Peto MacCallum Ltd.
CONSULTING ENGINEERS

FOUNDATION DESIGN TECHNICAL MEMORANDUM
for
WATERMAIN PROTECTION SLAB
HIGHWAY 404 AND MAJOR MACKENZIE DRIVE
YORK REGION, ONTARIO
AGREEMENT NO. 2015-E-0011-003
GWP NO. 2227-09-00

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1. INTRODUCTION

The Highway 404 W-S Ramp is proposed to be re-aligned at the intersection of Major Mackenzie Drive. As a result, the re-aligned ramp is expected to cross the existing high pressure watermain along Major Mackenzie Drive for a distance of approximately 75 m. To protect the watermain from the traffic load on the re-aligned ramp, it is proposed to construct a concrete slab over the watermain. This technical memorandum documents the assessment of alternative foundations to support the proposed concrete slab and provides geotechnical input for the design team to select the appropriate type of foundation.

The site is located at the southwest quadrant of Highway 404 and Major Mackenzie Drive interchange in York Region, Ontario.

This technical memorandum is based on the subsoil information obtained during the foundation investigation carried out by PML in November 2016.

AECOM Canada Limited (AECOM) has retained Peto MacCallum Ltd. (PML) to carry out the investigation and preparation of this report on behalf of the Ministry of Transportation of Ontario (MTO) as part of the Retainer Assignment task No. 2015-E-0011. The general terms of reference and scope of work for the foundation engineering services are outlined in MTO's Request for Proposal under Work Item No. 2015-E-0011-003, dated June 2016.

2. INVESTIGATION PROCEDURES

The site investigation consisted of drilling one (1) borehole designated PP-1 near the buried watermain pipe. This borehole was advanced after accurately proceeding with a vacuum truck test pit to locate the alignment. The borehole was drilled at about 1.5 m north of pipe edge.

The location of the borehole is appropriately shown on the attached Borehole Location Plan, Drawing PP-1

3. SUBSURFACE CONDITION

The subsoil in the drilled borehole included 200 mm of topsoil, which extends to elevation 215.8. The topsoil is followed by 1.3 m of hard clayey silt fill to 1.5 m depth, elevation 214.5. The “N”-values measured within this fill ranged from 32 to 41 blows/300 mm, indicating hard consistency. The fill is immediately underlain by hard clayey silt till, which extends to the maximum investigation depth of 6.2 m, elevation 209.8. The SPT values in this till deposit range from 68 blows/300 mm to 50 blows/80 mm, indicating hard consistency.

The gradation test results indicate that this deposit consists of 3% gravel, 35% sand, 44% silt and 18% clay. One Atterberg limit test was performed on selected sample and the results are provided on Figure PP-PC-1. Based on the Atterberg limit values, the soil may be classified as silts of low plasticity (CL-ML) in the Unified Soil Classification System (USCS).

The borehole was observed to be dry during and upon completion of drilling. The groundwater level may be expected to fluctuate due to the influence of precipitation and seasonal changes.

The subsurface conditions encountered during the course of the investigation, together with the field and laboratory test results are shown on the attached Record of Borehole Sheet.

4. ASSESSMENT OF FOUNDATION ALTERNATIVES

The proposed concrete slab over the watermain will be constructed between Sta. 4+452.41 and Sta. 4+524.84, along the Major Mackenzie Drive. The chainage referred in this memo are measured along the watermain.

The following two options are suggested for supporting the proposed concrete slab across the watermain:

1. Concrete slab designed as a rigid frame structure and supported on strip footings placed below the spring line of the watermain.
2. Concrete slab supported by a grade beam frame that is constructed on short caissons founded below the bedding of the watermain.

The Table 4.0 below compares the advantages, disadvantages, risks / consequences and relative costs of each alternative from the foundation perspective:

Table 4.0 – Comparison of Alternatives

ALTERNATIVE DRAINAGE PIPE REMEDIATION METHOD	ADVANTAGES	DISADVANTAGES	RISKS/ CONSEQUENCES	RELATIVE COSTS
1. Strip Footing	- Less complex design - Relatively short time required for construction	- Requires 3.1 m to 4.8 m deep excavation - Excavations may require shoring - Flexibility to adjust the elevation of the slab is limited	- May cause damage to watermain by the movement of heavy machinery adjacent to pipe - Excavation near the watermain may induce lateral movement	- Relatively lower cost than short caisson
2. Short Caissons	- Less disturbance to existing subgrade below watermain - Possibility to construct the support slab at a higher elevation - Relatively lesser time maybe required for construction - Safe construction process and minimize the risk of damage to watermain	- Complex design of beam on grade and supporting caissons - Special construction equipment required	- Minimal risks causing damage to watermain	- Higher cost than the conventional excavation

4.1 Strip Footing

In general, strip footing requires less complex design compared to supporting the slab on caissons. The construction of strip footing may require shorter time period and cost less than that of caisson. The depth of excavation for strip footings may range from 3.1 m to 4.8 m and require shoring system to support the excavation. A large amount of soil excavation and replacement will be required than using a short caisson and grade beam system. There will be risk associated with the construction of strip footings adjacent to the existing watermain resulting from excavation and mobilizing construction equipment.

4.2 Short Caissons

Alternatively, the slab over the watermain may be placed on grade beam and supported on short caissons. In this method, the short caissons will be installed in pre-augured hole and the grade beam will provide support for protection slab. This approach may cost more than the strip footing because of the use of special construction equipment, however, the excavation and backfilling of the pipe cover material will be minimized. Risk to cause damage to the watermain may also be minimised by supporting the slab on caissons, with the control provided by closely spaced watermain pipe vacuum test pits.

This method of construction has the flexibility to adjust the location of the slab above the watermain.

4.3 Frost Protection

The depth of frost penetration at this site is approximately 1.2 m. The strip footings or grade beams supported on short caissons should be provided with at least 1.2 m of earth cover or equivalent thermal insulation as protection against frost action.

5. FOUNDATION DESIGN RECOMMENDATIONS

Based on the existing watermain design drawing provided by AECOM, the recommended founding elevations and geotechnical resistance for a minimum of 1.0 m wide strip footings are summarized below on Table 5A:

Table 5A – Geotechnical Resistances - Spread Footings

STATION	EXISTING GROUND ELEVATION	FOUNDING ELEVATION	SUBGRADE SOILS	FACTORED GEOTECHNICAL AXIAL RESISTANCE AT ULS (kPa)	GEOTECHNICAL AXIAL RESISTANCE AT SLS (kPa)
4+430 to 4+450	215.1±	212.0	Hard Clayey Silt Till	400	250
4+450 to 4+470	215.5±	211.8	Hard Clayey Silt Till	400	250
4+470 to 4+490	215.7±	211.6	Hard Clayey Silt Till	400	250
4+490 to 4+510	216.0±	211.4	Hard Clayey Silt Till	400	250
4+510 to 4+530	216.0±	211.2	Hard Clayey Silt Till	400	250

The geotechnical resistance recommended at SLS corresponds to a total settlement in the order of 10 mm which is considered to be feasible to provide deformation of the compressible material over the pipe without transferring added load from the backfill.

Table 5B below provides the recommendations for the design of a 900 mm diameter and minimum of 6.0 m deep caissons:

Table 5B – Geotechnical Resistances - Caissons

STATION	MINIMUM CAISSON DEPTH BELOW EXISTING GRADE (m) (2)	BEARING RESISTANCE (Load)	
		FACTORED ULS (kN) (3)	SLS (kN) (1)
4+430 to 4+530	6.0	250	150

(1) The design of caissons should consider the weight of the caisson as a load.
(2) Elevations are not provided since the levels of roadway are being adjusted for final design.
(3) The Geotechnical bearing resistance calculated as per 900 mm Reinforced Concrete Caissons.

The edge of footings as well as the caissons should be placed at least 1.5 m away from the springline of the existing watermain.

6. CONSTRUCTION CONSIDERATIONS

6.1 General

A list of Ontario Provincial Standard Specifications relevant to this report is provided in Appendix 2.

6.2 Excavation

Based on the result of the borehole and the anticipated depths of excavation, it is expected that the proposed support slab will be constructed by means of conventional open cut or trenching method with temporary shoring.

Seasonal variations in groundwater levels should be anticipated, depending on the timing of construction. Excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA) and MTO regulations.

Based on the borehole data, the excavations for construction of the proposed support slab will be advanced through existing clayey silt fill underlain by clayey silt till. For classification purposes, the fill materials should be classified as Type 3 soils. The hard clayey silt till materials above the groundwater level would be classified as Type 2 soils. In the case of an excavation containing more than one soil type, the highest numbered soil type will govern the trench excavation and slope geometry.

In the event that the required slope cannot be maintained during the excavation, trench support systems such as trench boxes may be considered to achieve the founding level, if there is no structures adjoining the excavation. The excavation should meet the requirements of OPSS 401 (Construction Specification for Trenching, Backfilling, and Compacting).

Trench and excavation slopes should be continually inspected, particularly following periods of heavy rainfall, spring thaw, and when the trench has been left open for any extended period of time. Any cobbles or boulders exposed on the excavation slope faces must be removed.

Cobbles and boulders that may be encountered within the fill material or native deposits may hamper the progress of excavation.

7. CLOSURE

This Foundation Technical Memorandum was prepared by Mr. M. Khorsand, BSc, EIT., and reviewed by Mr. M. Vasavithasan, M.Sc.Eng., P.Eng., Senior Engineer. Mr. C. M. P. Nascimento, P. Eng., Project Manager and MTO Designated Principal Contact, conducted an independent review of the technical memo.

Yours very truly

Peto MacCallum Ltd.

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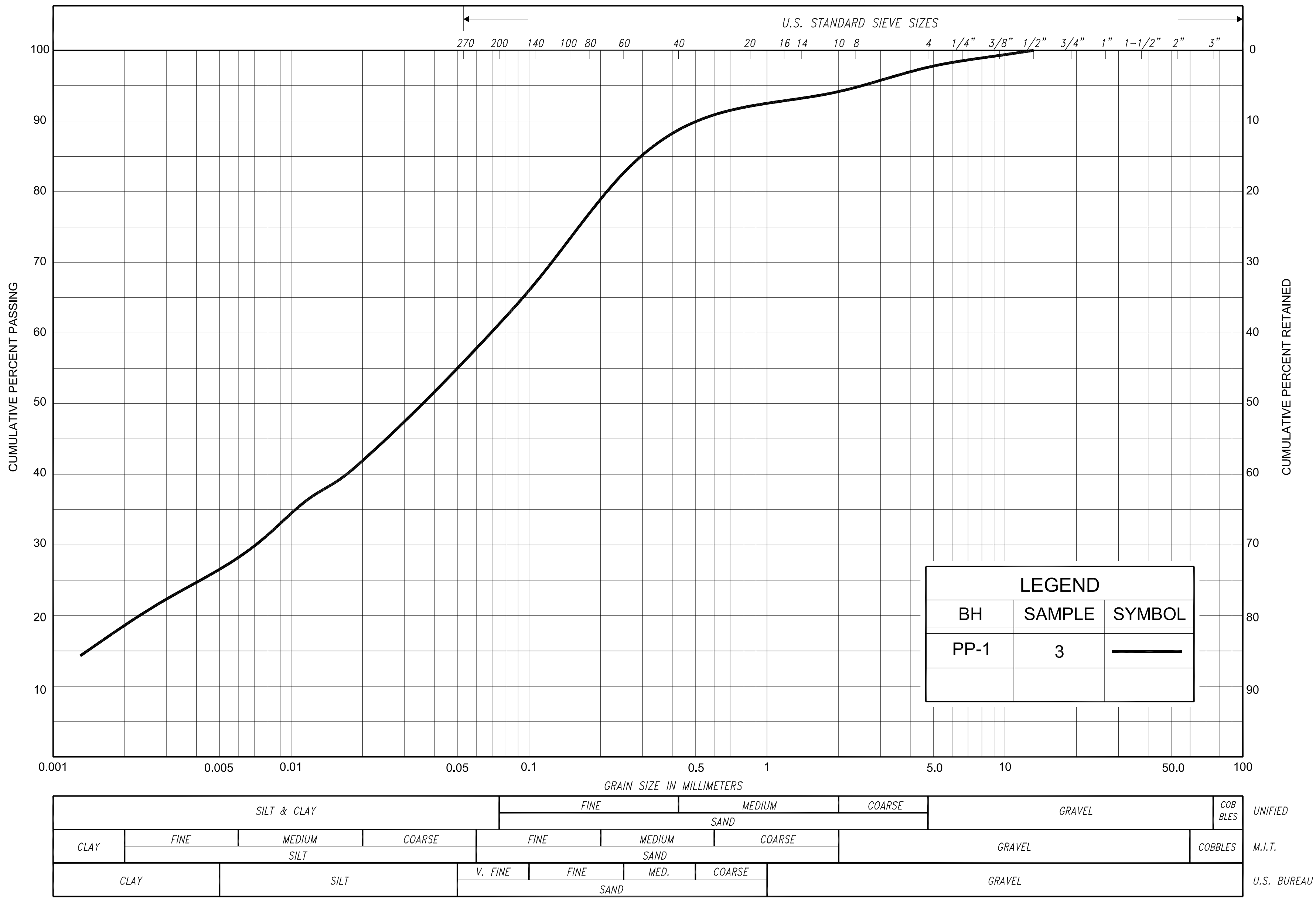
MK/MV/CN:mk-nk

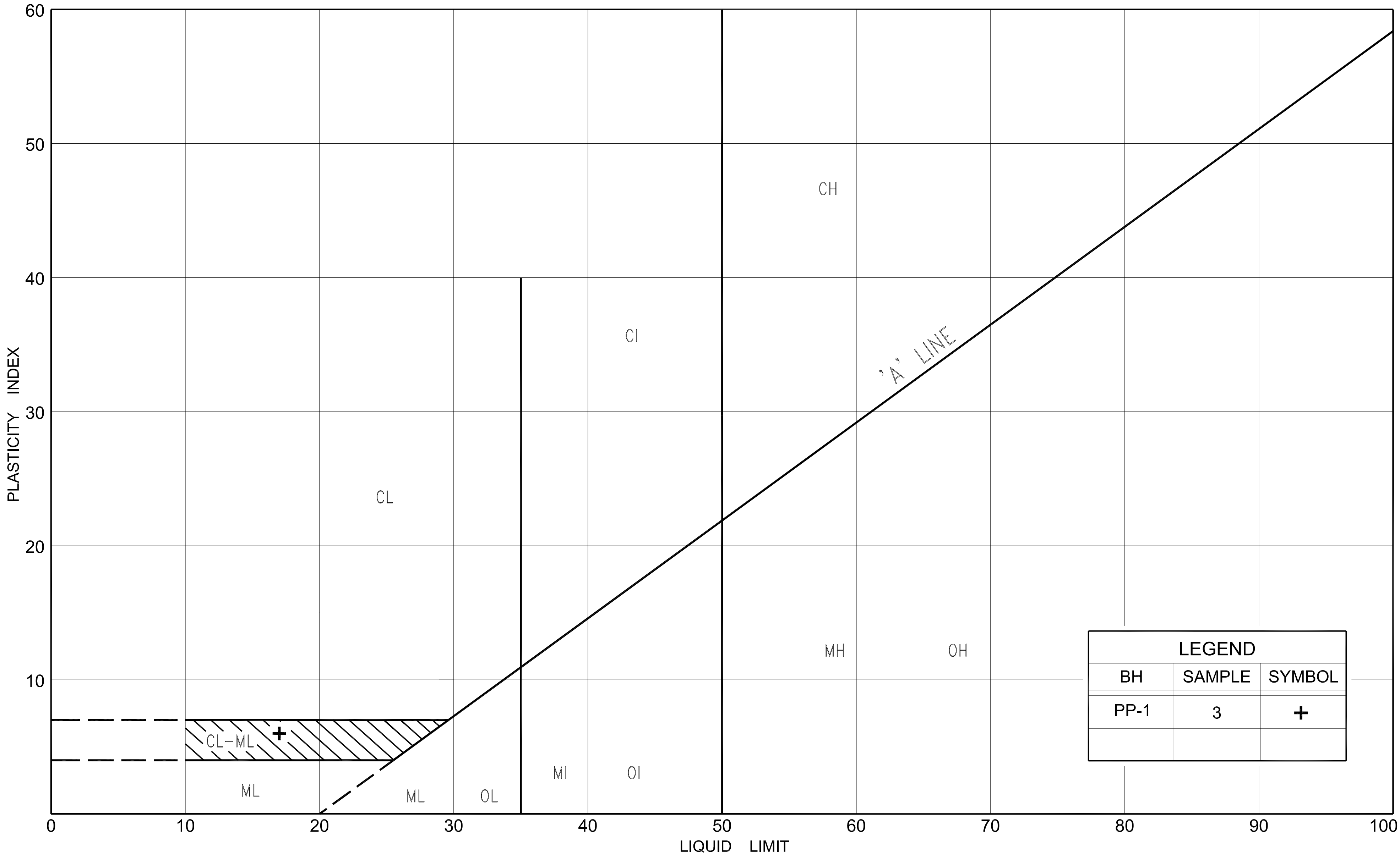


Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, SANDY, trace gravel (CL-ML)

FIG No.	PP-GS-1
HWY	404
TASK #	2015-E-0011 - 002



Ontario

PLASTICITY CHART

CLAYEY SILT, SANDY, trace gravel (CL-ML)

FIG No.	PP-PC-1
HWY	404
TASK #	2015-E-0011 - 002

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:

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
r_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'_{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

ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES
ρ_w	kg/m^3	DENSITY OF WATER
γ_w	kN/m^3	UNIT WEIGHT OF WATER
ρ	kg/m^3	DENSITY OF SOIL
γ	kN/m^3	UNIT WEIGHT OF SOIL
ρ_d	kg/m^3	DENSITY OF DRY SOIL
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL
e	1,%	VOID RATIO

n	1,%	POROSITY
w	1,%	WATER CONTENT
S_r	%	DEGREE OF SATURATION
w_L	%	LIQUID LIMIT
w_P	%	PLASTIC LIMIT
w_S	%	SHRINKAGE LIMIT
I_P	%	PLASTICITY INDEX $= w_L - w_P$
I_L	1	LIQUIDITY INDEX $= \frac{w - w_P}{I_P}$
I_C	1	CONSISTENCY INDEX $= \frac{w_L - w}{I_P}$
DTPL		DRIER THAN PLASTIC LIMIT
APL		ABOUT PLASTIC LIMIT
WTPL		WETTER THAN PLASTIC LIMIT

e_{max}	1,%	VOID RATIO IN LOOSEST STATE
e_{min}	1,%	VOID RATIO IN DENSEST STATE
I_D	1	DENSITY INDEX $= \frac{e_{max} - e}{e_{max} - e_{min}}$
D	mm	GRAIN DIAMETER
D_n	mm	n PERCENT - DIAMETER
C_u	1	UNIFORMITY COEFFICIENT
h	m	HYDRAULIC HEAD OR POTENTIAL
q	m^3/s	RATE OF DISCHARGE
v	m/s	DISCHARGE VELOCITY
i	1	HYDRAULIC GRADIENT
k	m/s	HYDRAULIC CONDUCTIVITY
j	kN/m^3	SEEPAGE FORCE

Ontario

Peto MacCallum Ltd. CONSULTING ENGINEERS

Foundation Design

RECORD OF BOREHOLE No PP-1

METRIC

G.W.P. 2227-09-00 LOCATION Co-ords: 4 860 257.7 N ; 314 231.6 E ORIGINATED BY S.A.

DIST Central BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY M.Kh.

DATUM Geodetic HWY 404 DATE November 25, 2016 CHECKED BY M.V.

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
216.0	Ground Surface				*			
215.8	Topsoil							
0.2	Clayey silt, with sand rootlets. Hard, Grey/brown, Moist (FILL)	1	SS	41			○	
		2	SS	32		215	○	
214.5 1.5	Clayey silt, sandy trace gravel. Hard, Brown, Moist (TILL)	3	SS	68		214	○ ├┤	3 35 44 18
		4	SS	50/10cm				
		5	SS	50/10cm		213	○	
						212		
		6	SS	50/8cm		211		
209.8 6.2	End of borehole	7	SS	50/13cm		210		

* Borehole dry upon completion of drilling

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60
UNIT WEIGHT γ kN/m³

$+^7$, $\times^5$: Numbers refer to Sensitivity

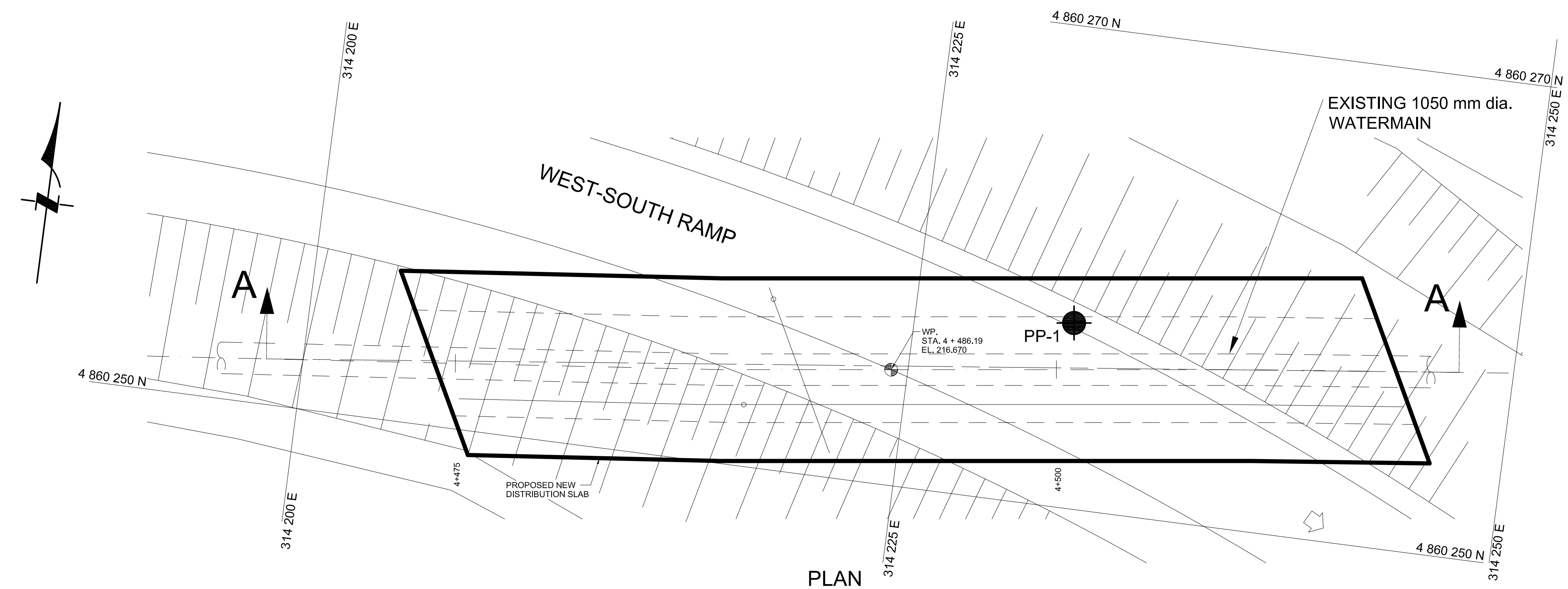
20 / 15 — 5 / 10 (%) STRAIN AT FAILURE

RETAINER ASSIGNMENT :
CA 2015-E-0011 - 002
G.W.P. 2227-09-00

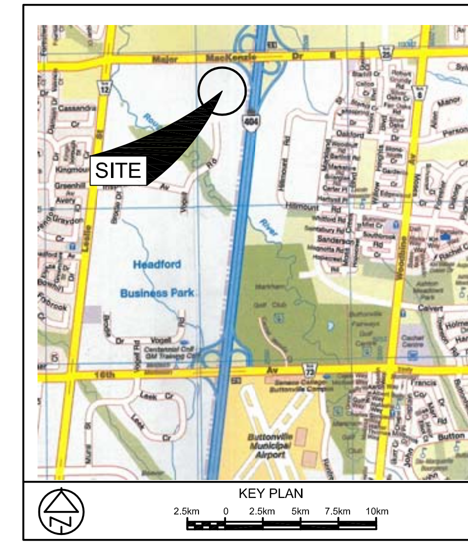
WATERMAIN PROTECTION
COMMUTER CARPOOL LOT
HIGHWAY 404 AND MAJOR MCKENZIE DRIVE
TOWN OF RICHMOND HILL, ONTARIO
BOREHOLE LOCATIONS

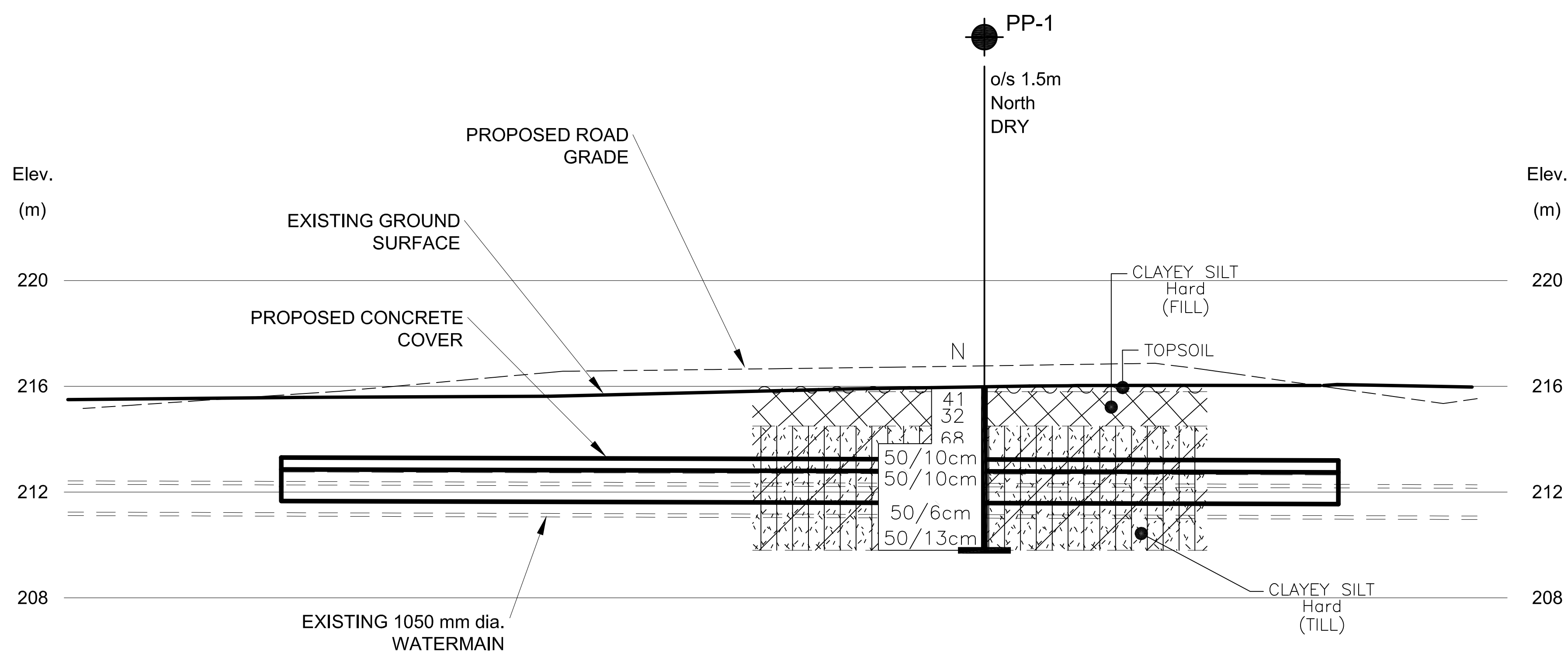
SHEET

Peto MacCallum Ltd.
CONSULTING ENGINEERS



PLAN
SCALE
2.5 0 2.5 5m





PROFILE A - A
SCALE
2.5 0 2.5 5m

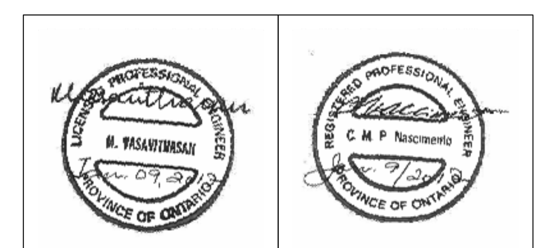
LEGEND

- Borehole
- Cone
- Borehole and Cone
- N Blows/0.3m (Std. Pen Test, 475 J/blow)
- CONE Blows/0.3m (60 Cone, 475 J/blow)
- WL at time of investigation October 2016
- WH Penetration due to weight of hammer and rod
- * Water level not established
- Head
- ARTESIAN WATER
- Encountered
- PIEZOMETER

BH No	ELEVATION	NORTHINGS	EASTINGS
PP-1	216.0	4 860 257.7	314 231.6

NOTES:

1. THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE TEXT OF REPORT AND RECORD OF BOREHOLE LOGS.
2. WATERMAIN PIPE LOCATION ON THIS DRAWING MAY NOT BE REPRESENTATIVE OF AS-BUILT CONDITIONS
3. THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.
4. DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETRES AND METRES.



REF AECOM Drawings: 01_Ramp Distributiob slab_ga.dgn dated December 2016

– 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. 30M14-459

HWY No 404			DIST CENTRAL
SUBM'D NA	CHECKED M.Kh.	DATE JAN. 09, 2017	SITE
DRAWN NA	CHECKED MV	APPROVED CN	DWG PP-1