The boreholes indicate the presence of sand with gravel embankment fill underlain by clay over a heterogenous layer of glacial till composed of a mixture of clay, silt, sand, gravel, and cobbles. The boreholes were terminated within the glacial till deposit at depths ranging from 21.4 to 23.4 m below the ground surface (approx. elev. 89.5 to 87.4 m).

The Record of Boreholes and Borehole Location & Soil Strata drawings from these three reports are included in Appendix E.

4. SITE INVESTIGATION AND FIELD TESTING

The current site investigation and field-testing program included advancing two boreholes identified as ONT22-01 and ONT22-02 between June 23rd and 28th, 2022. The borehole coordinates and elevations are also shown on the Borehole Location and Soil Strata drawing included in Appendix A, on the individual Record of Borehole sheets included in Appendix B and are summarized in Table 4-1.

Table 4-1: Borehole Summary

Borehole No.	Drilled Location	Northing (m)	Easting (m)	Ground Surface Elevation (m)	Termination Depth (m)
ONT22-01	West Side of North Foreslope	4 870 741.2	401 973.4	107.6	15.8
ONT22-02	East Side of North Foreslope	4 870 745.5	402 002.0	107.8	15.8

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

Borehole ONT22-01 was advanced using portable drilling equipment with NW casing and a 1/2 weight hammer for standard penetration testing and Borehole ONT22-02 was advanced using a track mounted D70 Turbo drill rig using NW casing.

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 during the completion of Standard Penetration Tests (SPT), following the methods described in ASTM Standard D1586-11. A hammer weight correction has been applied for the reported N-values in Borehole ONT22-01 for the SPTs carried out with the portable 1/2 weight hammer. All soil samples recovered from the boreholes were placed in moisture-proof containers and the samples were transported to Thurber's Pickering geotechnical laboratory for further examination and testing.

Following completion of the field investigation, ONT22-01 was decommissioned in accordance with O.Reg. 903, as amended. A 25 mm diameter piezometer was installed in Borehole ONT22-02 to allow for measurements of the groundwater level. The piezometer installation details are illustrated on the corresponding Record of Borehole sheets provided in Appendix B. The piezometer is scheduled to be decommissioned in accordance with Ontario MOE Regulation 903 early in 2023.

The as-drilled locations of the boreholes and ground surface elevations at the borehole locations were surveyed by Thurber on June 28th, 2022 using a Trimble Catalyst DA2 antenna with centimeter accuracy. The benchmark (HCP 104) identified on the base plans provided by the

MPLJV was used as a check for the GPS. The HCP was a round iron bar located on the south side of Highway 401 approximately 150 m west of the Ontario Road overpass and was identified on the base plans as having a geodetic elevation of 102.527 m. The borehole coordinates are referenced to MTM Zone 10 and the elevations are referenced to Geodetic datum.

5. LABORATORY TESTING

Geotechnical laboratory testing consisted of natural moisture content determination and visual identification of all soil samples in accordance with the current MTO standards. Grain size distribution analyses and Atterberg Limits testing were carried out on selected samples to MTO and ASTM standards.

The geotechnical laboratory test results are presented on the Record of Borehole sheets in Appendix B and are illustrated on the figures in Appendix C.

Chemical analysis for determination of pH, resistivity, conductivity, water soluble sulphate, sulfide and chloride concentrations was carried out on one soil sample. A copy of the chemical analysis results is provided 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 on the Borehole Location and Soil Strata Drawing included in Appendix A. Soil classification is in accordance with ASTM D2487 with cohesive soils described as per current MTO Guidelines for Foundation Engineering Services. A general description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following paragraphs. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description for interpretation of the site conditions. It must be recognized that the soil and groundwater conditions will vary between and beyond borehole locations.

In general, the stratigraphy in the area of the boreholes is characterized by embankment fill underlain by silty clay overlying cohesive glacial till. Bedrock was not encountered within the depth of excavation.

6.1 Embankment Fill

A layer of embankment fill was encountered from ground surface in Boreholes ONT22-01 and ONT22-02. The fill layer ranges in composition from non-cohesive silty clayey sand to cohesive sandy clayey silt and sandy silty clay with varying amounts of gravel and ranged from 3.0 to 4.1 m in thickness (base elev. 104.6 to 103.7 m). SPT N-values ranged from 6 to 15 blows per 0.3 m of penetration, indicating a loose to compact relative density for the non-cohesive portions. The cohesive portions of the embankment fill are estimated to be stiff in consistency.

Recorded moisture contents in the fill ranged from 6 to 19%. The results of gradation analyses completed on four samples of the embankment fill are illustrated on Figure C1 of Appendix C. The results of the tests are summarized in Table 6-1 and are presented on the Record of Borehole sheets in Appendix B.

Table 6-1: Gradation Results for Embankment Fill

Soil Particle	Percentage (%)
Gravel	2 – 14
Sand	27 – 49
Silt	26 – 35
Clay	14 – 32

The results of Atterberg Limit testing on the fines fraction (minus the gravel and coarse sand fraction) of two samples of sandy clayey silt to sandy silty clay from this embankment fill layer are summarized in Table 6-2 and indicate the cohesive embankment fill to be of low to intermediate plasticity (CL to CI). Atterberg Limits analysis results are illustrated on Figure C5 of Appendix C.

Table 6-2: Atterberg Limit Results for Embankment Fill

Parameter	Value
Liquid Limit	28 – 38
Plastic Limit	15 – 18
Plasticity index	13 – 20

6.2 Silty Clay (CI)

A native deposit of silty clay was encountered below the embankment fill in Boreholes ONT22-01 and ONT22-02. This layer ranged in thickness from 1.5 to 2.9 m (base elev. 102.2 to 101.7 m).

SPT N-values recorded in the layer ranged from 6 to 10 blows per 0.3 m of penetration. It is noted that the MTO ‘N’ vane was unable to penetrate the silty clay deposit. The consistency of the silty clay is estimated to be stiff.

Recorded moisture contents ranged from 23 to 38%. The results of gradation analyses completed on two samples of the silty clay layer are summarized in Table 6-3 and are illustrated on Figure C2 of Appendix C.

Table 6-3: Gradation Results for Silty Clay

Soil Particle	Percentage (%)
Gravel	0 – 1
Sand	4 – 5
Silt	39 – 47
Clay	47 – 57

The results of Atterberg Limit testing on one sample of the silty clay layer are summarized in Table 6-4 and indicate the silty clay to be of intermediate plasticity (CI). Atterberg Limits analysis results are illustrated on Figure C6 of Appendix C.

Table 6-4: Atterberg Limit Results for Silty Clay

Parameter	Value
Liquid Limit	41
Plastic Limit	20
Plasticity index	21

6.3 Glacial Till

A glacial till deposit consisting of a heterogeneous mixture of clay, silt, sand and gravel was encountered beneath the silty clay in Boreholes ONT22-01 and ONT22-02. The glacial till is generally cohesive but contains zones of non-cohesive till. The composition of the cohesive till varies from sandy clayey silt to clayey silt with sand while the composition of the non-cohesive till varies from silty sand trace gravel to silty sand some gravel.

The top of the glacial till deposit ranges from Elevation 101.7 to 102.2 m. Both boreholes were terminated within this deposit at a depth of 15.8 m (Elevation 92.0 to 91.8 m). SPT N-values ranged from 8 to 17 blows per 0.3 m of penetration. The blow counts within the non-cohesive till indicated the relative density to be compact. The MTO 'N' vane was unable to be used within the cohesive glacial till due to the presence of sand and gravel, the condition is estimated to be stiff. Although cobbles or boulders were not encountered within the glacial till, it should be noted that glacial tills inherently contain cobbles and boulders.

The moisture content of the sample tested ranged from 9% to 28%. The results of gradation analyses completed on seven samples of the glacial till layer are summarized in Table 6-5 and illustrated on Figures C3 and C4 of Appendix C.

Table 6-5: Gradation Results for Glacial Till

Soil Particle	Percentage (%)
Gravel	1 – 13
Sand	16 – 47
Silt	35 – 49
Clay	12 – 34

The results of Atterberg Limits testing on the fines fraction (minus the gravel and coarse sand fraction) of the samples are summarized in Table 6-6 and indicated the glacial till fines to be of low plasticity (ML to CL). Atterberg Limits analysis results are illustrated on Figure C7 of Appendix C.

Table 6-6: Atterberg Limit Results for Glacial Till

Parameter	Value
Liquid Limit	13 – 34
Plastic Limit	10 – 18
Plasticity index	3 – 16

6.4 Groundwater

The groundwater levels were measured in the standpipe piezometer installed in Borehole ONT 22-02. The measurements are presented on the Record Borehole sheet in Appendix B and in summarized in Table 6-7 below:

Table 6-7. Measured Water Levels

Location / Borehole	Date of Reading	Water Depth / Elevation (m)	Comment
ONT22-02	2022 06 28	10.2 / 97.6	Piezometer (Base of screen in glacial till at elev. 92.8 m)
	2022 08 23	5.1 / 102.7	
	2022 08 24	5.2 / 102.6	

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

The piezometer is scheduled to be decommissioned in accordance with Ontario MOE Regulation 903 early in 2023.

6.5 Analytical Testing

One sample of the silty clay layer was submitted to SGS Canada Inc. of Lakefield, Ontario for analysis of pH, water soluble sulphate, sulfide, conductivity, resistivity, and chloride concentrations. The analysis results are summarized in Table 6-8. A copy of the test results is provided in Appendix C.

Table 6-8: Results of Chemical Analysis

Borehole	Sample	Depth (m)	pH	Resistivity (Ohm-cm)	Conductivity (µS/cm)	Chloride (µg/g)	Sulphate (µg/g)	Sulphide (%)
ONT22-02	SS7	4.9	8.66	1,980	505	440	35	< 0.04

7. MISCELLANEOUS

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

Marathon Underground of Ottawa, Ontario supplied and operated the drilling equipment used to carry out the drilling, sampling, and in-situ testing, standpipe piezometer installation, and decommissioning of the 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 Alliance Traffic Control Inc. of Etobicoke, Ontario. The field investigations were supervised on a full-time basis by Mr. Scott Gittens and Mr. Sergey Gladkiy. Overall supervision of the field investigation program was provided by Mr. Christopher Murray, P.Eng.

Routine geotechnical laboratory testing was completed by Thurber’s laboratory in Pickering, Ontario. Analytical testing was completed by SGS Canada Inc. of Lakefield, Ontario. Interpretation of the factual data and preparation of this report was completed by Mr. Anderson de Oliveira, E.I.T. and 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.

Report Prepared By:

Anderson de Oliveira, M.A.Sc., EIT
Geotechnical Engineering Intern

Christopher Murray, M.A.Sc., P.Eng.
Geotechnical Engineer

Paul Carnaffan, M.Eng., P.Eng.
Principal | Branch Manager
Senior Geotechnical Engineer

Dr. P.K. Chatterji, P.Eng.
Designated Principal Contact
Senior Geotechnical Engineer

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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 proposed retaining wall below the north span of the existing Highway 401 underpass of County Road 28 to allow for the realignment of the CR 28 – Hwy 401 N/S-W Ramp 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 the McIntosh Perry | LEA joint venture (MPLJV) 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 Proposed Structure

It is understood that the existing Highway 401 underpass at County Road 28 bridge structure will not be replaced and that a short retaining wall within the foreslope in front of the north abutment is proposed to realign the CR 28 – Hwy 401 N/S-W ramp below the north span of the existing bridge to make room for the widened Highway 401 configuration. Based on the General

Arrangement (GA) provided by LEA and dated December 2022, the preferred retaining wall is an OPSD 3120.100, Type II toe wall with an embedment of 0.8 m, a maximum wall height of 1.75 m and a 2.5 m high 2H:1V slope above the toe wall.

8.2 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 (Ψ) 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 11.3.

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)[1]. The GSC seismic hazard calculation data sheet for this site for the *reference* ground condition (Site Class C) is presented in Appendix G. The site coefficients used to determine the design spectral acceleration values are a function of the Site

[1] https://earthquakescanada.nrcan.gc.ca/hazard-alea/interpolat/calc-en.php

Class, PGA and Sa(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 D based on the undrained shear strength.

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)[2]. The cohesionless foundation soils are not considered to be susceptible to liquefaction under the design earthquake.

The clay deposits at this site are classified as not susceptible to cyclic mobility during a seismic event when assessed using the Boulanger & Idriss (2007)[3] method.

10. EVALUATION OF DESIGN OPTIONS

Based on the soil stratigraphy and the relatively low height of the retaining wall both deep and shallow foundation options are considered feasible. The following foundation alternatives were considered for the new retaining wall:

- RSS Wall
- Steel H-Piles with Concrete Facing Panels (head room a concern)
- Concrete Toe Wall

These foundation alternatives are presented below and evaluated from a foundation perspective in terms of their respective advantages, disadvantages, risks and consequences. The evaluation

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[2] 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.

[3] 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.

is summarized in the table provided in Appendix F. A preferred retaining wall option from a geotechnical engineering perspective is recommended.

- RSS Wall
  An RSS wall is considered feasible from a geotechnical perspective retaining the toe of the existing north foreslope. RSS walls provide a flexible structure with more tolerance for differential settlement but require a minimum reinforcing length of 3.5 m. Based on the currently proposed ramp realignment, a protection system would be required to support the existing north bridge abutment to facilitate the construction of an RSS wall with the minimum reinforcement length.

- Steel H-Piles with Concrete Facing Panels
  Installation of H-Piles with concrete facing panels is considered a suitable option for retaining the existing north foreslope. Maintaining alignment tolerance during driving is critical when using precast concrete facing panels and could be difficult if boulders are encountered in the glacial till when driving H-Piles. This option would reduce the required excavation depth but would induce vibrations close to existing foundation elements and would require specialty equipment to install H-piles below the existing bridge. Depending on wall height, tie-backs may also be required to limit lateral deflections.

- Concrete Toe Wall
  Based on the relatively low height of the wall required, a concrete toe wall designed and constructed in accordance with OPSD 3120.100 Type II could be considered. This retaining wall option would be cost effective and constructed without the requirement of a temporary protection system.

11. FOUNDATION DESIGN RECOMMENDATIONS

Based on an evaluation of foundation alternatives presented above and the geometry of the proposed retaining wall structure, the recommended foundation approach from a geotechnical perspective is to retain the existing north foreslope with an OPSD 3120.100 Type II concrete toe wall supported on a spread footing.

Foundation recommendations and considerations for the preferred option are presented in the following sections.

11.1 Concrete Toe Wall

Based on the GA Drawing provided by LEA, the retaining wall is a maximum of 1.75 m above the proposed grade of the ramp with a 2.5 m high 2H:1V slope above the top of the wall. Based on the relatively low height of retained soil the concrete toe wall should be designed and constructed in accordance with OPSD 3120.100 Type II with the below recommendations.

11.1.1 Bearing Capacity

Based on the currently proposed layout, analysis indicates the concrete toe wall may be founded on the undisturbed stiff native clay.

An OPSD 3120.100 Type II concrete toe wall with a minimum embedment below final grade of 1.0 m founded at or below elevation 102.2 m may be designed based on the following factored geotechnical resistance:

Table 11-1: Factored Ultimate Geotechnical Resistance

Location	Founding Elevation (m)	ULS (kPa)
North Abutment Toe Wall	102.2	300

The subgrade soils may become disturbed when saturated and should be protected by prompt placement of a mud slab immediately after excavation and inspection. The toe wall should be backfilled with OPSS Granular A or Granular B Type II.

The factored geotechnical resistance includes the following factors:

- Consequence factor (Ψ) of 1.0
- Geotechnical resistance factors (CHBDC Table 6.2):
  - ϕ_{gu} = 0.5 (static analysis; typical degree of understanding)

The geotechnical resistance is for vertical concentric loading and will need to be adjusted for the effects of inclined or eccentric loading, if applicable. The geotechnical resistance should be calculated as illustrated in the CHBDC Clause 6.10.5. In addition, the geotechnical resistance assumes that the footing is constructed on horizontal ground.

11.1.2 Slope Stability

Provided the toe wall is constructed in accordance with the requirements outlined above and in OPSD 3120.100 the foreslope will meet stability requirements.

11.2 Backfill and Lateral Earth Pressure

11.2.1 Backfill

Retaining wall 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. 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.

11.2.2 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:

σ_h	=	static lateral earth pressure on the wall at depth d (kPa)
K	=	static earth pressure coefficient (see table below)
γ	=	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 are shown in Table 11-2.

Table 11-2: Static Earth Pressure Coefficients

Material	Unit Weight (kN/m³)	K_A (yielding wall)		K_0 (non-yielding wall)	
		Backslope		Backslope	
		Horizontal	2H:1V	Horizontal	2H:1V
OPSS Granular A & B Type II	22.8	0.27	0.39	0.43	0.62
OPSS Granular B Type I	21.2	0.31	0.47	0.47	0.68
Undisturbed Native Glacial Till	21.0	0.27	0.39	0.43	0.62
OPSS SSM & Existing Embankment Fill	20.0	0.33	0.54	0.50	0.72

For rigid structures it is recommended that at-rest lateral earth pressures be used for design. Active pressures should be used for the design of unrestrained walls.

The parameters in the table correspond to full mobilization of active and passive earth pressures and require certain relative movements between the wall and adjacent soil to produce these conditions. The values to be used in design can be assessed from Figure C6.27 of the Commentary to the CHBDC.

The use of a material with a high friction angle and low active pressure coefficient (e.g. Granular A, Granular B Type II) is generally preferred as it results in lower earth pressures acting on the wall.

The design of the retaining walls must incorporate measures such as weep holes and/or subdrains to permit drainage of the backfill and avoid the potential build-up of hydrostatic pressures behind the walls.

11.2.3 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 = ½ * 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 11-3 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 D.

Table 11-3: Combined Static and Seismic Earth Pressure Coefficients

Material	Unit Weight (kN/m^3)	K_{AE} (yielding wall)		K_{AE} (non-yielding wall)	
		Backslope		Backslope	
		Horizontal	2H:1V	Horizontal	2H:1V
OPSS Granular A & B Type II	22.8	0.31	0.50	0.35	0.72

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:

σ_{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_A for yielding walls, K_o for non-yielding walls)

γ = unit weight of retained soil (kN/m^3), adjusted below water level

K_{AE} = combined static and seismic earth pressure coefficient

H = total height of the wall (m)

11.3 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 existing pile cap to serve as frost protection.

It is noted that OPSD 3120.100 toe walls do not need to be founded below frost depth.

11.4 Cement Type and Corrosion Potential

Analytical testing was 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 with 35 μg/g, see Section 6.5. 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 6.5 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. CONSTRUCTION CONSIDERATIONS

12.1 Excavation

All excavations must be conducted in accordance with the requirements of the Occupational Health & Safety Act & Regulations (OHSA) for Construction Projects. The fills at this site above the water level should be classified as Type 3 in accordance with OHSA and the glacial till should be classified as Type 2 above the water level and Type 3 below the water level.

Subgrade preparation and construction of the toe wall and backfill must be carried out in the dry.

The structural designer must check that the proposed excavation will not compromise the lateral stability of the existing piles.

Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor.

12.2 Temporary Protection Systems

If required, temporary protection systems be provided 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 the existing north abutment. 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.

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.

12.3 Subgrade Sensitivity

Sensitive fine-grained soils are expected at the founding elevation of the proposed toe wall, these native soils are moisture sensitive and may become heavily disturbed when saturated or subjected to construction traffic. The subgrade soils should be protected by prompt placement of a mud slab immediately after excavation and inspection. An NSSP on protection of sensitive foundation soils has been provided in Appendix H.

12.4 Surface and Groundwater Control

Subgrade preparation and construction of foundations must be carried out in the dry. All excavations for toe wall 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 toe wall 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. CONSTRUCTION CONCERNS

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

- <u>Obstructions (ie: boulders, buried debris)</u>

  Buried obstructions may be encountered during construction and interfere with excavations and installation of temporary protection systems (if required). The Contractor must be prepared to dislodge or penetrate 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.

- Slope Stability

  Care must be taken during construction to ensure the stability of the existing abutment during construction of the toe wall. Surface Monitoring Points should be placed on the existing abutment and surveyed for movement regularly during toe wall construction.

- 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.

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14. 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.

Thurber Engineering Ltd.
Report Prepared By:

Christopher Murray, M.A.Sc., P.Eng.
Geotechnical Engineer

Paul Carnaffan, M.Eng., P.Eng.
Principal | Branch Manager
Senior Geotechnical Engineer

Dr. P.K. Chatterji, P.Eng.
Designated Principal Contact
Senior Geotechnical Engineer

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Appendix A Drawings

General Arrangement Drawing
Borehole Locations and Strata Drawing

FOR CONSTRUCTION

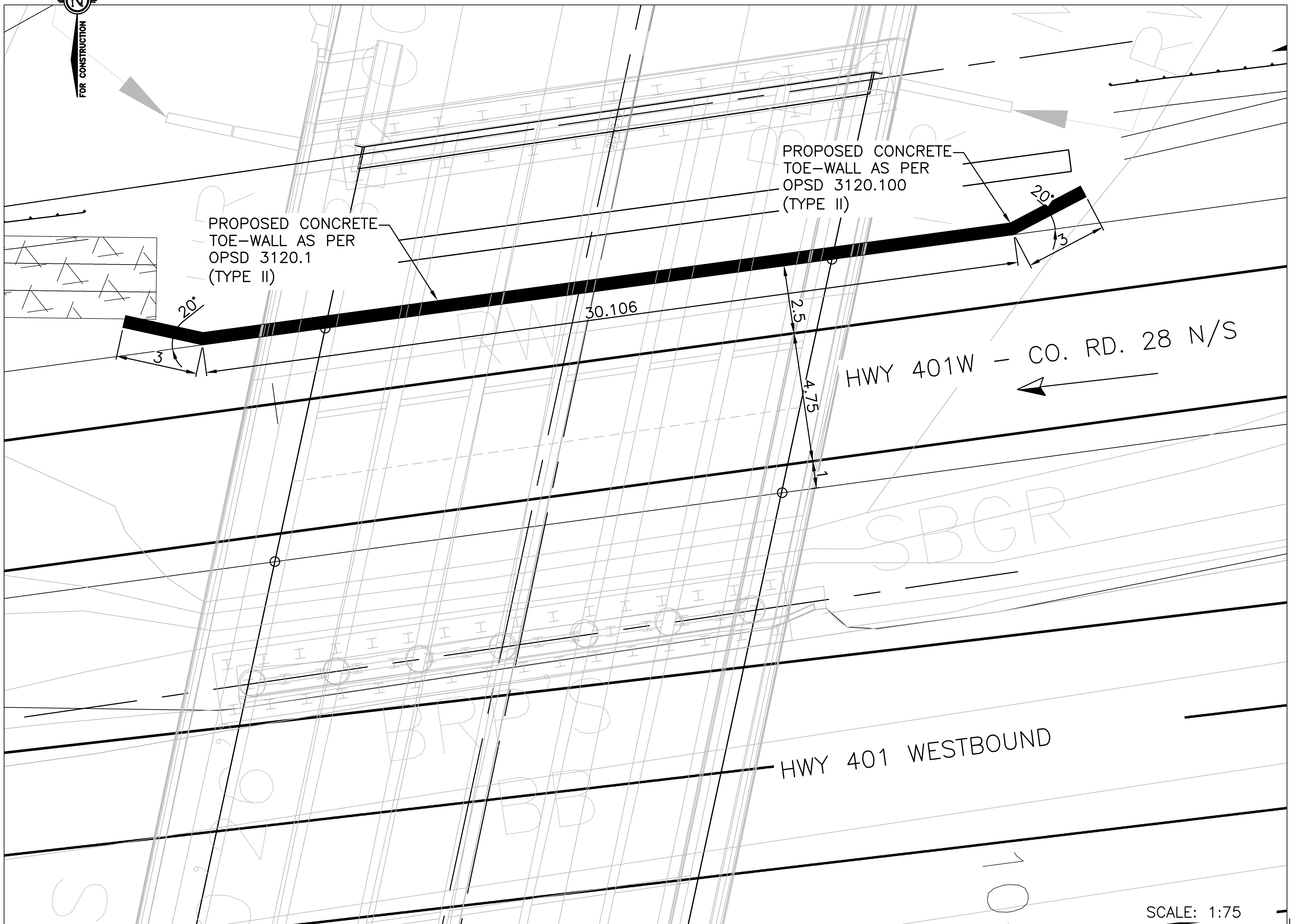
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN
DRAWING NOT TO BE SCALED
100mm ON ORIGINAL DRAWING

CONT	–
WP	–

COUNTY RD 28 UNDERPASS NORTH RAMP

RETAINING WALL PLAN

SHEET 01



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REVISIONS	DATE	BY		DESCRIPTION	
DESIGN –	CHK –	CODE –	LOAD		DATE DEC 2022
DRAWN	CHK –	SITE –			DWG

FILE NAME: \\MAR-FS01\active\21207\21207.18 Hwy 401 Choate Rd & Ganaraska River Bridge Replacement Detail Design\4. Bridge (Structural)\4.5 CADD\4.5.2 Final CAD Drawings\Retaining Walls\HWY 401 UP N Abut RW & VC\02 DWGs\HWY 401 UP N Abut RW & VC – Dec 14, 2022.dwg
MODIFIED: 2022-12-14 16:56

MINISTRY OF TRANSPORTATION, ONTARIO ANSI-D 2017-08

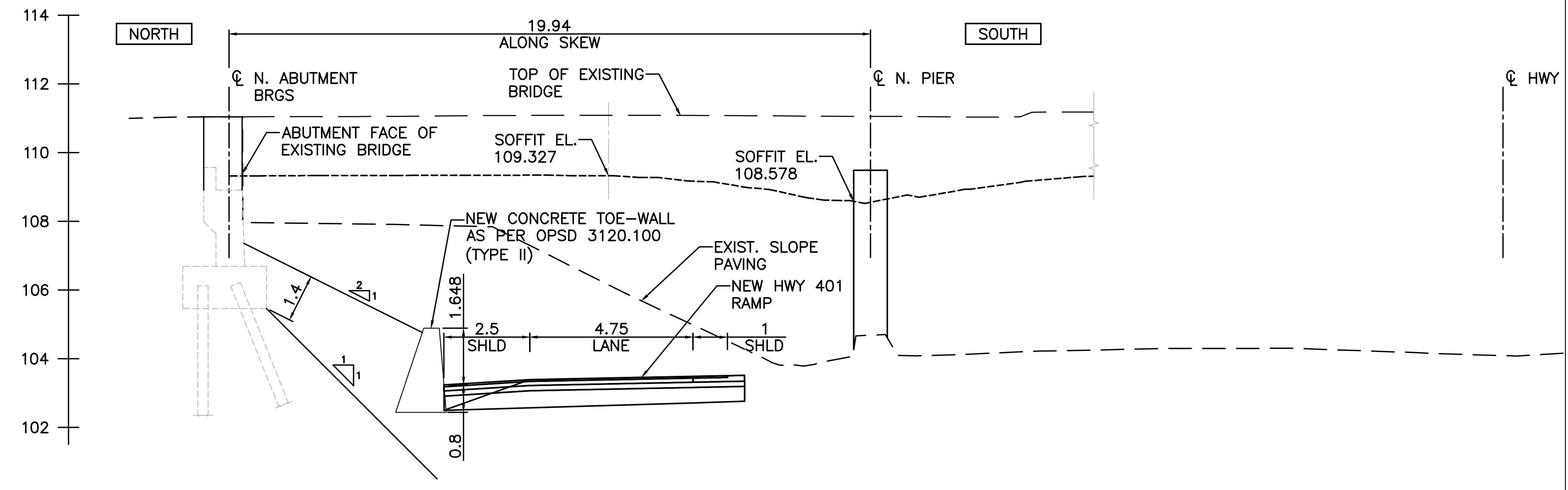
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN
DRAWING NOT TO BE SCALED
100mm ON ORIGINAL DRAWING

CONT –
WP –

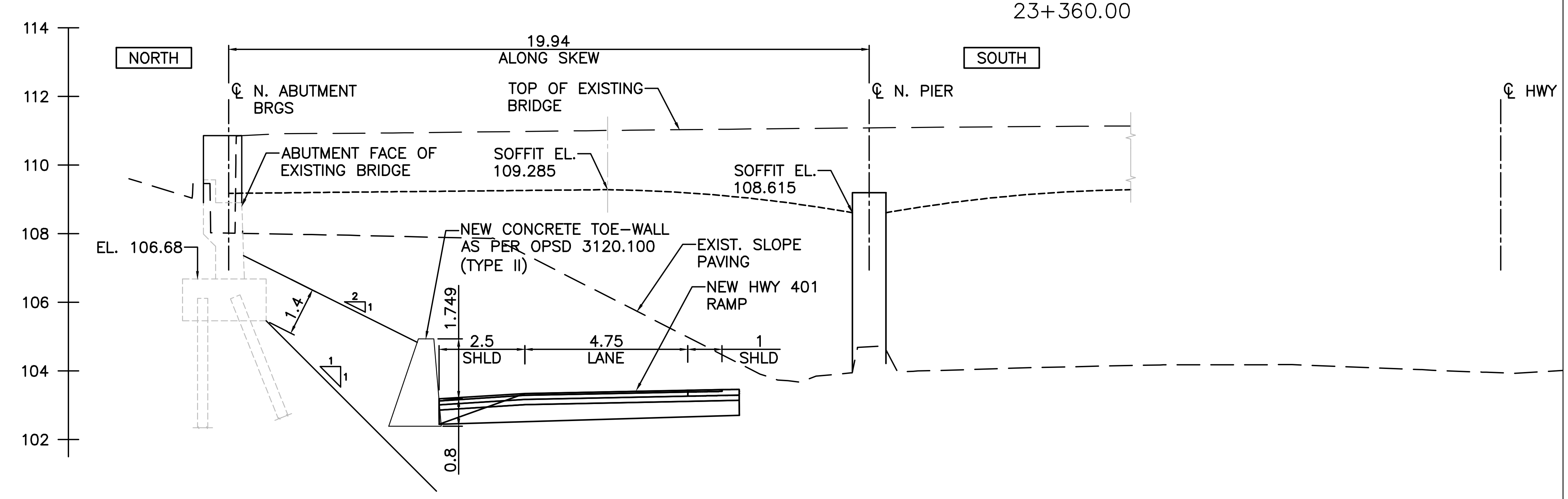
COUNTY RD 28 UNDERPASS
NORTH RAMP

RETAINING WALL SECTIONS

SHEET
02



23+360.00



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DRAWN –	CHK –	SITE –		DWG

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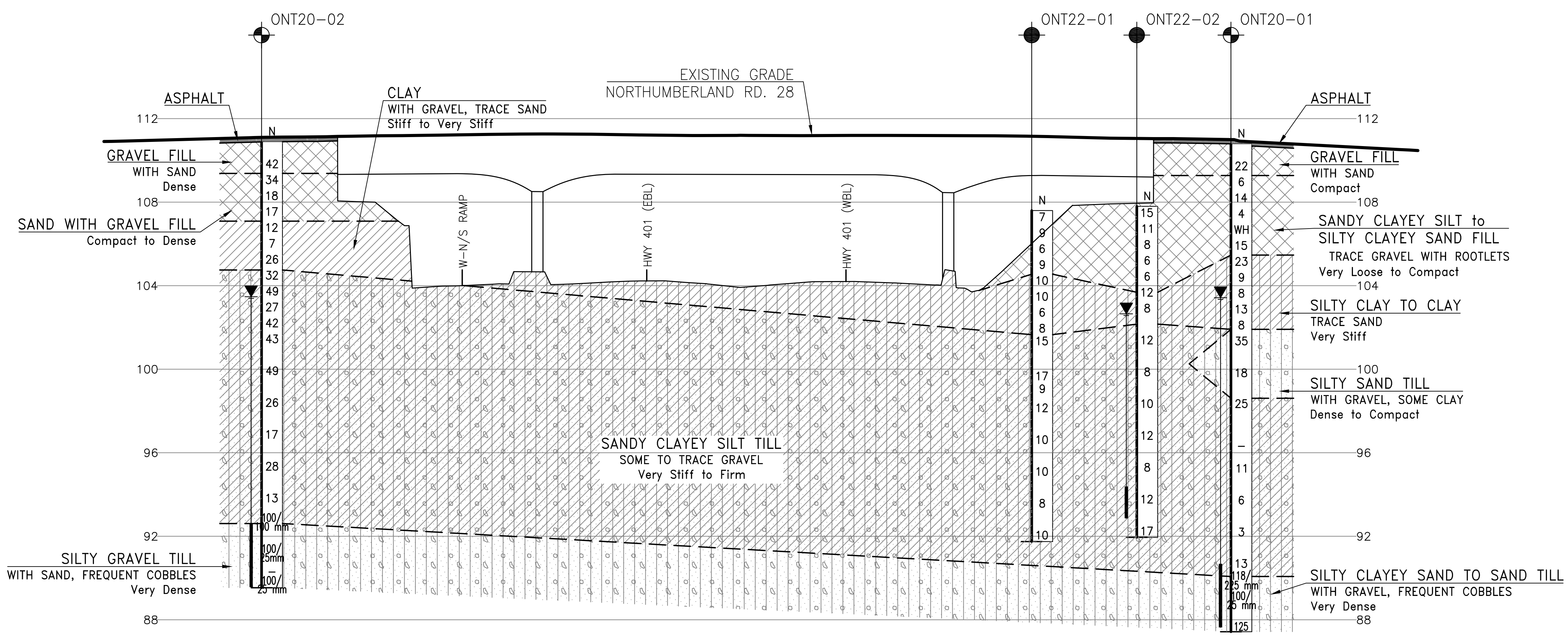
MODIFIED: 2022-12-14 16:56
MINISTRY OF TRANSPORTATION, ONTARIO ANSI-D 2017-08

MINISTRY OF TRANSPORTATION, ONTARIO

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

PLAN



PROFILE ALONG NORTHUMBERLAND RD. 28

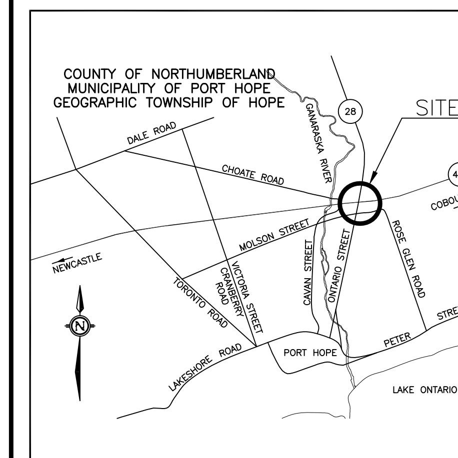
CONT No
WP No

HIGHWAY 401
NORTHUMBERLAND ROAD 28
BRIDGE REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

Ontario

THURBER ENGINEERING LTD.



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
▽	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
ONT20-01	110.8	4 870 758.6	401 983.2
ONT20-02	110.9	4 870 664.6	401 979.4
ONT22-01	107.6	4 870 741.2	401 973.4
ONT22-02	107.8	4 870 745.5	402 002.0

-NOTES-

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

GEOCRES No.

REVISIONS	DATE	BY	DESCRIPTION			
DESIGN CM	CHK –	CODE		LOAD	DATE DEC 2022	
DRAWN AN	CHK CM	SITE		STRUCT	DWG 1	

FILENAME: H:\Drafting\33000\33099\ED-33099-BHPP-TOE WALL.dwg
PLOTDATE: 12/15/2022 2:16 PM

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No
WP No

HIGHWAY 401
NORTHUMBERLAND ROAD 28
BRIDGE REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

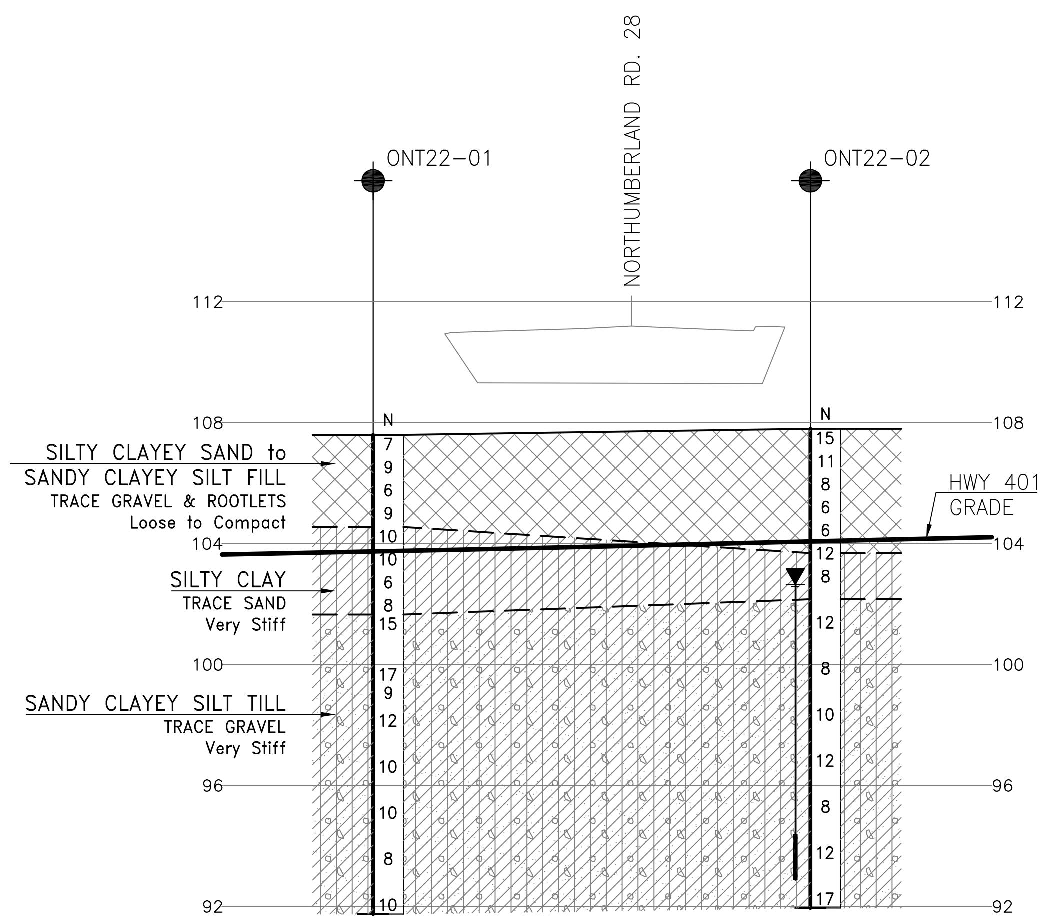
SHEET

Ontario

THURBER ENGINEERING LTD.

PLAN

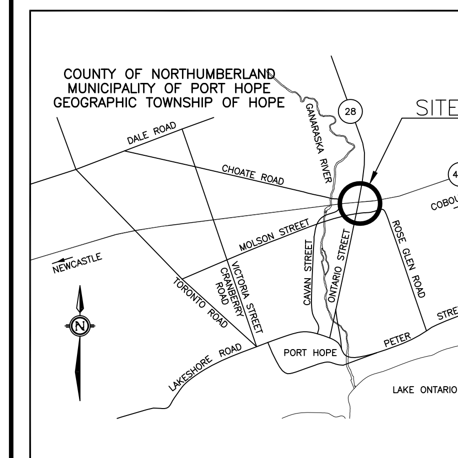
SCALE 1:500



SECTION ALONG A–A'

H 1:500

V 1:250



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
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
ONT20-01	110.8	4 870 758.6	401 983.2
ONT20-02	110.9	4 870 664.6	401 979.4
ONT22-01	107.6	4 870 741.2	401 973.4
ONT22-02	107.8	4 870 745.5	402 002.0

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3) Coordinate system is MTM NAD 83 Zone 10.

GEOCRES No.

REVISIONS	DATE	BY	DESCRIPTION

DESIGN CM	CHK –	CODE	LOAD	DATE DEC 2022
DRAWN AN	CHK CM	SITE	STRUCT	DWG 2

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Appendix B Field Investigation and Testing

Symbols and Terms
Record of Borehole Sheets

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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.

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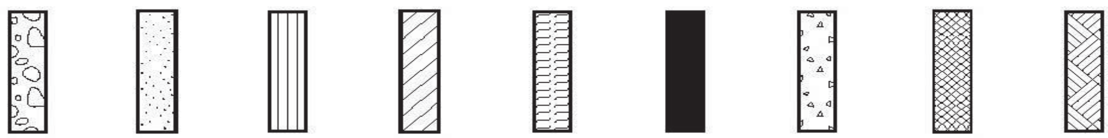
STRATA PLOT:

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

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 (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.

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

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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

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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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No ONT22-01

METRIC

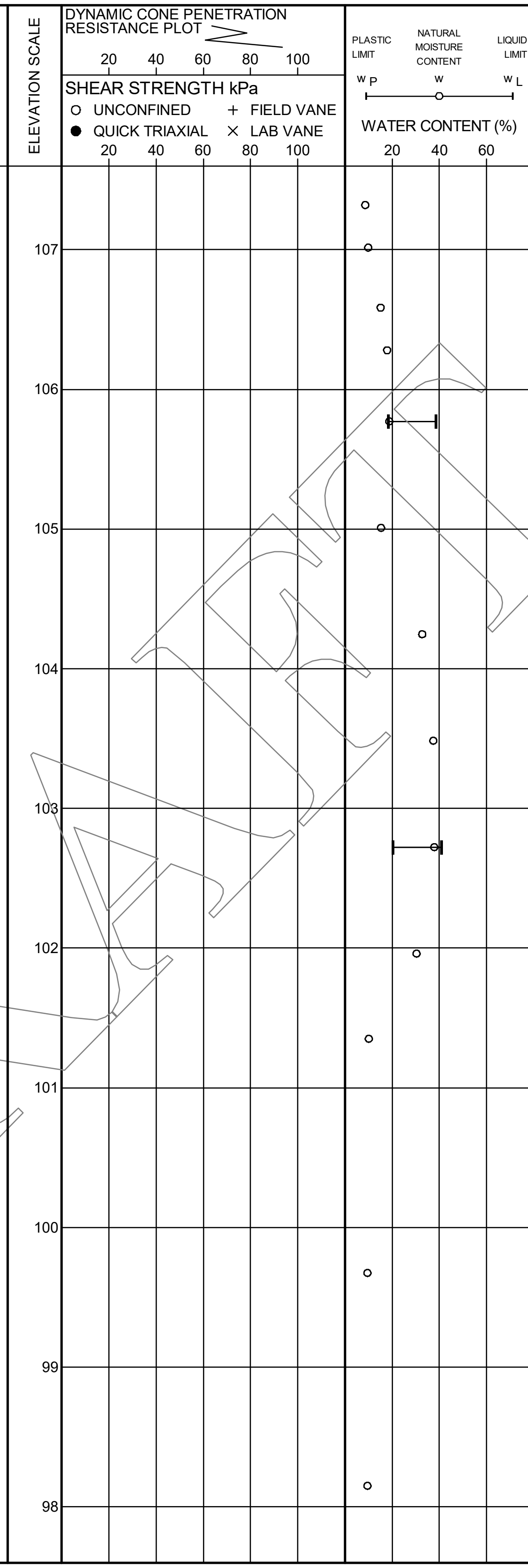
GWP# 4068-14-00	LOCATION	Lat: 43.970236°, Long: -78.288943° Highway 401/ Ontario Street, MTM z10: N 4 870 741.2 E 401 973.4	ORIGINATED BY SG
HWY 401	BOREHOLE TYPE	Portable / NW Casing / NQ Coring	COMPILED BY AO
DATUM Geodetic	DATE	2022.06.23 - 2022.06.28	CHECKED BY CM

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
107.6	Ground Surface
107.6 / 0.0	SILTY CLAYEY SAND to SANDY SILTY CLAY, Trace Gravel and Rootlets, Loose, Brown, **FILL**
104.6 / 3.0	**SILTY CLAY (CI)**, trace Sand, Very stiff, Brownish grey
101.7 / 5.9	**SILTY SAND** to **SANDY CLAYEY SILT**, Trace Gravel, Very stiff, Grey, **GLACIAL TILL**

SAMPLES

NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
1	SS	7	2	49	35	14
2	SS	9				
3	SS	6	6	27	35	32
4	SS	9				
5	SS	10				
6	SS	10	0	4	39	57
7	SS	6	1	5	47	47
8	SS	8				
9	SS	15	3	46	37	14
10	SS	17				
11	SS	9				
12	SS	12				



GROUND WATER CONDITIONS; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

DOUBLE LINE 33099 - HWY 401 CHOATE AND GANARASKA DD.GPJ 2012TEMPLATE(MTO).GDT 12-19-22

RECORD OF BOREHOLE No ONT22-01

METRIC

GWP# 4068-14-00

LOCATION Lat: 43.970236°, Long: -78.288943° Highway 401/ Ontario Street, MTM z10: N 4 870 741.2 E 401 973.4

ORIGINATED BY SG

HWY 401

BOREHOLE TYPE Portable / NW Casing / NQ Coring

COMPILED BY AO

DATUM Geodetic

DATE 2022.06.23 - 2022.06.28

CHECKED BY CM

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L – WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	SILTY SAND to **SANDY CLAYEY SILT** Trace Gravel Very stiff Grey **GLACIAL TILL**						97				
			13	SS	10				○		
							96				
			14	SS	10		95				
							94				
			15	SS	8				├─○		1 16 49 34
							93				
91.8			16	SS	10		92		○		
15.8	**End of Borehole** 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.										

+ 3, × 3: Numbers refer to Sensitivity

15 ⊕ 5 (20 above, 10 below) (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No ONT22-02

METRIC

GWP# 4068-14-00

LOCATION Lat: 43.9702701°, Long: -78.288586° Highway 401/ Ontario Street, MTM z10: N 4 870 745.5 E 402 002.0

ORIGINATED BY SG

HWY 401

BOREHOLE TYPE D70 Turbo Track Mount/ NW Casing / NQ Coring

COMPILED BY AO

DATUM Geodetic

DATE 2022.06.27 - 2022.06.28

CHECKED BY CM

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	GR	SA	SI	CL
107.8	Ground Surface								
0.0	SANDY CLAYEY SILT to SILTY CLAYEY SAND, Trace Gravel and Rootlets, Compact to loose, Brown, **FILL**	1	SS	15		8	41	30	21
		2	SS	11	107				
		3	SS	8	106				
		4	SS	6	105				
		5	SS	6		14	40	26	20
103.7 / 4.1	**SILTY CLAY (CI)**, trace Sand, Very stiff, Brownish grey	6	SS	12	104				
		7	SS	8	103				
102.2 / 5.6	**SILTY SAND** to **SANDY CLAYEY SILT**, Trace to some Gravel, Very stiff, Grey, **GLACIAL TILL**	8	SS	12	102	7	37	35	21
		9	SS	8	101 / 100	3	47	35	15
		10	SS	10	99 / 98				

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%)

Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No ONT22-02

METRIC

GWP# 4068-14-00

LOCATION Lat: 43.9702701°, Long: -78.288586° Highway 401/ Ontario Street, MTM z10: N 4 870 745.5 E 402 002.0

ORIGINATED BY SG

HWY 401

BOREHOLE TYPE D70 Turbo Track Mount/ NW Casing / NQ Coring

COMPILED BY AO

DATUM Geodetic

DATE 2022.06.27 - 2022.06.28

CHECKED BY CM

ELEV / DEPTH	DESCRIPTION (Continued From Previous Page)	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
	SILTY SAND to **SANDY CLAYEY SILT** Trace to some Gravel Very stiff Grey **GLACIAL TILL**				97				
		11	SS	12		13	38	37	12
					96				
		12	SS	8		3	36	39	22
					95				
		13	SS	12	94				
					93				
92.0		14	SS	17	92	5	26	45	24
15.8	**End of Borehole**								

Piezometer installed consists of 25-mm diameter Schedule 40 PVC pipe with a 1.5-m slotted screen.

Water level readings:

DATE	DEPTH (m)	ELEV. (m)
2022.06.28	10.2	97.6
2022.08.23	5.1	102.7
2022.08.24	5.2	102.6

Column headings: SOIL PROFILE; SAMPLES; STRAT PLOT; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20 40 60); UNIT WEIGHT γ kN/m³

$+^3, \times^3$: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

THURBER

Appendix C Laboratory Testing

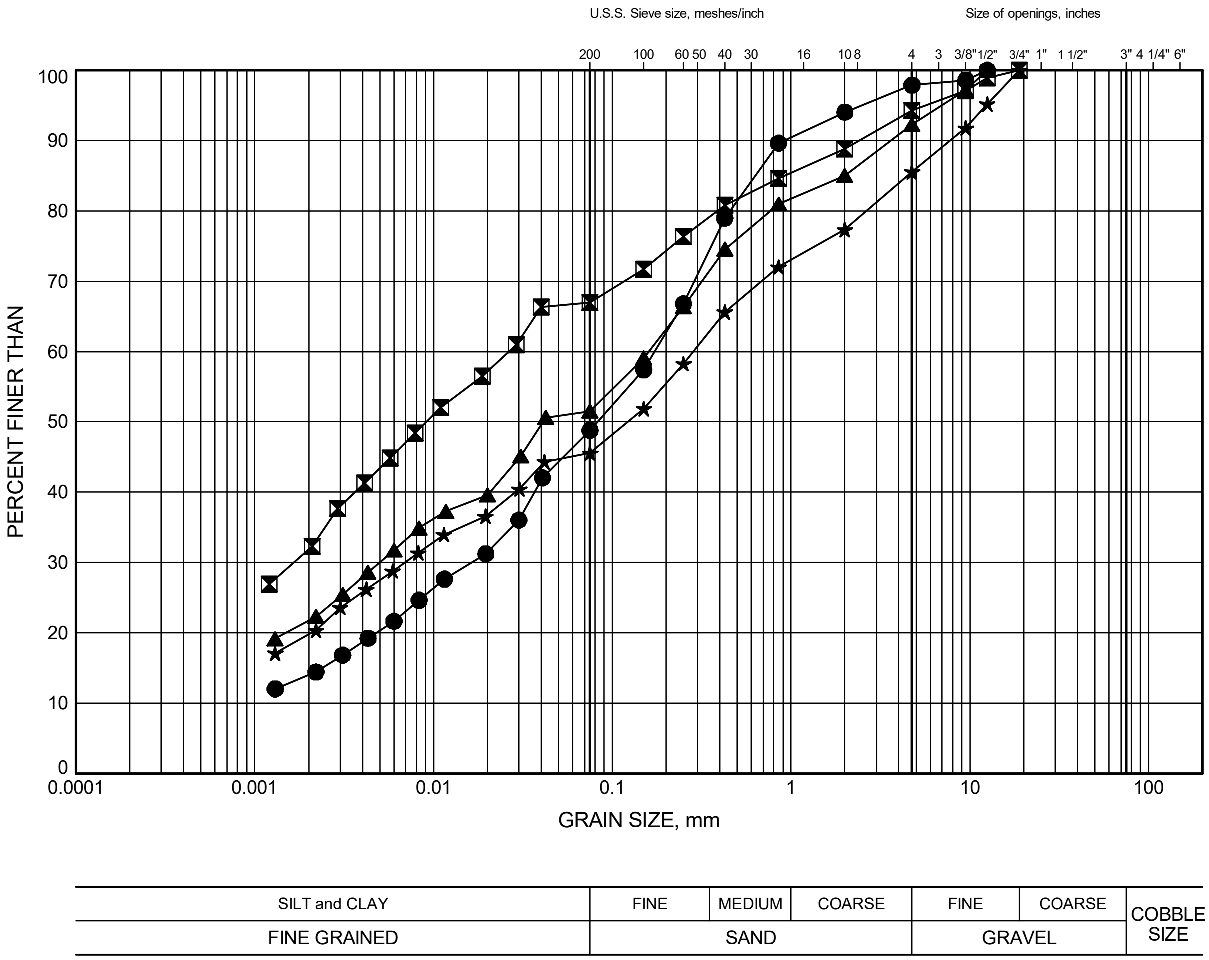
Particle Size Analysis Figures
Atterberg Limits Figures
Analytical Testing Results

Highway 401 Choate and Ganaraska Detailed Design

GRAIN SIZE DISTRIBUTION

FIGURE C1

Embankment Fill



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	ONT22-01	0.3	107.3
⧗	ONT22-01	1.8	105.8
▲	ONT22-02	0.3	107.5
★	ONT22-02	3.4	104.4

Date December 2022

GWP# 4068-14-00

THURBER

Prep'd RH

Chkd. CM

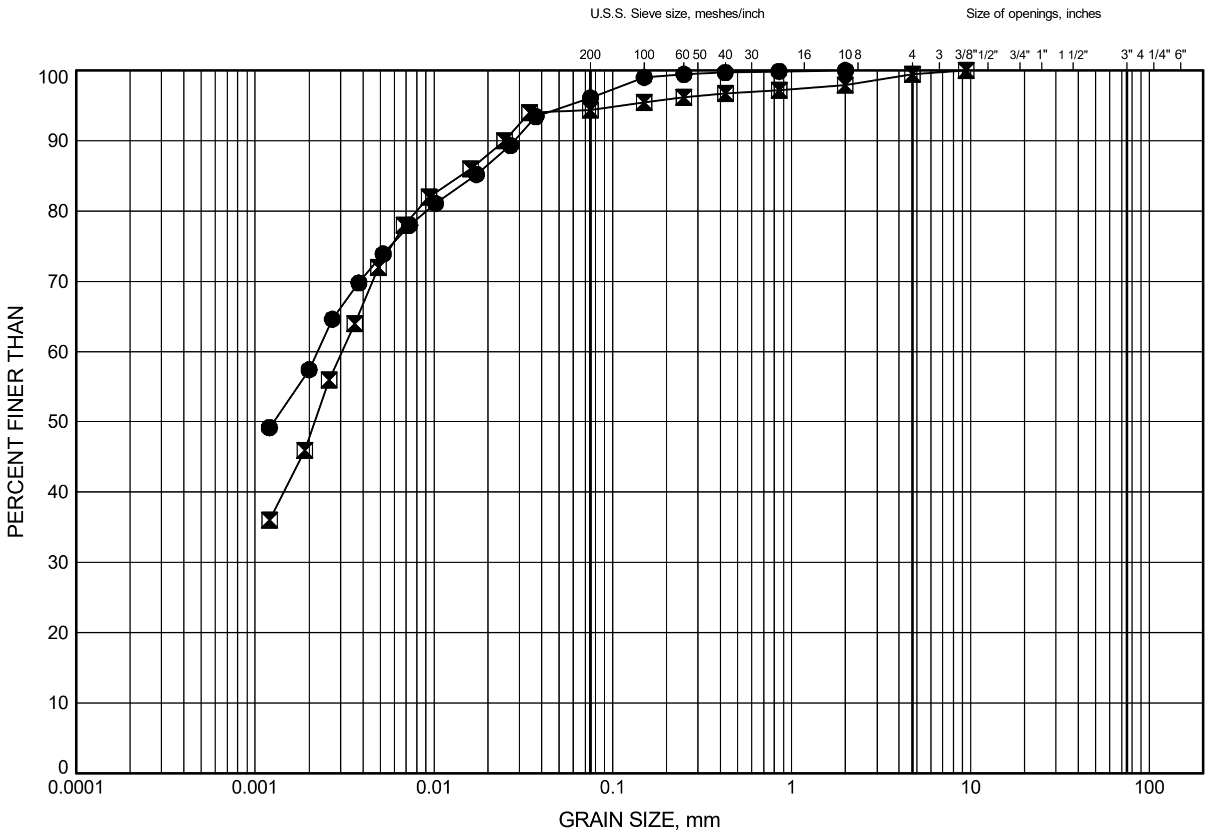
GRAIN SIZE DISTRIBUTION - THURBER 33099 - HWY 401 CHOATE AND GANARASKA DD.GPJ 12-15-22

Highway 401 Choate and Ganaraska Detailed Design

GRAIN SIZE DISTRIBUTION

FIGURE C2

Silty Clay (CI)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	ONT22-01	4.1	103.5
⧗	ONT22-01	4.9	102.7

Date December 2022

GWP# 4068-14-00

THURBER

Prep'd RH

Chkd. CM

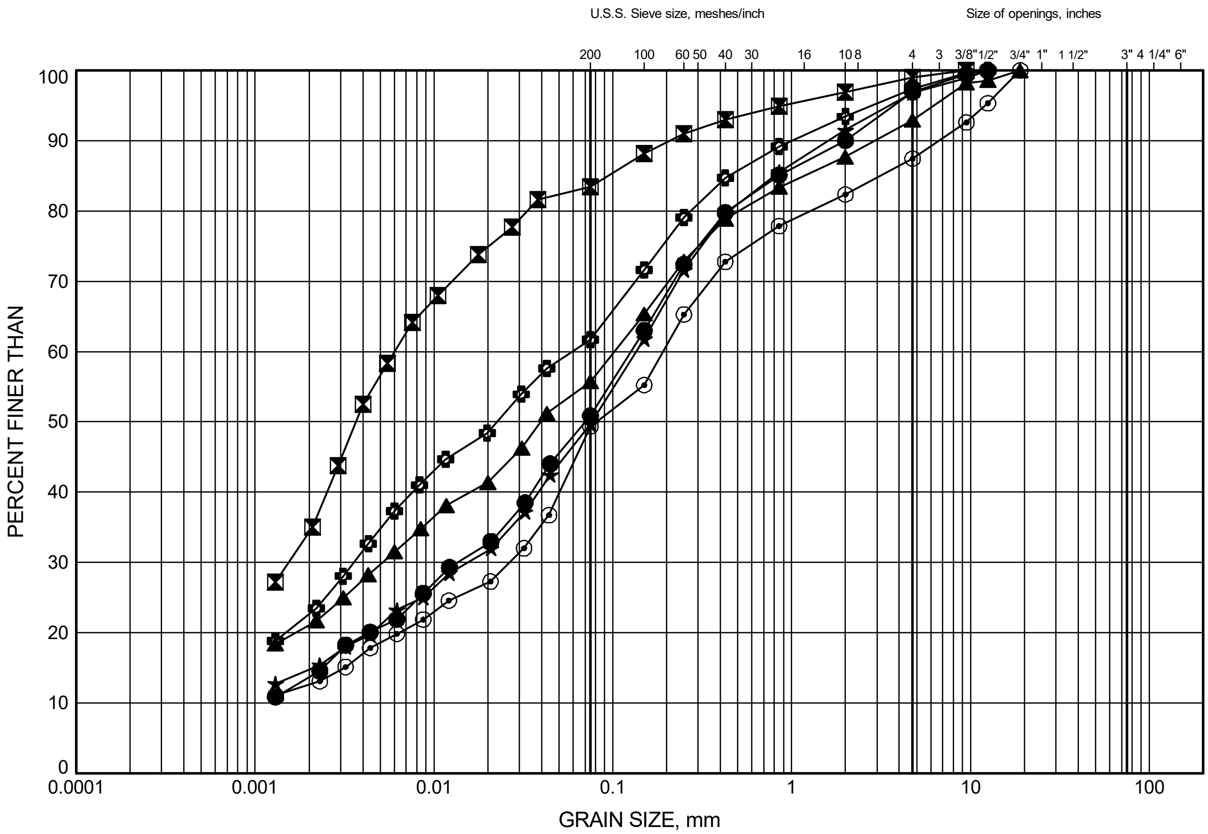
GRAIN SIZE DISTRIBUTION - THURBER 33099 - HWY 401 CHOATE AND GANARASKA DD.GPJ 12-15-22

Highway 401 Choate and Ganaraska Detailed Design

GRAIN SIZE DISTRIBUTION

FIGURE C3

Glacial Till



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	ONT22-01	6.2	101.4
⧗	ONT22-01	14.0	93.6
▲	ONT22-02	6.5	101.3
★	ONT22-02	7.9	99.9
⊙	ONT22-02	11.0	96.8
✿	ONT22-02	12.5	95.3

Date December 2022

GWP# 4068-14-00

THURBER

Prep'd RH

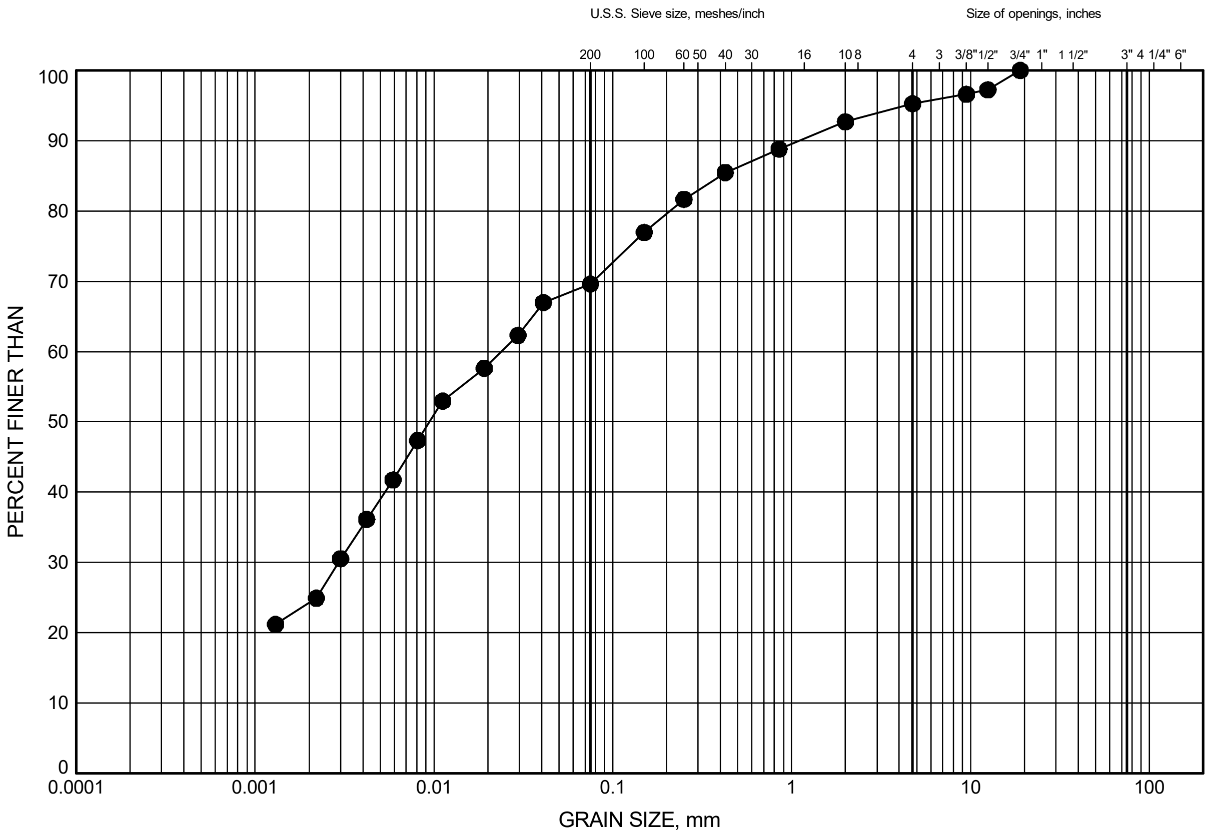
Chkd. CM

Highway 401 Choate and Ganaraska Detailed Design

GRAIN SIZE DISTRIBUTION

FIGURE C4

Glacial Till



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	ONT22-02	15.5	92.3

Date December 2022

GWP# 4068-14-00

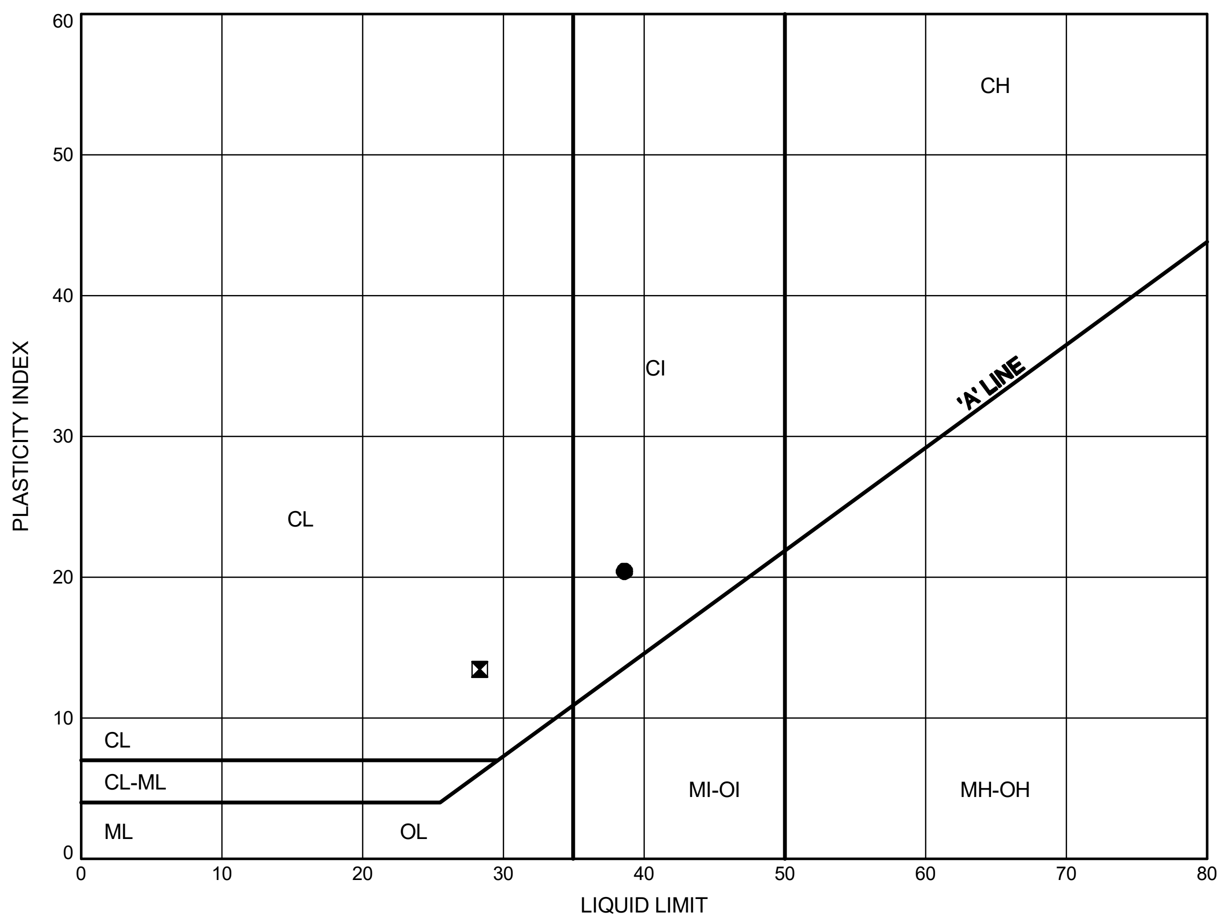
THURBER

Prep'd RH

Chkd. CM

ATTERBERG LIMITS TEST RESULTS

Embankment Fill



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	ONT22-01	1.8	105.8
⊠	ONT22-02	3.4	104.4

Date December 2022
GWP# 4068-14-00

THURBER

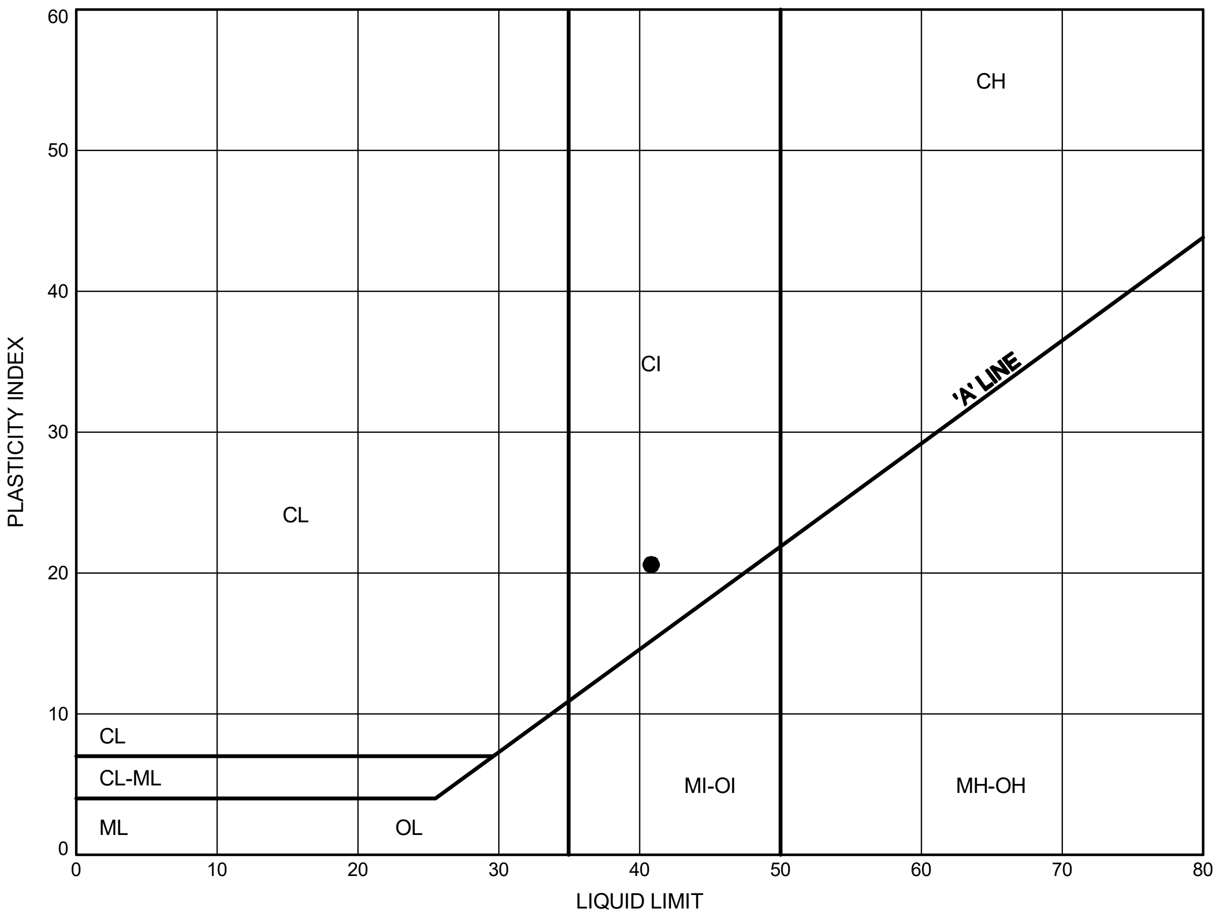
Prep'd RH
Chkd. CM

Highway 401 Choate and Ganaraska Detailed Design

ATTERBERG LIMITS TEST RESULTS

FIGURE C6

Silty Clay (CI)



LEGEND

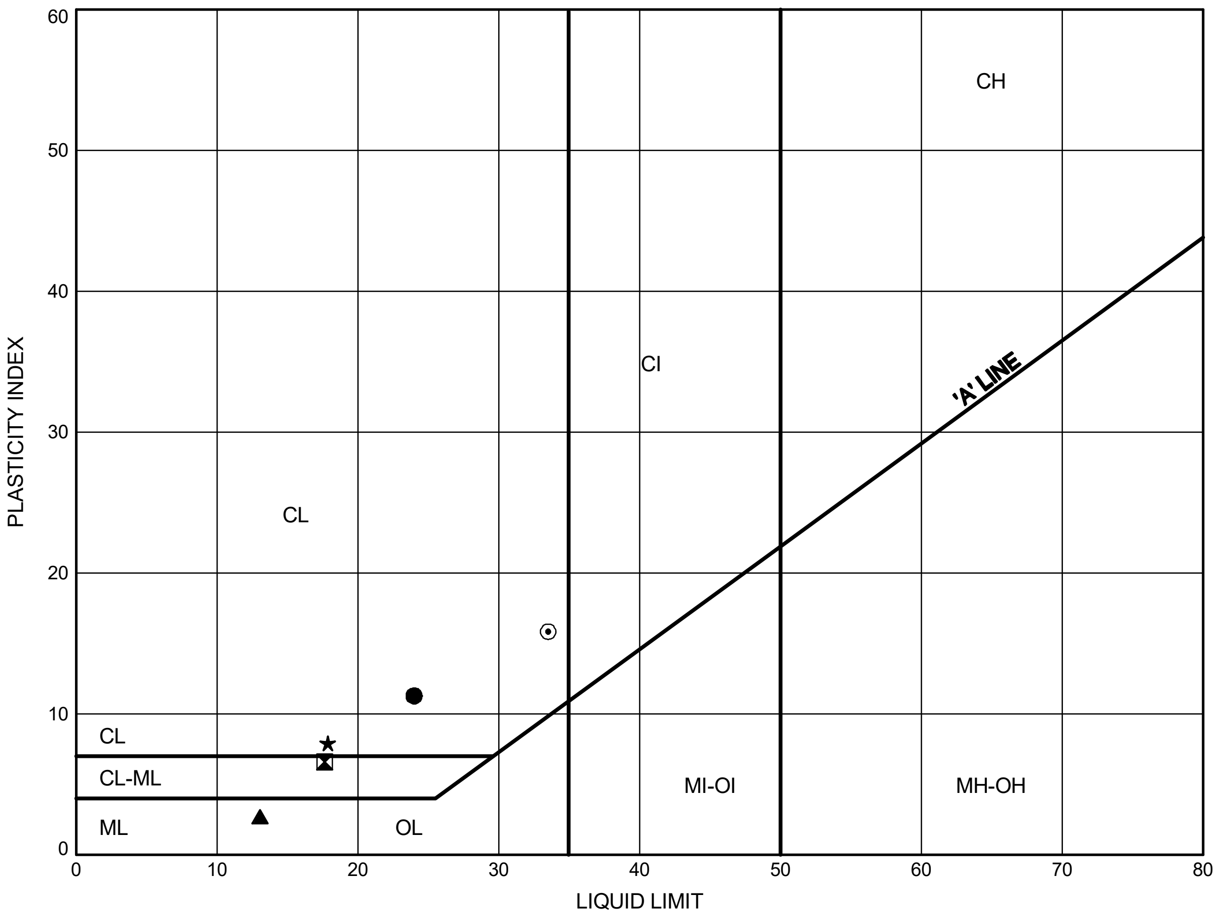
SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	ONT22-01	4.9	102.7

Highway 401 Choate and Ganaraska Detailed Design

ATTERBERG LIMITS TEST RESULTS

FIGURE C7

Glacial Till



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	ONT22-01	14.0	93.6
⊠	ONT22-02	6.5	101.3
▲	ONT22-02	7.9	99.9
★	ONT22-02	12.5	95.3
⊙	ONT22-02	15.5	92.3

THURBALT 33099 - HWY 401 CHOATE AND GANARASKA DD.GPJ 12-15-22

Date December 2022

GWP# 4068-14-00

THURBER

Prep'd RH

Chkd. CM

FINAL REPORT

Client: Thurber Engineering Ltd.

Project: 33099, Choate Road

Project Manager: Scott Gittens

Samplers: Scott Gittens

MATRIX: SOIL

			Sample Number	5	6
			Sample Name	BH-ONT-22-2 SS#7	B-HF-2 SS#2A
			Sample Matrix	Soil	Soil
			Sample Date	17/10/2022	17/10/2022
Parameter	**Units**	**RL**		**Result**	**Result**
Corrosivity Index					
Corrosivity Index	none	1		9	1
Soil Redox Potential	mV	no		239	272
Sulphide (Na2CO3)	%	0.04		< 0.04	< 0.04
pH	pH Units	0.05		8.66	8.[illegible]2
Resistivity (calculated)	ohms.cm	-9999		1980	3290
General Chemistry					
Conductivity	uS/cm	2		505	304
Metals and Inorganics					
Moisture Content	%	0.1		19.0	21.3
Sulphate	µg/g	0.4		35	60
Other (ORP)					
Chloride	µg/g	0.4		440	84

THURBER

Appendix D Site Photographs

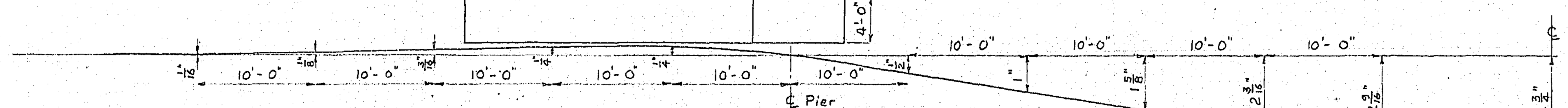
Photo 1: Looking west towards the crest of the existing north foreslope of the Highway 401 underpass of County Road 28

Photo 2: Looking east along the toe of the existing north foreslope of the Highway 401 underpass of County Road 28

THURBER

Appendix E Existing Information

Existing Structure - General Arrangement Drawing
Historical GEOCRES Borehole Information



DEAD LOAD DEFLECTION DIAGRAM.

Note. The Contractor must make allowance for dead load deflection & formwork creep.

EAST

	End of Wing Wall	Face of Ballast Wall	℄ Diaphragm	℄ Pier	℄ Diaphragm	℄ Structure	℄ Diaphragm	℄ Pier	℄ Diaphragm	Face of Ballast Wall	End of Wing Wall
Top of Sidewalk	364·64	364·80	365·16	365·44	365·64	365·76	365·81	365·78	365·66	365·43	365·35
Pavemt. at Curb		363·86	364·23	364·50	364·70	364·81	364·85	364·81	364·68	364·45	
Pavemt on ℄	-	364·45	364·79	365·04	365·22	365·31	365·33	365·27	365·13	364·93	
Pavemt. at Curb		364·07	364·38	364·61	364·77	364·84	364·84	364·76	364·60	364·36	
Top of Sidewalk	364·92	365·05	365·37	365·59	365·74	365·80	365·80	365·71	365·54	365·30	365·20

NORTH — SOUTH

WEST

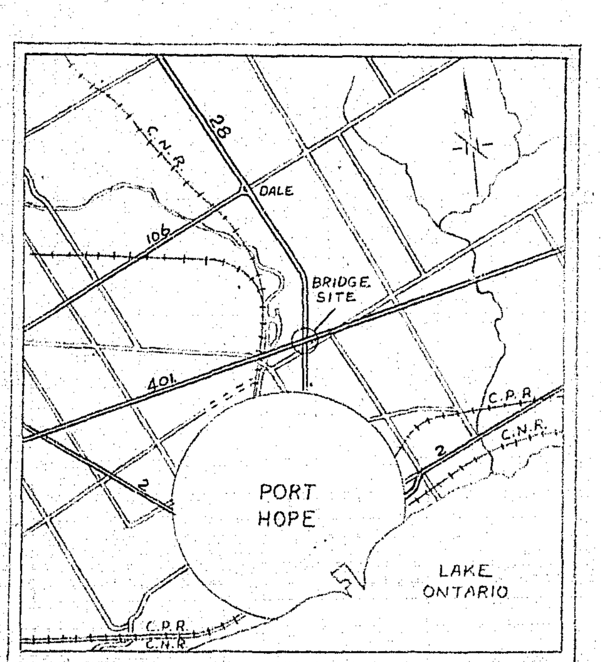
DECK ELEVATIONS

ESTIMATE OF PILING REQUIRED – 14 BP73

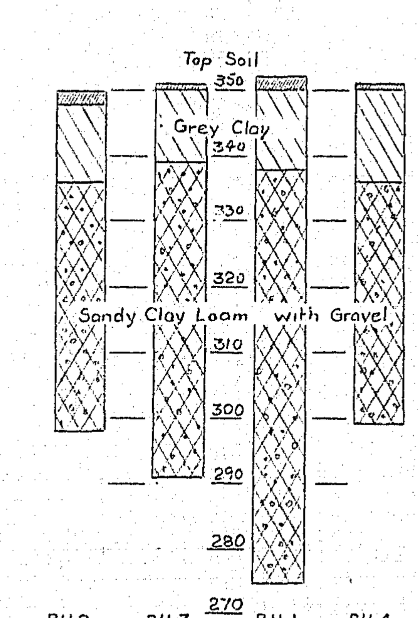
94 @ 40' – 3760'
36 @ 48' – 1728'
26 @ 53' – 1378' Total – 6866'

DRAWING LIST

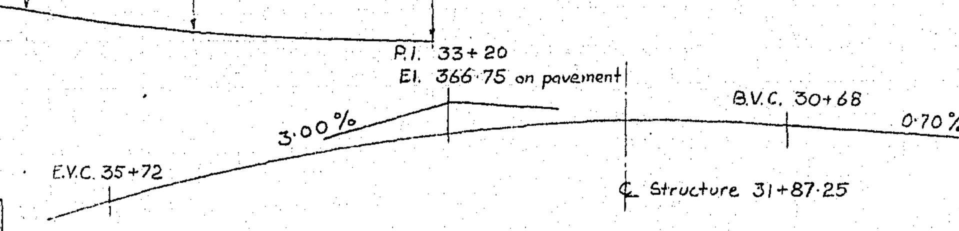
D 4001 – 1 General Layout.
2 Footing, Abutment & Pier Reinforcement & Details.
3 Deck, Curb & Handrail Reinforcement & Details.
4 Expansion Bearing Details.
5 Standard Steel Handrail Details.
6 Reinforcing Steel Schedule.
7 Reinforcing Steel Schedule.
BD 17-6 Details of Steel Posts for Handrail Panels.
& 17-6A



KEY PLAN
Scale: 1 in = 1 mile



SOIL BORING DATA
Scale: 1/20 in = 1 ft.



700'-V.C.
L.V.C. 504'

VERTICAL CURVE DATA HWY. 28

HWY. 401
Grade 0·75% up to the East. Elevation at Sta. 438+80 – 342·99 on pavement.

SKEW ANGLE 20°-30'-30"
Sin. 0·35034
Cos. 0·93662
Tan. 0·37405
Cot. 2·67340

PILING NOTE.
Structure to be supported on 14 BP 73 steel H piles driven to support a load of 50 tons. per pile. The piles shall be driven by air, steam or diesel hammer of types approved in advance by the Bridge Engineer developing not less than 13,000 ft.lb. of energy per blow for steam or air hammer and 22,000 ft. lb. for diesel hammer.

NOTE TO DISTRICT ENGINEER.
Concrete work on this structure must not be commenced until monuments to fix control points have been erected and checked by the District Engineer.

NOTE TO CONTRACTOR.
Structure to be built in accordance with Form No. 9 revised March 1957 and the Special Provisions, extra copies of which may be obtained from the District Engineer.
All Construction Joints must be approved by the Bridge Engineer.

CONCRETE MIX.
Footings – Min strength @ 28 days 2500 lb/in². Max size aggregate – 1½".
Structure – Min strength @ 28 days 3000 lb/in². Max size aggregate – ¾"
Add ¼ lb. Pozzolith "S" per bag of cement.

SOIL BORING DATA
The complete soil investigation report BA 646 may be examined at the Bridge Office, 280 Davenport Rd. Toronto. The Department does not guarantee the accuracy of this report or the abridged version shown on these plans.

REINFORCING STEEL COVER
3 inches clear cover to be provided over steel in faces in contact with ground. 2 inches clear cover to be provided on all other surfaces except where shown otherwise.

W.P. 44-57

DEPARTMENT OF HIGHWAYS:-ONTARIO-
BRIDGE OFFICE:-TORONTO

HOPE TOWNSHIP BRIDGE No. 18

HWY. 401 UNDERPASS

THE KING'S HIGHWAY No. 401 & 28 — DIST. No. 7
CO. DURHAM
TWP. HOPE — LOT 3 — CON. II

GENERAL LAYOUT

APPROVED
BRIDGE ENGINEER — DESIGN ENGINEER

REVISIONS: DATE	BY	DESCRIPTION	REFERENCE PLANS
			F 3131
			F 3131-1
			E 2869-1
			DM 4171-4

DESIGN	J.M.R.	CHECK	H.L.C.
DRAWING	J.M.R.	CHECK	D.S.F.
TRACING		CHECK	
DATE	MAY 1958		

CONTRACT NUMBERS: 58-191
LOADING: H 20 S 16
DRAWING NUMBER: D 4001 – 1

D-700

TWP# 7-232-1-A

~~21-232~~ ~~D4001~~ 1 to 8

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No ONT 20-01

METRIC

GWP#	4005-17-00	LOCATION	Lat: 43.970391°, Long: -78.288817° Ontario Street Underpass, MTM z10: N 4 870 758.6 E 401 983.2	ORIGINATED BY	RH
HWY	401	BOREHOLE TYPE	CME 75 Truckmount, HW / NW Casing	COMPILED BY	SH
DATUM	Geodetic	DATE	2020.05.27 - 2020.05.27	CHECKED BY	CM

ELEV / DEPTH	SOIL PROFILE: DESCRIPTION	SAMPLES: NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%): GR	SA	SI	CL
110.8								
0.0	**ASPHALT (200 mm)**							
0.2	GRAVEL with sand compact grey-brown **FILL**	1	SS	22	54	41	5 (SI+CL)	
109.3 1.5	SAND with gravel very loose to compact grey-brown **FILL**	2	SS	6				
		3	SS	14	43	55	2 (SI+CL)	
		4	SS	4				
		5	SS	WH				
		6	SS	15				
105.5 5.3	**CLAY (CI)**, gravelly with sand very stiff grey	7	SS	23	28	13	34	25
104.6 6.2	**CLAY (CI)** very stiff brown-grey	8	SS	9				
		9	SS	8				
		10	SS	13	1	4	43	52
		11	SS	8				
101.9 8.9	**SILTY SAND** with gravel, some clay compact to dense grey **GLACIAL TILL**	12	SS	35				

Chart column headings: STRAT PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE (110, 109, 108, 107, 106, 105, 104, 103, 102, 101); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20, 40, 60); UNIT WEIGHT γ kN/m3

Continued Next Page

+3, ×3: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

DOUBLE LINE 28171 PORT HOPE - ONT.GPJ 2012TEMPLATE(MTO).GDT 30/9/20

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No ONT 20-01

METRIC

GWP# 4005-17-00

LOCATION Lat: 43.970391°, Long: -78.288817°
Ontario Street Underpass, MTM z10: N 4 870 758.6 E 401 983.2

ORIGINATED BY RH

HWY 401

BOREHOLE TYPE CME 75 Truckmount, HW / NW Casing

COMPILED BY SH

DATUM Geodetic

DATE 2020.05.27 - 2020.05.27

CHECKED BY CM

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
	SILTY SAND with gravel, some clay compact to dense grey **GLACIAL TILL**									
		13	SS	18	100	○	21	40	29	10
					99					
98.6 12.2	**CLAYEY SILT (CL)** with sand some to trace gravel very stiff to firm grey **GLACIAL TILL**	14	SS	25		○				
					98					
	- frequent cobbles 13.7 m to 15.2 m				97					
		1	NQ	-	96					
		15	SS	11	95	○				
		16	SS	6	94	├○┤	4	24	48	24
					93					
		17	SS	3	92	○				
					91					

Column headings: SOIL PROFILE; SAMPLES; STRAT PLOT; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

THURBER

RECORD OF BOREHOLE No ONT 20-01

METRIC

GWP# 4005-17-00	LOCATION Lat: 43.970391°, Long: -78.288817° Ontario Street Underpass, MTM z10: N 4 870 758.6 E 401 983.2		ORIGINATED BY RH
HWY 401	BOREHOLE TYPE CME 75 Truckmount, HW / NW Casing		COMPILED BY SH
DATUM Geodetic	DATE 2020.05.27 - 2020.05.27		CHECKED BY CM

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
	CLAYEY SILT (CL) with sand some to trace gravel very stiff to firm grey **GLACIAL TILL**	18	SS	13						
90.1 / 20.7	**SILTY, CLAYEY SAND** with gravel frequent cobbles very dense grey **GLACIAL TILL**	19	SS	118/ 225 mm	90	plotted	16	38	34	12
		20	SS	100/ 25 mm	89					
87.9 / 22.9	**SAND** with gravel, trace silt frequent cobbles very dense grey **GLACIAL TILL**	21	SS	125	88	plotted	33	62	5 (SI+CL)	
87.4 / 23.4	End of Borehole									

25 mm standpipe piezometer installed on completion

WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
2020.05.29	7.4	103.4
2020.07.07	8.0	102.8
2020.07.14	8.0	102.8

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%)

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 / 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No ONT 20-02

METRIC

GWP#	4005-17-00	ORIGINATED BY	RH
LOCATION	Lat: 43.969545°, Long: -78.288882° Ontario Street Underpass, MTM z10: N 4 870 664.6 E 401 979.4	COMPILED BY	SH
HWY	401	CHECKED BY	CM
BOREHOLE TYPE	CME 75 Truckmount, HW / NW Casing		
DATUM	Geodetic	DATE	2020.05.28 - 2020.05.28

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
110.9								
0.0	**ASPHALT (215 mm)**							
0.2	GRAVEL with sand, dense, grey-brown, **FILL**	1	SS	42	57	40	3 (SI+CL)	
109.4 / 1.5	SAND with gravel, compact to dense, grey-brown, **FILL**	2	SS	34				
		3	SS	18				
		4	SS	17				
107.1 / 3.8	**CLAY** with gravel, trace sand, stiff, grey	5	SS	12				
		6	SS	7	17	5	47	31
105.6 / 5.3	**CLAY (CI)**, very stiff, brown	7	SS	26				
104.8 / 6.1	**CLAYEY SILT** to **SILTY CLAYEY SAND** with gravel, very stiff, grey, **GLACIAL TILL**	8	SS	32				
		9	SS	49	4	41	41	14
		10	SS	27				
		11	SS	42				
		12	SS	43				

Elevation scale: 110, 109, 108, 107, 106, 105, 104, 103, 102, 101

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE — 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ kN/m 3

REMARKS & GRAIN SIZE DISTRIBUTION (%)

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No ONT 20-02

METRIC

GWP#	4005-17-00	LOCATION	Lat: 43.969545°, Long: -78.288882° Ontario Street Underpass, MTM z10: N 4 870 664.6 E 401 979.4	ORIGINATED BY	RH
HWY	401	BOREHOLE TYPE	CME 75 Truckmount, HW / NW Casing	COMPILED BY	SH
DATUM	Geodetic	DATE	2020.05.28 - 2020.05.28	CHECKED BY	CM

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT / LIMITS	GR	SA	SI	CL
	CLAYEY SILT to **SILTY CLAYEY SAND** with gravel, very stiff, grey, **GLACIAL TILL**									
		13	SS	49	100	w	15	36	36	13
					99					
		14	SS	26		w				
					98					
		15	SS	17	97					
					96					
95.7 / 15.2	**SILTY, SANDY CLAY** with gravel, very stiff to stiff, grey, **GLACIAL TILL**									
		16	SS	28	95					
					94					
		17	SS	13		wP–w	16	29	40	15
					93					
92.6 / 18.3	**SILTY GRAVEL** with sand, frequent cobbles, very dense, grey, **GLACIAL TILL**	18	SS	100/ 100 mm		w	39	37	24 (SI+CL)	
					92					
	- Glacial till cored with full recovery from 19.8 m to 21.3 m	19	SS	100/	91					

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No ONT 20-02

METRIC

GWP# 4005-17-00
LOCATION Lat: 43.969545°, Long: -78.288882°
Ontario Street Underpass, MTM z10: N 4 870 664.6 E 401 979.4
ORIGINATED BY RH
HWY 401
BOREHOLE TYPE CME 75 Truckmount, HW / NW Casing
COMPILED BY SH
DATUM Geodetic
DATE 2020.05.28 - 2020.05.28
CHECKED BY CM

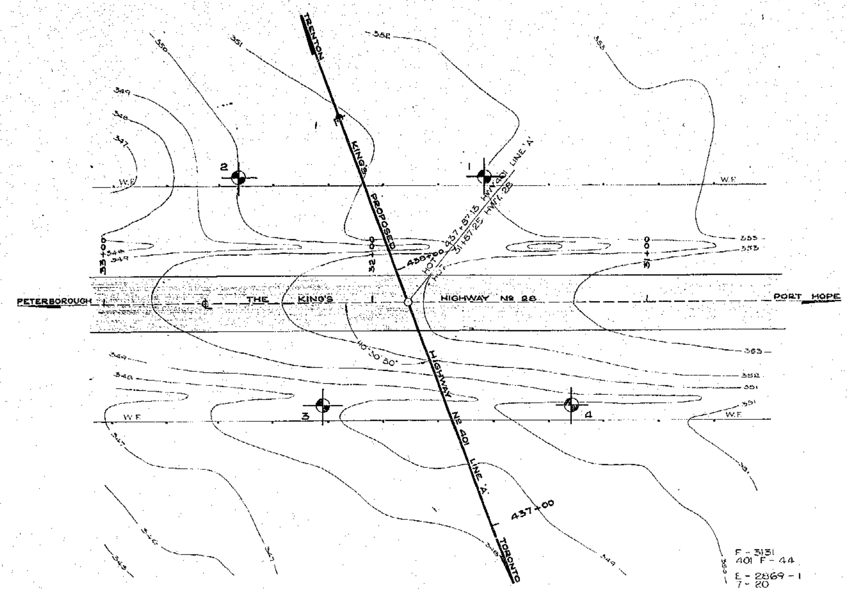
ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	STRAT PLOT	SAMPLES – NUMBER	SAMPLES – TYPE	SAMPLES – "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L – WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	SILTY GRAVEL with sand frequent cobbles very dense grey **GLACIAL TILL**		1	NQ	-	25mm	90				
89.5 / 21.4	End of Borehole 25 mm standpipe piezometer installed on completion		20	SS	100/ 25 mm						

WATER LEVEL READINGS:

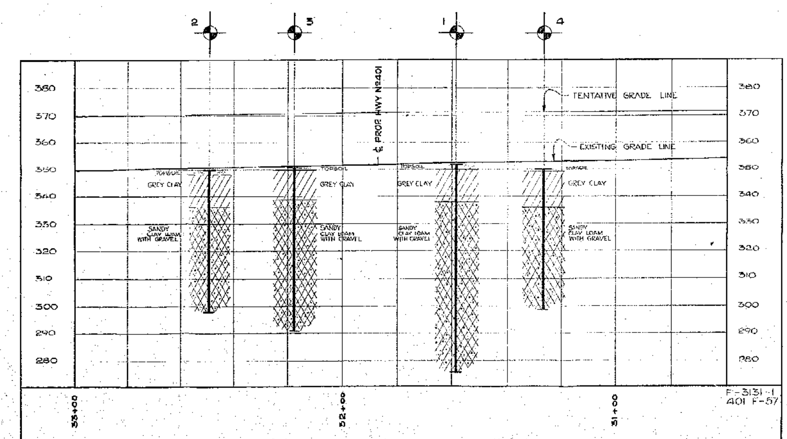
DATE	DEPTH (m)	ELEV. (m)
2020.05.29	7.4	103.5
2020.07.07	7.9	103.0
2020.07.14	8.0	102.9

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE



PLAN SCALE 1 IN = 20 FT



PROFILE

SCALE HOR / VER 1 IN = 20 FT

LEGEND

- BORE HOLES
- PENETRATION HOLE
- BORE & PENETRATION HOLE

HOLE NO.	ELEVATION	STATION	DISTANCE FROM 401 ℄ & PARALLEL TO HWY 28
1	351.0'	438+37'	45' RT.
2	350.0'	438+37'	45' LT.
3	348.9'	437+47'	45' LT.
4	350.0'	437+47'	45' RT.

— NOTE —

THE BOUNDARIES BETWEEN SOIL STRATA HAVE BEEN ESTABLISHED ONLY AT BORE HOLE LOCATIONS. BETWEEN BORE HOLES THE BOUNDARIES ARE ASSUMED FROM GEOLOGICAL EVIDENCE AND MAY BE SUBJECT TO CONSIDERABLE ERROR.

DEPARTMENT OF HIGHWAYS, ONTARIO

MATERIALS & RESEARCH SECTION – DOWNSVIEW

HIGHWAY Nº 28 PROPOSED CROSSING 1/2 MILE N. OF PORT HOPE

THE KING'S HIGHWAY No. 401 (LINE 'A') DIST. No. 7

CO. DURHAM

TWP. HOPE LOT 3 CON. II

POSITION & ELEVATION OF HOLES

APPROVED

ENGINEER CHIEF ENGINEER

DRAWN D.F.

CONTRACT NUMBER W.P. 44-57

DRAWING NUMBER F-57-7A

DATE AUGUST 12, 1957

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & RESEARCH BRANCH - FOUNDATIONS SECTION - DOWNSVIEW

OFFICE REPORT ON SOIL EXPLORATION

DRILL RIG 54-1 OPERATION BORE & PINETN JOB F 57-7 W.P. 44-57 BORING 1 STA. 438+37 (45' TO RT. PARALLEL TO HWY. 28)

CASING BX (standard samplers to fit unless noted) DATUM GEODETIC DATE REPORT JULY 1957

SAMPLER HAMMER WT. 250 LBS. DROP 19 INCHES COMPILED BY H.L. CHECKED BY A.L. DATE BORING 25 APRIL 1957

ABBREVIATIONS

V - INSITU VANE SHEAR TEST, M - MECHANICAL ANALYSIS, U - UNCONFINED COMPRESSION, Q_C - TRIAXIAL CONSOLIDATED QUICK, Q - TRIAXIAL QUICK, S - TRIAXIAL SLOW, W.L. - WATER LEVEL IN CASING, W.T. - WATER TABLE IN SOIL, K - PERMIABILITY, C - CONSOLIDATION, CA - CASING, γ - UNIT WEIGHT

SAMPLE TYPES

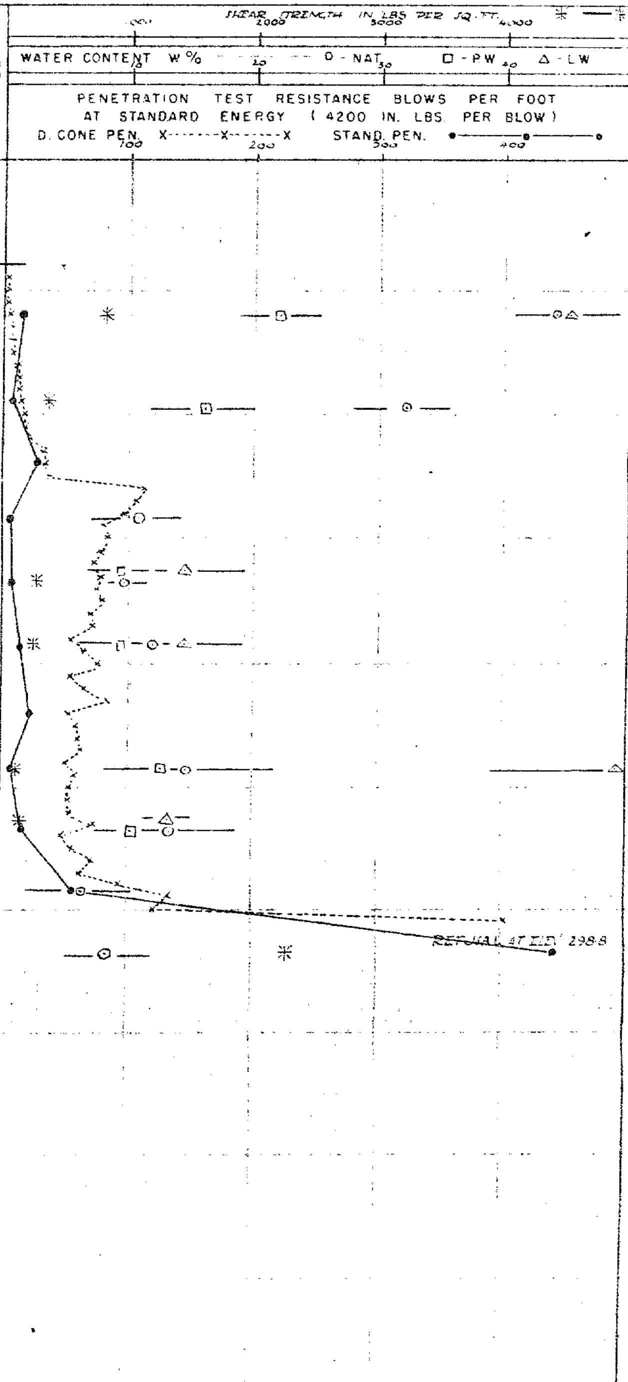
C.S. - CHUNK, D.O. - DRIVE OPEN, D.F. - DRIVE FOOT VALVE, T.O. - THIN WALLED OPEN, S.S. - SLEEVE SAMPLE, P.S. - PISTON SAMPLE, W.S. - WASHED SAMPLE, R.C. - ROCK CORE

SAMPLE CONDITION

DISTURBED, FAIR, GOOD, LOST

SOIL PROFILE

ELEVATION / DEPTH	WATER CONDITIONS	DESCRIPTION
351.8		GROUND LEVEL
349.8' / 2.0'		TOP SOIL
337.8' / 14.0'		GREY CLAY
275.8' / 76.0'		SANDY CLAY LOAM WITH GRAVEL
		END OF BOREHOLE



SAMPLES

OTHER TESTS	CONDITION	TYPE	NO.	PENETRATION RESISTANCE	ELEV. / RECOV. %
					351.8'
					348.8
γ=110.2 p.c.f.	GOOD	T.O.	1	11	100
					341.8'
γ=119.3 p.c.f.	GOOD	T.O.	2	6	50
					336.8'
W.S.	LOST	S.S.	3	28	—
					331.8'
	GOOD	S.S.	4	6	67
					326.8'
γ=114.0 p.c.f.	GOOD	S.S.	5	7	56
					321.8'
γ=138.3 p.c.f.	GOOD	S.S.	6	11	100
					316.8'
W.S.	LOST	T.O.	7	20	-
					311.8'
γ=129.7 p.c.f.	GOOD	S.S.	8	7	67
					306.8'
γ=136.9 p.c.f.	GOOD	S.S.	9	10	100
					301.8'
	GOOD	S.S.	10	56	33
					296.8'
γ=139 p.c.f.	GOOD	S.S.	11	>100	100
					287.8'
W.S.	LOST	S.S.		>100	—
					281.8'
	DRILLED				
					275.8'

CASING BLOWS (ACTUAL): 1, 9, 27, 19, 29, 32, 47, 50, 35, 55, 48, 24, 37, 43, 24, 27, 37, 35, 20, 27, 35, 42, 53, 27, 31, 51, 40, 38, 44, 45, 52, 44, 47, 53, 54, 80, 46, 100, 357, 297, 434, 73, 137, 586, 56, 75, 46, 86, 49, 50, 245, 44, 246, 490, 324, 400, 395, 425, 501, 303, 430

END OF CASING AT ELEV. 275.8'

Depth scale: 2, 12, 22, 32, 42, 52, 62, 72, 82

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & RESEARCH BRANCH - FOUNDATIONS SECTION - DOWNSVIEW

OFFICE REPORT ON SOIL EXPLORATION

DRILL RIG *54-1* OPERATION *BORE & PINET'N* JOB *F-57-7* W.P. *44-57* BORING *2* STA. *438+37* (*45' LT. PARALLEL TO HWY #2*)

CASING *BX* (standard samplers to fit unless noted) DATUM *GEODETIC* DATE REPORT *JULY 1957*

SAMPLER HAMMER WT. *250* LBS. DROP *19* INCHES COMPILED BY *H.L.* CHECKED BY *A.L.* DATE BORING *30 APRIL 1957*

ABBREVIATIONS

V - INSITU VANE SHEAR TEST
M - MECHANICAL ANALYSIS
U - UNCONFINED COMPRESSION
Q_C - TRIAXIAL CONSOLIDATED QUICK
Q - TRIAXIAL QUICK
S - TRIAXIAL SLOW
W.L. - WATER LEVEL IN CASING
W.T. - WATER TABLE IN SOIL
K - PERMIABILITY
C - CONSOLIDATION
CA. - CASING
γ - UNIT WEIGHT

SAMPLE TYPES

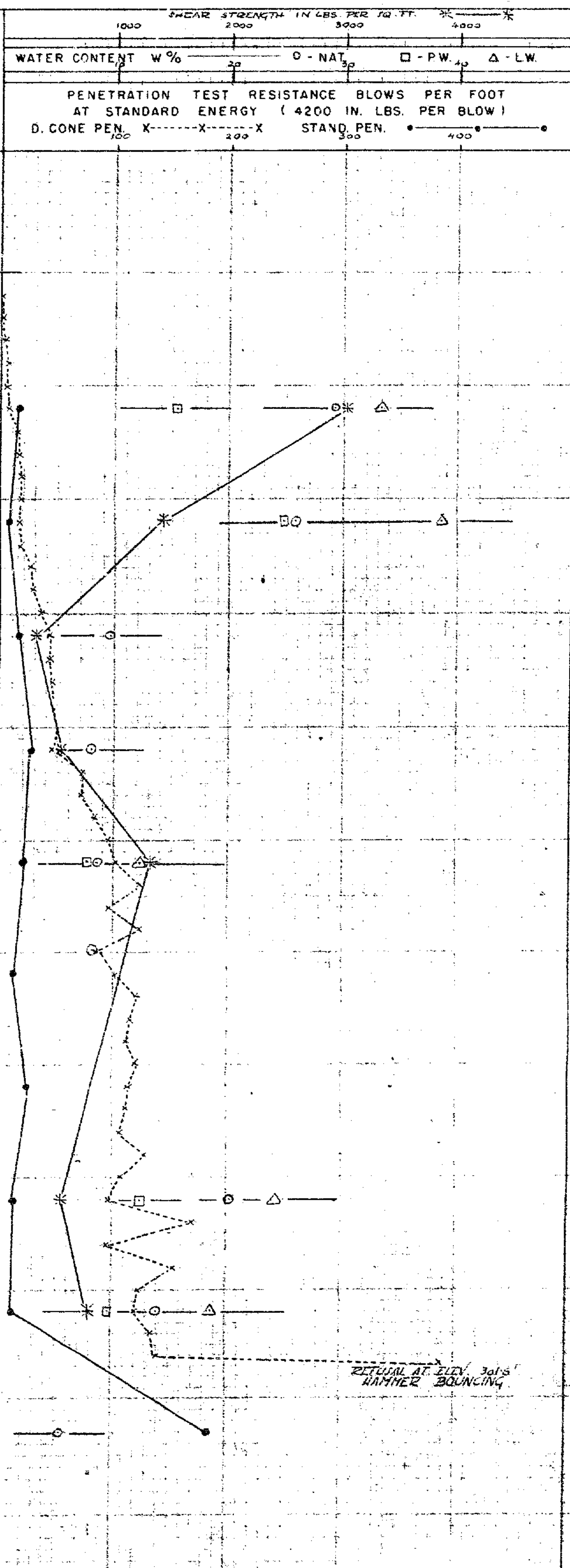
C.S. - CHUNK
D.O. - DRIVE OPEN
D.F. - DRIVE FOOT VALVE
T.O. - THIN WALLED OPEN
S.S. - SLEEVE SAMPLE
P.S. - PISTON SAMPLE
W.S. - WASHED SAMPLE
R.C. - ROCK CORE

SAMPLE CONDITION

- DISTURBED
- FAIR
- GOOD
- LOST

SOIL PROFILE

ELEVATION / DEPTH	WATER CONDITIONS	DESCRIPTION
350.0'		GROUND LEVEL
348.0' / 2.0'		TOP SOIL
336.0' / 14.0'		GREY CLAY
298.0' / 52.0'		SANDY CLAY LOAM WITH GRAVEL
		END OF BOREHOLE



CASING BLOWS (ACTUAL)

1, 2, 2, 5, 6, 11, 12, 11, 14, 14, 28, 22, 27, 28, 40, 39, 29, 22, 21, 17, 18, 24, 38, 60, 80, 44, 63, 70, 98, 90, 30, 38, 45, 51, 47, 41, 167, 56, 86, 59, 40, 43, 48, 62, 57, 38, 44, 60, 128, 260

END OF CASING AT ELEV. 300.0'

SAMPLES

OTHER TESTS	CONDITION	TYPE	NO.	PENETRATION RESISTANCE	ELEV.	RECOV. %
					350.0'	
					345.0'	
γ=122.5	GOOD	T.O.	1	16		100
					340.0'	
γ=125.6 p.c.f.	GOOD	T.O.	2	9		100
					335.0'	
γ=141.5 p.c.f.	GOOD	T.O.	3	18		50
					330.0'	
γ=149.5 p.c.f.	GOOD	T.O.	4	23		33
					325.0'	
γ=145.5 p.c.f.	GOOD	T.O.	5	20		83
					320.0'	
	GOOD	T.O.	6	11		100
					315.0'	
	LOST	T.O.	7	23		-
					310.0'	
γ=133.7 p.c.f.	GOOD	T.O.	8	11		71
					305.0'	
γ=131.5 p.c.f.	GOOD	T.O.	9	11		54
					300.0'	
	GOOD	T.O.	10	>100		12
	GOOD	F.T.	11	>100		58

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & RESEARCH BRANCH - FOUNDATIONS SECTION - DOWNSVIEW

OFFICE REPORT ON SOIL EXPLORATION

DRILL RIG 54-1 OPERATION BORE & PENET'N JOB F-57-7 W.P. 44-57 BORING 3 STA. 437+47 (4527 PARALLEL TO HWY #2)

CASING BX (standard samplers to fit unless noted) DATUM GEODETIC DATE REPORT JULY 1957

SAMPLER HAMMER WT. 250 LBS. DROP 19 INCHES COMPILED BY H.S. CHECKED BY A.L. DATE BORING 1 MAY 1957

ABBREVIATIONS

V - INSITU VANE SHEAR TEST; Q - TRIAXIAL QUICK; K - PERMIABILITY
M - MECHANICAL ANALYSIS; S - TRIAXIAL SLOW; C - CONSOLIDATION
U - UNCONFINED COMPRESSION; WL - WATER LEVEL IN CASING; CA. - CASING
Q_C TRIAXIAL CONSOLIDATED QUICK; WT. - WATER TABLE IN SOIL; γ - UNIT WEIGHT

SAMPLE TYPES

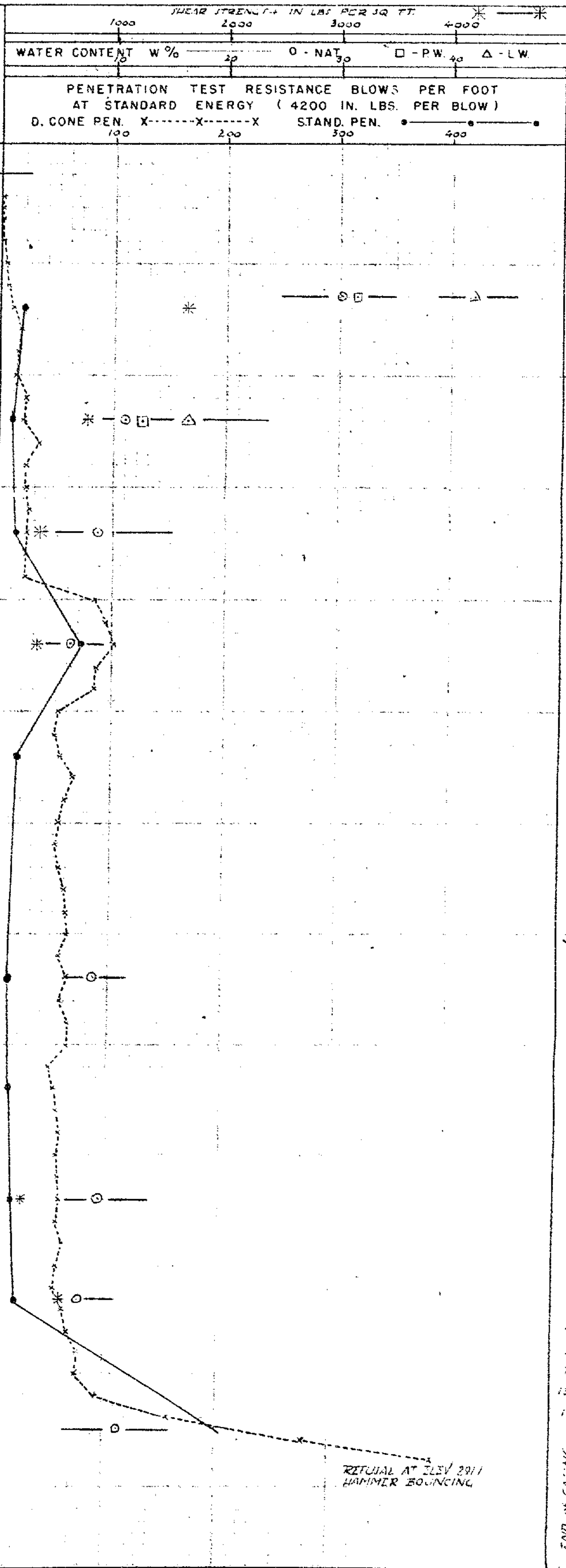
C.S. - CHUNK; S.S. - SLEEVE SAMPLE
D.O. - DRIVE OPEN; P.S. - PISTON SAMPLE
D.F. - DRIVE FOOT VALVE; W.S. - WASHED SAMPLE
T.O. - THIN WALLED OPEN; R.C. - ROCK CORE

SAMPLE CONDITION

- DISTURBED
- FAIR
- GOOD
- LOST

SOIL PROFILE

ELEVATION DEPTH	WATER CONDITIONS	DESCRIPTION
348.9'		GROUND LEVEL
347.9' 1.0'		TOPSOIL
		GREY CLAY
338.9' 10.0'		SANDY CLAY LOAM WITH GRAVEL
290.8' 58.0'		END of BOREHOLE



CASING BLOWS (ACTUAL): 3, 5, 7, 15, 13, 9, 22, 18, 24, 24, 42, 31, 24, 25, 30, 21, 21, 14, 20, 59, 23, 25, 42, 46, 60, 34, 40, 50, 62, 66, 68, 72, 77, 70, 70, 22, 38, 50, 54, 38, 35, 33, 42, 42, 39, 34, 33, 40, 49, 46, 37, 48, 76, 70, 137, 166

END of CASING AT ELEV 292.9'

SAMPLES

OTHER TESTS	CONDITION	TYPE	NO.	PENETRATION RESISTANCE	ELEV. RECOV. %
					348.9'
γ 117.3 p.c.f	GOOD	T.O	1	20	343.9' 100
γ 138.5 p.c.f	GOOD	T.O.	2	10	338.9' 96
γ 148.9 p.c.f	GOOD	T.O	3	12	333.9' 83
γ 131.8 p.c.f	GOOD	T.O.	4	72	328.9' 58
	DISTURBED	T.O	5	18	323.9' 17
	DISTURBED	P.S.	6	10	313.9' 8
	LOST	P.S.	7	11	308.9' -
γ 138.2 p.c.f	GOOD	P.S.	8	16	303.9' 25
γ 147.1 p.c.f	GOOD	P.S	9	20	298.9' 33
	GOOD	S.	10	>100	292.9 100

Depth (margin): 4, 9, 14, 19, 24, 29, 34, 39, 44, 49, 54, 59

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & RESEARCH BRANCH - FOUNDATIONS SECTION - DOWNSVIEW

OFFICE REPORT ON SOIL EXPLORATION

DRILL RIG 54-1 OPERATION BORE & PENETN JOB F-57-7 W.P. 44-57 BORING 4 STA. 437+?? (45' RT. PARALLEL TO HWY # 28)

CASING BX (standard samplers to fit unless noted) DATUM GEODETIC DATE REPORT JULY 1957

SAMPLER HAMMER WT. 250 LBS. DROP 19 INCHES COMPILED BY HJ CHECKED BY AL DATE BORING 4 MAY 1957

ABBREVIATIONS

V - INSITU VANE SHEAR TEST; Q - TRIAXIAL QUICK; K - PERMIABILITY
M - MECHANICAL ANALYSIS; S - TRIAXIAL SLOW; C - CONSOLIDATION
U - UNCONFINED COMPRESSION; WL - WATER LEVEL IN CASING; CA. - CASING
Q_C - TRIAXIAL CONSOLIDATED QUICK; W.T. - WATER TABLE IN SOIL; γ - UNIT WEIGHT

SAMPLE TYPES

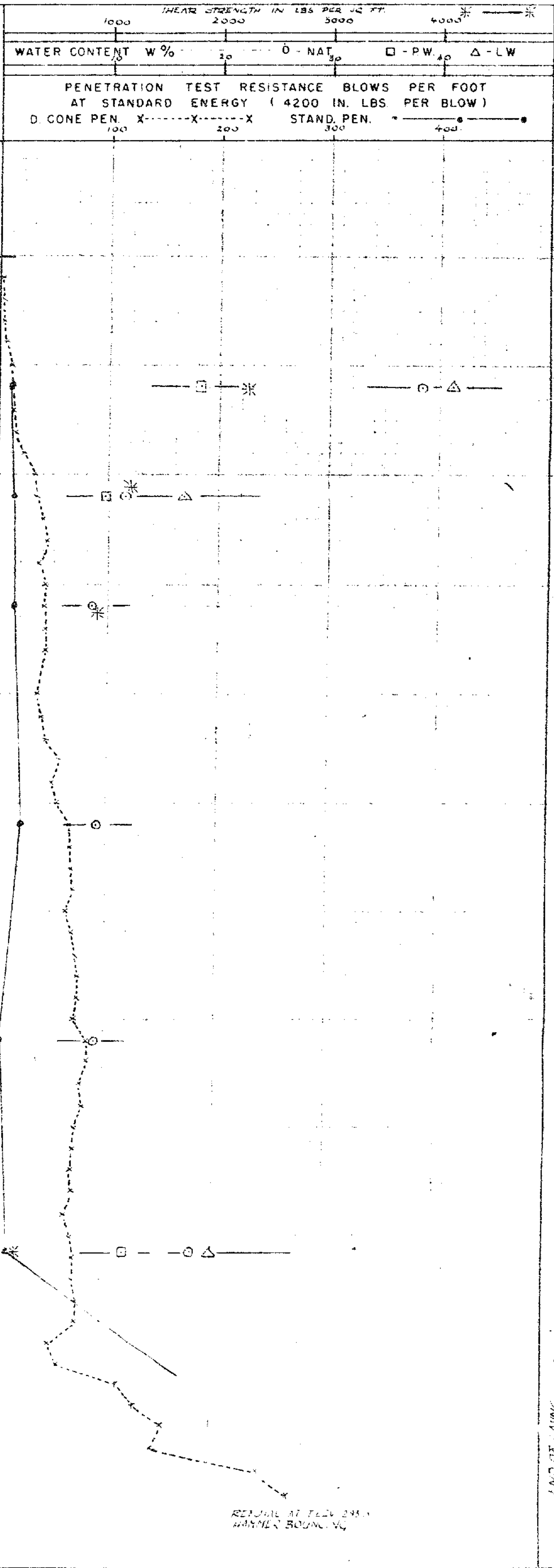
C.S. - CHUNK; S.S. - SLEEVE SAMPLE
D.O. - DRIVE OPEN; P.S. - PISTON SAMPLE
D.F. - DRIVE FOOT VALVE; W.S. - WASHED SAMPLE
T.O. - THIN WALLED OPEN; R.C. - ROCK CORE

SAMPLE CONDITION

- DISTURBED
- FAIR
- GOOD
- LOST

SOIL PROFILE

ELEVATION / DEPTH	WATER CONDITIONS	DESCRIPTION
350.0'		GROUND LEVEL
349.0' / 1.0'		TOPSOIL
336.0' / 14.0'		LIGHT CLAY
298.2' / 51.8'		SANDY CLAY LOAM WITH GRAVEL
		END of BOREHOLE



CASING BLOWS (ACTUAL): 5, 5, 6, 11, 9, 10, 13, 17, 30, 36, 32, 26, 31, 36, 40, 29, 30, 35, 43, 67, 84, 80, 95, 106, 120, 56, 57, 73, 83, 92, 98, 77, 77, 87, 54, 44, 46, 50, 57, 63, 50, 53, 47, 50, 37, 50, 51, 53, 61, 70, 121

END OF CASING AT ELEV 299.0

SAMPLES

OTHER TESTS	CONDITION	TYPE	NO.	PENETRATION RESISTANCE	ELEV.	RECOV. %
					350.0'	
					345.0	
γ=112.0 pcf	GOOD	TO	1	10		100
					340.0'	
γ=139.? pcf	GOOD	TO	2	14		100
					335.0'	
γ=101.2 pcf	GOOD	P.I.	3	14		38
					325.0'	
	GOOD	P.I.	4	21		92
					315.0'	
	GOOD	P.I.	5	7		38
					305.0'	
γ=135.0 pcf	GOOD	P.I.	6	12		56
					299.0'	
	DISTURBED	D.O.	7	>100		22

DEPTH: 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55

DIST No. 41 HWY 401
CONT No.
GWP No. 274-96-00

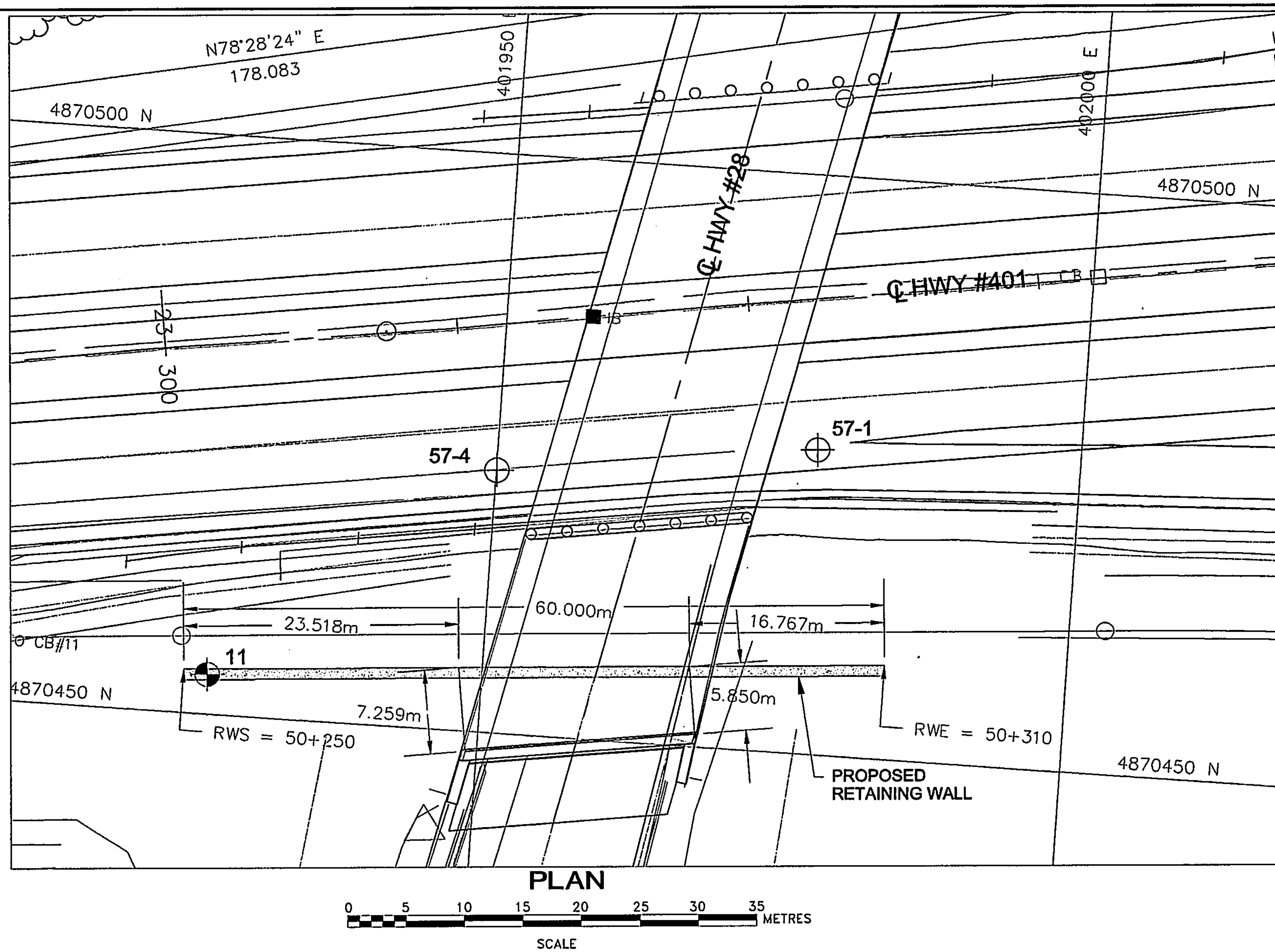
HIGHWAY 401 AT HWY 28 RETAINING WALL
BOREHOLE LOCATIONS & SOIL STRATA

SHEET

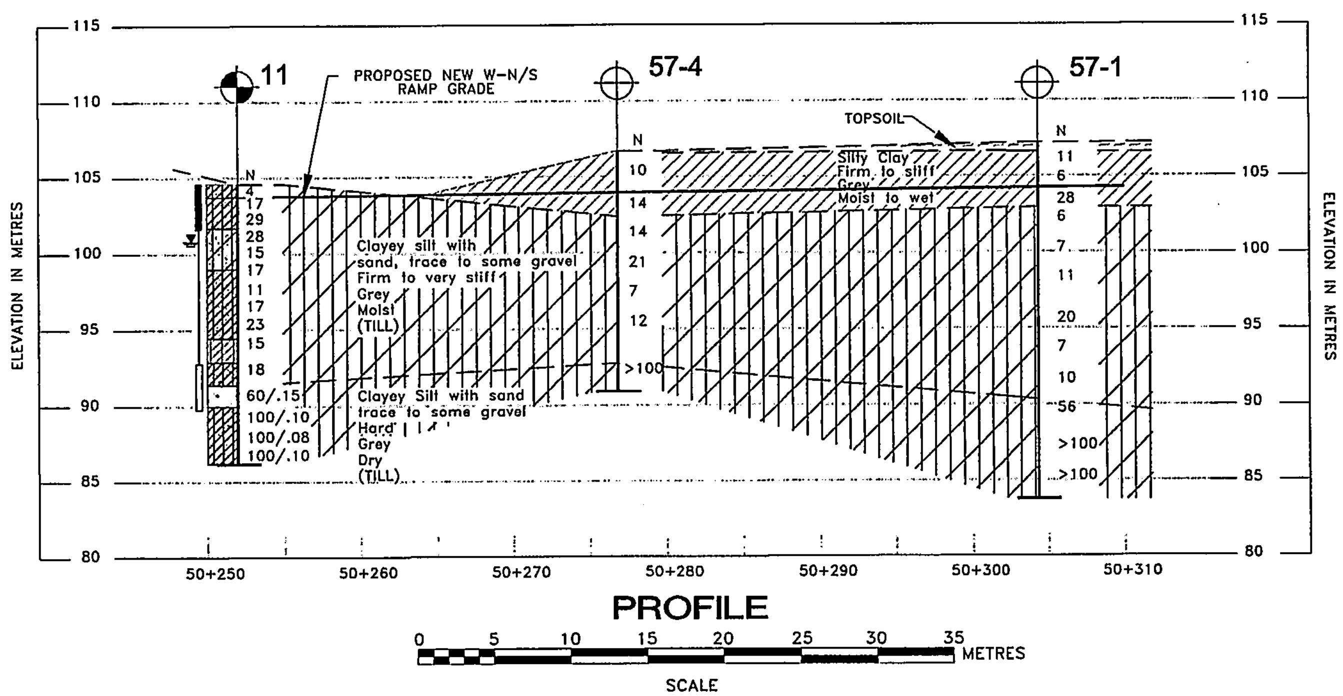
Golder Associates

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

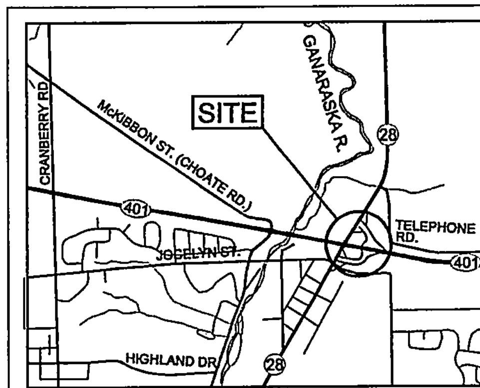


PLAN



PROFILE

NOTE:
Clayey silt (till) as encountered in Borehole 11 was described as "sandy clay loam with gravel" in Boreholes 57-1 and 57-4.



KEY PLAN

LEGEND

- Borehole – Current Golder Associates Ltd. Investigation
- Approximate location of boreholes from 1957 MTO investigation
- Seal
- Piezometer
- N Blows/0.3m (Std. Pen. Test, 475 J/blow)
- WL in piezometer on October 23, 2000
- WL upon completion of drilling

No.	ELEVATION	LOCATION NORTHINGS	LOCATION EASTINGS
11	104.58	4870453.41	401926.58
57-1	107.2	4870476.34	401977.38
57-4	106.7	4870472.70	401950.04

NOTE
Locations for Borehole 57-1 and 57-4 estimated from drawing included in GEOCRES No. 30M16-8 Report, dated 1957.

NOTE
The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

REFERENCE
This drawing was created from digital files "PL-RETWALL.dwg and PR-RETWALL.DWG" dated October 25, 2000 provided by The Greer Galloway Group Inc.

NO.	DATE	BY	REVISION

Geocres No.

HWY 401		PROJECT NO.: 001-1142	DIST. 41
SUBM'D. SP	CHKD: LCC	DATE: 2001 01 09	SITE
DRAWN: JFC	CHKD. LCC	APPD. ASP	DWG. 1

01142A01.DWG

LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
SS	Split-spoon
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:
The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; N_d:
The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure
PM: Sampler advanced by manual pressure
WH: Sampler advanced by static weight of hammer
WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)
A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Cohesionless Soils

Density Index (Relative Density)	N Blows/300 mm or Blows/ft.
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils

Consistency	c_u,s_u kPa	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

Note: 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

S:\FINALDATA\ABBREV\2000\LOFA-D00.DOC

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π = 3.1416
ln x, natural logarithm of x
$\log_{10}$ x or log x, logarithm of x to base 10
g acceleration due to gravity
t time
F factor of safety
V volume
W weight

II. STRESS AND STRAIN

γ shear strain
Δ change in, e.g. in stress: $\Delta\sigma$
ε linear strain
ε_v volumetric strain
η coefficient of viscosity
ν Poisson's ratio
σ total stress
σ' effective stress ($\sigma' = \sigma - u$)
σ'_{vo} initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$ principal stresses (major, intermediate, minor)
σ_{oct} mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ shear stress
u porewater pressure
E modulus of deformation
G shear modulus of deformation
K bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$ bulk density (bulk unit weight*)
$\rho_d(\gamma_d)$ dry density (dry unit weight)
$\rho_w(\gamma_w)$ density (unit weight) of water
$\rho_s(\gamma_s)$ density (unit weight) of solid particles
γ' unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R relative density (specific gravity)of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e void ratio
n porosity
S degree of saturation

* Density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density x acceleration due to gravity)

(a) Index Properties (con't.)

w water content
w_l liquid limit
w_p plastic limit
I_P plasticity Index = $(w_l - w_p)$
w_S shrinkage limit
I_L liquidity index = $(w - w_p)/I_p$
I_C consistency index = $(w_l - w)/I_p$
e_{max} void ratio in loosest state
e_{min} void ratio in densest state
I_D density index = $(e_{max} - e)/(e_{max} - e_{min})$ (formerly relative density)

(c) Hydraulic Properties

h hydraulic head or potential
q rate of flow
v velocity of flow
i hydraulic gradient
k hydraulic conductivity (coefficient of permeability)
j seepage force per unit volume

(d) Consolidation (one-dimensional)

C_c compression index (normally consolidated range)
C_r recompression index (overconsolidated range)
C_S swelling index
C_α coefficient of secondary consolidation
m_v coefficient of volume change
c_v coefficient of consolidation
T_v time factor (vertical direction)
U degree of consolidation
σ'_p pre-consolidation pressure
OCR Overconsolidation ratio $= \sigma'_p / \sigma'_{vo}$

(e) Shear Strength

τ_p, τ_r peak and residual shear strength
ϕ' effective angle of internal friction
δ angle of interface friction
μ coefficient of friction = $\tan\delta$
c' effective cohesion
c_u, s_u undrained shear strength ($\phi = 0$ analysis)
p mean total stress $(\sigma_1 + \sigma_3)/2$
p' mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q $(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u compressive strength $(\sigma_1 - \sigma_3)$
S_t sensitivity

Notes: 1. $\tau = c' + \sigma' \tan\phi'$
2. Shear strength = (Compressive strength)/2

Ministry of Transportation Ontario

Foundation Design

RECORD OF BOREHOLE No 11

METRIC

PROJECT 001-1142

W.P. 274-96-00 | LOCATION N 4870453.41; E 401926.58 | ORIGINATED BY SP

DIST 41 HWY 401 | BOREHOLE TYPE 114mm Solid Stem Augers | COMPILED BY SP

DATUM Geodetic | DATE Oct.10/00 | CHECKED BY LCC

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
104.58	GROUND SURFACE				
0.00	Clayey Silt with sand, trace gravel Firm to very stiff Brown Moist (Till) Trace roots and grass from ground surface to 0.3m depth.	1	SS	4	
		2	SS	17	
		3	SS	29	
		4	SS	28	
101.68 / 2.90	Silty Sand, some gravel, trace clay (non-plastic) to clayey silt with sand, some gravel Compact Grey Moist (Till)	5	SS	15	
		6	SS	17	19 43 28 10
98.98 / 5.60	Clayey Silt, some to with sand, trace gravel Stiff to very stiff Grey Moist (Till)	7	SS	11	
		8	SS	17	
		9	SS	23	
94.48 / 10.10	Silty Clay Very stiff Grey Moist	10	SS	15	
92.88 / 11.70	Clayey Silt with sand, trace gravel Very stiff Grey Moist to wet (Till)	11	SS	18	
91.38 / 13.20	Sand and Gravel Very dense Grey Wet	12	SS	60/.15	
89.98 / 14.60					

Columns also shown: STRAT PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE (104 to 90); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED (20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10, 20, 30); UNIT WEIGHT γ kN/m³.

Continued Next Page

+³, ×³: Numbers refer to Sensitivity   O³% STRAIN AT FAILURE

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 11

METRIC

PROJECT 001-1142			
W.P. 274-96-00	LOCATION N 4870453.41; E 401926.58		ORIGINATED BY SP
DIST 41	HWY 401	BOREHOLE TYPE 114mm Solid Stem Augers	COMPILED BY SP
DATUM Geodetic	DATE Oct.10/00		CHECKED BY LCC

Column headings: SOIL PROFILE (ELEV / DEPTH; DESCRIPTION; STRAT PLOT) · SAMPLES (NUMBER; TYPE; "N" VALUES) · GROUND WATER CONDITIONS · ELEVATION SCALE · DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100) · SHEAR STRENGTH kPa (O UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; X REMOULDED; 20, 40, 60, 80, 100) · PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L · WATER CONTENT (%) (10, 20, 30) · UNIT WEIGHT γ kN/m³ · REMARKS & GRAIN SIZE DISTRIBUTION (%) (GR, SA, SI, CL)

— CONTINUED FROM PREVIOUS PAGE —

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)
	Clayey Silt with sand, trace gravel Hard Grey Dry (Till)	13	SS	100/10	89	
		14	SS	100/08	88	~10
86.19 18.39		15	SS	100/10	87	
	END OF BOREHOLE Note: 1. Water level measured in piezometer at 3.8m depth (Elev.100.78m) on Oct.23, 2000.					

$+^3, \times^3$: Numbers refer to Sensitivity

$\circ^{3\%}$ STRAIN AT FAILURE

ON_MOT 001-1142.GPJ ON_MOT.GDT 9/1/01

Appendix F Comparison of Foundation Alternatives

COMPARISON OF RETAING WALL FOUNDATION ALTERNATIVES

	RSS Wall	***Steel H-Piles with Concrete Facing Panels***	***Concrete Toe Wall on spread footing***
Advantages	• Flexible structure with more tolerance for differential settlement	• Existing foreslope can mostly remain in place. • Higher geotechnical capacity than spread footings. • Lateral resistance provided by native soil.	• Existing foreslope can mostly remain in place. • A specialist contractor is not required. • Frost protection is not required for standard OPSD 3120.100 concrete toe wall design. • Typically less costly than deep foundations if there are no mitigating factors.
Disadvantages	• Large excavation would be required for the installation of reinforcing strips. • Assuming a minimum reinforcing length of 3.5 m a temporary protection system to support the perched abutment may be required.	• Cannot penetrate/displace large cobbles or boulders. • Requires a specialist contractor. • Vibrations could cause damage/movement to adjacent structures. • Higher unit cost than spread footings.	• Lower geotechnical resistances than deep foundations. • Deeper excavation than minimum for standard OPSD 3120.100 concrete toe wall design will be required due to clay subgrade.
Risks / Consequences	• Excavations to remove the existing foreslope will encroach on the existing bridge abutment, which would need to be supported with a temporary protection system that would increase costs significantly.	• Installing steel H-Piles below the existing bridge would be difficult due to the limited vertical clearance available.	• Excavation for the toe wall may encroach on the existing approach embankment and abutment foreslope. Staged construction may be required and would need to be assessed during detailed design.
Relative Cost	• Higher	• Higher	• Lower
Conclusion	• Not recommended for this site	• Feasible, but not recommended	• Recommended

THURBER

Appendix G 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

Site: 43.970N 78.289W **User File Reference:** Hwy 401 Ontario Street Underpass 2020-06-24 14:38 UT

Requested by: Thurber Engineering

Probability of exceedance per annum	0.000404	0.001	0.0021	0.01
Probability of exceedance in 50 years	2 %	5 %	10 %	40 %
Sa (0.05)	0.163	0.086	0.049	0.014
Sa (0.1)	0.204	0.114	0.069	0.021
Sa (0.2)	0.178	0.104	0.066	0.023
Sa (0.3)	0.140	0.085	0.056	0.020
Sa (0.5)	0.105	0.066	0.044	0.016
Sa (1.0)	0.059	0.038	0.025	0.008
Sa (2.0)	0.029	0.019	0.012	0.003
Sa (5.0)	0.007	0.004	0.003	0.001
Sa (10.0)	0.003	0.002	0.001	0.000
PGA (g)	0.112	0.063	0.038	0.012
PGV (m/s)	0.087	0.052	0.033	0.010

Notes: Spectral (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s^2). Peak ground velocity is given in m/s. Values are for "firm ground" (NBCC2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are highlighted in yellow. 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.**

References

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

Structural Commentaries (User's Guide - NBC 2015: Part 4 of Division B)
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 and www.nationalcodes.ca for more information

Appendix H List of Referenced Specifications and Contract Provisions

1. The following Special Provisions and OPSS Documents referenced in this report:
    - OPSS.PROV 501
    - OPSS.PROV 539
    - OPSS.PROV 902
    - OPSS.PROV 1010
    - OPSD 3090.101
    - OPSD 3120.100
    - SP105S09
    - SP110S06
    - FOUN0003

2. Contract Provision – Protection of Sensitive Foundation Soils

"The Contractor is advised that the soil that will be exposed at the toe wall subgrade level is moisture sensitive and may become disturbed or otherwise negatively impacted when subjected to construction or personnel traffic, freeze-thaw actions, ingress or ponding water. The Contractor shall be responsible for protecting the subgrade by implementing adequate groundwater control measures and minimizing construction and personnel traffic on the founding subgrade.

Immediately following excavation, the base should be inspected by the foundation engineering specialist to confirm that the exposed subgrade surface conforms to the design requirements. Once approved the subgrade should be protected with a mud slab placed between the native subgrade and the base of the toe wall."