

**Foundation Investigation and Design  
Report  
Removal of CNR Overhead  
Structures (Sites 5-49E and 5-49W)  
Highway 401 – Southwold Township,  
Ontario**

Highway 401 Reconstruction  
Southwold Township, ON

G.W.P. 3132-12-00  
Geocres No. 40114-188



Prepared for:  
Ministry of Transportation Ontario

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Project No. 165000909 (350)

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FOUNDATION INVESTIGATION REPORT

For  
G.W.P 3132-12-00

Removal of CNR Overhead Structures (Sites 5-49E and 5-49W)  
Station 14+341, Highway 401, Southwold Township, Ontario

## **1.0 INTRODUCTION**

Stantec Consulting Ltd. (Stantec) has been retained by the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the reconstruction of portions of Highway 401 in Southwold Township, Ontario.

Contract 4 (GWP 3132-12-00) of the overall project encompasses a length of approximately 14.5 km from Station 16+500 to Station 26+149 within the municipality of Dutton Dunwich and from Station 10+000 to Station 14+500 within Southwold Township. The foundation services component of Contract 4 includes foundation desktop studies and/or investigations at five culvert sites where replacement is planned, five highway underpass sites where bridge superstructure replacement is planned, a former CN Rail (CNR) corridor crossing location where removal of two bridges is planned, and locations of a series of ground-mounted signs.

This report presents the results of a foundation investigation conducted for the removal of the two existing CNR Overhead structures/bridges (Site Nos. 5-49E (Eastbound Lanes) and 5-49W (Westbound Lanes)) on Highway 401 approximately 2.3 km southwest of the Union Road underpass in Southwold Township, Ontario. The bridges will be removed and the area between the existing bridge abutments will be infilled.

The purpose of the foundation investigation was to assess the subsurface conditions at the site by drilling eight (8) boreholes, carrying out in-situ testing, and completing a laboratory testing program on selected soil samples obtained from the boreholes.

This foundation investigation report has been prepared specifically and solely for the proposed removal of the CN Overhead structures at Site Nos. 5-49E and 5-49W. Separate desktop and/or preliminary foundation investigation and design reports will be prepared for the other sites included in this Contract.

## **2.0 SITE DESCRIPTION AND GEOLOGY**

### **2.1 SITE LOCATION**

The location of the former CNR corridor is shown on the Key Plan inset to Drawing No. 1, provided in Appendix A. The former CNR corridor crosses below HWY 401 at Station ~14+341 (for

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reference, chainage along Highway 401 increases from west to east), approximately 2.3 km southwest of the Union Road crosses over Highway 401 in Southwold Township.

## **2.2 SITE DESCRIPTION**

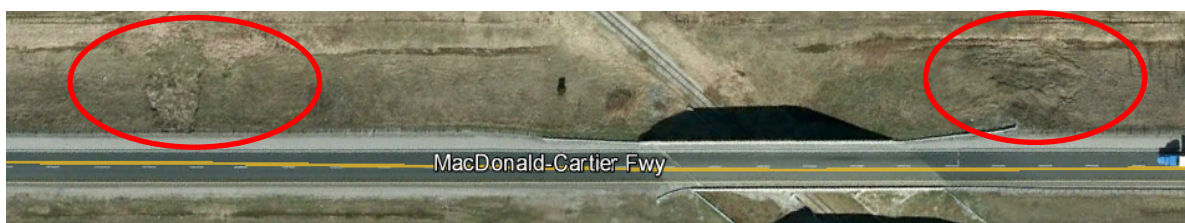
At the location of the CNR Overhead Structures, Highway 401 is a four-lane divided freeway with two lanes in each direction. The orientation of the highway at the CNR Overhead Structure site is approximately southwest-northeast. The railway corridor intersects the highway corridor at a skew angle of approximately 39 degrees. The CNR railway tracks have been removed.

The existing CNR Overhead structures were constructed in the early 1960's. Each bridge is a 3-span structure that is approximately 11 m wide by approximately 57 m long and conveys two lanes of highway traffic in one direction. The bridge abutments are supported on a series of 10.75-inch (~273 mm) diameter, concrete-filled steel pipe piles that were "to be driven to a capacity of 35 tons resistance" (~350 kN). Each bridge pier is supported on four individual pad footings that have plan dimensions of about 1.8 m by 2.4 m and are founded at elevations of about 227.8 m.

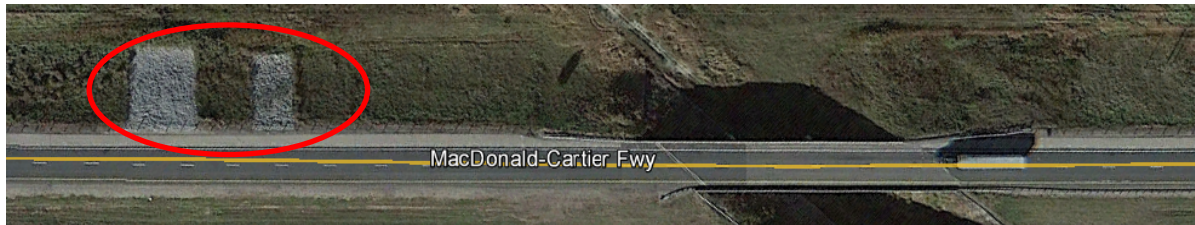
The asphalt surface on the highway at the bridges is at an elevation of approximately 239 m. Beyond the limits of the highway and the approach embankments for the bridges, the ground surface is generally flat. The ground surface elevation typically varies from approximately Elevation 229 m to 232 m.

The Eastbound Lanes (EBL) and Westbound Lanes (WBL) of the highway approaching the existing CNR Overhead Structures are located on a single approach embankment that is approximately 8 m to 9 m in height and has a crest to crest width slightly less than 40 m. The embankment side-slopes have inclinations of approximately 2 horizontal to 1 vertical (2H:1V).

Evidence of erosion and surficial sloughing of the embankment face on the north side of the approach embankments is visible in a 2005 air photo (refer to red circled areas in Photograph 1 below). Rockfill has been placed at two locations on the slope face on the north side of the west approach embankment approximately 100 m southwest of the WBL bridge as identified in the red circled areas on Photograph 2 below. This rockfill is inferred to have been placed to reinstate the slope face and provide protection against further erosion and sloughing.



**Photograph 1 - 2005 Air Photo Displaying Areas of Embankment Erosion and Sloughing**



**Photograph 2- 2015 Air Photo Displaying Rock Fill On West Approach Embankment**

A low gabion basket wall has been constructed at the toe of the slope beneath the bridge abutments and rockfill materials have been placed on the slope as shown on Photograph 3.



**Photograph 3 – Gabion Basket Wall and Rockfill on Slope Face Below Bridge Abutments**

## **2.3     PHYSIOGRAPHIC DESCRIPTION**

The site is located within a physiographic region known as the St. Clair Clay Plains. The predominant soil in the region consists of clay till.

Existing geological information indicates that the soils within the general area of the CN Rail crossing site consist predominantly of silty clay and clayey silt till.

Based on records for water wells in the general area of the site, the depth to bedrock is inferred to be at least 85 m below the ground surface.



### **3.0 AVAILABLE SUBSURFACE INFORMATION**

Subsurface information was obtained from the following document:

- GEOCRES Report titled "Foundation Report – Proposed Overpass Bridge at HWY 401 - Line 'A' and C.N.R. Crossing about 3 miles North-west of Shedden, Lot 10, (Conc. III), Twp. Of Southwold" prepared by Ontario Department of Highways Materials & Research Section, dated February 26, 1959 (GEOCRES Reference No. 40114-084) related to a site investigation completed in 1958.

Four boreholes, designated as Boreholes 1 to 4, were advanced as part of the foundation investigation for the bridges. The approximate locations of the boreholes are shown on the Borehole Location and Soil Strata drawing (Drawing No. 1) included in Appendix A and are based on the locations shown on the borehole location drawing titled 'CNR Proposed Crossing App. 3 Mi. W of Shedden' in the Geocres Report. The northing and easting coordinates for the boreholes from the previous investigations have been estimated based on the locations shown on Drawing No. 1 and should be considered approximate only.

Subsurface information from the GEOCRES report including site plans, borehole records and the results of laboratory testing, are included in Appendix B for reference. The following provides a summary of the subsurface conditions encountered during the 1958 investigation. The soil descriptions described below have been interpreted to correspond to current MTO soil description standards, using available laboratory data, and may vary from the information shown on the 1958 borehole records.

The subsurface conditions encountered consisted of surficial topsoil overlying near-surface sand deposits (in 3 of the 4 boreholes). The surficial topsoil was 0.3 m thick in each of the boreholes. The underlying sand was described as brown to brownish-grey in colour and extended to depths of 0.8 m to 2.8 m below ground surface. Standard Penetration Test 'N' values of between 27 and 29 blows per 0.3 m of penetration were recorded in the sand indicating these materials are compact.

The topsoil and sand deposits were underlain by an extensive deposit of clayey silt to silty clay till that extended to depths of more than 11 m below ground surface. The borehole records describe this soil as hard grey clay; however, the text/body of the report describe this soil as a silty clay till. The till deposit was described as having a very stiff to hard consistency based on the results of laboratory testing.

A perched groundwater table was identified within the sand deposit but the depth to the groundwater was not indicated.

## **4.0 FIELD INVESTIGATION**

### **4.1 FIELD INVESTIGATION PROCEDURES**

The current subsurface investigation was carried out in two stages and consisted of advancing eight boreholes. Four (4) boreholes, designated as Boreholes CN17-1 to CN17-4, were located at the highway level near the abutments of each overpass structure and were drilled in November 2017. An additional four (4) boreholes, designated as Boreholes CN18-5 to CN18-8, were located at the level of the former rail tracks and were advanced during the period of April 2nd to April 4th, 2018. The borehole locations are shown on the Borehole Location and Soil Strata Plan, Drawing No. 1, in Appendix A.

Prior to carrying out the investigation, Stantec contacted public utility authorities and retained a private utility locator to mark and clear the borehole locations of public and private utilities.

Drilling was carried out with truck and track-mounted drill rigs. The boreholes were advanced using continuous flight, hollow-stem augers.

The subsurface stratigraphy encountered in the boreholes was recorded in the field by a member of Stantec's geotechnical staff. Standard Penetration Tests (SPT) (ASTM D1586) were carried out in the boreholes at regular intervals (typically every 760 mm to approximately 6 m depth and 1500 mm below 6 m). In situ shear vane testing was completed in Boreholes BH18-7 and BH18-8 to provide an indication of the shear strength of the native clayey silt/silty clay till.

The split spoon samples recovered from the SPTs were returned to our Ottawa laboratory for detailed classification and testing. Relatively undisturbed Shelby Tube samples were also collected at select locations in Boreholes CN18-5 and CN18-7.

A vibrating wire piezometer was installed in Borehole CN18-6. The piezometer was installed to a depth of approximately 8.8 m. Sand backfill was placed from 300 mm below to approximately 1 m above the sensor tip. A mix of bentonite and drill cuttings was placed above the sand backfill. Water level measurements were carried out on April 4th, 13th, and 20th, 2018.

Observations of groundwater conditions were made in the open boreholes during drilling in all other boreholes. The boreholes were backfilled with auger cuttings mixed with bentonite and the boreholes at the highway level were sealed with cold patch asphalt.

### **4.2 LOCATION AND ELEVATION SURVEY**

The borehole locations and respective ground surface elevations were surveyed by Callon Dietz Incorporated, Ontario Land Surveyors. Table 3.1 below summarizes the borehole survey information and includes the drilling depth, end of borehole elevation and number of samples recovered for each borehole.



**Table 4.1: Borehole Information Summary**

	<b>Borehole Number</b>			
	<b>CN17-1</b>	<b>CN17-2</b>	<b>CN17-3</b>	<b>CN17-4</b>
MTM Zone 11 Coordinates Northing Easting	4735874 394756	4735945 394828	4735884 394814	4735940 394855
Ground Surface Elevation, m	238.5	238.6	238.8	238.6
Total Depth Drilled, m	11.3	11.3	11.3	11.3
End of Borehole Elevation, m	227.2	227.3	227.5	227.3
Number of soil samples	12	13	12	12
	<b>Borehole Number</b>			
	<b>CN18-5</b>	<b>CN18-6</b>	<b>CN18-7</b>	<b>CN18-8</b>
MTM Zone 11 Coordinates Northing Easting	4735907 394775	4735907 394807	4735914 394826	4735912 394856
Ground Surface Elevation, m	229.8	229.9	230.1	230.1
Total Depth Drilled, m	12.8	9.8	31.1	12.8
End of Borehole Elevation, m	217.0	220.1	199.0	217.3
Number of soil samples	14	11	22	13

## 4.3 LABORATORY TESTING

All samples were transported to our Ottawa laboratory where they were subjected to a detailed visual examination by a Geotechnical Engineer. Selected soil samples were submitted for gradation analysis, Atterberg Limits testing and moisture content testing. Two samples of the fill soil were also selected for consolidation testing. The geotechnical laboratory testing program completed on the borehole samples is summarized below in Table 3.2.

**Table 4.2: Laboratory Testing Program**

<b>Laboratory Test Type</b>	<b>Number of Tests</b>
<b>Moisture Content</b>	97
<b>Gradation Analysis</b>	26
<b>Atterberg Limits</b>	22
<b>Oedometer (Consolidation)</b>	2

Samples remaining after testing will be placed in storage for a period of one year after issue of the final report. After the storage period, the samples will be discarded unless we are directed otherwise by MTO.

## 5.0 SUBSURFACE CONDITIONS

### 5.1 FRAMEWORK & OVERVIEW

The detailed soil and groundwater conditions encountered in the boreholes from the 2017/2018 investigation program and the results of the in-situ and laboratory testing from this investigation are shown on the Stantec Record of Borehole sheets included in Appendix B. An explanation of the symbols and terms used on the Borehole Records is also provided in Appendix B. The results of the geotechnical laboratory testing are also displayed on Figures C1 to C8 included in Appendix C.

A borehole location plan and stratigraphic section of the soils encountered in the boreholes are provided on Drawing No. 1 in Appendix A. The stratigraphic boundaries on the borehole records and the strata plot are inferred from non-continuous sampling and therefore represent transitions between soil types rather than exact boundaries between geological units. The subsurface conditions will vary between and beyond the borehole locations.

The subsurface stratigraphy encountered in Boreholes CN17-1 to CN17-4, advanced near the abutments of the bridges, consisted of asphalt overlying 0.4 m to 2.0 m of granular fill materials that were underlain by clayey silt to silty clay fill that extends to depths of about 7.6 to 9.5 m below ground surface. The fill materials were underlain by a native silty sand layer and then by very stiff to hard native clayey silt to silty clay till deposits.

The subsurface stratigraphy encountered in Boreholes CN18-5 to CN18-8 consisted of between 0.6 m and 1.2 m of surficial fill materials that varied in composition from silty clay to sand and gravel and contained pieces of blast rock. Deposits of sand to silty sand were encountered to depths of 2.3 m below ground surface in Boreholes CN18-6 and CN18-7. The fill and sand/silty sand soils were underlain by a deposit of clayey silt to silty clay till.

All the boreholes from the current investigation were terminated in the clayey silt to silty clay till. More detailed descriptions of the subsurface conditions encountered in the boreholes are provided in the following sections.

### 5.2 OVERBURDEN

#### 5.2.1 Asphalt

Asphalt was encountered in Boreholes CN17-1 to CN17-4 which were advanced on the paved shoulders of the highway. The asphalt was between 76 mm to 127 mm thick in these boreholes.

#### 5.2.2 Topsoil

Topsoil was encountered at ground surface at the locations of Boreholes CN18-6 and CN18-7. The topsoil was 510 mm thick in both boreholes.

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A layer of buried topsoil was encountered in Borehole CN17-2 between elevations of about 229.1 m and 228.7 m. The buried topsoil was approximately 400 mm thick.

### **5.2.3 Fill**

Fill was encountered below the asphalt pavement in Boreholes CN17-1 to CN17-4, below the topsoil in Boreholes CN18-6 and CN18-7 and at the ground surface in Boreholes CN18-5 and CN18-8.

The fill materials encountered in the boreholes advanced through the highway approach embankments typically consisted of 0.4 m to 2 m of granular fill varying in composition from silty sand to sand and gravel underlain by cohesive fill composed of clayey silt to silty clay. The approach embankment fill materials were encountered to depths of 7.6 m to 9.5 m below ground surface corresponding to elevations of 229.1 m to 230.8 m.

The fill materials encountered in boreholes drilled at the level of the former railway track were highly variable in composition ranging from silty clay to sand and gravel (and mixtures thereof) and contained pieces of inferred blast rock. These fill materials were encountered to depths of 0.6 m to 1.2 m below ground surface corresponding to elevations of 228.8 m to 229.5 m.

Further details on the fill materials, divided into cohesionless and cohesive fill for ease of reference, are provided in the following sections.

#### **5.2.3.1 Cohesionless Fill**

The asphalt pavement in Boreholes CN17-1 to CN17-4 was underlain by granular fill associated with the highway pavement structure. The granular fill varied in composition from sand containing some silt and gravel to sand and gravel. This pavement granular fill was encountered to depths of approximately 0.5 to 2.1 m below the pavement surface corresponding to elevations of approximately 237.9 to 236.5 m.

Standard Penetration Test (SPT) 'N' values obtained in the granular fill ranged from 9 to 44 blows per 305 mm penetration. Based on the SPT 'N' values recorded, the granular fill was in a loose to dense state.

A 1.9 m thick layer of silty sand fill containing trace gravel with clayey silt inclusions was encountered near the base of the embankment fill materials in Borehole CN17-3 between elevations of about 229.3 to 231.2 m. A SPT 'N' value of 73 was recorded within this fill indicating it was in a very dense state.

Cohesionless fill materials ranging in composition from silty sand to sand and gravel with blast rock pieces were encountered in Boreholes CN18-5 and CN18-8. These fill materials were 1.1 m thick in Borehole CN18-5 and 0.6 m thick in Borehole CN18-8. SPT 'N' values obtained within these materials varied from 8 to 15 blows per 305 mm penetration. Based on these SPT 'N' values, the cohesionless fill material present at the former railway track level is in a loose to compact state.

Laboratory testing of the granular/cohesionless fill materials yielded moisture contents ranging from approximately 5% to 19% expressed as a percentage of the dry weight of the soil.

Gradation analyses were carried out on four (4) representative samples of the cohesionless fill materials obtained from Boreholes CN17-3, CN17-4, CN18-5 and CN18-7. The results of the tests are illustrated on the gradation curves on Figure No. C1 in Appendix C.

### **5.2.3.2 Cohesive Fill**

The granular fill materials in Boreholes CN17-1 to CN17-4 are underlain by clayey silt to silty clay fill containing some sand and trace gravel that were encountered to depths of approximately 7.6 m to 9.5 m below ground surface (corresponding to elevations ranging from approximately 230.8 to 229.1 m). Sandy seams/zones were encountered sporadically within the clayey silt to silty clay fill.

Silty clay fill was also encountered in Borehole CN18-7 between elevations of approximately 228.3 and 228.9 m.

Standard Penetration Test (SPT) 'N' values obtained in the cohesive embankment fill ranged from 7 to 55 blows. Based on the SPT 'N' values recorded, the cohesive approach embankment fill typically has a stiff to hard consistency.

Laboratory testing of the cohesive fill materials yielded moisture contents ranging from approximately 10% to 22%.

Gradation analyses were carried out on six (6) representative samples of the clayey silt to silty clay approach embankment fill materials obtained from Boreholes CN17-1 to CN17-4. The results of the tests are illustrated on the gradation curves on Figure No. C2 in Appendix C.

Atterberg Limits tests were carried out on the above noted six samples of the cohesive approach embankment fill and a sample of the clayey silt inclusions encountered within the silty sand fill in Borehole CN17-3. The tests typically yielded Liquid Limits of between 34% and 48%, Plastic Limits of between 15% and 17%, and Plasticity Indices of between 18% to 24%. The results of the Atterberg Limits test are illustrated on Figure C3 in Appendix C. Based on the combined test results for the samples tested, the cohesive fill materials vary from clayey silt (CL) of low plasticity to silty clay of intermediate plasticity (CI).

### **5.2.4 Silty Sand (SM) to Sand (SP)**

Native deposits of silty sand to sand containing trace clay and gravel were encountered beneath the fill materials in Boreholes CN17-1, CN17-3, CN17-4, CN18-6 and CN18-7.

The native silty sand deposit encountered in Boreholes CN17-1, CN17-3, and CN17-4, varied between 0.3 m and 3.1 m in thickness. The base of these deposits were encountered at approximately 9.4 m to 10.7 m below ground surface, corresponding to elevations ranging from approximately 227.8 m to 229.2 m.

A native silty sand to sand deposit containing some silt and trace gravel was also encountered in Boreholes CN18-6 and CN18-7 that were drilled at the level of the former CN Rail tracks. These deposits were 0.5 m to 1.7 m thick with the base of the deposit encountered at approximately 2.3 m in both boreholes, corresponding to elevations ranging from about 227.7 to 227.8 m.

Standard Penetration Test (SPT) resistance values obtained in the native silty sand to sand deposits ranged from 17 blows per 0.3 m of penetration to 100 blows per 0.25 m of penetration. Based on the SPT resistance values recorded, the silty sand to sand layer is in a compact to very dense state.

Laboratory testing of samples of the native silty sand to sand deposits yielded moisture contents ranging from approximately 10% to 16%.

Gradation analyses were carried out on three (3) representative samples of the silty sand to sand layer obtained from Boreholes CN17-1, CN17-3 and CN18-6. The results of these tests are illustrated on the gradation curves on Figure No. C4 in Appendix C.

### **5.2.5 Clayey Silt to Silty Clay (TILL)**

A deposit of clayey silt to silty clay till containing trace to some sand and trace gravel was encountered below the fill, topsoil and/or sand/silty sand deposits in all boreholes. The clayey silt to silty clay till was encountered between depths of approximately 9.4 to 10.7 m below ground surface (corresponding to elevations ranging from approximately 227.8 to 229.2 m) in the 2017 boreholes drilled from the highway surface and at depths of approximately 0.6 to 2.3 m below ground surface (corresponding to elevations ranging from approximately 227.8 to 229.5 m) in the 2018 boreholes drilled at the level of the former CN Rail tracks.

The 'N' values obtained from the SPTs conducted in the clayey silt to silty clay till ranged from 9 to 70 blows per 305 mm penetration. In-situ shear vane testing carried out in the till deposit yielded undrained shear strengths that ranged from about 147 kPa to greater than 267 kPa. The 1959 Geocres report indicated that the average shear strength of the till range from 144 kPa to 287 kPa based on laboratory testing.

The higher N-values and shear strengths were typically measured in the till immediately beneath the fill which is inferred to represent a desiccated crust that is about 5 m to 6 m thick. Based on the field and laboratory testing data, the desiccated crust of the clayey silt to silty clay till is considered to typically have a hard consistency, transitioning to very stiff below an elevation of about 223 m. The underlying till generally has a very stiff consistency and then becomes hard below an elevation of about 211 m.

Thirteen (13) samples of the clayey silt to silty clay till were selected for gradation analysis. The results of the tests are illustrated on the gradation curves in Figure No. C5 in Appendix C.

Atterberg Limits tests carried out on samples of the clayey silt to silty clay till yielded Liquid Limits of 32% to 41%, Plastic Limits of 15% to 18% and Plasticity Indices of 18% to 23%. The results of the tests are illustrated on the chart in Figure No. C6 in Appendix C. The 1958 Geocres investigation

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measured Liquid Limits of 19% to 38%, Plastic Limits of 11% to 24%, and Plasticity Indices of 8% to 20% on samples of the fill. Based on these test results, the fill deposits are considered to consist predominantly of silty clay of intermediate plasticity (CI) but contain zones of clayey silt of low plasticity (CL).

The results of consolidation testing conducted on two samples of the clayey silt to silty clay fill from Borehole CN18-7 are provided on Figure Nos. C7 and C8 in Appendix C. The consolidation and index property test results for these samples are summarized in Table 5-1 below.

**Table 5.1: Consolidation Test Results**

Sample ID	Sample Elevation	Moisture Content	Initial Void Ratio	Recompression Index, Cr	Compression Index, Cc	*Estimated Preconsolidation Stress, P <sub>c</sub>	OCR
CN18-7 ST-13	219.1 m	24%	0.66	0.025	0.2	500 kPa	3.3
CN18-7 ST-19	208.5 m	24%	0.67	0.025	0.2	610 kPa	2.3

\*Notes: Preconsolidation stress estimated using the Casagrande method.

OCR = Overconsolidation Ratio

Based on the field and laboratory testing results and the interpreted shear strengths, the clayey silt/silty clay fill is considered to be over-consolidated.

All boreholes were terminated in the clayey silt to silty clay fill soil at depths ranging from approximately 9.8 m to 31.1 m below the existing ground surface, corresponding to elevations of between 199 m and 227.5 m.

## 5.3 BEDROCK

Bedrock was not encountered to the termination depth of the boreholes.

## 5.4 GROUNDWATER CONDITIONS

The Geocres investigation report indicated that a perched water table was identified in the near surface sand deposits but did not identify a depth and/or elevation at which the perched water was encountered.

Groundwater was observed within the fill or native sand deposits in Boreholes CN17-3, CN17-4, CN18-6 and CN18-7 at elevations of approximately 228.6 m to 228.9 m during drilling.

Boreholes CN17-1, CN17-2, CN18-5, and CN18-8 were open and dry on completion of drilling.

A vibrating wire piezometer was installed in Borehole CN18-6 with the piezometer tip/sensor installed in the clayey silt/silty clay fill at a depth of 8.8 m below ground surface. The water level at this location was measured to be at a depth of 3.7 m below ground surface (corresponding to an elevation of about 226.2 m) on April 20<sup>th</sup>, 2018.



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Groundwater levels at the site, and in particular perched groundwater conditions in the near surface sandy soils and/or embankment fill materials, will be subject to fluctuations due to seasonal changes and precipitation events. The water levels should be expected to be higher during the spring season or during and following periods of heavy precipitation or snow melt.

## **6.0 MISCELLANEOUS**

The field work was carried out under the supervision of David Lee, P. Eng., under the direction of Kevin Nelson, P. Eng.

The private utility locates were conducted by Buffalo Locating Inc. based in Brant, Ontario.

The drilling equipment was supplied and operated by London Soil Testing based in London, Ontario and Landshard Drilling based in Brantford, Ontario.

The borehole location and elevation survey was carried out by Callon Dietz Incorporated based in London, Ontario.

Geotechnical laboratory testing was carried out at Stantec's laboratory in Ottawa.

This report was prepared by Shanti Ratmono, M. Eng., E.I.T., and reviewed by Kevin Nelson, P. Eng., and John J. Brisbois, MScE., P. Eng., MTO Designated Principal Contact.

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## 7.0 CLOSURE

A subsurface investigation is a limited sampling of a site. The subsurface conditions provided herein are based on information obtained at the specific borehole locations. Should any conditions at the site be encountered which differ from those at the borehole locations, we request that we be notified immediately to assess the additional information.

Respectfully Submitted;

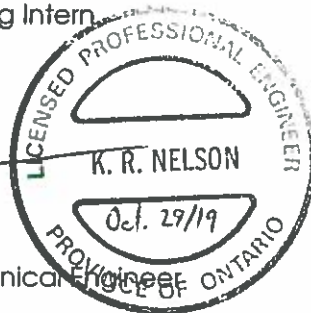
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MTO Designated Principal Foundation Contact



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FOUNDATION INVESTIGATION AND DESIGN REPORT

For  
G.W.P 3132-12-00

Removal of CNR Overhead Structures (Sites 5-49E and 5-49W)  
Station 14+341, Highway 401, Southwold Township, Ontario

## **8.0 DISCUSSIONS AND ENGINEERING RECOMMENDATIONS**

### **8.1 OVERVIEW**

This section provides foundation design recommendations for the proposed removal of the two existing bridge structures and associated construction of new highway embankments at the site referenced above. The recommendations are based on interpretation of the factual data obtained from the subsurface investigations completed at this site.

The discussion and foundation input presented herein is intended solely to provide the designers with information to carry out the design of the new highway embankments that will be constructed in the area of the existing bridges. As such, where comments are provided with respect to construction, the comments are intended to highlight those aspects that could affect the design of the project and for which special provisions may be required in the Contract Documents. Contractors bidding the work should make their own interpretation of the factual information provided as such interpretation may affect their design, equipment selection, proposed construction methods, scheduling and other aspects of execution of construction.

### **8.2 PROJECT DESCRIPTION**

Contract 4 (GWP 3132-12-00) of the overall project encompasses a length of approximately 14.5 km from Station 16+500 to Station 26+149 in the Municipality of Dutton Dunwich and from Station 10+000 to Station 14+500 in Southwold Township.

#### **8.2.1 Proposed Highway Reconfiguration**

This report presents the results of a foundation investigation conducted for the removal of two existing CNR Overhead structures (Site Nos. 5-49E (Eastbound Lanes) and 5-49W (Westbound Lanes)) on Highway 401 approximately 2.3 km southwest of the Union Road underpass in Southwold Township, Ontario. The location and alignment of the existing bridges are shown on Drawing 1 in Appendix A.

The existing bridge structures will be removed and a new highway embankment will be constructed beneath the area of the existing structures (i.e. the area between the existing bridge abutments will be filled in).

The approach embankments for the existing bridges are approximately 9 m high. To improve the vertical alignment of the highway we understand it is planned to lower the highway profile such that the highway surface in the area of infilling will be at an elevation of approximately 235 m. Based on this configuration, the thickness of the required infilling will be approximately 5 m. The new embankment (area of infilling) and the re-configured/re-graded approaches are planned to include an approximately 7 to 8 m wide, 8H:1V slope extending outward from the base of the pavement structure followed by an approximately 4 m high slope with inclinations of approximately 3H:1V (WBL) and 4H:1V (EBL). This slope geometry will extend approximately 200 m on either side of the area of infilling where the design slope inclinations of the final embankment then transition to 5H:1V or flatter.

### **8.2.2 Construction Staging & Detours**

The removal of the bridges, infilling of the space between the existing bridge abutments (i.e. the former rail corridor) and reconstruction of the EBLs and WBLs of the highway are planned to be carried out in two stages with one-lane of highway traffic diverted to the other side of the highway during each stage of construction.

The grade difference between the EBL and WBL of the highway during the first stage of construction will be accommodated by constructing a 2H:1V side-slope within the existing highway median. Temporary protection systems may be required to facilitate the removal of the existing bridge foundations and other sections of the excavations that are adjacent to the active traffic lanes during the staged construction as well as to facilitate placement of fill in the area of infilling without encroaching on and/or impacting the existing piers of bridge to remain in place during the initial stage of infilling.

## **8.3 DEGREE OF SITE AND PREDICTION MODEL UNDERSTANDING**

The Canadian Highway Bridge Design Code (CHBDC) [December 2014] requires an assessment of the “degree of site and prediction model understanding” as a component of the geotechnical engineering investigation and/or services. The site and prediction model understanding is based on the geotechnical properties of the subsurface stratigraphy and the accuracy and degree of confidence regarding the numerical performance prediction models to be used to estimate the geotechnical serviceability limit states reactions and ultimate limit states resistances.

Based on the scope and extent of the geotechnical investigation completed for this project, a “Typical Understanding” has been adopted for design purposes.

## **8.4 GEOTECHNICAL DESIGN PARAMETERS**

The soil conditions encountered in the boreholes generally consisted of fill materials in the existing approach embankments underlain by an extensive deposit of clayey silt to silty clay till that extends to depths in excess of 30 m below the ground surface. Buried topsoil was encountered in one of the boreholes advanced through the existing approach embankment

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and surficial topsoil was present at the locations of two of the boreholes advanced at the level of the former CN rail corridor. Sand to silty sand deposits up to 3 m in thickness were encountered underlying the approach embankment fill and/or surficial topsoil and above the clayey till in several boreholes.

For design purposes, the soil profile identified in Table 7.1 below can be used for the CN Rail Overhead site. Drawing D1 in Appendix D illustrates the geotechnical properties for the native soil stratigraphy encountered in the boreholes. The column on the right-hand side of the figure indicates the stratigraphy and geotechnical parameters recommended for use in design. Based on a comparison of undrained shear strengths (including strengths determined by laboratory testing) with SPT N-values on nearby sites with similar conditions, the undrained shear strengths ( $S_u$ ) provided on Drawing No. D1 have been estimated using a correlation factor of  $S_u = 10 \times 'N'$ -value.

The elevations of the soil strata boundaries provided on Drawing D1 and in Table 8.1 below reflect a synthesis of the borehole data and are not based on any specific location; reference should be made to the Borehole Records for conditions at specific locations.

**Table 8.1: Geotechnical Model for CN Rail Overhead Site (Station 14+341, Hwy 401)**

Elevation (m)		Soil Type	Design Parameters			
From	To		Total Unit Weight $\gamma$ (kN/m <sup>3</sup> )	Drained Friction Angle $\phi'$ (°)	Undrained Shear Strength $S_u$ (kPa)	Compressibility Characteristics E (MPa) or Cc and Cr
Varies	238	FILL: Compact to dense, SILTY SAND to SAND and GRAVEL (SM to SP/GP)	22	34	N/A	E = 40 MPa
238	230	FILL: Stiff to hard, CLAYEY SILT (CL) to SILTY CLAY (CI)	20.5	32	90 @ 238 m to 300 at and below 234 m	E = 30 MPa
230	229	Variable FILL: CLAYEY SILT/SILTY CLAY to SILTY SAND to SAND and GRAVEL	21	30	N/A	E = 15 MPa
229	228	Compact to dense SAND to SILTY SAND	21	32	N/A	E = 25 MPa
228	222	Very stiff to hard, CLAYEY SILT to SILTY CLAY (TILL) – Desiccated Crust	21 @ 228 m to 20.3 @ 222 m	32	375 @ 228 m to 150 @ 222 m	E = 100 MPa
222	211	Very stiff CLAYEY SILT to SILTY CLAY (TILL)	20.3	32	150 @ 222 m to 125 at and below 218 m	C <sub>c</sub> = 0.2 C <sub>r</sub> = 0.025
211	<199 m	Hard CLAYEY SILT to SILTY CLAY (TILL)	20.3	32	220	C <sub>c</sub> = 0.2 C <sub>r</sub> = 0.025

Notes: 1 The friction angle is applicable to drained conditions only  
2 The shear strength is applicable to undrained conditions only

The groundwater level recorded in the vibrating wire piezometer screened in the clayey silt/silty clay till was at an elevation of 226.2 m on April 20<sup>th</sup>, 2018 and the moisture content of the samples of the till collected from below this elevation were typically higher than samples collected above this elevation. A static groundwater level at an elevation of 226.2 m within the till is recommended for consideration in design. Perched groundwater conditions should also be expected in the existing embankment fill materials and in the surficial sandy soils (where present).

## **8.5 FROST PENETRATION**

In accordance with OPSD 3090.101, the design frost penetration depth for foundations,  $f$ , can be taken as 1.2 m at this site.

Footings for structures would typically therefore be provided with a minimum of 1.2 m of soil cover or equivalent insulation for protection against frost heaving.

The depth of frost penetration stated should be considered in the design of frost tapers required for the project.

## **8.6 SEISMIC DESIGN CONSIDERATIONS**

### **8.6.1 Site Class**

Based on the investigations completed at this site, the very stiff to hard clayey silt/silty clay till deposit extends to a depth in excess of 30 m below ground surface.

Based on this condition, a Site Class C as defined in Section 4.4.3 of the CHBDC (2014) can be used in the seismic design.

### **8.6.2 Liquefaction Potential**

Seismic hazard values for the Contract 4 study area were obtained from Natural Resources Canada (2015 National Building Code). Based on the peak ground acceleration identified in these hazard values, analyses were completed to assess the potential for liquefaction of the native soils.

The results of the analyses indicate that the factor of safety against liquefaction of the near-surface sand to silty sand soils is greater than 1.5 under the design earthquake loading conditions. As such, these soils are not considered to be liquefiable.

Liquefaction of the underlying clayey silt/silty clay till deposit is also not considered to be a concern due to the age of the soil deposits, the stiff nature (and over-consolidated condition), high fines/clay content and the low peak ground acceleration that applies for the site location.



## 8.7 HIGHWAY EMBANKMENTS

### 8.7.1 New Embankment Construction

In preparation for the placement of the required fill, all topsoil, organic matter or softened/loosened soils should be stripped from the area of planned fill placement. The gabion baskets present at the toe of the slopes below the existing abutments, the rockfill materials present on the slopes (i.e. above the gabion baskets) and the above-ground portions of the existing bridge piers could hinder the placement and compaction of the new fill and should also be removed prior to the placement of the fill.

The new embankment fill should be placed and compacted in accordance with MTO's Special Provisions 105S10 and 206S03.

All embankment slopes should be constructed at inclinations no steeper than 2H:1V; the proposed final embankment sideslope configuration is 3H:1V or flatter and meets this requirement. The fore-slopes of the existing approach embankments should be benched consistent with OPSD 208.010 to "key in" the new fill materials.

The boreholes advanced through the existing approach embankments indicated that the upper portion of the embankments (i.e. the portion that will be removed to facilitate the embankment lowering) consist of pavement granular fill overlying stiff to very stiff clayey silt/silt clay fill materials that typically have moisture contents of less than 20%. These materials are considered suitable for use as infill.

The material used to construct the highway embankment in the area of infilling should consist of material meeting the requirements of Select Subgrade Material as outlined in OPSS.PROV 1010.

The lowering of the highway embankment will result in exposure of the existing abutment pile caps and the top portions of the existing abutment piles which have design cut-off elevations varying between about 235.2 m and 235.3 m. It is recommended that the existing pile caps be completely removed and the piles be cut-off a minimum of 1 m below the underside of the pavement sub-base granular materials.

### 8.7.2 Stability of Slopes

As identified in Section 2.2 of this report, signs of erosion and surficial sloughing of the existing approach embankments to the north of the WBLs of the highway are visible in a 2005 air photo and rockfill materials have been placed at two locations on the slope face on the north side of the west approach embankment. The existing approach embankments are approximately 9 m high and do not have mid-height bench(es) which would be incorporated into the design of new MTO highway embankments of this height. The proposed embankment geometry, which incorporates a lower height embankment with flatter side-slopes (i.e. 3H:1V slope inclinations or flatter), will reduce the potential for similar, surficial instability to occur.

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A slope stability evaluation was carried out for a cross-section through the new highway embankment in the area of infilling. The analyses were completed using Slope/W (Geo-Slope, 2010). The analyses included an allowance for dynamic loading due to traffic by considering a static surcharge load equivalent to 0.8 m of additional fill consistent with Section 6.9.5 of the CHBDC.

A minimum factor of safety against global instability of 1.5 (corresponding to a  $\phi_{gu}$  of 0.65 based on a 'Typical' degree of understanding of the site soils and embankment materials) is considered acceptable for a permanent embankment under static conditions. The results of the slope stability analysis for static, drained conditions for the final embankment geometry are provided in Figure D-2 in Appendix D. For the planned embankment configuration and the subsurface conditions at the site, the factor of safety against global instability is greater than the required target value of 1.5 under static conditions.

A minimum factor of safety against global instability of 1.1 is considered acceptable for seismic conditions. The results of the slope stability analysis for the final embankment geometry under seismic conditions are provided in Figure D-3 in Appendix D. The evaluated factor of safety against global instability under seismic conditions exceeds this value.

### **8.7.3 Evaluation of Potential Settlements due to Embankment Construction**

The placement of fill required to construct the new embankment will result in immediate compression of the native sand to silty sand soil and longer-term consolidation/recompression of the underlying silty clay/clayey silt till soils.

The potential settlement was evaluated with consideration for the following:

- The typical soil profile given Table 8.1 was considered representative for the site;
- Soil moduli for the fill, native sandy soils and hard till 'crust' used in the analyses were based on typical values identified in the CHBDC;
- The underlying silty clay/clayey silt till deposit is over-consolidated. The pre-consolidation pressures of 500 kPa to 610 kPa calculated from the consolidation tests of the clayey silt/silty clay till soils are higher than the induced stresses under the applied load from the infill/new embankment. Therefore, settlement of the cohesive native silty clay/clayey silt till soils was assessed using the recompression index values ( $C_r$ );
- The maximum height of the new embankment will be approximately 5 m above existing site grades;
- The final embankment will have a similar crest-to-crest width as the existing embankment (i.e. just under 40 m). However, the embankment construction/infilling activities would be carried out in two stages. For the first stage of construction, an interim embankment crest-to-crest width of approximately 23 m was assessed.

Embankment settlements should meet the Post-Construction Settlement Criteria for New Embankments outlined in the MTO document titled 'Embankment Settlement Criteria for Design (2010)'. Evaluation of soil settlement was undertaken using Settle3D (Rocscience, 2009) which is a three-dimensional computer program for the analysis of the immediate settlement and

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consolidation settlement of soil under applied loads such as embankments. The evaluation was carried out with consideration for the use of earth borrow fill materials and the proposed permanent 4H:1V side-slopes.

Typical plots of the settlement contours from the Settle3D analyses are provided in Figures D-4 to D-6 of Appendix D. Figure D-4 illustrates the settlement profile resulting from the construction of the existing Highway 401 embankment (i.e. current conditions). Figure D-5 illustrates the settlement profile resulting from infilling on one side of the highway (i.e. conditions following Stage 1 of construction) assuming a construction period of less than 2 years. Figure D-6 illustrates the settlement profile for the final embankment configuration.

Since the existing Highway 401 embankments were constructed over 50 years ago, the settlements shown in Figure D-4 are considered to be complete. The difference in the magnitudes of settlement displayed in Figures D-5 and D-6, in comparison to the settlements outlined on Figure D-4, provides an estimate of the expected net settlement that will be caused by infilling following Stage 1 of construction and after construction is complete, respectively. The maximum post-construction settlement beneath the center of the infilled area is expected to be 50 mm or less. This magnitude of settlement meets the Post-Construction Settlement Criteria for New Embankments outlined in the MTO document titled 'Embankment Settlement Criteria for Design (2010)'.

Analyses were also carried out to estimate the magnitude of settlement that would occur in the area of the foundations of the bridge that will remain in place during the Stage 1 infilling. Based on the analyses, the pier footings closest to the infilling are estimated to settle less than 20 mm during the Stage 1 construction/fill placement (assumed to be 2 years or less). The piers furthest from the area of infilling would settle less than 10 mm.

The settlement estimates provided above do not include settlements associated with compression of the new fill materials used to construct the new embankments, which would occur during and after the construction of the embankment depending on the type of materials used. The anticipated potential 'self-weight' settlement for a well compacted earth borrow is approximately 0.5% of the fill height (Goodger and Leach, 1990). For a 5 m fill height, up to 25 mm could be anticipated. Self-weight settlement of general earth fills is assumed to occur over a period of approximately 10 years with more than 50% of the settlement occurring during the first year.

#### **8.7.4 Erosion Protection**

Vegetation on the new highway embankment slopes should be established as soon as possible after completion of the embankment construction to minimize the potential for surficial erosion.

## **9.0 CONSTRUCTION CONSIDERATIONS**

### **9.1 CONSTRUCTION STAGING**

The removal of the bridges, infilling of the space between the existing bridge abutments (i.e. the former rail corridor) and reconstruction of the EBLs and WBLs of the highway are planned to be carried out in two stages with one-lane of highway traffic diverted to the other side of the highway during each stage of construction.

The grade difference between the EBLs and WBLs of the highway during the first stage of construction will be accommodated by developing a temporary, 2H:1V side-slope within the existing highway median. Temporary protection systems may be required to facilitate the removal of the existing bridge abutments and/or pile foundations and for other excavations that are adjacent to the active traffic lanes during the staged construction.

A temporary protection system, located close to the existing highway median, is understood to be required to keep the new embankment fill placed during the first stage of construction from encroaching on top of/around the closest piers. This system would also facilitate removal of the piers once traffic was diverted to Stage 1 of the new embankment and alleviate difficulties in obtaining proper compaction of backfill placed in the vicinity of the piers.

### **9.2 TEMPORARY ROADWAY PROTECTION**

Temporary roadway protection is anticipated to form part of the staged construction approach that will be required to maintain traffic flow during construction excavations.

The contractor will ultimately be responsible to select and implement a roadway protection system meeting the requirements of OPSS.PROV 539, including establishing appropriate geotechnical design parameters.

Table 9.1 below compares the available roadway protection options available for this purpose.

**Table 9.1: Comparison of Roadway Protection Systems**

Option	Advantages	Disadvantages	Relative Cost	Risk & Consequences
Soldier piles with timber lagging; (struts/rakers as required)	<ul style="list-style-type: none"> <li>• Simple installation process</li> </ul>	<ul style="list-style-type: none"> <li>• Additional labour required</li> <li>• Groundwater seepage into the excavation can occur without groundwater control</li> <li>• Removal of soldier piles can be difficult</li> </ul>	Low	<ul style="list-style-type: none"> <li>• Potential for minor loss of ground at rear of lagging</li> </ul>
Steel sheet piles (SSP)	<ul style="list-style-type: none"> <li>• Simple installation process</li> <li>• Provides cut-off to groundwater seepage from sides of excavation</li> </ul>	<ul style="list-style-type: none"> <li>• Difficult to drive/install in very stiff to hard silty clay till particularly where cobbles/boulders are present</li> <li>• May require large pile sections where cantilever design is adopted</li> </ul>	Medium	<ul style="list-style-type: none"> <li>• Possible damage to sheet piles during driving</li> </ul>

Both support systems are considered feasible for use at this site. Soldier pile and lagging walls are considered to be more cost effective for temporary protection systems installed within the existing highway embankments. However, the current and previous foundation investigations encountered saturated silty sand to sand materials above the clayey silt/silty clay till. In this regard, the use of a steel sheet pile system around excavation areas carried out below the level of the former railway corridor (if any) would provide a cut-off to the potential groundwater inflows into the excavation from these stratigraphic units thereby reducing the requirements for dewatering operations at that level.

Roadway protection design should meet the requirements of Performance Level 2 in accordance with OPSS.PROV 539 and should consider traffic loading. Performance Level 2 specifies a Maximum Angular Distortion of 1:200 and a Maximum Horizontal Displacement of 25 mm.

Horizontal movement should be monitored throughout the abutment removal process as described in OPSS.PROV 539. The monitoring requirements are outlined in OPSS.PROV 539, including the milestone inspections to be completed by the Quality Verification Engineer.

From a geotechnical perspective, the temporary protection system can either be removed or left in place. Where removal is to be undertaken, the removal operations shall be in accordance with OPSS.PROV 539. If temporary protection system components are left in place, they should be cut off below the design frost penetration depth.

### **9.3 EXCAVATION AND BACKFILLING**

Excavation and backfill for the proposed highway embankment reconfiguration should be carried out in accordance with OPSS 902 Construction Specification for Excavation and Backfilling – Structures.

Any vegetation, organic soils, and other deleterious materials must be removed from beneath the new highway embankments. Where deleterious materials are encountered at the subgrade level for the new embankment fill, the materials should be excavated, removed and replaced with compacted granular fill materials.

All side slopes for open cut excavations should conform to the Occupational Health & Safety Act & Regulations for Construction Projects (OH&S Act). The excavations required for the planned embankment reconfiguration would be developed primarily through the existing approach embankment fill. Excavations that are required to be advanced at the level of the former railway corridor (e.g. to remove existing bridge foundations) are expected to encounter topsoil, variable fill materials and native soils that include the saturated, loose to compact sand to silty sand soils and the very stiff to hard clayey silt/silty clay till soils.

The fill and native sand/silty sand deposits would be classified as Type 3 soils provided they are above the water table or are dewatered prior to excavation. The clayey silt/silty clay till would also be classified as Type 3 soil. The OH&S Act indicates that temporary excavations made within these materials above the water table should be developed with side slopes no steeper than 1H:1V.

The native silty sand to sand deposit that is below the water level should be classified as Type 4 soils if not dewatered prior to excavation. Excavations in these materials should be sloped no steeper than 3H:1V based on OH&S Act requirements.

Grading work should be carried out in accordance with OPSS.PROV 206 Construction Specification for Grading and SP 206S03. If existing embankments are to be widened, the new fill materials should be benched into the existing embankments in accordance with OPSS 208.010.

The contractor should provide sediment control fences and erosion control blankets, as required, throughout the duration of the construction to prevent silt/sediment from running off the site.

## **9.4 TEMPORARY SURFACE WATER AND GROUNDWATER CONTROL**

Measurements obtained from the vibrating wire piezometer installed in CN18-6 indicate the static groundwater level within the clayey silt/silty clay till is at an elevation of about 226.2 m. However, water levels within the native sand/silty sand deposits were observed to be between elevations of about 228.6 m and 229.7 m in the open boreholes following completion of drilling.

Significant groundwater inflow is likely in excavations extending into the saturated sand to silty sand soils. Groundwater control consisting of cut-off measures (e.g. steel sheet piles extending through the granular soils into the underlying silty clay till) or external dewatering systems (e.g. well points/dewatering wells) could be used to control inflows through these deposits.

Seepage and infiltration from the clayey silt/silty clay till is anticipated to be very low given the inherent low hydraulic-conductivity of this soil.



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Surface water should be directed away from the area of the planned excavation.

All groundwater control required for the bridge removals and highway embankment reconfiguration should be designed and implemented in accordance with OPSS 517 Construction Specification for Dewatering and SP No. 517F01 (July 2017).

With consideration for the presence of the saturated sand to silty sand soil strata and anticipated inflow to open excavations, the Design Engineer Requirements box in the Dewatering Systems Section of Table A from SP No. 517F01 can be input as "Yes". As the thickness of the surficial, saturated sandy soils is limited, the maximum drawdown associated with dewatering activities is expected to be less than 2 m. Based on the over-consolidated nature of the underlying till deposits, a preconstruction survey related to dewatering activities is not required.

## 10.0 SPECIFICATIONS

The following specifications are referenced in this report:

**Table 11.1: Specifications Referenced in Report**

Document	Title
OPSD 208.010	Benching of Earth Slopes
OPSD 803.010	Backfill and Cover for Concrete Culverts
OPSD 3090.101	Foundation Frost Depths for Southern Ontario
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS 517	Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS 902	Construction Specification for Excavation and Backfilling – Structures
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material
OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 501	Construction Specification for Compacting
OPSS. PROV 539	Construction Specification for Temporary Protection System
OPSS.PROV 1010	Material Specification for Aggregates
OPSS.PROV 1205	Material Specification for Clay Seal
SP517F01	Dewatering System – Item No. Temporary Flow Passage System – Item No.
SP105S10	Construction Specification for Compaction
SP105S21	MTO's Special Provision (Amendment to OPSS 501).
SP 206S03	Earth Excavation, Grading

## 11.0 REFERENCES

- ASTM. 1999. Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils (ASTM D1586). ASTM International, West Conshohocken, PA.
- ASTM. 2000. Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) (ASTM D2487). ASTM International, West Conshohocken, PA.
- CHBDC. 2014. Canadian Highway Bridge Design Code. Canadian Standards Association, Mississauga, Ontario.
- NBC. 2015. National Building Code of Canada Vol.1. National Research Council of Canada, Ottawa, Ontario.
- OHSA. 2015. Occupational Health and Safety Act Regulations for Construction Projects. Carswell, Toronto Ontario.

## 12.0 CLOSURE

A soil investigation is a limited sampling of a site. The conclusions given herein are based on information gathered at the specific borehole locations. Should any conditions at the site be encountered which differ from those at the borehole locations, we request that we be notified immediately in order to assess the additional information and its effects on the above recommendations.

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

This report was prepared by Shanti Ratmono, M.Eng., E.I.T., and reviewed by Kevin Nelson, P.Eng., and John J. Brisbois, MScE., P. Eng., MTO Designated Principal Foundation Contact.

Respectfully submitted,

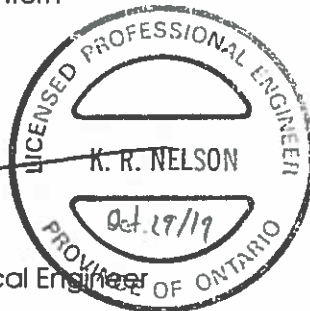
**STANTEC CONSULTING LTD.**



Shanti Ratmono, M.Eng., E.I.T.  
Geotechnical Engineering Intern



Kevin Nelson, P.Eng.  
Principal, Senior Geotechnical Engineer



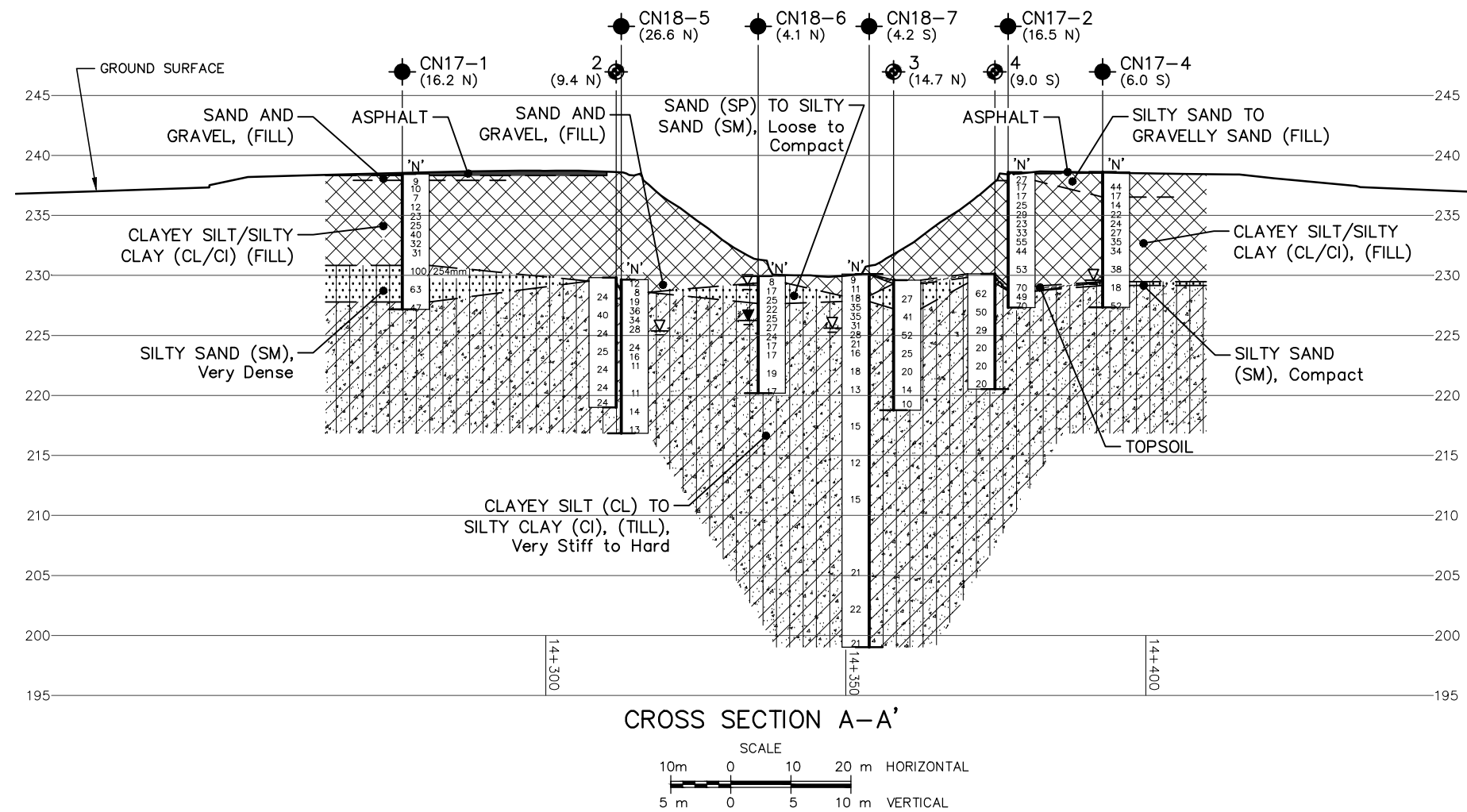
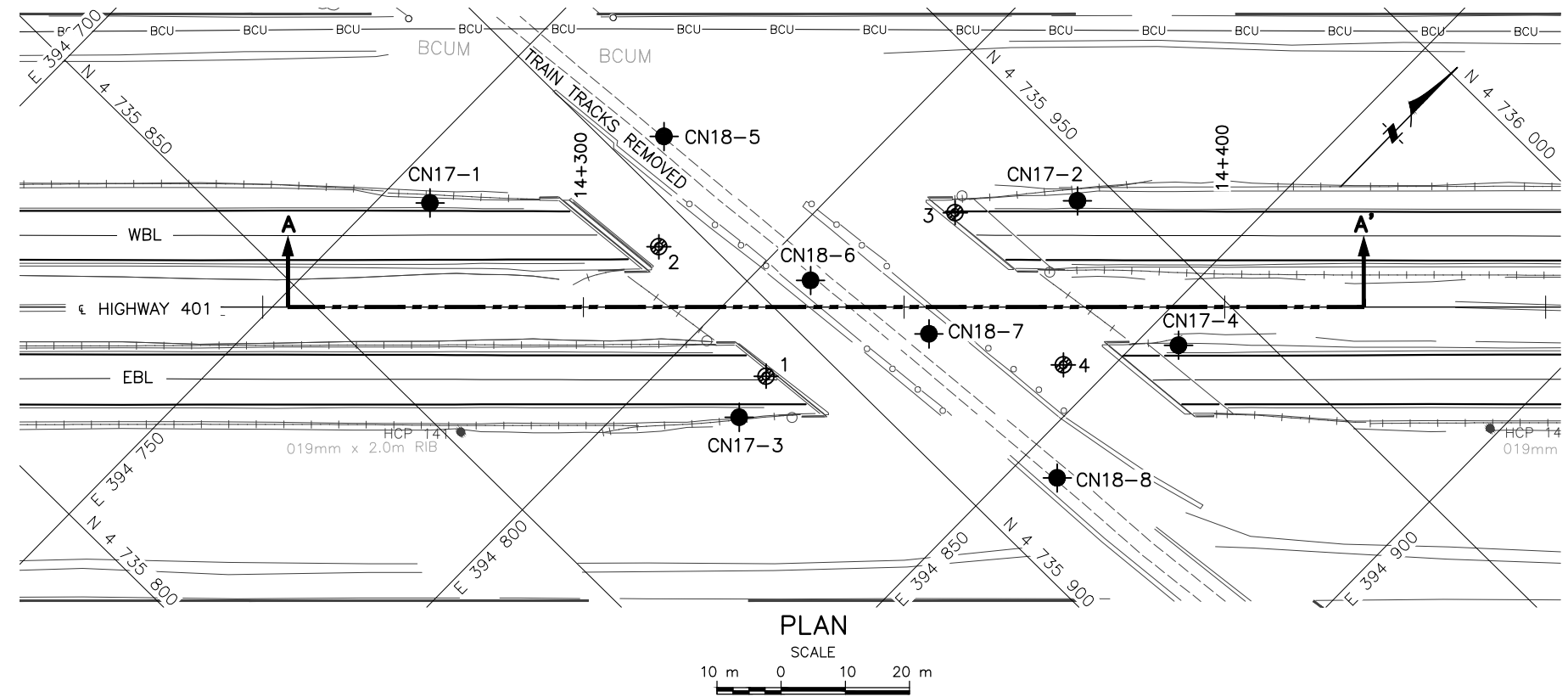
John J. Brisbois, MScE., P. Eng.  
Designated Principal MTO Foundation Contact



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## **APPENDIX A**

Drawing No. 1 – Borehole Location Plan and Soil Strata Plot



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

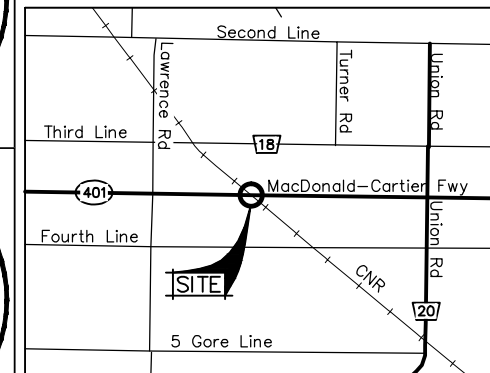


PLATE No  
**CONT**  
**GWP 3132-12-00**

CNR OVERHEAD STRUCTURES  
HIGHWAY 401  
BOREHOLE LOCATIONS & SOIL STRATA



**SHEET**



**LEGEND**

- Borehole (Stantec 2017/2018)
- Borehole, approximate location (DHO, 1959)
- (x.x S) Offset North/South from Cross Section Line in meters
- N Blows/0.3m (Std Pen Test, 475 J/blow)
- WL at time of investigation 2017/2018
- WL Measured on April 2018

No	ELEVATION	MTM_ZONE 11 NORTH	COORDINATES EAST
CN17-1	238.5	4 735 874	394 756
CN17-2	238.6	4 735 945	394 828
CN17-3	238.8	4 735 884	394 814
CN17-4	238.6	4 735 940	394 855
CN18-5	229.8	4 735 907	394 775
CN18-6	229.9	4 735 907	394 807
CN18-7	230.1	4 735 914	394 826
CN18-8	230.1	4 735 912	394 856
1	230.5	4 735 892	394 812
2	229.8	4 735 894	394 786
3	229.6	4 735 930	394 816
4	230.1	4 735 925	394 844

**NOTES**

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

Not all boreholes shown on the cross section for clarity purposes.

REVISIONS	DATE	BY	DESCRIPTION

GEOCREs No	4014-188	HWY No	401	DIST	
SUBM'D	KN	CHECKED		DATE	2019-10-28
DRAWN	GBB	CHECKED		APPROVED	
				DWG	1

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

## **APPENDIX B**

Available Subsurface Information from Geocres Report No. 40114-084  
Symbols and Terms Used on Borehole Records  
Borehole Records (2017 & 2018 Investigation)



## SUMMARY OF FIELD &amp; LABORATORY TESTS

JOB F-58-40W.P. 19-59

HOLE NO.	SAMP. NO.	SAMPLE DEPTH (FEET)	MATERIAL DESCRIPTION	PENET'N RESIST. BLOWS/FT.	MOIST. CONT. %	PLASTIC LIMIT %	LIQUID LIMIT %	SHEAR STRENGTH p.s.f.	UNIT WEIGHT p.c.f.	REMARKS
1	S1	5 - 6.5	Brown medium sand	29	15.2	-	-	-	-	
1	T2	10 - 11.8	Grey silty clay	34 for 9"	18.9	18.7	34.1	5750	128.5	
1	S3	15 - 16.5	" " " - (Till)	25	21.7	17.0	33.2	5100	138.0	
1	S4	20 - 21.5	" " " "	47	16.8	10.9	19.3	6700	141.5	
1	S5	25 - 26.5	" " " "	62	17.8	24.2	34.0	7000	135.5	
1	S6	30 - 31.5	" " " "	52	12.2	10.8	20.3	5850	139.0	
1	S7	34 - 35.5	" " " "	35	21.8	17.0	34.4	5500	137.3	
2	T1	5 - 6.7	Brownish grey silty clay	27 for 8"	18.2	18.8	38.3	6000	134.3	
2	T2	10 - 12	" " " "	40	20.7	19.6	38.0	5400	130.8	
2	S3	15 - 16.5	Grey silty clay - (Till)	24	22.5	15.5	32.8	4300	131.5	
2	S4	20 - 21.5	" " " "	25	21.9	14.2	34.5	5700	141.3	
2	S5	25 - 26.5	" " " "	24	18.9	15.4	32.2	5850	139.7	
2	S6	30 - 31.5	" " " "	24	19.1	16.2	34.4	4250	140.0	
2	S7	34 - 35.5	" " " "	24	21.7	18.7	31.6	4650	141.3	
3	T1	5 - 7	Brown clayey sand	27	37.2	-	-	-	-	
3	S2	10 - 11.5	Grey silty clay	41	18.9	17.1	30.7	5600	138.0	
3	S3	15 - 16.5	" " " (Till)	52	19.1	17.8	32.4	7000	135.5	
3	S4	20 - 21.5	" " " "	25	7.8	17.3	35.1	1850	139.0	
3	S5	25 - 26.5	" " " "	20	20.8	14.2	29.9	1850	137.0	
3	S6	30 - 31.5	" " " "	14	19.3	11.1	21.8	2600	137.0	
3	S7	34 - 35	" " " "	10	25.6	-	-	1650	137.0	

cont'd. page 2 ...

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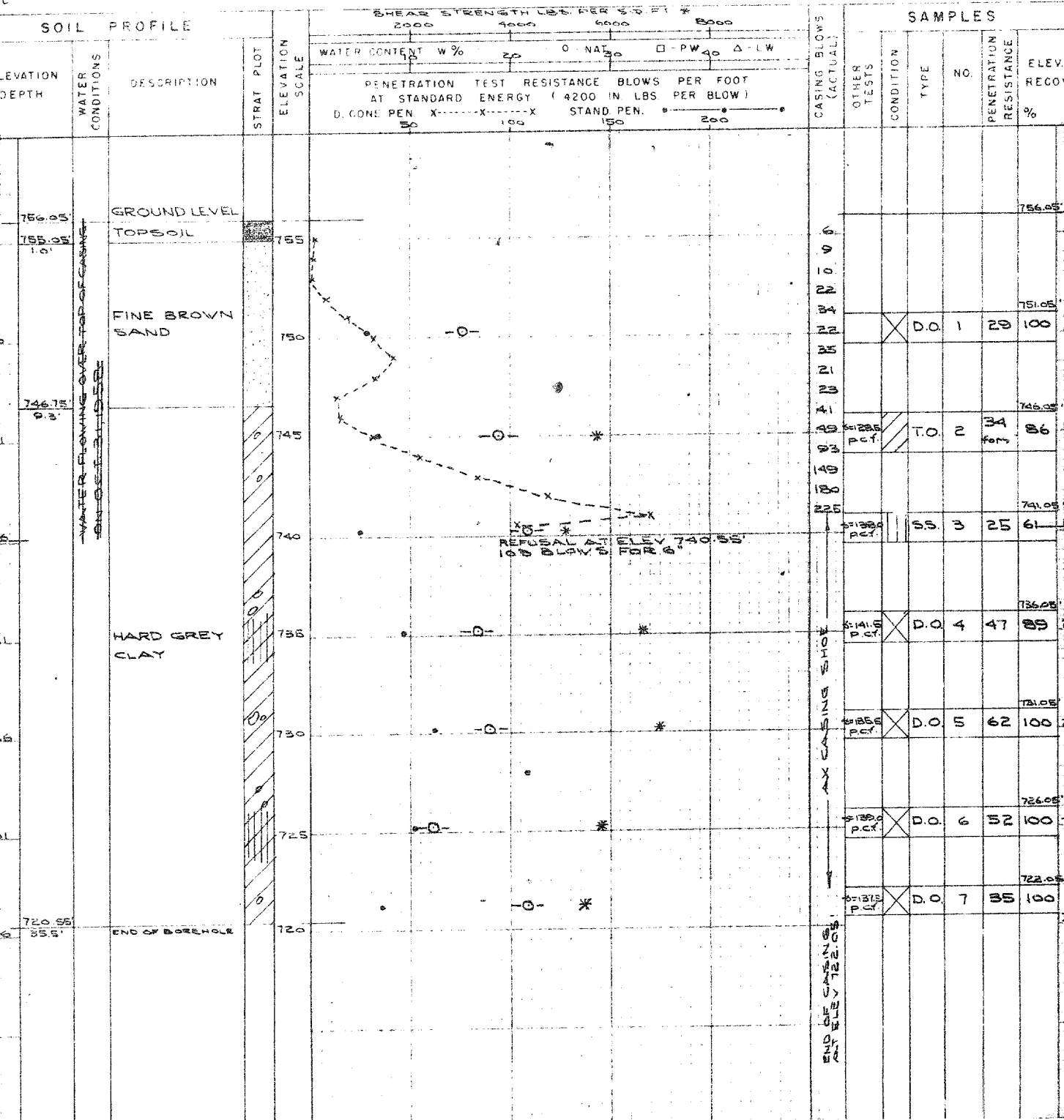
DEPARTMENT OF HIGHWAYS - ONTARIO  
MATERIALS & RESEARCH BRANCH - FOUNDATIONS SECTION - DOWNSVIEW  
**OFFICE REPORT ON SOIL EXPLORATION**

DRILL RIG 54-5 OPERATION BORE&PENET'N JOB F-58-40 WR 19-59 BORING 1 STA. 323+41(36'LT)  
CASING BX&AX (standard samplers to fit unless noted) DATUM GEODETIC DATE REPORT JAN. 1959  
SAMPLER HAMMER WT 250 LBS DROP 19 INCHES COMPILED BY HS CHECKED BY AL DATE BORING 30 OCT. 1958

**ABBREVIATIONS**  
V - INSITU VANE SHEAR TEST Q - TRIAXIAL QUICK K - PERMIABILITY CS - CHUNK  
M - MECHANICAL ANALYSIS S - TRIAXIAL SLOW C - CONSOLIDATION DO - DRIVE OPEN  
U - UNCONFINED COMPRESSION WL - WATER LEVEL IN CASING CA - CASING DF - DRIVE FOOT VALVE  
QC - TRIAXIAL CONSOLIDATED QUICK WT - WATER TABLE IN SOIL Y - UNIT WEIGHT TO - THIN WALLED OPEN WS - WASHED SAMPLE  
RC - ROCK CORE

**SAMPLE TYPES**  
SS - SLEEVE SAMPLE  
PS - PISTON SAMPLE  
WS - WASHED SAMPLE  
RC - ROCK CORE

**SAMPLE CONDITION**  
- DISTURBED  
- FAIR  
- GOOD  
- LOST







DEPARTMENT OF HIGHWAYS - ONTARIO  
MATERIALS & RESEARCH BRANCH - FOUNDATIONS SECTION - DOWNSVIEW  
**OFFICE REPORT ON SOIL EXPLORATION**

DRILL RIG 54-5 OPERATION BORE 4 PENET N JOB F-58-40 WP 19-59 BORING 4 STA 321+95 (29' LT)  
CASING BX 4 AX (standard samplers to fit unless noted) DATUM GEODETIC DATE REPORT JAN 1959  
SAMPLER HAMMER WT. 250 LBS. DROP 19 INCHES COMPILED BY H CHECKED BY AL DATE BORING 5 NOV 1958


**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  
Qc - TRIAXIAL CONSOLIDATED QUICK WT - WATER TABLE IN SOIL Y - UNIT WEIGHT

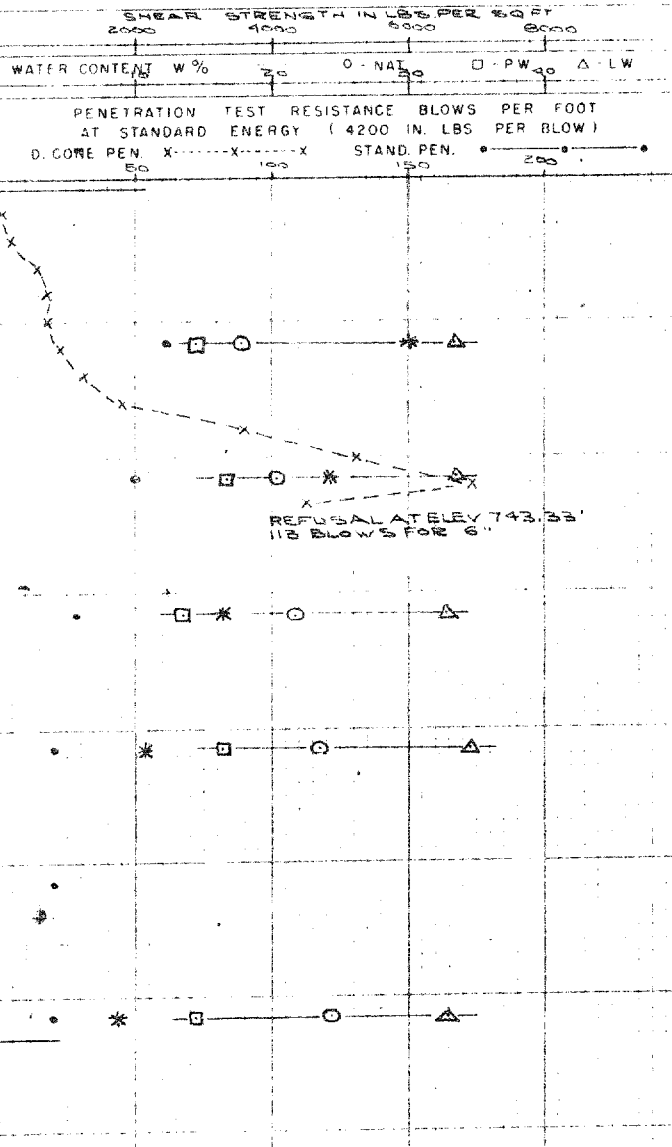
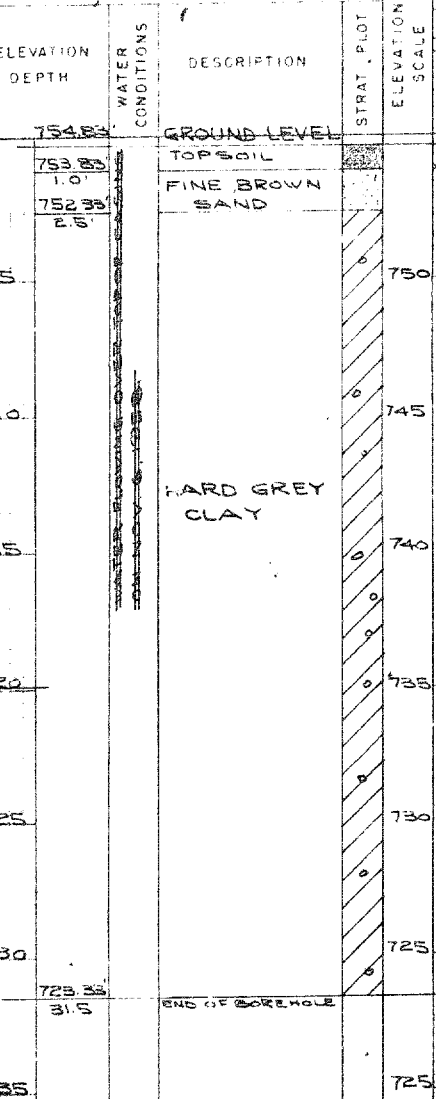
**SAMPLE TYPES**

- CS - CHUNK SS - SLEEVE SAMPLE  
DO - DRIVE OPEN PS - PISTON SAMPLE  
DF - DRIVE FOOT VALVE WS - WASHED SAMPLE  
TO - THIN WALLED OPEN RC - ROCK CORE

**SAMPLE CONDITION**

-  - DISTURBED  
- FAIR  
- GOOD  
- LOST

**SOIL PROFILE**



**SAMPLES**

CASING BLOWS (ACTUAL)	OTHER TESTS	CONDITION	TYPE	NO	PENETRATION RESISTANCE	ELEV. RECOVER
					%	
5						754.89
11						
20						
37						
64						749.89
28	1134.8 pcf	T.O.	1	62	39	
60						
83						
125						744.89
193	1130.5 pcf	S.S.	2	50	89	
						739.89
	1126.0 pcf	D.O.	3	20	100	
						734.89
	1081.3 pcf	D.O.	4	20	100	
						729.89
						724.89
	1013.0 pcf	D.O.	6	20	100	

## SYMBOLS AND TERMS USED ON BOREHOLE AND TEST PIT RECORDS

### SOIL DESCRIPTION

#### Terminology describing common soil genesis:

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

#### Terminology describing soil structure:

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

#### Terminology describing soil types:

The classification of soil types are made on the basis of grain size and plasticity in accordance with the Unified Soil Classification System (USCS) (ASTM D 2487 or D 2488). The classification excludes particles larger than 76 mm (3 inches). The USCS provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification.

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

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

<i>Trace, or occasional</i>	Less than 10%
<i>Some</i>	10-20%
<i>Frequent</i>	> 20%

#### Terminology describing compactness of cohesionless soils:

The standard terminology to describe cohesionless soils includes compactness (formerly "relative density"), as determined by the Standard Penetration Test N-Value (also known as N-Index). A relationship between compactness condition and N-Value is shown in the following table.

Compactness Condition	SPT N-Value
<i>Very Loose</i>	<4
<i>Loose</i>	4-10
<i>Compact</i>	10-30
<i>Dense</i>	30-50
<i>Very Dense</i>	>50

#### Terminology describing consistency of cohesive soils:

The standard terminology to describe cohesive soils includes the consistency, which is based on undrained shear strength as measured by *in situ* vane tests, penetrometer tests, or unconfined compression tests.

Consistency	Undrained Shear Strength	
	kips/sq.ft.	kPa
<i>Very Soft</i>	<0.25	<12.5
<i>Soft</i>	0.25 - 0.5	12.5 - 25
<i>Firm</i>	0.5 - 1.0	25 - 50
<i>Stiff</i>	1.0 - 2.0	50 - 100
<i>Very Stiff</i>	2.0 - 4.0	100 - 200
<i>Hard</i>	>4.0	>200



## ROCK DESCRIPTION

### Terminology describing rock quality:

RQD	Rock Mass Quality
0-25	<i>Very Poor</i>
25-50	<i>Poor</i>
50-75	<i>Fair</i>
75-90	<i>Good</i>
90-100	<i>Excellent</i>

Rock quality classification is based on a modified core recovery percentage (RQD) in which all pieces of sound core over 100 mm long are counted as recovery. The smaller pieces are considered to be due to close shearing, jointing, faulting, or weathering in the rock mass and are not counted. RQD was originally intended to be done on NW core; however, it can be used on different core sizes if the bulk of the fractures caused by drilling stresses are easily distinguishable from *in situ* fractures. The terminology describing rock mass quality based on RQD is subjective and is underlain by the presumption that sound strong rock is of higher engineering value than fractured weak rock.

### Terminology describing rock mass:

Spacing (mm)	Joint Classification	Bedding, Laminations, Bands
> 6000	<i>Extremely Wide</i>	-
2000-6000	<i>Very Wide</i>	<i>Very Thick</i>
600-2000	<i>Wide</i>	<i>Thick</i>
200-600	<i>Moderate</i>	<i>Medium</i>
60-200	<i>Close</i>	<i>Thin</i>
20-60	<i>Very Close</i>	<i>Very Thin</i>
<20	<i>Extremely Close</i>	<i>Laminated</i>
<6	-	<i>Thinly Laminated</i>

### Terminology describing rock strength:

Strength Classification	Unconfined Compressive Strength (MPa)
<i>Extremely Weak</i>	< 1
<i>Very Weak</i>	1 – 5
<i>Weak</i>	5 – 25
<i>Medium Strong</i>	25 – 50
<i>Strong</i>	50 – 100
<i>Very Strong</i>	100 – 250
<i>Extremely Strong</i>	> 250

### Terminology describing rock weathering:

Term	Description
<i>Fresh</i>	No visible signs of rock weathering. Slight discolouration along major discontinuities
<i>Slightly Weathered</i>	Discolouration indicates weathering of rock on discontinuity surfaces. All the rock material may be discoloured.
<i>Moderately Weathered</i>	Less than half the rock is decomposed and/or disintegrated into soil.
<i>Highly Weathered</i>	More than half the rock is decomposed and/or disintegrated into soil.
<i>Completely Weathered</i>	All the rock material is decomposed and/or disintegrated into soil. The original mass structure is still largely intact.

## STRATA PLOT

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



Boulders  
Cobbles  
Gravel



Sand



Silt



Clay



Organics



Asphalt



Concrete



Fill



Bedrock

## SAMPLE TYPE

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

## WATER LEVEL MEASUREMENT



measured in standpipe,  
piezometer, or well



inferred

## RECOVERY

For soil samples, the recovery is recorded as the length of the soil sample recovered. For rock core, recovery is defined as the total cumulative length of all core recovered in the core barrel divided by the length drilled and is recorded as a percentage on a per run basis.

## N-VALUE

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 140 pound (64 kg) hammer falling 30 inches (760 mm), required to drive a 2 inch (50.8 mm) O.D. split spoon sampler one foot (305 mm) into the soil. For split spoon samples where insufficient penetration was achieved and N-values cannot be presented, the number of blows are reported over sampler penetration in millimetres (e.g. 50/75). Some design methods make use of N value corrected for various factors such as overburden pressure, energy ratio, borehole diameter, etc. No corrections have been applied to the N-values presented on the log.

## DYNAMIC CONE PENETRATION TEST (DCPT)

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to A size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone one foot (305 mm) into the soil. The DCPT is used as a probe to assess soil variability.

## OTHER TESTS

S	Sieve analysis
H	Hydrometer analysis
k	Laboratory permeability
$\gamma$	Unit weight
$G_s$	Specific gravity of soil particles
CD	Consolidated drained triaxial
CU	Consolidated undrained triaxial with pore pressure measurements
UU	Unconsolidated undrained triaxial
DS	Direct Shear
C	Consolidation
$Q_u$	Unconfined compression
$I_p$	Point Load Index ( $I_p$ on Borehole Record equals $I_p(50)$ in which the index is corrected to a reference diameter of 50 mm)

	Single packer permeability test; test interval from depth shown to bottom of borehole
	Double packer permeability test; test interval as indicated
	Falling head permeability test using casing
	Falling head permeability test using well point or piezometer



## RECORD OF BOREHOLE No CN17-1

1 OF 1

METRIC

W.P. 3132-12-00 LOCATION CN Rail (Site # 5-49 E & W) N: 4 735 874 E: 394 756 ORIGINATED BY DL  
DIST West HWY 401 BOREHOLE TYPE Hollow Stem Auger - Split Spoon Sampler COMPILED BY SR  
DATUM Geodetic DATE 2017 11 13 CHECKED BY KN

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W <sub>P</sub>	W	W <sub>L</sub>		WATER CONTENT (%)			
								○ UNCONFINED      × FIELD VANE ● QUICK TRIAXIAL    × LAB VANE									
238.5								20 40 60 80 100									
238.4	127mm ASPHALT																
238.0	SAND and GRAVEL (GRANULAR BASE FILL)		1	SS	9		238										
0.5	Brown																
	CLAYEY SILT (CL) to SILTY CLAY (CI), some sand, trace gravel (FILL)		2	SS	10												
	Stiff to hard						237										
	Brown		3	SS	7												
	Moist to wet																
			4	SS	12		236									1	13 42 44
	SS5 contains occasional grey pockets and softer layers		5	SS	23		235										
			6	SS	25		234										
			7	SS	40												
			8	SS	32		233									2	13 42 43
	SS9 contains occasional sandy seams		9	SS	31		232										
230.9							231										
7.6	SILTY SAND (SM), trace clay and gravel		10	SS	100/ 254mm		230										
	Very dense																
	Brown to grey		11	SS	63		229									3	55 33 9 Non-Plastic
227.8							228										
10.7	SILTY CLAY (CI), trace sand and gravel (TILL)		12	SS	47												
227.2	Hard																
11.3	Brown																
	Moist																
	End of Borehole																
	Borehole collapsed at 8.5 m depth on completion of drilling.																
	No groundwater seepage observed.																

WH - Weight of Hammer

 $\times^3, \times^3$ : Numbers refer to Sensitivity $\circ^3$  STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC 165000909 HWY 401 RECONSTRUCTION (USE FOR CONTRACT 4).GPJ ONTARIO MOT.GDT 13/19



## RECORD OF BOREHOLE No CN17-2

1 OF 1

METRIC

W.P. 3132-12-00 LOCATION CN Rail (Site # 5-49 E & W) N: 4 735 945 E: 394 828 ORIGINATED BY DL  
DIST West HWY 401 BOREHOLE TYPE Hollow Stem Auger - Split Spoon Sampler COMPILED BY SR  
DATUM Geodetic DATE 2017 11 13 CHECKED BY KN

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)	
								○ UNCONFINED	✕ FIELD VANE							
238.6							20	40	60	80	100					
238.6 0.1	127mm ASPHALT															
237.9	SILTY GRAVELLY SAND (GRANULAR BASE FILL)		1	SS	27											
0.7	CLAYEY SILT (CL), some sand, trace gravel to SILTY CLAY (CI), trace sand (FILL) Very stiff to hard Dark brown to brown Moist		2	SS	17											
			3	SS	17											
			4	SS	25											
			5	SS	29											
			6	SS	23											
			7	SS	33											
			8	SS	55											
			9	SS	44											
			10	SS	53											
			11	SS	70											
229.1	SANDY SILTY CLAY, trace rootlets (BURIED TOPSOIL)															
9.5	Black															
228.7	Moist															
9.9	SILTY CLAY (CI), some sand, trace gravel (TILL) Hard Brown to grey Moist		12	SS	49											
			13	SS	70											
227.3	End of Borehole															
11.3	Borehole collapsed at 5.8 m depth upon completion of drilling.  No groundwater seepage observed.															

STN13-ONTARIO MTO STANTEC 165000909 HWY 401 RECONSTRUCTION (USE FOR CONTRACT 4).GPJ ONTARIO MOT.GDT 1/3/19

WH - Weight of Hammer

 $\times^3, \times^3$ : Numbers refer to  
Sensitivity $\circ$  3% STRAIN AT FAILURE



## RECORD OF BOREHOLE No CN17-3

1 OF 1

METRIC

W.P. 3132-12-00 LOCATION CN Rail (Site # 5-49 E & W) N: 4 735 884 E: 394 814 ORIGINATED BY DL  
DIST West HWY 401 BOREHOLE TYPE Hollow Stem Auger - Split Spoon Sampler COMPILED BY SR  
DATUM Geodetic DATE 2017 11 14 CHECKED BY KN

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W <sub>P</sub>	W	W <sub>L</sub>		GR   SA   SI   CL				
238.8	76mm ASPHALT																	
238.4	GRAVELLY SAND, some silt (FILL)		1	SS	39										27	57	13	3
238.5	Dense Brown Moist																	
237.6	GRAVELLY SAND (SP), some silt, trace clay (GRANULAR SUBBASE FILL)		2	SS	14													
237.7	Compact to dense Brown Wet																	
	SILTY CLAY (Cl), some sand (FILL)		3	SS	8													
	Stiff to hard Brown Moist, Sample 2 is wet																	
			4	SS	14													
			5	SS	12													
			6	SS	30													
			7	SS	27													
			8	SS	32													
	SS9 contains occasional sandy zones		9	SS	30													
231.2	SILTY SAND (SM), trace gravel (FILL)		10	SS	73													
231.3	Dense to very dense Light grey to dark brown Moist																	
	Wet and contains trace to some clayey silt inclusions below 9 m																	
229.3	SILTY SAND (SM), trace clay		11	SS	39													
229.4	Dense Brown Wet																	
228.1	SILTY CLAY (Cl), some gravel, trace sand (TILL)		12	SS	33													
227.5	Hard Brown Moist																	
11.3	End of Borehole																	
	Groundwater observed at 9.5 m depth during drilling.																	

STN13-ONTARIO MTO STANTEC 165000909 HWY 401 RECONSTRUCTION (USE FOR CONTRACT 4).GPJ ONTARIO MOT.GDT 1/3/19

WH - Weight of Hammer

 $\times^3, \times^3$ : Numbers refer to Sensitivity $\circ$  3% STRAIN AT FAILURE



## RECORD OF BOREHOLE No CN17-4

1 OF 1

METRIC

W.P. 3132-12-00 LOCATION CN Rail (Site # 5-49 E & W) N: 4 735 940 E: 394 855 ORIGINATED BY DL  
DIST West HWY 401 BOREHOLE TYPE Hollow Stem Auger - Split Spoon Sampler COMPILED BY SR  
DATUM Geodetic DATE 2017 11 14 CHECKED BY KN

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								20 40 60 80 100						
								20 40 60 80 100						
238.6	76mm ASPHALT													
238.6	305mm GRANULAR BASE (FILL)		1	AS	-									
238.2	SILTY SAND (SM), some gravel (FILL)						238							
0.4	Dense Brown Moist													
237.8	SAND (SP), some silt and gravel, trace clay (FILL)		2	SS	44									
0.8	Compact to dense Brown Moist to wet						237							
			3	SS	17									
236.5	SILTY CLAY (CI), trace to some sand, trace gravel (FILL)													
2.1	Very stiff to hard Brown Moist to wet		4	SS	14		236							
			5	SS	22		235							
			6	SS	24		234							
			7	SS	27		233							
			8	SS	35		232							
			9	SS	34		231							
			10	SS	38		230							
229.5	SILTY SAND (SM), some gravel													
9.1	Compact Dark brown Wet		11	SS	18		229							
229.2	CLAYEY SILT to SILTY CLAY (CL/CI), trace sand (TILL)													
9.4	Very stiff to hard Brown Moist						228							
			12	SS	52									
227.3	End of Borehole													
11.3	Groundwater noted below 9 m depth during drilling.													

STN13-ONTARIO MTO STANTEC 165000909 HWY 401 RECONSTRUCTION (USE FOR CONTRACT 4).GPJ ONTARIO MOT.GDT 13/19

WH - Weight of Hammer

 $\times^3, \times^3$ : Numbers refer to Sensitivity $\circ^3$  STRAIN AT FAILURE



## RECORD OF BOREHOLE No CN18-5

1 OF 1

METRIC

W.P. 3132-12-00 LOCATION CN Rail (Site # 5-49 E & W) N: 4 735 907 E: 394 775 ORIGINATED BY DL  
DIST West HWY 401 BOREHOLE TYPE Hollow Stem Auger - Split Spoon Sampler COMPILED BY SR  
DATUM Geodetic DATE 2018 04 04 CHECKED BY KN

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT		NATURAL MOISTURE CONTENT		LIQUID LIMIT		UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W <sub>P</sub>	W	W <sub>L</sub>		GR	SA	SI	CL	
								○ UNCONFINED	✕ FIELD VANE	● QUICK TRIAXIAL	✕ LAB VANE	WATER CONTENT (%)									
229.8 0.0	SAND and GRAVEL (SP-GP), some silt (FILL) Contains black rock Loose to compact Dark brown Wet		1	SS	12													50	39	(11)	
228.7 1.1	CLAYEY SILT (CL) to SILTY CLAY (CI), trace sand and gravel (TILL) Very stiff to hard Brown Moist		2	SS	8																
			3	SS	19																
			4	SS	36																
			5	SS	34																
			6	SS	28																
	Grey below 4.4m		7	ST	-																
			8	SS	24																
	Shelby tube samples were originally attempted at locations of sample 9 and 10 but no sample was obtained. SPT 'N' values for these samples may be influenced by sample disturbance.		9	SS	16																
			10	SS	11																
			11	ST	-																
			12	SS	11																
			13	SS	14																
			14	SS	13																
217.0 12.8	End of Borehole																				
	Borehole open and dry on completion of drilling.																				

STN/13-ONTARIO MTO STANTEC 165000909 HWY 401 RECONSTRUCTION (USE FOR CONTRACT 4).GPJ ONTARIO MOT.GDT 1/3/19

WH - Weight of Hammer

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

○ 3% STRAIN AT FAILURE





# RECORD OF BOREHOLE No CN18-6

1 OF 1

METRIC

W.P. 3132-12-00 LOCATION CN Rail (Site # 5-49 E & W) N: 4 735 907 E: 394 807 ORIGINATED BY DL  
 DIST West HWY 401 BOREHOLE TYPE Hollow Stem Auger - Split Spoon Sampler COMPILED BY SR  
 DATUM Geodetic DATE 2018 04 03 CHECKED BY KN

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)			GR
229.9	510 mm TOPSOIL							20	40	60	80	100								
229.6	SILTY SAND (SM), with gravel (FILL) Dark brown Wet		1	SS	8									10	20	30				
229.3	SAND (SP), some silt, trace gravel Compact Brown Wet		2	SS	17										15					
	Grey below 1.5m		3	SS	25										15					2 82 12 4
227.6	SILTY CLAY (CI), trace sand (TILL) Hard Grey Moist		4	SS	22										20					
			5	SS	25										25	35				0 8 42 50
			6	SS	27										20					
			7	SS	24															
	Very stiff below 5.3m		8	SS	17										20					
			9	SS	17										25					
			10	SS	19										25	35				0 5 43 52
			11	SS	17										20					
220.1	End of Borehole																			
9.8	Groundwater level in open borehole at 0.8 m depth on completion of drilling.  VWP Install: Silica sand from 9.1m to 7.9m VWP sensor at 8.8m Bentonite from 7.9m to 6.1m Bentonite and cutting from 6.1m to 0m  Water level in VWP measured to be at 6.9 m depth (~Elev. 223.0 m) on April 4, 2018. Water level in VWP measured to be at 4.9 m depth (~Elev. 225.0 m) on April 13, 2018. Water level in VWP measured to be at 3.7 m depth (~Elev. 226.2 m) on April 20, 2018.																			

STN13-ONTARIO MTO STANTEC 165000909 HWY 401 RECONSTRUCTION (USE FOR CONTRACT 4).GPJ ONTARIO MOT.GDT 1/3/19

WH - Weight of Hammer

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

○ 3% STRAIN AT FAILURE

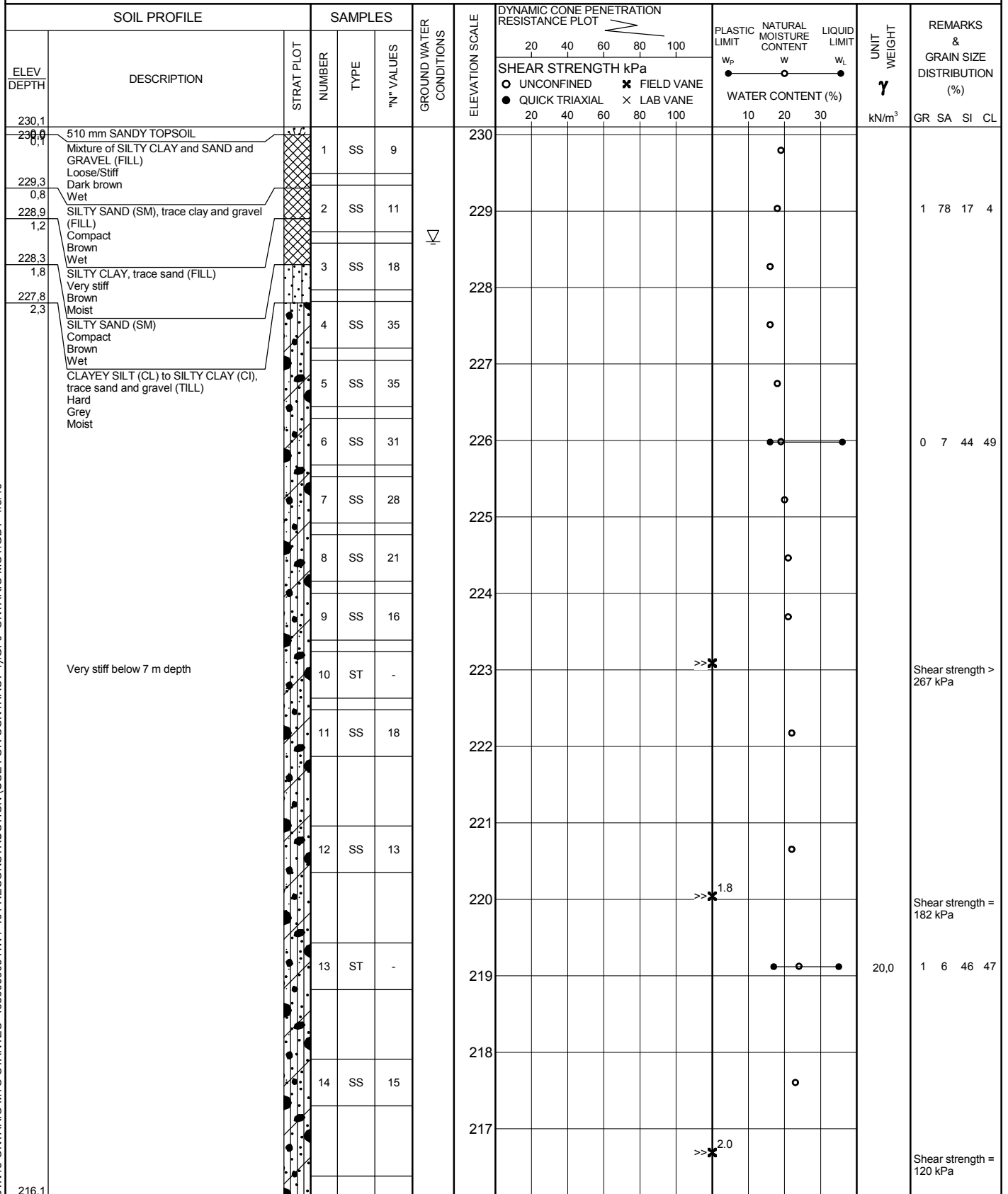


## RECORD OF BOREHOLE No CN18-7

1 OF 3

METRIC

W.P. 3132-12-00 LOCATION CN Rail (Site # 5-49 E & W) N: 4 735 914 E: 394 826 ORIGINATED BY DL  
DIST West HWY 401 BOREHOLE TYPE Hollow Stem Auger - Split Spoon Sampler COMPILED BY SR  
DATUM Geodetic DATE 2018 04 02 CHECKED BY KN



Continued Next Page

WH - Weight of Hammer

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

○ 3% STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC 165000909 HWY 401 RECONSTRUCTION (USE FOR CONTRACT 4).GPJ ONTARIO MOT.GDT 1/3/19

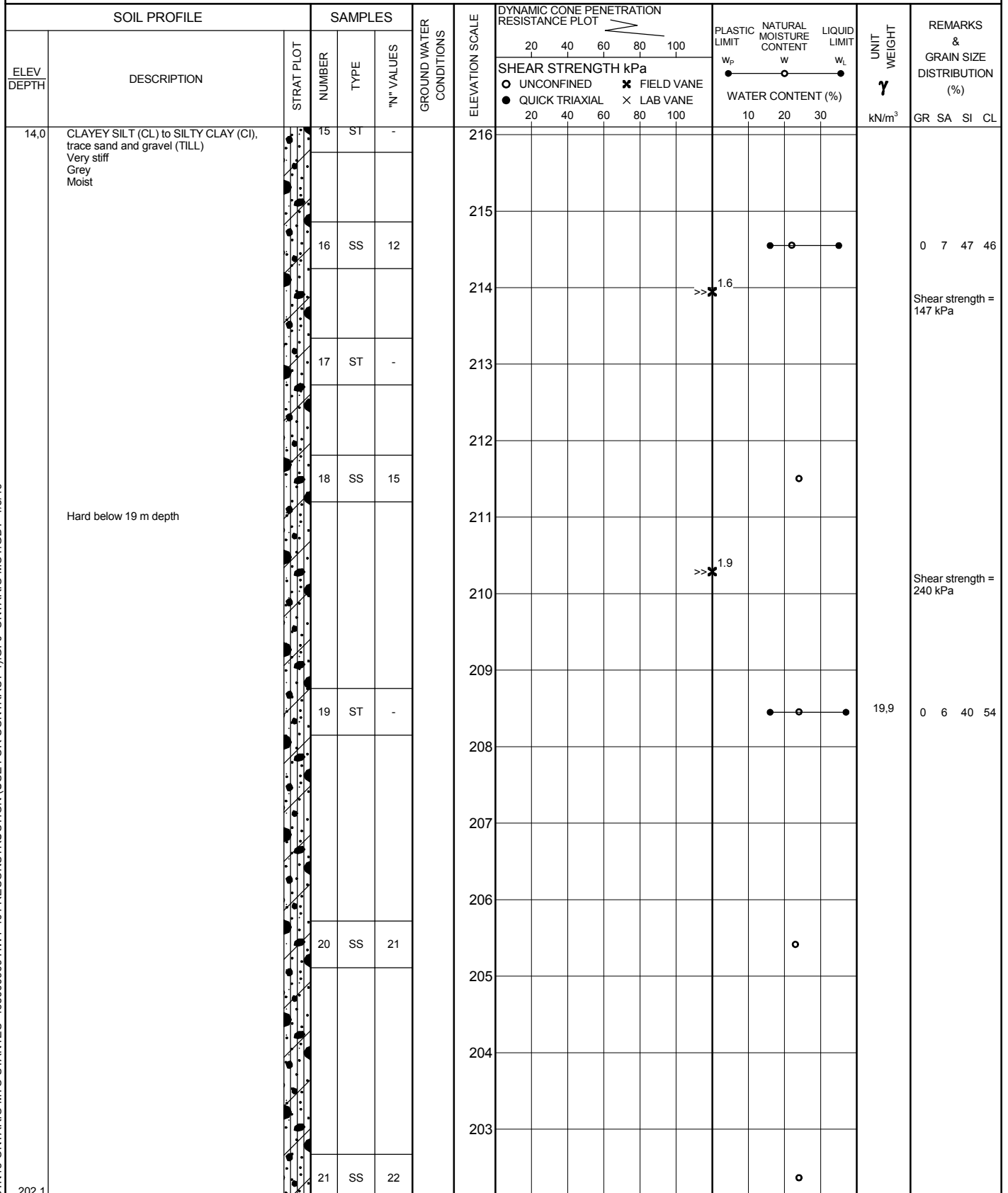


## RECORD OF BOREHOLE No CN18-7

2 OF 3

METRIC

W.P. 3132-12-00 LOCATION CN Rail (Site # 5-49 E & W) N: 4 735 914 E: 394 826 ORIGINATED BY DL  
DIST West HWY 401 BOREHOLE TYPE Hollow Stem Auger - Split Spoon Sampler COMPILED BY SR  
DATUM Geodetic DATE 2018 04 02 CHECKED BY KN



Continued Next Page

WH - Weight of Hammer

 $\times^3, \times^3$ : Numbers refer to Sensitivity $\circ^3$  STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC 165000909 HWY 401 RECONSTRUCTION (USE FOR CONTRACT 4).GPJ ONTARIO MOT.GDT 1/3/19



## RECORD OF BOREHOLE No CN18-7

3 OF 3

METRIC

W.P. 3132-12-00 LOCATION CN Rail (Site # 5-49 E & W) N: 4 735 914 E: 394 826 ORIGINATED BY DL  
DIST West HWY 401 BOREHOLE TYPE Hollow Stem Auger - Split Spoon Sampler COMPILED BY SR  
DATUM Geodetic DATE 2018 04 02 CHECKED BY KN

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)			
							20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>		
							20	40	60	80	100					
28,0	CLAYEY SILT (CL) to SILTY CLAY (CI), trace sand and gravel (TILL) Hard Grey Moist															
199,0			22	SS	21											
31,1	End of Borehole  Groundwater level in open borehole at 1.5 m depth on completion of drilling.															

STN13-ONTARIO MTO STANTEC 165000909 HWY 401 RECONSTRUCTION (USE FOR CONTRACT 4).GPJ ONTARIO MOT.GDT 1/3/19

WH - Weight of Hammer

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

○ 3% STRAIN AT FAILURE



## RECORD OF BOREHOLE No CN18-8

1 OF 1

METRIC

W.P. 3132-12-00 LOCATION CN Rail (Site # 5-49 E & W) N: 4 735 912 E: 394 856 ORIGINATED BY DL  
DIST West HWY 401 BOREHOLE TYPE Hollow Stem Auger - Split Spoon Sampler COMPILED BY SR  
DATUM Geodetic DATE 2018 04 04 CHECKED BY KN

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)		
								○ UNCONFINED ● QUICK TRIAXIAL	✕ FIELD VANE ✕ LAB VANE									
230.1							20 40 60 80 100											
0.0	SAND and GRAVEL, with blast rock pieces (FILL) Compact		1	SS	15													
229.5	Dark brown to black																	
0.6	SILTY CLAY (CI), trace sand (TILL) Hard Brown Moist		2	SS	22													
			3	SS	29													
			4	SS	35													
			5	SS	25													
			6	SS	10													
			7	SS	20													
			8	SS	16													
			9	SS	15													
			10	SS	16													
			11	SS	13													
			12	SS	9													
			13	SS	11													
217.3	End of Borehole																	
12.8	Borehole open and dry on completion of drilling.																	

STN13-ONTARIO MTO STANTEC 165000909 HWY 401 RECONSTRUCTION (USE FOR CONTRACT 4).GPJ ONTARIO MOT.GDT 1/3/19

WH - Weight of Hammer

 $\times^3, \times^3$ : Numbers refer to Sensitivity $\circ^3$  STRAIN AT FAILURE

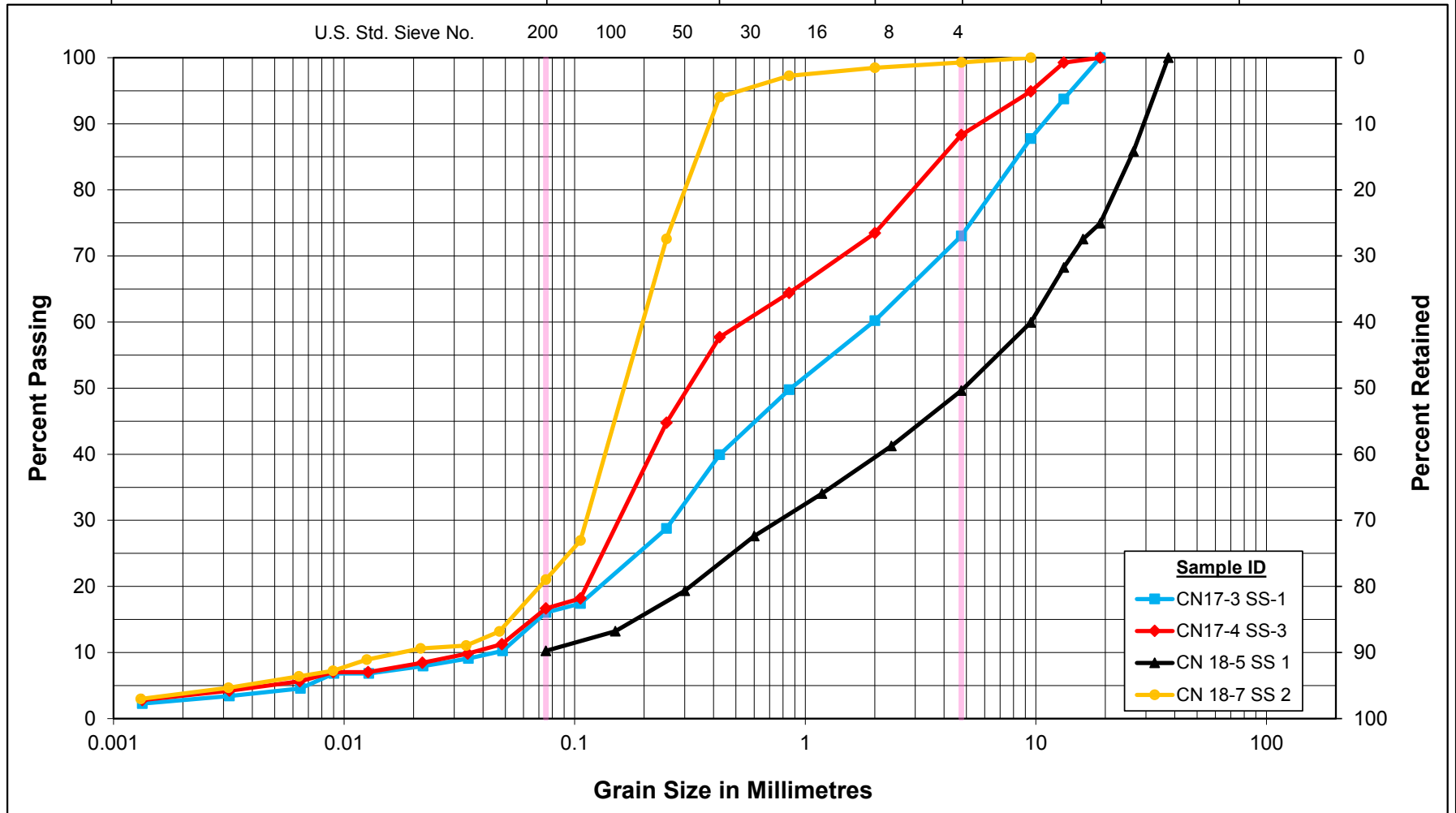
## APPENDIX C

Figures C1 to C6 – Laboratory Test Results (2017 and 2018 Investigation)

Figures C7 to C8 – 2018 Consolidation Tests – CN18-7 ST13 & CN18-7 ST-19

# Unified Soil Classification System

CLAY & SILT	SAND			Gravel	
	Fine	Medium	Coarse	Fine	Coarse



## GRAIN SIZE DISTRIBUTION

FILL: SILTY SAND (SM) to SAND and GRAVEL (SP/GP)

HWY 401 Reconstructon - CN Rail

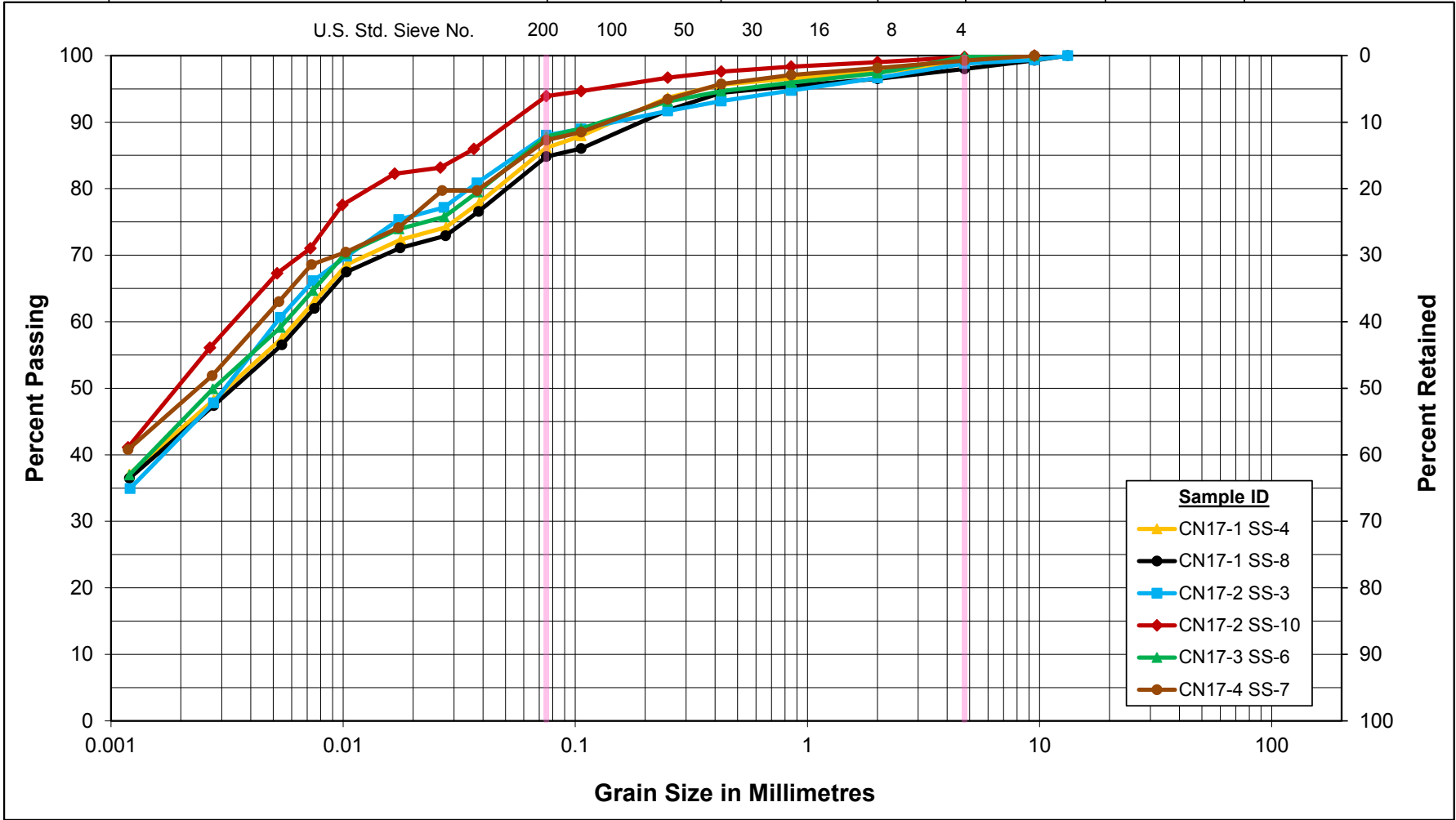
Figure No. C1

Project No. 165000909.350



# Unified Soil Classification System

			SAND			Gravel	
CLAY & SILT			Fine	Medium	Coarse	Fine	Coarse

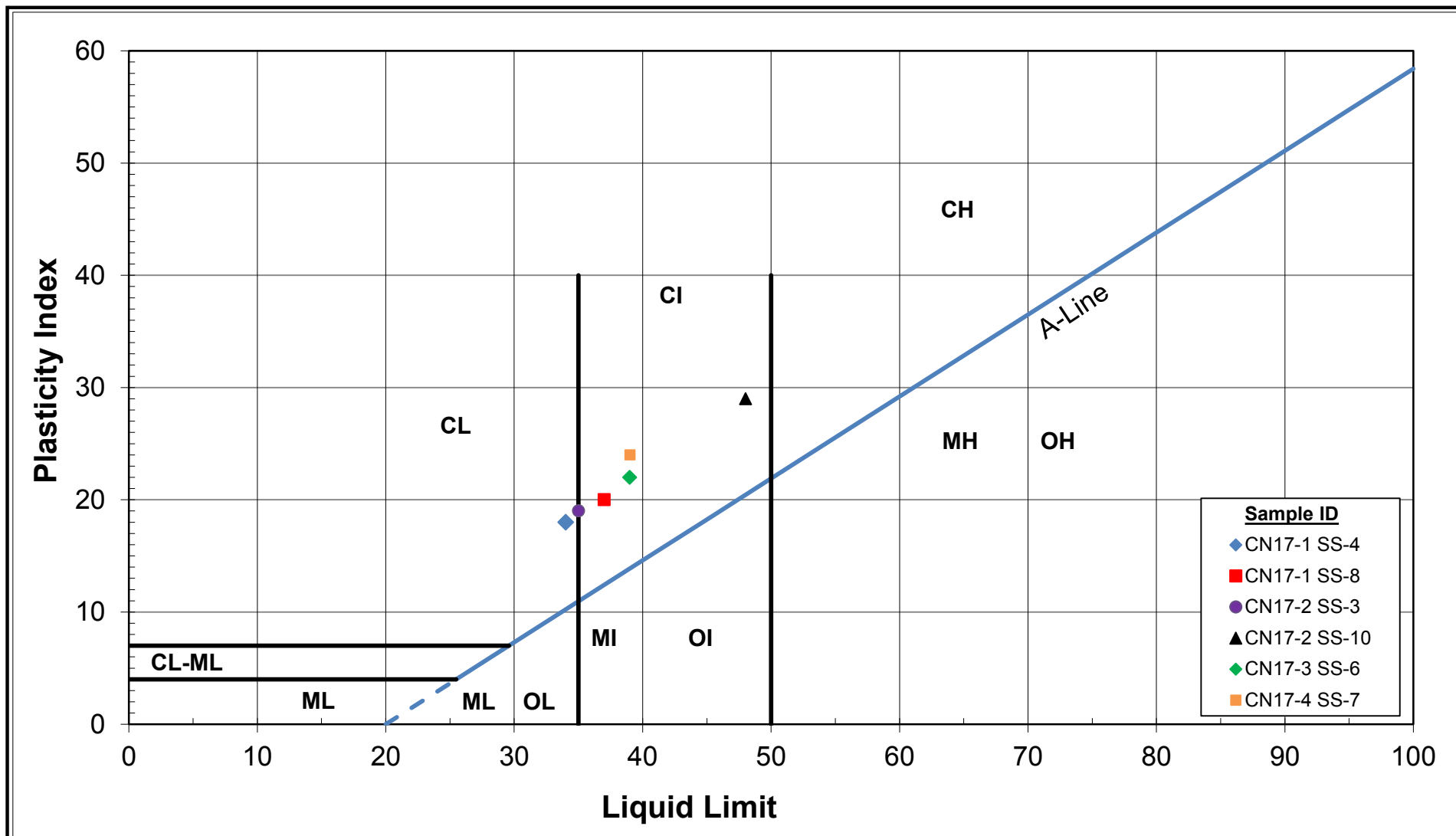


## GRAIN SIZE DISTRIBUTION

FILL: CLAYEY SILT (CL) to SILTY CLAY (CI)  
HWY 401 Reconstructon - CN Rail

Figure No. C2

Project No. 165000909.350



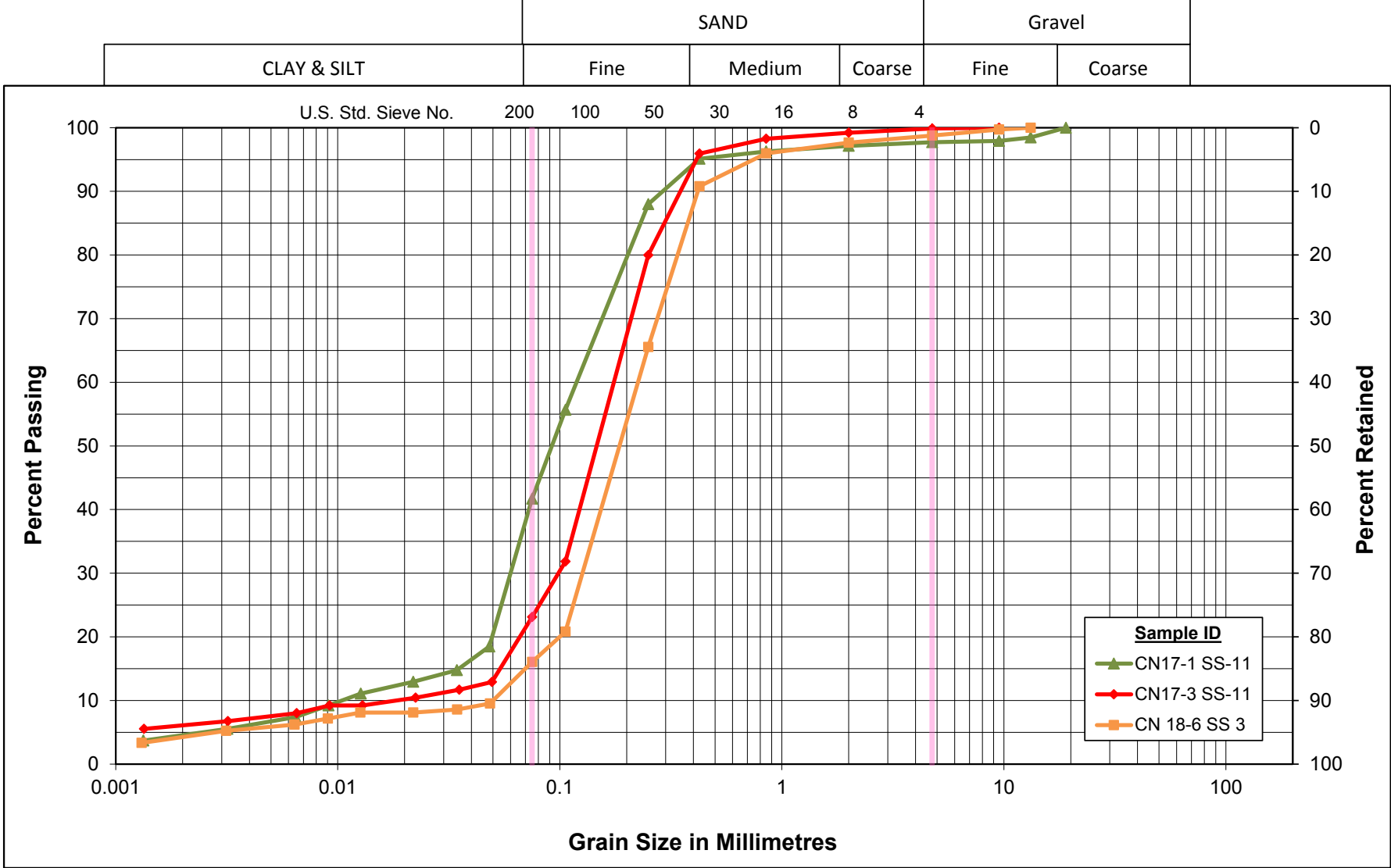
## PLASTICITY CHART

FILL: CLAYEY SILT (CL) to SILTY CLAY (CI)  
HWY 401 Reconstruction - CN Rail

Figure No. C3

Project No. 165000909.350

# Unified Soil Classification System



## GRAIN SIZE DISTRIBUTION

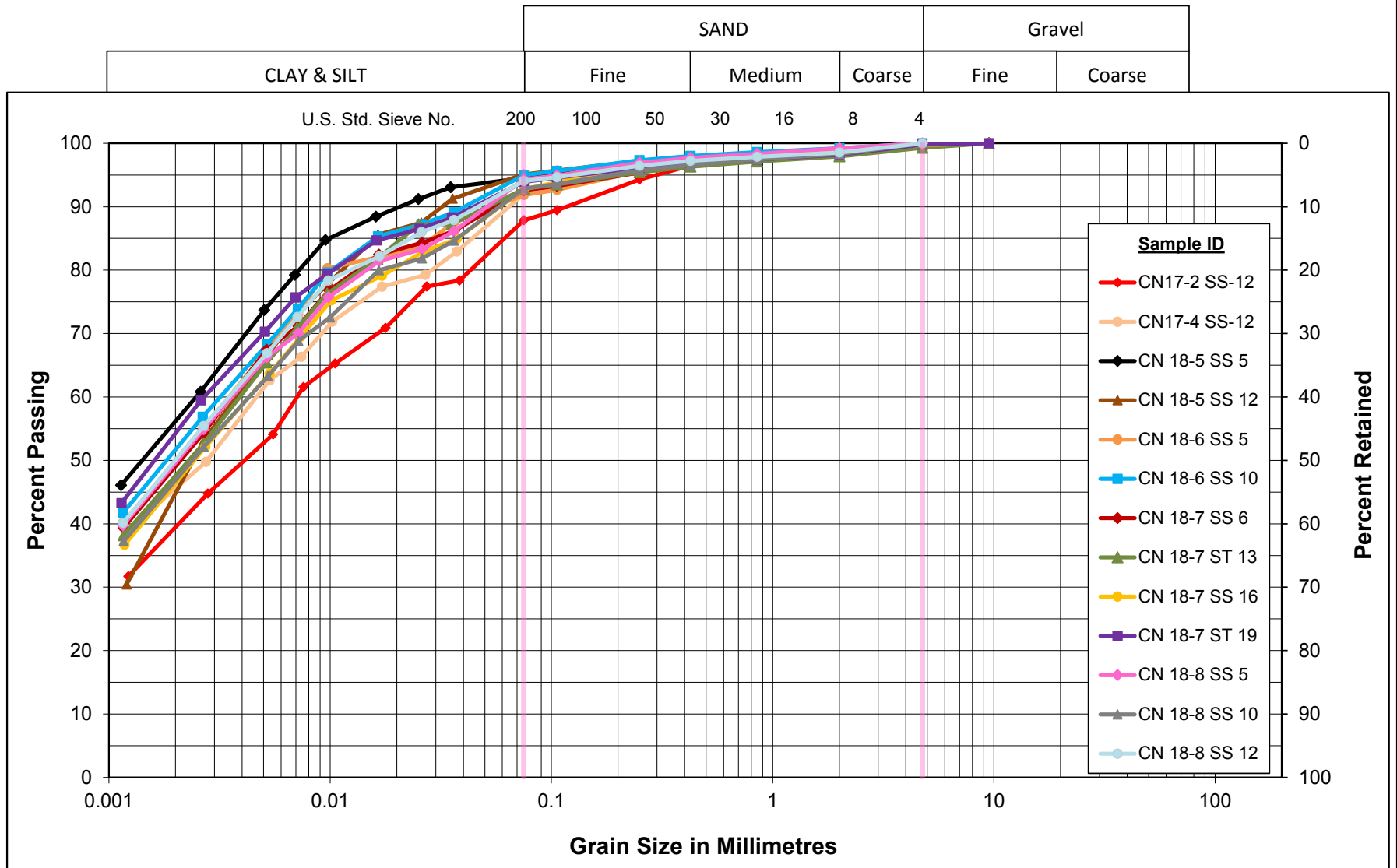
SAND (SP) to SILTY SAND (SM)

HWY 401 Reconstruction - CN Rail

Figure No. C4

Project No. 165000909.350

# Unified Soil Classification System



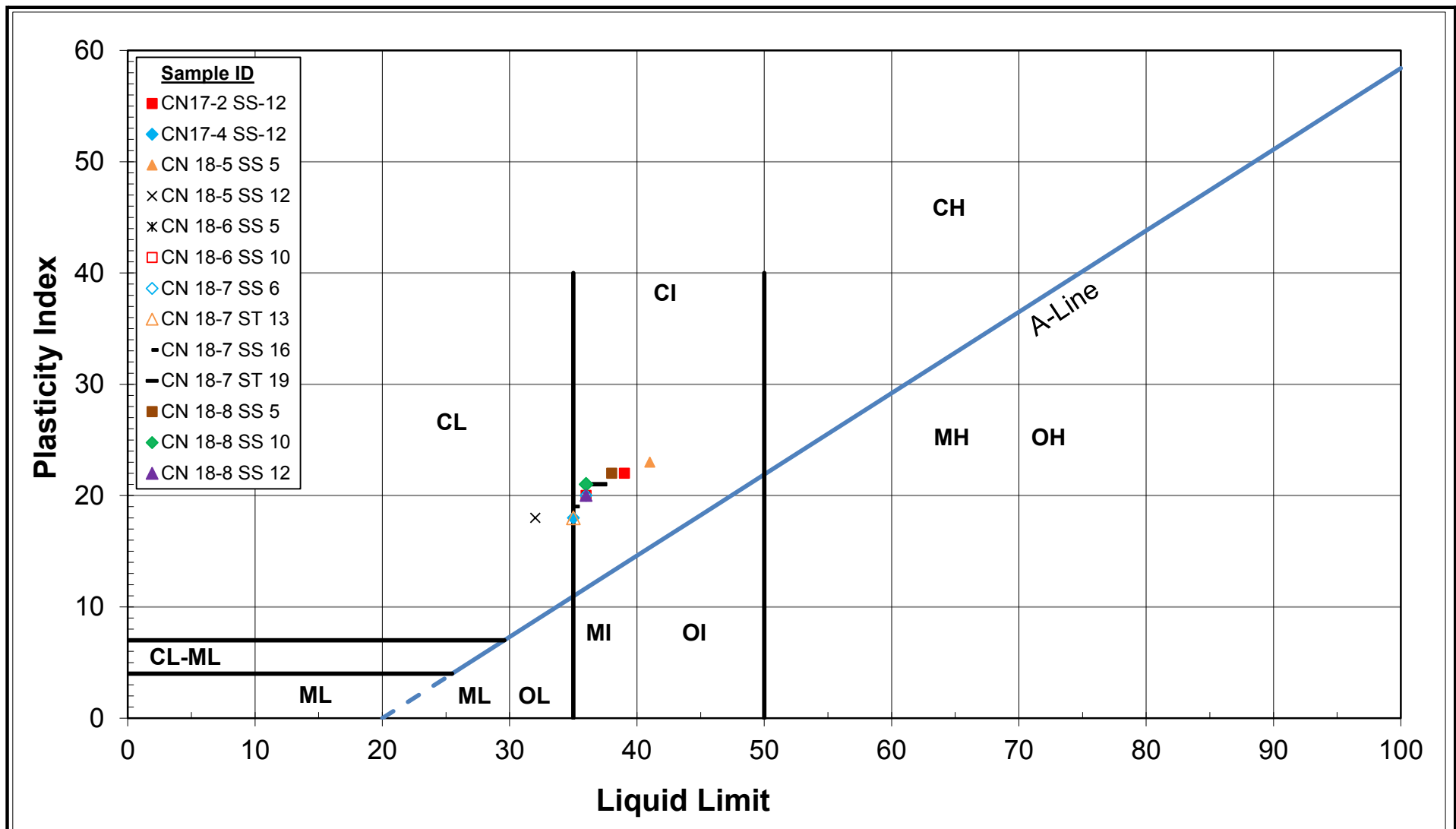
## GRAIN SIZE DISTRIBUTION

TILL: CLAYEY SILT (CL) to SILTY CLAY (CH)

HWY 401 Reconstruction - CN Rail

Figure No. C5

Project No. 165000909.350



# **PLASTICITY CHART** TILL: CLAYEY SILT (CL) to SILTY CLAY (CH) HWY 401 Reconstruction - CN Rail

Figure No. C6

Project No. 165000909.350

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

**Hwy 401 Reconstruction**  
**165000909.350**  
**CN 18-7**  
**ST-13**  
**35 - 37 ft**

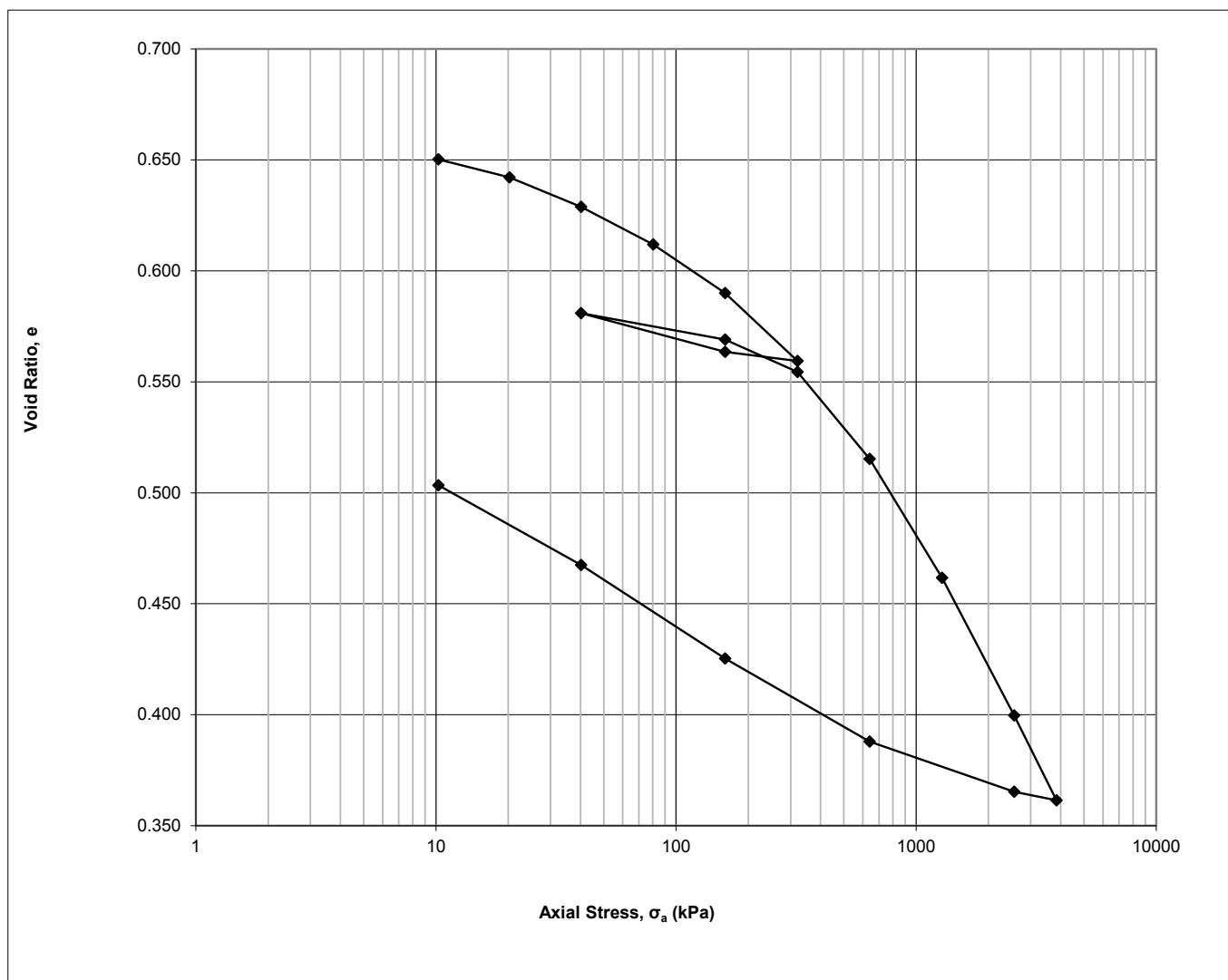


Figure No. C7

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

**Specimen Details**

Project Name	Hwy 401 Reconstruction
Project Location	Ontario, Canada
Borehole	CN 18-7
Sample No.	ST-13
Depth	35 - 37 ft
Sample Date	April 2, 2018
Test Number	One
Technician Name	Daniel Boateng

**Soil Description & Classification**

Silty Clay Till, Trace Sand, Brown, Moist	
Specific Gravity of Solids	2.726
Liquid Limit %	35
Plastic Limit %	17
Plasticity Index %	18
Average water content of trimmings %	24
<b>Additional Notes (information source, occurrence and size of large isolated particles etc.)</b>	

**Initial Specimen Conditions**

Height	mm	20.00
Diameter	mm	50.00
Area	mm <sup>2</sup>	1963
Volume	mm <sup>3</sup>	39270
Mass	g	80.18
Dry Mass	g	64.49
Density	Mg/m <sup>3</sup>	2.042
Dry Density	Mg/m <sup>3</sup>	1.642
Water Content	%	24.33
Degree of Saturation	%	100
Height of Solids	mm	12.05
Initial Void Ratio		0.660

**Final Specimen Conditions**

Water Content	%	20.39
Final Void Ratio		0.503

Figure No. C7



## One-Dimensional Consolidation Test using Incremental Loading

### ASTM D2435/D2435M - 11

**Specimen Details**

Project Name	Hwy 401 Reconstruction
Project Location	Ontario, Canada
Borehole	CN 18-7
Sample No.	ST-13
Depth	35 - 37 ft.
Sample Date	April 2, 2018
Test Number	One
Technician Name	Daniel Boateng

**Test Procedure**

Date Started	April 19, 2018
Date Finished	April 20, 2018
Machine Number	Frame C
Cell Number	C
Ring Number	C
Trimming Procedure	Turntable
Moisture Condition	Inundated
Axial Stress at Inundation	10 kPa
Water Used	Distilled
Test Method	B
Interpretation Procedure for $c_v$	2

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

--

**Calculations**

Load Increment	Increment Duration	Axial Stress	Corrected Deformation	Specimen Height	Axial Strain	Void Ratio
	min	$\sigma_a$ kPa	$\Delta H$ mm	H mm	$\epsilon_a$ %	e
Seating	0.0	10	0.0000	20.0000	0.00	0.660
1	14.8	10	0.1173	19.8827	0.59	0.650
2	20.0	20	0.2147	19.7853	1.07	0.642
3	26.5	40	0.3752	19.6248	1.88	0.629
4	29.8	80	0.5790	19.4210	2.90	0.612
5	36.5	160	0.8421	19.1579	4.21	0.590
6	69.3	320	1.2121	18.7879	6.06	0.559
7	15.0	160	1.1612	18.8388	5.81	0.564
8	30.0	40	0.9514	19.0486	4.76	0.581
9	18.3	160	1.0952	18.9048	5.48	0.569
10	28.3	320	1.2716	18.7284	6.36	0.554
11	51.8	640	1.7429	18.2571	8.71	0.515
12	60.0	1280	2.3888	17.6112	11.94	0.462
13	66.8	2560	3.1358	16.8642	15.68	0.400
14	66.8	3840	3.5965	16.4035	17.98	0.361
15	10.0	2560	3.5501	16.4499	17.75	0.365
16	23.3	640	3.2771	16.7229	16.39	0.388
17	53.3	160	2.8266	17.1734	14.13	0.425
18	103.5	40	2.3192	17.6808	11.60	0.467
19	156.0	10	1.8861	18.1139	9.43	0.503

Figure No. C7

## One-Dimensional Consolidation Test using Incremental Loading

### ASTM D2435/D2435M - 11

**Specimen Details**

Project Name	Hwy 401 Reconstruction
Project Location	Ontario, Canada
Borehole	CN 18-7
Sample No.	ST-13
Depth	35 - 37 ft
Sample Date	April 2, 2018
Test Number	One
Technician Name	Daniel Boateng

**Calculations**

Load Increment	Axial Stress $\sigma_a$ , average kPa	Calculated using Interpretation Procedure 2				Interpretation Procedure 1		Interpretation Procedure 2	
		Corrected Deformation $\Delta H_{50}$ mm	Specimen Height $H_{50}$ mm	Axial Strain $\epsilon_{a,50}$ %	Void Ratio $e_{50}$	Time $t_{50}$ sec	Coeff. Consol. $c_v$ mm <sup>2</sup> /s	Time $t_{90}$ sec	Coeff. Consol. $c_v$ mm <sup>2</sup> /s
Seating	5								
1	10	0.0964	19.9036	0.48	0.652			132	6.34E-01
2	15	0.1795	19.8205	0.90	0.645			168	4.95E-01
3	30	0.3126	19.6874	1.56	0.634			159	5.17E-01
4	60	0.4996	19.5004	2.50	0.618			298	2.70E-01
5	120	0.7138	19.2862	3.57	0.601			318	2.48E-01
6	240	0.9411	19.0589	4.71	0.582			78	9.92E-01
7	240	1.1754	18.8246	5.88	0.562				
8	100	1.0240	18.9760	5.12	0.575				
9	100	1.0360	18.9640	5.18	0.574			246	3.10E-01
10	240	1.1863	18.8137	5.93	0.561			305	2.46E-01
11	480	1.4885	18.5115	7.44	0.536			376	1.93E-01
12	960	2.0723	17.9277	10.36	0.488			446	1.53E-01
13	1920	2.7286	17.2714	13.64	0.433			296	2.14E-01
14	3200	3.3159	16.6841	16.58	0.385			245	2.41E-01
15	3200	3.5575	16.4425	17.79	0.365				
16	1600	3.3579	16.6421	16.79	0.381				
17	400	3.0089	16.9911	15.04	0.410				
18	100	2.7971	17.2029	13.99	0.428				
19	25	2.3110	17.6890	11.56	0.468				

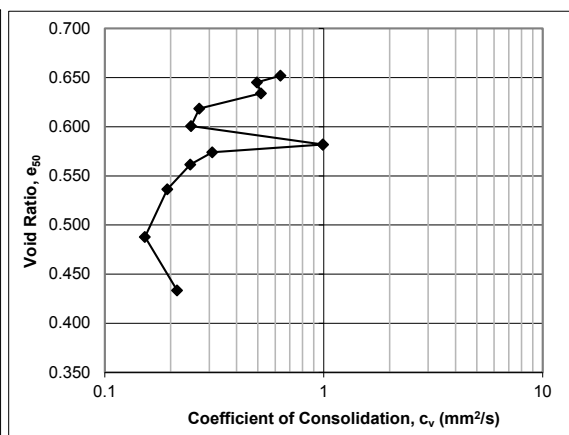
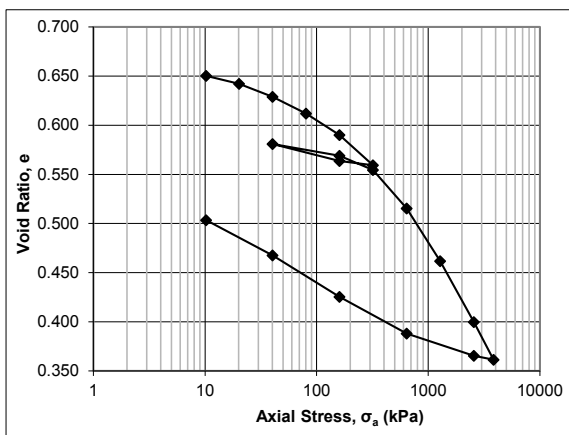



Figure No. C7

 <b>Stantec</b>	Project No.: 165000909.350	Photo Log
	Project Name: Hwy 401 Reconstruction	

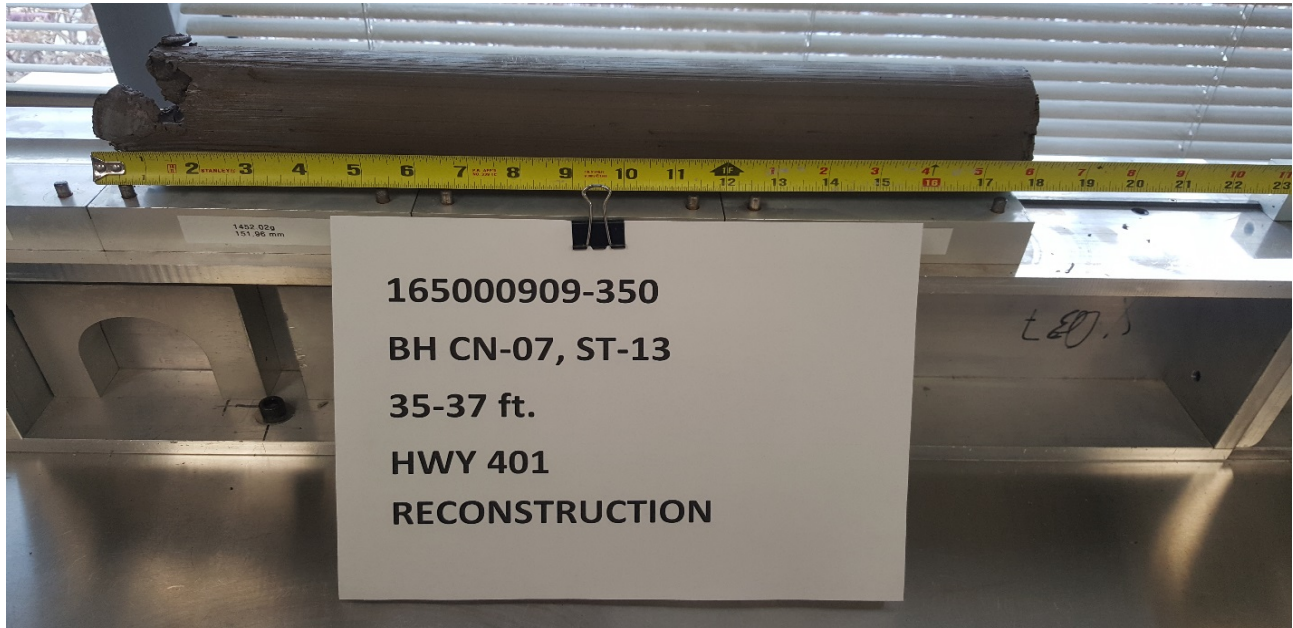


Photo No.: 1	Borehole: CN18-7, ST-13	Depth: 35 – 37 ft
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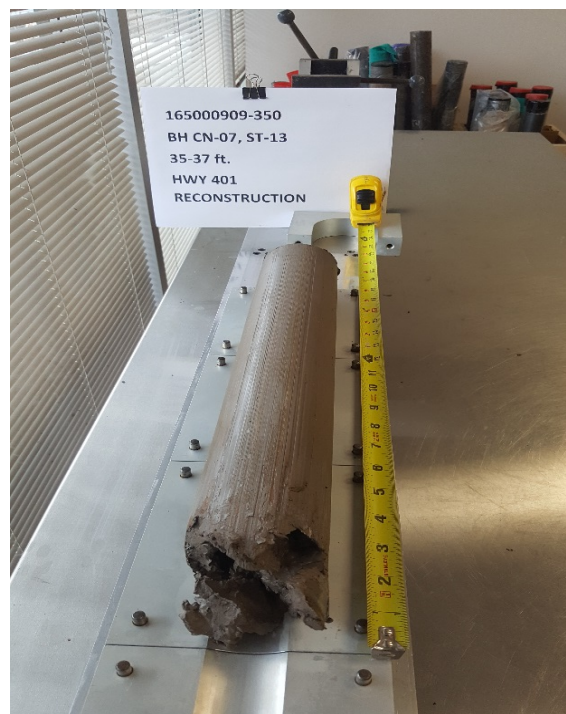


Photo No.: 2	Borehole: CN18-7, ST-13	Depth: 35 – 37 ft
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Figure No. C7

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

**Hwy 401 Reconstruction**  
**165000909.350**  
**CN 18-7**  
**ST-19**  
**70 - 72 ft**

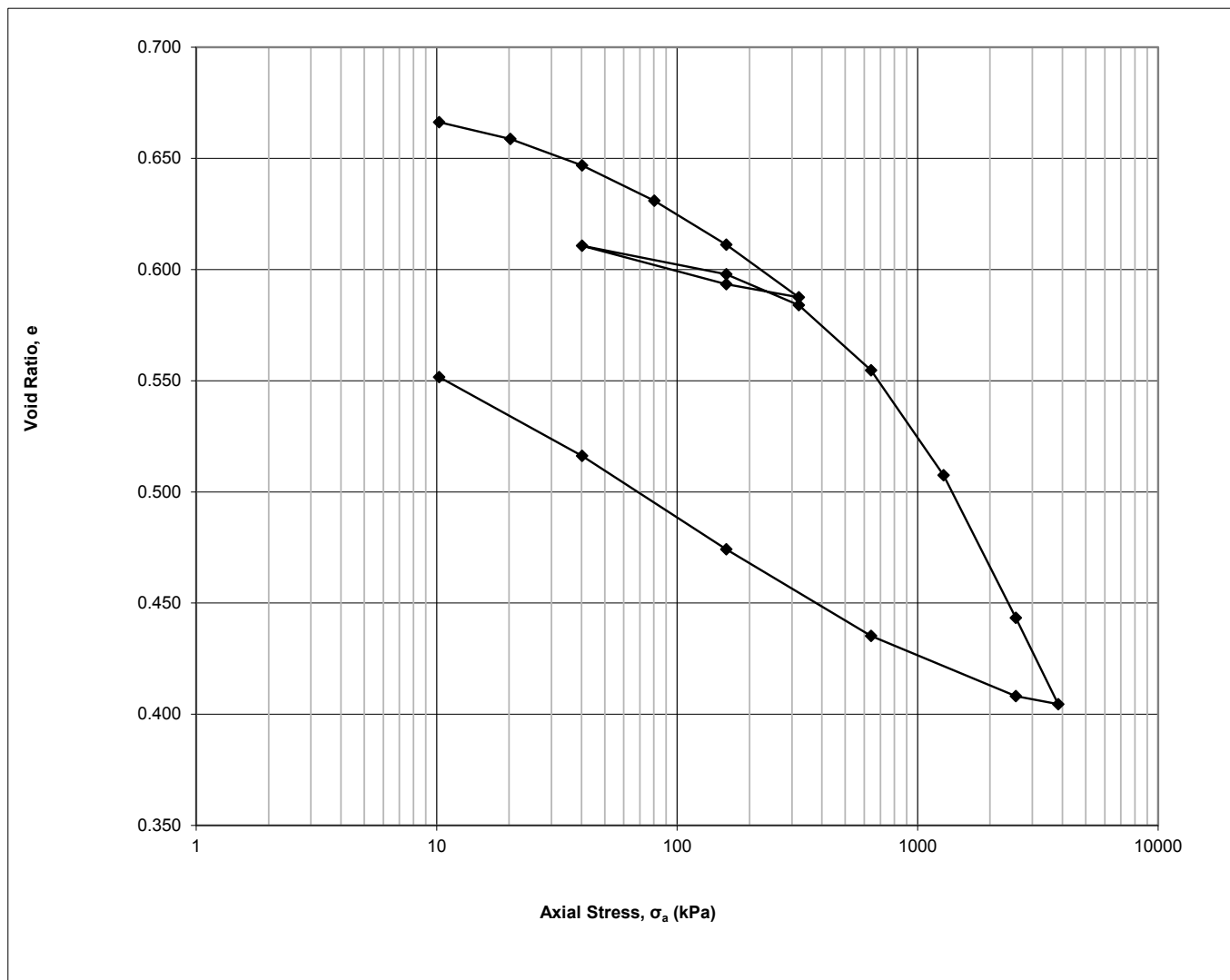


Figure No. C8

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

**Specimen Details**

Project Name	Hwy 401 Reconstruction
Project Location	Ontario, Canada
Borehole	CN 18-7
Sample No.	ST-19
Depth	70 - 72 ft
Sample Date	April 2, 2018
Test Number	Two
Technician Name	Daniel Boateng

**Soil Description & Classification**

Silty Clay Till, Trace Sand, Brown, Moist	
Specific Gravity of Solids	2.738
Liquid Limit %	37
Plastic Limit %	16
Plasticity Index %	21
Average water content of trimmings %	24
<b>Additional Notes (information source, occurrence and size of large isolated particles etc.)</b>	

**Initial Specimen Conditions**

Height	mm	20.00
Diameter	mm	50.00
Area	mm <sup>2</sup>	1963
Volume	mm <sup>3</sup>	39270
Mass	g	79.67
Dry Mass	g	64.26
Density	Mg/m <sup>3</sup>	2.029
Dry Density	Mg/m <sup>3</sup>	1.636
Water Content	%	23.98
Degree of Saturation	%	97.5
Height of Solids	mm	11.95
Initial Void Ratio		0.673

**Final Specimen Conditions**

Water Content	%	21.58
Final Void Ratio		0.552

Figure No. C8

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

**Specimen Details**

Project Name	Hwy 401 Reconstruction
Project Location	Ontario, Canada
Borehole	CN 18-7
Sample No.	ST-19
Depth	70 - 72 ft.
Sample Date	April 2, 2018
Test Number	Two
Technician Name	Daniel Boateng

**Test Procedure**

Date Started	April 19, 2018
Date Finished	April 20, 2018
Machine Number	Frame D
Cell Number	D
Ring Number	D
Trimming Procedure	Turntable
Moisture Condition	Inundated
Axial Stress at Inundation kPa	10
Water Used	Distilled
Test Method	B
Interpretation Procedure for $c_v$	2

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

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**Calculations**

Load Increment	Increment Duration min	Axial Stress $\sigma_a$ kPa	Corrected Deformation $\Delta H$ mm	Specimen Height H mm	Axial Strain $\epsilon_a$ %	Void Ratio e
Seating	0.0	10	0.0000	20.0000	0.00	0.673
1	13.3	10	0.0830	19.9170	0.42	0.666
2	18.3	20	0.1728	19.8272	0.86	0.659
3	19.8	40	0.3158	19.6842	1.58	0.647
4	23.3	80	0.5046	19.4954	2.52	0.631
5	26.5	160	0.7417	19.2583	3.71	0.611
6	30.0	320	1.0242	18.9758	5.12	0.588
7	15.0	160	0.9533	19.0467	4.77	0.593
8	31.5	40	0.7469	19.2531	3.73	0.611
9	20.0	160	0.9011	19.0989	4.51	0.598
10	23.3	320	1.0660	18.9340	5.33	0.584
11	51.8	640	1.4170	18.5830	7.09	0.555
12	48.3	1280	1.9816	18.0184	9.91	0.507
13	65.0	2560	2.7471	17.2529	13.74	0.443
14	65.0	3840	3.2114	16.7886	16.06	0.405
15	10.0	2560	3.1688	16.8312	15.84	0.408
16	25.0	640	2.8451	17.1549	14.23	0.435
17	58.3	160	2.3793	17.6207	11.90	0.474
18	105.3	40	1.8776	18.1224	9.39	0.516
19	144.3	10	1.4530	18.5470	7.27	0.552

**Figure No. C8**

## One-Dimensional Consolidation Test using Incremental Loading

### ASTM D2435/D2435M - 11

**Specimen Details**

Project Name	Hwy 401 Reconstruction
Project Location	Ontario, Canada
Borehole	CN 18-7
Sample No.	ST-19
Depth	70 - 72 ft
Sample Date	April 2, 2018
Test Number	Two
Technician Name	Daniel Boateng

**Calculations**

Load Increment	Axial Stress $\sigma_a$ , average kPa	Calculated using Interpretation Procedure 2				Interpretation Procedure 1		Interpretation Procedure 2	
		Corrected Deformation $\Delta H_{50}$ mm	Specimen Height $H_{50}$ mm	Axial Strain $\epsilon_{a,50}$ %	Void Ratio $e_{50}$	Time $t_{50}$ sec	Coeff. Consol. $c_v$ mm <sup>2</sup> /s	Time $t_{90}$ sec	Coeff. Consol. $c_v$ mm <sup>2</sup> /s
Seating	5								
1	10	0.0622	19.9378	0.31	0.668			135	6.23E-01
2	15	0.1415	19.8585	0.71	0.661			124	6.77E-01
3	30	0.2656	19.7344	1.33	0.651			143	5.75E-01
4	60	0.4257	19.5743	2.13	0.638			153	5.31E-01
5	120	0.6412	19.3588	3.21	0.620			282	2.82E-01
6	240	0.8987	19.1013	4.49	0.598			289	2.68E-01
7	240	0.9701	19.0299	4.85	0.592				
8	100	0.8140	19.1860	4.07	0.605				
9	100	0.8465	19.1535	4.23	0.602			276	2.82E-01
10	240	0.9878	19.0122	4.94	0.591			192	4.00E-01
11	480	1.2404	18.7596	6.20	0.569			279	2.68E-01
12	960	1.6947	18.3053	8.47	0.531			401	1.77E-01
13	1920	2.3215	17.6785	11.61	0.479			365	1.82E-01
14	3200	2.9358	17.0642	14.68	0.428			417	1.48E-01
15	3200	3.1779	16.8221	15.89	0.407				
16	1600	2.9592	17.0408	14.80	0.426				
17	400	2.5667	17.4333	12.83	0.458				
18	100	2.3643	17.6357	11.82	0.475				
19	25	1.8696	18.1304	9.35	0.517				

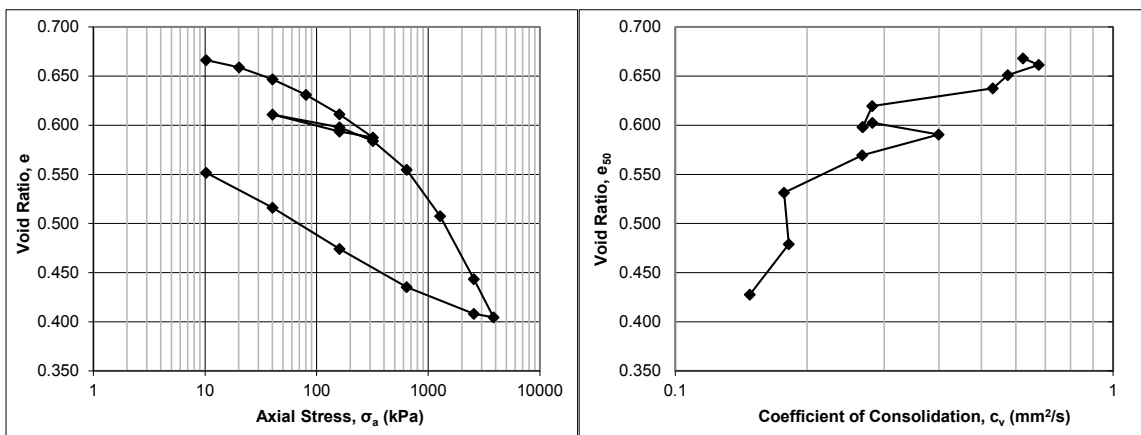



Figure No. C8



	Project No.: 165000909.350	Photo Log
	Project Name: Hwy 401 Reconstruction	

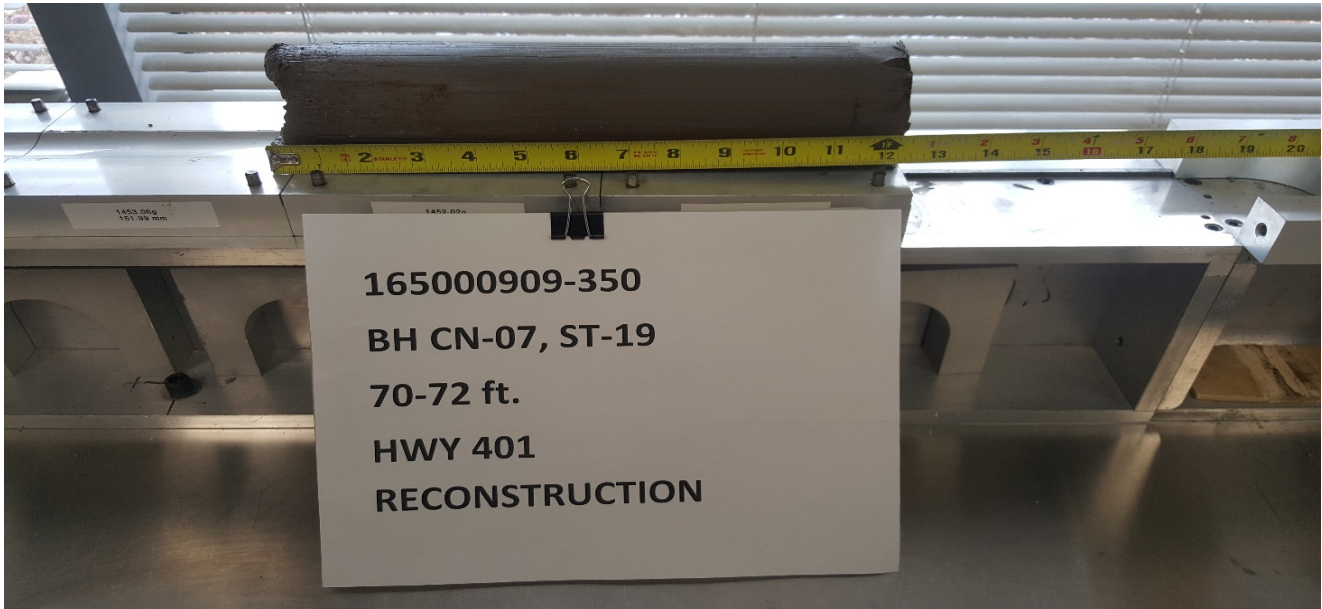


Photo No.:	1	Borehole: CN18-7, ST-19	Depth: 70 – 72 ft
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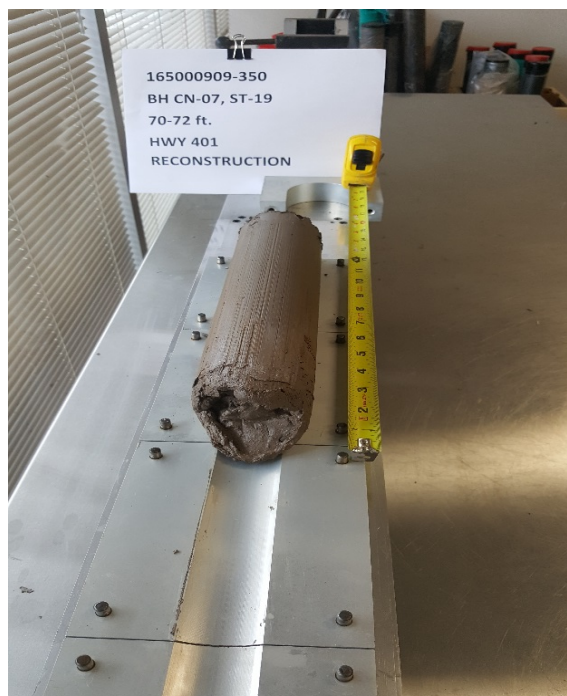


Photo No.:	2	Borehole: CN18-7, ST-19	Depth: 70 – 72 ft
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Figure No. C8



## **APPENDIX D**

Figure D-1 – Geotechnical Model

Figure D-2 – Slope Stability Analysis - Static Analysis (Drained)

Figure D-3 – Slope Stability Analysis - Seismic Analysis (Undrained)

Figures D-4 to D-6 – Settlement Analysis Results

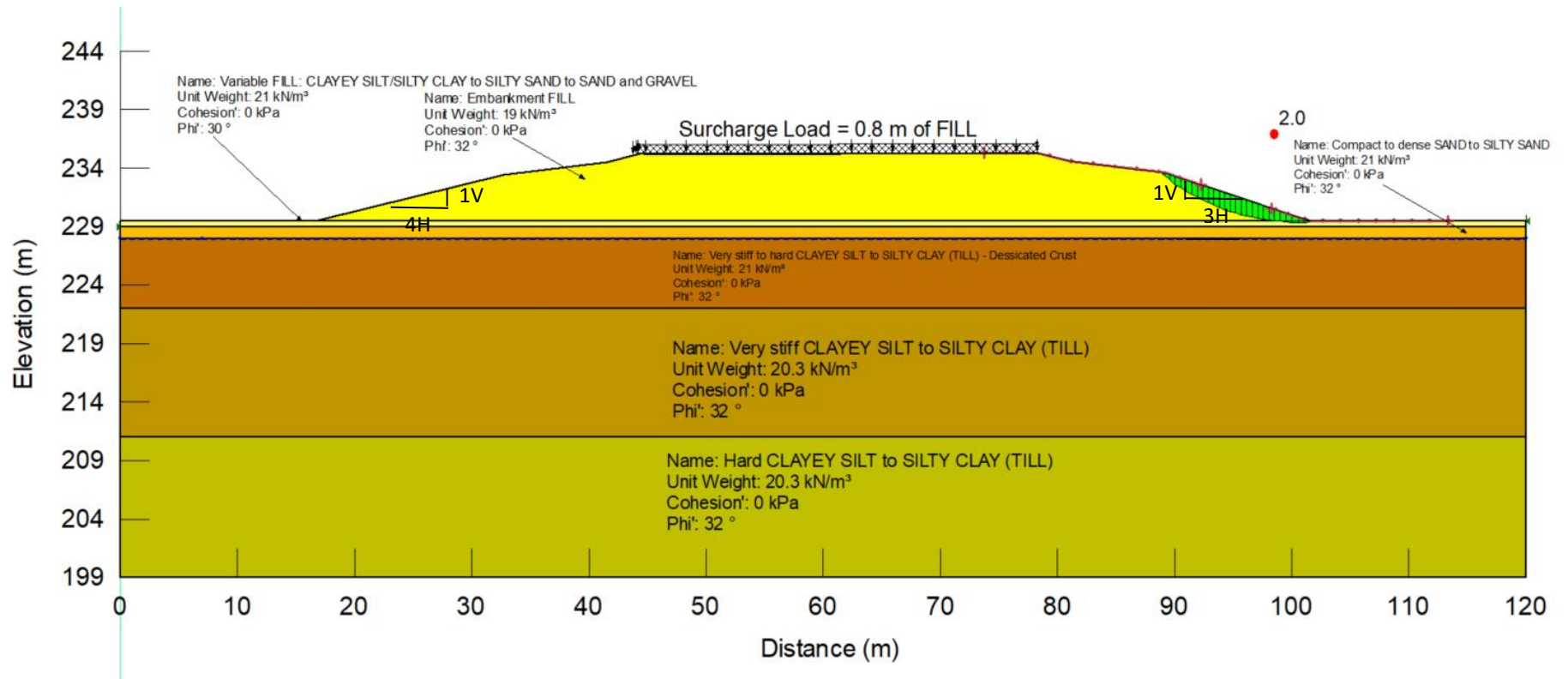




Project Name: Removal of CNR Overhead Structures

Project No.: 165000909 (350)

GeoSlope



Analysis: Static – Drained Analysis  
Final Embankment Configuration

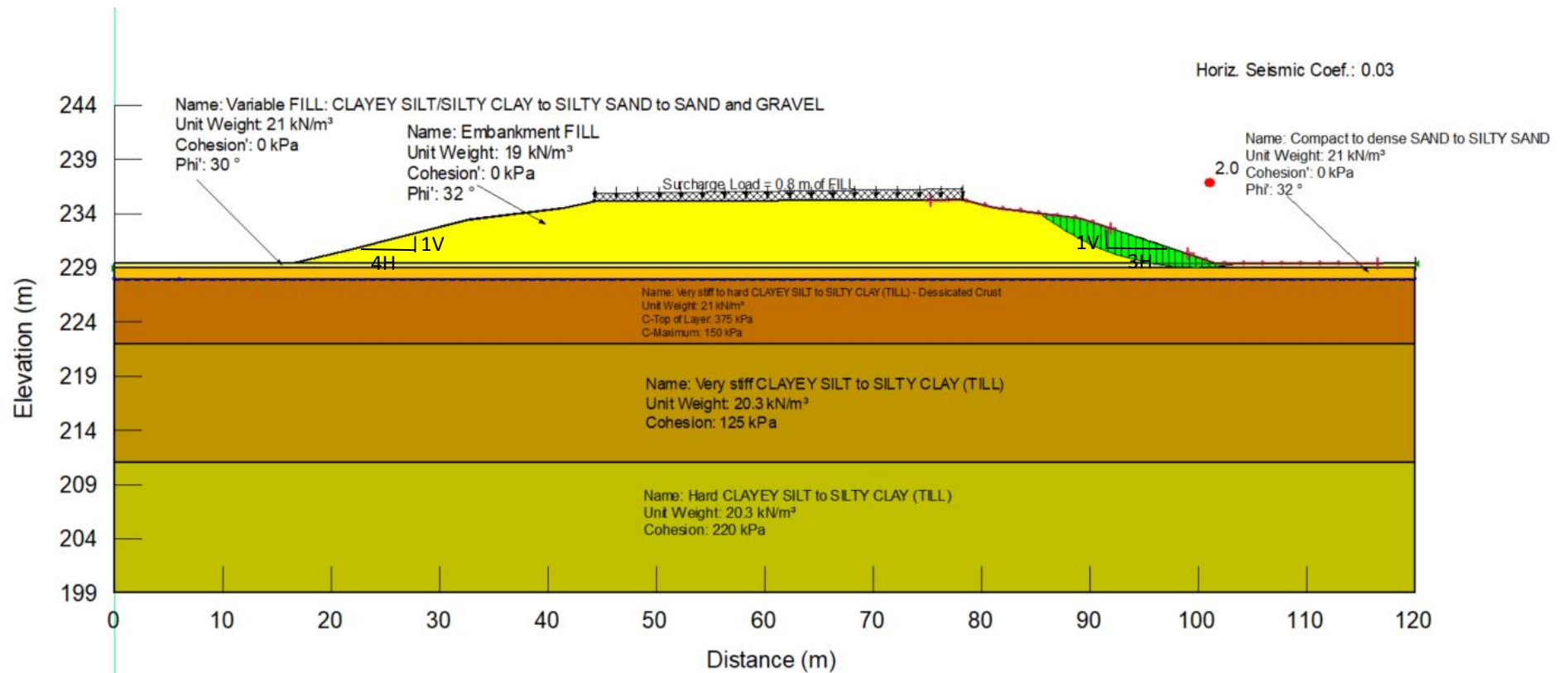
Figure No.: D2



Project Name: Removal of CNR Overhead Structures

Project No.: 165000909 (350)

GeoSlope

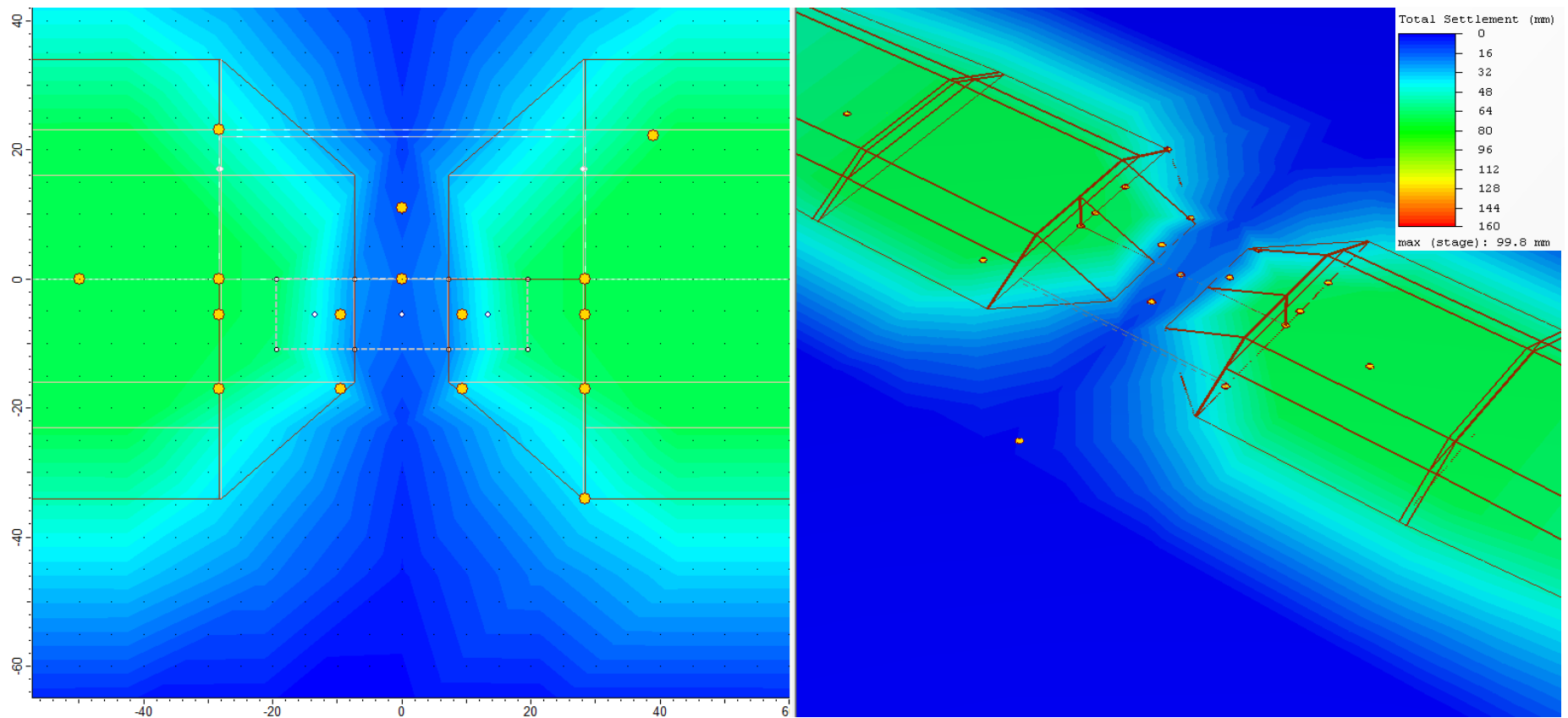


Analysis:

Seismic – Undrained Analysis  
Final Embankment Configuration

Figure No.:

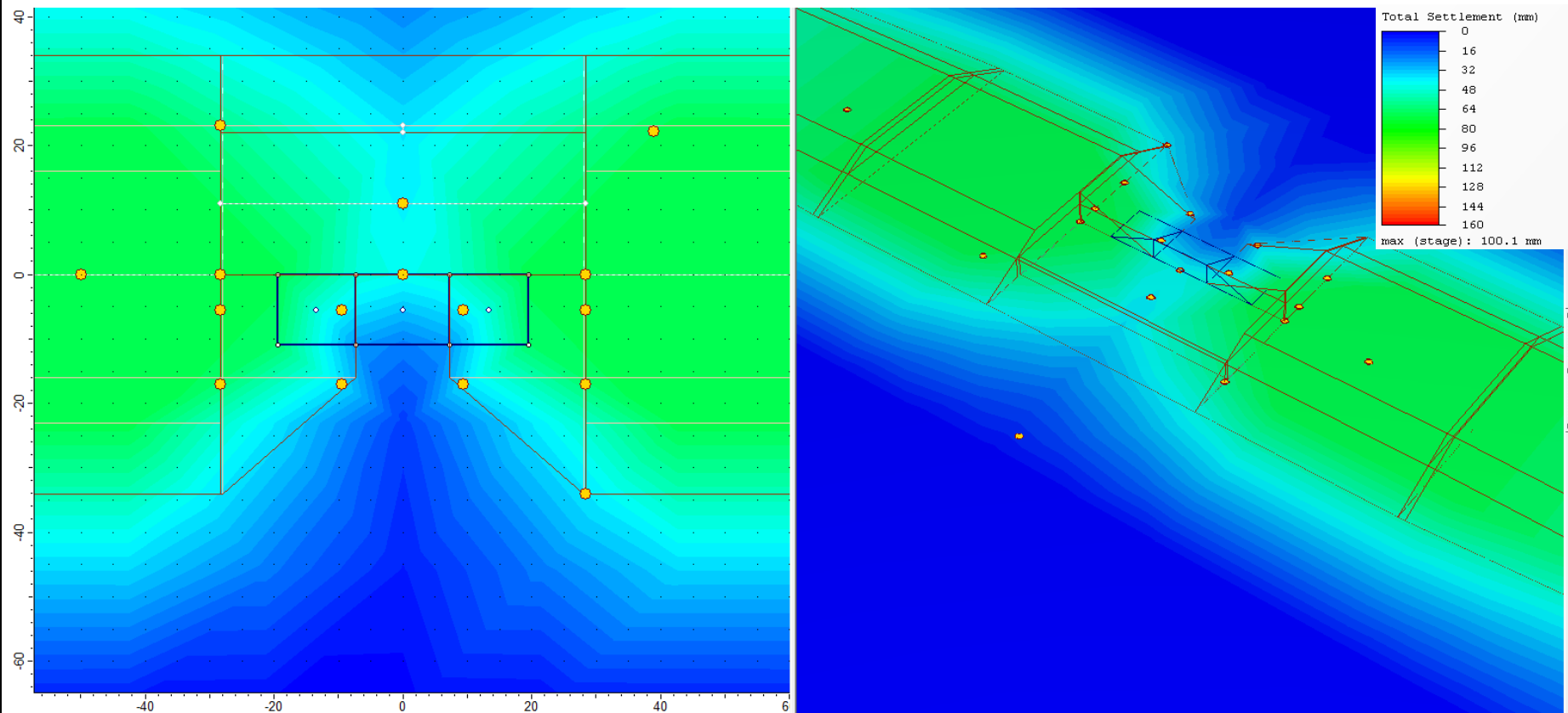
D3



**Settlement Analysis Results**  
**Current Conditions**  
**Hwy 401 - CN Rail**

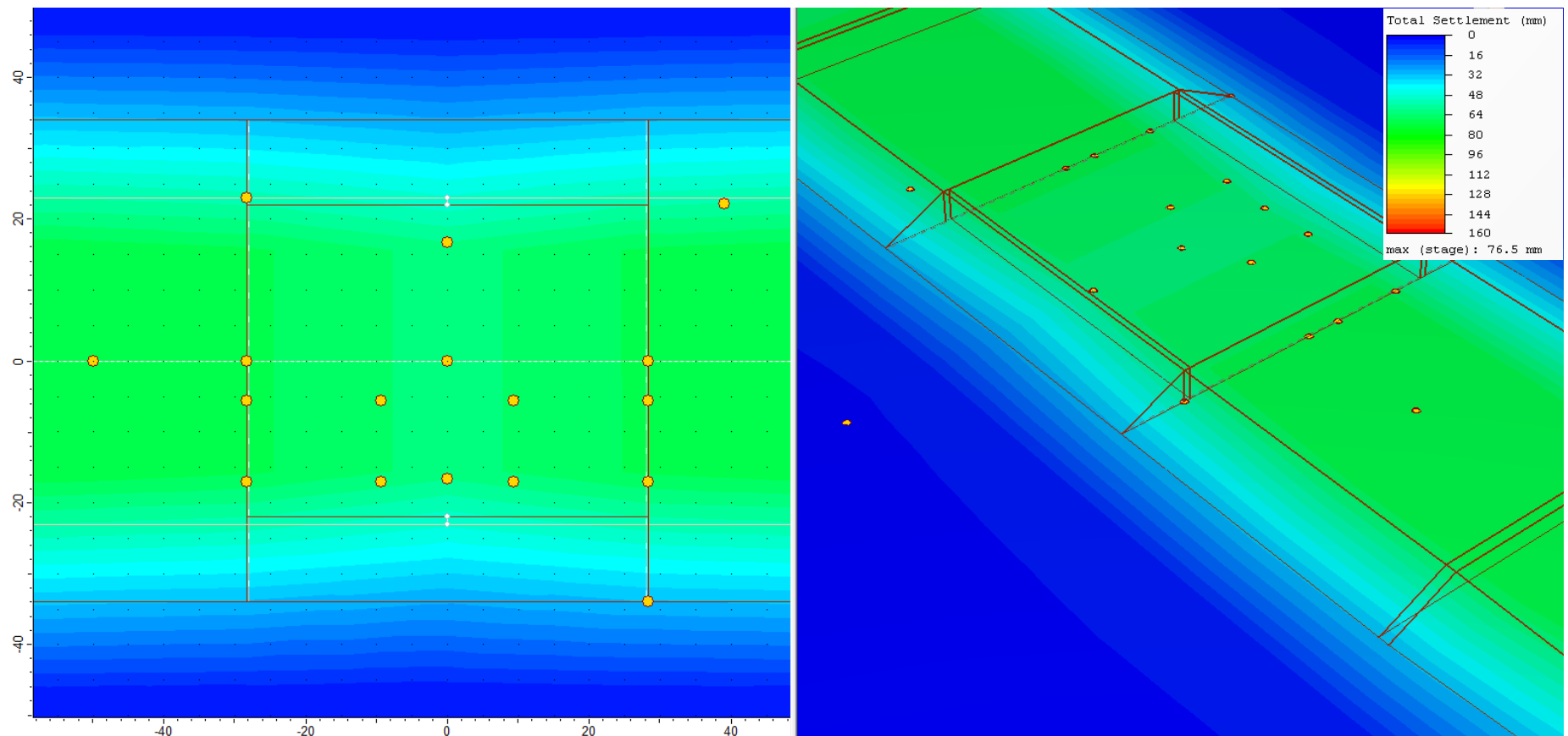
**Figure D-4**

**Project No.**  
**165000909.350**



**Settlement Analysis Results**  
**Stage 1 (Infilling on One Side of the Highway)**  
**Hwy 401 - CN Rail**

**Figure D-5**  
**Project No.**  
**165000909.350**



**Settlement Analysis Results**  
**Final 5.5 m High Embankment Configuration**  
**Hwy 401 - CN Rail**

**Figure D-6**

**Project No.**  
**165000909.350**