



**THURBER** ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
DEEP FILL CULVERT  
HIGHWAY 101, 7.3 KM EAST OF HIGHWAY 672 JUNCTION,  
STA. 12+700, HOLLOWAY TOWNSHIP  
ASSIGNMENT NO. 5018-E-0010, WORK ITEM NO. 9**

**GEOCRES NO.: 32D-36**

Report to:

**Ministry of Transportation Ontario, Northeastern Region**

Latitude: 48.521°  
Longitude: -79.721°

January 2022  
Thurber File No.: 31935



## TABLE OF CONTENTS

### PART 1. FACTUAL INFORMATION

1	INTRODUCTION .....	1
2	SITE DESCRIPTION .....	1
3	SITE INVESTIGATION AND FIELD TESTING.....	2
4	LABORATORY TESTING .....	3
5	DESCRIPTION OF SUBSURFACE CONDITIONS .....	3
5.1	Asphalt .....	4
5.2	Embankment Fill.....	4
5.2.1	Granular Fill .....	4
5.2.2	Clay Fill.....	5
5.3	Topsoil .....	5
5.4	(CI/CH) Clay .....	6
5.5	(SM) Silty Sand trace to with gravel and (SP-SM) Sand with Silt and Gravel – Till .	7
5.6	Refusal and Bedrock .....	7
5.7	Groundwater .....	8
5.8	Results of Analytical Tests .....	8
6	MISCELLANEOUS .....	9

### APPENDICES

APPENDIX A. DRAWINGS

APPENDIX B. RECORD OF BOREHOLE SHEETS

APPENDIX C. LABORATORY TESTING

APPENDIX D. SITE PHOTOGRAPHS



**FOUNDATION INVESTIGATION AND DESIGN REPORT  
DEEP FILL CULVERT  
HIGHWAY 101, 7.3 KM EAST OF HIGHWAY 672 JUNCTION,  
STA. 12+700, HOLLOWAY TOWNSHIP  
ASSIGNMENT NO. 5018-E-0010, WORK ITEM NO. 9**

**GEOCRES NO.: 32D-36**

**PART 1. FACTUAL INFORMATION**

## **1 INTRODUCTION**

This section of the report presents the factual findings obtained from a foundation investigation completed at a deep fill culvert located near Station 12+700 on Highway 101, approximately 7.3 km east of the Highway 672 Junction in Holloway Township. Thurber Engineering Ltd. (Thurber) carried out this investigation as a consultant to the Ministry of Transportation Ontario (MTO, or the Ministry) Northeastern Region under Assignment No. 5018-E-0010, Work Item No. 9.

The purpose of this investigation was to explore the subsurface conditions at the site and based on the data obtained, to provide a borehole location plan, records of boreholes, stratigraphic profile, laboratory test results, and a written description of the subsurface conditions. A model of the subsurface conditions influencing design and construction was developed in the course of the current investigation. No historical foundation investigation reports were available for this site within the online Geocres library.

## **2 SITE DESCRIPTION**

The existing culvert is described as a 37 m long corrugated steel pipe (CSP) with a diameter of 900 mm. The embankment at this location is approximately 5.2 m high and the side slopes are inclined at approximately 2.5H:1V to 3H:1V.

At the location of the culvert, Highway 101 is a two-lane wide asphalt paved roadway with narrow paved shoulders. It is understood that the AADT for this portion of Highway 101 in 2016 was approximately 500 including 150 trucks. Steel cable guiderails with wooden posts are present along both sides of the highway. The land area adjacent to the highway is undeveloped and heavily vegetated with trees and shrubs.

The depth of water in the creek was approximately 20 mm at the time of the investigation. An erosion-derived void was present approximately 250 mm below the upstream invert, and it appears that surface water flow from the creek was flowing through the embankment rather than the culvert. The pipe inlet was also significantly deformed. No other signs of distress were



observed on the embankment side slopes. The upstream and downstream invert elevations were surveyed to be approximately 291.1 and 290.4 m, respectively. The elevation of the road surface was surveyed to be approximately 296.3 m.

Select photographs showing the existing conditions at the time of the field investigation are included in Appendix D for reference.

### 3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing program was carried out between July 20 and 22, 2021. The field investigation consisted of advancing two on-road foundation boreholes (identified as 21-01 and 21-02), two off-road foundation boreholes (identified as 21-03 and 21-04), and four on-road pavement augerholes (identified as 21-05 through 21-08). Prior to commencement of drilling, utility clearances were obtained in the vicinity of the borehole locations.

A summary of the borehole locations, ground surface elevations, and termination depths is provided in Table 3-1. The borehole elevations were surveyed with a Nikon AP-8 auto level, with a reported accuracy of 1.5 mm. The elevations were surveyed relative to the obvert of the culvert at the downstream end, which has a geodetic elevation of approximately 291.2 m (per the MTO). The site is within MTM Zone 12.

**Table 3-1: Borehole Summary**

Borehole ID.	Drilled Location	Northing (m) (Latitude°)	Easting (m) (Longitude°)	Existing Ground Surface Elevation (m)	Termination Depth Below Existing Ground Surface (m)
21-01	1 m west of culvert (WB lane)	5 376 650.1 (48.52134°)	399 243.7 (79.72135°)	296.3	16.1
21-02	4 m east of culvert (EB lane)	5 376 646.9 (48.52131°)	399 241.4 (79.72139°)	296.3	14.2
21-03	culvert outlet	5 376 629.4 (48.52115°)	399 250.6 (79.72126°)	290.4	1.5
21-04	culvert inlet	5 376 664.7 (48.52147°)	399 240.8 (79.72139°)	291.1	1.5
21-05	30 m west of culvert (WB lane)	5 376 644.4 (48.52129)	399 215.3 (79.72174)	296.8	1.2
21-06	70 m west of culvert (WB lane)	5 376 637.3 (48.52123)	399 175.9 (79.72227)	297.3	2.8
21-07	70 m east of culvert (WB lane)	5 376 664.1 (48.52145)	399 313.4 (79.72041)	296.5	0.9
21-08	30 m east of culvert (WB lane)	5 376 656.5 (48.52139)	399 274.2 (79.72094)	296.3	2.7



The on-road foundation boreholes and pavement augerholes were advanced with a truck mounted CME 75 drill rig. The off-road boreholes were advanced with a manual hand-auger.

Within Boreholes 21-01 and 21-02, soil samples were obtained at near continuous intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) in accordance with ASTM D 1586. At the remaining boreholes, soil samples were collected as grab samples from the auger flights. Upon achieving practical refusal in Borehole 21-01, the bedrock was cored using HQ sized bedrock coring equipment.

The drilling and sampling operations were supervised on a full-time basis by a member of Thurber's geotechnical staff. The drilling supervisor logged the boreholes and processed the recovered soil and bedrock samples for transport to Thurber's laboratory for further examination and testing.

The boreholes were backfilled with bentonite holeplug and sealed with cold patch at the road surface.

The approximate borehole locations are shown on the Borehole Locations and Soil Strata Drawing included in Appendix A. The coordinates and elevations of the boreholes are provided on this drawing, Table 3-1 above, and on the Record of Borehole sheets included in Appendix B.

#### **4 LABORATORY TESTING**

Geotechnical laboratory testing consisted of natural moisture content determination and visual identification of all retained soil samples. Grain size distribution and Atterberg limits testing was also carried out on selected samples to MTO and ASTM standards. All rock cores were photographed and their total core recovery (TCR), solid core recovery (SCR) and rock quality designation (RQD) were measured. Chemical analysis for determination of pH, conductivity, resistivity, sulphate, sulphide and chloride concentrations was carried out on one sample.

The results of the geotechnical tests are summarized on the Record of Borehole sheets included in Appendix B and all laboratory results are presented on the figures included in Appendix C.

#### **5 DESCRIPTION OF SUBSURFACE CONDITIONS**

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix B and the Borehole Location and Soil Strata drawing included in Appendix A. A general description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following paragraphs. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description for interpretation of the site conditions. It must be recognized that the soil, bedrock and groundwater conditions will vary between and beyond borehole locations.



In general terms, the encountered stratigraphy consisted of asphalt and embankment fill overlying native deposits of clay and glacial till, which in turn is underlain by greenschist bedrock.

The soil classifications in this report are in accordance with ASTM D2487. Cohesive soils are described per current MTO protocols.

## 5.1 Asphalt

The asphalt encountered in Boreholes 21-01, 21-02, and 21-05 through 21-08 ranged in thickness from 90 to 110 mm. A 50 to 60 mm thick layer of buried asphalt was also encountered in Boreholes 21-06, 21-07 and 21-08 at a depth of approximately 0.3 to 0.5 m.

## 5.2 Embankment Fill

### 5.2.1 Granular Fill

Granular embankment fill ranging in composition from gravelly sand with silt, to silty gravel, to silty sand with gravel, to sand with silt and gravel was encountered below the asphalt in all of the on-road boreholes (21-01, 21-02, and 21-05 through 21-08). Occasional cobbles, boulders and recycled asphalt were noted in the granular fill. The granular fill varied in thickness from approximately 0.9 to 2.0 m and extended to base elevations ranging from approximately 294.2 to 296.4 m.

SPT N-Values within the granular fill generally ranged from 17 to 93 blows, indicating a compact to very dense relative density. One SPT refusal indicating 100 blows for 125 mm of penetration was also recorded within the fill; however, this refusal may represent the presence of cobbles or a boulder within the fill rather than the relative density of the soil matrix. Refusal on cobbles, boulders or rock fill was encountered in Boreholes 21-05 and 21-07 at depths of 1.2 and 0.9 m, respectively.

Recorded moisture contents of the granular fill ranged from 4 to 20%. The gradation analyses completed on two samples of the granular fill are illustrated on Figure C1 of Appendix C. The results of the tests are summarized below and are presented on the corresponding Record of Borehole sheets in Appendix B.

Soil Particle	Percentage (%)
Gravel	30 - 40
Sand	53 - 62
Silt	7 - 8
Clay	



### 5.2.2 Clay Fill

A layer of clay fill, classified as clay with gravel to clayey gravel, was encountered below the granular fill in Boreholes 21-01, 21-02, 21-04, 21-06, and 21-08. The clay fill had a thickness ranging from approximately 0.2 to 2.3 m with a base depth ranging from approximately 0.4 to 3.8 m below the existing ground surface (elevation 290.7 to 295.3 m).

A 200 mm nominally sized boulder was encountered within the clay fill layer in Borehole 21-01 at a depth of approximately 3.0 m (elevation 293.3 m). Rotary diamond drilling techniques were required to advance the borehole past this boulder.

SPT N-Values within the clay fill ranged from 7 to 13 blows.

Recorded moisture contents of the clay fill ranged from 36 to 48%.

The gradation analyses completed on two samples of the clay fill are illustrated on Figure C2 of Appendix C. The results of the tests are summarized below and are presented on the corresponding Record of Borehole sheets in Appendix B.

Soil Particle	Percentage (%)
Gravel	21 - 46
Sand	5 - 6
Silt	13 - 21
Clay	36 - 52

Atterberg Limit testing was completed on two samples of the clay fill. The results of the Atterberg Limit testing are summarized below and are illustrated on Figure C5 in Appendix C. The test results are also presented on the corresponding Record of Borehole sheets in Appendix B. The laboratory results indicate that the clay fill samples that were tested are of high plasticity.

Parameter	Value
Liquid Limit	62 - 66
Plastic Limit	25 - 26
Plasticity Index	37 - 40

### 5.3 Topsoil

Surficial topsoil was encountered at off-road Boreholes 21-03 and 21-04. The thickness of the topsoil at these locations ranged was approximately 150 to 200 mm.

#### 5.4 (CI/CH) Clay

A native deposit of clay was encountered below the embankment fill in Boreholes 21-01, 21-02, 21-03, 21-04, 21-06 and 21-08. Where fully penetrated (in Boreholes 21-01 and 21-02), the clay deposit had a thickness ranging from approximately 6.3 to 6.6 m, with a base depth of approximately 10.1 to 10.4 m below the existing ground surface (elevation 285.9 to 286.2 m). The clay was not fully penetrated in Boreholes 21-03, 21-04, 21-06, or 21-08 where the clay extended deeper than the target borehole depth (1.5 to 2.8 m below the existing ground surface).

The upper portion of the clay has generally been weathered to a grey-brown crust. SPT tests conducted in the grey-brown weathered crust gave N-values ranging from 4 to 6 blows, indicating a very stiff consistency for the weathered crust. Recorded moisture contents of the weathered crust ranged from 32% to 68%.

Unweathered grey clay was encountered beneath the weathered crust in Boreholes 21-01 and 21-02. SPT tests conducted in the grey clay gave N-values ranging from Weight of Hammer (WH) to 7 blows. Field vane testing carried out within the grey clay gave undrained shear strength values ranging from 44 to 52 kPa, indicating a firm to stiff consistency. Remolded field vane testing indicates that the clay is sensitive to extra-sensitive. Recorded moisture contents of the grey clay ranged from 28 to 59%.

The gradation analyses completed on four samples of the clay (two on weathered crust and two on unweathered grey clay) are illustrated on Figure C3 of Appendix C. The results of the tests are summarized below and are presented on the corresponding Record of Borehole sheets in Appendix B.

Soil Particle	Percentage (%)
Gravel	0
Sand	0 - 3
Silt	28 - 55
Clay	45 - 71

Atterberg Limit testing was completed on four samples of the clay (two on the weathered crust and two on the unweathered grey clay). The results of the Atterberg Limit testing are summarized below and are illustrated on Figure C6 in Appendix C. The test results are also presented on the corresponding Record of Borehole sheets in Appendix B. The laboratory results indicate that the clay samples that were tested are of intermediate to high plasticity (CI/CH).



Parameter	Value
Liquid Limit	35 - 65
Plastic Limit	21 - 29
Plasticity Index	14 - 39

### 5.5 (SM) Silty Sand trace to with gravel and (SP-SM) Sand with Silt and Gravel – Till

A deposit of glacial till was encountered below the clay in Boreholes 21-01 and 21-02. The till deposit was approximately 3.8 to 4.5 m thick with a base depth of approximately 14.2 to 14.6 m (elevation 281.7 to 282.1 m). The till varied in composition from silty sand trace to with gravel, to sand with silt and gravel, and contained occasional cobbles and boulders.

SPT N-values ranged from 28 blows for 300 mm penetration to 100 blows for 225 mm penetration, indicating a compact to very dense relative density. Recorded moisture contents ranged from 4 to 16%.

The results of a grain size analysis completed on two samples from this deposit are illustrated on Figure C4 of Appendix C. The results are summarized below and are presented on the corresponding Record of Borehole sheets in Appendix B.

Soil Particle	Percentage (%)
Gravel	4 - 28
Sand	61 - 63
Silt	10 - 30
Clay	1 - 3

### 5.6 Refusal and Bedrock

Bedrock underlying the overburden was proven by coring in Borehole 21-01. Practical refusal to borehole advancement was encountered at a similar elevation in Borehole 21-02 and is therefore inferred to represent the bedrock surface; however, it should be noted that practical refusal may also be due to a boulder within the glacial till. The depths and elevations of the bedrock surface is summarized in the following table:

Borehole No.	Depth to Bedrock (mbgs)	Bedrock Surface Elevation (m)
21-01	14.6	281.7
21-02	14.2*	282.1*

\* inferred from practical refusal to borehole advancement



The bedrock encountered consisted of fresh greenschist. The Total Core Recovery (TCR) measured on the recovered bedrock core was 98%, the Solid Core Recovery (SCR) was 62% and the Rock Quality Designation (RQD) was 62%. Based on the measured RQD values, the bedrock quality is classified as fair. Photographs of the bedrock core are provided in Appendix C.

## 5.7 Groundwater

Wash-boring techniques were used to advance the boreholes and therefore accurate groundwater levels could not be observed in the open boreholes during the investigation due to the water that was introduced to the boreholes. The water depth in the creek at the culvert outlet was observed to be approximately 0.1 m at the time of the investigation which corresponds to an approximate elevation of 290.3 m. These observations are considered short term and it should be noted that the level at the time of construction may be different and seasonal fluctuations of the groundwater and surface water level are to be expected. In particular, the levels may be at a higher elevation after periods of significant and/or prolonged precipitation

## 5.8 Results of Analytical Tests

One soil sample was selected and submitted for analysis of pH, sulphate, sulphide and chloride concentrations, and resistivity. The analysis results are included in Appendix C and are summarized in the following table.

Borehole	21-01
Sample	SS5
Depth (m)	3.8 – 4.4
Elevation (m)	292.2
Material	Clay
pH ( - )	7.39
Resistivity (Ohm-cm)	2,250
Chloride (ug/g)	108
Sulphate (ug/g)	12
Sulphide (%)	<0.04



## 6 MISCELLANEOUS

Borehole locations were selected relative to existing site features and anticipated foundation locations. Ground surface elevations at the investigated locations were recorded in relation to the obvert of the existing culvert, the geodetic elevation of which was provided by the MTO.

George Downing Estate Drilling from Hawkesbury, Ontario supplied and operated the drill rig to carry out the drilling, sampling, in-situ testing, and borehole decommissioning. Traffic control was provided by Beacon Lite of Kirkland Lake, Ontario. The field investigations were supervised by Anderson de Oliveira, EIT, of Thurber. Overall supervision of the investigation program was conducted by Stephen Dunlop, P.Eng. Routine geotechnical laboratory testing was carried out by Thurber's geotechnical laboratory in Ottawa, Ontario. Analytical testing was carried out by Paracel Laboratories Ltd. in Ottawa, Ontario. Interpretation of the data and preparation of this report were carried out by Lena Bryan, EIT, and Stephen Dunlop, P.Eng. The report was reviewed by Dr. Fred Griffiths, P.Eng., a Designated Principal Contact for MTO Foundation Projects.

Lena Bryan  
Geo-environmental EIT



Stephen Dunlop, M.A.Sc., P.Eng.  
Associate, Senior Geotechnical Engineer



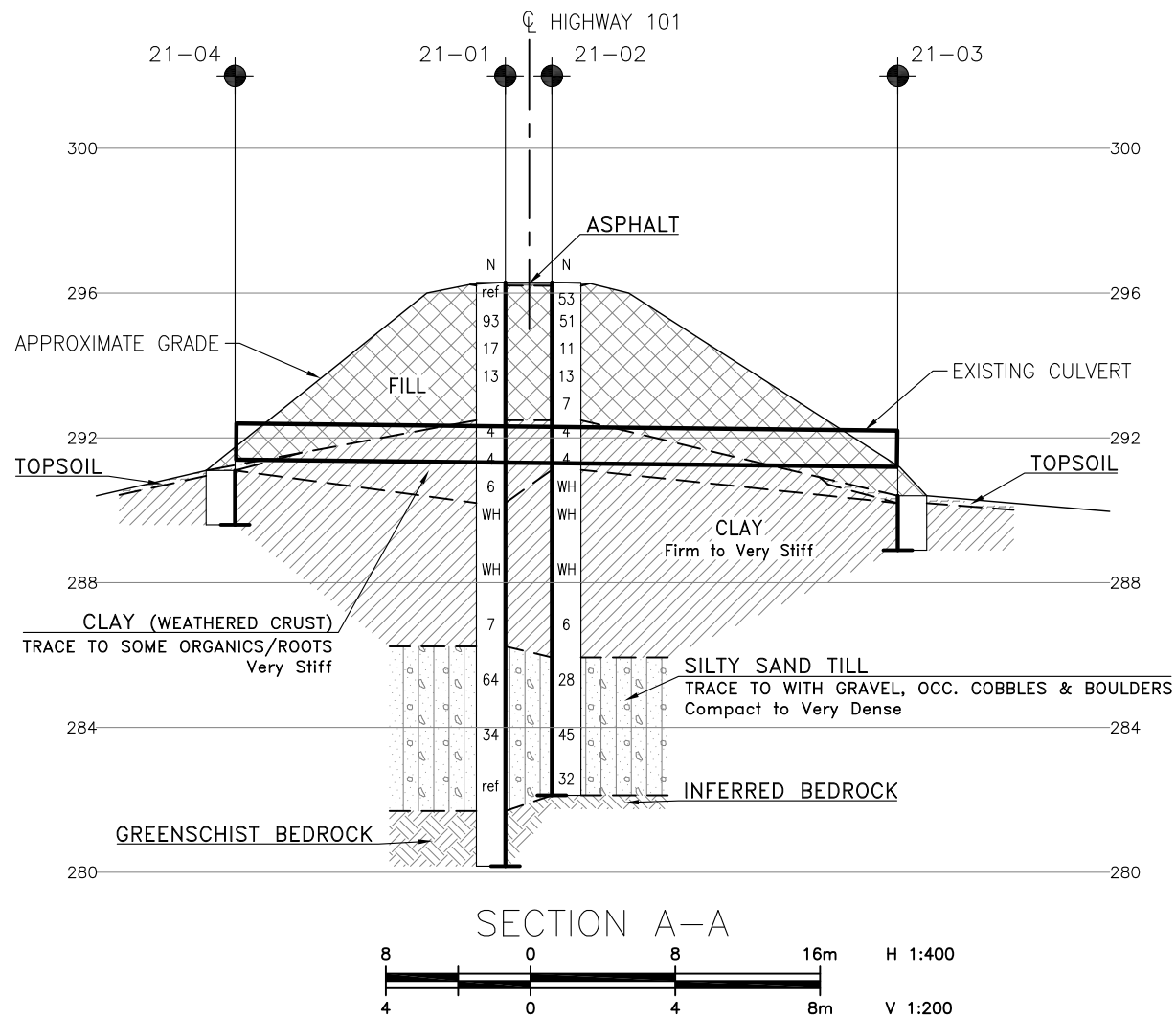
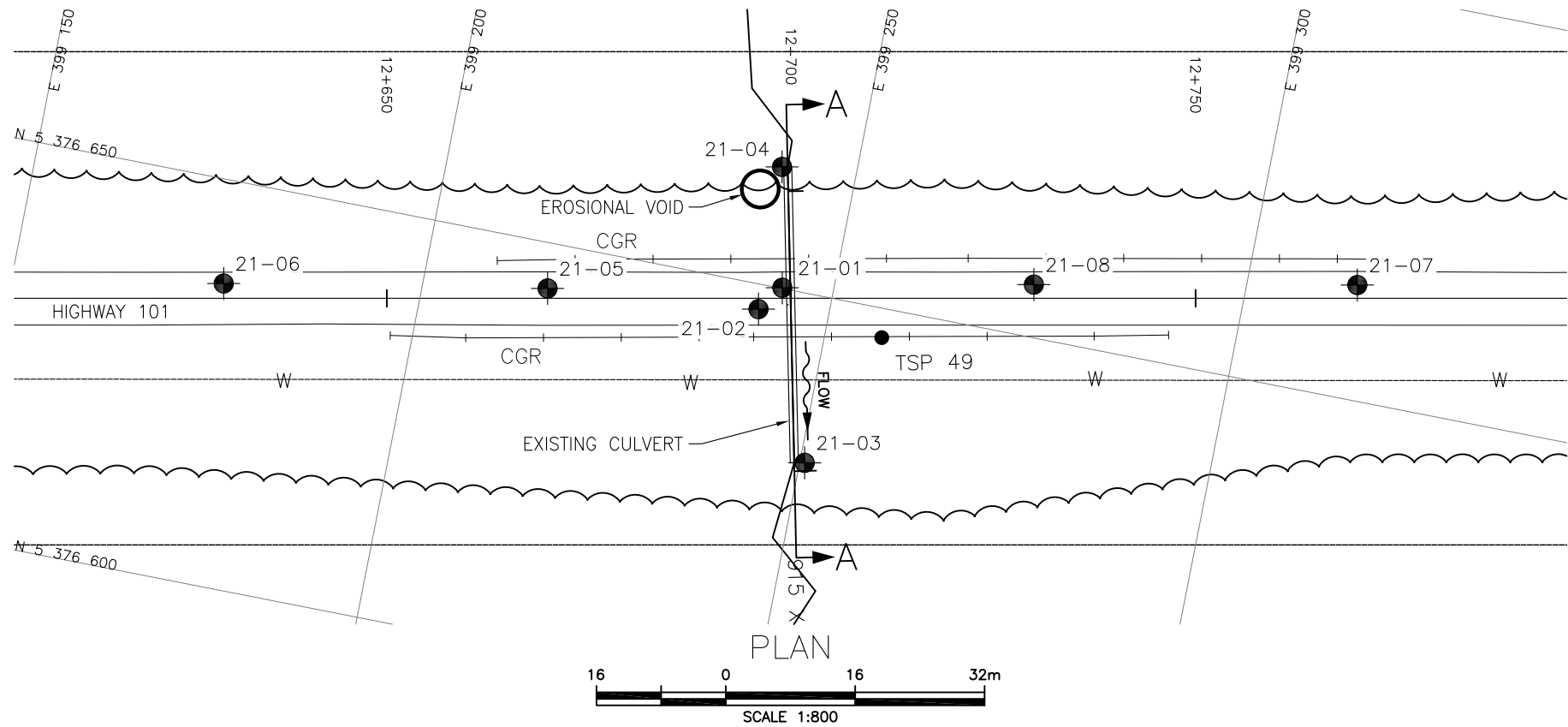
Fred Griffiths, P.Eng., Ph.D.  
Senior Associate  
Senior Geotechnical Engineer



## **Appendix A.**

### **Drawings**

Client: Ministry of Transportation Ontario, Northeastern Region  
File No. 31935  
e-File: 31935 tel fir hwy101 culvert



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

CONT No  
WP No

HIGHWAY 101  
DEEP FILL  
CULVERT REPLACEMENT  
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET



KEYPLAN

LEGEND

●	Borehole
⊙	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
≡	Water Level
≡	Head Artesian Water
≡	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
21-01	296.3	5 376 650.1	399 243.7
21-02	296.3	5 376 646.9	399 241.4
21-03	290.4	5 376 629.4	399 250.6
21-04	291.1	5 376 664.7	399 240.8
21-05	296.8	5 376 644.4	399 215.3
21-06	297.3	5 376 637.3	399 175.9
21-07	296.5	5 376 664.1	399 313.4
21-08	296.3	5 376 656.5	399 274.2

-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.
- Coordinate system is MTM NAD 83 Zone 12.

GEOCRES No. 32D-36

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	AO	CHK SD	CODE
DRAWN	MFA	CHK LB	SITE
LOAD	DATE	DEC 2021	DWG 1



## **Appendix B.**

### **Record of Borehole Sheets**

Client: Ministry of Transportation Ontario, Northeastern Region  
File No. 31935  
e-File: 31935 tel fir hwy101 culvert



## SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS

### TERMINOLOGY DESCRIBING COMMON SOIL GENESIS

Topsoil	mixture of soil and humus capable of supporting vegetative growth
Peat	mixture of fragments of decayed organic matter
Till	unstratified glacial deposit which may include particles ranging in sizes from clay to boulder
Fill	material below the surface identified as placed by humans (excluding buried services)

### TERMINOLOGY DESCRIBING SOIL STRUCTURE:

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

### RECOVERY:

For soil samples, the recovery is recorded as the length of the soil sample recovered.

### N-VALUE:

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 63.5 kg hammer falling 0.76 m, required to drive a 50 mm O.D. split spoon sampler 0.3 m into undisturbed soil. For samples where insufficient penetration was achieved and N-value cannot be presented, the number of blows are reported over the sampler penetration in millimetres (e.g. 50/75).

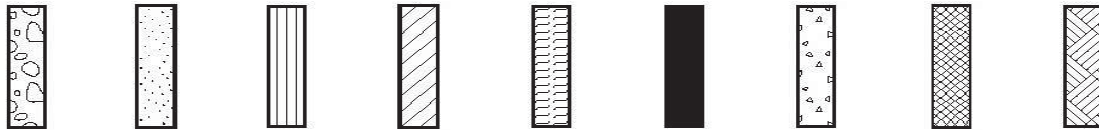
### DYNAMIC CONE PENETRATION TEST (DCPT):

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to an "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 0.3 m into the soil. The DCPT is used as a probe to assess soil variability.



### STRATA PLOT:

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



Boulders  
Cobbles  
Gravel      Sand      Silt      Clay      Organics      Asphalt      Concrete      Fill      Bedrock

### TEXTURING CLASSIFICATION OF SOILS

Classification	Particle Size
Boulders	Greater than 200 mm
Cobbles	75 – 200 mm
Gravel	4.75 – 75 mm
Sand	0.075 – 4.75 mm
Silt	0.002 – 0.075 mm
Clay	Less than 0.002 mm

### TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

Descriptive Term	Undrained Shear Strength (kPa)
Very Soft	12 or less
Soft	12 – 25
Firm	25 – 50
Stiff	50 – 100
Very Stiff	100 – 200
Hard	Greater than 200

NOTE: Clay sensitivity is defined as the ratio of the undisturbed strength over the remolded strength.

### SAMPLE TYPES

SS	Split spoon samples
ST	Shelby tube or thin wall tube
DP	Direct push sample
PS	Piston sample
BS	Bulk sample
WS	Wash sample
HQ, NQ, BQ etc.	Rock core sample obtained with the use of standard size diamond coring equipment

### TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

Descriptive Term	SPT "N" Value
Very Loose	Less than 4
Loose	4 – 10
Compact	10 – 30
Dense	30 – 50
Very Dense	Greater than 50



### MODIFIED UNIFIED SOIL CLASSIFICATION

Major Divisions		Group Symbol	Typical Description
COARSE GRAINED SOIL	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILT AND CLAY SOILS $W_L < 35\%$	ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		OL	Organic silts and organic silty-clays of low plasticity.
	SILT AND CLAY SOILS $35\% < W_L < 50\%$	MI	Inorganic compressible fine sandy silt with clay of medium plasticity, clayey silts.
		CI	Inorganic clays of medium plasticity, silty clays.
		OI	Organic silty clays of medium plasticity.
	SILT AND CLAY SOILS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy of silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other organic soils.

Note -  $W_L$  = Liquid Limit



## EXPLANATION OF ROCK LOGGING TERMS

### ROCK WEATHERING CLASSIFICATION

Fresh (FR)	No visible signs of weathering.
Fresh Jointed (FJ)	Weathering limited to surface of major discontinuities.
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock materials.
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structures are preserved.

### TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.
Solid Core Recovery: (SCR)	Percent ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1 m in length or larger, as a percentage of total core length
Unconfined Compressive Strength: (UCS)	Axial stress required to break the specimen.
Fracture Index: (FI)	Frequency of natural fractures per 0.3 m of core run.

### DISCONTINUITY SPACING

Bedding	Bedding Plane Spacing
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 to 2 m
Medium bedded	0.2 to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 to 60 mm
Laminated	6 to 20 mm
Thinly laminated	Less than 6 mm

### STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength (MPa)
Extremely Strong	Greater than 250
Very Strong	100 – 250
Strong	50 – 100
Medium Strong	25 – 50
Weak	5 – 25
Very Weak	1 – 5
Extremely Weak	0.25 – 1

## METRIC

CHECKED BY SD

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

# RECORD OF BOREHOLE No 21-01

2 OF 2

METRIC

Lat: 48.52134°, Long: 79.72135°  
MTM Zone 12: N 5 376 650.1 E 399 243.7

LOCATION

ORIGINATED BY AO

HWY 101

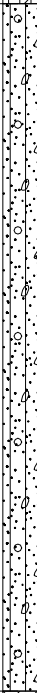

BOREHOLE TYPE Wash-boring with H-sized casing/NQ coring

COMPILED BY LB

DATUM Geodetic

DATE 2021.07.20 - 2021.07.21

CHECKED BY SD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL LIMIT      MOISTURE      LIQUID CONTENT      LIMIT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								○ UNCONFINED      + FIELD VANE				W <sub>P</sub> W      W <sub>L</sub>				
								● QUICK TRIAXIAL      × LAB VANE								
	Continued From Previous Page						20   40   60   80   100					20   40   60				
286.2	(SM) SILTY SAND trace to with gravel grey dense to very dense occasional cobbles and boulders TILL														4   63   30   3	
10.1			11	SS	64											
			12	SS	34											
			13	SS	100/ 225 mm											
281.7	GREENSCHIST BEDROCK fresh grey-green medium grained strong to very strong with quartz veins		1	RUN	-										RUN #1 TCR=98% SCR=62% RQD=62%	
14.6																
280.2	End of Borehole															
16.1	Backfilled with bentonite to surface. Sealed with cold patch.															

DOUBLE LINE TEMPLATE: HWY 101.GPJ 2012TEMPLATE(MTO).GDT 14/9/21

## METRIC

CHECKED BY SD

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 21-02

2 OF 2

METRIC

Lat: 48.52131°, Long: 79.72139°  
MTM Zone 12: N 5 376 646.9 E 399 241.4

LOCATION

ORIGINATED BY AO

HWY 101

BOREHOLE TYPE Wash-boring with H-sized casing

COMPILED BY LB

DATUM Geodetic

DATE 2021.07.21 - 2021.07.21

CHECKED BY SD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL LIQUID LIMIT      MOISTURE CONTENT			UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE				W <sub>P</sub> W      W <sub>L</sub>				
								20   40   60   80   100	20   40   60							
	Continued From Previous Page															
285.9							286									
10.4	(SP-SM) SAND with silt and gravel grey compact to dense occasional cobbles and boulders TILL		1	NQ	-											
			12	SS	28								○		28   61   10   1	
							285									
							284						○			
			13	SS	45											
							283						○			
			14	SS	32											
282.1																
14.2	End of Borehole - refusal on inferred bedrock  Backfilled with bentonite to surface. Sealed with cold patch.															

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity  
20  
15 10 5 10 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 21-03

1 OF 1

METRIC

LOCATION Lat: 48.52115°, Long: 79.72126°  
MTM Zone 12: N 5 376 629.4 E 399 250.6  
 ORIGINATED BY AO  
 HWY 101 BOREHOLE TYPE Hand Auger COMPILED BY LB  
 DATUM Geodetic DATE 2021.07.20 - 2021.07.20 CHECKED BY SD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT						UNIT WEIGHT  $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
290.4								20	40	60	80	100					
0.0	TOPSOIL (200 mm) brown		1	GS	-												
0.2	(Cl) CLAY trace roots, trace sand brown-grey firm to stiff		2	GS	-		290										
288.9							289										
1.5																	

# RECORD OF BOREHOLE No 21-04

1 OF 1

METRIC

Lat: 48.52147°, Long: 79.72139°  
MTM Zone 12: N 5 376 664.7 E 399 240.8

LOCATION

ORIGINATED BY AO

HWY 101

BOREHOLE TYPE Hand Auger

COMPILED BY LB

DATUM Geodetic

DATE 2021.07.20 - 2021.07.20

CHECKED BY SD

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 (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	W P	W	W L	WATER CONTENT (%)		
291.1							20 40 60 80 100							
0.0	TOPSOIL (150 mm)		1	GS	-									
290.7	dark brown		2	GS	-									
0.4	CLAY trace roots, sand and gravel brown FILL													
	(Cl) CLAY trace roots grey firm to stiff		3	GS	-									
289.6														
1.5														



**Highway 101 Deep Fill Culvert  
Holloway Township  
Assignment No.: 5018-E-0034, Work Item No. 9**

**Pavement Borehole Records**

Page 1 of 1

**BH21-05        2 LT C/L (WB) (El. 296.8 m)  
30 m west of culvert**

0	- 110	Asph
110	- 350	Gry-Br Gr(y) Sa W Si and RAP, moist, very D
350	- 700	Br Gr(y) Sa W Si, moist, very D
700	- 1.2	Dk Br Si(y) Sa W Gr, moist, Comp
1.2	- NFP	Cob/Blds/RF

**BH21-06        2 LT CL (WB) (El. 297.3 m)  
70 m west of culvert**

0	- 110	Asph
110	- 260	Dk Br Gr(y) Sa W Si and RAP, moist, very D
260	- 500	Br Sa W Si and Gr, moist, very D
500	- 560	Asph
560	- 900	Dk Br Gr(y) Sa W Si, moist, very D
900	- 2.0	Br Si(y) Cl, tr Gr, moist
2.0	- 2.8	Lt Br Cl, moist, very stiff (native)

**BH21-07        2 LT CL (WB) (El. 296.5 m)  
70 m east of culvert**

0	- 90	Asph
90	- 300	Dk Br Gr(y) Sa W Si, moist, very D
300	- 350	Asph
350	- 600	Br Gr(y) Sa W Si, moist, very D
600	- 900	Dk Br Gr(y) Sa W Si, moist, very D
900	- NFP	Cob/Blds/RF

**BH21-08        2 LT CL (WB) (El. 296.3 m)  
30 m east of culvert**

0	- 90	Asph
90	- 200	Br Gr(y) Sa W Si, moist, very D
200	- 350	Dk Br Gr(y) Sa W Si, moist, very D
350	- 400	Asph
400	- 650	Br Gr(y) Sa W Si, moist, very D
650	- 900	Dk Br Gr(y) Sa W Si, Occ Cob and Asph, moist, D
900	- 2.2	Br Si(y) Cl, tr Sa and Gr, moist
2.2	- 2.7	Br Cl, moist, very stiff (native)



## **Appendix C.**

### **Laboratory Testing**

Client: Ministry of Transportation Ontario, Northeastern Region  
File No. 31935  
e-File: 31935 tel fir hwy101 culvert



## **Appendix C.1**

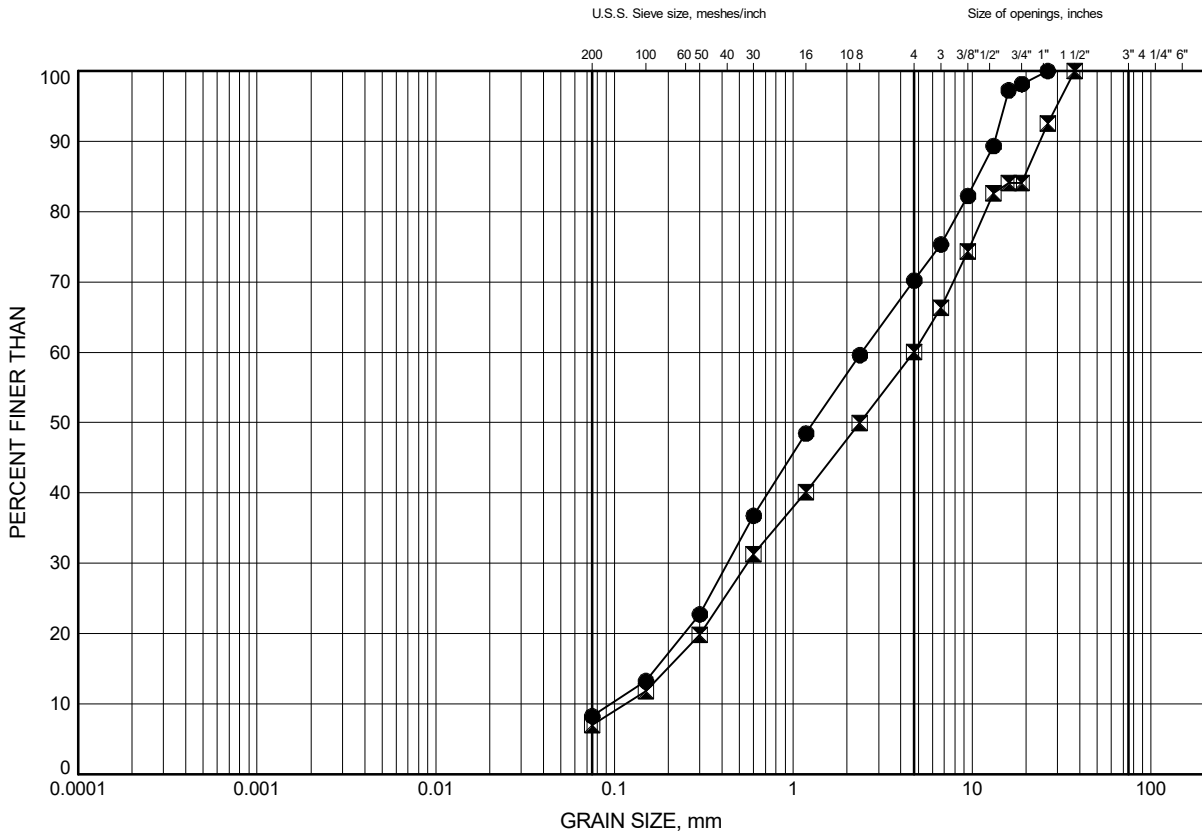
### **Particle Size Analysis and Atterberg Limits**

Client: Ministry of Transportation Ontario, Northeastern Region  
File No. 31935  
e-File: 31935 tel fir hwy101 culvert

# Highway 101 Deep Fill Culvert GRAIN SIZE DISTRIBUTION

FIGURE C1

## GRAVELLY SAND FILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	21-01	1.1	295.2
⊠	21-02	1.1	295.2

Date December 2021  
.....

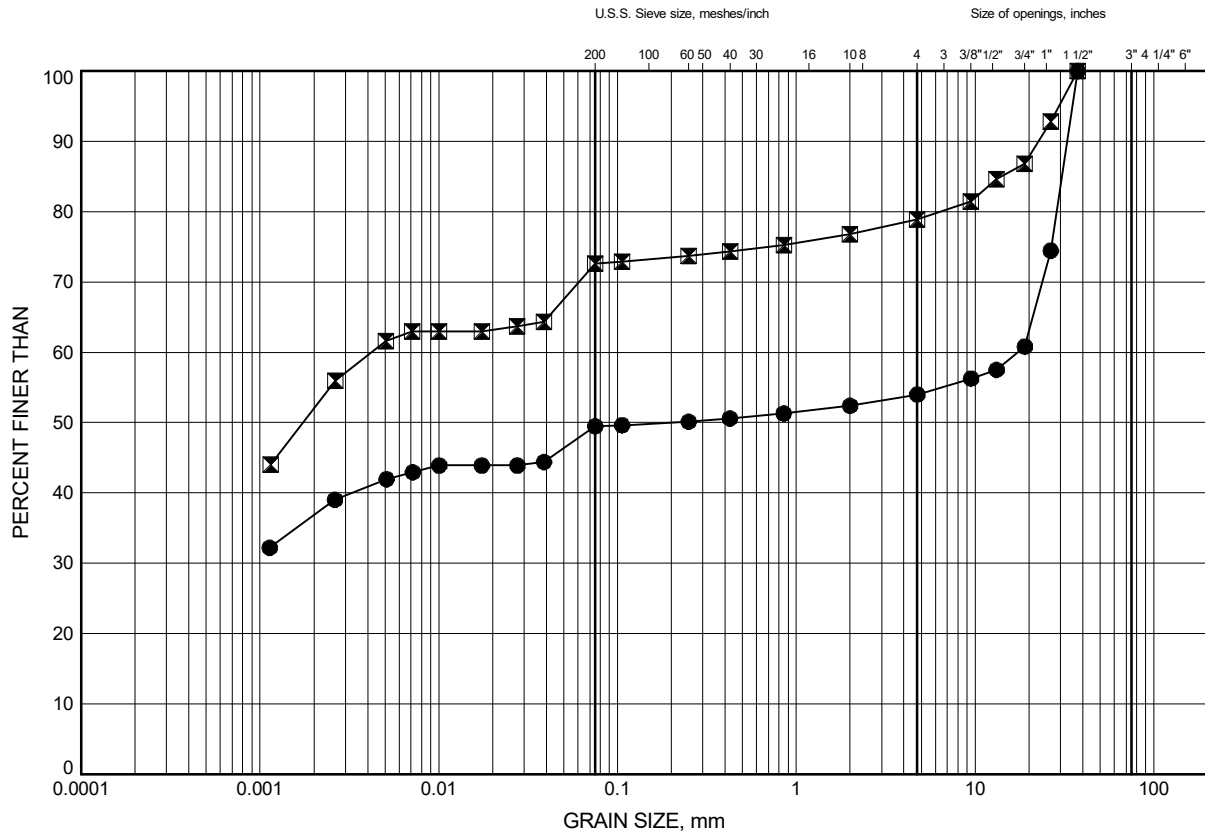


Prep'd SH  
Chkd. SD

# Highway 101 Deep Fill Culvert GRAIN SIZE DISTRIBUTION

FIGURE C2

## CLAY with gravel FILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

## LEGEND

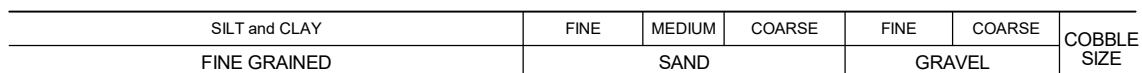
SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	21-01	2.6	293.7
⊠	21-02	1.8	294.5

Date December 2021



Prep'd SH  
Chkd. SD

## FIGURE C3



SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	21-01	4.9	291.4
☒	21-01	7.9	288.4
▲	21-02	4.1	292.2
★	21-02	7.9	288.4

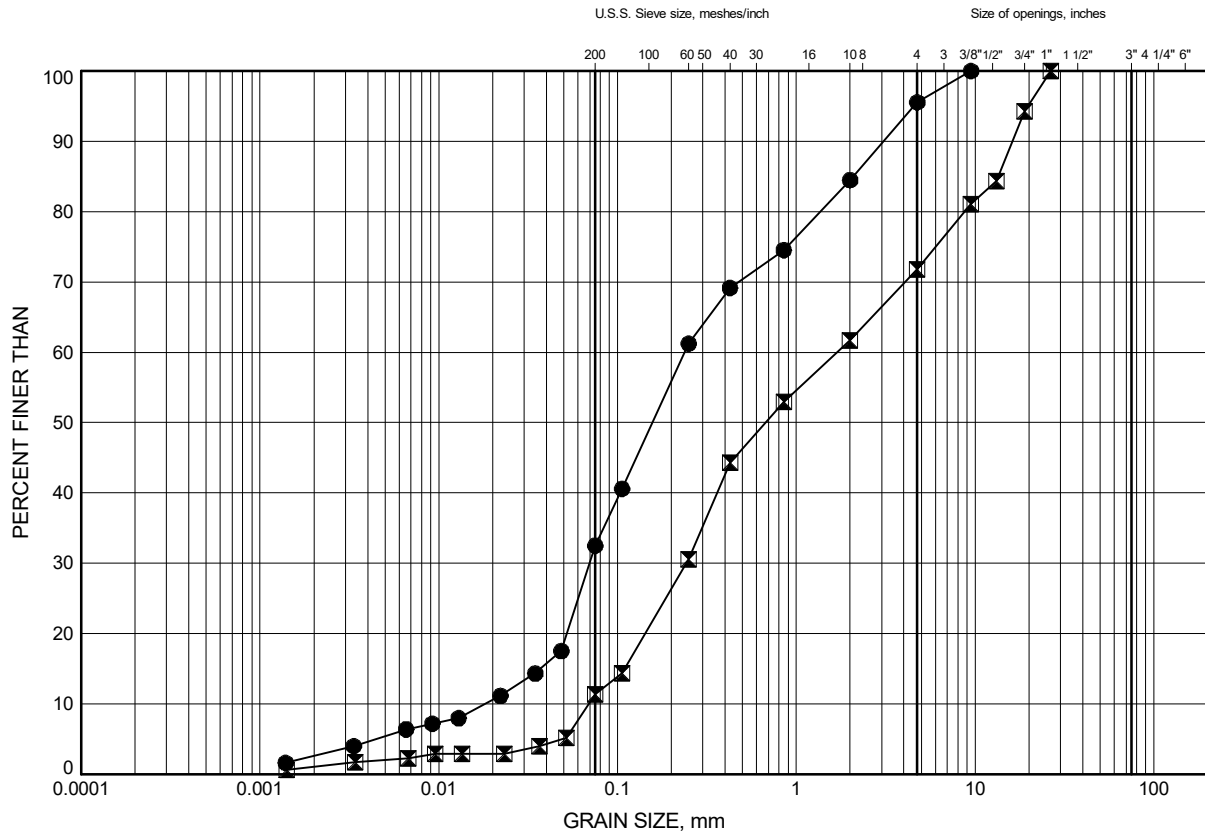


Prep'd .....SH.....  
Chkd. ....SD.....

# Highway 101 Deep Fill Culvert GRAIN SIZE DISTRIBUTION

FIGURE C4

## SAND with silt and gravel (TILL)



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	21-01	12.5	283.8
⊠	21-02	11.0	285.3

Date December 2021

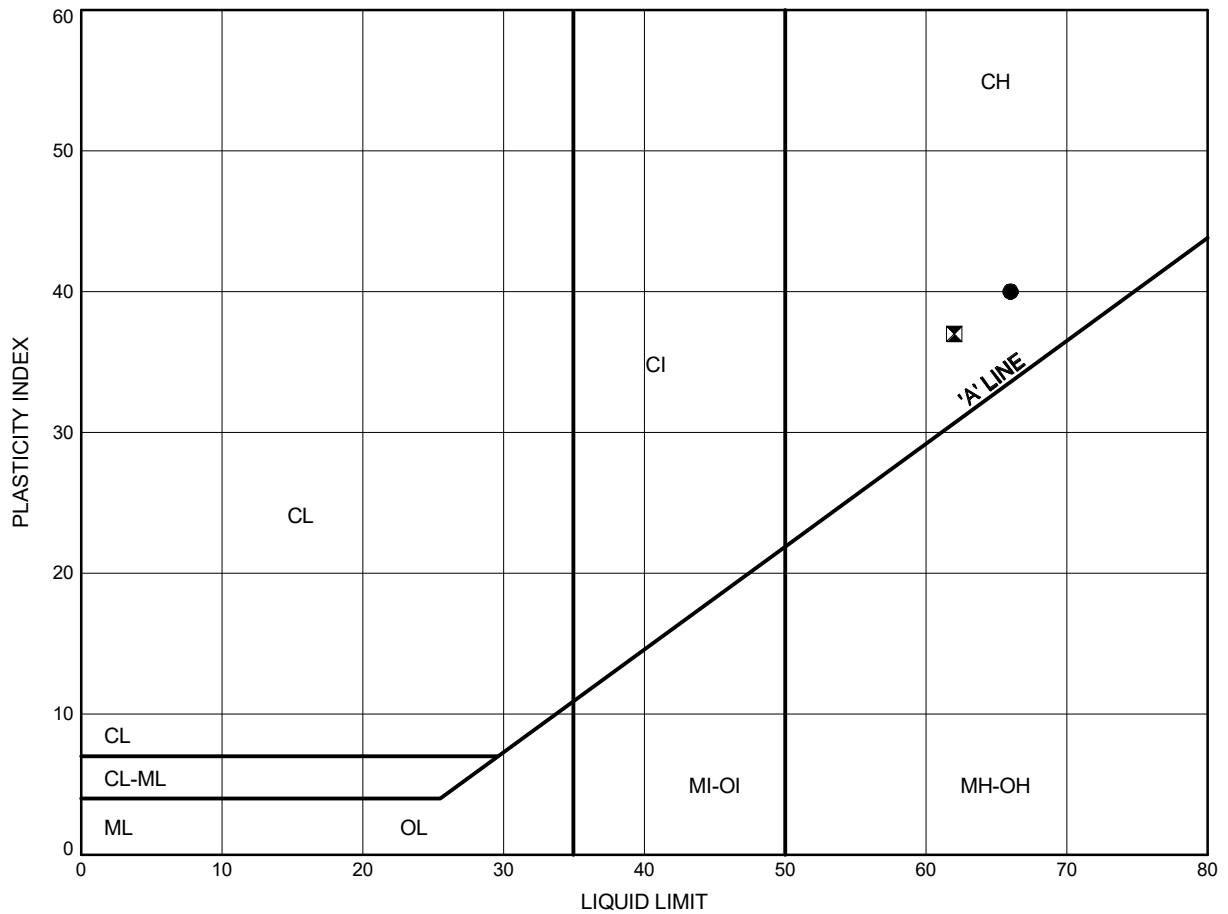


Prep'd SH  
Chkd. SD

# Highway 101 Deep Fill Culvert ATTERBERG LIMITS TEST RESULTS

FIGURE C5

### CLAY FILL



### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	21-01	2.6	293.7
⊠	21-02	1.8	294.5

Date December 2021

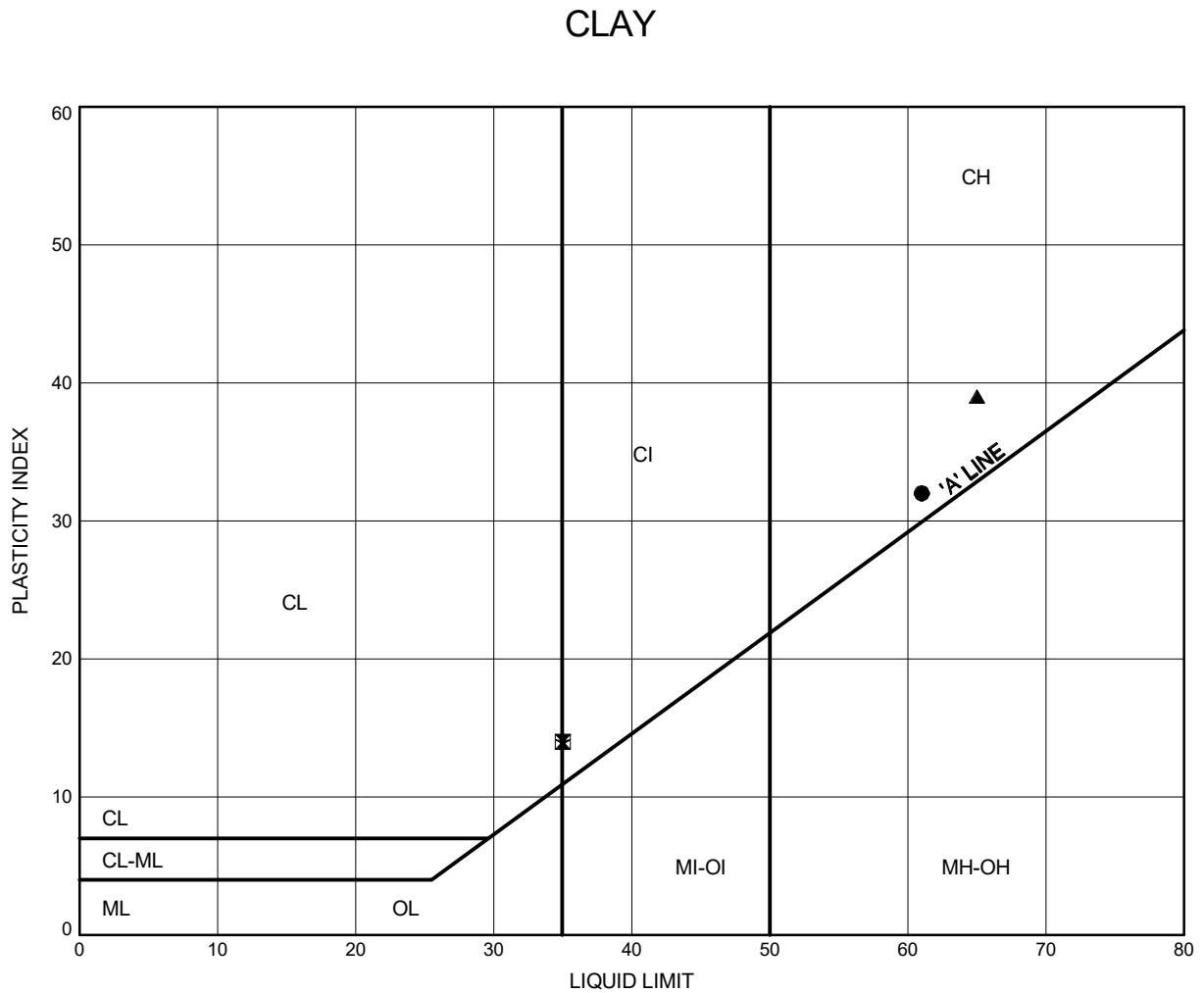


Prep'd SH  
Chkd. SD



# Highway 101 Deep Fill Culvert ATTERBERG LIMITS TEST RESULTS

FIGURE C6



### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	21-01	4.9	291.4
⊠	21-01	7.9	288.4
▲	21-02	4.1	292.2
★	21-02	7.9	288.4

Date December 2021



Prep'd SH  
Chkd. SD



## **Appendix C.2**

### **Analytical Testing Results**

Client: Ministry of Transportation Ontario, Northeastern Region  
File No. 31935  
e-File: 31935 tel fir hwy101 culvert

Certificate of Analysis

Report Date: 09-Aug-2021

Client: Thurber Engineering Ltd.

Order Date: 3-Aug-2021

Client PO:

Project Description: 31935

Client ID:	21-01 SS5	-	-	-
Sample Date:	20-Jul-21 09:00	-	-	-
Sample ID:	2132161-01	-	-	-
MDL/Units	Soil	-	-	-

**Physical Characteristics**

% Solids	0.1 % by Wt.	69.7	-	-	-
----------	--------------	------	---	---	---

**General Inorganics**

pH	0.05 pH Units	7.39	-	-	-
Resistivity	0.10 Ohm.m	22.5	-	-	-

**Anions**

Chloride	5 ug/g dry	108	-	-	-
Sulphate	5 ug/g dry	12	-	-	-

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.  
Lakefield - Ontario - K0L 2H0  
Phone: 705-652-2000 FAX: 705-652-6365

**Paracel Laboratories**

Attn : Dale Robertson

300-2319 St.Laurent Blvd.  
Ottawa, ON  
K1G 4K6, Canada

Phone: 613-731-9577  
Fax: 613-731-9064

24-August-2021

**Date Rec. :** 05 August 2021  
**LR Report:** CA12119-AUG21  
**Reference:** Project#: 2132161

**Copy:** #1

## CERTIFICATE OF ANALYSIS

### Final Report

Sample ID	Sample Date & Time	Sulphide (Na <sub>2</sub> CO <sub>3</sub> ) %
1: Analysis Start Date		23-Aug-21
2: Analysis Start Time		12:55
3: Analysis Completed Date		23-Aug-21
4: Analysis Completed Time		17:06
5: QC - Blank		< 0.04
6: QC - STD % Recovery		106%
7: QC - DUP % RPD		ND
8: RL		0.02
9: 21-01 SS5	20-Jul-21 09:00	< 0.04

RL - SGS Reporting Limit  
ND - Not Detected

Kimberley Didsbury  
Project Specialist,  
Environment, Health & Safety



## **Appendix C.2**

### **Rock Core Photographs**

Client: Ministry of Transportation Ontario, Northeastern Region  
File No. 31935  
e-File: 31935 tel fir hwy101 culvert

**21-01**

**Run 1 to 1 (of 1)**

**Elevation 281.7 m to 280.2 m**

Run 1 Start  
elev. 281.7m

Run 1 End  
elev. 280.2m





**Appendix D.**

**Site Photographs**





**Photo 1. Void under upstream culvert inlet. [July 20, 2021]**



**Photo 2. Culvert deformed at inlet. [July 20, 2021]**





**Photo 3. Culvert outlet [July 20, 2021]**



**Photo 4. South (downstream) embankment slope. [July 20, 2021]**





**Photo 5. North (upstream) embankment slope. [July 20, 2021]**



**Photo 6. Highway 101 looking west from the culvert. [July 20, 2021]**

Client: Ministry of Transportation Ontario, Northeastern Region  
File No. 31935  
e-File: 31935 tel fidr hwy101 culvert\_final\_2