



**PRELIMINARY FOUNDATION INVESTIGATION REPORT
for
GRAND RIVER BRIDGE, EBL AND WBL
HIGHWAY 403
MTO WEST REGION 59 STRUCTURE REHABILITATIONS
CONTRACT 1
GWP 3503-01-01/02
CITY OF BRANTFORD, ONTARIO**

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FOUNDATION INVESTIGATION REPORT

For

Grand River Bridge, EBL and WBL, Highway 403
MTO West Region 59 Structure Rehabilitations
Contract 1, GWP 3503-01-01/02
City of Brantford, Ontario

1. INTRODUCTION

This report summarizes the results of the foundation investigation carried out for the proposed rehabilitation of the Highway 403 Bridge over Grand River near the City of Brantford, Ontario. The proposed rehabilitation is a part of the assignment for the rehabilitation of 59 structures in MTO West Region along Highways 4, 6, 401, 402 and 403. The study was carried out by Peto MacCallum Ltd. (PML) for MMM Group Limited (MMM) on behalf of the Ministry of Transportation of Ontario (MTO).

A Technical Memorandum, attached in Appendix 1 was also prepared as a part of this assignment (reference: Predraft Foundation Technical Memorandum for Grand River Bridge, EBL and WBL, issued October 24, 2013). The purpose of this Technical memorandum was to summarize the subsurface and groundwater conditions based on available Geocres reports for the design project terms of reference and to update the foundation design recommendations provided in the available reports to the Limit State design terminology in conformance with the requirements of the Canadian Highway Bridge Design Code (CHBDC).

The purpose of this report was to summarize the subsurface stratigraphy encountered at the proposed structure site during the present preliminary investigation to supplement geotechnical data for temporary roadway protection.

For subsurface conditions from previous foundation investigations reference should be made to the Technical Memorandum. The present Foundation Investigation and Design Report should be read in conjunction with the Technical Memorandum.



2. SITE DESCRIPTION AND GEOLOGY

The existing structure is a four span bridge with spans of 48.8, 62.5, 62.5 and 48.8 m (from west to east). The bridge is located on Highway 403 approximately 1 km west of Oak Park Road in Brant County, Ontario.

The bridges are twin concrete deck slabs on steel plate girders with the north bridge carrying 2 lanes of Highway 403 WBL traffic and the south bridge carrying 2 lanes of Highway 403 EBL traffic. The Grand River is about 110 m wide and the western river bank is a relatively flat floodplain. A fill embankment was previously constructed on the west bank at the bridge approach. On the east bank, the ground rises at a two horizontal to one vertical overall slope to a higher flood river terrace.

The project site is located within the physiographic region known as the Norfolk Sand Plain. The Norfolk Sand Plain spans a 3130 km² area. The typical bedrock type in the project area is comprised of shale and dolomite of the Salina Formation which varies from about elevation 207.1 to 212.8 in the bridge area (see Technical Memorandum for further bedrock details).

3. INVESTIGATION PROCEDURES

The field work for this study was carried out on December 12 and 13, 2013. The investigation included two boreholes drilled at the west end of the existing WBL and EBL bridges (boreholes 1 and 3, respectively) and one borehole at the east end (borehole 2) of the existing WBL bridge as shown on Drawing GR-1.

The borehole locations were established in consultation with MMM. The borehole locations and elevations were surveyed in the field by MMM. All elevations in this report are expressed in metres.



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

Soil samples were recovered from the boreholes at regular 0.75, 1.5 or 3.0 m depth intervals using the standard penetration test method. Standard penetration tests were conducted to assess the strength characteristics of the substrata. Soils were identified in accordance with the MTO soil classification manual procedures.

The groundwater conditions in the boreholes were assessed during drilling by visual examination of the soil, the sampler and drill rods as the samples were retrieved. The groundwater levels in the boreholes following drilling were also obtained.

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

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

- Natural moisture content determinations (22)
- Grain size distribution analyses (9)
- Atterberg Limit Test (1)

The results of the laboratory grain size distribution analysis and Atterberg Limit Test) are presented in Figures GR-GS-1 to GR-GS-6 and GR-PC-1, respectively. All of the test results are summarized on the Record of Borehole Sheets.



4. SUMMARIZED SUBSURFACE CONDITIONS

Reference is made to the appended Record of Borehole Sheets for details of the subsurface conditions including soil classifications, inferred stratigraphy, standard penetration and groundwater observations. The results of laboratory particle size distributions, Atterberg Limit Testing and moisture content determinations are also shown on the Record of Borehole Sheets.

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

The subsurface stratigraphy revealed in the boreholes drilled at the west side of the bridge comprised topsoil over non-cohesive fill to a 11.8 and 13.7 m depth over very dense sandy gravel to gravelly sand that extended to the 13.9 and 18.7 m borehole termination depth. On the east side of the bridge the subsurface stratigraphy revealed pavement structure over non cohesive fill to a 8.5 m depth, over stiff to very stiff native clayey silt that extended to the 11.3 m borehole termination depth. It is noted that cobbles and boulders were encountered within the existing fill and gravelly sand to sandy gravel. Refusal to auger on likely bedrock was encountered in borehole 1 at 18.7 m (elevation 211.2)

A summary of the findings is given below.

4.1 Topsoil

A 0.2 m thick topsoil layer was encountered surficially at the west side of the bridge in boreholes 1 and 3 that extended to elevation 229.7 and 229.8, respectively.



4.2 Fill

On the east side of the bridge a 910 mm thick pavement structure comprising of 230 mm of asphaltic concrete over 180 mm of granular base above 500 mm of granular subbase was contacted surficially. The pavement structure extended to approximately elevation 233.3 where a gravelly sand to sand fill was encountered. The fill layer encountered was 7.4 m thick and extended to elevation 225.7. The gravelly sand to sand fill was compact to dense (SPT-“N” values of 11 to 42) and moist with moisture contents of 4 to 12%. Wood chips were noted within the fill.

On the west side of the bridge a 11.6 and 13.5 m thick fill unit was contacted below the surficial topsoil at 0.2 m (elevation 229.8 and 229.7) in boreholes 3 and 1, respectively that extended to 11.8 and 13.7 m (elevations 218.2 and 216.2). The fill was variable, comprising sand and gravel, gravelly sand, sand with silt, silty sand and silt with sand. The material was compact to very dense (SPT-“N” values of 21 blows to 81 blows for 25 cm) and moist (moisture contents of 3 to 11%). Cobbles, boulders, clayey silt pockets, and organic inclusions were noted within the fill material.

The results of 7 grain size distribution analyses conducted on samples of the fill are shown in figures GR-GS-1 to GR-GS-4.

4.3 Sandy Gravel to Gravelly Sand

On the west side of the bridge a 2.1 and 5.0 m thick layer of sandy gravel to gravelly sand was contacted beneath the fill at 11.8 and 13.7 m (elevation 218.2 and 216.2) in boreholes 3 and 1, respectively. The sandy gravel to gravelly sand extended to the 13.9 and 18.7 m (elevation 216.1 and 211.2) borehole termination depths in boreholes 3 and 1, respectively. The material was very dense (SPT-“N” values of 77 blows to 50 blows for 10 cm) and moist (moisture contents of 5 and 6%). Cobbles and boulders were noted within the deposit. The result of a grain size distribution analysis is presented on figure GR-GS-5.



4.4 Clayey silt

A 2.8 m thick clayey silt layer was contacted on the east side of the bridge in borehole 2 below the fill at 8.5 m (elevation 225.7) that extended to the 11.3 m (elevation 222.9) borehole termination depth. The material was stiff to very stiff (SPT-"N" values of 14 and 16) and drier than the plastic limit (moisture contents of 12%). The results of a grain size distribution analysis and Atterberg Limit Test are presented on figures GR-GS-6 and GR-PC-1.

4.5 Probable Bedrock

Refusal to auger was encountered on the west side of the bridge in borehole 1 at 18.7 m (elevation 211.2). This refusal to auger is consistent with the bedrock elevations discussed in the Foundation Technical Memorandum and likely represents refusal to auger on bedrock.

4.6 Groundwater

During augering, groundwater was observed on the west side of the bridge at 4.3 and 12.2 m (elevation 225.7 and 217.7) in boreholes 3 and 1, respectively. No free groundwater was encountered during augering on the east side of the bridge in borehole 2. Upon completion of drilling groundwater was not observed in any of the boreholes.

The groundwater levels are subject to seasonal fluctuation and rainfall patterns.



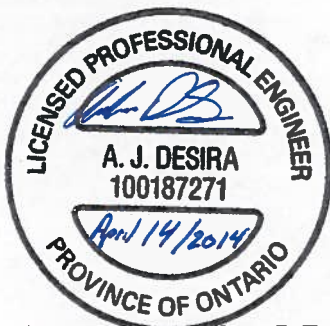
5. CLOSURE

Mr. F. Portela carried out the field investigation for this study under the supervision of Mr. A. DeSira, MEng, P.Eng., and Mr. C. M. P. Nascimento, P. Eng., Project Manager. London Soil Drilling 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 Foundation Investigation Report was prepared by Mr. A. DeSira, MEng, P.Eng. and reviewed by Mr. Robert Ng, MBA, PhD, P.Eng. Mr. C. M. P. Nascimento, P. Eng., MTO Designated Principal Contact conducted an independent review of the report.

Yours very truly

Peto MacCallum Ltd.



Andrew DeSira, MEng, P.Eng.
Project Engineer, Geotechnical Services

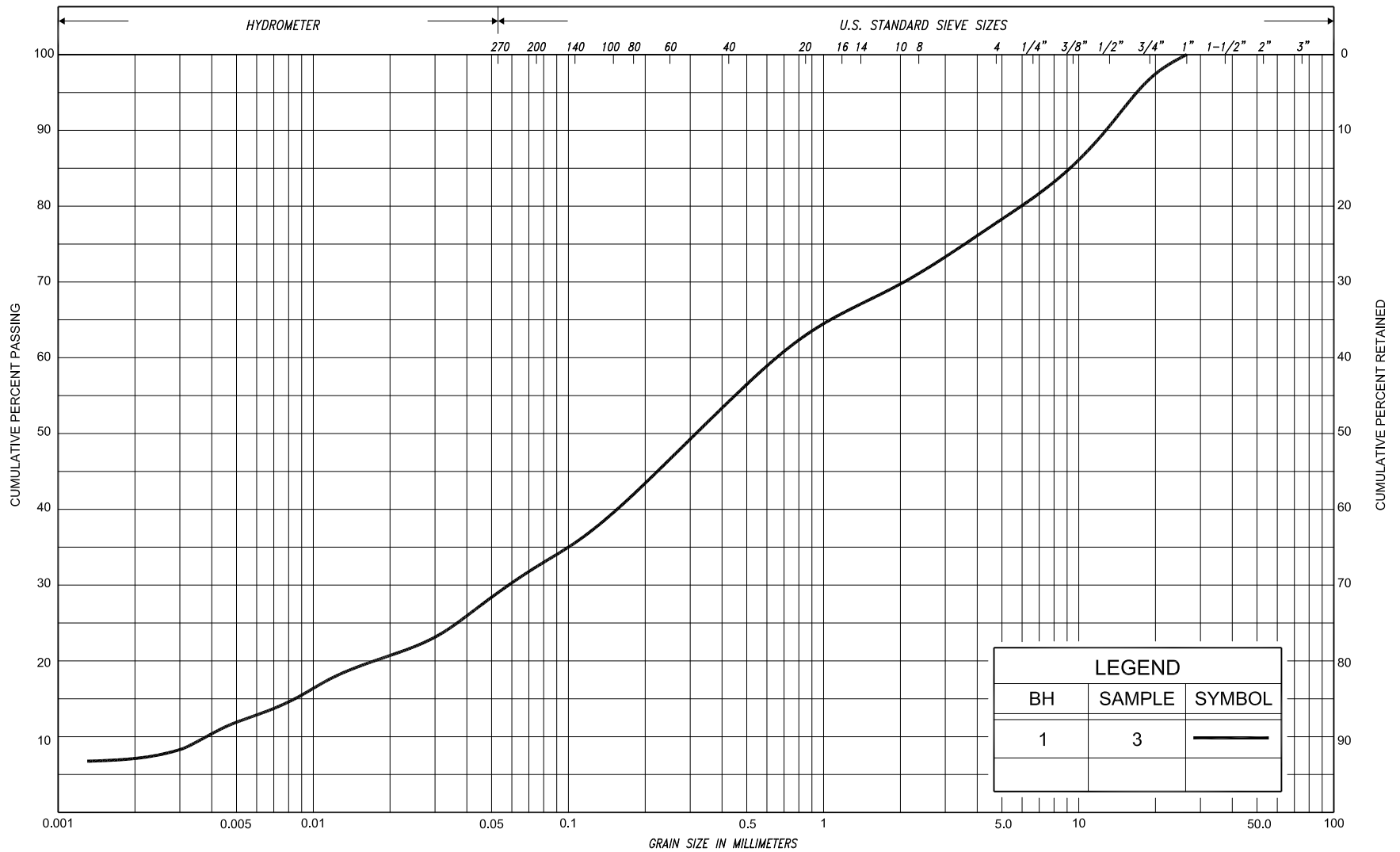


Robert Ng, MBA, PhD, P.Eng.
Senior Project Engineer



Carlos M.P. Nascimento, P.Eng.
MTO Designated Principal Contact

AD/CN/BRG:ad-gj-mi



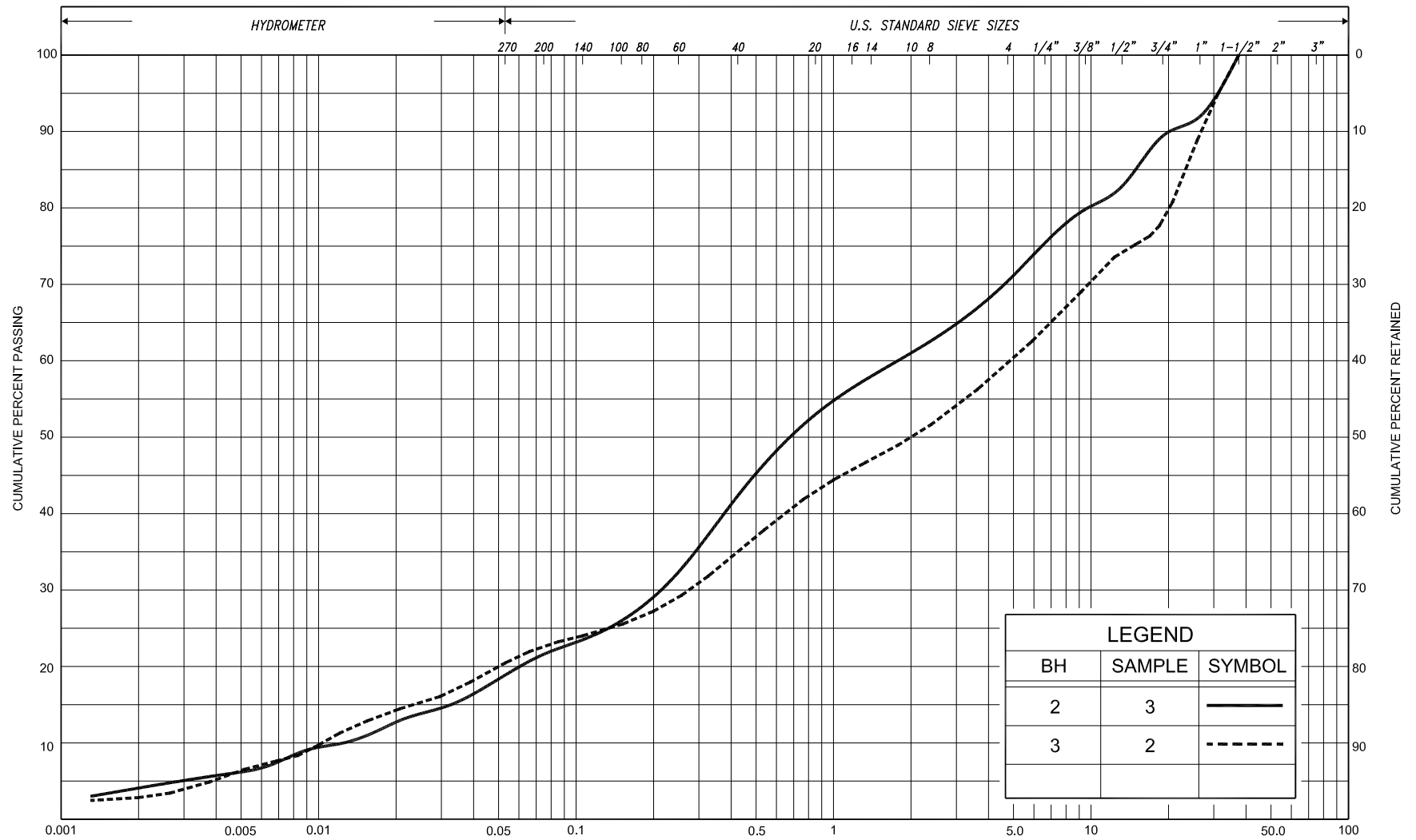
LEGEND		
BH	SAMPLE	SYMBOL
1	3	—

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



GRAIN SIZE DISTRIBUTION SAND, with gravel, with silt, trace clay (FILL)

FIG No.	GR-GS-1
HWY:	403
W.P. No.	3503-01-01/02

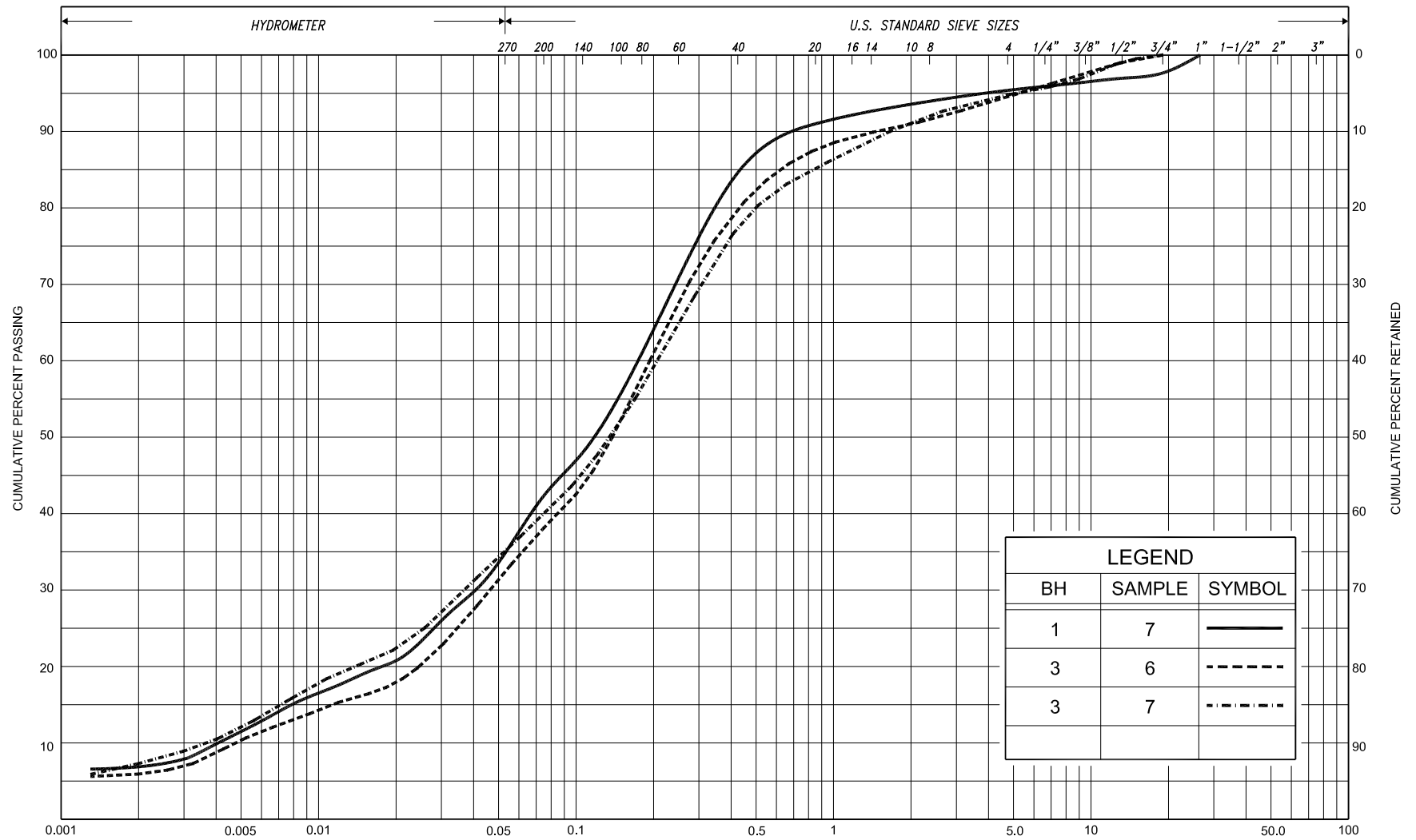


SILT & CLAY					FINE		MEDIUM		COARSE	GRAVEL			COBBLES	UNIFIED
CLAY	FINE		MEDIUM		COARSE	SAND			GRAVEL			COBBLES	M.I.T.	
	SILT				FINE		MEDIUM							COARSE
CLAY		SILT			V. FINE	FINE	MED.	COARSE	GRAVEL					U.S. BUREAU



GRAIN SIZE DISTRIBUTION GRAVELLY SAND to SAND AND GRAVEL, some silt, trace clay (FILL)

FIG No.	GR-GS-2
HWY:	403
G.W.P. No.	3503-01-01/02



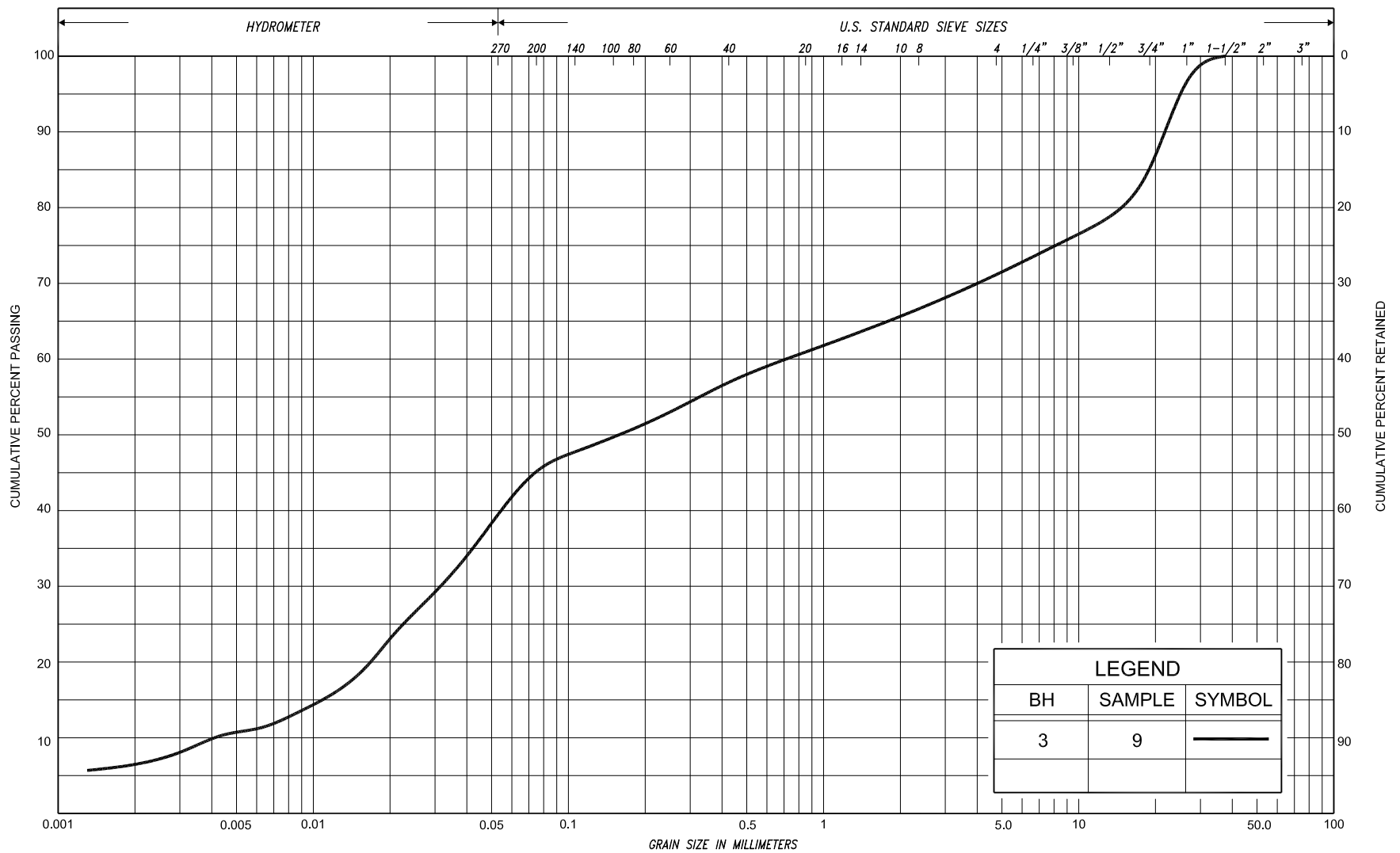
SILT & CLAY				FINE SAND			COARSE SAND	GRAVEL	COBBLES	UNIFIED
CLAY	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	GRAVEL	COBBLES	M.I.T.	
CLAY	SILT	V. FINE	FINE	MED.	COARSE	GRAVEL	COBBLES	U.S. BUREAU		

GRAIN SIZE DISTRIBUTION

SILTY SAND, trace clay, trace gravel
(FILL)

FIG No.	GR-GS-3
HWY:	403
G.W.P. No.	3503-01-01/02





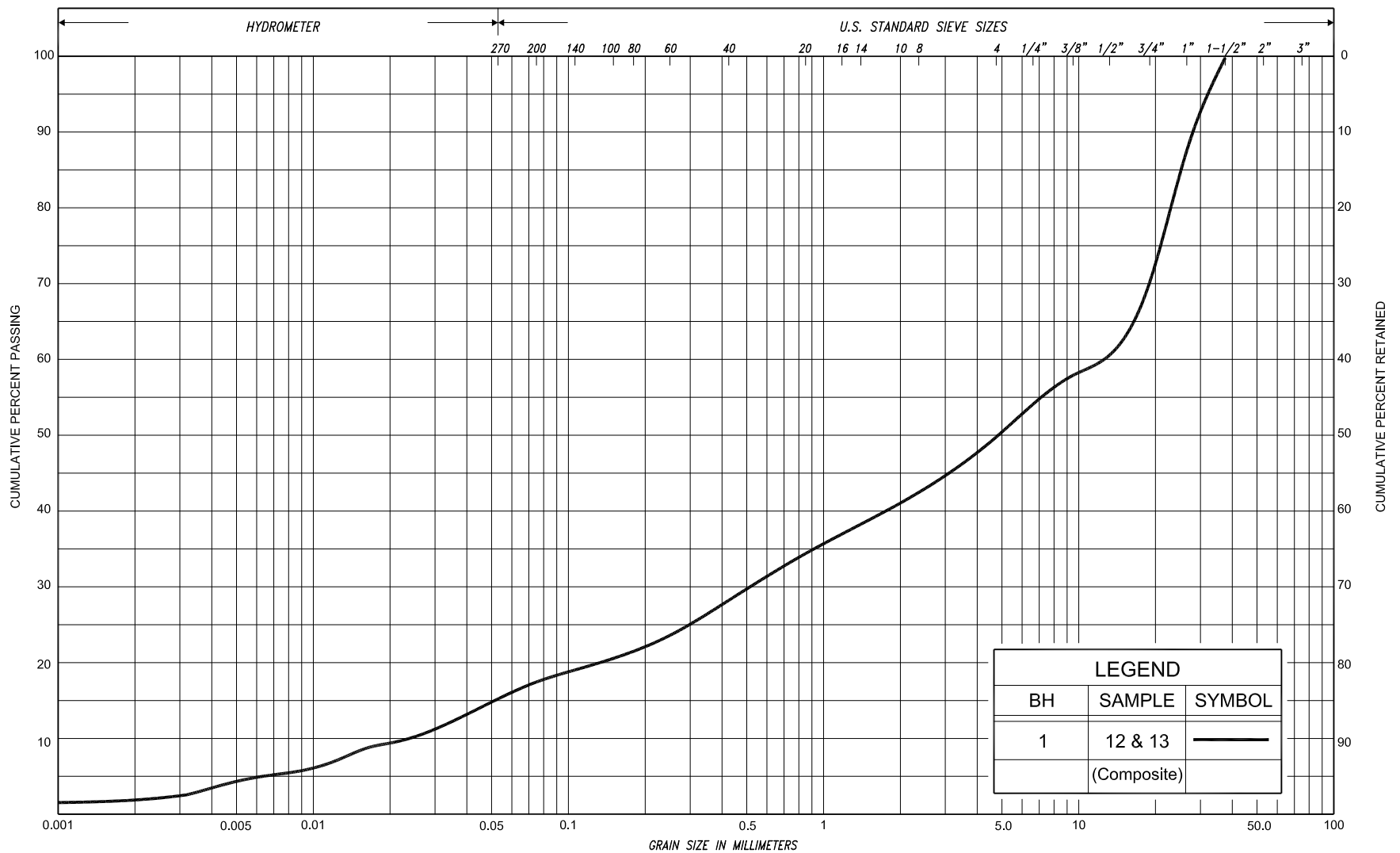
LEGEND		
BH	SAMPLE	SYMBOL
3	9	—

SILT & CLAY				FINE		MEDIUM		COARSE		GRAVEL				COBBLES	UNIFIED
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 SILT, with sand, with gravel, trace clay (FILL)

FIG No.	GR-GS-4
HWY:	403
W.P. No.	3503-01-01/02

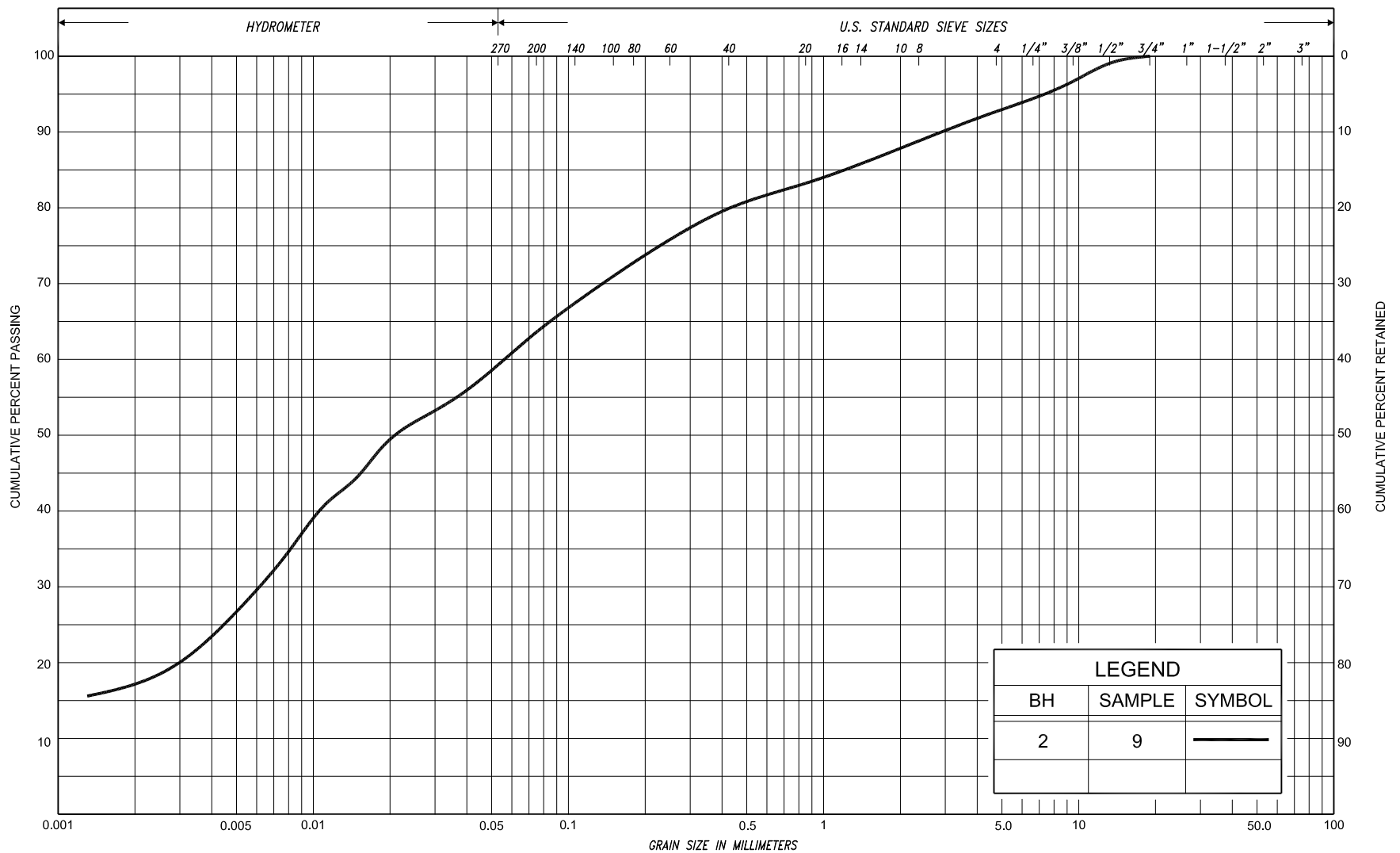


SILT & CLAY					FINE		MEDIUM		COARSE	GRAVEL				COB BLES	UNIFIED	
CLAY	FINE		MEDIUM		COARSE	FINE		MEDIUM		COARSE	GRAVEL				COBBLES	M.I.T.
	SILT					SAND										
CLAY		SILT			V. FINE	FINE	MED.	COARSE	GRAVEL							U.S. BUREAU



GRAIN SIZE DISTRIBUTION SANDY GRAVEL, some silt, trace clay (FILL)

FIG No.	GR-GS-5
HWY:	403
W.P. No.	3503-01-01/02



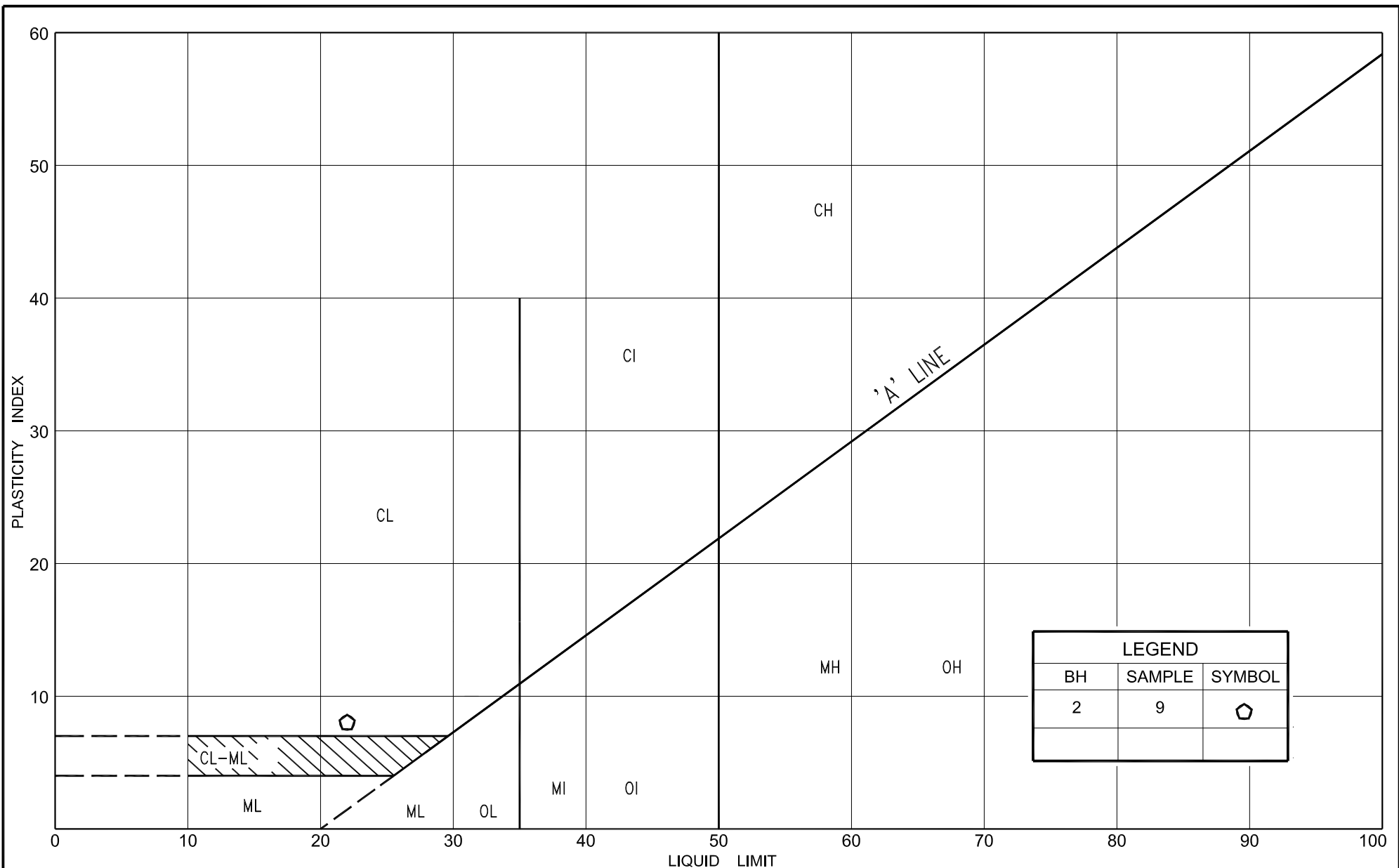
LEGEND		
BH	SAMPLE	SYMBOL
2	9	—

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



GRAIN SIZE DISTRIBUTION CLAYEY SILT, with sand, trace gravel

FIG No.	GR-GS-6
HWY:	403
W.P. No.	3503-01-01/02



PLASTICITY CHART
CLAYEY SILT, with sand, trace gravel

FIG No.	GR-PC-1
HWY:	403
W.P. No.	3503-01-01/02

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 (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
F V FIELD VANE	

STRESS AND STRAIN

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

MECHANICAL PROPERTIES OF SOIL

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

PHYSICAL PROPERTIES OF SOIL

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

RECORD OF BOREHOLE No. 1

1 of 2

METRIC

G.W.P. 3503-01-01/02 **LOCATION** Coords: 4 781 036.6 N; 235 464.8 E **ORIGINATED BY** F.P.
DIST London **HWY** 403 **BOREHOLE TYPE** Continuous Flight Hollow Stem Augers **COMPILED BY** A.D.
DATUM Geodetic **DATE** December 12, 2013 **CHECKED BY** R.N.


SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		SHEAR STRENGTH kPa									
							○ UNCONFINED + FIELD VANE									
							● QUICK TRIAXIAL × LAB VANE									
					WATER CONTENT (%)											
229.9	Ground Surface															
229.7	Topsoil		1	SS	20											
0.2	Sand and gravel															
	Compact Brown Moist															
	Sand — — — — with silt, with gravel trace clay cobbles and boulders organic inclusions		2	SS	23											
	Dense to Dark Moist compact brown		3	SS	36											
	(FILL)		4	SS	22											
			5	SS	32											
			6	SS	50/10cm											
	Silty sand — — — — trace clay, trace gravel															
	Dense to Brown Moist very dense	7	SS	36												
		8	SS	50/15cm												
		9	SS	93												
		10	SS	46												
		11	SS	90												
	Wet															
216.2			12	SS	77											
13.7	Sandy gravel some silt, trace clay cobbles and boulders															
	Very dense Brown Moist															
214.9	Cont'd															

RECORD OF BOREHOLE No. 1

2 of 2

METRIC

G.W.P. 3503-01-01/02 **LOCATION** Coords: 4 781 036.6 N; 235 464.8 E **ORIGINATED BY** F.P.
DIST London **HWY** 403 **BOREHOLE TYPE** Continuous Flight Hollow Stem Augers **COMPILED BY** A.D.
DATUM Geodetic **DATE** December 12, 2013 **CHECKED BY** R.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
214.9							20	40	60	80	100						
15.0	Sandy gravel some silt, trace clay cobbles and boulders Very dense Brown Moist (Cont'd.)		13	SS	50/10cm		214										
							213										
			14	SS	50/8cm		212										
211.2			15	SS	86/23cm												
18.7	End of borehole Refusal on probable bedrock Samples 6, 8, 14 and 15: Sampler bouncing * 2013 12 12 ▽ Water level observed during drilling ** Composite of samples 12 and 13																

RECORD OF BOREHOLE No. 2

1 of 1

METRIC

G.W.P. 3503-01-01/02 **LOCATION** Coords: 4 781 090.2 N; 235 710.5 E **ORIGINATED BY** F.P.
DIST London **HWY** 403 **BOREHOLE TYPE** Continuous Flight Hollow Stem Augers **COMPILED BY** A.D.
DATUM Geodetic **DATE** December 11, 2013 **CHECKED BY** R.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS *	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE										○		
								● QUICK TRIAXIAL × LAB VANE												
234.2	Ground Surface						20	40	60	80	100									
0.0	230mm thick asphalt over 180mm of granular base over 500mm of granular subbase		1	SS	81	234							○							
233.3	Very dense Brown Moist (PAVEMENT FILL)		2	SS	87/28cm	233							○							
0.9	Gravelly sand some silt, trace clay wood chips		3	SS	42	232							○			30 48 18 4				
	Dense to Brown Moist compact		4	SS	13	231														
			5	SS	13	230														
	Sand trace silt, trace gravel		6	SS	23	229							○							
	Compact Reddish Moist brown		7	SS	14	228														
	(FILL)		8	SS	11	227							○							
225.7	Clayey silt with sand, trace gravel		9	SS	14	226							○							
8.5	Stiff to Brown Moist very stiff		10	SS	16	225			■				○			7 29 46 18				
222.9	End of borehole					224														
11.3	Sample 2: Sampler bouncing					223			■				○							
	* Borehole dry																			
	■ Penetrometer test																			

RECORD OF BOREHOLE No. 3

1 of 1

METRIC

G.W.P. 3503-01-01/02 **LOCATION** Coords: 4 781 019.7 N; 235 474.8 E **ORIGINATED BY** F.P.
DIST London **HWY** 403 **BOREHOLE TYPE** Continuous Flight Hollow Stem Augers **COMPILED BY** A.D.
DATUM Geodetic **DATE** December 12, 2013 **CHECKED BY** R.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE										○		
								● QUICK TRIAXIAL × LAB VANE												
230.0	Ground Surface						20	40	60	80	100									
229.8	Topsoil																			
0.2	Sand and gravel some to with silt trace clay cobbles and boulders		1	SS	25	▽*							○			40 37 20 3				
	Compact Brown Moist		2	SS	21								○							
			3	SS	19								○							
	clayey silt pockets																			
			4	SS	39								○							
			5	SS	48															
	silty sand trace clay, trace gravel wet sand seams		6	SS	41								○			5 57 32 6				
	Dense to Brown Moist very dense																			
			7	SS	66								○			5 55 32 8				
	(FILL)																			
			8	SS	90/23cm															
	Silt with sand, with gravel trace clay shale fragments		9	SS	56								○			29 26 39 6				
	Very dense Brown Moist																			
			10	SS	81/25cm															
218.2																				
11.8	Gravelly sand trace silt, trace clay cobbles and boulders		11	SS	50/10cm															
	Very dense Brown Moist																			
216.1			12	SS	50/15cm															
13.9	End of borehole																			
	* 2013 12 12 ▽ Water level observed during drilling																			



APPENDIX 1

TECHNICAL MEMORANDUM



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Figure 1 Key Plan

Table 1 Bedrock and Groundwater Information

Table 2 Existing Foundation Design Parameters

Appendix A – General Layout Plan

Appendix B – Site Photographs from Field Reconnaissance

Appendix C – Borehole Location and Soil Stratigraphy

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FOUNDATION TECHNICAL MEMORANDUM

For

Grand River Bridge, EBL and WBL, Highway 403
MTO West Region 59 Structure Rehabilitations
Contract 1, GWP 3503-01-00
City of Brantford, Ontario

1. INTRODUCTION

The Foundation Engineering Services for the assignment involves the detail foundation investigation and design for rehabilitation of 59 structures in MTO West Region along Highways 4, 6, 401, 402 and 403. Ten (10) Group Work Projects (GWP's) are contemplated to be completed between 2014 and 2020. Contract 1 GWP 3503-01-00 is associated with the rehabilitation of the Grand River Bridge structure, East and West Bound Lanes over Highway 403 near the City of Brantford, Ontario.

This technical memorandum is based on review and compilation of existing subsurface information from relevant reports in the MTO GEOCRE Library. The Foundation Engineering recommendations from the initial bridge foundation reports are summarized and translated to limit state design terminology per the "Highway Bridge Design Code" (CHBDC) and follow, in general, the PEO "Guidelines for Professional Engineers providing Geotechnical Engineering Services".

It is understood that the scope of the Grand River Bridge rehabilitation project includes modification of the bridge abutments to semi-integral abutments and to provide roadway protection during the construction as provided in the email dated October 28, 2013.

The purpose of this Technical memo is to summarize the subsurface and groundwater conditions based on available reports for the design project team's reference and to update the foundation design recommendations provided in the available reports to limit state design terminology in conformance with the requirements of the Canadian Highway Bridge Design Code (CHBDC). Further, this technical memo comments on the current relevance and adequacy of the foundation design recommendations provided by the available reports and updates the essential recommendations for bearing resistance to the current standard for design.



2. SOURCE OF INFORMATION

The following reports, documents and maps were available for review and information for the Grand River Bridge. Reference 2 below represents the foundation investigation report for the final bridge alignment.

1. Preliminary Foundation Investigation Report, Proposed Grand River Crossing, HWY 403, District No. 2, W. P. 159-60, Paris, Ontario, Foundation Section, Materials and Research Division, Ministry of Transportation and communications Ontario, February 1963. A total of eight (8) boreholes were drilled to investigate four lines; Brown Line, Original Line, Red and Blue Line and Black Line. Foundation Investigation Report, Proposed Grand River and HWY 403, Line 'H', District No. 2 (London), W. P. 159-60, Township of Brantford, Ontario, Foundation Section, Materials and Testing Division, Ministry of Transportation and communications Ontario, May 1965. A total of 25 boreholes were drilled.
2. Subsurface Investigation, Proposed Grand River Bridge, HWY 403, Line 'K', District No. 4 (Hamilton), W. O. 71-11112, W. P. 159-60-00, Near Brantford, Ontario, Golder Associates, December 1971. The investigation was undertaken for Line 'K', the existing Grand River Bridge location. In Golder's investigation, 28 boreholes were drilled - 6 boreholes were drilled for 4 abutments, 21 boreholes for 6 piers and 1 borehole for the eastern approaches. Borehole Locations and Soil Strata (Drawings 71122-1, 71122-2, 71122-3) dated November 1971.
3. Memorandum from Foundations Office, Design Services Branch, Central Building, Downsview. December 3, 1971. MTC memorandum with foundation recommendations and comment on the foundation investigation for Line 'K' of the proposed Grand River Bridge.
4. General Layout (Drawing No. 75-132) dated November 1975.
5. Grand River Bridge W.B.L on Highway 403 – MTO Site No. 1-147-E. Underwater Inspection Report. Consultant Agreement No. 3008-E-0057. Prepared by AECOM for Ministry of Transportation of Ontario – Western Region. Project No. 60144747, dated June 1, 2011.



6. Grand River Bridge E.B.L on Highway 403 – MTO Site No. 1-147-W. Underwater Inspection Report. Consultant Agreement No. 3008-E-0057. Prepared by AECOM for Ministry of Transportation of Ontario – Western Region. Project No. 60144747, dated June 1, 2011.

3. PROJECT SITE BACKGROUND AND GEOLOGY

The Grand River Bridge on Highway 403 is located near Brantford in Brant County Ontario. A key plan shown in Figure 1. The ground conditions at this site consist of a shallow cover consisting of recent river flood plain deposits over a series of glacial tills which in turn overlies bedrock of Salina Formation. The bedrock in the river channel is likely covered by a relatively thin deposit of sand and gravel, and cobbles and boulders.

The bridge is a divided two-lane structure with east and west bound lanes (EBL and WBL); it comprises thin concrete deck slab on steel plate girders and each bridge carries two lanes of traffic. The Grand River is about 110 m wide and was about 1.0 m deep at the time of the previous investigation (Reference 2). The western river bank is a relatively flat floodplain about 3 m above the river level at the time of investigation. A fill embankment was previously constructed on the west bank as the bridge approach. On the east bank, the ground rises at a two horizontal to one vertical overall slope to a higher flood river terrace. There was a report of erosion gullying at the crest of the east slope during 1971 investigations. That erosion gully has since been in-filled.

The general layout drawing, Grand River Bridge-General Layout, HWY 403, Line 'K', District No. 4, W. P. 159-60-00, Ministry of Transportation and Communications Ontario, November 1975 is shown in Appendix A referring to Imperial units. The bridge is a four span bridge with east and west abutments and three piers in the river channel and flood plain with span geometry of approximately 48.8 m, 62.5 m, 62.5 m, 48.8 m from west to east. The pier foundation are footings reported to be founded in the order of 2m into bedrock constructed by tremie concrete, The abutments are founded on 12BP @74 steel H-piles driven to bedrock or practical refusal in dense till materials immediately above the bedrock.



The piezometers and standpipes installed within the bedrock indicate the water level is at river level.

4. SITE RECONNAISSANCE

As part of the current foundation engineering assessment study, a site reconnaissance of the Grand River Bridge was carried out on June 11, 2013. A photographic record of the site visit is attached in Appendix B.

4.1 Eastbound Lane (EBL) Structure (Site 1-147-1)

4.1.1 West Abutment and West Pier of EBL Structure

The site photos present current conditions at the west abutment and west pier of the EBL structure including the appearance of the structure as it relates to the performance of the foundations, visual conditions relating to slope stability, slope erosion, scour at the pier and slope vegetation conditions (photographs 12 to 22).

The south and north slopes were covered with grasses, bushes and trees. However, no vegetation was growing on the front slope area. Some minor erosion was found on the front slope of west abutment of the EBL structure possibly due to water leaking from the superstructure. The surfaces of slopes were stable. There were no obvious cracks observed on the pier. However, the effect of scouring (photographs 21 and 22) around the west pier of the EBL structure was observed to be about 1.0 m depth.

4.1.2 East abutment and East Pier of EBL Structure

The site photos present the current conditions at the east abutment and east pier of the EBL structure, including the appearance of the structure as it relates to the performance of the foundations, the visual condition related to slope stability, and the condition of the existing trail and vegetation on the slope (photographs 37 to 40 and 42 to 45).



The south, north and front slopes were covered with grasses, bushes and trees. The east abutment slope of the EBL structure has a cut in the original slope. The original slope was stepped down from south to north and used as a trail. Hence the upper portion of the front slope for a length of about 20 m was relatively flat. The lower portion was inclined at a significantly steeper geometry of about 1.5 horizontal to 1.0 vertical. The upper portion of the front slope was not vegetated. The lower portion of the front slope was covered by grasses, bushes and trees. No obvious cracks and soil erosion was found on the slopes. Based on the visual inspection, the slope appeared to be in stable condition. However, there could be some concern with the long-term performance of the steepened 1.5 horizontal to 1.0 vertical portion of the slope.

Some wood debris was piled up against the east side of the east pier of the EBL structure (photograph 35). Since the debris may be concealing scouring around the pier, the area should be examined further to assess whether scouring has taken place.

4.1.3 Middle (Center) Pier of EBL Structure

The site inspection examined the surficial appearance of the pier to infer the performance of the foundations of middle pier of the WBL structure (photographs 26 and 27). Some cracks were observed on the structure above the water surface at the pier by remote observations. However, the extent of scour cannot be made solely by remote observations.

4.2 Westbound Lane (WBL) Structure (Site 1-147-2)

4.2.1 West Abutment and West Pier of WBL Structure

The site photos illustrate current conditions at the west abutment and west pier of the WBL structure including the appearance of the structure, visual conditions relating to slope stability and soil erosion, and the visible vegetation environments (photographs 3 to 11).

The south and north slopes were covered with grasses, bushes and trees. However, no vegetation was growing on the front slope area. No obvious cracks were found on the pier and



abutment areas, and there was no major observable erosion on the slopes. The slopes appeared to be in stable condition during the time of visit.

4.2.2 East abutment and East Pier of WBL Structure

The site photos presented current conditions of the east abutment and east pier of the WBL structure including the appearance of the structure, the visual condition of slope stability, soil erosion, the trail path beneath the bridge deck at the abutment and the condition of vegetation on the slopes (photographs 28 to 36 and 41).

The south and north slopes were covered with grasses, bushes and trees. However, no vegetation was growing on the upper portion of the front slope area. The lower portion of the front slope was covered by grass. No obvious cracks were found on the abutment and pier areas and no significant erosion was observed on the slopes. The surface of slopes appeared to be in stable condition during the time of visit.

4.2.3 Middle (Center) Pier of WBL Structure

The site photos present the current conditions of the middle pier of the WBL structure (photographs 24 and 25). Some cracks were observed in the concrete of the piers above water line but the extent of any scouring effect at the pier location cannot be made by remote observations.

4.3 Drainage System on the East Bank

The site photos present current conditions of a drainage system on the east bank between the WBL and EBL structures (photographs 49 to 52).

The drainage system consists of a drainage pipe, "manhole", and a probable hidden drainage ditch between the WBL and EBL structures on the east bank of the Grand River. The drainage pipe may have been installed to facilitate seepage from the slope. The pipe had an outlet on the east bank. The probable hidden drainage ditch is expected to be a trench filled with crushed



stones. This drainage system is not shown on the provided drawings (General Layout Drawing No. 75-132) and hence its design or as-built condition cannot be confirmed.

No major soil erosion was observed on the east bank. The drainage system appeared to be functional at the time of the reported site visit. However, the current conditions of the pipe and outlet may require some regular maintenance to maintain them in state of good repair and operation.

4.4 Summary of the Site Reconnaissance

Based on visual inspection, the slopes were deemed to be stable.

- Some front slopes were exposed and not covered by vegetation. Erosion protection would be necessary to provide long-term performance.
- Erosion had occurred on the front slope of the west abutment of the EBL structure under the superstructure. This erosion could have resulted from water leakage from the deck and should be repaired to provide long term performance.
- Some cracks were observed above the water level of the middle (center) piers. The middle piers were observed at a distance only in order to assess the performance of their foundations and the underwater portion of the piers should be checked to condition as related to performance of the foundations and scour.
- Scouring and soil erosion around the west pier of EBL structure was observed to be about 1.0 m deep based on visual inspection. The full extent of the scour should be investigated using appropriate methods and appropriate remedial measures should be designed and constructed.
- Preventive and maintenance work is recommended to address the soil slope erosions. If exposed portions are not re-vegetated, they should be treated with erosion protection measures such as granular erosion blankets or equivalent measures for long term performance.
- The drainage system between the WBL and EBL structures on the east bank of the Grand River appears to be in working condition. However, as a minimum, some maintenance and inspection on a regular schedule basis should be carried out.



5. PREVIOUS FOUNDATION INVESTIGATIONS AND SUBSURFACE CONDITIONS

The site is located on Hwy 403 near the City of Brantford. The Grand River is about 110 m wide and flows southerly at the bridge location. A foundation investigation was completed by Golder Associates in January 1971. The investigation was undertaken for Line 'K' for the existing Grand River Bridge location. The general subsurface conditions presented in this section are based on the Foundation Investigation Report for Proposed Grand River Bridge C.A.H. #403, Line 'K' near Brantford, Ontario (Reference 2), and Department of Transportation and Communications Memorandum dated December 3, 1971 (Reference 3).

5.1 Foundation Investigation

In the previous investigation, 28 boreholes were drilled in November 1971. Six boreholes were drilled for 4 abutments, 21 boreholes for 6 piers and 1 borehole for the eastern approaches as shown on the borehole locations and Soil Strata plan in Appendix C.

This foundation investigation was carried out in the fall of 1971. The drilling was carried out using diamond drill rigs. With the exception of Borehole 28 at the crest of the east slope, all boreholes were advanced to the top of bedrock. At selected borehole locations, boreholes were advanced and cored into rock for a maximum 1.5 m or until "sound" bedrock was encountered.

Following borehole drilling, piezometer or standpipes were installed at selected boreholes. The water levels were observed in open boreholes upon completion of drilling and in piezometers. The water levels are provided in the Record of borehole sheets and also summarized in Table A.

The Record of Borehole sheets and bedrock and groundwater information of the 28 boreholes are presented in Appendix D.



5.2 Subsurface Conditions

The site descriptions may be divided into three general areas for reporting purpose, namely, West Bank of the Grand River, the River Channel Section, and East Bank of the Grand River. The following section provides a brief description of the subsurface conditions based on the previous Foundation Report. Details of soil and rock descriptions are available in the original documents.

The west bank is generally flat and the east bank rises at an approximate 2 horizontal to 1 vertical slope. The bedrock was generally flat, except where eroded or gently sloping and the bedrock elevation varied from about 207.1 to 212.8 m within the bridge area.

The eastern approaches to the abutment were cut into overburden while the western approaches consist of 17 m high fill embankments.

Along the east bank, there is an extensive deep deposit of interbedded and stratified glacial till overlying the bedrock. The overburden is about 21 m deep at the east abutment locations. At the east abutment location, bedrock surface is at approximate elevation 212.4 m (697ft) and closer to the river, the bedrock surface is at between approximate elevations 211.2 m (693 ft) and 209.7 m (688 ft). The difference between the bedrock surface elevations was suggested probably due to river erosion of the shale bedrock at the early stages of the river.

Within the river channel, the bedrock surface had been eroded to about 1.0 m below the bedrock surface on the adjacent banks. The bedrock elevations and depths are shown in Table A. The overlying subsoil generally consisted of a shallow cover of compact to dense silty sand and gravel, cobbles and boulders, except where eroded.

Along the west bank, the bedrock is covered by a shallow layer of recent river flood plain deposits and glacial till about 2.0 m thick at the location of the abutment. Because the bedrock surface under the west bank was higher than that exposed in the river channel at the time of investigation, it was suggested that the river channel has had been the main channel of the Grand River for an appreciable time.



The bedrock comprised shale and dolomite of the Salina Formation. It consists of interbedded greyish-green shale with inclusion and precipitates of gypsum. At the west pier locations, the upper surface was reported to consist of grey shale overlying shale and dolomite with gypsum cavities.

The river water level was measured at elevation 210.5 to 210.6 m at the time of the previous investigation. The groundwater was measured in open holes or piezometers during the previous investigation and is also shown in Table 1. The groundwater level on the west bank may likely be influenced by the river water level.

Some over-steepening surficial slump movements and surface erosion were observed within the overburden on the east slope during the investigation

Two soil samples from boreholes in the river channel were analyzed and showed 550 ppm and 1000 ppm concentration of soluble sulphate content. This concentration of soluble sulphate will necessitate using sulphate resistance cement in footings design and construction.

6. PREVIOUS FOUNDATION RECOMMENDATIONS

The foundation report (reference 2) recommended that either spread footings or caissons drilled into bedrock be used for the pier foundations. The report also pointed out that if it would be necessary to construct the foundations in the wet conditions, tremie concrete should be considered. It further recommended that the footings be founded on sound rock and hence 0.6 m weathered bedrock should be removed below the plan limits of the foundations, and in the river channel, footings were to be founded at 1.5 m below the bedrock surface to mitigate potential scouring by the river.

The report recommended that the west abutment be constructed within approach fill and supported on steel 12BP@74 H-piles driven to bedrock. The east abutment is located in a shallow fill location and it was recommended to be founded on steel 12BP@74 H-piles driven to bedrock or to practical refusal in the dense till strata. The old Imperial units pile section designation 12BP@74 is equivalent to the current HP 310 x 110 designation.



The foundation design for pile resistance and caisson resistance was given in the report (reference 2) and later in a MTC geotechnical memorandum dated December 3, 1971 (reference 3). The original foundation design bearing recommendations are summarized in Table 2 along with PML recommended upper level bearing resistance values updated to reflect current industry practice.

7. DISCUSSION

The Grand River Bridge is a multi-span twin bridge structure and is located on Hwy 403 near the City of Brantford. Based on the existing drawings, the west and east abutments are founded on 12BP @ 74 steel H-piles driven to bedrock and practical refusal in dense till materials, respectively. The piers of the Grand River Bridge are founded on tremie concrete embedded approximately 2.0 m into the bedrock.

An underwater investigation, carried out by MMM Group Limited (MMM) on June 22, 2013, revealed progressive scouring at the Pier 2 location at both the EBL and WBL structures. However, the scouring effect had not progressed into the underlying bedrock and the exposed concrete below the water showed no sign of erosion. It is recommended that action is required to reduce the risks associated with ongoing scour. Options could include protecting the foundations in the river with scour protection consisting of rock protection or a cofferdam. Either of these alternatives would require hydraulic analysis and design. However, it is understood that rock protection or installation of a protection cofferdam is not the preferred option at this time due to the cost and the environmental permitting requirements. In view of this preference, it is recommended that the risks associated with scour should be mitigated by performing an annual underwater inspection at the pier locations to monitor and report on the extent and trend of scour as there is a risk that over time, the underlying bedrock of Salina Formation could exhibit gypsum dissolution and cavity development and that scour could undermine the structural integrity of the pier foundations. Under the discretion of MMM, PML can advance two boreholes into the river bed to collect bedrock cores to review the quality of the underlying bedrock near the pier locations as a due diligence prerequisite to the monitoring and reporting mitigation scheme.



The underlying bedrock of the Salina Formation consists of interbedded grey and green, irregularly bedded, soft, calcareous and argillaceous shale and layers of hard dolomite. Further, gypsum inclusions and/or precipitates were noted in the boreholes that penetrated the bedrock during investigation (Reference 2). Due to the presence of moderate to high sulphate content due to the gypsum and anhydrite minerals, it was recommended that sulphate resistant cement be used for all concrete in the footings (Reference 2). Since effects of sulphate attack have not been documented, it is likely not a problematic feature in the present case. However, routine inspection of sulphate attacks on the concrete at the pier locations is recommended.

Based on the scope of the work, a field investigation at the Grand River Bridge was carried out at the abutment locations on December 11 and 12, 2013.

8. CLOSURE

It is understood that the scope of work for the Grand River Bridge rehabilitation will include modification of the bridge abutments to semi-integral abutments and roadway protection. Further, it is recommended that routine inspections of the piers for scouring and sulphate attacks be carried out. In addition, it is suggested that two boreholes be advanced into the bedrock near the pier locations to obtain rock samples and to examine the rock quality conditions.



This Technical Memorandum was prepared by Mr. Robert Ng, PhD, P.Eng with the assistance of Mr. Nazibur Rahman, P.Eng and was reviewed by Mr. David Dundas, P.Eng., Senior Engineer. Mr. Carlos Nascimento, P.Eng. carried out a quality review of the report. We trust this memo is sufficient for your immediate needs. Please do not hesitate to contact us if you have any inquiries and/or comments.

Yours very truly,

Peto MacCallum Ltd.



Robert Ng, MBA, PhD, P.Eng.
Senior Project Engineer



Carlos M. P. Nascimento, P.Eng
Project Manager
MTO Designated Principal Contact

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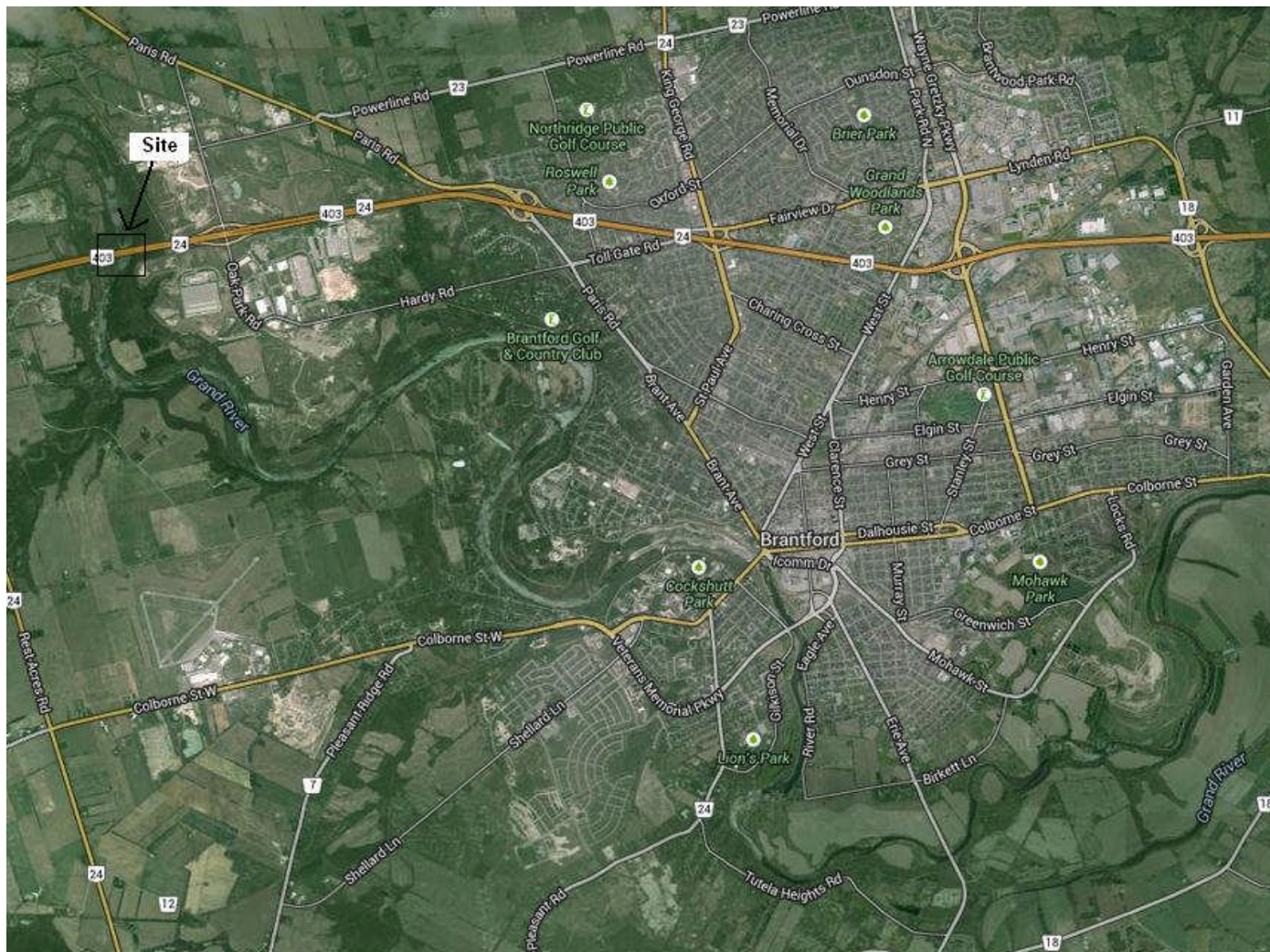


FIGURE 1- KEY PLAN



TABLE 1
BEDROCK AND GROUNDWATER INFORMATION

BH No.	Ground Surface Elevation (ft)	Ground Surface Elevation (m)	Bedrock Elevation (ft)	Bedrock Elevation (m)	Bedrock Depth (m)	Groundwater Elevation (ft)	Groundwater Elevation (m)
1	765.7	233.4	695.7	212.0	21.3	-	-
2	757.1	230.8	697.1	212.5	18.3	-	-
3	752.8	229.5	698.3	212.8	16.6	-	-
4	703.9	214.5	695.7	212.0	2.5	691.9	210.9 (P)
5	704.2	214.6	693.2	211.3	3.4	696.2	212.2 (O)
6	700.7	213.6	691.7	210.8	2.7	691.7	210.8 (O)
7	690.5	210.5	689.3	210.1	0.4	690.5	210.5 (O)
8	693.6	211.4	688.5	209.9	1.6	690.6	210.5 (O)
9	693.3	211.3	688.1	209.7	1.6	691.7	210.8 (O)
10	689.8	210.3	685.8	209.0	1.2	-	-
11	690.0	210.3	681.8	207.8	2.5	-	-
12	689.8	210.3	682.8	208.1	2.1	-	-
13	689.0	210.0	683.3	208.3	1.7	-	-
14	689.5	210.2	682.1	207.9	2.3	-	-
15	689.3	210.1	681.5	207.7	2.4	-	-
16	689.8	210.3	684.3	208.6	1.7	-	-
17	689.8	210.3	683.6	208.4	1.9	-	-
18	689.2	210.1	679.5	207.1	3.0	-	-
19	696.5	212.3	684.5	208.6	3.7	691.0	210.6 (P)
20	695.3	211.9	685.4	208.9	3.0	690.5	210.5 (P)
21	697.3	212.5	686.3	209.2	3.4	-	-
22	697.3	212.5	685.3	208.9	3.7	691.1	210.6 (P)
23	698.4	212.9	686.4	209.2	3.7	690.9	210.6 (O)
24	701.2	213.7	684.2	208.5	5.2	-	-
25	698.7	213.0	689.7	210.2	2.7	691.8	210.9 (O)
26	699.3	213.1	689.4	210.1	3.0	690.7	210.5 (O)
27	700.7	213.6	690.4	210.4	3.1	690.7	210.5 (O)
28	802.0	244.4	-	-	-	728.2	222.0 (P,A)
						777.5	237.0 (P,B)

Notes: 1. Bedrock elevation and depths are estimated from the borehole logs.
2. O: Water level in open hole; P: Water level in Piezometer
3. P,A: Water level in Pipe A of piezometer; P,B: Water level in Pipe B of piezometer

Please note that the above table are summarized data from record of borehole sheets and the SI units conversions were calculated from the imperial unit's values. The table is for reference purpose and is not meant for interpretation for design or construction purpose. The data should be read in conjunction with the geotechnical report (Geocres No. 40PO1-057). If discrepancies are found between the data given in the above table and the values in the report, please refer to original record of borehole sheets and original report as the correct version.



TABLE 2
FOUNDATION DESIGN PARAMETERS

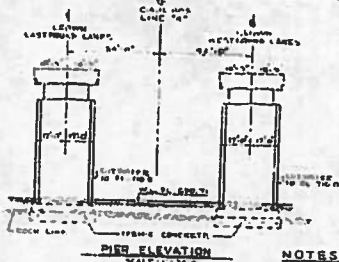
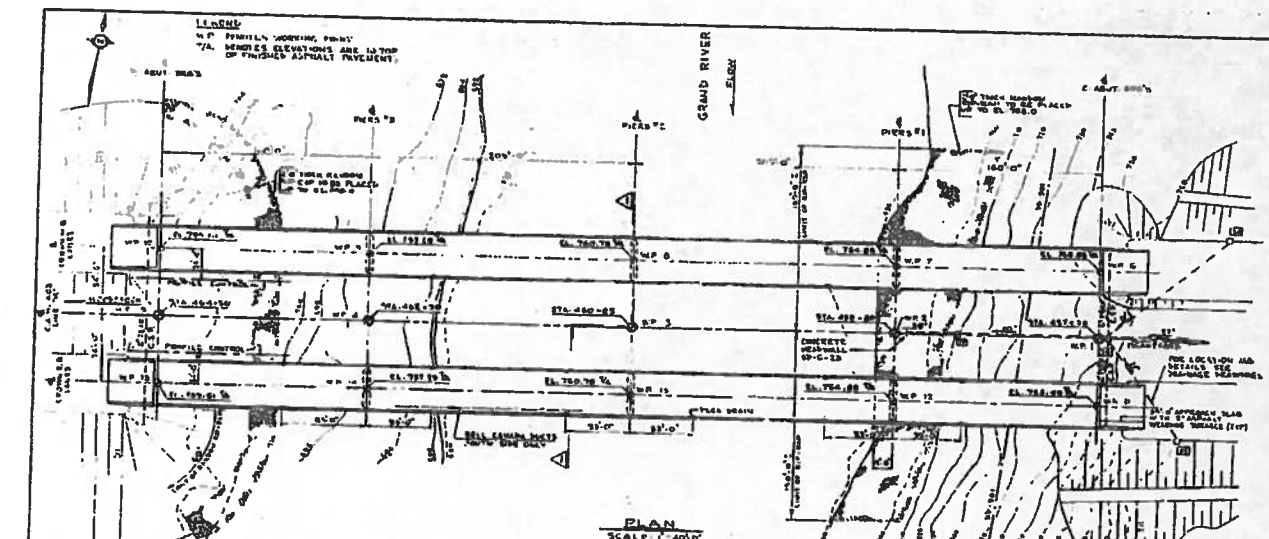
Foundation	Foundation Type	Founding Elevation		Previous Working Stress Values		Previous Equivalent Limit State Design Values				Limit State Design Values updated to current industry practice			
		(ft)	(m)	Safe Bearing Resistance (tons/sf)*	Safe Load Resistance (tons)*	Bearing Resistance (kPa)		Load Resistance (kN)		Bearing Resistance (kPa)		Load Resistance (kN)	
						SLS	Factored ULS	SLS	Factored ULS	SLS	Factored ULS	SLS	Factored ULS
Pier #1	Spread footing	681.0	207.6	10	—	1000	1500	—	—	1000	1500	—	—
Pier #2	Spread footing	675.0	205.7	10	—	1000	1500	—	—	1000	1500	—	—
Pier #3	Spread footing	677.0	206.3	10	—	1000	1500	—	—	1000	1500	—	—
East Abut. WBL	H-Pile (12BP74 = HP 310 x 110)	698.3	212.8	—	75	—	—	670	1000	—	—	1200	1800
West Abut. WBL	H-Pile (12BP74 = HP 310 x 110)	690.4	210.4	—	75	—	—	670	1000	—	—	1200	1800
East Abut. EBL	H-Pile (12BP74 = HP 310 x 110)	695.7	212.0	—	75	—	—	670	1000	—	—	1200	1800
West Abut. EBL	H-Pile (12BP74 = HP 310 x 110)	689.7	210.2	—	75	—	—	670	1000	—	—	1200	1800

Note: * Working stress design values. The Ultimate Limit State design values are based on the working stress. No field verifications were made.



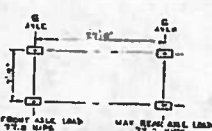
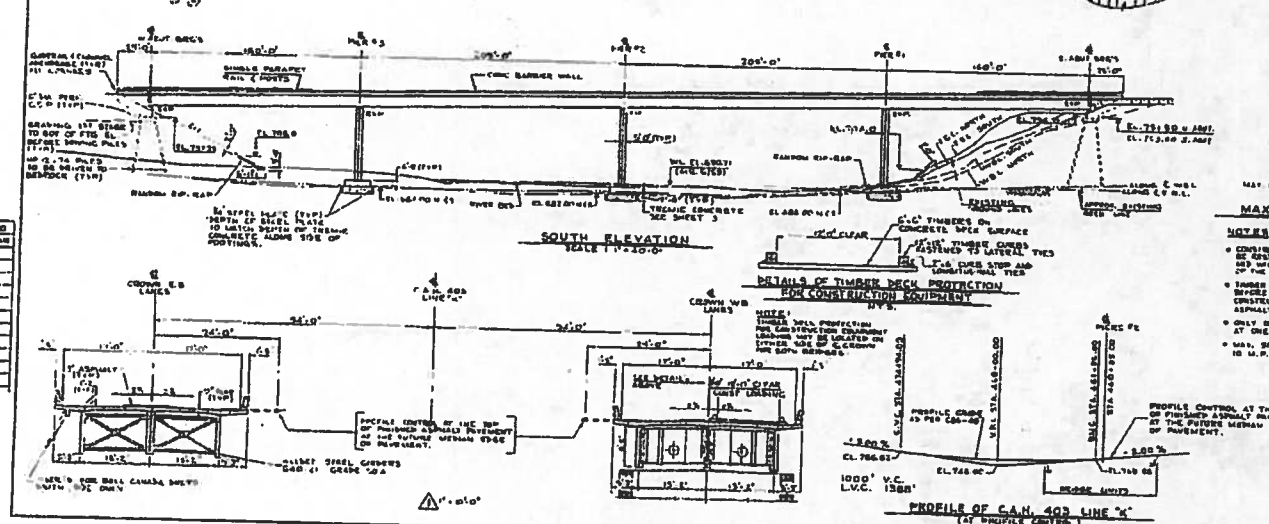
APPENDIX A

General Layout Plan



- DRAWING LIST**
- 1. GENERAL LAYOUT
 - 2. SOUTH ELEVATION
 - 3. WEST ELEVATION
 - 4. EAST ELEVATION
 - 5. WEST ABUTMENT
 - 6. EAST ABUTMENT
 - 7. PIER DETAILS
 - 8. PIER DETAILS
 - 9. STRUCTURAL STEEL I
 - 10. STRUCTURAL STEEL II
 - 11. STRUCTURAL STEEL III
 - 12. STRUCTURAL STEEL IV
 - 13. STRUCTURAL STEEL V
 - 14. DECK REINFORCEMENT
 - 15. EXPANSION JOINTS
 - 16. SCREENS
 - 17. CONCRETE BARRIER WALLS
 - 18. CONCRETE BARRIER WALLS
 - 19. STAIRCASE DETAILS
 - 20. STAIRCASE DETAILS
 - 21. STAIRCASE DETAILS
 - 22. UNFINISHED ELEV. 0 =

- NOTES:**
- CLASS OF MATERIALS**
- 1. REINFORCED CONCRETE 4000 P.S.I.
 - 2. CONCRETE CURB WALLS 4000 P.S.I.
 - 3. REINFORCED CONCRETE 4000 P.S.I.
 - 4. APPROXIMATE CLASS 4000 P.S.I.
 - 5. REINFORCEMENT 60000 P.S.I.
- CLASS OF STEEL**
- 1. STRUCTURAL STEEL I
 - 2. STRUCTURAL STEEL II
 - 3. STRUCTURAL STEEL III
 - 4. STRUCTURAL STEEL IV
 - 5. STRUCTURAL STEEL V
- CONSTRUCTION NOTES**
- 1. THE CONTRACTOR IS RESPONSIBLE FOR PROVIDING THE ELEVATIONS WITH A TOLERANCE OF 1/8".
 - 2. ALL CONCRETE SHALL BE PLACED ABOVE THE EXISTING GRADE LINE.
 - 3. ALL THE DECK HAS BEEN PLACED.
- CONCRETE QUANTITIES**
- CONCRETE QUANTITIES ARE LISTED BELOW FOR THE PRELIMINARY CONSTRUCTION OF THE BRIDGE:
- 1. CONCRETE IN CURB, ABUTMENTS, PIERS, AND WALLS 100,000 CU. YD.
 - 2. CONCRETE IN DECK 100,000 CU. YD.
 - 3. CONCRETE IN BARRIER WALLS 100,000 CU. YD.
 - 4. CONCRETE IN APPROACH SLABS 100,000 CU. YD.
- STRUCTURAL STEEL QUANTITIES**
- TOTAL LBS. OF STRUCTURAL STEEL 100,000 LBS.



- NOTES:**
- 1. CONSTRUCTION TRAFFIC ON THE STRUCTURE SHALL BE RESTRICTED TO THE MINIMUM EQUIPMENT LOADING AND SHALL BE PERMITTED ONLY IN DESIGNATED AREAS OF THE STRUCTURE.
 - 2. TRUCKS MAY NOT BE PLACED ON CONCRETE SLAB BEHIND THE ABUTMENT IS PLACED ON THE DECK. CONSTRUCTION LOADING IS PERMITTED AFTER APPROVAL IS PLACED IN THE DECK.
 - 3. ONLY ONE VEHICLE ALLOWED ON THE STRUCTURE AT ONE TIME.
 - 4. MAX. SPEED OF CONST. VEHICLES ON STRUCTURE 10 M.P.H.

B.M. 817.94
GEODETIC DATUM
N.E.W. 10 S. 80° E. 100' 0" 100' 0"

MINISTRY OF TRANSPORTATION AND COMMUNICATIONS
ONTARIO

GRAND RIVER BRIDGE
2.5 MILES WEST OF BRANTFORD, ONT.

GENERAL LAYOUT

APPROVED: [Signature] CONTRACT NO. 75-132

DATE: 10-1-60

FOR REDUCED PLAN

1" = 100'





APPENDIX B

Site Photographs from Field Reconnaissance



PHOTOGRAPH 1: Looking west from north shoulder of WBL of Hwy 403 at east bank of Grand River. (June 11, 2013)



PHOTOGRAPH 2: Looking east from north shoulder of WBL of Hwy 403 at west bank of Grand River. (June 11, 2013)



PHOTOGRAPH 3: West abutment of WBL. (June 11, 2013)



PHOTOGRAPH 4: Front slope of west abutment of WBL. (June 11, 2013)



PHOTOGRAPH 5: South slope of west abutment of WBL. (June 11, 2013)



PHOTOGRAPH 6: South slope of west abutment of WBL. (June 11, 2013)



PHOTOGRAPH 7: Vertical straight trees on south slope of west abutment of WBL. (June 11, 2013)



PHOTOGRAPH 8: North slope of west abutment of WBL. (June 11, 2013)



PHOTOGRAPH 9: North slope of west abutment of WBL. (June 11, 2013)



PHOTOGRAPH 10: West side of west pier of WBL. (June 11, 2013)



PHOTOGRAPH 11: East side and north side of west pier of WBL. (June 11, 2013)



PHOTOGRAPH 12: West abutment of EBL. (June 11, 2013)



PHOTOGRAPH 13: Front slope of west abutment of EBL. (June 11, 2013)



PHOTOGRAPH 14: South slope of west abutment of EBL. (June 11, 2013)



PHOTOGRAPH 15: South slope of west abutment of EBL. (June 11, 2013)



PHOTOGRAPH 16: North slope of west abutment of EBL. (June 11, 2013)



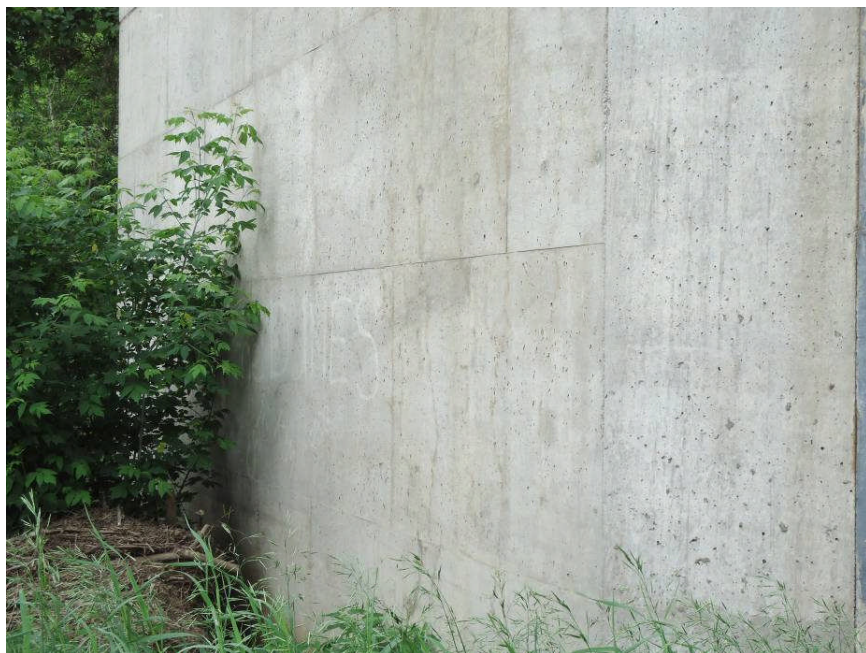
PHOTOGRAPH 17: North slope of west abutment of EBL. (June 11, 2013)



PHOTOGRAPH 18: Erosion on front slope of west abutment of EBL. (June 11, 2013)



PHOTOGRAPH 19: West side of west pier of EBL. (June 11, 2013)



PHOTOGRAPH 20: East side of west pier of EBL. (June 11, 2013)



PHOTOGRAPH 21: Scour at north side of west pier of EBL. (June 11, 2013)



PHOTOGRAPH 22: Scour at north and east sides of west pier of EBL. (June 11, 2013)



PHOTOGRAPH 23: East view from tope of slope between west abutments of WBL and EBL. (June 11, 2013)



PHOTOGRAPH 24: West side of middle pier of WBL. (June 11, 2013)



PHOTOGRAPH 25: East side of middle pier of WBL. (June 11, 2013)



PHOTOGRAPH 26: West side of middle pier of EBL. (June 11, 2013)



PHOTOGRAPH 27: East side of middle pier of EBL. (June 11, 2013)



PHOTOGRAPH 28: East abutments of WBL. (June 11, 2013)



PHOTOGRAPH 29: North slope of east abutments of WBL. (June 11, 2013)



PHOTOGRAPH 30: North slope of east abutments of WBL. (June 11, 2013)



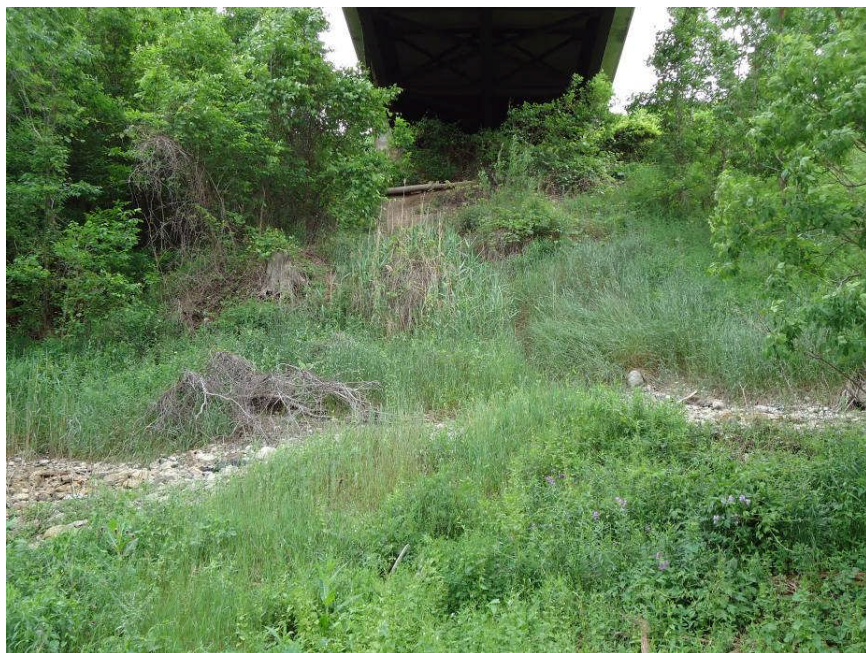
PHOTOGRAPH 31: South slope of east abutments of WBL. (June 11, 2013)



PHOTOGRAPH 32: South slope of east abutments of WBL. (June 11, 2013)



PHOTOGRAPH 33: Front slope of east abutments of WBL. (June 11, 2013)



PHOTOGRAPH 34: Front slope of east abutments of WBL. (June 11, 2013)



PHOTOGRAPH 35: East side of east pier of WBL. (June 11, 2013)



PHOTOGRAPH 36: West side of east pier of WBL. (June 11, 2013)



PHOTOGRAPH 37: Front slope of east abutment of EBL. (June 11, 2013)



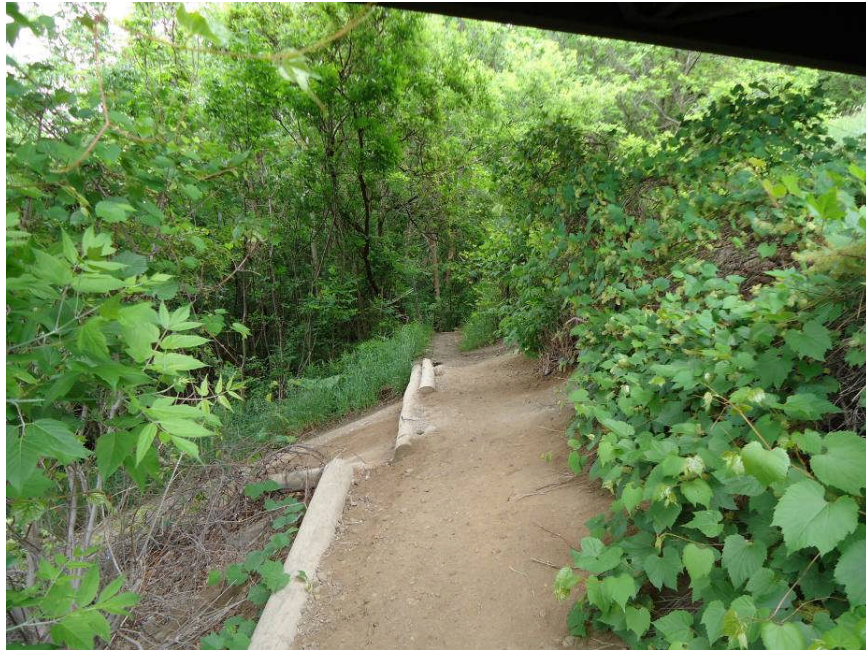
PHOTOGRAPH 38: Front slope of east abutment of EBL. (June 11, 2013)



PHOTOGRAPH 39: Front slope of east abutment of EBL. (June 11, 2013)



PHOTOGRAPH 40: A trail (south view) passing front slope of east abutment of EBL. (June 11, 2013)



PHOTOGRAPH 41: A trail (north view) passing front slope of east abutment of WBL. (June 11, 2013)



PHOTOGRAPH 42: South slope of east abutment of EBL. (June 11, 2013)



PHOTOGRAPH 43: South slope of east abutment of EBL. (June 11, 2013)



PHOTOGRAPH 44: North slope of east abutment of EBL. (June 11, 2013)



PHOTOGRAPH 45: Slope between east abutments of WBL and EBL.
(June 11, 2013)



PHOTOGRAPH 46: West view from tope of slope between east abutments
of WBL and EBL. (June 11, 2013)



PHOTOGRAPH 47: East side of east pier of EBL. (June 11, 2013)



PHOTOGRAPH 48: West side of east pier of EBL. (June 11, 2013)



PHOTOGRAPH 49: Manhole of drainage pipe between WBL and EBL on east bank of Grand River. (June 11, 2013)



PHOTOGRAPH 50: Surface drainage hidden ditch between WBL and EBL on east bank of Grand River. (June 11, 2013)



PHOTOGRAPH 51: Manhole of drainage pipe at slope top between east abutments of WBL and EBL. (June 11, 2013)

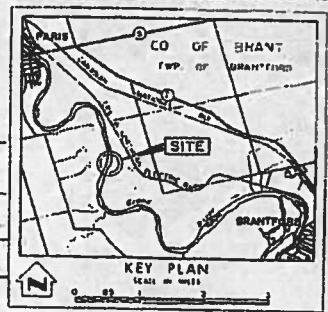
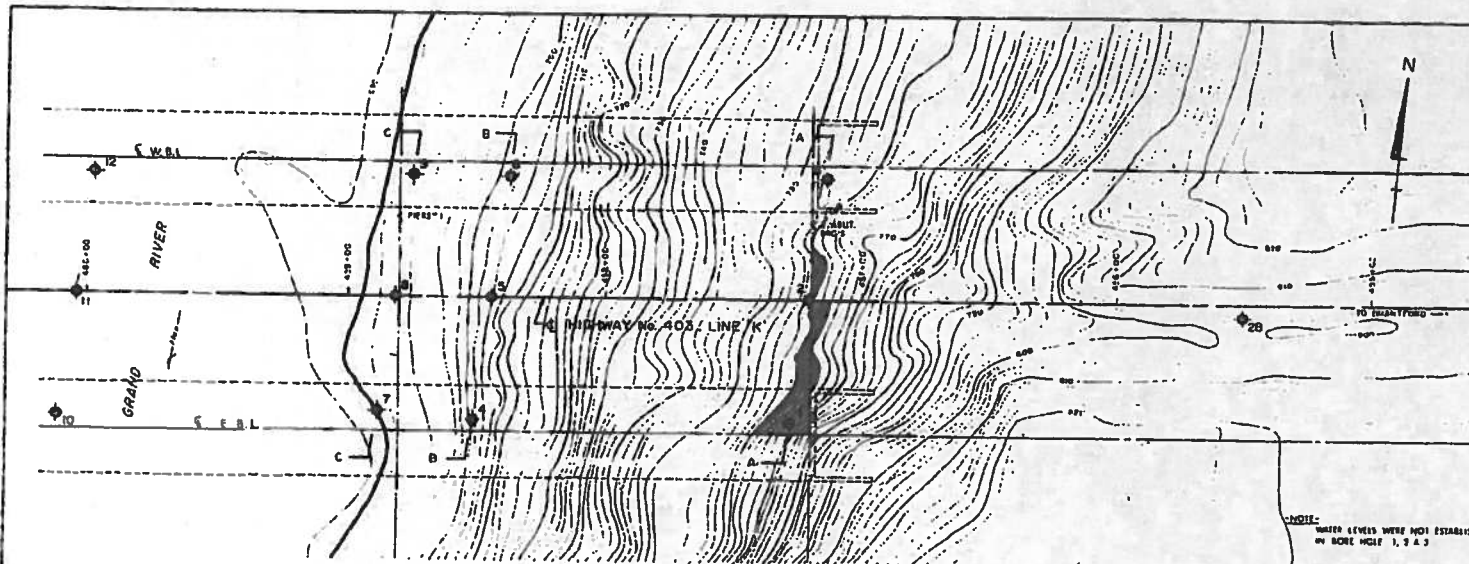


PHOTOGRAPH 52: Outlet of drainage pipe between WBL and EBL on east bank of Grand River. (June 11, 2013)



APPENDIX C

Borehole Location and Soil Stratigraphy

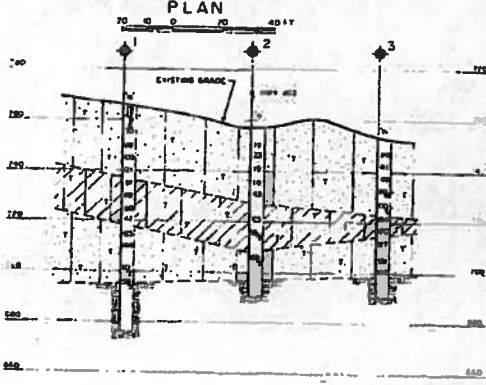
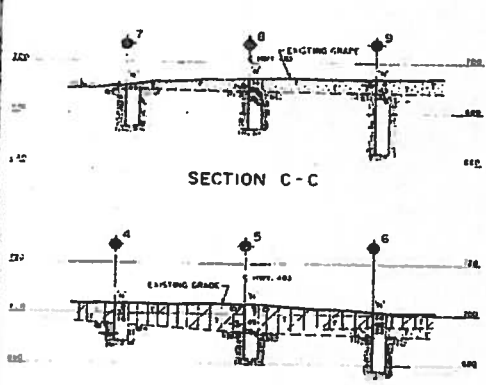


LEGEND

- Bore Hole
- ⊕ Core Penetration Test
- ⊕ Bore Hole & Core Test
- ⊕ Water Levels established on some of the bore holes (Oct - Nov 1971)

NO	ELEVATION	SECTION	OFFSET
1	738.7	497+21	40' S. 1
2	737.1	454+21	1
3	732.0	407+20	40' S. 1
4	703.9	436+40	40' S. 1
5	704.2	438+44	1
6	703.7	438+44	40' S. 1
7	690.3	438+44	40' S. 1
8	693.6	438+44	1
9	693.1	438+44	40' S. 1
10	690.0	438+44	40' S. 1
11	690.0	438+44	1
12	690.0	438+44	40' S. 1
13	690.0	438+44	1

NOTE: OFFSET MEASURED ON 8" BENCH FROM PLAN



- STRATIGRAPHY**
- 26 Coarse brown sandy silt to silt; sand with some gravel, cobbles and boulders (upper sandy silt till)
 - 12 Very silt in hard layered brown to grey silt clay to clayey silt with some sand, gravel, and cobbles (till)
 - 14 Very dense sandy silt to silt; sand with layers of sand and gravel, some cobbles (lower sandy silt till)
 - 27 BEDROCK - KALINA FORMATION

NOTE
The boundaries between soil units have been established on the basis of bore hole locations. Between bore holes the boundaries are derived from geologic log evidence and may be subject to considerable error.

NOTE FOR CONTRACT DOCUMENT
The complete foundation investigation report for this structure may be obtained at the Structural Office and Foundation Office, Brantford, and at the Hamilton, Ontario Office.

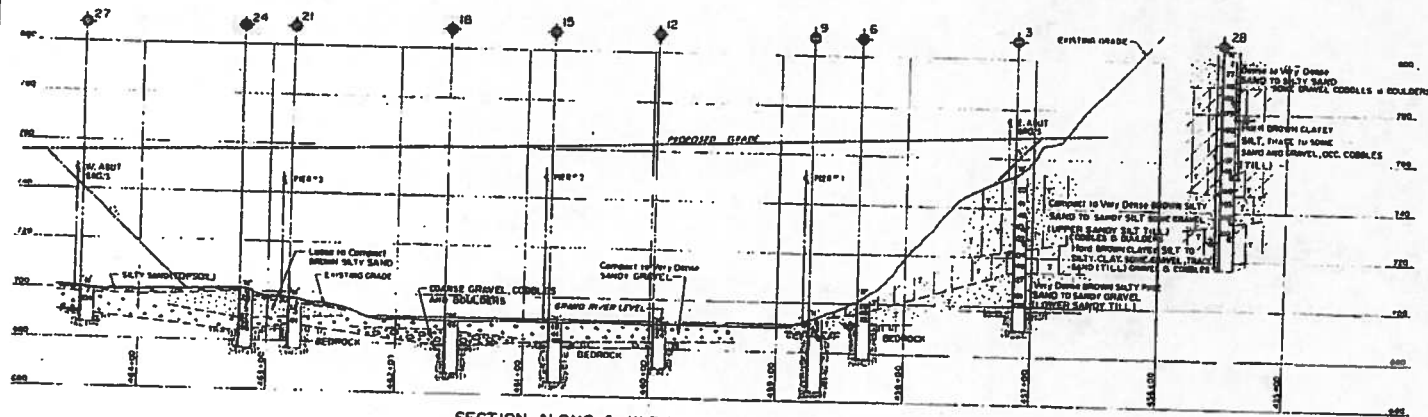
Geolder Associates
DEPARTMENT OF TRANSPORTATION & COMMUNICATIONS
HIGHWAY BRANCH
REGISTRATION OFFICE

GRAND RIVER

HIGHWAY NO. 403 - LINE "K" DIST. NO. 4
CO. OF BRANT
TWP. OF BRANT LOT 16 CON. 11

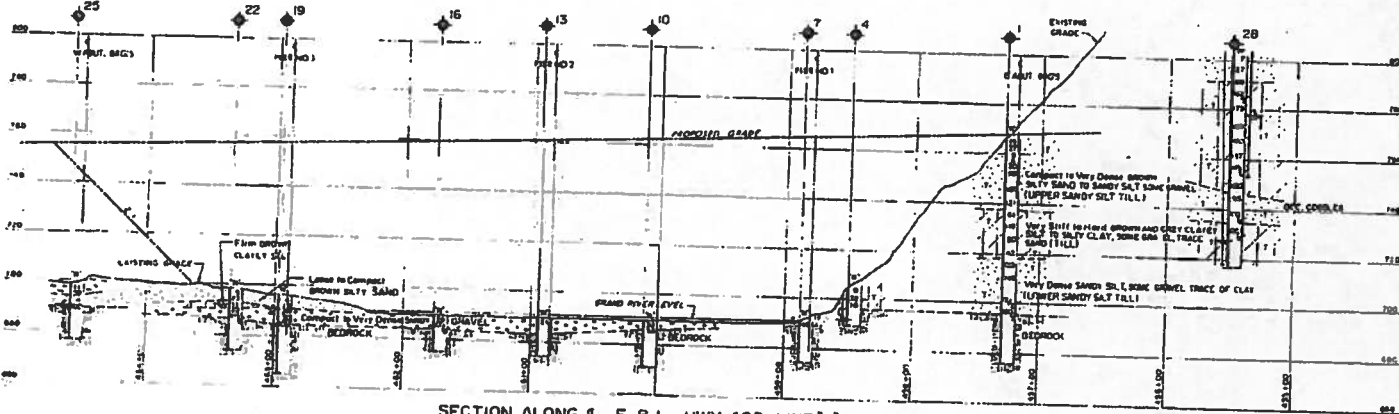
BORE HOLE LOCATIONS & SOIL STRATA

BORE HOLE	DATE	NO. OF PAGES	NO. OF PAGES	NO. OF PAGES
71122 - 1	71122	71122	71122	71122
71122 - 1	71122	71122	71122	71122
71122 - 1	71122	71122	71122	71122



SECTION ALONG W.B.L., HWY. 403, LINE "K"

NOTE: WATER LEVELS WERE NOT ESTABLISHED ON BORE HOLES 1, 2, 21 & 24



SECTION ALONG E.B.L., HWY. 403, LINE "K"

VERT. SCALE
1" = 20 FT
HORIZ. SCALE
1" = 100 FT

NOTE: FOR CONTRACT DOCUMENT
The complete foundation investigation report for this project may be obtained at the Investor's Office and Engineering Office, Department of Transportation & Communications, Grand River.

REFER DRAWING 71122-1

KEY PLAN
Scale 1/4" = 100'

LEGEND

- ◆ Bore Hole
- ⊕ Cone Penetration Test
- ⊕ Bore Hole & Cone Test
- ⊕ Water Level (established at time of field investigation 10/1 - 10/15/1971)
- ⊕ Parameter Water Level Shown This

NO	ELEVATION	STATION	OF SET
1	712.00	101+00	11
2	712.00	101+00	11
3	712.00	101+00	11
4	712.00	101+00	11
5	712.00	101+00	11
6	712.00	101+00	11
7	712.00	101+00	11
8	712.00	101+00	11
9	712.00	101+00	11
10	712.00	101+00	11
11	712.00	101+00	11
12	712.00	101+00	11
13	712.00	101+00	11
14	712.00	101+00	11
15	712.00	101+00	11
16	712.00	101+00	11
17	712.00	101+00	11
18	712.00	101+00	11
19	712.00	101+00	11
20	712.00	101+00	11
21	712.00	101+00	11
22	712.00	101+00	11
23	712.00	101+00	11
24	712.00	101+00	11
25	712.00	101+00	11
26	712.00	101+00	11
27	712.00	101+00	11
28	712.00	101+00	11

NOTE: FOR LOCATION AND ELEVATION OF BOREHOLES 1 TO 12 AND 20, REFER DRAWING 71122-1. BOREHOLES 13 TO 27 REFER DRAWING 71122-2.

NOTE: The boundaries between soil strata have been established only at borehole locations. Therefore they may be subject to considerable error.

Golder Associates	
DEPARTMENT OF TRANSPORTATION & COMMUNICATIONS	
GRAND RIVER	
SECTION NO. 403 - LINE "K"	
CD OF BRANT	DIST NO. 4
TWP. OF BRANTFORD	CON. 11
BORE HOLE LOCATIONS & SOIL STRATA	
DATE: NOV. 1971	DRAWING NO. 71122-3
APPROVED: [Signature]	PROJECT NO. 71122-3
DATE: NOV. 1971	CONTRACT NO. 71122-3



APPENDIX D

Relevant Record of Borehole Sheets

LIST OF ABBREVIATIONS

The abbreviations commonly employed on each "Record of Borehole," on the figures and in the text of the report, are as follows:

I. SAMPLE TYPES

AS auger sample
CS chunk sample
DO drive open
DS Denison type sample
FS foil sample
RC rock core
ST slotted tube
TO thin-walled, open
TP thin-walled, piston
WS wash sample

II. PENETRATION RESISTANCES

Dynamic Penetration Resistance: The number of blows by a 140-pound hammer dropped 30 inches required to drive a 2-inch diameter, 60 degree cone one foot, where the cone is attached to 'A' size drill rods and casing is not used.

Standard Penetration Resistance, *N*: The number of blows by a 140-pound hammer dropped 30 inches required to drive a 2-inch drive open sampler one foot.

WH sampler advanced by static weight—weight, hammer

PH sampler advanced by pressure—pressure, hydraulic

PM sampler advanced by pressure—pressure, manual

III. SOIL DESCRIPTION

(a) Cohesionless Soils

<i>Relative Density</i>	<i>N, blows/ft.</i>
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils

<i>Consistency</i>	<i>c_u, lb./sq. ft.</i>
Very soft	Less than 250
Soft	250 to 500
Firm	500 to 1,000
Stiff	1,000 to 2,000
Very stiff	2,000 to 4,000
Hard	over 4,000

IV. SOIL TESTS

C consolidation test
H hydrometer analysis
M sieve analysis
MH combined analysis, sieve and hydrometer¹
Q undrained triaxial²
R consolidated undrained triaxial²
S drained triaxial
U unconfined compression
V field vane test

NOTES:

¹Combined analyses when 5 to 95 per cent of the material passes the No. 200 sieve.

²Undrained triaxial tests in which pore pressures are measured are shown as \bar{Q} or \bar{R} .

LIST OF SYMBOLS

I. GENERAL

π	= 3.1416
e	= base of natural logarithms 2.7183
$\log_e a$ or $\ln a$	natural logarithm of a
$\log_{10} a$ or $\log a$	logarithm of a to base 10
t	time
g	acceleration due to gravity
V	volume
W	weight
M	moment
F	factor of safety

II. STRESS AND STRAIN

u	pore pressure
σ	normal stress
σ'	normal effective stress ($\bar{\sigma}$ is also used)
τ	shear stress
ϵ	linear strain
ϵ_{xy}	shear strain
ν	Poisson's ratio (μ is also used)
E	modulus of linear deformation (Young's modulus)
G	modulus of shear deformation
K	modulus of compressibility
η	coefficient of viscosity

III. SOIL PROPERTIES

(a) Unit weight

γ	unit weight of soil (bulk density)
γ_s	unit weight of solid particles
γ_w	unit weight of water
γ_d	unit dry weight of soil (dry density)
γ'	unit weight of submerged soil
G_s	specific gravity of solid particles $G_s = \gamma_s / \gamma_w$
e	void ratio
n	porosity
w	water content
S_r	degree of saturation

(b) Consistency

w_L	liquid limit
w_P	plastic limit
I_P	plasticity index
w_s	shrinkage limit
I_L	liquidity index $= (w - w_P) / I_P$
I_C	consistency index $= (w_L - w) / I_P$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
D_r	relative density $= (e_{max} - e) / (e_{max} - e_{min})$

(c) Permeability

h	hydraulic head or potential
q	rate of discharge
v	velocity of flow
i	hydraulic gradient
k	coefficient of permeability
j	seepage force per unit volume

(d) Consolidation (one-dimensional)

m_v	coefficient of volume change $= -\Delta e / (1+e) \Delta \sigma'$
C_c	compression index $= -\Delta e / \Delta \log_{10} \sigma'$
c_r	coefficient of consolidation
T_v	time factor $= c_r / d^2$ (d , drainage path)
U	degree of consolidation

(e) Shear strength

τ_f	shear strength
c'	effective cohesion intercept
ϕ'	effective angle of shearing resistance, or friction
c_u	apparent cohesion*
ϕ_u	apparent angle of shearing resistance, or friction
μ	coefficient of friction
S_f	sensitivity

$\left. \begin{array}{l} \text{in terms of effective stress} \\ \tau_f = c' + \sigma' \tan \phi' \end{array} \right\}$

$\left. \begin{array}{l} \text{in terms of total stress} \\ \tau_f = c_u + \sigma \tan \phi_u \end{array} \right\}$

*For the case of a saturated cohesive soil, $\phi_u = 0$ and the undrained shear strength $\tau_f = c_u$ is taken as half the undrained compressive strength.

RECORD OF BOREHOLE 1

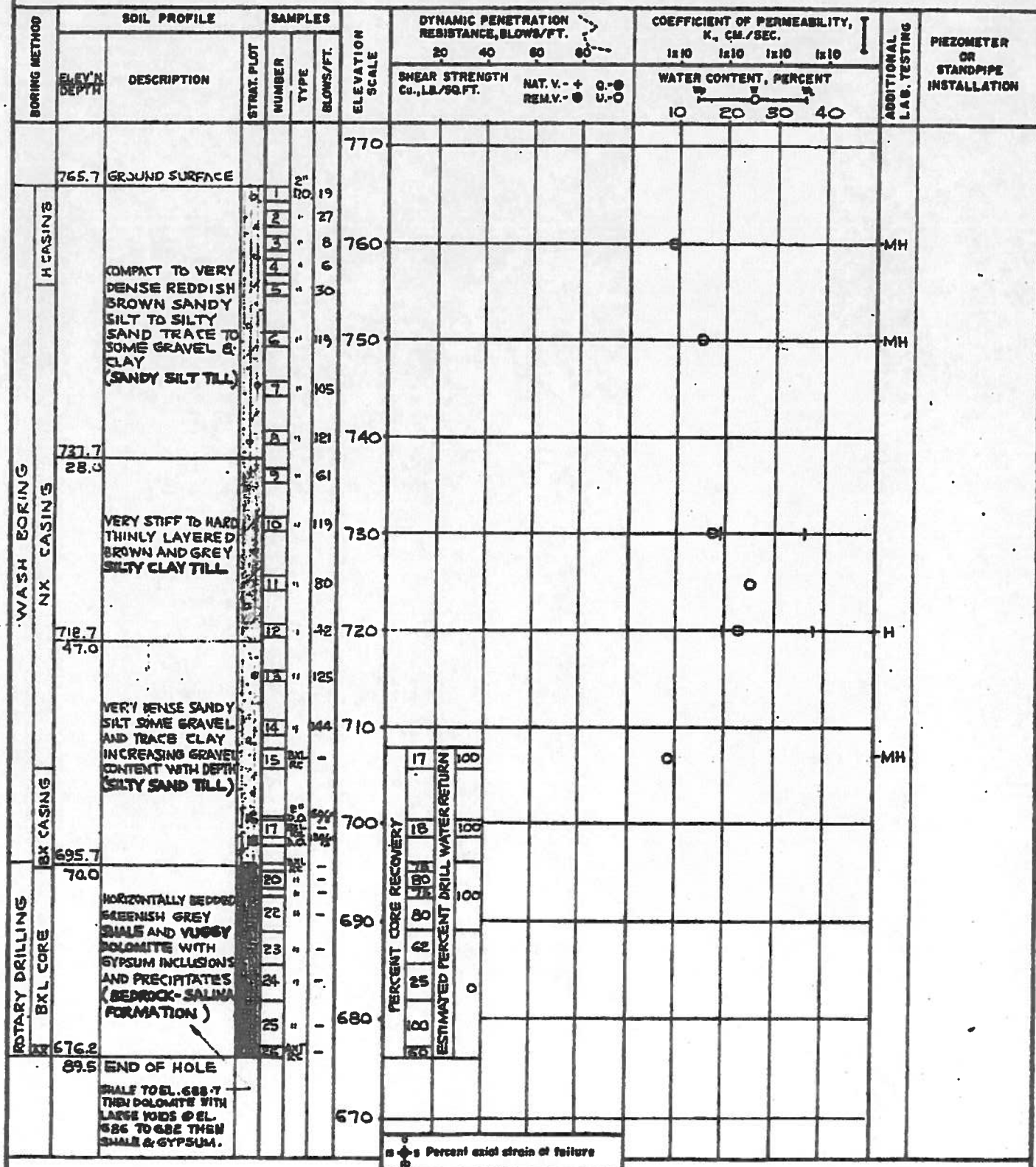
LOCATION See Figure 1

BORING DATE OCT. 28 TO NOV. 9, 1971

DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN.

PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.



Percent axial strain at failure

VERTICAL SCALE
1 IN TO 10 FT

Goldier Associates

DRAWN *[Signature]*
CHECKED *[Signature]*

RECORD OF BOREHOLE 2

LOCATION See Figure 1

BORING DATE NOV. 10-16, 1971

DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN.

PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.

BORING METHOD	SOIL PROFILE			SAMPLES			ELEVATION SCALE	DYNAMIC PENETRATION RESISTANCE, BLOWS/FT.				COEFFICIENT OF PERMEABILITY, K, CM./SEC.				ADDITIONAL L.A.B. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
	ELEV./N. DEPTH	DESCRIPTION	STRAT. PLAT	NUMBER	TYPE	BLOWS/FT.		20 40 60 80				1x10 1x10 1x10 1x10					
								SHEAR STRENGTH Cu., LB./SQ.FT. NAT. V. - + P. - O. REM. V. - O. - U. - O.				WATER CONTENT, PERCENT 10 20 30 40					
WASH BORING NX CASING	757.1	GROUND SURFACE					760									G.S. 7 SURFACE SEAL	
	0.0																
		COMPACT BROWN SANDY SILT WITH THIN LAYERS OF SILT AND FINE SAND SOME GRAVEL (SANDY SILT TILL)		1	"	19	750										
				2	"	22											
				3	"	19	740										
ROTARY DRILLING BX CASING	736.6						740									MH GRANULAR BACKFILL	
	20.5	COMPACT TO DENSE SILTY SAND SOME GRAVEL (SILTY SAND TILL)		4	"	18											
				5	"	43	730										
	723.1																
	23.0	HARD REDDISH - BROWN TO BROWN SILT, SOME SAND GRAVEL AND CLAY (SILTY CLAY TILL)		6	"	65	720										
				7	"	1/2											
	713.6																
	43.5	HARD REDDISH BROWN SILTY CLAY SOME SAND (TILL)		8	"	1	710										
	708.8																
	48.3	VERY DENSE BROWN SILTY SAND, SOME COBBLES & BOULDER THROUGHOUT (SILTY SAND TILL)		10	"	12 1/2											
BXL CORE	697.1						700									BENTONITE SEAL PIEZOMETER PEA GRAVEL BENTONITE SEAL GRANULAR BACKFILL	
	60.0	BLIND GREEN-GRAY SHALE (BEDROCK-SALINA FORMATION)		12	"	-											
	690.8			13	"	-											
	66.3	END OF HOLE					690									PIEZOMETER DRY TO ELEV. 701 - 1 NOV. 29, 1971	
		ZONES OF BRECCIA-LIKE CONGLOMERATE IN OLD VOIDS.					680										

Percent axial strain at failure

VERTICAL SCALE
1 IN. TO 10 FT.

Golder Associates

DRAWN *[Signature]*
CHECKED *[Signature]*

RECORD OF BOREHOLE 3

LOCATION See Figure 1

BORING DATE NOV. 18, 1971

DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN.

PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.

BORING METHOD	SOIL PROFILE			SAMPLES		ELEVATION SCALE	DYNAMIC PENETRATION RESISTANCE, BLOWS/FT.				COEFFICIENT OF PERMEABILITY, K, CM./SEC.				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION	
	ELEV'N DEPTH	DESCRIPTION	STRAT. PLT	NUMBER	TYPE		BLOWS/FT.	SHEAR STRENGTH				WATER CONTENT, PERCENT					
								C _u , LB./SQ.FT.				NAT. V. - + Q - ● REM. V. - ● U - ○					
ROTARY DRILLING	WASH BORING NX CASING	752.8	GROUND SURFACE														
		0.0															
			COMPACT TO DENSE SILTY SAND TO SANDY SILT SOME GRAVEL, COBBLES AND BOULDERS (SANDY SILT TILL)														
ROTARY DRILLING	NX CASING	722.8															
		30.0	HARD RED-BROWN CLAYEY SILT TRACE TO SOME SAND, GRAVEL & COBBLES (CLAYEY SILT TILL)														
		713.8															
		39.0	VERY DENSE BROWN SILTY FINE SAND (SILTY SAND TILL)														
ROTARY DRILLING	NX CASING	702.8															
		50.0	VERY DENSE BROWN SAND & GRAVEL (TILL)														
		698.3															
		54.5	WEATHERED GREEN SHALE WITH DOLOMITE LENS (BEDROCK - SALINA FORMATION)														
ROTARY DRILLING	NX CASING	690.3															
		62.5	END OF HOLE														

G.S.

BENTONITE SEAL

GRANULAR FILL

PIEZOMETER BENTONITE SEAL

PIEZOMETER DRY TO ELEV. 696.8 NOV. 29, 1971.

ESTIMATED PERCENT DRILL WATER RETURN

PERCENT CORE RECOVERY

Percent axial strain at failure

VERTICAL SCALE
1 IN. TO 10 FT.

Golder Associates

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CHECKED *[Signature]*

DATUM GENETIC

PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.

BORING METHOD		SOIL PROFILE			SAMPLES		ELEVATION SCALE	DYNAMIC PENETRATION RESISTANCE, BLOWS/FT.				COEFFICIENT OF PERMEABILITY, K, CM./SEC.				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION			
		ELEV. N. DEPTH	DESCRIPTION	STRAT. PLT.	NUMBER	TYPE		BLOWS/FT.	20	40	60	80	1x10	1x10	1x10			1x10		
ROTARY	WASH	COR'E	BX CASING	75.7	GROUND SURFACE															
				0.0	STIFF TO VERY STIFF REDDISH GREY BROWN CLAYEY SILT (TILL)	1	2"	8												
				635.7		2	"	32												
				8.2	GREENISH GREY SHALE WITH DOLOMITE & GYPSUM LAYERS (BEDROCK - S.F.)	3	"	18												
				659.1		5	"	-	100	100										
				14.8	END OF HOLE															
<p>DOLOMITE TO EL. 693.4 THIN SHALE WITH CLAY INCLUSIONS @ EL. 681</p> <p>ESTIMATED PERCENT DRILL WATER RETURN</p> <p>PERCENT CORE RECOVERY</p>																				
ROTARY	DRY	EXT. CORE	EXCAVATE	704.2	GROUND SURFACE															
				0.0	CLAYEY SILT WITH COBBLES & BOULDERS	1	2"	6												
				701.2		2	"	7												
				3.0	FIRM TO HARD BROWN SANDY CLAYEY SILT, SOME GRAVEL (TILL)	3	"	49												
				693.2		5	"	-	100	100										
				11.0	WEATHERED GREEN SHALE & FRACTURED MUGGY DOLOMITE (BEDROCK - SALINA FORMATION)	6	2"	-	74	100										
				652.5		7	"	-	42	0										
<p>END OF HOLE</p> <p>SHALE TO EL. 687 OVER HIGHLY FRACTURED DOLOMITE AND SHALE</p> <p>ESTIMATED PERCENT DRILL WATER RETURN</p> <p>PERCENT CORE RECOVERY</p>																				

W.L. IN STANDPIPE AT ELEV. 691.9 ON NOV. 6, 1971
STANDPIPE DESTROYED NOV. 29, 1971.

W.L. IN OPEN HOLE AT ELEV. 696.2, NOV. 8/71

VERTICAL SCALE
1 IN. TO 10 FT.

Golder Associates

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CHECKED *[Signature]*

RECORD OF BOREHOLES 6 & 7

LOCATION See Figure 1

BORING DATE NOV. 3 - 11, 1971

DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN.

PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.

BORING METHOD	SOIL PROFILE		SAMPLES		ELEVATION SCALE	DYNAMIC PENETRATION RESISTANCE, BLOWS/FT.				COEFFICIENT OF PERMEABILITY, K, CM./SEC.				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
	ELEV'TN DEPTH	DESCRIPTION	STRAT. PLAT	NUMBER TYPE		20	40	60	80	1x10	1x10	1x10	1x10		
ROTARY DRILLING BX CASING	700.7	GROUND SURFACE		1	28										
	695.7	VERY STIFF TO HARD BROWN CLAYEY SILT SOME SAND		2	48										
	691.7	COMPACT SANDY GRAVEL, SOME SILT		3	22										
	677.7	WEATHERED AND FRACTURED GREEN SHALE AND VUGGY DOLOMITE WITH GYPSUM INCLUSIONS (BEDROCK-SALINA FORMATION) BECOMING SOUND BELOW ELEV. 681		6	11	40	100								
				8		60									
				9		92	0								
	23.0	END OF HOLE													
ROTARY DRILLING BX CASING	690.5	GROUND SURFACE		1	45										
	673.9	INTERBEDDED GREENISH GREY SHALE AND DOLOMITE, BECOMING SOUND BELOW ELEV. 679 BUT WITH GYPSUM INCLUSIONS (BEDROCK-SALINA FORMATION)		3		47	10								
				4		61									
				7		16									
						98	100								
	16.6	END OF HOLE													
		INTERBEDDED SHALE AND DOLOMITE TO EL. 679													

Percent axial strain at failure

VERTICAL SCALE
1 IN. TO 10 FT.

Golder Associates

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CHECKED *[Signature]*

RECORD OF BOREHOLES 8 & 9

LOCATION See Figure 1

BORING DATE NOV. 1-3 1971

DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN.

PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.

BORING METHOD	SOIL PROFILE		SAMPLES			ELEVATION SCALE	DYNAMIC PENETRATION RESISTANCE, BLOWS/FT.				COEFFICIENT OF PERMEABILITY, K_v , CM./SEC.				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION	
	ELEV. N. DEPTH	DESCRIPTION	STRAT. PLT	NUMBER	TYPE		BLOWS/FT.										
								20	40	60	80	1x10	1x10	1x10			1x10
ROTARY CORE EX CASING	623.6	GROUND SURFACE														11 IN OPEN HOLE AT ELEV. 690-6 NOV. 3, 1971	
	688.5	DENSE FINE TO MEDIUM SAND WITH GRAVEL & BOULDER		1	1	14											
	5.1	WEATHERED GREY SHALE WITH LIGHT GREY DOLOMITE WITH GYPSUM INCLUSIONS (BEDROCK SALINA FORMATION)		4	1		15	50									
				5	1		39	5									
				6	1		70										
				7	1		30	0									
	673.9	END OF HOLE															
	19.7	WAGGY DOLOMITE LAYER BETWEEN EL. 664 & EL. 680															
ROTARY DRILLING BXL CORE EX CASING	633.3	GROUND SURFACE													11 IN OPEN HOLE AT ELEV. 691-7 NOV. 5, 1971		
	683.1	DENSE BROWN SAND, SOME GRAVEL, TRACE SILT		1	1	8											
	5.2	WEATHERED SHALE BECOMING SAND SHALE BELOW ELEV. 681 WITH DOLOMITE LAYERS CONTAINING INCLUSIONS AND PRECIPITATES OF GYPSUM (BEDROCK SALINA FORMATION)		2	1	43											
				3	1		100	100									
				4	1		57	100									
				5	1		23	25									
				6	1		61	0									
				7	1		100										
				8	1		68										
				9	1		100										
			10	1		100											
			11	1		100											
			12	1		100											
	23.1	END OF HOLE															
		DOLOMITE TO EL. 684, THEN SHALE TO EL. 677 OVERLYING THIN INTERBEDDED SHALE AND DOLOMITE.															

Percent axial strain at failure

VERTICAL SCALE
1 IN. TO 10 FT

Golden Associates

DRAWN
CHECKED

RECORD OF BOREHOLES 12 & 13

LOCATION See Figure 1 & 2

BORING DATE NOV. 9, 10, 11 & 22, 1971

DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN.

PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.

BORING METHOD	SOIL PROFILE			SAMPLES		ELEVATION SCALE	DYNAMIC PENETRATION RESISTANCE, BLOWS/FT.				COEFFICIENT OF PERMEABILITY, K., CM./SEC.				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION	
	ELEVATION DEPTH	DESCRIPTION	STRAT. PLT	NUMBER	TYPE		BLOWS/FT.	20 40 60 80				1x10 1x10 1x10 1x10					
								SHEAR STRENGTH Cu., LB./SQ. FT.				WATER CONTENT, PERCENT					
ROTARY DRILLING BX CASING BXL CORE	690.8	RIVER LEVEL															
	0.0	WATER															
	1.0	COMPACT TO VERY DENSE SANDY SILT WITH COBBLES AND BOULDERS		1	SP	56											
	682.8			2	"	24											
	8.0	FRACTURED GREY MUGGY DOLOMITE BECOMING SOUND BELOW ELEV. 680 WITH GYPSUM INCLUSIONS (BEDROCK - SALINA FORMATION)		6	"	111											
	672.1			7	"												
	18.7	END OF HOLE															
							12										

RECORD OF BOREHOLE S 14 & 15

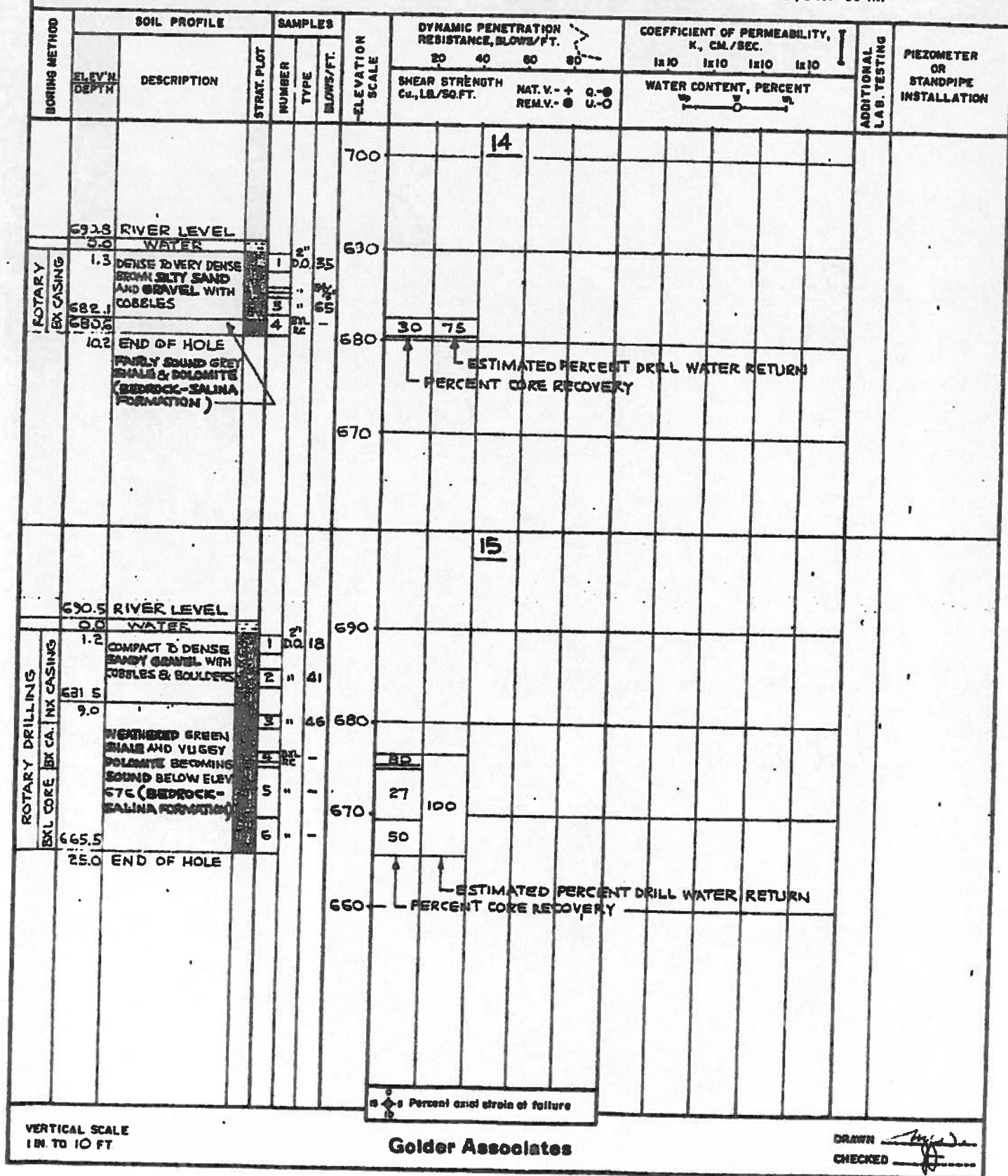
LOCATION See Figure 2

BORING DATE NOV. 18 & 24, 25 1971

DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN.

PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.



RECORD OF BOREHOLES 16 & 17

LOCATION See Figure 2

BORING DATE NOV. 12, 15 & 25, 1971

DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN.

PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.

BORING METHOD	SOIL PROFILE		SAMPLES			ELEVATION SCALE	DYNAMIC PENETRATION RESISTANCE, BLOWS/FT.				COEFFICIENT OF PERMEABILITY, K, CM./SEC.				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
	ELEV. N. DEPTH	DESCRIPTION	STRAT. PLT	NUMBER	TYPE		20	40	60	80	1x10	1x10	1x10	1x10		
ROTARY DRILLING EX. CORE (EX. CASING)	690.8	RIVER LEVEL														
	1.0	VERY DENSE SANDY GRAVEL WITH COBBLES AND BOULDERS		1	SD	58										
	684.3	WEATHERED INTERBEDDED SHALE AND DOLOMITE WITH CLAY LENS (BEDROCK-SALINA FORMATION)		2	SD	58										
	674.9	END OF HOLE		3	SD	58										
	15.9	SOUND SHALE BELOW EL. 678		4	SD	58										
ROTARY EX. CASING	690.8	RIVER LEVEL														
	1.0	DENSE TO VERY DENSE BROWN SAND & GRAVEL SOME SILT & COBBLES		1	SD	41										
	683.6	END OF HOLE		2	SD	90										
	681.6	FAIRLY SOUND DOLOMITE & SHALE (BEDROCK-SALINA FORMATION)		3	SD	90										
	9.2	END OF HOLE		4	SD	90										

Percent axial strain at failure

VERTICAL SCALE
1 IN. TO 10 FT.

Golder Associates

DRAWN 22.11.5
CHECKED 24

RECORD OF BOREHOLES 18 & 19

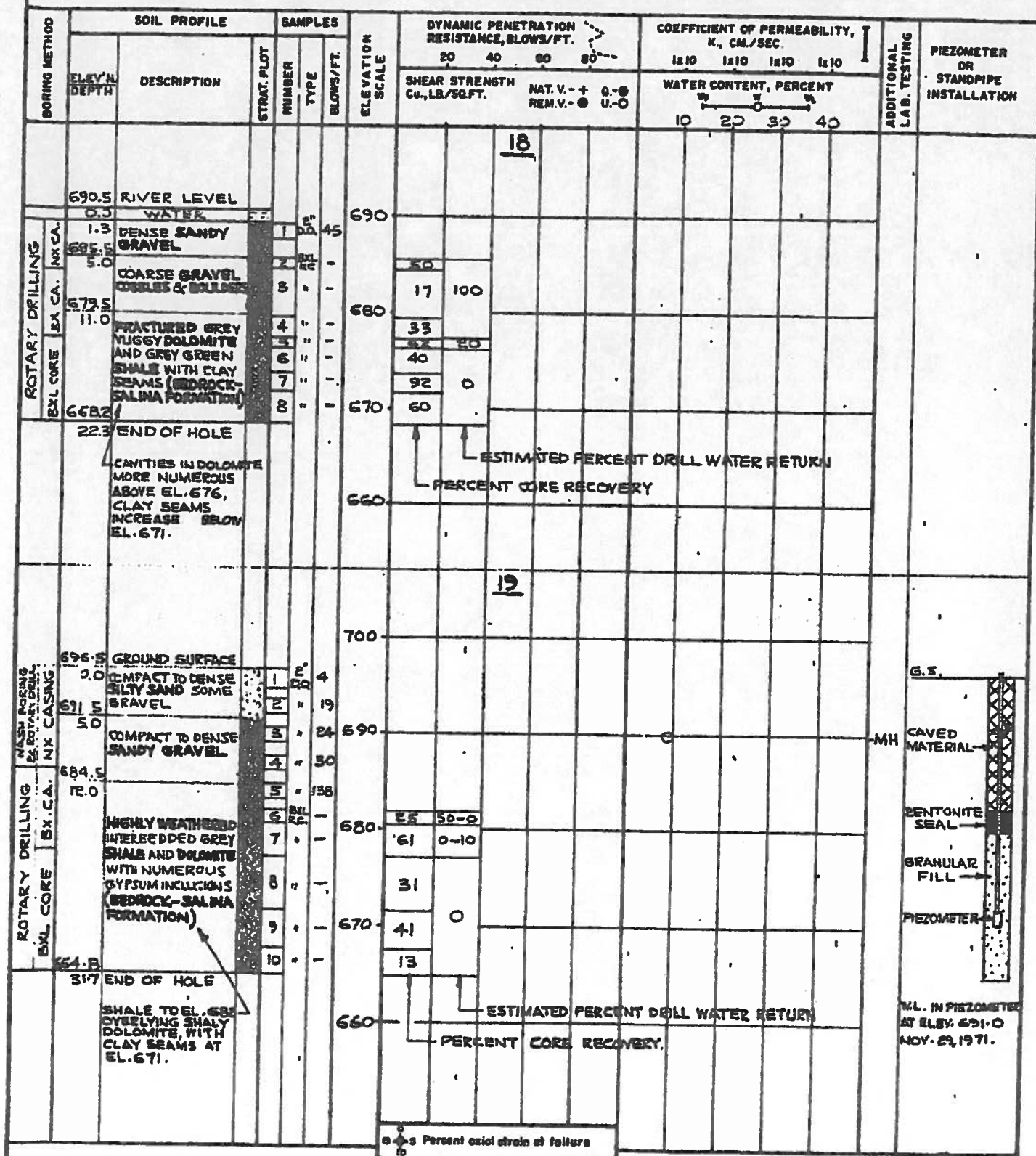
LOCATION See Figure 2

BORING DATE NOV. 11, 12, & 15, 1971

DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN.

PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.



DATUM GEODETIC

PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN:

BORING METHOD		SOIL PROFILE			SAMPLES			ELEVATION SCALE		DYNAMIC PENETRATION RESISTANCE, BLOWS/FT. 20 40 60 80	COEFFICIENT OF PERMEABILITY, K _v , CM./SEC.				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
		DEPTH FEET IN	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FT.		SHEAR STRENGTH C _u , LB./SQ.FT.	NAT. V. - + REM. V. - •	G.-O U.-O	WATER CONTENT, PERCENT				
DRY BORING UNCASED		695.3	GROUND SURFACE		1	2"	4	700								
		0.0	SILTY SAND (TOP SOIL)		1	DO	4									
		2.0	COMPACT SILTY SAND		2	"	22	690								
		4.0	COMPACT TO DENSE SANDY GRAVEL		3	"	59									
		685.4	END OF HOLE					680								
		11.0	HIGHLY WEATHERED SHALE BEDROCK													WELL IN OPEN HOLE AT ELEV. 680-5 NOV. 24, 1971
ROTARY WASH BORING NX CASING EXL CORE		697.3	GROUND SURFACE		1	2"	3	700								
		0.0	SILTY SAND (TOP SOIL)		1	DO	3									
		2.0	COMPACT TO LOOSE BROWN SILTY SAND		2	"	12									
		689.3	DENSE BROWN SILTY SAND AND GRAVEL		3	"	4	690								
		686.3	WEATHERED AND FRACTURED INTERBEDDED SHALE & DOLOMITE (BEDROCK-SALINA FORMATION)		4	"	81									
		11.0	END OF HOLE					680	20	50						
		676.8			5	"	-		75	20						
		20.5	END OF HOLE		7	"	-									
								670								

ESTIMATED PERCENT DRILL WATER RETURN

PERCENT ORE RECOVERY

VERTICAL SCALE
1 IN. TO 10 FT

Golder Associates

DRAWN *[Signature]*

CHECKED *[Signature]*

RECORD OF BOREHOLES 22 & 23

LOCATION See Figure 2

BORING DATE NOV. 16 & 24, 1971

DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN.

PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.

BORING METHOD	SOIL PROFILE			SAMPLES		ELEVATION SCALE	DYNAMIC PENETRATION RESISTANCE, BLOWE/FT.				COEFFICIENT OF PERMEABILITY, K., CM./SEC.				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION	
	ELEV. N. DEPTH	DESCRIPTION	STRAT. PLT	NUMBER	TYPE		BLOWE/FT.	SHEAR STRENGTH CU, LB./SQ. FT.				WATER CONTENT, PERCENT					
ROTARY DRILLING EXL. CORE DRY BR CASING	697.3	GROUND SURFACE															
	0.0	COMPACT BROWN SILTY SAND		1	DO	5											
	692.3	FIRM BROWN CLAYEY SILT		2	"	23											
	5.0	COMPACT SANDY GRAVEL, COBBLES		3	"	11											
	683.8	WEATHERED AND FRACTURED INTER-BEDDED GREY SHALE AND VUGGY DOLOMITE (BEDROCK-SALINA FORMATION)		4	"	25											
	3.0			5	"	10											
	685.3			6	"	1											
	12.0			7	"	680	29	10									
				8	"	680	62										
						670	50	50									
	672.4	END OF HOLE															
	24.9	DOLOMITE TO EL. 679 WITH CAVITIES BEGINNING AT EL. 682, CLAY INCLUSIONS BELOW EL. 679															
WASH DRILLING EXL. CORE DRY BR CASING	699.4	GROUND SURFACE															
	0.0	SILTY SAND (TOP SOIL)		1	DO	5											
	695.4	LOOSE BROWN SILTY SAND, TRACE OF ORGANIC MATTER		2	"	10											
	3.0			3	"	9											
	686.4	SHALE BEDROCK		4	"	139											
	684.5	END OF HOLE															
	12.5	(WEATHERED)															

S.S.

GRANULAR FILL

PIEZOMETER

W.L. IN PIEZOMETER AT ELEV. 691.1 NOV. 29, 1971

W.L. IN OPEN HOLE AT ELEV. 690.9 NOV. 25, 1971

VERTICAL SCALE
1 IN. TO 10 FT

Golder Associates

DRAWN
CHECKED

RECORD OF BOREHOLES 24 & 25

LOCATION See Figure 2

BORING DATE NOV. 17 & 26, 1971

DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DRDP 30 IN.

PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.

BORING METHOD	SOIL PROFILE		SAMPLES			ELEVATION SCALE	DYNAMIC PENETRATION RESISTANCE, BLOWS/FT.				COEFFICIENT OF PERMEABILITY, K., CM./SEC.				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION	
	ELEV. DEPTH	DESCRIPTION	STRAT. PLAT	NUMBER	TYPE		BLOWS/FT.	20 40 60 80				1x10 1x10 1x10 1x10					
								SHEAR STRENGTH Cu., LB./SQ.FT.				WATER CONTENT, PERCENT					
							NAT. V. - + 0-0 REM. V. - 0 U-0										
ROTARY DRILLING BY CASING DIL CORE	701.2	GROUND SURFACE															
	0.0	TOPSOIL		1	2"	9											
	1.0	COMPACT TO VERY LOOSE BROWN SANDY SILT TO SILTY FINE SAND TRACE OF CLAY AND SHELLS		2	"	26											
				3	"	7											
				4	"	3											
	689.2	12.0 VERY DENSE BROWN SAND AND GRAVEL SOME SILT		5	"	67											
				6	"	55											
	684.2	17.0 WEATHERED AND FRACTURED SHALE AND DOLOMITE (BEDROCK-SALINA FORMATION)		7	"	96											
				8	"	1											
	677.1	24.1 END OF HOLE		9	"	1											
							10	100									
							25	0									
							100										
							ESTIMATED PERCENT DRILL WATER RETURN										
							PERCENT CORE RECOVERY										
ROTARY DRILLING BY CASING DIL CORE	698.7	GROUND SURFACE															
	0.0	BLACK SILTY SAND (TOPSOIL)		1	2"	11											
	4.5	LOOSE BROWN SILTY SAND, TRACE GRAVEL		2	"	20											
				3	"	4											
	689.7	WEATHERED AND FRACTURED INTERBEDDED SHALE AND VUGGY DOLOMITE (BEDROCK-SALINA FORMATION)		4	"	100											
				5	"	1											
				6	"	1											
	677.2	21.5 END OF HOLE		7	"	1											
								52									
								50	50								
							42										
							ESTIMATED PERCENT DRILL WATER RETURN										
							PERCENT CORE RECOVERY										
							W.L. IN OPEN HOLE AT ELEV. 691.8 NOV. 18, 1971										
							SMALL CAVITIES IN DOLOMITE BELOW EL. 681.										
							Percent axial strain at failure										

RECORD OF BOREHOLES 26 & 27

LOCATION See Figure 2

BORING DATE NOV. 25, 1971

DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN.

PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.

BORING METHOD	SOIL PROFILE				SAMPLES		ELEVATION SCALE	DYNAMIC PENETRATION RESISTANCE, BLOWS/FT.				COEFFICIENT OF PERMEABILITY, K, CM./SEC.				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
	ELEVATION DEPTH	DESCRIPTION	STRAT. PLT	NUMBER	TYPE	BLOWS/FT.		20 40 60 80				1x10 1x10 1x10 1x10					
								SHEAR STRENGTH Cu, LB./SQ.FT.				WATER CONTENT, PERCENT					
DRY BORING W/VA NX CASING	571.3	GROUND SURFACE															
	695.8	SILTY SAND (TOP SOIL)		1	2"	5											
	689.4	HARD BROWN CLAYEY SILT, TRACE OF SAND AND GRAVEL (CLAYEY SILT TILL)		2	"	49											
	685.8	WEATHERED SHALE BEDROCK		3	"	38											
	685.8	END OF HOLE		4	"	50											
ROTARY BXL BX CASING	702.7	GROUND SURFACE															
	690.4	SILTY SAND (TOP SOIL)		1	2"	7											
	686.4	DENSE SAND AND GRAVEL, SOME COBBLES & BOULDERS, TRACE SILT		2	"	104											
	686.4	FAIRLY SOUND GREEN SHALE AND DOLOMITE BEDROCK		3	RYL RC	-	77	50									
	686.4	END OF HOLE															

26

27

ESTIMATED PERCENT DRILL WATER RETENTION

PERCENT CORE RECOVERY

Percent axial strain at failure

W.L. IN OPEN HOLE AT ELEV. 690.7 NOV. 25, 1971

W.L. IN OPEN HOLE AT ELEV. 690.7 NOV. 26, 1971

W.L. IN OPEN HOLE AT ELEV. 690.7 NOV. 25, 1971

W.L. IN OPEN HOLE AT ELEV. 690.7 NOV. 26, 1971

ESTIMATED PERCENT DRILL WATER RETENTION

PERCENT CORE RECOVERY

Percent axial strain at failure

VERTICAL SCALE 1 IN. TO 10 FT

Golder Associates

DRAWN
CHECKED

RECORD OF BOREHOLE 28

LOCATION See Figure 1

BORING DATE NOV. 19-26, 1971

DATUM GEODETIC

SAMPLER HAMMER WEIGHT 140 LB., DROP 30 IN.

PENETRATION TEST HAMMER WEIGHT 140 LB., DROP 30 IN.

BORING METHOD	SOIL PROFILE		SAMPLES			ELEVATION SCALE	DYNAMIC PENETRATION RESISTANCE, BLOWS/FT.				COEFFICIENT OF PERMEABILITY, K, CM/SEC.				ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION	
	ELEV. DEPTH	DESCRIPTION	STRAT. PLAT	NUMBER	TYPE		BLOWS/FT.	SHEAR STRENGTH				WATER CONTENT, PERCENT					
								20	40	60	80	1x10	1x10	1x10			1x10
ROTARY DRILLING NX CASING BX CASING BXL CORE	802.0	GROUND SURFACE															
	800.0	DENSE TO VERY DENSE SAND TO SILTY SAND, SOME GRAVEL, COBBLES AND BOULDERS		1	N	7											
	791.5			2	"	27											
	790.0			3	"	88											
	780.0			4	"	175											
	770.0	HARD RED-BROWN TO GREY-BROWN CLAYEY SILT, TRACE TO SOME SAND, GRAVEL AND OCCASIONAL COBBLES (TILL)		5	"	160											
	760.0			6	"	160											
	750.0			7	"	137											
	740.0			8	"	180											
	735.0	VERY DENSE BROWN SILTY SAND, SOME GRAVEL & COBBLES (SANDY TILL)		9	"	195											
	730.0			10	"	140											
	720.0	HARD BROWN CLAYEY SILT TO SILTY CLAY, SOME GRAVEL, TRACE OF SAND (SILTY TILL)		11	"	87											
	717.0			12	"	33											
	715.0			13	"	42											
	712.0			14	"	0											
	85.0	END OF HOLE		15	"												

G.S.
 BENTONITE SEAL
 GRAVEL FILTER
 PIEZOMETER 'B'
 BENTONITE SEAL
 GRAVEL FILTER
 PIEZOMETER 'A'

ESTIMATED PERCENT DRILL WATER RETURN
 PERCENT CORE RECOVERY

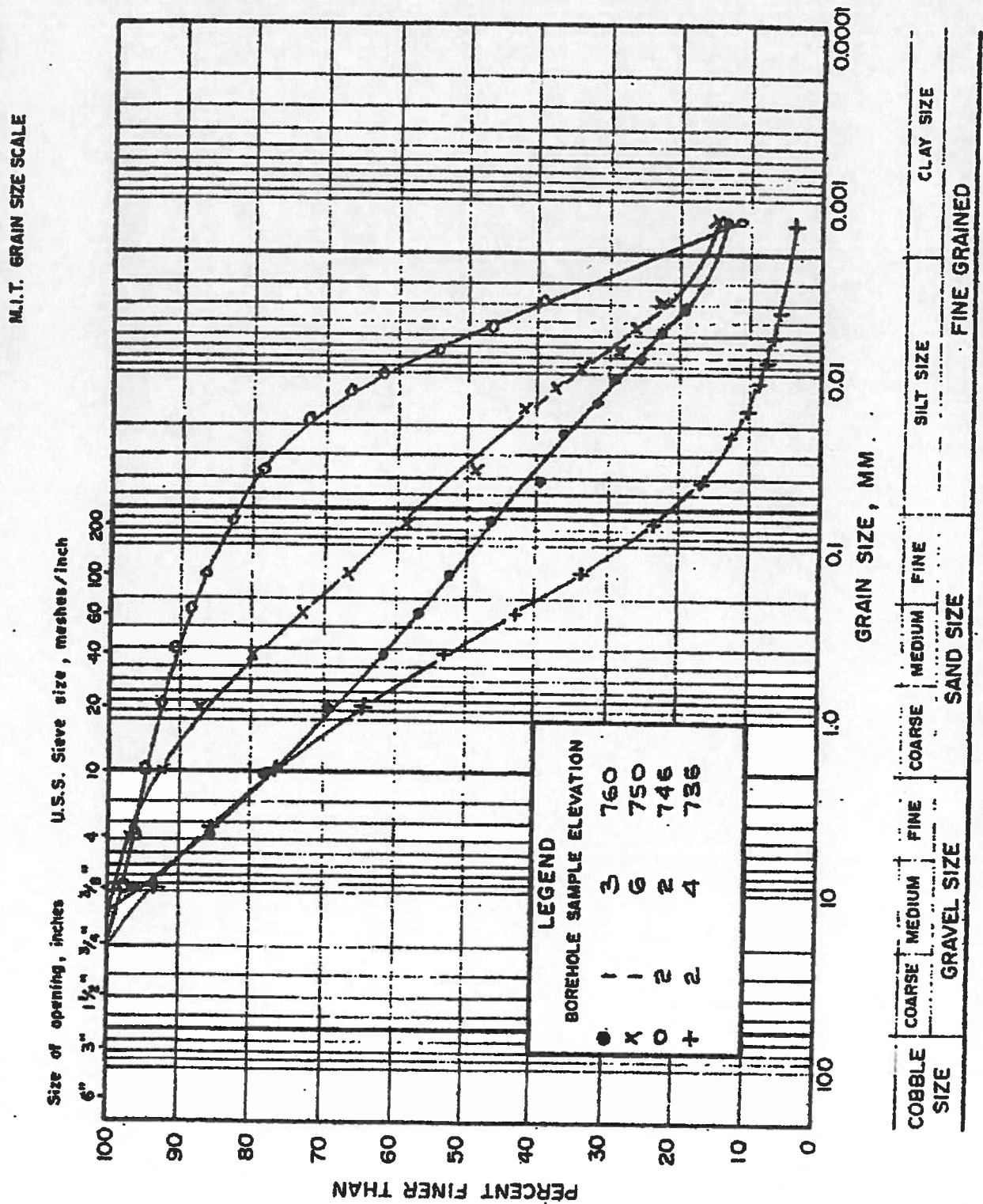
V.L.W. PIEZOMETER 'A' AT ELEV. 728.2
 AND PIEZOMETER 'B' AT ELEV. 771.5
 NOV. 23, 1971.

VERTICAL SCALE
 1 IN. TO 10 FT.

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DRAWN
 CHECKED

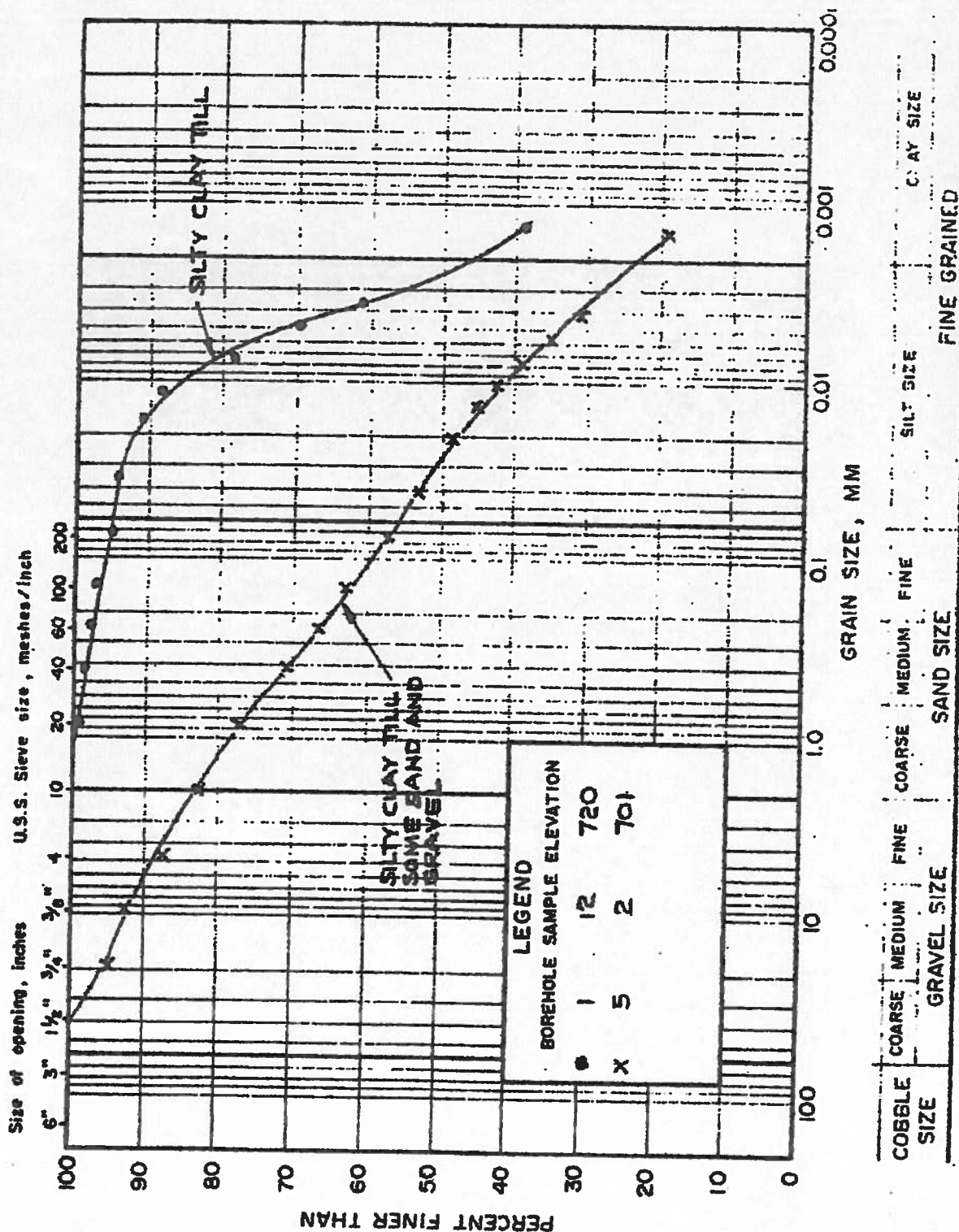
FIGURE 4



GRAIN SIZE DISTRIBUTION SILTY CLAY TILL

FIGURE 5

M.I.T. GRAIN SIZE SCALE

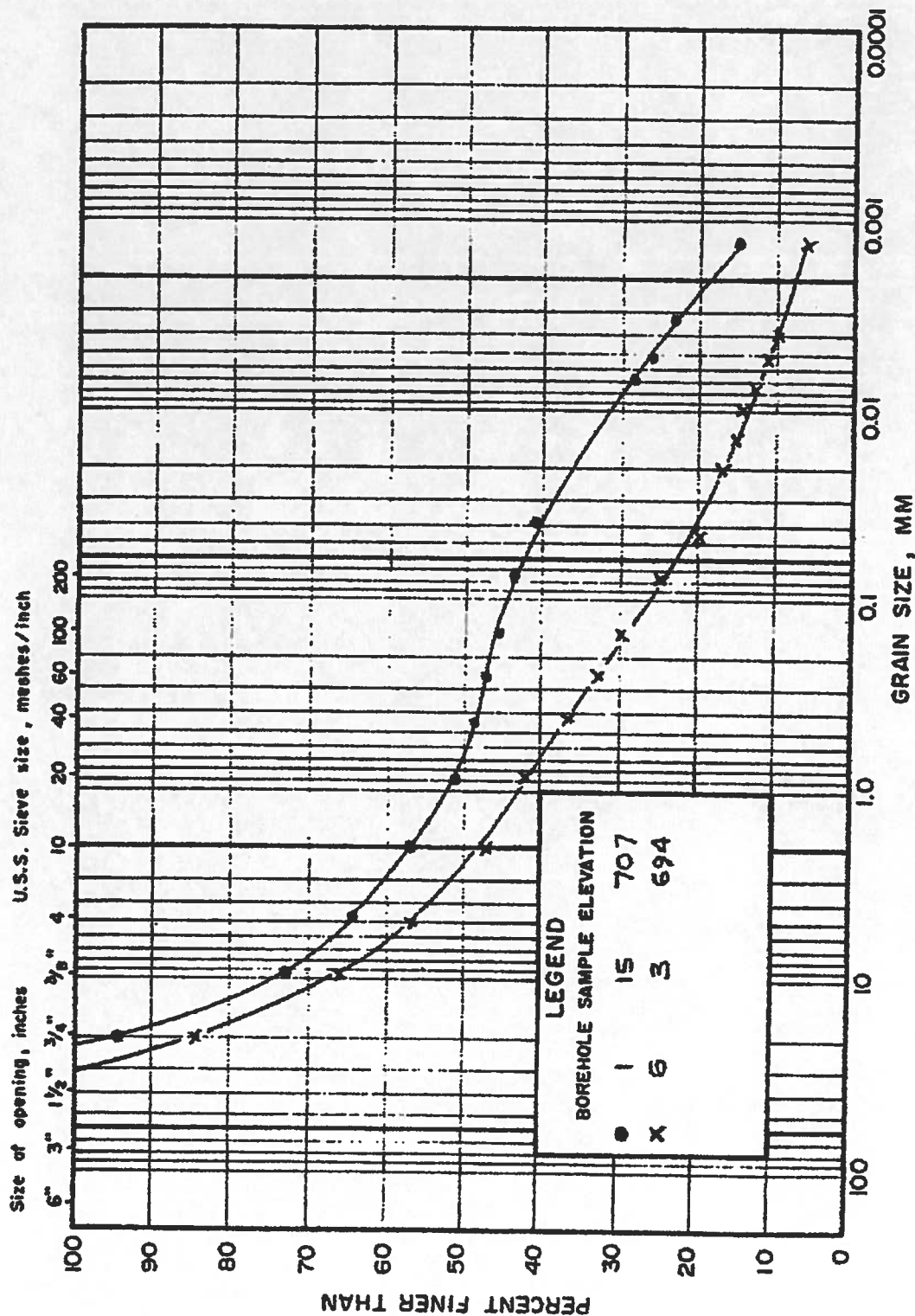


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GRAIN SIZE DISTRIBUTION LOWER SANDY SILT TILL

FIGURE 6

M.I.T. GRAIN SIZE SCALE



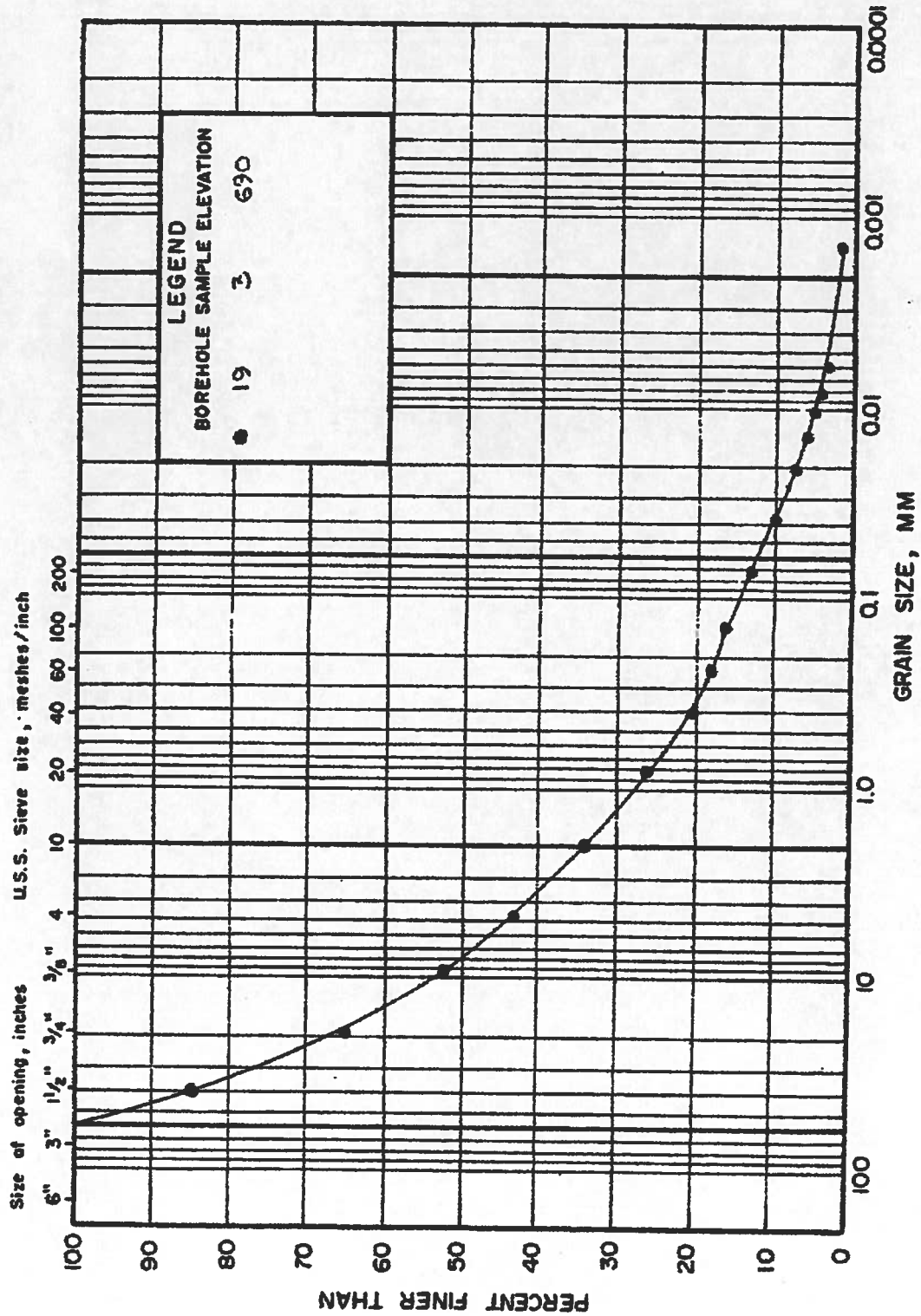
COBBLE SIZE	GRAVEL SIZE			SAND SIZE			SILT SIZE		CLAY SIZE	
	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE				
									FINE GRAINED	

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GRAIN SIZE DISTRIBUTION SANDY GRAVEL

FIGURE 7

M.L.T. GRAIN SIZE SCALE



COBBLE SIZE	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE
	GRAVEL SIZE			SAND SIZE			FINE GRAINED	

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