



**DRAFT**

**Foundation Investigation and  
Design Report – Replacement of  
Elliot-Laidlaw 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

Geocres No. TBD

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November 17, 2022



## **Table of Contents**

<b>1.0</b>	<b>INTRODUCTION .....</b>	<b>1</b>
<b>2.0</b>	<b>SITE DESCRIPTION .....</b>	<b>2</b>
2.1	SITE LOCATION .....	2
2.2	GENERAL SITE DESCRIPTION .....	2
2.3	EXISTING CULVERT .....	3
2.4	GEOLOGICAL INFORMATION .....	3
<b>3.0</b>	<b>REVIEW OF PREVIOUS INVESTIGATIONS .....</b>	<b>3</b>
<b>4.0</b>	<b>INVESTIGATION PROCEDURES .....</b>	<b>4</b>
4.1	FIELD INVESTIGATION .....	4
4.2	LOCATION AND ELEVATION SURVEY .....	5
4.3	LABORATORY TESTING .....	5
<b>5.0</b>	<b>SUBSURFACE CONDITIONS .....</b>	<b>6</b>
5.1	FRAMEWORK & OVERVIEW .....	6
5.2	OVERBURDEN .....	7
5.2.1	Pavement Structure .....	7
5.2.2	Fill .....	7
5.2.3	Upper Cohesionless Layer: Silt (including Silt with Sand, Sandy Silt, and Silty Sand) .....	9
5.2.4	Clayey Silt .....	9
5.2.5	Lower Cohesionless Layer: Silty Sand/Sandy Silt .....	10
5.3	BEDROCK .....	11
5.4	GROUNDWATER CONDITIONS .....	11
5.5	CHEMICAL ANALYSIS .....	11
<b>6.0</b>	<b>MISCELLANEOUS .....</b>	<b>11</b>
<b>7.0</b>	<b>CLOSURE .....</b>	<b>12</b>
<b>8.0</b>	<b>DISCUSSIONS AND ENGINEERING RECOMMENDATIONS .....</b>	<b>13</b>
8.1	PROJECT DESCRIPTION AND BACKGROUND .....	13
8.1.1	Project Purpose and Description .....	13
8.1.2	Existing and Proposed Structure .....	13
8.1.3	Degree of Site and Prediction Model Understanding .....	14
8.2	GEOTECHNICAL DESIGN PARAMETERS .....	14
8.3	FROST PENETRATION .....	15
8.4	SEISMIC DESIGN CONSIDERATIONS .....	15
8.4.1	Site Class .....	15
8.4.2	Peak Ground Acceleration (PGA) .....	15
8.4.3	Liquefaction Potential .....	15
8.5	FOUNDATION RECOMMENDATIONS FOR BOX CULVERT .....	16
8.5.2	Culvert Bedding, Backfill and Erosion/Scour Protection .....	18



**(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LAIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, Design-Build Project**

8.6	EARTH PRESSURES .....	19
8.6.1	Earth Pressures Under Static Conditions .....	19
8.6.2	Earth Pressures Under Seismic Conditions .....	19
8.7	HIGHWAY EMBANKMENTS .....	21
8.7.1	Embankment Construction .....	21
8.7.2	Stability of Slopes.....	21
8.7.3	Embankment Settlement .....	21
8.8	CEMENT TYPE AND CORROSION PROTECTION.....	22
<b>9.0</b>	<b>CONSTRUCTION CONSIDERATIONS.....</b>	<b>23</b>
9.1	CONSTRUCTION STAGING.....	23
9.2	TEMPORARY ROADWAY PROTECTION .....	23
9.3	SURFACE WATER AND GROUNDWATER CONTROL .....	24
9.4	EXCAVATION AND BACKFILLING .....	26
9.5	OBSTRUCTIONS.....	27
9.6	INSTRUMENTATION AND MONITORING.....	27
<b>10.0</b>	<b>SPECIFICATIONS .....</b>	<b>28</b>
<b>11.0</b>	<b>REFERENCES.....</b>	<b>29</b>
<b>12.0</b>	<b>CLOSURE.....</b>	<b>30</b>

**LIST OF TABLES**

Table 4.1:	Borehole Information Summary .....	5
Table 4.2:	Laboratory Testing Program .....	6
Table 5.1:	Results of Chemical Analysis .....	11
Table 8.1:	Geotechnical Model – Elliot-Laidlaw Drain Culvert (Site 19X-0651/C0) .....	14
Table 8.2:	Peak Ground Acceleration Data .....	15
Table 8.3:	Geotechnical Vertical Resistance & Reaction – Box Culvert.....	17
Table 8.4:	Recommended Static Earth Pressure Parameters (Horizontal Backfill) .....	19
Table 8.5:	Seismic Design Parameters to Estimate Lateral Earth Pressures.....	20
Table 8.6:	Recommended Seismic Earth Pressure Parameters (Horizontal Backfill).....	20
Table 8.7:	Results of Corrosion Potential Assessment .....	22
Table 9.1:	Comparison of Roadway Protection Systems.....	23
Table 9.2:	Comparison of Cofferdam Options for Surface Water Control .....	25
Table 10.1:	Specifications Referenced in Report.....	28



**(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO HIGHBURY AVENUE, DESIGN-BUILD PROJECT**

**LIST OF APPENDICES**

<b>APPENDIX A</b>	<b>A.1</b>
A.1 Drawing Nos. 1 and 2 – Borehole Location Plan and Soil Strata Plot	A.1
A.2 General Arrangement Drawing	A.1
<b>APPENDIX B</b>	<b>B.1</b>
B.1 Available Geocres Information	B.1
<b>APPENDIX C</b>	<b>C.1</b>
C.1 Symbols and Terms Used on Borehole Records	C.1
C.2 Borehole Records	C.1
<b>APPENDIX D</b>	<b>D.1</b>
D.1 Laboratory Test Results	D.1
<b>APPENDIX E</b>	<b>E.1</b>
E.1 2015 National Building Code Seismic Hazard Calculation	E.1



**(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, DESIGN-BUILD PROJECT**

Introduction  
November 17, 2022

**DRAFT FOUNDATION INVESTIGATION REPORT**

For

G.W.P. 3032-11-00

DB Contract Number 2022-3001

Replacement of Elliot-Laidlaw 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; and
- Sewers and storm water management facilities.



# **(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LAIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, DESIGN-BUILD PROJECT**

Site Description  
November 17, 2022

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 Elliot-Laidlaw Drain Culvert replacement (19X-0651/C0) and other project foundations engineering components are reported under separate covers.

## **2.0 SITE DESCRIPTION**

### **2.1 SITE LOCATION**

Elliot-Laidlaw drain culvert crosses Highway 401 immediately west of the Highbury Avenue Interchange 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 Elliot-Laidlaw Drain Culvert, Highway 401 is a divided freeway with three lanes in each direction and paved shoulders on both sides. The culvert also crosses Highway 401, and the W-N/S and N-W ramps of the Highbury Avenue Interchange, both containing a single traffic lane with paved left and right shoulders; the resulting culvert length is about 84 m. The orientation of the highway at the culvert site is approximately northeast-southwest and the orientation of the culvert is approximately northwest-southeast. For the purposes of this report, the orientation of Highway 401 and the Elliot-Laidlaw Drain Culvert are taken as east-west and north-south, respectively.

At the culvert site, Highway 401 is constructed on an embankment. The travelled surface of the highway is at approximate elevation 271.0 m; approximately 2 to 3 m higher than the surrounding lands on both sides of the highway. The base of the existing culvert is at approximate elevation 265.5 m. Beyond the culvert and associated drainage features, the overall topography surrounding the culvert site is relatively flat to gently sloping.

Flow in the Elliot-Laidlaw Drain Culvert is from north to south. The culvert inlet is located within the undeveloped lands north of Highway 401. There is a hydro tower approximately 60 m north, and a high-mast light pole approximately 50 m west of the culvert inlet. The area surrounding the inlet contains vegetative cover consisting of grass and scattered trees. The culvert outlet is located within the undeveloped lands south of Highway 401. The areas surrounding the culvert outlet contains grass and scattered trees.

The surrounding lands generally consist of open fields and industrial/commercial properties.



# **(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LAIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, Design-Build Project**

Review of Previous Investigations  
November 17, 2022

## **2.3 EXISTING CULVERT**

The existing Elliot-Laidlaw Drain culvert was constructed in 1953 and is a concrete, rigid frame, open footing culvert. The original 51.8 m long structure was subsequently extended with open footing rigid frame extensions to the north and south in 1989, and a box culvert extension added to the north in 1993, for a total length of about 84 m. The composite structure has a span of about 6.1 m, rise of 2.4 m, and approximately 1.6 m of soil cover.

## **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 undrained 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 more than 60 m below ground surface at the location of the culvert.

## **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:

GEOCREs Reference No. 40114-159

A preliminary foundation investigation and design report dated June 2015 was prepared by Golder Associates for the structural culvert replacement at the Elliot-Laidlaw 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  
Elliot-Laidlaw Drain, Site Number 19-651/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 701 to 703) advanced along the existing culvert to depths ranging from approximately 11.0 m to 12.6 m below grade in May 2013.



# **(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, Design-Build Project**

Investigation Procedures  
November 17, 2022

The boreholes encountered:

- Topsoil/ pavement structure; underlain by,
- Fill comprising sand and gravel, sandy silt and clayey silt to silty clay to depths ranging from approximately 4.4 m to 5.6 m below grade; underlain by,
- Loose to very dense sandy silt to silty sand to the depths of 7.3 m and 9.9 m below grade; interbedded with/underlain by,
- Compact to dense silt.

Groundwater was measured at elevations of 266.2 m and 266.6 m in the standpipe installed in Borehole 701 on June 5 and June 20, 2013; respectively. Water level in the drain was measured at approximately elevations 266.1 m and 266.3 m on May 13 and 16, 2013; respectively. Based on the observed groundwater levels, the surrounding topography and the water levels in the drain, the report concluded the groundwater level to be at approximate elevation 266.5 m.

For reference, copies of the Borehole Location Plan, stratigraphy along the culvert, borehole records and laboratory test results 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 Elliot-Laidlaw Drain Culvert replacement consisted of a total of four (4) boreholes, designated as Boreholes EL-01, EL-02, EL-03 and EL-04. Boreholes EL-01 to EL-03 were advanced from the median shoulder and Borehole EL-04 was advanced from the westbound outside shoulder of Highway 401. It is noted that EL-04 was moved due to auger grinding at shallow depths on possible buried shallow concrete structure(s) which were not identified by public and private locates, and the existing overheads. 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 CME 55 and B57 truck-mounted drill rigs equipped for soil sampling between the dates of July 15 and August 17, 2022. The boreholes were advanced using continuous flight 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. All recovered SPT samples were returned to our Markham laboratory for detailed classification and testing. A pocket penetrometer was also utilized to





# **(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, Design-Build Project**

Investigation Procedures  
November 17, 2022

estimate the strength of clayey soil samples at the site due to the anticipated very stiff to hard nature of site clayey soils.

Following completion of drilling, a 50-millimeter (mm) diameter groundwater monitoring well, screened over a depth of 7.6 m to 9.1 m below ground surface, was installed in Borehole EL-04. The borehole annulus surrounding the slotted pipe section was backfilled with sand. The remaining annulus was backfilled with bentonite up to the ground surface.

A groundwater level measurement was taken in borehole EL-04 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. The borehole survey data is considered accurate to 0.1 m for coordinates and elevations.

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

**Table 4.1: Borehole Information Summary**

Investigation Borehole	MTM Zone 10 Coordinates		Ground surface elevation (m)	Total depth drilled or advanced (m)	End of borehole elevation (m)	Number of soil samples
	Northing	Easting				
EL-01	4755922.9	412218.5	270.7	15.9	254.9	18
EL-02	4755931.6	412245.1	270.8	15.9	255.0	18
EL-03	4755943.4	412281.8	271.0	15.9	255.1	18
EL-04	4755946.9	412241.4	270.7	15.9	254.8	18

## **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.



**(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LAIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, Design-Build Project**

Subsurface Conditions  
November 17, 2022

**Table 4.2: Laboratory Testing Program**

Laboratory Test Type	Number of Tests
Moisture Content	74
Gradation Analysis	19
Atterberg Limits	6
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 issuance 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 D7 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 sand and gravel/silty sand with gravel/silty sand/silty clayey sand and clayey silt to the depths of approximately 2.3 m to 3.8 m below grade; underlain by,
- Upper cohesionless layer comprising Silt/Silt with Sand/Sandy Silt/Silty Sand (compact to very dense) to the depths of 10.6 m to 13.2 m below grade; underlain by,
- Clayey Silt (stiff to hard) to the depths of approximately 13.2 m to 14.8 m below grade; underlain by,
- Lower cohesionless layer comprising Silty Sand/Sandy Silt (compact to very dense).

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



**(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LAIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, Design-Build Project**

Subsurface Conditions

November 17, 2022

## **5.2 OVERBURDEN**

### **5.2.1 Pavement Structure**

Asphalt was encountered at ground surface at the borehole locations. The thickness of the asphalt was approximately 100 mm to 400 mm.

The asphalt was underlain by a granular fill layer in the boreholes. The granular fill layer can be associated with the pavement structure. The granular fill was approximately 375 mm to 400 mm thick.

N-values of 20 blows per 0.3 m penetration to more than 100 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 approximately 1% to 9%.

### **5.2.2 Fill**

Fill materials were encountered below the pavement structure in all boreholes. The fill comprised of a series of cohesionless soils (sand and gravel/silty sand with gravel/silty sand/silty clayey sand) and cohesive soils (clayey silt). The fill materials contained organics, asphalt and construction debris.

The fill materials extended to depths ranging from approximately 2.3 m to 3.8 m below ground surface, corresponding to elevations of approximately 268.5 m to 267.0 m.

Further details on these fill materials are provided below:

#### **5.2.2.1 Cohesionless Fill**

The fill materials encountered below the pavement structure comprised of a series of cohesionless soils consisting of brown sand and gravel/silty sand with gravel/silty sand/silty clayey sand containing trace clay. Construction debris and organics were also noted in the surficial samples obtained from the cohesionless fill layer.

The cohesionless fill layer was approximately 0.2 m to 3.1 m thick and extended to depths ranging from approximately 0.9 m to 3.8 m below grade, corresponding to elevations of approximately 269.8 m and 267.0 m, respectively.

N-values ranging from 4 to 36 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 8% to 22%, averaging 14%.



# **(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LAIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, Design-Build Project**

Subsurface Conditions  
November 17, 2022

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 records in Appendix C and on the gradation curve on Figure No. D1 in Appendix D. The tests yielded the following results:

- Gravel: 22%
- Sand: 56%
- Silt and clay: 22%

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 fill materials encountered in the boreholes consisted of cohesive soils comprising brown to grey to black clayey silt. Samples obtained from the cohesive fill layer contained various but minor amounts of sand and gravel and trace rootlets, organics and asphalt.

The cohesive fill layer was approximately 0.8 m to 3.0 m thick and extended to depths ranging from approximately 2.3 m to 3.7 m below grade, corresponding to elevations of approximately 268.5 m to 267.3 m.

N-values ranging from 4 to 15 blows per 0.3 m penetration were obtained from the SPTs advanced in the cohesive fill materials, indicating a firm to stiff condition.

Laboratory tests conducted on samples of the cohesive fill yielded natural moisture contents ranging from approximately 13% to 25%, averaging 19%.

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 record in Appendix C and on the gradation curve on Figure No. D2 in Appendix D. The tests yielded the following results:

- Gravel: 4%
- Sand: 29%
- Silt: 32%
- Clay: 35%

Atterberg Limits tests were conducted on the sample referenced above. The tests yielded a Liquid Limit of 25% and a Plastic Limit of 13%, corresponding to a Plasticity Index of 12%. The test results are illustrated on the borehole records in Appendix C and on the gradation curve on Figure No. D3 in Appendix D.

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



**(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, Design-Build Project**

Subsurface Conditions  
November 17, 2022

### **5.2.3 Upper Cohesionless Layer: Silt (including Silt with Sand, Sandy Silt, and Silty Sand)**

A cohesionless deposit comprised predominantly of brown to grey silt, with variable amounts of sand (silt, silt with sand, sandy silt, and silty sand) was encountered underlying the fill materials in all boreholes. Samples obtained from this deposit typically contained traces of clay and gravel.

This upper cohesionless deposit was approximately 8.4 m to 11.1 m thick and extended to depths ranging from approximately 10.7 m to 14.8 m below grade, corresponding to elevations of approximately 260.1 m to 256.2 m.

N-values ranging from 3 to 71 blows per 0.3 m penetration were obtained from the SPTs advanced in the silt deposit. If the lowest N-value of 3 and the highest N-value of 71 are disregarded, the remaining N-value range from 11 to 49 (with an average of 26) indicating compact to dense condition.

Laboratory tests carried out on samples of the upper cohesionless stratum yielded natural moisture contents ranging from approximately 16% to 25%, averaging 19%.

Gradation analyses were carried out on eleven (11) representative samples of the upper cohesionless 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 3%
- Sand: 0 to 78%
- Silt: 18 to 89%
- Clay: 4 to 19%

Based on the results of the laboratory tests, the samples tested can be classified as Silt/ Silt with Sand/ Sandy Silt with a group symbol of ML, and Silty Sand with a group symbol of SM based on the Unified Soil Classification System (USCS).

### **5.2.4 Clayey Silt**

A layer of grey clayey silt was encountered underlying the upper cohesionless deposit described in the preceding section in all boreholes except Borehole EL-03. Samples obtained from the clayey silt layer typically contained trace sand.

The clayey silt layer was approximately 0.8 m to 3.9 m thick and extended to the depths of approximately 13.2 m to 14.6 m below grade, corresponding to elevation of approximately 257.5 m to 256.1 m.

N-values ranging from 14 to 42 blows per 0.3 m penetration were obtained from the SPTs advanced in the clayey silt layer, indicating a stiff to hard condition.

Laboratory tests conducted on samples of the clayey silt layer yielded natural moisture contents ranging from approximately 17% to 26%, averaging 21%.



# **(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LAIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, Design-Build Project**

Subsurface Conditions

November 17, 2022

Gradation analyses were carried out on two (2) representative samples of the clayey silt soils. The test results are illustrated on the borehole records in Appendix C and on the gradation curve on Figure No. D5 in Appendix D. The tests yielded the following results:

- Gravel: 0 %
- Sand: 2 and 6%
- Silt: 45 and 69%
- Clay: 30 and 49%

Atterberg Limits tests were conducted on the samples referenced above. The tests yielded Liquid Limits of 19% and 23%, Plastic Limits of 13%, and corresponding Plasticity Indices of 6% and 10%. The test results are illustrated on the borehole records in Appendix C and on the gradation curve on Figure No. D6 in Appendix D.

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

## **5.2.5 Lower Cohesionless Layer: Silty Sand/Sandy Silt**

A layer of grey silty sand to sandy silt was encountered underlying the soils described in the preceding sections of this report in all boreholes. Samples obtained from this deposit typically contained trace clay.

All boreholes were terminated in the silty sand to sandy silt layer after penetrating approximately 1.1 m to 2.7 m in the layer.

N-values ranging from 12 to more than 100 blows per 0.3 m penetration were obtained from the SPTs advanced in the silty sand to sandy silt layer. If the single refusal in Borehole EL-03 is disregarded, the remaining N-value range from 12 to 25 indicating compact condition.

Laboratory tests conducted on samples of the silty sand stratum yielded natural moisture contents ranging from approximately 15% to 23%, averaging 18%.

Gradation analyses were carried out on four (4) representative samples of the lower silty sand to sandy silt layer. The test results are illustrated on the borehole records in Appendix C and on the gradation curves on Figure No. D7 in Appendix D. The tests yielded the following results:

- Gravel: 0%
- Sand: 46 to 85%
- Silt and clay: 15 to 55% (clayey size particle 3-7%)

Based on the results of the laboratory tests, the samples tested can be classified as Silty Sand with a group symbol of SM and Sandy Silt with a group symbol of ML based on the Unified Soil Classification System (USCS).



# **(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, Design-Build Project**

Miscellaneous  
November 17, 2022

## **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 EL-04 was recorded at a depth of 4.0 m below existing grade (corresponding to an elevation of 266.7 m) on September 12, 2022.

Groundwater observations were not made during and upon completion of drilling due to the drilling methodology used (i.e., filling boreholes with water/drilling mud to minimize any possible soil disturbance due to possible groundwater pressure).

Groundwater level can be inferred at depths ranging from approximately 3.7 m to 6.9 m below grade, corresponding to elevation of approximately 267.3 m and 263.8 m respectively, based on a colour change from brown to grey noted in the samples obtained from boreholes.

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 summarized in below table and included in Appendix D for reference.

**Table 5.1: Results of Chemical Analysis**

Borehole No	Sample No.	Depth (m)	pH	Chloride (µg/g)	Sulphate (µg/g)	Resistivity (Ohm-cm)
EL-02	SS6	3.8 – 4.4	7.38	1290	155	376
EL-04	SS6	3.8 – 4.4	9.26	713	83	694

## **6.0 MISCELLANEOUS**

The field work was carried out under the supervision of Justin Moleta, 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.



**(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LAIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, Design-Build Project**

Closure

November 17, 2022

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,

**STANTEC CONSULTING LTD.**

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**(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, Design-Build Project**

Discussions and Engineering Recommendations  
November 17, 2022

**DRAFT FOUNDATION DESIGN REPORT**

For

G.W.P. 3032-11-00

DB Contract Number 2022-3001

Replacement of Elliot-Laidlaw 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 Elliot-Laidlaw Drain Culvert crossing of Highway 401, immediately west of Highbury Avenue Interchange, will be replaced.

This foundation investigation and design report has been prepared specifically for the proposed Elliot-Laidlaw Drain Culvert replacement (19X-0651/C0) and other project foundations engineering components are reported under separate covers.

#### **8.1.2 Existing and Proposed Structure**

The existing Elliot-Laidlaw Drain culvert was constructed in 1953 and is a concrete, rigid frame, open footing culvert. The original 51.8 m long structure was subsequently extended with open footing rigid frame extensions to the north and south in 1989, and a box culvert extension added to the north in 1993, for a total length of about 84 m. The composite structure has a span of about 6.1 m, height of 2.4 m, and approximately 1.6 m of soil cover.

The General Arrangement drawing for the Elliot-Laidlaw Drain Culvert indicates that the existing culvert is planned to be replaced with a new culvert with approximately the same length (i.e., approximately 84 m), with a clear span of 6.1 m and a height of 3.3 m (internal opening height). According to the bid Inquiry No. BE 2022-3004-125 dated December 23, 2021, an open footing culvert is not acceptable and was deemed not technically preferred due to various risks associated with long-term performance of open footing culverts during the preliminary investigation and design stage. In this respect, a cast-in-place concrete rigid frame box culvert is being considered for this site. The General Arrangement drawing also indicates that the base of the new culvert will be at approximate elevation 265.5 m. The General Arrangement drawing is included in Appendix A for reference.



# (DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, Design-Build Project

Discussions and Engineering Recommendations  
November 17, 2022

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 wall or wingwalls are currently being considered for the site.

## 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 silt/silt with sand/sandy silt, underlain by a layer of clayey silt underlain by silty sand.

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 – Elliot-Laidlaw Drain Culvert (Site 19X-0651/C0)**

Elevation (m)		Soil Type	Design Parameters			
From	To		Total Unit Weight $\gamma$ (kN/m <sup>3</sup> )	Drained Friction Angle <sup>1</sup> $\phi'$ (°)	Undrained Shear Strength $S_u$ <sup>2</sup> (kPa)	Soil Modulus $E$ (MPa)
Highway Level	269.8 to 267.0	Cohesionless FILL: Loose to very dense SAND and Gravel/Silty SAND with Gravel/Silty SAND (SM)/Silty Clayey SAND (SC-SM)	21	30	N/A	30
269.8 to 267.0	267.3	Cohesive FILL: Firm to stiff CLAYEY SILT (CL)	20	28	50	20
267.3	257.6	Compact to dense SILT/SILT with Sand/ Sandy SILT (ML)/Silty SAND (SM), trace clay	21	32	N/A	50
257.6	256.1	Stiff to hard CLAYEY SILT (CL-ML to CL), trace sand	21	30	150	75
256.1	254.8	Compact to very dense Silty SAND (SM)/Sandy SILT (ML), trace clay	21.5	32	N/A	75

Notes:



# (DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LAIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, Design-Build Project

Discussions and Engineering Recommendations  
November 17, 2022

- <sup>1</sup> The friction angle is applicable to drained conditions only  
<sup>2</sup> The shear strength is applicable to undrained conditions only

The groundwater level in the monitoring well installed in Borehole EL-04-1 (screened within the silt deposit) was recorded at a depth of 4.0 m below existing grade (corresponding to an elevation of 266.7 m). A static groundwater level at an elevation of 266.7 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 done 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 Elliot Laidlaw Drain Culvert site were obtained from Natural Resources Canada (2015 National Building Code Canada). Table 8.2 below summarizes the parameters obtained and recommended for use in the design based on a 2475-year return period.

**Table 8.2: Peak Ground Acceleration Data**

$PGA$	$S_a(0.2)$	$PGA_{ref}$	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:



# **(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, Design-Build Project**

Discussions and Engineering Recommendations  
November 17, 2022

- (a) relatively low Peak Ground Acceleration, and
- (b) compact to very dense / firm to hard nature of the site soils

## **8.5 FOUNDATION RECOMMENDATIONS FOR BOX CULVERT**

### **8.5.1.1 Overview**

As referenced in a preceding section and according to the DB Bid Inquiry No. BE 2022-3004-125 dated December 23, 2021, an open footing culvert is not acceptable and was deemed not technically preferred due to various risks associated with long-term performance of open footing culverts during preliminary investigation and design stage and a cast-in-place concrete rigid frame box culvert is being considered for this site. In this respect, the open footing culvert option is not further discussed in this report.

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).

### **8.5.1.2 Foundation Subgrade Preparation**

The base of new box culvert is planned to be at approximately elevation 265.2 m, slightly below the footing base elevation of the existing culvert. Excavation required for the installation of a concrete mud mat/working slab will extend to an elevation of about 264.7 m.

Based on the conditions encountered in the boreholes, the subgrade exposed at the design founding level of the new culvert is anticipated to consist of the native compact to dense silt soils and/or fill materials. The native compact to dense silt materials are considered suitable for support of the replacement culvert provided they are dewatered, as described below, and are protected from disturbance. The fill materials 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 silt deposit that underlie the culvert is approximately 2 m above the anticipated base of the excavation required for construction of the replacement culvert. These conditions could result in groundwater inflows, and disturbance and potentially basal instability of the foundation subgrade materials unless adequate dewatering is provided. To address this issue, a dewatering/groundwater control program should be implemented to lower the water level within the silt 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 9.3 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.



# **(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, Design-Build Project**

Discussions and Engineering Recommendations  
November 17, 2022

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 Granular A bedding should be placed on top of the work 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 leveling course/pad and throughout construction and backfilling of the culvert.

## **8.5.1.3 Geotechnical Resistances and Reactions**

The geotechnical resistance and reactions provided in Table 8.3 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 8.5.1.2. 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 8.3: Geotechnical Vertical Resistance & Reaction – Box Culvert**

Founding Element	Founding Elevation (m)	Culvert Width (m)	Factored Geotechnical Resistance at ULS <sub>r</sub> (kPa) $\phi_{gu} = 0.5$	Factored Geotechnical Reaction at SLS (kPa) $\phi_{gs} = 0.8$
Box Culvert	± 265	6.1	270	160

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

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

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

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



# **(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LAIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, Design-Build Project**

Discussions and Engineering Recommendations  
November 17, 2022

It is noted that no settlement issues were observed for the existing culvert. Given that existing culvert will be replaced with larger opening box culvert, 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.

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

The unfactored horizontal resistance to sliding of the cast-in-place 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 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 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.



# (DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LAIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, Design-Build Project

Discussions and Engineering Recommendations

November 17, 2022

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/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  $\gamma$  is the unit weight of the backfill soil. Values for  $K_a$ ,  $K_p$ ,  $K_o$  and  $\gamma$  are provided in Table 8.4 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 8.4: Recommended Static Earth Pressure Parameters (Horizontal Backfill)**

Parameter	OPSS Gran B Type I	OPSS Gran A and Gran B Type II	Existing Fill Materials
Bulk Unit Weight, $\gamma$ (kN/m <sup>3</sup> )	22	22	21
Effective Friction Angle, $\Phi$ (°)	32	35	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:

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



**(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LAIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, Design-Build Project**

Discussions and Engineering Recommendations  
November 17, 2022

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

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  
 $\gamma$  = 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 8.5: Seismic Design Parameters to Estimate Lateral Earth Pressures**

Site Adjusted <i>PGA</i>	Horizontal Acceleration Coefficient, $k_{ho}$	Horizontal Acceleration Coefficient, $k_h$
	Non-Yielding	Yielding ( <i>wall movements of 25 mm to 50 mm</i> )
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 <i>PGA</i> 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 Table 8.6 for horizontal backfill configuration. These values should be adjusted if sloped backfill is considered.

**Table 8.6: 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, $\gamma$ (kN/m <sup>3</sup> )	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
<b>Yielding Wall</b>			
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
<b>Non-Yielding Wall</b>			
Active Earth Pressure ( $K_{AE}$ ) for Non-Yielding Wall	0.36	0.32	0.42





# **(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LAIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO HIGHBURY AVENUE, DESIGN-BUILD PROJECT**

Discussions and Engineering Recommendations

November 17, 2022

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
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## **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 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.



# **(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, Design-Build Project**

Discussions and Engineering Recommendations  
November 17, 2022

## **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 ( $\text{SO}_4$ ) content of the adjacent soil is equal to or greater than 0.10%; or,
- Sulphate ( $\text{SO}_4$ ) 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 replacement site (water soluble sulphate in soil samples  $<0.10\%$  which is equivalent to  $1000\mu\text{g/g}$ ).

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 8.7: Results of Corrosion Potential Assessment**

Borehole No	Sample No.	Depth (m)	Corrosion Potential
EL-02	SS6	3.8 – 4.4	Aggressive
EL-04	SS6	3.8 – 4.4	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 should be a decision of the design engineer who takes into account all design considerations including CSA A23.1 Section 4.1.1 durability requirements.



November 17, 2022

## 9.0 CONSTRUCTION CONSIDERATIONS

### 9.1 CONSTRUCTION STAGING

The replacement of the sections of the existing culvert below the W-N/S and N-W ramps is expected to be completed in a single stage with the ramps fully closed to traffic. The replacement of the sections of the existing culvert below Highway 401 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)	<ul style="list-style-type: none"><li>Simple installation process</li><li>Provides cut-off to groundwater seepage from excavation sides</li><li>Can be extended into clayey soils to cut-off lateral flow through silt deposits thereby reducing groundwater inflow volumes into excavation.</li></ul>	<ul style="list-style-type: none"><li>Difficult to drive/install where cobbles/boulders are present</li><li>May require large sections where cantilever design is adopted</li></ul>	Medium	<ul style="list-style-type: none"><li>Possible misalignment of, or damage to, sheet piles during installation due to obstructions</li></ul>
Soldier piles with timber lagging;	<ul style="list-style-type: none"><li>Simple installation process provided suitable dewatering is implemented</li></ul>	<ul style="list-style-type: none"><li>Dewatering required to lower water table below base of excavation prior to</li></ul>	Low	<ul style="list-style-type: none"><li>Potential for groundwater seepage and loss of ground</li></ul>



**(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LAIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, Design-Build Project**

Construction Considerations  
November 17, 2022

Option	Advantages	Disadvantages	Relative Cost	Risk & Consequences
(struts/rakers as required)	<p>prior to installation of protection system</p> <ul style="list-style-type: none"> <li>The native soils at the site, within the depth of expected excavation consist of silts, which are very difficult to dewater</li> </ul>	<p>lagging installation to reduce loss of ground</p> <ul style="list-style-type: none"> <li>Removal of soldier piles can be difficult</li> <li>Additional labour required</li> </ul>		<p>unless groundwater control measures are implemented</p> <ul style="list-style-type: none"> <li>Potential for minor loss of ground at rear of lagging</li> </ul>

Given the presence of the silt deposit and the anticipated difficulty associated with dewatering silt, the use of steel sheet piles would be considered the better option. In the case where the excavation is to extend below the water table, within the silt, the use of soldier piles and timber lagging is not recommended.

Roadway/temporary protection system design should meet the requirements of Performance Level 2 in accordance with DB SP 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 DB SP 539. The monitoring requirements are outlined in OPSS.PROV 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 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 SSP 517F01. The following inputs should be included in the Dewatering Systems section of Table A in SP517F01:

- The preconstruction survey distance should be identified as 50 m.
- Given the fine-grained nature of the silt deposit to be dewatered, the Design Engineer Requirements box should be input as "Yes".

Control of 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.



**(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LAIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, Design-Build Project**

Construction Considerations  
November 17, 2022

**Table 9.2: Comparison of Cofferdam Options for Surface Water Control**

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

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.

Groundwater flow into the excavations should be expected from the native silty deposit encountered at the site. As referenced in a previous section, based on the conditions encountered in the investigation, a groundwater elevation of 266.7 m is recommended for design purposes.

Excavations for installation of the replacement culvert will be required to extend to depths of about 2 m below this groundwater level. These conditions could result in disturbance of the foundation subgrade materials and potentially basal instability unless adequate dewatering is provided. To address this issue, a dewatering/groundwater control program should be implemented to lower the water level within the silt/sandy silt soil a minimum of 0.5 m below the base of the excavation required for the construction of the new culvert.



# **(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LAIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, Design-Build Project**

Construction Considerations

November 17, 2022

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. Therefore, 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.

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.PROV 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). Construction Specification for Excavation and Backfilling – Structures. 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 silty soils would be classified as Type 3 soils provided they are above the water table and the water level in the drain, or are dewatered prior to excavation. The OH&S Act indicates that temporary excavations in these materials where above the water table or dewatered should be developed with side slopes no steeper than 1H:1V.



# **(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LAIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, Design-Build Project**

Construction Considerations

November 17, 2022

Cohesionless fill materials associated with the existing culvert and/or the native silty 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 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 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.



**(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LAIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, Design-Build Project**

November 17, 2022

## 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





**(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LAIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, Design-Build Project**

November 17, 2022

## **11.0 REFERENCES**

ASTM. 1999. Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils (ASTM D1586). ASTM International, West Conshohocken, PA.

ASTM. 2000. Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) (ASTM D2487). ASTM International, West Conshohocken, PA.

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

Golder Associates. 2015. Preliminary Foundation Investigation and Design Report , Structural Culvert Replacement, Elliot-Laidlaw Drain Culvert, Site Number 19-651/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

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



**(DRAFT) FOUNDATION INVESTIGATION AND DESIGN REPORT – REPLACEMENT OF ELLIOT-LAIDLAW DRAIN CULVERT- HIGHWAY 401 REHABILITATION FROM WELLINGTON ROAD TO Highbury Avenue, Design-Build Project**

Closure

November 17, 2022

## **12.0 CLOSURE**

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

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

This report was prepared by 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,

**STANTEC CONSULTING LTD.**

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Senior Geotechnical Engineer

Raymond Haché, M.Sc., P. Eng.  
MTO Designated Principal Foundation Contact

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Appendix A

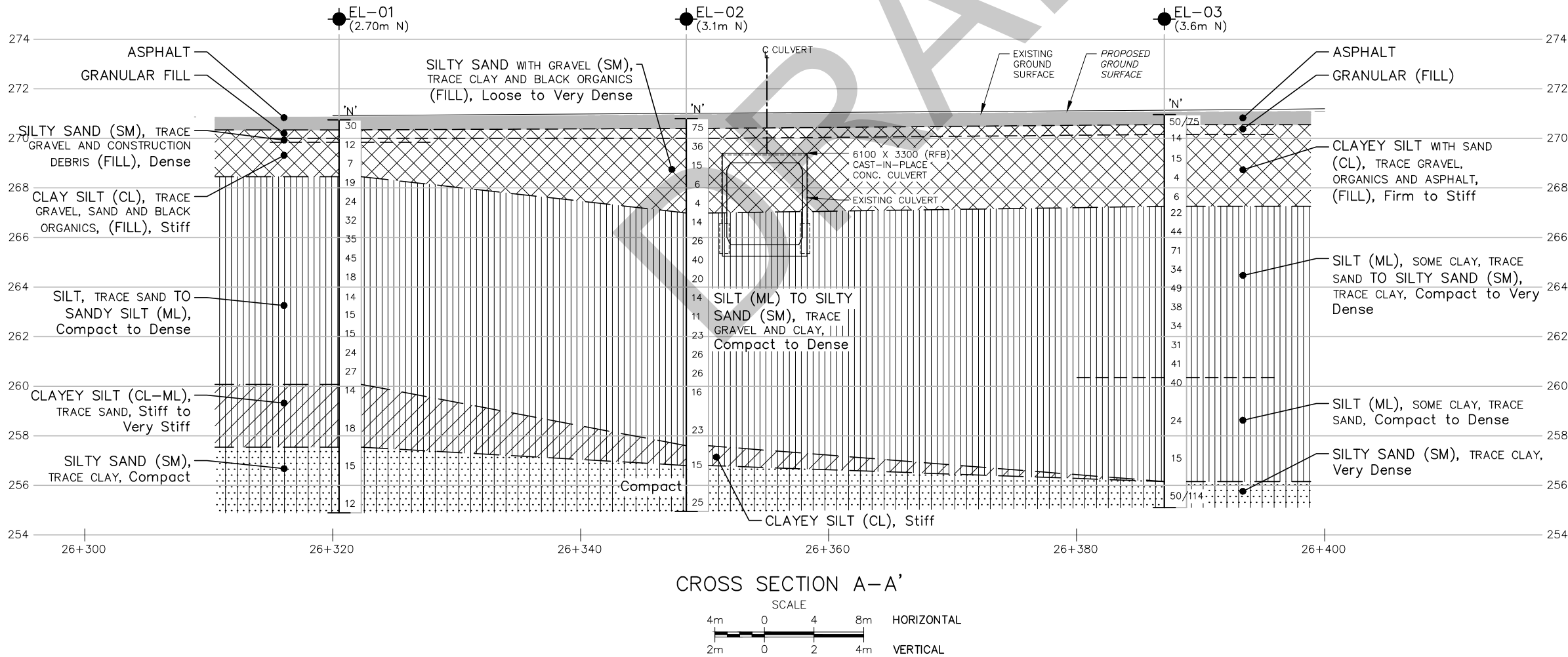
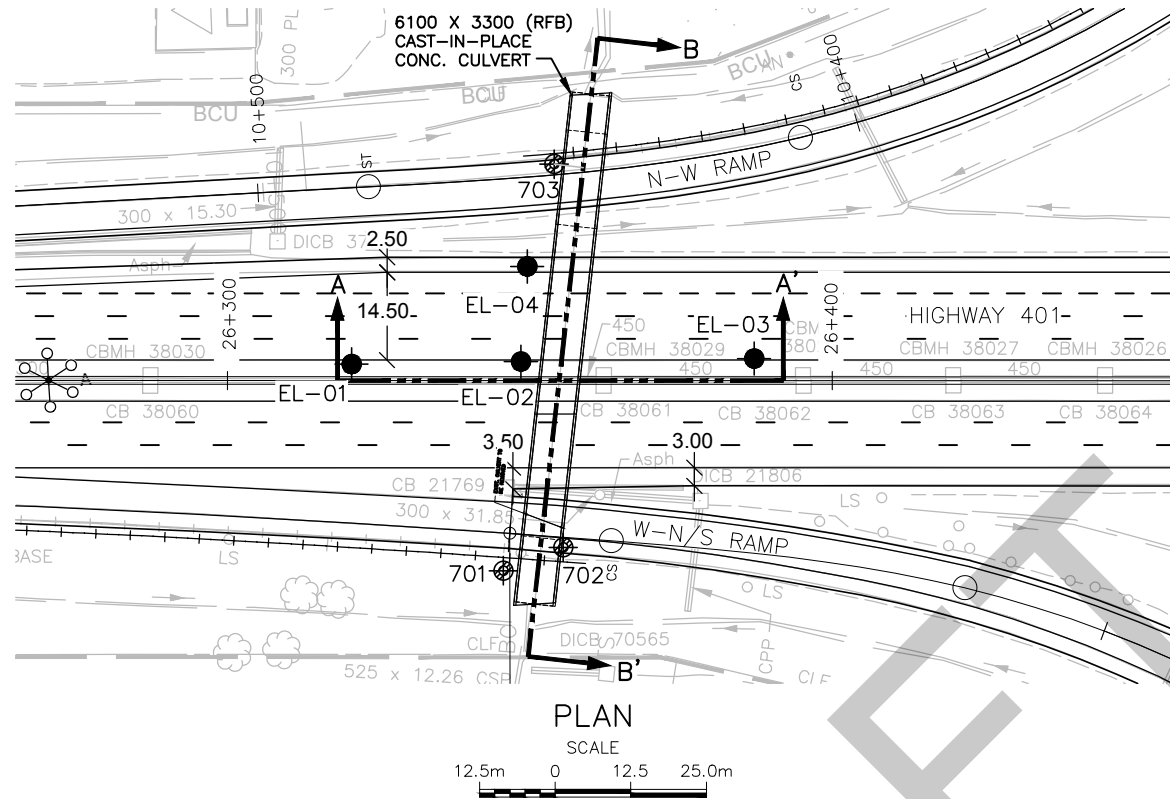
## APPENDIX A

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

### A.2 GENERAL ARRANGEMENT DRAWING

DRAFT



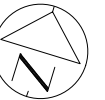


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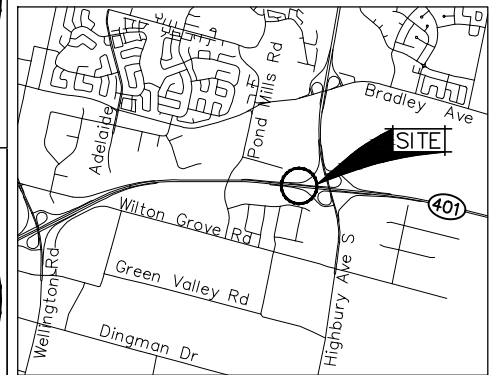


PLATE No  
CONT 2022-3004  
WP 3032-11-00

HIGHWAY 401  
ELLIOT LAIDLAW CULVERT  
BOREHOLE LOCATIONS & SOIL STRATA



SHEET  
-



KEY PLAN  
800m 0 800 1600m

#### LEGEND

- 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)

No	ELEV	MTM ZONE 11 NORTH	COORDINATES EAST
EL-01	270.7	4 775 922.9	412 218.5
EL-02	270.8	4 755 931.6	412 245.1
EL-03	271.0	4 755 943.4	412 281.8
EL-04	270.7	4 755 946.9	412 241.4
701	269.5	4 775 897.7	412 252.5
702	270.4	4 755 904.3	412 260.8
703	270.5	4 755 964.4	412 240.7

#### NOTES

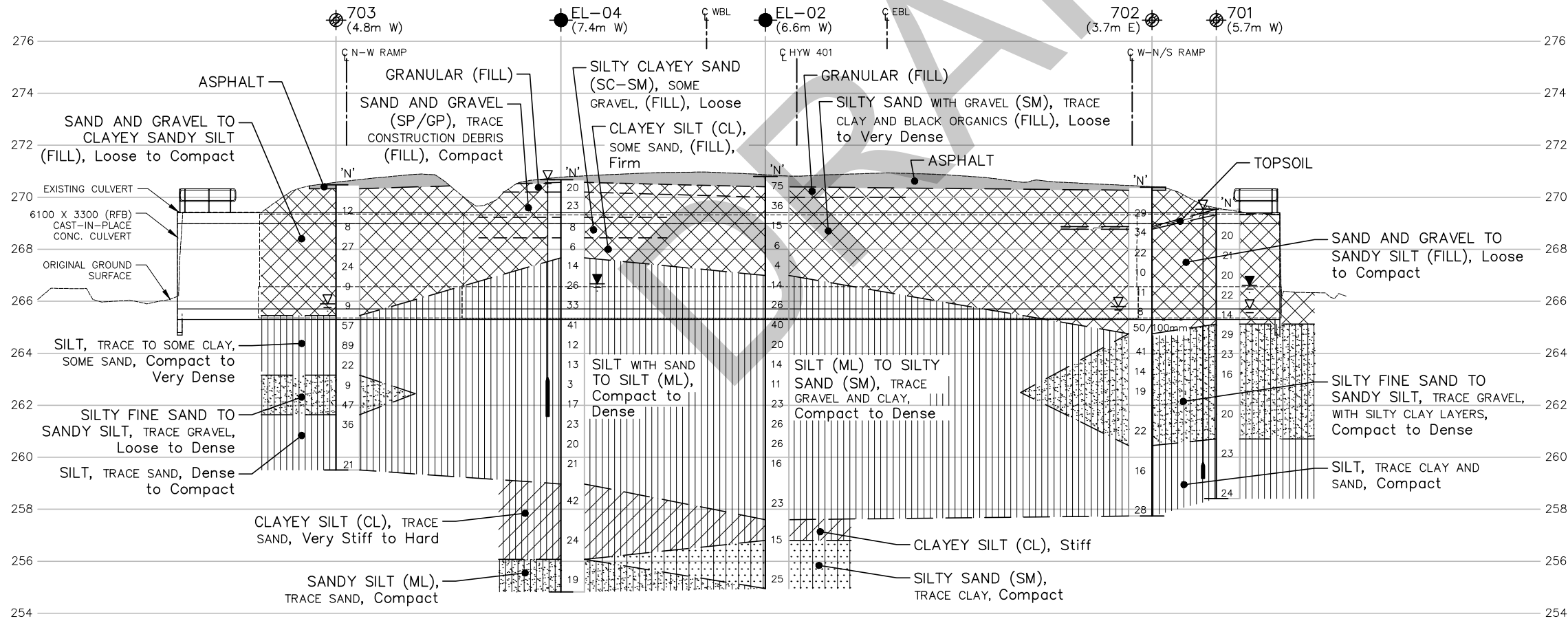
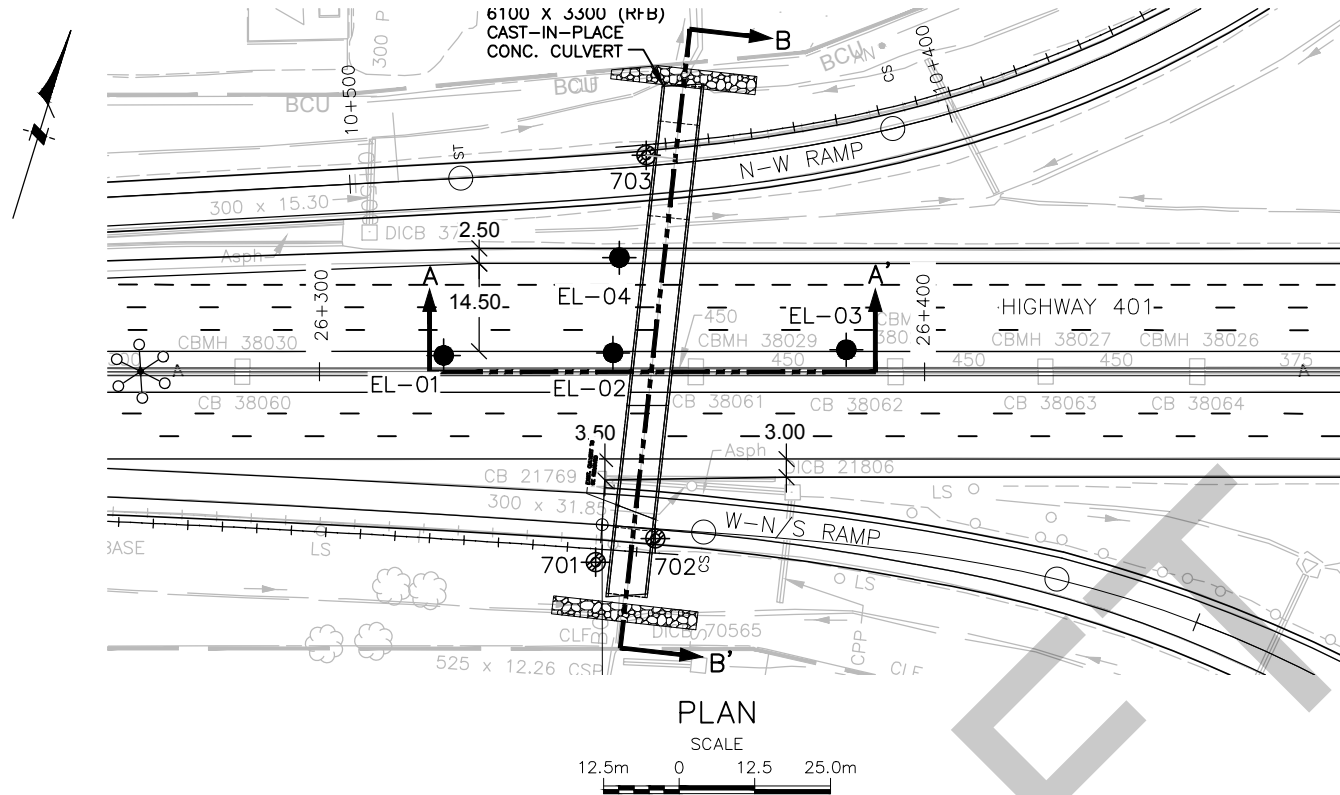
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

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

GEORES No	
HWY No 401	
SUBM'D GR	CHECKED
DRAWN GBB	CHECKED
DATE 2022-10-24	APPROVED
SITE 19X-0651/CO	DWG 1



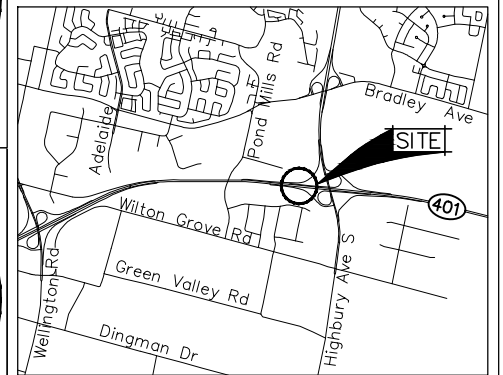
CROSS SECTION B-B'  
SCALE  
4m 0 4 8m HORIZONTAL  
2m 0 2 4m VERTICAL

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AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN



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

HIGHWAY 401  
ELLIOT LAIDLAW CULVERT  
BOREHOLE LOCATIONS & SOIL STRATA



KEY PLAN  
800m 0 800 1600m

LEGEND

- 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 NORTH	COORDINATES EAST
EL-01	270.7	4 775 922.9	412 218.5
EL-02	270.8	4 755 931.6	412 245.1
EL-03	271.0	4 755 943.4	412 281.8
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701	269.5	4 775 897.7	412 252.5
702	270.4	4 755 904.3	412 260.8
703	270.5	4 755 964.4	412 240.7

NOTES

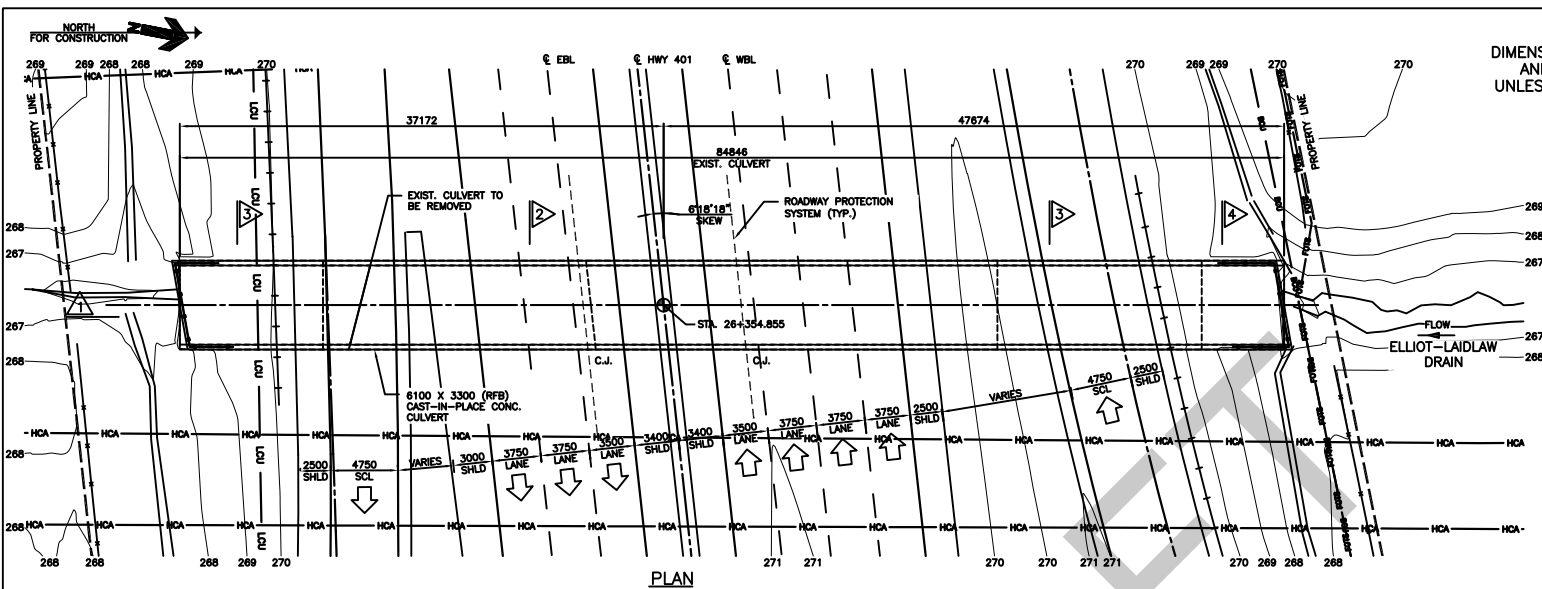
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

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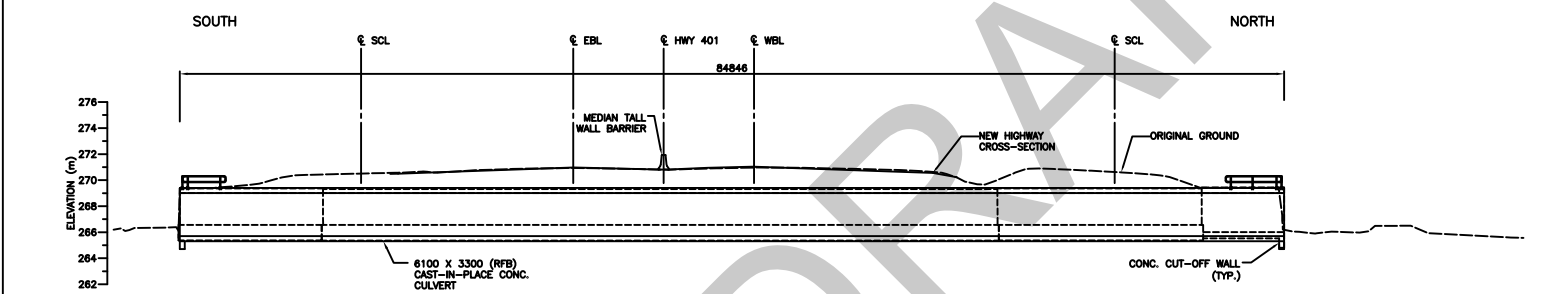
NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2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

REVISIONS	DATE	BY	DESCRIPTION

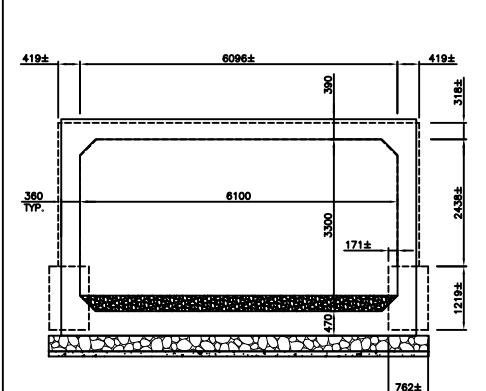
GEORES No	
HWY No 401	
SUBM'D GR	CHECKED
DRAWN	GBB
CHECKED	
DATE	2022-10-24
APPROVED	
SITE	19X-0651/CO
DWG	2



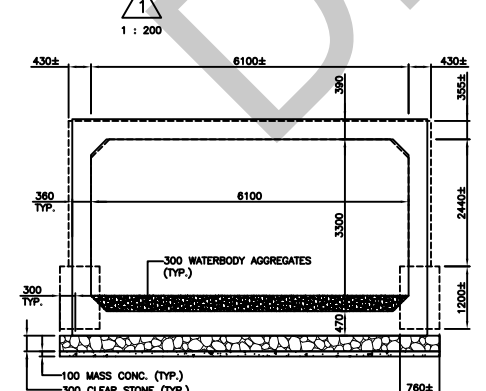
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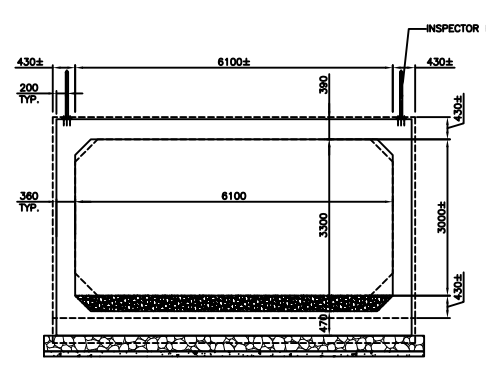
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1 : 200



2  
1 : 50



3  
1 : 50

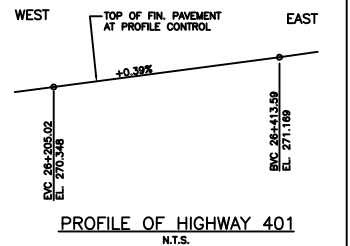


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HWY 401 CONT 2022-3004 WP 3054-11-00		
ELLIOT-LAIDLAW DRAIN CULVERT REPLACEMENT PRELIMINARY GENERAL ARRANGEMENT		
		SHEET

- GENERAL NOTES:**
- SPECIFIED 28-DAY CONCRETE COMPRESSIVE STRENGTH:**  
ALL CONC. UNLESS OTHERWISE NOTED 30 MPa
  - CLEAR COVER TO REINFORCING STEEL:**  
BOT OF TOP SLAB 50±10  
BOT OF BOT SLAB 100±25  
REMAINDER 60±10  
UNLESS OTHERWISE NOTED.
  - REINFORCING STEEL:**  
REINFORCING STEEL SHALL BE GRADE 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:**
- 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.
  - DEBRIS FROM STRUCTURE REMOVALS SHALL BE PREVENTED FROM ENTERING THE WATERCOURSE.
  - 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.
  - THE CONTRACTOR SHALL ISOLATE WORK AREAS FROM THE WATERCOURSE FLOW FOR CULVERT REPLACEMENT AS REQUIRED TO COMPLETE ALL WORK IN THE DRY.
  - ROADWAY PROTECTION SYSTEMS SHALL BE DESIGNED FOR PERFORMANCE LEVEL 2.



REVISIONS	DATE	BY	DESCRIPTION

DRAWING NOT TO BE SCALED  
100 mm ON ORIGINAL DRAWING

DESIGN F.S.A./CHK M.D. CODE CSA-S6-19 LOAD Q-88-QNT DATE SEPT 2022  
DRAWN H.L. CHK.F.S.A. SITE 18K-061/00/STRUCT SCHEME DWG. 1

## APPENDIX B

### B.1 AVAILABLE GEOCRETS INFORMATION

DRAFT



## **LIST OF ABBREVIATIONS**

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

<b>I. SAMPLE TYPE</b>		<b>III. SOIL DESCRIPTION</b>	
AS	Auger sample		<b>(a) Cohesionless Soils</b>
BS	Block sample		
CS	Chunk sample		
SS	Split-spoon	<b>Density Index</b>	<b>N</b>
DS	Denison type sample	<b>(Relative Density)</b>	<b><u>Blows/300 mm or Blows/ft.</u></b>
FS	Foil sample	Very loose	0 to 4
RC	Rock core	Loose	4 to 10
SC	Soil core	Compact	10 to 30
ST	Slotted tube	Dense	30 to 50
TO	Thin-walled, open	Very dense	over 50
TP	Thin-walled, piston		
WS	Wash sample		
<b>II. PENETRATION RESISTANCE</b>			<b>(b) Cohesive Soils</b>
<b>Standard Penetration Resistance (SPT), N:</b>		<b>Consistency</b>	
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.)			
<b>Dynamic Cone Penetration Resistance; <math>N_d</math>:</b>		<b>kPa</b>	<b><math>c_u s_u</math></b>
The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).		Very soft	0 to 12
<b>PH:</b>	Sampler advanced by hydraulic pressure	Soft	12 to 25
<b>PM:</b>	Sampler advanced by manual pressure	Firm	25 to 50
<b>WH:</b>	Sampler advanced by static weight of hammer	Stiff	50 to 100
<b>WR:</b>	Sampler advanced by weight of sampler and rod	Very stiff	100 to 200
<b>Piezo-Cone Penetration Test (CPT)</b>		Hard	over 200
A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm <sup>2</sup> 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.		<b>IV. SOIL TESTS</b>	
		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 <sup>1</sup>
		CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup>
		$D_R$	relative density (specific gravity, $G_s$ )
		DS	direct shear test
		M	sieve

## LIST OF SYMBOLS

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

<b>I.</b>	<b>General</b>		<b>(a) Index Properties (continued)</b>
$\pi$	3.1416	w	water content
$\ln x$ ,	natural logarithm of x	$w_L$	liquid limit
$\log_{10}$	x or log x, logarithm of x to base 10	$w_p$	plastic limit
g	acceleration due to gravity	$I_p$	plasticity index = $(w_L - w_p)$
t	time	$w_s$	shrinkage limit
F	factor of safety	$I_L$	liquidity index = $(w - w_p)/I_p$
V	volume	$I_C$	consistency index = $(w_L - w)/I_p$
W	weight	$e_{\max}$	void ratio in loosest state
		$e_{\min}$	void ratio in densest state
<b>II.</b>	<b>STRESS AND STRAIN</b>	$I_D$	density index = $(e_{\max} - e)/(e_{\max} - e_{\min})$ (formerly relative density)
$\gamma$	shear strain		<b>(b) Hydraulic Properties</b>
$\Delta$	change in, e.g. in stress: $\Delta \sigma$	h	hydraulic head or potential
$\epsilon$	linear strain	q	rate of flow
$\epsilon_v$	volumetric strain	v	velocity of flow
$\eta$	coefficient of viscosity	i	hydraulic gradient
$\nu$	poisson's ratio	k	hydraulic conductivity (coefficient of permeability)
$\sigma$	total stress	j	seepage force per unit volume
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )		<b>(c) Consolidation (one-dimensional)</b>
$\sigma'_{vo}$	initial effective overburden stress	$C_c$	compression index (normally consolidated range)
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)	$C_r$	recompression index (over-consolidated range)
$\sigma_{oct}$	mean stress or octahedral stress = $(\sigma_1 + \sigma_2 + \sigma_3)/3$	$C_s$	swelling index
$\tau$	shear stress	$C_a$	coefficient of secondary consolidation
u	porewater pressure	$m_v$	coefficient of volume change
E	modulus of deformation	$c_v$	coefficient of consolidation
G	shear modulus of deformation	$T_v$	time factor (vertical direction)
K	bulk modulus of compressibility	U	degree of consolidation
<b>III.</b>	<b>SOIL PROPERTIES</b>	$\sigma'_p$	pre-consolidation pressure
	<b>(a) Index Properties</b>	OCR	over-consolidation ratio = $\sigma'_p/\sigma'_{vo}$
$\rho(\gamma)$	bulk density (bulk unit weight*)		<b>(d) Shear Strength</b>
$\rho_d(\gamma_d)$	dry density (dry unit weight)	$\tau_p, \tau_r$	peak and residual shear strength
$\rho_w(\gamma_w)$	density (unit weight) of water	$\phi'$	effective angle of internal friction
$\rho_s(\gamma_s)$	density (unit weight) of solid particles	$\delta$	angle of interface friction
$\gamma'$	unit weight of submerged soil ( $\gamma' = \gamma - \gamma_w$ )	$\mu$	coefficient of friction = $\tan \delta$
$D_R$	relative density (specific gravity) of solid particles ( $D_R = \rho_s/\rho_w$ ) (formerly $G_s$ )	$c'$	effective cohesion
e	void ratio	$c_{us}, S_u$	undrained shear strength ( $\phi = 0$ analysis)
n	porosity	p	mean total stress $(\sigma_1 + \sigma_3)/2$
S	degree of saturation	$p'$	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





PROJECT		RECORD OF BOREHOLE No 703				1 OF 1		METRIC			
W.P.		3030-11-00		LOCATION		N 4755964.4 , E 412240.7		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			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)							
								20 40 60 80 100		20 40 60 80 100		20 40 60 80 100		10 20 30						
						○ UNCONFINED + FIELD VANE					w <sub>p</sub> w w <sub>L</sub>									
						● QUICK TRIAXIAL × LAB VANE														
270.48	PAVEMENT SURFACE					▽	270								26	24	42	8		
0.00	ASPHALT																			
0.16	FILL, sand and gravel, trace silt, crushed																			
0.27	Brown																			
269.81	FILL, sand and gravel, trace silt																			
0.67	Brown		1	SS	12															
269.20	FILL, clayey silt, some sand, some gravel, trace topsoil																			
1.28	Stiff		2	SS	8															
268.80	Brown																			
1.68	FILL, sandy silt, some sand, trace gravel, trace topsoil																			
1.98	Loose		3	SS	27															
	Brown																			
	FILL, clayey silt, trace sand, trace gravel																			
	Stiff		4	SS	24															
	Brown																			
266.97	FILL, sandy silt, trace clay, some gravel to gravelly, trace topsoil																			
3.51	Compact		5	SS	9															
	Grey																			
	FILL, sandy silt, some gravel, trace topsoil																			
	Loose		6	SS	9															
	Grey																			
265.45	SILT, trace to some clay, some sand																			
5.03	Compact to very dense		7	SS	57															
	Grey																			
			8	SS	89															
			9	SS	22															
263.16	SILT, trace sand, with clayey silt layers																			
7.32	Dense																			
	Grey		10	SS	9															
262.40	SANDY SILT																			
8.08	Dense		11	SS	47															
	Grey																			
261.64	SILT, trace sand, with clayey silt layers																			
8.84	Dense to compact																			
	Grey		12	SS	36															

**METRIC**  
DIMENSIONS ARE IN METRES AND/OR  
MILLIMETRES UNLESS OTHERWISE SHOWN.  
STATIONS IN KILOMETRES + METRES.

CONT No.  
WP No. 3054-11-00

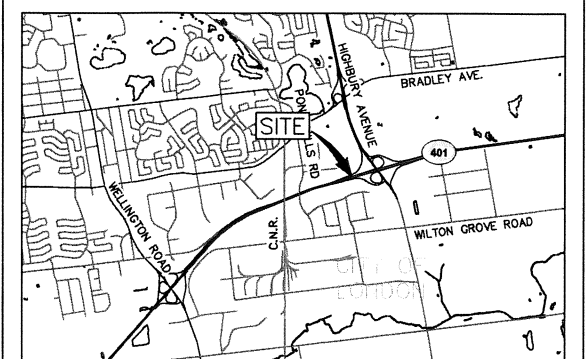
STRUCTURAL CULVERT REPLACEMENT  
STATION 26+360  
HIGHWAY 401 IMPROVEMENTS  
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET



**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

No.	ELEVATION	CO-ORDINATES (MTM ZONE 10)	
		NORTHING	EASTING
701	269.54	4 755 897.7	412 252.5
702	270.39	4 755 904.3	412 260.8
703	270.48	4 755 964.4	412 240.7

## NOTES

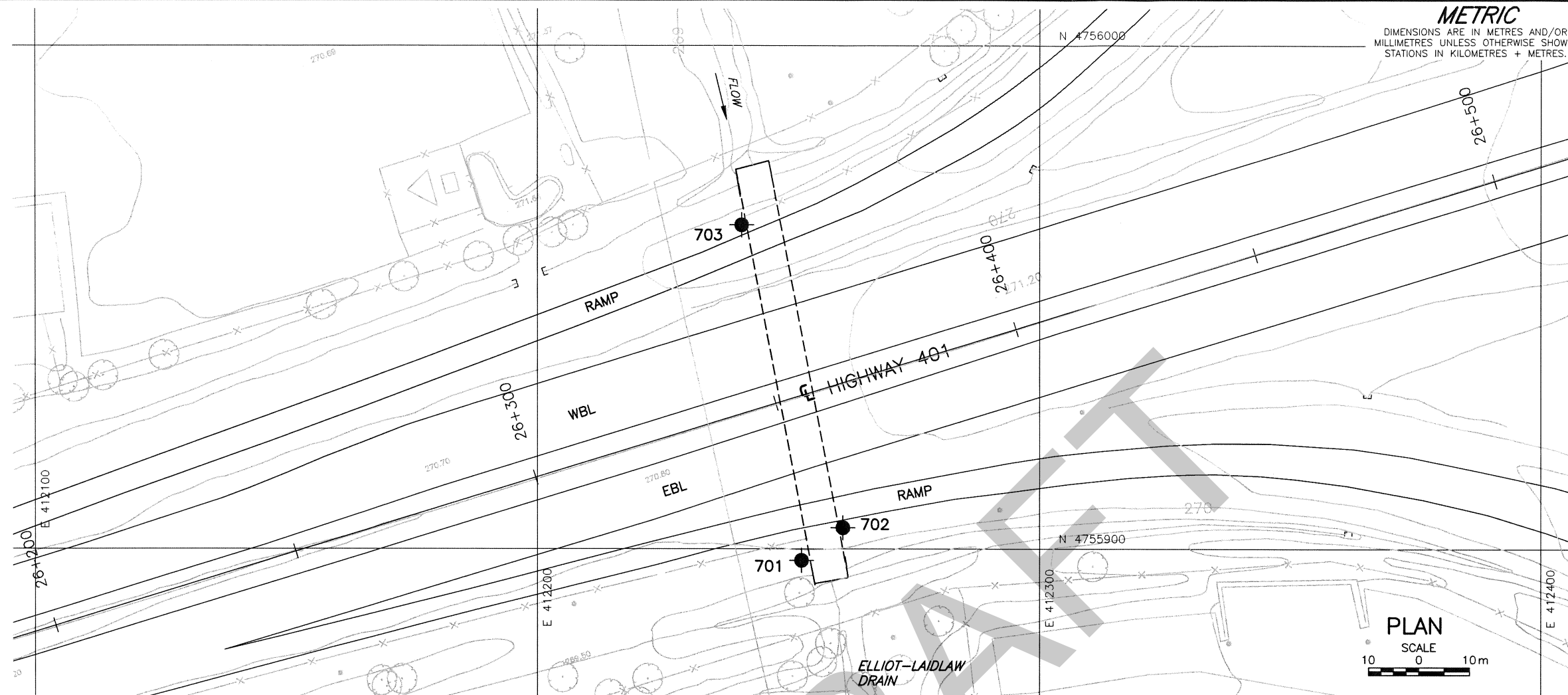
This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

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

## REFERENCE

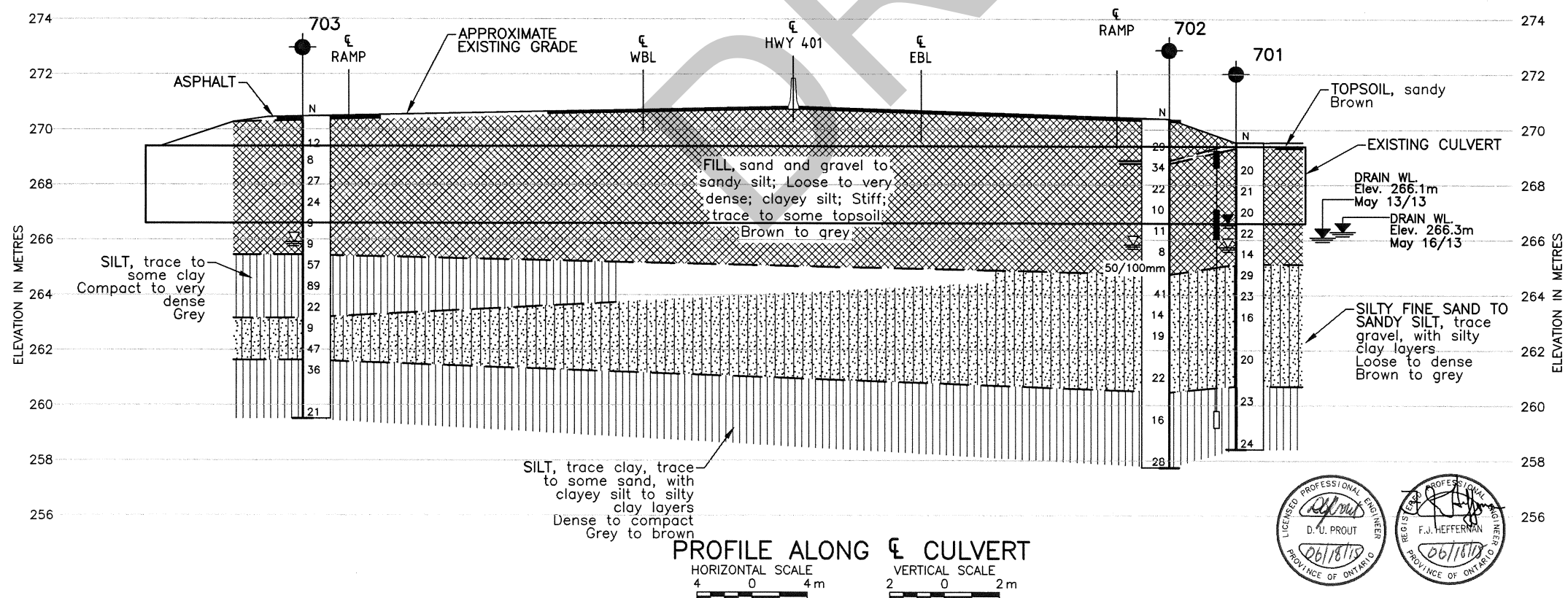
Base plans based on City of London Digital Mapping Disc 2011  
(converted to MTM ZONE 11)

NO.	DATE	BY	REVISION
Geocres No.	4014-159		
HWY.	401	PROJECT NO.	12-1132-0076
SUBM'D.	NG	CHKD.	NAG
DRAWN:	WDF/LMK	CHKD.	DUP
DATE:	Aug. 08/13	APPD.	FJH
SITE:	19-651/C	DWG.	1



## PLAN

SCALE  
10 0 10m

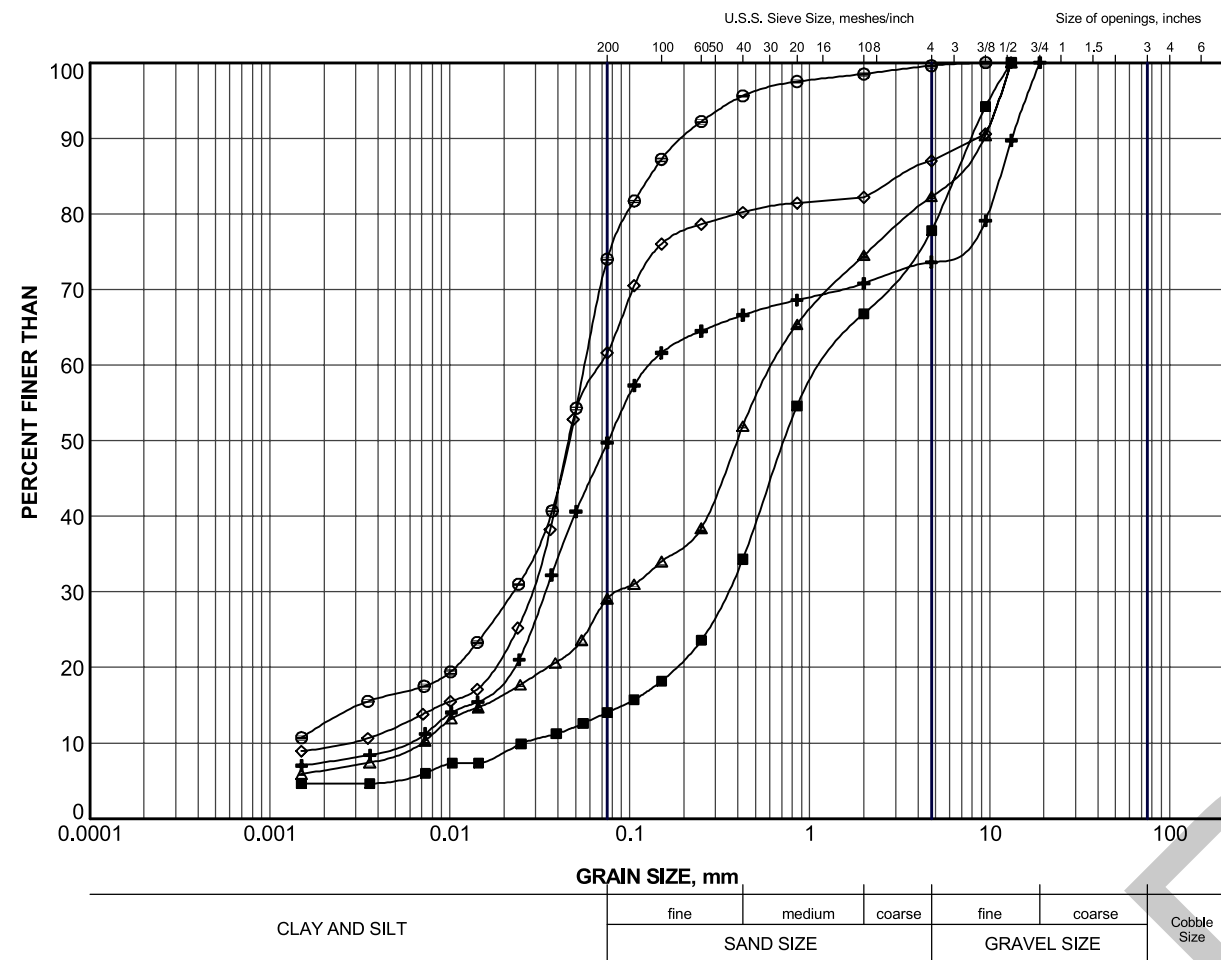


## PROFILE ALONG CULVERT

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



LDN MTO GSD GLDR LDNGDT




LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
⊖	701	3	267.0
■	702	3	267.9
▲	702	5	266.4
+	703	4	267.4
◇	703	5	266.6

PROJECT

STRUCTURAL CULVERT REPLACEMENT 19-651/C  
HIGHWAY 401 INTERCHANGE IMPROVEMENTS  
GWP 3054-11-00

TITLE

GRAIN SIZE DISTRIBUTION  
FILL



PROJECT No.

12-1132-0076

FILE No.

1211320076-1001-F05BA1

SCALE

N/A

REV.

DRAWN

LMK/WDF

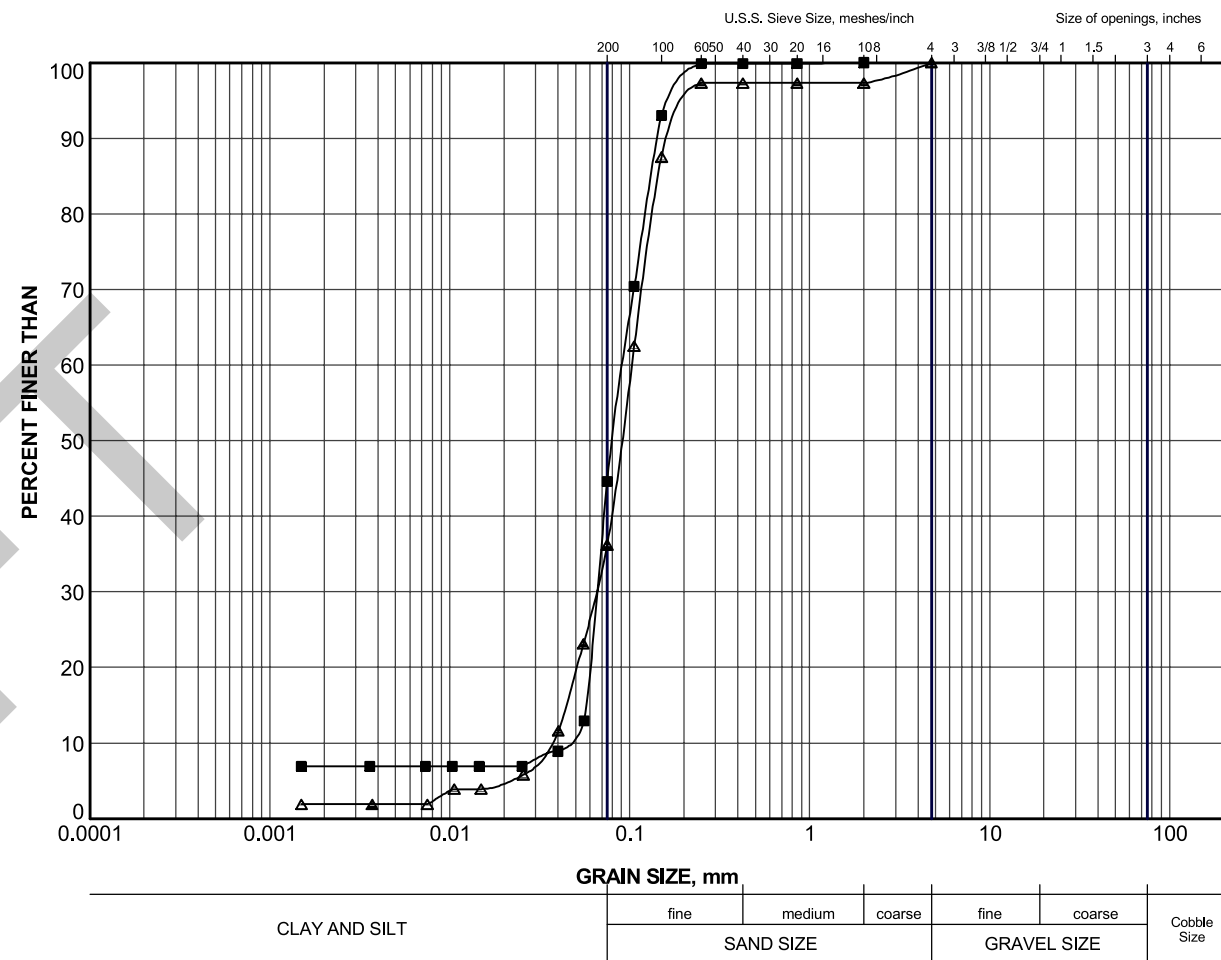
Aug. 07/13

CHECK

FIGURE

A-1

LDN MTO GSD GLDR LDNGDT




LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
⊖	701	6	264.7
■	702	10	262.5
▲	703	10	262.8

PROJECT

STRUCTURAL CULVERT REPLACEMENTS  
HIGHWAY 401 INTERCHANGE IMPROVEMENTS  
GWP 3054-11-00

TITLE

GRAIN SIZE DISTRIBUTION  
SILTY FINE SAND



PROJECT No.

12-1132-0076-1001

FILE No.

1211320076-1001-F050A2

SCALE

N/A

REV.

DRAWN

LMK/WDF

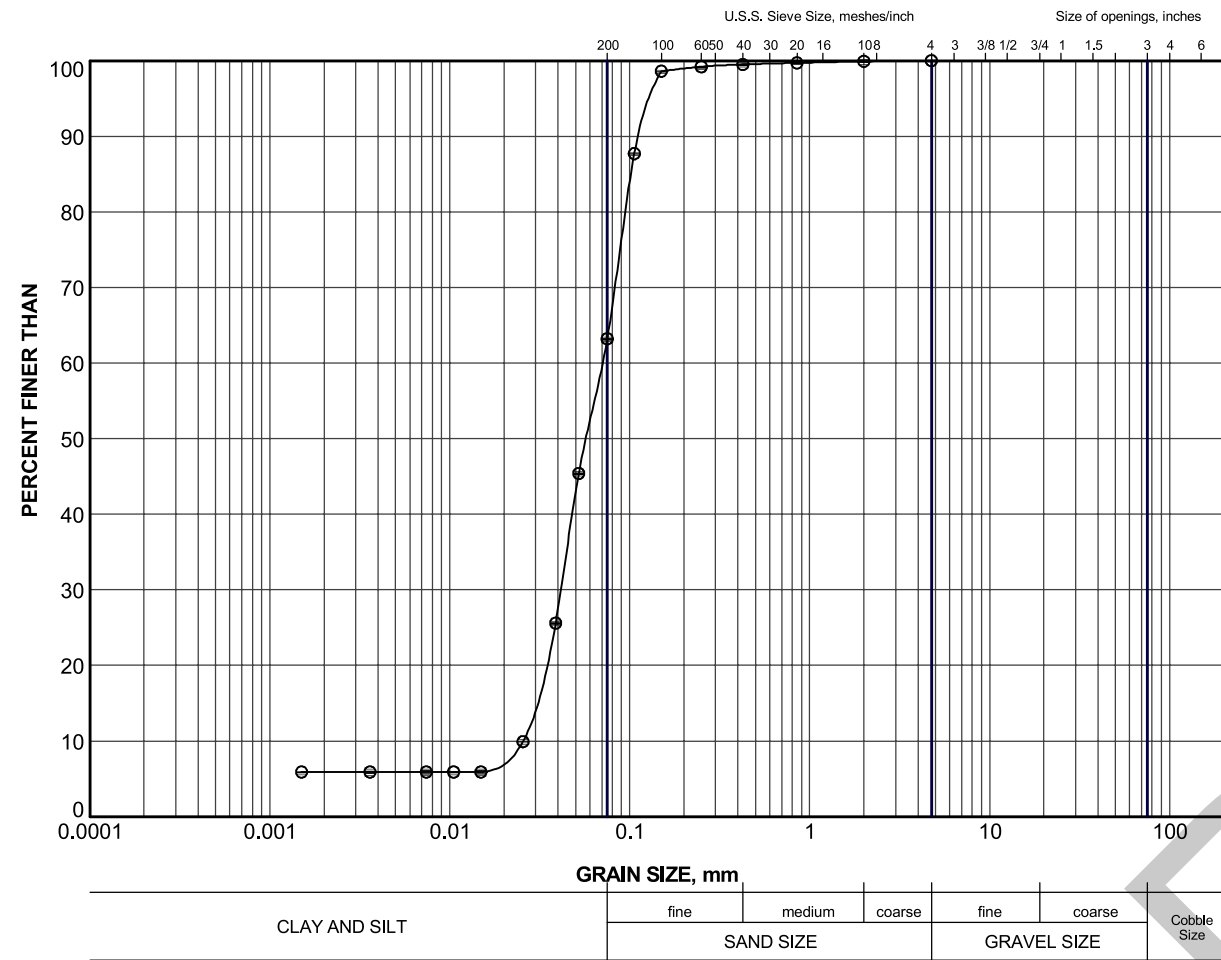
Aug. 07/13

CHECK

FIGURE

A-2

LDN MTO GSD GLDR LDNGDT




LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
⊖	701	6	264.7

PROJECT

STRUCTURAL CULVERT REPLACEMENT 19-651/C  
HIGHWAY 401 INTERCHANGE IMPROVEMENTS  
GWP 3054-11-00

TITLE

GRAIN SIZE DISTRIBUTION  
SANDY SILT



PROJECT No.

12-1132-0076

FILE No.

1211320076-1001-F05BA3

SCALE

N/A

REV.

DRAWN

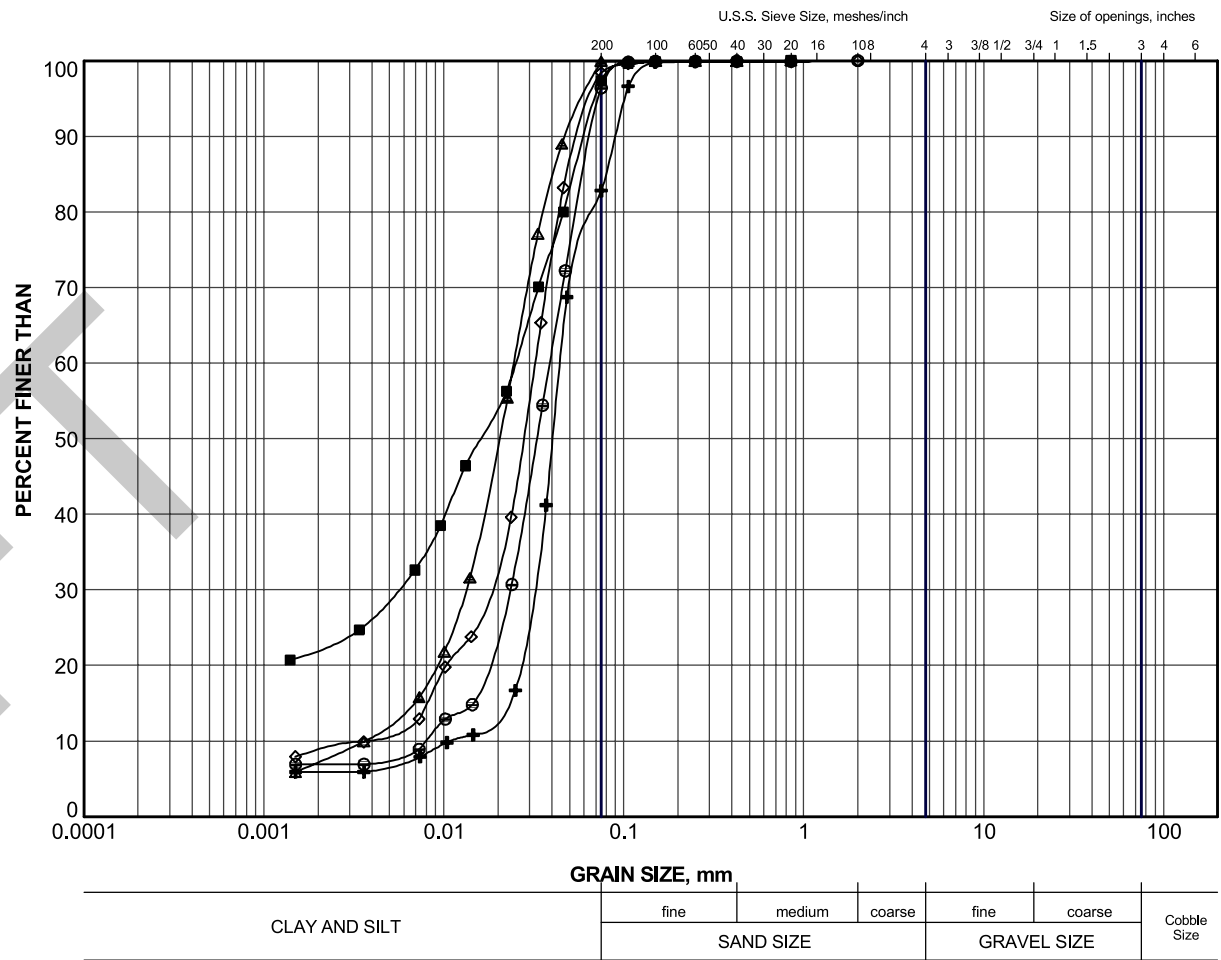
LMKWDF

Aug. 07/13

CHECK

FIGURE A-3

LDN MTO GSD GLDR LDNGDT




LEGEND			
SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
⊖	701	10	260.2
■	702	12	259.5
△	702	13	258.0
+	703	9	263.5
◇	703	12	261.3

PROJECT

STRUCTURAL CULVERT REPLACEMENT 19-651/C  
HIGHWAY 401 INTERCHANGE IMPROVEMENTS  
GWP 3054-11-00

TITLE

GRAIN SIZE DISTRIBUTION  
SILT



PROJECT No.

12-1132-0076

FILE No.

1211320076-1001-F05BA4

SCALE

N/A

REV.

DRAWN

LMKWDF

Aug. 07/13

CHECK

FIGURE A-4

## APPENDIX C

### C.1 SYMBOLS AND TERMS USED ON BOREHOLE RECORDS

### C.2 BOREHOLE RECORDS

DRAFT



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

### SOIL DESCRIPTION

#### Terminology describing common soil genesis:

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

#### Terminology describing soil structure:

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

#### Terminology describing soil types:

The classification of soil types are made on the basis of grain size and plasticity in accordance with the Unified Soil Classification System (USCS) (ASTM D 2487 or D 2488) which excludes particles larger than 75 mm. For particles larger than 75 mm, and for defining percent clay fraction in hydrometer results, definitions proposed by Canadian Foundation Engineering Manual, 4<sup>th</sup> Edition are used. The USCS provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification.

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

Terminology describing materials outside the USCS, (e.g. particles larger than 75 mm, visible organic matter, and construction debris) is based upon the proportion of these materials present:

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

#### Terminology describing compactness of cohesionless soils:

The standard terminology to describe cohesionless soils includes compactness (formerly "relative density"), as determined by the Standard Penetration Test (SPT) N-Value - also known as N-Index. The SPT N-Value is described further on page 3. A relationship between compactness condition and N-Value is shown in the following table.

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

#### Terminology describing consistency of cohesive soils:

The standard terminology to describe cohesive soils includes the consistency, which is based on undrained shear strength as measured by *in situ* vane tests, penetrometer tests, or unconfined compression tests. Consistency may be crudely estimated from SPT N-Value based on the correlation shown in the following table (Terzaghi and Peck, 1967). The correlation to SPT N-Value is used with caution as it is only very approximate.

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

## ROCK DESCRIPTION

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

### Terminology describing rock quality:

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

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

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

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

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

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

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

### Terminology describing rock strength:

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

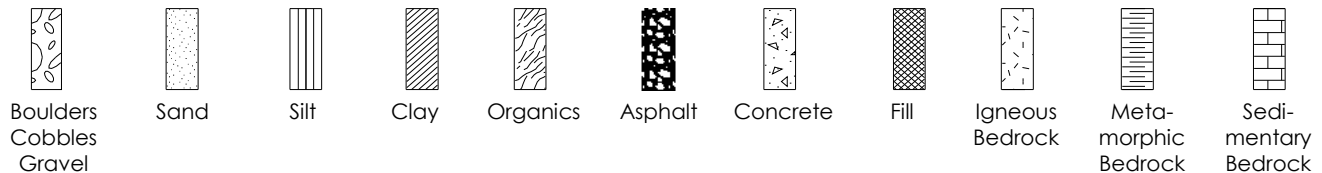
### Terminology describing rock weathering:

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



## STRATA PLOT

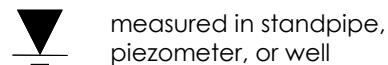
Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



## SAMPLE TYPE

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

## WATER LEVEL MEASUREMENT



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
y	Unit weight
G <sub>s</sub>	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 <sub>u</sub>	Unconfined compression
I <sub>p</sub>	Point Load Index (I <sub>p</sub> on Borehole Record equals I <sub>p</sub> (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 EL-01

1 OF 2

METRIC

W.P. 3032-11-00 LOCATION Highway 401/ Highbury, London, Ontario ORIGINATED BY JM  
 DIST West HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY JM  
 DATUM Geodetic DATE 2022.07.15 - 2022.07.15 LATITUDE 42.935532 LONGITUDE -81.1838962 CHECKED BY GR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W <sub>p</sub>	W	W <sub>L</sub>		
								○ UNCONFINED   + FIELD VANE ● QUICK TRIAXIAL   × LAB VANE	WATER CONTENT (%)					
270.7	Asphalt						20   40   60   80   100							
0.0	400 mm ASPHALT													
270.3			1	SS	30									
0.4	375 mm GRANULAR FILL													
270.0														
269.8	FILL: Silty SAND (SM), trace gravel and construction debris Brown Dense Moist		2	SS	12									
0.9	FILL: CLAY SILT (CL), trace gravel, sand, and black organics Brown Stiff Moist		3	SS	7									
268.5														
2.3	SILT, trace sand to Sandy SILT (ML), trace clay Brown Compact to dense Moist to wet		4	SS	19									0   9   82   8
			5	SS	24									
			6	SS	32									
			7	SS	35									
			8	SS	45									
			9	SS	18									0   32   62   6
	Grey below 6.9 m		10	SS	14									
			11	SS	15									
			12	SS	15									
			13	SS	24									

Continued Next Page

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

# RECORD OF BOREHOLE No EL-01

2 OF 2

**METRIC**

W.P. 3032-11-00 LOCATION Highway 401/ Highbury, London, Ontario ORIGINATED BY JM  
 DIST West HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY JM  
 DATUM Geodetic DATE 2022.07.15 - 2022.07.15 LATITUDE 42.935532 LONGITUDE -81.1838962 CHECKED BY GR


























SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)					
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE									
						20   40   60   80   100				20   40   60			GR   SA   SI   CL				
260.1	SILT, trace sand to Sandy SILT (ML), trace clay Brown Compact to dense Moist to wet ( <i>continued</i> )		14	SS	27	260										0   2   69   30	
10.7	CLAYEY SILT (CL-ML), trace sand Grey Stiff to very stiff Wet		15	SS	14												
			16	SS	18												
257.5	Silty SAND (SM), trace clay Grey Compact Wet						258										
13.2																	
					257										0   85   12   3 non-plastic		
		17	SS	15													
					256												
					255												
		18	SS	12													
254.9	END OF BOREHOLE																
15.9																	

# RECORD OF BOREHOLE No EL-02

1 OF 2

METRIC

W.P. 3032-11-00 LOCATION Highway 401/ Highbury, London, Ontario ORIGINATED BY JM  
 DIST West HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY JM  
 DATUM Geodetic DATE 2022.07.26 - 2022.07.26 LATITUDE 42.9356062 LONGITUDE -81.1835683 CHECKED BY GR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)				GR	SA	SI	CL
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE	20	40	60					80	100	20	40	60			
270.8 0.0	Asphalt 400 mm ASPHALT																							
270.4 0.4	375 mm GRANULAR FILL		1	SS	75								○											
270.0 0.8	FILL: Silty SAND with Gravel (SM), trace clay and black organics Brown Loose to very dense Dry to moist		2	SS	36								○											
			3	SS	15								○						22	56	15	7		
			4	SS	6								○											
			5	SS	4								○											
267.0 3.8	SILT (ML) to silty SAND (SM), trace gravel and clay Brown Compact to dense Moist to wet  Grey below 4.6 m		6	SS	14								○						3	12	78	7		
			7	SS	26								○											
			8	SS	40								○											
			9	SS	20								○											
			10	SS	14								○											
			11	SS	11								○						0	78	18	4		
			12	SS	23								○											
			13	SS	26								○											
																								
																								
																								
																								
																								
																								
																								
																								
																								
																								
																								

Continued Next Page

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

ONTARIO MTO 165001239\_MTO\_HWY\_401\_HIGHBURY.GPJ ONTARIO.MTO.GDT 10/24/22

## METRIC

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

# RECORD OF BOREHOLE No EL-03

1 OF 2

METRIC

W.P. 3032-11-00 LOCATION Highway 401/ Highbury, London, Ontario ORIGINATED BY JM  
DIST West HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY RR  
DATUM Geodetic DATE 2022.07.24 - 2022.07.24 LATITUDE 42.9357076 LONGITUDE -81.1831165 CHECKED BY GR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)		
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL						× LAB VANE		
271.0	Asphalt						20	40	60	80	100							
0.0	400 mm ASPHALT																	
270.6	400 mm GRANULAR FILL		1	SS	50/ 75													
0.4																		
270.2	FILL: CLAYEY SILT with Sand (CL), trace gravel, trace organics and asphalt Brown Firm to stiff Moist		2	SS	14		270											
0.8			3	SS	15		269									4 29 32 35		
			4	SS	4		268											
			5	SS	6													
267.3	SILT (ML), some clay, trace sand to Silty SAND (SM), trace clay Grey Compact to very dense Wet		6	SS	22		267									0 7 77 16		
3.7			7	SS	44		266											
			8	SS	71		265											
			9	SS	34		264											
			10	SS	49													
			11	SS	38		263									0 53 42 5		
			12	SS	34		262											
			13	SS	31													

Continued Next Page

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

## METRIC

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

# RECORD OF BOREHOLE No EL-04

1 OF 2

METRIC

W.P. 3032-11-00 LOCATION Highway 401/ Highbury, London, Ontario ORIGINATED BY JM  
DIST West HWY 401 BOREHOLE TYPE Solid Stem Augers COMPILED BY JM  
DATUM Geodetic DATE 2022.08.17 - 2022.08.17 LATITUDE 42.9357447 LONGITUDE -81.18361 CHECKED BY GR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)						
270.7	Asphalt							20	40	60	80	100									
270.6	100 mm ASPHALT																				
0.1	375 mm GRANULAR FILL		1	SS	20																
270.2																					
0.5	FILL: SAND and GRAVEL (SP/GP), trace construction debris Brown to black Compact Moist		2	SS	23		270														
269.2																					
1.5	FILL: SILTY CLAYEY SAND (SC-SM), some gravel Brown Loose Moist		3	SS	8		269														
268.4																					
2.2	FILL: CLAYEY SILT (CL), some sand Brown to black Firm Moist		4	SS	6		268														
267.7																					
3.0	SILT with Sand to SILT (ML), trace clay Brown Compact to dense Wet		5	SS	14		267										1	15	79	6	
	Grey below 3.8 m		6	SS	26																
			7	SS	33		266														
			8	SS	41		265														
			9	SS	12		264														
			10	SS	13													0	8	85	6
	SS11 very loose		11	SS	3		263														
			12	SS	17		262														
			13	SS	23		261														

Continued Next Page

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



**METRIC**

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

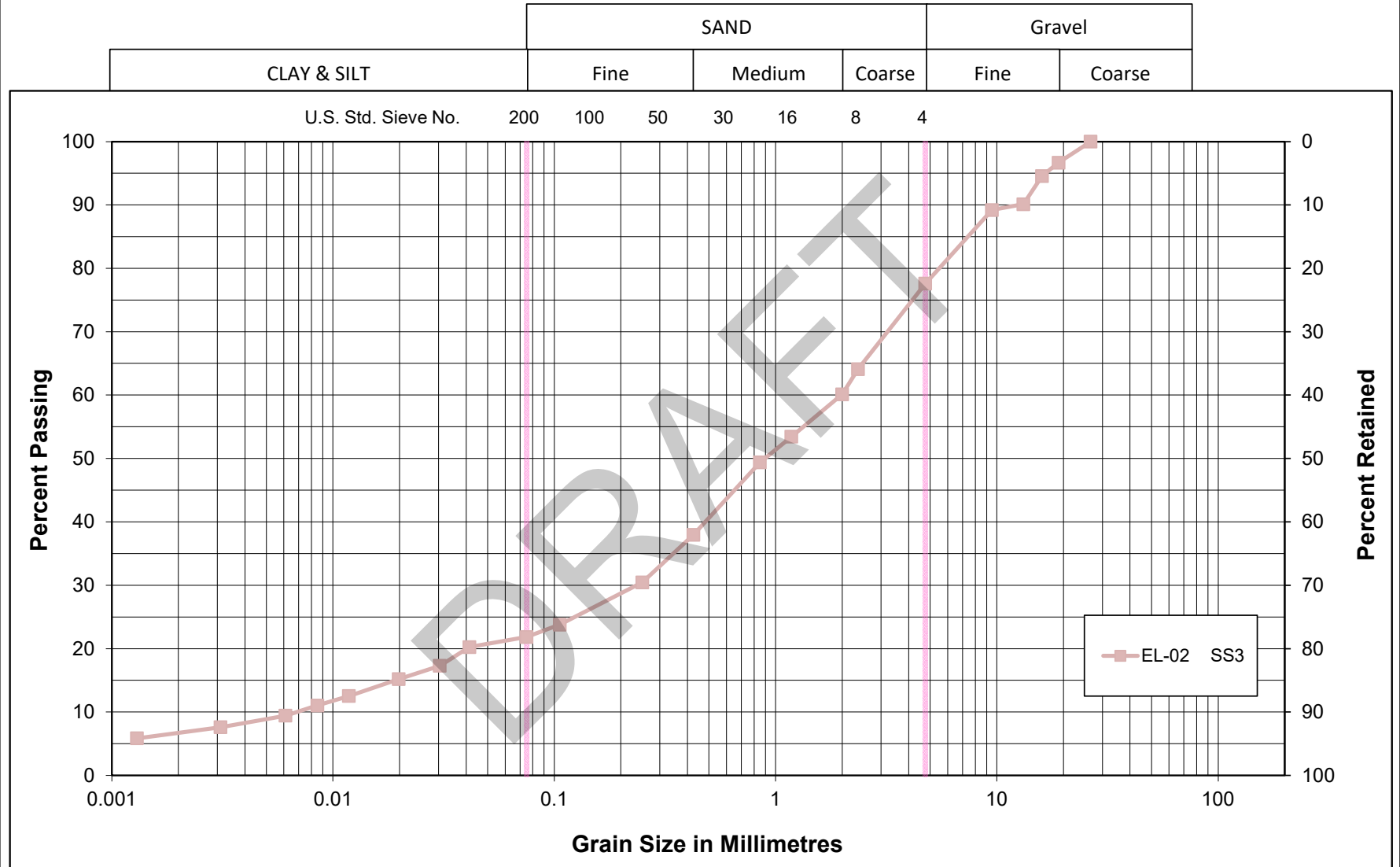
## APPENDIX D

### D.1 LABORATORY TEST RESULTS

DRAFT



# Unified Soil Classification System

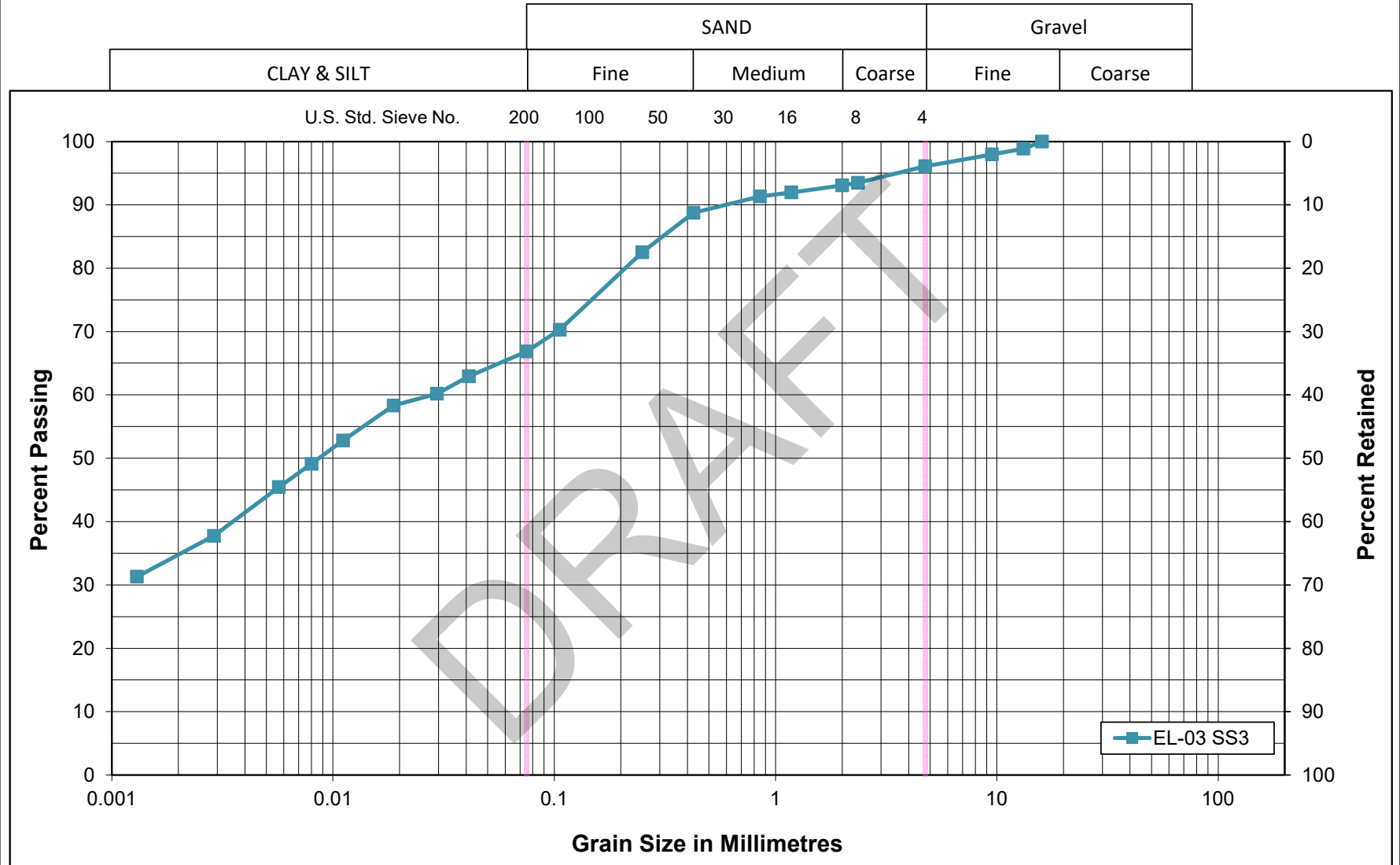


**Silty SAND with Gravel (SM)**  
 Ministry of Transportation (MTO)  
 HWY 401 RECONSTRUCTION - Elliot Laidlaw Culvert

Figure No. D1

Project No. 165001239

# Unified Soil Classification System



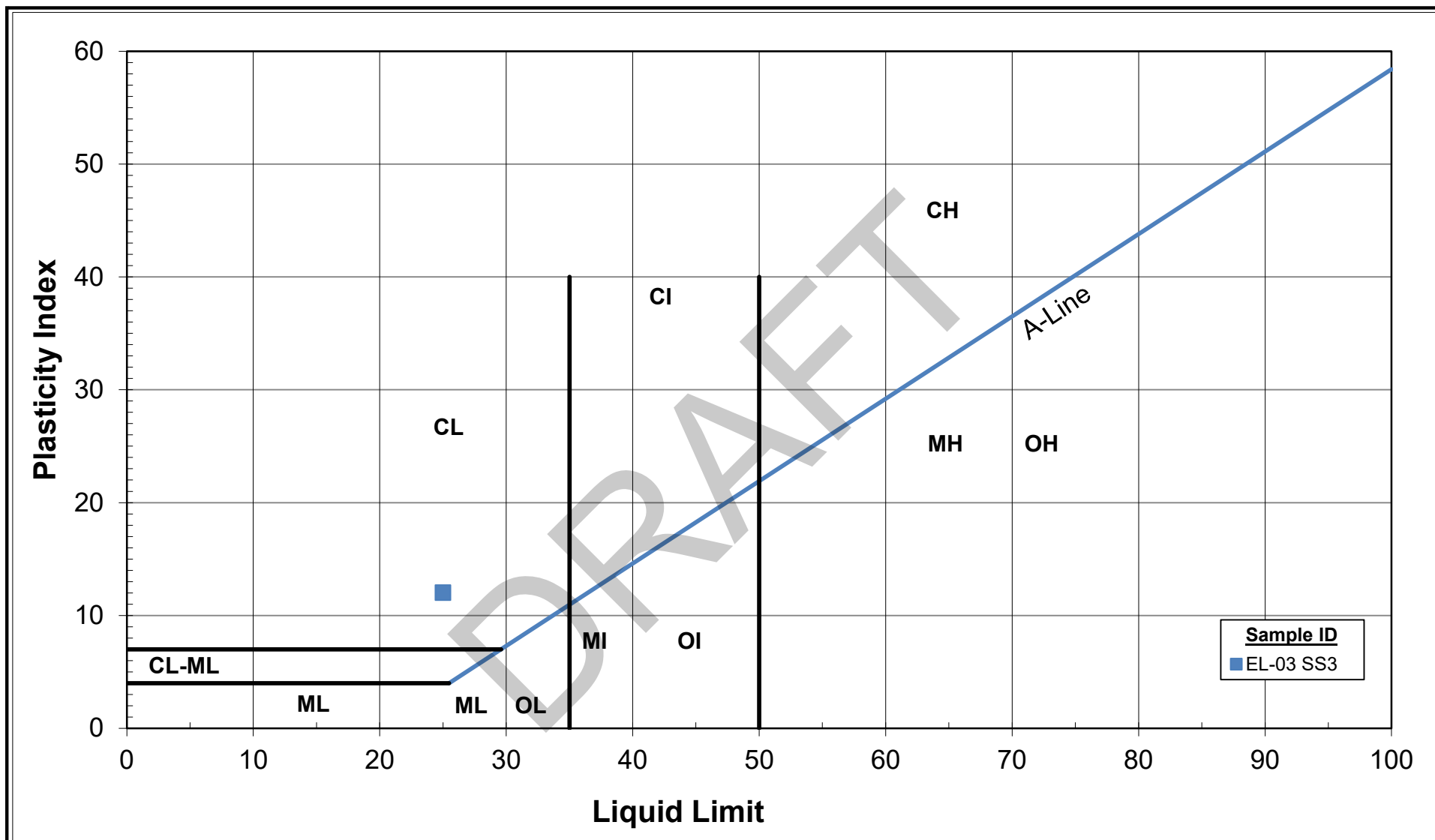
**CLAYEY SILT with Sand (CL)**

**Ministry of Transportation (MTO)**

**HWY 401 RECONSTRUCTION - Elliot Laidlaw Culvert**

**Figure No. D2**

**Project No. 165001239**



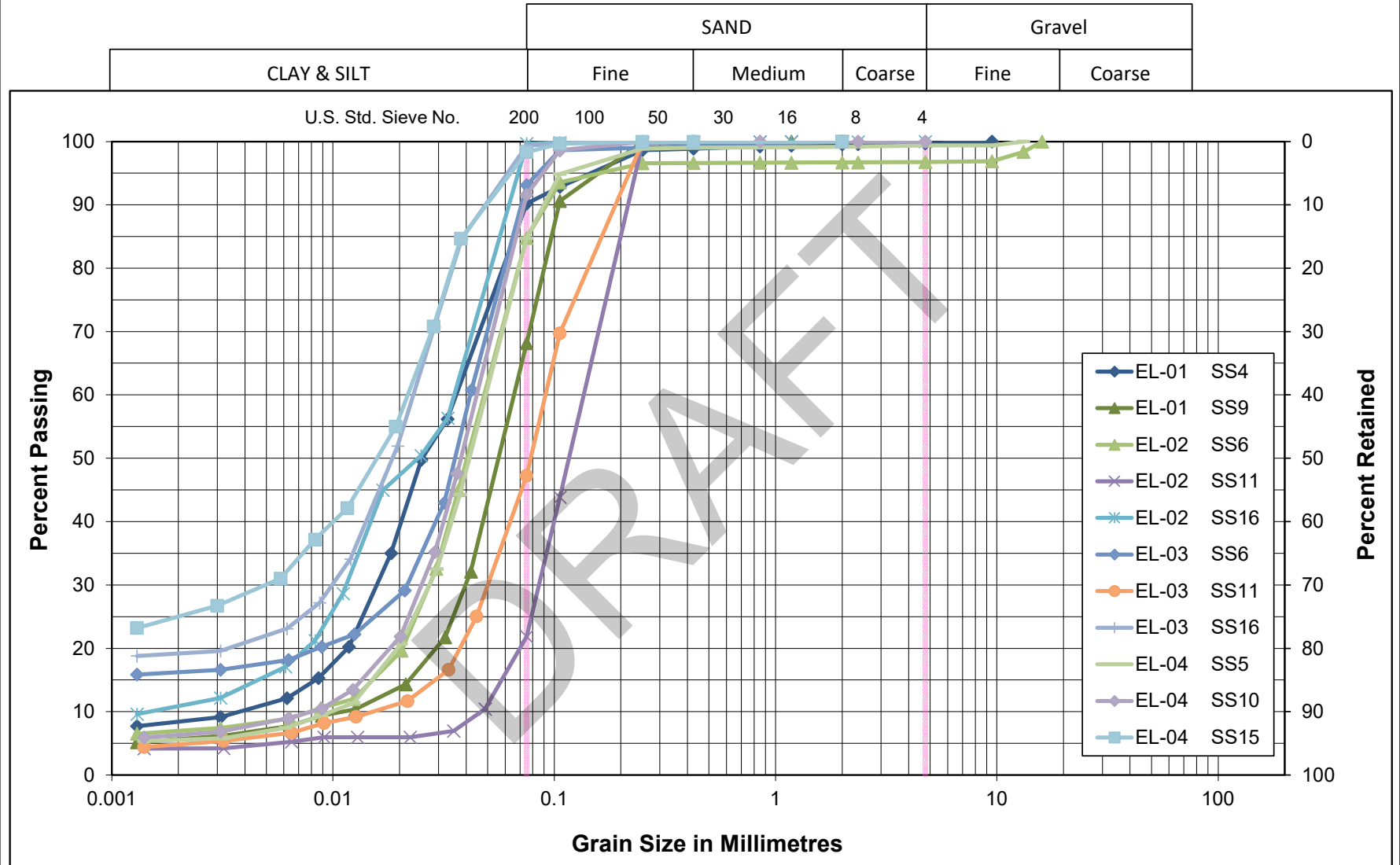
Ministry of Transportation (MTO)  
HWY 401 RECONSTRUCTION - ELLIOT LAIDLAW CULVERT

CLAYEY SILT with Sand (CL)

Figure No. D3

Project No. 165001239

# Unified Soil Classification System

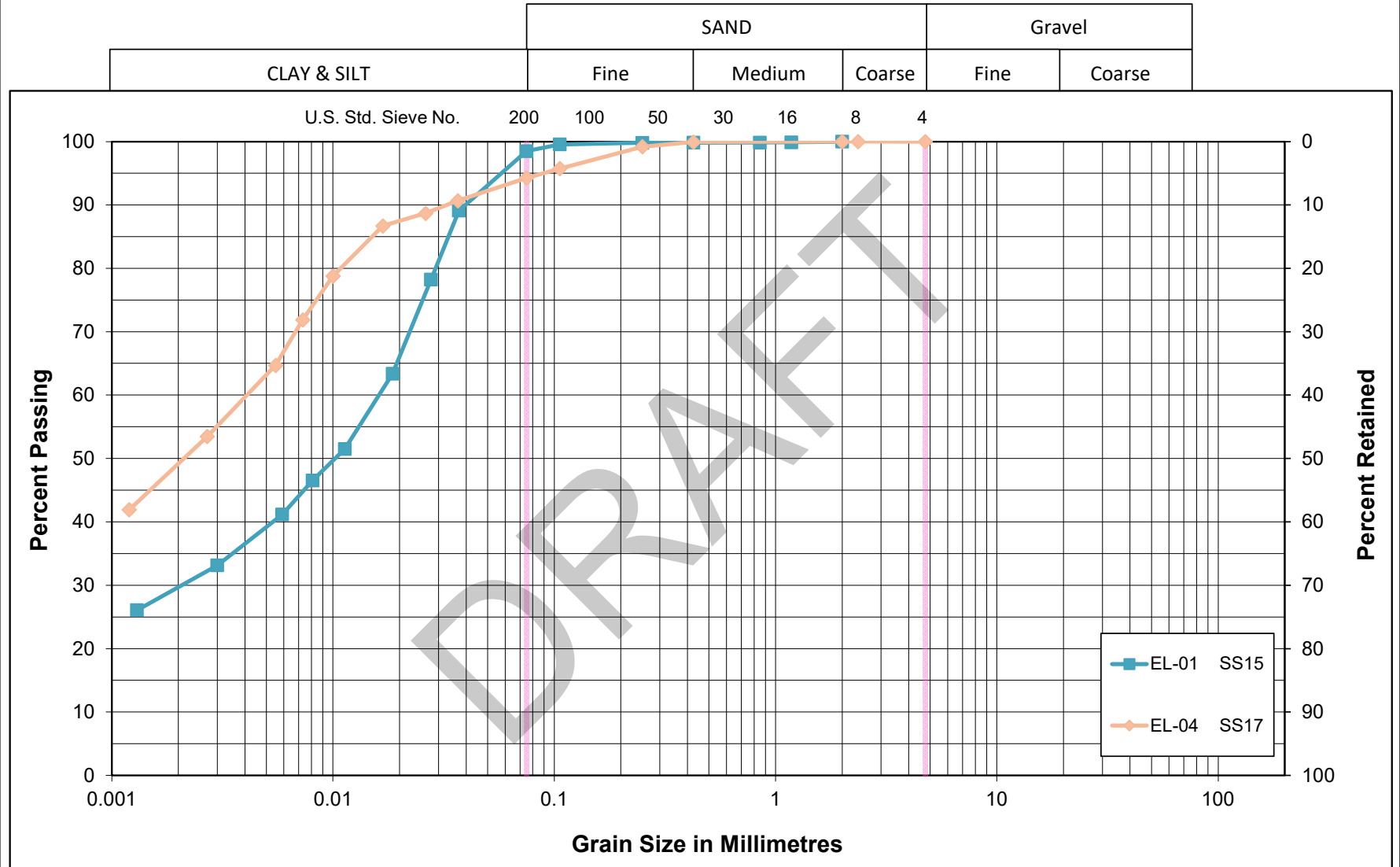


SILT/SILT with Sand/Sandy SILT (ML) to Silty  
SAND (SM)  
Ministry of Transportation (MTO)  
HWY 401 RECONSTRUCTION - Elliot Laidlaw Culvert

Figure No. D4

Project No. 165001239

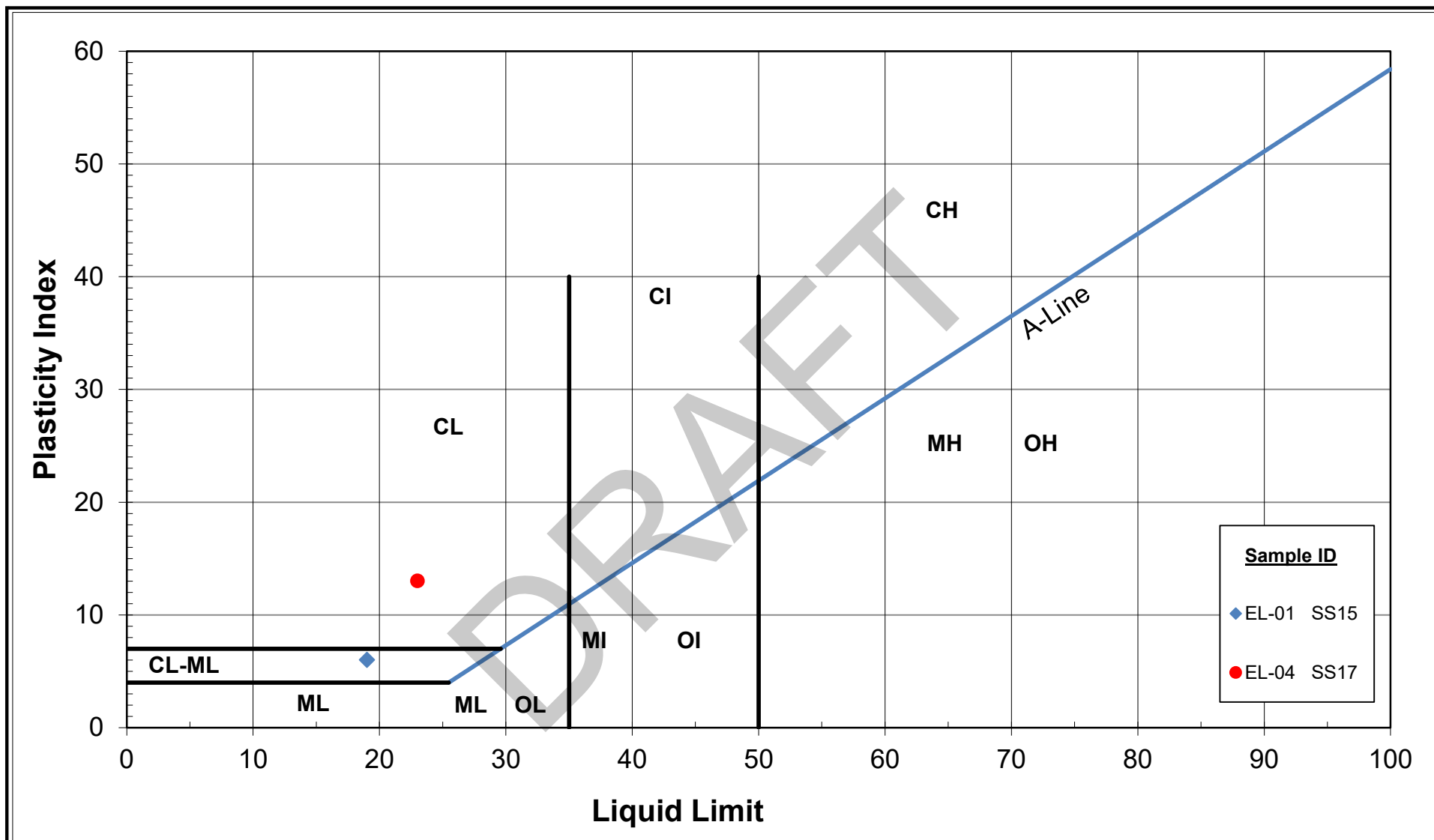
# Unified Soil Classification System



**CLAYEY SILT (CL-ML to CL)**  
 Ministry of Transportation (MTO)  
 HWY 401 RECONSTRUCTION - Elliot Laidlaw Culvert

Figure No. D5

Project No. 165001239



Ministry of Transportation (MTO)  
HWY 401 RECONSTRUCTION - ELLIOT LAIDLAW CULVERT

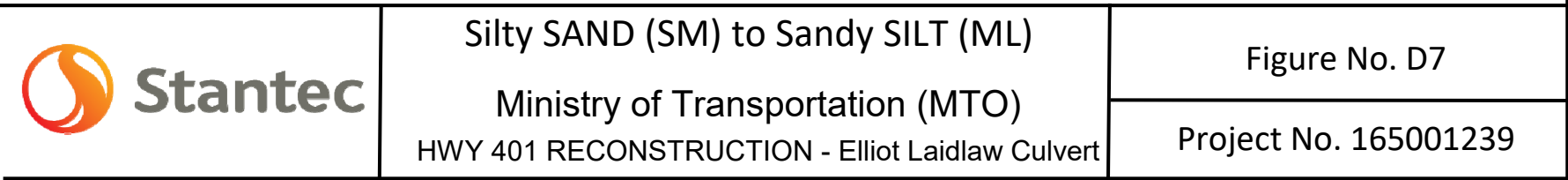
CLAYEY SILT (CL-ML to CL)

Figure No. D6

Project No. 165001239



	SAND			Gravel	
CLAY & SILT	Fine	Medium	Coarse	Fine	Coarse



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.
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- 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

SAMPLING SITE:

ATTENTION TO: Amoldeep Gill

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:



## 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

SAMPLING SITE:

ATTENTION TO: Amoldeep Gill

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:



*Nine Basil*

## 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			Method Blank	REFERENCE MATERIAL		METHOD BLANK SPIKE		MATRIX SPIKE	
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	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:



## 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			Method Blank	REFERENCE MATERIAL		METHOD BLANK SPIKE		MATRIX SPIKE	
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	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:


*Nivine Basily*

## Method Summary

CLIENT NAME: STANTEC CONSULTING LTD

PROJECT: 165001239.651

SAMPLING SITE:

AGAT WORK ORDER: 22T944869

ATTENTION TO: Amoldeep Gill

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



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

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

Company: \_\_\_\_\_  
Contact: \_\_\_\_\_  
Address: \_\_\_\_\_

**GW** Ground Water    **O** Oil  
**SW** Surface Water    **P** Paint  
**SD** Sediment        **S** Soil

1. Name: Amoldeep Gill  
Email: amoldeep.gill@stantec.com
2. Name: Gwangha Roh  
Email: gwangha.roh@stantec.com

☐ Coarse      ☐ Fine

☐ Storm

☐ None

If "Yes", please use the *Drinking Water Chain of Custody Form*

☐ Yes      ☐ No[illegible]

Page \_\_\_\_ of \_\_\_\_

NO:

White Copy - AGAT



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: 22T948205

ROCK ANALYSIS REVIEWED BY: Heather Offord, Client Service Representative

SOIL ANALYSIS REVIEWED BY: Nivine Basily, Inorganics Report Writer

DATE REPORTED: Sep 30, 2022

PAGES (INCLUDING COVER): 11

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: 22T948205

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

SAMPLING SITE:

ATTENTION TO: Amoldeep Gill

SAMPLED BY:

### (283-042) Sulfide (CGY)

DATE RECEIVED: 2022-09-22

DATE REPORTED: 2022-09-30

		SAMPLE DESCRIPTION:		(S-04-1)-SS8	(S-01-1)-SS5	(HL-08)-SS5	(S-03)-SS6	(EL-04-4)-SS6	(HB-01)-SS6	(HL-11)-SS6	(HL-15-1)-SS9
		SAMPLE TYPE:		Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
		DATE SAMPLED:		2022-09-20	2022-09-20	2022-09-20	2022-09-20	2022-09-20	2022-09-20	2022-09-20	2022-09-20
Parameter	Unit	G / S	RDL	4335332	4335453	4335454	4335455	4335456	4335457	4335458	4335459
Sulfide	%			0.01	0.01	0.01	0.01	<0.01	0.02	0.01	0.03
		SAMPLE DESCRIPTION:		(HL-10)-SS4	(HL-17)-SS5	(HL-14)-SS4	(HL-12)-SS2	(HF-10)-SS5	(HF-11)-SS6	(HL-05)-SS7	(HL-03)-SS5
		SAMPLE TYPE:		Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
		DATE SAMPLED:		2022-09-20	2022-09-20	2022-09-20	2022-09-20	2022-09-20	2022-09-20	2022-09-20	2022-09-20
Parameter	Unit	G / S	RDL	4335460	4335461	4335462	4335463	4335480	4335481	4335482	4335483
Sulfide	%			0.01	0.01	0.01	<0.01	<0.01	0.01	0.01	0.01
		SAMPLE DESCRIPTION:		(HL-01)-SS4	(HL-16-1)-SS13	(HL-04)-SS3	(HL-13-1)-SS12	(HL-07)-SS4	(HL-06)-SS8	(HL-02)-SS5	(HL-09-1)-SS5
		SAMPLE TYPE:		Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
		DATE SAMPLED:		2022-09-20	2022-09-20	2022-09-20	2022-09-20	2022-09-20	2022-09-20	2022-09-20	2022-09-20
Parameter	Unit	G / S	RDL	4335484	4335485	4335486	4335487	4335488	4335489	4335490	4335491
Sulfide	%			0.01	<0.01	0.01	<0.01	0.01	<0.01	0.03	0.02
		SAMPLE DESCRIPTION:		(S-05-1)-SS8	(HL-18-1)-SS8						
		SAMPLE TYPE:		Soil	Soil						
		DATE SAMPLED:		2022-09-20	2022-09-20						
Parameter	Unit	G / S	RDL	4335571	4335572						
Sulfide	%			0.01	0.04	<0.01					

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

Analysis performed at AGAT Calgary (unless marked by \*)

Certified By:



## Certificate of Analysis

AGAT WORK ORDER: 22T948205

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

SAMPLING SITE:

ATTENTION TO: Amoldeep Gill

SAMPLED BY:

### Corrosivity Package

DATE RECEIVED: 2022-09-22

DATE REPORTED: 2022-09-30

		SAMPLE DESCRIPTION:		(S-04-1)-SS8	(S-01-1)-SS5	(HL-08)-SS5	(S-03)-SS6	(EL-04-4)-SS6	(HB-01)-SS6	(HL-11)-SS6	(HL-15-1)-SS9
		SAMPLE TYPE:		Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
		DATE SAMPLED:		2022-09-20	2022-09-20	2022-09-20	2022-09-20	2022-09-20	2022-09-20	2022-09-20	2022-09-20
Parameter	Unit	G / S	RDL	4335332	4335453	4335454	4335455	4335456	4335457	4335458	4335459
Chloride (2:1)	µg/g	2	449	438	702	1080	713	816	14	89	
Sulphate (2:1)	µg/g	2	23	27	28	32	83	30	5	187	
pH (2:1)	pH Units	NA	9.41	7.30	9.68	9.15	9.26	9.04	8.76	8.91	
Electrical Conductivity (2:1)	mS/cm	0.005	0.950	0.875	1.36	1.99	1.44	1.43	0.110	0.470	
Resistivity (2:1) (Calculated)	ohm.cm	1	1050	1140	735	503	694	699	9090	2130	
Redox Potential 1	mV	NA	320	270	251	268	290	236	240	236	
Redox Potential 2	mV	NA	331	283	262	279	295	240	240	238	
Redox Potential 3	mV	NA	343	290	273	286	298	242	242	239	
		SAMPLE DESCRIPTION:		(HL-10)-SS4	(HL-17)-SS5	(HL-14)-SS4	(HL-12)-SS2	(HF-10)-SS5	(HF-11)-SS6	(HL-05)-SS7	(HL-03)-SS5
		SAMPLE TYPE:		Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
		DATE SAMPLED:		2022-09-20	2022-09-20	2022-09-20	2022-09-20	2022-09-20	2022-09-20	2022-09-20	2022-09-20
Parameter	Unit	G / S	RDL	4335460	4335461	4335462	4335463	4335480	4335481	4335482	4335483
Chloride (2:1)	µg/g	2	214	14	23	20	83	129	337	304	
Sulphate (2:1)	µg/g	2	11	5	6	14	24	33	28	19	
pH (2:1)	pH Units	NA	9.31	9.08	8.85	8.43	8.06	7.91	7.85	7.72	
Electrical Conductivity (2:1)	mS/cm	0.005	0.433	0.111	0.124	0.186	0.314	0.372	0.688	0.629	
Resistivity (2:1) (Calculated)	ohm.cm	1	2310	9010	8060	5380	3180	2690	1450	1590	
Redox Potential 1	mV	NA	261	252	273	236	248	229	242	221	
Redox Potential 2	mV	NA	264	258	284	246	253	243	253	237	
Redox Potential 3	mV	NA	265	264	293	253	258	249	259	229	

Certified By:



*Amoldeep Gill*



## Certificate of Analysis

AGAT WORK ORDER: 22T948205

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

SAMPLING SITE:

ATTENTION TO: Amoldeep Gill

SAMPLED BY:

### Corrosivity Package

DATE RECEIVED: 2022-09-22

DATE REPORTED: 2022-09-30

		SAMPLE DESCRIPTION:		(HL-01)-SS4	(HL-16-1)-SS13	(HL-04)-SS3	(HL-13-1)-SS12	(HL-07)-SS4	(HL-06)-SS8	(HL-02)-SS5	(HL-09-1)-SS5
		SAMPLE TYPE:		Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
		DATE SAMPLED:		2022-09-20	2022-09-20	2022-09-20	2022-09-20	2022-09-20	2022-09-20	2022-09-20	2022-09-20
Parameter	Unit	G / S	RDL	4335484	4335485	4335486	4335487	4335488	4335489	4335490	4335491
Chloride (2:1)	µg/g	2	460	253	985	733	1650	423	253	1030	
Sulphate (2:1)	µg/g	2	36	20	61	16	83	142	28	20	
pH (2:1)	pH Units	NA	8.18	8.38	8.47	8.08	8.50	7.95	7.84	7.68	
Electrical Conductivity (2:1)	mS/cm	0.005	0.920	0.533	2.00	1.28	3.43	0.916	0.569	1.87	
Resistivity (2:1) (Calculated)	ohm.cm	1	1090	1880	500	781	292	1090	1760	535	
Redox Potential 1	mV	NA	250	285	255	268	259	272	255	255	
Redox Potential 2	mV	NA	254	292	258	277	269	277	262	259	
Redox Potential 3	mV	NA	256	293	260	285	271	280	263	264	
		SAMPLE DESCRIPTION:		(S-05-1)-SS8	(HL-18-1)-SS8						
		SAMPLE TYPE:		Soil	Soil						
		DATE SAMPLED:		2022-09-20	2022-09-20						
Parameter	Unit	G / S	RDL	4335571	4335572						
Chloride (2:1)	µg/g	2	165	1790							
Sulphate (2:1)	µg/g	2	126	196							
pH (2:1)	pH Units	NA	7.66	10.8							
Electrical Conductivity (2:1)	mS/cm	0.005	0.492	3.68							
Resistivity (2:1) (Calculated)	ohm.cm	1	2030	272							
Redox Potential 1	mV	NA	271	222							
Redox Potential 2	mV	NA	286	226							
Redox Potential 3	mV	NA	287	228							

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

4335332-4335572 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:



## Quality Assurance

CLIENT NAME: STANTEC CONSULTING LTD

PROJECT: 165001239.651

SAMPLING SITE:

AGAT WORK ORDER: 22T948205

ATTENTION TO: Amoldeep Gill

SAMPLED BY:

### Rock Analysis

RPT Date: Sep 30, 2022			DUPLICATE			Method Blank	REFERENCE MATERIAL		METHOD BLANK SPIKE		MATRIX SPIKE	
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper

(283-042) Sulfide (CGY)

Total Sulfur 4335332 4335332 0.01 0.01 NA &lt; 0.01 102%

Sulfate 4335332 4335332 &lt;0.01 &lt;0.01 NA &lt; 0.01 94%

(283-042) Sulfide (CGY)

Total Sulfur 2 4335488 0.02 0.01 NA &lt; 0.01 102%

Sulfate 4335487 4335487 &lt;0.01 &lt;0.01 NA &lt; 0.01 97%

(283-042) Sulfide (CGY)

Total Sulfur 4335488 4335488 &lt;0.01 0.02 0% &lt; 0.01

Certified By:



## Quality Assurance

CLIENT NAME: STANTEC CONSULTING LTD

PROJECT: 165001239.651

SAMPLING SITE:

AGAT WORK ORDER: 22T948205

ATTENTION TO: Amoldeep Gill

SAMPLED BY:

### Soil Analysis

RPT Date: Sep 30, 2022			DUPLICATE			Method Blank	REFERENCE MATERIAL		METHOD BLANK SPIKE		MATRIX SPIKE	
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper

#### Corrosivity Package

Chloride (2:1)	4335332	4335332	449	445	0.9%	< 2	99%	70%	130%	100%	80%	120%	NA	70%	130%
Sulphate (2:1)	4335332	4335332	23	22	4.4%	< 2	105%	70%	130%	102%	80%	120%	101%	70%	130%
pH (2:1)	4336014		6.58	6.87	4.3%	NA	113%	80%	120%						
Electrical Conductivity (2:1)	4336014		0.227	0.232	2.2%	0.006	97%	80%	120%						
Redox Potential 1	4335332					NA	99%	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.

Matrix spike NA: Spike level &lt; native concentration. Matrix spike acceptance limits do not apply and are not calculated.

#### Corrosivity Package

pH (2:1)	4335332	4335332	9.41	9.54	1.4%	NA	101%	80%	120%						
Electrical Conductivity (2:1)	4335332	4335332	0.950	0.959	0.9%	< 0.005	92%	80%	120%						

Comments: NA signifies Not Applicable.

pH duplicates QA acceptance criteria was met relative as stated in Table 5-15 of Analytical Protocol document.

#### Corrosivity Package

Chloride (2:1)	4335488	4335488	1650	1650	0.5%	< 2	99%	70%	130%	100%	80%	120%	NA	70%	130%
Sulphate (2:1)	4335488	4335488	83	83	0.0%	< 2	105%	70%	130%	102%	80%	120%	101%	70%	130%

Comments: NA signifies Not Applicable.

pH duplicates QA acceptance criteria was met relative as stated in Table 5-15 of Analytical Protocol document.

Matrix spike NA: Spike level &lt; native concentration. Matrix spike acceptance limits do not apply and are not calculated.

Certified By:


*Nivine Basily*

## Method Summary

CLIENT NAME: STANTEC CONSULTING LTD

PROJECT: 165001239.651

SAMPLING SITE:

AGAT WORK ORDER: 22T948205

ATTENTION TO: Amoldeep Gill

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



## Chain of Custody Record

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

**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 UseRegion Indicate one☐ Sanitary

 Storm

Regulation 558

☐ CCME☐ Other (specify) \_\_\_\_\_

## Prov. Water Quality Objectives (PWQO)

☐ None

**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	Metal S	Hydride	Client	ORPs: <input type="checkbox"/> EC <input type="checkbox"/> NO <sub>3</sub> y	Nutrient <input type="checkbox"/> NO <sub>3</sub>	VOC: <input type="checkbox"/>	CCME	ABNs	PAHs	Chloro	PCBs	Organic	TCLP M	TCLP:	Sewer	Corrosi	sulph	chlor			
(S-04-1) - SS8	20-Sept-22			1	17.5'																	X	X	X			
(S-01-1) - SS5	20-Sept-22			1	10'																	X	X	X			
(HL-08) - SS5	20-Sept-22			1	10'																	X	X	X			
(S-03) - SS6	20-Sept-22			1	12.5'																	X	X	X			
(EL-04-4) - SS6	20-Sept-22			1	12.5'																	X	X	X			
(HB-01) - SS6	20-Sept-22			1	15'																	X	X	X			
(HL-11) - SS6	20-Sept-22			1	12.5'																	X	X	X			
(HL-15-1) - SS9	20-Sept-22			1	20'																	X	X	X			
(HL-10) - SS4	20-Sept-22			1	7.5'																	X	X	X			
(HL-17) - SS5	20-Sept-22			1	10'																	X	X	X			
(HL 14) SS4	20 Sept 22			1	7.5'																	X	X	X			
(HL-12) - SS2	20-Sept-22			1	2.5'																	X	X	X			

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:





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## Ph.: 905.712.5100 • Fax: 905.712.5122 • Toll Free: 800.856.6261

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.

Same: Yes ☒ No ☐

Company: \_\_\_\_\_  
Contact: \_\_\_\_\_  
Address: \_\_\_\_\_

**GW** Ground Water    **O** Oil  
**SW** Surface Water    **P** Paint  
**SD** Sediment        **S** Soil

1. Name: Amoldeep Gill  
Email: amoldeep.gill@stantec.com
2. Name: Gwangha Roh  
Email: gwangha.roh@stantec.com

Regulation 153/09  
(reg. 511 Amend.)

Table

---

Indicate one

- ☐ Ind/Com
- ☐ Res/Park
- ☐ Agriculture

Soil Texture (check one)

- ☐
- Coarse
- ☐
- Fine

**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*

☐ Sewer Use

Region \_\_\_\_\_  
Indicate one

- ☐ Sanitary
- ☐ Storm

Regulation 558

- ☐ CCME
- ☐ Other (specify) \_\_\_\_\_

#### Prov. Water Quality Objectives (PWQO)

☐ None

Is this submission for a **Record of Site Condition?**

- ☐
- Yes
- ☐
- No

[illegible]

Samples Relinquished by (print name & sign):

Date/Time
-----------

Samples Received by (Print name & sign):

[illegible]

Pink Copy - Client

Yellow + Golden Copy – AGAT

White Copy - AGAT

Page        of       

NO:

Document ID: DIV-78-1511.006

Date Issued: July 20, 2011





# AGAT

# Laboratories

## Sample Temperature Log

Client: STANTEC

COC# or Work Order#: \_\_\_\_\_

# of Coolers: 3 boxes

# of Submissions: \_\_\_\_\_

Arrival Temperatures - Branch/Driver

Arrival Temperatures - Laboratory

Cooler #1: 19.8 / 20.0 / 20.1

Cooler #1: \_\_\_\_\_ / \_\_\_\_\_ / \_\_\_\_\_

Cooler #2: 18.7 / 18.8 / 19.3

Cooler #2: \_\_\_\_\_ / \_\_\_\_\_ / \_\_\_\_\_

Cooler #3: 19.7 / 19.8 / 19.9

Cooler #3: \_\_\_\_\_ / \_\_\_\_\_ / \_\_\_\_\_

Cooler #4: \_\_\_\_\_ / \_\_\_\_\_ / \_\_\_\_\_

Cooler #4: \_\_\_\_\_ / \_\_\_\_\_ / \_\_\_\_\_

Cooler #5: \_\_\_\_\_ / \_\_\_\_\_ / \_\_\_\_\_

Cooler #5: \_\_\_\_\_ / \_\_\_\_\_ / \_\_\_\_\_

Cooler #6: \_\_\_\_\_ / \_\_\_\_\_ / \_\_\_\_\_

Cooler #6: \_\_\_\_\_ / \_\_\_\_\_ / \_\_\_\_\_

Cooler #7: \_\_\_\_\_ / \_\_\_\_\_ / \_\_\_\_\_

Cooler #7: \_\_\_\_\_ / \_\_\_\_\_ / \_\_\_\_\_

Cooler #8: \_\_\_\_\_ / \_\_\_\_\_ / \_\_\_\_\_

Cooler #8: \_\_\_\_\_ / \_\_\_\_\_ / \_\_\_\_\_

Cooler #9: \_\_\_\_\_ / \_\_\_\_\_ / \_\_\_\_\_

Cooler #9: \_\_\_\_\_ / \_\_\_\_\_ / \_\_\_\_\_

Cooler #10: \_\_\_\_\_ / \_\_\_\_\_ / \_\_\_\_\_

Cooler #10: \_\_\_\_\_ / \_\_\_\_\_ / \_\_\_\_\_

IR Gun ID: \_\_\_\_\_

IR Gun ID: \_\_\_\_\_

Taken By: \_\_\_\_\_

Taken By: \_\_\_\_\_

Date

Date (mm/dd/yy): \_\_\_\_\_ Time: \_\_\_\_\_ AM / PM

Date (mm/dd/yy): \_\_\_\_\_ Time: \_\_\_\_\_ AM / PM

Instructions for use of this form: 1) complete all fields of info including total # of coolers and # of submissions, 2) Print and copy and paste in each submission prior to giving a WOH, 3) Proceed as normal, write the WOH and scan (please make sure to scan the WOH and the form).

Document ID: SR-78-9511-003

Date Issued: 2017-2-23

Page: \_\_\_\_\_ of \_\_\_\_\_

## APPENDIX E

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

DRAFT



# 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: 42.936N 81.184W

User File Reference: Elliot Laidlaw Drain Culvert

2022-10-30 08:37 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)	0.120	0.072	0.045	0.014
Sa (0.2)	0.111	0.068	0.044	0.015
Sa (0.3)	0.092	0.057	0.038	0.014
Sa (0.5)	0.071	0.045	0.030	0.011
Sa (1.0)	0.041	0.027	0.018	0.005
Sa (2.0)	0.021	0.013	0.008	0.002
Sa (5.0)	0.005	0.003	0.002	0.001
Sa (10.0)	0.002	0.001	0.001	0.000
PGA (g)	0.067	0.040	0.025	0.008
PGV (m/s)	0.056	0.034	0.021	0.006

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

## References

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

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

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

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



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