



January 8, 2019

FOUNDATION INVESTIGATION AND DESIGN REPORT

**STRUCTURAL BUNDLE - 11 STRUCTURES ON HIGHWAYS 129, 532
AND 556**

**HIGHWAY 556 - KINIHAN CREEK CULVERTS REHABILITATION,
59.5 KM EAST OF HIGHWAY 17 (SITE NO. 38S-0022/C0)
HUGHES TOWNSHIP, ALGOMA DISTRICT, ONTARIO
MINISTRY OF TRANSPORTATION, ONTARIO
GWP 5272-14-00; WP 5307-14-02**

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REPORT





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PART A

FOUNDATION INVESTIGATION REPORT
STRUCTURAL BUNDLE – 11 STRUCTURES ON HIGHWAYS 129, 532 AND
556
HIGHWAY 556 – KINIHAN CREEK CULVERTS REHABILITATION, 59.5 KM
EAST OF HIGHWAY 17 (SITE NO. 38S-0022/C0)
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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by AECOM on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services to aid in the design of the temporary excavation support and dewatering works for the rehabilitation of the Kinihan Creek culverts on Highway 556 (Site No. 38S-0022/C0) in Hughes Township, Algoma District, Ontario.

The purpose of the field investigation is to establish the subsurface conditions near the inlet and outlet of the existing culverts by methods of borehole drilling, in-situ testing and laboratory testing on selected soil samples.

This report summarizes the factual results of the field and laboratory work (including field investigation procedures, borehole stratigraphy, and geotechnical laboratory test results) as well as a description of the interpreted soil and groundwater conditions at the Kinihan Creek culverts site, including those from a previous subsurface investigation.

The Terms of Reference and Scope of Work for the foundation investigation are outlined in MTO's Request for Proposal dated May 2016 (Agreement No. 5016E0029) as well as change request letter dated April 24, 2018 which was approved by MTO on June 11, 2018 (Change Order No. CO5016E0029001). Golder's proposal for foundation engineering services is contained in Section 17.8 of AECOM's Technical Proposal for this assignment.

2.0 PROJECT AND SITE DESCRIPTION

2.1 Project Description

The existing twin culverts at the site convey Kinihan Creek under Highway 556 in a northwest to southeast direction. The culverts were constructed in 1988 under Contract No. 87-213 and there is no history of the culverts having undergone rehabilitation works since that time. It is understood that a structural assessment of the existing culverts was carried out in 2015 at which time the culverts were identified as being in fair structural condition with minor deterioration of several elements, with more significant deterioration of the structural steel coatings. As such, it is our understanding that the culverts are expected to be rehabilitated by lining the barrels of the existing culverts.

2.2 Site Description

The site of the existing culverts is located about 59.9 km east of Highway 17 on Highway 556 in Hughes Township, Algoma District, Ontario.

As noted above, the site consists of two culverts as follows:

- Eastern Culvert at about Station 12+457; and,
- Western Culvert at about Station 12+452.

The existing culvert structures consist of twin cell Arched Structural Plate Corrugated Steel Pipe (ASPCSP), with each cell being approximately 3 m in diameter and 26 m in length. The invert of the inlet of the twin culverts is at approximately Elevation 315.0 m and the outlet of the twin culverts is at approximately Elevation 314.7 m. Concrete cut-off walls surrounding the open ends of the culverts, each approximately 10.8 m long by 2.1 m high, are located at the inlet and outlet of the culverts. The top of the concrete cut-off wall is at approximately Elevation 315.8 m at the inlet and at approximately Elevation 315.4 m at the outlet. There is about 0.8 m of roadway fill cover above the culverts.



The Kinihan Creek at the location of the existing culverts is approximately 6 m wide and flows in a generally north to south direction.

Highway 556 at the location of the culvert is supported by an approximately 4 m to 4.5 m high embankment that carries one lane of traffic in each direction. The travelled portion of the highway consists of a gravel surface, which is at approximately Elevation 319.0 m in the vicinity of the culvert.

In general, the topography in the area of the culvert is relatively flat, with sparse tree/brush cover along the highway right-of-way and dense vegetation outside of the highway right-of-way.

3.0 INVESTIGATION PROCEDURES

3.1 Previous (1986 and 1987) Investigation

A previous foundation investigation was carried out at the site by Peto MacCallum Ltd. in January 1986 and an additional investigation was carried out at the same site by MTO's Foundation Engineering Section in January 1987 in support of the re-alignment of Highway 556 in that area. It is understood that Kinihan Creek was originally located about 20 m west of the current creek, but was shifted to its current location to accommodate the current Highway 556 alignment and the twin culverts. Two boreholes (designated as boreholes No. 5 and No. 9), two Dynamic Cone Penetration Test (DCPT) holes (designated as boreholes No. 13 and No. 14), and two combined boreholes/DCPT test holes (designated as No. 10 and No. 11) were advanced within the footprint of the proposed culverts to provide foundation recommendations for the culverts. Other boreholes associated with this investigation have been advanced at this site, but these boreholes are located outside the limits of the current project and are not referenced herein. The existing information is summarized in the following report:

- **MTO Geocres No. 41J-045:** "Foundation Investigation, Kinnihan Creek Structure, Highway 556, (Site 38S-22), District of Sault Ste. Marie for Ministry of Transportation and Communications, W.P. 278-85-01" by Peto MacCallum Ltd., dated February 1986.

The relevant boreholes/DCPTs were advanced to depths ranging between about 2.2 m and 6.4 m below existing ground surface. Details of the soil stratigraphy encountered in the relevant boreholes from the original Foundation Investigation Report (FIR) are presented in Appendix A and the approximate locations of these boreholes are shown in plan on Drawing 1. Geotechnical laboratory test results associated with these boreholes are also included in Appendix A.

In general, the subsurface conditions encountered consisted of 0.8 m to 2.1 m of very soft peat, underlain by a deposit of very loose to compact medium coarse sand to sandy gravel, that transitions to a finer-grained material consisting of sand and silt to sand at some locations. The sand to sandy gravel to sand and silt deposit was investigated to depths of 0.7 m to 3.6 m and all of the previous investigation boreholes were terminated in this deposit. Cobbles and boulders were noted to be present in the granular deposit. The subsurface conditions encountered during the 1986 and 1987 field investigations are generally consistent with the subsurface conditions encountered during the 2018 field investigation (described herein).

It is noted that the ground surface elevations at the locations of the boreholes and DCPT holes (as presented on the borehole records in Appendix A from the original FIR) do not coincide with the ground surface elevation contour lines shown on Drawing 1 nor with the ground surface elevations surveyed at the locations of the boreholes from the current investigation. The current elevation contour lines are based on a recent topographic survey and are considered representative of the existing site conditions.



3.2 Current (2018) Investigation

The recent field work at the Kinihan Creek Culverts site was carried out between August 20 and 22, 2018 during which time two boreholes (designated as Boreholes KCC-01 and KCC-02) were advanced near the inlet and outlet of the culverts, respectively.

The subsurface soil conditions encountered in the boreholes are shown in detail on the Records of Boreholes in Appendix A. Lists of abbreviations and symbols are also provided in Appendix A to assist in the interpretation of the borehole records. The locations of the as-drilled boreholes are shown in plan on Drawing 1.

The boreholes were advanced using portable drilling equipment supplied and operated by Ohlmann Geotechnical Services (OGS) Drilling Inc. of Almonte, Ontario. Both boreholes were advanced using 'BW' casing with wash boring and coring techniques, as required to penetrate through cobbles and boulders. The soil samples were generally obtained at intervals of depth of about 0.75 m and 1.5 m, using a 50 mm outer diameter split-spoon sampler driven by a manual hammer in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586).

The boreholes were advanced to depths of 5.9 m and 5.5 m below existing ground surface, with a DCPT carried out to a depth of 9.1 m and 5.8 m below ground surface in Boreholes KCC-01 and KCC-02, respectively. The boreholes were backfilled upon completion in accordance with Ontario Regulation 903 (Wells) (as amended).

Prior to commencement of the field work, Golder arranged for the clearance of underground utilities/services. The field work was observed on a full-time basis by a member of Golder's engineering staff who monitored the drilling and sampling operations and logged the boreholes in the field. The soil samples were transported to Golder's Mississauga geotechnical laboratory where the samples underwent further visual examination and geotechnical laboratory testing.

Geotechnical index testing (i.e., water content and grain size distribution) was carried out on selected soil samples. The results of the geotechnical laboratory testing are summarized on the borehole records in Appendix B and the details of the geotechnical testing are provided in Appendix C. All of the laboratory tests were carried out in accordance with MTO Laboratory and/or ASTM Standards, as appropriate.

Temporary benchmarks were established and surveyed near the existing culvert by Callon Dietz Inc. prior to the drilling crew mobilizing to site. Upon completion of drilling, borehole offsets and corresponding ground surface elevation changes were recorded and tied-in to the surveyed benchmark locations to determine the as-drilled borehole locations and ground surface elevations. The borehole survey information, including northing and easting coordinates (presented in the MTM NAD83 Zone 13 and latitude / longitude coordinate systems) and the ground surface elevations referenced to Geodetic datum, are provided on the borehole records in Appendix B, presented on Drawing 1, and summarized below.



Borehole No.	Approximate Location	Coordinates (MTM NAD83 Zone 13)		Ground Surface Elevation	Borehole Depth (DCPT termination depth)
		Northing (Latitude)	Easting (Longitude)		
KCC-01	Inlet – north toe of Highway 556 embankment	5186197.3 (46.815027°)	324749.9 (-83.738574°)	316.3 m	5.9 m (9.1 m)
KCC-02	Outlet – south toe of Highway 556 embankment	5186172.0 (46.814798°)	324774.7 (-83.738250°)	316.6 m	5.5 m (5.8 m)

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain (NOEGTS)¹ mapping, the Kinihan Creek culverts site is located within an outwash plain, valley train consisting primarily of sandy and gravelly soils, bordered by bedrock outcrops. The area is generally described as undulating to rolling with areas of low relief where watercourses and lakes have formed.

Based on geological mapping developed by the Ontario Ministry of Northern Development and Mines (MNDM)², the site is underlain by strong bedrock consisting of foliated to gneissic tonalite to granodiorite.

4.2 Subsurface Conditions

The subsurface soil and groundwater conditions encountered in the boreholes advanced at this site, together with the results of the in-situ and geotechnical laboratory testing, are presented on the Records of Boreholes (provided in Appendix B) and the laboratory test figures/sheets (provided in Appendix C). The results of the in-situ field tests (i.e., SPT 'N'-values) as presented on the borehole records are uncorrected and are based on sampling procedures carried out with a manual hammer at the locations of Boreholes KCC-01 and KCC-02.

The stratigraphic boundaries shown on the borehole records and on the soil strata profile (i.e., Drawing 1) are inferred from observations of drilling progress, non-continuous sampling, and in-situ testing and therefore, represent transitions between soil types rather than exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations.

In general, the subsurface conditions encountered at the Kinihan Creek culverts site consists of a granular fill, underlain by a granular deposit consisting of sand to sand and gravel. The presence of cobbles and boulders was noted during advancement of the boreholes through the native granular deposit, from the rock fragments recovered during coring and from the difficult drilling conditions.

Detailed descriptions of the subsurface conditions encountered in the boreholes advanced at this site during the 2018 investigation are provided in the following subsections.

¹ Ontario Ministry of Natural Resources and Forestry. Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 41JNW, Study Number 92.

² Ministry of Northern Development of Mines. Bedrock Geology of Ontario – East Central Sheet, Ontario Geological Survey – Map 2544.



4.2.1 Cobbles and Boulders

Cobbles and boulders were observed on/above the creek bed near the inlets and outlets of the culverts (refer to Photograph 1).



Photograph 1: Cobbles and boulders on/above the creek bed, especially near the shore (looking downstream from outlet near Borehole KCC-02)

The presence of cobbles and boulders was also inferred within the granular fill and granular native deposits encountered at the site through the recovery of rock fragments and difficulty advancing the boreholes in these layers/deposits (refer to Sections 4.2.2 to 4.2.4).

4.2.2 Sand and Gravel to Sandy Gravel (Fill)

An approximately 2.2 m thick layer of sand and gravel to sandy gravel, trace to some silt, trace clay was encountered at ground surface, Elevation 316.3 m, in Borehole KCC-01 (culvert inlet). This non-cohesive fill layer also contains trace rootlets and wood fragments. The presence of cobbles in this fill layer are inferred through the recovery of rock fragments and difficulty advancing Borehole KCC-01 in this layer.

The SPT 'N'-values measured within this non-cohesive fill range from 22 blows to 30 blows per 0.3 m of penetration, indicating a compact state of compactness.

The water contents measured on samples of this fill range between about 8% and 16%.

The results of a grain size distribution test carried out on one sample of this fill is shown on Figure C1 in Appendix C.



4.2.3 Gravelly Organic Silty Sand (Fill)

An approximately 0.7 m thick layer of gravelly organic silty sand, trace clay was encountered at ground surface, Elevation 316.6 m, in Borehole KCC-02 (culvert outlet). The presence of cobbles in this fill layer are inferred through the recovery of rock fragments and difficulty advancing Borehole KCC-02 in this layer.

A SPT 'N'-value measured within this fill is 24 blows for 0.3 m of penetration, indicating a compact state of compactness.

The water content measured on a sample of this fill is about 50%.

The results of an organic content test carried out on one sample of this deposit indicates the soil has an organic content of about 9%.

4.2.4 Gravelly Sand to Sand and Gravel

An extensive deposit of gravelly sand, trace to some silt, trace clay to sand and gravel, trace silt, trace clay was encountered below the non-cohesive fill layers in Boreholes KCC-01 and KCC-02. This deposit extends to depths of at least 5.9 m to 5.5 m, corresponding to Elevations 310.4 m and 311.1 m in Boreholes KCC-01 and KCC-02, respectively. In Borehole KCC-01, at the inlet, a 0.7 m thick finer granular material, comprised of silt and sand, was interlayered within the sand to sand and gravel at a depth of 3.0 m (Elevation 313.3 m). The presence of cobbles and boulders in this deposit are inferred through the recovery of rock fragments and difficulty advancing Boreholes KCC-01 and KCC-02 in this layer.

The SPT 'N'-values measured within this granular deposit range from 5 blows to 58 blows per 0.3 m of penetration, indicating a loose to very dense state of compactness. A SPT 'N'-value measured within the silt and sand interlayer is 10 blows per 0.3 m of penetration, indicating a compact state of compactness.

The water contents measured on samples of this granular deposit range between about 6% and 22%.

The results of grain size distribution tests carried out on four samples of this granular deposit are shown on Figure C2 in Appendix C. The results of a grain size distribution test carried out on a sample of the silt and sand interlayer is shown on Figure C3 in Appendix C.

4.3 Groundwater Conditions

The groundwater level was measured at a depth of about 3.1 m (corresponding to Elevation 313.2 m) and 0.2 m below existing ground surface (corresponding to Elevation 316.4 m) in Boreholes KCC-01 and KCC-02, respectively. However, these groundwater levels are not considered representative of the groundwater level at the site due to introduction of drilling water to accommodate wash boring techniques.

Given the presence of Kihinan Creek and the predominantly granular (i.e., non-cohesive) deposits encountered at the site, the groundwater level in the area of the culvert is anticipated to be coincident with the water level in the creek. The creek water level, at the location of the existing culvert, was measured in June 2017 at approximately Elevation 315.9 m (in the culvert).

The water level in the creek and the degree of saturation of the embankment fill is subject to seasonal fluctuations and precipitation events and are expected to be higher during wet seasons and sustained periods of precipitation.



5.0 CLOSURE

This report was prepared by Ms. Alysha Kobylinski, B.A.Sc. and reviewed by Mr. Tomasz Zalucki, P.Eng., a geotechnical engineer at Golder. Mr. Paul Dittrich, P.Eng., a Principal and MTO Foundations Designated Contact for Golder, conducted an independent quality control review of the report.



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PART B

FOUNDATION DESIGN REPORT

STRUCTURAL BUNDLE – 11 STRUCTURES ON HIGHWAYS 129, 532 AND 556

HIGHWAY 556 – KINIHAN CREEK CULVERTS REHABILITATION, 59.5 KM EAST OF HIGHWAY 17 (SITE NO. 38S-0022/C0)

HUGHES TOWNSHIP, ALGOMA DISTRICT, ONTARIO

MINISTRY OF TRANSPORTATION, ONTARIO

GWP 5272-14-00 ; WP 5307-14-02



6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

This section of the report provides foundation design recommendations for the in support of the rehabilitation of the Kinihan Creek culverts under Highway 556 (Site No. 38S-0022/C0). These recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the field investigation. The discussion and recommendations presented are intended to provide the designers with sufficient information to assess feasible temporary protection systems and dewatering alternatives that may be required as part of the culvert rehabilitation. The foundation investigation report, discussion and recommendations are intended for the use of MTO and its designers and shall not be used or relied upon for any other purpose or by any other parties, including the construction or design-build contractor.

Contractors must make their own interpretation based on the factual data presented in the Foundation Investigation Report (Part A of this report). Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project and for which special provisions may be required in the Contract Documents. Those requiring information on aspects of construction must make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

6.1 General

It is understood that the existing 3.0 m diameter Arched Structural Plate Corrugated Steel Pipe (ASPCSP) culverts will be rehabilitated. The rehabilitation work is anticipated to entail lining of the barrel of each of the culverts with a 2.7 m diameter polymer laminated CSP liner, with the annular space between the old culvert and the new liner filled with grout. Consequently, a temporary protection system or cofferdam will be required at inlet and outlet of the culverts to enable the rehabilitation work to be carried out in-the-dry.

6.2 Temporary Cofferdam Systems

Temporary cofferdams near the inlet and outlet of the culverts are required to support the rehabilitation works. The intent is to divert creek water through one of the two culverts using a temporary flow passage while the other culvert is rehabilitated. Since the depth of water in the creek near the inlet and outlet of the culverts is relatively shallow (i.e., up to about 0.4 m, as measured by the design team surveyor in June 2017), it may be possible to construct the temporary cofferdams and divert the creek water using one of the following methods:

- Small inflatable bladder cofferdams;
- Water dams consisting of industrial grade, impermeable, composite fabrics formed into flexible tubes containing one or more chambers; or,
- Multiple rows of large sand bags (“super-bags” or “bulk-bags”) lined with an impermeable layer.

Given the relatively constrained access to the site, the use of smaller, more modular or inflatable cofferdams may be preferred as these systems can be maneuvered by small equipment and/or by hand. However, the viability and effectiveness of such systems will depend on the creek water level at the time of construction as well as the available space between where the diversion structure(s)/temporary cofferdams will be located relative to the excavation for the new culvert. In addition, any obstructions such as cobbles and boulders may need to be moved from the location of the cofferdam created from modular inflatable bladders, water dams, or large sand bags.



If water levels in the creek are high, it may be necessary to install a more robust groundwater cut-off system (e.g., interlocking steel sheet piles driven to a suitable depth) to avoid excavation instability, a “boiling” or “quick” condition that would loosen/soften any of the soils and/or cause disturbance of the foundation subgrade within the footprint of the excavation area. The installation of sheet piles for temporary cofferdams may be impeded by the presence of cobbles and boulders encountered at the creek bed and within the granular fill and native granular deposit encountered adjacent to the existing culverts. Given the presence of these obstructions, consideration should be given to protecting the tips of the sheet piles and/or the use of heavier sheet pile sections and/or pre-excavation to loosen or remove the larger cobbles and boulders prior to sheet pile installation, assuming a sheet pile system is selected.

The temporary cofferdams at the site should be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems*) to Performance Level 3. The design of the temporary cofferdam system should include an evaluation of tolerable lateral movement, base stability and hydraulic uplift as defined in the *Canadian Foundation Engineering Manual* (CFEM, 2006). The contractor is responsible for the design and construction of the cofferdam system.

For conceptual purposes, to aid the designer in assessing the approximate construction cost of the temporary cofferdam system, the system may be designed using the parameters provided below.

Fill / Soil Type	Bulk Unit Weight, γ (kN/m ³)	Internal Angle of Friction, ϕ' (degrees)	Undrained Shear Strength, s_u (kPa)	Lateral Earth Pressure Coefficients ⁽¹⁾		
				K_p (Passive) ²	K_o (At-Rest)	K_a (Active)
Compact sandy gravel to sand and gravel (Fill)	21	34	--	3.54	0.44	0.28
Loose to compact sand and gravel to silt and sand to gravelly sand	20	32	--	3.25	0.47	0.31
Dense sand and gravel to gravelly sand	21	36	--	3.85	0.41	0.26

Notes:

1. The lateral earth pressure coefficients presented above are based on a horizontal surface adjacent to the excavation. If sloped surfaces are expected, the coefficients should be corrected accordingly.
2. The total passive resistance below the base of the creek bed or excavation, if required, may be calculated based on the values of K_p indicated above but reduced by an appropriate factor that considers the allowable wall movement in accordance with Figure C6.16 of the Canadian Highway Bridge Design Code (CHBDC, 2014) to account for the fact that a large strain would be required for mobilization of the full passive resistance.

6.3 Obstructions

As described in Section 4.2.1, cobbles/boulders were noted in the granular fill and native granular deposits encountered in both boreholes. In addition, cobbles and boulders were present on/above the creek bed. Conventional construction equipment should be capable of excavating through and/or driving through such obstructions. It is recommended that a Notice to Contractor be included in the contract documents to address these obstructions (refer to Appendix D).



6.4 Control of Groundwater and Surface Water

Given that the rehabilitation work will need to be carried out in the dry, control of groundwater / creek flow will be required.

The method and extent of groundwater control required will ultimately depend on the method employed to divert the creek flow during construction and/or on the type of temporary cofferdam system selected by the contractor (described in Section 6.2). If temporary shoring is comprised of sheet pile cut-off walls, the requirements for groundwater control will be lessened. However, if temporary shoring is comprised of inflatable bladders, flexible tubes or sand bags (for cofferdams around the culvert inlet and outlet), the requirements for groundwater control could be more extensive. The contractor is responsible for the design and installation of all groundwater control measures giving due consideration to the type of temporary cofferdam system selected as well as the requirements for maintaining the stability/integrity of the culvert foundation. It is recommended that MTO's Special Provision 517F01 (*Temporary Flow Passage System*), which is included in Appendix D, be included in the Contract Documents.

If construction water pumping volumes are anticipated to exceed 50 m³/day, an Environmental Activity Section Registry (EASR) will be required as per the recently introduced changes to the Environmental Protection Act by the Ontario Ministry of Environment and Climate Change (MOECC).

Surface water should be directed away from the work area to prevent ponding of water that could interfere with the rehabilitation work.

7.0 CLOSURE

This Foundation Design Report was prepared by Ms. Alysha Kobylinski, B.A.Sc. and reviewed by Mr. Tomasz Zalucki, P.Eng. Mr. Paul Dittrich, P.Eng., a Principal and MTO Foundations Designated Contact for Golder, conducted an independent quality control review of the report.



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Ontario Ministry of Northern Development of Mines. Bedrock Geology of Ontario – East Central Sheet, Ontario Geological Survey – Map 2544.

ASTM International:

ASTM D1586 Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils

Ontario Provincial Standard Specifications (OPSS), Construction:

OPSS.PROV 539 Construction Specification for Temporary Protection Systems

Ontario Regulations:

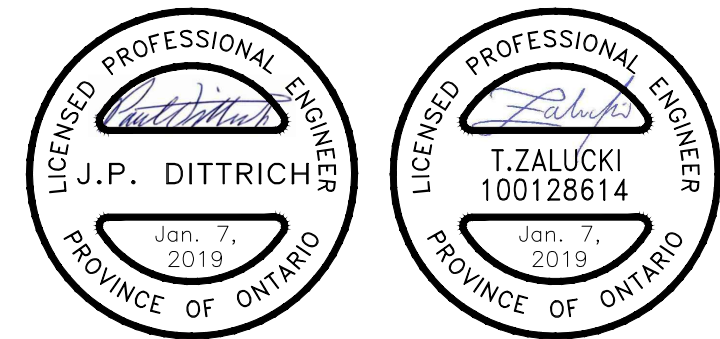
R.R.O 1990, Regulation 903 Wells, under Ontario Water Resources Act, R.S.O. 1990, c. O.40

Ontario Special Provisions (SP):

SP 517F01 Temporary Flow Passage System



DRAWINGS



- BOREHOLE CO-ORDINATES (NAD83 MTM ZONE 13)

NOTES

The northing and easting co-ordinates tabulated above for the previous investigation boreholes are considered approximate only. Previous investigation boreholes shown on the plan were advanced in January 1987 and January 1987 as part of an original field investigation (MTO Geocres No. 41J-45) for the current twin culverts at the Kihinai Creek site. The survey information in the 41J-45 report indicates that the average ground surface elevation in the area of the culvert is approximately 352.5 m. However, the survey associated with the 2018 field investigation indicates that the average ground surface elevation is approximately 316.5 m. Given the discrepancy between the 1986/1987 and 2018 surveys, the existing boreholes are not shown on the soil strata profile, but the existing boreholes are addressed in the Foundation Investigation Report for the Kihinai Creek Culvert.

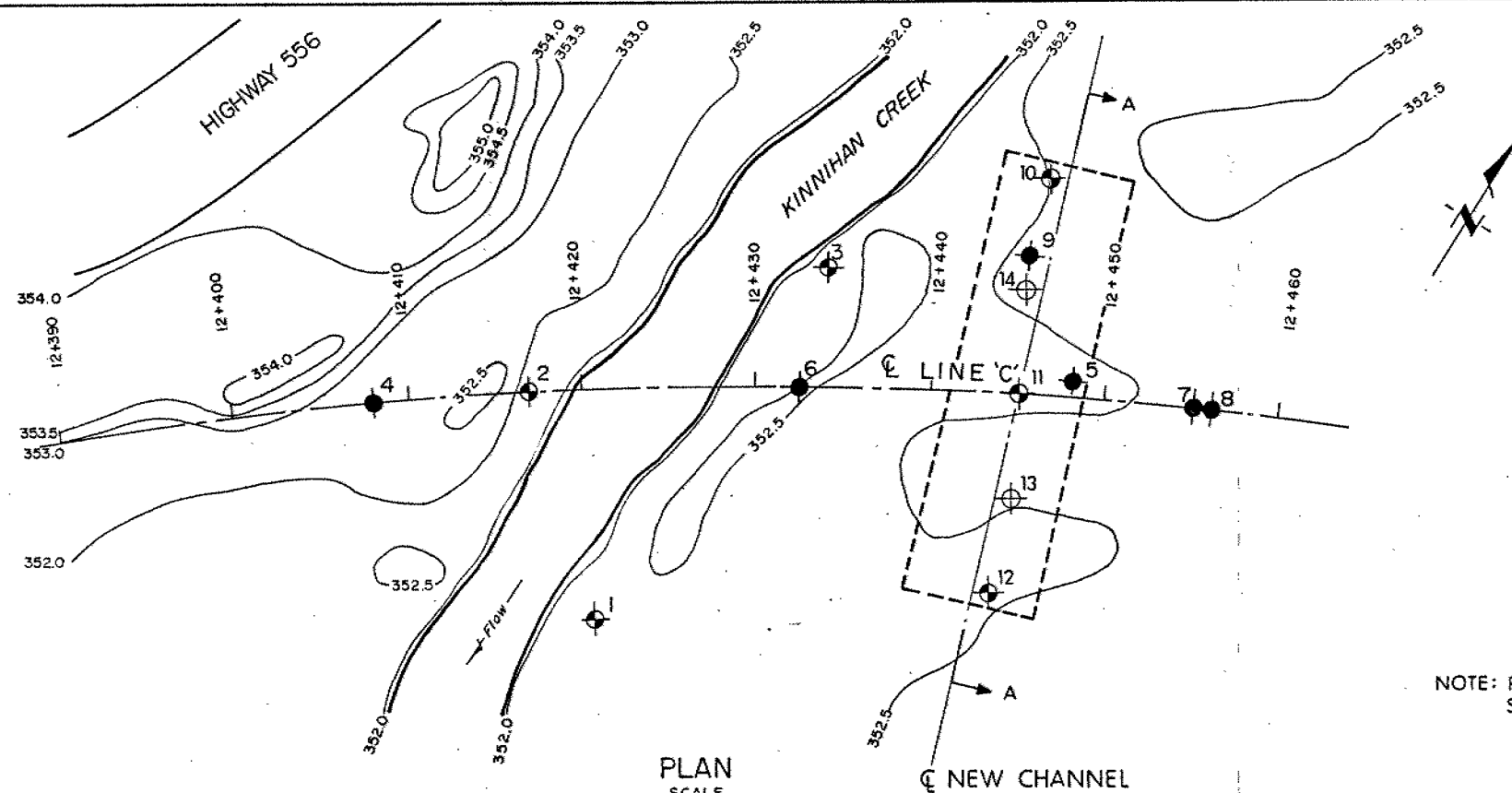
Base plans provided in digital format by AECOM, drawing file no 60546679-S20.dwg, received AUG 24, 2018.

NO.	DATE	BY	REVISION		
Geocres No. 41J-119					
HWY. 556		PROJECT NO. 1670846		DIST. ALGOMA	
SUBM'D. TZ		CHKD. TZ		DATE: 1/7/2019	
DRAWN: TB		CHKD. JPD		APPD. JPD	
				SITE: 38S-0022/C	
				DWG. 1	

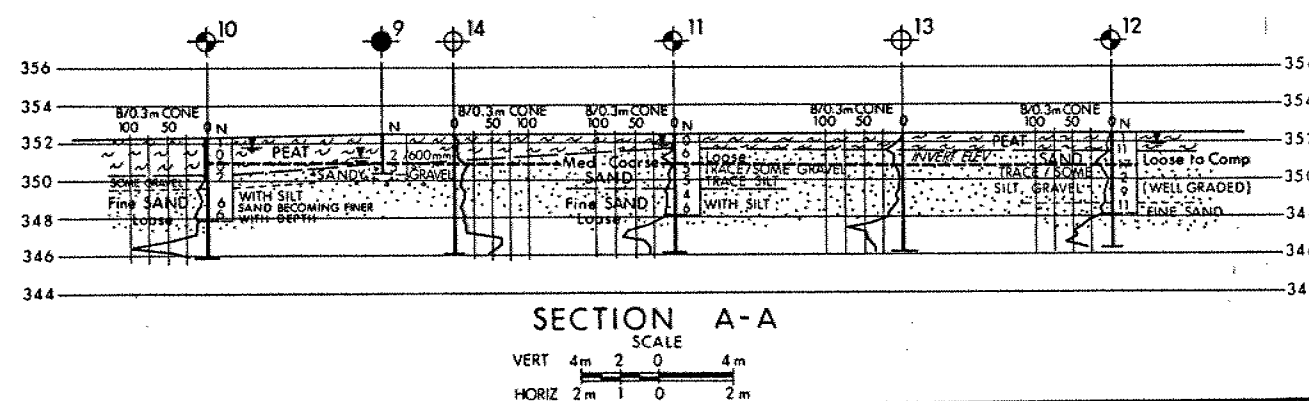
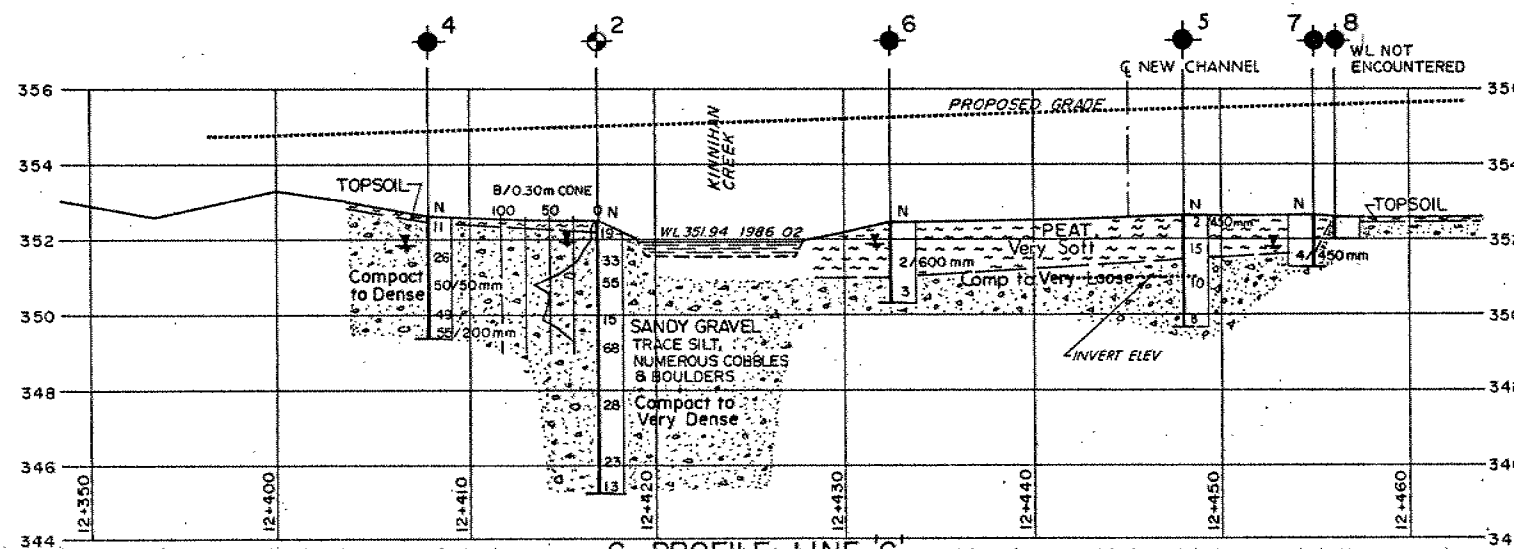


APPENDIX A

Previous Borehole Investigation (MTO Geocres No. 41J-045)



NOTE: REFER TO RECORD OF BORE HOLE FOR SOIL DESCRIPTION FOR BH 1 & 3



METRIC

DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES UNLESS
OTHERWISE SHOWN.
STATIONS ARE IN KILOMETRES
+ METRES

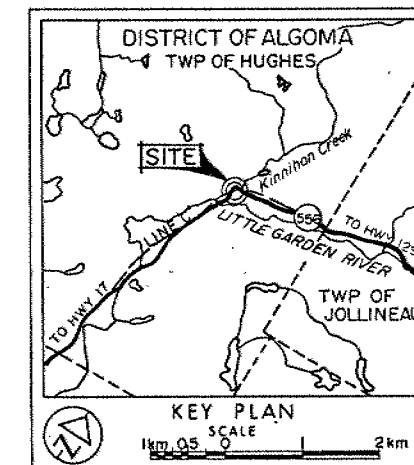
CONT No
WP No 278-85-01

KINNIHAN CREEK STRUCTURE
AT HIGHWAY 556
BORE HOLE LOCATIONS & SOIL STRATA



SHEET

PETO MacCALLUM LTD.



LEGEND

- Bore Hole
- ⊕ Dynamic Cone Penetration Test (Cone)
- ⊙ Bore Hole & Cone
- N Blows/0.3m (Std Pen Test, 475 J/blow)
- CONE Blows/0.3m (60° Cone, 475 J/blow)
- W L at time of investigation 1986 02 & 1987 01

No	ELEVATION	STATION	OFFSET
1	352.39	12+420	13m RT
2	352.54	12+417	€
3	352.52	12+434	7m LT
4	352.67	12+408	€
5	352.68	12+448	1m LT
6	352.51	12+432.5	€
7	352.69	12+455	€
8	352.62	12+456	€
9	352.51	12+445	8m LT
10	352.3	12+446	12.5 m LT
11	352.5	12+445	€
12	352.5	12+444	11.5 m RT
13	352.5	12+445	6 m RT
14	352.5	12+445	6 m LT

1987 01
MTC

=NOTE=

The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

DATE	BY	DESCRIPTION
8703	SO	SECTION A-A REVISED

Geocres No 41J-45

HWY No 556 LINE 'C'	DIST 18
SUBM'D GM CHECKED DATE 1986 02 24	SITE 385-22
DRAWN KZ CHECKED SR APPROVED S.P.	DWG 2788501-A

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 \bar{N} .

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J 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

MECHANICAL PROPERTIES OF SOIL

m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_a	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 = $\frac{c_u}{\tau_r}$

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
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
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

PHYSICAL PROPERTIES OF SOIL

ρ_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 = $\frac{e_{max} - e}{e_{max} - e_{min}}$
ρ_w	kg/m^3	DENSITY OF WATER	w	1, %	WATER CONTENT	D	mm	GRAIN DIAMETER
γ_w	kN/m^3	UNIT WEIGHT OF WATER	S_r	%	DEGREE OF SATURATION	D_n	mm	n PERCENT - DIAMETER
ρ	kg/m^3	DENSITY OF SOIL	w_L	%	LIQUID LIMIT	C_u	1	UNIFORMITY COEFFICIENT
γ	kN/m^3	UNIT WEIGHT OF SOIL	w_p	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
ρ_d	kg/m^3	DENSITY OF DRY SOIL	w_s	%	SHRINKAGE LIMIT	q	m^3/s	RATE OF DISCHARGE
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL	I_p	%	PLASTICITY INDEX = $w_L - w_p$	v	m/s	DISCHARGE VELOCITY
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	1	HYDRAULIC GRADIENT
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL	I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL	e_{max}	1, %	VOID RATIO IN LOOSEST STATE	j	kN/m^2	SEEPAGE FORCE
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL						

RECORD OF BOREHOLE No 5

METRIC

W P 278-85-01 LOCATION Sta. 12 + 448 o/s 1m Lt. & line 'C' ORIGINATED BY PC
 DIST 18 HWY 556 BOREHOLE TYPE Hollow Stem Auger COMPILED BY GM
 DATUM Geodetic DATE 1986 02 03 CHECKED BY gla

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	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			20	40	60	80	100					
352.68	Ground Level															
	Peat		1	SS	2/450mm											
	Sand layers below 0.60m															
351.48	Very Soft Dark Brown		2	SS	15											
1.20	Sandy gravel, trace silt, numerous cobbles and boulders		3	SS	10											
349.63	Compact to Loose Grey		4	SS	8											
3.05	End of Borehole															

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 9

METRIC

W P 278-85-01 LOCATION Sta. 12 + 445 o/s 8m Lt. of Line 'C' ORIGINATED BY PC
DIST 18 HWY 556 BOREHOLE TYPE Hollow Stem Auger COMPILED BY GM
DATUM Geodetic DATE 1986 02 05 CHECKED BY *gln*

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 Y	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60					
352.51	Ground Level														
0.00	Peat														
351.01	Very Soft Dark Brown		1	SS	2/60mm										
1.50	Sandy gravel, trace														
350.36	silt, numerous cobbles		2	SS	5										
2.15	and boulders														
	Loose Brown														
	End of Borehole														

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 10

METRIC

W P 278-85-01 LOCATION Sta. 12 + 446 O/S 12.5 Lt Q Hwy 556 ORIGINATED BY MJ
 DIST 18 HWY 556 BOREHOLE TYPE Hollow Stem Auger, Cone Test COMPILED BY LP
 DATUM Geodetic DATE 1987 01 20 CHECKED BY _____

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES								
352.3	Ground Surface												
0.0	Peat some gravel Fine sand with silt sand becoming finer with depth Loose		1	SS	1								1 60 (39)
			2	SS	0								
			3	SS	0								
350.2			4	SS	2								
2.1			5	SS	6								
			6	SS	6								
347.9	End of Borehole												
4.4													
345.9	End of Cone Test												
6.4													



RECORD OF BOREHOLE No 11

METRIC

W P 278-85-01 LOCATION Sta. 12 + 445 at Q Hwy. 556 ORIGINATED BY MJ
 DIST 18 HWY 556 BOREHOLE TYPE Hollow Stem Auger, Cone Test COMPILED BY LP
 DATUM Geodetic DATE 1987 01 20 CHECKED BY sp

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L		
352.5	Ground Surface												
0.0	Peat		1	SS	0		352						
351.7			2	SS	6								
0.8	Med. Coarse Sand, trace/some gravel, trace silt		3	SS	5								
			4	SS	5								
349.5	Loose		5	SS	4								
3.0	Fine sand with silt		6	SS	6								
348.1	Loose												
4.4	End of Borehole												
346.1													
6.4	End of Cone Test												

+³, x⁵: Numbers refer to
Sensitivity

20
15 ϕ 5 (%) STRAIN AT FAILURE
10



RECORD OF BOREHOLE No 13

METRIC

W P 278-85-01 LOCATION Sta. 12 + 445 O/S 6 RT Q Hwy. 556 ORIGINATED BY MJ
DIST 18 HWY 556 BOREHOLE TYPE Cone Test COMPILED BY LP
DATUM Geodetic DATE 1987 01 20 CHECKED BY 10

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE	PLASTIC LIMIT W _p NATURAL MOISTURE CONTENT W LIQUID LIMIT W _L WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES							
352.5 0.0	Ground Surface						352					
							350					
							348					
346.1												
6.4	End of Cone Test											

RECORD OF BOREHOLE No 14

METRIC

W P 278-85-01 LOCATION Sta. 12 + 445 O/S 6 LT C Hwy. 556 ORIGINATED BY MJ
 DIST 18 HWY 556 BOREHOLE TYPE Cone Test COMPILED BY LP
 DATUM Geodetic DATE 1987 01 20 CHECKED BY _____

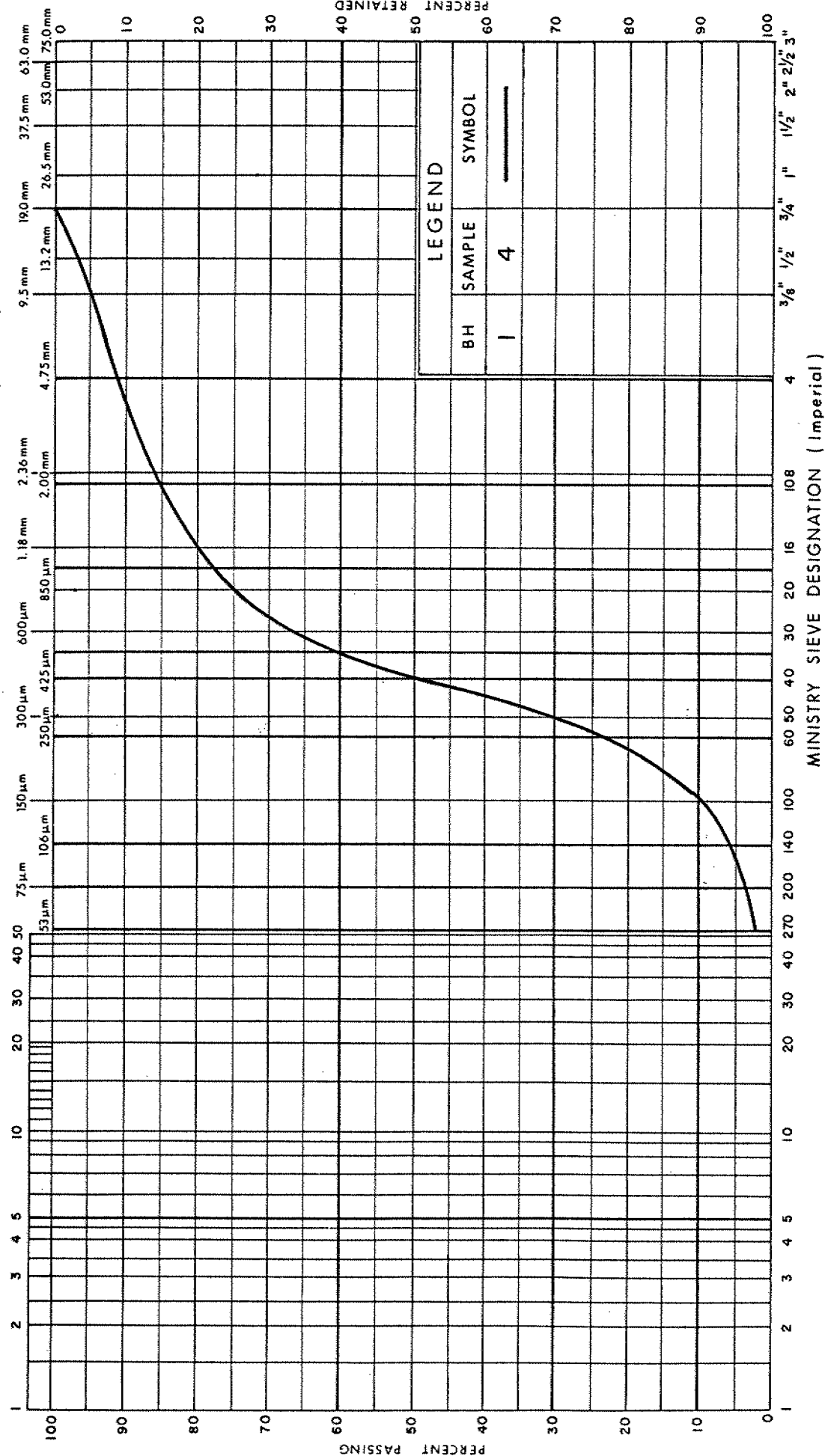
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES								
352.5													
0.0													
346.1													
6.4	End of Cone Test												

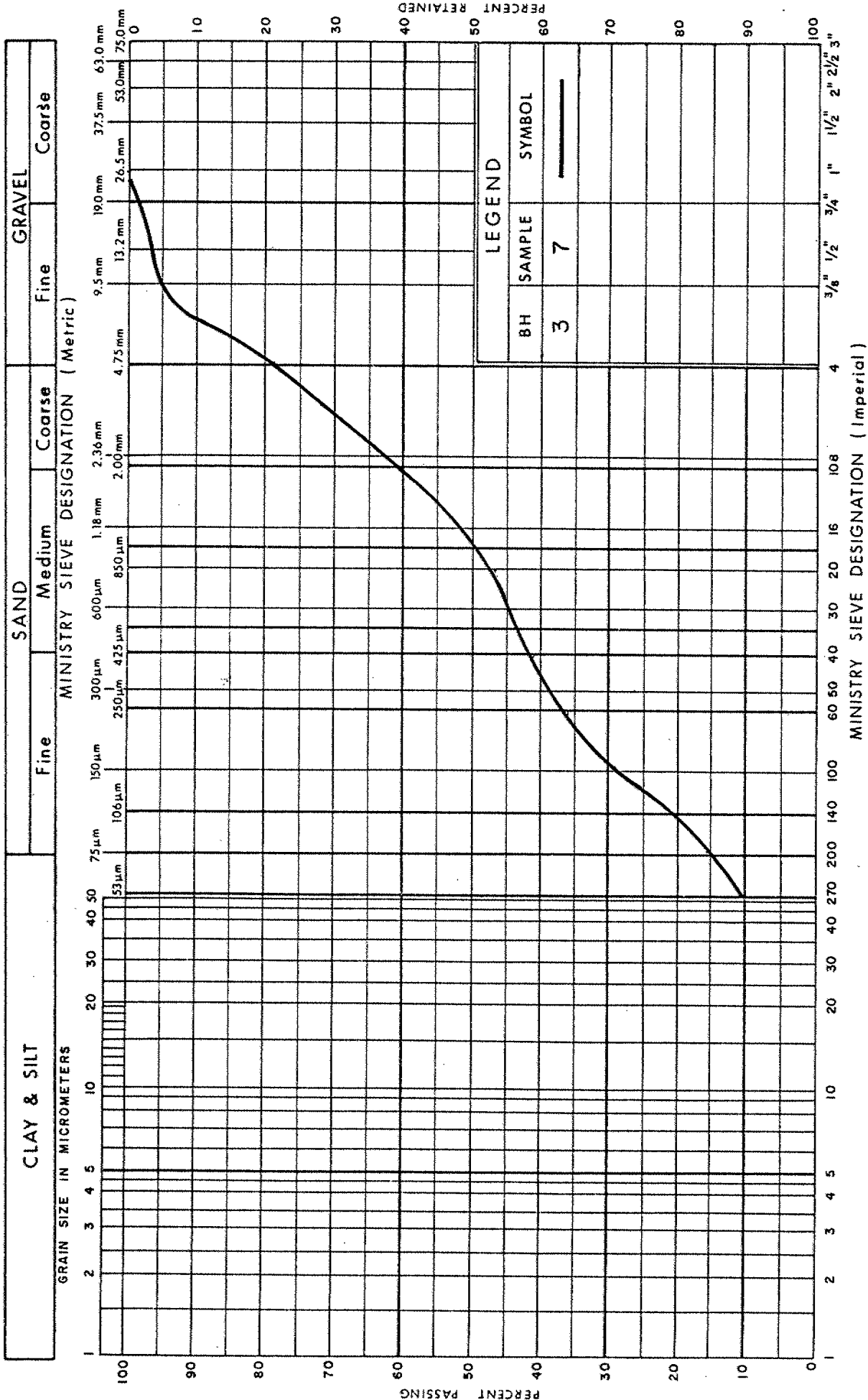
UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT		SAND			GRAVEL		
		Fine		Medium	Coarse	Fine	Coarse

GRAIN SIZE IN MICROMETERS

MINISTRY SIEVE DESIGNATION (Metric)





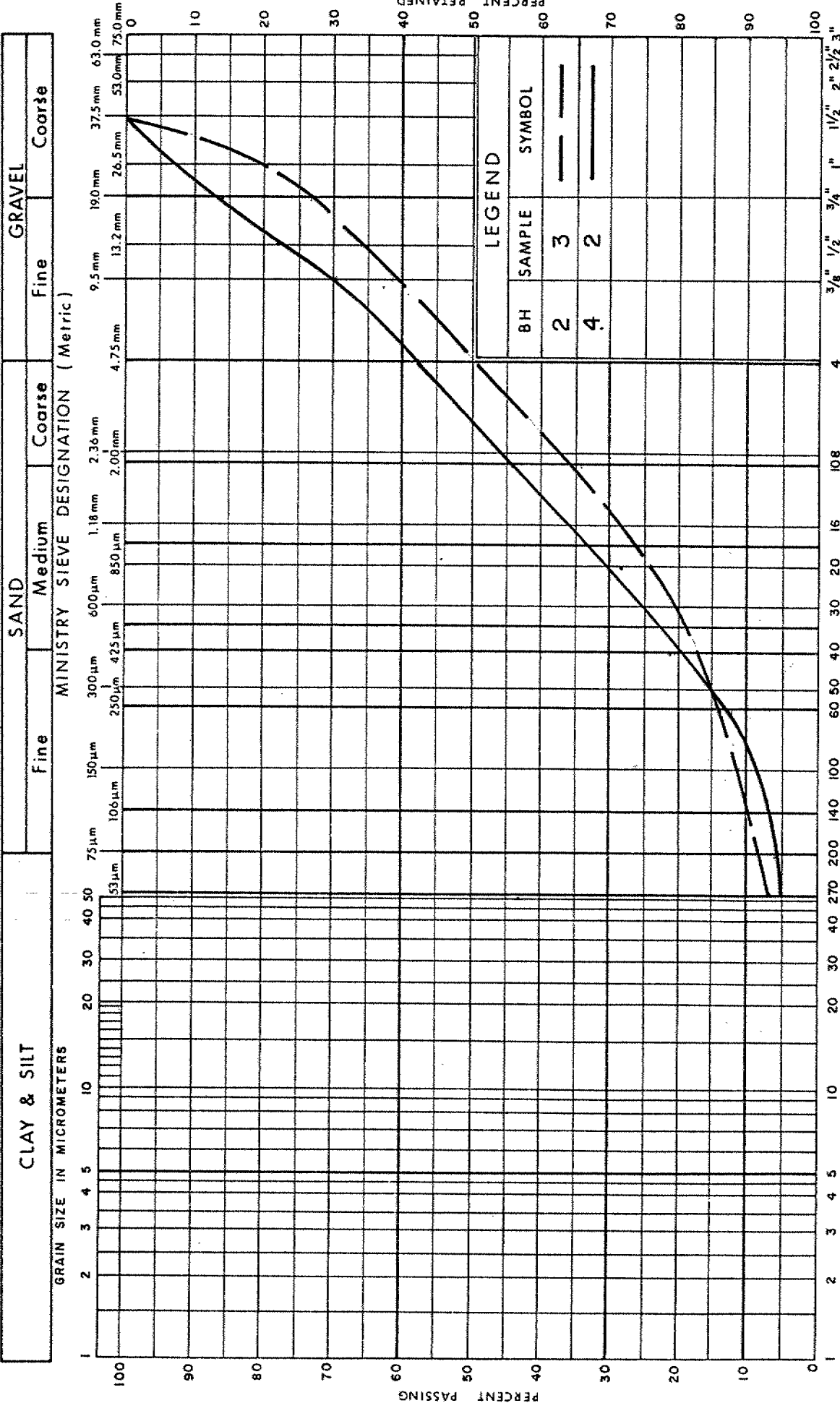
GRAIN SIZE DISTRIBUTION
GRAVELLY FINE TO COARSE SAND

Ministry of
Transportation and
Communications

FIG No 2

W P 278 - 85 - 01

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
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Communications



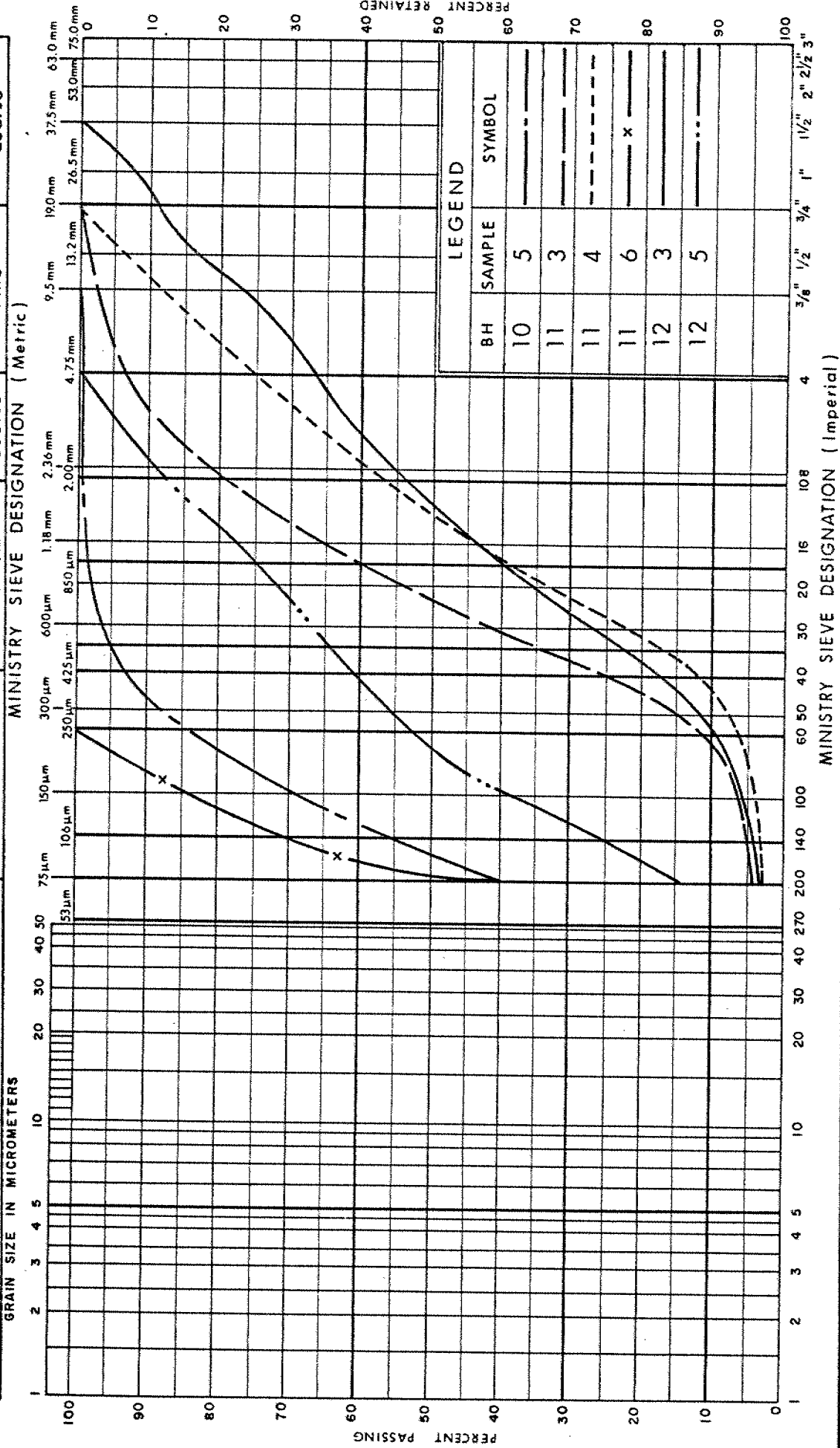
GRAIN SIZE DISTRIBUTION
SANDY GRAVEL
TRACE SILT, NUMEROUS COBBLES & BOULDERS

FIG No 3

W P 278 - 85 - 01

UNIFIED SOIL CLASSIFICATION SYSTEM

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



Ministry of
Transportation and
Communications

GRAIN SIZE DISTRIBUTION

FIG No 4

W P 278-85-01



APPENDIX B

Records of Borehole Sheets



LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
$\ln x$,	natural logarithm of x
\log_{10}	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
FoS	factor of safety

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta \sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a)	Index Properties
$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_c	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_{α}	secondary compression index
m_v	coefficient of volume change
C_v	coefficient of consolidation (vertical direction)
C_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio = σ'_p / σ'_{vo}

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = $\tan \delta$
c'	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

* Density symbol is ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

Notes: 1
2

$$\tau = c' + \sigma' \tan \phi'$$

$$\text{shear strength} = (\text{compressive strength})/2$$



LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; N_d :

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

Condition	N Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils Consistency

	c_u, s_u kPa	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO ₄	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

Note: 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand

PROJECT		RECORD OF BOREHOLE				No KCC-01				SHEET 1 OF 1				METRIC			
W.P.		5261-13-02		LOCATION		N 5186197.3; E 324749.9 MTM NAD 83 ZONE 13 (LAT. 46.815027; LONG. -83.738574)				ORIGINATED BY				MB			
DIST		ALGOMA HWY 556		BOREHOLE TYPE		Wash Boring; NQ Coring				COMPILED BY				AK			
DATUM		Geodetic		DATE		August 21 and 22, 2018				CHECKED BY				TZ			
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)					
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED									
316.3	GROUND SURFACE						20 40 60 80 100										
0.0	Sandy gravel to sand and gravel, trace to some silt, trace clay, with cobbles and rock fragments (FILL) Compact Brown Moist to wet		1	SS	22	▽	316									60 29 9 2	
			2	SS	30		315										
			3	SS	23		314										
314.1			4	SS	16		313									35 59 4 2	
313.3	SAND and GRAVEL, trace silt, trace clay, trace organics, with cobbles and rock fragments Compact Grey Wet		5	SS	10		312									16 41 41 2	
312.6	SILT and SAND, some gravel, trace clay Compact Grey Wet		6	SS	35		311										
310.4	SAND, trace gravel to SAND and GRAVEL, trace silt, trace clay, with cobbles and rock fragments Dense Brown Wet		7	SS	45		310									40 55 4 1	
307.2	END OF BOREHOLE Dynamic Cone Penetration Test (DCPT)		8	SS	32		309										
9.1	END OF DCPT						308										
Note: 1. Water level at a depth of 3.1 m below ground surface (Elev. 313.2 m) upon completion of drilling.																	

PROJECT		1670846		RECORD OF BOREHOLE		No KCC-02		SHEET 1 OF 1		METRIC							
W.P.		5261-13-02		LOCATION		N 5186172.0; E 324774.7 MTM NAD 83 ZONE 13 (LAT. 46.814798; LONG. -83.738250)		ORIGINATED BY		MB							
DIST		ALGOMA HWY 556		BOREHOLE TYPE		Wash Boring; NQ Coring		COMPILED BY		AK							
DATUM		Geodetic		DATE		August 20, 2018		CHECKED BY		TZ							
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	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
316.6	GROUND SURFACE																
0.0	Gravelly organic silty sand, trace clay, with cobbles and rock fragments (FILL)		1	SS	24												OC = 8.6%
315.9	Compact Brown Wet		2	SS	15												58 36 4 2
0.7	Gravelly SAND, trace to some silt, trace clay to SAND and GRAVEL, trace silt, trace clay, with cobbles and rock fragments		3	SS	5												
	Loose to very dense Brown to grey Wet		4	SS	10												
			5	SS	16												23 69 7 1
			6	SS	41												
			7	SS	58												
311.1	END OF BOREHOLE																
310.8	Dynamic Cone Penetration Test (DCPT)																
5.8	END OF DCPT																
	Note:																
	1. Water level at a depth of 0.2 m below ground surface (Elev. 316.4 m) upon completion of drilling.																



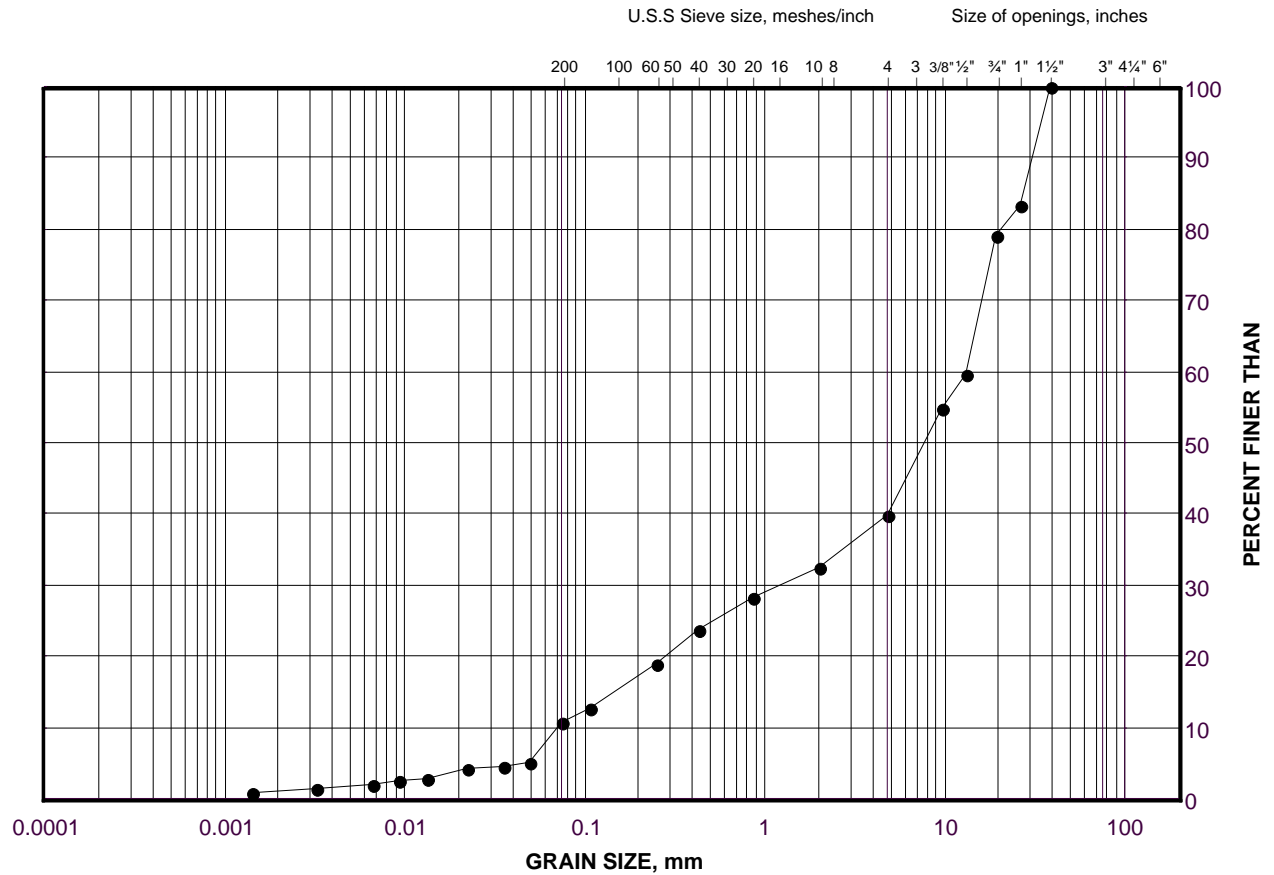
APPENDIX C

Geotechnical Laboratory Test Results

GRAIN SIZE DISTRIBUTION

Sandy Gravel (Fill)

FIGURE C1



SILT AND CLAY SIZES		FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED		SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
•	KCC-01	1	315.7

Project Number: 1670846

Checked By: TZ

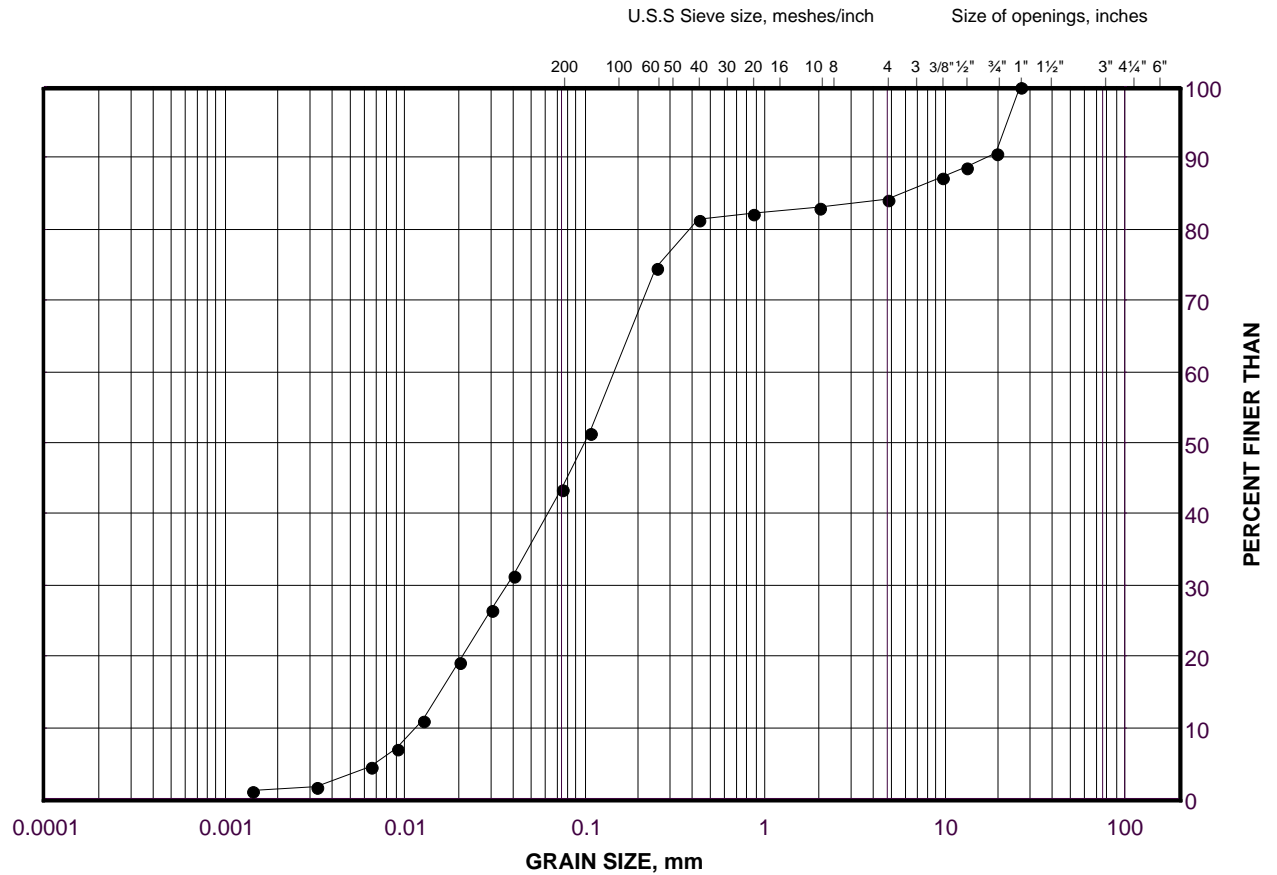
Golder Associates

Date: 05-Oct-18

GRAIN SIZE DISTRIBUTION

Silt and Sand

FIGURE C3



SILT AND CLAY SIZES		FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED		SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
•	KCC-01	5	309.6

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Checked By: TZ

Golder Associates

Date: 05-Oct-18



APPENDIX D

Special Provisions

NOTICE TO CONTRACTOR - Obstructions During Installtion of Temporary Cofferdam Systems

Special Provision

The Contactor is advised of the presence of cobbles and boulders encountered within the granular fill layers and native granular deposits at the site, and on and within the creek bed, especially within the vicinity of the inlet and outlet of the existing twin culverts, located at approximately Station 12+455 (Hughes Township).

Consideration of the presence of the cobbles and boulders must be made in the selection of appropriate equipment/tools for excavation and/or installation of temporary cofferdams systems.

TEMPORARY FLOW PASSAGE SYSTEM - Item No.

Special Provision No. 517F01

July 2017

Amendment to OPSS 517, November 2016

Design Storm Return Period and Preconstruction Survey Distance

517.01 SCOPE

Section 517.01 of OPSS 517 is deleted in its entirety and replaced with the following:

This specification covers the requirements for the design, operation, and removal of a dewatering or temporary flow passage system or both to control water during construction, and the control of the water prior to discharge to the natural environment and sewer systems.

517.04 DESIGN AND SUBMISSION REQUIREMENTS

517.04.01 Design Requirements

Subsection 517.04.01 of OPSS 517 is amended by deleting the first paragraph in its entirety and replacing it with the following:

A dewatering or temporary flow passage system or both shall be designed to control water at the locations specified in the Contract Documents and at any other location where a system is necessary to complete the work. The design of the system shall be sufficient to permit the work at each location to be carried out as specified in the Contract Documents.

Subsection 517.04.01 of OPSS 517 is further amended by deleting the second last paragraph in its entirety and replacing it with the following:

Temporary flow passage systems shall be designed, as a minimum, for a 2 year design storm return period and groundwater discharge, except for the work specified in Table A. For the work specified in Table A, the temporary flow passage system shall be designed, as a minimum, for the design storm return period specified in Table A and groundwater discharge. A longer return period shall be used when determined appropriate for the work.

Intensity-Duration Factor (IDF) curve location, site specific minimum return period, return period flow estimates, and other information is provided in Table A. The IDF information can be accessed through the MTO IDF Curve Look up Tool on the Drainage and Hydrology page of MTO's website. The return period flow estimates do not include flow volumes from groundwater discharge. The Owner specifically excludes these flow estimates from the warranty in the Reliance on Contract Documents subsection of OPSS 100, MTO General Conditions of Contract.

Table A

IDF Curve Location	Latitude: 46.812500		Longitude: -83.737500			
Temporary Flow Passage Systems						
Site Name / Station Reference	Minimum Return Period (Years)	Return Period Flow Estimates (m³/s)				Design Engineer Requirements (Note 1)
		2 Year	5 Year	10 Year	25 Year	
Kinihan Creek Culvert (Site No. 38S-0022/C0) Rehabilitation (12+454.34)	2	7.1	9.8	12.5	15.3	Yes
Dewatering Systems						
Site Name / Station Reference	Preconstruction Survey Distance (Note 2) (m)					Design Engineer Requirements (Note 1)
Kinihan Creek Culvert (Site No. 38S-0022/C0) Rehabilitation (12+454.34)	N/A					N/A
Note:						
1. “Yes” means the design Engineer and design-checking Engineer shall have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work. “No” means a minimum experience level is not required for the design Engineer and design-checking Engineer.						
2. “N/A” indicates a preconstruction survey is not required.						

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