

GEOCPES No:
31B-64



Golder Associates Ltd.
CONSULTING ENGINEERS

REPORT TO

TOTTEN SIMS HUBICKI ASSOCIATES

FOUNDATION INVESTIGATION

PROPOSED SOUTH NATION RIVER OVERPASS

HIGHWAY 416 NORTH BOUND LANES

482-90-01

W.P. ~~177-89-02~~, SITE 16-189B

GEOCPES # 31B-64

DISTRICT 9 (OTTAWA) EASTERN REGION

Distribution:

3 copies	-	Totten Sims Hubicki Associates Whitby, Ontario
3 copies	-	Ministry of Transportation Ontario Eastern Region Structural Section Kingston, Ontario
1 copy	-	Ministry of Transportation Ontario Foundation Design Section Downsview, Ontario
2 copies	-	Golder Associates Ltd. Ottawa, Ontario

October 1990

891-2582-5

TABLE OF CONTENTS

	<u>Page No.</u>
1. INTRODUCTION	1
2. SITE DESCRIPTION AND GEOLOGY	2
3. PROCEDURE	2
4. SUBSURFACE CONDITIONS	4
4.1 General	4
4.2 Topsoil, Alluvium, Fill	5
4.3 Silty Clay, Clayey Silt, Silt	6
4.4 Silty Sand	6
4.5 Glacial Till	6
4.6 Auger Refusal	7
4.7 Groundwater	7
5. PROPOSED SOUTH NATION RIVER OVERPASS (HIGHWAY 416 NORTH BOUND LANES)	8
5.1 Bridge Foundations	8
5.2 Abutment Wall Backfill and Earth Pressures	10
5.3 Embankment Stability and Settlement	11
5.4 Corrosion of Buried Structures	12
5.5 Construction Considerations	13
EXPLANATION OF TERMS USED IN THE REPORT	In Order Following
RECORD OF BOREHOLE SHEETS	Page 15
FIGURE 1 AND DRAWING 1778902-B	
APPENDIX I - RECORD OF PREVIOUS BORINGS BY MINISTRY OF TRANSPORTATION ONTARIO	

1. INTRODUCTION

Golder Associates Ltd. has been retained by Totten Sims Hubicki Associates, consultants to the Ministry of Transportation Ontario (MTO), to carry out a subsurface investigation at the site of a proposed overpass for the north bound lanes of Highway 416 at the South Nation River (see Key Plan, Figure 1). The purpose of the investigation was to determine the subsurface conditions at the site and, based on the factual information obtained, to provide recommendations on the geotechnical design aspects of this project, including construction considerations which could influence design decisions.

The proposed overpass structure for the north bound lanes is to be located adjacent to the east side of the present Highway 16 bridge over the South Nation River. The proposed overpass will consist of a three span concrete bridge having a length of about 52 metres and a width of about 9 to 12 metres. The approach embankments will have a maximum height of about 4 metres above existing ground surface.

Golder Associates Ltd. has also carried out a subsurface investigation for the proposed Highway 416 south bound lane overpass at the South Nation River. The results of that work are provided in report 891-2582-4, entitled: "Foundation Investigation, Proposed South Nation River Bridge, Highway 416 South Bound Lanes, W.P. 177-89-02, Site 16-189-A, District 9 (Ottawa), Eastern Region", dated October 1990. That report should be read in conjunction with this report.

2. SITE DESCRIPTION AND GEOLOGY

The site is located adjacent to the east side of the existing Highway 16 bridge over the South Nation River. The topography adjacent to the existing roadway embankment is relatively flat and low lying. The south side of the river is lightly tree covered.

As part of the construction of the existing Highway 16 overpass, the South Nation River channel was realigned to the south. Based on available drawings, the centre line of the former river channel was about 45 metres north of its present position.

Geology maps suggest that this area is underlain by deposits of silty clay of marine origin. Bedrock is expected to consist of Oxford formation dolostone. Drift thickness maps suggest that the overburden thickness may be about 11 metres.

A previous subsurface investigation was carried out for the existing Highway 16 bridge over the South Nation River by MTO in 1967. The results of that work show that this site is underlain by deposits of loose sand extending to about 3 metres below ground surface, followed by successive deposits of very stiff clayey silt and glacial till. Bedrock was previously encountered in the borings at the existing bridge site at depths of about 10.4 to 11.4 metres below existing ground surface (elevation 76.0 to 76.5 metres).

3. PROCEDURE

The field work for this investigation was carried out between May 18 to 24, and September 10 to 12, 1990. During this time, two (2) boreholes, numbered 4-6 and 4-7, were advanced on land at the locations of the proposed abutments using a track

mounted hollow stem auger drill rig, and two (2) boreholes numbered 4-8 and 4-9 were put down over water using a portable electric drill rig operating from a small floating raft. The land boreholes were advanced to practical auger refusal at the bridge abutment locations for foundation design purposes while the over water borings were taken to a depth of about 3 metres below river level at the approximate locations of the bridge piers. Standard penetration tests were carried out in the boreholes and samples of the soils encountered were recovered using drive open sampling equipment. The groundwater levels at the site were determined by measuring the position of the water level in the open boreholes following the completion of drilling. The field work was supervised throughout by members of our engineering staff.

Logs of the soil and groundwater conditions encountered in the borings put down during this investigation are shown on the Record of Borehole sheets following the text of this report. The locations of the boreholes are given on the Borehole Locations and Soil Strata, Drawing 1778902-B. As well, attached in Appendix I of this report are copies of the logs of the borings put down in 1967 by MTO for the existing Highway 16 bridge. The approximate locations of these borings relative to the existing site conditions are shown on Drawing 1778902-B.

Samples of the soils encountered were taken to our laboratory for examination and laboratory testing. Samples of the soil were tested for moisture content and organic content. The results of the laboratory testing are given on the Record of Borehole sheets.

The borehole locations and elevations were determined by Totten Sims Hubicki Associates personnel. The elevations are referenced to Geodetic datum.

4. SUBSURFACE CONDITIONS

4.1 General

The borehole logs indicate the approximate subsurface conditions only at the specific test locations. Boundaries between zones on the logs are often not distinct, but rather are transitional and have been interpreted. The precision with which subsurface conditions are indicated depends on the method of boring, the frequency of sampling, the method of sampling and the uniformity of the subsurface conditions.

Subsurface conditions between the boreholes may vary significantly from conditions encountered at the boreholes.

Groundwater conditions described in this report refer only to those observed at the place and time of observation noted in the report. These conditions may vary seasonally or as a consequence of construction activities.

The soil descriptions in this report are based on commonly accepted methods of classification and identification employed in geotechnical practice. Classification and identification of soil involves judgement and Golder Associates Ltd. does not guarantee descriptions as exact, but infers accuracy to the extent that is common in current geotechnical practice.

The soil conditions described in this report are those observed at the time of the study. Unless otherwise noted, those conditions form the basis of the recommendations in this report.

The condition of the soil may be significantly altered by construction activities such as construction traffic, excavation, pile driving, etc. Excavation may expose the soils to changes due to wetting, drying, or frost.

As previously indicated the detailed soil and groundwater conditions determined from the boreholes are given on the Record of Borehole sheets following the text of this report. The following sections present descriptions of the soil and groundwater conditions encountered in the boreholes.

4.2 Topsoil, Alluvium, Fill

A surficial deposit of topsoil having a thickness of 0.3 metres was encountered in borehole 4-6 advanced on the south side of the river.

Borehole 4-7, advanced on the north side of the river, encountered surficial fills composed of sand with gravel and cobbles to a depth of 0.9 metres, followed by alluvium. Alluvium was also encountered at river bottom in boreholes 4-8 and 4-9. The alluvium deposit is comprised of silty clay, clayey silt, sandy silt and sand and has a thickness ranging from about 0.1 metres on the river bottom to about 2.3 metres to the north of the existing river channel. Standard penetration tests carried out within the alluvium gave N values of 2 to 5 blows per 0.3 metres, which reflect a very loose to loose relative density.

The measured organic content of the alluvium is about 2.6 to 3.1 percent. The moisture content of these deposits is about 22 to 28 percent.

4.3 Silty Clay, Clayey Silt, Silt

Deposits of silty clay, clayey silt, and silt were encountered beneath the topsoil at borehole 4-6 and beneath the alluvium at boreholes 4-7, 4-8, and 4-9. These deposits were found to have a total thickness of about 4.2 to 5.3 metres and extend to depths ranging from 5.0 to 8.5 metres below existing ground surface (elevation 79.6 to 82.1 metres).

Standard penetration testing carried out within the silty clay and clayey silt deposits gave N values of 6 to 30 blows per 0.3 metres, which reflect a very stiff consistency. In the silt deposit, standard penetration N values of between 18 and 27 were obtained, which reflect a compact relative density.

4.4 Silty Sand

A deposit of silty sand having a thickness of about 0.5 metres was encountered beneath the upper deposits of grey brown silty clay at borehole 4-6. The silty sand is indicated to have a compact relative density.

4.5 Glacial Till

Deposits of glacial till were encountered beneath the clayey silt and silt deposits. The glacial till is indicated from the previous borings to have a thickness of about 2.5 to 5.5 metres. The glacial till consists of a heterogeneous mixture of all grain sizes, but may be generally described as a sandy silt with gravel, clay, cobbles and boulders.

Standard penetration tests carried out within the glacial till gave N values of 19 to greater than 100 blows per 0.3 metres, which reflect a somewhat variable, compact to very dense relative density.

The moisture content of the glacial till ranges from about 9 to 10 percent.

4.6 Auger Refusal

Practical auger refusal was encountered at depths of 10.5 and 11.0 metres below ground surface (elevation 76.6 to 77.1 metres). These results are in general agreement with the bedrock elevation results obtained in previous cored boreholes put down by MTO for the existing Highway 16 bridge. It should be noted however, that auger refusal can sometimes be obtained within dense or bouldery material and that it may not necessarily be representative of the upper surface of the bedrock at the refusal location.

4.7 Groundwater

Groundwater levels were obtained by observing the water level in the open boreholes at the completion of drilling. The groundwater level in the open boreholes was found to range from 0.2 to 1.5 metres below ground surface (elevation 86.6 to 86.9 metres).

5. PROPOSED SOUTH NATION RIVER OVERPASS
(HIGHWAY 416 NORTH BOUND LANES)

5.1 Bridge Foundations

The proposed three span structure is to be supported on two end abutments and on two piers located in the river channel. It is understood that this structure will be relatively sensitive to post construction differential movement of the foundation; the allowable differential movement is understood to be about 15 millimetres.

Since the existing alluvial deposits encountered on the north side of the river would not be suitable for the support of the structure on conventional spread footings, it is recommended that the structure be founded on driven end bearing piles. Based on the auger refusal information and previous bedrock core information, the piles may be expected to terminate at about elevation 76 to 77 metres provided that large boulders are not encountered by the piles during driving within the glacial till.

As a design example, the Serviceability Limit State (SLS) load for a 245 millimetre diameter closed ended steel pipe pile having a wall thickness of 12 millimetres may be taken as 1150 kilonewtons; the factored capacity at Ultimate Limit State (ULS) can be taken as 1350 kilonewtons. These values assume that 350 megapascal strength steel and 30 megapascal concrete are used. The pipe piles should be set to a final termination of 10 blows for the last 12 millimetres of penetration using a hammer transferring about 40 kilojoules of energy per blow to the piles.

Alternatively, for an HP 310x110 steel H pile, the SLS and ULS loads could be taken as 1150 and 1600 kilonewtons,

respectively. In this case, the H-piles should be set to a termination of 10 blows for the last 12 millimetres of penetration using a hammer transferring about 60 kilojoules of energy per blow to the pile.

Based on piling experience in this area, it is possible that several rounds of restriking could be required to achieve permanence of the final set. Therefore, provision should be made for restriking all of the piles at least once to confirm the set. Piles that do not meet the design set criteria on the first or subsequent restrike would require additional restriking. A minimum of two days should be allowed before restriking a pile.

Since the glacial till contains boulders and is indicated to have a very dense relative density, some pile alignment difficulties and hard driving conditions should be expected; some of the piles may be driven off plumb, or bend, or may terminate erratically in the glacial till. In this regard, pipe piles offer some advantage over H-piles since they can be inspected for damage following installation and can be checked for plumbness and curvature. Steel H-piles should be equipped with cast steel driving shoes to reduce pile damage during driving; for closed ended steel pipe piles, the need for a driving shoe could be assessed following the driving and inspection of the first few piles.

The nature of the fill materials used in the existing approach embankments for the Highway 16 bridge has not been investigated. If boulders are present in these fills below the level of the proposed pile caps, pile driving difficulties could be encountered in advancing the piles through the fills.

Allowance should be made for pile load testing at the time of construction.

For snow cleared or covered areas such as the abutments, the pile caps should be provided with at least 1.8 metres of earth cover for frost protection purposes. The river channel piers could be provided with at least 1.2 metres of earth cover (including rip rap) or should be positioned to provide at least 0.3 metres of rip rap over the pile caps. However, if the river is expected to freeze throughout its depth at the pier locations, the earth cover for the river channel piers should be increased to at least 1.5 metres.

5.2 Abutment Wall Backfill and Earth Pressures

The abutments should be backfilled with compacted non frost susceptible, free draining backfill such as that meeting Ontario Provincial Standards Specifications (OPSS) for Granular B Type I or II. The granular fill should extend at least 1.5 metres beyond the inside face of the abutments and should be compacted in thin lifts to at least 95 percent of standard Proctor density. If lateral movement at the top of the abutment of about 0.05 percent of the retained height is expected to occur, "active" earth pressure coefficients (K_a) should be used in determining the horizontal load on the abutments. If the wall movement is expected to be less, then "at rest" pressure coefficients (K_o) should be used.

Assuming that a well graded sand and gravel backfill material meeting OPSS Granular B Type I material is used behind the abutments, a material unit weight of 21.2 kilonewtons per cubic metre could be used together with the following earth pressure coefficients in determining the lateral load on the abutments.

Earth Pressure
Coefficient

At Ultimate Limit State (ULS)

"at rest" condition	0.55
"active" condition	0.38

At Serviceability Limit State (SLS)

"at rest" condition	0.47
"active" condition	0.31

Earth pressure parameters for other materials could be provided if necessary.

To reduce compaction induced stress on the abutment walls, the granular fill near the abutments should be compacted with walk behind compaction equipment.

Highway live loads should be considered on the abutments unless approach slabs are used.

5.3 Embankment Stability and Settlement

The approach embankments within 30 metres of the bridge will have a maximum height of about 4 metres above existing ground surface. Initial calculations indicate that no short term or long term stability problems are expected for the embankments within 30 metres of the abutments. Embankment fill should meet the requirements of OPSS 212 for borrow material, and should be placed and compacted in accordance with OPSS 206. If sandy earth borrow, rock borrow, or select subgrade material is used, embankment side slopes may be constructed at 2 horizontal to 1 vertical. If silty or clayey earth borrow is used, embankment side slopes should be 2.5 horizontal to 1 vertical or flatter. Erosion protection of the side slopes using seeding or mulching should be carried out to reduce surficial erosion and gullyng.

The south side of the river was found to be underlain by thin surficial deposits of topsoil followed by deposits of very stiff silty clay and clayey silt, and compact sand. Provided that all surficial topsoil or disturbed soil is removed from the proposed south approach embankment area, the long term settlement of the south approach embankment should be minimal.

The north approach embankment area near the proposed bridge however was found to be underlain by fill followed by very loose to loose alluvium having a thickness of about 2.3 metres. If the alluvial deposits are left in place, it is expected that the north approach embankment will settle for some time after construction. To reduce the effects of post construction settlement of the north approach embankment near the rigidly supported bridge, the north embankment could be constructed a few months in advance of the bridge construction and an approach slab could be used for the bridge. The embankment subgrade should be inspected to ensure that any surface peat, highly organic or deleterious soils are removed from the embankment area. Settlement monitoring should be carried out during and after construction of the embankment to ensure that most of the settlement has occurred prior to the bridge construction.

The banks and bottom of the river near the pile supported abutment and piers should be protected from erosion by means of rip rap underlain by a suitable non woven geotextile.

5.4 Corrosion of Buried Structures

The investigation for the south bound lane bridge over the South Nation River showed that the groundwater in this area has a sulphate content of 4 milligrams per litre. According to CSA CAN 3 A23.1-M90, this measured level of sulphate should

not be corrosive to concrete where normal Portland Type 10 cement is used.

Based on the elevated conductivity and low pH value of the groundwater, this site can be classified as slightly aggressive toward unprotected steel. Corrosion of driven piles in the native homogenous and undisturbed soil below the groundwater level is not expected to be a problem. However, the potential exists at this site for corrosion of the driven piles along that portion of the pile within the perched abutment fill, at the interface of the abutment fill and the native subsoil, and within the groundwater fluctuation zone. To reduce this corrosion potential, it is suggested that all piles at this site be provided with a bituminous coating (such as Bakelite 700-1) and that the pile cap be designed such that the steel pile is electrically isolated from the remainder of the bridge structure i.e. no steel to steel contact with the piles in the pile cap.

5.5 Construction Considerations

Pile driving and excavation for the proposed bridge piers will be carried out within the existing river channel. Excavation and construction of the river channel piers could either be carried out within driven interlocking sheet piling advanced to within the clayey silt, or providing space permits, within an earth cofferdam cell constructed over the clayey silt subgrade using suitable compacted earth materials. A working mat of concrete or crushed stone would likely be required in the pile driving area. Water inflow should be controlled by pumping from sumps.

Open cut excavations within the existing embankment fill materials should be carried out using 1 horizontal to 1 vertical side slopes.

It is recommended that the pile driving equipment proposed by the contractor be reviewed in light of the contract pile type and set criteria, and be accepted by the geotechnical engineer well in advance of any pile driving operations. Also, all piling operations should be inspected throughout by qualified geotechnical personnel.

Groundwater and surface water control may be required while placing and compacting the lower lifts of fill for the embankments. To facilitate pile driving and to limit disturbance of the bituminous coating on the piles, the fill material beneath the abutments should consist of pit run sand, free of gravel, cobble or boulder size material.

The soils at this site are highly susceptible to frost heaving. Therefore, the native soils around the piles should be protected from freezing during construction to prevent pile jacking due to freeze effects.

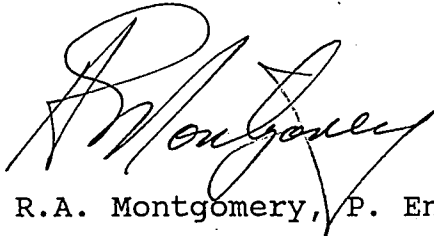
If welded pile splices are to be used, a licensed welding inspector should be retained during the pile driving to periodically inspect the welding procedures used by the contractor.

We trust that this report contains sufficient information for your purposes. Should you have any questions, please call us.

GOLDER ASSOCIATES LTD.



A.F. Chevrier, P. Eng.



R.A. Montgomery, P. Eng.



AFC:RAM:cr:jf
Disk 17

Att.

EXPLANATION OF TERMS USED IN REPORT

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

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

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

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

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

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

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

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

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

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

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

JOINTING AND BEDDING:

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

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

STRESS AND STRAIN

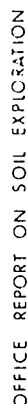
u_w	kPa	PORE WATER PRESSURE
r_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

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

PHYSICAL PROPERTIES OF SOIL

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



METRIC

+3, x5: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 4-7

METRIC

W P 177-89-02 LOCATION Sta. 23 + 727.5 17.4 Rt. ORIGINATED BY D.J.S.
 DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger COMPILED BY A.C.
 DATUM Geodetic DATE May 18, 1990 CHECKED BY A.C.

OFFICE REPORT ON SOIL EXPLORATION

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100	W _p	W	W _L		
88.1	Ground Surface																
0.0	Fill, sand, gravel and cobbles																
87.2	Brown																
0.9	Alluvium, silty clay and clayey silt, trace sand and organic matter		1	SS	4											Org. Content = 3.1%	
86.3	Firm to stiff																
1.8	Alluvium, sandy silt to sand, some silt, trace organic matter and wood		2	SS	2											Org. Content = 2.6%	
84.9	Loose																
3.2	Clayey silt		3	SS	5												
			4	SS	12												
			5	SS	19												
			6	SS	11												
	Very stiff																
81.7			7	SS	18												
6.4	Silt																
	Compact		8	SS	25												
79.6																	
8.5	Sandy silt, some gravel and clay, occasional cobbles and boulders (glacial till)		9	SS	19												
	Compact to very dense		10	SS	>100												
77.1																	
11.0	End of Borehole																
	Auger Refusal																

+3, x5: Numbers refer to Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 4-8

METRIC

W P 177-89-02 LOCATION Sta. 23+706.5 - 12.5m Rt NBL ORIGINATED BY R.B.
 DIST 9 HWY 416 BOREHOLE TYPE Wash Boring COMPILED BY R.A.M.
 DATUM Geodetic DATE September 11, 1990 CHECKED BY R.A.M.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40						60	80	100
								SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE									
86.3	Water Surface																
	Water (South Nation River)						86										
84.8	River Bottom						85										
1.6	Alluvium, silty sand, trace gravel, some organic material		1	SS	12												
	Clayey silt		2	SS	14		84										
			3	SS	19												
			4	SS	30		83										
			5	SS	20		82										
81.7	Very stiff Grey																
4.6	End of Borehole						81										

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 4-9

METRIC

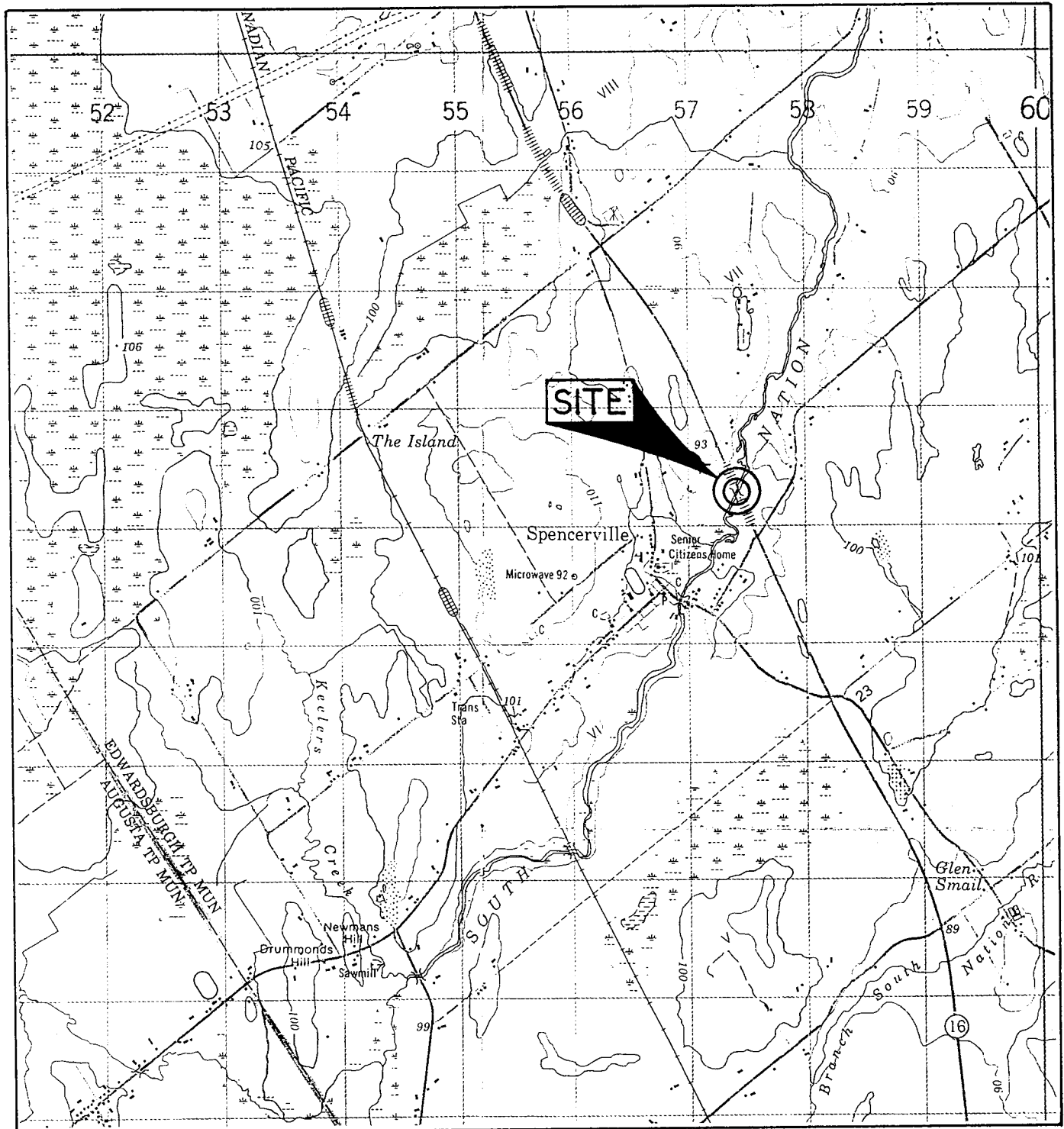
W P 177-89-02 LOCATION Sta. 23+686 - 11.0 m Rt NBL ORIGINATED BY R.A.M.
 DIST 9 HWY 416 BOREHOLE TYPE Wash Boring COMPILED BY R.A.M.
 DATUM Geodetic DATE September 10, 1990 CHECKED BY R.A.M.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
86.3	Water Surface																
85.0	Water (South Nation River)						86										
85.0	River Bottom						85										
1.4	Alluvium, sandy silt, trace gravel, some organic material		1	SS	8												
	Clayey silt		2	SS	21		84										
			3	SS	26		83										
			4	SS	13		82										
81.7	Very stiff Grey		5	SS	14		81										
4.6	End of Borehole																

OFFICE REPORT ON SOIL EXPLORATION

KEY PLAN

FIGURE I
WP 177-89-02



SCALE
1: 50,000



SPECIAL NOTE
THIS DRAWING IS TO BE READ IN CONJUNCTION
WITH ACCOMPANYING REPORT

Date AUG. 23, 1990
Project 891-2582-5

Golder Associates

Drawn JC
Chkd.

APPENDIX I

RECORD OF BOREHOLE SHEETS
PREVIOUS BORINGS BY MINISTRY
OF TRANSPORTATION ONTARIO

RECORD OF BOREHOLE NO. 2

FOUNDATION SECTION

JOB 67-P-55

LOCATION: Sta. 148 + 73; 23¹ Rt. of NE

ORIGINATED BY 1008

NY P. 253-66-03

BORING DATE July 10, 1967

COMPILED BY **AKB**

DATUM Geodetic

BOREHOLE TYPE Washboring, BI Casing

CHECKED BY

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT	Liquid Limit ——— W _L Plastic Limit ——— W _P Water Content ——— W	BULK DENSITY Y P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT		SHEAR STRENGTH P.S.F.	WATER CONTENT % 10 20 30		
285.9	GROUND LEVEL									
0.0	Silty sand. Compact	[Pattern]								285.0'
277.9			1	SS	34	280				
8.0	Silty clay becoming clayey silt to silt. Very stiff to hard	[Pattern]	2	SS	23					
			3	SS	31	270				
267.4										
265.9	Glacial Till. Hard.	[Pattern]	4	SS	100/??					
20.0	End of Borehole					260				
						250				

MATERIALS & TESTING DIVISION

FOUNDATION SECTION

ORIGINATED BY AEB

COMPILED BY AJB

CHECKED BY 

SOIL PROFILE			SAMPLES			DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT						LIQUID LIMIT ——— WL PLASTIC LIMIT ——— WP WATER CONTENT ——— W			BULK DENSITY P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLT	NUMBER	TYPE	BLOWS / FOOT	ELEV. SCALE	SHEAR STRENGTH P.S.F. • Unconfined • Quick Triaxial					WATER CONTENT % wp y wL 10 20 30				
286.7	GROUND LEVEL						1000	2000	3000	4000	5000					
0.0	Silty sand.	[dots]														283.5'
	Compact		1	SS	24											
278.7			2	SS	10	280										
8.0	Clayey silt.	[diagonal lines]	3	TN	PM										127	
	Stiff to very stiff		4	TN	PH										130	
			5	TN	PH	270									132	
264.7			6	SS	100/3.5"											
22.0	Clayey silt with gravel.	[vertical lines]				260										
	Boulders Hard			AXT R.C.												
256.8																
29.9	End of Borehole															

JOB 67-1-55

LOCATION Sta. 442 + 441 23' Rt. of E

ORIGINALTED BY ALOB

NY 100-253-66-03

BORING DATE July 2, 1967

COMPILED BY **2108**

DATE March 1, 1968

ONE HOLE TYPE Washboring, BX Casing

COMPLETED BY

0000 14:40 FROM LHO. MAT. 011. 0000 00:40
 1:000. 0000

OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS - ONTARIO

RECORD OF BOREHOLE NO. 5

FOUNDATION SECTION

MATERIALS & TESTING DIVISION

JOB 67-F-55

LOCATION Sta. 449 + 95, 23/ Lt. of R

ORIGINATED BY AKB

W.P. 253-66-03

BORING DATE July 6, 1967

COMPILED BY AKB

DATUM Geodetic

BOREHOLE TYPE Washboring, BX Casing

CHECKED BY AKB

SOIL PROFILE		SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE				LIQUID LIMIT — WL			BULK DENSITY	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE		BLOWS / FOOT				PLASTIC LIMIT — WP	WATER CONTENT — W			
286.2	GROUND LEVEL					SHEAR STRENGTH P.S.F.				WP	WL			
0.0	Silty sand. Very loose		1	SS	1	280								28.83 81.8 & 1.17
278.0			2	SS	12									
8.2	Clayey silt Stiff to very stiff		3	SS	24									
			4	SS	19	270								
			5	SS	16									
			6	SS	16	260								
256.2			7	SS	24									
30.0	Clayey silt with gravel. Hard													
251.2	Boulders													
35.0	End of Borehole					250								

040041740177 0P 14101600473 - 000TA1010

RECORD OF BOREHOLE NO. 6

FOUNDATION SECTION

MATERIALS & TESTING DIVISION

67-155

LOCATION Sta. 150 + 38, 23' Rt. of C

ORIGINATED BY AJB

W. P. 253-66-03






BOILING DATE July 6, 1967

COMPILED BY **AIR**

DATUM Geodetic

WASHBORO, NY Casing

CHECKED BY _____

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT		LIQUID LIMIT ——— W _L PLASTIC LIMIT ——— W _P WATER CONTENT ——— W		BULK DENSITY Y P.C.F.	REMARKS		
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT		SHEAR STRENGTH P.S.F. • Unconfined • Quick Triaxial		WATER CONTENT % 10 20 30					
286.7	Ground Level						1000	2000	3000	4000	5000			
0.0	Silty sand					280								
278.7	Very loose to loose		1	SS	3									
8.0	Clayey silt		2	SS	7	270							132	
	Stiff to very stiff		3	TM	PM									
			4	TM	PM									
263.2			5	TM	PM	260							134	
23.5	Clayey silt with gravel & boulders. Hard		6	SS	13									
257.2			7	SS	100.0"									
29.5	End of Borehole					250								

DECLASSIFIED BY 607 HIGGINS - EXTAS

RECORD OF BOREHOLE NO. 7

FOUNDATION SECTION

MATERIALS & TESTING DIVISION

JOE 67-8-55

LOCATION Sta. 150 + 58, 23' lt. of #

ORIGINATED BY AJB

253-66-03

BOOKING DATE July 5, 1967

COMPILED BY

DATUM Geodetic

◆ ONE HOLE TYPE Washboring, BX Casing

CHECKED BY

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT	Liquid Limit — WL Plastic Limit — WP Water Content — W _p	BULK DENSITY P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT		SHEAR STRENGTH P.S.F.	WATER CONTENT %		
285.0	Ground Level									
0.0	Silty sand. Very loose to loose	[Pattern]	1	SS	3	280				
277.0			2	SS	5					
8.0	Clayey silt. Firm to stiff	[Pattern]	3	SS	5					
			4	SS	16	270				
			5	SS	11					
			6	SS	13					
261.0						260				
24.0	Clayey silt with gravel (Glacial Till) Stiff to very stiff	[Pattern]	7	SS	25					
			8	SS	11					
51.0						250				
34.0	Dolomite - Bedrock	[Pattern]	9	RC	100% Rec					
245.7										
39.3	End of Borehole									

OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS - ONTARIO

RECORD OF BOREHOLE NO. 8

FOUNDATION SECTION

MATERIALS & TESTING DIVISION

JOB 67-R-55

W.P. 253-66-03

DATUM Geodetic

LOCATION Sta. 150 + 93 23' Rt. of W

BORING DATE July 5, 1967

BOREHOLE TYPE Washboring, BX Casing

ORIGINATED BY AKS

COMPILED BY AKS

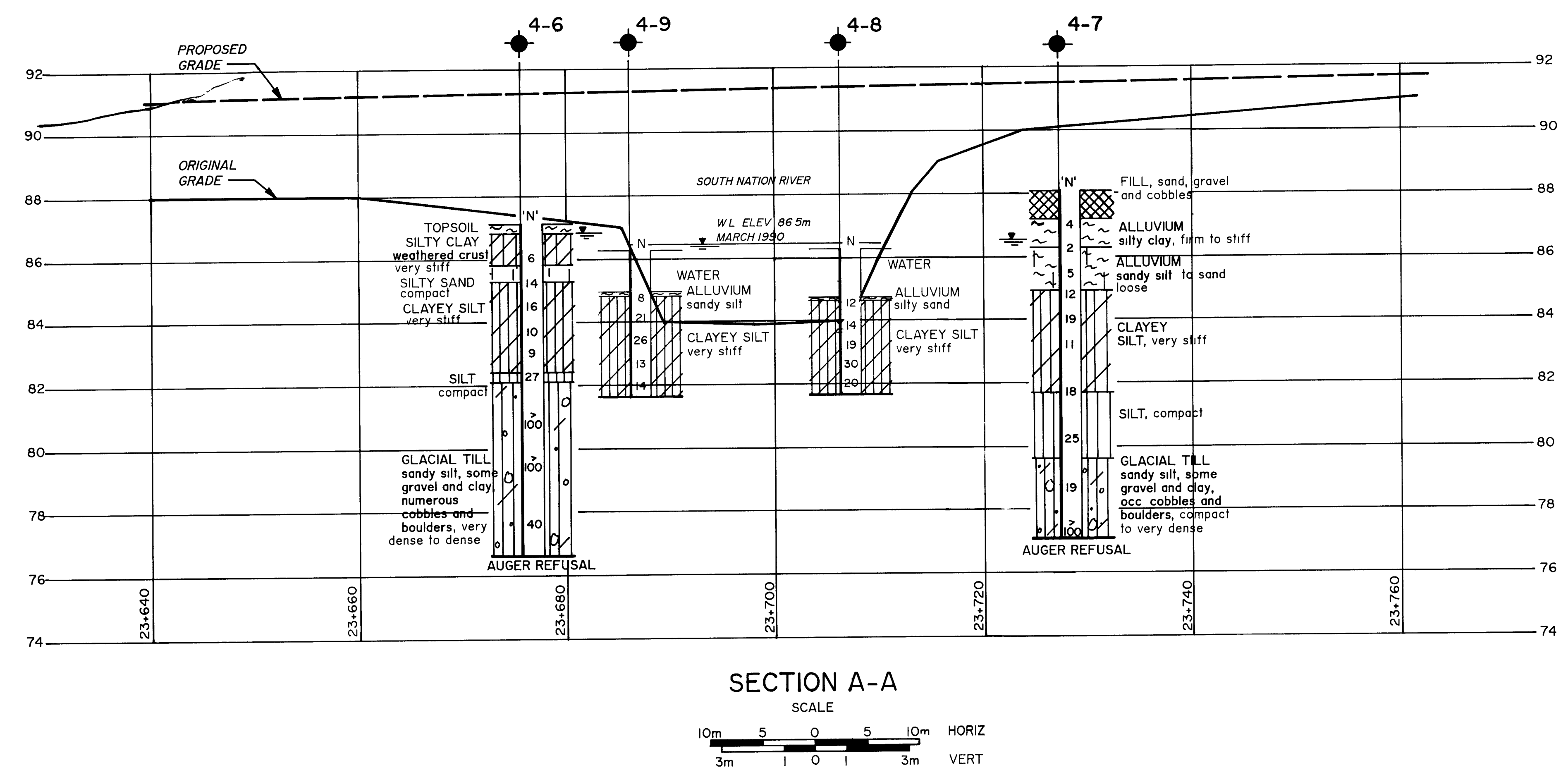
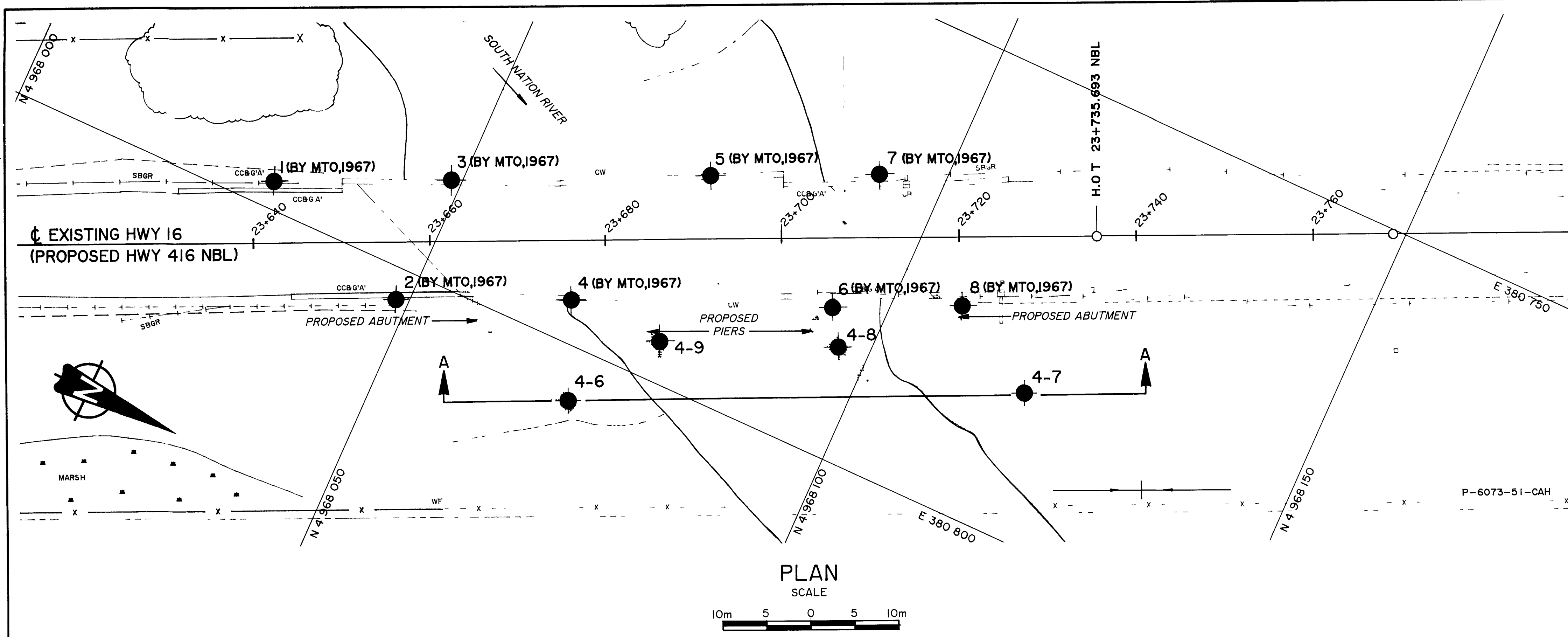
CHECKED BY HL

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE		LIQUID LIMIT — VL PLASTIC LIMIT — PP WATER CONTENT — W		BULK DENSITY P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT		BLOWS / FOOT	SHEAR STRENGTH P.S.F. • Unconfined	WATER CONTENT %	WATER CONTENT %		
285.5	GROUND LEVEL											
0.0	Silty sand. Loose		1	SS	4							
278.5			2	SS	9							
271.0	Clayey silt Stiff to very stiff		3	SS	27							
			4	SS	14							
			5	TV	FM							
			6	TV	FM							
262.0			7	SS	38							
23.5	Clayey silt to silt with gravel (Gl. Till) Hard.		8	SS	136							
253.3	Boulders of Br.											
32.2	End of Borehole											

End of Comp test

Art. 286.8

Art. 255.0



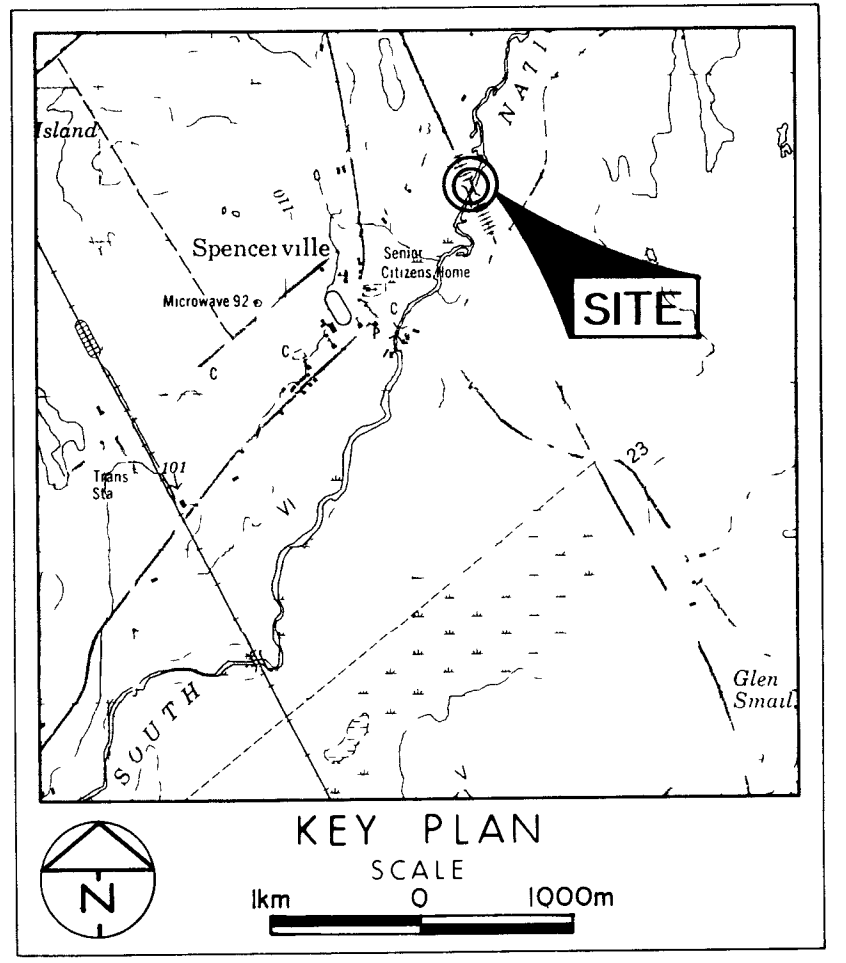
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES UNLESS
OTHERWISE SHOWN. STATIONS
IN KILOMETRES + METRES

CONT No
WP No ~~177-89-02~~
482-90-01

SOUTH NATION RIVER OVERPASS
HWY 416 NORTH BOUND LANES
BORE HOLE LOCATIONS & SOIL STRATA

SHEET

Golder Associates Ltd.



- LEGEND
- Bore Hole
 - Dynamic Cone Penetration Test (Cone)
 - Bore Hole & Cone
 - N Blows/0.3m (Std Pen Test, 475 J/blow)
 - CONE Blows/0.3m (60° Cone, 475 J/blow)
 - W.L. at time of investigation (MAY 1990)

No	ELEVATION	STATION	OFFSET
4-6	871	23+675.8	17.9m Rt
4-7	881	23+727.5	17.4m Rt
4-8	863	23+706.5	12.5m Rt
4-9	863	23+686.0	11.0m Rt

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

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

REV	DATE	BY	DESCRIPTION
1			
Geocres No 31B-64			
HWY No 416 NBL			DIST 9
SUBMD AC [CHECKED AC] DATE 90/08/23			SITE 16-189B
DRAWN JC [CHECKED] APPROVED			DWG 1778902-B