



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
WEST CORBETT CREEK CULVERT REHABILITATION
BRIDGE AND CULVERT REHABILITATION FOR HWY 401
WHITBY, ONTARIO
G.W.P. 2165-16-00, SITE NO. 22-447/C
LATITUDE: 43.868050°, LONGITUDE: -78.907207°**

GEOCRES No.: 30M155-331

Report

to

Consor Engineers, LLC

Date: May 17, 2021
File: 25682



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PART 1: FACTUAL INFORMATION

1. INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted at the West Corbett Creek culvert under Highway 401 west of Thickson Road, located in the town of Whitby, Regional Municipality of Durham, Ontario.

The purpose of this investigation was to explore the subsurface conditions near the inlet and outlet of the culvert and, based on the data obtained, to provide a borehole location plan, records of boreholes, stratigraphic profile, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions was developed from the data obtained in the course of the investigation.

Thurber carried out the investigation as a sub-consultant to Consor Engineers, LLC, under the Ministry of Transportation Ontario (MTO) Agreement Number 2018-E-0066.

Reference has been made to information on subsurface conditions contained in a previous foundation report prepared by others for this site. The title of this report is:

- Foundation Investigation Report for West Corbett Creek Culvert Replacement, Hwy. 401 and Thickson Road Interchange, W.P 38-77-01, District 6, Toronto, prepared by the then Ministry of Transportation and Communications, GEOCRES No. 30M15-52, dated March 4, 1980. (Reference 1).



2. SITE DESCRIPTION

The culvert is located on Highway 401, approximately 230 m west of Thickson Road in the town of Whitby, Ontario. The structure consists of a single reinforced cast-in-place concrete box culvert. The 127 m span consists of an original 69 m long original barrel, a 20 m long north barrel extension and a 38 m long south barrel extension. The culvert width is 3.05 m for the original barrel and 4.88 m for the north and south barrel extensions. The culvert has a north-to-south orientation. West Corbett Creek flows from north to south through the culvert.

The site topography is generally flat to gently undulating, sloping down towards West Corbett Creek from the west and the east. This creek drains the adjacent land, flowing south to merge with East Corbett Creek which empties into Lake Ontario approximately 2.1 km southeast of the site. The 50-year flood high water level of the West Corbett Creek is recorded at Elevation 88.1.

Photographs in Appendix C show the general nature of the site and the existing culvert.

The site lies within the physiographical region known as the Iroquois Plain, based on L.J. Chapman and D.F. Putnam's 1984 edition of The Physiography of Southern Ontario. The area typically consists of a mosaic of till plains, drumlins and areas of silty lacustrine deposits. Based on the Ontario Geological Survey (OGS) Map MRD128, titled "Surficial Geology of Southern Ontario", dated 2010, the surficial geology typically consists of fine-textured glaciolacustrine deposits of silt and clay, with minor sand and gravel. Based on local geological maps bedrock consists of shale and limestone of the Georgian Bay formation located at depths greater than 10 m.

3. INVESTIGATION PROCEDURES

The site investigation and field testing for this project was carried out between March 31, 2020 and April 3, 2020. Two sampled boreholes, identified as COB20-01 and COB20-02, were advanced at the inlet and the outlet, respectively. The approximate borehole locations are shown on the attached Borehole Locations and Soil Strata Drawing in Appendix D.

Borehole COB20-01 was drilled approximately 1.0 m north and 7.0 m west of the northwest edge of the inlet of the culvert, on the west bank of West Corbett Creek. Borehole COB20-02 was drilled approximately 5.5 m south and 4.3 m west of the southwest edge of the outlet of the culvert, on the west bank of West Corbett Creek. Both boreholes were terminated at a depth of 9.8 m (Elevation 73.4 m and 72.9 m, respectively).

A standpipe piezometer was installed in Borehole COB20-01 and consisted of a 19 mm Schedule 40 PVC pipe with a 1.5 m long slotted screen, enclosed in a column of filter sand to permit



groundwater level monitoring. Piezometer installation details, groundwater level observations and water level readings are shown on the Record of Borehole sheets. Upon completion of the field investigation in April 2020, the piezometer was decommissioned as per O.Reg. 903.

Details of the drilling program, including drilling depths, piezometer installation and completion details are summarized in Table 3.1 below.

Table 3.1 – Borehole Completion Details

Boreholes	Borehole Depth / Base Elevation (m)	Piezometer Tip Depth / Elevation (m)	Completion Details
COB20-01	9.8 / 73.4	9.4 / 73.8	Piezometer with 1.5 m slotted screen installed with sand filter to 7.2 m and bentonite holeplug from 7.2 m to 4.1 m, then sand to ground surface.
COB20-02	9.8 / 72.9	None installed	Borehole backfilled with bentonite holeplug and auger cuttings to surface.

All boreholes were advanced using a portable tripod equipment using wash boring techniques. In all boreholes, soil samples were obtained at selected intervals with a 50 mm outside diameter split spoon sampler driven in conjunction with the Standard Penetration Test (SPT) in general accordance with ASTM D1586.

Thurber obtained the borehole co-ordinates in the field using a hand-held GPS unit and provided those co-ordinates to Consor, who in turn obtained the ground surface elevations based on their topographic survey data. It is understood that the horizontal accuracy of the co-ordinates meets the MTO terms of reference requirements. The accuracy of the borehole elevations is the same as that of the topographic survey. The coordinates and elevations of the boreholes are given on the individual Record of Borehole Sheets and the drawings in Appendices A and D.

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



4. LABORATORY TESTING

All recovered soil samples were subjected to visual identification and natural moisture content determination. The results of this testing are shown on the Record of Borehole sheets included in Appendix A. Selected samples were subjected to grain size distribution analyses (sieve and hydrometer) and Atterberg Limits testing, and the results of this testing program are summarized on the Record of Borehole sheets in Appendix A and are shown on the figures included in Appendix B.

5. DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets included in Appendix A. Details of the encountered soil stratigraphy are presented in these sheets and on the Borehole Locations and Soil Strata drawing in Appendix D. 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. It must be recognized that soil conditions may vary between and beyond the borehole locations.

In summary, the subsurface stratigraphy generally consists of soft to stiff silty clay fill overlying peat or organic deposits which is further underlain by native very soft to firm silty clay. The groundwater is within 0.5 m of the existing ground surface. More detailed descriptions of individual strata are presented below.

5.1 Topsoil

Topsoil was encountered at ground surface in Borehole COB20-01. The thickness of the topsoil was 175 mm.

5.2 Peat and Organics

A layer of black peat and organics was encountered at the ground surface in Borehole COB20-02, with a thickness of 1.2 m and an underside depth of 1.2 m (Elevation 81.4 m). Another layer was also encountered below the silty clay fill in Borehole COB20-01, with a thickness of 0.6 m and an underside depth of 1.8 m (Elevation 81.3 m).

SPT 'N' values measured in the peat and organic layer ranged from 1 to 12 blows per 0.3 m penetration, indicating a very soft to stiff condition. Recorded moisture contents ranged from 69 percent to 81 percent.



5.3 Silty Clay Fill

Brown silty clay fill was encountered below the topsoil in Borehole COB20-01, and contained some sand to sandy, trace gravel and occasional organics. The thickness of the silty clay fill was 1.0 m, with an underside depth of 1.2 m (Elevation 81.9).

SPT 'N' values measured in the silty clay fill were 3 and 14 blows per 0.3 m penetration indicating a soft to stiff condition. Recorded moisture contents were 9 percent and 24 percent.

The results of one grain size analysis and Atterberg Limit testing conducted on a sample of the silty clay fill are provided on the Record of Borehole sheets in Appendix A and plotted in Figures B1 and B3 of Appendix B. The results of the grain size distribution are summarized as follows:

Soil Particle	Percentage (%)
Gravel	4
Sand	22
Silt	44
Clay	30

The results of Atterberg Limits testing are summarized below:

Parameter	Percentage (%)
Liquid Limit	34
Plastic Limit	18
Plasticity Index	16

The laboratory results indicate the silty clay fill exhibits low plasticity (CL).

5.4 Silty Clay

Silty clay was encountered below the peat and organics layer in both boreholes. The silty clay was brown to grey in colour and contained trace sand to sandy and trace gravel.

Borehole COB20-01 was terminated in the silty clay at a depth of 9.8 m (Elevation 73.4 m) and Borehole COB20-02 was terminated in the silty clay at a depth of 9.8 m (Elevation 72.9 m).

SPT 'N' values in the silty clay ranged from zero (weight of hammer) to 8 blows per 0.3 m penetration. 'N' values between 4 and 8 blows were measured within the upper 2 m which appear to indicate a weathered crust. Field vane shear tests measured undrained shear strength ranging from 11 kPa to 24 kPa. The SPT 'N' values and shear vane tests indicate a generally very soft to soft but occasionally firm consistency in the silty clay. Shear strengths correlated from pocket penetrometer test results typically ranged from 0 to 25 kPa. Vane tests measured that the



sensitivity of the silty clay ranged from 2.8 to 8.7 indicating that the silty clay has low to medium sensitivity.

Results of field vane, laboratory vane, unconfined compression and quick triaxial testing from Boreholes 1, 2 and 9 in Reference 1 reported undrained shear strengths ranging between 5 kPa and 75 kPa but typically between 5 and 25 kPa, indicating a very soft to soft consistency.

The results of grain size analysis and Atterberg Limit testing conducted on samples of the silty clay from Boreholes COB20-01 and COB20-02 are provided on the Record of Borehole sheets in Appendix A and plotted in Figures B2 and B4 of Appendix B. The results of the grain size distribution are summarized as follows:

Soil Particle	Percentage (%)
Gravel	0 to 10
Sand	3 to 33
Silt	37 to 50
Clay	20 to 49

The results of Atterberg Limits testing are summarized below:

Parameter	Percentage (%)
Liquid Limit	18 to 41
Plastic Limit	10 to 17
Plasticity Index	8 to 23

The laboratory results indicate the silty clay exhibits low to medium plasticity (CL – CI).

5.5 Groundwater Conditions

A piezometer was installed in Borehole COB20-01 to monitor groundwater levels after completion of drilling. The measured groundwater levels are summarized in the table below.

Borehole	Date	Depth (m)	Elevation (m)
COB20-01	April 9, 2020	0.4	82.7
	April 14, 2020	0.3	82.8

It should also be noted that the groundwater level may differ at the time of construction and seasonal fluctuations are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation and spring snow melts. The water level in the creek was at approximately 83.0 m in June 2019.



6. MISCELLANEOUS

Borehole locations were selected and established in the field by Thurber Engineering Ltd. The borehole coordinates were established by Thurber and the elevations were established by Consor based on topographic survey information.

Thurber obtained utility clearances for the borehole locations prior to drilling.

Ohlmann Geotechnical Services (OGS) Inc. of Almonte, Ontario supplied a portable Hilti drill and conducted the drilling, sampling and in-situ testing operations for the boreholes.

The field investigation was supervised on a full-time basis by Mr. Ajaz Yusufi of Thurber. Overall supervision of the field program was provided by Ms. Nancy Berg, P.Eng of Thurber and interpretation of the data and preparation of this report was carried out by Ms. Judy Mei, EIT and reviewed by Dr. Sydney Pang , P.Eng. Dr. P.K. Chatterji, P.Eng. carried out a final review as a Designated Principal Contact for MTO Foundations Projects.



THURBER ENGINEERING LTD.



Sydney Pang, P.Eng.
Associate, Senior Foundation Engineer



P.K. Chatterji, P.Eng.
Review Principal, Designated MTO Contact



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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7. GENERAL

This report presents interpretation of the geotechnical data in the factual report and provides foundation recommendations pertinent to the design of a suitable cofferdam for the rehabilitation of the existing culvert. It is understood that the rehabilitation will include localized patching and crack injection, repair to gabion baskets, placement of rip rap and sedimentation removal.

This foundation investigation and design report with the interpretations and recommendations is intended for the use of the Ministry of Transportation and Consor and shall not be used or relied upon for any other purposes or by any other parties including the construction contractors. The contractors must make their own interpretations based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

8. COFFERDAM AND DEWATERING

Construction of cofferdams will be required to carry out the culvert rehabilitation in the dry. The surface water, e.g. water from the creek or surrounding swampy areas, must be excluded from the construction area. It is likely that temporary creek diversion will be required to divert the creek flow during the rehabilitation works. In conjunction, sandbag cofferdams may be used to minimize water ingress into the excavations. In view of the presence of soft, compressible and more permeable peat and organics at or near the surface, the effectiveness of sand-bagging may be enhanced by sub-excavating some of these surficial deposits prior to placing the sand bags.



Pumping from filtered sumps may also be used to supplement the sand bags. Alternatively, cofferdams in the form of steel interlocking sheetpile enclosures will provide an effective groundwater cutoff, which will need to be designed by the Contractor. Accumulation of water from precipitation, surface runoff and seepage must be anticipated within the cofferdam. This may be removed by such means as pumping from sumps within the cofferdam enclosures.

The designer of the cofferdam enclosures should check whether the penetration depth is sufficiently deep to provide base fixity and to maintain overall stability. It is anticipated that the sheetpiles should be extended to sufficient depth in order to develop the required toe resistance. The system may be stiffened by corner and cross bracings where applicable.

Given the presence of the very soft to soft silty clay, it is important that the undrained (total stress) conditions of all design configurations be checked for stability in addition to the effective stress design.

The soil parameters provided below may be used for design of the temporary cofferdam system.

Soil Bulk Unit Weight	γ	=	20 kN/m ³ (silty clay fill)
		=	16 kN/m ³ (organics/peat)
		=	18 kN/m ³ (silty clay)
Submerged Unit Weight (below gwl)	γ'	=	10 kN/m ³ (silty clay fill)
		=	6 kN/m ³ (organics/peat)
		=	8 kN/m ³ (silty clay)
Coefficient of Active Pressure	K_a	=	0.36 (silty clay fill)
		=	0.4 (organics/peat)
		=	0.36 (silty clay)
Coefficient of Passive Pressure	K_p	=	2.8 (silty clay fill)
		=	2.5 (organics/peat)
		=	2.8 (silty clay)
Undrained Shear Strength	C_u	=	30 kPa (silty clay \geq Elev. 79 m)
		=	12 kPa (silty clay < Elev. 79 m)

It is recommended that the lateral earth pressures acting on the wall be computed in accordance with the CHBDC 2019. The surcharge should include soil loadings above the retained soil and other loadings adjacent to the cofferdam. Full hydrostatic pressure should be considered



assuming a water level at least equal to the design creek water level. The actual pressure distribution acting on the shoring system is a function of construction sequence and the relative flexibility of the wall and these factors must be considered when designing the system.

The short term groundwater level to be used for design of the cofferdam is creek level (~Elev. 83m).

The design of a dewatering system that will be required is the responsibility of the Contractor, and the Contract Documents must alert him to this responsibility.

Dewatering of all excavations including the use of a temporary flow passage system (creek diversion) shall be carried out in accordance with OPSS.PROV 517, SP 517F01 Amendment to OPSS 517, November 2016 (issued July 2017), OPSS.PROV 902 and NSSP FOUN0003. A design engineer with a minimum five years relevant experience will be required to design and implement a dewatering system. A pre-construction condition survey of existing structures is not required at this site.

Further assessment of the need for a PTTW should be carried out by specialists experienced in this field.

The depth of frost penetration at this site is approximately 1.4 m, as per OPSD 3090.101. It is noted that the peat, organics and the surficial fill are frost susceptible.

9. EROSION CONTROL

Erosion protection should be provided and/or reinstated at the culvert inlet and outlet areas. Design of the erosion protection measures must consider hydrologic and hydraulic factors and should be carried out by specialists experienced in this field. Typically, rock protection should be provided over all surfaces with which creek water is likely to be in contact. Treatment at the outlets should be in accordance with OPSD 810.010.

A vegetation cover should be re-established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS.PROV 804.

10. TEMPORARY EXCAVATIONS

If any excavations are required for rehabilitation at this site, they must be carried out in accordance with the Occupational Health and Safety Act (OHSA). The excavation and backfilling must be carried out in accordance with OPSS.PROV 902.



For the purposes of OHSA, the fill at this site may be classified as Type 3 materials, while the surficial alluvial deposits, peat and silty clay may be classified as Type 4 soils.

Temporary protection, where required, should be designed using the soil parameters provided in Section 8.

The selection of the method of excavation is the responsibility of the contractor and must be based on his equipment, experience and interpretation of the site conditions. Excavations should be inspected regularly for evidence of instability. Exposed soil slopes should be covered with plastic sheeting to protect against precipitation and surface runoff.

Based on currently available information, a water level at Elevation 83 m should be used for design.

As a further precaution, the construction works should not be undertaken during wet weather periods when the creek level is high.

11. CONSTRUCTION CONCERNS

Potential construction concerns include, but are not necessarily limited to, the following:

- A suitable dewatering/unwatering system must be employed to enable culvert rehabilitation/repair in the dry, and prevent sloughing and instability of the excavation walls. Temporary creek diversion is likely required.
- Seasonal fluctuations of the groundwater and creek level are to be expected. In particular, the water level may be at a higher elevation after the spring snowmelt or after periods of heavy rainfall, which may impact the construction.
- Soft, compressible and more permeable peat and organics are present near the surface at the site. The effectiveness of sand-bagging may be enhanced by sump pumping. Otherwise, interlocking sheetpile enclosures may be required to provide more effective groundwater cutoff.
- The Contractor's selection of construction equipment and methodology should include assessment of the capability of the existing embankment to support the proposed construction equipment and any temporary structures or fill (i.e., as a pad for crane support). Site conditions may limit the type of equipment suitable for use during construction. The design and safety of any temporary works is the responsibility of the Contractor.



12. CLOSURE

Engineering analysis and preparation of the design report were carried out by Ms. Judy Mei, EIT and Mr. Cory Zanatta, P.Eng. The report was reviewed by Dr. Sydney Pang, P.Eng. and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

THURBER ENGINEERING LTD.



Sydney Pang, P.Eng.
Associate, Senior Foundation Engineer



P.K. Chatterji, P.Eng.
Review Principal, Designated MTO Contact



Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT ⁽¹⁾ 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

- 1) Laboratory Triaxial Testing
- 2) Field Insitu Vane Testing
- 3) Laboratory Vane Testing
- 4) SPT value
- 5) Pocket Penetrometer

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE	SS Split Spoon Sample	WS Wash Sample	AS Auger (Grab) Sample
	TW Thin Wall Shelby Tube Sample	TP Thin Wall Piston Sample	
	PH Sampler Advanced by Hydraulic Pressure	PM Sampler Advanced by Manual Pressure	
	WH Sampler Advanced by Self Static Weight	RC Rock Core	SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$


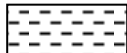



 Water Level
 Shear Strength Determination by Pocket Penetrometer

- (1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS W _L < 50%	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. (W _L < 30%).
		CI	Inorganic clays of medium plasticity, silty clays. (30% < W _L < 50%).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS W _L > 50%	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

EXPLANATION OF ROCK LOGGING TERMS

<u>ROCK WEATHERING CLASSIFICATION</u>		<u>SYMBOLS</u>	
Fresh (FR)	No visible signs of weathering.		
Fresh Jointed (FJ)	Weathering limited to the surface of major discontinuities.		CLAYSTONE
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.		SILTSTONE
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.		SANDSTONE
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.		COAL
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved.		Bedrock (general)

<u>DISCONTINUITY SPACING</u>		<u>STRENGTH CLASSIFICATION</u>			
Bedding	Bedding Plane Spacing	Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
			(MPa)	(psi)	
Very thickly bedded	Greater than 2m	Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Thickly bedded	0.6 to 2m				
Medium bedded	0.2 to 0.6m	Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Thinly bedded	60mm to 0.2m	Strong			
Very thinly bedded	20 to 60mm		50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Laminated	6 to 20mm	Medium Strong			
Thinly Laminated	Less than 6mm		25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
		Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
		Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
		Extremely Weak (Rock)			
			0.25 to 1.0	35 to 150	Indented by thumbnail
<u>TERMS</u>					
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.				
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.				
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a percentage of total core run length.				
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen				
Fracture Index: (FI)	Frequency of natural fractures per 0.3m of core run.				

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

ONTMT4S2(CPEN) MTO-25682.GPJ 2017TEMPLATE(MTO).GDT 5/20/21

RECORD OF BOREHOLE No COB 20-01

2 OF 2

METRIC

W.P. 2165-16-00 LOCATION Corbett Creek Culvert N 4 858 955.9 E 352 381.3 ORIGINATED BY AY
DIST Central HWY 401 BOREHOLE TYPE Tripod COMPILED BY BH
DATUM Geodetic DATE 2020.03.31 - 2020.03.31 LATITUDE 43.869042 LONGITUDE -78.908005 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W _p	W	W _L		
	Continued From Previous Page																
	Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2020.04.09 0.4 82.7 2020.04.14 0.3 82.8																

ONTMT4S2(CPEN) MTO-25682.GPJ 2017TEMPLATE(MTO).GDT 5/20/21

RECORD OF BOREHOLE No COB 20-02

1 OF 2

METRIC

W.P. 2165-16-00 LOCATION Corbett Creek Culvert N 4 858 841.7 E 352 437.8 ORIGINATED BY AY
DIST Central HWY 401 BOREHOLE TYPE Tripod COMPILED BY BH
DATUM Geodetic DATE 2020.04.03 - 2020.04.03 LATITUDE 43.868011 LONGITUDE -78.907311 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL ▲ C _{pen}	WATER CONTENT (%)						
82.7	GROUND SURFACE														
0.0	TOPSOIL and PEAT: (1200mm) Very Soft to Soft Black Wet		1	SS	1	▽									
			2	SS	3										
81.4															
1.2	Silty CLAY , trace sand Firm Grey Moist to Wet		3	SS	8									0 3 48 49	
			4	SS	5										
			5	SS	4									0 5 50 45	
			6	SS	4										
	Very Soft to Soft		7	SS	3										
			8	SS	1										
			9	SS	1										
	Some sand to sandy		10	SS	WH									0 24 46 30	
			11	SS	3										
			12	SS	1										
72.9															
9.8	END OF BOREHOLE AT 9.8m.														

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

ONTMT4S2(CPEN) MTO-25682.GPJ 2017TEMPLATE(MTO).GDT 5/20/21

RECORD OF BOREHOLE No COB 20-02 2 OF 2 METRIC

W.P. 2165-16-00 LOCATION Corbett Creek Culvert N 4 858 841.7 E 352 437.8 ORIGINATED BY AY
 DIST Central HWY 401 BOREHOLE TYPE Tripod COMPILED BY BH
 DATUM Geodetic DATE 2020.04.03 - 2020.04.03 LATITUDE 43.868011 LONGITUDE -78.907311 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W _p	W	W _L		
	Continued From Previous Page																
	WATER LEVEL AT 0.3m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO SURFACE.																

ONTMT4S2(CPEN) MTO-25682.GPJ 2017TEMPLATE(MTO).GDT 5/20/21



Ministry of
Transportation and
Communications

HIGHWAY ENGINEERING DIVISION-ENGINEERING MATERIALS OFFICE-SOIL MECHANICS SECTION

RECORD OF BOREHOLE No 1

W P 38-77-01 LOCATION Sta. 302 + 73, 0/S 112' Lt. # Hwy. 401 ORIGINATED BY T.J.K.
DIST 6 HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY T.J.K.
DATUM Geodetic DATE Dec. 17, 1979 CHECKED BY AS

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			20	40	60	80	100					
275.0	Ground Surface																
0.0	Silty Clay orge. and Trace Sand root structure		1	SS	7												
269.0	- Occ. Silt Inclusions Firm		2	SS	5												
6.0	Silty Clay weathered to Clay		3	SS	4												
	Medium Plasticity		4	TW	PH												
	- Occ. Banded Structure		5	TW	PM												
	- Random Mottling of Silt Inclusions		6	TW	PM												
	Very Soft to Soft		7	TW	PM												
			8	SS	3												
241.5																	
33.5	Silty Sand		9	SS	3												
	Trace of Clay and Gravel		10	SS	5												
	Very Loose																
228.0			11	SS	-												
47.0	End of Borehole																

+3, x5: Numbers refer to 20
Sensitivity 15 + 5 (%) STRAIN AT FAILURE
10

OFFICE REPORT ON SOIL EXPLORATION



RECORD OF BOREHOLE No 2

W P 38-77-01 LOCATION Sta. 302 + 79, 0/S 117' Rt. 6 Hwy. 401 ORIGINATED BY T.J.K.
DIST 6 HWY 401 BOREHOLE TYPE Hollow Stem Augers COMPILED BY T.J.K.
DATUM Geodetic DATE Dec. 18, 1979 CHECKED BY AS

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			20 40 60 80 100	100	Wp	W	WL		
273.5	Ground Surface											PCF	GR SA SI CL
0.0	Silty Clay Low Plasticity With Sand Some Organics and Root Struc. Firm		1	SS	5								
			2	SS	4								
269.0			3	SS	5								
4.5			4	TW	PH								
	Weathered ----- Silty Clay to Clay												
	Medium Plasticity -Banded Structure -Random Mottling With Irregular Silt Inclusions		5	TW	PH								
			6	TW	PH								
	Very Soft to Soft		7	SS	3								
			8	SS	4								
243.5													
30.0	Silty Sand Trace Gravel and Clay Very Loose		9	TW	PH								
			10	SS	3								
237.5													
36.0	End of Borehole												

3, x 5: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10

OFFICE REPORT ON SOIL EXPLORATION



RECORD OF BOREHOLE No 9 (Formerly W.P. 44-71-20)

W P 38-77-01 LOCATION Sta. 302 + 06, O/S 200' LT of Hwy. 401 ORIGINATED BY T.L.
DIST 6 HWY 401 BOREHOLE TYPE Hollow Stem Augers & Cone COMPILED BY R.S.
DATUM Geodetic DATE October 29, 1976 CHECKED BY RS

[illegible]

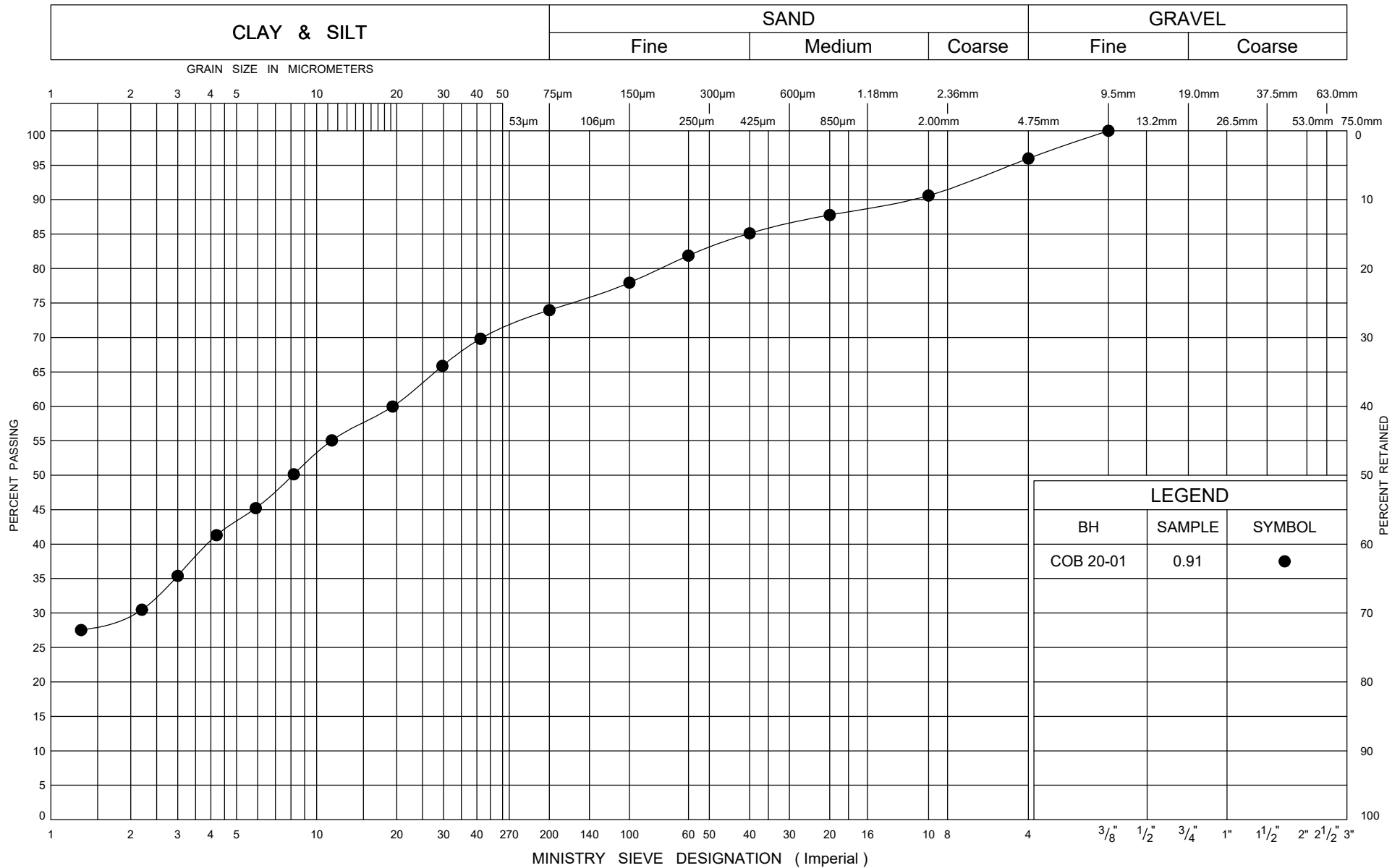
*3, x5: Numbers refer to Sensitivity

20
15 ϕ 5 (%) STRAIN AT FAILURE
10

OFFICE REPORT ON SOIL EXPLORATION

Appendix B

Laboratory Test Results



Ministry of
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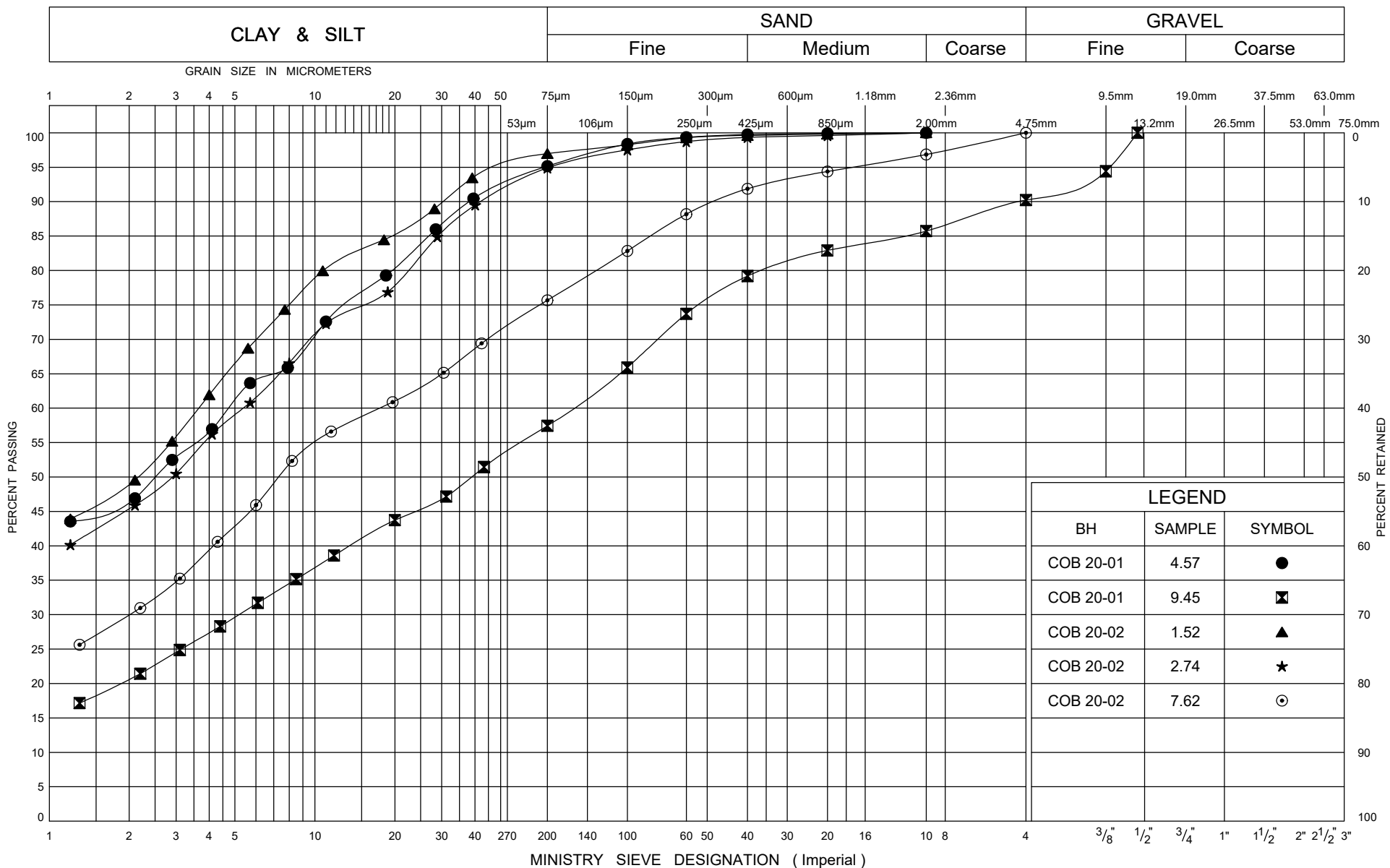
GRAIN SIZE DISTRIBUTION

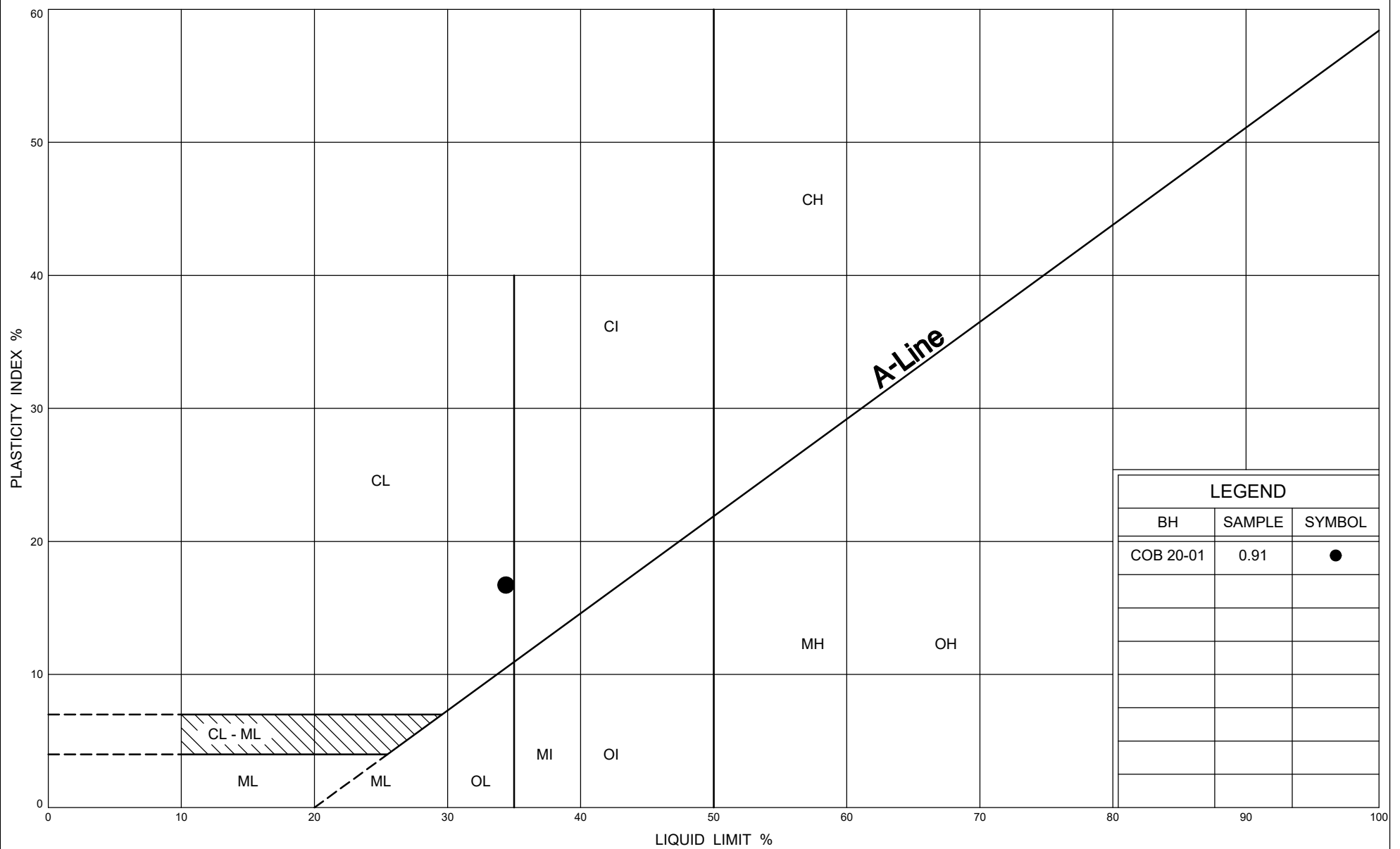
Silty CLAY FILL

FIG No B1

W P 2165-16-00

Corbett Creek Culvert





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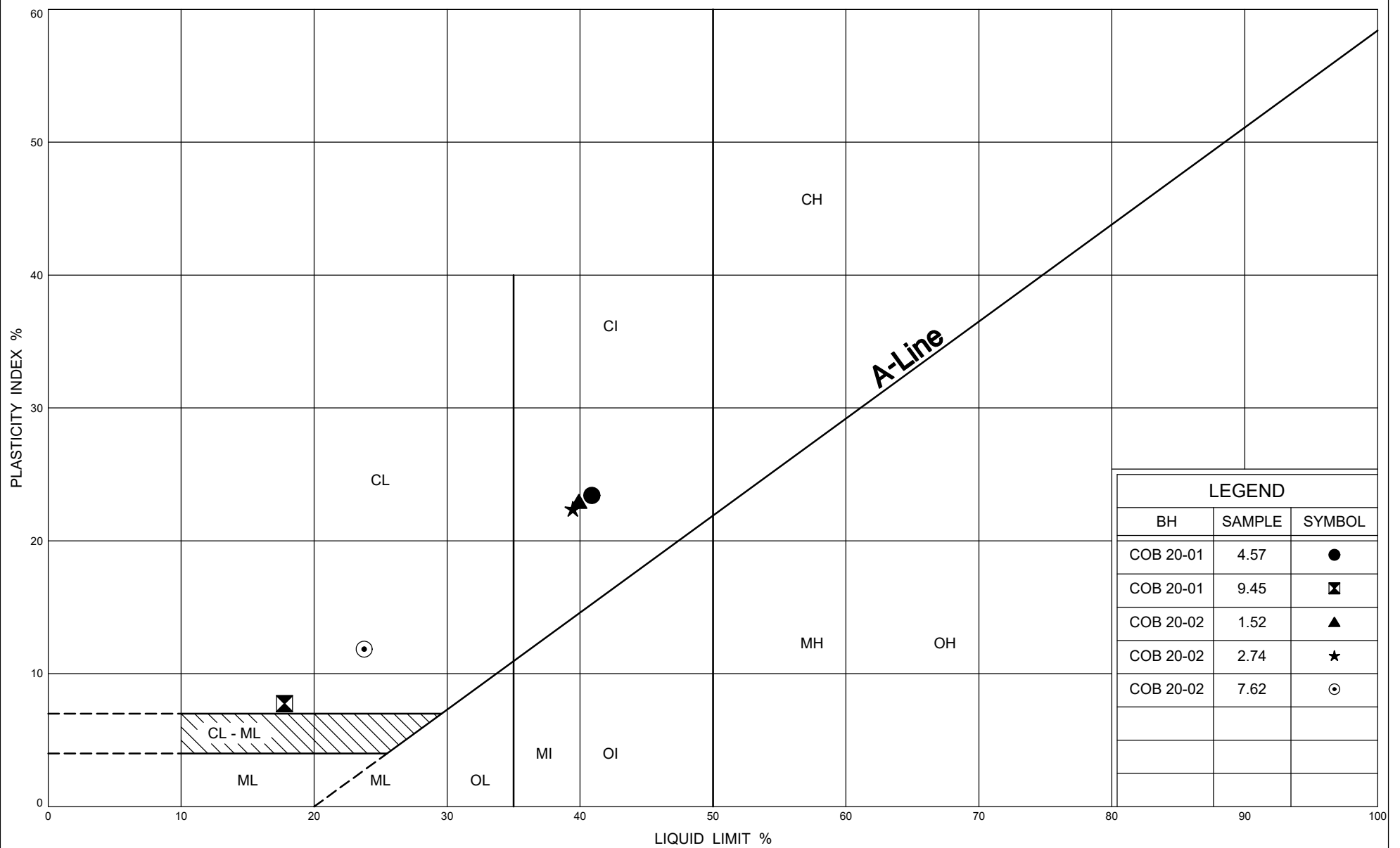
PLASTICITY CHART

Silty CLAY FILL

FIG No B3

W P 2165-16-00

Corbett Creek Culvert



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Transportation

PLASTICITY CHART

Silty CLAY

FIG No B4

W P 2165-16-00

Corbett Creek Culvert



Appendix C

Site Photographs



Figure 1: Looking northeast at COB20-01 and the existing culvert inlet (March 2020)



Figure 2: Looking southwest at COB20-02 and the existing culvert outlet (April 2020)



Figure 3: Culvert inlet to the north of Highway 401 (June 2019)



Figure 4: Culvert outlet to the south of Highway 401 (June 2019)



Figure 5: Upstream of West Corbett Creek (June 2019)

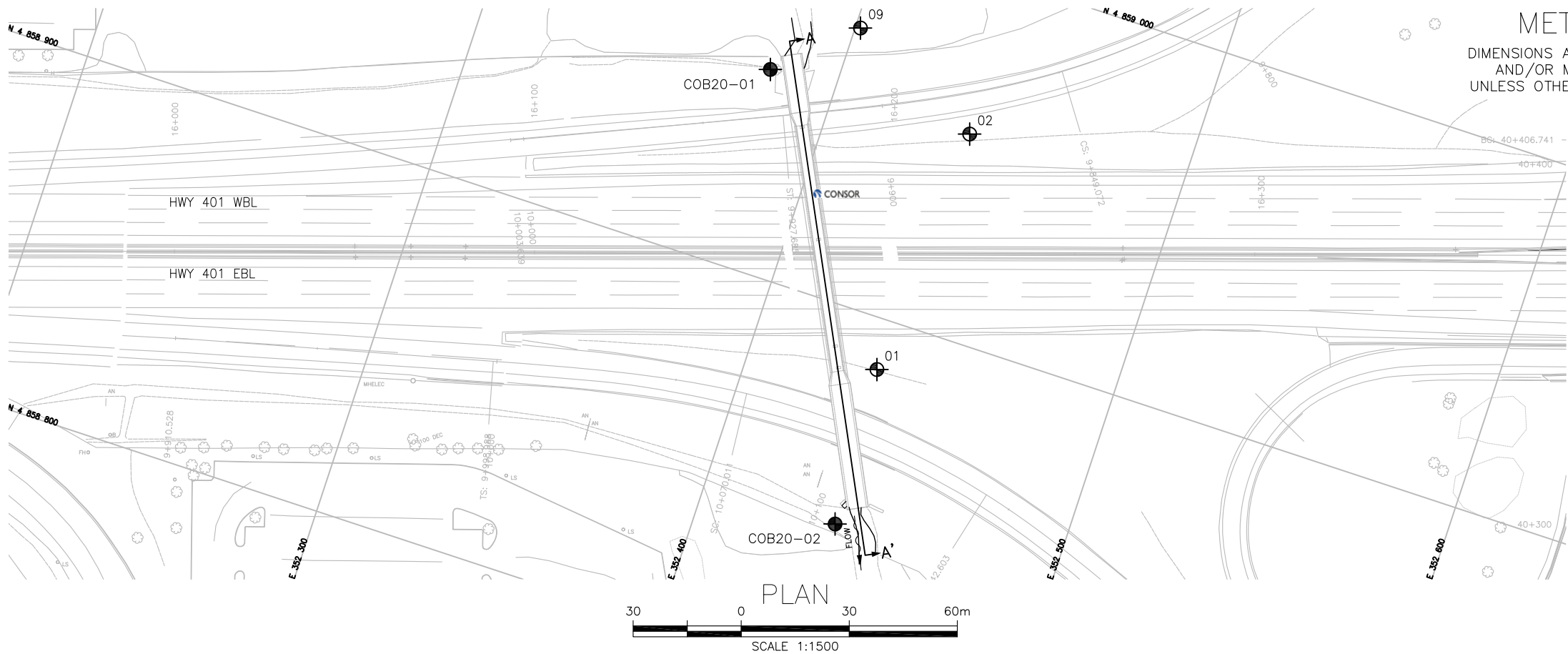


Figure 6: Downstream of West Corbett Creek (June 2019)



Appendix D

Borehole Locations and Soil Strata Drawing



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

CONT No
WP No 2165-16-00

HIGHWAY 401
WEST CORBETT CREEK
CULVERT REHABILITATION
BOREHOLE LOCATIONS AND SOIL STRATA

CONSOR

THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

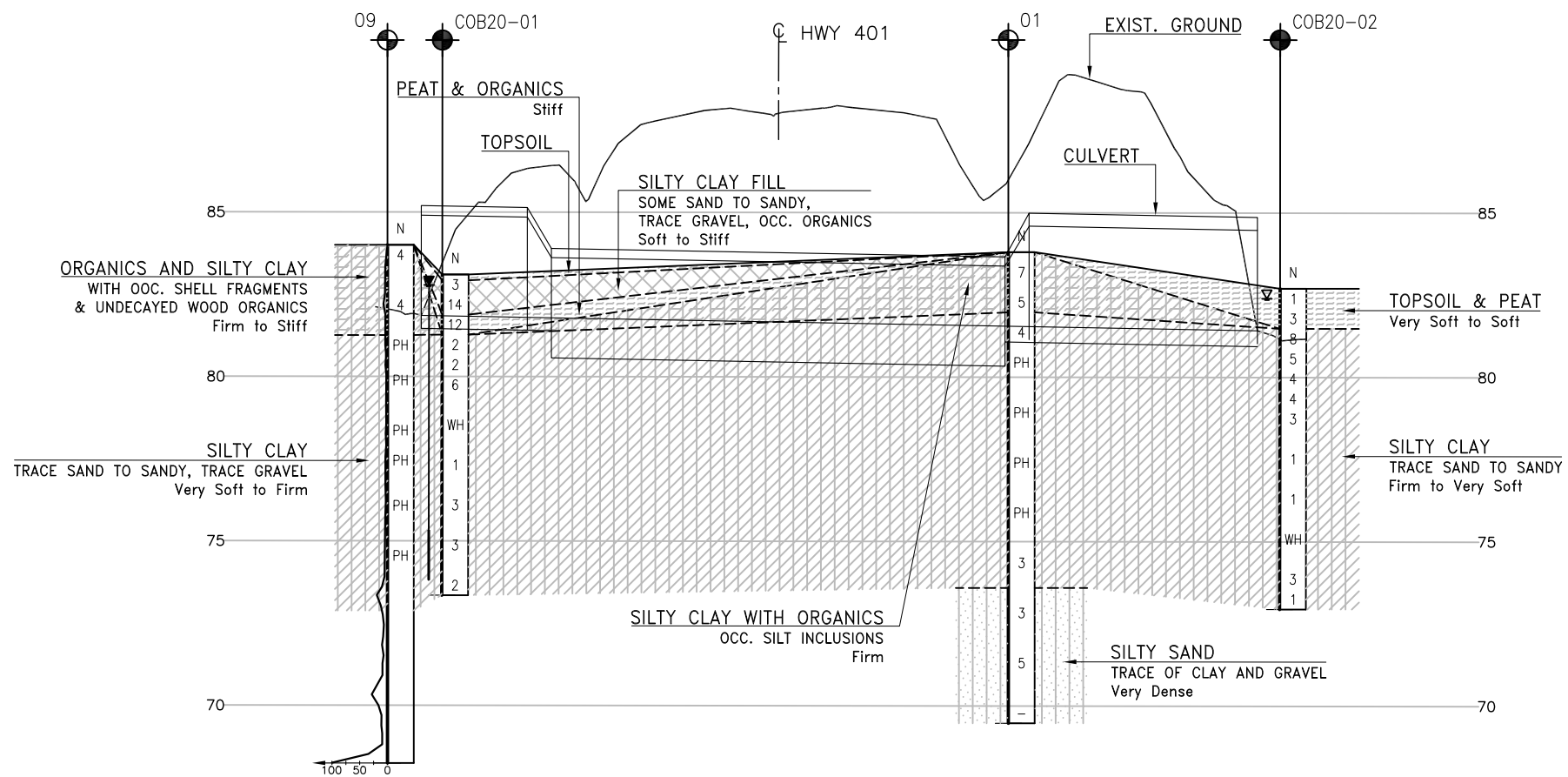
●	Borehole (Current Investigation)
⊕	Borehole (Previous Investigation By Others)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level
⊥	Water Level
⊥	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
01	83.8	4 858 886.1	352 435.4
02	83.4	4 858 956.2	352 439.4
09	84.0	4 858 974.7	352 401.4
COB20-01	83.1	4 858 955.9	352 381.3
COB20-02	82.7	4 858 841.7	352 437.8

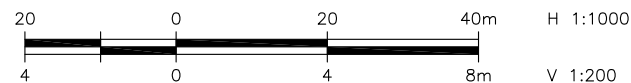
-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Coordinate system is MTM NAD 83 Zone 10.

GEOCRES No. 30M15-331



PROFILE ALONG A-A'



REVISIONS	DATE	BY	DESCRIPTION
DESIGN	JM	CHK NB	CODE
DRAWN	BH	CHK JM	SITE
			LOAD
			DATE
			MAY 2021
			STRUCT
			DWG 1



Appendix E

List of OPSS and Special Provisions



1. List of OPSS and OPSD Documents Relevant to this Project

- OPSS 511 (Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting)
- OPSS 517 (Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation)
- OPSS PROV 804 (Construction Specification for Seed and Cover)
- OPSS 902 (Construction Specification for Excavating and Backfilling – Structures)
- OPSD 3090.101 (Foundation Frost Penetration Depths for Southern Ontario)