FOUNDATION INVESTIGATION REPORT

STRUCTURAL CULVERT SITE NO. 30-673/C
TOWNSHIP OF RAMA
HIGHWAY 12 FROM GAMEBRIDGE TO RAMA ROAD 25

W.P. 365-98-00
Agreement # 2004-E-0070

I.E. Group

MTO GEOCRES No. 31D-485

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Prepared for:
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Prepared by:

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PART A – FOUNDATION INVESTIGATION

1.0 INTRODUCTION

This report presents the results of a foundation investigation carried out in December 2008 and January and February 2009 by Infrastructure Engineering Group Inc. (IEG) on behalf of Morrison Hershfield Limited (Morrison Hershfield).

This assignment involves the rehabilitation of approximately 24 km of Highway 12, from Rama Road to Gamebridge. The original scope of the rehabilitation is based on addressing the immediate and short term deficiencies identified in the Ministry's Highway Assessment Report for W.O. #03-20019 (February 2005). The scope of work may include rehabilitation, extension or replacement of seven (7) non-structural culverts and four (4) structural culverts.

Foundation investigation and recommendations are required for the design and construction of culvert replacements and/or extensions as part of the improvement of Highway 12. Seven (7) non-structural culverts and four (4) structural culverts are to be investigated. This report covers the site of Structural Culvert No. 30-673/C, also described in the culvert summary as Culvert 14.

The purpose of the investigation was to obtain information about the subsurface conditions at the site by means of boreholes and, based on the findings, to provide geotechnical recommendations for the foundation elements.

This culvert is an equalizing culvert for the wetlands located on both sides of Highway 12. The hand drilled borehole or dynamic cone penetration tests located east of the existing culvert cannot be completed during the field work between December 2008 and February 2009 due to inundation of the wetland.

Based on the information presented in the Culvert Summary provided by Morrison Hershfield, and verbal discussion with the project team, it is understood that no further work will be carried out on Culvert No. 30-673/C for this contract. The geotechnical investigation report is completed for the records and future use, if required.

Authorization to complete this assignment was given by Mr. Stanley Ma, P. Eng., of Morrison Hershfield, the TPM Consultant who is completing this assignment for MTO under Agreement # 2004-E-0070.

2.0 SITE DESCRIPTION

2.1 Site Location

The project alignment starts in Gamebridge, at Station 10+000 and extends northerly to approximately Station 19+200 just south of County Road 169, then extends north-westerly to approximately Station 24+800 just before Side Road 15, then extends westerly to Station 34+000 just east of Rama Road 25. For the purpose of description, standard MTO conventional descriptions will be used, i.e. a site north pointing in the direction of increasing chainage. When facing the direction of increasing chainage, the right hand side is referred to as east, and the left hand side is referred to as west. Any directions with clarifications in brackets (e.g. north-west) are given with reference to the true north direction.

Structure 30-673/C is located on Highway 12, approximately 10.1 km north of the south limit of this Contract (Station 10+000 at Gamebridge), located at Station 20+081. Photographs of this culvert site are presented in Appendix "D". The existing structure is a reinforced concrete, rigid frame open footing culvert with a span of 3.05 m, a height of 0.5 m, a length of 25.00 m (3.06 m span by 0.91 m height by 25.00 m length in accordance with ETR Plate No. 205-12/36-0), with an overfill height of approximately 0.8 m. The culvert opening dimensions were obtained from the Culvert Summary provided by Morrison Hershfield and compared with the ETR drawings provided in the RFP.

The culvert site is located between two wetlands severed by Highway 12, and is used as an equalizing culvert for the severed wetlands. The approach embankments were built on both the east and west sides of the culvert, with a maximum height of approximately 1.7 m. The embankment slopes are typically 3H:1V or flatter, with localized steeper zones, and are grass and weed covered. No signs of embankment slope instability were observed at the time of this foundation investigation.

There are no headwalls for this culvert and the ends of the culvert protrude beyond the road embankment. The areas adjacent to the ends of the culvert were inundated, with peat or muck present below the mucky water. The water levels in the wetlands were 50 mm above the top of the concrete culvert at the time of the field work, in the winter season of 2008/2009.

Photographs taken on March 1 and 2, 2002, as shown in Appendix B of the Highway Assessment Study Report indicate that an estimated wetland water level to be slightly lower than those observed during the field work. Photographs taken by Morrison Hershfield on September 3, 2008 indicate that the water level was slightly below obvert of the culvert.

2.2 Physiography and Topography

The project alignment, except for the extreme western portion, is located within the Simcoe Lowlands physiographic region (Chapman and Putnam, 1984). This area was previously flooded by glacial Lake Algonquin. The portion of the alignment located east of the Atherley Narrows (narrows between Lakes Couchiching and Simcoe) is comprised of an elevated, drumlinized till

plain comprised primarily of undifferentiated sand to sandy silt (Chapman and Putnam, 1984). The character of local topography and soils proximity to the highway corridor elsewhere are predominantly comprised of clay plain with interspersed elongated drumlins which comprised of calcareous till (kame moraine) (Chapman and Putnam, 1984). There is a large patch of peat/muck located on the east shore of Lake Simcoe associated with several of the wetland features located along the lakeshore. There is also a section of Carden limestone plain located north of the Talbot River at the south end of the study area. This area is characterized as limestone overlaid with a very shallow overburden (Chapman and Putnam, 1984).

The topography of the study area is primarily flat with scattered drumlin features. The area slopes gently down towards Lake Simcoe. There are numerous headwater areas of small size that traverse the ROW of Highway 12. Movement of shallow groundwater is confined by the tight till and clay soils and would follow surficial topography towards Lake Simcoe.

There are six provincially significant wetlands (PSW) located in part within the project alignment. From west to east, they include the Orillia Filtration Swamp, Victoria Point Wetland, Atherley Wetlands, Mud Lake Wetland, Barnstable Bay Wetland, and the Lagoon City Wetland.

The asphalt pavement surface over the existing culvert is near Elevation 221.0 m while the ground surface at the base of the embankment and in the wetland is approximately at Elevation 219.3 m.

3.0 INVESTIGATION PROCEDURES

3.1 Field Investigation

Between December 2 and 17, 2008, a CME 55 truck-mounted drill rig was supplied by London Soil Test Ltd. and used on site for drilling and Standard Penetration Testing (SPT, following the procedures of ASTM D 1586). Two (2) boreholes (Boreholes C14-2 and C14-3) were drilled and sampled to obtain data for foundation design of the proposed rehabilitation work and potential culvert replacement. Rock coring was carried out on February 17, 2009 in Borehole C14-3 to provide geotechnical data as per the requirements of our proposal for this work. A hand-drilled borehole cannot be completed at the location of Borehole C14-1 due to inundation of the area, and a series of dynamic cone penetration tests were carried out instead on February 17, 2009. The locations of the boreholes are shown on Drawing 1.

The culvert borehole numbering system was established from the Culvert Summary spreadsheet provided by Morrison Hershfield. The subject culvert was identified as Culvert C14, with a Structure Number 30-673/C as presented in the Culvert Summary. The boreholes for this culvert are numbered C14-1 to C14-4 accordingly and the depths of sampling were as follows:

Borehole No.	Depth of Sampling (m)
C14-1 (DCP only)	4.44
C14-2	5.33
C14-3 (with rock coring)	7.32
C14-4	TO BE COMPLETED

The sampled boreholes were drilled using continuous flight solid stem or hollow stem augers. Soil samples were retrieved at selected intervals throughout the depths of the boreholes in conjunction with Standard Penetration Tests (SPT). Samples were generally taken at intervals of depth of 0.75 m to the maximum depth of exploration.

The undrained shear strengths were obtained by shear vane tests, with the sensitivity measured. Field pocket penetrometer was used on the retrieved SPT samples, where applicable, to determine the undrained shear strength of the cohesive soil deposits. These undrained shear strengths are used to supplement the properties of the cohesive soils. It is noted that the measured shear strength value on the retrieved SPT samples would be slightly lower than the actual value due to sampling disturbance. Thin-walled Shelby tube samples were obtained for laboratory consolidation test.

Rock cores were retrieved using NQ core assembly (47.6 mm ID). The rock core samples were identified in the field and physical index properties were determined by visual examination and also by measurement of rock quality designations (RQD's) and rock core recovery. All rock

cores were placed in wooden core boxes and transported to our laboratory for further examination, to confirm the field logging, and laboratory testing.

Seepage and water levels were noted in each borehole during and at the completion of drilling and sampling. All boreholes were grouted with a bentonite/cement mix at completion of sampling in accordance with Ontario Regulation 903.

Our field engineer, Mr. Ralph Billings, P. Eng., supervised the fieldwork and worked under the direction of the project engineer, Mr. Eric Chung, P. Eng. Our field staff cleared the location of buried utilities and logged the boreholes. The soil samples obtained were placed in labeled containers and transported to IEG's London laboratory for further examination and laboratory testing.

The chainages and offsets at the borehole locations were provided to Morrison Hershfield and the ground surface elevations and UTM co-ordinates (northing and easting) were provided by Morrison Hershfield to Infrastructure Engineering Group Inc. for the purpose of this report.

The results of the drilling, sampling, in-situ testing and groundwater observations are summarized on the Record of Borehole sheets and enclosed in Appendix "A".

3.2 Laboratory Analysis

Geotechnical laboratory testing consisted of natural moisture content determinations and visual classifications of all retrieved soil samples. In addition, grain size analyses, Atterberg Limit tests and unit weight tests were performed on selected samples.

A one-dimensional consolidation test (ASTM D 2435) was conducted on a relatively undisturbed thin-walled (Shelby tube) sample obtained from Borehole C14-3 at a depth of 3.81 m. The consolidation test was carried out by Trow Associates Inc. of Brampton (Trow) and the results are provided in a Void Ratio versus Pressure curve plot enclosed in Appendix B as Figure 7.

A section of the rock core (at 5.49 m depth from Borehole C14-3) was selected for unconfined compressive strength testing in accordance with ASTM 2938. The testing was performed by Trow Associates Inc. of Brampton and the results are presented as Figure 8 in Appendix B.

The results of the laboratory testing are presented on the Record of Borehole sheets (Appendix "A"), and Laboratory Test Results (Figures 1 to 8, Appendix "B").

4.0 SUBSURFACE CONDITIONS

4.1 General Subsurface Conditions

Reference is made to the Record of Borehole sheets (Appendix "A") and Laboratory Test Results (Appendix "B") for detailed subsurface soil and groundwater conditions encountered in the boreholes. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling and, consequently, represent transitions between soil types rather than exact planes of geological change. The soil profiles depicting the subsurface conditions on Drawing 1 will vary between and beyond the borehole locations.

In general, the subsurface deposits at the site consist of compact embankment fill to 1.22 m depth, placed on peat or buried topsoil underlain by concrete extending to depths of 2.13 to 2.59 m (Elevations 218.12 to 218.68 m). The peat, buried topsoil and/or concrete were underlain by a firm to stiff, varved clay stratum which was further underlain by limestone bedrock (contacted between Elevations 215.48 and 215.53 m).

4.1.1 Pavement, Fill, Topsoil

Borehole C14-2, located at the south edge of existing pavement in the shoulder area, encountered 100 mm shoulder gravel. Underlying the shoulder gravel is the embankment fill material that extended to a depth of 1.22 m (Elevation 219.59 m). The fill beneath the shoulder gravel consists of a mixture of silty sand and gravel to sandy silt with clay lumps. The embankment fill is placed on a 910 mm thick layer of partially decomposed peat.

Borehole C14-3, located at the north edge of existing pavement in the shoulder area, encountered 100 mm shoulder gravel. Underlying the shoulder gravel is the embankment fill material that extended to a depth of 1.22 m (Elevation 219.49 m). The fill beneath the shoulder gravel consists of a mixture of silty sand and gravel to sandy silt with clay lumps. The embankment fill is placed on, in turn, a 300 mm thick layer of concrete, a 230 mm thick layer of buried topsoil and then a 840 mm thick layer of concrete. The bottom of the lower concrete layer is located at Elevation 218.12 m.

The results of four (4) grain size distribution analyses of the embankment fill are shown on Figure 1 of Appendix "B".

Standard penetration tests yielded "N"-values from 14 to 18 blows per 0.3 m. This fill is brown to dark brown in colour and the measured natural moisture contents range from 6 to 30%.

Unit weight of the fill was not determined due to the disturbance of the soil samples during sampling and sample retrieval.

Based on the above field and laboratory test results, together with visual and tactile examination, the fill beneath the shoulder gravel consists of a mixture of sandy silt and sand and gravel and in a compact condition.

4.1.2 Varved Clay

A stratum of grey varved clay was contacted below the peat and/or concrete and extended to the limestone bedrock contacted between depths of 5.33 m and 5.18 m below the existing ground surface, at Elevations 215.48 m and 215.55 m, respectively at Boreholes C14-2 and C14-3. Based on examination of the SPT samples, the varved clay contains thin layers and larger pockets of silt. The soil sample was described by Trow as layered silty clays, red, grey and dark grey, friable, blocky and slickensided.

Two (2) grain size analyses were performed on the varved clay deposit and the results are presented on Figure 2 of Appendix "B". Two (2) samples were tested and exhibited the following Atterberg Limits. These results are shown in Figure 3 of Appendix "B" and summarized below:

Atterberg Limit	Minimum	Maximum	Average
Liquid Limit (W_L) %	45.0	58.0	51.5
Plastic Limit (W_P) %	17.0	23.0	20.0
Plasticity Index (I_p) %	28.0	35.0	31.5

The results of the Atterberg Limit tests reveal a clay of medium to high plasticity (CI to CH). The natural moisture contents of the varved clay were in the range of 15 to 43%.

Field vane tests carried out at a depth of 3.81 m (Elevation 216.99 m) in Borehole C14-2 yielded an undrained shear strength of 30.5 kPa with a sensitivity of 2.5, and classified as medium sensitivity. Field vane tests carried out at a depth of 3.05 m (Elevation 217.66 m) in Borehole C14-3 yielded undrained shear strength of 39 kPa with a sensitivity of 9.4, and classified as extra sensitive. The high sensitivity reported in Borehole C14-3 is attributed to the layered structure of the deposit, and could reflect the presence of sand to silt seams and pockets present within the test zone. The extra sensitive soil could easily be disturbed upon excavation. The undrained shear strength as determined from a single field pocket penetrometer yielded a value of 60 kPa in Borehole C14-2. Standard penetration tests yielded "N"-values from 4 to 9 blows per 0.3 m.

Based on the above field and laboratory test results, together with visual and tactile examination, the varved clay deposit generally exhibited firm to stiff consistency.

The unit weight of the varved clay was measured on one (1) sample to be 18.2 kN/m^3.

A one-dimensional consolidation test (ASTM D 2435) was conducted on a relatively undisturbed thin-walled (Shelby tube) sample of the firm to stiff layer taken from Borehole C14-3 at a depth of 3.81 m. These results are shown in Figure 7 of Appendix B and summarized below:

Sample Depth:	3.81 m
Elevation:	216.90 m
Liquid Limit (W_L)	45%
Plastic Limit (W_P)	17%
Natural Moisture Content (W)	33%
Compression Index (C_C)	0.540
Recompression Index (C_r)	0.055
Pre-consolidation Pressure (σ_p)	500 kPa
Effective Overburden Pressure (σ'_{vo})	32 kPa

The consolidation test was carried out by Trow. The pre-consolidation pressure interpreted from Void Ratio versus Pressure plot for the consolidation test appears to be unusually high for the varved clay.

4.1.3 Minor Pockets within Varved clay

A gravelly pocket within the varved clay was contacted at depths of 2.13 to 3.51 m at Borehole C14-2. The results of a grain size distribution are provided in Figure 4.

A clayey silt sand pocket within the varved clay was contacted at depths of 4.57 to 5.18 m at Borehole C14-3. The results of a grain size distribution and Atterberg Limit test are provided in Figures 5 and 6.

4.1.4 Limestone Bedrock

The varved clay is underlain by a stratum of grey to tan limestone bedrock. The appearance of the rock core sample is fossiliferous with sections that are coralliferous, with close to wide bedding planes.

Recovery of the rock core sample varies from 83% to 100%. Rock Quality Designation (RQD) varies from 83% to 87%, and the limestone bedrock is considered to be of good to excellent quality.

A single uniaxial compressive strength determination carried out on a section of rock core sample yielded a result of 110 MPa and thus the limestone bedrock is considered to be “very strong”. The uniaxial compressive strength test report is enclosed in Appendix B as Figure 8.

4.2 Groundwater Conditions

The groundwater condition was monitored during and upon completion of sampling.

The water level in the wetlands are slightly above the obverts (soffits) of the culvert on December 2, 17 and 19, 2008, and likely reflected a high water level condition. On February 19, 2009, the water level was observed to be near Elevation 220.34 m.

On completion of drilling, water levels were recorded at a depth of 0.9 m in both Boreholes C14-2 and 3. The water levels measured in the boreholes may not have stabilized for the short duration that the boreholes were kept opened. It is reasonable to assume that the groundwater level to be consistent with the water levels of the severed wetlands at the time of the investigation.

It should be noted that the groundwater level will fluctuate seasonally and in response to weather events. Under adverse conditions, water could be perched within the embankment fill and on top of the organic deposits. It is reasonable to assume that groundwater could be similar to the water level in the wetland during high flow conditions, and may be well above the obvert of the culvert.

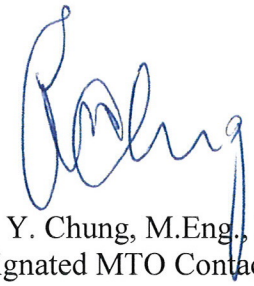
5.0 STATEMENT OF LIMITATION

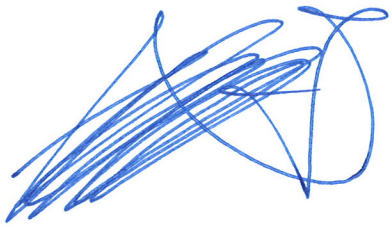
We recommend that once the details of the proposed structure are finalized, our recommendations should be reviewed for their specific applicability.

The Limitations of Report, as Quoted in Appendix "C", is an integral part of this report.

We trust that we have completed the assignment within the Terms of Reference for this project. If there are any questions concerning this report, please do not hesitate to contact our office.

Yours truly,
Infrastructure Engineering Group Inc.





Eric Y. Chung, M.Eng., P.Eng.
Designated MTO Contact

Joseph Law, P.Eng.
Project Manager

Tom O'Dwyer, P. Eng.
Quality Review Engineer

Drawing 1

Borehole Locations

And

Soil Strata

METRIC

DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

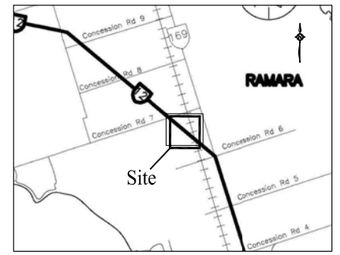
CONT No xxxx–xxxx
WP No GWP 365–98–00

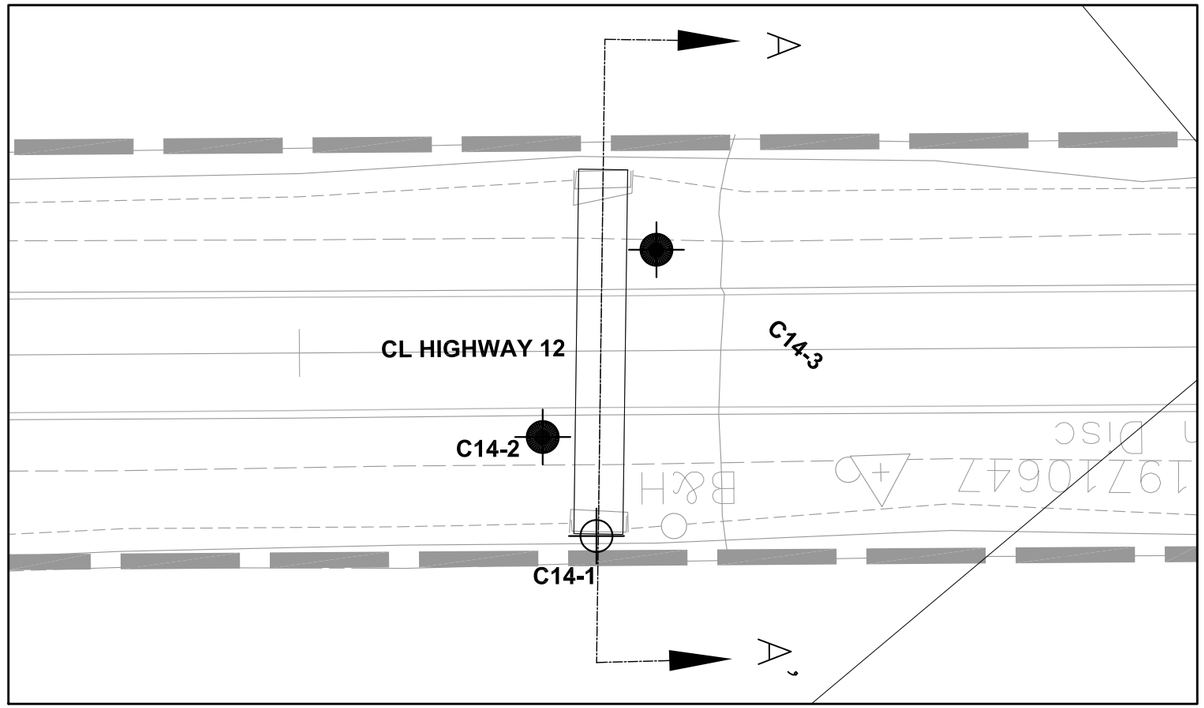
Structural Culvert 30–673/C
Highway 12
BOREHOLE LOCATION PLAN & PROFILE

SHEET 1

I.E. Group — Infrastructure Engineering Group Inc.
Pavement & Construction Materials Consulting Engineers
GTA • Kitchener • London • Windsor

KEYPLAN NTS



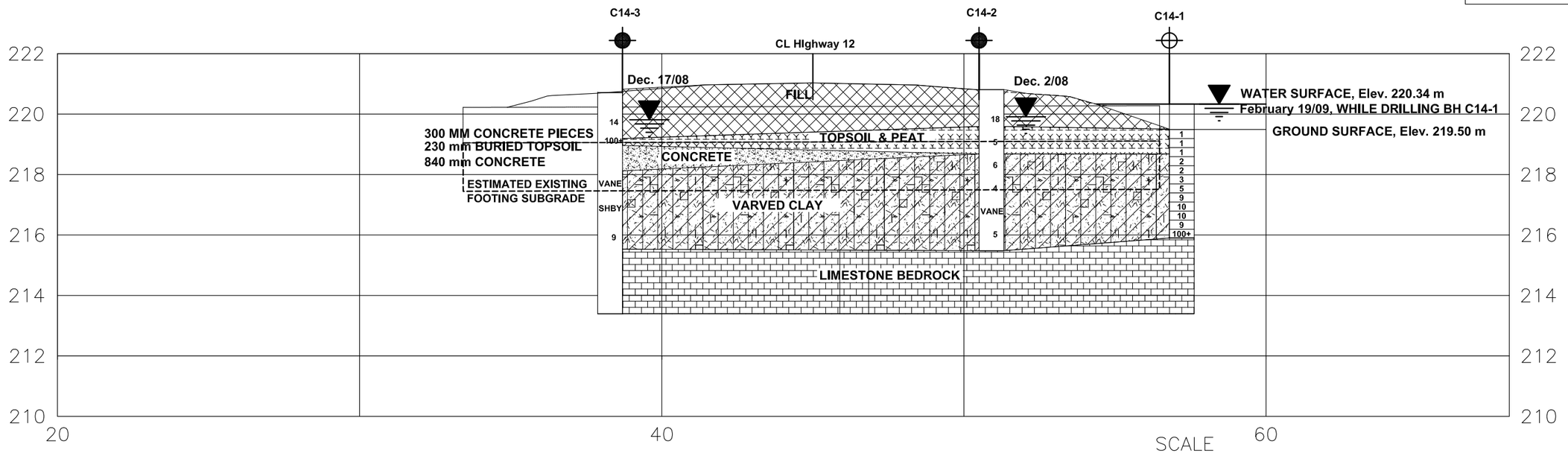


SCALE
20m 0 10m

LEGEND

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

BOREHOLE LOCATION PLAN



SECTION A-A' - CENTERLINE OF CULVERT

SCALE
5m 0 2m
Horizontal and Vertical

NOTES
1. THE COMPLETE FOUNDATION INVESTIGATION AND DESIGN REPORT FOR THIS PROJECT AND OTHER RELATED DOCUMENTS MAY BE EXAMINED AT THE ENGINEERING MATERIALS OFFICE, DOWNSVIEW. INFORMATION CONTAINED IN THIS REPORT AND RELATED DOCUMENTS ARE SPECIFICALLY EXCLUDED IN ACCORDANCE WITH THE CONDITIONS OF SECTION GC2.01 of OPS GEN. COND.
2. THE BOUNDARIES BETWEEN SOIL STRATA HAVE BEEN ESTABLISHED ONLY AT BOREHOLE LOCATIONS. BETWEEN BOREHOLES AND BOUNDARIES ARE ASSUMED FROM GEOLOGICAL EVIDENCE.
3. SUBGRADE ELEVATION OF THE EXISTING FOOTING NOT KNOWN AND IS ESTIMATED TO BE AT 1.6m BELOW THE CREEK BED.
4. THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.

BOREHOLE NO.	ELEVATION	UTM CO–ORDINATES NORTH	EAST
C14–1	220.34	4937317	328955
C14–2	220.81	4937324	328956
C14–3	220.71	4937328	328969
C14–4	???.??	???????	???????

REVISIONS			
06/09/09	J.L.	Final	
18/05/09	J.L.	Draft	
DATE	BY	DISCRIPTION	

Geocres : 31D–485

HWY No.	HWY 12		DIST	CENTRAL
SUBM'D J.L.	CHECKED E.C.	DATE 25/03/09	SITE	30–673/C
DRAWN J.L.	CHECKED J.L.	APPROVED E.C.	DWG	1

Appendix A

Explanation of Terms Used in Report

Record of Borehole Sheet

Boreholes C14-1 TO C14-4

EXPLANATION OF TERMS USED IN REPORT

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

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

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

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

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

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

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

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

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

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

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

JOINTING AND BEDDING:

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

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

STRESS AND STRAIN

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

MECHANICAL PROPERTIES OF SOIL

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

PHYSICAL PROPERTIES OF SOIL

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

e	1, %	VOID RATIO
n	1, %	POROSITY
w	1, %	WATER CONTENT
S_r	%	DEGREE OF SATURATION
w_L	%	LIQUID LIMIT
w_P	%	PLASTIC LIMIT
w_s	%	SHRINKAGE LIMIT
I_P	%	PLASTICITY INDEX = $w_L - w_P$
I_L	1	LIQUIDITY INDEX = $\frac{w - w_P}{I_P}$
I_C		CONSISTENCY INDEX = $\frac{w_L - w}{I_P}$
e_{max}	1, %	VOID RATIO IN LOOSEST STATE

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

RECORD OF BOREHOLE No C14-1

1 OF 1 **METRIC**

W.P. WP 365-98-00 LOCATION Northing - 4937317, Easting - 328955 ORIGINATED BY RB

DIST Central Region HWY Highway 12 BOREHOLE TYPE Dynamic Cone COMPILED BY JL

DATUM Geodetic DATE 02.19.09 - 02.19.09 CHECKED BY EC

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	PENETR. RESISTANCE: STANDARD ● DYN. CONE (20 40 60 80 100) / SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
220.34	Water										
0.00	840 mm WATER						220				31.75 Kg (70lbs.) hammer used for driving dynamic cone. Nc values corrected for standard 63 kg (140 lbs.) hammer.
219.50											
0.84	GROUND SURFACE						219				
							218				
							217				
215.90							216				
4.44	End of borehole.										Dynamic cone refusal @ 4.44 m on presumed bedrock.

$+^{3}, \times^{3}$: Numbers refer to Sensitivity

$\circ^{150}$ UNCONFINE SHEAR STRENGTH INFERRED FROM POCKET PENETROMETER READINGS

RECORD OF BOREHOLE No C14-2

1 OF 1 **METRIC**

W.P. WP 365-98-00 LOCATION Northing - 4937324, Easting - 328956 ORIGINATED BY RB

DIST Central Region HWY Highway 12 BOREHOLE TYPE S/S Augering 110 mm Dia. COMPILED BY JL

DATUM Geodetic DATE 12.02.08 - 12.02.08 CHECKED BY EC

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	PENETR. RESISTANCE STANDARD ● DYN. CONE / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
220.81	Ground										
0.00	100 mm SHOULDER GRAVEL.										
	FILL Brown to Dark Brown, moist, compact, consisting mainly of Silty Sand and Gravel to Sandy Silt trace gravel, trace organics and occasional silty clay lumps.		1	GRAB							4 56 30 10 (41)
219.59			2	SPT	18	▽	220				37 44 14 5 (19)
1.22	PEAT Black, moist, partially decomposed.		3	SPT	5		219		52		Water level measured @ 0.9m @ completion of drilling.
218.68								Sample not sufficient for Atterberg Limit Determinations.			
2.13	gravelly		4	SPT	6				40		20 9 45 26 (71)
218.07							218				
2.74			5	SPT	4			60	43		0 1 37 62 (99)
	VARVED CLAY , CH Grey, moist, firm to stiff, layered, with frquent silt seams and pockets, and embedded gravel.		6	VANE			217	2.5			
			7	SPT	5		216		43		
215.48											
5.33	End of borehole.										Auger and sampler refusal @ 5.33 m on presumed bedrock.

$+^{3}$, $\times^{3}$: Numbers refer to Sensitivity

$\circ^{150}$ UNCONFINE SHEAR STRENGTH INFERRED FROM POCKET PENETROMETER READINGS

RECORD OF BOREHOLE No C14-3

1 OF 1 **METRIC**

W.P. WP 365-98-00 LOCATION Northing - 4937328, Easting - 328969 ORIGINATED BY RB

DIST Central Region HWY Highway 12 BOREHOLE TYPE H/S Augering 110 mm Inside Dia. COMPILED BY JL

DATUM Geodetic DATE 12.17.08 - 12.17.08 CHECKED BY EC

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	PENETR. RESISTANCE STANDARD ● DYN. CONE / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
220.71	Ground										
0.00	100 mm SHOULDER GRAVEL.										
	FILL Brown to Dark Brown, moist, compact, consisting mainly of Silty Sand and Gravel to Sandy Silt trace gravel, trace organics and occasional silty clay lumps.		1	GRAB		▽	220				21 65 10 4 (15)
219.49			2	SPT	14						2 27 52 18 (70) Water level measured @ 0.9m @ completion of drilling.
1.22 / 219.19	CONCRETE Pieces.										
1.52	TOPSOIL Buried, black, peaty.		3	SPT	100+		219				
	CONCRETE							augered through concrete, no sample taken @ 2.29 m.			
218.12			4	None			218				
2.59	VARVED CLAY, CI Grey, moist, firm, layered, with frequent silt seams and with embedded gravel, occasional clayey silty sand pockets.		5	VANE				9.4			
			6	SH			217		45	18.2	0 4 39 57 (97)
216.14											
4.57	clayey silty sand pocket		7	SPT	9		216			22.6	11 41 31 17 (48)
215.53								Rock coring carried out on Dec. 17, 2008			
5.18	LIMESTONE BEDROCK Tan to grey, fossiliferous, medium strong to very strong, good to excellent quality, close to wide bedding plane.		8	CORE	NQWL		215				Rock core with NQ wireline. Recovery - 100%, RQD - 87% Uniaxial Compressive Strength = 110 MPa
							214				
213.39			9	CORE	NQWL						Recovery - 83%, RQD - 83%
7.32	End of borehole.										

$+^3, \times^3$: Numbers refer to Sensitivity

○ 150 UNCONFINE SHEAR STRENGTH INFERRED FROM POCKET PENETROMETER READINGS

RECORD OF BOREHOLE No C14-4

1 OF 1 **METRIC**

W.P. WP 365-98-00 LOCATION Northing - , Easting - ORIGINATED BY RB

DIST Central Region HWY Highway 12 BOREHOLE TYPE Dynamic Cone COMPILED BY JL

DATUM Geodetic DATE CHECKED BY EC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	PENETR. RESISTANCE STANDARD ● DYN. CONE (20 40 60 80 100) / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
0.00 Ground	TO BE COMPLETED.										
3.05											

$+^{3}$, $\times^{3}$: Numbers refer to Sensitivity

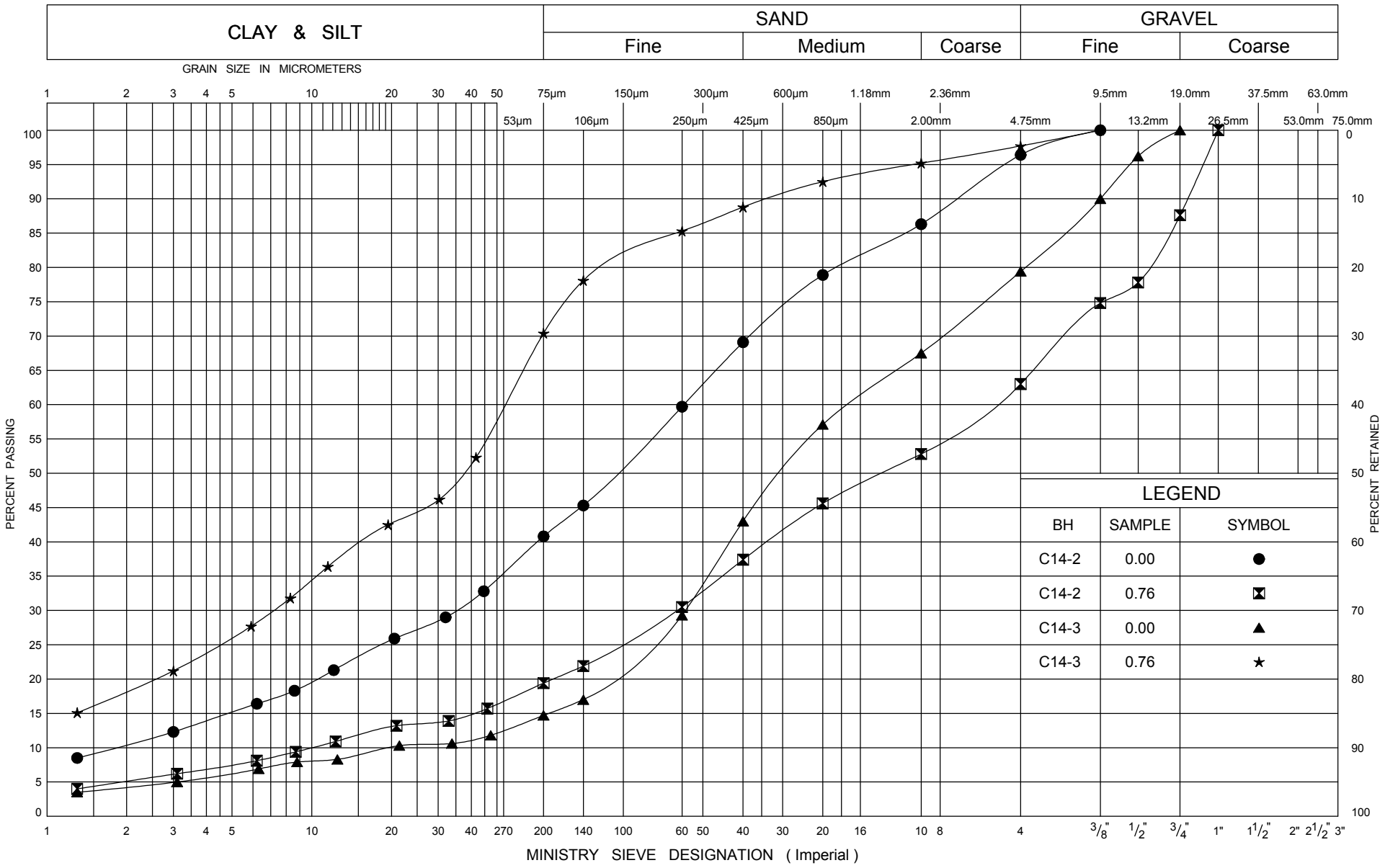
$\circ^{150}$ UNCONFINE SHEAR STRENGTH INFERRED FROM POCKET PENETROMETER READINGS

Appendix B

Laboratory Test Results

Grain Size Distribution	Figures 1, 2, 4 and 5
Plasticity Chart	Figures 3 and 6
Consolidation Plot	Figure 7
Rock Core Report	Figure 8

UNIFIED SOIL CLASSIFICATION SYSTEM



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GRAIN SIZE DISTRIBUTION

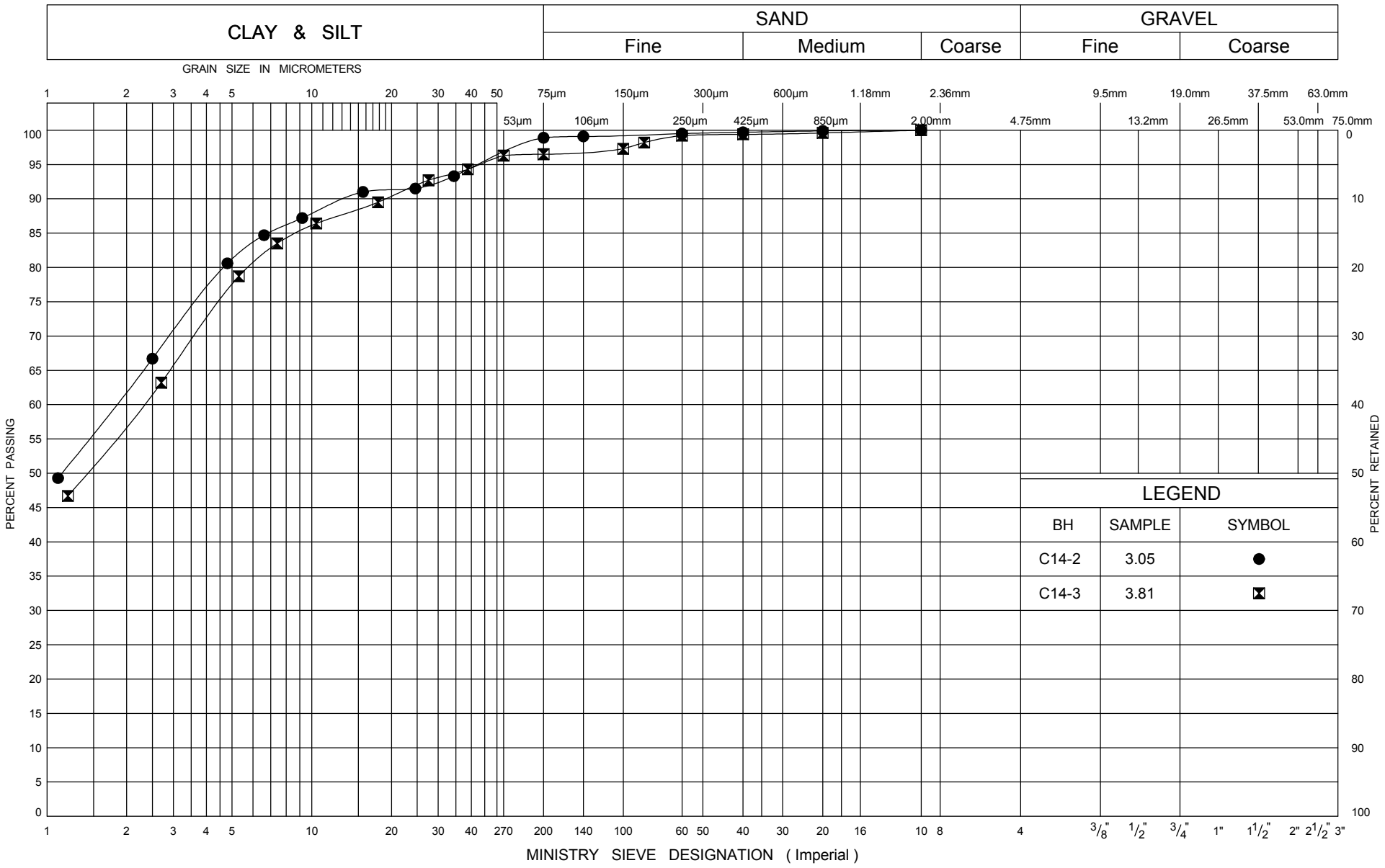
FILL

FIG No 1

WP 365-98-00

Highway 12, Rama Road to Gamebridge

UNIFIED SOIL CLASSIFICATION SYSTEM



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GRAIN SIZE DISTRIBUTION

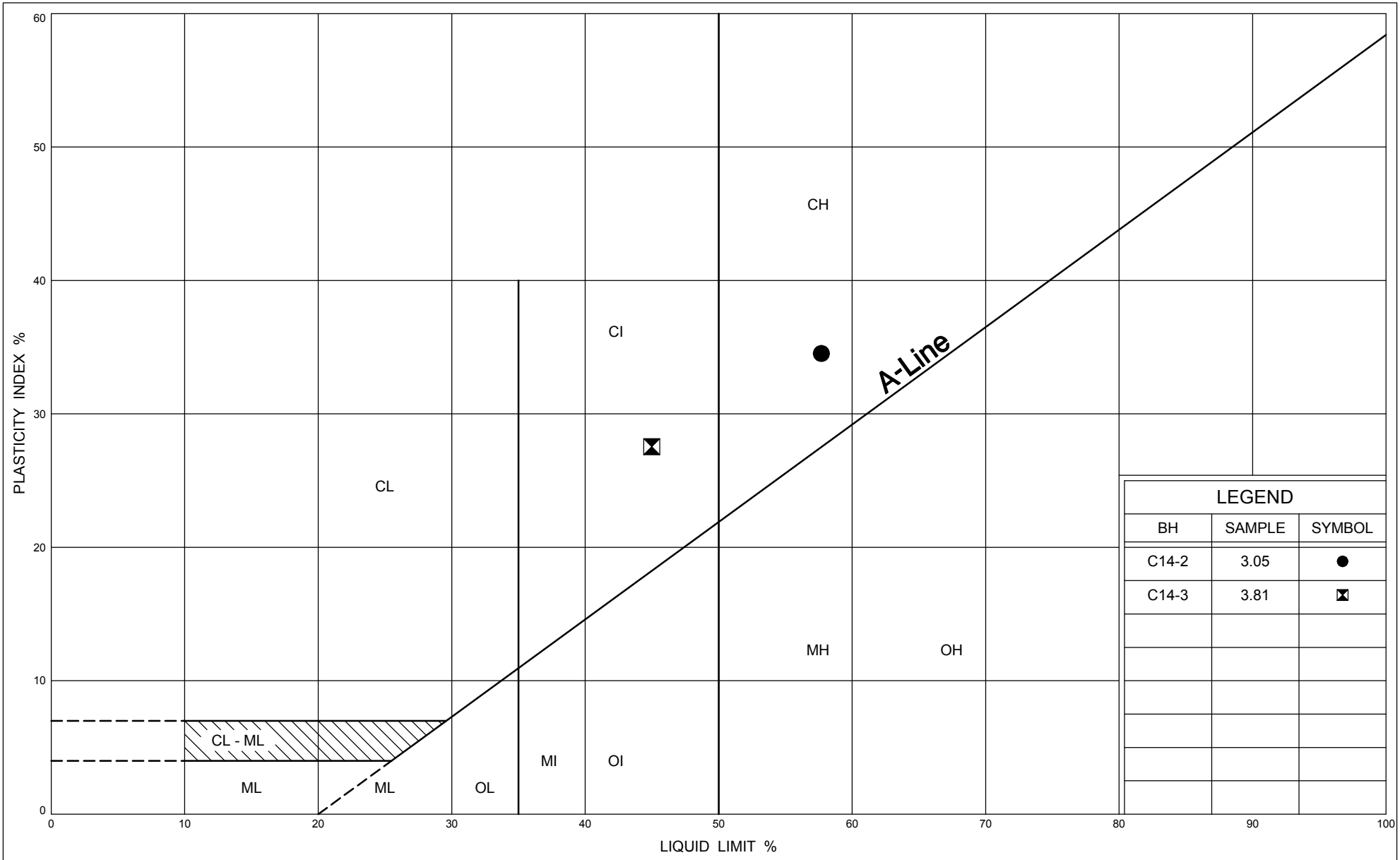
VARVED CLAY, CI TO CH

FIG No 2

WP 365-98-00

Highway 12, Rama Road to Gamebridge

Oct 75, FF - S - 21



ONTARIO MOT PLASTICITY CHART LARGE CULVE 08-1-IEG6 CULVERTS.GPJ ONTARIO MOT.GDT 04/24/09

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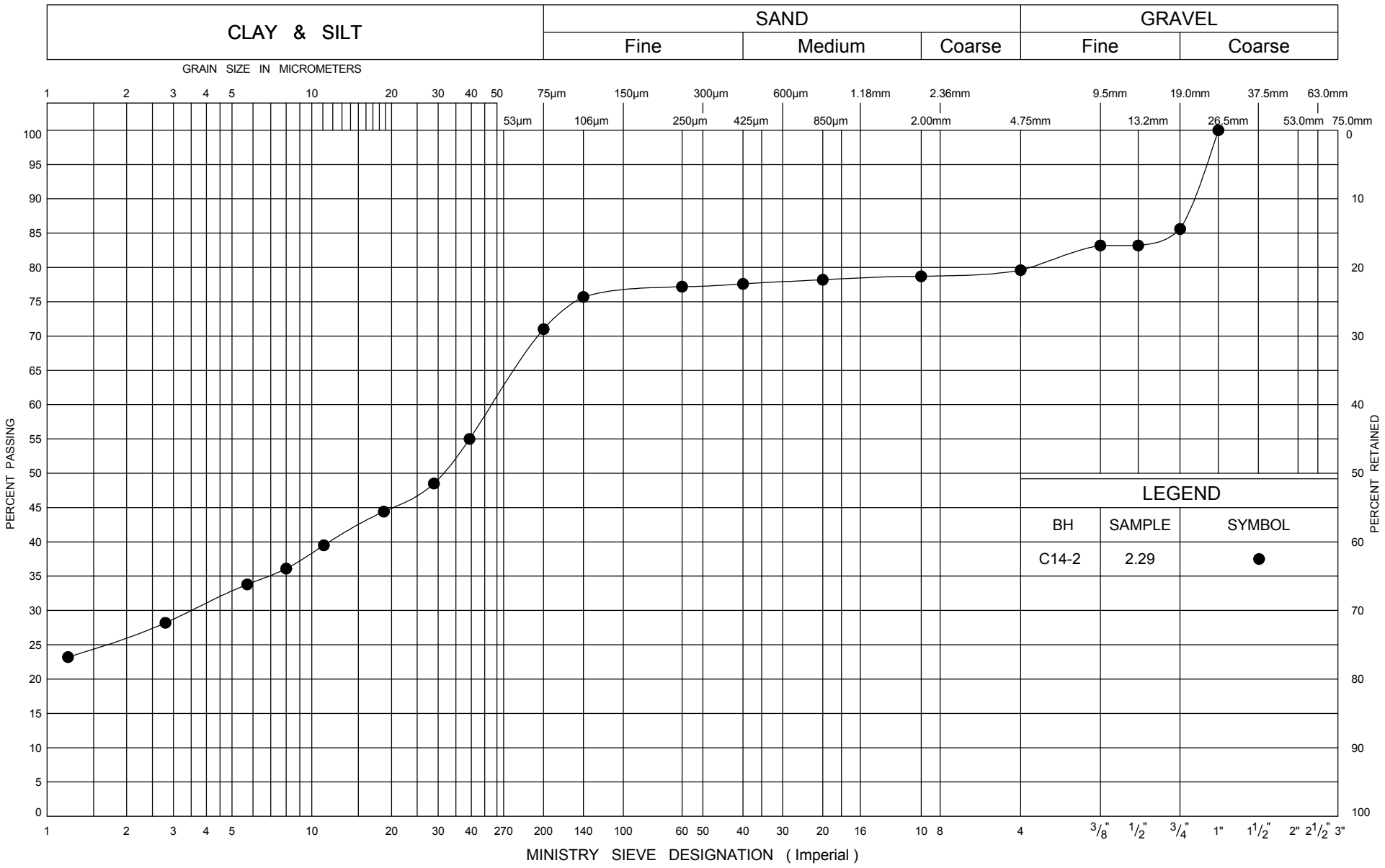
PLASTICITY CHART
VARVED CLAY, CI TO CH

FIG No 3

WP 365-98-00

Highway 12, Rama Road to Gamebridge

UNIFIED SOIL CLASSIFICATION SYSTEM



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GRAIN SIZE DISTRIBUTION

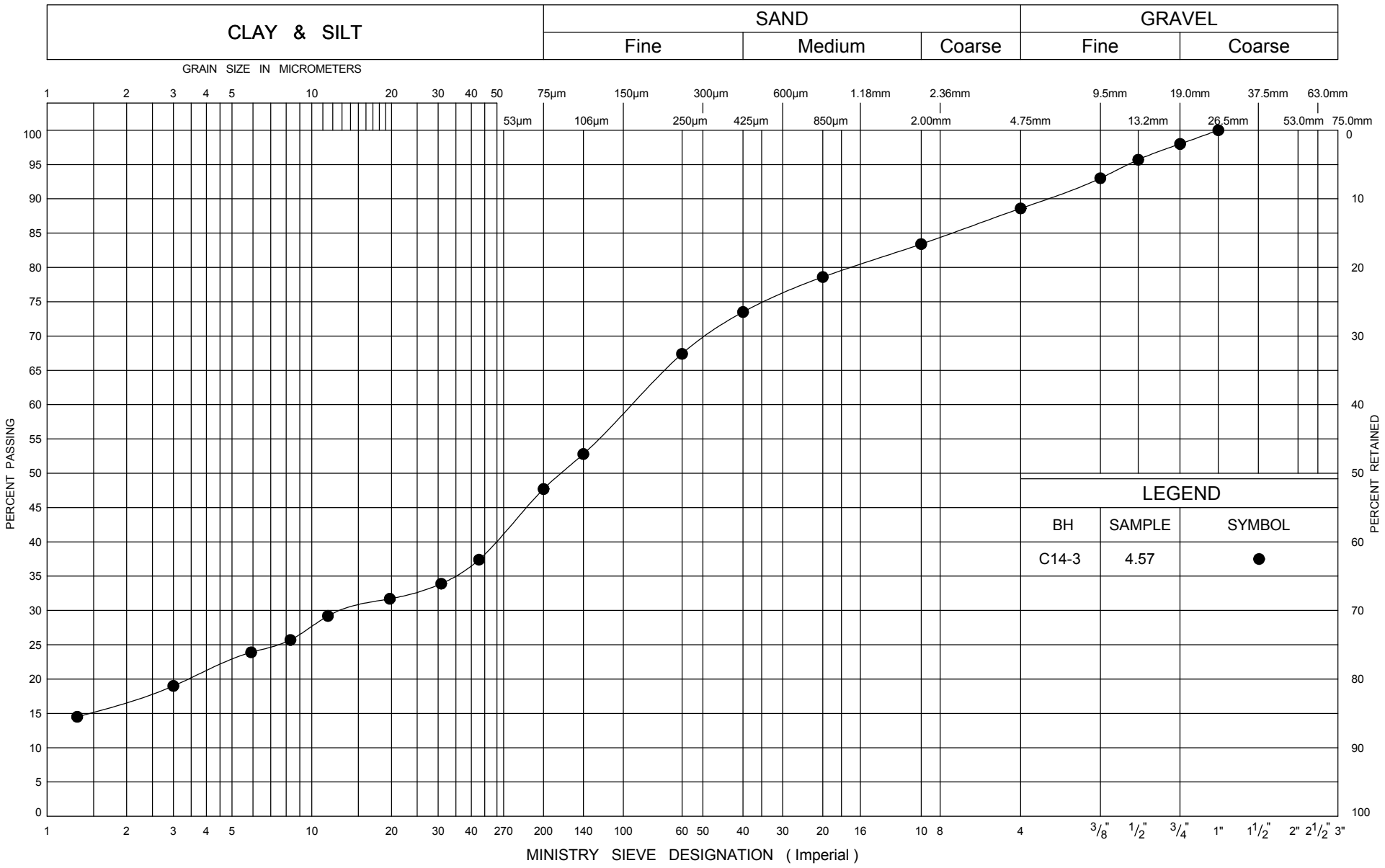
GRAVELLY POCKET WITHIN VARVED CLAY

FIG No 4

WP 365-98-00

Highway 12, Rama Road to Gamebridge

UNIFIED SOIL CLASSIFICATION SYSTEM



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GRAIN SIZE DISTRIBUTION

CLAYEY SILTY SAND POCKET WITHIN VARVED CLAY, SC

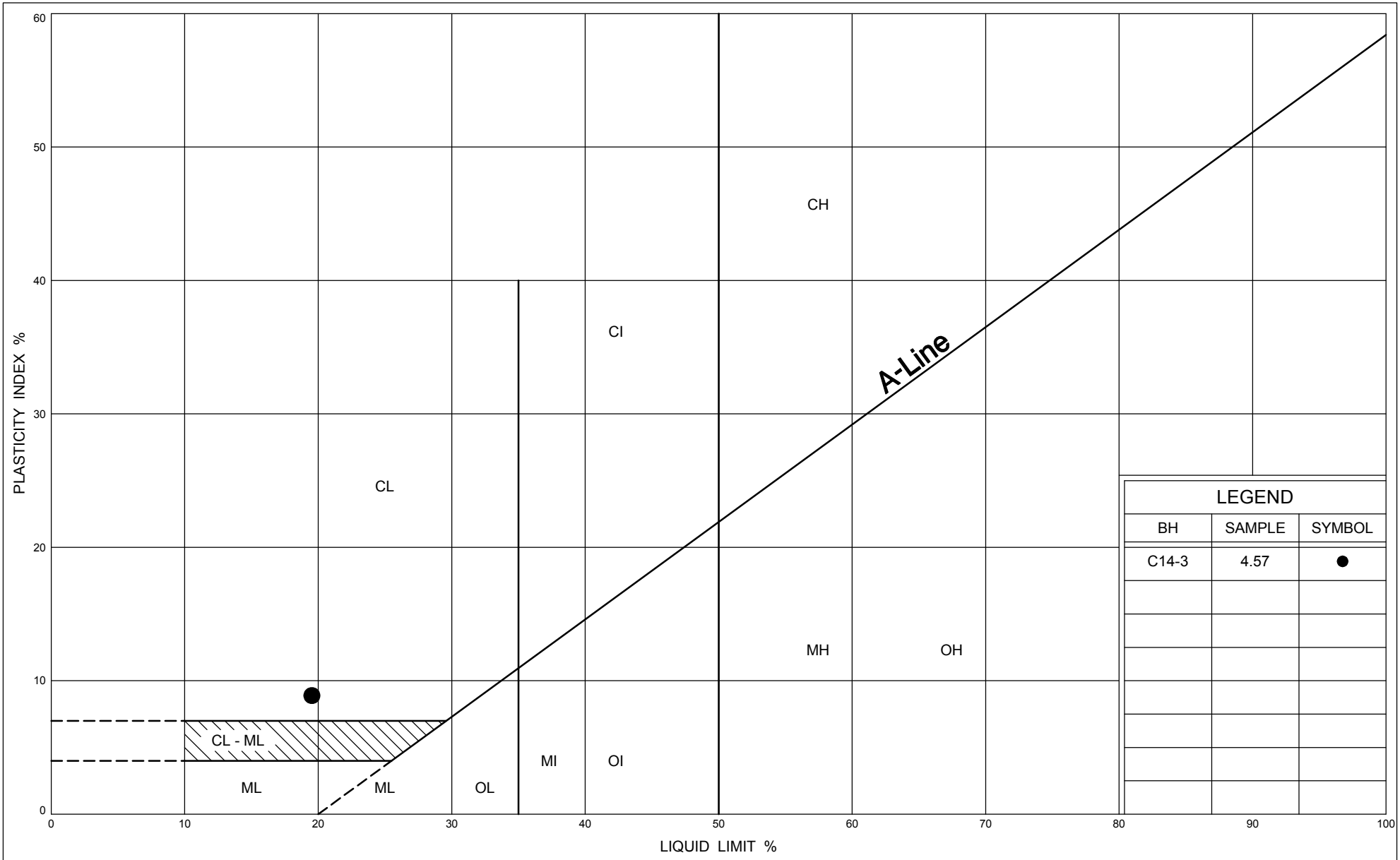
FIG No 5

WP 365-98-00

Highway 12, Rama Road to Gamebridge

ONTARIO MOT GRAIN SIZE LARGE CULVERTS 08-1-IEG6 CULVERTS.GPJ ONTARIO MOT.GDT 04/24/09

Oct 75, FF - S - 21



ONTARIO MOT PLASTICITY CHART LARGE CULVE 08-1-IEG6 CULVERTS.GPJ ONTARIO MOT.GDT 04/24/09

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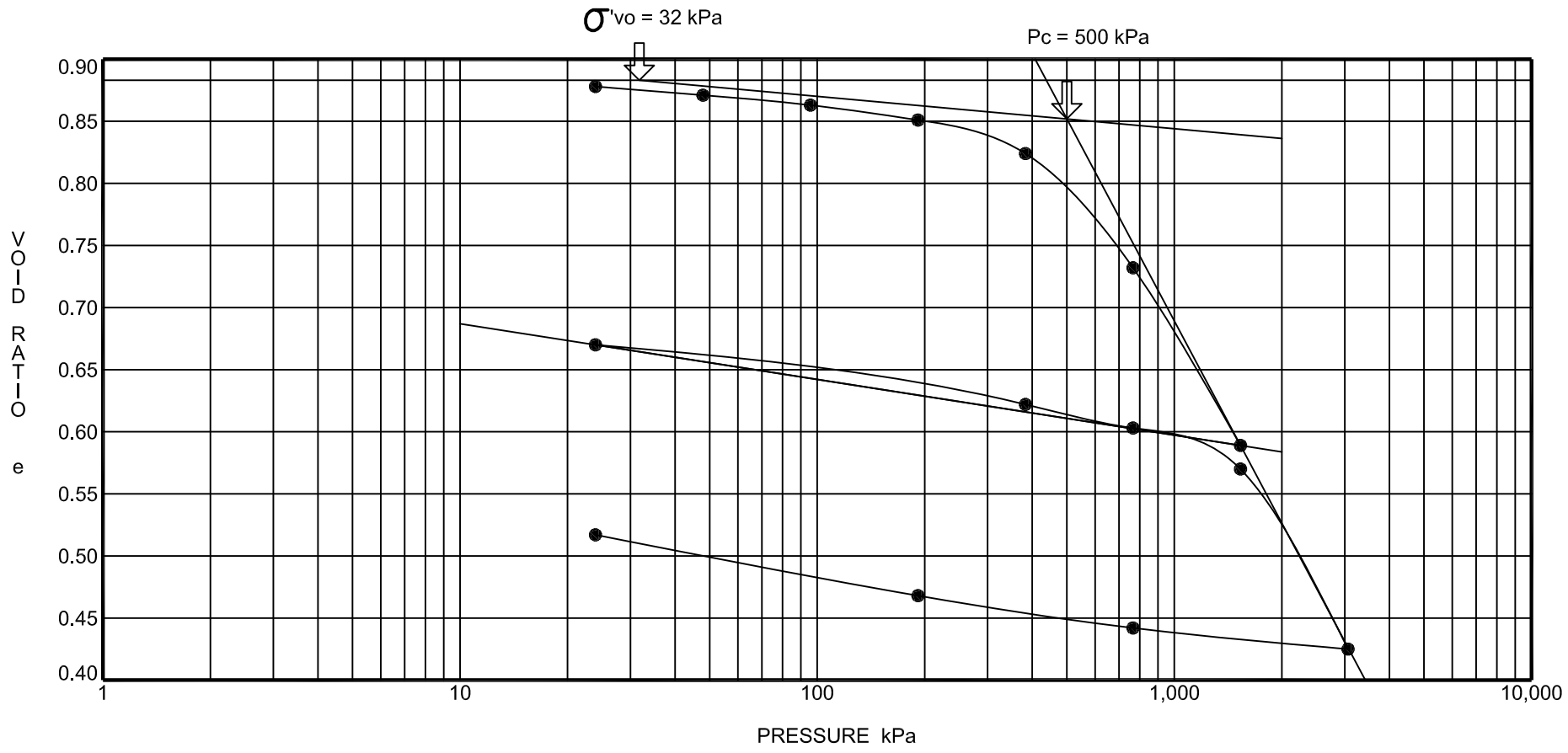
PLASTICITY CHART

CLAYEY SILTY SAND POCKET WITHIN VARVED CLAY, SC

FIG No 6

WP 365-98-00

Highway 12, Rama Road to Gamebridge



	BH	DEPTH	ELEV.	W_L	W_P	W	C_C	C_R	σ'_{vo}	γ_d	Classification
●	C14-3	3.81	216.90	45	17	33	0.540	0.055	32	13.3	VARVED CLAY, CI

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VOID RATIO - PRESSURE CURVE

FIG No 7

WP 365-98-00

Highway 12, Rama Road to Gamebridge

Trow 50 YEARS

Rock Core Test Report

Project No.: LAGM00289085C **Project Name:** Hwy 12 – 03/20019

Core No.	BH C14-3
Location	18'0"-18'10"
Date Cored	
Date Tested	April 7, 2009
Height - (mm)	125.4
Average Diameter - (mm)	45.8
Corrected Compressive Strength - (MPa)	110.1

Testing Laboratory Representative Signature
Ammanuel Yousif

Date: April 8/09

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Ministry of Transportation Ontario	ROCK CORE UNIAXIAL COMPRESSIVE STRENGTH REPORT	FIG No 8
		WP 365-98-00
		Highway 12, Rama Road to Gamebridge

Appendix C

Limitations of Report

APPENDIX C

LIMITATIONS OF REPORT

The conclusions and recommendations given in this report are based on information determined at the testhole locations. Subsurface and groundwater conditions between and beyond the testholes may differ from those encountered at the testhole locations, and conditions may become apparent during construction which could not be detected or anticipated at the time of the site investigation. It is recommended practice that the Soils Engineer be retained during construction to confirm that the subsurface conditions throughout the site do not deviate materially from those encountered in the testholes.

The comments made in this report on potential construction problems and possible methods are intended only for the guidance of the designer. The number of testholes may not be sufficient to determine all the factors that may affect construction methods and costs. For example, the thickness of surficial topsoil or fill layers may vary markedly and unpredictably. The contractors bidding on this project or undertaking the construction should, therefore, make their own interpretation of the factual information presented and draw their own conclusion as to how the subsurface conditions may affect their work.

The benchmark and elevations mentioned in this report were obtained strictly for use in the geotechnical design of the project and by this office only, and should not be used by any other parties for any other purposes.

Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Infrastructure Engineering Group Inc. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

This report does not reflect the environmental issues or concerns unless otherwise stated in the report.

The design recommendations given in this report are applicable only to the project described in the text and then only if constructed substantially in accordance with the details stated in this report. Since all details of the design may not be known, IEG recommends that we be retained during the final design stage to verify that the design is consistent with our recommendations, and that assumptions made in our analysis are valid.

Appendix D

Site Photographs

C14 - Station 20+081 - Looking North

C14 - Station 20+081 - Looking Downstream (west)

C14 - Station 20+081 - Looking Upstream (east)

SITE PHOTOGRAPHS **SITE NO.:30-673/C**

Photo 1 **Roadway Above Culvert / South Approach Roadway**

Photo 2 **West Elevation**

Photo 3 **Asphalt Deterioration Along Roadway**

PHOTOS PROVIDED BY MORRISON HERSHFIELD TO BE CAPTIONED