Terraprobe

Consulting Geotechnical & Environmental Engineering

Construction Materials Inspection & Testing

PRELIMINARY
FOUNDATION INVESTIGATION REPORT
UNNAMED CREEK CULVERT REPLACEMENT
HIGHWAY 634
ASSIGNMENT No. 5013-E-0018
MINISTRY OF TRANSPORTATION, ONTARIO
G.W.P. No. 5379-11-00, SITE 39E-244C
GEOCRES NO. 42H-61

PREPARED FOR: MMM Group Limited
2655 North Sheridan Way, Suite 300
Mississauga, Ontario
L5K 2P8

Attention: Mr. Trevor Small, M.Sc., P.Eng.

File No. 11-14-4066
June 28, 2016

Distribution:

3 Copies- MTO Project Manager (Northeastern Region)
1 Copy - MTO Pavements and Foundations Section
1 Copy - MMM Group Limited, Mississauga
1 Copy - Terraprobe Inc., Brampton

TABLE OF CONTENTS

PART A – FOUNDATION INVESTIGATION REPORT

UNNAMED CREEK CULVERT REPLACEMENT, SITE 39E-244C
HIGHWAY 634
TOWNSHIP OF ADANAC, DISTRICT OF COCHRANE, ONTARIO
ASSIGNMENT No. 5013-E-0018, G.W.P. 5379-11-00

1.0 INTRODUCTION

Terraprobe Inc. (Terraprobe) has been retained by MMM Group Limited (MMM) on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services in support of preliminary designs for the rehabilitation of structures identified in MTO's Request for Proposal (RFP) titled *"Preliminary Design, Rehabilitation/Replacement of Twelve Structures on Highway 11, 101, 577, 579, 634 & 668, in New Liskeard Area", Contract Number. 5013-E-0018*.

The terms of reference and scope of work for the foundation engineering services are outlined in MTO's RFP, and in Section 5.7 of MMM's *Technical Proposal* for this assignment. This report presents factual data on the subsurface conditions at the Unnamed Creek Culvert, Site 39E-244C on Highway 634, Township of Adanac, District of Cochrane, Ontario.

2.0 SITE DESCRIPTION

The site is located on Highway 634 (Latitude 49.553°, Longitude – 81.510°), approximately 2.3 km south of the highway's east junction with Island Falls Road in the Township of Adanac, Ontario. Island Falls is located east of the site and the main community of Smooth Rock Falls is situated approximately 35 km south of the site. The key plan on the Borehole Locations and Soil Strata Drawing, (Drawing 1) provides an overview of the site location.

The existing culvert located at Station 10+355 is a 2.4 m diameter and 30.3 m long round Structural Plate Corrugated Steel Pipe (SPCSP) with upstream and downstream invert elevations of 93.8± m. The Highway 634 embankment is approximately 6.7± m high at the culvert site with a pavement centre line elevation of 100.7± m. The watercourse flows through the culvert below Highway 634 from west to east. Vegetation at the site consists primarily of a coniferous forest with grass and shrubs.

3.0 INVESTIGATION PROCEDURES

The field work for this project was carried out between August 18 and August 22, 2014 and consisted of drilling and sampling three boreholes to depths ranging from 4.3 m to 23.8 m below ground surface. Dynamic cone penetration tests (DCPT's) were also carried out at two locations to depths of 3.9 m and 4.6 m below ground surface. The approximate borehole and DCPT locations are shown on Drawing 1.

Terraprobe's staff staked out the borehole locations in the field relative to on-site features and MMM surveyors established Control Point HCP 101 with a geodetic elevation of 100.00 m. The data from this control point was used by Terraprobe's staff to determine the ground surface elevations and local site coordinates of the boreholes. This data is summarized in the following table.

Borehole Details

Borehole No.	Local Site Coordinates		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (m)	Easting (m)		
BH1	91 770.9	7 878.0	97.1	19.2
BH2	91 785.6	7 856.9	100.6	23.8
BH3	91 785.2	7 840.9	94.7	4.3
C1	91 785.2	7 839.9	94.7	4.6
C2	91 785.2	7 837.9	94.7	3.9

The boreholes were drilled with track-mounted CME 55 and portable drill rigs supplied and operated by specialist drilling contractors. Samples of the overburden soils were generally obtained at intervals of 0.75 m and 1.5 m depth using a 50 mm outer diameter (O.D.) split-spoon sampler in conjunction with the Standard Penetration Testing (SPT) procedures as specified in ASTM Method D 1586[1]. Two Dynamic Cone Penetration Tests were also performed from ground surface to refusal at distances of 1± m and 3± m west of Borehole 3. The bedrock was also cored by NQ-size diamond coring techniques in Boreholes 1 and 2. The field work was monitored on a full-time basis by a member of Terraprobe's staff who observed the drilling, sampling and in situ testing operations and logged the boreholes.

Ground water conditions in the open boreholes were observed during the drilling operations and a standpipe piezometer was installed in Boreholes 1 and 2 to permit longer term ground water level monitoring. The boreholes were backfilled in accordance with current MTO procedures and Ontario Regulation 903 (as amended).

The recovered soil samples were subjected to Visual Identification (VI) and select samples were also subjected to a laboratory testing programme consisting of natural moisture content, grain size distribution analyses and Atterberg limits determinations in accordance with MTO and/or ASTM Standards as appropriate.

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Surficial sediments in this area were deposited during the Late Wisconsinan glaciation. The main overburden units deposited during this time are till, debris flows, glaciofluvial and glaciolacustrine sediments. The most prominent surficial deposit found within this area is a dense, massive, impervious clay-rich till that contains rounded pebbles (Ontario Geological Survey 2001).

A compilation of studies undertaken in the general area shows that the bedrock geology is dominated largely by metasedimentary gneissic rocks. Other rock types occurring within the study area include large batholiths of granitic intrusive rocks such as granodiorite. The bedrock age ranges from Precambrian to Cenozoic (Ontario Geological Survey 2001).

4.2 Subsurface Conditions

Reference is made to the Record of Borehole Sheets in Appendix A. Details of the encountered soil stratigraphy are presented in this appendix and on the "Borehole Locations and Soil Strata" drawing. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole Sheets governs any interpretation of the site conditions.

The stratigraphic boundaries shown on the Record of Boreholes and on the interpreted stratigraphic section are inferred from non-continuous soil sampling and therefore represent transitions between soil types rather than exact planes of geological change. The subsurface conditions will vary between and beyond the borehole locations.

1 ASTM D1586 – Standard Test Method for Standard Penetration Tests and Split Barrel Sampling of Soils.

In summary, the site is generally underlain by topsoil, the highway pavement, very loose to compact sand and silty sand fill soils and soft to firm clayey silt fill. The fill soils are underlain by peat, deposits of stiff to hard clayey silt to silty clay till and dense to very dense silt. The overburden soils are further underlain by Granodiorite Schist bedrock. A more detailed description of the subsurface conditions is provided in the following sections.

4.2.1 Topsoil

A 100 mm thick layer of topsoil was encountered at this site in Borehole 3. Topsoil thickness may vary between and beyond the boreholes.

4.2.2 Flexible Pavement

Borehole 2, which was drilled through Highway 634, encountered a flexible pavement consisting of a 25 mm thick layer of asphalt concrete underlain by a 375 mm thick layer of gravelly sand fill that extends to elevation 100.2 m.

A Standard Penetration test carried out in the gravelly sand fill gave an SPT N-value of 93 blows for 0.3 m of penetration indicating a very dense relative density. The natural water content of a sample of the granular fill is 8% by weight.

4.2.3 Fill – Sand

The flexible pavement in Borehole 2 is underlain by a 1.7 m thick layer of sand fill that extends to elevation 98.5 m. Standard Penetration tests carried out in the sand fill measured SPT N-values ranging from 3 to 20 blows for 0.3 m of penetration suggesting a very loose to compact relative density. The moisture content (by weight) of a sample of the sand fill is 11%.

The grain size distribution curve of a sample of the sand fill is shown on Figure B1 in Appendix B. The results show a grain size distribution consisting of 18% gravel, 75% sand and 7% silt and clay size particles.

4.2.4 Fill – Silty Sand

A 2.3 m thick layer of silty sand fill was encountered in Borehole 2 extending to a depth of 4.4 m below ground surface or to elevation 96.2 m. Standard Penetration tests performed in the silty sand fill gave SPT N-values that range from 5 to 12 blows for 0.3 m of penetration indicating a loose to compact relative density. The natural water content of samples of the silty sand fill varies from 13% to 18% by weight.

The grain size distribution curve of a sample of the silty sand fill is shown on Figure B2 in Appendix B. The results show a grain size distribution consisting of 1% gravel, 58% sand, 34% silt and 7% clay size particles.

4.2.5 Fill – Clayey Silt to Silty Clay

Clayey silt to silty clay fill was encountered across the site. The locations, thicknesses, depths and base elevations of the silty clay fill are summarized in the following table.

Silty Clay Fill Borehole Data

Borehole No.	Fill Thickness (m)	Fill Depth (m)	Fill Base Elevation (m)
BH1	0.7	0.7	96.4
BH2	2.3	6.7	93.9
BH3	0.6	0.7	94.0

Standard Penetration tests performed in the clayey silt to silty clay fill gave N-values that range from 2 to 6 blows for 0.3 m of penetration indicating a soft to firm consistency. The natural water content of samples of the clayey silt to silty clay fill range from 12% to 19% by weight.

The grain size distribution plots of two samples of the clayey silt to silty clay fill are depicted on Figure B3 in Appendix B. The results show a grain size distribution consisting of 0% and 1% gravel, 14% and 31% sand, 51% and 64% silt and, 17% and 22% clay size particles.

Atterberg limits tests were also carried out on two samples of the clayey silt to silty clay fill and the results are plotted on the plasticity chart, Figure B4 in Appendix B. These values indicate that the fill is a low plasticity cohesive soil (CL-ML and CL). The results from the Atterberg limits tests are summarized below:

Liquid Limit:	18% and 24%
Plastic Limit:	13% and 16%
Plasticity Index:	5% and 8%
Natural Moisture Content:	19%

4.2.6 Peat

A layer of fibrous peat was encountered in Borehole 3 below the silty clay fill. The peat layer is 0.7 m thick and it extends to elevation 93.3 m.

A Standard Penetration test carried out in the peat layer measured a SPT N-value of 2 blows for 0.3 m of penetration. The moisture content (by weight) of a sample of the peat is 88%.

4.2.7 Clayey Silt to Silty Clay Till

Till units ranging in composition from clayey silt to silty clay were encountered. The clayey silt to silty clay till deposit is divided into upper and lower layers by an interbedded silt layer. Summarized in the following table are the locations, thicknesses, explored depths and base elevations of the clayey silt to silty clay till.

Clayey Silt to Silty Clay Till Borehole Data

Borehole No.	Clayey Silt to Silty Clay Till Thickness (m)	Clayey Silt to Silty Clay Till Depth of Deposit (m)	Clayey Silt to Silty Clay Base Elevation (m)
Upper Clayey Silt Till Layer			
BH1	3.7	4.4	92.7
BH2	2.6	9.3	91.3
BH3	2.9	4.3*	90.4
Lower Clayey Silt to Silty Clay Till Layer			
BH1	11.9	17.9	79.2
BH2	10.8	20.9	79.7

* Borehole termination depth.

Standard Penetration tests carried out in this deposit measured SPT N-values that range from 10 to more than 100 blows per 0.3 m of penetration indicating a stiff to hard consistency. The natural water content of samples retrieved from these strata range from 8% to 37% by weight.

Grain size distribution tests were carried out on six samples of the clayey silt to silty clay till and the results are illustrated in Figure B5 in Appendix B. The results show a grain size distribution consisting of 0% to 1% gravel, 5% to 17% sand, 61% to 72% silt and 20% to 27% clay size particles.

Frequent cobble and boulder inclusions were encountered in Borehole 2 at a depth of 18.9 m to 20.9 m below ground surface and NQ-size diamond coring techniques were used to extend the borehole below the cobbles and boulders. Photographs of the cobbles and boulders are provided in Figure B8 in Appendix B.

Atterberg limits tests were also carried out on six samples of the clayey silt to silty clay till and the results are plotted on the plasticity chart, Figure B6 in Appendix B. The results indicate that the till matrix generally consists of low plasticity (CL-ML and CL) clayey silt to silty clay soils. The Atterberg limits test results are summarized below.

Liquid Limit:	16% to 23%
Plastic Limit:	12% to 15%
Plasticity Index:	4% to 8%
Natural Moisture Content:	12% to 19%

4.2.8 Silt

Embedded between the clayey silt to silty clay till layers, there exists a layer of silt. Summarized below are the locations, thicknesses, depths and base elevations of the silt deposit.

Silt Borehole Data

Borehole No.	Silt Thickness (m)	Silt Depth (m)	Silt Base Elevation (m)
BH1	1.6	6.0	91.1
BH2	0.8	10.1	90.5

The N-values of Standard Penetration tests carried out in the silt deposit range from 44 to 62 blows per 0.3 m of penetration, suggesting a dense to very dense relative density and, the moisture content of two samples of this deposit are 20% and 21% by weight.

The grain size distribution curve of a sample of the silt is shown on Figure B7 in Appendix B. The results show a grain size distribution consisting of 0% gravel, 0% sand, 95% silt and 5% clay size particles.

4.2.9 Bedrock

The overburden soils are underlain by granodiorite schist bedrock. Summarized below are the depths to bedrock and the bedrock surface elevations.

Bedrock Borehole Data

Borehole No.	Depth to Bedrock (m)	Top of Bedrock Elevation (m)
BH1	17.9	79.2
BH2	20.9	79.7

The granodiorite schist bedrock is described as unweathered, massive brownish grey rock of very high strength (estimated by chipping rock specimens with a geological hammer). Photographs of the bedrock core samples are provided in Figures B9 in Appendix B. Summarized below are the Rock Quality Designation, Rock Mass Quality, Total Core Recovery and Solid Core Recovery.

Rock Core Sample Data

Borehole No.	Rock Quality Designation (RQD)	Rock Mass Quality[2]	Total Core Recovery (TCR)	Solid Core Recovery (SCR)
BH1	87%	Good	100%	87%
BH2	100%	Excellent	100%	100%

4.3 Ground Water Levels

The ground water conditions were observed in the boreholes during and upon completion of drilling and standpipe piezometers were installed in Borehole 1 and Borehole 2. The ground water levels measured in the piezometers are summarized in the following table:

Ground Water Level Data

Borehole No.	Date	Water Levels	
		Depth (m)	Elevation (m)
BH1	September 16, 2014 October 27, 2014	0.1 0.3	97.0 96.8
BH2	September 16, 2014 October 27, 2014	2.7 2.4	97.9 98.2

2 Deere et al., 1967.

The ground water elevations in Borehole 1 and 2 are higher than the floodplain elevation of the creek indicating that a hydrostatic head exists in the lower clayey silt to silty clay till in which the piezometer screens were made. The free water level at this site is estimated to be at an approximate elevation of 94.0± m (flood plain level) based on the soil moisture conditions and the ground surface topography.

5.0 MISCELLANEOUS

The investigation was carried out using drilling equipment supplied and operated by Landcore Drilling of Chelmsford, Ontario. The field operations were supervised by Mr. Wen Zhu and the routine laboratory testing was carried out at Terraprobe's Brampton laboratory.

This report was prepared by Mr. Rehman Abdul, P.Eng., a Senior Geotechnical Engineer and Principal with Terraprobe with assistance provided by Ms. Sepideh D-Monfared, MESc. Mr. Michael Tanos, P.Eng., Terraprobe's Designated MTO Contact conducted an independent quality control review.

Terraprobe Inc.

Rehman Abdul, P.Eng.
Principal, Senior Geotechnical Engineer

Michael Tanos, P.Eng.
Designated MTO Contact

REFERENCES

Bowles, J.E., 1984. *Physical and Geotechnical Properties of Soils*, Second Edition. McGraw Hill Book Company, New York.

Canadian Geotechnical Society, 2006. *Canadian Foundation Engineering Manual*, 4th Edition. The Canadian Geotechnical Society c/o BiTech Publisher Ltd, British Columbia.

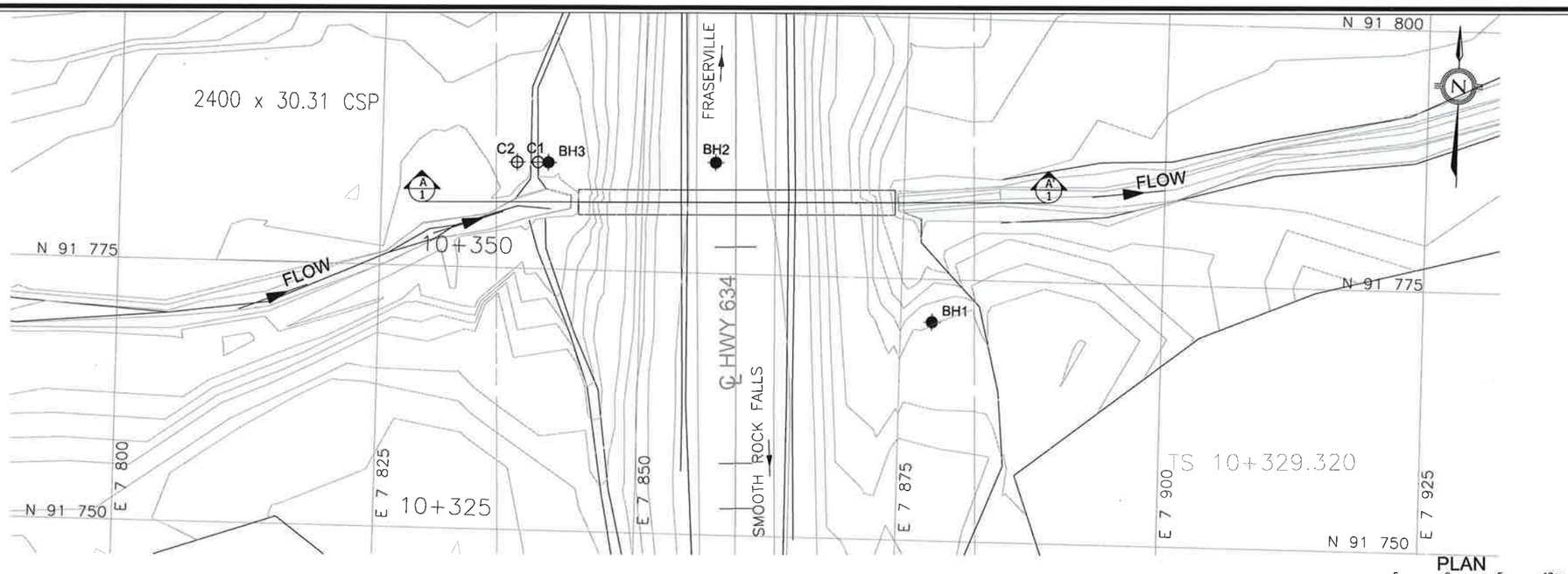
Canadian Highway Bridge Design Code (CHBDC) and Commentary on CAN/CSA S6 06. 2006. CSA Special Publication, S6.1 06. Canadian Standard Association.

McClenaghan, M.B. 1990. *Summary of results from the Black River – Matheson (BRiM) reconnaissance surface till sampling program*. Ontario Geological Survey, Open File Report 5749, p. 197.

Ontario Geological Survey 2001. *Results of modern alluvium sampling, Kapuskasing-Fraserdale area, northeastern Ontario: Operation Treasure Hunt-Kapuskasing Structural Zone*. Ontario Geological Survey, Open File Report 6044, 146p..

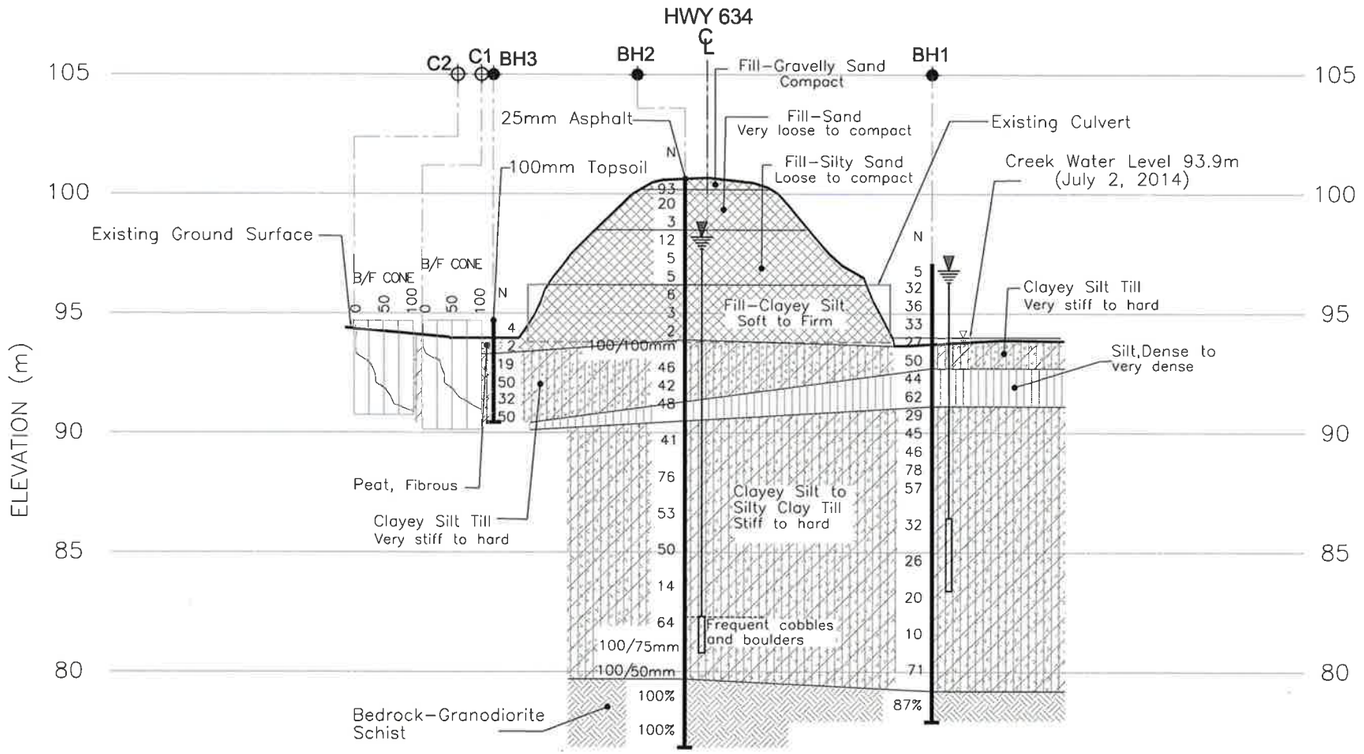
Terzaghi, K., and Peck, R. B. (1967). *Soil Mechanics in Engineering Practice.* Wiley, New York.

DRAWING



PLAN

SCALE 5 0 5 10m



SECTION A-A' CULVERT AT STATION 10+354
HIGHWAY 634

HORIZ. SCALE 5 0 5 10m
VERT. SCALE 5 0 2.5 5m

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

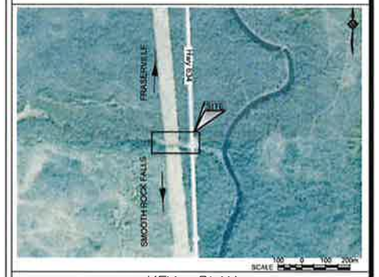
GWP No 5379–11–00

HWY 634
UNNAMED CREEK CULVERT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

MMM Group Limited
2655 North Sheridan Way, Suite 300
Mississauga, ON Canada L5K 2P8
t: 905.823.8500, f: 905.823.8503

Terraprobe Inc.
Consulting Geotechnical & Environmental Engineering
Construction Materials Engineering, Inspection & Testing
11 Indell Lane - Brampton Ontario L6T 3Y3 (905) 796-2650



KEY PLAN

LEGEND

●	Bore Hole
⊕	Dynamic Cone Penetration Test
⊕	Bore Hole And Cone
'N'	Blows/0.3m (Std Pen Test, 475 J/blow)
CONE	Blows/0.3m (60° Cone, 475 J/blow)
▽	WL at Time of Investigation
▼	WL in Piezometer (October 2014)
	Piezometer
90%	Rock Quality Designation
A/R	Auger Refusal

No	ELEV. (m)	LOCAL SITE COORDINATES (m) NORTHING	EASTING
BH 1	97.1	91770.9	7878.0
BH 2	100.6	91785.6	7856.9
BH 3	94.7	91785.2	7840.9
C1	94.7	91785.2	7839.9
C2	94.7	91785.2	7837.9

LICENSED PROFESSIONAL ENGINEER
R.A. ABDUL
June 28, 2016.
PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL ENGINEER
M. TANOS
PROVINCE OF ONTARIO

NOTE

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

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

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 this report and related documents are specifically excluded in accordance with Section GC 2.01 of OPS General Conditions

REFERENCE

Drawings provided in digital format by MMM Group Ltd. by CD (Assignment 5013-E-0018 Preliminary Design for Rehab/Replacement of 12 Structures on Highways in New Liskeard Area) drawing files B11180634004, DTM11180634004, received September 11, 2014

REVISIONS	DATE	BY	DESCRIPTION

HWY. 634	PROJECT No. 11-14-4066		Geocres No: 42H-61
SUBM'D. HA	CHKD. RA	DATE: June 2016	SITE: 39E-244
DRAWN: KC	CHKD. RA	APP'D: MT	DWG. 1

APPENDIX A
Record of Borehole Sheets

LIMITATIONS AND RISK

Procedures

The soil conditions were confirmed at the borehole locations only and conditions may vary between and beyond the boreholes. The boundaries between the various strata as shown on the logs are based on non-continuous sampling. These boundaries represent an inferred transition between the various strata, rather than a precise plane of stratigraphic change.

This investigation has been carried out using investigation techniques and engineering analysis methods consistent with those ordinarily exercised by Terraprobe and other engineering practitioners, working under similar conditions and subject to the time, financial and physical constraints applicable to this project. The discussions and recommendations that have been presented are based on the factual data obtained.

It must be recognized that there are special risks whenever engineering or related disciplines are applied to identify subsurface conditions. Even a comprehensive sampling and testing programme implemented in accordance with the most stringent level of care may fail to detect certain conditions. Terraprobe has assumed for the purposes of providing design parameters and advice, that the conditions that exist between sampling points are similar to those found at the sample locations. The conditions that Terraprobe has interpreted to exist between sampling points can differ from those that actually exist.

It may not be possible to drill a sufficient number of boreholes or sample and report them in a way that would provide all the subsurface information that could affect construction costs, techniques, equipment and scheduling. Contractors bidding on or undertaking work on the project should be directed to draw their own conclusions as to how the subsurface conditions may affect them, based on their own investigations and their own interpretations of the factual investigation results, cognizant of the risks implicit in the subsurface investigation activities.

Changes In Site And Scope

It must be recognized that the passage of time, natural occurrences, and direct or indirect human intervention at or near the site have the potential to alter subsurface conditions. Groundwater levels are particularly susceptible to seasonal fluctuations.

The design advice is based on the factual data obtained from this investigation made at the site by Terraprobe and are intended for use by the owner and its retained designers in the design phase of the project. If there are changes to the project scope and development features, or there is any additional information relevant to the interpretations made of the subsurface information, the geotechnical design parameters and comments relating to constructibility issues and quality control may not be relevant or complete for the revised project. Terraprobe should be retained to review the implications of such changes with respect to the contents of this report.

EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg. FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS ú.

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60/ CONE ANGLE) DRIVEN BY 475J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0 – 12	12 – 25	25 – 50	50 – 100	100 – 200	>200
	VERY SOFT	*SOFT*	*FIRM*	*STIFF*	*VERY STIFF*	*HARD*

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 – 5	5 – 10	10 – 30	30 – 50	>50
	VERY LOOSE	*LOOSE*	*COMPACT*	*DENSE*	*VERY DENSE*

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND/OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (RQD), FOR MODIFIED RECOVERY IS:

RQD (%)	0 – 25	25 – 50	50 – 75	75 – 90	90 – 100
	VERY POOR	*POOR*	*FAIR*	*GOOD*	*EXCELLENT*

JOINTING AND BEDDING:

SPACING	50mm	50 – 300mm	0.3m – 1m	1m – 3m	>3m
JOINTING	*VERY CLOSE*	*CLOSE*	*MOD. CLOSE*	*WIDE*	*VERY WIDE*
BEDDING	*VERY THIN*	*THIN*	*MEDIUM*	*THICK*	*VERY THICK*

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

SS	SPLIT SPOON	TP	THINWALL PISTON
WS	WASH SAMPLE	OS	OSTERBERG SAMPLE
ST	SLOTTED TUBE SAMPLE	RC	ROCK CORE
BS	BLOCK SAMPLE	PH	TW ADVANCED HYDRAULICALLY
CS	CHUNK SAMPLE	PM	TW ADVANCED MANUALLY
TW	THINWALL OPEN	FS	FOIL SAMPLE

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_α	1	RATE OF SECONDARY CONSOLIDATION
C_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	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

r_s	kg/m^3	DENSITY OF SOLID PARTICLES	e	1,%	VOID RATIO	e_{min}	1,%	VOID RATIO IN DENSEST STATE
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES	n	1,%	POROSITY	I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
r_w	kg/m^3	DENSITY OF WATER						
γ_w	kN/m^3	UNIT WEIGHT OF WATER	w	1,%	WATER CONTENT	D	mm	GRAIN DIAMETER
r	kg/m^3	DENSITY OF SOIL	S_r	%	DEGREE OF SATURATION	D_n	mm	n PERCENT - DIAMETER
γ	kN/m^3	UNIT WEIGHT OF SOIL	w_L	%	LIQUID LIMIT	C_u	1	UNIFORMITY COEFFICIENT
r_d	kg/m^3	DENSITY OF DRY SOIL	w_P	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL	w_S	%	SHRINKAGE LIMIT	q	m^3/s	RATE OF DISCHARGE
r_{sat}	kg/m^3	DENSITY OF SATURATED SOIL	I_P	%	PLASTICITY INDEX = $(w_L - w_P)$	v	m/s	DISCHARGE VELOCITY
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = $(w - w_P)/I_P$	i	1	HYDRAULIC GRADIENT
r'	kg/m^3	DENSITY OF SUBMERGED SOIL	I_C	1	CONSISTENCY INDEX = $(w_L - w)/I_P$	k	m/s	HYDRAULIC CONDUCTIVITY
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL	e_{max}	1,%	VOID RATIO IN LOOSEST STATE	j	kN/m^3	SEEPAGE FORCE

Ministry of Transportation
Ontario

Terraprobe

RECORD OF BOREHOLE No 1

1 of 2

METRIC

G.W.P. _____ LOCATION Coords: E:7878 N:91770.9 ORIGINATED BY W.Z

DIST _____ HWY 634 BOREHOLE TYPE CASING AND WASH BORING/NQ CORING COMPILED BY S.D

DATUM LOCAL DATE 2014-8-20 CHECKED BY R.A

ELEV / DEPTH (m)	DESCRIPTION	NUMBER	TYPE	SPT 'N' VALUE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
97.1	**GROUND SURFACE**				
0.7 (96.4)	**FILL**, clayey silt, sandy, trace gravel, firm, brown, moist	1	SS	5	
	CLAYEY SILT, trace to some sand, very stiff to hard, grey, moist (GLACIAL TILL)	2	SS	32	0 14 66 20
		3	SS	36	
		4	SS	33	sampler wet at 2.3m
		5	SS	27	
4.4 (92.7)		6	SS	50	0 8 72 20
	SILT, trace clay, dense to very dense, grey, wet	7	SS	44	
6.0 (91.1)		8	SS	62	0 0 95 5
	CLAYEY SILT to SILTY CLAY, trace sand, stiff to hard, grey, moist (GLACIAL TILL)	9	SS	29	
		10	SS	45	
		11	SS	46	0 5 68 27
		12	SS	78	
		13	SS	57	
		14	SS	32	
		15	SS	26	
		16	SS	20	

ELEVATION SCALE: 97, 96, 95, 94, 93, 92, 91, 90, 89, 88, 87, 86, 85, 84, 83

DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100)

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

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L

WATER CONTENT (%) (10 20 30)

UNIT WEIGHT γ kN/m^3

GROUND WATER CONDITIONS

Continued Next Page

+ ^{3}, × ^{3}: Numbers refer to Sensitivity

○ $^{3\%}$ STRAIN AT FAILURE

report: mto-terraprobe soil file: 3- unknown creek culvert (39e-244) bh logs - copy rev2.gpj

Ministry of Transportation
Ontario

Terraprobe

RECORD OF BOREHOLE No 1

2 of 2

METRIC

G.W.P. | LOCATION Coords: E:7878 N:91770.9 | ORIGINATED BY W.Z

DIST | HWY 634 | BOREHOLE TYPE CASING AND WASH BORING/NQ CORING | COMPILED BY S.D

DATUM LOCAL | DATE 2014-8-20 | CHECKED BY R.A

ELEV / DEPTH (m)	DESCRIPTION (continued)	STRAT PLOT	SAMPLES NUMBER	TYPE	SPT 'N' VALUE	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH (kPa)	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
	CLAYEY SILT to SILTY CLAY, trace sand, stiff to hard, grey, moist (GLACIAL TILL)		17	SS	10		82				
							81				
			18	SS	71		80				
79.2	cobble										
17.9	**BEDROCK - GRANODIORITE SCHIST**, unweathered, massive, brownish grey, very high strength (with secondary weak planes)		1	RUN	NQ		79				Run #1 TCR: 100% SCR: 87% RQD: 87%
77.9							78				
19.2	**END OF BOREHOLE**										

Borehole filled with drill water upon completion of drilling.

Piezometer installation consists of a 19mm diameter schedule 40PVC pipe with a 3.0m slotted screen.

WATER LEVEL READINGS

Date	Water Depth (m)	Elevation (m)
Sep 16, 2014	0.1	97.0
Oct 27, 2014	0.3	96.8

+^{3}, ×^{3}: Numbers refer to Sensitivity

○$^{3\%}$ STRAIN AT FAILURE

report: mto-terraprobe soil file: 3- unknown creek culvert (39e-244) bh logs - copy rev2.gpj

Ministry of Transportation
Ontario

Terraprobe

RECORD OF BOREHOLE No 2

1 of 2

METRIC

G.W.P. | LOCATION: Coords: E:7856.9 N:91785.6 | ORIGINATED BY: W.Z

DIST | HWY: 634 | BOREHOLE TYPE: CASING AND WASH BORING/NQ CORING | COMPILED BY: S.D

DATUM: LOCAL | DATE: 2014-8-18 - 2014-8-19 | CHECKED BY: R.A

ELEV / DEPTH (m)	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	SPT 'N' VALUE	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (kPa) (20 40 60 80 100): ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
100.6	**GROUND SURFACE**										
100.2	25mm **ASPHALTIC CONCRETE**										
0.4	375mm **FILL**, gravelly sand, trace silt, very dense, brown, moist to wet		1	SS	93						
	FILL, sand, some gravel, trace silt, very loose to compact, brown, wet		2	SS	20						18 75 *(7)*
			3	SS	3						
98.5											
2.1	**FILL**, silty sand, trace clay, trace gravel, loose to compact, brown, wet		4	SS	12	▼					
			5	SS	5						
			6	SS	5						1 58 34 7
96.2											
4.4	**FILL**, clayey silt, sandy, trace gravel, soft to firm, brown, moist		7	SS	6						
			8	SS	3						1 31 51 17
			9	SS	2						
93.9											
6.7	**CLAYEY SILT**, trace to some sand, trace gravel, containing cobbles and boulders, hard, grey, moist (GLACIAL TILL)		10	SS	100 / 100mm						
			11	SS	46						
			12	SS	42						
91.3											
9.3	**SILT**, trace clay, dense, grey, wet		13	SS	48						August 18, 2014
90.5											August 19, 2014
10.1	**CLAYEY SILT to SILTY CLAY**, trace sand, stiff to hard, grey, moist (GLACIAL TILL)		14	SS	41						0 8 69 23
			15	SS	76						
			16	SS	53						

Continued Next Page

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

Ministry of Transportation
Ontario

Terraprobe

RECORD OF BOREHOLE No 2

2 of 2 **METRIC**

G.W.P. | LOCATION Coords: E:7856.9 N:91785.6 | ORIGINATED BY W.Z

DIST | HWY 634 | BOREHOLE TYPE CASING AND WASH BORING/NQ CORING | COMPILED BY S.D

DATUM LOCAL | DATE 2014-8-18 - 2014-8-19 | CHECKED BY R.A

ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	SPT 'N' VALUE	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (kPa) (20 40 60 80 100): ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	(continued)									
	CLAYEY SILT to SILTY CLAY, trace sand, stiff to hard, grey, moist (GLACIAL TILL)		17	SS	50		85			
			18	SS	14		84			
			19	SS	64		83			1 17 61 21
	frequent cobbles and boulders		20	RC			82			
			21	SS	100 / 75mm		81			
			22	RC			80			
79.7										
20.9	**BEDROCK - GRANODIORITE SCHIST**, unweathered, massive, brownish grey, very high strength (with secondary weak planes)		23	SS	100 / 50mm		79			
			1	RUN	NQ		78			Run #1 TCR: 100% SCR: 100% RQD: 100%
			2	RUN	NQ		77			Run #2 TCR: 100% SCR: 100% RQD: 100%
76.8										
23.8	**END OF BOREHOLE**									

Borehole filled with drill water upon completion of drilling.

Piezometer installation consists of a 19mm diameter schedule 40PVC pipe with a 1.52m slotted screen.

WATER LEVEL READINGS

Date	Water Depth (m)	Elevation (m)
Sep 16, 2014	2.7	97.9
Oct 27, 2014	2.4	98.2

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

report: mto-terraprobe soil file: 3- unknown creek culvert (39e-244) bh logs - copy rev2.gpj

Ministry of Transportation
Ontario

Terraprobe

RECORD OF BOREHOLE No 3

1 of 1

METRIC

G.W.P. | LOCATION Coords: E:7840.9 N:91785.2 | ORIGINATED BY W.Z

DIST | HWY 634 | BOREHOLE TYPE PORTABLE EQUIPMENT AND SPT SAMPLING | COMPILED BY S.D

DATUM LOCAL | DATE 2014-8-21 - 2014-8-22 | CHECKED BY R.A

ELEV / DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	SPT 'N' VALUE	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (kPa) ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
94.7	**GROUND SURFACE**									
	100mm **TOPSOIL**		1	SS	4					0 14 64 22
94.0 / 0.7	**FILL**, silty clay, some sand, trace organics, soft, brown, moist						94		88	
	PEAT, fibrous, black, wet		2	SS	2					
93.3 / 1.4	**CLAYEY SILT**, trace to some sand, very stiff to hard, grey, moist (GLACIAL TILL)		3	SS	19		93			
			4	SS	50		92			0 17 63 20
			5	SS	32					
			6	SS	50		91			August 21, 2014 August 22, 2014
90.4 / 4.3	**END OF BOREHOLE**									

.

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

report: mto-terraprobe soil file: 3- unknown creek culvert (39e-244) bh logs - copy rev2.gpj

Ministry of Transportation
Ontario

Terraprobe

RECORD OF BOREHOLE No C1

1 of 1

METRIC

G.W.P. | LOCATION Coords: E:7839.9 N:91785.2 | ORIGINATED BY W.Z

DIST | HWY 634 | BOREHOLE TYPE DYNAMIC CONE PENETRATION TEST | COMPILED BY S.D

DATUM LOCAL | DATE 2014-8-22 | CHECKED BY R.A

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT / NATURAL MOISTURE CONTENT / LIQUID LIMIT	UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	SPT 'N' VALUE						
94.7	**GROUND SURFACE**										
	Refer to BH3 for inferred soil stratigraphy										
90.1											
4.6	**END OF BOREHOLE**										

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L

WATER CONTENT (%): 10 20 30

UNIT WEIGHT γ kN/m^3

REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

94
93
92
91
>>

+ ^{3}, × ^{3}: Numbers refer to Sensitivity

○ $^{3\%}$ STRAIN AT FAILURE

report: mto-terraprobe soil file: 3- unknown creek culvert (39e-244) bh logs - copy rev2.gpj

Ministry of Transportation
Ontario

Terraprobe

RECORD OF BOREHOLE No C2

1 of 1

METRIC

G.W.P. | LOCATION Coords: E:7837.9 N:91785.2 | ORIGINATED BY W.Z

DIST | HWY 634 | BOREHOLE TYPE DYNAMIC CONE PENETRATION TEST | COMPILED BY S.D

DATUM LOCAL | DATE 2014-8-22 | CHECKED BY R.A

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH (kPa)	PLASTIC LIMIT / NATURAL MOISTURE CONTENT / LIQUID LIMIT	UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	SPT 'N' VALUE						
94.7	**GROUND SURFACE**							20 40 60 80 100	w_P w w_L	γ kN/m^3	GR SA SI CL
	Refer to BH3 for inferred soil stratigraphy						94	○ UNCONFINED + FIELD VANE	WATER CONTENT (%)		
							93	● QUICK TRIAXIAL × LAB VANE	10 20 30		
							92	20 40 60 80 100			
90.8							91				
3.9	**END OF BOREHOLE**										

.

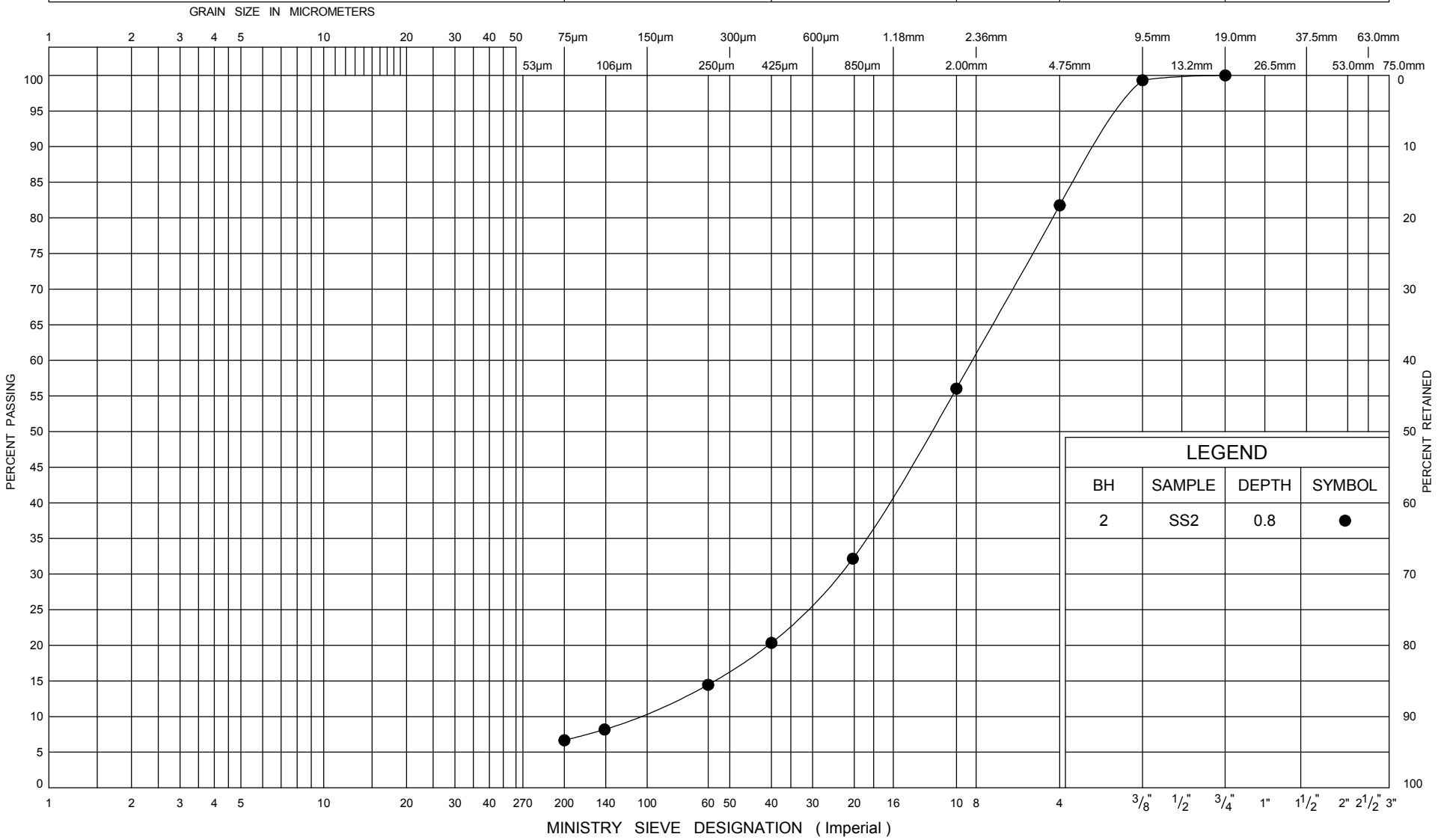
+^{3}, ×^{3}: Numbers refer to Sensitivity ○$^{3\%}$ STRAIN AT FAILURE

report: mto-terraprobe soil file: 3- unknown creek culvert (39e-244) bh logs - copy rev2.gpj

APPENDIX B
Laboratory Test Results
&
Photographs

Terraprobe

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION
FILL-SAND

FIG No B1

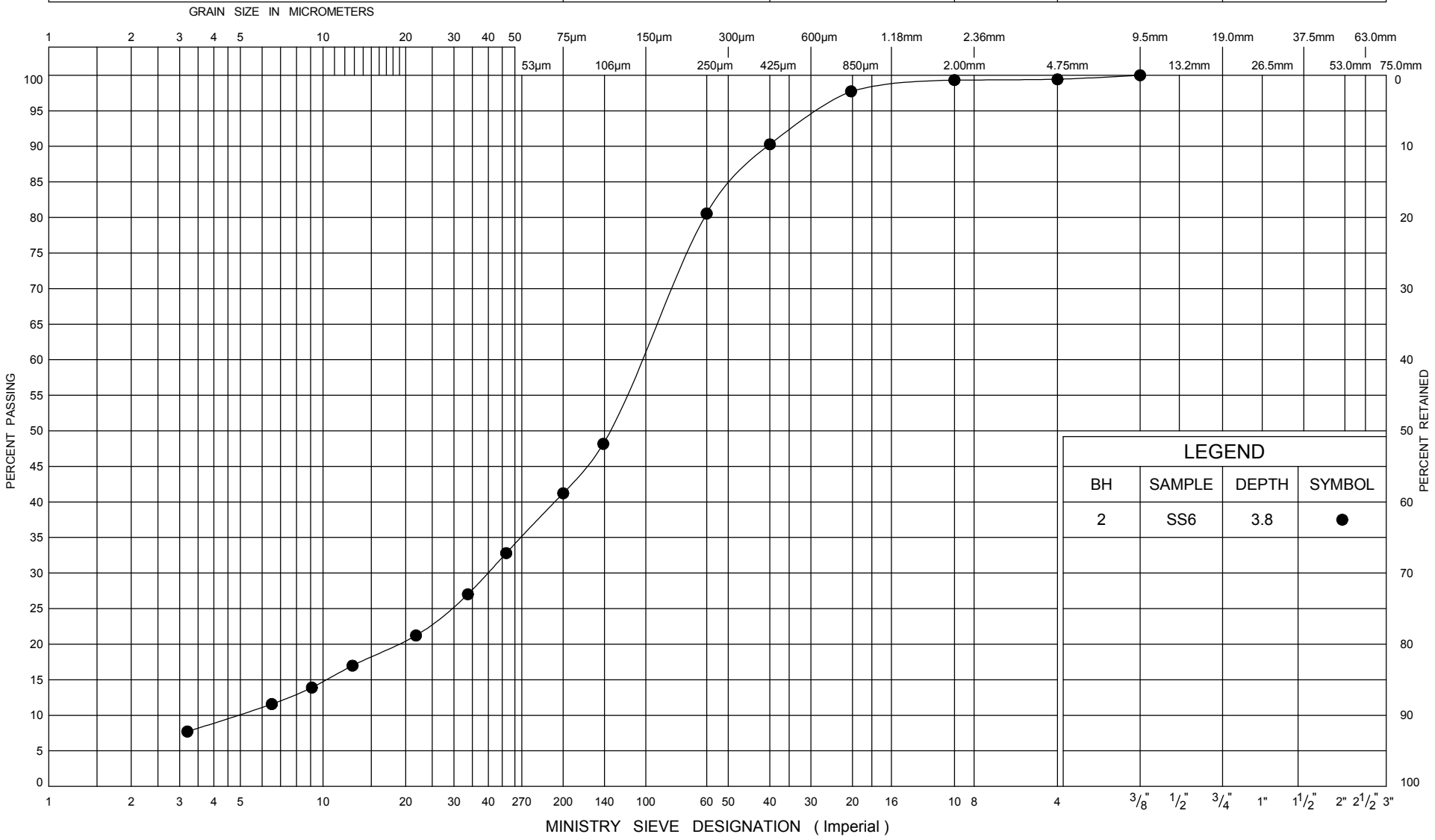
G W P 5379-11-00

Unnamed Creek Culvert (39E-244)

Terraprobe

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse



LEGEND

BH	SAMPLE	DEPTH	SYMBOL
2	SS6	3.8	●

Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION
FILL-SILTY SAND

FIG No B2

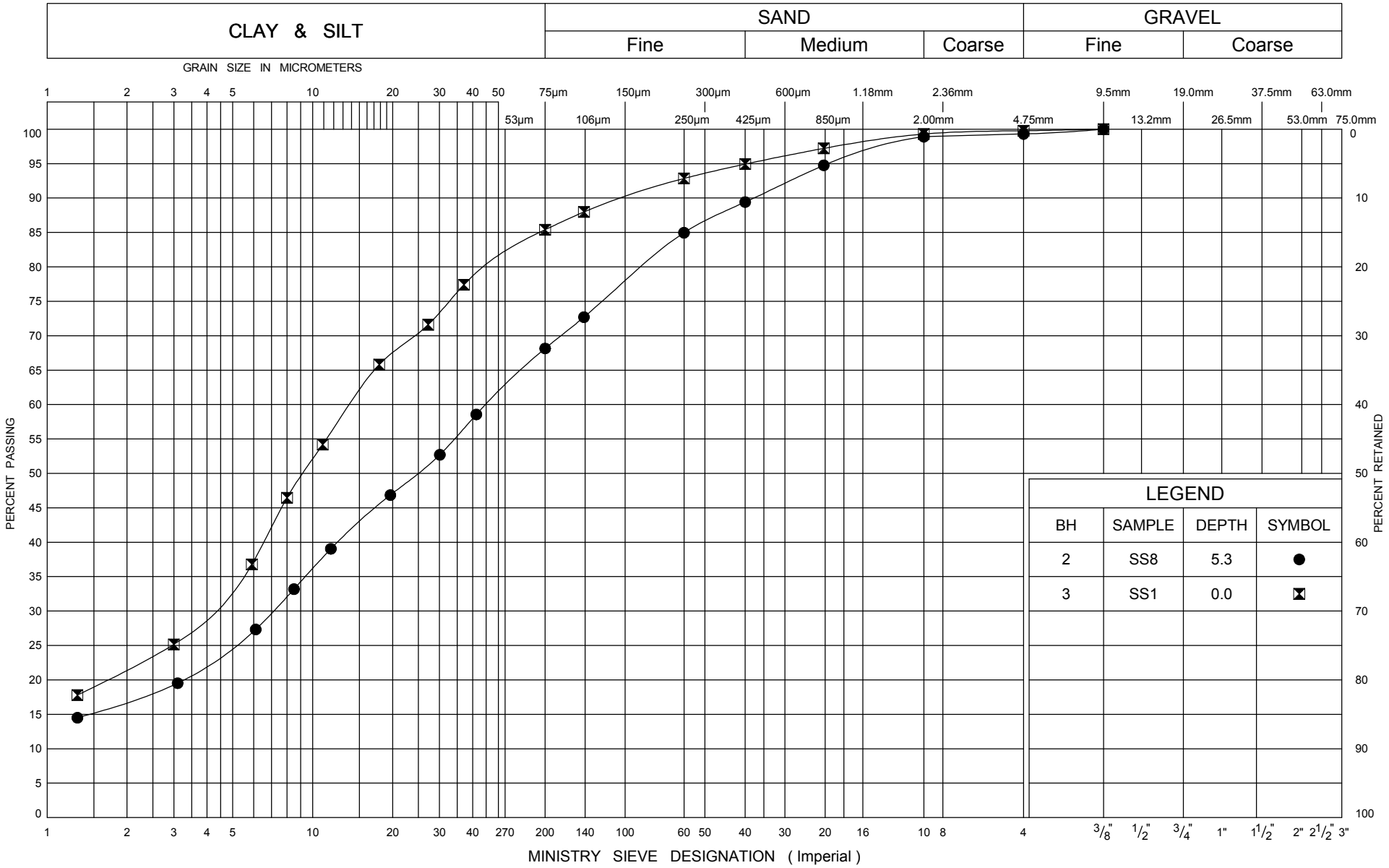
G W P 5379-11-00

Unnamed Creek Culvert (39E-244)

library: library - terraprobe gint - mtd.glb **report:** mto grain size (old format) **file:** 3- unknown creek culvert (39e-244) bh logs - copy rev2.gpj

Terraprobe

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of Transportation
Ontario

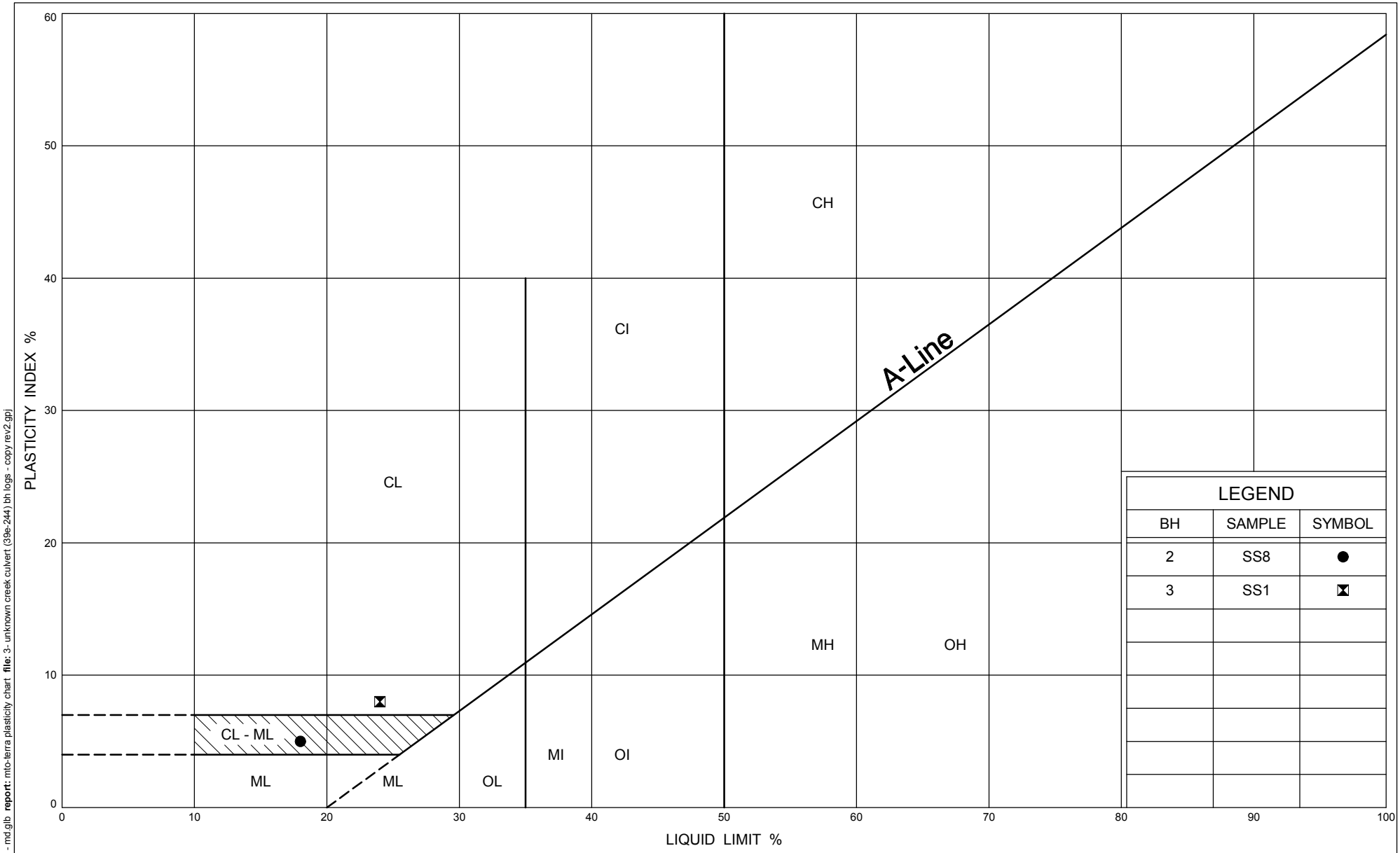
GRAIN SIZE DISTRIBUTION
FILL-CLAYEY SILT TO SILTY CLAY

FIG No B3

G W P 5379-11-00

Unnamed Creek Culvert (39E-244)

Terraprobe



Ministry of Transportation
Ontario

PLASTICITY CHART

FILL-CLAYEY SILT TO SILTY CLAY

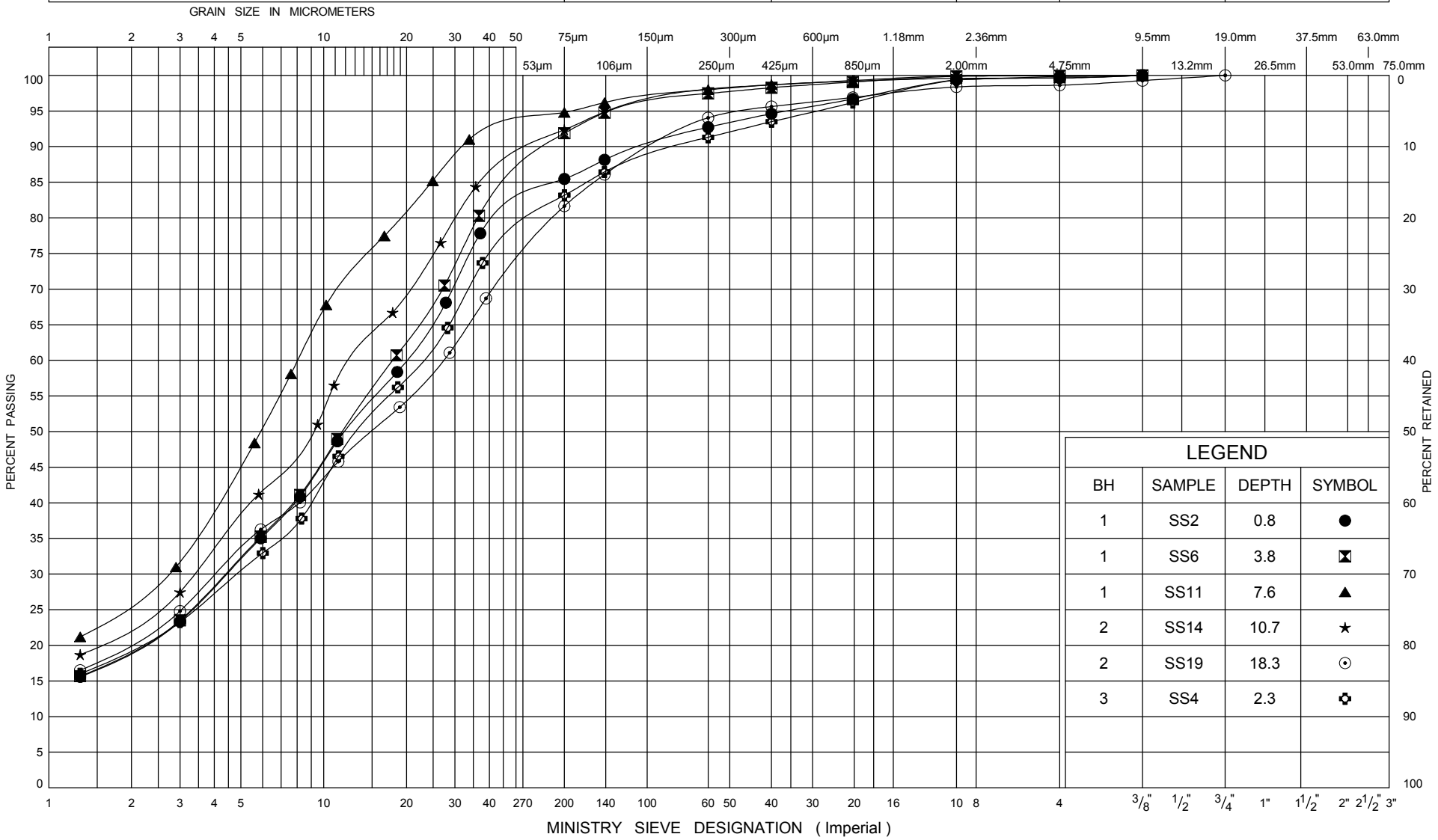
FIG No B4

G W P 5379-11-00

Unnamed Creek Culvert (39E-244)

Terraprobe

UNIFIED SOIL CLASSIFICATION SYSTEM



LEGEND			
BH	SAMPLE	DEPTH	SYMBOL
1	SS2	0.8	●
1	SS6	3.8	⊠
1	SS11	7.6	▲
2	SS14	10.7	★
2	SS19	18.3	⊙
3	SS4	2.3	✿

Ministry of Transportation
Ontario

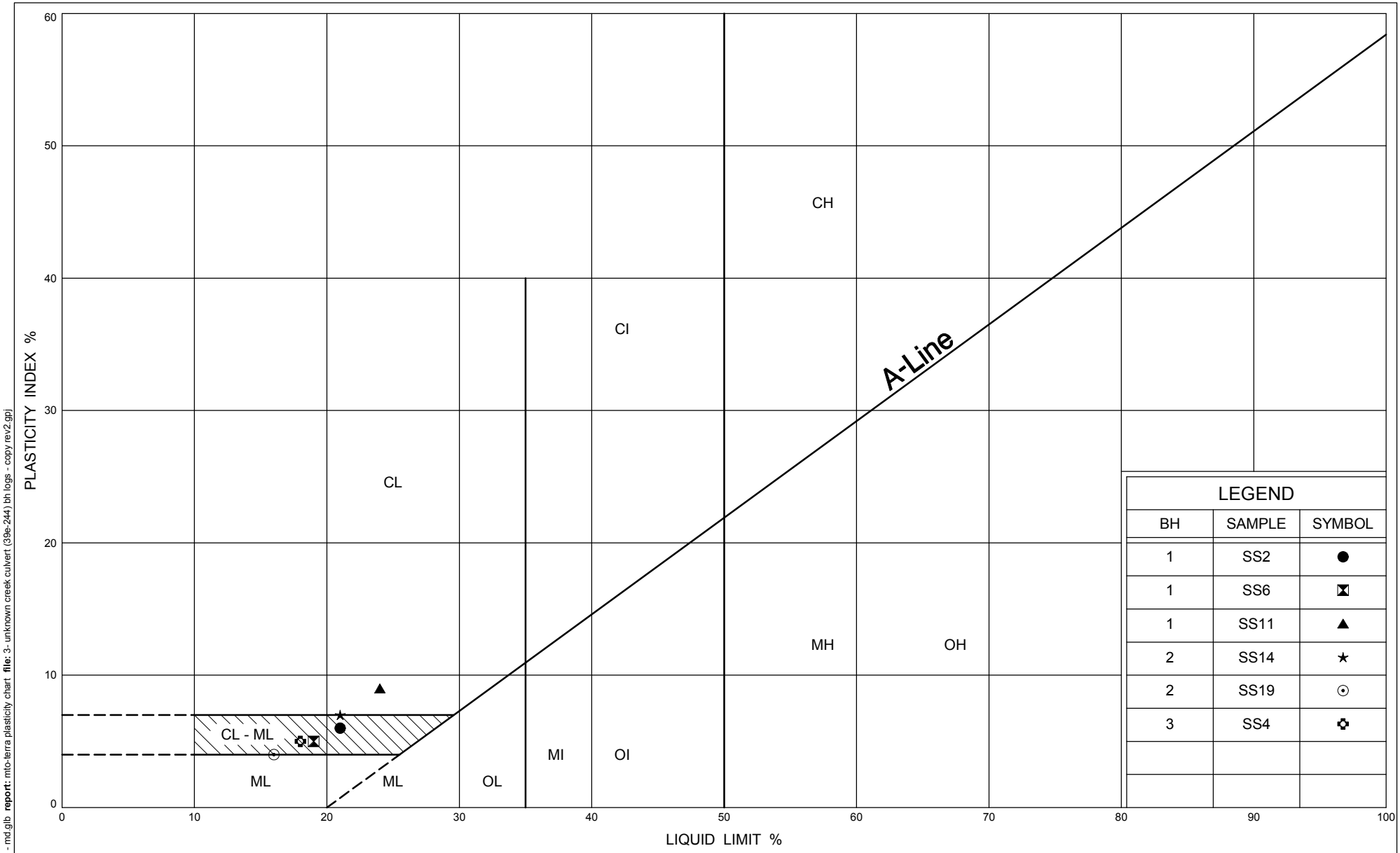
GRAIN SIZE DISTRIBUTION
CLAYEY SILT TO SILTY CLAY TILL

FIG No B5

G W P 5379-11-00

Unnamed Creek Culvert (39E-244)

Terraprobe



Ministry of Transportation
Ontario

PLASTICITY CHART

CLAYEY SILT TO SILTY CLAY TILL

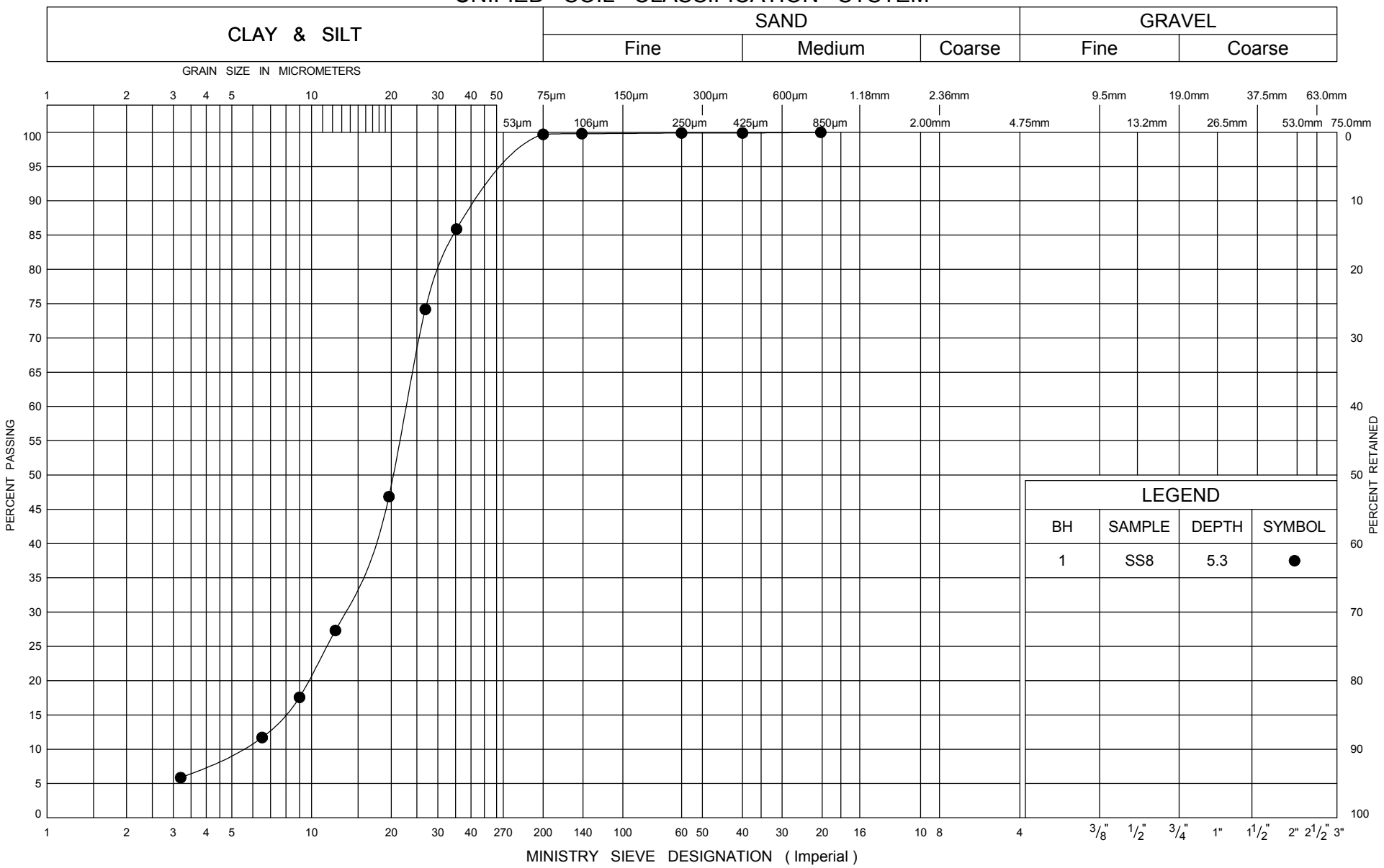
FIG No B6

G W P 5379-11-00

Unnamed Creek Culvert (39E-244)

Terraprobe

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION
SILT

FIG No B7

G W P 5379-11-00

Unnamed Creek Culvert (39E-244)

PHOTOGRAPH OF COBBLES AND BOULDERS	FIGURE B8

UNNAMED CREEK CULVERT (Site 39E-244)

C:\Users\smonfared\Desktop\11-14-4066\Unnamed 244\Spread Sheets\e0-P'c-Cc-Cr-Cu.xls

Project No. : 11-14-4066
Date : June, 2015

Terraprobe Inc.

Prepared by : SD
Checked by : RA

PHOTOGRAPHS OF BEDROCK CORE SAMPLES	FIGURE B9

UNNAMED CREEK CULVERT (Site 39E-244)

Project No. : 11-14-4066
Date : June, 2015

Terraprobe Inc.

Prepared by : SD
Checked by : RA

C:\Users\smonfared\Desktop\11-14-4066\Unnamed 244\Spread Sheets\e0-P'c-Cc-Cr-Cu.xls