



**FOUNDATION INVESTIGATION AND DESIGN REPORT**

**for**

**HIGHWAY 400 UPGRADING LATERAL SEWER SOUTHERN PART  
APPROXIMATELY FROM INNISFIL BEACH ROAD TO MAPLEVIEW  
DRIVE**

**RETAINER ASSIGNMENT – TASK NO. 2013-E-0039-010**

**WP 2184-10-00**

**TOWN OF INNISFIL AND CITY OF BARRIE, SIMCOE COUNTY,  
ONTARIO**

**PREPARED FOR MINISTRY OF TRANSPORTATION OF ONTARIO**

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PML Ref.: 15TF020-4  
Index No.: 035FIR and 036FDR  
GEOCRES No.: 31D-657  
June 30, 2016



**PART A - FOUNDATION INVESTIGATION REPORT**

**for**

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**PART A**  
**FOUNDATION INVESTIGATION REPORT**

For  
Highway 400 Upgrading - Lateral Sewers  
Southern Part from Innisfil Beach Road to Mapleview Drive  
Retainer Assignment – Task No. 2013-E-0039-010, WP2184-10-00  
Town of Innisfil and City of Barrie, Simcoe County, Ontario

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**1. INTRODUCTION**

This report presents the factual findings obtained from the geotechnical investigation carried out at the above mentioned site along the median of Highway 400 from Innisfil Beach Road to Mapleview Drive, for the installation of lateral storm sewers, replacement of existing sewer line along the median, and inspection holes (manhole). The field work was carried out between March 7 and 9, 2016. The purpose of the investigation was to explore the subsurface conditions at this site to provide anticipated subsurface conditions influencing the design and installation of the sewer lines and associated inspection holes (Manholes).

Peto MacCallum Ltd. (PML) carried out the investigation and prepared this report for the Ministry of Transportation of Ontario (MTO) as part of the Retainer Assignment task No. 2013-E-0039-010.

The assignment includes preparation of five (5) geotechnical investigation reports for the following locations:

<b>PML REF. No.</b>	<b>FIR AND FIDR DESCRIPTION</b>
15TF020-1	Highway 400 Upgrading - Median Sewers Northern Part from Mapleview Drive to Essa Road
15TF020-2	Highway 400 Upgrading - Lateral Sewers Northern Part from Mapleview Drive to Essa Road
15TF020-3	Highway 400 Upgrading - Median Sewers Southern Part from Innisfil Beach Road to Mapleview Drive
15TF020-4	Highway 400 Upgrading - Lateral Sewers Southern Part from Innisfil Beach Road to Mapleview Drive
15TF020-5	Highway 400 Culvert Headwalls for Culvert 96 and Inlet Headwall for Culvert 107





The scope of project involves the installation of new lateral and longitudinal sewer pipes along the median together with replacement of existing lateral and longitudinal sewer pipes and manholes. This report provides subsurface conditions for the southern part of the assignment covering from Innisfil Beach Road to Mapleview Drive (Sta. 20+214 to Sta. 26 + 297).

It should be noted that the window for carrying out the field work for this investigation was limited. As a result, boreholes were strategically located to obtain an approximate model of subsurface conditions covering the project area. A limited number of boreholes were advanced due to constraints for carrying out the field work. The Contractor shall be advised to carry out additional field investigation, such as excavate test pits to confirm the depth of the fill, especially in the area where there are existing storm sewer lines, which are proposed to be replaced.

## **2. SITE DESCRIPTION**

The topography of the project area is generally flat to gently undulating, except for the highway embankments. The grade of Highway 400 at the crossing of Innisfil Beach Road Overpass is set at approximately 3 m higher than the surrounding area of the interchange. Several commercial developments are intermittently located between the interchanges of Highway 400 and Innisfil Beach Road, and Highway 400 and Mapleview Drive. The site is generally lined by farmland and heavily wooded area along Highway 400.

## **3. FIELD INVESTIGATION PROCEDURES**

A Key Plan of the project site is provided on Drawing 400WM-A. The investigation included advancing ten (10) boreholes numbered SR-BH 1 to SR-BH 10 to maximum depths ranging from 4.7 m to 5.2 m. Borehole locations are shown on the attached Drawing Nos. 1/25 to 16/25.

The underground services at the borehole locations were cleared by the respective utility companies and then the locations were established in the field by portable GPS device. Boreholes were strategically located to provide a minimum safe distance from the existing sewer pipes. PML carried out the survey of the borehole locations and elevations and provided the co-ordinates of



locations in MTM NAD 83 northings and eastings. All elevations reported in this report are referred to Geodetic and expressed in metres.

All of the boreholes were advanced from the shoulder adjoining the median of the Highway 400. Boreholes were advanced using continuous flight solid stem augers, powered by a track-mounted CME-75 drill rig. The drill rig used for drilling was owned and operated by Tri-Phase of Mississauga, Ontario. Tri-Phase is a specialist drilling contractor, was working under the full-time supervision of a member of PML's engineering staff.

Representative soil samples were recovered from the boreholes at 0.75 m intervals using a conventional 51 mm O.D split spoon sampler in accordance with the Standard Penetration Test (SPT) procedure. Standard penetration tests were conducted simultaneously with the sampling operation to assess the strength characteristics of the substrata.

The groundwater conditions at the borehole locations were observed during drilling by visual examination of the soil samples, sampler and drill rods as the samples were retrieved. In addition, water level measurements were taken in open boreholes. A total of five (5) piezometer were installed in Boreholes SR-BH 2, SR-BH 5, SR-BH 6, SR-BH 7 and SR-BH 9 for continuous monitoring of groundwater level. The installation details of the piezometers are provided on the Record of Borehole Sheets. Upon completion of drilling, the boreholes were backfilled with bentonite/cement grout in accordance with the MTO guidelines and MOE Regulation 903 for borehole abandonment procedures. The piezometers were not decommissioned and are still in place for monitoring of groundwater during construction.

The recovered soil samples were returned to our laboratory for detailed visual examination, and index tests.



#### **4. LABORATORY TEST PROCEDURES**

Laboratory tests on representative SPT samples recovered during the field work were carried out by the laboratory owned by PML, located in Toronto. The laboratory testing program included the following:

- Natural moisture content determinations (63)
- Grain size distribution analyses (20)
- Atterberg Limits Tests (8)

The laboratory tests to determine the index properties were performed in accordance with the MTO test procedures, which follow American Society for Testing Materials (ASTM) test procedures, with the exception of hydrometer test (LS-702). The results of the grain size distribution analyses and Atterberg limits tests are presented in Figures SRS-GS-1 to SRS-GS-3 and SRS-PC-1, respectively. All of the test results are summarized on the attached Record of Borehole sheets.

#### **5. SITE GEOLOGY AND SUBSURFACE CONDITIONS**

##### **5.1 Site Geology**

The project site is located within the Simcoe Lowlands Physiographic Region of Southern Ontario. The physiographic region of Simcoe Lowlands is bordered by Georgian Bay and Lake Simcoe. This region falls into two major divisions separated by the uplands of Simcoe County. The plains to the west of Simcoe County are draining into Nottawasaga Bay by way of the Nottawasaga River and this area is called "Nottawasaga Basin". The low lying area to the east of Simcoe County is referred to as the "Lake Simcoe" basin.

The Nottawasaga basin and Lake Simcoe basin are connected at Barrie by a flat-floored valley. Both of these low lands and transverse valleys were flooded by Lake Algonquin and are bordered by shore cliffs, beaches and boulder terraces. Thus these basins are floored by sand, silt and



clay. The surficial soils of these sections of the Simcoe lowlands consist primarily of sand although silt, clay or peat may be found in low-lying areas.

## **5.2 Subsurface Conditions**

In general, the subsoil conditions consist of 400 mm to 800 mm pavement structure consisting of asphalt ranging in thickness from 150 mm to 280 mm, followed by 250 mm to 620 mm of sand with varying proportions of gravel (granular base). Pavement structure is underlain by 400 mm to as thick as 3.7 m sand to silty sand fill. The sandy fill in most of the locations is underlain by sand to silty sand, with varying proportions of gravel, which extends to the depth of termination. In a few of the borehole locations (SR-BH-7 and SR-BH-9), the sandy fill is underlain by silt to clayey silt. For classification purposes, the soils encountered at this site can be divided into four distinct zones.

- a) Pavement Structure
- b) Sand to Silty Sand, Trace Gravel, Trace Clay (Fill)
- c) Sand to Silty Sand, Trace Gravel, Trace Clay
- d) Silt to Clayey Silt, Trace Sand

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 Sheets. The borehole locations and stratigraphic profile sections are shown on Drawings 400WM-1/25 to 400WM-16/25. 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. Description of the soil strata encountered are summarised below.

### **5.2.1 Pavement Structure**

Asphalt layer ranging in thickness from 150 mm to 280 mm was encountered in all the boreholes. Pavement structure consists of compact to very dense sand with varying proportions of gravel. This granular base layer ranges in thickness from 250 mm to 620 mm and extends to a depth of 300 mm to 800 mm (El. 305.5 to El. 279.0). The moisture content of the granular base layer ranged from 1% to 11%.



#### 5.2.2 Sand to Silty Sand, Trace Gravel, Trace Clay (Fill)

The pavement structure is immediately followed by sand to silty sand fill layer in all of the boreholes located on the median. This fill layer ranges in thickness from 400 mm to as high as 3.7 m and extends to a depth ranging from 1.2 m to 4.2 m (El. 302.9 to El. 275.8) from the asphalt surface. The SPT values in this fill layer varies widely ranging from as low as 2 blows/300 mm to 32 blows/300 mm, indicating very loose to dense state of compaction.

The moisture content of this fill material varies from 3% to as high as 22%. The results of the grain size distribution analyses of nine representative samples from this fill layer are shown on Figure SRS-GS-1 appended to this report. The test results reveal that the sand to silty sand fill consists of 0% to 9% gravel, 56% to 86% sand, 9% to 38% silt and 3% to 13% clay.

#### 5.2.3 Sand to Silty Sand, Trace Gravel, Trace Clay

The embankment fill in all of the boreholes, with the exception of SR-BH-7 and SR-BH-9, is underlain by sand to silty sand deposit at a depth ranging from 1.2 m to 3.7 m (El. 302.9 to El. 276.5) below the asphalt surface. In SR-BH-7 and 9, the embankment fill is underlain by silt clayey silt (CL-ML). In all of the boreholes, with the exception of SR-BH-6, this sandy deposit extends to the maximum depth of investigation of 5.2 m (El. 274.9). In SR-BH-6, this sand to silty sand deposit extends only to a depth of 4.5 m (El. 278.6) below the asphalt surface. Occasional cobble layers were encountered in SR-BH-1 and SR-BH-5, which is reflected by the high SPT values. In general, SPT values in this deposit range from 24 blows/300 mm to almost refusal (86 blows/300 mm), indicating compact to very dense state of compaction.

Moisture content of this deposit varies from 3% to 18%. The sand and silt contents of this deposit vary widely. The results of the sieve analysis test performed on six representative samples from this deposit are provided on Figure SRS-GS-2. The test results indicate that the sand to silty sand deposit consists of 0% to 14% gravel, 40% to 79% sand, 17% to 35% silt and 4% to 13% clay. However, the Sample SS7 from SR-BH-4 consisted of 1% gravel, 26% sand, 83% silt, and 8 % clay.



#### 5.2.4 Silt to Clayey Silt, Trace Sand

In Boreholes SR-BH 7 and SR-BH 9, the embankment fill is immediately underlain by this silt to clayey deposit. However, in SR-BH 6, this deposit was observed following the sand to silty sand deposit. This silt to clayey silt deposit extends to the maximum depth of investigation of 5.2 m (El.274.2) at all three locations. The SPT values in this deposit range from 15 blows/300 mm to 37 blows/300 mm, indicating very stiff to hard consistency.

The moisture content of three samples tested varied from 22% to 28%. The results of the sieve analysis test performed on three representative samples from this deposit are provided on Figure SRS-GS-3. The test results indicate that this deposit consists of 0% gravel, 2% to 4% sand, 79% to 94% silt and 4% to 18% clay. Atterberg limit test was performed on one sample and the results are provided on Figure SRS-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).



### 5.3 Groundwater

All of the boreholes, with the exception of SR-BH-6, SR-BH-7 and SR-BH-8, were observed to be dry upon completion of drilling. In SR-BH-1, groundwater was first encountered at a depth of 2.4 m below the ground level and the borehole was found to be dry upon completion. It may be a perched water since the borehole was found to be dry on completion. The groundwater levels in SR-BH-6, SR-BH-7 and SR-BH-8 were measured at a depth of 2.7 m to 3.5 m (El. 276.7 to El. 279.9), below the existing ground surface.

The groundwater levels were monitored from March 7 to April 19, 2016. The groundwater levels measured in the piezometers installed in Boreholes SR-BH 2, SR-BH 5, SR-BH 6, SR-BH 7 and SR-BH 9 are provide in the Table 5.3.

**Table 5.3 – Piezometer Water Level**

Borehole No.	March 7 to 9, 2016		April 19, 2016	
	Depth (m)	Elevation (m)	Depth (m)	Elevation (m)
SR-BH 2	Dry	Dry	Dry	Dry
SR-BH 5	Dry	Dry	3.3	300.5
SR-BH 6	3.2	279.9	2.5	280.6
SR-BH 7	2.7	276.7	3.1	276.3
SR-BH 9	Dry	Dry	3.4	283.9

The groundwater level may be expected to fluctuate due to the influence of precipitation and seasonal changes.

## 6. CLOSURE

Mr. D. Woodcock and Mr. S. Aziz carried out the field investigation for this study under the supervision of Mr. M. Khorsand, BSc, E.I.T., and Mr. C. M. P. Nascimento, P. Eng., Project Manager. Tri-Phase Drilling Inc. supplied the drill rig for the subsurface exploration. The laboratory testing of the selected samples was carried out in the PML laboratory in Toronto.



This report was prepared by Mr. M. Khorsand, BSc, E.I.T., and reviewed by Mr. M. Vasavithasan, M.Sc.Eng., P.Eng. Senior Engineer, Geotechnical Services. Mr. C. M. P. Nascimento, P. Eng., MTO Designated Principal Contact, conducted an independent review of the report.

Yours very truly

Peto MacCallum Ltd.

A handwritten signature in blue ink, reading "Mansoor", is positioned above the name of the Project Supervisor.

Mansoor Khorsand, BSc, EIT  
Project Supervisor, Geotechnical Services



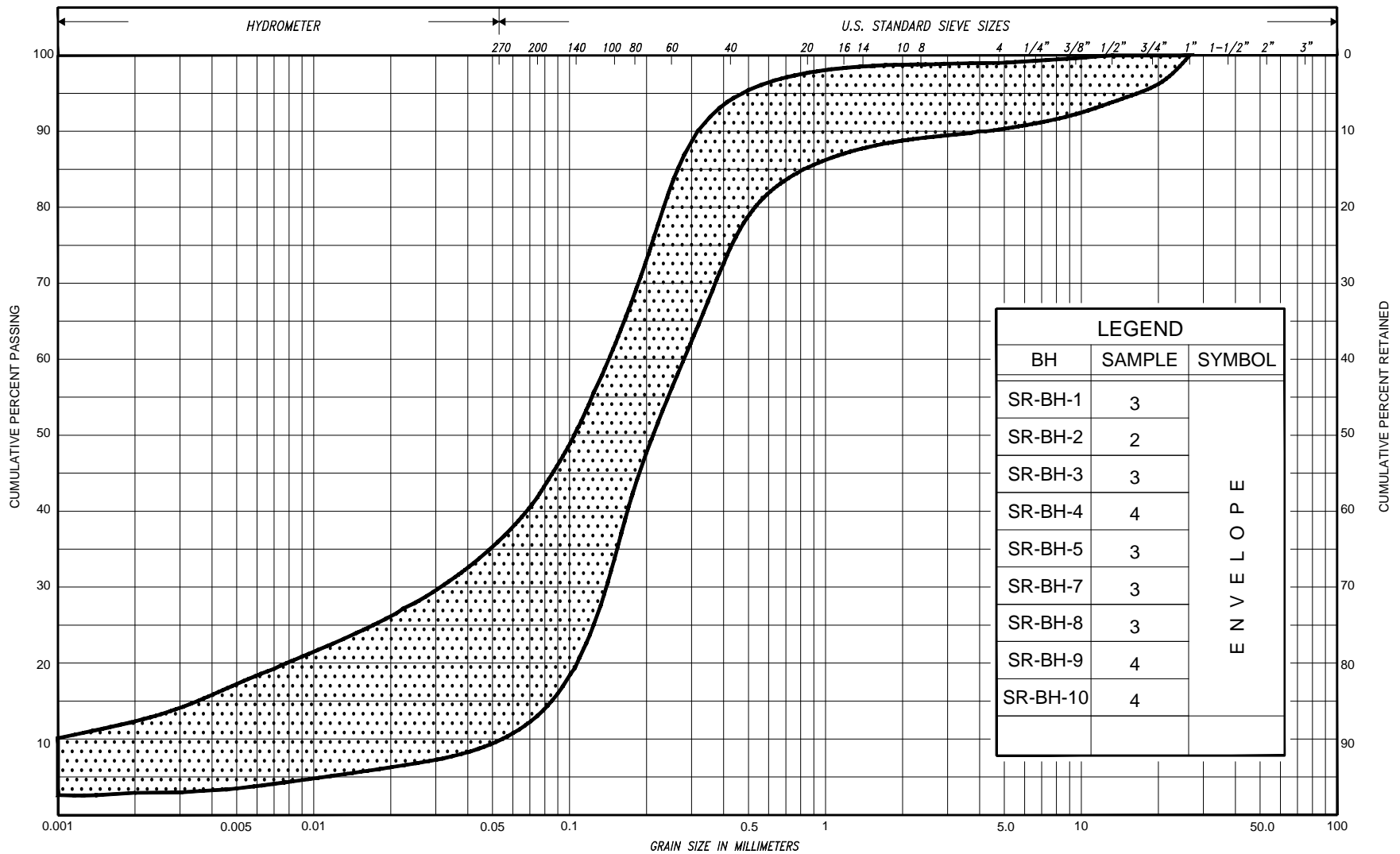
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Project Manager and  
MTO Designated Principal Contact

MKH/MV/CN:jk





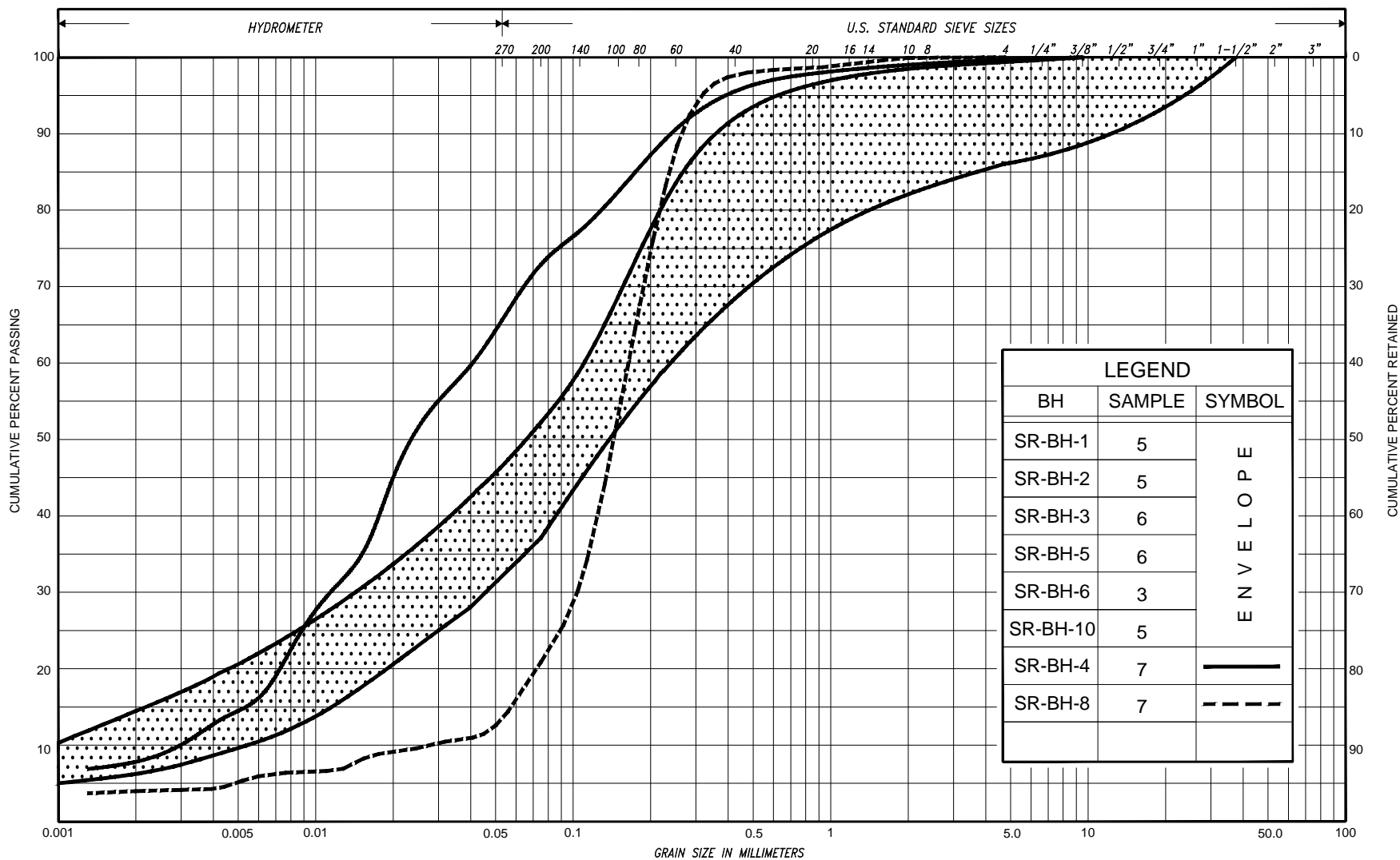
SILT & CLAY				FINE		MEDIUM		COARSE		GRAVEL				COBBLES	UNIFIED			
CLAY	FINE		MEDIUM		COARSE		SAND		FINE		MEDIUM		COARSE		GRAVEL	COBBLES	M.I.T.	
	SILT				SAND													
CLAY		SILT				V. FINE		FINE		MED.		COARSE		GRAVEL				U.S. BUREAU

## GRAIN SIZE DISTRIBUTION

SAND to SILTY SAND, trace to some clay, trace gravel  
(FILL)

FIG No.	SRS-GS-1
HWY:	400
W.P. No.	2184-10-00





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



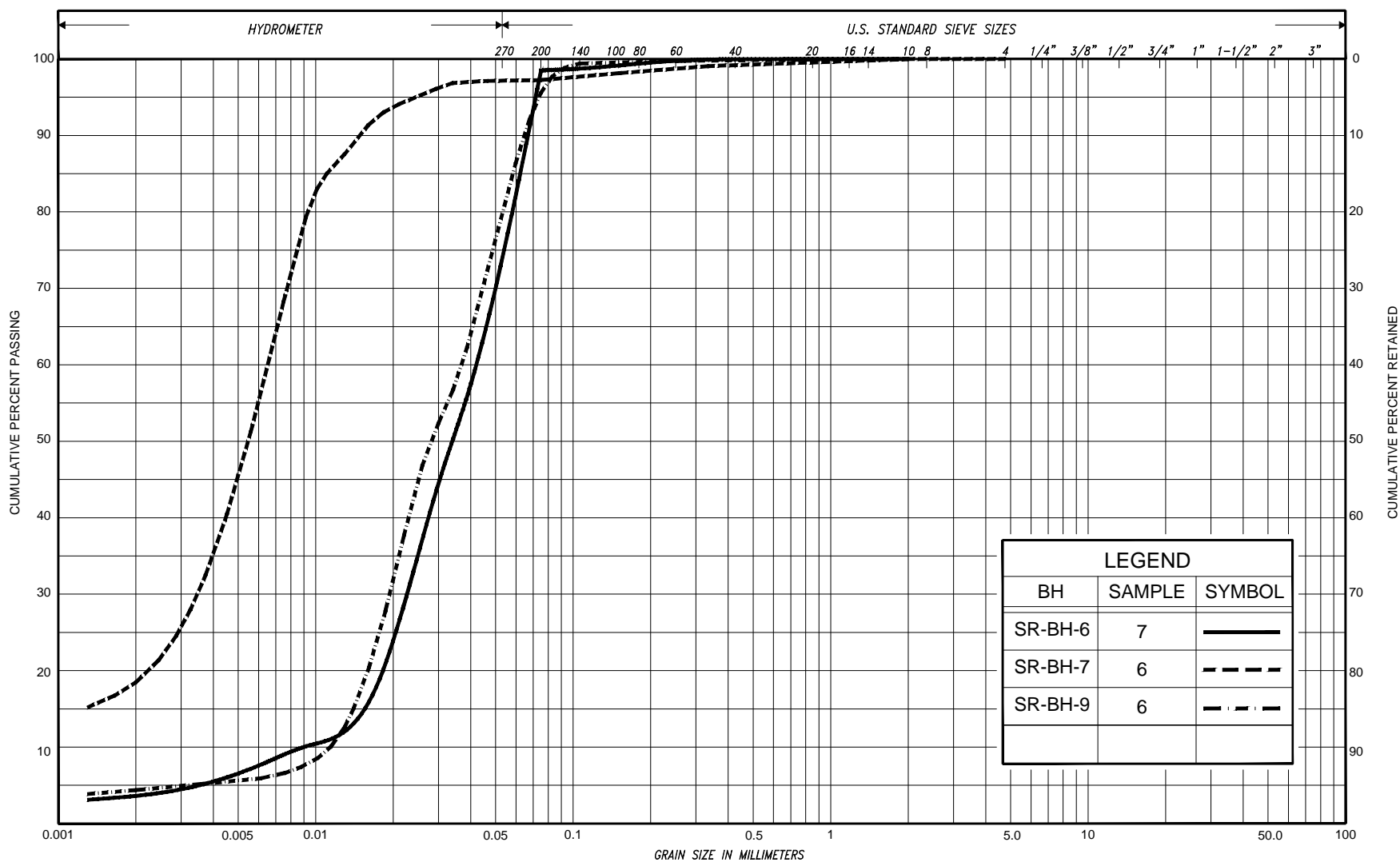
## GRAIN SIZE DISTRIBUTION

SAND to SILTY SAND, trace to some clay, trace gravel

FIG No. SRS-GS-2

HWY: 400

W.P. No. 2184-10-00



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



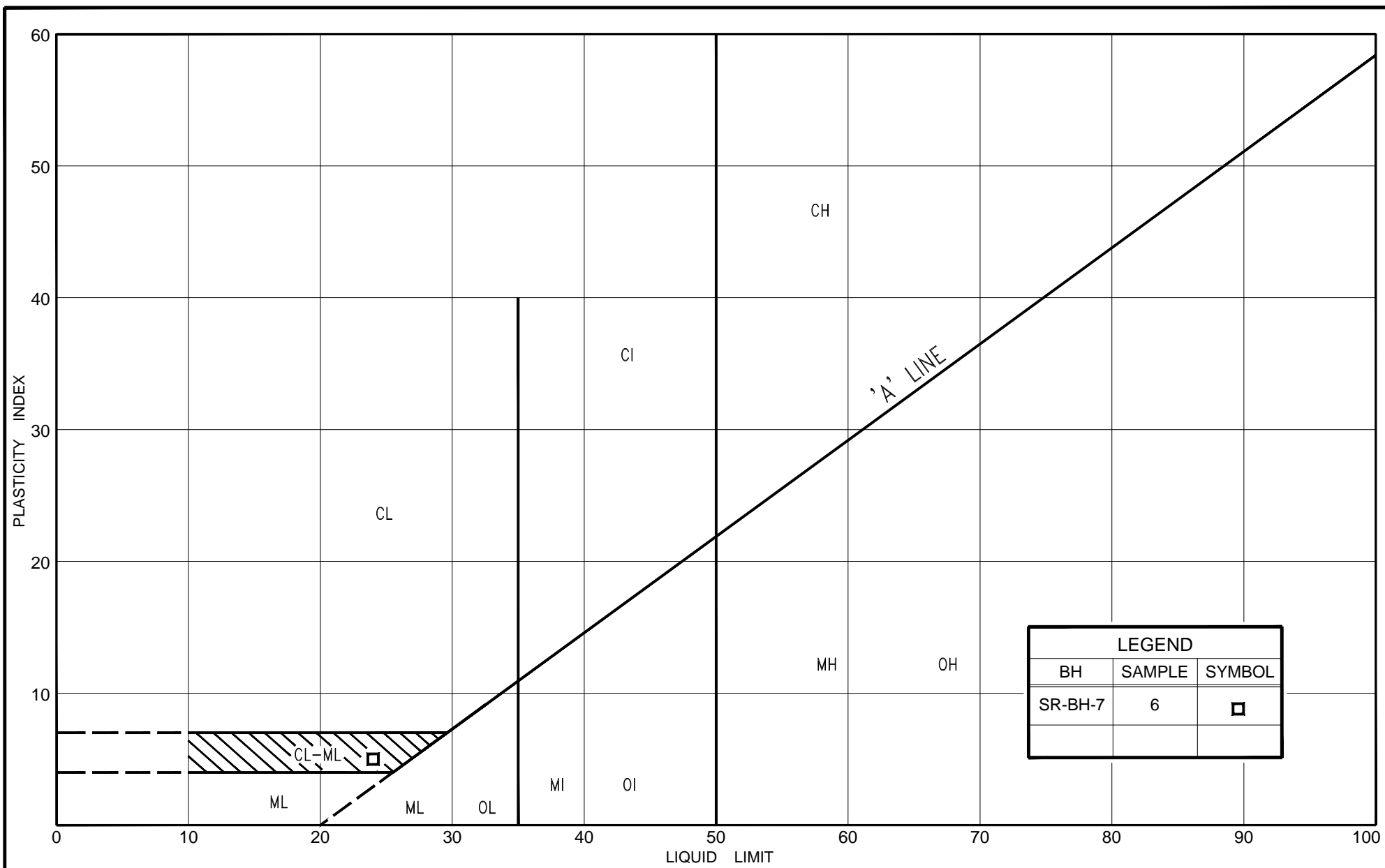
## GRAIN SIZE DISTRIBUTION

SILT to CLAYEY SILT, trace sand

FIG No. SRS-GS-3

HWY: 400

W.P. No. 2184-10-00



PLASTICITY CHART

SILT to CLAYEY SILT, trace sand (CL-ML)

FIG No.	SRS-PC-1
HWY:	400
W.P. No.	2184-10-00

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

### MECHANICAL PROPERTIES OF SOIL

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

### PHYSICAL PROPERTIES OF SOIL

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

# RECORD OF BOREHOLE No SR-BH-1

1 of 1

## METRIC

W.P.	2184-10-00	LOCATION	Co-ords: 4 905 955.2 N; 290 285.6 E	ORIGINATED BY	S.A.
DIST	Central	HWY	400	BOREHOLE TYPE	Continuous Flight Solid Stem Augers
DATUM	Geodetic	DATE	March 07 and 08, 2016	CHECKED BY	M.V.






SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED      + FIELD VANE												
								● QUICK TRIAXIAL      × LAB VANE												
305.6 0.0	Ground Surface 150mm asphalt over sand																			
305.1 0.5	Compact      Grey (PAVEMENT FILL)		1	SS	28	▽*	305													
	Sand to silty sand trace to some clay, trace to some gravel		2	SS	14		304													
	Compact      Grey/ brown (FILL)		3	SS	17		303										6 56 25 13			
			4	SS	27		302										First water strike at 2.4m			
302.7 2.9	Sand to silty sand trace to some clay, trace to some gravel		5	SS	23		301										14 49 25 12			
	Compact to Grey/ very dense brown      Moist																			
	cobbles		6	SS	82/25cm															
300.4 5.2	End of borehole																			
	  *      2016    03    07 and 08  ▽      Water level observed during drilling  Upon completion of augering, no free water, no cave-in																			

**RECORD OF BOREHOLE No SR-BH-2**

1 of 1

**METRIC**

W.P. 2184-10-00 LOCATION Co-ords: 4 906 154.0 N; 290 248.2 E ORIGINATED BY S.A.  
DIST Central HWY 400 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY M.Kh.  
DATUM Geodetic DATE March 07 and 08, 2016 CHECKED BY M.V.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								20 40 60 80 100									
304.1	Ground Surface					*											
0.0	150mm asphalt over sand						304										
303.6	Compact Brown/ grey (PAVEMENT FILL)		1	SS	22								o				
0.5	Sand to silty sand trace clay, trace gravel		2	SS	12		303						o			4 62 25 9	
	Loose to Brown/ Moist compact grey (FILL)		3	SS	11		302						o				
			4	SS	8		301						o				
301.1	Sand to silty sand trace to some clay, trace to some gravel		5	SS	86/28cm		300						o			5 48 34 13	
3.0	Very dense Grey/ brown Moist		6	SS	82/28cm		299						o				
298.9	End of borehole																
5.2																	
	* Borehole dry																
	Upon completion of augering, no cave-in																
	<u>Piezometer Readings:</u>																
	Date Depth Elev.																
	(m)																
	Mar.08/'16 Dry -----																
	Apr.19/'16 Dry -----																
	<u>Piezometer Legend:</u>																
	 Flush cover and concrete																
	 Bentonite seal																
	 Filter sand																
	 Screen																
	 Backfill																

**RECORD OF BOREHOLE No SR-BH-3**

1 of 1

**METRIC**

W.P. 2184-10-00 LOCATION Co-ords: 4 906 451.1 N; 290 193.6 E ORIGINATED BY D.W.  
DIST Central HWY 400 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY M.Kh.  
DATUM Geodetic DATE March 07, 2016 CHECKED BY M.V.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS *	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT						PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa											WATER CONTENT (%)		
								○ UNCONFINED			+ FIELD VANE								● QUICK TRIAXIAL		
306.3	Ground Surface							20	40	60	80	100									
0.0	180mm asphalt over sand, trace gravel						306														
305.5	Dense Brown (PAVEMENT FILL)		1	SS	34									○							
0.8	Sand to silty sand trace clay, trace gravel		2	SS	20									○							
	Loose to Brown Wet compact (FILL)		3	SS	8		305							○			2 56 37 5				
			4	SS	4		304							○							
302.9			5	SS	6		303							○							
3.4	Sand to silty sand trace to some clay, trace to some gravel													○							
	Compact Brown		6	SS	27		302							○			12 40 35 13				
														○							
301.1			7	SS	30																
5.2	End of borehole																				
	* Borehole dry  Upon completion of augering, no cave-in																				



**RECORD OF BOREHOLE No SR-BH-4**

1 of 1

**METRIC**

W.P. 2184-10-00 LOCATION Co-ords: 4 906 933.5 N; 290 124.4E ORIGINATED BY D.W.  
DIST Central HWY 400 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY M.Kh.  
DATUM Geodetic DATE March 07, 2016 CHECKED BY M.V.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS *	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m³	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 (%)												
305.8	Ground Surface						20	40	60	80	100						
0.0	250mm asphalt over sand, trace gravel																
305.0	Very dense Brown (PAVEMENT FILL)		1	SS	59												
0.8	Sand to silty sand trace clay, trace gravel		2	SS	32												
	Very loose Brown Moist to wet (FILL)		3	SS	6												
			4	SS	2												
			5	SS	3												
302.1	Silty sand to sandy silt trace clay, trace gravel		6	SS	24												
3.7	Compact Brown Wet to dense		7	SS	39												
300.6	End of borehole																
5.2																	
	* Borehole dry  Upon completion of augering, no cave-in																

# RECORD OF BOREHOLE No SR-BH-5

1 of 1

METRIC

W.P.	2184-10-00	LOCATION	Co-ords: 4 907 079.5 N; 290 218.1 E	ORIGINATED BY	S.A.
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DIST Central HWY 400 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY M.Kh.

DATUM Geodetic DATE March 07 and 08, 2016 CHECKED BY M.V.

[illegible]

**RECORD OF BOREHOLE No SR-BH-6**

1 of 1

**METRIC**

W.P. 2184-10-00 LOCATION Co-ords: 4 908 477.9 N; 290 186.7 E ORIGINATED BY D.W.  
DIST Central HWY 400 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY M.Kh.  
DATUM Geodetic DATE March 07, 2016 CHECKED BY M.V.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
283.1	Ground Surface							20	40	60	80	100					
0.0	230mm asphalt over sand with some gravel						283										
282.3	Dense Brown (PAVEMENT FILL)		1	SS	41												
0.8	Silty sand, trace gravel		2	SS	30		282										
281.9	Compact Brown (FILL)																
1.2	Sand to silty sand some gravel, trace clay		3	SS	33												13 48 32 7
	Dense to Brown Moist/ very dense wet		4	SS	33		281										
			5	SS	25		280										
			6	SS	63		279										First water strike at 3.5m
278.6	Silt to clayey silt trace sand																
4.5	Hard Brown Moist		7	SS	37		278										0 2 94 4
277.9	End of borehole																
5.2																	
	<div>* 2016 03 07</div> <div>▽ Water level observed during drilling</div> <div>▼ Water level measured after drilling</div> <div>Water level measured in piezometer</div> <div>Upon completion of augering, free water on 3.2m cave-in at 4m</div> <div>Piezometer Readings:</div> <div><div>Date</div><div>Depth (m)</div><div>Elev.</div><div>Mar.07/'16 3.2 279.9</div><div>Apr.19/'16 2.5 280.6</div></div> <div><div>Piezometer Legend:</div><div><div>Flush cover and concrete</div><div>Bentonite seal</div><div>Filter sand</div><div>Screen</div><div>Backfill</div></div></div>																

**RECORD OF BOREHOLE No SR-BH-7**

1 of 1

**METRIC**

W.P. 2184-10-00 LOCATION Co-ords: 4 908 716.2 N; 290 192.7 E ORIGINATED BY S.A.  
DIST Central HWY 400 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY M.Kh.  
DATUM Geodetic DATE March 8 and 9, 2016 CHECKED BY M.V.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								20	40	60	80	100				
279.4	Ground Surface															
0.0	150mm asphalt over sand															
279.0																
0.4	Dense Grey (PAVEMENT FILL)		1	SS	31		279									
	Sandy silt to silty sand, trace clay, trace gravel		2	SS	23											
	Compact Brown/ Moist to wet grey						278									
			3	SS	18											
	(FILL)		4	SS	21		277									
			5	SS	14		276									
275.8	Silt to clayey silt trace sand															
3.6	Stiff to Grey Moist very stiff															
							275									
			6	SS	15											
274.2	End of borehole															
5.2																

**RECORD OF BOREHOLE No SR-BH-8**

1 of 1

**METRIC**

W.P. 2184-10-00 LOCATION Co-ords: 4 908 825.7 N; 290 202.0 E ORIGINATED BY D.W.  
DIST Central HWY 400 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY M.Kh.  
DATUM Geodetic DATE March 08, 2016 CHECKED BY M.V.
















SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ  kN/m³	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		○
280.1	Ground Surface						20	40	60	80	100									
0.0	230mm asphalt over sand, trace gravel																			
279.3	Dense Brown (PAVEMENT FILL)		1	SS	33															
0.8	Sand to silty sand some to trace gravel, organic inclusions		2	SS	15															
	Very loose Brown Moist to compact to wet (FILL)		3	SS	3															
			4	SS	15															
			5	SS	14															
276.5	Silty sand, trace clay																			
3.6	Dense Grey Moist		6	SS	41															
			7	SS	30															
274.9	End of borehole																			
5.2																				
														</						

**RECORD OF BOREHOLE No SR-BH-9**

1 of 1

**METRIC**

W.P. 2184-10-00 LOCATION Co-ords: 4 909 122.6 N; 290 214.5 E ORIGINATED BY S.A.  
DIST Central HWY 400 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY M.Kh.  
DATUM Geodetic DATE April 14 and 20, 2016 CHECKED BY M.V.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ  kN/m³	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																	
287.3	Ground Surface					*	20	40	60	80	100																								
0.0	150mm asphalt over sand						287																												
286.8	Dense Grey (PAVEMENT FILL)		1	SS	31		287																												
0.5	Sand to silty sand trace clay, trace gravel		2	SS	20		286																												
	Compact Brown Moist (FILL)		3	SS	21		285																												
			4	SS	20		284									1 86 9 4																			
			5	SS	11		283																												
283.1	Silt to clayey silt trace sand						283																												
4.2	Very stiff Grey Moist		6	SS	20											0 4 92 4																			
282.1	End of borehole																																		
5.2																																			
	<p>* Borehole dry</p> <p>Water level measured in piezometer</p> <p>Upon completion of augering, no cave-in</p> <p><u>Piezometer Readings:</u></p> <table><tr><td>Date</td><td>Depth (m)</td><td>Elev.</td></tr><tr><td>Mar.09/'16</td><td>Dry</td><td>-----</td></tr><tr><td>Apr.14/'16</td><td>3.4</td><td>283.9</td></tr></table> <p><u>Piezometer Legend:</u></p> <table><tr><td></td><td>Flush cover and concrete</td></tr><tr><td></td><td>Bentonite seal</td></tr><tr><td></td><td>Filter sand</td></tr><tr><td></td><td>Screen</td></tr><tr><td></td><td>Backfill</td></tr></table>	Date	Depth (m)	Elev.	Mar.09/'16	Dry	-----	Apr.14/'16	3.4	283.9		Flush cover and concrete		Bentonite seal		Filter sand		Screen		Backfill															
Date	Depth (m)	Elev.																																	
Mar.09/'16	Dry	-----																																	
Apr.14/'16	3.4	283.9																																	
	Flush cover and concrete																																		
	Bentonite seal																																		
	Filter sand																																		
	Screen																																		
	Backfill																																		

**RECORD OF BOREHOLE No SR-BH-10**

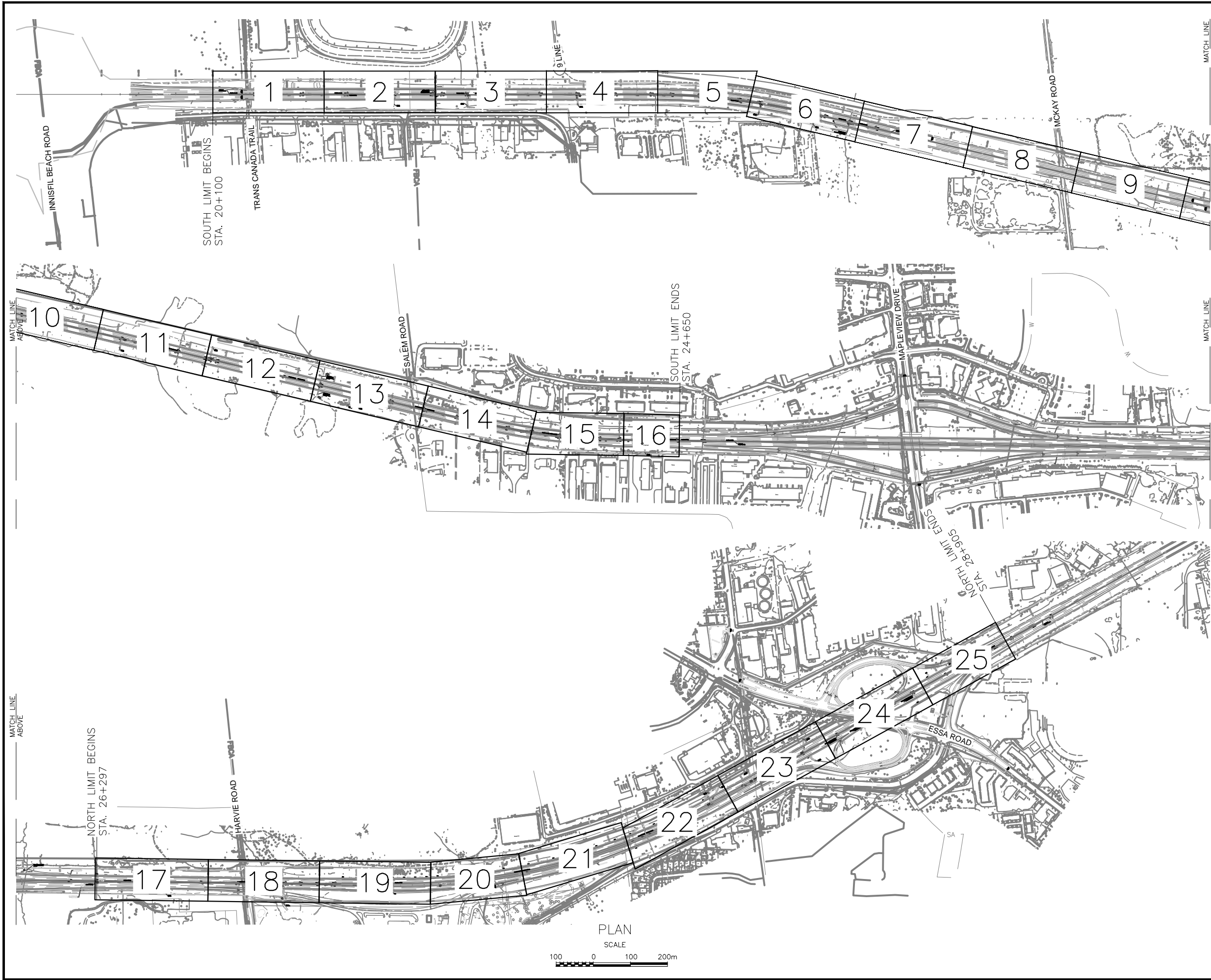
1 of 1

**METRIC**

W.P. 2184-10-00 LOCATION Co-ords: 4 909 901.6 N; 290 201.5 E ORIGINATED BY D.W.  
DIST Central HWY 400 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY M.Kh.  
DATUM Geodetic DATE March 08, 2016 CHECKED BY M.V.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS *	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m³	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												
292.5	Ground Surface						20	40	60	80	100									
0.0	280mm asphalt over sand, trace gravel						292													
291.7	Very dense Brown sand, trace gravel (PAVEMENT FILL)		1	SS	51															
0.8	Silty sand to sandy silt trace clay, trace gravel		2	SS	11															
	Very loose Brown Moist to compact (FILL)		3	SS	9															
			4	SS	4															
			5	SS	2															
289.0						289														
3.5	Silty sand to sandy silt trace to some gravel, trace clay		6	SS	60/15cm															
	Very dense Brown																			
287.8			7	SS	60/15cm	288														
4.7	End of borehole																			
			</																	





TASK No 2016-E-0039-010  
WP No 2184-10-00



HIGHWAY 400 SEWER REPLACEMENT

SHEET

KEY PLAN



KEY PLAN  
SCALE  
0 5 10 15km

LEGEND

25 Site Plan Sheet Number

BH No	BOREHOLE LOCATION PLAN
SR-BH-1	Refer to Sheet No. 400WM-2/25
SR-BH-2	Refer to Sheet No. 400WM-3/25
SR-BH-3	Refer to Sheet No. 400WM-4/25
SR-BH-4	Refer to Sheet No. 400WM-6/25
SR-BH-5	Refer to Sheet No. 400WM-6/25
SR-BH-6	Refer to Sheet No. 400WM-11/25
SR-BH-7	Refer to Sheet No. 400WM-12/25
SR-BH-8	Refer to Sheet No. 400WM-12/25
SR-BH-9	Refer to Sheet No. 400WM-13/25
SR-BH-10	Refer to Sheet No. 400WM-16/25

— 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. 31D-657

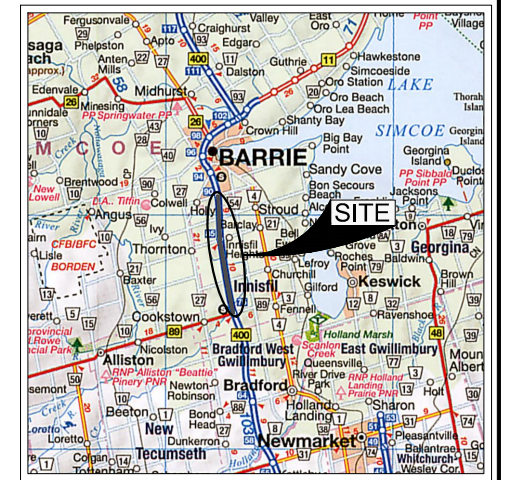
HWY No	400	DIST	CENTRAL
SUBM'D	NA	CHECKED M.KH	DATE JUNE 27, 2016
DRAWN	NL	CHECKED MV	APPROVED CN
DWG	400WM-A		





SHEET 11

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466
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KEY PLAN  
SCALE  
5 0 5 10 15km

#### LEGEND

----- Existing Sewer  
 ——— Replacement/New Sewer

BH No	ELEVATION	CO-ORDINATES	
		NORTHINGS	EASTINGS

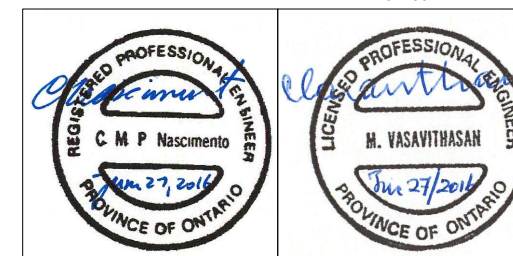
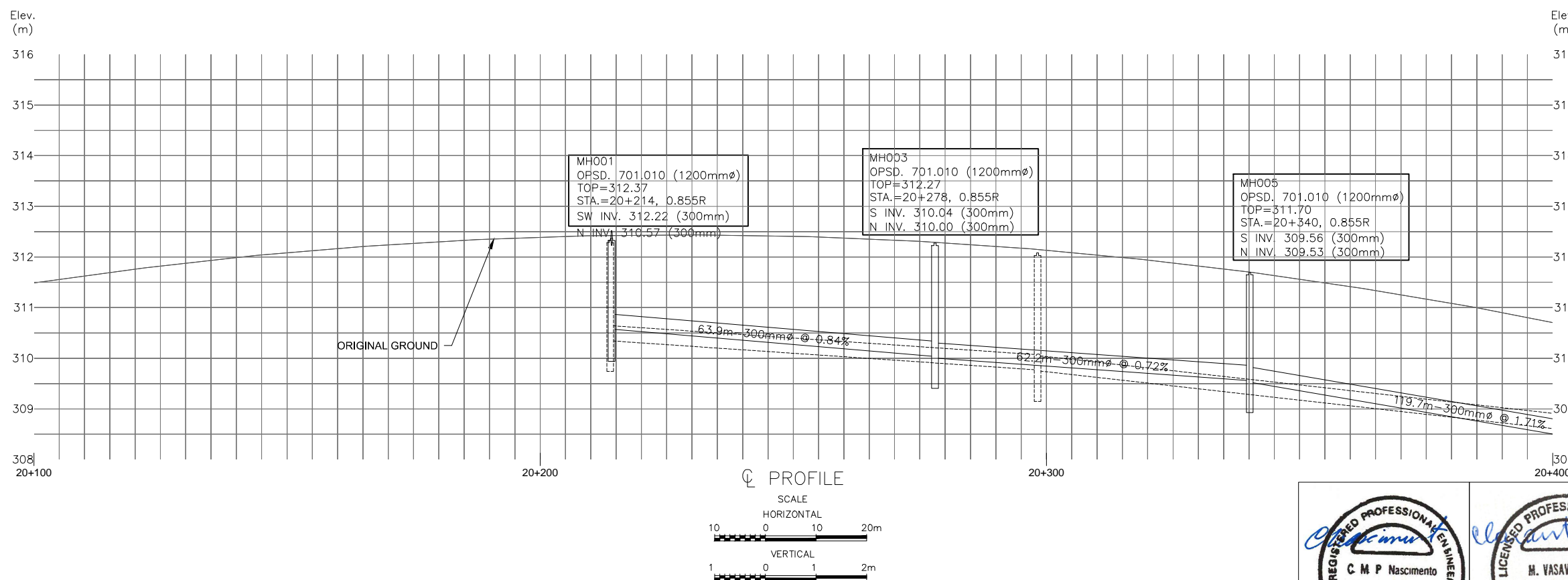
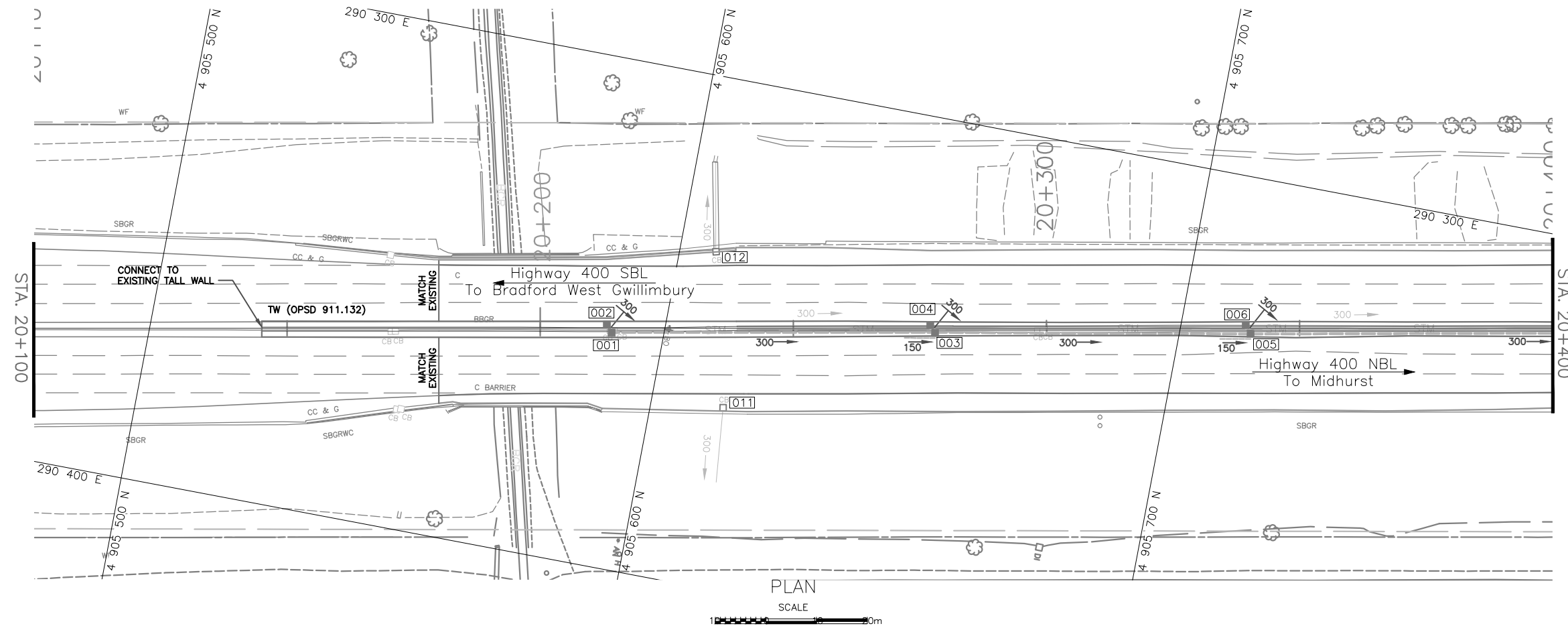
- NOTE -

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

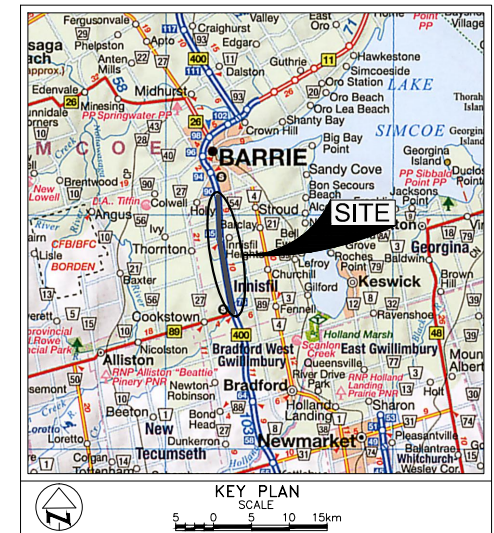
REVISIONS			
	DATE	BY	DESCRIPTION

Geocres No. 31D-657

HWY No 400				DIST CENTRAL
SUBM'D	NA	CHECKED M.Kh	DATE JUNE 27, 2016	SITE
DRAWN	NL	CHECKED MV	APPROVED CN	DWG 400WM-1/25

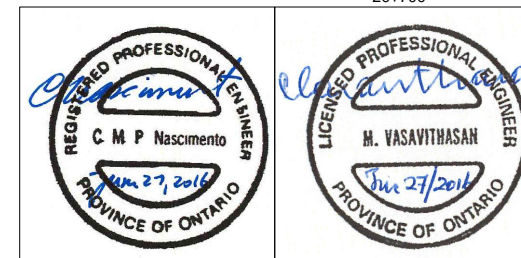
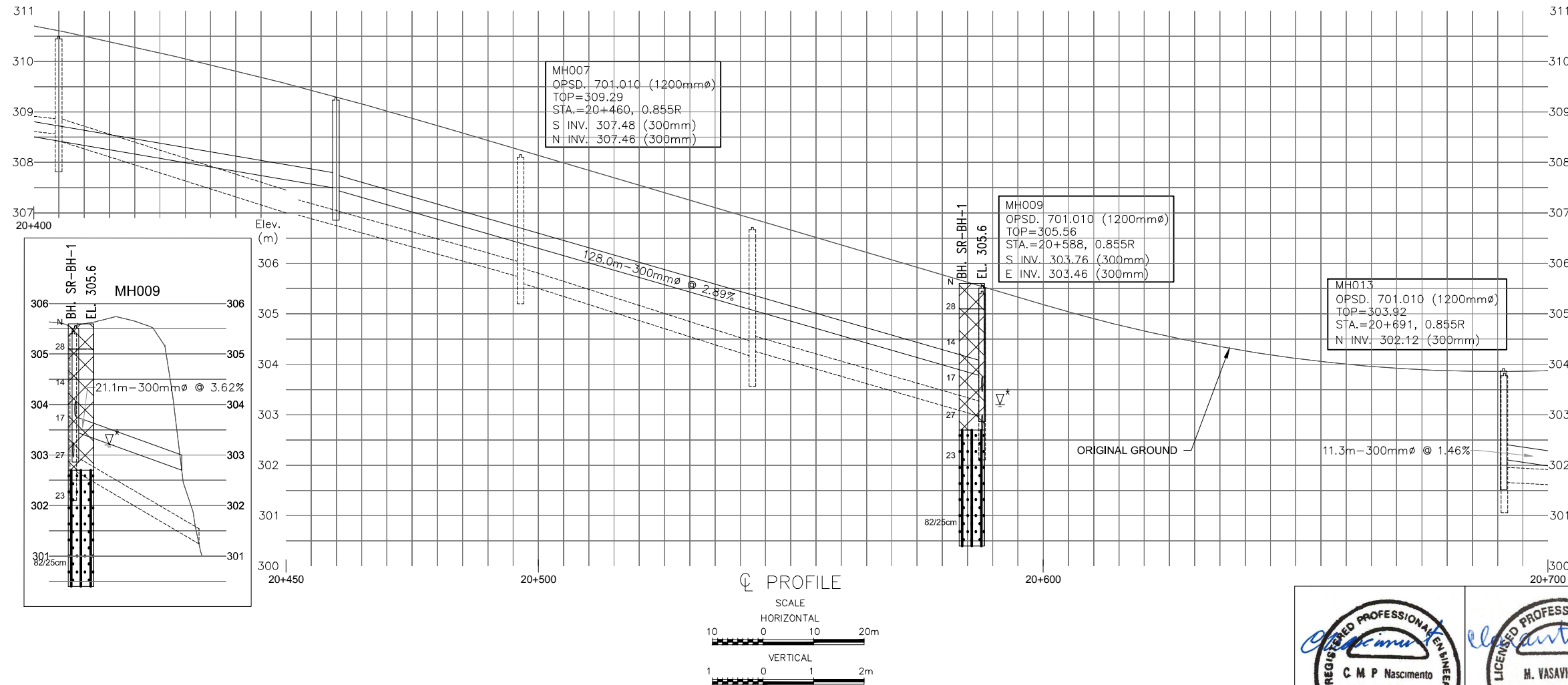
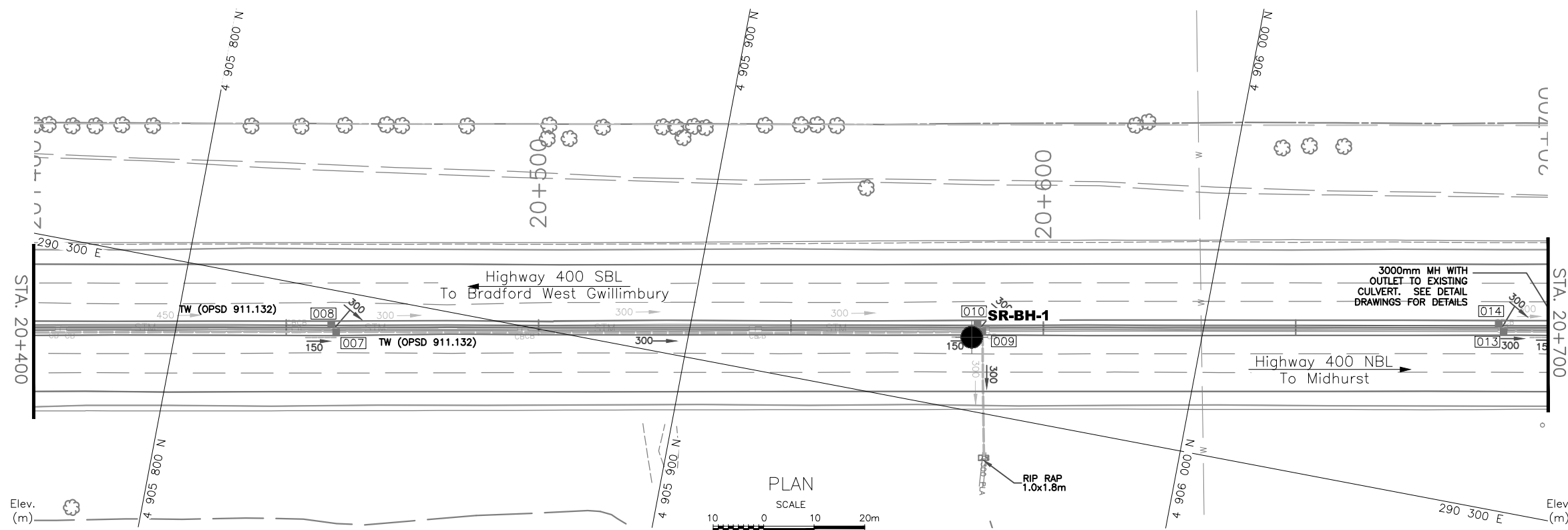


REF MTO Drawings; 09.NEWCONS-For FDN.dwg & 10.PROFILES.dwg;  
dated January 13, 2016 & January 12, 2016, respectively.



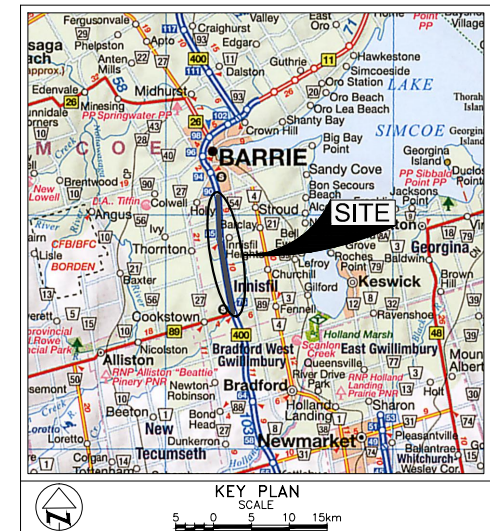
LEGEND				
	Borehole Location			
	Blows/0.3m (Std. Pen Test, 475 J / blow)			
	Piezometer			
	WL observed during drilling (March 2016)			
	Existing Sewer			
	Replacement/New Sewer			
	FILL			
	SAND TO SILTY SAND			
BH No		ELEVATION	CO-ORDINATES	
			NORTHINGS	EASTINGS
SR-BH-1		305.6	4 905 955.2	290 285.6

REVISIONS		
DATE	BY	DESCRIPTION
Geocres No. 31D-657		
HWY No	400	DIST CENTRAL
SUBM'D	NA	CHECKED M.KH DATE JUNE 27, 2016 SITE
DRAWN	NL	CHECKED MV APPROVED CN DWG 400WM-2/25



REF MTO Drawings; 09.NEWCONS-For FDN.dwg & 10.PROFILES.dwg;  
dated January 13, 2016 & January 12, 2016, respectively.





LEGEND			
	Borehole Location		
	Blows/0.3m (Std. Pen Test, 475 J / blow)		
	Piezometer		
	Existing Sewer		
	Replacement/New Sewer		
	FILL		
	SAND TO SILTY SAND		
BH No	ELEVATION	CO-ORDINATES	
		NORTHINGS	EASTINGS
SR-BH-2	304.1	4 909 154.0	290 248.2

- NOTE -

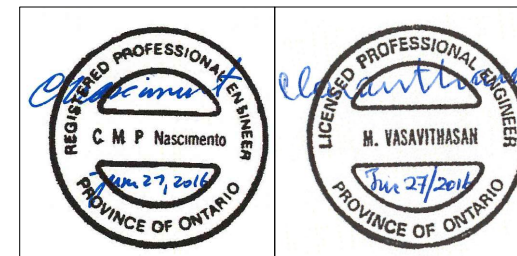
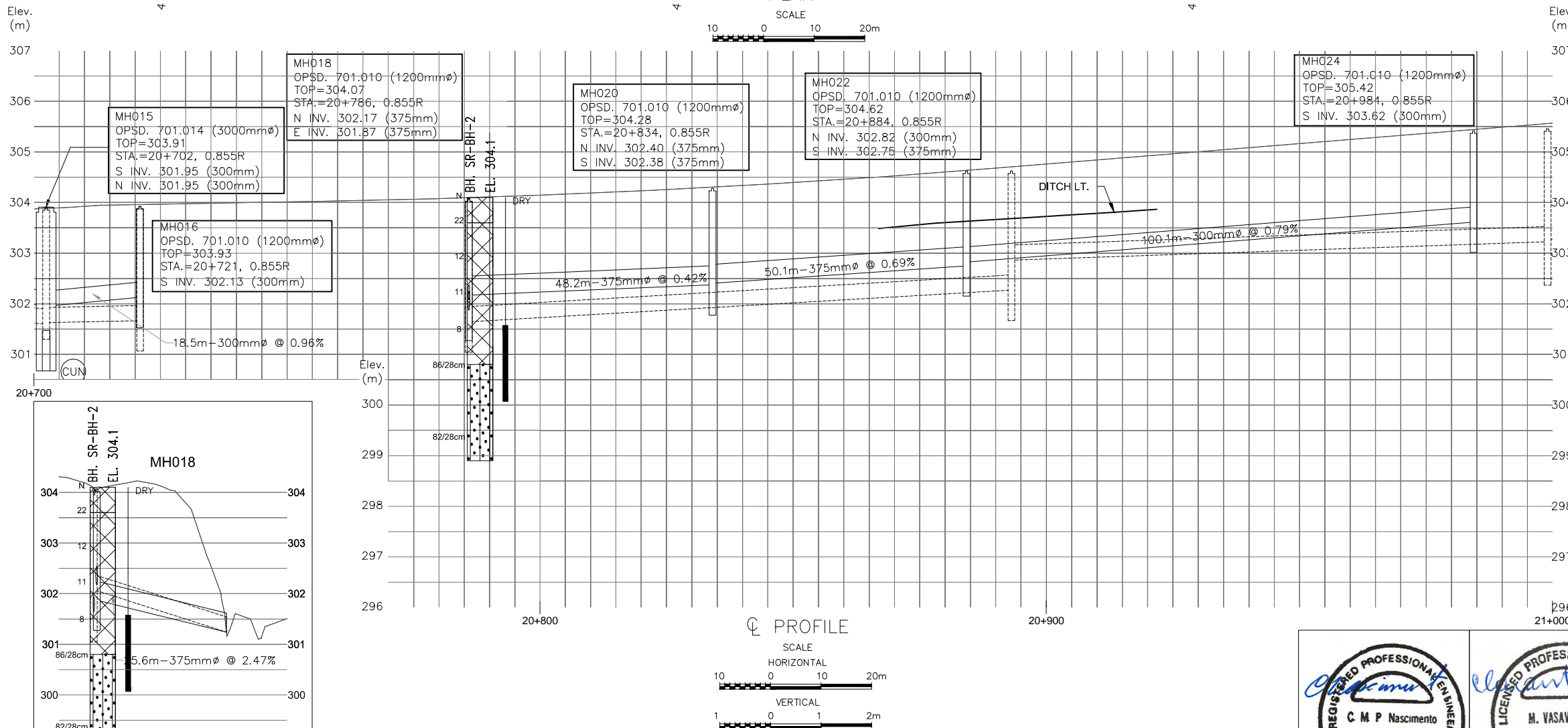
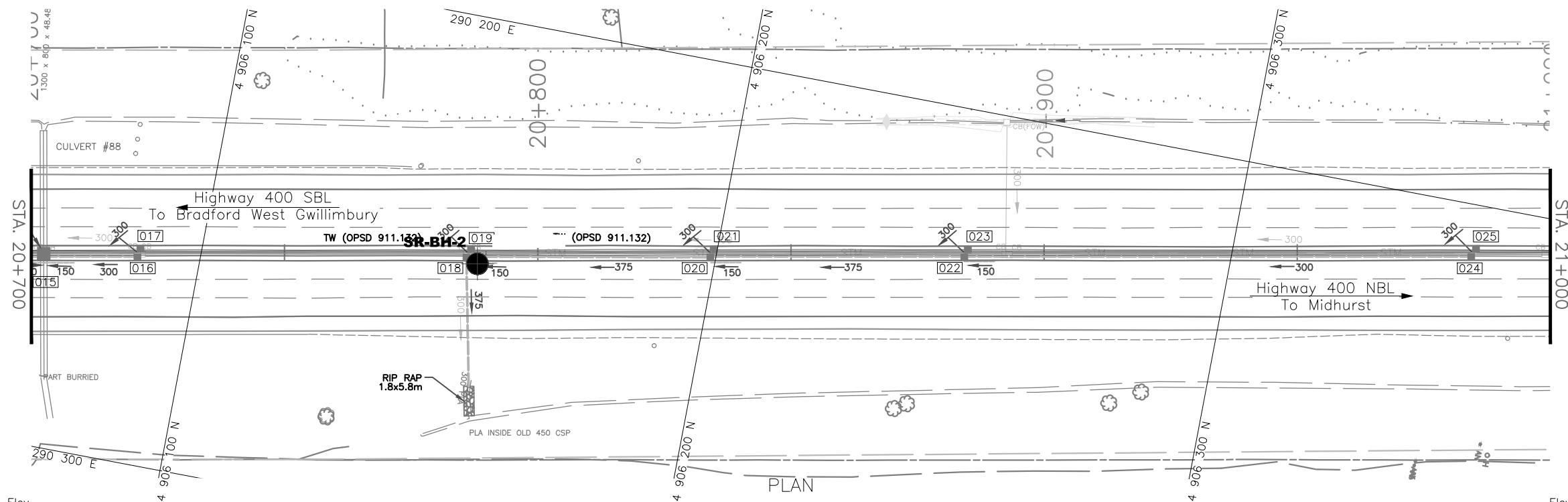
The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

REVISIONS

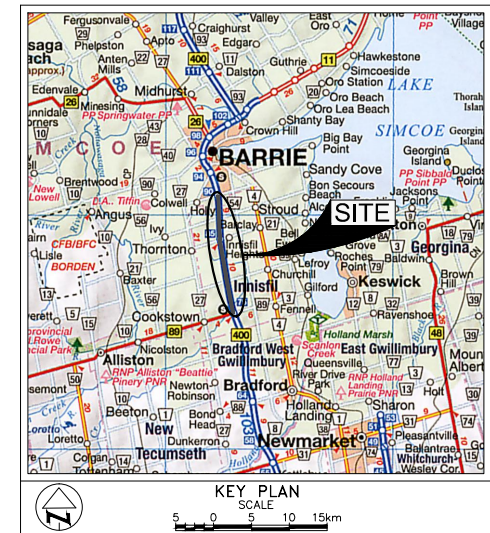
DATE	BY	DESCRIPTION

Geocres No. 31D-657

HWY No	400			DIST	CENTRAL
SUBM'D	NA	CHECKED	M.KH	DATE	JUNE 27, 2016
DRAWN	NL	CHECKED	MV	APPROVED	CN
					DWG 400WM-3/2

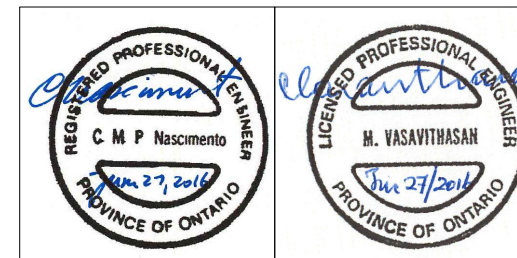
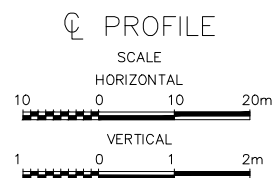
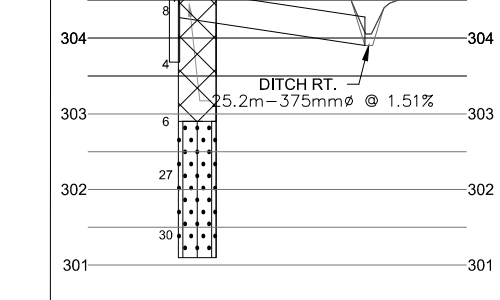
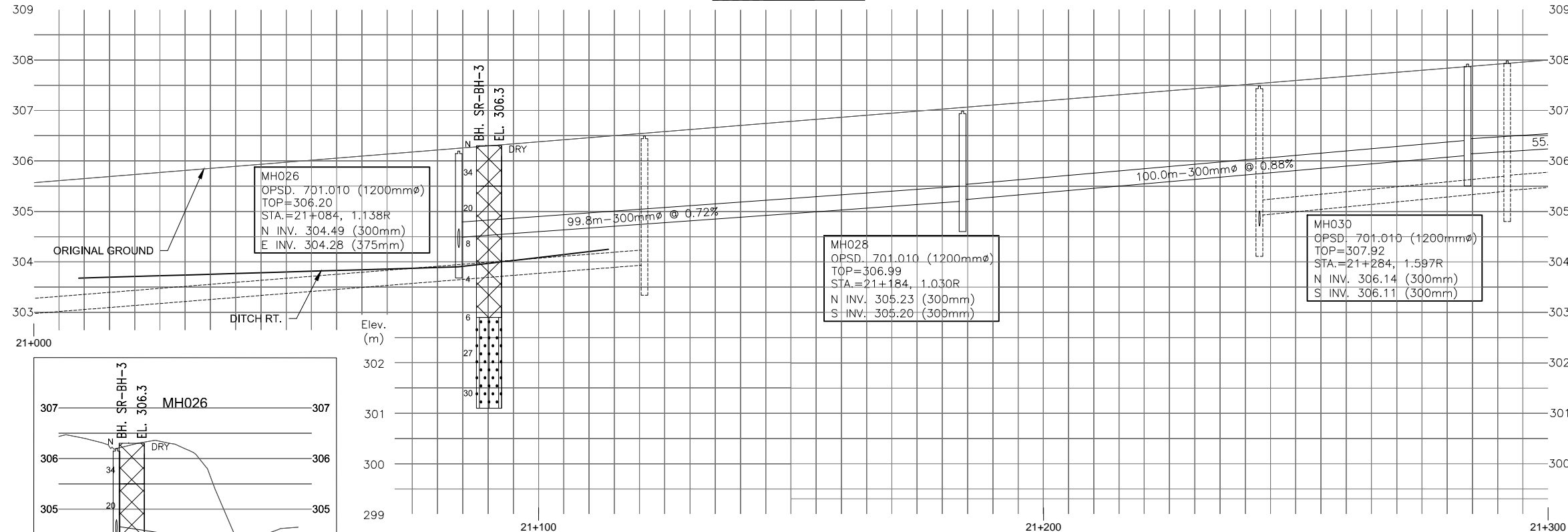
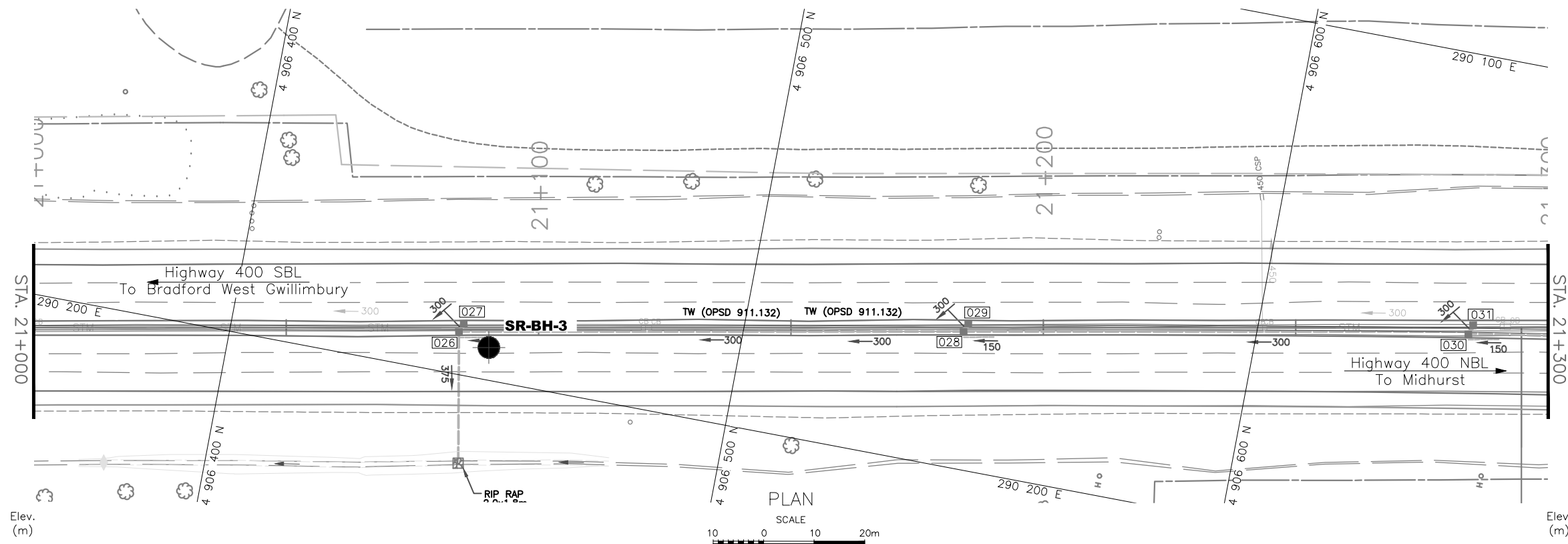


REF MTO Drawings; 09.NEWCONS-For FDN.dwg & 10.PROFILES.dwg;  
dated January 13, 2016 & January 12, 2016, respectively.



LEGEND				
	Borehole Location			
	Blows/0.3m (Std. Pen Test, 475 J / blow)			
	Piezometer			
	Existing Sewer			
	Replacement/New Sewer			
	FILL			
	SAND TO SILTY SAND			
BH No	ELEVATION	CO-ORDINATES		
		NORTHINGS	EASTINGS	
SR-BH-3	306.3	4 906 451.1	290 193.6	

REVISIONS			
DATE	BY	DESCRIPTION	
Geocres No. 31D-657			
HWY No	400	DIST	CENTRAL
SUBM'D	NA	CHECKED M.KH	DATE JUNE 27, 2016
DRAWN	NL	CHECKED MV	APPROVED CN

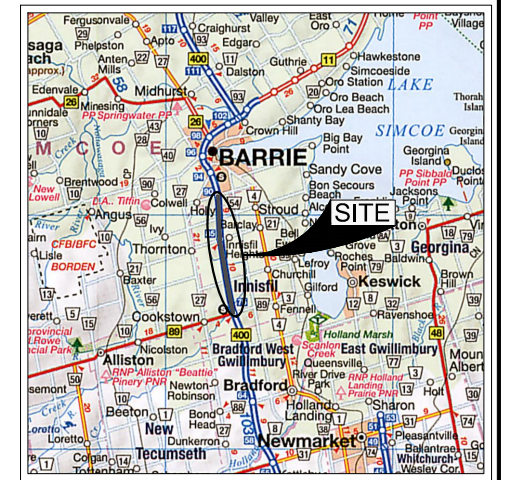






SHEET

1000



LEGEND	
-----	Existing Sewer
=====	Replacement/New Sewer

BH No	ELEVATION	CO-ORDINATES	
		NORTHINGS	EASTINGS

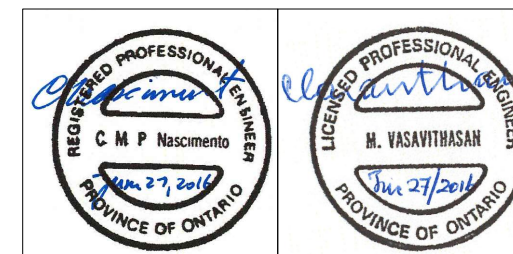
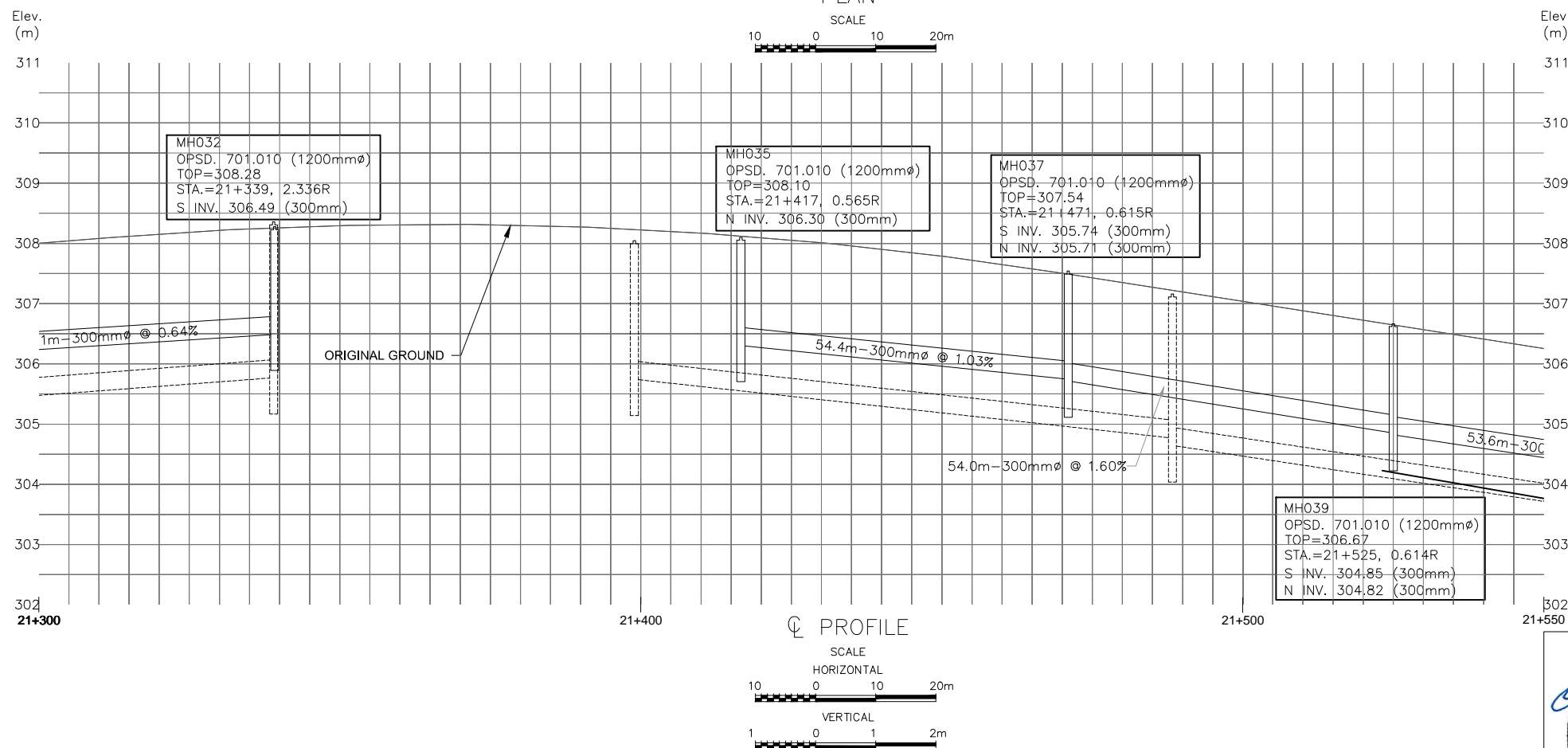
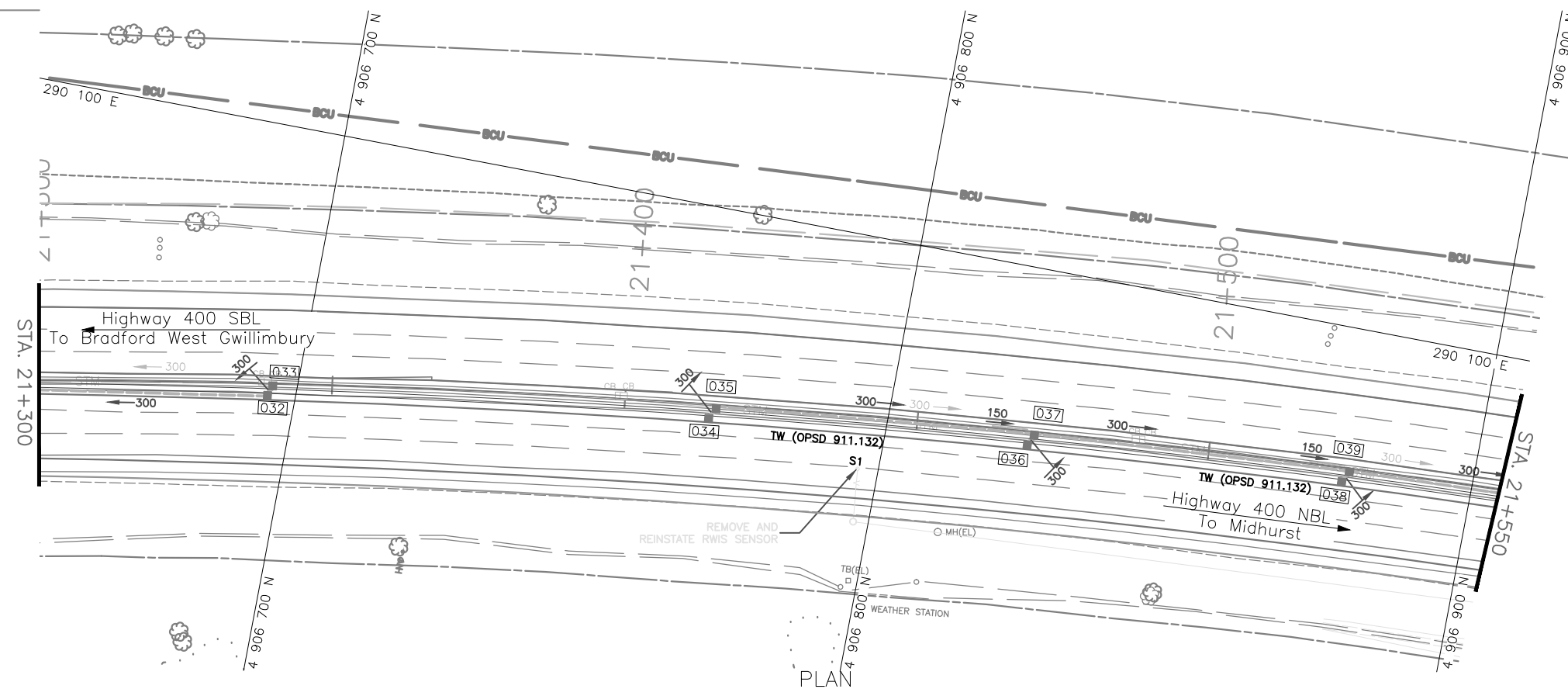
- NOTE -

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

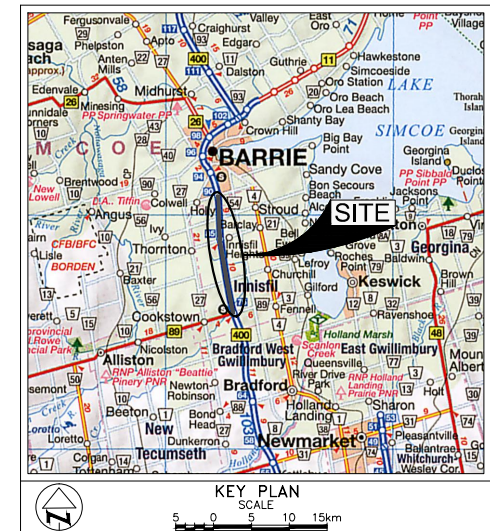
REVISIONS			
	DATE	BY	DESCRIPTION

Geocres No. 31D-657

HWY No 400				DIST CENTRAL	
SUBM'D	NA	CHECKED M.Kh	DATE JUNE 27, 2016		SITE
DRAWN	NL	CHECKED MV	APPROVED CN		DWG 400WM-5/25



REF MTO Drawings; 09.NEWCONS-For FDN.dwg & 10.PROFILES.dwg;  
dated January 13, 2016 & January 12, 2016, respectively.



LEGEND				
	Borehole Location			
	Blows/0.3m (Std. Pen Test, 475 J / blow)			
	Piezometer			
	WL in Piezometer (April 2016)			
	Existing Sewer			
	Replacement/New Sewer			
	FILL			
	SILTY SAND TO SANDY SILT			
	SAND TO SILTY SAND			
BH No		ELEVATION	CO-ORDINATES	
			NORTHINGS	EASTINGS
SR-BH-4		305.8	4 906 933.5	290 124.4
SR-BH-5		303.8	4 907 079.5	290 218.1

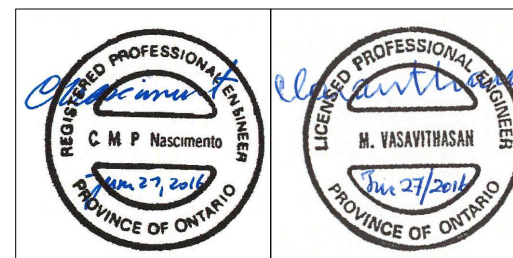
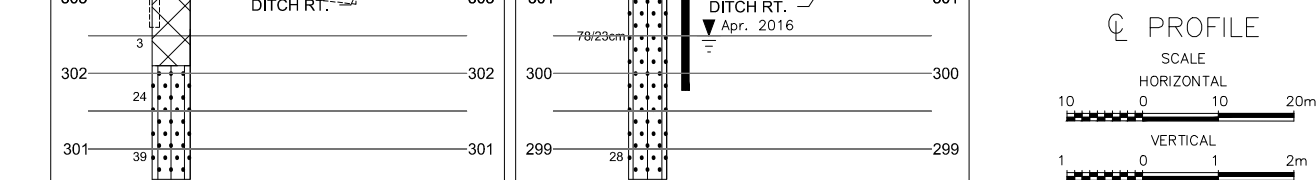
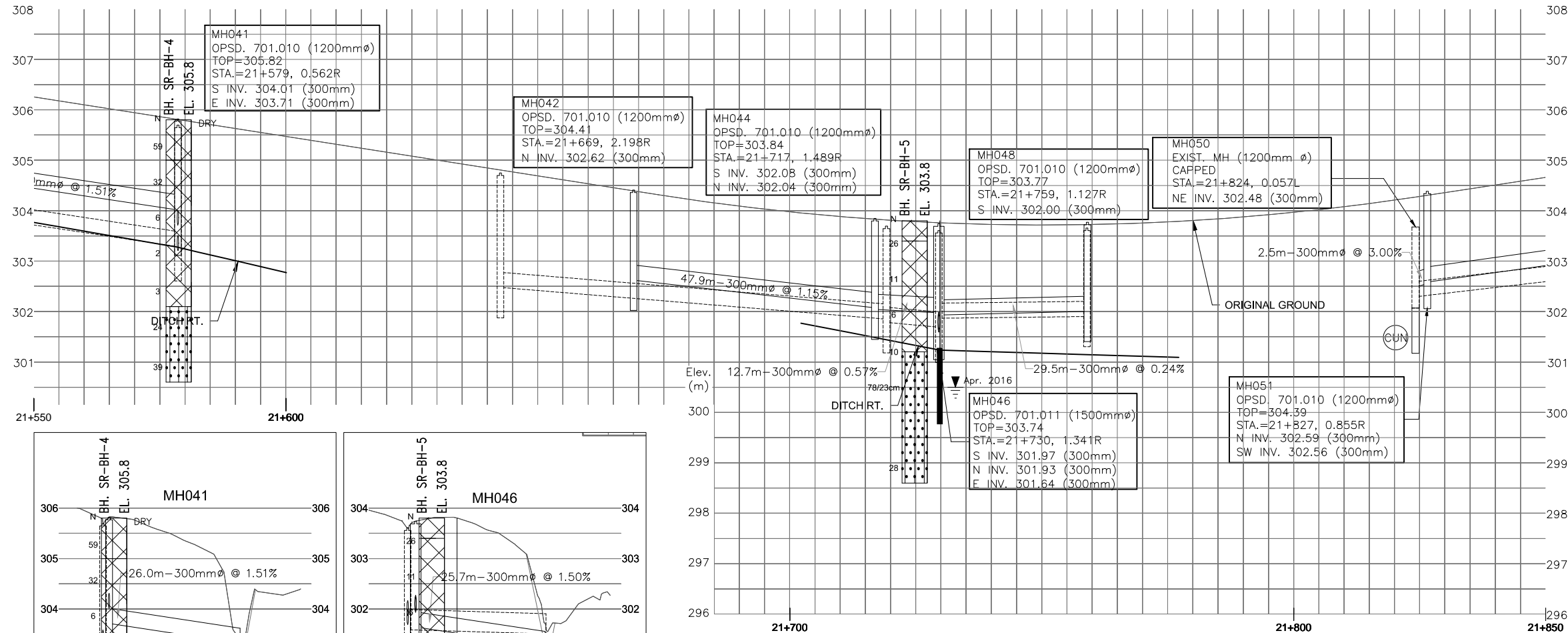
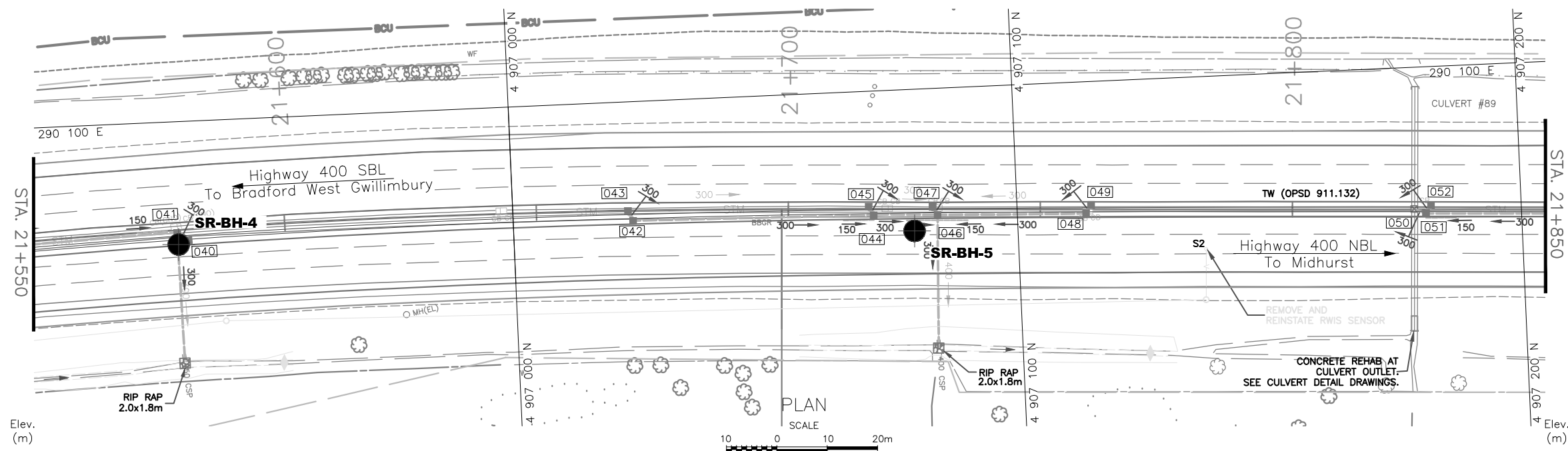
— NOTE —  
The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

REVISIONS		
DATE	BY	DESCRIPTION

Geocres No. 31D-657

HWY No	400	DIST	CENTRAL
SUBM'D	NA	CHECKED M.KH	DATE JUNE 27, 2016
DRAWN	NL	CHECKED MV	APPROVED CN

REF MTO Drawings; 09.NEWCONS-For FDN.dwg & 10.PROFILES.dwg;  
dated January 13, 2016 & January 12, 2016, respectively.







SHEET

1000



LEGEND

[illegible]

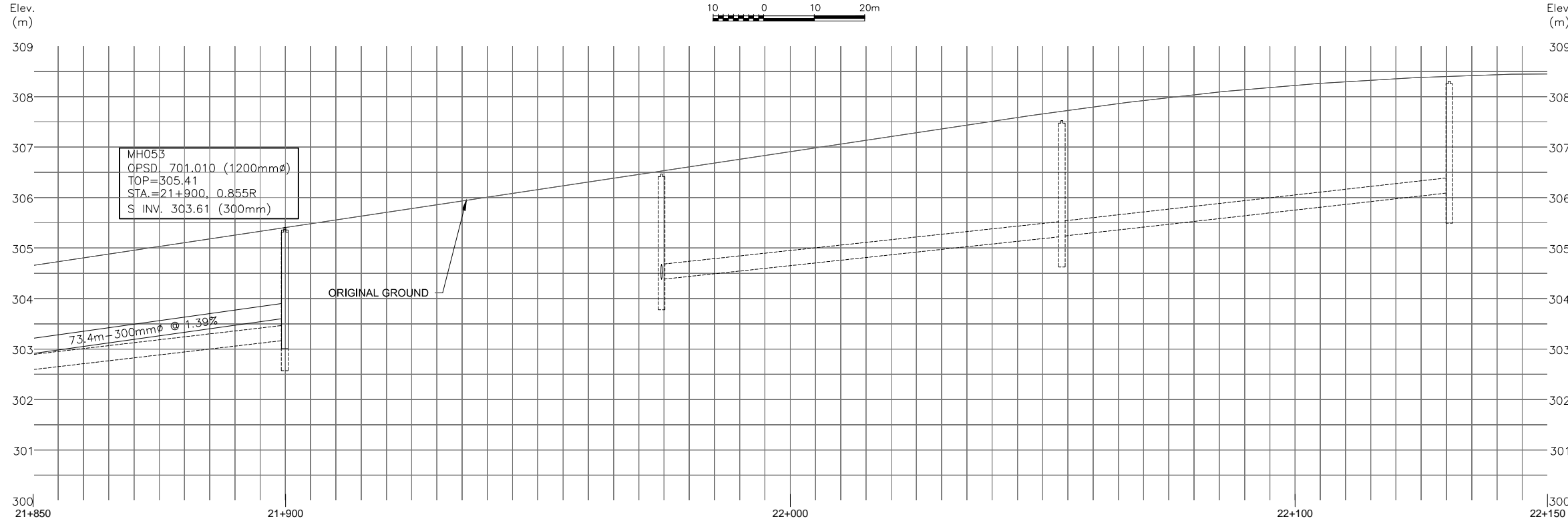
BH No	ELEVATION	CO-ORDINATES	
		NORTHINGS	EASTINGS

5			

REVISION		
DATE	BY	DESCRIPTION

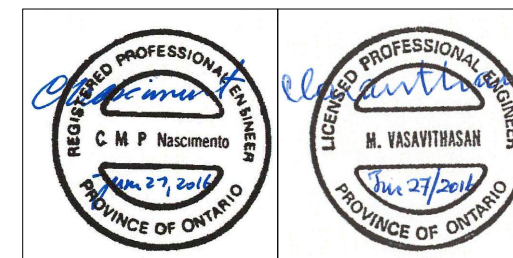
Geocres No. 31D-657

HWY No 400			DIST CENTRAL	
SUBM'D NA	CHECKED M.Kh	DATE JUNE 27, 2016		SITE
DRAWN NL	CHECKED MV	APPROVED CN		DWG 400WM-7/25



Q PROFILE

Figure 1 shows two scales. The top scale is labeled 'SCALE HORIZONTAL' and has markings at 10, 0, 10, and 20m. The bottom scale is labeled 'SCALE VERTICAL' and has markings at 1, 0, 1, and 2m. Both scales have a checkered pattern between the 10 and 0 markings.



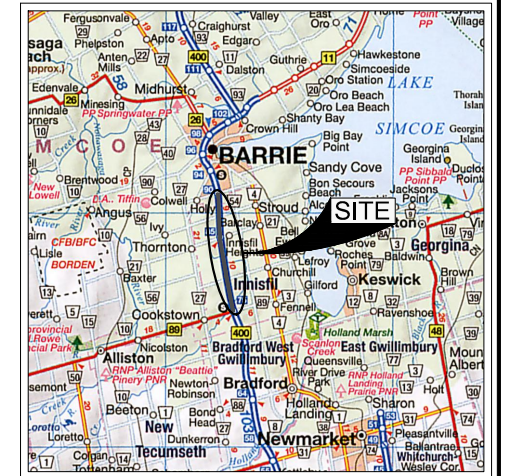
REF MTO Drawings; 09.NEWCONS-For FDN.dwg & 10.PROFILES.dwg;  
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HWY No 400			DIST CENTRAL	
SUBM'D NA	CHECKED M.Kh	DATE JUNE 27, 2016	SITE	
DRAWN NL	CHECKED MV	APPROVED CN	DWG 400WM-7/25	



SHEET

1000



LEGEND

[illegible]

BH No	ELEVATION	CO-ORDINATES	
		NORTHINGS	EASTINGS

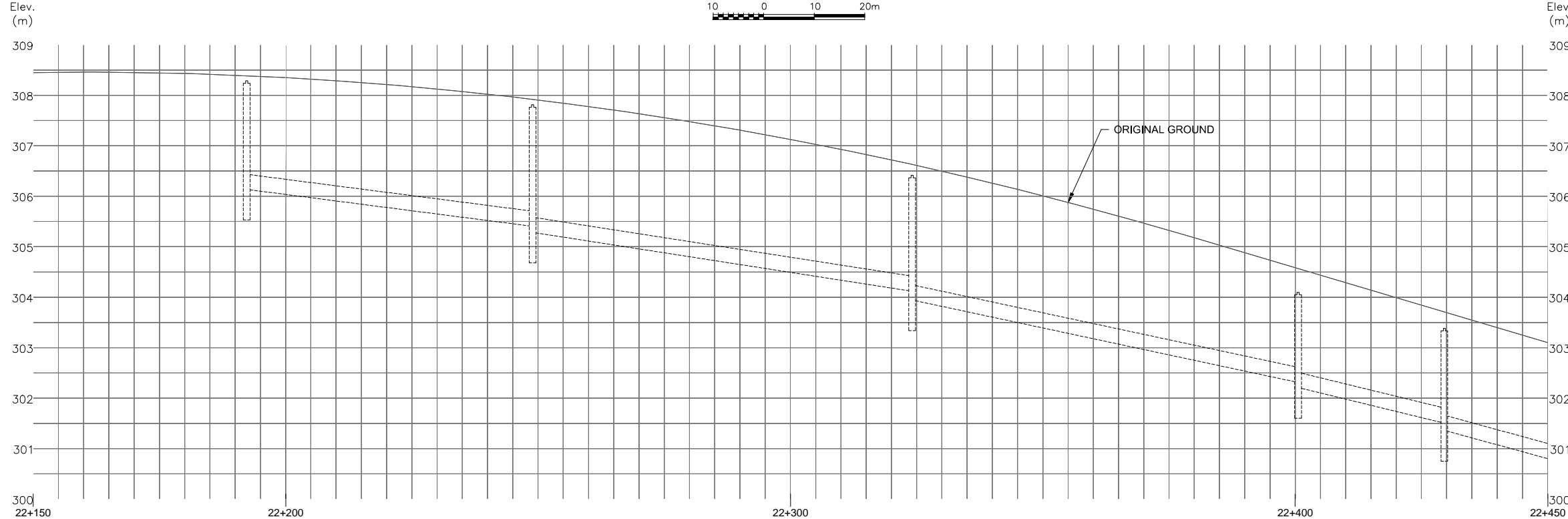
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REVISION		
DATE	BY	DESCRIPTION

HWY No	400	DIST	CENTRAL
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SUBM'D	NA	CHECKED M.Kh	DATE JUNE 27, 2016	SITE
DRAWN	NI	CHECKED MV	APPROVED CN	DWG 400WM-8/25

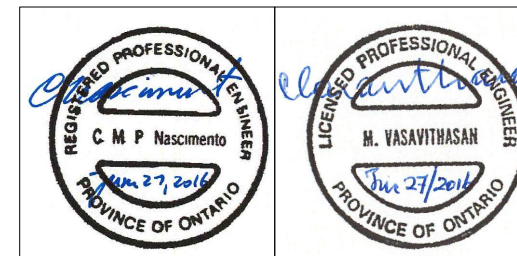
DATE	FILE	CHECKED BY	APPROVED BY	DWG. NUMBER	3/20
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SCALE

A horizontal number line with tick marks at 0 and 1. The segment between 0 and 1 is divided into two equal parts by a tick mark at 1/2. The region from 0 to 1/2 is shaded with a black and white checkerboard pattern. The region from 1/2 to 1 is unshaded.

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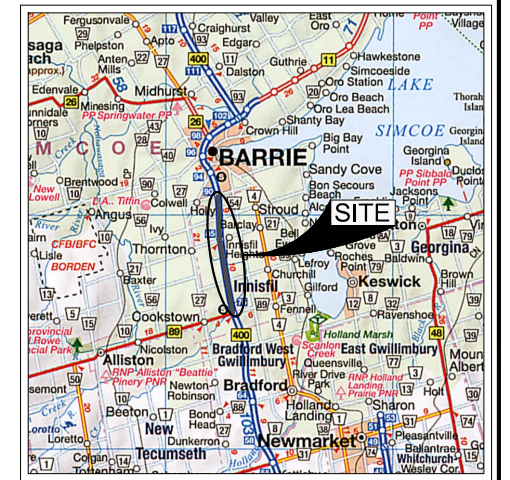
REF MTO Drawings; 09.NEWCONS-For FDN.dwg & 10.PROFILES.dwg;  
dated January 13, 2016 & January 12, 2016, respectively.





SHEET

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466
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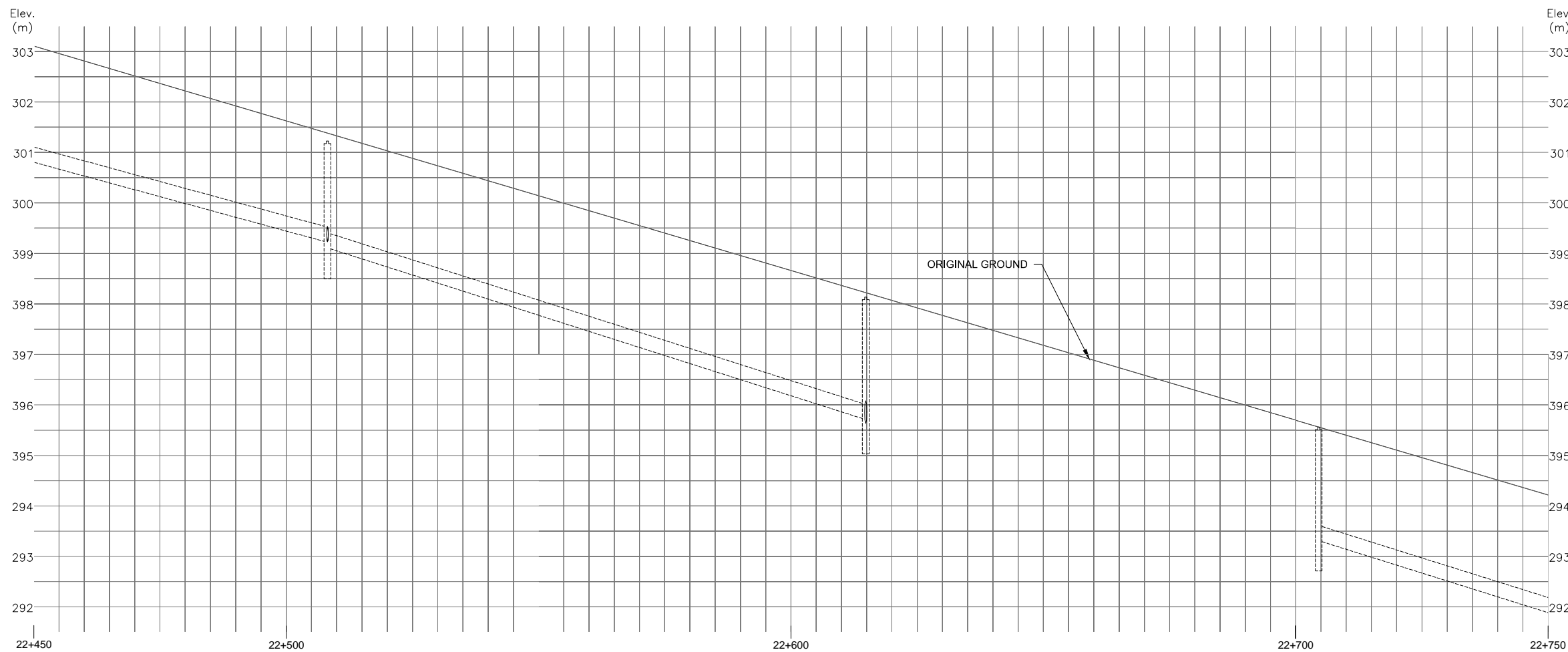
----- Existing Sewer  
 ————— Replacement/New Sewer

- NOTE -

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

Geocres No. 31D-657

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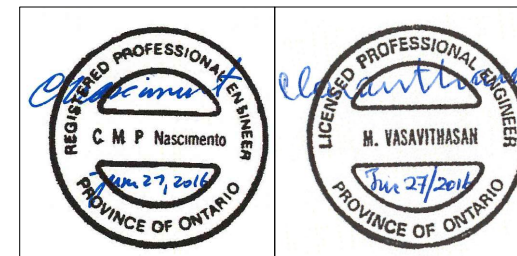


SCALE  
HORIZONTAL

10 0 10 20m

VERTICAL

1 0 1 2m



REF MTO Drawings; 09.NEWCONS-For FDN.dwg & 10.PROFILES.dwg;  
dated January 13, 2016 & January 12, 2016, respectively.





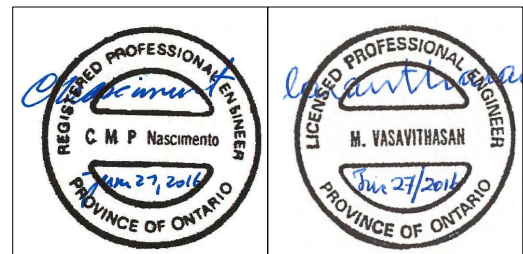
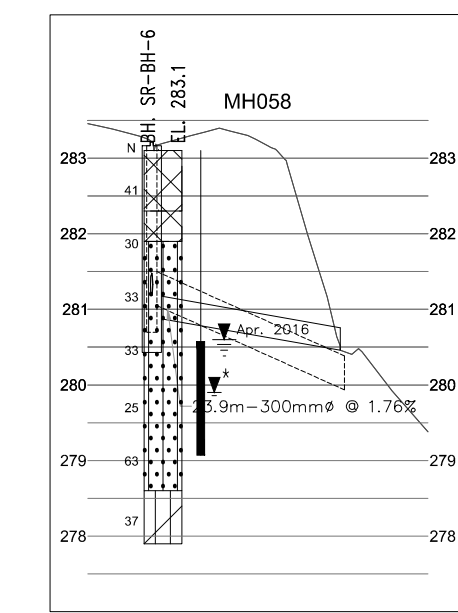
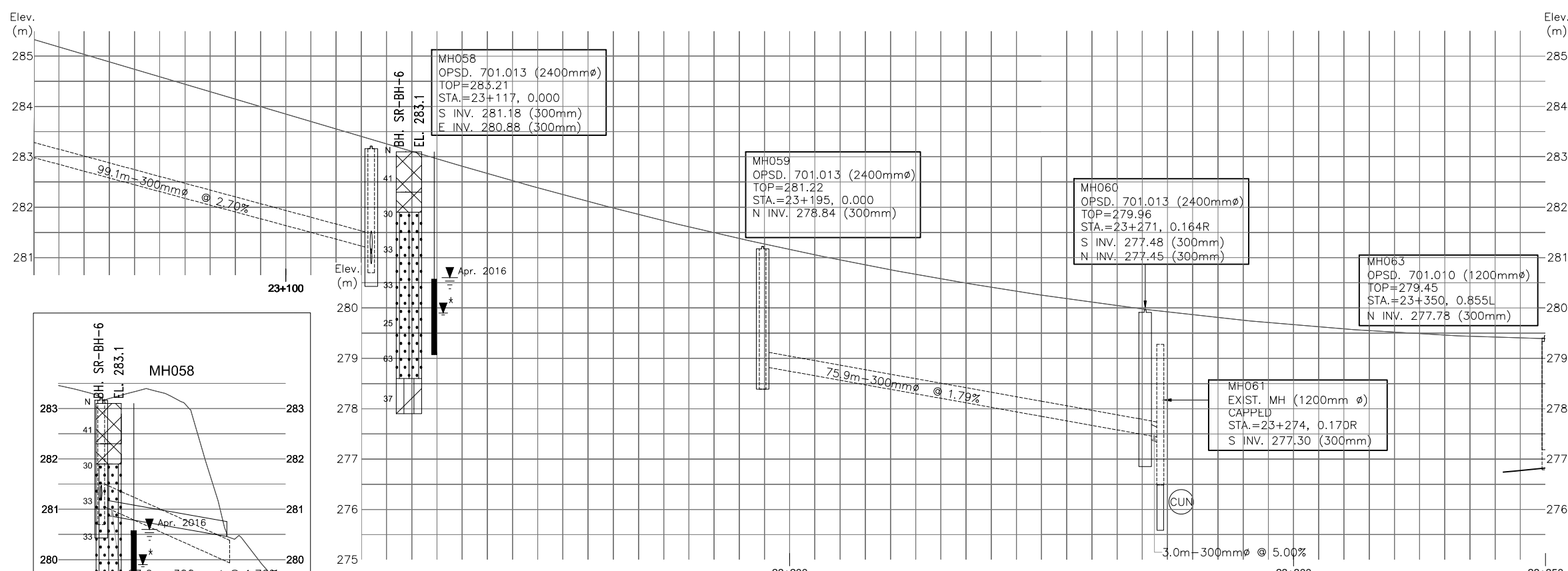
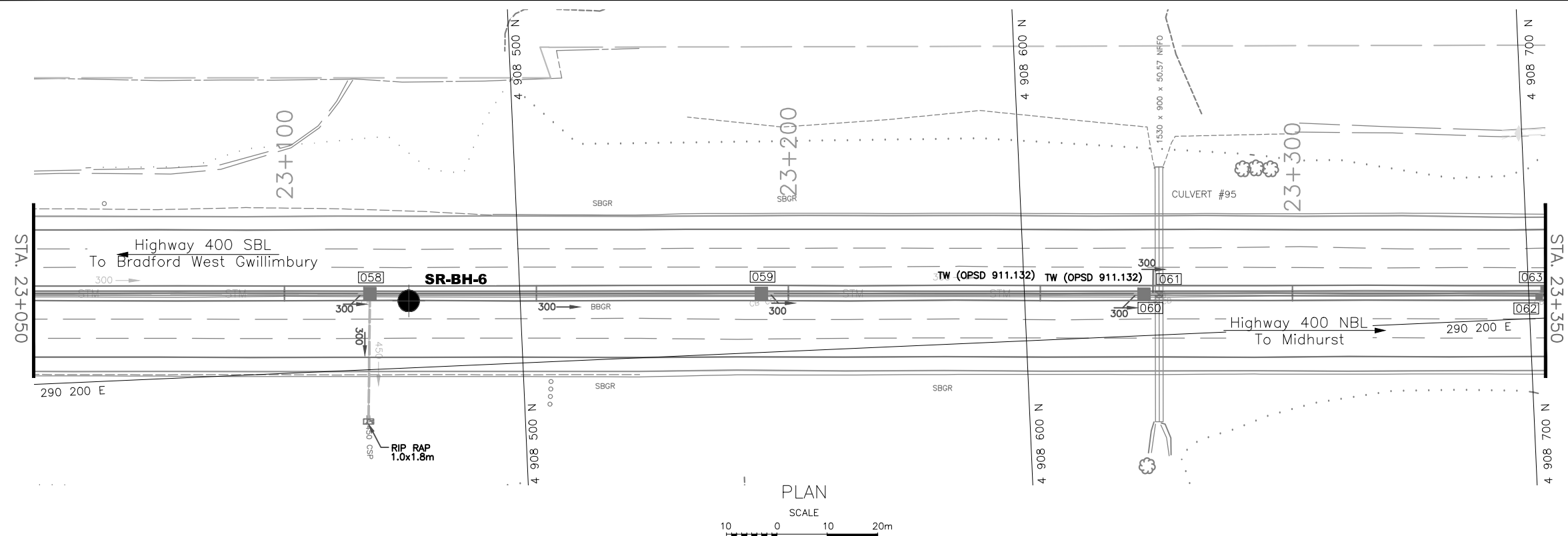
LEGEND				
	Borehole Location			
	Blows/0.3m (Std. Pen Test, 475 J / blow)			
	Piezometer			
	WL at time of investigation (March 2016)			
	WL in Piezometer (April 2016)			
	Existing Sewer			
	Replacement/New Sewer			
	FILL			
	SAND TO SILTY SAND			
	SILT TO CLAYEY SILT			
BH No	ELEVATION	CO-ORDINATES		
		NORTHINGS	EASTINGS	
SR-BH-6	283.1	4 908 477.9	290 186.7	

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

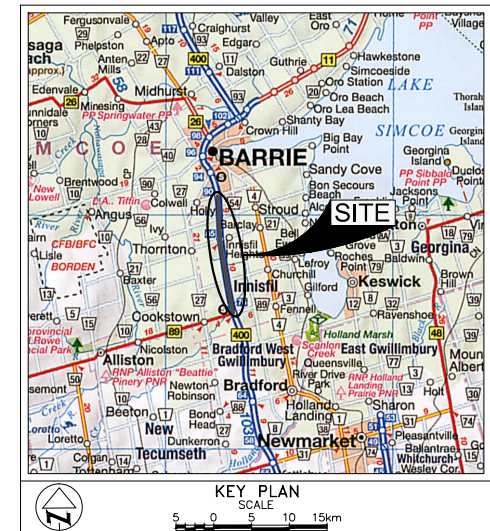
REVISIONS	DATE	BY	DESCRIPTION

Geocres No. 31D-657

HWY No	400	DIST	CENTRAL
SUBM'D	NA	CHECKED	M.KH
DRAWN	NL	CHECKED	MV
DATE	JUNE 27, 2016	APPROVED	CN
DATE	JUNE 27, 2016	APPROVED	CN

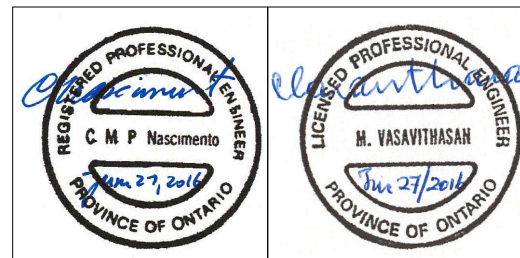
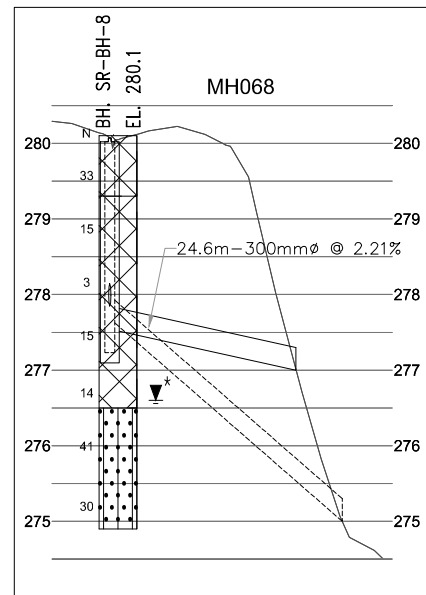
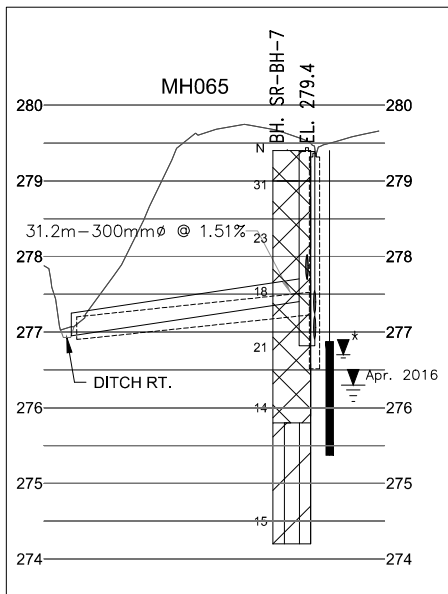
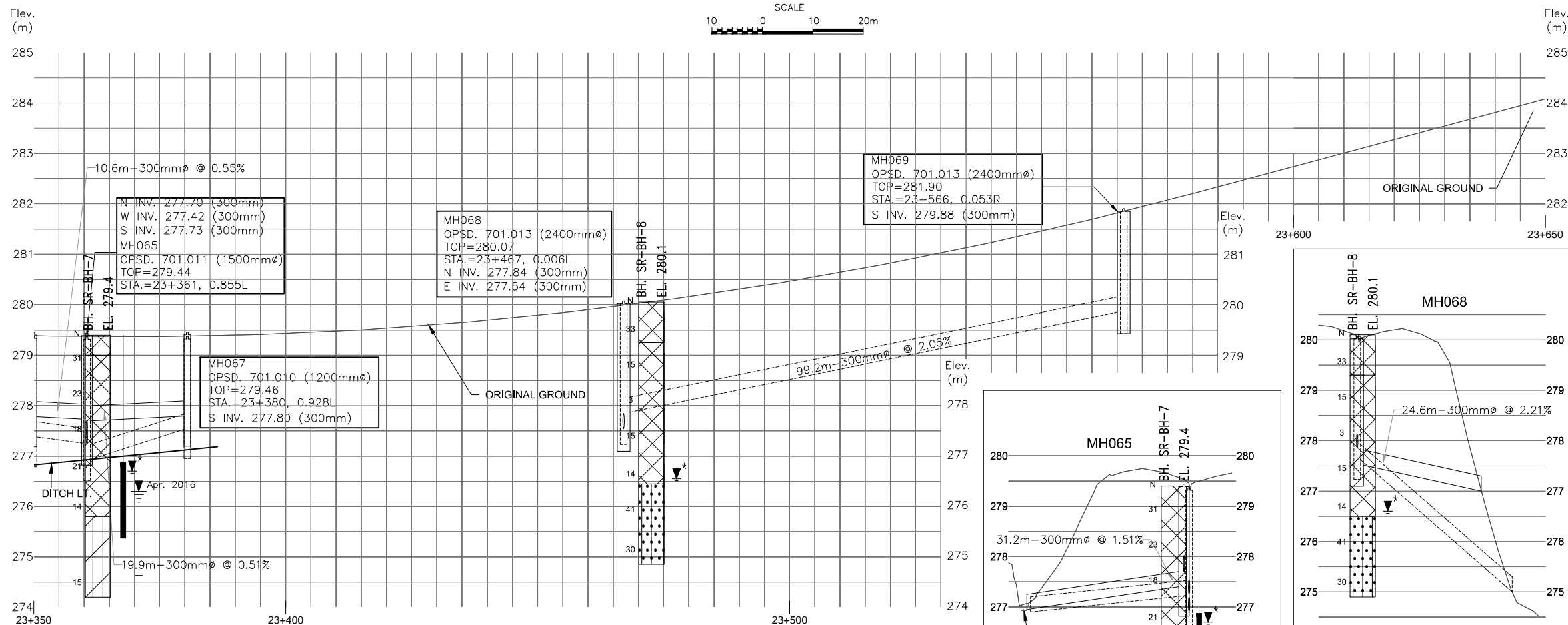
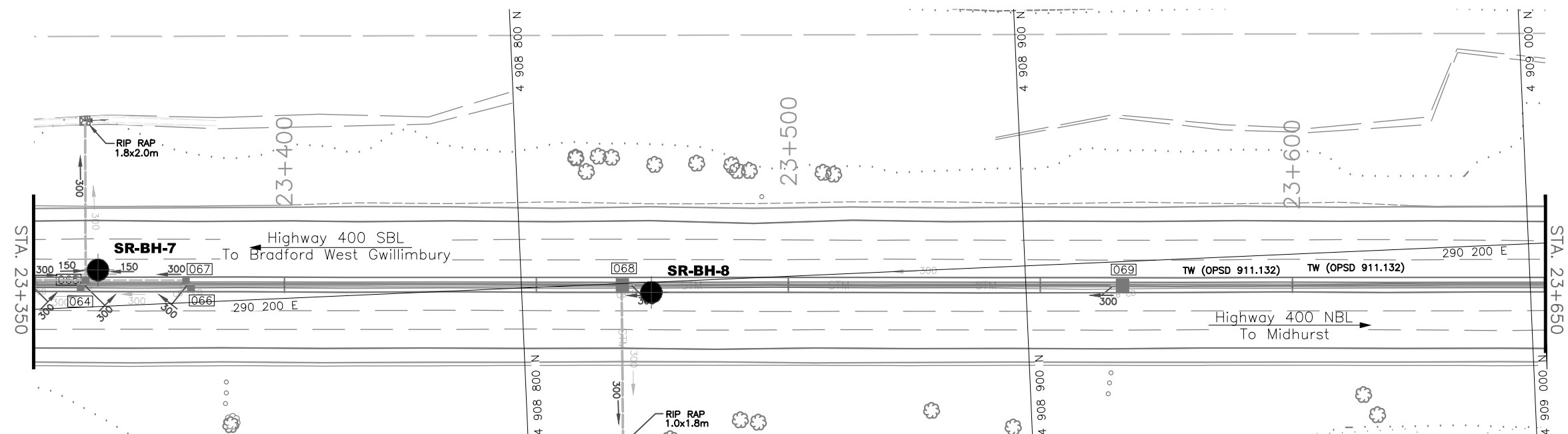






LEGEND				
	Borehole Location			
	Blows/0.3m (Std. Pen Test, 475 J / blow)			
	Piezometer			
	WL at time of investigation (March 2016)			
	WL in Piezometer (April 2016)			
	Existing Sewer			
	Replacement/New Sewer			
	FILL			
	SILT TO CLAYEY SILT			
	SILTY SAND			
BH No		ELEVATION	CO-ORDINATES	
			NORTHINGS	EASTINGS
SR-BH-7		279.4	4 908 716.2	290 192.7
SR-BH-8		280.1	4 908 825.7	290 202.0

REVISIONS			
DATE	BY	DESCRIPTION	
Geocres No. 31D-657			
HWY No	400	DIST	CENTRAL
SUBM'D	NA	CHECKED M.KH	DATE JUNE 27, 2016
DRAWN	NL	CHECKED MV	APPROVED CN



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dated January 13, 2016 & January 12, 2016, respectively.



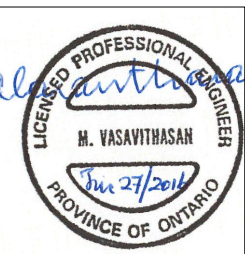
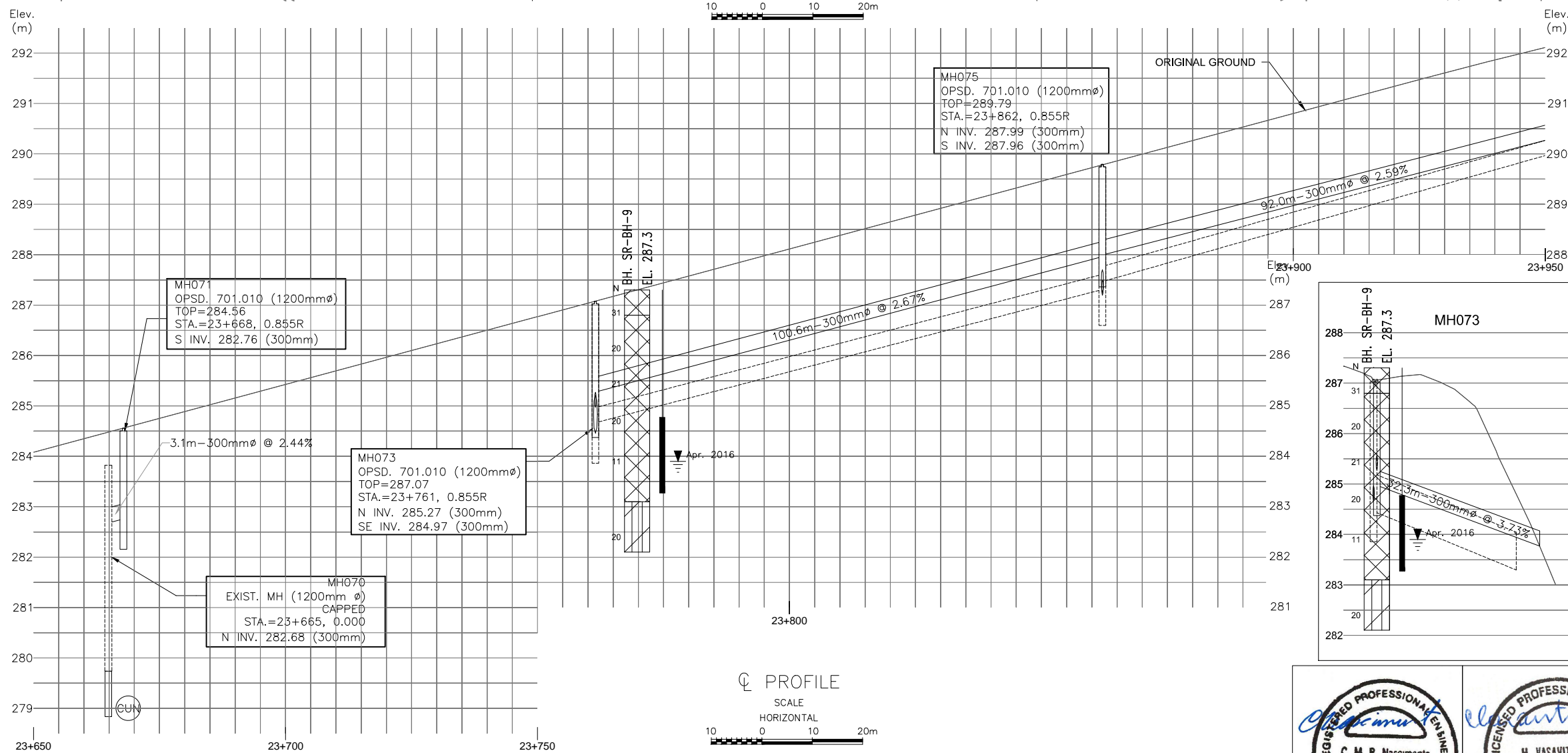
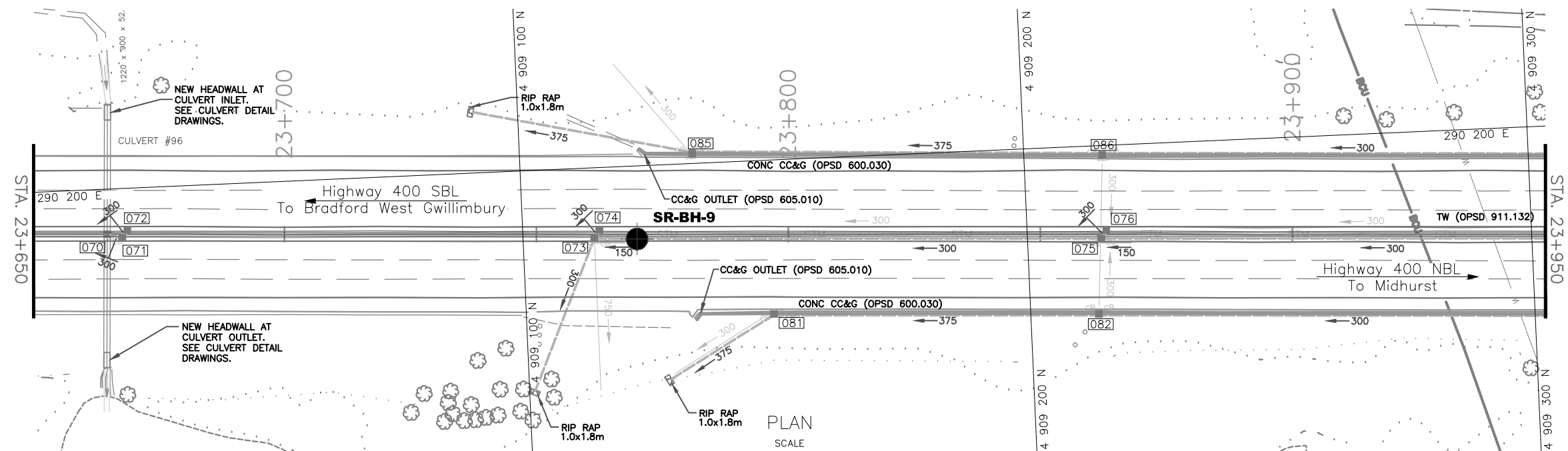
LEGEND				
	Borehole Location			
	Blows/0.3m (Std. Pen Test, 475 J / blow)			
	Piezometer			
	WL in Piezometer (April 2016)			
	Existing Sewer			
	Replacement/New Sewer			
	FILL			
	SILT TO CLAYEY SILT			
BH No	ELEVATION	CO-ORDINATES		
		NORTHINGS	EASTINGS	
SR-BH-9	287.3	4 909 122.6	290 214.5	

— 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. 31D-657

HWY No	400	DIST	CENTRAL
SUBM'D	NA	CHECKED	M.K.H. DATE JUNE 27, 2016
DRAWN	NL	CHECKED	MV APPROVED CN



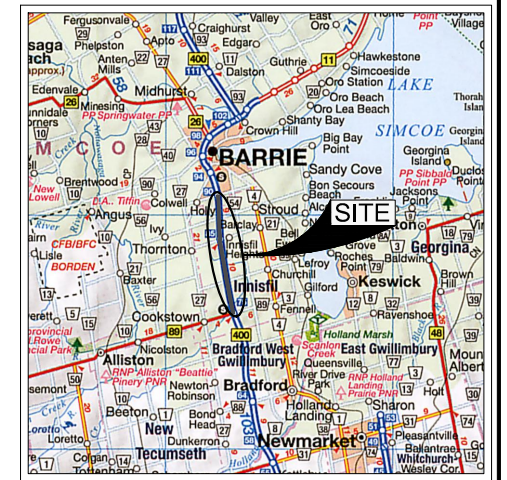
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SHEET

1000







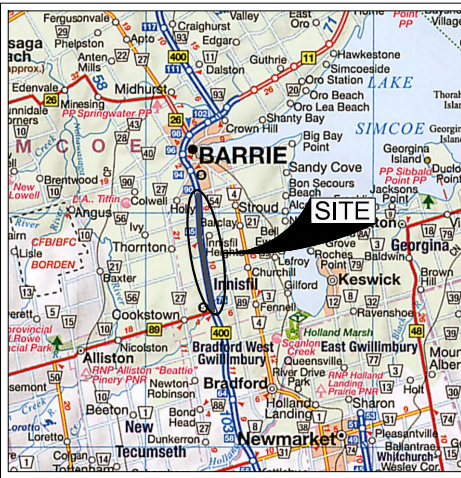
TASK No 2016-E-0039-010  
WP No 2184-10-00



HIGHWAY 400 SEWER REPLACEMENT

SHEET

BOREHOLE LOCATIONS AND SOIL STRATA



KEY PLAN  
SCALE  
0 5 10 15km

LEGEND

- Borehole Location
- N Blows/0.3m (Std. Pen Test, 475 J / blow)
- Piezometer
- Existing Sewer
- Replacement/New Sewer



SILTY SAND TO SILTY SAND

BH No	ELEVATION	CO-ORDINATES	
		NORTHINGS	EASTINGS
SR-BH-10	292.5	4 909 901.6	290 201.5

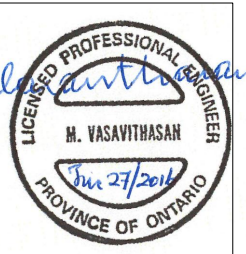
NOTE

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

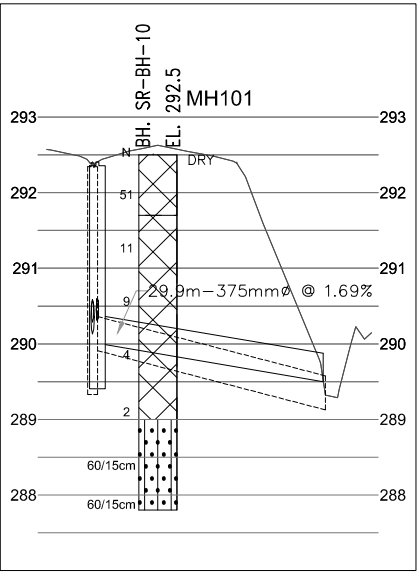
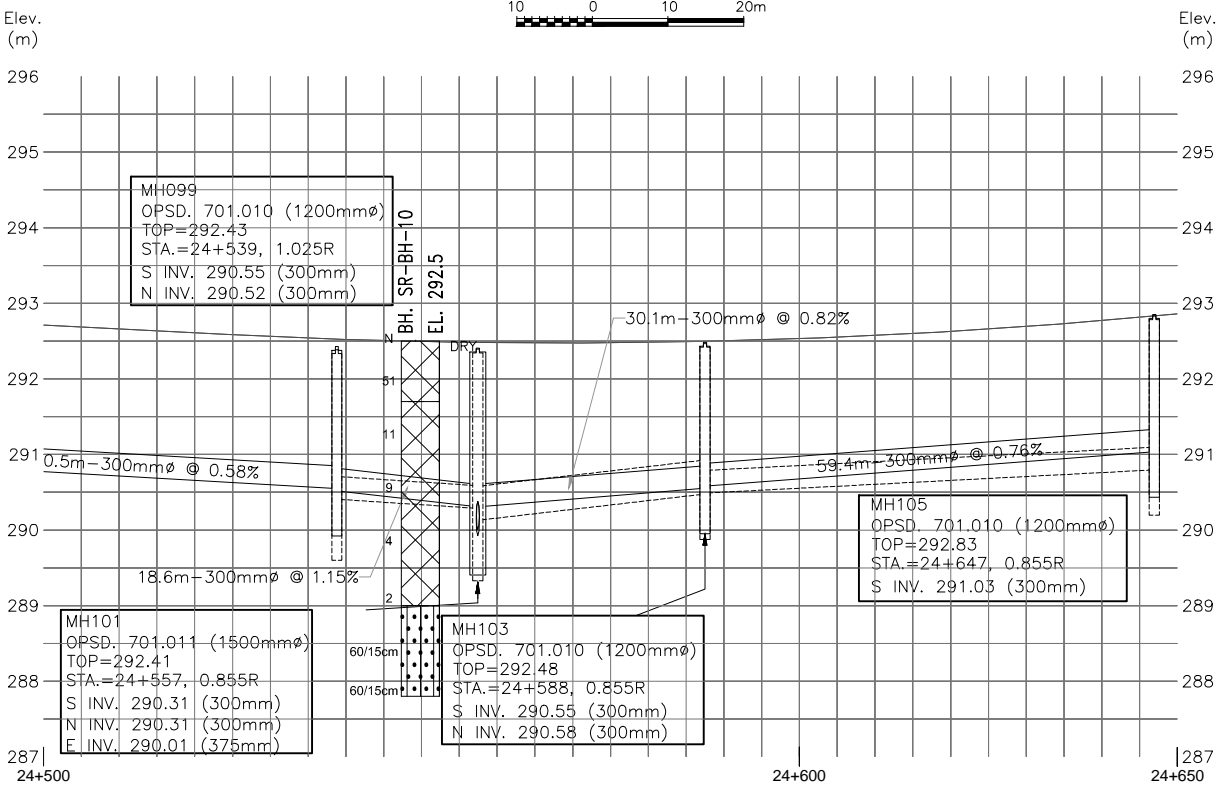
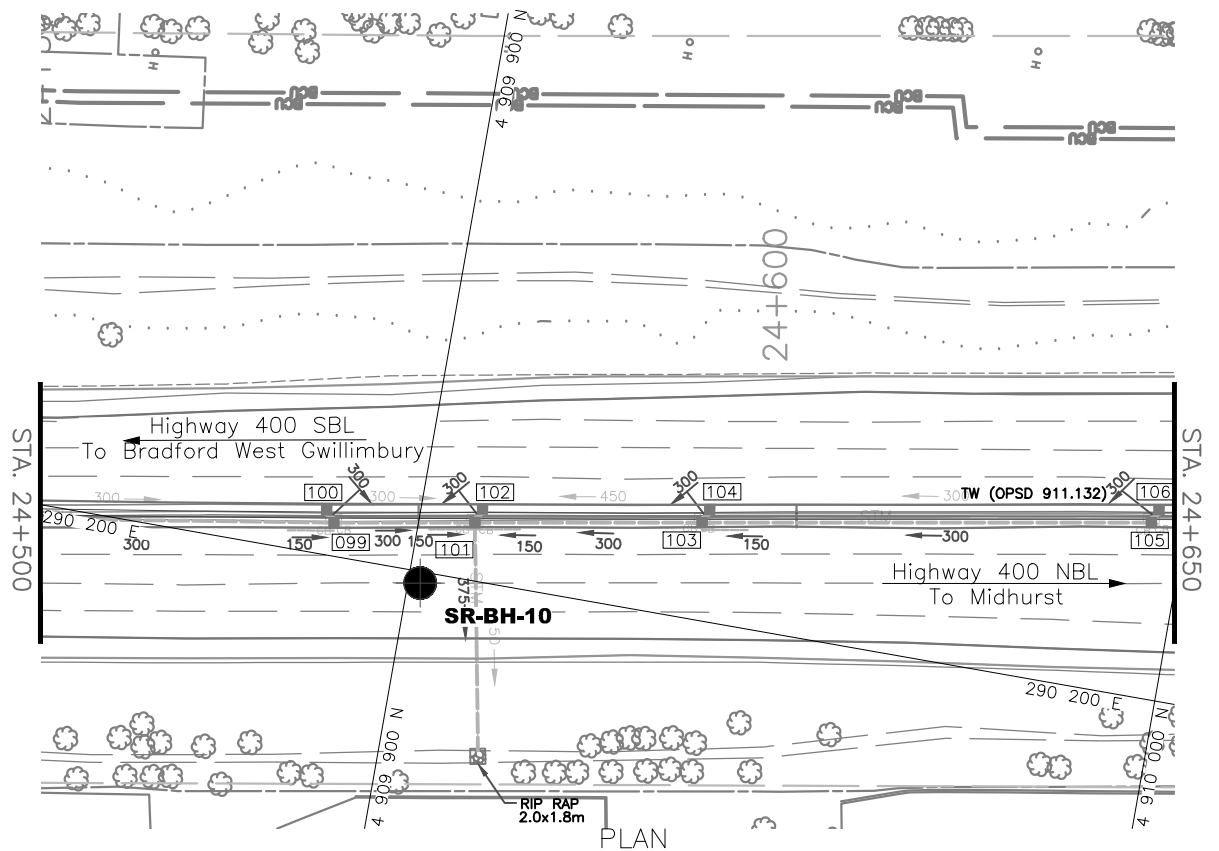
REVISIONS	DATE	BY	DESCRIPTION

Geocres No. 31D-657

HWY No	400	DIST	CENTRAL
SUBM'D	NA	CHECKED M.KH	DATE JUNE 27, 2016
DRAWN	NL	CHECKED MV	APPROVED CN



REF MTO Drawings; 09.NEWCONS-For FDN.dwg & 10.PROFILES.dwg;  
dated January 13, 2016 & January 12, 2016, respectively.







**PART B - FOUNDATION DESIGN REPORT**

**for**

**HIGHWAY 400 UPGRADING LATERAL SEWERS SOUTHERN  
PART APPROXIMATELY FROM INNISFIL BEACH ROAD TO  
MAPLEVIEW DRIVE**

**RETAINER ASSIGNMENT – TASK NO. 2013-E-0039-010  
WP 2184-10-00**

**TOWN OF INNISFIL AND CITY OF BARRIE, SIMCOE COUNTY,  
ONTARIO**

**PREPARED FOR MINISTRY OF TRANSPORTATION OF ONTARIO**

PETO MacCALLUM LTD.  
165 CARTWRIGHT AVENUE  
TORONTO, ONTARIO  
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**Distribution:**

1 cc: MTO Project Manager + 1 digital copy (pdf)  
1 cc: MTO, Pavements and Foundations Section  
+ 1 digital copy (pdf)  
1 cc: PML Toronto

PML Ref.: 15TF020-4  
Index No.: 036FDR  
GEOCRES No.: 31D-657  
June 30, 2016



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List of Standard Specifications Relevant to Report

Non-Standard Specific Provision (NSSP)

**PART B  
FOUNDATION DESIGN REPORT**

For  
Highway 400 Upgrading - Lateral Sewers  
Southern Part from Innisfil Beach Road to Mapleview Drive  
Retainer Assignment – Task No. 2013-E-0039-010, WP2184-10-00  
Town of Innisfil and City of Barrie, Simcoe County, Ontario

---

**6. INTRODUCTION**

This report provides recommendations for the design and construction of the proposed installation of new lateral storm sewers as well as replacement of the existing lateral sewers between Innisfil Beach Road and Mapleview Drive (Sta. 20+214 to Sta. 26+300) south of City of Barrie in the Town of Innisfil. The lateral pipes, ranging in diameter from 300 mm to 375 mm, are proposed to be connected to the storm sewer line located along the median of Highway 400. The comments made on the construction issues are intended to highlight those aspects that could have impact or affect the detail design and construction of the proposed storm sewers.

This Foundation Design Report is for the sole purpose of the Ministry of Transportation and shall not be used for any other purposes or by any other parties including the contractor who will be carrying out the construction. The recommendations are provided based on the contract drawings provided to PML. Refer to the associated contract drawings for design requirements.

Where comments are made on construction, they are provided solely to identify aspects that could affect the design of the project. Contractors should make their own assessment of the factual information provided in Part A - Foundation Investigation portion of this report, for their decisions related to construction including, but not limited to, equipment selection, proposed construction methods and scheduling.

**7. GEOTECHNICAL DISCUSSIONS AND RECOMMENDATIONS**

**7.1 General**

The plan and profiles of Highway 400 provided in the 60% Design package indicate that the new and replacement laterals will be connected from the median storm sewer to the drainage ditches located along the highway. In order to minimize the impact or interruption of highway traffic during



construction, it is understood that the majority of the installation of lateral connections will be carried out by employing trenchless methods. The trench that will be excavated for the replacement of median sewer may be used, where feasible, to accommodate the entry or exit pits required for the trenchless methods.

## 7.2 Lateral Sewer Pipes Foundation Considerations

Based on the plan and profiles provided in the 60% Design Package, it appears that the new lateral sewer pipes will be installed at the same or at a higher elevation than that of the existing sewers. As a result, the replacement as well as new lateral sewer pipes will be placed within the existing highway embankment fill, the backfill for the sewer trenches, or on native soils, depending on the location as identified in the Foundation Investigation Report. The details of the new and replacement laterals to be installed are as follows:

**Table 7.2 (a) - Details of Lateral Pipes**

Location of Lateral (Sta.)	Invert Elevations of Laterals		Type of Lateral	Soil Type at Reference Borehole Location <sup>(1)</sup>
	Median	Ditch/MH		
20+588 (E)	303.46	302.69	Replacement	Fill
20+786 (E)	301.87	301.48	Replacement	Fill
21+084 (E)	304.28	303.90	New	Fill
21+579 (E)	303.71	303.31	Replacement	Fill
21+730 (E)	301.46	301.25	Replacement	Fill
23+117 (E)	280.88	280+46	Replacement	Sand to Silty Sand
23+361 (W)	277.42	276.94	Replacement	Fill
23+467 (E)	277.54	276.99	Replacement	Fill
23+761 (SE)	284.97	283.76	Replacement	Fill
24+557 (E)	290.01	289.50	Replacement	Fill

- (1) Boreholes were located far apart and the soil conditions may vary from borehole location to location. It should be noted that the subsoil conditions reported in Part A of this report may differ from the soil types indicated on Table 7-2 (a).

The invert of the sewer pipes should be placed a minimum of 1.5 m below the finished grade to provide adequate frost protection as required by OPSD 3090.101. The net increase in bearing pressures at the new or existing manhole locations is expected to be none to negligible. However,



geotechnical bearing resistances at each borehole location provided in Table 7.2 (b) are to assess the bearing capacity of the supporting soil at the inverts.

The recommended geotechnical bearing resistances at ultimate and serviceability limit states (ULS and SLS) for the proposed replacement of manholes associated with the sewer pipes placed on native soils or existing fill are as follows:

**Table 7.2 (b) – Geotechnical Bearing Resistances**

SEWER TYPE	BORE-HOLE	ANTICIPATED INVERT DEPTH (m)	FOUNDATION MATERIAL <sup>(1)</sup>	FACTORED ULS (kPa)	SLS (kPa)
Replacement	SR-BH 1	1.5 to 3.0	Existing Fill	100	80
		3.0 to 5.2	Sand to Silty Sand	150	100
	SR-BH 2	1.5 to 3.0	Existing Fill	80	60
		3.0 to 5.2	Sand to Silty Sand	150	100
	SR-BH 3	1.5 to 3.5	Existing Fill	- (2)	- (2)
		3.5 to 5.2	Sand to Silty Sand	150	100
	SR-BH 4	1.5 to 3.7	Existing Fill	- (2)	- (2)
		3.7 to 5.2	Silty Sand To Sandy Silt	150	100
	SR-BH 5	1.5 to 2.6	Existing Fill	- (2)	- (2)
		2.6 to 5.2	Sand to Silty Sand	150	100
	SR-BH 6	1.5 to 4.5	Sand to Silty Sand	150	100
		4.5 to 5.2	Silt to Clayey Silt	150	100
	SR-BH 7	1.5 to 3.6	Existing Fill	100	80
		3.6 to 5.2	Silt to Clayey Silt	150	100
	SR-BH 8	1.5 to 3.6	Existing Fill	100	80
		3.6 to 5.2	Silty Sand	150	100
Replacement and New section	SR-BH 10	1.5 to 3.5	Existing Fill	100	80
		3.5 to 4.7	Sand to Silty Sand	150	100

- (1) Boreholes were located far apart and the soil conditions may vary from borehole location to location. It should be noted that the subsoil conditions reported in Part A of this report may differ from the soil types indicated on Table 7.2 (a).
- (2) Geotechnical resistances are not provided because of the poor soil conditions encountered at the associated founding elevations. Placing sewers at these levels are not recommended.



It was assumed that the subgrade soil conditions are consistent with that encountered in the reference boreholes. The bearing resistance were calculated assuming a uniform soil conditions.

## **8. GENERAL RECOMMENDATIONS**

### **8.1 Installation Methods**

Both open excavation (trenching) and number of trenchless methods are feasible, considering the subsoil conditions within the project area and the proposed invert levels of the laterals to be installed. However, trenching method will involve deep excavation and subsequent settlement of trench backfill. In addition, interruption of traffic during construction will be a major concern, particularly on a 400 series highway. In view of these, trenchless method is the most practical option for installation of new laterals. The presence of fill material under the pavement in most of the project area and groundwater conditions should be taken into consideration for the selection of the trenchless method.

In the area where the laterals are to be replaced, the existing sewer pipes will be a major obstruction to employ the trenchless methods along the same alignment and open excavation is the only feasible option. For this reason, the laterals at these locations will have to be relocated if trenchless method is to be employed. The replacement laterals should be located at a distance equivalent to at least two times the diameters of pipe or a minimum of 1.0 m away from the location of existing pipes. The relocation of laterals will require construction of new manholes and entry/exit pits at the median. The excavation for entry/exit pits and manholes will require a roadway protection system in the direction of NBL and SBL of Highway 400. The roadway protection system should meet the Performance Level 2 requirements of OPSS 539.

The detailed requirements for open cut and trenchless techniques are addressed below.

#### **8.1.1 Open Cut Excavation (Location, Borehole SR-BH 9)**

The trenching (open-cut) method using a roadway protection system may be used to install the replacement laterals in the area where there are existing sewer pipes. Depending on the timing of



construction, groundwater levels higher than those encountered during the investigation should be anticipated due to seasonal variations. Excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA) and MTO regulations.

Based on the record of boreholes, the excavations for the installation of replacement sewer pipes will be advanced through existing asphaltic concrete, pavement structure, and granular fill material to the native sand to silty sand deposit. For OHSA classification purposes, the fill materials should be classified as Type 3 soils, including silts below the water level. For excavations through multiple soil types, the side slope geometry is governed by the soil with the highest number designation.

The boreholes were drilled at a minimum safe distance from the existing sewer lines to avoid damage to the pipes. As a result, the boreholes may have been terminated well above the base of the existing trenches or the borehole data presented may not reveal the full depth of the trench backfill and bedding materials. For these reasons, the depth of fill indicated on the borehole logs may not be representative of the fill materials that may be at the proposed locations of sewer replacement.

Trench and slopes of excavation 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 faces of excavation slope must be removed.

Occasional cobble layers encountered within the fill as well as in the native materials may hamper the installation of shoring system or progress of excavation.



### 8.1.1.1 Earth Pressures, Temporary Roadway Protection and Shoring

The temporary support system should be designed by a Professional Engineer in accordance with OPSS 539 (Temporary Protection Systems) and OPSS 404 (Construction Specification for Support Systems). The temporary protection system should be designed to meet the Performance Level 2 specified in OPSS 539. The design of protection system should consider the maximum water level that may be expected during the construction.

The lateral earth pressure on the supporting structure is strongly dependent on the permissible lateral deformation. The pressure distribution for the sandy material encountered in the project area remains close to a triangular distribution. The lateral earth pressure for the design of temporary protection system shall be calculated assuming the soil parameters recommended below:

$$P_h = K_o \cdot \gamma \cdot h + K_o \cdot q$$

Where:

- $P_h$  = horizontal pressure at depth  $h$  (kN/m<sup>2</sup>)
- $\gamma$  = unit weight of soil as shown in Table 8.1.1.1
- $h$  = depth of excavation below ground surface (m)
- $q$  = surcharge load at ground surface (kPa)
- $K_o$  = coefficient of lateral earth pressure at rest for a horizontal ground surface condition as shown in Table 8.1.1.1

**Table 8.1.1.1 – Lateral Earth Pressure Parameters**

Parameter	Existing Fill Material (*)	Native Soils
Angle of Internal Friction ( $\phi$ ), degrees (°)	30	32
Unit Weight ( $\gamma$ ) (kN/m <sup>3</sup> )	21	20
Active Earth Pressure Coefficient ( $K_a$ )	0.33	0.30
At-Rest Earth Pressure Coefficient ( $K_o$ )	0.5	0.47
Passive Earth Pressure Coefficient ( $K_p$ )	3.0	3.25

(\*) Assumes cohesionless fill materials similar to those encountered in the boreholes.

The submerged unit weight of the soil shall be assumed below the groundwater table. The supporting system should be designed to resist the hydrostatic pressure in addition to the earth pressure.





#### 8.1.1.2 Dewatering

All of the boreholes were observed to be dry upon completion of drilling, with the exception of SR-BH 1, SR-BH 6, SR-BH 7 and SR-BH 8. Groundwater was observed in those boreholes at depths ranging from 2.4 to 3.5 m (El. 303.2 to 276.6) below the existing ground surface. The depth of ground water level measured in piezometers as of April 19, 2016 range from 2.5 m to 3.4 m below the existing ground level (El. 294.1 to 267.3).

If any groundwater or surface run-off is encountered during the excavation, a sump and pump method supplemented with perimeter drains should be adequate to control the water.

It should be noted that dewatering along the sewer alignment would be challenging due to the nature of the subsoil conditions. In order to maintain a dry condition during construction, the groundwater should be lowered to at least 500 mm below the bottom of the excavation. However, a temporary diversion scheme should be in place during the installation of replacement pipes to divert the storm water from the existing sewer lines. In addition, the dewatering scheme shall meet the requirements of OPSS 517 for utilities and pipes.

The contractor should assess the groundwater conditions in an open excavation of the subject pipe location prior to commencement of construction, to assess the conditions and to design an appropriate dewatering scheme.

#### 8.1.1.3 Bedding and Backfilling

Considering the relative strength of the sandy materials expected at the founding levels of the storm sewers, the foundation may be considered unyielding. Bedding for the storm sewer shall be granular material in accordance with Section 401.05.02 of OPSS 401. Bedding material meeting the OPSS.PROV 1010 Granular A or B Type II shall be used from at least 150 mm below the invert to the spring-line of the pipe. The founding material at the invert levels may be classified as Type 2 or Type 3 soils. Depending on the type of sewer pipes used, i.e., rigid or flexible, the embedment and cover shall be in accordance with OPSD 802.010, or OPSD 802.031.



Clear stone shall not be used as bedding material, in order to eliminate migration of fine material into the open voids of the stone, which will result in subsequent loss of ground resulting in surface settlement of the road. In case clear stone is used, it shall be surrounded by suitable filter cloth to prevent migration of fine material from the subgrade and wall of the trench. The placement of bedding and cover materials shall be in accordance with Sections 401.07.10.03 and 401.07.10.04 of OPSS 401. Any loose or soft materials observed at the founding level of the sewer pipes should be sub-excavated and replaced with Granular A or Granular B Type II and compacted in accordance with OPSS 501 (Construction Specification for Compacting).

From the Spring-line of the sewer pipe to at least 300 mm above the crown the trench shall be backfilled with sandy material compacted to 95% of Standard Proctor Maximum Dry Density (SPMDD) in accordance with MTO LS-706. Care shall be taken to prevent any damage to the pipe while placing and compacting the backfill material.

The excavated materials from the trenches is expected to consist of granular base from the pavement, sand to silty sand fill, and native soils. The excavated materials could be reused as back fill or cover materials. If the sandy fill or the native sandy soil encountered at the site is considered for trench backfill, the moisture content of the fill material should ideally be near Proctor optimum moisture content (OMC) so that neither reduction in moisture by drying nor increase in moisture by addition of water is necessary to meet the compaction standard. Any frozen, organic, excessively wet or other deleterious materials shall not be used for backfill purposes. These materials should be separated and set aside for non-critical purposes. The backfill should be placed in horizontal lift of uniform thickness of no more than 300 mm before compaction. It should be placed at appropriate moisture content and compacted to at least 95% standard Proctor density (SPMDD).

In paved areas, frost tapers within the granular backfill should be constructed in accordance with Ontario Provincial Standard Drawing OPSD 3101.150. The upper zone of the trench fill should consist of Granular B Type I and/or Type III material and meet the requirements of OPSS PROV.1010 (Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material).



### 8.1.2 Trenchless Method of Installation

Open cut or trenching method to install the laterals will have major traffic interruption, especially on a 400 series highway. To minimize the impact on traffic during construction, number of trenchless technologies are employed in the industry depending on the site conditions and the size of the pipe to be installed. The installation of sewer pipes in all of the locations requires boring through existing sandy fill or sand to silty sand (native) material. The sandy fill and the native materials encountered at the interface of these two layers at borehole SR-BH 2, 3, 4, 5 and 10 are observed to be very loose to loose. In view of this, the invert of the pipes to be installed at those location should be located at least one diameter below the interface between the fill and the native material.

The diameter of the laterals to be installed varies from location to location and range from 300 mm to 375 mm. All of the laterals are to be constructed on a grade ranging from 1.50% to 3.73%. Construction of laterals on a grade may limit the number of options to employ trenchless method. Pipe jacking method is generally used where the minimum diameter of the boring is 1.1 m and the use of this method is not feasible for this project. Pipe bursting method is used to replace concrete or Polyvinyl Chloride (PVC) pipes and it is usually used when the new pipe installed through the existing pipe by breaking the pipe walls. Therefore, it may not feasible for replacing corrugated steel pipes. Other option is to swallow the existing pipes by installing oversize pipes probably by pipe ramming method. Based on the 60% design drawing, the replaced pipes will be installed at a higher elevation, which cannot be reached by pipe swallowing method. In this case, manholes need to be replaced or adjustments may have to be made to connect the oversized pipe. Considering the diameter of the pipes and the subsoil conditions, feasibility of employing Horizontal Directional Drilling (HDD), Pipe Ramming, Micro-Tunneling and Jack and Bore are evaluated for the installation of laterals. The general requirements for the method of installation shall be addressed with a Non Standard Special provision (NNSP) and the contractor shall be asked to submit the detail plan to MTO for review, prior to commencement or mobilizing equipment.

Contractor shall be requested to submit a monitoring plan to monitor settlement or heave of the road during boring and after installation of sewer pipes. It is important to take effective measures to prevent potential cave-in, blow-out or steering difficulties at the time of boring. Upon completion of



pipe installation, the existing surface and any other affected areas or facilities should be restored to the original condition. Further recommendations are provided in Section 8.1.2.7 of this report.

#### *8.1.2.1 Horizontal Directional Drilling (HDD)*

HDD method of installation involves a three phase process and uses a steerable arc drilling rig. In the first phase, a drill bit tool creates a pilot-hole approximately 25 mm to 125 mm in diameter, from the entry to the receiving locations at an angle of 5 to 30 degrees from the ground surface. The second phase of the process is reaming to enlarge the boring by approximately 50% and prepares it for placement of casing. In this phase, a reamer tool replaces the drill bit and is pulled back or pushed forward by the HDD machinery to expand the pilot-hole. Third phase is the pullback of the pipe into place by attaching the pipe to the reamer and pulling through the HDD borehole. Drilling fluid is used to suspend and remove cuttings, reduce friction, cool and lubricate the drill bit. HDD method is a surface launched and no entry or exit pits are required, other than work space at both ends for staging, storage and equipment.

The proposed 300 mm to 375 mm diameter pipes to be used for laterals falls under Midi-HDD Class used to install medium size pipes. Pipes generally used in this class are made of high density polyethylene (HDPE), ductile iron or steel. A significantly long staging area will be required to lay out and align the pipe before it can be pulled into the HDD tunnel. A long gently sloping slot trench may have to be excavated to provide the grade needed to pull back or push forward the pipes to be installed. A pipe layout and assembly area will also be needed beyond the slot trench that could be placed in highway off-shoulder.

The boring for HDD method required to be oversized to facilitate the installation of pipe. However, OPSS 450 limits the final staged ream to no more than 1.5 times the largest outside diameter of the pipe and requires that the drilling mud in the annular space shall not be removed after installation of pipe, and permitted to solidify to provide support for the pipe and surrounding soil. The boring and pipe installation shall be in accordance with the requirements of OPSS 450 (Construction Specification for Pipeline and Utility Installation in Soil by Horizontal Directional Drilling) and OPSS 415 (Construction Specification for Pipeline Installation by Tunnelling).



#### 8.1.2.2 Pipe Ramming

Pipe ramming uses a pneumatic ramming tool to hammer thick walled steel pipes or casings through the ground from drive shaft to the reception pit. The casing can be used without a pipe installed through it or a production pipe can be installed through the casing and grouted in place with low density grout. The process of pipe ramming is simple and similar to pile driving operations. Continuous support is provided during the driving operation with no over excavation needed. The spoils or soil cuttings stay in the pipe and are mechanically removed when the drive is completed.

Considering the type of soil (sand to silty sand) encountered in the project area, auguring is the preferred method to remove the spoils. If the spoils within the pipe cannot be removed by auguring, use of a pipe shovel will be required. A pipe shovel is essentially a special scoop made from a pipe which fits inside the casing.

The initial setup is the critical factor in the success of any pipe ramming project. The drive shaft must be located on very stable ground or a concrete slab must be placed under the casing. The pipe in this method is unguided so the floor of the drive shaft must be engineered to be on the same line and grade as the pipe to provide the accuracy needed. Pipe ramming can be used for wide range of soil conditions including high groundwater table. However, subsidence can occur in loose to compact sandy material similar to that was encountered at this site, due to the compaction resulting from the vibratory action of the hammer. In addition, the casing will have the tendency to drift downward slightly due to gravitational forces, as the ramming proceeds.

This method does not require extensive groundwater control measures along the installation path because the soil cuttings within the pipe is not removed until the driving of the pipe to the reception pit is completed. The soil retained within the pipe will tend to act as a plug, reducing the potential for groundwater seepage and flowing of soil freely through the pipe.

However, groundwater control measures may require at the entry and receiving pits. Dewatering scheme implemented should cover the zone of influence of the tunnel area. This will generally reduce the potential seepage of groundwater through the boring during construction.



Pipe ramming is considered generally feasible for the proposed installation of laterals provided that an experienced or skilled operator capable of adjusting the installation procedures in response to the settlement observations and to install the pipe on an inclined grade.

#### *8.1.2.3 Micro-Tunnelling*

Micro-tunnelling is a remotely controlled and guided pipe jacking technique that provides continuous support to the excavation face. The TBM and the tunnel segments are pushed from the jacking pit while the line and grade are controlled by the tunnel boring machine as it advances. These machines typically utilize pressurized bentonite slurry to counterbalance the earth and water pressures acting at the tunnel face. The excavated soil slurry is withdrawn in a controlled manner to prevent loss of ground during tunnel advance. The slurry is circulated back through the tunnel to transport cuttings to a settling tank. In the case of micro-tunnelling, operator has the ability to control the soil and water pressure at the face and a dewatering scheme prior to advancing the boring is not required. However, groundwater control measures at the jacking and exit shafts will still be required.

Micro-tunnelling is the preferred tunneling method considering the subsurface conditions, size of the pipes to be installed and the grade requirements. However, cost effectiveness will depend on the availability of a contractor and previously used TBMs meeting the required sizes. In the absence of these, the cost associated with micro-tunneling may be substantial and uneconomical.

#### *8.1.2.4 Jack and Bore*

Jack and bore is a process of simultaneously jacking casing while removing the spoil material by means of an auger. The pipe for employing this method must resist abrasion caused by the rotation of augers and steel is the typical material used. A rotating cutting head is attached to the leading edge of the auger string and the spoil is transported back by the rotation of the auger flights within the steel pipe casing being installed. Surface subsidence and heave during construction may pose major problems. This method requires entry and receiving pits and the pits may have to be excavated to a depth of 3.0 m to 4.0 m below the existing grade at the median of Highway 400.



Lubrication system is optional for jack and bore method and the lubricants are typically bentonite and polymer mix. In some cases, the lead casing is equipped with a shield or thickened leading edge to cause slight over break to reduce resistance to the advancing casing. The most critical part of using this method is positioning the track system on the same alignment and grade as the bore. The drive shaft should have a stable foundation and an adequate thrust block to transmit the horizontal jacking force.

Jack and bore shall be carried out in accordance with OPSS 416 (Construction Specifications for Pipeline and Utility Installation by Jacking and Boring) and OPSS 415 (Construction Specification for Pipeline Installation by Tunnelling).

#### 8.1.2.5 Comparison of Alternate Trenchless Methods

The following table summarizes the advantages and disadvantages of the installation methods evaluated above:

**Table 8.1.2.5 - Comparison of Alternate Methods**

<b>TUNNELLING METHOD</b>	<b>ADVANTAGES</b>	<b>DISADVANTAGES</b>
1. Horizontal Directional Drilling	<ul style="list-style-type: none"> <li>Does not require deep staging pits</li> <li>Minimal groundwater control required</li> </ul>	<ul style="list-style-type: none"> <li>Longer staging area required for placing pipe Potential for inadvertent drilling returns</li> <li>Larger drilling equipment may be required</li> <li>Requires drilling fluid to maintain the bore which could allow subsidence</li> <li>Precise grade control not feasible</li> </ul>
2. Pipe Ramming	<ul style="list-style-type: none"> <li>Minimal groundwater control required along the installation route</li> <li>Relatively faster installation than Jack and Bore</li> </ul>	<ul style="list-style-type: none"> <li>Groundwater control is required for the entry/exit pits</li> <li>Poor grade control</li> <li>Effects of vibrations on nearby pipes must be assessed and possibly monitored</li> </ul>
3. Micro-tunnelling	<ul style="list-style-type: none"> <li>Does not require groundwater lowering for the tunnel</li> <li>Machine is able to counter-balance earth and water pressures in a controlled manner, thereby reducing the risk of ground losses during tunnelling</li> <li>Good grade control</li> </ul>	<ul style="list-style-type: none"> <li>Contractor availability</li> <li>Cost effectiveness depends on availability of existing adequate TBM</li> <li>Groundwater control is required for staging pits</li> </ul>



**Table 8.1.2.5 - Comparison of Alternate Methods**

<b>TUNNELLING METHOD</b>	<b>ADVANTAGES</b>	<b>DISADVANTAGES</b>
4. Jack and Bore	<ul style="list-style-type: none"> <li>▪ Contractor availability</li> <li>▪ Good for shorter tunnel lengths</li> <li>▪ Good gradient control</li> <li>▪ Good for low gradient</li> </ul>	<ul style="list-style-type: none"> <li>▪ Groundwater control is required for the bore and for the entry/exit pits</li> <li>▪ High potential for ground subsidence and heaving</li> <li>▪ Profile needs to be approximately horizontal</li> <li>▪ Jacking and receiving pit/shaft required</li> <li>▪ Limited ability to direct the casing</li> </ul>

#### **8.1.2.6 Recommended Trenchless Method**

The availability of space along the median for locating entry pit is limited. Micro-tunneling and jack and bore methods require large area and significant depth of excavation for staging entry pits. Further, installation of sewer pipes using trenchless methods on grades ranging from 1.50% to 3.73% imposes greater difficulty to precisely control the vertical alignment of the pipes. For these reasons, HDD method is recommended for the installation of new laterals. This method minimises the traffic interruption and provide the fastest boring rate. It is advised that where feasible, the entry for the pilot hole be located in the direction of down grade for better control of the pipe alignment.

#### **8.1.2.7 Entry and Exit Pits**

It should be noted that the excavation for entry and exit pits need to be carried out by open excavation using the conventional equipment. A properly designed shoring system would be required to resist the lateral pressure from the soils, protect the existing roadway and the workers. The shoring design should meet the requirements of OPSS 539, performance level 2.

Thrust block should be designed so that the allowable compressive strength of the supporting soil is not exceeded. The compact to dense sand to silty sand soils encountered within the depths of entry pits are capable of providing adequate support for the thrust blocks. The horizontal compressive strength to provide support for the thrust block may be designed using coefficient of horizontal subgrade reaction of the sandy material.





The coefficient of horizontal subgrade reaction  $k_s$  (kN/m<sup>3</sup>) for the sandy soils should be computed as follows:

$$k_s = n_h z / b$$

Where  $n_h$  = coefficient related to compactness of cohesionless soil, kN/m<sup>3</sup>  
= 1,500 for native sand/silt  
= 500 for compact sandy fill  
 $z$  = depth, m  
 $b$  = thrust block width, m

The subgrade material underlying the proposed loading pads at the entry/exit pit comprises of compact to dense sand to silty sand deposit. The recommended factored bearing pressures/resistances at Ultimate/Serviceability Limits States (ULS) and (SLS) will be 150 kPa and 100 kPa, respectively for depths ranging from 3.0 m to 5.0 m. It should be noted that the native soils at the site are susceptible to disturbance by construction activities, resulting in reduced shear strengths. In order to prevent deterioration of the founding surface, construction activities directly on the final grade should be minimised and the exposed subgrade is protected. Upon exposure of the final grade, the exposed sandy/silty soils shall be covered with a minimum of 200 mm thick layer of 19 mm clear crushed stone or equivalent. The thickness of the cover material may be increased to improve the load carrying capacity of the subgrade. The clear crushed stone base should be immediately covered with a 100 mm thick concrete (mud slab) to prevent deterioration of subgrade resulting from construction activities.

#### 8.1.2.8 Monitoring

The ground surface in the close proximity of the laterals may settle or heave due to the tunnelling operations. The most common type of surface settlement is caused by loss of ground around the tunnel. Heave of the ground surface occurs when excessive force is applied to the face of excavation and inadvertent drilling fluid returns are also possible depending on the type of installation.

The ground surface distress is generally prevented or minimized by good construction practices and proper planning and monitoring. The contractor shall be asked to present a monitoring plan prior to



commencement of mobilising the equipment. The requirements for monitoring during installation shall be addressed by a NSSP.

Monitoring points should be installed over the proposed tunnelling route at a maximum interval of 5 m. The existing conditions of the area where installations are proposed must be surveyed. The monitoring of the alignment along the proposed installations shall extend throughout its construction and shall be continued at least 2 weeks after completion of tunnelling. Measurement of the monitoring points should be done at least 3 times a day during construction period. A pavement condition survey should also be carried out prior to commencement and following completion of construction.

Monitoring points shall be marked and the points shall be functional throughout the monitoring period. The monitoring points shall not be disturbed or deteriorate because of traffic, maintenance activities, or weather conditions. Any buried nearby utility and service pipes should also be checked for disturbance from tunnelling. This should involve inspection of the pipes prior to construction, throughout construction and after tunnelling has been completed. The inspection requirements should be prepared or approved by the utility owners.

If distress is observed during construction, the contractor should proactively take corrective action immediately. Specific corrective action will be dependent on the nature of the distress and the type of installation. Regardless, the process should be outlined in the monitoring program and it should be part of the contingency actions in the contractor's installation plan.

Settlement or heave of the roadway from the trenchless methods recommended in the report shall not exceed 10 mm. If settlement or heave of the ground surface exceeds 10 mm, the construction process should be reviewed and adjusted to mitigate further disturbances for the remainder of the tunnelling work.

If total settlement or heave exceeds 15 mm, tunnelling operations should be terminated, the site should be secured against further deterioration and actions should be undertaken immediately to reinstate the roadway, ditches and/or the existing utilities.



## 9. CLOSURE

This Foundation Investigation and Design Report was prepared by Mr. M. Khorsand, BSc., EIT and was reviewed by Mr. M. Vasavithasan, M.Sc.Eng., P.Eng., Senior Engineer, Geotechnical Services. Mr. C. Nascimento, P.Eng. Principal Designate MTO Contact conducted an independent review of the report.

Sincerely

Peto MacCallum Ltd.

A blue ink signature of Mansoor Khorsand, written in a cursive style.

Mansoor Khorsand, BSc., EIT  
Project Supervisor, Geotechnical Services



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Carlos M. P. Nascimento, P.Eng  
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## LIST OF STANDARD SPECIFICATIONS RELEVANT TO REPORT

DOCUMENT	TITLE
OPSS.PROV 1010	Material Specification for Aggregates - Base, Subbase, Select Subgrade, And Backfill Material
OPSS 401	Construction Specification for Trenching, Backfilling, and Compacting
OPSS 404	Construction Specification for Support Systems
OPSS 415	Construction Specification for Pipeline installation by Tunnelling
OPSS 416	Construction Specification for Pipeline and Utility Installation by Jacking and Boring
OPSS 450	Construction Specification for Pipeline and Utility Installation in Soil by Horizontal Directional Drilling
OPSS 501	Construction Specification for Compacting
OPSS 517	Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation
OPSS 539	Construction Specification for Temporary Protection Systems
OPSD 3090.101	Ontario Provincial Standard Drawing. Foundation. Frost Penetration Depths
OPSD 802.010	Flexible Pipe, Embedment and Backfill, Earth Excavation
OPSD 802.030	Rigid Pipe Bedding, Cover, and Backfill, Type 1 or 2 Soil - Earth Excavation
OPSD 802.031	Rigid Pipe Bedding, Cover, and Backfill, Type 3 Soil - Earth Excavation



### **NSSP for Piezometer Decommissioning**

The Contractor is advised that piezometers installed for this project were not decommissioned to allow for groundwater readings prior to construction.

The Contractor shall carry out the decommissioning of these piezometers as they are encountered during the construction.

### **NSSP for Dewatering**

The Contractor shall take measures to lower the prevailing groundwater level a minimum of 0.5 m below the base of excavations or foundation bases for construction in-the-dry.

The contractor should assess the groundwater conditions in an open excavation of the subject pipe location prior to commencement of construction, to assess the conditions and to design an appropriate dewatering scheme.

The Contractor shall be responsible for designing and implementing the proper bypass system for existing sewer system prior to replace the pipes.

### **NSSP for Confirmation of Fill Depth at Site**

The boreholes were drilled at a minimum safe distance from the existing sewer lines to avoid damage to the pipes. As a result, the boreholes may have been terminated well above the base of the existing trenches or the borehole data presented may not reveal the full depth of the trench backfill and bedding materials. For these reasons, the depth of fill indicated on the borehole logs may not be representative of the fill materials at the proposed locations of sewer replacement.

The Contractor is advised to excavate test pits or employ other appropriate method of investigation to confirm the depth of cover or backfill, especially in the area where there are existing storm sewer lines, which are proposed to be replaced.



### **NSSP for Monitoring Procedure**

Monitoring points shall be installed over the proposed tunnelling route at a maximum interval of 5 m. The existing conditions of the area where installations are proposed shall be surveyed. Prior to commencement of work, the monitoring of the alignment along the proposed installations shall extend throughout its construction and shall be continued at least 2 weeks after completion of tunnelling. Measurement of the monitoring points shall be carried out at least 3 times a day during construction period. A pavement condition survey should also be carried out prior to commencement and following completion of construction.

Monitoring points shall be marked and the points shall be functional throughout the monitoring period. The monitoring points shall not be disturbed or deteriorate because of traffic, maintenance activities, or weather conditions. Any buried nearby utility and service pipes should also be checked for disturbance from tunnelling. This should involve inspection of the pipes prior to construction, throughout construction and after tunnelling has been completed. The inspection requirements shall be prepared or approved by the utility owners.

If distress is observed during construction, the contractor shall proactively take corrective action immediately. Specific corrective action will be dependent on the nature of the distress and the type of installation. Regardless, the process shall be outlined in the monitoring program and it shall be part of the contingency actions in the contractor's installation plan.

Settlement or heave of the roadway from the trenchless methods recommended in the report shall not exceed 10 mm. If settlement or heave of the ground surface exceeds 10 mm, the construction process shall be reviewed and adjusted to mitigate further disturbances for the remainder of the tunnelling work.

If total settlement or heave exceeds 15 mm, tunnelling operations shall be terminated, the site shall be secured against further deterioration and actions shall be undertaken immediately to reinstate the roadway, ditches and/or the existing utilities.