

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
PROPOSED FEEDERMAINS WITH  
TRENCHLESS CROSSING UNDER HIGHWAY 401  
REVISED ALIGNMENT  
TRAFALGAR ROAD INTERCHANGE AT HIGHWAY 401  
MILTON AND HALTON HILLS, ONTARIO**

**Report to**

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**PART 1: FACTUAL INFORMATION**

**1 INTRODUCTION**

This report presents the factual findings obtained from a foundation investigation carried out along the revised alignment of proposed feeder mains which will cross under Highway 401 and the associated ramps on the west side of Trafalgar Road in Milton and Halton Hills, Ontario. The work is a part of the Region of Halton's Zone 4 Feedermain project which extends along Trafalgar Road from Britannia Road to 1 km north of 5 Side Road and along Derry Road from Fifth Line to Trafalgar Road.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan and soil strata drawings with a stratigraphic profile, records of boreholes, laboratory test results and written descriptions of the subsurface conditions. A model of the subsurface conditions was developed for the site based on the data obtained from the present investigation.

A separate hydrogeological technical memorandum has been prepared by Palmer Environmental Consulting Group Inc. (Palmer) (*Technical Memorandum – Preliminary Hydrogeological Foundation Investigation and Design, Proposed Halton Zone 4 Feedermain Tunnel Crossing below Highway 401 at Trafalgar Road Interchange, Milton, ON*). This memorandum was referenced for assessment regarding groundwater conditions and dewatering.

Thurber carried out the investigation as a sub-consultant to Associated Engineering Ltd. who are preparing the detailed design of the feeder mains for The Regional Municipality of Halton.

**2 SITE DESCRIPTION**

The proposed feeder main will run from a temporary shaft (Shaft 1-14) located on a private property on the west side of Trafalgar Road and south of the interchange. From this shaft the feeder main will run northwards and parallel to Trafalgar Road, across Highway 401 to a second shaft (Shaft 1-15) located on MTO property north of the interchange ramps. From Shaft 1-15 the feeder main alignment heads north off of MTO property. Highway 401 at the site is a six lane divided highway

with a concrete median barrier. For the purpose of this report, Highway 401 is considered to run in an east-west orientation.

The lands surrounding the project area are generally agricultural with a faintly undulating topography. A small tributary of the Sixteen Mile Creek crosses Trafalgar Road from northeast to southwest immediately south of the interchange.

The project site is located within the physiographic region known as the Peel Plain, characterized by a discontinuous veneer of glacio-lacustrine clay and silt underlain by glacial till consisting of clayey silt to silty clay (Halton Till). The underlying bedrock consists of the Queenston Formation, a reddish brown shale with siltstone and limestone interbeds.

### **3 SITE INVESTIGATION AND FIELD TESTING**

The site investigation and field testing for this project was carried out in two stages. The investigation for the original alignment was carried out in March and April, 2015 and involved drilling a total of 8 boreholes along the proposed feedermain alignment. The boreholes were designated numbers 14-63 to 14-70. Investigation of the revised alignment was carried out in October 2015 and involved drilling an additional 5 boreholes, designated numbers 14-105 to 14-109. The borehole depths ranged between 15.4 and 20.4 m (Elevation 177.1 and 188.8 m).

The approximate locations of the boreholes are shown on the Borehole Locations and Stratigraphic Profile Drawing in Appendix D. The co-ordinates and elevations at the borehole locations were collected by Thurber using a differential GPS unit with horizontal and vertical accuracy of +/- 0.3 m.

Utility clearances at the borehole locations and the required permits were obtained prior to the start of drilling.

Track-mounted and truck-mounted drill rigs were used to drill and sample the boreholes. Hollow stem augers and tricone bits were used to advance the boreholes. Bedrock was encountered only in Borehole 14-105 during the investigation. Soil samples were obtained using a 50 mm nominal diameter split spoon sampler in conjunction with the Standard Penetration Test (SPT).

A member of Thurber's technical staff supervised the drilling and sampling operations on a full time basis. The supervisor logged the boreholes, placed the soil samples in labelled containers and transported the samples to Thurber's laboratory for further examination and testing.

Results of the field drilling and sampling are presented on the Record of Borehole sheets in Appendix A.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. Monitoring wells, each consisting of a 50 mm diameter Schedule 40 PVC pipe with a 1.5 m or 3.0 m long slotted screen, were installed in Boreholes 14-65, 14-68 and 14-70, 14-105, 14-107 and 14-109. The details of monitoring well installation and borehole completion are summarized in

Table 3.1 below. Boreholes without monitoring wells were decommissioned in general accordance with O. Reg. 903.

**Table 3.1 – Borehole Completion and Monitoring Well Installation Details**

<b>Borehole Number</b>	<b>Well Tip Depth / Elevation (m)</b>	<b>Sand Screen Depth / Elevation (m)</b>	<b>Completion Details</b>
14-63	None installed		Bentonite grout to 1.2 m, then bentonite holeplug to surface.
14-64	None Installed		Backfilled with grout to 1.2 m, then bentonite holeplug to surface.
14-65	14.3 / 187.8	15.7 to 10.7 / 186.4 to 191.4	Bentonite holeplug from 10.7 m to surface.
14-66	None Installed		Backfilled with grout to 1.8 m, then bentonite holeplug to 0.1 m, then concrete to surface.
14-67	None installed		Backfilled with grout to 1.8 m, then bentonite holeplug to 0.1 m, then concrete to surface.
14-68	7.6 / 196.6	7.9 to 4.0 / 196.3 to 200.2	Bentonite holeplug from 4.0 m to 0.9 m, then sand from 0.9 m to 0.2 m, then concrete to surface.
14-69	None installed		Backfilled with bentonite holeplug to 0.2 m, then cuttings to surface.
14-70	18.3 / 188.6	18.4 to 14.6 / 188.5 to 192.4	Bentonite holeplug from 14.6 m to 14.0 m, then cement/bentonite grout to 3.7 m, then bentonite holeplug to 1.2 m, then sand to surface.
14-105	10.7 / 184.9	11.0 to 8.5 / 184.6 to 187.1	Cement/bentonite grout from 8.5 m to 0.4 m, then sand from 0.4 m to 0.2 m, then concrete to surface.
14-106	None installed		Backfilled with cement/bentonite grout to 1.5 m, then bentonite holeplug to surface.
14-107	19.8 / 181.3	20.4 to 17.7 / 180.7 to 183.4	Bentonite holeplug from 17.7 m to 17.1 m, then cement/bentonite grout from 17.1 m to 1.6 m, then bentonite holeplug from 1.6 m to 0.3 m then concrete to surface.
14-108	None installed		Backfilled with cement/bentonite grout to 0.6 m, then bentonite holeplug to surface.
14-109	19.4 / 184.7	19.9 to 17.2 / 184.2 to 186.9	Cement/bentonite grout from 17.2 m to 0.6 m, then sand from 0.6 m to 0.3 m, then concrete to surface.

#### 4 LABORATORY TESTING

All recovered soil samples were subjected to visual identification and to natural moisture content determination. Selected soil samples were subjected to grain size distribution analysis (sieve and

hydrometer). Atterberg Limits tests were carried out on selected samples of cohesive soils to determine the plasticity characteristics. The results of the laboratory testing program are shown on the Record of Borehole sheets in Appendix A and on the figures in Appendix B.

## **5 DESCRIPTION OF SUBSURFACE CONDITIONS**

Reference should be made to the Record of Borehole sheets included in Appendix A for details of the soil stratigraphy encountered in the boreholes. A stratigraphic profile along the proposed feedermain crossing under the Highway 401 corridor is presented on the “Borehole Locations and Stratigraphic Profile” drawing in Appendix D.

General descriptions of the stratigraphy based on the borehole information are given in the following paragraphs. However, the factual information presented in the Record of Borehole sheets governs any interpretation of site conditions. Subsurface conditions should be expected to vary between and beyond the borehole locations.

In general, the subsurface stratigraphy at the site consists of fill and/or topsoil overlying a layer of native silty clay till, underlain by silt and sand layers. At the south end of the crossing a layer of sand and silt till was encountered under the silty clay till and above the sand and silt layers. Near the midpoint of the crossing the sands and silts were found directly below the fill. The measured groundwater level is generally close to ground surface, with an artesian condition identified south of the interchange.

### **5.1 Topsoil/Organic Rich Soils**

Topsoil/organic rich soil of between 100 mm and 690 mm in thickness was encountered in Boreholes 14-63, 14-64, 14-65, 14-68 and 14-105. The topsoil/organic rich soil thickness may vary between and beyond the borehole locations, and the limited data in this report should not be used for quantity estimating purposes.

### **5.2 Pavement Structure**

An asphalt pavement structure was encountered in Boreholes 14-66 and 14-67 which were drilled on the median and north shoulder of Highway 401 respectively. The asphalt thickness was 150 mm in both boreholes. The thickness of the underlying gravelly sand was 540 mm. The lower boundary of the granular material was found at a depth of 0.7 m (Elevations 201.8 m to 202.4 m).

Borehole 14-70 was drilled through the asphalt pavement structure of Trafalgar Road and encountered 150 mm of asphalt overlying 540 mm of gravelly sand. The lower boundary of the granular material was found at a depth of 0.7 m (Elevation 206.3 m).

Boreholes 14-69 and 14-109 were drilled through the gravel road used to access the tower at the northwest corner of the interchange. The thickness of the gravelly sand to sand some gravel base was 0.7 m in Borehole 14-69 and 0.8 m in 14-109.

An SPT value of 15 blows per 0.3 m of penetration indicates that the sand fill has a compact relative density. Moisture contents measured in the fill ranged from 2% to 5%.

### 5.3 Fill

A layer of clay fill was encountered in all boreholes, except Boreholes 14-68, 14-105 and 14-109, either from the ground surface or below either the topsoil or the pavement structure. The fill was described as silty clay with trace sand to sandy, trace gravel and occasional organic material such as rootlets. The thickness of silty clay fill layer ranged from 0.6 m to 3.6 m. The lower boundary of the clay fill was found at depths ranging from 0.7 m to 3.7 m (Elevations 194.8 m to 204.8 m).

SPT 'N' values recorded in the silty clay fill ranged from 5 to 28 blows per 0.3 m of penetration, indicating a firm to very stiff consistency. Measured moisture contents of samples of the clay fill ranged from approximately 10% to 25%.

One sample of silty clay fill was subjected to gradation analysis and Atterberg Limits testing. The results of these tests are summarized on the tables below as well as on the Record of Borehole sheets included in Appendix A. Figure B1 in Appendix B presents the grain size distribution curve for this sample, and Figure B15 illustrates the result of the Atterberg Limits Test on a plasticity chart.

Soil Particles	Percentage
Gravel	0
Sand	25
Silt	45
Clay	30

Soil Particles	Percentage
Liquid Limit	30
Plasticity Index	13

The results of the Atterberg Limits test indicate that the fill is of low plasticity (CL).

A layer of silty sand fill was encountered under the clay fill in Borehole 14-70. The layer was 0.8 m thick and the bottom boundary was found at a depth of 3.0 m (Elevation 204.0 m). One SPT 'N' value of 61 blows for 0.3 m of penetration was measured indicating a very dense state. A moisture content of 10% was measured in this fill.

### 5.4 Silty Clay Till

Glacial till with a silty clay to clayey silt matrix, some sand to sandy, and trace gravel was encountered below the topsoil, fill and/or sand, in all boreholes advanced along the



feedermain alignment except Boreholes 14-66, 14-67, 14-105 and 14-108. The till was generally described as brown to grey in colour. In Boreholes 14-105 and 14-106 isolated deposits of reddish brown till were encountered at depth within/below sands and silts.

The thickness of the plastic till layer ranged between 1.4 m and 9.5 m, with a lower boundary at depths of 2.2 m to 14.8 m (Elevations 191.1 m to 202.0 m). Borehole 14-106 was terminated within the silty clay till at a depth of 19.5 m (Elevation 179.3 m). A layer of very dense silt 1.5 m thick was encountered within the clay till in Borehole 14-69.

SPT 'N' values recorded in the plastic till ranged from 15 blows per 0.3 m of penetration to 50 blows for only 75 mm of penetration, indicating a very stiff to hard consistency. Measured moisture contents of samples of the plastic till ranged from approximately 4% to 24%, typically 8% to 14%.

Selected samples of silty clay till were subjected to gradation analysis and Atterberg Limits testing. The results of these tests are summarized in the tables below as well as on the Record of Borehole sheets included in Appendix A. Figures B2 and B3 in Appendix B present the grain size distribution curves for these samples, and Figure B16 illustrates the results of the Atterberg Limits tests on plasticity charts.

Soil Particles	Percentage
Gravel	0 to 9
Sand	19 to 42
Silt	34 to 62
Clay	14 to 35

Soil Particles	Percentage
Liquid Limit	19 to 29
Plasticity Index	7 to 12

The results of the Atterberg Limits tests indicate that this till is of low plasticity (CL).

It should be noted that glacial tills inherently contain cobbles and boulders. Also the refusal blow counts recorded within this till in Boreholes 14-69, 14-70, 14-105 and 14-106 may indicate the presence of cobbles or boulders.

## 5.5 Sand and Silt Till

Glacial till with a sand and silt to silty sand matrix, trace to some clay, trace to some gravel was encountered below the plastic till described above in Boreholes 14-63, 14-64, 14-70 and 14-106, and below a sand layer in Borehole 14-105. This till was described as reddish brown to grey in colour.

The thickness of the non-plastic till layer ranged between 2.4 m and 5.0 m, with a lower boundary at depths of 6.9 m to 10.4 m (Elevations 188.1 m to 193.3 m). Borehole 14-70 was terminated within this till deposit at 18.4 m depth (Elevation 188.5 m).

SPT 'N' values recorded in the non-plastic till ranged from 29 blows per 0.3 m of penetration to 100 blows for only 150 mm of penetration, indicating a compact to very dense condition, typically dense to very dense. Measured moisture contents of samples of the non-plastic till ranged from approximately 5% to 20%.

Selected samples of sand and silt to silty sand till were subjected to gradation analysis. The results of these tests are summarized in the tables below as well as on the Record of Borehole sheets included in Appendix A. Figures B4 and B5 in Appendix B presents the grain size distribution curves for these samples.

Soil Particles	Percentage
Gravel	5 to 19
Sand	36 to 59
Silt	21 to 47
Clay	6 to 14

It should be noted that glacial tills inherently contain cobbles and boulders. Also the refusal blow counts recorded within this till in Boreholes 14-63, 14-64, 14-70, 14-105 and 14-106 may indicate the presence of cobbles or boulders.

## 5.6 Silts and Sands

Deposits of sand, sand and gravel, gravelly sand, silty sand, sand and silt, sandy silt and/or silt were found below the fill layer in Boreholes 14-66, 14-67, 14-70 and 14-108, below the organic rich soil in Borehole 14-105 and below the till deposits in all other boreholes. These deposits sometimes contained trace to some clay and/or trace gravel. All boreholes except Borehole 14-70, 14-105 and 14-106 were terminated within the sand/silt at depths of 15.2 to 20.4 m. In Borehole 14-70 the sandy silt layer was 2.4 m thick with the bottom boundary at a depth of 5.3 m (Elevation 201.6 m). In Borehole 14-105 a shallow gravelly sand layer 2.1 m thick with a bottom boundary at a depth of 2.7 m (Elevation 192.9 m) and a deep sand to silt layer 8.8 m thick with a bottom boundary at a depth of 16.3 m (Elevation 179.3 m) were encountered. In Borehole 14-106 a silt to sand layer 10.5 m thick with a bottom boundary at a depth of 19.2 m (Elevation 179.6 m) was encountered.

SPT 'N' values recorded in the silt to sand varied from 11 blows for 0.3 m of penetration to 50 blows for 75 mm of penetration, indicating a compact to very dense condition.

Typically the SPT 'N' values exceeded 50 blows for 0.3 m of penetration indicating a very dense condition. Measured moisture contents of samples of these soils ranged from approximately 4% to 25%, typically 13% to 20%.

Samples of the silts and sands were subjected to gradation analysis. The results of these tests are summarized in the table below as well as on the Record of Borehole sheets included in Appendix A. Figures B6 to B13 present the grain size distribution curves for these samples.

Soil Particles	Percentage	
	Sand and Gravel to Sand and Silt	Silt to Sandy Silt
Gravel	0 to 44	0 to 2
Sand	40 to 89	0 to 31
Silt	11 to 50	61 to 94
Clay	2 to 10	3 to 24

### 5.7 Silty Clay

A silty clay layer with trace to some sand was encountered within the silt and sand deposit in Borehole 14-107. The silty clay was described as grey in colour. The layer was 1.5 m thick with the lower boundary at a depth of 5.2 m (Elevation 195.9 m).

SPT 'N' values recorded in the silty clay ranged from 50 blows for 125 mm of penetration to 88 blows for 225 mm of penetration indicating a hard condition. Measured moisture contents of samples of these soils were between 12% and 16%.

One sample of silty clay was subjected to gradation analysis. The result of this test are summarized in the table below as well as on the Record of Borehole sheets included in Appendix A. Figure B14 in Appendix B presents the grain size distribution curve for this sample.

Soil Particles	Percentage
Gravel	0
Sand	11
Silt	60
Clay	29

### 5.8 Shale Bedrock

Shale bedrock was encountered at the base of Borehole 14-105 at a depth of 18.4 m (Elevation 177.2 m). The shale bedrock was described as reddish brown and is from the Queenston Formation.

## 5.9 Water Levels

Monitoring wells were installed in Boreholes 14-62, 14-65, 14-68, 14-70, 14-105, 14-107 and 14-109 to facilitate groundwater level monitoring. Water levels were also observed in two open boreholes on completion of drilling. Measured and observed water levels in the wells and the open holes are presented in Table 5.1 below.

**Table 5.1 - Water Level Measurements**

Borehole Number	Date of Reading	Water Level Depth (m)	Water Level Elevation (m)	Comment
14-63	March 18, 2015	0.8**	198.1**	Open borehole
14-64	March 19, 2015	1.3**	202.4**	Open borehole
14-65	March 18, 2015	0.4**	201.7**	Open borehole
	April 21, 2015	3.0	199.1	Well
	April 28, 2015	3.6	198.5	Well
	April 29, 2015	3.6	198.5	Well
14-68	April 21, 2015	2.3	201.9	Well
	April 28, 2015	2.8	201.4	Well
	April 29, 2015	2.8	201.4	Well
14-70	April 28, 2015	5.8	201.2	Well
14-105	October 27, 2015	1.7*	197.3	Well
14-107	October 27, 2015	3.0	198.1	Well
14-109	October 27, 2015	4.8	199.3	Well

\* Above ground surface

\*\* Not stabilized

The above observations indicate that the groundwater level along the feedermain alignment is above the ground surface or within 5.8 m depth below the existing ground surface. In Borehole 14-105, a piezometric level of 1.7 m above existing ground surface (artesian) was measured.

All groundwater observations at this site are short term and the levels are expected to fluctuate seasonally and subject to climatic conditions/events.

## 6 MISCELLANEOUS

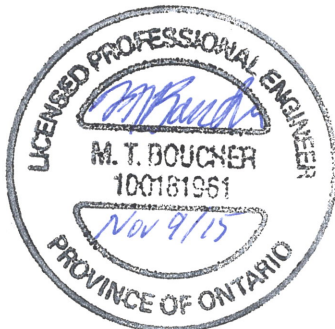
Thurber staked out the boreholes relative to existing site features prior to drilling and subsequently determined the co-ordinates and ground elevations at borehole locations using a differential GPS unit. Underground utility clearances were obtained for the borehole locations prior to drilling.

DBW Drilling Ltd. of Toronto supplied the drill rigs and conducted the drilling, sampling and in-situ testing operations.

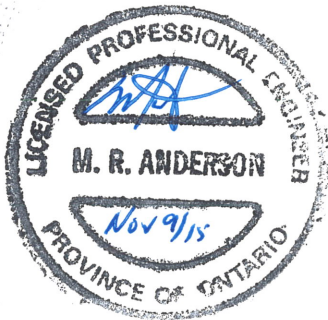
Full time supervision of the field activities, including obtaining utility clearances, was carried out by various field technicians provided by Thurber Engineering. Overall supervision of the field program was performed by Mr. Matthew Boucher, P.Eng. of Thurber. Geotechnical laboratory testing was carried out in Thurber's Toronto area laboratory.

Interpretation of the data and preparation of this report was carried out by Mr. Matthew Boucher, P.Eng. The report was reviewed by Mr. Murray Anderson, P.Eng. and Dr. Paulo Branco, P.Eng., a Designated Principal Contact for MTO Foundations projects.

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**PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS**

**7 GENERAL**

This section of the report presents interpretation of the geotechnical data in the factual report and provides foundation recommendations for the design and installation of the proposed feeder mains.

For the purpose of this report, Highway 401 is considered to run in an east-west orientation, and the feeder main alignment in a general north-south orientation.

The design drawings provided by Associated Engineering indicate that the proposed feeder mains will comprise twin 900 mm diameter concrete pressure pipe (CPP) or steel pipe. The feeder mains will cross under Highway 401 and the associated ramps. Trenchless methods will be used to install the feeder mains from a launch shaft (Shaft 1-14) on the south side of the interchange (Station 15+376) to the retrieval shaft (Shaft 1-15) on the north side of the highway (Station 15+834), a length of approximately 458 m between the two shafts. The feeder mains will also be installed north of Shaft 1-15 to beyond MTO property using trenchless methods.

Both feeder mains will be installed in one casing with an outside diameter of approximately 3.2 m. The casing crossing under Highway 401 will have an invert level approximately 7 m to 14 m below existing grade of the ramps and highway, rising from Elevation 188.0 m to 194.0 m from south to north. A minimum 6.0 m clearance will be provided under Highway 401 and under the associated ramps.

At the south end of the alignment, the subsurface stratigraphy along the feeder main alignment generally consists of fill or topsoil overlying a layer of very stiff to hard silty clay till, underlain by a dense to very dense sand and silt till layer, underlain by dense to very dense sands and silts. Further north, under Highway 401, the till layers are absent and the fill is underlain directly by layers of dense to very dense sands and silts. The clay till layer is again present north of the highway. North of Shaft 1-15 the fill is underlain by a thin silt deposit which is underlain by till. The measured groundwater level ranges from 1.7 m above ground surface to 5.8 m below ground surface.

The discussion and recommendations presented in this report are based on the information provided by Associated Engineering and on the factual data obtained in the course of the investigation.

## **8 TRENCHLESS METHODS**

The preliminary drawings indicate that the feedermain will be installed under Highway 401 within a casing with an inside diameter of 2,700 mm and an approximate outside diameter of 3,200 mm. The casing will extend for the entire length of the trenchless crossing. The casing will have an invert level approximately 7.0 m to 14.0 m below existing grade, rising from Elevation 188.0 m to 194.0 m from south to north.

### **8.1 Subsurface Conditions**

Based on the borehole information (Boreholes 14-63 to 14-70 and 14-105 to 14-109), the proposed tunnel horizon will be mostly located within the deposits of dense to very dense sands and silts. The south end of the tunnel, for approximately 120 m, will be excavated in very dense sand and silt till. The north end of the tunnel will be excavated in hard silty clay till. The groundwater level ranges from 1.7 m above ground surface to 5.8 m below ground surface. The subsurface information is summarized on the Borehole Locations and Stratigraphic Profile Drawing in Appendix D.

Cobbles and boulders should be anticipated along the entire alignment especially within the till soils. Cobbles and boulders are expected to comprise both fragments of local bedrock (shale and limestone) as well as much stronger granitic bedrock. The Contractor must be prepared to deal with these obstructions.

### **8.2 Tunnelling Methods**

Selection of an appropriate trenchless method should be the responsibility of the Contractor and will depend on the relative costs and risks associated with each method. The experience of the Contractor is of primary importance for trenchless installation. The Contractor must submit a detailed work plan including the proposed trenchless methodology and means of maintenance of alignment.

The sands and silts through which the tunnel will extend are expected to exhibit a running behaviour if dewatering is not provided in advance of open face tunnelling methods. However, we understand that active dewatering is not permitted due to the potential for adverse impacts on local groundwater users. For additional information regarding the restriction on dewatering refer to the hydrogeology report. Use of a closed face tunnelling method is therefore required. Feasible tunnelling/trenchless installation methods include the use of micro-tunnel boring machine (MTBM) or an earth pressure balance tunnel boring machine (EPBTBM).



While micro-tunnelling is considered feasible, the proposed tunnel diameter of 3.2 m is near the upper limit of this technology. Consideration could be given to installing the feedermain in twin smaller diameter casings installed using two separate drives of a smaller diameter MTBM.

Commonly used trenchless methods including jack and bore, pipe ramming and horizontal directional drilling are not considered to be feasible due to either the length of the crossing, the required casing diameter and/or the restriction on dewatering. Also, tunnelling using a conventional tunnel boring machine or hand-mining are not recommended due to the dewatering requirements.

The Contractor should be alerted to the presence of sands and silts below the water table which will tend to flow without advance dewatering or supporting pressure resulting in instability at the tunnel face. The Contractor must also anticipate encountering cobbles and boulders within the till deposit when selecting the tunnelling methodology. The Contractor should be equipped to handle such obstructions at the bore face if required.

### **8.3 Ground Behaviour**

The Tunnelman's Ground Classification System is a framework for describing soil behaviour in an unsupported tunnel heading under atmospheric conditions. It was initially developed by Terzhagi in 1950 and modified by Heuer in 1974. A summary of the Tunnelman's Ground Classification System according to Heuer, 1974, is presented in Appendix E.

Using this system, the silts and sands below the water level may be considered as "fast ravelling" to "flowing" soil types and will require immediate and full support. When stabilized by dewatering, the sands and silts will exhibit "slow ravelling" to "fast ravelling" behaviour. The non-plastic sand and silt till will exhibit "cohesive running" to "fast ravelling" behaviour below the water table. The hard silty clay till will exhibit firm behaviour.

## **9 SETTLEMENT AND SETTLEMENT MONITORING**

Selection of the trenchless technique employed for installing the casing must take into account the need to avoid settlement and loss of ground below the roadway pavement on Highway 401. Assuming appropriate methodology is selected and bore face stability is maintained, settlement is not expected to exceed 20 mm. However, confirmatory monitoring of the highway and ramp surfaces should be carried out during construction.

A settlement monitoring program and condition survey for tunnelling under the Hwy 401 right-of-way will need to be prepared in accordance with the appendix (Settlement Monitoring Guideline – Tunneling) to MTO's Guidelines for Foundation Engineering - Tunnelling Specialty for Corridor Encroachment Permit Application included in Appendix F.



It is recommended that a pre-construction condition survey be carried out to document the existing conditions of the highway pavement and any other facilities adjacent to the proposed feedermain alignment.

## 10 TEMPORARY LAUNCHING AND RECEIVING SHAFTS

### 10.1 Temporary Excavation and Shoring

Temporary excavation for the launch shaft (Shaft 1-14) construction is anticipated to extend through fill, compact gravelly sand, dense to very dense silty sand till and into the compact to dense sand to a depth of approximately 8.0 m below ground surface. Excavation for the receiving shaft (Shaft 1-15) is expected to extend through fill, a layer of hard clayey silt till and into the very dense sand to silt deposit to a depth of approximately 11.5 m below ground surface. Excavation of both shafts will extend below the measured water level and an artesian condition is expected at the launch shaft.

All temporary excavations must be carried out in accordance with the current Occupational Health and Safety Act (OHSA) of Ontario and local regulations. The silty clay till, and the sand and silt till are classified as Type 2 soils under OHSA; the silts and sands above the groundwater level are a Type 2 soil. Silts and sands below groundwater level are Type 4 soils. Slopes of temporarily unsupported cuts should conform with the requirements of OHSA, but should not be steeper than 1H:1V.

Given the depth of excavation, a temporary support system will likely be required for shaft construction. The selection and design of the shoring system is the responsibility of the Contractor. However, the use of advance dewatering is not permitted. This precludes the use of non-watertight shoring systems such as a soldier pile and lagging system.

The temporary braced shoring system employed for the conditions at the site may be designed using the lateral pressure distribution shown on Figure C1 for the plastic soils (clay till) and on Figure C2 for non-plastic soils (sand, silt, sand and silt till). The following parameters can be used with Figures C1 and C2.

K	=	0.33 for Figure C1
K <sub>a</sub>	=	0.30 for Figure C2
γ	=	20 kN/m <sup>3</sup> for fill
	=	21 kN/m <sup>3</sup> for native soils
h <sub>w</sub>	=	height of water above the base of excavation for watertight shoring system (assume water level at Elev. 197.5 m for launch shaft and at Elev. 201.5 m for receiving shaft)

The apparent earth pressure distribution for layered strata may be assessed using the approximate method outlined in Section 26.10.7 of the Canadian Foundation Engineering Manual.

The shoring system should be designed to extend below the base of excavation to satisfy horizontal equilibrium.

The temporary shoring system should be designed by a licensed Professional Engineer experienced in such designs, with consideration of adjacent traffic loads and any sloping retained surfaces. Roadway protection systems, if required, should be provided as per OPSS 539 which should be included in the contract documents. Performance Level 2 corresponding to a maximum ground movement of 25 mm is recommended for this project.

Before commencing shaft construction, the designer should determine if any protective measures are required for adjacent utilities or structures. This may require discussions with relevant owners of these facilities and design of temporary protection and support systems for particular utilities where required.

The base of each shaft is expected to lie in very dense sand to sand and silt below the groundwater level. Appropriate preventative measures must be provided to avoid basal instability.

The following options may be considered to maintain basal stability and control groundwater seepage through the base of the watertight shafts:

- Extend the watertight shoring system, such as secant piles or slurry trench walls, a sufficient depth below the base of the excavation to cut off groundwater flow and prevent instability due to piping or boiling. Sump pumping will be required at the base of the excavation to maintain reasonably dry excavations throughout construction.
- Carry out the shaft excavation and casting of the base slab underwater. Conceptually this method may involve increasing the base slab thickness and incorporating mechanical connection of the base slab to the shaft walls to resist hydrostatic uplift pressures, and construction using placement of tremie concrete. It is critical that the groundwater level inside the excavation be maintained at the same level as the groundwater outside the shaft until shaft construction including installation of the base slab is complete. To eliminate the need to maintain the water inside the excavation above the ground surface, depressurization to lower the water level below the ground surface is recommended in conjunction with underwater construction.

The use of sheet piling is not considered feasible at this site as driven sheet piles will not readily penetrate the very dense soils and may encounter cobbles and boulders within the till.

Provision should be made for handling and removal of possible cobbles and boulders in the glacial till during the shoring installation and excavation.

## 10.2 Shaft Break-In and Break-Out

The soils located outside of the shaft walls where the tunnelling machine will break-in/break-out of the shafts consist of non-plastic soils below the groundwater table. These soils along with the groundwater will tend to flow into the shaft once the watertight shaft wall is penetrated. The contractor must anticipate this and have the appropriate preventative measures in place in advance of breaking-in and/or out of the shafts.

## 10.3 Permanent Chambers

Preliminary drawings indicate that isolation valve chambers (Chamber Nos. 15 and 16) will be installed in both the launch and receiving shafts. The chamber structures should be designed to withstand hydrostatic pressure, hydrostatic uplift pressure and effective stresses in accordance with the following equation:

$$p = K (\gamma h_1 + \gamma' h_2 + q) + \gamma_w h_2$$

where

$$\begin{aligned} K &= \text{lateral earth pressure coefficient} \\ &= 0.5 \end{aligned}$$

$$\begin{aligned} \gamma &= \text{unit weight of soil above the design water level} \\ &= 21.5 \text{ kN/m}^3 \end{aligned}$$

$$\begin{aligned} \gamma' &= \text{buoyant unit weight of soil below design water level} \\ &= 11.7 \text{ kN/m}^3 \end{aligned}$$

$$h_1 = \text{depth below final grade (m), above water level (m)}$$

$$h_2 = \text{depth below design water level (m)}$$

$$q = \text{any surcharge load (kN/m}^2\text{)}$$

$$\begin{aligned} \gamma_w &= \text{unit weight of water} \\ &= 9.8 \text{ kN/m}^3 \end{aligned}$$

The design water level of 197.5 m (above ground surface) is recommended for the launch shaft. The design water level of 201.5 m is recommended for the receiving shaft.

The above parameters are based on the assumption that the space between the permanent structure and the temporary shoring will be backfilled with compacted granular fill or approved earth fill.

If granular fill is used to backfill around the permanent chamber in the launch shaft, a 5 m thick layer of unshrinkable fill should be used above Elevation 188 m to minimize upward groundwater seepage due to the artesian conditions. The unshrinkable fill will replace the till aquitard that was removed during shaft excavation.

Where unshrinkable fill (lean concrete) is used for backfilling to the top of the chamber, the chamber structure should be designed for hydrostatic pressure applied by the fill in its fluid state. Fill placement must be carried out in stages in order to avoid imposing hydrostatic pressure on the structure larger than those assumed in the design, prior to setting and hardening of the concrete.

It is understood that the permanent chambers will be designed as watertight structures and, as the base of the chambers is below the groundwater table, the chamber should be designed to resist hydrostatic uplift. Design water levels of 197.5 m (artesian) and 201.5 m should be used in the assessment of uplift forces at the launch shaft and receiving shaft, respectively. Resistance to uplift is usually achieved by increasing the weight of the structure, extending the base slab laterally, or providing soil anchors.

## **11 CONSTRUCTION CONCERNS**

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

### **11.1 Groundwater**

Shaft excavation, at both shafts, will take place in sands and silts below the water table. Basal instability and sloughing will occur if appropriate precautions are not put in place. The methodology selected for excavation must anticipate these conditions.

### **11.2 Loss of Ground**

Selection of the trenchless technique employed for installing the casing must take into account the need to avoid settlement and loss of ground below the roadway pavement on Highway 401 and interchange ramps. As long as an appropriate installation methodology is selected and good construction practices are followed, the proposed pipe installation is not expected to impact the roadway pavement. However, confirmatory monitoring of the roadway surface should be carried out during construction, and contingency plans should be prepared to manage any adverse impacts that may arise.

### **11.3 Obstructions**

Glacially derived soils typically contain cobbles and boulders. The Contractor's excavation/trenchless equipment and methodology must be selected to handle such obstructions and mitigate potential alignment issues if encountered.

### **11.4 Buried Utilities**

The Contractor must accurately establish the locations of any existing buried utilities in the vicinity of the proposed feedermain alignment.

## 12 CLOSURE

Engineering analysis and preparation of Part 2 Engineering Discussion and Recommendations of this report was carried out by Mr. Matthew Boucher, P.Eng.

The report was reviewed by Mr. Murray Anderson, P.Eng. and Dr. Paulo Branco, P.Eng., who is a Designated Principal Contact for MTO Foundations Projects.

### THURBER ENGINEERING LTD.



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

### **Record of Borehole Sheets**



# UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS W <sub>L</sub> < 50%	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. (W <sub>L</sub> < 30%).
		CI	Inorganic clays of medium plasticity, silty clays. (30% < W <sub>L</sub> < 50%).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS W <sub>L</sub> > 50%	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

## EXPLANATION OF ROCK LOGGING TERMS


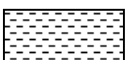

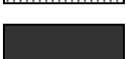

### ROCK WEATHERING CLASSIFICATION

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

### DISCONTINUITY SPACING

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

### SYMBOLS

	CLAYSTONE
	SILTSTONE
	SANDSTONE
	COAL
	BEDROCK

### STRENGTH CLASSIFICATION

<b>Rock Strength</b>	<b>Approximate Uniaxial Compressive Strength</b>		<b>Field Estimation of Hardness*</b>
	<b>(MPa)</b>	<b>(psi)</b>	
Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

### TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length
Solid Core Recovery:(SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run
Rock Quality Designation:(RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a % of total core run length.
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen
Fracture Index:(FI)	Frequency of natural fractures per 0.3m of core run.

## **SYMBOLS AND TERMS USED ON TEST HOLE LOGS**

### **TEXTURAL CLASSIFICATION OF SOILS**

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 300mm	same
Cobbles	75 to 300mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to naked eye

### **COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)**

TERMINOLOGY	PROPORTION
Trace or Occasional	< 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

### **TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)**

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROX. SPT <sup>(1)</sup> "N" VALUE
Very Soft	< 10	< 2
Soft	10 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	> 200	> 30

(1) Standard Penetration Test – the number of blows from a 63.5kg hammer falling through 0.76m to advance a 60 degree truncated cone 0.3m

### **TERMS DESCRIBING DENSITY(COHESIONLESS SOILS)**

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	< 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	> 50


### **HIERARCHY OF SOIL STRENGTH PREDICTION**

- 1) Laboratory Triaxial Testing
- 2) Field Insitu Vane Testing
- 3) Laboratory Vane Testing
- 4) SPT Value
- 5) Pocket Penetrometer

### **LEGEND FOR TEST HOLE LOGS**

 Shelby Tube   
  A – Casing   
  SPT   
  Grab/Auger sample   
  Core   
  No Recovery

- MC – Moisture Content (% by Weight) as determined by sample

	Water Level
C <sub>vane</sub>	Shear Strength Determination by Field Insitu Vane
C <sub>pen</sub>	Shear Strength Determination by Pocket Penetrometer
C <sub>lab</sub>	Shear Strength Determination using a Laboratory Vane Apparatus
C <sub>U</sub>	Undrained Shear Strength determined by Unconfined Compression Test
AS/GS/BS	Auger Sample/Grab Sample/ Block Sample
SS	Split-spoon
SC	Soil core
AED	Oedometer test
TXL	Triaxial test

# RECORD OF BOREHOLE 14-063

PROJECT : Zone 4 Feeder mains  
 LOCATION : Milton/Halton Hills, ON  
 STARTED : March 17, 2015  
 COMPLETED : March 18, 2015

N 4 824 725.0 E 594 657.5

Project No. 17-123-902

SHEET 1 OF 2

DATUM Geodetic

DEPTH SCALE (metres)	BORING METHOD	SOIL PROFILE		SAMPLES			COMMENTS	SHEAR STRENGTH: Cu, KPa		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE		nat V - ● rem V - ●	Q - X Cpen ▲		
		GROUND SURFACE		198.86							
		TOPSOIL: (175mm)		198.60							
1		CLAY, silty, sandy, trace gravel, very stiff, brown, dry: (FILL)		0.18	1	SS	18			>>▲	
					2	SS	23			>>▲	
2		CLAY, silty, sandy, trace gravel, hard, grey, dry: (TILL)		1.52	3	SS	41			>>▲	
					4	SS	70			>>▲	
3		occasional shale fragments			5	SS	79				
					6	SS	81				
4		SAND and SILT, trace to some gravel, trace clay, very dense, grey/reddish brown, wet: (TILL)		3.81	7	SS	80				
					8	SS	40				
5					9	SS	79				
6					10	SS	50/				
7					11	SS	100/				
8											
9		SILT, trace clay, trace sand, dense, grey, wet		8.53	12	SS	31				
					13	SS	89				
10											
11		SAND, some silt, trace clay, very dense, grey, wet		10.67	14	SS	85				
					15	SS	72				
12											
13											
14					16	SS	81				

## GROUNDWATER ELEVATIONS

▽ WATER LEVEL UPON COMPLETION  
 March 18, 2015

▽ WATER LEVEL IN WELL/PIEZOMETER

LOGGED : ES  
 CHECKED : MTB



# RECORD OF BOREHOLE 14-063

PROJECT : Zone 4 Feeder mains  
 LOCATION : Milton/Halton Hills, ON  
 STARTED : March 17, 2015  
 COMPLETED : March 18, 2015

Project No. 17-123-902

SHEET 2 OF 2

N 4 824 725.0 E 594 657.5

DATUM Geodetic

DEPTH SCALE (metres)	BORING METHOD	SOIL PROFILE			SAMPLES			COMMENTS	SHEAR STRENGTH: Cu, KPa				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV.	NUMBER	TYPE	BLOWS/0.3m	DYNAMIC CONE PENETRATION RESISTANCE PLOT	WATER CONTENT, PERCENT					
				DEPTH (m)					wp  -----  w  -----  wl 10 20 30 40					

## GROUNDWATER ELEVATIONS

∇ WATER LEVEL UPON COMPLETION  
 March 18, 2015

▼ WATER LEVEL IN WELL/PIEZOMETER

LOGGED : ES  
 CHECKED : MTB



# RECORD OF BOREHOLE 14-064

PROJECT : Zone 4 Feeder mains  
 LOCATION : Milton/Halton Hills, ON  
 STARTED : March 18, 2015  
 COMPLETED : March 19, 2015

N 4 824 782.4 E 594 581.9

Project No. 17-123-902

SHEET 1 OF 2

DATUM Geodetic

DEPTH SCALE (metres)	BORING METHOD	SOIL PROFILE		SAMPLES			COMMENTS	SHEAR STRENGTH: Cu, KPa		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION		
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE		BLOWS/0.3m	WATER CONTENT, PERCENT				
									nat V -			rem V -	Q -
		GROUND SURFACE		203.72									
		TOPSOIL: (125mm)		200.00									
1		CLAY, silty, some sand, trace gravel, stiff to very stiff, brown, dry: (FILL)		0.13	1	SS	11						
	2			SS	14								
2				3	SS	18							
				4	SS	6							
3				Becoming firm	5	SS	12						
4		CLAY, silty, some sand to sandy, trace gravel, occasional silt seams, very stiff, brown, dry to damp: (TILL)		199.98	6	SS	20						
				3.73	7	SS	19	Grain Size Analysis: Gr 0%/ Sa 24%/ Si 41%/ Cl 35%					
5				8	SS	29							
6				becoming hard	9	SS	61						
				10	SS	69							
7				196.10	11	SS	59	Grain Size Analysis: Gr 9%/ Sa 36%/ Si 44%/ Cl 11%					
8		SAND and SILT, trace to some clay, trace gravel, very dense to dense, reddish brown, wet: (TILL)		7.62	12	SS	48						
				13	SS	97	Grain Size Analysis: Gr 5%/ Sa 41%/ Si 40%/ Cl 14%						
9				14	SS	50/ 0.150							
10				15	SS	52	Grain Size Analysis: Gr 0%/ Sa 27%/ Si 67%/ Cl 6%						
				16	SS	62							
11		SILT, sandy, trace clay, very dense, grey, wet		193.28	17	SS	66	Grain Size Analysis: Gr 0%/ Sa 20%/ Si 73%/ Cl 7%					
				10.44	18	SS	60						
12					19	SS	59						
13													
14													

## GROUNDWATER ELEVATIONS

WATER LEVEL UPON COMPLETION  
 March 19, 2015

WATER LEVEL IN WELL/PIEZOMETER

LOGGED : GA  
 CHECKED : MTB



# RECORD OF BOREHOLE 14-064






PROJECT : Zone 4 Feeder mains  
 LOCATION : Milton/Halton Hills, ON  
 STARTED : March 18, 2015  
 COMPLETED : March 19, 2015

N 4 824 782.4 E 594 581.9

Project No. 17-123-902

SHEET 2 OF 2

DATUM Geodetic

DEPTH SCALE (metres)	BORING METHOD	SOIL PROFILE			SAMPLES			COMMENTS	SHEAR STRENGTH: Cu, KPa				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m		nat V - 	rem V - 	Q - 	Cpen 		
								DYNAMIC CONE PENETRATION RESISTANCE PLOT 	WATER CONTENT, PERCENT					
								20 40 60 80 100	wp 10 20 30 40		wl			
16		dense			20	SS	48							
17		SAND, some silt, very dense, grey, wet		186.96 16.76	21	SS	75							
18														
19					22	SS	71							
20														
21		END OF BOREHOLE AT 20.27m. BOREHOLE OPEN TO 20.27m AND WATER LEVEL AT 1.27m. BOREHOLE BACKFILLED WITH GROUT FROM 20.27m TO 1.22m AND BENTONITE HOLEPLUG TO SURFACE.		183.45 20.27	23	SS	89							
22														
23														
24														
25														
26														
27														
28														
29														

## GROUNDWATER ELEVATIONS



WATER LEVEL UPON COMPLETION  
 March 19, 2015



WATER LEVEL IN WELL/PIEZOMETER

LOGGED : GA

CHECKED : MTB



# RECORD OF BOREHOLE 14-065

PROJECT : Zone 4 Feeder mains  
 LOCATION : Milton/Halton Hills, ON  
 STARTED : March 18, 2015  
 COMPLETED : March 18, 2015

N 4 824 842.0 E 594 524.4

Project No. 17-123-902

SHEET 1 OF 2

DATUM Geodetic

DEPTH SCALE (metres)	BORING METHOD	SOIL PROFILE		SAMPLES			COMMENTS	SHEAR STRENGTH: Cu, KPa		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION	
		DESCRIPTION	STRATA PLOT	ELEV.	NUMBER	TYPE		BLOWS/0.3m	nat V -			Q -
				DEPTH (m)			rem V -		Cpen			WATER CONTENT, PERCENT
								wp	wl			
		GROUND SURFACE		202.09								
1		TOPSOIL: (175mm)		200.00	1	SS	10					
		0.18										
		CLAY, silty, sandy, occasional rootlets, stiff, dark brown, damp			2	SS	15					
2		CLAY, silty, sandy, trace gravel, very stiff to hard, brown, dry: (TILL)		200.56				Grain Size Analysis: Gr 8%/ Sa 27%/ Si 35%/ Cl 30%			>>	
				1.52	3	SS	25					
3					4	SS	36	Grain Size Analysis: Gr 2%/ Sa 22%/ Si 46%/ Cl 30%			>>	
					5	SS	80					
4					6	SS	81	Grain Size Analysis: Gr 5%/ Sa 64%/ Si 27%/ Cl 4%				Bentonite/ Cement/ Grout
5		SILT, some sand, trace gravel, very dense, brown, wet		197.51	7	SS	86					
		SAND, silty, trace clay, trace gravel, very dense, brown, wet		196.75	8	SS	92	Grain Size Analysis: Gr 5%/ Sa 64%/ Si 27%/ Cl 4%				
				5.33								
6		SILT, trace sand, trace clay, very dense, grey, wet		196.14	9	SS	92					
7					10	SS	57	Grain Size Analysis: Gr 0%/ Sa 0%/ Si 94%/ Cl 6%				
					11	SS	58					
8					12	SS	89	Grain Size Analysis: Gr 0%/ Sa 26%/ Si 68%/ Cl 6%				
9		becoming sandy			13	SS	77					
10												
11					14	SS	75				Bentonite Holeplug	
12		SAND, some silt, very dense, grey, wet		190.20							Filter Sand	
				11.89	15	SS	86					
13											Slotted Screen	
14					16	SS	52					

## GROUNDWATER ELEVATIONS

WATER LEVEL UPON COMPLETION

WATER LEVEL IN WELL/PIEZOMETER

April 29, 2015

LOGGED : GA

CHECKED : MTB





# RECORD OF BOREHOLE 14-065

PROJECT : Zone 4 Feeder mains  
LOCATION : Milton/Halton Hills, ON  
STARTED : March 18, 2015  
COMPLETED : March 18, 2015

Project No. 17-123-902

SHEET 2 OF 2

DATUM Geodetic

N 4 824 842.0 E 594 524.4

[illegible]

## GROUNDWATER ELEVATIONS

 WATER LEVEL UPON COMPLETION

 WATER LEVEL IN WELL/PIEZOMETER

April 29, 2015

LOGGED : GA

CHECKED : MTB



THURBER2S 3902.GPJ 11/9/15

# RECORD OF BOREHOLE 14-066









PROJECT : Zone 4 Feeder mains  
 LOCATION : Milton/Halton Hills, ON  
 STARTED : April 13, 2015  
 COMPLETED : April 13, 2015

Project No. 17-123-902

SHEET 1 OF 2

N 4 824 860.3 E 594 488.5

DATUM Geodetic

DEPTH SCALE (metres)	BORING METHOD	SOIL PROFILE		SAMPLES			COMMENTS	SHEAR STRENGTH: Cu, KPa				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE		nat V - 	rem V - 	Q - 	Cpen 		
							DYNAMIC CONE PENETRATION RESISTANCE PLOT 	40 80 120 160					
							20 40 60 80 100	WATER CONTENT, PERCENT					
								wp 		w 	wl 		
								10 20 30 40					
		GROUND SURFACE		202.50									
		ASPHALT: (150mm)		202.00									
		SAND, gravelly, trace silt, trace asphalt, brown, moist: (FILL)		0.15	1	GS							
1		CLAY, silty, sandy, trace gravel, stiff to very stiff, brown, moist: (FILL)		201.81	1	SS 11							
				0.69									
2					2	SS 9							
					3	SS 20							
3				199.53									
		SAND and SILT, trace clay, dense to very dense, brown, moist		2.97	4	SS 44							
4							Grain Size Analysis: Gr 0%/ Sa 51%/ Si 44%/ Cl 5%						
					5	SS 77/ 0.250							
5													
					6	SS 78							
6													
					7	SS 98/ 0.250							
7				195.79			Grain Size Analysis: Gr 0%/ Sa 49%/ Si 46%/ Cl 5%						
		SILT, trace to some clay, trace to some sand, very dense, grey, moist to wet		6.71	8	SS 85/ 0.250							
8													
					9	SS 97/ 0.250							
9							Grain Size Analysis: Gr 0%/ Sa 7%/ Si 71%/ Cl 22%						
					10	SS 95/ 0.225							
10													
					11	SS 50/ 0.100							
11							Grain Size Analysis: Gr 0%/ Sa 19%/ Si 72%/ Cl 9%						
					12	SS 50/ 0.125							
12													
					13	SS 97/ 0.250							
13				190.18									
		SAND, some silt, trace clay, very dense, grey, moist		12.32	14	SS 98/ 0.275							
14							Grain Size Analysis: Gr 0%/ Sa 80%/ Si 15%/ Cl 5%						
					15	SS 85							

## GROUNDWATER ELEVATIONS



WATER LEVEL UPON COMPLETION



WATER LEVEL IN WELL/PIEZOMETER

LOGGED : ME

CHECKED : MTB



# RECORD OF BOREHOLE 14-066

PROJECT : Zone 4 Feeder mains  
 LOCATION : Milton/Halton Hills, ON  
 STARTED : April 13, 2015  
 COMPLETED : April 13, 2015

Project No. 17-123-902

SHEET 2 OF 2

N 4 824 860.3 E 594 488.5

DATUM Geodetic

DEPTH SCALE (metres)	BORING METHOD	SOIL PROFILE			SAMPLES			COMMENTS	SHEAR STRENGTH: Cu, KPa				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV.	NUMBER	TYPE	BLOWS/0.3m	DYNAMIC CONE PENETRATION RESISTANCE PLOT	WATER CONTENT, PERCENT					
				DEPTH (m)					wp ——— w ——— wl					
16						16	SS	80						
17					185.30 17.20	17	SS	89/ 0.275						
18		END OF BOREHOLE AT 17.20m. BOREHOLE BACKFILLED WITH GROUT/CEMENT TO 1.8m, HOLEPLUG TO 0.1m, THEN CONCRETE TO SURFACE.												
19														
20														
21														
22														
23														
24														
25														
26														
27														
28														
29														

## GROUNDWATER ELEVATIONS



WATER LEVEL UPON COMPLETION



WATER LEVEL IN WELL/PIEZOMETER

LOGGED : ME

CHECKED : MTB



# RECORD OF BOREHOLE 14-067

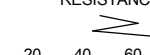
PROJECT : Zone 4 Feeder mains  
 LOCATION : Milton/Halton Hills, ON  
 STARTED : April 14, 2015  
 COMPLETED : April 14, 2015

N 4 824 886.4 E 594 480.8

Project No. 17-123-902

SHEET 1 OF 2

DATUM Geodetic

DEPTH SCALE (metres)	BORING METHOD	SOIL PROFILE			SAMPLES			COMMENTS		SHEAR STRENGTH: Cu, KPa nat V - ●      Q - X rem V - ●      Cpen ▲			ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION		
		DESCRIPTION	STRATA PLOT	ELEV.	NUMBER	TYPE	BLOWS/0.3m	DYNAMIC CONE PENETRATION RESISTANCE PLOT 	WATER CONTENT, PERCENT							
				DEPTH (m)					wp	w	wl					
		GROUND SURFACE		203.11												
1		ASPHALT: (150mm)		202.06												
		SAND, gravelly, some silt, trace asphalt, brown, moist: (FILL)		0.15	1	GS										
		CLAY, silty, sandy, trace gravel, stiff to very stiff, grey: (FILL)		202.42												
2		some topsoil rootlets		0.69	1	SS	11									
3		SILT, sandy, trace clay, trace gravel, compact to very dense, brown, moist		200.69					Grain Size Analysis: Gr 0%/ Sa 25%/ Si 45%/ Cl 30%							
				2.41	3	SS	30									
4					4	SS	27									
5					5	SS	62									
6					6	SS	56		Grain Size Analysis: Gr 0%/ Sa 28%/ Si 66%/ Cl 6%							
7		SAND and SILT, trace clay			7	SS	80/ 0.250									
8				196.40					Grain Size Analysis: Gr 0%/ Sa 51%/ Si 44%/ Cl 5%							
				6.71	9	SS	90/ 0.275									
9				195.56												
				7.54	10	SS	92/ 0.275									
10					11	SS	93/ 0.225		Grain Size Analysis: Gr 0%/ Sa 18%/ Si 70%/ Cl 12%							
11					12	SS	50/ 0.100									
12		SAND, silty, trace clay, very dense, grey, moist		191.60					Grain Size Analysis: Gr 0%/ Sa 71%/ Si 23%/ Cl 6%							
				11.51	14	SS	93/ 0.250									
13					15	SS	90/ 0.275									
14																

## GROUNDWATER ELEVATIONS



WATER LEVEL UPON COMPLETION



WATER LEVEL IN WELL/PIEZOMETER

LOGGED : ME

CHECKED : MTB



# RECORD OF BOREHOLE 14-067

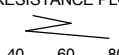
PROJECT : Zone 4 Feeder mains  
 LOCATION : Milton/Halton Hills, ON  
 STARTED : April 14, 2015  
 COMPLETED : April 14, 2015

Project No. 17-123-902

SHEET 2 OF 2

N 4 824 886.4 E 594 480.8

DATUM Geodetic

DEPTH SCALE (metres)	BORING METHOD	SOIL PROFILE			SAMPLES			COMMENTS	SHEAR STRENGTH: Cu, KPa				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV.	NUMBER	TYPE	BLOWS/0.3m	DYNAMIC CONE PENETRATION RESISTANCE PLOT 	WATER CONTENT, PERCENT					
				DEPTH (m)					nat V - ●	rem V - ●	Q - X	Cpen ▲		
16		END OF BOREHOLE AT 15.70m. BOREHOLE BACKFILLED WITH GROUT/CEMENT TO 1.8m, HOLEPLUG TO 0.1m, THEN CONCRETE TO SURFACE.		187.41 15.70	16	SS	86							
17														
18														
19														
20														
21														
22														
23														
24														
25														
26														
27														
28														
29														

## GROUNDWATER ELEVATIONS

▽ WATER LEVEL UPON COMPLETION

▼ WATER LEVEL IN WELL/PIEZOMETER

LOGGED : ME

CHECKED : MTB



# RECORD OF BOREHOLE 14-068

PROJECT : Zone 4 Feeder mains  
 LOCATION : Milton/Halton Hills, ON  
 STARTED : March 20, 2015  
 COMPLETED : March 23, 2015

N 4 824 937.6 E 594 403.6

Project No. 17-123-902

SHEET 1 OF 2

DATUM Geodetic

DEPTH SCALE (metres)	BORING METHOD	SOIL PROFILE		SAMPLES			COMMENTS	SHEAR STRENGTH: Cu, KPa				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE		nat V -	rem V -	Q -	Cpen		
		GROUND SURFACE		204.16									
		TOPSOIL: (100mm)		203.08									
1		CLAY, silty, sandy, trace gravel, very stiff to hard, brown, dry: (TILL)		0.10	1	SS	15						Concrete
					2	SS	22						Filter Sand
2					3	SS	40						
					4	SS	41						Bentonite Holeplug
3		SILT, some clay, trace sand, occasional iron oxide staining, dense to very dense, brown, wet		201.95									
				2.21	5	SS	72						
4					6	SS	50						
5					7	SS	72						Filter Sand
					8	SS	52						
6		SAND, silty, trace clay, trace gravel, very dense, brown, moist		199.06									
				5.11	9	SS	94/						
7					10	SS	50/						
					11	SS	80						
8					12	SS	50/						
9					13	SS	50/						
					14	SS	50/						
10		SILT, sandy, trace clay, very dense, grey, moist		194.18									
				9.98	15	SS	50/						
11					16	SS	50/						
12													
13													
14		becoming some clay, trace sand											Caved

## GROUNDWATER ELEVATIONS

∇ WATER LEVEL UPON COMPLETION

▼ WATER LEVEL IN WELL/PIEZOMETER

April 29, 2015

LOGGED : GA/ME

CHECKED : MTB



# RECORD OF BOREHOLE 14-068

PROJECT : Zone 4 Feeder mains  
LOCATION : Milton/Halton Hills, ON  
STARTED : March 20, 2015  
COMPLETED : March 23, 2015

Project No. 17-123-902

SHEET 2 OF 2

DATUM Geodetic

N 4 824 937.6 E 594 403.6

[illegible]

## GROUNDWATER ELEVATIONS

 WATER LEVEL UPON COMPLETION

 WATER LEVEL IN WELL/PIEZOMETER

April 29, 2015

LOGGED : GA/ME

CHECKED : MTB



THURBER2S 3902.GPJ 11/9/15

# RECORD OF BOREHOLE 14-069






















PROJECT : Zone 4 Feeder mains  
 LOCATION : Milton/Halton Hills, ON  
 STARTED : March 23, 2015  
 COMPLETED : March 24, 2015

N 4 825 002.2 E 594 373.3

Project No. 17-123-902

SHEET 1 OF 2

DATUM Geodetic

DEPTH SCALE (metres)	BORING METHOD	SOIL PROFILE		SAMPLES			COMMENTS	SHEAR STRENGTH: Cu, KPa		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE		nat V -  rem V - 	Cpen 		
							DYNAMIC CONE PENETRATION RESISTANCE PLOT 	40 80 120 160			
								WATER CONTENT, PERCENT			
								wp 	wl 		
								10 20 30 40			
		GROUND SURFACE		205.99							
		SAND, gravelly, some clayey silty clay pockets, brown, moist: (FILL)		0.00	1	GS					
1		CLAY, silty, sandy, trace gravel, trace oxide staining, very stiff, brown, moist		205.34 0.66	1	SS 21					
2		CLAY, silty, sandy, trace gravel, trace of cobble fragments, hard, brown, moist: (TILL)		204.55 1.45	2	SS 45					
3		becoming dry			3	SS 80/ 0.250	Grain Size Analysis: Gr 0%/ Sa 27%/ Si 55%/ Cl 18%				
4		SILT, some clay, trace sand, very dense, brown, wet		202.44 3.56	4	SS 50/ 0.100					
5					5	SS 50/ 0.100					
6		CLAY, silty, sandy, trace gravel, trace of cobble fragments, hard, brown to grey, moist: (TILL)		200.89 5.11	6	SS 50/ 0.100	Grain Size Analysis: Gr 0%/ Sa 21%/ Si 57%/ Cl 22%				
7		SAND, some silt, trace gravel, very dense, brown, moist		199.36 6.63	7	SS 50/ 0.075					
8					8	SS 50/ 0.150	Grain Size Analysis: Gr 3%/ Sa 83%/ Si & Cl 14%				
9		SAND and SILT, trace gravel, trace clay, very dense, grey, moist		197.08 8.92	9	SS 50/ 0.100					
10					10	SS 50/ 0.100					
11					11	SS 50/ 0.150					
12					12	SS 50/ 0.125	Grain Size Analysis: Gr 0%/ Sa 62%/ Si 35%/ Cl 3%				
13					13	SS 50/ 0.150					
14		SAND, some silt, trace clay, very dense, grey, moist		191.60 14.40	14	SS 50/ 0.100					

## GROUNDWATER ELEVATIONS



WATER LEVEL UPON COMPLETION



WATER LEVEL IN WELL/PIEZOMETER

LOGGED : ME

CHECKED : MTB





# RECORD OF BOREHOLE 14-069

PROJECT : Zone 4 Feeder mains  
 LOCATION : Milton/Halton Hills, ON  
 STARTED : March 23, 2015  
 COMPLETED : March 24, 2015

Project No. 17-123-902

SHEET 2 OF 2

N 4 825 002.2 E 594 373.3

DATUM Geodetic

DEPTH SCALE (metres)	BORING METHOD	SOIL PROFILE		SAMPLES		COMMENTS	SHEAR STRENGTH: Cu, KPa		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER TYPE	BLOWS/0.3m				
							DYNAMIC CONE PENETRATION RESISTANCE PLOT 			
							WATER CONTENT, PERCENT wp   10 20 30 40   wl			
16		SILT, sandy, trace clay, very dense, grey, moist		189.89 16.10	18 SS 50/ 0.200	Grain Size Analysis: Gr 0%/ Sa 82%/ Si 15%/ Cl 3%				
17					19 SS 85/ 0.150					
18										
19		END OF BOREHOLE AT 18.44m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.15m, THEN SAND TO SURFACE.		187.55 18.44	20 SS 72/ 0.150					
20										
21										
22										
23										
24										
25										
26										
27										
28										
29										

## GROUNDWATER ELEVATIONS



WATER LEVEL UPON COMPLETION



WATER LEVEL IN WELL/PIEZOMETER

LOGGED : ME

CHECKED : MTB



# RECORD OF BOREHOLE 14-070

PROJECT : Zone 4 Feeder mains  
LOCATION : Milton/Halton Hills, ON  
STARTED : February 23, 2015  
COMPLETED : February 24, 2015

Project No. 17-123-902

SHEET 1 OF 2

DATUM Geodetic

N 4 825 080.0 E 594 322.9

[illegible]

## GROUNDWATER ELEVATIONS

 WATER LEVEL UPON COMPLETION

 WATER LEVEL IN WELL/PIEZOMETER

April 28, 2015

LOGGED : ME

CHECKED : MTB



THURBER2S 3902.GPJ 11/9/15

# RECORD OF BOREHOLE 14-070


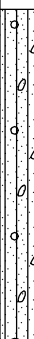
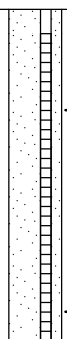
PROJECT : Zone 4 Feeder mains  
 LOCATION : Milton/Halton Hills, ON  
 STARTED : February 23, 2015  
 COMPLETED : February 24, 2015

N 4 825 080.0 E 594 322.9

Project No. 17-123-902

SHEET 2 OF 2

DATUM Geodetic

DEPTH SCALE (metres)	BORING METHOD	SOIL PROFILE		SAMPLES		COMMENTS	SHEAR STRENGTH: Cu, KPa		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT ELEV. DEPTH (m)	NUMBER	TYPE		nat V - rem V -	Q - Cpen		
						DYNAMIC CONE PENETRATION RESISTANCE PLOT 	40 80 120 160			
							wp           wl			
							10 20 30 40			
16		SAND and SILT, trace gravel, trace clay, very dense, grey, moist: (TILL)		18	SS	80				Filter Sand 
17				19	SS	50/				
18				20	SS	50/				
19		END OF BOREHOLE AT 18.44m. Well installation consists of 50mm diameter Schedule 40 PVC pipe with a 3.05m slotted screen.	188.52 18.44			0.150				
20		WATER LEVEL READINGS: DATE DEPTH(m) ELEV.(m) Apr. 28/15 5.78 201.18								
21										
22										
23										
24										
25										
26										
27										
28										
29										

## GROUNDWATER ELEVATIONS

∇ WATER LEVEL UPON COMPLETION

▼ WATER LEVEL IN WELL/PIEZOMETER

April 28, 2015

LOGGED : ME

CHECKED : MTB



# RECORD OF BOREHOLE 14-105





PROJECT : Zone 4 Feeder mains  
 LOCATION : Milton/Halton Hills, ON  
 STARTED : September 29, 2015  
 COMPLETED : October 1, 2015

N 4 824 632.1 E 594 708.9

Project No. 17-123-902

SHEET 1 OF 2

DATUM Geodetic

DEPTH SCALE (metres)	BORING METHOD	SOIL PROFILE		SAMPLES			COMMENTS	SHEAR STRENGTH: Cu, KPa				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m		nat V - 	rem V - 	Q - 	Cpen 		
		GROUND SURFACE	195.60										
		<b>ORGANICS</b> , silt, clayey, trace to some sand, trace gravel, trace roots, loose, brown, moist	0.00	1	SS	6							
1		<b>SAND</b> , gravelly, some silt, trace clay, trace organic material, compact, brown, wet	194.91 0.69	2	SS	19							
2				3	SS	20	Grain Size Analysis: Gr 28%/ Sa 53%/ Si & Cl 19%						
3		<b>SAND</b> , silty, trace clay, trace to some gravel, dense to very dense, brown, moist: (TILL)	192.86 2.74	4	SS	21							
4		occasional cobbles and shale/limestone fragments		5	SS	47							
5				6	SS	50/ 0.156							
6				7	SS	69	Grain Size Analysis: Gr 19%/ Sa 43%/ Si 31%/ Cl 7%						
7				8	SS	67							
8				9	SS	68							
9				10	SS	44	Grain Size Analysis: Gr 14%/ Sa 59%/ Si 21%/ Cl 6%						
10		<b>SAND</b> , trace to some silt, compact to dense, grey, wet	188.06 7.54	11	SS	33							
11				12	SS	32	Grain Size Analysis: Gr 0%/ Sa 89%/ Si & Cl 11%						
12				13	SS	23							
13		<b>SILT</b> , trace to some clay, trace sand, dense, grey, wet	184.02 11.58	14	SS	33							
14		<b>CLAY</b> , silty, some sand, trace gravel, occasional shale fragments, very hard, reddish brown, moist: (TILL)	182.34 13.26	15	SS	33	Grain Size Analysis: Gr 0%/ Sa 3%/ Si 87%/ Cl 10%						
				16	SS	50/ 0.100	Grain Size Analysis: Gr 0%/ Sa 19%/ Si 55%/ Cl 26%						
		<b>SAND</b> , trace to some silt, compact, grey,	180.82 14.78										

## GROUNDWATER ELEVATIONS

 WATER LEVEL UPON COMPLETION

 WATER LEVEL IN WELL/PIEZOMETER

October 27, 2015

LOGGED : ME

CHECKED : MTB



# RECORD OF BOREHOLE 14-105

PROJECT : Zone 4 Feeder mains  
 LOCATION : Milton/Halton Hills, ON  
 STARTED : September 29, 2015  
 COMPLETED : October 1, 2015

Project No. 17-123-902

SHEET 2 OF 2

N 4 824 632.1 E 594 708.9

DATUM Geodetic

DEPTH SCALE (metres)	BORING METHOD	SOIL PROFILE		SAMPLES			COMMENTS	SHEAR STRENGTH: Cu, KPa				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION	
		DESCRIPTION	STRATA PLOT	ELEV.	NUMBER	TYPE		BLOWS/0.3m	WATER CONTENT, PERCENT					
				DEPTH (m)					wp ———— w ———— wl					
	Hollow Stem Augers/Tritone	moist						Grain Size Analysis: Gr 0%/ Sa 87%/ Si 11%/ Cl 2%						
16														
		CLAY, silty, some sand, trace gravel, occasional shale fragments, very hard, reddish brown, moist: (TILL)												
17														
18		occasional oxide staining												
		SHALE, reddish brown: (Queenston Formation)												
19		END OF BOREHOLE AT 18.49m. ARTESIAN CONDITIONS NOTED UPON COMPLETION OF BOREHOLE DRILLING. BOREHOLE BACKFILLED WITH CEMENT BENTONITE GROUT. A SECOND BOREHOLE WAS DRILLED 3.0m WEST OF THE ORIGINAL BOREHOLE FOR THE WELL INSTALLATION. Monitoring Well installation consists of 51mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.												
20														
21														
22														
23		WATER LEVEL READINGS: DATE        DEPTH(m)        ELEV.(m) Oct. 27/15        -1.67        197.27 (Water level above ground surface)												
24														
25														
26														
27														
28														
29														

## GROUNDWATER ELEVATIONS

▽ WATER LEVEL UPON COMPLETION

▼ WATER LEVEL IN WELL/PIEZOMETER  
 October 27, 2015

LOGGED : ME

CHECKED : MTB



# RECORD OF BOREHOLE 14-106

PROJECT : Zone 4 Feeder mains  
 LOCATION : Milton/Halton Hills, ON  
 STARTED : October 7, 2015  
 COMPLETED : October 7, 2015

Project No. 17-123-902

SHEET 1 OF 2

N 4 824 719.8 E 594 612.8

DATUM Geodetic

DEPTH SCALE (metres)	BORING METHOD	SOIL PROFILE		SAMPLES			COMMENTS	SHEAR STRENGTH: Cu, KPa				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE		nat V - ●	rem V - ●	Q - ✕	Cpen ▲		
		GROUND SURFACE		198.80									
1		CLAY, silty, with organic material, trace sand, trace gravel, trace roots, firm, brown, moist: (FILL)		0.00	1	SS 7							
2		CLAY, silty, sandy, trace gravel, very stiff, greyish brown, moist: (TILL)		197.43 1.37	2	SS 22							
3		reddish brown											
4		SILT and SAND, trace to some clay, trace gravel, very dense, reddish brown, moist: (TILL)		195.07 3.73	3	SS 20	Grain Size Analysis: Gr 6%/ Sa 35%/ Si 39%/ Cl 20%						
5					4	SS 90/ 0.275							
6					5	SS 50/ 0.150							
7		occasional shale fragments			6	SS 50/ 0.100	Grain Size Analysis: Gr 7%/ Sa 41%/ Si 39%/ Cl 13%						
8		becoming compact to dense, wet			7	SS 50/ 0.100							
9		grey			8	SS 29							
10		SILT, trace sand, trace clay, dense to very dense, grey, wet		190.11 8.69	9	SS 37	Grain Size Analysis: Gr 7%/ Sa 37%/ Si 44%/ Cl 12%						
11					10	SS 38							
12		sand seam (50mm)			11	SS 56							
13					12	SS 80	Grain Size Analysis: Gr 0%/ Sa 6%/ Si 87%/ Cl 7%						
14		SAND, some silt to silty, dense to very dense, grey, wet		186.68 12.12	13	SS 87							
					14	SS 74	Grain Size Analysis: Gr 2%/ Sa 8%/ Si 87%/ Cl 3%						
					15	SS 40							
					16	SS 57							

## GROUNDWATER ELEVATIONS



WATER LEVEL UPON COMPLETION



WATER LEVEL IN WELL/PIEZOMETER

LOGGED : ME

CHECKED : MTB



# RECORD OF BOREHOLE 14-106

PROJECT : Zone 4 Feeder mains  
LOCATION : Milton/Halton Hills, ON  
STARTED : October 7, 2015  
COMPLETED : October 7, 2015

Project No. 17-123-902

SHEET 2 OF 2

DATUM Geodetic

N 4 824 719.8 E 594 612.8

[illegible]

## GROUNDWATER ELEVATIONS

 WATER LEVEL UPON COMPLETION

 WATER LEVEL IN WELL/PIEZOMETER

LOGGED : ME

CHECKED : MTB



# RECORD OF BOREHOLE 14-107

PROJECT : Zone 4 Feeder mains  
 LOCATION : Milton/Halton Hills, ON  
 STARTED : October 5, 2015  
 COMPLETED : October 7, 2015

Project No. 17-123-902

SHEET 1 OF 2

N 4 824 820.4 E 594 506.4

DATUM Geodetic

DEPTH SCALE (metres)	BORING METHOD	SOIL PROFILE		SAMPLES			COMMENTS	SHEAR STRENGTH: Cu, KPa				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV. DEPTH (m)	NUMBER	TYPE		nat V - ●	rem V - ●	Q - ✕	C <sub>pen</sub> ▲		
		GROUND SURFACE		201.10									
1		CLAY, silty, sandy, with organic material, trace roots, stiff, brown, moist: (FILL)		0.00	1	SS	9						Concrete
2		CLAY, silty, sandy, trace gravel, hard, brown, moist: (TILL)		199.88 1.22	2	SS	38						Bentonite
3		very hard		197.75 3.35	3	SS	51						
4		SILT, some sand, trace clay, trace gravel, very dense, brown, moist		197.37 3.73	4	SS	88/ 0.225						
5		CLAY, silty, trace to some sand, hard, grey, moist			5	SS	50/ 0.125						
6		SAND and GRAVEL, some silt, trace clay, very dense, grey, wet		195.92 5.18	6	SS	86						
7		SILT, some clay, trace sand, occasional clay layers, very dense, grey, moist		194.39 6.71	7	SS	75						
8					8	SS	69						
9					9	SS	99/ 0.225						
10		SILT, sandy, some clay, trace gravel, some sandy seams, very hard, grey, moist		192.03 9.07	10	SS	78						
11					11	SS	71						
12		SAND, some silt to silty, trace clay, very dense, grey, wet		191.35 9.75	12	SS	73						
13					13	SS	63						
14					14	SS	69						
					15	SS	65						
					16	SS	90/ 0.250						

## GROUNDWATER ELEVATIONS

▽ WATER LEVEL UPON COMPLETION

▼ WATER LEVEL IN WELL/PIEZOMETER

October 27, 2015

LOGGED : ME

CHECKED : MTB





# RECORD OF BOREHOLE 14-107

PROJECT : Zone 4 Feeder mains  
 LOCATION : Milton/Halton Hills, ON  
 STARTED : October 5, 2015  
 COMPLETED : October 7, 2015

N 4 824 820.4 E 594 506.4

Project No. 17-123-902

SHEET 2 OF 2

DATUM Geodetic

DEPTH SCALE (metres)	BORING METHOD	SOIL PROFILE			SAMPLES			COMMENTS	SHEAR STRENGTH: Cu, KPa				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT	ELEV.	NUMBER	TYPE	BLOWS/0.3m	DYNAMIC CONE PENETRATION RESISTANCE PLOT	nat V -  Q - rem V -  Cpen					
				DEPTH (m)					WATER CONTENT, PERCENT					
									wp	w	wl			
									10	20	30	40		
16	Hollow Stem Augers/Tricone	occasional cobbles			17	SS	78	Grain Size Analysis: Gr 0%/ Sa 80%/ Si 17%/ Cl 3%						
17					18	SS	73							
18														
19					19	SS	70							
20														
20		moist		20	SS	86								
21		END OF BOREHOLE AT 20.42m. Monitoring Well installation consists of 51mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.		180.68 20.42										
22		WATER LEVEL READINGS: DATE DEPTH(m) ELEV.(m) Oct. 27/15 2.98 198.12												
23														
24														
25														
26														
27														
28														
29														

## GROUNDWATER ELEVATIONS

▽ WATER LEVEL UPON COMPLETION

▼ WATER LEVEL IN WELL/PIEZOMETER  
 October 27, 2015

LOGGED : ME  
 CHECKED : MTB



# RECORD OF BOREHOLE 14-108


PROJECT : Zone 4 Feeder mains  
 LOCATION : Milton/Halton Hills, ON  
 STARTED : October 1, 2015  
 COMPLETED : October 2, 2015

Project No. 17-123-902

SHEET 1 OF 2

N 4 824 910.9 E 594 408.2

DATUM Geodetic

DEPTH SCALE (metres)	BORING METHOD	SOIL PROFILE		SAMPLES			COMMENTS	SHEAR STRENGTH: Cu, KPa				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION		
		DESCRIPTION	STRATA PLOT	ELEV.	NUMBER	TYPE		BLOWS/0.3m	DYNAMIC CONE PENETRATION RESISTANCE PLOT						
				DEPTH (m)					<div><div></div><div>20406080100</div></div>						
		GROUND SURFACE		202.70											
1	Hollow Stem Augers/Tricone	SILT, clayey, with organic material, some sand, trace gravel, trace roots, stiff, brown, moist: (FILL)		0.00	1	SS	11	Grain Size Analysis: Gr 0%/ Sa 26%/ Si 63%/ Cl 11%							
2		SAND, some silt to silty, trace clay, loose to compact, brown, moist		200.72	2	SS	9								
3															
4		SILT, sandy, trace clay, trace gravel, very dense, grey, moist		198.97	3	SS	11								
5				3.73	4	SS	45								
6		occasional clayey silt seams				5	SS		90/0.275						
						6	SS		50/0.156						
						7	SS		98/0.250						
						8	SS		80						
						9	SS		50/0.156						
						10	SS		50/0.156	Grain Size Analysis: Gr 0%/ Sa 30%/ Si 61%/ Cl 9%					
						11	SS		100/0.228						
						12	SS		50/0.100	Grain Size Analysis: Gr 0%/ Sa 22%/ Si 73%/ Cl 5%					
						13	SS		50/0.125						
						14	SS		50/0.075	Grain Size Analysis: Gr 0%/ Sa 70%/ Si 27%/ Cl 3%					
12	SAND, silty, trace clay, trace gravel, very dense, grey, moist		191.42												
13			11.28												
14															
14		SILT, some clay, trace sand, very dense, grey, moist		189.44	16	SS	50/0.100								

## GROUNDWATER ELEVATIONS



WATER LEVEL UPON COMPLETION



WATER LEVEL IN WELL/PIEZOMETER

LOGGED : ME

CHECKED : MTB



# RECORD OF BOREHOLE 14-108

PROJECT : Zone 4 Feeder mains  
 LOCATION : Milton/Halton Hills, ON  
 STARTED : October 1, 2015  
 COMPLETED : October 2, 2015

N 4 824 910.9 E 594 408.2

Project No. 17-123-902

SHEET 2 OF 2

DATUM Geodetic

DEPTH SCALE (metres)	BORING METHOD	SOIL PROFILE		SAMPLES		COMMENTS	SHEAR STRENGTH: Cu, KPa		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT ELEV. DEPTH (m)	NUMBER	TYPE		nat V - ● rem V - ●	Q - X Cpen ▲		
						DYNAMIC CONE PENETRATION RESISTANCE PLOT 	WATER CONTENT, PERCENT wp   10 20 30 40   wl			
16	Hollow Stem Augers/Tricone	SAND, some silt, trace clay, trace gravel, very dense, grey, moist	186.55 16.15	17	SS 50/ 0.075					
17				18	SS 50/ 0.100					
18				19	SS 100/ 0.225	Grain Size Analysis: Gr 0%/ Sa 78%/ Si 18%/ Cl 4%				
20			182.64 20.06	20	SS 50/ 0.100					
21		END OF BOREHOLE AT 20.06m. BOREHOLE BACKFILLED WITH CEMENT BENTONITE GROUT TO 0.61m, THEN BENTONITE HOLEPLUG TO SURFACE.								
22										
23										
24										
25										
26										
27										
28										
29										

## GROUNDWATER ELEVATIONS



WATER LEVEL UPON COMPLETION



WATER LEVEL IN WELL/PIEZOMETER

LOGGED : ME

CHECKED : MTB



# RECORD OF BOREHOLE 14-109

PROJECT : Zone 4 Feeder mains  
 LOCATION : Milton/Halton Hills, ON  
 STARTED : October 2, 2015  
 COMPLETED : October 5, 2015

Project No. 17-123-902

SHEET 1 OF 2

N 4 824 957.3 E 594 358.6

DATUM Geodetic

DEPTH SCALE (metres)	BORING METHOD	SOIL PROFILE		SAMPLES			COMMENTS		SHEAR STRENGTH: Cu, KPa		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
		DESCRIPTION	STRATA PLOT	ELEV.	NUMBER	TYPE	BLOWS/0.3m	DYNAMIC CONE PENETRATION RESISTANCE PLOT	nat V -  rem V -  Q -  Cpen				WATER CONTENT, PERCENT																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
				DEPTH (m)					40 80 120 160	wp   w   wl			10 20 30 40																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
		GROUND SURFACE		204.12																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
1	Hollow Stem Augers/Tricone	SAND, some gravel, some silt, trace clay, compact, brown, moist: (FILL)		0.00	1	SS	15			O																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									

## GROUNDWATER ELEVATIONS

WATER LEVEL UPON COMPLETION

WATER LEVEL IN WELL/PIEZOMETER

October 27, 2015

LOGGED : ME

CHECKED : MTB



# RECORD OF BOREHOLE 14-109


PROJECT : Zone 4 Feeder mains  
 LOCATION : Milton/Halton Hills, ON  
 STARTED : October 2, 2015  
 COMPLETED : October 5, 2015

Project No. 17-123-902

SHEET 2 OF 2

N 4 824 957.3 E 594 358.6

DATUM Geodetic

DEPTH SCALE (metres)	BORING METHOD	SOIL PROFILE		SAMPLES		COMMENTS	SHEAR STRENGTH: Cu, KPa		ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DESCRIPTION	STRATA PLOT ELEV. DEPTH (m)	NUMBER	TYPE		nat V - rem V -	Q - Cpen		
						DYNAMIC CONE PENETRATION RESISTANCE PLOT 	40 80 120 160			
							wp           wl			
							10 20 30 40			
16	Hollow Stem Augers/Tricone	SAND, silty, trace clay, trace gravel, very dense, grey, moist	187.81	17	SS	507				
			16.31			0.100				
17				18	SS	507				
						0.100				
18		SILT, sandy, trace clay, very dense, grey, moist	184.92	19	SS	507				
			19.20			0.100				
19										
20		END OF BOREHOLE AT 19.89m. Monitoring Well installation consists of 51mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.	184.23	20	SS	507				
			19.89			0.075				
21										
22										
23										
24										
25										
26										
27										
28										
29										

## GROUNDWATER ELEVATIONS

∇ WATER LEVEL UPON COMPLETION

▼ WATER LEVEL IN WELL/PIEZOMETER

October 27, 2015

LOGGED : ME

CHECKED : MTB



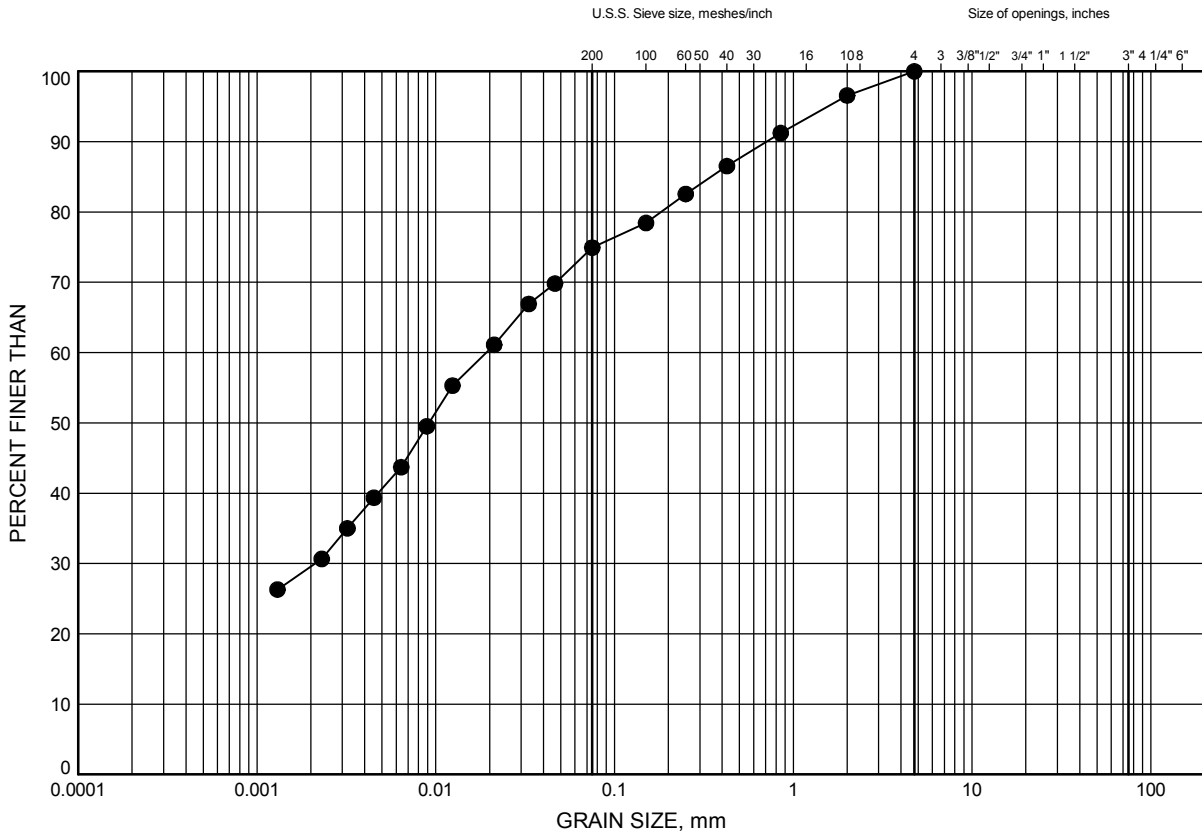
## **Appendix B**

### **Laboratory Test Results**

Zone 4 Feeder mains  
GRAIN SIZE DISTRIBUTION

FIGURE B1

Silty Clay Fill



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-067	1.83	201.28

Date November 2015  
Project 17-123-902

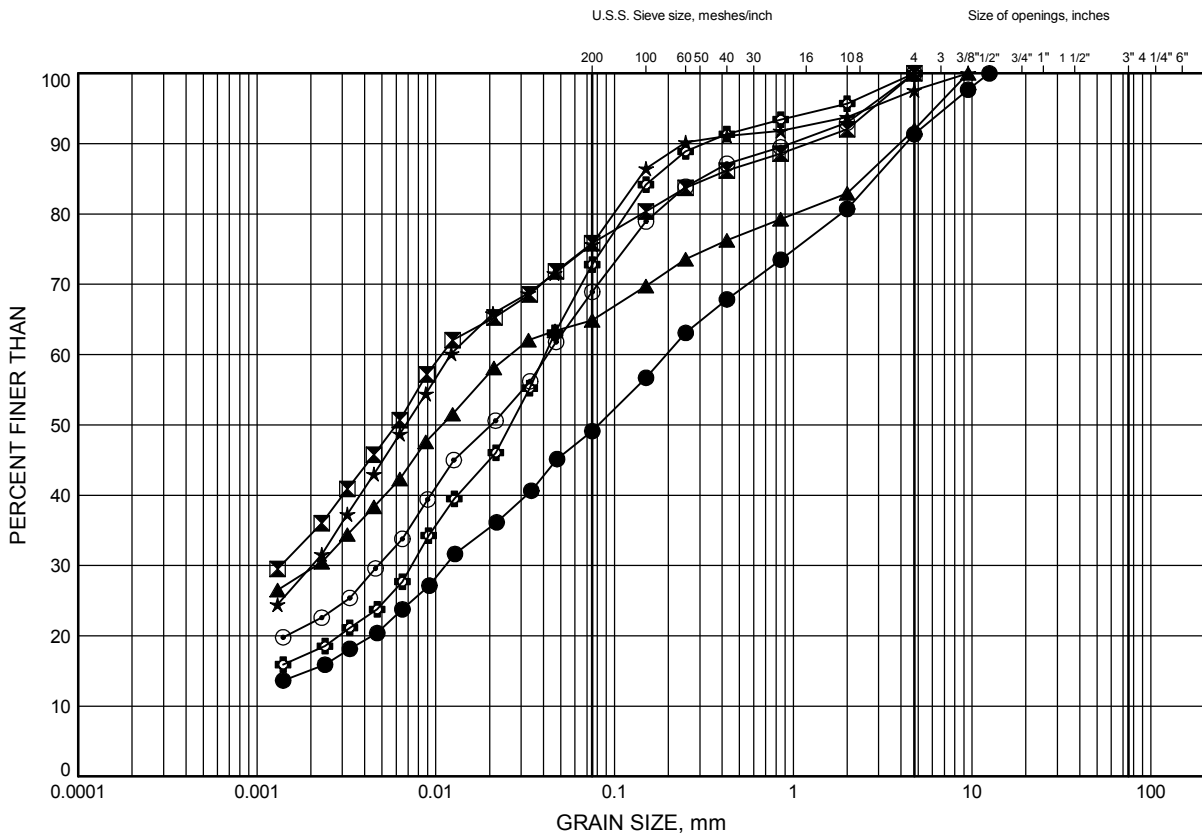


Prep'd MFA  
Chkd. MTB

# Zone 4 Feeder mains GRAIN SIZE DISTRIBUTION

FIGURE B2

## Silty Clay Till



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-063	3.35	195.51
⊠	14-064	4.88	198.84
▲	14-065	2.59	199.50
★	14-065	4.11	197.97
⊙	14-068	1.83	202.33
⊕	14-069	2.59	203.40

Date November 2015  
Project 17-123-902



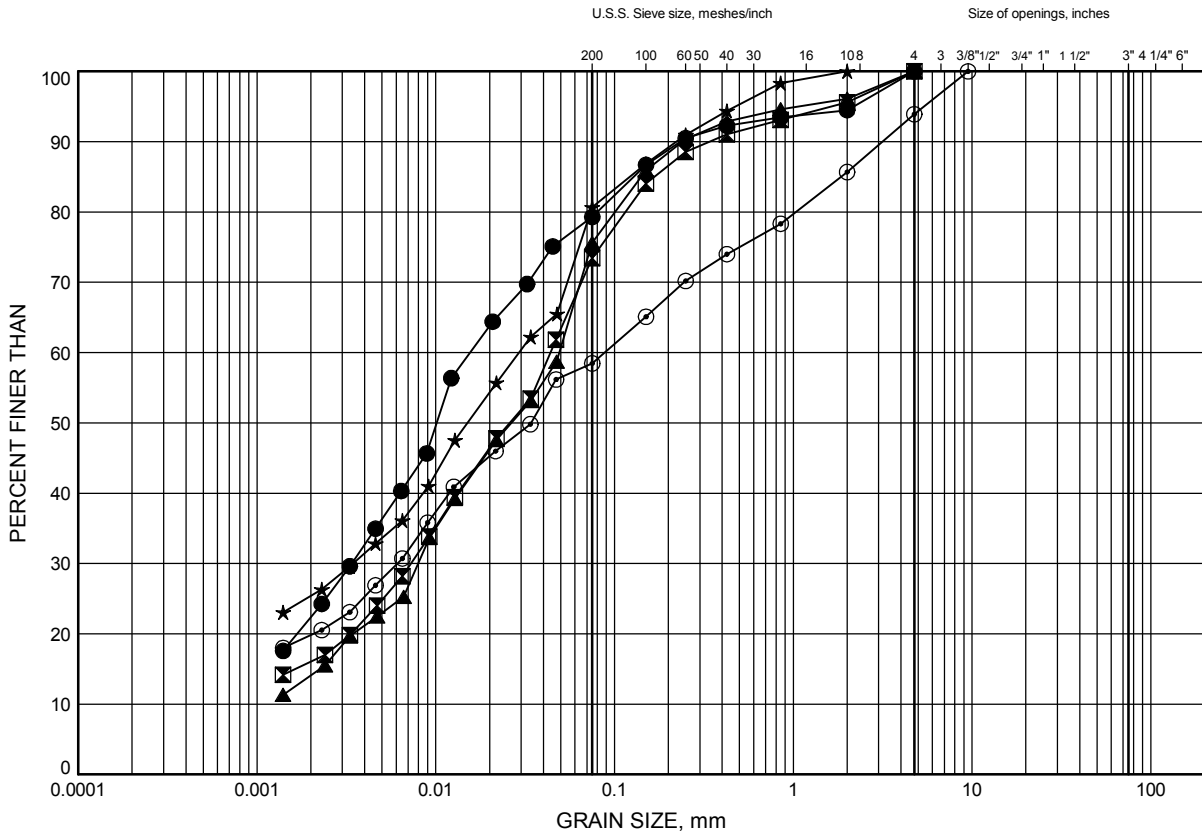
Prep'd MFA  
Chkd. MTB



# Zone 4 Feeder mains GRAIN SIZE DISTRIBUTION

FIGURE B3

## Silty Clay Till



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-069	5.45	200.54
⊠	14-070	6.23	200.73
▲	14-070	9.45	197.51
★	14-105	13.84	181.76
⊙	14-106	3.35	195.45

Date November 2015  
Project 17-123-902

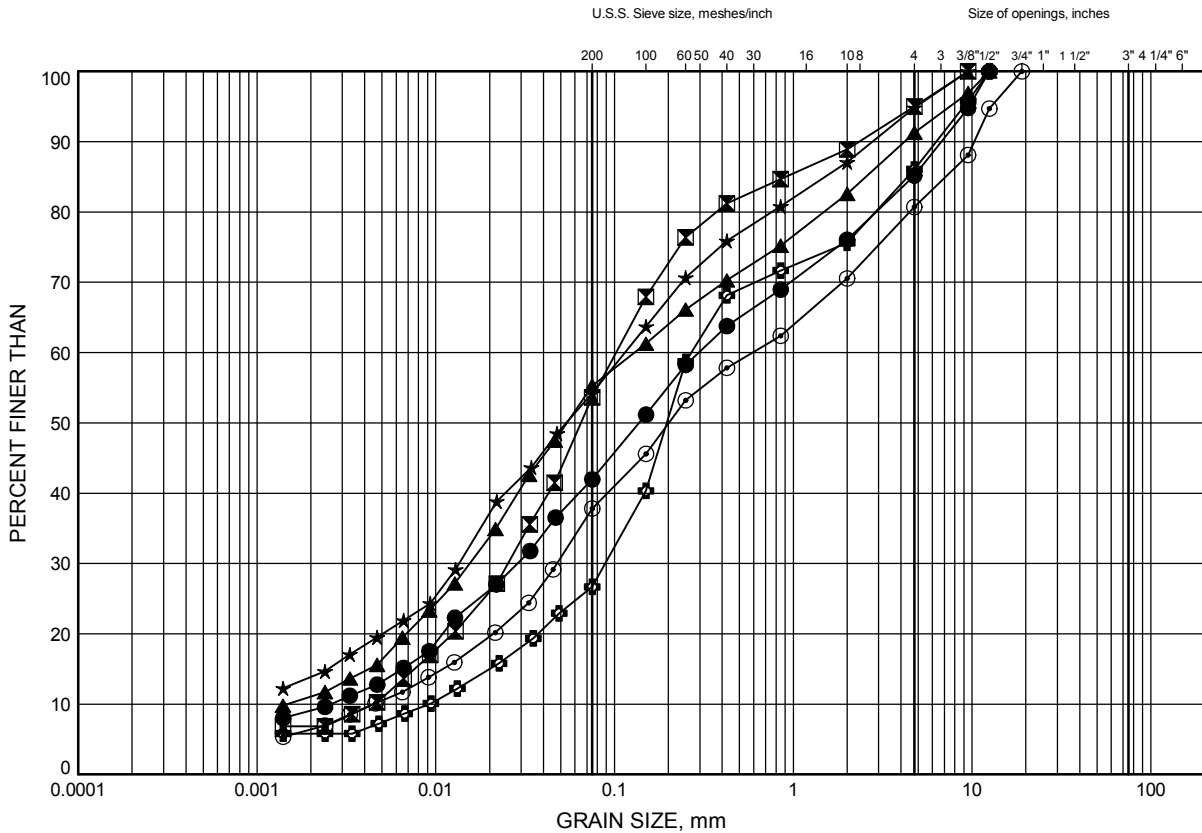


Prep'd MFA  
Chkd. MTB

# Zone 4 Feeder mains GRAIN SIZE DISTRIBUTION

FIGURE B4

## Sand and Silt Till



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-063	4.11	194.75
⊠	14-063	5.64	193.22
▲	14-064	7.92	195.79
★	14-064	9.45	194.27
⊙	14-105	4.88	190.72
⊕	14-105	7.16	188.44

Date November 2015

Project 17-123-902



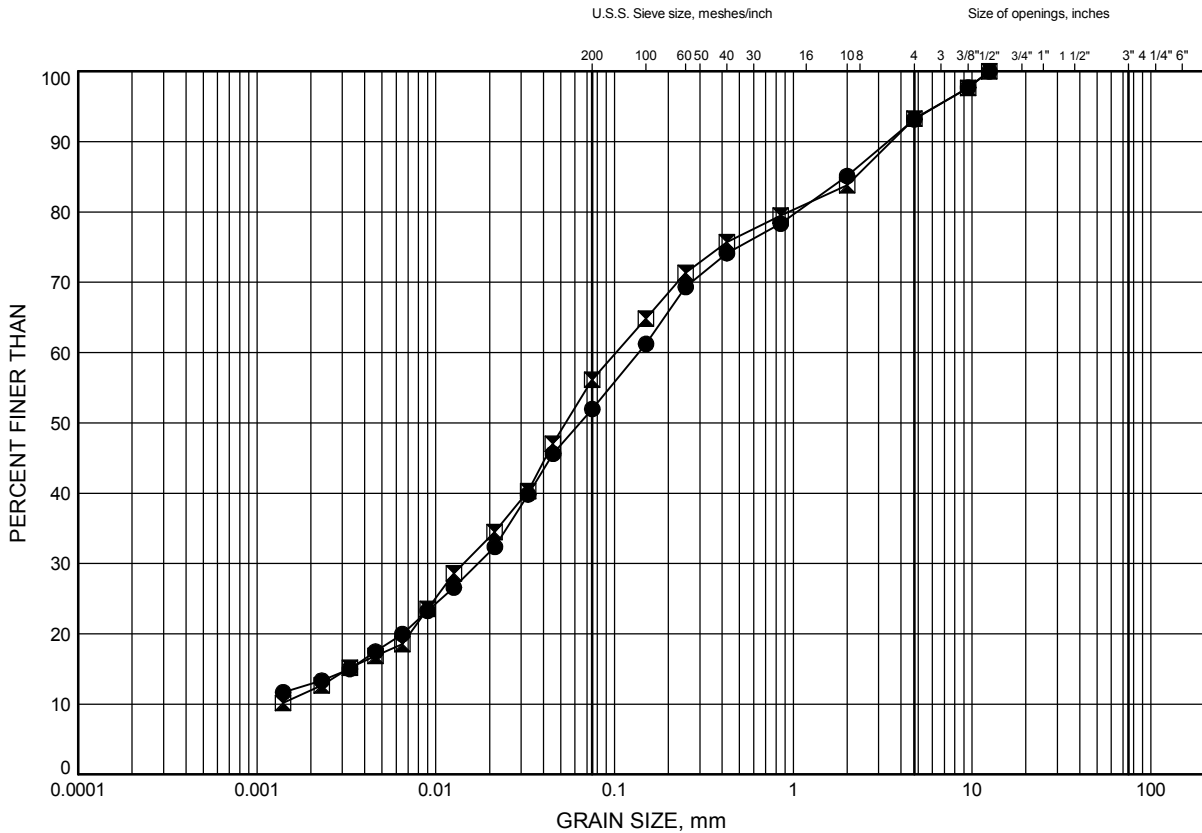
Prep'd MFA

Chkd. MTB

# Zone 4 Feeder mains GRAIN SIZE DISTRIBUTION

FIGURE B5

## Sand and Silt Till



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-106	5.46	193.34
⊠	14-106	8.49	190.31

Date November 2015  
Project 17-123-902

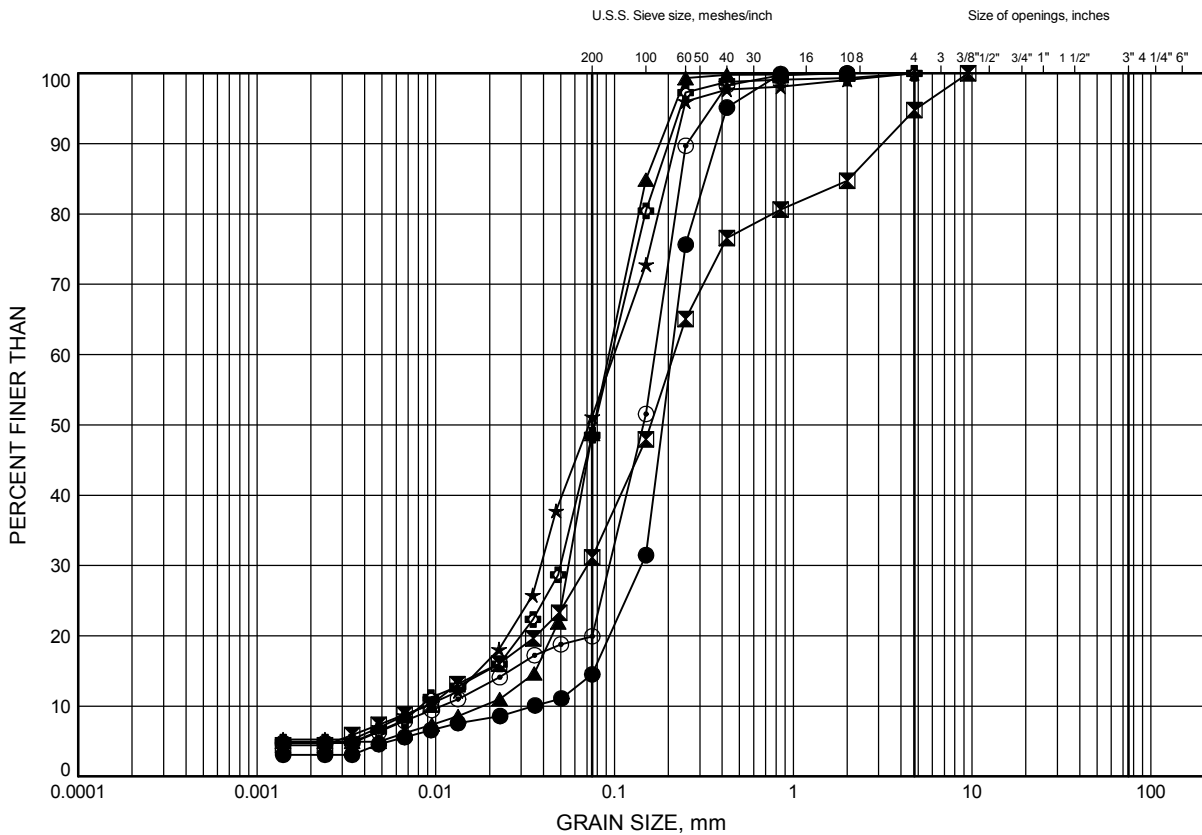


Prep'd MFA  
Chkd. MTB

# Zone 4 Feeder mains GRAIN SIZE DISTRIBUTION

FIGURE B6

## Sand and Gravel to Sand and Silt



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-063	10.97	187.89
⊠	14-065	5.64	196.45
▲	14-066	3.94	198.56
★	14-066	6.30	196.20
⊙	14-066	14.02	188.48
⊕	14-067	7.16	195.94

Date November 2015  
Project 17-123-902



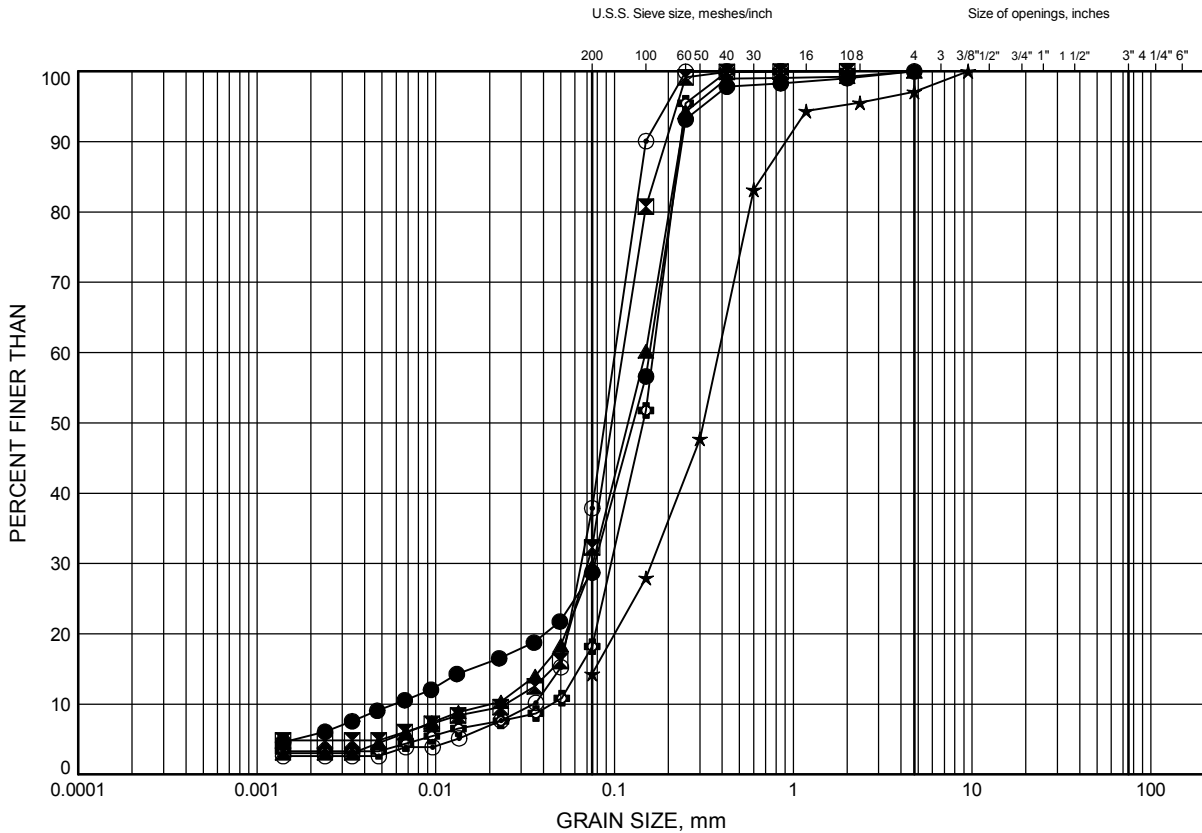
Prep'd MFA  
Chkd. MTB

# Zone 4 Feeder mains

## GRAIN SIZE DISTRIBUTION

FIGURE B7

### Sand and Gravel to Sand and Silt



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-067	12.40	190.71
⊠	14-068	5.64	198.52
▲	14-068	7.85	196.31
★	14-069	6.98	199.01
⊙	14-069	11.51	194.49
⊕	14-069	15.54	190.45

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Project 17-123-902

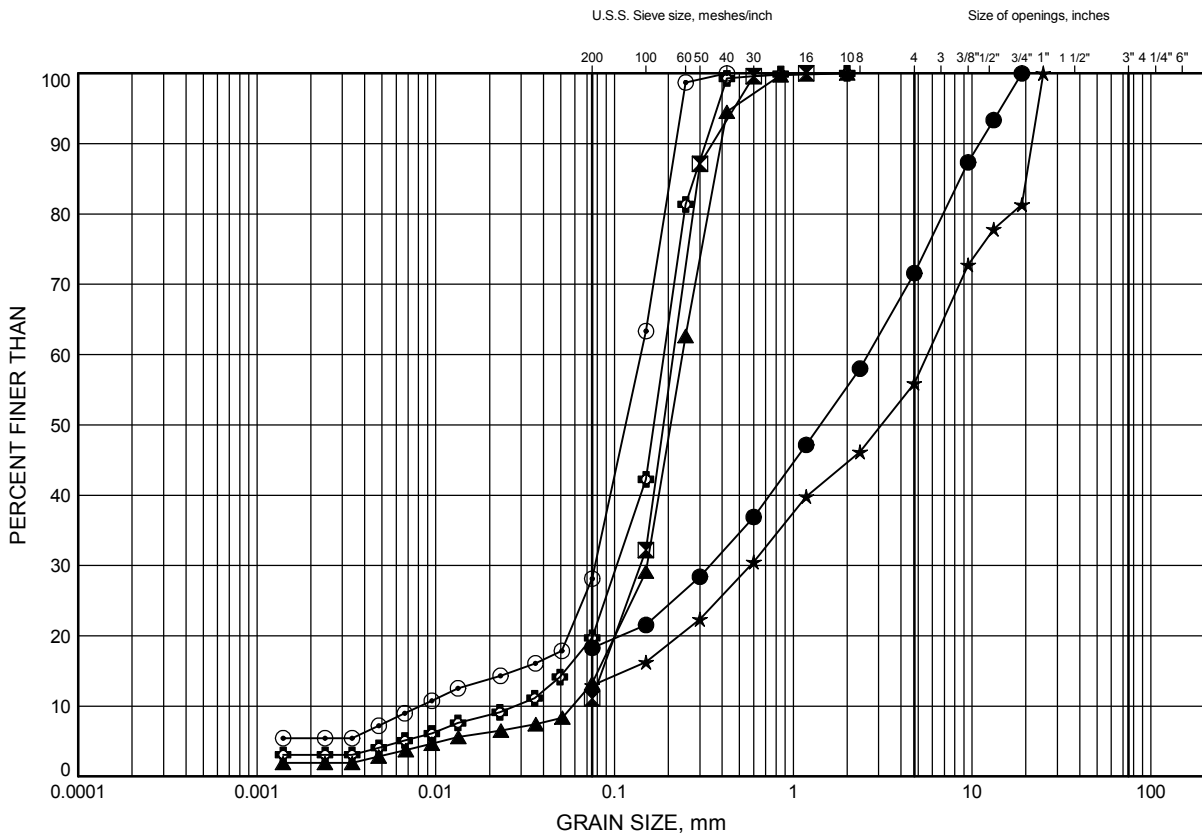


Prep'd MFA  
Chkd. MTB

# Zone 4 Feeder mains GRAIN SIZE DISTRIBUTION

FIGURE B8

## Sand and Gravel to Sand and Silt



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-105	1.83	193.77
⊠	14-105	8.69	186.91
▲	14-105	15.54	180.06
★	14-107	6.32	194.78
⊙	14-107	10.97	190.13
⊕	14-107	15.54	185.56

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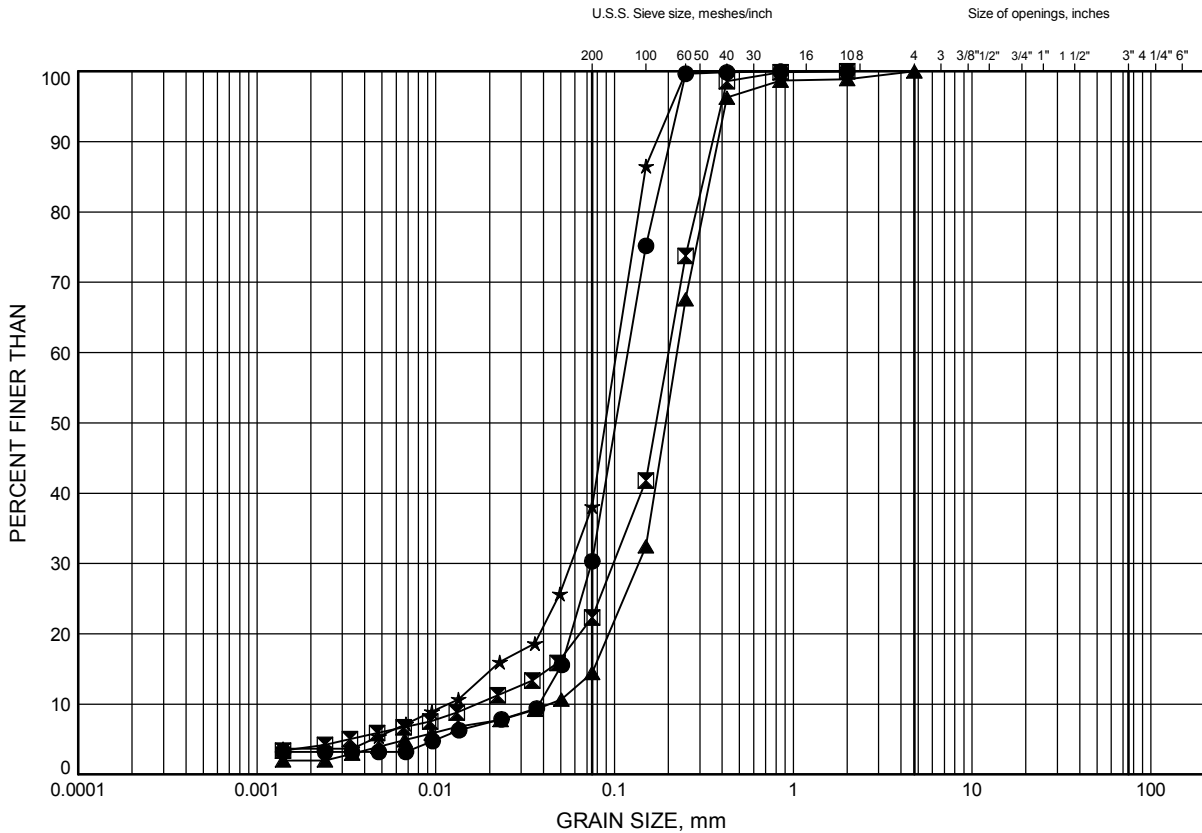
Chkd. MTB

# Zone 4 Feeder mains

## GRAIN SIZE DISTRIBUTION

FIGURE B9

### Sand and Gravel to Sand and Silt



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-108	11.55	191.15
⊠	14-108	18.48	184.22
▲	14-109	7.74	196.38
★	14-109	18.34	185.78

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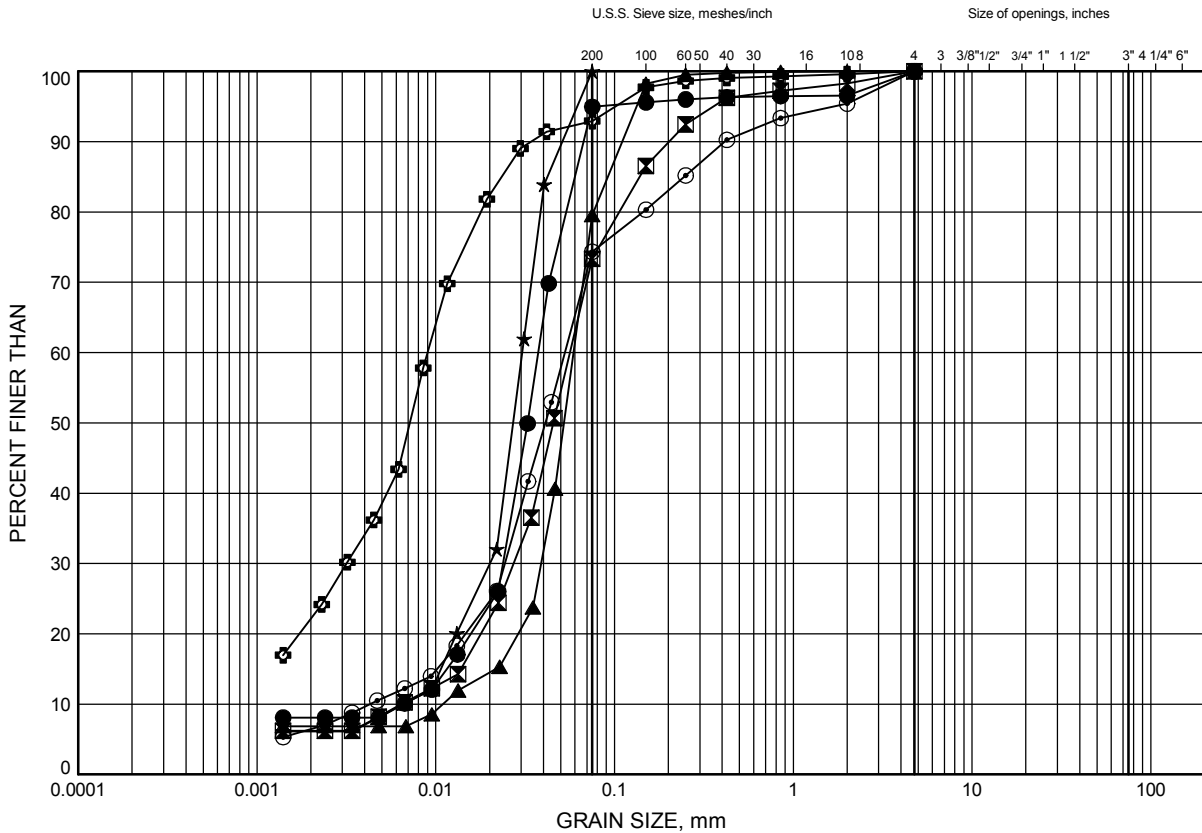


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Chkd. MTB

# Zone 4 Feeder mains GRAIN SIZE DISTRIBUTION

FIGURE B10

## Silt to Sandy Silt



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

## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-063	8.69	190.18
⊠	14-064	10.97	192.74
▲	14-064	12.50	191.22
★	14-065	7.92	194.16
⊙	14-065	9.45	192.64
⊕	14-066	7.81	194.69

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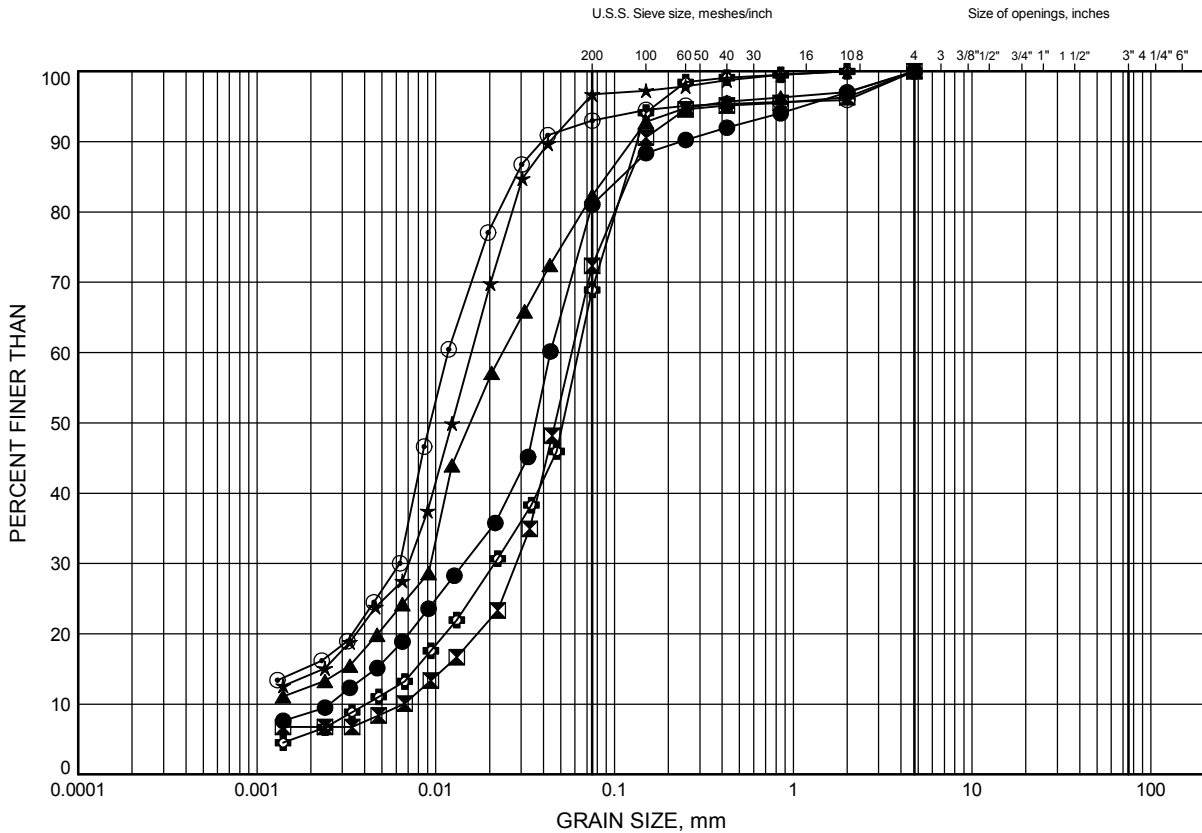


# Zone 4 Feeder mains

## GRAIN SIZE DISTRIBUTION

FIGURE B11

### Silt to Sandy Silt



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-066	10.87	191.63
⊠	14-067	4.88	198.23
▲	14-067	9.27	193.83
★	14-068	3.35	200.81
⊙	14-068	15.30	188.86
⊕	14-070	4.11	202.85

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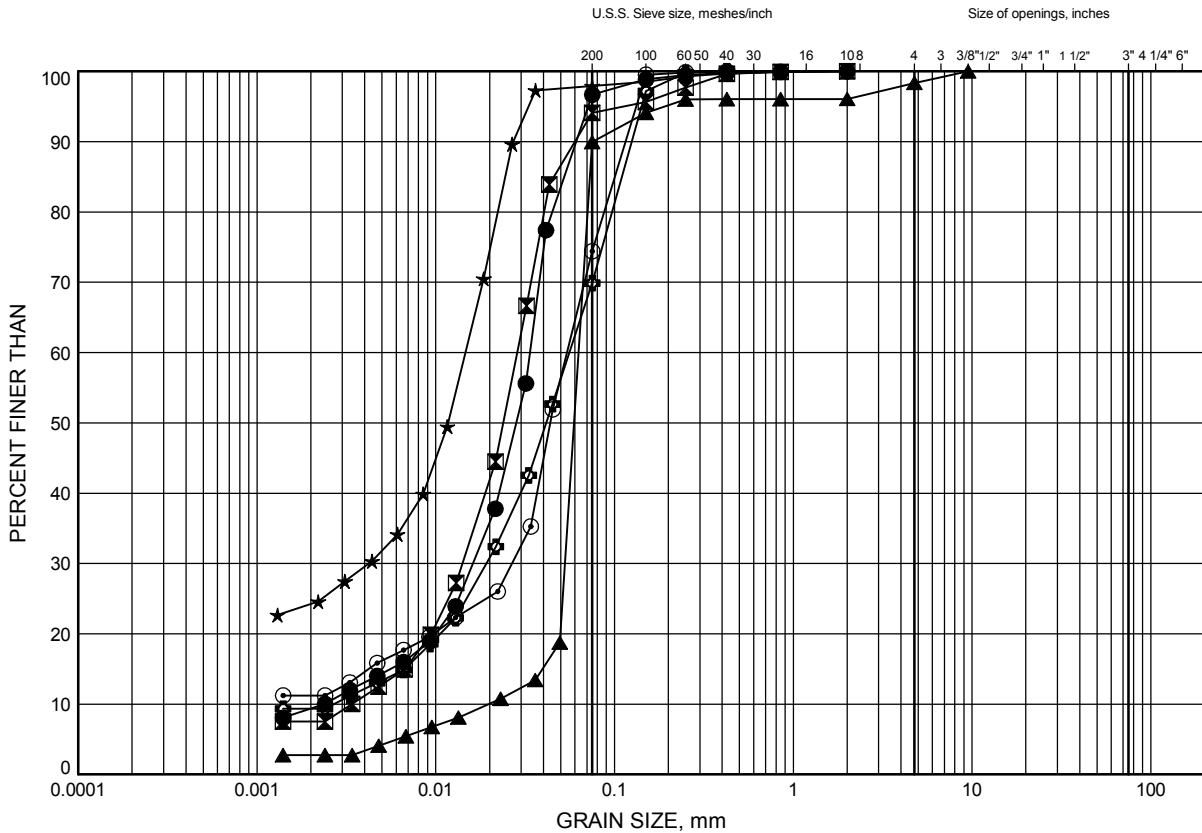
Chkd. MTB

# Zone 4 Feeder mains

## GRAIN SIZE DISTRIBUTION

FIGURE B12

### Silt to Sandy Silt



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-105	12.50	183.10
⊠	14-106	10.21	188.59
▲	14-106	11.73	187.07
★	14-107	8.65	192.45
⊙	14-108	5.64	197.06
⊕	14-108	8.53	194.17

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Project 17-123-902



Prep'd MFA

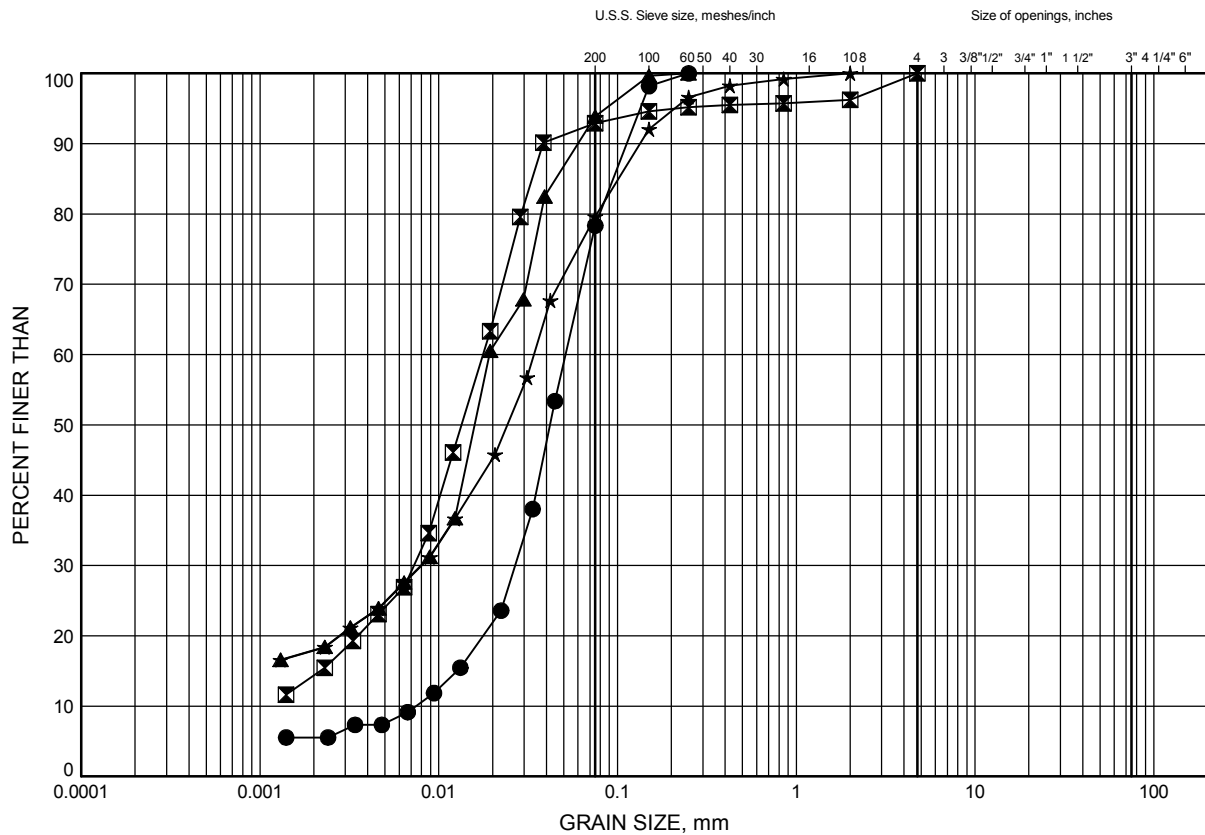
Chkd. MTB

# Zone 4 Feeder mains

## GRAIN SIZE DISTRIBUTION

FIGURE B13

### Silt to Sandy Silt



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-108	10.03	192.67
⊠	14-109	4.70	199.42
▲	14-109	11.48	192.64
★	14-109	13.78	190.34

Date November 2015

Project 17-123-902



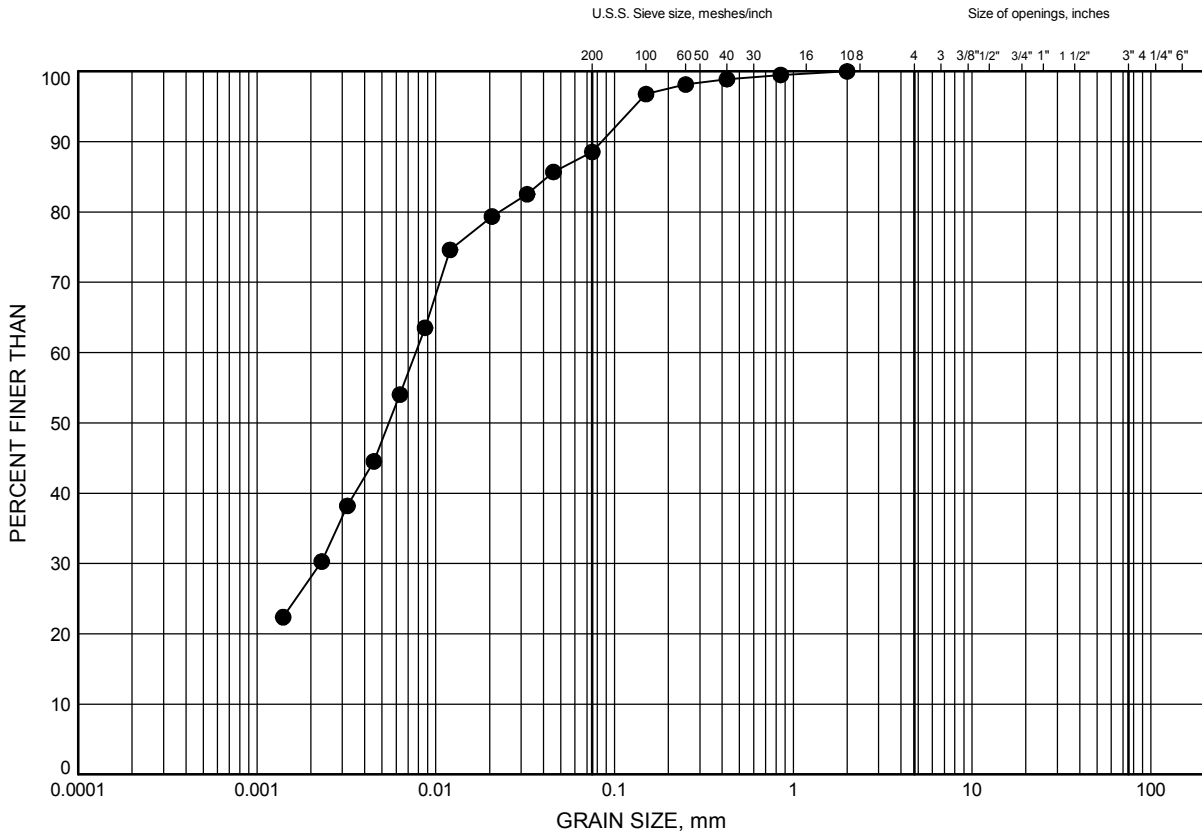
Prep'd MFA

Chkd. MTB

Zone 4 Feeder mains  
GRAIN SIZE DISTRIBUTION

FIGURE B14

Silty Clay



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-107	4.58	196.52

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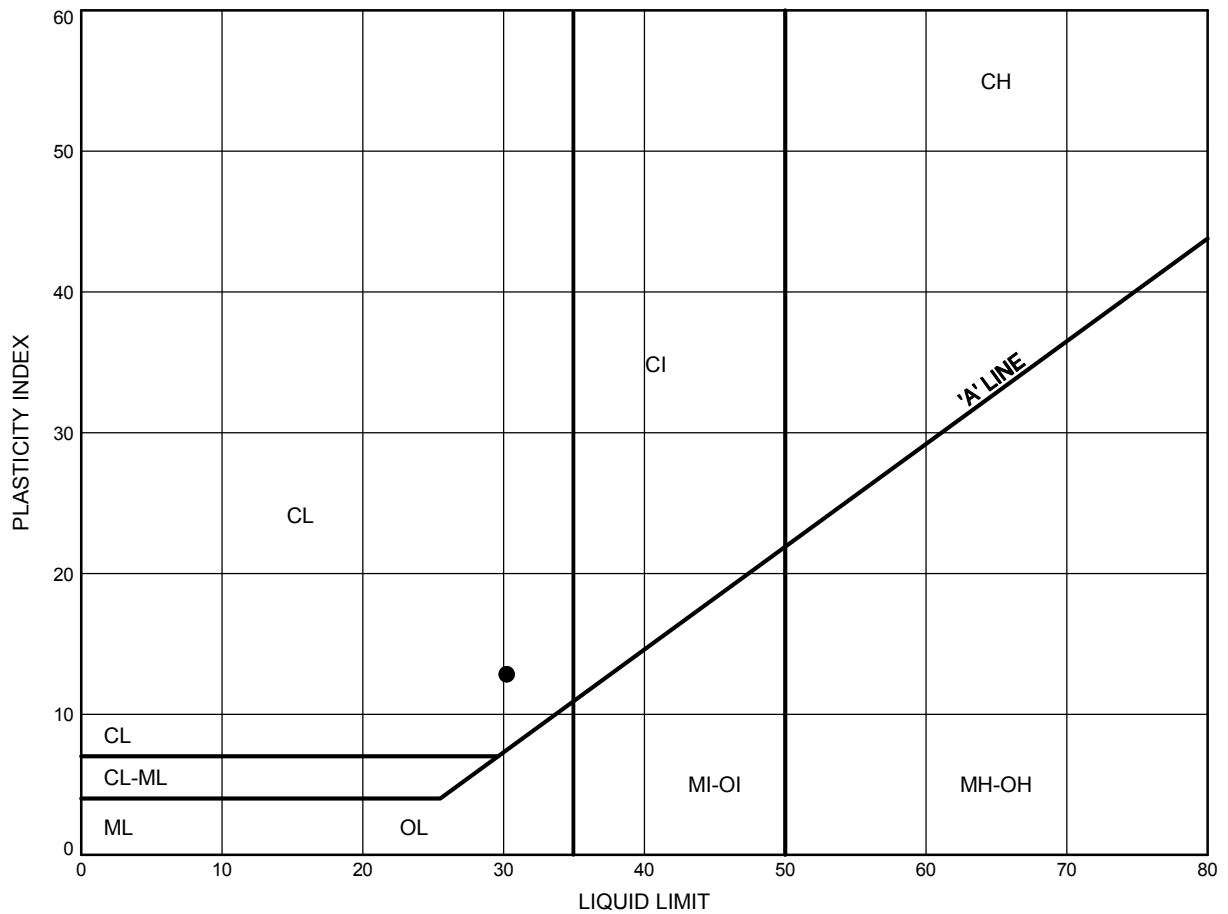
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Chkd. MTB

Zone 4 Feeder mains

# ATTERBERG LIMITS TEST RESULTS

FIGURE B15

Silty Clay Fill



## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-067	1.83	201.28

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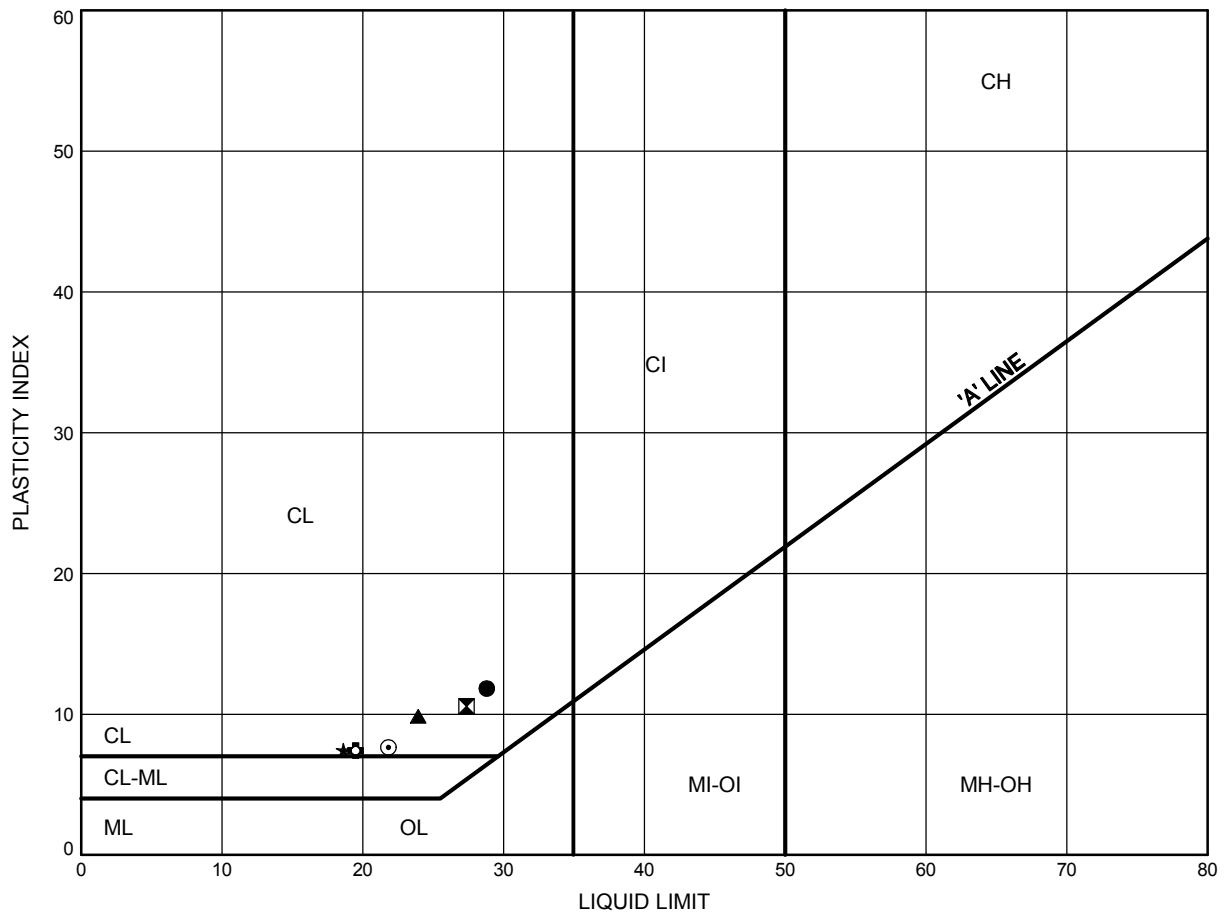
Prep'd MFA  
 Chkd. MTB

Zone 4 Feeder mains

# ATTERBERG LIMITS TEST RESULTS

FIGURE B16

Silty Clay Till



## LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	14-064	4.88	198.84
⊠	14-065	2.59	199.50
▲	14-069	2.59	203.40
★	14-070	9.45	197.51
⊙	14-105	13.84	181.76
⊕	14-106	3.35	195.45

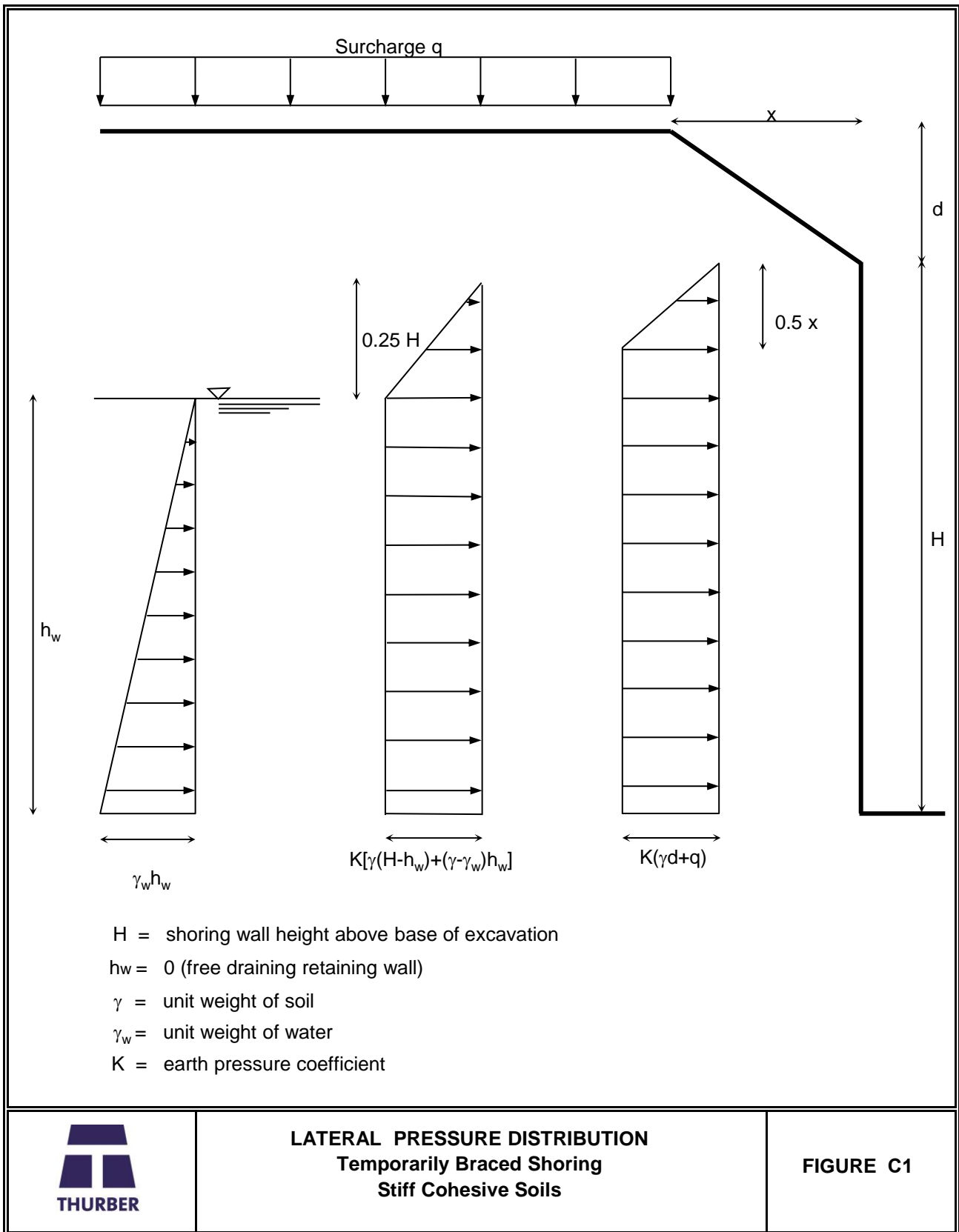
Date November 2015  
Project 17-123-902



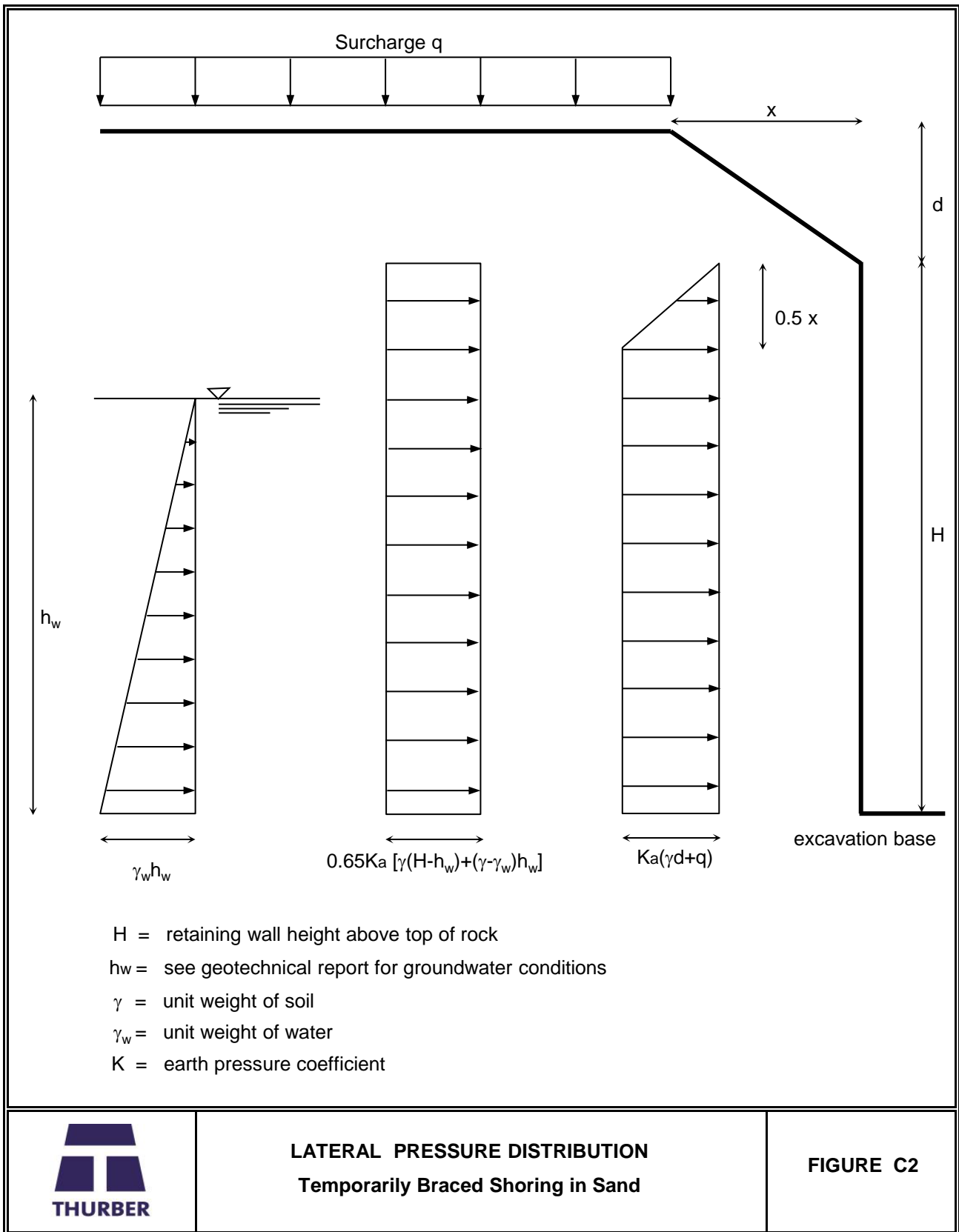
Prep'd MFA  
Chkd. MTB

## **Appendix C**

### **Figures**

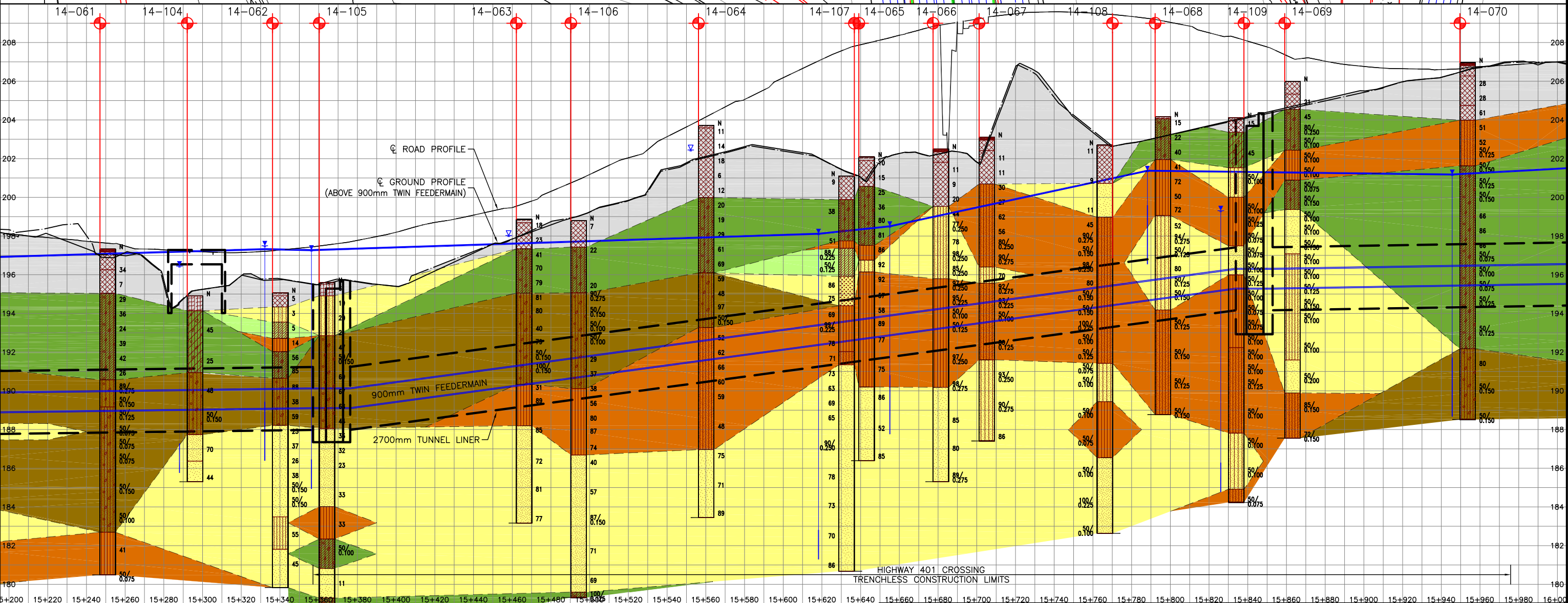
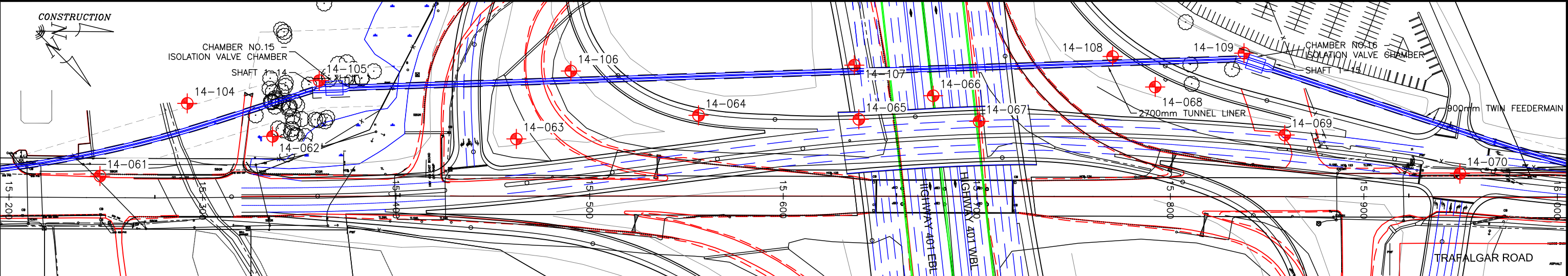






## **Appendix D**

### **Boreholes Locations and Stratigraphic Profile Drawing**



**LEGEND:**

APPROXIMATE BOREHOLE LOCATION

WATER LEVEL MEASURED IN STANDPIPE PIEZOMETER

'N' SPT VALUE

WATER LEVEL

**CLASS A - FILL**

FILL

TOPSOIL/ORGANICS

**CLASS B - SAND**

SAND

SILTY SAND

SAND AND SILT

**CLASS C - SILT**

SANDY GRAVEL/ SAND & GRAVEL

GRAVELLY SAND

SILT

SANDY SILT

SAND TILL

**CLASS D - NON-PLASTIC TILL**

SAND TILL

**CLASS E - CLAY**

CLAY

SILTY CLAY

**CLASS F - PLASTIC TILL**

CLAYEY SILT

SILTY CLAY TILL

CLAYEY SILT TILL

**CLASS G - BEDROCK**

SHALE

ASSOCIATED ENGINEERING

**ZONE 4 FEEDERMAINS**

HIGHWAY 401 CROSSING

BOREHOLE LOCATIONS AND STRATIGRAPHIC PROFILE

JOB# 17-123-902

**THURBER ENGINEERING LTD.**

ENGINEER: MTB

DATE: OCTOBER 2015

DRAWN: MFA

SCALE: AS SHOWN

APPROVED: MRA

DRAWING No: 17-123-902-1

20 0 40 60m

H 1:2000

V 1:200

## **Appendix E**

### **Tunnelman's Ground Classification System**

### Tunnelman's Ground Classification System (after Heuer, 1974)

Classification		Behaviour	Typical Soil Type
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	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.
	Fast Raveling		
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 with raveling at excavation surface and squeezing at depth behind surface.
Running	Cohesive Running	Granular materials without cohesion are unstable at a slope greater than their angle of repose (+/-30° to 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 behaviour is cohesive-running.
	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 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 pre-consolidated clay with plasticity index in excess of about 30, generally containing significant percentages of montmorillonite.

**Modified from Terzaghi (1950)**

## **Appendix F**

### **Settlement Monitoring Guidelines - Tunneling**

## **APPENDIX: SETTLEMENT MONITORING GUIDELINES - TUNNELING**

**The purpose of settlement monitoring is to prevent damage to existing utilities and highway structures along the tunnel alignment. Ground settlement include settlement due to lost ground and dewatering/drainage.**

### **Instrumentation Arrays**

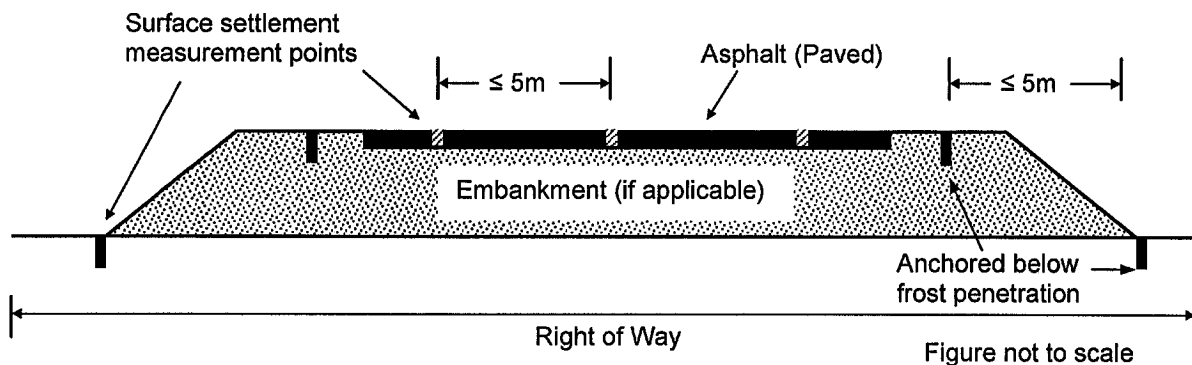
All measurement points shall be installed and surveyed before the start of excavation to establish benchmarks/baseline.

#### **Surface Monitoring Points**

Surface monitoring points will be installed to cover the whole length of the tunnel with in the right of way under the jurisdiction of MTO (Figure 1).

Surface monitoring points will be located at not greater than 5m intervals along the tunnel alignment. The surface monitoring will be identified using paint marks on the pavement. Surface monitoring points installed on the unpaved right of way shall be founded below frost penetration depths. The interval and/or marking of the points should be changed with MTO's approval where traffic disruptions might occur.

The final instrumentation plan should be finalised when Contractor's proposed construction method is available.



**Figure 1:** Typical configuration of surface settlement monitoring points along the tunnel alignment.

## **Condition Survey**

A condition survey for the pavement will be carried out prior to commencement of construction and documented for the purpose of requirement of restoration. The condition survey shall document visible flaws such as cracks, distortions and deviations, heaves, and depressions. This surface survey will be completed during the installation of the monitors and again once the tunnel has been completed.

## **Reading Frequency**

An average of at least two readings shall be taken to establish the initial conditions.

The reading and collection of data from the surface monitoring points shall be read and recorded by the Contractor during the construction period and after construction for period of at least 2 weeks provided that further settlement has stopped.

A minimum of three (3) sets of reading be taken daily, provided that movements are within anticipated limits. Otherwise, the frequencies should increase according to a pre-planned interval.

Monitoring of movements is required during work stoppages, such as during non-operation period (off-shifts) or weekends. A minimum of three (3) sets of readings should be taken daily.

Measurements of the monitoring points shall be reported promptly to MTO for review.

## **Data Collection and Data Transfer**

A procedure is required to be established in consultation with MTO so that the monitoring data and the interpreted data will reach all parties as soon as necessary. The contract administrator/consultant and the Contractor should interpret monitoring data as needed for the purpose of on-going construction. The Foundation Engineer should be contacted for technical support to the prime Consultant in the interpretation of ground movements and review of the Contractor's response when Review and Alert Levels are reached.

## **Criteria for Assessment**

The acceptable surface settlement (or heave) will be according to criteria as specified below.

**Baseline Reading** – A baseline reading of the instrumentation shall be taken prior to commencement of the work. An average of at least two initial readings shall be recorded as baseline reading.



Review Level – A maximum value of 10 mm relative to the baseline readings is suggested for this project. If this level is reached, the method, rate or sequence of construction, or ground stabilization measures should be reviewed or modified to mitigate further ground displacements.

Alert Level – A maximum value of 15mm relative to the baseline readings is suggested for this project. If this level is reached, the Contractor shall cease construction operations and to execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic.

### **Review of Contractor's Proposed Method**

MTO, the Proponent's prime consultant and Foundation Engineer should review the Contractor's proposed method of construction. The proposed method should include a description of the potential loss of ground, and calculation of the maximum settlement in relation to the Contractor's procedure and equipment, alternative/remedial measures when review level of measurement is reached; and contingency/remedial measures when alert level of measurement is reached.

### **Contractor's Responsibility For Restoration and Warranty Provision**

In addition to the monitoring program to assess the adequacy of the construction method to control potential ground movements and groundwater, the Contractor is responsible for reinstatement (such as surface paving) should movements or other surface distress occur, and provide a reasonable warranty period acceptable to MTO. Remedial measures shall be approved by MTO; however, MTO maintains the right to perform the maintenance at the proponent's expense.

### **Construction Monitoring**

The Proponent shall retain a qualified Geotechnical Consultant to supervise the installation of surface settlement points on site and to provide direction, technical input and field inspection on this project.