



**Foundation Investigation Report
Highway 17, Embankment Stabilization for Westbound Lane
Station 10+000 to Station 10+160
Township of Wiggins**

GWP 6081-09-00

Geocres No.: 42D-27

**Prepared for
Ministry of Transportation, Northwestern Region**

**Prepared By:
TBT Engineering**

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May 2, 2012, Final

Ref. No. 11-325

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Part A - FOUNDATION INVESTIGATION REPORT

1 Introduction

TBT Engineering (TBTE) has been retained by the Ministry of Transportation (MTO) to provide foundation investigation and design services for the stabilization works on Highway 17 embankment located between Sta. 10+000 and 10+160 Township of Wiggins (approximately 40 km east of Nipigon). The foundation investigation was carried out to investigate deformations of the westbound lane (north side of the embankment) observed to have crescent cracking extending to the middle of the road indicating movement to the north.

An earlier foundation investigation was carried out by the Ministry for the widening to the north and grade raise of the highway embankment; ("Foundation Report for Hwy 17, Station 10+000 to 10+160, Grade Raise and Widening, Slope Stability Investigation, W.P. 909-76-01 (B), TWP of Wiggins, District Thunder Bay", dated August 1993, Geocres Number 42D-18). The subsurface information in the report consists of two boreholes and two dynamic cone penetration tests at the north toe of the highway embankment (on the left side of the highway Centreline). This current investigation is to augment the available subsurface information and to revisit the embankment stabilization requirements.

This investigation consisted of 4 boreholes drilled along the north toe of the embankment, laboratory testing and geotechnical analysis of the data. This report (Part A) describes the subsurface conditions encountered during the investigation.

The foundation section has assigned GEOCREs No. 42D-27 to this site.

2 Site Description

The foundation investigation was carried out to investigate subsurface conditions between Sta. 10+000 and Sta. 10+160 in the Township of Wiggins (approximately 40 km east of the Town of Nipigon along Hwy.17). The highway embankment crosses a valley between two bedrock outcrops. The existing 9 m high embankment is understood to be composed of rock fill. An 8 m wide mid-height berm exists on the south side of the embankment. Extensive patching is evident along the west bound lane (north side) at two locations as illustrated below (Figure 1).



Figure 1, Patching Along West Bound Lane, Looking West

Crescent shaped cracking is evident at the patch locations.

A photograph taken along the north side guide rail indicates possible lateral shifting of the north side crest (Figure 2).



Figure 2, Guide Rail Along North Side Crest, Looking West

2.1 Site History

In 1993 a report was prepared by MTO Foundation Design Section; “WP 909-76-01(B), Dist 19, Hwy 17 STR Site, Station 10+000 to 10+160 Grade Raise and Widening Slope Stability Investigation, Twp. of Wiggins, August 17, 1993”. This report indicates that the existing embankment is constructed from rock fill over a silty clay subgrade. In addition, it was reported that the south side slope had experience previous slope failures requiring the placement of rock fill along the base of the slope together with slope flattening.

An 8 m wide mid-height berm was constructed on the south side of the embankment in 1995 (Contract 95-217).

It has been reported by MTO Maintenance that approximately 2 to 3 years ago (2009 to 2010) patching along the west bound lane was required. Patching was required again in October of 2011 to address settlements of up to 40 mm of the west bound travel lane.

2.2 Surficial Geology

The topography consists of up to 9 m high fill embankment which appears to be composed of rock-fill with large boulders exposed on the slope faces. The surrounding valley consists of a mixture of swamp and forest wet land birch, poplar and spruce trees. The valley walls rise steeply on either end of the site, with bedrock visible at the surface.

Based on review of surface geology mapping, the site is located in an area of bedrock knob terrain with subordinate land forms consisting of till ground moraine and organic terrain over bedrock knobs.

3 Investigation Procedures

A geotechnical site investigation was undertaken between December 21 and 22, 2011 which included 4 boreholes (Borehole 1-2011 to 4-2011). The 2011 borehole logs are provided in Appendix A. Previous boreholes were carried out in 1993 and have been included in Appendix E. For this report, the 1993 boreholes have been referenced as 1-1993, 2-1993 and 3-1993. The borehole locations are illustrated on the Borehole Location Plan found in Appendix C.

The 2011 boreholes were advanced using a portable power auger with solid stem augers (50 mm o.d.). A portable tripod equipped with a cat head was used to carry out standard penetration testing (SPT) and dynamic cone penetration testing (DCPT). Soil samples were obtained at the boreholes using a split spoon sampler as a part of the Standard Penetration Testing (SPT). The SPT involves driving a thick walled sampler into the soils under a standardized energy (63.5 kg, falling 760 mm). The number of blows required to drive the sampler 0.3 m is known as the SPT blow count (N). Dynamic Cone Penetrometer Testing (DCPT) was also carried out at Borehole 2 starting at a depth of 6.4 m and extending to a depth of 10.8 m. In addition, field vane testing was carried out and relatively undisturbed thin walled tube samples obtained in cohesive soils.

Surveys were conducted using North American Datum 1983, MTM CSRS Zone 14 and Canadian Geodetic Vertical Datum 1928, 1978 Adjustment. Control was established from existing published Horizontal Control Monuments and Geodetic Benchmarks. The

survey was completed using a Trimble R8 Series 3 RTK GPS with radio and an engineering level. Survey data was processed using Land Desktop 2009.

The borehole characteristics are summarized in Table 1.

Table 1: Borehole Summary

BH	Surface El. m	Station	Offset m	End of Borehole El. m / (Depth m)	Ground Water Level * El. m / (Depth m)	Base of Peat/Organics El. m / (Depth m)	Comments
1-1993	194.7	10+025	23 Lt	181.5 (13.2)	194.7 (0.0)	194.3 (0.4)	Bedrock at El. 183.1 m
2-1993	194.5	10+050	23 Lt	183.5 (11.0)	Wet at Surface	193.5 (1.0)	Estimated Peat Depth, DCPT Only
3-1993	194.6	10+075	23 Lt	184.9 (9.7)	194.6 (0.0)	193.6 (1.0)	0.6 m Water at Surface
1-2011	194.2	10+074	27.0 Lt	188.1 (6.1)	193.1 (1.1)	-	No Peat
2-2011	194.1	10+056.2	28.3 Lt	183.3 (10.8)	193.7 (0.4)	193.95 (0.15)	DCPT from El. 197.7 to 183.3m
3-2011	194.3	10+041.6	30.0 Lt	187.6 (6.7)	194 (0.3)	193.2 (1.1)	
4-2011	194.7	10+021.3	28.9 Lt	188.7 (6.0)	194.4 (0.3)	192.8 (1.9)	

*Measured within 18 hrs of borehole completion

The 2011 boreholes were backfilled at the completion of the investigations using a bentonite backfill mixture to ensure the environmental integrity of the site and in compliance with Ontario Regulation 903.

Soil samples from the 2011 investigation were transported to TBT Engineering's laboratory in Thunder Bay for testing. Routine testing included moisture content, Atterberg limits and grain size analysis. The results of this testing are shown on the Borehole Logs (Appendix A) and on the laboratory data reports (Appendix B).

4 Sub-Surface Conditions

Details of the subsurface conditions are provided on the borehole logs (Appendix A) and on the Soil Strata Drawings (Appendix C). The following subsurface stratigraphy pertains to the soils beyond the north side toe of the embankment.

4.1 Fill

Granular fill was encountered in Boreholes 1-2011, 3-2011 and 4-2011. The fill ranged in thickness from 0.2 to 0.8 m. Grain size analyses carried out on selected sample indicates the fills can consist of 6 % gravel, 81 % sand, and 13 % silt and clay sized particles. The fill is in a very loose condition with SPT (N) values of 1 to 3 blows/0.3 m.

4.2 Peat/Organics

Peat and organics with trace to some silt and sand was encountered below the above noted fills at Boreholes 3-2011 and 4-2011 and at the surface of Boreholes 2-2011, 1-1993 and 3-1993. The peat/organics range in thickness from 0.15 m to 1.6 m and extends to elevations of 192.8 to 194.3 m at the boreholes. Deeper zones may exist between and/or outside of the test hole locations. The natural moisture contents of the peat varied from 70 to 110% (dry weight basis).

4.3 Sand

Sand was encountered below the peat in Borehole 2. The sand is 0.5 m thick and is silty with a trace of clay. The sand is in a very loose condition with SPT "N" values of 3 blows / 0.3 m.

4.4 Clay

Clay was encountered underlying the fill and sand in Boreholes 1-2011 and 2-2011 and below the peat in Boreholes 3-2011, 4-2011, 1-1993, 3-1993 and at the surface of Borehole 2-1993. The top of the clay layer was encountered between elevations of 192.8 to 194.5 m (0.2 to 1.9 m below grade). In general the clay is varved, consisting of alternating layers of clay of varying plasticity, silt content and colour. The varves typically ranged in thickness from 2 to 20 mm. Occasional silt seams were also identified. The consistency of the clay varies from soft to very stiff as indicated by field vane tests between 16 and 191 kPa. There is a firm to stiffer crust overlying a soft to

stiff clay (increasing with depth). A graph of undrained shear strength vs. elevation has been illustrated in Figure 3. The undrained shear strengths have been determined based on the field vane tests corrected with respect to plasticity index (Bjerrum, 1972). SPT “N” values generally varied from 1 to 15 blows/0.3 m. The measured sensitivity of the clay varied from 3 to 10.

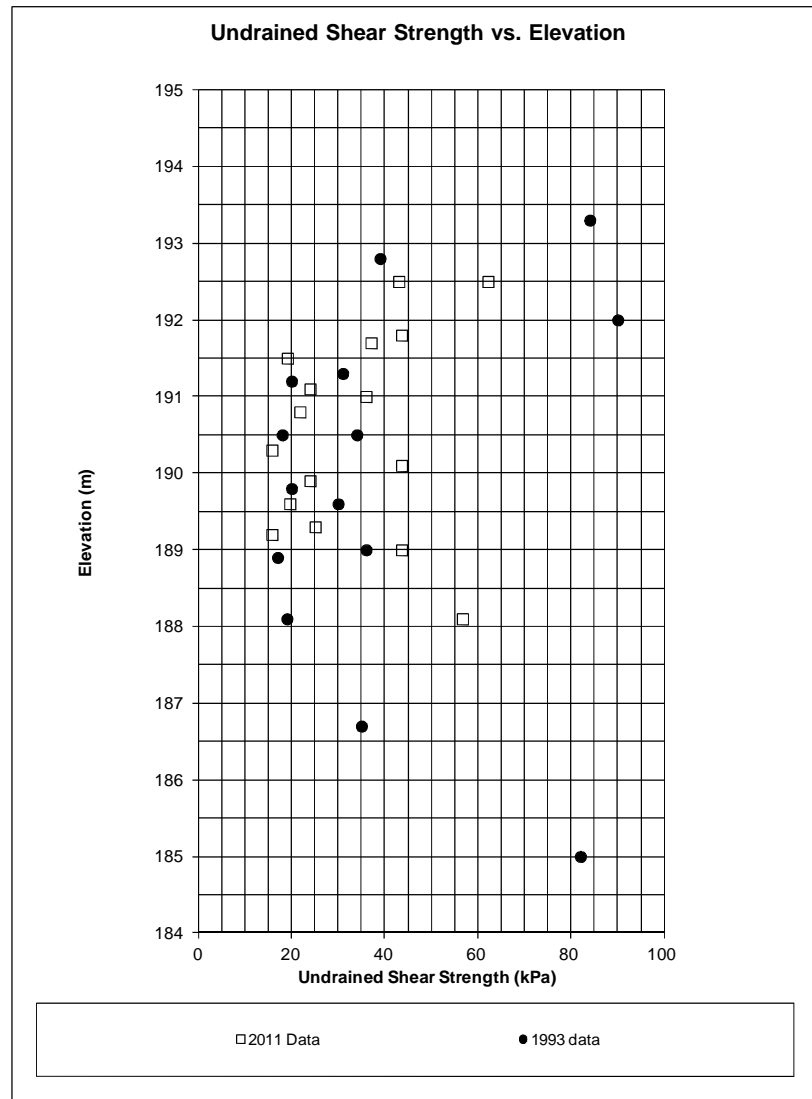


Figure 3, Undrained Shear Strength vs. Elevation

Atterberg limit testing indicates the clay is of low to medium plasticity. The natural moisture content generally exists between the liquid and plastic limits within the upper 2.5 m of the clay stratum (crust). Below a depth of 2.5 m (Elevation 192), the natural moisture contents approach and/or exceed the liquid limit.

The results of a consolidation test were reported in the 1993 report as follows:

- $e_o = 0.575$
- $C_c = 0.1702$
- $P'_c = 110 \text{ kPa}$
- $P'_o = 83 \text{ kPa}$

Two vertical silt seams were noted within the clay stratum in Borehole 1-2011 and 2-2011. The vertical seams exist between depths of 1.8 and 2.4 m.

4.5 Heterogeneous Mixture of Silt/Sand/Gravel - Till

A non – cohesive heterogeneous mixture of silt, sand and gravel with trace of Clay and numerous boulders and cobbles was encountered in one borehole (1-1993) starting at a depth of 10.1 m (el. 184.5 m) with a thickness of 1.5 m below the clay stratum. This deposit lies directly above the bedrock surface. As inferred by DCPT testing, the till exists at a depth of 10.5 m (el. 183.0 m) at Borehole 2-2001.

Two grain size distribution tests carried out in 1993 indicate this material contains primarily gravel and sand.

A standard penetration tests conducted in this layer had an 'N' value of 79 blows/0.3 m indicating a very dense condition.

4.6 Bedrock / Refusal

The overburden was underlain by dark reddish to light brown Conglomerate bedrock at depths of 11.6 m and 6.7 m in Boreholes (1-1993 and 3-1993) respectively. The rock was described as medium strong, unweathered to slightly weathered.

Auger refusal was encountered at a depth of 6.1 m (el. 188.1 m) at Borehole 1-2001. Refusal to DCPT's carried out at Boreholes 2-2011 and 2-1993 occurred at depths of 10.8 m (el. 183.3 m) and 11.0 m (el. 183.5 m), respectively. Refusals may be on cobbles, boulders, or bedrock.

4.7 Ground Water

The ground water levels observed during the 1993 and 2011 field investigations have been provided in Table 1. Ground water level readings taken upon completion of the boreholes carried out in 2011 generally varied from El. 193 to 194 m and may not have had time to stabilize. The current ground water level is likely near the peat surface at about elevation 193.5 to 194.5 m. Ground water levels measured in April of 1993 varied from El. 194.5 to 194.7 m. In 1993, 0.6 m of standing water at elevation 194.6 m was observed at Borehole 3-1993. Ground water levels will vary from season to season and from the effects of heavy precipitation events.

5 Miscellaneous

Laboratory testing for the 2011 investigation was carried out at the TBT Engineering laboratory in Thunder Bay. The drill equipment for this investigation was operated by TBT Engineering Limited. The field operations for the 2011 investigation were supervised by Allan Finke. Laboratory testing was supervised by T. Fummerton C.E.T. This report was prepared by Gordon Maki, P.Eng, and reviewed by W. Hurley, P.Eng.

6 Limitations

Subsurface and groundwater conditions between and beyond test hole locations may differ from those encountered at the test hole locations. Conditions may become apparent during construction that were not detected and could not be anticipated at the time of the site investigation.

Groundwater levels indicated are based on the information described within the report. The presence of all conditions that could affect the type and scope of dewatering procedures which may be considered cannot readily be determined from boreholes. These include local and seasonal fluctuations of the groundwater level, changes in soil conditions between test locations, thin and/or discontinuous layers of highly permeable soils, etc.

The information contained within this report in no way reflects any environmental aspect of the site or soil.

7 Closure

We trust the above addresses your project requirements at this time. Should you have any questions or comments, please do not hesitate the contact us at your convenience.

Yours truly,

For TBT ENGINEERING



Gordon Maki, P.Eng
Manager of Geotechnical Engineering



Wayne Hurley, P.Eng.
Vice President of Engineering

APPENDIX A

Borehole Logs

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

STRESS AND STRAIN

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

MECHANICAL PROPERTIES OF SOIL

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

PHYSICAL PROPERTIES OF SOIL

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

TBT Engineering Consulting Group			RECORD OF Borehole No 1-2011			1 OF 1		METRIC	
W.P. 6081-09-00			PROJECT Gravel River			SITE NO. _____		ORIGINATED BY A.F.	
DIST 61 HWY 17			LOCATION Sta. 10+074.0 o/s 27.0 Lt			TBTE JOB# 11-325		COMPILED BY T.B.	
DATE 2011 December 21			BOREHOLE TYPE SS Auger - 50 mm			DATUM Geodetic		CHECKED BY S.S.	
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS		DYNAMIC CONE PENETRATION RESISTANCE PLOT	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		ELEVATION SCALE	SHEAR STRENGTH kPa	
								20 40 60 80 100 ○ UNCONFINED ✕ FIELD VANE ■ SPT (N) ★ LAB VANE 20 40 60 80 100	
								PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W _p W W _L WATER CONTENT (%)	
								UNIT WEIGHT γ kN/m ³	
								REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
194.2 194.0 0.2	FILL - SAND/GRAVEL/CLAY - Silty, occasional cobbles, brown/CLAY - varved, occasional silt seam, trace sand, brown, very stiff		1	SS	7		194		
			2	SS	15		193		
	----- - grey/brown, vertical silt seam, firm		3	SS	3		192		
	----- - grey/black, firm		4	TW			191		
	----- - soft		5	SS	2		190		
			6	SS	3		189		
188.1 6.1	End of Borehole @ 6.1 m. Auger Refusal.		7	SS	100+				

ON_MOT_BH-10 11-325 MTO GRAVEL RIVER.GPJ ON_MOT.GDT 12/3/1

TBT Engineering Consulting Group		RECORD OF Borehole No 2-2011				2 OF 2		METRIC					
W.P. 6081-09-00		PROJECT Gravel River				SITE NO. _____		ORIGINATED BY A.F.					
DIST 61 HWY 17		LOCATION Sta. 10+056.2 o/s 28.3 Lt				TBTE JOB# 11-325		COMPILED BY T.B.					
DATE 2011 December 22		BOREHOLE TYPE SS Auger - 50 mm				DATUM Geodetic		CHECKED BY S.S.					
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)					
184													
183.3													
10.8	End of DCPT Testing @ 10.8 m. DCPT Refusal.												

ON_MOT_BH-10 11-325 MTO GRAVEL RIVER.GPJ ON_MOT.GDT 12/3/1

TBT Engineering Consulting Group **RECORD OF Borehole No 3-2011** 1 OF 1 **METRIC**

W.P. **6081-09-00** PROJECT **Gravel River** SITE NO. _____ ORIGINATED BY **A.F.**

DIST **61** HWY **17** LOCATION **Sta. 10+041.6 o/s 30.0 Lt** TBTE JOB# **11-325** COMPILED BY **T.B.**

DATE **2011 December 22** BOREHOLE TYPE **SS Auger - 50 mm** DATUM **Geodetic** CHECKED BY **S.S.**

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
194.3															
0.0	FILL - SAND - some silt, trace gravel, trace organics, brown, very loose		1	SS	1		194								6 81 (13)
193.5															
0.8	PEAT - brown		2	SS	1										
193.2															
1.1	CLAY - varved, occasional silt seam, brown, stiff		3	SS	5		193								
	----- - grey/brown, soft		4	SS	3		192								
			5	SS	1		191								
			6	SS	1		190								
	----- - trace sand, grey						189								
			7	SS	5		188								
187.6															
6.7	End of Borehole @ 6.7 m.														

x³, *³: Numbers refer to Sensitivity
 NP Non Plastic
 ○ 3% STRAIN AT FAILURE

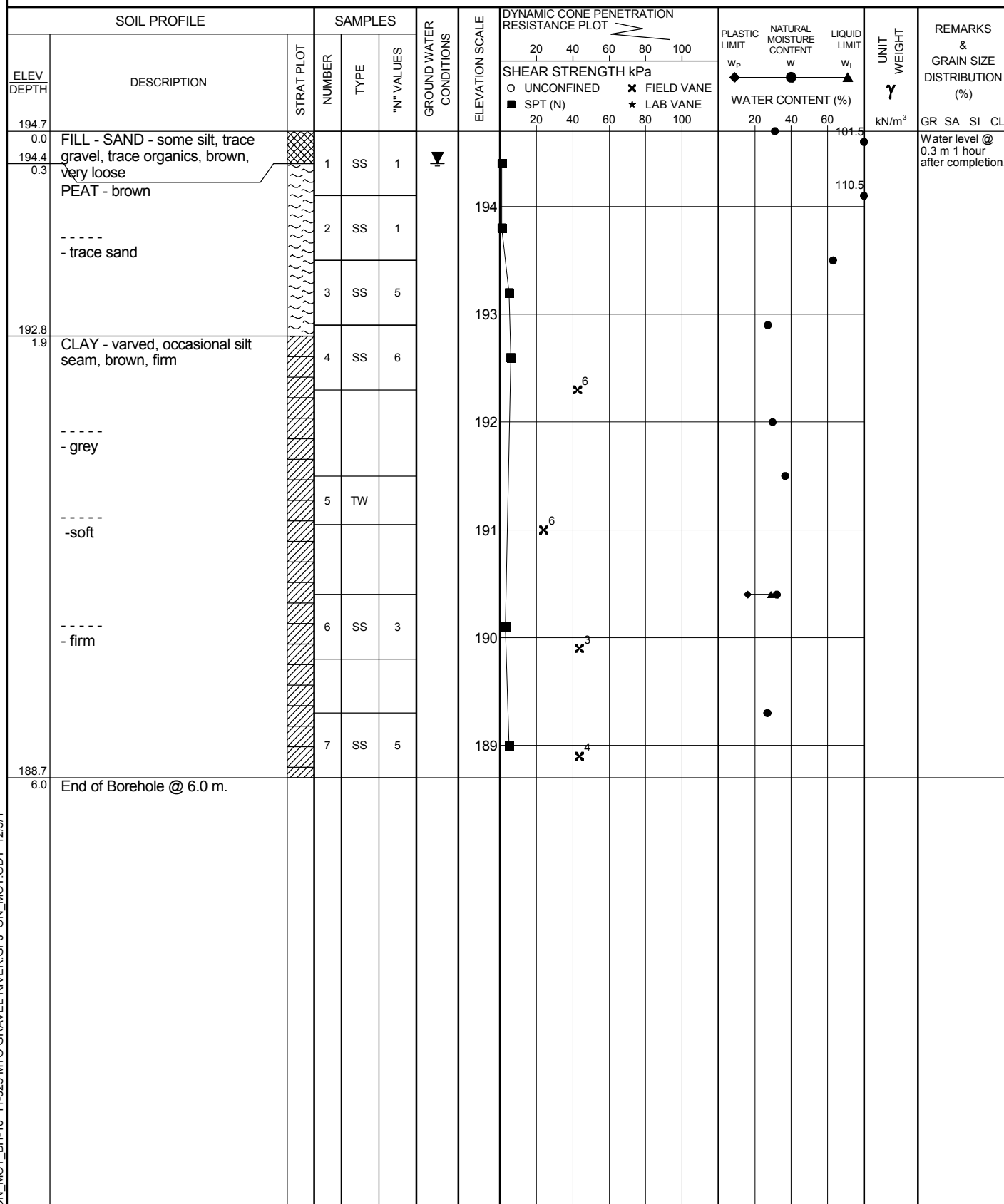
ON_MOT_BH-10 11-325 MTO GRAVEL RIVER.GPJ ON_MOT.GDT 12/3/1

TBT Engineering Consulting Group **RECORD OF Borehole No 4-2011** 1 OF 1 **METRIC**

W.P. **6081-09-00** PROJECT **Gravel River** SITE NO. _____ ORIGINATED BY **A.F.**

DIST **61** HWY **17** LOCATION **Sta. 10+021.3 o/s 28.9 Lt** TBTE JOB# **11-325** COMPILED BY **T.B.**

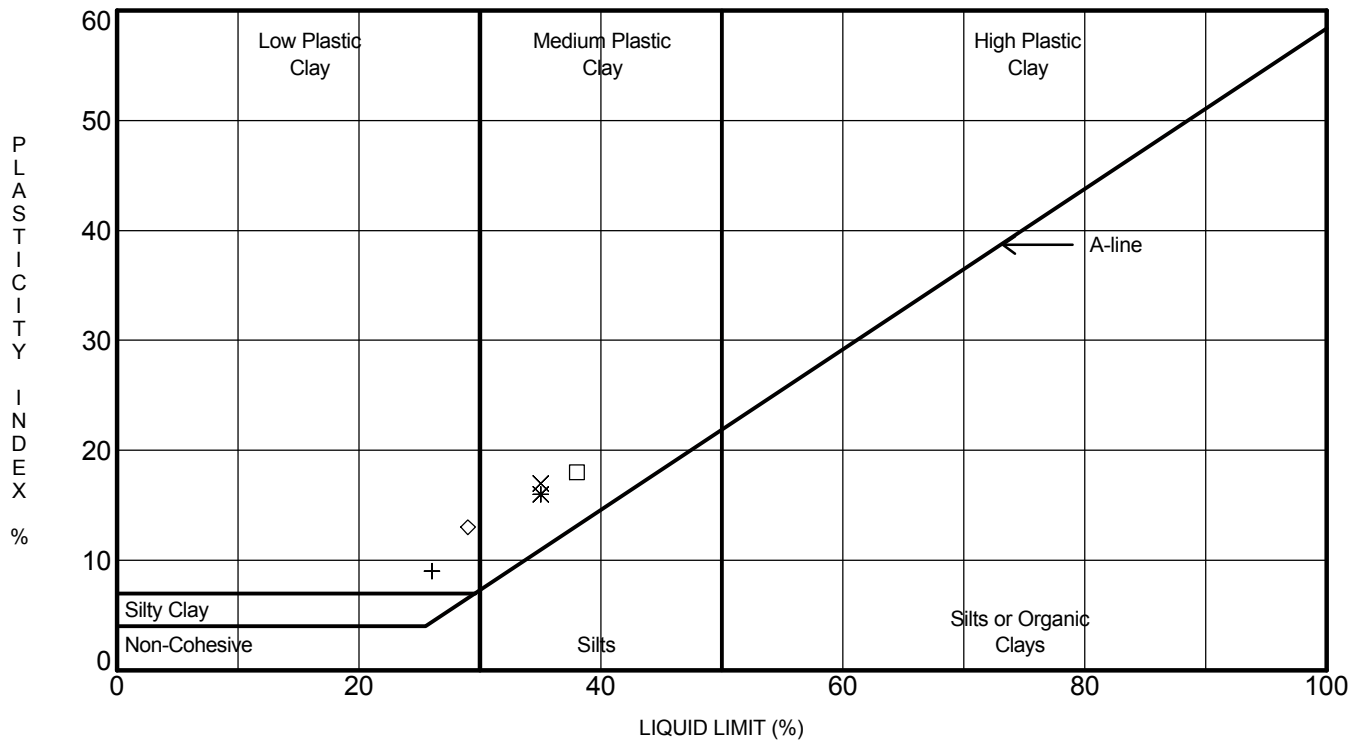
DATE **2011 December 22** BOREHOLE TYPE **SS Auger - 50 mm** DATUM **Geodetic** CHECKED BY **S.S.**



ON_MOT_BH-10 11-325 MTO GRAVEL RIVER.GPJ ON_MOT.GDT 12/3/1

APPENDIX B

Laboratory Test Data



Test Hole	Sample No.	Depth (m)	LL %	PL %	PI %	M/C %
□ 1-2011		0.60	38	20	18	26
* 1-2011		1.80	35	19	16	31
× 2-2011		2.70	35	18	17	34
+ 3-2011		4.60	26	17	9	28
◇ 4-2011		4.30	29	16	13	32



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 Fax: 807-264-5161

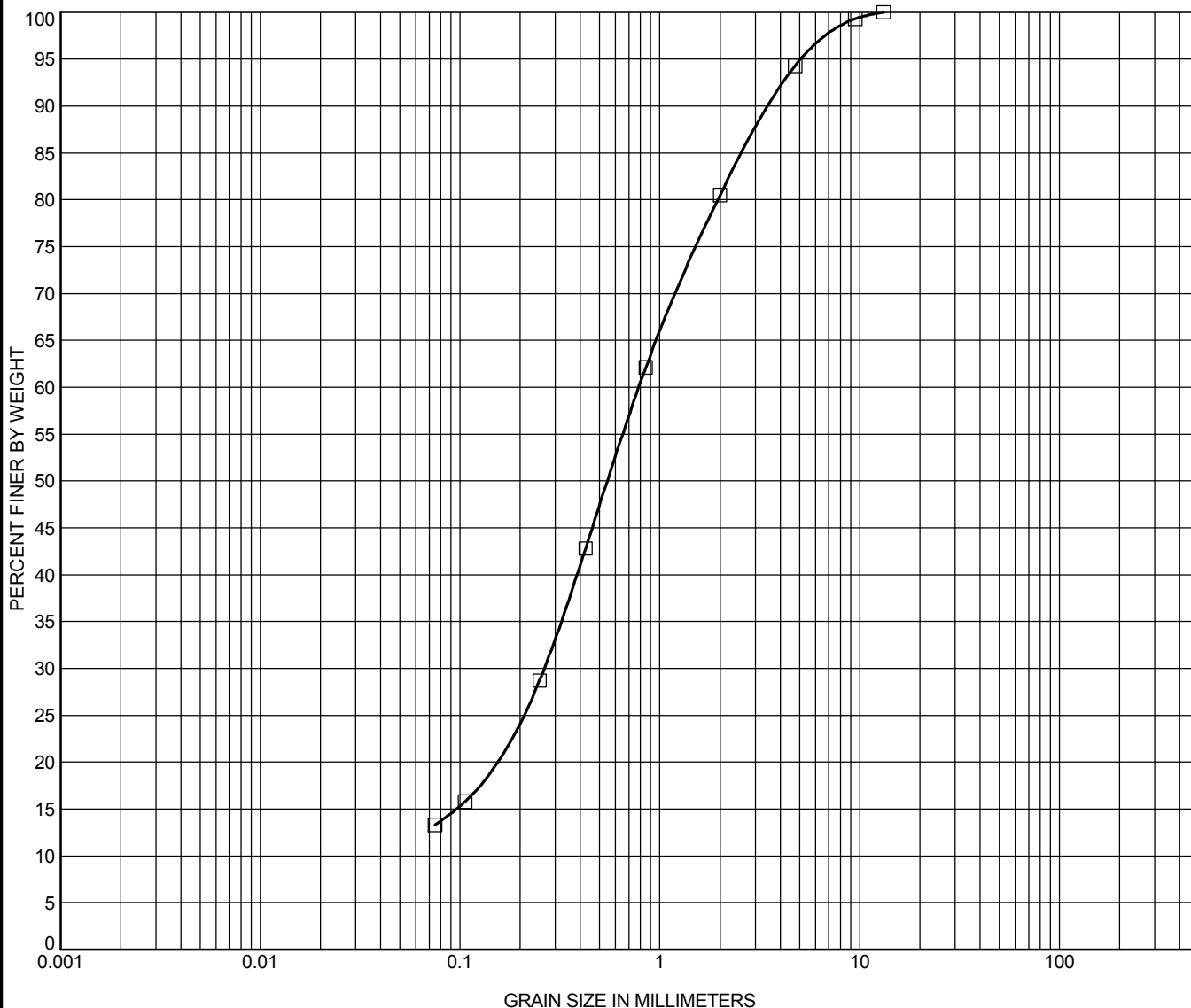
ATTERBERG LIMIT RESULT

Project:

Location:

Number:

ENCLOSURE 1



SILT OR CLAY	SAND			GRAVEL		COBBLES
	fine	medium	coarse	fine	coarse	

Remarks:
SAND - some silt

Test Hole	Depth	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
3-2011	0.00	13.2	0.788	0.263		5.7	81.0	13.3	



TBT Engineering Limited
1918 Yonge Street
Thunder Bay, Ontario P7C 6T9
PH: 807-624-5160
FX: 807-264-5161
Email: tbte@tbte.ca
Web: www.tbte.ca

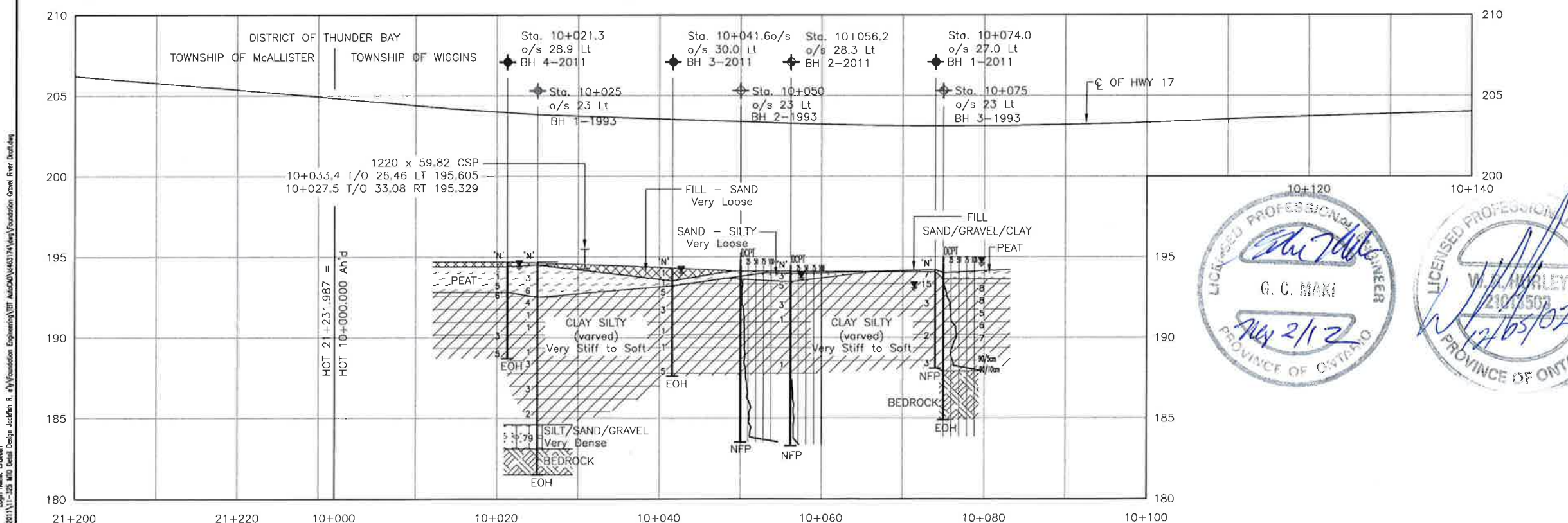
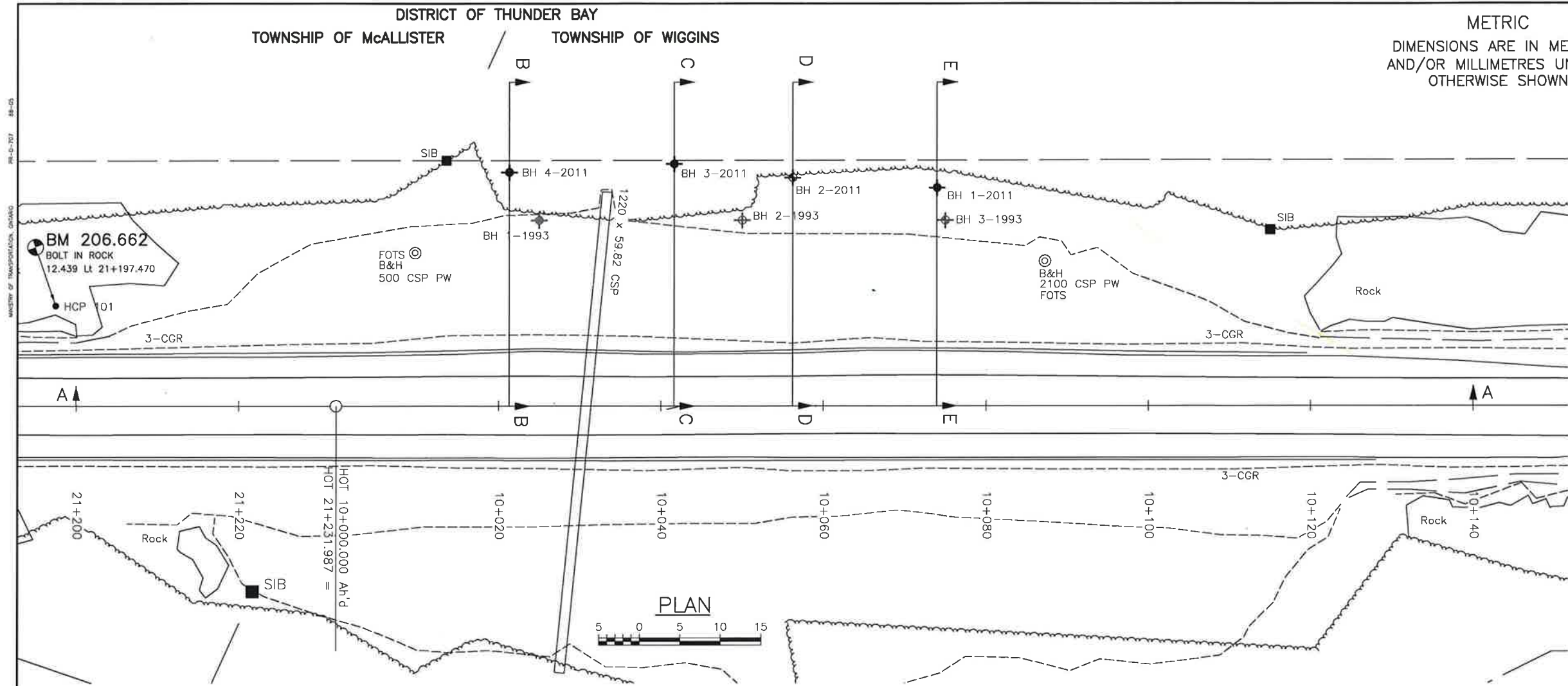
GRAIN SIZE DISTRIBUTION

Project: Gravel River

W P: 6081-09-00

DIST: 61 HWY: 17

APPENDIX C
Borehole Locations, Drawings and Sections



GEOCRE No. 42D-27
CONT No. 2012-xxxx
WP No. 6081-09-00

HWY 17, STA. 10+050 WIGGINS TOWNSHIP
EMBANKMENT STABILIZATION
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

Ministry of Transportation
Northwestern Region
Structural Section

TBT ENGINEERING
CONSULTING GROUP

KEY PLAN
1.0 km 0 1.0 km
SCALE 1:50,000

SOIL STRATA SYMBOLS

PEAT	CLAY - SILTY (VARVED)
FILL	SILT/SAND/ GRAVEL
SAND	BEDROCK

LEGEND

- Borehole
- Borehole with Dynamic Cone Penetration Test (DCPT)
- Borehole - Previous Investigation
- DCPT - Previous Investigation
- Borehole & DCPT - Previous Investigation
- Sid Pen Test (Blows/0.3m)
- Water Level
- NFP No Further Progress

No	ELEVATION	CO-ORDINATES (MTM, NAD 83 ZONE 14)	
		NORTHING	EASTING
TBT BOREHOLES			
1-2011	194.2	5420809.7	245121.7
2-2011	194.1	5420803.8	245105.0
3-2011	194.3	5420799.5	245090.9
4-2011	194.7	5420790.5	245072.7
PREVIOUS BOREHOLES			
1-1993	194.7	5420786.5	245078.4
2-1993	194.5	5420796.5	245101.4
3-1993	194.6	5420806.4	245124.3

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

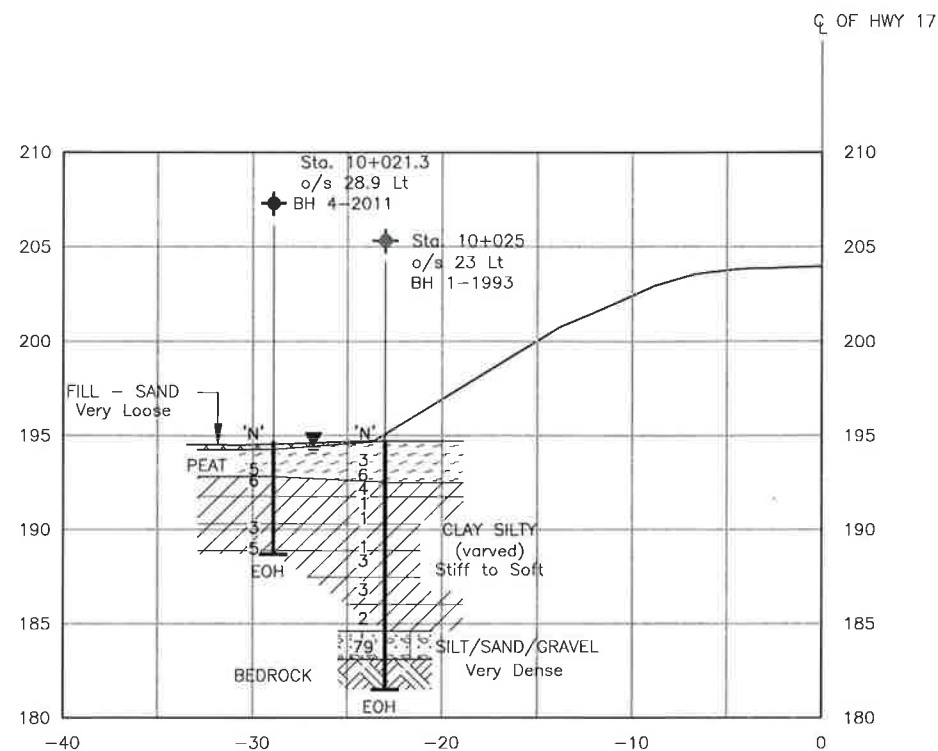
SECTION A-A
HORIZONTAL 5 0 5 10 15 20m
VERTICAL 2.5 0 2.5 5 7.5 10m

REVISIONS

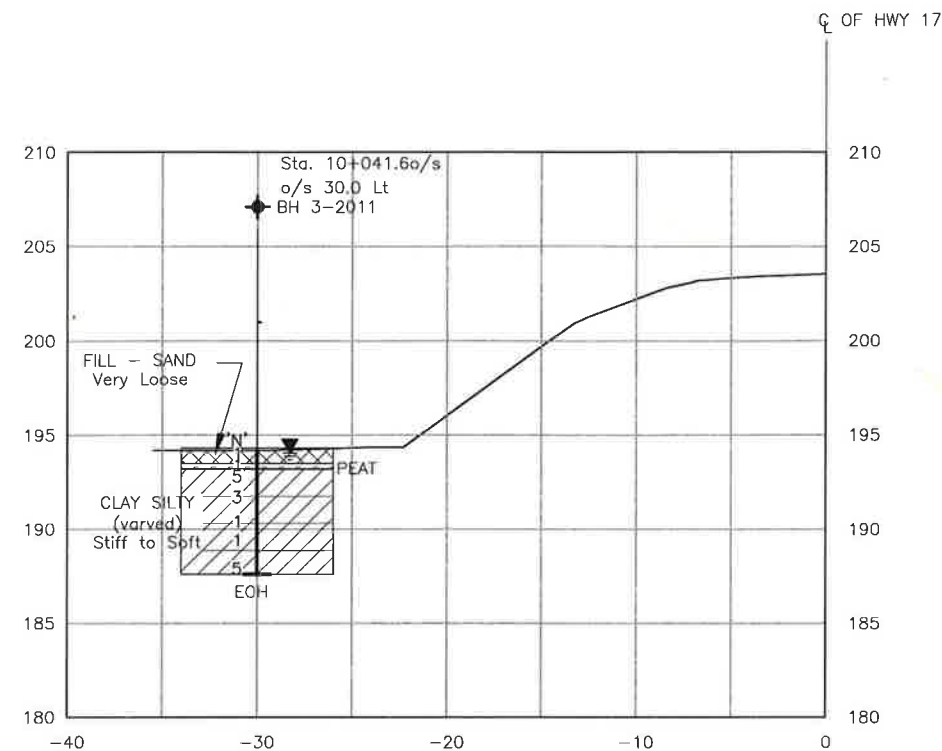
NO	DATE	BY	REVISION
02/05/12	W.H.		FINAL
16/04/12	G.M.		REISSUED IN DRAFT
01/03/12	G.M.		ISSUED FOR DRAFT
DDMMYY		BY	REVISION

DESIGNATION: XXXX-XX LOAD XX-XXX-XX DATE: 01/03/12
DRAWN: TB CHK WH SITE XXX-XXX DWG: 1

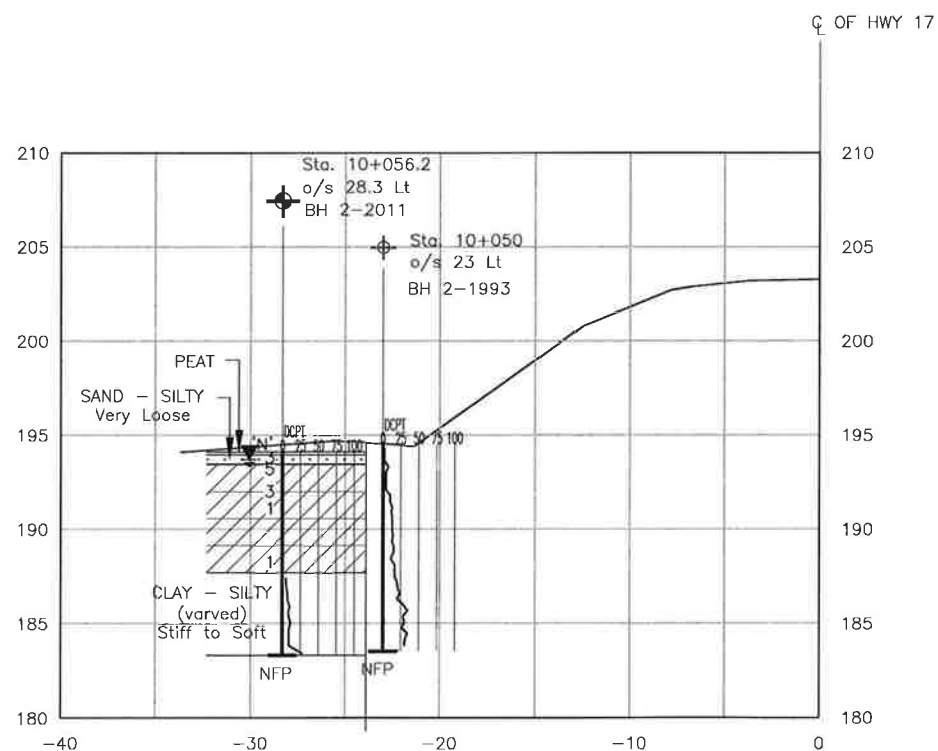
REFERENCE DRAWING SUPPLIED BY CLIENT.



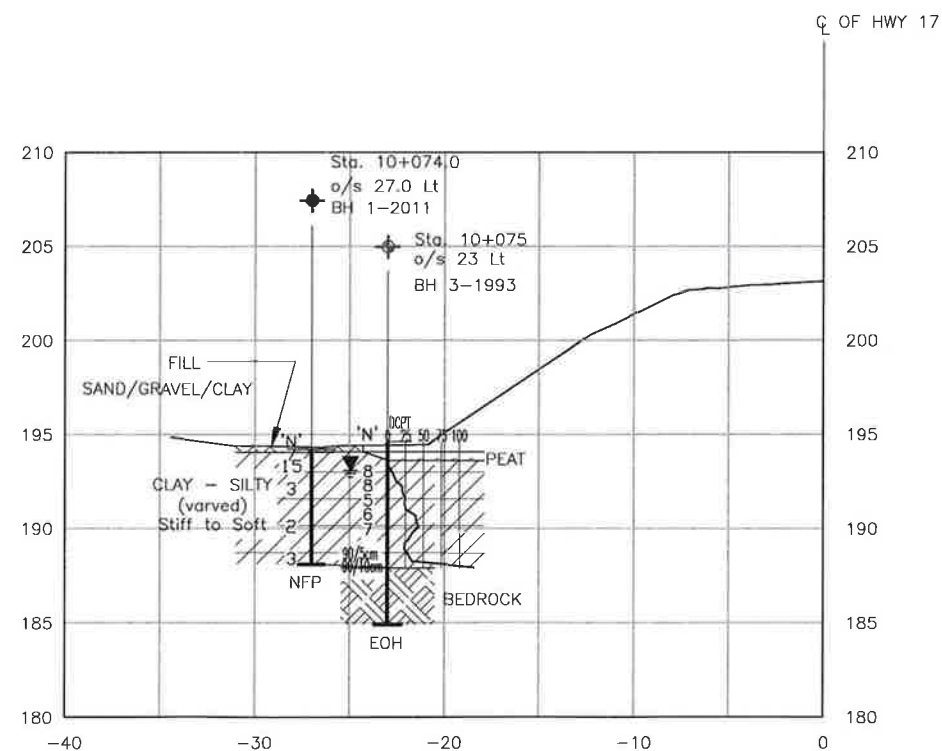
SECTION B-B



SECTION C-C



SECTION D-D



SECTION E-E



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

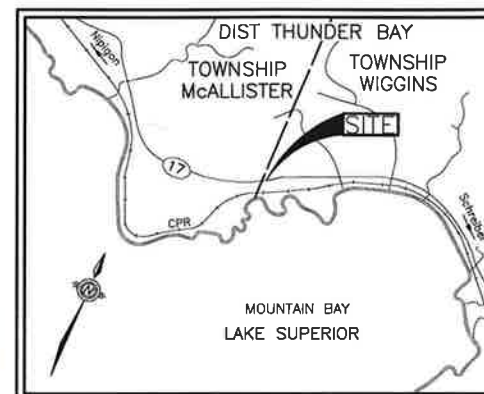
GEOCRES No.	42D-27
CONT No.	2012-xxxx
WP No.	6081-09-00

HWY 17, STA. 10+050 WIGGINS TOWNSHIP
EMBANKMENT STABILIZATION
SOIL STRATA CROSS-SECTIONS

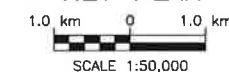
SHEET

















Ministry of Transportation
Northwestern Region
Structural Section



KEY PLAN



SOIL STRATA SYMBOLS		
	PEAT	
	FILL	
	SAND	
		
		CLAY - SILTY (VARVED)
		
		SILT/SAND/ GRAVEL
		
		BEDROCK

LEGEND	
	Borehole
	Borehole with Dynamic Cone Penetration Test (DCPT)
	Borehole - Previous Investigation
	DCPT - Previous Investigation
	Borehole & DCPT - Previous Investigation
	Sid Pen Test (Blows/0.3m)
	Water Level
	No Further Progress

No	ELEVATION	CO-ORDINATES (MTM, NAD 83 ZONE 14)	
		NORTHING	EASTING
TBT BOREHOLES			
1-2011	194.2	5420809.7	2451217.7
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3-2011	194.3	5420799.5	245090.9
4-2011	194.7	5420780.5	245072.7
PREVIOUS BOREHOLES			
1-1993	194.7	5420786.5	245078.4
2-1993	194.5	5420806.5	245101.4
3-1993	194.6	5420796.4	245124.3

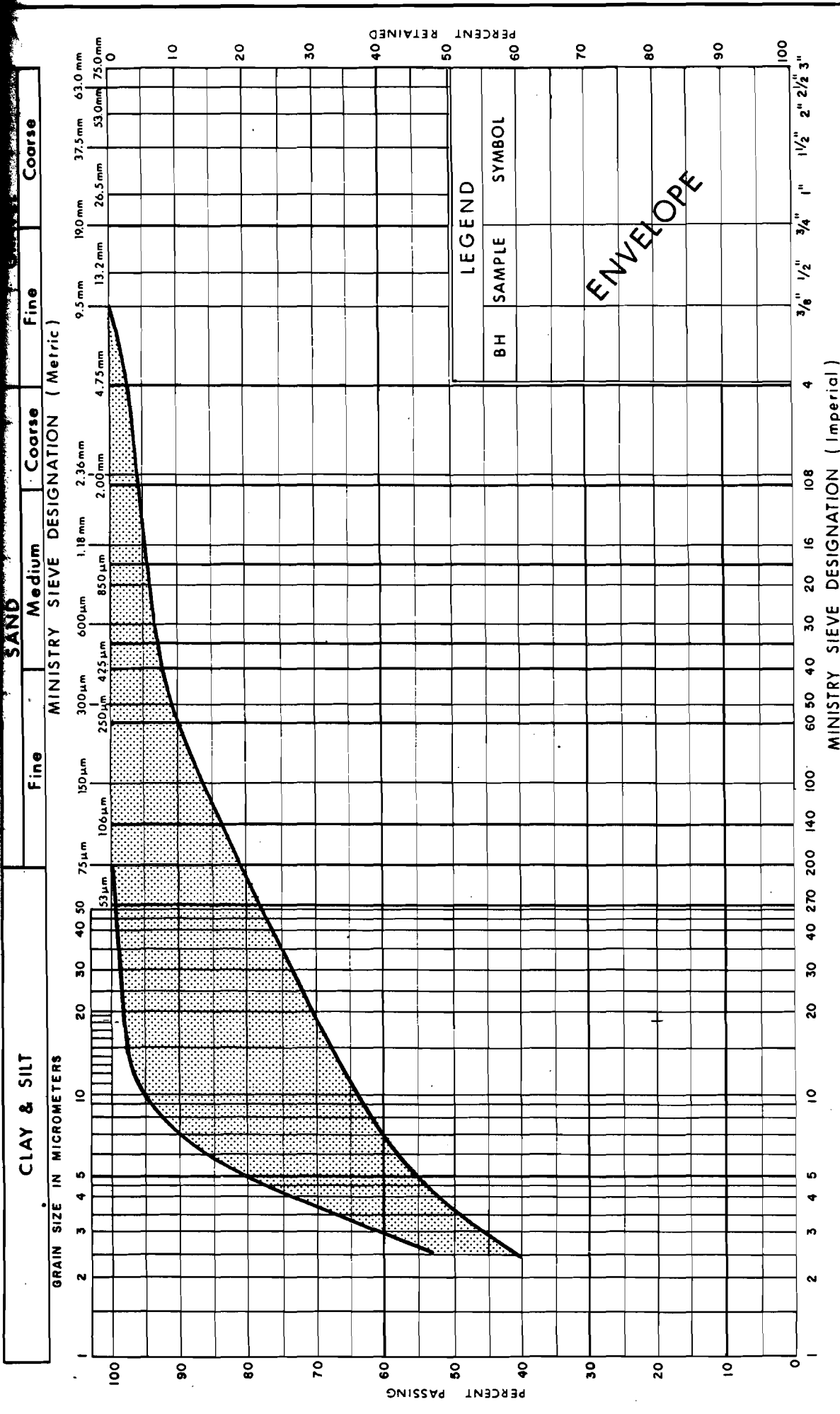
—NOTE—

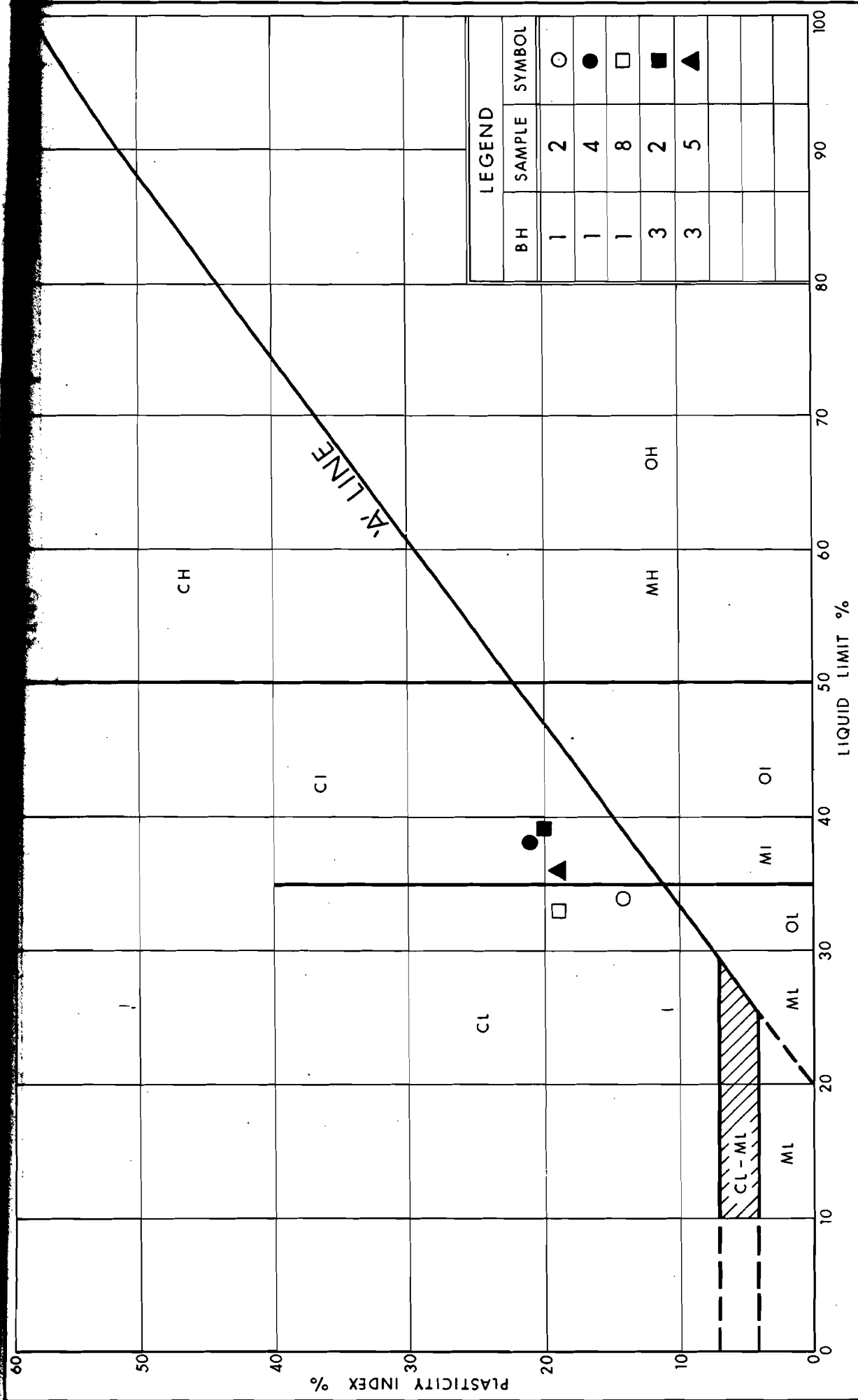
The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

REVISIONS	02/05/12	W.H.	FINAL				
	16/04/12	G.M.	REISSUED IN DRAFT				
	01/03/12	G.M.	ISSUED FOR DRAFT				
	XXXXXX	BY	REVISION				
	DESCRIPTION						
DESIGN	CHK	CHK	CODE	XXXX-XX	LOAD	XX-XX-XX	DATE 01/03/12
DRAWN	TR	CHK	WH/SITE	XXX-XXX			DWG

APPENDIX D

1993 Borehole Data and Laboratory Test Data







Ministry of
Transportation
Ontario

PLASTICITY CHART

SILTY CLAY

FIG No 2

W P 909 -76-01 (B)

CLAY & SILT

GRAIN SIZE IN MICROMETERS

Fine

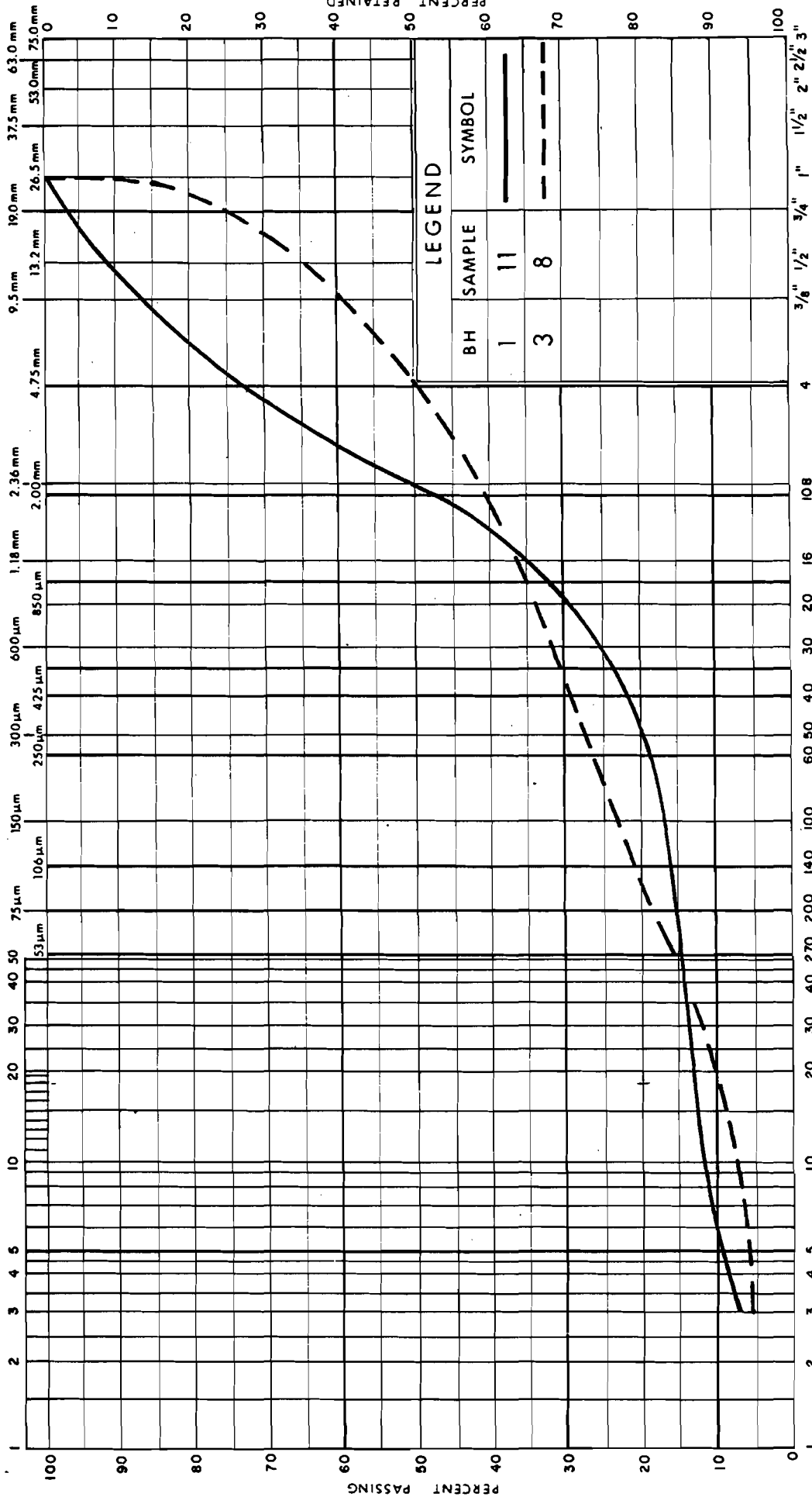
Medium

Coarse

Very Coarse

Very Fine

MINISTRY SIEVE DESIGNATION (Metric)



LEGEND

BH	SAMPLE	SYMBOL
1	11	—
3	8	- - -

Ministry of
Transportation



GRAIN SIZE DISTRIBUTION HET MIXTURE OF SILT, SAND & GRAVEL

FIG No 3

W P 909-76-01(B)

EXPLANATION OF TERMS USED IN REPORT

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

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

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

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

SPLIT SPOON	T P	THINWALL PISTON
WASH SAMPLE	O S	OSTERBERG SAMPLE
NOTED TUBE SAMPLE	R C	ROCK CORE
ROCK SAMPLE	P H	T W ADVANCED HYDRAULICALLY
TRUNK SAMPLE	P M	T W ADVANCED MANUALLY
THINWALL OPEN	F S	FOIL SAMPLE

STRESS AND STRAIN

kPa	PORE WATER PRESSURE
1	PORE PRESSURE RATIO
kPa	TOTAL NORMAL STRESS
kPa	EFFECTIVE NORMAL STRESS
kPa	SHEAR STRESS
kPa	PRINCIPAL STRESSES
%	TENSILE STRAIN
%	PRINCIPAL STRAINS
kPa	MODULUS OF LINEAR DEFORMATION
kPa	MODULUS OF SHEAR DEFORMATION
1	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

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

PHYSICAL PROPERTIES OF SOIL

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

RECORD OF BOREHOLE No 1

1 OF 1

METRIC

W.P. 909-76-01(B) LOCATION Sta. 10+025 o/s 23 m Lt. of Centerline Hwy. 17
DIST 19 HWY 17 BOREHOLE TYPE Hollow Stem Augers, BXL Rock Core
DATUM Geodetic DATE 93 04 01
ORIGINATED BY M.M.
COMPILED BY M.M.
CHECKED BY T.K.

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100					
184.7	Ground Surface - Wet Swamp												
0.0	Organics Trace Sand Dark Brown Brown												
	Some Gravel Some Sand	1	SS	3		194							
		2	SS	6		193							
		3	SS	4		192							
		4	SS	1		191							
		5	SS	1		190							
	Silty Clay Soft to Stiff	6	TW	PH		189							
		7	SS	1		188							
		8	SS	3		187							
		9	SS	3		186							
		10	SS	2		185							
184.6	Brown					184							
10.1	Red/Grey					183							
	Heterogeneous Mixture of Silt, Sand and Gravel Trace Clay Red/Grey Very Dense	11	SS	79		182							
183.1	Red/Grey												
11.6	Reddish Brown to Greenish Grey	12	RC	REC 58%									
	Bedrock Conglomerate Fine to Coarse Grained Medium Strong Unweathered to Slightly Weathered	13	RC	REC 100%									
181.5													
13.2	End of Borehole												

RECORD OF BOREHOLE No 2

1 OF 1

METRIC

W.P. 909-76-01(B) LOCATION Sta. 10+050 a/s 23 m Lt. of Centerline Hwy. 17 ORIGINATED BY M.M.
DIST 19 HWY 17 BOREHOLE TYPE Cone Penetration Test COMPILED BY M.M.
DATUM Geodetic DATE 93 04 02 CHECKED BY T.K.

[illegible]

+3, x5: Numbers refer to Sensitivity

20
15-5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 3

1 OF 1

METRIC

W.P. 909-76-01(B) LOCATION Sta. 10+075 o/s 23 m Lt. of Centerline Hwy. 17 ORIGINATED BY M.M.
DIST 19 HWY 17 BOREHOLE TYPE Hollow Stem Augers, BXL Rock Core & Cone Test COMPILED BY M.M.
DATUM Geodetic DATE 93 04 01 CHECKED BY T.K.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
194.6	Water Surface																
0.0																	
194.0	Swamp Bed																
0.6	Organics Dark Brown Brown																
			1	SS	8												
			2	SS	8												
			3	SS	5												
			4	SS	6												
			5	SS	7												
			6	TW	PH												
			7	SS	90	/5cm											
187.9	Some Gravel, Some Sand		8	SS	90	/10cm											
6.7	Reddish Brown to Greenish Grey		9	RC	REC 100%												
			10	RC	REC 100%												
			11	RC	REC 97%												
184.9	End of Borehole																
9.7																	

+3, x5: Numbers refer to 20
Sensitivity 15-5 (%) STRAIN AT FAILURE
10

ROCK CORE DESCRIPTION **WP 909-76-01(B)**

Page 1 of 1

CORE RECOVERY					CORE DESCRIPTION	
BH#	RC#	DEPTH (m)	% CR*	% RQD*	DEPTH (m)	DESCRIPTION
1	12	11.58-11.89	58	58	11.58-13.18	CONGLOMERATE, dark reddish brown to greenish grey matrix; fine to coarse grained; medium strong; unweathered to slightly weathered; fractures moderate to extremely close spaced, dipping to flat, undulating to planar, smooth to rough.
	13	11.89-13.18	100	96		
3	9	6.10-6.63	100	76	6.10-9.14	CONGLOMERATE, dark reddish brown to light brown to greenish grey matrix; fine to coarse grained; medium strong; unweathered to slightly weathered; fractures wide to very close spaced, dipping to flat, undulating to planar, smooth to rough.
	10	6.63-8.21	100	95		
	11	8.21-9.14	97	95		

*CR = CORE RECOVERY

*RQD = ROCK QUALITY DESIGNATION

Note: Depths are approximated where core recovery is less than 100%
Logged by: DAW, Soils and Aggregates Section