



**FOUNDATION INVESTIGATION REPORT
for
MILBERTA CREEK CULVERT REPLACEMENT
SITE NO. 47-290/C
HIGHWAY 65
G.W.P. 5126-05-00
TOWNSHIP OF HUDSON
NEW LISKEARD AREA, ONTARIO**

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TABLE OF CONTENTS

1. INTRODUCTION	1
2. SITE DESCRIPTION AND GEOLOGY	1
3. INVESTIGATION PROCEDURES	2
4. SUMMARIZED SUBSURFACE CONDITIONS	3
4.1 Milberta Creek Culvert Replacement – Sta. 15+467, Township of Hudson.....	4
4.1.1 Fill	4
4.1.2 Peat	4
4.1.3 Varved Clayey Soils.....	5
4.1.4 Probable Silty / Sandy Soils.....	6
4.1.5 Groundwater.....	6
4.2 Roadway Protection – Sta. 15+425 to 15+525, Township of Hudson	6
4.2.1 Fill	7
4.2.2 Peat	7
4.2.3 Varved Clayey Soils.....	7
4.2.4 Probable Silty / Sandy Soils.....	8
4.2.5 Groundwater.....	9
5. MISCELLANEOUS	9
6. CLOSURE.....	10

Table A– List of Atterberg Limit Results

Figures MC-GS-1 to MC-GS-4 – Grain Size Distribution Charts

Figures MC-PC-1 to MC-PC-3 – Plasticity Charts

Explanation of Terms Used in Report

Record of Borehole Sheets

Drawing MC-1 – Borehole Locations and Soil Strata

Appendix A – Site Photographs 1 to 4

Appendix B – Laboratory Photographs 1 and 2

FOUNDATION INVESTIGATION REPORT

for
Milberta Creek Culvert Replacement
Site No. 47-290/C
Highway 65
GWP 5126-05-00
Township of Hudson
New Liskeard Area, Ontario

1. INTRODUCTION

This report summarizes the results of the foundation investigation carried out for the Milberta Creek culvert replacement as part of the rehabilitation of Highway 65, project extending from 8.2 km west of the Highway 562 easterly 13.1 km including to Maybrook Road. The study was carried out by Peto MacCallum Ltd. (PML) for AECOM Canada Ltd (AECOM) on behalf of the Ministry of Transportation of Ontario (MTO).

The existing Milberta Creek Structural Plate Corrugated Steel Pipe culvert of 3.51 × 2.44 × 23.5 m will be replaced with a precast 3.6 × 2.1 × 32.0 m concrete culvert at approximate Station 15+467, Highway 65 chainage, in the Township of Hudson (ref. General Arrangement Drawing 'Milberta Creek Culvert' prepared by AECOM dated March 2012).

The purpose of this report was to summarize the subsurface stratigraphy encountered in the foundation investigation at the Milberta Creek culvert and at the roadway protection which may be required for culvert replacement.

2. SITE DESCRIPTION AND GEOLOGY

The replacement culvert is located on the existing Highway 65 about 140 m west of the existing Sawmill Road / Highway 65 at-grade crossing and about 40 m east of the existing Hooper Road. The site is about 12 km east of the Town of New Liskeard.

Land use in the vicinity of the site includes the existing Highway 65 transportation corridor and the Hooper Road and scattered residential houses north and south of the highway. The local topography of the site is generally flat with low-lying swampy areas north and south of the



highway. The Milberta Creek flows approximately in a southeast to northwest direction at Highway 65. The ground cover includes grasses in the swampy area and bushes and stands of trees elsewhere. Site Photographs of the culvert location are attached in Appendix A.

The project site is situated in a glaciolacustrine plain comprising varved clay soils which overlies Precambrian New Liskeard and Wabi group rocks.

3. INVESTIGATION PROCEDURES

The subsurface investigation was carried out during the period of September 27 to 30, 2011 and October 3, 2011. A total of five boreholes (M-1 to M-5) were drilled to 13.1 to 21.9 m at the locations shown on Drawing MC-1, appended. A dynamic cone penetration test was carried out in borehole M-1 from 16.3 to 30.5 m depth to verify the competent soils.

The boreholes were advanced using continuous flight hollow stem augers through the soil cover with a track-mounted CME 55 drill rigs, supplied and operated by a specialist drilling contractor, working under the full-time supervision of a PML field supervisor.

Soil samples were recovered from the boreholes at regular 0.75 and 1.5 m intervals of depth using the standard penetration test method. Standard penetration tests, field vane tests and dynamic cone test were conducted to assess the strength characteristics of the substrata. Soils were identified in accordance with the MTO soil classification manual procedures.

The groundwater conditions in the boreholes were assessed during drilling by visual examination of the soil, the sampler and drill rods as the samples were retrieved and, where encountered, by measuring the groundwater level in the open holes.

The boreholes were backfilled with a bentonite/cement mixture where required in accordance with the MTO guideline and MOE Reg. 903 for borehole abandonment.



The co-ordinates and ground elevations at the borehole locations were provided by exp Geomatics Ltd. All elevations in this report are reported in metres.

The recovered soil samples were returned to our laboratory in Toronto for detailed visual examination, laboratory testing and classification. The laboratory testing program included the following tests:

- Natural moisture content determinations (81)
- Grain size distribution analyses (16)
- Atterberg Limits (16)
- Unconfined compression tests (2)

The laboratory grain size distribution charts are presented in Figures MC-GS-1 to MC-GS-4 and Atterberg Limits results are presented in Figures MC-PC-1 to MC-PC-3. The Atterberg Limits results are summarized in Table A. All of the test results are summarized on the Record of Borehole sheets. The laboratory photographs of 2 extruded thin wall samples of varved clayey soil are included in Appendix B.

4. SUMMARIZED SUBSURFACE CONDITIONS

Reference is made to the appended Record of Borehole Sheets for details of the subsurface conditions including soil classifications, inferred stratigraphy, standard penetration test, dynamic cone penetration data and field vane test results and groundwater observations. The results of laboratory particle size distributions, Atterberg Limits, unconfined compression tests and moisture content determinations are also shown on the Record of Borehole Sheets.

The borehole locations, stratigraphic profile and cross-sections prepared from the borehole data are shown on Drawing MC-1. The boundaries between soil strata have been established at the borehole locations only. Between and beyond the boreholes, the boundaries are assumed and may vary.

A summary of the findings is given below.



4.1 Milberta Creek Culvert Replacement – Sta. 15+467, Township of Hudson

The Milberta Creek culvert is orientated at a 43° skew to the centreline of Highway 65.

Three boreholes (M-1 to M-3) were drilled along the alignment of this culvert to 13.1 to 21.9 m. A dynamic cone penetration test was carried out in borehole M-1 from 16.3 to 30.5 m. The subsurface stratigraphy revealed in the boreholes generally comprised a road embankment / topsoil fill overlying peat or cohesive varved clayey soils followed by probable cohesionless silty/sandy soils. Groundwater was observed in two boreholes.

4.1.1 Fill

A 3.1 m thick fill was encountered in borehole M-2 drilled on the existing embankment shoulder. The fill unit extended to 3.1 m (elevation 244.2). The fill layer includes sand and gravel over sand containing cobbles. N values varied from 3 to 12, locally 1 indicating compact to very loose relative density.

In addition, a 500 and 600 mm thick fill was encountered surficially in boreholes M-1 and M-3 extending to elevation 245.4 and 245.5. The fill contains topsoil with sand and gravel. N values were 5 and 15.

The results of grain size distribution analysis for a sand fill sample from borehole M-2 are included in Figure MC-GS-1. The moisture content results varied from 5 to 22%, locally 29 and 38% due to organics in boreholes M-1 and M-3.

4.1.2 Peat

A 800 and 900 mm thick peat layer was encountered below the fill at 0.5 and 0.6 m (elevation 245.4 and 245.5) in boreholes M-1 and M-3. The layer extended to 1.4 m (elevation 244.5 and 244.7). The peat was fine fibrous. The moisture content determinations were 55 and 76%.



4.1.3 Varved Clayey Soils

A cohesive varved clay to clayey silt deposit was encountered below the peat at 1.4 m (elevation 244.5 and 244.7) in boreholes M-1 and M-3 and below the fill unit at 3.1 m (elevation 244.2) in borehole M-2.

The upper 0.8 m thick layer contains organics extending to 2.2 m (elevation 243.7) in borehole M-1. The varved clayey soils were light grey to grey containing silt and sandy silt partings. The laboratory photographs of 2 extruded thin wall samples of varved clayey soil are included in Appendix B.

The stratum was at least 11.7 to 18.8 m thick extending to borehole termination depths of 13.1 to 21.9 m (elevation 225.4 to 233.0), probably to 22.0 m (elevation 223.9) in borehole M-1.

Undrained shear strength values obtained from field vane tests typically varied from 17 to 36 kPa, locally 10 and 13 kPa (sensitivity of 2 to 5). The deposit typically exhibited soft to firm consistency with local very soft layers. Unconfined compression tests on 2 samples yielded shear strength values of 10 kPa (strain at failure of 5%). N values were WR (weight of rods) to WH (weight of hammer and rods).

The results of grain size distribution analysis for clay/silty clay/clayey silt samples are included in Figures MC-GS-2 to MC-GS-4. The plasticity charts are presented in Figures MC-PC-1 to MC-PC-3. The Atterberg Limits results are summarized in Table A. The liquid and plastic limits of a clay sample were 52 and 22 with the corresponding plasticity index of 30. The liquid and plastic limits of silty clay samples ranged from 35 to 39 and 18 to 21, respectively with plasticity index values of 14 to 20. The liquid and plastic limits of clayey silt samples ranged from 25 to 34 and 15 to 20 with plasticity index values of 10 to 15. The moisture content determinations ranged from 32 to 80%, typically higher than the liquid limit values.



4.1.4 Probable Silty / Sandy Soils

Below the varved clayey soils in borehole M-1, a cohesionless probable silty/sandy deposit was inferred by dynamic cone penetration test data at 22.0 m (elevation 223.9) extending to termination depth of 30.5 m (elevation 215.4). The unit was loose to dense relative density based on dynamic cone penetration data.

4.1.5 Groundwater

Groundwater was encountered in boreholes M-1 and M-2. During augering in borehole M-2, groundwater was observed at 16.0 m (elevation 231.3) after sample 17. The groundwater level also was observed at sample 18 to rise from a depth of 16.8 to 12.2 m. The groundwater level also was observed at sample 19 to rise from a depth of 12.2 to 7.6 m. The groundwater was measured upon completion of drilling at 7.3 m (elevation 240.0) in borehole M-2. The groundwater was measured in borehole M-1 at the surface (elevation 245.9) 12 hours after completion. No water was encountered in borehole M-3. It was inferred that artesian groundwater condition exists in silty sand layers found below about 15.0 m depth at the site.

The water level in the Milberta Creek was at about elevation 245.4 at the time of the investigation. The groundwater level is subject to seasonal fluctuation and rainfall patterns.

4.2 Roadway Protection – Sta. 15+425 to 15+525, Township of Hudson

A roadway protection may be required for culvert replacement. For preliminary purposes, the extent of the roadway protection was investigated approximately between Sta. 15+425 to 15+525 in the Township of Hudson. Two boreholes (M-4 and M-5) were drilled for the roadway protection and two culvert boreholes (M-1 and M-2) were also utilized for this roadway protection. The boreholes were advanced to depths ranging from 13.1 to 21.9 m. A dynamic cone penetration test was carried out in borehole M-1 from 16.3 to 30.5 m



The subsurface stratigraphy revealed in the boreholes generally comprised a road embankment or topsoil fill overlying peat or cohesive varved clayey soils followed by probable cohesionless silty/sandy soils. Groundwater was observed in two boreholes.

4.2.1 Fill

A 1.4 to 3.1 m thick fill was encountered in boreholes M-2, M-4 and M-5 drilled on the existing embankment shoulder. The fill unit extended to 1.4 to 3.1 m (elevation 244.2 to 246.6). The fill layer includes sand and gravel to containing cobbles overlying cohesive clayey silt/silty clay with organic inclusions. N values varied from 3 to 47, locally 1 indicating loose to compact relative density with local very loose layers.

In addition, a 500 mm thick fill was encountered surficially in borehole M-1 extending to elevation 245.4. The fill contains topsoil with sand and gravel. One N value of 5 was recorded.

The results of grain size distribution analysis for a sand fill sample from borehole M-2 are included in Figure MC-GS-1. The moisture content results varied from 3 to 22%, locally 39% due to organics in borehole M-1.

4.2.2 Peat

A 900 mm thick peat layer was encountered below the fill at 0.5 m (elevation 245.4) in borehole M-1. The layer extended to 1.4 m (elevation 244.5). The peat was fine fibrous. One moisture content determination was 55%.

4.2.3 Varved Clayey Soils

A cohesive varved clayey soil deposit was encountered below the peat at 1.4 m (elevation 244.5) in borehole M-1 and below the fill unit at 1.4 to 3.1 m (elevation 244.2 to 246.6) in borehole M-2, M-4 and M-5. The upper 0.6 to 2.3 m thick layer contains organics extending to 2.2 to 3.7 m (elevation 243.7 to 245.9) in boreholes M-1, M-4 and M-5. The varved clayey soil was light grey



to grey containing silt layers and sandy silt partings. The varved clayey soil stratum was at least 14.6 to 18.8 m thick extending to borehole termination depths of 16.3 to 21.9 m, probably to 22.0 m (elevation 223.9 to 231.9). The laboratory photographs of 2 extruded thin wall samples of varved clayey soil are included in Appendix B.

Undrained shear strength values obtained from field vane tests typically varied from 17 to 36 kPa, locally 10 and 13 kPa (sensitivity of 2 to 5). Unconfined compression tests on 2 samples yielded shear strength values of 10 kPa (strain at failure of 5%). The layer typically exhibited soft to firm consistency with local very soft layers. N value was WH (weight of hammer and rods).

The results of grain size distribution analysis for clay/silty clay/clayey silt samples are included in Figures MC-GS-2 to MC-GS-4. The plasticity charts are presented in Figures MC-PC-1 to MC-PC-3. The Atterberg Limits results are summarized in Table A. The liquid and plastic limits of a clay sample were 52 and 22 with the corresponding plasticity index of 30. The liquid and plastic limits of silty clay samples ranged from 35 to 46 and 18 to 21, respectively with plasticity index values of 14 to 26. The liquid and plastic limits of clayey silt samples ranged from 25 to 34 and 15 to 20 with plasticity index values of 10 to 15. The moisture content determinations ranged from 32 to 80%, typically higher than the liquid limit value.

4.2.4 Probable Silty / Sandy Soils

Below the varved clayey soils in borehole M-1, a cohesionless probable silty/sandy deposit was inferred by dynamic cone penetration test at 22.0 m (elevation 223.9) extending to termination depth of 30.5 m (elevation 215.4). The unit was loose to dense relative density based on dynamic cone penetration data.



4.2.5 Groundwater

Groundwater was encountered in boreholes M-1 and M-2. During augering in borehole M-2, groundwater was observed at 16.0 m (elevation 231.3) after sample 17. The groundwater level was observed at sample 18 to rise from a depth of 16.8 to 12.2 m. The groundwater level also was observed at sample 19 to rise from a depth of 12.2 to 7.6 m. The groundwater was measured upon completion of drilling at 7.3 m (elevation 240.0) in borehole M-2. The groundwater was measured in borehole M-1 at the surface (elevation 245.9) 12 hours after completion of the borehole. No water was encountered in boreholes M-4 and M-5. It was inferred that artesian groundwater condition exists in silty sand layers found below about 15.0 m depth at the site.

The water level in the Milberta Creek was at about elevation 245.4 at the time of the investigation. The groundwater level is subject to seasonal fluctuation and rainfall patterns.

5. MISCELLANEOUS

Mr. F. Portela carried out the field investigation for this study under the supervision of Mrs. N .S. Balakumaran, P. Eng., and Mr. C. M. P. Nascimento, P. Eng., Project Manager. LandCore Drilling Ltd. supplied the drill rig for the subsurface exploration. The laboratory testing of the selected samples was carried out in the PML laboratory in Toronto.



6. CLOSURE

This Foundation Investigation Report was prepared by Mrs. N. S. Balakumaran, P. Eng., and reviewed by Mr. B. R. Gray, MEng, P.Eng., MTO Designated Principal Contact. Mr. C. M. P. Nascimento, P. Eng., Project Manager conducted an independent review of the report.

Yours very truly

Peto MacCallum Ltd.



Nesam S. Balakumaran, P.Eng.
Project Engineer



Carlos M.P. Nascimento, P.Eng.
Project Manager



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

NB/CN/BRG:nb-mi



TABLE A
LIST OF ATTERBERG LIMIT RESULTS

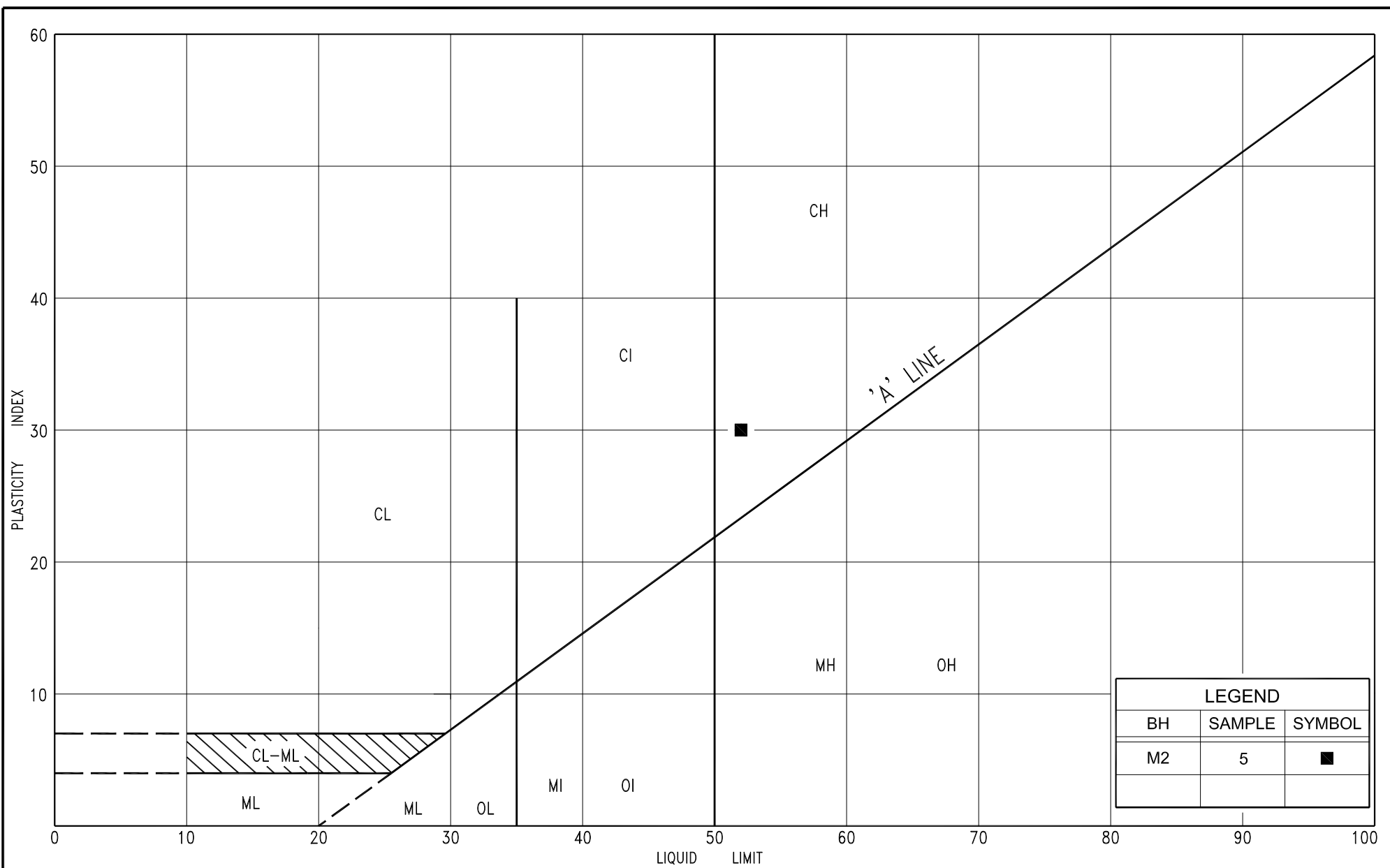
SOIL TYPE	BOREHOLE NO.	SAMPLE NO.	DEPTH (m)	ELEVATION	MOISTURE CONTENT (W) %	LIQUID LIMIT (LL)	PLASTIC LIMIT (PL)	PLASTICITY INDEX (PI)
Clay (CH)	M-2	5	3.5	243.8	58	52	22	30
Silty Clay (CI)	M-1	6	4.2	241.7	59	35	21	14
		9	6.3	239.6	58/70 (*)	38	18	20
	M-2	10	7.7	239.6	50/57 (*)	39	20	19
		12	10.9	236.4	40/80 (*)	37	19	18
	M-4	5	3.4	244.6	64	46	20	26
		9	6.3	241.7	57	35	20	15
		11	9.4	238.6	55	36	19	17



TABLE A
LIST OF ATTERBERG LIMIT RESULTS

SOIL TYPE	BOREHOLE NO.	SAMPLE NO.	DEPTH (m)	ELEVATION	MOISTURE CONTENT (W) %	LIQUID LIMIT (LL)	PLASTIC LIMIT (PL)	PLASTICITY INDEX (PI)
Clayey Silt (CL)	M-1	11	9.2	236.7	39/58 (*)	32	19	13
		12	11.1	234.8	49	32	19	13
		14	14.1	231.8	45	30	20	10
	M-2	8	5.6	241.7	56	34	19	15
		14	13.9	233.4	37	32	19	13
		17	16.9	230.4	32	25	15	10
		21	20.0	227.3	40	30	20	10
	M-4	13	12.5	235.5	47	31	20	11

(*) Two moisture content determinations were carried out on shelly tube samples. High moisture content values were obtained for high clay content layers while low moisture content values for less clay content layers.



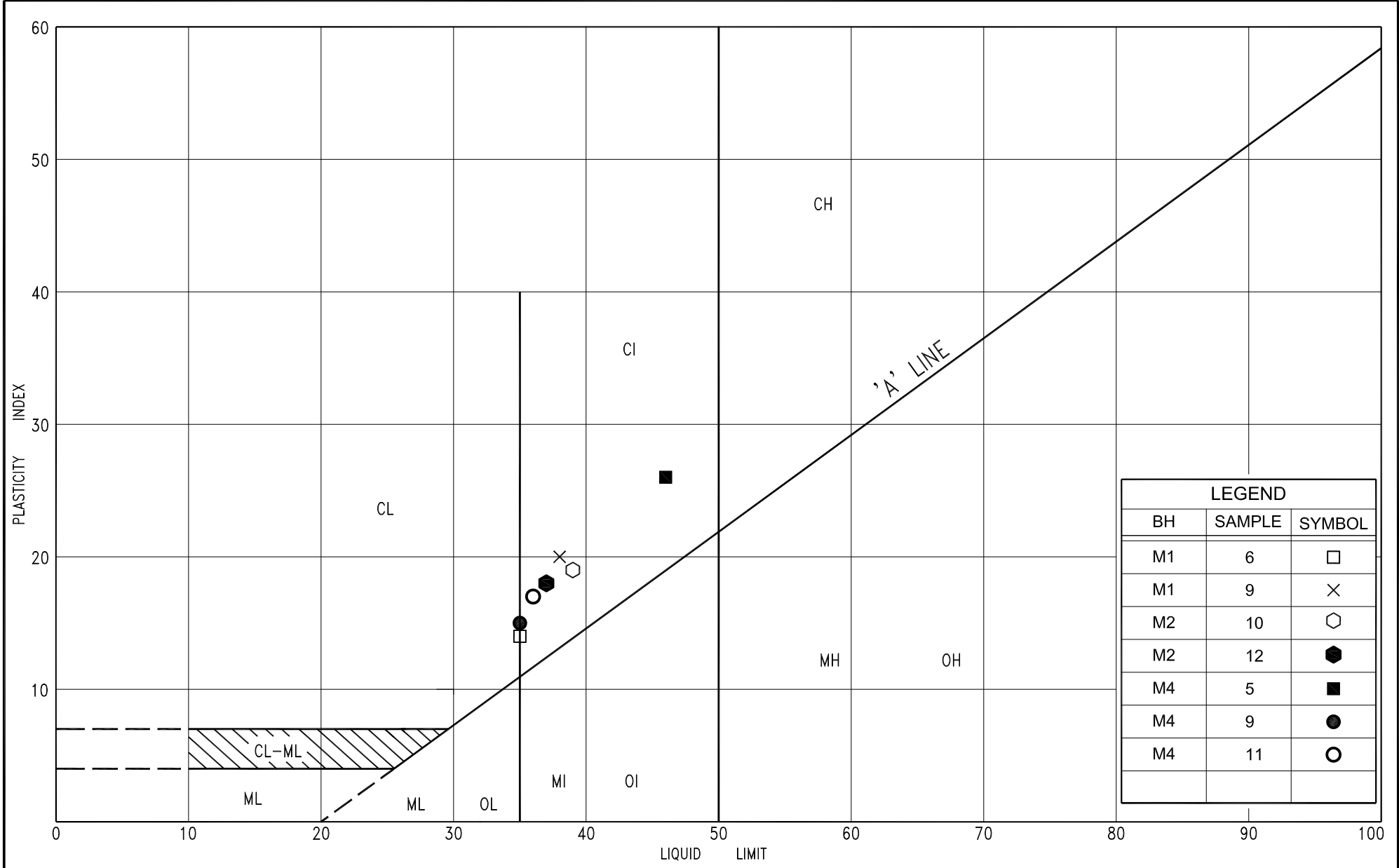
PLASTICITY CHART

CLAY, trace sand (CH)

FIG No. MC-PC-1

HWY: 65

G.W.P. No. 5126-05-00

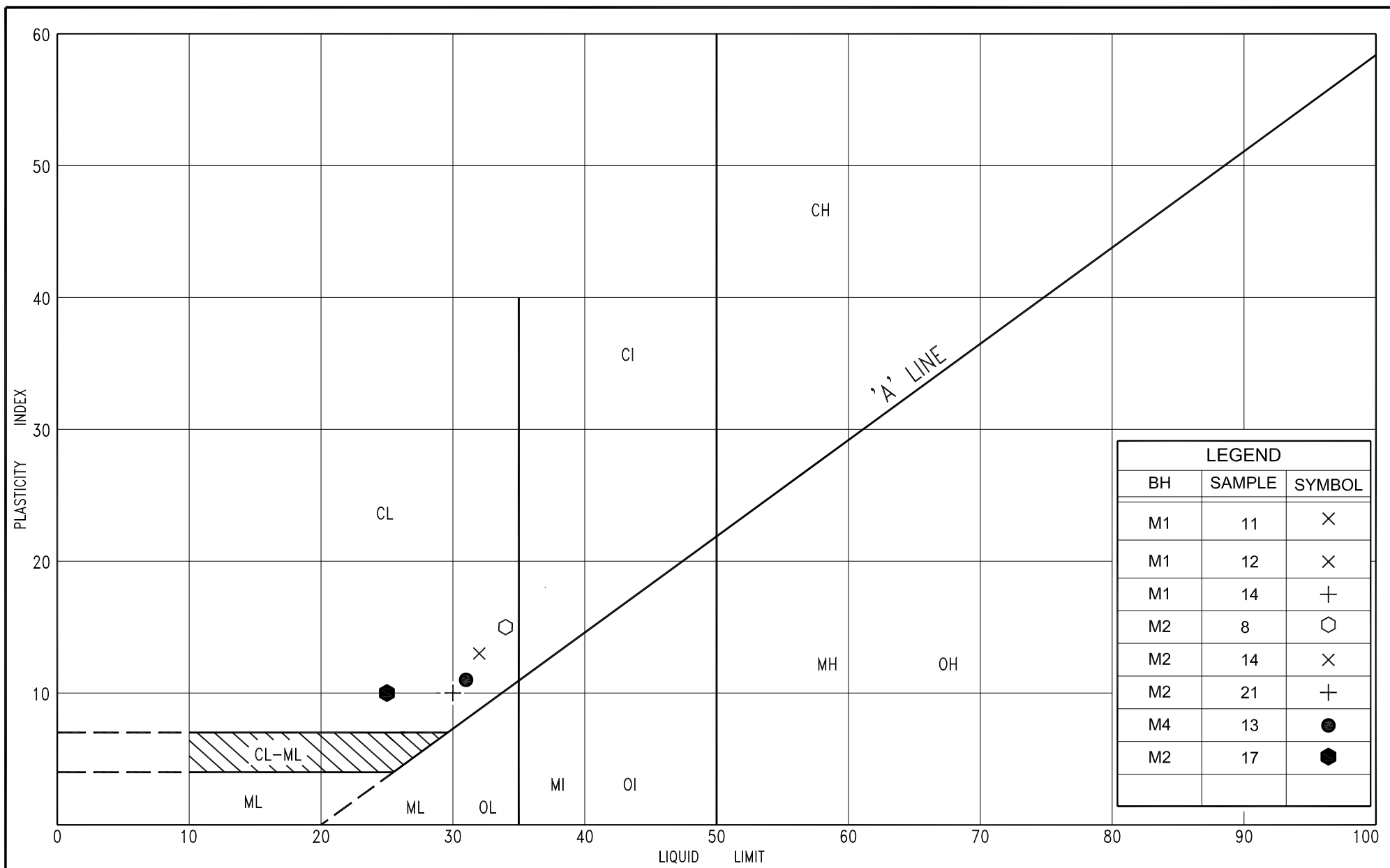


LEGEND		
BH	SAMPLE	SYMBOL
M1	6	□
M1	9	×
M2	10	⬡
M2	12	⬢
M4	5	■
M4	9	●
M4	11	○



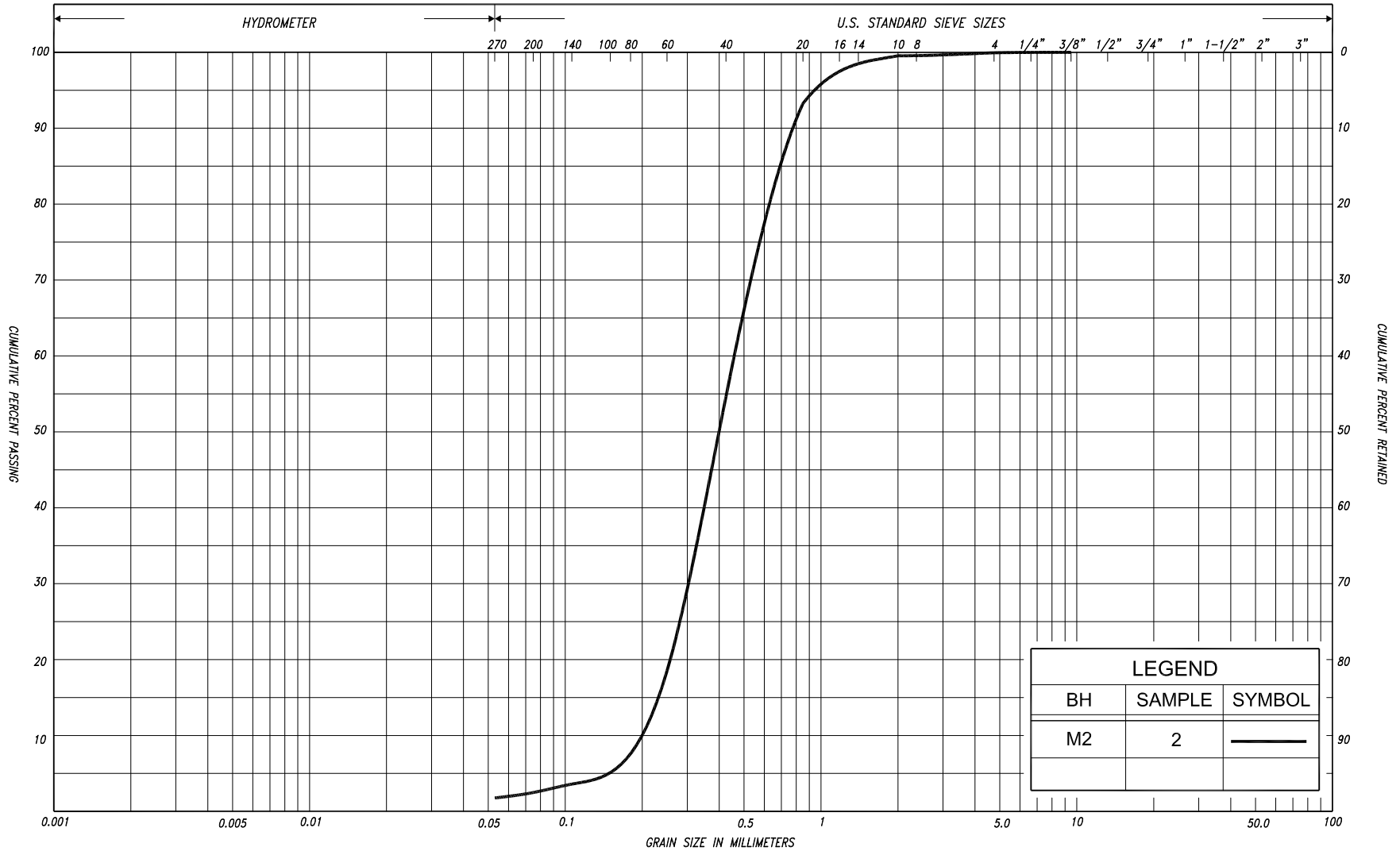
PLASTICITY CHART
 SILTY CLAY, trace sand (CI)

FIG No.	MC-PC-2
HWY:	65
G.W.P. No.	5126-05-00



PLASTICITY CHART
CLAYEY SILT, trace to some sand (CL)

FIG No. MC-PC-3
HWY: 65
G.W.P. No. 5126-05-00



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												

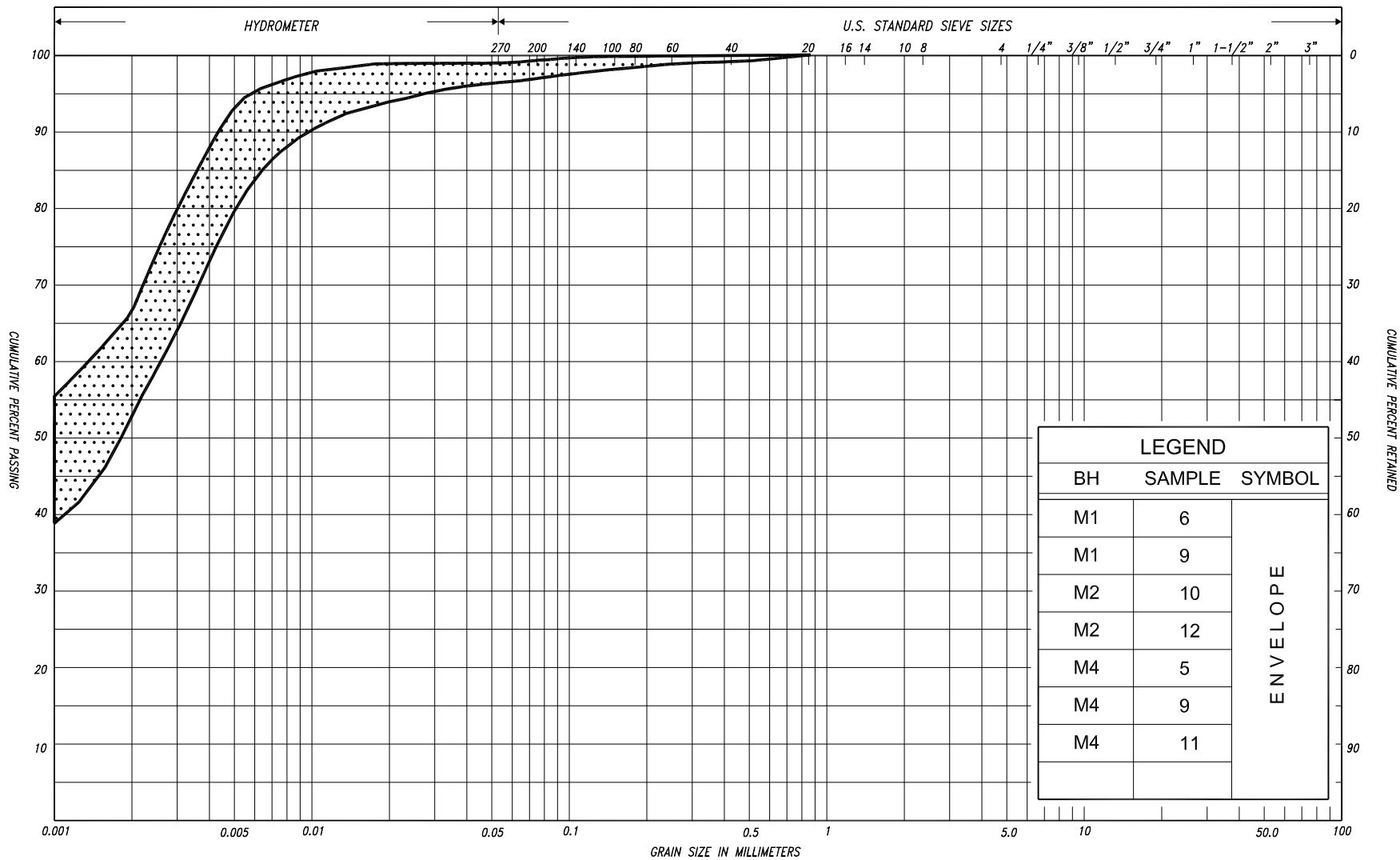


GRAIN SIZE DISTRIBUTION SAND, trace silt (FILL)

FIG No. MC-GS-1

HWY: 65

G.W.P. No. 5126-05-00



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												



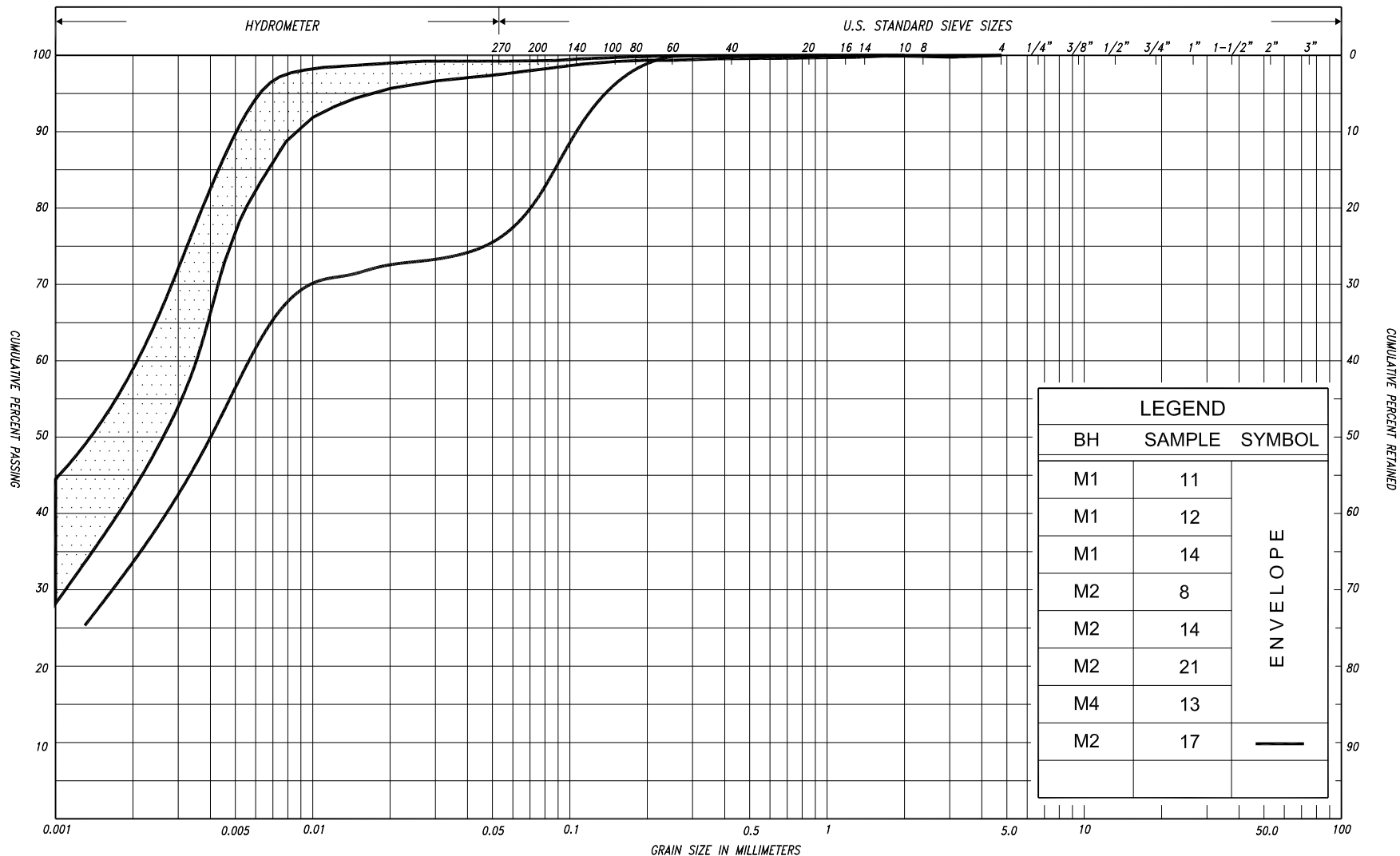
GRAIN SIZE DISTRIBUTION

SILTY CLAY, trace sand (CI)

FIG No. MC-GS-3

HWY: 65

G.W.P. No. 5126-05-00



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



GRAIN SIZE DISTRIBUTION

CLAYEY SILT, trace to some sand (CL)

FIG No. MC-GS-4

HWY: 65

G.W.P. No. 5126-05-00

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.

COMPOSITION: SECONDARY SOIL COMPONENTS ARE DESCRIBED ON THE BASIS OF PERCENTAGE BY MASS OF THE WHOLE SAMPLE AS FOLLOWS:

PERCENT BY MASS	0 - 10	10 - 20	20 - 30	30 - 40	> 40
	TRACE	SOME	WITH	ADJECTIVE (SILTY)	AND (AND SILT)

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 (R Q D), FOR MODIFIED RECOVERY, IS:

R Q D (%)	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
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

m_v	kPa ⁻¹	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	1	RATE OF SECONDARY CONSOLIDATION
c_v	m ² /s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{v0}	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	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

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

RECORD OF BOREHOLE No M-1

1 of 3

METRIC

G.W.P. 5126-05-00

LOCATION

Hwy 65, Sta. 15+448.1, o/s 12.1m Lt.
Coords: 5 267 149.9 N; 393 179.7 E

ORIGINATED BY F.P.

DIST New Liskeard HWY 65

BOREHOLE TYPE C.F.H.S.A. and Dynamic Cone Penetration Test

COMPILED BY N.S.B.

DATUM Geodetic

DATE

September 27 & 28, 2011

CHECKED BY B.R.G.

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									
								○ UNCONFINED + FIELD VANE									
								● QUICK TRIAXIAL × LAB VANE									
WATER CONTENT (%)																	
245.9	Ground Surface						20	40	60	80	100						
0.0	Topsoil with sand and gravel		1	SS	5												
245.4	(FILL)																
0.5	Peat, fine fibrous																
	Dark Wet		2	SS	1		245										
	brown																
244.5																	
1.4	Silty clay organics to 2.2m		3	SS	WH**		244										
	Soft to Grey Wet																
	firm clayey silt layers		4	SS	WH		243										
	varved		5	SS	WH		242										
	Light grey/dark grey		6	SS	WH		241										
	clayey silt/ silty clay layers		7	SS	WH		240										
				FV													
			8	SS	WH		239										
				FV													
			9	TW	PM		238										
				FV													
			10	SS	WH		237										
				FV													
			11	TW	PM		236										
				FV													
			12	SS	WH		235										
				FV													
			13	SS	WH		234										
				FV													
			14	SS	WH		233										
				FV													

Cont'd

RECORD OF BOREHOLE No M-1

2 of 3

METRIC

G.W.P. 5126-05-00

LOCATION

Hwy 65, Sta. 15+448.1, o/s 12.1m Lt.
Coords: 5 267 149.9 N; 393 179.7 E

ORIGINATED BY F.P.

DIST New Liskeard HWY 65

BOREHOLE TYPE C.F.H.S.A. and Dynamic Cone Penetration Test

COMPILED BY N.S.B.

DATUM Geodetic

DATE September 27 & 28, 2011

CHECKED BY B.R.G.

[illegible]

RECORD OF BOREHOLE No M-1

3 of 3

METRIC

G.W.P. 5126-05-00

LOCATION

Hwy 65, Sta. 15+448.1, o/s 12.1m Lt.
Coords: 5 267 149.9 N; 393 179.7 E

ORIGINATED BY F.P.

DIST New Liskeard HWY 65

BOREHOLE TYPE C.F.H.S.A. and Dynamic Cone Penetration Test

COMPILED BY N.S.B.

DATUM Geodetic

DATE

September 27 & 28, 2011

CHECKED BY B.R.G.

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			20	40	60	80	100					
215.9 30.0	Probable silty/sandy soils	•															
215.4 30.5	(Cont'd)	•															
	End of dynamic cone penetration test																
	* 2011 09 28																
	▼ Water level measured after drilling																
	WH** denotes penetration due to weight of rods and hammer																
	Note: Water level rose to surface 12 hrs after borehole completion (September 27, 2011, overnight)																
	C.F.H.S.A. denotes Continuous Flight Hollow Stem Augers																

RECORD OF BOREHOLE No M-2

1 of 2

METRIC

G.W.P. 5126-05-00

LOCATION

Hwy 65, Sta. 15+466.5, o/s 6.3m Lt.
Coords: 5 267 140.7 N; 393 196.5 E

ORIGINATED BY F.P.

DIST New Liskeard HWY 65

BOREHOLE TYPE Continuous Flight Hollow Stem Augers

COMPILED BY N.S.B.

DATUM Geodetic

DATE

September 29 & 30, 2011

CHECKED BY B.R.G.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	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									
							○ UNCONFINED + FIELD VANE									
							● QUICK TRIAXIAL × LAB VANE									
					WATER CONTENT (%)											
247.3	Ground Surface					20	40	60	80	100	20	40	60			
0.0	Sand and gravel		1	SS	12						○					
	Sand, trace silt		2	SS	3						○				0 97 (3)	
	Compact Brown Moist to loose		3	SS	7						○					
			4	SS	1						○					
244.2	with gravel cobbles															
3.1	Very loose Wet (FILL)															
	Silty clay, trace sand clay layers		5	SS	WH**							┌───┐	○		0 4 18 78	
	Very soft Light Wet to firm grey/grey		6	SS	WH								○			
			7	SS	WH								○			
	clayey silt layers varved			FV												
			8	SS	WH							┌──┐	○		0 2 40 58	
				FV												
			9	SS	WH											
				FV												
												</				

Cont'd

RECORD OF BOREHOLE No M-2

2 of 2

METRIC

G.W.P. 5126-05-00

LOCATION

Hwy 65, Sta. 15+466.5, o/s 6.3m Lt.
Coords: 5 267 140.7 N; 393 196.5 E

ORIGINATED BY F.P.

DIST New Liskeard HWY 65

BOREHOLE TYPE Continuous Flight Hollow Stem Augers

COMPILED BY N.S.B.

DATUM Geodetic

DATE September 29 & 30, 2011

CHECKED BY B.R.G.

[illegible]

RECORD OF BOREHOLE No M-3

1 of 1

METRIC

G.W.P. 5126-05-00

LOCATION

Hwy 65, Sta. 15+471.1, o/s 13.6m Rt.
Coords: 5 267 120.3 N; 393 197.6 E

ORIGINATED BY F.P.

DIST New Liskeard HWY 65

BOREHOLE TYPE Continuous Flight Hollow Stem Augers

COMPILED BY N.S.B.

DATUM Geodetic

DATE

September 27 & 28, 2011

CHECKED BY B.R.G.

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/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)
								20 40 60 80 100										
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE										
246.1 0.0	Ground Surface																	
245.5 0.6	Topsoil with sand and gravel (FILL)		1	SS	15		246											
244.7 1.4	Peat, fine fibrous																	
	Dark brown Wet		2	SS	4		245											
	Silty clay																	
	Soft to Grey Wet firm clayey silt layers		3	SS	1		244											
	varved																	
	Light grey/grey		4	SS	WH**		243											
	clayey silt /silt layers																	
			5	SS	WH		242											
			6	SS	WH		241											
			7	SS	WH		240											
			8	SS	WH		239											
			9	SS	WR**		238											
			10	TW	PM		237											
			11	SS	WH		236											
			12	TW	PM		235											
			13	SS	WH		234											
233.0 13.1	End of borehole						233											
	* Borehole dry																	
	WH** denotes penetration due to weight of rods and hammer																	
	WR** denotes penetration due to weight of rods																	

RECORD OF BOREHOLE No M-4

1 of 2

METRIC

G.W.P. 5126-05-00

LOCATION

Hwy 65, Sta. 15+422.9, o/s 6.4m Rt.
Coords: 5 267 136.9 N; 393 152.7 E

ORIGINATED BY F.P.

DIST New Liskeard HWY 65

BOREHOLE TYPE Continuous Flight Hollow Stem Augers

COMPILED BY N.S.B.

DATUM Geodetic

DATE September 28, 2011

CHECKED BY B.R.G.

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 _p W W _L				GR	SA	SI	CL	
								○ UNCONFINED + FIELD VANE					WATER CONTENT (%)								
								● QUICK TRIAXIAL × LAB VANE													
248.0	Ground Surface							20	40	60	80	100									
0.0	Sand and gravel		1	SS	47									○							
	Dense _____ Brown _____ Moist _____																				
	Sand		2	SS	6									○							
	Loose _____ Wet _____																				
246.6	clayey silt layers (FILL)													○							
1.4	Clayey silt, trace sand organics, oxidized		3	SS	21									○							
	Very stiff Grey _____ Moist to soft																				
245.4	Silty clay organics to 3.7m		4	SS	2											○					
2.6	Soft to firm _____ Grey _____ Wet _____		5	SS	WH**										┌───┐		○			0 3 31 66	
	varved _____																				
	_____ Light grey/grey _____		6	SS	WH												○				
	clayey silt layers		7	SS	WH												○				
			8	SS	WH												○				
				FV										3	+						
			9	SS	WH											┌──┐		○		0 1 46 53	
				FV										3	+						
			10	SS	WH													○			
				FV										4	+						
			11	SS	WH											┌──┐		○		0 1 41 58	
				FV										3	+						
			12	SS	WH													○			
				FV										4	+						
			13	SS	WH											┌──┐		○		0 1 53 46	
				FV										3	+						
	silty sand partings																				
			14	SS	WH													○			
				FV										3	+						
233.0																					

RECORD OF BOREHOLE No M-4

2 of 2

METRIC

G.W.P. 5126-05-00

LOCATION

Hwy 65, Sta. 15+422.9, o/s 6.4m Rt.
Coords: 5 267 136.9 N; 393 152.7 E

ORIGINATED BY F.P.

DIST New Liskeard HWY 65

BOREHOLE TYPE Continuous Flight Hollow Stem Augers

COMPILED BY N.S.B.

DATUM Geodetic

DATE

September 28, 2011

CHECKED BY B.R.G.

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/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
233.0								20	40	60	80	100					
15.0	Silty clay organics																
	Firm Grey Wet <div>(Cont'd)</div>		15	SS	WH										o		
				FV			232			3							
231.7																	
16.3	End of borehole																
	<div>* Borehole dry</div> <div>WH** denotes penetration due to weight of rods and hammer</div>																

RECORD OF BOREHOLE No M-5

1 of 2

METRIC

G.W.P. 5126-05-00

LOCATION

Hwy 65, Sta. 15+524.0, o/s 5.0m Rt.
Coords: 5 267 122.2 N; 393 252.0 E

ORIGINATED BY F.P.

DIST New Liskeard HWY 65

BOREHOLE TYPE Continuous Flight Hollow Stem Augers

COMPILED BY N.S.B.

DATUM Geodetic

DATE

October 03, 2011

CHECKED BY B.R.G.

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 (%)		
								○ UNCONFINED + FIELD VANE												
								● QUICK TRIAXIAL × LAB VANE												
248.2	Ground Surface						20	40	60	80	100									
0.0	Sand and gravel		1	SS	19															
	Compact Brown Moist (FILL)																			
	Silty clay organic inclusions		2	SS	17															
246.5	Very stiff Grey Moist		3	SS	21															
1.7	Silty clay organics to 2.3m																			
	Very stiff Black/ Moist to firm grey		4	SS	9															
			5	SS	5															
	varved		6	SS	WH**															
	Soft to Light Wet firm grey/grey		7	SS	WH															
				FV																
	clayey silt layers silty sand partings		8	SS	WH															
				FV																
			9	SS	WH															
				FV																
			10	SS	WH															
				FV																
		11	SS	WH																
			FV																	
		12	SS	WH																
			FV																	
		13	SS	WH																
			FV																	
		14	SS	WH																
			FV																	
233.2																				

Cont'd

RECORD OF BOREHOLE No M-5

2 of 2

METRIC

G.W.P. 5126-05-00

LOCATION

Hwy 65, Sta. 15+524.0, o/s 5.0m Rt.
Coords: 5 267 122.2 N; 393 252.0 E

ORIGINATED BY F.P.

DIST New Liskeard HWY 65

BOREHOLE TYPE Continuous Flight Hollow Stem Augers

COMPILED BY N.S.B.

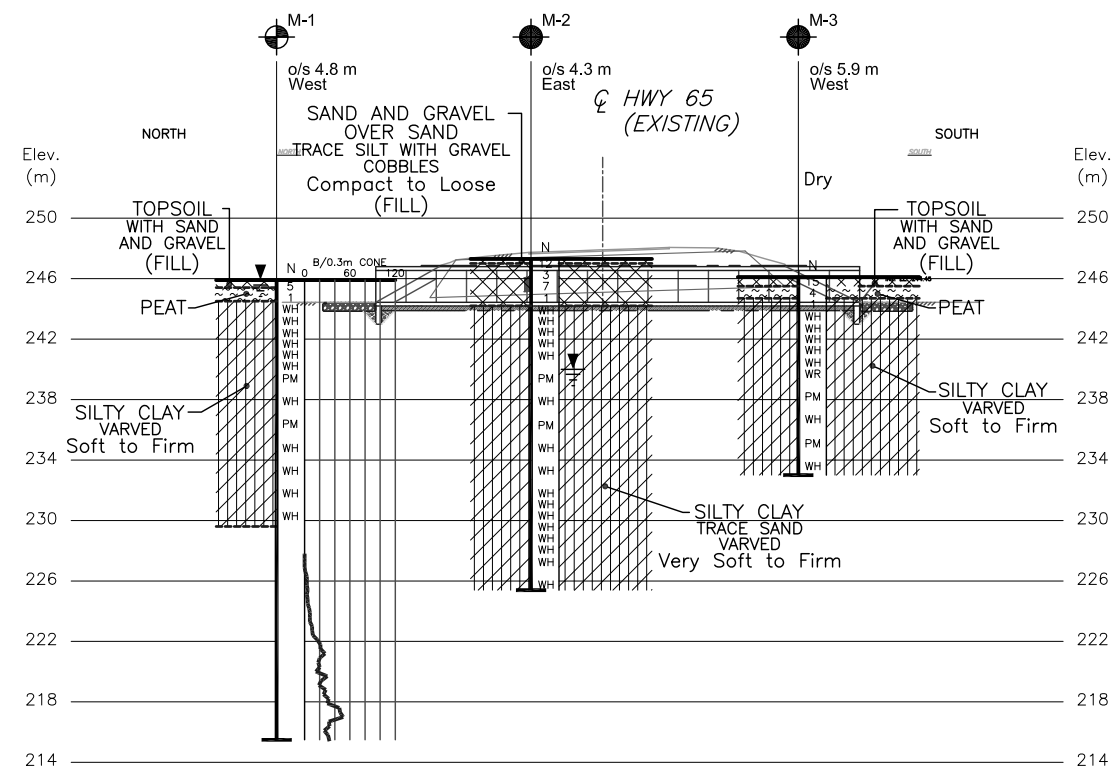
DATUM Geodetic

DATE

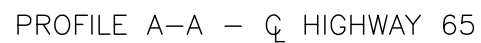
October 03, 2011

CHECKED BY B.R.G.

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														
								○ UNCONFINED	+	FIELD VANE												
								● QUICK TRIAXIAL	×	LAB VANE												
233.2							20	40	60	80	100											
15.0	Silty clay clayey silt layers silty sand partings																					
	Firm Light Wet grey/ grey		15	SS	WH									○								
231.9	(Continued)				FV			+	3													
16.3	End of borehole																					



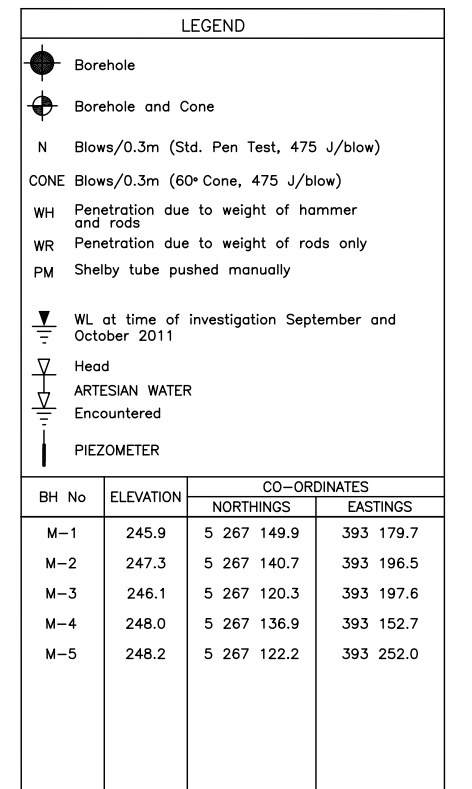
PLAN



1. THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE TEXT AND RECORD OF BOREHOLE LOGS.
2. THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.
3. DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETRES AND METRES.



Peto MacCallum Ltd
CONSULTING ENGINEERS



- NOTE -

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

REVIEWS				
	DATE	BY	DESCRIPTION	
Geocres No. 31M-97				
HWY No 65				DIST New Liskeard
SUBM'D	NA	CHECKED NSB	DATE AUG. 08, 2012	SITE 47-290/C
DRAWN	NA	CHECKED BRG	APPROVED CN	DWG MC-1



APPENDIX A

Site Photographs 1 to 4



Photograph 1: View looking east from Highway 65 eastbound shoulder. Sawmill Road is in distance. (November 1, 2011)



Photograph 2: View south from eastbound shoulder close-up view of south end of culvert. (November 1, 2011)



Photograph 3: View looking west from eastbound shoulder, Hooper Road is in distance. (November 1, 2011)



Photograph 4: View north looking from culvert location at Highway 65 westbound shoulder. Drill rig at borehole M-1. (November 1, 2011)



APPENDIX B

Laboratory Photographs 1 and 2



Photograph 1: Extruded thin wall sample from borehole M-3 at 6.1 to 6.7 m depth. Varved clay soils contain 50 mm spacing with high plastic layers (12 mm thick). (October 12, 2011)



Photograph 2: Extruded thin wall sample from borehole M-2 at 10.7 to 11.3 m depth. Varved clay soils contain about 25 mm spacing less plastic clay soils (5 mm thick). (October 12, 2011)