



**DETAIL FOUNDATION INVESTIGATION AND DESIGN REPORT**

**for**

**WATERMAIN TUNNELS**

**HOWARD AVENUE/CPR GRADE SEPARATION**

**CITY OF WINDSOR**

**GWP 3030-06-00**

**DISTRICT 32, LONDON, ONTARIO**

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PML Ref.: 07TF022A-6  
Index No.: 182FIR and 183FDR  
GEOCRES No.: 40J6-22  
May 5, 2009



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Table A – List of Atterberg Limits and Moisture Content Results

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Figure PC-TU-1 and PC-TU2– Plasticity Chart

Explanation of Terms Used in Report

Record of Borehole Sheets

Drawing TU-1 – Borehole Locations Plan

**DETAIL FOUNDATION INVESTIGATION REPORT**

for  
Watermain Tunnels  
Howard Avenue/CPR Grade Separation  
GWP 3030-06-00  
City of Windsor  
District 32, London, Ontario

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**1. INTRODUCTION**

This report summarizes the results of the foundation investigation carried out for the proposed watermain tunnels included in the Howard Avenue/Canadian Pacific Railway (CPR) grade separation project in the City of Windsor, Ontario. Peto MacCallum Ltd. (PML) conducted the foundation investigation for McCormick Rankin Corporation (MRC) on behalf of the Ministry of Transportation of Ontario (MTO).

The proposed project involves construction of three watermain tunnels. For the ease of reference, PML identified tunnel locations with area numbers 1, 2 and 3. The identification number and location of tunnels are shown on the attached Drawing TU-1 and are listed below.

<b>TUNNEL LOCATION</b>	<b>AREA NO.</b>
East of Howard Avenue between Brazil Avenue and South Pacific Avenue	Area 1
East of Howard Avenue and crosses the CPR	Area 2
At the centreline of Howard Avenue and crosses the Essex Terminal Railway	Area 3

This report pertains to the watermain tunnels for the project. Other foundation facets of this project were reported separately to efficiently incorporate changes in the design. The following separate reports were prepared:

<b>PML REF. NO.</b>	<b>REPORT TITLE</b>
07TF022A-1	Canadian Pacific Railway Overhead
07TF022A-2	Retaining Walls
07TF022A-3	Road Cuts and Deep Sewers
07TF022A-4	Pumping Station
07TF022A-5	SWM Ponds
07TF022A-6	Watermain Tunnels

The Final Detail Foundation Investigation Report should be listed in SP 109F10.  
All elevations in this report are expressed in metres.



## **2. SITE DESCRIPTION AND GEOLOGY**

The project site is about 5 km north of the Highway 401/Howard Avenue Interchange in the City of Windsor. The proposed tunnel areas are located east (Areas 1 and 2) and at the centerline (Area 3) of Howard Avenue as shown on the site plan, Drawing TU-1.

Land use in the vicinity of the site comprises transportation corridors of the existing Howard Avenue, Canadian Pacific Railway, Essex Terminal Railway, Memorial Drive and other residential streets. Land use also includes professional buildings such as the Windsor Professional Centre and Aversa Family Dentistry buildings, other commercial/industrial buildings to the east and west of Howard Avenue and residential use along Memorial Drive.

The local topography of the site is generally flat. The ground cover beyond the paved roads and parking lots comprises grassed and gravel areas with local stands of trees along Howard Avenue and Memorial Drive.

The project is situated within the deep clay till glacial deposits of the Essex Clay Plain, a sub region of the St. Clair Clay Plain. Bedrock comprises middle Devonian limestone of Palaeozoic Era. The soil/bedrock interface is generally deep about 30 m.

## **3. INVESTIGATION PROCEDURES**

The subsurface investigation was carried out on October 9 and during periods from October 15 to 17, 2007 and from October 6 to 9, 2008. A total of 6 boreholes were put down (including the reused borehole 107) at the three sites and identified as boreholes T1 to T5 and 107. The T-series boreholes were drilled to a uniform depth of 5.0 m and borehole 107 was advanced to depth of 38.8 m at the locations shown on Drawing TU-1.

PML laid out and cleared the locations of the boreholes for the presence of underground services and utilities. Callon Dietz Ltd. (CD) surveyed the boreholes locations. All elevations in this report are expressed in metres and are referred to the geodetic datum.



The T-series boreholes were advanced using continuous solid stem augers and equipment powered by a track-mounted CME-55 drill rig, supplied and operated by a specialist drilling contractor, working under the full-time supervision of Field Supervisor from PML engineering staff. Borehole 107 was drilled with hollow stem augers, mud rotary drilling to the bedrock surface and extended 6.6 m into the bedrock using NQ diamond rock coring equipment.

Representative samples of the soils were recovered in the boreholes at frequent depth intervals of 0.75 and 1.5 m. The soil samples were obtained using a split spoon sampler in conjunction with standard penetration tests. Penetrometer and in-situ vane shear testing was also performed to assess the shear strength of the cohesive soils. It is noted that the results of penetrometer tests may be lower than the actual values due to sample disturbance.

The groundwater conditions at the borehole locations were assessed during drilling by visual examination of soil, the sampler and drill rods as the samples were retrieved and, when appropriate, by measurement of the water level in the open boreholes. The water level observations are noted on the attached record of boreholes. A piezometer was installed in borehole 107.

All boreholes were backfilled in accordance with the MTO guidelines and MOE Reg. 903 for borehole abandonment procedures using a bentonite/cement mixture grout.

Soils were identified in the field in accordance with the MTO Soil Classification procedures. Recovered soil samples were returned to our laboratory for detailed visual examination, soil classification and laboratory testing. The laboratory testing program included the following tests:

- Natural moisture content determinations (44)
- Grain Size analyses (12)
- Atterberg Limits (11)

The results of the laboratory natural moisture content determinations, grain size analyses and Atterberg limits are shown on the Record of Borehole sheets. The grain size distribution charts are presented on Figures GS-TU-1, GS-TU-2 and GS-TU-3. The Atterberg limits results are presented on Figures PC-TU-1 and PC-TU-2 and are listed in the attached Table A.



#### **4. SUMMARIZED SUBSURFACE CONDITIONS**

##### **4.1 General**

We refer to the attached Record of Borehole sheets for details of the subsurface conditions including soil classifications, inferred stratigraphy, soil levels and soil and rock boundary levels and groundwater observations. The results of laboratory Atterberg limits, grain size distribution analyses and natural moisture content determination are also shown on the Record of Borehole sheets.

The borehole locations are presented on the Foundation Drawing TU-1.

The strata encountered in each tunnel areas are summarized below for each of the three areas investigated.

##### **4.2 Area 1 (Boreholes T4 and T5)**

The watermain tunnel Area 1 extends along the laneway running between Brazil Avenue and South Pacific Avenue east of Howard Avenue and behind commercial buildings, such as Merrifield's Investments Ltd. and Aversa Health Care Facility Ltd.

Boreholes T4 and T5 were advanced in Area 1. The surficial soil stratigraphy revealed in the boreholes comprised 600 mm thick fill and 200 mm thick asphaltic concrete and associated pavement granular base material in borehole T5. The pavement in borehole T5 was underlain by a 200 mm thick topsoil layer. The surficial fills and locally underlying topsoil are underlain by continuous deposits of cohesive sandy clayey silt till. The glacial till deposit was found to be stiff to hard. The two boreholes terminated at 5.0 m depths within the clayey silt till deposit.

###### **4.2.1 Fill/Topsoil**

A 600 and 200 mm thick fill unit was present surficially in boreholes T4 and T5. The unit is composed of silt and sand in borehole T4 drilled at the south end of the laneway and 125 mm of asphaltic concrete over 75 mm of granular base material in borehole T5 drilled at the north end. The fill units extended to elevations 186.9 and 187.2.



Overlain by fill at 0.2 m depth (elevation 187.2), a 0.2 m thick topsoil layer was locally encountered in borehole T5 extending to 0.4 m depth (elevation 187.0).

#### 4.2.2 Sandy Clayey Silt Till

A continuous glacial till deposit of cohesive sandy clayey silt was encountered at 0.6 m depth (elevation 186.9) below the fill in borehole T4 and beneath the topsoil at 0.4 m depth (elevation 187.0) in borehole T5. The stratum extended to the 5.0 m termination depth of both boreholes (elevations 182.5 and 182.4). The till exhibited the fissured/blocks characteristics of desiccated cohesive soils.

This cohesive deposit typically exhibits stiff to very stiff consistencies with some local hard layers. N-values varied from 7 to 40.

The grain size distribution charts of representative samples of the sandy clayey silt till are included in the envelope shown on Figure GS-TU-1. The Atterberg plasticity limits are shown on the plasticity charts presented on Figure PC-TU-1. The liquid limit of the clayey silt till was 26 and 27 and the plastic limit was 14 and 15, giving the common plasticity index value of 12. The water content of the clayey silt till varied from 12 to 17%. The liquidity index value of - 0.25 and 0.25 indicated that the materials were desiccated.

#### 4.2.3 Groundwater

Groundwater was measured upon completion of drilling in borehole T5 at 4.5 m depth (elevation 182.9). No water was observed in borehole T4. It should be noted that borehole T5 was drilled near a stormwater catchbasin and a very soft and wet zone was encountered between 1.6 and 1.8 m depth (elevations 185.8 and 185.6). It is therefore inferred that the groundwater measurement in borehole T5 was likely perched water within the nearby manhole backfill. The groundwater levels are subjected to fluctuations due to seasonal and rainfall patterns.



### **4.3 Area 2 (Borehole T1 and 107)**

The watermain tunnel in Area 2 (Sta. 10+184 to 10+228) will involve the construction of a watermain tunnel beneath the CPR tracks and about 45 m to the east of Howard Avenue.

Boreholes T1 and 107 were advanced in Area 2. The soil stratigraphy revealed in the boreholes included 700 mm thick fill or 200 mm thick topsoil overlying deposits of cohesive silty clay till and clayey silt till in the boreholes. The clayey silt till extended to the limestone bedrock which was found at 38.8 m depth in borehole 107. A 1.5 m thick cohesionless and compact silty sand till was present in borehole 107 at 5.4 m depth (elevation 182.2). The upper glacial till deposits within the zone of influence of the proposed tunnel typically exhibit very stiff to hard consistencies.

#### **4.3.1 Fill/Topsoil**

A 700 mm thick fill unit was present surficially in borehole T1. The unit is composed of sand and gravel over sand and silt with pieces of coal extending to 0.7 m depth, elevation 187.2. The unit was found to be compact with one N-value of 10.

A 200 mm thick topsoil unit was encountered at the surface in borehole 107 and extending to the underlying clayey silt till at 0.2 m depth, elevation 187.4.

#### **4.3.2 Silty Clay Till**

A cohesive, 1.4 m thick silty clay till deposit was locally contacted at 0.7 m depth (elevation 187.2) beneath the fill in borehole T1. The till deposit comprised silty clay with sand and contained trace amounts of gravel. The deposit extended to the underlying sandy clayey silt till at 2.1 m depth (elevation 185.8).

The silty clay exhibited a very stiff consistency. A penetrometer test on a sample of the silty clay till indicated a shear strength of 113 kPa.

The grain size distribution chart of a representative sample of the silty clay till is shown on Figure GS-TU-2. The Atterberg plasticity limits are plotted on the plasticity chart presented on Figure PC-TU-2. The liquid limit of the silty clay till was 36 and the plastic limit 18, giving a plasticity index value of 18. The water content of the silty clay till varied from 13 to 14%. The liquidity index of one of the samples was - 0.22 indicating desiccated conditions.



#### 4.3.3 Clayey Silt Till

A continuous glacial till deposit of cohesive clayey silt and clayey silt containing variable sand content was encountered below the silty clay till or topsoil in the boreholes.

The cohesive clayey silt till was encountered below the topsoil and silty clay till at depths of 0.2 and 2.1 m (elevations 187.4 and 185.8) in boreholes 107 and T1, respectively. The stratum was locally interbedded with a 1.5 m thick layer of silty sand till at 5.4 m depth (elevation 182.2) in borehole 107. The till extended to the 5.0 m termination depth (elevation 182.9) of borehole T1. The till extended to the underlying bedrock at 38.8 m depth (elevation 148.8) in borehole 107.

The consistency of the clayey silt till was typically very stiff to hard to about 4 to 5 m depths and firm to stiff at depth. The results of in situ vane testing carried out in the lower zone of the deposit yielded undisturbed shear strength values in a typical range of 50 to 100 kPa (soil sensitivity of 2). Penetrometer tests on samples of the till indicated a shear strength varying between 20 and 100 kPa. Unconfined compression testing on a representative sample of the deposit gave an undrained shear strength value of 31 kPa (strain at failure of 13%).

The envelope of grain size distribution charts of representative samples of the clayey silt till is shown on Figure GS-TU-1. The Atterberg plasticity limits are plotted on the Plasticity Chart presented on Figure PC-TU-1. The liquid limits of the cohesive glacial till ranged from 24 to 30 and the plastic limits from 13 to 16, giving the plasticity index values of 11 to 15. The water content of the cohesive glacial till varied from 13 to 20%. The liquidity index of the values in two soil samples obtained within the upper 4.5 m zone was – 0.15 while samples from three boreholes 107 taken below the 4.5 m depth decreased with depth from 0.50 to 0.33, indicating lesser desiccation characteristics at depth.

#### 4.3.4 Silty Sand Till

A localized 1.5 m thick deposit of silty sand till was interbedded between 5.4 and 6.9 m depths (elevation 182.2 and 180.7) within the clayey silt till in borehole 107. The layer was found to be compact with a single N-value of 21.

The grain size distribution chart of a representative sample of the silty sand till is shown on Figure GS-TU-3. The tested silty sand till sample was non-plastic according to Atterberg



determination and manual examination. The water content of the silty sand till was 18%, indicating wet conditions.

#### 4.3.5 Bedrock

Limestone bedrock was encountered below the clayey silt till deposit in borehole 107 at 38.8 m depth (elevation 148.8). The bedrock was cored for 6.6 m in borehole 107.

#### 4.3.6 Groundwater

No water was observed in borehole T1 during or upon completion of drilling. A piezometer was installed adjacent to borehole 107 and readings indicated water levels at 17.0 m depth or deeper, elevation 170.6 as shown on the record of borehole sheet. The water content profile in the boreholes and the piezometer observations indicate that the groundwater at this site is located below a depth of about 6.0 m. Perched water conditions are likely to occur with the upper desiccated and fissured clayey till soils.

It is noted that the groundwater levels are subjected to fluctuations due to seasonal and rainfall patterns.

### 4.4 Area 3 (Boreholes T2 and T3)

The watermain tunnel in Area 3 extends beneath the Essex Terminal Railway tracks along the centerline of Howard Avenue.

Boreholes T2 and T3 were advanced in Area 3. The soil stratigraphy revealed in the boreholes generally included 500 and 600 mm thick pavement fills overlying 400 and 100 mm thick topsoil layers underlain by deposits of glacial silty clay till and/or clayey silt till. The till deposits exhibit stiff to hard consistencies. Both boreholes terminated at 5.0 m depth (elevation 183.6).

#### 4.4.1 Pavement

Boreholes T2 and T3 were drilled from Howard Avenue and encountered 500 and 600 mm thick pavement fill structures. The units included 280 mm of asphaltic concrete over a 200 mm concrete slab in borehole T2 and 25 mm of asphaltic concrete over a 280 mm thick concrete slab over a 250 mm granular base material in borehole T3.



The pavement structures extended to 0.5 and 0.6 m depths, elevations 188.1 and 188.0.

#### 4.4.2 Topsoil

A 400 and 100 mm thick layer of buried topsoil was present below the pavements in boreholes T2 and T3, respectively and extended to depths of 0.9 and 0.7 m (elevations 187.7 and 187.9).

#### 4.4.3 Clayey Silt Till/Silty Clay Till

Continuous glacial till deposits of cohesive clayey silt till with discontinuous slightly more plastic silty clay till layers were encountered below the topsoil at depths of 0.9 and 0.7 m (elevations 187.7 and 187.9) in boreholes T2 and T3, respectively. The deposit extended to the 5.0 m termination depth (elevation 183.6) of both boreholes. The soils exhibited a fissured structure which is typical of desiccated cohesive deposits.

These glacial tills typically exhibit very stiff to hard consistencies with local stiff layers. N-values varied from 9 to 35.

The grain size distribution charts of representative samples of the clayey silt till were included in the envelope shown on Figure GS-TU-1. The Atterberg plasticity limits were plotted on the plasticity chart presented on Figure PC-TU-1. The range of liquid limits of the clayey silt till in this area was between 22 and 28 and the range of the plastic limit values was between 13 and 16, giving the plasticity index values of 9 to 12. The water content of the cohesive glacial till ranged from 12 to 19%. The liquidity index values of the clayey silt till samples ranged between - 0.33 and 0.11, indicating that the materials typically are desiccated.

#### 4.4.4 Groundwater

No water was observed in any of the boreholes during or upon completion of drilling. Based on the water content profile of the soil samples in both boreholes, it is considered that the groundwater table is located below the depths investigated. Perched water conditions are likely in these soils within the fissures found in the soil samples.

The groundwater levels are subjected to fluctuations due to seasonal and rainfall patterns.



## 5. MISCELLANEOUS

The field work was carried out under the supervision of Mr. M. Rapsey, Senior Technician and the direction of Mr. C.M.P. Nascimento, P.Eng., Senior Project Engineer. Aardvark Drilling Inc. supplied the drilling equipment. The laboratory work was carried out in the PML laboratory in Toronto.

This Detail Foundation Investigation Report was prepared by Mr. C.M.P. Nascimento, P.Eng., with the assistance of Ms. N.S. Balakumaran, E.I.T., and was independently reviewed by Mr. B. R. Gray, MEng, P.Eng., MTO Designated Principal Contact.

Yours very truly,

Peto MacCallum Ltd.



C. M. P. Nascimento, P.Eng.  
Senior Project Engineer



Brian R. Gray, MEng, P.Eng.  
MTO Designated Principal Contact

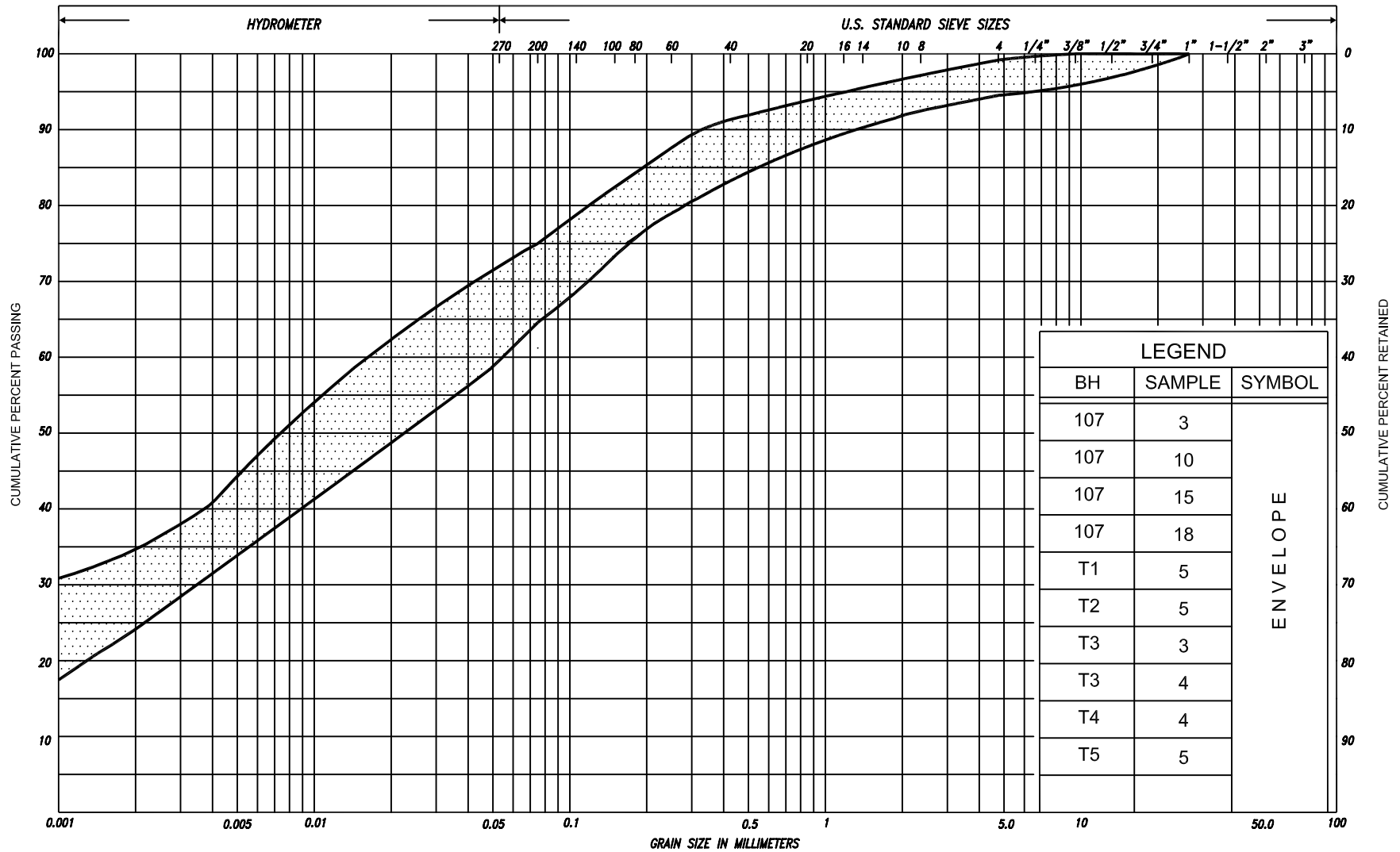
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**TABLE A**  
**LIST OF ATTERBERG LIMITS AND MOISTURE CONTENT RESULT**

SOIL TYPE	BOREHOLE NO.	SAMPLE NO.	SAMPLE DEPTH (m)	ELEVATION (m) *	LIQUID LIMIT (W <sub>L</sub> )	PLASTIC LIMIT (W <sub>P</sub> )	PLASTICITY INDEX (PI)	MOISTURE CONTENT (W)	LIQUIDITY INDEX
Silty Clay Till	T1	3	1.5 – 2.1	186.4	36	18	18	14	- 0.22
Clayey Silt Till to Sandy Clayey Silt Till	T1	5	3.1 – 3.5	184.8	28	15	13	13	- 0.15
	107	3	1.5 – 2.0	186.1	28	15	13	13	- 0.15
	T3	3	2.3 – 2.7	186.3	25	15	10	13	- 0.20
	T3	4	3.1 – 3.5	185.5	28	16	12	12	- 0.33
	T4	4	3.1 – 3.5	184.4	27	15	12	12	- 0.25
	T2	5	4.6 – 5.0	184.0	22	13	9	14	0.11
	T5	5	4.6 – 5.0	182.8	26	14	12	17	0.25
	107	10	9.1 – 9.6	178.5	26	14	12	20	0.50
	107	15	16.8 – 17.3	170.8	24	13	11	18	0.45
	107	18	24.4 – 24.9	163.2	30	15	15	20	0.33

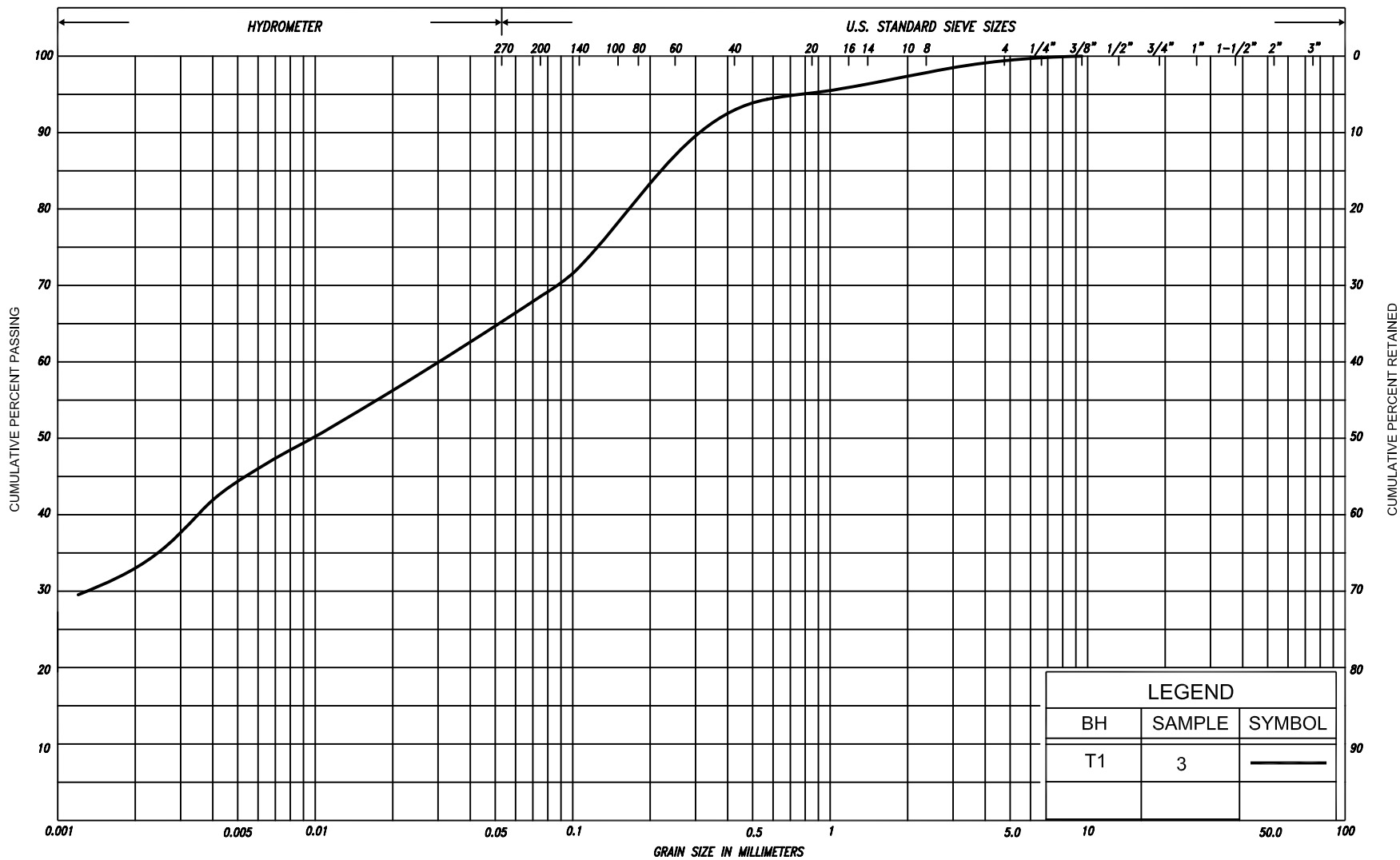
\* Elevation listed is the top of sample



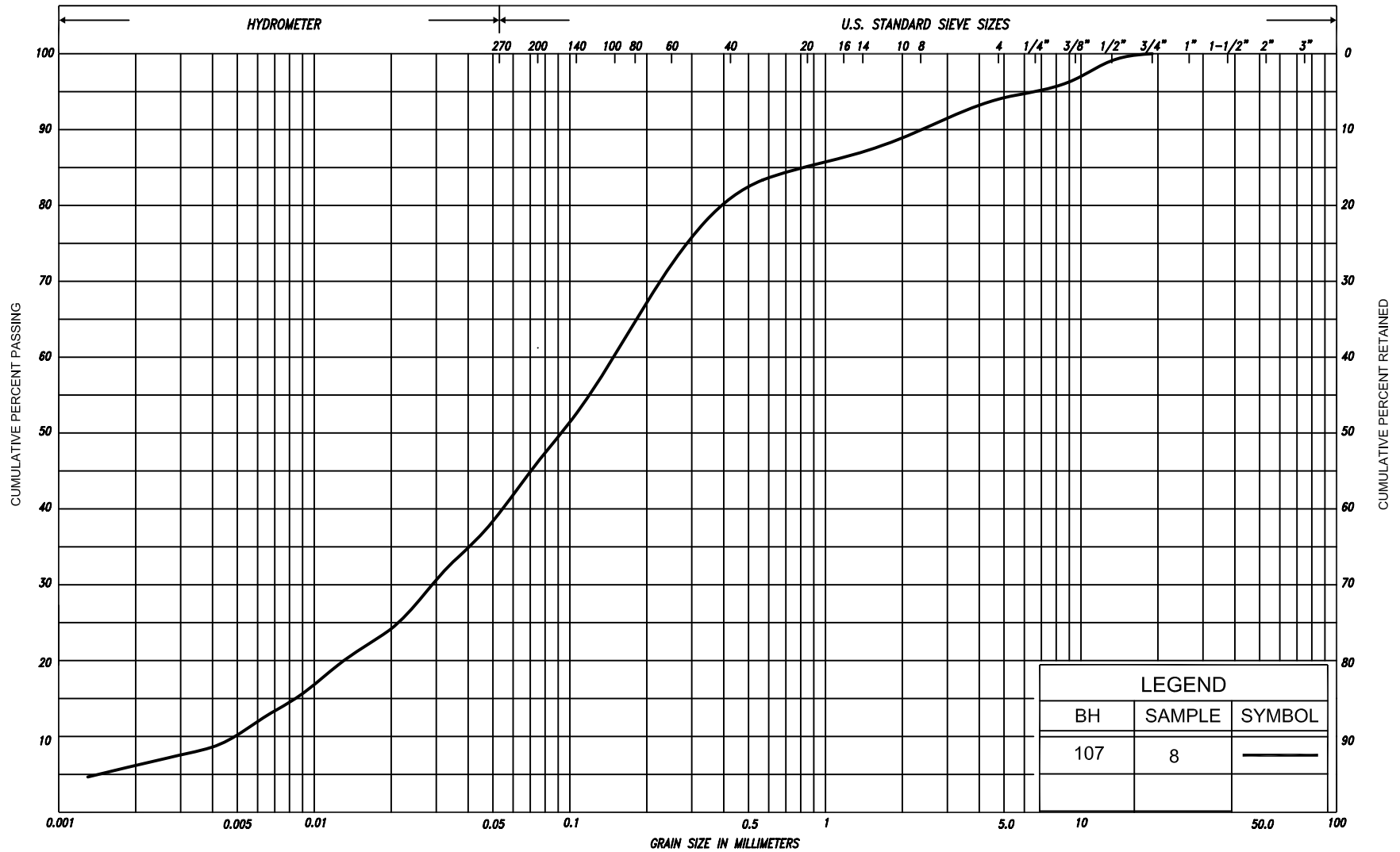
SILT & CLAY				FINE		MEDIUM		COARSE		GRAVEL				COBBLES	UNIFIED			
				SAND														
CLAY	FINE		MEDIUM		COARSE		FINE		MEDIUM		COARSE		GRAVEL			COBBLES	M.I.T.	
	SILT								SAND								U.S. BUREAU	
CLAY		SILT			V. FINE	FINE	MED.	COARSE		GRAVEL								
					SAND													

# GRAIN SIZE DISTRIBUTION CLAYEY SILT, with sand to sandy, trace gravel (TILL)

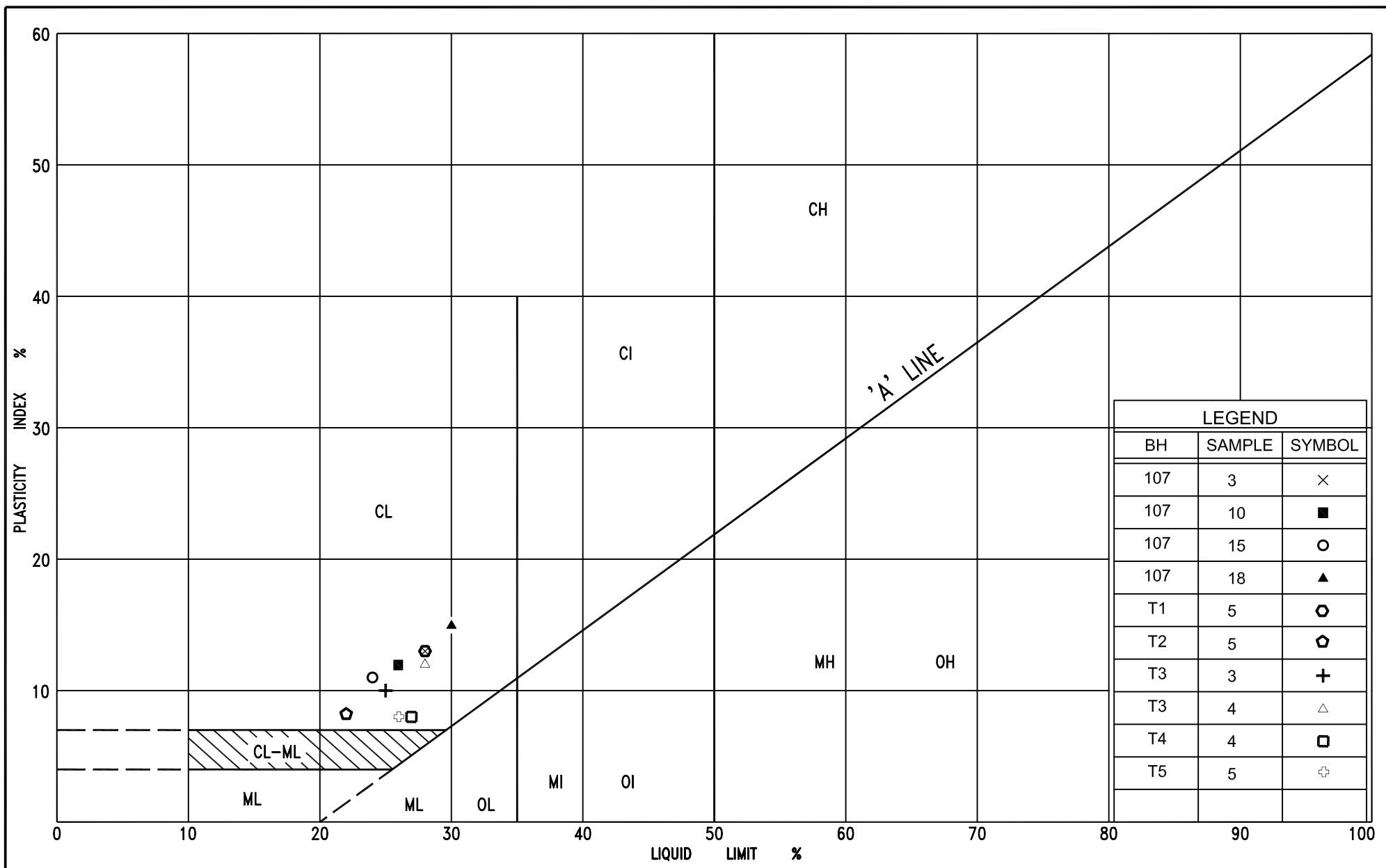
FIG No. GS-TU-1  
HWY: HOWARD AVENUE  
G.W.P. No. 3030-06-00

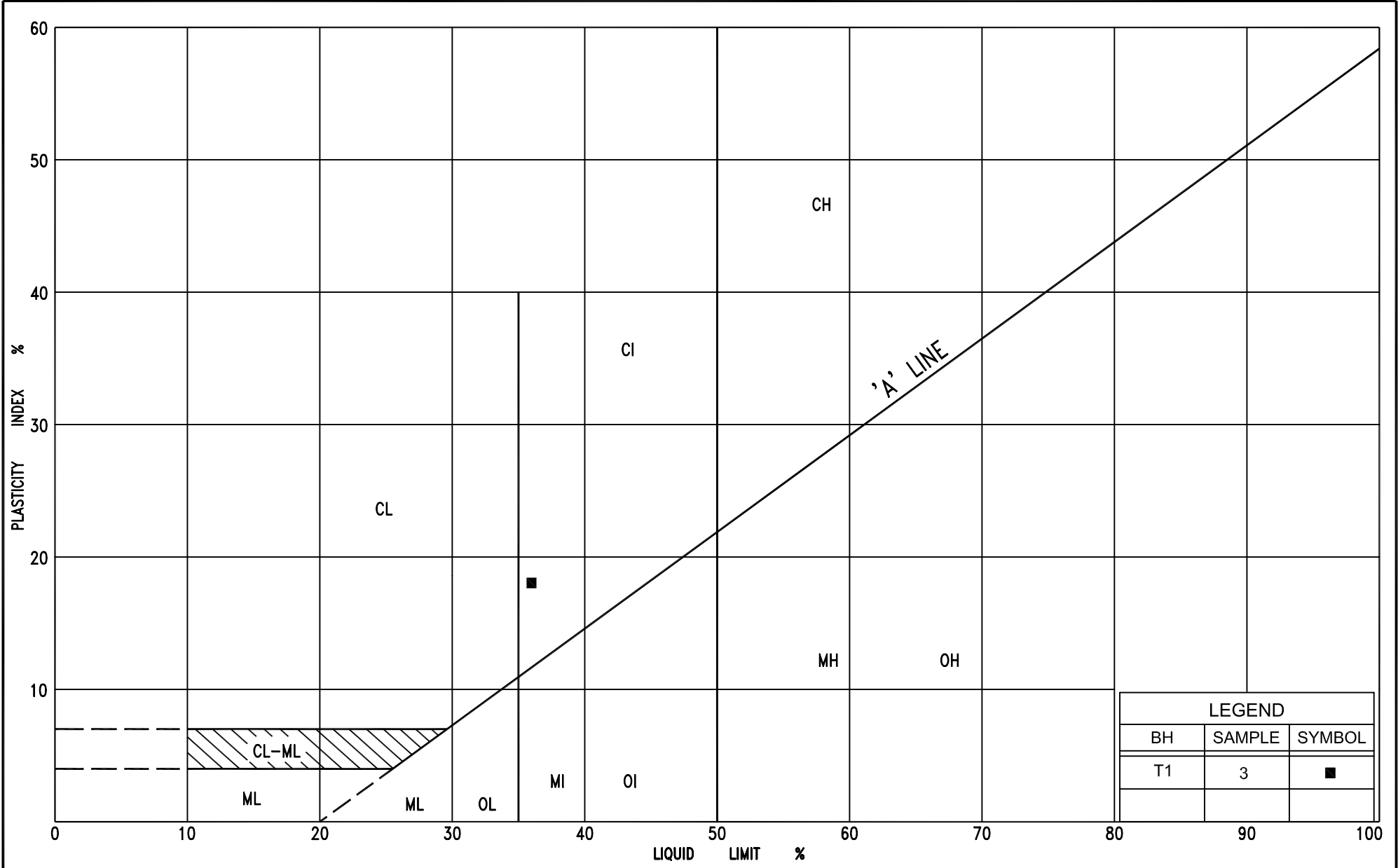


SILT & CLAY					FINE		MEDIUM		COARSE		GRAVEL			COB BLES	UNIFIED		
					SAND												
CLAY	FINE		MEDIUM		COARSE		FINE		MEDIUM		COARSE		GRAVEL			COBBLES	M.I.T.
	SILT																
CLAY		SILT			V. FINE	FINE	MED.	COARSE	GRAVEL							U.S. BUREAU	
					SAND												



SILT & CLAY					FINE		MEDIUM		COARSE	GRAVEL			COBBLES	UNIFIED
					SAND									
CLAY	FINE		MEDIUM	COARSE	FINE		MEDIUM		COARSE	GRAVEL			COBBLES	M.I.T.
	SILT						SAND							
CLAY		SILT			V. FINE	FINE	MED.	COARSE	GRAVEL					U.S. BUREAU
					SAND									





LEGEND		
BH	SAMPLE	SYMBOL
T1	3	■

## EXPLANATION OF TERMS USED IN REPORT

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

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

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

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

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

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

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

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

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

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

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

**JOINTING AND BEDDING:**

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

## ABBREVIATIONS AND SYMBOLS

### FIELD SAMPLING

S S	SPLIT SPOON	T P	THINWALL PISTON
W S	WASH SAMPLE	O S	OSTERBERG SAMPLE
S T	SLOTTED TUBE SAMPLE	R C	ROCK CORE
B S	BLOCK SAMPLE	P H	T W ADVANCED HYDRAULICALLY
C S	CHUNK SAMPLE	P M	T W ADVANCED MANUALLY
T W	THINWALL OPEN	F S	FOIL SAMPLE
F V	FIELD VANE		

### STRESS AND STRAIN

$u_w$	kPa	PORE WATER PRESSURE
$u$	1	PORE PRESSURE RATIO
$\sigma$	kPa	TOTAL NORMAL STRESS
$\sigma'$	kPa	EFFECTIVE NORMAL STRESS
$\tau$	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
$\epsilon$	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
$\mu$	1	COEFFICIENT OF FRICTION

### MECHANICAL PROPERTIES OF SOIL

$m_v$	$\text{kPa}^{-1}$	COEFFICIENT OF VOLUME CHANGE
$C_c$	1	COMPRESSION INDEX
$C_s$	1	SWELLING INDEX
$C_\alpha$	1	RATE OF SECONDARY CONSOLIDATION
$c_v$	$\text{m}^2/\text{s}$	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
$T_v$	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
$\sigma'_{vo}$	kPa	EFFECTIVE OVERBURDEN PRESSURE
$\sigma'_p$	kPa	PRECONSOLIDATION PRESSURE
$\tau_f$	kPa	SHEAR STRENGTH
$c'$	kPa	EFFECTIVE COHESION INTERCEPT
$\phi'$	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
$c_u$	kPa	APPARENT COHESION INTERCEPT
$\phi_u$	-°	APPARENT ANGLE OF INTERNAL FRICTION
$\tau_R$	kPa	RESIDUAL SHEAR STRENGTH
$\tau_r$	kPa	REMOULDED SHEAR STRENGTH
$S_t$	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

### PHYSICAL PROPERTIES OF SOIL

$\rho_s$	$\text{kg}/\text{m}^3$	DENSITY OF SOLID PARTICLES	n	1, %	POROSITY	$e_{\max}$	1, %	VOID RATIO IN LOOSEST STATE
$\gamma_s$	$\text{kN}/\text{m}^3$	UNIT WEIGHT OF SOLID PARTICLES	w	1, %	WATER CONTENT	$e_{\min}$	1, %	VOID RATIO IN DENSEST STATE
$\rho_w$	$\text{kg}/\text{m}^3$	DENSITY OF WATER	$S_r$	%	DEGREE OF SATURATION	$I_D$	1	DENSITY INDEX = $\frac{e_{\max} - e}{e_{\max} - e_{\min}}$
$\gamma_w$	$\text{kN}/\text{m}^3$	UNIT WEIGHT OF WATER	$w_L$	%	LIQUID LIMIT	D	mm	GRAIN DIAMETER
$\rho$	$\text{kg}/\text{m}^3$	DENSITY OF SOIL	$w_p$	%	PLASTIC LIMIT	$D_n$	mm	n PERCENT - DIAMETER
$\gamma$	$\text{kN}/\text{m}^3$	UNIT WEIGHT OF SOIL	$w_s$	%	SHRINKAGE LIMIT	$C_u$	1	UNIFORMITY COEFFICIENT
$\rho_d$	$\text{kg}/\text{m}^3$	DENSITY OF DRY SOIL	$I_p$	%	PLASTICITY INDEX = $w_L - w_p$	h	m	HYDRAULIC HEAD OR POTENTIAL
$\gamma_d$	$\text{kN}/\text{m}^3$	UNIT WEIGHT OF DRY SOIL	$I_L$	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	q	$\text{m}^3/\text{s}$	RATE OF DISCHARGE
$\rho_{\text{sat}}$	$\text{kg}/\text{m}^3$	DENSITY OF SATURATED SOIL	$I_C$	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	v	m/s	DISCHARGE VELOCITY
$\gamma_{\text{sat}}$	$\text{kN}/\text{m}^3$	UNIT WEIGHT OF SATURATED SOIL	DTPL		DRIER THAN PLASTIC LIMIT	i	1	HYDRAULIC GRADIENT
$\rho'$	$\text{kg}/\text{m}^3$	DENSITY OF SUBMERGED SOIL	APL		ABOUT PLASTIC LIMIT	k	m/s	HYDRAULIC CONDUCTIVITY
$\gamma'$	$\text{kN}/\text{m}^3$	UNIT WEIGHT OF SUBMERGED SOIL	WTPL		WETTER THAN PLASTIC LIMIT	j	$\text{kN}/\text{m}^2$	SEEPAGE FORCE
e	1, %	VOID RATIO						

**RECORD OF BOREHOLE No 107**

1 of 4

**METRIC**

G.W.P. 3030-06-00 LOCATION Co-ords: 4 684 048 N; 334 075 E ORIGINATED BY M.R.  
DIST 32 HWY Howard Avenue BOREHOLE TYPE C.F.H.S.A. + Mud Rotary + NQ Coring COMPILED BY M.N.  
DATUM Geodetic DATE October 15 to 17, 2007 and October 6 to 8, 2008 CHECKED BY C.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	*N VALUES			SHEAR STRENGTH kPa					w <sub>p</sub>	w	w <sub>L</sub>		GR	SA	SI	CL	
								○ UNCONFINED	● QUICK TRIAXIAL	+ FIELD VANE	× LAB VANE	WATER CONTENT (%)									
187.6	Ground Surface																				
0.0	Topsoil																				
187.4	Clayey silt with sand, trace gravel		1	SS	12																
0.2	Stiff to Brown Moist hard (TILL)		2	SS	13																
			3	SS	24																
			4	SS	25																
			5	SS	37																
	Mottled grey		6	SS	30																
	Grey		7	SS	12																
182.2	Silty sand trace clay, trace gravel																				
5.4	Compact Grey Wet (TILL)		8	SS	21																
180.7	Clayey silt with sand, trace gravel																				
6.9	Firm to Grey Moist stiff (TILL)		9	SS	3																
			FV																		
		10	TW	PH																	
			FV																		
		11	SS	6																	
			FV																		
		12	SS	4																	
			FV																		
		13	SS	3																	
			FV																		
172.6																					

**RECORD OF BOREHOLE No 107**

2 of 4

**METRIC**

G.W.P. 3030-06-00 LOCATION Co-ords: 4 684 048 N; 334 075 E ORIGINATED BY M.R.  
DIST 32 HWY Howard Avenue BOREHOLE TYPE C.F.H.S.A. + Mud Rotary + NQ Coring COMPILED BY M.N.  
DATUM Geodetic DATE October 15 to 17, 2007 and October 6 to 8, 2008 CHECKED BY C.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT		LIQUID LIMIT	UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		w <sub>p</sub>	w			
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE					
172.6							20	40	60	80	100			
15.0	Clayey silt with sand, trace gravel  Firm to Grey Moist stiff (TILL)		14	SS	4									
				FV										
			15	SS	4									
			16	SS	5									
			17	SS	7									
			18	SS	7									
			19	SS	7									

**METRIC**








**+<sup>7</sup>, ×<sup>5</sup>:** Numbers refer to Sensitivity

**RECORD OF BOREHOLE No 107**

4 of 4

**METRIC**

G.W.P. 3030-06-00 LOCATION Co-ords: 4 684 048 N; 334 075 E ORIGINATED BY M.R.  
DIST 32 HWY Howard Avenue BOREHOLE TYPE C.F.H.S.A. + Mud Rotary + NQ Coring COMPILED BY M.N.  
DATUM Geodetic DATE October 15 to 17, 2007 and October 6 to 8, 2008 CHECKED BY C.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL															
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>																	
142.6 45.0																																
142.2 45.4	End of borehole																															
	* 2008 10 16   Water level measured after drilling   Penetrometer test  Piezometer Legends :   Bentonite seal  Filter sand  Screen  Bentonite bed  Native bed  Water Level Readings : <table border="1"> <thead> <tr> <th>Date</th> <th>Depth (m)</th> <th>Elev.</th> </tr> </thead> <tbody> <tr> <td>10/08/2008</td> <td>19.3</td> <td>168.3</td> </tr> <tr> <td>10/10/2008</td> <td>18.9</td> <td>168.7</td> </tr> <tr> <td>10/14/2008</td> <td>17.7</td> <td>169.9</td> </tr> <tr> <td>10/15/2008</td> <td>17.4</td> <td>170.2</td> </tr> <tr> <td>10/16/2008</td> <td>17.0</td> <td>170.6</td> </tr> </tbody> </table> C.F.H.S.A: denotes Continuous Flight Hollow Stem Augers	Date	Depth (m)	Elev.	10/08/2008	19.3	168.3	10/10/2008	18.9	168.7	10/14/2008	17.7	169.9	10/15/2008	17.4	170.2	10/16/2008	17.0	170.6													
Date	Depth (m)	Elev.																														
10/08/2008	19.3	168.3																														
10/10/2008	18.9	168.7																														
10/14/2008	17.7	169.9																														
10/15/2008	17.4	170.2																														
10/16/2008	17.0	170.6																														

**RECORD OF BOREHOLE No T1**

1 of 1

**METRIC**

G.W.P. 3030-06-00 LOCATION Co-ords: 4 683 993 N; 334 111 E ORIGINATED BY M.R.  
DIST 32 HWY Howard Avenue BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY N.S.B  
DATUM Geodetic DATE October 09, 2008 CHECKED BY C.N.
































SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS *	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					w <sub>p</sub> w w <sub>L</sub>				
187.9	Ground Surface						20	40	60	80	100						
0.0	Sand and gravel, trace silt Brown Moist		1	SS	10								○				
187.2	Sand and silt, some gravel coal inclusions Brown Moist (FILL)		2	SS	10								○				
0.7	Silty clay with sand, trace gravel fissured, oxidized stains		3	SS	6								○	—		1 30 36 33	
185.8	Very stiff Brown Moist (TILL)		4	SS	27								○				
2.1	Clayey silt sandy, trace gravel fissured, oxidized stains		5	SS	33								○	—		2 31 38 29	
	Very stiff Grey Moist to hard (TILL)												○	—			
	Stiff																
182.9			6	SS	14								○				
5.0	End of borehole																
	* Borehole dry																
	■ Penetrometer test																

**RECORD OF BOREHOLE No T2**

1 of 1

**METRIC**

G.W.P. 3030-06-00 LOCATION Co-ords: 4 684 217 N; 333 969 E ORIGINATED BY M.R.  
 DIST 32 HWY Howard Avenue BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY N.S.B  
 DATUM Geodetic DATE October 09, 2008 CHECKED BY C.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS *	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE									
								WATER CONTENT (%)									
188.6 0.0	Ground Surface 280mm asphaltic concrete over 200mm concrete						20	40	60	80	100						
188.1 0.5	(FILL)																
187.7 0.9	Topsoil																
	Silty clay with sand, trace gravel fissured, oxidized stains		1	SS	10								○				
	Stiff      Brown      Moist (TILL)		2	SS	9								○				
186.5 2.1	Clayey silt with sand, trace gravel fissured, oxidized stains												○				
	Hard to      Brown      Moist very stiff																
	(TILL)		4	SS	28								○				
	sandy      —      —      —      —																
																	
																	
																	
																	
																	
																	
																	
																	
																	
																	
																	
																	
																	
																	
																	
																	
																	
																	
																	
																	
																	
																	
183.6 5.0	End of borehole																
	*      Borehole dry																

**RECORD OF BOREHOLE No T3**

1 of 1

**METRIC**

G.W.P. 3030-06-00 LOCATION Co-ords: 4 684 266 N; 333 957 E ORIGINATED BY M.R.  
 DIST 32 HWY Howard Avenue BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY N.S.B  
 DATUM Geodetic DATE October 09, 2008 CHECKED BY C.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS *	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED		+ FIELD VANE								● QUICK TRIAXIAL		× LAB VANE
188.6 0.0	Ground Surface						20	40	60	80	100									
188.0 0.6	25mm asphaltic concrete over 280mm concrete over 250mm crushed sand and gravel, some silt																			
187.9 0.7	Brown Moist (FILL)		1	SS	11								○							
	Topsoil																			
	Clayey silt with sand, trace gravel fissured, oxidized stains		2	SS	20								○							
	Stiff to Brown Moist hard																			
	(TILL)		3	SS	27								○	—		4 28 37 31				
	sandy		4	SS	35								○	—		1 31 39 29				
183.6 5.0	End of borehole		5	SS	19								○							
	* Borehole dry																			

**RECORD OF BOREHOLE No T4**

1 of 1

**METRIC**

G.W.P. 3030-06-00 LOCATION Co-ords: 4 683 953 N; 334 123 E ORIGINATED BY M.R.  
 DIST 32 HWY Howard Avenue BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY N.S.B.  
 DATUM Geodetic DATE October 09, 2008 CHECKED BY C.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS *	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE												
187.5	Ground Surface						20	40	60	80	100									
0.0	Silt and sand, some gravel																			
186.9	Brown Moist																			
0.6	(FILL)																			
	Clayey silt sandy, trace gravel fissured, blocky		1	SS	18								○							
	Very stiff Brown Moist to hard		2	SS	31								○							
	(TILL)																			
			3	SS	36								○							
			4	SS	37								○							
	Stiff Grey												○							

**METRIC**

**+<sup>7</sup>, ×<sup>5</sup>:** Numbers refer to Sensitivity

20  
15 — ○ — 5  
10

(%) STRAIN AT FAILURE

METRIC

DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES UNLESS  
OTHERWISE SHOWN. STATIONS  
IN KILOMETRES + METRES

CONT No

GWP No 3030-06-00

WATERMAINS TUNNELS

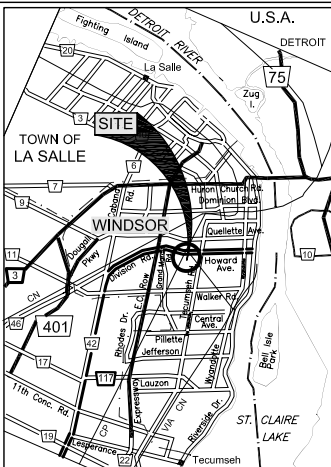
HOWARD AVENUE/ CPR GRADE SEPARATION

BOREHOLE LOCATIONS AND SOIL STRATA



SHEET

**PMI Peto MacCallum Ltd.**  
CONSULTING ENGINEERS



KEY PLAN

SCALE

2 0 2 4 6km

LEGEND

- Borehole
- Dynamic Cone Penetration Test (Cone)
- Borehole & Cone
- N Blows/0.3m (Std. Pen Test, 475 J/blow)
- CONE Blows/0.3m (60° Cone, 475 J/blow)
- W L at time of investigation Oct 2008
- Head
- ARTESIAN WATER
- Encountered
- PIEZOMETER

BH No	ELEVATION	COORDINATES	
		NORTHINGS	EASTINGS
107	187.6	4 684 048	334 075
T1	187.9	4 683 993	334 111
T2	188.6	4 684 217	333 969
T3	188.6	4 684 266	333 957
T4	187.5	4 683 953	334 123
T5	187.4	4 683 896	334 119

— NOTE —

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

REVISIONS	DATE	BY	DESCRIPTION

Geocres No. 40J6-22

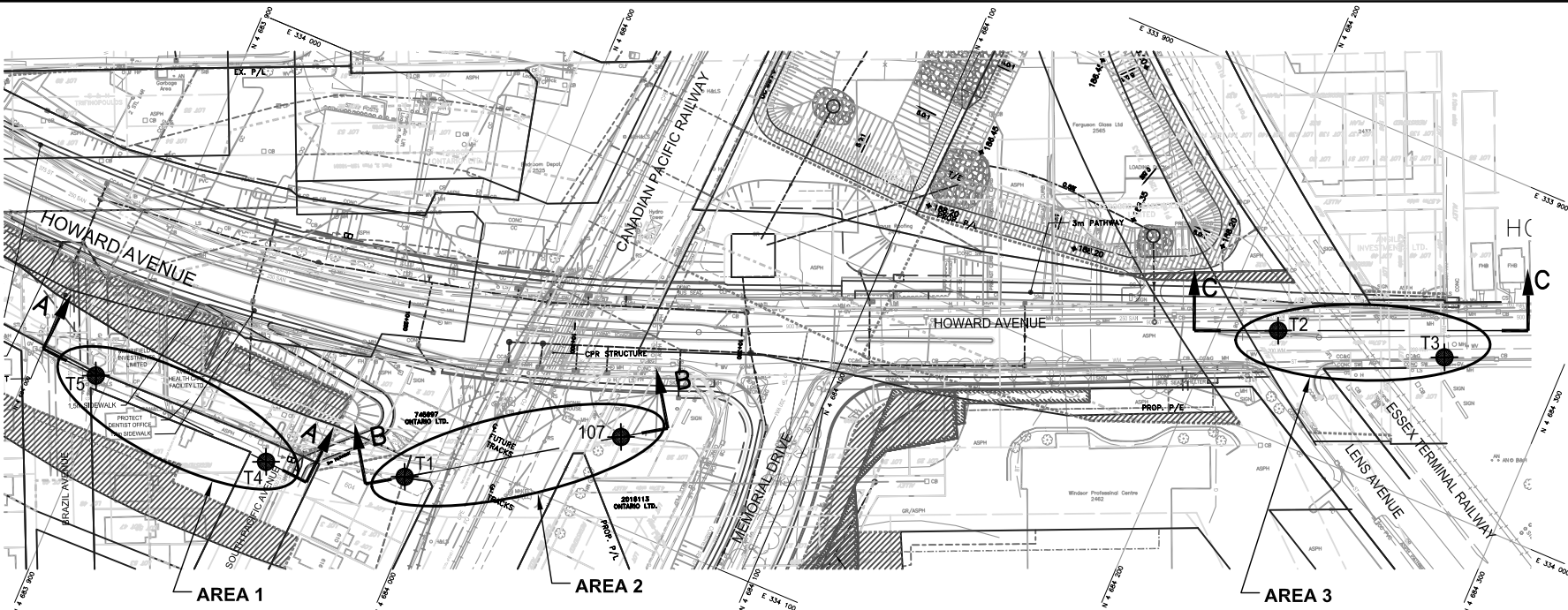
HWY No	HOWARD AVENUE	DIST	32
SUBM'D	NSB	CHECKED	MN
DRAWN	NA	CHECKED	CN
APPROVED	BRG	DWG	TU-1



REF No MRC DRAWINGS: H6933XA01.dwg; H6933XB01.dwg;  
H6933XN01.dwg; H6933xu01.dwg; H6933XY2.dwg  
and H6933Xd2-prop-reg.dwg; dated May 13, 2008

NOTE:

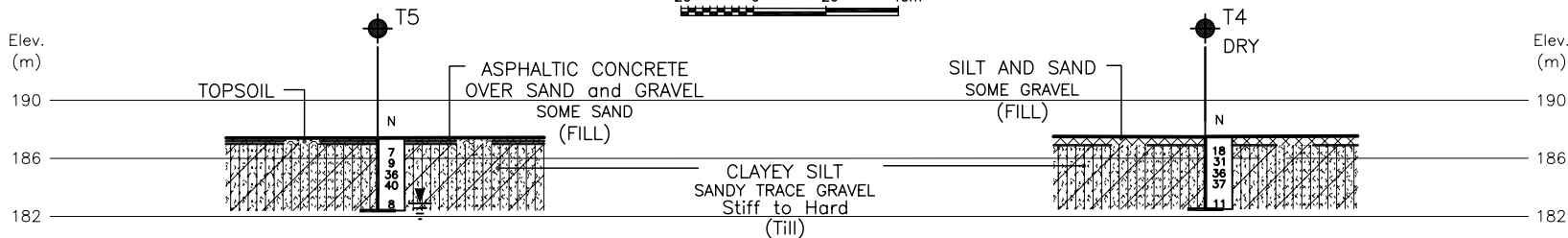
THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE  
DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.



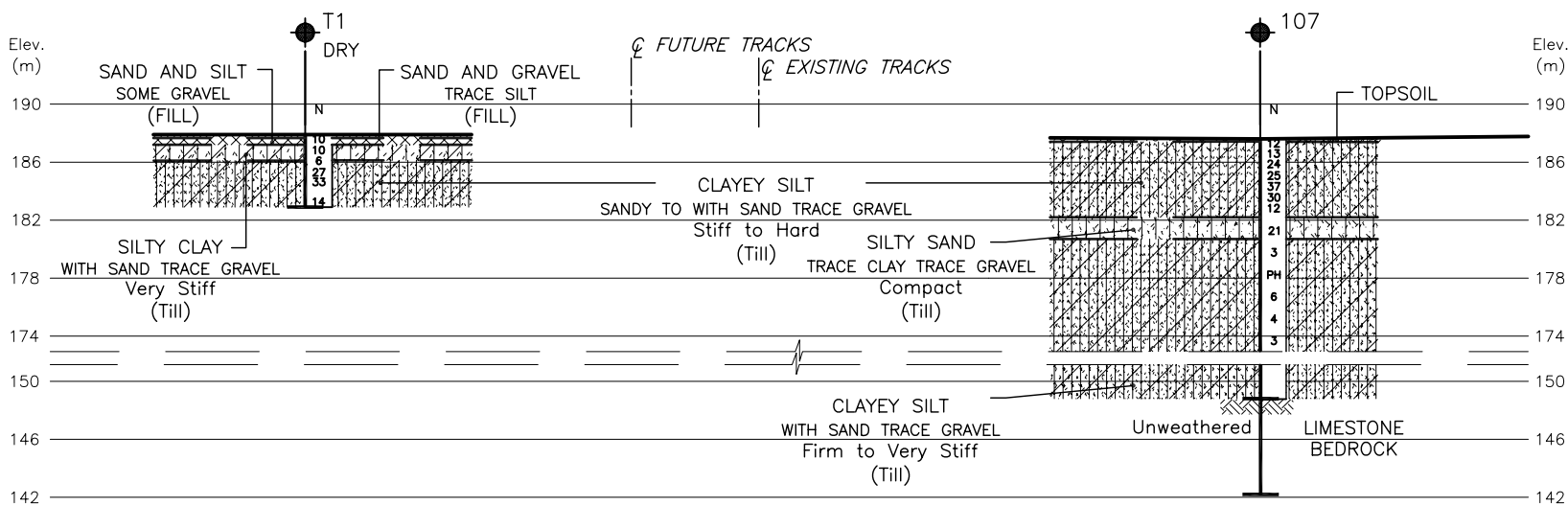
PLAN

SCALE

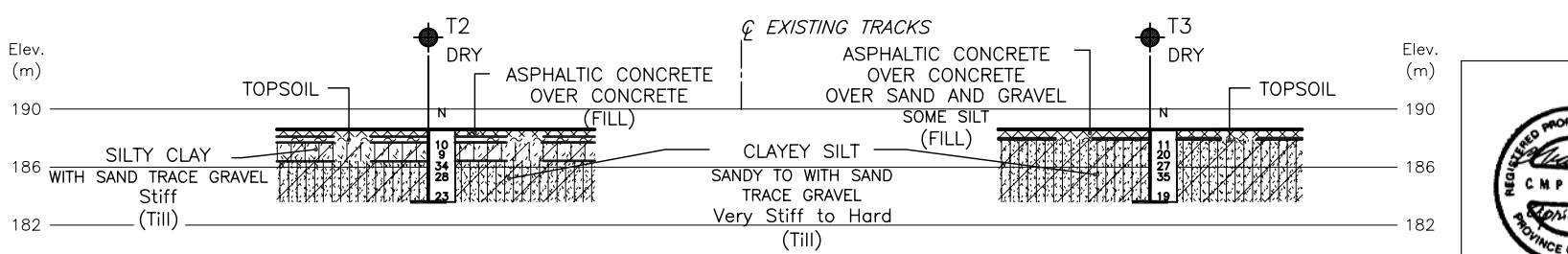
20 0 20 40m



PROFILE A-A



PROFILE B-B



PROFILE C-C

SCALE

5 0 5 10m



**DETAIL FOUNDATION DESIGN REPORT**  
**for**  
**WATERMAIN TUNNELS**  
**HOWARD AVENUE/CPR GRADE SEPARATION**  
**CITY OF WINDSOR**  
**GWP 3030-06-00**  
**DISTRICT 32, LONDON, ONTARIO**

PETO MacCALLUM LTD.  
165 CARTWRIGHT AVENUE  
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M6A 1V5  
Phone: (416) 785-5110  
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**Distribution:**

- 5 cc: McCormick Rankin Corporation (MRC) for distribution to MTO, Project Manager – WBIIG (London) + 1 digital copy (pdf)
- 5 cc: Foundation Investigation Report only to MRC for distribution to MTO, Project Manager – WBIIG (London) + 1 digital copy (pdf) and Drawing (AutoCAD)
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PML Ref.: 07TF022A-6  
Index No.: 183FDR  
GEOCRES No.: 40J6-22  
May 5, 2009



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Table 1 – List of Standard Specifications Referenced in Report

**DETAIL FOUNDATION DESIGN REPORT**

for  
Watermain Tunnels  
Howard Avenue/CPR Grade Separation  
GWP 3030-06-00  
City of Windsor  
District 32, London, Ontario

---

**1. INTRODUCTION**

**1.1 General**

This report provides the foundation engineering design recommendations and comments for construction of the proposed watermain tunnels included in the Howard Avenue/CPR grade separation project in the city of Windsor, Ontario. Peto MacCallum Ltd. (PML) conducted the foundation investigation for McCormick Rankin Corporation (MRC) on behalf of the Ministry of Transportation of Ontario (MTO).

The proposed project includes the construction of three watermain tunnels at the locations described in following table. For the ease of reference, PML identified tunnel locations with area numbers 1 to 3.

<b>TUNNEL AREA NO.</b>	<b>TUNNEL LOCATION</b>	<b>WATERMAIN STATIONS</b>
Area 1	East of Howard Avenue between Brazil Avenue and South Pacific Avenue	Sta. 10+085 to 10+122
Area 2	East of Howard Avenue and under the CPR Tracks	Sta. 10+184 to 10+228
Area 3	West edge of Howard Avenue NBL and under the Essex Terminal Railway Tracks	Sta. 30+149 to 30+173

According to the watermain drawings prepared by MRC, the length of tunnels ranged from 24 to 44 m. The proposed length, diameter, depth and elevation range of the watermain tunnels are detailed in the following table.



AREA No.	LENGTH (m)	DIAMETER (mm)	ELEVATION RANGE (Bottom of Pipe)	INVERT DEPTH RANGE (m)
Area 1	37	300 (Pipe)	185.3 (Level)	2.1 to 2.2
Area 2	44	610 (Casing)	185.3 (S) to 185.4 (N)	2.2 to 2.6
Area 3	24	610 (Casing)	186.3 (S) to 186.4 (N)	2.2 to 2.3

The subgrade soils at the location of the watermain tunnels are included in the upper zone of desiccated cohesive glacial till deposits encountered in the boreholes. The native soils are typically very stiff to hard and exhibit a characteristic fissured structure. Cobbles and boulders which typically are of concern for the installation of tunnels were not encountered in the boreholes. The occurrence of these large particles within glacial till deposits should, however be considered and their removal should be included as an allowance in the project.

It is considered that the installation of the proposed watermain tunnels is feasible based on the results of the subsurface investigation. Since perched water will accumulate in the fissures typically encountered in the desiccated soils unwatering of the tunnel excavation should be allowed during construction.

The "red flag" issues outlined in the preceding paragraphs and the recommended methods of overcoming these issues noted in the following sections of the report are intended to alert and aid the designer and the contractor. These comments and recommendations are based on the conditions revealed during the investigations and no responsibility is assumed by the consultants or the MTO for alerting the contractor to all critical issues for each foundation alternative. The requirements to deliver acceptable construction quality remain the responsibility of the contractor.

All elevations in this report are expressed in metres. A list of the Ontario Provincial Standard documents referenced in this report is enclosed in Table 1.



## **1.2 Installation Methods**

### **1.2.1 General**

The proposed 300 mm diameter watermain and 600 mm steel liner installations can be achieved by using horizontal directional drilling (HDD), jacking and boring or tunnelling techniques. An open cut installation technique is considered to be impractical for the particular areas due to the high traffic volume railway tracks (Areas 2 and 3) and limited space and traffic in the laneway (Area 1).

The proposed installation methods are the HDD method for Area 1 since the laneway traffic loads are relatively light and the jack and bore method with the 300 mm watermain pipe installed within a 600 mm diameter steel liner for Areas 2 and 3 in view of the high railway traffic loads. The following sections provide for HDD and jack and bore considerations and recommendations for Areas 1 to 3.

### **1.2.2 Horizontal Directional Drilling Considerations**

In summary the subsurface stratigraphy revealed in Area 1 included a unit of fill (underlain by topsoil in borehole T4 (Sta. 10+085)) overlying clayey silt till. At the proposed tunnel level, stiff to hard fissured clayey silt till was encountered. It is noted that a soft/wet zone was present at the exit point (at approximate Sta. 10+122) indicating that fissures contain perched water in particular near existing sewers and utility trenches. Groundwater was measured in borehole T5 (Sta. 10+122) at 4.5 m depth (elevation 182.9). Cobbles and boulders were not encountered in the boreholes, however these particles should be anticipated within the native glacial till deposits.

Prior to commencement of the watermain installation using HDD method, the Contractor should submit a work plan, drilling fluid management plan, list of personnel, safety plan and traffic control plan to the Engineer for review and approval in accordance with OPSS 450.



The exact locations and depths of the existing structures and utility services at the site should be determined. Utility companies and relevant agencies should be contacted to assess the magnitude of allowable movement prior to watermain installation. Existing underground facilities should be exposed to verify its horizontal and vertical locations when the boring path comes within 1.0 m horizontally or vertically of the existing facility. Preservation and protection of existing facilities should be carried out according to OPSS 504.

The Contractor should use proper boring equipment and drilling fluid. A suitable drilling bit and proper drilling fluid are critical to accomplish the installations. During installation, the design alignment, depth and grade should be maintained. Verification record requirements of the alignment and depth of installed watermain should be specified. A closed circuit television (CCTV) inspection should be conducted according to OPSS 409.

Upon completion of watermain installation, the Contractor performing the work should restore the pavement surface and other affected areas or facilities to their original states. The site restoration should be carried out according to OPSS 507 or as otherwise specified by the project designer.

### 1.2.3 Jacking and Boring Considerations

As indicated in section 1.2.1, it is proposed that the watermain installations in Area 2 (Sta. 10+184 to 10+228) and Area 3 (Sta. 30+149 to 30+173) be carried out using jacking and boring techniques. Conventional tunnelling is not considered to be practical due to the relatively small diameter of the steel liner.

In summary, the subsurface stratigraphy revealed in Area 2 generally comprised a surficial unit of fill or topsoil overlying cohesive glacial till deposits silty clay till or clayey silt till. A layer silty sand till was encountered between 5.4 and 6.9 m depths (elevations 182.2 and 180.7) is about 3.2 m lower than the invert of the proposed tunnel and is not expected to affect the installation. At the proposed tunnel level, stiff to hard clayey silt till was present.



The subsurface stratigraphy revealed at Area 3 generally comprised the Howard Avenue pavement overlying topsoil and these units were underlain by silty clay till and/or clayey silt till. At the proposed tunnel levels, very stiff to hard clayey silt till and/or silty clay till soils were present.

It is considered feasible to install the proposed crossings by jacking and boring method, based on the results of the investigation. The jacking and boring method should be designed and carried out in accordance with OPSS 416.

Considerable force may need to be applied to overcome the friction and the soil resistance in front of the casing in the competent soil strata. A slightly oversized shield or an extension at the roof of the shield may be considered to reduce the friction forces. Friction on the pipe could be also reduced by the injection of bentonite or polymer-based slurry into the annular space between the pipe and the soils. Upon completion of each pipe jacking, any voids should be grouted to prevent potential ground movement. The maximum grouting pressure should not exceed the overburden pressure, otherwise, heaving at ground surface or a blow-out could occur.

The gap between the steel casing and the watermain pipe should also be pressure grouted. During the pipe jacking operation, a plug of soil should be left inside the front end of the casing at all times to maintain stability and to prevent a potential flowing or running condition to develop. However, the choice of the construction method should be left to the Contractor.

To estimate the required jacking resistance provided by the native soils in the jacking pits an undrained shear resistance of the clayey silt till of 150 kPa should be used. Alternatively, the contractor should use his local site experience.

Although cobbles and boulders were not encountered in the boreholes, these particles are anticipated within the native glacial till deposits and if encountered, their presence will hamper the progress of the pipe jacking. An allowance should be considered in the contract for this purpose.



### **1.3 Excavation Considerations**

Entry and exit pits are anticipated for HDD and for jacking and boring operations. It is considered that these excavations may be carried out in open cuts using conventional equipment. All works should be carried out in accordance with the Occupational Health and Safety Act (OHSA). To this end, the fills, topsoil and any soft/wet zones should be considered Type 3 soils and the very stiff and hard soils should be considered Type 2 soils.

Where spatial limitation exist, the pits should be excavated within protection systems in accordance with SP 105S19. For protection of roadways, a performance level of 2 should be provided. The detail design of the protection systems should be provided by the Contractor.

### **1.4 Groundwater Control**

It is anticipated that no major groundwater problems are encountered during watermain installations in all areas, which are generally above groundwater levels. Water from soil fissures and surface run off should be expected and this flow should be adequately handled by conventional sump pumping. It is noted that the groundwater levels are subjected to fluctuations due to seasonal and rainfall patterns.

### **1.5 Settlement Monitoring**

Ground movement, surface or in-ground movement at depth, should be monitored closely during and after pipe installation to detect any ground subsidence or heaving of the surface, and to regulate the progress and procedure if required.



Monitoring during tunnelling will provide feedback to the consultant and contractor to adjust the construction procedures to control ground movements. Accordingly, changes to the progress and procedures can be made before the construction reaches locations where ground movements could be potentially damaging to the roadway or rail crossing.

The monitoring program should be utilized to measure the vertical ground movements. Surface monitoring points are to be located at not greater than 2.5 m (Areas 2 and 3) or 5 m (Area 1) intervals along the tunnel alignment.

The suggested maximum surface settlement (or heave) is recommended to be 20 mm for Area 1 and 10 mm for Areas 2 and 3 with review and alert levels at 50% and 75% of the values, respectively. The AREMA manual for Railway Engineering should also be reviewed in regards to tolerable settlements that may arise during and after the watermain installation under the railway tracks (Areas 2 and 3).

The baseline reading, alert and review levels should be specified in the Contract within a Settlement Monitoring Plan in accordance with OPSS 416, to ensure adequate performance of the jack and bore contractor. A condition survey of the pavement and rail tracks directly above the pipe alignment should be carried out before and after the installation. Contingency allowances should be carried in the contract for repair of the pavements over the watermain crossings.



## 2. CLOSURE

This Detail Foundation Design Report was prepared by Mr. C.M.P. Nascimento, P.Eng., with the assistance of Ms. N.S. Balakumaran, E.I.T, and independently reviewed by Mr. B.R. Gray, MEng, P.Eng., MTO Designated Principal Contact.

Yours very truly,

Peto MacCallum Ltd.



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CN/BRG:nb-lnr



**TABLE 1**  
**LIST OF STANDARD SPECIFICATIONS REFERENCED IN REPORT**

<b>DOCUMENT</b>	<b>TITLE</b>
OPSS 450	Construction Specification for Compacting
OPSS 504	Construction Specification for Preservation, Protection and Reconstruction of Existing Facilities
OPSS 409	Construction Specification for Closed Circuit Television Inspection of Pipelines
OPSS 507	Construction Specification for Site Restoration for Underground Utilities
OPSS 416	Construction Specification for Pipeline Utility Installation by Jacking and Boring
SP 105S19	Construction Specification for Protection Systems
SP 109F10	Structural Reference Plans and Reports