

SUD-00014543-AG

Submitted: December 4, 2017



Foundation Investigation
Report

Agreement No. 5016-E-0016

GWP 411-00-00

GEOCRES No. 410-32

**Culvert Replacement, Stn. 14+457
Highway 129, Reaney Township,
District of Sudbury**

Prepared For:

**Ministry of Transportation
Northeast Region**

**447 McKeown Avenue, Suite 301
North Bay, Ontario P1B 9S9**

**Attn: Nasr Slabi, Project Manager
Geotechnical Section**

exp Services Inc.

885 Regent Street
Sudbury, Ontario P3E 5M4
Tel: (705) 674-9681
Fax: (705) 674-5583

The Ministry of Transportation

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Assignment No. 5016-E-0016
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Project Name:

Culvert Replacement, Strn. 14+457
Highway 129, Reaney Township, District of Sudbury

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Prepared By:

Ian MacMillan, P.Eng.

Reviewed By:

Andy Schell, M.Sc. (Eng.), P.Eng.
TaeChul Kim, M.E.Sc., P.Eng.
Stan E. Gonsalves, M.Eng., P.Eng.

exp Services Inc.
885 Regent Street
Sudbury, ON P3E 5M4
Canada
T: 705.674.9681
F: 705.674.5583
www.exp.com



Ian MacMillan, P.Eng.
Senior Geotechnical Engineer



Stan E. Gonsalves, M.Eng., P.Eng.
Principal Engineer
Designated MTO Foundation Contact

Date Submitted:

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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 centreline culvert located on Highway 129 at Station 14+457, within Reaney 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 14+457 within Reaney Township. The site is located approximately 30.5 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 non-structural, corrugated steel pipe (CSP), approximately 900 mm in diameter and 32.14 m long. 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 5.5 m high on both sides of the roadway, having side slopes of approximately 2.2H:1V on the west embankment and 1.9H:1V on the east embankment, from the top to toe of the 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 waterway 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 the time of the assessment, the water levels appeared low, with standing water on the inlet side.

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 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 poor to fair shape, with moderate wheel track rutting and moderate transverse, longitudinal, and map cracking. Immediately above the culvert, moderate to severe transverse cracking has occurred across the full width of the roadway.



1.2.2 Geological Setting

In accordance with Ontario Geological Survey Northern Ontario Engineering Geology Terrain Study 80, the dominant landform at the culvert site is ground moraine consisting mainly of till. Local relief is generally low (< 15 m) and the terrain is generally undulating to rolling. Overall drainage is good (dry).

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 December 6, 2016 and January 28 and 29, 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 northbound lane, as close as possible to the crest of the eastern embankment. 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 contractor, Landcore Drilling. Each borehole was advanced to refusal at depths ranging from 5.2 to 9.5 m below existing grades. As refusal depths were encountered greater than 2.0 m below the culvert invert, coring was not required in accordance with the TOR.

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. 14+450. The TBM was assigned an elevation of 462.4 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 borehole logs 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 borehole log 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 fill materials, peat, and native silt/sand, and assumed till. At the toes of the embankment slopes (BH-2 and BH-3), the subsurface conditions encountered consist of silt and sand fill, peat, native silt/sand, and till materials. 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 thicknesses may further vary beyond the borehole location.

1.4.2 Fill Materials

Fill materials were encountered below the asphalt at Borehole BH-1 and at the surface of BH-3. The fill materials extended to approximately 6.3 m depth at BH-1 and 2.3 m depth at BH-3.

At BH-1, the fill material layers ranged in composition, including:

- gravelly sand fill;
- sandy silt fill;
- sand fill; and,
- silt fill.

At BH-3, the fill materials consisted of silt and sand fill, with some organics, changing to organic silt and sand fill with peat.

Further details on the fill layers are outlined in the following sections.



1.4.2.1 Gravelly Sand Fill

An approximately 3.0 m thick layer of gravelly sand fill was encountered below the asphalt at Borehole BH-1. The fill material was brown in colour, moist, and contained trace silt.

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:

- 3 to 7 %

Grain Size Distribution:

- 28 % gravel
- 64 % sand
- 7 % fines

The results of the moisture content and grain size distribution tests are provided on the borehole log for BH-1 in Appendix C. The result of the grain size distribution test is also provided on Figure 1 in Appendix D.

1.4.2.2 Sandy Silt Fill

Underlying the gravelly sand fill at 3.1 m depth at Borehole BH-1 was an approximately 0.7 m thick layer of sandy silt fill. The fill material was brown in colour, moist, and contained trace organics, trace gravel, trace clay, and some cobbles and boulders. One SPT was performed within the sandy silt fill, with a resulting uncorrected "N" value of 45 blows per 300 mm, classifying the soil as dense in compactness condition.

Laboratory testing performed on a sample consisted of one (1) moisture content test and one (1) grain size analysis. The test results are as follows:

Moisture Content:

- 16 %

Grain Size Distribution:

- 5 % gravel
- 30 % sand
- 63 % silt
- 3 % clay

The results of the moisture content and grain size distribution tests are provided on the borehole log for BH-1 in Appendix C. The result of the grain size distribution test is also provided on Figure 2 in Appendix D.

1.4.2.3 Sand Fill

Underlying the sandy silt fill at 3.8 m depth at Borehole BH-1 was an approximately 1.5 m thick layer of sand fill. The fill material was brown in colour, moist, and contained trace to some silt, trace roots, trace to some gravel, and some cobbles and boulders. Uncorrected SPT "N" values within the fill ranged from 28 to 53 blows per 300 mm, classifying the fill as compact to very dense in compactness condition.

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



Moisture Content:

- 9 and 17 %

The results of the moisture content tests are provided on the borehole log for BH-1 in Appendix C.

1.4.2.4 Silt Fill

Underlying the sand fill at 5.3 m depth at Borehole BH-1 was an approximately 1.0 m thick layer of silt fill. The fill material was brown to dark brown in colour, wet, and contained some organics, some sand, and trace clay. One SPT was performed within the silt fill, with a resulting uncorrected "N" value of 9 blows per 300 mm, classifying the soil as loose in compactness condition.

Laboratory testing performed on a sample consisted of one (1) moisture content test and one (1) grain size analysis. The test results are as follows:

Moisture Content:

- 23 %

Grain Size Distribution:

- 7 % gravel
- 16 % sand
- 74 % silt
- 3 % clay

The results of the moisture content and grain size distribution tests are provided on the borehole log for BH-1 in Appendix C. The result of the grain size distribution test is also provided on Figure 3 in Appendix D.

1.4.2.5 Silt and Sand Fill to Organic Silt and Sand Fill

Extending from the surface of BH-3 to 2.3 m depth was silt and sand fill changing to organic silt and sand fill. The fill materials were grey to black in colour, wet, and contained some organics in the upper 0.8 m, with an increasing proportion of organics with depth. Uncorrected SPT "N" values within the fill ranged from 3 to 9 blows per 300 mm, classifying the fill as very loose to loose in compactness condition.

Laboratory testing performed on selected samples consisted of three (3) moisture content tests. The test results are as follows:

Moisture Content:

- 27 to 128 %

The results of the moisture content tests are provided on the borehole log for BH-3 in Appendix C.

1.4.3 Peat

Peat was encountered at the surface of Borehole BH-2 and at 6.3 m depth at BH-1, and 2.3 m depth at BH-3. The peat layer ranged in thickness from 1.6 to 2.6 m. The peat was grey to black in colour, wet, and contained some to with silty sand, some gravel, and wood. Uncorrected SPT "N" values within the peat ranged from 1 to 6 blows per 300 mm, classifying the peat as very loose to loose in compactness condition. The lower blows counts were found in the surficial peat at BH-2.

Laboratory testing performed on selected samples consisted of nine (9) moisture content tests. The test results are as follows:



Moisture Content:

- 27 to 282 %

The results of the moisture content tests are provided on the borehole logs in Appendix C.

1.4.4 Silt and Sand

Underlying the peat at 7.9 m depth at Borehole BH-1 and 2.6 m depth at BH-2 was an approximately 1.2 to 3.5 m thick layer of native silt and sand. The silt and sand was grey in colour, wet, and contained some organics, trace clay, and trace gravel. Uncorrected SPT "N" values within the soil ranged from 0 to 13 blows per 300 mm, classifying the soil as very loose to compact in compactness condition.

Laboratory testing performed on selected samples consisted of three (3) moisture content tests and two (2) grain size analyses. The test results are as follows:

Moisture Content:

- 15 to 45 %

Grain Size Distribution:

- 1 to 7 % gravel
- 40 to 41 % sand
- 45 to 56 % silt
- 3 to 6 % clay

The results of the moisture content and grain size distribution tests are provided on the borehole log for BH-1 and BH-2 in Appendix C. The results of the grain size distribution tests are also provided on Figure 4 in Appendix D.

1.4.5 Silty Gravelly Sand Till

Underlying the peat at 4.6 m depth at Borehole BH-3 and extending to the refusal depth of 5.2 m, was native silty gravelly sand till. The till was grey in colour, wet, and contained trace clay. One SPT performed within the till resulted in an uncorrected "N" value of 110 blow per 300 mm, classifying the till as very dense in compactness condition.

At BH-1 and BH-2, very little soil material was recovered from the sampler at the refusal depths of 9.5 m and 6.2 m, respectively. The soil that was recovered from the split spoon generally consisted of gravel. It is suspected that refusal in these boreholes was within the same till layer as encountered at BH-3.

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

Moisture Content:

- 12 %

Grain Size Distribution:

- 32 % gravel
- 35 % sand
- 32 % silt
- 1 % clay



The results of the moisture content and grain size distribution test are provided on the borehole log for BH-3 in Appendix C. The result of the grain size distribution test is also provided on Figure 5 in Appendix D.

1.4.6 Refusal Depths

Refusal was encountered in each borehole between approximately Elev. 450.0 m to 453.0 m. At Borehole BH-1, observations made by the field technician during drilling suggest the encountered refusal was likely on bedrock (though not confirmed). At Borehole BH-2, there were no indications during drilling that could help distinguish whether refusal was on bedrock or on very dense till. At Borehole BH-3, the split spoon sampler advanced at the refusal depth was bent when extracted from the borehole, suggesting refusal was likely on bedrock (though not confirmed).

As coring was not utilized beyond the refusal depths noted, the presence of bedrock could not be confirmed.

1.5 Groundwater and Surface Water Conditions

Groundwater was observed in Borehole BH-1 upon completion at approximately 2.9 m depth, Elev. 459.5 m. Note, however, that this water elevation is not likely accurate as water was pumped into the borehole for the washboring techniques utilized. Washboring techniques were also used at BH-2 and BH-3 with the portable equipment utilized, and thus, no groundwater measurements were made in these boreholes. As such, accurate groundwater measurements could not be obtained in the boreholes upon completion.

Note, however, that samples within BH-1 were generally wet below 5.3 m depth, Elev. 457.1 m. In addition, samples at BH-2 and BH-3 were wet from surface, Elev. 456.2 to 457.8 m. This could infer a groundwater level located between Elev. 456.2 and 457.8 m.

The water level within the adjacent open water was measured at the time of the investigation (January 2017) and it was at approximately Elev. 457.0 (top of ice) at the culvert inlet and at Elev. 455.8 m at the culvert outlet. This is generally at the same level as the wet samples encountered within the boreholes, 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 and with weather conditions. 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 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.



Ian MacMillan, P.Eng.
Senior Geotechnical Engineer

Andy Schell, M.Sc.(Eng.), P.Eng.
Senior Geotechnical Engineer

TaeChul Kim, M.E.Sc., P.Eng.
Senior Geotechnical Engineer/Foundation
Specialist

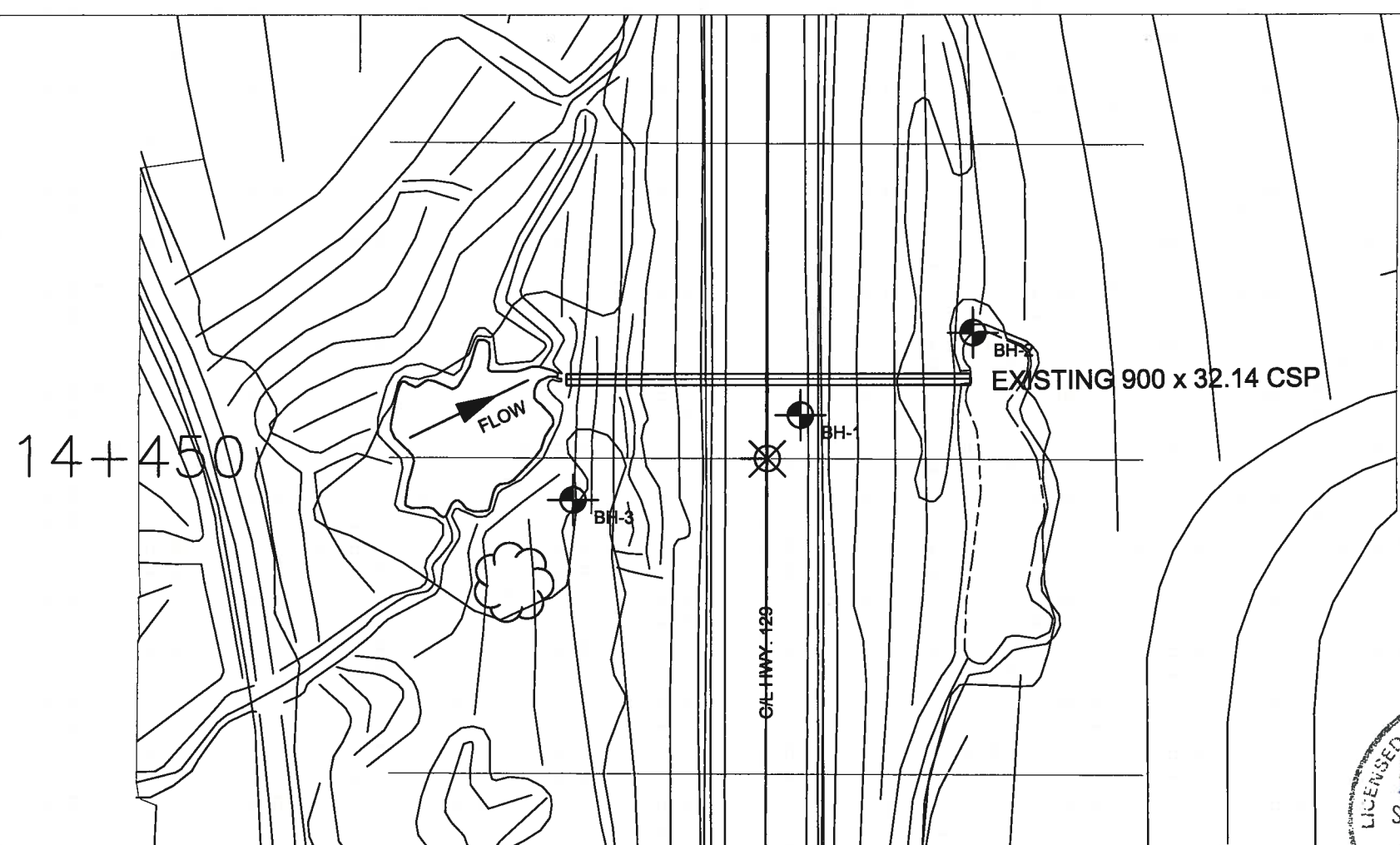
Stan E. Gonsalves, M.Eng., P.Eng.
Principal Engineer
Designated MTO Foundation Contact



Appendix A – Drawings

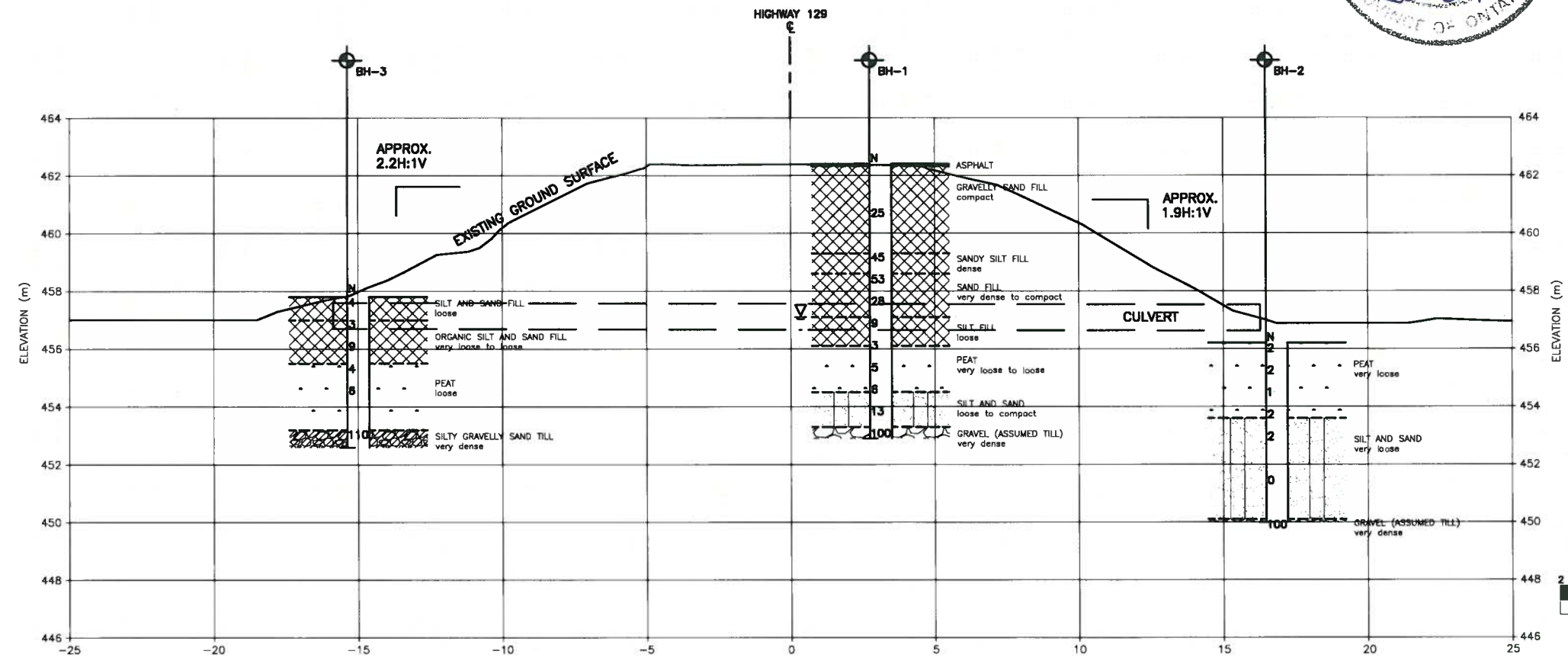


14+450



PLAN

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



CROSS SECTION AT CULVERT CENTRELINE



Agreement No. 5016-E-0016
GWP 411-00-00
GEOCRES No. 410-32

CULVERT REPLACEMENT, STN. 14+457
HIGHWAY 129, REANEY TOWNSHIP
DISTRICT OF SUDBURY
BOREHOLE LOCATION PLAN AND SOIL
STRATA

exp Services Inc.

KEY PLAN - NTS

LEGEND

BOREHOLE COORDINATES

NOTES

SOIL STRATA SYMBOLS

REVISIONS

SCALE: AS NOTED
SUBMD: IM
DRAWN: IM

PROJECT NO.: SUD-00014543-AG
DATE: 2017.6.26
CHECKED: AS
APPROVED: SG

DWG. 1

Appendix B – Photographs





Photograph No. 1 – Highway 129 at Culvert, Stn. 14+457 (Facing North)



Photograph No. 2 – Pavement Condition at Culvert (Facing North-East)



Photograph No. 3 – Eastern Embankment at Culvert Outlet (Facing North)



Photograph No. 4 – Culvert Outlet (Facing North-East)



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



Photograph No. 6 – Culvert Inlet (Facing 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		
<div><div>0.002</div><div>0.006</div><div>0.02</div><div>0.06</div><div>0.2</div><div>0.6</div><div>2.0</div><div>6.0</div><div>20</div><div>60</div><div>200</div></div>											
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	$5 \leq Pp \leq 10\%$
Little	$15 \leq Pp \leq 25\%$
Some	$30 \leq Pp \leq 45\%$
Mostly	$50 \leq Pp \leq 100\%$

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	$5 \leq N < 10$
Compact	$10 \leq N < 30$
Dense	$30 \leq N < 50$
Very Dense	$50 \leq N$

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:

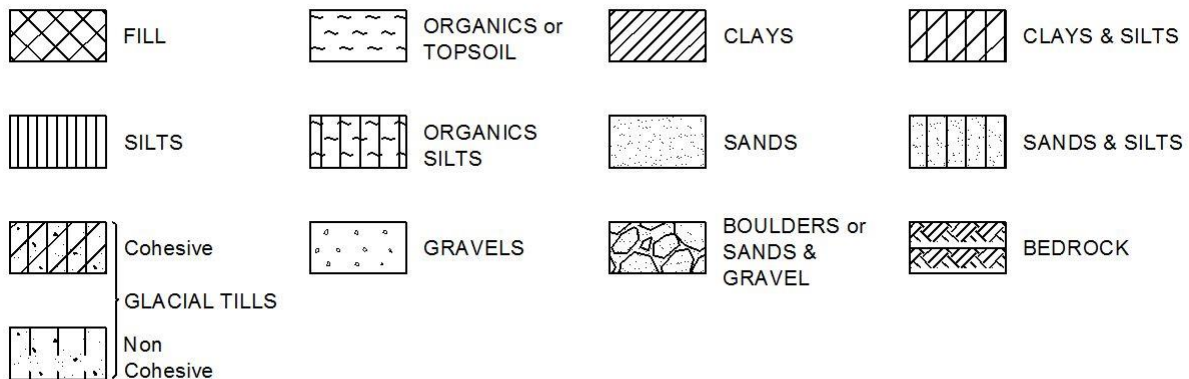
Table c: Consistency of Cohesive Soil

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



Open Borehole or Test Pit



Monitoring Well, Piezometer or Standpipe

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

MECHANICAL PROPERTIES 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'	—°	Effective angle of internal friction
c_u	kPa	Apparent cohesion intercept
ϕ_u	—°	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

1 OF 1

METRIC

W.P. 411-00-00,5016-E-0016 LOCATION Stn. 14+455, MTM-13, 5266613.63N, 364209.1E, Non-Structural Culvert at Stn. 14+457 ORIGINATED BY NW
 DIST Sudbury HWY 129 BOREHOLE TYPE Continuous Flight HSA and Washboring with NW Casing COMPILED BY IM
 DATUM Geodetic DATE 2016.12.06 - 2016.12.06 LATITUDE 47.53601 LONGITUDE -83.21087 CHECKED BY IM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	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	x LAB VANE							
462.4	Pavement Surface																	
462.0	ASPHALT (~ 76 mm thick)		1	AS			462									28 64 (7)		
	FILL, gravelly sand, trace silt, brown, moist, compact.		2	AS														
	No sample returned at ~ 1.5 m depth due to lodged stone in split spoon sampler. Auger sample obtained.		3	SS	25		461											
							460											
459.4																		
3.1	FILL, sandy silt, trace organics, trace gravel, trace clay, brown, moist, dense.		4	SS	45		459								5 30 63 3			
458.6	some cobbles and boulders below ~ 3.5 m depth.																	
3.8	FILL, sand, trace silt, trace to some gravel, some cobbles and boulders, brown, moist, very dense to compact.		5	SS	53		458											
	some silt, trace roots, grey below ~ 4.6 m depth.		6	SS	28													
457.1							457								7 16 74 3			
5.3	FILL, silt, some organics, some sand, trace clay, brown to dark brown, wet, loose.		7	SS	9													
456.1							456											
6.3	PEAT, with wood, black, moist to wet, very loose to loose.		8	SS	3													
	No soil sample returned at ~ 6.9 m depth due to lodged wood in split spoon sampler.		9	SS	5		455											
454.5																		
7.9	SILT AND SAND, trace clay, trace gravel, grey, moist, loose to compact.		10	SS	6		454								1 40 56 3			
453.3																		
9.1	GRAVEL, grey, moist. (Assumed Till)		12	SS	100		453											
453.0																		
9.5	END OF BOREHOLE Borehole terminated at ~ 9.5 m depth due to refusal on suspected very dense till or bedrock																	
	NOTES: 1. This drawing to be read with the subject report and project numbers as presented above. 2. Multiple attempts made to advance borehole beyond refusal depth. 3. Groundwater condition noted may not be accurate as water was pumped into hole due to washboring techniques utilized.																	

RECORD OF BOREHOLE No BH-2

1 OF 1

METRIC

W.P. 411-00-00,5016-E-0016 LOCATION Stn. 14+460, MTM-13, 5266625.95N, 364218.01E, Non-Structural Culvert at Stn. 14+457 ORIGINATED BY ST
DIST Sudbury HWY 129 BOREHOLE TYPE Portable Tripod With Cathead and Hilti D200 Drill COMPILED BY IM
DATUM Geodetic DATE 2017.01.29 - 2017.01.29 LATITUDE 47.53612 LONGITUDE -83.21075 CHECKED BY IM









SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
456.2	Ground Surface													
0.0	PEAT, some to with silty sand, some gravel, grey to black, wet, very loose. no gravel below ~ 0.8 m depth.		1	SS	2		456							
			2	SS	2		455						94.4	
			3	SS	1		454						134.7	
453.6			4	SS	2		453							
2.6	SILT AND SAND, some organics, trace gravel, trace clay, grey, wet, very loose.		5	SS	2		452							
			6	SS	0		451							
450.1			7	SS	100									
450.0	GRAVEL, grey, wet. (Assumed Till)													
6.2	END OF BOREHOLE Borehole terminated at ~ 6.2 m depth due to refusal on suspected very dense till or bedrock NOTES: 1. This drawing to be read with the subject report and project numbers as presented above. 2. Multiple attempts made to advance borehole beyond refusal depth. 3. Groundwater level not measured within borehole as water was pumped into hole due to washboring technique utilized.													

RECORD OF BOREHOLE No BH-3

1 OF 1

METRIC

W.P. 411-00-00,5016-E-0016 LOCATION Stn. 14+447, MTM-13, 5266599.04N, 364196.45E, Non-Structural Culvert at Stn. 14+457 ORIGINATED BY ST
DIST Sudbury HWY 129 BOREHOLE TYPE Portable Tripod With Cathead and Hilti D200 Drill COMPILED BY IM
DATUM Geodetic DATE 2017.01.28 - 2017.01.28 LATITUDE 47.53588 LONGITUDE -83.21104 CHECKED BY IM

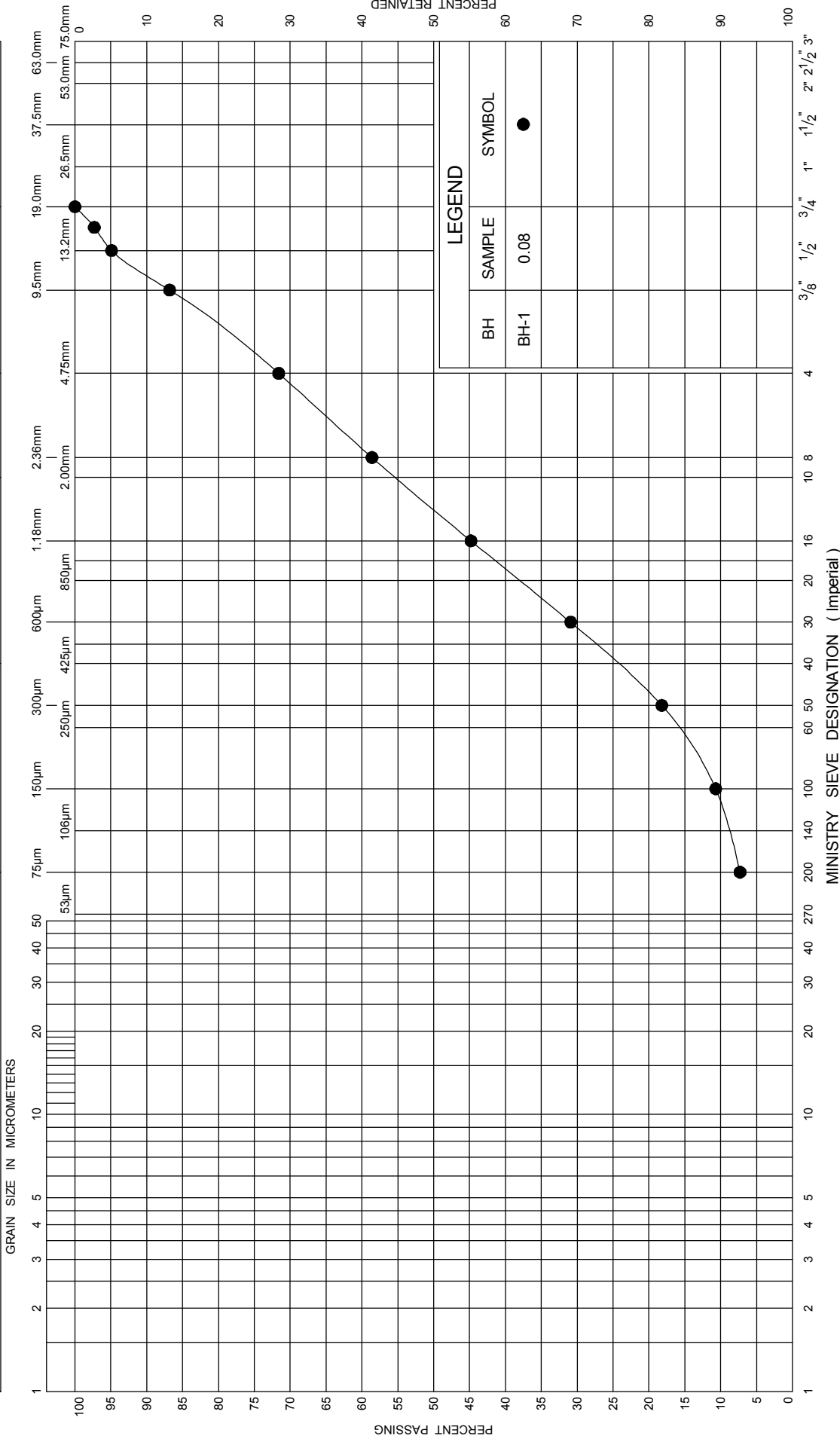
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
457.8	Ground Surface						20	40	60	80	100						
0.0	FILL , silt and sand, some organics, grey, wet, loose.		1	SS	4												
457.0																	
0.8	FILL , organic silt and sand, with peat, grey to black, wet, very loose to loose.		2	SS	3												
			3	SS	9												
455.5																	
2.3	PEAT , with silty sand, black, wet, loose.		4	SS	4												
																	
			5	SS	6												
																	
453.2																	
4.6	TILL , silty gravelly sand, trace clay, grey, wet, very dense.		6	SS	110											32 35 32 1	
452.6																	
5.2	END OF BOREHOLE Borehole terminated at ~ 5.2 m depth due to refusal on suspected very dense till or bedrock																
	NOTES: 1. This drawing to be read with the subject report and project numbers as presented above. 2. Multiple attempts made to advance borehole beyond refusal depth. 3. Groundwater level not measured within borehole as water was pumped into hole due to washboring technique utilized.																

Appendix D – Laboratory Test Results



UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT			SAND			GRAVEL		
GRAIN SIZE IN MICROMETERS			Fine			Medium		
			Coarse			Fine		



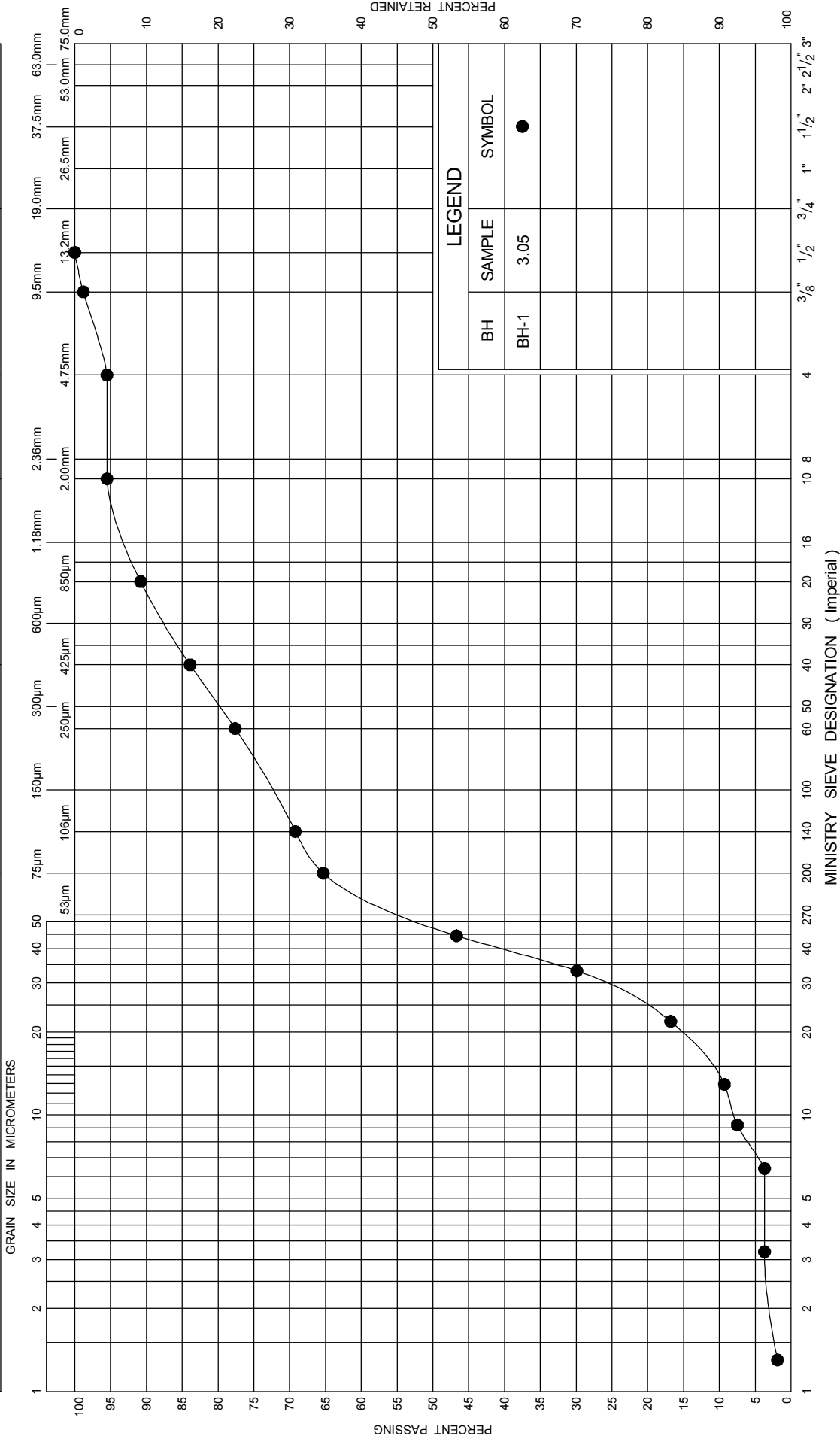
GRAIN SIZE DISTRIBUTION
GRAVELLY SAND FILL

FIG No 1

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

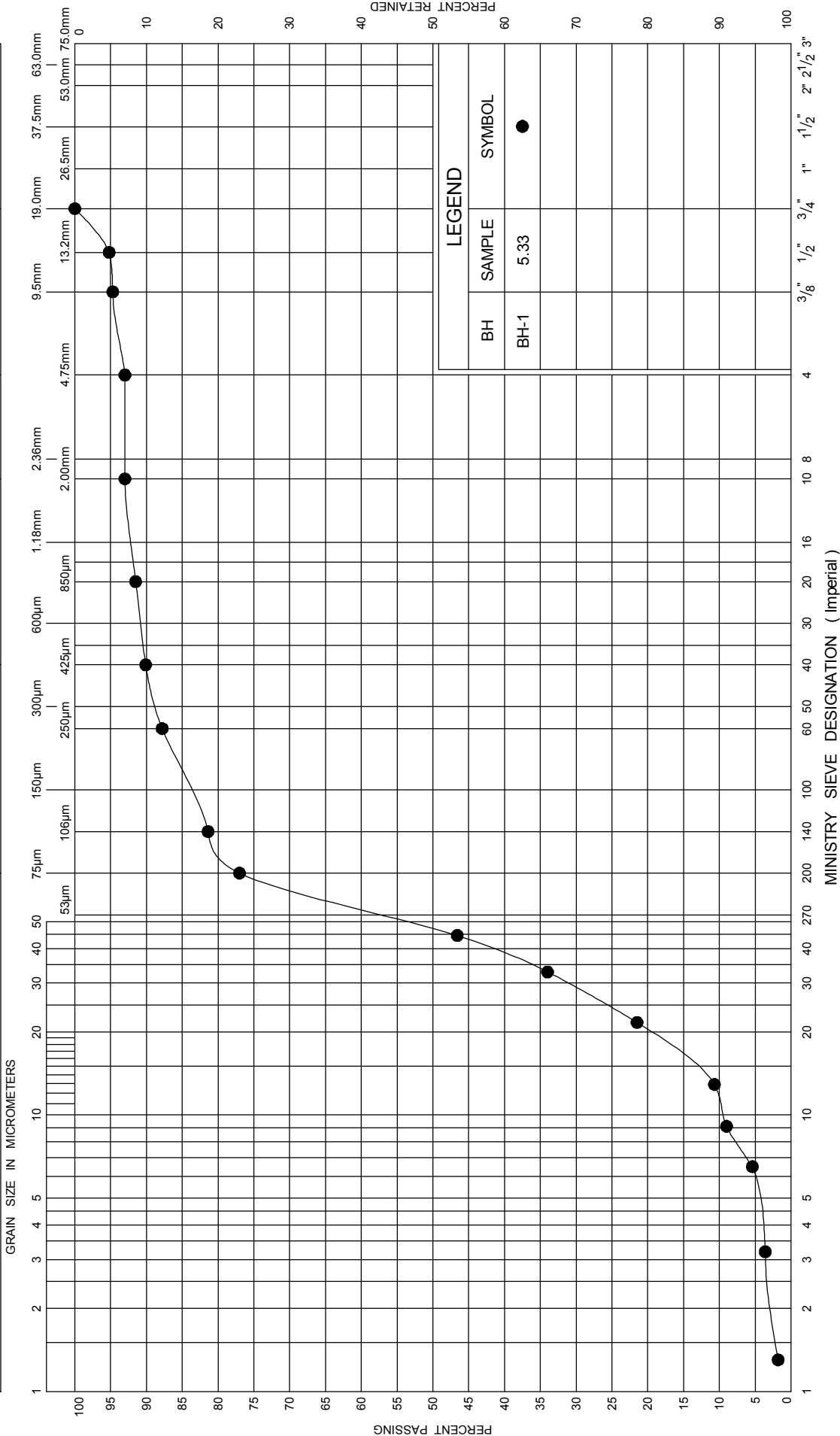
UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT		SAND			GRAVEL	
		Fine		Medium	Fine	Coarse



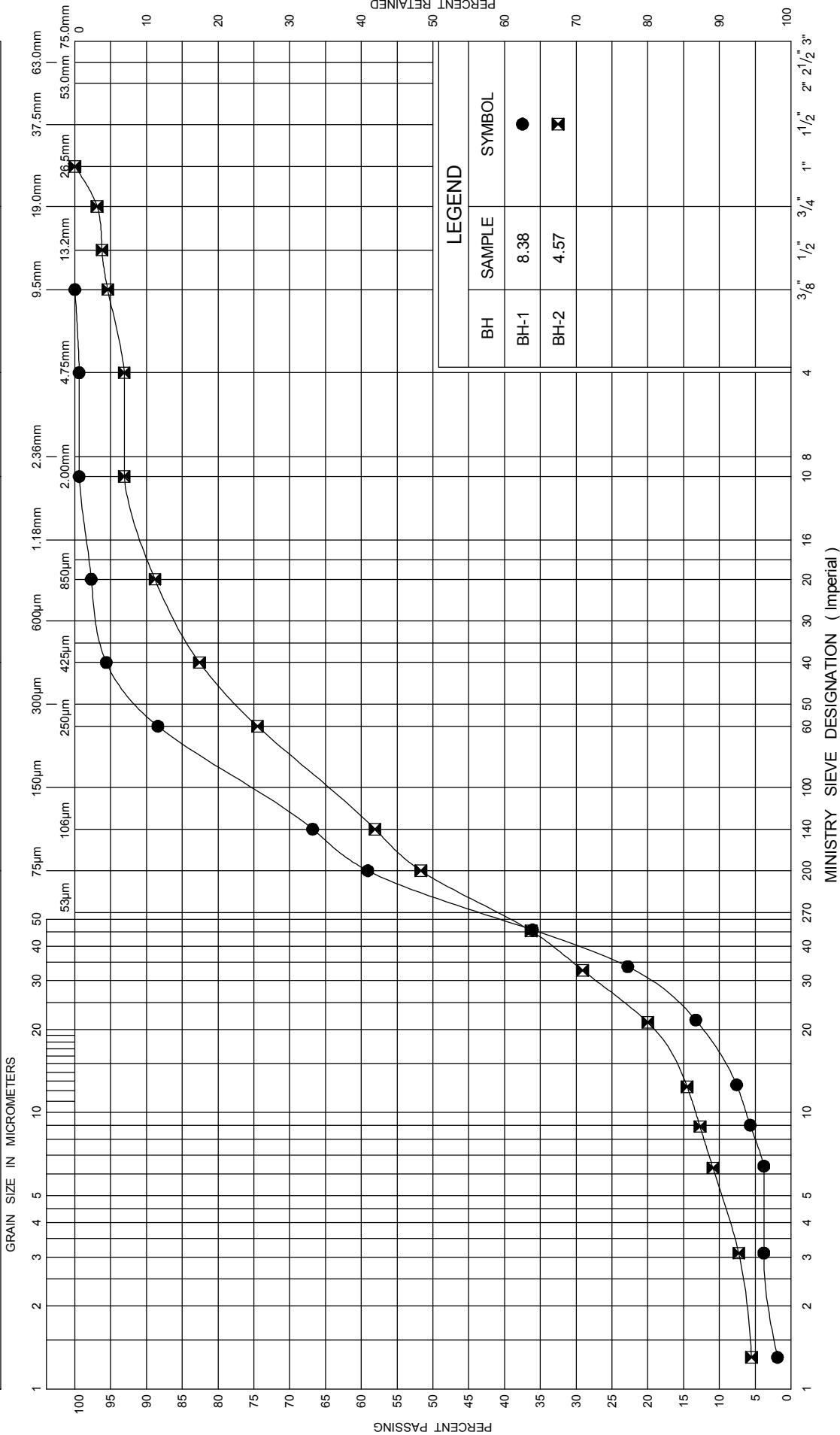
UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT		SAND			GRAVEL	
		Fine	Medium	Coarse	Fine	Coarse



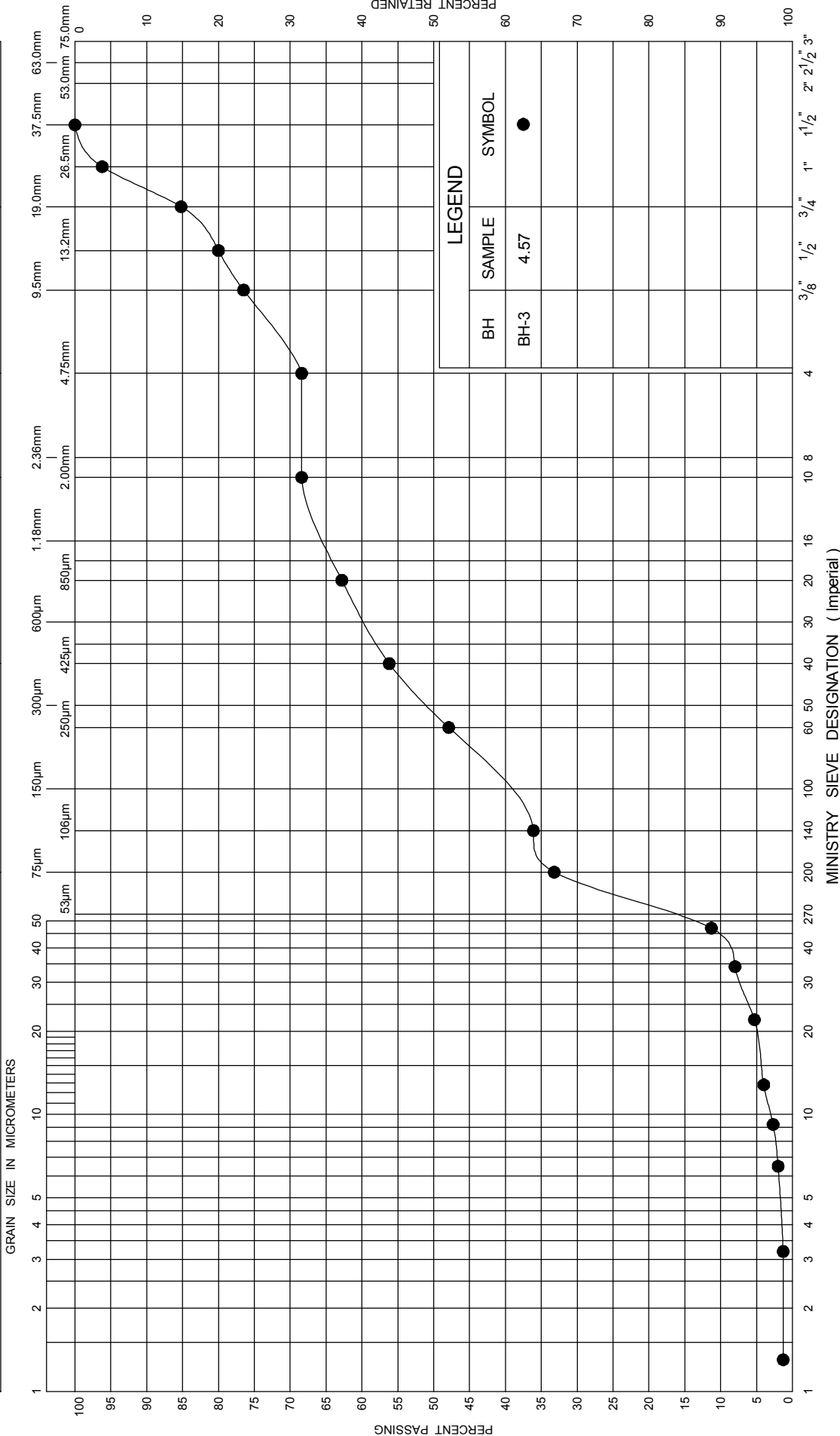
UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT		SAND			GRAVEL	
		Fine	Medium	Coarse	Fine	Coarse



UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT		SAND			GRAVEL	
		Fine		Medium	Fine	Coarse



GRAIN SIZE DISTRIBUTION

SILTY GRAVELLY SAND TILL

FIG No 5

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

Culvert Replacement