FOUNDATION DESIGN REPORT

for

THREE CULVERTS AT STA. 13+274, 14+291 AND 15+034
HIGHWAY 69 FOUR-LANING FOR 21.5 KM
FROM 4.5 KM NORTH OF HIGHWAY 64
TO 8.7 KM NORTH OF HIGHWAY 637
G.W.P. 5379-02-00
TOWNSHIP OF SERVOS
DISTRICT 54, SUDBURY, ONTARIO

PHASE 1, STA. 12+200 TO 15+400
TOWNSHIP OF SERVOS

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CONSULTING ENGINEERS

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District 54, Sudbury, Ontario

Phase 1, Sta. 12+200 to 15+400
Township of Servos

1. INTRODUCTION

This report provides foundation engineering comments and recommendations for the proposed installation of three concrete culverts with less than 3 m span within Phase 1 of the four-laning of a 21.5 km long section of Highway 69 that extends from 4.5 km north of Highway 64 to 8.7 km north of Highway 637, about 45 km south of Sudbury, Ontario. This report was prepared for Totten Sims Hubicki Associates (TSH) on behalf of the Ministry of Transportation of Ontario (MTO).

For ease of reference, the culverts in the report are identified by numbers that correspond to those designated in the Request for Proposal. The identification number, location and proposed type of each culvert are given in the following table:

CULVERT Ref. No.	APPROXIMATE STATION (New Highway 69, Servos Township)	PROPOSED CULVERT TYPE
C-3	13+274	Rigid Frame Concrete Box
C-7	14+291	Rigid Frame Concrete Box
C-9	15+034	Rigid Frame Concrete Box

This report pertains to design and construction of the proposed culverts and associated bedding/backfill zones.

The culverts will be constructed in areas where the embankment fill will have been placed along the new alignment of Highway 69. Based on the proposed road grade and ground surface elevations, the embankment fill height at the culvert locations varies widely between 8 and 18 m.

The typical subsurface stratigraphy revealed in the boreholes drilled at the locations of the culverts generally comprised surficial topsoil / peat overlying firm to stiff clayey silt / silty clay and/or compact sand / sandy silt. Cobbles and boulders were encountered within the cohesionless soils at the culvert locations. Bedrock was contacted or inferred at variable depths of 0.9 to 16.4 m below existing grade.

The groundwater level measured during the field investigation conducted in March 2007 was variable at the culvert locations and ranged from 1.6 m below to 1.2 m above the inferred founding subgrade level of the culverts.

It is considered that the subgrade conditions are suitable for installation of the proposed concrete box culverts at these sites.

The foundation frost penetration depth at the sites is 2.0 m according to OPSD 3090.100.

It is noted that no responsibility or liability is assumed 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.

A list of standard specifications referenced in this report is compiled in Table 1. All elevations in the report are expressed in metres.

2. FOUNDATIONS

2.1 Culvert C-3 at Sta. 13+274

The invert of the proposed concrete box culvert C-3 is specified to be near elevations 201.6 at the west end and 209.0 at the east end. The subgrade level of the granular bedding is interpreted to be about 0.5 m below the invert level at elevation 201.1 to 208.5 allowing for the thickness of the concrete base of the culvert and for the granular bedding and levelling courses.

Based on the proposed road grade and ground surface elevations at the toes of slope, the embankment fill height at the culvert location (measured at the toe of slopes) varies between about 15 and 18 m.

The subgrade material revealed in the boreholes below these elevations comprises localized cohesive soft clayey silt / silty clay at the west end of the culvert and cohesionless compact sand along the remainder of the culvert alignment. It is noted, however, that the clayey subgrade at the west end will be excavated and the platform subgrade following completion of the recommended treatment for construction of the southbound lane embankment will comprise rockfill placed on sand.

Groundwater at the time of the field investigation was at elevation 201.5 to 208.0, some 0.9 m above the subgrade level at the west end of the culvert and 0.6 to 1.6 m below the subgrade along the remainder of the culvert alignment.

The future rockfill and native compact sand exposed in the boreholes within the zone of influence below the design subgrade level are considered capable of adequately supporting the stress imposed by the embankment and concrete box culvert foundations. However, the future 3.4 m thick rockfill under the western section of the culvert will undergo estimated total settlements of about 70 mm with some 50% occurring after construction. The magnitude of settlement under the culvert will depend on the timing of construction of the embankment and the culvert. If the culvert is constructed concurrently or prior to the embankment, the total settlement will occur. It is recommended that the culvert be constructed after the embankment to reduce settlements and the magnitude of the required camber.

To compensate for the long-term differential post construction settlements under the western section of the culvert, it is recommended that the culvert be provided with a structural joint located about 15 m from the west end. The western section should also be cambered up about 40 mm. It is noted that the alternative method involving excavation of the rockfill and replacement with compacted granular fill is not considered feasible due to the high groundwater conditions. The estimated settlements at characteristic sections of the culvert are provided in the following table:

Approximate offset from CL Median	55.0 m Lt	38.0 m Lt	19.0 m Lt	CL	19.0 m Rt	50.0 m Rt
Estimated Total Settlement, mm (*)	40	5	5 – 10	5	5 – 10	<5

(*) Settlement after construction, assuming embankment is constructed prior to the culvert

The recommended bearing resistance at ultimate and serviceability limit states (ULS and SLS) for a minimum 1.2 m span box culvert constructed on the sand or rockfill is as follows:

SOIL TYPE	**FACTORED GEOTECHNICAL RESISTANCE AT ULS (kPa)**	**GEOTECHNICAL RESISTANCE AT SLS (kPa)**
Compact sand	500	200
Rockfill (west section)	900	250

The resistance at SLS normally allows for 25 mm compression of the founding medium. In addition, the rockfill settlement at the west end as discussed previously in this section should be accounted for. 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.

2.2 Culvert C-7 at Sta. 14+291

The invert of culvert C-7 is specified to be near elevations 203.6 at the west end and 202.5 at the east end. The subgrade level of the granular bedding is interpreted to be about 0.5 m below the invert level at elevation 202.0 to 203.1 allowing for the thickness of the concrete base of the culvert and for the granular bedding and levelling courses.

Based on the proposed road grade and ground surface elevations at the toes of slope, the embankment fill height at the culvert location is about 8 m.

The subgrade material along the alignment of the culvert currently comprises firm to stiff silty clay/clayey silt. These materials are compressible and will be excavated for construction of the highway embankment. Following completion of the recommended swamp treatment, the subgrade will comprise rockfill placed on bedrock. The subgrade will also locally comprise exposed or shallow bedrock as encountered in borehole C7-2. Groundwater at the time of the field investigation was at elevation 202.6 at the centreline median, some 0.2 m below the subgrade level.

The exposed and shallow depth bedrock along the alignment of the culvert should be locally excavated to a depth of up to 2 m to reduce the magnitude of differential settlement (about 20 mm after construction) due to the varying thickness of rockfill. The excavated rock should be replaced with rockfill to raise the subgrade to the design level. Cambering of this culvert is not considered necessary in view of the relatively uniform thickness of rockfill.

The foundations of a minimum 1.2 m span box culvert constructed on rockfill should be designed using the following geotechnical resistance at ULS and SLS:

SOIL TYPE	FACTORED BEARING RESISTANCE AT ULS (kPa)	BEARING RESISTANCE AT SLS (kPa)
Rockfill	900	250

The resistance at SLS normally allows for 25 mm compression of the founding medium. For this site, however, additional 50 mm settlement resulting from self-weight compaction of the rockfill under the culvert should be expected because the material will be placed underwater with no compaction. About 50% of the settlement is expected to occur within the first year after construction of the embankment and the remaining amount during the following 5 to 10 years.

2.3 Culvert C-9 at Sta. 15+034

The invert of culvert C-9 is specified to be near elevations 197.8 at the west end and 202.3 at the east end. The subgrade level of the granular bedding is interpreted to be about 0.5 m below the invert level at elevation 197.3 to 201.8 allowing for the thickness of the concrete base of the culvert and for the granular bedding and levelling courses.

Based on the proposed road grade and ground surface elevations at the toes of slope, the embankment fill height at the culvert location varies between 12 and 16 m.

The subgrade material revealed in the boreholes below the subgrade elevations comprises bedrock overlain by 0.6 to 2.4 m of probable topsoil and cohesionless sandy silt containing cobbles and boulders. It is recommended that the native and/or fill soils along the alignment of the culvert be removed to bedrock and replaced with rockfill. The bedrock should be locally excavated to a depth of up to 2.5 m to reduce the magnitude of differential settlement (10 to 20 mm after construction) and avoid stress concentrations developing between the yielding rockfill and the unyielding bedrock that may potentially damage the culvert. The excavated rock should be replaced with rockfill to raise the subgrade to the design level. Cambering of this culvert is not considered necessary in view of the relatively uniform thickness of rockfill.

The groundwater level at the time of the field investigation was at existing grade (elevation 200.6 to 202.9), some 0.1 to 1.1 m above the founding subgrade level, due to surface water entering two boreholes.

The foundations of a minimum 1.2 m span box culvert constructed on rockfill should be designed using the following geotechnical resistance at ULS and SLS:

SOIL TYPE	FACTORED BEARING RESISTANCE AT ULS (kPa)	BEARING RESISTANCE AT SLS (kPa)
Rockfill	900	250

The resistance at SLS normally allows for 25 mm compression of the founding medium. In addition, about 40 mm settlement resulting from self-weight compaction of the rockfill under the culvert should be expected because the material will be placed underwater and without compaction. About 50% of the settlement is expected to occur within the first year after construction of the embankment and the remaining during the following 5 to 10 years.

2.4 General Comments

2.4.1 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.

The topsoil and any other deleterious soils revealed at and below the subgrade should be excavated prior to placement of the granular base below the box culvert and replaced with compacted granular fill.

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 3090.100. 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.

A minimum 300 mm thick layer of compacted granular bedding material should be placed on the rockfill prior to construction of the culvert. The bedding material should comprise Granular A or Granular B Type II or Type III compacted to 100% of the standard Proctor maximum dry density in conformance to OPSS 501 (Method A).

If Granular A is employed or the rockfill surface is not chinked in accordance with the requirements of SP 206S03, the granular cover should be separated from the rockfill by a geosynthetic filter fabric to prevent loss of the granular materials into the voids of the rockfill. 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 beneath the bedding and extend to the top of the bedding and/or granular cover material.

In view of the anticipated presence of rockfill below culverts C-7, C-9 and their construction shortly after the rockfill is placed to the subgrade level, settlements of the culvert foundations are expected to exceed the 25 mm compression of the founding medium normally allowed for by SLS resistance values. The capability of the culvert to sustain such settlements as well as 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.

2.4.2 Modulus of Subgrade Reaction

The estimated values of the modulus of subgrade reaction for culverts constructed on the sand or rockfill are as follows:

SOIL TYPE	**MODULUS OF SUBGRADE REACTION, MN/m^3**
Compact sand	30
Rockfill	50

2.4.3 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.

PARAMETER	GRANULAR A OR GRANULAR B TYPE II OR TYPE III	COMPACT SAND
Friction Angle, degrees	35	32
Cohesion, kPa	0	0
Unit Weight, kN/m^3	22.8	20.5

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

2.4.4 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 Canadian Highway Bridge Design Code (CHBDC).

3. CULVERT BACKFILL

Backfill adjacent to the culverts should be placed in accordance with OPSD 803.010, OPSD 3121.150, 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.

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:

$$P = K(\gamma h_1 + \gamma' h_2 + q) + \gamma_w h_2 + Cp + Cs$$

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
Cp = compaction pressure (refer to clause 6.9.3 of CHBDC)
Cs = earth pressure induced by seismic events, kPa (refer to clause 4.6.4 of CHBDC)
where Ø = angle of internal friction of retained soil (35º for Granular A)
δ = angle of friction between soil and wall (23.5º for Granular A)

The following parameters are recommended for design:

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

The design should consider both the maximum water level in the stream and the stabilised groundwater level condition. The groundwater level measured during the field investigation was variable at the culvert locations and ranged from 1.6 m below to 1.1 m above the inferred founding subgrade level. The groundwater was typically encountered at or below the culvert founding subgrade level. 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.

If headwalls and wing walls are utilised, a weeping tile system and/or weep holes 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 drainage pipe should be placed on a positive grade and lead to a frost free outlet.

4. HEADWALLS AND WINGWALLS

If headwalls and wing walls are utilised, the previous recommendations and geotechnical parameters for culvert foundations and backfill should be used for the design of their foundations. 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 for cast-in-place concrete foundations.

A weeping tile system and/or weep holes should be installed as indicated in the previous section of the report.

5. EXCAVATION AND GROUNDWATER CONTROL

Excavation to the anticipated founding level of the culverts is expected to extend through the rockfill or the native deposits of sand / sandy silt. Provision for excavation of cobbles and boulders at all culvert sites should be made. Subject to adequate groundwater control, excavation of the soils should be feasible using conventional equipment.

According to the Occupational Health and Safety Act (Ontario Regulation 213/91) criteria, the typical in situ soils (cohesive firm to stiff clayey silt/silty clay or compact sand) are classified as Type 3 soils necessitating temporary cut slopes to be inclined at 1H:1V (horizontal to vertical). The need to excavate flatter sideslopes below the groundwater table or if excessively soft/wet materials or concentrated seepage zones are encountered locally during construction should be considered.

Excavation of bedrock will be required at the locations of culverts C-7 and C-9. 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 width should be at least 1 m wider than the plan area of a culvert. 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.

The groundwater level observed in the boreholes at the time of the field investigation was 1.6 m below to 1.1 m above the anticipated base of excavation. The higher groundwater only occurs at the west end of culvert C-3 and east end of culvert C-9. 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 culvert locations. 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. Conventional procedures such as dam and pump and/or diversion of the stream should be sufficient. Groundwater levels are subject to seasonal fluctuations and precipitation patterns.

It is understood that a permit to take water is required by the Ministry of the Environment for flows over 50,000 litres per day. The expected daily flows at each culvert location 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 minimise the amount of groundwater inflow to be handled and the volume of surface water, if any, to be diverted from the construction area.

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

6. EMBANKMENT FILL

The height of road embankment at the culvert locations varies widely between 8 and 18 m.

The anticipated subgrade for the embankments comprises bedrock or compact sandy soils. 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.

It is considered that the subgrade soils are capable of supporting the 8 to 18 m high embankments. Settlement of the embankment platform surface is assessed to be in the order of 100 to 150 mm, including 40 to 90 mm from the settlement of new fill above grade. The settlement is expected to be essentially complete within four to six months following fill placement.

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.

7. 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 or Type III. 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 1.10.5.6 and 1.10.11.6.5 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 wing walls (if provided) should be covered with topsoil and seeded (as per 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:

SOIL TYPE	K FACTOR
Sand / Sandy Silt	0.2

8. DISCUSSION OF FOUNDATION ALTERNATIVES

8.1 Advantages and Disadvantages of Foundation Alternatives

The following table summarises the advantages, disadvantages and inferred risks/consequences of two foundation alternatives for installation of the culverts:

CULVERT LOCATION	PRECAST CONCRETE BOX CULVERT		CAST-IN-PLACE BOX CULVERT	
	ADVANTAGES	DISADVANTAGES	ADVANTAGES	DISADVANTAGES
C-3 at Sta. 13+274 C-7 at Sta. 14+291 C-9 at Sta. 15+034 (Servos Township)	Shorter culvert construction schedule than cast-in-place concrete culvert construction	Precast concrete provides lower sliding resistance than cast-in-place concrete	Cast-in-place concrete provides higher sliding resistance than precast concrete	Longer culvert construction schedule than precast concrete culvert construction

The precast concrete option constructed at the design invert levels is considered to be less costly than the cast-in-place concrete alternative since construction of the culvert will be expedited without the forming and setting time needed for cast-in-place concrete construction. It is expected, however, that the construction of cut-off walls will offset some of the cost advantages of the box culvert construction.

8.2 Preferred Foundation Option Considerations

From the foundation perspective, either box culvert alternative (precast or cast-in-place concrete) is feasible.

It is noted that the selection of culvert type also depends on other considerations such as potential fish habitat and commercially available (off the shelf) precast culvert sizes. These facets are to be evaluated by TSH.

9. CLOSURE

This report was prepared by Mr. G.O. Degil, PhD, P.Eng., Senior Foundation Engineer, and reviewed by Mr. C.M.P. Nascimento, P.Eng., Senior Project Engineer. Mr. B.R. Gray, MEng, P.Eng., MTO Designated Contact, conducted an independent review of the report.

Yours very truly

Peto MacCallum Ltd.

Grigory O. Degil, PhD, P.Eng.
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Signed and Stamped on Hard Copies

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GD:gd-mi/lnr

TABLE 1

LIST OF STANDARD SPECIFICATIONS REFERENCED IN REPORT

DOCUMENT	TITLE	DATE
OPSS 120	General Specification for the Use of Explosives	November 2003
OPSS 422	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut	April 2004
OPSS 501	Construction Specification for Compacting	November 2005
OPSS 511	Construction Specification for Rip-Rap, Rock Protection and Granular Sheeting	November 2004
OPSS 570	Construction Specification for Topsoil	August 1990
OPSS 571	Construction Specification for Sodding	November 2001
OPSS 572	Construction Specification for Seed and Cover	November 2003
OPSS 902	Excavation and Backfilling of Structures	November 2002
OPSS 1004	Material Specification for Aggregates – Miscellaneous	November 2006
OPSS 1860	Material Specification for Geotextiles	November 2004
SP 105S10	Construction Specification for Compaction	November 2004
SP 206S03	Construction Specification for Grading	November 2006
SP 422S01	Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers	April 2000
SP 902S01	Excavation and Backfilling of Structures	June 2006
OPSD 803.010	Backfill and Cover for Concrete Culverts	November 2006
OPSD 810.010	Rip-Rap Treatment for Sewer and Culvert Outlets	November 2001
OPSD 3090.100	Foundation Frost Depth for Northern Ontario	November 2005
OPSD 3121.150	Minimum Granular Backfill Requirements – Retaining Walls	November 2005
NSSP	Dowels Into Concrete	December 2002