THURBER ENGINEERING LTD.

FOUNDATION INVESTIGATION AND DESIGN REPORT
COUNTY ROAD 30 - GABION WALL ON EAST CUT SLOPE
BETWEEN STATIONS 11+580 AND 11+640
BRIGHTON, ON
G.W.P. 4016-13-01

GEOCRES NO. 31C-266

Report

to

AECOM

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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 design and construction of the proposed gabion wall in County Road 30, Brighton, Ontario on the east side slope located approximately 230 m north of Newton Lane. 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 a borehole location plan and soil strata drawing 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 present investigation.

2 SITE AND PROJECT DESCRIPTION

The site is located on County Road 30, approximately 300 m south of Highway 401 in Brighton, Ontario. Based on the preliminary road grading drawings and cross section drawings provided by AECOM, the road grade between approximately Sta.11+460 and 11+760 on County Road 30 will be lowered; resulting in widening the cut slope adjacent to the Road. The east slope of the widened cut will encroach into private property beyond MTO's right-of-way between approximately Sta.11+580 and 11+640. Therefore, construction of a mid-slope gabion wall has been proposed so that the east slope of the final cut could remain within MTO's right-of-way. To provide foundation and construction recommendations for the gabion wall, a geotechnical investigation is required.

The existing east slope between Stations 11+580 and 11+640 has an inclination of 2H:1V with a height of approximately 5 to 6.5 m. The vegetation on the slope is limited to local grass with some trees and shrubs.

From published geological information in *The Physiography of Southern Ontario* by Chapman and Putnam (1984), the site lies within the physiographic region known as Iroquois Plain. The Iroquois Plain generally consists of glacio-lacustrine sand and silty sand. The overburden soils are underlain by limestone bedrock.

3 INVESTIGATION PROCEDURES

The site investigation for this project was carried out between October 3 and October 5, 2016 during which time a total of two (2) boreholes denoted as Boreholes GW 16-01 and GW 16-02 were advanced to a depth of 9.3 m (see Table 3.1).

Borehole GW 16-01 was advanced approximately 10 m south of the north edge of the proposed gabion wall; whereas, borehole GW 16-02 was drilled approximately 20 m north of the south edge of the gabion wall. The locations of the two boreholes are shown on the Borehole Locations and Soil Strata Drawing provided in Appendix C.

Table 3.1 – Borehole Details

Borehole Number	Approximate Station	Approximate Ground Elevation (m)	Borehole Termination Depth (m)	Borehole Termination Elevation (m)
GW 16-01	11+630	204.5	9.3	195.2
GW 16-02	11+605	203.5	9.3	194.2

Drilling was carried out using portable tri-pod equipment with wash boring technique. All drilling equipment was supplied and operated by OGS Inc. Soil samples were obtained at selected intervals using a 50 mm diameter split spoon sampler in conjunction with Standard Penetration Testing (SPT).

Groundwater conditions were observed in the open boreholes throughout the drilling operations. Upon completion of drilling, the two boreholes were backfilled in general accordance with Ontario Regulation 903.

Table 3-2. Borehole Backfilling Details

Borehole	Borehole Termination Depth/ Elevation (m)	Borehole Backfilling Details
GW16-01	9.3 / 195.2	Borehole backfilled with bentonite holeplug to surface.
GW16-02	9.3 / 194.2	Borehole backfilled with bentonite holeplug to surface.

The field work was supervised on a full-time basis by a member of Thurber's technical staff who marked/staked the boreholes in the field, arranged for the clearance of buried utilities, directed the drilling, sampling and in-situ testing operations, logged the boreholes and processed the recovered soil samples for transport to Thurber's laboratory for further examination and testing.

4 LABORATORY TESTING

Geotechnical laboratory testing was carried out at Thurber's laboratory. All recovered soil samples were subjected to visual identification and to natural moisture content determination. Selected samples were also subjected to grain size distribution analysis (hydrometer and/or sieve analysis). Laboratory testing results are summarized on the Record of Borehole sheets included in Appendix A and are presented on the figures 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 paragraphs. 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 stratigraphy encountered in boreholes GW 16-01 and GW 16-02 consists of surficial topsoil overlying sandy silt fill, underlain by glacial till ranging from sand, silty sand, sandy silt to silt to a termination depth of 9.3 m. The groundwater levels are in the order of 4 to 5 m below ground surface at the borehole locations.

5.1 Topsoil

A 75 mm thick topsoil layer was encountered at ground surface in both Boreholes GW 16-01 and GW 16-02.

5.2 Sandy Silt Fill

A fill layer consisting of brown sandy silt with some clay and trace roots and organics was encountered immediately beneath the topsoil in both boreholes. The thickness of the sandy silt fill layer was 0.7 m.

SPT ‘N’ values recorded in the sandy silt fill ranged between 7 and 11 blows per 0.3 m of penetration, indicating a loose to compact condition. Measured moisture contents within the fill were 12% to 13%.

The result of grain size distribution analysis carried out on one sample of the sandy silt fill is presented on the Record of Borehole Sheets included in Appendix A and on Figure B1 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	0
Sand	21
Silt	64
Clay	15

5.3 Silt Till

A layer of silt till with trace to some clay, trace sand, and trace gravel was encountered below the fill in Boreholes GW 16-01 and GW 16-02. The thickness of this till layer varied from 5.0 m to 7.7 m (Base Elevation ranged from 196.0 m to 197.7 m).

SPT 'N' values recorded in this layer ranged from 79 blows per 0.3 m penetration to greater than 50 blows for less than 0.3 m of penetration, indicating a very dense condition. Measured moisture contents within this layer varied between 11% and 24%.

The results of grain size distribution analyses carried out on selected samples of this layer are presented on the Record of Borehole Sheets included in Appendix A and on Figure B2 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	0 to 10
Sand	0 to 12
Silt	68 to 91
Clay	9 to 11

Glacial tills inherently contain cobbles and boulders. The high blow counts may represent the presence of cobbles and boulders.

5.4 Silty Sand to Sandy Silt Till

A deposit of silty sand to sandy silt till with trace to some gravel and trace clay was encountered below the silt till in Boreholes GW16-01 and GW16-02. The two boreholes were terminated within this till layer at a depth of 9.3 m below the ground surface.

SPT 'N' values recorded in this layer were greater than 50 blows for less than 0.3 m of penetration, indicating a very dense condition. Measured moisture contents within this layer varied between 18% and 22%.

The results of grain size distribution analyses carried out on one sample of the silty sand to sandy silt till layer is presented on the Record of Borehole Sheets included in Appendix A and on Figures B3 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	0
Sand	58
Silt and Clay	42

Glacial tills inherently contain cobbles and boulders. The high blow counts may represent the presence of cobbles and boulders.

5.5 Sand

An interlayer of native sand with some silt and trace clay and gravel was encountered within the silt till layer in Borehole GW 16-01. The thickness of this sand layer was 1.8 m (Top and Base Elevations were 202.2 m and 200.4 m, respectively).

SPT 'N' values recorded in the sand layer were typically greater than 50 blows for less than 0.3 m of penetration, indicating a very dense condition. Measured moisture contents within the sand were 8% to 15%.

The result of grain size distribution analysis carried out on one sample of the sand layer is presented on the Record of Borehole Sheets included in Appendix A and on Figure B4 of Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	6
Sand	79
Silt and Clay	15

5.6 Groundwater Conditions

Groundwater conditions were observed during drilling operations and groundwater levels were measured in the open boreholes upon completion of drilling. The groundwater levels measured in the boreholes GW 16-01 and GW 16-02 were 4.6 and 4.3 m below ground surface, respectively.

These levels are short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant or prolonged precipitation events.

6 MISCELLANEOUS

Thurber marked and/or staked the borehole locations in the field and obtained buried utility clearances prior to drilling.

Geotechnical laboratory testing was carried out at Thurber's MTO approved high complexity Toronto area laboratory.

OGS Inc. 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 a member of Thurber's technical staff. Overall supervision of the investigation program was conducted by Dr. Mohamad Hosney, P.Eng. Compilation of data and preparation of the report was carried out by Dr. Mohamad Hosney, P.Eng. and Mr. Jason Lee, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., who is a Designated Principal Contact for MTO Foundations Projects.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This report provides interpretation of the geotechnical data in the factual report and presents geotechnical recommendations for the design of the proposed gabion wall in County Road 30, Brighton, Ontario.

This foundation 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. 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 to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the information provided as it may affect equipment selection, proposed construction methods and scheduling.

Preliminary road grading and cross section drawings were provided by AECOM to Thurber on September 15, 2016. These drawings indicate that, from Stations 11+580 to 11+640, the road grade of County Road 30 will be lowered by 1.5 m to 2 m. The grade lowering will result in widening of the east cut slope which will then encroach beyond the MTO right-of-way. As a solution, construction of a mid-slope gabion wall has been proposed to retain the cut slope and keep the final east slope within the MTO right-of-way.

8 LAYOUT OF GABION WALL

A 60 m long gabion wall is proposed part way up the east cut slope between Stations 11+580 and 11+640 on County Road 30. The proposed gabion wall is approximately 2.5 m in height with a base width of 2 m. The proposed foundation elevation of the gabion wall varies between 201.1 and 202.2 m.

The bearing capacity and the global stability of the gabion wall are addressed in the following sections.

9 FOUNDATION OF GABION WALL

According to the GA drawings, the foundation elevation for the gabion wall varies between 201.1 m and 202.2 m. The soils encountered at these elevations are very dense silt till at station 11+605 and very dense sand at station 11+630.

It is recommended that the gabion walls be founded on a 300 mm thick pad of engineered fill resting on the native very dense silt, or on the native very dense sand. The engineered fill pad is required to provide subgrade uniformity along the gabion wall alignments. This pad should consist of compacted Granular A materials and have a minimum thickness of 300 mm.

The following geotechnical capacities are recommended for design of a gabion wall foundation of 2 m in width founded at or below Elev. 201.1 m on the subgrade described above:

- Factored Geotechnical Resistance at ULS of 400 kPa
- Geotechnical Resistance at SLS (for up to than 25 mm of settlement) of 260 kPa.

The ULS resistance and settlement are dependent on the gabion wall footprint, configuration and applied loads. As indicated on the drawings provided by AECOM, the width of the gabion wall base is 2.0 m and the foundation depth is approximately 1.5 m below the ground surface. The east cut slope has a design slope inclination of 2H:1V. The geotechnical resistances should be reviewed if the foundation dimensions, thickness of soil above footings, slope inclination, and/or founding elevation differ from that given above.

The geotechnical resistances presented above are for vertical, concentric loads. Where eccentric or inclined loads are applied, the resistance used in design must be reduced in accordance with the CHBDC 2014, Clause 6.10.3 and Clause 6.10.4.

The internal stability of the gabion wall must be checked against various modes of failure including but not limited to sliding and overturning. Resistance to lateral forces / sliding resistance between the gabion basket and the compacted Granular A subgrade should be calculated assuming an ultimate coefficient of friction of 0.60. In addition, gabion wall should be designed to resist external loadings including frost forces, lateral earth pressures, hydrostatic pressure, weight of backfill, and surcharge due to construction equipment.

Prior to constructing the engineered fill pad, the subgrade should be inspected, and any surficial or buried topsoil, loose, soft soils or otherwise disturbed materials should be removed. The exposed sand till and silt till subgrade must be properly prepared to avoid prolonged exposure. Placement and compaction of the Granular A pad must be carried out in the dry in general accordance with OPSS.PROV 501.

Excavation and backfilling for foundation construction should be carried out with reference to the requirements in OPSS 902. Special attention and care should be given to excavation operations in order not to destabilize the existing slopes.

10 GLOBAL STABILITY

Based on the slope configurations provided by AECOM, limit equilibrium stability analyses were carried out for a representative case. The stability analyses were carried out using the commercially available slope stability program GEO-SLOPE and employing the Morgenstern-Price method of slices for limit equilibrium.

As per MTO practice, a minimum Factor of Safety (F.S.) of 1.3 is acceptable for maintaining global stability for a typical highway cut.

The geotechnical parameters used in the stability analyses were determined from the in-situ testing conducted during the field investigation and/or estimated from soil index correlations.

All stability analyses were carried out under static conditions for the current conditions and after the construction of the gabion wall both using drained shear strength parameters. Fill consisting of OPSS Granular B Type I material was assumed to be used behind the gabion wall. These parameters and the results of the stability analyses are shown on the Figures D1 and D2 in Appendix D. For the case examined, a factor of safety of 1.26 was estimated for the existing condition and a factor of safety of 1.34 was calculated for the case after the construction of the gabion wall. This slope stability analyses indicate that the Factors of Safety acceptance criteria outlined above are generally satisfied for the cases analysed.

11 SETTLEMENT

Foundation settlement in response to the fill placement behind the gabion wall is estimated to be less than 25 mm and will be essentially complete at the end of construction. It is anticipated that post-construction foundation settlement is negligible.

12 BACKFILL AND LATERAL PRESSURES

The backfill to the gabion wall should be in accordance with OPSS 902. Any backfill to the wall should be free draining and consist of Granular A or Granular B Type II material meeting the requirements of OPSS.PROV 1010.

Earth pressures acting on the gabion wall may be assumed to be triangular and to be governed by the characteristics of the backfill. For a fully drained condition, the pressures should be computed in accordance with the CHBDC but are generally given by the expression:

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

where: p_h = horizontal pressure on the wall at depth h (kPa)

K = earth pressure coefficient (see Table 12.1)

γ = unit weight of retained soil (see Table 12.1)

h = depth below top of fill where pressure is computed (m)

q = value of any surcharge (kPa).

In accordance with Clause 6.9.3 of the CHBDC, a compaction surcharge should be added. Compaction equipment to be used adjacent to retaining structures should be restricted in accordance with OPSS.PROV 501.

Earth pressure coefficients for backfill to the retaining wall are dependent on the material used as backfill. Typical values are shown in Table 12.1.

Table 12.1 – Earth Pressure Coefficients

Wall Condition	Earth Pressure Coefficients (K)			
	OPSS Granular A and Granular B Type II $\phi = 35°$, $\gamma = 22.8$ kN/m^3		OPSS Granular B Type I and Type III $\phi = 32°$, $\gamma = 21.2$ kN/m^3	
	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.40*	0.31	0.48
At rest (Restrained Wall)	0.43	-	0.47	-
Passive (Movement towards soil mass)	3.7	-	3.3	-

* For 2H:1V backfill slope behind proposed gabion wall

If the wall is permitted to yield (unrestrained system), active horizontal earth pressure may be used in the geotechnical design of the wall. If the wall is not allowed to yield (restrained system), at-rest horizontal earth pressures should be used.

In conventional design, the use of a material with a high friction angle and low active pressure coefficient (e.g. Granular A, Granular B Type II) might be preferred as it results in lower earth pressures acting on the wall.

The factors in Table 12.1 are “ultimate” values and require certain movements for the respective conditions to be mobilized. The values to be used in design can be estimated from Figure C6.16 in the Commentary to the CHBDC 2014.

Prior to fill placement behind the gabion wall, the subgrade must be adequately prepared to receive the fill. Within fill areas, all soft/loosened or wet soils should be sub-excavated. All subgrade should be inspected and approved prior to placing fill.

Vegetation cover should be established on all exposed earth slopes for protection against surficial erosion. Reference should be made to OPSS.PROV 804.

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13 EXCAVATION AND GABION WALL CONSTRUCTION

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

Excavation for gabion wall construction will extend predominantly through the sandy silt fill and into the native glacial till. For the purpose of OHSA, the existing fill may be classified as Type 3 soils. Native soils are Type 2 above water table and Type 3 below water table.

All excavations must be carried out in a manner that avoids destabilising the existing slopes.

Excavation and backfilling for foundation construction should be carried out with reference to the requirements in OPSS 902. Where required, excavation for cut slope construction should be carried out in accordance with OPSS.PROV 206.

Material specifications for components used for the construction of the gabion wall (e.g., aggregates, wire mesh, PVC coating, fasteners, etc.) should meet the requirements of OPSS. 1430 and OPSS.PROV 1004.

14 GROUNDWATER AND EROSION CONTROL

Since the excavations for the gabion wall foundation are not expected to extend below the groundwater level, groundwater control will likely be limited to diverting surface runoff and preventing precipitation from entering the excavations. However, groundwater perched in the sand layer within the silt till deposit may seep into local excavations. The design of the gabion wall foundations will not be influenced by the groundwater, but the Contractor must make provision to control the water seepage and ponding by using sump pumps to remove any accumulated water from the foundation base prior to compacting granular fill. Surface runoff may also tend to pond in the excavations. Control of groundwater seepage and surface water flow is the responsibility of the Contractor.

Temporary drainage of the cut slopes should be provided to maintain a relatively dry, stable excavation. Permanent drainage of the cut slope must also be provided. Roadside ditches are expected to provide an adequate level of surface drainage at this site.

Where fine-grained silt soils are exposed on a cut slope, the native soils may become negatively impacted after spring thaw and/or ingress of surface water. The properties of the soils are such that the fluctuation in moisture content is likely to soften the soils and to result in erosion and/or sloughing of the soils and resulting in instability of the cut slopes. Such areas must be protected from erosion both on a temporary and permanent basis.

Temporary and/or permanent erosion and sedimentation control measures must be in place and maintained at all times so as to prevent any deleterious material or fines from entering into any drainage feature or watercourse.

15 SEISMIC CONSIDERATIONS

The seismic site classification for this is site is based on the N_{60} criteria. The harmonic mean of the typical N_{60} values provided above is 50 blows, which corresponds to a Seismic Site Class C in accordance with Table 4.1, Clause 4.4.3.2 of the CHBDC. The peak ground acceleration, PGA, for a 2% in 50 years probability of exceedance at this site is 0.105 as per the National Building Code of Canada (NBCC).

In accordance with Clause 4.6.5 of the CHBDC 2014, retaining structures should be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in Table 14.1 may be used:

Table 14.1 – Earth Pressure Coefficients for Earthquake Loading

Condition	Earth Pressure Coefficient (K)	
	OPSS Granular A or Granular B Type II $\phi = 35°, \gamma = 22.8$ kN/m^3	OPSS Granular B Type I or Type III $\phi = 32°, \gamma = 21.2$ kN/m^3
Active (K_{AE})*	0.33	0.37
Passive (K_{PE})	3.5	3.1
At Rest (K_{OE})**	0.61	0.65

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

Given that the main deposit at the site location is very dense glacial till, in view of the potential for seismic activity in the area, liquefaction is not considered to be a concern at this site

16 FROST PROTECTION

The depth of frost penetration at this site is approximately 1.4 m as per OPSD 3090.1010.

17 TEMPORARY ROADWAY PROTECTION DESIGN

Temporary roadway protection may be required during the gabion wall construction . The design of roadway protection should be the responsibility of the Contractor. Any protection system must be designed by licensed Professional Engineers experienced in such designs. An item titled "Protection System" as per OPSS.PROV 539 (Level 2) should be included in the contract documents

A potential temporary roadway protection system is a temporary interlocking sheet pile system however installation of such system into very dense silt till may be difficult. The temporary roadway protection system may be designed using the parameters in the table below:

Soil Parameter	Existing Fill	Native Very Dense Sand / Till
Bulk Unit Weight (γ)	20 kN/m^3	21 kN/m^3
Submerged Unit Weight (γ_w)	10 kN/m^3	11 kN/m^3
Coefficient of Active Earth Pressure (K_a)	0.33	0.26
Coefficient of Passive Earth Pressure (K_p)	3.0	3.8

The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall, and these factors must be considered when designing the shoring system.

18 CONSTRUCTION CONCERNS

During construction, the Contract Administrator should employ experienced foundation/geotechnical staff to observe construction activities.

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

- The water level may fluctuate and be at higher elevation at the time of construction than indicated in the report. Although not encountered in the boreholes, a perched water table may be present and groundwater from water-bearing sands in the cut slope should be expected.
- The cut slopes should be inspected during and after construction. No material stockpiling should be allowed at the crest of the slope. Where necessary, remedial measures such as hydroseeding and/or placement of gravel sheeting may be required.
- In areas with gabion wall construction, care must be exercised during excavation to avoid disturbing the founding subgrade. When the excavation reaches the required elevation, the subgrade should be inspected and approved by qualified geotechnical personnel

19 CLOSURE

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

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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

C_{pen} 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)**	**(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			

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No GW16-01

METRIC

W.P. 4016-13-01	LOCATION Gabion Retaining Wall N 4 882 115.2 E 203 317.1		ORIGINATED BY OA
HWY County Rd. 30	BOREHOLE TYPE Tripod		COMPILED BY AN
DATUM Geodetic	DATE 2016.10.03 - 2016.10.04		CHECKED BY MH

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
204.5	GROUND SURFACE
0.0 / 0.1	**TOPSOIL:** (75mm)
203.7 / 0.8	Sandy **SILT**, some clay, some organics, trace roots. Compact. Brown. Damp. (FILL)
202.2 / 2.3	**SILT**, some sand, trace gravel. Very Dense. Grey. Moist. (TILL)
200.4 / 4.1	**SAND**, some silt, trace clay, trace gravel. Very Dense. Grey. Moist
196.0 / 8.5	**SILT**, some sand, some gravel, some clay. Very Dense. Grey. Wet. (TILL)
195.2 / 9.3	Sandy **SILT**, some gravel, trace clay. Very Dense. Grey. Moist. (TILL)
	END OF BOREHOLE AT 9.3m. BOREHOLE OPEN AND WATER LEVEL AT 4.6m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	11	0	21	64	15
2	SS	50/ 0.100				
3	SS	50/ 0.125				
4	SS	50/ 0.100	6	79	15 (SI+CL)	
5	SS	50/ 0.075				
6	SS	50/ 0.125				
7	SS	50/ 0.075	10	12	68	10
8	SS	50/ 0.125				
9	SS	50/ 0.075				
10	SS	50/ 0.125				

GROUND WATER CONDITIONS: water level symbol at approx. elev. 200.0

ELEVATION SCALE: 204, 203, 202, 201, 200, 199, 198, 197, 196

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

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No GW16-02

METRIC

W.P.	4016-13-01	LOCATION	Gabion Retaining Wall N 4 882 091.1 E 203 327.5	ORIGINATED BY	OA
HWY	County Rd. 30	BOREHOLE TYPE	Tripod	COMPILED BY	AN
DATUM	Geodetic	DATE	2016.10.05 - 2016.10.05	CHECKED BY	MH

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
203.5	GROUND SURFACE
0.0	**TOPSOIL:** (75mm)
0.1	Sandy **SILT**, some clay, trace organics, trace roots Loose Brown Moist (FILL)
202.7 0.8	**SILT**, trace to some clay, trace sand, trace gravel Very Dense Grey Moist (TILL) 125mm boulders and cobbles at 5.8m
197.7 5.8	Silty **SAND**, trace clay, trace gravel Very Dense Grey Moist (TILL)
194.2 9.3	END OF BOREHOLE AT 9.3m. BOREHOLE OPEN AND WATER LEVEL AT 4.3m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.

Continued Next Page

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	7				
2	SS	79	0	4	87	9
3	SS	50/ 0.150				
4	SS	50/ 0.075	0	0	89	11
5	SS	50/ 0.125				
6	SS	50/ 0.075	0	0	91	9
7	SS	50/ 0.150				
8	SS	50/ 0.150				
9	SS	50/ 0.150				
10	SS	50/ 0.150	0	58	42 (SI+CL)	

GROUND WATER CONDITIONS: water level symbol at approx. elevation 199.2

ELEVATION SCALE: 203, 202, 201, 200, 199, 198, 197, 196, 195

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

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

ONTMT4S 0620.GPJ 2015TEMPLATE(MTO).GDT 12/22/16

THURBER

Appendix B

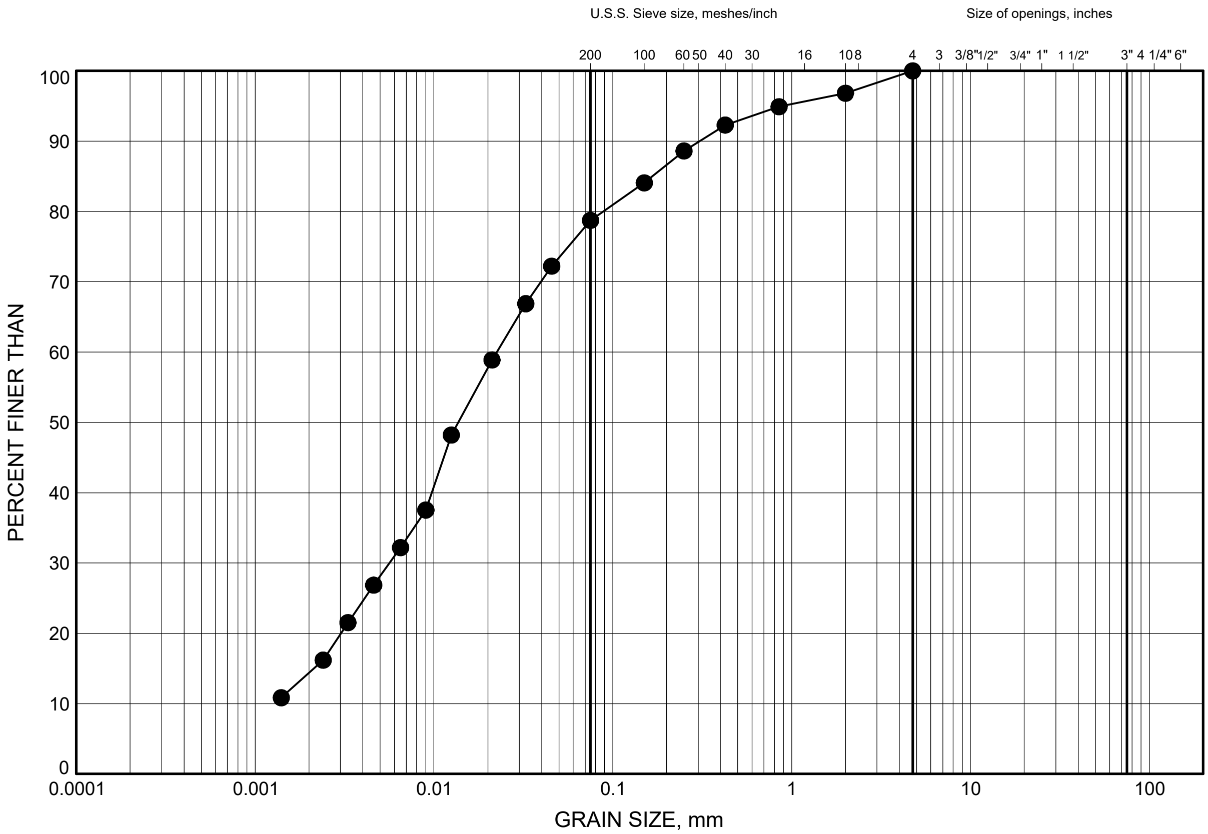
Laboratory Test Results

Gabion Retaining Wall

GRAIN SIZE DISTRIBUTION

FIGURE B1

Sandy SILT FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	GW16-01	0.30	204.20

Date December 2016

W.P. 4016-13-01

THURBER

Prep'd AN

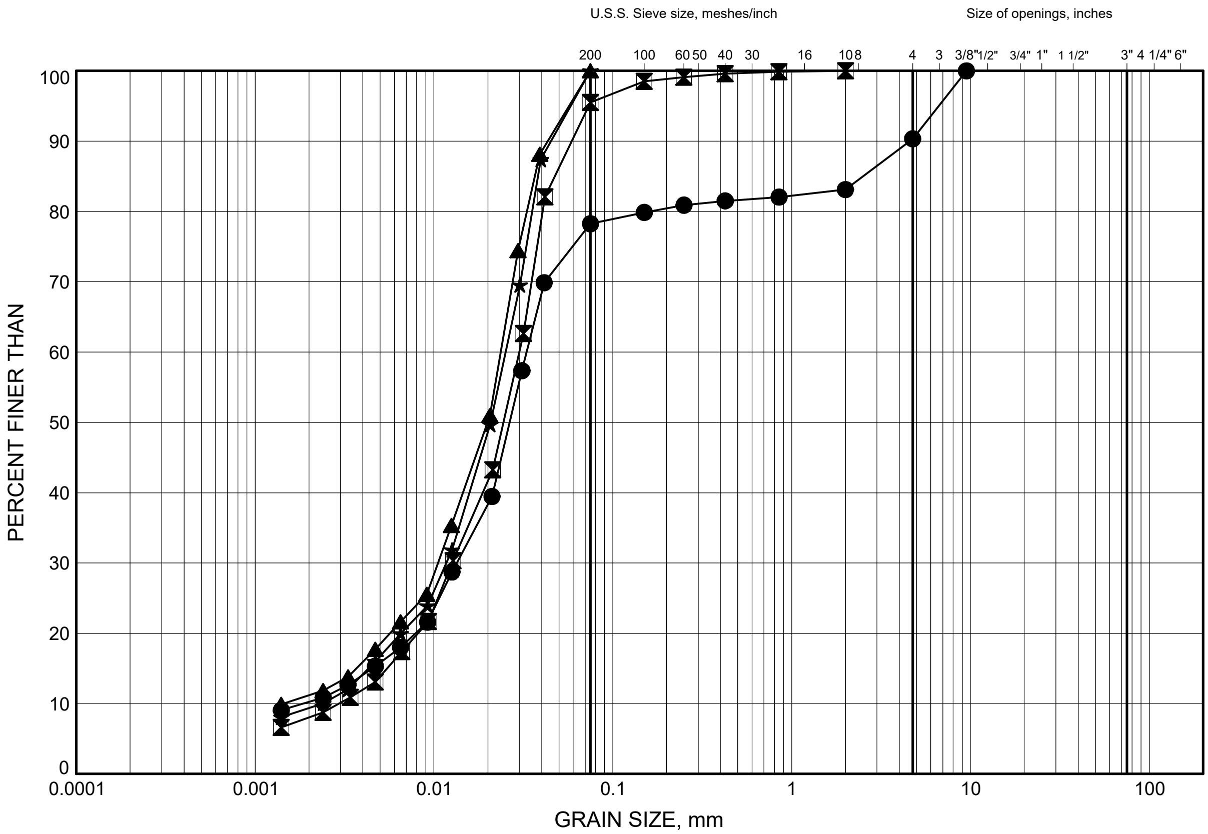
Chkd. MH

Gabion Retaining Wall

GRAIN SIZE DISTRIBUTION

FIGURE B2

Sandy SILT to SILT TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	GW16-01	5.41	199.09
⧗	GW16-02	1.07	202.43
▲	GW16-02	2.40	201.10
★	GW16-02	4.76	198.74

Date December 2016

W.P. 4016-13-01

THURBER

Prep'd AN

Chkd. MH

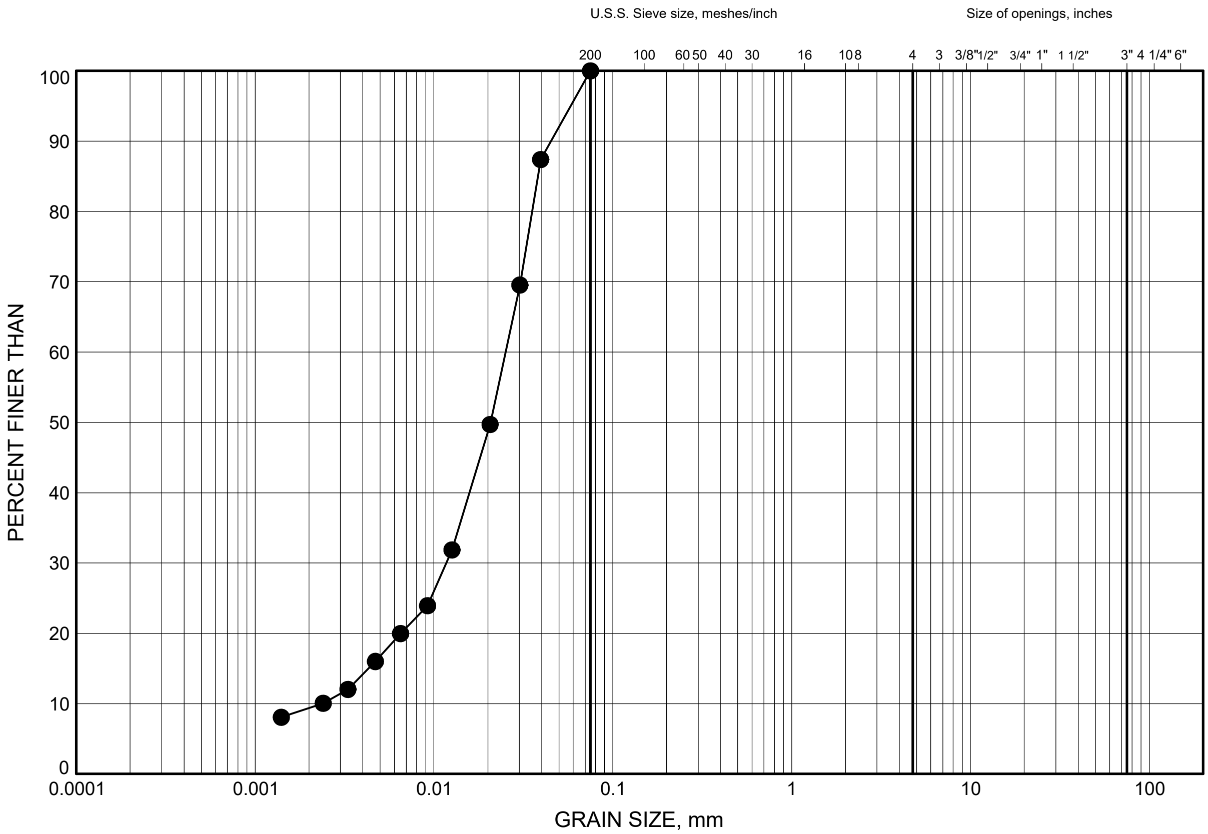
GRAIN SIZE DISTRIBUTION - THURBER 0620.GPJ 12/16/16

Gabion Retaining Wall

GRAIN SIZE DISTRIBUTION

FIGURE B3

Silty SAND TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	GW16-02	4.76	198.74

Date December 2016

W.P. 4016-13-01

THURBER

Prep'd AN

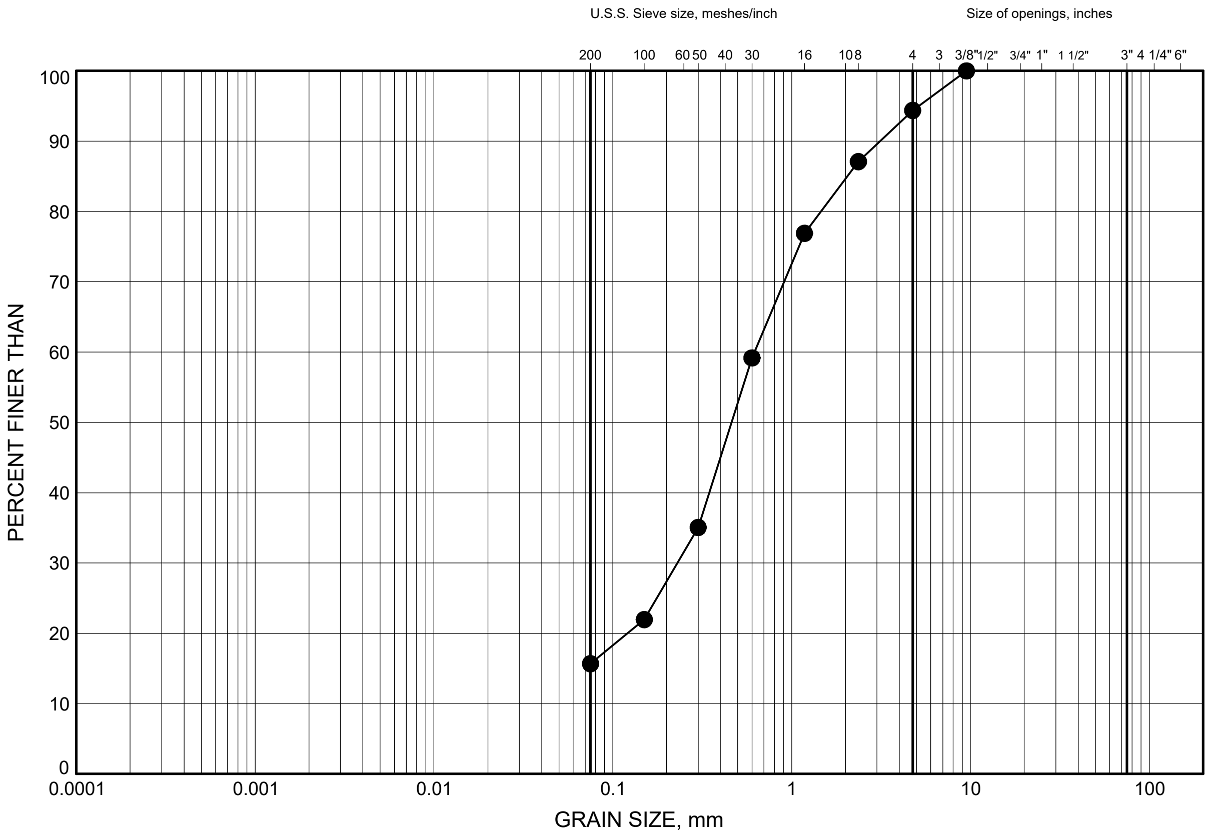
Chkd. MH

Gabion Retaining Wall

GRAIN SIZE DISTRIBUTION

FIGURE B4

SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	GW16-01	2.41	202.09

GRAIN SIZE DISTRIBUTION - THURBER 0620.GPJ 12/16/16

Date December 2016

W.P. 4016-13-01

THURBER

Prep'd AN

Chkd. MH

THURBER

Appendix C

Drawing titled "Borehole Locations and Soil Strata"

MINISTRY OF TRANSPORTATION, ONTARIO

METRIC

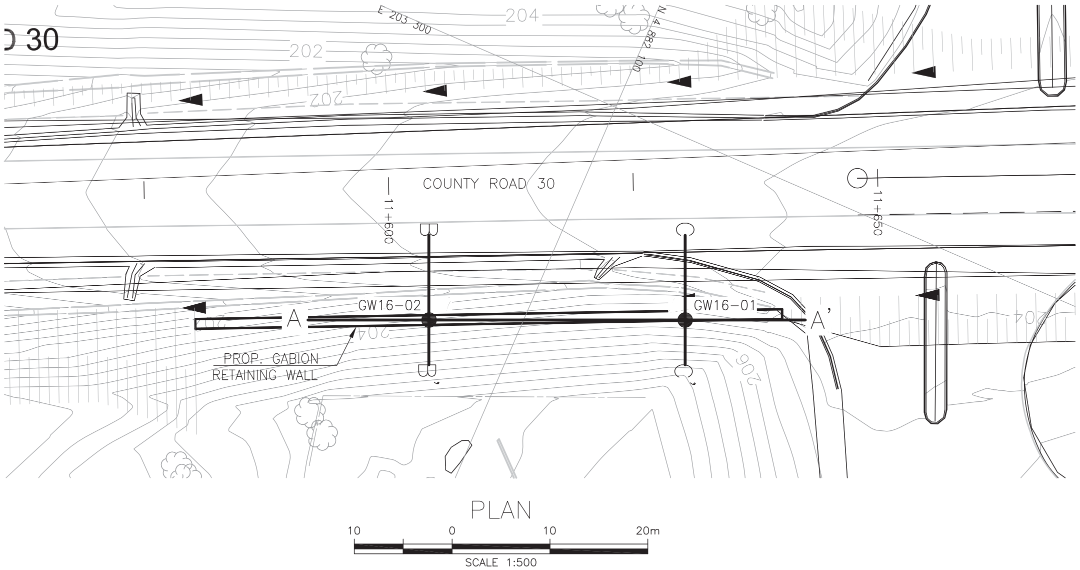
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No
WP No 4016-13-01

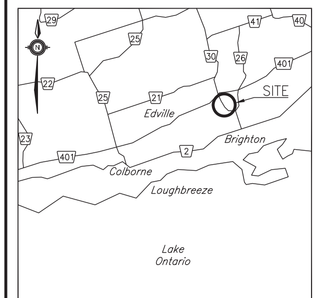
HIGHWAY 401
COUNTY ROAD 30
GABOIN RETAINING WALL
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

THURBER ENGINEERING LTD.



PLAN

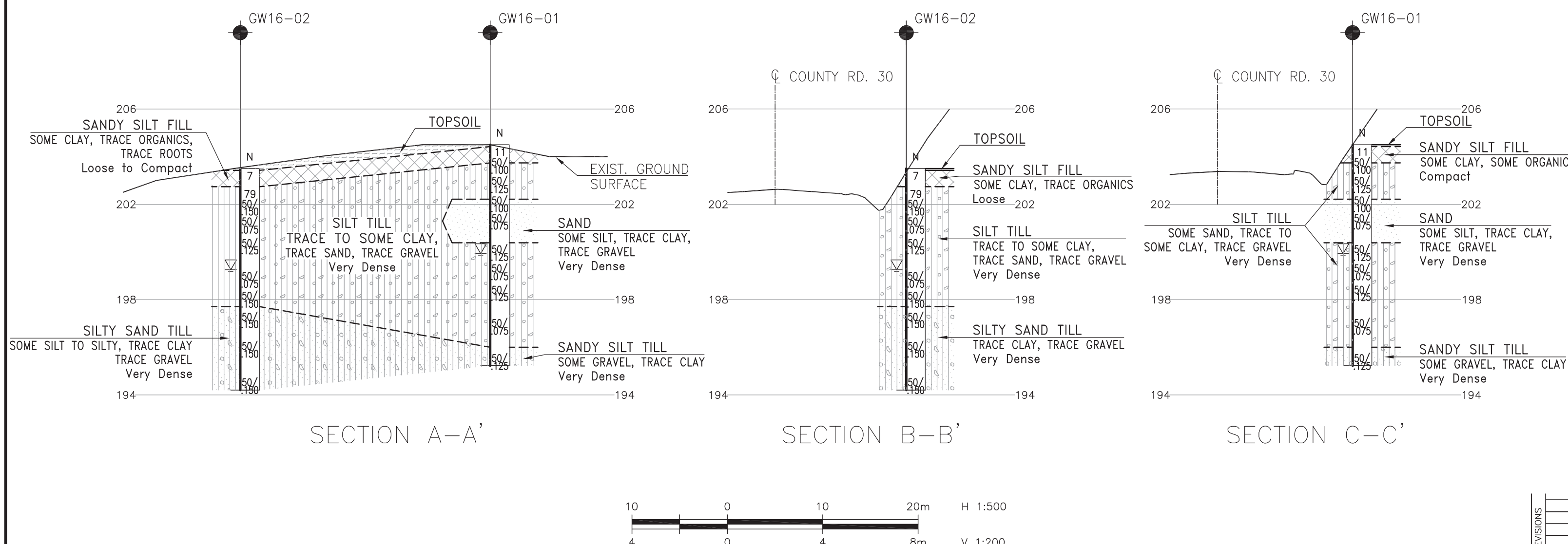


KEYPLAN

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
GW16-01	204.5	4 882 115.2	203 317.1
GW16-02	203.5	4 882 091.1	203 327.5



SECTION A-A'

SECTION B-B'

SECTION C-C'

-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-266

REVISIONS	DATE	BY	DESCRIPTION

DESIGN PP	CHK SKP	CODE	LOAD	DATE DEC 2016
DRAWN AN	CHK PP	SITE	STRUCT	DWG 1

FILENAME: H:\Drafting\19\4406\20\ted0620-Plan&Profile(GabionWall).dwg
PLOTDATE: 12/22/2016 11:51 AM

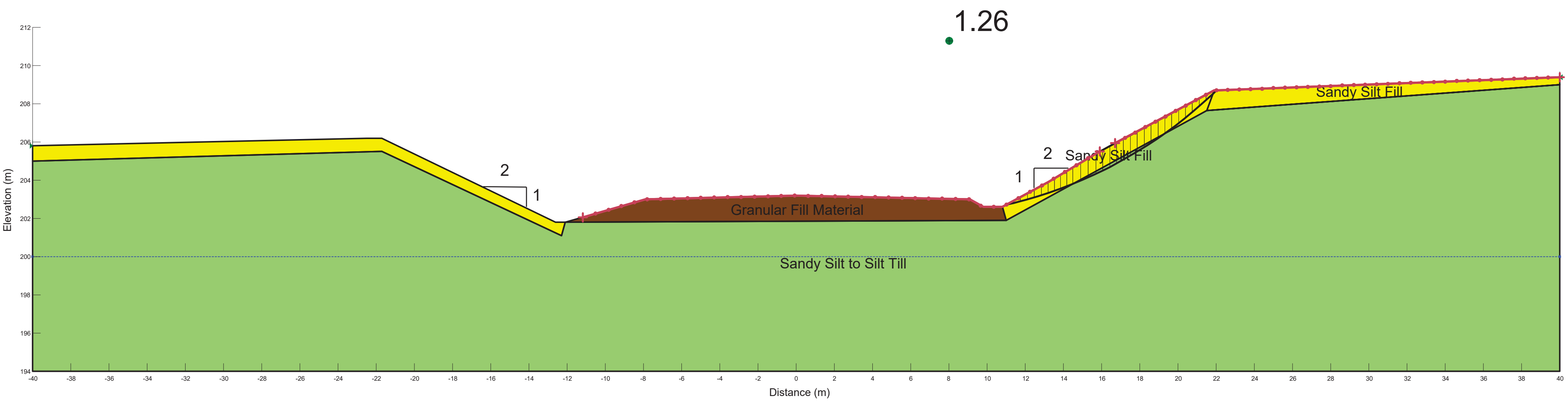
Appendix D

Slope Stability Analyses Results

MEGA FOUR – COUNTY ROAD 30 – GABION WALL
BRIGHTON, ON
SLOPE STABILITY ANALYSIS
STA. 11+620 EXISTING CONDITION

FIGURE D1

Name: Granular Fill Material Model: Mohr-Coulomb Unit Weight: 21 kN/m³ Cohesion: 0 kPa Phi: 32 °
Name: Sandy Silt to Silt Till Model: Mohr-Coulomb Unit Weight: 21 kN/m³ Cohesion: 0 kPa Phi: 36 °
Name: Sandy Silt Fill Model: Mohr-Coulomb Unit Weight: 17 kN/m³ Cohesion: 0 kPa Phi: 30 °



County Road 30 - Existing Condition - Slope Stability Analysis

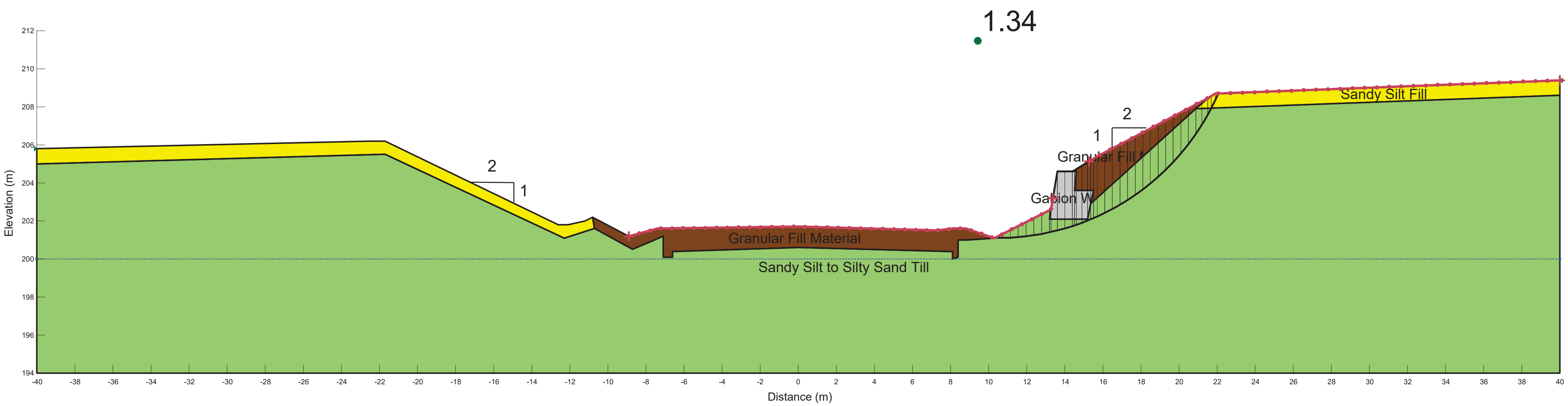
Date: December 2016
File No.: 19-4406-20

Analysis By: PP
Reviewed By: JL

MEGA FOUR – COUNTY ROAD 30 – GABION WALL
BRIGHTON, ON
SLOPE STABILITY ANALYSIS
STA. 11+620 AFTER CONSTUCTION

FIGURE D2

Name: Gabion Wall Model: Mohr-Coulomb Unit Weight: 22 kN/m³ Cohesion: 200 kPa Phi: 35 °
Name: Granular Fill Material Model: Mohr-Coulomb Unit Weight: 21 kN/m³ Cohesion: 0 kPa Phi: 32 °
Name: Sandy Silt to Silty Sand Till Model: Mohr-Coulomb Unit Weight: 21 kN/m³ Cohesion: 0 kPa Phi: 36 °
Name: Sandy Silt Fill Model: Mohr-Coulomb Unit Weight: 17 kN/m³ Cohesion: 0 kPa Phi: 30 °



County Road 30 - Gabion Wall - Slope Stability Analysis

Date: December 2016
File No.: 19-4406-20

Analysis By: PP
Reviewed By: JL