WWW.THURBER.CA

THURBER ENGINEERING LTD.

Foundation Investigation and Design Report

Highway 17 Culvert Replacement (Culvert No.NW-867-0017-0026)
Township of Lecours
District of Thunder Bay, Ontario
Agreement No. 6022-E-0022, Work Order No. 5
G.W.P. 6058-13-00

Latitude: 48.691811°, Longitude: -86.004067°

GEOCRES No. 42D09-001

Client Name: Gannett Fleming Canada ULC
Date: September 19, 2024
File: 51583

Suite 11, 1815 Ironstone Manor, Pickering, Ontario L1W 3W9 | Phone: (905) 829-8666

TABLE OF CONTENTS

PART A: FACTUAL INFORMATION

1. INTRODUCTION 1
2. SITE DESCRIPTION 1
3. INVESTIGATION PROCEDURE 2
4. GEOTECHNICAL LABORATORY TESTING 4
5. SUBSURFACE CONDITIONS 4
   - 5.1 Site Geology 4
   - 5.2 General Description of Subsurface Conditions 4
   - 5.3 Asphalt 5
   - 5.4 Gravelly Silty Sand Fill 5
   - 5.5 Rock Fill 5
     - 5.5.1 Coarse Gravel, Cobbles and Boulders 5
     - 5.5.2 Gravel to Gravel and Sand Fill 6
     - 5.5.3 Sandy Silty Clay Fill 7
   - 5.6 Groundwater Conditions 8
   - 5.7 Analytical Laboratory Testing 9
6. MISCELLANEOUS 10

PART A: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7. GENERAL 11
8. METHOD OF INSTALLATION 11
9. APPLICABLE CODES AND DESIGN CONSIDERATIONS 13
10. REPLACEMENT CULVERT 13
11. TEMPORARY MODULAR BRIDGE 14
12. OPEN CUT EXCAVATION 14
13. TEMPORARY EMBANKMENT WIDENING 14
14. EMBANKMENT REINSTATEMENT 15
15. CORROSION POTENTIAL 15
16. CONSTRUCTION CONCERNS 16
   - 16.1 Placement of Material Stockpiles and Construction Equipment 16
   - 16.2 Excavation of Rock Fill 16
17. RECOMMENDATIONS FOR FUTURE WORKS 16

18. CLOSURE 17

STATEMENT OF LIMITATIONS AND CONDITIONS

APPENDICES

APPENDIX A

Site Photographs

APPENDIX B

Borehole Location Plan and Soil Strata Drawing

Record of Borehole Sheets

APPENDIX C

Geotechnical and Analytical Laboratory Test Results

Rock Fill Core Photographs

PART A – FACTUAL INFORMATION

1. INTRODUCTION

This report presents the factual data obtained from a foundation investigation carried out by Thurber Engineering Ltd. (Thurber) at Culvert No. NW-867-0017-0026 located at STA 21+478 on Highway 17 in the Township of Lecours, District of Thunder Bay, Ontario.

The purpose of this preliminary investigation was to explore the subsurface conditions at the culvert site and, based on the data obtained, to provide a borehole location plan, stratigraphic profile, records of boreholes, laboratory test results, and a written description of the subsurface conditions.

Thurber carried out the investigation as a subconsultant to Gannett Fleming Canada ULC (Gannett Fleming), under the Ministry of Transportation, Ontario (MTO) Retainer Agreement No. 6022-E-0022 for Work Order No. 5.

It is a condition of this report that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions.

2. SITE DESCRIPTION

The existing culvert is located on Highway 17, approximately 11.3 km west of the junction with Highway 614 in the Township of Lecours, Ontario. For project orientation purposes, Highway 17 is herein described as oriented east-west and the culvert is described as oriented north-south. Details of the existing culvert are as follows:

Station	Culvert Size and Type	Length of Culvert (m)	Invert Elevation at Inlet (m)	Invert Elevation at Outlet (m)
21+478	1860 mm concrete box with an 1800 mm CSP extension on the downstream end	62.5 m long	286.60 (north)	283.81 (south)

The existing culvert allows flow in a north to south direction under a rock fill embankment cover of over 9 m. The highway grade at the culvert is at approximately Elev. 297.0 m with overall embankment side slopes of approximately 1.5 horizontal to 1 vertical (1.5H:1V).

Based on visual observations, no signs of slope instability of the embankment were noted at the culvert site. Minor surficial erosions were observed along the crest of the south embankment

slope. The highway embankment is surrounded by thick mixed forest with bedrock outcrops located approximately 40 m east and 125 m west of the culvert location along Highway 17. Site photographs are presented in Appendix A.

At the culvert site, Highway 17 consists of three, 3.75 m wide paved lanes (two eastbound lanes and one westbound lane) and partially paved shoulders. The eastbound passing lane extends from about 0.9 km west of the culvert to about 1 km east of the culvert. The paved shoulders are narrow and are flanked by guide rails on both sides of the highway. Overhead utility lines are present on both sides of the embankment. Furthermore, a gravel entrance of an access road to the hydro corridor is located on the north side of the highway, approximately 100 m west of the culvert.

3. INVESTIGATION PROCEDURE

The field investigation and testing for this project was carried out from June 24 to 26, 2024, and consisted of drilling and sampling three boreholes, designated as Boreholes C-01 to C-03, to depths of between 1.9 m and 17.7 m (corresponding to Elev. 293.8 m and 279.1 m). Boreholes C-01 and C-03 were advanced at/near the abutments of the proposed temporary modular bridge (TMB), while Borehole C-02 was extended to approximately 17.7 m below the existing highway grade.

The Record of Borehole sheets for the boreholes, and the Borehole Location and Soil Strata Drawing (Drawing 1) are included in Appendix B.

Utility clearances were obtained prior to mobilization to the site. The as-drilled borehole locations were determined using handheld GPS unit and through measurements relative to the highway centreline and shoulder. The elevations of the boreholes were established by superimposing the as-drilled locations on a base plan/contour plan provided by MTO. In accordance with MTO's Guideline for Foundation Engineering Services, the survey readings have a vertical and horizontal accuracy of 0.1 m, and 0.5 m, respectively. The location and elevation of the boreholes as presented on the record of boreholes and borehole location drawing are positioned relative to coordinate system MTM NAD 83, Zone 14.

Borehole C-02 was drilled using a truck-mounted CME 75 drill rig using wash boring technique with NW casing and NQ coring equipment, while Boreholes C-01 and C-03 were advanced with hollow stem augers. Soils samples were obtained at selected intervals using a split-spoon sampler in conjunction with Standard Penetration Testing (SPT) in general accordance with ASTM D1586. The maximum particle size that can be sampled from the standard split-spoon

hammer used in the investigation is limited to 35 mm and therefore, particles that may exist within the soils larger than this dimension would not be recovered or represented in the grain size analyses.

The drilling and sampling operations were supervised on a full-time basis by a member of Thurber's technical staff, who logged the boreholes and processed the recovered soil samples and rock fill core for transport to Thurber's laboratory for further examination and testing.

The rock cores were logged along with soil within the rock fill material.

Groundwater condition observed in Borehole C-02 upon completion of drilling; however, it is not considered stabilized due to the introduction of water throughout the drilling operation. Boreholes C-01 and C-03 were dry upon completion of drilling. Monitoring wells were not installed during the investigation. The borehole completion details are summarized below:

Table 3-1 Borehole Details

Borehole	Top of Borehole Elevation	Depth and Elevation at the Base of Borehole (m)	Northing and Easting MTM NAD83 Zone 14	Completion Details
C-01	295.5	2.0 / 293.5	N 5,395,282.7 E 378,081	Backfilled with bentonite pellets, and asphalt patch at surface.
C-02	296.7	17.6 / 279.1	N 5,395,293.8 E 378,117.0	
C-03	297.7	2.1 / 295.6	N 5,395,299.8 E 378,141	

Upon completion of drilling, all boreholes were abandoned in accordance with O.Reg. 903 (as amended) and was backfilled using bentonite pellets.

The investigation was supervised by a member of our technical staff, who located the boreholes, arranged for the clearance of underground services, observed the drilling, sampling, and in situ testing operations, logged the boreholes, and examined and cared for the soil samples. The samples identified in the field were placed in appropriate containers, labelled, and transported to our Pickering geotechnical laboratory where the samples underwent further visual examination and laboratory testing. All laboratory tests were carried out to MTO and/or ASTM standards, as appropriate. Routine classification testing consisting of moisture content, grain size analysis, and Atterberg limits were carried out on selected soil samples.

4. GEOTECHNICAL LABORATORY TESTING

All recovered soil samples were subjected to visual identification (VI) and natural moisture content determination. Selected samples were subjected to grain size distribution analyses (sieve and/ or hydrometer). Unconfined compressive strength testing was carried out on selected rock fill cores. The results of this testing program are summarized on the Record of Borehole sheets in Appendix B and are shown on the laboratory figures included in Appendix C.

Testing was carried out on a sample of the sandy silty clay fill within the rock fill matrix to assess the potential for sulphate attack on buried concrete structures, as well as the potential for corrosion associated with buried steel elements of the structures. The results of the analytical testing are summarized in this report and presented in Appendix C.

5. SUBSURFACE CONDITIONS

5.1 Site Geology

Based on Northern Ontario Engineering Geology Terrain Study (NOEGTS), Map No. 42CNW "White River" and Map No. 42DNE "Heron Bay" conducted by the Ontario Ministry of Natural Resources in 1980, the topography in the immediate vicinity of the culvert and the surrounding area is generally described as moderate relief of a knobby and hummocky signature.

Based on the OGS Map MRD126 titled "Bedrock Geology of Ontario", dated 2011, the underlying bedrock at the site is metasedimentary rock consisting of wacke, siltstone, and arkose.

5.2 General Description of Subsurface Conditions

A general description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following sections. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description for interpretation of the site conditions. Soil classification is in general accordance with MTO's Guideline for Foundation Services Manual (April 2022).

The results of in-situ testing (including standard penetration testing) as presented in the record of boreholes and in Section 5 are uncorrected. The boundaries between soil deposits on the record of boreholes have been inferred from non-continuous sampling, observation of the progress of drilling, and the results of Standard Penetration Testing. Therefore, the boundaries represent the

transitions between soil deposits rather than exact planes of geological change. Variation on the stratigraphic boundaries between and beyond boreholes will exist and is to be expected.

In general, the subsurface conditions consist of asphalt, and gravelly silty sand fill, over rock fill.

5.3 Asphalt

Asphalt was encountered at the ground surface in all boreholes with thicknesses between 255 mm and 305 mm.

5.4 Gravelly Silty Sand Fill

A granular layer of gravelly silty sand trace clay was encountered beneath the asphalt in all boreholes, which extends to depths of 1.5 m to 2.1 m below ground surface (Elev. 295.8 m to 293.5 m). Boreholes C-01 and C-03 were terminated within the fill upon encountering auger refusal on probable rock fill and/or bedrock. Measured SPT N-values in the granular fill were 11 blows and 46 blows per 0.3 m of penetration, indicating a compact to dense condition.

The moisture content of the sand and gravel fill ranged from 2% to 9%. The results of a grain size analysis carried out on a sample of the silty sand and gravel fill are presented in Figure C1 of Appendix C and are summarized on the Record of Borehole sheet in Appendix B and in Table 5-1 below.

Table 5-1 Gradation Results for Gravelly Silty Sand Fill

Soil Particle	Percentage (%)
Gravel	24 – 32
Sand	53 – 62
Silt	13 – 14
Clay	1 – 2

5.5 Rock Fill

5.5.1 Coarse Gravel, Cobbles and Boulders

In Borehole C-02, a layer of coarse gravel, cobbles and boulders was encountered underlying the gravelly silty sand fill where the borehole was terminated at a depth of 17.7 m (Elev. 279.1 m). To advance the borehole, coring equipment consisting of NW casing and NQ core barrel was

used. Particle sizes recovered from coring equipment ranged from 50 mm to 350 mm, indicating the rock fill generally consists of coarse gravel, cobbles and boulders.

The results of the Unconfined Compressive Strength (UCS) testing carried out on a samples of rock fill are presented in Appendix C and summarized in the Record of Borehole C-02 and in Table 5-2. Based on the test result, the rock fill material is classified as medium strong (R3) to very strong (R5).

Table 5-2 Summary of Unconfirmed Compressive Strength

Borehole and Run Number	Depth and Elevation of Core Run (m)	Unconfined Compressive Strength (UCS) (MPa)	Classification
Borehole C-02 Run 3	5.3 to 5.6 / 291.4 to 291.1	90.4	Strong (R4)
Borehole C-02 Run 5	8.9 to 9.0 / 287.8 to 287.7	105.5	Very Strong (R5)
Borehole C-02 Run 8	11.7 to 12.1 / 285.0 to 284.6	48.3	Medium Strong (R3)

5.5.2 Gravel to Gravel and Sand Fill

Between the coarse gravel-, cobbles-, and boulder-sized particles within the rock fill matrix, granular fill consisting of gravel to gravel and sand was encountered between depths of 1.5 m and 9.0 m (Elev. 295.2 m to 287.8 m), and 13.7 m and 17.7 m (Elev. 283.0 m to 279.1 m). SPT N-values measured in the coarse-grained fill ranged from 1 blow per 0.3 m of penetration to 35 blows per 0.08 m of penetration, indicating a very loose to very dense condition.

The moisture content of coarse-grained fill ranges from 5% to 12%. The results of grain size analysis completed on a sample of the coarse-grained fill within the rock fill matrix are presented on Figure C-2 of Appendix C and summarized on the Record of Borehole sheets in Appendix B and in Table 5-3 below.

Table 5-3 Gradation Results for Gravel to Gravel and Sand Fill within Rock Fill Matrix

Soil Particle	Percentage (%)
Gravel	50 – 82
Sand	14 – 46
Silt	3
Clay	1

5.5.3 Sandy Silty Clay Fill

A layer of sandy silty clay trace gravel was also encountered within the rock fill matrix in Borehole C-02 between a depth of 9.0 m and 13.7 m (Elev. 287.8 m to 283.0 m). SPT N-values measured in the fine-grained fill were 15 blows per 0.3 m of penetration, inferring a stiff consistency.

The moisture content of clay fill ranges from 30% to 40%. The results of grain size analysis completed on a sample of the cohesive fill are presented on Figure C-3 of Appendix C. The results of the test are summarized in Table 5-4 and on the Record of Borehole sheets in Appendix B.

Table 5-4 Gradation Results for Silty Clay Fill within Rock Fill Matrix

Soil Particle	Percentage (%)
Gravel	0 – 3
Sand	26 – 31
Silt	19 – 26
Clay	40 – 55

The result of Atterberg limits test completed on a sample of the sandy clay fill is presented on Figure C-4 of Appendix C and is summarized on the Record of Borehole sheets in Appendix B, and in Table 5-5 below.

Table 5-5 Atterberg Limit Results for Silty Clay Fill within Rock Fill Matrix

Parameter	Value
Liquid Limit	45
Plastic Limit	16
Plasticity index	29

The result indicates that the material is a silty clay of intermediate plasticity (CI).

5.6 Groundwater Conditions

Details of the water level observed in the boreholes upon completion of drilling are presented on the Record of Borehole sheet in Appendix B and summarized in Table 5-6 below.

Table 5-6 Measured Water Levels in the Open Boreholes

Borehole	Date of Measurement	Depth (m)	Remark
C-01	June 26, 2024	--	Borehole dry upon completion of the drilling
C-02	June 25, 2024	3.7	Water was introduced in the borehole during drilling and as such, the measured water level in the borehole may not be representative of the natural groundwater level.
C-03	June 26, 2024	--	Borehole dry upon completion of the drilling

It should be noted that the measured groundwater levels may not reflect the groundwater level at the site. Furthermore, the groundwater levels may be at a higher elevation during spring and after periods of significant or prolonged precipitation.

5.7 Analytical Laboratory Testing

A sample of the sandy silty clay fill within the rock fill matrix was submitted for analytical testing for corrosivity analysis and sulphide content. The analytical test results for the soil are presented in Appendix C and are summarized in Table 5-7 below.

Table 5-7 Summary of Analytical Test Results

Borehole / Sample	C-02 / SS8
Depth (m)	9.0 – 9.6
Elevation (m)	287.7 – 287.1
Sulphide (Na_2CO_3) %	0.02
Chloride (µg/g)	920
Sulphate (µg/g)	180
pH	8.04
Conductivity (µS/cm)	1760
Resistivity (Ohm-cm)	568

6. MISCELLANEOUS

Downing Drilling Ltd. of Hawkesbury, Ontario, supplied and operated the drilling equipment to carry out the drilling, sampling, and in-situ testing. The drilling and sampling operations were supervised on a full-time basis by Mr. Oleksandr Pogurzhelskyy of Thurber. The Foundation Investigation Report was prepared by Messrs. Ali Rajaei, P. Eng. and Christopher Ng, P.Eng. The report was reviewed by Mr. Jason Lee, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Ali Rajaei, P.Eng.,
Geotechnical Engineer

LICENSED PROFESSIONAL ENGINEER
C.C. NG
100086170
2024/09/19
PROVINCE OF ONTARIO

Christopher Ng, P.Eng.,
Associate, Senior Geotechnical Engineer

LICENSED PROFESSIONAL ENGINEER
J. P. K. LEE
100086735
2024/09/19
PROVINCE OF ONTARIO

Jason Lee, P.Eng.,
Partner, Senior Geotechnical Engineer
Designated MTO Contact

Date: ***September 19, 2024***
File: ***51583***

PART B: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7. GENERAL

This report provides an interpretation of the geotechnical data in the foundation investigation report and presents foundation design recommendations for the proposed replacement of Culvert No. NW-867-0017-0026 on Highway 17 located approximately 11.3 km west of the junction of Highway 614 in the Township of Lecours, District of Thunder Bay, Ontario.

The discussions and recommendations in this report are intended for the use of the Ministry of Transportation, Ontario 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 contractor undertaking the work must make their own interpretation based on the information presented in the factual section of the report (Part A of this report). Where comments are made on construction, they are provided to highlight those aspects which could affect the design of the project. The contractor must make their own interpretation of the data provided as it may affect equipment selection, proposed construction methods, scheduling, and the like.

The purpose of this report is to evaluate different alternatives for the methods to replace the culvert from a foundation perspective and to provide preliminary foundation recommendation, taking into consideration that the embankment is over 9 m high and is constructed with rock fill. The alternatives being evaluated include trenchless technology, open cut excavation with temporary protection systems, as well as open cut excavation with a temporary modular bridge (TMB).

8. METHOD OF INSTALLATION

For preliminary design, the following method of installation has been evaluated:

Trenchless Installation

- Typically, trenchless installation techniques are adopted where there is a desire to reduce traffic disruptions and the need for a large excavation through the existing highway embankment. However, given the subsurface conditions at the site, it will be difficult, if not impractical, to undertake trenchless installation techniques due to the significant amounts of cobble- and boulder-sized particles contained in the rock fill embankment. If adopted, misalignment of the tunnel is to be expected.
- Misalignment can be reduced or mitigated by installing larger casing than the designed culvert diameter. Upon installing the casing, the new culvert can be inserted in casing, adjusted to the appropriate alignment, and the annular space between the casing and the new culvert

grouted. Larger casing diameters are also less likely to be deflected and will allow for the removal of large obstructions. However, a larger tunnel may add significant costs to the overall construction.

- Due to the composition of the embankment fill, trenchless installation carries a certain level of risk associated with loss of ground as a result of potential mixed face conditions containing varying sizes of soil particles ranging from sand to boulders.
- For the reasons above, trenchless installation method for the replacement this culvert is not recommended and would not be discussed further herein.

Open Cut with Temporary Protection System

- Due to the presence of rock fill within the embankment, installation of temporary protection systems will be difficult. Protection system constructed with interlocking sheet piles are not expected to be able to penetrate the over 9 m thick rock fill.
- Installation of a soldier pile and lagging systems may be possible; however, the process is expected to be laborious given the need for socketing soldier piles in pre-augered holes. Furthermore, given the depth of the excavation, it is likely that rakers will be required to provide the soldier pile and lagging system additional lateral support. The use of soil anchors will not be practical through the rock fill embankment.
- In addition, the protection system will require to extend below the base of the excavation for fixity; however, there are risks that there may not be sufficient depth for this purpose given the highly variable bedrock surface based on the depth of the investigation and bedrock outcrop observed to the east and west of the site.
- For the reasons above, open cut excavation with temporary protection systems is not recommended and would not be discussed further herein.

Open Cut Excavation with Temporary Modular Bridge (TMB)

- Installation of proposed culvert using an open cut excavation with a temporary modular bridge (TMB) to provide a single lane of traffic passage over the open excavation is both technically feasible and practical and therefore, it is the recommended alternative from a foundation perspective. Although this alternative would disrupt traffic due to staged construction, it offers the least amount of risk and uncertainty as compared to the other alternatives. In addition, the rock fill embankment would provide adequate geotechnical resistance to support the abutments of the TMB.

9. APPLICABLE CODES AND DESIGN CONSIDERATIONS

The geotechnical assessment presented below has been prepared based on the available data regarding the proposed foundations, existing ground surface conditions and in accordance with the Canadian Highway Bridge Design Code (CHBDC) version CSA S6-19.

In accordance with the CHBDC, the analysis and design of the structure takes into consideration the importance of the structure and the consequence associated with exceeding limit states design. The importance category and consequence classification are defined by the Regulatory Authority, which, in this case, is the Ministry of Transportation, Ontario (MTO).

A consequence classification of *Typical Consequence*, in accordance with Section 6.5 of the CHBDC, has been adopted for the temporary modular bridge (TMB). Accordingly, a consequence factor (Ψ) of 1.0, as per Table 6.1 of the CHBDC, has been used in assessing factored geotechnical resistances. If this consequence classification changes, the geotechnical assessment and recommendations provided within this report will need to be reviewed and revised.

As per Section 6.5.3 of the CHBDC, the degree of site prediction model understanding is *Typical* based on the current information.

10. REPLACEMENT CULVERT

A record drawing for the new culvert was not available during the preparation of this report; however, it is understood that the new culvert will be either a 2100 mm diameter CSP or a 2100 mm box culvert and will be installed along the existing culvert alignment. As such, the following factored geotechnical resistances may be used for preliminary planning and design purposes of the new culvert based on limited subsurface information.

Table 10-1 Factored Geotechnical Resistances for Replacement Culvert

Culvert Type (m)	Culvert Dimensions (m)	Assumed Founding Condition	Factored Geotechnical Resistances	
			ULS (kN)	SLS (kN)
CSP or Concrete Box	2100 mm dia. or 2100 mm box	Rock Fill	450	300 (1)

Notes: (1) For 25 mm of settlement.

11. TEMPORARY MODULAR BRIDGE

A record drawing for the temporary modular bridge was not available during the preparation of this report; however, it is understood that the temporary modular bridge (TMB) will be 60 m long, single-lane structure supported on precast concrete footings. As such, the following factored geotechnical resistances may be used for preliminary design.

Table 11-1 Factored Geotechnical Resistances for Precast Footings of Temporary Modular Bridge

Width of Footing (1) (m)	Depth of Footing (m)	Distance Between Edge of Footing to Crest of Slope (m)	Assumed Founding Condition	Factored Geotechnical Resistances	
				ULS (kN)	SLS (kN)
3.0 (1)	0.3 (2)	3.0 (3)	Rock Fill	375	250 (4)

Notes: (1) Footing width based on discussions with Gannett Fleming.
(2) Assumed nominal depth of embedment of precast footing.
(3) Offset/bench distance based on discussions with Gannett Fleming.
(4) For 25 mm of settlement.

12. OPEN CUT EXCAVATION

All temporary open cut excavations must be carried out in accordance with the latest Occupational Health and Safety Act (OHSA) of Ontario and local regulations. The embankment fill is classified as a Type I soil under OHSA when it is above the groundwater table, and Type 2 soils when it is below the groundwater table. In accordance with OHSA, temporary cut slopes for Type 1 and Type 2 soils should have a minimum gradient of 1H:1V; however, it is recommended that the open cut excavation be constructed to 1.5H:1V or flatter when considering the anticipated duration of construction.

13. TEMPORARY EMBANKMENT WIDENING

It is understood that the stage construction will require a temporary embankment widening of up to 2 m and 4 m to the north and south of the highway, respectively. Given that there are no visual indications of instability of the embankment observed during the investigation, temporary embankment widening is expected to be stable provided that the widening is constructed with rock fill of similar specification to the existing rock fill embankment with side slopes of 1.5H:1V or flatter.

The use of granular fill is not recommended for the construction of the temporary widening due to the dissimilarity of particle sizes with the existing rock fill, which may lead to the loss of granular material into the voids of the rock fill embankment.

14. EMBANKMENT REINSTATEMENT

The existing highway embankment side slopes are generally sloped at approximately 1.5H:1V and did not show any visible signs of global instability at the time of the investigation.

Construction of the embankment should be carried out in accordance with OPSS.PROV 206 with embankment side slope constructed to 1.5H:1V or flatter provided the embankment reinstatement is completed with rock fill above the cover of the culvert. The top surface of the rock fill should be chinked to form the subgrade prior to the placement of roadway subbase in accordance with OPSS.PROV 206.

Where OPSS.PROV 1010 Granular B Type II is to be used, the embankment side slope should be reconstructed to 2H:1V or flatter. In addition, fill placement and compaction of Granular B Type II should be carried out in accordance with OPSS.PROV 501, as amended by Special Provision 105S22.

If the embankment envelope remains unchanged after reinstatement, foundation settlement is expected to be negligible.

Given the height of embankment, the magnitude of the embankment self-compression constructed with compacted rock fill is in the order of 0.75% of the newly reconstructed embankment height and is expected to occur predominantly during fill placement.

15. CORROSION POTENTIAL

Based on results of corrosivity testing on a sample of the sandy silty clay fill within the rock fill matrix, the following statements can be made in reference to the MTO Gravity Pipe Design Guideline. However, the effects of road de-icing salts/chemicals should be considered when selecting pipe material and/or corrosion mitigation measures.

- The resistivity of the sandy silty clay fill was measured to be 568 ohm-cm, which indicates the soil has a corrosiveness of severe corrosion potential (2,000 ohm-cm > R) according to Table 3.2 of the MTO Gravity Pipe Design Guideline.
- The sulphate concentration of the sandy silty clay fill was measured to be 180 µg/g, which is considered to have a negligible degree of sulphate attack on concrete according to Table 7.2 of the MTO Gravity Pipe Design Guideline.

- The pH level of the sandy silty clay fill was measured to be 8.04, and according to Section 7.1.1 of the MTO Gravity Pipe Design Guideline, pH levels between 5.5 and 8.5 in soil or water are not considered detrimental to the durability of the culvert.

16. CONSTRUCTION CONCERNS

Potential construction concerns that have been identified for this project include the following:

16.1 Placement of Material Stockpiles and Construction Equipment

Material stockpiling is a temporary construction measure and as such, the associated stability implications are the responsibility of the Contractor. The selection and placement of construction equipment (such as cranes) and construction of temporary construction access roads are also the Contractor's responsibility. Placement of the material stockpiles and construction equipment must not destabilize the embankment.

16.2 Excavation of Rock Fill

Based on the exposed rock fill on the embankment slopes (as shown on the photographs in Appendix A), the existing highway embankment will likely contain rock fill particles greater than 1 m. The Contractor's equipment and methodology must be able to handle such obstructions and successfully remove them without jeopardizing the performance or operation of the highway.

17. RECOMMENDATIONS FOR FUTURE WORKS

During detailed design, it is recommended that boreholes be advanced near the inlet and outlet of the new culvert to characterize the founding conditions at the culvert ends. It is noted that access to the inlet and outlet could be difficult and would likely require the use of portable drilling equipment; however, portable drilling equipment may encounter difficulty penetrating rock fill.

In addition to the boreholes near the culvert inlet and outlet, a borehole should also be advanced near the centre of the new culvert that penetrates through the rock fill embankment and into the underlying soils and/or bedrock. Furthermore, if the construction is to proceed with open cut excavation with temporary modular bridge, boreholes should be advanced into the existing embankment at the proposed abutment locations to confirm the founding conditions.

Should temporary protection systems be considered, additional boreholes should be advanced along the highway to quantify the size and frequency of rock fill, and to assess the depth of bedrock to verify whether there is sufficient depth of embedment for the design of protection systems.

Given the installation of the new culvert will require the temporary widening of the existing embankment, analysis to assess the stability of the embankment and settlement of the founding soils should be carried out during detailed design subject to the type of soils encountered.

Furthermore, monitoring wells should be installed to assess stabilized groundwater level for design and the need for dewatering during construction.

18. CLOSURE

The Foundation Design Report was prepared by Mr. Christopher Ng, P.Eng and was reviewed by Mr. Jason Lee, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Christopher Ng, P.Eng.,
Associate / Senior Geotechnical Engineer

Jason Lee, P.Eng.
Partner / Senior Geotechnical Engineer
Designated MTO Contact

Date: ***September 19, 2024***
File: ***51583***

THURBER

STATEMENT OF LIMITATIONS AND CONDITIONS

1. STANDARD OF CARE

This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or made.

2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report, which is of a summary nature and is not intended to stand alone without reference to the instructions given to Thurber by the Client, communications between Thurber and the Client, and any other reports, proposals or documents prepared by Thurber for the Client relative to the specific site described herein, all of which together constitute the Report.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. THURBER IS NOT RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF REPORT

The Report has been prepared for the specific site, development, design objectives and purposes that were described to Thurber by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the Report, subject to the limitations provided herein, are only valid to the extent that the Report expressly addresses proposed development, design objectives and purposes, and then only to the extent that there has been no material alteration to or variation from any of the said descriptions provided to Thurber, unless Thurber is specifically requested by the Client to review and revise the Report in light of such alteration or variation.

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT THURBER'S WRITTEN CONSENT AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS THURBER MAY EXPRESSLY APPROVE. Ownership in and copyright for the contents of the Report belong to Thurber. Any use which a third party makes of the Report, is the sole responsibility of such third party. Thurber accepts no responsibility whatsoever for damages suffered by any third party resulting from use of the Report without Thurber's express written permission.

5. INTERPRETATION OF THE REPORT

a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and the Report is delivered subject to the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. If special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

b) Reliance on Provided Information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to Thurber. Thurber has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Thurber does not accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by Thurber. Thurber is entitled to rely on such representations, information and instructions and is not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.

c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.

d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

7. INDEPENDENT JUDGEMENTS OF CLIENT

The information, interpretations and conclusions in the Report are based on Thurber's interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Thurber does not accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.

APPENDIX A

Site Photographs

Photograph #1 – On north side of Highway17, west of existing culvert looking west. Bedrock outcrop on both sides of the highway. (June 2024)

Photograph #2 – North embankment slope looking east. (June 2024)

Photograph #3 – On north side of Highway 17 looking east. Note the large outcrop on south side of the highway. (June 2024)

Photograph #4 – On north side of Highway 17, east of culvert, looking west. (June 2024)

Photograph #5 – Culvert inlet obstructed with vegetation and other debris. (June 2024)

Photograph #6 – Existing culvert from inlet. (June 2024)

Photograph #7 – South embankment slope looking west. (June 2024)

Photograph #8 – Rock fill on steep south embankment slope looking east. (June 2024)

Photograph #9 – South embankment slope looking east. (June 2024)

Photograph #10 – Surficial erosion at the crest of embankment beyond the south shoulder. (June 2024)

Photograph #11 – On south side of Highway17, west of existing culvert, looking west. Note the bedrock outcrops on both sides of the highway. (June 2024)

Photograph #12 – CSP extension at culvert outlet. (June 2024)

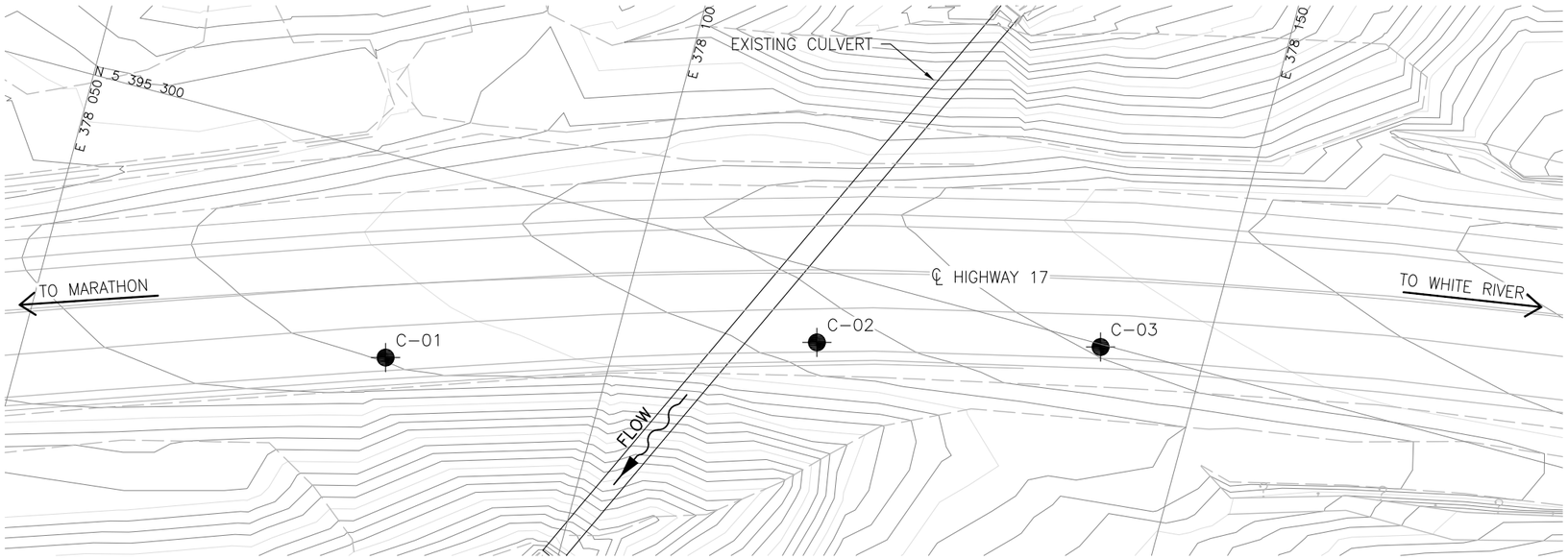
Photograph #13 – Existing culvert at outlet. (June 2024)

APPENDIX B

Borehole Location Plan and Soil Strata Drawing

Record of Borehole Sheets

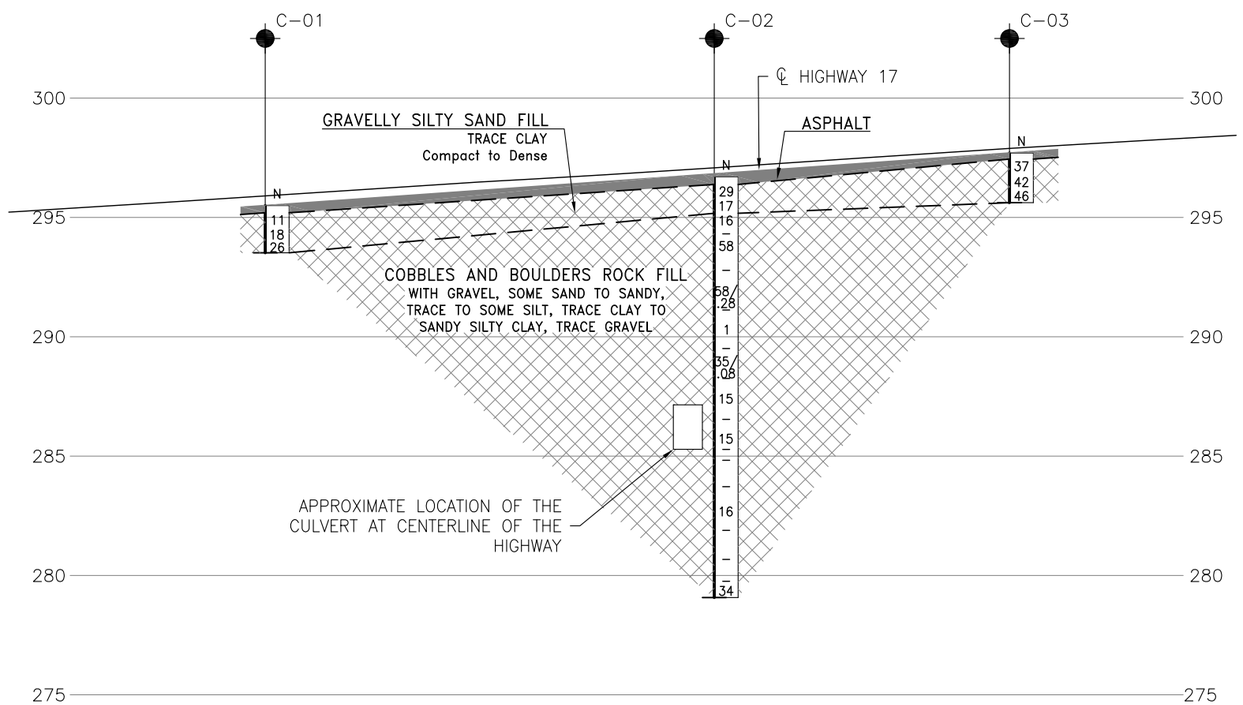
MINISTRY OF TRANSPORTATION, ONTARIO



PLAN

10 0 10 20m

SCALE 1:500



PROFILE ALONG ℄ HWY 17

10 0 10 20m H 1:500

5 0 5 10m V 1:250

METRIC

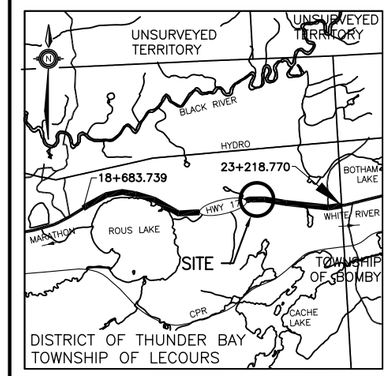
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No
GWP No

HIGHWAY 17 CULVERT REPLACEMENT
CULVERT NO. NW-867-0017-0026
STA 21+478
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

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 Upon Completion of Drilling
▼	Water Level in Monitoring Well/Piezometer
┃	Monitoring Well/Piezometer Screen
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
C-01	295.5	5 395 282.7	378 081.0
C-02	296.7	5 395 293.8	378 117.0
C-03	297.7	5 395 299.8	378 141.0

-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.
3) Coordinate system is MTM NAD 83 Zone 14.

GEOCRES No. 42D09-001

LICENSED PROFESSIONAL ENGINEER C.C. NG 100088170 2024/09/19 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER J.P.K. LEE 100086735 2024/09/19 PROVINCE OF ONTARIO

REVISIONS

DATE	BY	DESCRIPTION

DESIGN RB	CHK AR	CODE	LOAD	DATE SEP 2024
DRAWN MC	CHK CN	SITE	STRUCT	DWG 1

FILENAME: H:\Drafting\51000\51583\TED-51583 PLPR.dwg
PLOTDATE: 9/13/2024 2:41 PM

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No C-01

METRIC

WP# 6058-13-00 LOCATION MTM Zone 14: N 5 395 282.7 E 378 081.0 ORIGINATED BY OP

DIST Thunder Bay HWY 17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AS

DATUM Geodetic DATE 2024.06.26 - 2024.06.26 LATITUDE 48.691713 LONGITUDE -86.004530 CHECKED BY AR

SOIL PROFILE ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
295.5	GROUND SURFACE										
0.0 / 295.2	**ASPHALT:** (300 mm)										
0.3	Gravelly silty **SAND**, trace clay Compact Grey Moist (FILL)		1	SS	11		295		○		32 53 13 2
			2	SS	18		294		○		
293.5			3	SS	26				○		
2.0	END OF BOREHOLE. AUGER REFUSAL ON PROBABLE ROCK FILL AT A DEPTH OF 2.0 m. NOTES: 1. Borehole was dry upon completion of drilling. 2. Borehole was backfilled with bentonite, concrete, and cold patch at surface.										

+ 3, × 3: Numbers refer to Sensitivity

15 20 5 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No C-02

METRIC

WP# 6058-13-00 | LOCATION MTM Zone 14: N 5 395 293.8 E 378 117.0 | ORIGINATED BY OP

DIST Thunder Bay HWY 17 | BOREHOLE TYPE CME 75, Wash Boring, NW Casing Advance, NQ Coring | COMPILED BY AS

DATUM Geodetic | DATE 2024.06.24 - 2024.06.25 | LATITUDE 48.691808 | LONGITUDE -86.004039 | CHECKED BY AR

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
296.7	GROUND SURFACE							
0.0 / 296.4	**ASPHALT:** (305 mm)							
0.3	Gravelly silty **SAND**, trace clay Compact Grey Moist (FILL)	1	SS	29	24	62	13	1
		2	SS	17				
295.2								
1.5	**COBBLES** and **BOULDERS**, with gravel, some sand to sandy, trace to some silt, trace clay (ROCK FILL)	3	SS	16				
	NQ1 (2.1 m to 2.6 m): - Gravels up to 50 mm - 1 x 150 mm cobble	1	NQ	-				
		4	SS	58	82	14	3	1
	NQ2 (3.0 m to 4.6 m): - Gravels up to 50 mm	2	NQ	-				
		5	SS	58/0.28				
	NQ3 (5.2 m to 6.1 m): - Gravels up to 75 mm - 1 x 175 mm cobble - 1 x 200 mm boulder	3	NQ	-	UCS = 90.4 MPa			
		6	SS	1				
	NQ4 (6.7 m to 7.8 m): - Gravels up to 50 mm - 1 x 100 mm cobble	4	NQ	-				
		7	SS	35/0.08				
	NQ5 (7.6 m to 8.6 m): - Gravels up to 50 mm - 2 x 150 mm cobbles	5	NQ	-	UCS = 105.5 MPa			
287.8								
9.0	**COBBLES** and **BOULDERS**, with sandy silty clay, trace gravel (ROCK FILL)	8	SS	15	3	31	26	40

GROUND WATER CONDITIONS: ▽

ELEVATION SCALE: 296, 295, 294, 293, 292, 291, 290, 289, 288, 287

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

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

WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m^3

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

15 20 10 5 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No C-02

METRIC

WP# 6058-13-00 LOCATION MTM Zone 14: N 5 395 293.8 E 378 117.0 ORIGINATED BY OP

DIST Thunder Bay HWY 17 BOREHOLE TYPE CME 75, Wash Boring, NW Casing Advance, NQ Coring COMPILED BY AS

DATUM Geodetic DATE 2024.06.24 - 2024.06.25 LATITUDE 48.691808 LONGITUDE -86.004039 CHECKED BY AR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						GR SA SI CL
	Continued From Previous Page										
	COBBLES and **BOULDERS**, with sandy silty clay, trace gravel (ROCK FILL)		6	NQ	-						
	NQ6 (9.2 m to 10.7 m): - No recovery						286				
			9	SS	15				○		0 26 19 55
	NQ7 (10.7 m to 11.5 m): - 1 x 100 mm cobble		7	NQ	-						
			8	NQ	-		285				UCS = 48.3 MPa
	NQ8 (11.5 m to 12.2 m): - 3 x 50 mm gravels - 1 x 100 mm cobble - 1 x 350 mm boulder										
			9	NQ	-		284				
	NQ9 (12.2 m to 13.7 m): - Cobbles up to 100 mm										
283.0											
13.7	**COBBLES** and **BOULDERS**, with gravel and sand, trace silt, trace clay (ROCK FILL)		10	SS	16		283		○		50 46 3 1
	NQ10 (13.7 m to 15.2 m): - Gravels up to 75 mm - 1 x 150 mm cobble		10	NQ	-		282				
			11	NQ	-		281				
	NQ11 (15.2 m to 16.7 m): - Gravels up to 50 mm										
			12	NQ	-		280				
	NQ12 (16.7 m to 17.1 m): - No recovery										
			11	SS	34				○		
279.1											
17.6	END OF BOREHOLE AT A DEPTH OF 17.6 m.										

NOTES:
1. Water was introduced in borehole during drilling.
2. Water level at a depth of 3.7 m below ground surface (Elev. 293.0 m) in open borehole prior to borehole abandonment.
3. Borehole was backfilled with bentonite pellets and cold patch at surface.

+ 3, × 3: Numbers refer to Sensitivity

20 15 5 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No C-03

METRIC

WP# 6058-13-00 LOCATION MTM Zone 14: N 5 395 299.8 E 378 141.0 ORIGINATED BY OP

DIST Thunder Bay HWY 17 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AS

DATUM Geodetic DATE 2024.06.26 - 2024.06.26 LATITUDE 48.691859 LONGITUDE -86.003712 CHECKED BY AR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						GR SA SI CL
297.7	GROUND SURFACE										
0.0 / 297.4	**ASPHALT:** (255 mm)										
0.3	Gravelly silty **SAND**, trace clay Dense Grey Moist (FILL)		1	SS	37		297				25 60 14 1
			2	SS	42						
			3	SS	46		296				
295.6											
2.1	END OF BOREHOLE. AUGER REFUSAL ON PROBABLE ROCK FILL OR BEDROCK AT A DEPTH OF 2.1 m. NOTES: 1. Borehole backfilled with bentonite, concrete and asphalt patch to surface. 2. Borehole was dry upon completion of drilling.										

+ ³, × ³: Numbers refer to Sensitivity

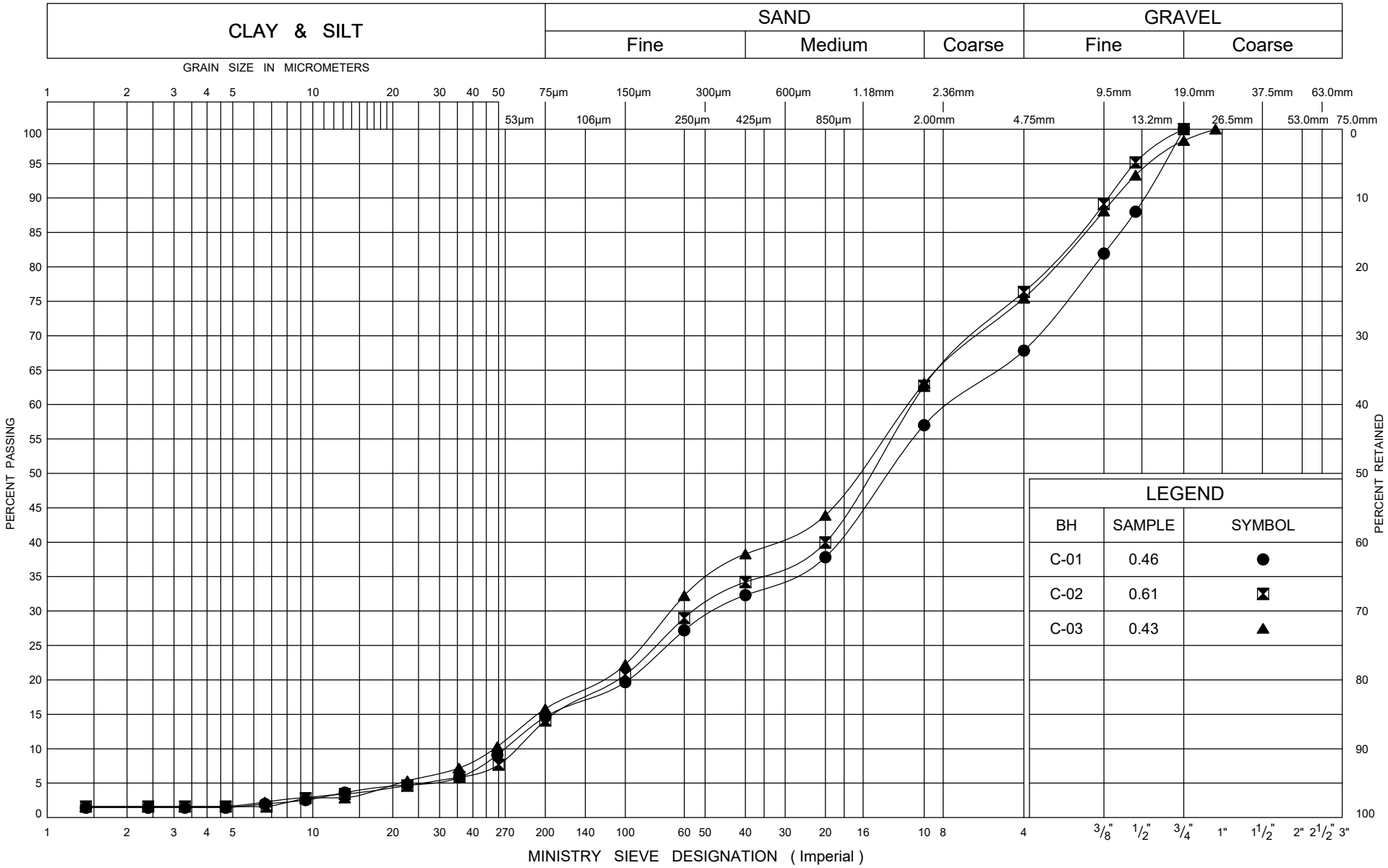
15 20 5 10 (%) STRAIN AT FAILURE

ONTMT4S2 2020LIBRARY(MTO).GLB MTO-51583.GPJ 8/16/24

APPENDIX C

Geotechnical and Analytical Laboratory Test Results

Rock Fill Core Photographs



Ministry of Transportation
Ontario

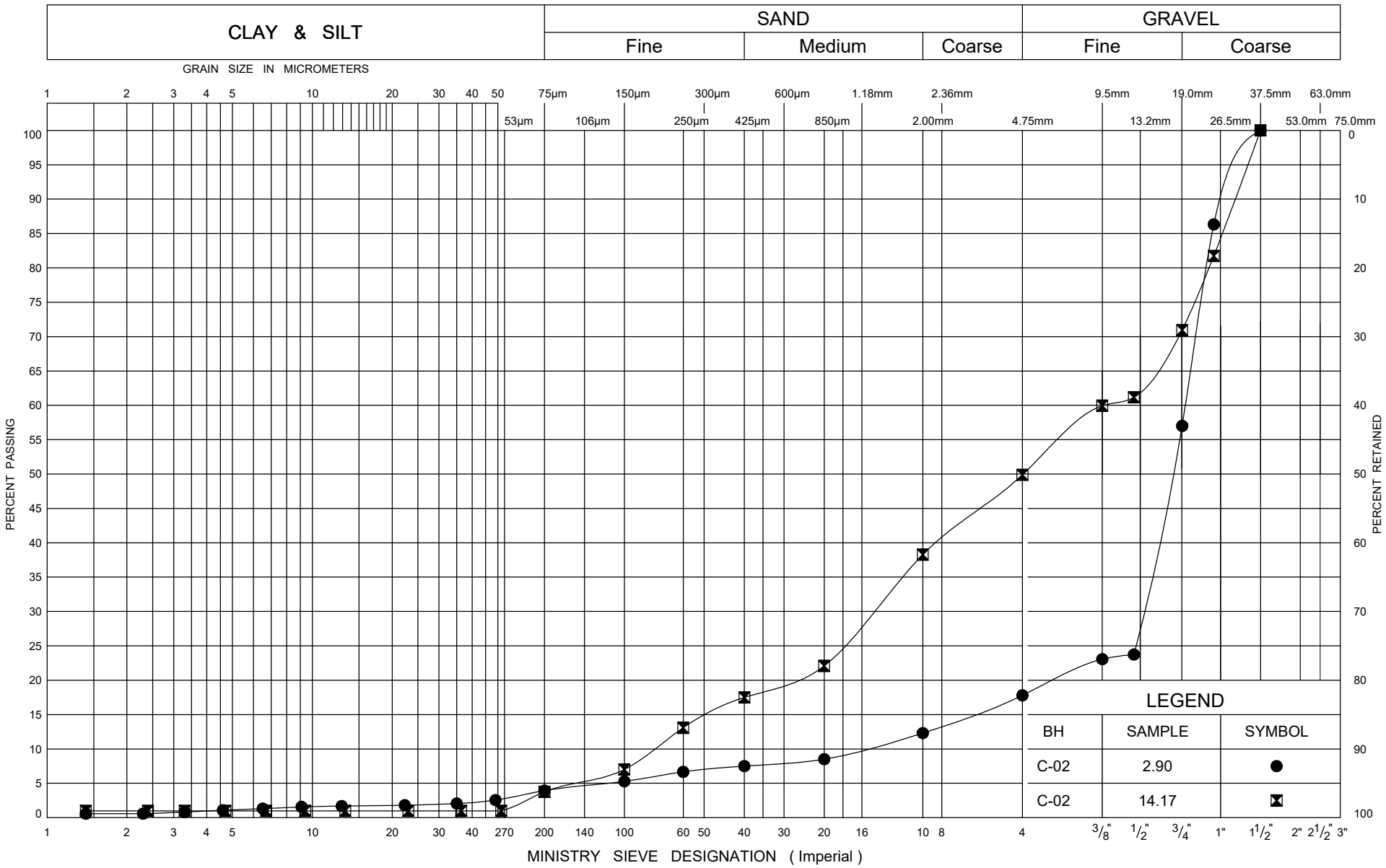
GRAIN SIZE DISTRIBUTION

Gravelly Silty Sand FILL

FIG No C1

WP# 6058-13-00

78 12 M



Ministry of Transportation

Ontario

GRAIN SIZE DISTRIBUTION

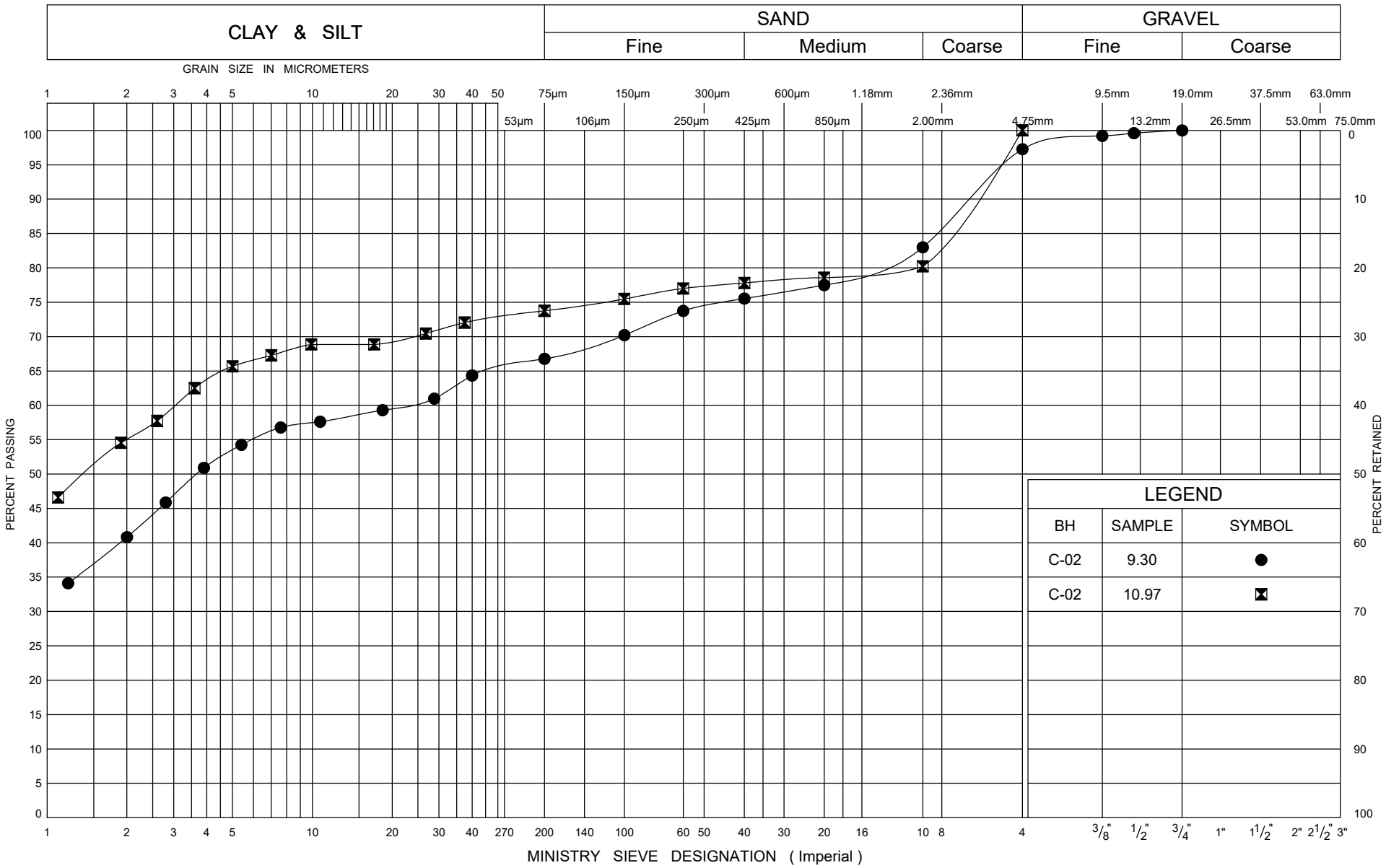
Gravel to Gravel and Sand FILL
within Rock Fill Matrix

FIG No C2

WP# 6058-13-00

ONTARIO MOT GRAIN SIZE 2 MTO-51583.GPJ ONTARIO MOT.GDT 8/1/24

78 12 M



ONTARIO MOT GRAIN SIZE 2 MTO-51583.GPJ ONTARIO MOT.GDT 8/1/24

Ministry of Transportation
Ontario

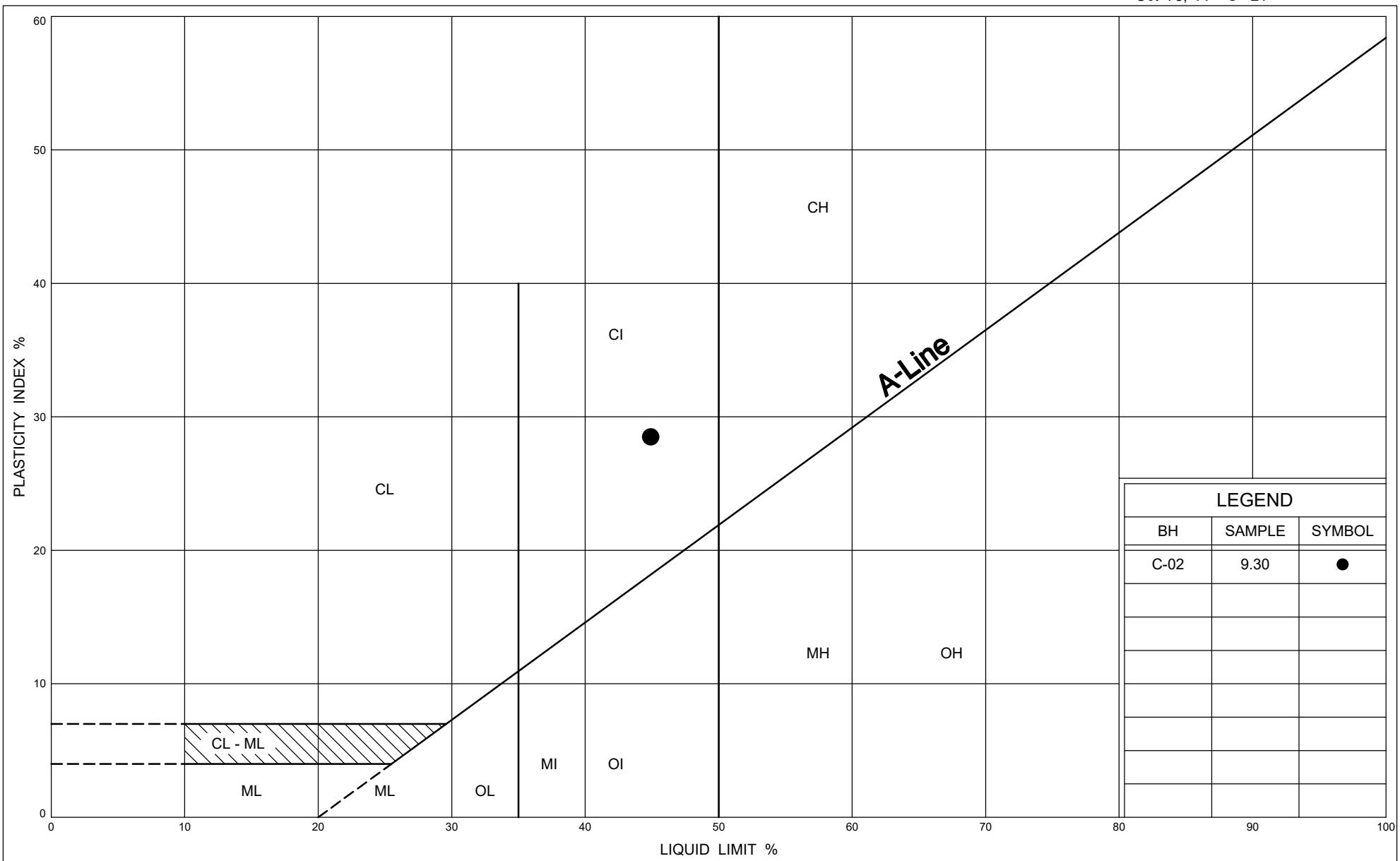
GRAIN SIZE DISTRIBUTION

Sandy Silty Clay FILL
within Rock Fill Matrix

FIG No C3

WP# 6058-13-00

Oct 75, FF - S - 21



Ministry of Transportation
Ontario

PLASTICITY CHART

Sandy Silty Clay Fill
within Rock Fill Matrix

FIG No C4

WP# 6058-13-00

ONTARIO MOT PLASTICITY CHART MTO-51583.GPJ ONTARIO MOT.GDT 8/2/24

Highway 17 Culvert Replacement – Culvert No. NW-867-0017-0026
Appendix C – Rock Fill Core Photographs

RUN ID	Depth (m)	RUN ID	Depth (m)	RUN ID	Depth (m)
NQ1	2.2 – 2.6	NQ6 (No Recovery)	9.0 – 10.7	NQ11	15.2 – 16.8
NQ2	3.2 – 4.6	NQ7	10.7 – 11.5	NQ12	16.8 – 17.1
NQ3	4.6 – 6.1	NQ8	11.5 – 12.2		
NQ4	6.1 – 7.6	NQ9	12.2 – 13.7		
NQ5	7.6 – 9.0	NQ10	13.7 – 15.2		

Rock Laboratory Testing Results

A report submitted to:

Ali Rajaei
Thurber Engineering Ltd.
Unit 1, 1795 Ironstone Manor
Pickering, Ontario
Canada, L1W 3W9

Prepared by:

Bryan Tatone, PhD, PEng

Omid Mahabadi, PhD, PEng
Geomechanica Inc.
#14-1240 Speers Rd.
Oakville ON
L6L 2X4 Canada
Tel: +1-647-478-9767
lab@geomechanica.com

July 23, 2024
Project number: 51583

Abstract

This document summarizes the results of rock laboratory testing, including 3 Uniaxial Compressive Strength (UCS) tests. The UCS values and Young's modulus along with photographs of samples before and after testing are presented herein.

In this document:

1 Uniaxial Compressive Strength Tests 1
Appendices 4

Disclaimer: This report was prepared by Geomechanica Inc. for Thurber Engineering Ltd. . The material herein reflects Geomechanica Inc.'s best judgment given the information available at the time of preparation. Any use which a third party makes of this report, any reliance on or decision to be made based on it, are the responsibility of such third parties. Geomechanica Inc. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

1 Uniaxial Compressive Strength Tests

1.1 Overview

This section summarizes the results of uniaxial compressive strength (UCS) testing. The testing was performed in Geomechanica Inc.'s rock testing laboratory using a 150 ton (1.3 MN) Forney loading frame equipped with pressure-compensated control valve to maintain an axial strain rate of approximately 0.05 mm/min (Figure 1). The preparation and testing procedure for each specimen included the following:

1. Unwrapping the core sample, inspecting it for damage, and, if weak or moisture sensitive, re-wrapping it in electrical tape to minimize exposure to moisture during subsequent specimen preparation.
2. Diamond cutting the core sample to obtain cylindrical specimens with an appropriate length (length:diameter = 2:1) and nearly parallel end faces.
3. Diamond grinding the specimen to obtain flat (within ± 0.025 mm) and parallel end faces (within 0.25°).
4. Placing the specimen into the loading frame, applying a 1 kN axial load, and removing the electrical tape if present.
5. Axially loading the specimens to rupture while continuously recording axial force to determine the peak strength (UCS) and the axial strain to determine the tangent Young's modulus.

Figure 1: Forney loading frame setup for UCS testing.

Using a precision V-block mounted on the magnetic chuck of the surface grinder, test specimens met the end flatness, end parallelism, and perpendicularity criteria set out in ASTM D4543-19. The side straightness criteria, as checked with a feeler gauge, and the minimum length:diameter criteria were met for all specimens unless noted otherwise in Table 1. Testing of the specimens included the measurement of the UCS and elastic

modulus, but not the Poisson's ratio. This represents a hybrid between Methods C and D of ASTM D7012-14.

1.2 Results

The results of UCS testing are summarized in Table 1. The corresponding stress-strain curves are presented in Figure 2. The Young's modulus is the tangent modulus, calculated as the slope of the best fit line through ±300 data points defining the stress-strain curve at 50.0% of the peak strength. Additional specimen and test details are provided on the summary spreadsheet that accompanies this report.

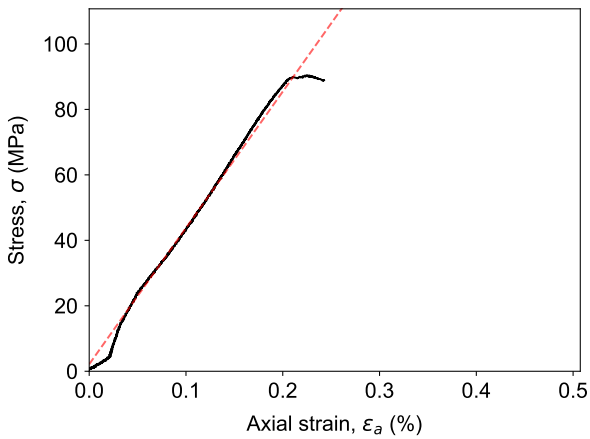
Table 1: Summary of Uniaxial Compression test results.

Sample	Depth (ft' in")	Bulk density ρ (g/cm^3)	UCS (MPa)	Young's modulus E (GPa)	Lithology	Failure description
Borehole C-02 Run 3	17'6" - 18'4"	2.789	90.4	41.6	Wacke, siltstone	1, 2
Borehole C-02 Run 5	29'1" - 29'6"	2.726	105.5	46.8	Wacke, siltstone	1
Borehole C-02 Run 8	38'4" - 39'8"	2.934	48.3	37.9	Wacke, siltstone	3

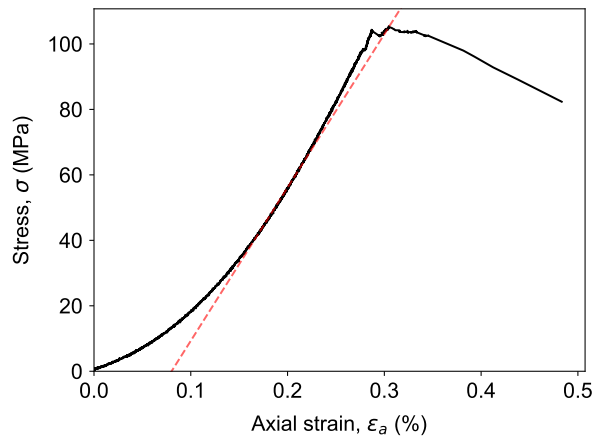
[1] Inclined shear fracture and axial splitting failure
[2] Failure partly along pre-existing structure
[3] Inclined shear failure

1.3 Specimen photographs

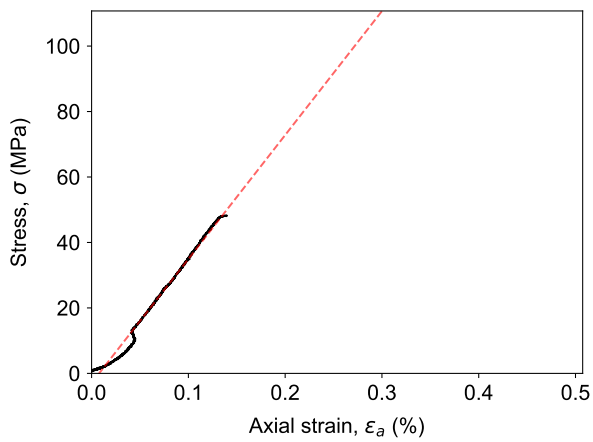
Photographs of the specimens before and after testing are presented in the Appendix of this report.



(a) BH-C-2-RUN3



(b) BH-C-2-RUN5



(c) BH-C-2-RUN8

Figure 2: Measured stress-strain curves.

Appendices

Specimen sheets

- BH C-2 RUN3
- BH C-2 RUN5
- BH C-2 RUN8

GEOMECHANICA

Uniaxial Compression Test

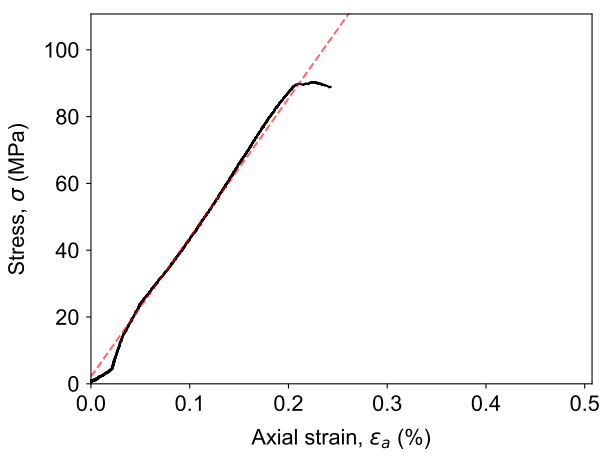
Client	Thurber Engineering Ltd.	**Project**	51583
Sample	BH C-2 RUN3	**Depth**	17’6” - 18’4”

Specimen parameters	
Diameter (mm) [a]	47.16
Length (mm) [a]	94.83
Bulk density ρ (g/cm^3)	2.789
UCS (MPa)	90.4
Young’s modulus E (GPa) [b]	41.6
Lithology	Wacke, siltstone
Failure description [c]	1, 2

[a] Additional specimen measurement/details provided in accompanying summary spreadsheet.
[b] Tangent modulus, calculated as the slope of the best fit line through ±300 data points on either side of the point representing 50.0% of the peak strength.
[c] Failure description: [1] Inclined shear fracture and axial splitting failure; [2] Failure partly along pre-existing structure;

Prior to testing

After testing



Remarks: Loading rate: 0.05 mm/min.

Performed by	HG	**Date**	2024-07-18

GEOMECHANICA

Uniaxial Compression Test

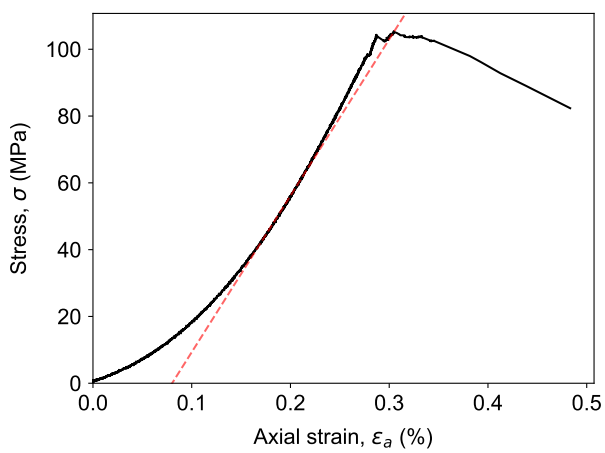
Client	Thurber Engineering Ltd.	**Project**	51583
Sample	BH C-2 RUN5	**Depth**	29’1” - 29’6”

Specimen parameters	
Diameter (mm) [a]	47.19
Length (mm) [a]	95.10
Bulk density ρ (g/cm^3)	2.726
UCS (MPa)	105.5
Young’s modulus E (GPa) [b]	46.8
Lithology	Wacke, siltstone
Failure description [c]	1

[a] Additional specimen measurement/details provided in accompanying summary spreadsheet.
[b] Tangent modulus, calculated as the slope of the best fit line through ±300 data points on either side of the point representing 50.0% of the peak strength.
[c] Failure description: [1] Inclined shear fracture and axial splitting failure;

Prior to testing

After testing



Remarks: Loading rate: 0.05 mm/min.

Performed by	HG	**Date**	2024-07-18

GEOMECHANICA

Uniaxial Compression Test

Client	Thurber Engineering Ltd.	**Project**	51583
Sample	BH C-2 RUN8	**Depth**	38’4” - 39’8”

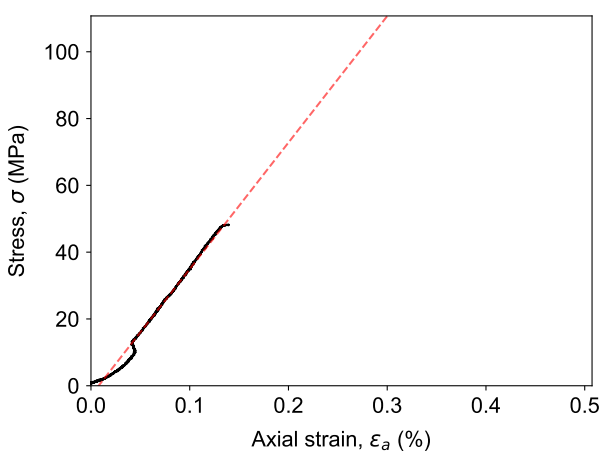
Specimen parameters

Diameter (mm) [a]	47.19
Length (mm) [a]	95.86
Bulk density ρ (g/cm^3)	2.934
UCS (MPa)	48.3
Young’s modulus E (GPa) [b]	37.9
Lithology	Wacke, siltstone
Failure description [c]	3

[a] Additional specimen measurement/details provided in accompanying summary spreadsheet.
[b] Tangent modulus, calculated as the slope of the best fit line through ±263 data points on either side of the point representing 50.0% of the peak strength.
[c] Failure description: [3] Inclined shear failure;

Prior to testing

After testing



Remarks: Loading rate: 0.05 mm/min.

Performed by	HG	**Date**	2024-07-18

FINAL REPORT

CA40134-JUL24 R1

51583

Prepared for

Thurber Engineering Ltd.

FINAL REPORT

First Page

CLIENT DETAILS		LABORATORY DETAILS	
Client	Thurber Engineering Ltd.	Project Specialist	Brad Moore Hon. B.Sc
		Laboratory	SGS Canada Inc.
Address	1908 Ironoak Way, Suite 202 Oakville, ON L6H 0N1. Canada	Address	185 Concession St., Lakefield ON, K0L 2H0
Contact	Ali Rajaei	Telephone	705-652-2143
Telephone		Facsimile	705-652-6365
Facsimile		Email	brad.moore@sgs.com
Email	arajaei@thurber.ca; jzoldy@thurber.ca	SGS Reference	CA40134-JUL24
Project	51583	Received	07/17/2024
Order Number		Approved	07/23/2024
Samples	Soil (1)	Report Number	CA40134-JUL24 R1
		Date Reported	07/23/2024

COMMENTS

Temperature of Sample upon Receipt: 8 degrees C
Cooling Agent Present:yes
Custody Seal Present:yes

Chain of Custody Number:n/a

Corrosivity Index is based on the American Water Works Corrosivity Scale according to AWWA C-105. An index greater than 10 indicates the soil matrix may be corrosive to cast iron alloys.

SIGNATORIES

Brad Moore Hon. B.Sc

TABLE OF CONTENTS

First Page..... 1

Index..... 2

Results..... 3

QC Summary..... 4-5

Legend..... 6

Annexes..... 7

FINAL REPORT

CA40134-JUL24 R1

Client: Thurber Engineering Ltd.
Project: 51583
Project Manager: Ali Rajaei
Samplers: Abdul Basit

MATRIX: SOIL

Sample Number	5
Sample Name	C-2 SS8
Sample Matrix	Soil
Sample Date	24/06/2024

Parameter	Units	RL		Result
Corrosivity Index				
Corrosivity Index	none	1		14
Soil Redox Potential	mV	no		192
Sulphide (Na2CO3)	%	0.01		0.02
pH	pH Units	0.05		8.04
Resistivity (calculated)	ohms.cm	-9999		568
General Chemistry				
Conductivity	uS/cm	2		1760
Metals and Inorganics				
Moisture Content	%	0.1		20.7
Sulphate	µg/g	0.4		180
Other (ORP)				
Chloride	µg/g	0.4		920

QC SUMMARY

Anions by IC

Method: EPA300/MA300-Ions1.3 | Internal ref.: ME-CA-[ENV]IC-LAK-AN-001

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Chloride	DIO0382-JUL24	µg/g	0.4	<0.4	5	35	102	80	120	95	75	125
Sulphate	DIO0382-JUL24	µg/g	0.4	<0.4	16	35	96	80	120	82	75	125

Carbon/Sulphur

Method: ASTM E1915-07A | Internal ref.: ME-CA-[ENV]ARD-LAK-AN-020

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Sulphide (Na2CO3)	ECS0064-JUL24	%	0.01	< 0.01								

Conductivity

Method: SM 2510 | Internal ref.: ME-CA-[ENV]EWL-LAK-AN-006

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Conductivity	EWL0447-JUL24	uS/cm	2	< 2	0	20	100	90	110	NA		

QC SUMMARY

pH

Method: SM 4500 | Internal ref.: ME-CA-[ENV]EWL-LAK-AN-001

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
pH	EWL0447-JUL24	pH Units	0.05	NA	1		100			NA		

Method Blank: a blank matrix that is carried through the entire analytical procedure. Used to assess laboratory contamination.

Duplicate: Paired analysis of a separate portion of the same sample that is carried through the entire analytical procedure. Used to evaluate measurement precision.

LCS/Spike Blank: Laboratory control sample or spike blank refer to a blank matrix to which a known amount of analyte has been added. Used to evaluate analyte recovery and laboratory accuracy without sample matrix effects.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate laboratory accuracy with sample matrix effects.

Reference Material: a material or substance matrix matched to the samples that contains a known amount of the analyte of interest. A reference material may be used in place of a matrix spike.

RL: Reporting limit

RPD: Relative percent difference

AC: Acceptance criteria

Multielement Scan Qualifier: as the number of analytes in a scan increases, so does the chance of a limit exceedance by random chance as opposed to a real method problem. Thus, in multielement scans, for the LCS and matrix spike, up to 10% of the analytes may exceed the quoted limits by up to 10% absolute and the spike is considered acceptable.

Duplicate Qualifier: for duplicates as the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.

Matrix Spike Qualifier: for matrix spikes, as the concentration of the native analyte increases, the uncertainty of the matrix spike recovery increases. Thus, the matrix spike acceptance limits apply only when the concentration of the matrix spike is greater than or equal to the concentration of the native analyte.

LEGEND

FOOTNOTES

NSS	Insufficient sample for analysis.
RL	Reporting Limit.
↑	Reporting limit raised.
↓	Reporting limit lowered.
NA	The sample was not analysed for this analyte
ND	Non Detect

Results relate only to the sample tested.
Data reported represent the sample as submitted to SGS. Solid samples expressed on a dry weight basis.
"Temperature Upon Receipt" is representative of the whole shipment and may not reflect the temperature of individual samples.
Analysis conducted on samples submitted pursuant to or as part of Reg. 153/04, are in accordance to the "Protocol for Analytical Methods Used in the Assessment of Properties under Part XV.1 of the Environmental Protection Act and Excess Soil Quality" published by the Ministry and dated March 9, 2004 as amended.

SGS provides criteria information (such as regulatory or guideline limits and summary of limit exceedances) as a service. Every attempt is made to ensure the criteria information in this report is accurate and current, however, it is not guaranteed. Comparison to the most current criteria is the responsibility of the client and SGS assumes no responsibility for the accuracy of the criteria levels indicated.

SGS Canada Inc. statement of conformity decision rule does not consider uncertainty when analytical results are compared to a specified standard or regulation.
This document is issued, on the Client's behalf, by the Company under its General Conditions of Service available on request and accessible at http://www.sgs.com/terms_and_conditions.htm.
The Client's attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein. Any other holder of this document is advised that information contained hereon reflects the Company's findings at the time of its intervention only and within the limits of Client's instructions, if any. The Company's sole responsibility is to its Client and this document does not exonerate parties to a transaction from exercising all their rights and obligations under the transaction documents. Reproduction of this analytical report in full or in part is prohibited.

This report supersedes all previous versions.

-- End of Analytical Report --

Request for Laboratory Services and CHAIN OF CUSTODY

SGS Environment, Health & Safety - Lakefield: 185 Concession St., Lakefield, ON K0L 2H0 Phone: 705-652-2000 Fax: 705-652-6365 Web: www.sgs.com/environment
- London: 657 Consortium Court, London, ON, N6E 2S8 Phone: 519-672-4500 Toll Free: 877-848-8060 Fax: 519-672-0361

No:

Page 1 of 1

Laboratory Information Section - Lab use only

Received By: Sean Gerner
Received Date (mm/dd/yy): 7/17/24
Received Time: 12:30
Received By (signature): [signature]
Custody Seal Present: ☑
Custody Seal Intact: ☑
Cooling Agent Present: ☑ Ice Pak
Temperature Upon Receipt (°C) 8°
LAB LIMS #: CA40134-Jul24

REPORT INFORMATION	INVOICE INFORMATION	PROJECT INFORMATION
Company: Thurber Engineering Ltd.	☑ (same as Report Information)	Quotation #:
Contact: Ali Rajaei	Company:	P.O. #:
Address: Unit 11, 1815 Ironstone Manor, Pickering, ON, L1W 3W9	Contact:	Project #: 51583
Phone: 416 575 9069	Address:	Site Location/ID:
Email: arajaei@thurber.ca	Phone:	
Email:	Email:	

TURNAROUND TIME (TAT) REQUIRED

☑ Regular TAT (5-7days) — TAT's are quoted in business days (exclude statutory holidays & weekends). Samples received after 6pm or on weekends: TAT begins next business day

RUSH TAT (Additional Charges May Apply): ☐ 1 Day ☐ 2 Days ☐ 3 Days ☐ 4 Days

PLEASE CONFIRM RUSH FEASIBILITY WITH SGS REPRESENTATIVE PRIOR TO SUBMISSION

Specify Due Date: Rush Confirmation ID:

REGULATIONS

Regulation 153/04: ☐ Table 1 ☐ Table 2 ☐ Table 3 ☐ Table ____ ☐ R/P/I ☐ I/C/C ☐ A/O
Soil Texture: ☐ Coarse ☐ Medium ☐ Fine

Other Regulations: ☐ Reg 347/558 (3 Day min TAT) ☐ PWQO ☐ MMER ☐ CCME ☐ Other: ☐ MISA

Sewer By-Law: ☐ Sanitary ☐ Storm
Municipality:

NOTE: DRINKING (POTABLE) WATER SAMPLES FOR HUMAN CONSUMPTION MUST BE SUBMITTED WITH SGS DRINKING WATER CHAIN OF CUSTODY

RECORD OF SITE CONDITION (RSC) ☐ YES ☑ NO

ANALYSIS REQUESTED

	SAMPLE IDENTIFICATION	DATE SAMPLED	TIME SAMPLED	# OF BOTTLES	MATRIX	Field Filtered (Y/N)	Metals & Inorganics	PAH ☐ ABN ☐ SVOC(all) ☐	PCB Total ☐ Aroclor ☐	PHC F1-F4 ☐ VOC ☐ BTEX ☐ BTEX/F1 ☐ F2-F4 ☐	VOC ☐ BTEX ☐ THM ☐	Pesticides OC ☐ OP ☐	TCLP M&I ☐ VOC ☐ PCB ☐ B(a)P ☐ ABN ☐ Ignit. ☐	Water Pkg Gen. ☐ Ext. ☐	Sewer Use:	Corrosivity/Resistivity					COMMENTS:
1	C-2 SS8	6/24/24	AM	1	Soil		☐	☐	☐	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	
2							☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
3							☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
4							☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
5							☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
6							☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
7							☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
8							☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
9							☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
10							☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
11							☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
12							☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

Observations/Comments/Special Instructions

Sampled By (NAME): Abdul Basit	**Signature:** AB	Date: 07/16/24	(mm/dd/yy)	Pink Copy - Client
Relinquished by (NAME): Abdul Basit	**Signature:** AB	Date: 07/16/24	(mm/dd/yy)	Yellow & White Copy - SGS

Revision #: 1.1
Date of Issue: 04 April, 2018