SUD-00014543-AG

Submitted: December 4, 2017

Foundation Investigation Report

Agreement No. 5016-E-0016
GWP 411-00-00
GEOCRES No. 41O-33

Culvert Replacement, Stn. 17+150 Highway 129, Birch Township, District of Sudbury

Prepared For:
Ministry of Transportation
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The Ministry of Transportation

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Project Name:
Culvert Replacement, Stn. 17+150
Highway 129, Birch Township, District of Sudbury

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Project Number:
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Date Submitted:
2017-12-04

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1 Foundation Investigation Report

1.1 Introduction

This Foundation Investigation Report (FIR) presents the results of a geotechnical investigation completed by **exp** Services Inc. (**exp**) for the replacement of a structural culvert located on Highway 129 at Station 17+150, within Birch Township, District of Sudbury, Ministry of Transportation (MTO) Northeastern Region. This work was undertaken under Agreement No. 5016-E-0016, GWP 411-00-00. The terms of reference (TOR) were presented in the MTO Request for Quotation Document dated August 22, 2016.

The purpose of the investigation is to evaluate the subsurface conditions along the proposed culvert replacement alignment in order to provide geotechnical information necessary for the design of the culvert replacement. The site specific geotechnical investigation consisted of borings, soil sampling, borehole logging, and field and laboratory testing.

This FIR has been prepared specifically and solely for the project described herein. It contains the factual results of the investigation and the laboratory testing completed for this project.

1.2 Site Description and Geological Setting

1.2.1 Site Description

The centreline culvert replacement site is located on Highway 129 at Station 17+150 within Birch Township. The site is located approximately 47.7 km south of the South Junction of Highway 101. The location of the culvert and a cross section of the existing culvert alignment are shown on Dwg. No. 1 in Appendix A.

The existing culvert consists of a structural plate corrugated steel pipe arch (SPCSPA), approximately 4,800 mm in width and 15.62 m long with bevelled ends. At this site, Highway 129 is an asphalt paved, two lane, north/south roadway having approximately 1.0 m wide granular shoulders and cable guide rails on both sides of the roadway. The highway embankment at the investigated location is approximately 3.5 m high on both sides of the roadway, having side slopes of approximately 2H:1V from the top to toe of each embankment. Photographs of the site and existing culvert are included in Appendix B.

The general site conditions were assessed on November 16, 2016. The existing Buttonshoe Creek flows from the west to the east through the existing culvert. Immediately adjacent to the waterway on both sides of the roadway embankment, the terrain generally consists of marshy, low lying vegetation and grasses, surrounded by a thick forest consisting of both deciduous and coniferous trees.

At both the inlet and the outlet, the creek alignment turns to the south away from the culvert. At the time of assessment, water levels within the culvert appear to be near the culvert springline. Water levels appear lower than the highest levels that may occur at the site, based on the observed rust line above the water level within the culvert (refer to Photograph 3 in Appendix B).

The side slopes of the highway embankment are covered with grass and light vegetation, with trees and larger vegetation generally located towards the embankment toes. Guardrails and signs at the top of the embankment and trees near the embankment toe all appeared to generally be standing vertically, suggesting there is not likely any stability issues with the current embankment. Bedrock outcrops were not observed at the site. The surface of Highway 129 near the culvert location was in fair shape, with slight to moderate transverse, longitudinal, and edge cracking.

1.2.2 Geological Setting

In accordance with Ontario Geological Survey Northern Ontario Engineering Geology Terrain Study 86, the dominant landform at the culvert site is ground moraine consisting mainly of till. Local relief is generally moderate (15 to 60 m) and the terrain is generally undulating to rolling. Overall drainage is good (dry). Within Birch Township, rock knobs generally occur within the ground moraine.

Ministry of Northern Development and Mines (MNDM) Map 2543, Bedrock Geology of Ontario East-Central Sheet indicates the bedrock at the culvert location consists of tonalite to granodiorite, foliated to gneissic, with minor supracrustal inclusions.

1.3 Investigation Procedures

1.3.1 Site Investigation and Field Testing

The field investigation was performed on January 16, 17, and April 4, 2017. The field program consisted of the advancement of three (3) sampled boreholes (BH-1 to BH-3). The boreholes were located along the existing culvert alignment to provide subsurface information for the design of the proposed new culvert. Borehole BH-1 was located within the travelled southbound lane and Boreholes BH-2 and BH-3 were advanced at accessible locations near the outlet and inlet, respectively, of the culvert. The borehole locations are shown on Dwg. No. 1 in Appendix A.

Borehole BH-1 was advanced using a truck mounted CME-55 drill rig equipped with hollow stem augers, NW casing, and standard soil sampling equipment. Due to access restrictions, Boreholes BH-2 and BH-3 were advanced with portable tripod mounted equipment with a cathead and Hilti D200 drill. The drilling equipment was operated by a specialist drilling contactor, Landcore Drilling. Boreholes BH-1 and BH-3 were advanced to approximately 15.9 and 9.8 m depth, respectively. Equipment refusal on suspected boulders was encountered in Borehole BH-2 at approximately 5.5 m depth.

The borehole locations (referenced to MTM NAD83 coordinate system, Zone 13) and their ground surface elevations were surveyed by **exp** personnel following drilling using hand-held GPS equipment. The geodetic borehole and water elevations were surveyed using a Temporary Benchmark (TBM) established on the roadway centreline at Stn. 17+150. The TBM was assigned an elevation of 447.004 m based on a survey of the site provided to **exp** by the MTO. The borehole and TBM locations are shown on Dwg. No. 1 in Appendix A.

Soil samples were obtained using a 51 mm outside diameter split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586) at intervals ranging from 0.75 m to 1.5 m in depth as shown on the attached borehole logs in Appendix C. The original field (uncorrected) SPT “N” values were recorded on the borehole logs and used to provide an assessment of the in-situ compactness condition of encountered cohesionless soils.

Upon completion of the boreholes, groundwater measurements were carried out within the boreholes in accordance with MTO guidelines. The measured groundwater levels after completion were recorded on the borehole logs as shown in Appendix C. The boreholes were decommissioned using bentonite in accordance with the Ministry of the Environment Regulation 903, as amended by Regulation 128/03 (the well regulation under the Ontario Water Resources Act).

The fieldwork was supervised by members of **exp**’s engineering staff who directed the drilling and sampling operations, logged borehole data in accordance with the MTO Soil Classification System, and retrieved soil samples for subsequent laboratory testing and identification.

All of the recovered soil samples were placed in labelled moisture-proof bags and returned to **exp**’s Sudbury Laboratory for additional visual, textural, olfactory examination, and selective testing.

1.3.2 Laboratory Testing

All samples returned to the laboratory were subjected to visual examination and classification. The laboratory testing program included determination of natural moisture content on all samples and particle size distribution for approximately 25% of the collected soil samples. All of the laboratory tests were carried out in accordance with MTO and/or ASTM Standards as appropriate.

The laboratory test results are summarized on the attached Record of Borehole Sheets in Appendix C. The results of the particle size analyses are presented graphically in Appendix D.

1.4 Subsurface Conditions

The detailed subsurface conditions encountered in the boreholes advanced during this investigation are presented on the Record of Borehole Sheets in Appendix C. Laboratory test results are provided in Appendix D. The "Explanation of Terms Used in Report" preceding the borehole logs in Appendix C forms an integral part of and should be read in conjunction with this report.

A borehole location plan and stratigraphic section are provided in Appendix A. It should be noted that the stratigraphic boundaries indicated on the borehole logs and stratigraphic section are inferred from semi-continuous sampling, observations of the drilling progress, and results of the Standard Penetration Tests. These boundaries typically represent transitions from one soil type to another and should not be interpreted as exact planes of geological change. Furthermore, subsurface conditions may vary between and beyond the borehole locations.

In general, the subsurface conditions encountered within the embankment (BH-1) consist of asphalt overlying sand fill, peat, and native sand, silty sand, and sand and silt till. At the toes of the embankment slopes (BH-2 and BH-3), the subsurface conditions encountered consist of organic silty sand, peat, and topsoil overlying native silty sand, sand, and sandy gravel till. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

1.4.1 Asphalt

Asphalt was encountered at the surface of Borehole BH-1 and was approximately 76 mm thick. Asphalt thickness may further vary beyond the borehole location.

1.4.2 Sand Fill

Sand fill was encountered below the asphalt at BH-1 and extended to approximately 5.0 m depth below existing grade. The sand fill was brown in colour, moist becoming wet with depth, and contained trace silt, and trace to and gravel, with the percentage of gravel decreasing with depth. Uncorrected SPT "N" values within the fill ranged from 2 to 15 blows per 300 mm, with blows counts generally decreasing with depth. As such, the fill is classified as being very loose to compact in compactness condition.

Laboratory testing performed on selected samples consisted of seven (7) moisture content tests and two (2) grain size analyses. The test results are as follows:

Moisture Content:

- 3 to 18 %

Grain Size Distribution:

- 4 to 12 % Gravel
- 78 to 90 % Sand
- 6 to 9 % Fines

The results of the moisture content and grain size distribution tests are provided on the Record of Borehole Sheet for BH-1 in Appendix C. The result of the grain size distribution tests are also provided on Figure 1 in Appendix D.

1.4.3 Topsoil

Topsoil was encountered at the surface of Borehole BH-2 and was approximately 50 mm thick. Topsoil thickness may further vary beyond the borehole location.

1.4.4 Organic Sandy Silt

Organic sandy silt was encountered at the surface of Borehole BH-3 and extended to approximately 1.5 m below existing grade. The organic sandy silt was dark brown in colour, moist to wet, and contained some roots. Uncorrected SPT “N” values within the organic sandy silt ranged from 1 to 2 blows per 300 mm, classifying the soil as very loose in compactness condition.

Laboratory testing performed on samples of the soil consisted of two (2) moisture content tests. The test results are as follows:

Moisture Content:

- 66 and 97 %

The results of the moisture content tests are provided on the Record of Borehole Sheets in Appendix C.

1.4.5 Peat

Underlying the sand fill at BH-1 and below the organic sandy silt at BH-3 was peat. The peat layer ranged in thickness from approximately 0.4 m at BH-1 to 1.7 m at BH-3. The peat was black in colour, wet, and fibrous. Uncorrected SPT “N” values within the peat ranged from 2 to 3 blows per 300 mm, classifying the peat as very loose to loose in compactness condition.

Laboratory testing performed on samples of the peat consisted of two (2) moisture content tests. The test results are as follows:

Moisture Content:

- 125 and 203 %

The results of the moisture content tests are provided on the Record of Borehole Sheets in Appendix C.

1.4.6 Silty Sand

Underlying the topsoil at BH-2 and the peat at BH-1 and BH-3, was native silty sand. The silty sand layers ranged in thickness from approximately 2.1 to 3.1 m. The silty sand was brown to dark brown and moist to wet at BH-2, and grey and moist to wet at BH-1 and BH-3. The silty sand generally contained trace to some gravel and trace clay. At BH-2, the silty sand was generally mixed some organics and trace wood. At BH-1, the silty sand contained a layer of cobbles and boulders at approximately 6.1 m depth. Uncorrected SPT “N” values within the silty sand ranged from 1 to 68 blows per 300 mm, classifying the soil as very loose to very dense in compactness condition. The lower “N’ values (1 to 6 blows per 300 mm) were generally encountered where the silty sand was mixed with organics at BH-2 and in the upper portion of the soil layer at BH-3.

Laboratory testing performed on selected samples consisted of eleven (11) moisture content tests and three (3) grain size analyses. The test results are as follows:

Moisture Content:

- 3 to 18 %

Grain Size Distribution:

- 0 to 18 % Gravel
- 49 to 68 % Sand
- 29 to 32 % Silt
- 0 to 1 % Clay

The results of the moisture content and grain size distribution tests are provided on the Record of Borehole Sheets in Appendix C. The result of the grain size distribution tests are also provided on Figure 2 in Appendix D.

1.4.7 Sand

Underlying the silty sand at BH-3 was native sand. The sand layer was greater than 4.5 m thick as it extended to the borehole termination depth at 9.8 m. The sand was brown in colour, wet, and contained some silt. Uncorrected SPT "N" values within the sand ranged from 4 to 16 blows per 300 mm, classifying the sand as being loose to compact in compactness condition.

Laboratory testing performed on selected samples consisted of four (4) moisture content tests and one (1) grain size analysis. The test results are as follows:

Moisture Content:

- 19 to 21 %

Grain Size Distribution:

- 90 % Sand
- 10 % Fines

The results of the moisture content and grain size distribution tests are provided on the Record of Borehole Sheets in Appendix C. The results of the grain size distribution test are also provided on Figure 3 in Appendix D.

1.4.8 Till

Native till was encountered below the silty sand at both Borehole BH-1 and BH-2. The till extended to the borehole termination depth of approximately 15.9 m at BH-1 and to refusal on suspected boulders in BH-2 at approximately 5.5 m depth.

The till materials ranged in composition from a silt and sand at BH-1 to a sandy gravel at BH-2. Further details on the till layers are outlined in the following sub-sections.

1.4.8.1 Silt and Sand Till

Native silt and sand till was encountered below the silty sand at BH-1. The silt and sand till contained trace gravel and trace clay. Below approximately 10.7 m depth, the till contained cobbles and boulders. The till was grey in colour and wet. Uncorrected SPT "N" values within the silt and sand till ranged from 69 to 100 blows per 300 mm, classifying the till as very dense in compactness condition. Borehole BH-1 was terminated in the till at approximately 15.9 m depth and refusal was not encountered.

Laboratory testing performed on selected samples consisted of six (6) moisture content tests and one (1) grain size analysis. The test results are as follows:

Moisture Content:

- 7 to 14 %

Grain Size Distribution:

- 10 % Gravel
- 41 % Sand
- 44 % Silt
- 5 % Clay

The results of the moisture content and grain size distribution tests are provided on the Record of Borehole Sheets in Appendix C. The results of the grain size distribution test are also provided on Figure 4 in Appendix D.

1.4.8.2 Sandy Gravel Till

Native sandy gravel till was encountered below the silty sand at BH-2. The sandy gravel till contained some to and silt. Below approximately 4.0 m depth, the till contained cobbles and boulders. The till was brown in colour becoming grey with depth and wet. Uncorrected SPT “N” values within the sandy gravel till ranged from 28 to 100 blows per 300 mm, classifying the till as compact to very dense in compactness condition. The “N” value of 100 blows per 300 mm was likely due to the encountered boulders within the till. The till extended to equipment refusal on suspected boulders at approximately 5.5 m depth.

Laboratory testing performed on selected samples consisted of three (3) moisture content tests and one (1) grain size analysis. The test results are as follows:

Moisture Content:

- 7 to 14 %

Grain Size Distribution:

- 56 % Gravel
- 27 % Sand
- 17 % Fines

The results of the moisture content and grain size distribution tests are provided on the Record of Borehole Sheets in Appendix C. The results of the grain size distribution test are also provided on Figure 4 in Appendix D.

1.5 Groundwater and Surface Water Conditions

Groundwater was observed in Borehole BH-1 upon completion at approximately 3.2 m depth (Elev. 443.9 m). At Boreholes BH-2 and BH-3, washboring techniques were utilized, which required water to be pumped into the boreholes. As such, accurate groundwater measurements could not be obtained in the boreholes upon completion. Note, however, that samples within each borehole were generally wet below approximately Elev. 443.5 m. This could infer a groundwater level at or near this depth.

The water level within Buttonshoe Creek was measured in June 2017 and it was at approximately Elev. 443.6 m at both the culvert inlet and outlet. This is generally at the same level as the measured groundwater level in BH-1 and the wet samples encountered within BH-2 and BH-3, which also further supports the inference above regarding the groundwater level.

Groundwater would be expected to reflect levels in the adjacent open water and to fluctuate seasonally. Seasonal variations in the water table should be expected, with higher levels occurring during wetter periods of the year and lower levels during drier periods.

2 Closure

A subsurface investigation is a limited sampling of a site. The subsurface conditions have been established only at the test hole locations noted. Should any conditions at the site be encountered that differ from those reported at the test locations, we require that we be notified immediately in order to allow reassessment of our recommendations. It may then be necessary to perform additional investigation and analysis.

The number of test holes required to determine the localized underground conditions between test holes affecting construction costs, techniques, sequencing, equipment, scheduling, etc. could be greater than has been carried out for design purposes. Contractors bidding on or undertaking the works should, in this light, decide on their own investigations, as well as their own interpretations of the factual test hole results, so that they may draw their own conclusions as to how the subsurface conditions may affect them.

This Foundation Investigation and Design Report has been prepared by Ian MacMillan, P.Eng. It has been reviewed by Andy Schell, M.Sc.(Eng.), P.Eng., TaeChul Kim, M.E.Sc., P.Eng., and by Stan E. Gonsalves, M.Eng., P.Eng., Designated MTO Foundation Contact. The field investigation was supervised by Shane Tobias and Nicole Wyld.

Yours truly,

exp Services Inc.

LICENSED PROFESSIONAL ENGINEER
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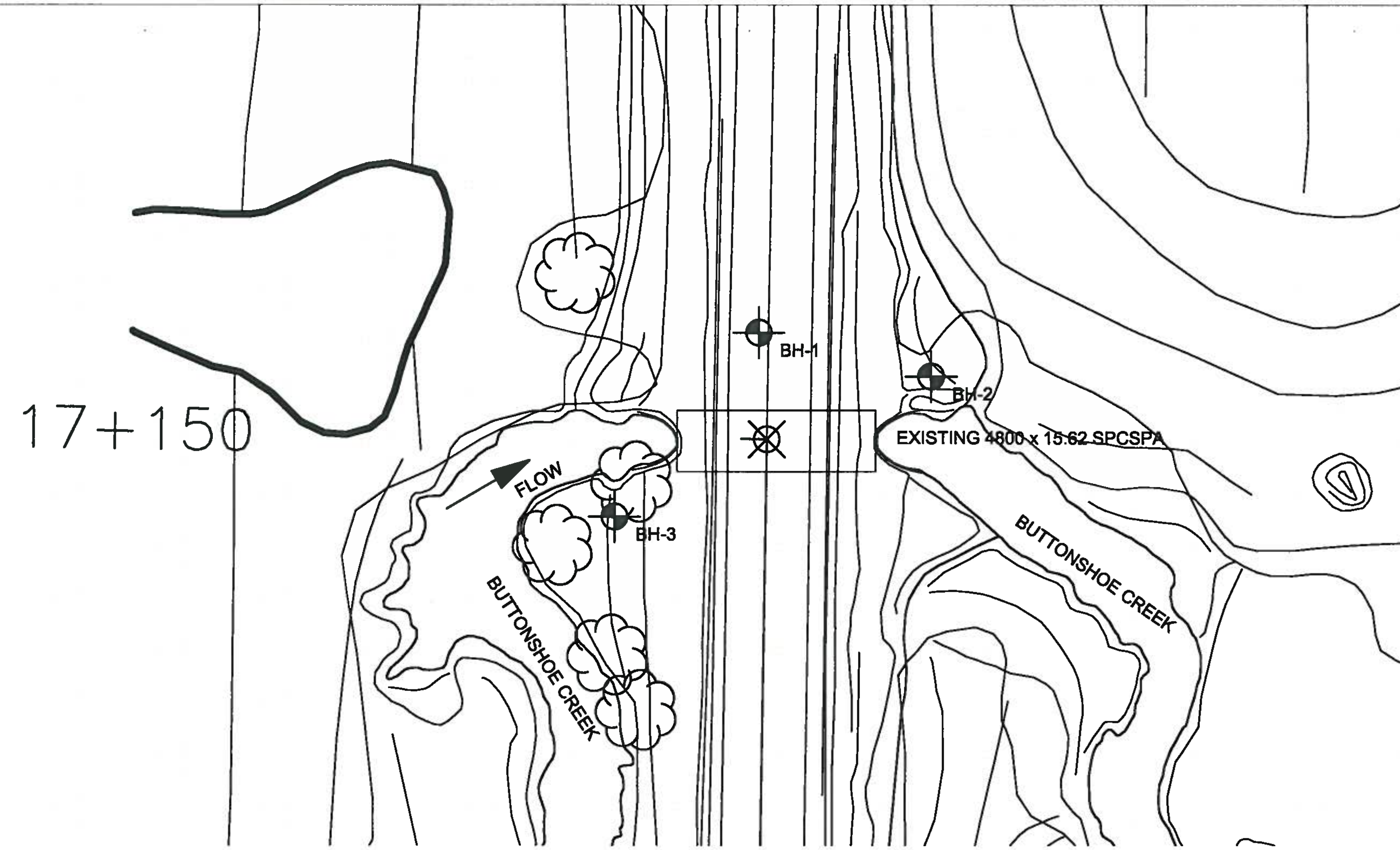
Appendix A – Drawings

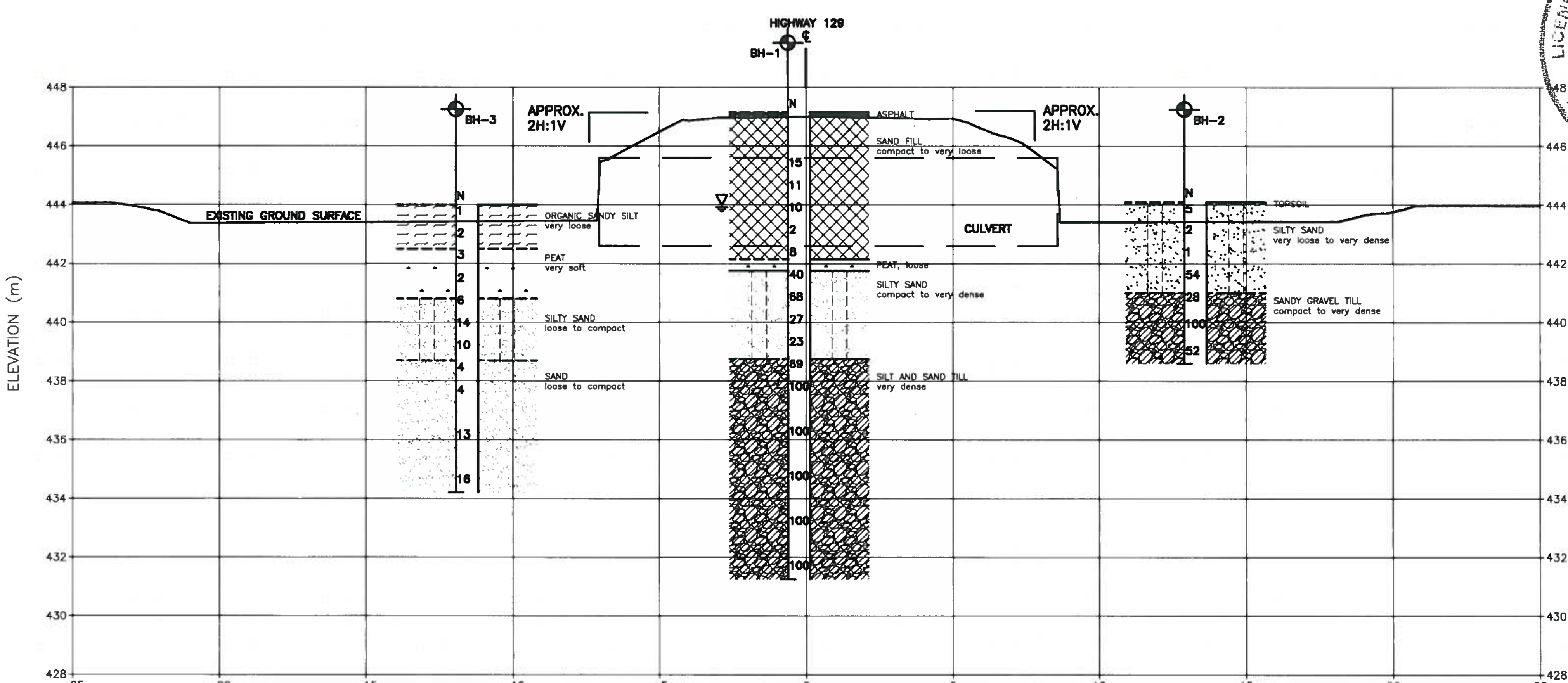
METRIC

DIMENSIONS ARE IN METERS AND/OR MILLIMETERS UNLESS OTHERWISE SHOWN.
STATIONS ARE IN KILOMETERS +METERS



1:500
PLAN

PLAN



CROSS SECTION AT CULVERT CENTRELINE

1:200
HORIZONTAL/VERTICAL

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CULVERT REPLACEMENT, STN. 17+150
HIGHWAY 129, BIRCH TOWNSHIP
DISTRICT OF SUDBURY

BOREHOLE LOCATION PLAN AND SOIL STRATA

SHEET 1

exp Services Inc.

KEY PLAN - NTS

LEGEND

- BOREHOLE LOCATION
- N — STANDARD PENETRATION TEST (BLOWS/300mm)
- TEMPORARY BENCHMARK (EL. 447.0 m)
- ESTIMATED WATER LEVEL IN BOREHOLE

BOREHOLE COORDINATES

BOREHOLE NO.	APPROX. ELEV. (m)	MTM COORDINATES	
		NORTHING	EASTING
BH-1	447.1	5249912.9	365148.8
BH-2	444.1	5249908.3	365161.9
BH-3	444.0	5249899.4	365136.3

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contract Documents.

The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in the report and related documents are specifically excluded in accordance with the conditions of Section GC 2.01 of OPS Gen. Cond.

SOIL STRATA SYMBOLS

ASPHALT, SILTY SAND, SAND, FILL, ORGANIC SANDY SILT, PEAT, TILL

REVISIONS

DATE	BY	DESCRIPTION
2017.8.05	IM	SUBMISSION FOR MTO REVIEW
2017.11.28	IM	FINAL REPORT SUBMISSION

SCALE: AS NOTED		PROJECT NO.: SUD-00014543-AG
SUBM'D: IM	CHECKED: AS	DATE: 2017.8.05
DRAWN: IM	CHECKED: SG	APPROVED: SG — DWG. 1

Appendix B – Photographs

Photograph No. 1 – Highway 129 at Culvert, Stn. 17+150 (Facing North)

Photograph No. 2 – Eastern Embankment at Culvert Outlet (Facing North)

Photograph No. 3 – Culvert Outlet (Facing North-West)

Photograph No. 4 – Culvert Outlet (Facing East)

Photograph No. 5 – Western Embankment at Culvert Inlet (Facing South)

Photograph No. 6 – Culvert Inlet (Facing South-West)

Photograph No. 7 – Culvert Inlet (Facing North-West)

Appendix C – Borehole Logs

Explanation of Terms Used on Borehole Records

SOIL DESCRIPTION

Terminology describing common soil genesis:

Topsoil: mixture of soil and humus capable of supporting good vegetative growth.

Peat: fibrous fragments of visible and invisible decayed organic matter.

Fill: where fill is designated on the borehole log it is defined as indicated by the sample recovered during the boring process. The reader is cautioned that fills are heterogeneous in nature and variable in density or degree of compaction. The borehole description may therefore not be applicable as a general description of site fill materials. All fills should be expected to contain obstruction such as wood, large concrete pieces or subsurface basements, floors, tanks, etc.; none of these may have been encountered in the boreholes. Since boreholes cannot accurately define the contents of the fill, test pits are recommended to provide supplementary information. Despite the use of test pits, the heterogeneous nature of fill will leave some ambiguity as to the exact composition of the fill. Most fills contain pockets, seams, or layers of organically contaminated soil. This organic material can result in the generation of methane gas and/or significant ongoing and future settlements. Fill at this site may have been monitored for the presence of methane gas and, if so, the results are given on the borehole logs. The monitoring process does not indicate the volume of gas that can be potentially generated nor does it pinpoint the source of the gas. These readings are to advise of the presence of gas only, and a detailed study is recommended for sites where any explosive gas/methane is detected. Some fill material may be contaminated by toxic/hazardous waste that renders it unacceptable for deposition in any but designated land fill sites; unless specifically stated the fill on this site has not been tested for contaminants that may be considered toxic or hazardous. This testing and a potential hazard study can be undertaken if requested. In most residential/commercial areas undergoing reconstruction, buried oil tanks are common and are generally not detected in a conventional geotechnical site investigation.

Till: the term till on the borehole logs indicates that the material originates from a geological process associated with glaciation. Because of this geological process the till must be considered heterogeneous in composition and as such may contain pockets and/or seams of material such as sand, gravel, silt or clay. Till often contains cobbles (60 to 200 mm) or boulders (over 200 mm). Contractors may therefore encounter cobbles and boulders during excavation, even if they are not indicated by the borings. It should be appreciated that normal sampling equipment cannot differentiate the size or type of any obstruction. Because of the horizontal and vertical variability of till, the sample description may be applicable to a very limited zone; caution is therefore essential when dealing with sensitive excavations or dewatering programs in till materials.

Terminology describing soil structure:

Desiccated: having visible signs of weathering by oxidization of clay minerals, shrinkage cracks, etc.

Stratified: alternating layers of varying material or color with the layers greater than 6 mm thick.

Laminated: alternating layers of varying material or color with the layers less than 6 mm thick.

Fissured: material breaks along plane of fracture.

Varved: composed of regular alternating layers of silt and clay.

Slickensided: fracture planes appear polished or glossy, sometimes striated.

Blocky: cohesive soil that can be broken down into small angular lumps which resist further breakdown.

Lensed: inclusion of small pockets of different soil, such as small lenses of sand scattered through a mass of clay; not thickness.

Seam: a thin, confined layer of soil having different particle size, texture, or color from materials above and below.

Homogeneous: same color and appearance throughout.

Well Graded: having wide range in grain sized and substantial amounts of all predominantly on grain size.

Uniformly Graded: predominantly on grain size.

All soil sample descriptions included in this report follow generally the ASTM D2487-11 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) with some modification to reflect current MTO practices. The system divides soils into three major categories: (1) coarse grained, (2) fine-grained, and (3) highly organic. The soil is then subdivided based on either gradation or plasticity characteristics. The system provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification. The classification excludes particles larger than 76 mm. Please note that, with the exception of those samples where a grain size analysis has been made, all samples are classified visually in accordance with ASTM D2488-09a Standard Practice for Description and Identification of Soils (Visual-Manual Procedure). Visual classification is not sufficiently accurate to provide exact grain sizing or precise differentiation between size classification systems. Others may use different classification systems; one such system is the ISSMFE Soil Classification.

ISSMFE SOIL CLASSIFICATION

CLAY	SILT			SAND			GRAVEL			COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE		

0.002	0.006	0.02	0.06	0.2	0.6	2.0	6.0	20	60	200

EQUIVALENT GRAIN DIAMETER IN MILLIMETRES

CLAY (PLASTIC) TO	FINE	MEDIUM	CRS.	FINE	COARSE
SILT (NONPLASTIC)	SAND			GRAVEL	

UNIFIED SOIL CLASSIFICATION

Terminology describing materials outside the USCS, (e.g. particles larger than 76 mm, visible organic matter, construction debris) is based upon the proportion of these materials present and as described below in accordance with Note 16 in ASTM D2488-09a:

Table a: Percent or Proportion of Soil, Pp

	Criteria
Trace	Particles are present but estimated to be less than 5%
Few	5≤Pp≤10%
Little	15≤Pp≤25%
Some	30≤Pp≤45%
Mostly	50≤Pp≤100%

The standard terminology to describe cohesionless soils includes the compactness as determined by the Standard Penetration Test 'N' value:

Table b: Apparent Density of Cohesionless Soil

	'N' Value (blows/0.3 m)
Very Loose	N<5
Loose	5≤N<10
Compact	10≤N<30
Dense	30≤N<50
Very Dense	50≤N

The standard terminology to describe cohesive soils includes consistency, which is based on undrained shear strength as measured by insitu vane tests, penetrometer tests, unconfined compression tests or similar field and laboratory analysis, Standard Penetration Test 'N' values can also be used to provide an approximate indication of the consistency and shear strength of fine grained, cohesive soils:

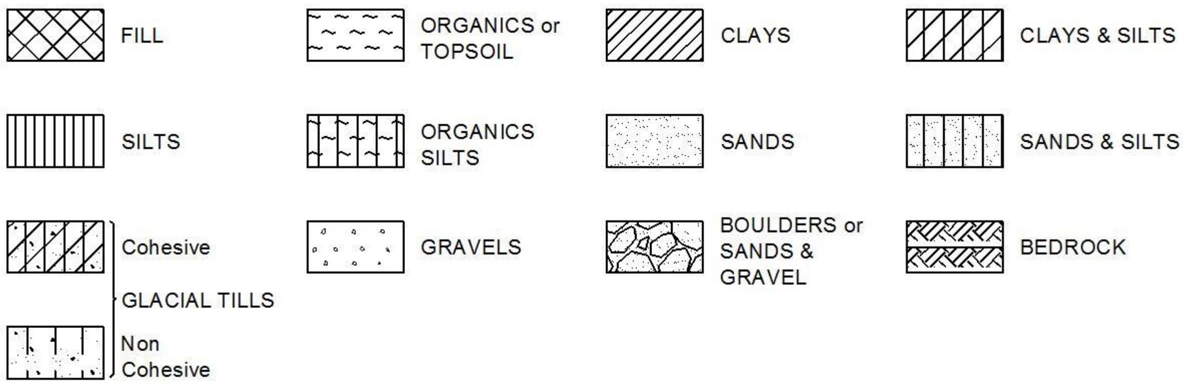
Table c: Consistency of Cohesive Soil

Consistency	Vane Shear Measurement (kPa)	'N' Value
Very Soft	<12.5	<2
Soft	12.5-25	2-4
Firm	25-50	4-8
Stiff	50-100	8-15
Very Stiff	100-200	15-30
Hard	>200	>30

Note: 'N' Value - The Standard Penetration Test records the number of blows of a 140 pound (64kg) hammer falling 30 inches (760mm), required to drive a 2 inch (50.8mm) O.D. split spoon sampler 1 foot (305mm). For split spoon samples where full penetration is not achieved, the number of blows is reported over the sampler penetration in meters (e.g. 50/0.15).

STRATA PLOT

Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols:



WATER LEVEL MEASUREMENT

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

SS	Split spoon sample (obtained from the Standard Penetration Test)
WS	Wash sample
BS	Bulk sample
TW	Thin wall sample or Shelby tube
PS	Piston sample
AS	Auger sample
VT	Vane test
GS	Grab sample
HQ, NQ, etc.	Rock core samples obtained with the use of standard size diamond drilling bits

STRESS AND STRAIN

u_w	kPa	Pore water pressure
r_u	1	Pore pressure ratio
σ	kPa	Total normal stress
σ'	kPa	Effective normal stress
τ	kPa	Shear stress
$\sigma_1, \sigma_2, \sigma_3$	kPa	Principal stresses
ε	%	Linear strain
$\varepsilon_1, \varepsilon_2, \varepsilon_3$	%	Principal strains
E	kPa	Modulus of linear deformation
G	kPa	Modulus of shear deformation
μ	1	Coefficient of friction

MECHANICALL PROPERIES OF SOIL

m_v	kPa^{-1}	Coefficient of volume change
c_c	1	Compression index
c_s	1	Swelling index
c_r	1	Recompression index
c_v	m^2/s	Coefficient of consolidation
H	m	Drainage path
T_V	1	Time factor
U	%	Degree of consolidation
σ'_{v0}	kPa	Effective overburden pressure
σ'_P	kPa	Preconsolidation pressure
τ_f	kPa	Shear strength
c'	kPa	Effective cohesion intercept
ϕ'	$-^\circ$	Effective angle of internal friction
c_u	kPa	Apparent cohesion intercept
ϕ_u	$-^\circ$	Apparent angle of internal friction
τ_R	kPa	Residual shear strength
τ_r	kPa	Remoulded shear strength
S_t	1	Sensitivity = c_u/τ_r

PHYSICAL PROPERTIES OF SOIL

P_s	kg/m^3	Density of solid particles
γ_s	kN/m^3	Unit weight of solid particles
ρ_w	kg/m^3	Density of water
γ_w	kN/m^3	Unit weight of water
ρ	kg/m^3	Density of soil
γ	kN/m^3	Unit weight of soil
ρ_d	kg/m^3	Density of dry soil
γ_d	kN/m^3	Unit weight of dry soil
ρ_{sat}	kg/m^3	Density of saturated soil
γ_{sat}	kN/m^3	Unit weight of saturated soil
ρ'	kg/m^3	Density of submerged soil
γ'	kN/m^3	Unit weight of submerged soil
e	1, %	Void ratio
n	1, %	Porosity
w	1, %	Water content
S_r	%	Degree of saturation
W_L	%	Liquid limit
W_P	%	Plastic limit
W_s	%	Shrinkage limit
I_P	%	Plasticity index = $(W_L - W_P)$
I_L	%	Liquidity index = $(W - W_P)/I_P$
I_C	%	Consistency index = $(W_L - W)/I_P$
e_{max}	1, %	Void ratio in loosest state
e_{min}	1, %	Void ratio in densest state
I_D	1	Density index = $(e_{max} - e)/(e_{max} - e_{min})$
D	mm	Grain diameter
D_n	mm	N percent - diameter
C_u	1	Uniformity coefficient
h	m	Hydraulic head or potential
q	m^3/s	Rate of discharge
v	m/s	Discharge velocity
i	1	Hydraulic gradient
k	m/s	Hydraulic conductivity
j	kN/m^3	Seepage force

RECORD OF BOREHOLE No BH-1

METRIC

W.P.	411-00-00,5016-E-0016	LOCATION	Stn. 17+156, MTM-13, 5249912.85N, 365148.75E, Structural Culvert at Stn. 17+150	ORIGINATED BY	ST
DIST	Sudbury HWY 129	BOREHOLE TYPE	Continuous Flight HSA and NW Casing	COMPILED BY	IM
DATUM	Geodetic	DATE	2017.04.25 - 2017.04.25 LATITUDE 47.385709 LONGITUDE -83.20067	CHECKED BY	IM

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/m³ / REMARKS & GRAIN SIZE DISTRIBUTION (%)

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	GR	SA	SI	CL
447.1	Pavement Surface								
447.0 / 0.1	**ASPHALT** (~ 76 mm thick)								
	FILL, sand, some to and gravel, trace silt, brown, moist.	1	AS						
		2	AS			12	78	(9)	
	trace gravel, compact below ~ 1.5 m depth.	3	SS	15					
		4	SS	11					
		5	SS	10	∇ (~444)	4	90	(6)	
	wet, very loose to loose below ~ 3.8 m depth.	6	SS	2					
		7	SS	8					
442.1 / 5.0	**PEAT,** black, fibrous, wet.								
441.8 / 5.4	**SILTY SAND,** grey, moist to wet, dense to very dense.	8	SS	40					
	with cobbles and boulders below ~ 6.1 m depth.	9	SS	68					
	no cobbles or boulders, some gravel, trace clay, wet, compact below ~ 6.8 m depth.	10	SS	27		18	49	32	1
		11	SS	23					
438.8 / 8.4	**TILL,** silt and sand, trace gravel, trace clay, grey, wet, very dense.	12	SS	69		10	41	44	5
		13	SS	100					
	with cobbles and boulders below ~ 10.7 m depth.	14	SS	100					
		15	SS	100					
		16	SS	100					

Elevation scale: 447, 446, 445, 444, 443, 442, 441, 440, 439, 438, 437, 436, 435, 434, 433

Continued Next Page

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

Ministry of Transportation Ontario

Foundation Design

RECORD OF BOREHOLE No BH-1

METRIC

W.P. 411-00-00,5016-E-0016 LOCATION Stn. 17+156, MTM-13, 5249912.85N, 365148.75E, Structural Culvert at Stn. 17+150 ORIGINATED BY ST

DIST Sudbury HWY 129 BOREHOLE TYPE Continuous Flight HSA and NW Casing COMPILED BY IM

DATUM Geodetic DATE 2017.04.25 - 2017.04.25 LATITUDE 47.385709 LONGITUDE -83.20067 CHECKED BY IM

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (O 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
	TILL, silt and sand, trace gravel, trace clay, grey, wet, very dense. *(continued)*		17	SS	100		432		o		
431.3 15.9	**END OF BOREHOLE** Borehole terminated at ~ 15.9 m depth. **NOTES:** 1. This drawing to be read with the subject report and project numbers as presented above.										

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

ONTARIO MTO SUD-00014543-AG - HWY. 129 - STR CULVERT 17+150.GPJ ONTARIO MTO.GDT 9/26/17

RECORD OF BOREHOLE No BH-2

METRIC

W.P. 411-00-00,5016-E-0016 LOCATION Stn. 17+157, MTM-13, 5249908.31N, 365161.94E, Structural Culvert at Stn. 17+150 ORIGINATED BY ST

DIST Sudbury HWY 129 BOREHOLE TYPE Portable Tripod With Cathead and Hilti D200 Drill COMPILED BY IM

DATUM Geodetic DATE 2017.01.17 - 2017.01.17 LATITUDE 47.385667 LONGITUDE -83.200496 CHECKED BY IM

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
444.1	Ground Surface				
444.0 0.1	**TOPSOIL** (~ 50 mm thick)				
	SILTY SAND, trace to some gravel, brown, moist, loose.	1	SS	5	
	brown to dark brown, some gravel, some organics, wet, very loose below ~ 0.8 m depth.	2	SS	2	15 56 29 0
	trace wood below ~ 1.5 m depth.	3	SS	1	
	no wood, no organics, trace to some gravel, very dense below ~ 2.3 m depth.	4	SS	54	
441.0 3.1	**TILL,** sandy gravel, some to and silt, brown, wet, compact.	5	SS	28	56 27 (17)
	with cobbles and boulders, very dense below ~ 4.0 m depth.	6	SS	100	
	grey below ~ 4.9 m depth.	7	SS	52	
438.6 5.5	**END OF BOREHOLE** Borehole terminated at ~ 5.5 m depth due to refusal on suspected boulders				

Chart columns: STRAT PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE (444, 443, 442, 441, 440, 439); 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.

NOTES:
1. This drawing to be read with the subject report and project numbers as presented above.
2. Groundwater level not measured within borehole as water was pumped into hole due to washboring technique utilized.

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

RECORD OF BOREHOLE No BH-3

METRIC

W.P. 411-00-00,5016-E-0016	LOCATION Stn. 17+141, MTM-13, 5249899.38N, 365136.29E, Structural Culvert at Stn. 17+150		ORIGINATED BY ST
DIST Sudbury HWY 129	BOREHOLE TYPE Portable Tripod With Cathead and Hilti D200 Drill		COMPILED BY IM
DATUM Geodetic	DATE 2017.01.16 - 2017.01.16	LATITUDE 47.385589 LONGITUDE -83.200837	CHECKED BY IM

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20, 40, 60, 80, 100

SHEAR STRENGTH kPa: O 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

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	GR SA SI CL
444.0	Ground Surface					
0.0	**ORGANIC SANDY SILT,** some roots, dark brown, moist to wet, very loose.	1	SS	1	97.4	
		2	SS	2	125	
442.5 / 1.5	**PEAT,** black, wet, very loose to loose.	3	SS	3	203.4	
		4	SS	2	109.7	
440.8 / 3.2	**SILTY SAND,** grey, wet, loose to compact.	5	SS	6		0 68 32 0
		6	SS	14		
		7	SS	10		
438.7 / 5.3	**SAND,** some silt, brown, wet, loose to compact.	8	SS	4		
		9	SS	4		0 90 (10)
		10	SS	13		
		11	SS	16		
434.2 / 9.8	**END OF BOREHOLE** Borehole terminated at ~ 9.8 m depth					

ELEVATION SCALE: 443, 442, 441, 440, 439, 438, 437, 436, 435

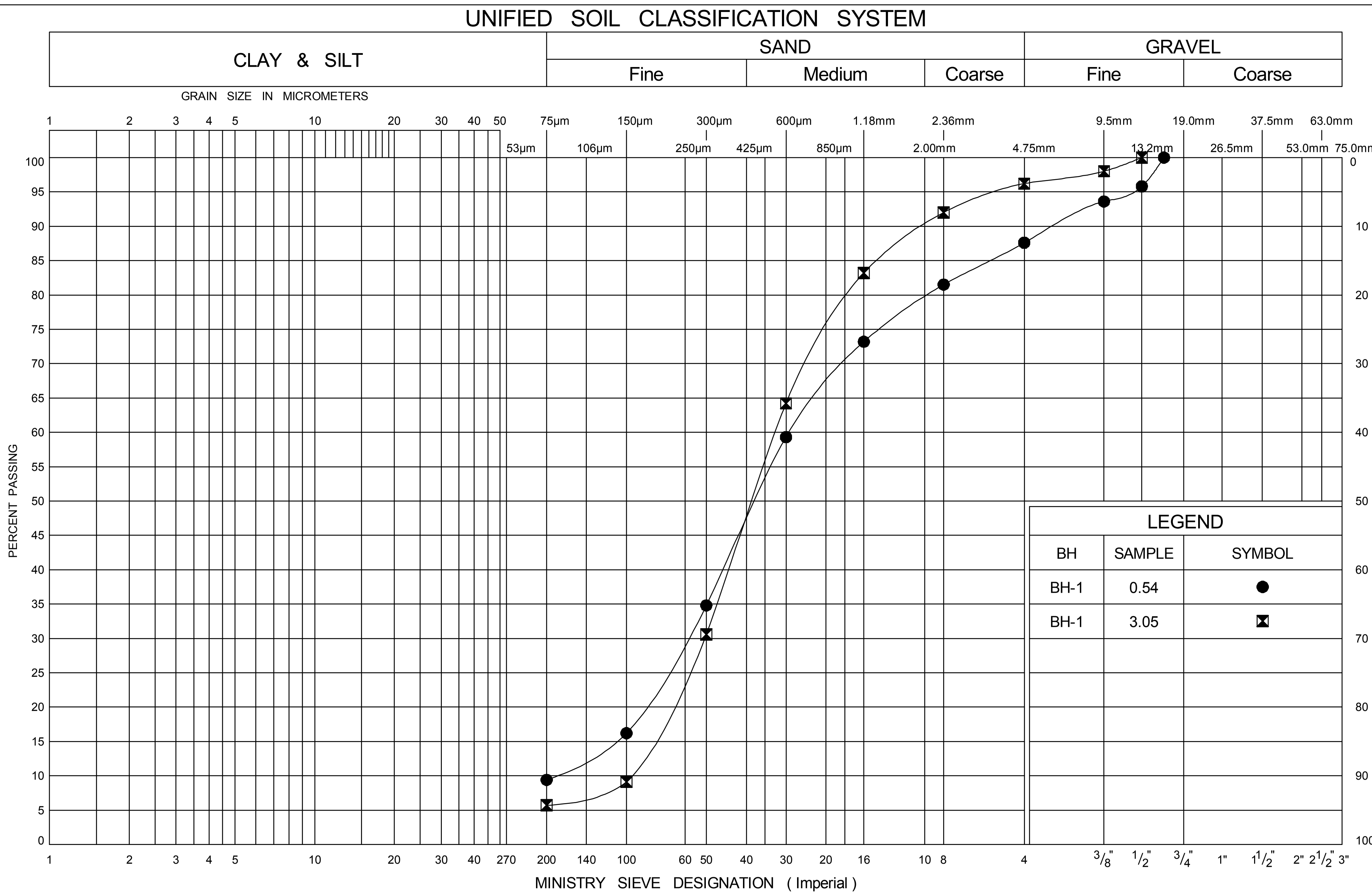
NOTES:
1. This drawing to be read with the subject report and project numbers as presented above.
2. Groundwater level not measured within borehole as water was pumped into hole due to washboring technique utilized.

+³, ×³: Numbers refer to Sensitivity

O ³% STRAIN AT FAILURE

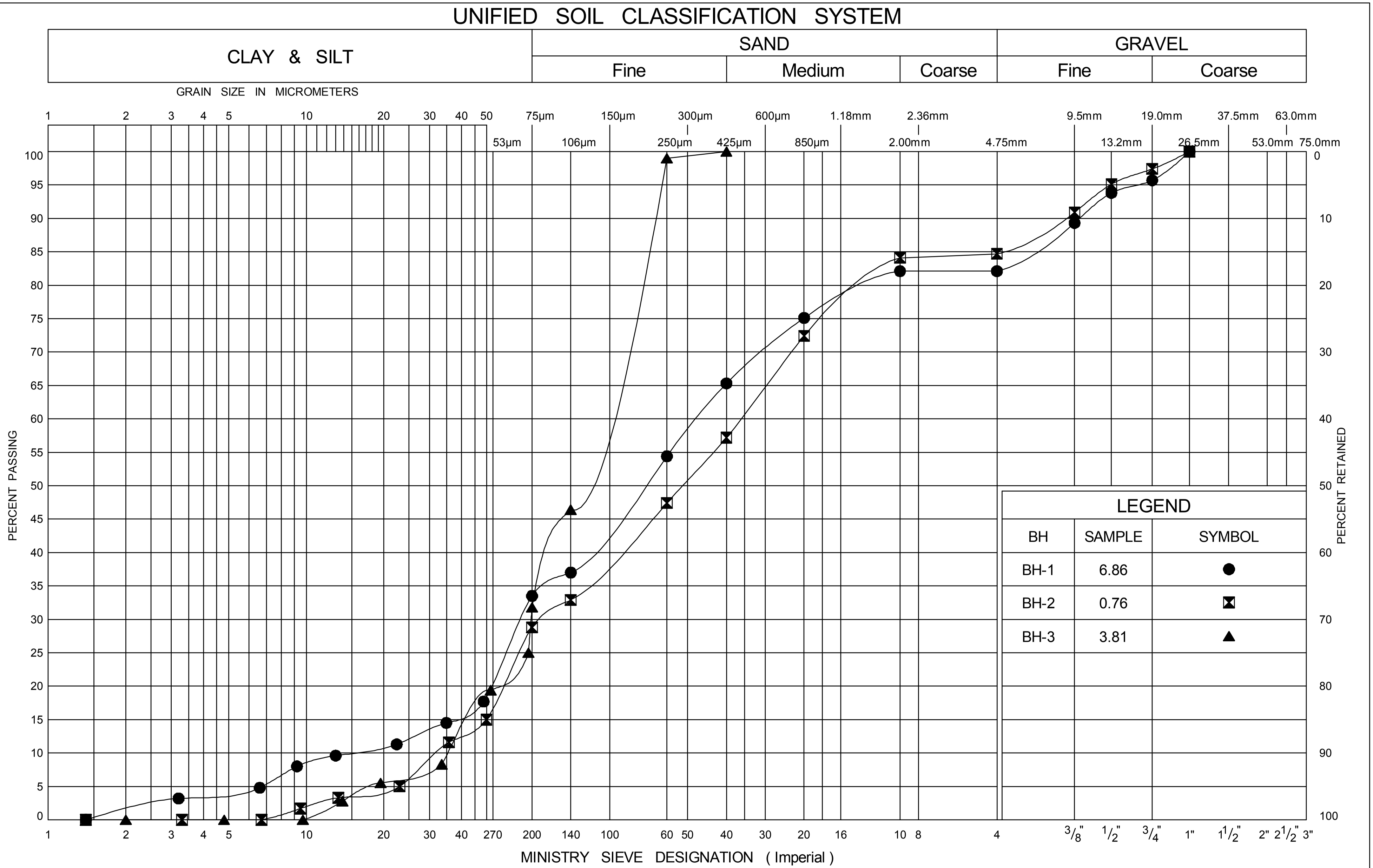
Appendix D –
Laboratory Test Results

78 12 M



Ministry of Transportation Ontario	GRAIN SIZE DISTRIBUTION	FIG No 1
	SAND FILL	W P 411-00-00,5016-E-0016
		Culvert Replacement

78 12 M



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GRAIN SIZE DISTRIBUTION

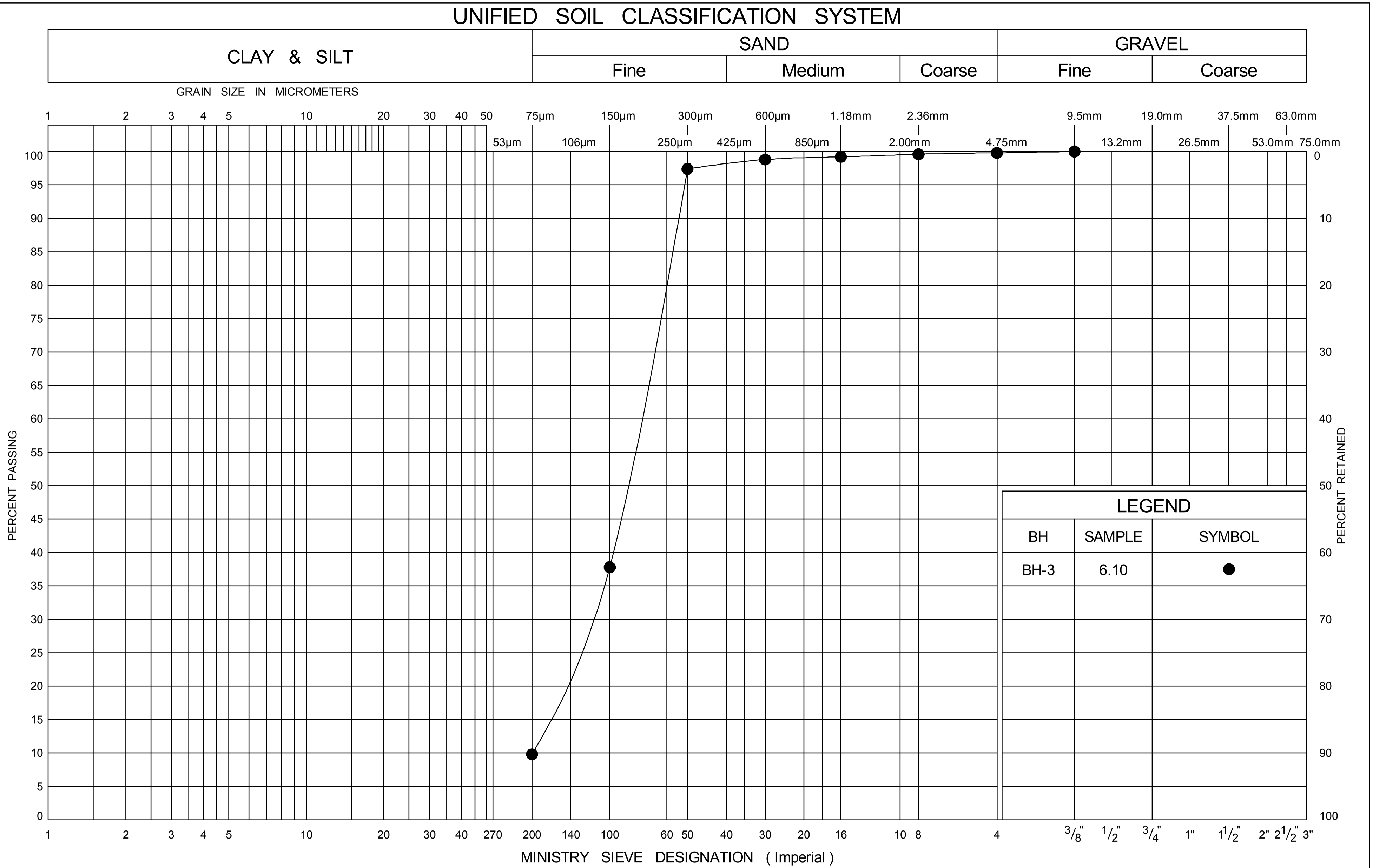
SILTY SAND

FIG No 2

W P 411-00-00,5016-E-0016

Culvert Replacement

78 12 M



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GRAIN SIZE DISTRIBUTION

SAND

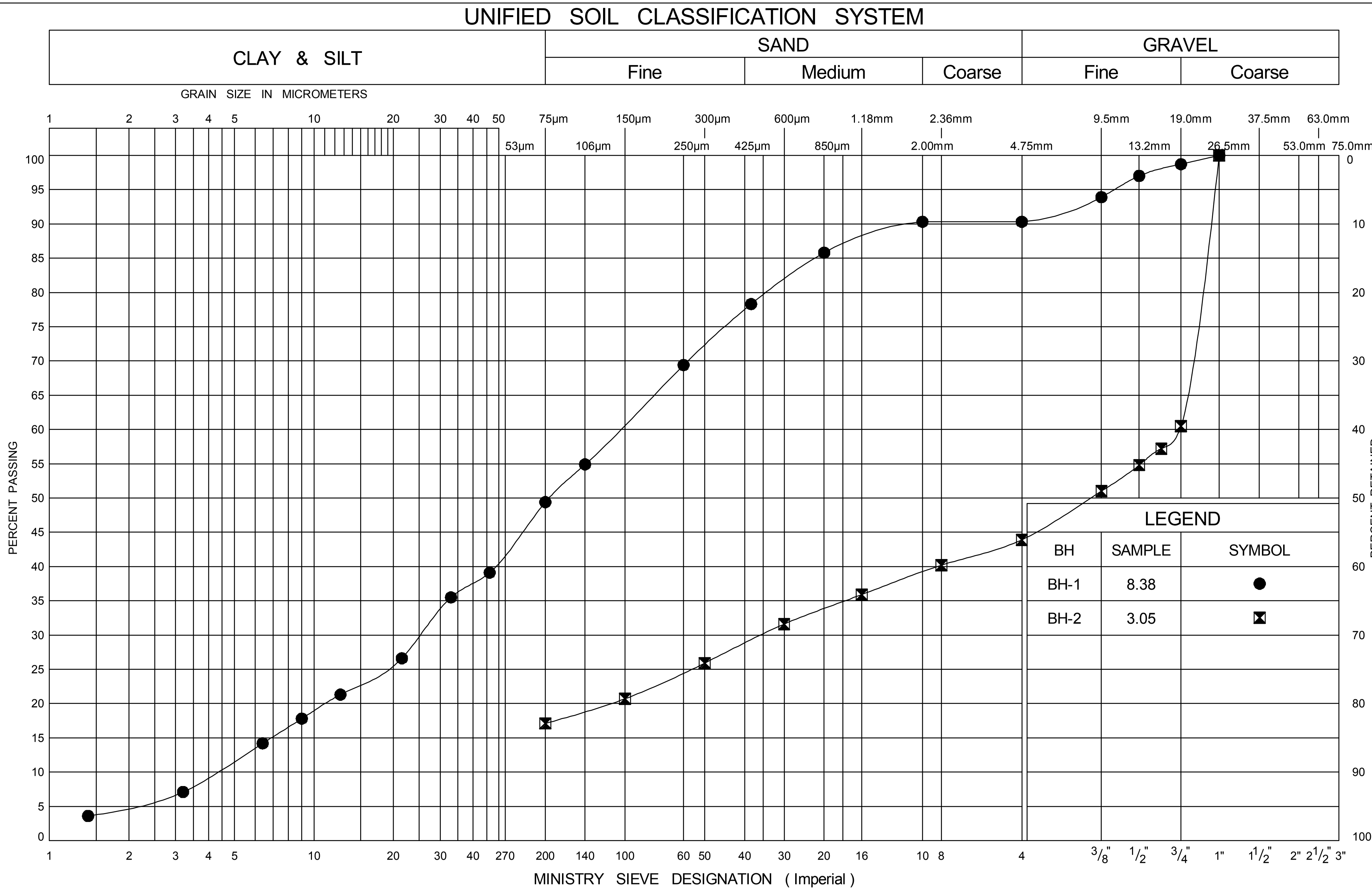
FIG No 3

W P 411-00-00,5016-E-0016

Culvert Replacement

ONTARIO MOT GRAIN SIZE SUD-00014543-AG - HWY. 129 - STR CULVERT 17+150.GPJ ONTARIO MOT.GDT 8/1/17

78 12 M



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GRAIN SIZE DISTRIBUTION

TILL

FIG No 4

W P 411-00-00,5016-E-0016

Culvert Replacement