Foundation Investigation and Design Report – Replacement of Tributary to Murray Drain Culvert - Highway 401 Rehabilitation from Wellington Road to Highbury Avenue, Design-Build Project

Highway 401 City of London, ON

West Region

DB Contract Number: 2022-3004
GWP 3032-11-00

Latitude 42.931307
Longitude -81.199604

Geocres No. 40I14-205

Prepared for:

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Project No. 165001239

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For
G.W.P. 3032-11-00
DB Contract Number 2022-3004

Replacement of Tributary to Murray Drain Culvert
Highway 401 Rehabilitation from Wellington Road to Highbury Avenue, Design-Build Project
West Region
City of London, Ontario

1.0 INTRODUCTION

CRH Canada Group Inc. (CRH) is constructing the Highway 401 Five Structure Replacement project, which includes the Highbury Avenue Interchange improvements, and the Highway 401 rehabilitation and improvements in the City of London, on behalf of the Ontario for the Ministry of Transportation (MTO), under a Design-Build (DB) agreement. Stantec Consulting Ltd. (Stantec) was retained by CRH to undertake additional foundation investigations and detailed foundation designs for the project.

The overall project extends along Highway 401 from 675 m east of Wellington Road easterly 5.5 km to 630 m west of Old Victoria Road, along Pond Mill Road from 60 m north to 60 m south of Highway 401, and along Highbury Avenue from Bradley Avenue to Wilton Grove Road. The project includes following foundations engineering components:

- All deep cut areas and foundations for the new bridge structures, including:
  - CNR Overhead (London-Port Stanley Railway (Site No. 19X-0371/B0);
  - Pond Mills Overpass (Site No. 19X-0372/B0);
  - Highbury Avenue Underpass (Site No. 19X-0373/B0);
- Structural culvert replacements, including:
  - Tributary to Murray Drain Culvert (Site No. 19X-650/C0);
  - Elliot-Laidlaw Drain Culvert (Site No. 19X-651/C0);
- High mast lights;
- Overhead signs;
- Retaining walls (at the bridges and Overhead sign footings); 1.5:1 reinforced side slope between Station 25+110 and Station 25+270 westbound (changed to 2H:1V slopes); and
- Sewers and storm water management facilities.

The MTO reference numbers for this DB project are as follows:

GWP: 3032-11-00
DB Contract Number: 2022-3004

This foundation investigation report has been prepared specifically for the proposed Tributary to Murray Drain Culvert replacement (19X-0650/C0) and other project foundations engineering components are reported under separate covers.

2.0 SITE DESCRIPTION

2.1 SITE LOCATION

The existing Tributary to Murray Drain Culvert crosses Highway 401 approximately 450 m west of the CNR overhead structure in the City of London, Ontario. The site location is shown on the Key Plan inset to Drawing No. 1 included in Appendix A.

2.2 GENERAL SITE DESCRIPTION

At the location of the Tributary to Murray Drain Culvert, Highway 401 is a divided six-lane freeway with three lanes in each direction and paved shoulders on both sides. The orientation of the highway at the culvert site is approximately northeast-southwest. For the purposes of this report, the orientation of Hwy 401 and Tributary to Murray Drain Culvert are taken as east-west and north-south, respectively.

At the culvert site, Hwy 401 has been constructed on an embankment. The travelled surfaces of the WBLs and EBLs of the highway are at approximate elevation 266.5 m and 266.0 m respectively; and are approximately 2 m to 2.5 m higher than the surrounding lands on both sides of the highway. The base of the existing culvert is at approximate elevation 261.5 m. Beyond the culvert and associated drainage features, the overall topography surrounding the culvert site is relatively flat to gently sloping.

Flow in the Tributary to Murray Drain Culvert is from south to north. The culvert inlet is located within the undeveloped land south of Hwy 401. The area surrounding the inlet contains vegetative cover consisting of grass. The culvert outlet is located within the industrial developments north of Hwy 401. The area surrounding the culvert outlet contains grass and paved surfaces.

The surrounding lands are generally open fields with industrial and commercial properties located further north and south of Hwy 401.

2.3 EXISTING CULVERT

The Tributary to Murray Drain Culvert is a single span reinforced concrete culvert with a clear span of 3.05 m and height of 1.83 m. The original 51.8 m long section is an open-footing, non-rigid frame culvert. The culvert was the subsequently extended to the north and south with open-footing, rigid-frame culvert extensions for a total structure length of 74.0 m.

Water flows from north to south through the culvert.

2.4 GEOLOGICAL INFORMATION

This project lies within a physiographic region known as the Westminster Moraine. The physiographic mapping indicates that the culvert site is situated on an undrumlinized till plane (Chapman and Putnam, 1984). Geology mapping indicates that the surficial material consists of Port Stanley silty clay till and clayey silt till, in places covered by thin patches of lacustrine silt. The rock formation in the area of the culvert site is described as medium brown, microcrystalline limestone of the Dundee Formation which belongs to the Hamilton Group of Middle Devonian Age. The bedrock surface is estimated to be at about elevation 210 m, which is approximately 60 m below ground surface at the location of the culvert.

2.5 EXISTING UTILITIES

There is a Bell Canada National Fiber Optics Tactical System (FOTS) line at the north side of the Highway 401 right-of-way. The Bell FOTS line is not considered to conflict with the culvert replacement.

3.0 REVIEW OF PREVIOUS INVESTIGATIONS

Subsurface information for this site was obtained from the following document contained in the MTO Foundation Library GEOCRES system and the DB RFP:

GEOCRES Reference No. 40I14-158

A preliminary foundation investigation and design report dated June 2015 was prepared by Golder Associates for the structural culvert replacement at the Tributary to Murray Drain, as part of the Highway 401 Interchange Improvements/ structural replacements. The report was referenced as follows:

> Preliminary Foundation Investigation and Design Report
> Structural Culvert Replacement
> Tributary to Murray Drain, Site Number 19-650/C
> Highway 401 Interchange Improvements/ Structural Replacements
> GWP 3054-11-00, Assignment No. 1 (3011-E-0046)
> Ministry of Transportation, Ontario – West Region
> Submitted to Dillon Consulting Limited
> Prepared by Golder Associates and dated June 2015

The investigation included three (3) boreholes (BH 601 to 603) advanced along the existing culvert to depths ranging from approximately 7.5 m to 9.4 m below grade in May 2013.

The boreholes encountered:

- Topsoil/ pavement structure; underlain by,
- Fill comprising clayey silt to silty clay to depths ranging from approximately 1.9 m to 4.2 m below grade; underlain by,
- Compact to very dense silt (in two boreholes) to the depths of 6.3 m and 7.3 m below grade; underlain by,
- Stiff to hard clayey silt to depths ranging from approximately 7.5 m to 9.4 m below grade.

Groundwater was measured at elevation 263.9 m in the standpipe installed in Borehole 601. The groundwater level in Borehole 603 was measured at approximate elevation 263 m. Based on the observed groundwater levels in the standpipe and borehole and the surrounding topography the report concluded the groundwater level to be at approximate elevation 263.5 m.

For reference, copies of the Borehole Location Plan, stratigraphy along the culvert, borehole records and laboratory test results referenced herein are included in Appendix B. The boreholes are also included in the Soil Strata and Cross Sections presented on Drawing Nos. 1 and 2 in Appendix A.

4.0 INVESTIGATION PROCEDURES

4.1 FIELD INVESTIGATION

The foundation investigation for the detail design of the proposed Tributary to Murray Drain Culvert replacement consisted of a total of three (3) boreholes, designated as Boreholes MC-01, MC-02 and MC-03. Borehole MC-01 was advanced from the westbound outside shoulder and MC-02 and MC-03 were advanced from the median shoulder of Hwy 401.The locations of these boreholes are shown on the Borehole Locations and Soil Strata Plan, Drawing Nos. 1 and 2, 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.

The boreholes were advanced using a CME 55 truck-mounted drill rig equipped for soil sampling between the dates of June 23 to July 11, 2022. The boreholes were advanced using continuous flight hollow and solid stem augers.

The subsurface stratigraphy encountered in each borehole was recorded in the field by an experienced Stantec field technician. Standard Penetration Tests (SPT) were carried out in the drilled holes and split spoon samples were collected at regular intervals (0.75 m interval for the shallow depth / critical zone and 1.5 m interval to a depth of 20 m below ground surface to meet the typical MTO subsurface investigation sampling requirements) in accordance with ASTM D1586. All recovered SPT samples were returned to our Markham laboratory for detailed classification and testing. The undrained shear strength of cohesive soils was determined using an in-situ shear vane (MTO N-vane) in accordance with ASTM D2573 wherever applicable. A pocket penetrometer was also used to estimate the strength/consistency of clayey soil samples at the site.

Following completion of drilling, a 50-millimeter (mm) diameter groundwater monitoring well, screened over a depth of 4.6 m to 6.1 m below ground surface, was installed in Borehole MC-01. The borehole annulus surrounding the slotted pipe section was backfilled with sand. The remaining annulus was backfilled with bentonite up to the ground surface.

Groundwater level measurement was carried out on September 12, 2022.

Groundwater was also observed in open boreholes during and upon completion of drilling.

After completion of drilling, boreholes were backfilled with a mix of bentonite and drill cuttings.

Boreholes advanced on the roadways were sealed with cold patch asphalt.

4.2 LOCATION AND ELEVATION SURVEY

The borehole locations and respective ground surface elevations were surveyed by Stantec Geomatics personnel using Trimble R10-2 (horizontal accuracy of 8 mm+0.5 ppm and vertical accuracy of 15 mm+0.5 ppm as per the Trimble GNSS datasheet) to meet the survey accuracy requirements (vertical accuracy of 0.1 m and horizontal accuracy of 0.5 m) of the Guideline for MTO Foundation Engineering Services V2.

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

Investigation Borehole	MTM Zone 11 Coordinates		Ground surface elevation (m)	Total depth drilled or advanced (m)	End of borehole elevation (m)	Number of soil samples
	Northing	Easting				
MC-01	4755445.6	410932.8	266.4	15.9	250.5	18
MC-02	4755424.6	410923.5	265.8	15.9	249.9	18
MC-03	4755445.7	410965.8	266.6	15.8	250.8	17

4.3 LABORATORY TESTING

All samples were taken to Stantec's Markham laboratories where they were subjected to a detailed visual and tactile examination. The geotechnical laboratory testing program completed on the borehole samples is summarized in Table 4.2. Two soil samples were tested for pH, soluble sulphate content, chloride content, and resistivity. Samples remaining after testing will be placed in storage for a period of one year after issuance of the final report. After the storage period, the samples will be discarded unless we are directed otherwise by MTO.

Table 4.2: Laboratory Testing Program

Laboratory Test Type	Number of Tests
Moisture Content	56
Gradation Analysis	13
Atterberg Limits	10
Chemical Analysis	2

Two soil samples were forwarded to AGAT Laboratories. The samples were tested for pH, soluble sulphate content, chloride content, electrical conductivity, resistivity, and redox potential.

Samples remaining after testing will be placed in storage for a period of one year after the 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 C. An explanation of the symbols and terms used to describe the Borehole Records is also provided in Appendix C. The results of the geotechnical laboratory testing are presented on Figures D1 to D6 contained in Appendix D.

A borehole location plan and two stratigraphic sections of the soils encountered in the boreholes (along and perpendicular to the culvert alignment) are provided on Drawing Nos. 1 and 2 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 consisted of:

- Ground surface cover (asphalt and pavement structure); underlain by,
- Fill comprising silty gravel with sand to sand and clayey silt to silty clay to depths of approximately 3.7 m to 4.5 m below grade; underlain by,
- Clayey Silt to Silty Clay (firm to hard) to depths of 15.4 m to 15.9 m below grade; underlain by/interbedded with,
- Silt (dense to very dense) in Borehole MC-02 from 7.5 m to 10.6 m below grade and Silt with Sand (very dense) 15.4 m below grade in Borehole MC-03.

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

5.2 OVERBURDEN

5.2.1 Pavement Structure

Asphalt was encountered at ground surface at all three borehole locations. The thickness of the asphalt was approximately 180 mm.

The asphalt was underlain by a granular fill layer in all three boreholes. The granular fill layer can be associated with the pavement structure. The granular fill was approximately 280 mm to 600 mm thick.

N-values of 25, 59 and 71 blows per 0.3 m penetration were obtained from the SPTs advanced in the granular fill layer, indicating a compact to very dense condition.

Laboratory tests conducted on samples of the granular fill yielded natural moisture contents of 3% to 4%, expressed as a percentage of the dry weight of the soil.

5.2.2 Fill

Fill materials were encountered below the pavement structure in all boreholes. The fill comprised of a cohesionless layer (silty gravel with sand to sand) underlain by a cohesive layer (clayey silt to silty clay). The fill materials contained trace rootlets and topsoil.

The fill materials extended to depths ranging from approximately 3.7 m to 4.5 m below ground surface, corresponding to elevations of approximately 262.1 m to 261.9 m.

Further details on those fill materials are provided below:

5.2.2.1 Cohesionless Fill

The fill materials encountered below the pavement structure comprised of cohesionless soils consisting of brown silty gravel with sand to sand containing trace clay. Clayey topsoil was noted in the sample obtained from the cohesionless fill layer in Borehole MC-01.

The cohesionless fill layer was approximately 0.5 m to 2.2 m thick and extended to depths ranging from approximately 1.0 m to 3.0 m below grade, corresponding to elevations of approximately 264.9 m and 263.6 m, respectively.

N-values ranging from 5 to 32 blows per 0.3 m penetration were obtained from the SPTs advanced in the cohesionless fill materials, indicating loose to dense condition. The range confirms the variability of the fill materials.

Laboratory tests conducted on samples of the cohesionless fill yielded natural moisture contents ranging from approximately 3% to 11%, averaging 6%.

Gradation analyses were carried out on a single sample of the cohesionless fill materials obtained from the boreholes. The test results are illustrated on the borehole record in Appendix C and on the gradation curves on Figure No. D1 in Appendix D. The tests yielded the following results:

- Gravel: 34%
- Sand: 48%
- Silt and Clay: 18%

Based on the results of the laboratory tests, the sample obtained from the cohesionless fill can be classified as silty sand with gravel with a group symbol of SM based on the Unified Soil Classification System (USCS).

5.2.2.2 Cohesive Fill

The cohesionless fill materials described in the preceding section were underlain by a cohesive fill layer comprising brown to grey clayey silt to silty clay in all boreholes. Samples obtained from the cohesive fill layer contained various but minor amounts of sand and gravel and trace rootlets.

The cohesive fill layer was approximately 1.5 m to 2.7 m thick and extended to depths ranging from approximately 3.7 m to 4.5 m below grade, corresponding to elevations of approximately 262.1 m to 261.9 m.

N-values ranging from 3 to 16 blows per 0.3 m penetration (with an average of 8 blows per 0.3 m penetration) were obtained from the SPTs advanced in the cohesive fill materials. Undrained shear strengths ranging from approximately 13 kPa to 215 kPa were estimated for the cohesive fill based on the results of pocket penetrometer tests. Based on the results of SPT and pocket penetrometer tests, the cohesive fill is described as soft to very stiff. Relatively softer consistency of cohesive fill was noted at the cohesive fill-native soil boundary below groundwater table.

Laboratory tests conducted on samples of the cohesive fill yielded natural moisture contents ranging from approximately 13% to 27%, averaging 21%.

Gradation analyses were carried out on a single sample of the cohesive fill materials obtained from the boreholes. The test results are illustrated on the borehole records in Appendix C and on the gradation curves on Figure No. D2 in Appendix D. The tests yielded the following results:

- Gravel: 1%
- Sand: 24%
- Silt: 32%
- Clay: 43%

Atterberg Limits tests were conducted on the sample referenced above. The test yielded a Liquid Limit of 44%, a Plastic Limit of 21% and a corresponding Plasticity Index of 23%. The results of the Atterberg Limits tests are illustrated on the borehole records in Appendix C and on Figure No. D3 in Appendix D.

Based on the results of the laboratory tests, the sample from the cohesive fill can be classified as silty clay with sand with a group symbol of CI based on the Unified Soil Classification System (USCS).

5.2.3 Clayey Silt to Silty Clay

A deposit of brown to grey clayey silt underlain by silty clay was encountered underlying the fill materials in the boreholes. Samples obtained from this stratum typically contained trace sand. A layer of silt (described in the proceeding section) was noted interbedded in this deposit in Borehole MC-02.

Boreholes MC-01 and MC-02 terminated in this deposit after penetrating approximately 11.4 m into the deposit. The clayey silt to silty clay deposit was fully penetrated in Borehole MC-03 where it was approximately 11.7 m thick and extended to a depth of approximately 15.4 m below grade, corresponding to an elevation of approximately 250.4 m.

N-values ranging from 5 to 46 blows per 0.3 m penetration (with an average of 18 blows per 0.3 m penetration) were obtained from the SPTs advanced in the clayey silt to silty clay deposit. Four (4) field shear vane tests were attempted in this deposit and encountered refusal (Su>100 kPa). Based on the results of pocket penetrometer tests, undrained shear strengths ranging from approximately 94 kPa to

241 kPa and 13 kPa to 148 kPa (generally from 27 kPa to 40 kPa) were estimated for the clayey silt and underlying silty clay, respectively. In this respect, the clayey silt to silty clay deposit can be described as firm to hard.

Laboratory tests conducted on samples of the clayey silt stratum yielded natural moisture contents ranging from approximately 14% to 26%, averaging 18%.

Gradation analyses were carried out on nine (9) representative samples of the clayey silt to silty clay deposit. The test results are illustrated on the borehole records in Appendix C and on the gradation curves on Figure No. D4 in Appendix D. The tests yielded the following results:

- Gravel: 0 to 1%
- Sand: 0 to 3%
- Silt: 41 to 66%
- Clay: 31 to 58%

Atterberg Limits tests were conducted on the samples referenced above. The tests yielded Liquid Limits of 19% to 33%, Plastic Limits of 12% to 13% corresponding to Plasticity Indices of 7% to 20%. The results of the Atterberg Limits tests are illustrated on the borehole records in Appendix C and on Figure No. D5 in Appendix D.

Based on the results of the laboratory tests, the samples tested can be classified as clayey silt to silty clay with a group symbol of CL based on the Unified Soil Classification System (USCS).

5.2.4 Silt to Silt with Sand

A layer of grey silt was encountered interbedded within the clayey silt to silty clay deposit described in the preceding section in Borehole MC-02. A layer of grey silt with sand was also encountered at depth in Borehole MC-03. Samples obtained from the silt to silt with sand layer typically contained minor amounts of clay.

The silt interlayer was approximately 3.1 m thick and extended to a depth of approximately 10.6 m below grade, corresponding to an elevation of approximately 256.0 m. Borehole MC-03 terminated in the silt with sand layer after penetrating approximately 0.4 m into the layer.

N-values ranging from 32 to 79 blows per 0.3 m penetration (with an average of 50 blows per 0.3 m penetration) were obtained from the SPTs advanced in the silt layer, indicating a dense to very dense condition.

Laboratory tests conducted on samples of the silt to silt with sand layers yielded natural moisture contents ranging from approximately 16% to 18%, averaging 17%.

Gradation analyses were carried out on two samples of the silt to silt with sand soils. The test results are illustrated on the borehole records in Appendix C and on the gradation curves on Figure No. D6 in Appendix D. The tests yielded the following results:

- Gravel: 0%
- Sand: 0 and 23%
- Silt: 57 and 76%
- Clay: 20 and 23%

Based on the results of the laboratory tests, the samples tested can be classified as silt to silt with sand with a group symbol of ML based on the Unified Soil Classification System (USCS).

5.3 BEDROCK

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

5.4 GROUNDWATER CONDITIONS

The groundwater level in the monitoring well in Borehole MC-01 was recorded at a depth of 2.6 m below existing grade (corresponding to an elevation of 263.8 m) on September 12, 2022.

Groundwater was observed upon completion of drilling at the depths of approximately 4.0 m and 3.0 m below ground surface, corresponding to elevations of approximately 262.6 m to 262.8 m in Boreholes MC-02 and MC-03 respectively.

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

5.5 CHEMICAL ANALYSIS

Two soil samples were forwarded to AGAT Laboratories to be tested for pH, soluble sulphate content, chloride content, electrical conductivity, resistivity, and redox potential. The results of the tests are shown in below table and are included in Appendix D.

Table 5.1: Results of Chemical Analysis

Borehole No	Sample No.	Depth (m)	pH	Chloride (µg/g)	Sulphate (µg/g)	Resistivity (Ohm-cm)
MC-01	SS8	5.3 – 5.9	6.68	470	97	1090
MC-02	SS8	5.3 – 5.9	6.66	287	403	1090

6.0 MISCELLANEOUS

The field work was carried out under the supervision of Akshat Shukla, EIT, Binoy Debnath, EIT and Wuhib Tamrat, EIT under the direction of Gwangha Roh, P. Eng., Ph.D.

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

The drilling equipment was supplied and operated by DBW Drilling based in North York, Ontario and Landshark Drilling based in Brantford, Ontario.

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

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

This report was prepared by Roshan Rashed, P.Eng., and reviewed by Gwangha Roh, P. Eng., Ph.D., and Raymond Haché, M.Sc., P.Eng., Designated Principal MTO Foundation 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;

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FOUNDATION DESIGN REPORT
For
G.W.P. 3032-11-00
DB Contract Number 2022-3004

Replacement of Tributary to Murray Drain Culvert
Highway 401 Rehabilitation from Wellington Road to Highbury Avenue, Design-Build Project
West Region
City of London, Ontario

8.0 DISCUSSIONS AND ENGINEERING RECOMMENDATIONS

8.1 PROJECT DESCRIPTION AND BACKGROUND

8.1.1 Project Purpose and Description

This project involves the replacement of five structures, Highbury Avenue Interchange improvement and Highway 401 pavement rehabilitation and improvement. As part of the project, the existing Tributary to Murray Drain Culvert, crossing Highway 401 approximately 450 m west of the CNR overhead, will be replaced.

This foundation investigation and design report has been prepared specifically for the proposed Tributary to Murray Drain Culvert replacement (19X-0650/C0); other project foundations engineering components are reported under separate covers.

8.1.2 Existing Structure

The Tributary to Murray Drain Culvert is a single span reinforced concrete culvert with a clear span of 3.05 m and height of 1.83 m. The original 51.8 m long section is an open-footing, non-rigid frame culvert. The culvert was subsequently extended to the north and south with open-footing, rigid-frame culvert extensions for a total structure length of 74.0 m.

The General Arrangement drawing for the Tributary to Murray Drain Culvert indicates that the existing culvert is planned to be replaced with a new culvert with approximately the same length (i.e., approximately 74 m), with a clear span of 1.8 m and a height of 2.1 m.

It is understood that two alternatives were previously considered for the proposed replacement: replacing the existing culvert with a box culvert and replacing the existing culvert with an open-footing culvert. It is also understood that removal of the existing culvert and replacing it with a precast box culvert is the preferred alternative. The General Arrangement drawing also indicates that the proposed new box culvert invert will be at approximate elevation 262.0 m. The General Arrangement drawing is included in Appendix A for reference.

The final embankment configuration is planned to match existing conditions with minor grade changes. 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.

8.1.3 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 include 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.

8.2 GEOTECHNICAL DESIGN PARAMETERS

The soil conditions encountered in the boreholes advanced at the site generally consist of a surficial layer of asphalt with associated pavement structure, underlain by fill materials, underlain by a deposit of native clayey silt to silty clay, underlain by a layer of silt with sand in one of the boreholes (MC-03). An interlayer of silt was also noted in the clayey silt to silty clay deposit in one of the boreholes (MC-02).

Table 8.1 below outlines 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.

Table 8.1: Geotechnical Model – Tributary to Murray Drain Culvert (Site 19X-0650/C0)

Elevation (m)		Soil Type	Design Parameters			
From	To		Total Unit Weight γ (kN/m^3)	Drained Friction Angle [1] ϕ' (°)	Undrained Shear Strength S_u [2] (kPa)	Soil Modulus E (MPa)
Highway Level	264.9 to 263.6	Cohesionless FILL: Loose to very dense Silty SAND with gravel (SM) to SAND, trace to some gravel (SP)	21	32	N/A	30
264.9 to 263.6	261.9	Cohesive FILL: Soft to very stiff CLAYEY SILT to SILTY CLAY, trace to some sand, trace gravel (CL to CI)	20	30	50	20
261.9	250.4	Firm to hard CLAYEY SILT to SILTY CLAY, trace sand (CL to CI)	20.5	30	100	45
259.1	256.0	Dense to very dense SILT, some clay, trace sand (ML) - in Borehole MC-02	22	32	N/A	60

250.4	250.0	Very dense SILT with Sand, some clay (ML)- in Borehole MC-03	22.5	34	N/A	75

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

The groundwater level in the monitoring well installed in Borehole MC-01 (screened within the clayey silt deposit) was recorded at a depth of 2.6 m below existing grade (corresponding to an elevation of 263.8 m). A static groundwater level at an elevation of 263.8 m is recommended for design purposes.

8.3 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.

8.4 SEISMIC DESIGN CONSIDERATIONS

8.4.1 Site Class

The seismic site class determination is based on the soil conditions in the upper 30 m of the stratigraphy as encountered in the boreholes for the Geotechnical Investigation.

Based on the current and previously geotechnical investigations' findings, this site is assessed to be Seismic Site Class D as per CHBDC S6-19 Commentary Table 4.1.

8.4.2 Peak Ground Acceleration (PGA)

Seismic hazard values for the Tributary to Murray Drain Culvert site were obtained from Natural Resources Canada (2015 National Building Code Canada). 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

PGA	$S_a(0.2)$	PGA_{ref}	**Site Class**	Site Adjusted PGA
0.067g	0.111g	0.054g	D	0.086g

The 2015 NBCC Seismic Hazard calculation sheet is provided in Appendix E.

8.4.3 Liquefaction Potential

The potential liquefaction of the site soil under seismic loading conditions was assessed. The evaluation indicated that liquefaction of the foundation soils is not a concern for this site due to:

(a) relatively low Peak Ground Acceleration,
(b) firm to hard / compact to dense nature of the site soils, and
(c) relatively high fraction of fines content in the shallow soils.

8.5 FOUNDATION OPTIONS FOR CULVERT REPLACEMENT

8.5.1 Assessment of 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 Foundation Alternatives for the Tributary to Murray Drain Culvert Replacement

Option	Advantages	Disadvantages	Cost	Risk/ Consequences
Box Culvert	• Minimize depth of excavation, excavation support and dewatering requirements compared to open footing option • Pre-cast box sections expected to allow faster construction than cast-in-place open footings, with shorter duration for dewatering and surface water pumping • More tolerant of differential settlement than open footing culvert	• Where excavation extends below the groundwater level, dewatering would still be required	Medium	• Some risk of disturbance of the subgrade during construction; can be mitigated with appropriate groundwater control and use of a concrete working slab
Open Footing Culvert	• May be feasible to build culvert on pre-cast footing sections, to accelerate construction schedule and reduce time for dewatering and	• Excavation depths are greater than for box culvert option, resulting in increased excavation support and possible protection system	Higher than box culvert	• Some risk of disturbance of the subgrade during construction; can be mitigated with appropriate groundwater

Option	Advantages	Disadvantages	Cost	Risk/ Consequences
	surface water pumping	requirements for staged construction • Cast-in-place footings may require a longer duration for construction, including dewatering and surface water pumping, as compared with pre-cast culvert segments of footing elements.		control and use of a concrete working slab

Based on the considerations provided in the table above, the box culvert replacement type/system is the preferred option from a foundation engineering perspective.

8.5.2 Foundation Recommendations

The design recommendations presented in the following sections have been developed in accordance with the requirements and methods described in the Canadian Highway Bridge Design Code (CHBDC, 2019) and MTO Guideline for Foundation Engineering Services.

8.5.2.1 Foundation Subgrade Preparation

The Sections 2 and 3 included in the General Arrangement drawing (Appendix A) indicates that the foundation elevation of the original open bottom culvert is at approximately 262.3 m which is slightly higher than the proposed excavation elevation. The culvert extensions on the south and north have slightly deeper foundation than the original culvert section. The founding elevation for the new box culvert is planned to be at approximate elevation 262 m. Within the original open bottom culvert section, excavation required for the installation of a concrete mud mat/working slab will extend to an elevation of about 261.5 m. Where deeper existing fill is encountered during the culvert replacement, fill excavations followed by approved granular fill material or lean concrete placement will be required to achieve the foundation elevation.

The Section 3 included in the General Arrangement drawing indicates that the inlet and outlet parts of the existing open bottom culvert (culvert extension) foundations are located approximately 0.2 m and 0.5 m deeper than the proposed culvert excavation elevation. Following excavation for removal of the existing culvert within these sections, the site should be brought up to the proposed foundation elevation for the new box culvert using lean concrete or approved granular fill material.

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 stiff to hard clayey silt and compact to very dense silt. These materials are considered suitable for support of the replacement culvert provided they are dewatered (especially for silt), as described below, and are protected from disturbance. Fill materials encountered in the boreholes extended to elevation 261.9 m near the planned founding elevation; any existing fill encountered at the subgrade level during construction should be removed and replaced with engineered/structural fill materials.

The foundation investigation identified that the groundwater level in the clayey silt to silt soils that underlie the culvert is more than 2 m above the anticipated excavation base level required for construction of the culvert replacement. These conditions could result in groundwater inflows, and disturbance of the foundation subgrade materials unless adequate dewatering is provided especially where silt subgrade is expected. To address this issue, a dewatering/groundwater control program should be implemented to lower the water level within the silt deposit 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; further discussion regarding dewatering is provided in Section **Error! Reference source not found.** of this report.

All soils disturbed during the removal of the existing culverts, any soft/loose organic soils and any existing fill materials 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 accordance with SP109S12. It is recommended that a minimum 100 mm thick concrete working slab be placed immediately following inspection and approval of the founding surface to protect the subgrade (special provision FOUND0001 Working Slab). A 300 mm thick OPSS Clear Stone should be placed on top of the working slab as per the RFP Section 2.4.8.4 Culvert Design and Construction. A leveling course/pad consisting of a 75 mm thick layer of uncompacted OPSS Granular A materials should be placed over the bedding as per OPSS.803.010.

The dewatering operations should continue during the excavation, placement of any required structural fill, placement of the mud mat/working slab, placement of the bedding and leveling course throughout construction and backfilling of the culvert.

8.5.2.2 Box Culvert

Geotechnical Resistances and Reactions

The geotechnical resistance and reactions provided in Table 8.4 below may be used in the design of a precast box culvert. The values developed are based on the construction of the box culvert on the concrete working slab overlying the undisturbed native soils plus bedding and levelling course as described in Section 8.5.2.1. 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 – Box Culvert

Founding Element	Founding Elevation (m)	Culvert Width (m)	Factored Geotechnical Resistance at ULS_f (kPa) $\phi_{gu} = 0.5$	Factored Geotechnical Reaction at SLS (kPa) $\phi_{gs} = 0.8$
Box Culvert	± 262.0	2.6 (1.8 m inner span)	270	160

Notes: The founding elevation represents the approximate, inferred base of the box culvert. The materials immediately below this level should consist of 100 mm concrete working slab, 300 mm clear stone bedding and 75 mm of uncompacted OPSS Granular A material as outlined in Section 8.5.2.1.

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_f).

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.

It is noted that no settlement issues were observed for the existing open-footing culvert. Given that box culverts are less sensitive to settlement, and that no major grade raise is being considered at the culvert site, settlement is not anticipated to be an issue for the replacement culvert.

Geotechnical Horizontal Resistance (Sliding)

The unfactored horizontal resistance to sliding of the pre-cast box culvert may be calculated using the following unfactored coefficient of friction:

- 0.60 between OPSS Clear Stone and concrete
- 0.55 between OPSS Granular A and concrete
- 0.40 between clayey silt/silt and concrete (mud mat)

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.

8.5.2.3 Open Footing Culvert

Geotechnical Resistances and Reactions

The geotechnical resistance and reactions provided in Table 8.5 below may be used in the design of strip footings founded on the native stiff to hard subgrade. 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 8.5: Geotechnical Vertical Resistance & Reaction – Open Footing Culvert

Founding Element	Founding Elevation (m)	Footing Width (m)	Factored Geotechnical Resistance at ULS_f (kPa) $\phi_{gu} = 0.5$	Factored Geotechnical Reaction at SLS (kPa) $\phi_{gs} = 0.8$
Open Footing Culvert	± 261.0	1.0	250	160

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 0.8 has been applied in calculating the geotechnical reaction at Serviceability Limit State (SLS) which corresponds to a maximum settlement of 25 mm.

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_f).

Geotechnical Horizontal Resistance (Sliding)

The unfactored horizontal resistance to sliding of the cast-in-place open footing culvert may be calculated using the following unfactored coefficient of friction:

0.55 between OPSS Granular A and concrete
0.40 between clayey silt/silt and concrete (mud mat/footing)

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.

8.5.3 Culvert Bedding, Backfill and Erosion/Scour Protection

The bedding, levelling course, backfill, cover materials and frost taper (backfill transition) for the replacement culvert should be as outlined in OPSS 422 (Construction Specification for Precast Reinforced Concrete Box Culverts in Open Cut), OPSD 803.010 (Backfill and Cover for Concrete Culverts) and DB SP 3271 (Performance Requirements for Design and Construction of Structural Culverts). As previously discussed in this report, OPSD 3090.101 indicates that the frost penetration depth is at 1.2 m. This frost penetration depth should be used for the design of the culvert frost tapers.

As per the RFP Section 2.4.8.4 Culvert Design and Construction, Box culverts should be provided with at least 300 mm of OPSS.PROV 1004 clear stone for bedding purposes. 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 on each side of structure simultaneously and compacted in accordance with MTO's Special Provision SP105S21 (Amendment to OPSS 501).

Erosion protection should be provided at the culvert inlet and outlet. In order to minimize the potential for seepage through the clear stone bedding and granular backfill materials and avoid consequent erosion of these materials, a concrete cut-off wall or clay seal should be installed to sufficient depth and/or extent at the culvert inlet and outlet. For the case of a box culvert installation, the vertical concrete cut-off walls at the inlet and outlet locations should extend to below the existing open footing foundation elevations to restrict flow through the existing fill materials.

The clay seal should have a minimum thickness of 0.5 m, completely surround the culvert, extend laterally the width of the granular backfill material, extend above the high-water level and the material used should conform to the requirements of OPSS 1205.

Slope protection and drainage measures will be required to provide for the long-term surficial stability of the embankment slopes at the locations of culvert inlet and outlet. 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.

8.6 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 effects of compaction should be accounted for by applying a compaction surcharge as outlined in Section 6.12.3 and as shown in Figure 6.8 of the CHBDC (2019).

8.6.1 Earth Pressures Under Static Conditions

The total at rest, (P_O) active (P_A) and passive (P_P) thrusts can be calculated using the following equations:

$$P_A = \frac{1}{2} K_a \gamma H^2$$
$$P_O = \frac{1}{2} K_o \gamma H^2$$
$$P_P = \frac{1}{2} K_p \gamma H^2$$

where H is the height of the wall and γ is the unit weight of the backfill soil. Values for K_a, K_p, K_o and γ are provided in Table 8.6 for horizontal backfill conditions. These values should be adjusted if sloped backfill is considered. The thrust acts at a point one third up the height of the wall.

Table 8.6: 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, γ (kN/m^3)	22	22	21
Effective Friction Angle, Φ (°)	32	35	28
Coefficient of Earth Pressure at Rest, K_o	0.47	0.43	0.53
Coefficient of Active Earth Pressure, K_a	0.31	0.27	0.36
Coefficient of Passive Earth Pressure, K_p	3.25	3.69	2.77

8.6.2 Earth Pressures Under Seismic Conditions

The total active and passive thrusts under seismic loading conditions can be calculated using the following equations:

$$P_{AE} = \frac{1}{2} K_{AE} \gamma H^2 (1 - k_V)$$
$$P_{PE} = \frac{1}{2} K_{PE} \gamma H^2 (1 - k_V)$$

where:

K_{AE} = active earth pressure coefficient (combined static and seismic)
K_{PE} = passive earth pressure coefficient (combined static and seismic)
H = height of wall
k_h = horizontal acceleration coefficient
k_v = vertical acceleration coefficient
γ = total unit weight

For this site, the following design parameters were used to develop the recommended K_{AE} and K_{PE} values as per CHBDC 2019.

Table 8.7: Seismic Design Parameters to Estimate Lateral Earth Pressures

Site Adjusted PGA	Horizontal Acceleration Coefficient, k_{ho}	Horizontal Acceleration Coefficient, k_h
	Non-Yielding	Yielding ($wall\ movements\ of\ 25\ mm\ to\ 50\ mm$)
0.0864g	0.086	0.043
Note: k_{ho} is the seismic horizontal acceleration coefficient that corresponds to zero wall movement and is equal to the site-adjusted PGA estimated at ground surface. The vertical acceleration coefficient (k_v) should be ignored in the calculations as per CHBDC 2019, section C4.14.7.2.		

The angle of friction between the soil and the wall has been set at 0° to provide a conservative estimate.

The seismic earth pressures may be calculated using the parameters detailed in **Error! Reference source not found.** for horizontal backfill configuration. These values should be adjusted if sloped backfill is considered.

Table 8.8: Recommended Seismic 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, γ (kN/m^3)	22	22	21
Effective Friction Angle	32	35	28
Passive Earth Pressure, (K_{PE})	3.18	3.61	2.70
Height of Application of P_{PE} from base as a ratio of wall height, (H)	0.327	0.327	0.326
Yielding Wall			
Active Earth Pressure (K_{AE}) for Yielding Wall	0.33	0.29	0.39
Height of Application of P_{AE} from base as a ratio of wall height, (H) for Yielding Wall	0.353	0.354	0.352
Non-Yielding Wall			
Active Earth Pressure (K_{AE}) for Non-Yielding Wall	0.36	0.32	0.42
Height of Application of P_{AE} from base as a ratio of wall height, (H) for Non-Yielding Wall	0.372	0.374	0.369

8.7 HIGHWAY EMBANKMENTS

8.7.1 Embankment Construction

Based on the General Arrangement Drawing, the profile and footprint of the existing highway 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. In preparation for any minor modifications of the existing embankments, all topsoil, organic matter or softened/loosened soils including disturbed portions of the native soils should be stripped from areas where widening or regrading is required.

The embankment fill for widening or regrading 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 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.

8.7.2 Stability of Slopes

Based on the planned embankment configuration (which is similar to the existing embankment), the prevailing subsurface conditions and the suitable embankment performance experienced to date, no issues with the global slope stability of the planned embankment are 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.

8.7.3 Embankment Settlement

Based on the planned embankment configuration, 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 the subsurface soil conditions present at the site, the proposed minor regrading works are not expected to result in settlements that would impact the embankment performance.

8.8 CEMENT TYPE AND CORROSION PROTECTION

The results of the analytical tests on two (2) samples of the native soils are presented in Section 5.5 and Appendix D.

As per the MTO Structural Manual (2021) section 2.8.5, concrete is considered subject to sulphate attack when

- Water-soluble sulphate (SO_4) content of the adjacent soil is equal to or greater than 0.10%; or,
- Sulphate (SO_4) in groundwater is equal to or greater than 150 mg/L.

When concrete is identified as subject to sulphate attack, the concrete shall be resistant to sulphate attack as required by Special Provision CONC0006. Based on the test results, concrete will not be subject to sulphate attack for this culvert site (water soluble sulphate in soil samples <0.10% which is equivalent to 1000μg/g).

In addition, the analytical test results were compared to CSA A23.1 Table 3 Additional requirements for concrete subject to sulphate attack on concrete. The sulphate concentrations measured in the tested samples are below the exposure class of S-3 (Moderate). Therefore, based on the samples tested, when the designer is selecting the exposure class for the structure, the effects of sulphates may not need to be considered.

The analytical test results were also compared to Table 7.2 of the U.S. Federal Highway Administration Publication No. FHWA-NHI-14-007 (2015) Criteria for Assessing Ground Corrosion Potential for the potential attack on buried steel. The results are provided below in Table 8.9.

Table 8.9: Results of Corrosion Potential Assessment (FHWA-NHI-14-007)

Borehole No	Sample No.	Depth (m)	Corrosion Potential
MC-01	SS8	5.3 – 5.9	Aggressive
MC-02	SS8	5.3 – 5.9	Aggressive

Based on the results of the samples tests consideration should be given by the designer to designing for a “C” type exposure class as defined by CSA A23.1 Table 1.

It should be noted that the final selection of exposure class and corrosion mitigation measures is the responsibility of the design engineer who will take into account all design considerations including CSA A23.1 Section 4.1.1 durability requirements.

9.0 CONSTRUCTION CONSIDERATIONS

9.1 CONSTRUCTION STAGING

The replacement of the existing culverts could be carried out in two stages requiring alternating closures of the WBLs and EBLs of the highway.

The removal of the existing culvert and construction of the replacement culvert may be carried out either via an open cut excavation or within a supported (shored) excavation. Where open cut excavation methods are adopted, as a minimum, temporary protection systems are anticipated to be required at the central median (i.e. near the connection point between the two stages) and for any other sections of the excavations that are adjacent to the active traffic lanes.

Recommendations for temporary roadway protection and temporary excavations are provided in the following sections of this report.

9.2 TEMPORARY ROADWAY PROTECTION

Temporary roadway protection systems may be required to facilitate the work (e.g. to form part of the staged construction approach that would be required to maintain traffic flow during replacement culvert construction).

The roadway protection system should meet the requirements of DB SP 539 (amendment to OPSS.PROV 539).

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

Table 9.1: Comparison of Roadway Protection Systems

Option	Advantages	Disadvantages	Relative Cost	Risk & Consequences
Steel sheet piles (SSP)	• Simple installation process • Provides cut-off to groundwater seepage from excavation sides • Can be extended into clayey soils to cut-off lateral flow through silt deposits thereby reducing groundwater inflow volumes into excavation.	• Difficult to drive/install where cobbles/boulders are present • May require large sections where cantilever design is adopted	Medium	• Possible misalignment of, or damage to, sheet piles during installation due to obstructions
Soldier piles with timber lagging; (struts/rakers as required)	• Simple installation process provided suitable dewatering is implemented prior to installation of protection system	• Dewatering required to lower water table below base of excavation prior to lagging installation to reduce loss of ground • Removal of soldier piles can be difficult • Additional labour required	Low	• Potential for groundwater seepage and loss of ground unless groundwater control measures are implemented • Potential for minor loss of ground at rear of lagging

Both protection systems described above are considered suitable at this site provided dewatering is carried out.

Roadway/temporary protection system design should meet the requirements of Performance Level 2 in accordance with SP DB 539 and should consider traffic loading. Performance Level 2 specifies a Maximum Angular Distortion of 1:200 and a Maximum Horizontal Displacement of 25 mm. Horizontal movements should be monitored throughout the culvert replacement process as described in OPSS.PROV 539. The monitoring requirements are outlined in DB SP 539 , including the milestone inspections to be completed by the Contractor’s Engineer.

From a geotechnical perspective, the temporary protection system can either be removed, provided this can be completed without disturbing the culvert, or left in place. Where removal is to be undertaken, the removal operations shall be in accordance with DB SP 539 . If temporary protection system components are left in place, they should be cut off at least below the design frost penetration depth.

9.3 SURFACE WATER AND GROUNDWATER CONTROL

Temporary flow passage systems should follow the requirements of OPSS 517 as amended by SP 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 50 m.

- Given the fine-grained nature of the clayey silt deposit to be dewatered, the Design Engineer Requirements box should be input as "Yes".

Control of 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 culvert construction and into/through the temporary flow passage system.

Table 9.2 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 works.

Table 9.2: Comparison of Cofferdam Options for Surface Water Control

Option	Advantages	Disadvantages	Relative Cost	Risk/ Consequences
Sandbag Dam	• Able to be installed in limited work areas • Decreased sedimentation compared to earth dams.	• Slower installation compared to other cofferdam systems. • Allows groundwater flow beneath cofferdam	Low to Medium	• Low risk option
Aqua Dams	• Decreased sedimentation compared to earth dams. • Fast installation	• Allows groundwater flow beneath cofferdam	Low to Medium	• Low risk option
Granular Fill Dams	• Fast installation. • Low cost.	• Increased environmental impact (i.e. sediment deposition in watercourse) • Increased streambed disturbance during dam removal • Allows groundwater flow beneath cofferdam	Low	• Increased potential for washout and sediment transport and deposition during storm events
Steel sheet piles (SSP)	• Simple installation process • 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.	• Requires larger construction equipment • Difficult to drive/install where cobbles/boulders are present	Medium to high	• Possible misalignment of, or damage to, sheet piles during installation due to obstructions

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 (MECP) 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.

Excavations for the installation of the replacement culvert will be required to extend to depths of about 2 m below this water level. Based on the boreholes drilled as part of the current investigation, the excavations are anticipated to extend within cohesive clayey silt soils and limited disturbances due to groundwater inflow would be expected. Typical construction dewatering measures would be anticipated.

Based on Golder boreholes 601 and 602, both drilled outside of the highway embankment footprint, a non-cohesive silt could be encountered at the ends of the culvert. This soil type, if encountered, would be prone to disturbance as a result of groundwater inflow, suggesting that the foundation subgrade could become disturbed unless adequate dewatering is provided. Should a non-cohesive silt be encountered, 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.

For non-cohesive silt, 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 its fine-grained nature. Therefore, if encountered, the implementation of an external dewatering system consisting of a series of sanded-in vacuum well-points or eductor wells installed in the silty soils around the perimeter of the excavation is expected to be required to lower the groundwater level below the excavation level in advance of culvert construction. Based on the borehole information, dewatering effort within non-cohesive silts would only be required at the ends of the proposed culvert location.

All groundwater control systems required for the culvert rehabilitation works should be designed and implemented in accordance with SP 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 805.

9.4 EXCAVATION AND BACKFILLING

Excavation and backfill for the new culvert should be carried out in accordance with OPSS 422 and DB SP 902 (amendment to OPSS.PROV 902). 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.

Any vegetation, existing foundations, fill, organic soils, and other unsuitable soft or loose 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 5 m below the existing travelled surface of Highway 401. The excavations will encounter fill materials (embankment fill and culvert bedding and backfill) and clayey silt soils. Where space permits, these excavations may be undertaken via open cut methods provided suitable dewatering is carried out prior to excavation.

Moving construction equipment over the wet clayey silt 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.

The fill and native clayey silt soils would be classified as Type 3 soils provided they are above the groundwater table or are properly dewatered prior to excavation. The OH&S Act indicates that temporary excavations in these materials, where above the groundwater table or dewatered should be developed with side slopes no steeper than 1H:1V.

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

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

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

9.5 OBSTRUCTIONS

Relatively large obstructions such as cobbles and/or boulders were not encountered during this investigation but may be present in the fill materials associated with the highway embankment and native soils. These materials could impede excavations and the installation of temporary roadway protection system components.

9.6 INSTRUMENTATION AND MONITORING

Depending on the depth of the temporary shoring system, an Instrumentation and Monitoring Plan may be required. This plan should be prepared at least three months prior to commencement of the culvert replacement. The Plan should include the following:

- Monitoring before (including pre-construction survey as necessary), during and after construction to check the safety of the work;
- Discussion of dewatering-induced settlements and potential for ground movements and impacts to Highway 401;

- Buried utility monitoring within the earthwork and dewatering zone of influence;
- Temporary protection system monitoring as per DB SP 539.
- Discussion of displacement monitoring requirements before, during and following construction.

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.PROV 206	Construction Specification for Grading
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 517	Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS.PROV 539	Construction Specification for Temporary Protection System
OPSS.MUNI 804	Construction Specification for Seed and Cover
OPSS.PROV 804	Construction Specification for Temporary Erosion Control
OPSS 805	Construction Specification for Temporary Erosion and Sediment Control Measures
OPSS.PROV 902	Construction Specification for Excavation and Backfilling – Structures
OPSS.PROV 1004	Material Specification for Aggregates - Miscellaneous
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
SP FOUN0001	Requirements for Concrete Working Slab under Structure Foundations
SP FOUN003	Dewatering Structure Excavations (Amendment to OPSS 902)
DB SP 539	Amendment to OPSS 539
DB SP 902	Amendment to OPSS 902
DB SP 3271	Performance Requirements for Design and Construction of Structural Culverts

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.

Golder Associates. 2015. Preliminary Foundation Investigation and Design Report, Structural Culvert Replacement, Tributary to Murray Drain, Site Number 19-650/C, Highway 401 Interchange Improvements/ Structural Replacement, GWP 3054-11-00, Assignment No. 1 (3011-E-0046), Ministry of Transportation, Ontario – West Region

Ministry of Transportation Ontario, 2003, Concrete Culvert Design and Detailing Manual

Ministry of Transportation Ontario, 2020, Guideline for MTO Foundation Engineering Services V.2

OHSA. 2021. Occupational Health and Safety Act Regulations for Construction Projects. Carswell, Toronto Ontario.

11.0 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 Roshan Rashed, P.Eng., and reviewed by Gwangha Roh, P. Eng., Ph.D., and Raymond Haché, M.Sc., P.Eng., Designated Principal MTO Foundation Contact.

Respectfully submitted,

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APPENDIX A

A.1 DRAWING NOS. 1 AND 2 – BOREHOLE LOCATION PLAN AND SOIL STRATA PLOT

A.2 GENERAL ARRANGEMENT DRAWING

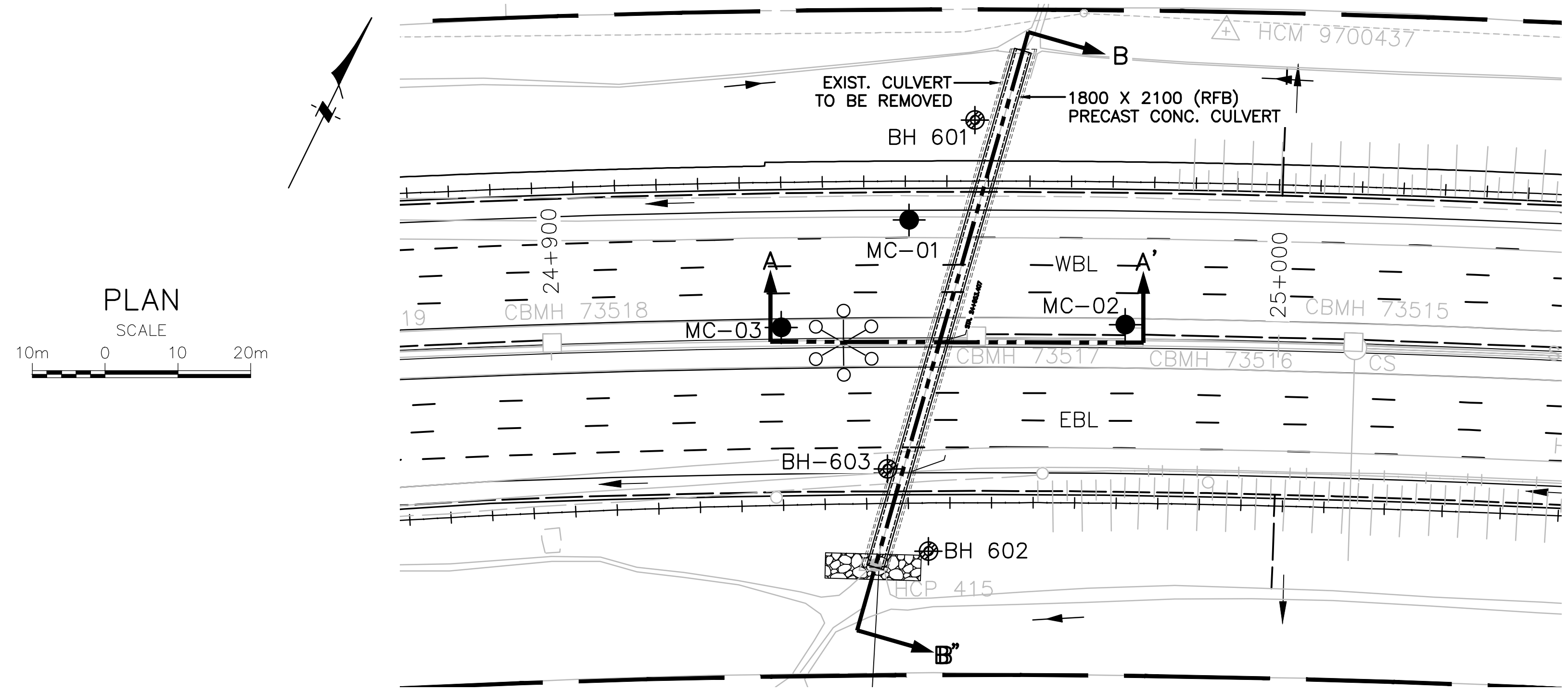
HIGHWAY 401 MURRAY DRAIN CULVERT
BOREHOLE LOCATIONS & SOIL STRATA

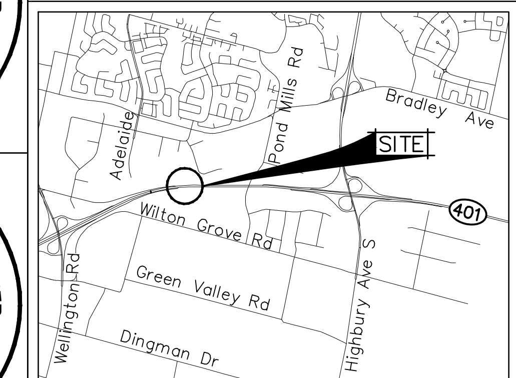
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

PLATE No	SHEET
CONT 2022-3004 WP 3032-11-00	-

Stantec

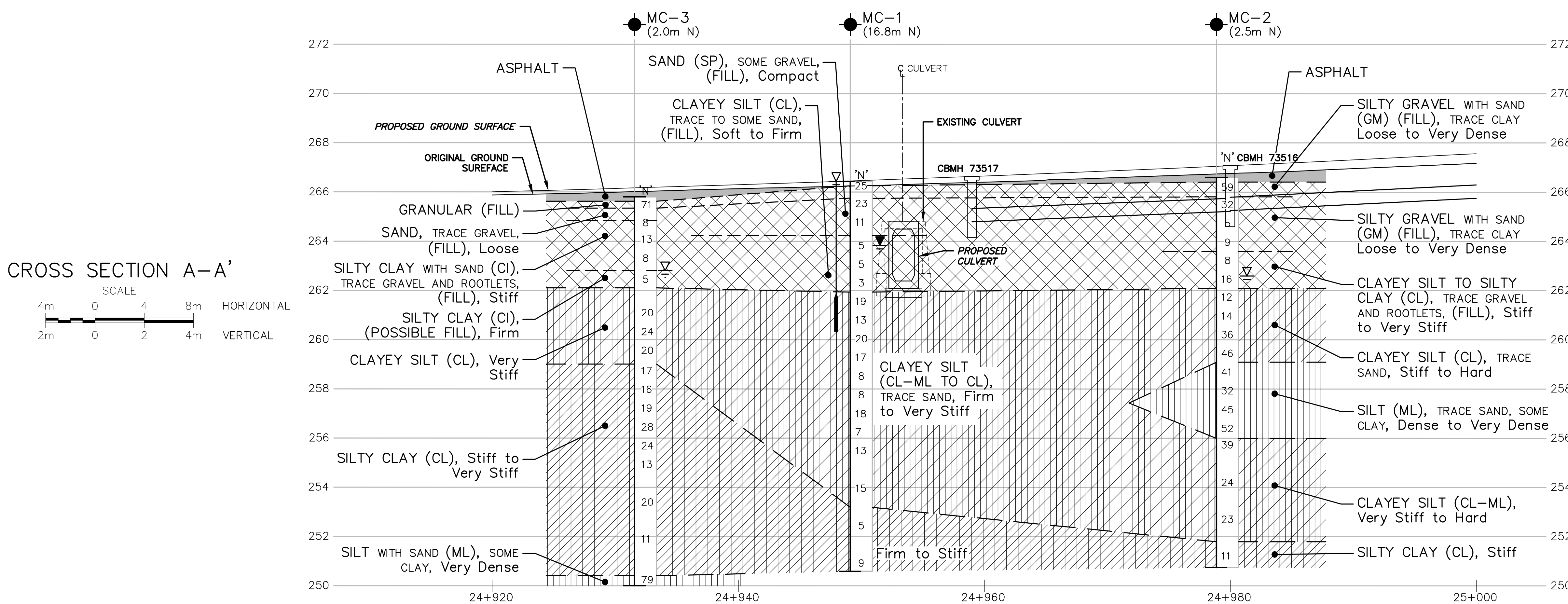
PLAN





KEY PLAN
800m 0 800 1600m

CROSS SECTION A–A'



LEGEND

Symbol	Description
(symbol)	Borehole (Stantec, 2022)
(symbol)	Borehole (Golders, 2013)
(x.x m)	Offset from Cross Section Line in meters
N	Blows/0.3m (Std Pen Test, 475 J/blow)
(symbol)	WL at time of investigation June 2022
(symbol)	WL measured on September 2022
(symbol)	Piezometer

No	ELEV	MTM ZONE 11 COORDINATES NORTH	EAST
MC-01	266.4	4 755 445.6	410 932.8
MC-02	266.6	4 755 445.7	410 965.8
MC-03	265.8	4 755 424.6	410 923.5
601	266.0	4 755 461.9	410 934.9
602	263.8	4 755 405.9	410 955.1
603	265.8	4 755 413.6	410 945.1

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 40I14-205

HWY No 401			DIST
SUBM'D GR	CHECKED	DATE 2023-01-11	SITE 19X-0650/C0
DRAWN GBB	CHECKED	APPROVED	DWG 1

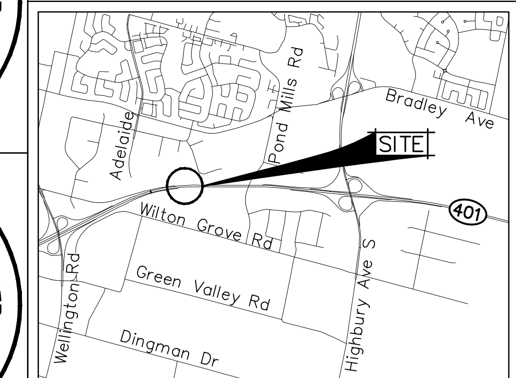
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

PLATE No	
CONT	2022-3004
WP	3032-11-00

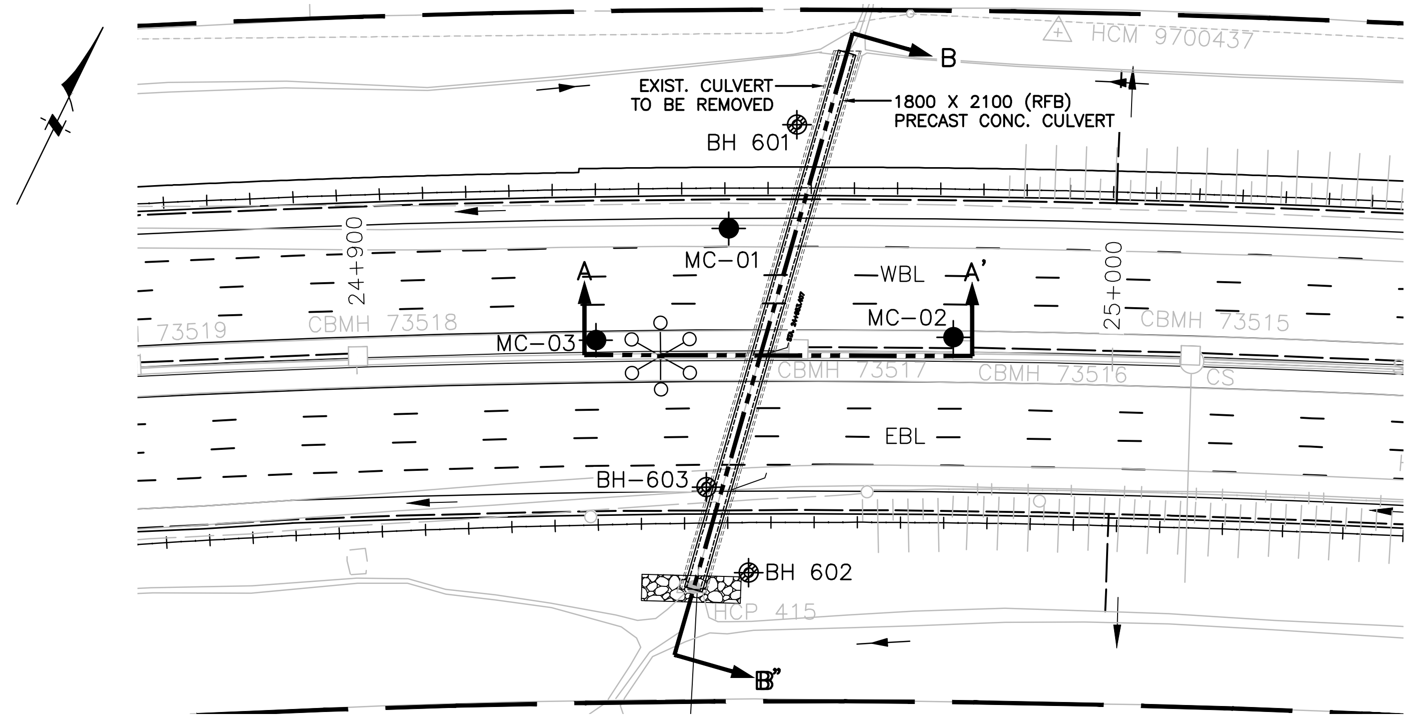
HIGHWAY 401
MURRAY DRAIN CULVERT
BOREHOLE LOCATIONS & SOIL STRATA

SHEET
-

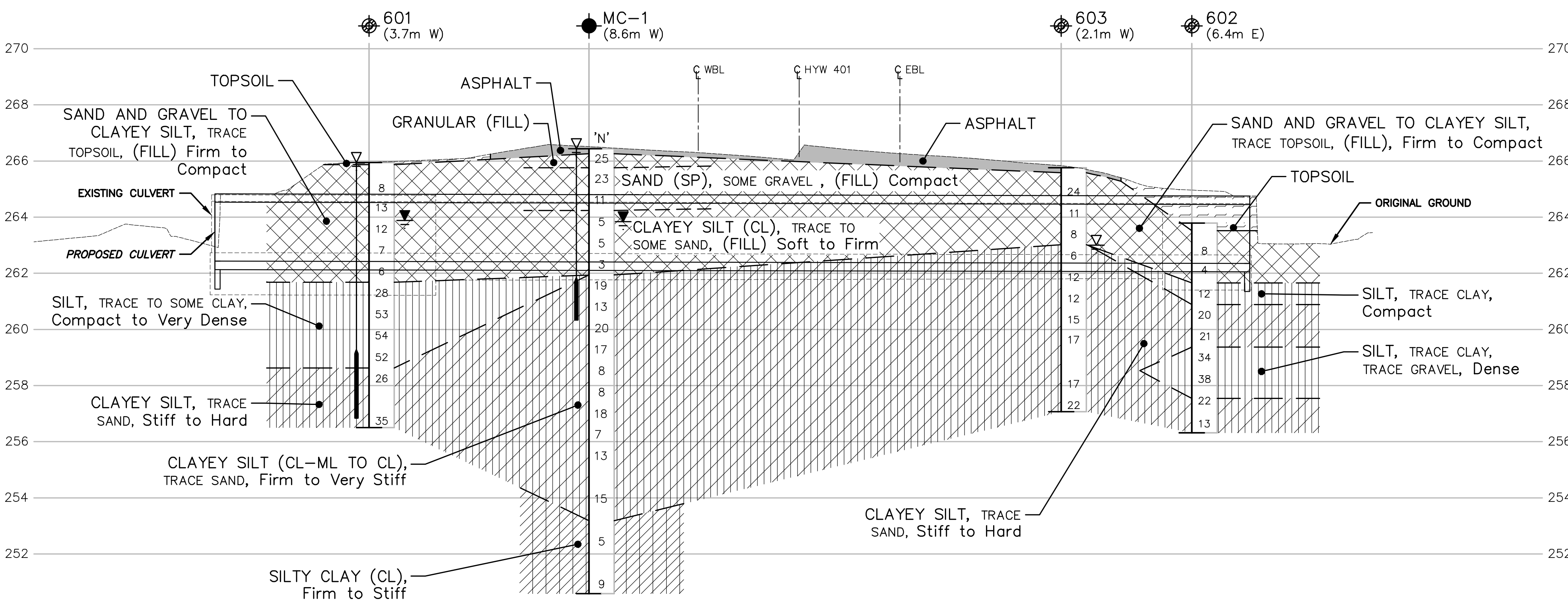
Stantec



KEY PLAN
800m 0 800 1600m



PLAN
SCALE
10m 0 10 20m



CROSS SECTION B-B'
SCALE
4m 0 4 8m HORIZONTAL
2m 0 2 4m VERTICAL

LEGEND

Symbol	Description
●	Borehole (Stantec, 2022)
⊕	Borehole (Golders, 2013)
(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 May 2013
▼	WL Measured on June 2013 & September 2022
▮	Piezometer

No	Elev	MTM ZONE 11 COORDINATES NORTH	EAST
MC-01	266.4	4 755 445.6	410 932.8
MC-02	266.6	4 755 445.7	410 965.8
MC-03	265.8	4 755 424.6	410 923.5
601	266.0	4 755 461.9	410 934.9
602	263.8	4 755 405.9	410 955.1
603	265.8	4 755 413.6	410 945.1

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 40I14-205

HWY No 401			DIST
SUBM'D GR	CHECKED	DATE 2023-01-11	SITE 19X-0650/C0
DRAWN GBB	CHECKED	APPROVED	DWG 2

DRAWING NAME: 165001239_Murray Drain Culvert_P&CS_20230111.dwg
CREATED BY: GBB
MODIFIED: C:\Users\gbriones\appdata\local\temp\AcPublish_21064\165001239_Murray Drain Culvert_P&CS_20230111.dwg (B-B') Printed: Jan 11, 2023

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

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

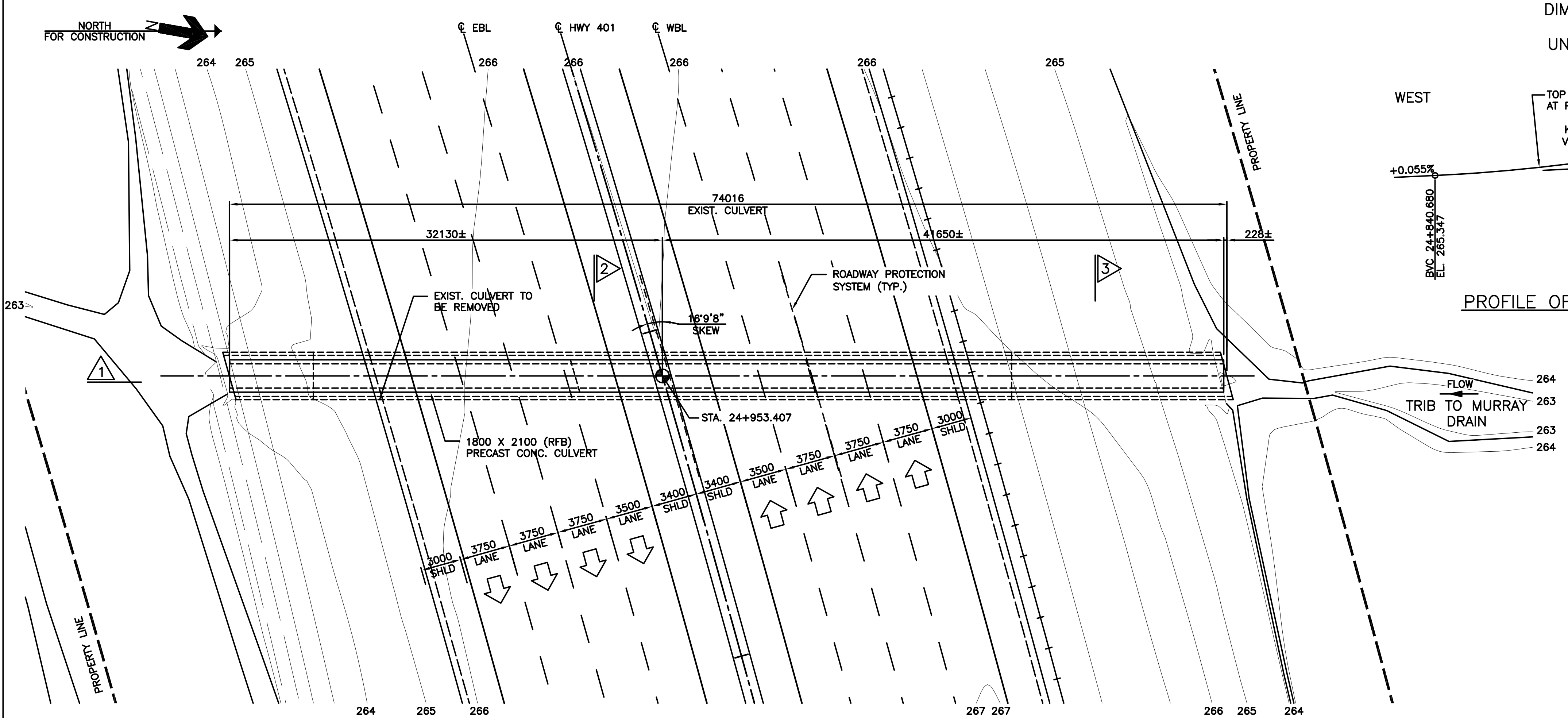
HWY 401
CONT 2022–3004
WP 3054–11–00

TRIBUTARY TO MURRAY DRAIN CULVERT REPLACEMENT
PRELIMINARY GENERAL ARRANGEMENT

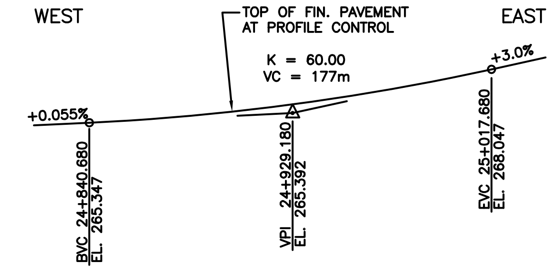
SHEET ----

Stantec

Dufferin Construction



PLAN
1 : 200



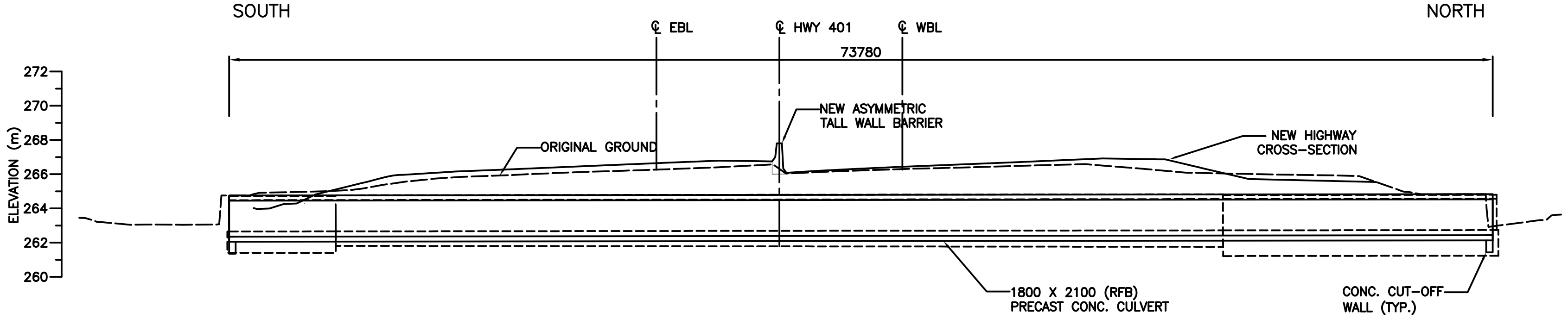
PROFILE OF HIGHWAY 401
N.T.S.

GENERAL NOTES:

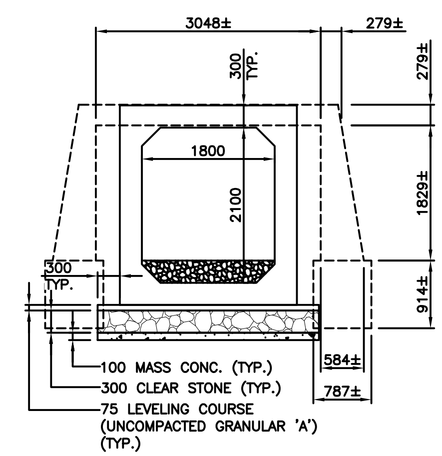
1. SPECIFIED 28–DAY CONCRETE COMPRESSIVE STRENGTH:
   - CUT–OFF WALL 30 MPa
   - PRECAST CONCRETE 45 MPa
2. CLEAR COVER TO REINFORCING STEEL:
   - CUT–OFF WALL 70±20
   - REMAINDER 50±10
   - UNLESS OTHERWISE NOTED.
3. REINFORCING STEEL:
   - REINFORCING STEEL SHALL BE GRADE 400W OR 500W UNLESS OTHERWISE SPECIFIED.
   - TENSION LAP LENGTHS NOT INDICATED ON THE CONTRACT DRAWINGS SHALL BE CLASS B.
   - BAR HOOKS SHALL HAVE STANDARD HOOK DIMENSIONS USING MINIMUM BEND DIAMETERS, WHILE STIRRUPS AND TIES SHALL HAVE MINIMUM HOOK DIMENSIONS. ALL HOOKS SHALL BE IN ACCORDANCE WITH THE STRUCTURAL STANDARD DRAWING SS112–1. UNLESS INDICATED OTHERWISE

CONSTRUCTION NOTES:

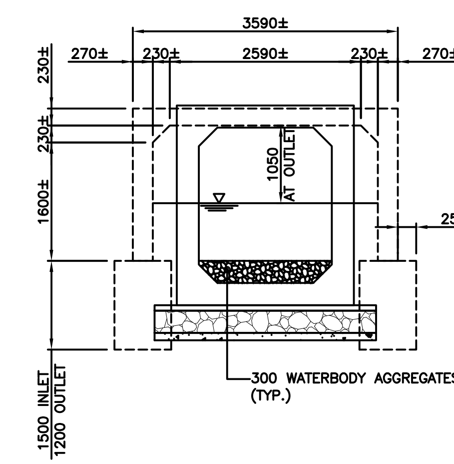
1. THE CONTRACTOR SHALL VERIFY ALL DIMENSIONS, DETAILS AND ELEVATIONS OF THE EXISTING STRUCTURE THAT ARE RELEVANT TO THE WORK SHOWN ON THE DRAWINGS PRIOR TO COMMENCEMENT OF THE WORK. ANY DISCREPANCIES SHALL BE REPORTED TO THE CONTRACT ADMINISTRATOR AND THE PROPOSED ADJUSTMENT OF THE WORK REQUIRED TO MATCH THE EXISTING STRUCTURE SHALL BE SUBMITTED FOR APPROVAL.
2. DEBRIS FROM STRUCTURE REMOVALS SHALL BE PREVENTED FROM ENTERING THE WATERCOURSE.
3. BACKFILL SHALL BE PLACED SIMULTANEOUSLY BEHIND BOTH CONCRETE WALLS KEEPING THE HEIGHT OF THE BACKFILL APPROXIMATELY THE SAME. AT NO TIME SHALL THE DIFFERENCE IN ELEVATION BE GREATER THAN 500mm.
4. THE CONTRACTOR SHALL ISOLATE WORK AREAS FROM THE WATERCOURSE FLOW FOR CULVERT REPLACEMENT AS REQUIRED TO COMPLETE ALL WORK IN THE DRY.
5. ROADWAY PROTECTION SYSTEMS SHALL BE DESIGNED FOR PERFORMANCE LEVEL 2.



1
1 : 200



2
1 : 50



3
1 : 50

DRAWING NOT TO BE SCALED
100 mm ON ORIGINAL DRAWING

REVISIONS	DATE	BY	DESCRIPTION		
DESIGN F.S.A.	CHK M.D.	CODE CSA–S6–19	LOAD CL–625–ONT	DATE SEPT 2022	
DRAWN H.L.	CHK F.S.A.	SITE 19X–0650/C0	STRUCT	SCHEME	DWG. 1

165001239–19–650–MURRAY–C–GA.DWG Sep 16 2022

APPENDIX B

B.1 AVAILABLE GEOCRES INFORMATION

LIST OF ABBREVIATIONS

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

I. SAMPLE TYPE

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

II. PENETRATION RESISTANCE

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

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

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

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

III. SOIL DESCRIPTION

(a) Cohesionless Soils

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

(b) Cohesive Soils

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

IV. SOIL TESTS

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

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

LIST OF SYMBOLS

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

I. General

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

II. STRESS AND STRAIN

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

III. SOIL PROPERTIES

(a) Index Properties

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

(a) Index Properties (continued)

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

(b) Hydraulic Properties

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

(c) Consolidation (one-dimensional)

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

(d) Shear Strength

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

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

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

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 601

 METRIC

PROJECT 12-1132-0076

W.P. 3054-11-00 | LOCATION N 4755461.9 , E 410934.9 | ORIGINATED BY MA

DIST | HWY 401 | BOREHOLE TYPE POWER AUGER, HOLLOW STEM | COMPILED BY LMK

DATUM GEODETIC | DATE May 16, 2013 | CHECKED BY

SOIL PROFILE

ELEV / DEPTH (m)	DESCRIPTION
265.95	GROUND SURFACE
0.08	TOPSOIL, sandy, trace gravel Brown
0.21	FILL, sand and gravel, some silt Brown
	FILL, clayey silt, some sand to sandy, some gravel, some topsoil, with asphalt pieces Stiff Brown
264.73 / 1.22	FILL, clayey silt, some sand, trace gavel, with silt layers Stiff to firm Brown
261.68 / 4.27	SILT, trace to some clay Compact to very dense Brown turning grey at about elev. 260.7m
258.63 / 7.32	CLAYEY SILT Very stiff to hard
256.50 / 9.45	END OF BOREHOLE Borehole dry during drilling on May 16, 2013. Water level measured in standpipe at elev. 263.85m on June 5, 2013. Water level measured in standpipe at elev. 263.88m on June 20, 2013.

SAMPLES

NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
1	SS	8				
2	SS	13				
3	SS	12				
4	SS	7	0	8	62	30
5	SS	6				
6	SS	28				
7	SS	53	0	1	90	9
8	SS	54				
9	SS	52				
10	SS	26	0	0	71	29
11	SS	35				

GROUND WATER CONDITIONS: Cuttings; Granular bentonite; Cuttings; Granular bentonite; Cuttings; Standpipe; Caved material

ELEVATION SCALE: 265, 264, 262, 261, 260, 259, 258, 257

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

LDN_MTO_06 12-1132-0076-1001.GPJ LDN_MTO.GDT 05/11/13

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

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 602

METRIC

PROJECT	12-1132-0076
W.P.	3054-11-00
LOCATION	N 4755405.9 , E 410955.1
ORIGINATED BY	MA
DIST	
HWY	401
BOREHOLE TYPE	POWER AUGER, HOLLOW STEM
COMPILED BY	LMK
DATUM	GEODETIC
DATE	May 15, 2013
CHECKED BY	

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
263.79	GROUND SURFACE
0.00	TOPSOIL, silty, trace sand, trace gravel
0.27 / 263.18	FILL, clayey silt, some sand, some gravel, trace topsoil Brown
0.61	FILL, silty clay, some sand, trace topsoil Firm Mottled brown and grey
261.66 / 2.13	SILT, trace clay, with clayey silt layers Compact Brown
260.89 / 2.90	CLAYEY SILT, with silt seams and layers Very stiff Grey
259.37 / 4.42	SILT, trace sand, trace gravel, with clayey silt layers Dense Grey
257.54 / 6.25	CLAYEY SILT, trace sand, with silt seams and layers Stiff to very stiff Grey
256.32 / 7.47	END OF BOREHOLE Borehole dry during drilling on May 15, 2013.

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	8	
2	SS	4	
3	SS	12	
4	SS	20	0 0 72 28
5	SS	21	
6	SS	34	4 1 75 20
7	SS	38	
8	SS	22	0 0 70 30
9	SS	13	

Column headings: GROUND WATER CONDITIONS; ELEVATION SCALE (263, 262, 261, 260, 259, 258, 257); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L, WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³

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

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 603

METRIC

PROJECT	12-1132-0076
W.P.	3054-11-00
LOCATION	N 4755413.6 , E 410945.1
ORIGINATED BY	MA
DIST	
HWY	401
BOREHOLE TYPE	POWER AUGER, HOLLOW STEM
COMPILED BY	LMK
DATUM	GEODETIC
DATE	May 15, 2013
CHECKED BY	

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
265.76	PAVEMENT SURFACE
0.00	ASPHALT
0.18	FILL, sand and gravel, trace silt, crushed Brown
0.37	FILL, sand and gravel, with cobbles Compact Brown
264.54 / 1.22	FILL, silty clay, trace sand, trace gravel, with topsoil layers Stiff Brown
263.02 / 2.74	CLAYEY SILT, trace sand, trace gravel Firm Mottled brown and grey
262.25 / 3.51	CLAYEY SILT, trace sand, with silt seams and partings Stiff to very stiff Brown turning grey at about elev. 260.4m
257.07 / 8.69	END OF BOREHOLE Groundwater encountered at about elev. 263.0m during drilling on May 15, 2013.

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	24	
2	SS	11	
3	SS	8	0 6 56 38
4	SS	6	
5	SS	12	0 2 68 30
6	SS	12	
7	SS	15	
8	SS	17	
9	SS	17	0 0 76 24
10	SS	22	

Liquid limit at sample 3: 47

Column headings: GROUND WATER CONDITIONS; ELEVATION SCALE (265, 264, 263, 262, 261, 260, 259, 258); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L, WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³

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

SCALE
0 1000 2000m
1:50,000

REFERENCE

PLAN BASED ON CANMAP STREETFILES V.2008.5.

NOTE

THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ACCOMPANYING TEXT.

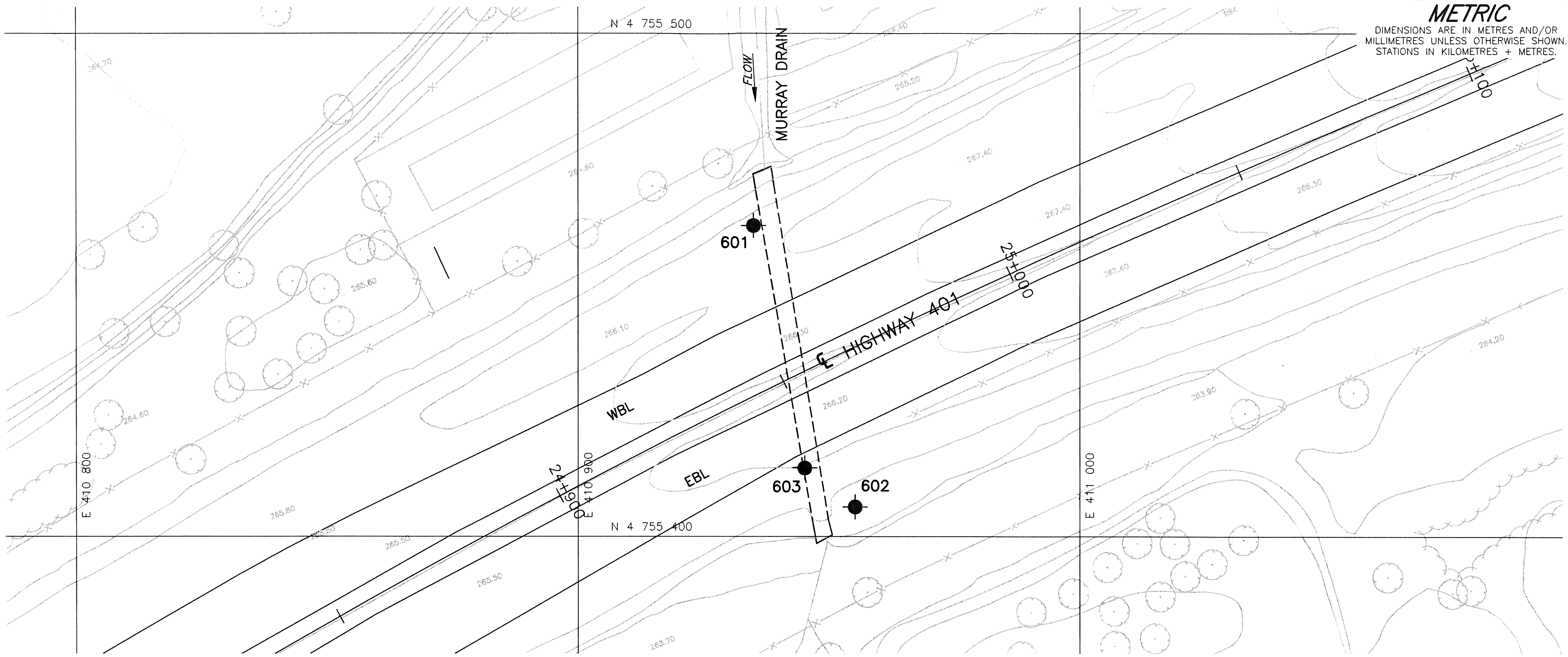
PROJECT
STRUCTURAL CULVERT REPLACEMENT 19-650/C
HIGHWAY 401 INTERCHANGE IMPROVEMENTS
GWP 3054-11-00

TITLE
KEY PLAN

Golder Associates
LONDON, ONTARIO

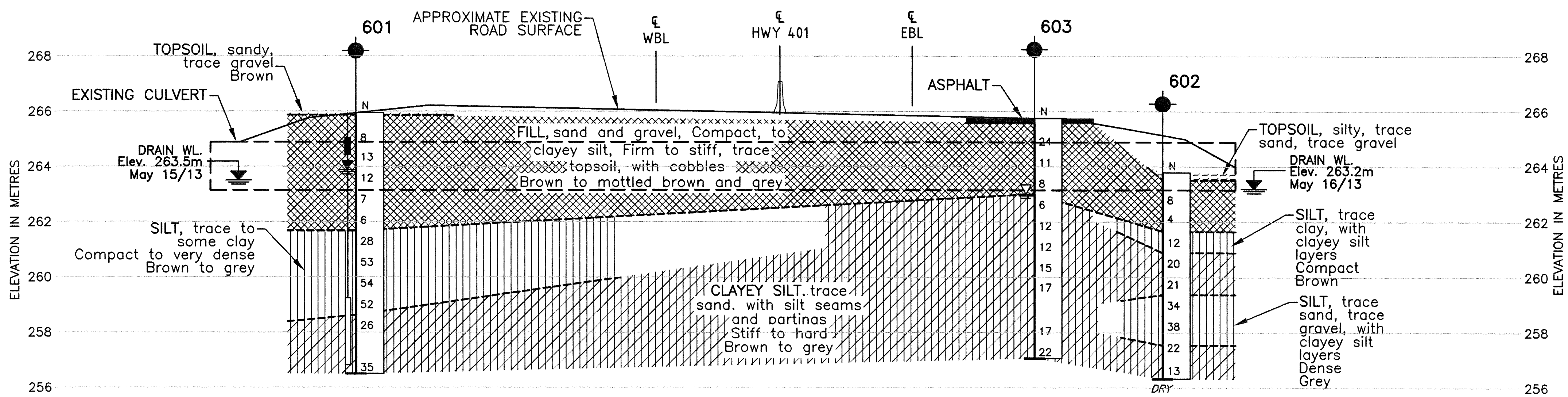
PROJECT No.		12-1132-0076	FILE No. 1211320076-1001-F05A01		
			SCALE	AS SHOWN	REV. 0
CADD	LMK/WDF	Nov. 01/13	**FIGURE 1**		
CHECK					

Drawing file: 1211320076-1001-F05A01.dwg Nov 05, 2013 - 10:45am



PLAN

SCALE 10 0 10m



PROFILE ALONG ℄ CULVERT

HORIZONTAL SCALE 4 0 4m VERTICAL SCALE 2 0 2m

CONT No.

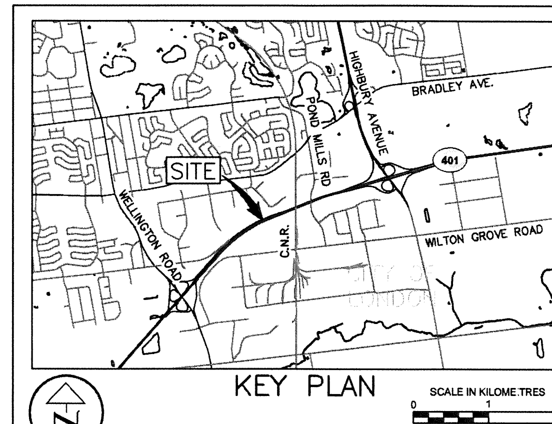
WP No. 3054-11-00

SHEET

STRUCTURAL CULVERT REPLACEMENT
STATION 24+954
HIGHWAY 401 INTERCHANGE IMPROVEMENTS
BOREHOLE LOCATIONS AND SOIL STRATA

Golder Associates

Golder Associates Ltd.
LONDON, ONTARIO, CANADA



KEY PLAN

SCALE IN KILOMETRES 0 1 2

LEGEND

- Borehole – Current Investigation
- Seal
- Standpipe
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- WL measured on June 20, 2013.
- WL encountered during drilling
- DRY Water level not established

No.	ELEVATION	CO-ORDINATES (MTM ZONE 10) NORTHING	EASTING
601	265.95	4 755 461.9	410 934.9
602	263.79	4 755 405.9	410 955.1
603	265.76	4 755 413.6	410 945.1

NOTES

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

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

REFERENCE

Base plans based on City of London Digital Mapping Disc 2011 (converted to MTM ZONE 11)

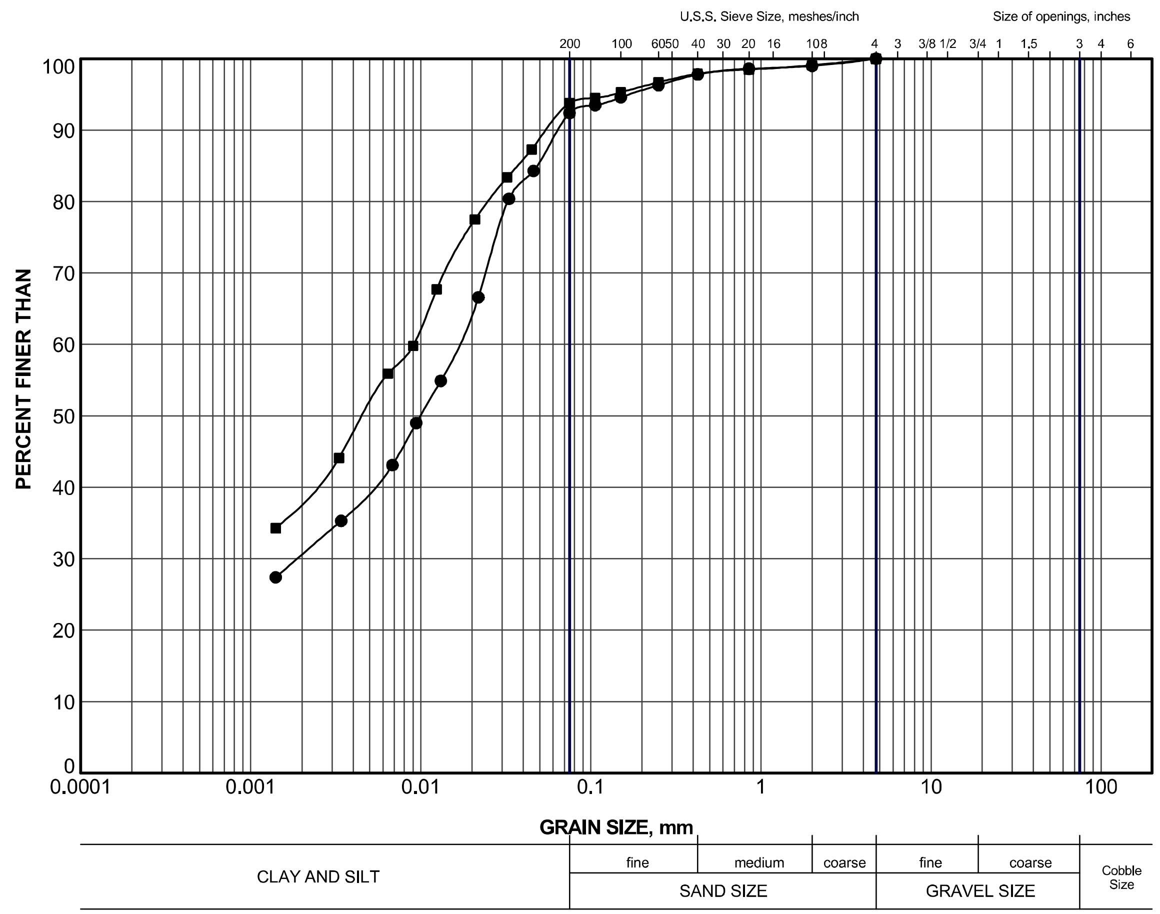
LICENSED PROFESSIONAL ENGINEER D. U. PROUT 06/18/15 PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL ENGINEER F.J. HEFFERNAN 06/18/15 PROVINCE OF ONTARIO

NO.	DATE	BY	REVISION

Geocres No. 40I14-158

HWY. 401		PROJECT NO. 12-1132-0076	DIST.
SUBM'D. NG	CHKD. NAG	DATE: Aug. 07/13	SITE: 19-650/C
DRAWN: WDF/LMK	CHKD. DUP	APPD. FJH	DWG. 1



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	601	4	263.4
■	603	3	263.4

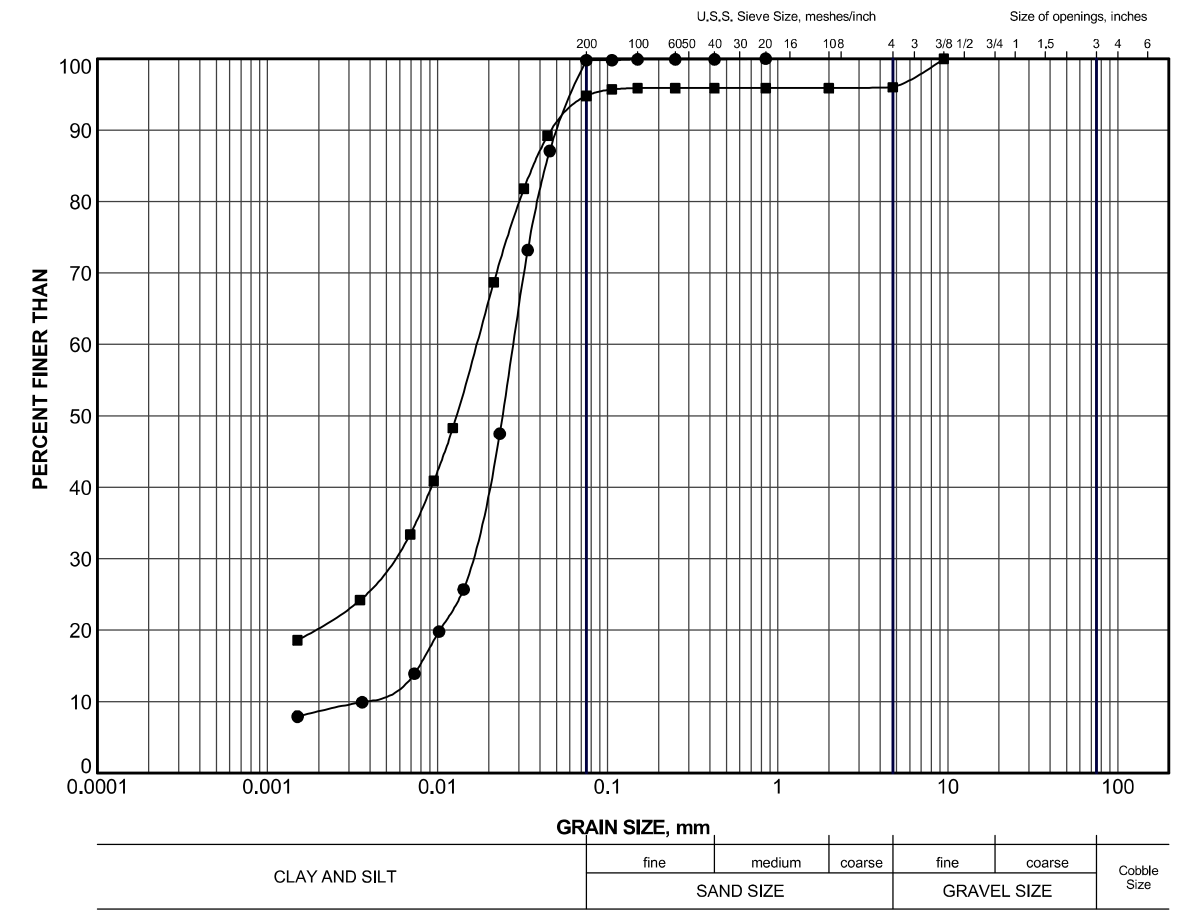
PROJECT STRUCTURAL CULVERT REPLACEMENT 19-650/C
HIGHWAY 401 INTERCHANGE IMPROVEMENTS
GWP 3054-11-00

TITLE
GRAIN SIZE DISTRIBUTION
FILL

Golder Associates LONDON, ONTARIO

PROJECT No.	12-1132-0076	FILE No. 1211320076-1001-F05AA1	
		SCALE N/A	REV.
DRAWN LMK\WDF	Aug. 07/13	**FIGURE A-1**	
CHECK			

LDN_MTO_GSD GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	601	7	260.5
■	602	6	259.0

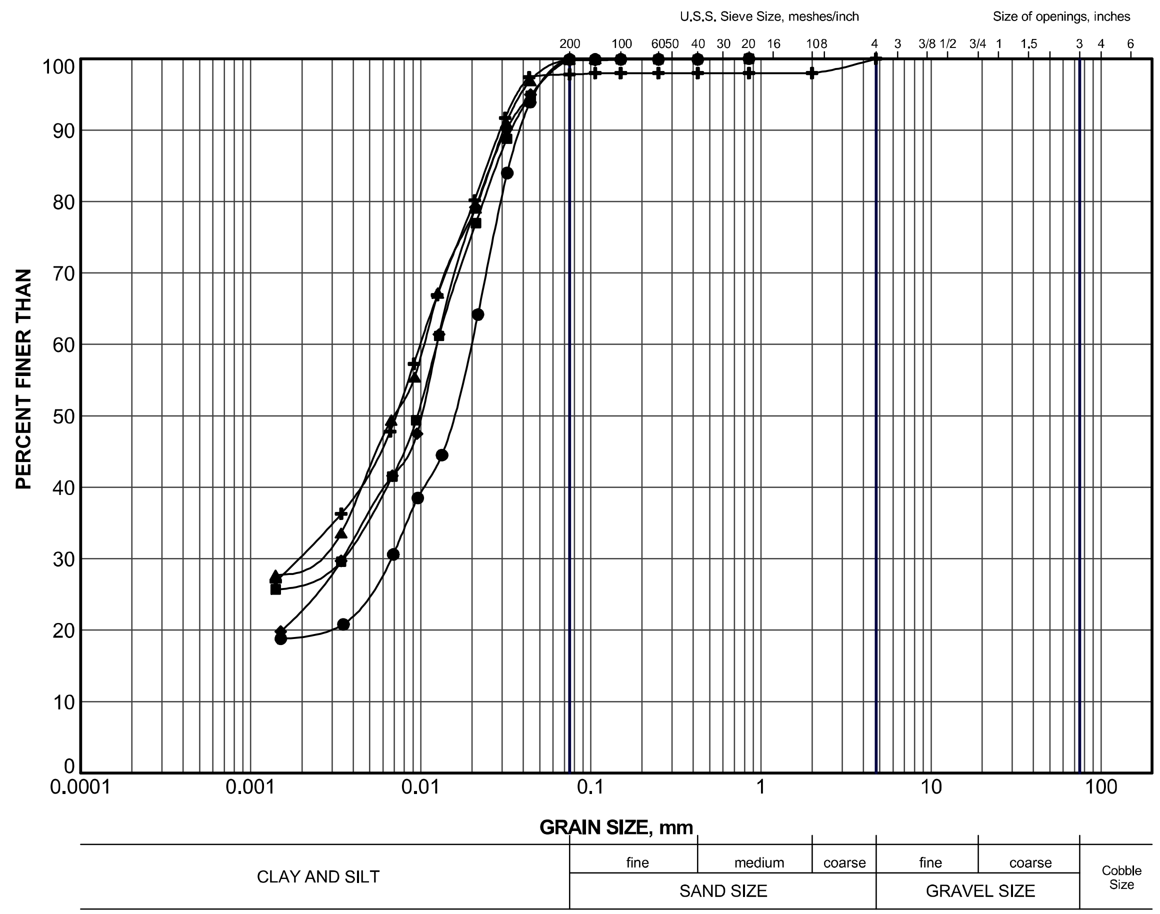
PROJECT STRUCTURAL CULVERT REPLACEMENT 19-650/C
HIGHWAY 401 INTERCHANGE IMPROVEMENTS
GWP 3054-11-00

TITLE
GRAIN SIZE DISTRIBUTION
SILT

Golder Associates LONDON, ONTARIO

PROJECT No.	12-1132-0076	FILE No. 1211320076-1001-F05AA2	
		SCALE N/A	REV.
DRAWN LMK\WDF	Aug. 07/13	**FIGURE A-2**	
CHECK			

LDN_MTO_GSD GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	601	10	258.0
■	602	4	260.5
▲	602	8	257.4
✚	603	5	261.9
◆	603	9	258.1

PROJECT STRUCTURAL CULVERT REPLACEMENT 19-650/C
HIGHWAY 401 INTERCHANGE IMPROVEMENTS
GWP 3054-11-00

TITLE

GRAIN SIZE DISTRIBUTION

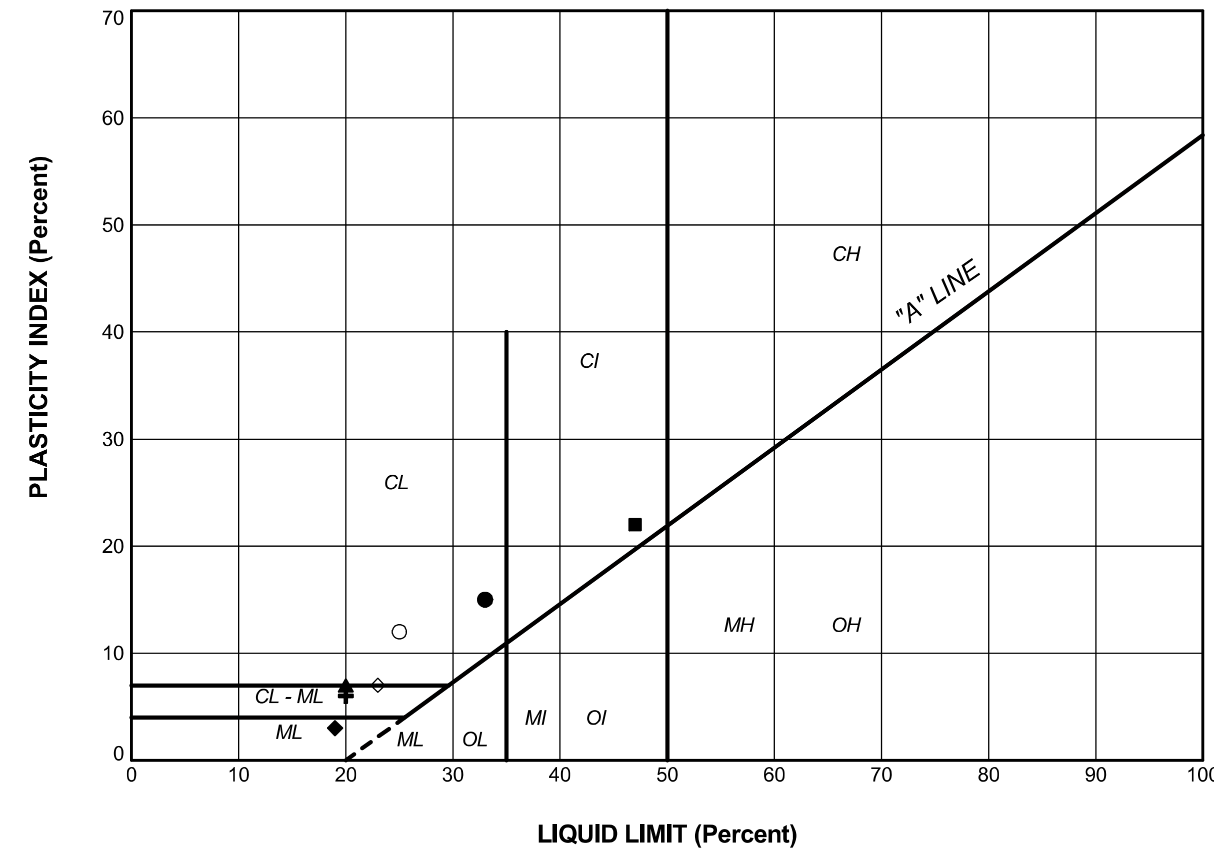
CLAYEY SILT

Golder Associates
LONDON, ONTARIO

PROJECT No. 12-1132-0076-1001 | FILE No. 1211320076-1001-F05AA3 | SCALE N/A | REV.
DRAWN LMK Jun 28/13 | CHECK

FIGURE A-3

LDN_MTO_GSD GLDR_LDN.GDT



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
FILL					
●	601	4	32.9	18.0	14.9
■	603	3	46.8	24.7	22.1
CLAYEY SILT					
▲	601	10	19.5	13.3	6.2
✚	602	4	20.2	14.5	5.7
◆	602	8	19.3	15.6	2.7
◇	603	5	23.0	15.5	7.5
○	603	9	24.8	13.1	11.7

PROJECT STRUCTURAL CULVERT REPLACEMENT 19-650/C
HIGHWAY 401 INTERCHANGE IMPROVEMENTS
GWP 3054-11-00

TITLE

PLASTICITY CHART

Golder Associates
LONDON, ONTARIO

PROJECT No. 12-1132-0076 | FILE No. 1211320076-1001-F05AA4 | SCALE N/A | REV.
DRAWN LMK\WDF Aug. 07/13 | CHECK

FIGURE A-4

LDN_MTO_PI GLDR_LDN.GDT

APPENDIX C

C.1 SYMBOLS AND TERMS USED ON BOREHOLE RECORDS

C.2 BOREHOLE RECORDS

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 MC-01

METRIC

W.P. 3032-11-00 | LOCATION Highway 401/ Highbury, London, Ontario | ORIGINATED BY AS

DIST West | HWY 401 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY RR

DATUM Geodetic | DATE 2022.06.28 - 2022.06.28 | LATITUDE 42.9314163 | LONGITUDE -81.1997347 | CHECKED BY GR

ELEV / DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
266.4	Asphalt				
0.0	180 mm ASPHALT				
266.3 / 0.2	500 mm GRANULAR FILL	1	SS	25	
265.8 / 0.7	FILL: SAND (SP), some gravel Brown Compact Dry SS2 contains clayey topsoil	2	SS	23	
		3	SS	11	
264.2 / 2.2	FILL: CLAYEY SILT (CL), trace to some sand Brown to grey Soft to firm Moist SS4 contains trace rootlets	4	SS	5	
		5	SS	5	PP= 1.25 Su= 67 kPa
		6	SS	3	PP= 0.25 Su= 13 kPa
261.9 / 4.5	CLAYEY SILT (CL-ML to CL), trace sand Brown Firm to very stiff Moist	7	SS	19	PP= 2.5 Su= 134 kPa
		8	SS	13	PP= 2.25 Su= 121 kPa
		9	SS	20	1 3 65 31 PP=2.75 Su= 148 kPa
	Grey below 6.8 m	10	SS	17	PP= 1.75 Su= 94 kPa
					Su > 100 kPa
		11	SS	8	PP= 2.25 Su= 121 kPa
		12	SS	8	0 1 60 40 PP= 1.75 Su= 94 kPa
		13	SS	18	PP= 2.0 Su= 107 kPa

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE (266, 265, 264, 263, 262, 261, 260, 259, 258, 257); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued Next Page

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

RECORD OF BOREHOLE No MC-01

METRIC

W.P. 3032-11-00 LOCATION Highway 401/ Highbury, London, Ontario ORIGINATED BY AS

DIST West HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY RR

DATUM Geodetic DATE 2022.06.28 - 2022.06.28 LATITUDE 42.9314163 LONGITUDE -81.1997347 CHECKED BY GR

ELEV DEPTH	SOIL PROFILE DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	CLAYEY SILT (CL-ML to CL), trace sand Brown Firm to very stiff Moist *(continued)*	14	SS	7	256	PP= 2.5 Su= 134 kPa
		15	SS	13	255	PP= 2.25 Su= 121 kPa
		16	SS	15	254	0 0 65 35 PP= 2.0 Su= 107 kPa
253.2 13.3	SILTY CLAY (CL) Grey Firm to stiff Wet				253	Su > 100 kPa
		17	SS	5	252	0 0 45 55 PP= 0.75 Su= 40 kPa
		18	SS	9	251	PP= 0.75 Su= 40 kPa
250.6 15.9	End of Borehole Monitoring well installed in borehole, screened from approximately 4.6 m to 6.1 m below grade. Ground water level measured in monitoring well at approximately 2.6 m below grade on September 12, 2022.					

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

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

RECORD OF BOREHOLE No MC-02

METRIC

W.P. 3032-11-00 | LOCATION Highway 401/ Highbury, London, Ontario | ORIGINATED BY DB

DIST West | HWY 401 | BOREHOLE TYPE Solid Stem Augers | COMPILED BY JM

DATUM Geodetic | DATE 2022.06.23 - 2022.06.23 | LATITUDE 42.9314128 | LONGITUDE -81.1993304 | CHECKED BY GR

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
266.6	Asphalt					
0.0	180 mm ASPHALT					
266.4 / 0.2	600 mm GRANULAR FILL	1	SS	59		
265.8 / 0.8	FILL: Silty SAND with Gravel (SM), trace clay Brown Loose to very dense Dry	2	SS	32		34 48 13 5
		3	SS	5		
		4	SS	9		
263.6 / 3.0	FILL: CLAYEY SILT to SILTY CLAY (CL), trace gravel and rootlets Brown Stiff to very stiff Moist	5	SS	8		PP=2.25 Su= 121 kPa
		6	SS	16	∇	PP=1.25 Su= 67 kPa
262.1 / 4.5	CLAYEY SILT (CL), trace sand Brown Stiff to hard Moist	7	SS	12		0 1 64 35 PP=2.0 Su= 107 kPa
	Grey below 5.3 m	8	SS	14		PP=2.25 Su= 121 kPa
		9	SS	36		PP=3.0 Su= 161 kPa
		10	SS	46		
259.1 / 7.5	SILT (ML), trace sand, some clay Grey Dense to very dense Moist	11	SS	41		0 0 76 23
		12	SS	32		
	Wet below 9.1 m	13	SS	45		

Elevation scale: 266, 265, 264, 263, 262, 261, 260, 259, 258, 257

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60
UNIT WEIGHT γ kN/m^3

Continued Next Page

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

RECORD OF BOREHOLE No MC-02

METRIC

W.P. 3032-11-00 LOCATION Highway 401/ Highbury, London, Ontario ORIGINATED BY DB

DIST West HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY JM

DATUM Geodetic DATE 2022.06.23 - 2022.06.23 LATITUDE 42.9314128 LONGITUDE -81.1993304 CHECKED BY GR

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SILT (ML), trace sand, some clay Grey Dense to very dense Moist *(continued)*	14	SS	52		
256.0 / 10.6	CLAYEY SILT (CL-ML) Grey Very stiff to hard Wet	15	SS	39	256	0 0 64 36
					255	
		16	SS	24	254	PP=3.0 Su= 161 kPa
					253	
		17	SS	23		PP=2.5 Su= 134 kPa
					252	
251.8 / 14.8	SILTY CLAY (CL), trace sand Grey Stiff Wet	18	SS	11	251	0 1 41 58 PP=0.75 Su= 40 kPa
250.7 / 15.9	END OF BOREHOLE Groundwater and cave-in measured at approximately 4.0 m and 13.7 m below grade, respectively.					

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

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

UNIT WEIGHT γ kN/m³

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

RECORD OF BOREHOLE No MC-03

METRIC

W.P. 3032-11-00	LOCATION Highway 401/ Highbury, London, Ontario		ORIGINATED BY WT
DIST West HWY 401	BOREHOLE TYPE Solid Stem Augers		COMPILED BY RR
DATUM Geodetic	DATE 2022.07.11 - 2022.07.11	LATITUDE 42.9312289 LONGITUDE -81.1998531	CHECKED BY GR

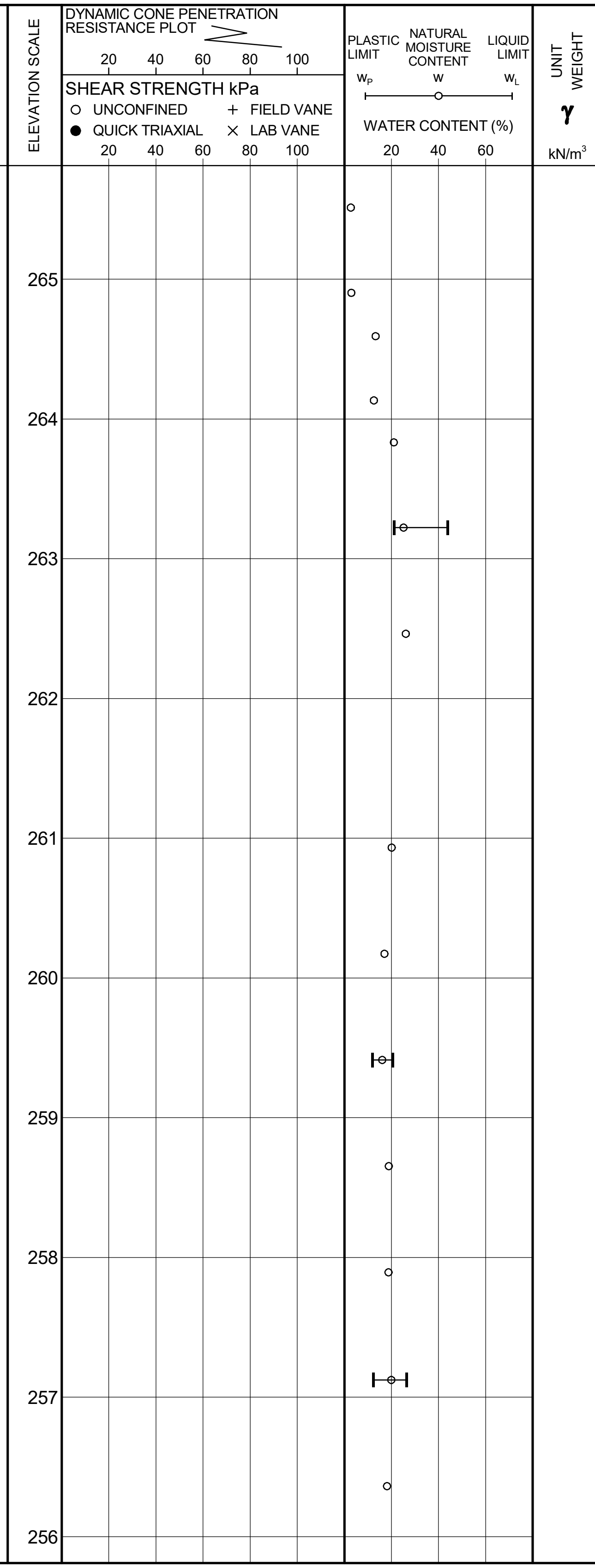
SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
265.8	Asphalt
265.6 / 0.0	180 mm ASPHALT
0.2	280 mm GRANULAR FILL
265.4 / 0.5	FILL: SAND (SP), trace gravel Brown Loose Dry
264.9 / 1.0	FILL: SILTY CLAY with Sand (CI), trace gravel and rootlets Brown Stiff Dry
262.8 / 3.0	POSSIBLE FILL: SILTY CLAY (CI) Brown to grey Firm Dry
262.1 / 3.7	CLAYEY SILT (CL) Brown Very stiff Dry to moist Grey below 5.3 m
259.0 / 6.8	SILTY CLAY (CL) Grey Stiff to very stiff Moist to wet

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	71	
2	SS	8	PP=4.0 Su= 215 kPa
3	SS	13	PP=2.0 Su= 107 kPa
4	SS	8	1 24 32 43 PP=1.75 Su= 94 kPa
5	SS	5	PP=0.5 Su= 27 kPa
	VANE		Su > 100 kPa
6	SS	20	PP=1.75 Su= 94 kPa
7	SS	24	PP=1.75 Su= 94 kPa
8	SS	20	0 1 66 34 PP= 4.5 Su= 241 kPa
9	SS	17	PP=1.75 Su= 94 kPa
10	SS	16	PP=2.75 Su= 148 kPa
11	SS	19	0 0 50 49 PP=0.5 Su= 27 kPa
12	SS	28	PP=2.5 Su= 134 kPa

GROUND WATER CONDITIONS: water level symbol at approx. elev. 262.8



Continued Next Page

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

RECORD OF BOREHOLE No MC-03

METRIC

W.P.	3032-11-00	LOCATION	Highway 401/ Highbury, London, Ontario	ORIGINATED BY	WT
DIST	West HWY 401	BOREHOLE TYPE	Solid Stem Augers	COMPILED BY	RR
DATUM	Geodetic	DATE	2022.07.11 - 2022.07.11 LATITUDE 42.9312289 LONGITUDE -81.1998531	CHECKED BY	GR

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SILTY CLAY (CL) Grey Stiff to very stiff Moist to wet *(continued)*	13	SS	24	PP=0.5 Su= 27 kPa
		14	SS	13	PP=0.25 Su= 13 kPa
	100 mm silt seam at 12.6 m	15	SS	20	PP=0.75 Su= 40 kPa
		16	SS	11	PP=0.5 Su= 27 kPa
			VANE		Su > 100 kPa
250.4 15.4	SILT with Sand (ML), some clay Grey Very dense Wet	17	SS	79	0 23 57 20 PP= 4.5 Su= 241 kPa
250.0 15.8	END OF BOREHOLE				

Elevation scale: 255, 254, 253, 252, 251

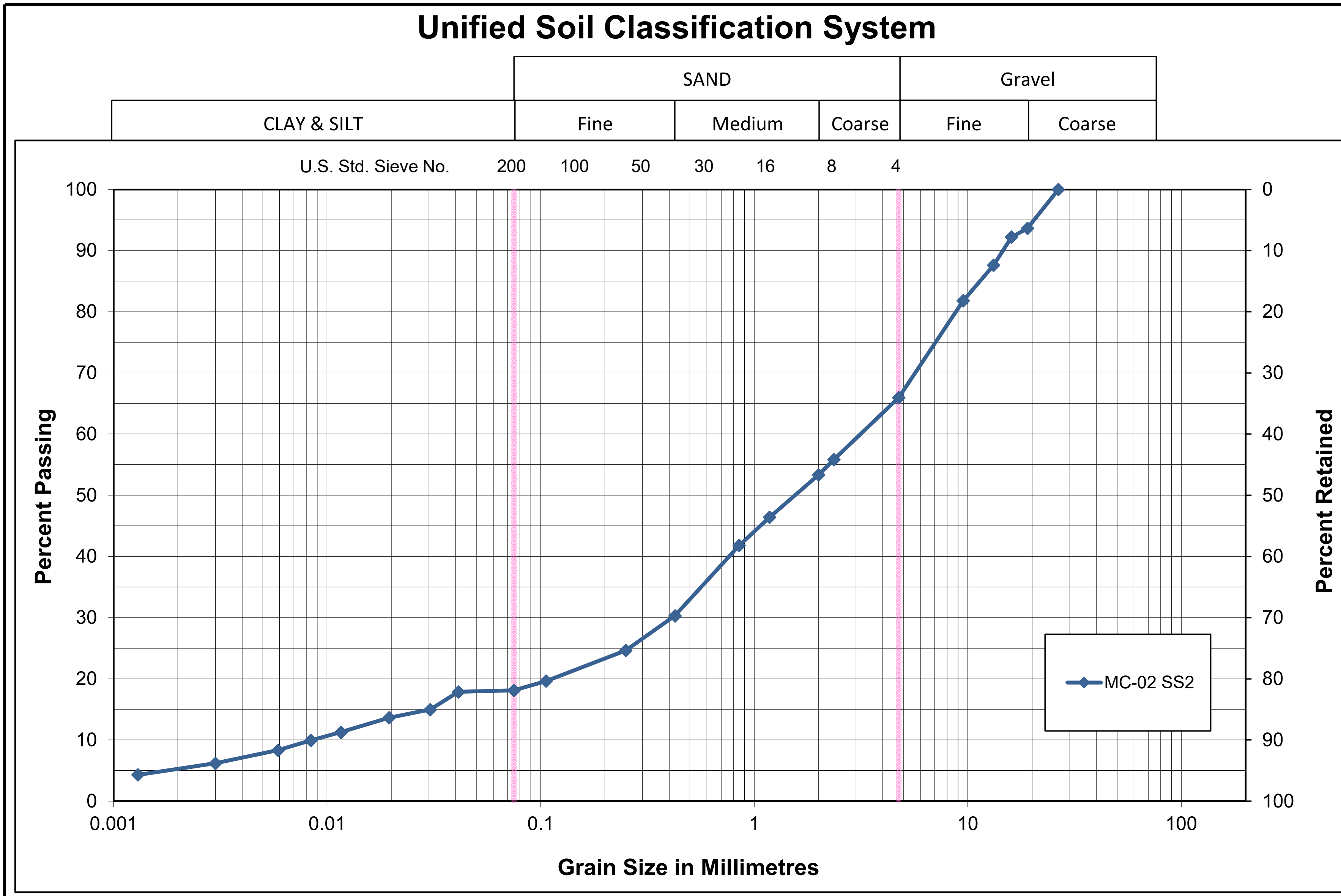
DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE — 20 40 60 80 100
PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60
UNIT WEIGHT γ kN/m³

Groundwater level and cave-in measured at approximately 3 m and 5.2 below grade, respectively; in open borehole.

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

APPENDIX D

D.1 LABORATORY TEST RESULTS



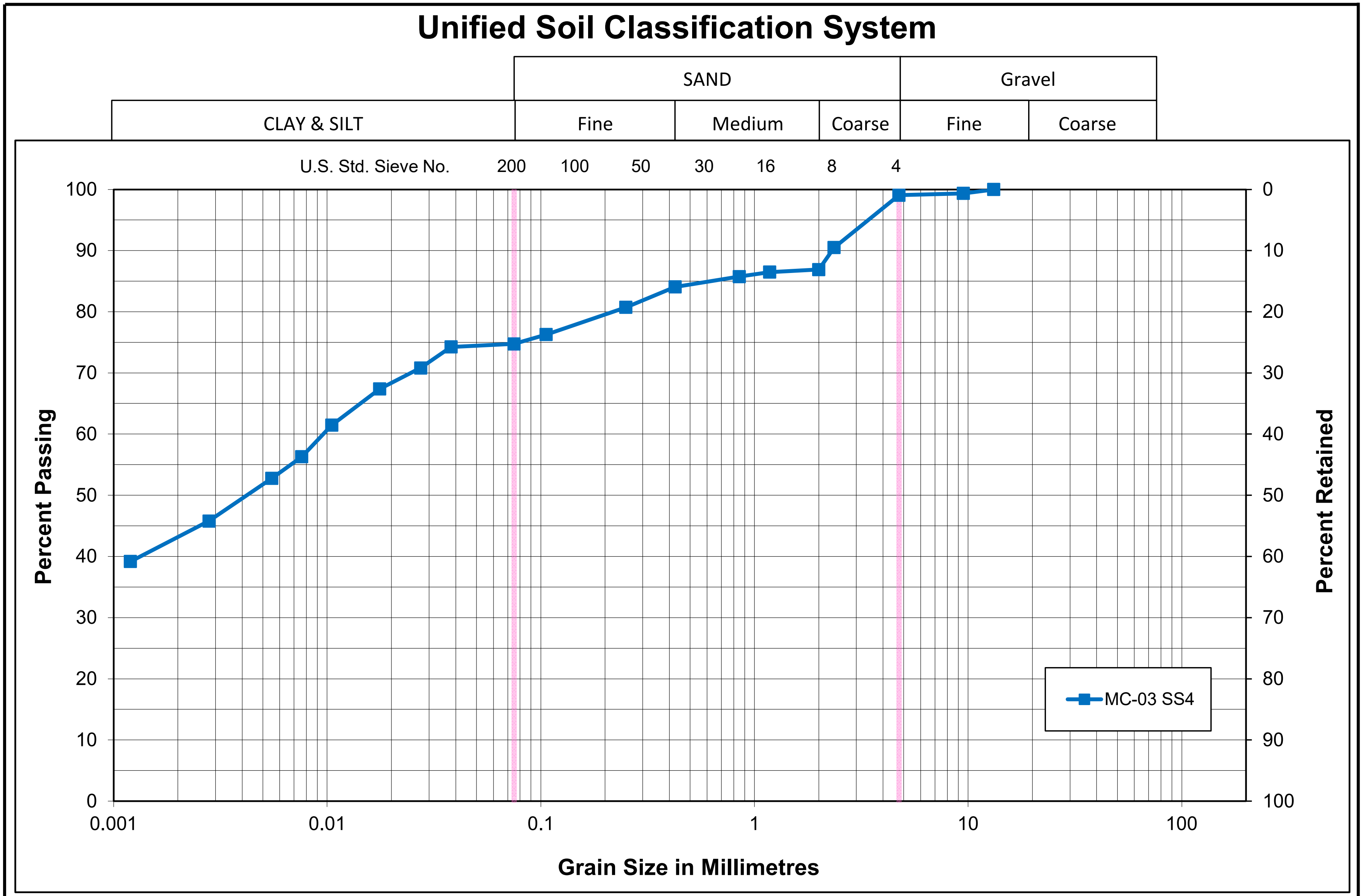
FILL: Silty SAND with Gravel (SM)

Ministry of Transportation (MTO)

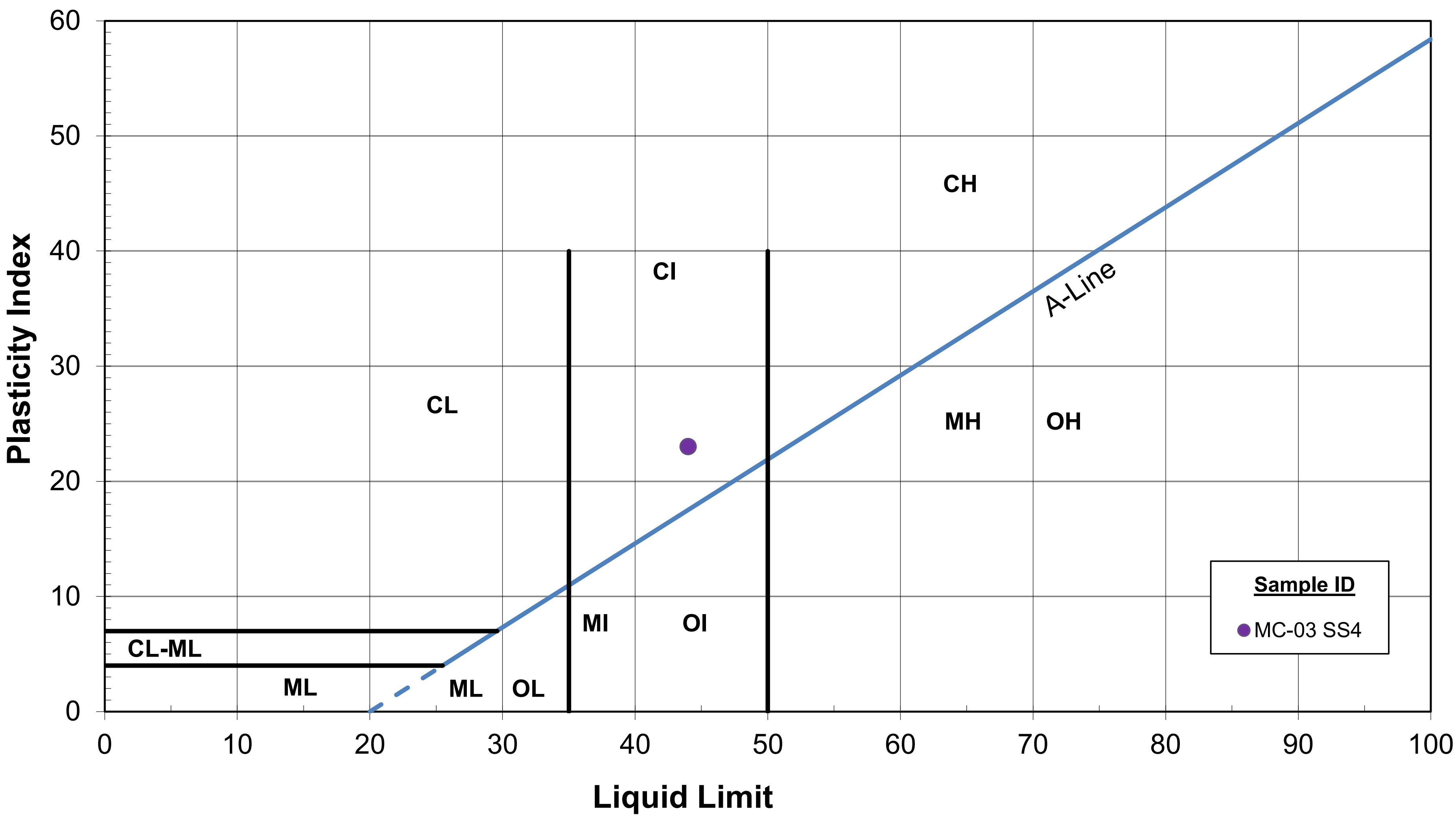
HWY 401 RECONSTRUCTION - MURRAY DRAIN

Figure No. D1

Project No. 165001239



Stantec	FILL: Silty CLAY with Sand (CI) Ministry of Transportation (MTO) HWY 401 RECONSTRUCTION - MURRAY DRAIN	Figure No. D2 Project No. 165001239



Stantec

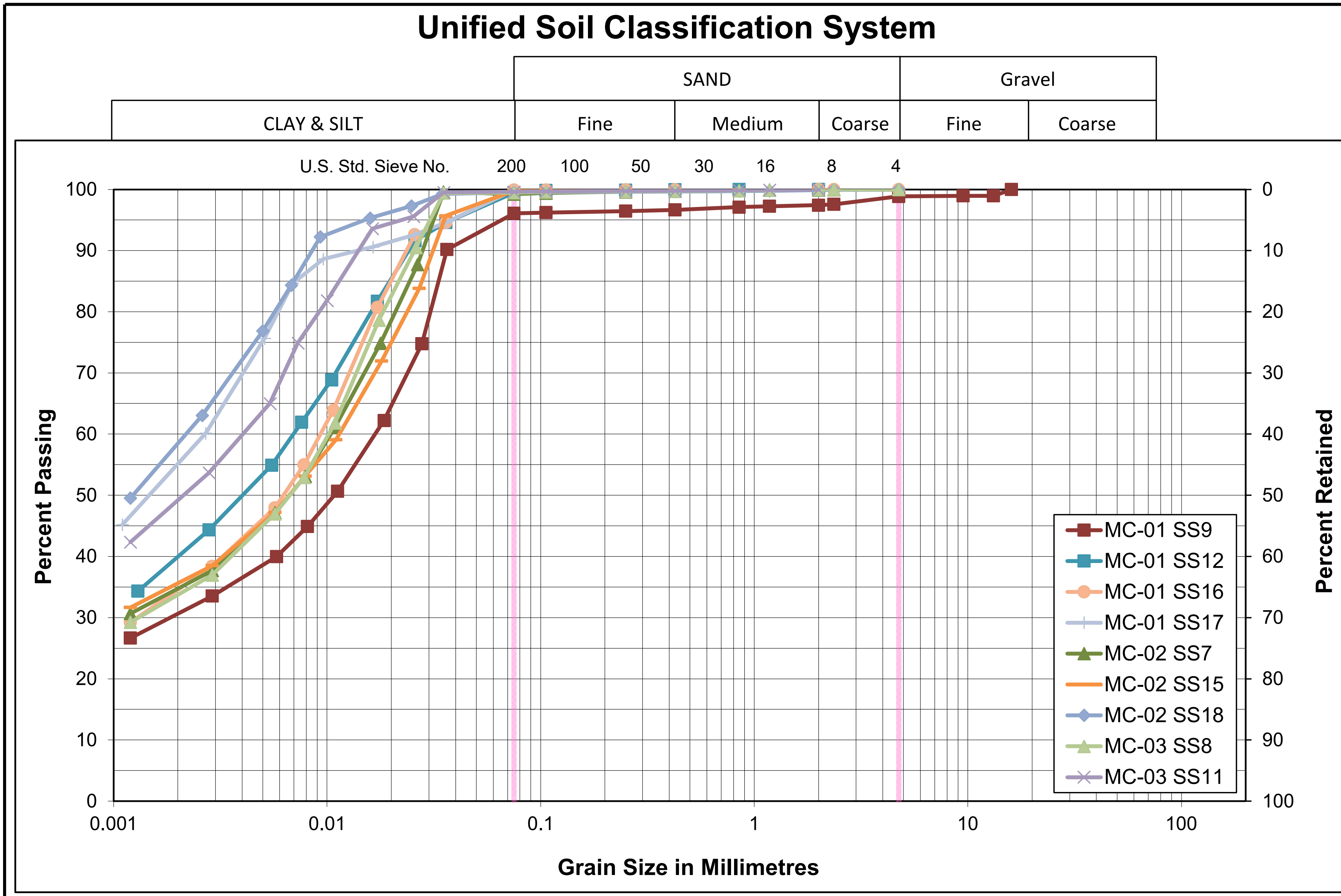
Ministry of Transportation (MTO)

HWY 401 RECONSTRUCTION - MURRAY DRAIN

FILL: Silty CLAY with Sand (CI)

Figure No. D3

Project No. 165001239



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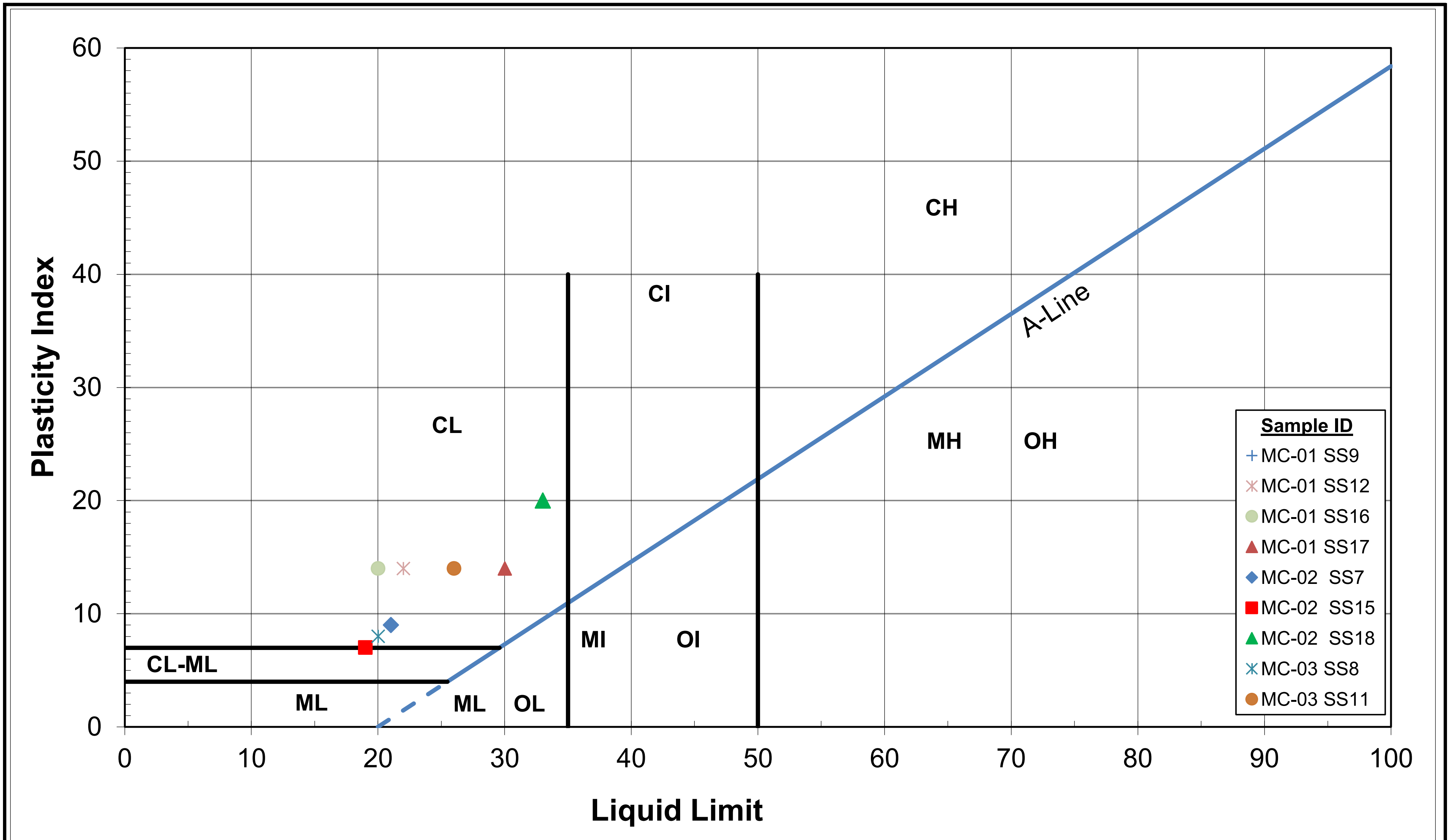
CLAYEY SILT to SILTY CLAY (CL)

Ministry of Transportation (MTO)

HWY 401 RECONSTRUCTION - MURRAY DRAIN

Figure No. D4

Project No. 165001239



Stantec

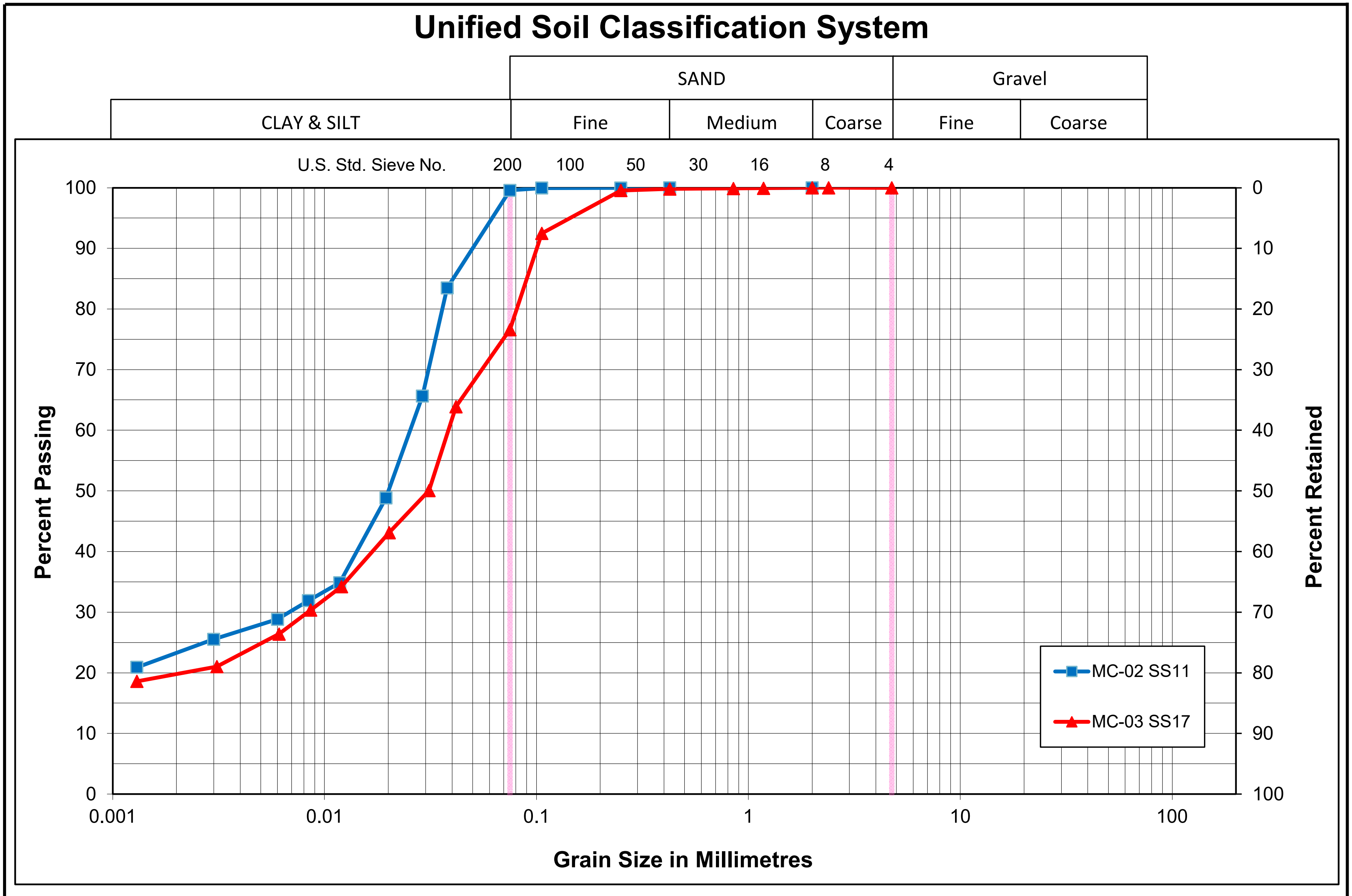
Ministry of Transportation (MTO)

HWY 401 RECONSTRUCTION - MURRAY DRAIN

CLAYEY SILT to SILTY CLAY (CL)

Figure No. D5

Project No. 165001239



Stantec	SILT to SILT with Sand (ML) Ministry of Transportation (MTO) HWY 401 RECONSTRUCTION - MURRAY DRAIN	Figure No. D6 Project No. 165001239

2910 12TH STREET NE
CALGARY, ALBERTA
CANADA T2E 7P7
TEL (403)735-2005
FAX (403)735-2771
http://www.agatlabs.com

CLIENT NAME: STANTEC CONSULTING LTD
300-675 Cochrane Drive
MARKHAM, ON L3R0B8
(905) 444-7777

ATTENTION TO: Amoldeep Gill

PROJECT: 165001239.651

AGAT WORK ORDER: 22T944869

ROCK ANALYSIS REVIEWED BY: Meredith White, Senior Technician

SOIL ANALYSIS REVIEWED BY: Nivine Basily, Inorganics Report Writer

DATE REPORTED: Sep 23, 2022

PAGES (INCLUDING COVER): 7

VERSION*: 1

Should you require any information regarding this analysis please contact your client services representative at (403) 735-2005

*Notes

Disclaimer:

- *All work conducted herein has been done using accepted standard protocols, and generally accepted practices and methods. AGAT test methods may incorporate modifications from the specified reference methods to improve performance.*
- *All samples will be disposed of within 30 days after receipt unless a Long Term Storage Agreement is signed and returned. Some specialty analysis may be exempt, please contact your Client Project Manager for details.*
- *AGAT's liability in connection with any delay, performance or non-performance of these services is only to the Client and does not extend to any other third party. Unless expressly agreed otherwise in writing, AGAT's liability is limited to the actual cost of the specific analysis or analyses included in the services.*
- *This Certificate shall not be reproduced except in full, without the written approval of the laboratory.*
- *The test results reported herewith relate only to the samples as received by the laboratory.*
- *Application of guidelines is provided "as is" without warranty of any kind, either expressed or implied, including, but not limited to, warranties of merchantability, fitness for a particular purpose, or non-infringement. AGAT assumes no responsibility for any errors or omissions in the guidelines contained in this document.*
- *All reportable information as specified by ISO/IEC 17025:2017 is available from AGAT Laboratories upon request.*

Certificate of Analysis

AGAT WORK ORDER: 22T944869
PROJECT: 165001239.651

2910 12TH STREET NE
CALGARY, ALBERTA
CANADA T2E 7P7
TEL (403)735-2005
FAX (403)735-2771
http://www.agatlabs.com

CLIENT NAME: STANTEC CONSULTING LTD **ATTENTION TO: Amoldeep Gill**
SAMPLING SITE: **SAMPLED BY:**

(283-042) Sulfide (CGY)

DATE RECEIVED: 2022-09-14 **DATE REPORTED: 2022-09-23**

			SAMPLE DESCRIPTION:	(MC-01) - SS8	(S-06-3) - SS8	(S-08-1) - SS8	(PM-03-2) - SS8	(PM-02-1) - SS6	(S-02) - SS6	(S-07) - SS8	(EL-02-1) - SS6
			SAMPLE TYPE:	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
			DATE SAMPLED:	2022-09-12	2022-09-12	2022-09-12	2022-09-12	2022-09-12	2022-09-12	2022-09-12	2022-09-12
Parameter	**Unit**	**G / S**	**RDL**	4302866	4302868	4302869	4302870	4302871	4302872	4302873	4302874
Sulfide	%		0.01	0.02	0.06	0.05	0.07	<0.01	0.01	0.01	0.05

			SAMPLE DESCRIPTION:	(MC-02) - SS8	(MS-01) - SS4
			SAMPLE TYPE:	Soil	Soil
			DATE SAMPLED:	2022-09-12	2022-09-12
Parameter	**Unit**	**G / S**	**RDL**	4302875	4302881
Sulfide	%		0.01	0.07	0.03

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard
Analysis performed at AGAT Calgary (unless marked by *)

Certified By:

AGAT Laboratories

Certificate of Analysis

AGAT WORK ORDER: 22T944869

PROJECT: 165001239.651

2910 12TH STREET NE
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CANADA T2E 7P7
TEL (403)735-2005
FAX (403)735-2771
http://www.agatlabs.com

CLIENT NAME: STANTEC CONSULTING LTD

ATTENTION TO: Amoldeep Gill

SAMPLING SITE:

SAMPLED BY:

Corrosivity Package

DATE RECEIVED: 2022-09-14

DATE REPORTED: 2022-09-23

			SAMPLE DESCRIPTION:	(MC-01) - SS8	(S-06-3) - SS8	(S-08-1) - SS8	(PM-03-2) - SS8	(PM-02-1) - SS6	(S-02) - SS6	(S-07) - SS8	(EL-02-1) - SS6
			SAMPLE TYPE:	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
			DATE SAMPLED:	2022-09-12	2022-09-12	2022-09-12	2022-09-12	2022-09-12	2022-09-12	2022-09-12	2022-09-12
Parameter	**Unit**	**G / S**	**RDL**	**4302866**	**4302868**	**4302869**	**4302870**	**4302871**	**4302872**	**4302873**	**4302874**
Chloride (2:1)	µg/g		2	470	89	199	8	206	486	1090	1290
Sulphate (2:1)	µg/g		2	97	120	98	96	16	62	35	155
pH (2:1)	pH Units		NA	6.68	6.65	6.81	6.79	6.62	7.31	7.09	7.38
Electrical Conductivity (2:1)	mS/cm		0.005	0.916	0.390	0.571	0.221	0.471	0.990	2.09	2.66
Resistivity (2:1) (Calculated)	ohm.cm		1	1090	2560	1750	4520	2120	1010	478	376
Redox Potential 1	mV		NA	417	415	343	321	295	257	317	202
Redox Potential 2	mV		NA	417	415	348	323	304	265	317	211
Redox Potential 3	mV		NA	416	415	349	324	309	274	317	207

			SAMPLE DESCRIPTION:	(MC-02) - SS8	(MS-01) - SS4
			SAMPLE TYPE:	Soil	Soil
			DATE SAMPLED:	2022-09-12	2022-09-12
Parameter	**Unit**	**G / S**	**RDL**	**4302875**	**4302881**
Chloride (2:1)	µg/g		2	287	296
Sulphate (2:1)	µg/g		2	403	29
pH (2:1)	pH Units		NA	6.66	7.45
Electrical Conductivity (2:1)	mS/cm		0.005	0.920	0.687
Resistivity (2:1) (Calculated)	ohm.cm		1	1090	1460
Redox Potential 1	mV		NA	216	243
Redox Potential 2	mV		NA	226	249
Redox Potential 3	mV		NA	233	248

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard

4302866-4302881 EC, pH, Chloride and Sulphate were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil). Resistivity is a calculated parameter.
Redox potential measured on as received sample. Due to the potential for rapid change in sample equilibrium chemistry with exposure to oxidative/reduction conditions laboratory results may differ from field measured results.
Redox potential measurement in soil is quite variable and non reproducible due in part, to the general heterogeneity of a given soil. It is also related to the introduction of increased oxygen into the sample after extraction. The interpretation of soil redox potential should be considered in terms of its general range rather than as an absolute measurement.

Analysis performed at AGAT Toronto (unless marked by *)

Certified By:

2910 12TH STREET NE
CALGARY, ALBERTA
CANADA T2E 7P7
TEL (403)735-2005
FAX (403)735-2771
http://www.agatlabs.com

Quality Assurance

CLIENT NAME: STANTEC CONSULTING LTD
PROJECT: 165001239.651
SAMPLING SITE:

AGAT WORK ORDER: 22T944869
ATTENTION TO: Amoldeep Gill
SAMPLED BY:

Rock Analysis

RPT Date: Sep 23, 2022			DUPLICATE				REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD	Method Blank	Measured Value	Acceptable Limits Lower	Acceptable Limits Upper	Recovery	Acceptable Limits Lower	Acceptable Limits Upper	Recovery	Acceptable Limits Lower	Acceptable Limits Upper
(283-042) Sulfide (CGY)															
Total Sulfur	4302866	4302866	0.02	0.02	NA	< 0.01									
Sulfate	4302866	4302866	0.01	0.01	1.5%	< 0.01	101%								

Certified By:

2910 12TH STREET NE
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Quality Assurance

CLIENT NAME: STANTEC CONSULTING LTD
PROJECT: 165001239.651
SAMPLING SITE:

AGAT WORK ORDER: 22T944869
ATTENTION TO: Amoldeep Gill
SAMPLED BY:

Soil Analysis

RPT Date: Sep 23, 2022			DUPLICATE				REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD	Method Blank	Measured Value	Acceptable Limits Lower	Acceptable Limits Upper	Recovery	Acceptable Limits Lower	Acceptable Limits Upper	Recovery	Acceptable Limits Lower	Acceptable Limits Upper
Corrosivity Package															
Chloride (2:1)	4305151		77	74	4.0%	< 2	98%	70%	130%	102%	80%	120%	100%	70%	130%
Sulphate (2:1)	4305151		70	68	2.9%	< 2	107%	70%	130%	105%	80%	120%	104%	70%	130%
pH (2:1)	4302866	4302866	6.68	6.67	0.1%	NA	101%	80%	120%						
Electrical Conductivity (2:1)	4302866	4302866	0.916	0.920	0.4%	< 0.005	92%	80%	120%						
Redox Potential 1	4302866						100%	90%	110%						

Comments: NA signifies Not Applicable.
pH duplicates QA acceptance criteria was met relative as stated in Table 5-15 of Analytical Protocol document.

Certified By: CHARTERED NIVINE BASILY CHEMIST — ASSOCIATION OF THE CHEMICAL PROFESSION OF ONTARIO

AGAT Laboratories
2910 12TH STREET NE
CALGARY, ALBERTA
CANADA T2E 7P7
TEL (403)735-2005
FAX (403)735-2771
http://www.agatlabs.com

Method Summary

CLIENT NAME: STANTEC CONSULTING LTD **AGAT WORK ORDER: 22T944869**
PROJECT: 165001239.651 **ATTENTION TO: Amoldeep Gill**
SAMPLING SITE: **SAMPLED BY:**

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Soil Analysis			
Chloride (2:1)	INOR-93-6004	modified from SM 4110 B	ION CHROMATOGRAPH
Sulphate (2:1)	INOR-93-6004	modified from SM 4110 B	ION CHROMATOGRAPH
pH (2:1)	INOR 93-6031	modified from EPA 9045D and MCKEAGUE 3.11	PH METER
Electrical Conductivity (2:1)	INOR-93-6075	modified from MSA PART 3, CH 14 and SM 2510 B	PC TITRATE
Resistivity (2:1) (Calculated)	INOR-93-6036	McKeague 4.12, SM 2510 B,SSA #5 Part 3	CALCULATION
Redox Potential 1	INOR-93-6066	G200-20, SM 2580 B	REDOX POTENTIAL ELECTRODE
Redox Potential 2	INOR-93-6066	G200-20, SM 2580 B	REDOX POTENTIAL ELECTRODE
Redox Potential 3	INOR-93-6066	G200-20, SM 2580 B	REDOX POTENTIAL ELECTRODE

5835 Coopers Avenue
Mississauga, Ontario
L4Z 1Y2
www.agatlabs.com · webearth.agatlabs.com

AGAT Laboratories

Chain of Custody Record

Ph.: 905.712.5100 · Fax: 905.712.5122 · Toll Free: 800.856.6261

Laboratory Use Only
Arrival Temperature: 20.8/20.9/21.4
AGAT WO #: 22T944869
Lab Temperature:
Notes: 1 box / No Ice

Client Information:
Company: Stantec Consulting Ltd.
Contact: Amoldeep Gill
Address: 300-675 Cochran Drive West Tower
Phone: 905-479-9345 Fax: 905-944-9889
Project: 165001239.651 PO:
AGAT Quotation #:

Please note, if quotation number is not provided, client will be billed full price for analysis.

Regulatory Requirements:
☐ Regulation 153/09 (reg. 511 Amend.) Table ____ Indicate one
☐ Ind/Com ☐ Res/Park ☐ Agriculture
Soil Texture (check one) ☐ Coarse ☐ Fine
☐ Sewer Use Region ____ Indicate one
☐ Sanitary ☐ Storm
☐ Regulation 558
☐ CCME
☐ Other (specify) ____
☐ Prov. Water Quality Objectives (PWQO)
☐ None

Turnaround Time Required (TAT) Required*
Regular TAT
☑ 5 to 7 Working Days
Rush TAT (please provide prior notification)
Rush Surcharges Apply
☐ 3 Working Days
☐ 2 Working Days
☐ 1 Working Day
OR
Date Required (Rush surcharges may apply):
*TAT is exclusive of weekends and statutory holidays

Invoice To: Same: Yes ☑ No ☐
Company:
Contact:
Address:

Is this a drinking water sample? (potable water intended for human consumption) ☐ Yes ☐ No
If "Yes", please use the *Drinking Water Chain of Custody Form*

Is this submission for a **Record of Site Condition?** ☐ Yes ☐ No

Legend Matrix
GW Ground Water · O Oil
SW Surface Water · P Paint
SD Sediment · S Soil

Report Information – reports to be sent to:
1. Name: Amoldeep Gill
Email: amoldeep.gill@stantec.com
2. Name: Gwangha Roh
Email: gwangha.roh@stantec.com

Sample Identification	Date Sampled	Time Sampled	Sample Matrix	# of Containers	Comments Site/Sample Information	Metals and Inorganics	Metal Scan	Hydride Forming Metals	Client Custom Metals	ORPs: ☐ B-HWS ☐ Cl- ☐ CN- ☐ EC ☐ FOC ☐ Cr+6 ☐ SAR ☐ NO_3/NO_2 ☐ N-Total ☐ Hg ☐ pH	Nutrients: ☐ TP ☐ NH_3 ☐ TKN ☐ NO_3 ☐ NO_2 ☐ NO_3/NO_2	VOC: ☐ VOC ☐ THM ☐ BTEX	CCME Fractions 1 to 4	ABNs	PAHs	Chlorophenols	PCBs	Organochlorine Pesticides	TCLP Metals/Inorganics	TCLP:	Sewer Use	Corrosivity Pckg (pH, Redox Potential,	sulphates and sulphides contents,	chlorides contents and resistivity)
(MC-01) - SS8	12-Sep-22			1	17.5'																	X	X	X
(S-06-3) - SS8	12-Sep-22			1	17.5'																	X	X	X
(S-08-1) - SS8	12-Sep-22			1	17.5'																	X	X	X
(PM-03-2) - SS8	12-Sep-22			1	25'																	X	X	X
(PM-02-1) - SS6	12-Sep-22			1	15'																	X	X	X
(S-02) - SS6	12-Sep-22			1	12.5'																	X	X	X
(S-07) - SS8	12-Sep-22			1	17.5'																	X	X	X
(EL-02-1) - SS6	12-Sep-22			1	12.5'																	X	X	X
(MC-02) - SS8	12-Sep-22			1	17.5'																	X	X	X
(MS-01) - SS4	12-Sep-22			1	7.5'																	X	X	X

Samples Relinquished by (print name & sign): Date/Time
Samples Received by (Print name & sign): Anthony Dasilva [signature] Date/Time
Samples Relinquished by (print name & sign): Date/Time
Samples Received by (Print name & sign): Date/Time

Pink Copy – Client
Yellow + Golden Copy AGAT
White Copy – AGAT

Page ____ of ____
NO:

Document ID: DIV-78-1511.006
Date Issued: July 20, 2011

'22 SEP 14 9:56 AM

APPENDIX E

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: 42.931N 81.200W **User File Reference:** Tributary to Murray Drain Culvert 2022-10-30 08:38 UT

Requested by: Gwangha Roh, 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)	0.089	0.051	0.031	0.009
Sa (0.1)	0.119	0.071	0.045	0.014
Sa (0.2)	0.111	0.068	0.044	0.015
Sa (0.3)	0.091	0.057	0.038	0.014
Sa (0.5)	0.071	0.045	0.030	0.010
Sa (1.0)	0.041	0.027	0.017	0.005
Sa (2.0)	0.021	0.013	0.008	0.002
Sa (5.0)	0.005	0.003	0.002	0.000
Sa (10.0)	0.002	0.001	0.001	0.000
PGA (g)	0.067	0.040	0.025	0.008
PGV (m/s)	0.056	0.034	0.021	0.006

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

References

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

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

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

See the websites www.EarthquakesCanada.ca and www.nationalcodes.ca for more information