Final Foundation Investigation and Design Report

Highway 24 Resurfacing and
Replacement of Culvert at
Station 17+001 (Site No. 23)
Township of South Dumfries, ON

G.W.P. 3065-11-00

Geocres No. 40P08-238

Prepared for:
Ministry of Transportation Ontario

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Project No. 165000903

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FOUNDATION INVESTIGATION REPORT
For
G.W.P 3065-11-00

Highway 24 – Replacement of Culvert at Station 17+001
Site No. 23
Township of South Dumfries

1.0 INTRODUCTION

Stantec Consulting Ltd. (Stantec) was retained by the Ministry of Transportation, Ontario (MTO) to undertake the detailed design for resurfacing of Highway 24, Township of South Dumfries, Ontario. The geotechnical investigations are required to support the design of the replacement of six non-structural culverts located on Highway 24 between Highway 5 and Glen Morris Road East. The culvert numbers along with their approximate easting and northing coordinates given in Table 1.1 below.

Table 1.1: Coordinates of Culverts on Highway 24, Township of South Dumfries, ON (MTM Zone 10)

Culvert Station (Site No.)	Easting	Northing	Culvert Station (Site No.)	Easting	Northing
15+138 (10)	240328.968	4790308.382	16+453 (17)	239955.403	4791538.822
15+738 (12)	240146.455	4790857.376	17+001 (23)	239823.628	4792085.529
16+167 (16)	240028.947	4791272.063	17+845 (29)	239596.513	4792892.253

This Foundation Investigation Report has been prepared specifically and solely for the replacement of Culvert No. 23 which is located at Station 17+001.

Project Number:	G.W.P. 3065-11-00
Project Location:	Highway 24, 24 m south of McLean School Road

The work was carried out under MTO Agreement Number 3013-E-0019 with Stantec Consulting Ltd. , the Detailed Design Consultant for this project.

2.0 SITE DESCRIPTION AND GEOLOGY

Site Location

The site location is shown on the Key Plan inset to Drawing No. 1, provided in Appendix A. The existing Culvert crosses beneath Highway 24 near Station 17+001, approximately 24 m south of the intersection of Highway 24 and McLean School Road.

General Site Description

It is noted that Highway 24 runs approximately north to south at the project location with chainage increasing from south to north. In the vicinity of the culvert, Highway 24 has a two lane rural cross-section, plus an eastbound turning lane onto McLean School Road, with approximately 1 m wide paved shoulder with wood guide rails on both sides.

The culvert allows the water of the watercourses on the east and west sides of the highway to follow under the road. The road embankment has side slopes of approximately 1.5H:1V to 2H:1V. The paved surface of the highway is approximately 5.9 to 6.1 m higher than the ditches surface on both sides of the road. The area beyond the water course is covered with brush and trees. Site photos are shown in Appendix A.

Existing Culvert

The terms of reference indicate the existing culvert type is a Corrugated Steel Pipe (CSP). The culvert has a diameter of 1.2 m and a length of 40.17 m. The culvert is covered with approximately 4.5 m of fill. The approximate alignment of the existing culvert is shown on Drawing No. 1 in Appendix A.

3.0 INVESTIGATION PROCEDURES

3.1 REVIEW OF PREVIOUS INVESTIGATION

A review of the Geocres report for the Alder Creek Culvert Replacement within the study area suggests that the surficial geology of the site consists of silty sand with gravel to silty gravel with sand till deposits. Depth of bedrock is anticipated greater than 10 m.

3.2 FIELD INVESTIGATION – CULVERT SITE

A field investigation consisting of four boreholes was carried out for this assignment. The boreholes were designated BH15-13, BH15-14, BH15-15, and BH15-16 and their locations are shown on the Borehole Location Plan, Drawing No.1 in Appendix A.

Prior to carrying out the investigation, Stantec contacted the public utility authorities to clear the borehole locations of public utilities.

The field drilling program was carried out on June 10 and 25, 2015. Boreholes BH15-14 and BH15-15 were advanced with hollow-stem augers using a truck mounted drill rig equipped for soil and bedrock sampling owned and operated by Downing Drilling of Hawkesbury, ON. Boreholes BH15-13 and BH15-16 were advanced using portable drilling equipment owned and operated by Sonic Soil Sampling of Concord, ON.

The subsurface stratigraphy encountered in each borehole was recorded in the field by experienced Stantec personnel. In BH15-14 and BH15-15, split spoon samples were collected at regularly spaced intervals (typically every 760 mm) during the course of Standard Penetration Testing (ASTM D1586). In BH15-13 and BH15-15, Dynamic Cone Penetration Testing (DCPT) was performed using a 70 lb weight; a 50% correction factor has been applied to the DCPT results presented on the borehole records. Samples were collected using a split spoon sample advanced using a Pionjar jackhammer within approximately 1 m of the DCPT location. All samples recovered were returned to Stantec's Ottawa laboratory for detailed classification and testing.

Groundwater readings were carried out in open holes immediately upon completion of drilling. Boreholes were backfilled with auger cuttings mixed with bentonite.

3.3 LOCATION AND ELEVATION SURVEY

The borehole locations and geodetic elevations were surveyed in the field by Stantec personnel using a Trimble Geo XH GPS. The elevations are accurate to 0.1 m. Table 3.1 summarizes the borehole information.

Table 3.1: Borehole Summary

	Boreholes			
	BH15-13	**BH15-14**	**BH15-15**	**BH15-16**
MTM Zone 10 Coordinates Northing Easting	 4792086 239824	 4792074 239811	 4792082 239798	 4792072 239784
Ground Surface Elevation, m	290.5	296.4	296.4	290.3
Total Depth Drilled, m	6.1	12.0	12.0	6.1
End of Borehole Elevation, m	284.5	284.4	284.4	284.2
Depth Augered, m	NA	12.0	12.0	NA
Depth of DCPT from ground surface	6.1	NA	NA	6.1
Depth of Sampling	6.1	12.0	12.0	6.1
Number of Soil Samples	8	16	16	8

3.4 LABORATORY TESTING

All samples were taken to our Ottawa laboratory where they were subjected to a detailed visual examination by a Geotechnical Engineer. Selected soil samples underwent gradation analysis, Atterberg limits testing and moisture content testing. Three samples were submitted to Parcel

Laboratories of Ottawa for analysis of pH, soluble sulphate content, chloride content and resistivity. Laboratory testing summary is shown in the Table below.

Table 3.2: Laboratory Testing for Culvert Site

Laboratory Testing	Moisture Content	Gradation Analysis	Atterberg Limits	Chemical Analysis
Number of Tests	52	14	10	3

Samples remaining after testing will be placed in storage for a period of one year after issuance of the final report. After the storage period, the samples will be discarded unless we are directed otherwise by MTO.

4.0 SUBSURFACE CONDITIONS

4.1 SUBSURFACE PROFILE

The subsurface conditions observed in the boreholes are presented in detail on the Borehole Records provided in Appendix B. An explanation of the symbols and terms used to describe the Borehole Records is also provided.

In general, the subsurface stratigraphy consisted of a pavement structure or topsoil over, fill over, clayey silt over, sandy silt underlain by silty sand. A layer of peat was also encountered in one borehole.

Borehole location plans and stratigraphic section of the soils encountered within the boreholes are provided on Drawing No. 1 in Appendix A.

4.1.1 PAVEMENT

60 mm and 50 mm thick layer of asphalt pavement was encountered in BH15-14 and BH15-15 respectively.

4.1.2 TOPSOIL

380 mm and 200 mm thick layer of organic topsoil was encountered in BH15-13 and BH15-16 respectively.

4.1.3 Fill

Fill material was encountered beneath the topsoil layer and asphalt pavement. The fill consisted of brown to grey silty sand. The fill was approximately 1.1 m, 3.1 m, and 3.8 m thick and extended to the elevations of 289.1 m, 293.4 m, and 292.6 m in BH15-13, BH15-14, and BH15-15, respectively.

In this layer, the SPT N-values ranged from 9 to 33 blows per 0.3 m. The DCPT results ranged from 2 to 6. The results suggest a loose to dense state of compactness. The fill contained trace amounts of gravel to a depth of 0.76 m in BH15-14. Cobbles and boulders were encountered in the fill material from 2.6 m to 2.9 m in BH15-14. Fill material was described as moist to wet.

Moisture content and grain size distribution tests carried out on representative samples of the fill yielded the following results:

Gravel: 1 and 10%
Sand: 57 and 61%
Silt and Clay: 33 and 38%
Moisture Content: 3 to 24%

The grain size distribution curve for the fill material is provided in Figure No. 1 of Appendix C.

4.1.4 PEAT

100 mm thick layer of peat was encountered beneath the fill in BH15-13 and extended to an elevation of 289.0 m.

4.1.5 Sandy Clayey SILT to Clayey SILT with SAND

Sandy clayey silt to clayey silt with sand layer (clayey silt) was encountered beneath the peat in BH15-13. The deposit was approximately 1.3 m and 1.5 m thick and extended to elevations of 287.8 m and 291.9 m in BH15-13 and BH15-14 respectively. This deposit was also encountered interlayered with the sandy silt between elevations of 286.7 m and 285.9 m in BH15-13.

In this layer, the SPT N-values ranged from 17 to 20 blows per 0.3 m. The DCPT results ranged from 3 to 16. The results suggest a stiff consistency. The clayey silt was described as wet.

Moisture content, Atterberg limits, and grain size distribution tests carried out on a representative sample of the clayey silt yielded the following results:

Gravel: 3 to 6%
Sand: 25 to 37%
Silt: 46 to 59%
Clay: 11 to 13%
Moisture Content: 25 to 51%

The grain size distribution curve for the deposit is provided in Figure No. 2 of Appendix C.

Two Atterberg Limit tests were also performed on the deposit. The Atterberg Limit test yielded plasticity index from 5 to 10 and liquid limit from 17 to 26. The results suggest a low plasticity. The results are shown in Figure No. 5 of Appendix C.

4.1.6 Sandy SILT

Sandy silt layer was encountered beneath the clayey silt in BH15-13 and BH15-14, beneath the fill in BH15-15, and beneath the topsoil in BH15-16. The sandy silt layer was approximately 5.3 m and

6.9 m thick and extended to the elevations of 286.5 m and 285.8 m in BH15-14 and BH15-15 respectively. The sandy silt layer extended to the termination depths of BH15-13 and BH15-16. Clayey silt was encountered interlayered with the sandy silt between elevations of 286.7 m and 285.9 m in BH15-13. The sandy silt contained a trace amount of organic material to a depth of 1.5 m in BH15-16.

In this layer, the SPT N-values ranged from 3 to 28 blows per 0.3 m and the DCPT results ranged from 1 to 34. The results suggest very loose to compact state of density.

Moisture content, Atterberg limits, and grain size distribution tests carried out on representative samples of the sandy silt yielded the following results:

Gravel:	2 to 8%
Sand:	38 to 46%
Silt:	40 to 47%
Clay:	7 to 10%
Moisture Content:	9 to 21%

The grain size distribution curves for the sandy silt material are provided in Figure No. 3 of Appendix C.

Five Atterberg Limit tests were also performed on the sandy silt samples. The Atterberg Limit tests yielded that three samples were non-plastic and two samples had plasticity index values from 2 to 4 and liquid limits from 15 to 16. The results are shown in Figure No. 5 of Appendix C.

4.1.7 Silty SAND

A silty sand layer was encountered beneath the sandy silt in BH15-14 and BH15-15 and extended to the termination depths of these boreholes.

In this layer, the SPT N-values ranged from 11 to 17 blows per 0.3 m suggesting compact state of compactness.

Moisture content, Atterberg limits, and grain size distribution tests carried out on representative samples of the silty sand yielded the following results:

Gravel:	2 to 13%
Sand:	38 to 60%
Silt:	33 to 41%
Clay:	5 to 10%
Moisture Content:	9 to 15%

The grain size distribution curves for the silty sand material are provided in Figure No. 4 of Appendix C.

Two Atterberg Limit tests were also performed on the silty sand samples. The Atterberg Limit tests yielded that both samples were none plastic. The results are shown in Figure No. 5 of Appendix C.

4.1.8 Groundwater

The groundwater levels were inferred from samples moisture states at the time of drilling. Groundwater levels are provided in the Table below.

Table 4.1: Inferred and Measured Groundwater levels

Borehole No.	Observation/Measurement Date	Groundwater Depth (m)	Ground Surface Elevation(m)	Groundwater Elevation (m)
BH15-13	June 25, 2015	0.4 (inferred)	290.5	290.1
BH15-14	June 10, 2015	3.8 (inferred)	296.4	292.6
BH15-15	June 10, 2015	5.3 (inferred)	296.4	291.1
BH15-16	June 25, 2015	0.2 (inferred)	290.3	290.1

Fluctuations in the groundwater due to seasonal variations or in response to a particular precipitation event should be anticipated.

5.0 CHEMICAL ANALYSIS

One soil sample was submitted to Paracel Laboratories in Ottawa, Ontario, for analysis of pH, water soluble sulphate and chloride concentration, and resistivity. The analysis results are provided in Table 5.1.

Table 5.1: Results of Chemical Analysis

Borehole No	Sample No.	Depth (m)	pH	Chloride (µg/g)	Sulphate (µg/g)	Resistivity (Ohm-m)
BH15-13	SS1B	0.0 to 0.38	7.05	148	151	22.4
BH15-14	SS5	3.05 to 3.66	7.53	333	28	13.4
BH15-15	SS6	3.81 to 4.57	7.43	401	14	13.1

6.0 MISCELLANEOUS

The field work was carried out under the supervision of Athir Nader, E.I.T., under the direction of Christopher McGrath, P.Eng.

USL-1 Underground Service Locators Inc. of Ottawa, Ontario, carried out the private and public utility locates for the boreholes.

The CME 75 drilling equipment drilling equipment was supplied and operated by Downing Drilling of Hawkesbury, Ontario on June 10, 2015. Portable drilling equipment was supplied and operated by Sonic Soil Sampling of Concord, Ontario on June 25, 2015.

Elevation and location survey of the borehole locations was carried out by Stantec personnel.

Geotechnical laboratory testing was carried out at Stantec's Ottawa laboratory.

This report was prepared by Athir Nader, and reviewed by Christopher McGrath and Raymond Haché, MTO Designated Principal Contact.

7.0 CLOSURE

A subsurface investigation is a limited sampling of a site. The subsurface conditions given herein are based on information gathered at the specific borehole locations. Should any conditions at the site be encountered which differ from those at the borehole locations, we request that we be notified immediately in order to assess the additional information.

Respectfully Submitted;

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FOUNDATION INVESTIGATION REPORT
For
G.W.P 3065-11-00
Site No. 23
Highway 24 – Replacement of Culvert at Station 17+001
Township of South Dumfries

8.0 GENERAL BACKGROUND

Project Purpose/Justification

Resurfacing of Highway 24, Township of South Dumfries, Ontario is proposed. Foundation investigations were carried out to support the detailed design of the replacement of six culverts located on Highway 24 between Highway 5 and Glen Morris Road East. The results of the foundation investigation and the geotechnical engineering recommendations for the replacement of a Culvert at Station 17+001 are presented in this report.

Proposed Structures

The terms of reference indicate that the existing culvert type is a corrugated steel pipe (CSP). The existing culvert has a diameter of 1.2 m and a length of 40.17 m and it is covered with approximately 4.5 m of fill. The invert elevation of the existing culvert is between elevations of 290.5 m and 290.3 m. The existing culvert has been identified for replacement; replacement of the culvert by open cut excavation or trenchless construction techniques are both being considered.

If open cut installation is carried out, the existing CSP culvert will be replaced with 2.4 m by 1.8 m and 54.1 long pre-cast concrete box culvert. The alignment of the proposed culvert replacement will match the existing culvert alignment. The proposed invert elevations of the culvert at upstream and downstream ends are 290.8 m and 290.2 m respectively.

If trenchless technology is carried out for the installation the proposed culvert will be installed about 5 m to the north or south of the existing culvert alignment. The construction will likely consist of the installation of a 1.4 m to 1.5 m diameter steel casing with a 1.2 m to 1.3 m diameter concrete pipe grouted within the steel casing.

Construction Staging & Detours

It is understood that a short term local road detour is not anticipated for the culvert replacement.

For an open cut installation, the culvert replacement will require roadway protection. Since each half of the culvert will be replaced separately, a single lane could be used with highway traffic being controlled by a continual flagging operation or temporary lights.

Alternatively, trenchless technology is being considered for the installation which would not require roadway protection.

9.0 ENGINEERING RECOMMENDATIONS

The following sections provide geotechnical design parameters, evaluates trenchless and open cut methods for the culvert replacement and provides geotechnical recommendations for the design and construction of the culvert replacement.

9.1 GEOTECHNICAL DESIGN PARAMETERS

The soil conditions at this site generally consist of a pavement structure or topsoil over fill over clayey silt over sandy silt over silty sand.

For design purposes, the following soils profile will be used:

Table 9.1: Geotechnical Model for Culvert

Approximate Elevation		Soil Type	Design Properties
From	To		
296.3 m	293.4 m	FILL: silty SAND Cobbles and Boulders Trace of Gravel	Total Unit Weight = 20.0 kN/m^3 Friction Angle, ϕ = 32° E' = 12 MPa
293.4 m	291.9 m	Sandy Clayey SILT to Clayey SILT with Sand Stiff	Total Unit Weight = 19.9 kN/m^3 Friction Angle, ϕ = 30° E' = 8 MPa
291.9 m	286.5 m	Sandy SILT Very Loose to Compact	Total Unit Weight = 22.0 kN/m^3 Friction Angle, ϕ = 30° E' = 8 MPa
286.5 m	284.4 m	Silty SAND Compact	Total Unit Weight = 20.0 kN/m^3 Friction Angle, ϕ = 32° E' = 15 MPa

A design water level elevation of 290.1 m will be considered for the culvert site. This water level reflects the water level observed beneath the topsoil in BH15-13 and BH15-16. Water level observed in BH15-14 and BH15-15 is higher than the water levels observed in BH15-13 and BH15-16 and it may not represent the groundwater level.

9.2 CULVERT REPLACEMENT WITH TRENCHLESS TECHNOLOGY

The preferred trenchless technology approach for the culvert installation is Jack and Bore. This method would involve installing a 1.4 m to 1.5 m diameter steel casing. The steel casing would be advanced through the soil "Jacked" and a rotating auger within the casing is used to remove the soil. The new culvert is then installed in the casing and grouted in place.

Table 9.2 summarizes the trenchless technology methods and their typical limitations (Geotechnical and Geoenvironmental Engineering Handbook, Rowe, R.K., 2001).

Table 9.2: Summary of Trenchless Technology Methods

Method	Pipe Internal Diameter (mm)	Drive Length (m)	Ground Conditions	Directional Control
Pipe jacking	900 – 3000+	Typically 100-500	All soils	Yes; accuracy ± 50-100 mm
Microtunneling	250-1000	Up to about 120	All soils; problems with obstructions, e.g. boulders	Yes; accuracy ± 25-50 mm
Auger boring or Jack and Bore	150-900	Up to about 120	All except hard rock; problems in unstable soils, below water table, also with obstructions, e.g. boulders	Some control; accuracy ≈ 50 mm
Horizontal directional drilling	50-1500	Up to about 2000	All soils; problems with obstructions, e.g. boulders	Steerable both horizontally and vertically; accuracy ≈ 1% of length
Guided drilling	50-600	Up to about 600	All soils; problems with obstructions, e.g. boulders	Steerable both horizontally and vertically; accuracy ≈ 150 mm
Moling	50-200	Typically 10-20; up to 75 possible	Not hard rock or very soft soils; beware obstructions	Only if steerable moles are used; accuracy ±50-100 mm
Pipe bursting	100-500	Up to about 120	Most soils	Follows line of existing pipe
Pipe ramming	50-1200	Up to about 75	Not through rock	None

9.2.1 Suitability of Preferred Approach

The following bullets provide a brief review of the suitability of the jack and bore approach for this project.

- Cobbles and boulders were encountered within the fill in borehole BH15-14; the casing alignment should be designed to avoid the fill material.
- The native soil encountered within the boreholes consisted of sandy silt. Penetration of this soil via jack and bore is not anticipated to be a concern.
- The site has sufficient space for staging areas for the jack and bore equipment. The operation of Highway 24 should not be disrupted during jack and bore operations.
- The stability factor for the tunneling was estimated between 1 and 2 for the cohesive soil, this corresponds to a tunnel behavior of stable to small creep for Clayey Soils and Silty Sand (Bickel et al. 1996). The tunnel behavior for granular soil was determined to be flowing.

9.2.2 Constraints to the Preferred Approach

The following bullets provide a brief review of the constraints of the jack and bore approach for this project.

- The complexity of the tunneling operation is "Medium" for this project due to the size of the casing (>1 m & ≤ 2 m), the pipe cover (> 3 pipe diameters) and the crossing is beneath a freeway.
- It is noted that there are below grade utilities in the area that will need to be protected during the work. Subsurface Utility Mapping (SUM) should be reviewed to locate the existing buried infrastructure; it should be the contractor's responsibility to clear utilities for construction.
- The end of the auger should not be advanced to the edge of the casing; a soil plug should be maintained in the casing to prevent surface settlement.
- Monitoring points should be installed along the proposed alignment and the settlement should be monitored during tunneling. Additional information regarding settlement monitoring is provided in Section 9.2.7.
- It is estimated that about 5 mm of settlement at road surface could occur during tunneling. This magnitude of settlement may cause cracks in the pavement surface.
- The excavation for entry/exit pits will need to be supported.

9.2.3 Entry Point and Exit Pit

Two entry/exit pits are proposed for the crossings. The location of the pits will likely be in the ditch line to the east and west of the highway and within close proximity to the embankments for Highway 24. The pits should be supported with a shoring system.

The shoring design should be carried out by a Professional Engineer retained by the Contractor, licensed to practice in the Province of Ontario, and that signed and sealed drawings will be available prior to commencement of the trenching operations.

Upon completion of the culvert installation, the shoring should be removed and the excavation backfilled and compacted. The disturbed area should be restored to an equivalent or better condition than existed prior to the commencement of construction. Trenching, backfilling and compacting for entry and exit pits or other locations along the pipe path should be in accordance with OPSS 514.

9.2.4 Recommendations

It is recommended that the profile of the pipe be designed so the obvert elevation of the pipe is at least 4 m below the roadway surface for the crossing of Highway 24.

<u>Non Standard Special Provision</u>

The tender for the proposed culvert installation should include a special provision for trenchless construction the document titled "Pipe Installation by Trenchless Method, Non Standard Special

Provision (NSSP)", dated December 2014 has been provided for consideration; a copy of this document is provided in Appendix D.

The NSSP includes the general requirements relating to the installation of pipes by trenchless methods including specifications for jack and bore and instrumentation monitoring.

The contractor should provide a complete submission consistent with the requirements of the NSSP.

Monitoring Points

Monitoring points should be installed along the alignment of the pipe. The monitoring points should include in-ground monitoring points along the shoulder of the highway which should consist of 10 mm diameter steel rods grouted in place 2 m below ground surface and protected with a 50 mm PVC casing. Additional details are provided in Section 9.2.7.

9.2.5 UNWATERING

The groundwater elevation was inferred to be between elevation 290.1 m and 292.6 m. It should be practical to undertake unwatering in the entry/exit pits using conventional sump and pump techniques. Provided the base of the pits are not significantly below the groundwater level, construction stage unwatering is expected to have a negligible impact on existing infrastructure. The entry/exit pits will likely be located near the ditch line, during precipitation events the water flow in the ditches will need to be controlled.

9.2.6 SITE PREPARATION

Given the existing conditions observed and recorded via the geotechnical investigation, clearing and grubbing is not anticipated as a component of site preparation activities.

9.2.7 MONITORING

Typically, the most common type of distress for trenchless technology applications is settlement caused by loss of ground around the tunnel. Heave of the ground surface and or inadvertent drilling fluid returns are also possible depending on the type of installation. Distortions of this nature would be a serious safety concern and could lead to serviceability issues of the highway.

Distress at the ground surface is generally prevented or minimized by planning and good construction practices. The preparation of an installation plan that includes appropriate mitigation measures and contingencies is typically required for these applications. To lay the groundwork for the contractor to prepare a suitable installation plan, the following measures are set forth.

A condition survey of the pavement structure should be carried out prior to the commencement of construction and documented for the purpose of restoration, if necessary. The condition survey should be completed during the installation of the in-ground monitoring points and after completion of the culvert installation. Interim surveys should be completed if movement greater than 10 mm is detected in the in-ground monitoring points.

A high precision surveyor should be engaged for the purpose of monitoring in-ground and surface monitoring points during construction. Monitoring points should be identified and located at 5.0 m intervals along the tunnel alignment and with 1.5 m offsets to the right and left at each interval, consistent with the requirements of the NSSP.

Surface monitoring points should be established on the asphalt surface of Highway 24.

An array of three in-ground measurement points installed at the pipe centerline and off-set a lateral distance of 1.5 m on either side of the pipe centerline is recommended. The in-ground measurement points should be installed 0.5 m to 2.0 m below ground surface. Arrays should be located at the following locations:

- Two arrays: Shoulder of the Hwy 24 eastbound lanes and roadway embankment side slope
- Two arrays: Shoulder of the Hwy 24 westbound lanes and roadway embankment side slope

Consistent with the requirements of the NSSP, the surveyor should compile the following:

- Three (3) sets of readings prior to construction to establish "base-line" data.
- Three (3) sets of readings during each day of construction presuming that movements remain within the anticipated limits. If movements are recorded, the frequency of monitoring will be adjusted consistent with the NSSP.
- Weekly readings after completion of the work for one month, or until a time when all parties agree that further movements have stopped.

The NSSP referenced above includes specifics on: in-ground monitoring points; surface monitoring points; reading frequency; and criteria for assessment, and specify a maximum acceptable surface settlement (or heave) of 10 mm.

The baseline reading, alert level, and review level are described as follows:

- Baseline Reading – The baseline readings will be reviewed by the surveyor and the Ministry of Transportation to confirm consistency and reliability in the initial readings. The readings will be conveyed to all parties for the record, prior to commencement of the work.
- Review Level – A movement of 10 mm relative to the baseline readings will be established for this purpose. If this level is reached, the Ministry of Transportation will be advised accordingly and changes to the installation method, rate/progress of installation, or sequence of construction, will be required for implementation to mitigate further ground displacement.
- Alert Level – A movement of 15 mm relative to the baseline readings will be established for this purpose. If this level is reached, the Contractor shall cease construction operations and execute pre-planned measures to secure the site, to mitigate further displacement, to assure public safety, and to maintain traffic flow on the Highway.

The reporting process for issue of the survey data should be as follows:

- If the surveyed displacement is below the Review Level, the data obtained should be forwarded within 24 hours of collection to the Ministry of Transportation project contact.
- If the surveyed displacement is above the Review Level, the General Contractor's Project Manager and the tunneling Contractor's Representative should notify the Ministry of Transportation immediately and adjust the construction process (see comments provided above). The survey data should be forwarded within 1 hour of collection to the Ministry of Transportation project contact.
- If the surveyed displacement is above the Alert Level, the General Contractor's Project Manager and the tunneling Contractor's Representative should notify the Ministry of Transportation immediately, stop work and implement contingencies to mitigate any displacements and/or damages incurred. The survey data should be forwarded within 1 hour of collection to the Ministry of Transportation project contact. A site meeting should be scheduled to review the data and the conditions observed to discuss the nature of the Alert Level, with a view to revising the construction approach and to coordinate the requirement for design and implementation of the remedial measures.

A data distribution list, identifying all parties with the appropriate contact information, should be established prior to commencement of the work.

9.3 CULVERT REPLACMENT WITH OPEN CUT EXCAVATION

If open cut installation is carried out, the current CSP culvert will be replaced by a 2.4 m x 1.8 m pre-cast concrete box culvert. Also the retaining walls/head walls will not be required for culvert replacement.

The soil conditions at the site should be suitable to support the culvert options. Table 9.3 compares the culvert structure options from a constructability perspective.

Table 9.3: Comparison of the Replacement Options for Culvert at Station 17+001

Option	Advantages	Disadvantages	Relative Cost	Risk/ Consequences	Rank
Precast Rigid Frame Box	• Low bearing pressure on the sandy silt • Use of precast sections reduces construction period • Slightly less unwatering volume	• Needs heavy lifting equipment • Poorer hydraulic performance	Medium		1
Rigid Frame Open Footing		• Higher bearing pressure • Slower construction process • Greater unwatering volume require	High	• Higher risk of unwatering related issues • Concrete curing process	4

Option	Advantages	Disadvantages	Relative Cost	Risk/ Consequences	Rank
		- Poorer hydraulic performance - Concrete not readily available - Requires RSS at inlet			
Open Bottom Steel Arch with Concrete Footing	- Low material and installation cost	- Requires RSS at inlet - Concrete not readily available	Low to Medium	- Higher risk of unwatering related issues - Concrete curing process	3
Corrugated Steel Pipe	- Low material and installation cost	- Maintenance Requirements	Low	- Corrosion of steel - Short design life	2

The comparison indicates the preferred culvert replacement option is precast rigid frame box. Additional recommendations regarding bedding and backfill material is provided in Section 9.8.

9.3.1 CONSTRUCTION STAGING

The culvert replacement is anticipated to involve a staged construction. This will involve the closure of one lane at a time for a short duration using appropriate traffic control. Two options are being evaluated for the construction staging:

Option 1: Support the excavation with temporary roadway protection near the centerline of the highway. Recommendations for temporary roadway protection are provided in Section 9.5.

Option 2: Temporarily lowering the profile of the roadway at the culvert and replacing the culvert without temporary roadway protection. Recommendations for temporary excavation side slope are presented in Section 9.8.

9.4 FOUNDATION RECOMMENDATIONS

The design recommendations presented in the following sections have been developed in accordance with the requirements and methods described in the Canadian Highway Bridge Design Code (CHBDC, 2006).

9.4.1 Shallow Foundation

This section provides recommendations for the design of spread footings founded on undisturbed soil.

9.4.1.1 Geotechnical Vertical Resistance

The geotechnical resistances provided in Table 9.4 may be used in the design, provided the footings are placed on undisturbed soil.

Table 9.4: Geotechnical Resistance for Shallow Foundation (Spread Footing)

Founding Element	Founding Elevation (m)	Culvert Dimension (m)	Factored Geotechnical Resistance at ULS_f (kPa)	Geotechnical Resistance at SLS (kPa)
Spread footing on undisturbed soil	± 290.2	2.4 x 54.1	500	125

In accordance with Section 6.6.2 of the CHBDC, a resistance factor of 0.5 has been applied in calculating the factored geotechnical resistance at Ultimate Limit State (ULS_f).

The axial reaction at SLS corresponds to a vertical deflection (settlement) of 25 mm. The relatively high SLS values relative to the soil conditions considers the soil compression which has occurred beneath the existing embankment weight.

9.4.1.2 Geotechnical Horizontal Resistance (Sliding)

The unfactored horizontal resistance of spread footings may be calculated using the following unfactored coefficients of friction:

0.55	Between OPSS Granular A and concrete
0.45	between native soil and concrete

In accordance with Table 6.1 of the CHBDC, a resistance factor against sliding of 0.8 should be applied to obtain the resistance at ULS_f.

9.5 TEMPORARY PROTECTION SYSTEMS (CULVERT REPLACEMENT OPTION)

A culvert invert elevation of approximately 290.2 m will require a maximum excavation depth of approximately 6.7 m. Based on the recommended excavation site slope of 1.5H:1V (Section 9.8) a temporary roadway protection will be required for the culvert replacement. The roadway protection or the culvert replacement will necessitate excavation below the groundwater levels. As such, unwatering of the excavation will be required for the culvert replacement, and may also be required during installation of the roadway protection system.

The following table compares the available roadway protection options considered for the culvert replacement:

Table 9.5: Comparison of Roadway Protection Systems

Option	Advantages	Disadvantages	Relative Cost	Risk & Consequences
H-Piles with timber lagging; struts/rakers	• Simple installation	• Dewatering more difficult	Low	• Lack of ground stability when extending below the water table
Steel sheet pile (SSP); rakers/ tieback anchors or internal bracing	• No unwatering required during roadway protection installation • The excavation level is expected to extend to the sandy clayey silt to silty clay soil. A coffered sheet pile approach would allow for a construction area kept dry using conventional unwatering practices	• Difficult to drive/install in dense soil with cobbles	High	• Damage or loss of sheet pile walls during driving

Since the excavation is expected to extend to about elevation 289.7 m and the water level at elevation 290.1 m, the use of a simple soldier pile wall along the centerline of the road is not likely a feasible option.

The contractor may choose to use coffered sheet piles to control groundwater issues. The subsurface conditions at the proposed invert level of the culvert consist of saturated, very loose sandy silt. This material will be easily disturbed and prone to basal instability. The groundwater level should be lowered to at least 0.5 m below the subgrade level of the culvert to provide a stable base. The sheet piles should also extend below the base of the excavation.

Assuming the water table to be approximately 0.4 m above the excavation depth it is anticipated that provided the sheet piles are driven to at least 1.0 m below the excavation depth, conventional sump pumping from within the sheet piled excavation would be feasible. Sheet piles would be strutted or driven deeper to provide horizontal stability.

Although the embankment fill was not dense, damage to sheet piles during driving is possible due to the cobbles and boulders observed on site. A Notice to Contractor is provided in Appendix D which alerts the contractor of the presence of cobbles and boulders in the soil.

The contractor will ultimately be responsible to develop and implement a roadway protection system meeting the requirements of OPSS 539, including establishing appropriate geotechnical design parameters.

Shoring design should meet the requirements of Performance Level 2 as per OPSS 539 and should consider traffic loading. Performance Level 2 specifies a Maximum Angular Distortion of

1:200 and a Maximum Horizontal Displacement of 25 mm. Pile and raker spacing must be designed not to exceed these limits. Horizontal movement should be monitored throughout the culvert replacement process as described in OPSS 539. The monitoring requirements outlines in OPSS 539 are considered to be appropriate for this project.

9.5.1 Lateral Earth Pressures

9.5.1.1 Lateral Earth Pressures under Static Conditions

Earth pressures will need to be considered in the design of the temporary roadway protection system.

Computation of earth pressures should be in accordance with Section 6.9 of the CHBDC and the Occupational Health and Safety Act Regulations for Construction Projects. The distribution of earth pressures acting on the protection system could be estimated using the Canadian Foundation Engineering Manual. For retaining walls that are designed to allow rotation, active earth pressure may be used for design. For rigidly tied and unyielding structures, the at-rest earth pressure should be used for design. The unfactored soil parameters provided in Table 9.1 may be used for design of walls and protection systems with a horizontal backfill. The effects of compaction should be accounted for by applying a compaction surcharge as shown in Figure 6.6 of the CHBDC.

Values for K_a, K_o, K_p, and γ are provided in Tables 9.6 and 9.7 for horizontal and 2H:1V backfill.

Table 9.6: Recommended Non-Seismic Earth Pressure Parameters (Horizontal Backfill)

Parameter	OPSS Gran A and Gran B Type II	FILL	Sandy Clayey SILT to Clayey SILT with Sand	Sandy SILT	Silty SAND
Bulk Unit Weight, γ (kN/m^3)	22	22.8	19.9	22.0	23.2
Effective Friction Angle	35°	32°	30°	30°	32°
Coefficient of Earth Pressure at Rest (K_o)	0.43	0.47	0.50	0.50	0.47
Coefficient of Active Earth Pressure (K_a)	0.27	0.31	0.36	0.33	0.31
Coefficient of Passive Earth Pressure (K_p)	3.69	3.25	3.00	3.00	3.25

Table 9.7: Recommended Non-Seismic Earth Pressure Parameters (2H:1V Backfill)

Parameter	OPSS Gran A and Gran B Type II	FILL	Sandy Clayey SILT to Clayey SILT with Sand	Sandy SILT	Silty SAND
Bulk Unit Weight, γ (kN/m^3)	22	22.8	19.9	22.0	23.2
Effective Friction Angle	35°	32°	30°	30°	32°
Coefficient of Earth Pressure at Rest (K_o)	0.43	0.47	0.53	0.50	0.47
Coefficient of Active Earth Pressure (K_a)	0.39	0.47	0.62	0.53	0.47

9.6 EMBANKMENTS

The roadway profile at the culvert location will not be raised above the existing profile. Some minor embankment widening may be carried out to accommodate construction staging.

9.6.1 Embankment Construction

Embankment construction should be carried out in conformance with SP 206503.

Embankment slopes should be constructed at no steeper than 2H:1V. The existing slopes should be benched as per OPSD 208.010 if widening is proposed. New fill materials should consist of OPSS Select Subgrade Material (or better) placed in 300 mm thick lifts compacted to at least 95% Standard Proctor Maximum Dry Density.

9.6.2 Stability of Slopes

No sign of embankment instability was observed during the foundation drilling. Stantec is not aware of a history of slope instabilities at the culvert location. The proposed slopes will be reinstated at 2H:1V or gentler.

The proposed slopes are considered stable with respect to deep seated failures with factors of safety of greater than 1.3. Surficial and toe failures could occur if proper erosion control is not provided for the new embankments.

9.6.3 Embankment Settlement

The profile and footprint of the existing embankment is not anticipated to be significantly altered.

Settlement of the underlying soil is anticipated to be less than 25 mm. Self settlement of the new fill material is anticipated to be less than 25 mm and should occur during construction.

9.7 EROSION AND SCOUR PROTECTION

All slopes within 3 m of the culvert inlets and outlets should be surfaced with rip-rap at least 300 mm thick placed on a Class II non-woven filter fabric.

Normal slope vegetation should be established as soon as possible after completion of embankment fills in order to control surficial erosion.

A clay seal should be provided at the inlet of the pre-cast concrete box culvert to prevent seepage through the backfill material. The clay seal should be constructed as follows:

- Clay should meet OPSS 1205 specifications.
- At least 0.6 m thick.
- Extend from 0.3 m above the high water level to the full depth of excavation.

- Seal should not be located beneath the pavement structure.

The contractor should provide silt fences and erosion control blankets, as required, throughout the duration of the construction to prevent silt/sediments from running off the site.

9.8 EXCAVATION AND BACKFILLING

Excavation and backfill for the new pre-cast concrete box culvert should be carried out in accordance with:

- OPSS 902
- MTOD 803.021

Bedding and backfill material should be provided for the culvert as per the appropriate OPSD specification. The bedding material should include a 275 mm thick layer of OPSS Granular A consisting of a 75 mm thick uncompacted levelling course over a 200 mm thick compacted layer. Organic soil encountered within the footprint of the bedding layer should be subexcavated and the bedding layer thickness increased accordingly. The subsurface condition at the base of the excavation is expected to consist of saturated, very loose sandy silt. The sand silt layer is easily disturbed; to help provide a stable subgrade we recommend placing a 75 mm thick layer of lean concrete. The backfill material should consist of free-draining, non-frost susceptible granular material such as OPSS Granular A or Granular B Type I. The bedding and backfill material should be placed in 300 mm thick lifts compacted to at least 95% SPMDD.

The groundwater level should be lowered at least 0.5 m below the subgrade level of the culverts to provide a stable base during placement of culvert bedding material.

OPSD 3090.101 indicates that the frost penetration depth at the site is 1.4 m. The frost penetration depth should be used for the design of the culvert frost taper.

Side slopes for open cut excavations (if any) should conform to Occupational Health and Safety Act (OHSA) regulations for Construction Projects. The soils encountered at the site may be classified as Type 3 Soil. The excavation walls should be sloped from its bottom with a slope having a minimum gradient of 1H:1V. Excavation below the water table will require gentler slopes.

9.9 UNWATERING

Replacement of the culvert will require excavation below the groundwater level encountered during the investigation. Control of groundwater during construction is required. The groundwater level should be lowered to at least 0.5 m below the subgrade level of the culvert to provide a stable base during placement of culvert bedding material.

The native soils within the anticipated depth of excavation have a low to moderate hydraulic conductivity, in the order of 10^{-3} to 10^{-5} cm/s. For the case of sheet piles extending to at least

1.0 m below the bottom of excavation, unwatering of the culvert excavation using conventional sump and pump techniques should be adequate.

9.10 CEMENT TYPE AND CORROSION PROTECTION

One sample of the native soils was submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water soluble sulphate and chloride concentrations, and resistivity. The testing was completed to determine the potential for degradation of the concrete in the presence of soluble sulphates and the potential for corrosion of exposed steel used in foundations and buried infrastructure. The analysis results are summarized in Table 5.1.

The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. The soluble sulphate concentrations for the samples were 14 to 151 µg/g. Soluble sulphate concentrations less than 1000 µg/g generally indicate that a low degree of sulphate attack is expected for concrete in contact with soil and groundwater. Type GU (General Use) Portland Cement should therefore be suitable for use in concrete at this site.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The soil pH values were 7.05 to 7.53 which are within what is considered the normal range for soil pH of 5.5 to 9.0. The pH levels of the tested soil do not indicate a highly corrosive environment. The test results provided in Table 5.1 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects.

10.0 SPECIFICATIONS

The following specifications are referenced in this report:

Table 10.1: Specifications Referenced in Report

Document	Title
NSSP	Pipe Installation by Trenchless Method
OPSD 3090.101	Foundation, Frost Depths for Southern Ontario
OPSS 539	Construction Specification for Temporary Protection System
OPSS 902	Construction Specification for Excavation and Backfilling – Structures
MTOD 803.021	Bedding and Backfill for Precast Concrete Box Culvert
OPSS 1205	Material Specification for Clay Seal

11.0 REFERENCES

ASTM. 1999. Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils (ASTM D1586). ASTM International, West Conshohocken, PA.

ASTM. 2000. Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) (ASTM D2487). ASTM International, West Conshohocken, PA.

CHBDC. 2006. Canadian Highway Bridge Design Code. Canadian Standards Association, Mississauga, Ontario

Rowe, R. K, Geotechnical and Geoenvironmental Engineering Handbook. Boston; Kluwer Academic, 2001.

12.0 CLOSURE

A soil investigation is a limited sampling of a site. The conclusions given herein are based on information gathered at the specific borehole locations. Should any conditions at the site be encountered which differ from those at the borehole locations, we request that we be notified immediately in order to assess the additional information and its effects on the above recommendations.

We trust the information presented herein meets your present requirements. Should you have any questions or require additional information, please do not hesitate to contact us.

This report was prepared by Athir Nader, and reviewed by Christopher McGrath and Raymond Haché.

Respectfully submitted,

STANTEC CONSULTING LTD.

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Designated Principal MTO Foundation Contact

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APPENDIX A

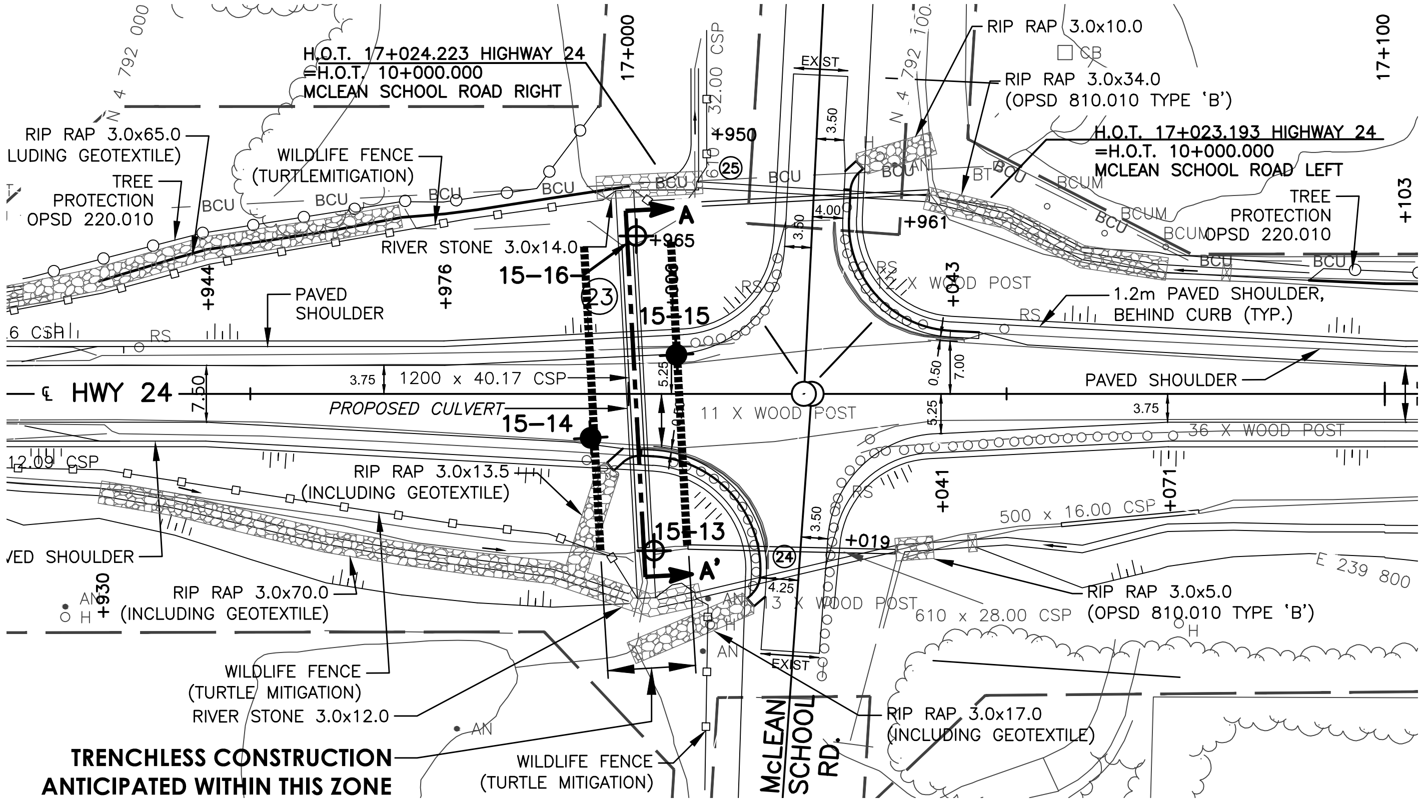
Drawing No. 1 – Borehole Location Plan and Soil Strata Plot

Site Photos

MINISTRY OF TRANSPORTATION, ONTARIO   PR-D-707   88-05

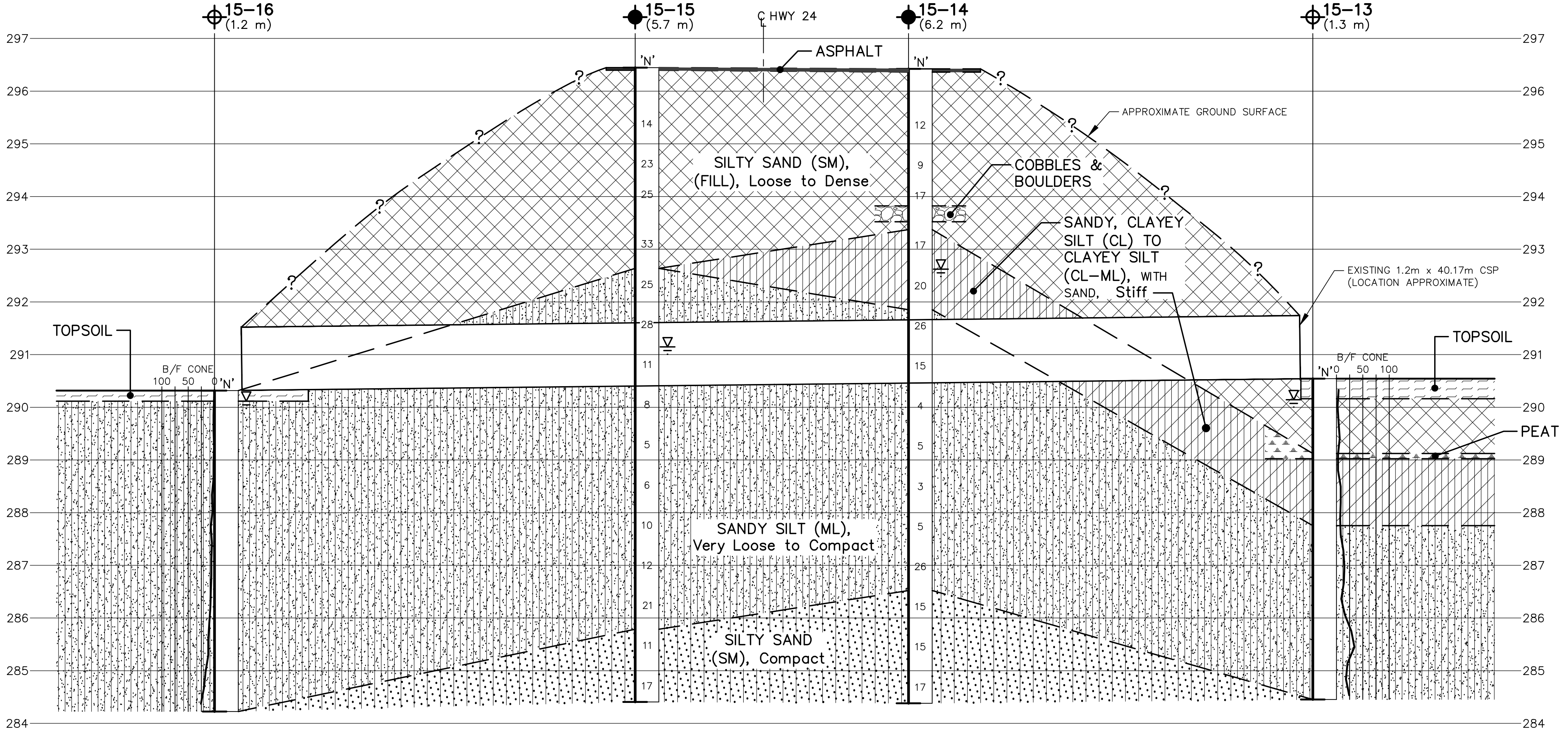
PLAN

SCALE
10 m 0 10 20 m



CROSS SECTION A-A'

SCALE
2 m 0 2 4 m HORIZONTAL
1 m 0 1 2 m VERTICAL



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

C. McGRATH
2017-01-09

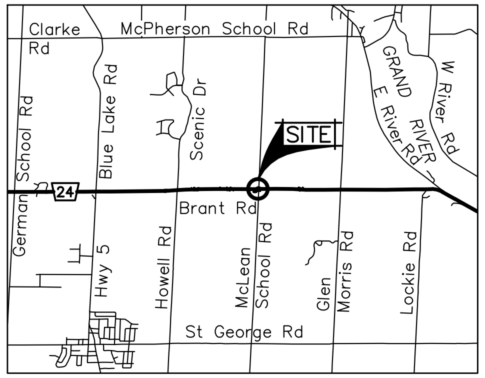
J.G.A.R. HACHÉ
2017-01-09

PLATE No
CONT
WP 3065-11-00

SHEET

HWY 24, TWP OF S DUMFRIES, ON
CULVERT AT STA 17+001 (SITE 23)
BOREHOLE LOCATIONS & SOIL STRATA

Stantec



KEY PLAN
1 km 0 1 2 3 km

LEGEND

●	Borehole
⊕	Dynamic Cone Penetration Test (Cone)
(x.x m)	Offset from Cross Section Line in meters
N	Blows/0.3m (Std Pen Test, 475 J/blow)
CONE	Blows/0.3m (60° Cone, 475 J/blow)
▽	Inferred WL at time of investigation, June 2015

No	ELEVATION	MTM ZONE 10 COORDINATES NORTH	EAST
15-13	290.5	4 792 085.5	239 823.6
15-14	296.4	4 792 073.5	239 811.4
15-15	296.4	4 792 081.6	239 797.8
15-16	290.3	4 792 072.3	239 784.1

NOTES

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

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

REVISIONS		
2017-01-09	CM	ADDED GEOCRES NUMBER
DATE	BY	DESCRIPTION

GEOCRES No 40P08-238

HWY No HWY	24		DIST
SUBM'D AN	CHECKED	DATE 2016-09-29	SITE C23
DRAWN GBB	CHECKED	APPROVED	DWG 1

DRAWING NAME: 165000903_Culverts_P&XS_Final.dwg
CREATED BY: GBB MODIFIED: 2017-01-09
T:\Autocad\Drawings\Project Drawings\2017\165000903\Culverts\Hwy 24\Emailed\2017\165000903_Culverts_P&XS_Final_C23.dwg (C23) Printed: Jan 09, 2017

Stantec	Project No.: 165000903	GWP: 3065-11-00	Site Photographs
	Project Name: Culvert at Station 17+001, Highway 24 Pavement Rehabilitation, Township of South Dumfries, ON		Date: June 10, 2015

Site Photo No.: 1 Looking north on BH15-14

Site Photo No.: 2 Looking south on BH15-14

Stantec	Project No.: 165000903	GWP: 3065-11-00	Site Photographs
	Project Name: Culvert at Station 17+001, Highway 24 Pavement Rehabilitation, Township of South Dumfries, ON		Date: June 10, 2015

Site Photo No.: 3	Looking east toward BH15-13 on BH15-14

Site Photo No.: 4	Looking west toward BH15-16 on BH15-14

Site Photo No.: 5	Looking south toward BH15-13 from McLean School Road

Site Photo No.: 6	Looking west toward BH15-16 on BH15-15

Site Photo No.: 7	Looking southwest on BH15-13

Site Photo No.: 8	Looking east on BH15-16

APPENDIX B

Symbols and Terms Used on Borehole Records

Borehole Records

SYMBOLS AND TERMS USED ON BOREHOLE AND TEST PIT RECORDS

SOIL DESCRIPTION

Terminology describing common soil genesis:

Rootmat	- vegetation, roots and moss with organic matter and topsoil typically forming a mattress at the ground surface
Topsoil	- mixture of soil and humus capable of supporting vegetative growth
Peat	- mixture of visible and invisible fragments of decayed organic matter
Till	- unstratified glacial deposit which may range from clay to boulders
Fill	- material below the surface identified as placed by humans (excluding buried services)

Terminology describing soil structure:

Desiccated	- having visible signs of weathering by oxidization of clay minerals, shrinkage cracks, etc.
Fissured	- having cracks, and hence a blocky structure
Varved	- composed of regular alternating layers of silt and clay
Stratified	- composed of alternating successions of different soil types, e.g. silt and sand
Layer	- > 75 mm in thickness
Seam	- 2 mm to 75 mm in thickness
Parting	- < 2 mm in thickness

Terminology describing soil types:
The classification of soil types are made on the basis of grain size and plasticity in accordance with the Unified Soil Classification System (USCS) (ASTM D 2487 or D 2488) which excludes particles larger than 75 mm. For particles larger than 75 mm, and for defining percent clay fraction in hydrometer results, definitions proposed by Canadian Foundation Engineering Manual, 4th Edition are used. The USCS provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification.

Terminology describing cobbles, boulders, and non-matrix materials (organic matter or debris):
Terminology describing materials outside the USCS, (e.g. particles larger than 75 mm, visible organic matter, and construction debris) is based upon the proportion of these materials present:

Trace, or occasional	Less than 10%
Some	10-20%
Frequent	> 20%

Terminology describing compactness of cohesionless soils:
The standard terminology to describe cohesionless soils includes compactness (formerly "relative density"), as determined by the Standard Penetration Test (SPT) N-Value - also known as N-Index. The SPT N-Value is described further on page 3. A relationship between compactness condition and N-Value is shown in the following table.

Compactness Condition	SPT N-Value
Very Loose	<4
Loose	4-10
Compact	10-30
Dense	30-50
Very Dense	>50

Terminology describing consistency of cohesive soils:
The standard terminology to describe cohesive soils includes the consistency, which is based on undrained shear strength as measured by *in situ* vane tests, penetrometer tests, or unconfined compression tests. Consistency may be crudely estimated from SPT N-Value based on the correlation shown in the following table (Terzaghi and Peck, 1967). The correlation to SPT N-Value is used with caution as it is only very approximate.

Consistency	Undrained Shear Strength		Approximate SPT N-Value
	kips/sq.ft.	kPa	
Very Soft	<0.25	<12.5	<2
Soft	0.25 - 0.5	12.5 - 25	2-4
Firm	0.5 - 1.0	25 - 50	4-8
Stiff	1.0 - 2.0	50 – 100	8-15
Very Stiff	2.0 - 4.0	100 - 200	15-30
Hard	>4.0	>200	>30

ROCK DESCRIPTION

Except where specified below, terminology for describing rock is as defined by the International Society for Rock Mechanics (ISRM) 2007 publication "The Complete ISRM Suggested Methods for Rock Characterization, Testing and Monitoring: 1974-2006"

Terminology describing rock quality:

RQD	Rock Mass Quality
0-25	*Very Poor Quality*
25-50	*Poor Quality*
50-75	*Fair Quality*
75-90	*Good Quality*
90-100	*Excellent Quality*

Alternate (Colloquial) Rock Mass Quality	
Very Severely Fractured	*Crushed*
Severely Fractured	*Shattered or Very Blocky*
Fractured	*Blocky*
Moderately Jointed	*Sound*
Intact	*Very Sound*

RQD (Rock Quality Designation) denotes the percentage of intact and sound rock retrieved from a borehole of any orientation. All pieces of intact and sound rock core equal to or greater than 100 mm (4 in.) long are summed and divided by the total length of the core run. RQD is determined in accordance with ASTM D6032.

SCR (Solid Core Recovery) denotes the percentage of solid core (cylindrical) retrieved from a borehole of any orientation. All pieces of solid (cylindrical) core are summed and divided by the total length of the core run (It excludes all portions of core pieces that are not fully cylindrical as well as crushed or rubble zones).

Fracture Index (FI) is defined as the number of naturally occurring fractures within a given length of core. The Fracture Index is reported as a simple count of natural occurring fractures.

Terminology describing rock with respect to discontinuity and bedding spacing:

Spacing (mm)	Discontinuities	Bedding
>6000	*Extremely Wide*	-
2000-6000	*Very Wide*	*Very Thick*
600-2000	*Wide*	*Thick*
200-600	*Moderate*	*Medium*
60-200	*Close*	*Thin*
20-60	*Very Close*	*Very Thin*
<20	*Extremely Close*	*Laminated*
<6	-	*Thinly Laminated*

Terminology describing rock strength:

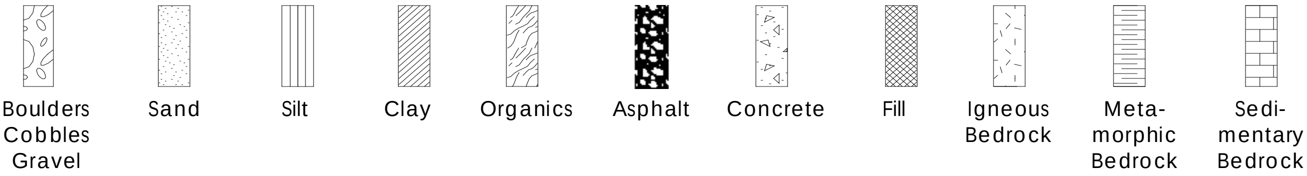
Strength Classification	Grade	Unconfined Compressive Strength (MPa)
Extremely Weak	R0	<1
Very Weak	R1	1 – 5
Weak	R2	5 – 25
Medium Strong	R3	25 – 50
Strong	R4	50 – 100
Very Strong	R5	100 – 250
Extremely Strong	R6	>250

Terminology describing rock weathering:

Term	Symbol	Description
Fresh	W1	No visible signs of rock weathering. Slight discoloration along major discontinuities
Slightly	W2	Discoloration indicates weathering of rock on discontinuity surfaces. All the rock material may be discolored.
Moderately	W3	Less than half the rock is decomposed and/or disintegrated into soil.
Highly	W4	More than half the rock is decomposed and/or disintegrated into soil.
Completely	W5	All the rock material is decomposed and/or disintegrated into soil. The original mass structure is still largely intact.
Residual Soil	W6	All the rock converted to soil. Structure and fabric destroyed.

STRATA PLOT

Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



SAMPLE TYPE

SS	Split spoon sample (obtained by performing the Standard Penetration Test)
ST	Shelby tube or thin wall tube
DP	Direct-Push sample (small diameter tube sampler hydraulically advanced)
PS	Piston sample
BS	Bulk sample
HQ, NQ, BQ, etc.	Rock core samples obtained with the use of standard size diamond coring bits.

WATER LEVEL MEASUREMENT

▼	measured in standpipe, piezometer, or well
▽	inferred

RECOVERY

For soil samples, the recovery is recorded as the length of the soil sample recovered. For rock core, recovery is defined as the total cumulative length of all core recovered in the core barrel divided by the length drilled and is recorded as a percentage on a per run basis.

N-VALUE

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 140 pound (63.5 kg) hammer falling 30 inches (760 mm), required to drive a 2 inch (50.8 mm) O.D. split spoon sampler one foot (300 mm) into the soil. In accordance with ASTM D1586, the N-Value equals the sum of the number of blows (N) required to drive the sampler over the interval of 6 to 18 in. (150 to 450 mm). However, when a 24 in. (610 mm) sampler is used, the number of blows (N) required to drive the sampler over the interval of 12 to 24 in. (300 to 610 mm) may be reported if this value is lower. For split spoon samples where insufficient penetration was achieved and N-Values cannot be presented, the number of blows are reported over sampler penetration in millimetres (e.g. 50/75). Some design methods make use of N-values corrected for various factors such as overburden pressure, energy ratio, borehole diameter, etc. No corrections have been applied to the N-values presented on the log.

DYNAMIC CONE PENETRATION TEST (DCPT)

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to ‘A’ size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone one foot (300 mm) into the soil. The DCPT is used as a probe to assess soil variability.

OTHER TESTS

S	Sieve analysis
H	Hydrometer analysis
k	Laboratory permeability
γ	Unit weight
G_s	Specific gravity of soil particles
CD	Consolidated drained triaxial
CU	Consolidated undrained triaxial with pore pressure measurements
UU	Unconsolidated undrained triaxial
DS	Direct Shear
C	Consolidation
Q_u	Unconfined compression
I_p	Point Load Index (I_p on Borehole Record equals $I_p(50)$ in which the index is corrected to a reference diameter of 50 mm)

	Single packer permeability test; test interval from depth shown to bottom of borehole
	Double packer permeability test; test interval as indicated
	Falling head permeability test using casing
	Falling head permeability test using well point or piezometer

Stantec

RECORD OF BOREHOLE No BH15-13

1 OF 1 **METRIC**

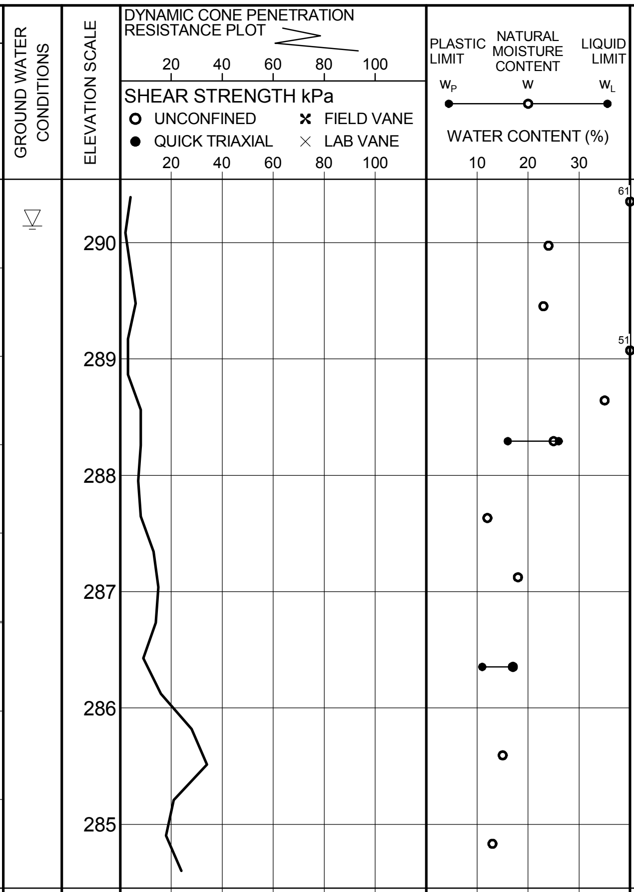
W.P. 3065-11-00	LOCATION Hwy 24, Township of South Dumfried, ON	N: 4 792 086 E: 239 824	ORIGINATED BY AN
DIST South Dumfries HWY 24	BOREHOLE TYPE Portable Equipment, DCPT - Pionjar Split spoon Sampler		COMPILED BY AN
DATUM Geodetic	DATE 2015 06 25 - 2015 06 25		CHECKED BY CM

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
290.5	
0.0	380 mm TOPSOIL
290.2 0.4	FILL: silty SAND (SM) Loose to dense Brown to grey, wet -Groundwater observed at a depth of 0.4 m
289.1 1.4	PEAT
289.0 1.5	Sandy clayey SILT (CL) to clayey SILT (CL-ML) with sand Stiff Brown to grey, wet
287.8 2.8	SILT (ML) with sand to sandy SILT (ML) Very loose to compact Brown to grey, wet
286.7 3.8	Clayey SILT (CL-ML) with sand
286.0 4.6	SILT (ML) with sand to sandy SILT (ML) Very loose to compact Brown to grey, wet -basal heave in augurs between elevations of 286 m and 285 m
284.5 6.1	End of Borehole -Split spoon sampler was advanced using a Pionjar jackhammer -DCPT was carried out using a 70 lb weight hammer and 30 in. drop -DCPT values corrected for 50% of the field values

SAMPLES

NUMBER	TYPE	"N" VALUES	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	-					
2	SS	-		1	61	34	4
3	SS	-		3	25	59	13
4	SS	-					
5	SS	-					
6	SS	-		2	22	64	12
7	SS	-					
8	SS	-					



✕ 3, × 3: Numbers refer to Sensitivity

O 3% STRAIN AT FAILURE

Stantec

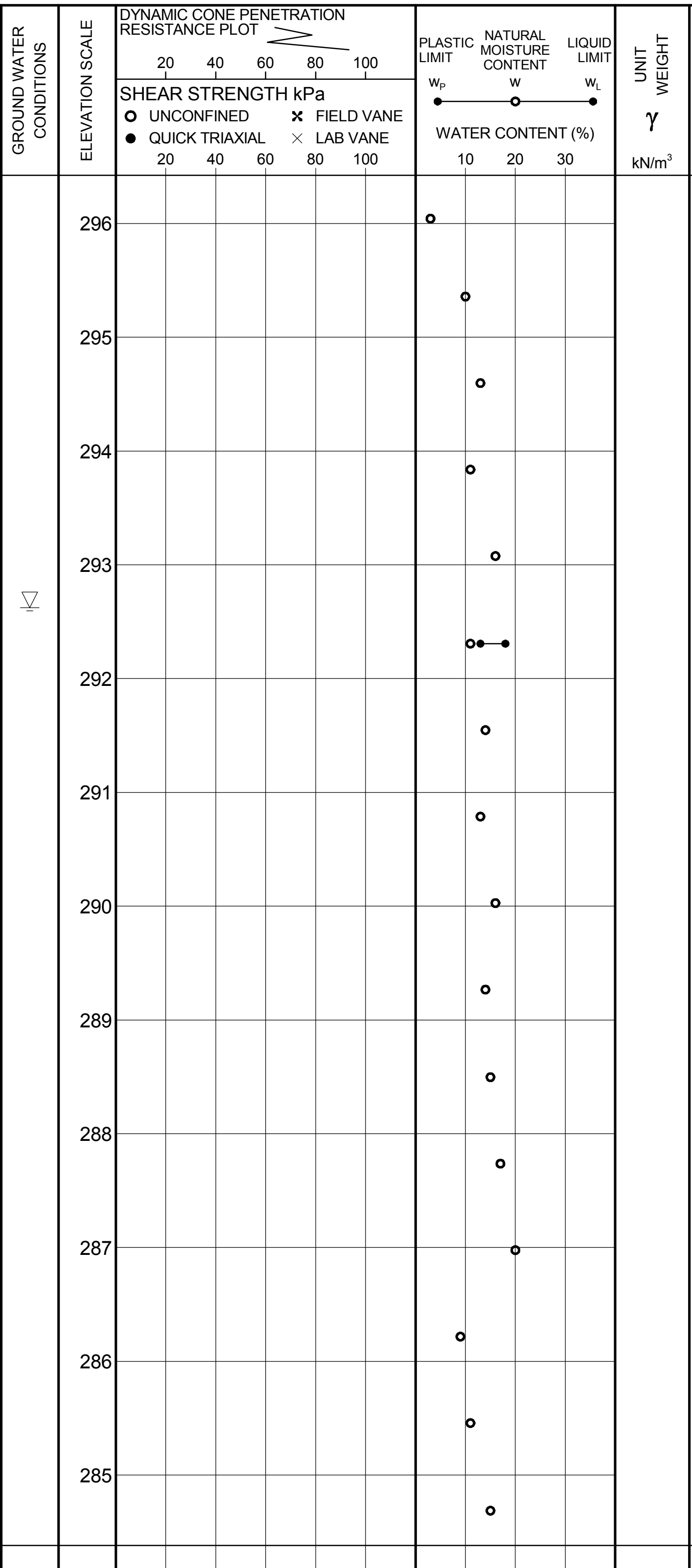
RECORD OF BOREHOLE No BH15-14

1 OF 1 **METRIC**

W.P. 3065-11-00	LOCATION Hwy 24, Township of South Dumfried, ON	N: 4 792 074 E: 239 811	ORIGINATED BY AN
DIST South Dumfries HWY 24	BOREHOLE TYPE Hollow Stem Augers - Split spoon Sampler		COMPILED BY AN
DATUM Geodetic	DATE 2015 06 10 - 2015 06 10		CHECKED BY CM

ELEV DEPTH	SOIL PROFILE DESCRIPTION
296.4	
296.4 0.0	60 mm ASPHALT
0.1	Fill: silty SAND (SM) Loose to dense Brown to grey, moist to wet -Trace of gravel to a depth of 0.76 m -Cobbles and boulders encountered between 2.6 m and 2.9 m
293.4 3.1	Sandy clayey SILT (CL) to clayey SILT (CL-ML) with sand Stiff Brown to grey, wet -Groundwater observed at a depth of 3.8 m
291.9 4.6	Sandy SILT (ML) Very loose to compact Brown to grey, wet
286.5 9.9	Silty SAND (SM) Compact Grey, wet -Cobbles and boulders encountered between 9.9 m and 10.5 m
284.4 12.0	End of Borehole

SAMPLES NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	GS	-				
2	SS	12				
3	SS	9	6	61	(33)	
4	SS	17				
5	SS	17				
6	SS	20	6	37	46	11
7	SS	26				
8	SS	15				
9	SS	4	4 non-plastic	46	42	8
10	SS	5				
11	SS	3				
12	SS	5				
13	SS	26				
14	SS	15	13 non-plastic	38	41	8
15	SS	15				
16	SS	17	2	60	33	5



✖ 3, × 3: Numbers refer to Sensitivity

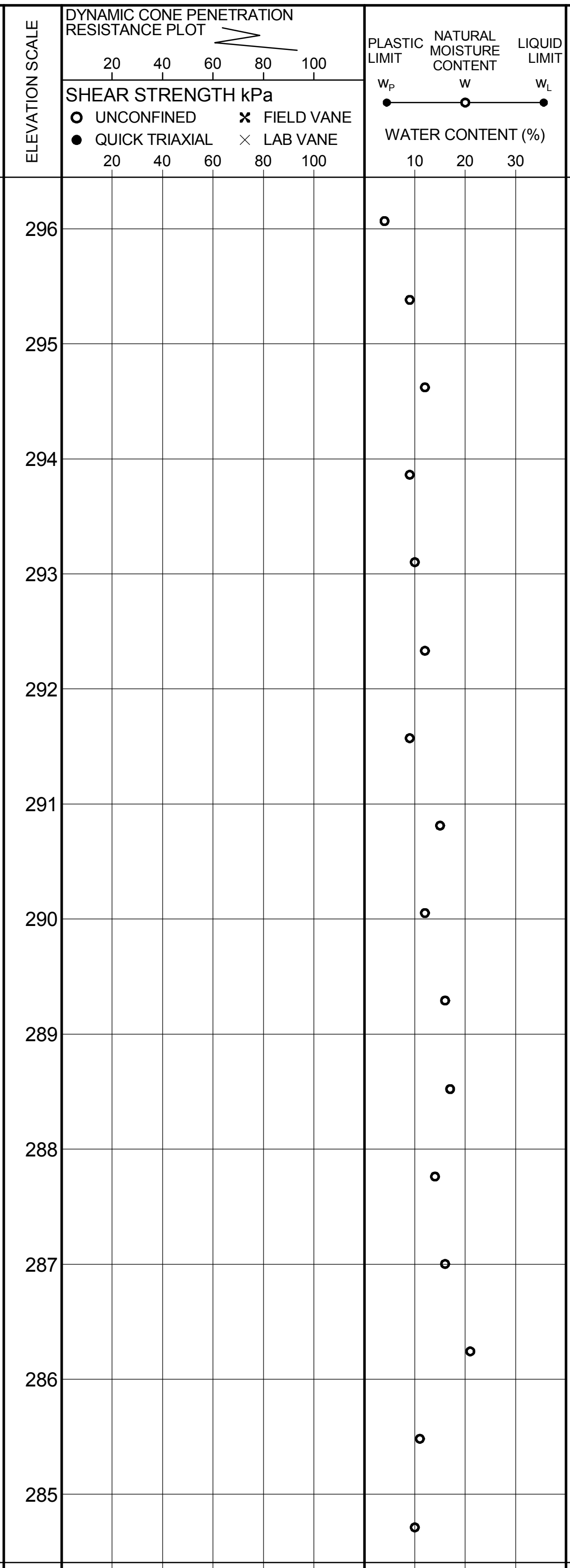
○ 3% STRAIN AT FAILURE

Stantec

RECORD OF BOREHOLE No BH15-15

1 OF 1 **METRIC**

W.P. 3065-11-00	LOCATION Hwy 24, Township of South Dumfried, ON	N: 4 792 082 E: 239 798	ORIGINATED BY AN
DIST South Dumfries HWY 24	BOREHOLE TYPE Hollow Stem Augers - Split spoon Sampler		COMPILED BY AN
DATUM Geodetic	DATE 2015 06 10 - 2015 06 10		CHECKED BY CM



ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
296.4											
296.4 0.0 0.1	50 mm ASPHALT										
	Fill: silty SAND (SM) Loose to dense Brown to grey, moist to wet		1	GS	-						
			2	SS	14						
			3	SS	23			10	57	(33)	
			4	SS	25						
			5	SS	33						
292.6 3.8	Sandy SILT (ML) Very loose to compact Brown to grey, wet -Groundwater observed at a depth of 5.3 m		6	SS	25						
			7	SS	28			8 non-plastic	42	40	10
						▽					
			8	SS	11						
			9	SS	8						
			10	SS	5			8 non-plastic	38	45	9
			11	SS	6						
			12	SS	10						
			13	SS	12						
	-clayey silt seam		14	SS	21						
285.8 10.7	Silty SAND (SM) Compact Grey, wet		15	SS	11			7 non-plastic	50	33	10
			16	SS	17						
284.4 12.0	End of Borehole										

×3, ×3: Numbers refer to Sensitivity

O 3% STRAIN AT FAILURE

STN13-ONTARIO MTO STANTEC 165000903 - PAVEMENT REHAB HWY 24 - MTO.GPJ ONTARIO MOT.GDT 12/14/15

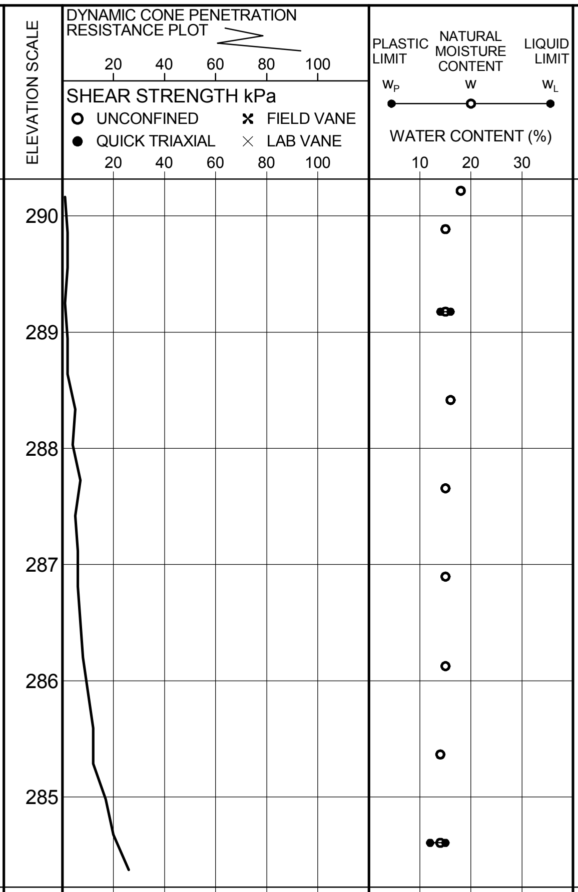
Stantec

RECORD OF BOREHOLE No BH15-16

1 OF 1 **METRIC**

W.P. 3065-11-00
LOCATION Hwy 24, Township of South Dumfried, ON N: 4 792 072 E: 239 784
ORIGINATED BY AN
DIST South Dumfries HWY 24
BOREHOLE TYPE Portable Equipment, DCPT - Pionjar Split spoon Sampler
COMPILED BY AN
DATUM Geodetic
DATE 2015 06 25 - 2015 06 25
CHECKED BY CM

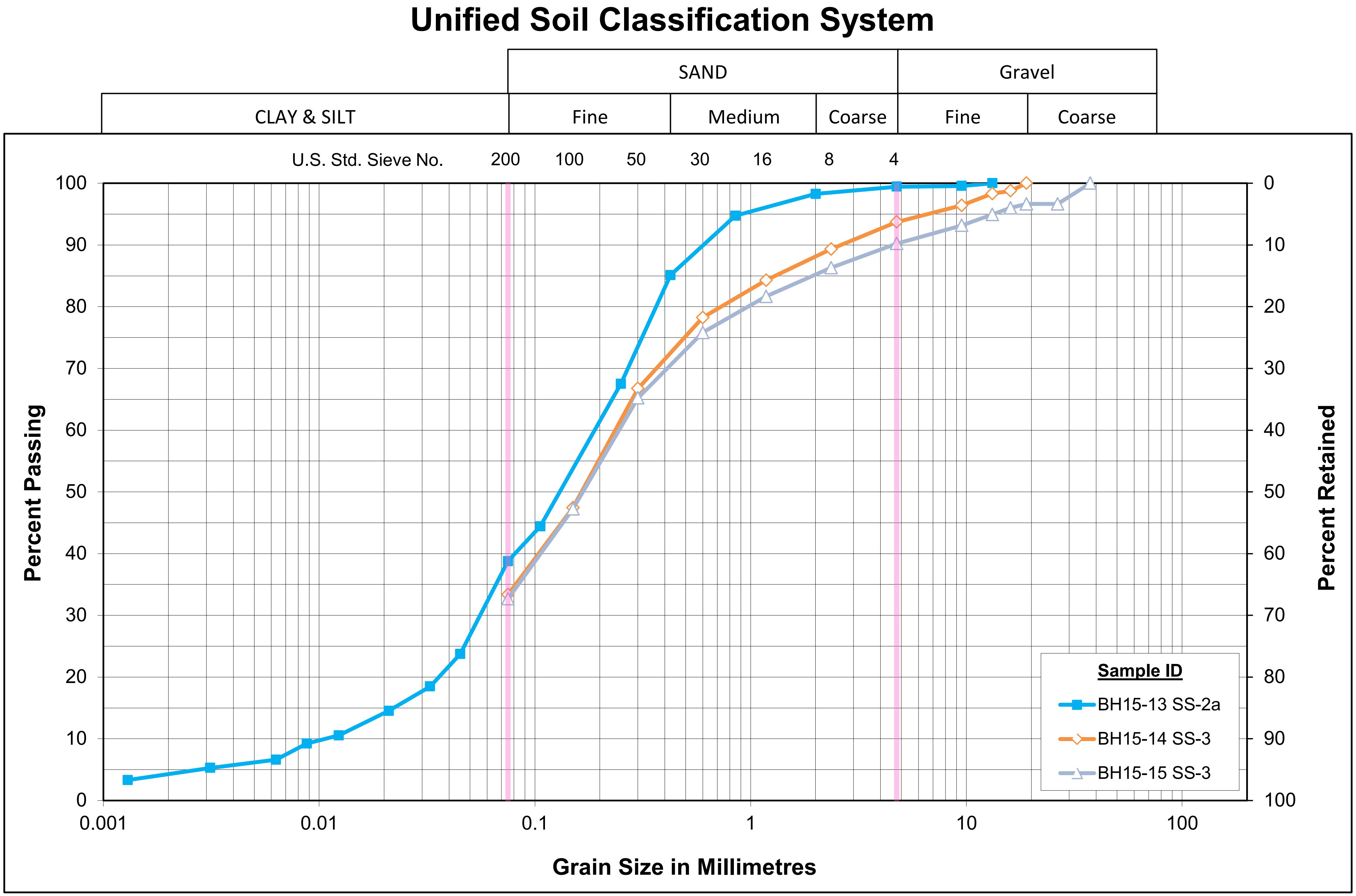
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
290.3 0.0										
290.1	200 mm TOPSOIL									
0.2	Sandy SILT (ML) Very loose to compact Brown to grey, wet -Groundwater observed at a depth of 0.2 m -Trace of organic material to a depth of 1.5 m	1	SS	-	▽					
		2	SS	-			8	38	47	7
		3	SS	-						
		4	SS	-						
		5	SS	-						
		6	SS	-						
		7	SS	-						
		8	SS	-			2	43	47	8
284.2 6.1	End of Borehole -Split spoon sampler was advanced using a Pionjar jackhammer -DCPT was carried out using a 70 lb weight hammer and 30 in. drop -DCPT values corrected for 50% of the field values									



✕ 3, × 3: Numbers refer to Sensitivity
○ 3% STRAIN AT FAILURE

APPENDIX C

Laboratory Test Result



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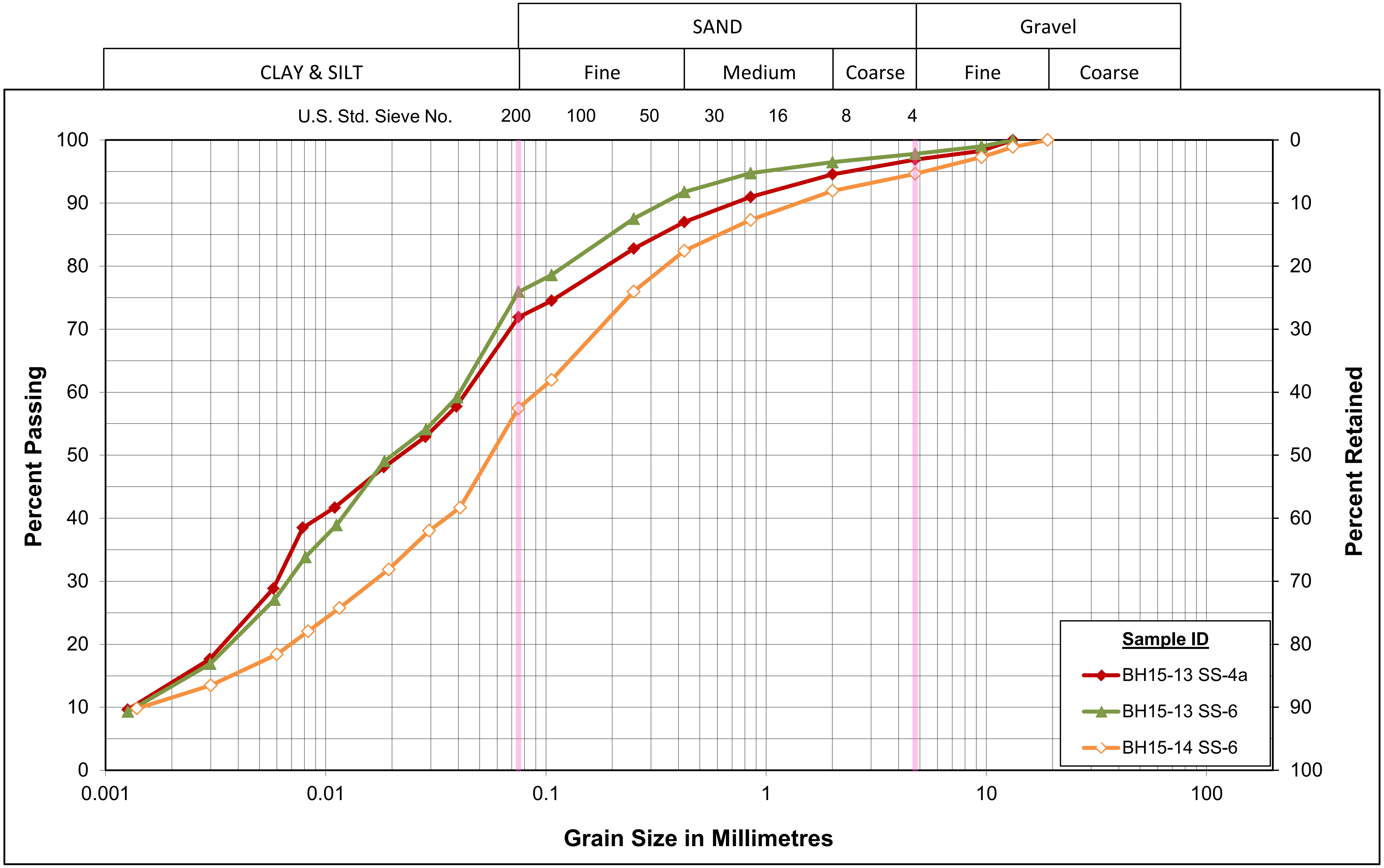
GRAIN SIZE DISTRIBUTION
FILL: Silty SAND (SM)

Figure No. 1

Project No. 165000903

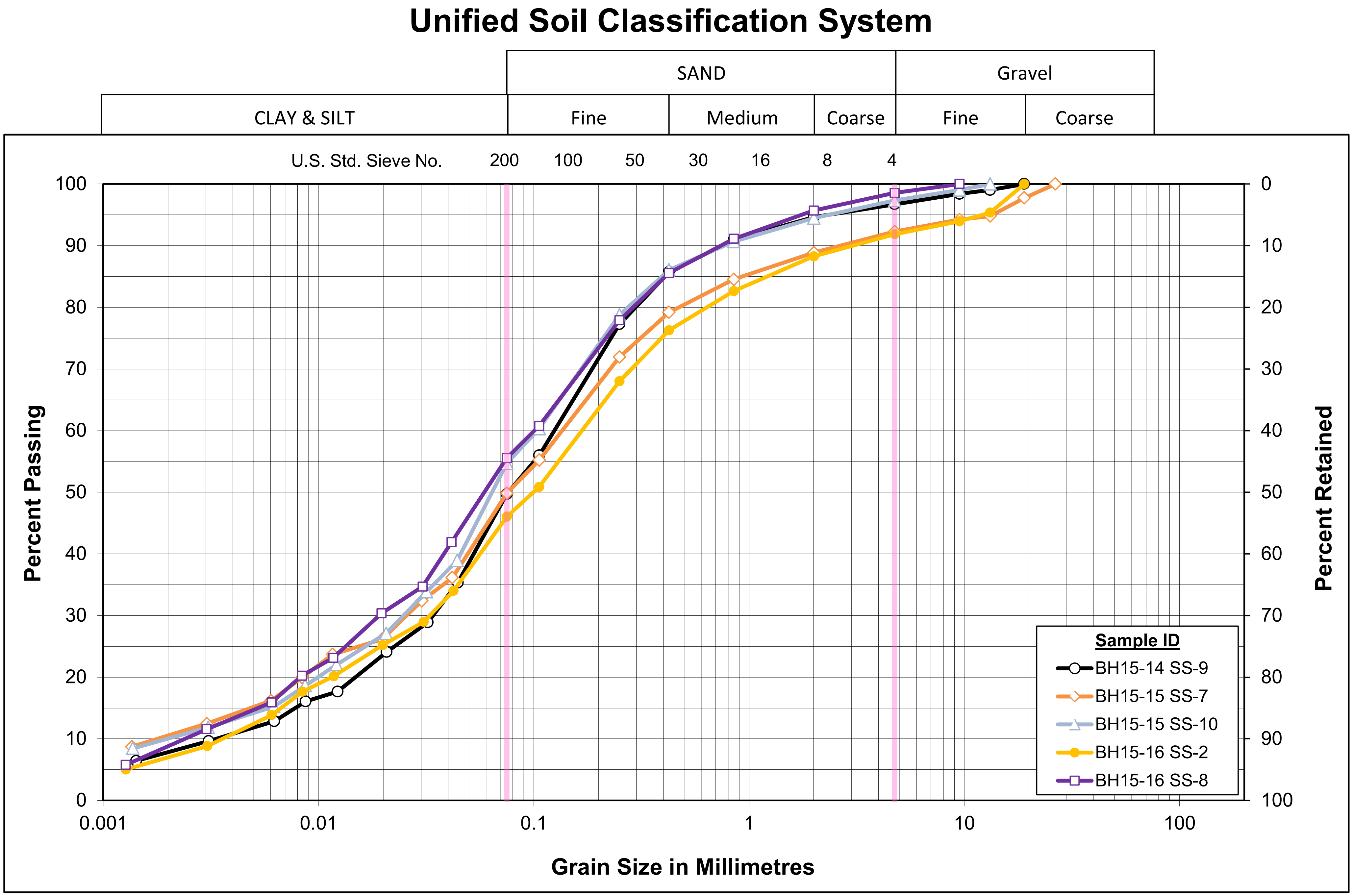

Unified Soil Classification System

Stantec

GRAIN SIZE DISTRIBUTION
Sandy Clayey SILT (CL-ML)
to Clayey SILT (CL) with Sand

Figure No. 2

Project No. 165000903

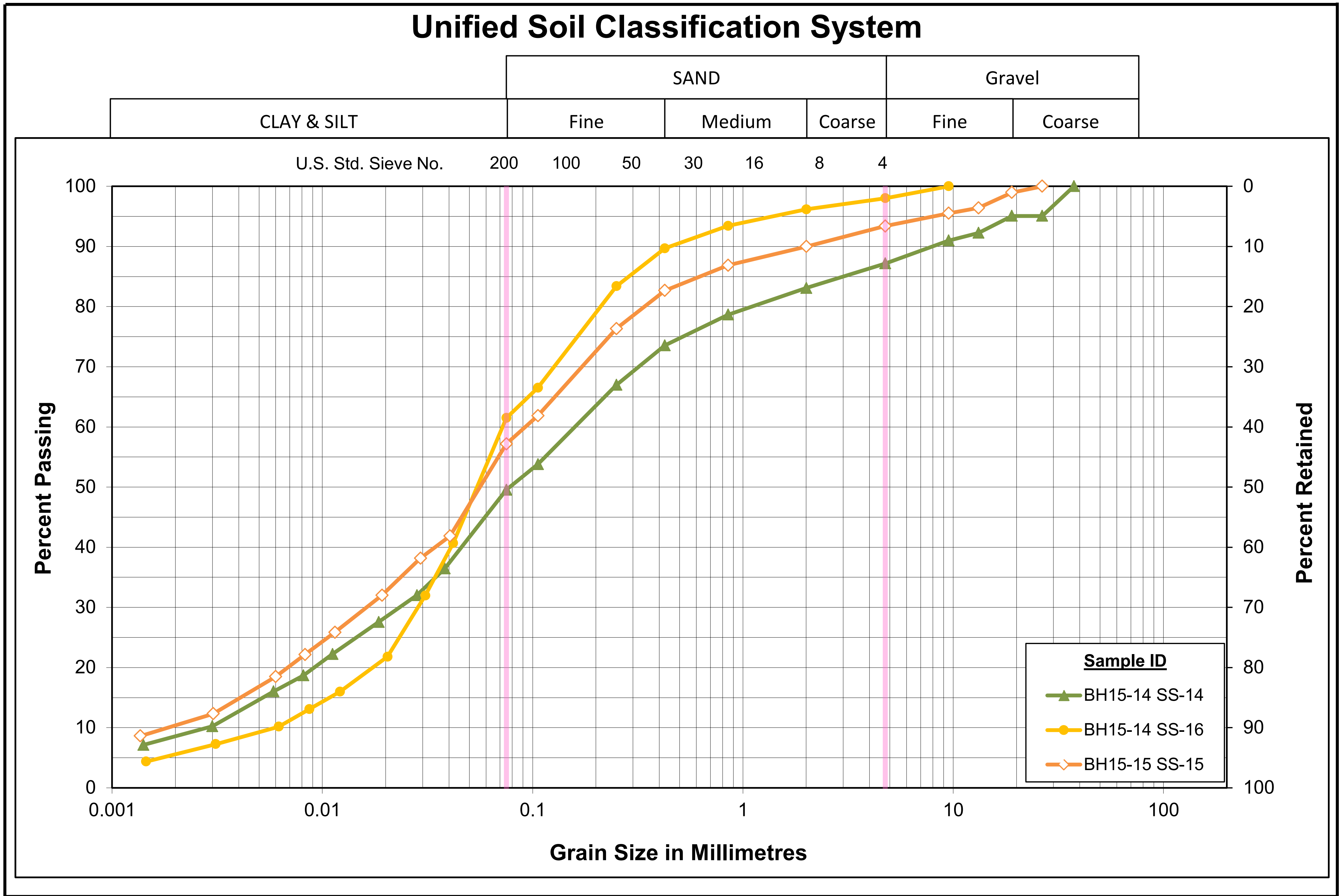


Stantec

GRAIN SIZE DISTRIBUTION
Sandy SILT (ML)

Figure No. 3

Project No. 165000903

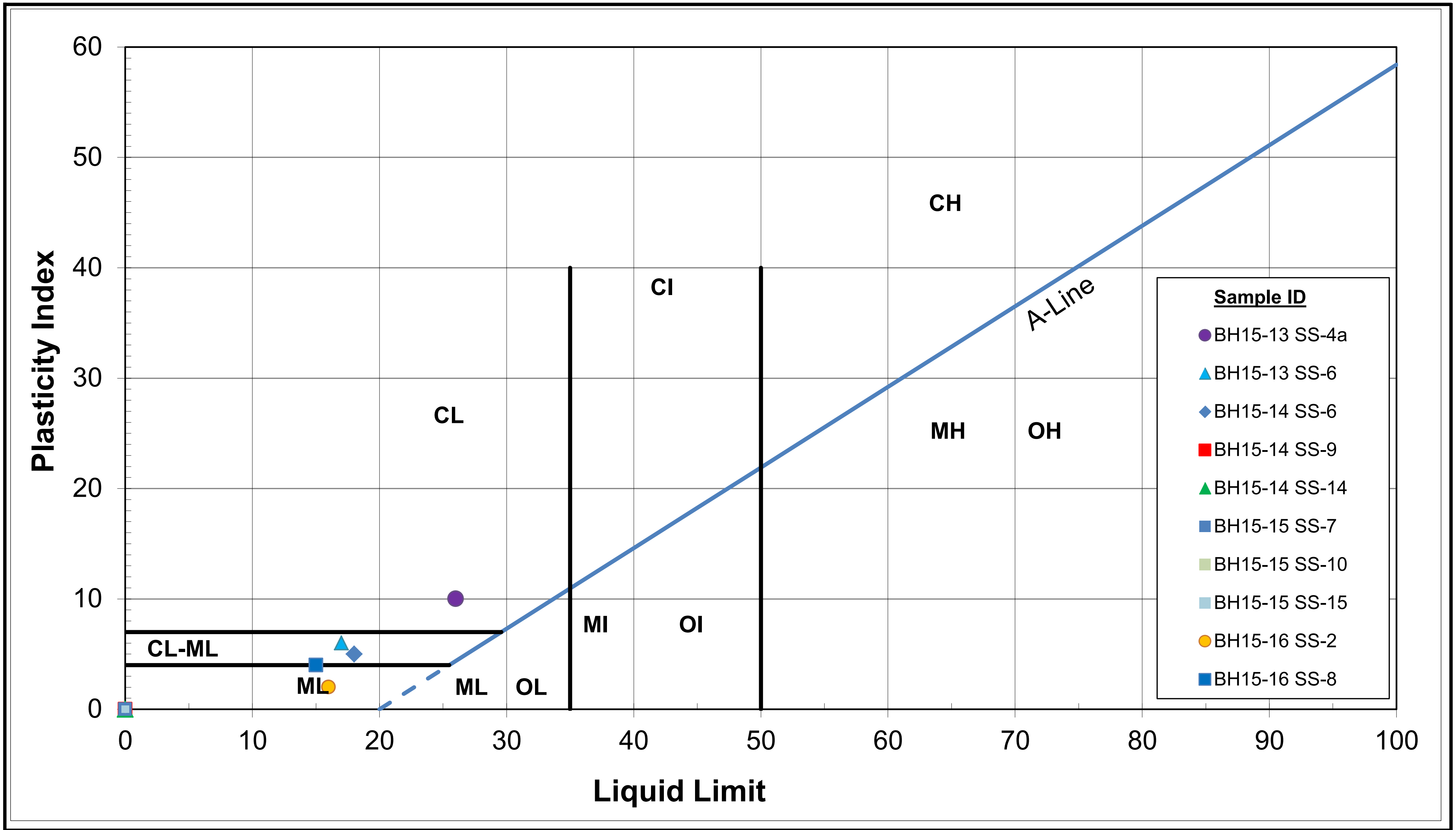


Stantec

GRAIN SIZE DISTRIBUTION
Silty SAND (SM)

Figure No. 4

Project No. 165000903



Stantec	PLASTICITY CHART	Figure No. 5
		Project No. 165000903

APPENDIX D

Notice to Contractor – Presence of Cobbles and Boulders

Pipe Installation by Trenchless Method

NOTICE TO CONTRACTOR – Cobbles and Boulders

Special Provision

Cobbles and Boulders within Soil

Cobbles and boulders were inferred during drilling of the boreholes at several of the culvert replacement locations. Cobbles and boulders were inferred during drilling and the observations are documented in the Foundation Investigations noted below. It recommended that the bidder review the Foundation Investigation Reports and borehole records provided in the Reports with respect to the presence of cobbles and boulders.

Presence of cobbles and boulders are noted in the following Foundation Investigation Report:

- Foundation Investigation and Design Report titled Highway 24 Resurfacing and Replacement of Culvert at Station 17+001 (Site No. 23) Township of South Dumfries, ON
  (Project No. 165000903)

PIPE INSTALLATION BY TRENCHLESS METHOD – Item No.

Special Provision

1. SCOPE

This specification covers the general requirements for the installation of pipes by trenchless methods, including Jack & Bore, Pipe Ramming, Directional Drilling, and Tunnelling. The Contractor shall determine the most appropriate method of installation for each of the crossing locations.

This specification shall supersede OPSS 415 (Construction Specification for Pipeline Installation by Tunneling), OPSS 416 (Construction Specification for Pipeline and Utility Installation by Jacking and Boring) and OPSS 450 (Construction Specification for Pipeline and Utility Installation in Soil by Horizontal Directional Drilling).

2. REFERENCES

This specification refers to the following standards, specifications, or publications:

Ontario Provincial Standard Specifications, General

OPSS 180	Management and Disposal of Excess Materials

Ontario Provincial Standard Specifications, Construction

OPSS 401	Trenching, Backfilling, and Compacting
OPSS 404	Support Systems
OPSS 491	Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 492	Site Restoration Following Installation of Pipelines, Utilities and Associated Structures
OPSS 517	Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS.PROV 539	Temporary Protection Systems

Ontario Provincial Standard Specifications, Material

OPSS.PROV 1004	Aggregates - Miscellaneous
OPSS.PROV 1350	Concrete - Materials and Production
OPSS.PROV 1440	Steel Reinforcement for Concrete
OPSS 1802	Smooth Walled Steel Pipe
OPSS.PROV 1820	Circular and Elliptical Concrete Pipe
OPSS 1840	Non-Pressure Polyethylene (PE) Plastic Pipe Products

American Society for Testing and Materials (ASTM) International Standards

ASTM A252-93	Welding and Seamless Steel Pipe Piles
ASTM D2657-03	Standard Practice for Heat Fusion Joining of Polyelofin Pipe and Fittings
ASTM D3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
ASTM F894	Polyethylene Large Diameter Profile Wall Sewer and Drain Pipe

Canadian Standards Association Standards:

CSA B182.6	Profile Polyethylene Sewer Pipe and Fittings.
CAN/CSA A5-93	Portland Cement
CSA W59	Welded Steel Construction (Metal Arc Welding)

3. DEFINITIONS

For the purpose of this specification, the following definitions apply:

Auger Jack & Bore: a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking ahead and rotating a cutter head, followed by removal of material from inside the bore by using an auger.

Backreamer: a cutting head suitably designed for the subsurface conditions that is attached to the end of a drill string to enlarge the pilot bore during a pullback operation.

Bore Path: a drilled path according to the grade and alignment tolerances specified in the Contract Documents.

Design Engineer: means the Engineer retained by the Contractor who produces the original design and working drawings. The design engineer shall be licensed to practice in the Province of Ontario.

Design Checking Engineer: means the Engineer retained by the Contractor who checks the original design and working drawings. The design checking engineer shall be licensed to practice in the Province of Ontario.

Digger Shield/Hand Mining: a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking ahead while tunnelling advances using hand–mining (man-entry operation or "Jack and Mine) or a "digger" type shield with a hydraulic excavator arm to remove materials from inside the liner pipe.

Drilling Fluids: a mixture of water and additives, such as bentonite, polymers, surfactants, and soda ash, designed to block the pore space on a bore wall, reduce friction in the bore, and to suspend and carry cuttings to the surface.

Drilling Fluid Fracture or Frac Out: a condition where the drilling fluid's pressure in the bore is sufficient to overcome the in situ confining stress, thereby fracturing the soil and/or rock materials and allowing the drilling fluids to migrate to the surface at an unplanned location.

Engineer: a Professional Engineer licensed by the Professional Engineers of Ontario to practice in the Province of Ontario.

Excavation: includes all materials encountered regardless of type and extent. Excavation shall include removal of natural soil, large boulders, cobbles, wood and fill regardless of means necessary to break consolidated materials for removal.

Environmentally Sensitive Area (ESA): areas adjacent to construction that are off limits to the Contractor as specified elsewhere in the Contract.

Fill: man-made mixture of previously placed/handled materials such as sand, clay, silt, gravel, broken rock, sometimes containing organic and/or deleterious materials, placed in an excavation or other area to raise the surface elevation.

Grouting: injection of grout into voids.

Guidance System: an electronic system capable of locating the position, depth and orientation of the drill head during the directional drilling process.

Directional Drilling (DD): directional boring or guided boring.

HDPE: high density polyethylene.

Inadvertent Returns: the flow of unexpected fluids, saturated materials (or running soil) towards the drilling rig that typically originated from an artesian aquifer encountered during the drilling process.

Loss of Circulation: the discontinuation of the flow of drilling fluid in the bore back to the entry or exit point or other planned recovery points.

Pilot Bore: the initial bore to set directional controlled horizontal and vertical alignment between the connecting points.

Pipe Jacking: a method for installing steel casing or concrete pipe in the subsurface utilizing hydraulically operated jacks of adequate number and capacity to ensure smooth and uniform advancement without overstressing the liner/pipe.

Pipe Ramming: a method for installing steel casings utilizing the energy from a percussion hammer to advance a steel casing with a cutting shoe attached at the front end of the casing.

Primary Liner (Support): system installed prior to or concurrent with excavation, to maintain stability of an excavation and to support earth or rock and any structure utilities or other facilities in or on the supported earth or rock mass, until the excavation is completed.

Product: pipe culverts, pipe sewers, watermain pipe and sanitary pipe.

Pullback: that part of the DD method in which the drill string is pulled back through the bore path to the entry point.

Quality Verification Engineer (QVE): an Engineer who has a minimum of five (5) years experience in the field of pipe installation using trenchless methods or alternatively has demonstrated expertise by providing satisfactory quality verification services for the work at a minimum of two (2) projects of similar scope to the contract. The Quality Verification Engineer shall be retained by the Contractor to certify that the work is in general conformance with the contract documents and to issue Certificate(s) of Conformance.

Reaming: a process for pulling a tool attached to the end of the drill string through the bore path to enlarge the bore and mix the cuttings with the drilling fluid. This typically includes multiple passes.

Rock: natural beds or massive fragments, or the hard, stable, cemented part of the earth's crust, igneous, metamorphic, or sedimentary in origin, which may or may not be weathered and includes boulders having a size equivalent to 0.3 m in diameter or greater.

Secondary Liner: concrete pipe, HDPE pipe or un-reinforced cast-in-place concrete, installed subsequent to tunnel excavation.

Shaft: vertically sided excavation used as entry and/or exit points from which the trenchless method is initiated or directed for the installation of product.

Strike Alert: a system that is intended to alert and protect the operator in the case of inadvertent drilling into an electrical utility cable. The strike alert system consists of a sensor and an alarm connected to the drill rig and a grounding stake. The alarm may be audio or visual or both.

Slurry: a mixture of soil and/or rock cuttings, and drilling fluid.

Soil: all materials except those defined as rock, and excludes stone masonry, concrete, and other manufactured materials; includes rock fragments having an equivalent size less than 0.3 m in diameter.

Trenchless Installation: an underground method of constructing a passage open at both ends that involves installing a pipe. For the purpose of this specification, the pipe may be installed by any of the various methods defined herein such as Auger Jack & Boring, Pipe Jacking, Pipe Ramming, Directional Drilling, or using a tunnelling machine or hand mining methods.

Tunnelling: An underground method of constructing a passage using a tunnel boring machine (TBM), a microtunnel boring machine (MTBM) or hand mining using a shield to support the opening.

4. DESIGN AND SUBMISSION REQUIREMENTS

4.01 General

The Contractor's documentation, submission requirements and installation methods shall specifically consider and address the subsurface conditions at each pipe crossing as identified in the Foundation Investigation Report or elsewhere in the Contract Documents.

4.02 Working Drawings

Three copies of stamped working drawings for portal or shaft construction, primary liner, excavation, secondary lining, dewatering and groundwater control and grouting shall be submitted to the Contract Administrator (CA) at least one week prior to the commencement of the work for information purposes. All submissions shall bear the seal and signature of the Design Engineer and Design Checking Engineer. The Contractor shall have a copy of the stamped working drawings at the site during construction.

As a minimum, working drawings/details pertaining to the tunnel design and construction shall include the following (as appropriate):

a) Plans, Elevations and Details:

- A work plan outlining the materials, procedures, methods and schedule to be used to execute the work;
- A list of personnel, including backup personnel, and their qualifications and experience;
- A safety plan including the company safety manual and emergency procedures;
- The work area layout;
- An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail;
- A drilling fluid management plan, if applicable, that addresses control of frac-out pressures, any potential environmental impacts and includes a contingency plan detailing emergency procedures in the event that the fluid management plan fails;

- Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations; and
- Excavated materials disposal plan.

b) Design Criteria:

- Primary liner design details, if applicable;
- Design assumption and material data when materials other than those specified are proposed for use; and
- Drill path design, details of alignment and alignment control, maximum curvature and reaming stages.

c) Materials:

- Certification from the manufacturer that the product furnished on the contract meets the specifications cited in the manufacturer's product specification and that the materials supplied are suitable for the application; and
- Material mixture for filling voids and installation procedures.

d) Upstream/Downstream Portal Installation Procedure:

- The access shaft or entry/exit pit details designed and stamped/signed by the Design Engineer, as applicable; and
- Face support and other temporary support details, if applicable.

e) Primary Liner/Secondary Liner Installation and Grouting Procedure:

- Excavation and pipe installation procedures, including methods to handle obstructions and prevent soil cave-in; and
- Details of tunnelling equipment/methods to be used for the works.

f) Excavation and Dewatering:

- Ground control/dewatering details, as applicable, describing the proposed method for control, handling, treatment, and disposal of water.

g) Monitoring Method:

- The methods to be employed to monitor and maintain the alignment of the installation.

4.03 Site Survey

Prior to commencing the work, the Contractor shall, at each pipe location, lay-out the alignment and install settlement monitoring points.

4.04 Certificate of Conformance

The Contractor shall submit details of the sequence and method of construction to the Quality Verification Engineer for review, prepared and stamped by the Design Engineer. The Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer a minimum of one week prior to commencement of work under this item. The Certificate shall state that the construction procedures are in conformance with the requirements and specifications of the contract documents.

The Contractor shall submit to the Contract Administrator a Certificate of Conformance sealed and signed by the Quality Verification Engineer upon completion of each of the following operations and prior to commencement of each subsequent operation for each pipe installation:

Site Surveying (as noted in Section 4.02)
Excavation for pits including dewatering of excavations
Jacking/Ramming/Directional Drilling of Casing/Liner
Installation of the Product
Grouting Operations

Each Certificate of Conformance shall state that the work has been carried out in general conformance with the contract documents, specifications and/or stamped working drawings.

In addition, upon completion of the installation of the pipe at each location, the Contractor shall submit to the Contract Administrator a final Certificate of Conformance sealed and signed by the Quality Verification Engineer. The Certificate shall state that the pipe has been installed in general conformance with the Contractor's Submission and Design Requirements, stamped working drawings and contract documents.

The Design Engineer will not be permitted to carry out the work of the Quality Verification Engineer.

5. MATERIALS

5.01 Product

The product shall be concrete pipe or high density polyethylene pipe as specified.

5.02 Concrete

Concrete shall be according to OPSS.PROV 1350. The concrete strength shall be as specified in the Contractor's design submission.

5.03 Concrete Reinforcement

Steel reinforcing for concrete work shall be according to OPSS.PROV 1440.

5.04 Timber

Timber shall be sound, straight, and free from cracks, shakes and large or loose knots.

5.05 Grout

The Contractor shall submit the proposed grout mix design for grouts to be used for lubricating jacking pipe and for filling of voids and annular spaces. Purging grout shall consist of a mixture of one part Portland cement conforming to the requirements of CAN/CSA A5-93 and two parts mortar sand conforming to OPSS.PROV 1004 wetted with only sufficient water to make the mixture plastic.

5.06 Auger Jack & Bore Materials

5.06.01 Pipe Materials

Steel pipe shall conform with ASTM A252-93 welded joints suitable for jacking operations. The Contractor shall select pipe class for pipe jacking.

Concrete pipe as per OPSS.PROV 1820.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

5.07 Pipe Ramming Materials

5.07.01 Pipe Materials

Steel pipe shall conform with ASTM A 252-93 welded joints.

New steel casing when specified shall be smooth wall carbon steel pipe according to ASTM A252-93 Grade 2.

Used steel casing can be used provided that the steel casing can resist the applicable static and dynamic loadings.

Pipe wall thickness shall be determined by the Contractor based on static and dynamic loads from traffic loading and anticipated ramming forces for selected pipe and driven pipe lengths. The wall thickness shall be increased as required to ensure the casing is not damaged during handling and installation. The pipe minimum wall thickness shall be as per Table 1 of OPSS 1802.

Pipe segments shall be determined by the Contractor.

Steel pipe joints shall be pressure fit type or welded.

All steel casing pipe shall be square cut.

Steel casing pipe shall have roundness such that the difference between the major and minor outside diameters shall not exceed 1% of the specified nominal outside diameter or 6 mm, whichever is less.

Steel casing pipe shall have a minimum allowable straightness of 1.5 mm maximum per metre of length.

5.07.02 Mill Certificates

For permanent casing, the Contractor shall submit to the Contract Administrator at the time of delivery one copy of the mill certificate, indicating that the steel meets the requirements for the appropriate standards for casings.

Where mill test certificates originate from a mill outside Canada or the United States of America the Contractor shall have the information on the mill certificate verified by testing by a Canadian laboratory. The laboratory shall be accredited by a Canadian National Accreditation Body to comply with the requirements of ISO/IEC Guide 25 for the specific tests or type of tests required by the material standard specified on the mill test certificate. The mill test certificates shall be stamped with the name of the Canadian testing laboratory and appropriate wording stating that the material conforms to the specified material requirements. The stamp shall include the appropriate material specification number, the date and the signature of an authorized officer of the Canadian testing laboratory.

5.08 Directional Drilling Materials

5.08.01 Drilling Fluids

The drilling fluids shall be mixed according to the manufacturer's recommendations and be appropriate for the anticipated subsurface conditions.

5.08.02 Pipe Materials

High Density Polyethylene (HDPE) pipe as per OPSS 1840 shall be used in accordance with ASTM D3350.

The requirements for fittings shall be suitable for and compatible with the class and type of pipe with which they will be used and in according to CAN/CSA-B182.6 or ASTM F894.

The Contractor shall determine the required dimensional ratio (DR) of the HDPE pipe to support all subsurface conditions and hydrostatic pressures, and to withstand the grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

The Contractor's submission shall demonstrate, in conjunction with the manufacturer's specifications, that the heat resistance of the pipe material is sufficient to tolerate without damage the heat of hydration generated by grout curing.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

Jointing of HDPE piping shall be completed by thermal butt fusion in accordance with manufacturer's recommended procedures and as outlined in the latest revision of ASTM D2657. All manufacturer's recommendations and procedures shall be followed during the jointing process.

Jointing of HDPE piping to other piping materials or appurtenances shall be completed using flanged connections.

5.09 Tunnelling Materials

5.09.01 Primary Liner

Tunnelling methods will require installation of a primary liner. The primary liner shall be designed by the Contractor and the design/drawings shall be stamped/signed by the Design Engineer. The design shall be submitted to the Contract Administrator as specified herein.

5.09.02 Secondary Liner

Concrete or High Density Polyethylene Pipe shall be used according to the following requirements.

5.09.02.01 Concrete Pipe

Concrete pipe as per OPSS.PROV 1820 shall be used. The Contractor shall select the pipe class to withstand grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

5.09.02.02 High Density Polyethylene (HDPE)

High Density Polyethylene (HDPE) pipe as per OPSS 1840 shall be used in accordance with ASTM D3350.

The requirements for fittings shall be according to CAN/CSA-B182.6 or ASTM F894.

The Contractor shall determine the required dimensional ratio (DR) to withstand the grouting pressure and installation forces. The Contractor shall identify these forces in his submission requirements.

Fittings shall be suitable for and compatible with the class and type of pipe with which they will be used.

Jointing of HDPE piping shall be completed by thermal butt fusion in accordance with manufacturer's recommended procedures and as outlined in the latest revision of ASTM D2657. All manufacturer's recommendations and procedures shall be followed during the jointing process.

Jointing of HDPE piping to other piping materials shall be completed using flanged connections.

6. EQUIPMENT

6.01 Auger Jack & Bore Equipment

Pipe auger jack & bore equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

Specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the liner shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

6.02 Pipe Ramming Equipment

Pipe ramming equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

The pipe ramming hammer(s) shall be capable of driving the pipe casing from the drive pit through the existing subsurface conditions at the site.

Specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the pipe shall be submitted to the Contract Administrator for information purposes prior to proceeding with the works.

6.03 Directional Drilling Equipment

6.03.01 General

The directional drilling equipment shall consist of a directional drilling rig and a drilling fluid mixing and delivery system of sufficient capacity to successfully complete the product installation without exceeding the maximum tensile strength of the product being installed.

6.03.02 Drilling Rig

The directional drilling rig shall:

- consist of a leak free hydraulically powered boring system to rotate, push, and pull hollow drill pipe into the ground at a variable angle while delivering a pressurized fluid mixture to a guidable drill head;
- contain a guidance system to accurately guide boring operations;
- be anchored to the ground to withstand the rotating, pushing, and pulling forces required to complete the product installation; and
- be grounded during all operations unless otherwise specified by the drilling rig manufacturer.

6.03.03 Drill Head

The drill head shall be steerable by changing its rotation, be equipped with the necessary cutting surfaces and drilling fluid jets, and be of the type for the anticipated subsurface conditions,

6.03.04 Guidance System

The guidance system shall be setup, installed, and operated by trained and experienced personnel. The operator shall be aware of any magnetic or electromagnetic anomalies and shall consider such influences in the operation of the guidance system when a magnetic or electromagnetic system is used.

6.03.05 Drilling Fluid Mixing System

The drilling fluid mixing system shall be of sufficient size to thoroughly and uniformly mix the required drilling fluid.

6.03.06 Drilling Fluid Delivery System

The delivery system shall have a means of measuring and controlling fluid pressures and be of sufficient flow capacity to ensure that all slurry volumes are adequate for the length and diameter of the final bore and the anticipated subsurface conditions. Connections between the delivery pump and drill pipe shall be leak-free.

6.04 Tunnelling Equipment

Tunnelling equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

Specific details of the manner in which rock or boulders will be broken and removed from the tunnel face shall be submitted to the Contract Administrator information purposes. Use of rock fracturing chemicals shall only be considered subject to a field demonstration satisfactory to the Ministry prior to its use.
Use of explosives is prohibited.

7. CONSTRUCTION

7.01 General

The Contractor shall notify the Contract Administrator at least 48 hours in advance of starting work. The proposed method of pipe installation to be used by the Contractor shall be submitted to the Contract

Administrator for information purposes prior to commencing the work and shall be subject to the limitations presented in the following subsections.

7.01.01 Layout, Alignment and Depth Control

The location of the installation shall be established from the lines, elevations and tolerances specified in the Contract Documents. The pipe installation shall be to the horizontal and vertical alignments specified in the Contract Drawings. Deviations from location, alignment, grades and/or invert levels shall be corrected by the Contractor at no cost to the Ministry.

All reference points necessary to construct the pipe installation and appurtenances shall be laid out.

The Contractor shall calibrate tracking and locating equipment at the beginning of each work day, and shall monitor and record the alignment and depth readings provided by the tracking system at every 5 m in normal conditions and every 2 m where precise alignment control is necessary;

The Contract Administrator shall be provided with the assistance and access necessary to check the layout of the pipe installation and associated appurtenances.

All excavations shall be carried out in accordance with the Occupational Health and Safety Act (OHSA) of Ontario.

For directional drilling, the contractor shall ensure that during pilot hole drilling the maximum degree of deviation or “dog-leg” shall be 2.5 degrees per 9m drill pipe length. Any deviation exceeding 2.5 degrees will necessitate a pull-back and straightening of the alignment at the Contractor’s sole expense. The pilot hole exit location shall be within 0.5m of the target location.

7.01.02 Construction Shafts

Construction shafts shall be specified in the Contractor's submission. The boundaries and protection of these shall be as required to contain all disturbances to areas outside of the ESA limits.

Shafts shall be maintained in a drained condition.

A minimum 2.4 m high secure fence shall be installed around the perimeter of the construction shaft area with gates and truck entrances. The fence shall be removed on completion of the work.

7.01.03 Protection Systems

The construction of all protection systems shall be according to OPSS.PROV 539. Where the stability, safety, or function of an existing roadway, watercourse, other works, proposed works or ESA’s may be impaired due to the method of operation, protection shall be provided. Protection may include sheathing, shoring, and piles where necessary to prevent damage to such works or proposed works.

7.01.04 Settlement or Heave

Any disturbance to the ground surface (settlement or heave) as a result of the pipe installation shall be immediately corrected by the Contract, at no additional cost to the Ministry.

7.01.05 Stability of Excavation

The construction methods, plant, procedures, and precautions employed shall ensure that excavations are stable, free from disturbance, and maintained in a drained condition.

The construction methods, plant, and materials employed shall prevent the migration of soil and/or rock material into the excavation from adjacent ground.

7.01.06 Preservation and Protection of Existing Facilities

Preservation and protection of existing facilities shall be according to OPSS 491.

Minimum horizontal and vertical clearances to existing facilities as specified in the Contract Documents shall be maintained. Clearances shall be measured from the nearest edge of the largest cut diameter required to the nearest edge of the facility being paralleled or crossed.

Existing underground facilities shall be exposed to verify its horizontal and vertical locations when the outlet pipe path comes within 1.0 m horizontally or vertically of the existing facility. Existing facilities shall be exposed by non-destructive methods. The number of exposures required to monitor work progress shall be as specified in the Contract Documents.

7.01.07 Transporting, Unloading, Storing and Handling Materials

Manufacturer's handling and storage recommendations shall be followed.

7.01.08 Trenching, Backfilling and Compacting

Trenching, backfilling, and compacting for entry and exit points or other locations along the pipe path shall be according to OPSS 401.

7.01.09 Support Systems

Support systems shall be according to OPSS 404.

If any open excavation will encroach into the highway embankment the protection system shall satisfy the requirements for Performance Level 2 as specified in OPSS.PROV 539.

7.01.10 Dewatering

The work of this Section includes control, handling, treatment, and disposal of groundwater. The Contractor shall review the foundation investigation report for reference to soil and groundwater conditions on the project site and plan a dewatering scheme accordingly.

The Contractor shall control groundwater inflows to excavations to maintain stability of surrounding ground, to prevent erosion of soil, to prevent softening of ground exposed in the excavation, and to avoid interfering with execution of the work.

The Contractor shall maintain excavations free of standing water at all times during excavation, including while concrete is curing.

Should water enter the excavation in amounts that could adversely affect the performance of the work or could cause loss of ground, the Contractor shall take immediate steps to control the inflow.

The Contractor is alerted that seepage zones of perched water within the fill materials should be expected, particularly where granular materials are excavated.

Dewatering shall be according to OPSS 517.

7.01.11 Removal of Boulders

The Contractor is alerted that cobbles and boulders should be anticipated in the soil deposits at the site. Accordingly, the Contractor shall address the removal of cobbles and boulders in the proposed method of construction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered.

7.01.12 Record Keeping

Verification record requirements of the alignment and depth of the installation shall be as specified in the Contract Documents. A copy of the verification records shall be given to the Contract Administrator at the completion of the installation.

7.01.13 Testing

Testing of the product installation shall consist of verifying the specified grade between the two ends of the pipe and passing of water from the inlet end of the pipe to the outlet end to confirm gravity flow conditions.

7.01.14 Management and Disposal of Excess Material

Management and disposal of excess material shall be according to OPSS 180. Satisfactory re-usable excavated material required for backfill shall be separated from unsuitable excavated material.

7.01.15 Site Restoration

Site restoration shall be according to OPSS 492.

7.01.16 Supervision

A qualified individual, who is experienced in the pipe installation by trenchless methods shall supervise the work at all times.

7.02 Auger Jack & Bore Installation

7.02.01 Method of Installation Procedure

The installation procedure to be used shall be subject to the following limitations:

- Hydraulically operated jacks of adequate number and capacity shall be provided to ensure smooth and uniform advancement without over-stressing of the pipe.
- A suitably padded jacking head or collar shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.
- The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.

- Selection of the excavation method and jacking equipment shall take into consideration the conditions at each pipe crossing.

7.02.02 Pipe Installation

Concrete pipe joints shall be water tight and according to OPSS.PROV 1820 and must withstand jacking forces, determined by the Contractor.

During the jacking of the liner the space between the liner and the wall of the excavation shall be kept filled with bentonite slurry. Upon completion of jacking, the space between the liner and the wall of the excavation shall be filled with grout.

The annular space between the liner and the product shall be fully grouted with a water tight, expandable and stable grout.

7.03 Pipe Ramming Installation

For pipe ramming installation the following requirements apply:

Only smooth walled steel pipe shall be used. But welding of pipe joints shall conform to CAS W59.

Ramming equipment of adequate capacity shall be provided to ensure smooth and uniform advancement without overstressing of the pipe. Delays shall be avoided between ramming operations.

A ramming head shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.

Two or more lubricated guide rails or sills shall be provided of sufficient length to fully support the pipe at the specified line and grade in the ramming pit. Pipe shall be installed to the line and grade specified.

Following installation of the liner pipe, all material shall be removed from the pipe to the satisfaction of the Contract Administrator. Any voids remaining between the pipe and the excavation wall shall be grouted as soon as the pipe is rammed. The annular space between the liner pipe and the product shall be fully grouted with a water tight, expandable and stable grout.

7.04 Directional Drilling Installation

7.04.01 General

When strike alerts are provided on a drilling rig, they shall be activated during drilling and maintained at all times.

7.04.02 Site Preparation

The work site shall be graded or filled to provide a level working area for the drilling rig. No alterations beyond what is required for DD operations are to be made. All activities shall be confined to designated work areas.

7.04.03 Pilot Bore

The pilot bore shall be drilled along the bore path in accordance with the grade, alignment, and tolerances as indicated on the Contractor's submitted drilling plan to ensure that the product is installed to the line and grade shown on the Contract Drawings. The Contractor's methods shall take into consideration the conditions at each crossing within the pipe alignment and shall be suitable to advance through such obstructions such as cobbles and boulders and address the potential for deflection off these obstruction and/or soil conditions.

In the event the pilot bore deviates from the submitted path, the Contract Administrator shall be notified. The Contract Administrator may require the Contractor to pullback and re-drill from the location along the bore path before the deviation.

In the event that a drilling fluid fracture, inadvertent returns, or loss of circulation occurs during pilot bore drilling operations, the Contract Administrator shall be advised of the event and action shall be taken in accordance with the Contractor's submitted contingency plan.

At the entry and exit points, there is potential for ravelling of the existing soil, fill and or weathered rock areas along the alignment. This is conventionally addressed by the use of drilling fluid. However, casing may be required. The Contractor's methods shall take into consideration the potential need to install sections of casing to manage ravelling at or near ground surface.

If a drill hole beneath the highway must be abandoned, the hole shall be backfilled with grout or bentonite to prevent future subsidence.

The Contractor shall maintain drilling fluid pressure and circulation throughout the DD process, including during the initial pilot bore and during the reaming process.

The Contractor shall at all times and for the entire length of the installation alignment be able to demonstrate the horizontal and vertical position of the alignment, the fluid volume used, return rates and pressures.

7.04.04 Drilling Fluid Fracture (Frac-Out)

In order to reduce the potential for hydraulic fracturing of the hole during directional drilling, a minimum depth of cover of 5m is normally maintained between the pipe and the ground surface. Sections of the pipe close to the exit pit with less than 5m cover shall be cased. The Contractor shall ensure that drilling fluid pressures are properly set and controlled to prevent frac-out, for the depth of cover available between the bottom of the pavement structure (bottom of the subbase material) and the top of the bore.

Since fluid loss normally occurs in fault zones, fracture zones, or seams of coarse material, fluid migration does not always gravitate to the surface, thus making detection difficult. Once a fluid loss is detected, the Contractor shall halt operations immediately and conduct a detailed examination of the drill path and implement measures to mitigate fluid loss. If no surface migration is evident, resume operation while paying particular attention to fluid monitoring.

In the event of a fluid migration to the surface occurring, the Contractor shall halt all operations immediately, isolate the migration site, and recover fluids. Once the fracture is controlled, continue drilling operations with the operator paying particular attention to the fracture points

7.04.05 Reaming

The bore shall be reamed using the appropriate tools to a diameter at least 50% greater than the outside diameter of the product.

7.04.06 Product Installation

7.04.06.0 General

The product shall be jointed according to manufacturer's recommendations. The length of the product to be pulled shall be jointed as one length before commencement of the continuous pulling operation.

The product shall be protected from damage during the pullback operation.

The minimum allowable bending radius for the product shall not be exceeded.

Product shall be allowed to recover before connections to new or existing facility are made. Product recovery time shall be according to manufacturers recommendations.

7.04.06.02 Pullback and Grouting

After successfully reaming the bore to the required diameter, the product shall be pulled through the bore path. Once the pullback operation has commenced, it shall continue without interruption until the product is completely pulled into bore unless otherwise approved by the Contract Administrator.

A swivel shall be used between the reamer and the product being installed to prevent rotational forces from being transferred to the product. When specified in the Contract Documents, a weak link or breakaway connector shall be used to prevent excess pulling force from damaging the product.

The product shall be inspected for damage where visible at excavation pits and where it exits the bore. Any damage noted shall be rectified to the satisfaction of the Contract Administrator,

The pull back and reaming operations shall not exceed the fluid circulation rate capabilities. Reaming and back pulling operations shall be planned to insure that, once started, all reaming and back pulling operations are completed without stopping and within the permitted work hours.

The space between the pipe and the excavation walls shall be filled with grout.

7. 05 Tunnelling Installation

7.05.01 General

The method of tunnelling shall be selected by the Contractor and shall be submitted to the Contract Administrator prior to commencement of the work for information purposes.

Excavation of native soil and fill shall be done in a manner to control groundwater inflow to the excavation and to prevent loss of ground into the excavation.

Methods of excavating the tunnel shall be capable of fully supporting the face and shall accommodate the removal of boulders and other oversize objects from the face. Continuous ground support shall be maintained during excavation.

As the excavation progresses, the Contractor shall continuously monitor (every 2 m) indications of support distress, such as cracking, deflection or failure of support system and subsidence of ground near the excavation.

The Contractor shall advance the ventilation system as a regular part of the normal excavation cycle.

The Contractor shall provide lighting in accordance with OHSA requirements for the entire length of the tunnel.

The tunnel is to be kept sufficiently dry at all times to permit work to be performed in a safe and satisfactory manner.

The Contractor shall maintain clean working conditions at all times in tunnels.

In the event that excavation threatens to endanger personnel, the Work, or adjacent property, the Contractor shall cease excavation. The Contractor shall then evaluate methods of construction and revise as necessary to ensure the safe continuation of the work.

The Contractor shall maintain tunnel excavation line and grade to provide for construction of final lining within specified tolerances.

7.05.01 Tunnelling Method

The tunnelling method shall be suitable to provide face support in changing ground conditions that may be encountered during the progress of the work. The selection of the tunnelling method should consider the soil conditions at each pipe crossing and the presence of obstructions, such as cobbles and boulders, with respect to the tunnel alignment.

7.05.02 Primary Liner (Support System)

Primary support systems shall prevent deterioration, loosening, or unravelling of ground surfaces exposed by excavation.

The primary liner support system shall be designed and installed to achieve the intended performance requirements.

Primary liner support system shall maintain the safety of personnel, minimize ground movement into the excavation, ensure stability and maintain strength of ground surrounding the excavation.

The primary liner shall be designed to support all subsurface conditions and hydrostatic pressures and to withstand any additional loads caused by installation and grouting, and shall ensure that no ground loading or other loading will be placed on the new work until after design strength has been reached.

The primary liner shall be installed so that the exterior is as tight as possible to the excavated surface of the tunnel and allows the placement of the full design thickness of the secondary lining.

Primary support systems shall be compatible with the encountered ground conditions, with the method of excavation, with methods for control of water, and with placement of the permanent lining.

All voids between the primary lining and the surface of the excavation shall be filled with cement grout. If an unexpanded liner is used, the space outside the liner plates shall be grouted at least daily.

7.05.03 Secondary Liner

7.05.03.01 Placing of Grout

The void outside the finished secondary liner shall be filled with cement grout according to the Contractor's submission.

Grout shall not be placed until the lining has achieved 85% of its specified strength or 30 MPa. Grouting shall be limited to such sequences and programs as are necessary to avoid damaging any part of the works or any other structure or property.

7.06 Instrumentation Monitoring

The work specified in this Section includes furnishing and installing instruments for monitoring of settlement and ground stability.

Surface settlement markers for monitoring ground stability shall be installed at the pavement/ground surface level on the shoulder, side slope and pavement at not greater than 5 m intervals along the tunnel alignment and as an array of three in-ground (1.5 m depth) measurement points on the shoulder of the highway perpendicular to the alignment. The equipment and procedures used for settlement monitoring during construction must be capable of surveying the settlement point elevations to within ± 1 mm of the actual elevation.

Surface settlement markers shall be hardened steel markers treated or coated to resist corrosion, with an exposed convex head having a minimum diameter of 12 mm and similar to surveyor's PK nails. Markers shall be rigidly affixed so as not to move relative to the surface to which it is attached. Traffic shall be managed by the contractor using short-term lane closures in accordance with the Ontario Traffic Manual (OTM).

In general, settlement monitoring points shall be 12-18 mm rebar encased in a 50-70 mm, SCH40 PVC pipe, set to a depth of 1.5 m below ground surface. The assembly shall be placed in a drill hole and backfilled with uniform sand.

The Contractor shall install all surface settlement instruments a minimum of one week prior to the start of works.

The surface settlement instruments shall be clearly labelled for easy identification.

The Contractor shall submit to the Contract Administrator a site plan showing the locations of the monitoring points, a geodetic survey of the settlement monitoring points including station, offset and elevation recorded at the following time intervals:

- Three consecutive readings at least one week prior to commencement of the work (Baseline Reading);
- Once per shift during tunnelling operations period; and
- Weekly after completion of the work for one month, or until such time at which all parties agree that further movement has stopped.

All readings shall be submitted to the Contract Administrative for information purposes on a weekly basis. Each report shall include all survey data collected in tabular and graphical format as plots of time versus settlement in comparison to survey data collected prior to commencement of the work.

7.07 Criteria for Assessment of Roadway Subsidence/Heave

Based on the monitoring of ground movement as specified in Subsections 4.02 and 7.06, the following represents trigger levels that define magnitude of movement and corresponding action:

- Review Level: If a maximum value of 10 mm relative to the baseline readings is reached, the Contractor shall review or modify the method, rate or sequence of construction or ground stabilization measures to mitigate further ground displacement. If this Review Level is exceeded, the Contractor shall immediately notify the CA and review and discuss response actions. The Contractor shall submit a plan of action to prevent Alert Levels from being reached. All construction work shall be continued such that the Alert Level is not reached.
- Alert Level: If a maximum value of 15 mm relative to the baseline readings is reached, the Contractor shall cease construction operations, inform the Contract Administrator and execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic. No construction shall take place until all of the following conditions are satisfied:
    - The cause of the settlement has been identified.
    - The Contractor submits a corrective/preventive plan.
    - Any corrective and/or preventive measure deemed necessary by the Contractor is implemented.
    - The CA deems it is safe to proceed.

The Contractor shall avoid damaging instrumentation during construction. Instrumentation that is damaged as a result of the Contractor's operation shall be repaired or replaced by the Contractor within one business day. The costs for replacement/repair shall be borne by the Contractor.

At the completion of the job, the Contractor shall abandon all instrumentations installed during the course of the Work.

9. MEASUREMENT FOR PAYMENT

Measurement shall be by Plan Quantity Payment as may be revised by Adjusted Plan Quantity Payment in metres, following along the centre line of the pipes from centre to centre of maintenance holes or chambers (catch basins) or from/to the end of the pipe where no maintenance hole or chamber is installed, of the actual length of pipe installed by trenchless methods.

10. BASIS OF PAYMENT

Payment at the contract price shall be full compensation for all labour, equipment and materials required for excavation (regardless of material encountered), dewatering, sheathing and shoring, supply and installation of pipe liners, settlement instrumentation and monitoring, site restoration, and all other work necessary to complete the installation as specified.

Payment for the rigid or flexible pipe conduits installed inside the pipe liners shall be paid separately under the appropriate tender items.

Where a protection system is made necessary because of the Contractor’s operations (e.g. choice of trenchless installation method), the cost shall be included in this item and shall be full compensation for all labour, equipment and materials required to carry out the work including subsequently removing the temporary protection system and performing any necessary restoration work.

Payment for connecting intercepted drains and service connections shall be made on the following basis:

(a) Where such drains and service connections are shown on the contract drawings the cost of connections shall be included in the contract price for pipe installation.

(b) Where such drains and service connections are not shown on the contract drawings, the cost of connections will be considered an allowable extra to the contract.

Payment for removal of boulders/obstructions greater than an equivalent 0.3 m in diameter shall be on a time and materials basis. The Contractor shall inform the Contract Administrator when boulders/obstructions are encountered and prior to removal to allow for proper and accurate tracking of time and material charges.