



**TECHNICAL MEMORANDUM FOR CULVERTS IN PHASE 1  
ADDENDUM TO FOUNDATION INVESTIGATION  
AND DESIGN REPORT  
CULVERT C56 - DELAMERE TOWNSHIP  
HIGHWAY 69 FOUR-LANING FOR 24.7 KM  
FROM 3.8 KM NORTH OF HIGHWAY 522  
TO 4.5 KM NORTH OF HIGHWAY 64  
SITE NO. 46-563 C1 NBL / 46-563 C2 SBL  
W.P. 5566-09-01 NBL / 5567-09-01 SBL  
G.W.P. 5206-06-00 (PART OF G.W.P. 5378-02-00)  
SUDBURY AREA, ONTARIO**

PETO MacCALLUM LTD.  
165 CARTWRIGHT AVENUE  
TORONTO, ONTARIO  
M6A 1V5  
Phone: (416) 785-5110  
Fax: (416) 785-5120  
Email: toronto@petomaccallum.com

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Mr. Francois Doyon, P. Eng.  
Project Manager  
McCormick Rankin Corporation  
2655 North Sheridan Way  
Mississauga Ontario  
L5K 2P8

Dear Mr. Doyon

**Technical Memorandum for Culverts in Phase 1  
Addendum to Foundation Investigation and Design Report  
Culvert C56 - Delamere Township  
Highway 69 Four-Laning for 24.7 km  
From 3.8 km North of Highway 522  
to 4.5 km North of Highway 64, Site No. 46-563 C1 NBL / 46-563 C2 SBL  
W.P. 5566-09-01 NBL / 5567-09-01 SBL, G.W.P. 5206-06-00 (Part of G.W.P. 5378-02-00)  
Sudbury Area, Ontario**

Planned within the 11.1 km long Phase 1 of the project is the installation of several concrete culverts. Nine of these culverts have been selected for foundation investigation.

This memorandum summarises the results of the field investigation conducted at the location of culverts 42 and 43 at station 12+780, Delamere Township which were assigned a reference number C56. This memorandum also pertains to the design and construction of this proposed culvert and associated bedding/backfill zones.

A timber crib culvert was noted under the existing Highway 69 embankment about 20 m south of the proposed northbound culvert C56.

The field work for culvert C56 was carried out on November 6 and 7, 2008. The subsurface investigation comprised a total of 3 boreholes advanced to depths of 4.3 to 6.3 m below existing grade.

The locations of the boreholes put down along the culvert are shown on Drawing C56-1. The borehole logs, drawing and figures are identified by the prefix codes to reflect the specific culvert number for ease of reference.

**1. SUMMARIZED SUBSURFACE CONDITIONS**

Reference is made to the appended Record of Borehole sheets for details of the subsurface conditions including soil classifications, inferred stratigraphy, soil boundary elevations, standard penetration resistance values, in-situ vane shear and penetrometer test data and groundwater observations. The results of laboratory Atterberg plasticity limits tests, grain size distribution analyses and moisture content determinations are also shown on the Record of Borehole sheets.

Three boreholes were drilled along the alignment of culvert C56. The subsurface stratigraphy revealed in the boreholes included a thin surficial peat layer overlying either a 1.3 to 1.8 m thick



layer of cobbles and boulders in boreholes C56-1 and C56-2 or silty clay overlying a thinner 0.2 m thick layer of cobbles in borehole C56-3. Bedrock was contacted at depths of 1.5 to 3.4 m (elevations 197.4 to 202.8). Groundwater was observed at elevation 199.3 in borehole C56-3.

Reference should be made to the previous boreholes conducted in swamp 101 (boreholes 101-7 to 101-18) that were drilled near the southbound and northbound culverts. Typically the boreholes reveal similar subsurface conditions with refusal on probable bedrock at elevations 199.3 to 204.9, also generally sloping down from west to east.

### **1.1 Peat**

A deposit of peat was found surficially in all boreholes. The fine fibrous peat was 100 to 200 mm thick. The peat deposit extended to depths of 0.1 to 0.2 m, elevations 204.1, 203.7 and 200.7 in boreholes C56-1, C56-2 and C56-3, respectively.

### **1.2 Silty Clay**

Underlying the peat at 0.1 m depth in borehole C56-3 a firm to stiff silty clay deposit was contacted. The silty clay deposit was 3.1 m thick and extended to an underlying deposit of cobbles at 3.2 m depth (elevation 197.6). Two N values of 2 and 8 were obtained. Penetrometer testing on a sample of the silty clay indicated a shear strength of 100 kPa.

The results of Atterberg plasticity limits testing and grain size distribution analysis conducted on a sample of the silty clay from culvert C56 are presented in respective Figures C56-PC-1 and C56-GS-1.

The liquid limit and plastic limit of the silty clay was 42 and 24, respectively, with a plasticity index value 18. The water content of the silty clay was 33%.

### **1.3 Cobbles and Boulders**

Underlying the peat at 0.1 to 0.2 m depth in boreholes C56-1 and C56-2 was a deposit of cobbles and boulders which included layers of sand with trace silt. Underlying the silty clay at 3.2 m depth in borehole C56-3 a deposit of cobbles was encountered. The deposits extended to the underlying bedrock at 1.5, 1.9 and 3.4 m depth (elevations 202.8, 201.9 and 197.4) in boreholes C56-1, C56-2 and C56-3, respectively.

### **1.4 Bedrock**

Bedrock was contacted at depths of 1.5 to 3.4 m (elevations 197.4 to 202.8), with the bedrock surface elevation decreasing from west to east. Locally, refusal on probable bedrock and bedrock at surface were encountered at elevations 202.4 and 204.5 in boreholes 101-12 and 101-16 which are located in close proximity to the east end of the northbound culvert and about 5 m north and south indicating variable bedrock levels. Based on the three boreholes 101-11 and 101-12 (shown on the stratigraphy profile in Drawing C56-1) the rock surface is relatively level (elevations 201.6 to 202.8) to the west and under the existing Highway 69 embankment, dipping 4.8 m to the east of the Highway 69 east shoulder (between boreholes 101-12 and C56-3).



The bedrock has a variable composition including pink to grey Granite/Granitic Gneiss at borehole C56-1, black becoming pink Migmatite at borehole C56-2 and grey becoming dark grey Migmatite with black layers at borehole C56-3. The rock exhibited high strength in all borehole locations. A detailed description of the rock cores retrieved from boreholes C56-1, C56-2 and C56-3 is given in Table A, appended.

The measured core recovery was 93 to 100%. The RQD determined from the rock cores typically was in a range of 80 to 100%, thus indicating good to excellent quality rock. The rock core obtained between 4.5 and 5.1 m in borehole C56-2 had a very poor RQD of 0%.

### **1.5 Groundwater**

Groundwater was measured at 1.5 m depth, elevation 199.3 in borehole C56-3. During the investigation for the swamp 101 crossing between August and November 2006 the groundwater level was measured in boreholes around southbound culvert about 3.6 to 4.9 m higher at levels ranging from elevations 202.9 to 204.2. No water was observed in boreholes around the northbound culvert. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

## **2. ENGINEERING RECOMMENDATIONS**

It is understood that precast box culverts are capable of withstanding some 100 mm of differential settlement, provided the settlement is not abrupt. Cast-in-place culverts typically tolerate a maximum of 25 mm of differential settlement, after which, cracking may appear within the culvert. Expansion joints should be provided at the design engineer's discretion to accommodate the differential settlement.

The foundation frost penetration depth at the sites is 2.0 m according to OPSD 3090.101.

It is noted that no responsibility or liability is assumed by MTO or by the consultants for alerting the contractor and to "red-flag" all critical issues. The requirement to deliver acceptable construction quality remains the responsibility of the contractor.

All elevations in the memorandum are expressed in metres. A list of standard specifications referenced in this memorandum is compiled in Table 1. The Granular A and B materials referenced in this memorandum should conform to OPSS 1010.

For culvert C56, separate box culverts are proposed under the northbound and southbound lanes of the new Highway 69 (designated northbound and southbound culverts). The invert levels of the proposed 3.0 m wide concrete box culverts are specified near elevation 201.5 at the west end of the southbound culvert and elevation 200.6 at the east end of the northbound culvert, indicating an west to east flow. The subgrade level of the granular bedding should be about 0.5 m below the proposed invert levels at elevations 200.1 to 201.0 allowing for the thickness of the concrete base of the culvert and for the granular bedding and levelling courses.

Culvert C56 is located within swamp 101. The recommended treatment for this section of the swamp was placement of a surcharge load without the removal of the in-situ compressible soils. At the proposed southbound and northbound culvert locations, fills and cuts ranging from 0.5 m to 0.7 m



from the existing grade will be required to achieve the proposed southbound and northbound road centreline grade elevations 204.7 and 204.8, respectively.

In summary, at the west end of the southbound culvert and centreline median, bedrock was encountered at elevations 202.8 and 201.9, respectively. These levels were consistent with the probable bedrock level in borehole 101-11, elevation 201.6. Accordingly, bedrock is 1.3 m above the west proposed southbound culvert invert level and 0.6 m above the east proposed invert level.

In borehole C56-3 drilled about 8 m east of the east end of the northbound culvert, the subgrade soils will comprise firm to stiff silty clay overlying a thin deposit of cobbles. These soils mantle bedrock at 3.4 m depth, elevation 197.4. Probable bedrock was found at a 5.0 m higher level elevation 202.4 in borehole 101-12, drilled 6 m west and 5 m south of the east end of the culvert and a bedrock outcrop was found at elevation 204.5 in borehole 101-16, drilled 7.5 m north of the culvert outlet.

An alternative foundation design using a rock base with side walls dowelled into the bedrock may also be constructed at this site.

Groundwater at the time of the field investigation for the culvert was encountered at 1.5 m depth, elevation 199.3 at the east end of the proposed northbound culvert. This level is 1.7 to 0.8 m, respectively below the anticipated subgrade levels of the southbound and northbound culverts. During the investigation for the swamp 101 crossing between August and November 2006 the groundwater level was about 3.6 to 4.9 m higher at levels ranging from elevations 202.9 to 204.2.

## **2.1 Foundations for Culvert C56 Under Southbound and Northbound Lanes**

### **2.1.1 Box Culvert Considerations**

For box culvert construction, the relatively shallow depth bedrock encountered or inferred under both the northbound and southbound culverts and centerline median should be excavated to the proposed west and east culvert subgrade levels. Accordingly, excavation of up to 1.8 m of bedrock at the west end (to elevation 201.0), up to 1.5 m (to elevations 200.8 and 200.4) at the median, and up to 2.0 m (to elevation 200.1) at the east end will be required to provide a minimum thickness of 300 mm of bedding and levelling course below the underside of the culvert.

The excavated rock should be replaced with Granular A or Granular B Type II material to raise the subgrade to the design level. Granular B Type II should be preferred for construction under wet conditions. The prepared subgrade should be inspected during construction and any bedrock less than 300 mm below the underside of the culvert should be removed to minimize the influence of point loads.

The bedrock level dips down beyond the east end (outlet) of the proposed northbound culvert and the rock subgrade may need to be locally raised using mass concrete.

### **2.1.2 Rock Base Considerations**

Alternatively, the culvert may be constructed with a rock base having the sidewalls dowelled into the bedrock.



The rock excavation should be carefully carried out to produce a shatter free bedrock mass/surface that is adequate to receive the steel dowels. To this end, excavation using mechanical excavations will be preferred.

A bedding and levelling course is not required for this foundation scheme.

## **2.2 Geotechnical Bearing Resistance For Culvert C56**

The recommended geotechnical bearing resistances at ultimate and serviceability limit states (ULS and SLS) for the proposed 3.0 m wide box culvert typically constructed on the structural fill (Granular A or Granular B Type II) over bedrock, or directly on bedrock are as follows:

CULVERT SECTION	SOIL TYPE	FACTORED GEOTECHNICAL RESISTANCE AT ULS (kPa)	GEOTECHNICAL RESISTANCE AT SLS (kPa)
Southbound Or Northbound	Structural Fill (Granular A or Granular B Type II)	900	350
	Bedrock	10,000	N/A

The geotechnical resistance at SLS normally allows for 25 mm compression of the founding medium. A foundation embedment depth of 2.0 m and groundwater at about the level of the culvert invert were assumed for computation of the geotechnical resistance.

The geotechnical resistance at SLS for foundations on the bedrock is not applicable because the median is considered to be non-welding.

If required, mass concrete could be placed to provide a level founding surface below the side walls of the culvert. Further recommendations in this regards are included in following section of this memorandum.

## **2.3 Subgrade Preparation**

Preparation of the subgrade for construction of the culverts should be performed and monitored in accordance with OPSS 902 and SP 902S01. This should include site review by qualified geotechnical personnel during preparation of the subgrade as well as during placement and compaction of the granular fill and during the removal of existing culverts where applicable.

Where the Ministry has approved the substitution of precast box culverts for cast-in-place box culverts, it is recommended to provide 300 mm of granular bedding below the culvert. The bedding material should comprise Granular A compacted to 100% of the ASTM D-698 (standard Proctor) maximum dry density in conformance to OPSS 501 (Method A).

The topsoil and any other deleterious soils revealed at and below the subgrade level should be excavated prior to placement of the granular base below the box culvert and replaced with compacted Granular A or Granular B Type II.



Subgrade preparation, cover, backfill and frost treatment for the proposed culverts should be carried out in accordance with OPSD 803.010, OPSS 422 and SP 422S01. A foundation frost penetration depth in the area is at least 2.0 m according to OPSD 3090.101.

If culvert C56 is constructed with a bedrock base, mass concrete could be employed to raise the bedrock subgrade to the design level of the side walls, if required. Mass concrete could also be placed to provide a level founding surface for the wing wall or headwall footings, if required. Alternatively, the rock surface could be “stepped” to follow variations in the bedrock surface elevation thereby creating a level subgrade by a combination of rock excavation and placement of mass concrete.

The need to expand the plan area at the base of the mass concrete to provide for stress distribution (2V:1H), place reinforcing steel in the mass concrete and/or use high strength concrete to prevent overstressing will be dictated by the actual thickness of the mass concrete and structural design considerations.

Subject to these comments, the geotechnical bearing resistance provided for footings bearing on bedrock is considered to be appropriate for mass concrete with an unconfined compressive strength of at least 35 MPa.

Comments concerning excavation of bedrock to enable construction of the footings are provided in Section 5 of the memorandum.

## **2.4 Modulus of Subgrade Reaction**

The estimated values of the modulus of subgrade reaction for culvert C56 constructed on structural fill (Granular A or B Type II) is as follows:

SOIL TYPE	MODULUS OF SUBGRADE REACTION MN/m <sup>3</sup>
Granular A or B Type II	45

## **2.5 Sliding Resistance**

The following parameters should be used for sliding resistance of cast-in-place culvert foundations. The friction angle in case of precast concrete should be reduced by a factor of 0.67.

SOIL TYPE	Friction Angle, degrees	Cohesion, kPa	Unit Weight, kN/m <sup>3</sup>
GRANULAR A OR GRANULAR B TYPE II	35	0	22.8

The structural designer should use a factor of 0.8 for the above values of friction angle and cohesion when checking the sliding resistance.

If the footings are poured directly on the surface of the bedrock (bedrock surface not roughened by excavation/construction activities), an unfactored friction factor of 0.6 should be employed



since this bedrock surface is relatively smooth, presumably as a result of weathering and/or glaciation. If excavation of the bedrock is required, an unfactored friction factor of 0.7 could be used.

The lateral resistance of footings founded on bedrock could be increased by means of a shear key and/or by installing dowels/anchors into the bedrock (SP 999S26). The increased lateral resistance will be provided by the shear strength of steel dowels if used, the horizontal resistance of the bedrock, the horizontal component of tensile forces developed in any inclined anchors and/or a greater frictional resistance between the footing and rock if the anchors are prestressed to increase the vertical pressure. The factored horizontal resistance at ULS of the bedrock is considered to be 5000 kPa.

If anchors are installed, a factored bond stress at the rock/grout interface of 1.4 MPa at ULS (a resistance factor of 0.4 is applied for a minimum 35 MPa grout) is recommended for design. The anchors should extend a minimum 30 bar diameters into sound bedrock and be spaced at a distance of at least four times the diameter of the anchor hole. The total capacity of a group of closely spaced anchors may be less than the summed capacities of the individual anchors; the impact of anchor interaction should be assessed if the spacing is less than one-fifth of the anchor length. Design, installation and testing of the anchors subjected to tensile stresses should be conducted in accordance with SP 999S26 and clause 6.10.4 of the Canadian Highway Bridge Design Code (CHBDC).

## **2.6 Seismic Site Coefficient**

The seismic site coefficient for the conditions at the culvert sites is 1.0 – Type I soil profile as per clause 4.4.6 of the CHBDC.

## **3. CULVERT BACKFILL**

Backfill adjacent to the culverts should be placed in accordance with OPSD 803.010, OPSS 422 and SP 422S01.

Backfill should be brought up simultaneously on each side of the culvert and operation of heavy equipment within 0.5 times the height of the culvert (each side) restricted to minimise the potential for movement and/or damage of the culvert due to the lateral earth pressure induced by compaction. Refer to SP 105S10 for additional comments.

The culverts and headwalls must be designed to support the stress imposed by the overlying fill as well as to resist the unbalanced lateral earth pressure and compaction pressure exerted by the backfill adjacent to the culvert walls. Recommendations for headwalls and wingwalls are also provided in Section 4 of this memorandum.





The lateral earth and water pressure,  $p$  (kPa), should be computed using the equivalent fluid pressures presented in Section 6.9 of the CHBDC or employing the following equation assuming a triangular pressure distribution:

$$P = K (\gamma h_1 + \gamma' h_2 + q) + \gamma_w h_2 + C_p + C_s$$

where  $K$  = lateral earth pressure coefficient  
 $\gamma$  = unit weight of free draining granular material above the design water level ( $\text{kN/m}^3$ )  
 $\gamma'$  = unit weight of backfill submerged below the design water level ( $\text{kN/m}^3$ )  
 $h_1$  = depth below final grade (m), above the design water level  
 $h_2$  = depth below the design water level (m)  
 $q$  = any surcharge load ( $\text{kN/m}^2$ )  
 $\gamma_w$  = unit weight of water equal to  $9.8 \text{ kN/m}^3$   
 $C_p$  = compaction pressure (refer to clause 6.9.3 of CHBDC)  
 $C_s$  = earth pressure induced by seismic events, kPa (refer to clause 4.6.4 of CHBDC)  
where  $\phi$  = angle of internal friction of retained soil ( $35^\circ$  for Granular A)  
 $\delta$  = angle of friction between soil and wall ( $23.5^\circ$  for Granular A)

The following parameters are recommended for design:

PARAMETER	GRANULAR A, GRANULAR B TYPE II	ROCKFILL
Angle of Internal Friction, degrees	35	42
Unit Weight, $\text{kN/m}^3$	22.8	18.0
Active Earth Pressure Coefficient ( $K_a$ )	0.27	0.20
At-Rest Earth Pressure Coefficient ( $K_o$ )	0.43	0.33
Passive Earth Pressure Coefficient ( $K_p$ )	3.69	5.04

The design should consider both the maximum water level in the stream and the stabilised groundwater level condition. Groundwater at the time of the field investigation for the culvert was encountered at 1.5 m depth, elevation 199.3 at the east end of the proposed northbound culvert. This level is 1.7 to 0.8 m, respectively below the anticipated subgrade levels of the southbound and northbound culverts. The maximum stream water level will be dictated by flood flow conditions and should be defined by the project hydraulic engineer.

The coefficient of earth pressure at rest should be employed to design rigid and unyielding walls and the active earth pressure coefficient for unrestrained structures.

#### 4. HEADWALLS AND WINGWALLS

For headwalls and wingwalls, the previous recommendations and geotechnical parameters for culvert foundations and backfill should be used for the design of their foundations, and in accordance with OPSD 3121.150. The wall founding levels should match those of the respective culverts where the walls are designed integral with the culvert structure. For walls designed separately from the culvert structure, the founding levels should be established minimum 2.0 m below the culvert invert level for adequate frost protection.



The design of the walls should be checked for sliding resistance using the geotechnical parameters provided in Section 2.5 for cast-in-place concrete foundations.

For headwalls and wingwalls, a weeping tile system should be installed to minimise the build-up of hydrostatic pressure behind the wall. The weeping tiles should be surrounded by a properly designed granular filter or non-woven Class II geotextile (with an FOS of 75-150 µm according to OPSS 1860) placed to prevent migration of fines into the system. The wall drainage pipe should outlet onto a positive slope away from the wall and where possible lead to a frost free outlet.

## **5. EXCAVATION**

Excavation to the anticipated founding level of the culverts is expected to extend through the cobbles and boulders, existing fill and native silty clay deposits. Provision for excavation of cobbles and boulders should be made. Subject to adequate groundwater control, excavation of the soils should be feasible using conventional equipment. All excavations should be conducted in accordance with OPSS 902 and SP 902S01.

According to the Occupational Health and Safety Act (Ontario Regulation 213/91) criteria, typically the in situ soils (cobbles and boulders and cohesive firm to stiff silty clay) are classified as Type 3 soils necessitating temporary cut slopes to be inclined at 1H:1V.

Excavation of bedrock will likely be required at culvert C56. Conventional rock excavation techniques such as blasting as per OPSS 120 and jack-hammering should be suitable. It is important that blasting/excavation of the rock is controlled to prevent fracturing and/or disturbance of the bedrock surface directly beneath the culverts. The equipment required and method of excavation within the bedrock will be dependent upon the actual geometry of cut and relative depth of excavation into the bedrock.

Mechanical means such as a large excavator equipped with a tiger-toothed bucket in conjunction with a jack-hammer or hoe ram is the preferred method of excavation to shallow depths in rock at foundation locations. Mass concrete could be employed to level minor variations in the bedrock surface.

If blasting is required, a NSSP should be prepared to provide specific direction to the contractor to control the blasting/excavation of the rock to prevent fracturing and/or disturbance of the bedrock surface, require that a blasting specialist be retained to establish the charge to minimise overbreak, advise that any overblasting/overexcavation will be the sole responsibility of the contractor and require that loosened rock resulting from blasting operations be removed by mechanical means.

The excavation at the culvert sites should allow for the backfill and cover requirements in accordance with OPSD 803.010. Near vertical sidewalls may be utilised for excavations in bedrock. Examination of the sidewalls and removal of any loosened rock fragments should be carried out continually for the safety of workmen.

## **6. GROUNDWATER CONTROL**

Groundwater at the time of the field investigation for the culvert was encountered at 1.5 m depth, elevation 199.3 at the east end of the proposed northbound culvert. This level is 1.7 to 0.8 m,



respectively below the anticipated subgrade levels of the southbound and northbound culverts. During the investigation for the swamp 101 crossing between August and November 2006 the groundwater level was about 3.6 to 4.9 m higher at levels ranging from elevations 202.9 to 204.2.

It is considered that dewatering with conventional sump pumping techniques will generally be sufficient to handle groundwater seepage or surface water inadvertently entering the excavations, provided surface water flow is controlled. The contract documents should have a specific item to clearly state that groundwater control of excavations is the contractor's responsibility.

It will be necessary to implement measures to control surface water flow at both of the culvert sites. Conventional procedures such as dam and pump and/or diversion of the stream should be sufficient to control surface water flow.

In case the cast-in-place headwalls and wingwalls are designed separately from the culverts and to allow for dry conditions for the construction of cut-off walls, the groundwater levels would range from 0.2 m below to 1.1 m above the founding levels.

The subgrade materials will range from deposits of cobbles and boulders at the southbound culvert to silty clay at the east end of the northbound culvert. Dewatering will likely be required to temporarily lower the groundwater table and permit construction, pending the actual hydraulic conditions after the recommended swamp treatment is implemented. The dewatering system must be designed and installed by specialists in the field. The groundwater level should be lowered to a minimum 0.5 m below the proposed founding levels.

In accordance with the Ontario Water Resources Act, the Water Taking and Transfer Regulation 387/04, a Permit to Take Water (PTTW) from the Ministry of Environment is required if the dewatering discharge is greater than 50,000 L/day. It is anticipated that a PTTW will be necessary for temporary dewatering operations considering the relatively pervious soils at some of the culvert sites (rockfill, cobbles and boulders, sand and gravel).

It must be noted that the assessment of the need for an application for a PTTW will be undertaken by others. This will include the expected daily flows at each culvert location which should be assessed by the hydraulic engineer.

It is recommended that the work be carried out during the dry months of June to September to minimize the amount of groundwater inflow to be handled and the volume of surface water, if any, to be diverted from the construction area.

Groundwater levels are subject to seasonal fluctuations and precipitation patterns.

All construction work should be carried out in accordance with the Occupational Health and Safety Act and with local/MTO regulations.

## **7. EMBANKMENT FILL**

The anticipated subgrade for the embankments will comprise rockfill, existing embankment fill, cobbles and boulders or silty clay. The construction specifications for grading in SP 206S03 should be followed. In particular, the topsoil and other excessively loose, soft, organic or



otherwise deleterious materials within the limits of the embankment fill should be subexcavated prior to fill placement. The new embankment fill should be placed and compacted in accordance with OPSS 501 and SP 105S10.

The rockfill embankment side slopes should be inclined no steeper than 1.25H:1V. A vegetation cover over slope flattening material or other measures should be established to control surface runoff and minimise erosion of the embankment slopes.

## **8. EROSION CONTROL**

The protective measures noted in the OPSD 800 series to deal with erosion (inlet/outlet treatment, headwalls, cut-off walls, etc.) are considered to be appropriate. The backfill should comprise OPSS Granular A or Granular B Type II. The cut-off walls should extend laterally to protect the granular backfill material and to a depth at least equal to the fluctuation of the water level at each culvert location to prevent flow below the culvert that could erode the granular base/bedding material. The requirements of CHBDC clauses 1.9.5.6 and 1.9.11.6.5 should be applied.

Inlet and outlet protection in accordance with OPSS 511 and 1004 and OPSD 810.010 is recommended to prevent erosion adjacent to the culvert as well as scour that could undermine the culvert and/or embankment foundation. The actual design requirements concerning the length and width of aprons at the inlet/outlet of the culvert as well as the rock size, apron thickness, height of erosion protection on the embankment slope and type of material (clay seals at the inlet, drainage and/or filter blankets at the outlet) will be dictated by stream hydraulics, stream configuration, the water level in the stream and should be established by a hydraulic engineer. A non-woven Class II geotextile with an FOS of 75-150 µm according to OPSS 1860 should be placed below the rip-rap to minimise the potential for erosion of fine particles from below the treatment.

All newly constructed embankment slopes and retained soils behind the headwalls and wingwalls (if provided) should be covered with topsoil or suitable excess earth material from swamps or muskeg areas and seeded in accordance with OPSS 570 and 572, as soon after grading as possible to prevent erosion. Where slopes are inclined at 2.5H:1V or steeper, the permanent slopes should be protected with erosion control blankets. Also, sod (as per OPSS 571) shall be placed where it currently exists with a view to aesthetics. Additional appropriate erosion control measures for the project should be assessed using the following erodibility K factor:

<b><u>SOIL TYPE</u></b>	<b><u>K FACTOR</u></b>
Clayey Silt	0.45
Clay / Silty Clay	0.2 to 0.3
Gravelly Sand	0.1



This technical memorandum was prepared by Mr. C.M.P. Nascimento, P.Eng. with the assistance of Mr. M.J. Narduzzi, BEng., and was independently reviewed by Mr. B. R. Gray, MEng, P.Eng., MTO Designated Principal Contact.

Yours very truly

Peto MacCallum Ltd.



Carlos M. P. Nascimento, P.Eng.  
Senior Project Engineer



Brian R. Gray, MEng, P.Eng.  
MTO Designated Principal Contact

MN/CN/BRG:mn-mi

Enclosure(s):

Table A – Rock Core Descriptions  
Table 1 – List of Standard Specifications Referenced in Memorandum  
Figure C56-PC-1 – Results of Atterberg Limits Testing  
Figure C56-GS-1 – Results of Grain Size Distribution Analyses  
Explanation of Terms Used in Report  
Record of Borehole Sheets  
Drawing C56-1 – Borehole Locations and Soil Strata  
Appendix A – Rock Core Photographs



**TABLE A**  
**ROCK CORE DESCRIPTION**

LOCATION (BH)	CORE RECOVERY				CORE DESCRIPTION	
	RC	DEPTH (m)	REC (%)	RQD (%)	DEPTH (m)	DESCRIPTION
C56-1	1	1.5 – 2.8	100	100	1.5 – 4.3	GRANITE/GRANITIC GNEISS: Pink to grey, fine grained, with 25 mm thick dipping black biotite rich layer, high strength, unweathered, close to moderate spaced flat to dipping cross joints, rough planar, tight, excellent quality.
	2	2.8 – 4.3	93	93		
C56-2	1	0.7 – 1.9	-	-	0.7 – 1.9	BOULDERS/COBBLES/GRAVEL  MIGMATITE: Black, fine grained, with minor Pyrite, near vertical banding, becoming pink, high strength, slightly weathered to unweathered, close to moderate spaced flat to dipping cross joints, rough (locally slickensided) planar, tight to slightly altered with yellow, red or green oxidation stains on partings, with near vertical fissure below 4.5 m depth, alteration to 10 mm, becoming tight, with green scale on partings at depth, excellent becoming very poor quality below 4.5 m.
	2	1.9 – 3.0	93	93	1.9 – 5.1	
	3	3.0 – 4.5	100	93		
	4	4.5 – 5.1	100	0		
C56-3	3	3.2 – 4.3	88	88	3.2 – 3.4	COBBLES/GRAVEL  MIGMATITE: Light grey to pink, fine grained, with black layers, becoming dark grey, high strength, unweathered, moderate to wide spaced dipping cross joints, rough (locally slickensided) planar, tight, good to excellent quality.
	4	4.3 – 5.8	98	98	3.4 – 6.3	
	5	5.8 – 6.3	100	100		

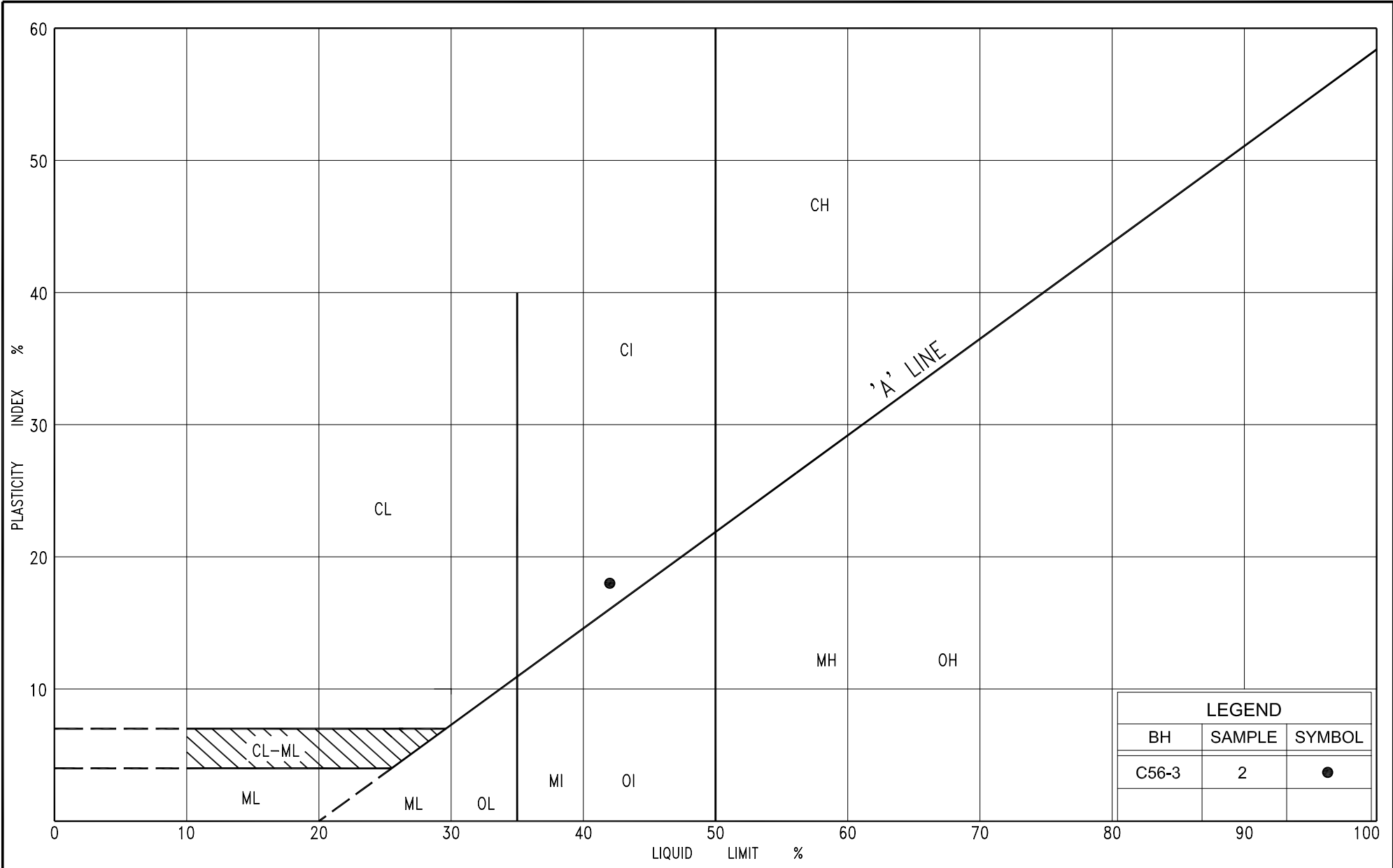
RQD = Rock Quality Designation

Originated: FP  
Compiled: JFW  
Checked: MN / CN

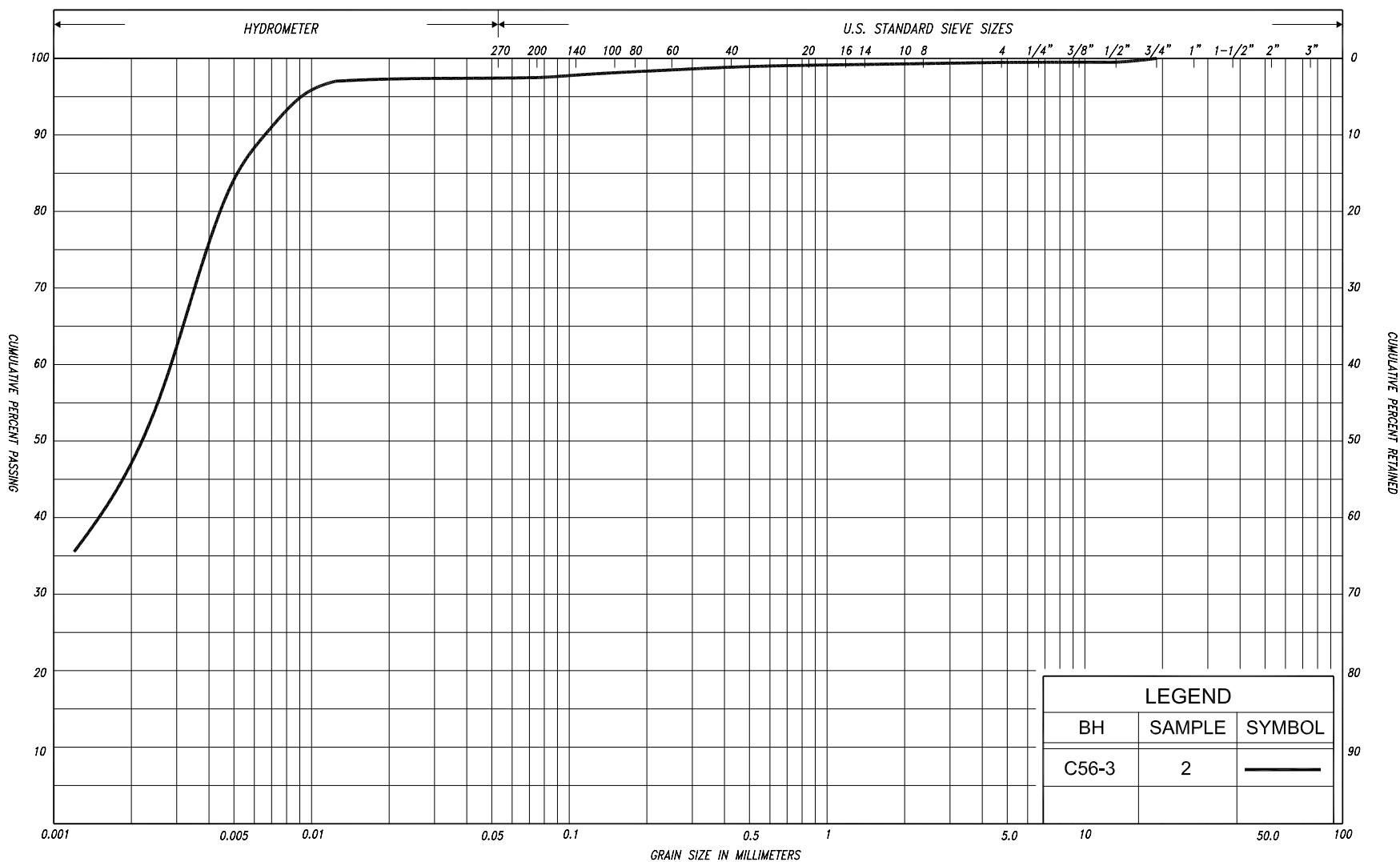


**TABLE 1**  
**LIST OF STANDARD SPECIFICATIONS REFERENCED IN MEMORANDUM**

<b>DOCUMENT</b>	<b>TITLE</b>
OPSS 120	General Specification for the Use of Explosives
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS 501	Construction Specification for Compacting
OPSS 511	Construction Specification for Rip-Rap, Rock Protection and Granular Sheeting
OPSS 570	Construction Specification for Topsoil
OPSS 571	Construction Specification for Sodding
OPSS 572	Construction Specification for Seed and Cover
OPSS 902	Excavation and Backfilling of Structures
OPSS 1004	Material Specification for Aggregates – Miscellaneous
OPSS 1010	Material Specification for Aggregates, Base, Subbase, Select Subgrade and Backfill Material
OPSS 1860	Material Specification for Geotextiles
SP 105S10	Construction Specification for Compaction
SP 206S03	Construction Specification for Grading
SP 422S01	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers
SP 902S01	Excavation and Backfilling of Structures
SP 999S26	Design, Installation and Testing of Pre-Stressed Anchors in Soil and Rock
OPSD 803.010	Backfill and Cover for Concrete Culverts
OPSD 810.010	Rip-Rap Treatment for Sewer and Culvert Outlets
OPSD 3090.101	Foundation Frost Depth for Southern Ontario
OPSD 3121.150	Minimum Granular Backfill Requirements – Retaining Walls







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

## EXPLANATION OF TERMS USED IN REPORT

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

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

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

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

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

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

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

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

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

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

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

**JOINTING AND BEDDING:**

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

## ABBREVIATIONS AND SYMBOLS

### FIELD SAMPLING

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

### STRESS AND STRAIN

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

### MECHANICAL PROPERTIES OF SOIL

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

### PHYSICAL PROPERTIES OF SOIL

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

**METRIC**



20  
15 — 5 (%) STRAIN AT FAILURE  
10

**RECORD OF BOREHOLE No C56-2**

1 of 1

**METRIC**

G.W.P. 5206-06-00 LOCATION Coords: 5 109 768 N; 329 357 E ORIGINATED BY M.R.  
 DIST 54 HWY 69 BOREHOLE TYPE C.F.H.S.A. AND NQ DIAMOND CORING COMPILED BY M.N.  
 DATUM Geodetic DATE November 06, 2008 CHECKED BY C.N.

SOIL PROFILE			SAMPLES			GROUND WATER * CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	*N* VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE									
203.8 0.0	Ground Surface						20	40	60	80	100						
203.7 0.1	Peat, fine fibrous Dark brown      Wet																
	Cobbles and boulders sand trace silt layers		1	RC NQ	-		203										
201.9 1.9	Migmatite Bedrock																
	Slightly weathered to unweathered		2	RC NQ	REC 100%		202										
	High strength						201										
	Excellent quality						200										
			3	RC NQ	REC 100%												
			4	RC NQ	REC 100%												
198.7 5.1	End of borehole																

**RECORD OF BOREHOLE No C56-3**

1 of 1

**METRIC**

G.W.P. 5206-06-00 LOCATION Coords: 5 109 786 N; 329 387 E ORIGINATED BY M.R.  
DIST 54 HWY 69 BOREHOLE TYPE C.F.H.S.A. AND NQ DIAMOND CORING COMPILED BY M.N.  
DATUM Geodetic DATE November 07, 2008 CHECKED BY C.N.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								○ UNCONFINED      + FIELD VANE		● QUICK TRIAXIAL      × LAB VANE		w <sub>p</sub> w      w <sub>L</sub>				
200.8 0.0	Ground Surface					20	40	60	80	100	20	40	60		GR SA SI CL	
200.7 0.1	Peat, fine fibrous Dark brown      Wet		1	SS	2										1   2   50   47	
	Silty clay trace sand, trace gravel															
	Firm to Black/ Moist stiff grey		2	SS	8											
197.6 3.2	Cobbles/gravel															
197.4 3.4	sand trace silt layers															
	Migmatite Bedrock		3	RC NQ	REC 88%										RQD   88%	
	Unweathered															
	High strength															
	Good to excellent quality		4	RC NQ	REC 98%										RQD   98%	
194.5 6.3	End of borehole		5	RC NQ	REC 100%										RQD   100%	

**RECORD OF PENETRATION TEST No 101-7**

1 of 1 **METRIC**

G.W.P. 5206-06-00 LOCATION Hwy 69(New), Sta. 12+762.5, o/s 34.5m Lt. CL median ORIGINATED BY F.P.  
 DIST 54 HWY 69 BOREHOLE TYPE Dynamic Cone Penetration Test COMPILED BY G.D.  
 DATUM Geodetic DATE November 07, 2006 CHECKED BY G.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>		
205.1 0.0	Ground Surface																
	Probable clayey silt																
204.5 0.6	Soft																
	End of dynamic cone penetration test																
	Refusal on probable bedrock																

RECORD OF BOREHOLE No 101-8

1 of 1

METRIC


G.W.P. 5206-06-00 LOCATION Hwy 69(New), Sta. 12+762.5, o/s 4.5m Lt. CL median ORIGINATED BY F.P.  
 DIST 54 HWY 69 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY G.D.  
 DATUM Geodetic DATE November 07, 2006 CHECKED BY G.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					W <sub>p</sub> W                  W <sub>L</sub>				
								○ UNCONFINED                  + FIELD VANE ● QUICK TRIAXIAL                  × LAB VANE					WATER CONTENT (%)				
202.9	Ground Surface							20	40	60	80	100					
0.0 202.6	Peat, fine fibrous		1	SS	3												
0.3	Clayey silt, some sand trace gravel, organics layers of silt																
	Firm to Brown Moist stiff		2	SS	12		202							41			3 17 60 20
	sandy, some gravel cobbles and boulders		3	SS	31		201							41			18 37 32 13
	Very Grey stiff to hard						200										
199.7	End of borehole		4	SS	15/5cm												
3.2	Refusal on probable bedrock																
	Sample 3: Sampler bouncing																
	* 2006 11 07																
	Water level observed during drilling																
	Water level measured after drilling																

RECORD OF PENETRATION TEST No 101-9

1 of 1 METRIC

G.W.P. 5206-06-00 LOCATION Hwy 69(New), Sta. 12+762.5, o/s 4.5m Rt. CL median ORIGINATED BY F.P.  
DIST 54 HWY 69 BOREHOLE TYPE Dynamic Cone Penetration Test COMPILED BY G.D.  
DATUM Geodetic DATE November 07, 2006 CHECKED BY G.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT  w <sub>p</sub>	NATURAL MOISTURE CONTENT  w	LIQUID LIMIT  w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE							
202.7 0.0	Ground Surface  Probable peat Probable clayey silt Soft to stiff   sandy Very stiff														
199.8 2.9	End of dynamic cone penetration test  Refusal on probable bedrock														



RECORD OF BOREHOLE No 101-10

1 of 1

METRIC

G.W.P. 5206-06-00 LOCATION Hwy 69(New), Sta. 12+762.5, o/s 34.5m Rt. CL median ORIGINATED BY F.P.  
DIST 54 HWY 69 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY G.D.  
DATUM Geodetic DATE November 07, 2006 CHECKED BY G.D.








SOIL PROFILE			SAMPLES			* GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  γ  kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					w <sub>p</sub>	w	w <sub>L</sub>		GR	SA	SI	CL	
								20	40	60	80	100	WATER CONTENT (%)								
201.4	Ground Surface					201															
0.0	Peat, fine fibrous		1	SS	2																
200.9	amorphous																				
0.5	Clayey silt trace sand, organics silty clay layers		2	SS	15	200															
	Firm to very stiff   Brown   Moist to wet																				
199.3			3	SS	9																
2.1	End of borehole Refusal on probable bedrock																				
	<div>*   Borehole dry on completion of drilling</div> <div>■   Penetrometer test</div>																				

RECORD OF BOREHOLE No 101-11

1 of 1

METRIC

G.W.P. 5206-06-00 LOCATION Hwy 69(New), Sta. 12+775, o/s 18.8m Lt. CL median ORIGINATED BY F.P.  
 DIST 54 HWY 69 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY G.D.  
 DATUM Geodetic DATE November 07, 2006 CHECKED BY G.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT  w <sub>p</sub>	NATURAL MOISTURE CONTENT  w	LIQUID LIMIT  w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa												
								○ UNCONFINED	● QUICK TRIAXIAL	✕ LAB VANE	✚ FIELD VANE									
204.5	Ground Surface						204													
0.0 204.2	Peat, fine fibrous		1	SS	5															
0.3	Sand, with silt trace gravel, organics cobbles and boulders  Loose to Grey Wet dense																			
			2	SS	18															
			3	SS	22/15cm															
201.6 2.9	End of borehole Refusal on probable bedrock						202													
	Sample 3: Sampler bouncing																			
	* 2006 11 07																			
	 Water level observed during drilling																			
	 Water level measured after drilling																			

RECORD OF BOREHOLE No 101-12

1 of 1

METRIC

G.W.P. 5206-06-00 LOCATION Hwy 69(New), Sta. 12+775, o/s 23.5m Rt. CL median ORIGINATED BY F.P.  
 DIST 54 HWY 69 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY G.D.  
 DATUM Geodetic DATE September 21, 2006 CHECKED BY G.D.













SOIL PROFILE			SAMPLES			* GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT  w <sub>p</sub>	NATURAL MOISTURE CONTENT  w	LIQUID LIMIT  w <sub>L</sub>	UNIT WEIGHT  γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE												
205.3	Ground Surface							20	40	60	80	100								
0.0	Sand and gravel		1	SS	13		205													
	Compact    Brown    Moist (PAVEMENT FILL)		2	SS	15		204													
			3	SS	14															
203.1	boulders (rockfill)						203													
2.2																				
202.4	End of borehole																			
2.9	Refusal on probable bedrock																			
	  <																			

RECORD OF BOREHOLE No 101-13

1 of 1

METRIC




G.W.P. 5206-06-00 LOCATION Hwy 69(New), Sta. 12+787.5, o/s 32.5m Lt. CL median ORIGINATED BY F.P.  
 DIST 54 HWY 69 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY G.D.  
 DATUM Geodetic DATE November 07, 2006 CHECKED BY G.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT  w <sub>p</sub>	NATURAL MOISTURE CONTENT  w	LIQUID LIMIT  w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE												
204.5	Ground Surface							20	40	60	80	100								
0.0	Peat, fine fibrous		1	SS	5		204													
204.2	Sand, some silt trace to with gravel organics cobbles and boulders  Very loose    Grey        Wet to dense  _____    _____ gravelly																			
0.3		2	SS	19																
		3	SS	20/15cm																
202.4	End of borehole																			
2.1	Refusal on probable bedrock																			
	Sample 3: Sampler bouncing																			
	*    2006   11   07																			
	 Water level observed during drilling																			
	 Water level measured after drilling																			

**RECORD OF PENETRATION TEST No 101-14**

1 of 1 **METRIC**

G.W.P. 5206-06-00 LOCATION Hwy 69(New), Sta. 12+787.5, o/s 6.5m Lt. CL median ORIGINATED BY F.P.  
 DIST 54 HWY 69 BOREHOLE TYPE Dynamic Cone Penetration Test COMPILED BY G.D.  
 DATUM Geodetic DATE November 07, 2006 CHECKED BY G.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>		
204.5	Ground Surface																
0.0	Probable peat																
	Probable sand																
203.4	Loose to compact																
1.1	End of dynamic cone penetration test																
	Refusal on probable bedrock																

**RECORD OF BOREHOLE No 101-15**

1 of 1

**METRIC**

G.W.P. 5206-06-00 LOCATION Hwy 69(New), Sta. 12+787.5 o/s 6.5m Rt. CL median ORIGINATED BY F.P.  
 DIST 54 HWY 69 BOREHOLE TYPE Manual Hand Sampling COMPILED BY G.D.  
 DATUM Geodetic DATE August 15, 2006 CHECKED BY G.D.

SOIL PROFILE		SAMPLES			* GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					W <sub>p</sub>	W		
						20	40	60	80	100						
204.2	Ground surface															
0.0	Topsoil															
0.2	Sand															
203.6	with silt, trace gravel															
0.6	Brown Moist															
	End of borehole															
	Refusal on probable boulders															
	* Borehole dry															

**RECORD OF BOREHOLE No 101-16**

1 of 1

**METRIC**

G.W.P. 5206-06-00 LOCATION Hwy 69(New), Sta. 12+787.5 o/s 32.5m Rt. CL median ORIGINATED BY F.P.  
 DIST 54 HWY 69 BOREHOLE TYPE Manual Hand Sampling COMPILED BY G.D.  
 DATUM Geodetic DATE August 15, 2006 CHECKED BY G.D.


SOIL PROFILE				SAMPLES			* GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE					WATER CONTENT (%)							GR	SA	SI	CL																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
204.5	Ground surface										20	40	60	80	100																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				

**RECORD OF BOREHOLE No 101-17**

1 of 1

**METRIC**

G.W.P. 5206-06-00 LOCATION Hwy 69(New), Sta. 12+800 o/s 18.8m Lt. CL median ORIGINATED BY F.P.  
 DIST 54 HWY 69 BOREHOLE TYPE Manual Hand Sampling COMPILED BY G.D.  
 DATUM Geodetic DATE August 15, 2006 CHECKED BY G.D.

SOIL PROFILE			SAMPLES			* GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE									WATER CONTENT (%)			
205.5	Ground surface																			
0.0	Topsoil																			
0.2	Clayey silt some sand, trace gravel																			
204.9							205													
0.6	<div>Brown</div> <div>Moist</div>																			
	End of borehole																			
	Refusal on probable bedrock																			
	*    Borehole dry																			



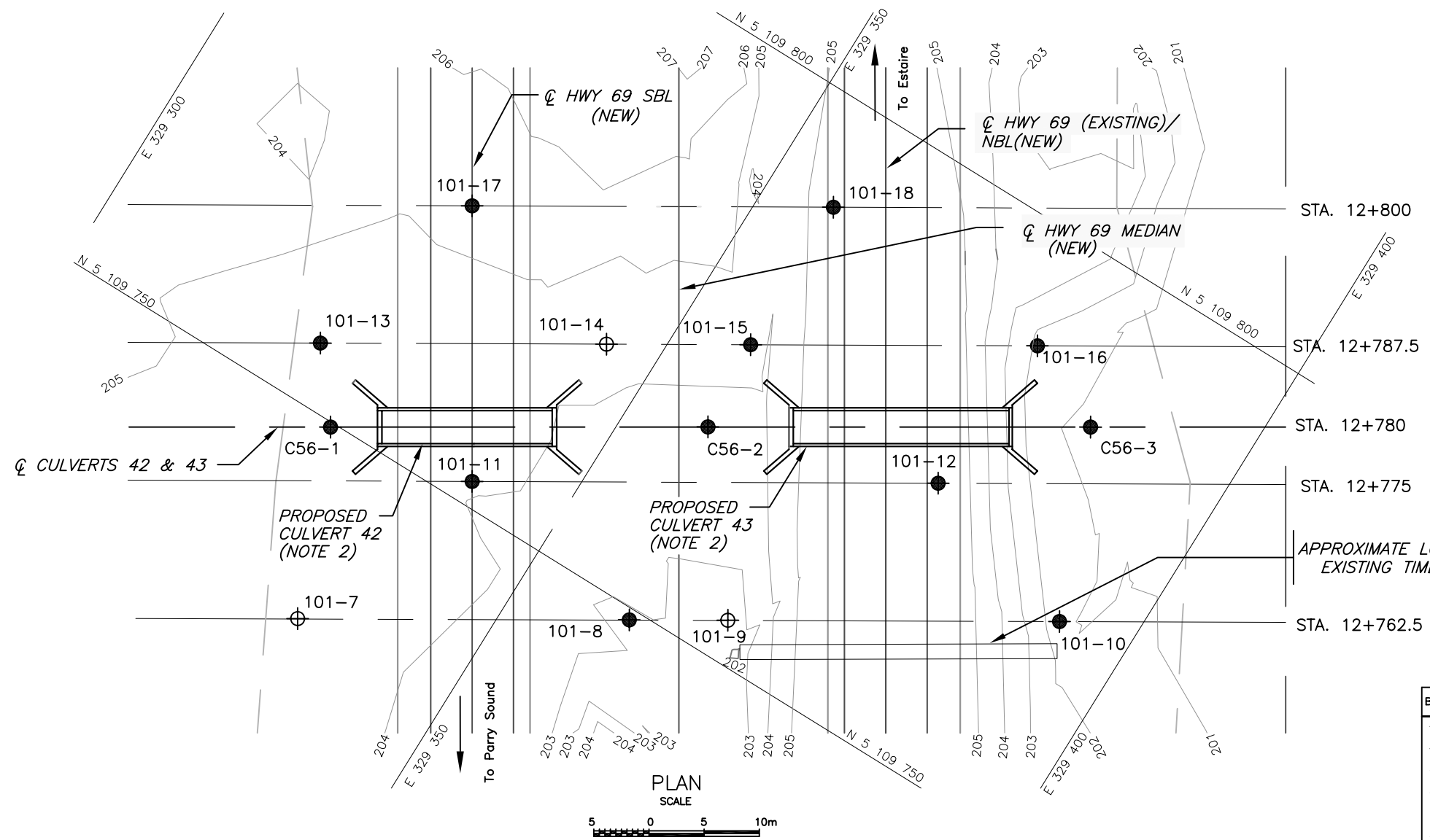
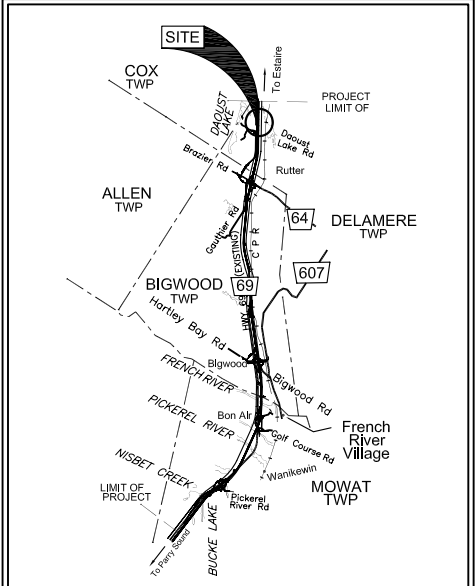
**RECORD OF BOREHOLE No 101-18**

1 of 1

**METRIC**

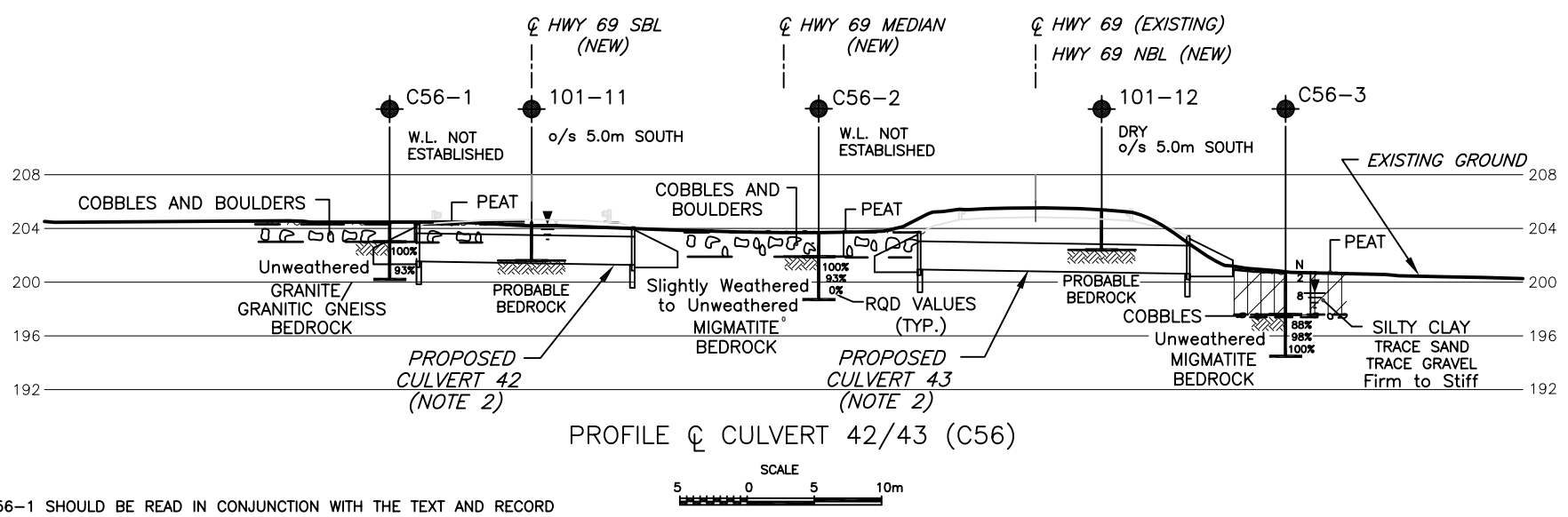
G.W.P. 5206-06-00 LOCATION Hwy 69(New), Sta. 12+800, o/s 14.0m Rt. CL median ORIGINATED BY F.P.  
 DIST 54 HWY 69 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY G.D.  
 DATUM Geodetic DATE September 21, 2006 CHECKED BY G.D.

SOIL PROFILE				SAMPLES			* GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT						PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	SHEAR STRENGTH kPa													
						○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE													
205.1	Ground Surface																		
0.0	Sand and gravel		1	SS	12		205												
	Compact      Brown      Moist																		
	(PAVEMENT FILL)		2	SS	16		204												
203.3			3	SS	20/13cm														
1.8	End of borehole																		
	Refusal on probable bedrock																		
	Sample 3: Sampler bouncing																		
	Exposed bedrock at toe of slope 1.8m below borehole																		
	*      Borehole dry																		



(Legend Continued)

BH No	ELEVATION	STA DELAMERE TWP	o/s CL MED
101-7	205.1	12+762.5	34.5m Lt.
101-8	202.9	12+762.5	4.5m Lt.
101-9	202.7	12+762.5	4.5m Rt.
101-10	201.4	12+762.5	34.5m Rt.
101-11	204.5	12+775	18.8m Lt.
101-12	205.3	12+775	23.5m Rt.
101-13	204.5	12+787.5	32.5m Lt.
101-14	204.5	12+787.5	6.5m Lt.
101-15	204.2	12+787.5	6.5m Rt.
101-16	204.5	12+787.5	32.5m Rt.
101-17	205.5	12+800	18.8m Lt.
101-18	205.1	12+800	14.0m Rt.



LEGEND

	Borehole
	Dynamic Cone Penetration Test (Cone)
	Borehole & Cone
N	Blows/0.3m (Std. Pen Test, 475 J/blow)
CONE	Blows/0.3m (60° Cone, 475 J/blow)
	W L at time of investigation Nov 2008
	Head
	ARTESIAN WATER
	Encountered
	PIEZOMETER

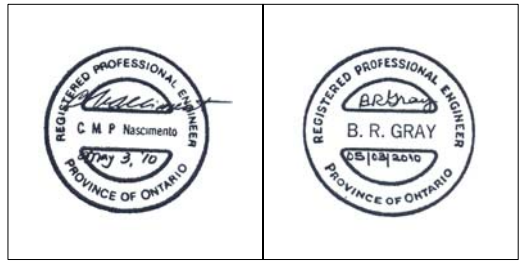
BH No	ELEVATION	CO-ORDS	
		NORTHINGS	EASTINGS
C56-1	204.3	5 109 750	329 328
C56-2	203.8	5 109 768	329 357
C56-3	200.8	5 109 786	329 387

(Legend Continues)

— NOTE —

The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

- NOTES:
- DRAWING C56-1 SHOULD BE READ IN CONJUNCTION WITH THE TEXT AND RECORD OF BOREHOLES.
  - CULVERT 42/43 WAS DESIGNATED AS C56 FOR THE INVESTIGATION.
  - THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.
  - ALL DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE NOTED. STATIONS ARE IN KILOMETRES AND METRES.



REF.: MRC DRAWINGS: 6454 ds Plan View of Phase 1 Culverts 090821.dwg; 6454 ds Culvert Xsect Phase 1 Zone 12 Mainline Culverts 090821.dwg; H6454\_PHASE1\_XA01.dwg; H6454\_PHASE1\_XN01.dwg and X6454xb02 contours zone 12.dwg.

REVISIONS	06/18/10	CN	WP No. AND SITE No. ADDED, AS PER MRC EMAIL DATED JUNE 17, 2010						
	DATE	BY	DESCRIPTION						

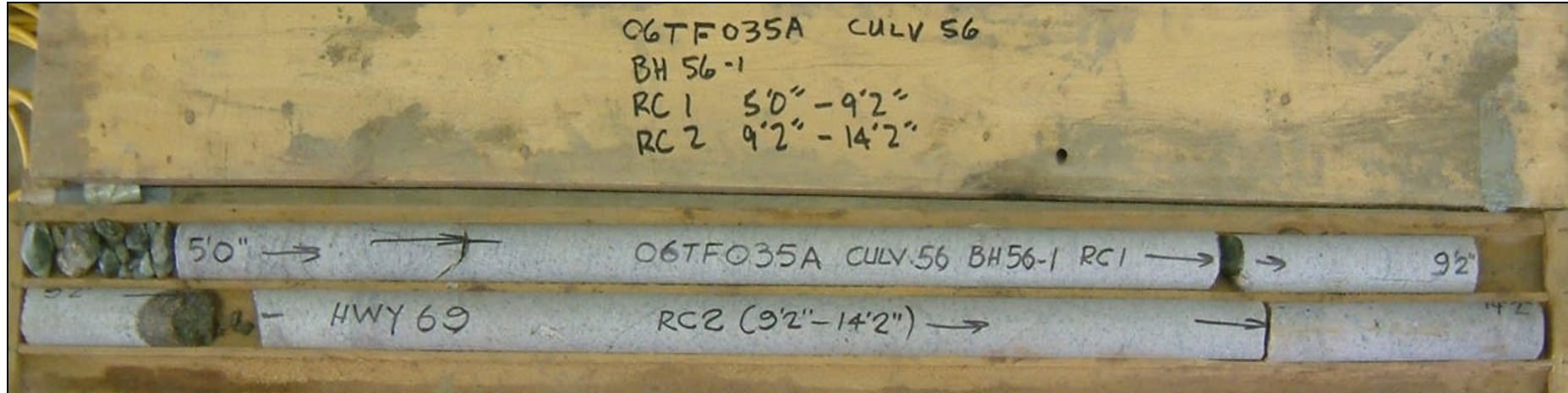
Geocres No. 411-257

HWY No 69						DIST 54	
SUBM'D MN	CHECKED MN	DATE MAY 03, 2010				SITE 46-563/C1&C2	
DRAWN NA	CHECKED CN	APPROVED BRG				DWG C56-1	



## **APPENDIX A**

### ROCK CORE PHOTOGRAPHS

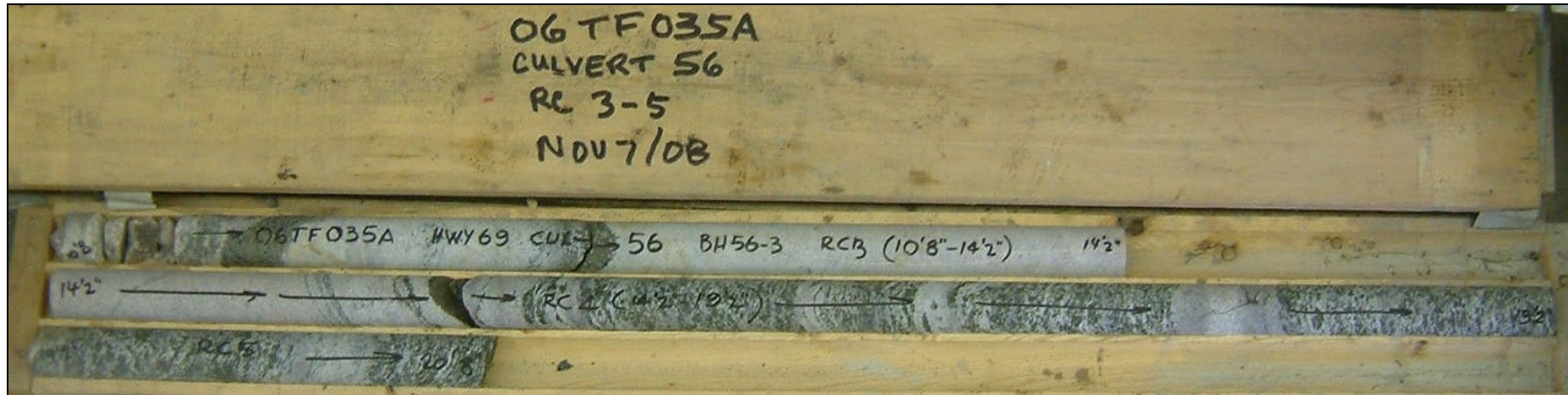


**Photograph 1:** Culvert C56, borehole C56-1, samples RC-1 and RC-2



**Photograph 2:** Culvert C56, borehole C56-2, samples RC-1, RC-2, RC-3 and RC-4





Appendix A, Page 2 of 2