

**Foundation Investigation and Design Final Report
Wolf River Culvert Replacement
Highway 522
Pringle Township
G.W.P. 476-98-00
GEOCRES No. 31E-260**

Prepared for:

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Part 1 Foundation Investigation

1.1 Introduction

This submission presents the results of a geotechnical investigation completed by Trow Associates Inc. (Trow) for the replacement of the Wolf River Culvert (4830 mm by 3050 mm by approximately 26.0 m long Structural Plate Pipe Arch (SPPA), located on Highway 522 at station 13+475 within Pringle Township. The culvert is listed at Station 13+466 in the Request For Quotation (RFQ) but was determined in the field to be located at Station 13+475. The culvert replacement is to consist of a pre-cast concrete box culvert 4200 mm wide by 3000 mm high and approximately 26.0 m long. Photographs of the site are included in Appendix A.

The purpose of this geotechnical investigation was to determine the existing soil conditions within the proposed construction limits by field investigation and laboratory testing.

The MTO's explanation of terms, abbreviations and symbols are included in Appendix C.

1.2 Site Description and Geological Setting

1.2.1 Site Description

The Wolf River Culvert is located in the Pringle Township at Station 13+475 on Highway 522.

The site plan and cross section profiles of the Wolf River Culvert are as shown on Sheets No. 1 and 2 in Appendix B.

The overall terrain in the area consists of undifferentiated igneous and metamorphic rock, exposed at the surface or covered by a discontinuous layer of drift. The vegetation in the area consists of a mixture of deciduous and coniferous trees and smaller low lying shrubs and grass. The drainage in the area generally consists of roadside ditches which drain into Wolf River.

1.2.2 Geological Setting

According to the Ontario Geological Survey (OGS) Maps 2544 and 2556, the site is located in the Mesoproterozoic era within the central gneiss belt, which falls under the mafic rocks, amphibolite, gabbro, diorite and mafic gneisses. The topography in the area consists of undulating bedrock outcrops separated by intervening marshy zones and wooded areas. As such, the surface soils in the area consist of intervening shallow organic deposits (peat), with fluvial deposits consisting of gravel, sand, silt and clay.

1.3 Investigative Procedures

1.3.1 General

The fieldwork for this project was carried out from June 13th to June 15th and on June 22nd, 2006. The investigation consisted of a total of 3 boreholes (BH-1 to BH-3). Borehole BH-1 was drilled at the culvert inlet (west end of culvert) and borehole BH-3 was drilled at the culvert outlet (east end of culvert), to verify the soil conditions below the existing culvert. Borehole BH-2 was drilled along the east side of the existing culvert embankment to verify embankment fill materials and soil conditions.

All boreholes were advanced with a Mobile CME-55 track mounted drilling rig equipped with continuous flight hollow stem augers and standard soil sampling equipment. All boreholes were advanced by Landcore Drilling.

From the drilling program, soil samples were obtained using a 51 mm (2 inch) outside diameter split spoon sampler in conjunction with Standard Penetration Tests (ASTM D 1586), at 0.75 m intervals for the upper 3.0 m and at 1.5 m intervals thereafter. The Standard Penetration Test (SPT) "N" values were recorded and used to provide an assessment of the in-situ relative density of the overburden soils. All boreholes were backfilled with auger cuttings and sealed with bentonite pellets.

All fieldwork was supervised by a member of Trow's engineering staff who directed the drilling and sampling operations, logged the factual borehole data, and retrieved soil samples for subsequent laboratory testing and identification. All geodetic borehole elevations were determined in the field by Sutcliffe Rody Quesnel (SRQ). The locations of the boreholes and geodetic elevations are shown on Sheet 1, with a cross-section of the boreholes on Sheet 2 in Appendix B.

1.4 Laboratory

The soil samples obtained in the field were carefully transported to our Sudbury laboratory and examined for further verification and classification. A laboratory testing program for the selected soil consisted of Natural Moisture Content Determination (LS 701), Particle Size Analyses (LS 702), Liquid Limit (LS 703) and Plastic Limit and Plasticity Index (LS 704).

The laboratory test results are summarized on the attached borehole logs in Appendix C, as well as in Appendix D.

1.5 Subsurface Conditions

1.5.1 General

The subsurface conditions encountered during the field investigation are summarized on the borehole logs located in Appendix C. The following is a description of the subsurface conditions encountered during the field investigation.

1.5.2 Stratigraphy, Culvert Inlet

In general, the stratigraphy within borehole BH-1 at the west end of the culvert consisted of interlayered sand, and sand and silt, overlying a layer of silty clay, which overlaid sand and suspected bedrock.

In borehole BH-1, the interlayered sand, and sand and silt were encountered from ground surface to approximately 10.7 m below grade. The interlayered material was generally brown to grey in colour, dry to damp above 2.1 m depth and wet below, well graded, fine to coarse grained and contained trace fine grained gravel. Recorded uncorrected SPT “N” values within the interlayered material ranged from 0 to 6 blows per 300 mm inferring a very loose to loose material in relative density. Underlying the interlayered material was a 1.5 m thick layer of silty clay, which extended to a depth of 12.2 m. The silty clay was grey in colour, wet, of low plasticity and contained trace fine grained sand. The recorded uncorrected SPT “N” value within the silty clay was 2 blows per 300 mm inferring a very soft material in consistency. Underlying the silty clay was a 0.6 m thick layer of sand, which extended to the SPT refusal depth. The sand was grey in colour, wet, poorly graded, fine grained and contained trace to some silt. The recorded uncorrected SPT “N” value within the sand was 8 blows per 300 mm inferring a loose material in relative density. Underlying the sand was suspected bedrock.

1.5.3 Stratigraphy, Culvert Outlet and East Embankment

In general, the stratigraphy within boreholes BH-2 (east embankment) and BH-3 (culvert outlet, east end) consisted of sand fill overlying sand, silt and sand, and silty clay.

In borcholes BH-2 and BH-3, sand fill was encountered from the ground surface to between approximately 3.2 m (BH-3) to 6.1 m below grade. The sand fill was brown in colour, damp above approximately 3.1 m depth and wet below, well graded, fine to coarse grained and contained trace fine to coarse grained gravel, trace silt and trace organics. Recorded uncorrected SPT “N” values within the sand fill ranged from 3 to 9 blows per 300 mm inferring a very loose to loose material in relative density. Underlying the sand fill was sand, which extended to depths between 12.2 m (BH-3) and 14.8 m (BH-2). The sand was brown to grey in colour, wet, poor to well graded, fine to coarse grained and contained trace to some fine grained gravel and trace to with silt. Recorded uncorrected SPT “N” values within the sand material ranged from 2 to 17 blows per 300 mm inferring a very loose to compact material in relative density. A 1.6 m thick layer of silty clay was encountered within the sand in borehole BH-2 between 7.6 and 9.2 m below grade. The silty clay was grey in colour, wet and of low to medium plasticity. The recorded uncorrected SPT “N” value within the silty clay was 1 blow per 300 mm inferring a very soft material in consistency. Underlying the sand in borehole BH-3 was a 2.8 m thick layer of silt and sand, which extended to the borehole termination depth. The silt and sand was brown to grey in colour, wet, well graded and contained fine to coarse grained sand. Recorded uncorrected SPT “N” values with the silt and sand were 13 blows per 300 mm above 13.7 m, depth inferring a compact material in relative density and 4 blows per 300 mm below, inferring a very loose material in relative density.

Boreholes BH-2 and BH-3 were terminated between approximately 14.8 and 15.0 m below grade respectively.

1.6 Groundwater Conditions

Groundwater was encountered in boreholes BH-1 to BH-3 between Elevations 221.81 and 223.12 m. This infers a groundwater level slightly below creek level at the time of the investigation. The lower water levels within the borcholes could be due to disturbance in the holes at the time of drilling or that the boreholes had not stabilized prior to backfilling. As such, for design purposes the groundwater level should be assumed to be equal to the creek water elevation, which was 223.70 m at the time of the investigation.

Seasonal variations in the water table should be anticipated, with higher levels occurring during wetter periods of the year (such as spring thaw and late fall) and lower levels during drier periods.

Part 2 Engineering Discussions and Recommendations

2.1 Introduction

The following subsections address the geotechnical design and construction considerations for the proposed Wolf River culvert (4200 mm wide by 3000 mm high pre-cast concrete box culvert) located on Highway 522 at Station 13+475 within Pringle Township. The new culvert is to be 26.0 m long. Photographs are included in Appendix A.

2.2 Culvert Replacement at Wolf River Highway 522

It is understood by Trow that the existing 4830 mm by 3050 mm by approximately 26.0 m long Structural Plate Pipe Arch (SPPA) culvert is to be replaced with a pre-cast concrete box culvert 4200 mm wide by 3000 mm high. The proposed invert will be placed at approximately the same invert as the existing culvert between elevations 222.66 m (west end - inlet) and 222.63 m (east end - outlet).

For the invert of the concrete box culvert to be founded at approximately the same invert as the existing culvert, the underside of the proposed culvert will be founded near Elevations 222.21 m (inlet) and 222.18 m (outlet), which accounts for the thickness of concrete (approximately 150 mm) and the bedding layer (minimum 300 mm). At these elevations the proposed culvert will be founded on or near the in-situ native sand material. In borehole BH-2, approximately 2.1 m of sand fill will need to be removed to found the culvert on the in-situ native sand material. The native sand material encountered between Elevations 220.1 and 222.4 m in boreholes BH-1 to BH-3 had recorded uncorrected SPT "N" values ranging from 0 to 7 blows per 300 mm, which infers a very loose to loose material in relative density. The groundwater elevations that were observed within the boreholes were between Elevations 221.8 and 223.1 m, and therefore likely affected the relative density determinations from the Standard Penetration Tests in the field.

For the proposed culvert founded on the in-situ native sand material or engineered fill, a Factored Bearing Resistance at ULS of 150 kPa and a Factored Bearing Resistance at SLS of 50 kPa is recommended in accordance with the Canadian Highway Bridge Design Code, Section 6.7, Shallow Foundations. Prior to the placement of the culvert, all fill material must be removed down to the native material, which must be cleared of any soft, loose or disturbed soil. Any loose areas are to be sub-excavated and replaced with Granular "A" or Granular "B" Type II (OPSS 1010) compacted to a minimum of 100% of the Standard Proctor Maximum Dry Density (SPMDD). The groundwater level needs to be controlled below excavation levels to avoid disturbance, and any surface or groundwater seepage should be removed from within the excavation prior to the culvert replacement to allow placement of granular backfill in the dry. A non-woven geotextile separator (Terrafix 270R or equivalent) is to be used between the subgrade soils and the Granular material to stabilize the native soils.

Provided the existing highway grades are maintained, the anticipated maximum total settlements for the concrete box culvert are not expected to exceed 25 mm, assuming good construction practice. Any potential settlements within the underlying sand material are expected to occur during construction.

2.2.1 Culvert Bedding

The culvert bedding should consist of Granular "A" (OPSS 1010) with a minimum thickness of 300 mm beneath the culvert and extend a minimum of 300 mm horizontally on either side of the culverts edge and slope down at 1H:1V. The granular material should be compacted to 100% of the SPMDD in maximum 150 mm thick lifts and placed in dry conditions. Prior to placing any fill material, a non-woven geotextile (such as Terrafix 270 R or equivalent) is to be placed between the native soils and the engineered fill to assist in material placement and maintain the integrity of the granular materials. If construction proceeds during the winter months, the base of the trench should not be allowed to freeze prior to placing the bedding material. In areas where the base of the trench experiences loose or soft material, the area may have to be sub-excavated and replaced with Granular "A" or Granular "B" Type II material to stabilize the trench base.

Prior to placement of any fill material, the native sand and boulders are to be relatively level and visually inspected by a qualified engineer.

2.2.2 Culvert Backfill

Any organics and other deleterious material should be excavated as outlined in OPSD 803.010, attached in Appendix E. The culvert backfill should consist of stone free Granular "B", Type I or Granular "A" (OPSS 1010) placed in maximum 150 mm lifts kept at the same elevation on both sides of the culvert. The granular backfill should be compacted to 100% of SPMDD.

The culvert should be encased with a minimum of 300 mm of compacted material. Typical backfill diagrams are presented in Appendix E, OPSD 803.010. The minimum height of fill over the top of the culvert for heavy equipment during construction shall be 1000 mm, unless otherwise noted by the structural engineer. In addition the Contractor is to follow SP No. 902S01, regarding backfilling for structures.

2.2.3 Lateral Earth Pressure

Culvert walls and temporary shoring that may be required for excavation should be designed to resist lateral earth pressure. The expression for calculating lateral earth pressure is given by

$$p = K (\gamma h + q)$$

where p = Lateral earth pressure (kPa).

K = Coefficient of earth pressure.

γ = Unit weight of backfill (kN/m^3).

h = Depth to point of interest (m).

q = Surcharge load acting adjacent to the wall at the ground surface (kPa).

The above expression does not take into account hydrostatic pressure, which must be included for the groundwater level at existing ground surface.

Table 1 below lists various earth pressure properties for given materials.

Table 1 - Material Types and Earth Pressure Properties

Material	Friction Angle ϕ (unfactored)	Coefficient of Active Earth Pressure (k_a)	Coefficient of Passive Earth Pressure (k_p)	Coefficient of Earth Pressure at Rest (k_o)	Unit Weight γ (kN/m^3)
Granular A	35°	0.27	3.7	0.43	22
Granular B Type I	32°	0.33	3	0.5	21
Granular B Type II	35°	0.27	3.7	0.43	21
Rock Fill	42°	0.2	5	0.33	21

Note: Values given for horizontal earth pressures are for horizontal backfill. For sloping backfill, the design requirements outlined in Sec C6.9.1(c) of the Canadian Highway Bridge Design Code should be used. A unit weight of $\gamma=21 \text{ kN/m}^3$ is based on well graded rockfill.

The mobilization of full active or passive resistance requires a measurable and perhaps significant wall movement or rotation. Therefore, unless the structural element can tolerate these deflections, the at-rest earth pressure should be used in design.

The effects of compaction surcharge should be taken into account in the calculations of active and at rest earth pressures. The lateral pressure due to compaction should be taken as at least 12 kPa at the surface, and its magnitude should be assumed to diminish linearly with depth to zero at the depth where the active (or at rest) pressure is equal to 12 kPa. This pressure distribution should be added to the calculated active (or at rest) pressure. Notwithstanding, lighter compaction equipment and smaller lifts should be used adjacent to walls to prevent overstraining.

2.2.4 Design Parameters

The design of the culvert is based on the following soil parameters as outlined in Table 2.

Table 2 - Material Types and Strength Parameters

Material	Friction Angle ϕ	Cohesion c' (kPa)	Unit Weight γ (kN/m ³)
Granular A	35°	0	22
Granular B Type I	32°	0	21
Granular B Type II	35°	0	21
Sand / Sand Fill	32°	0	21
Sand and Silt	30°	0	21

2.2.5 Sliding Resistance

A friction angle, θ' , of 30° can be used for sliding resistance along the Granular “A” and a pre-cast concrete box culvert and 32 degrees for cast in place concrete box culvert if applicable.

2.2.6 Erosion Protection Outlet

Rip-rap protection should be provided where the culvert discharges into the open river. The rip-rap should extend approximately 5 m beyond the ends of the culvert and line the embankment slope to the spring line of the culvert. The size of the rip-rap is a function of the rivers hydrology. As a rule of thumb the thickness of the rip-rap should be a minimum of twice the median particle size, and 300 mm thick as a minimum. The rip-rap configuration at the river bed should generally follow the OPSD 810.010, which is included in Appendix E of this report. Rip-rap placed at 1V:1H will be stable.

2.2.7 Erosion Protection Inlet

Rip-rap protection should be provided where the open river enters the culvert. The rip rap should begin approximately 5 m before the culvert inlet and line the embankment slope to the spring line of the culvert. The size of the rip-rap is a function of the rivers hydrology. As a rule of thumb the thickness of the rip-rap should be a minimum of twice the median particle size, and 300 mm thick as a minimum. The rip-rap configuration at the river bed should generally follow the OPSD 810.010, which is included in Appendix E of this report. Rip-rap placed at 1V:1H will be stable.

Where rip-rap is not present the embankment side slopes are to be vegetated with sodding, seeding or planting as necessary depending on the flow rate and volume. Should seeding be utilized, a 100 mm thick layer of topsoil should be placed along with a degradable erosion blanket to help minimize erosion until the vegetation begins to grow.

2.2.8 Clay Seal

A clay seal should be placed at the inlet of the proposed culvert, to prevent the migration of material along the face of the culvert, the formation of flow paths, and any potential internal erosion within the highway embankment. The following outlines the installation procedures and minimum material requirement of the clay seal:

- The clay seal should be placed against the constructed embankment, and subsequently protected by the inlet erosion protection extending a minimum of 1.0 m along the side of the culvert and extending out laterally 1.0 m from the culvert.
- The clay seal should be placed along the top and side of the culvert only. The clay must not be placed below the culvert.
- The clay should have a Liquid Limit greater than 50% and a Plasticity Index greater than 17.5%.
- The clay seal is to be place in maximum 150 mm thick lifts and compacted to 95% SPMDD within 2% of the optimum moisture content.

2.2.9 Stream Bed Rip-Rap

The Stream Bed rip-rap thickness is to be twice the median particle size, and/or 300 mm thick as a minimum as outlined by OPSD 810.010 included in Appendix E of this report.

2.2.10 Frost Protection

A frost penetration depth of up to 1.9 m can occur in open areas in the Pringle Township area without snow cover. The underlying sand fill, sand, and sand and silt materials are considered to have a low to moderate susceptibility to frost heaving, according to the MTO Guidelines for Soil Frost Susceptibility. To minimize potential movements, the frost protection treatment as outlined in OPSD 803.030 and 803.031 included in Appendix E of this report should be applied.

2.2.11 Excavations

All excavations must be conducted in accordance with the Occupational Health and Safety Act and Regulations for Construction (OHSARC). The sand fill, sand, and sand and silt may be classified as Type 3 soils above the groundwater level and Type 4 soils below the groundwater level, in conformance with the OHSARC. Excavations are expected to be below the groundwater levels measured during this investigation. To avoid disturbance of the founding materials and to allow placement of fill in dry conditions, groundwater must be controlled to below the proposed excavation levels.

Temporary excavation side slopes for Type 3 soils should not exceed 1H:1V. Temporary excavation side slopes in Type 4 soils should not exceed 3H:1V. There is a potential for sloughing to occur if the trench remains open for an extended period of time (i.e. 24-48 hours) or during a rainfall event. Therefore, it is recommended that excavations be supported by a trench box if they are to be open for an extended period of time or for rain events.

When excavations cannot be safely sloped to maintain stability during construction, suitably designed temporary shoring should be used. Systems such as steel sheet piles or steel "I" beam piles with timber lagging (soldier piles and lagging) can be employed for temporary excavations. It will be the Contractor's responsibility to design a suitable temporary support system for the MTO review prior to installation. In addition the Contractor is to follow SP No. 902S01, regarding excavations for structures and SP No. 105S19, regarding protection systems (e.g. sheet piles or timber lagging).

2.2.12 Dewatering

The soils encountered below the groundwater table and within potential excavation depths consist of sand, sand fill, and sand and silt. The estimated hydraulic conductivity, “k” of these materials is outlined in Table 3.

Table 3 Estimated Hydraulic Conductivity

Materials	Hydraulic Conductivity “k” (m/s)
Sand / Sand fill	$10^{-3} - 10^{-5}$
Sand and Silt	$10^{-4} - 10^{-6}$

Dewatering requirements will be governed by the water levels in the river at the time of construction. It is the responsibility of the Contractor to propose a suitable dewatering system based on the time of construction, groundwater levels and river flow conditions for prior approval of the MTO. The method used should not undermine the existing road.

Erosion and sediment control during culvert construction should be as per the MTC Drainage Manual, Volume 2. Silt fences and other sediment control measures should be included to protect the river environment from the construction activities. All flow must be appropriately controlled during construction.

2.2.13 Construction Recommendations

In order to minimize the disruption to traffic, it is recommended that the replacement of the culverts through Highway 522, be conducted in two construction stages. Each stage will consist of removing and replacing the culverts on one side of the Highway at a time as to provide a throughway lane at all times.

Although the excavations are expected to remain stable at a slope of 1H:1V above the groundwater table and 3H:1V below the groundwater table, sloughing will occur if the trench remains open for an extended period of time. Where this may occur, it may be necessary to use temporary shoring. Suitably designed temporary shoring systems, such as sheet pile or soldier piles and lagging, can be used. It will be the Contractors responsibility to design a suitable temporary support system for the MTO review prior to installation. In addition, the contractor should follow SP No. 105S19, regarding protection systems (e.g. sheets piles or timber lagging).

Provided that the existing highway embankments are restored to as near as possible to the existing grades and embankment slopes, using an equivalent engineered fill material, a slope stability analysis is not required and any potential settlements will be negligible.

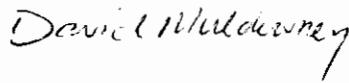
3.0 CLOSURE

This report has been prepared by D. Muldowney, B.Eng., and reviewed by T. Crilly M.Sc., P.Eng. and S. Gonsalves, M.Eng., P.Eng. Designated MTO Foundation Contact. The field investigation was conducted by Craig St. Amant.

We trust this report is satisfactory for your purposes. Should you have any questions, please do not hesitate to contact this office.

Yours truly,

Trow Associates Inc.



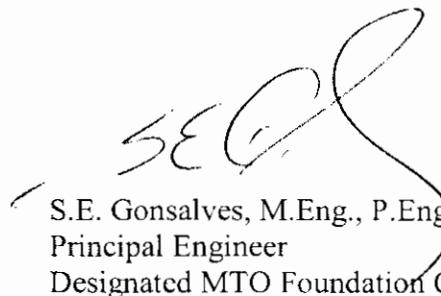
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Encl.

Dist: Northland Engineering (1987) Limited (7)

APPENDIX A

Photographs



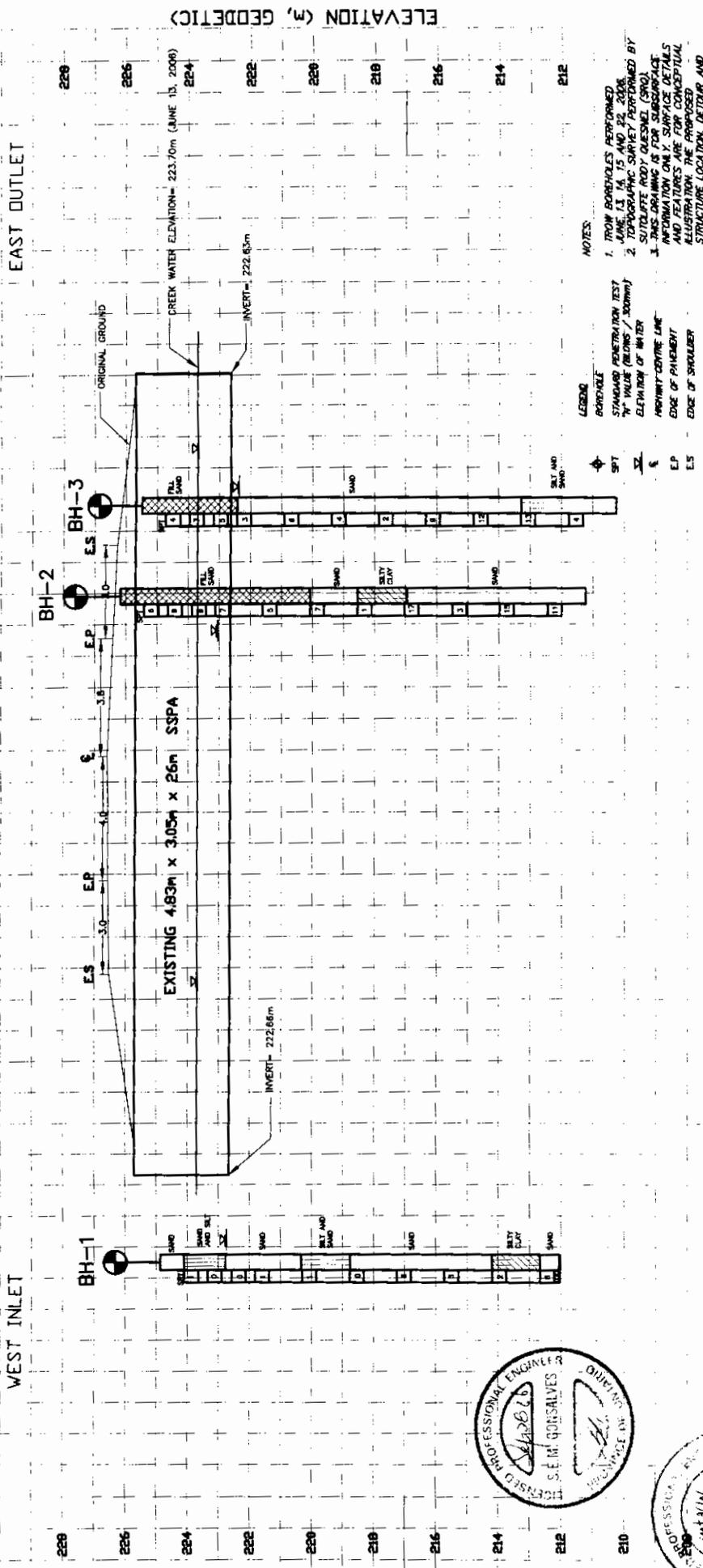
**Photograph #1 – Station 13+475, Pringle Township, Facing North
Photograph taken June 13th, 2006**



**Photograph #2 – Station 13+475, Pringle Township, Facing West
Photograph taken June 13th, 2006**

APPENDIX B

Drawings



NO.	ELEVATION	NORTHING	EASTING	OFFSET (m)
BH-1	224.86	508237.54	283330.27	16.3 LT
BH-2	228.17	508044.33	283381.00	3.1 RT
BH-3	225.48	508293.70	283363.68	8.0 RT

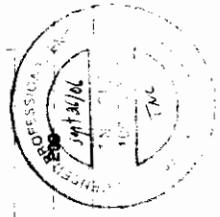
- NOTES:**
1. TROW BOREHOLES PERFORMED WITH 1.5m DIAMETER. ALL TESTS PERFORMED BY TROW.
 2. TOPOGRAPHIC SURVEY PERFORMED BY SUTCLIFFE ROYD GUESNEL (SRO).
 3. THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION. THE PROPOSED STRUCTURE LOCATION, DETOUR AND ELEVATIONS ARE FOR INFORMATION ONLY AND MAY NOT BE CONSISTENT WITH THE FINAL DESIGN CONFIGURATION AS SHOWN ELSEWHERE IN THE CONTRACT DOCUMENT.
 4. THE BOUNDARIES BETWEEN SOIL STRATA HAVE BEEN ESTABLISHED ONLY AT BOREHOLES. BOUNDARIES BETWEEN BOREHOLES ARE ASSUMED FROM GEOLOGICAL EVIDENCE.

- LEGEND:**
- BOREHOLE
 - STANDARD PENETRATION TEST
 - "N" VALUE (BLIND / 300mm)
 - ELEVATION OF WATER
 - PROBABLE PENETRATION TEST
 - EDGE OF PAVEMENT
 - EDGE OF SHOULDER

SECTION A - A

WOLF RIVER CULVERT PROFILE

SCALE: 1:125



APPENDIX C

Borehole Logs

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 31mm 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 (31mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 1/2" 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.

ROCK 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	30mm	30 - 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

SS	SPLIT SPOON	TP	THINWALL PISTON
WS	WASH SAMPLE	OS	OSTERBERG SAMPLE
ST	SLOTTED TUBE SAMPLE	RC	ROCK CORE
BS	BLOCK SAMPLE	PH	TW ADVANCED HYDRAULICALLY
CS	CHUNK SAMPLE	PM	TW ADVANCED MANUALLY
TW	THINWALL OPEN	FS	FOIL SAMPLE

MECHANICAL PROPERTIES OF SOIL

e_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/p	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_f	kPa	REMOULDED SHEAR STRENGTH
S_r	1	SENSITIVITY = $\frac{c_u}{\tau_f}$

STRESS AND STRAIN

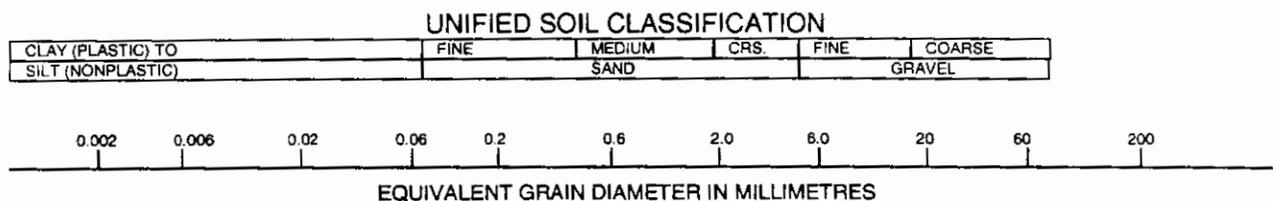
u_w	kPa	PORE WATER PRESSURE
u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS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

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES	e	1, %	VOID RATIO	e_{min}	1, %	VOID RATIO IN DENSEST STATE
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES	n	1, %	POROSIITY	I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
ρ_w	kg/m^3	DENSITY OF WATER	w	1, %	WATER CONTENT	D	mm	GRAIN DIAMETER
γ_w	kN/m^3	UNIT WEIGHT OF WATER	S_r	%	DEGREE OF SATURATION	D_n	mm	n PERCENT - DIAMETER
ρ	kg/m^3	DENSITY OF SOIL	w_L	%	LIQUID LIMIT	C_u	1	UNIFORMITY COEFFICIENT
γ	kN/m^3	UNIT WEIGHT OF SOIL	w_p	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
ρ_d	kg/m^3	DENSITY OF DRY SOIL	w_s	%	SHRINKAGE LIMIT	q	m^3/s	RATE OF DISCHARGE
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL	I_p	%	PLASTICITY INDEX = $w_L - w_p$	v	m/s	DISCHARGE VELOCITY
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	1	HYDRAULIC GRADIENT
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL	I_C	1	CONSISTENCY INDEX = $\frac{w - w_p}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL	e_{max}	1, %	VOID RATIO IN LOOSEST STATE	j	kN/m^2	SEEPAGE FORCE
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL						

Notes On Sample Descriptions

- All sample descriptions included in this report follow the Unified Soil Classification System (USCS) as outlined by the Ministry of Transportation. Different classification systems may be used by others; one such system is the International Society for Soil Mechanics and Foundation Engineering (ISSMFE), as outlined in the Canadian Foundations Engineering Manual. Please note that, with the exception of those samples where a grain size analysis has been made, all samples are classified visually. Visual classification is not sufficiently accurate to provide exact grain sizing or precise differentiation between size classification systems.



ISSMFE SOIL CLASSIFICATION

CLAY	SILT			SAND			GRAVEL			COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE		

- Fill:** Where fill is designated on the borehole log it is defined as indicated by the sample recovered during the boring process. The reader is cautioned that fills are heterogeneous in nature and variable in density or degree of compaction. The borehole description may therefore not be applicable as a general description of site fill materials. All fills should be expected to contain obstruction such as wood, large concrete pieces or subsurface basements, floors, tanks, etc., none of these may have been encountered in the boreholes. Since boreholes cannot accurately define the contents of the fill, test pits are recommended to provide supplementary information. Despite the use of test pits, the heterogeneous nature of fill will leave some ambiguity as to the exact composition of the fill. Most fills contain pockets, seams, or layers of organically contaminated soil. This organic material can result in the generation of methane gas and/or significant ongoing and future settlements. Fill at this site may have been monitored for the presence of methane gas and, if so, the results are given on the borehole logs. The monitoring process does not indicate the volume of gas that can be potentially generated nor does it pinpoint the source of the gas. These readings are to advise of the presence of gas only, and a detailed study is recommended for sites where any explosive gas/methane is detected. Some fill material may be contaminated by toxic/hazardous waste that renders it unacceptable for deposition in any but designated land fill sites; unless specifically stated the fill on this site has not been tested for contaminants that may be considered toxic or hazardous. This testing and a potential hazard study can be undertaken if requested. In most residential/commercial areas undergoing reconstruction, buried oil tanks are common and are generally not detected in a conventional geotechnical site investigation.
- Till:** The term till on the borehole logs indicates that the material originates from a geological process associated with glaciation. Because of this geological process the till must be considered heterogeneous in composition and as such may contain pockets and/or seams of material such as sand, gravel, silt or clay. Till often contains cobbles (75 to 200 mm) or boulders (over 200 mm). Contractors may therefore encounter cobbles and boulders during excavation, even if they are not indicated by the borings. It should be appreciated that normal sampling equipment cannot differentiate the size or type of any obstruction. Because of the horizontal and vertical variability of till, the sample description may be applicable to a very limited zone; caution is therefore essential when dealing with sensitive excavations or dewatering programs in till materials.

Notes On Soil Descriptions

4. The following table gives a description of the soil based on particle sizes. With the exception of those samples where grain size analyses have been performed, all samples are classified visually. The accuracy of visual examination is not sufficient to differentiate between this classification system or exact grain size.

Soil Classification		Terminology	Proportion
Clay and Silt	<0.075 mm		
Sand	0.075 to 4.75 mm	"trace" (e.g. Trace sand)	0% to 10%
Gravel	4.75 to 75 mm	"some" (e.g. Some sand)	10% to 20%
Cobbles	75 to 200 mm	with (e.g. with sand)	20% to 35%
Boulders	>200 mm	and (e.g. and sand)	35% to 50%

For a given material listed as an adjective (e.g. silty sand) means the predominant grain size is sand sized with 30 to 40% silt sized particles.

The compactness of Cohesionless soils and the consistency of the cohesive soils are defined by the following:

Cohesionless Soil		Cohesive Soil	
Compactness	Standard Penetration Resistance "N" Blows/ 0.3 m	Consistency	Undrained Shear Strength (kPa)
Very Loose	0 to 5	Very soft	<12
Loose	5 to 10	Soft	12 to 25
Compact	10 to 30	Firm	25 to 50
Dense	30 to 50	Stiff	50 to 100
Very Dense	Over 50	Very Stiff	100 to 200
		Hard	>200

5. ROCK CORING

Where rock drilling was carried out, the term RQD (Rock Quality Designation) is used. The RQD is an indirect measure of the number of fractures and soundness of the rock mass. It is obtained from the rock cores by summing the length of the core covered, counting only those pieces of sound core that are 100 mm or more length. The RQD value is expressed as a percentage and is the ratio of the summed core lengths to the total length of core run. The classification based on the RQD value is given below.

RQD Classification	RQD (%)
Very Poor Quality	<25
Poor Quality	25 to 50
Fair Quality	50 to 75
Good Quality	75 to 90
Excellent Quality	90 to 100

$$\text{Recovery Designation \% Recovery} = \frac{\text{Length of Core Per Run}}{\text{Total Length of Run}} \times 100$$



RECORD OF BOREHOLE No BH-1

SHEET 1 OF 1

METRIC

PROJECT NO. SO10242G/C LOCATION Wolf River - Hwy 522 Sta 13+475, 16.3m LT of Centerline ORIGINATED BY CS
 DIST Parry Sound HWY 522 BOREHOLE TYPE Hollow Stem Auger COMPILED BY TA
 DATUM Geodetic DATE 6/13/2006 CHECKED BY TC

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	SPT TEST (N-Value) ● DYNAMIC CONE PENETRATION  20 40 60 80 100	PLASTIC LIMIT PL	NATURAL WATER CONTENT w	LIQUID LIMIT LL	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE								
224.9 0.0	SAND, brown, dry, very loose, well graded, fine to medium grained.		1	BAG								
224.1 0.8	SAND AND SILT, brown, damp to wet, very loose, well graded, sand fine to coarse grained, trace fine gravel.		2	SS	1	224						
			3	SS	0	223						3 55 42
222.8 2.1	SAND, brown, wet, very loose, well graded, fine to coarse grained, trace fine grained gravel, trace silt. trace wood below ~ 3.05 m depth.		4	SS	0	222						1 90 9
			5	SS	1	221						1 95 4
220.3 4.6	SILT AND SAND, grey, wet, very loose, well graded, sand fine to coarse grained, trace fine grained gravel.		6	SS	1	220						1 40 59
218.8 6.1	SAND, grey, wet, very loose to loose, well graded, fine grained, trace to some silt.		7	SS	0	218						
			8	SS	6	217						
			9	SS	3	215						
214.2 10.7	SILTY CLAY, grey, wet, very soft, low plasticity, trace fine grained sand.		10	SS	2	214						
212.7 12.2	SAND, grey, wet, loose, poorly graded, fine grained, trace to some silt.		11	SS	8	212						
212.1 12.8	SPT REFUSAL AT ~ 12.80 m DEPTH ON SUSPECTED BEDROCK				100							

ON MOT - 242 - WOLF CREEK G.P.J. ON MOT GDT 06/09/22

+ 3 x 3 Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No BH-2

SHEET 1 OF 1

METRIC

PROJECT NO. SO10242G/C LOCATION Wolf River - Hwy 522 Sta 13+475, 5.1m RT of Centerline ORIGINATED BY CS
 DIST Parry Sound HWY 522 BOREHOLE TYPE Hollow Stem Auger COMPILED BY TA
 DATUM Geodetic DATE 6/15/2006 CHECKED BY TC

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	SPT TEST (N-Value) ●		DYNAMIC CONE PENETRATION	PLASTIC LIMIT PL	NATURAL WATER CONTENT w	LIQUID LIMIT LL	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
			NUMBER	TYPE	"N" VALUES			20	40							60	80	100
226.2	FILL SAND, brown, damp, loose, well graded, fine to coarse grained, trace fine to coarse grained gravel, trace fine grained gravel, trace silt below ~ 0.76 m depth. wet below ~ 3.05 m depth.	[Hatched pattern]	1	BAG		▽	226											
0.0			2	SS	6		225	●										
			3	SS	9		224	●								1	94	5
			4	SS	9		223	●										
			5	SS	7		222	●										
			6	SS	5		221	●										
220.1	SAND, brown, wet, loose, well graded, fine to coarse grained, trace fine grained gravel, trace silt.		7	SS	7		220	●										
218.6	SILTY CLAY, grey, wet, very soft, low to medium plasticity.	[Diagonal hatched pattern]	8	SS	1		218	●										
217.0	SAND, grey, wet, compact, poor to well graded, fine to coarse grained, trace to some fine grained gravel, some to with silt. very loose below ~ 10.67 m depth. compact below ~ 12.19 m depth.	[Hatched pattern]	9	SS	17		217	●										
			10	SS	3	215	●											
			11	SS	15	214	●											
			12	SS	11	212	●											
211.4	BOREHOLE TERMINATED AT ~ 14.80 m DEPTH																	

ON MOT 10242 - WOLF CREEK.GPJ ON MOT GDT 06/09/22

+ 3, x 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE



RECORD OF BOREHOLE No BH-3

SHEET 1 OF 1

METRIC

PROJECT NO. SO10242G/C LOCATION Wolf River - Hwy 522 Sta 13+475, 8.0, RT of Centerline ORIGINATED BY CS
 DIST Parry Sound HWY 522 BOREHOLE TYPE Hollow Stem Auger COMPILED BY TA
 DATUM Geodetic DATE 6/22/2006 CHECKED BY TC

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	SPT TEST (N-Value) ● DYNAMIC CONE PENETRATION  20 40 60 80 100	PLASTIC LIMIT PL	NATURAL WATER CONTENT w	LIQUID LIMIT LL	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE									"N" VALUES
225.5	FILL SAND, brown, damp, very loose to loose, well graded, fine to coarse grained, trace fine to coarse grained gravel, trace silt, trace organics.		1	BAG									
225.0			2	SS	4								
224.5			3	SS	3								
224.0			4	SS	5								
222.4	SAND, brown to grey, wet, very loose to loose, well graded, fine to coarse grained, with silt. trace silt below ~ 6.10 m depth.		5	SS	3							88 22	
222.0			6	SS	6								
221.5			7	SS	4								95 5
221.0			8	SS	2								
220.5			9	SS	9								
220.0			10	SS	12								
213.3	SILT AND SAND, grey, wet, compact, well graded, sand fine to coarse grained. very loose below ~ 13.72 m depth.		11	SS	13							47 53	
212.2			12	SS	4								
210.7	BOREHOLE TERMINATED AT ~ 15.04 m DEPTH												
14.8													

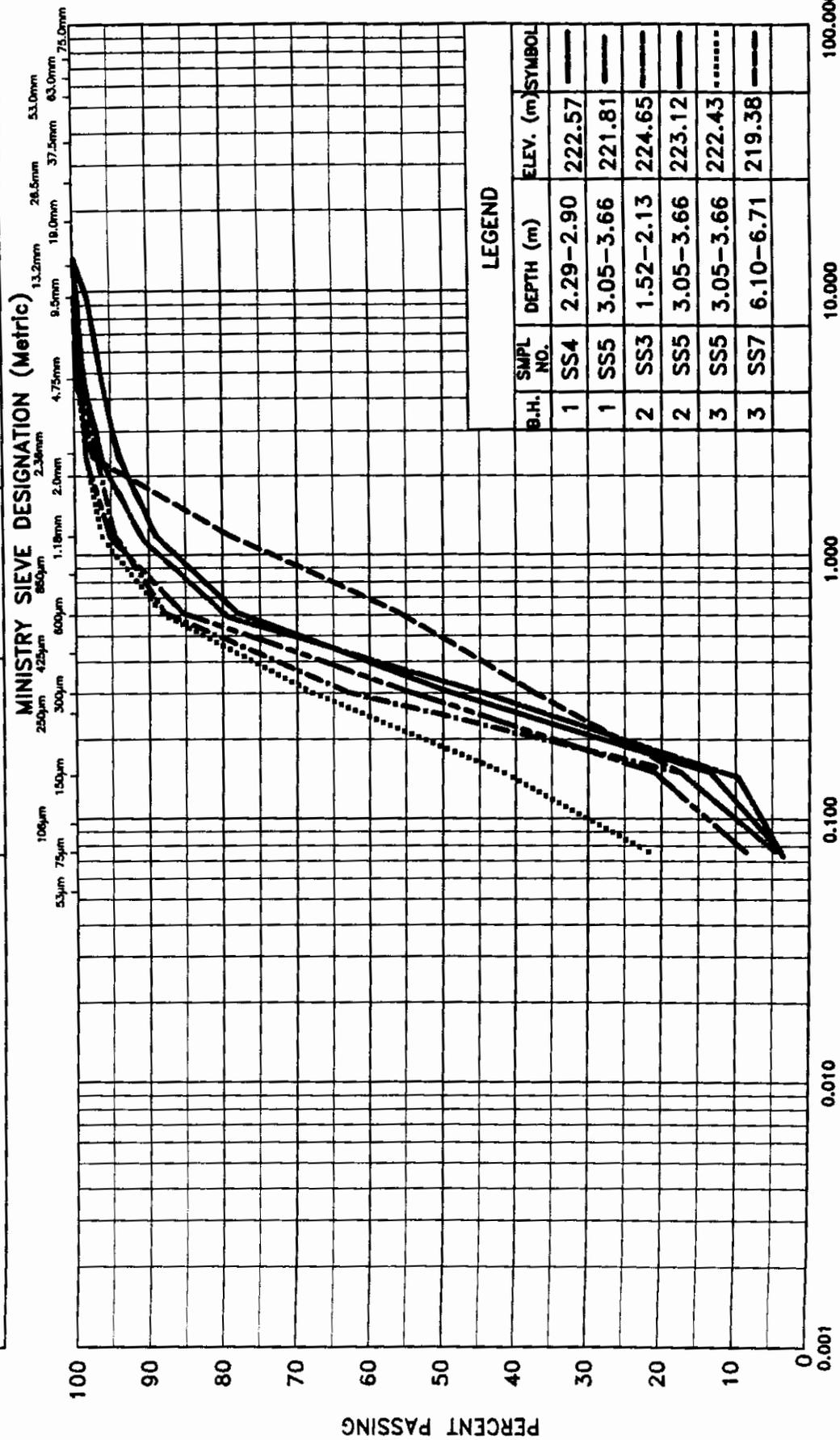
ON MOT. 10242 - WOLF CREEK G.P.J. ON MOT. GDT. 06/09/22

+ 3 x 3 Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

APPENDIX D
Laboratory Data

UNIFIED SOIL CLASSIFICATION

CLAY AND SILT		SAND			GRAVEL		
	FINE	MEDIUM	COARSE		FINE	COARSE	



GRAIN SIZE DISTRIBUTION
SAND/SAND FILL

FIGURE No. D1
G.W.P. 478-98-00
WOLF RIVER CULVERT
REF. S010242G/C

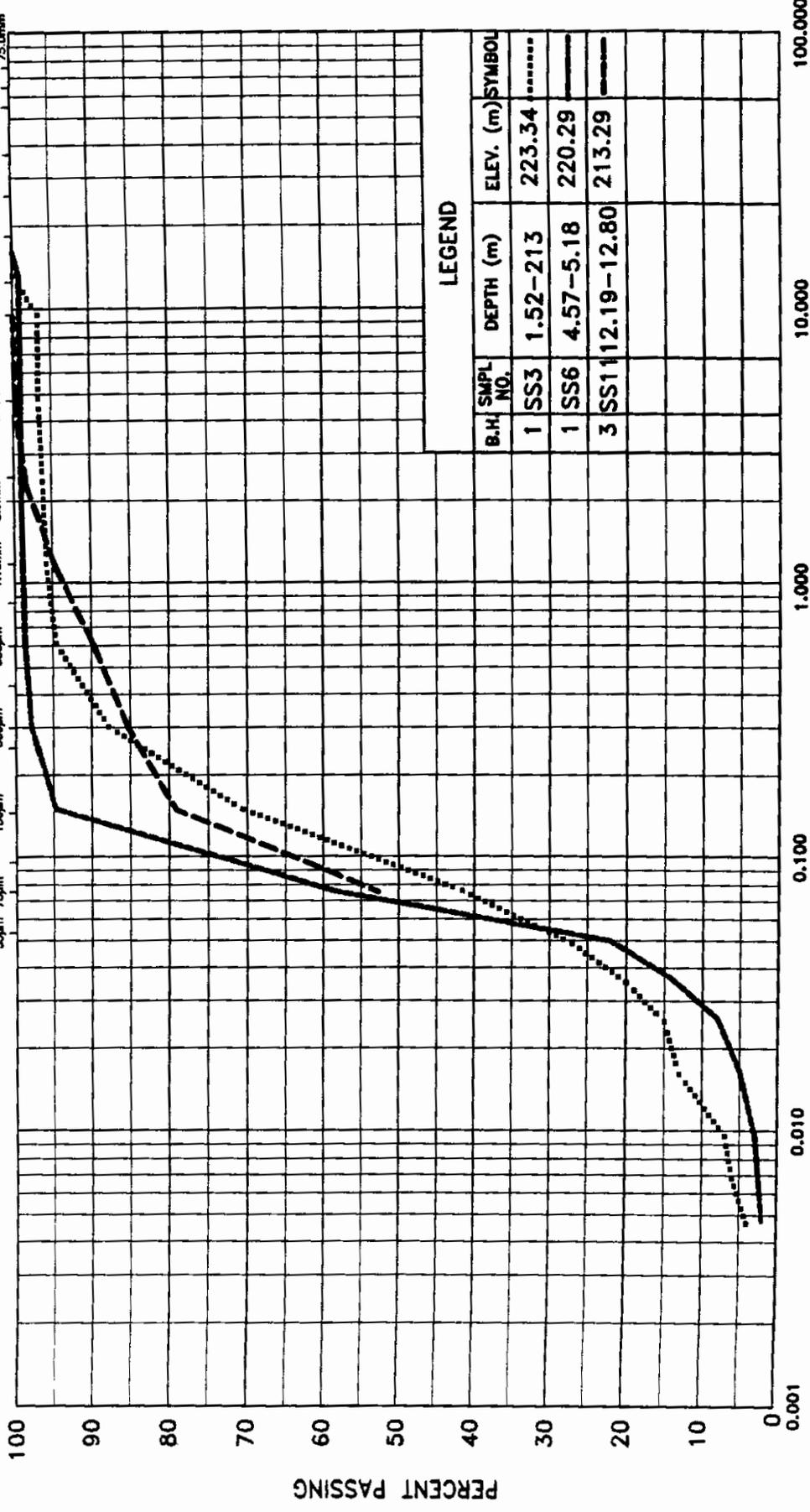


UNIFIED SOIL CLASSIFICATION

CLAY AND SILT		SAND			GRAVEL	
FINE	MEDIUM	COARSE	FINE	COARSE		

MINISTRY SIEVE DESIGNATION (Metric)

53µm 75µm 106µm 150µm 250µm 300µm 425µm 600µm 850µm 1.18mm 2.0mm 2.36mm 4.75mm 9.5mm 13.2mm 19.0mm 26.5mm 37.5mm 53.0mm 83.0mm 75.0mm



Ministry of Transportation
METRIC

GRAIN SIZE DISTRIBUTION
SILT AND SAND

FIGURE No. D2

G.W.P. 478-98-00

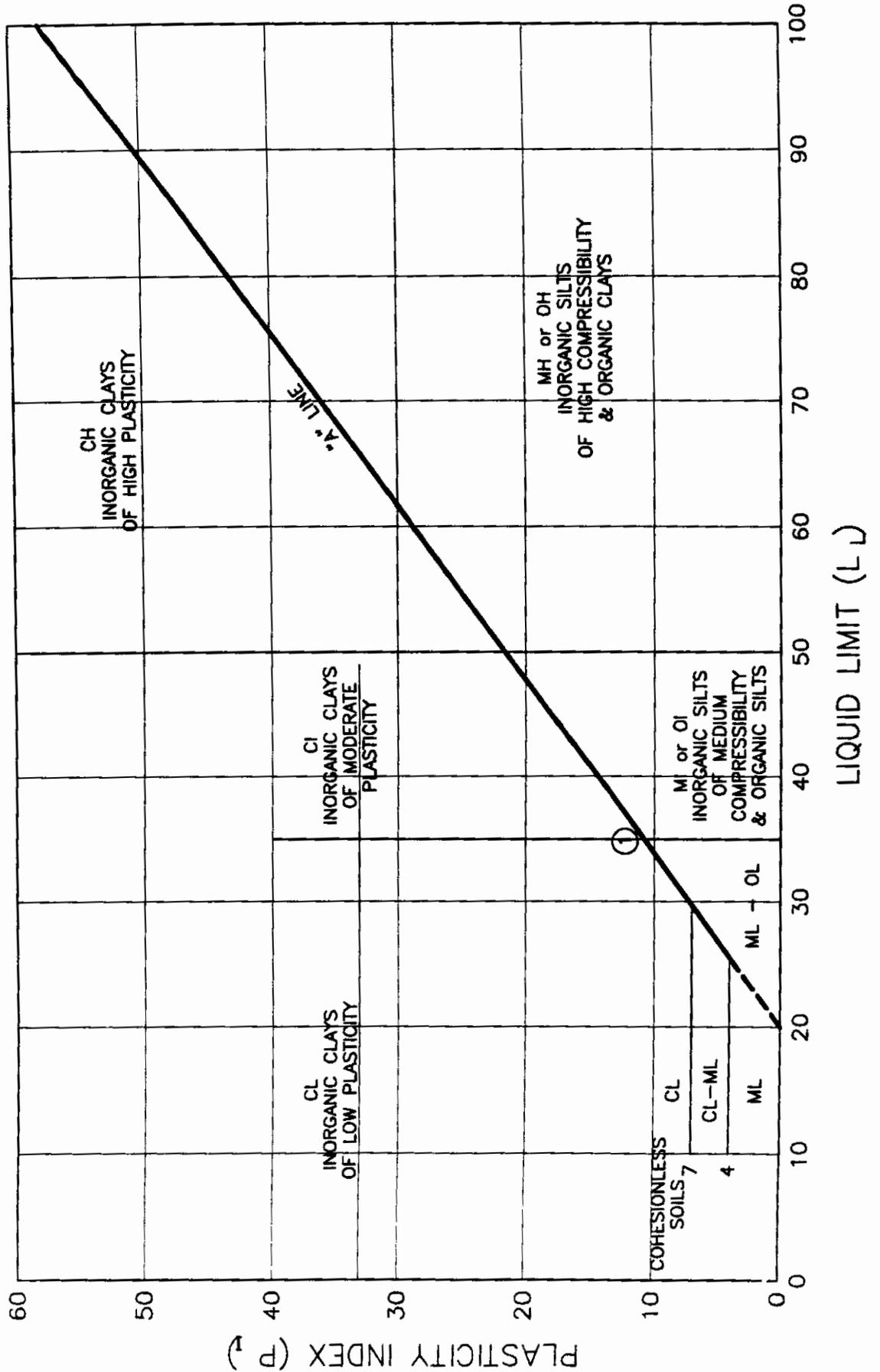
WOLF RIVER CULVERT

REF. S010242G/C

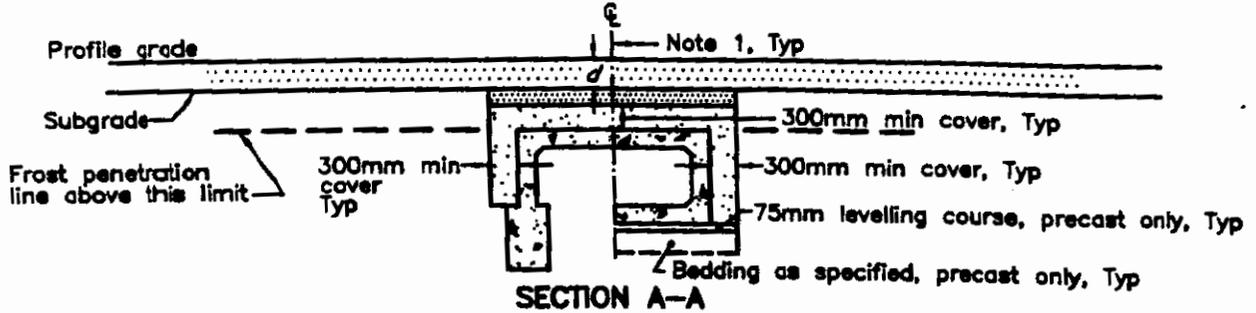
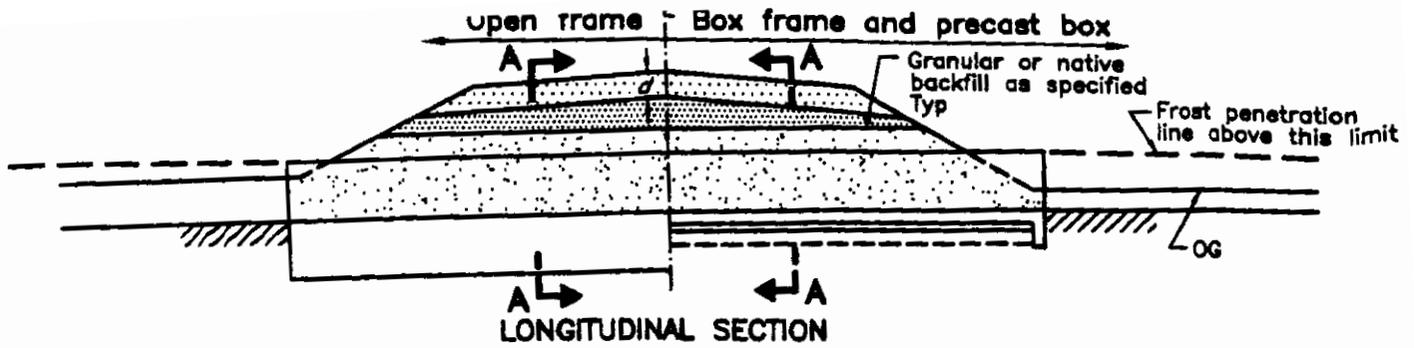


ATTEBERG LIMITS - O.P.S.S. PLASTICITY CHART

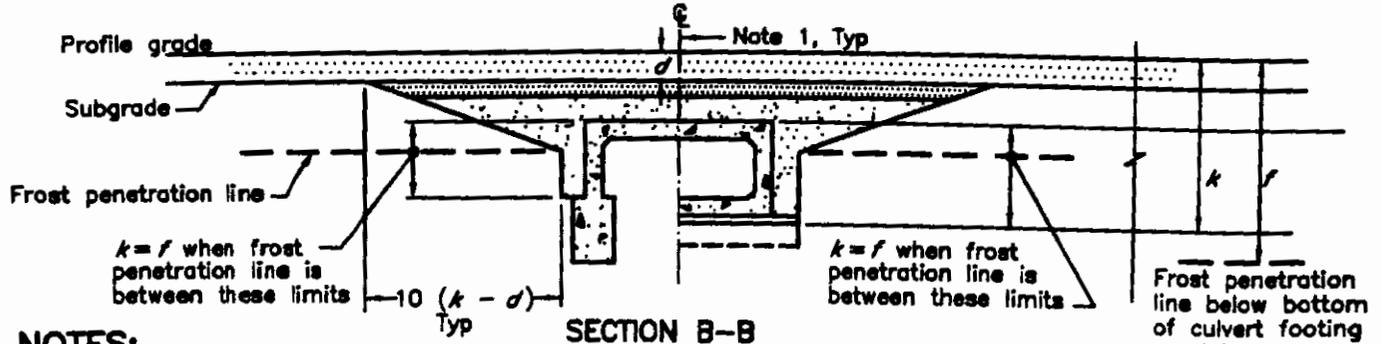
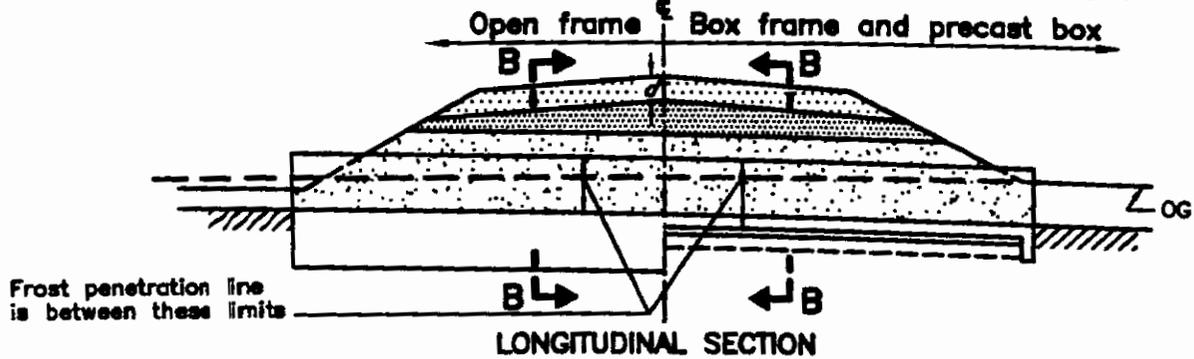
① BH-2, SS8 (7.62-8.23m)



Appendix E
OPSD Specifications



FROST PENETRATION LINE BELOW TOP OF CULVERT



NOTES:

- 1 Condition of frost treatment symmetrical about centreline of culvert.
- A Bedding, levelling and cover material to be granular as specified.
- B This standard applies to rigid and non-rigid cast-in-place and precast concrete culverts.

C All dimensions are in millimetres unless otherwise shown.

LEGEND:

- d = depth of roadbed granular
- k = depth of frost treatment
- f = depth of frost penetration

ONTARIO PROVINCIAL STANDARD DRAWING

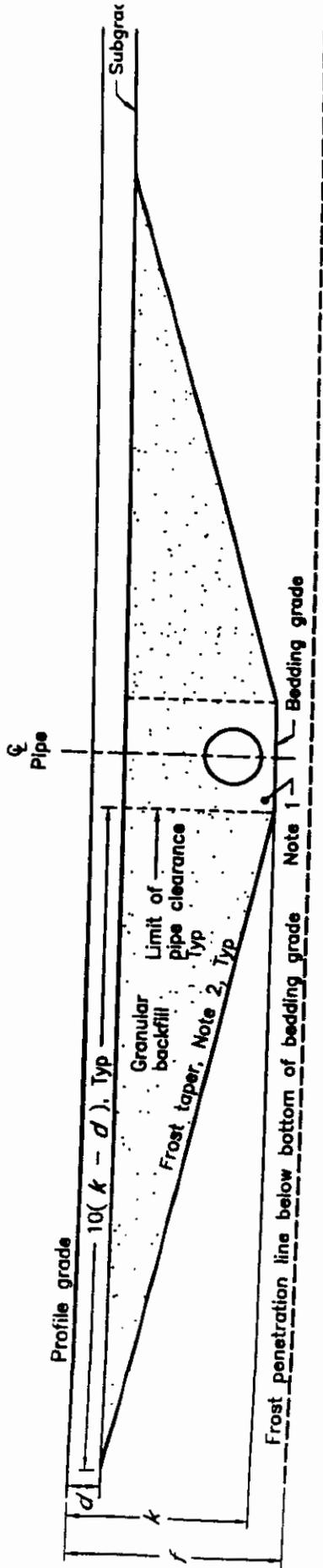
Nov 1999

Rev

BACKFILL AND COVER FOR CONCRETE CULVERTS



OPSD - 803.010



FROST TREATMENT - RIGID AND FLEXIBLE PIPE

NOTES:

- 1 Pipe embedment or bedding, cover, and backfill according to:
 - a) Flexible - OPSD-802.010, 802.013, 802.014, 802.020, 802.023, and 802.024
 - b) Rigid - OPSD-802.030, 802.031, 802.032, 802.033, 802.034, 802.050, 802.051, 802.052, 802.053, and 802.054.
- 2 Frost tapers start at bedding grade.

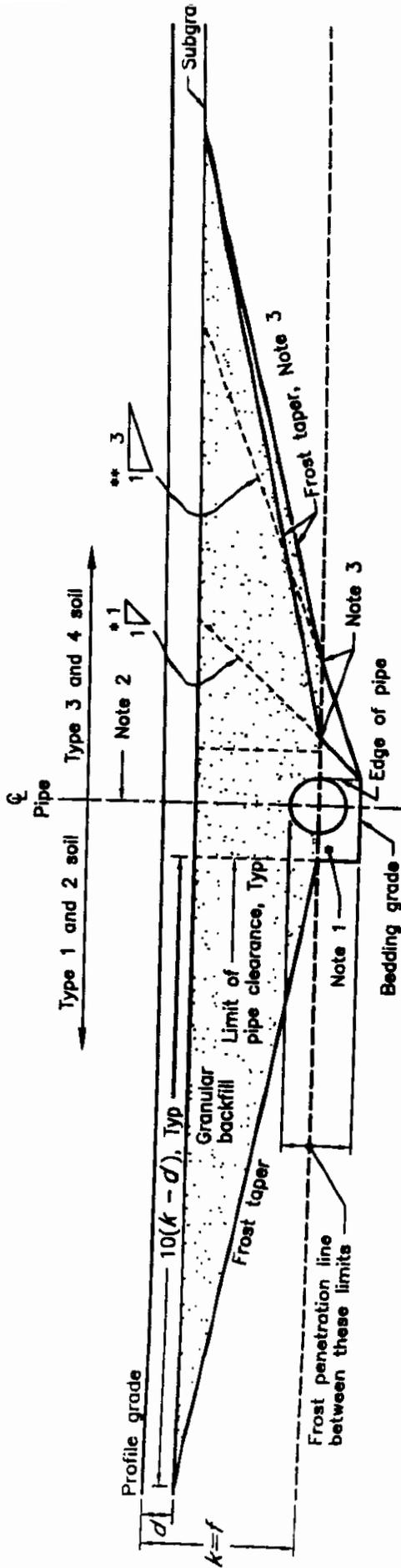
A Frost tapers are not required in rock embankment.

LEGEND:

- d -depth of roadbed granular
- k -depth of frost treatment
- f -depth of frost penetration

	Nov 2005	Rev 1
ONTARIO PROVINCIAL STANDARD DRAWING FROST TREATMENT - PIPE CULVERTS FROST PENETRATION LINE BELOW BEDDING GRADE		

OPSD - 803.030



FROST TREATMENT - RIGID AND FLEXIBLE PIPE

NOTES:

- 1 Pipe embedment or bedding, cover, and backfill according to:
 - a) Flexible - OPSD-802.010, 802.013, 802.014, 802.020, 802.023 and 802.024
 - b) Rigid - OPSD-802.030, 802.031, 802.032, 802.033, 802.034, 802.050, 802.051, 802.052, 802.053, and 802.054
- 2 Condition of frost treatment symmetrical about centreline of pipe.
- 3 Frost tapers start at the intersection of the 1H:1V or 3H:1V slope and the frost penetration line.

- A Frost tapers are not required in rock embankment.
- B Frost tapers not required when frost line is above the top of pipe.
- C Soil types as defined in the Occupational Health and Safety Act and Regulations for Construction Projects.

LEGEND:

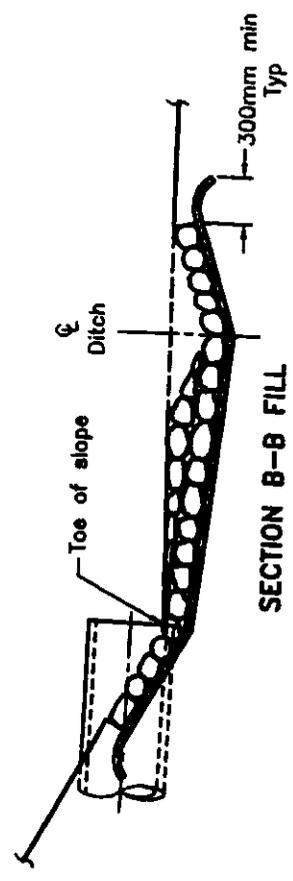
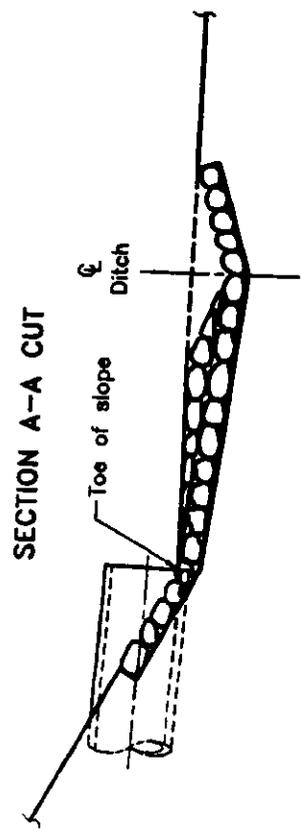
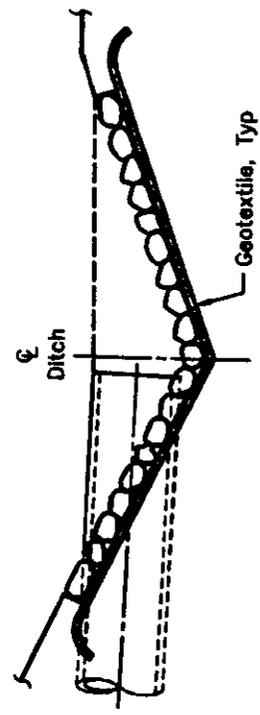
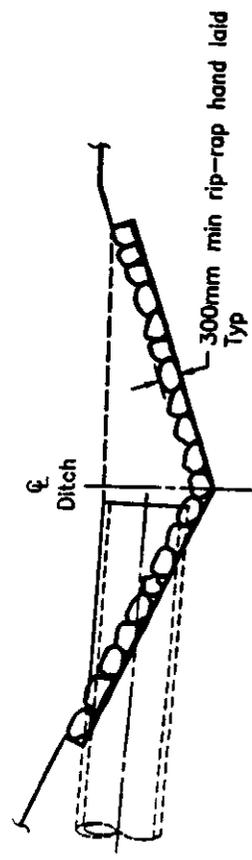
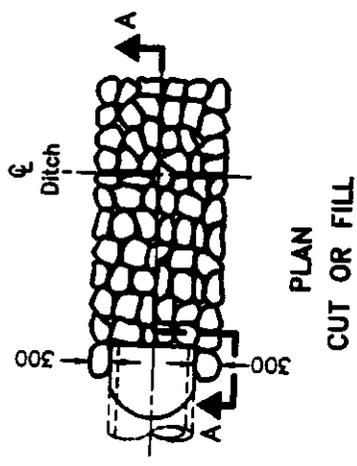
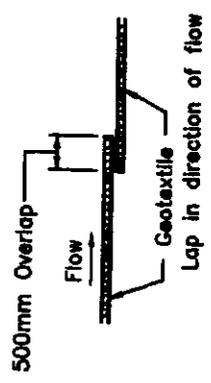
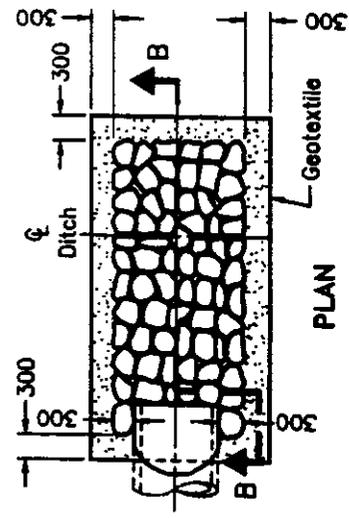
- d - depth of roadbed granular
- k - depth of frost treatment
- f - depth of frost penetration
- * - Type 3 soil
- ** - Type 4 soil

ONTARIO PROVINCIAL STANDARD DRAWING
 FROST TREATMENT - PIPE CULVERTS
 FROST PENETRATION LINE BETWEEN
 TOP OF PIPE AND BEDDING GRADE

Nov 2005 Rev 2



OPSD - 803.031



TYPE B - WITH GEOTEXTILE

TYPE A - WITHOUT GEOTEXTILE



ONTARIO PROVINCIAL STANDARD DRAWING

Nov 2001 Rev 0

**RIP-RAP TREATMENT
FOR SEWER AND CULVERT OUTLETS**

OPSD - 810.010

NOTES:
A All dimensions are in millimetres unless otherwise shown.