



**TECHNICAL MEMORANDUM FOR CULVERTS IN PHASE 1
ADDENDUM TO FOUNDATION INVESTIGATION
AND DESIGN REPORT
CULVERT C54 - 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. 46-531 C1 NBL / 46-531 C2 SBL
W.P. 5177-08-01 NBL / 5192-08-01 SBL
G.W.P. 5206-06-00 (PART OF G.W.P. 5378-02-00)
SUDBURY AREA, ONTARIO**

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Dear Mr. Doyon

Technical Memorandum for Culverts in Phase 1
Addendum to Foundation Investigation and Design Report
Culvert C54 - 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. 46-531 C1 NBL / 46-531 C2 SBL
W.P. 5177-08-01 NBL / 5192-08-01 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 36 and 37 at station 11+555, Delamere Township which were assigned a reference number C54. 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 35 m south of the proposed northbound culvert C54.

The field work for culvert C54 was carried during the period of November 10 to 15, 2008. The subsurface investigation comprised a total of 3 boreholes advanced to depths of 5.0 to 11.3 m below existing grade.

The locations of the boreholes put down along the culvert are shown on Drawing C54-1. 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 C54. The subsurface stratigraphy revealed in these boreholes was uniform in boreholes C54-1 and C54-2 drilled west of the Highway 69 embankment and included a surficial peat layer overlying silty clay extending to



bedrock at depths of 2.0 to 2.8 m (elevations 198.0 to 199.5). Locally at borehole C54-3 drilled east of the existing Highway 69 embankment the soil cover was thicker and included silty clay underlain by deposits of clay, clayey silt, silt and cobbles and boulders. These soils covered bedrock at a depth of 8.2 m (elevation 192.8). Groundwater was observed at the ground surface at elevations 200.8 to 201.0 in boreholes C54-2 and C54-3.

Reference should be made to the previous boreholes conducted in swamp 102 and 103 (boreholes 102-6 to 102-8, 103-18 and 103-19) that were drilled for the swamp crossing near the southbound and northbound culverts. Typically the boreholes reveal similar soils conditions with refusal on probable bedrock at elevations 194.0 to 197.4, also generally sloping down from west to east from the centreline median area.

1.1 Peat

A deposit of peat was found surficially in all borehole locations. The coarse to fine fibrous peat was 100 to 200 mm thick. The peat extended to 0.1 to 0.2 m depths, elevations 201.4, 200.6 and 200.9 in boreholes C54-1, C54-2 and C54-3, respectively.

1.2 Sand and Silt

Overlain by peat at 0.1 m depth in borehole C54-1 was a localized deposit of very loose sand and silt. The cohesionless sand and silt was 700 mm thick and extended to 0.8 m depth (elevation 200.7). The N value obtained for the unit was 4. The deposit was wet with a water content of 57%. The high water content reflects the organic inclusions within the deposit.

1.3 Silty Clay

Underlying the sand and silt at 0.8 m depth and peat at 0.2 and 0.1 m depths in boreholes C54-1, C54-2 and C54-3, respectively, a continuous silty clay deposit was contacted. The silty clay thickness ranged from 1.2 to 2.6 m and the deposit was firm to very stiff in consistency. The N values ranged from 2 to 17. Penetrometer testing on samples of the silty clay from borehole C54-2 and C54-3 indicated a range of shear strength values from 63 to 138 kPa. The silty clay deposit extended to 2.4 m depth (elevation 198.6) in borehole C54-3 and to the underlying bedrock at 2.0 and 2.8 m depth (elevations 199.5 and 198.0) in boreholes C54-1 and C54-2, respectively.

The water content of two representative samples of the silty clay was 38 and 39%.

1.4 Clay

Overlain by silty clay at 2.4 m depth in borehole C54-3 was a deposit of clay trace sand. The clay deposit was 1.9 m thick and had a firm consistency. The N value recorded for the clay was 2. In situ field vane shear testing carried out within the clay indicated a shear strength of 36 kPa. The deposit was penetrated at 4.3 m depth (elevation 196.7).



The results of Atterberg limits testing and grain size distribution analysis conducted on the sample of the clay are presented in respective Figures C54-PC-1 and C54-GS-1. The liquid limit and plastic limit of the clay was 55 and 23, respectively, with a plasticity index value 32. The water content of the clay was 67%, indicating a wetter than plastic limit plasticity.

1.5 Clayey Silt

Beneath the clay at 4.3 m depth in borehole C54-3 was a deposit of cohesive firm clayey silt. The clayey silt deposit was 1.5 m thick. The N value obtained in the clayey silt was 1. In situ field vane shear testing carried out within the clayey silt indicated a shear strength of 36 kPa. The deposit was penetrated at 5.8 m depth (elevation 195.2).

The results of Atterberg limits testing and grain size distribution analysis conducted on a sample of the clayey silt are presented in respective Figures C54-PC-2 and C54-GS-2. The liquid limit and plastic limit of the clayey silt was 29 and 20, respectively, with a plasticity index value 9. The water content of the clayey silt was 32%.

1.6 Silt

Underlying the clayey silt at 5.8 m depth in borehole C54-3 was a deposit of cohesionless very loose silt with trace sand and clay. The silt deposit was 1.2 m thick and an N value of 1 was found. The deposit extended to underlying cobbles and boulders at 7.0 m depth (elevation 194.0). The water content of the silt was 29%.

1.7 Cobbles and Boulders

A deposit of cobbles and boulders was encountered underneath the silt unit at 7.0 m depth. The deposit included sand trace silt layers. The deposit extended to the underlying bedrock at 8.2 m depth (elevation 192.8).

1.8 Bedrock

Bedrock was contacted at varying depths from 2.0 to 8.2 m (elevations 192.8 to 199.5), with the bedrock surface elevation generally sloping down from west to east. The bedrock was relatively level in borehole C54-1 and C54-2 (elevations 199.5 and 198.0) and sloped down from about 5.2 m (between elevations 198.0 and 192.8) from boreholes C54-2 and C54-3. Locally, refusal on probable bedrock was encountered at elevation 197.4 in the previous borehole 102-6 and elevation 194.1 in borehole 103-18 which are located in close proximity to the centre at the southbound culvert and to the east end of the northbound culvert, and about 5 m south, respectively, confirming the bedrock levels in the current boreholes.

The bedrock composition is variable including grey Migmatite over black Amphibolite at borehole C54-1, pink to grey Granitic Gneiss at borehole C54-2 and grey Migmatite with occasional black layers at borehole C54-3, nevertheless 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 87 to 100%. The RQD determined from the rock cores was in a range of 50 to 100%, thus indicating fair to excellent quality rock. The RQD of the rock was RC7 in borehole C54-3 was lowered by the presence of cobbles and boulders mantling the bedrock formation.

1.9 Groundwater

Groundwater was observed at the ground surface at elevations 200.8 to 201.0 in boreholes C54-2 and C54-3, respectively. During the investigation for the swamps 102 and 103 crossings in October and November 2006 the groundwater level was about the same level to 2.8 m lower, at levels ranging from elevations 198.2 to 200.8. No water was observed in borehole C54-1. 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 C54, 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 4.5 m wide concrete box culverts are specified near elevation 200.2 at the west end of the southbound culvert and 200.1 at the east end of the northbound culvert, indicating a west to east flow. The subgrade level of the granular bedding is interpreted to be about 0.5 m below the proposed invert levels at elevations 199.6 to 199.7 allowing for the thickness of the concrete base of the culvert and for the granular bedding and levelling courses.

Culvert C54 is located within swamps 102 and 103. At the culvert location, the southbound lanes will require up to 2.5 m of embankment fill from existing grades to achieve the proposed road centreline grade elevation 203.4.

In view of the proposed road rehabilitation planned for the northbound lanes only minor cuts of up to 0.3 m will be required at the northbound culvert location. A road surface centreline grade elevation 202.7 is proposed at this location.



In summary, the soils revealed in the boreholes below the proposed southbound culvert subgrade levels typically comprise firm to very stiff silty clay, mantling bedrock at elevations 199.5 and 198.0 at the west end of the southbound culvert and at centreline median. The soils revealed below the proposed east end northbound culvert subgrade level, elevation 199.6, comprised very stiff to firm silty clay/ clay and clayey silt to 4.4 m depth, elevation 195.2, overlying cohesionless very loose silt and cobbles and boulders extending to bedrock at 6.8 m depth, elevation 192.8.

Groundwater at the time of the field investigation for the culvert was encountered surficially at elevations 200.8 and 201.0. These levels are 1.1 to 1.4 m, respectively above the anticipated subgrade founding level at the east end of the southbound and northbound culvert alignments. During the investigation for the swamp 102 and 103 crossings in October and November 2006 the groundwater level was about the same to 2.8 m lower than the levels in the current boreholes at levels ranging from elevations 198.2 to 200.8.

Culvert C54 is within a previously identified area of swamp 102 that will require special treatment to construct the southbound lanes to maintain the stability of the existing NBL road embankment (specifically between Sta. 11+550 to Sta. 11+650). The treatment includes a partial excavation to a maximum depth of 5.0 m at the centreline median and extending for a 5.0 m wide strip from the centreline median to the west after which the excavation can be deepened at a backslope of 1H:1V to bedrock or competent soil. However, the results of the site-specific investigation at the culvert location indicated that this precaution will not be required for the southbound culvert construction since the bedrock was found at levels higher than anticipated and the swamp excavation will be less than 5.0 m deep at the centreline median.

2.1 Foundations for Culvert C54 Under Southbound Lanes

The silty clay subgrade soil underlying the proposed southbound culvert will be excavated and the platform subgrade will be made of rockfill following completion of the recommended treatment for construction of the embankment of the southbound lanes. The rockfill is envisioned to extend below the subgrade level of the culvert to approximate depths of 0.2 m about elevation 199.5 at the west end to 1.7 m about elevation 198.0 at the east end of the culvert. Accordingly, the rockfill under the southbound culvert will be placed directly on bedrock.

At the southbound culvert, the future rockfill within the zone of influence below the design subgrade level is considered capable of adequately supporting the stress imposed by the embankment and concrete box culvert foundations.

The proposed 0.2 to 1.7 m thick rockfill under the west end of the culvert will undergo negligible settlements and at east end of the culvert the estimated total settlements of about 30 mm are anticipated with some 50% occurring after construction. The estimated settlements assume that the groundwater level will be above the anticipated subgrade level; accordingly the rockfill will most likely be end dumped and placed with minimal or no compaction effort.



The estimated magnitude of settlement under the culvert is relatively small and the 30 mm differential settlement which would slightly lower the outlet is considered to be tolerable. Therefore, either a cast-in-place or precast culvert could be constructed concurrently with the embankment. However, since the new southbound embankment will be surcharged for a period of 12 months, it is recommended that the culvert be constructed after the embankment fill has been placed and the surcharge period has been carried out to optimize the culvert performance (especially for a cast-in-place culvert given the estimated settlement slightly exceeds the allowable criteria) and facilitate construction of the highway. The surcharging will result in a settlement of about 20 mm under the east end of the culvert. A surcharge stage will reduce the estimated post-construction settlements 10 mm at the east end of the culvert.

Various materials could be employed for surcharging the proposed culvert location. For ease of handling and the constant and uniform unit weight, granular materials are recommended for surcharging. If granular materials are not selected, the proposed subgrade level of the culvert should be covered with a geosynthetic filter fabric to prevent loss of materials into the voids of the rockfill. When selecting a surcharge material the unit weight and stability of the material should not be susceptible to changing weather conditions over the course of the surcharge period.

2.2 Foundations for Culvert C54 Under Northbound Lanes

The recommended treatment for the northbound lanes of the new Highway 69 at the proposed culvert C54 location will comprise pavement rehabilitation of the existing Highway 69. The existing silty clay/ clay and clayey silt subgrade underlying the existing embankment will therefore remain intact along the northbound alignment of the highway.

Reference is made to borehole 103-18 which contacted the embankment fill soils to 3.0 m depth, elevation 199.6 under the existing northbound road platform.

The subgrade level of the northbound culvert is anticipated to be approximately elevation 199.6 and accordingly 3.0 m thick fill is currently placed above the subgrade level. Because only minor cuts will be required for the pavement rehabilitation and the underlying cohesive soils have been loaded with some 3.0 m of fill for a substantial period of time (estimated over 20 years), only negligible settlement is anticipated from the underlying cohesive or cohesionless soils after the culvert is installed.

The cohesive fill soils, as encountered in borehole 103-18 to elevation 199.6, the anticipated northbound culvert subgrade level should be excavated. Any fill soils encountered beyond the subgrade level should also be excavated and replaced with compacted 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.



2.3 Geotechnical Bearing Resistance For Culvert C54

The recommended geotechnical bearing resistances at ultimate and serviceability limit states (ULS and SLS) for the proposed 4.5 m span box culvert constructed on alternative founding soils/materials are as follows:

CULVERT SECTION	SOIL TYPE	FACTORED GEOTECHNICAL RESISTANCE AT ULS (kPa)	GEOTECHNICAL RESISTANCE AT SLS (kPa)
Southbound	Rockfill	900	250
Northbound	Stiff Silty Clay	250	150
	Structural Fill (Granular A or Granular B Type II)	900	350

The geotechnical resistance at SLS normally allows for 25 mm compression of the founding medium. In addition, the rockfill settlement at the east and west ends of the southbound culvert as discussed previously in this section should be considered.

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 resistances.

2.4 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. Rockfill does not require frost tapers.



Rockfill should be placed in accordance with SP 206S03. This is particularly important above the water level within the zone of influence of the culvert, defined by an imaginary line inclined downwards at 2H:1V from a point located at the invert level 1 m beyond the edge of the culvert.

For the southbound culvert, the granular bedding material and rockfill material should be separated by a geosynthetic filter fabric to prevent loss of the granular materials into the voids of the rockfill. The rockfill surface should be chinked in accordance with the requirements of SP 206S03, prior to placing the geotextile. The filter fabric should conform to OPSS 1860 and comprise a Class II non-woven geotextile with a filtration opening size (FOS) of 105 to 210 μm . The filter fabric should be placed horizontally beneath the bedding and extend up on each side and to the top of the bedding and/or granular cover material.

In view of the anticipated presence of rockfill below the southbound culvert, settlements of the culverts may exceed the 25 mm compression of the founding medium normally allowed for by SLS resistance values in particular where a surcharge stage cannot be completed. The capability of the culvert to sustain such settlements, the need to shape the invert of the culvert to conform to the predicted settlements and reduce the structural distress that may result from the differential settlement as well as minimise 'low areas' in the culvert when settlement is complete should be reviewed by the structural designer.

2.5 Modulus of Subgrade Reaction

The estimated values of the modulus of subgrade reaction for culvert C54 constructed on native silty clay, structural fill (Granular A or B Type II) or on rockfill are as follows:

SOIL TYPE	MODULUS OF SUBGRADE REACTION MN/m^3
Stiff Silty Clay	10
Granular A or B Type II	45
Rockfill	50

2.6 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^3
STIFF SILTY CLAY	0	100	21.5
GRANULAR A OR GRANULAR B TYPE II	35	0	22.8
ROCKFILL	42	0	18.0

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



2.7 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

γ = unit weight of free draining granular material above the design water level (kN/m^3)

γ' = unit weight of backfill submerged below the design water level (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 (kN/m^2)

γ_w = unit weight of water equal to 9.8 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 ϕ = angle of internal friction of retained soil (35° for Granular A)

δ = angle of friction between soil and wall (23.5° 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, 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 was observed at the ground surface at elevations 200.8 to 201.0 in boreholes C54-2 and C54-3, respectively. During the investigation for the swamps 102 and 103 crossings in October and November 2006 the groundwater level was about the same level to 2.8 m lower, at levels ranging from elevations 198.2 to 200.8. No water was observed in borehole C54-1. 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 2.6 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 μ m 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 rockfill and/or existing fill, native clayey silt and 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 (cohesive firm to stiff clayey silt/ silty clay over compact sand and gravel) are classified as Type 3 soils necessitating temporary cut slopes to be inclined at 1H:1V.

The recommended treatment for the new northbound lanes of the new Highway 69 at the proposed culvert C54 will comprise pavement rehabilitation of the existing Highway 69. The existing firm to stiff clayey silt and silty clay subgrade will therefore remain intact along the northbound alignment of the highway.

To maintain basal stability at the subgrade level in the existing firm to stiff soils, special treatment for the temporary cut slopes of the excavation should be applied during the construction of the proposed culvert C54 under the northbound lanes.

The temporary cut slopes should be excavated at 1H:1V and partially excavated (benched) to ensure a maximum height of 1.5 m is maintained for the excavation cut slopes above the subgrade level adjacent to the culvert. The width of each bench should be equal to the total depth of the excavation including if applicable, the surcharge fill height. Heavy construction equipment should not be permitted on the benches adjacent to the culvert excavation.

6. GROUNDWATER CONTROL

Groundwater at the time of the field investigation for the culvert was encountered surficially at elevations 200.8 and 201.0. These levels are 1.1 to 1.4 m, respectively above the anticipated subgrade founding level at the east end of the southbound and northbound culvert alignments. During the investigation for the swamp 102 and 103 crossings in October and November 2006 the groundwater level was about the same to 2.8 m lower than the levels in the current boreholes at levels ranging from elevations 198.2 to 200.8.

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 at the northbound culvert C54, 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 2.6 to 2.9 m above the founding levels.

The subgrade materials will range from rockfill at the southbound culvert C54 and silty clay along the entire northbound culvert C54. 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, 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 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:

<u>SOIL TYPE</u>	<u>K FACTOR</u>
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
Figures C54-PC-1 and C54-PC-2 – Results of Atterberg Limits Testing
Figures C54-GS-1 and C54-GS-2 – Results of Grain Size Distribution Analyses
Explanation of Terms Used in Report
Record of Borehole Sheets
Drawing C54-1 – 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
C54-1	3	2.0 – 3.1	100	58	2.0 – 4.4	MIGMATITE: Grey, fine grained, high strength, unweathered to slightly weathered, few vertical partings, rough planar, open to 0.5 mm, with yellow oxidation on parting surface, also close (locally very close) spaced dipping cross joints, rough planar, tight to oxidized, occasionally with slight scale and/or green residue on surface, fair quality. AMPHIBOLITE: Black, fine grained, high strength, unweathered, close (locally very close) spaced dipping cross joints, rough planar, tight to slightly altered, with purple Micaceous material on partings, good quality.
	4	3.1 – 4.6	100	75		
	5	4.6 – 5.0	100	83	4.4 – 5.0	
C54-2	3	2.8 – 4.4	100	100	2.8 – 5.9	GRANITIC GNEISS: Pink to grey, fine grained, with occasional layers of coarse crystalline Feldspar (Pegmatite), high strength, unweathered, moderate spaced dipping cross joints, rough planar, generally tight, locally open to 1 mm with secondary crystal growth, excellent quality.
	4	4.4 – 5.9	100	95		
C54-3	7	7.5 – 9.0	87	50	7.5 – 8.2	BOULDERS/COBBLES/GRAVEL MIGMATITE: Light grey to grey with occasional black layers (possible Amphibolite from 9.3 to 10.4 m), fine grained, becoming gneiss like at depth, high strength, unweathered, close to wide spaced dipping cross joints, rough planar, tight to slightly altered with black or brown scale on parting, locally silty, excellent quality.
	8	9.0 – 10.5	100	100	8.2 – 11.3	
	9	10.5 – 11.3	100	100		

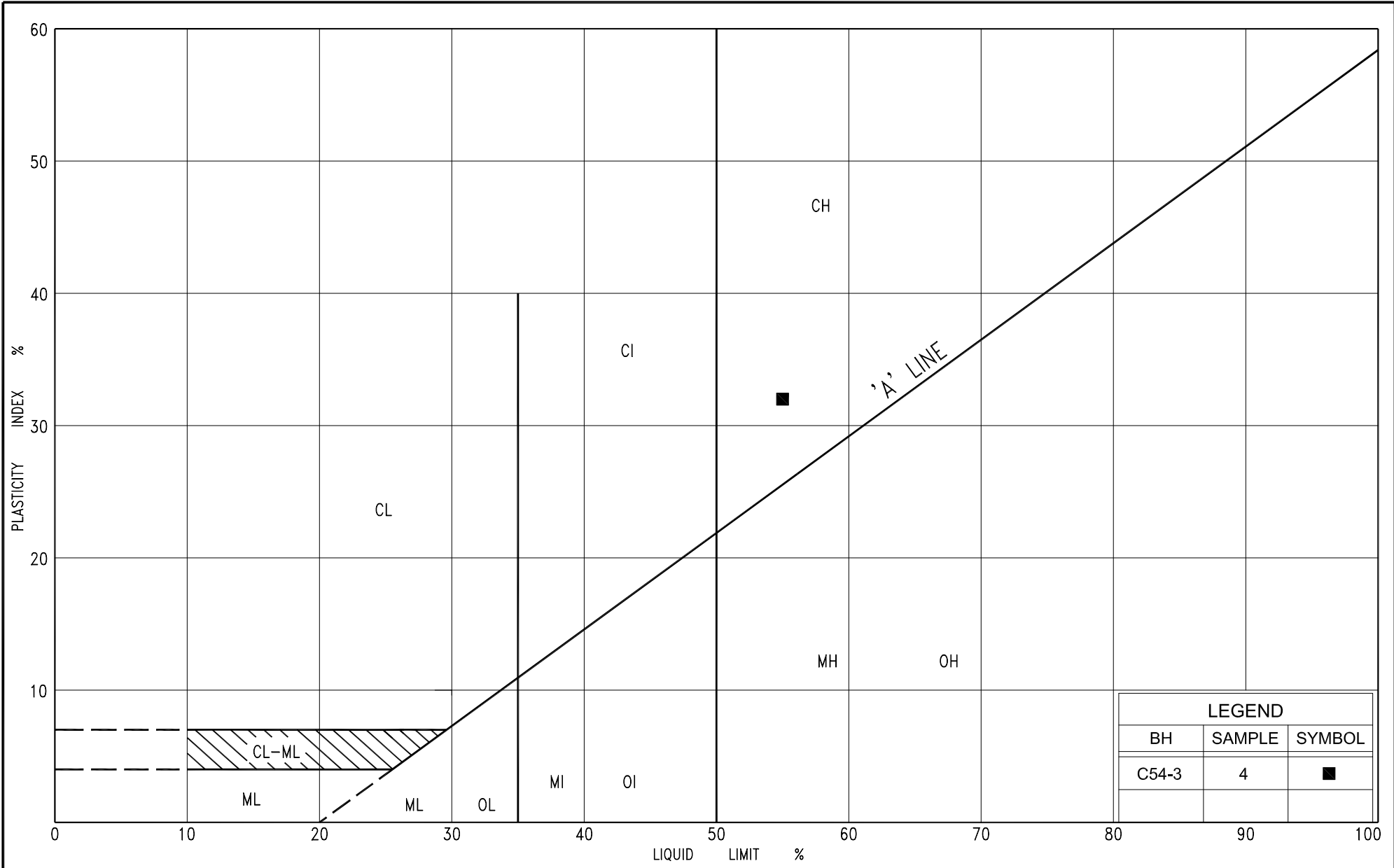
RQD = Rock Quality Designation

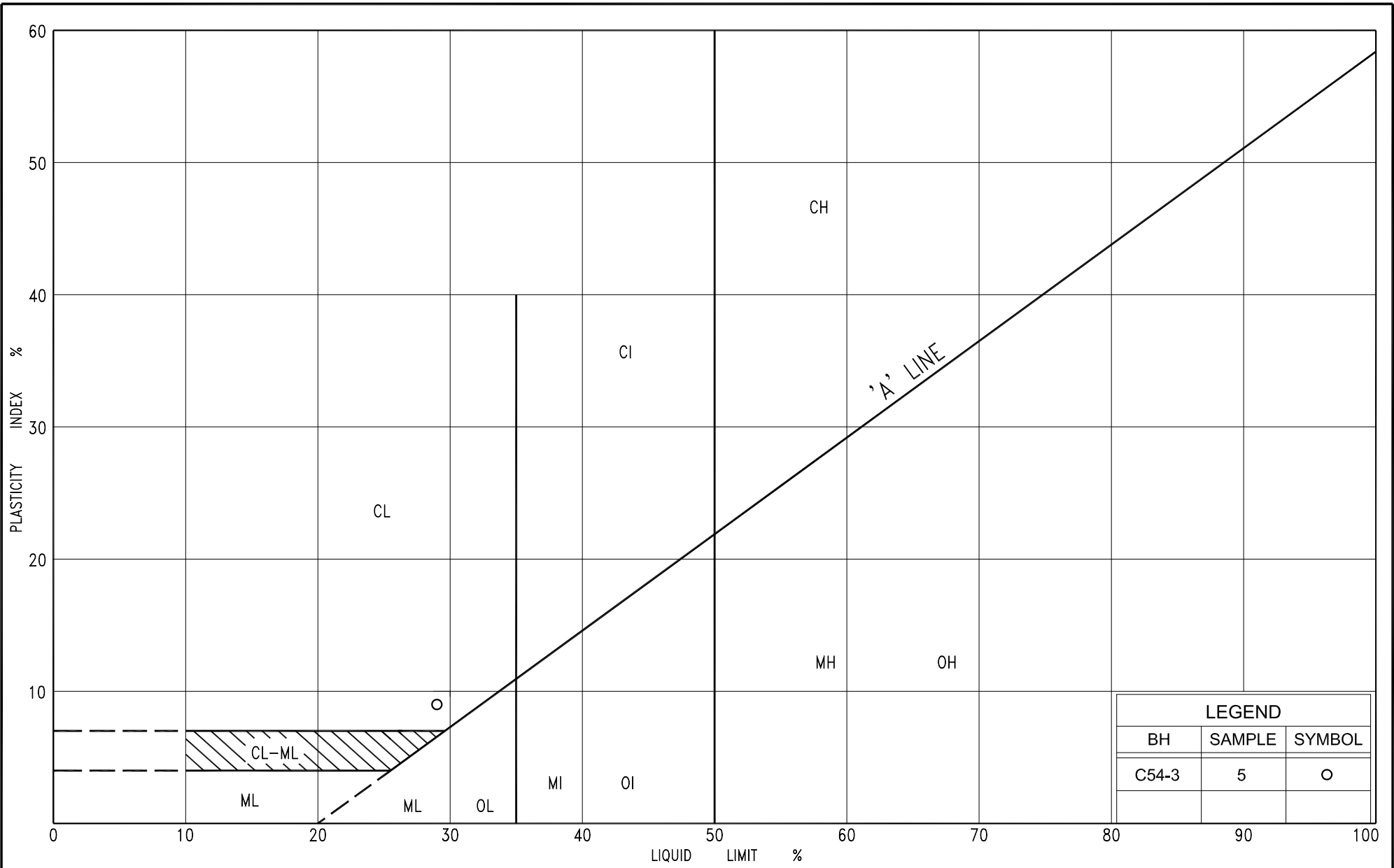
Originated: FP
Compiled: JFW
Checked: MN / CN

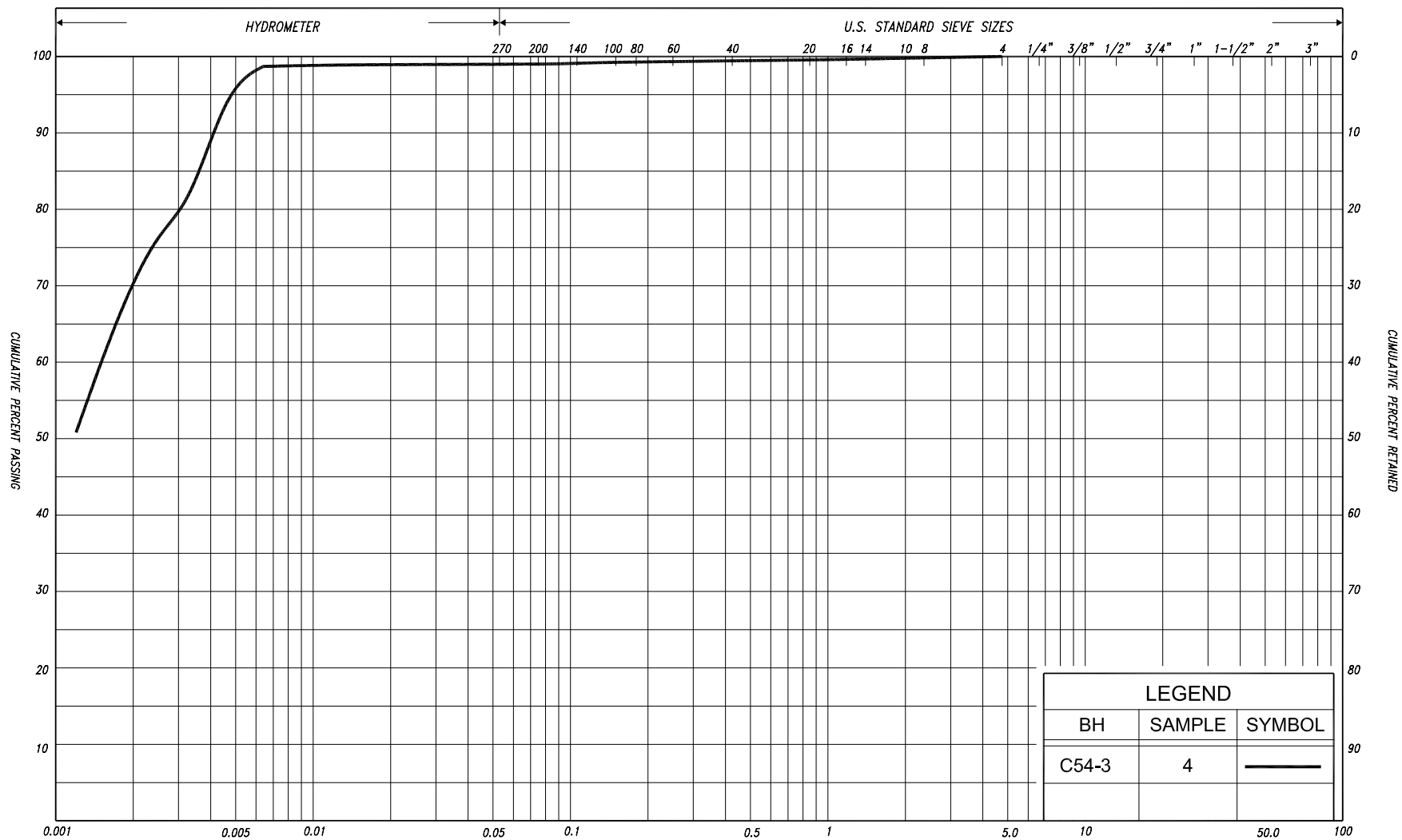


TABLE 1
LIST OF STANDARD SPECIFICATIONS REFERENCED IN MEMORANDUM

DOCUMENT	TITLE
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
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										

GRAIN SIZE DISTRIBUTION

CLAY, trace sand

FIG No. C54-GS-1

HWY: 69

G.W.P. No. 5206-06-00

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


MECHANICAL PROPERTIES OF SOIL

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

PHYSICAL PROPERTIES OF SOIL

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

METRIC

SOIL PROFILE				SAMPLES		GROUND WATER * CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 	PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT w_p w w_L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	"N" VALUES						
201.5 0.0	Ground Surface									kN/m ³	GR SA SI CL

ON_MOT VER3 06TF035A-BH.GPJ ON MOT.GDT 11/27/2009 9:18:33 AM

(%) STRAIN AT FAILURE

METRIC

+⁷, ×⁵: Numbers refer to Sensitivity

20
15 — ○ — 5
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 102-6

1 of 1

METRIC

G.W.P. 5206-06-00 LOCATION Hwy 69(New), Sta. 11+550, 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 October 29, 2006 CHECKED BY G.D.

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										
201.2	Ground Surface							20	40	60	80	100						
0.0	Peat, fine fibrous		1	SS	3		201											
0.2	Clayey silt, trace sand thin silty clay layers																	
	Firm to Brown Moist very stiff		2	SS	13		200						175					
			3	SS	8													
198.9	Clay, trace sand						199											
2.3	Firm Brown Moist																	
	sand seams		4	SS	3		198											
197.4	Grey Wet																	
3.8	End of borehole Refusal on probable bedrock																	
<div>* 2006 10 29</div> <div>▽ Water level observed during drilling</div> <div>▼ Water level measured after drilling</div> <div>■ Penetrometer test</div>																		


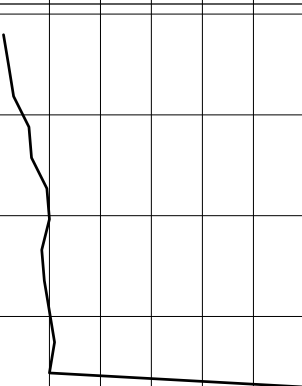
RECORD OF PENETRATION TEST No 102-7

1 of 1 **METRIC**

G.W.P.	5206-06-00	LOCATION	Hwy 69(New), Sta. 11+575, o/s 38.5m Lt. CL median	ORIGINATED BY	F.P.
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DIST	54	HWY	69	BOREHOLE TYPE	Dynamic Cone Penetration Test	COMPILED BY	G.D.
------	----	-----	----	---------------	-------------------------------	-------------	------

DATUM Geodetic DATE October 29, 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 (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								W _p	W	W _L
								○ UNCONFINED	● QUICK TRIAXIAL	+ FIELD VANE								
201.1 0.0	Ground Surface Probable peat Probable clayey silt Firm to stiff						201											
197.3 3.8	End of dynamic cone penetration test Refusal on probable bedrock								120/15cm									

RECORD OF BOREHOLE No 102-8

1 of 1

METRIC

G.W.P. 5206-06-00 LOCATION Hwy 69(New), Sta. 11+575 CL median ORIGINATED BY F.P.
DIST 54 HWY 69 BOREHOLE TYPE Continuous Flight Solid Stem Augers COMPILED BY G.D.
DATUM Geodetic DATE October 28, 2006 CHECKED BY G.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED	● QUICK TRIAXIAL	✕ LAB VANE	✚ FIELD VANE						
200.8	Ground Surface						20	40	60	80	100						
0.0	Peat, amorphous layers of silty clay		1	SS	1												
			2	SS	4												
199.1																	
1.7	Clay, trace sand thin clayey silt layers		3	SS	8												
	Stiff Grey Wet																
197.8																	
3.0	Silty clay, trace sand																
	Firm Grey Wet		4	SS	1												
				FV													
196.2																	
4.6	Clayey silt, trace sand		5	SS	1												
	Firm Grey Wet			FV													
	sand seams																
194.4			6	SS	21/15cm												
6.4	End of borehole																
	Refusal on probable bedrock																
	Sample 6: Sampler bouncing																
	* 2006 10 28																
	▽ Water level observed during drilling																
	▼ Water level measured after drilling																

METRIC

M^{+7}, X^{5} : Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 103-19

1 of 1

METRIC

G.W.P.	5206-06-00	LOCATION	Hwy 69(New), Sta. 11+575 o/s 38.5m Rt. CL median	ORIGINATED BY	F.P.
DIST	54	HWY	69	BOREHOLE TYPE	Continuous Flight Hollow Stem Augers
DATUM	Geodetic	DATE	November 01, 2006	COMPILED BY	G.D.
				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			20	40	60	80	100	W _p	W	W _L		GR	SA	SI	CL	
200.9	Ground Surface																				
0.0	Peat, fine fibrous		1	SS	2																
0.3	Clayey silt																				
200.2	silty clay layers																				
0.7	Firm Mottled Moist Clay, trace sand grey/brown		2	SS	8																
	Stiff Brown Moist to firm to wet		3	SS	6																
			4	SS	2																
				FV																	
			5	SS	1																
				FV																	
194.6																					
6.3	Silty sand trace clay, trace gravel		6	SS	23																
194.0	Compact Grey Wet (TILL)																				
6.9	End of borehole Refusal on probable bedrock																				
<div>* 2006 11 01</div> <div>▽ Water level observed during drilling</div> <div>▼ Water level measured after drilling</div> <div>■ Penetrometer test</div>																					

Technical Memorandum – Culvert C54, Highway 69 Four-Laning
Phase 1, Site No. 46-531 C1 NBL/ 46-531 C2 SBL
W.P. 5177-08-01 NBL/ 5192-08-01 SBL, G.W.P. 5206-06-00 (Part of G.W.P. 5378-02-00)
Index No.: 2178LET, PML Ref.: 06TF035A, June 28, 2010

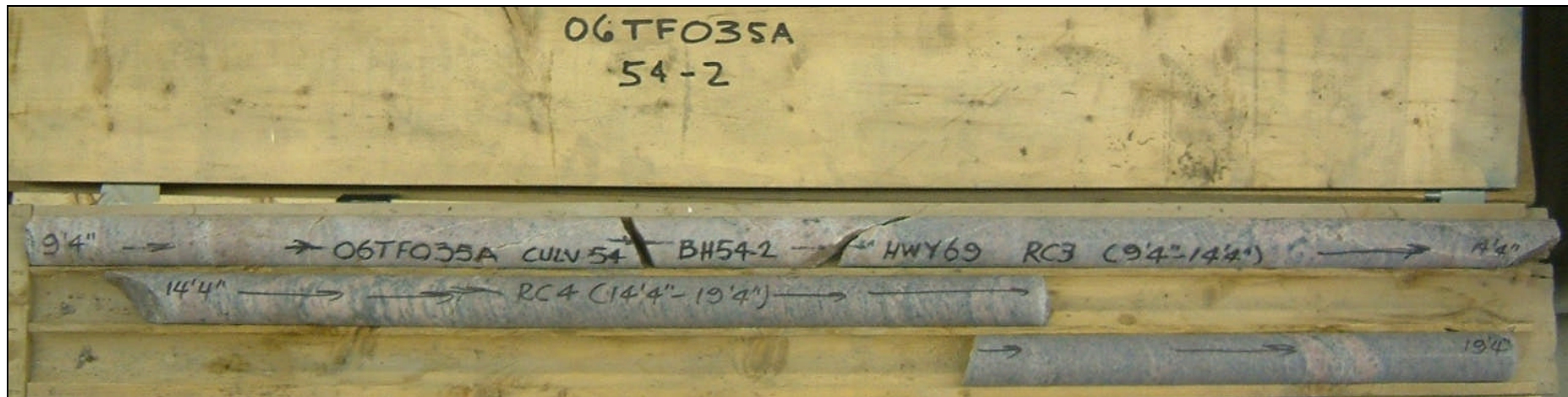


APPENDIX A

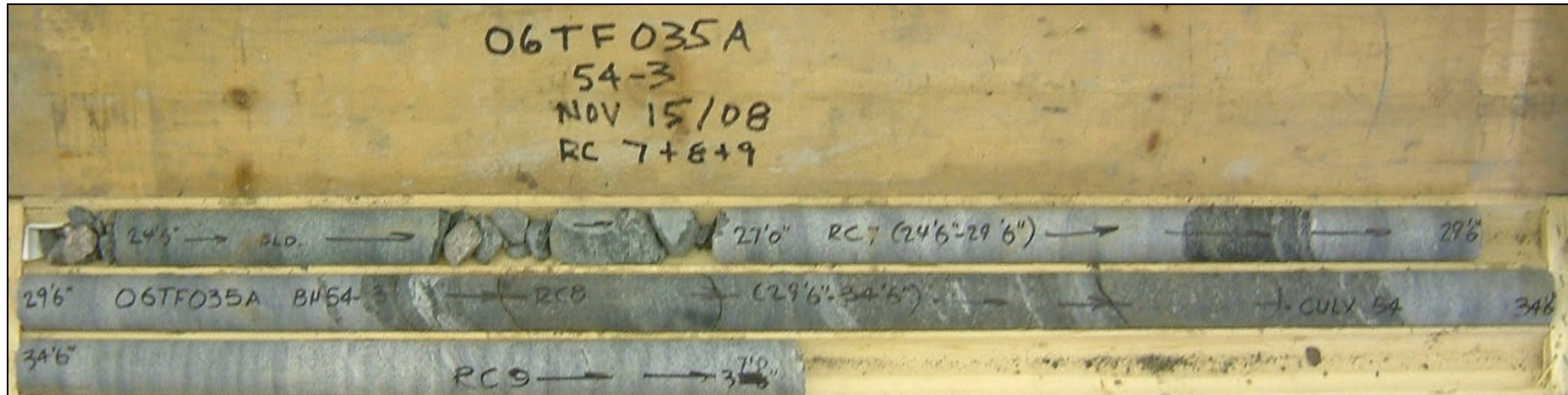
ROCK CORE PHOTOGRAPHS



Photograph 1: Culvert C54, borehole C54-1, samples RC-3, RC-4 and RC-5



Photograph 2: Culvert C54, borehole C54-2, samples RC-3 and RC-4



Photograph 3: Culvert C54, borehole C54-3, samples RC-7, RC-8 and RC-9