

Terraprobe

Consulting Geotechnical & Environmental Engineering

Construction Materials Inspection & Testing

**FOUNDATION INVESTIGATION AND DESIGN REPORT
ALECTRA UTILITIES DUCT INSTALLATIONS
HIGHWAY 410 CROSSING AT VODDEN STREET EAST
THE CITY OF BRAMPTON, ONTARIO
MINISTRY OF TRANSPORTATION
CENTRAL REGION
MTO Project No.: W.O. 2018-11009
GEOCRES No: 30M12-421**

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PART A – FOUNDATION INVESTIGATION REPORT

**ALECTRA UTILITIES DUCT INSTALLATIONS
HWY. 410 AT VODDEN STREET EAST
THE CITY OF BRAMPTON, ONTARIO
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1.0 INTRODUCTION

Terraprobe Inc. (Terraprobe) has been retained by NBM Engineering Inc. (NBM) on behalf of Alectra Utilities, to provide foundation engineering services in support of Alectra Utilities duct installations below Highway 410 on the south side of the Vodden Street East underpass in the City of Brampton, Ontario.

The scope of work for the foundation engineering services is outlined in Terraprobe's proposal titled *"Proposal for Geotechnical Engineering Services, Installation of Electrical Cable Ducts below Hwy. 410 at Vodden Street East, City of Brampton"* dated November 08, 2017. This report provides factual data on the subsurface conditions at the site.

2.0 SITE DESCRIPTION

The site is located where Vodden Street East crosses Highway 410 via a two span underpass in the City of Brampton, Ontario. The key plan on the Borehole Locations and Soil Strata Drawing, (Drawing 1) provides an overview of the site location.

At this site Highway 410 is a north to south oriented divided freeway consisting of an unpaved median with three lanes in each direction, and fully paved inner and outer shoulders. The Vodden Street East grade separation structure links Vodden Street East on the east and west sides of Highway 410.

3.0 INVESTIGATION PROCEDURES

The fieldwork for this project was carried out during the period of March 04 to 07, 2018. Three boreholes numbered Borehole 1, 2 and 3 were drilled and sampled to depths ranging from 10.9 m to 17.1 m below ground surface at the approximate locations shown on Drawing 1. The boreholes were marked in the field by Terraprobe's staff in relation to existing features shown on the drawings provided by NBM taking into consideration access restrictions on the east side of Highway 410. Boreholes were surveyed for coordinates and geodetic elevation with a Trimble R10 Receiver connected to the Global Navigation Satellite System. This data is summarized in the following table.

Borehole Details

Borehole No.	MTM NAD 83 Coordinates (Zone 10)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (m)	Easting (m)		
BH 1	4 841 363.0	284 814.6	232.2	16.2
BH 2	4 841 406.8	284 853.7	226.6	10.9
BH 3	4 841 455.0	284 891.5	233.1	17.1

The boreholes were drilled with a truck-mounted drill rig supplied and operated by a specialist drilling contractor. Terraprobe's staff observed and recorded the drilling, sampling and in situ testing operations and logged the boreholes.

Samples of the overburden soils were generally obtained at intervals of 0.75 m depth using a 50 mm outer diameter (O.D.) split-spoon sampler in conjunction with the Standard Penetration Testing (SPT) procedures as specified in ASTM Method D 1586¹.

Ground water conditions in the open boreholes were observed during the drilling operations and standpipe piezometers were installed in Boreholes 1 and 3 to permit longer term ground water level monitoring. The boreholes were backfilled in accordance with current MTO procedures and Ontario Regulation 903 (as amended).

The recovered soil samples were subjected to Visual Identification (VI). Select soil samples were also subjected to a laboratory testing programme consisting of natural moisture content, grain size distribution analyses and Atterberg limits determinations.

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

The site is located in the physiographic region of Southern Ontario referred to as the Peel Plain² and the youngest glacial deposit in this area is Halton Till. This area of low relief was affected by a succession of changing levels of glacial Lake Peel and within the Halton Till can be found intervening areas of glaciofluvial and glaciolacustrine deposits consisting of gravel, sand, silt, and clay.

The overburden soils are underlain by bedrock of the Georgian Bay Formation. The Georgian Bay Formation is of Middle Ordovician Age and is predominantly shale with interbeds of calcareous sandstone, siltstone and grey argillaceous limestone.

4.2 Subsurface Conditions

Reference is made to the Record of Borehole Sheets in Appendix A. Details of the encountered soil stratigraphy are presented in this appendix and on the "Borehole Locations and Soil Strata" drawing. An overall description of the stratigraphy is given in the following paragraphs.

The stratigraphic boundaries shown on the Record of Borehole Sheets and on the interpreted stratigraphic section are inferred from non-continuous soil sampling and therefore represent transitions between soil types rather than exact planes of geological change. The subsurface conditions will vary between and beyond the borehole locations.

In summary, a flexible pavement, topsoil and fill soils consisting of loose to dense gravelly sand, stiff to very stiff clayey silt and compact sand and silt were encountered at the site. The native overburden deposits consist of compact to very dense silty sand to sandy silt till and very dense silt.

¹ ASTM D1586 – Standard Test Method for Standard Penetration Tests and Split Barrel Sampling of Soils.

² Karrow, P.F. 2005, "Quaternary geology of the Brampton Area", Ontario Geological Survey, Report 257, 2005.

4.2.1 Flexible Pavement

Borehole 3 encountered a flexible pavement consisting of 145 mm thick asphaltic concrete, underlain by gravelly sand fill. Gravelly sand fill was also encountered in Boreholes 1 and 2. The locations, thicknesses and base elevations of the gravelly sand fill are summarized in the following table.

Borehole No.	Fill Thickness (m)	Fill Depth (m)	Fill Base Elevation (m)
BH 1	0.4	0.5	231.7
BH 2	0.7	0.7	225.9
BH 3	0.6	0.8	232.3

Standard Penetration tests carried out in the gravelly sand fill measured SPT N-values of 10 to 32 blows for 0.3 m of penetration indicating a loose to dense relative density. The natural water content of two samples of the gravelly sand fill are 5% and 9% by weight.

The grain size distribution curve of a sample of the gravelly sand fill is depicted on Figure B1 in Appendix B. The results show a grain size distribution consisting of 29% gravel, 48% sand, 19% silt and 4% clay size particles.

4.2.2 Topsoil

An approximately 100 mm thick topsoil layer was encountered at Borehole 1. Topsoil thickness may vary between and beyond the boreholes.

4.2.3 Fill – Clayey Silt

Clayey silt fill was encountered at this site. The locations, thicknesses, depths and base elevations of the clayey silt fill are summarized in the following table.

Borehole No.	Fill Thickness (m)	Fill Depth (m)	Fill Base Elevation (m)
BH 1	0.4	0.9	231.3
BH 3	1.2	2.4	230.7

Standard Penetration tests carried out in the clayey silt fill measured SPT N-values ranging from 10 to 26 blows for 0.3 m of penetration indicating a stiff to very stiff consistency. The natural water content of a sample of the clayey silt fill is 15% by weight.

A grain size distribution test was carried out on a sample of the clayey silt fill and the grain size distribution curve is illustrated in Figure B2 in Appendix B. The test results show a grain size distribution consisting of 3% gravel, 44% sand, 37% silt and, 16% clay size particles.

An Atterberg limits test was also carried out on a sample of the clayey silt fill. The results presented in Figure B3 in Appendix B, indicate that the clayey silt fill is a low plasticity (CL to CL-ML) cohesive soil. The results from the Atterberg limits test are summarized below:

Liquid Limit:	21%
Plastic Limit:	14%
Plasticity Index:	7%
Natural Moisture Content:	15%

4.2.4 Fill – Sand and Silt

Sand and silt fill material was encountered at Borehole 3. The sand and silt fill layer is approximately 0.4 m thick and extends to a depth of 1.2 m, i.e. elevation 231.9 m. A Standard Penetration test carried out in the sand and silt fill measured a SPT N-value of 29 blows for 0.3 m of penetration indicating a compact relative density. The natural water content of a sample of the sand and silt fill is 13% by weight.

A sample of the sand and silt fill was subjected to a grain size distribution test and the grain size distribution curve is illustrated in Figure B4 in Appendix B. The test results show a grain size distribution consisting of 2% gravel, 54% sand, 37% silt and, 7% clay size particles.

4.2.5 Silty Sand to Sandy Silt Till

A native till deposit with a soil matrix composition that ranges from silty sand to sandy silt was encountered at this site. The locations, thicknesses, depths, and base elevations of the silty sand to sandy silt till are summarized in the following table.

Borehole No.	Thickness (m)	Depth (m)	Base Elevation (m)
BH 1	15.3	16.2*	216.0
BH 2	6.4	7.1	219.5
	0.8	10.9*	215.7
BH 3	8.1	10.5	222.6
	5.6	17.1*	216.0

* Borehole termination depth.

Standard Penetration tests carried out in the silty sand to sandy silt till deposit measured SPT N-values that range from 26 to more than 100 blows for 0.3 m of penetration, indicating a compact to very dense relative density. The natural water content of samples of the silty sand to sandy silt till deposit range from 6% to 14% by weight.

Grain size distribution tests were carried out on seven samples of the silty sand to sandy silt till deposit and the grain size distribution curves are illustrated in Figure B5 in Appendix B. These results show a grain size distribution consisting of 6% to 23% gravel, 30% to 49% sand, 25% to 48% silt and 5% to 16% clay size particles. Resistance to augering in the silty sand to sandy silt till unit was also encountered during drilling which suggests that random cobble and boulder inclusions are likely present.

4.2.6 Silt

A native silt deposit was encountered at this site. The locations, thicknesses, depths, and base elevations of the silt deposit are summarized in the following table.

Borehole No.	Thickness (m)	Depth (m)	Base Elevation (m)
BH 2	3.0	10.1	216.5
BH 3	1.0	11.5	221.6

The measured SPT N-values of Standard Penetration tests carried out in the silt deposit were more than 100 blows for 0.3 m of penetration, indicating a very dense relative density. The natural water content of samples of the silt deposit range from 12% to 20% by weight.

Three samples of the silt deposit were subjected to grain size distribution tests and the grain size distribution curves are illustrated in Figures B6 in Appendix B. The test results show a grain size distribution consisting of 1% to 2% gravel, 7% to 17% sand, 72% to 85% silt and 7% to 10% clay size particles.

4.3 Ground Water Levels

The ground water conditions were observed in the boreholes during and upon completion of drilling. Standpipe piezometers were also installed in selected boreholes and the measured ground water levels in the piezometers are summarized in the following table:

Borehole No	Date	Water Levels	
		Depth (m)	Elevation (m)
BH 1	March 15, 2018	7.0	225.2
	April 04, 2018	7.0	225.2
BH 3	March 15, 2018	7.8	225.3
	April 04, 2018	7.8	225.3

Based on the recorded water levels in the standpipe piezometers, ground water observations during drilling and, the measured water contents of the soil samples, the estimated ground water table elevation is $225.5 \pm$ m. The ground water level is expected to fluctuate seasonally and is expected to rise during wet periods of the year.

5.0 MISCELLANEOUS

The investigation was carried out using drilling equipment supplied and operated by DBW Drilling Limited of Ajax, Ontario. The field operations were organized and monitored by Ms. Fatemeh Yazdandoust, MSc. The laboratory testing was carried out at Terraprobe's Brampton laboratory.

This report was prepared by Ms. Sepideh D-Monfared, MEng. and reviewed by Mr. Rehman Abdul, P.Eng., a Senior Geotechnical Engineer and Principal with Terraprobe. Mr. Michael Tanos, P.Eng., Terraprobe's Designated MTO Contact conducted an independent quality control review.

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PART B – FOUNDATION DESIGN REPORT

**ALECTRA UTILITIES DUCT INSTALLATIONS
HWY. 410 AT VODDEN STREET EAST
THE CITY OF BRAMPTON, ONTARIO
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6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This report presents interpretation of the geotechnical data in the factual report and presents geotechnical design recommendations to assist the design team to carry out designs for the Alectra Utilities duct installations at the Vodden Street East crossing at Highway 410. The discussion and recommendations presented in this report are based on our understanding of the project and our interpretation of the factual data obtained from the subsurface investigations.

Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project, and for which special provisions or operational constraints may be required in the Contract Documents. Those requiring information on the aspects of construction should make their own interpretation of the factual information provided, as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

Alectra Utilities electrical cables will be installed on the south side of Vodden Street East below Highway 410. Summarized below are the relevant design details:

- The cables will cross below Highway 410 and, MTO requires a minimum vertical clearance of 5 m measured from the highway's top of pavement to the duct obvert;
- The proposed installation consists of two Horizontal Directional Drilling (HDD) drives as outlined below:
 - Both bore paths are approximately $117.0 \pm$ m long extending from Sta. 0+000, $33.0 \pm$ m west of the Hwy. 410 South Bound shoulder, easterly to Sta. 0+117. Four High Density Polyethylene (HDPE) ducts will be installed in each bore path. The profile of both HDD bore paths are shown on Drawing 1;
 - The horizontal distance between HDD bore paths is $4.8 \pm$ m and both bore paths will be installed at the same range of vertical elevations; and
- The HDD bores will be approximately 350 mm in diameter.

6.2 Installation Methods

The diameter, length and anticipated subsurface conditions limits the range of installation techniques that are economically viable. Each method considered has advantages, disadvantages or limitations and these are discussed further below.

Ground behaviour will be, in part, dependent on the installation method adopted and this report provides guidance on the influence of ground behaviour on some possible installation methods. It should not be construed that the Contractor is restricted to the methods considered herein, and in the event of alternative methods, the Contractor must make his own interpretation of the anticipated ground behaviour, based on the factual information provided in this report under Part A, Foundation Investigation Report.

Trenchless installation methods such as microtunnelling were considered but this methodology is ruled out as being uneconomical and possibly impractical due to the close proximity of the electrical ducts. The construction methodologies evaluated and the recommendations for selecting the preferred method took into consideration the risks and consequences of each alternative, relative construction costs, as well as the need to minimize traffic disruptions and reduce user delay costs during construction. A trenchless alternative is generally more expensive compared to an open-cut excavation, and there is always a

possibility that excavations may be required to retrieve tunnelling equipment or, equipment may have to be abandoned if adverse subsurface conditions are encountered. Practical alternatives are:

- Open Cut Excavation; and
- Horizontal Directional Drilling (HDD).

6.2.1 Open Cut Excavation

An open cut excavation involves a trench excavation and excavation sidewall support; bedding placement, duct installation followed by cover material placement and trench backfilling. The open cut method reduces the potential for delays resulting from encountering obstructions and provides the least risk of unanticipated damage to the active roadways.

The major disadvantages with an open cut installation is the requirement for proper construction staging to minimize traffic disruption, the need for relatively large and deep excavations; and the potential for post construction settlement of the backfill materials. Open cut excavations are not recommended for installations below Highway 410. The open cut excavation method is therefore limited to the two bore pits at the entry and exit points of the HDD bore path and relatively short sections of the alignment in these two areas.

6.2.2 Horizontal Directional Drilling (HDD)

Horizontal directional drilling involves drilling an initial pilot hole from an entry point to an exit point using drilling mud to support the drill hole sidewalls. Following completion of the pilot hole, the hole is reamed successively in increasing diameters until the drill hole is of sufficient size to permit installation of a product pipe. The product pipe is then typically installed by attaching it to the drill rods and pulling it back through the drill hole from the exit point to the entry point.

HDD can be carried out in both soil and rock, and there are no specific limitations below ground water. Some restrictions may apply in very loose coarse sand or gravel. These soils will have a tendency to collapse in the bore path causing either excessive spoil removal or in some cases stopping the installation. The accuracy of HDD is dependent on the accuracy in determining the drill head location and depth. Accuracy is typically 2% to 5% of the depth.

The HDD alignment is designed such that the radii of curvature of all sections of the alignment (including those which may involve complex curves), are sufficiently large such that the HDD drill rods can accommodate the proposed curvature and; the cables can be installed/pulled along the bore path without being overstressed. The minimum radius of curvature will be dependent on the contractor's drill rod size and length, and the flexibility of the cables.

Typically, the electrical cables are packaged and stored on reels. After the bore path is reamed to its desired size, the cable ends are tied together and pulled through the bore path while the reels are gradually unrolled. It is essential to minimize the cable installation time because the bore path has the potential to degrade with time.

6.3 Assessment of Tunnelling Alternatives

To reduce the risk of subsidence or heave, tunnelling installations require a minimum depth of overburden cover over the tunnel crown. As the depth of overburden cover decreases, the risk of concentrated subsidence or heave increases, as does the risk of extreme events such as sinkholes, or in the case of HDD, frac-outs forming at the ground surface. In Ontario, the general practice is to maintain a minimum depth of cover equivalent to 2 to 3 tunnel diameters.

There are inherent risks and consequences involved with trenchless installations that could include some or all the following:

- Obstructions within the tunnel reach that could increase the level of construction effort. Adequate equipment such as mandrels, pneumatic breakers or chisels, and augers are required to break and remove obstructions. If such efforts prove futile the tunnel will have to be abandoned or, an open cut excavation would be required to remove the obstruction.
- Inability to correct for line and grade within the design tolerances. If misalignment occurs, it may be necessary to abandon the bore and grout the open section. Alternatively, an open cut excavation may be the most efficient way of completing the installation.

Table 1 following the text of this report, provides a summary of the HDD bore path elevations, bore path dimension, the range of overburden cover depths, the depth of cover to HDD bore path diameter ratios and; the subsurface conditions encountered in the boreholes from ground surface to the respective HDD bore path.

The SPT N-values and the coefficient of uniformity (which is an indication of how well the soil is graded, and is expressed as the ratio of the particle size at which 60% of the particles are finer than to the particle size at which 10% are finer than), assist in classifying the soil behaviour according to the Tunnelman's Ground Classification System (Terzaghi, 1950). This system is commonly used to describe the potential behaviour of an unsupported tunnel face during excavation and it uses qualitative "stand-up time" criteria to classify the ground at and above the tunnel face into the following principal categories: firm, slow ravelling, fast ravelling, squeezing, cohesive running, running, flowing and swelling. Efforts to predict soil behaviour must also be tempered by experience and engineering judgement.

The soil conditions within the HDD bore path are classified in Table 2 following the text of this report. The soil conditions generally range from "firm to slow ravelling", "slow ravelling to fast ravelling" and "running". It is therefore essential to select a suitable drill mud and to control the drill mud viscosity, application pressure and volume, in order to maintain a stable bore path in running soils. A comparison of the advantages, disadvantages, risks and consequences associated with an HDD installation and an open cut excavation is presented in Table 3 following the text of this report.

6.4 Preferred Alternative

The alternatives described in Section 6.2 are ranked on a numerical scale in order of preference with one (1) being assigned to the most preferred alternative and two (2) being assigned to the least preferred option. The preferred alternative was selected based on installation costs, the requirement to complete each bore path in a single drive and the availability of construction equipment and local construction knowledge.

Alternative	Ranking of Alternatives
Horizontal Directional Drilling (HDD)	1
Open Cut Excavation	2

From a geotechnical perspective, we recommend installing the utility ducts below Highway 410 by HDD techniques since it is the most feasible and practical alternative. Open cut excavations below the highway are not recommended. The advantages, disadvantages, risks and consequences of the installation methods are provided in Table 3. HDD shall be carried out in accordance with the Non Standard Special Provision "*Pipe Installation By Trenchless Method*" a copy of which is included in Appendix D.

6.5 Settlement

The zone of influence of soils disturbed by the HDD operations will be about 2 tunnel diameters and construction of the HDD bore path will result in ground movements that will produce a settlement trough above and ahead of the bore path.

After a tunnel is constructed, the transverse settlement trough that develops can be described by a Gaussian distribution curve as:

$$S = S_{\max} \exp \left(\frac{-x^2}{2i^2} \right)$$

Where

- S = settlement observed at a distance x from the tunnel axis;
- S_{\max} = maximum settlement above the tunnel axis;
- x = horizontal distance from the tunnel axis; and
- i = horizontal distance from the tunnel axis to the inflexion point on the settlement trough.

The settlement trough induced by tunnelling can be characterized by means of two parameters namely the volume of settlement per unit length of tunnel (V_s) and the horizontal distance from the tunnel axis to the inflexion point (i).

The volume of the settlement trough (V_s) is difficult to evaluate as this parameter is dependent on construction methods and workmanship. This parameter (V_s), is usually compared to the volume of ground loss produced at the tunnel level and is expressed as a percentage of the theoretical volume of excavated soils (V_t).

Correlations by Mair and Taylor (1997)³ concluded that the parameter i, can be reasonably estimated using the following expression:

$$i = K Z$$

Where

- K = is the trough width parameter and its value is a function of ground type; and
- Z = depth to the tunnel centre line.

The equations outlined above were used to estimate settlement due to tunnelling below the highway. A trough width parameter of 0.25 was selected for tunnels in non-cohesive soils. The estimated maximum settlement below Highway 410 at the tunnel centreline assuming a 4% volume of ground loss, is approximately 5± mm. This estimate is based on the assumption that the work will be carried out by

3 Mair, R. J. and Taylor, R. N. (1997). Bored tunnelling in the urban environment, Theme Lecture, Plenary Session 4, 14th International Conference on Soil Mechanics and Foundation Engineering, Hamburg, 6-12 September.

experienced tunnellers with great care and good workmanship. However, more ground loss and settlement can occur if unanticipated conditions such as cobbles and boulders are encountered in the HDD bore path.

6.6 Instrumentation and Monitoring

Active roadway surfaces shall be monitored before, during and after construction. A precondition survey should also be carried out prior to construction, to document the existing conditions of the pavement and any nearby structures; for the purpose of determining any restoration that may be required due to construction impacts. An instrumentation and monitoring program has been developed for this project consistent with the *"Guidelines for Foundation Engineering Tunnelling Specialty for Corridor Encroachment Permit Application (MTO, 2008)"*, modified as appropriate and the inclusion of instrumentation monitoring arrays aligned perpendicular to the duct alignment. The instrumentation and monitoring program is required to:

- Document the effects of the installation on the overlying roadway;
- Obtain prior warning of ground movements that could occur due to construction methods and equipment or unforeseen ground condition;
- Verify the Contractor's compliance with the settlement limits imposed in the Contract; and,
- Allow adjustments to be made to the HDD methodology such that the established settlement limits are not exceeded.

For a HDD installation, in-ground monitoring points shall be installed in the overburden soils and surface monitoring points shall be installed on roadways. These monitoring points are considered sufficient in providing an advance indicator of subsurface disturbance and the potential for settlement/heave at the ground surface due to the HDD operation.

The Settlement Monitoring Plan presented in Appendix C illustrates the approximate locations of the monitoring instruments and provide typical instrument details. The monitoring point locations are approximate and must be confirmed by the Contractor in consultation with the Geotechnical Engineer prior to installation and construction and may have to be adjusted in the field to suit local conditions/constraints.

Monitoring points should be installed under the supervision of a geotechnical engineer at least seven days prior to any excavation. Before the start of tunnelling all monitoring points should be surveyed for elevation at least three times on three separate days to establish a pre-construction baseline. All points behind the face of the excavation and those within 10 m in front of the face, should be surveyed for elevation a minimum of three times per day over the duration of the tunnel drive. Monitoring is also required three times daily during off-shift and weekend periods.

A MTO RAQS registered specialist surveying firm shall be retained to confirm the set-up and to carry out the monitoring during construction. Their equipment and procedures must be capable of surveying the instruments laterally and vertically to within ± 2 mm. The survey data shall be submitted by the surveyor to a MTO RAQS registered medium complexity tunnelling foundation engineering consultant, the Contract Administrator, Owner and MTO on an ongoing basis, for prompt review.

For this project, a Review Level of 10 mm and an Alert Level of 15 mm is considered appropriate for horizontal and vertical displacements. The following procedure should be followed if displacements reach the Review and Alert Levels.

- If the Review Level is reached the Contractor shall provide a formal plan that clearly states what measures will be taken to ensure that the Alert Level is not reached; and,
- If the Alert Level is reached, the Contractor shall stop all work and the Contract Administrator, the Owner and MTO shall have the authority to order the Contractor to alter the construction methodology to maintain integrity of existing conditions. The Contractor Administrator, the Owner and MTO shall also have the authority to order the Contractor to make the mined excavation stable and suspend all tunneling until an approved mitigation solution is developed. The Contractor must have an emergency plan in place to ensure public safety.

6.7 Entry and Exit Point Excavations

Supported open excavations will be required at the entry and exit points of the HDD operation to contain the drilling fluid and to connect the ducts to utility manholes. Tabulated below are the approximate entry and exit point locations, a summary of the soil units at these locations and the anticipated soil conditions at the excavation base (outlined in bold letters). The estimated ground water level, the anticipated ground behaviour and suggested treatments that will be required to maintain base stability are also included in the table.

Entry and Exit Point Excavations – Summarized Ground Conditions and Treatments

Bore Path	Approximate Station Excavation Depth (m) and Borehole No.	Ground Water Level Relative to Excavation Base (m)	Remarks
#1 and #2	0+000 0.5 m (BH 1)	Below Base	<ul style="list-style-type: none"> ■ Loose to compact gravelly sand fill; and ■ Stiff to very stiff clayey silt fill. ■ Maintain dry excavation by pumping from filtered sumps.
	0+117 3.5 m (BH 3)	Below Base	<ul style="list-style-type: none"> ■ Stiff clayey silt fill; and ■ Compact to very dense silty sand to sandy silt till. ■ Maintain dry excavation by pumping from filtered sumps
	0+113 to Vodden Street 1.5 m (BH 3)	Below Base	<ul style="list-style-type: none"> ■ Dense gravelly sand fill; ■ Compact sand and silt fill; ■ Stiff clayey silt fill; and ■ Compact to very dense silty sand to sandy silt till. ■ Maintain dry excavation by pumping from filtered sumps

6.8 Trenching, Backfilling and Compaction Requirements

The majority of the fill and native site soils are generally considered suitable for reuse as backfill in trenches and at entry and exit point excavations, provided they are free of topsoil, organic material or other deleterious material. Trench backfill materials should be placed in maximum 300 mm loose lifts and uniformly compacted to at least 95% of Standard Proctor Maximum Dry Density (SPMDD).

To achieve the specified compaction, soils must neither be too wet nor too dry of their optimum moisture content. Soils that are too wet cannot be used immediately because the material will have to be dried to a

moisture content of $\pm 2\%$ of optimum. If the construction operations are time sensitive, the use of imported granular material may be considered. Soils that are dry of optimum can be used immediately provided that the material is moisture conditioned (i.e. water added) to achieve a moisture content of $\pm 2\%$ of optimum.

Normal post-construction settlement of the compacted backfill, equivalent to about 1% of the backfill height should be anticipated. The majority of this settlement will take place within about six months following the completion of the backfilling operations. If this post-construction settlement cannot be tolerated, it is recommended that the trench be backfilled with Granular "B" Type I compacted to a minimum of 98% of the material's SPMDD at a moisture content within $\pm 2\%$ of the optimum value.

The duct installation must conform to the requirements of OPSD 2100.010 (Cable Installation in Trenches). Additional bedding and backfill requirements that may be imposed by the pipe supplier and Alectra Utilities must also be followed.

Prior to placing the sand bedding, any accumulation of water at the base of the excavation should be removed and any soft/loose soils should be subexcavated and replaced with compacted sand fill.

The bedding material should be placed in 150 mm thick loose lifts and uniformly compacted to at least 95% of the materials SPMDD using suitable vibratory compaction equipment. Trenching, backfilling and compacting should be carried out in accordance with OPSS.PROV 401.

6.9 Temporary Protection Systems

Decisions regarding shoring methods and sequencing are the responsibility of the Contractor. Temporary protection systems should be designed in accordance with OPSS.PROV 539 and the designs should be carried out by a licensed Professional Engineer experienced in shoring design. Support systems for shallower excavations should be installed in accordance with OPSS.404. All temporary protection systems installed within the MTO Right-Of-Way shall be removed after construction is complete.

The shape of the soil pressure distribution diagram behind a temporary protection system depends upon the type of soil to be encountered and the amount of movement that can be permitted. The sequence of work will also alter the shape of the shoring pressure diagram during the various construction phases.

Earth pressure computations must also take into account the ground water level. Above the ground water level, earth pressure is computed using the bulk unit weight of the retained soil. Below the ground water level, the earth pressures are computed using the submerged unit weight of the soil. A hydrostatic pressure is also applied if the retained soil is not fully drained.

Flexible shoring should be designed on the basis of the active earth pressure coefficient (K_a). In this case, the performance level should be Level 2 – Angular Distortion 1:200 but shall not be more than 25 mm. Where limited shoring movement (Performance Level 1A or 1B) is required the design should be based on the at rest earth pressure coefficient (K_o). For "kick out" design the lateral resistance should be computed on the basis of the passive earth pressure coefficient (K_p). It should be noted that the lateral earth pressure coefficients chosen for design require certain movements for the active and passive conditions to be mobilized.

The appropriate lateral earth pressure parameters for use in the design of temporary protection systems are provided in the following table. The lateral earth pressure coefficients are based on the assumption that the ground surface behind the temporary protection system is horizontal. Where the retained ground

is sloping, the lateral earth pressure coefficients must be adjusted to account for the slope and, these earth pressure coefficients can be estimated from the equations provided on Figures C6.17 and C6.18 of the Canadian Highway Bridge Design Code (CHBDC) S6.1-14. The values tabulated below are guideline values and the responsibility for selecting the appropriate design parameters is the responsibility of the shoring designer.

Temporary Protection System Design Parameters

Stratigraphic Unit	Friction Angle ϕ (degrees)	Unit Weight γ (kN/m ³)	Active Earth Pressure Coefficient	At - Rest Earth Pressure Coefficient	Passive Earth Pressure Coefficient
			K_a	K_o	K_p
Fill Soils	28	19	0.36	0.53	2.77
Silty Sand to Sandy Silt Till	33	21	0.29	0.46	3.39

The lateral earth pressure coefficients tabulated above are ultimate values and require specific movements for the active and passive conditions to be mobilized. The values to use in design can be estimated from Figure C6.16 in the CHBDC S6.1-14.

6.10 Erosion Control

Proper erosion control measures should be implemented both during construction and permanently. Temporary erosion and sediment control must be provided in accordance with OPSS 805 and, excavated areas as well as areas disturbed by construction shall be reinstated with permanent erosion protection in accordance with OPSS 803 and OPSS.PROV 804.

6.11 Excavations

All excavations must be carried out in accordance with the guidelines outlined in the *Occupational Health and Safety Act (OHSA) and Regulations for Construction Projects*. Where workers must enter excavations extending deeper than 1.2 m, the trench walls must be suitably sloped and/or braced in accordance with the OHSA. For the purposes of the OHSA the subsurface soils encountered at this site in the areas where open cut excavations are proposed are classified as follows:

- Fill soils – Type 3 soils; and
- Compact to very dense silty sand to sandy silt till – Type 3 soil.

The side slopes of temporary excavations may be formed no steeper than 1H:1V for Type 3 soils. Excavations at steeper inclinations will require temporary support. Excavations should be undertaken in accordance with OPSS.PROV 401.

6.12 Ground Water Control

Surface water and ground water control will be required to maintain sufficiently dry conditions during construction. Extensive dewatering techniques will not be required where open cut excavations are made through and into relatively impermeable silty clay soils or where perched water is encountered in the sand deposits above the ground water table. For these conditions, any surface water run-off into excavations as

well as minor subsurface seepage from any wet seams within the overburden can be controlled by employing a system of gravity drainage and pumping from strategically placed filtered sumps.

The design, installation, operation and maintenance of the dewatering system is the Contractor's responsibility. A suitable dewatering system that can be employed is gravity drainage and pumping from strategically placed filtered sumps.

6.13 Design Frost Depth

At this site, a depth of 1.2 m of earth cover should be provided for protection from frost penetration (OPSD 3090.101 Foundation Frost Penetration Depths for Southern Ontario).

6.14 HDD Considerations

It is anticipated that the HDD operation would be advanced through stiff to very stiff clayey silt fill and compact to very dense silty sand to sandy silt till.

There is a potential for deviation in the alignment when transitioning between soil deposits or if cobbles and boulders are encountered. Therefore, the contractor should select appropriate equipment including drill bits and reamers in order to deal with these subsurface soil conditions.

High fluid pressures that may develop during drilling may also require the installation of pressure relief pits in order to mitigate "frac outs". Pressure relief pits will also minimize the potential for "hydrolock", a condition where circulation from the bore is lost due to cuttings inhibiting mud circulation, which then causes pressure build-up ahead of the advancing pipe. The maximum drilling fluid pressures and static confining stresses should also be considered by the Contractor in the design of the HDD bore path.

Prior to construction the contractor should submit for review a comprehensive drilling plan that addresses all aspects of the HDD operation, such as equipment type, drilling fluids to be used, bore path design, pull back calculations and construction methodology. The borehole locations in this study shall also be located in the field and, the Contractor shall offset the horizontal alignment of the proposed HDD bore path a minimum distance of $2.0\pm$ m to mitigate the potential of frac-out through the boreholes.

7.0 CLOSURE

This report was prepared by Ms. Sepideh D-Monfared, MEng. and reviewed by Mr. Rehman Abdul, P.Eng., a Senior Geotechnical Engineer and Principal with Terraprobe. Mr. Michael Tanos, P.Eng., Terraprobe's Designated MTO Contact conducted an independent quality control review.

Terraprobe Inc.



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Principal, Senior Geotechnical Engineer



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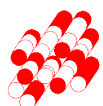
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Ontario Provincial Standard Specifications (OPSS)

OPSS. PROV 401	Construction Specification For Trenching, Backfilling and Compacting
OPSS 404	Construction Specification For Support Systems
OPSS.PROV 539	Construction Specification For Temporary Protection Systems.
OPSS 803	Construction Specification For Sodding.
OPSS.PROV 804	Construction Specification For Seed and Cover.
OPSS 805	Construction Specification For Temporary Erosion And Sediment Control Measures.

Ontario Provincial Standard Drawings (OPSD)

OPSD 2100.010	Cable Installation in Trenches.
OPSD 3090.101	Foundation Frost Penetration Depths for Southern Ontario.



TUNNELMAN'S GROUND CLASSIFICATION FOR SOILS¹

CLASSIFICATION		BEHAVIOUR	TYPICAL SOIL TYPES
Firm		Heading can be advanced without initial support, and final lining can be constructed before ground starts to move.	Loess above water table; hard clay, marl, cemented sand and gravel when not highly overstressed.
Raveling	Slow raveling ----- Fast raveling	Chunks or flakes of material begin to drop out of the arch or walls sometime after the ground has been exposed, due to loosening or to overstress and "brittle" fracture (ground separates or breaks along distinct surfaces, opposed to squeezing ground). In fast raveling ground, the process starts within a few minutes, otherwise the ground is slow raveling.	Residual soils or sand with small amounts of binder may be fast raveling below the water table, slow raveling above. Stiff fissured clays may be slow or fast raveling depending upon degree of overstress.
Squeezing		Ground squeezes or extrudes plastically into tunnel, without visible fracturing or loss of continuity, and without perceptible increase in water content. Ductile, plastic yield and flow due to overstress.	Ground with low frictional strength. Rate of squeeze depends on degree of overstress. Occurs at shallow to medium depth in clay of very soft to medium consistency. Stiff to hard clay under high cover may move in combination of raveling at excavation surface and squeezing at depth behind surface
Running	Cohesive running ----- Running	Granular materials without cohesion are unstable at a slope greater than their angle of repose (approximately 30° – 35°). When exposed at steeper slopes they run like granulated sugar or dune sand until the slope flattens to the angle of repose.	Clean, dry granular materials. Apparent cohesion in moist sand, or weak cementation in any granular soil, may allow the material to stand for a brief period of raveling before it breaks down and runs. Such behavior is cohesive-running.
Flowing		A mixture of soil and water flows into the tunnel like a viscous fluid. The material can enter the tunnel from the invert as well as from the face, crown, and walls, and can flow for great distances, completely filling the tunnel in some cases.	Below the water table in silt, sand, or gravel without enough clay content to give significant cohesion and plasticity. May also occur in highly sensitive clay when such material is disturbed.
Swelling		Ground absorbs water, increases in volume, and expands slowly into the tunnel.	Highly preconsolidated clay with plasticity index in excess of about 30, generally containing significant percentages of montmorillonite.

¹ Modified by Heuer (1974) from Terzaghi (1950)

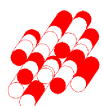


TABLE 1
CONSTRUCTIBILITY REVIEW OF HORIZONTAL DIRECTIONAL DRILLING

Bore Path	Max Bore Path Diameter (mm)	Approximate Station and Bore Path Elevation (m)		Proposed HDD Length (m)	Depth of Overburden Cover (m)	Depth of Cover to HDD Bore Path Diameter Ratio	Anticipated Subsurface Conditions Within the Zone of Tunnelling	Estimated Groundwater Depth Relative to HDD Bore Path
		From	To					
#1 and #2	350	0+000 EL: 233.0±	0+039 EL: 221.4±	39 ±	0.0 to 6.2±	0.0 – 17.7	Loose to compact gravelly sand fill; Stiff to very stiff clayey silt fill; and Compact to very dense silty sand to sandy silt till.	7.8 m± below to 1.1 m± above
		0+039* EL: 221.4±	0+087* EL: 221.4±	48 ±	5.0 to 5.5±	14.3 – 15.7	Very dense silty sand to sandy silt till.	1.1 m± to 1.2 m± above
		0+087 EL: 221.4±	0+117 EL: 231.2±	30 ±	3.1 to 5.6±	8.6 – 16.0	Compact to very dense silty sand to sandy silt till.	1.2 m± above to 5.9 m± below

* Depth of overburden cover equal to or greater than 5.0 m below Hwy. 410.

TABLE 2
FEASIBILITY OF HORIZONTAL DIRECTIONAL DRILLING (Bore Path #1 and #2)

Bore Path	Max Bore Path Diameter (mm)	Approximate Station and Bore Path Elevation (m)		Depth of Overburden Cover (m)	Reference Borehole Number	Soil Conditions ¹ (Ground surface to pipe invert)	Fines Content ² (%)	SPT N-Values	Coefficient of Uniformity ³	Soil Behaviour (Within the HDD Bore Path)
		From	To							
#1 and #2	350	0+000 EL: 233.0±	0+039 EL: 221.4±	0.0 to 6.2±	BH 1	Fill – Gravelly Sand	- ⁴	10	- ⁴	Running
						Fill – Clayey Silt	- ⁴	10, 26	- ⁴	Firm to Slow Raveling
						Silty Sand to Sandy Silt Till	51, 49, 64	26, 64, Below Elev. 230.0± >100/0.3m	32, 18, >50	Slow Ravelling to Fast Ravelling
		0+039 EL: 221.4±	0+087 EL: 221.4±	5.0 to 5.5±	BH 2	Fill – Gravelly Sand	23	15	>50	-
						Silty Sand to Sandy Silt Till	47	58, Below Elev. 225.0± >100/0.3m	16	Fast Ravelling
		0+087 EL: 221.4±	0+117 EL: 231.2±	3.1 to 5.6±	BH 2	Fill – Gravelly Sand	23	15	>50	-
						Silty Sand to Sandy Silt Till	47	58, Below Elev. 225.0± >100/0.3m	16	Slow Ravelling to Fast Ravelling
					BH 3	Silty Sand to Sandy Silt Till	31, 39	29, Below Elev. 230.0± >100/0.3m	>50, 29	Slow Ravelling to Fast Ravelling

1. Soil conditions from ground surface to pipe invert; bold soil conditions indicate soil conditions within tunnel horizon.
2. Fines content is defined as the percentage by weight of soil particles passing the No. 200 Sieve.
3. Coefficient of uniformity of soil within and above the tunnel horizon reported for coarse grained soils only. Not applicable for fine grained soils.
4. No tests performed within that area of interest or the Coefficient of Uniformity parameter is not applicable for that specific soil type. Contractor shall also control/manage raveling at the entry and exit pit locations to minimize hydraulic fracturing close to the ground surface, in addition to controlling drilling fluid containment.

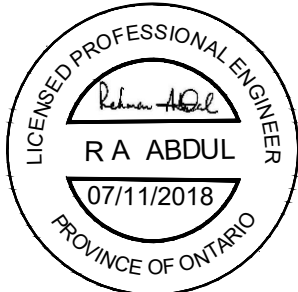
TABLE 3
EVALUATION OF INSTALLATION METHODS

Installation Method	Ranking	Advantages	Disadvantages	Risk/Consequences
Horizontal Directional Drilling	1	<p>Minimal traffic disruption.</p> <p>Precludes the requirement for large entry and exit pit footprint areas i.e. minimal impact on surrounding area.</p> <p>Long drilling distances as much as 1500 -1800 m achievable in a single bore.</p> <p>Does not require ground water lowering since the drill path will be kept open with drill fluid.</p> <p>Can be used to install ducts at relative close spacing compared to other tunneling methods.</p> <p>Less expensive than open cut excavation.</p>	<p>Requires a skilled construction workforce.</p> <p>Difficult to control vertical and horizontal alignment if drill bit deflections occur off cobbles and boulders.</p>	<p>Possible inadvertent returns (Frac-out) or surface heave due to poor subsurface soil conditions or high fluid pressure especially within 30m of the entry point, due to the reduced depth of the bore path below ground surface.</p>
Open Cut Excavation	2	<p>Best control of gradient and alignment.</p> <p>Reduced potential for delays due to obstructions.</p> <p>Least risk of unanticipated damage to active roadways.</p> <p>Equipment and skilled construction workforce readily available.</p>	<p>Requires construction staging in order to maintain traffic on roadways which could result in traffic delays.</p> <p>Relatively large and deep excavations required along some sections of the alignment.</p> <p>Dewatering required for installations at/below ground water level.</p>	<p>Increased traffic disruption.</p>

DRAWINGS

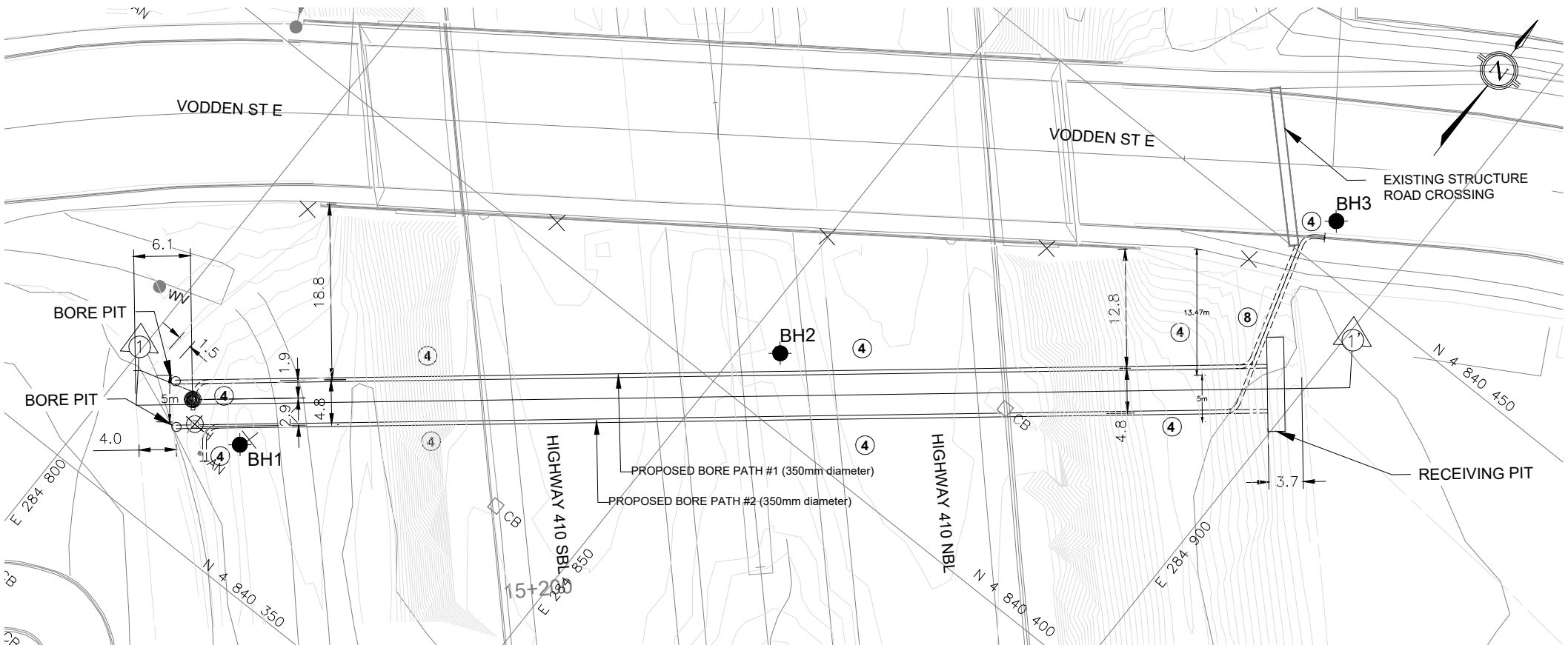


METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETERS UNLESS
OTHERWISE SHOWN



PLAN

SCALE 5 0 5 10m



ALECTRA UTILITIES DUCT INSTALLATIONS
HWY 410 AT VODDEN STREET EAST,
BRAMPTON

BOREHOLE LOCATIONS AND SOIL STRATA
(BORE PATH #1 AND #2)



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KEY PLAN

LEGEND	
	Bore Hole
	Blows/0.3m (Std Pen Test, 475 J/blow)
	Blows/0.3m (60" Cone, 475 J/blow)
	WL at Time of Investigation
	WL in Piezometer
	Piezometer
	90% Rock Quality Designation
	Auger Refusal

No	ELEV. (m)	COORDINATES (MTM NAD83, ZONE 10)	
		NORTHING (m)	EASTING (m)
BH1	232.2	4 841 363.0	284 814.6
BH2	226.6	4 841 406.8	284 853.7
BH3	233.1	4 841 455.0	284 891.5

NOTE

This drawing is for subsurface information only. The proposed structure details/works if shown are for illustration purposes only and may not be consistent with final design configuration as shown elsewhere in the contract documents.

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

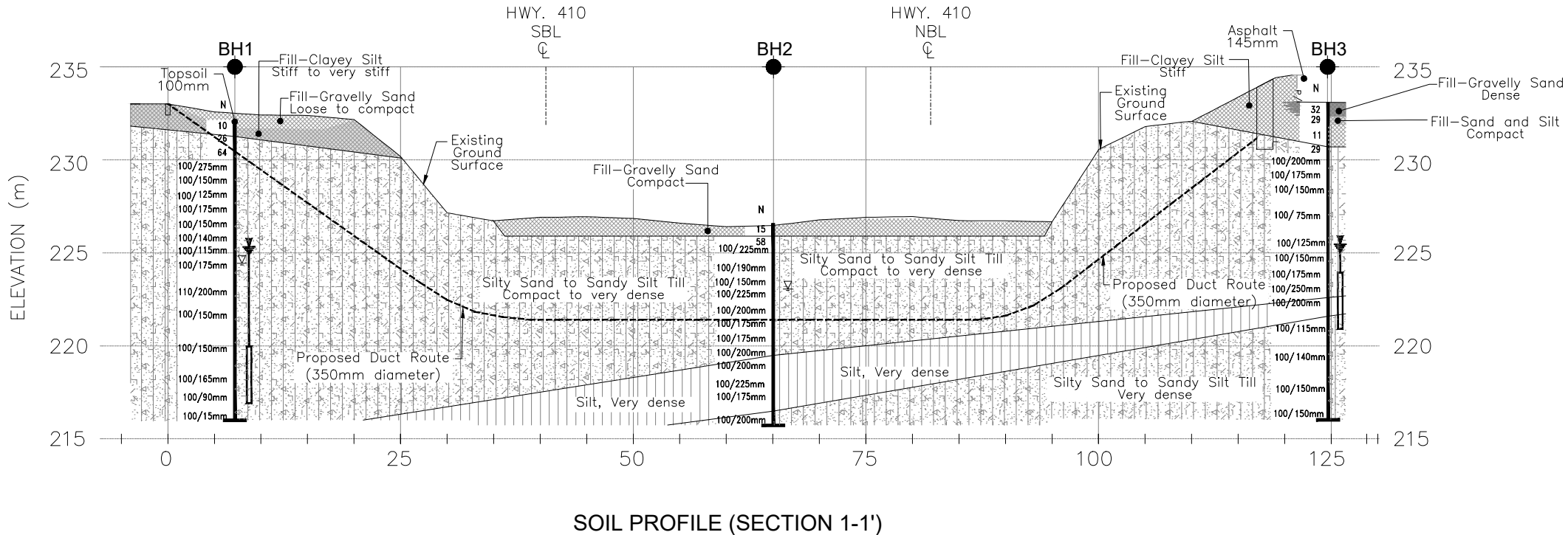
The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents are specifically excluded in accordance with Section GC 2.01 of OPS General Conditions

REFERENCE

Drawings provided in digital format by NBM Engineering Inc. emailed July 03, 2018.

REVISIONS	DATE	BY	DESCRIPTION

HWY. 410	PROJECT No. 1-17-0839	Geocres No. 30M12-421
SUBM'D.SD	CHKD: RA	DATE: July 2018
DRAWN: KC	APPD: MT	W.O. 2018-11009
		DWG. 1



Horiz. Scale 5 0 5 10m
Vert. Scale 2.5 0 2.5 5

APPENDIX A

Record of Borehole Sheets



EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg. FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS \bar{u} .

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0 – 12	12 – 25	25 – 50	50 – 100	100 – 200	>200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 – 5	5 – 10	10 – 30	30 – 50	>50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND/OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (RQD), FOR MODIFIED RECOVERY IS:

RQD (%)	0 – 25	25 – 50	50 – 75	75 – 90	90 – 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

JOINTING AND BEDDING:

SPACING	50mm	50 – 300mm	0.3m – 1m	1m – 3m	>3m
JOINTING	VERY CLOSE	CLOSE	MOD. CLOSE	WIDE	VERY WIDE
BEDDING	VERY THIN	THIN	MEDIUM	THICK	VERY THICK

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

SS	SPLIT SPOON	TP	THINWALL PISTON
WS	WASH SAMPLE	OS	OSTERBERG SAMPLE
ST	SLOTTED TUBE SAMPLE	RC	ROCK CORE
BS	BLOCK SAMPLE	PH	TW ADVANCED HYDRAULICALLY
CS	CHUNK SAMPLE	PM	TW ADVANCED MANUALLY
TW	THINWALL OPEN	FS	FOIL SAMPLE

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
r_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

m_v	kPa ⁻¹	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_{α}	1	RATE OF SECONDARY CONSOLIDATION
C_v	m ² /s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	- °	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	- °	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_r	1	SENSITIVITY = c_u / τ_r

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m ³	DENSITY OF SOLID PARTICLES	e	1.0%	VOID RATIO	e_{min}	1.0%	VOID RATIO IN DENSEST STATE
γ_s	kN/m ³	UNIT WEIGHT OF SOLID PARTICLES	n	1.0%	POROSITY	I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
ρ_w	kg/m ³	DENSITY OF WATER	w	1.0%	WATER CONTENT	D	mm	GRAIN DIAMETER
γ_w	kN/m ³	UNIT WEIGHT OF WATER	S_r	%	DEGREE OF SATURATION	D_n	mm	n PERCENT - DIAMETER
ρ	kg/m ³	DENSITY OF SOIL	w_L	%	LIQUID LIMIT	C_u	1	UNIFORMITY COEFFICIENT
γ	kN/m ³	UNIT WEIGHT OF SOIL	w_p	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
ρ_d	kg/m ³	DENSITY OF DRY SOIL	w_S	%	SHRINKAGE LIMIT	q	m ³ /s	RATE OF DISCHARGE
γ_d	kN/m ³	UNIT WEIGHT OF DRY SOIL	I_p	%	PLASTICITY INDEX = $(w_L - w_p)$	v	m/s	DISCHARGE VELOCITY
ρ_{sat}	kg/m ³	DENSITY OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = $(w - w_p)/I_p$	i	1	HYDRAULIC GRADIENT
γ_{sat}	kN/m ³	UNIT WEIGHT OF SATURATED SOIL	I_C	1	CONSISTENCY INDEX = $(w_L - w)/I_p$	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m ³	DENSITY OF SUBMERGED SOIL	e_{max}	1.0%	VOID RATIO IN LOOSEST STATE	j	kN/m ³	SEEPAGE FORCE
γ'	kN/m ³	UNIT WEIGHT OF SUBMERGED SOIL						

LIMITATIONS AND RISK

Procedures

The soil conditions were confirmed at the borehole locations only and conditions may vary between and beyond the boreholes. The boundaries between the various strata as shown on the logs are based on non-continuous sampling. These boundaries represent an inferred transition between the various strata, rather than a precise plane of stratigraphic change.

This investigation has been carried out using investigation techniques and engineering analysis methods consistent with those ordinarily exercised by Terraprobe and other engineering practitioners, working under similar conditions and subject to the time, financial and physical constraints applicable to this project. The discussions and recommendations that have been presented are based on the factual data obtained.

It must be recognized that there are special risks whenever engineering or related disciplines are applied to identify subsurface conditions. Even a comprehensive sampling and testing programme implemented in accordance with the most stringent level of care may fail to detect certain conditions. Terraprobe has assumed for the purposes of providing design parameters and advice, that the conditions that exist between sampling points are similar to those found at the sample locations. The conditions that Terraprobe has interpreted to exist between sampling points can differ from those that actually exist.

It may not be possible to drill a sufficient number of boreholes or sample and report them in a way that would provide all the subsurface information that could affect construction costs, techniques, equipment and scheduling. Contractors bidding on or undertaking work on the project should be directed to draw their own conclusions as to how the subsurface conditions may affect them, based on their own investigations and their own interpretations of the factual investigation results, cognizant of the risks implicit in the subsurface investigation activities.

Changes In Site And Scope

It must be recognized that the passage of time, natural occurrences, and direct or indirect human intervention at or near the site have the potential to alter subsurface conditions. Groundwater levels are particularly susceptible to seasonal fluctuations.

The design advice is based on the factual data obtained from this investigation made at the site by Terraprobe and are intended for use by the owner and its retained designers in the design phase of the project. If there are changes to the project scope and development features, or there is any additional information relevant to the interpretations made of the subsurface information, the geotechnical design parameters and comments relating to constructibility issues and quality control may not be relevant or complete for the revised project. Terraprobe should be retained to review the implications of such changes with respect to the contents of this report.

This report was prepared for the express use of Alectra Utilities, its retained design consultants and NBM Engineering Inc. It is not for use by others. This report is copyright of Terraprobe Inc. and no part of this report may be reproduced by any means, in any form, without the prior written permission of Terraprobe Inc. The Ministry of Transportation, Alectra Utilities, its retained design consultants and NBM Engineering Inc, are authorized users.

RECORD OF BOREHOLE No 1

1 of 2

METRIC

G.W.P. _____ LOCATION _____ Coords: E:284814.6 N:4841363.0 ORIGINATED BY FY
 DIST _____ HWY 410 BOREHOLE TYPE SOLID STEM AUGERS COMPILED BY SD
 DATUM GEODETIC DATE 2018-3-7 CHECKED BY RA

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	SPT 'N' VALUE		20	40	60	80	100					
232.2	GROUND SURFACE															
231.7	100mm TOPSOIL		1	SS	10											
231.3	FILL, gravelly sand, trace to some silt, trace clay, loose to compact, brown, wet		2	SS	26											
231.3	FILL, clayey silt, some sand to sandy, trace gravel, trace organics, stiff to very stiff, brown, moist		3	SS	64											8 41 44 7
230	SILTY SAND to SANDY SILT, trace to some clay, trace to some gravel, compact to 1.4 m, very dense below, brown to 5.8 m, grey below, moist to wet (GLACIAL TILL)		4	SS	100 / 275mm											
229			5	SS	100 / 150mm											
228			6	SS	100 / 125mm											
227			7	SS	100 / 175mm											
226			8	SS	100 / 150mm											
225			9	SS	100 / 140mm											14 37 44 5
224			10	SS	100 / 115mm											
223			11	SS	100 / 175mm											
222			12	SS	110 / 200mm											
221			13	SS	100 / 150mm											6 30 48 16
220			14	SS	100 / 150mm											resistance to augering from 11.6 m to 11.9 m
219			15	SS	100 / 165mm											sampler wet at 13.7 m
218																resistance to

Continued Next Page


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

RECORD OF BOREHOLE No 1

2 of 2

METRIC

G.W.P. _____ LOCATION _____ Coords: E:284814.6 N:4841363.0 ORIGINATED BY _____ FY
 DIST _____ HWY 410 BOREHOLE TYPE SOLID STEM AUGERS COMPILED BY _____ SD
 DATUM GEODETIC DATE 2018-3-7 CHECKED BY _____ RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	SPT 'N' VALUE								
(continued)													
216.0			16	SS	100 / 90mm		217						
16.2			17	SS	100 / 15mm		216						

END OF BOREHOLE

Piezometer installation consists of a 50mm diameter PVC pipe with a 3.0 m slotted screen.

Auger refusal at 16.2 m below ground surface. Borehole terminated.

Unstabilized water level measured at 7.9 m below ground surface; borehole caved to 8.2 m below ground surface upon completion of drilling.

WATER LEVEL READINGS

Date	Water Depth (m)	Elevation (m)
Mar 15, 2018	7.0	225.2
Apr 4, 2018	7.0	225.2

RECORD OF BOREHOLE No 2

1 of 1

METRIC

G.W.P. _____ LOCATION _____ Coords: E:284853.7 N:4841406.8 ORIGINATED BY FY
 DIST _____ HWY 410 BOREHOLE TYPE SOLID STEM AUGERS COMPILED BY SD
 DATUM GEODETIC DATE 2018-3-4 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	SPT 'N' VALUE			20 40 60 80 100							PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT
								SHEAR STRENGTH (kPa)							W _p W W _L		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							WATER CONTENT (%)		
						20 40 60 80 100	10 20 30					GR SA SI CL					
226.6	GROUND SURFACE																
225.9	FILL, gravelly sand, some silt, trace clay, compact, brown, moist		1	SS	15		226					○			29 48 19 4		
0.7	SILTY SAND to SANDY SILT, trace to some gravel, trace clay, very dense, brown to 1.4 m, grey below, moist to wet (GLACIAL TILL)		2	SS	58		225					○			resistance to augering from 1.8 m to 3.0 m		
			3	SS	100 / 225mm		224					○					
			4	SS	100 / 190mm		223					○					
			5	SS	100 / 150mm		222					○					
			6	SS	100 / 225mm		221										
			7	SS	100 / 200mm		220					○					
			8	SS	100 / 175mm		219					○					
			9	SS	100 / 175mm		218					○					
			10	SS	100 / 200mm		217										
			219.5	SILT, some sand, trace gravel, trace to some clay, very dense, grey, wet		11	SS	100 / 200mm		216						○	
12	SS	100 / 225mm							○		2 13 77 8						
13	SS	100 / 175mm							○								
216.5	SILTY SAND to SANDY SILT, some gravel to gravelly, some clay, very dense, grey, wet (GLACIAL TILL)		14			SS	100 / 200mm						○		1 17 72 10		
215.7																	
10.9															23 31 33 13		

END OF BOREHOLE

Unstabilized water level measured at 3.7 m below ground surface; borehole was open upon completion of drilling.

METRIC

SOIL PROFILE			SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			SPT 'N' VALUE	SHEAR STRENGTH (kPa)						WATER CONTENT (%)			
								20	40	60	80			100	W _p	W	W _L
233.1	GROUND SURFACE																
232.9 0.2	145mm ASPHALTIC CONCRETE		1	SS	32												
232.3 0.8	FILL, gravelly sand, trace to some silt, dense, brown, moist		2	SS	29								2 54 37 7				
231.9 1.2	FILL, sand and silt, trace gravel, trace clay, compact, grey, wet																
	FILL, clayey silt, and sand, trace gravel, stiff, brown, moist		3	SS	11								3 44 37 16				
230.7 2.4	SILTY SAND to SANDY SILT, some gravel to gravelly, trace clay, compact to 2.9 m, very dense below, brown to 6.9 m, grey below, moist to wet (GLACIAL TILL)		4	SS	29												
			5	SS	100 / 200mm								23 46 25 6				
			6	SS	100 / 175mm												
			7	SS	100 / 150mm												
			8	SS	100 / 75mm												
			9	SS	100 / 125mm												
			10	SS	100 / 150mm								12 49 33 6				
			11	SS	100 / 175mm												
	some gravel		12	SS	100 / 250mm								sampler wet at 9.9 m				
222.6 10.5	SILT, trace sand, trace gravel, trace clay, very dense, grey, wet		13	SS	100 / 200mm								1 7 85 7				
221.6 11.5	SILTY SAND to SANDY SILT, trace to some gravel, trace clay, very dense, grey, wet (GLACIAL TILL)		14	SS	100 / 15mm												
			15	SS	100 / 140mm												



+³, ×³: Numbers refer to Sensitivity **○^{3%}** STRAIN AT FAILURE

RECORD OF BOREHOLE No 3

2 of 2

METRIC

G.W.P. _____ LOCATION _____ Coords: E:284891.5 N:4841455.0 ORIGINATED BY _____ FY _____
 DIST _____ HWY 410 BOREHOLE TYPE SOLID STEM AUGERS COMPILED BY _____ SD _____
 DATUM GEODETIC DATE 2018-3-6 CHECKED BY _____ RA _____

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	SPT 'N' VALUE								
	(continued)												
	SILTY SAND to SANDY SILT, trace to some gravel, trace clay, very dense, grey, wet (GLACIAL TILL)		16	SS	100 / 150mm		218						
							217						
216.0 17.1			17	SS	100 / 150mm								

END OF BOREHOLE

Piezometer installation consists of a 50mm diameter PVC pipe with a 3.0 m slotted screen.

Wet cave at 9.9 m below ground surface upon completion of drilling.

WATER LEVEL READINGS

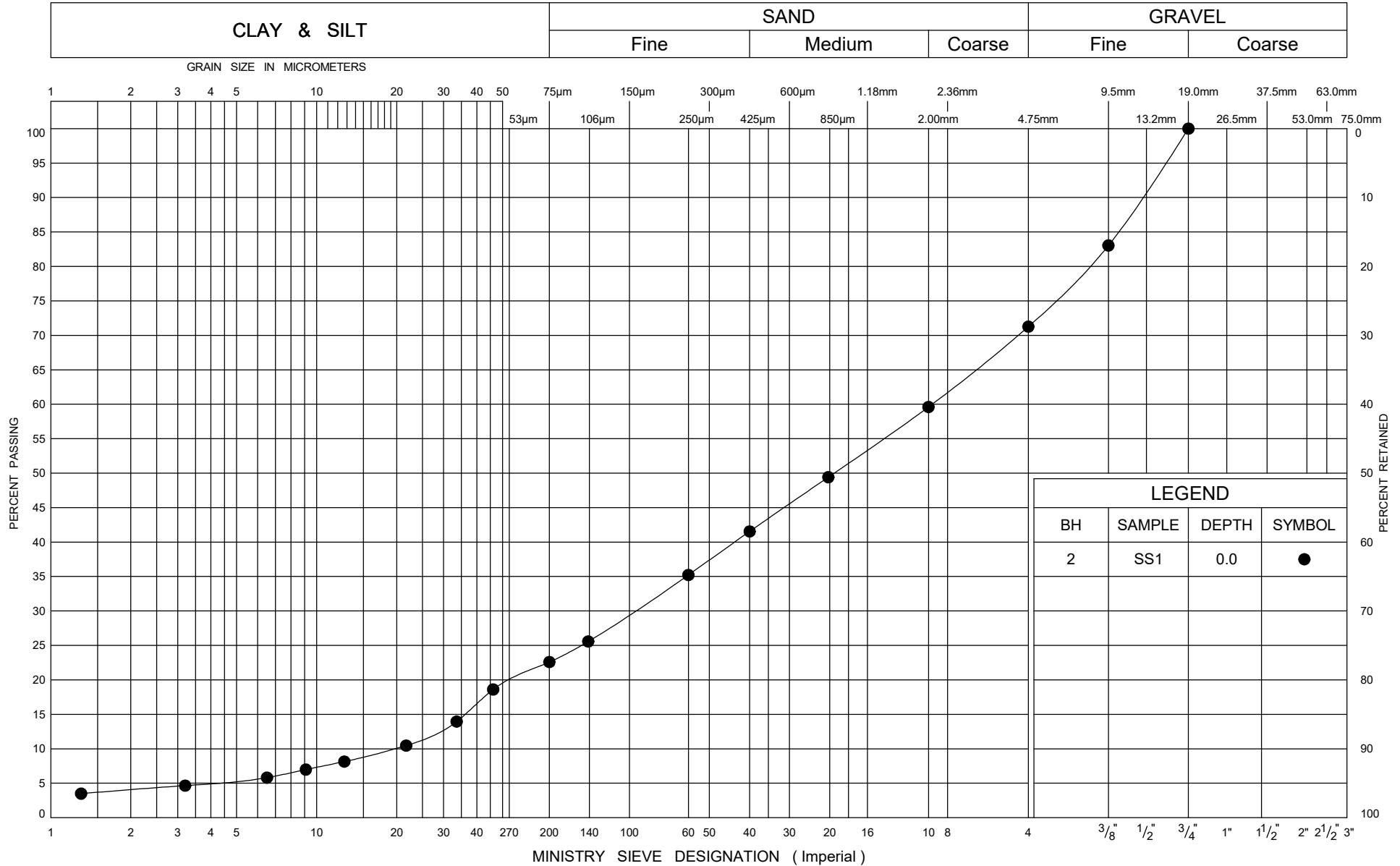
Date	Water Depth (m)	Elevation (m)
Mar 15, 2018	7.8	225.3
Apr 4, 2018	7.8	225.3

APPENDIX B

Laboratory Test Results



UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
Transportation

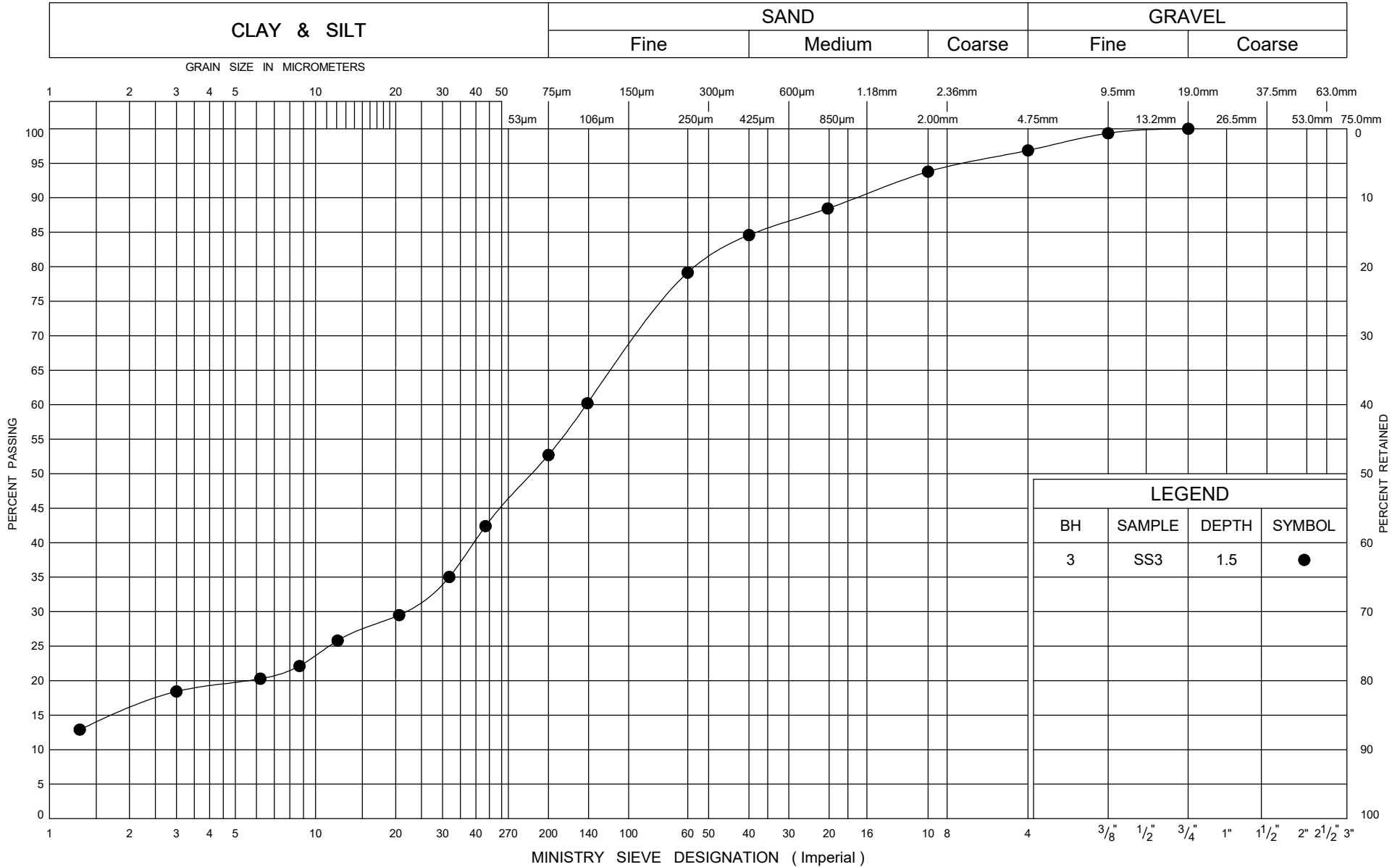
GRAIN SIZE DISTRIBUTION FILL - GRAVELLY SAND

FIG No B1

G W P

Alectra Utilities Duct Crossing

UNIFIED SOIL CLASSIFICATION SYSTEM



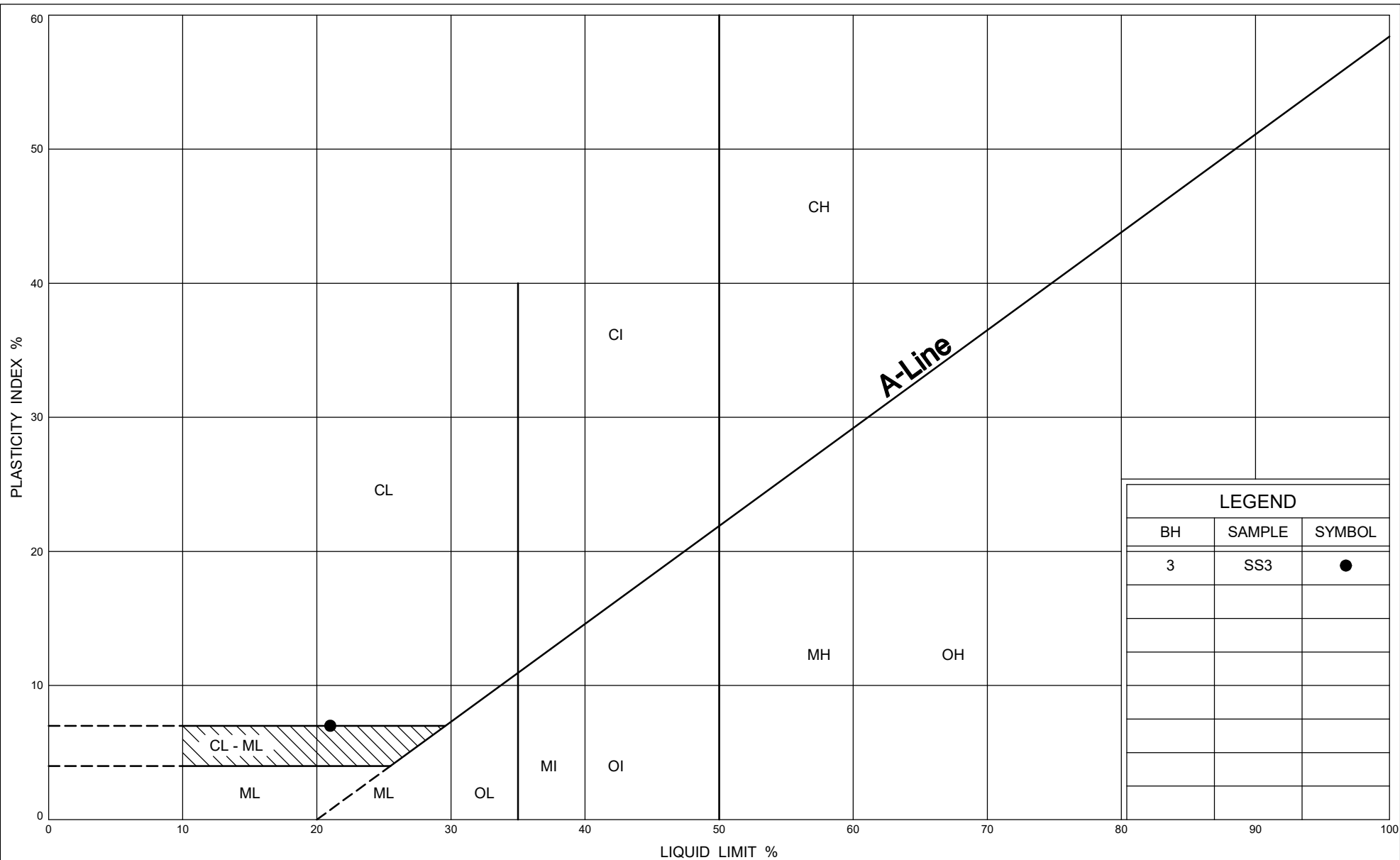
Ministry of
Transportation

GRAIN SIZE DISTRIBUTION FILL - CLAYEY SILT

FIG No B2

G W P

Alectra Utilities Duct Crossing



file: 1-17-0839-01 bh logs.gpj



Ministry of
Transportation

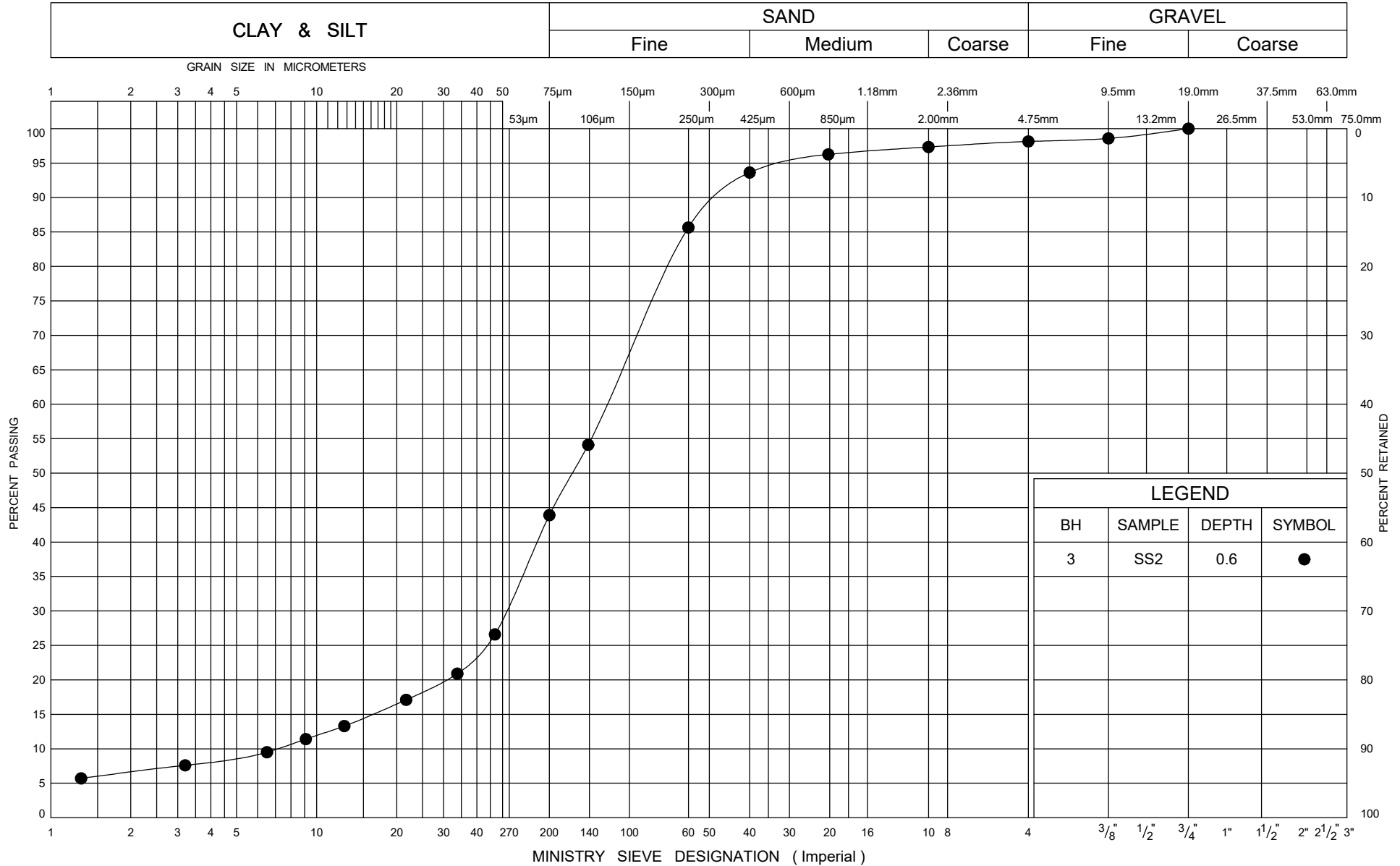
PLASTICITY CHART
FILL - CLAYEY SILT

FIG No B3

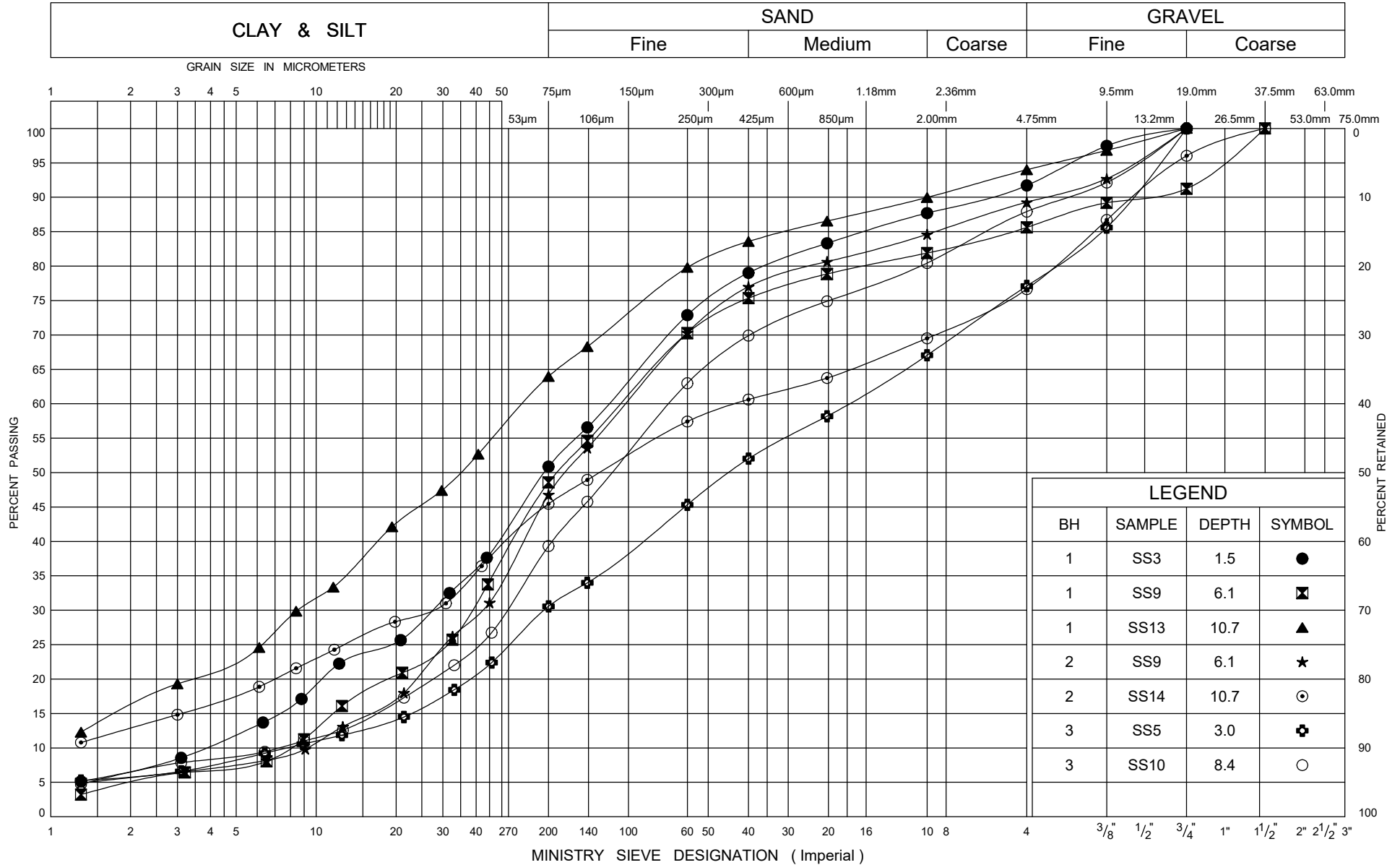
G W P

Alectra Utilities Duct Crossing

UNIFIED SOIL CLASSIFICATION SYSTEM



UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
Transportation

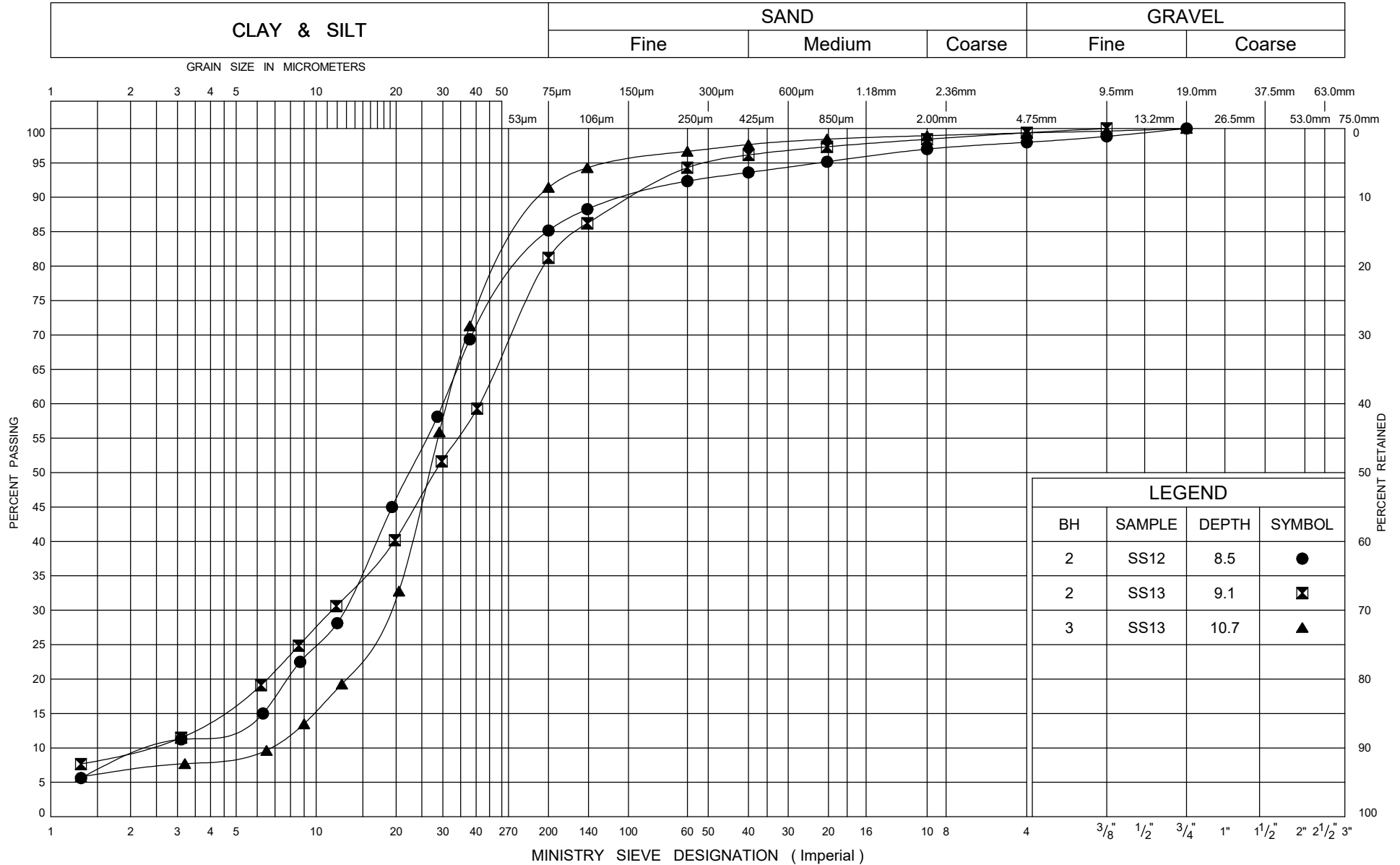
GRAIN SIZE DISTRIBUTION SILTY SAND TO SANDY SILT (GLACIAL TILL)

FIG No B5

G W P

Alectra Utilities Duct Crossing

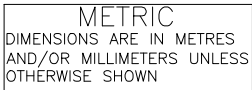
UNIFIED SOIL CLASSIFICATION SYSTEM



APPENDIX C

Settlement Monitoring Programme





SETTLEMENT MONITORING PROGRAMME



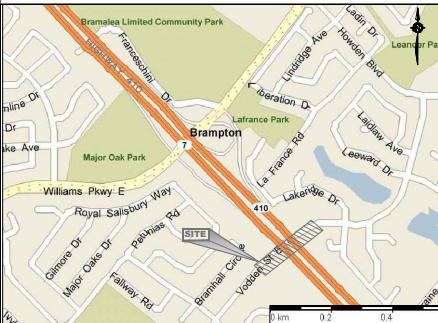
1525 CORNWALL RD - UNIT 27, OAKVILLE, ONTARIO, L6J 0B3
Tel. 905.257.0888, Fax 905.257.8488
nbm@nbmengineering.com



Terraprobe Inc.




Consulting Geotechnical & Environmental Engineering
Construction Materials Engineering, Inspection & Testing

11 Indell Lane - Brampton Ontario L6T 3Y3 (905) 796-2650



KEY PLAN

LEGEND

- | | |
|---|----------------------------------|
|  | BOREHOLE |
|  | IN GROUND MONITORING POINT |
|  | SURVEY POINT
(PAVED ROADWAYS) |

No	ELEV. (m)	COORDINATES (MTM NAD83, ZONE 10)	
		NORTHING (m)	EASTING (m)
BH1	232.2	4 841 363.0	284 814.6
BH2	226.6	4 841 406.8	284 853.7
BH3	233.1	4 841 455.0	284 891.5

NOTE

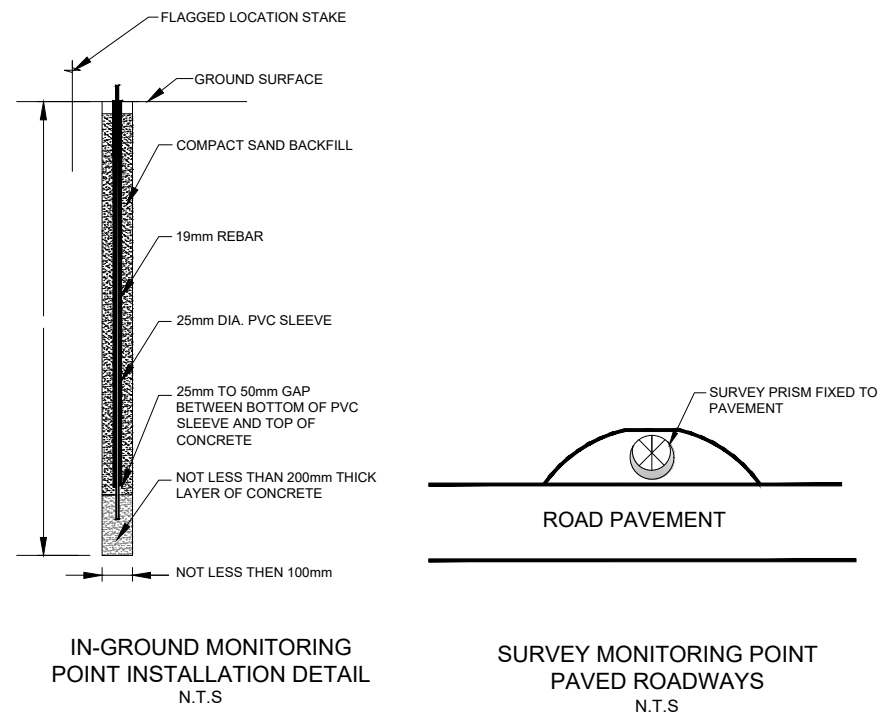
THE PROPOSED DETAILS / WORKS ARE SHOWN FOR ILLUSTRATION
PURPOSES ONLY AND MAY NOT BE CONSISTENT WITH FINAL DESIGN
CONFIGURATION AS SHOWN ELSEWHERE IN THE CONTRACT DOCUMENTS

REFERENCE

Drawings provided in digital format by NBM Engineering Inc. emailed July 03, 2018.

REVISIONS			
	DATE	BY	DESCRIPTION

HWY. 410	PROJECT No. 1-17-0839		Geocres No.30M12-42
SUBM'D.SD	CHKD. RA	DATE: July 2018	W.O 2018-11009
DRAWN: KC	APPD: MT		DWG. 2



- NOTES:

1. THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH TERRAPROBE INC. REPORT No. 1-17-0839, DATED JULY 2018.
2. ALL MONITORING LOCATIONS SHOULD BE CONSIDERED APPROXIMATE AND MUST BE CONFIRMED BY THE CONTRACTOR IN CONSULTATION WITH THE CONTRACT ADMINISTRATOR, GEOTECHNICAL ENGINEER, PRIOR TO INSTALLATION/CONSTRUCTION AND MAY HAVE TO BE ADJUSTED IN THE FIELD TO SUIT LOCAL CONDITIONS/CONSTRAINTS.
3. THE CONSULTANT SHALL RETAIN A SURVEYOR REGISTERED IN ONTARIO FOR ESTABLISHING AND SURVEYING THE MONITORING POINTS FOR THE DURATION OF CONSTRUCTION.
4. ALL MONITORING INSTRUMENTS SHALL BE INSTALLED AT LEAST 7 DAYS PRIOR TO ANY EXCAVATION OR TUNNELLING TAKING PLACE.
5. IN-GROUND MONITORING POINTS SHALL BE FOUNDED BELOW FROST PENETRATION DEPTH (1.2m), AT A DEPTH OF 1.5m BELOW EXISTING GRADE. SURFACE MONITORING POINTS ON PAVED ROADWAYS SHALL BE INSTALLED IN ACCORDANCE WITH THE MANUFACTURER'S INSTRUCTIONS.
6. THE CONTRACTOR SHALL ESTABLISH TWO TEMPORARY BENCHMARKS OUTSIDE THE AREA OF CONSTRUCTION. THE CONTRACTOR SHALL SUBMIT THE PROPOSED BENCHMARK LOCATIONS TO THE CONTRACT ADMINISTRATOR FOR APPROVAL. PRIOR TO CONSTRUCTION ALL MONITORING POINTS SHALL BE SURVEYED FOR ELEVATION AND LOCATION TO A TOLERANCE OF NOT MORE THAN 2mm IN THE VERTICAL AND HORIZONTAL DIRECTION.
7. DURING TUNNELLING, ALL POINTS SHALL BE SURVEYED A MINIMUM OF 3 TIMES PER DAY.
8. THE SPECIFIED SETTLEMENT REVIEW LEVEL IS 10mm AND THE SPECIFIED SETTLEMENT ALERT LEVEL IS 15mm RELATIVE TO THE BASELINE READING. IF SETTLEMENTS REACH THE REVIEW LEVEL THE CONTRACTOR SHALL PROVIDE A FORMAL PLAN TO ENSURE FURTHER SETTLEMENTS DO NOT OCCUR. IF SETTLEMENTS REACH THE ALERT LEVEL, THE CONTRACTOR SHALL SUSPEND TUNNELLING AND THE CONTRACTOR ADMINISTRATOR, OWNER AND MTO WILL HAVE THE AUTHORITY TO ORDER THE CONTRACTOR TO SUSPEND ALL TUNNELLING UNTIL AN APPROVED MITIGATION SOLUTION IS DEVELOPED.
9. AFTER TUNNELLING HAS BEEN COMPLETED, THE CONTRACTOR SHALL SURVEY THE MONITORING POINTS ONCE PER DAY FOR 10 DAYS OR UNTIL DATA INDICATES THAT ALL MOVEMENTS HAVE ESSENTIALLY CEASED.
10. WITHIN 24 HOURS OF COMPLETION OF ANY MEASUREMENT A COPY OF THE RESULTS SHALL BE MADE AVAILABLE TO THE CONTRACT ADMINISTRATOR, OWNER AND MTO.
11. THE CONTRACTOR SHALL MAKE ALL ARRANGEMENTS FOR TRAFFIC CONTROL IN ACCORDANCE WITH ONTARIO TRAFFIC MANUAL BOOK 7.
12. REMOVE ALL MONITORING POINTS ON COMPLETION OF SURVEY, SUBJECT TO APPROVAL FROM THE CONTRACT ADMINISTRATOR AND GEOTECHNICAL ENGINEER.

APPENDIX D

Non Standard Special Provision Pipe Installation By Trenchless Method



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 Polyolefin 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 OSHA 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.