



## **Foundation Investigation and Design Report**

Rehabilitation of Highway 402 – Colonel  
Talbot Road to Highway 401  
Replacement of CB Smith Municipal  
Drain Culverts – W-N/S Ramp

(Site No. 19X-0763/C0)  
Highway 402, City of London, ON

Latitude 42.898829

Longitude -81.272730

G.W.P. 3108-18-00

Geocres No. 40114-198

December 16, 2021

Prepared for:

Ministry of Transportation Ontario

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Project No. 165001222 (340)



**FOUNDATION INVESTIGATION AND DESIGN REPORT  
REHABILITATION OF HIGHWAY 402 – COLONEL TALBOT ROAD TO HIGHWAY 401  
REPLACEMENT OF CB SMITH MUNICIPAL DRAIN CULVERTS – SITE 19X-0763/C0**

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Introduction  
December 16, 2021

**FOUNDATION INVESTIGATION REPORT**

For

G.W.P. 3108-18-00

Rehabilitation of Highway 402 – Colonel Talbot Road to Highway 401

Replacement of CB Smith Municipal Drain Culverts

Site No. 19X-0763/C0, W-N/S Off-Ramp to Wonderland Road

City of London, Middlesex County, Ontario

## **1.0 INTRODUCTION**

Stantec Consulting Ltd. (Stantec) was retained by the Ministry of Transportation, Ontario (MTO) under Retainer Agreement 3019-E-0009 to complete the Class Environmental Assessment, detailed design, and construction contract preparation for GWP 3108-18-00, Rehabilitation of Highway 402 between Colonel Talbot Road and Highway 401, in the City of London.

The highway rehabilitation is proposed to include the replacement or rehabilitation of corrugated steel plate (CSP) structural culverts at three locations, pavement rehabilitation and the installation of traffic signals at the Wonderland Road south ramp terminal. The foundations engineering component for this GWP includes provision of foundation investigation and engineering services at the three structural culvert sites where culvert rehabilitation or replacement is planned.

This report presents the results of a foundation investigation conducted for the replacement of the twin CSP structural culverts at Site No. 19X-0763/C0 which is located at approximately Station 0+340 on the Highway 402 W-N/S off-ramp of the Wonderland Road South interchange. The culvert site is located at Latitude 42.898829° and Longitude - 81.272730° approximately 315 m west of Wonderland Road South.

The purpose of the foundation investigation was to obtain subsurface soil and groundwater information by drilling three (3) boreholes, carrying out in-situ testing, installing a temporary groundwater monitoring well, 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 replacement of the structural culverts at Site No. 19X-0763/C0. Separate foundation investigation and design reports have been prepared for the other sites included in this Contract.



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Site Description and Geology

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## **2.0 SITE DESCRIPTION AND GEOLOGY**

### Site Location

The location of Site No. 19X-0763/C0 is shown on the Key Plan inset to Drawing No. 1 provided in Appendix A. The existing twin CB Smith Municipal Drain culverts cross beneath the W-N/S off-ramp from Highway 402 to Wonderland Road South approximately 315 m west of Wonderland Road South in the City of London. The culverts cross the ramp near Station 0+340 of the ramp (for reference, chainage along the ramp increases from west to east).

### General Site Description

Within the project study area, Highway 402 is a four-lane freeway with two lanes in each direction that are divided by a wide, grass-covered median. At the subject site, the orientation of the highway is approximately southwest-northeast. The W-N/S ramp connects the eastbound lanes of Highway 402 to Wonderland Road South. At the location of Site No. 19X-0763/C0, the W-N/S ramp is oriented approximately east-west and consists of a single traffic lane with a wide paved shoulder on the right-hand side.

Both the highway and the off-ramp have been constructed on embankments. The paved surface of the W-N/S ramp is at an elevation of about 254 m to 254.5 m, which is approximately 4 m higher than the base of the municipal drain channel on both sides of the ramp embankment. The drain channel is estimated to be about 1.5 m to 2 m lower than the surrounding grades.

The CB Smith Municipal Drain channel also passes underneath Highway 402 approximately 50 m to the northwest of the site at Site No. 19X-0764/C0. Beyond the channel and associated drainage features, the overall topography surrounding the culvert site is relatively flat to gently sloping.

Vegetative cover on the side slopes of the ramp embankment consists of grass and weeds whereas trees and brush vegetation are present beyond the ends of the culverts. A tree is present between the barrels of the twin culverts just beyond the outlets on the north side of the ramp.

### Existing Culverts

The CB Smith Municipal Drain culverts were constructed circa 1998 and consist of twin corrugated steel pipe (CSP) culverts, each with a diameter of 2.44 m and an overall length of about 31.7 m. The culverts are oriented at a skew of approximately 35° to the direction of the ramp. There is approximately 1.5 m of fill on top of the culvert beneath the travelled surface of the ramp. The approximate alignments of the existing culverts are shown on Drawing No. 1 in Appendix A. Flow in the culverts is from south to north.

An August 2021 inspection of the culverts by Stantec personnel indicated that the CSPs have corrosion with section loss, including a significant number of small perforations, along the waterline.





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The following photos illustrate the conditions at the ends of the existing culverts at the time of the investigation.



**Photo No. 1: View of the north end of the culverts**



**Photo No. 2: View of the south end of the culverts**



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Available Subsurface Information  
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Physiographic Description

The site is located within a physiographic region known as the Mount Elgin Ridges. According to the Physiography of Southern Ontario, by Chapman and Putnam (1984), this region is generally composed of “moraines of pale brown calcareous clay or silty clay and vales that commonly comprise alluvium of gravel, sand, or silt”.

Available Surficial Geology Mapping of Southern Ontario indicates that the culvert is located within fine-textured glaciolacustrine deposits consisting of silt and clay with minor sand and gravel.

A review of well records in the Ontario Ministry of Environment, Conservation, and Parks (MECP) database for wells within an approximate 1 km radius of the site indicated bedrock was encountered at depths greater than 50 m below the ground surface in the vicinity of the site.

### **3.0 AVAILABLE SUBSURFACE INFORMATION**

No foundation investigation reports were available for Site No. 19X-0763/C0 in the MTO GEOCREs database/library. However, subsurface information at the site of the Wonderland Road underpass at Highway 402, located about 400 m northeast of the culverts, was obtained from the following document:

- ‘Foundation Investigation Report for Bostwick Road Bridge, Hwy. 402, Twp. Of Westminster, Dist. 2, London, W.P. 4I-66-07, Site 19-545’, GEOCREs No. 40I14-96, prepared by Ministry of Transportation and Communication’s Soil Mechanics Section and dated July 15, 1975.

The report included subsurface information from three (3) sampled boreholes advanced to a maximum depth of approximately 41.6 m at the bridge site between the dates of May 29th and June 4th, 1975. A borehole location plan and borehole records from this investigation are included in Appendix B for reference.

The subsurface stratigraphy encountered in the boreholes consisted of a compact to dense sandy silt deposit that extended to depths of between 5.2 m and 6.4 m below ground surface (corresponding to Elevations of about 247 m and 248 m); which was underlain by an extensive deposit of firm to hard clayey silt that extended to a depth of at least 41.6 m at the deepest borehole (corresponding to an elevation of approximately 212 m).

Groundwater was encountered in the sandy silt deposit at depths of approximately 0.9 m and 1.5 m below ground surface in two boreholes (corresponding to Elevations of about 251.9 m to 252.2 m).





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Investigation Procedures  
December 16, 2021

## **4.0 INVESTIGATION PROCEDURES**

### **4.1 FIELD INVESTIGATION**

The subsurface investigation for the culvert replacement consisted of advancing three boreholes, designated as Boreholes 21-763-1 to 21-763-3. Borehole 21-763-1 was drilled near the north end (outlet) of the culverts, Borehole 21-763-2 was drilled through the paved shoulder of the ramp embankment and Borehole 21-763-3 was drilled near the south end (inlet) of the culverts. The locations of the boreholes 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 to mark and clear the borehole locations of public and MTO-owned utilities.

Drilling was carried out with a Diedrich D-50T rubber track-mounted drill rig equipped for soil sampling. The boreholes were advanced using continuous flight hollow-stem augers. Water was added to the top of the augers during drilling to reduce the hydrostatic pressure thereby minimizing the potential for soil heaving inside the bottom of the 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 thereafter). The split spoon samples recovered from the SPTs were returned to Stantec's Ottawa laboratory for detailed classification and testing. In situ shear vane testing using a N-size vane was attempted at several depths in the boreholes.

Following completion of drilling, a 50-millimeter (mm) diameter groundwater monitoring well, screened over a depth of about 3.8 m to 6.9 m below ground surface, was installed in Borehole 21-763-2. The borehole annulus surrounding the slotted pipe section was backfilled with sand. The remainder of the borehole annulus was backfilled with bentonite up to the ground surface. Groundwater level measurements were obtained on July 19<sup>th</sup>, and in the morning and in the afternoon of July 20<sup>th</sup>, 2021 and the monitoring well was subsequently decommissioned.

The remaining two boreholes were backfilled with bentonite chips on completion of drilling.

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

The borehole locations and respective ground surface elevations were surveyed by Stantec Geomatics personnel. The borehole survey data is considered accurate to 0.1 m for coordinates and elevations.

Table 4.1 below summarizes the borehole survey information and includes the drilling depth, end of borehole elevation and number of samples recovered for each borehole.



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Subsurface Conditions

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**Table 4.1: Borehole Information Summary**

	Borehole Number		
	21-763-1	21-763-2	21-763-3
MTM Zone 11 Coordinates Northing Easting	4751744.7 405010.7	4751731.7 405044.6	475173.7 405038.6
Ground Surface Elevation, m	252.0	254.3	253.1
Total Depth Drilled, m	11.9	15.9	12.8
End of Borehole Elevation, m	240.1	238.4	240.3
Number of soil samples	13	16	13

## 4.3 LABORATORY TESTING

All samples were visually examined by a Geotechnical Engineer. Select soil samples were submitted for gradation analysis, Atterberg Limits testing and moisture content testing. The geotechnical laboratory testing program completed on the borehole samples is summarized below in Table 4.2.

**Table 4.2: Laboratory Testing Program**

Laboratory Test Type	Number of Tests
Moisture Content	41
Gradation Analysis	11
Atterberg Limits	9

In addition to the geotechnical laboratory testing, chemical analysis consisting of pH, sulphate content, chloride content and resistivity was completed by Paracel Laboratories in Ottawa on one sample from Site 19X-0763/C0 and three samples from nearby Site 19X-0764/C0.

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 and the results of the in situ and laboratory testing are shown on the Borehole Records included in Appendix B. An explanation of the symbols and terms used to describe the Borehole Records is also provided in Appendix B. The results of the geotechnical laboratory testing are presented on Figures C1 to C7 contained 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



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rather than exact boundaries between geological units. The subsurface conditions will vary between and beyond the borehole locations.

In general, the subsurface stratigraphy encountered in the boreholes consists of surficial topsoil or asphalt that is underlain by fill materials varying in composition from clayey silt to sandy silt to sand and gravel. The fill materials are underlain by cohesionless deposits of silt/sandy silt which are in turn underlain by native clayey silt and at increasing depth by clayey silt till. The silty/sandy silt deposits contain layers/zones of clayey silt and were typically encountered to depths of 5.3 m to 7.6 m below ground surface (corresponding to Elevations at about 246.5 m to 246.7 m). The clayey silt contains trace sand with frequent thin silt interlayers or partings and extended to depths of about 8.5 m to 10.8 m below ground surface (corresponding to Elevations at about 243.2 m to 243.5 m). All boreholes were terminated in the clayey silt till at depths of about 10.8 m to 12.8 m below ground surface (corresponding to Elevations at about 240.1 m to 243.5 m).

More detailed descriptions of the subsurface conditions encountered in the boreholes are provided in the following sections.

## **5.2 OVERBURDEN**

### **5.2.1 Topsoil**

Topsoil was encountered at the ground surface in Boreholes 21-763-1 and 21-763-3. The topsoil was approximately 150 mm and 250 mm thick, respectively, at these borehole locations.

### **5.2.2 Asphaltic Concrete**

Asphaltic concrete was encountered at the ground surface in Borehole 21-763-2. The asphalt layer was approximately 100 mm thick.

### **5.2.3 Fill**

Fill materials were encountered below the topsoil or the asphaltic concrete in all three boreholes. The fill was heterogeneous in nature and varied from cohesive fill in Borehole 21-763-1 to predominantly cohesionless fill in Boreholes 21-763-2 and 21-763-3. The cohesive fill consisted of clayey silt containing some sand and trace gravel. The cohesionless fill varied in composition from sandy silt to sand/gravelly sand to sand and gravel and contained clayey silt inclusions. Cobbles and/or boulders were encountered at various locations within the fill materials.

The fill materials were encountered to depths of approximately 0.9 m to 3.4 m below ground surface, corresponding to elevations ranging between approximately 250.8 m and 251.0 m.

Standard Penetration Test (SPT) 'N' values recorded in the fill generally ranged from 6 to 16 blows per 300 mm advancement of the split spoon sampler indicating these materials are loose to compact. An SPT 'N' value of 27 was recorded in the granular, pavement structure fill in Borehole 21-763-2.



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Laboratory tests conducted on samples of the fill yielded natural moisture contents ranging from 3% to 20% expressed as a percentage of the dry weight of the soil.

Two (2) samples of the cohesionless fill materials were selected for gradation analysis. The laboratory test results are shown on the borehole records in Appendix B and on the gradation curves on Figure No. C1 in Appendix C. Based on the test results, the cohesionless fill materials tested vary in composition from sand (SM) to sand and gravel (SP/GP).

#### **5.2.4 SILT/SANDY SILT**

The fill materials are underlain by native deposits varying in composition from silt to sandy silt that contain thin layers or zones of clayey silt and zones of silty sand. Thicker interbeds of clayey silt ranging from approximately 0.6 m to 0.8 m in thickness were encountered within the silt/sandy silt strata in Boreholes 21-763-1 and 21-763-3 at depths of approximately 3.2 m and 4.5 m below ground surface, respectively.

The silt/sandy silt deposits were encountered to depths between 5.3 m and 7.6 m below ground surface, which correspond to elevations of between 246.5 m and 246.7 m.

SPT 'N' values in the silt/sandy silt deposits varied from 2 to 14 but were more typically in the 5 to 10 range which indicate these materials are generally loose to compact zones.

Laboratory testing of samples of the native silt deposits yielded moisture contents ranging from 16% to 24% expressed as a percentage of the dry weight of the soil.

Five (5) samples of the native silt/sandy silt deposits containing layers/zones of clayey silt were selected for gradation analysis. The laboratory test results are shown on the borehole records in Appendix B and on the gradation curves on Figure No. C2 in Appendix C.

Atterberg Limits tests were also carried out on the five samples referenced above. One sample (Sample 6 from Borehole 21-763-2) was determined to be non-plastic. The tests on the remaining samples, which were typically carried out on the zones of clayey silt within the overall silt deposit, yielded Liquid Limits ranging from 21% to 34%, Plastic Limits ranging from 14% to 21%, and Plasticity Indices ranging from 7% to 14%. The results of the Atterberg Limits test are shown on the borehole records and are illustrated on Figure C3 in Appendix C.

Based on the test results, these materials are classified as silt/sandy silt (ML) to clayey silt (CL to CL-ML) of low plasticity in accordance with the Unified Soil Classification System (USCS). However, the CL to CL-ML results are interpreted to be representative of the clayey silt zones/layers within the silt/sandy silt deposit but not the overall silt deposit.

#### **5.2.5 CLAYEY SILT**

A deposit of clayey silt was encountered beneath the silt/sandy silt deposits in all three boreholes. This deposit contained varying amounts of sand with occasional thin silt layers and seams.



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**Subsurface Conditions**

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The clayey silt stratum was encountered to depths between 8.5 m and 10.8 m below ground surface corresponding to elevations of between 243.2 m and 243.5 m.

SPT 'N' values in the clayey silt ranged from 4 to 10 blows. In situ shear vane tests were attempted at various depths within the clayey silt deposits in all three boreholes but the vane could not be turned. Based on the field testing and manual examination of the retrieved samples, the consistency of the clayey silt is considered to vary from firm to very stiff but this deposit is typically stiff to very stiff.

Laboratory testing of samples of clayey silt yielded moisture contents ranging from 19% to 25%.

Three (3) samples of the clayey silt, including one sample of the thicker clayey silt layer encountered within the silt/sandy silt deposit in Borehole 21-763-1) were selected for gradation analysis. The results of the tests are shown on the borehole records and are illustrated on the gradation curves in Figure No. C4 in Appendix C.

Atterberg Limits tests were carried out on portions of the three samples referenced above. The tests yielded Liquid Limits ranging from 21% to 27%, Plastic Limits ranging from 12% to 14%, and Plasticity Indices ranging from 7% to 15%. The results of the Atterberg Limits test are shown on the borehole records and are illustrated on Figure C5 in Appendix C. The laboratory results indicate that the materials tested are comprised of clayey silt of low plasticity and have a group symbol of CL in accordance with the Unified Soil Classification System (USCS).

### **5.2.6 CLAYEY SILT (TILL)**

A deposit of glacial till consisting of clayey silt to sandy clayey silt was encountered beneath the clayey silt in all three boreholes. This deposit contained varying amounts of sand and trace gravel and occasional cobbles. Low/poor sample recovery in Borehole 21-763-3 at a depth of 12.2 m (Sample SS13) was inferred to have been caused by the presence of cobbles. The till deposits of southern Ontario are known to contain cobbles and boulders and these materials should be anticipated to be present throughout the till deposit at this site.

The boreholes were terminated within the glacial till stratum at depths of between 8.5 m and 10.8 m below ground surface, corresponding to elevations of approximately 238.4 m to 240.3 m.

SPT 'N' values in the glacial till ranged from 16 to 32. Based on the field testing, the glacial till is considered to have a very stiff to hard consistency.

Laboratory testing of samples of the glacial till yielded moisture contents ranging from 10% to 20%.

One (1) sample of the glacial till was selected for gradation analysis. The results of this test are shown on the borehole record and are illustrated on the gradation curve in Figure No. C6 in Appendix C.

An Atterberg Limits test was carried out on the sample referenced above. The test yielded Liquid Limit of 28%, Plastic Limit of 15%, and Plasticity Index of 13%. The results of the Atterberg Limits test are shown on the borehole record and are illustrated on Figure C7 in Appendix C. The laboratory results indicate that the glacial till is comprised of sandy, clayey silt of low plasticity (CL).



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Subsurface Conditions

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### **5.3 BEDROCK**

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

### **5.4 GROUNDWATER CONDITIONS**

Boreholes 21-763-1 and 21-763-3 were advanced near the ends of the culverts. Free groundwater was observed in the open boreholes at the time of drilling at depths of approximately 2.0 m to 2.8 m below ground surface corresponding to elevations of about 250.0 m to 250.3 m.

Borehole 21-763-2 was drilled on the paved shoulder of the ramp. A monitoring well was installed in the sandy silt and silt deposits in this borehole. The water level in the monitoring well was recorded at a depth of 3.4 m below existing grade (corresponding to an elevation of 250.9 m) on the morning and afternoon of July 20<sup>th</sup>, 2021. The monitoring well was decommissioned after taking the final water level reading.

Groundwater levels at the site will be subject to fluctuations due to seasonal changes, precipitation events and the water level in the municipal drain. The water levels should be expected to be higher during the spring season or during and following periods of heavy precipitation or snow melt.

### **5.5 CHEMICAL ANALYSIS**

Chemical analyses related to parameters associated with the potential for corrosion or sulphate attack (i.e. pH, resistivity, and chloride and sulphate content) were completed by Paracel Laboratories Inc. on one (1) sample (of the native sandy silt soil) from this culvert Site 19X-0763/C0 and three (3) samples (one of the clay fill, one of the native silty sand soil, and one of the native sandy silt soil) from the adjacent Site 19X-0764/C0. These analysis results are summarized in Table 5.1.

**Table 5.1: Results of Chemical Analysis**

<b>Borehole No</b>	<b>Sample No.</b>	<b>Depth (m)</b>	<b>pH</b>	<b>Chloride (µg/g)</b>	<b>Sulphate (µg/g)</b>	<b>Resistivity (Ohm-m)</b>
21-763-3	5	3 - 3.6	7.72	10	218	33.2
21-764-1	2	0.75 - 1.35	7.56	672	100	7.2
21-764-3	7	4.6 - 5.2	7.65	301	191	14.0
21-764-4	6	3.8 – 4.4	7.49	642	189	7.9





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## **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.

Utility locates were arranged by Stantec staff prior to initiation of drilling.

The drilling equipment was supplied and operated by London Soil Test Ltd. based in London, Ontario.

The borehole locations and elevations were surveyed by Stantec's Geomatics division.

Geotechnical laboratory testing was carried out at Stantec's laboratories in Markham and Ottawa, Ontario.

This report was prepared by David Lee, P.Eng., 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 described 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;

**STANTEC CONSULTING LTD.**



David Lee, P.Eng.  
Geotechnical Engineer



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Designated Principal MTO Foundation Contact



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**FOUNDATION INVESTIGATION AND DESIGN REPORT**

For

G.W.P. 3108-18-00

Rehabilitation of Highway 402 – Colonel Talbot Road to Highway 401

Replacement of CB Smith Municipal Drain Culverts

Site No. 19X-0763/C0, W-N/S Off-Ramp to Wonderland Road

City of London, Middlesex County, Ontario

## **8.0 DISCUSSIONS AND ENGINEERING RECOMMENDATIONS**

### **8.1 OVERVIEW**

This section provides foundation design recommendations for the proposed replacement of the existing culverts at the site referenced above. The recommendations are based on interpretation of the factual data obtained from the subsurface investigation and the results of the laboratory testing program completed on samples obtained from the subsurface investigation. The discussion and input presented herein is intended to provide the designers with sufficient information to assess the feasible foundation alternatives and to complete the design of the culvert replacement.

Comments provided with respect to construction 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**

#### **8.2.1 Proposed Works**

The existing CB Smith Municipal Drain culverts that cross beneath the W-N/S off-ramp from Highway 402 to Wonderland Road South in the City of London consist of twin corrugated steel pipe (CSP) culverts, each with a diameter of 2.44 m and an overall length of about 31.7 m. The locations and alignment of these culverts are shown on Drawing 1 in Appendix A.

The existing twin CSP culverts are planned to be replaced with a single rigid frame concrete box culvert that is planned to be located on the same alignment as the existing eastern culvert. Based on preliminary design plans, it is understood that the replacement culvert will have a span of approximately 4.8 m and a height of approximately 2.7 m. The new culvert is to consist of precast concrete box units and will have an invert level of about 250.25 m which translates to a founding elevation for the base of the new box culvert of approximately 249.9 m.



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The final embankment configuration is planned to match existing conditions or to be flattened slightly. Final embankment side-slopes are to be 2 horizontal to 1 vertical (2H:1V) or flatter. No retaining walls or wing walls are planned as part of the culvert replacement.

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

Replacement of the culverts at Site No. 19X-0763/C0 is planned to be completed with the W-N/S ramp fully closed during construction requiring detours for local traffic. No temporary road protection systems are envisioned to be required for the excavations since there should not be any adjacent active traffic during construction.

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

The Canadian Highway Bridge Design Code (CHBDC) [2019] 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 includes the geotechnical properties on the site 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” and a “Typical Consequence” Classification have been adopted for design purposes.

## **8.4 GEOTECHNICAL DESIGN PARAMETERS**

The soil conditions encountered in the boreholes advanced near the planned culvert replacement generally consist of surficial layers of topsoil fill or asphalt, underlain by fill materials, underlain by a stratum of native sandy silt to silt, underlain by deposits of clayey silt to clayey silt till.

Table 8.1 provides the geotechnical properties for the stratigraphy encountered in the boreholes.

The elevations provided in Table 8.1 reflect a synthesis of the borehole data and are not based on any specific location; reference should be made to the Record of Boreholes for conditions at specific locations.



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**Table 8.1: Geotechnical Model – CB Smith Municipal Drain Culvert (Site 19X-0763/C0)**

Elevation (m)		Soil Type	Design Parameters			
From	To		Total Unit Weight $\gamma$ (kN/m <sup>3</sup> )	<sup>2</sup> Drained Friction Angle $\phi'$ (°)	<sup>3</sup> Undrained Shear Strength $S_u$ (kPa)	<sup>4</sup> Soil Modulus $E$ (MPa)
Ramp Surface	251.0	Embankment FILL: Loose to compact, SAND / SAND and GRAVEL to loose Sandy SILT (ML)	21	30	N/A	15
251.0	246.5	Loose to compact, Sandy SILT to SILT (ML) with clayey silt zones and layers	19	28	N/A	15
246.5	243.5	Stiff to very stiff, CLAYEY SILT (CL) with silt seams/interlayers	20	30	100	35
243.5	<239	TILL: Very stiff to hard, CLAYEY SILT (CL)	21	32	150	75

- Notes:
- 1 It is presumed that the FILL materials immediately adjacent to the existing culverts extend to an elevation of about 250.2 m (e.g. the inferred level of the bedding material below the existing culverts).
  - 2 The friction angle is applicable to drained conditions only
  - 3 The shear strength is applicable to undrained conditions only
  - 4 As the final embankment and loading conditions will be similar to the existing conditions, the unload/reload modulus has been used for the native soils.

The groundwater level measured in the monitoring well installed in Borehole 21-763-2 (screened in the native silt/sandy silt soils) was at an elevation of approximately 250.9 m at the time of the investigation. A static groundwater level at an elevation of 251 m is recommended for design purposes.

## 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.

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. However, frost protection is not required for a box culvert as this type of culvert can typically tolerate a small magnitude of movement associated with freeze-thaw cycles.

The depth of frost penetration stated should, however, be considered in the design of frost tapers for the culvert backfill.

## 8.6 SEISMIC DESIGN CONSIDERATIONS

### 8.6.1 Classification for Seismic Design

The structural design team will need to confirm the seismic design requirements in accordance with the CHBDC. The culvert falls within the “Other Bridges” Seismic Importance Category outlined in the CHBDC.



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Based on subsurface information available from the previous investigation at the nearby Wonderland Road underpass site (GEOCRETS No. 40114-96), the very stiff to hard clayey silt till deposit that was encountered beneath the near-surface silt/sandy silt and clayey silt deposits during the current investigation is inferred to extend to depths in excess of 30 m below the founding level for the replacement culvert.

Based on the subsurface conditions at the site, it is recommended that Site Class D as defined in Section 4.4.3 of the CHBDC (2019) be used in the seismic design.

Seismic hazard values for the location of the culvert site were obtained from Natural Resources Canada (2015 National Building Code). Table 8.2 below summarizes the parameters obtained and recommended for use in the design based on a 2475-year return period.

**Table 8.2: Peak Ground Acceleration Data**

<i>PGA</i>	<i>S<sub>a</sub>(0.2)</i>	<i>PGA<sub>ref</sub></i>	<b>Site Class</b>	Site Adjusted <i>PGA</i>
0.066g	0.110g	0.056g	D	0.085g

The 2015 NBC Seismic Hazard calculation sheet is provided in Appendix D.

Based on the relatively low *PGA* and *S<sub>a</sub>(0.2)* values at this site and the Seismic Site Class of D, the Seismic Performance Category for this culvert is expected to be Category 1.

### **8.6.2 Vertical Acceleration Ratio (*A<sub>v</sub>*)**

Section 7.8.5.1 of the CHBDC related to the design of buried structures indicates that the additional force effects due to earthquake loads shall be accounted for by multiplying the force effects due to self-weight and earth load by the vertical acceleration ratio, *A<sub>v</sub>*. The CHBDC indicates that the vertical acceleration ratio, *A<sub>v</sub>*, is to be taken as two-thirds of the Site Adjusted *PGA* value for the site. Based on the Site Adjusted *PGA* value provided in the preceding section, the recommended *A<sub>v</sub>* value for use in design would be 0.057g.

### **8.6.3 Liquefaction Potential**

The potential for soil liquefaction of the near surface silt/sandy silt materials was evaluated by comparing the cyclic stress ratio (CSR) caused by the design earthquake with the soil resistance expressed in terms of the cyclic resistance ratio (CRR). The evaluation followed the analysis methodology suggested by Idriss and Boulanger (2008) and was based on the following input parameters:

- The SPT 'N' blow count values obtained from boreholes corrected for confining pressure and fines content.
- A Site Adjusted *PGA* of 0.085g.
- An earthquake magnitude *M<sub>w</sub>* of 6.2.
- A groundwater level/elevation of 251 m.





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Based on the results of these analyses, the factor of safety against liquefaction of these soils is greater than 1.5 under the design earthquake loading conditions and, as such, these soils are not considered to be liquefiable.

Liquefaction of the underlying clayey silt and clayey silt till deposits is also not considered to be a concern due to the low peak ground acceleration that applies for the site location, and the stiff to hard nature and the high fines/clay content of these deposits.

## 8.7 CULVERT FOUNDATION OPTIONS

Based on the subsurface conditions encountered in the boreholes, only shallow foundation options have been considered for the replacement of the culvert. The use of deep foundations is not considered to be a practical or economical option to support the new culvert as shallow foundations will provide the required support.

Table 8.3 provides a summary of the alternative foundation options with advantages, disadvantages, risks and relative costs.

**Table 8.3: Comparison of the Replacement Options for Culvert**

Option	Advantages	Disadvantages	Relative Cost	Risk/ Consequences
Precast Concrete Box	<ul style="list-style-type: none"> <li>Shallower excavation depth and slightly lower unwatering volume than open footing culvert.</li> <li>Foundation loads distributed over a larger area, therefore reducing settlement magnitudes</li> <li>Use of precast sections reduces construction period</li> </ul>	<ul style="list-style-type: none"> <li>Needs heavy lifting equipment</li> <li>Need to control groundwater / unwater for foundation construction</li> </ul>	Moderate	<ul style="list-style-type: none"> <li>Low risk option</li> </ul>
Cast-in-place Concrete Box	<ul style="list-style-type: none"> <li>Shallower excavation depth and slightly lower unwatering volume than open footing culvert.</li> <li>Foundation loads distributed over a larger area, therefore reducing settlement magnitudes</li> </ul>	<ul style="list-style-type: none"> <li>Increased cost and time associated with forming culvert in comparison to precast structure.</li> <li>Need to control groundwater / unwater for foundation construction</li> </ul>	Moderate cost, higher than precast box	<ul style="list-style-type: none"> <li>Low risk option</li> <li>On-site concrete curing could be impacted by weather or flood events</li> </ul>
Rigid Frame Open Footing Culvert	<ul style="list-style-type: none"> <li>Maintains a natural streambed</li> </ul>	<ul style="list-style-type: none"> <li>Higher bearing pressures than box culverts can lead to greater settlement</li> <li>Slower construction process</li> <li>Deeper excavations and greater unwatering volume required</li> </ul>	Moderate cost, higher than precast box	<ul style="list-style-type: none"> <li>Low risk</li> <li>On-site concrete curing could be impacted by weather</li> </ul>



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As previously noted, we understand that the existing culverts at Site No. 19X-0763/C0 are planned to be replaced with a single precast concrete box culvert. Based on the considerations provided in the table above, this culvert replacement type/system is also the preferred option from a foundation engineering perspective. As an important factor, we note that as the culvert is planned to be replaced during a closure of the ramp, the use of a precast culvert is considered favourable in comparison to cast-in-place options which would require a much longer ramp closure period.

## **8.8 FOUNDATION RECOMMENDATIONS**

The design recommendations presented in the following sections have been developed in accordance with the requirements and methods described in the CHBDC [2019].

### **8.8.1 Concrete Box Culvert**

#### **8.8.1.1 Foundation Subgrade Preparation**

The inverts of the existing corrugated steel pipe (CSP) culverts are understood to be at an elevation of approximately 250.55 m. The invert of the new box culvert is planned to be located approximately 0.3 m lower than the invert of the existing culverts, resulting in a founding elevation of approximately 249.9 m.

Based on the conditions encountered in the boreholes, the subgrade exposed at the design founding level of the new culvert is anticipated to consist of the native silt/sandy silt deposit containing zones/layers of clayey silt. These materials are considered suitable for support of the replacement culvert provided they are dewatered, as described below, and are protected from disturbance.

The results of the foundation investigations conducted at the site have identified that the groundwater level in the silt/sandy silt soils that underlie the culvert is greater than 1 m above the anticipated base of the excavation required for construction of the replacement culvert. These conditions could result in groundwater inflows, and disturbance and potentially basal instability (i.e. boiling or piping) of the foundation subgrade materials unless adequate dewatering is provided. To address this issue, a dewatering/groundwater control program should be implemented to lower the water level within the silt/sandy silt soils a minimum of 0.5 m below the base of the excavation required for the construction of the new culvert. Pumping from filtered sumps established in the floor of the excavations and/or the use of conventional well-points is unlikely to effectively dewater the excavation due to the fine-grained nature of the silt. It is therefore considered that the implementation of an external dewatering system consisting of a series of sanded-in vacuum well-points or eductor wells installed into the silt/sandy silt soils would be required to lower the piezometric level below the excavation level in advance of culvert construction.

All soils disturbed as a result of the removal of the existing culverts, any soft/loose organic soils and any fill surrounding the existing culverts should be sub-excavated and replaced with structural fill consisting of compacted OPSS Granular A material.

Following completion of the preparation of the founding surface, a milestone inspection should be conducted by foundation/geotechnical personnel arranged for by the Contract Administrator in



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accordance with SP109S12. It is recommended that a minimum 100 mm thick concrete mud mat/working slab be placed immediately following inspection and approval of the subgrade to protect the subgrade from softening. A draft version of a sample NSSP for the concrete working slab is provided in Appendix E. A leveling course/pad consisting of a 75 mm thick layer of uncompacted OPSS Granular A materials should be placed over the concrete mud mat.

The dewatering should continue during the excavation, foundation subgrade preparation activities (i.e. during placement of any required structural fill, the mud mat/working slab, and the leveling course/pad etc.) and throughout construction and backfilling of the culvert to reduce the potential for disturbance of the culvert bedding and backfill due to upward seepage forces.

### 8.8.1.2 Geotechnical Resistances and Reactions

The geotechnical resistance and reaction provided in Table 8.4 below may be used in the design of a cast-in-place box culvert. The values developed are based on the construction of the box culvert on the concrete mud mat/working slab and granular leveling course/pad overlying the undisturbed native soils as described in Section 8.8.1.1 above. The resistance and reaction provided will also apply where structural fill is required to backfill any localized sub-excavated zones of soft/loose materials, organics, or previously existing fill materials.

**Table 8.4: Geotechnical Vertical Resistance & Reaction**

Founding Element	Founding Elevation (m)	Culvert Span (m)	Factored Geotechnical Resistance at ULS <sub>r</sub> (kPa) $\phi_{gu} = 0.5$	Factored Geotechnical Reaction at SLS (kPa) $\phi_{gs} = 0.8$
Rigid Frame Box Culvert	± 249.9	4.8	300	75

Notes: (1) The founding elevation represents the approximate, inferred base of the box culvert. The materials immediately below this level should be sub-excavated replaced with the concrete mud mat and 75 mm of uncompacted OPSS Granular A material as outlined in Section 8.8.1.1.

In accordance with Table 6.1 in the CHBDC, the ULS Resistance and SLS Reaction were determined based on a consequence level of “Typical” with a consequence factor equal to 1.

In accordance with Table 6.2 of Section 6.9.1 in the CHBDC and the consequence and site understanding classification of “Typical”, a resistance factor of 0.5 has been applied in calculating the factored geotechnical resistance at Ultimate Limit State (ULS<sub>r</sub>).

In accordance with Table 6.2 of Section 6.9.1 in the CHBDC and the consequence and site understanding classification of “Typical”, a resistance factor of 0.8 has been applied in calculating the geotechnical reaction at Serviceability Limit State (SLS) which corresponds to a maximum settlement of 25 mm.



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### **8.8.2 Geotechnical Horizontal Resistance (Sliding)**

The unfactored horizontal resistance to sliding of the box culvert and/or strip footings for the rigid frame open box may be calculated using the following unfactored coefficient of friction:

- 0.55 between OPSS Granular A and concrete
- 0.35 between silt/sandy silt and concrete

In accordance with Table 6.2 of the CHBDC and the consequence and site understanding classification of “Typical”, a resistance factor against sliding of 0.8 (frictional) should be applied to obtain the resistance at  $ULS_f$ .

## **8.9 CULVERT BACKFILL**

The backfill and cover materials and the construction of a frost taper (backfill transition) for the replacement culvert should be as outlined in OPSS 422 and OPSD 803.010 (Backfill and Cover for Concrete Culverts). As previously discussed in this report, OPSD 3090.101 indicates that the frost penetration depth in the area of the site is 1.2 m. This frost penetration depth should be used for the design of the culvert frost tapers.

The backfill material should consist of granular fill meeting the requirements of OPSS.PROV 1010 Granular A or Granular B Type II materials. The backfill should be placed and compacted in accordance with MTO’s Special Provision SP105S21 (Amendment to OPSS 501).

A clay seal should be provided at the upstream and downstream ends of the culvert to act as a barrier to piping within the granular backfill. Clay seal materials should meet the requirements set out in OPSS.PROV 1205.

## **8.10 EARTH PRESSURES**

Calculation of loads and earth pressures acting on the box culvert should be in accordance with Section 7.8.6.3 of the CHBDC (2019). The un-factored unit weights provided in Table 8.6 below can be used in calculating  $w_c$  (weight of a column of unit area of fill above a reference point on the culvert).

**Table 8.5: Recommended Static Earth Pressure Parameters (Horizontal Backfill)**

Parameter	OPSS Gran B Type I	OPSS Gran A and Gran B Type II	Existing Fill Materials
Bulk Unit Weight, $\gamma$ (kN/m <sup>3</sup> )	22	22	21
Effective Friction Angle, $\Phi$ (°)	32	35	30
Coefficient of Earth Pressure at Rest, $K_o$	0.47	0.43	0.50
Coefficient of Active Earth Pressure, $K_a$	0.31	0.27	0.33
Coefficient of Passive Earth Pressure, $K_p$	3.25	3.69	3.0



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### **8.10.1 Earth Pressures Under Seismic Conditions**

The culvert walls should also be designed to resist the earth pressures/forces induced under seismic loading conditions in accordance with Section 7.8.5.4 of the CHBDC incorporating the  $A_v$  value provided in the Seismic Design Considerations section of this report.

## **8.11 RAMP EMBANKMENT**

Based on the preliminary design information, the profile and footprint of the existing embankment is anticipated to remain similar to the existing embankment configuration. However, there may be minor, localized regrading required near the inlet and outlet of the replacement culvert but the placement of new fill will be limited both in height/thickness and extent.

### **8.11.1 Embankment Construction**

In preparation for any modification of the existing ramp embankment and for reconstruction of the embankment in areas where the existing culverts are being removed, any topsoil, organic matter or softened/loosened soils including disturbed portions of the native sandy silt layer should be stripped from areas where widening (if required) is to be undertaken.

The embankment fill for widening and reconstruction 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 slope configuration meets this requirement. The existing slopes should be benched consistent with OPSD 208.010 to "key in" new fill materials where widening is to be undertaken. The fill material cut from the existing embankment side slope for construction of the benches is commonly re-used for the embankment widening below/adjacent to each bench area. Additional fill required for embankment widening could consist of earth fill that is free of organics, debris and/or other deleterious materials, granular fill, or fill material meeting the requirements of OPSS Select Subgrade Material.

### **8.11.2 Stability of Slopes**

No indication of embankment instability was observed at the time of the drilling investigation and Stantec is not aware of any history of embankment/slope instability at the culvert location.

Based on the planned embankment configuration (which is similar to or has slightly flatter side-slopes than the existing embankment), the prevailing subsurface conditions and the suitable embankment performance experienced to date, no issues with the stability of the planned embankment is anticipated.

Appropriate erosion protection measures should be implemented to prevent shallow surficial sloughing and potential toe instability. Additional comments in this regard are provided in a subsequent section of this report.



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### **8.11.3 Embankment Settlement**

Based on the preliminary General Arrangement drawing, the profile and footprint of the existing embankment is anticipated to remain similar to the existing embankment configuration. Based on the proposed embankment configuration and subsurface conditions present at the site, the proposed regrading works are not expected to result in settlements that would impact the embankment performance.

## **8.12 EROSION AND SCOUR PROTECTION**

Slope protection and drainage measures will be required to provide for the long-term surficial stability of the embankment slopes. All slopes within 3 m of the culvert inlet and outlet should be surfaced with rip-rap at least 300 mm thick placed on a Class II non-woven filter fabric; the rip-rap should extend up the slope to 0.3 m above the design high water level. The requirements for, and design of, erosion protection measures within the channel at the culvert inlet and outlet should be assessed by the hydraulic design engineer.

Where embankment construction includes earth fill, vegetation on the slopes should be established as soon as possible after completion of the embankment construction to minimize the potential for surficial erosion.

## **8.13 CEMENT TYPE AND CORROSION PROTECTION**

One (1) sample from this culvert Site 19X-0763/C0 and three (3) samples from the adjacent Site 19X-0764/C0 were submitted for analysis of pH, water soluble sulphate and chloride concentrations, and resistivity. The testing was completed to determine the potential for degradation of the concrete in the presence of soluble sulphates and the potential for corrosion of exposed steel used in foundations and buried infrastructure. The results of the analysis are summarized in Table 5.1 in a preceding section of this report.

The concentration of soluble sulphates provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater. The soluble sulphate concentrations for the samples tested ranged from 100 µg/g to 218 µg/g. Soluble sulphate concentrations less than 1000 µg/g generally indicate that a low degree of sulphate attack is expected for concrete in contact with soil and groundwater. Therefore, based on the soil testing results, Type GU (General Use) Portland Cement should therefore be suitable for use in buried concrete. The selection of the concrete type should also consider the potential for sulphates within the water present in the municipal drain.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The soil pH values were 7.49 and 7.72, which are within what is considered the normal range for soil pH of 5.5 to 9.0. The pH levels of the tested soil do not indicate a highly corrosive environment. However, a comparison of the resistivity test results to literature references indicate a severe or extremely corrosive environment. The additional test results provided in Table 5.1





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may be used to aid in the selection of coatings and corrosion protection systems for buried infrastructure incorporating steel components.

## **9.0 CONSTRUCTION CONSIDERATIONS**

### **9.1 CONSTRUCTION STAGING**

The construction of the replacement culvert at Site No. 19X-0763/C0 is expected to be completed in a single stage using an open cut construction method with the W-N/S ramp fully closed to traffic.

No temporary traffic protection systems are envisioned to be required for the excavations, as there should not be any adjacent active traffic during construction.

### **9.2 SURFACE WATER CONTROL**

The design of surface water control and temporary flow passage systems associated with the culvert replacement and rehabilitation works is the responsibility of the contractor. Temporary flow passage systems should follow the requirements of OPSS 517 as amended by SSP 517F01. The following inputs should be included in the Dewatering Systems section of Table A in SP517F01:

- The preconstruction survey distance should be identified as 100 m.
- Given the fine-grained nature of the silt deposit to be dewatered, the Design Engineer Requirements box should be input as “Yes”.

Control of the surface water including drainage flows will be necessary to allow excavation and foundation construction to be carried out in dry conditions. Temporary cofferdams may be needed to divert drain channel flows away from the work area for the replacement culvert and into/through the temporary flow passage system.

Table 9.1 provides a summary of alternative cofferdam options, with advantages, disadvantages, risks and relative costs, that could be implemented if cofferdams are installed on either end of the culvert to facilitate the proposed replacement.



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**Table 9.1: Comparison of Cofferdam Options for Surface Water Control**

Option	Advantages	Disadvantages	Relative Cost	Risk/Consequences
Sandbag Dam	<ul style="list-style-type: none"> <li>• Able to be installed in limited work areas</li> <li>• Decreased sedimentation compared to earth dams.</li> </ul>	<ul style="list-style-type: none"> <li>• Slower installation compared to other cofferdam systems.</li> <li>• Allows groundwater flow beneath cofferdam</li> </ul>	Low to Medium	<ul style="list-style-type: none"> <li>• Low risk option</li> </ul>
Aqua Dams	<ul style="list-style-type: none"> <li>• Decreased sedimentation compared to earth dams.</li> <li>• Fast installation</li> </ul>	<ul style="list-style-type: none"> <li>• Allows groundwater flow beneath cofferdam</li> </ul>	Low to Medium	<ul style="list-style-type: none"> <li>• Low risk option</li> </ul>
Granular Fill Dams	<ul style="list-style-type: none"> <li>• Fast installation.</li> <li>• Low cost.</li> </ul>	<ul style="list-style-type: none"> <li>• Increased environmental impact (i.e. sediment deposition in watercourse)</li> <li>• Increased streambed disturbance during dam removal</li> <li>• Allows groundwater flow beneath cofferdam</li> </ul>	Low	<ul style="list-style-type: none"> <li>• Increased potential for washout and sediment transport and deposition during storm events</li> </ul>
Steel sheet piles (SSP)	<ul style="list-style-type: none"> <li>• Simple installation process</li> <li>• Provides cut-off to groundwater seepage. Can be extended into silt deposits to further cut-off/reduce lateral flow thereby reducing groundwater inflow volumes into work areas.</li> </ul>	<ul style="list-style-type: none"> <li>• Requires larger construction equipment</li> <li>• Difficult to drive/install where cobbles/boulders are present</li> </ul>	Medium to high	<ul style="list-style-type: none"> <li>• Possible misalignment of, or damage to, sheet piles during installation due to obstructions</li> </ul>

## 9.3 GROUNDWATER CONTROL

The design of dewatering/unwatering systems is the responsibility of the contractor. Depending on the water taking/dewatering volumes and source(s) of water, the dewatering activities may require a Permit to Take Water (PTTW) from the Ministry of Environment, Conservation and Parks (MOECP) or registration of the water taking activity in the Environmental Activity and Sector Registry (EASR). The permit/registration requirements are outlined in Table 1.0 of CDED B517.

Groundwater flow into the excavations should be expected from the native silt/sandy silt deposit encountered at the site. As referenced in a previous section, based on the conditions encountered in the investigation, a groundwater elevation of 251 m is recommended. Excavations for installation of the replacement culvert will be required to extend to depths of 1 m or more below this water level. These conditions could result in disturbance of the foundation subgrade materials and potentially basal instability (i.e., boiling, piping etc.) unless adequate dewatering is provided. To address this issue, a dewatering/groundwater control program should be implemented to lower the water level within the silt/sandy silt soil a minimum of 0.5 m below the base of the excavation required for the construction of the new culvert. Pumping from filtered sumps established in the floor of the excavations and/or the use of conventional well-points is unlikely to effectively dewater the excavation due to the fine-grained nature of



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the silt. Therefore, the implementation of an external dewatering system consisting of a series of sanded-in vacuum well-points or eductor wells installed in the silt to sandy silt soils around the perimeter of the excavation is expected to be required to lower the piezometric level below the excavation level in advance of culvert construction.

The Contractor should be alerted to the presence of the groundwater conditions and the associated requirements for the selection of appropriate materials, equipment and methodologies to effectively depressurize/lower the piezometric level in the underlying soils to prevent 'boiling' and/or disturbance to the foundation subgrade soils. A sample Notice to Contractor associated with this issue has been provided in Appendix E.

All groundwater control systems required for the culvert rehabilitation works should be designed and implemented in accordance with NSSP No. FOUN 0003 (Amendment to OPSS 902) Dewatering Structure Excavations.

Temporary erosion and sediment control measures, including controlling the discharge of water, shall be according to OPSS.PROV 805.

## **9.4 EXCAVATION AND BACKFILLING**

Excavation and backfill for the new culvert should be carried out in accordance with OPSS 902 Construction Specification for Excavation and Backfilling – Structures.

Any vegetation, fill, organic soils, and other deleterious materials must be removed from beneath the proposed replacement culvert. Where deleterious materials are encountered, the materials should be excavated, removed and replaced with compacted granular fill materials. The lateral extent of the zone of sub-excavation (and replacement) should include all deleterious material within the influence zone of the culvert box.

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 culvert replacement will extend to depths in the order of 4 to 5 m below the existing travel surface of the Highway 402 W-N/S ramp. The excavations are expected to encounter fill materials (embankment fill and culvert bedding and backfill), and silt/sandy silt soils containing zones/interlayers of clayey silt and silty sand soil. These excavations may be undertaken via open cut methods provided dewatering is carried out prior to excavation.

Moving construction equipment over the wet silt/silt and sand material may not be possible and could cause extensive disturbance to the foundation subgrade. It is therefore recommended that construction equipment not be permitted on the foundation subgrade. A sample Operational Constraint related to protection of the subgrade materials has been provided in Appendix E.

The fill and native silt/sandy silt soils are classified as Type 3 soils where they are above the water table and the water level in the drain channel or are dewatered prior to excavation. The OH&S Act indicates



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that temporary excavations made in Type 3 soils can be undertaken with side slopes no steeper than 1H:1V.

Cohesionless fill materials associated with the existing culvert and/or the native silt/sandy silt soils that are below the water level should be classified as Type 4 soils. In the absence of dewatering, excavations in these materials should be sloped no steeper than 3H:1V based on OH&S Act requirements.

Excavation requirements are based on the lowest soil type encountered, which for the soil stratigraphy and groundwater conditions encountered, would be Type 4. However, as noted previously, dewatering is required to lower the piezometric level in the silt/sandy silt deposits that underlie the culvert to a minimum of 0.5 m below the base of the intended excavation to reduce the potential for 'boiling' and disturbance of the subgrade soils. The excavation requirements can be based on Type 3 soils where the fill materials and native silt and sandy silt soils are dewatered and the groundwater level is maintained at a level below the bottom of the excavation under an active dewatering system.

If the existing west CSP culvert is to remain in place as a flow conduit during installation of the replacement box culvert, the excavation for the replacement box culvert must be carried out in a manner that protects the existing CSP. Construction of the new replacement culvert must be undertaken to avoid uneven lateral loading conditions that could affect the performance of the existing west CSP.

Grading work should be carried out in accordance with OPSS.PROV 206 Construction Specification for Grading and SP 206S03. Where minor modifications to the existing embankments are to be undertaken, the new fill materials should be benched into the existing embankments in accordance with OPSD 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.

## **9.5 OBSTRUCTIONS**

Occasional cobbles and boulders are present in the fill materials present at this site. These materials could obstruct excavations and the installation of temporary flow passage system or dewatering system components.

The contractor should be made aware of the potential for difficulties in temporary flow passage system or dewatering system components through the fill and native soils due to the presence of cobbles and boulders.

A Non-Standard Special Provision (NSSP) should be included in the contract to address these items. A draft version of a sample NSSP is provided in Appendix E.



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## 10.0 SPECIFICATIONS

The following specifications are referenced in this report:

**Table 10.1: 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 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



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References

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## **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. 2019. Canadian Highway Bridge Design Code. Canadian Standards Association, Mississauga, Ontario.

Ministry of Transportation and Communications. 1975. Foundation Investigation Report for Bostwick Road Bridge, Hwy 402 – Twp. Of Westminster – District No. 2 (London) – W.P. 41-66-07. GeoCres No. 40114-96.

Ministry of Transportation. 2013. Contract Design, Estimating and Documentation (CDED) Manual

NBC. 2015. National Building Code of Canada Vol.1. National Research Council of Canada, Ottawa, Ontario.

OHSA. 2020. Occupational Health and Safety Act Regulations for Construction Projects. Carswell, Toronto Ontario.





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Closure

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## 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 David Lee, P.Eng., and reviewed by Kevin Nelson, P. Eng., and John J. Brisbois, MScE., P. Eng., MTO Designated Principal Contact.

Respectfully submitted,

**STANTEC CONSULTING LTD.**



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Geotechnical Engineer



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Designated Principal MTO Foundation Contact



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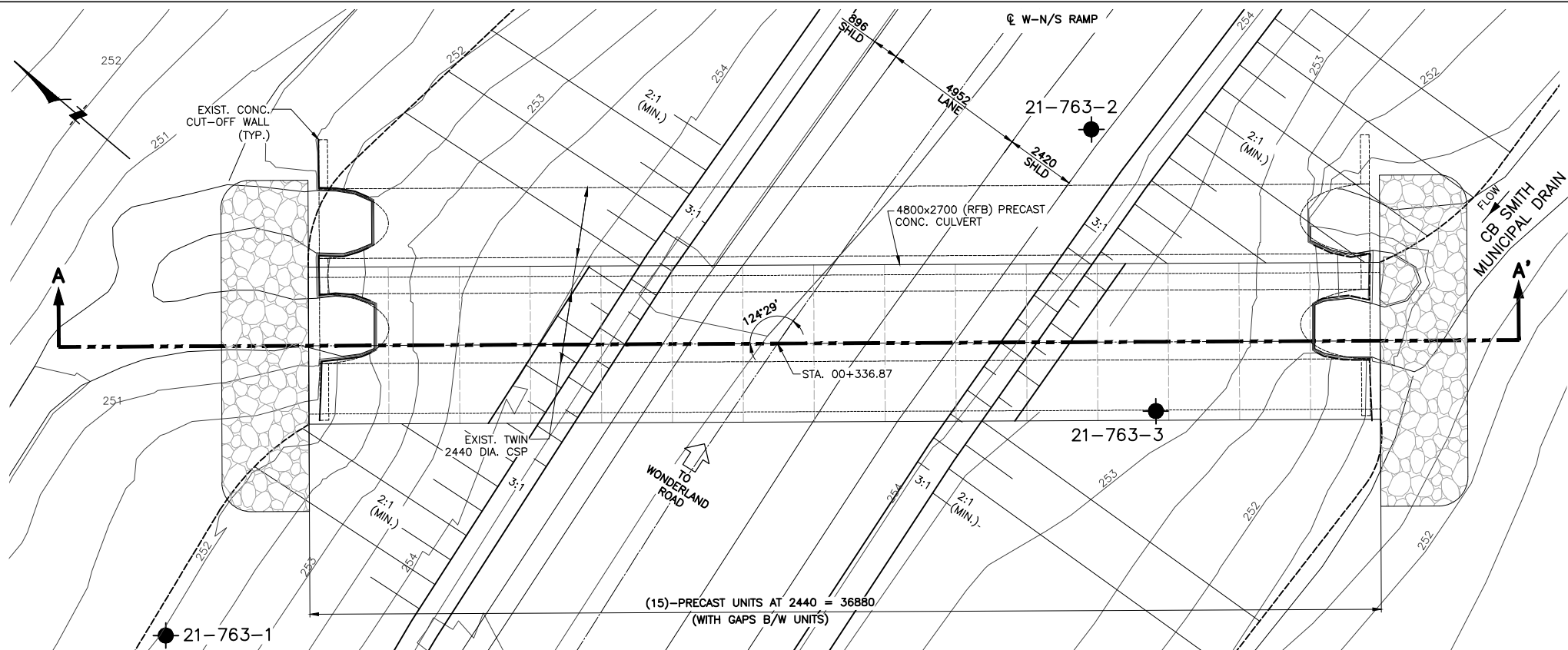


## APPENDIX A

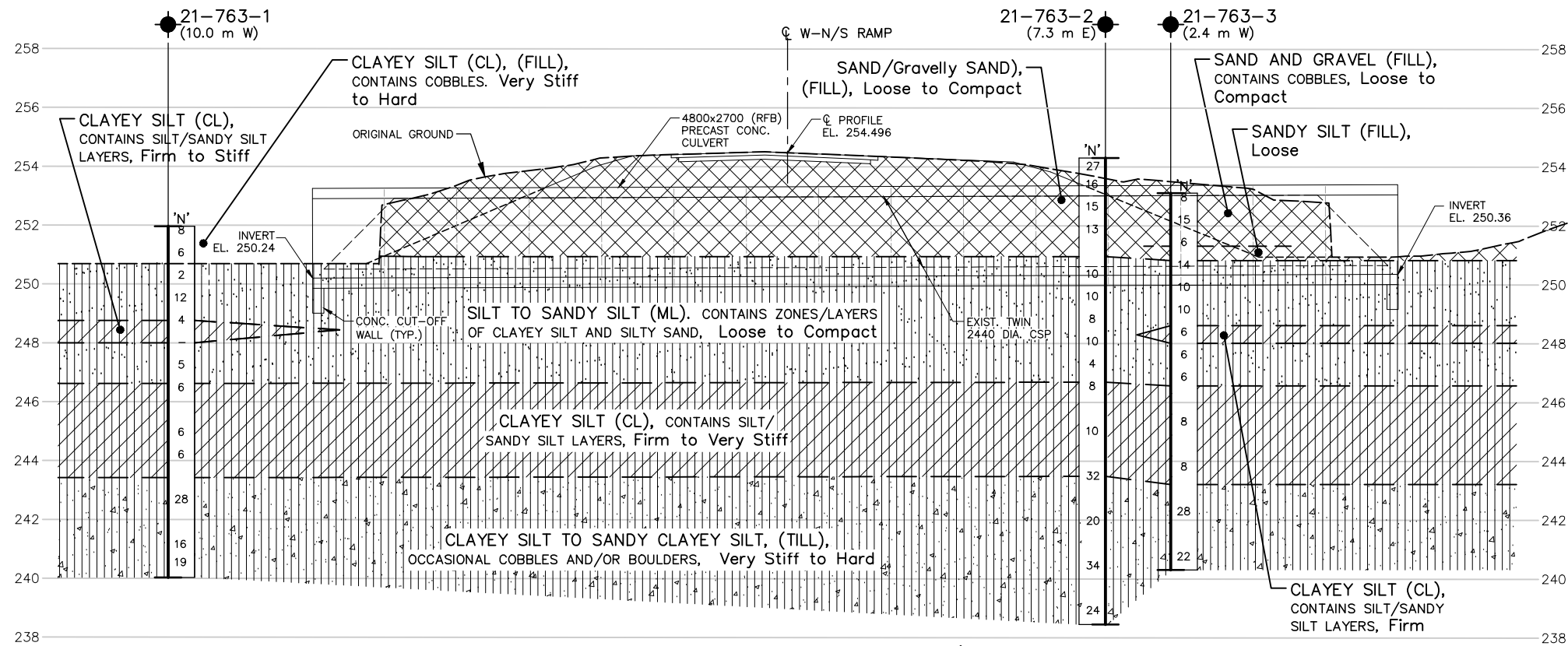
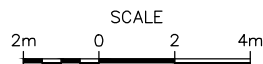
### A.1 DRAWING NO. 1 – BOREHOLE LOCATION PLAN AND SOIL STRATA PLOT



BB-05  
PR-D-207  
MINISTRY OF TRANSPORTATION, ONTARIO  
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Printed: Dec 10, 2021  
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PLAN



CROSS SECTION A-A'

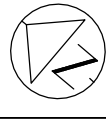


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DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN

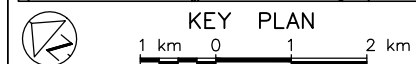
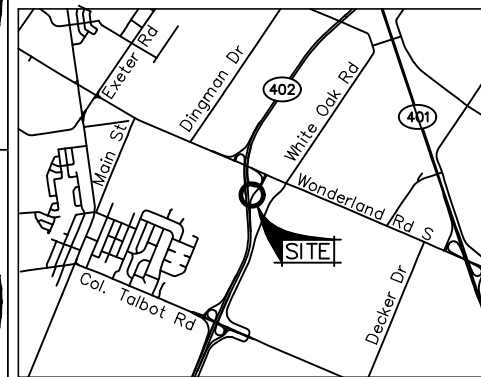


PLATE No  
**CONT**  
**GWP** 3108-18-00

HIGHWAY 402 REHABILITATION  
SITE 19X-0763/CO  
BOREHOLE LOCATIONS & SOIL STRATA



**SHEET**  
—



LEGEND

- Borehole
- (x.x m) Offset from Cross Section Line in meters
- N Blows/0.3m (Std Pen Test, 475 J/blow)
- ▽ WL at time of Investigation July 2021
- ▽ WL Measured on July 20, 2021

No	ELEV	MTM ZONE 11 NORTH	COORDINATES EAST
21-763-1	252.0	4 751 744.7	405 010.7
21-763-2	254.3	4 751 731.7	405 044.6
21-763-3	253.1	4 751 723.7	405 038.6

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.

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.

REVISIONS	DATE	BY	DESCRIPTION

GEOCREs No 40114-198

HWY No 402			DIST
SUBM'D KN	CHECKED	DATE 2021-12-10	SITE 19X-0763/CO
DRAWN GBB	CHECKED	APPROVED	DWG 1

## **APPENDIX B**

### **B.1 SYMBOLS AND TERMS USED ON BOREHOLE RECORDS**

### **B.2 BOREHOLE RECORDS**

### **B.3 SUBSURFACE INFORMATION FROM GEOCRES REPORT 40I14-96**



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

### SOIL DESCRIPTION

#### Terminology describing common soil genesis:

<i>Rootmat</i>	- vegetation, roots and moss with organic matter and topsoil typically forming a mattress at the ground surface
<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) which excludes particles larger than 75 mm. For particles larger than 75 mm, and for defining percent clay fraction in hydrometer results, definitions proposed by Canadian Foundation Engineering Manual, 4<sup>th</sup> Edition are used. 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 75 mm, visible organic matter, and 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 (SPT) N-Value - also known as N-Index. The SPT N-Value is described further on page 3. 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 may be crudely estimated from SPT N-Value based on the correlation shown in the following table (Terzaghi and Peck, 1967). The correlation to SPT N-Value is used with caution as it is only very approximate.

Consistency	Undrained Shear Strength		Approximate SPT N-Value
	kips/sq.ft.	kPa	
<i>Very Soft</i>	<0.25	<12.5	<2
<i>Soft</i>	0.25 - 0.5	12.5 - 25	2-4
<i>Firm</i>	0.5 - 1.0	25 - 50	4-8
<i>Stiff</i>	1.0 - 2.0	50 - 100	8-15
<i>Very Stiff</i>	2.0 - 4.0	100 - 200	15-30
<i>Hard</i>	>4.0	>200	>30

## ROCK DESCRIPTION

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

### Terminology describing rock quality:

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

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

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

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

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

### Terminology describing rock with respect to discontinuity and bedding spacing:

Spacing (mm)	Discontinuities	Bedding
>6000	Extremely Wide	-
2000-6000	Very Wide	Very Thick
600-2000	Wide	Thick
200-600	Moderate	Medium
60-200	Close	Thin
20-60	Very Close	Very Thin
<20	Extremely Close	Laminated
<6	-	Thinly Laminated

### Terminology describing rock strength:

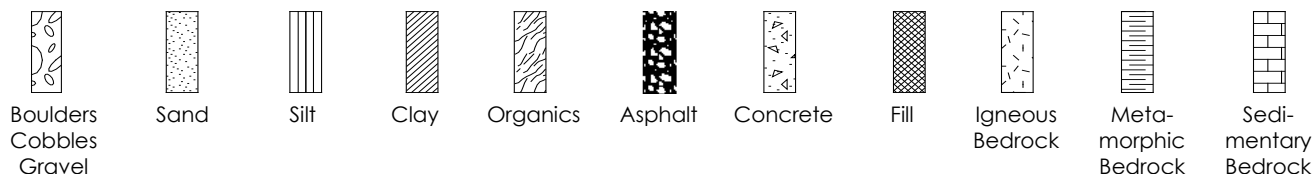
Strength Classification	Grade	Unconfined Compressive Strength (MPa)
Extremely Weak	R0	<1
Very Weak	R1	1 – 5
Weak	R2	5 – 25
Medium Strong	R3	25 – 50
Strong	R4	50 – 100
Very Strong	R5	100 – 250
Extremely Strong	R6	>250

### Terminology describing rock weathering:

Term	Symbol	Description
Fresh	W1	No visible signs of rock weathering. Slight discoloration along major discontinuities
Slightly	W2	Discoloration indicates weathering of rock on discontinuity surfaces. All the rock material may be discolored.
Moderately	W3	Less than half the rock is decomposed and/or disintegrated into soil.
Highly	W4	More than half the rock is decomposed and/or disintegrated into soil.
Completely	W5	All the rock material is decomposed and/or disintegrated into soil. The original mass structure is still largely intact.
Residual Soil	W6	All the rock converted to soil. Structure and fabric destroyed.

## STRATA PLOT

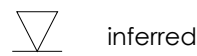
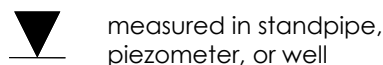
Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



## 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
HQ, NQ, BQ, etc.	Rock core samples obtained with the use of standard size diamond coring bits.

## WATER LEVEL MEASUREMENT



## 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 (63.5 kg) hammer falling 30 inches (760 mm), required to drive a 2 inch (50.8 mm) O.D. split spoon sampler one foot (300 mm) into the soil. In accordance with ASTM D1586, the N-Value equals the sum of the number of blows (N) required to drive the sampler over the interval of 6 to 18 in. (150 to 450 mm). However, when a 24 in. (610 mm) sampler is used, the number of blows (N) required to drive the sampler over the interval of 12 to 24 in. (300 to 610 mm) may be reported if this value is lower. 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-values 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 (300 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 21-763-1

1 OF 1

METRIC

W.P. GWP 3108-18-00 LOCATION Hwy 402, London, Ontario N: 4751744.7 E: 405010.7 ORIGINATED BY DL  
DIST West HWY 402 BOREHOLE TYPE Hollow Stem Auger - Split Spoon COMPILED BY RR  
DATUM Geodetic DATE 2021.07.20 - 2021.07.20 LATITUDE 42.898908 LONGITUDE -81.272933 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  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							w <sub>p</sub> w w <sub>L</sub>		
252.0							20	40	60	80	100	20	40	60	GR SA SI CL		
250.0	150 mm TOPSOIL		1	SS	8	▽											
0.2	CLAYEY SILT (CL), some sand and trace gravel (FILL). Contains occasional cobbles and/or boulders. Hard																
251.0	Brown Moist		2	SS	6												
0.9	Sandy SILT (CL-ML), trace gravel. Contains zones of CLAYEY SILT (CL). Loose to compact																
	Brown Moist		3	SS	2											0 31 46 23	
	Becomes wet below ~ 2m.		4	SS	12												
248.8																	
3.2	CLAYEY SILT (CL), trace sand. Firm to stiff		5	SS	4											0 0 60 39	
	Grey Wet																
248.0																	
4.0	SILT to Sandy SILT (ML). Contains thin layers and zones of clayey silt (CL). Loose		6	SS	-											Su>118 kPa (N-vane refusal)	
	Grey Wet		7	SS	5											No SPT N-value recorded for SS6 due to soil disturbance	
246.6																	
5.3	CLAYEY SILT (CL). Contains SILT layers up to 50 mm in thickness. Firm to stiff		8	SS	6										0 0 52 48		
	Grey Wet																
			9	SS	6										Su>118 kPa (N-vane refusal)		
			10	SS	6												
243.4																	
8.5	CLAYEY SILT (CL), trace to some sand, trace gravel (TILL) Very stiff to hard														Su>118 kPa (N-vane refusal)		
	Grey Moist		11	SS	28												
			12	SS	16												
			13	SS	19												
240.1																	
11.9	End of Borehole																
	Groundwater observed below a depth of approximately 2 m (~Elev. 250 m).																

+ 3, X 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ONTARIO MTO 165001222 HWY 402 REHABILITATION GPJ ONTARIO MTO GDT 10/28/21



# RECORD OF BOREHOLE No 21-763-2

1 OF 2

METRIC

W.P. GWP 3108-18-00 LOCATION Hwy 402, London, Ontario N: 4751731.7 E: 405044.6 ORIGINATED BY DL  
 DIST West HWY 402 BOREHOLE TYPE Hollow Stem Auger - Split Spoon COMPILED BY RR  
 DATUM Geodetic DATE 2021.07.19 - 2021.07.19 LATITUDE 42.898786 LONGITUDE -81.27252 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						
								○ UNCONFINED + FIELD VANE						
								● QUICK TRIAXIAL × LAB VANE						
								20 40 60 80 100						
254.3														
254.0	100 mm ASPHALTIC CONCRETE													
0.1	SAND, some gravel, trace silt (FILL) Compact Brown Moist		1	SS	27		254			○				
253.2	Occasional clayey silt inclusions below 0.76 m		2	SS	16		253			○				
1.1	Gravelly SAND, trace silt (FILL) Compact Brown Moist		3	SS	15		252			○				
252.8	SAND, some gravel, trace silt (FILL) Loose to compact Brown Moist		4	SS	13		251			○				
1.5							250							
250.9	Sandy SILT (ML). Contains zones of clayey silt and silty sand Loose to compact Bluish-grey to brown Wet		5	SS	5		249			○				
3.4			6	SS	10		248			○				
			7	SS	10		247			○				
248.8	SILT (ML), trace sand. Contains thin layers and zones of clayey silt (CL-ML) Loose to compact Grey Wet		8	SS	8		246			○				
5.5			9	SS	10		245			○				
247.4	Sandy SILT (ML) Very loose to loose Grey Wet		10	SS	4		244			○				
6.9			11	SS	8		243			○				
246.7	CLAYEY SILT (CL), trace sand. Stiff to very stiff Grey Wet		12	SS	10		242			○				
7.6							241							
	50 mm silt seam with free groundwater at 9.6 m													
243.5	CLAYEY SILT (CL), trace to some sand, trace gravel (TILL). Contains occasional cobbles. Very stiff to hard Grey Moist		13	SS	32									
10.8			14	SS	20									
			15	SS	34									

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 21-763-2

2 OF 2

METRIC

W.P. GWP 3108-18-00 LOCATION Hwy 402, London, Ontario N: 4751731.7 E: 405044.6 ORIGINATED BY DL  
DIST West HWY 402 BOREHOLE TYPE Hollow Stem Auger - Split Spoon COMPILED BY RR  
DATUM Geodetic DATE 2021.07.19 - 2021.07.19 LATITUDE 42.898786 LONGITUDE -81.27252 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  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				GR	SA	SI	CL	
				○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE																
								20	40	60	80	100								

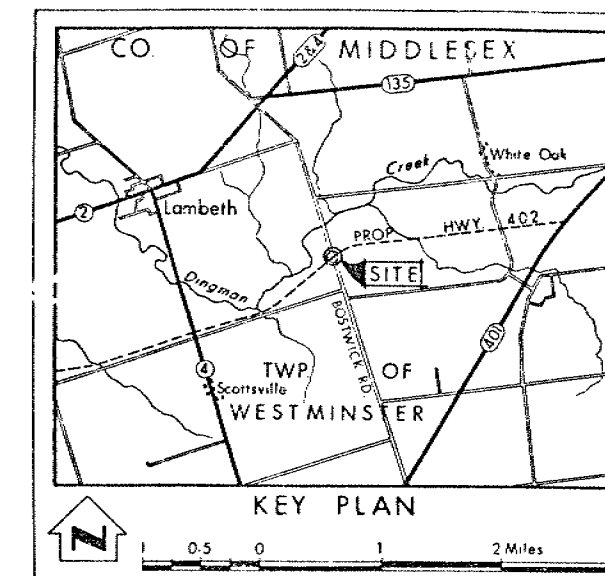
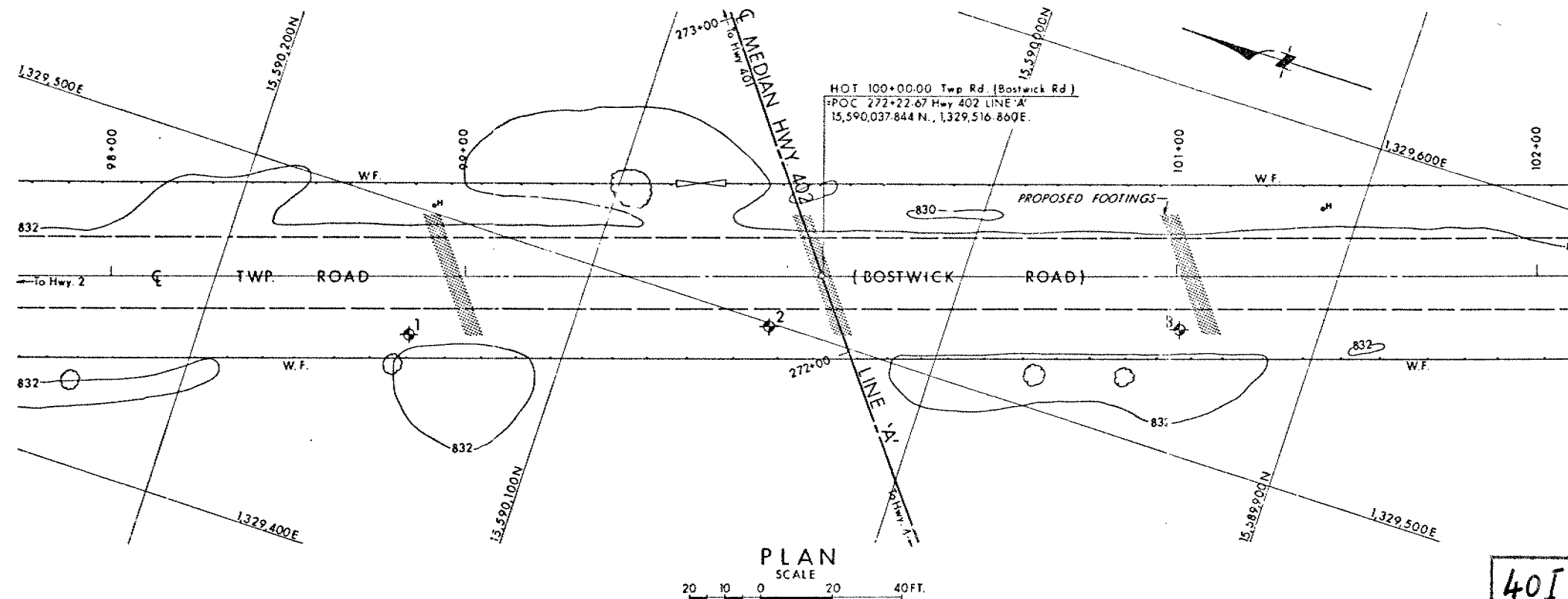
**METRIC**[illegible]

ONTARIO MTO 165001222 HWY 402 REHABILITATION.GPJ ONTARIO MTO.GDT 10/28/21

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○<sup>3%</sup> STRAIN AT FAILURE

## **SUBSURFACE INFORMATION FROM GEOCRES REPORT 40I14-96**

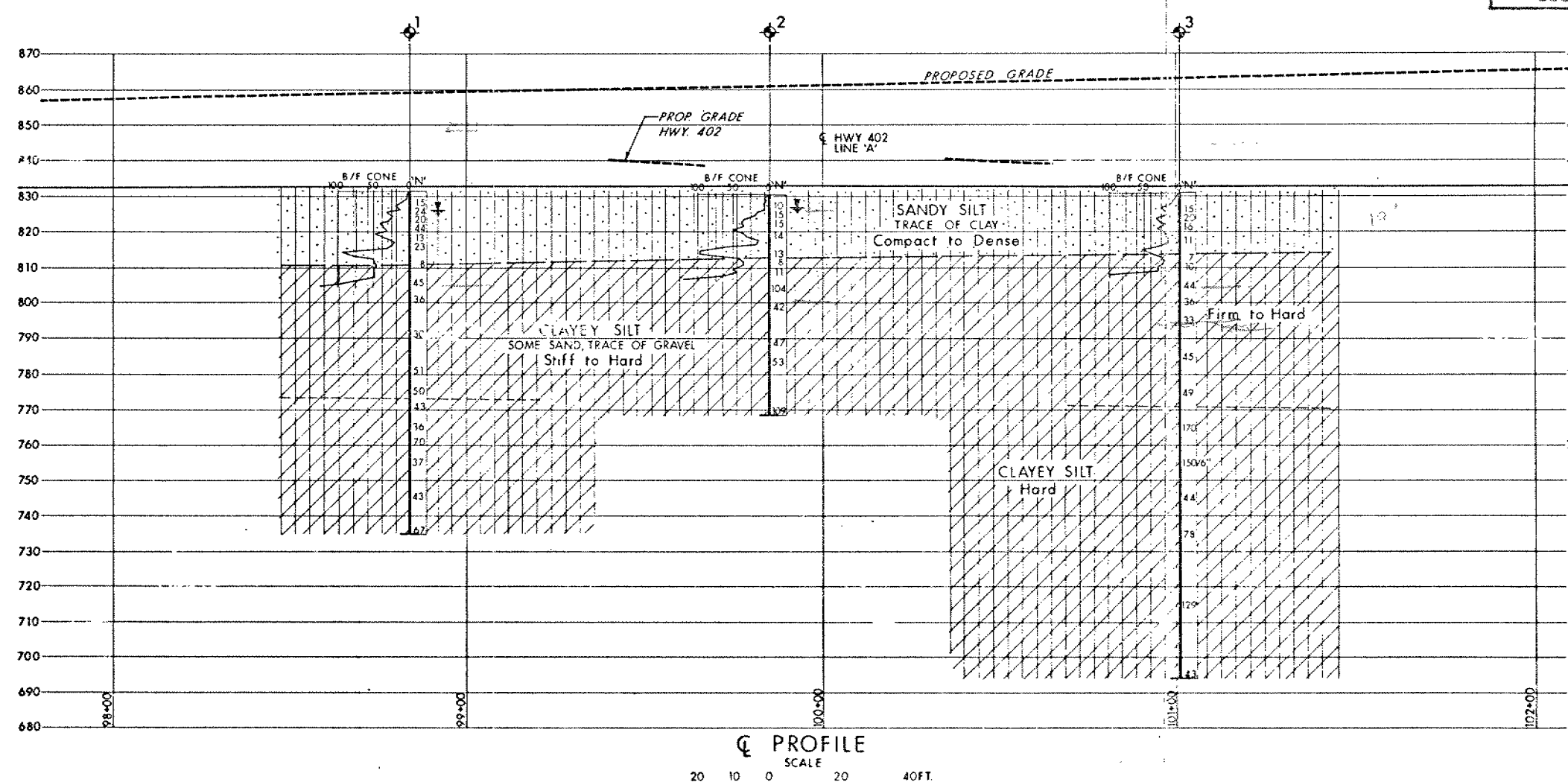




LEGEND			
	Bore Hole		
	Dynamic Cone Penetration Test		
	Bore Hole & Cone Test		
	Water Levels established at time of field investigation, May & June 1975		
	W.L. in Borehole 3 not established		
NO.	ELEVATION	CO-ORDINATES NORTH	EAST
1	831.5	15,590,143	1,329,465
2	830.3	15,590,048	1,329,499
3	830.9	15,589,937	1,329,534

NOTE: FOR CONTRACT DOCUMENT  
The complete foundation investigation report for this structure may be examined at the Structural Office and Foundations Office, Downsview, and at the LONDON District Office.

— NOTE —  
The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.



MINISTRY OF TRANSPORTATION AND COMMUNICATIONS—ONTARIO ENGINEERING SERVICES BRANCH—GEOTECHNICAL OFFICE—SOIL MECHANICS SECTION			
BOSTWICK ROAD			
HIGHWAY NO. Prop. 402 LINE 'A' DIST NO. 2			
CO. MIDDLESEX			
TWP. WESTMINSTER			
LOTS 24 & 62 CON 4 & ENBTR			
BORE HOLE LOCATIONS & SOIL STRATA			
SUBMITTALS	CHECKED	WP NO 41-66-07	DRAWING NO
DRAWN	CHECKED	WP NO	416607-A
DATE July 9, 1975	SITE NO 19-545	BRIDGE DRAWING NO	
APPROVED	CONE NO		

# ABBREVIATIONS & SYMBOLS USED IN THIS REPORT

## PENETRATION RESISTANCE

'N' STANDARD PENETRATION RESISTANCE : - THE NUMBER OF BLOWS REQUIRED TO ADVANCE A STANDARD SPLIT SPOON SAMPLER 12 INCHES INTO THE SUBSOIL, DRIVEN BY MEANS OF A 140 POUND HAMMER FALLING FREELY A DISTANCE OF 30 INCHES.

DYNAMIC PENETRATION RESISTANCE : - THE NUMBER OF BLOWS REQUIRED TO ADVANCE A 2 INCH, 60 DEGREE CONE, FITTED TO THE END OF DRILL RODS, 12 INCHES INTO THE SUBSOIL, THE DRIVING ENERGY BEING 350 FOOT POUNDS PER BLOW.

## DESCRIPTION OF SOIL

THE CONSISTENCY OF COHESIVE SOILS AND THE RELATIVE DENSITY OR DENSENESS OF COHESIONLESS SOILS ARE DESCRIBED IN THE FOLLOWING TERMS :-

<u>CONSISTENCY</u>	<u>c LB/SQ. FT.</u>	<u>DENSENESS</u>	<u>'N' BLOWS / FT.</u>
VERY SOFT	0 - 250	VERY LOOSE	0 - 4
SOFT	250 - 500	LOOSE	4 - 10
FIRM	500 - 1000	COMPACT	10 - 30
STIFF	1000 - 2000	DENSE	30 - 50
VERY STIFF	2000 - 4000	VERY DENSE	> 50
HARD	> 4000		

TERMS TO BE USED IN DESCRIBING SOILS:-

TRACE < 10% , SOME 10-25% , WITH 25-40% , > 40% SILTY, SANDY, GRAVELLY, CLAYEY ETC.

## TYPE OF SAMPLE

S.S.	SPLIT SPOON	T.W.	THINWALL OPEN
W.S.	WASHED SAMPLE	T.P.	THINWALL PISTON
S.T.	SLOTTED TUBE SAMPLE	O.S.	OESTERBERG SAMPLE
A.S.	AUGER SAMPLE	F.S.	FOIL SAMPLE
C.S.	CHUNK SAMPLE	R.C.	ROCK CORE

P.H. SAMPLE ADVANCED HYDRAULICALLY

P.M. SAMPLE ADVANCED MANUALLY

## SOIL TESTS

U	UNCONFINED COMPRESSION	L.V.	LABORATORY VANE
UU	UNCONSOLIDATED UNDRAINED TRIAXIAL	F.V.	FIELD VANE
CU	CONSOLIDATED ISOTROPIC UNDRAINED TRIAXIAL	C	CONSOLIDATION
CID	" " DRAINED "	S	SENSITIVITY
CAU	" ANISOTROPIC UNDRAINED "		
CAD	" " DRAINED "		

ABBREVIATIONS & SYMBOLS USED IN THIS REPORTSOIL PROPERTIES

$\gamma$	UNIT WEIGHT OF SOIL (BULK DENSITY)
$\gamma_s$	UNIT WEIGHT OF SOLID PARTICLES
$\gamma_w$	UNIT WEIGHT OF WATER
$\gamma_d$	UNIT DRY WEIGHT OF SOIL (DRY DENSITY)
$\gamma'$	UNIT WEIGHT OF SUBMERGED SOIL
G	SPECIFIC GRAVITY OF SOLID PARTICLES $G = \frac{\gamma_s}{\gamma_w}$
e	VOID RATIO
n	POROSITY
w	WATER CONTENT
$S_r$	DEGREE OF SATURATION
$w_L$	LIQUID LIMIT
$w_p$	PLASTIC LIMIT
$I_p$	PLASTICITY INDEX
$w_s$	SHRINKAGE LIMIT
$I_L$	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$
$I_c$	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$
$e_{max}$	VOID RATIO IN LOOSEST STATE
$e_{min}$	VOID RATIO IN DENSEST STATE
$I_D$	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
	RELATIVE DENSITY $D_r$ IS ALSO USED
h	HYDRAULIC HEAD OR POTENTIAL
q	RATE OF DISCHARGE
v	VELOCITY OF FLOW
i	HYDRAULIC GRADIENT
k	COEFFICIENT OF PERMEABILITY
j	SEEPAGE FORCE PER UNIT VOLUME
$m_v$	COEFFICIENT OF VOLUME CHANGE = $\frac{-\Delta e}{(1+e)\Delta\sigma}$
$c_v$	COEFFICIENT OF CONSOLIDATION
$C_c$	COMPRESSION INDEX = $\frac{\Delta e}{\Delta \log_{10} \sigma}$
$T_v$	TIME FACTOR = $\frac{c_v t}{d^2}$ (d, DRAINAGE PATH)
U	DEGREE OF CONSOLIDATION
$\tau_f$	SHEAR STRENGTH
$c'$	EFFECTIVE COHESION INTERCEPT
$\phi'$	EFFECTIVE ANGLE OF SHEARING RESISTANCE, OR FRICTION
$c_u$	APPARENT COHESION
$\phi_u$	APPARENT ANGLE OF SHEARING RESISTANCE, OR FRICTION
$\mu$	COEFFICIENT OF FRICTION
$S_f$	SENSITIVITY

GENERAL

$\pi$	= 3.1416
e	BASE OF NATURAL LOGARITHMS 2.7183
$\log_e \sigma$ OR $\ln \sigma$	NATURAL LOGARITHM OF $\sigma$
$\log_{10} \sigma$ OR $\log \sigma$	LOGARITHM OF $\sigma$ TO BASE 10
t	TIME
g	ACCELERATION DUE TO GRAVITY
V	VOLUME
W	WEIGHT
M	MOMENT
F	FACTOR OF SAFETY

STRESS AND STRAIN

u	PORE PRESSURE
$\sigma$	NORMAL STRESS
$\sigma'$	NORMAL EFFECTIVE STRESS ( $\bar{\sigma}$ IS ALSO USED)
$\tau$	SHEAR STRESS
$\epsilon$	LINEAR STRAIN
$\gamma$	SHEAR STRAIN
$\nu$	POISSON'S RATIO ( $\mu$ IS ALSO USED)
E	MODULUS OF LINEAR DEFORMATION (YOUNG'S MODULUS)
G	MODULUS OF SHEAR DEFORMATION
K	MODULUS OF COMPRESSIBILITY
$\eta$	COEFFICIENT OF VISCOSITY

EARTH PRESSURE

d	DISTANCE FROM TOP OF WALL TO POINT OF APPLICATION OF PRESSURE
$\delta$	ANGLE OF WALL FRICTION
K	DIMENSIONLESS COEFFICIENT TO BE USED WITH VARIOUS SUFFIXES IN EXPRESSIONS REFERRING TO NORMAL STRESS ON WALLS
$K_0$	COEFFICIENT OF EARTH PRESSURE AT REST

FOUNDATIONS

B	BREADTH OF FOUNDATION
L	LENGTH OF FOUNDATION
D	DEPTH OF FOUNDATION BENEATH GROUND
N	DIMENSIONLESS COEFFICIENT USED WITH A SUFFIX APPLYING TO SPECIFIC GRAVITY, DEPTH AND COHESION ETC. IN THE FORMULA FOR BEARING CAPACITY
$k_s$	MODULUS OF SUBGRADE REACTION

SLOPES

H	VERTICAL HEIGHT OF SLOPE
D	DEPTH BELOW TOE OF SLOPE TO HARD STRATUM
$\beta$	ANGLE OF SLOPE TO HORIZONTAL

RECORD OF BOREHOLE NO 1

W.P. 41-66-07

LOCATION Co-ords. 15,590,143 N; 1,329,465 E.

ORIGINATED BY RD

DIST. 2 HWY. 402

BORING DATE May 29, 1975

COMPILED BY PJS

DATUM Geodetic

BOREHOLE TYPE Hollow Stem Auger

CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER ELEV.	DYNAMIC CONE PENETRATION RESISTANCE PLOT					LIQUID LIMIT $W_L$ PLASTIC LIMIT $W_P$ WATER CONTENT $W$			UNIT WEIGHT $\gamma$	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100	$W_P$	$W$	$W_L$		
831.5	Ground Level															
0.0	Sandy silt, trace of clay.		1	SS	15	830										0 35 62 3
	Compact to Dense		2	SS	24											0 39 60 1
			3	SS	20											
			4	SS	44	820										
			5	SS	13											
			6	SS	23											
810.5			7	SS	8	810										
21.0	Clayey silt, some sand, trace of gravel		8	SS	45											3 17 52 25
	Stiff to Hard		9	SS	36	800										
			10	SS	30	790										2 10 51 37
			11	SS	51	780										
			12	SS	50											
	Clayey silt		13	SS	43	770										0 0 71 29
	Hard		14	SS	36											
			15	SS	70	760										
			16	SS	37											
			17	SS	43	750										
735.0			18	SS	67	740										0 0 67 33
96.5	End of Borehole															



RECORD OF BOREHOLE NO 2

W.P. 41-66-07 LOCATION Co-ords. 15,590,048 N; 1,329,499 E. ORIGINATED BY RD  
 DIST. 2 HWY. 402 BORING DATE June 2, 1975 COMPILED BY PJS  
 DATUM Geodetic BOREHOLE TYPE Hollow Stem Auger CHECKED BY GP.

SOIL PROFILE			SAMPLES			GROUND WATER ELEV.	DYNAMIC CONE PENETRATION RESISTANCE PLOT					LIQUID LIMIT $w_L$ PLASTIC LIMIT $w_p$ WATER CONTENT $w$			UNIT WEIGHT $\gamma$	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100	$w_p$	$w$	$w_L$		
830.3	Ground Level															
0.0	Sandy silt, trace of clay.		1	SS	10											0 18 71 11
	Compact		2	SS	15											0 38 60 2
			3	SS	15											
			4	SS	14											
813.3			5	SS	13											1 41 56 2
17.0	Clayey silt, some sand, trace of gravel.		6	SS	8											6 24 41 29
	Stiff to Hard		7	SS	11											
			8	SS	104											
			9	SS	42											
			10	SS	47											2 4 60 34
			11	SS	53											
768.8			12	SS	109											0 1 78 21
61.5	End of Borehole															

MINISTRY OF TRANSPORTATION AND COMMUNICATIONS-ONTARIO

ENGINEERING SERVICES BRANCH-GEOTECHNICAL OFFICE-SOIL MECHANICS SECTION

RECORD OF BOREHOLE NO 3

W.P. 41-66-07

LOCATION Co-ords, 15,589,937 N; 1,329,534 E.

ORIGINATED BY RD

DIST. 2 HWY. 402

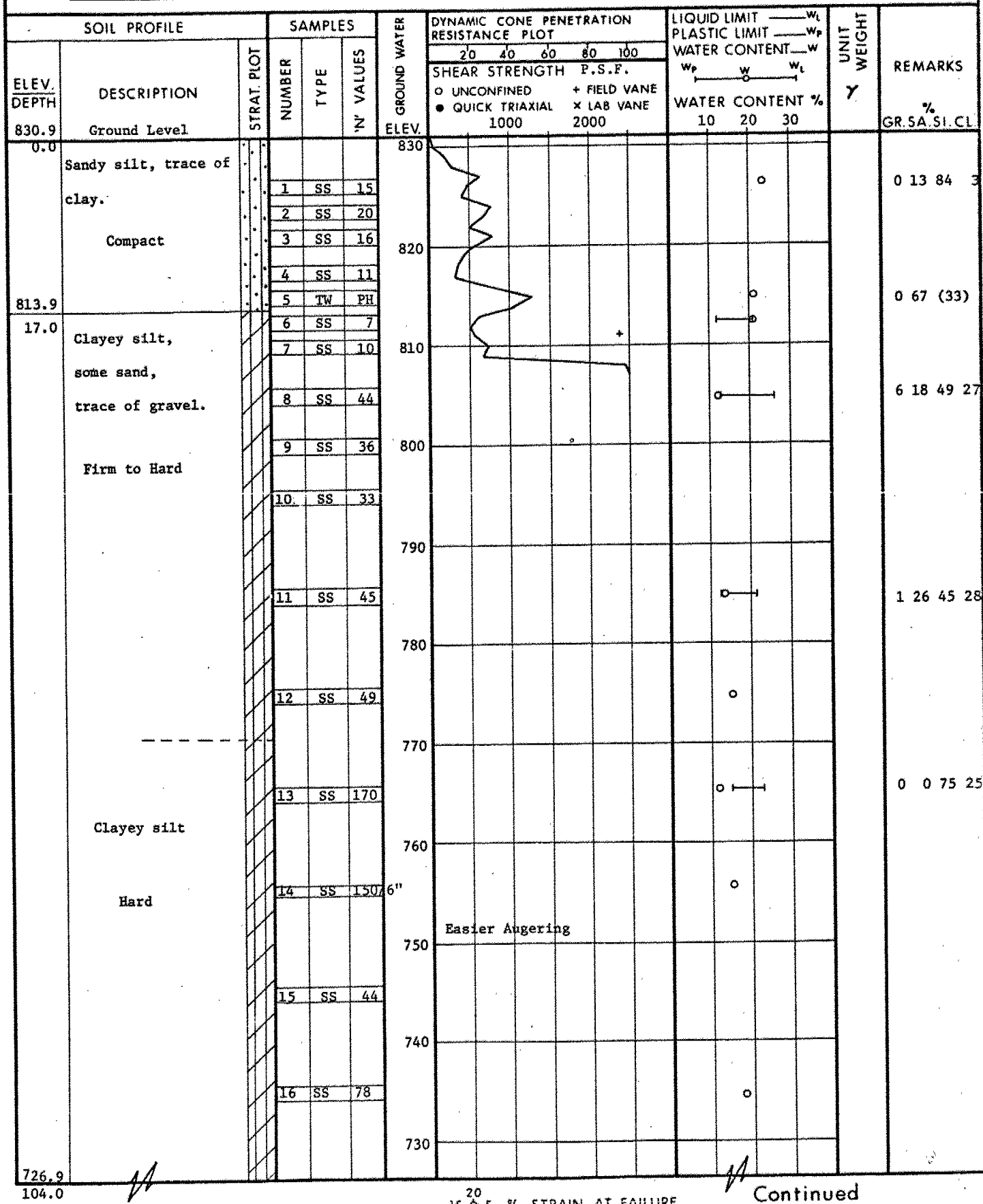
BORING DATE June 3 & 4, 1975

COMPILED BY PJS

DATUM Geodetic

BOREHOLE TYPE Hollow Stem Auger

CHECKED BY CP



OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 3 Continued

W.P. 41-66-07 LOCATION Co-ords. 15,589,937 N; 1,329,534 E. ORIGINATED BY RD  
 DIST. 2 HWY. 402 BORING DATE June 3 & 4, 1975 COMPILED BY BIS  
 DATUM Geodetic BOREHOLE TYPE Hollow Stem Auger CHECKED BY [Signature]

SOIL PROFILE			SAMPLES			GROUND WATER ELEV.	DYNAMIC CONE PENETRATION RESISTANCE PLOT					LIQUID LIMIT $w_L$ PLASTIC LIMIT $w_p$ WATER CONTENT $w$			UNIT WEIGHT $\gamma$	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100	$w_p$	$w$	$w_L$		
726.9	continued															
104.0	Clayey Silt  Hard		17	SS	129	720										
						710										
						700										
694.4			18	SS	43											
136.5	End of Borehole  Note: Water Level not established.															

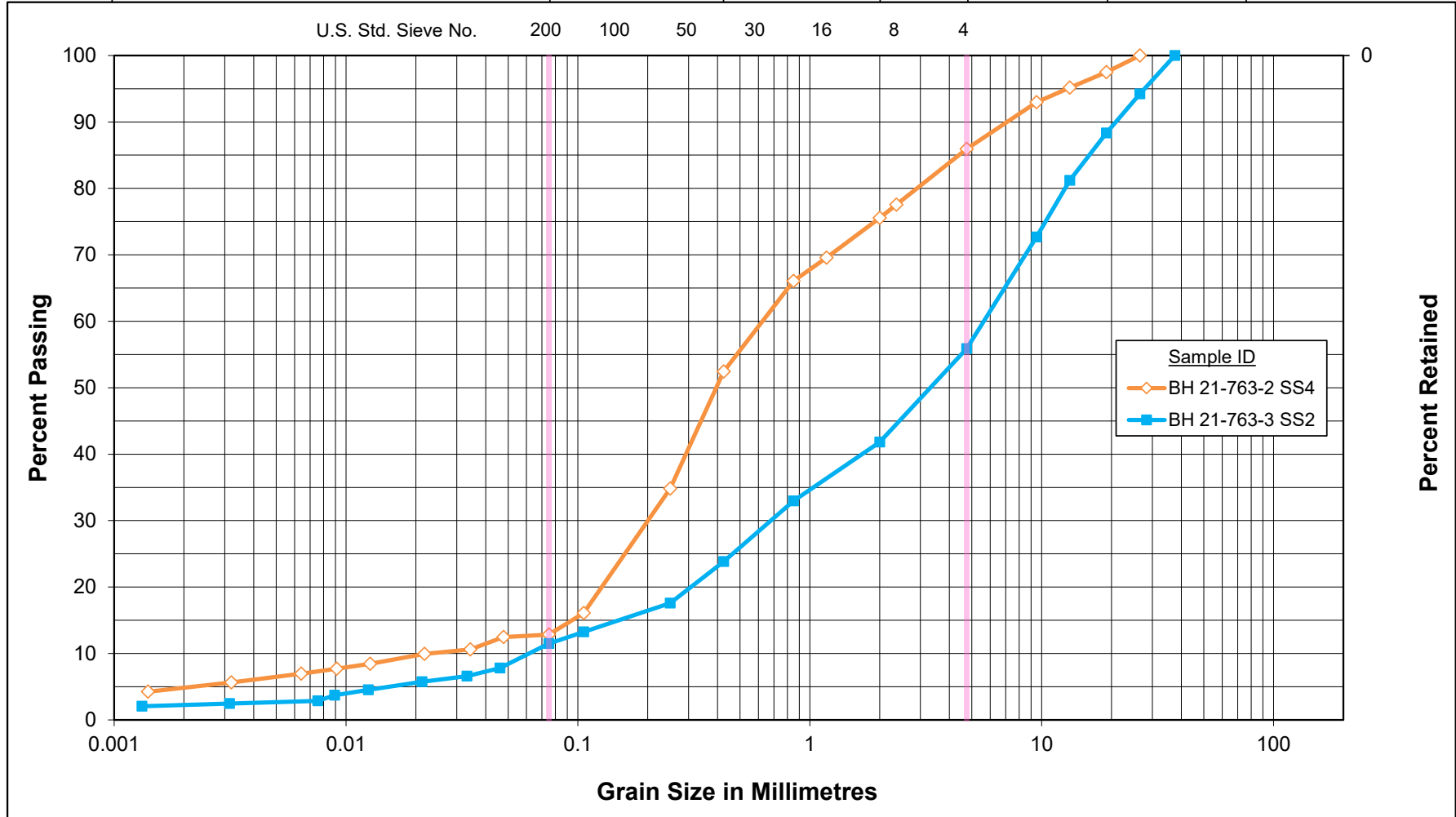
## APPENDIX C

### C.1 LABORATORY TEST RESULTS



# Unified Soil Classification System

			SAND			Gravel	
CLAY & SILT			Fine	Medium	Coarse	Fine	Coarse



## GRAIN SIZE DISTRIBUTION

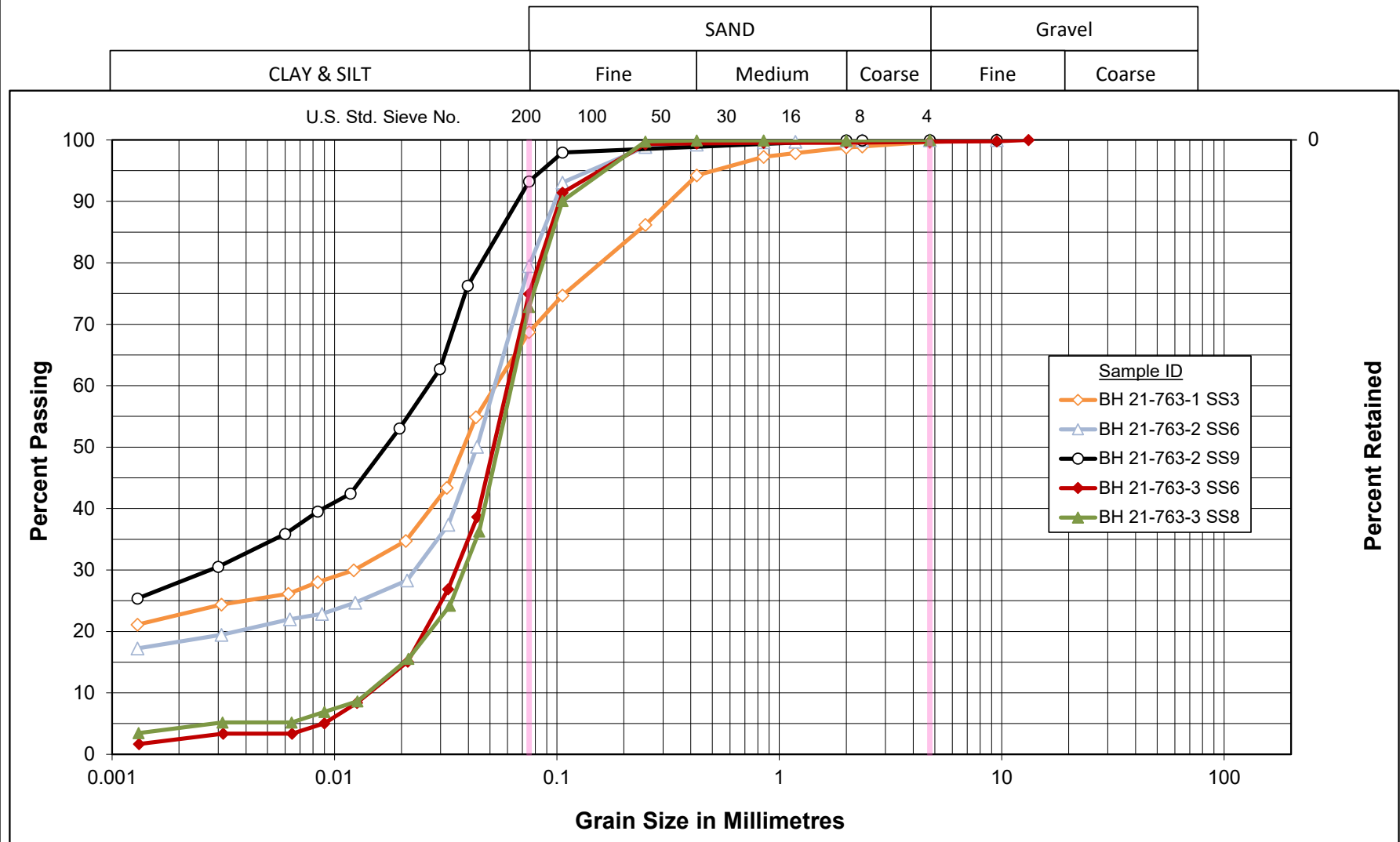
FILL: SAND (SM) to SAND and GRAVEL (SP/GP)

Hwy 402 Rehabilitation - Site 19X-0763/C0

Figure No. C1

Project No. 165001222 (340)

# Unified Soil Classification System



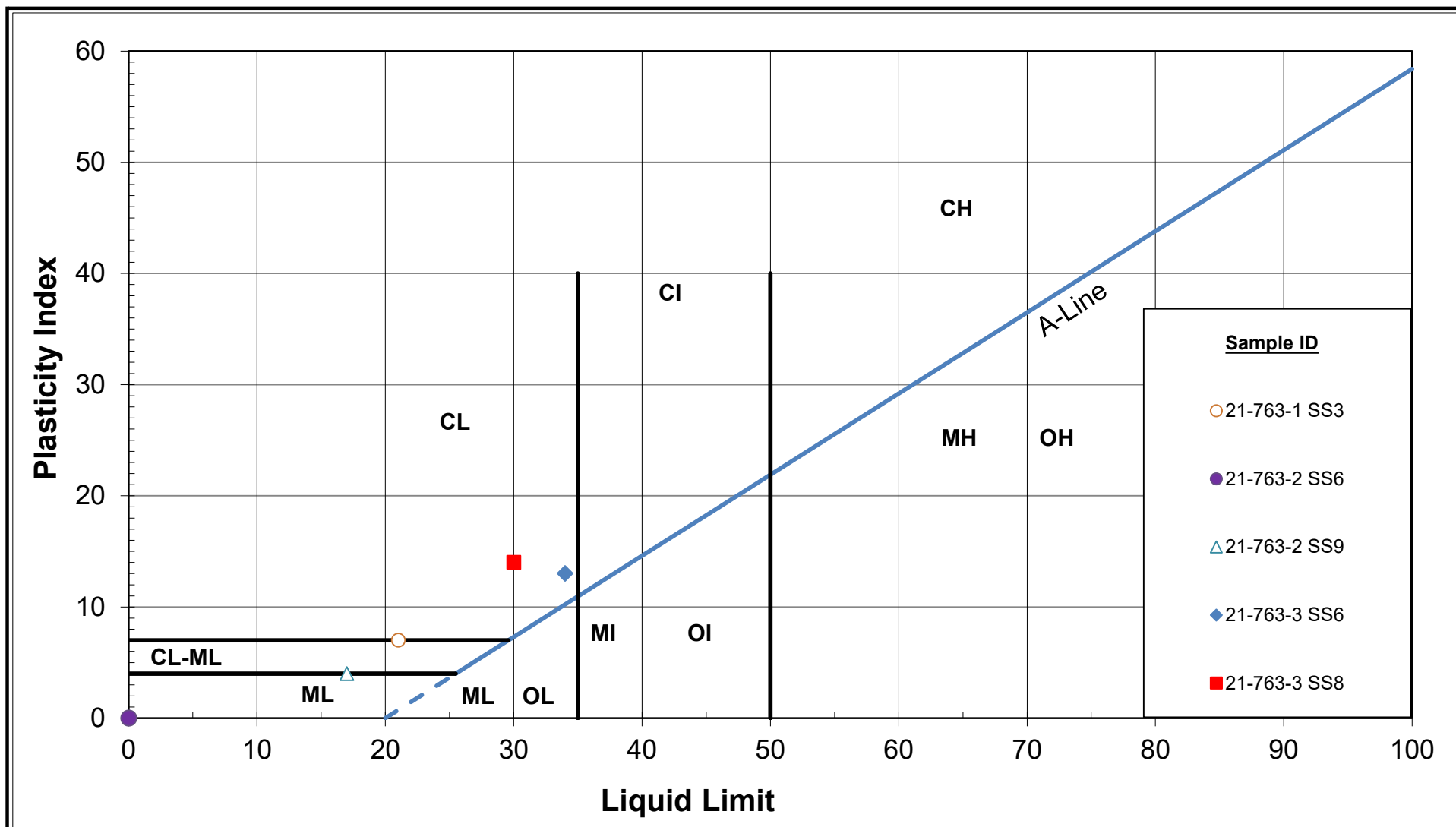
## GRAIN SIZE DISTRIBUTION

SILT/Sandy SILT (ML) to CLAYEY SILT (CL to CL-ML)

Hwy 402 Rehabilitation - Site 19X-0763/C0

Figure No. C2

Project No. 165001222 (340)



Hwy 402 Rehabilitation - Site 19X-0763/C0  
SILT (ML) to CLAYEY SILT (CL to CL-ML)

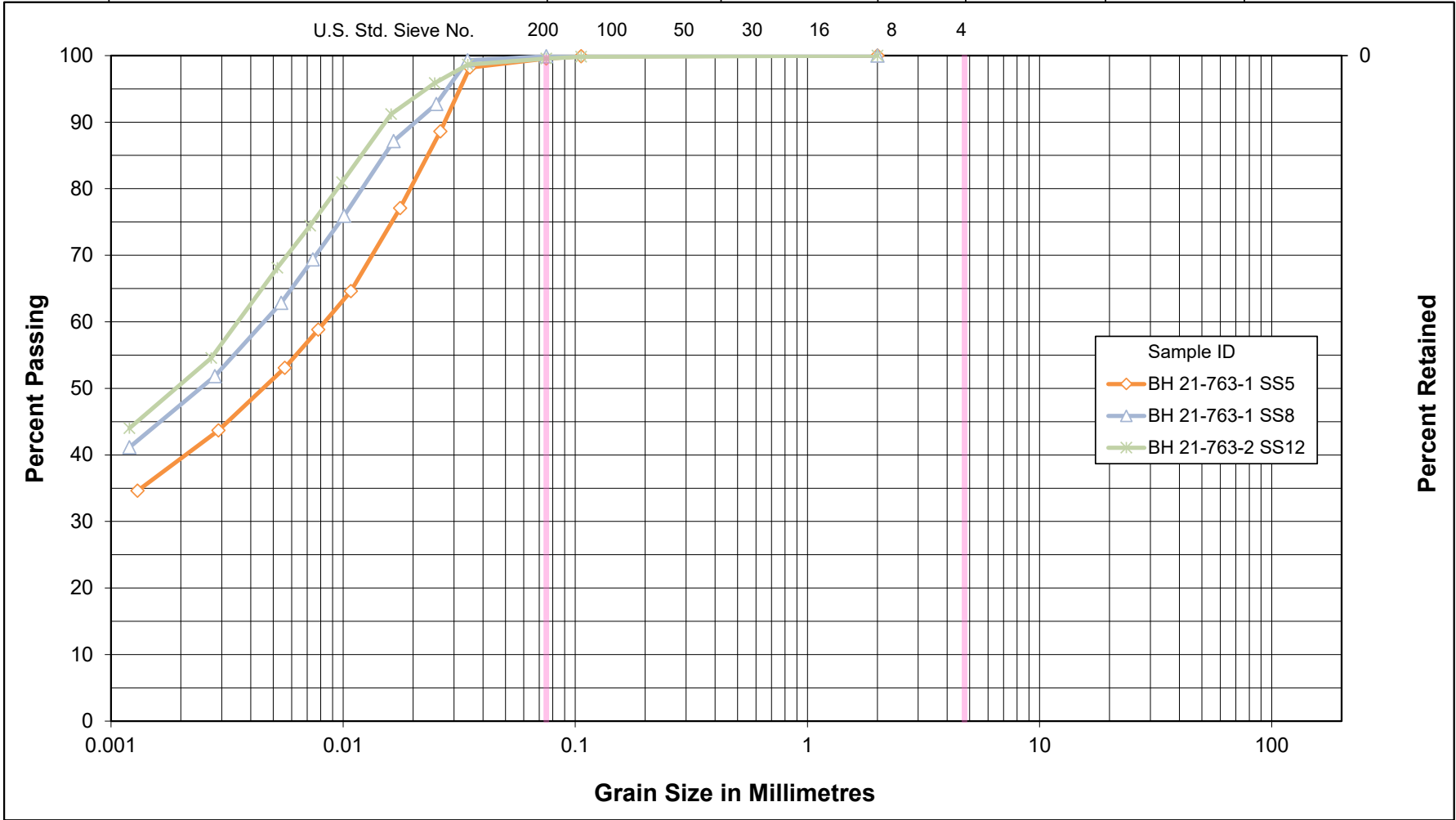
## PLASTICITY CHART

Figure No. C3

Project No. 165001222 (340)

# Unified Soil Classification System

			SAND			Gravel	
CLAY & SILT			Fine	Medium	Coarse	Fine	Coarse



## GRAIN SIZE DISTRIBUTION

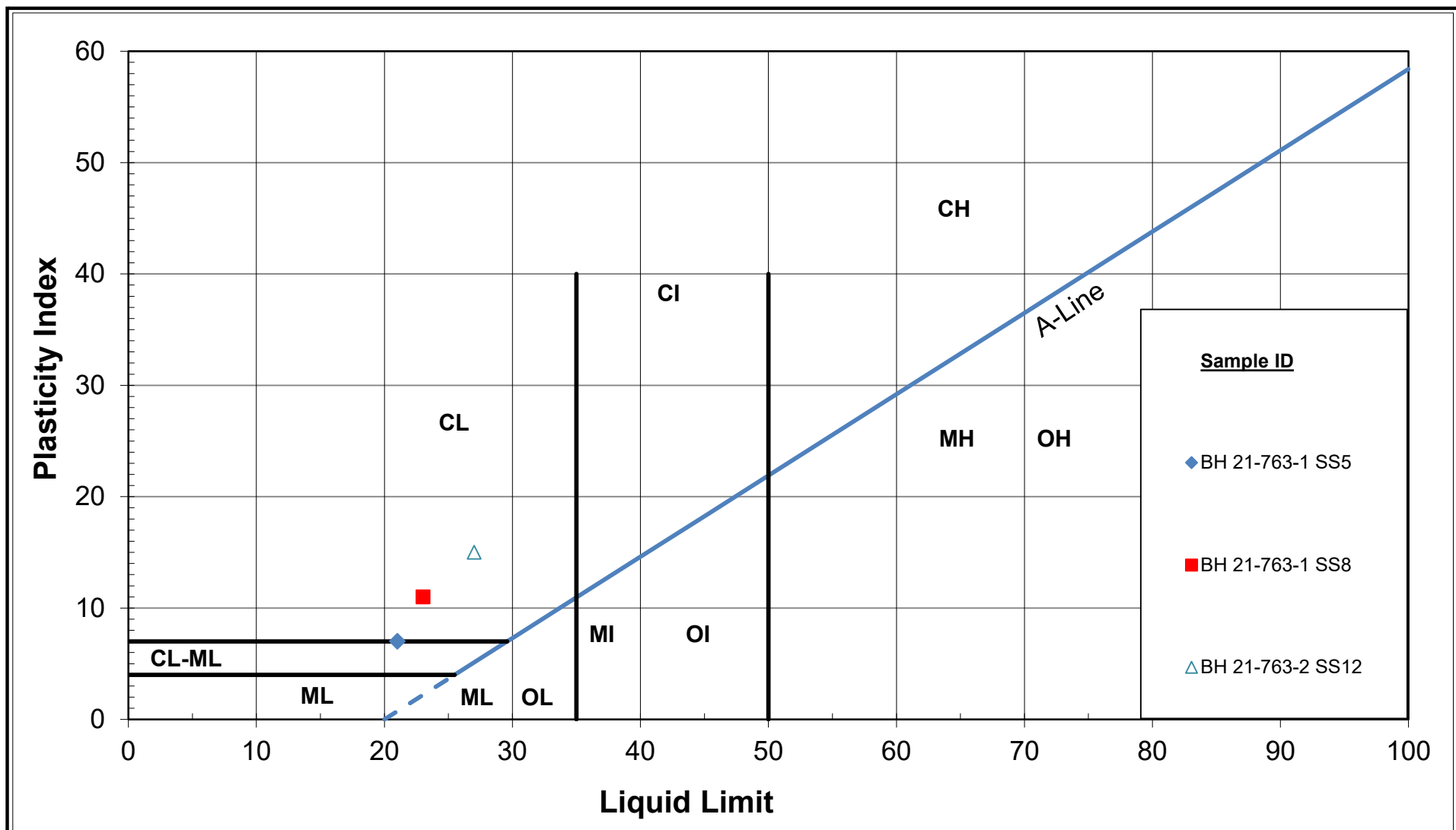
CLAYEY SILT (CL)

Hwy 402 Rehabilitation - Culvert Site 19X-0763/C0

Figure No. C4

Project No. 165001222 (340)





Hwy 402 Rehabilitation - Site 19X-0763/C0

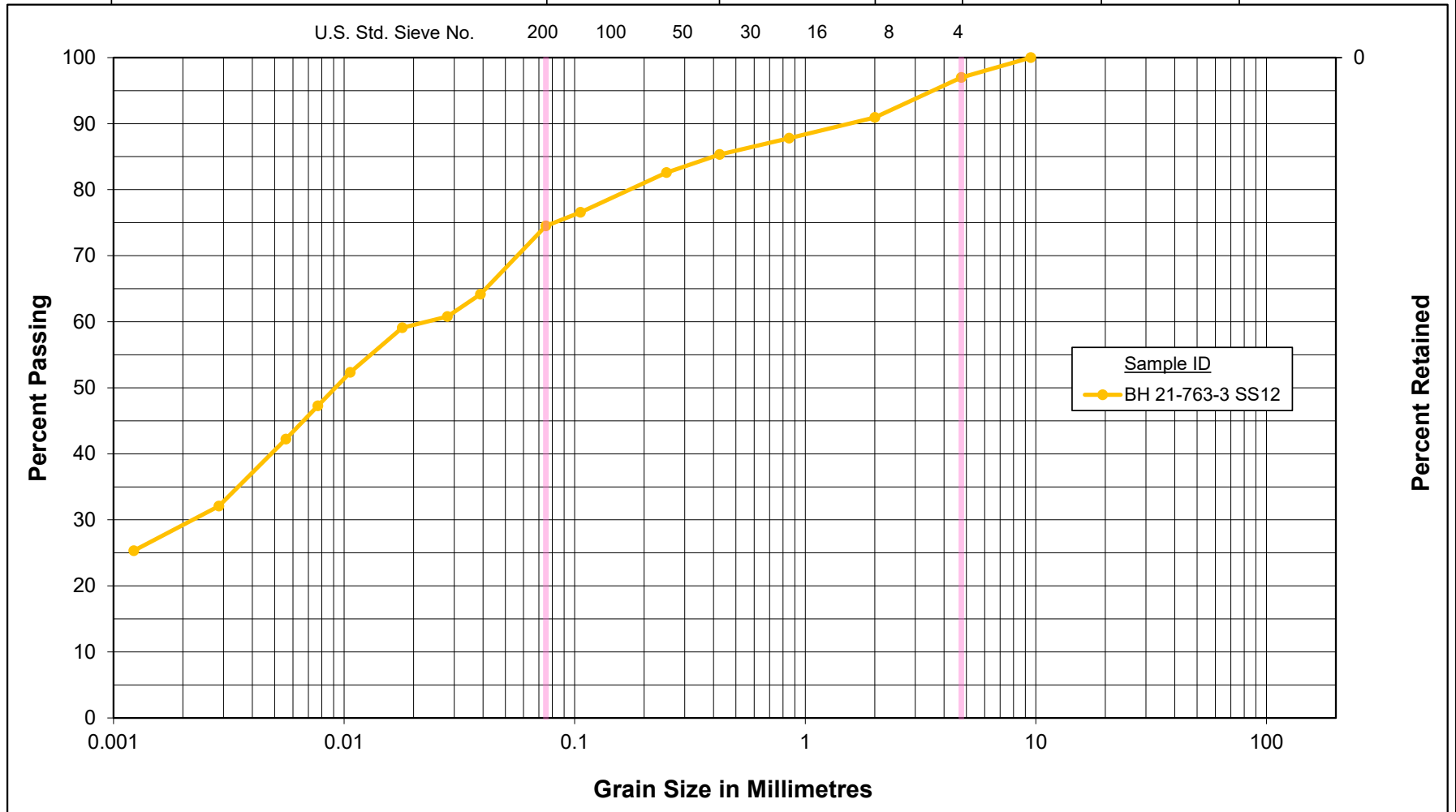
CLAYEY SILT (CL)  
**PLASTICITY CHART**

Figure No. C5

Project No. 165001222 (340)

# Unified Soil Classification System

			SAND			Gravel	
CLAY & SILT			Fine	Medium	Coarse	Fine	Coarse



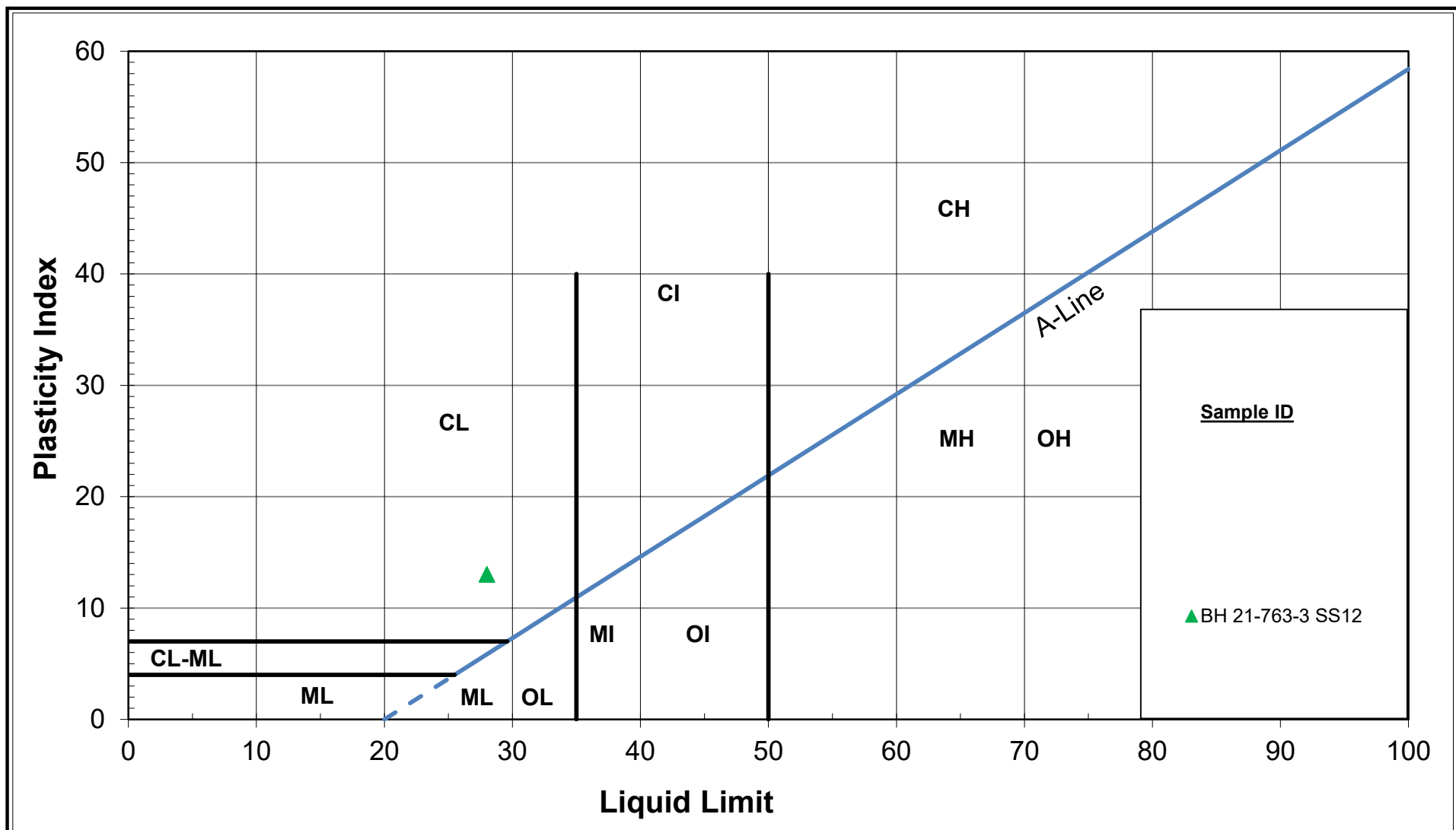
## GRAIN SIZE DISTRIBUTION

TILL: Sandy CLAYEY SILT (CL)

Hwy 402 Rehabilitation - Site 19X-0763-C0

Figure No. C6

Project No. 165001222 (340)



Hwy 402 Rehabilitation - Site 19X-0763/C0

TILL: Sandy CLAYEY SILT (CL)

**PLASTICITY CHART**

Figure No. C7

Project No. 165001222 (340)

## APPENDIX D

### D.1 2015 NATIONAL BUILDING CODE SEISMIC HAZARD CALCULATION



# 2015 National Building Code Seismic Hazard Calculation

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

Site: 42.899N 81.274W

User File Reference: Site No. 19X-0764/C0

2021-09-09 17:30 UT

Requested by: Stantec

Probability of exceedance per annum	0.000404	0.001	0.0021	0.01
Probability of exceedance in 50 years	2 %	5 %	10 %	40 %
Sa (0.05)	0.087	0.050	0.031	0.009
Sa (0.1)	0.118	0.070	0.044	0.014
Sa (0.2)	0.110	0.068	0.044	0.015
Sa (0.3)	0.090	0.057	0.038	0.013
Sa (0.5)	0.070	0.045	0.030	0.010
Sa (1.0)	0.041	0.026	0.017	0.005
Sa (2.0)	0.021	0.013	0.008	0.002
Sa (5.0)	0.005	0.003	0.002	0.001
Sa (10.0)	0.002	0.001	0.001	0.000
PGA (g)	0.066	0.039	0.025	0.007
PGV (m/s)	0.056	0.034	0.021	0.006

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

## References

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

**Structural Commentaries (User's Guide - NBC 2015: Part 4 of Division B)**  
**Commentary J:** Design for Seismic Effects

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

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



Natural Resources  
Canada

Ressources naturelles  
Canada

Canada

## APPENDIX E

### E.1 SAMPLE NSSPS



## **WORKING SLAB - Item No.**

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Special Provision No. FOUN0001

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### **REQUIREMENTS FOR CONCRETE WORKING SLAB UNDER STRUCTURE FOUNDATIONS**

#### **1.0 SCOPE**

This specification covers the requirements for the supply and placement of a concrete working slab under structure foundations.

#### **2.0 REFERENCES**

This specification refers to the following standards, specifications or publications:

##### **Ontario Provincial Standard Specifications, Construction**

OPSS 902      Excavating and Backfilling - Structures

#### **3.0 DEFINITIONS - Not Used**

#### **4.0 DESIGN AND SUBMISSION REQUIREMENTS - Not Used**

#### **5.0 MATERIALS**

Concrete for working slabs shall have a minimum 28-day strength of 20 MPa.

#### **6.0 EQUIPMENT - Not Used**

#### **7.0 CONSTRUCTION**

##### **7.01 Excavation**

Excavation for the working slab shall be according to OPSS 902.

##### **7.02 Protection of Founding Soil**

Following inspection and approval of the prepared subgrade, a concrete working slab with a minimum thickness of 100 mm shall be placed on the foundation subgrade as specified in the Contract Documents.

##### **7.04 Dewatering**

Dewatering shall be carried out according to OPSS 902.

**8.0                      QUALITY ASSURANCE - Not Used**

**9.0                      MEASUREMENT FOR PAYMENT - Not Used**

**10.0                    BASIS OF PAYMENT**

**10.01                  Working Slab - Item**

Payment at the Contract price for the above tender item shall be full compensation for all labour, Equipment and Material to do the work.



## **NOTICE TO CONTRACTOR – Elevated Groundwater Conditions**

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### **Special Provision**

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#### **Presence of Elevated Groundwater Conditions**

The foundation investigation program conducted for the proposed replacement culvert identified the presence of groundwater pressures within the subsurface strata that are above the base of the excavations required for installation of the replacement culvert.

It is recommended that the bidders review the contents of the Foundation Investigation Report (FIR) with respect to the groundwater conditions at the site.

Based on these conditions, the silt/sandy silt subgrade soils at the base of the excavation for the culvert replacement will be susceptible to 'boiling' and disturbance due to the unbalanced hydrostatic head and upward seepage forces. These conditions could lead to base instability/heave. An appropriate dewatering/groundwater control program will be required to maintain the integrity of the foundation subgrade soils and stability of the foundation excavation.

External dewatering systems (e.g. vacuum-assisted well points or eductor wells located outside of the excavation) could be used to control groundwater. Alternatively, cut-off measures (e.g. steel sheet piles extending through the granular soils into the underlying silty clay till) combined with pumping from wells installed within the enclosure could be used to control groundwater. If this approach is adopted, the sheet piles should provide an enclosure around the entire perimeter of the excavation.

The dewatering system should be installed and operated to lower the water level in the silt/sandy silt deposit to a minimum of 0.5 m below the base of the excavation required for the construction of the new culvert. The dewatering system should be implemented prior to the excavation extending below Elevation 251 m.

Dewatering should continue throughout construction including excavation below Elevation 251 m, placement and compaction of bedding/levelling pads, concrete placement and curing, culvert installation and backfilling.

## **Obstructions - Item No.**

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### Special Provision

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#### **1.0 SCOPE**

This Special Provision identifies requirements for the supply of construction equipment and implementation of procedures to address obstructions, including cobbles and/or boulders and components of the existing culvert structures, present at the site that could impact excavations and/or the installation of temporary dewatering and/or flow passage system elements.

#### **2.0 CONSTRUCTION**

Cobbles and boulders were identified in the fill materials and native soil deposits at the site. Concrete associated with the existing culverts (e.g. cut-off walls, potential mud slabs) could also be present.

Cobbles, boulders and concrete may obstruct excavation activities and the installation of temporary dewatering systems and temporary flow passage systems.

The Contractor is advised that appropriate equipment and construction procedures will be required to penetrate through or remove obstructions, such as concrete, and cobbles and boulders, to permit excavations and installation of temporary flow passage and dewatering system elements.

The removal of cobbles and boulders from excavations may lead to undermining of materials in the sidewalls of excavations. The contractor shall implement appropriate measures to prevent instability resulting from the removal of cobbles, boulders or other obstructions

#### **3.0 BASIS OF PAYMENT**

Payment at the Contract price for the appropriate tender items associated with excavations, temporary flow passage and dewatering systems shall include full compensation for all labour, equipment and materials to complete the work.

## **OPERATIONAL CONSTRAINT (FOUNDATION) – Protection of Foundation Subgrade**

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### Special Provision

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Construction operations shall be carried out in such a manner as to protect the integrity of the foundation subgrade soils prior to/during the installation of the replacement culvert.

The foundation investigation identified that the foundation subgrade materials consist of silt to silt and sand and that the groundwater level in these soils is more than 1 m above the anticipated base of the excavation required for construction of the replacement culvert. These conditions could result in groundwater inflows, and disturbance and potential basal instability (i.e. boiling or piping) of the foundation subgrade materials unless adequate dewatering is provided. To address this issue, the Contractor must implement a dewatering/groundwater control program to lower the water level within the silt/sandy silt soils a minimum of 0.5 m below the base of the excavation required for the construction of the new culvert.

The Contractor shall arrange their work activities to avoid construction equipment moving/travelling directly on the silt/silt and sand materials at the subgrade level as this could result in disturbance of the subgrades soils which could impact the performance of the replacement culvert.

Following completion of the preparation of the founding surface, a milestone inspection should be conducted by foundation/geotechnical personnel arranged for by the Contract Administrator in accordance with SP109S12.

A minimum 100 mm thick concrete mud mat/working slab shall be placed immediately following the inspection and approval of the subgrade to protect the subgrade.