



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
SILVER CREEK CULVERT
HIGHWAY 7
COUNTY OF LANARK, ONTARIO
W.P. 4014-13-01, SITE 15-165/C**

GEOCRES No.: 31C-267

Report

to

AECOM

Date: February 08, 2018
File: 19-4406-20



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PART 1: FACTUAL INFORMATION

1. INTRODUCTION

This report presents the factual findings obtained from a foundation investigation carried out by Thurber Engineering Ltd. (Thurber) for the proposed rehabilitation work of the existing Silver Creek Culvert (Site No. 15-165/C) located approximately 2 km west of the Village of Maberly, County of Lanark, Ontario. Thurber was retained by AECOM to carry out the foundation investigation at this site on behalf of the Ministry of Transportation Ontario (MTO).

The purpose of the investigation was to explore the subsurface conditions at the site and, based on the data obtained, provide borehole location plan and soil strata drawings with stratigraphic profile and cross-section(s), records of boreholes, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions was developed from the data obtained during the course of the investigation.

2. SITE AND PROJECT DESCRIPTION

The existing culvert carries Highway 7 over Silver Creek, approximately 2 km west of the junction of Highway 7 and Elphin Maberly Road, Maberly, ON. At the existing culvert, Highway 7 runs in an east-west direction; whereas the culvert is aligned in the north-south direction. The site is generally surrounded by areas with vegetation consisting of tall grass, shrubs and trees. The year of culvert construction is unknown and it is our understanding that the culvert has never been rehabilitated. The Silver Creek flows from north to south at the culvert site.

Based on the preliminary General Arrangement (GA) drawing provided by AECOM and dated April 2017, the existing structure is a one-span open footing concrete culvert which carries Highway 7 EBL and WBL traffic over Silver Creek. The span of the culvert is 6.1 m and the overall length is 21.3 m. The rise of the culvert is approximately 1.4 m. The highway embankment in the vicinity of the culvert is approximately 1.5 m high.

From published geological information in *The Physiography of Southern Ontario* by Chapman and Putnam (1984), the site lies within the physiographic region known as Algonquin Highlands. The



subsurface condition in this area is characterized by glacial tills and outwash sand and gravel of varying thicknesses overlying Precambrian granitic bedrock. Locally, this site lies within swampy terrain where Silver Creek flows under the highway. Site photographs are attached in Appendix D.

3. INVESTIGATION PROCEDURES

The field work for this geotechnical investigation was carried out on February 02, 2017 during which a total of four (4) boreholes denoted as Boreholes 17-01 to 17-04 were advanced to depths ranging from 2.0 m to 5.8 m (Elevations 176.50 to 172.68). Bedrock was proven in Boreholes 17-01 and 17-03 by coring 3.1 to 3.2 m into bedrock.

The approximate locations of the boreholes are shown in Table 3.1 below and on the Borehole Location Plan and Soil Strata drawing provided in Appendix C.

Table 3.1 – Borehole Details

Borehole Number	Approximate Borehole Location	Approximate Ground Elevation (m)	Borehole Termination Depth (m)	Borehole Termination Elevation (m)
17-01	5.5 m East of the C.L. of the Culvert on WBL	178.5	5.8	172.7
17-02	9.5 m West of the C.L. of the Culvert on WBL	178.5	2.0	176.5
17-03	5.5 m West of the C.L. of the Culvert on EBL	178.5	5.5	173.0
17-04	9.5 m East of the C.L. of the Culvert on EBL	178.5	3.8	174.7

The boreholes were drilled using a rubber track-mounted CME 75 drill rig. The boreholes were initially advanced using hollow stem augers and then switched to NQ coring with water to obtain rock core samples, where required. 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). Groundwater conditions in the open boreholes were noted upon completion of drilling. All boreholes were backfilled in general accordance with Ontario Regulation (O. Reg.) 903.

The field investigation was carried out under the full-time supervision of Thurber technical staff. All boreholes were logged in the field. Soil samples were identified, placed in labelled containers



and transported back to Thurber's laboratory in Oakville for further examination and testing. Bedrock core samples were also recovered during the investigation, logged and photographed in the field, packaged in core boxes with moist paper towel and parafilm wrap, and transported back to Thurber's laboratory for further examination and testing.

4. LABORATORY TESTING

Geotechnical laboratory testing was carried out at Thurber's laboratory. The recovered soil samples were subjected to visual identification and to natural moisture content determination. Selected samples were also subjected to grain size distribution analyses (sieve and/or hydrometer). Laboratory testing results are summarized on the Record of Borehole sheets included in Appendix A and are presented on the figure included in Appendix B.

All recovered cores of the bedrock were visually examined in the laboratory to confirm and supplement the field description. Selected core samples were also subjected to laboratory point load tests in the diametral directions to assess the unconfined compressive strength of the bedrock. The results are presented on the Record of Borehole sheets in Appendices A and on the tables included in Appendix B.

5. DESCRIPTION OF SUBSURFACE CONDITIONS

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix A and on the Borehole Location and Soil Strata drawing in Appendix C. A general description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following paragraph. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description and must be used for interpretation of the site conditions. It should be recognized and expected that soil conditions may vary between and beyond borehole locations.

In general, the subsurface conditions encountered in the boreholes on the highway platform consisted of asphalt pavement underlain by gravelly sand to sand fill. The fill layer is underlain by a slightly weathered, very strong, grey, granite bedrock. More detailed descriptions of the individual strata are provided in the following sections.

5.1 Asphalt



All boreholes were drilled through the existing pavement structure of Highway 7 and encountered a surface layer of asphalt having a thickness varying between 175 mm and 200 mm.

5.2 Gravelly Sand to Sand Fill

A fill layer was encountered below the asphalt in all boreholes. The fill consisted of sand to gravelly sand with trace cobbles, trace to some silt and trace clay. The upper part of the fill contains trace asphalt. Some organics were noted in the lower part of the fill in Boreholes 17-02 and 17-04. The total thicknesses of the fill layer varied between 1.8 m and 3.6 m. The base of the fill was at Elevation ranging from 174.7 m (at Borehole 17-04) to 176.5 m (at Borehole 17-02).

SPT 'N' values recorded in the fill layer ranged from 12 blows per 0.3 m of penetration to 100 blows per 0.15 m of penetration, indicating a compact to very dense condition. Lower SPT "N" value (SPT 'N' of 3 blows per 0.3 m of penetration) was measured within the sand fill layer in Borehole 17-03 between depths 1.5 m to 2.3 m below ground surface, indicating a very loose condition. Measured moisture contents within the fill ranged from 2% to 12%. Higher moisture content values (22% to 26%) were measured close to the base of the fill layer in Boreholes 17-02 and 17-04 due to the presence of some organics. Peat was encountered within the granular fill material in Borehole 17-04 at depths 2.3 m to 2.8 m below the ground surface, which resulted in a high measured moisture content of 109% between these depths.

The results of grain size distribution analyses carried out on samples of the fill are presented on the Record of Borehole sheets in Appendix A, and on Figure B1 Appendix B. The results are summarized as follows:

Soil Particle	Percentage (%)
Gravel	6 to 29
Sand	55 to 81
Silt & Clay	5 to 23

5.3 Bedrock

The fill layer described above is underlain by grey granite bedrock. The depths and elevations of the bedrock surface encountered at the boreholes are summarized in the table below. A schematic profile showing the bedrock levels is provided in Appendix C. Selected photographs of the recovered rock cores are presented in Appendix D.



Borehole No.	Bedrock Surface	
	Depth (m)	Elevation
17-01	2.7	175.8
17-02	2.0 (*)	176.5 (*)
17-03	2.3	176.2
17-04	3.8 (*)	174.7 (*)

Note: (*) inferred by auger refusal

Horizontal and sub-vertical fractures were noted throughout the bedrock cores. Total Core Recovery (TCR) in the bedrock ranged from 83% to 100% with Solid Core Recovery (SCR) ranging from 73% to 100%. The Rock Quality Designation (RQD) determined from the recovered cores ranged from 68% to 100%, indicating a fair to excellent rock quality.

From correlation with point load test results, the estimated unconfined compressive strength of intact granite rock cores generally ranged from about 139 to 180 MPa indicating a very strong rock. The results of these tests are summarized on the Record of Borehole sheets included in Appendix A and on the Point Load Test Sheets in Appendix B.

5.4 Groundwater Conditions

Water levels were observed in the open boreholes upon completion of drilling and prior to coring or backfilling. The open hole water levels are summarized in the table below.

Table 5.4 – Groundwater Levels

Borehole	Date	Water Level below G.S. (m)	
		Depth	Approximate Elevation
17-01	February 2, 2017	Dry	
17-02	February 2, 2017	Dry	
17-03	February 2, 2017	1.8	176.7
17-04	February 2, 2017	1.8	176.7

The groundwater levels observed in the open boreholes are short-term readings. The GA drawing provided by AECOM indicated that the creek level was at an average Elevation of 176.328 m on December 8, 2016. The groundwater level is expected to reflect the creek water level at this site. It should be noted that the groundwater levels are expected to fluctuate seasonally. Higher groundwater levels are expected during wet periods of the year such as spring or after periods of significant or prolonged precipitation.



6. MISCELLANEOUS

Thurber marked the borehole locations in the field and obtained utility locates prior to drilling.

Eastern Ontario Diamond Drilling Ltd. of Hawkesbury, Ontario supplied and operated the drilling, sampling and in-situ testing equipment for the field investigation. The field investigation was supervised on a full-time basis by Mr. Troy Mackinnon of Thurber.

Interpretation of the field data and preparation of this report was carried out by Mr. Mohamed Hosney, P.Eng.. The report was reviewed by Mr. Jason Lee, P.Eng. and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundation Projects.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7. GENERAL

This section of the report provides an interpretation of the geotechnical data in the factual report, and presents geotechnical recommendations for the proposed rehabilitation work for Silver Creek Culvert located on Highway 7, approximately 2 km west of the junction of Highway 7 and Elphin Maberly Road, Maberly, ON.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation, and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. The contractors must make their own interpretation 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.

Information on the existing culvert was obtained from the preliminary General Arrangement (GA) drawing dated April 2017 provided by AECOM. According to the GA drawing, the existing culvert is a one-span open footing rigid frame concrete culvert with a length of 21.3 m, a span width of 6.1 m and a clearance height of 1.4 m above the top of footing. The highway embankment in the vicinity of the culvert is approximately 1.5 m high.

According to the inspection report titled "*Culvert Condition Survey Report, Site No. 15-165/C, Silver Creek Culvert, County of Lanark, ON*" prepared by the Bridge Check Canada Ltd. and dated April 22, 2016, it is understood that the structure is in an overall fair to good condition exhibiting some cracks, spalls, delaminations, and rust stains. In addition, the draft underwater inspection report prepared by WSP dated March 2017 indicated the following notable observations:



- The structure was originally built with some deformities associated with formwork settlement during construction with possible settlement as well. The deformities have a minimal impact on the performance of the structure.
- The stream bed consists of gravel, sand and boulders covered with a thin layer of soft sediments and organic material (twigs). Scouring of the streambed was not observed.
- Undermining of the footings was not observed. Maximum height of the exposed footing was 450 mm and probing into streambed showed at least 50 mm of soft sediments and the probe stick did not detect the bottom of footing.

Based on the GA drawing, the proposed rehabilitation work will include the removal of the delaminated and deteriorated concrete from the existing roof slab of the culvert followed by installation of a 0.65-m-thick new concrete slab above the existing roof slab. The proposed finished road grade at the culvert centerline will be at Elev. 178.5. In addition, a 6 m long new approach slab is proposed to be installed on each side of the culvert. The top surface of the new roof slab and approach slabs will be covered by a 90-mm-thick asphalt and waterproofing system. As a result of the above, it is of our understanding that there will be an increase of load on the foundation by about 10%. An evaluation of the geotechnical capability of the existing foundations to support the increase in load is discussed below. Geotechnical design and construction recommendations are also provided.

The discussions and recommendations presented in this report are based on information provided by AECOM and on the factual data obtained during the course of the field investigation.

8. GEOTECHNICAL ASSESSMENT AND CULVERT FOUNDATION

The subsurface stratigraphy encountered at the site consists of gravelly sand fill overlying bedrock. Bedrock and probable bedrock were encountered at depths of 2.0 to 2.3 m (Elev. 176.5 to 176.2) along the west side of the culvert and 2.7 to 3.8 m (Elev. 175.7 to 174.7) along the east side. The groundwater level at the site is expected to be at an approximate elevation 176.7 m and would vary with the change in the water level in the creek.

There is no historic drawing nor other information available for the footing dimensions and founding stratum. According to the dimensions provided in the GA drawing, it is estimated that the river bed varies between Elev. 175 m and 176 m and it may be assumed that the culvert is found at least 2.5 m below the road grade. Using the proposed finished road grade at Elev. 178.5 m, the founding level of the culvert should be below Elev. 176 m. Based on the borehole information, the anticipated foundation conditions of the existing culvert footings are as follows:



Table 8.1 – Anticipated Conditions at Founding Level

Location		Borehole	Founding Level	Anticipated Foundation Subgrade
West Side	WBL	17-02	176.5 or below	Bedrock
	EBL	17-03	176.2 or below	Bedrock
East Side	WBL	17-01	~176.0	Gravelly Sand Fill
			175.8 or below	Bedrock
	EBL	17-04	~176.0	Gravelly Sand Fill (with peat/organics)
			174.7 or below	Bedrock

The following geotechnical resistances are recommended for design of spread footings founded on the bedrock or compact to very dense granular fill at or below the above founding levels:

Geotechnical Resistance ^(b)	Foundation Subgrade	
	Gravelly Sand Fill	Bedrock
Factored Geotechnical Resistance at ULS (kPa)	300	3,000
Geotechnical Resistance at SLS not exceeding 25mm of settlement (kPa)	200	N/A ^(a)

Note ^(a): The geotechnical resistance at the Service Limit State (SLS) does not govern in this case

^(b): Assumed footing width of 1.1 m as per GA drawing

The pressures applied on the foundation soil/bedrock due to existing culvert load and the load increase due to the rehabilitation of culvert must not exceed the geotechnical resistances given above. For structural design/analysis of the culvert, the geotechnical resistance values for gravelly sand fill should govern.

The geotechnical resistance values are for vertical, concentric loads. Effect of the eccentric and/or inclined loading on the geotechnical resistance must be estimated as illustrated in the CHBDC 2014 Clauses 6.10.3 and 6.10.4.

The lateral resistance of the footings may be computed using an unfactored friction coefficient of 0.55 on the gravelly sand fill. For footings on bedrock, an unfactored friction coefficient of 0.7 is recommended. These values require a degree of sliding movement to occur to fully mobilize the resistance.



Foundation settlement in response to the load increase is estimated to be less than 10 mm and will be essentially complete at the end of construction. It is anticipated that post-construction foundation settlement is negligible.

9. SCOUR AND EROSION PROTECTION

Despite the 2017 underwater inspection report indicated that undermining of the footings was not observed, evaluation of the existing scheme of protection against future erosion and scour must be carried out for the culvert foundations as well as the culvert inlet and outlet. According to the Pavement Design and Rehabilitation Manual (2nd Edition), the erodibility of the cohesionless embankment fill soil at the silver creek culvert was estimated to be low. However, scour and erosion protection system must be provided at the inlet and outlet. The evaluation and design of the erosion protection measures must consider the hydrologic and hydraulic conditions and should be carried out by specialists experienced in this field.

A vegetation cover should be established on all other exposed embankment slope and earth surfaces to protect against surficial erosion, in general accordance with OPSS 804.

10. TEMPORARY EXCAVATION AND DEWATERING SYSTEM

Temporary excavations will be required during construction at this site to install the new slabs. All temporary excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA).

Excavation will take place through the existing granular fill. For the purpose of OHSA, the existing granular fill may be classified as Type 3 soils above water level and Type 4 below water level.

All excavations must be carried out in a manner that avoids undermining or destabilising the foundations of the existing culvert and any other adjacent structures and utilities, if any.

Excavation and backfilling for foundation construction should be carried out in accordance with the requirements in OPSS 902.

According to the GA drawing, the excavations for the installation of the new roof slab and approach slabs adjacent to the culvert are proposed to be carried out above the creek level. Excavation below creek level will require prior dewatering which should be done in accordance with OPSS 517. Suggested wording for an NSSP on dewatering is included in Appendix E.

Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor. The Contract Documents should advise the Contractor of the high creek/groundwater levels, cohesionless soils and cobbles at this site that may impact



construction. Suggested wording for an NSSP on potential obstructions during the excavation is included in Appendix E.

11. BACKFILL AND LATERAL EARTH PRESSURE

Backfill to the culvert should consist of free-draining, non-frost susceptible granular materials such as Granular A or Granular B Type II conforming to OPSS.PROV 1010. Backfill should be placed and compacted in accordance with OPSS.PROV 501 and OPSS 902. The backfill should be placed and compacted in simultaneous lifts on both sides of the culvert, and the top of backfill elevation should not differ more than 500 mm on both sides of the culvert at all times. Heavy compaction equipment should not be used adjacent to the walls and on the roof of the culvert. Compaction equipment to be used adjacent to the culvert should be restricted in accordance with OPSS.PROV 501.

The lateral earth pressures acting on the retaining structures may be assumed to be triangularly distributed and governed by the characteristics of the backfill and/or existing fill. For a fully drained condition, the pressures should be computed in accordance with the CHBDC (2014) but generally are given by the following equation:

$$p_h = K (\gamma h + q)$$

Where:

p_h	=	horizontal pressure on the wall at depth h (kPa)
K	=	coefficient of lateral earth pressure (see table below)
γ	=	unit weight of retained soil (see table below)
h	=	depth below top of fill where pressure is computed (m)
q	=	value of any surcharge (kPa)

Earth pressure coefficients for backfill to the culvert walls are dependent on the material used as backfill. Recommended values are shown in the table below.

For rigid structures such as rigid frame concrete culverts, at-rest horizontal earth pressures should be used for design. Active pressures should be used for any unrestrained wall. The use of a material with a high friction angle and low active pressure coefficient (e.g., Granular A, Granular B Type II) is preferred as it results in lower earth pressures acting on the culvert.



Loading Condition	OPSS Granular A or Granular B Type II $\phi = 35^\circ$; $\gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I (modified) $\phi = 32^\circ$; $\gamma = 21.2 \text{ kN/m}^3$		Existing Fill $\phi = 30^\circ$; $\gamma = 20 \text{ kN/m}^3$	
	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	Sloping Backfill (2H:1V)
Active (K_A) (Unrestrained Wall)	0.27	0.40	0.31	0.48	0.33	0.54
At-rest (K_O) (Restrained Wall)	0.43	0.62	0.47	0.70	0.50	0.76
Passive (K_P)	3.7	-	3.3	-	3.0	-

In accordance with Clause 6.12.3 of the CHBDC 2014, a compaction surcharge should be added. The magnitude of the surcharge should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 1.7 m for Granular B Type I, or at a depth of 2.0 m for Granular A or B Type II.

12. TEMPORARY PROTECTION SYSTEMS

According to the GA drawing provided by AECOM and dated April 2017, it is understood that staging for the proposed structural rehabilitation work requires maintaining traffic on a single lane on Highway 7. It is also understood that excavations for the proposed rehabilitation work will be limited to shallow depth (<1m) below the road surface.

Installation of soldier pile and lagging or interlocking sheet piles is not practical at this site due to presence of shallow bedrock. Provided that the single lane traffic during construction can be diverted to the outer most shoulder lane, a temporary roadway protection system consisting of an adequate temporary side slope and jersey barrier walls is a possible option. The temporary roadway protection system should be implemented in accordance with OPSS PROV 539 and designed for Performance Level 2. The soil parameters in the table below may be used for design of the temporary roadway protection system with horizontal backfill.

Soil Parameter	Existing Fill
γ (total unit weight)	20 kN/m ³
γ' (effective unit weight)	10 kN/m ³
K_a	0.33
K_p	3.0



Full hydrostatic pressure should be considered assuming a water level at least equal to the creek water level.

The design of temporary protection system is the responsibility of the Contractor. The actual lateral pressure distribution acting on the protection system is a function of the construction sequence and traffic loading, and these factors should be taken into consideration when designing the protection system. All protection systems should be designed by a Professional Engineer experienced in such designs, who will determine an appropriate support system.

13. SEISMIC CONSIDERATIONS

In accordance with the CHBDC, the selection of the seismic site class is based on the soil conditions encountered in the upper 30 m of the ground profile. The stratigraphy at this site generally consists of a compact to very dense granular fill overlying granite bedrock. The depth to bedrock varies from 2.0 to 3.8 m below existing grade. As per Table 4.1, Clause 4.4.3.2 of the CHBDC, the site may be classified as Seismic Site Class C (very dense soil and soft rock).

Based on the National Building Code of Canada (NBCC 2015), the peak horizontal ground acceleration (PGA), corresponding to a design earthquake having a 2 percent probability of being exceeded in 50 years (i.e. 2,475 year return period) is 0.118 g at the site.

The compact to very dense granular fill at this site are not considered susceptible to liquefaction under seismic loading.

In accordance with Clause 4.6.5 of the CHBDC, retaining structures should be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading.

For the design of retaining walls under seismic loading, the coefficients of horizontal earth pressure in Table 13.1 may be used:

Table 13.1 – Earth Pressure Coefficient for Earthquake Loading

Loading Condition	Granular A or Granular B Type II $\phi = 35^\circ$; $\gamma = 22.8 \text{ kN/m}^3$	OPSS Granular B Type I or Type III $\phi = 32^\circ$; $\gamma = 21.2 \text{ kN/m}^3$
Active (K_{AE})*	0.30	0.34
At Rest (K_{OE})**	0.54	0.59
Passive (K_{PE})	3.6	3.1

* After Mononobe and Okabe, passive case assumes a horizontal surface in front of the wall.

** After Woods (1973).



Given the compact to very dense granular fill material in the site, liquefaction is not considered to be a concern at this site.

14. FROST PROTECTION

The depth of frost penetration at this site is approximately 1.8 m as per OPSD 3090.1010.

15. CONSTRUCTION CONCERNS

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

- The water level in the creek may fluctuate and be at higher elevation at the time of construction than indicated in the report;
- Buried obstructions may be encountered during excavation in the existing fill and may interfere with installation of the temporary roadway protection system;
- The Contractor's selection of construction equipment and methodology should include assessment of the capability of the existing culvert to support the proposed construction equipment and any temporary structure or fill. The design and safety of any temporary works is the responsibility of the Contractor.



16. CLOSURE

Engineering analysis and preparation of this report was carried out by Mr. Mohamed Hosney, P.Eng. The report was reviewed by Mr. Jason Lee, P.Eng. and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.



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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.

EXPLANATION OF ROCK LOGGING TERMS


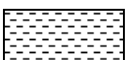

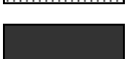

ROCK WEATHERING CLASSIFICATION

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

DISCONTINUITY SPACING

Bedding	Bedding Plane Spacing
Very thickly bedded	Greater than 2m
Thickly bedded	0.6 to 2m
Medium bedded	0.2 to 0.6m
Thinly bedded	60mm to 0.2m
Very thinly bedded	20 to 60mm
Laminated	6 to 20mm
Thinly Laminated	Less than 6mm

SYMBOLS

	CLAYSTONE
	SILTSTONE
	SANDSTONE
	COAL
	BEDROCK

STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength (MPa)	Approximate Uniaxial Compressive Strength (psi)	Field Estimation of Hardness*
Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Medium Strong	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

TERMS

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 % 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.

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			

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No BH17-03

1 OF 1

METRIC

W.P. 4014-13-01 LOCATION Silver Creek Culvert N 4 966 018.4 E 300 320.3 ORIGINATED BY TM
 HWY 7 BOREHOLE TYPE Hollow Stem Augers/NQ Coring COMPILED BY AN
 DATUM Geodetic DATE 2017.02.02 - 2017.02.02 CHECKED BY MH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				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					
178.5	GROUND SURFACE												
0.0	ASPHALT:(200mm)												
0.2	Gravelly SAND, trace silt, trace clay, trace cobbles Compact Brown Moist (FILL)		1	GS									
			1	SS	17								14 81 5 (SI+CL)
177.0													
1.5	SAND, some silt, trace gravel, trace clay Very Loose Brown Wet (FILL)		2	SS	3								6 71 18 5
176.2													
2.3	GRANITE slightly weathered, very strong, grey												
	Rubble zone at 3.3m and 3.7m		1	RUN									RUN #1 TCR=100% SCR=100% RQD=100% UCS=175MPa (Average)

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No BH17-04

1 OF 1

METRIC

W.P. 4014-13-01 LOCATION Silver Creek Culvert N 4 966 028.3 E 300 335.7 ORIGINATED BY TM
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2017.02.02 - 2017.02.02 CHECKED BY MH

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
178.5	GROUND SURFACE																
0.0	ASPHALT: (200mm)		1	SS	100/												
0.2	Gravelly SAND, some silt, trace cobbles, trace asphalt Compact to Very Dense Brown Moist (FILL)		2	SS	14												
			3	SS	100/												
					0.125												
	Peat		4	SS	12												
	Some organics		5	SS	19												
174.7																	
3.8	END OF BOREHOLE AT 3.8m UPON AUGER REFUSAL ON POSSIBLE BEDROCK. BOREHOLE OPEN AND WATER LEVEL AT 1.8m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS, THEN ASPHALT COLD PATCH TO THE SURFACE.																



Appendix B

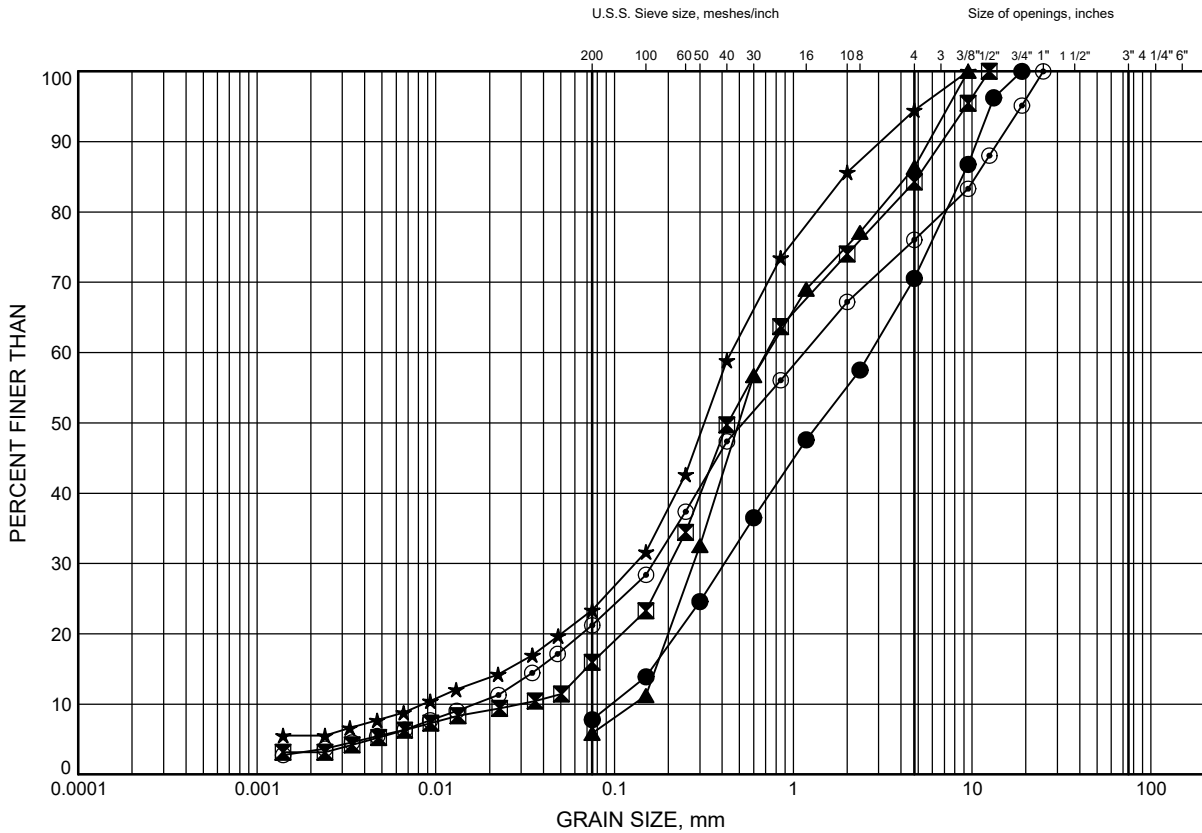
Laboratory Test Results

Silver Creek Culvert

GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND to Gravelly SAND FILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	BH17-01	0.3	178.2
⊠	BH17-02	1.7	176.8
▲	BH17-03	1.1	177.4
★	BH17-03	1.8	176.7
⊙	BH17-04	3.4	175.1

Date July 2017
W.P. 4014-13-01



Prep'd AN
Chkd. MH



THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No: 19-4406-20
Client: AECOM
Project Name: Silver Creek Culvert
Core Size: NQ BH No : 17-01

Date Drilled: 02-Feb-17
Date Tested: 03-Mar-17
Tester: AQ
Reviewed by: MH

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_{s(50)}$ (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	2.7	D	17.2	47.0	558.0	7.2	172.1	Granite	Very Strong
2	1	4.0	D	14.0	47.0	325.0	5.8	140.0	Granite	Very Strong
3	2	5.3	D	13.9	47.0	495.0	5.8	139.0	Granite	Very Strong
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* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have $0.7 \times D$ on either side of test point.

* Correlation factor to obtain UCS values is 24.

Last Modified: September 14, 2016



THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET

ASTM D5731-08

Job No: 19-4406-20
Client: AECOM
Project Name: Silver Creek Culvert
Core Size: NQ BH No : 17-03

Date Drilled: 02-Feb-17
Date Tested: 03-Mar-17
Tester: AQ
Reviewed by: MH

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	$I_{s(50)}$ (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	2.4	D	16.0	47.0	110.0	6.7	160.3	Granite	Very Strong
2	1	3.1	D	19.0	47.0	320.0	7.9	190.5	Granite	Very Strong
3	2	4.0	D	19.7	47.0	68.0	8.2	197.3	Granite	Very Strong
4	2	4.4	D	16.1	47.0	104.0	6.7	161.7	Granite	Very Strong
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* It is ideal to perform axial test on core specimens with D/L ratio of 1.1 ± 0.1

Long pieces of core can be tested diametrically to produce suitable lengths for axial testing

* Diametral Test should have $0.7 \times D$ on either side of test point.

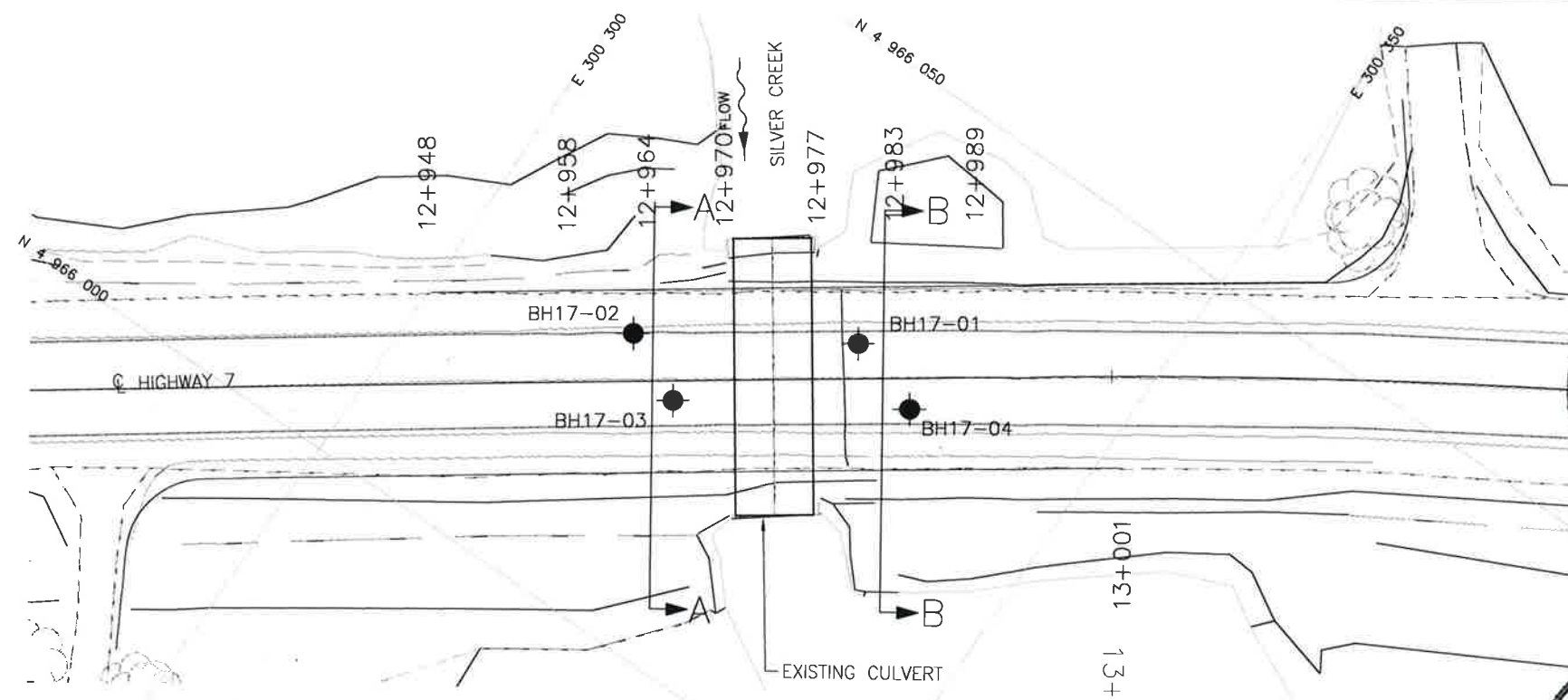
* Correlation factor to obtain UCS values is 24.

Last Modified: September 14, 2016



Appendix C

Borehole Location Plan and Stratigraphic Profiles



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

CONT No
WP No 4014-13-01

HIGHWAY 17
SILVER CREEK CULVERT
REHABILITATION
BOREHOLE LOCATIONS AND SOIL STRATA






URS

THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

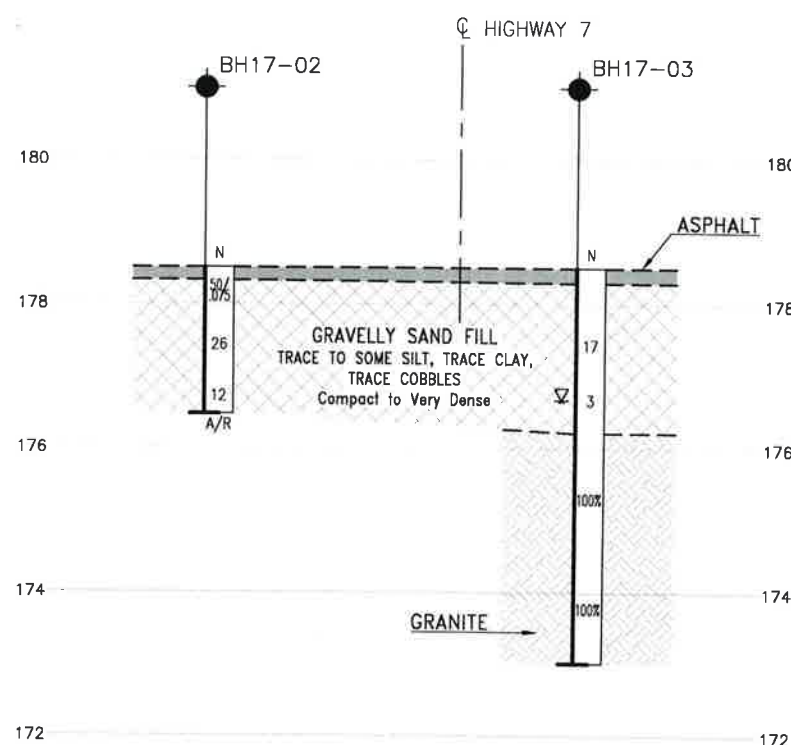
	Borehole
	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
BH17-01	178.5	4 966 030.2	300 329.7
BH17-02	178.5	4 966 020.9	300 314.8
BH17-03	178.5	4 966 018.4	300 320.3
BH17-04	178.5	4 966 028.3	300 335.7

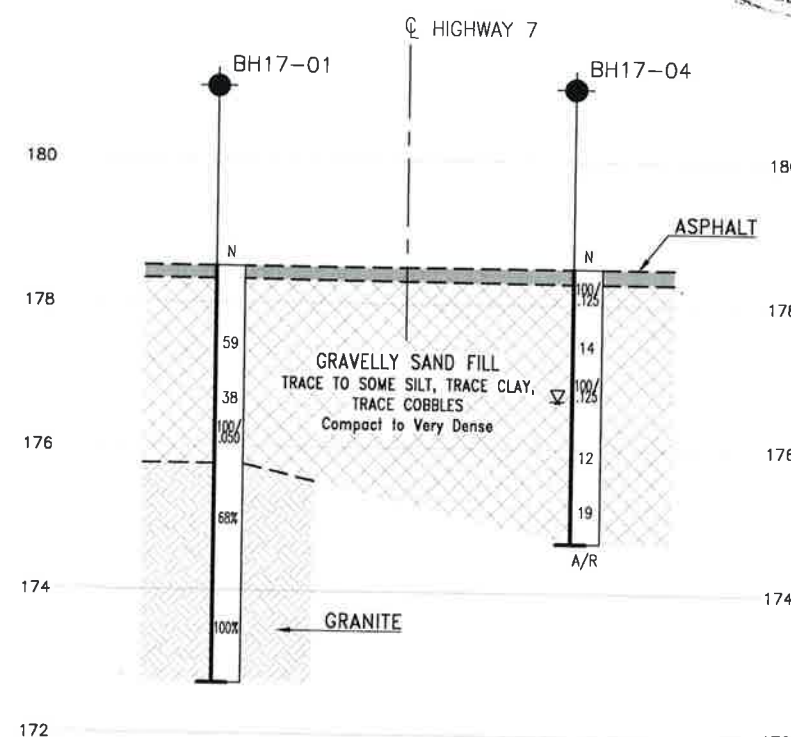
-NOTES-

- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No. 31C-267



SECTION A-A



SECTION B-B

[illegible]



Appendix D

Site and Bedrock Photographs

Silver Creek Culvert Rehabilitation
SITE 15-165/C, Highway 7
Site Photographs



Photograph 1 – Looking east towards the north end of the culvert



Photograph 2 – Looking west towards the north end of the culvert

Silver Creek Culvert Rehabilitation
SITE 15-165/C, Highway 7
Site Photographs



Photograph 3 – Looking west towards the south end of the culvert

**Silver Creek Culvert
Rehabilitation of The Existing Culvert
Photographs of Rock Core**

Borehole 16-10, Run 1



Borehole 16-3, Runs 1 and 2





Appendix E

Suggested Wording for NSSP



1. Suggested Wording for NSSP on “Dewatering”

Dewatering will be required where excavations extend beneath the water-table. Dewatering system shall be sufficient to maintain stable and dry excavations for the duration of construction. The Contractor is notified that failure to implement dewatering in advance of excavating below the groundwater table may result in sloughing and boiling of the soil in the excavation and a loss in stability and bearing resistance. Design and provision of an effective dewatering system is the responsibility of the Contractor. The dewatering system must remain operational and effective until the culvert rehabilitation is completed and any excavation below the ground water table is backfilled.

2. Suggested Wording for NSSP on “Obstructions”

The excavation below the existing grade level may encounter obstructions such as cobbles and boulders embedded in the cohesionless soils. Such obstructions may impact the construction progress. The Contractor shall be prepared to remove and/or drill through these obstructions to achieve the required depth of excavation.