Foundation Investigation 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. 40I14-198

December 16, 2021

Prepared for:

Ministry of Transportation Ontario

Prepared by:

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Project No. 165001222 (340)

Table of Contents

1.0 INTRODUCTION 1

2.0 SITE DESCRIPTION AND GEOLOGY 2

3.0 AVAILABLE SUBSURFACE INFORMATION 4

4.0 INVESTIGATION PROCEDURES 5
4.1 FIELD INVESTIGATION 5
4.2 LOCATION AND ELEVATION SURVEY 5
4.3 LABORATORY TESTING 6

5.0 SUBSURFACE CONDITIONS 6
5.1 FRAMEWORK & OVERVIEW 6
5.2 OVERBURDEN 7
5.2.1 Topsoil 7
5.2.2 Asphaltic Concrete 7
5.2.3 Fill 7
5.2.4 SILT/SANDY SILT 8
5.2.5 CLAYEY SILT 8
5.2.6 CLAYEY SILT (TILL) 9
5.3 BEDROCK 10
5.4 GROUNDWATER CONDITIONS 10
5.5 CHEMICAL ANALYSIS 10

6.0 MISCELLANEOUS 11

7.0 CLOSURE 12

LIST OF TABLES

Table 4.1: Borehole Information Summary 6
Table 4.2: Laboratory Testing Program 6
Table 5.1: Results of Chemical Analysis 10

LIST OF APPENDICES

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

APPENDIX B B.1
B.1 Symbols and Terms Used on Borehole Records B.1
B.2 Borehole Records B.1
B.3 Subsurface Information from GEOCRES Report 40I14-96 ..... B.1

APPENDIX C C.1
C.1 Laboratory Test Results C.1

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.

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.

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

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 Westminister, 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).

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 19th, and in the morning and in the afternoon of July 20th, 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.

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

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.

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.

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 is 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).

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 20th, 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

Borehole No	Sample No.	Depth (m)	pH	Chloride (µg/g)	Sulphate (µg/g)	Resistivity (Ohm-m)
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

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.

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

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

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

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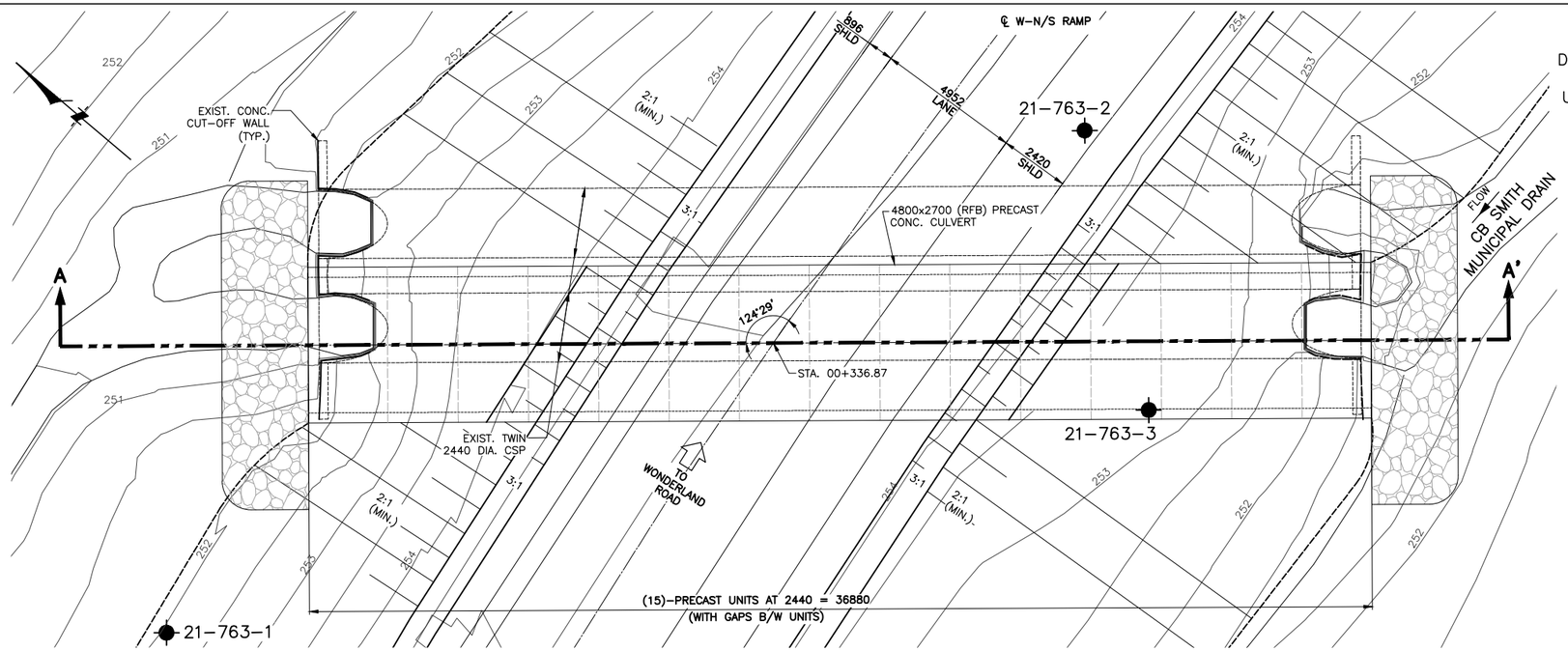
APPENDIX A

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

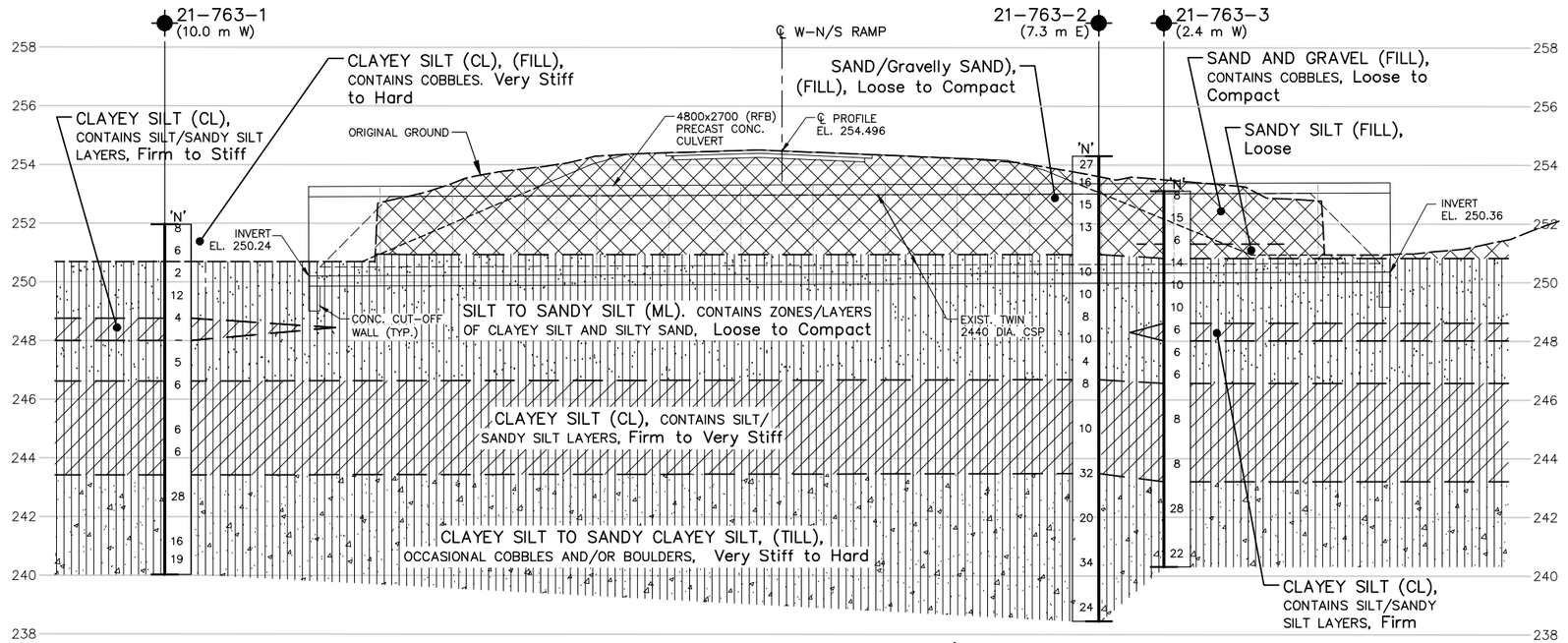
MINISTRY OF TRANSPORTATION, ONTARIO PR-D-707 88-05



PLAN

SCALE

2m 0 2 4m



CROSS SECTION A–A'

SCALE

2m 0 2 4m

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

LICENSED PROFESSIONAL ENGINEER
K. NELSON
2021/12/16
PROVINCE OF ONTARIO

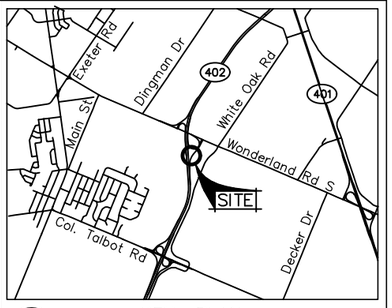
LICENSED PROFESSIONAL ENGINEER
J. BRISBOIS
2021/12/16
PROVINCE OF ONTARIO

PLATE No
CONT
GWP 3108–18–00

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

SHEET
–

Stantec



KEY PLAN

1 km 0 1 2 km

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 COORDINATES NORTH	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 40I14–198

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

DRAWING NAME: 165001222_19X-0763_GA.dwg
CREATED BY: GBB MODIFIED:
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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:

Rootmat	- vegetation, roots and moss with organic matter and topsoil typically forming a mattress at the ground surface
Topsoil	- mixture of soil and humus capable of supporting vegetative growth
Peat	- mixture of visible and invisible fragments of decayed organic matter
Till	- unstratified glacial deposit which may range from clay to boulders
Fill	- material below the surface identified as placed by humans (excluding buried services)

Terminology describing soil structure:

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

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, 4th 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:

Trace, or occasional	Less than 10%
Some	10-20%
Frequent	> 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
Very Loose	<4
Loose	4-10
Compact	10-30
Dense	30-50
Very Dense	>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	
Very Soft	<0.25	<12.5	<2
Soft	0.25 - 0.5	12.5 - 25	2-4
Firm	0.5 - 1.0	25 - 50	4-8
Stiff	1.0 - 2.0	50 – 100	8-15
Very Stiff	2.0 - 4.0	100 - 200	15-30
Hard	>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.

Boulders Cobbles Gravel | Sand | Silt | Clay | Organics | Asphalt | Concrete | Fill | Igneous Bedrock | Meta-morphic Bedrock | Sedi-mentary Bedrock

SAMPLE TYPE

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

WATER LEVEL MEASUREMENT

measured in standpipe, piezometer, or well

inferred

RECOVERY

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

N-VALUE

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 140 pound (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
γ	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

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
252.0											
251.8	150 mm TOPSOIL										
0.2	CLAYEY SILT (CL), some sand and trace gravel (FILL). Contains occasional cobbles and/or boulders. Hard Brown Moist		1	SS	8						
251.0											
0.9	Sandy SILT (CL-ML), trace gravel. Contains zones of CLAYEY SILT (CL). Loose to compact Brown Moist Becomes wet below ~ 2m.		2	SS	6		251				
			3	SS	2	▽	250				0 31 46 23
			4	SS	12		249				
248.8											
3.2	CLAYEY SILT (CL), trace sand. Firm to stiff Grey Wet		5	SS	4						0 0 60 39
248.0							248				
4.0	SILT to Sandy SILT (ML). Contains thin layers and zones of clayey silt (CL) Loose Grey Wet		6	SS	-			+			Su>118 kPa (N-vane refusal) No SPT N-value recorded for SS6 due to soil disturbance
			7	SS	5		247				
246.6											
5.3	CLAYEY SILT (CL). Contains SILT layers up to 50 mm in thickness. Firm to stiff Grey Wet		8	SS	6						0 0 52 48
							246				
								+			Su>118 kPa (N-vane refusal)
			9	SS	6		245				
			10	SS	6		244				
243.4								+			
8.5	CLAYEY SILT (CL), trace to some sand, trace gravel (TILL) Very stiff to hard Grey Moist										Su>118 kPa (N-vane refusal)
			11	SS	28		243				
							242				
			12	SS	16		241				
240.1			13	SS	19						
11.9	End of Borehole Groundwater observed below a depth of approximately 2 m (~Elev. 250 m).										

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

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

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
254.3											
254.2	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				○		
1.1	Gravelly SAND, trace silt (FILL)						253				
252.8	Compact										
1.5	Brown Moist		3	SS	15				○		
	SAND, some gravel, trace silt (FILL) Loose to compact Brown Moist		4	SS	13		252		○		14 73 8 5
250.9			5	SS	5	▼	251		○		
3.4	Sandy SILT (ML). Contains zones of clayey silt and silty sand Loose to compact Bluish-grey to brown Wet		6	SS	10				○		0 20 61 18 Non-Plastic
			7	SS	10		250		○		
248.8							249				
5.5	SILT (ML), trace sand. Contains thin layers and zones of clayey silt (CL-ML) Loose to compact Grey Wet		8	SS	8				○		
			9	SS	10		248		H ○		0 7 65 28
247.4											
6.9	Sandy SILT (ML) Very loose to loose Grey Wet		10	SS	4		247		○		
246.7											
7.6	CLAYEY SILT (CL), trace sand. Stiff to very stiff Grey Wet		11	SS	8				○		
							246				
			12	SS	10		245		H ○		0 0 49 51
	50 mm silt seam with free groundwater at 9.6 m							+			Su>118 kPa (N-vane refusal)
243.5							244				
10.8	CLAYEY SILT (CL), trace to some sand, trace gravel (TILL). Contains occasional cobbles. Very stiff to hard Grey Moist		13	SS	32				○		
							243				
			14	SS	20		242		○		
			15	SS	34		241		○		

Continued Next Page

+ 3, × 3: 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

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (20 40 60 80 100): ○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	CLAYEY SILT (CL), trace to some sand, trace gravel (TILL). Contains occasional cobbles. Very stiff to hard Grey Moist *(continued)*										
			16	SS	24		239		○		
238.4											
15.9	End of Borehole Water level recorded in monitoring well at 3.8 m depth (~Elev. 250.5 m) on July 19 and 3.4 m depth (~Elev. 250.9 m) on July 20, 2021. Well decommissioned on July 20, 2021.										

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

RECORD OF BOREHOLE No 21-763-3

1 OF 1

METRIC

W.P. GWP 3108-18-00 LOCATION Hwy 402, London, Ontario N: 4751723.7 E:405038.6 ORIGINATED BY DL

DIST West HWY 402 BOREHOLE TYPE Hollow Stem Auger - Split Spoon COMPILED BY RR

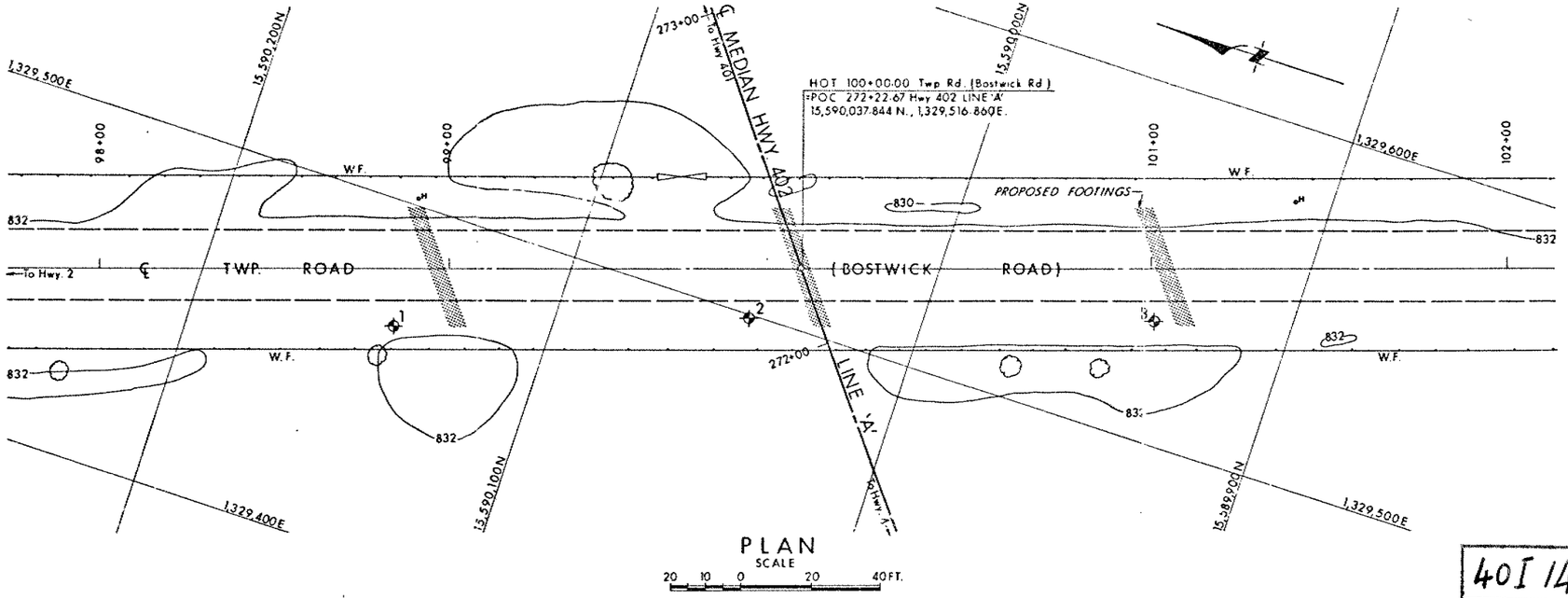
DATUM Geodetic DATE 2021.07.20 - 2021.07.20 LATITUDE 42.898715 LONGITUDE -81.272595 CHECKED BY KN

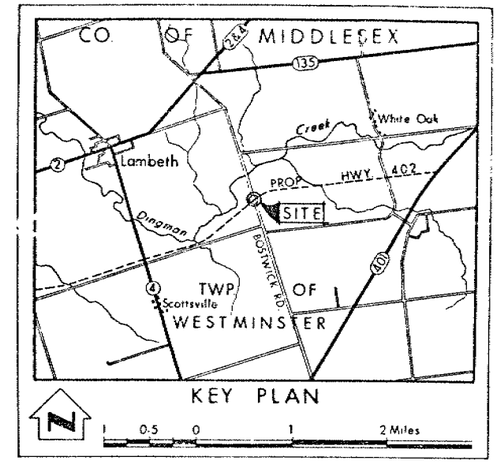
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
253.1 / 0.0	250 mm TOPSOIL						253				
252.8 / 0.3	SAND and GRAVEL, trace silt and clay (FILL) Loose to compact Brown Dry Contains occasional cobbles and/or boulders below 0.8 m.		1	SS	8						
			2	SS	15		252				44 45 8 3
251.3			3	SS	6						
250.8 / 1.8	Sandy SILT (FILL) Loose Brown to dark grey						251				
2.3	Moist to wet Sandy SILT, trace clay (ML) to Silty SAND (SM) with silt layers Compact Orangey brown Wet Becomes grey below 2.8 m		4	SS	14	▽					
			5	SS	10		250				
248.6			6	SS	10		249				0 25 72 3
248.0 / 4.5	CLAYEY SILT (CL) Firm Grey Wet		7	SS	6						
5.1	Sandy SILT, trace clay (ML) Loose Grey Wet		8	SS	6		248				0 27 69 4
246.5			9	SS	6		247				
6.6	CLAYEY SILT (CL) Firm to stiff Grey Wet						246	+			Su>118 kPa (N-vane refusal)
	SS10 contains sandy silt layers		10	SS	8		245				
								+			Su>118 kPa (N-vane refusal)
243.2			11	SS	8		244				
9.9	SANDY CLAYEY SILT (CL), trace gravel (TILL). Contains occasional cobbles and/or boulders. Very stiff to hard Grey Moist						243	+			Su>118 kPa (N-vane refusal)
			12	SS	28		242				3 22 46 29
	Low recovery in SS13 due to inferred cobbles and/or boulders		13	SS	22		241				
240.3											
12.8	End of Borehole Groundwater observed below approximately 2.8 m depth (~Elev. 250.3 m).										

+³, ×³: Numbers refer to Sensitivity

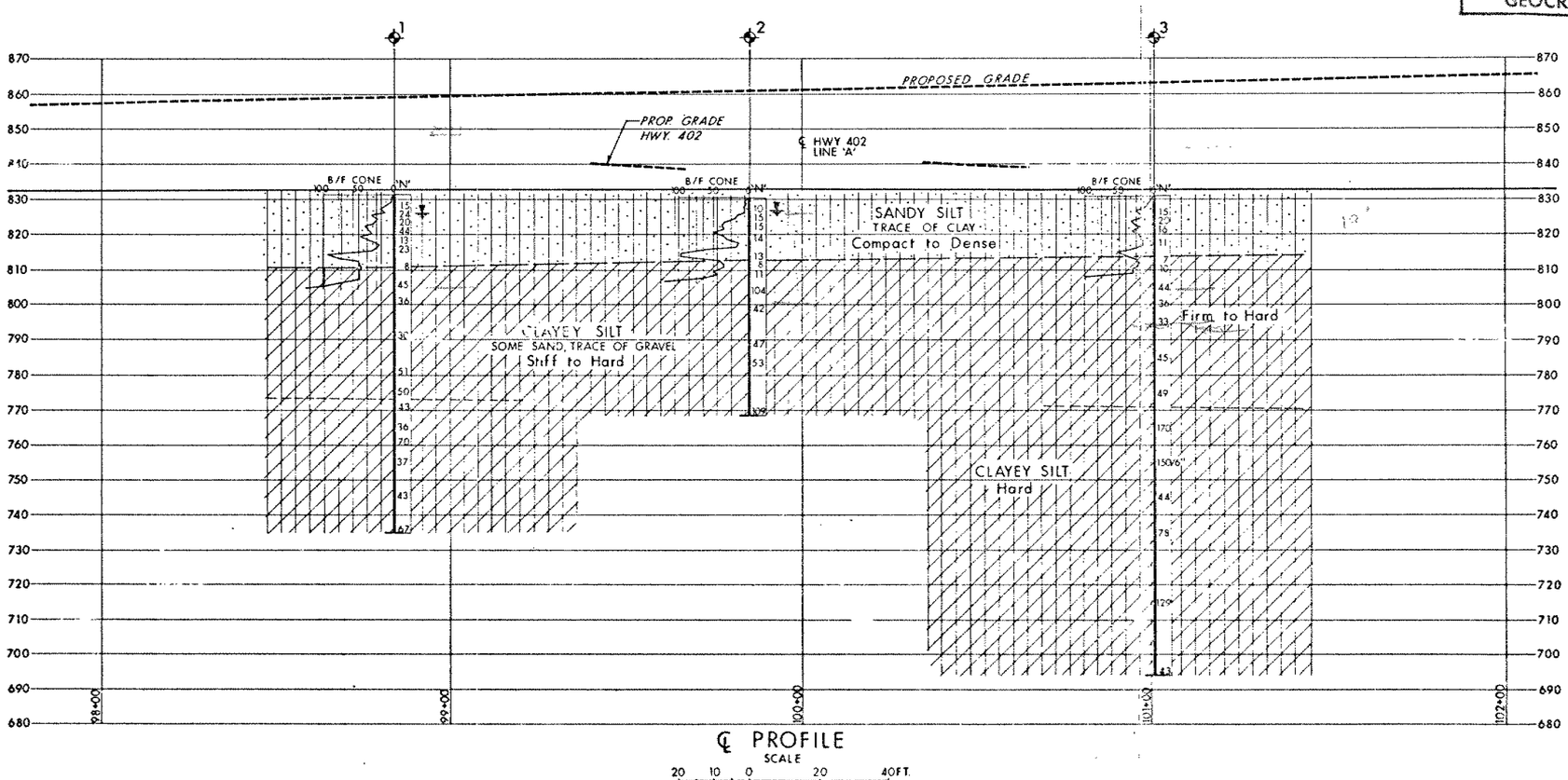
○ 3% STRAIN AT FAILURE

SUBSURFACE INFORMATION FROM GEOCRES REPORT 40I14-96





401 14-96
GEOCRES No.



LEGEND

- Bore Hole
- Dynamic Cone Penetration Resistance Test B/F CONE - Blows/Ft. Cone Test (350 ft.lbs. energy/blow)
- 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.

REVISIONS	DATE	BY	DESCRIPTION

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 & 67 CON 4 & ENBTR

BORE HOLE LOCATIONS & SOIL STRATA

SUBMD P.J.S	CHECKED	W.P. NO 41-66-07	DRAWING NO 416607-A
DRAWN	CHECKED	AGT NO	
DATE July 9, 1975		SITE NO 19-545	BRIDGE DRAWING NO
APPROVED		CONT NO	

REF NO E-5375-1; April 1975

FF-A-24 (a) (Rev. Jan. 73)

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 :-

CONSISTENCY	c LB./SQ.FT.
VERY SOFT	0 - 250
SOFT	250 - 500
FIRM	500 - 1000
STIFF	1000 - 2000
VERY STIFF	2000 - 4000
HARD	> 4000

DENSENESS	'N' BLOWS / FT.
VERY LOOSE	0 - 4
LOOSE	4 - 10
COMPACT	10 - 30
DENSE	30 - 50
VERY DENSE	> 50

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
CIU	CONSOLIDATED ISOTROPIC UNDRAINED TRIAXIAL	C	CONSOLIDATION
CID	" " DRAINED "	S	SENSITIVITY
CAU	" ANISOTROPIC UNDRAINED "		
CAD	" " DRAINED "		

FF-A-24(b) (Rev. Jan. 73)

ABBREVIATIONS & SYMBOLS USED IN THIS REPORT

SOIL PROPERTIES

γ	UNIT WEIGHT OF SOIL (BULK DENSITY)
γ_s	UNIT WEIGHT OF SOLID PARTICLES
γ_w	UNIT WEIGHT OF WATER
γ_d	UNIT DRY WEIGHT OF SOIL (DRY DENSITY)
γ'	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
τ_f	SHEAR STRENGTH
c'	EFFECTIVE COHESION INTERCEPT
ϕ'	EFFECTIVE ANGLE OF SHEARING RESISTANCE, OR FRICTION
	IN TERMS OF EFFECTIVE STRESS $\tau_f = c' + \sigma' \tan \phi'$
c_u	APPARENT COHESION
ϕ_u	APPARENT ANGLE OF SHEARING RESISTANCE, OR FRICTION
	IN TERMS OF TOTAL STRESS $\tau_f = c_u + \sigma \tan \phi$
μ	COEFFICIENT OF FRICTION
S_t	SENSITIVITY

GENERAL

π	= 3·1416
e	BASE OF NATURAL LOGARITHMS 2·7183
$\log_e a$ OR $\ln a$	NATURAL LOGARITHM OF a
$\log_{10} a$ OR $\log a$	LOGARITHM OF a 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
σ	NORMAL STRESS
σ'	NORMAL EFFECTIVE STRESS ($\bar{\sigma}$ IS ALSO USED)
τ	SHEAR STRESS
ε	LINEAR STRAIN
γ	SHEAR STRAIN
ν	POISSON'S RATIO (μ IS ALSO USED)
E	MODULUS OF LINEAR DEFORMATION (YOUNGS MODULUS)
G	MODULUS OF SHEAR DEFORMATION
K	MODULUS OF COMPRESSIBILITY
η	COEFFICIENT OF VISCOSITY

EARTH PRESSURE

d	DISTANCE FROM TOP OF WALL TO POINT OF APPLICATION OF PRESSURE
δ	ANGLE OF WALL FRICTION
K	DIMENSIONLESS COEFFICIENT TO BE USED WITH VARIOUS SUFFIXES IN EXPRESSIONS REFERRING TO NORMAL STRESS ON WALLS
K_o	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
β	ANGLE OF SLOPE TO HORIZONTAL

MINISTRY OF TRANSPORTATION AND COMMUNICATIONS – ONTARIO

ENGINEERING SERVICES BRANCH – GEOTECHNICAL OFFICE – SOIL MECHANICS SECTION

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

ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES	GROUND WATER ELEV.
831.5	Ground Level					
0.0	Sandy silt, trace of clay. Compact to Dense		1	SS	15	830
			2	SS	24	
			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 Stiff to Hard		8	SS	45	
			9	SS	36	800
			10	SS	30	790
			11	SS	51	780
			12	SS	50	
	Clayey silt Hard		13	SS	43	770
			14	SS	36	
			15	SS	70	760
			16	SS	37	
			17	SS	43	750
735.0			18	SS	67	740
96.5	End of Borehole					

DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100)

SHEAR STRENGTH P.S.F. (1000 2000)

○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE

+ 3680

LIQUID LIMIT w_L PLASTIC LIMIT w_P WATER CONTENT w

w_P w w_L

WATER CONTENT % (10 20 30)

UNIT WEIGHT γ

REMARKS	% GR.	SA.	SI.	CL.
	0	35	62	3
	0	39	60	1
	3	17	52	28
	2	10	51	37
	0	0	71	29
	0	0	67	33

15 20 10 5 % STRAIN AT FAILURE

OFFICE REPORT ON SOIL EXPLORATION

MINISTRY OF TRANSPORTATION AND COMMUNICATIONS – ONTARIO

ENGINEERING SERVICES BRANCH – GEOTECHNICAL OFFICE – SOIL MECHANICS SECTION

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 ELEV./DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER ELEV.
830.3	Ground Level					830
0.0	Sandy silt, trace of clay. Compact		1	SS	10	
			2	SS	15	
			3	SS	15	
			4	SS	14	820
813.3			5	SS	13	
17.0	Clayey silt, some sand, trace of gravel. Stiff to Hard		6	SS	8	
			7	SS	11	810
			8	SS	104	
			9	SS	42	800
			10	SS	47	790
			11	SS	53	
						780
768.8			12	SS	109	770
61.5	End of Borehole					

DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100)

SHEAR STRENGTH P.S.F. (1000 2000)

○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE

LIQUID LIMIT —— w_L

PLASTIC LIMIT —— w_P

WATER CONTENT —— w

w_P w w_L

WATER CONTENT % (10 20 30)

UNIT WEIGHT γ

REMARKS	% GR.	SA.	SI.	CL.
	0	18	71	11
	0	38	60	2
	1	41	56	2
	6	24	41	29
	2	4	60	34
	0	1	78	21

OFFICE REPORT ON SOIL EXPLORATION

15 20 S % STRAIN AT FAILURE

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

ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER ELEV.
830.9	Ground Level					830
0.0	Sandy silt, trace of clay. Compact		1	SS	15	
			2	SS	20	
			3	SS	16	820
			4	SS	11	
813.9			5	TW	PH	
17.0	Clayey silt, some sand, trace of gravel. Firm to Hard		6	SS	7	
			7	SS	10	810
			8	SS	44	
			9	SS	36	800
			10	SS	33	
			11	SS	45	790
			12	SS	49	
			13	SS	170	780
	Clayey silt Hard		14	SS	150/6"	770
			15	SS	44	760
			16	SS	78	
726.9						750
104.0						740
						730

DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100)

SHEAR STRENGTH P.S.F. (1000 2000)

o UNCONFINED + FIELD VANE

● QUICK TRIAXIAL × LAB VANE

LIQUID LIMIT W_L PLASTIC LIMIT W_P WATER CONTENT W

WATER CONTENT % (10 20 30)

UNIT WEIGHT γ

Easier Augering

REMARKS	% GR. SA. SI. CL
	0 13 84 3
	0 67 (33)
	6 18 49 27
	1 26 45 28
	0 0 75 25

15 20 5 % STRAIN AT FAILURE

Continued

OFFICE REPORT ON SOIL EXPLORATION

MINISTRY OF TRANSPORTATION AND COMMUNICATIONS – ONTARIO

ENGINEERING SERVICES BRANCH – GEOTECHNICAL OFFICE – SOIL MECHANICS SECTION

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 BJS

DATUM Geodetic BOREHOLE TYPE Hollow Stem Auger CHECKED BY

SOIL PROFILE ELEV./DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER ELEV.	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH P.S.F. (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	LIQUID LIMIT W_L, PLASTIC LIMIT W_P, WATER CONTENT W, WATER CONTENT %	UNIT WEIGHT γ	REMARKS % GR. SA. SI. CL.
726.9	continued						20 40 60 80 100; 1000 2000	10 20 30		
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.									

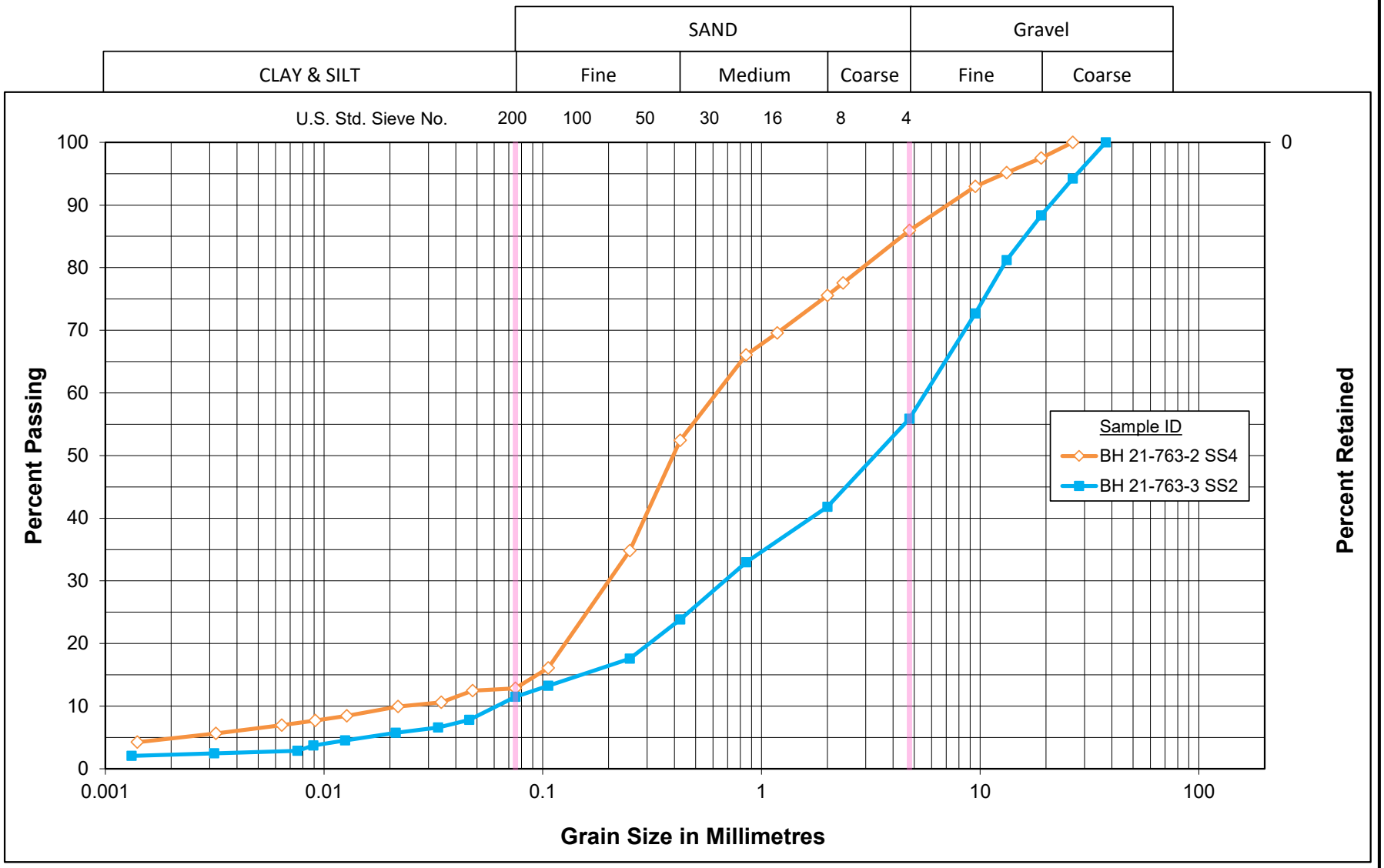
OFFICE REPORT – SOIL EXPLORATION

15 20 10 5 % STRAIN AT FAILURE

APPENDIX C

C.1 LABORATORY TEST RESULTS

Unified Soil Classification System



Stantec

GRAIN SIZE DISTRIBUTION

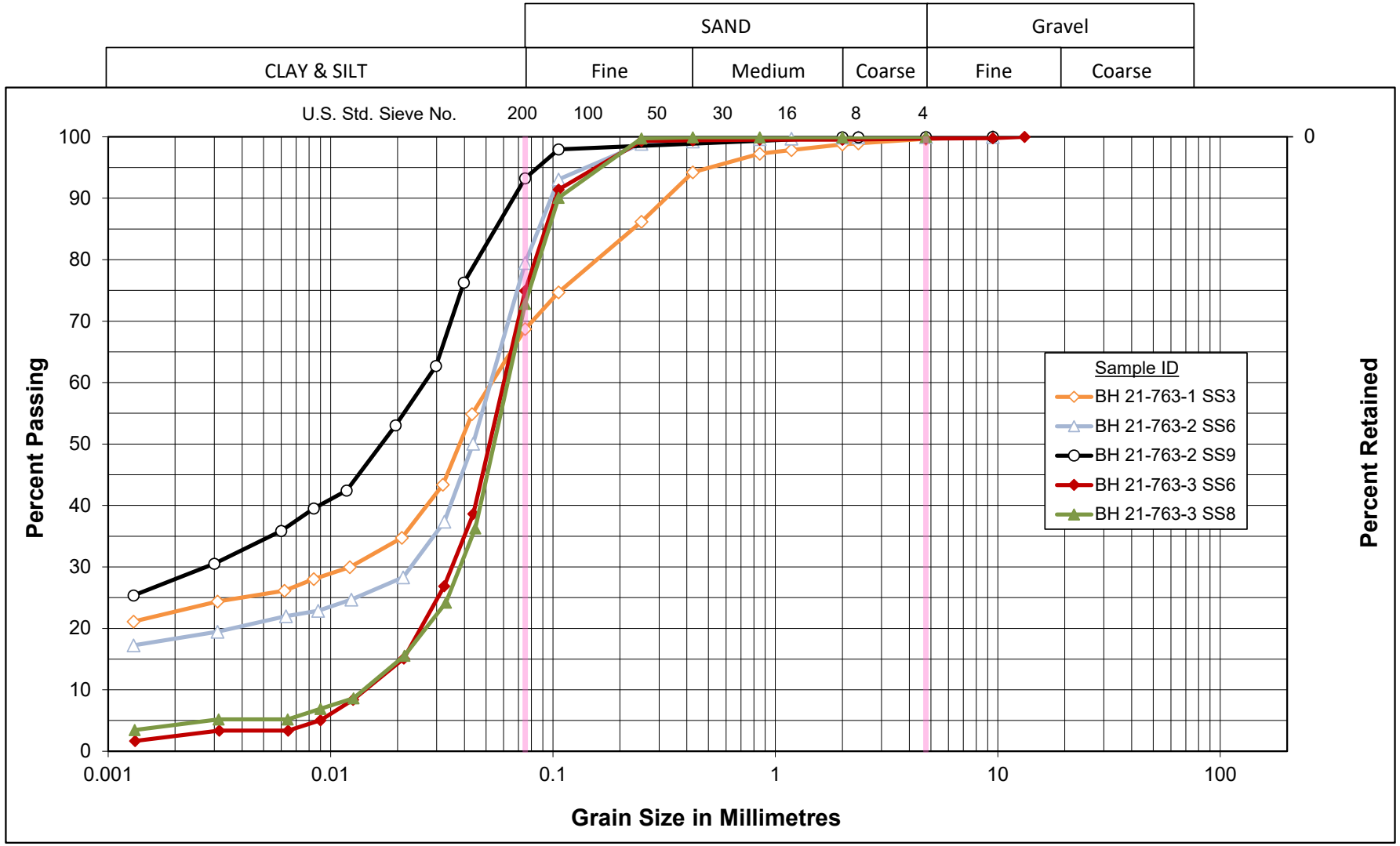
FILL: SAND (SM) to SAND and GRAVEL (SP/GP)

Hwy 402 Rehabilitation - Site 19X-0763/C0

Figure No. C1

Project No. 165001222 (340)

Unified Soil Classification System



Stantec

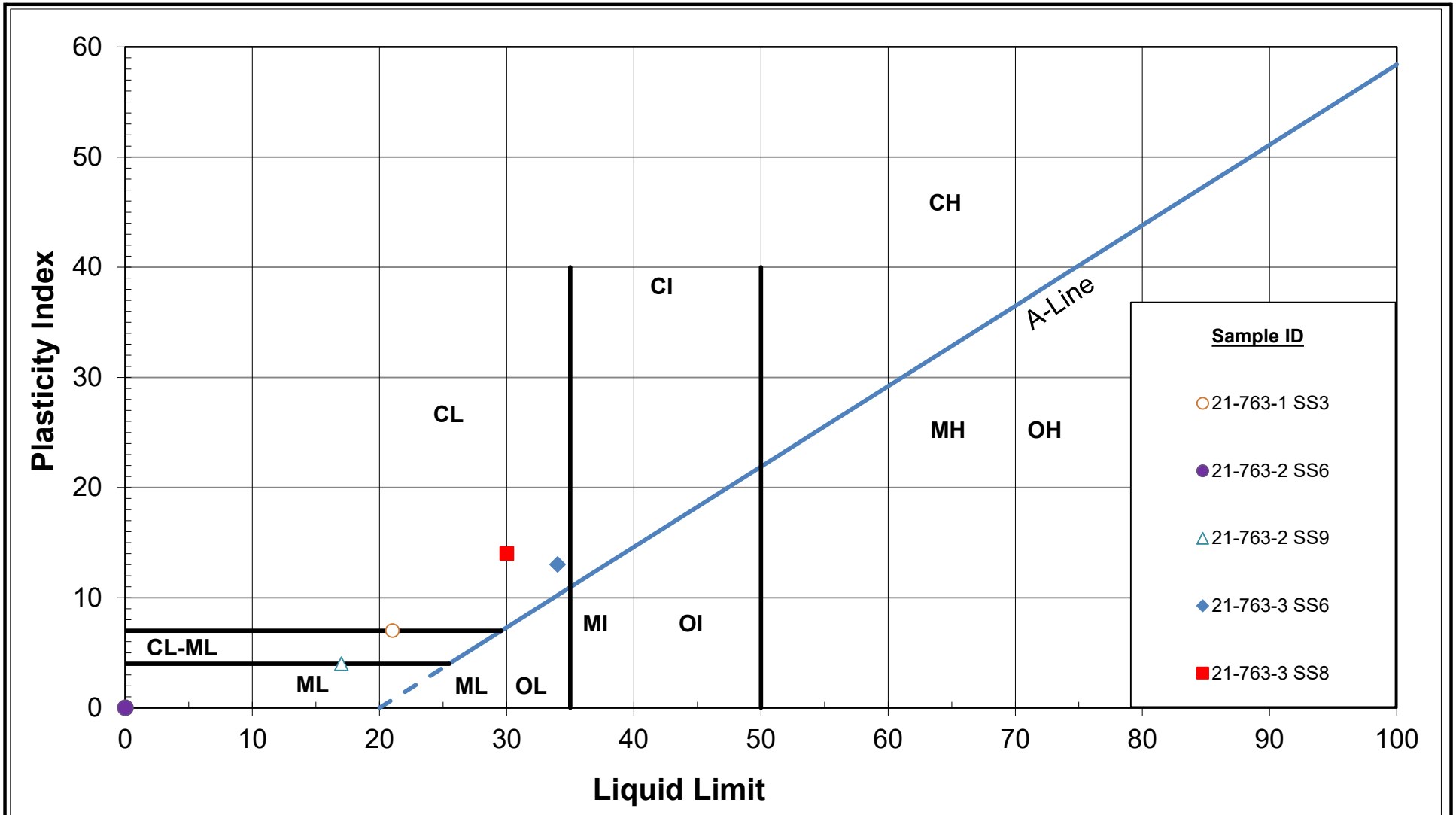
GRAIN SIZE DISTRIBUTION

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)



Stantec

Hwy 402 Rehabilitation - Site 19X-0763/C0

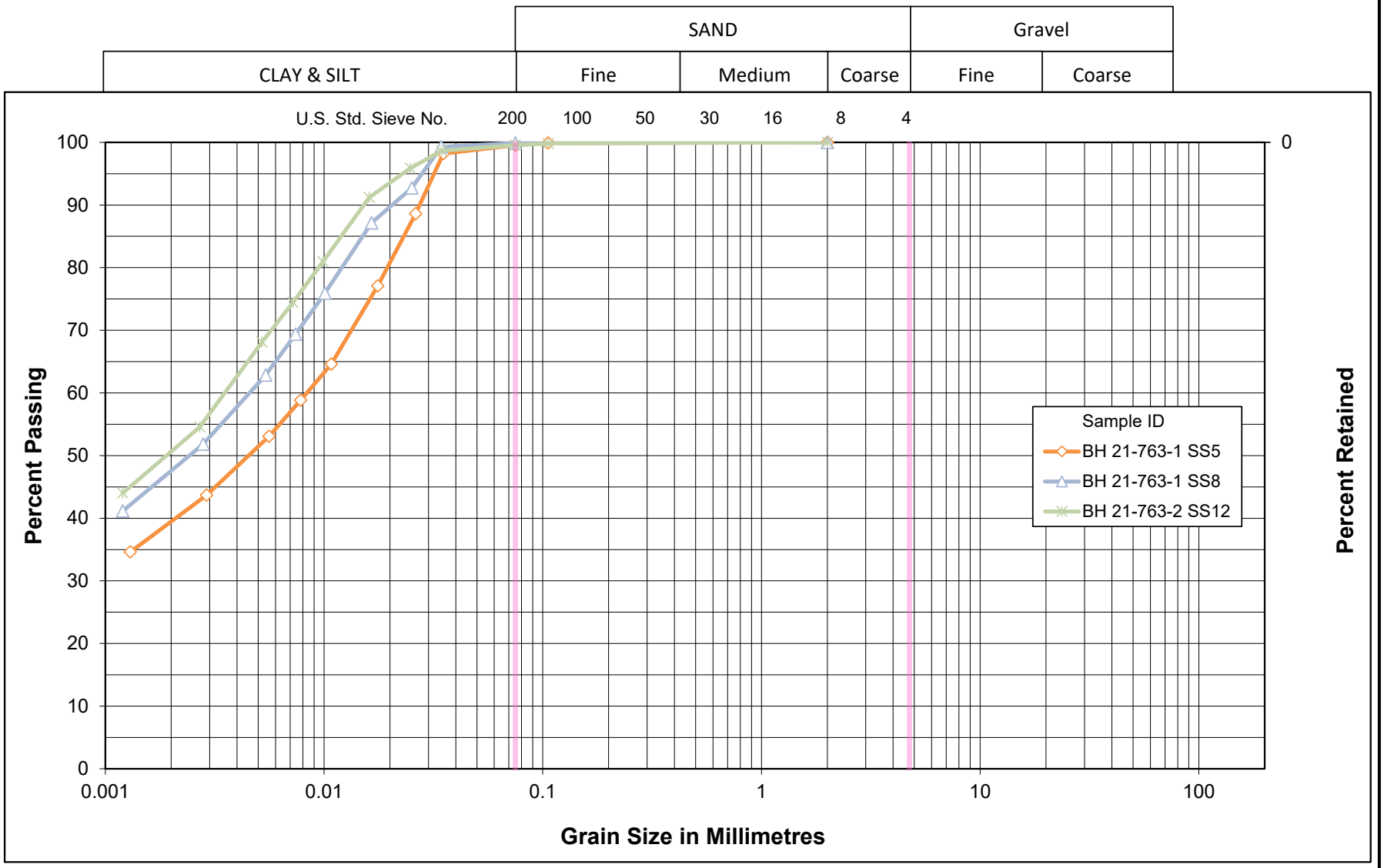
SILT (ML) to CLAYEY SILT (CL to CL-ML)

PLASTICITY CHART

Figure No. C3

Project No. 165001222 (340)

Unified Soil Classification System



Stantec

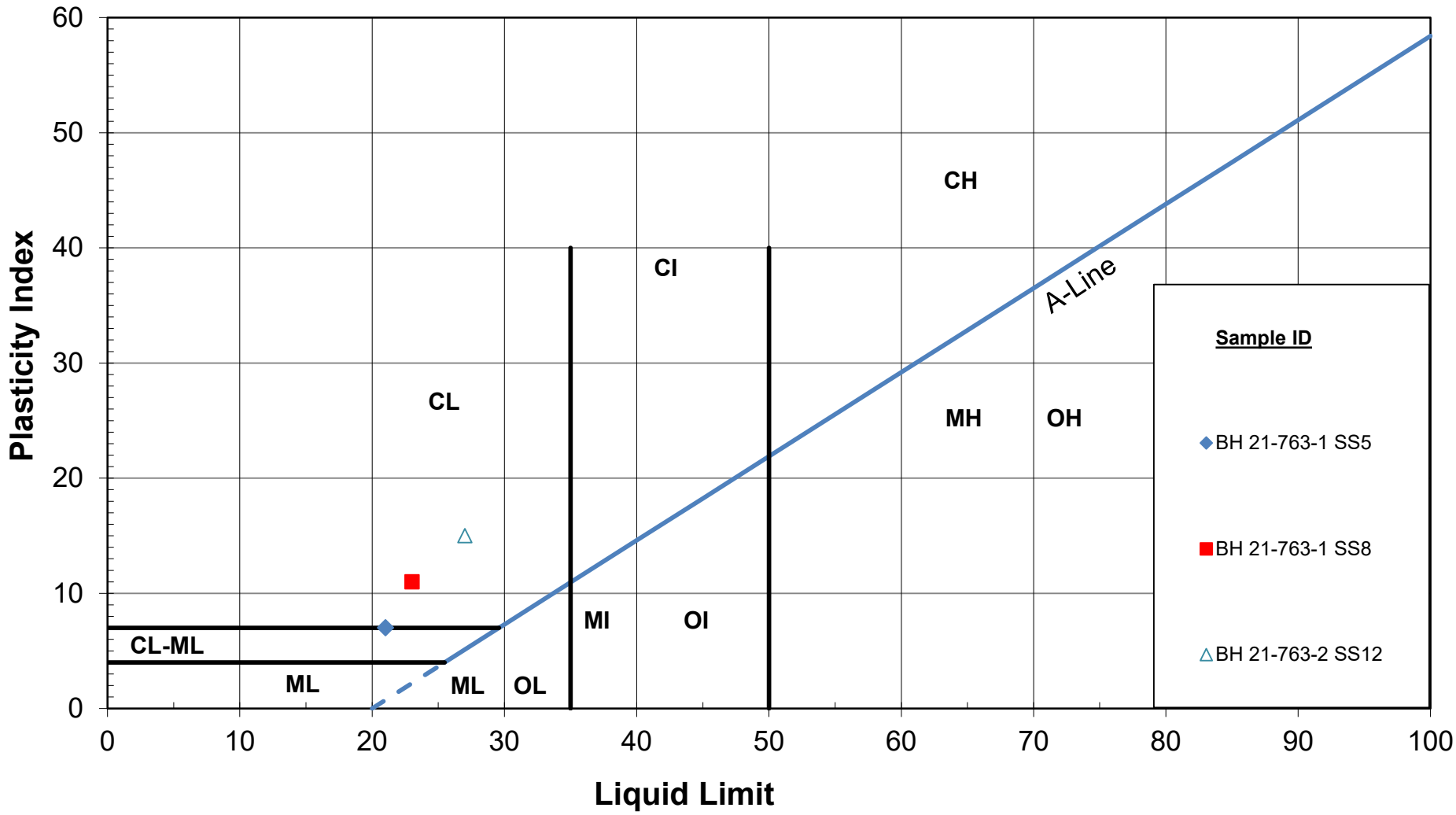
GRAIN SIZE DISTRIBUTION

CLAYEY SILT (CL)

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

Figure No. C4

Project No. 165001222 (340)



Stantec

Hwy 402 Rehabilitation - Site 19X-0763/C0

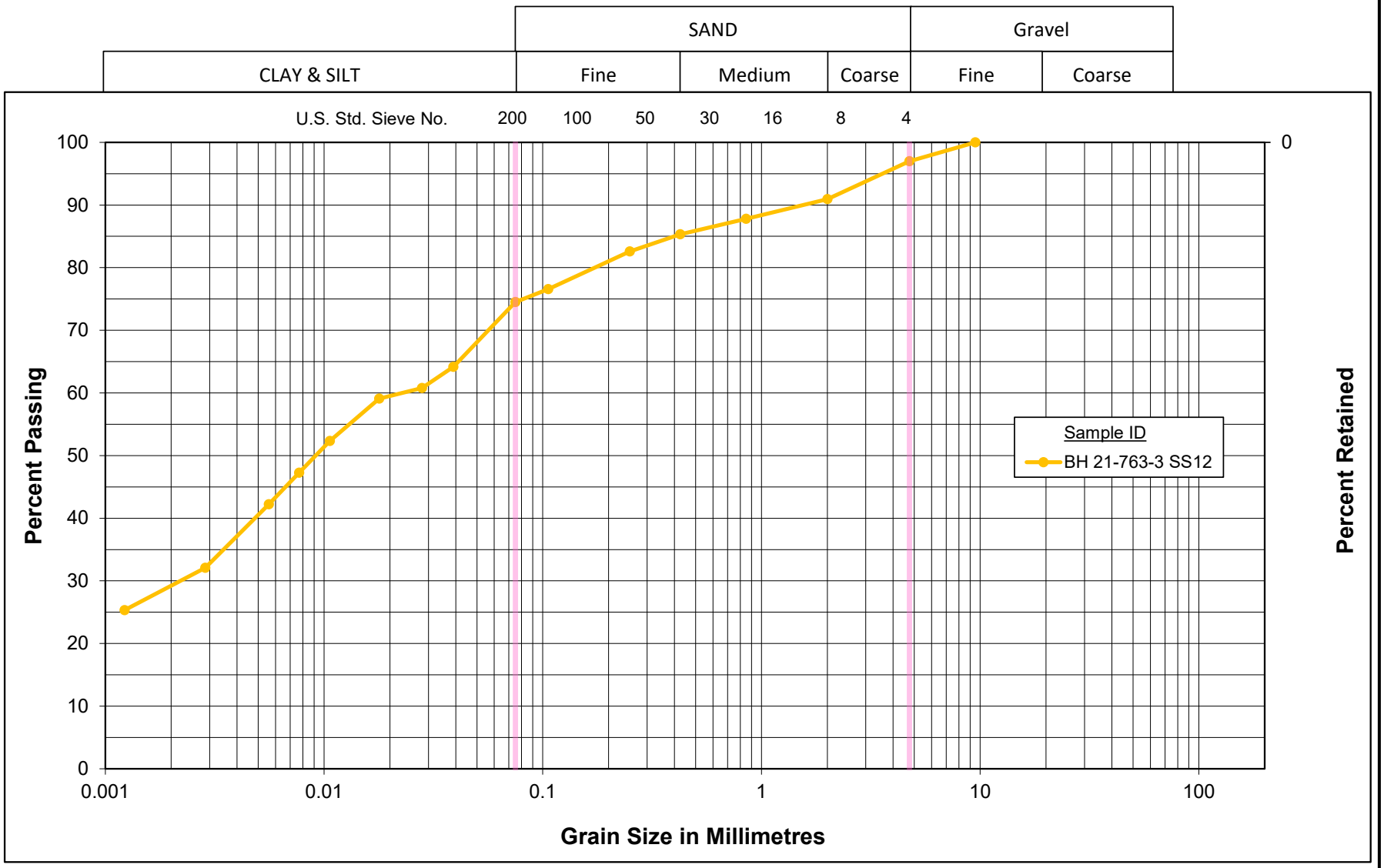
CLAYEY SILT (CL)

PLASTICITY CHART

Figure No. C5

Project No. 165001222 (340)

Unified Soil Classification System



Stantec

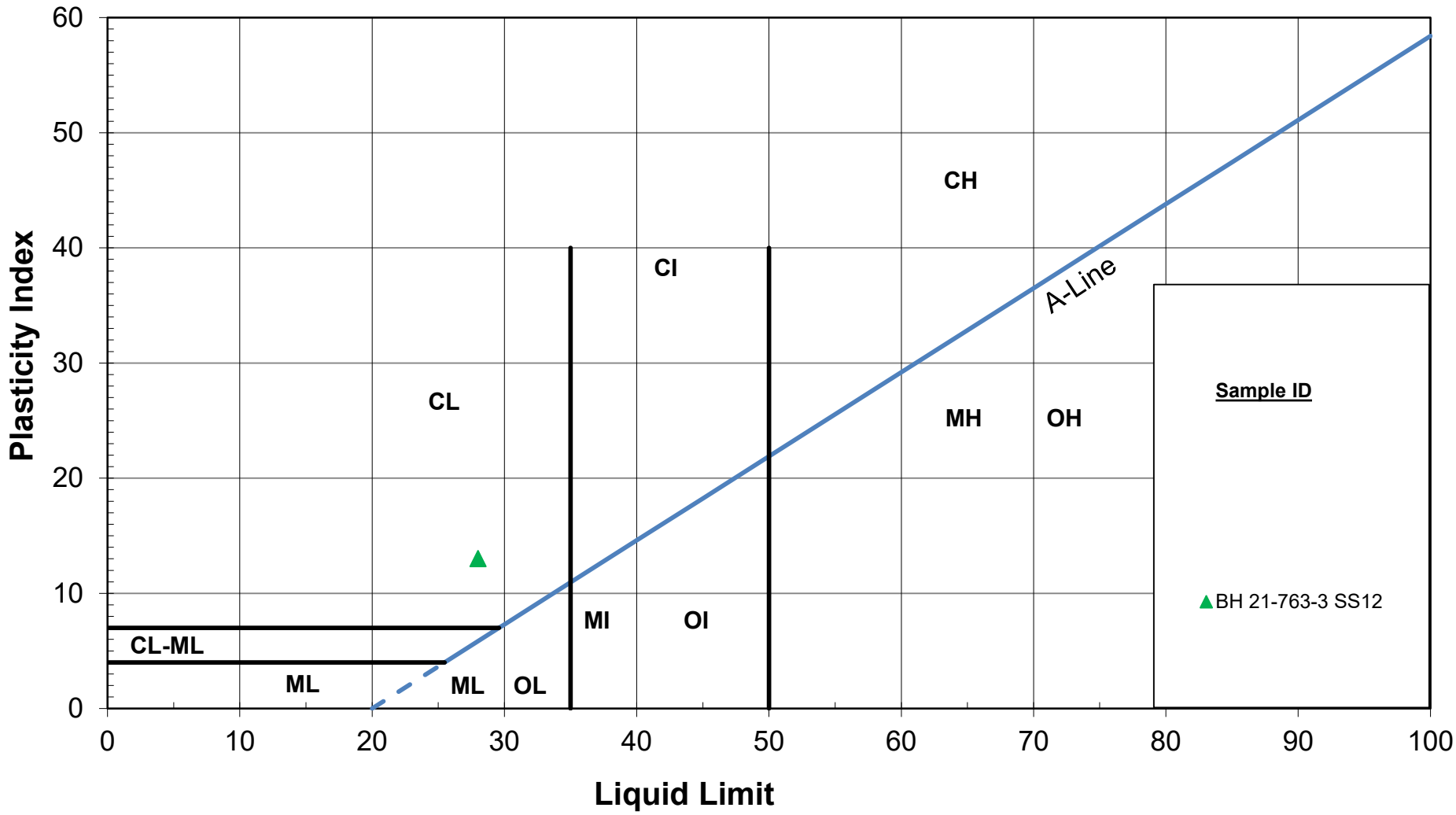
GRAIN SIZE DISTRIBUTION

TILL: Sandy CLAYEY SILT (CL)

Hwy 402 Rehabilitation - Site 19X-0763-C0

Figure No. C6

Project No. 165001222 (340)



Stantec

Hwy 402 Rehabilitation - Site 19X-0763/C0

TILL: Sandy CLAYEY SILT (CL)

PLASTICITY CHART

Figure No. C7

Project No. 165001222 (340)