

**PRELIMINARY
FOUNDATION INVESTIGATION AND DESIGN REPORT
WELLINGTON COUNTY ROAD 86 UNDERPASS
HIGHWAY 7-NEW, KITCHENER TO GUELPH
G.W.P. 408-88-00**

Geocres Number: 40P9-43

Report to:

**Ministry of Transportation Ontario
Southwestern Region**

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a preliminary foundation investigation conducted at the site of the proposed underpass structure to carry Wellington County Road 86 over Highway 7-New in Wellington County, Ontario.

The purpose of the investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan, records of boreholes, a stratigraphic profile, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions under the potential foundation footprint was developed from the data obtained in the course of the investigation.

The information collected in the course of the investigation and presented in this report is intended for preliminary design purposes only. Additional site investigation, field testing and engineering analysis will be required at the detail design stage. The extent of the additional investigation will depend, in part, on the final location and General Arrangement of the structure.

Thurber carried out the investigation for the Ministry of Transportation Ontario, Southwestern Region (MTO) under Purchase Order Number 3006-E-0123.

2 SITE DESCRIPTION

At the site, the Highway 7-New alignment runs approximately parallel to the existing Highway 7 alignment and 900 m to the north. The site is also described as lying a short distance northwest of the developed area of the City of Guelph.

Based on the Ontario Geological Survey Special Volume 2, The Physiography of Southern Ontario, Third Edition by Chapman and Putnam, the site lies within an area referred to as the Guelph Drumlin Field, an area of drumlinized till plain, also mapped as containing eskers. The till is described as stony and the occurrence of surface boulders is noted. Chapman and Putnam give a



typical gradation of the till as being 50% sand, 35% silt and 15% clay. Swampy valleys are reported to occur between the drumlins and associated gravel terraces.

The site lies within an area of active farms some 400 to 500 m north of the limit of urban development in Guelph. There are farmsteads to the east and west of Wellington County Road 86 just to the south of the Highway 7-New alignment and another farmstead on the east side of the road a short distance to the north.

A photograph of the site, looking north along Wellington County Road 86 is included in Appendix D and shows the general nature of the surrounding land. The sign advising of the future construction of Highway 7-New is visible in the right of the photograph. The back of the corresponding southbound sign is visible left of centre in the photograph, to the left of the approaching vehicle.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field-testing at this site was carried out between May 20 and May 21, 2008. Three boreholes, 08-211, 08-212 and 08-213, were drilled approximately at the north abutment, pier and south abutment of a possible two-span structure arrangement. The depths of the boreholes ranged from 7.4 to 9.0 m. The Record of Borehole sheets for the boreholes are included in Appendix A. The approximate locations of the three boreholes are shown on the attached Borehole Locations and Soil Strata Drawing in Appendix E.

Prior to commencing the site investigation, clearance was obtained from utility companies having plant in the area.

The boreholes were drilled using both solid stem and hollow stem auger equipment on a truck-mounted drill rig. Samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) in the overburden soils.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. In the middle borehole (08-212) a standpipe piezometer consisting of 25 mm PVC pipe with a slotted screen was installed and enclosed in filter sand to permit longer term groundwater level monitoring. The locations and completion details of the piezometers are shown in Table 3.1. Boreholes without piezometer installations were grouted with bentonite upon completion. The borehole completion details are shown in Table 3.1.

The completion of the boreholes and the standpipe piezometer were carried out in accordance with the requirements of O.Reg 903 (as amended by O.Reg. 372/07).

A member of Thurber's technical staff supervised drilling and sampling operations on a full time basis. The supervisor logged the boreholes and processed the recovered soil samples for transport to Thurber's laboratory for further examination and testing.

Table 3.1 – Borehole Completion Details

| Borehole Location | Piezometer Tip Depth/ Elevation (m) | Completion Details |
|--------------------------|--|---|
| 08-211 North Abutment | No Installation | Bentonite grout from bottom of borehole to 0.5 m, bentonite/soil/sand mixture to ground surface. |
| 08-212 Pier | 7.5/337.1 | Piezometer with 1.5 m slotted screen installed with sand filter to 5.5 m, bentonite seal to 4.9 m, bentonite and soil to 0.6 m, sand to 0.45, cement grout to ground surface. |
| 08-213 South Abutment | No Installation | Bentonite grout from bottom of borehole to 2.7 m, bentonite/soil mixture to 0.5 m and sand to ground surface. |

4 LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. The results of this testing are shown on the Record of Borehole sheets in Appendix A. Selected samples were also subjected to gradation analysis and the results of this testing program are shown on the Record of Borehole sheets in Appendix A and on the figures contained in Appendix B.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets in Appendix A. Details of the encountered soil stratigraphy along the proposed alignment are presented in this appendix and on the “Borehole Locations and Soil Strata” drawing in Appendix E. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole Sheets governs any interpretation of the site conditions.

In general, the site is underlain by granular fill overlying two distinct, glacial till deposits within the depth of exploration.

5.1 Fill

A layer of fill was encountered at all three exploration locations at this site. The fill consists of sand and gravel, presumably placed to construct the existing embankment for County Road 86.

The thickness of the fill ranges from 1.9 m at each abutment to 2.1 m at the pier and the elevation of the underside ranges from 341.8 at the north to 343.2 at the south.

The fill is classified as compact to dense, based on SPT values ranging from 22 to 38 blows for 0.3 m of penetration. One value of 100 blows for 0.125 m of penetration, encountered in BH 08-211, is believed to be due to the presence of large gravel or a cobble.

The natural moisture content ranged from 3 to 10%.

The gradation of the fill is as follows:

| | |
|---------------|-----------|
| Gravel | 12 to 42% |
| Sand | 44 to 45% |
| Silt and Clay | 13 to 44% |

The grain size distribution curve for the fill is shown in Figure B1 in Appendix B.

5.2 Upper Sandy Silt Till

Below the fill, all three boreholes at this site encountered a layer of sandy silt, trace to some gravel, trace clay. This soil is yellow-brown to grey in colour and non-indurated. The gravel sizes observed in the samples were rounded to sub-angular.

The thickness of this layer ranged from 1.7 m at the pier to 5.9 m at the south abutment. The underside of the layer ranged from Elevation 340.8 at the pier to Elevation 337.3 at the south abutment.

This upper till is classed as compact to very dense, based on SPT values ranging from 17 blows for 0.3 m of penetration to well over 100 blows for 0.3 m of penetration. The layer is generally compact at the top, becoming very dense towards the base.

The natural moisture contents generally lay around 10 to 12%.

The gradation of the upper till is as follows:

| | |
|--------|-----------|
| Gravel | 7 to 17% |
| Sand | 33 to 49% |
| Silt | 29 to 49% |
| Clay | 4 to 11% |

The grain size distribution curve for the sandy silt till is shown in Figure B2 in Appendix B.

5.3 Lower Sandy Silt Till

The gradation of the lower sandy silt till varies only slightly from the upper, in that it contains slightly less gravel size material and slightly more clay size. This layer is generally grey and fairly well indurated. The gravel sizes are smaller than the upper layer and are mostly well-rounded.

This material extends at least to the depth of exploration and the thicknesses sampled ranged from 1.2 m at the south abutment to 3.7 m at the pier.

Based on SPT values always exceeding 100 blows for 0.3 m of penetration, this layer is classed as very dense.

The natural moisture contents generally lay in the range of 7 to 10%.

The gradation of the lower till is as follows:

| | |
|--------|-----------|
| Gravel | 3 to 9% |
| Sand | 29 to 35% |
| Silt | 47 to 56% |
| Clay | 10 to 13% |

The grain size distribution curve for the lower sandy silt till is shown in Figure B3 in Appendix B.

5.4 Groundwater Conditions

A standpipe piezometer was installed in one borehole (BH 08-212) to monitor the groundwater level. The water level readings in the piezometer and in the open boreholes are presented in Tables 5.1.

Table 5.1: Water Level Measurements for County Road 86

| | BH 08-211 | | BH 08-212 | | BH 08-213 | |
|--------------|----------------------|--------------|----------------------|--------------|----------------------|--------------|
| Date | Depth (m) | Elev. | Depth (m) | Elev. | Depth (m) | Elev. |
| May 20, 2008 | 2.4 | 341.3 | - | - | 1.8 | 343.3 |
| May 21, 2008 | | | Dry | - | | |
| May 27, 2008 | - | - | 1.8 | 342.8 | - | - |

These are short term water level readings and they are expected to vary seasonally and after severe or prolonged weather events. However, as they are springtime readings they are expected to represent an upper rather than lower range of values.

6 MISCELLANEOUS

All-Terrain Drilling of Waterloo, Ontario supplied a truck-mounted CME 75 drill rig and conducted the drilling, sampling and in-situ testing operations.

The drilling and sampling operations in the field were supervised on a full time basis by Mr. Stephane Loranger, C.E.T. of Thurber, under the direction of Mr. Alastair E. Gorman, P.Eng.

The coordinates for the boreholes and the ground surface elevations were obtained by Thurber Engineering Ltd. using GPS equipment.

Mr. Alastair E. Gorman, P.Eng prepared the Foundation Investigation Report.

Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations projects, reviewed the report.

Alastair E. Gorman, P.Eng.,
Senior Foundations Engineer



P.K. Chatterji, P.Eng.,
Review Principal, Designated MTO Contact



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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This report presents interpretation of the geotechnical data in the factual report and presents preliminary geotechnical design recommendations to assist the design team to select and design a suitable foundation system for the new structure.

Based on the Plate 21 of the E.A:

- The mainline will be in a cut 3 to 4 m deep at Elevation 341
- County Road 86 will be at Elevation 348.5 with approach embankments 3 to 5 m high

The discussion and recommendations presented in this report are based on our understanding of the project and on the factual data obtained in the course of this investigation.

8 STRUCTURE FOUNDATIONS

The stratigraphy identified in the preliminary investigation consisted primarily of a two layer system of glacial till. The natural soils are overlain by sand and gravel fill, presumably placed during construction of County Road 86. The local terrain is hummocky and groundwater is less than 2 below the ground surface.

In the preparation of the preliminary geotechnical design recommendations, consideration was given to the following foundation types:

- Spread footings bearing on native soil
- Spread footings on engineered fill
- Steel H-piles driven into the very dense soil

A comparison of the foundation alternatives based on advantages and disadvantages of each is included in Appendix C.

8.1 Spread Footings on Native Soil

Spread footings bearing on native soil generally are the least expensive form of construction.

The existing fill is not considered to be suitable for the support of spread footings and the footings must be placed on the underlying native soils.

The design of spread footings bearing on native soil must be in accordance with the elevations and bearing resistances given in Table 8.1.

Table 8.1 – Bearing Resistances for Spread Footings

| Element | Elev. | ULS _r (kPa) | SLS (kPa) |
|--------------------------------------|-------------|------------------------|-----------|
| North Abutment (BH 08-211) | Below 341.5 | 300 | 200 |
| | Below 339.5 | 750 | 500 |
| Pier (BH 08-212) | Below 342.0 | 300 | 200 |
| | Below 340.5 | 750 | 500 |
| South Abutment (BH 08-213) | Below 343.0 | 300 | 200 |
| | Below 341.0 | 750 | 500 |

The bearing resistances in Table 8.1 are for vertical, concentric loading. In the case of eccentric or inclined loading, the bearing resistance must be adjusted as shown in the CHBDC (2006) Clause 6.7.3 and Clause 6.7.4.

These founding elevations are generally below the groundwater level observed during the investigation and also lies in the non-indurated till, increasing the risk of soil disturbance due to excavating below the water table.

8.2 Spread Footings on Engineered Fill

Spread footings can also be founded on Granular “A” engineered fill pads. These would be most useful at the pier or in the case of perched abutments on footings.

Typically, spread footings on pads of engineered granular fill at least 2 m thick may be designed for the following geotechnical resistances:

- Factored ULS 900 kPa
- SLS 350 kPa

All topsoil and other deleterious material must be removed below the footprint of the engineered fill pad. The Granular A must be compacted to 100% Standard proctor maximum dry density (SPMDD) at optimum moisture content $\pm 2\%$. The geometry of the fill pad must conform to the general requirements shown in Figure 1.

The highest elevations at which the engineered fill pads may be founded are given in Table 8.2.

Table 8.2 – Founding Elevations for Engineered Fill Pads

| North Abutment (BH 08-211) | Pier (BH 08-212) | South Abutment (BH 08-213) |
|---------------------------------------|-----------------------------|---------------------------------------|
| 341.5 | 342.5 | 343.0 |

8.3 Steel H-Piles

The soil stratigraphy encountered at this site is considered to be suitable for the support of foundations on driven steel piles.

It is recommended that the H-piles be driven to achieve resistance in the very dense glacial soils encountered at the site. Based on an HP 310 X 110 pile, a minimum embedment depth of 6 m is required. The preliminary information in EA Plate 21 indicates that this depth of embedment should be achieved at the abutments. At the pier, pile installation would probably require pre-augering to achieve sufficient embedment.

8.3.1 Axial Resistance

For preliminary design, the following geotechnical resistances can be used for piles founded in the very dense native soils:

| Pile Section | Geotechnical Resistance (kPa) | |
|---------------------|--------------------------------------|------------|
| | Factored ULS | SLS |
| HP 310 X 110 | 1,600 | 1,400 |
| HP 360 X 132 | 1,800 | 1,600 |

The structural resistance of the pile must be checked by the structural designer.

The highest recommended tip elevations for the H-piles are as follows:

| | Highest Pile Tip Elevation | Comments |
|---------------------------------------|---------------------------------------|--|
| North Abutment (BH 08-211) | 338.5 | A minimum pile length of 6 m must be achieved. Depending on final design, pre-augering may be required. |
| Pier (BH 08-212) | 339.0 | A minimum pile length of 6 m must be maintained. At the pier this will most probably require pre-augering. |
| South Abutment (BH 08-213) | 340.0 | A minimum pile length of 6 m must be achieved. Depending on final design, pre-augering may be required. |

Installation of the piles must be in accordance with SP 903S01 and must be controlled using the Hiley Formula and an ultimate resistance of 3,200 kN for an HP 310 X 110 and 3,600 kN for the HP 360 X 132.

These are preliminary recommendations and may change during detail design based on the final alignment, final bridge arrangement and the results of the site investigation and field testing to be completed at that time.

Higher geotechnical resistances may be achieved by installing the piles to greater depth but this will require pre-augering. For piles extending below Elevation 337 (approximately) a greater depth of exploration is required and must be addressed during the detail design phase. This analysis must also address the drivability of the piles.

8.3.2 Downdrag

Downdrag on the piles is not an issue at this site.

8.4 Abutment Design Considerations

From a geotechnical perspective, the conditions at this site are considered to be suitable for the design of conventional, semi-integral or integral abutments. Depending on final grades, integral abutment design may require pre-augering to install the piles and achieve the upper flexibility required in the upper 3 m.

8.5 Frost Depth

The design depth of frost penetration for this site is 1.4 m. All footing bases and undersides of pile caps/abutment stems must be provided with at least 1.4 m of soil cover, or an equivalent combination of soil cover and extruded polystyrene (EPS) insulation. A 25 mm thickness of EPS is equivalent to 600 mm of soil cover.

8.6 Recommended Foundation

From a geotechnical perspective, and based on current information, the recommended abutment foundation consists of steel H-piles driven into the very dense/hard native soil, despite the higher cost noted in Appendix C. The recommended foundation at the pier is a spread footing on very dense/hard soil.

9 BRIDGE APPROACHES AND EMBANKMENTS

Based on the three boreholes drilled at the site, the approach embankments will be constructed over compact, non-cohesive sandy silt till and may incorporate the sand and gravel fill of the existing embankment.

No long term settlement or global stability issues are anticipated for approach embankments built at this site. Similarly, the 3 to 5 m high embankments likely to be constructed will be stable at side slopes of 2H:1V if constructed using SSM or granular fill.

The mainline cut shown on EA Plate 21 may penetrate a short distance below the groundwater table. During detail design, when the grade has been finalized, permanent drainage and slope protection requirements must be addressed. Subject to drainage control, the cut slopes will be stable at slopes with a maximum inclination of 2H: 1V.

The potential impact on the local groundwater table should be addressed by a hydrogeologist, who should also consider the need to apply for an MOE Permit to Take Water.

10 CONSTRUCTION CONCERNS

Based on the Recommended Alignment and the preliminary geotechnical information, potential construction concerns include, but are not necessarily limited to:

1. Pile Installation

The presence of very dense/hard soil at comparatively shallow depth will limit the length of pile that can be driven. If design requires longer piles, pre-augering will be required.

2. Excavation

Hydraulic equipment is expected to be capable of excavating to the required depths at this site. If excavations advance below the existing groundwater level, groundwater control measures may have to be implemented in order to maintain stable sides and base in the excavation.

11 INVESTIGATION FOR DETAIL DESIGN

During the detail design phase of the project, additional site investigation and field testing will be required. The following minimum program is recommended:

1. Boreholes for structure foundations.

Additional boreholes may be required for the structure foundations, especially if the structure is built off the current County Road 86 alignment and thus removed from the alignment of the current investigation. Particular attention should be paid to groundwater levels and exploration off the existing road embankment is recommended.

2. Pile Design

For piles extending below Elevation 337 (approximately) a greater depth of exploration is required and must be addressed during the detail design phase.

3. Boreholes for approaches.

A minimum of one borehole is recommended in each approach fill on County Road 86. Similarly, at least one borehole is required in the mainline cut to either side of the structure. The boreholes in the cut must include piezometers for groundwater monitoring.

12 CLOSURE

Engineering analysis and preparation of the Foundation Design Report were carried out by Mr. Alastair E. Gorman, P.Eng.

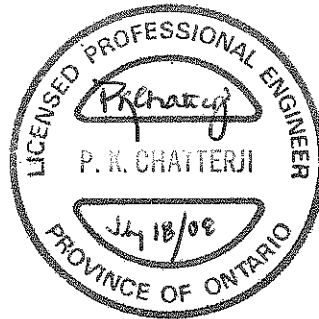
The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

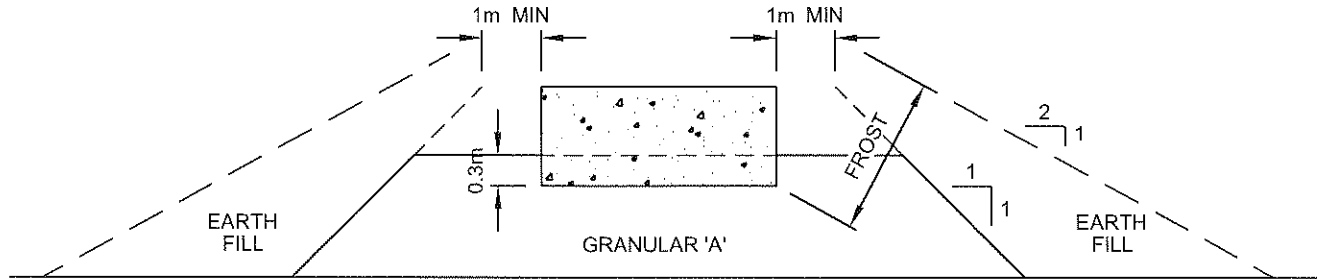
Thurber Engineering Ltd.

Alastair E. Gorman, P.Eng.,
Senior Foundations Engineer

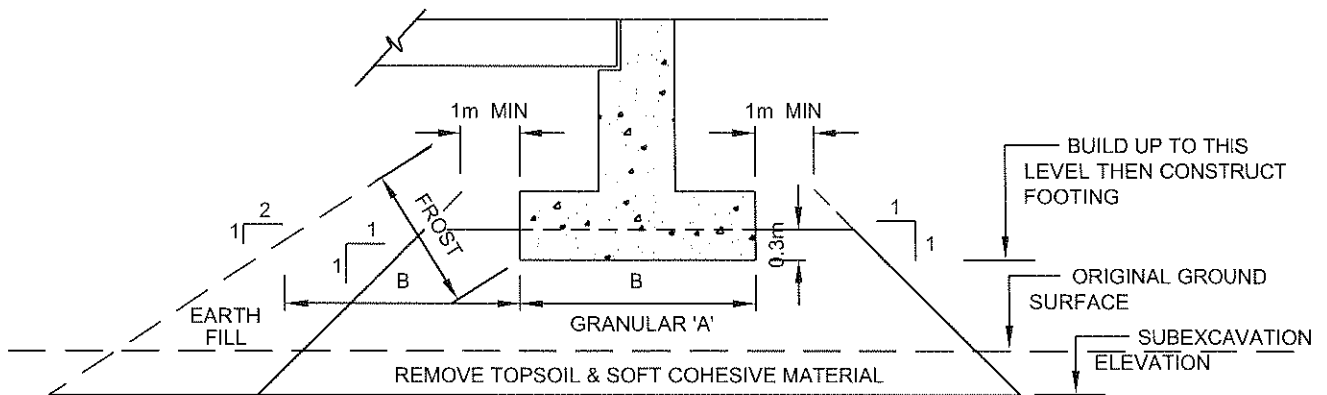


P. K. Chatterji, P.Eng.,
Review Principal





CROSS-SECTION



LONGITUDINAL SECTION

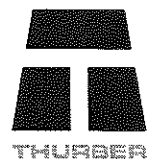
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NOTES:

1. REMOVE TOPSOIL AND SOFT SILTY CLAY SUBSOIL UNDER FOOTPRINT OF COMPACTED GRANULAR 'A'.
2. PLACE GRANULAR 'A' AND EARTH FILL TO BOTTOM OF FOOTING LEVEL, COMPACTED ACCORDING TO O.P.S.S. 501.
3. CONSTRUCT CONCRETE FOOTING.
4. PLACE REMAINDER OF GRANULAR 'A' AND EARTH FILL AS REQUIRED.
5. SOURCE M.T.C. 1982.

| | |
|----------|--------------|
| ENGINEER | AEG |
| DRAWN | SS |
| DATE | April , 2004 |
| APPROVED | PKC |
| SCALE | NTS |

ABUTMENT ON COMPACTED FILL SHOWING
GRANULAR A CORE



DWG. NO.

FIGURE 1

Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

| CLASSIFICATION | PARTICLE SIZE | VISUAL IDENTIFICATION |
|----------------|--------------------|---|
| Boulders | Greater than 200mm | same |
| Cobbles | 75 to 200mm | same |
| Gravel | 4.75 to 75mm | 5 to 75mm |
| Sand | 0.075 to 4.75mm | Not visible particles to 5mm |
| Silt | 0.002 to 0.075mm | Non-plastic particles, not visible to the naked eye |
| Clay | Less than 0.002mm | Plastic particles, not visible to the naked eye |

2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

| DESCRIPTIVE TERM | UNDRAINED SHEAR STRENGTH (kPa) | APPROXIMATE SPT ⁽¹⁾ 'N' VALUE |
|------------------|--------------------------------|--|
| Very Soft | 12 or less | Less than 2 |
| Soft | 12 to 25 | 2 to 4 |
| Firm | 25 to 50 | 4 to 8 |
| Stiff | 50 to 100 | 8 to 15 |
| Very Stiff | 100 to 200 | 15 to 30 |
| Hard | Greater than 200 | Greater than 30 |

NOTE: Hierarchy of Soil Strength Prediction

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



4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

| DESCRIPTIVE TERM | SPT "N" VALUE |
|------------------|-----------------|
| Very Loose | Less than 4 |
| Loose | 4 to 10 |
| Compact | 10 to 30 |
| Dense | 30 to 50 |
| Very Dense | Greater than 50 |

5. LEGEND FOR RECORDS OF BOREHOLES

| SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE | SS Split Spoon Sample | WS Wash Sample | AS Auger (Grab) Sample |
|---|---|--|------------------------|
| | TW Thin Wall Shelby Tube Sample | TP Thin Wall Piston Sample | |
| | PH Sampler Advanced by Hydraulic Pressure | PM Sampler Advanced by Manual Pressure | |
| | WH Sampler Advanced by Self Static Weight | RC Rock Core | SC Soil Core |

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$



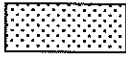


 Water Level
 Shear Strength Determination by Pocket Penetrometer

- (1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

UNIFIED SOILS CLASSIFICATION

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

EXPLANATION OF ROCK LOGGING TERMS

| ROCK WEATHERING CLASSIFICATION | | SYMBOLS | |
|--------------------------------|---|---|-------------------|
| Fresh (FR) | No visible signs of weathering. | | |
| Fresh Jointed (FJ) | Weathering limited to the surface of major discontinuities. |  | CLAYSTONE |
| Slightly Weathered (SW) | Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material. |  | SILTSTONE |
| Moderately Weathered (MW) | Weathering extends throughout the rock mass, but the rock material is not friable. |  | SANDSTONE |
| Highly Weathered (HW) | Weathering extends throughout the rock mass and the rock is partly friable. |  | COAL |
| Completely Weathered (CW) | Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved. |  | Bedrock (general) |

| DISCONTINUITY SPACING | | STRENGTH CLASSIFICATION | | | |
|-----------------------|-----------------------|-------------------------|---|---------------------|---|
| Bedding | Bedding Plane Spacing | Rock Strength | Approximate Uniaxial Compressive Strength | | Field Estimation of Hardness* |
| | | | (MPa) | (psi) | |
| Very thickly bedded | Greater than 2m | Extremely Strong | Greater than 250 | Greater than 36,000 | Specimen can only be chipped with a geological hammer |
| Thickly bedded | 0.6 to 2m | | | | |
| Medium bedded | 0.2 to 0.6m | Very Strong | 100-250 | 15,000 to 36,000 | Requires many blows of geological hammer to break |
| Thinly bedded | 60mm to 0.2m | | | | |
| Very thinly bedded | 20 to 60mm | Strong | 50-100 | 7,500 to 15,000 | Requires more than one blow of geological hammer to break |
| Laminated | 6 to 20mm | | | | |
| Thinly Laminated | Less than 6mm | Medium Strong | 25.0 to 50.0 | 3,500 to 7,500 | Breaks under single blow of geological hammer. |

| TERMS | | | | | |
|-------------------------------------|--|-----------------------|-------------|--------------|--|
| Total Core Recovery: (TCR) | Core recovered as a percentage of total core run length. | Weak | 5.0 to 25.0 | 750 to 3,500 | Can be peeled by a pocket knife with difficulty |
| Solid Core Recovery: (SCR) | Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run. | Very Weak | 1.0 to 5.0 | 150 to 750 | Can be peeled by a pocket knife, crumbles under firm blows of geological pick. |
| Rock Quality Designation: (RQD) | Total length of sound core recovered in pieces 0.1m in length or larger as a percentage of total core run length. | Extremely Weak (Rock) | 0.25 to 1.0 | 35 to 150 | Indented by thumbnail |
| Uniaxial Compressive Strength (UCS) | Axial stress required to break the specimen | | | | |
| Fracture Index: (FI) | Frequency of natural fractures per 0.3m of core run. | | | | |

RECORD OF BOREHOLE No 08-211

1 OF 1

METRIC

G.W.P. 408-88-00 LOCATION N 4 823 036.58 E 238 356.66 ORIGINATED BY SLL/WB
 HWY 7 BOREHOLE TYPE Solid Stem Augers COMPILED BY MFA
 DATUM Geodetic DATE 2008.05.20 - 2008.05.20 CHECKED BY RPR

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) | | |
|---------------|--|------------|---------|------|------------|----------------------------|-----------------|---|----|----|----|-----|---|---|--|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | | | |
| 343.7 | | | | | | | | 20 | 40 | 60 | 80 | 100 | | | | |
| 0.0 | SAND and GRAVEL Dense Brown Moist (FILL) SAND, some gravel, occasional cobbles, trace topsoil Very Dense to Dense Brown Moist (FILL) | | 1 | AS | | | | | | | | | | | | |
| 343.3 | | | | | | | | | | | | | | | | |
| 0.4 | | | | | | | | | | | | | | | | |
| | | | 1 | SS | 100/ | | | | | | | | | | | |
| | | | | | .125 | | | | | | | | | | | |
| | | | 2 | SS | 34 | | | | | | | | | | | |
| 341.8 | | | | | | | | | | | | | | | | |
| 1.9 | Sandy SILT, trace to some gravel, trace clay Dense to Very Dense Brown Moist (TILL) | | 3 | SS | 35 | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| | | | | | 4 | SS | 40 | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| | | | | | 5 | SS | 100/ | | | | | | | | | |
| 339.1 | | | | | .150 | | | | | | | | | | | |
| 4.7 | Sandy SILT, some clay, trace gravel, occasional cobbles Hard Grey Moist (TILL) | | 6 | SS | 100/ | | | | | | | | | | | |
| | | | | | | .150 | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| 336.3 | | | 7 | SS | 100/ | | | | | | | | | | | |
| 7.4 | END OF BOREHOLE AT 7.4m AND WATER LEVEL AT 2.4m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE TO 0.5m AND A MIXTURE OF BENTONITE, AUGER CUTTINGS AND SAND TO SURFACE. | | | | .100 | | | | | | | | | | | |

ONTMT4S 6417.GPJ 5/30/08

RECORD OF BOREHOLE No 08-212

1 OF 1

METRIC

G.W.P. 408-88-00 LOCATION N 4 823 000.40 E 238 375.55 ORIGINATED BY SLL
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY WM
 DATUM Geodetic DATE 2008.05.21 - 2008.05.21 CHECKED BY RPR

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|---------------|--|------------|---------|------|--------------|----------------------------|-----------------|---|-----------------|-----------------|-----------------|-----------------|--|---|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | 20 40 60 80 100 | 20 40 60 80 100 | 20 40 60 80 100 | 20 40 60 80 100 | 20 40 60 80 100 | | |
| 344.6 0.0 | SAND and GRAVEL Dense Brown Moist (FILL) | | 1 | AS | | | | | | | | | | |
| | | | 1 | SS | 38 | | 344 | | | | | | | 42 45 13 (SI+CL) |
| | | | 2 | SS | 23 | | 343 | | | | | | | 12 45 38 5 |
| 342.5 | trace topsoil | | | | | | | | | | | | | |
| 2.1 | Sandy SILT, trace clay, trace to some gravel Compact Brown Moist (TILL) | | 3 | SS | 18 | | 342 | | | | | | | |
| | | | 4 | SS | 21 | | | | | | | | | |
| 340.8 | | | | | | | 341 | | | | | | | |
| 3.8 | Sandy SILT, trace to some clay, trace gravel Hard Grey Moist (TILL) | | 5 | SS | 100/ .125 | | 340 | | | | | | | 5 29 56 10 |
| | | | 6 | SS | 100/ .125 | | 339 | | | | | | | |
| | | | | | | | 338 | | | | | | | |
| 337.2 | | | 7 | SS | 100/ .150 | | | | | | | | | 9 31 47 13 |
| 7.5 | END OF BOREHOLE AT 7.5m. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH(m) ELEV.(m) 2008.05.21 Dry - 2008.05.27 1.8 342.8 2008.06.18 2.1 342.5 | | | | | | | | | | | | | |

+³, X³: Numbers refer to Sensitivity 20 15 10 5 0 5 10 15 20 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 08-213

1 OF 2

METRIC

G.W.P. 408-88-00 LOCATION N 4 822 981.65 E 238 409.98 ORIGINATED BY SLL/WB
 HWY 7 BOREHOLE TYPE Solid Stem Augers COMPILED BY MFA
 DATUM Geodetic DATE 2008.05.20 - 2008.05.20 CHECKED BY RPR

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|---------------|--|------------|---------|------|--------------|----------------------------|-----------------|---|------------------------------------|-------------------------------------|---|---|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | 20 40 60 80 100 | PLASTIC LIMIT W _p | NATURAL MOISTURE CONTENT W | LIQUID LIMIT W _L | |
| 345.1 0.0 | SAND and GRAVEL Compact Brown Moist (FILL) | | 1 | AS | | | 345 | | | | | |
| | | | 1 | SS | 22 | | 344 | | | | | |
| | | | 2 | SS | 25 | | | | | | | |
| 343.2 1.9 | Sandy SILT, trace to some clay, trace gravel Compact to Very Dense Brown to Grey Moist to Wet (TILL) | | 3 | SS | 56 | | 343 | | | | | 17 49 29 5 |
| | | | 4 | SS | 17 | | 342 | | | | | |
| | | | 5 | SS | 100/ 250 | | 341 | | | | | 7 33 49 11 |
| | | | 6 | SS | 100/ .125 | | 340 | | | | | |
| | | | 7 | SS | 100/ .075 | | 339 | | | | | |
| 337.3 7.8 | Sandy SILT, some clay, trace gravel Hard Grey Moist (TILL) | | | | | | 338 | | | | | |
| 336.2 9.0 | END OF BOREHOLE AT 9.0m. BOREHOLE CAVED TO 3.8m AND WATER LEVEL AT 1.8m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE TO 2.7m, THEN A MIXTURE OF BENTONITE AND | | 8 | SS | 100/ .125 | | 337 | | | | | 3 34 50 13 |

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity 20
15 5
10 (%) STRAIN AT FAILURE

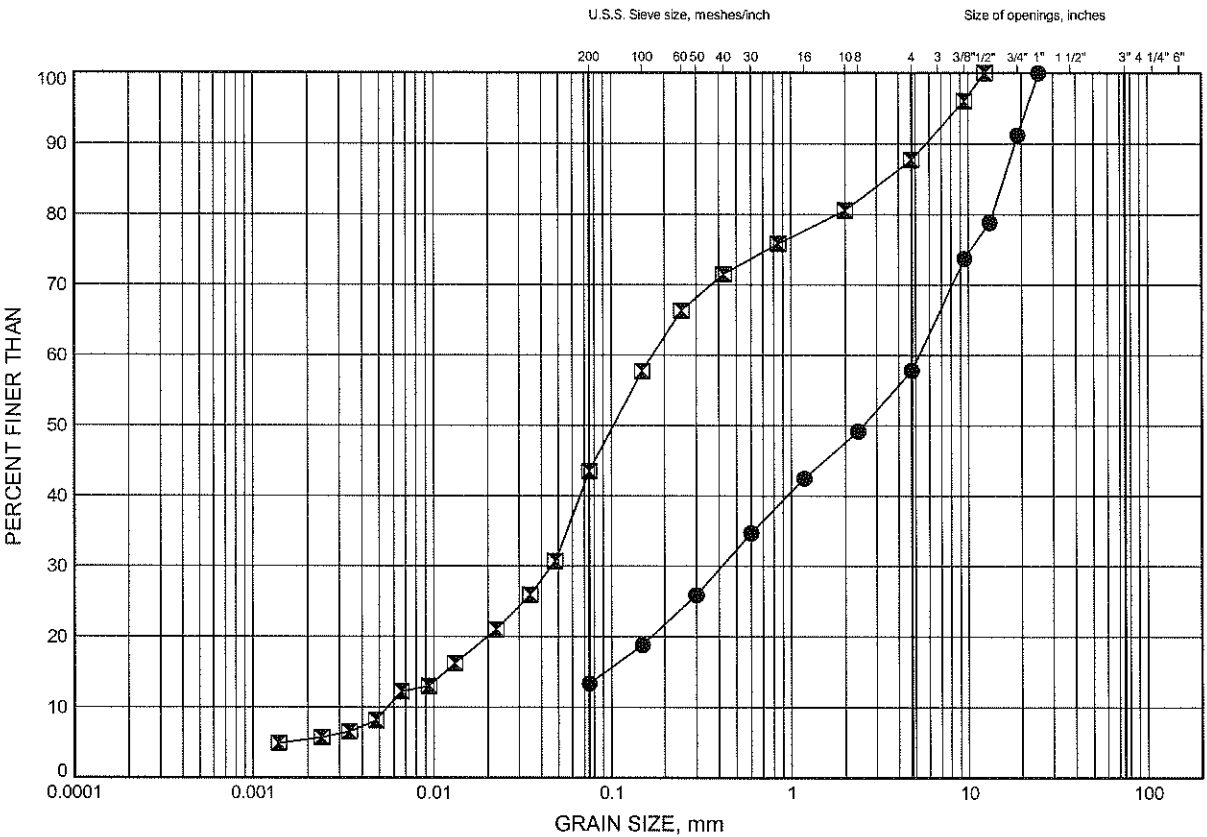
Appendix B

Laboratory Test Results

Highway 7 - New
GRAIN SIZE DISTRIBUTION

FIGURE B1

SAND AND GRAVEL FILL



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

LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|--------|----------|-----------|-----------|
| ● | 08-212 | 0.84 | 343.81 |
| ⊠ | 08-212 | 1.68 | 342.97 |

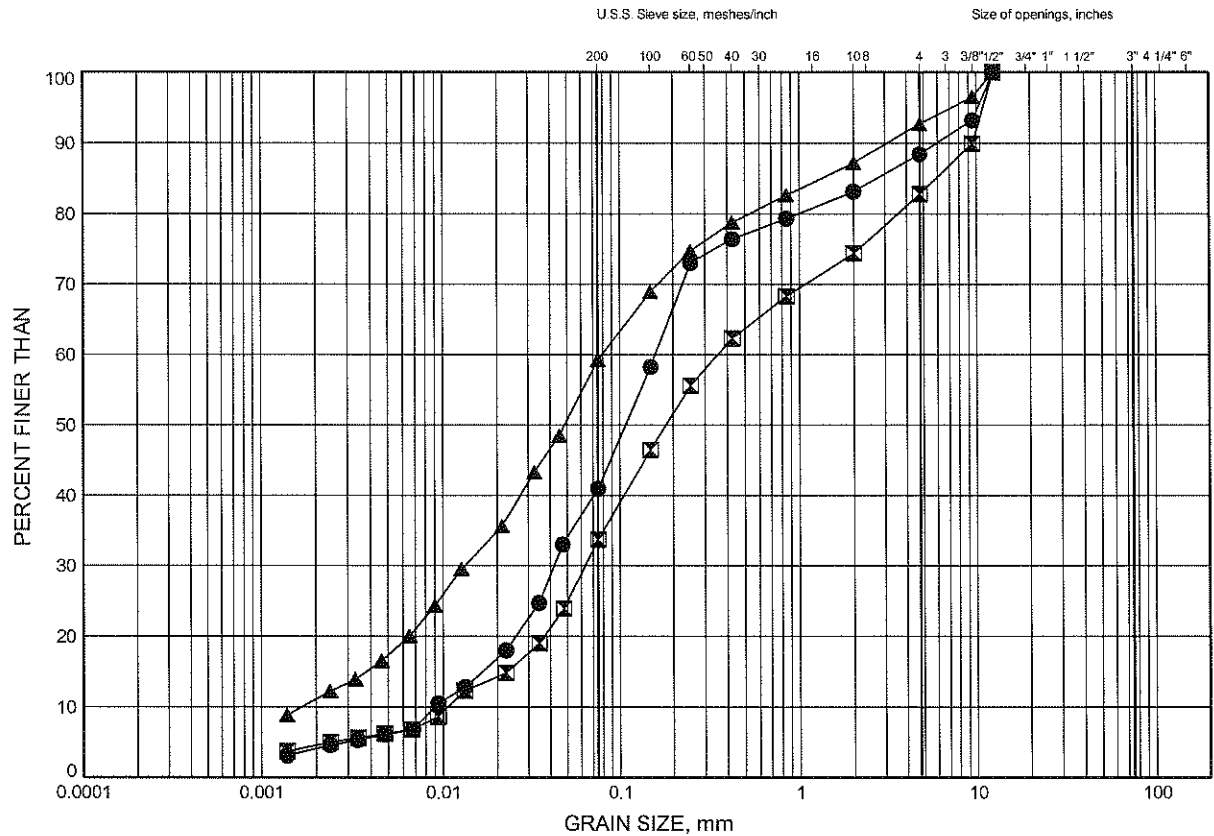


W.P.# 408-88-00
Prepared By MFA
Checked By AEG

Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE B2

UPPER SANDY SILT TILL



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

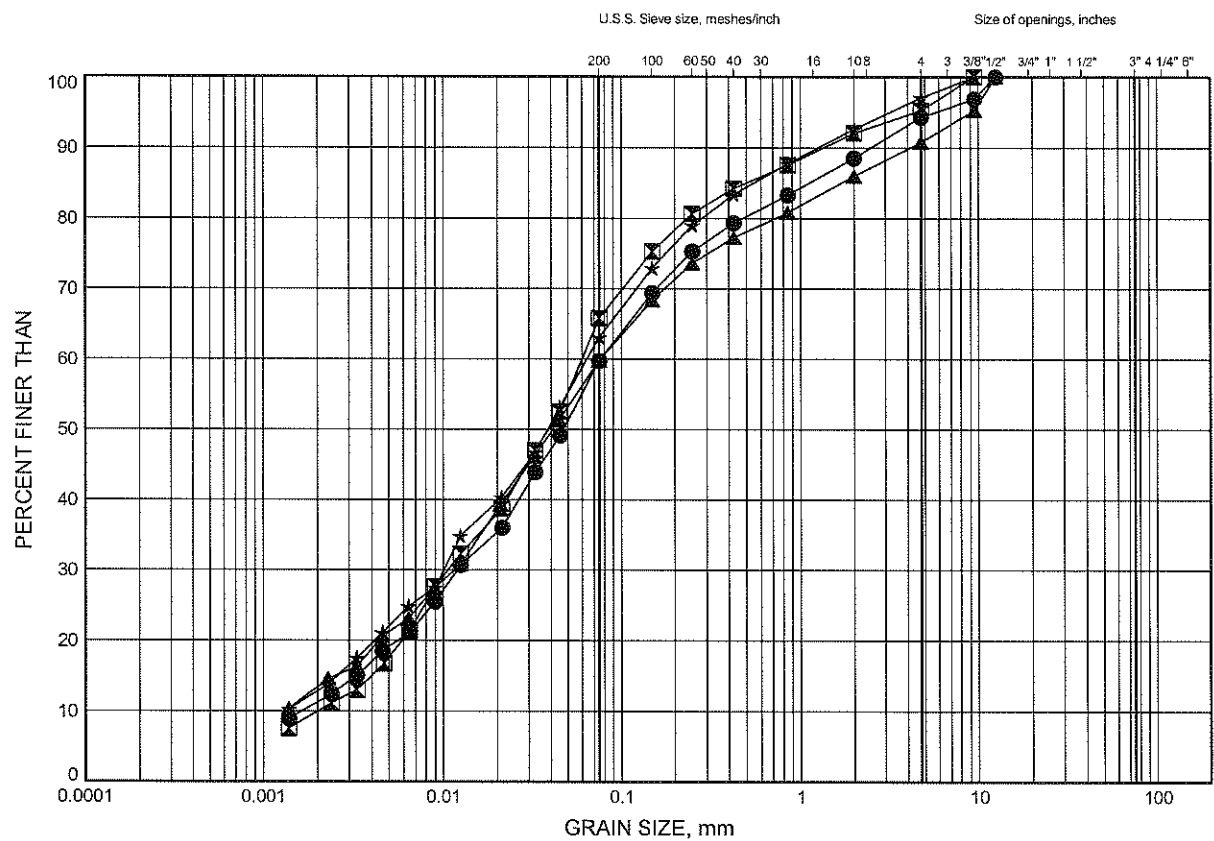
LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|--------|----------|-----------|-----------|
| ● | 08-211 | 3.05 | 340.70 |
| ◻ | 08-213 | 2.29 | 342.84 |
| ▲ | 08-213 | 4.48 | 340.65 |

Highway 7 - New
GRAIN SIZE DISTRIBUTION

FIGURE B3

LOWER SANDY SILT TILL



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

LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|--------|----------|-----------|-----------|
| ● | 08-211 | 5.87 | 337.88 |
| ■ | 08-212 | 4.40 | 340.25 |
| ▲ | 08-212 | 7.39 | 337.26 |
| ☆ | 08-213 | 8.92 | 336.21 |

GRAIN SIZE DISTRIBUTION - THURBER 6417R.GPJ 7/19/08

W.P.# 408-88-00
Prepared By MFA
Checked By AEG



Appendix C

Foundation Comparison

COMPARISON OF FOUNDATION ALTERNATIVES FOR EACH FOUNDATION ELEMENT

| Foundation Element | Spread Footings | Spread Footings on Engineered Fill | Driven Piles |
|--------------------|--|--|--|
| Abutments | <p>Advantages:</p> <ul style="list-style-type: none"> i. Generally less costly construction than deep foundation elements. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Lower geotechnical resistance available due to founding on compact soils near the surface. ii. Dewatering may be required, depending on depth of excavation. <p>NOT RECOMMENDED</p> | <p>Advantages:</p> <ul style="list-style-type: none"> i. Generally less costly construction than deep foundation elements. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Better geotechnical resistance than spread footings on native, but still influenced by the compact soils at the surface. ii. Dewatering may be required, depending on depth of excavation. <p>NOT RECOMMENDED</p> | <p>Advantages:</p> <ul style="list-style-type: none"> i. High geotechnical resistance may be developed by driving the piles into very dense/hard soils. ii. Comparatively short abutment stem possible iii. Permits integral abutment design <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Higher unit cost compared to footings. ii. Very dense/hard soils at shallow depth will limit length of pile and geotechnical resistance that can be developed. <p>RECOMMENDED</p> |
| Pier | <p>Advantages:</p> <ul style="list-style-type: none"> i. Generally less costly construction than deep foundation elements. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Dewatering may be required, depending on depth of excavation. <p>RECOMMENDED</p> | <p>Advantages:</p> <ul style="list-style-type: none"> i. Generally less costly construction than deep foundation elements. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Dewatering may be required, depending on depth of excavation. <p>NOT RECOMMENDED</p> | <p>Advantages:</p> <ul style="list-style-type: none"> i. High geotechnical resistance may be developed by driving the piles into very dense/hard soils. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Higher unit cost compared to footings. ii. Very dense/hard soils at shallow depth will limit length of pile and geotechnical resistance that can be developed. <p>NOT RECOMMENDED</p> |

Appendix D

Site Photographs

County Road 86 Underpass
Highway 7-New, Kitchener to Guelph



Photo 1. Looking north along County Road 86 – structure site in middle ground.

Photo 2.

Appendix E

Drawing

