

**Foundation Investigation and Design Final Report
Unknown Creek Culverts Replacement
Highway 522
East Mills Township
G.W.P. 476-98-00
GEOCRES No. 31E-262**

Prepared for:

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Project No: SUGE00010242/C
September 26, 2006

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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 Unknown Creek culverts (twin 1830 mm diameter by approximately 26.0 m long Corrugated Steel Pipe (CSP)), located on Highway 522 at Stations 21+516 and 21+518 within East Mills Township. The culvert replacement is to consist of a single pre-cast concrete box culvert 2000 mm wide by 1500 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 Unknown Creek culverts are located in the East Mills Township at Stations 21+516 and 21+518 on Highway 522.

The site plan and cross section profiles of the Unknown Creek culverts 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 mainly of deciduous trees, some coniferous trees and smaller low lying shrubs and grass. The drainage in the area generally consists of roadside ditches, which drain into Unknown Creek.

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 on June 23rd and June 24th, 2006. The investigation consisted of a total of 4 boreholes (BH-1 to BH-4). Borehole BH-1 was drilled along the north side of the highway embankment and boreholes BH-3 and BH-4 were drilled along the south side of the highway embankment to verify embankment fill materials and soil conditions below the existing culvert. Borehole BH-2 was drilled near the culvert outlet (north end of culvert), to verify soil conditions below the existing culverts. All boreholes were advanced with a Mobile CME-55 track mounted drill rig equipped with continuous flight hollow stem augers and standard soil sampling equipment. All boreholes were advanced by Landcore Drilling. The original intent was to drill borehole BH-4 at the culvert inlet (south end of culvert). However, due to the topography of the land extensive reconfiguration would have been required to facilitate advancing a borehole near the culvert inlet. Therefore, subsurface conditions at the inlet locations are unknown for design and construction. Foundation design for the new culvert inlet must be based on extrapolation of subsurface conditions at the other borehole locations.

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 "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 the 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 Particle Size Analyses (LS 702).

The laboratory test results are summarized on the borehole logs located 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

Borehole BH-1 was drilled along the north side of the highway embankment, borehole BH-2 was drilled near the culvert outlet (north end of culvert), and boreholes BH-3 and BH-4 were drilled along the south side of the highway embankment.

In general, the stratigraphy within boreholes BH-1 to BH-4 consisted of a thin layer of asphalt overlying sand fill, silt and sand, and boulders overlying suspected bedrock.

The asphalt ranged in thickness from approximately 40 (BH-1) to 50 mm (BH-3 and BH-4) thick. Asphalt was not encountered in borehole BH-2. Underlying the asphalt in boreholes BH-1, BH-3 and BH-4 and the from ground surface in borehole BH-2, was a 2.5 (BH-1) to 3.7 m (BH-1) thick layer of sand fill. The sand fill was brown in colour, damp to wet, well graded, fine to coarse grained and contained trace to with fine to coarse grained gravel and trace to with silt. Recorded uncorrected Standard Penetration Test (SPT) "N" values within the sand fill ranged from 3 to 58 blows per 300 mm inferring a very loose to very dense material in relative density. Underlying the sand fill in borehole BH-1 was a 1.4 m thick layer of boulders, which was cored from 3.7 to 5.1 m below grade. The boulders mainly consisted of granite and gneiss and were up to 0.28 m in diameter. Underlying the sand fill in borehole BH-3 was a 1.4 m thick layer of silt and sand, which extended to 4.5 m below grade. The silt and sand was brown to grey in colour, wet, poorly graded, fine to coarse grained (sand), and contained trace fine grained gravel. The recorded uncorrected SPT "N" value within the silt and sand was 8 blows per 300 mm inferring a loose material in relative density. Standard Penetration Test (SPT) refusal (i.e. >100 blows per 300 mm) was encountered in boreholes BH-2 to BH-4 between 2.54m (BH-2) and 4.47 m (BH-3) below grade.

Bedrock was encountered in borehole BH-1 underlying the boulder material at approximately 5.1 m below existing grade. A 2.8 m core was taken from the bedrock. The bedrock consisted of granite and gneiss. The bedrock was fresh, intact, light grey to pink in colour, fine to medium grained and very strong. The Rock Quality Designation (RQD) was between 82% and 97%, indicating a good to excellent quality of rock. The RQD is also included in the attached borehole logs in Appendix C.

1.6 Groundwater Conditions

Groundwater elevations observed within boreholes BH-1 to BH-3 were between 232.75 and 233.69 m. This infers a groundwater level slightly below creek level at the time of the investigation. The lower water levels within the boreholes could be due to disturbance in the holes at the time of drilling and 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 233.87 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 Unknown Creek culvert (2000 mm wide by 1500 mm high pre-cast concrete box culvert) located on Highway 522 between Stations 21+516 and 21+518 within East Mills Township. The new culvert is to be 26.0 m long. Photographs are included in Appendix A.

2.2 Culvert Replacement at Unknown Creek Highway 522

It is understood by Trow that the existing twin 1830 mm diameter by 26.0 m long Corrugated Steel Pipe (CSP) culverts are to be replaced with a pre-cast concrete box culvert 2000 mm wide by 1500 mm high. The proposed invert is to be placed at approximately the same invert as the existing culvert between elevations 232.43 m (north end-outlet) and 232.64 m (south end-inlet).

For the underside of the proposed concrete box culvert to be founded at approximately the same invert as the existing culverts, the underside of the proposed culvert invert will be founded near Elevations 231.98 m (outlet) and 232.19 m (inlet), which accounts for the thickness of concrete (approximately 150 mm) and bedding layer (minimum 300 mm). For the proposed culvert, Trow recommends the following two options.

- Found the culvert on the boulder material, which was encountered in borehole BH-1 at approximately Elevation 232.8 m.
- Found the culvert on bedrock, which was encountered in borehole BH-1 at approximately Elevation 231.3 m.

For the proposed culvert founded on engineered fill overlying boulders, a Factored Bearing Resistance at ULS of 500 kPa and a Factored Bearing Resistance at SLS of 250 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 to the boulder material. The boulder surface is to be properly “blinded and chinked” with a large bulldozer (minimum D6 Caterpillar or equivalent). 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 dry conditions. A non-woven geotextile separator (Terrafix 270R or equivalent) is to be used between the boulders and the up-fill material to stabilize the soils and prevent the migration of fines into the boulder material.

For the proposed culvert founded on engineered fill overlying bedrock, a Factored Bearing Resistance at ULS of 800 kPa and a Factored Bearing Resistance at SLS of 400 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 and boulder material must be removed to bedrock, which must be cleaned of all loose debris and shatter using air hose or water jetting procedures. The up-fill material is to consist of Granular "A" or Granular "B" Type II Ontario Provincial Standards and Specifications 1010 (OPSS 1010). The granular material is to be placed in maximum 150 mm thick lifts and compacted to a minimum of 100% of the Standard Proctor Maximum Dry Density (SPMDD) within $\pm 2\%$ of the optimum moisture content. 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 dry conditions.

Provide the existing highway grades are maintained, the anticipated maximum settlements for the concrete box culvert are not expected to exceed 25 mm, assuming good construction practice.

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 placement of any fill material, the bedrock or boulder material is to be relatively level and visually inspected by a qualified geotechnical 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/m³).

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_0)	Unit Weight γ (kN/m ³)
Granular A	35°	0.27	3.7	0.43	22
Granular B Type I	32°	0.31	3.3	0.47	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 $\gamma=21$ kN/m³ 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 oversteering.

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 θ	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 Fill	32°	0	21
Silt and Sand	30°	0	21
Boulders	40°	0	21

Note: A unit weight of $\gamma=21$ kN/m³ is based on well graded boulders.

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 a 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 creek. 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 creeks 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 creek 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 creek 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 creeks 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 creek 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 East Mills area without snow cover. The underlying sand fill, and silt and sand 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, and silt and sand may be classified as Type 3 soil above the groundwater table and a Type 4 soil below the groundwater table, 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 soil should not exceed 1H:1V. Temporary excavation side slopes for Type 4 soil 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 excavation. It will be the Contractors 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. soldier piles and timber lagging).

2.2.12 Dewatering

The soils encountered below the groundwater table and within potential excavation depths consist of sand, silt and sand, and boulders. 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 Fill	$10^{-3} - 10^{-5}$
Silt and Sand	$10^{-4} - 10^{-6}$
Boulders	>1

Dewatering requirements will be governed by the water levels in the creek 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 creek 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 creek 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 culvert 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. soldier piles and 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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S.E. Gonsalves

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Principal Engineer
Designated MTO Foundation Contact



Encl.

Dist: Northland Engineering (1987) Limited (7)

APPENDIX A

Photographs



Photo #1 – Stations 21+516 and 21+518, East Mills Township, Facing North
Photo taken on June 23, 2006

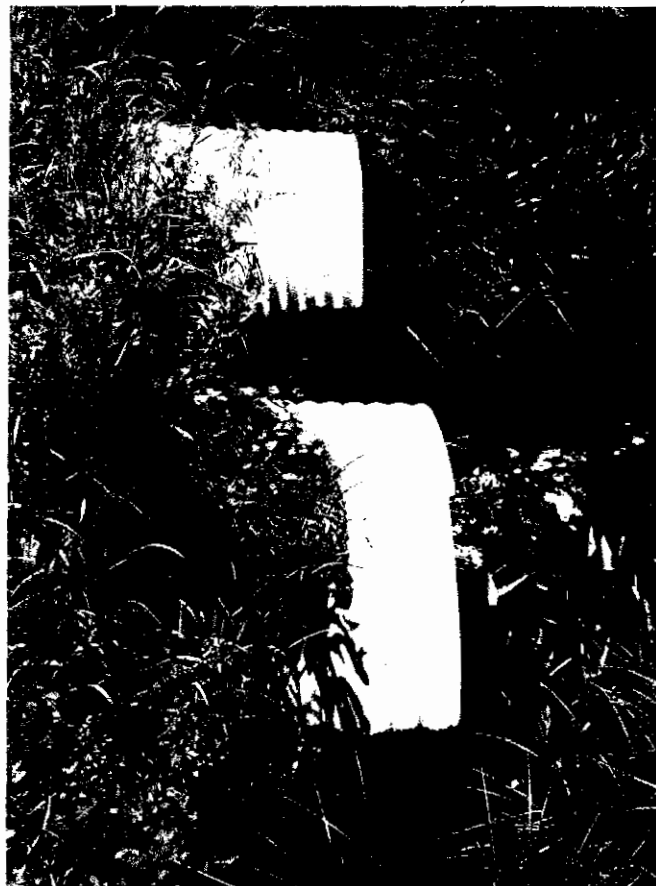
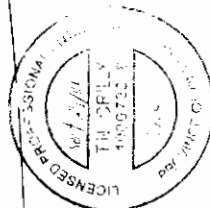


Photo #2 – Stations 21+516 and 21+518, East Mills Township, Facing East
Photo taken on June 23, 2006

APPENDIX B

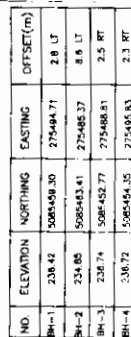
Drawings

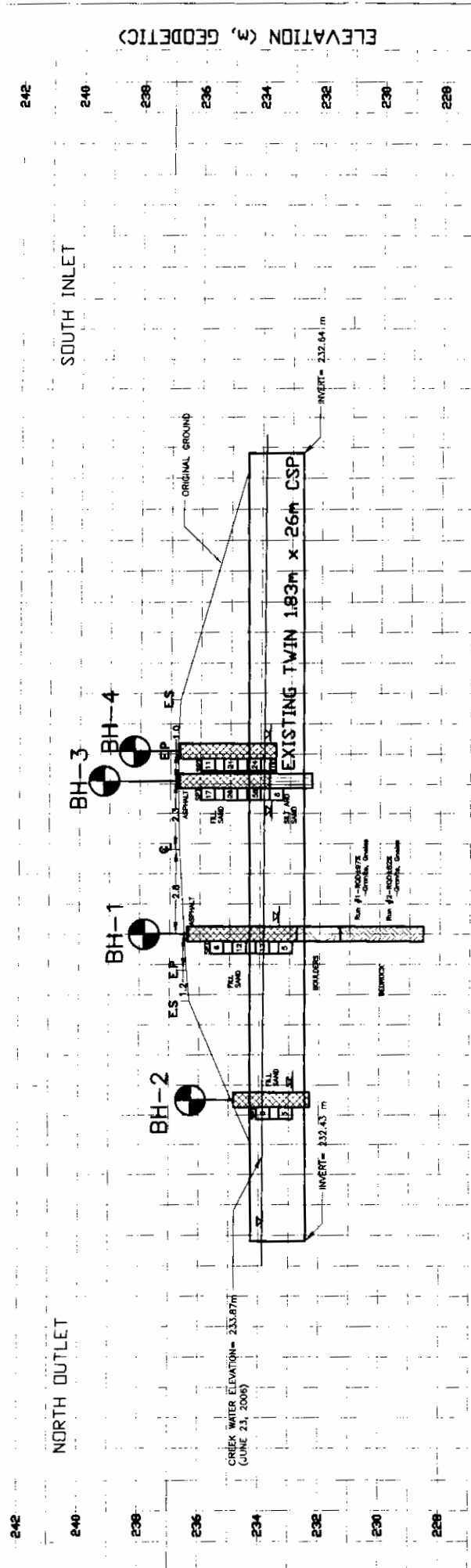




***Trow**
ASSOCIATES INC.

UNKNOWN CREEK,
STATION 21+516 AND 21+518
CULVERT REPLACEMENT
BOREHOLE LOCATIONS

1
SHEET





METRIC DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN	 GEOCRESS No. 31E-262 GWP 476-98-00	SHEET 2
 Trow ASSOCIATES INC.	UNKNOWN CREEK, STATIONS 21+516 AND 21+518 GROUNDWATER DEPLETION BOREHOLE LOCATIONS PROFILE	

NOTES

1. TROW BORINGS PERFORMED
JUNE 23 AND 24, 2006
2. TOPOGRAPHIC SURVEY PERFORMED BY
SUTCLIFFE BODY QUENSEL (SBO)
3. THIS DRAWING IS FOR SURFACE DETAILS
INFORMATION ONLY. SURFACE DETAILS
AND FEATURES ARE FOR CONCEPTUAL
ILLUSTRATION. THE PROPOSED
PRODUCTION LOCATION, DETAIL AND
STATIONING PURPOSES 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
TROW BORINGS. THE BOUNDARIES BETWEEN BORINGS
ARE BASED ON THE ASSUMPTION FROM
GEOLOGICAL EVIDENCE.

0-5357

BORCHOLT	
STANDARD	
"N" VALVE	
ELEVATION	
HIGHWAY	
EDGE OF	
EDGE OF	

NO.	ELEVATION	NORTHING	EASTING	OFFSET(m)
BN-1	238.42	5085489.30	275484.71	2.8 LT
BN-2	234.85	5085483.41	275485.37	0.6 LT
BN-3	238.74	5085492.77	275488.81	2.5 RT
BN-4	238.72	5085494.25	275485.03	2.3 RT

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 SAMPLE 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 473 J IMPACT ENERGY ON 1/4" SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3M ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

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

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

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

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

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

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

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

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

JOINTING AND BEDDING:

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

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

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
u	l	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	l	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

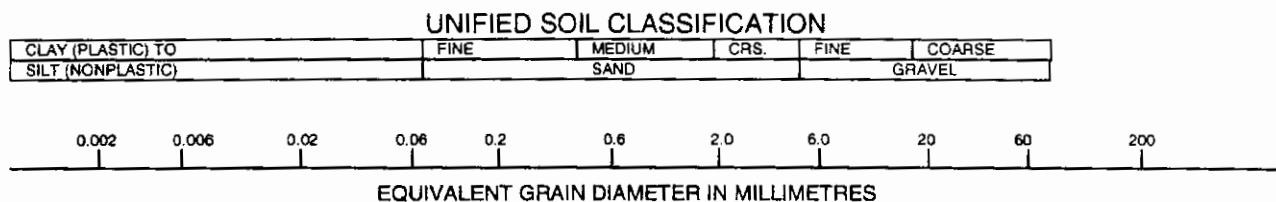
a_v	kPa ⁻¹	COEFFICIENT OF VOLUME CHANGE
C_c	l	COMPRESSION INDEX
C_s	l	SWELLING INDEX
C_{α}	l	RATE OF SECONDARY CONSOLIDATION
C_v	m ² /s	COEFFICIENT OF CONSOLIDATION
N	m	DRAINAGE PATH
T_v	l	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
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	l	SENSITIVITY = $\frac{C_u}{\tau_f}$

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m ³	DENSITY OF SOLID PARTICLES	e	l, %	VOID RATIO	e_{min}	l, %	VOID RATIO IN DENSEST STATE
γ_s	kN/m ³	UNIT WEIGHT OF SOLID PARTICLES	n	l, %	POROSITY	I_D	l	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
ρ_w	kg/m ³	DENSITY OF WATER	w	l, %	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	l	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	l	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	l	HYDRAULIC GRADIENT
γ_{sat}	kN/m ³	UNIT WEIGHT OF SATURATED SOIL	I_C	l	CONSISTENCY INDEX = $\frac{w - w_L}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m ³	DENSITY OF SUBMERGED SOIL	e_{max}	l, %	VOID RATIO IN LOOSEST STATE	j	kN/m ²	SEEPAGE FORCE
γ'	kN/m ³	UNIT WEIGHT OF SUBMERGED SOIL						

Notes On Sample Descriptions

1. 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		

2. **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.
3. **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

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



Trow Associates Inc.
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Brampton, Ontario L6T 4V1

RECORD OF BOREHOLE No BH-1

SHEET 1 OF 1

METRIC

PROJECT NO. SO10242C LOCATION Unknown Creek - Hwy 522 Sta 21+517, 2.8m LT of Centerline ORIGINATED BY CS
DIST Parry Sound HWY 522 BOREHOLE TYPE Hollow Stem Auger COMPILED BY TA
DATUM Geodetic DATE 6/23/2006 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								
236.4 0.0	ASPHALT 40mm depth. FILL SAND, brown, damp, loose to compact, well graded, fine to coarse grained sand, some fine to coarse grained gravel, trace silt, trace fine grained gravel, some silt below ~ 0.76 m depth.		1	BAG		236						6 81 13
			2	SS	8	235						
			3	SS	12	234						
			4	SS	12	233						
			5	SS	5	232						
232.8 3.7	BOULDERS: granite, gneiss up to 0.28 m in size.											
231.3 5.1	BEDROCK: granite, gneiss Run #1 At ~ 5.11-6.48 m depth Rec=97% RQD=Excellent +/-97% High water return (75%), light grey Run #2 At ~ 6.48-7.87 m depth Rec=82% RQD=Good +/-82% High water return (75%), light grey											
228.6 7.9	BOREHOLE TERMINATED AT ~ 7.87 m DEPTH											

ON LOT 10242 - EAST MILLS GPJ ON MOT.GDT 06/09/22



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RECORD OF BOREHOLE No BH-2

SHEET 1 OF 1

METRIC

PROJECT NO. SO10242C LOCATION Unknown Creek - Hwy 522 Sta 21+517, 8.6m LT of Centerline ORIGINATED BY CS
DIST Parry Sound HWY 522 BOREHOLE TYPE Hollow Stem Auger COMPILED BY TA
DATUM Geodetic DATE 6/23/2006 CHECKED BY TC

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	SPT TEST (N-Value) ●		PLASTIC LIMIT PL	NATURAL WATER CONTENT w	LIQUID LIMIT LL	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	DYNAMIC CONE PENETRATION					
234.9							20 40 60 80 100	20 40 60 80 100					
0.0	FILL SAND, brown, damp, loose, well graded, fine to coarse grained, some fine to coarse grained gravel, trace silt, trace organics. some asphalt below ~ 0.76 m depth. very loose, trace fine grained gravel, with silt below ~ 1.52 m depth. wet below ~ 2.10 m depth.		1	BAG									
			2	SS	8	234							
			3	SS	3	233							5 70 25
232.3	SPT REFUSAL AT ~ 2.54 m DEPTH ON SUSPECTED BOULDERS OR BEDROCK												
2.5													



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RECORD OF BOREHOLE No BH-3

SHEET 1 OF 1

METRIC

PROJECT NO. SO10242C LOCATION Unknown Creek - Hwy 522 Sta 21+517, 2.5m RT of Centerline ORIGINATED BY CS
DIST Parry Sound HWY 522 BOREHOLE TYPE Hollow Stem Auger COMPILED BY TA
DATUM Geodetic DATE 6/24/2006 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 Y KN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV. DEPTH	DESCRIPTION	STRAT. PLT	NUMBER	TYPE								
236.7	ASPHALT 50mm depth.											
236.7	FILL SAND, brown, damp, compact, well graded, fine to coarse grained, with fine to coarse grained gravel, trace silt. trace fine grained gravel below ~ 0.30 m depth.		1	BAG								
			2	SS	17							
			3	SS	26							
	very dense below ~ 2.29 m depth.		4	SS	58							
233.7	SILT AND SAND, brown to grey, wet, loose, poorly graded, sand fine to coarse grained, trace fine grained gravel.		5	SS	8							3 44 53
232.3	SPT REFUSAL AT ~ 4.47 m DEPTH ON SUSPECTED BOULDERS OR BEDROCK											



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RECORD OF BOREHOLE No BH-4

SHEET 1 OF 1

METRIC

PROJECT NO. SO10242C LOCATION Unknown Creek - Hwy 522 Sta 21+517, 2.3m RT of Centerline ORIGINATED BY CS
DIST Parry Sound HWY 522 BOREHOLE TYPE Hollow Stem Auger COMPILED BY TA
DATUM Geodetic DATE 6/24/2006 CHECKED BY TC

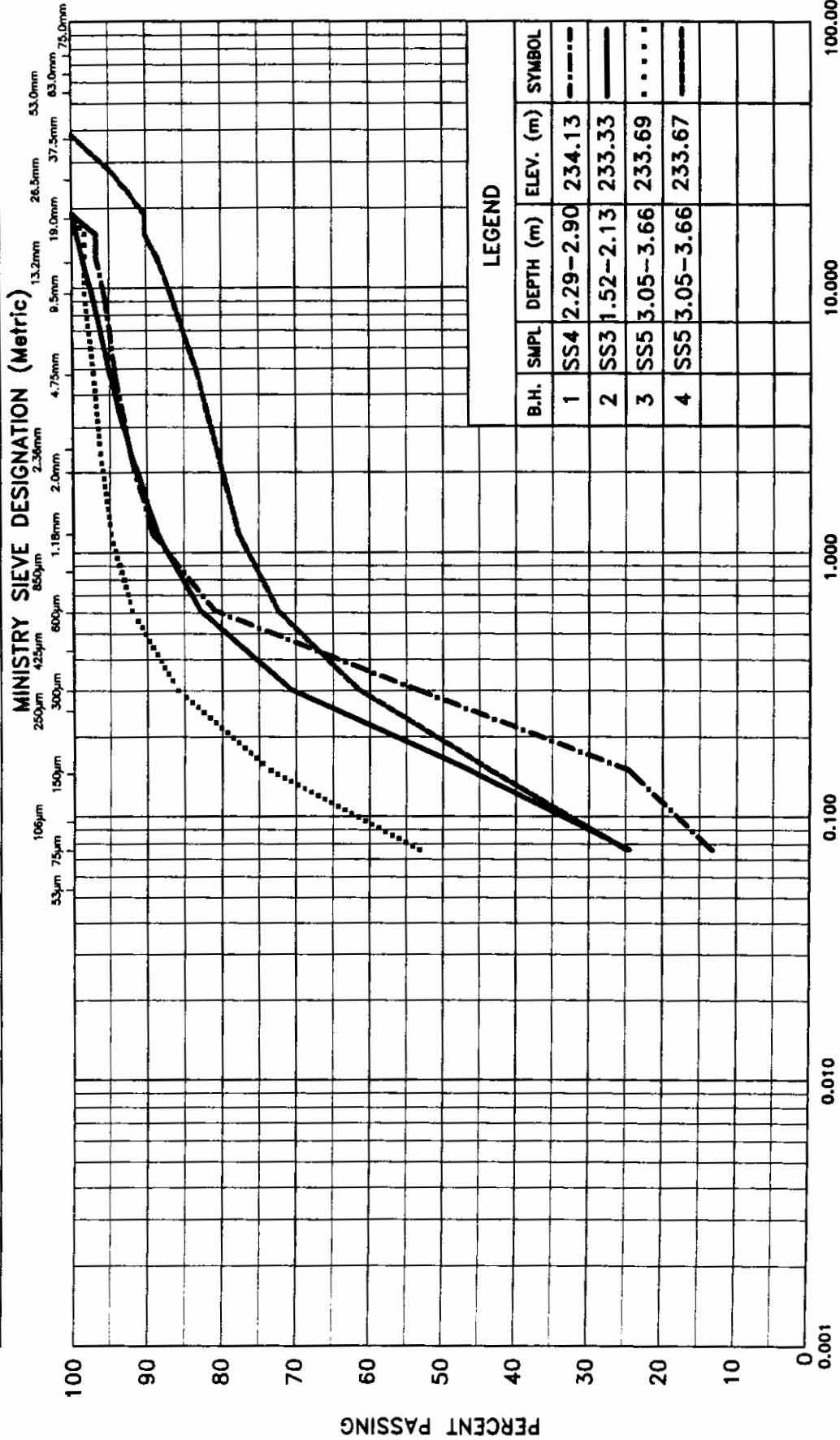
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	SPT TEST (N-Value) • DYNAMIC CONE PENETRATION 20 40 60 80 100	PLASTIC LIMIT PL	NATURAL WATER CONTENT w	LIQUID LIMIT LL	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE								
236.7	0.1	ASPHALT 50mm depth. FILL SAND, brown, damp, compact, well graded, fine to coarse grained, with fine to coarse grained gravel, trace silt, trace fine grained gravel below ~ 0.25 m depth.										
			1	BAG								
			2	SS	11							
			3	SS	21							
		some silt below ~ 2.29 m depth.	4	SS	24							
233.5	3.3	wet, trace fine grained gravel, with silt below ~ 3.05 m depth. SPT REFUSAL AT ~ 3.25 m DEPTH ON SUSPECTED BOULDERS OR BEDROCK	5	SS	100							17 58 25

APPENDIX D

Laboratory Data

UNIFIED SOIL CLASSIFICATION

CLAY AND SILT		SAND			GRAVEL		
		FINE	MEDIUM	COARSE	FINE	COARSE	

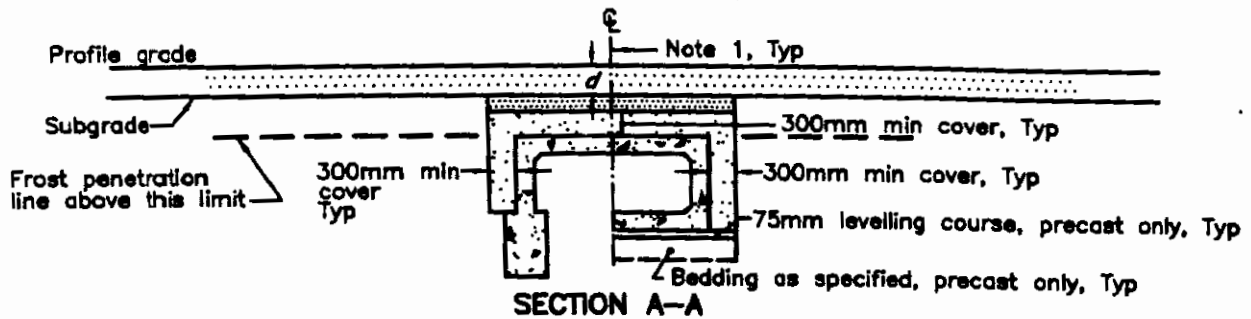
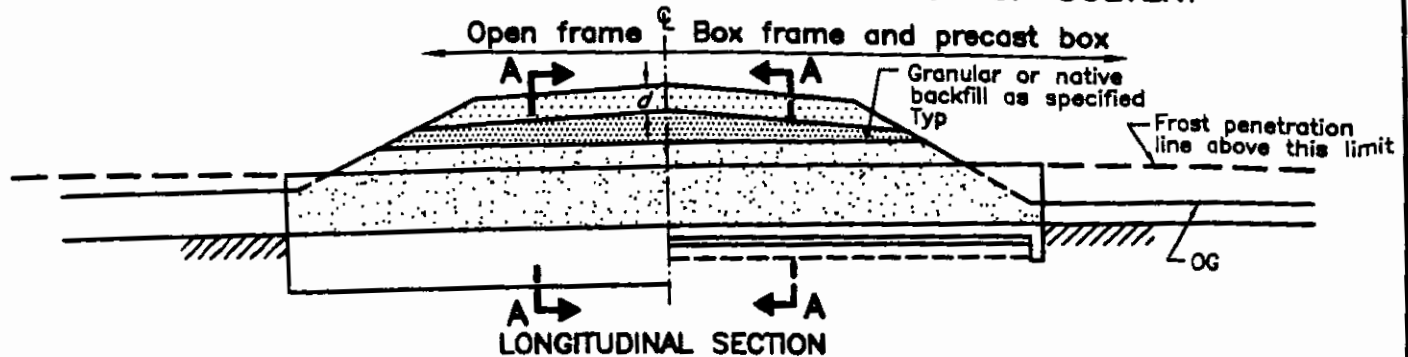


GRAIN SIZE DISTRIBUTION

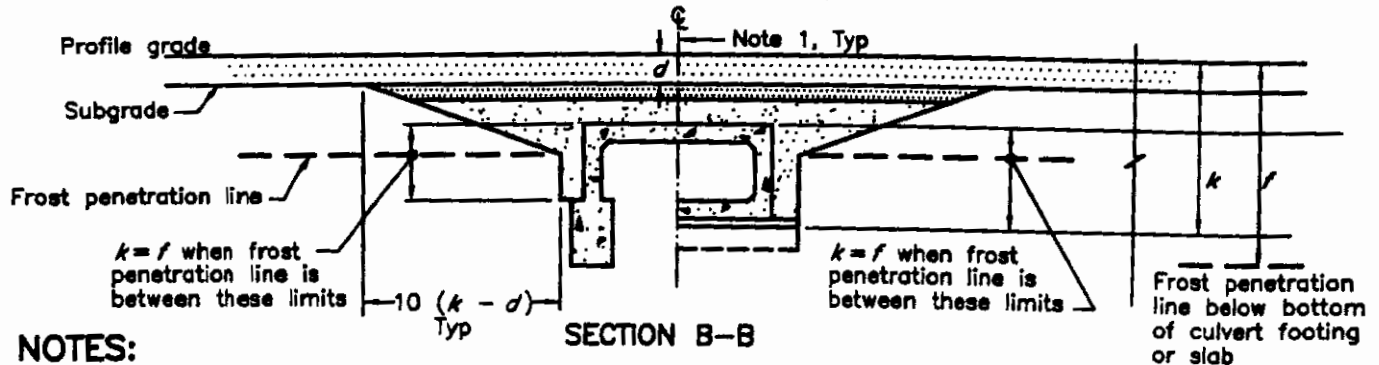
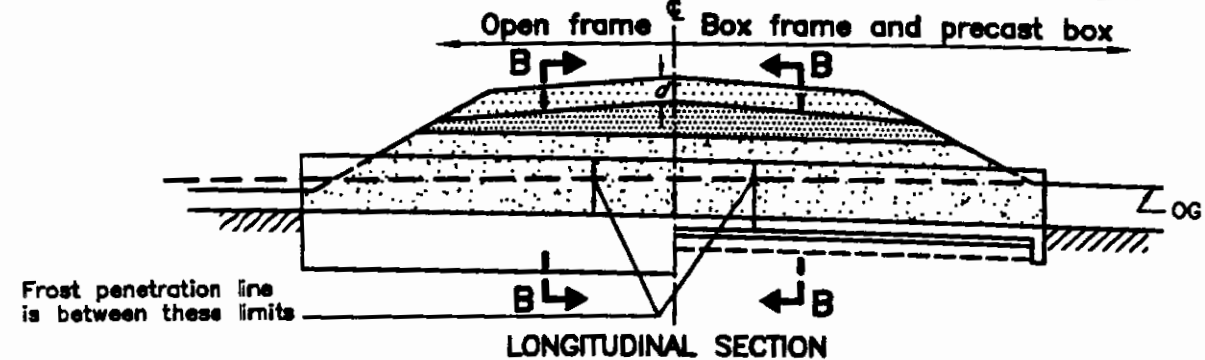
APPENDIX E

OPSD Specifications

FROST PENETRATION LINE AT OR ABOVE TOP OF CULVERT



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

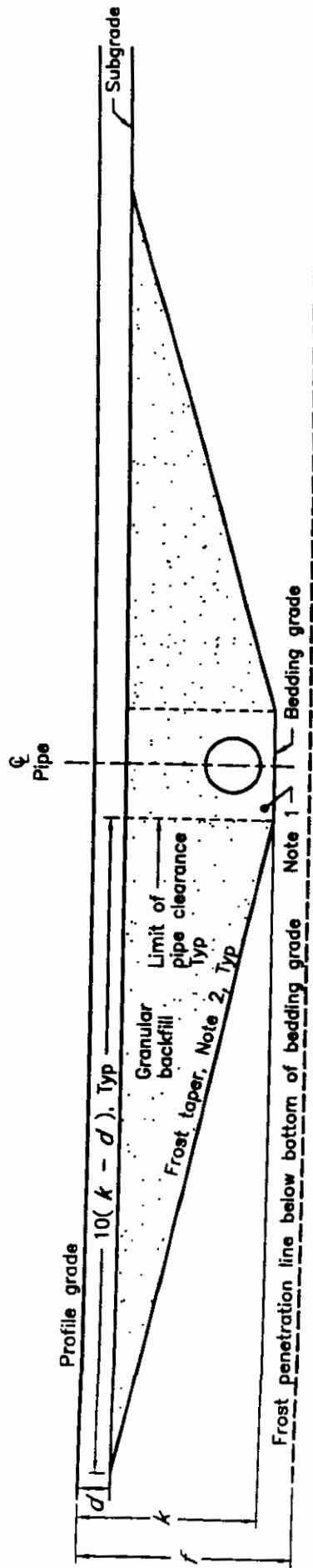
Nov 1999

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

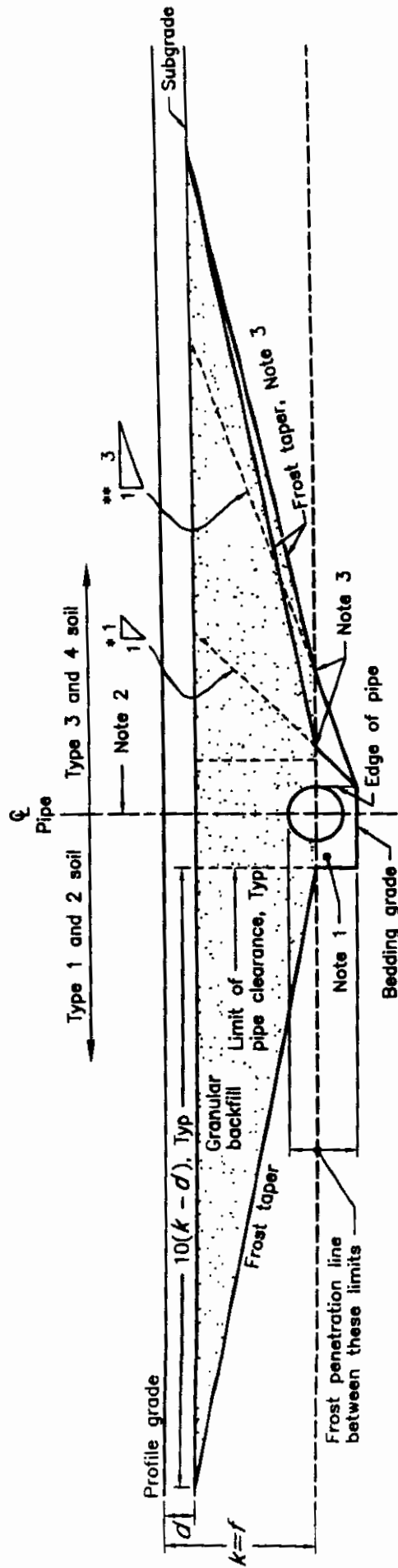
ONTARIO PROVINCIAL STANDARD DRAWING

FROST TREATMENT - PIPE CULVERTS
FROST PENETRATION LINE BELOW
BEDDING GRADE

Nov 2005 Rev 1



OPSD - 803.030



FROST TREATMENT - RIGID AND FLEXIBLE PIPE

NOTES:

1 Pipe embedment or bedding, cover, and backfill according to:

- Flexible - OPSD-802.010, 802.013, 802.014, 802.020, 802.023 and 802.024
- 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

