THURBER ENGINEERING LTD.

FOUNDATION INVESTIGATION REPORT
NON-STRUCTURAL CULVERT, STN 10+187, N/S-E RAMP
HIGHWAY 401/COUNTY ROAD 30, BRIGHTON, ON
AGREEMENT 4017-E-0047
ASSIGNMENT 4

Geocres No.: 31C-282

Report to:

Ontario Ministry of Transportation

Latitude: 44.073526
Longitude: -77.769891

September 2019
Thurber File No.: 24731

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PART 1. FACTUAL INFORMATION

1 INTRODUCTION

This section of the report presents the factual findings obtained from a foundation investigation completed at a culvert beneath the N/S-E ramp of the Highway 401 and County Road 30 Interchange, within the County of Northumberland. Thurber carried out the investigation as a consultant to the Ministry of Transportation (MTO) as part of Assignment No. 4 under Retainer Agreement No. 4017-E-0047.

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 previous foundation investigation information was available for the subject culvert site within the online Geocres Library.

2 SITE DESCRIPTION

The existing culvert conveys drainage flow from within the interchange loop westerly under the N/S-E ramp towards the nearby Proctor Creek. Highway 401 in this area consists of a four lane freeway with a rural cross-section and vegetated median of variable width. The terrain ranges from flat to gently rolling and the land adjacent to the highway typically consists of farm fields or occasional forest.

The existing culvert is a non-structural corrugated steel pipe (CSP) culvert with a diameter of 0.61 m and a length of 39.4 m. The invert of the culvert was surveyed at approximate elevations of 191.1 and 190.4 m at the inlet (east) and outlet (west), respectively.

At the location of the culvert, the N/S-E ramp is a single lane on-ramp with curbs and gravel shoulders. The ramp fill height above the culvert is approximately 5.2 m with the road surface at approximate elevation 196.6 m. The existing embankment slopes are inclined at approximately 2.4H:1V and 2.1H:1V for the east and the west slopes, respectively. Steel

guiderails are present on both sides of the ramp in the vicinity of the culvert. The highway ramp embankment is generally performing well with no noticeable signs of surface settlement. However, a gully has formed on the eastern side-slope due to erosion where surface water is directed onto the slope.

Based on published geological information in *The Physiography of Southern Ontario* by Chapman and Putnam (1984), the culvert site lies within the physiographic region known as Iroquois Plain. The Iroquois Plain generally consists of glacio-lacustrine sand and silty sand. The soil deposit is underlain by limestone bedrock.

Photographs showing the existing conditions in the area of the culvert 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 November 29th and December 4th, 2018. The field investigation consisted of advancing three boreholes identified as 18-1 through 18-3. The drilling was carried out using portable equipment for off-road Boreholes 18-1 and 18-3 and a truck-mounted CME 55 drill rig for on-road Borehole 18-2. Prior to commencement of drilling, utility clearances were obtained in the vicinity of the borehole locations.

The northing, easting and elevation of the boreholes are shown on the Borehole Location and Soil Strata Drawing No. 1 in Appendix A, the individual Record of Borehole sheets in Appendix B and in Table 3-1. The termination depth of each borehole is also provided, below. The site is within MTM Zone 9.

Table 3-1: Borehole Summary

Borehole No.	Drilled Location	Northing (m)	Easting (m)	Ground Surface Elevation (m)	Termination Depth Below Ground Surface (m)
18-1	Inlet	4 882 288.4	203 101.4	193.1	8.2
18-2	Ramp Embankment	4 882 288.4	203 083.4	196.6	16.4
18-3	Outlet	4 882 273.9	203 069.2	192.3	10.3

Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). A half-weight (32 kg) hammer was used for the SPT testing in off-road Boreholes 18-1 and 18-3. The N-values reported herein for the off-road boreholes have been corrected to an equivalent standard weight hammer (64 kg). A standard weight hammer (64 kg) was used for SPT testing for on-road Borehole 18-2.

Off-road Borehole 18-1 was drilled from a platform due to accessibility issues. The depths presented on the Record of Borehole Sheet for Borehole 18-1 are from the surface of the platform which was 0.2 m higher than the ground surface.

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

A 19 mm diameter standpipe piezometer was installed in Borehole 18-3 to allow for measurements of the groundwater level after completion of drilling. The piezometer installation details are illustrated on the respective Record of Borehole Sheet provided in Appendix B. The boreholes were backfilled in accordance with MOE requirements (O.Reg 903, as amended). Borehole 18-2 was backfilled with granular material within the depth of pavement structure to reinstate the shoulder surface.

The horizontal positions of the as-drilled boreholes were determined using a measuring tape in the field relative to the existing site features (culvert inlet and outlet, and edge of asphalt) and then converted to northing and easting grid coordinates (MTM Zone 9) based on the georeferenced CAD drawing provided by the MTO. The ground surface elevations at the borehole locations were surveyed by Thurber using a rod and level relative to geodetic benchmark GBM 819698089 which is set horizontally in one of the south pillars of the Highway 401/County Road 30 underpass. The accuracy of the horizontal and vertical surveys are 0.5 m and 0.1 m, respectively, in accordance with the Terms of Reference.

4 LABORATORY TESTING

The recovered soil samples were subjected to inspection and to natural moisture content determination. Selected samples were also subjected to gradation analysis (hydrometer and/or sieve) and Atterberg Limit testing. The results of these tests are summarized on the Record of Borehole Sheets included in Appendix B. One sample of soil recovered from Borehole 18-3 was selected and submitted for analytical testing of corrosivity parameters. All laboratory test results are provided in Appendix C. The borehole and sample numbers for the tested samples are indicated on the Borehole Records in Appendix B and the Laboratory results in Appendix C.

5 GENERAL 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 sections. However, the factual data presented on the Borehole Records takes precedence over the Soil Strata Drawing and the general

description. It must be recognized that the soil and groundwater conditions may vary between and beyond borehole locations.

In general terms, the site was found to be underlain by embankment fill overlying native deposits of sandy silt to silt over glacial till.

5.1 Pavement Structure Fill: Silty Sand with Gravel

From surface in Borehole 18-2, a pavement structure fill consisting of silty sand with gravel was observed. The underside of the pavement structure was at 1.5 m below the existing roadway surface (elev. 195.1 m).

The SPT tests conducted in the silty sand with gravel fill gave N-values of 22 and 10 blows, indicating a compact relative density.

Recorded moisture contents were 4 and 9%. The results of a grain size analysis conducted on one sample of the pavement structure fill indicated this material to consist of 20% gravel, 48% sand, and 32% fines. These results are illustrated on Figure C1 in Appendix C.

5.2 Topsoil/Fill: Silty Sand to Silt

At surface in Boreholes 18-1 and 18-3 was a layer of topsoil fill consisting of silty sand to silt with trace gravel. Some roots and organics were also encountered throughout this layer. The thickness of the topsoil fill ranged from 0.3 to 1.0 m (underside elev. 191.3 to 192.6 m), respectively.

The SPT tests conducted in the topsoil fill gave N-values ranging from 3 to 5 blows, indicating a very loose to loose relative density.

Recorded moisture contents ranged from 14 to 25%.

5.3 Embankment Fill: Sandy Silt to Sand

A layer of embankment fill consisting of sandy silt trace to some gravel was encountered below the pavement structure fill in Borehole 18-2 and the topsoil fill in Boreholes 18-1 and 18-3. A layer of sand with a thickness of 0.3 m was encountered within this fill in Borehole 18-3 (underside elev. 190.5 m). Some organics were also encountered within the embankment fill in Boreholes 18-1 and 18-3. The thickness of the embankment fill ranged from 0.8 to 4.6 m (underside elev. 190.5 to 191.6 m), respectively.

The SPT tests conducted in the embankment fill gave N-values ranging from 3 to 14 blows, indicating a very loose to compact relative density.

Recorded moisture contents ranged from 9 to 37%. The results of grain size analyses conducted on three samples of the embankment fill are summarized in the table below and are illustrated on Figure C2 in Appendix C.

Soil Particle	Percentage (%)
Gravel	3 – 12
Sand	37 – 43
Silt	38 – 50
Clay	4 – 13

Atterberg Limit tests were completed on three samples of the embankment fill and indicated that the two samples from Boreholes 18-1 and 18-2 are non-plastic. The results of Atterberg Limit testing completed on the sample from Borehole 18-3 is summarized in the table below and illustrated on Figure C7 in Appendix C.

Parameter	Value
Liquid Limit	16
Plastic Limit	14
Plasticity Index	2

The laboratory results indicated that the sandy silt has low plasticity (ML).

5.4 Fill: Gravel with Silt and Sand

A layer of fill consisting of gravel with silt and sand was encountered below the embankment fill in all boreholes. Occasional cobbles were noted within this fill in Boreholes 18-1 and 18-3. The gravel fill ranged from 0.7 to 1.5 m in thickness with base elevations between 189.0 and 190.3 m.

SPT tests conducted in the gravel fill gave N-values ranging from 31 to 43 blows, indicating a dense relative density.

Recorded moisture contents ranged from 7 to 11%. The results of a grain size analysis conducted on one sample of the gravel fill indicated this material to consist of 48% gravel, 43% sand, and 9% fines. These results are illustrated on Figure C3 in Appendix C.

5.5 Sandy Silt to Silt (ML)

A native deposit of sandy silt to silt with trace to some gravel was encountered below the gravel fill in all boreholes. In Borehole 18-2 the silt deposit was noted to be 6.1 m thick with a base elevation of 182.9 m. Boreholes 18-1 and 18-3 were terminated within the deposit at elevations of 184.9 and 182.0 m, respectively (total depths of 8.0 and 10.3 m below ground surface, respectively). The presence of cobbles was inferred at a depth of 3.7 m (elev. 188.6m) in Borehole 18-3.

SPT tests conducted in the deposit gave N-values ranging from 4 to 40 blows, indicating a relative density of loose to dense.

Recorded moisture contents ranged from 15 to 26%. The results of grain size analyses conducted on four samples are summarized in the table below and are illustrated on Figure C4 in Appendix C.

Soil Particle	Percentage (%)
Gravel	0 – 14
Sand	8 – 38
Silt	51 – 80
Clay	4 – 9

Atterberg Limit tests completed on four samples of the deposit indicated that the material is non-plastic.

5.6 Silty Sand (SM)

A thin layer of silty sand with a thickness of 0.3 m was encountered within the silt layer at a depth of 7.4 m (elev. 185.5 m) in Borehole 18-1.

An SPT test conducted in the silty sand layer gave an N-value of 81 blows, indicating a very dense relative density.

The recorded moisture content of the silty sand was 11%. The results of a grain size analysis conducted on one sample of the silty sand layer indicated the material to consist of 0% gravel, 74% sand and 26% fines. The results of the grain size analysis are illustrated on Figure C5 in Appendix C.

5.7 Silty Sand (SM) with Gravel – Glacial Till

A deposit of glacial till consisting of silty sand with gravel was encountered below the silt layer in Borehole 18-2. Borehole 18-2 was terminated 2.7 m into the glacial till at a base elevation of 180.2 m (total depth of 16.4 m below ground surface).

SPT tests conducted in this layer gave N-values ranging from 4 to 88 blows, indicating a very loose to very dense relative density.

Recorded moisture contents ranged from 11 to 16%. The results of a grain size analysis conducted on one sample of the till indicates this material consists of 15% gravel, 41% sand, 39% silt and 5% clay. These results are illustrated on Figure C6 in Appendix C.

An Atterberg Limit test completed on one sample of the till indicated that the material is non-plastic.

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5.8 Groundwater

The groundwater water level measured in the standpipe piezometer installed in Borehole 18-3 was at 0.2 m above the ground surface (elev. 192.5 m) on December 7, 2018. The culvert was dry at the time of the field investigation.

Following the completion of drilling on-road Borehole 18-2, the open borehole water level was measured at 4.9 m below the road surface (elev. 191.7 m). Upon completion of drilling off-road Borehole 18-1 and 18-3, slight artesian conditions were noted, with water elevations of 193.4 and 192.7 m, respectively (0.5 and 0.4 m above ground surface, respectively).

These observations are considered short term and it should be noted that the groundwater level at the time of construction may be different and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation.

5.9 Analytical Testing

One sample of the native soils encountered at the site was submitted for analysis of pH, water soluble sulphate, sulphide, chloride, conductivity and resistivity. The analysis results are summarized in Table 5-1. A copy of the test results is provided in Appendix C.

Table 5-1: Results of Chemical Analysis

Borehole (Sample)	Depth (mbgs)	Sulphate (μg/g)	pH (-)	Resistivity (Ohm-cm)	Conductivity (uS/cm)	Chloride (μg/g)	Sulphide (%)
18-3 (SS4)	1.8 – 2.4	9	7.70	4260	235	52	<0.02

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6 MISCELLANEOUS

Borehole locations were selected by Thurber relative to existing site features and the existing culvert location. The as-drilled locations and ground surface elevation of the boreholes were measured by Thurber following completion of the field program. Survey elevation benchmarks were provided by MTO.

CCC Geotechnical and Environmental Drilling Ltd. of Ottawa, Ontario and Forage M3 of Hawkesbury, Ontario supplied and operated the drilling equipment for the on-road and off-road boreholes, respectively, and carried out the drilling, soil sampling, in-situ testing, standpipe installation and borehole decommissioning. Beacon Lite of Kingston, Ontario supplied the traffic control equipment and personnel for shoulder closures required for the field investigation. The field investigation was supervised on a full time basis by Allison Chow, EIT and Sean O'Bryan CET of Thurber. Overall supervision of the investigation program was provided by Stephen Dunlop, P.Eng.

Low complexity laboratory testing was completed by Thurber's laboratory in Ottawa, Ontario. Analytical testing was completed by Paracel Laboratories in Ottawa, Ontario. Interpretation of the factual data and preparation of this report were carried out by Allison Chow, EIT, and Stephen Dunlop P.Eng. The report was reviewed by Dr. Fred Griffiths, P.Eng., a Designated Principal Contact for MTO Foundation Projects.

Allison Chow
Sept 13, 2019

Allison Chow, B.A.Sc
Geotechnical E.I.T.

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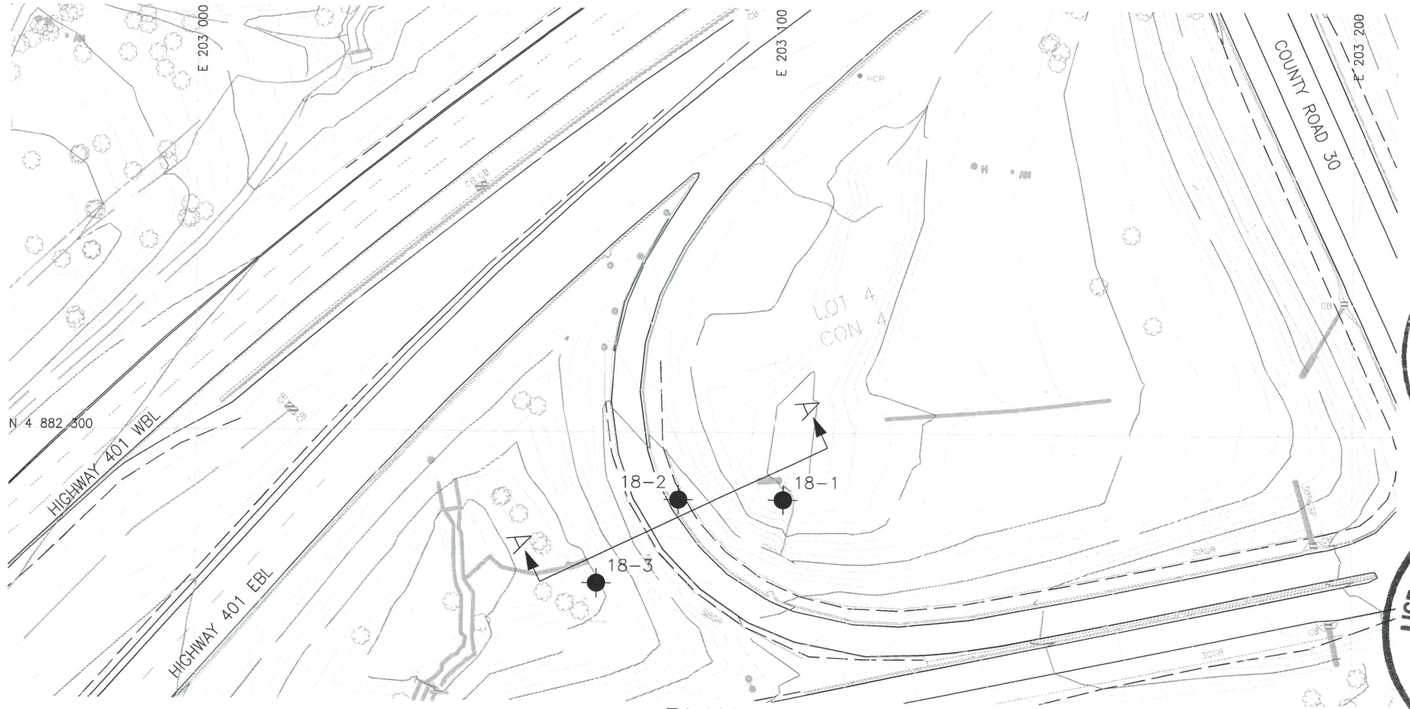
MTO Review Principal
Senior Geotechnical Engineer

Appendix A.

Borehole Location Plan and Stratigraphic Drawings

MINISTRY OF TRANSPORTATION, ONTARIO



PLAN

20 0 20 40m

SCALE 1:1000

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

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S. W. DUNLOP
1001
Sept. 13/19
PROVINCE OF ONTARIO

CONT No
WP No

HIGHWAY 401
COUNTY ROAD 30
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

Ontario

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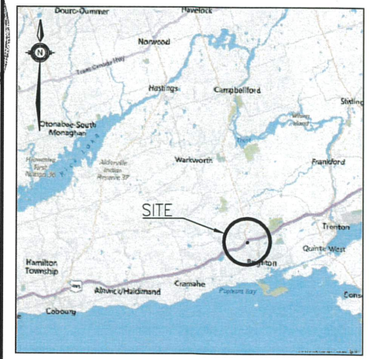
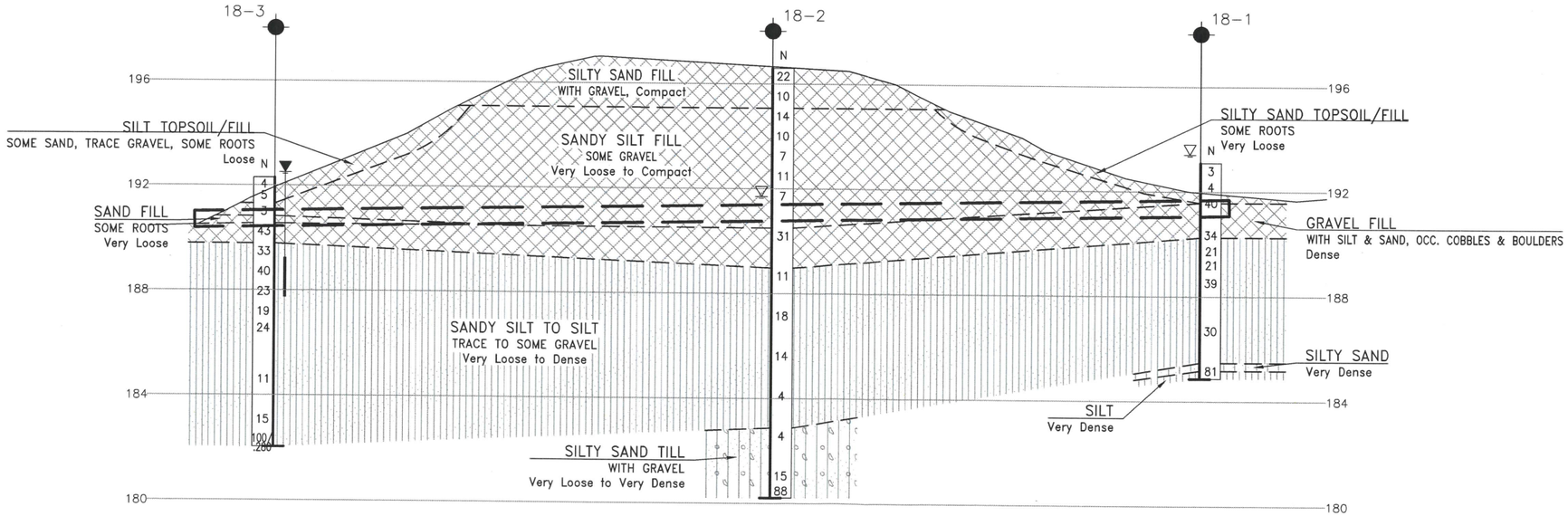


KEYPLAN

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
18-1	193.1	4 882 288.4	203 101.4
18-2	196.6	4 882 288.4	203 083.4
18-3	192.3	4 882 273.9	203 069.2



SECTION A-A

4 0 4 8m H 1:200

4 0 4 8m V 1:200

-NOTES-

1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
3) Coordinate system is MTM NAD 83 Zone 9.

GEOCRES No. 31C-282

REVISIONS			
DATE	BY	DESCRIPTION	
DESIGN AC	CHK –	CODE	LOAD
DRAWN MFA	CHK AC	SITE	STRUCT

DATE SEP 2019
DWG 1

FILENAME: H:\Drafting\24000\24731\TED-24731-BHPP-CV.dwg
PLOTDATE: 9/12/2019 1:58 PM

Appendix B.

Record of Borehole Sheets

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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.

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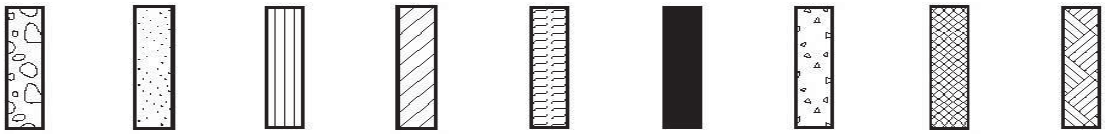
STRATA PLOT:
Strata plots symbolize the soil and bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



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

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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

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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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 18-1

1 OF 2

METRIC

GWP# 4012-18-00 LOCATION Lat: 44.073532°, Long: -77.769657° MTM z9: N 4 882 288.4 E 203 101.4 ORIGINATED BY AC

HWY 401/CR 30 BOREHOLE TYPE Hilti Portable/NW casing COMPILED BY AC

DATUM Geodetic DATE 2018.11.29 - 2018.11.30 CHECKED BY SD

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
193.1											
0.0	Platform						193				
0.2 / 192.6	SILTY SAND some roots very loose dark grey **TOPSOIL/FILL**		1	SS	3						
0.5			2	SS	4						3 43 50 4 non-plastic
	SANDY SILT some organics trace gravel						192				
191.6	loose		3	SS	40						
1.5	grey **FILL**										
	GRAVEL with silt and sand occasional cobbles dense brown **FILL**						191				
190.3			4	SS	34						
2.8	**SANDY SILT to SILT (ML)** trace to some gravel compact to dense grey brown		5	SS	21		190				
			6	SS	21						
							189				
			7	SS	39						2 38 51 9 non-plastic
							188				
							187				
			8	SS	30						
185.5							186				
7.6 / 185.2	**SILTY SAND (SM)** very dense		9	SS	81						0 74 26 (SI+CL)
7.9 / 184.9	dark grey						185				
8.2	**SILT** very dense grey-brown Practical Refusal Notes: 1) Practical refusal to advancement was encountered after the casing jammed and 2.1 m of "blow-up" occurred at 8.2 m depth.										

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15 \oplus 5}$ (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 18-1 2 OF 2 METRIC

GWP# 4012-18-00 LOCATION Lat: 44.073532°, Long: -77.769657° MTM z9: N 4 882 288.4 E 203 101.4 ORIGINATED BY AC

HWY 401/CR 30 BOREHOLE TYPE Hilti Portable/NW casing COMPILED BY AC

DATUM Geodetic DATE 2018.11.29 - 2018.11.30 CHECKED BY SD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						GR SA SI CL
	Continued From Previous Page										
	2) A half-weight (32 kg) drop hammer was used to advance the split-spoon sampler. The "N" values above have been corrected to estimate the "N" value that would have been obtained with a standard 64 kg hammer. 3) Slight artesian condition noted at elev. 185.5 m during drilling, water rose to elev. 193.4 m within casing.										

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

DOUBLE LINE 24731 - HWY 401 CR 30 CULVERT.GPJ 2012TEMPLATE(MTO).GDT 13/9/19

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 18-2 1 OF 2 METRIC

GWP# 4012-18-00 LOCATION Lat: 44.073531°, Long: -77.769881° MTM z9: N 4 882 288.4 E 203 083.4 ORIGINATED BY SOB

HWY 401/CR 30 BOREHOLE TYPE HSA COMPILED BY AC

DATUM Geodetic DATE 2018.12.04 - 2018.12.04 CHECKED BY SD

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
196.6											
0.0	SILTY SAND with gravel compact brown **FILL**		1	SS	22		196	○	○		
			2	SS	10				○		20 48 32 (SI+CL)
195.1							195				
1.5	SANDY SILT some gravel loose to compact brown **FILL**		3	SS	14				○		
			4	SS	10		194		○		
			5	SS	7				○		
			6	SS	11		193		○		
			7	SS	7	▼	192		○		12 37 38 13 non-plastic
190.5							191				
6.1	GRAVEL with silt and sand dense brown **FILL**		8	SS	31		190		○		48 43 9 (SI+CL)
189.0							189				
7.6	**SANDY SILT to SILT (ML)** trace to some gravel compact grey brown		9	SS	11		188		○		
			10	SS	18		187		○		0 27 68 5 non-plastic

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15 \oplus 5}$ (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 18-2 2 OF 2 METRIC

GWP# 4012-18-00 LOCATION Lat: 44.073531°, Long: -77.769881° MTM z9: N 4 882 288.4 E 203 083.4 ORIGINATED BY SOB

HWY 401/CR 30 BOREHOLE TYPE HSA COMPILED BY AC

DATUM Geodetic DATE 2018.12.04 - 2018.12.04 CHECKED BY SD

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	SANDY SILT to SILT (ML) trace to some gravel compact grey brown						186				
			11	SS	14				○		
							185				
	very loose to loose below 12.2 m depth		12	SS	4		184		○		
182.9							183				
13.7	**SILTY SAND (SM)** with gravel **TILL** very loose to very dense grey		13	SS	4				○		
							182				
			14	SS	15		181		○		15 41 39 5 non-plastic
180.2			15	SS	88				○		
16.4	End of Borehole Water level in open borehole upon completion of drilling at elev. 191.7 m.										

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\overset{20}{15\text{-}\oplus\text{-}5}$ $\overset{}{10}$ (%) STRAIN AT FAILURE

DOUBLE LINE 24731 - HWY 401 CR 30 CULVERT.GPJ 2012TEMPLATE(MTO).GDT 13/9/19

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 18-3

1 OF 2

METRIC

GWP# 4012-18-00 LOCATION Lat: 44.073397°, Long: -77.770056° MTM z9: N 4 882 273.9 E 203 069.2 ORIGINATED BY AC

HWY 401/CR 30 BOREHOLE TYPE Hilti Portable/NW casing COMPILED BY AC

DATUM Geodetic DATE 2018.12.03 - 2018.12.04 CHECKED BY SD

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
192.3									
0.0	SILT some sand trace gravel some roots loose brown to grey-brown **TOPSOIL/FILL**		1	SS	4		192		
191.3			2	SS	5				
1.0	SANDY SILT some gravel very loose grey-brown		3	SS	3		191		11 38 41 10
190.8	**FILL**								
1.5	SAND								
190.5	some roots very loose black		4	SS	43		190		
1.8	**FILL**								
189.8	GRAVEL with silt and sand occasional cobbles dense orange-brown		5	SS	33				14 19 63 4 non-plastic
2.5	**FILL**								
	SANDY SILT to SILT (ML) trace to some gravel compact to dense grey-brown		6	SS	40		189		
	inferred cobbles at 3.7 m (elev. 188.6 m)		7	SS	23		188		
			8	SS	19		187		
			9	SS	24				
							186		
							185		
			10	SS	11				7 8 80 5 non-plastic
							184		
			11	SS	15		183		

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

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

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

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

DOUBLE LINE 24731 - HWY 401 CR 30 CULVERT.GPJ 2012TEMPLATE(MTO).GDT 13/9/19

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 18-3 2 OF 2 METRIC

GWP# 4012-18-00 LOCATION Lat: 44.073397°, Long: -77.770056° MTM z9: N 4 882 273.9 E 203 069.2 ORIGINATED BY AC

HWY 401/CR 30 BOREHOLE TYPE Hilti Portable/NW casing COMPILED BY AC

DATUM Geodetic DATE 2018.12.03 - 2018.12.04 CHECKED BY SD

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (20 40 60 80 100): ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
182.0	**SANDY SILT to SILT (ML)**		12	SS	100/						
10.3	trace to some gravel compact to dense grey-brown				280 mm						
	Refusal Notes: 1) Water level in 19 mm standpipe measured at 0.2 m above ground surface (elev. 192.5 m) on 2018.12.07 2) A half-weight (32 kg) drop hammer was used to advance the split-spoon sampler. The "N" values above have been corrected to estimate the "N" value that would have been obtained with a standard 64 kg hammer. 3) Slight artesian conditions noted at elev. 184.4 m during drilling, water rose to elev. 192.7 m within casing.										

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15}\oplus\frac{5}{10}$ (%) STRAIN AT FAILURE

Appendix C.

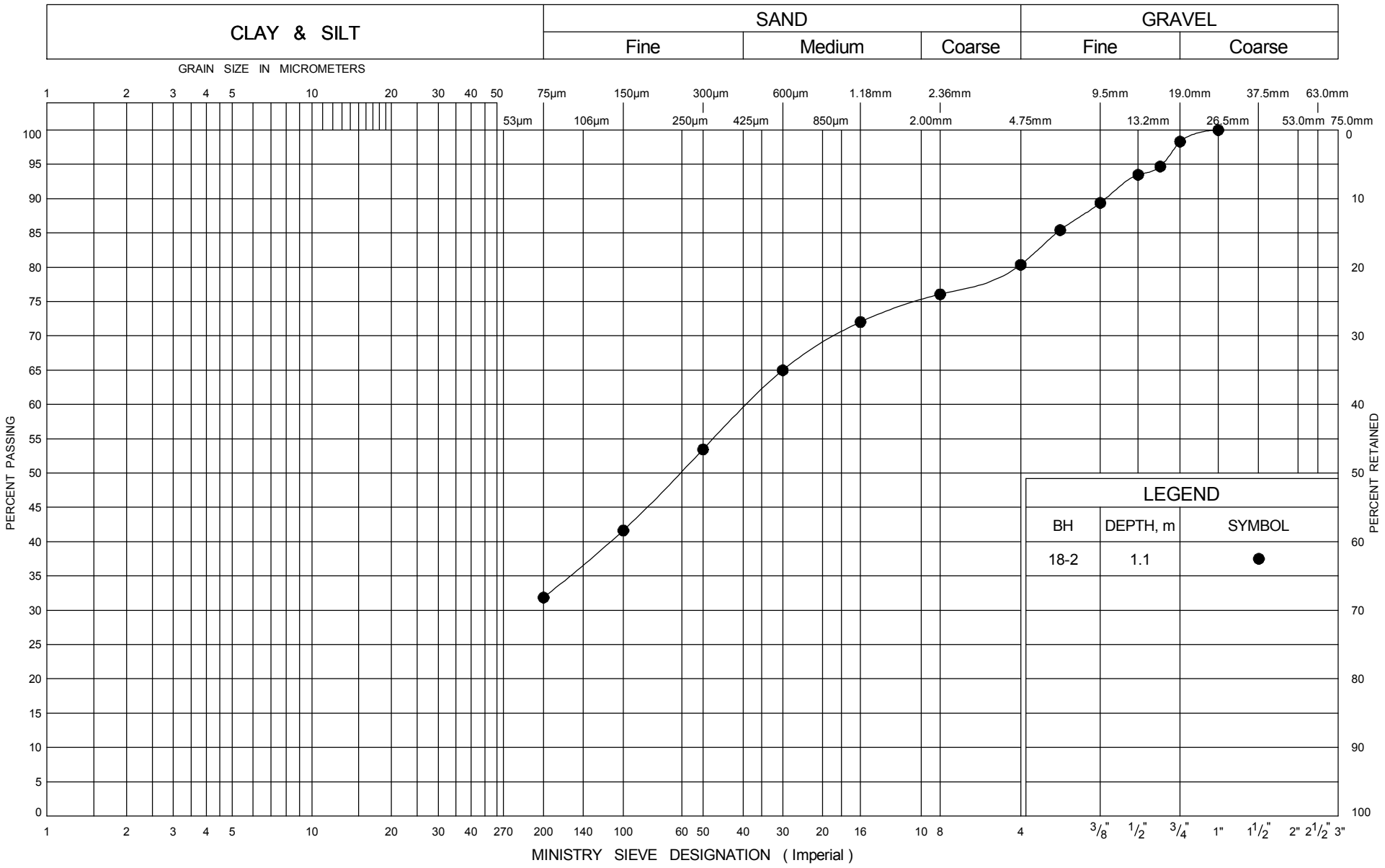
Laboratory Testing

Appendix C.1

Particle Size Analysis Figures

Atterberg Limit Test Results

UNIFIED SOIL CLASSIFICATION SYSTEM



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Ontario

GRAIN SIZE DISTRIBUTION

Fill: Silty Sand with Gravel

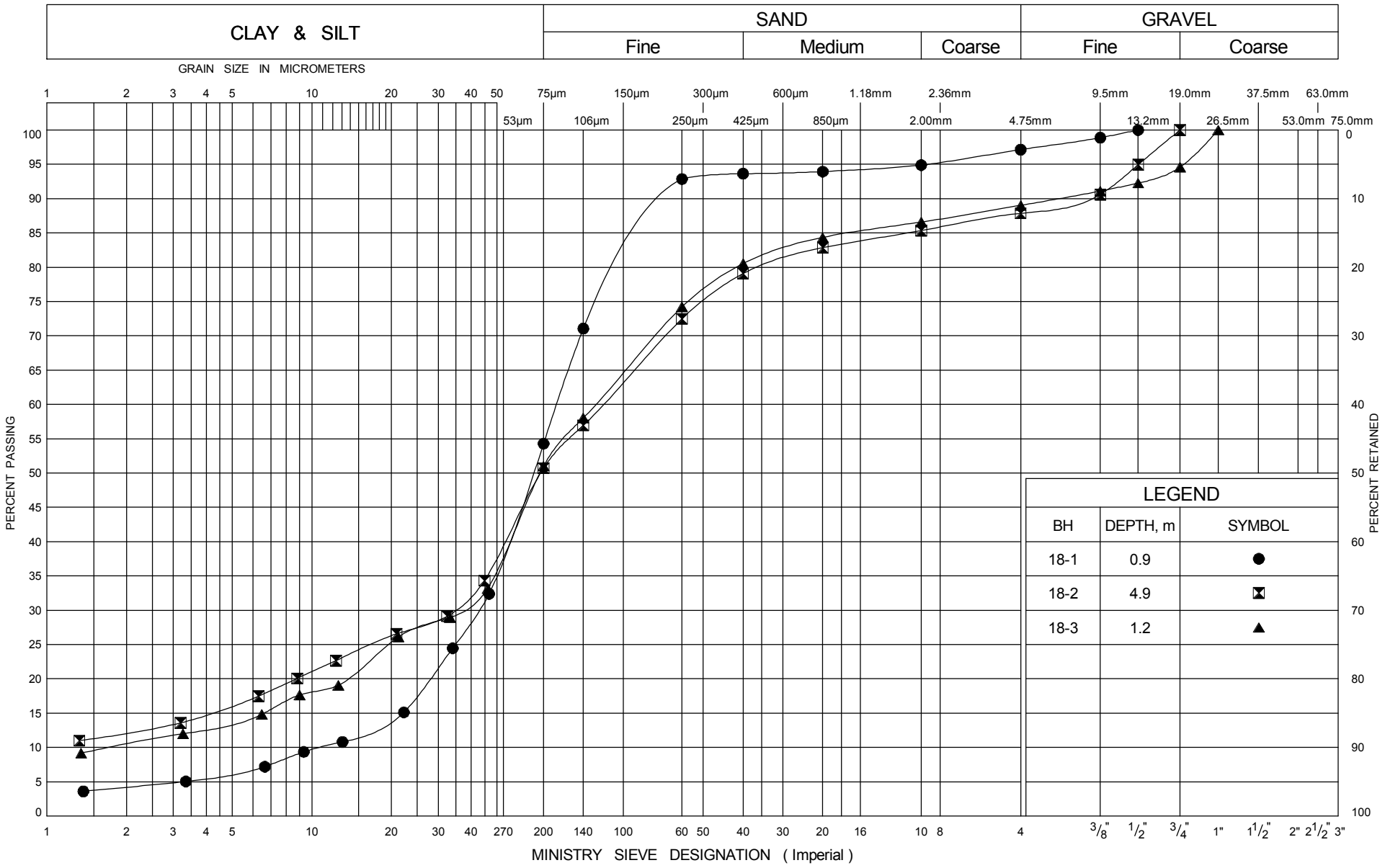
FIG No C1

W P -

HWY 401/CR 30

ONTARIO MOT GRAIN SIZE 24731 - HWY 401 CR 30 CULVERT.GPJ ONTARIO MOT.GDT 20/12/18

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION

Embankment Fill: Silty Sand to Silt

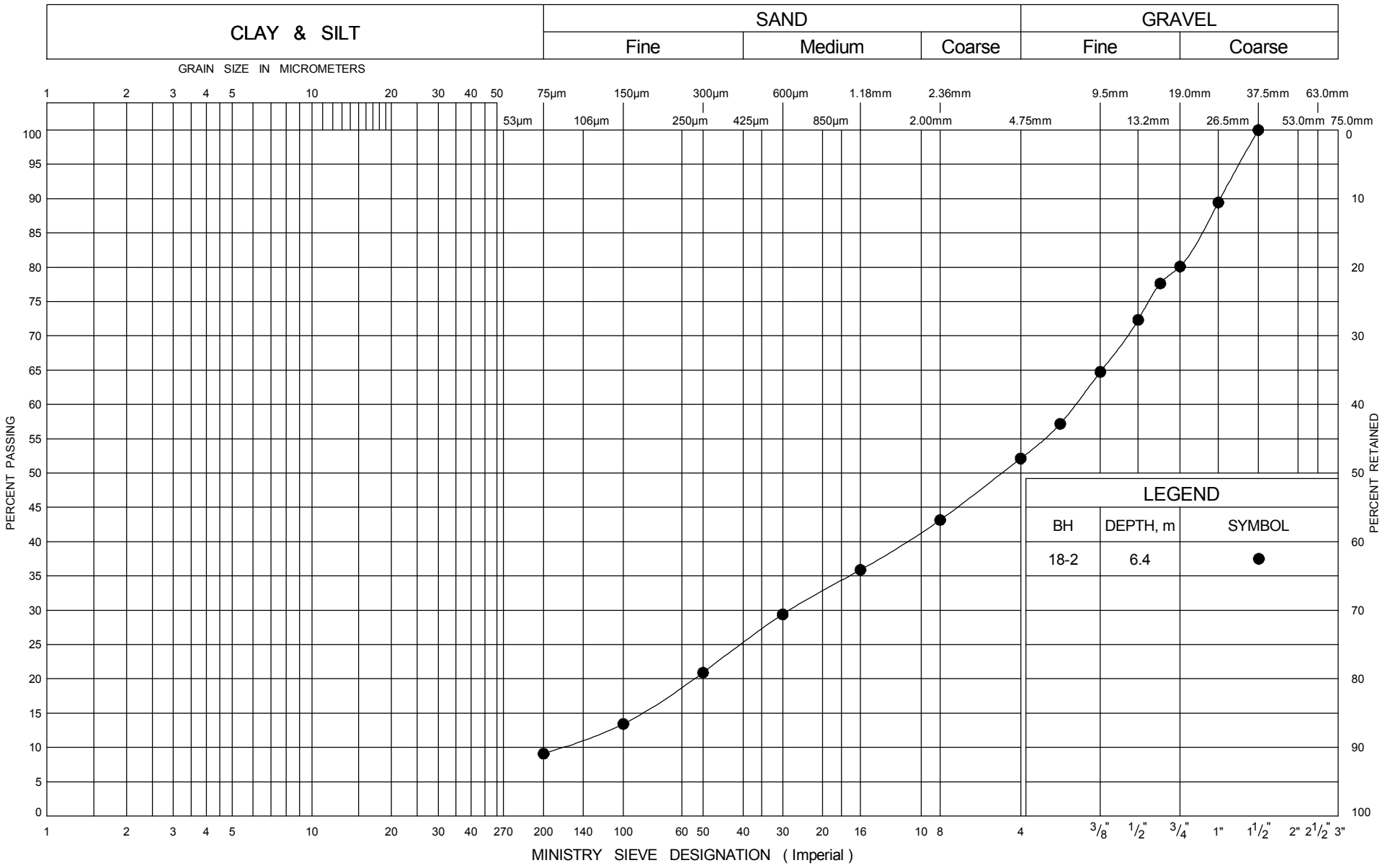
FIG No C2

W P -

HWY 401/CR 30

ONTARIO MOT GRAIN SIZE 24731 - HWY 401 CR 30 CULVERT.GPJ ONTARIO MOT.GDT 20/12/18

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION

Fill: Gravel with Silt and Sand

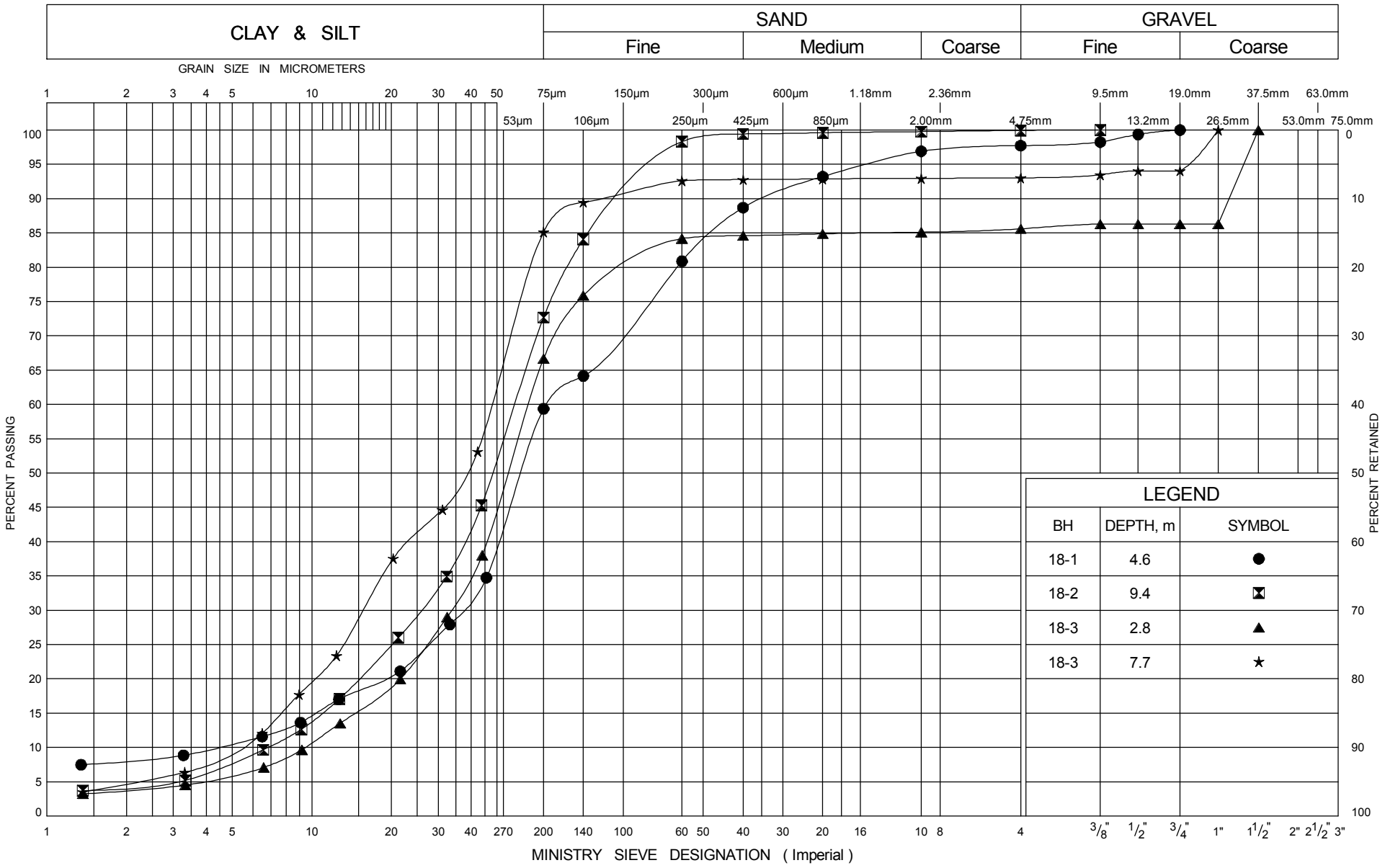
FIG No C3

W P -

HWY 401/CR 30

ONTARIO MOT GRAIN SIZE 24731 - HWY 401 CR 30 CULVERT.GPJ ONTARIO MOT.GDT 20/12/18

UNIFIED SOIL CLASSIFICATION SYSTEM



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GRAIN SIZE DISTRIBUTION

Sandy Silt to Silt (ML)

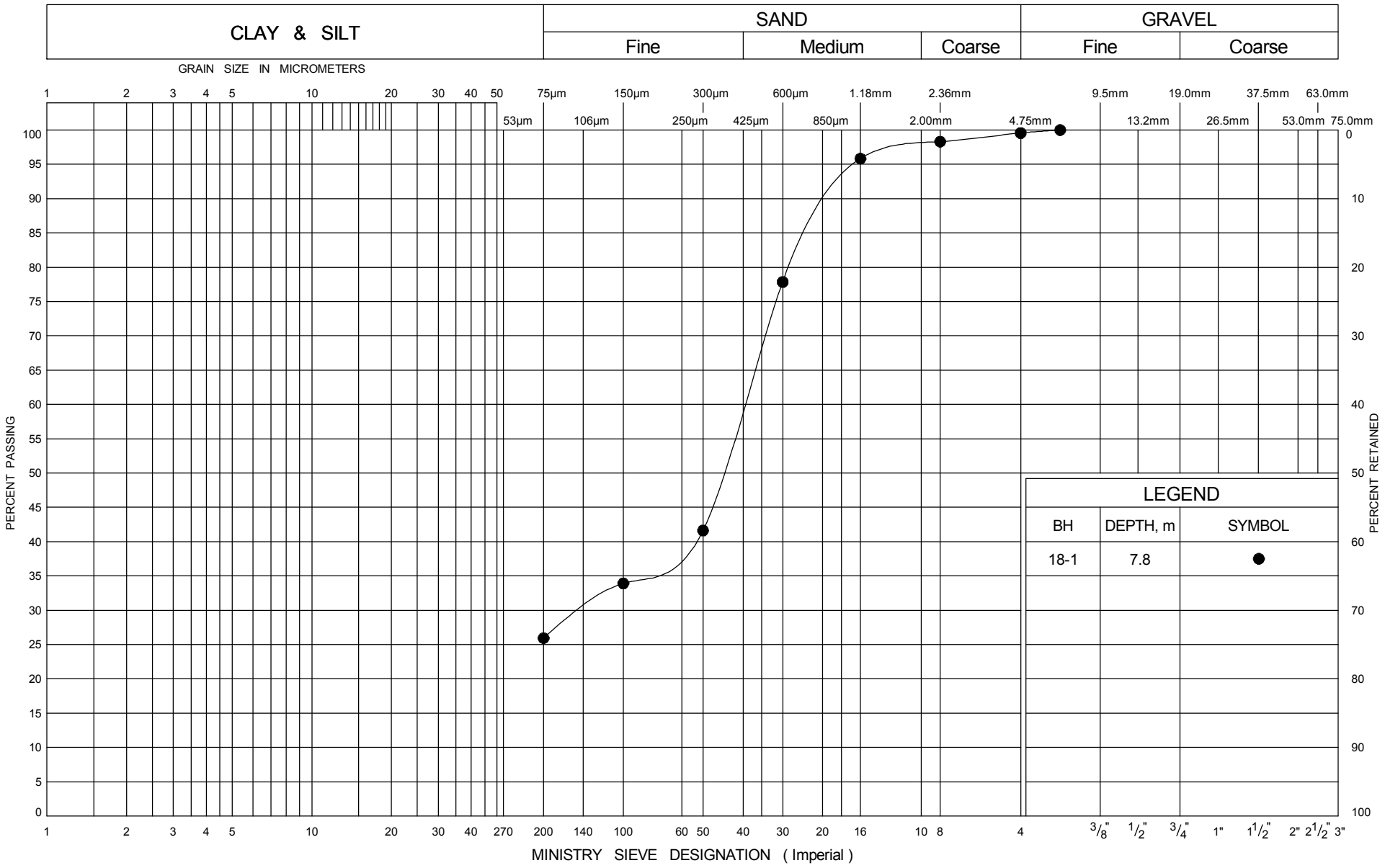
FIG No C4

W P -

HWY 401/CR 30

ONTARIO MOT GRAIN SIZE 24731 - HWY 401 CR 30 CULVERT.GPJ ONTARIO MOT.GDT 20/12/18

UNIFIED SOIL CLASSIFICATION SYSTEM



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GRAIN SIZE DISTRIBUTION

Silty Sand (SM)

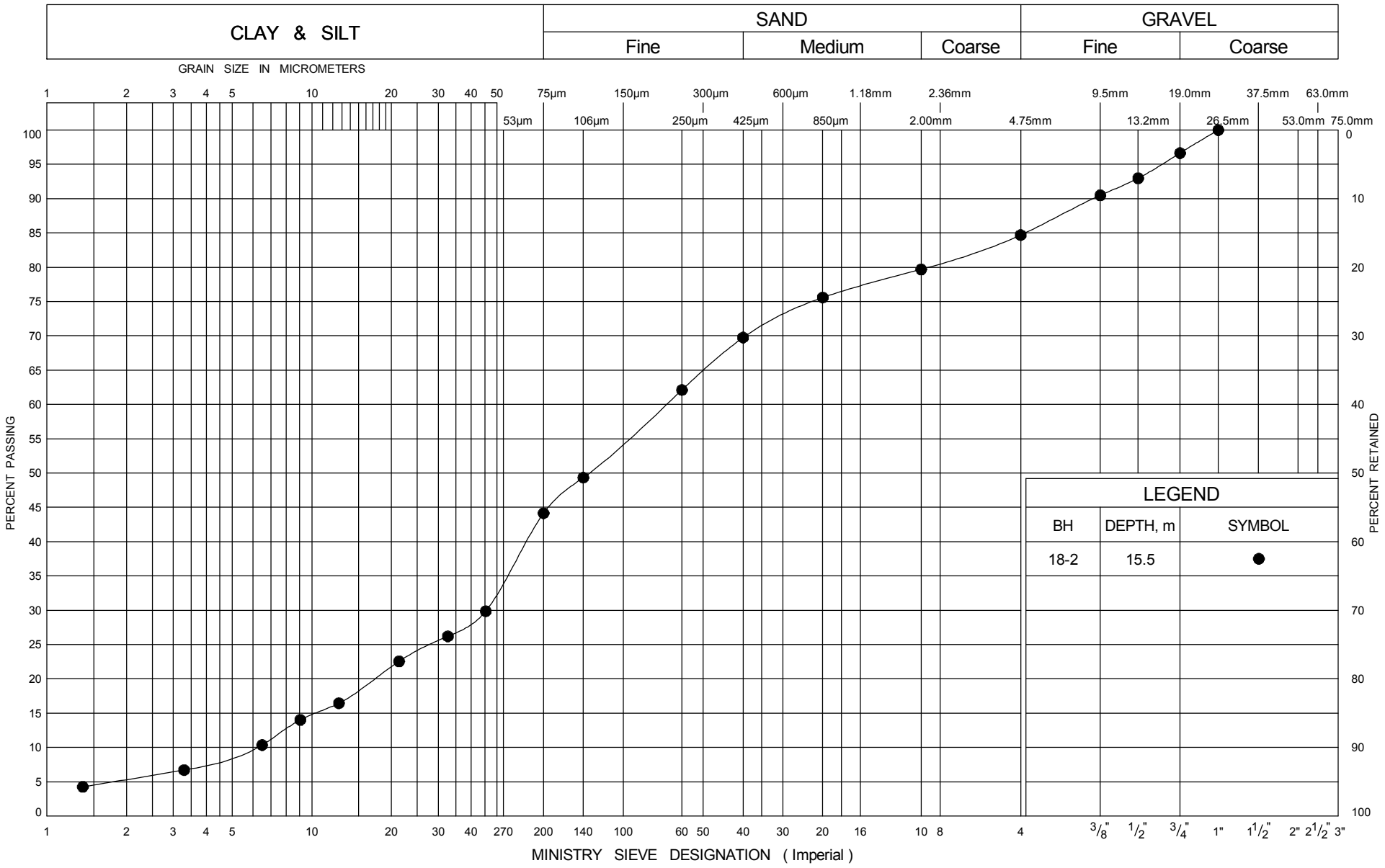
FIG No C5

W P -

HWY 401/CR 30

ONTARIO MOT GRAIN SIZE 24731 - HWY 401 CR 30 CULVERT.GPJ ONTARIO MOT.GDT 20/12/18

UNIFIED SOIL CLASSIFICATION SYSTEM



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GRAIN SIZE DISTRIBUTION

Silty Sand (SM) with Gravel - (Glacial Till)

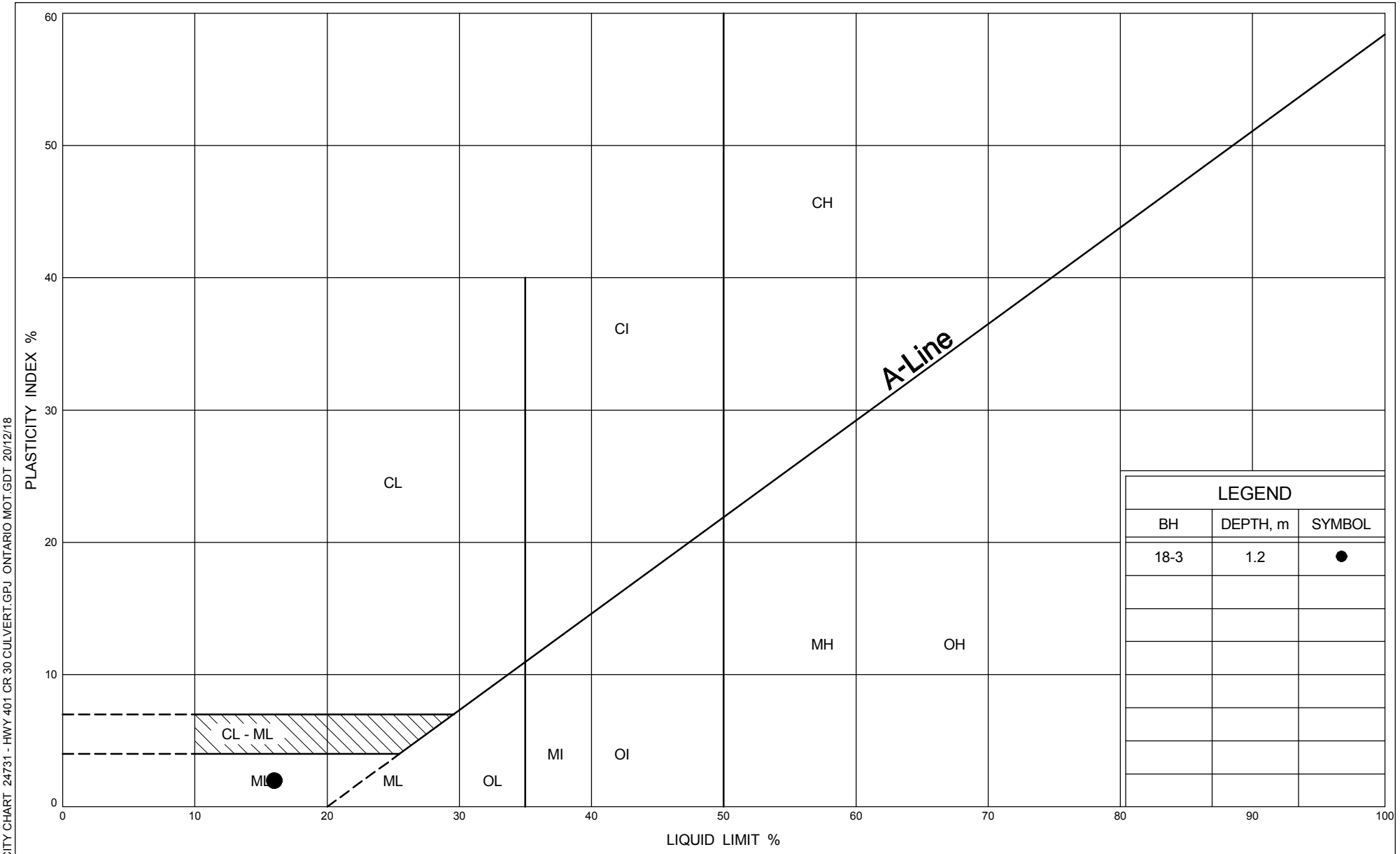
FIG No C6

W P -

HWY 401/CR 30

ONTARIO MOT GRAIN SIZE 24731 - HWY 401 CR 30 CULVERT.GPJ ONTARIO MOT.GDT 20/12/18

Oct 75, FF - S - 21



ONTARIO MOT PLASTICITY CHART 24731 - HWY 401 CR 30 CULVERT.GPJ ONTARIO MOT.GDT 20/12/18

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Ontario

PLASTICITY CHART

Topsoil/Fill: Silty Sand to Silt

FIG No C7

W P -

HWY 401/CR 30

Appendix C.2

Analytical Testing Results

PARACEL LABORATORIES LTD.

Order #: 1849437

Certificate of Analysis
Client: Thurber Engineering Ltd.
Client PO: 24731

Report Date: 12-Dec-2018
Order Date: 6-Dec-2018
Project Description: HWY 401/CR30

	Client ID:	18-3, SS4, 5'9"-7'9"	18-4, SS5, 10'-12'	18-5, SS4, 7'6"-9'6"	-
	Sample Date:	12/03/2018 09:00	12/03/2018 09:00	12/03/2018 09:00	-
	Sample ID:	1849437-01	1849437-02	1849437-03	-
	MDL/Units	Soil	Soil	Soil	-
Physical Characteristics					
% Solids	0.1 % by Wt.	89.9	93.4	88.3	-
General Inorganics					
Conductivity	5 uS/cm	235	298	417	-
pH	0.05 pH Units	7.70	7.97	7.78	-
Resistivity	0.10 Ohm.m	42.6	33.5	24.0	-
Anions					
Chloride	5 ug/g dry	52	128	184	-
Sulphate	5 ug/g dry	9	11	8	-
Subcontract					
Sulphide	0.02 %	<0.02 [1]	<0.02 [1]	<0.02 [1]	-

Appendix D.

Site Photographs

Photo 1. Looking north towards culvert crossing (2018/12/07)

Photo 2. Looking west towards culvert outlet (2018/12/04)

Photo 3. Looking southwest at culvert inlet (2018/11/28)