PRELIMINARY DRAINAGE REPORT

Highway 401 Planning, Preliminary Design, and Environmental Study

GWP 4060-11-00

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Ministry of Transportation, Ontario
East Region
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1.0 Introduction

1.1 Overview

Stantec Consulting Ltd. has been retained by the Ministry of Transportation (MTO) to undertake a Planning, Preliminary Design, and Class Environmental Assessment (Class EA) Study on Highway 401 for the replacement and rehabilitation of structures, interchange modifications, establishing future footprints of the highway, and commuter parking lot expansions, from 2.0 km east of Nagle Road to 0.8 km east of Percy Street (approximately 18 km).

Under existing conditions, Highway 401 is classified as a rural freeway within the study limits. Within the study area, Highway 401 is a four-lane divided freeway with a posted speed of 100 km/h. The western 1.7 km has a grassed median while the remaining eastern portion has a concrete barrier.

Under proposed conditions, the highway will be widened to include 6-lands and potentially 8-lanes under the ultimate scenario. Figure A shows the typical cross-sections for these two scenarios with the existing highway cross-section shown below both.

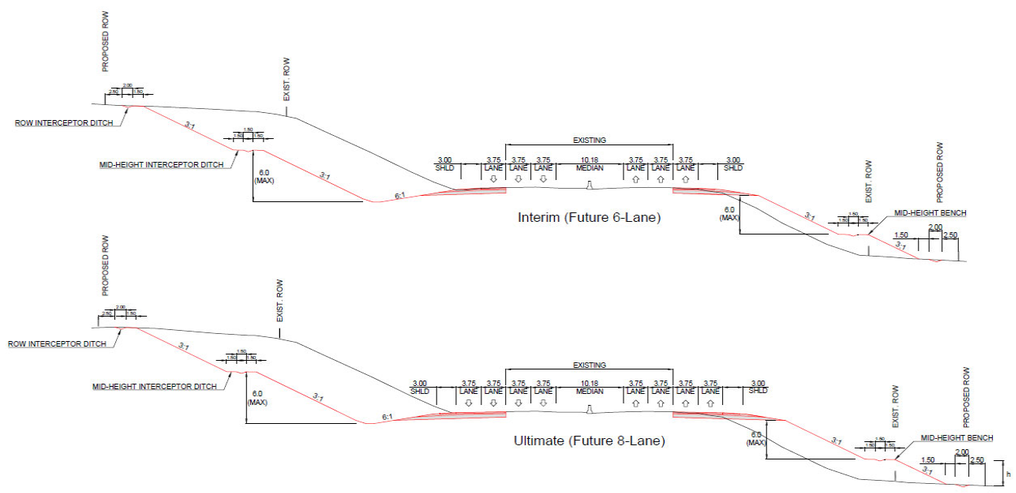


Figure A: Typical Highway Cross-Sections

1.2 Background Information

The following information was reviewed or consulted in developing the analysis and design of the existing and proposed conditions:

- *Final Culvert Condition Report – Highway 401 – Cramahe Township. Agreement No. 4014-E-0003, Assignment No. 2.* Ainley Group. 2015.
- *Highway Drainage Design Standards.* Ontario Ministry of Transportation. 2008.
- *Drainage Management Manual.* Ontario Ministry of Transportation. 1997

1.3 Study Area

The study limits for GWP 4060-11-00 include the eastbound and westbound lanes from 2 km east of Nagle Road to 0.8 km east of Percy Street (approximately 18 km). The study area passes through the following municipalities within Northumberland County: Town of Cobourg, Township of Cramahe, Hamilton Township and Alnwick/Haldimand Township. A key plan of the study area is shown on Figure B.

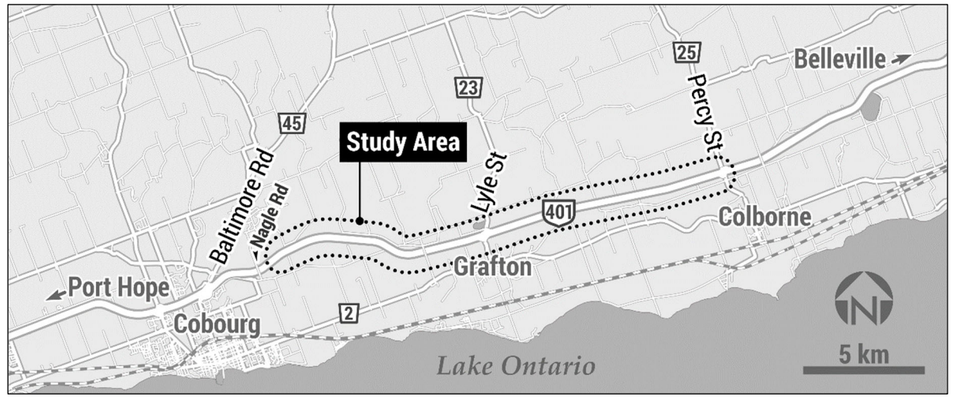


Figure B: Study Area

1.4 Purpose of Report

This report presents the results of hydrologic and hydraulic analysis related to the proposed highway improvements and provides recommendations to ensure stormwater flows are not increased as a result of the work. The intent of this report is to provide an existing conditions drainage summary of the Highway 401 and surrounding area as well as make recommendations for culvert retention, rehabilitation, or replacement based on the physical condition or hydraulic capacity of the culvert. This report does not assess the condition of storm sewers, storm sewer outlets, or sideroad culverts outside of interchanges or the hydraulic capacity of any existing system.

2.0 Background Information

2.1 Field Inspection

A detailed field review of existing culverts (centreline, interchange ramps), ditching, and other drainage infrastructure was carried out in July and December 2018.

2.1.1 Centreline Culverts

Within the project limits, there are a total of 32 centreline culverts as shown in Appendix B. Of the 32 centreline culverts within the study limits:

- Seven are structural culverts (five concrete box culverts; two concrete arch culverts)
- Nine are non-structural concrete box culverts
- 16 additional non-structural culverts
    - Two circular concrete culverts lining original smooth walled, steel culverts
    - 12 corrugated steel pipe (CSP) circular culverts (some lined with plastic)
    - Two corrugated steel pipe (CSP) arch culverts

The depth of fill at the centreline culvert locations varies between 1 to 15 m.

Culvert repairs were conducted in 2018 (prior to and during Stantec's field assessment) as well as in 2019 (after Stantec's field assessment). These repairs included culvert cleanout, repairs and lining. Culvert recommendations have taken both the repairs in 2018 as well as the proposed repairs in 2019 into account. Culverts that have been lined with plastic are proposed to be replaced as part of the highway widening due to the difficulties and risks associated with extending plastic liners. This will maintain the long-term performance of culverts after the widening is completed. A summary culvert inspection table based on condition is included in Table 1, with more detailed observations included in Appendix B, while culvert photographs are included in Appendix C.

Fish and fish habitat field investigations were conducted June 13 to June 16, 2017 (spring survey) and September 18 to September 21, 2017 (summer survey). The details of this investigation are discussed in detail within the report *Fish and Fish Habitat Existing Conditions Report – Highway 401 Planning Study from Cobourg to Colborne (GWP 4060-11-00) and Highway 401 Nagle Road Interchange Study (GWP 4059-17-00)* (Stantec, 2018). The purpose of the field work was to document aquatic ecological conditions in the Study Areas. The findings of this investigation as they relate to fish habitat at centerline culvert locations are included in Table 1.

Table 1 : Highway 401 Centreline Culvert Summary

Culvert ID (DAID)	Township	Station	Material	Shape	Diameter or Span x Rise (mm)	Length (m)	Depth of Cover (m)	Fish Habitat?	Comments/Observations
CV-0401-001882	Hamilton	23+330	CSP - Plastic Lined	Circular	900	53.7	3.0	-	Recently ditched upstream and downstream; CSP lined with plastic liner same size; liner generally in good shape but will need to be replaced when highway widened.
CV-0401-002059	Hamilton	23+605	CSP - Plastic Lined	Circular	900	56.9	3.0	-	Recently ditched upstream and downstream; CSP lined with plastic same size; culvert dented near south end.
CV-0401-001881	Hamilton	24+810	Concrete	Box	2450 x 1850	73.1	9.0	Yes	Generally good condition; Some spalling of concrete; 1.2m opening height downstream.
21-467/C	Haldimand	10+715	Concrete	Box	3100 x 1800	147.1	15.0	Yes	Scour pool at outlet with fish; exposed footing visible in pool; groundwater entering downstream creek from both sides with pipe on southeast (possibly abandoned?); 0.45 m water depth & 0.75 m scour depth downstream; Pipes draining into culvert from both sides; small scour pool upstream (potentially from SWM pond?).
CV-0401-001858	Haldimand	11+705	CSP	Circular	900	51.5	1.8	-	Culvert rusting; almost full of sediment and standing water; ditching downstream required.
CV-0401-001857	Haldimand	12+090	CSP - Plastic Lined	Circular	900	52.8	2.4	-	Upstream end is open and flowing; Upstream channel is slightly eroding; South end has been ditched but the culvert is in a pool of water well below water surface; Looks to be lined.
21-468/C	Haldimand	12+420	Concrete	Box	3100 x 1500	71.7	2.0	Yes	Appears to be SWM feature on north east side with step pool; tree almost growing in culvert inlet that should be removed; Some scour at inlet; Exposed footing; 0.7m opening height downstream.
CV-0401-001855	Haldimand	12+720	Concrete	Box	1540 x 1570	60.9	5.0	-	SWM ponds upstream; Recent repair to embankment downstream with rip rap is starting to fail; Repair scour and embankments downstream; Some leakage in culvert; Generally, in good shape upstream; Extreme scour downstream; Perched ~1.5m.
CV-0401-001873	Haldimand	13+030	Concrete	Box	1200 x 1200	73.8	9.0	-	Couldn't locate upstream end – appears to be buried; Perched downstream.
21-469/C	Haldimand	14+135	Concrete	Box	3700 x 1800	91.5	12.0	-	Heavily wooded area; Channel ok; No major erosion or scour on upstream end; Some cracks in culvert.
21-270/C	Haldimand	14+200	Concrete	Arch	9000 x 4500	85.0	10.0	Yes	Channel and embankments generally in good shape; Scour pool just before inlet; Scour pools after each weir throughout barrel.
CV-0401-001791/825	Haldimand	14+660	Steel - Concrete lined	Circular	800	24.1	1.5	-	Concrete lined steel pipe; Drains into SWM pond; Concrete is in good condition.
CV-0401-001721	Haldimand	15+150	CSP - Plastic Lined	Circular	900	48.3	1.8	Yes	CSP lined with plastic same size; Recently ditched upstream and downstream; Multiple dents throughout barrel; Liner generally in good shape but will need to be replaced when highway widened.
CV-0401-001885/824	Haldimand	15+480	CSP	Circular	900	45.0	1.5	-	Did not assess; Results from 2014 show CSP was in poor condition; Potentially is now lined with plastic pipe similar to culvert at station 15+150 (000904010068); will need to be replaced when highway widened.
CV-0401-001912	Haldimand	16+390	CSP	Arch	1100 x 700	58.8	1.5	-	Rusting through on north end; Recently ditched upstream and downstream.
CV-0401-001908/880	Haldimand	16+620	CSP	Arch	1066 x 660	63.0	1.5	-	Culvert starting to rust and downstream end is slightly crushed; Almost completely buried at north end; could only see CSP ribs.
21-470/C	Haldimand	17+170	Concrete	Box	3100 x 1800	91.6	15.0	Yes	Repair scour downstream; Culvert is perched at downstream end; Exposed footing at upstream end; Rust stains and cracks throughout.
CV-0401-001862	Haldimand	17+640	CSP	Circular	900	50.2	1.8	-	Upstream end blocked with sediment and straw bales; Ditching required; New culvert on upstream end; Downstream end half-filled with sediment and water; Culvert looks ok but likely rusted through below water surface.
21-272/C	Haldimand	19+340	Concrete	Arch	15200 x 7700	100.5	8.0	Yes	Some embankment erosion near upstream headwall; Fast flowing water; Boulders and cobbles; Concrete arch culvert; Some embankment erosion in upstream channel.
CV-0401-001893	Haldimand	20+590	Concrete	Box	1800 x 1550	79.5	10.0	Yes	Culvert is proposed to be repaired in 2020/2021. The ESL is 25 years. During inspection, downstream end breaking apart and should be repaired; South west ditch near culvert eroding out even with recent repair; Exposed footing upstream; Bottom of culvert seems to have worn down; Some spalling throughout.
CV-0401-001906	Haldimand	20+930	CSP	Circular	900	68.2	10.0	-	Rusting; Partially filled downstream; Ditching could be improved downstream; Rusting on bottom with a few perforations; sag in middle.
CV-0401-001907	Haldimand	21+030	Concrete	Box	1500 x 1200	86.8	8.0	Yes	Culvert was repaired in 2019, further repairs planned for 2020. During the inspection, downstream end barely exposed; Major erosion of embankment that is encroaching to roadway; Culvert generally in good shape; Major erosion of embankment downstream end; Needs immediate repair.
CV-0401-001854	Haldimand	21+615	CSP/Concrete	Circular	900	48.0	2.0	-	900mm upstream, 825mm downstream; Rusted through on upstream end; Catch basin in middle; CSP upstream in poor condition; Concrete lined steel pipe good condition on downstream end.
21-576/C	Haldimand	22+125	Concrete	Box	3100 x 2500	81.0	8.0	Yes	Pool at northwest end; Flow could be undermining culvert; Upstream end requires repairs to fix scour/undermining; Downstream end is ok; Fish downstream; Culvert footing exposed; Lots of erosion of bank immediately around upstream end; Heavily wooded area.
CV-0401-001853	Haldimand	22+315	Concrete	Box	1200 x 1200	60.3	4.5	Yes	Culvert in good condition; Only 0.45m opening on downstream end; Standing water.
CV-0401-001914	Haldimand	22+480	CSP	Circular	900	65.2	6.0	-	Ditching required downstream; Rusted through upstream end; 0.55m opening downstream; standing water.
CV-0401-001852	Haldimand	22+700	Concrete	Box	1200 x 1200	62.9	6.0	No	Culvert in fair condition; 0.9m opening height on downstream end with lots of vegetation.
CV-0401-001851	Haldimand	23+770	Concrete	Box	1850 x 1800	70.1	9.0	Yes	Culvert was repaired in 2019. During inspection, some leakage in culvert; Some spalling downstream; Scour pool on downstream end; Culvert generally in good condition; Erosion in the area (ditches and banks); Fast flowing stream.
CV-0401-001850	Haldimand	24+940	CSP	Circular	900	55.2	2.0	-	Rusting with some flaking; Rip rap upstream.
CV-0401-001837	Cramahe	10+396	CSP	Circular	900	49.5	1.8	-	Rusting with some perforations; Rip rap upstream; Full of water downstream.
CV-0401-001835	Cramahe	11+143	Concrete	Box	1800 x 1500	52.4	1.5	Yes	Culvert in good condition downstream; Scour/perched downstream at end of wingwall; DICB in north ditch.
CV-0401-001910	Cramahe	11+478	CSP	Circular	900	54.9	1.5	-	Culvert rusting through; Half-filled with sediment and standing water; Replace or line.

2.1.2 Interchange Culverts

Within the project limits, there are two interchanges: Lyle Street and Percy Street. Each of these interchanges contain a combination of storm sewers and culverts to drain the interchange. As stated earlier, storm sewers were not examined as part of this contract and therefore only the culverts within the interchanges were documented. Within the two interchanges, a total of nine culverts were assessed. Results of the field assessment are available in Table 2 below:

Table 2: Highway 401 Interchange Culvert Summary

Culvert ID DAID)	Township	Station	Location	Material	Shape	Diameter or Span x Rise (mm)	Depth of Cover (m)	Comments
			Lyle Street Interchange					
CV-0401-002019	Haldimand	15+940	W-N/S Ramp	CSP	Circular	600	1	Rusting
CV-0401-002012	Haldimand	16+024	N/S-E Ramp	CSP	Circular	600	4	Rusting at upstream end
CV-0401-002050	Haldimand	16+050	Entrance	CSP	Circular	800	4	Rusting
CV-0401-001894	Haldimand	16+350	E-N/S Ramp	CSP	Circular	600	1.5	Almost fully buried, standing water, exposed pipe is rusting
			Percy Street interchange					
CV-0401-001838	Cramahe	11+052	W-N/S Ramp	CSP	Circular	900	3	Discharges to SWM feature; Upstream end crushed
CV-0401-001839	Cramahe	11+128	W-N/S & N/S-E Ramps	Concrete	Box	1800 x 1500	4	Generally good condition
CV-0401-001879	Cramahe	11+195	Sideroad	CSP	Circular	900	1.5	Rusting
CV-0401-001866	Cramahe	11+195	Sideroad	CSP	Circular	900	1.5	Culvert not located
CV-0401-002023	Cramahe	11+195	Sideroad	CSP	Circular	600	2	Generally good condition
CV-0401-001898	Cramahe	11+387	E-N/S Ramp	CSP	Circular	450	1	Rusting; crushed and buried on one end. Culvert lined in 2019

A detailed culvert inspection table, including recommendations, is included in Appendix B, while culvert photographs are included in Appendix C.

MTO has identified drainage issues around the Lyle Street interchange having to do with the conveyance of flows across private land downstream of the highway. To-date, the issues have included blocking the passage of flows across private land from sediment releases or intentional placement of material within the drainage system. In the north east quadrant of the interchange, immediately north of the E-N/S ramp, sediment originating from private property has been observed to be entering the MTO drainage system. In the south east corner of the Lyle Street interchange, a ditch has been plugged by a property owner which has resulted in water backing up in the storm sewer. The impact to the drainage system caused by these alterations has yet to be determined at the time of this reports submission. These issues will require further investigation at detail design stage. If necessary, resolutions will be considered upon confirmation of details.

These issues require further investigation at detail design stage.

2.1.3 Remaining Drainage Infrastructure

Outside of the centreline culverts, the existing highway drainage system generally consists of a median storm sewer system outletting to the roadside ditch as well as culverts and storm sewers conveying drainage within the interchanges and across road embankments for overpasses. There are also several ponds and step pools within the study area that appear to provide some level of water quality and/or erosion control prior to discharge to downstream systems. A small number of culverts within the study area have been abandoned. The abandoned culverts observed during the field visit were CSP that had been filled with concrete.

Recent roadwork in the study area at the time of the field visit included several areas of recently cleaned out ditching as well as uncovered pipes and storm sewer outlets that were buried or poorly draining prior to the improvements. As noted by MTO maintenance, storm sewer outlets throughout this area are prone to sedimentation and clogging, which will be taken into consideration during the proposed storm sewer design.

Storm sewers and associated storm sewer outlets were not examined as part of this study as they will all be replaced as part of future highway widening, however, details of condition for these pipes can be found in the *Final Culvert Condition Report – Highway 401 – Cramahe Township. Agreement No. 4014-E-0003, Assignment No. 2.* (Ainley Group, 2015).

2.1.4 Roadside Ditches

Generally, roadside drainage flows east and west along the roadside ditches towards the crossing culverts. Ditches along the length of the project were generally found to be in fair condition. Vegetation, sediment accumulation, and standing water was noted downstream of several of the culverts and storm sewer outlets.

2.1.5 Highway Embankments

Due to the highly erodible soils and steep embankments within the study area, embankment erosion was observed during the field investigation at various culverts throughout the study limits.

2.1.6 External Drainage Infrastructure and Planning

There are no existing Master Drainage Plans that cover any area within the study limits. A background review of information available through Land Information Ontario indicates that there are no Municipal Drains in the area.

2.2 Design Criteria

The design of watercourse crossings in Ontario is influenced by several design criteria. These criteria can be used to evaluate existing culverts and to design future culverts.

Design Flood

In accordance with MTO *Highway Drainage Design Standards* (HDDS, 2008, WC-1), for freeways, culverts less than 6 m wide should be designed to pass the 50-year design flood and culverts greater than 6 m wide should be designed to pass the 100-year design flood. A check storm equivalent to 130% of the 100-year storm was used to determine scour (HDDS, 2008, WC-1). Highway ramps are classified as freeways.

Freeboard

Freeboard for culvert design is measured from the high-water level (design flood level) to the edge of the travelled lane (HDDS 2008, WC-7). MTO criteria specify that freeboard shall not be less than 1.0 m for highways, arterials, and collector roads on a watercourse unless otherwise approved (HDDS 2008, WC-2). For culverts not on a watercourse the minimum freeboard for the design flow is 0.3 m.

Flood Depth at Culverts

MTO criteria specify that the ratio of the flood depth at the upstream face of a culvert to the diameter or rise of the culvert (HW/D) shall be less than or equal to 1.5 for closed bottom culverts with a diameter or rise less than 3.0 m. For culverts with a diameter or rise between 3.0 and 4.5 m, HW/D shall be less than or equal to 4.5 m. For open bottom culverts the minimum vertical clearance above the high-water level is 0.3 m from a straight soffit. Clearance is the distance between the high-water level and the lowest point of the soffit. In addition, the check storm should not exceed the elevation of the roadway (i.e., should not overtop the road).

Relief Flow

The fraction of the Regulatory Flow that bypasses the main structure at a water crossing by flowing over the roadway or through a relief culvert or bridge is called the Relief Flow. The Regulatory Flow is typically calculated as the peak flow generated by the Regional Storm. The design of a water crossing shall incorporate passage of the Relief Flow over the roadway on Regulated Watercourses where Floodline Mapping is available, where there is a potential risk to public safety, or where there is potential damage to adjacent properties. Where Relief Flow is provided:

- The maximum depth of flow on the roadway shall not exceed 0.3 m
- The product of the velocity and depth of flow on the roadway shall not exceed 0.8 m^2/s

Minimum Culvert Sizes

In accordance with *MTO Highway Drainage Design Standards* (HDSS, WC-8), centreline culverts on a freeways and highway ramps should have a minimum culvert diameter of 800 mm for circular culverts and a minimum rise of 900 mm for box culverts.

Icing and Debris

Where experience or physical evidence indicate that there are issues with debris and/or ice build-up at a culvert, consideration must be given to the hydraulic impacts resulting from potential inlet blockage. For closed bottom culverts, MTO criteria state that culvert soffit clearance shall be 0.3 m above the maximum observed ice/debris build-up plus winter flow, and culvert width shall be increased to accommodate the observed static ice width plus 10% where appropriate to prevent property damage (HDDS, WC-11).

Fish Passage

Where culverts convey fish bearing streams that have been confirmed as fish habitat, consideration must be given to facilitate fish passage through hydraulic structures. The two-year return period is typically the design flow for fish passage as it represents the bankfull flow conditions. MTO criteria outline a number of hydraulic and physical characteristics that guide culvert design for fish passage, discussed in detail in WC-12 of the HDDS (MTO, 2008). The criteria state that maximum velocity in the culvert shall not exceed the natural channel velocity, the depth of water in the culvert should be consistent with upstream and downstream levels, and that no sudden drops exceeding 0.15 m should exist within or adjacent to the culvert. Please refer to the HDDS for all specific design criteria.

Storm Sewers

In accordance with *MTO Highway Drainage Design Standards* (HDDS, SD-1), the minimum design flows used for designing minor flows within road surface drainage systems will be the 10-year storm event.

Storm sewers will be designed in accordance with Section SD-4 (Storm Sewer System) of the HDDS. Freeways must accommodate the 10-year storm. Storm sewers draining to low points in the road must accommodate the 100-year storm to limit ponding on the roadway. MTO standards also specify a minimum flow velocity of 0.75 m/s in smooth walled trunk sewers and 1.5 m/s in lateral sewers (HDDS, SD-4). This standard ensures that the storm sewers are self-cleaning and will not fill with sediment.

Consideration for Climate Change

As stated in the Provincial Engineering Memorandum: Implementation of the Ministry's Climate Change Consideration in the Design of Highway Drainage Infrastructure, dated October 28, 2016, all highway drainage designs must take into consideration changes to future rainfall parameters. This is done through the use of the MTO Intensity Duration Frequency (IDF) curves application Version 3 to determine present and future rainfall values. The proposed design must meet all performance standards through the design life of the structure(s) for the 50% to 1% probability of exceedance flows and Regulatory flow, in accordance with the applicable standards outlined in the MTO Highway Drainage Design Standards. Future rainfall values for the year corresponding to the end of the Design Service Life (DSL) of the structure(s) must be used in the design for conveyance, erosion, scour, and stormwater management components. The design for fish passage shall meet the fish passage design drainage standard requirements at the present and future flow conditions.

When using empirical analysis methods to determine design flow rates that do not rely on IDF curves, the ratio of future rainfall values to the current values shall be determined using the IDF curves tool at the location of the drainage infrastructure. This ratio shall be applied to the design values obtained using the empirical.

2.3 Public and Agency Consultation

The following comments and concerns were brought forward by MTO personnel regarding the local drainage conditions:

- Storm sewers/ditches are prone to filling with sediment
- All soil throughout the study area is very unstable. Special attention is required to stabilize and hold slope in a maintainable state. Slope stability and erosion concerns were reiterated as the largest maintenance issue in the corridor
- Interceptor ditches that were used on the adjacent construction project worked well but quickly filled with sediment and based on their location on the slope are very difficult to clean out
- Several storm sewer outlets have high flows during storms and become pressurized. These flows blow out the pond walls and erode ditches causing the Ministry of the Environment Conservation and Parks (MECP) to threaten litigation against the MTO
- Additional storm outlets may be needed to provide drainage from extra lanes upon highway widening

At the time of this report, no additional comments were received from the public or other agencies pertaining to the study limits.

3.0 Hydrologic Analysis

3.1 Hydrologic Model

A detailed surface water assessment was completed to quantify surface drainage characteristics of lands contributing drainage within the study area to assess the performance of the drainage system. Hydrologic and hydraulic analyses were undertaken for all centerline culverts. Hydrologic event modelling was used to quantify the peak flow rates upstream of each of the culverts in the study area for the design and check flows. The hydrologic model HEC-HMS v. 4.3 was used to determine peak flows to the highway. For structural culverts, the peak flow rates were modelled using a variety of methods and the highest peak flow produced from the different models was selected for design. Flood Frequency Analysis, the Unified Ontario Method, and hydrologic modelling were all considered in the process of selecting the highest peak flow for the design of structural culverts. Topography and Surface Drainage

Highway 401 runs in an east-west direction between Cobourg and Colborne. Land use in the area draining to the highway is predominantly agricultural and forested areas. Land use was assessed using aerial photography, and information obtained during the field inspections. Topography for the study area is rolling to hilly.

Catchment areas for the centerline culverts were delineated based on topographical information from the South-Central Ontario Orthophotography Project (SCOOP) produced by the Ontario Ministry of Natural Resources and Forestry (MNRF). Site topography and the existing drainage areas are shown on Figures 1 to 10, included in Appendix A.

3.2 Geotechnical Information

Soil data was determined based on Soil Survey Mapping for the area provided by the MNRF. Site soils are generally well draining sandy loams, with some areas of sand, loam, and muck.

3.3 Precipitation

To assess the drainage system, the area was modelled using precipitation data obtained from the MTO's IDF Curve Online Design Tool Version 3 for the study area (Location 44.004167 N, 78.029167 W). Data was collected for the year 2094, based on a 75-year design service life (DSL) to consider climate change. Catchments were modelled using the 24-hour SCS Type II distribution as land use throughout the study area is consistently agricultural and forested areas. A comparison of peak flows (included in Appendix D) showed that the 24-hour SCS Type II distribution was produced the highest peak flows for all catchments, therefore it is an applicable and conservative distribution to use for modelling flows.

Detailed precipitation data and the catchment modeling parameters are provided in Appendix D.

3.4 Existing Conditions

3.4.1 Centreline Culverts

Existing catchment areas for the centreline culverts are shown on Figures 1 to 10. Drainage information was based on topography, aerial photography of the area, and information obtained during the site visit. The existing conditions catchment parameters and the hydrologic model files are provided in Appendix D. Hydrologic and hydraulic analyses were completed for all existing centreline culverts in the study area. Table 3 summarizes peak flows for the 32 existing centreline culverts.

Table 3: Summary of Existing Centreline Culvert Drainage Characteristics

Culvert ID (DAID)	Township	Station	Drainage Area (ha)	Diameter or Span x Rise (mm)	Peak Flows (m3/s)	
					Design	Check
CV-0401-001882	Hamilton	23+330	8.11	900	0.60	0.90
CV-0401-002059	Hamilton	23+605	10.47	900	0.68	1.02
CV-0401-001881	Hamilton	24+810	253.48	2450 x 1850	5.29	8.07
21-467/C	Haldimand	10+715	337.26	3100 x 1800	10.84	16.43
CV-0401-001858	Haldimand	11+705	54.81	900	2.67	4.01
CV-0401-001857	Haldimand	12+090	10.10	900	0.88	1.30
21-468/C	Haldimand	12+420	229.76	3100 x 1500	9.14	13.65
CV-0401-001855	Haldimand	12+720	23.59	1540 x 1570	0.35	0.57
CV-0401-001873	Haldimand	13+030	38.26	1200 x 1200	1.10	1.75
21-469/C	Haldimand	14+135	45.10	3700 x 1800	2.37	3.57
21-270/C	Haldimand	14+200	1911.57	9000 x 4500	33.56	43.63
CV-0401-001791/825	Haldimand	14+660	11.68	800	0.49	0.76
CV-0401-001721	Haldimand	15+150	5.30	900	0.25	0.38
CV-0401-001885/824	Haldimand	15+480	21.78	900	1.34	2.01
CV-0401-001912	Haldimand	16+390	12.51	1100 x 700	1.10	1.63
CV-0401-001908/880	Haldimand	16+620	9.83	1066 x 660	0.91	1.35
21-470/C	Haldimand	17+170	276.89	3100 x 1800	6.35	12.51
CV-0401-001862	Haldimand	17+640	15.54	900	0.51	0.77
21-272/C	Haldimand	19+340	6045.43	15200 x 7700	67.57	87.84
CV-0401-001893	Haldimand	20+590	186.88	1800 x 1550	2.35	3.61
CV-0401-001906	Haldimand	20+930	14.57	900	0.78	1.17
CV-0401-001907	Haldimand	21+030	41.02	1500 x 1200	1.57	2.39
CV-0401-001854	Haldimand	21+615	4.73	900	0.50	0.74
21-576/C	Haldimand	22+125	749.93	3100 x 2500	10.70	16.85
CV-0401-001853	Haldimand	22+315	35.35	1200 x 1200	0.61	0.96
CV-0401-001914	Haldimand	22+480	10.05	900	0.29	0.46
CV-0401-001852	Haldimand	22+700	85.62	1200 x 1200	1.94	2.99
CV-0401-001851	Haldimand	23+770	481.05	1850 x 1800	3.78	5.69
CV-0401-001850	Haldimand	24+940	28.59	900	1.24	1.87
CV-0401-001837	Cramahe	10+396	14.48	900	0.98	1.45
CV-0401-001835	Cramahe	11+143	110.62	1800 x 1500	3.98	5.92
CV-0401-001910	Cramahe	11+478	47.51	900	2.38	3.53

Notes: Design Storm = 50-year event for culverts having total span ≤ 6.0 m; 100-year event for culverts having total span > 6.0 m
Check Storm = 130% of 100-year event for culverts on a watercourse

3.4.2 Interchange Culverts

Hydrologic analysis was not completed for existing interchange culverts as they are no longer relevant under the proposed interchange and ramp alignments. Please refer to Section 3.5.2 for the hydrologic analysis of proposed culverts.

3.5 Proposed Conditions

3.5.1 Centreline Culverts

The proposed highway improvements within the study area include highway widening, median sewer replacement, commuter parking lot expansions, rehabilitation of the pavement structure, and improving the overall operational characteristics of Highway 401. Catchment areas were considered to be generally the same under existing and proposed conditions as there is no significant modifications in the road alignment under proposed conditions. The catchment areas determined for the existing and proposed conditions analysis were conservatively bounded by the downstream edge of the highway.

Given the large size of the catchments, the marginal increase in impervious coverage resulting from the highway widening has a negligible impact on flows at the upstream face of the centerline culverts. Flows are not increased throughout the catchments but rather within the right-of-way, representing a small portion of each catchment. Any significant increase in flows caused by the highway widening within the right-of-way will be mitigated by directing median storm sewer drainage to SWM controls on the downstream side of the highway, which is discussed in Section 6 in further detail. Therefore, the increase in peak flows will not occur at the face of the culvert and will be mitigated prior to discharging to the downstream system. Table 4 summarizes peak flows for the proposed centreline culverts.

Table 4: Summary of Proposed Centreline Culvert Drainage Characteristics

Catchment ID (DAID)	Township	Station	Drainage Area (ha)	Peak Flows (m3/s)	
				Design	Check
CV-0401-001882	Hamilton	23+330	18.57	0.60	0.90
CV-0401-002059	Hamilton	23+605	10.47	0.68	1.02
21-467/C	Haldimand	10+715	337.26	10.84	16.43
CV-0401-001858	Haldimand	11+705	54.81	2.67	4.01
CV-0401-001857	Haldimand	12+090	10.10	0.88	1.30
21-468/C	Haldimand	12+420	229.76	9.40	14.60
21-469/C	Haldimand	14+135	45.10	2.37	3.57
21-270/C	Haldimand	14+200	1911.57	33.56	44.38
CV-0401-001791/825	Haldimand	14+660	11.68	0.49	0.76
CV-0401-001721	Haldimand	15+150	5.30	0.25	0.38
CV-0401-001885/824	Haldimand	15+480	21.78	1.34	2.01
CV-0401-001912	Haldimand	16+390	12.51	1.10	1.63
CV-0401-001908/880	Haldimand	16+620	9.83	0.91	1.35
21-470/C	Haldimand	17+170	276.89	6.35	12.51
CV-0401-001862	Haldimand	17+640	15.54	0.51	0.77
21-272/C	Haldimand	19+340	6045.43	67.57	87.84
CV-0401-001906	Haldimand	20+930	14.57	0.78	1.17
CV-0401-001907	Haldimand	21+030	41.02	1.57	2.39
CV-0401-001854	Haldimand	21+615	4.73	0.50	0.74
21-576/C	Haldimand	22+125	749.93	10.70	16.85
CV-0401-001914	Haldimand	22+480	10.05	0.29	0.46
CV-0401-001850	Haldimand	24+940	28.6	1.24	1.87
CV-0401-001837	Cramahe	10+396	14.48	0.98	1.45
CV-0401-001835	Cramahe	11+143	110.62	3.98	5.92
CV-0401-001910	Cramahe	11+478	47.51	2.38	3.53

Notes: Design Storm = 50-year event for culverts having total span ≤ 6.0 m; 100-year event for culverts having total span > 6.0 m
Check Storm = 130% of 100-year event for culverts on a watercourse

Five existing culverts within the study area are considered for abandonment in the interest of reducing costs and risk associated with installation and maintenance. Flows conveyed by the existing culverts considered for abandonment would be redirected to nearby downstream culverts. The successful redirection of flows depends on whether ditch grading can be modified to adequately convey flows to the proposed outlets. This report assumes these culverts can be successfully abandoned when determining flows and culvert sizes. An analysis of whether abandonment of these culverts is possible from a grading perspective will need to be conducted at the detail design stage when detailed survey information is available.

The culverts identified as having potential for abandonment and the existing culverts that flow would be redirected to are as follows:

- CV-0401-002059 redirected to CV-0401-001882
- CV-0401-001855 redirected to 21-468/C
- CV-0401-001791/825 redirected to 21-270/C
- CV-0401-001721 redirected to CV-0401-001885/824
- CV-0401-001906 redirected to CV-0401-001907

Flows from abandoned culverts were redirected to downstream culverts with the results are summarized in Table 5.

Table 5: Summary of Proposed Centreline Culvert Drainage Characteristics for Sites Downstream of Abandoned Culverts

Catchment ID (DAID)	Township	Station	Drainage Area (ha)	Peak Flows (m3/s)	
				Design	Check
CV-0401-001882 (including flows redirected from CV-0401-002059)	Hamilton	23+330	29.04	1.28	1.92
21-468/C (including flows redirected from CV-0401-001855)	Haldimand	12+420	253.35	9.75	14.60
21-270/C (including flows redirected from CV-0401-001791/825)	Haldimand	14+200	1923.25	34.05	44.38
CV-0401-001885/824 (including flows redirected from CV-0401-001721)	Haldimand	15+480	27.08	1.51	2.27
CV-0401-001907 (including flows redirected from CV-0401-001906)	Haldimand	21+030	55.06	2.33	3.54

Notes: Design Storm = 50-year event for culverts having total span ≤ 6.0 m; 100-year event for culverts having total span > 6.0 m
Check Storm = 130% of 100-year event for culverts on a watercourse

3.5.2 Interchange Culverts

Changes related to the interchanges at Lyle Street and Percy Street include improved access and egress to and from the Highway 401, involving the construction and/or realignment of new ramps. Under proposed conditions, flow patterns generally remain the same as existing conditions with minor changes due to expansion of the interchanges. Design and check flows used to size and analyze interchange culverts were determined by the transposition of flood discharges from catchments adjacent to or surrounding interchange catchments. This method works by transposing a known discharge from a particular catchment to another area on the same watercourse or in a nearby catchment with similar characteristics (MTO, 1997).

Table 6 below summarizes peak flows for the proposed centreline culverts.

Table 6: Summary of Proposed Interchange Culvert Drainage Characteristics

Location	Township	Station	Drainage Area (ha)	Peak Flows (m3/s)	
				Design	Check
Lyle Street Interchange					
Lyle	Haldimand	9+800	2.00	0.22	0.34
Lyle	Haldimand	10+200	2.00	0.28	0.41
Lyle (Carpool Lot)	Haldimand	10+200b	2.00	0.28	0.41
Lyle	Haldimand	10+300	1.00	0.13	0.20
W-N/S	Haldimand	10+230	2.50	0.26	0.40
W-N/S	Haldimand	10+350	2.00	0.22	0.34
E-N/S	Haldimand	10+450	3.50	0.42	0.63
N-E	Haldimand	9+780	2.00	0.22	0.34
S-W	Haldimand	9+975	2.00	0.28	0.41
Percy Street Interchange					
Percy	Cramahe	9+525	2.00	0.20	0.292
Percy	Cramahe	9+525b	30.00	1.50	2.223
Percy	Cramahe	9+650	20.00	1.10	1.64
Percy	Cramahe	9+675	40.00	1.86	2.759
Percy	Cramahe	9+790	4.00	0.33	0.491
Percy	Cramahe	9+975	1.50	0.16	0.235
Percy	Cramahe	10+025	47.50	2.38	3.533
W-N/S	Cramahe	10+510	5.00	0.39	0.58
W-N/S	Cramahe	10+610	158.13	5.21	7.735
S-E	Cramahe	9+460	1.00	0.12	0.173
E-N/S	Cramahe	10+130	47.50	2.38	3.533

4.0 Hydraulic Analysis

In accordance with MTO HDDS, all culverts should accommodate the design flow. Throughout the study area, Highway 401 is classified as a rural freeway under existing and proposed conditions.

The calculated peak flows were used along with the culvert information in the hydraulic modelling program CulvertMaster. CulvertMaster is a program used to assist in the design and analysis of culverts and to determine the conveyance capacity of each culvert under existing and proposed conditions. No culverts were noted as having significant backwater or downstream restrictions during the field visit and all culverts outlet to a downstream channel with a larger cross-sectional area than the culvert. The tailwater level is expected to be below the top of the culvert opening and a tailwater level at 60% of the culvert height was chosen as a typical tailwater level. A water level at or above the top of the culvert is overly conservative and may result in larger culverts than would otherwise be required.

Two of the existing large, arch structural culverts were modeled using HEC-RAS v. 5.0.7 due to their large size in order to increase model accuracy and better test potential options for rehabilitation/replacement. The two locations include Site 21-270/C (Grafton Creek Culvert) and Site 21-272 (Shelter Valley Creek Culvert). These models were based on cross-sections built from photogrammetric survey mapping and model parameters using a combination of survey, field data, photos and aerial imagery.

4.1 Existing Conditions

4.1.1 Centreline Culverts

Hydraulic analysis was completed for centerline culverts within the project limits. Detailed results of these hydraulic analyses are included in Appendix E and are summarized in Table 7. Invert elevations, lengths, dimensions, and other culvert characteristics were estimated from photogrammetric survey data for the site.

Table 7: Hydraulic Assessment of Existing Centreline Culverts

Culvert ID (DAID)	Township	Station	Dimensions (mm)		Depth of Cover (m)	Drainage Area (ha)	Design Flow (m^3/s)	Summary of Hydraulic Performance		
								Design Storm		Check Storm
			Span	Rise/ Diameter				Freeboard from Road at Spill Point > 1.0 m	Headwater/ Diameter (or rise) < 1.5	Water Level < Edge of Pavement
CV-0401-001882	Hamilton	23+330	-	900	2.1	8.11	0.60	Yes	Yes	Yes
CV-0401-002059*	Hamilton	23+605	-	900	2.1	10.47	0.68	Yes	Yes	Yes
CV-0401-001881	Hamilton	24+810	2450	1850	8.2	253.48	5.29	Yes	Yes	Yes
21-467/C	Haldimand	10+715	3100	1800	5.7	337.26	10.84	Yes	Yes	Yes
CV-0401-001858	Haldimand	11+705	-	900	1.6	54.81	2.67	No	No	No
CV-0401-001857	Haldimand	12+090	-	900	1.6	10.10	0.88	No	Yes	Yes
21-468/C	Haldimand	12+420	3100	1500	2.5	229.76	9.14	Yes	Yes	Yes
CV-0401-001855*	Haldimand	12+720	1540	1570	2.9	23.59	0.35	Yes	Yes	Yes
CV-0401-001873	Haldimand	13+030	1200	1200	8.8	38.26	1.10	Yes	Yes	Yes
21-469/C	Haldimand	14+135	3700	1800	11.2	45.10	2.37	Yes	Yes	Yes
21-270/C	Haldimand	14+200	9760	4880	8.1	1911.57	33.56	Yes	Yes	Yes
CV-0401-001791/825*	Haldimand	14+660	-	800	0.7	11.68	0.49	No	Yes	Yes
CV-0401-001721*	Haldimand	15+150	-	900	1.1	5.30	0.25	Yes	Yes	Yes
CV-0401-001885/824	Haldimand	15+480	-	900	1.1	21.78	1.34	No	Yes	No
CV-0401-001912	Haldimand	16+390	1100	700	0.8	12.51	1.10	No	No	No
CV-0401-001908/880	Haldimand	16+620	1066	686	0.8	9.83	0.91	No	Yes	No
21-470/C	Haldimand	17+170	3100	1800	9.2	276.89	6.35	Yes	Yes	Yes
CV-0401-001862	Haldimand	17+640	-	900	1.1	15.54	0.51	Yes	Yes	Yes
21-272/C	Haldimand	19+340	15200	7700	11.0	6045.43	67.57	Yes	Yes	Yes
CV-0401-001893	Haldimand	20+590	1800	1550	7.4	186.88	2.35	Yes	Yes	Yes
CV-0401-001906*	Haldimand	20+930	-	900	6.1	14.57	0.78	Yes	Yes	Yes
CV-0401-001907	Haldimand	21+030	1500	1200	5.8	41.02	1.57	Yes	Yes	Yes
CV-0401-001854	Haldimand	21+615	-	900	0.6	4.73	0.50	No	Yes	Yes
21-576/C	Haldimand	22+125	3100	2500	8.0	749.93	10.70	Yes	Yes	Yes
CV-0401-001853	Haldimand	22+315	1200	1200	3.8	35.35	0.61	Yes	Yes	Yes
CV-0401-001914	Haldimand	22+480	-	900	5.1	10.05	0.29	Yes	Yes	Yes
CV-0401-001852	Haldimand	22+700	1200	1200	5.3	85.62	1.94	Yes	Yes	Yes
CV-0401-001851	Haldimand	23+770	1850	1800	6.7	481.05	3.78	Yes	Yes	Yes
CV-0401-001850	Haldimand	24+940	-	900	0.6	28.59	1.24	No	Yes	No
CV-0401-001837	Cramahe	10+396	-	900	0.8	14.48	0.98	No	Yes	Yes
CV-0401-001835	Cramahe	11+143	1800	1500	0.5	110.62	3.98	No	Yes	Yes
CV-0401-001910	Cramahe	11+478	-	900	0.6	47.51	2.38	No	No	No

Notes: Design Storm = 50-year event for culverts having total span ≤ 6.0 m; 100-year event for culverts having total span > 6.0 m
Check Storm = 130% of 100-year event for culverts on a watercourse
* Denotes culverts outlined for potential to be abandoned

Based on the hydraulic analysis of the existing culverts presented in the table above, the following conclusions can be made:

- 11 culverts do not meet MTO standards because they are undersized. Of these eleven culverts;
    - Three culverts fail to meet all four criteria listed in Table 7
    - Five culverts have less than 1 m freeboard from the road at the spill point during the design storm
    - Three culverts have less than 1 m freeboard from the road surface at the spill point during the design storm and the check storm water level exceeds the edge of pavement

4.1.2 Interchange Culverts

No hydraulic analysis was completed on the existing interchange culverts for Lyle Street or Percy Street as they are not relevant under the proposed interchange and ramp alignments. Please refer to Section 4.2.2 for the hydraulic analysis of proposed culverts.

4.2 Proposed Conditions

4.2.1 Centreline Culverts

This section of the report identifies the Highway 401 centreline culvert replacement requirements based on observed conditions and hydraulic analysis. As stated earlier, of the 32 existing centreline culverts, 11 do not meet MTO standards and are proposed for replacement due to inadequate capacity. There are seven additional non-structural culverts that require replacement due to their poor condition alone, which are proposed to be replaced with the same size as existing and bring the total number of proposed replacements of non-structural culverts to 18. This number does not include the structural culvert sites, which are documented in Structural Planning Reports. As shown in previous sections, all the existing structural culverts meet MTO hydraulic requirements. One site, 21-469/C, is proposed to be lined and extended with a 3.4m x 1.8m CSP arch within the existing box culvert structure, which will reduce the hydraulic capacity but still meet all MTO criteria as seen in the table below. The other structural culverts are assumed to maintain the same or larger cross-sectional area under proposed conditions and have not been included in the table.

It is assumed that the replaced culverts will have the same slope as the existing culverts, and the spill elevation in proposed conditions would match existing. The lengths of the new culverts will be extended as required to accommodate the highway widening and will be remodeled upon final design. Proposed culvert sizes were identified for all locations in order to meet MTO design criteria.

Proposed culvert sizes are outlined in Table 8 below for both culverts requiring replacement due to inadequate capacity and those being replaced due to poor condition. The table shows the required sizes for individual culverts assuming no culverts are abandoned.

Table 8: Hydraulic Assessment of Proposed Centreline Culverts

Culvert ID (DAID)	Township	Station	Dimensions		Depth of Cover (m)	Drainage Area (ha)	Design Flow (m^3/s)	Summary of Hydraulic Performance		
								Design Storm		Check Storm
			Span (mm)	Rise/ Diameter (mm)				Freeboard from Road at Spill Point > 1.0 m	Headwater/ Diameter (or rise) < 1.5	Water Level < Edge of Pavement
CV-0401-001882	Hamilton	23+330	-	900	2.1	18.6	0.60	Yes	Yes	Yes
CV-0401-002059	Hamilton	23+605	-	900	2.1	10.5	0.68	Yes	Yes	Yes
CV-0401-001858	Haldimand	11+705	-	1500	1.0	54.8	2.67	Yes	Yes	Yes
CV-0401-001857	Haldimand	12+090	-	1200	1.3	10.1	0.88	*No	Yes	Yes
21-469/C	Haldimand	14+135	3400	1800	11.5	45.1	2.37	Yes	Yes	Yes
CV-0401-001791/825	Haldimand	14+660	-	900	0.6	11.7	0.49	*No	Yes	Yes
CV-0401-001721	Haldimand	15+150	-	900	1.1	5.3	0.25	Yes	Yes	Yes
CV-0401-001885/824	Haldimand	15+480	-	1200	0.8	21.8	1.34	Yes	Yes	Yes
CV-0401-001912	Haldimand	16+390	1630	1120	0.4	12.5	1.10	*No	Yes	Yes
CV-0401-001908/880	Haldimand	16+620	1390	970	0.5	9.8	0.91	*No	Yes	Yes
CV-0401-001862	Haldimand	17+640	-	900	6.1	15.54	0.51	Yes	Yes	Yes
CV-0401-001906	Haldimand	20+930	-	900	5.8	14.6	0.78	Yes	Yes	Yes
CV-0401-001854	Haldimand	21+615	-	900	0.6	4.7	0.50	*No	Yes	Yes
CV-0401-001914	Haldimand	22+480	-	900	5.1	10.1	0.29	Yes	Yes	Yes
CV-0401-001850	Haldimand	24+940	-	1200	0.3	28.6	1.24	*No	Yes	Yes
CV-0401-001837	Cramahe	10+396	-	1050	0.7	14.5	0.98	*No	Yes	Yes
CV-0401-001835	Cramahe	11+143	2400	1500	0.5	110.6	3.98	*No	Yes	Yes
CV-0401-001910	Cramahe	11+478	1800	900	0.6	47.5	2.38	**No	Yes	Yes

Notes: Design Storm = 50-year event for culverts having total span ≤ 6.0 m; 100-year event for culverts having total span > 6.0 m
Check Storm = 130% of 100-year event for culverts on a watercourse
*Doesn't meet freeboard requirement due to low cover, but design storm level remains below obvert.
**Doesn't meet freeboard requirement due to low cover and design storm exceeds obvert by 0.07m

As outlined in the table above, a few locations do not meet the freeboard requirement but meet all remaining MTO criteria. The culverts that do not meet the freeboard requirement are in locations with limited cover, which makes it very difficult to achieve the required 1m of freeboard. The design storm water level remains below the culvert obvert in all of these locations, except for one (CV-0401-001910 at Cramahe Township Station 11+478), where the design storm exceeds the obvert by only 0.07 m. In addition, the check storm does not overtop the highway in any locations and therefore the existing size of these culverts is sufficient. As mentioned in previous sections of this report, there is a possibility that five culverts will be abandoned, with flow being redirected to downstream culverts. Four of the five existing culverts have capacity to take on the additional drainage from abandoned culverts without having to increase their size. Culvert CV-0401-001882 at Hamilton Township Station 23+330 will have to be upsized from Ø900 mm to Ø1200 mm in order to convey flows from the abandoned culvert CV-0401-002059 at Hamilton Township Station 23+605. Table 9 shows the proposed sizes of the culverts with increased flow resulting from the abandonment of upstream culverts.

Table 9: Hydraulic Assessment of Proposed Centreline Culverts Conveying Additional Flow from Abandoned Culverts

Culvert ID (DAID)	Township	Station	Dimensions		Depth of Cover (m)	Drainage Area (ha)	Design Flow (m3/s)	Summary of Hydraulic Performance		
								Design Storm		Check Storm
			Span (mm)	Rise/ Diameter (mm)				Freeboard from Road at Spill Point > 1.0 m	Headwater/ Diameter (or rise) < 1.5	Water Level < Edge of Pavement
CV-0401-001882 (including flows redirected from CV-0401-002059)	Hamilton	23+330	-	1200	1.8	29.0	1.28	Yes	Yes	Yes
21-468/C (including flows redirected from CV-0401-001855)	Haldimand	12+420	3100	1500	2.5	253.3	9.75	Yes	Yes	Yes
21-270/C (including flows redirected from CV-0401-001791/825)	Haldimand	14+200	7200	4150	8.1	1923.2	34.05	Yes	Yes	Yes
CV-0401-001885/824 (including flows redirected from CV-0401-001721)	Haldimand	15+480	-	1200	0.8	27.1	1.51	Yes	Yes	Yes
CV-0401-001907 (including flows redirected from CV-0401-001906)	Haldimand	21+030	1500	1200	5.8	55.6	2.33	Yes	Yes	Yes

Notes: Design Storm = 50-year event for culverts having total span ≤ 6.0 m; 100-year event for culverts having total span > 6.0 m
Check Storm = 130% of 100-year event for culverts on a watercourse

4.2.2 Interchange Culverts

No significant changes to existing drainage patterns and flows occur within the Lyle Street or Percy Street interchanges. All culverts replaced as a part of this contract will have a minimum diameter of 800 mm to satisfy sizing requirements for interchanges on freeways. In locations where the existing culvert is larger than 800 mm diameter, the replacement culvert will be the same size or larger than the existing culvert. Where applicable, culverts larger than the required minimum of 800 mm shall be at least as large as any upstream culvert on the same watercourse/flow path. Interchange culverts have been modelled assuming a depth of cover of 1 m and the minimum required slope of 0.5%. as ramp and sideroad profiles have not been finalized at the time of the submission of this report.

Nine new culverts are proposed at the Lyle Street interchange and the immediate surrounding area, including a carpool lot. The minimum culvert diameter of 800 mm is sufficient for all nine of the culverts proposed at Lyle Street.

11 culverts are required to adequately drain the Percy Street interchange and immediate surrounding area, which also includes a carpool lot. The minimum culvert diameter of 800 mm is sufficient for five of the proposed culverts at Percy Street, but larger culverts are required in areas with larger catchments, or locations that are up or downstream of larger box culverts centreline to Highway 401.

Table 10 shows the proposed sizes for the culverts required to drain the interchanges at Lyle Street and Percy Street with detailed calculations provided in Appendix E.

Table 10: Hydraulic Assessment of Proposed Interchange Culverts

Location	Township	Station	Dimensions		Drainage Area (ha)	Summary of Hydraulic Performance			
						Design Storm			Check Storm
			Span	Height/ Diameter		Freeboard from Road at Spill Point > 0.3 m	Freeboard from Road at Spill Point > 1.0 m	Depth of Headwater < 1.5xCulvert Diameter	Water Level < Edge of Pavement
Lyle Street Interchange									
Lyle	Haldimand	9+800		800	2.0	Yes	Yes	Yes	Yes
Lyle	Haldimand	10+200		800	2.0	Yes	Yes	Yes	Yes
Lyle (Carpool Lot)	Haldimand	10+200b		800	2.0	Yes	Yes	Yes	Yes
Lyle	Haldimand	10+300		800	1.0	Yes	Yes	Yes	Yes
W-N/S	Haldimand	10+230		800	2.5	Yes	Yes	Yes	Yes
W-N/S	Haldimand	10+350		800	2.0	Yes	Yes	Yes	Yes
E-N/S	Haldimand	10+450		800	3.5	Yes	Yes	Yes	Yes
N-E	Haldimand	9+780		800	2.0	Yes	Yes	Yes	Yes
S-W	Haldimand	9+975		800	2.0	Yes	Yes	Yes	Yes
Percy Street Interchange									
Percy	Cramahe	9+525		800	2.0	Yes	Yes	Yes	Yes
Percy	Cramahe	9+525b		1200	30.0	Yes	Yes	Yes	Yes
Percy	Cramahe	9+650		1200	20.0	Yes	Yes	Yes	Yes
Percy	Cramahe	9+675		1500	40.0	Yes	Yes	Yes	Yes
Percy	Cramahe	9+790		800	4.0	Yes	Yes	Yes	Yes
Percy	Cramahe	9+975		800	1.5	Yes	Yes	Yes	Yes
Percy	Cramahe	10+025	1800	900	47.5	Yes	Yes	Yes	Yes
W-N/S	Cramahe	10+510		900	5.0	Yes	Yes	Yes	Yes
W-N/S	Cramahe	10+610	2400	1500	158.1	Yes	Yes	Yes	Yes
S-E	Cramahe	9+460		800	1.0	Yes	Yes	Yes	Yes
E-N/S	Cramahe	10+130	1800	900	47.5	Yes	Yes	Yes	Yes

5.0 Culvert Recommendations Summary

Of the 32 Highway 401 centreline culverts assessed within the study limits:

- Eight culverts are proposed to be retained
    - Four culverts are proposed to be retained without repairs
    - Four culverts are proposed to be retained after repairs are completed
- 17 culverts are proposed to be replaced
    - Eight Culverts to be replaced based on both condition and capacity
    - Seven culverts to be replaced based on condition alone
    - Two culverts to be replaced based on capacity alone
- Seven are structural culverts with recommendations submitted under separate cover. All existing culverts meet MTO standards
    - Site 21-469/C is proposed to be lined and extended with a 3.4 m x 1.3 m arch within the existing box culvert, which will reduce the hydraulic capacity, but still meet all MTO hydraulic criteria
    - All remaining sites will either be replaced or retained/rehabilitated and extended with a structure of similar or increased hydraulic capacity

Nine new culverts are proposed to service the Lyle Street interchange, while 11 culverts are proposed to service the Percy Street interchange. All culverts satisfy MTO hydraulic criteria and will need to have depth of cover and related parameters determined at detail design.

Please refer to Table 11 below for information on specific centreline culverts to be replaced, their location, and overall recommendations. Detailed recommendations are included in Appendix B and E.

Table 11: Summary of Centreline Culvert Recommendations and Proposed Sizing

Station	Catchment ID (DAID)	Material	Shape	Existing Culvert Dimensions (mm)		Depth of Cover (m)	Fish Habitat?	Culvert Condition Recommendation	Culvert Capacity Recommendation	Overall Culvert Recommendation	Proposed Culvert Size (mm) (hydraulic opening)	Notes on Abandoning Culvert
				Span	Height/ Diam.							
Highway 401 - Hamilton Township												
23+330	CV-0401-001882	CSP - Plastic Lined	Circular		900	2.1	-	Replace	Retain	Replace	900 (1200 if 23+605 is abandoned)	-
23+605	CV-0401-002059	CSP - Plastic Lined	Circular		900	2.1	-	Replace	Retain	Replace	900 (or abandon and re-grade to 23+330)	Potential to Abandon if grading works
24+810	CV-0401-001881	Concrete	Box	2450	1850	8.2	Yes	Retain	Retain	Retain	-	-
Highway 401 - Haldimand Township												
10+715	21-467/C	Concrete	Box	3100	1800	5.7	Yes	Refer to Structural Planning Report	Retain	Refer to Structural Planning Report	-	-
11+705	CV-0401-001858	CSP	Circular		900	1.0	-	Replace	Replace	Replace	1500	-
12+090	CV-0401-001857	CSP - Plastic Lined	Circular		900	1.3	-	Replace	Replace	Replace	1200 (or abandon and re-grade to 12+420)	Potential to Abandon if grading works
12+420	21-468/C	Concrete	Box	3100	1500	2.5	Yes	Refer to Structural Planning Report	Retain	Refer to Structural Planning Report	-	-
12+720	CV-0401-001855	Concrete	Box	1540	1570	2.9	-	Retain (repair scour & embankment)	Retain	Retain	-	-
13+030	CV-0401-001873	Concrete	Box	1200	1200	8.8	-	Retain (uncover upstream end and repair scour downstream)	Retain	Retain	-	Don't abandon due to potential watercourse and scour at adjacent culvert.
14+135	21-469/C	Concrete	Box	3700	1800	11.2	-	Refer to Structural Planning Report	Retain	Refer to Structural Planning Report	-	-
14+200	21-270/C	Concrete	Arch	9760	4880	8.1	Yes	Refer to Structural Planning Report	Retain	Refer to Structural Planning Report	-	-
14+660	CV-0401-001791/825	Steel - Concrete lined	Circular		800	0.6	-	Retain	Replace	Replace	900 (or abandon and re-grade to 14+200)	Potential to Abandon if grading works
15+150	CV-0401-001721	CSP - Plastic Lined	Circular		900	1.1	Yes	Replace	Retain	Replace	900 (1200 if 15+480 is abandoned)	-
15+480	CV-0401-001885/824	CSP	Circular		900	1.1	-	Replace	Replace	Replace	1200 (or abandon and re-grade to 15+150)	Potential to Abandon if grading works
16+390	CV-0401-001912	CSP	Arch	1100	700	0.4	-	Replace	Replace	Replace	1600 x 1100 CSP Arch or 1800 x 900 Concrete Box	-
16+620	CV-0401-001908/880	CSP	Arch	1066	686	0.5	-	Replace	Replace	Replace	1400 x 1000 CSP Arch or 1800 x 900 Concrete Box	Don't abandon due to low cover on adjacent culvert.
17+170	21-470/C	Concrete	Box	3100	1800	9.2	Yes	Refer to Structural Planning Report	Retain	Refer to Structural Planning Report	-	-
17+640	CV-0401-001862	CSP	Circular		900	1.1	-	Replace	Retain	Replace	-	-
19+340	21-272/C	Concrete	Arch	15200	7700	11.0	Yes	Refer to Structural Planning Report	Retain	Refer to Structural Planning Report	-	-

Station	Catchment ID (DAID)	Material	Shape	Existing Culvert Dimensions (mm)		Depth of Cover (m)	Fish Habitat?	Culvert Condition Recommendation	Culvert Capacity Recommendation	Overall Culvert Recommendation	Proposed Culvert Size (mm) (hydraulic opening)	Notes on Abandoning Culvert
				Span	Height/ Diam.							
20+590	CV-0401-001893	Concrete	Box	1800	1550	7.4	Yes	Repair	Retain	Retain	-	-
20+930	CV-0401-001906	CSP	Circular		900	6.1	-	Replace	Retain	Replace	900 (or abandon and re-grade to 21+030)	Potential to Abandon if grading works
21+030	CV-0401-001907	Concrete	Box	1500	1200	5.8	Yes	Retain (repair embankment)	Retain	Retain	Works even if 20+930 is redirected to this culvert	-
21+615	CV-0401-001854	CSP/Concrete	Circular		900	0.6	-	Replace	Retain	Replace	900	-
22+125	21-576/C	Concrete	Box	3100	2500	8.0	Yes	Refer to Structural Planning Report	Retain	Refer to Structural Planning Report	-	-
22+315	CV-0401-001853	Concrete	Box	1200	1200	3.8	Yes	Retain	Retain	Retain	-	-
22+480	CV-0401-001914	CSP	Circular		900	5.1	-	Replace	Retain	Replace	900	-
22+700	CV-0401-001852	Concrete	Box	1200	1200	5.3	No	Retain	Retain	Retain	-	-
23+770	CV-0401-001851	Concrete	Box	1850	1800	6.7	Yes	Retain	Retain	Retain	-	-
24+940	CV-0401-001850	CSP	Circular		900	0.3	-	Replace	Replace	Replace	1200	-
Highway 401 - Cramahe Township												
10+396	CV-0401-001837	CSP	Circular		900	0.7	-	Replace	Replace	Replace	1200	-
11+143	CV-0401-001835	Concrete	Box	1800	1500	0.5	Yes	Retain (repair scour)	Replace	Replace	2400 x 1500 Concrete Box	-
11+478	CV-0401-001910	CSP	Circular		900	0.6	-	Replace	Replace	Replace	1800 x 1200 Concrete Box	-

6.0 Gravity Pipe Analysis

A detailed gravity pipe analysis was undertaken to evaluate the various pipe materials available for culverts. This analysis looks at several pipe materials including:

- Concrete (both reinforced and non-reinforced - Concrete-R and Concrete-NR).
- High Density Polyethylene – Smooth Inside Corrugated Outside (HDPE-SICO).
- High Density Polyethylene – Closed Profile Wall Smooth Inside and Outside (HDPE-CPSIO).
- Polyvinyl Chloride – Profile Wall Smooth Inside and Corrugated Outside (PVC-SICO).
- Polyvinyl Chloride – Solid Wall Smooth Inside (PVC-SWSI).
- Polypropylene Pipe (PP).
- Plain Galvanized Steel (Steel – PG).
- Aluminized Type 2 Steel (Steel – ALT2).
- Polymer Laminated Steel (Steel – P).

The selection of pipe size and material type of all replacement culverts and storm sewers will be in accordance with the MTO *Gravity Pipe Design Guidelines* (April, 2014). In accordance with MTO *Gravity Pipe Guidelines, the Design Service Life* (DSL) for all new installations would be 50 years for centreline culverts and 75 years for storm sewers on Highway 401.

7.0 Stormwater Management (SWM)

7.1 General Information

Widening of the highway and interchange reconfiguration will increase flows and pollutant runoff from the highway. The 6-lane scenario will result in an approximately 50% increase in paved area from the current 4-lanes of traffic. Interchanges are assumed to remain approximately the same and no significant increase in paved area is anticipated in these areas.

Highway drainage generally exits the MTO right-of-way at centreline culverts and outlets to downstream watercourse and non-watercourse channels. Increased pollutant runoff has the potential to affect water quality in the downstream system including impacts to fish habitat, while increased flows have the potential to affect downstream flood risk and erosion. Highway sections that have a larger increase in pavement area relative to the receiving watercourse (usually on smaller watersheds) generally have more significant downstream impacts.

Highway areas draining to fish habitat require additional water quality controls to minimize potential impacts. Adequate stormwater management controls will be implemented throughout the study area to mitigate the potential fish habitat impacts.

Highway areas that result in large increases in pavement area relative to their total upstream drainage area, either because the upstream drainage area is relatively small or because the drainage area includes a large section of highway. These result in a larger potential for erosion, flood risk, and water quality degradation in these watercourses.

7.2 Highway Drainage Outlets

Widening the highway will result in increased flows from the additional pavement surface, although the proposed flow increase is usually less than 10% at all outlets. The relative increase in flows and pollutants from highway widening are generally negligible, but not zero. Any increase in flows could potentially result in property damage downstream and additional liability for MTO. The risk and potential cost of a claim must be considered against the cost of providing the SWM controls required to avoid a claim. Drainage analysis that clearly shows zero impact on adjacent landowners (no negative impact on upstream or downstream properties) can be used as a defense in cases where a landowner claims a negative impact on their land.

Drainage outlets discharging from the MTO right of way within the study area generally correspond to existing culvert locations. All culverts discussed in this report convey a small amount of highway runoff in addition to flows from their respective drainage areas. Of the 32 identified outlets, 14 exist on natural watercourses. The relative flow increases in the existing natural watercourses that result from highway widening are low and no significant downstream impacts are anticipated. The remaining 18 outlets are not located on natural watercourses and are typically discharged to forested areas or roadside ditches which eventually flow into downstream watercourses.

A summary of the highway drainage outlets within the study area is provided in Table 12.

Table 12: Summary of Highway Drainage Outlets

Township	Outlet Number	Station	Contributing Area (Station)	Fish Habitat	Outlet Description	Comments/Potential concerns
Hamilton	CV-0401-001882	23+330	23+300 to 23+600	No	Non-watercourse outlets through forest to watercourse	Flows south through woodlot
Hamilton	CV-0401-002059	23+605	23+600 to 23+800	No	Non-watercourse outlets through forest to watercourse	Flows south through woodlot
Hamilton	CV-0401-001881	24+810	23+800 to 10+080	Yes	Watercourse	
Haldimand	21-467/C	10+715	10+080 to 11+340	Yes	Watercourse	
Haldimand	CV-0401-001858	11+705	11+340 to 11+705	No	Non-watercourse outlets through forest to watercourse	
Haldimand	CV-0401-001857	12+090	11+705 to 12+090	No	Non-watercourse ditch to watercourse	Drains to watercourse at 12+420
Haldimand	21-468/C	12+420	12+090 to 12+420	Yes	Watercourse	
Haldimand	CV-0401-001855	12+720	12+420 to 13+030	No	Non-watercourse outlets through forest to watercourse	Flows south through woodlot
Haldimand	CV-0401-001873	13+030	13+030 to 13+660	No	Non-watercourse outlets through forest to watercourse	Flows south through woodlot
Haldimand	21-469/C	14+135	13+660 to 14+150	No	Non-watercourse outlets through forest to watercourse	Flows south through woodlot
Haldimand	21-270/C	14+200	14+150 to 14+660	Yes	Watercourse	
Haldimand	CV-0401-001791/825	14+660	14+660 to 15+020	No	Non-watercourse ditch to watercourse	Routed to SWMF at 14+660 in existing conditions
Haldimand	CV-0401-001721	15+150	15+020 to 15+400	No	Watercourse	Routed to SWMF at 14+660 in existing conditions
Haldimand	CV-0401-001885/824	15+480	15+400 to 16+040	No	Non-watercourse outlets through forest to watercourse	
Haldimand	CV-0401-001912	16+390	16+040 to 16+500	No	Non-watercourse ditch to forest	Flows south along east side of Lyle St
Haldimand	CV-0401-001908/880	16+620	16+500 to 16+650	No	Non-watercourse ditch to forest	Flows south along east side of Lyle St
Haldimand	21-470/C	17+170	16+650 to 17+640	Yes	Watercourse	
Haldimand	CV-0401-001862	17+640	17+640 to 18+100	No	Non-watercourse ditch to watercourse	Flows to watercourse at 17+170
Haldimand	21-272/C	19+340	18+100 to 20+000	Yes	Watercourse	Shelter Valley Creek
Haldimand	CV-0401-001893	20+590	20+000 to 20+800	Yes	Watercourse	
Haldimand	CV-0401-001906	20+930	20+800 to 21+000	No	Non-watercourse ditch to watercourse	Flows south to watercourse on east side of Vernonville Rd
Haldimand	CV-0401-001907	21+030	21+000 to 21+100	Yes	Watercourse	
Haldimand	CV-0401-001854	21+615	21+100 to 21+620	No	Non-watercourse ditch to watercourse	May discharge into ponds on private property (at Station 22+000) before outletting into watercourse
Haldimand	21-576/C	22+125	21+620 to 22+200	Yes	Watercourse	
Haldimand	CV-0401-001853	22+315	22+200 to 22+450	Yes	Watercourse	
Haldimand	CV-0401-001914	22+480	22+450 to 22+600	No	Non-watercourse to open field/pasture	Potential for erosion/flooding downstream in field, small dry channel bed present across field
Haldimand	CV-0401-001852	22+700	22+600 to 23+600	No	Watercourse	
Haldimand	CV-0401-001851	23+770	23+600 to 24+700	Yes	Watercourse	
Haldimand	CV-0401-001850	24+940	24+700 to 10+250	No	Non-watercourse ditch through forest to watercourse	Flows south towards Dudley Rd
Cramahe	CV-0401-001837	10+396	10+250 to 10+750	No	Non-watercourse ditch through forest to watercourse	Flows south towards Dudley Rd
Cramahe	CV-0401-001835	11+143	10+750 to 11+300	Yes	Watercourse	
Cramahe	CV-0401-001910	11+478	11+300 to 12+250	No	Non-watercourse ditch to watercourse	Flows to watercourse at 11+143

To quantify the increase in peak flows, a hydrologic model was developed to assess flows from existing and proposed drainage catchments. The proposed conditions include a higher impervious percentage that represents the highway widening. Preliminary model results show that the flows increase from existing to proposed conditions as shown in Table 13 for the existing outlets.

Table 14 shows the flow increase for culverts incorporating the flow from upstream culverts considered for abandonment.

Table 13: Proposed Flow Increases for Centreline Culverts

Catchment ID (DAID)	Geographic Township	Station	Drainage Area	Percent Flow Increase		
				5 -year Event	50-year Event	100-year Event
CV-0401-001882	Hamilton	23+330	8.1	12.36	7.30	6.61
CV-0401-002059*	Hamilton	23+605	10.5	4.15	2.52	2.17
CV-0401-001881	Hamilton	24+810	253.5	1.59	1.06	0.98
21-467/C	Haldimand	10+715	337.3	0.74	0.51	0.46
CV-0401-001858	Haldimand	11+705	54.8	1.99	1.42	1.30
CV-0401-001857	Haldimand	12+090	10.1	5.92	3.98	3.61
21-468/C	Haldimand	12+420	229.8	0.67	0.44	0.40
CV-0401-001855*	Haldimand	12+720	23.6	16.49	8.96	7.83
CV-0401-001873	Haldimand	13+030	38.3	6.01	3.62	3.26
21-469/C	Haldimand	14+135	45.1	5.38	3.29	3.01
21-270/C	Haldimand	14+200	1911.6	0.00	0.00	0.00
CV-0401-001791/825*	Haldimand	14+660	11.7	13.19	7.51	6.85
CV-0401-001721*	Haldimand	15+150	5.3	9.47	5.84	5.30
CV-0401-001885/824	Haldimand	15+480	21.8	10.23	7.09	6.47
CV-0401-001912	Haldimand	16+390	12.5	8.29	5.37	4.87
CV-0401-001908/880	Haldimand	16+620	9.8	8.89	5.69	5.31
21-470/C	Haldimand	17+170	276.9	0.79	0.54	0.49
CV-0401-001862	Haldimand	17+640	15.5	14.05	8.68	8.00
21-272/C	Haldimand	19+340	6045.4	0.00	0.00	0.00
CV-0401-001893	Haldimand	20+590	186.9	2.58	1.72	1.59
CV-0401-001906*	Haldimand	20+930	14.6	2.92	1.79	1.66
CV-0401-001907	Haldimand	21+030	41.0	2.33	1.59	1.41
CV-0401-001854	Haldimand	21+615	4.7	10.27	6.75	6.16
21-576/C	Haldimand	22+125	749.9	1.06	0.65	0.59
CV-0401-001853	Haldimand	22+315	35.3	3.46	2.09	1.81
CV-0401-001914	Haldimand	22+480	10.1	9.17	5.87	5.25
CV-0401-001852	Haldimand	22+700	85.6	1.82	1.16	1.05
CV-0401-001851	Haldimand	23+770	481.1	0.67	0.46	0.43
CV-0401-001850	Haldimand	24+940	28.6	6.69	4.54	4.16
CV-0401-001837	Cramahe	10+396	14.5	12.50	7.90	7.25
CV-0401-001835	Cramahe	11+143	110.6	1.25	0.85	0.77
CV-0401-001910	Cramahe	11+478	47.5	2.61	1.68	1.55

Notes: *** Denotes culverts proposed to be abandoned**

Table 14: Proposed Flow increases for Centreline Culverts Conveying Flows from Abandoned Culverts

Catchment ID (DAID)	Geographic Township	Station	Drainage Area	Percent Flow Increase		
				5 -year Event	50-year Event	100-year Event
CV-0401-001882 (including CV-0401-002059	Hamilton	23+330	29.04	7.72	4.77	4.33
21-468/C (including CV-0401-001855)	Haldimand	12+420	253.35	0.79	0.50	0.46
21-270/C (including CV-0401-001791/825)	Haldimand	14+200	1923.25	0.01	0.01	0.01
CV-0401-001885/824 (including CV-0401-001721)	Haldimand	15+480	27.08	10.97	6.81	6.26
CV-0401-001907 (including CV-0401-001906)	Haldimand	21+030	55.6	2.58	1.76	1.58

Any outlet not located directly on a natural watercourse has some potential drainage risk such as downstream flooding, erosion, or scour which could be attributed to MTO. Natural watercourses typically have a defined bed, banks, and floodplain that provide stability and resilience against seasonal or storm-based fluctuation in flow. Culverts discharging to natural watercourses do not pose a risk as those systems convey water year-round and can adapt to minor changes in hydraulic condition. Where culverts outlet to a non-watercourse the potential for flood damage depends on the downstream receiver. Unimproved lands (wetland and forests) have generally reached a steady state and are resistant to further damage. Improved lands (agricultural land or lawns) are often not in a steady state (with active farming / plowing). The improved lands also tend to be actively monitored where flood damage (erosion and property flooding) is readily visible.

Most complaints resulting from MTO drainage onto adjacent property tend to be from non-watercourse outlets onto improved land.

7.3 Stormwater Management Design Alternatives

A Stormwater Management (SWM) strategy was considered as a method to minimize/mitigate environmental impacts due to the proposed highway improvements. A range of SWM controls are available on any given site, and an evaluation of site conditions and physical constraints is required to determine which options are most appropriate. Physical constraints include topography, soils, bedrock elevation, groundwater elevation, and drainage area. Various design alternatives were considered for the overall SWM strategy including:

- **Distributed or Lot Level Controls:** Lot level controls include vegetated conveyance systems such as grassed swales, vegetated buffer strips, and filter strips which provide passive water quality treatment for adjacent roads, primarily filtering sediments and heavy metals prior to out-letting. Additional treatment can also be provided with the use of enhanced grass swales which utilize permanent rock check dams used to reduce in-channel flow velocities to allow finer sediment to settle. Distributed infiltration measures such as infiltration trenches, porous pavements, and sand filters provide water quantity benefits while also contributing to groundwater levels
- **End-of-Pipe Controls:** End-of-Pipe storage facilities such as wet ponds, dry ponds, constructed wetlands, and infiltration basins can be effective control measures, providing both water quality and quantity control measures

7.4 Proposed Stormwater Management Design Strategy

The proposed SWM strategy was designed to meet SWM design guidelines and policies as outlined in the MTO *Drainage Management Manual* (1997), the Ministry of the Environment *Stormwater Management Planning and Design Manual* (2003) and the MTO *Highway Drainage Design Standards* (HDSS) (2008).

Industry-standard approaches to assessing the potential for hydrologic impacts related to changes in the amount of urban impervious coverage, as supported by literature (*Impacts of Impervious Cover on Aquatic System, Watershed Protection Research Monograph No. 1*, Schueler, T., Center for Watershed Protection, March 2003 and *The Importance of Imperviousness, from Watershed Protection Techniques, Vol. I, No.3 - Fall 1994*, Schueler, T., Centre for Watershed Protection, 1994), generally conclude that watersheds typically maintain pre-development hydrology characteristics until they exceed 10-15% impervious coverage. Of the 32 catchments within the Study limits, 11 have a proposed imperviousness greater than 10% and of those 11 catchments, 7 are proposed to have SWM facilities to control flows. The remaining 4 catchments are relatively small (10 to 30 ha) and are positioned parallel to the highway (a high percentage of the catchment consists of roadway. No significant downstream impacts are anticipated from widening the highway at these outlets due to the minor increase in flows (less than 10%).

Water quantity controls should be considered for locations that experience a significant increase in peak flows resulting from the proposed highway widening and associated increase in impervious area. End-of-pipe dry and/or wet facilities may be required at locations where the highway widening has caused flows to increase by a significant amount (>10%). Hydrologic modelling (as discussed in Section 3.0) was performed to quantify the increase in runoff resulting from highway widening within the median and the ditches.

In total, eight locations requiring SWM controls were identified within the study area. Seven locations were identified as having significant increases in peak flow (>10%) that require quantity controls. One of these seven locations is a site that would receive flow diverted from an abandoned culvert (Culvert 000904010071/44 at Haldimand Township Station 15+480, includes flows from the abandoned CV-0401-001721), and both alternatives were modelled and presented in Table 15.

An additional site (Culvert CV-0401-001914 at Haldimand Township Station 22+480) experiences a 9% increase in peak flow due to highway widening and was noted to be upstream of agricultural/improved land. As discussed in Section 6.2, outlets discharging to non-watercourse receivers can present risks associated with potential damage to downstream properties during high flows. The outlet at Station 22+480 – Haldimand has been included in the areas proposed for SWM control due to these circumstances.

The hydrologic modelling software HEC-HMS was used to determine preliminary storage volumes required to control the post-construction peak flows to the existing conditions. The increase in peak flows at these locations is caused only by the highway widening, and there are no hydrologic changes occurring outside of the right-of-way. To control the increased runoff from the widened highway, it is proposed that dry pond facilities be established at locations that will capture median and ditch runoff where flows have increased by a significant margin.

To reduce the potential for damage to downstream properties, the identified areas will be subject to stormwater management controls to reduce the peaks to the existing flow rates. The SWM facilities will be located on the south (downstream) side of Highway 401 and attenuate drainage from the median and the south ditch. They will discharge to the centreline culvert outlet so that the total flows are maintained below the existing levels.

The locations requiring quantity control and the corresponding required storage volumes are stated in Table 15 below.

Table 15: Proposed SWMF Locations and Storage Volumes

Culvert ID (DAID)	Township	Station	Contributing Drainage Area (ha)	Existing 100-year flow (m^3/s)	Proposed Conditions 100-year Flow (Uncontrolled) (m^3/s)	Proposed Conditions 100-year Flow (Controlled) (m^3/s)	Required Storage Volume (m^3)
CV-0401-001882	Hamilton	23+330	1.94	0.70	0.74	0.65	450
CV-0401-001855	Haldimand	12+720	1.59	0.61	0.66	0.59	1,450
CV-0401-001791/825	Haldimand	14+660	1.41	0.58	0.62	0.55	1,100
CV-0401-001885/824	Haldimand	15+480	3.07	1.55	1.65	1.51	1,250
* CV-0401-001885/824 (including flows redirected from CV-0401-001721)	Haldimand	15+480	3.70	1.98	2.10	1.89	1,250
CV-0401-001862	Haldimand	17+640	2.22	0.98	1.05	0.95	1,100
CV-0401-001854	Haldimand	21+615	0.93	0.57	0.60	0.54	250
CV-0401-001914	Haldimand	22+480	0.74	0.46	0.48	0.45	550
CV-0401-001837	Cramahe	10+396	2.52	1.12	1.20	1.06	800

Notes: * Denotes alternative situation in the event that a culvert is abandoned.

Dry facilities are recommended for all proposed locations identified in Table 15 based on the maximum suitable drainage area of 5 ha for dry facilities as stated in SW-2 of the MTO HDSS. Note that the required storage volume of the SWM facilities required at station 15+480 is the same regardless of whether culvert 00090401068 is abandoned and its flows are routed to 00904010071/44. Given that flows for the catchment corresponding to culvert 00904010068 experience a 9.5% increase (as listed in Table 13) it is highly recommended that flows are routed to the proposed SWMF at station 15+480 regardless of whether culvert 00904010068 is abandoned.

Aerial imagery shows that there are existing SWM facilities within the study area. Known SWM facilities are located at Station 14+660 (Culvert ID 00904010065/46) and within the interchanges at Lyle Street North (Within the E-N/S ramp and N/S-E ramp) and potentially one dry facility on the west side of the E – N/S ramp at Percy Street. Details on exact limits or design of these existing facilities was not available at the time of this report. Given that there are not existing SWM facilities at all locations identified in Table 15, it is possible that land acquisition beyond the right-of-way may be required in order to satisfy the SWM constraints. All locations where property acquisition may be required as a result of SWM controls has been identified in the Recommended Drainage Plans included in Appendix A.

Each facility was designed to use the available space efficiently and reduce the amount of land to be acquired. Typically facilities assume a long and narrow footprint with a low slope to fit in the right-of-way There are some locations where steep slopes within the existing topography do not allow for this configuration and the facilities must be made wider to produce sufficient storage volume to reduce peak flows. If local topography does not provide sufficient gradient to meet the minimum 0.5% slope, wet ponds may need to be considered at a future design stage.

It is necessary to calculate footprint of the proposed dry SWM facilities in order to determine the amount of land required to achieve the peak flow reductions discussed in this section. All SWM facilities were modelled as dry retention areas within the roadside ditch. Footprints were calculated assuming the facilities are trapezoidal ditches with 3:1 side slopes, depth's ranging from 1 – 1.5 m, and bottom slopes ranging from of 0.5 - 3%. Maximum depth and slope were selected to fit each location. The bottom width of the dry retention facility was adjusted until the required storage was achieved.

Some of the proposed SWM facilities receive highway drainage from only one side of the outlet, while others receive drainage from both sides of the outlet (east and west). Facilities that receive drainage from only one direction require a single SWM facility upstream of the main outlet to control peak flows from that portion of the highway. Areas that receive drainage from both directions are proposed to have SWM facilities on either side of the main outlet to adequately control peak flows and avoid routing highway drainage across existing culverts, channels, or other flow paths. Table 16 shows the proportions of the total controlled drainage area that flow from the east or west to each culvert outlet location. Where two SWM facilities are required, the sizes for each are provided in Table 16.

Table 16: Proposed SWMF Area Requirements

Culvert ID (DAID)	Township	Station	Contributing Drainage Area (ha)		Bottom Width (m)		Top Width (m)		Length (m)		Depth (m)		Slope (%)		Required SWMF area (m^2) (Flow storage area only)		Total Required SWMF Area (m^2) (Flow storage + buffer)	
			From West	From East	West	East	West	East	West	East	West	East	West	East	West	East	West	East
CV-0401-001882	Hamilton	23+330	-	1.94	N/A	6.0	N/A	15.0	N/A	75	N/A	1.5	N/A	2	N/A	1,125	N/A	2,175
CV-0401-001855	Haldimand	12+720	0.79	0.8	3.5	3.5	12.5	12.5	150	150	1.5	1.5	1	1	1,875	1,875	3,625	3,625
CV-0401-001791/825	Haldimand	14+660	-	1.41	N/A	2.0	N/A	11.0	N/A	300	N/A	1.5	N/A	0.5	N/A	3,300	N/A	6,520
CV-0401-001885/824	Haldimand	15+480	0.38	2.69	1.5	2.0	7.5	11.0	100	300	1	1.5	1	0.5	750	3,300	1,900	6,520
* CV-0401-001885/824 (including flows redirected from CV-0401-001721)	Haldimand	15+480	1.67	2.03	3.0	2.5	9.0	11.5	200	150	1	1.5	0.5	1	1,800	1,725	3,980	3,455
CV-0401-001862	Haldimand	17+640	-	2.22	N/A	2	N/A	11.0	N/A	300	N/A	1.5	N/A	0.5	N/A	3,300	N/A	6,520
CV-0401-001854	Haldimand	21+615	0.93	-	0.5	N/A	9.5	N/A	100	N/A	1.5	N/A	1.5	N/A	950	N/A	2,140	N/A
CV-0401-001914	Haldimand	22+480	-	0.74	N/A	12	N/A	21.0	N/A	50	N/A	1.5	N/A	3	N/A	1,050	N/A	1,970
CV-0401-001837	Cramahe	10+396	0.76	1.76	0.5	2	6.5	11.0	200	150	1	1.5	0.5	1	1,300	1,650	3,430	3,370

Notes: * Denotes alternative situation in the event that a culvert is abandoned

Additional area is required to accommodate service and maintenance access areas, grading, and other potential requirements to satisfy regulatory and design criteria in addition to the area required for flow storage. The facility footprint was estimated by assuming a 10 m buffer on the upstream and downstream ends of each facility as well as along the highway ditch of the flow storage footprint required to accommodate storage volumes listed in Table 15. Precise dimensions and the configuration of each facility will need to be refined at a future design stage.

The dry facilities are all proposed to exist within the ditch parallel to Highway 401 with the exception of the facility at Station 23+330 (Township of Hamilton) at culvert CV-0401-001882. The facility at Station 23+330 (Township of Hamilton) will be located parallel and to the east of the receiving watercourse, perpendicular to the ditches alongside Highway 401 to avoid complications with steep topography sloping south away from the highway.

The proposed facility at Station 12+720 (Township of Haldimand) at culvert CV-0401-001855 is not required if this culvert is abandoned. Since the area to this culvert is relatively small, the increase in flows from the highway widening is more significant. If abandoned and redirected to the nearby structural culvert, the increase in flow is minimal since the upstream catchment to the structural culvert is so large. This facility has been included in the table above to provide the option for if this culvert is not able to be abandoned down the line.

Water quality control is required at all outlets and is provided by vegetated ditches as well as dry SWM facilities. The storm sewer system should be designed to outlet a minimum of 100 m from the nearest watercourse in order to provide sufficient length of water quality control in the ditch, where possible. Oil and grit separator units or other Low Impact Development (LID) Features can also be used to provide water quality control as required.

Vegetated ditches are recommended as the primary water quality controls for enhancing the storm drainage from the proposed highway and will provide sufficient water quality control for the highway. In addition to being consistent with design features typically implemented in highway drainage systems, these types of water quality features typically have lower maintenance costs than centralized stormwater management basins.

It is recommended that water quality control be provided for the highway through the use of grass swales. The MTO HDSS (SW-3) requires that roadside ditches have a minimum base width of 1.0 m and a minimum length of 40 m. Highway embankments can also be used to improve water quality. The highway embankment should be a minimum 3.0 m in length measured from the edge of the shoulder to the invert of the roadside ditch to maximize sediment removal. This is most important for road areas that do not drain to a roadside ditch but drain directly to a watercourse.

Highway embankments and roadside ditches should be planted with dense vegetation to prevent erosion and trap sediments. Check dams can be used along steep grades to reduce velocities and erosion.

7.5 Storm Sewers

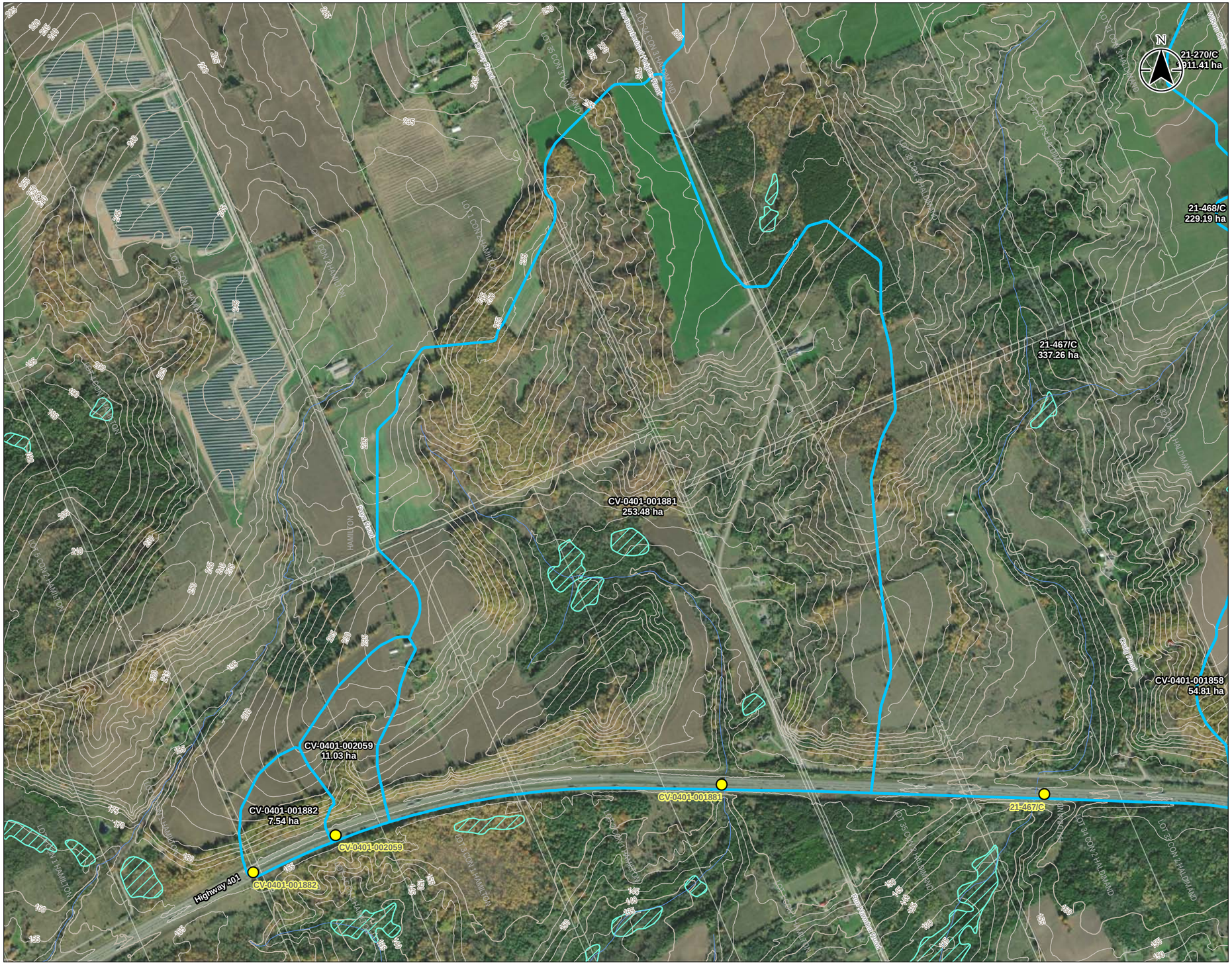
The existing and proposed highway designs include a paved median with concrete tall wall with a storm sewer system draining the middle lanes of the highway. Under proposed conditions, the area draining to the median is not expected to change significantly as the existing crown locations will be preserved. A small superelevated area (~1.6 km in length) of the highway consists of a grassed median which will also not experience significant hydrologic changes. Water quality control for the highway is recommended to be provided using grass swales and dry ponds. Where possible, the storm sewer will be designed to outlet approximately 100 to 200 m away from the nearest watercourse in order to provide water quality control for the road right-of-way. The storm sewer system will outlet to the downstream side of the highway where possible so that the capacity of the centreline culverts will not be affected.

8.0 Conclusions and Recommendations

Based on the culvert inspection, hydrological and hydraulic analysis of the culverts along the Highway 401 within the study area, it is concluded/recommended that;

- Based on the existing conditions culvert inspection of 32 centreline culverts; Eight culverts are proposed to be retained and 17 culverts are proposed to be replaced as summarized in Table 11.
- Nine new culverts are required to adequately drain the Lyle Street interchange, all of which are proposed to be 800 mm diameter CSP.
- 11 new culverts are required to drain the Percy Street interchange, ranging in size and material from 800 mm diameter CSP to 2400 x 1500 mm concrete box.
- Seven Structural Culverts within the study area are discussed under a separate cover. Proposed structural culvert rehabilitations or replacements with the same or larger hydraulic capacity as the existing structures will meet all MTO hydraulic requirements. Site 21-469/C will still meet MTO hydraulic requirements if lined with a 3.4 m x 1.8 m CSP arch culvert.
- Five culverts being considered for abandonment can successfully have flows diverted to downstream existing culverts. The downstream culverts have hydraulic capacity for the increased flow; however, abandonment will ultimately depend on whether ditches can be graded to convey flows from abandoned sites to the downstream culverts.
- A series of dry SWM facilities will be required within the study area to provide water quantity control to mitigate higher peak flow rates after the highway widening. The proposed dry SWM facilities range in volume from 250 m^3 to 1450 m^3 and in surface area from 800 m^2 to 5750 m^2.
- Water quality control is provided through the use of grass swales under the existing and proposed conditions.

APPENDIX A:
Figures



Stantec

Legend

- Culvert Location
- Culvert Catchment Area
- Watercourse (Intermittent)
- Watercourse (Permanent)
- Contour (20 m Interval)
- Contour (5 m Interval)
- Wetland, Not evaluated per OWES
- Lot

0 300 600 metres

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Notes

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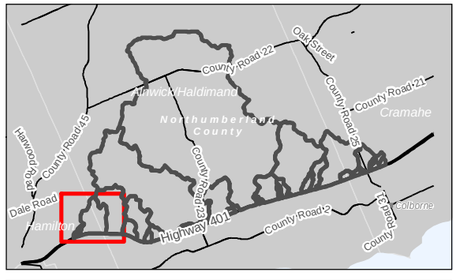

Project Location
County of Northumberland

165001090 REVA
Prepared by BCC/JW on 2020-12-08

Client/Project
MINISTRY OF TRANSPORTATION ONTARIO (MTO)
HWY 401 PD COBOURG TO COLBORNE

Figure No.
1

Title
Culvert Drainage Area

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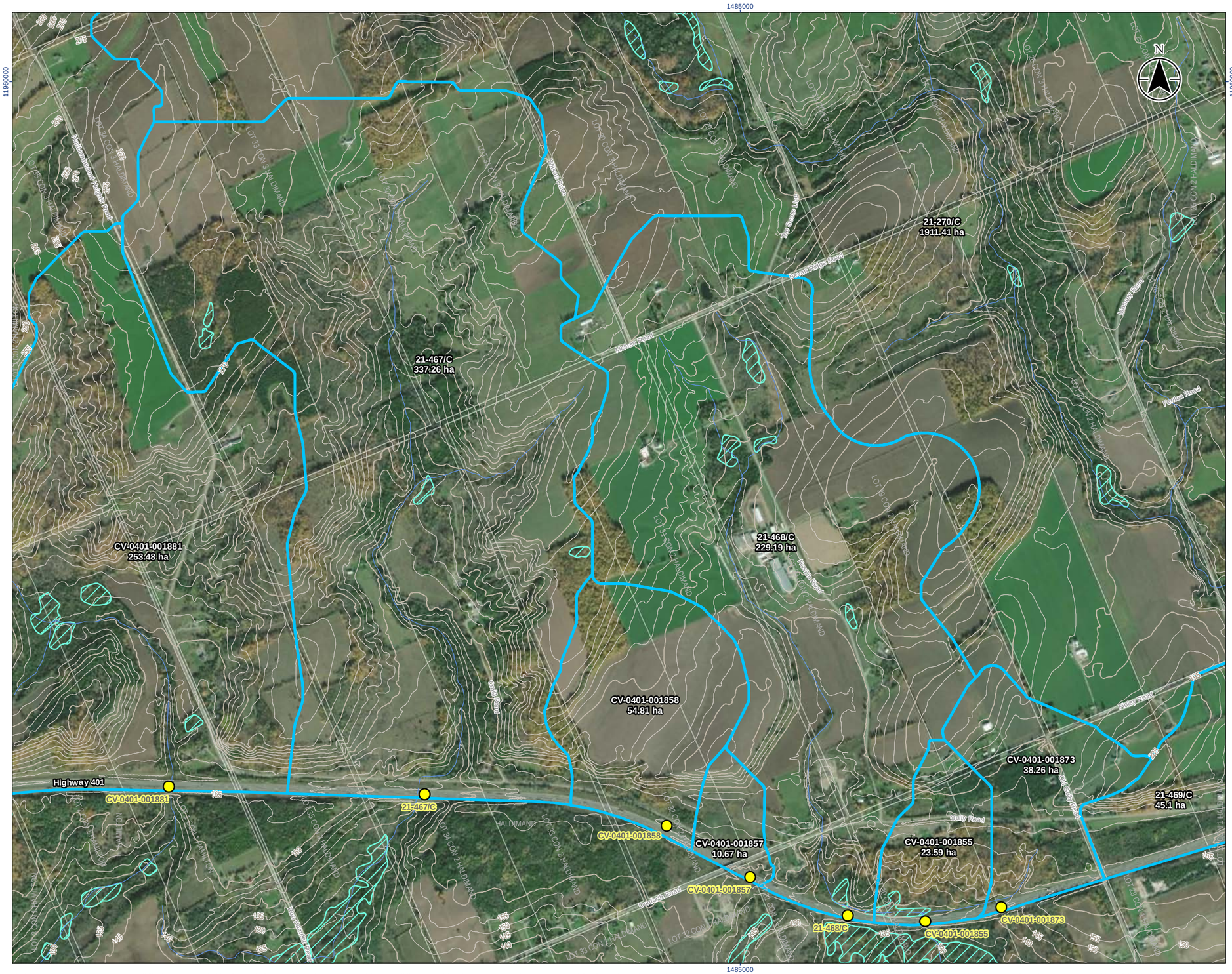
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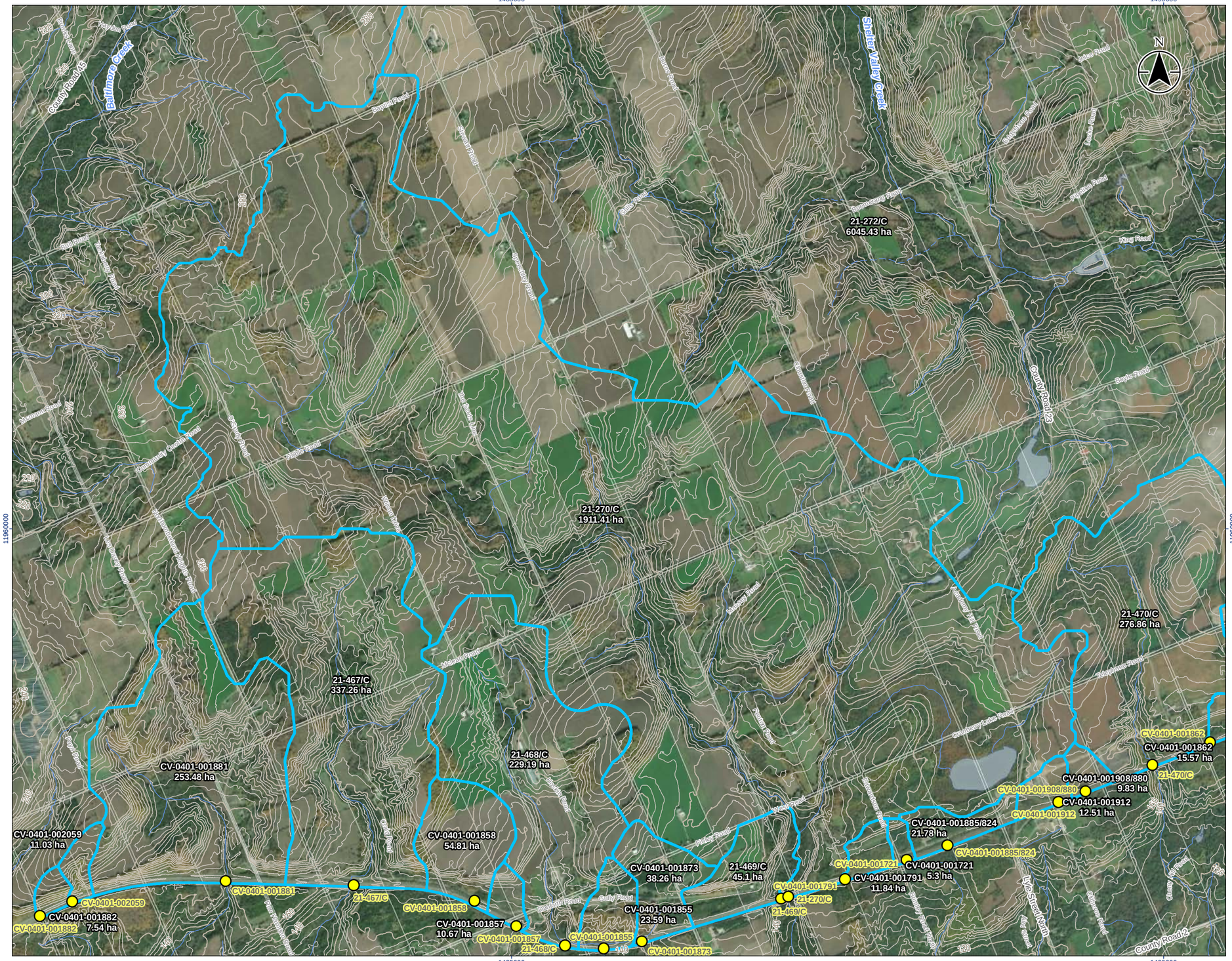
11960000
N
21-270/C
1911.41 ha
21-467/C
337.26 ha
21-468/C
229.19 ha
CV-0401-001881
253.48 ha
CV-0401-001858
54.81 ha
CV-0401-001873
38.26 ha
21-469/C
45.1 ha
CV-0401-001857
10.67 ha
CV-0401-001855
23.59 ha
Highway 401
Mcleod Road
Regent Ridge Road
Wilson Pierce
Jug Creek
Nelson Road
Perkins Road
Hagan Road
Bailey Road
Gully Road
Ireland Road
Burnham Road
Lot 34 Con 2 Haldimand
Lot 33 Con 3 Haldimand
Lot 32 Con 4 Haldimand
Lot 31 Con 5 Haldimand
Lot 30 Con 6 Haldimand
Lot 29 Con 7 Haldimand
Lot 28 Con 8 Haldimand
Lot 27 Con 9 Haldimand
Lot


1485000
1490000
11960000
Shelter Valley Creek
Baltimore Creek
County Road 45
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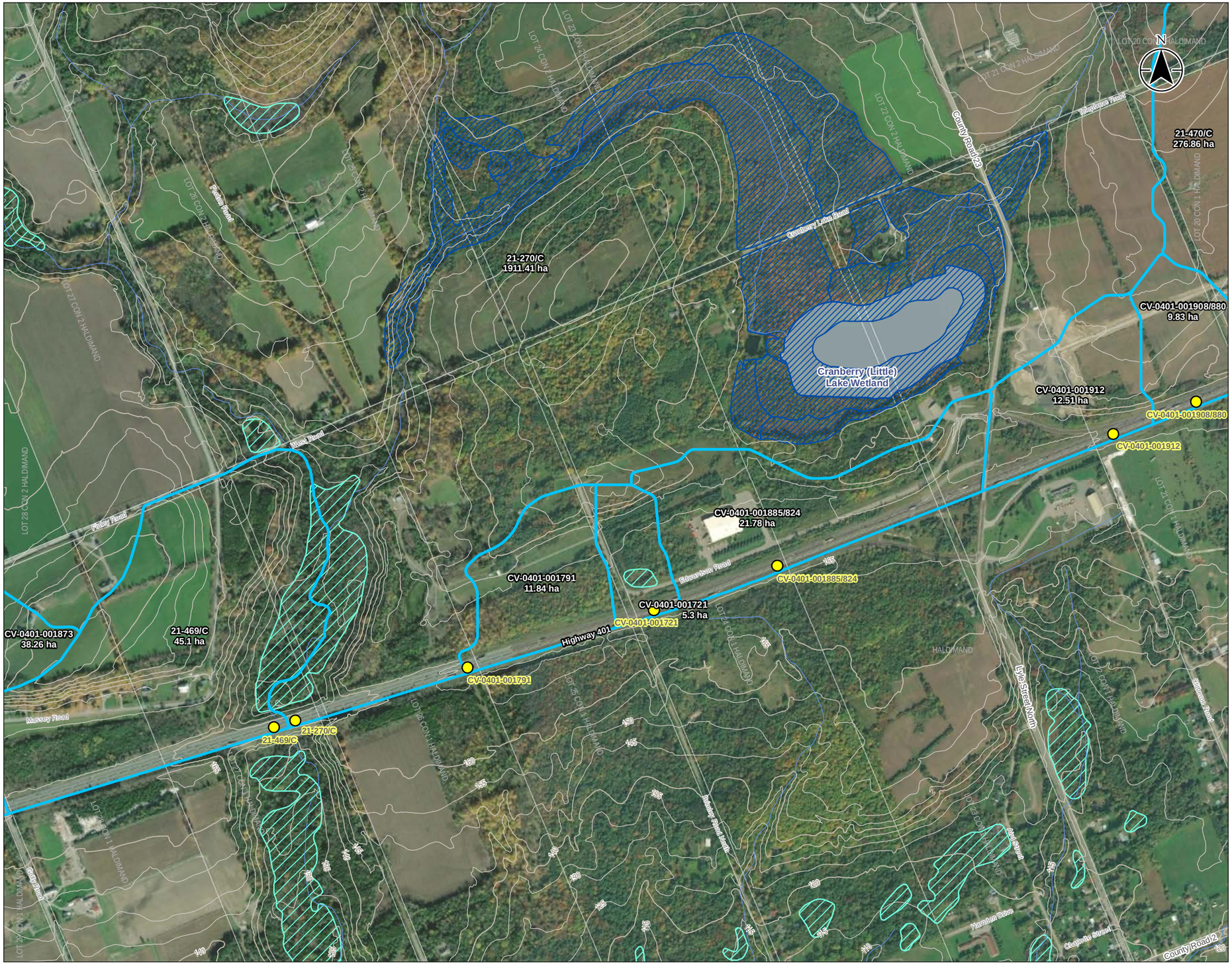
6045.43 ha
21-270/C
1911.41 ha
21-467/C
337.26 ha
21-468/C
229.19 ha
21-469/C
45.1 ha
21-470/C
276.86 ha
CV-0401-001881
253.48 ha
CV-0401-002059
11.03 ha
CV-0401-001882
7.54 ha
CV-0401-001858
54.81 ha
CV-0401-001857
10.67 ha
CV-0401-001855
23.59 ha
CV-0401-001873
38.26 ha
CV-0401-001791
11.84 ha
CV-0401-001721
5.3 ha
CV-0401-001885/824
21.79 ha
CV-0401-001908/880
9.83 ha
CV-0401-001912
12.51 ha
CV-0401-001862
15.57 ha
County Road 2
Boyds Road
Bagnall Road
Seymour Road
Grills Road
Bunce Road
Elizabeth Road
Lester Road
Pipeline Road
King Road
Seymour Lake Road
Mapleton Road
Mapleton Line
Mapleton Hills Road
Maple Road
Middle Road
Cuddy Road
Telephone Road
Tulip Road
Tulip Rd
Ivy Street North
Ivy Street
Cobourg
Colborne
Hamilton
Dale Road
Hamilton Township
Northumberland County
Cramahe
Alnwick/Haldimand
County Road 22
County Road 21
County Road 45
County Road 25
County Road 23
Highway 401
Oak Street
Peter Road
Cuddy Road
Red Mill Road
Mill Street
Mill Street North
Cobourg Lake Road
Bowmanton Road
Bowmanton Line
Bowmanton Hills Road
Peter Street
Peter Road
Maple Grove Road
Maple Grove
Mapleton Road
Mapleton Line
Mapleton Hills Road
Hamilton Township Hills Road
Low Bridge Road
Peter Street
Peter Road
Cuddy



Legend

- Culvert Location
- Culvert Catchment Area
- Watercourse (Intermittent)
- Watercourse (Permanent)
- Contour (20 m Interval)
- Contour (5 m Interval)
- Wetland, Provincially Significant
- Wetland, Not evaluated per OWES
- Lot
- Waterbody

0 250 500 metres

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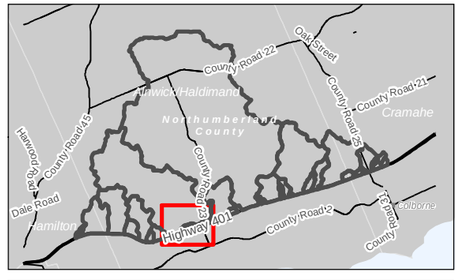

Project Location
County of Northumberland

165001090 REVA
Prepared by BCC/JW on 2020-12-08

Client/Project
MINISTRY OF TRANSPORTATION ONTARIO (MTO)
HWY 401 PD COBOURG TO COLBORNE

Figure No.
4

Title
Culvert Drainage Area

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1490000

11960000

11960000

1490000

Shelter Valley Complex

21-272/C
6045.43 ha

21-470/C
276.86 ha

21-270/C
1911.41 ha

CV-0401-001862
15.57 ha

CV-0401-001908/880
9.83 ha

CV-0401-001912
12.51 ha

CV-0401-001885/824
21.78 ha

Cranberry (Little) Lake Wetland

Shelter Valley Creek

County Road 22

Highway 401

Massey Road

Cranberry Lake Road

Annicky Hill Road

Telephone Road

Brodin Road

Dale Road

Hamilton

Cramahe

Colborne

HALDIMAND

Stantec

Legend

- Culvert Location
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0 300 600 metres

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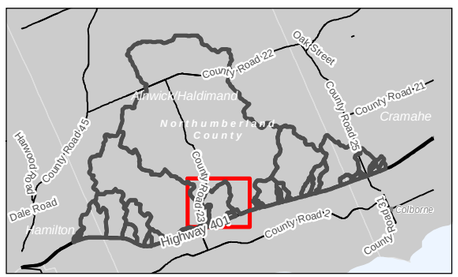

Project Location
County of Northumberland

165001090 REVA
Prepared by BCC/JW on 2020-12-08

Client/Project
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HWY 401 PD COBOURG TO COLBORNE

Figure No.
5

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Culvert Drainage Area

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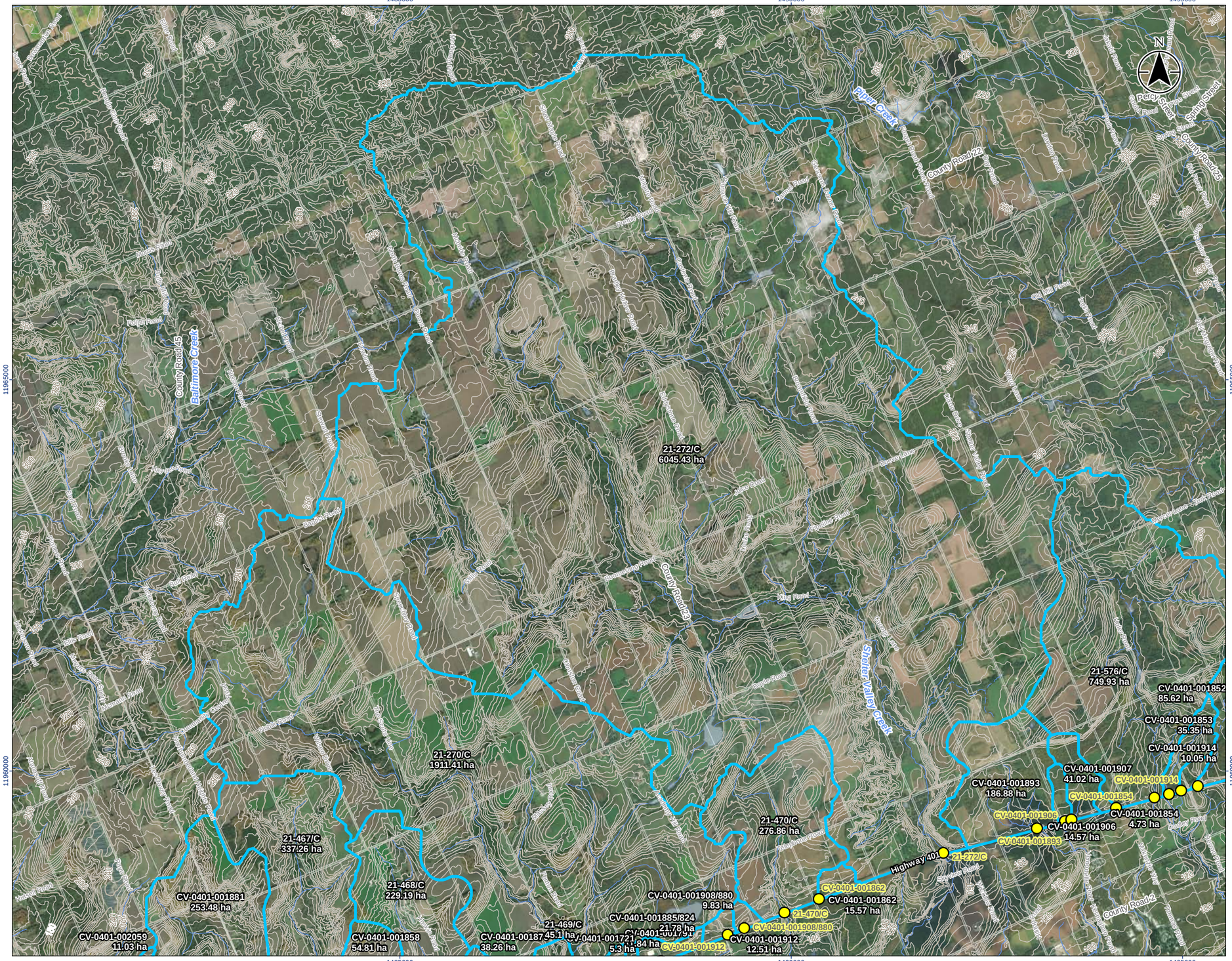

Stantec

Legend

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0 1,250 2,500 metres

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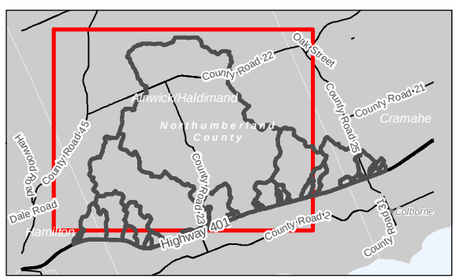

Project Location
County of Northumberland

165001090 REVA
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Client/Project
MINISTRY OF TRANSPORTATION ONTARIO (MTO)
HWY 401 PD COBOURG TO COLBORNE

Figure No.
6

Title
Culvert Drainage Area

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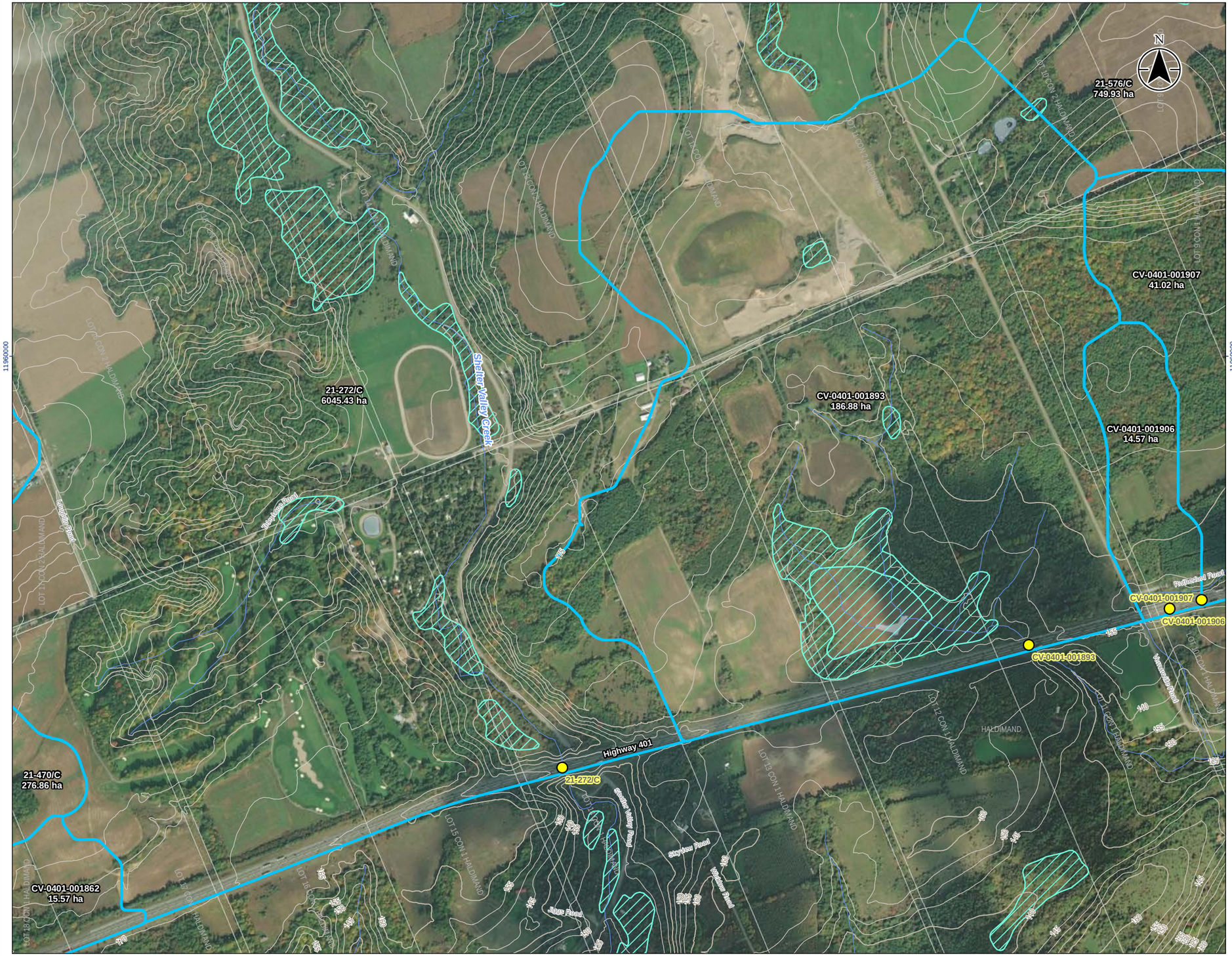

Stantec

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- Contour (5 m Interval)
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- Lot
- Waterbody

0 250 500 metres

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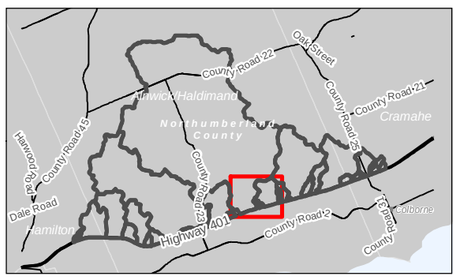

Project Location
County of Northumberland

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Client/Project
MINISTRY OF TRANSPORTATION ONTARIO (MTO)
HWY 401 PD COBOURG TO COLBORNE

Figure No.
7

Title
Culvert Drainage Area

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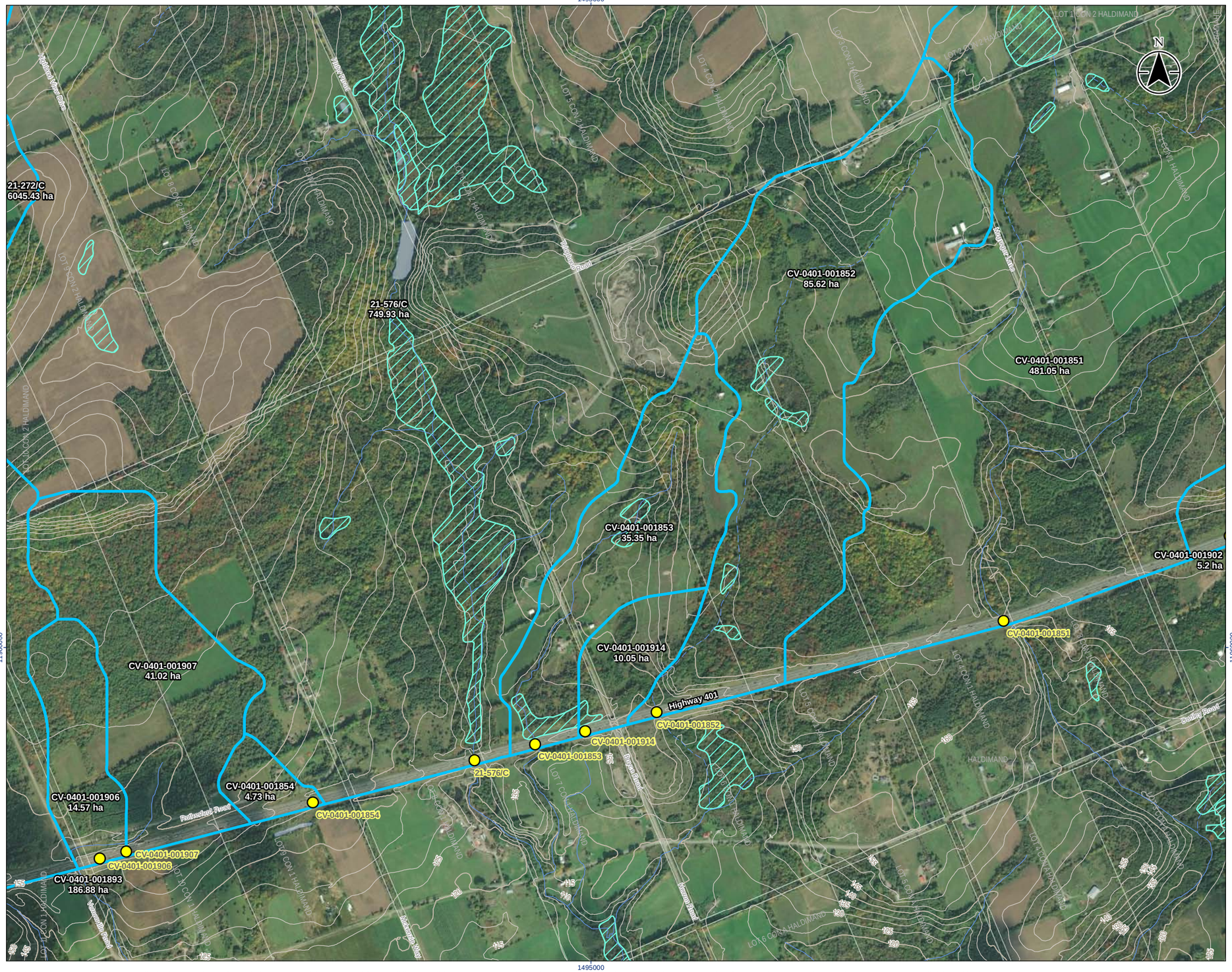
Revised: 2020-12-08 By: jswimmer
\\CA1224-f021\work_group\00650\active\165001090\preliminary\gis\MXD\Water Resources\Report\Figure\165001090_WR_fig_1_to_10_Culvert_Catchments_v6r2.mxd



Stantec

Legend

- Culvert Location
- Culvert Catchment Area
- Watercourse (Intermittent)
- Watercourse (Permanent)
- Contour (20 m Interval)
- Contour (5 m Interval)
- Wetland, Not evaluated per OWES
- Lot
- Waterbody

0 300 600 metres

1:12,000 (At original document size of 11x17)

Notes

1. Coordinate System: NAD 1983 Lambert Conformal Conic
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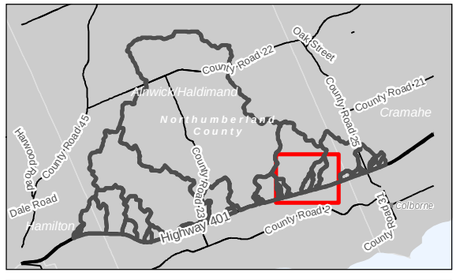
3. Orthoimagery Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.



Project Location
County of Northumberland

165001090 REVA
Prepared by BCC/JW on 2020-12-08

Client/Project
MINISTRY OF TRANSPORTATION ONTARIO (MTO)
HWY 401 PD COBOURG TO COLBORNE

Figure No.
8

Title
Culvert Drainage Area

\\Cd1224-f021\work_group\01650\active\165001090\preliminary\gis\MXD\Water Resources\Report\figures\165001090_WR_fig_1_to_10_Culvert Catchments_ver3.mxd Revised: 2020-12-08 By: jswanner

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1495000

11960000

1496000

21-272/C
6045.43 ha

21-576/C
749.93 ha

CV-0401-001851
481.05 ha

CV-0401-001835
110.62 ha

CV-0401-001852
85.62 ha

CV-0401-001837
14.48 ha

CV-0401-001850
28.59 ha

CV-0401-001902
5.2 ha

CV-0401-001853
35.35 ha

CV-0401-001914
10.05 ha

CV-0401-001893
186.88 ha

CV-0401-001907
41.02 ha

CV-0401-001854
4.73 ha

CV-0401-001906
14.57 ha

Cold Creek N Wetland Compl

Turk Road

Meyers Lane

County Road 25

Highway 401

Telephone Road

Bowmanville Road

Baldwin Road

Bethany Road

Brimacombe Road

Bowmanville Creek

Bethany Creek

Highland West Branch

Stantec

Legend

- Culvert Location
- Culvert Catchment Area
- Watercourse (Intermittent)
- Watercourse (Permanent)
- Contour (20 m Interval)
- Contour (5 m Interval)
- Wetland, Provincially Significant
- Wetland, Not evaluated per OWES
- Lot
- Waterbody

0 500 1,000 metres

1:20,000 (At original document size of 11x17)

Notes

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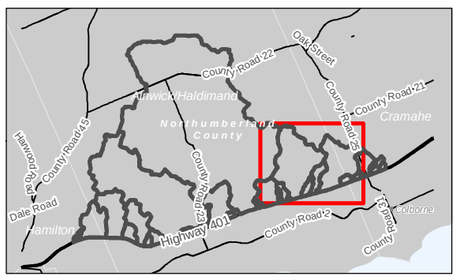
3. Orthoimagery Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.



Project Location
County of Northumberland

165001090 REVA
Prepared by BCC/JW on 2020-12-08

Client/Project
MINISTRY OF TRANSPORTATION ONTARIO (MTO)
HWY 401 PD COBOURG TO COLBORNE

Figure No.
9

Title
Culvert Drainage Area

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Revised: 2020-12-08 By: jswimmer
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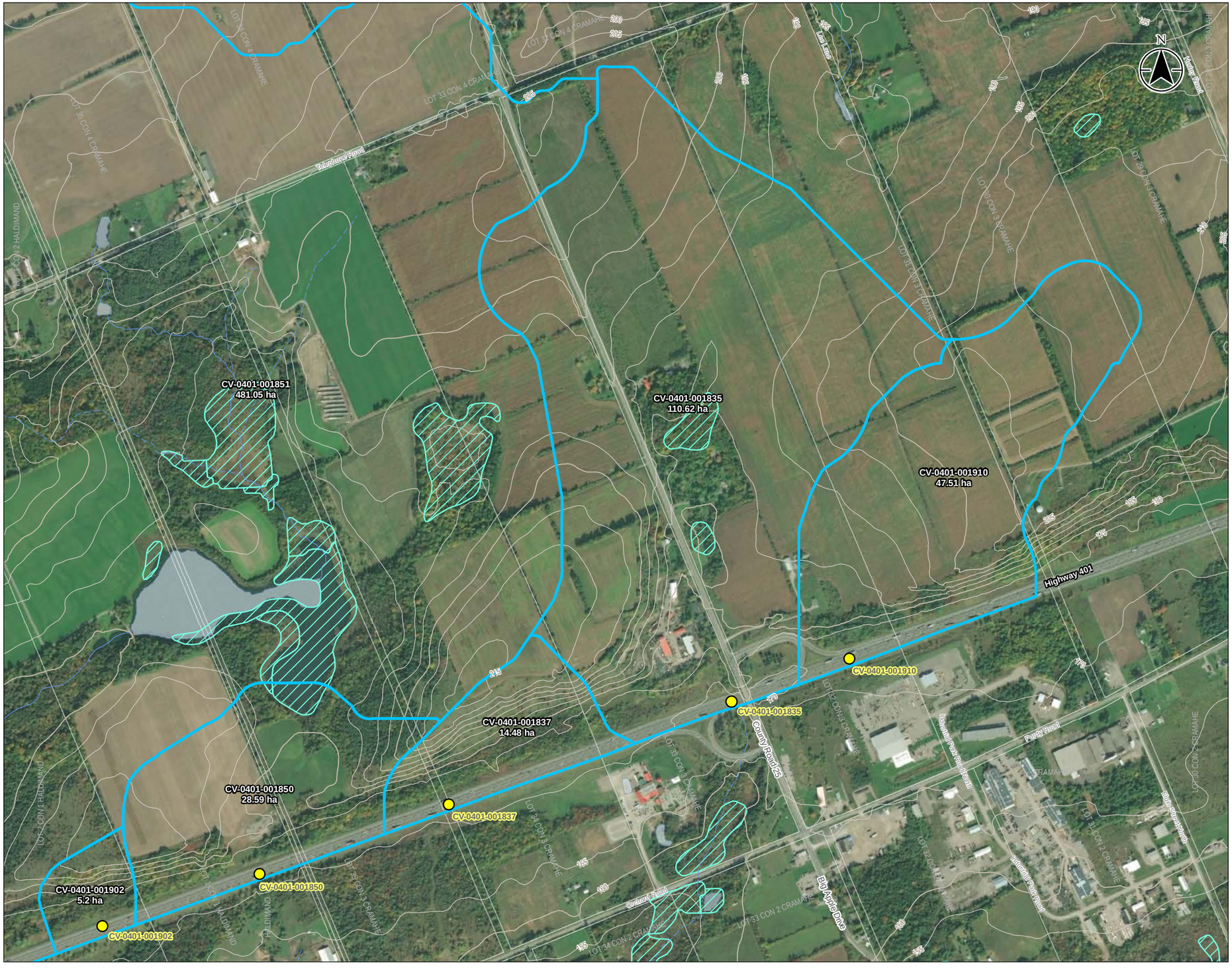

Stantec

Legend

- Culvert Location
- Culvert Catchment Area
- Watercourse (Intermittent)
- Watercourse (Permanent)
- Contour (20 m Interval)
- Contour (5 m Interval)
- Wetland, Not evaluated per OWES
- Lot
- Waterbody

0 250 500 metres

1:10,000 (At original document size of 11x17)

Notes

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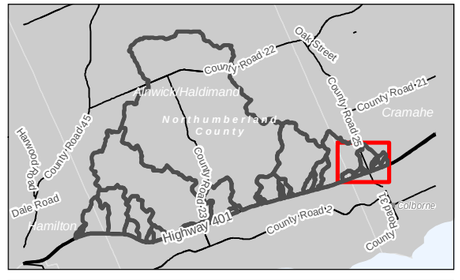

Project Location
County of Northumberland

165001090 REVA
Prepared by BCC/JW on 2020-12-08

Client/Project
MINISTRY OF TRANSPORTATION ONTARIO (MTO)
HWY 401 PD COBOURG TO COLBORNE

Figure No.
10

Title
Culvert Drainage Area

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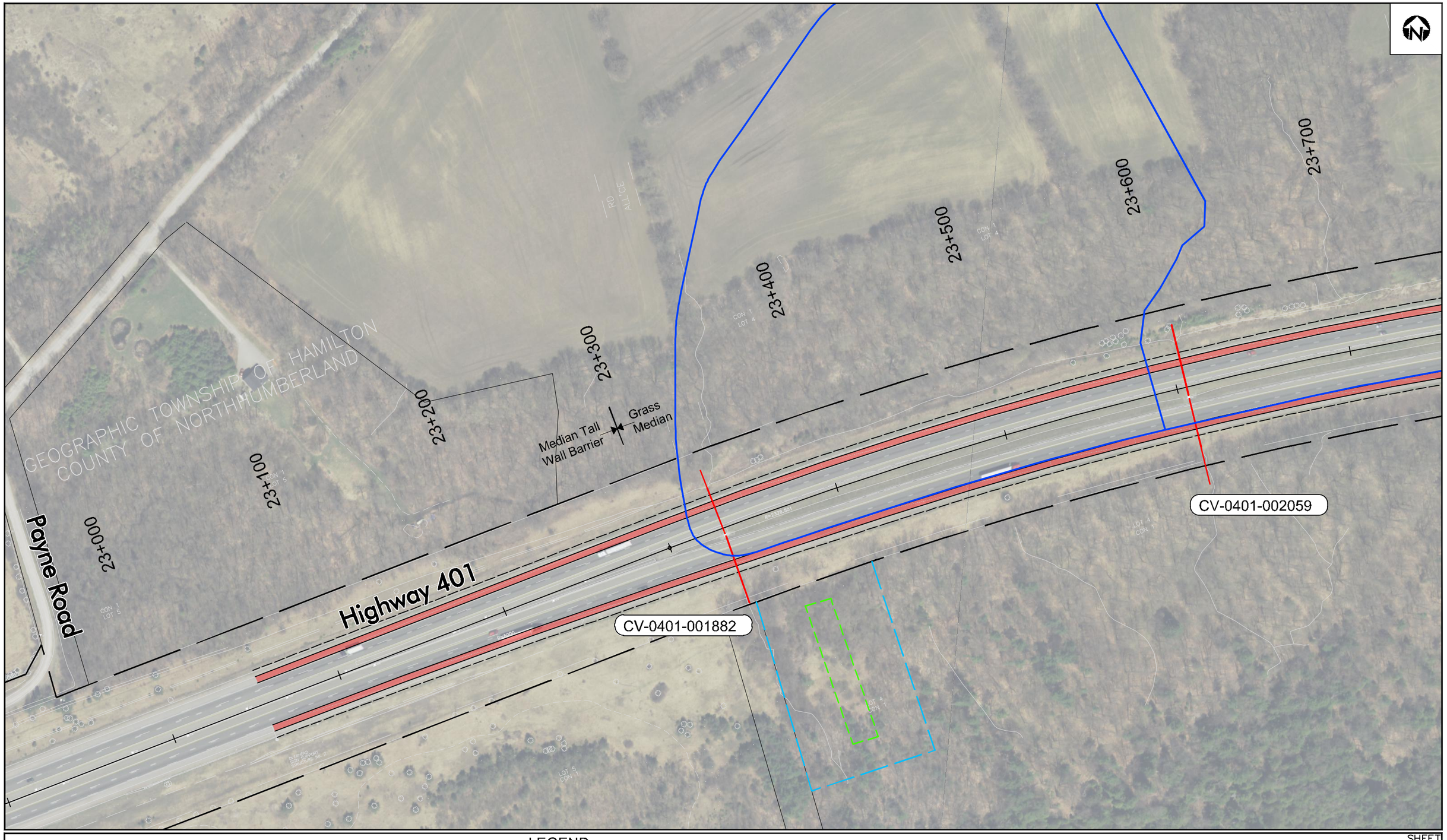
\\Cd1220-f021\work_group\01650\active\165001090\preliminary\gis\MXD\Water Resources\Report\figures\165001090_WR_fig_1_to_10_Culvert_Catchments_ver3.mxd Revised: 2020-12-08 By: jswanmer



HIGHWAY 401 Planning Study
from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

Stantec

LEGEND

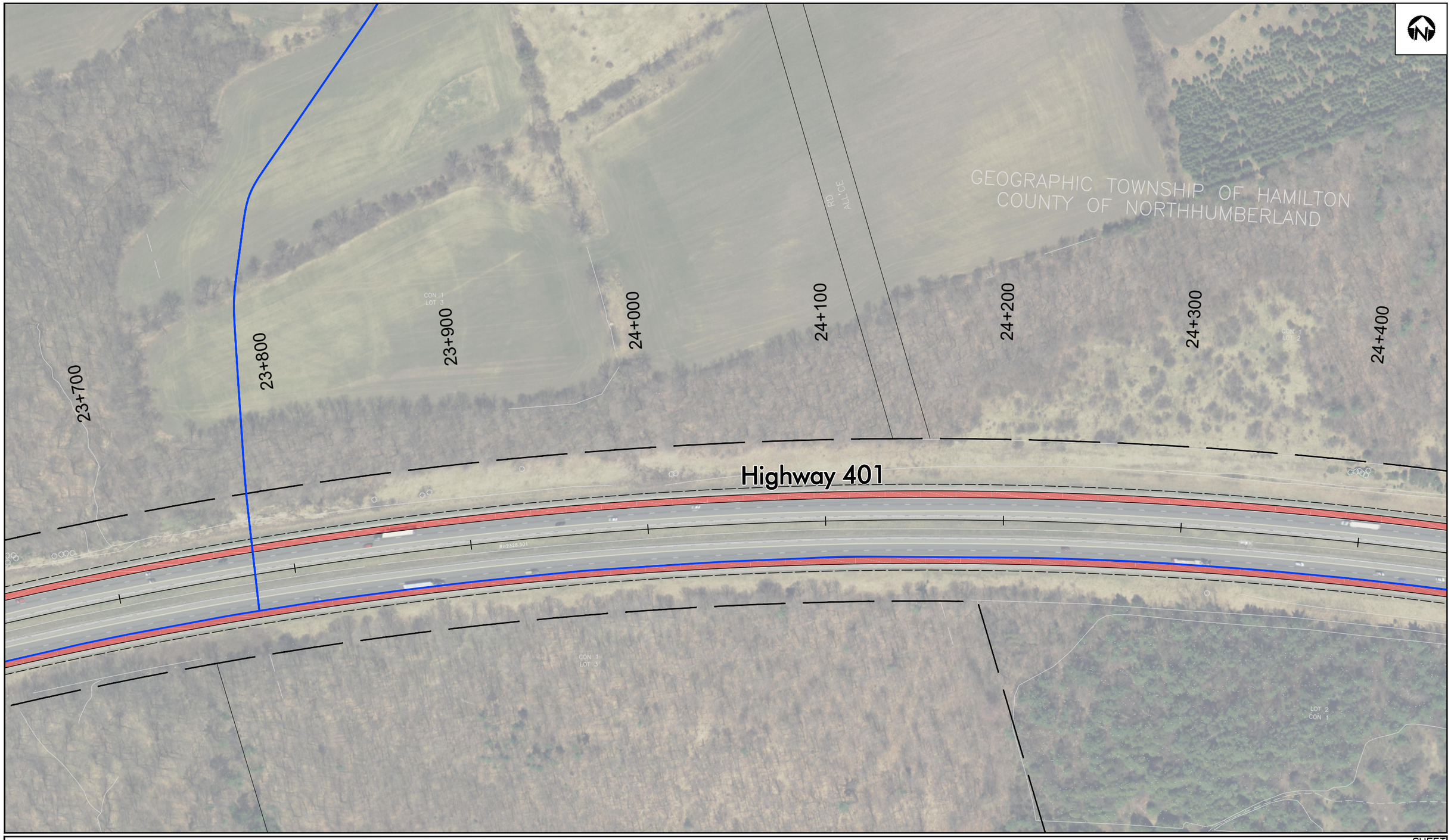
- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan

HIGHWAY 401
Sta 23+000 to Sta 23+700
Hamilton Township

SHEET
1



Stantec

HIGHWAY 401 Planning Study

from Cobourg to Colborne

Preliminary Design &

Class Environmental Assessment

GWP 4060-11-00

LEGEND

- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m

1:2000

Recommended Drainage Plan

HIGHWAY 401

Sta 23+700 to Sta 24+400

Hamilton Township

SHEET 2

GEO. TWP OF HAMILTON
CNTY OF NORTHHUMBERLAND

GEO. TWP OF
HALDIMAND
CNTY OF
NORTHHUMBERLAND

Township
of
Alnwick/Haldimand

Township
of
Hamilton

Northumberland
Heights Road

Ron Harnden Road

Highway 401

24+400
24+500
24+600
24+700
24+800
24+900
25+000
10+000
10+100

CV-0401-001881

Grass
Median

Median Tall
Wall Barrier

CON 1
LOT 1

CON 2
LOT 35

LOT 2
CON 1

LOT 1
CON 1

Stantec

HIGHWAY 401 Planning Study
from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

LEGEND

- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan
HIGHWAY 401
Sta 24+400 to Sta 10+100
Hamilton & Haldimand Townships

SHEET
3

GEOGRAPHIC TOWNSHIP OF HALDIMAND
COUNTY OF NORTHHUMBERLAND

ALL. CE RD

CON 2
LOT 35

CON 2
LOT 34

10+100
10+200
10+300
10+400
10+500
10+600
10+700
10+800

Northumberland Heights Road

Highway 401

Site 21X-0467/CO

Ron Harnden Road

LOT 35
CON 2

LOT 35
CON 2

Township
of
Alnwick/Haldimand

HIGHWAY 401 Planning Study
from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

Stantec

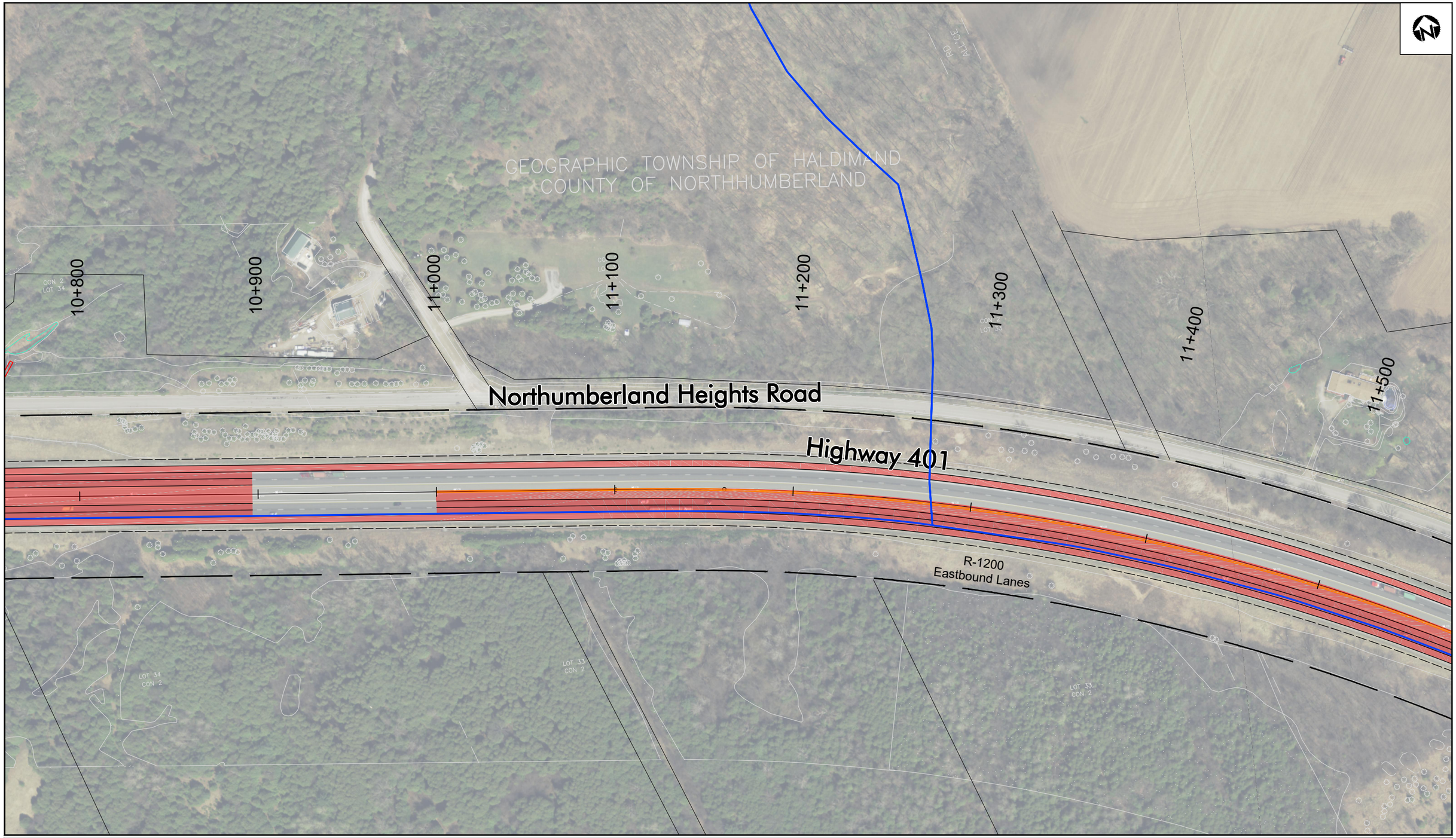
LEGEND

- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan
HIGHWAY 401
Sta 10+100 to Sta 10+800
Haldimand Township

SHEET
4



Stantec

HIGHWAY 401 Planning Study
from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

LEGEND

- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan
HIGHWAY 401
Sta 10+800 to Sta 11+500
Haldimand Township

SHEET
5

GEOGRAPHIC TOWNSHIP OF HALDIMAND
COUNTY OF NORTHUMBERLAND

11+500
11+600
11+700
11+800
11+900
12+000
12+100
12+200
9+800
9+900
10+000
10+100
10+200
R-30

Northumberland Heights Road

Highway 401

Danforth Road

R-1200
Eastbound Lanes

CV-0401-001858

CV-0401-001857

Danforth Road

HIGHWAY 401 Planning Study
from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

Stantec

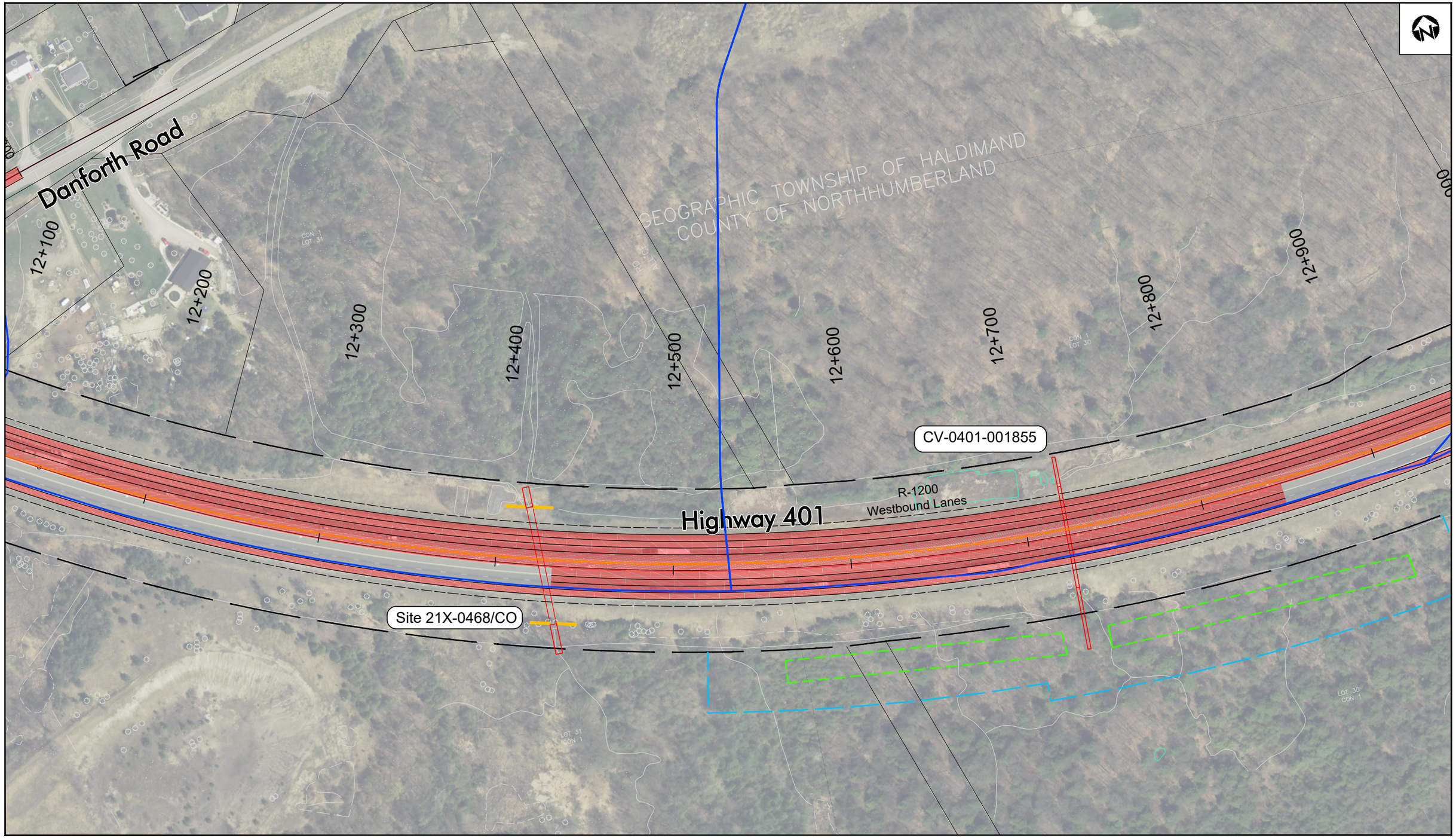
LEGEND

- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan
HIGHWAY 401
Sta 11+500 to Sta 12+200
Haldimand Township

SHEET
6



Stantec

HIGHWAY 401 Planning Study

from Cobourg to Colborne

Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

LEGEND

- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan

HIGHWAY 401
Sta 12+200 to Sta 12+900
Haldimand Township

SHEET
7

GEOGRAPHIC TOWNSHIP OF HALDIMAND
COUNTY OF NORTHHUMBERLAND

Massey Road

Highway 401

Gully Road

CV-0401-001873

12+900
13+000
13+100
13+200
13+300
9+835
13+400
9+900
13+500
13+600
10+000
10+100
10+200

CON 1
LOT 28
LOT 29
CON 1

HIGHWAY 401 Planning Study
from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

Stantec

LEGEND

- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan
HIGHWAY 401
Sta 12+900 to Sta 13+600
Haldimand Township

SHEET
8

GEOGRAPHIC TOWNSHIP OF HALDIMAND
COUNTY OF NORTHUMBERLAND

Massey Road

13+600
13+700
13+800
13+900
14+000
14+100
14+200
14+300

Griffin Creek

Highway 401

Site 21X-0469/CO

Site 21X-0270/CO

NOTE 1
DENSE WOODS

NOTE 2
DENSE WOODS

NOTE 3
DENSE WOODS

NOTE 4
DENSE WOODS

NOTE 5
DENSE WOODS

NOTE 6
DENSE WOODS

NOTE 7
DENSE WOODS

NOTE 8
DENSE WOODS

CON 1
LOT 28

LOT 28
CON 1

LOT 27
CON 1

RD
ALL'CE

RD
ALL'CE

Stantec

HIGHWAY 401 Planning Study
from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

LEGEND

- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan
HIGHWAY 401
Sta 13+600 to Sta 14+300
Haldimand Township

SHEET
9

GEOGRAPHIC TOWNSHIP OF HALDIMAND
COUNTY OF NORTHHUMBERLAND

Grafton Creek

14+300
14+400
14+500
14+600
14+700
14+800
14+900
15+000

CV-0401-001791

Highway 401

NOTE 8 DENSE WOODS
NOTE 9 DENSE WOODS
NOTE 7 DENSE WOODS
NOTE 10 DENSE WOODS
NOTE 11 DENSE WOODS

CON 1 LOT 26
CON 1 LOT 25
LOT 26 CON 1
LOT 25 CON 1
RD ALL'CE

HIGHWAY 401 Planning Study
from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

Stantec

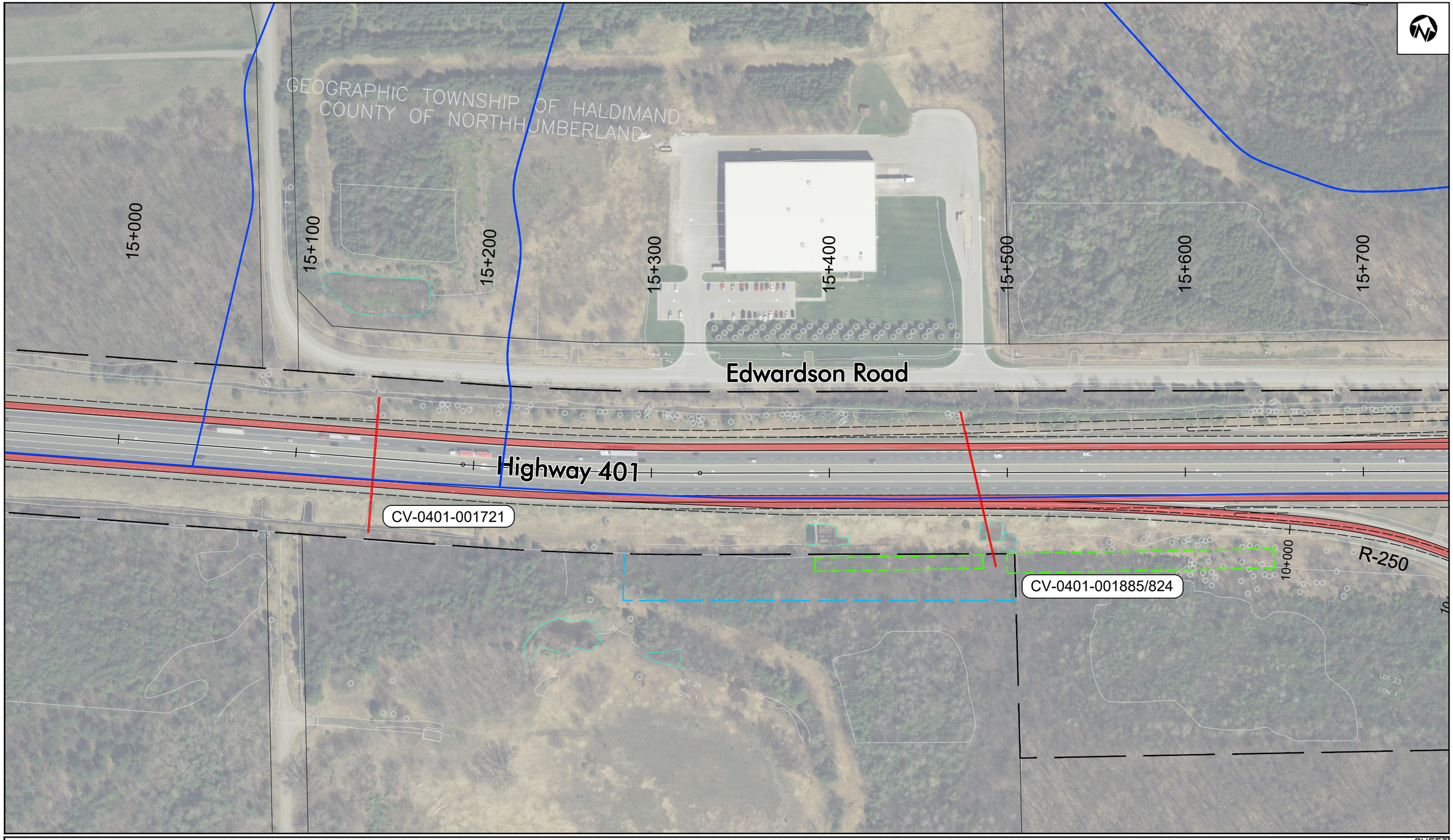
LEGEND

- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan
HIGHWAY 401
Sta 14+300 to Sta 15+000
Haldimand Township

SHEET
10



HIGHWAY 401 Planning Study
from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

Stantec

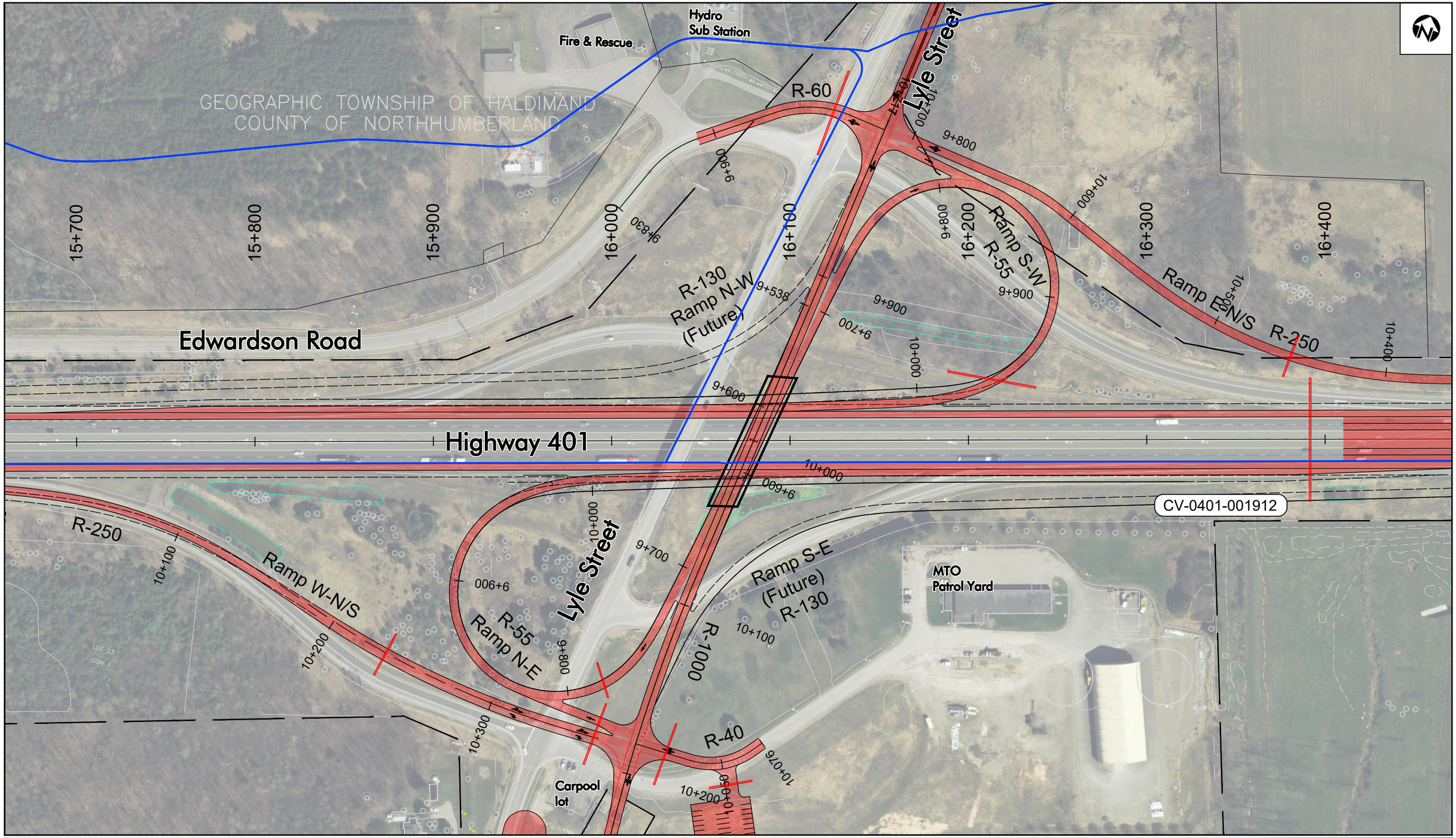
LEGEND

- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan
HIGHWAY 401
Sta 15+000 to Sta 15+700
Haldimand Township

SHEET
11



Stantec

HIGHWAY 401 Planning Study

from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

LEGEND

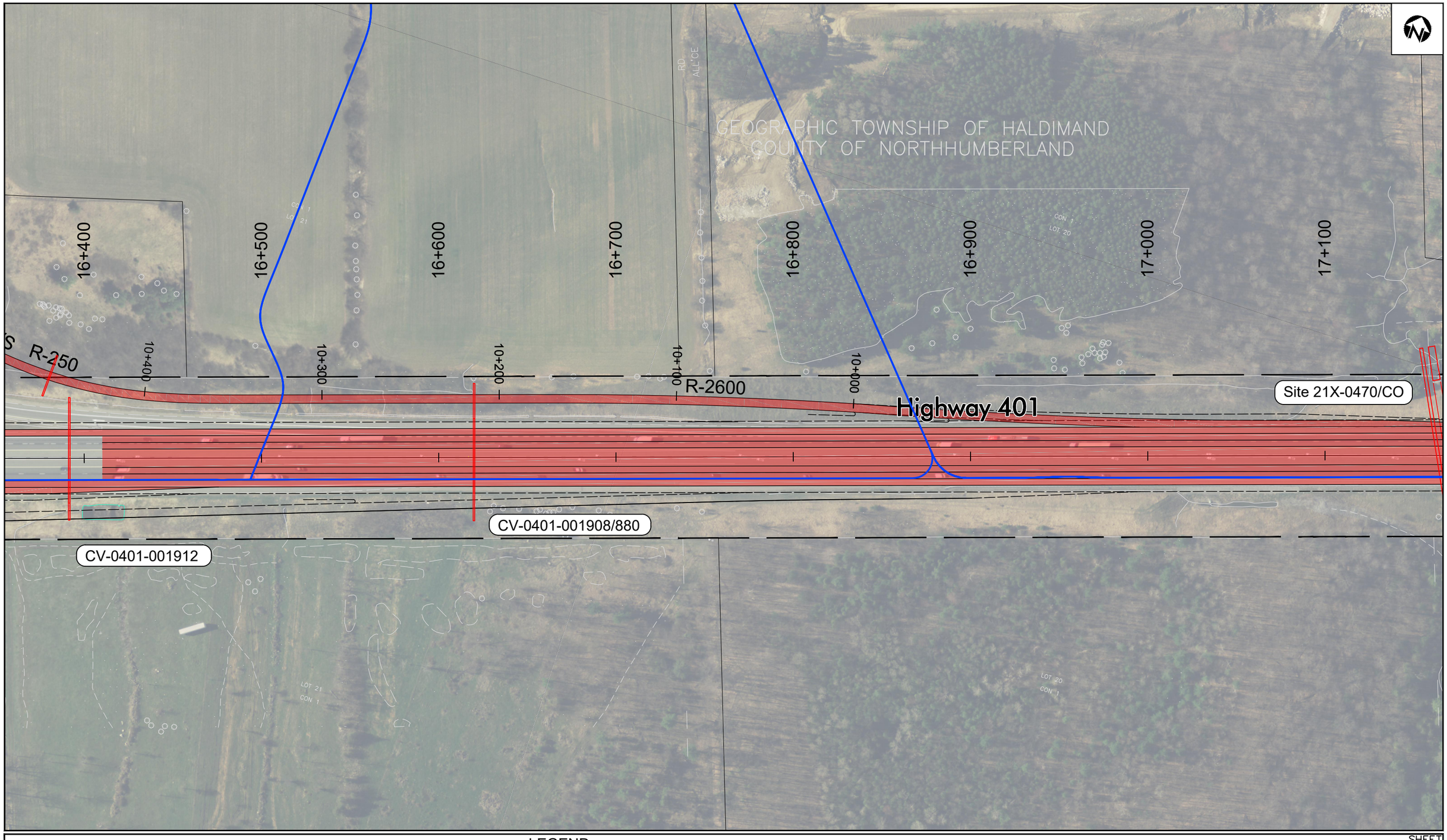
- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan

HIGHWAY 401
Sta 15+700 to Sta 16+400
Haldimand Township

SHEET
12



HIGHWAY 401 Planning Study
from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

Stantec

LEGEND

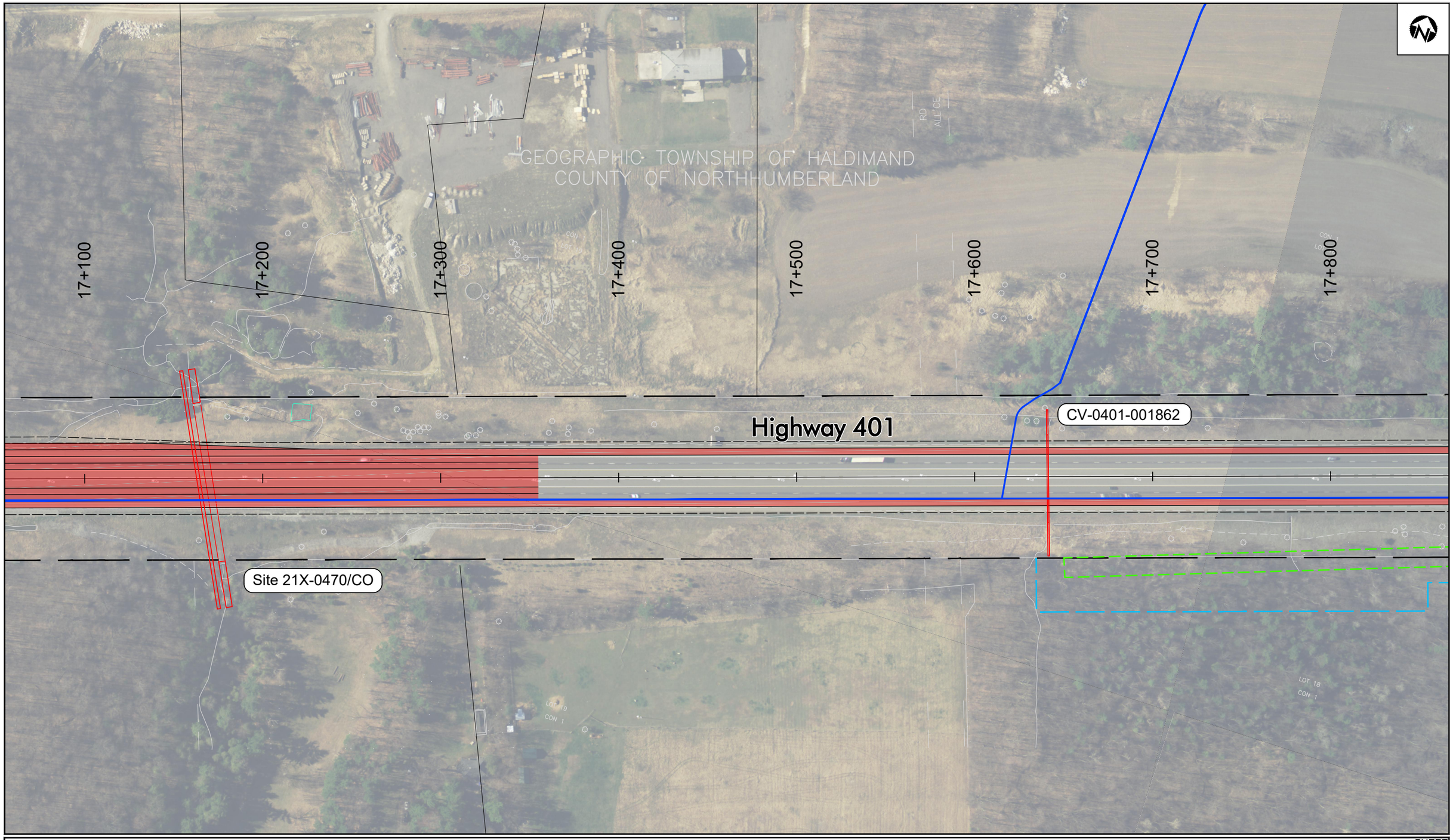
- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan

HIGHWAY 401
Sta 16+400 to Sta 17+100
Haldimand Township

SHEET
13



HIGHWAY 401 Planning Study
from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

Stantec

LEGEND

- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan
HIGHWAY 401
Sta 17+100 to Sta 17+800
Haldimand Township

SHEET
14

GEOGRAPHIC TOWNSHIP OF HALDIMAND
COUNTY OF NORTHUMBERLAND

17+800
17+900
18+000
18+100
18+200
18+300
18+400
18+500

Highway 401

RD ALLOCE

CON 1 LOT 18
CON 1 LOT 17

HIGHWAY 401 Planning Study
from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

Stantec

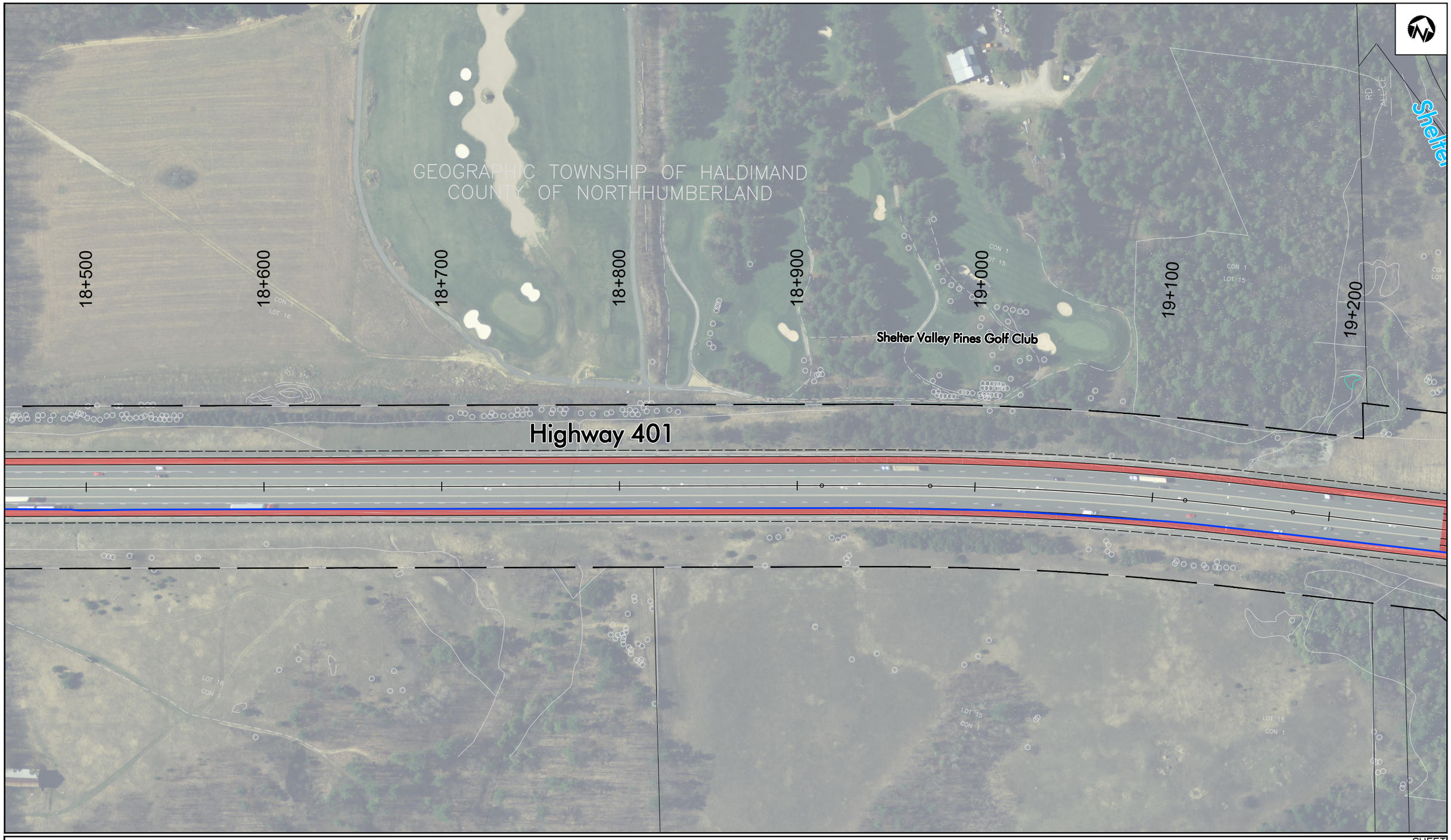
LEGEND

- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan
HIGHWAY 401
Sta 17+800 to Sta 18+500
Haldimand Township

SHEET
15



Stantec

HIGHWAY 401 Planning Study
from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

LEGEND

- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan
HIGHWAY 401
Sta 18+500 to Sta 19+200
Haldimand Township

SHEET
16

Shelter Valley Creek

Shelter Valley Road

GEOGRAPHIC TOWNSHIP OF HALDIMAND
COUNTY OF NORTHUMBERLAND

19+200
19+300
19+400
19+500
19+600
19+700
19+800
19+900

Highway 401

Site 21X-0272/CO - Shelter Valley Creek

Site 21X-0273/CO - Shelter Valley Road

HIGHWAY 401 Planning Study
from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

Stantec

LEGEND

- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan
HIGHWAY 401
Sta 19+200 to Sta 19+900
Haldimand Township

SHEET
17

GEOGRAPHIC TOWNSHIP OF HALDIMAND
COUNTY OF NORTHHUMBERLAND

CON 1
LOT 13

RD ALL'CE

19+900

20+000

20+100

CON 1
LOT 12

20+200

20+300

20+400

20+500

20+600

CON 1
LOT 11

CV-0401-001893

Highway 401

LOT 12
CON 1

RD ALL'CE

HIGHWAY 401 Planning Study
from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

Stantec

LEGEND

- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan
HIGHWAY 401
Sta 19+900 to Sta 20+600
Haldimand Township

SHEET
18

GEOGRAPHIC TOWNSHIP OF HALDIMAND
COUNTY OF NORTHHUMBERLAND

20+600
20+700
20+800
20+900
21+000
21+100
21+200
21+300

Vernonville Road

Rutherford Road

Highway 401

CV-0401-001893

CV-0401-001906

CV-0401-001907

LOT 11
CON 1

CON 1
LOT 10

LOT 10
CON 1

HIGHWAY 401 Planning Study
from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

Stantec

LEGEND

- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan
HIGHWAY 401
Sta 20+600 to Sta 21+300
Haldimand Township

SHEET
19

GEOGRAPHIC TOWNSHIP OF HALDIMAND
COUNTY OF NORTHUMBERLAND

CON 1
LOT 9

CON 1
LOT 8

21+300
21+400
21+500
21+600
21+700
21+800
21+900
22+000

Rutherford Road

Highway 401

CV-0401-001854

LOT 9
CON 1

LOT 8
CON 1

RD ALLOCE

HIGHWAY 401 Planning Study
from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

Stantec

LEGEND

- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan
HIGHWAY 401
Sta 21+300 to Sta 22+000
Haldimand Township

SHEET
20

GEOGRAPHIC TOWNSHIP OF HALDIMAND
COUNTY OF NORTHHUMBERLAND

CON 1
LOT 7

22+000
22+100
22+200
22+300
22+400
22+500
22+600
22+700

Boyce Road

9+879
9+900
10+000
10+100

Highway 401

Site 21X-0576/CO

CV-0401-001853

CV-0401-001914

CV-0401-001852

LOT 7
CON 1

HIGHWAY 401 Planning Study
from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

Stantec

LEGEND

- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan
HIGHWAY 401
Sta 22+000 to Sta 22+700
Haldimand Township

SHEET
21

GEOGRAPHIC TOWNSHIP OF HALDIMAND
COUNTY OF NORTHHUMBERLAND

22+700
22+800
22+900
23+000
23+100
23+200
23+300
23+400

CON 1
LOT 6

CON 1
LOT 5

RD ALL'CE

CV-0401-001852

Highway 401

LOT 6
CON 1

LOT 5
CON 1

RD ALL'CE

Stantec

HIGHWAY 401 Planning Study
from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

LEGEND

- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan
HIGHWAY 401
Sta 22+700 to Sta 23+400
Haldimand Township

SHEET
22

GEOGRAPHIC TOWNSHIP OF HALDIMAND
COUNTY OF NORTHHUMBERLAND

RD ALL'CE

23+400

23+500

CON 1

23+600

23+700

23+800

23+900

24+000

24+100

Highway 401

CV-0401-001851

LOT 3
CON 1

LOT 4
CON 1

RD ALL'CE

HIGHWAY 401 Planning Study

from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

Stantec

LEGEND

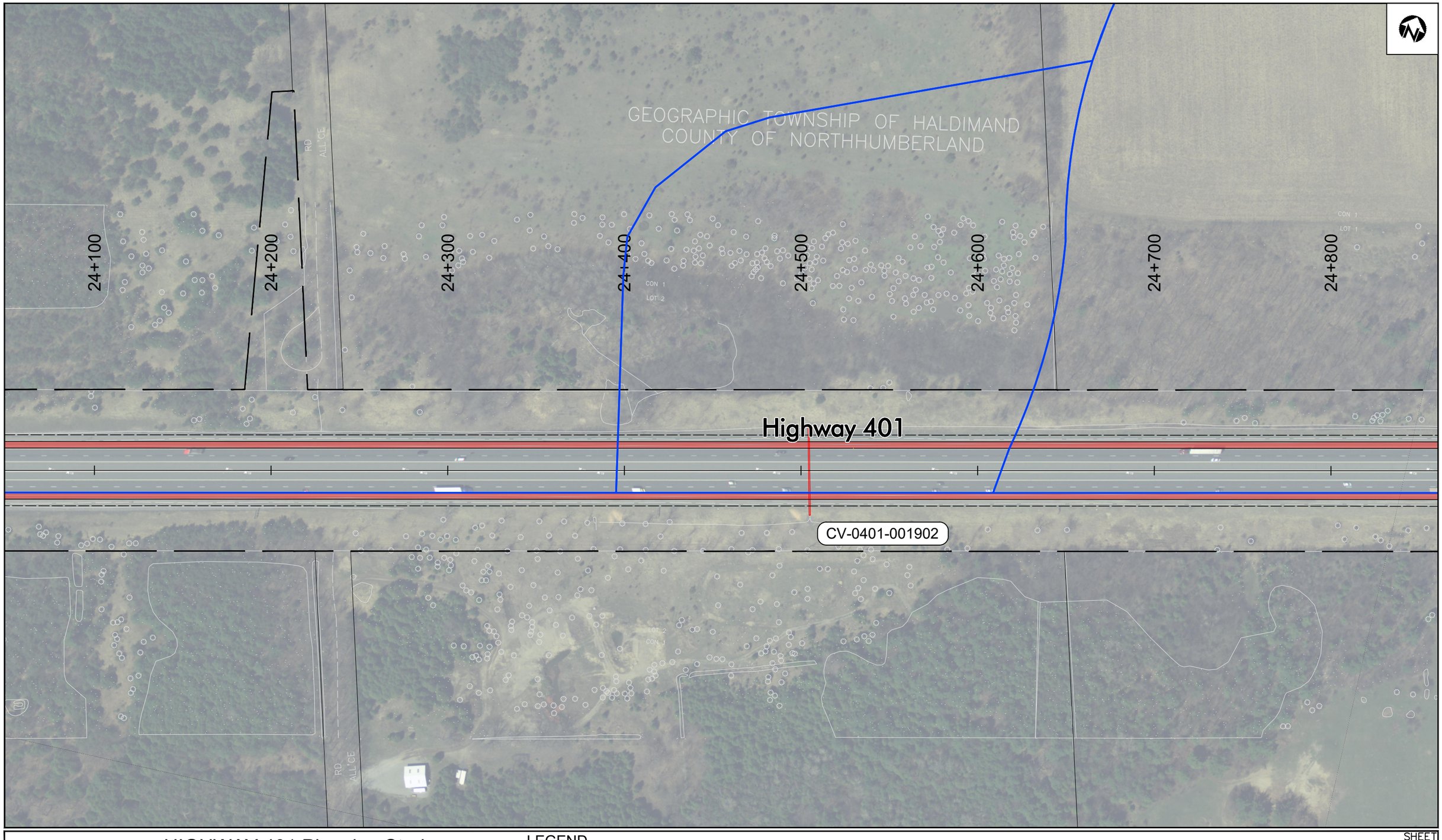
- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan

HIGHWAY 401
Sta 23+400 to Sta 24+100
Haldimand Township

SHEET
23



HIGHWAY 401 Planning Study

from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

Stantec

LEGEND

- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan

HIGHWAY 401
Sta 24+100 to Sta 24+800
Haldimand Township

SHEET
24

GEOGRAPHIC TOWNSHIP OF CRAMAHE
COUNTY OF NORTHHUMBERLAND

24+800
24+900
25+000
10+000
10+100
10+200
10+300
10+400

Highway 401

CV-0401-001850

CV-0401-001837

Township
of
Alnwick/Haldimand

Township
of
Cramahe

HIGHWAY 401 Planning Study
from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

Stantec

LEGEND

- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan
HIGHWAY 401
Sta 24+800 to Sta 10+400
Haldimand & Cramahe Townships

SHEET
25

GEOGRAPHIC TOWNSHIP OF CRAMAHE
COUNTY OF NORTHUMBERLAND

10+400
10+500
10+600
10+700
10+800
10+900
11+000
11+100

Highway 401

R-130
Ramp N-W
(Futu

R-3000
10+000
10+100
10+200
10+300
10+400

CV-0401-001837

R-250
Ramp W-N/S
10+500

The Big Apple

R-55
Ramp N-E
10+000
9+900
10+600

HIGHWAY 401 Planning Study
from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

Stantec

LEGEND

- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan
HIGHWAY 401
Sta 10+400 to Sta 11+100
Cramahe Township

SHEET
26

GEOGRAPHIC TOWNSHIP OF CRAMAHE
COUNTY OF NORTHUMBERLAND

Percy Street

R-950

R-130
Ramp N-W
(Future)

Ramp S-W
R-75

Ramp E-N/S

R-250

CV-0401-001835

CV-0401-001910

Highway 401

Percy Street

Ramp W-N/S

R-55
Ramp N-E

Ramp S-E

R-130

11+100 11+200 11+300 11+400 11+500 11+600 11+700 11+800

9+300 9+400 9+500 9+600 9+700 9+800 9+900 10+000 10+100 10+200 10+300 10+400 10+500 10+600 10+691 10+694

HIGHWAY 401 Planning Study
from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

Stantec

LEGEND

- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan
HIGHWAY 401
Sta 11+100 to Sta 11+800
Cramahe Township

SHEET
27

GEOGRAPHIC TOWNSHIP OF CRAMAHE
COUNTY OF NORTHHUMBERLAND

11+800
11+900
12+000
12+100
12+200
12+300
12+400
12+500

Highway 401

9+900
10+000

LOT 30
CON 3
LOT 29
CON 3

Stantec

HIGHWAY 401 Planning Study
from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

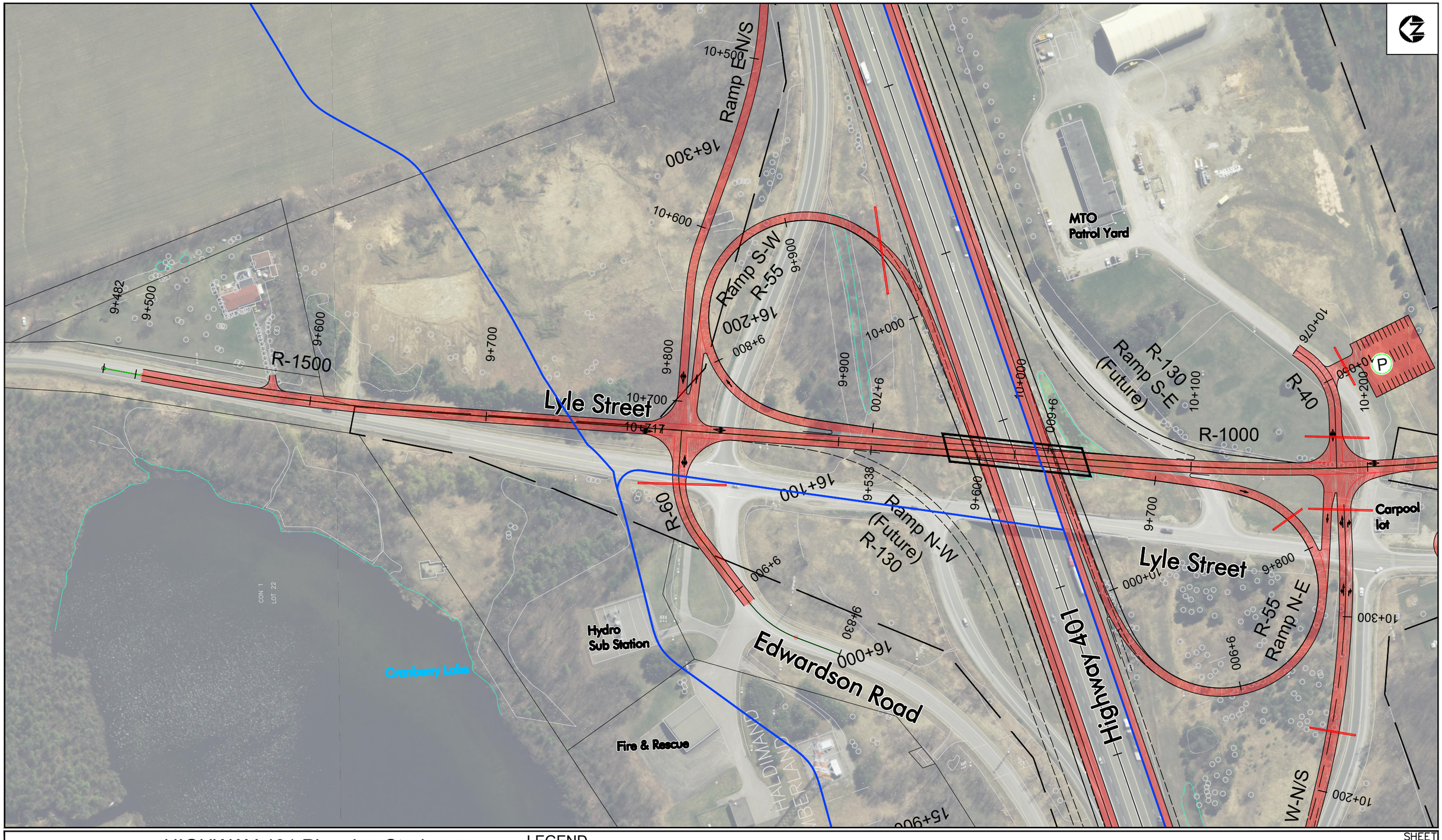
LEGEND

- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan
HIGHWAY 401
Sta 11+800 to Sta 12+500
Cramahe Township

SHEET
28



Stantec

HIGHWAY 401 Planning Study

from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

LEGEND

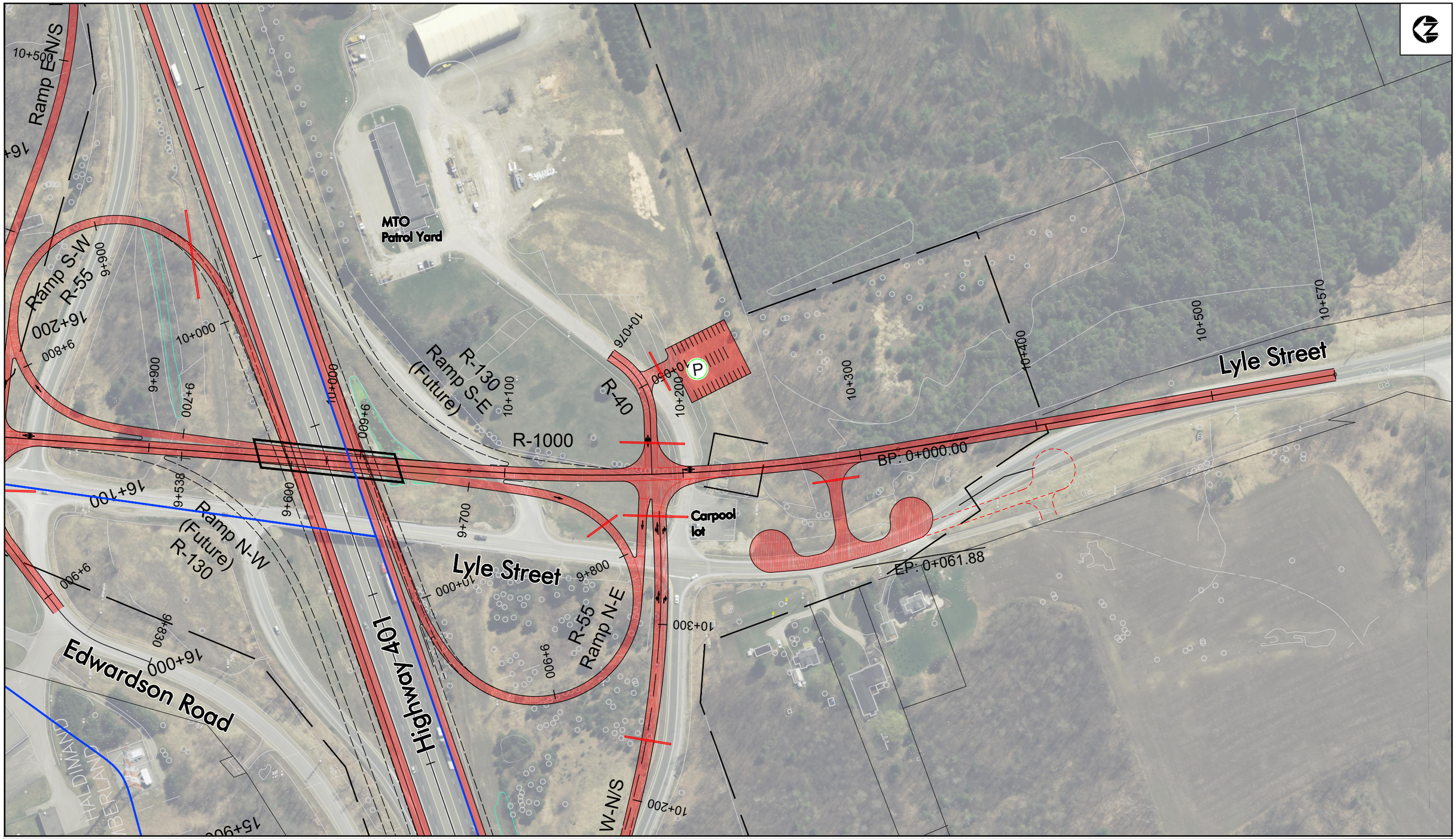
- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan

Lyle Street (Conty Road 23)
Sta 9+460 to Sta 10+200
Haldimand Township

SHEET
29



Stantec

HIGHWAY 401 Planning Study
from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

LEGEND

- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan
Lyle Street (County Road 23)
Sta 9+900 to Sta 10+570
Haldimand Township

SHEET
30

CV-0401-001910

CV-0401-001835

Ramp E-N/S

Ramp S-W

R-75

Ramp S-E

R-130

Ramp N-W (Future)

R-55 Ramp N-E

Ramp W-N/S

R-950

Percy Street

Carpool Lot

Union Cemetery

P

9+529 9+600 9+700 9+800 9+900 10+000 10+096 10+100 10+200 10+300 10+400 11+100 11+200 11+300 11+400 9+400 9+500 9+600 9+691 10+500 10+600

HIGHWAY 401 Planning Study

from Cobourg to Colborne

Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

Stantec

LEGEND

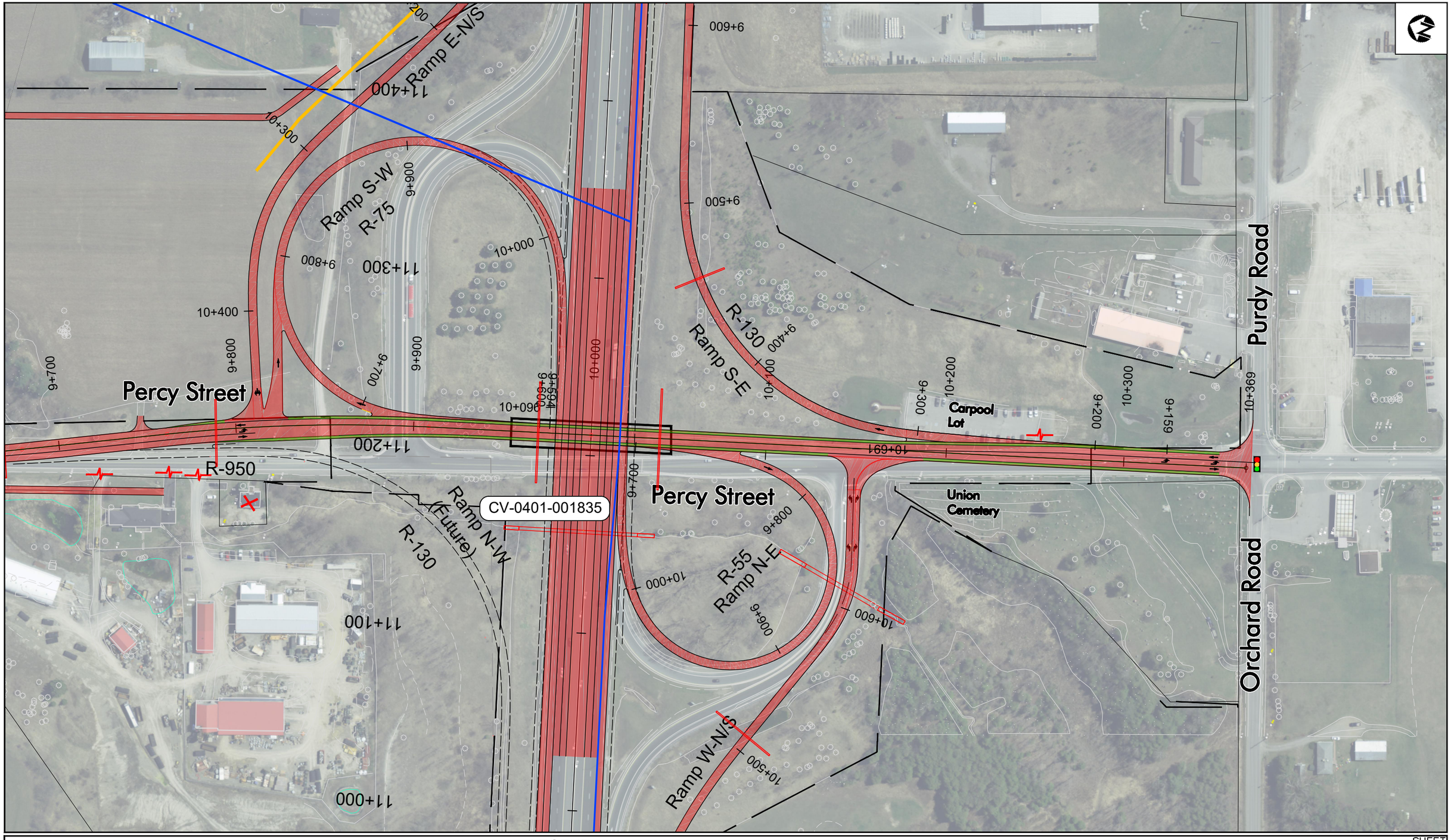
- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan

Percy Street (County Road 25)
Sta 9+529 to Sta 10+200
Cramahe Township

SHEET 31



Stantec

HIGHWAY 401 Planning Study
from Cobourg to Colborne
Preliminary Design &
Class Environmental Assessment
GWP 4060-11-00

LEGEND

- Drainage Catchment Boundary to Highway Centreline Culvert
- Culvert
- Proposed Stormwater Management Facility
- Property Required for Stormwater Management Facility
- Recommended Highway Design

25 m
1:2000

Recommended Drainage Plan
Percy Street (County Road 25)
Sta 9+700 to Sta 10+369
Cramahe Township

SHEET
32

APPENDIX B:
Inspection Results

Ministry of Transportation - Highway 401 Widening, Cobourg to Colborne
165001090 (GWP 4060-11-00)
Existing Conditions Assessment - Centreline Culverts

Original MTO ID	DVID	Highway	Township	Chainage	Status	Material	Shape	Diameter / Span (mm)	Rise (mm)	Length (m)	Depth of Cover (m)	Fish Habitat	Material	Joints	Shape	Capacity	Embankment	Channel	Roadway Settling	Scour/ Footings	Head/ Endwall	Recommended Actions	Comments	Water Present?	Direction of Flow
804010053	CV-0401-001882	401	Hamilton	23+330	Active	CSP - Plastic Lined	Circular	900		53.7	3.0	N	2	0	2	0	0	0	0	1	0	Replace	Recently ditched upstream and downstream; CSP lined with plastic liner same size; liner generally in good shape, but will need to be replaced when highway widened.	Y	S
804010044	CV-0401-002059	401	Hamilton	23+605	Active	CSP - Plastic Lined	Circular	900		56.9	3.0	N	2	1	2	0	0	1	0	0	0	Replace	Recently ditched upstream and downstream; CSP lined with plastic same size; culvert dented in near south end.	Y	S
804010047	CV-0401-001881	401	Hamilton	24+810	Active	Concrete	Box	2450	1850	73.1	9.0	Y	2	1	0	1	1	0	0	0	0	Retain	Ice forming on upstream wing walls; generally good condition; Some spalling of concrete; icicles across top with some rust stains; 1.2m opening height downstream.	Y	S
21-467/C	21-467/C	401	Haldimand	10+715	Active	Concrete	Box	3100	1800	147.1	15.0	Y	2	1	0	0	1	1	0	1	0	Refer to Stuctural Planning Report for Site 21-467/C	Site 21-467/C: Scour pool at outlet with fish in it; exposed footing in pool; groundwater coming into downstream creek from both sides with pipe on south east (maybe abandoned?); 0.45m water depth downstream & 0.75m depth with scour; not much depth upstream ; Pipes ounching into culvert from both sides; small scour pool upstream (potentially from swm pond?).	Y	S
904010054	CV-0401-001858	401	Haldimand	11+705	Active	CSP	Circular	900		51.5	1.8	N	3	0	1	2	2	2	0	0	0	Replace	Culvert rusting; almost full of sediment and standing water; ditching downstream required.	Y	S
904010052	CV-0401-001857	401	Haldimand	12+090	Active	CSP - Plastic Lined	Circular	900		52.8	2.4	N	1	0	0	2	1	2	0	0	0	Replace	The only solution is likely replacing the culver and maybe raising the outlet; upstream is open with decent flow in; upstream channel is slightly eroding ; South end has been ditched but is now in pool of water well below water surface; looks to be lined.	Y	S
21-468/C	21-468/C	401	Haldimand	12+420	Active	Concrete	Box	3100	1500	71.7	2.0	Y	2	1	0	1	0	1	0	1	0	Refer to Stuctural Planning Report for Site 21-468/C	Site 21-468/C: Appears to be swm feature on north east side with step pool; tree almost growing in culvert inlet that should be removed; looks to be flatter sloped on culvert partway through to outlet; Some scour at inlet; exposed footing; only 0.7m opening height downstream.	Y	S
904010048	CV-0401-001855	401	Haldimand	12+720	Active	Concrete	Box	1540	1570	60.9	5.0	N	2	1	0	0	2	2	0	2	0	Retain; Repair Scour and embankment at outlet.	Swm ponds upstream; recent repair to embankment downstream with rip rap is already starting to fail; repair scour and embankments downstream; Some leakage in culvert; generally in good shape upstream; extreme scour downstream; perched ~1.5m.	Y	S
904010047	CV-0401-001873	401	Haldimand	13+030	Active	Concrete	Box	1200	1200	73.8	9.0	N	2	1	0	2	2	0	0	2	0	Retain; Uncover upstream end; repair scour at outlet	Couldn't locate upstream end - likely buried?; Perched downstream; couldn't see through from downstream end (confirming upstream buried).	Y	S
21-469/C	21-469/C	401	Haldimand	14+135	Active	Concrete	Box	3700	1800	91.5	12.0	N	2	1	0	0	1	0	0	0	0	Refer to Stuctural Planning Report for Site 21-469/C	Site 21-469/C: Not much flow; heavily wooded area; channel ok; No major erosion or scour on upstream end; Some cracks in culvert.	Y	S
21-270/C	21-270/C	401	Haldimand	14+200	Active	Concrete	Arch	9000	4500	85.0	10.0	Y	2	4	0	0	1	0	0	1	0	Refer to Stuctural Planning Report for Site 21-270/C	Site 21-270/C: channel and embankments generally in good shape; fill in scour pools throughout culvert?; Scour pool just before inlet; scour pools after each weir throughout barrel.	Y	S
904010065	CV-0401-001791	401	Haldimand	14+660	Active	Steel - Concrete lined	Circular	800		24.1	1.5	N	1	0	0	0	0	0	0	0	0	Retain	Concrete lined steel pipe; drains into swm pond; goes all the way across highway; concrete is in good cond.	N	S
904010068	CV-0401-001721	401	Haldimand	15+150	Active	CSP - Plastic Lined	Circular	900		48.3	1.8	N	2	0	2	0	1	2	0	0	0	Replace	CSP lined with plastic same size; recently ditched upstream and downstream; multiple dents throughout barrel; liner generally in good shape, but will need to be replaced when highway widened.	N	S
000904010071/000904010044	CV-0401-001885/824	401	Haldimand	15+480	Active	CSP	Circular	900		45.0	1.5	N	3	0	1	1	0	0	0	0	0	Replace	Did not assess; results from 2014 show CSP was in poor condition; potentially is now lined with plastic pipe similar to culvert at station 15+150 (000904010068); will need to be replaced when highway widened.		S
904010037	CV-0401-001912	401	Haldimand	16+390	Active	CSP	Arch	1100	700	58.8	1.5	N	3	1	2	0	0	0	0	0	0	Replace	Rusting through on north end; recently ditched upstream and downstream.	N	S
904010080/000904010035	CV-0401-001908/880	401	Haldimand	16+620	Active	CSP	Arch	1066	686	63.0	1.5	N	4	0	2	2	0	0	0	1	0	Replace	Culvert starting to rust and downstream end slightly crushed; potential to line or replace; Almost completely buried at north end; could only see CSP ribs.	N	S
21-470/C	21-470/C	401	Haldimand	17+170	Active	Concrete	Box	3100	1800	91.6	15.0	Y	2	1	0	0	1	1	0	2	1	Refer to Stuctural Planning Report for Site 21-470/C	Site 21-470/C: Repair scour downstream; Culvert is perched at downstream end; also exposed footing at upstream end; Rust stains and cracks throughout.	Y	S
904010083	CV-0401-001862	401	Haldimand	17+640	Active	CSP	Circular	900		50.2	1.8	N	3	1	1	1	0	1	0	0	0	Replace	Upstream end blocked with sediment and straw bails; ditching required; new culvert on upstream end; downstream end half filled with sediment and water; culvert looks ok but likely rusted through below water.	Y	S
21-272/C	21-272/C	401	Haldimand	19+340	Active	Concrete	Arch	15200	7700	100.5	8.0	Y	2	1	0	0	1	1	0	0	2	Refer to Stuctural Planning Report for Site 21-272/C	Site 21-272/C: Some embankment erosion near upstream headwall; Fast flowing water; boulders and cobbles; Concrete Arch culvert; Some embankment erosion in upstream channel.	Y	S
904010033	CV-0401-001893	401	Haldimand	20+590	Active	Concrete	Box	1800	1550	79.5	10.0	Y	3	1	0	0	1	0	0	1	1	Repair Concrete; Repair embankment erosion.	This culvert is proposed to be repaired in 2020/2021 with ESL of 25 years. During inspection, downstream end breaking apart and should be repaired; south west ditch near culvert eroding out even with recent repair; Exposed footing upstream; bottom of culvert seems to have worn down; some spalling throughout.	Y	S
904010085	CV-0401-001906	401	Haldimand	20+930	Active	CSP	Circular	900		68.2	10.0	N	2	1	2	1	1	1	0	0	0	Replace	Rusting; partially filled downstream; ditch downstream; rusting on bottom slightly with a few perforations; sag in middle.	Y	S
904010086	CV-0401-001907	401	Haldimand	21+030	Active	Concrete	Box	1500	1200	86.8	8.0	Y	1	1	0	2	2	1	0	0	0	Retain; Repair embankment immediately; Lower ditching downstream.	Culvert was repaired in 2019 and further repairs are planned in 2020. During inspection, downstream end barely exposed; major erosion of embankment that is encroaching to roadway; Culvert generally in good shape; major erosion of embankment downstream end; needs immediate repair.	Y	S
904010015/000904010015A	CV-0401-001854	401	Haldimand	21+615	Active	CSP/Concrete	Circular	900		48.0	2.0	N	4	1	4	0	0	0	0	0	0	Replace	Can't see through (probably cb in middle); 900 upstream, 825 DS; Rusted through on upstream end; catch basin in middle; CSP upstream in poor condition and Concrete lined with steel outside and good condition on downstream end.	Y	S
21-576/C	21-576/C	401	Haldimand	22+125	Active	Concrete	Box	3100	2500	81.0	8.0	Y	2	1	0	0	1	1	0	2	1	Refer to Stuctural Planning Report for Site 21-576/C	Site 21-576/C: Pool at northwest end; flow could be undermining culvert; upstream end requires repairs to fix scour/undermining; downstream end is fine; fish downstream ; Culvert footing exposed; lots of erosion of bank immediately around upstream end; heavily woodedarea.	Y	S
904010014	CV-0401-001853	401	Haldimand	22+315	Active	Concrete	Box	1200	1200	60.3	4.5	Y	1	0	0	1	0	1	0	0	0	Retain; Lower ditching downstream	Culvert in good condition; only 0.45m opening on downstream end; standing water.	Y	S
904010007	CV-0401-001914	401	Haldimand	22+480	Active	CSP	Circular	900		65.2	6.0	N	4	1	1	1		1	0	0	0	Replace	Potential to line? Ditch required downstream; Rusted through upstream end; 0.55m opening downstream; standing water.		S
904010004	CV-0401-001852	401	Haldimand	22+700	Active	Concrete	Box	1200	1200	62.9	6.0	N	1	0	0	1	0	1	0	0	0	Retain; Lower ditching downstream	Culvert in decent condition; 0.9m opening height on downstream end with lots of vegetation.	Y	S
904010003	CV-0401-001851	401	Haldimand	23+770	Active	Concrete	Box	1850	1800	70.1	9.0	Y	1	0	0	0	1	0	0	1	0	Retain	Culvert was repaired in 2019. During inspection, some leakage in culvert; some spalling downstream; scour pool on downstream end; Culvert generally in good condition; erosion in the area (ditches and banks); fast flowing stream.	Y	S
904010001	CV-0401-001850	401	Haldimand	24+940	Active	CSP	Circular	900		55.2	2.0	N	3	1	0	0	0	0	0	0	0	Replace	Rusting with some flaking; rip rap upstream.	N	S
1004010032	CV-0401-001837	401	Cramahe	10+396	Active	CSP	Circular	900		49.5	1.8	N	3	1	1	2	0	0	0	0	0	Replace	Rusting with some perforations; rip rap upstream; full of water downstream.	N	S
1004010030	CV-0401-001835	401	Cramahe	11+143	Active	Concrete	Box	1800	1500	52.4	1.5	Y	1	0	0	0	0	1	0	2	0	Retain; repair scour at outlet	Culvert in good condition ds; scour/perched ds at end of wingwall; DICB in north ditch.	Y	S
1004010041	CV-0401-001910	401	Cramahe	11+478	Active	CSP	Circular	900		54.9	1.5	N	4	1	1	1	0	1	0	0	0	Replace	Culvert rusting through; half filled with sediment and standing water; replace or line.	Y	S

Ministry of Transportation - Highway 401 Widening, Cobourg to Colborne
165001090 (GWP 4060-11-00)
Existing Conditions Assessment - Interchange Culverts

Original MTO ID	DVID	Highway	Township	Chainage	Location	Type	Material	Shape	Diameter / Span (mm)	Rise (mm)	Length (m)	Depth of Cover (m)	Material	Joints	Shape	Capacity	Embankment	Channel	Roadway Settling	Scour/ Footings	Head/ Endwall	Recommended Actions	Comments	Direction of Flow
Lyle Street Interchange																								
904010146	CV-0401-002019	401	Haldimand	15+940	W-N/S Ramp	Culvert	CSP	Circular	600	-	19.9	1.0	3	3	1	0	0	0	0	0	0	Replace	Culvert Rusting.	N
904010138	CV-0401-002012	401	Haldimand	16+024	N/S-E Ramp	Culvert	CSP	Circular	600	-	17.9	4.0	2	0	0	0	0	0	0	0	0	No Action	Starting to rust on upstream end	N
00090401AC02I	CV-0401-002050	401	Haldimand	16+050	Entrance	Culvert	CSP	Circular	800	-	37.5	4.0	3	2	0	0	0	0	0	0	0	Replace	Culvert is rusting and should be replaced	N
904010038	CV-0401-001894	401	Haldimand	16+350	E-N/S Ramp	Culvert	CSP	Circular	600	-	17.3	1.5	3	0	2	2	0	2	0	0	0	Replace	Almost completely buried; standing water; exposed pipe was rusting	S
Percy Street Interchance																								
1004010036	CV-0401-001838	401	Cramahe	11+052	W-N/S Ramp	Culvert	CSP	Circular	900	-	28.0	3.0	1	0	3	1	0	0	0	0	0	Repair End Section	Discharges to SWM feature; Upstream end crushed in; other than that looks in good condition.	S
1004010037	CV-0401-001839	401	Cramahe	11+128	W-N/S & N/S-E Ramps	Culvert	Concrete	Box	1800	1500	48.6	4.0	1	0	0	0	0	0	0	0	0	No Action	Generally in good condition; couldn't access outlet fully as fence was blocking.	S
1004010039	CV-0401-001879	401	Cramahe	11+195	Sideroad	Culvert	CSP	Circular	900	-	29.9	1.5	2	0	0	0	0	0	0	0	0	Replace	CSP rusting; potential to line or replace.	W
1004010090	CV-0401-002023	401	Cramahe	11+195	Sideroad	Culvert	CSP	Circular	600	-	25.1	2.0	1	0	1	0	1	0	0	0	0	No Action	Culvert generally in good condition.	W
1004010027	CV-0401-001898	401	Cramahe	11+387	E-N/S Ramp	Culvert	CSP	Circular	450	-	16.8	1.0	3	1	3	2	0	1	0	0	0	Replace	Culvert is rusting, crushed and buried on one end; replace.	W

Barrel Material Rating Criteria

Barrel Material Rating Criteria – Corrugated Metal Culverts	
Rating	**Description**
0	New condition, may also exhibit slight discolouration of surface, galvanizing partially gone along invert.
1	Discolouration of surface, galvanizing completely gone along invert but no layers of rust. Minor pinholes in pipe material located at end of pipe but not located beneath roadway.
2	Layers of rust forming. Sporadic pitting of invert, minor pinholes forming through out pipe.
3	Heavy rust, thick scaling throughout pipe. Deep pitting, perforations throughout in invert.
4	Extensive Heavy rust, extensive perforations through out pipe. End sections corroded away. Bottom portion completely corroded exposing underlying granular. Partially to fully collapsed.

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Barrel Material Rating Criteria – Concrete Culverts	
Category Rating	**Description**
0	New Condition, Hairline cracking without rust staining or delaminations, surface in good condition, isolated damage from construction.
1	Hairline cracking parallel to the direction of traffic with no crack greater than 1mm and without rust staining. Light scaling on less than 10% of the exposed surface area and greater than 3 mm deep. Delaminated/spalled area less than 1% of surface area.
2	Map cracking. Cracks parallel to traffic no greater than 4 mm, cracks transverse to traffic no greater than 2 mm. Rust staining and leakage occurring. Scaling on less than 30% of exposed area and less than 5 mm deep. Spalled areas with exposed reinforcing less than 10%.
3	Transverse cracks greater than 3 mm wide with extensive rust staining. Spalling at numerous locations, extensive surface scaling on invert greater than 15 mm Extensive cracking with cracked open more than 4mm. Spalling has caused exposure of heavily corroded reinforcing steel in bottom or top slab. Extensive surface scaling on invert greater then 25 mm.
4	Full depth holes. Extensive cracking greater then 15 mm. Spalled areas with exposed reinforcing greater then 25%. Total delaminated, spalled concrete areas are greater than 50% of surface area. Perimeter of reinforcing bars is completely exposed.

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Barrel Material Rating Criteria – Plastic Culverts	
Category Rating	**Description**
0	Minor isolated rip caused by floating debris or construction. Minor discolouration.
1	Slit no longer than 150 mm and no wider than 10 mm at two or three locations. Damage (cuts, gouges or distortions) to ends sections from construction or maintenance. Perforations caused by abrasion located within 1.5 meters of outlet and not under roadway.
2	Slit longer than 150 mm and wider than 10 mm at two or three locations.
3	Slit longer than 150 mm and wider than 10 mm at several locations. Perforations throughout the pipe.
4	Slits in pipe causing the loss of backfill. Section loses throughout the pipe caused by abrasion. Invert eroded away. Partially collapsed.

Note: This type of material has not been in service for a sufficient period of time to obtain accurate pictures to show the various stages of deterioration.

Barrel Material Rating Criteria – Timber Culverts		
Category	**Rating**	**Description**
Weathering,Checks, Splits and Shakes	0	New Condition, no deficiencies found.
	1	Tissue separations are short and extend for less than 5% into the member.
	2	Tissue separations are long and extend for 5% to 10% into the member.
	3	Tissue separations are long and extend for 10% to 20% into the member.
	4	Tissue separations are long and extend for more than 20% into the member.
Rot or Decay	0	New Condition with slight changes in colour
	1	Slight change in colour. The wood sounds solid and cannot be penetrated by a sharp object.
	2	Surface is discoloured with black and brown streaks. The wood sounds hollow when tapped and offers limited resistance to penetration by a sharp object.
	3	Surface is fibrous, checked or crumbly and fungal fruiting bodies are growing on it. The wood sounds hollow when tapped and offers little resistance to penetration by a sharp object.
	4	The wood can be crumbled and disintegrated with ease
Insect damage	0	New Condition with no entrance or exist hole present
	1	Occasional entrance or exist holes are present. The wood is solid and cannot be easily penetrated by a sharp object.
	2	Several entrance or exit holes are visible, and larvae or mature insects may be observed. The wood sounds hollow when tapped, and offers limited resistance to penetration by a sharp object.
	3	Extensive tunnelling and holes are present in the wood. Larvae and insects are readily visible. The wood sounds hollow when tapped, and offers little resistance to penetration by a sharp object.
	4	Extensive tunnelling, holes, larvae and insects present. Wood can be crumbled and is disintegrated with ease.
Cracking, Splintering, Crushing and Shattering	0	New condition, not damage from construction
	1	Damage is mainly superficial with less than 5% section loss.
	2	Considerable damage with 5% to 10% section loss.
	3	Significant damage with 10% to 20% section loss.

Barrel Material Rating Criteria – Timber Culverts		
Category	**Rating**	**Description**
	4	Extensive damage with section loss in excess of 20%.
Fire and Chemical Damage	0	New condition, no evidence of fire or chemical damage
	1	Slight charring or softening of the wood surface with less than 5% section loss. Connectors unaffected.
	2	Deeper charring or softening with 5% to 10% section loss. Connectors slightly loosened.
	3	Section loss between 10% and 20% with several connectors loosened or deformed.
	4	Extensive damage with section loss greater than 20% at critical locations. Many loose and severely deformed connectors.

Note: No Pictures are available at this time

Joint Rating Criteria

Joints Rating Criteria – Steel Culvert	
Rating	**Description**
0	New Condition. Tight; no openings in joints or seams.
1	Tight, no openings or displacement. Minor pitting at the joints.
2	Minor cracking at a few bolt holes; minor joint or seam openings; Some water infiltration no backfill infiltration.
3	Plate cracking from bolt to bolt on one seam near top of pipe; deflection of pipe end caused by loss of backfill through open joints.
4	Significant separation at joints has compromised the integrity of culvert, plate cracking from bolt to bolt at multiple seam locations within the culvert.

Note: No Pictures are available at this time

Joints Rating Criteria – Concrete	
Rating	**Description**
0	New Condition with tight joints.
1	Tight, no openings or displacement. Minor hairline cracking / tears. Minor spalling in concrete
2	Minor joint separation, <10mm. Minor joint displacement, <1/4 wall thickness. Significant cracking / tearing <10mm in width. Spalling in concrete, <5mm thickness lost. Pitting in metal <5mm thickness lost.
3	Significant joint opening / displacement (over 1.5 wall thickness) with piping or infiltration of backfill material into culvert.
4	Significant separation at joints has compromised the integrity of culvert.

Note: No Pictures are available at this time

Joints Rating Criteria – Plastic Culverts (HDPE and PVC)	
Rating	**Description**
0	New Condition. No deficiencies found.
1	Minor movement in the joint but no infiltration/exfiltration of water or soil particles at the joint.
2	Some movement in the joint but no separation. Evidence of water infiltration/infiltrations. no backfill infiltration at joints.
3	Differential movement and separation of joints; significant infiltration or exfiltration at joints; deflection caused by loss of backfill through open joints.
4	Significant openings; dislocated joints in several locations exposing fill materials; infiltration or exfiltration causing misalignment and deflection of pipe and roadway settlement.

Note: No Pictures are available at this time

Shape Rating Criteria

Shape Rating Criteria	
Rating	**Description**
0	Smooth curvature in barrel. Span dimension within 3% of design
1	Smooth curvature in top half of barrel with flattening on bottom portion. Span dimension up to 5% greater than design.
2	Slight distortion in one location on the top portion. Bottom has slight reverse curvature in one location. Span dimension up to 10% greater than design. Non-symmetrical shape.
3	Significant distortion through out length. Lower 1/3 may be kinked. Span dimension up to 15% greater than design.
4	Extreme deflection at isolated locations. Flattening at top of arch or crown. Bottom has reverse curvature through out. Span dimension greater than 15% of design. Extremely non-symmetrical

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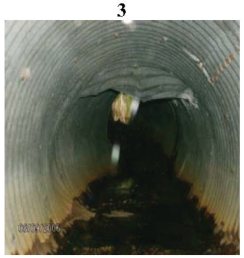

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Condition Rating

General Conditions Surrounding Culvert Barrel

This condition category describes the condition of the different elements surrounding the culvert barrel. This condition corresponds to the rating value that will be used in the development of the overall culvert rating. These elements, depending on their condition, will require repair and will not effect any replacement decision of the culvert barrel itself.

Capacity Rating Criteria

General Conditions - Capacity Rating Criteria	
Rating	**Description**
0	Little to no sediment build-up in pipe. Culvert ends are undamaged. Little to no debris blocking flow.
1	Minor debris and sediment, less than 30% blockage. Possible infiltration of fine roots. No evidence of flooding of roadway or adjacent land.
2	Major debris and sediment more than 30% blockage, flooding of roadway and/or adjacent properties. Possible infiltration of tap roots causing major flow restriction.

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Condition Ratings

Embankment Slope

General Conditions- Embankment Slope Criteria	
Rating	**Description**
0	Embankment slopes are intact and stable.
1	Minor erosion of embankment, less than 100mm around ends. Still protected or well vegetated.
2	Major erosion of slope, greater than 200mm around culvert ends, guardrail displaced / settled, posts loosened / separated from soil.

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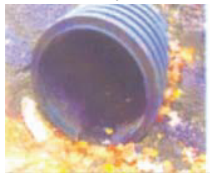
Channel Upstream and Downstream

General Conditions– Channel Upstream and Downstream	
Rating	**Description**
0	No evidence of channel bed or bank erosion. Intermittent patches of grass and exposed earth.
1	Minor channel erosion. Minor damage to channel protection.
2	Bank protection eroded. Bank protection debris causing blockage and more significant channel erosion. Channel alignment causing scour holes, bank erosion, and is threatening end treatment. Major erosion of channel.

0



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Roadway Settlement Rating Criteria

General Conditions - Roadway Settlement Rating Criteria	
Rating	**Description**
0	Minor hairline pavement cracks over culvert.
1	Hairline cracks in pavement, less than20mm gaps between the bottom of a 3 m straight edge and the pavement surface
2	Broken pavement, moderate to major potholes, settlement in excess of 30 mm with deteriorated ride quality

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Scour/Footing Rating Criteria

General Conditions - Scour/Footing Rating Criteria	
Rating	**Description**
0	Minor scour holes developing at inlet or outlet. Top of footing not exposed.
1	Scour holes developing at inlet or outlet that are 300 mm or less in depth. Footings along sides are exposed. Probing indicates soft material in scour hole.
2	Scour holes at inlet or outlet that are in excess of 600 mm in depth. Erosion occurring behind headwall that threatens to undermine culvert.

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Headwall/Endwall Condition Rating Criteria

Headwall/Endwall Condition - Concrete	
Rating	**Description**
0	New Condition, Hairline cracking without rust staining or delamination, surface in good condition.
1	Spalled area measuring between 100 mm to 300 mm in any direction or between 25 mm and 50 mm in depth. Cracking, some cracks, less than 3 mm wide
2	Spalled area greater than 300 mm in any direction or greater than 50 mm in depth. Joint separation from culvert. Cracking, multiple crack greater than 3mm wide

Note: No Pictures are available at this time

Headwall/Endwall Condition - Steel	
Rating	**Description**
0	New condition, may also exhibit slight discolouration of surface, galvanizing intact
1	Layers of rust forming. Sporadic pitting at the bottom of the wall, minor pinholes forming through out pipe..
2	Heavy rust, thick scaling throughout wall. Deep pitting, perforations in lower section of wall. Joint separation from culvert.

Note: No Pictures are available at this time

APPENDIX C:
Photographic Inventory

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Hamilton - Station 22+350 (LT)

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Centreline Culverts - Photographic Inventory

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Centreline Culverts - Photographic Inventory

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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

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Highway 401, Cobourg to Colborne
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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

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Highway 401, Cobourg to Colborne
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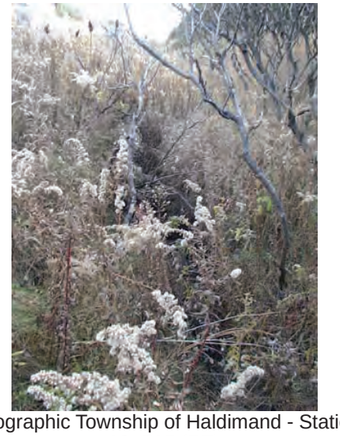
Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory



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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

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Centreline Culverts - Photographic Inventory

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Centreline Culverts - Photographic Inventory

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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

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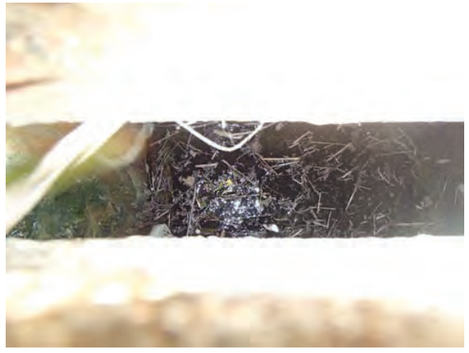

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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

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17+170 (RT)

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17+640 (LT)

Geographic Township of Haldimand - Station
17+640 (LT)

Geographic Township of Haldimand - Station
17+640 (LT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
17+640 (LT)

Geographic Township of Haldimand - Station
17+640 (RT)

Geographic Township of Haldimand - Station
17+640 (RT)

Geographic Township of Haldimand - Station
17+640 (RT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
19+340 (LT)

Geographic Township of Haldimand - Station
19+340 (LT)

Geographic Township of Haldimand - Station
19+340 (LT)

Geographic Township of Haldimand - Station
19+340 (LT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
19+340 (LT)

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Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
19+340 (LT)

Geographic Township of Haldimand - Station
19+340 (LT)

Geographic Township of Haldimand - Station
19+340 (LT)

Geographic Township of Haldimand - Station
19+340 (RT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
19+340 (RT)

Geographic Township of Haldimand - Station
19+340 (RT)

Geographic Township of Haldimand - Station
19+340 (RT)

Geographic Township of Haldimand - Station
19+340 (RT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
19+340 (RT)

Geographic Township of Haldimand - Station
19+340 (RT)

Geographic Township of Haldimand - Station
19+340 (RT)

Geographic Township of Haldimand - Station
19+340 (RT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

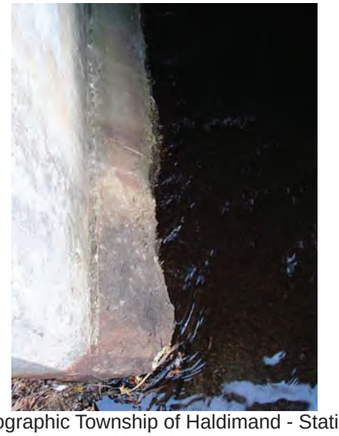
Geographic Township of Haldimand - Station
20+590 (LT)

Geographic Township of Haldimand - Station
20+590 (LT)

Geographic Township of Haldimand - Station
20+590 (LT)

Geographic Township of Haldimand - Station
20+590 (LT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory



Geographic Township of Haldimand - Station
20+590 (LT)

Geographic Township of Haldimand - Station
20+590 (LT)

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20+590 (LT)

Geographic Township of Haldimand - Station
20+590 (RT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
20+590 (RT)

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20+590 (RT)

Geographic Township of Haldimand - Station
20+590 (RT)

Geographic Township of Haldimand - Station
20+930 (LT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
20+930 (LT)

Geographic Township of Haldimand - Station
20+930 (LT)

Geographic Township of Haldimand - Station
20+930 (LT)

Geographic Township of Haldimand - Station
20+930 (LT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
20+930 (RT)

Geographic Township of Haldimand - Station
20+930 (RT)

Geographic Township of Haldimand - Station
21+030 (LT)

Geographic Township of Haldimand - Station
21+030 (LT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
21+030 (LT)

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21+030 (LT)

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Geographic Township of Haldimand - Station
21+030 (RT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
21+030 (RT)

Geographic Township of Haldimand - Station
21+030 (RT)

Geographic Township of Haldimand - Station
21+030 (RT)

Geographic Township of Haldimand - Station
21+030 (RT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
21+615 (LT)

Geographic Township of Haldimand - Station
21+615 (LT)

Geographic Township of Haldimand - Station
21+615 (LT)

Geographic Township of Haldimand - Station
21+615 (LT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
21+615 (LT)

Geographic Township of Haldimand - Station
21+615 (LT)

Geographic Township of Haldimand - Station
21+615 (RT)

Geographic Township of Haldimand - Station
21+615 (RT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
21+615 (RT)

Geographic Township of Haldimand - Station
21+615 (RT)

Geographic Township of Haldimand - Station
22+125 (LT)

Geographic Township of Haldimand - Station
22+125 (LT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
22+125 (LT)

Geographic Township of Haldimand - Station
22+125 (LT)

Geographic Township of Haldimand - Station
22+125 (LT)

Geographic Township of Haldimand - Station
22+125 (LT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
22+125 (LT)

Geographic Township of Haldimand - Station
22+125 (LT)

Geographic Township of Haldimand - Station
22+125 (LT)

Geographic Township of Haldimand - Station
22+125 (LT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
22+125 (LT)

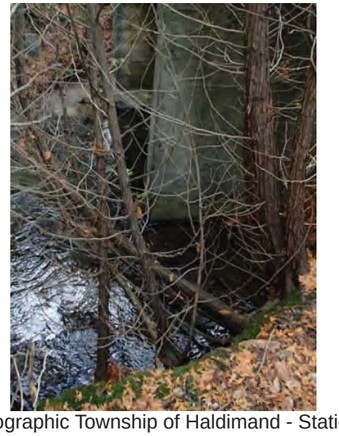
Geographic Township of Haldimand - Station
22+125 (LT)

Geographic Township of Haldimand - Station
22+125 (LT)

Geographic Township of Haldimand - Station
22+125 (LT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
22+125 (LT)



Geographic Township of Haldimand - Station
22+125 (LT)

Geographic Township of Haldimand - Station
22+125 (RT)

Geographic Township of Haldimand - Station
22+125 (RT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
22+125 (RT)

Geographic Township of Haldimand - Station
22+125 (RT)

Geographic Township of Haldimand - Station
22+125 (RT)

Geographic Township of Haldimand - Station
22+315 (LT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
22+315 (LT)

Geographic Township of Haldimand - Station
22+315 (LT)

Geographic Township of Haldimand - Station
22+315 (LT)

Geographic Township of Haldimand - Station
22+315 (LT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
22+315 (RT)

Geographic Township of Haldimand - Station
22+315 (RT)

Geographic Township of Haldimand - Station
22+315 (RT)

Geographic Township of Haldimand - Station
22+315 (RT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
22+480 (LT)

Geographic Township of Haldimand - Station
22+480 (LT)

Geographic Township of Haldimand - Station
22+480 (LT)

Geographic Township of Haldimand - Station
22+480 (LT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
22+480 (LT)

Geographic Township of Haldimand - Station
22+480 (RT)

Geographic Township of Haldimand - Station
22+480 (RT)

Geographic Township of Haldimand - Station
22+480 (RT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
22+480 (RT)

Geographic Township of Haldimand - Station
22+700 (LT)

Geographic Township of Haldimand - Station
22+700 (LT)

Geographic Township of Haldimand - Station
22+700 (LT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
22+700 (LT)

Geographic Township of Haldimand - Station
22+700 (RT)

Geographic Township of Haldimand - Station
22+700 (RT)

Geographic Township of Haldimand - Station
22+700 (RT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
22+700 (RT)

Geographic Township of Haldimand - Station
23+770 (LT)

Geographic Township of Haldimand - Station
23+770 (LT)

Geographic Township of Haldimand - Station
23+770 (LT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
23+770 (LT)

Geographic Township of Haldimand - Station
23+770 (LT)

Geographic Township of Haldimand - Station
23+770 (LT)

Geographic Township of Haldimand - Station
23+770 (LT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
23+770 (RT)

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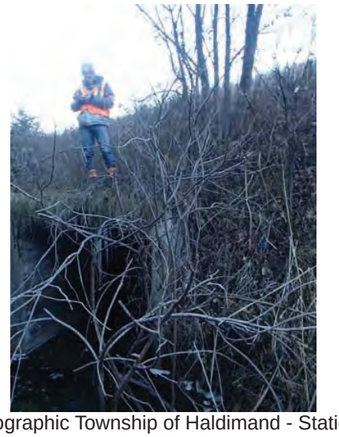
23+770 (RT)

Geographic Township of Haldimand - Station
23+770 (RT)



Geographic Township of Haldimand - Station
23+770 (RT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
24+510 (LT)

Geographic Township of Haldimand - Station
24+510 (RT)

Geographic Township of Haldimand - Station
24+510 (RT)

Geographic Township of Haldimand - Station
24+510 (RT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station
24+940 (LT)

Geographic Township of Haldimand - Station
24+940 (LT)

Geographic Township of Haldimand - Station
24+940 (LT)

Geographic Township of Haldimand - Station
24+940 (LT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station 24+940 (LT)

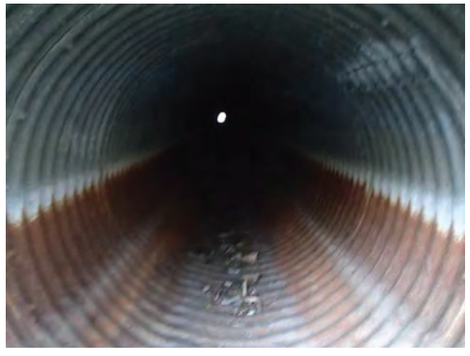
Geographic Township of Haldimand - Station 24+940 (LT)

Geographic Township of Haldimand - Station 24+940 (RT)

Geographic Township of Haldimand - Station 24+940 (RT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Haldimand - Station 24+940 (RT)



Geographic Township of Haldimand - Station 24+940 (RT)

Geographic Township of Haldimand - Station 24+940 (RT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Cramahe - Station 10+396 (LT)

Geographic Township of Cramahe - Station 10+396 (LT)

Geographic Township of Cramahe - Station 10+396 (LT)

Geographic Township of Cramahe - Station 10+396 (LT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Cramahe - Station 10+396 (RT)

Geographic Township of Cramahe - Station 10+396 (RT)

Geographic Township of Cramahe - Station 10+396 (RT)

Geographic Township of Cramahe - Station 11+143 (RT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Cramahe - Station 11+143 (RT)

Geographic Township of Cramahe - Station 11+143 (RT)

Geographic Township of Cramahe - Station 11+143 (RT)

Geographic Township of Cramahe - Station 11+143 (RT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Cramahe - Station 11+143 (RT)

Geographic Township of Cramahe - Station 11+143 (RT)

Geographic Township of Cramahe - Station 11+143 (RT)

Geographic Township of Cramahe - Station 11+143 (RT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Cramahe - Station 11+143 (RT)

Geographic Township of Cramahe - Station 11+143 (RT)

Geographic Township of Cramahe - Station 11+478 (LT)

Geographic Township of Cramahe - Station 11+478 (LT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Cramahe - Station 11+478 (LT)

Geographic Township of Cramahe - Station 11+478 (LT)

Geographic Township of Cramahe - Station 11+478 (LT)

Geographic Township of Cramahe - Station 11+478 (RT)

Highway 401, Cobourg to Colborne
Centreline Culverts - Photographic Inventory

Geographic Township of Cramahe - Station 11+478 (RT)

Geographic Township of Cramahe - Station 11+478 (RT)

APPENDIX D:
Hydrologic Modelling

Ontario IDF CURVE LOOKUP

Active coordinate

44° 0' 15" N, 78° 1' 45" W (44.004167,-78.029167)

Retrieved: Wed, 30 Jan 2019 21:26:27 GMT

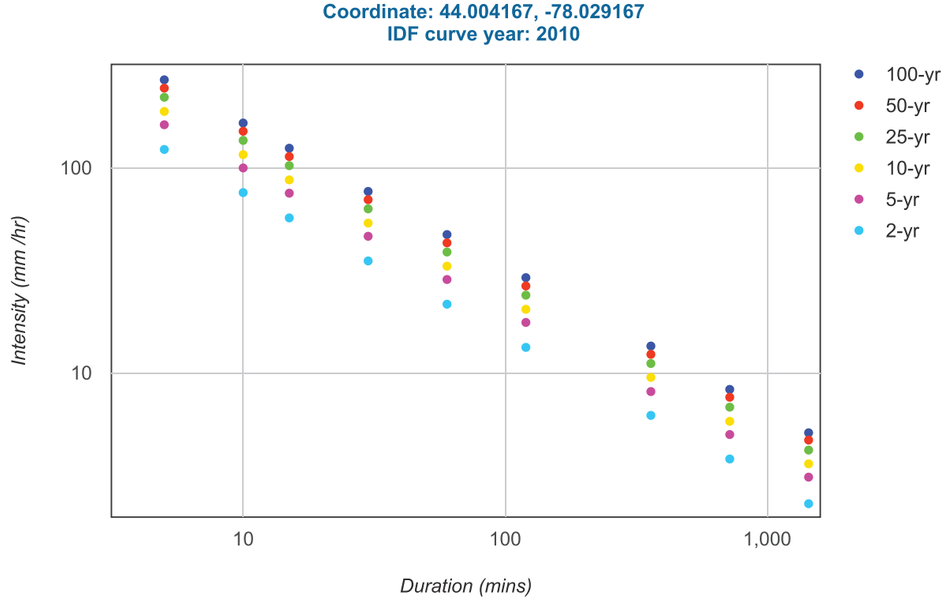
Location summary

These are the locations in the selection.

IDF Curve: 44° 0' 15" N, 78° 1' 45" W (44.004167,-78.029167)

Results

An IDF curve was found.



Coefficient summary

IDF Curve: 44° 0' 15" N, 78° 1' 45" W (44.004167,-78.029167)

Retrieved: Wed, 30 Jan 2019 21:26:27 GMT

Data year: 2010
IDF curve year: 2010

Return period	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
A	21.6	28.5	33.1	38.8	43.0	47.2
B	-0.699	-0.699	-0.699	-0.699	-0.699	-0.699

Statistics

Rainfall intensity (mm hr^{-1})

Duration	5-min	10-min	15-min	30-min	1-hr	2-hr	6-hr	12-hr	24-hr
2-yr	122.7	75.6	56.9	35.1	21.6	13.3	6.2	3.8	2.3
5-yr	161.9	99.7	75.1	46.3	28.5	17.6	8.1	5.0	3.1
10-yr	188.0	115.8	87.2	53.7	33.1	20.4	9.5	5.8	3.6
25-yr	220.4	135.8	102.3	63.0	38.8	23.9	11.1	6.8	4.2
50-yr	244.2	150.5	113.3	69.8	43.0	26.5	12.3	7.6	4.7
100-yr	268.1	165.1	124.4	76.6	47.2	29.1	13.5	8.3	5.1

Rainfall depth (mm)

Duration	5-min	10-min	15-min	30-min	1-hr	2-hr	6-hr	12-hr	24-hr
2-yr	10.2	12.6	14.2	17.5	21.6	26.6	37.0	45.6	56.2
5-yr	13.5	16.6	18.8	23.1	28.5	35.1	48.9	60.2	74.2
10-yr	15.7	19.3	21.8	26.9	33.1	40.8	56.8	69.9	86.2
25-yr	18.4	22.6	25.6	31.5	38.8	47.8	66.5	82.0	101.0
50-yr	20.4	25.1	28.3	34.9	43.0	53.0	73.7	90.8	111.9
100-yr	22.3	27.5	31.1	38.3	47.2	58.2	80.9	99.7	122.9

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Last Modified: September 2016

Ontario IDF CURVE LOOKUP

Active coordinate

44° 0' 15" N, 78° 1' 45" W (44.004167,-78.029167)

Retrieved: Wed, 30 Jan 2019 21:27:12 GMT

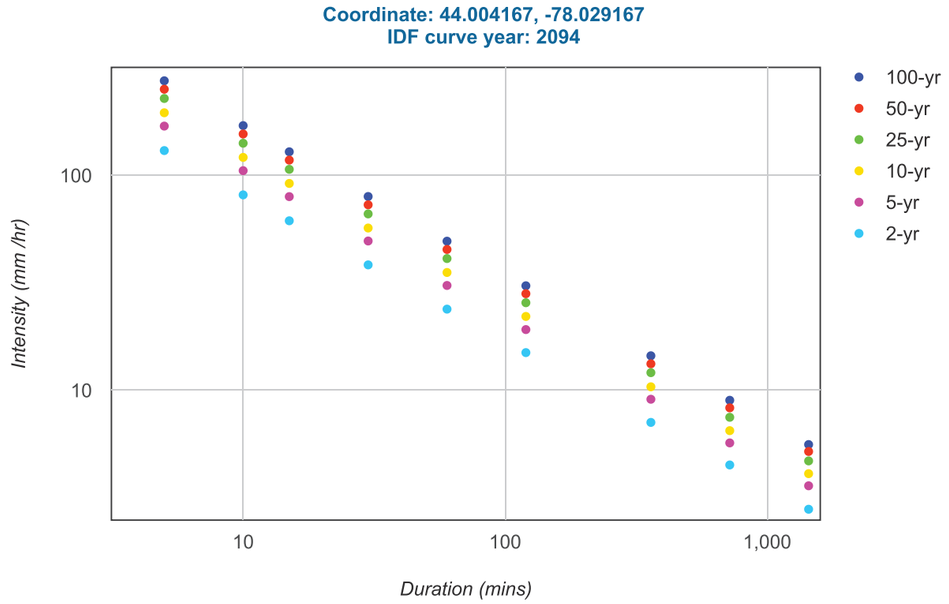
Location summary

These are the locations in the selection.

IDF Curve: 44° 0' 15" N, 78° 1' 45" W (44.004167,-78.029167)

Results

An IDF curve was found.



Coefficient summary

IDF Curve: 44° 0' 15" N, 78° 1' 45" W (44.004167,-78.029167)

Retrieved: Wed, 30 Jan 2019 21:27:12 GMT

Data year: 2010
IDF curve year: 2094

Statistics

Rainfall intensity (mm hr^{-1})

Duration	5-min	10-min	15-min	30-min	1-hr	2-hr	6-hr	12-hr	24-hr
2-yr	130.7	81.3	61.6	38.4	23.9	15.0	7.1	4.5	2.8
5-yr	169.9	105.4	79.8	49.6	30.8	19.2	9.1	5.7	3.6
10-yr	196.0	121.5	91.9	57.0	35.4	22.1	10.4	6.5	4.1
25-yr	228.4	141.4	106.9	66.3	41.1	25.6	12.1	7.5	4.7
50-yr	252.2	156.1	118.0	73.1	45.3	28.2	13.3	8.3	5.2
100-yr	276.1	170.8	129.0	79.9	49.5	30.7	14.5	9.0	5.6

Rainfall depth (mm)

Duration	5-min	10-min	15-min	30-min	1-hr	2-hr	6-hr	12-hr	24-hr
2-yr	10.9	13.6	15.4	19.2	23.9	30.0	42.6	54.0	67.2
5-yr	14.2	17.6	19.9	24.8	30.8	38.4	54.6	68.4	86.4
10-yr	16.3	20.3	23.0	28.5	35.4	44.2	62.4	78.0	98.4
25-yr	19.0	23.6	26.7	33.1	41.1	51.2	72.6	90.0	112.8
50-yr	21.0	26.0	29.5	36.5	45.3	56.4	79.8	99.6	124.8
100-yr	23.0	28.5	32.3	40.0	49.5	61.4	87.0	108.0	134.4

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Last Modified: September 2016

Ministry of Transportation - Highway 401 Widening - 165001090
GWP 4060-11-00
Existing Conditions

Soil Type	Hydrologic Soil Group
Fine Sandy Loam	A
Loamy Sand	B
Clay Loam, Silty Clay Loam	C
Clay	D

TABLE OF CURVE NUMBERS (CN's)

Land Use		Hydrologic Soil Type							Source
		A	AB	B	BC	C	CD	D	
Meadow	"Good"	30	44	58	64.5	71	74.5	78	MTO
Woodlot	"Fair"	36	48	60	66.5	73	76	79	MTO
Lawns	"Good"	39	50	61	67.5	74	77	80	USDA
Pasture/Range		58	61.5	65	70.5	76	78.5	81	MTO
Crop		66	70	74	78	82	84	86	MTO
Bare Soil (Fallow)		77	82	86	89	91	93	94	MTO
Impervious		98	98	98	98	98	98	98	MTO

MTO - Ministry of Transportation Ontario Drainage Manual (1997), Design Chart 1.09-Soil/Land Use Curve Numbers
USDA - United States Department of Agriculture (2004), National Engineering Handbook, Part 630 Hydrology,
Chapter 9 Hydrologic Soil Cover Compexes

HYDROLOGIC SOIL TYPE (%) - Existing Conditions

CVID	DAID	Station	Hydrologic Soil Type							TOTAL
			A	AB	B	BC	C	CD	D	
Highway 401 - Hamilton Township										
000804010053	CV-0401-001882	23+330	16		84		0		0	100
000804010044	CV-0401-002059	23+605	6		94		0		0	100
000804010047	CV-0401-001881	24+810	11		85		4		0	100
Highway 401 - Haldimand Township										
21-467/C	21-467/C	10+715	4		96		0		0	100
000904010054	CV-0401-001858	11+705	0		100		0		0	100
000904010052	CV-0401-001857	12+090	0		100		0		0	100
21-468/C	21-468/C	12+420	7		88		4		0	100
000904010048	CV-0401-001855	12+720	85		15		0		0	100
000904010047	CV-0401-001873	13+030	34		66		0		0	100
21-469/C	21-469/C	14+135	11		81		8		0	100
21-270/C	21-270/C	14+200	9		77		11		2	100
000904010065/46	CV-0401-001791	14+660	34		66		0		0	100
000904010068	CV-0401-001721	15+150	39		61		0		0	100
000904010071/44	CV-0401-001885/824	15+480	28		72		0		0	100
000904010037	CV-0401-001912	16+390	9		91		0		0	100
000904010080/35	CV-0401-001908/880	16+620	0		100		0		0	100
21-470/C	21-470/C	17+170	22		77		0		0	100
000904010083	CV-0401-001862	17+640	100		0		0		0	100
21-272/C	21-272/C	19+340	45		44		6		4	100
00904010033	CV-0401-001893	20+590	61		21		17		0	100
000904010085	CV-0401-001906	20+930	0		62		38		0	100
000904010086	CV-0401-001907	21+030	0		75		25		0	100
000904010015	CV-0401-001854	21+615	0		100		0		0	100
21-576/C	21-576/C	22+125	57		41		3		0	100
000904010014	CV-0401-001853	22+315	91		4		5		0	100
000904010007	CV-0401-001914	22+480	100		0		0		0	100
000904010004	CV-0401-001852	22+700	45		42		13		0	100
000904010003	CV-0401-001851	23+770	25		73		2		0	100
000904010001	CV-0401-001850	24+940	22		78		0		0	100
Highway 401 - Cramahe Township										
001004010032	CV-0401-001837	10+396	16		84		0		0	100
001004010030	CV-0401-001835	11+143	0		100		0		0	100
001004010041	CV-0401-001910	11+478	0		100		0		0	100

LAND USE (%) - Existing Conditions

CVID	DAID	Station	Meadow	Woodlot	Lawns	Pasture Range	Crop	Bare Soil	Lakes and Wetlands	Impervious	Total
Highway 401 - Hamilton Township											
000804010053	CV-0401-001882	23+330		34			53		0	13.0	100
000804010044	CV-0401-002059	23+605		33			63		0	3.9	100
000804010047	CV-0401-001881	24+810		48			49		1	1.8	100
Highway 401 - Haldimand Township											
21-467/C	21-467/C	10+715		39			60		0	1.0	100
000904010054	CV-0401-001858	11+705		24			74		0	2.9	100
000904010052	CV-0401-001857	12+090		3			88		0	8.6	100
21-468/C	21-468/C	12+420		16			81		1	1.6	100
000904010048	CV-0401-001855	12+720		57			32		4	6.9	100
000904010047	CV-0401-001873	13+030		68			25		0	6.7	100
21-469/C	21-469/C	14+135		40			44		9	7.4	100
21-270/C	21-270/C	14+200		23			71		6	0.1	100
000904010065/46	CV-0401-001791	14+660		48			41		0	10.1	100
000904010068	CV-0401-001721	15+150		25			53		6	15.9	100
000904010071/44	CV-0401-001885/824	15+480		27			54		0	18.7	100
000904010037	CV-0401-001912	16+390		16			72		0	12.7	100
000904010080/35	CV-0401-001908/880	16+620		7			80		0	12.6	100
21-470/C	21-470/C	17+170		33			65		1	0.9	100
000904010083	CV-0401-001862	17+640		6			73		10	12.0	100
21-272/C	21-272/C	19+340		31			61		8	0.1	100
00904010033	CV-0401-001893	20+590		34			55		8	3.0	100
000904010085	CV-0401-001906	20+930		65			31		0	4.5	100
000904010086	CV-0401-001907	21+030		75			22		0	3.5	100
000904010015	CV-0401-001854	21+615		3			80		0	16.4	100
21-576/C	21-576/C	22+125		41			53		6	0.2	100
000904010014	CV-0401-001853	22+315		28			64		6	2.6	100
000904010007	CV-0401-001914	22+480		25			65		3	7.2	100
000904010004	CV-0401-001852	22+700		37			59		2	1.9	100
000904010003	CV-0401-001851	23+770		24			70		5	0.9	100
000904010001	CV-0401-001850	24+940		27			62		3	7.4	100
Highway 401 - Cramahe Township											
001004010032	CV-0401-001837	10+396		19			67		0	14.6	100
001004010030	CV-0401-001835	11+143		8			87		1	3.6	100
001004010041	CV-0401-001910	11+478		7			89		0	4.2	100

CURVE NUMBER (CN) - Existing Conditions

CVID	DAID	Station	Meadow	Woodlot	Lawns	Pasture Range	Crop	Bare Soil	Lakes and Wetlands	Impervious	Weighted CN w/ imp area	Weighted CN w/o imp area
Highway 401 - Hamilton Township												
000804010053	CV-0401-001882	23+330		19			38			12.7	70.3	66.2
000804010044	CV-0401-002059	23+605		20			46			3.8	69.5	68.4
000804010047	CV-0401-001881	24+810		28			36		1	1.8	66.6	66.0
Highway 401 - Haldimand Township												
21-467/C	21-467/C	10+715		23			44		0	1.0	68.4	68.1
000904010054	CV-0401-001858	11+705		14			54			2.8	71.4	70.6
000904010052	CV-0401-001857	12+090		2			65			8.4	75.6	73.5
21-468/C	21-468/C	12+420		10			60		1	1.5	71.9	71.5
000904010048	CV-0401-001855	12+720		23			21		3	6.8	53.9	50.6
000904010047	CV-0401-001873	13+030		35			18			6.5	59.9	57.1
21-469/C	21-469/C	14+135		23			33		7	7.2	70.4	68.3
21-270/C	21-270/C	14+200		14			53		5	0.1	71.3	71.2
000904010065/46	CV-0401-001791	14+660		25			30			9.9	64.6	60.8
000904010068	CV-0401-001721	15+150		13			38		5	15.6	70.8	65.6
000904010071/44	CV-0401-001885/824	15+480		14			39			18.3	71.7	65.7
000904010037	CV-0401-001912	16+390		9			52			12.5	74.0	70.5
000904010080/35	CV-0401-001908/880	16+620		4			59			12.4	76.0	72.9
21-470/C	21-470/C	17+170		18			47		1	0.8	66.6	66.3
000904010083	CV-0401-001862	17+640		2			48		8	11.7	69.3	65.4
21-272/C	21-272/C	19+340		16			43		7	0.1	65.9	65.9
00904010033	CV-0401-001893	20+590		16			39		6	3.0	64.4	63.3
000904010085	CV-0401-001906	20+930		42			24			4.4	70.2	68.9
000904010086	CV-0401-001907	21+030		47			16			3.4	67.3	66.1
000904010015	CV-0401-001854	21+615		2			60			16.1	77.5	73.5
21-576/C	21-576/C	22+125		19			37		5	0.2	61.0	60.9
000904010014	CV-0401-001853	22+315		11			43		4	2.5	60.5	59.5
000904010007	CV-0401-001914	22+480		9			43		2	7.1	61.1	58.2
000904010004	CV-0401-001852	22+700		19			42		1	1.8	64.5	63.8
000904010003	CV-0401-001851	23+770		13			51		5	0.8	68.7	68.5
000904010001	CV-0401-001850	24+940		15			45		2	7.2	69.7	67.5
Highway 401 - Cramahe Township												
001004010032	CV-0401-001837	10+396		10			49			14.3	73.3	69.1
001004010030	CV-0401-001835	11+143		5			64		1	3.5	73.8	72.9
001004010041	CV-0401-001910	11+478		4			66			4.2	74.1	73.0

Notes:

AMC II assumed

Hydrological Soil Groups taken from MTO Drainage Manual and OMAFRA

*1 Catchments with impervious greater than 20% - only pervious portions used for CN calculation

Ministry of Transportation - Highway 401 Widening - 165001090

GWP 4060-11-00

Proposed Conditions

Soil Type	Hydrologic Soil Group
Fine Sandy Loam	A
Loamy Sand	B
Clay Loam, Silty Clay Loam	C
Clay	D

TABLE OF CURVE NUMBERS (CN's)

Land Use		Hydrologic Soil Type							Source
		A	AB	B	BC	C	CD	D	
Meadow	"Good"	30	44	58	64.5	71	74.5	78	MTO
Woodlot	"Fair"	36	48	60	66.5	73	76	79	MTO
Lawns	"Good"	39	50	61	67.5	74	77	80	USDA
Pasture/Range		58	61.5	65	70.5	76	78.5	81	MTO
Crop		66	70	74	78	82	84	86	MTO
Bare Soil (Fallow)		77	82	86	89	91	93	94	MTO
Impervious		98	98	98	98	98	98	98	MTO

MTO - Ministry of Transportation Ontario Drainage Manual (1997), Design Chart 1.09-Soil/Land Use Curve Numbers

USDA - United States Department of Agriculture (2004), National Engineering Handbook, Part 630 Hydrology,
Chapter 9 Hydrologic Soil Cover Compexes

HYDROLOGIC SOIL TYPE (%) - Proposed Conditions

CVID	DAID	Station	Hydrologic Soil Type							TOTAL
			A	AB	B	BC	C	CD	D	
Highway 401 - Hamilton Township										
000804010053	CV-0401-001882	23+330	16		84		0		0	100
000804010044	CV-0401-002059	23+605	6		94		0		0	100
000804010047	CV-0401-001881	24+810	11		85		4		0	100
Highway 401 - Haldimand Township										
21-467/C	21-467/C	10+715	4		96		0		0	100
000904010054	CV-0401-001858	11+705	0		100		0		0	100
000904010052	CV-0401-001857	12+090	0		100		0		0	100
21-468/C	21-468/C	12+420	7		88		4		0	100
000904010048	CV-0401-001855	12+720	85		15		0		0	100
000904010047	CV-0401-001873	13+030	34		66		0		0	100
21-469/C	21-469/C	14+135	11		81		8		0	100
21-270/C	21-270/C	14+200	9		77		11		2	100
000904010065/46	CV-0401-001791	14+660	34		66		0		0	100
000904010068	CV-0401-001721	15+150	39		61		0		0	100
000904010071/44	CV-0401-001885/824	15+480	28		72		0		0	100
000904010037	CV-0401-001912	16+390	9		91		0		0	100
000904010080/35	CV-0401-001908/880	16+620	0		100		0		0	100
21-470/C	21-470/C	17+170	22		77		0		0	100
000904010083	CV-0401-001862	17+640	100		0		0		0	100
21-272/C	21-272/C	19+340	45		44		6		4	100
00904010033	CV-0401-001893	20+590	61		21		17		0	100
000904010085	CV-0401-001906	20+930	0		62		38		0	100
000904010086	CV-0401-001907	21+030	0		75		25		0	100
000904010015	CV-0401-001854	21+615	0		100		0		0	100
21-576/C	21-576/C	22+125	57		41		3		0	100
000904010014	CV-0401-001853	22+315	91		4		5		0	100
000904010007	CV-0401-001914	22+480	100		0		0		0	100
000904010004	CV-0401-001852	22+700	45		42		13		0	100
000904010003	CV-0401-001851	23+770	25		73		2		0	100
000904010001	CV-0401-001850	24+940	22		78		0		0	100
Highway 401 - Cramahe Township										
001004010032	CV-0401-001837	10+396	16		84		0		0	100
001004010030	CV-0401-001835	11+143	0		100		0		0	100
001004010041	CV-0401-001910	11+478	0		100		0		0	100

LAND USE (%) - Proposed Conditions											
CVID	DAID	Station	Meadow	Woodlot	Lawns	Pasture Range	Crop	Bare Soil	Lakes and Wetlands	Impervious	Total
Highway 401 - Hamilton Township											
000804010053	CV-0401-001882	23+330		34			46		0	19.3	100
000804010044	CV-0401-002059	23+605		33			61		0	5.7	100
000804010047	CV-0401-001881	24+810		48			48		1	2.7	100
Highway 401 - Haldimand Township											
21-467/C	21-467/C	10+715		39			60		0	1.5	100
000904010054	CV-0401-001858	11+705		24			72		0	4.3	100
000904010052	CV-0401-001857	12+090		3			84		0	12.8	100
21-468/C	21-468/C	12+420		16			81		1	1.9	100
000904010048	CV-0401-001855	12+720		57			29		4	9.7	100
000904010047	CV-0401-001873	13+030		68			23		0	8.6	100
21-469/C	21-469/C	14+135		40			42		9	9.9	100
21-270/C	21-270/C	14+200		23			71		6	0.1	100
000904010065/46	CV-0401-001791	14+660		48			37		0	15.0	100
000904010068	CV-0401-001721	15+150		25			48		6	20.9	100
000904010071/44	CV-0401-001885/824	15+480		27			49		0	24.4	100
000904010037	CV-0401-001912	16+390		16			66		0	18.1	100
000904010080/35	CV-0401-001908/880	16+620		7			74		0	18.7	100
21-470/C	21-470/C	17+170		33			65		1	1.3	100
000904010083	CV-0401-001862	17+640		6			67		10	17.8	100
21-272/C	21-272/C	19+340		31			61		8	0.1	100
00904010033	CV-0401-001893	20+590		34			54		8	4.0	100
000904010085	CV-0401-001906	20+930		65			29		0	6.4	100
000904010086	CV-0401-001907	21+030		75			20		0	5.0	100
000904010015	CV-0401-001854	21+615		3			73		0	24.3	100
21-576/C	21-576/C	22+125		41			53		6	0.4	100
000904010014	CV-0401-001853	22+315		28			63		6	3.6	100
000904010007	CV-0401-001914	22+480		25			62		3	9.8	100
000904010004	CV-0401-001852	22+700		37			58		2	2.8	100
000904010003	CV-0401-001851	23+770		24			70		5	1.3	100
000904010001	CV-0401-001850	24+940		27			59		3	10.9	100
Highway 401 - Cramahe Township											
001004010032	CV-0401-001837	10+396		19			60		0	21.6	100
001004010030	CV-0401-001835	11+143		8			86		1	4.3	100
001004010041	CV-0401-001910	11+478		7			87		0	6.3	100

CURVE NUMBER (CN) - Proposed Conditions												
CVID	DAID	Station	Meadow	Woodlot	Lawns	Pasture Range	Crop	Bare Soil	Lakes and Wetlands	Impervious	Weighted CN w/ imp area	Weighted CN w/o imp area
Highway 401 - Hamilton Township												
000804010053	CV-0401-001882	23+330		19			34			18.9	71.9	65.7
000804010044	CV-0401-002059	23+605		20			45			5.6	70.0	68.3
000804010047	CV-0401-001881	24+810		28			35		1	2.6	66.8	65.9
Highway 401 - Haldimand Township												
21-467/C	21-467/C	10+715		23			44		0	1.5	68.5	68.1
000904010054	CV-0401-001858	11+705		14			53			4.2	71.7	70.6
000904010052	CV-0401-001857	12+090		2			62			12.5	76.6	73.5
21-468/C	21-468/C	12+420		10			60		1	1.9	72.0	71.5
000904010048	CV-0401-001855	12+720		23			20		3	9.5	54.8	50.1
000904010047	CV-0401-001873	13+030		35			17			8.5	60.4	56.8
21-469/C	21-469/C	14+135		23			31		7	9.7	71.1	68.1
21-270/C	21-270/C	14+200		14			53		5	0.1	71.3	71.2
000904010065/46	CV-0401-001791	14+660		25			26			14.7	65.9	60.2
000904010068	CV-0401-001721	15+150		13			34		5	20.4	72.1	65.3
000904010071/44	CV-0401-001885/824	15+480		14			35			23.9	73.2	65.2
000904010037	CV-0401-001912	16+390		9			48			17.8	75.3	70.3
000904010080/35	CV-0401-001908/880	16+620		4			55			18.3	77.5	72.8
21-470/C	21-470/C	17+170		18			46		1	1.3	66.7	66.3
000904010083	CV-0401-001862	17+640		2			44		8	17.4	71.1	65.3
21-272/C	21-272/C	19+340		16			43		7	0.1	65.9	65.9
00904010033	CV-0401-001893	20+590		16			38		6	4.0	64.7	63.3
000904010085	CV-0401-001906	20+930		42			22			6.2	70.6	68.7
000904010086	CV-0401-001907	21+030		47			15			4.9	67.6	66.0
000904010015	CV-0401-001854	21+615		2			54			23.8	79.4	73.4
21-576/C	21-576/C	22+125		19			37		5	0.4	61.1	60.9
000904010014	CV-0401-001853	22+315		11			42		4	3.5	60.8	59.5
000904010007	CV-0401-001914	22+480		9			41		2	9.6	61.9	58.0
000904010004	CV-0401-001852	22+700		19			42		1	2.7	64.7	63.8
000904010003	CV-0401-001851	23+770		13			50		5	1.2	68.8	68.5
000904010001	CV-0401-001850	24+940		15			42		2	10.7	70.6	67.3
Highway 401 - Cramahe Township												
001004010032	CV-0401-001837	10+396		10			43			21.2	75.1	68.8
001004010030	CV-0401-001835	11+143		5			64		1	4.2	74.0	72.9
001004010041	CV-0401-001910	11+478		4			64			6.2	74.5	73.0

Notes:

AMC II assumed

Hydrological Soil Groups taken from MTO Drainage Manual and OMAFRA

[*1] Catchments with impervious greater than 20% - only pervious portions used for CN calculation

Ministry of Transportation - Highway 401 Widening - 165001090
HEC-HMS Parameters

Existing Conditions

CVID	DAID	Station	Area (ha)	Area (km2)	CN	TIMP (%)	XIMP (%)	Rise (m)	Length (m)	Slope (%)	R.C.	Tc (hrs)	Tp (hrs)	Tp (mins)
Highway 401 - Hamilton Township														
000804010053	CV-0401-001882	23+330	8.1	0.08	70.3	13	13	45	400	11.3	0.3	0.39	0.23	14
000804010044	CV-0401-002059	23+605	10.5	0.10	69.5	4	4	65	600	10.8	0.3	0.49	0.29	17
000804010047	CV-0401-001881	24+810	253.5	2.53	66.6	2	2	85	2300	3.7	0.3	2.03	1.22	73
Highway 401 - Haldimand Township														
21-467/C	21-467/C	10+715	337.3	3.37	68.4	1	1	110	3200	3.4	0.3	2.61	1.57	94
000904010054	CV-0401-001858	11+705	54.8	0.55	71.4	3	3	65	1400	4.6	0.3	0.98	0.59	35
000904010052	CV-0401-001857	12+090	10.1	0.10	75.6	9	9	45	500	9.0	0.3	0.47	0.28	17
21-468/C	21-468/C	12+420	229.8	2.30	71.9	2	2	115	2900	4.0	0.3	2.05	1.23	74
000904010048	CV-0401-001855	12+720	23.6	0.24	53.9	7	7	70	800	8.8	0.3	0.60	0.36	22
000904010047	CV-0401-001873	13+030	38.3	0.38	59.9	7	7	55	1000	5.5	0.3	0.78	0.47	28
21-469/C	21-469/C	14+135	45.1	0.45	70.4	7	7	55	700	7.9	0.3	0.58	0.35	21
21-270/C	21-270/C	14+200	1911.6	19.12	71.3	0	0	135	13000	1.0	0.3	5.02	3.01	181
000904010065/46	CV-0401-001791	14+660	11.7	0.12	64.6	10	10	20	600	3.3	0.3	0.72	0.43	26
000904010068	CV-0401-001721	15+150	5.3	0.05	70.8	16	16	25	350	7.1	0.3	0.43	0.26	15
000904010071/44	CV-0401-001885/824	15+480	21.8	0.22	71.7	19	19	20	550	3.6	0.3	0.67	0.40	24
000904010037	CV-0401-001912	16+390	12.5	0.13	74.0	13	13	20	350	5.7	0.3	0.46	0.27	16
000904010080/35	CV-0401-001908/880	16+620	9.8	0.10	76.0	13	13	20	350	5.7	0.3	0.46	0.27	16
21-470/C	21-470/C	17+170	276.9	2.77	66.6	1	1	50	2500	2.0	0.3	2.95	1.77	106
000904010083	CV-0401-001862	17+640	15.5	0.16	69.3	12	12	20	600	3.3	0.3	0.72	0.43	26
21-272/C	21-272/C	19+340	6045.4	60.45	65.9	0	0	190	20700	0.9	0.3	7.76	4.66	279
009040100333	CV-0401-001893	20+590	186.9	1.87	64.4	3	3	60	2000	3.0	0.3	2.13	1.28	77
000904010085	CV-0401-001906	20+930	14.6	0.15	70.2	5	5	20	700	2.9	0.3	0.81	0.49	29
000904010086	CV-0401-001907	21+030	41.0	0.41	67.3	4	4	25	1000	2.5	0.3	1.02	0.61	37
000904010015	CV-0401-001854	21+615	4.7	0.05	77.5	16	16	15	250	6.0	0.3	0.38	0.23	14
21-576/C	21-576/C	22+125	749.9	7.50	61.0	0	0	95	6000	1.6	0.3	2.55	1.53	92
000904010014	CV-0401-001853	22+315	35.3	0.35	60.5	3	3	70	1500	4.7	0.3	1.01	0.61	36
000904010007	CV-0401-001914	22+480	10.1	0.10	61.1	7	7	35	550	6.4	0.3	0.55	0.33	20
000904010004	CV-0401-001852	22+700	85.6	0.86	64.5	2	2	80	2300	3.5	0.3	1.38	0.83	50
000904010003	CV-0401-001851	23+770	481.1	4.81	68.7	1	1	70	5200	1.3	0.3	6.11	3.67	220
000904010001	CV-0401-001850	24+940	28.6	0.29	69.7	7	7	30	600	5.0	0.3	0.63	0.38	23
Highway 401 - Cramahe Township														
001004010032	CV-0401-001837	10+396	14.5	0.14	73.3	15	15	45	700	6.4	0.3	0.62	0.37	22
001004010030	CV-0401-001835	11+143	110.6	1.11	73.8	4	4	40	1800	2.2	0.3	1.77	1.06	64
001004010041	CV-0401-001910	11+478	47.5	0.48	74.1	4	4	40	1400	2.9	0.3	1.15	0.69	41

Parameter Notes:

TIMP — Total percent impervious
XIMP — Percent impervious directly connected

Time of Concentration calculated using the SCS Lag Equation
(For areas greater than 100 ha)

$Tc = [259L^{0.8}[(1000 / CN) - 9]^{0.7}] / [1900S^{0.5}]$
Where: L = Length of Overland Flow (m)
CN = SCS Curve Number
S = Slope (%)

Time of Concentration calculated using the Airport Method
(For areas less than 100 ha)

$Tc = [3.26 (1.1-C) L^{0.5}] / S^{0.33}$
Where: C = Runoff Coefficient = 0.3 for undeveloped areas
L = Length of Overland Flow (m)
S = Slope (%)

Time to Peak — Tp = 0.6Tc

Time of Concentration calculated using
(For areas greater than 1000 ha)

$Tc = T_{ph} + T_{sc} + T_{ch}$
Where: T_{ph} = Sheet Flow Travel Time (hr)
T_{sc} = Shallow concentrated travel time (hr)
T_{ch} = Channel flow time (hr)

T_{ph} = Sheet Flow Travel Time (hr) -
Natural Resources conservation Service (NRCS) variation of the Kinematic Wave Equation

$$T_{sh} = \frac{0.091 (n_{ol} L_{sh})^{0.8}}{P_{2-yr}^{0.5} S_{sh}^{0.4}}$$

Where: n_{ol} = Overland Flow Roughness Coefficient
L_{sh} = Sheet Flow Length (m)
P_2 = 2-year, 24-hr rainfall depth (mm)
S_{ph} = Sheet flow slope (m/M)
T_{ph} = Sheet Flow Travel Time (hr)

T_{sc} = Shallow concentrated travel time (hr) - Based on Manning's equation with n=0.05 and R=0.122 m

$$T_{sc} = \frac{L_{sc}}{3600 K S_{sc}^{0.5}}$$

Where: L_{sc} = Shallow concentrated flow length (m)
K = 4.9178 for unpaved surface
S_{sc} = Shallow concentrated flow slope
T_{sc} = Shallow concentrated travel time (hr)

T_{ch} = Channel flow time (hr) - Manning's Equation

$$T_{ch} = \frac{L_{ch}}{3600 \left(\frac{1}{n}\right) R^{2/3} S_{ch}^{0.5}}$$

Where: L_{ch} = Channel flow length (m)
S_{ch} = Channel flow slope
n = Manning's roughness coefficient
R = Channel hydraulic radius (m)
T_{ch} = Channel flow time (hr)

Time of Concentration (hr) = $T_{ph} + T_{sc} + T_{ch}$
Time to Peak — Tp = 0.6Tc

Ministry of Transportation - Highway 401 Widening - 165001090
HEC-HMS Parameters

Proposed Conditions

CVID	DAID	Station	Area (ha)	Area (km2)	CN	TIMP (%)	XIMP (%)	Rise (m)	Length (m)	Slope (%)	R.C.	Tc (hrs)	Tp (hrs)	Tp (mins)
Highway 401 - Hamilton Township														
000804010053	CV-0401-001882	23+330	8	0.08	71.9	19	19	45	400	11.3	0.3	0.39	0.23	14
000804010044	CV-0401-002059	23+605	10	0.10	70.0	6	6	65	600	10.8	0.3	0.49	0.29	17
000804010047	CV-0401-001881	24+810	253	2.53	66.8	3	3	85	2300	3.7	0.3	2.02	1.21	73
Highway 401 - Haldimand Township														
21-467/C	21-467/C	10+715	337.3	3.37	68.5	1	1	110	3200	3.4	0.3	2.61	1.56	94
000904010054	CV-0401-001858	11+705	54.8	0.55	71.7	4	4	65	1400	4.6	0.3	0.98	0.59	35
000904010052	CV-0401-001857	12+090	10.1	0.10	76.6	13	13	45	500	9.0	0.3	0.47	0.28	17
21-468/C	21-468/C	12+420	229.8	2.30	72.0	2	2	115	2900	4.0	0.3	2.04	1.22	73
000904010048	CV-0401-001855	12+720	23.6	0.24	54.8	10	10	70	800	8.8	0.3	0.60	0.36	22
000904010047	CV-0401-001873	13+030	38.3	0.38	60.4	9	9	55	1000	5.5	0.3	0.78	0.47	28
21-469/C	21-469/C	14+135	45.1	0.45	71.1	10	10	55	700	7.9	0.3	0.58	0.35	21
21-270/C	21-270/C	14+200	1911.6	19.12	71.3	0	0	135	13000	1.0	0.3	5.02	3.01	181
000904010065/46	CV-0401-001791	14+660	11.7	0.12	65.9	15	15	20	600	3.3	0.3	0.72	0.43	26
000904010068	CV-0401-001721	15+150	5.3	0.05	72.1	21	21	25	350	7.1	0.3	0.43	0.26	15
000904010071/44	CV-0401-001885/824	15+480	21.8	0.22	73.2	24	24	20	550	3.6	0.3	0.67	0.40	24
000904010037	CV-0401-001912	16+390	12.5	0.13	75.3	18	18	20	350	5.7	0.3	0.46	0.27	16
000904010080/35	CV-0401-001908/880	16+620	9.8	0.10	77.5	19	19	20	350	5.7	0.3	0.46	0.27	16
21-470/C	21-470/C	17+170	276.9	2.77	66.7	1	1	50	2500	2.0	0.3	2.94	1.76	106
000904010083	CV-0401-001862	17+640	15.5	0.16	71.1	18	18	20	600	3.3	0.3	0.72	0.43	26
21-272/C	21-272/C	19+340	6045.4	60.45	65.9	0	0	190	20700	0.9	0.3	7.76	4.66	279
009040100333	CV-0401-001893	20+590	186.9	1.87	64.7	4	4	60	2000	3.0	0.3	2.12	1.27	76
000904010085	CV-0401-001906	20+930	14.6	0.15	70.6	6	6	20	700	2.9	0.3	0.81	0.49	29
000904010086	CV-0401-001907	21+030	41.0	0.41	67.6	5	5	25	1000	2.5	0.3	1.02	0.61	37
000904010015	CV-0401-001854	21+615	4.7	0.05	79.4	24	24	15	250	6.0	0.3	0.38	0.23	14
21-576/C	21-576/C	22+125	749.9	7.50	61.1	0	0	95	6000	1.6	0.3	2.55	1.53	92
000904010014	CV-0401-001853	22+315	35.3	0.35	60.8	4	4	70	1500	4.7	0.3	1.01	0.61	36
000904010007	CV-0401-001914	22+480	10.1	0.10	61.9	10	10	35	550	6.4	0.3	0.55	0.33	20
000904010004	CV-0401-001852	22+700	85.6	0.86	64.7	3	3	80	2300	3.5	0.3	1.38	0.83	50
000904010003	CV-0401-001851	23+770	481.1	4.81	68.8	1	1	70	5200	1.3	0.3	6.09	3.66	219
000904010001	CV-0401-001850	24+940	28.6	0.29	70.6	11	11	30	600	5.0	0.3	0.63	0.38	23
Highway 401 - Cramahe Township														
001004010032	CV-0401-001837	10+396	14.5	0.14	75.1	15	15	45	700	6.4	0.3	0.62	0.37	22
001004010030	CV-0401-001835	11+143	110.6	1.11	74.0	4	4	40	1800	2.2	0.3	1.76	1.06	63
001004010041	CV-0401-001910	11+478	47.5	0.48	74.5	4	4	40	1400	2.9	0.3	1.15	0.69	41

Parameter Notes:

TIMP — Total percent impervious
XIMP — Percent impervious directly connected

Time of Concentration calculated using the SCS Lag Equation
(For areas greater than 100 ha)

$Tc = [259L^{0.8}[(1000 / CN) - 9]^{0.7}] / [1900S^{0.5}]$
Where: L = Length of Overland Flow (m)
CN = SCS Curve Number
S = Slope (%)

Time of Concentration calculated using the Airport Method
(For areas less than 100 ha)

$Tc = [3.26 (1.1-C) L^{0.5}] / S^{0.33}$
Where: C = Runoff Coefficient = 0.3 for undeveloped areas
L = Length of Overland Flow (m)
S = Slope (%)

Time to Peak — Tp = 0.6Tc

Time of Concentration calculated using
(For areas greater than 1000 ha)

$Tc = T_{ph} + T_{sc} + T_{ch}$
Where: T_{ph} = Sheet Flow Travel Time (hr)
T_{sc} = Shallow concentrated travel time (hr)
T_{ch} = Channel flow time (hr)

T_{ph} = Sheet Flow Travel Time (hr) -
Natural Resources conservation Service (NRCS) variation of the Kinematic Wave Equation

$$T_{sh} = \frac{0.091 (n_{ol} L_{sh})^{0.8}}{P_{2-yr}^{0.5} S_{sh}^{0.4}}$$

Where: n_{ol} = Overland Flow Roughness Coefficient
L_{sh} = Sheet Flow Length (m)
P_2 = 2-year, 24-hr rainfall depth (mm)
S_{ph} = Sheet flow slope (m/M)
T_{ph} = Sheet Flow Travel Time (hr)

T_{sc} = Shallow concentrated travel time (hr) - Based on Manning's equation with n=0.05 and R=0.122 m

$$T_{sc} = \frac{L_{sc}}{3600 K S_{sc}^{0.5}}$$

Where: L_{sc} = Shallow concentrated flow length (m)
K = 4.9178 for unpaved surface
S_{sc} = Shallow concentrated flow slope
T_{sc} = Shallow concentrated travel time (hr)

T_{ch} = Channel flow time (hr) - Manning's Equation

$$T_{ch} = \frac{L_{ch}}{3600 \left(\frac{1}{n}\right) R^{2/3} S_{ch}^{0.5}}$$

Where: L_{ch} = Channel flow length (m)
S_{ch} = Channel flow slope
n = Manning's roughness coefficient
R = Channel hydraulic radius (m)
T_{ch} = Channel flow time (hr)

Time of Concentration (hr) = $T_{ph} + T_{sc} + T_{ch}$
Time to Peak — Tp = 0.6Tc

Ministry of Transportation - Highway 401 Widening - 165001090
HEC-HMS Parameters

Proposed Controlled Conditions

Catchment Number	Nearby Culvert DAID	Station	Area (ha)	Area (km2)	CN	TIMP (%)	XIMP (%)	Rise (m)	Length (m)	Slope (%)	R.C.	Tc (hrs)	Tp (hrs)	Tp (mins)
Highway 401 - Hamilton Township														
000804010053	CV-0401-001882	23+330	6.16	0.06	71.90	19	19	45	400	11	0.3	0.39	0.23	14
000804010053_CTRL			1.95	0.02	82.28			2	275	1	0.7	0.44	0.26	16
Highway 401 - Haldimand Township														
000904010048	CV-0401-001855	12+720	22.00	0.22	54.8	10	10	70	800	9	0.3	0.60	0.36	22
000904010048_CTRL			1.59	0.02	88.92			8	300	3	0.7	0.27	0.16	10
000904010065/46	CV-0401-001791	14+660	10.29	0.10	65.90	14.97	14.97	20	600	3	0.3	0.72	0.43	26
000904010065/46_CTRL			1.39	0.01	88.92			2	380	1	0.7	0.52	0.31	19
000904010071/44	CV-0401-001885/824	15+480	18.73	0.19	73.20	24.42	24.42	20	550	4	0.3	0.67	0.40	24
000904010071/44_CTRL			3.05	0.03	88.92			2	500	0	0.7	0.66	0.39	24
000904010068+71/44	CV-0401-001721 + CV-0401-001885/824	15+150	23.40	0.23	72.10	20.85	20.85	25	600	4	0.3	0.66	0.40	24
000904010068+71/44_CTRL			3.70	0.04	88.92			3	600	1	0.7	0.67	0.40	24
000904010083	CV-0401-001862	17+640	13.28	0.13	71.10	17.76	17.76	20	600	3	0.3	0.72	0.43	26
000904010083_CTRL			2.26	0.02	88.92			4	430	1	0.7	0.46	0.28	17
000904010015	CV-0401-001854	21+615	3.77	0.04	79.40	24.33	24.33	15	250	6	0.3	0.38	0.23	14
000904010015_CTRL			0.96	0.01	88.92			12	500	2	0.7	0.36	0.22	13
000904010007	CV-0401-001914	22+480	9.30	0.09	61.10	10	10	35	550	6	0.3	0.55	0.33	20
000904010007_CTRL			0.70	0.01	88.92			9	250	4	0.7	0.23	0.14	8
Highway 401 - Cramahe Township														
001004010032	CV-0401-001837	10+396	11.98	0.12	75.10	15	15	45	700	6.4	0.3	0.62	0.37	22
001004010032_CTRL			2.50	0.03	88.92			1	200	1	0.7	0.39	0.23	14

Parameter Notes:

TIMP — Total percent impervious
XIMP — Percent impervious directly connected

Time of Concentration calculated using the SCS Lag Equation
(For areas greater than 100 ha)

$Tc = [259L^{0.8} [(1000 / CN) - 9]^{0.7}] / [19005^{0.5}]$
Where: L = Length of Overland Flow (m)
CN = SCS Curve Number
S = Slope (%)

Time of Concentration calculated using the Airport Method
(For areas less than 100 ha)

$Tc = [3.26 (1.1-C) L^{0.5}] / S^{0.33}$
Where: C = Runoff Coefficient = 0.3 for undeveloped areas
L = Length of Overland Flow (m)
S = Slope (%)

Time to Peak — $Tp = 0.6Tc$

Time of Concentration calculated using
(For areas greater than 1000 ha)

$Tc = T_{sh} + T_{sc} + T_{ch}$
Where: T_{sh} = Sheet Flow Travel Time (hr)
T_{sc} = Shallow concentrated travel time (hr)
T_{ch} = Channel flow time (hr)

T_{sh} = Sheet Flow Travel Time (hr) -
Natural Resources conservation Service (NRCS) variation of the Kinematic Wave Equation

$$T_{sh} = \frac{0.091 (n_{ol} L_{sh})^{0.8}}{P_{2-yr}^{0.5} S_{sh}^{0.4}}$$

Where: n_{ol} = Overland Flow Roughness Coefficient
L_{sh} = Sheet Flow Length (m)
P_2 = 2-year, 24-hr rainfall depth (mm)
S_{sh} = Sheet flow slope (m/M)
T_{sh} = Sheet Flow Travel Time (hr)

T_{sc} = Shallow concentrated travel time (hr) - Based on Manning's equation with n=0.05 and R=0.122 m

$$T_{sc} = \frac{L_{sc}}{3600 K S_{sc}^{0.5}}$$

Where: L_{sc} = Shallow concentrated flow length (m)
K = 4.9178 for unpaved surface
S_{sc} = Shallow concentrated flow slope
T_{sc} = Shallow concentrated travel time (hr)

T_{ch} = Channel flow time (hr) - Manning's Equation

$$T_{ch} = \frac{L_{ch}}{3600 \left(\frac{1}{n}\right) R^{2/3} S_{ch}^{0.5}}$$

Where: L_{ch} = Channel flow length (m)
S_{ch} = Channel flow slope
n = Manning's roughness coefficient
R = Channel hydraulic radius (m)
T_{ch} = Channel flow time (hr)

Time of Concentration (hr) = $T_{sh} + T_{sc} + T_{ch}$
Time to Peak — $Tp = 0.6Tc$

HEC-HMS Results

Project: Hwy 401 Widening, Cobourg to Colborne

Simulation Run: Future 50-yr, Existing Conditions

Hydrologic Element	Drainage Area (km^2)	Peak discharge (m^3/s)	Time of Peak	Volume ($1000m^3$)
804010044	0.1	0.68	01Jan2000, 12:15	4.9
804010047	2.53	6.02	01Jan2000, 13:30	109.9
804010053	0.08	0.60	01Jan2000, 12:15	4.1
904010001	0.29	1.65	01Jan2000, 12:15	14.3
904010003	4.81	5.65	01Jan2000, 16:45	228.3
904010004	0.86	2.34	01Jan2000, 13:00	34
904010007	0.1	0.38	01Jan2000, 12:15	3.4
904010014	0.35	0.91	01Jan2000, 12:45	11.4
904010015	0.05	0.66	01Jan2000, 12:00	3.3
904010033	1.87	3.72	01Jan2000, 13:30	73.7
904010037	0.13	1.10	01Jan2000, 12:15	7.6
904010047	0.38	1.10	01Jan2000, 12:30	12
904010052	0.1	0.88	01Jan2000, 12:15	6.2
904010054	0.55	2.67	01Jan2000, 12:30	29.1
000904010065/46	0.12	0.49	01Jan2000, 12:30	4.8
904010068	0.05	0.38	01Jan2000, 12:15	2.6
000904010071/44	0.22	1.34	01Jan2000, 12:15	11.8
000904010080/35	0.1	0.91	01Jan2000, 12:15	6.3
904010083	0.16	0.84	01Jan2000, 12:30	7.8
904010085	0.15	0.78	01Jan2000, 12:30	7.6
904010086	0.41	1.57	01Jan2000, 12:45	18.4
904040048	0.24	0.48	01Jan2000, 12:30	5.3
1004010030	1.11	3.98	01Jan2000, 13:15	64.2
1004010032	0.14	0.98	01Jan2000, 12:15	7.9
1004010041	0.48	2.38	01Jan2000, 12:45	28.1
21-270/C	19.116	43.53	01Jan2000, 15:15	1006.3
21-272/C	60.454	76.87	01Jan2000, 17:15	2547.8
21-467/C	3.37	10.84	01Jan2000, 13:30	158
21-468/C	2.298	10.39	01Jan2000, 13:15	123.8
21-469/C	0.451	3.83	01Jan2000, 12:15	22.9
21-470/C	2.769	7.47	01Jan2000, 13:45	120.3
21-576/C	7.499	15.97	01Jan2000, 13:45	250.5
47+48	0.62	1.58	01Jan2000, 12:30	17.3
52+21-468	2.398	10.68	01Jan2000, 13:15	129.9
53+44	0.18	1.28	01Jan2000, 12:15	9
65/46+21-270	19.236	43.62	01Jan2000, 15:15	1011.1
71/44+68	0.27	1.72	01Jan2000, 12:15	14.3
80/35+37	0.23	2.01	01Jan2000, 12:15	13.8
85+86	0.56	2.33	01Jan2000, 12:30	25.9

HEC-HMS Results

Project: Hwy 401 Widening, Cobourg to Colborne

Simulation Run: Future 100-yr, Existing Conditions

Hydrologic Element	Drainage Area (km^2)	Peak discharge (m^3/s)	Time of Peak	Volume ($1000m^3$)
804010044	0.1	0.78	01Jan2000, 12:15	5.6
804010047	2.53	7.05	01Jan2000, 13:30	127
804010053	0.08	0.70	01Jan2000, 12:15	4.6
904010001	0.29	1.92	01Jan2000, 12:15	16.4
904010003	4.81	6.54	01Jan2000, 16:30	262.2
904010004	0.86	2.77	01Jan2000, 13:00	39.5
904010007	0.1	0.46	01Jan2000, 12:15	3.9
904010014	0.35	1.10	01Jan2000, 12:45	13.4
904010015	0.05	0.74	01Jan2000, 12:00	3.7
904010033	1.87	4.41	01Jan2000, 13:30	85.6
904010037	0.13	1.25	01Jan2000, 12:15	8.6
904010047	0.38	1.35	01Jan2000, 12:30	14.2
904010052	0.1	1.00	01Jan2000, 12:15	7
904010054	0.55	3.09	01Jan2000, 12:30	33.1
000904010065/46	0.12	0.58	01Jan2000, 12:30	5.5
904010068	0.05	0.43	01Jan2000, 12:15	2.9
000904010071/44	0.22	1.55	01Jan2000, 12:15	13.4
000904010080/35	0.1	1.04	01Jan2000, 12:15	7.1
904010083	0.16	0.98	01Jan2000, 12:30	8.9
904010085	0.15	0.90	01Jan2000, 12:30	8.7
904010086	0.41	1.84	01Jan2000, 12:45	21.2
904040048	0.24	0.61	01Jan2000, 12:30	6.4
1004010030	1.11	4.55	01Jan2000, 13:15	72.7
1004010032	0.14	1.12	01Jan2000, 12:15	9
1004010041	0.48	2.72	01Jan2000, 12:45	31.8
21-270/C	19.116	50.09	01Jan2000, 15:15	1147.6
21-272/C	60.454	89.91	01Jan2000, 17:15	2948.1
21-467/C	3.37	12.64	01Jan2000, 13:30	181.6
21-468/C	2.298	11.93	01Jan2000, 13:15	140.9
21-469/C	0.451	4.43	01Jan2000, 12:15	26.2
21-470/C	2.769	8.77	01Jan2000, 13:45	138.9
21-576/C	7.499	19.22	01Jan2000, 13:45	294.5
47+48	0.62	1.96	01Jan2000, 12:30	20.6
52+21-468	2.398	12.26	01Jan2000, 13:15	147.9
53+44	0.18	1.48	01Jan2000, 12:15	10.2
65/46+21-270	19.236	50.18	01Jan2000, 15:15	1153.1
71/44+68	0.27	1.98	01Jan2000, 12:15	16.3
80/35+37	0.23	2.29	01Jan2000, 12:15	15.6
85+86	0.56	2.73	01Jan2000, 12:30	29.8

HEC-HMS Results

Project: Hwy 401 Widening, Cobourg to Colborne

Simulation Run: Regional, Existing Conditions

Hydrologic Element	Drainage Area (km^2)	Peak discharge (m^3/s)	Time of Peak	Volume ($1000m^3$)
804010044	0.1	0.69	01Jan2000, 07:00	10.3
804010047	2.53	10.78	01Jan2000, 09:15	240.8
804010053	0.08	0.59	01Jan2000, 07:00	8.4
904010001	0.29	1.83	01Jan2000, 07:00	30.1
904010003	4.81	13.61	01Jan2000, 12:30	485.9
904010004	0.86	3.69	01Jan2000, 09:00	76.8
904010007	0.1	0.50	01Jan2000, 07:00	8
904010014	0.35	1.41	01Jan2000, 07:30	27.5
904010015	0.05	0.47	01Jan2000, 07:00	6.3
904010033	1.87	7.34	01Jan2000, 09:30	166.6
904010037	0.13	1.03	01Jan2000, 07:00	15.1
904010047	0.38	1.63	01Jan2000, 07:15	29.2
904010052	0.1	0.81	01Jan2000, 07:00	12.1
904010054	0.55	3.19	01Jan2000, 07:15	59.7
000904010065/46	0.12	0.63	01Jan2000, 07:15	10.8
904010068	0.05	0.37	01Jan2000, 07:00	5.3
000904010071/44	0.22	1.45	01Jan2000, 07:15	24.1
000904010080/35	0.1	0.83	01Jan2000, 07:00	12.2
904010083	0.16	0.97	01Jan2000, 07:15	16.4
904010085	0.15	0.90	01Jan2000, 07:15	15.8
904010086	0.41	2.08	01Jan2000, 07:30	39.8
904040048	0.24	0.84	01Jan2000, 07:15	14.6
1004010030	1.11	5.70	01Jan2000, 09:00	128.2
1004010032	0.14	0.99	01Jan2000, 07:00	16
1004010041	0.48	2.83	01Jan2000, 07:30	55.8
21-270/C	19.116	80.44	01Jan2000, 10:45	2071.2
21-272/C	60.454	185.20	01Jan2000, 13:00	5635.6
21-467/C	3.37	15.82	01Jan2000, 08:45	337.6
21-468/C	2.298	12.87	01Jan2000, 08:00	252.9
21-469/C	0.451	3.27	01Jan2000, 07:00	47.7
21-470/C	2.769	12.07	01Jan2000, 09:15	263.5
21-576/C	7.499	28.30	01Jan2000, 09:15	598.4
47+48	0.62	2.48	01Jan2000, 07:15	43.8
52+21-468	2.398	13.39	01Jan2000, 08:00	265
53+44	0.18	1.28	01Jan2000, 07:00	18.8
65/46+21-270	19.236	80.78	01Jan2000, 10:45	2082
71/44+68	0.27	1.81	01Jan2000, 07:00	29.4
80/35+37	0.23	1.85	01Jan2000, 07:00	27.3
85+86	0.56	2.95	01Jan2000, 07:30	55.6

HEC-HMS Results

Project: Hwy 401 Widening, Cobourg to Colborne

Simulation Run: Future 50-yr, Proposed Conditions (uncontrolled)

Hydrologic Element	Drainage Area (km^2)	Peak discharge (m^3/s)	Time of Peak	Volume ($1000m^3$)
804010044	0.1	0.69	01Jan2000, 12:15	5
804010047	2.53	6.08	01Jan2000, 13:30	110.9
804010053	0.08	0.65	01Jan2000, 12:15	4.3
904010001	0.29	1.73	01Jan2000, 12:15	14.9
904010003	4.81	5.67	01Jan2000, 16:45	229.3
904010004	0.86	2.36	01Jan2000, 13:00	34.3
904010007	0.1	0.40	01Jan2000, 12:15	3.5
904010014	0.35	0.93	01Jan2000, 12:45	11.6
904010015	0.05	0.54	01Jan2000, 12:15	3.5
904010033	1.87	3.79	01Jan2000, 13:30	74.7
904010037	0.13	1.16	01Jan2000, 12:15	7.9
904010047	0.38	1.14	01Jan2000, 12:30	12.3
904010052	0.1	0.91	01Jan2000, 12:15	6.4
904010054	0.55	2.71	01Jan2000, 12:30	29.4
000904010065/46	0.12	0.53	01Jan2000, 12:30	5.1
904010068	0.05	0.40	01Jan2000, 12:15	2.7
000904010071/44	0.22	1.44	01Jan2000, 12:15	12.4
000904010080/35	0.1	0.97	01Jan2000, 12:15	6.6
904010083	0.16	0.91	01Jan2000, 12:30	8.4
904010085	0.15	0.79	01Jan2000, 12:30	7.7
904010086	0.41	1.60	01Jan2000, 12:45	18.6
904040048	0.24	0.52	01Jan2000, 12:30	5.6
1004010030	1.11	4.02	01Jan2000, 13:15	64.6
1004010032	0.14	1.05	01Jan2000, 12:15	8.5
1004010041	0.48	2.42	01Jan2000, 12:45	28.5
21-270/C	19.116	43.53	01Jan2000, 15:15	1006.3
21-272/C	60.454	76.87	01Jan2000, 17:15	2547.8
21-467/C	3.37	10.90	01Jan2000, 13:30	158.7
21-468/C	2.298	10.44	01Jan2000, 13:15	124.2
21-469/C	0.451	3.95	01Jan2000, 12:15	23.6
21-470/C	2.769	7.51	01Jan2000, 13:45	120.8
21-576/C	7.499	16.08	01Jan2000, 13:45	251.8
47+48	0.62	1.67	01Jan2000, 12:30	17.9
52+21-468	2.398	10.74	01Jan2000, 13:15	130.6
53+44	0.18	1.34	01Jan2000, 12:15	9.3
65/46+21-270	19.236	43.62	01Jan2000, 15:15	1011.3
71/44+68	0.27	1.83	01Jan2000, 12:15	15.2
80/35+37	0.23	2.12	01Jan2000, 12:15	14.5
85+86	0.56	2.37	01Jan2000, 12:30	26.3

HEC-HMS Results

Project: Hwy 401 Widening, Cobourg to Colborne

Simulation Run: Future 100-yr, Proposed Conditions (uncontrolled)

Hydrologic Element	Drainage Area (km^2)	Peak discharge (m^3/s)	Time of Peak	Volume ($1000m^3$)
804010044	0.1	0.80	01Jan2000, 12:15	5.7
804010047	2.53	7.12	01Jan2000, 13:30	128
804010053	0.08	0.74	01Jan2000, 12:15	4.9
904010001	0.29	2.00	01Jan2000, 12:15	17
904010003	4.81	6.57	01Jan2000, 16:30	263.2
904010004	0.86	2.80	01Jan2000, 13:00	39.9
904010007	0.1	0.48	01Jan2000, 12:15	4.1
904010014	0.35	1.12	01Jan2000, 12:45	13.6
904010015	0.05	0.60	01Jan2000, 12:15	3.9
904010033	1.87	4.48	01Jan2000, 13:30	86.7
904010037	0.13	1.31	01Jan2000, 12:15	9
904010047	0.38	1.39	01Jan2000, 12:30	14.5
904010052	0.1	1.03	01Jan2000, 12:15	7.2
904010054	0.55	3.13	01Jan2000, 12:30	33.5
000904010065/46	0.12	0.62	01Jan2000, 12:30	5.9
904010068	0.05	0.46	01Jan2000, 12:15	3.1
000904010071/44	0.22	1.65	01Jan2000, 12:15	14.1
000904010080/35	0.1	1.09	01Jan2000, 12:15	7.4
904010083	0.16	1.05	01Jan2000, 12:30	9.5
904010085	0.15	0.92	01Jan2000, 12:30	8.8
904010086	0.41	1.87	01Jan2000, 12:45	21.4
904040048	0.24	0.66	01Jan2000, 12:30	6.8
1004010030	1.11	4.59	01Jan2000, 13:15	73.2
1004010032	0.14	1.20	01Jan2000, 12:15	9.6
1004010041	0.48	2.76	01Jan2000, 12:45	32.2
21-270/C	19.116	50.09	01Jan2000, 15:15	1147.6
21-272/C	60.454	89.91	01Jan2000, 17:15	2948.1
21-467/C	3.37	12.70	01Jan2000, 13:30	182.3
21-468/C	2.298	11.98	01Jan2000, 13:15	141.4
21-469/C	0.451	4.56	01Jan2000, 12:15	26.9
21-470/C	2.769	8.82	01Jan2000, 13:45	139.5
21-576/C	7.499	19.34	01Jan2000, 13:45	295.9
47+48	0.62	2.05	01Jan2000, 12:30	21.3
52+21-468	2.398	12.32	01Jan2000, 13:15	148.6
53+44	0.18	1.54	01Jan2000, 12:15	10.6
65/46+21-270	19.236	50.19	01Jan2000, 15:15	1153.4
71/44+68	0.27	2.10	01Jan2000, 12:15	17.2
80/35+37	0.23	2.40	01Jan2000, 12:15	16.4
85+86	0.56	2.77	01Jan2000, 12:30	30.2

HEC-HMS Results

Project: Hwy 401 Widening, Cobourg to Colborne

Simulation Run: Future 50-yr, Proposed Conditions (controlled)

Hydrologic Element	Drainage Area (km^2)	Peak discharge (m^3/s)	Time of Peak	Volume ($1000m^3$)
804010044	0.1	0.69	01Jan2000, 12:15	4.9
804010047	2.53	6.08	01Jan2000, 13:30	105.5
804010053	0.06	0.45	01Jan2000, 12:15	3
904010001	0.29	1.73	01Jan2000, 12:15	14.6
904010003	4.81	5.67	01Jan2000, 16:45	180.5
904010004	0.86	2.36	01Jan2000, 13:00	33.1
904010007	0.1	0.40	01Jan2000, 12:15	3.4
904010014	0.35	0.93	01Jan2000, 12:45	11.2
904010015	0.04	0.40	01Jan2000, 12:15	2.6
904010033	1.87	3.79	01Jan2000, 13:30	70.6
904010037	0.13	1.16	01Jan2000, 12:15	7.8
904010047	0.38	1.14	01Jan2000, 12:30	12
904010052	0.1	0.91	01Jan2000, 12:15	6.3
904010054	0.55	2.71	01Jan2000, 12:30	28.7
000904010065/46	0.1	0.41	01Jan2000, 12:30	3.9
904010068	0.05	0.40	01Jan2000, 12:15	2.7
000904010071/44	0.19	1.16	01Jan2000, 12:15	10
000904010080/35	0.1	0.97	01Jan2000, 12:15	6.5
904010083	0.13	0.68	01Jan2000, 12:30	6.2
904010085	0.15	0.79	01Jan2000, 12:30	7.5
904010086	0.41	1.60	01Jan2000, 12:45	18.1
904040048	0.22	0.44	01Jan2000, 12:30	4.8
1004010030	1.11	4.02	01Jan2000, 13:15	62.2
1004010032	0.12	0.84	01Jan2000, 12:15	6.7
1004010041	0.48	2.42	01Jan2000, 12:45	27.8
010_032_Ctrl	0.02	0.29	01Jan2000, 12:00	1.9
010_032_Out	0.14	0.94	01Jan2000, 12:15	8.5
010_032_SWMF	0.02	0.14	01Jan2000, 12:45	1.8
08_53_Ctrl	0.02	0.23	01Jan2000, 12:15	1.5
08_53_Out	0.08	0.57	01Jan2000, 12:15	4.5
08_53_SWMF	0.02	0.15	01Jan2000, 12:45	1.5
09_15_Ctrl	0.01	0.15	01Jan2000, 12:00	0.9
09_15_Out	0.05	0.48	01Jan2000, 12:15	3.5
09_15_SWMF	0.01	0.09	01Jan2000, 12:30	0.9
09_48_Ctrl	0.02	0.36	01Jan2000, 12:00	1.9
09_48_Out	0.24	0.46	01Jan2000, 12:30	5.8
09_48_SWMF	0.02	0.04	01Jan2000, 13:30	1
09_65/46_Ctrl	0.02	0.26	01Jan2000, 12:15	1.8
09_65/46_Out	0.12	0.45	01Jan2000, 12:30	5.3
09_65/46_SWMF	0.02	0.07	01Jan2000, 13:30	1.4
09_71/44_Ctrl	0.03	0.42	01Jan2000, 12:15	2.8
09_71/44_Out	0.22	1.32	01Jan2000, 12:30	12.7
09_71/44_SWMF	0.03	0.19	01Jan2000, 13:00	2.7
09_71/44+68	0.23	1.84	01Jan2000, 12:15	12.3
09_71/44+68_Ctrl	0.04	0.37	01Jan2000, 12:30	3.7
09_71/44+68_Out	0.27	2.17	01Jan2000, 12:15	16
09_71/44+68_SWMF	0.04	0.37	01Jan2000, 12:30	3.7
09_83_Ctrl	0.03	0.40	01Jan2000, 12:15	2.8
09_83_Out	0.16	0.83	01Jan2000, 12:30	9
09_83_SWMF	0.03	0.16	01Jan2000, 13:00	2.8
21-270/C	19.12	43.53	01Jan2000, 15:15	910.9
21-272/C	60.45	76.87	01Jan2000, 17:15	2035.7
21-467/C	3.37	10.90	01Jan2000, 13:30	151.4
21-468/C	2.3	10.44	01Jan2000, 13:15	120.1
21-469/C	0.45	3.95	01Jan2000, 12:15	23.3
21-470/C	2.77	7.51	01Jan2000, 13:45	114.3
21-576/C	7.5	16.08	01Jan2000, 13:45	238.5
47+48	0.62	1.61	01Jan2000, 12:30	17.8
52+21-468	2.4	10.74	01Jan2000, 13:15	126.4
53+44	0.18	1.26	01Jan2000, 12:15	9.5
65/46+21-270	19.24	43.65	01Jan2000, 15:15	916.2
71/44+68	0.27	1.68	01Jan2000, 12:15	15.4
80/35+37	0.23	2.12	01Jan2000, 12:15	14.4
85+86	0.56	2.37	01Jan2000, 12:30	25.7

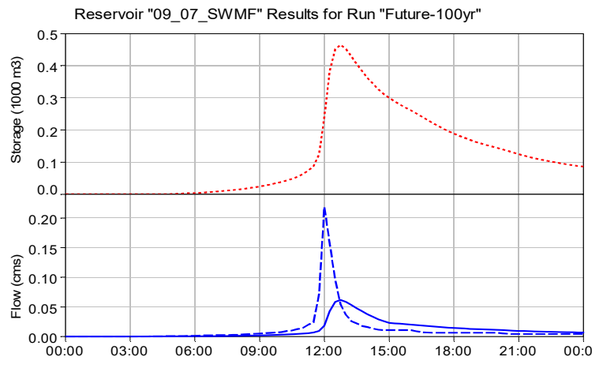
HEC-HMS Results
Project: Hwy 401 Widening, Cobourg to Colborne
Simulation Run: Future 100-yr, Proposed Conditions (controlled)

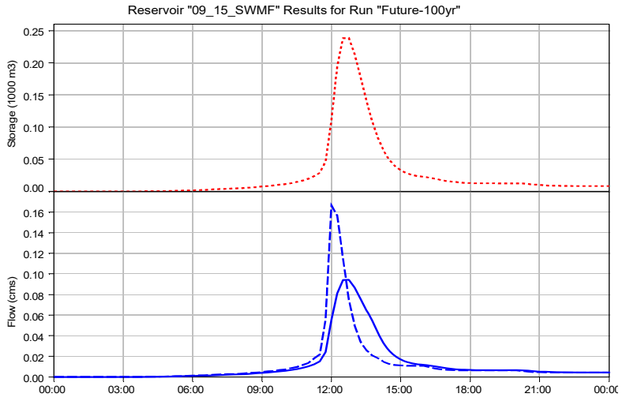
Hydrologic Element	Drainage Area (km^2)	Peak discharge (m^3/s)	Time of Peak	Volume ($1000m^3$)
804010044	0.1	0.80	01Jan2000, 12:15	5.7
804010047	2.53	7.12	01Jan2000, 13:30	122
804010053	0.06	0.52	01Jan2000, 12:15	3.4
904010001	0.29	2.00	01Jan2000, 12:15	16.7
904010003	4.81	6.57	01Jan2000, 16:30	208.3
904010004	0.86	2.80	01Jan2000, 13:00	38.5
904010007	0.09	0.41	01Jan2000, 12:15	3.5
904010014	0.35	1.12	01Jan2000, 12:45	13.2
904010015	0.04	0.45	01Jan2000, 12:15	2.9
904010033	1.87	4.48	01Jan2000, 13:30	82.1
904010037	0.13	1.31	01Jan2000, 12:15	8.9
904010047	0.38	1.39	01Jan2000, 12:30	14.2
904010052	0.1	1.03	01Jan2000, 12:15	7.1
904010054	0.55	3.13	01Jan2000, 12:30	32.8
000904010065/46	0.1	0.49	01Jan2000, 12:30	4.5
904010068	0.05	0.46	01Jan2000, 12:15	3.1
000904010071/44	0.19	1.34	01Jan2000, 12:15	11.4
000904010080/35	0.1	1.09	01Jan2000, 12:15	7.3
904010083	0.13	0.79	01Jan2000, 12:30	7.1
904010085	0.15	0.92	01Jan2000, 12:30	8.6
904010086	0.41	1.87	01Jan2000, 12:45	20.9
904040048	0.22	0.56	01Jan2000, 12:30	5.8
1004010030	1.11	4.59	01Jan2000, 13:15	70.5
1004010032	0.12	0.96	01Jan2000, 12:15	7.6
1004010041	0.48	2.76	01Jan2000, 12:45	31.4
010_032_Ctrl	0.02	0.32	01Jan2000, 12:00	2
010_032_Out	0.14	1.06	01Jan2000, 12:15	9.6
010_032_SWMF	0.02	0.16	01Jan2000, 12:45	2
08_53_Ctrl	0.02	0.25	01Jan2000, 12:15	1.7
08_53_Out	0.08	0.65	01Jan2000, 12:15	5.1
08_53_SWMF	0.02	0.16	01Jan2000, 12:45	1.7
09_07_Ctrl	0.01	0.22	01Jan2000, 12:00	1
09_07_Out	0.1	0.45	01Jan2000, 12:30	4.4
09_07_SWMF	0.01	0.06	01Jan2000, 12:45	0.9
09_15_Ctrl	0.01	0.17	01Jan2000, 12:00	1
09_15_Out	0.05	0.54	01Jan2000, 12:15	3.9
09_15_SWMF	0.01	0.09	01Jan2000, 12:45	1
09_48_Ctrl	0.02	0.39	01Jan2000, 12:00	2
09_48_Out	0.24	0.59	01Jan2000, 12:30	7
09_48_SWMF	0.02	0.05	01Jan2000, 13:30	1.2
09_65/46_Ctrl	0.02	0.28	01Jan2000, 12:15	2
09_65/46_Out	0.12	0.55	01Jan2000, 12:30	6.3
09_65/46_SWMF	0.02	0.09	01Jan2000, 13:15	1.8
09_71/44_Ctrl	0.03	0.46	01Jan2000, 12:15	3.1
09_71/44_Out	0.22	1.51	01Jan2000, 12:30	14.4
09_71/44_SWMF	0.03	0.21	01Jan2000, 13:00	3
09_71/44+68	0.23	1.60	01Jan2000, 12:15	13.7
09_71/44+68_Ctrl	0.04	0.49	01Jan2000, 12:15	4.1
09_71/44+68_Out	0.27	1.89	01Jan2000, 12:30	17.7
09_71/44+68_SWMF	0.04	0.35	01Jan2000, 12:45	4
09_83_Ctrl	0.03	0.44	01Jan2000, 12:15	3.1
09_83_Out	0.16	0.95	01Jan2000, 12:30	10.2
09_83_SWMF	0.03	0.18	01Jan2000, 13:00	3
21-270/C	19.12	50.09	01Jan2000, 15:15	1041.5
21-272/C	60.45	89.91	01Jan2000, 17:15	2369.6
21-467/C	3.37	12.70	01Jan2000, 13:30	174.1
21-468/C	2.3	11.98	01Jan2000, 13:15	136.8
21-469/C	0.45	4.56	01Jan2000, 12:15	26.6
21-470/C	2.77	8.82	01Jan2000, 13:45	132.2
21-576/C	7.5	19.34	01Jan2000, 13:45	280.8
47+48	0.62	1.99	01Jan2000, 12:30	21.1
52+21-468	2.4	12.32	01Jan2000, 13:15	143.9
53+44	0.18	1.45	01Jan2000, 12:15	10.8
65/46+21-270	19.24	50.22	01Jan2000, 15:15	1047.8
71/44+68	0.27	1.93	01Jan2000, 12:15	17.4
80/35+37	0.23	2.40	01Jan2000, 12:15	16.2
85+86	0.56	2.77	01Jan2000, 12:30	29.5

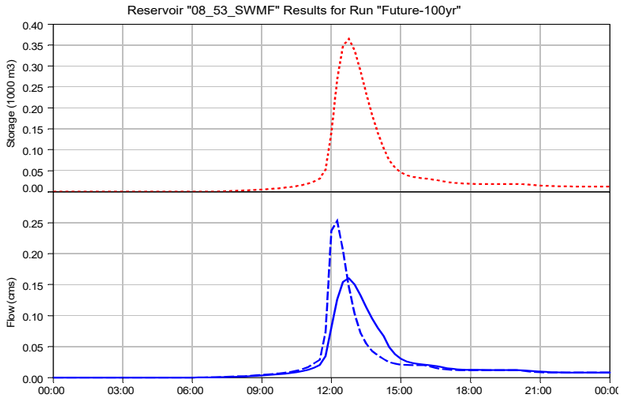
HEC-HMS Results
Project: Hwy 401 Widening, Cobourg to Colborne
Proposed SWMF Results (100-yr storm)

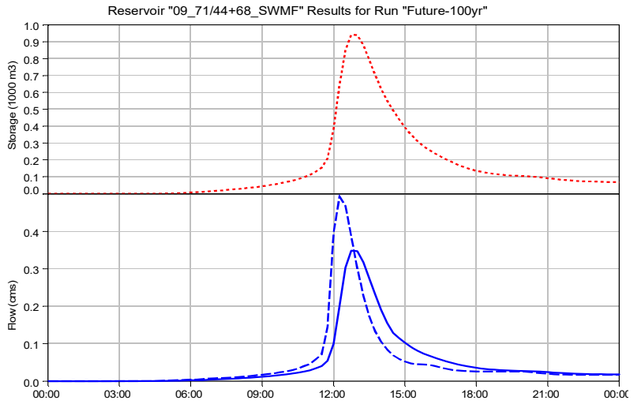
Legend:

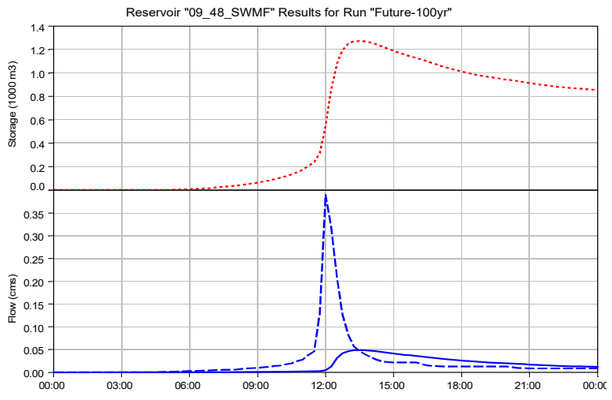
Run:Future-100yr Element_SWMF Result:Storage
Run:Future-100yr Element_SWMF Result:Outflow
Run:Future-100yr Element_SWMF Result:Combined Inflow

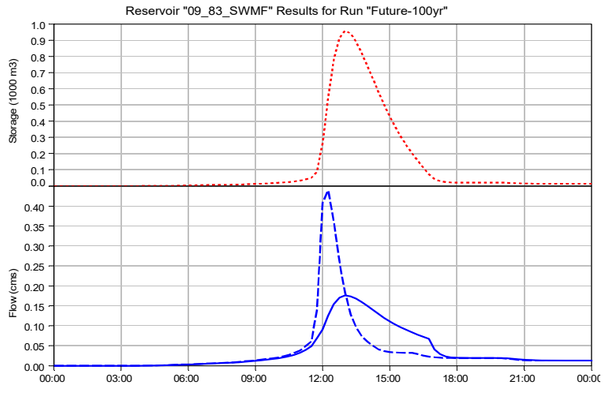


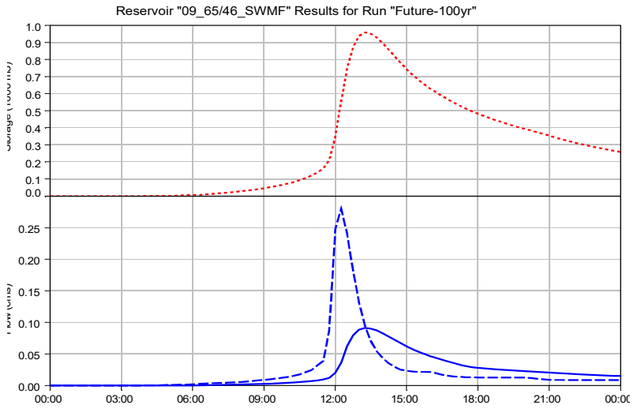


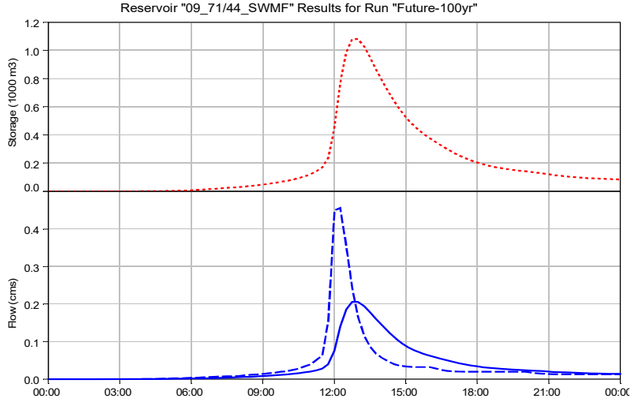


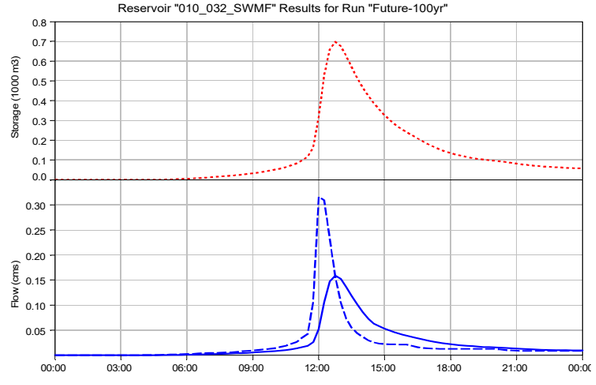












HEC-HMS - Peak Flow Comparison
Project: Hwy 401 Widening, Cobourg to Colborne
Simulation Run: Future 2-yr, Proposed Conditions (uncontrolled)

2-Year Storm Results

Drainage ID	Area (km^2)	1 hr	6 hr	12 hr	24 hr	Largest Peak
21-272/C	60.45	0.00	4.47	9.90	15.38	24-hr
21-270/C	19.12	0.14	4.26	7.16	10.61	24-hr
000904010065/46	0.12	0.00	0.02	0.05	0.09	24-hr
65/46+21-270	19.24	0.14	4.26	7.18	10.64	24-hr
21-576/C	7.50	0.00	0.40	1.02	2.00	24-hr
904010003	4.81	0.00	0.45	0.90	1.32	24-hr
21-467/C	3.37	0.00	0.74	1.38	2.24	24-hr
21-470/C	2.77	0.00	0.43	0.84	1.41	24-hr
804010047	2.53	0.00	0.37	0.71	1.16	24-hr
21-468/C	2.30	0.06	0.92	1.61	2.51	24-hr
904010052	0.10	0.02	0.11	0.18	0.27	24-hr
52+21-468	2.40	0.06	0.97	1.68	2.62	24-hr
904010033	1.87	0.00	0.19	0.38	0.65	24-hr
1004010030	1.11	0.05	0.45	0.72	1.06	24-hr
904010004	0.86	0.00	0.10	0.21	0.38	24-hr
904010047	0.38	0.00	0.02	0.05	0.12	24-hr
904040048	0.24	0.00	0.00	0.01	0.02	24-hr
47+48	0.62	0.00	0.02	0.06	0.14	24-hr
904010085	0.15	0.00	0.06	0.10	0.17	24-hr
904010086	0.41	0.00	0.09	0.18	0.30	24-hr
85+86	0.56	0.00	0.14	0.28	0.47	24-hr
904010054	0.55	0.01	0.22	0.40	0.64	24-hr
1004010041	0.48	0.03	0.26	0.43	0.65	24-hr
21-469/C	0.45	0.02	0.25	0.49	0.86	24-hr
904010014	0.35	0.00	0.02	0.05	0.10	24-hr
904010001	0.29	0.01	0.12	0.23	0.38	24-hr
904010068	0.05	0.00	0.03	0.06	0.10	24-hr
000904010071/44	0.22	0.02	0.13	0.23	0.36	24-hr
71/44+68	0.27	0.02	0.16	0.28	0.45	24-hr
904010037	0.13	0.02	0.12	0.21	0.32	24-hr
000904010080/35	0.10	0.03	0.12	0.20	0.29	24-hr
80/35+37	0.23	0.05	0.24	0.41	0.61	24-hr
804010044	0.10	0.00	0.04	0.08	0.14	24-hr
804010053	0.08	0.00	0.05	0.09	0.15	24-hr
53+44	0.18	0.01	0.09	0.17	0.30	24-hr
904010083	0.16	0.00	0.07	0.12	0.21	24-hr
1004010032	0.14	0.02	0.11	0.19	0.28	24-hr
904010007	0.10	0.00	0.01	0.02	0.05	24-hr
904010015	0.05	0.02	0.08	0.13	0.18	24-hr

HEC-HMS - Peak Flow Comparison
Project: Hwy 401 Widening, Cobourg to Colborne
Simulation Run: Future 10-yr, Proposed Conditions (uncontrolled)

10-Year Storm Results

Drainage ID	Area (km^2)	1 hr	6 hr	12 hr	24 hr	Largest Peak
21-272/C	60.45	1.56	19.17	30.66	44.57	24-hr
21-270/C	19.12	2.41	13.32	19.05	26.83	24-hr
000904010065/46	0.12	0.02	0.11	0.18	0.30	24-hr
65/46+21-270	19.24	2.41	13.34	19.09	26.89	24-hr
21-576/C	7.50	0.05	2.88	4.97	8.30	24-hr
904010003	4.81	0.20	1.58	2.46	3.44	24-hr
21-467/C	3.37	0.47	2.85	4.31	6.43	24-hr
21-470/C	2.77	0.23	1.84	2.84	4.31	24-hr
804010047	2.53	0.19	1.51	2.32	3.50	24-hr
21-468/C	2.30	0.74	3.05	4.47	6.47	24-hr
904010052	0.10	0.11	0.31	0.44	0.60	24-hr
52+21-468	2.40	0.77	3.16	4.64	6.68	24-hr
904010033	1.87	0.07	0.87	1.37	2.11	24-hr
1004010030	1.11	0.34	1.29	1.82	2.55	24-hr
904010004	0.86	0.05	0.50	0.82	1.30	24-hr
904010047	0.38	0.00	0.17	0.31	0.56	24-hr
904040048	0.24	0.00	0.04	0.10	0.21	24-hr
47+48	0.62	0.00	0.21	0.40	0.77	24-hr
904010085	0.15	0.05	0.21	0.32	0.48	24-hr
904010086	0.41	0.06	0.38	0.59	0.92	24-hr
85+86	0.56	0.12	0.58	0.90	1.38	24-hr
904010054	0.55	0.20	0.77	1.13	1.65	24-hr
1004010041	0.48	0.23	0.77	1.10	1.55	24-hr
21-469/C	0.45	0.28	0.99	1.59	2.40	24-hr
904010014	0.35	0.00	0.15	0.27	0.47	24-hr
904010001	0.29	0.12	0.46	0.70	1.04	24-hr
904010068	0.05	0.03	0.11	0.17	0.25	24-hr
000904010071/44	0.22	0.13	0.43	0.63	0.90	24-hr
71/44+68	0.27	0.16	0.54	0.77	1.14	24-hr
904010037	0.13	0.13	0.37	0.54	0.75	24-hr
000904010080/35	0.10	0.13	0.34	0.48	0.64	24-hr
80/35+37	0.23	0.25	0.71	1.02	1.39	24-hr
804010044	0.10	0.04	0.17	0.27	0.41	24-hr
804010053	0.08	0.05	0.18	0.28	0.40	24-hr
53+44	0.18	0.10	0.34	0.55	0.82	24-hr
904010083	0.16	0.06	0.25	0.38	0.56	24-hr
1004010032	0.14	0.11	0.34	0.47	0.67	24-hr
904010007	0.10	0.00	0.06	0.11	0.20	24-hr
904010015	0.05	0.08	0.21	0.28	0.37	24-hr

HEC-HMS - Peak Flow Comparison
Project: Hwy 401 Widening, Cobourg to Colborne
Simulation Run: Future 25-yr, Proposed Conditions (uncontrolled)

25-Year Storm Results

Drainage ID	Area (km^2)	1 hr	6 hr	12 hr	24 hr	Largest Peak
21-272/C	60.45	3.95	29.83	44.15	61.59	24-hr
21-270/C	19.12	4.38	19.37	26.32	35.73	24-hr
000904010065/46	0.12	0.04	0.18	0.28	0.42	24-hr
65/46+21-270	19.24	4.38	19.41	26.38	35.81	24-hr
21-576/C	7.50	0.42	5.06	7.90	12.34	24-hr
904010003	4.81	0.40	2.36	3.43	4.62	24-hr
21-467/C	3.37	0.96	4.35	6.21	8.77	24-hr
21-470/C	2.77	0.53	2.88	4.17	5.98	24-hr
804010047	2.53	0.43	2.36	3.37	4.86	24-hr
21-468/C	2.30	1.32	4.49	6.25	8.59	24-hr
904010052	0.10	0.17	0.44	0.59	0.77	24-hr
52+21-468	2.40	1.36	4.67	6.47	8.85	24-hr
904010033	1.87	0.20	1.40	2.05	2.99	24-hr
1004010030	1.11	0.56	1.84	2.48	3.33	24-hr
904010004	0.86	0.14	0.83	1.23	1.86	24-hr
904010047	0.38	0.03	0.31	0.51	0.86	24-hr
904040048	0.24	0.00	0.10	0.19	0.37	24-hr
47+48	0.62	0.03	0.41	0.70	1.23	24-hr
904010085	0.15	0.09	0.32	0.46	0.65	24-hr
904010086	0.41	0.14	0.60	0.88	1.28	24-hr
85+86	0.56	0.23	0.91	1.31	1.90	24-hr
904010054	0.55	0.35	1.15	1.59	2.22	24-hr
1004010041	0.48	0.38	1.10	1.50	2.02	24-hr
21-469/C	0.45	0.51	1.52	2.30	3.23	24-hr
904010014	0.35	0.03	0.27	0.43	0.71	24-hr
904010001	0.29	0.22	0.71	0.99	1.40	24-hr
904010068	0.05	0.06	0.17	0.24	0.33	24-hr
000904010071/44	0.22	0.22	0.64	0.87	1.18	24-hr
71/44+68	0.27	0.28	0.79	1.09	1.51	24-hr
904010037	0.13	0.20	0.53	0.74	0.97	24-hr
000904010080/35	0.10	0.19	0.48	0.64	0.82	24-hr
80/35+37	0.23	0.39	1.01	1.37	1.78	24-hr
804010044	0.10	0.08	0.26	0.39	0.56	24-hr
804010053	0.08	0.09	0.27	0.39	0.53	24-hr
53+44	0.18	0.17	0.53	0.78	1.10	24-hr
904010083	0.16	0.12	0.38	0.53	0.75	24-hr
1004010032	0.14	0.18	0.48	0.65	0.88	24-hr
904010007	0.10	0.02	0.11	0.18	0.30	24-hr
904010015	0.05	0.12	0.29	0.37	0.46	24-hr

HEC-HMS - Peak Flow Comparison
Project: Hwy 401 Widening, Cobourg to Colborne
Simulation Run: Future 50-yr, Proposed Conditions (uncontrolled)

50-Year Storm Results

Drainage ID	Area (km^2)	1 hr	6 hr	12 hr	24 hr	Largest Peak
21-272/C	60.45	6.33	38.36	56.15	76.87	24-hr
21-270/C	19.12	6.14	24.06	32.67	43.53	24-hr
000904010065/46	0.12	0.06	0.24	0.36	0.53	24-hr
65/46+21-270	19.24	6.14	24.10	32.74	43.62	24-hr
21-576/C	7.50	0.90	6.93	10.69	16.08	24-hr
904010003	4.81	0.60	2.96	4.27	5.67	24-hr
21-467/C	3.37	1.42	5.57	7.89	10.90	24-hr
21-470/C	2.77	0.82	3.72	5.35	7.51	24-hr
804010047	2.53	0.67	3.04	4.33	6.08	24-hr
21-468/C	2.30	1.83	5.63	7.79	10.44	24-hr
904010052	0.10	0.22	0.53	0.72	0.91	24-hr
52+21-468	2.40	1.88	5.84	8.06	10.74	24-hr
904010033	1.87	0.33	1.83	2.66	3.79	24-hr
1004010030	1.11	0.75	2.26	3.06	4.02	24-hr
904010004	0.86	0.23	1.09	1.62	2.36	24-hr
904010047	0.38	0.06	0.44	0.71	1.14	24-hr
904040048	0.24	0.00	0.16	0.29	0.52	24-hr
47+48	0.62	0.07	0.60	1.00	1.67	24-hr
904010085	0.15	0.13	0.41	0.58	0.79	24-hr
904010086	0.41	0.21	0.78	1.13	1.60	24-hr
85+86	0.56	0.34	1.18	1.67	2.37	24-hr
904010054	0.55	0.49	1.44	1.98	2.71	24-hr
1004010041	0.48	0.51	1.36	1.84	2.42	24-hr
21-469/C	0.45	0.72	1.95	2.91	3.95	24-hr
904010014	0.35	0.05	0.37	0.60	0.93	24-hr
904010001	0.29	0.31	0.90	1.25	1.73	24-hr
904010068	0.05	0.08	0.21	0.30	0.40	24-hr
000904010071/44	0.22	0.30	0.79	1.08	1.44	24-hr
71/44+68	0.27	0.38	0.99	1.36	1.83	24-hr
904010037	0.13	0.26	0.66	0.90	1.16	24-hr
000904010080/35	0.10	0.25	0.58	0.77	0.97	24-hr
80/35+37	0.23	0.51	1.24	1.67	2.12	24-hr
804010044	0.10	0.12	0.34	0.50	0.69	24-hr
804010053	0.08	0.12	0.34	0.49	0.65	24-hr
53+44	0.18	0.24	0.68	0.99	1.34	24-hr
904010083	0.16	0.17	0.48	0.67	0.91	24-hr
1004010032	0.14	0.24	0.59	0.80	1.05	24-hr
904010007	0.10	0.03	0.16	0.25	0.40	24-hr
904010015	0.05	0.16	0.34	0.44	0.54	24-hr

HEC-HMS - Peak Flow Comparison

Project: Hwy 401 Widening, Cobourg to Colborne

Simulation Run: Future 100-yr, Proposed Conditions (uncontrolled)

100-Year Storm Results

Drainage ID	Area (km^2)	1 hr	6 hr	12 hr	24 hr	Largest Peak
21-272/C	60.45	9.21	47.58	44.15	89.91	24-hr
21-270/C	19.12	8.14	29.04	26.32	50.09	24-hr
000904010065/46	0.12	0.09	0.31	0.28	0.62	24-hr
65/46+21-270	19.24	8.14	29.08	26.38	50.19	24-hr
21-576/C	7.50	1.54	9.01	7.90	19.34	24-hr
904010003	4.81	0.82	3.61	3.43	6.57	24-hr
21-467/C	3.37	1.96	6.88	6.21	12.70	24-hr
21-470/C	2.77	1.18	4.64	4.17	8.82	24-hr
804010047	2.53	0.96	3.77	3.37	7.12	24-hr
21-468/C	2.30	2.40	6.84	6.25	11.98	24-hr
904010052	0.10	0.27	0.64	0.59	1.03	24-hr
52+21-468	2.40	2.47	7.10	6.47	12.32	24-hr
904010033	1.87	0.50	2.30	2.05	4.48	24-hr
1004010030	1.11	0.97	2.71	2.48	4.59	24-hr
904010004	0.86	0.34	1.38	1.23	2.80	24-hr
904010047	0.38	0.11	0.59	0.51	1.39	24-hr
904040048	0.24	0.02	0.23	0.19	0.66	24-hr
47+48	0.62	0.13	0.82	0.70	2.05	24-hr
904010085	0.15	0.18	0.50	0.46	0.92	24-hr
904010086	0.41	0.30	0.97	0.88	1.87	24-hr
85+86	0.56	0.47	1.46	1.31	2.77	24-hr
904010054	0.55	0.64	1.76	1.59	3.13	24-hr
1004010041	0.48	0.65	1.64	1.50	2.76	24-hr
21-469/C	0.45	0.94	2.42	2.30	4.56	24-hr
904010014	0.35	0.10	0.49	0.43	1.12	24-hr
904010001	0.29	0.41	1.10	0.99	2.00	24-hr
904010068	0.05	0.10	0.26	0.24	0.46	24-hr
000904010071/44	0.22	0.39	0.96	0.87	1.65	24-hr
71/44+68	0.27	0.49	1.19	1.09	2.10	24-hr
904010037	0.13	0.33	0.79	0.74	1.31	24-hr
000904010080/35	0.10	0.31	0.69	0.64	1.09	24-hr
80/35+37	0.23	0.64	1.48	1.37	2.40	24-hr
804010044	0.10	0.16	0.42	0.39	0.80	24-hr
804010053	0.08	0.16	0.42	0.39	0.74	24-hr
53+44	0.18	0.31	0.84	0.78	1.54	24-hr
904010083	0.16	0.22	0.59	0.53	1.05	24-hr
1004010032	0.14	0.31	0.71	0.65	1.20	24-hr
904010007	0.10	0.05	0.21	0.18	0.48	24-hr
904010015	0.05	0.19	0.40	0.37	0.60	24-hr

165001090 - 401 Cobourg to Colborne
Flood Frequency Analysis - Sturctural Culverts

Catchment Information									Transposed Flows (m3/s)								
Site #	Structure Name	Station	Highway	Draiange Area (ha)	Draiange Area (km^2)	Flow Gauge Name	Flow Gauge Area	Flow Gauge Station ID	100%	50%	43%	20%	10%	4%	2%	1%	0.50%
									1-year	2-year	2.33-year	5-year	10-year	25-year	50-year	100-year	200-year
21-467/C	-	10+715	401	334.0	3.3	Shelter Valley Creek near Grafton - 02HD010	63.8	02HD010	0.58	1.42	1.56	2.31	3.11	4.40	5.61	7.07	8.83
21-468/C	-	12+420	401	229.8	2.3	Shelter Valley Creek near Grafton - 02HD010	63.8	02HD010	0.44	1.07	1.18	1.75	2.35	3.32	4.23	5.34	6.67
21-469/C	-	14+135	401	45.1	0.5	Shelter Valley Creek near Grafton - 02HD010	63.8	02HD010	0.13	0.32	0.35	0.52	0.69	0.98	1.25	1.57	1.97
21-270/C	Grafton Creek Culvert	14+200	401	1911.6	19.1	Shelter Valley Creek near Grafton - 02HD010	63.8	02HD010	2.16	5.26	5.79	8.56	11.50	16.27	20.74	26.14	32.67
21-470/C	Northumberland Culvert	17+170	401	276.9	2.8	Shelter Valley Creek near Grafton - 02HD010	63.8	02HD010	0.51	1.24	1.36	2.01	2.70	3.82	4.87	6.14	7.67
21-272/C	Shelter Valley Creek Culvert	19+340	401	6045.4	60.5	Shelter Valley Creek near Grafton - 02HD010	63.8	02HD010	5.12	12.48	13.73	20.31	27.27	38.58	49.19	62.00	77.48
21-576/C	Boyce's Road Culvert	22+125	401	749.9	7.5	Shelter Valley Creek near Grafton - 02HD010	63.8	02HD010	1.07	2.61	2.87	4.24	5.70	8.06	10.28	12.96	16.19

APPENDIX E:
Hydraulic Modelling

Ministry of Transportation - Highway 401 Widening - 165001090
GWP 4060-11-00
Hydraulic Assessment of Culverts

Existing Conditions

Station	DAID	CVID	Geographic Township	Culvert Description	Material	Shape	Number of Barrels	Dimensions (mm)		Length	Total Drainage Area	Flow Direction	Upstream Invert	Downstream Invert	Upstream Obvert	Downstream Obvert	Slope	Unadjusted Flows (m3/s)		Lake / Wetland Reduction Factor	Lake/ Wetland Reduction Area	Adjusted Flows (m3/s)		Tail water Elev.	Road Elev. At Spill Point	Road Elev. At Culvert	Required Headwater Elev. (m)	Required Headwater Elev. (m)	Depth of Headwater / Height of Opening (HW/D)	Depth of Headwater / Height of Opening (HW/D)	HW/D <1.5 (Design Storm)	Freeboard From Road at Spill Point (m)	Freeboard From Road at Spill Point (m)	Clearance (m)	Freeboard > 0.3 m (Design Storm)	Freeboard > 1.0 m (Design Storm)	HW<Spill point (Check Storm)
								Span	Height / Diam.	(m)	(ha)		(m)	(m)	(m)	(m)	(%)	Design	Check	(%)	(%)	Design	Check	(m)	(m)	(m)	Design	Check	Design	Check	(Yes/No)	Design	Check	Design	(Yes/No)	(Yes/No)	(Yes/No)
Highway 401 - Hamilton Township																																					
23+330	CV-0401-001882	000804010053	Hamilton	Centreline	CSP - Plastic Lined	Circular	1		900	53.7	8.1	S	166.00	165.00	166.90	165.90	1.86	0.60	0.90	100%	0.0	0.60	0.90	165.54	168.50	169.00	166.74	166.95	0.82	1.06	Yes	1.76	1.55	0.16	Yes	Yes	Yes
23+605	CV-0401-002059	000804010044	Hamilton	Centreline	CSP - Plastic Lined	Circular	1		900	56.9	10.5	S	167.00	165.50	167.90	166.40	2.64	0.68	1.02	100%	0.0	0.68	1.02	166.04	169.50	170.00	167.83	168.07	0.92	1.19	Yes	1.67	1.43	0.07	Yes	Yes	Yes
24+810	CV-0401-001881	000804010047	Hamilton	Centreline	Concrete	Box	1	2450	1850	73.1	253.5	S	156.50	153.50	158.35	155.35	4.10	6.02	9.17	88%	0.0	5.29	8.07	154.61	166.50	166.50	157.89	158.34	0.75	0.99	Yes	8.61	8.16	0.46	Yes	Yes	Yes
Highway 401 - Haldimand Township																																					
Centrelines																																					
10+715	21-467/C	21-467/C	Haldimand	Centreline	Concrete	Box	1	3100	1800	147.1	337.3	S	147.50	140.75	149.30	142.55	4.59			100%	0.0	7.35	0.00	141.83	154.70	155.00	149.40	150.01	1.06	1.39	Yes	5.30	4.69	-0.10	Yes	Yes	Yes
11+705	CV-0401-001858	000904010054	Haldimand	Centreline	CSP	Circular	1		900	51.5	54.8	S	162.50	162.00	163.40	162.90	0.97	2.67	4.01	100%	0.0	2.67	4.01	162.54	165.00	165.00	167.86	174.04	5.96	12.82	No	-2.86	-9.04	-4.46	No	No	No
12+090	CV-0401-001857	000904010052	Haldimand	Centreline	CSP - Plastic Lined	Circular	1		900	52.8	10.1	S	152.50	150.00	153.40	150.90	4.74	0.88	1.30	100%	0.0	0.88	1.30	150.54	154.00	155.00	153.45	153.73	1.06	1.37	Yes	0.55	0.27	-0.05	Yes	No	Yes
12+420	21-468/C	21-468/C	Haldimand	Centreline	Concrete	Box	1	3100	1500	71.7	229.8	S	140.00	138.50	141.50	140.00	2.09			88%	0.0	5.43	0.00	139.40	144.00	144.00	141.70	142.24	1.13	1.49	Yes	2.30	1.76	-0.20	Yes	Yes	Yes
12+720	CV-0401-001855	000904010048	Haldimand	Centreline	Concrete	Box	1	1540	1570	60.9	23.6	S	136.00	132.50	137.57	134.07	5.74	0.48	0.80	72%	0.0	0.35	0.57	133.44	140.50	140.50	136.26	136.38	0.17	0.24	Yes	4.24	4.12	1.31	Yes	Yes	Yes
13+030	CV-0401-001873	000904010047	Haldimand	Centreline	Concrete	Box	1	1200	1200	73.8	38.3	S	139.50	138.50	140.70	139.70	1.35	1.10	1.75	100%	0.0	1.10	1.75	139.22	149.50	149.50	139.74	140.01	0.20	0.42	Yes	9.76	9.49	0.96	Yes	Yes	Yes
14+135	21-469/C	21-469/C	Haldimand	Centreline	Concrete	Circular	1	3100	1500	91.5	45.1	S	142.50	140.30	144.00	141.80	2.40			62%	0.0	1.92	0.00	141.20	155.00	155.50	143.23	143.45	0.49	0.63	Yes	11.77	11.55	0.77	Yes	Yes	Yes
14+200	21-270/C+CV-0401-001791	21-270/C + 000904010065/46	Haldimand	Centreline	Concrete	Arch	1	7200	4150	85.0	1923.2	S	143.15	140.45	147.30	144.60	3.18			67%	0.0	33.06	0.76	142.94	155.00	156.00	144.77	145.01	0.39	0.45	Yes	10.23	9.99	2.53	Yes	Yes	Yes
14+660	CV-0401-001791/825	000904010065/46	Haldimand	Centreline	Smooth	Circular	1		900	48.0	11.7	S	165.00	164.50	165.90	165.40	1.04	0.49	0.76	100%	0.0	0.49	0.76	165.04	166.50	166.50	165.59	165.76	0.66	0.84	Yes	0.91	0.74	0.31	Yes	No	Yes
15+150	CV-0401-001721	000904010068	Haldimand	Centreline	Smooth or Rough	Circular	1		900	48.3	5.3	S	165.50	165.00	166.40	165.90	1.04	0.38	0.56	67%	0.0	0.25	0.38	165.54	167.50	167.50	165.93	166.04	0.48	0.60	Yes	1.57	1.46	0.47	Yes	Yes	Yes
	V-0401-001721 + CV-0401-001885/82	000904010068 +	Haldimand	Centreline	Smooth or Rough	Circular	1		1200	48.3	27.1	S	165.50	165.00	166.70	166.20	1.04	1.72	2.57	88%	0.00	1.51	2.27	165.72	167.50	167.50	166.50	166.79	0.83	1.07	Yes	1.00	0.71	0.20	Yes	Yes	Yes
15+480	CV-0401-001885/824	000904010071/44	Haldimand	Centreline	Smooth or Rough	Circular	1		1200	45.0	21.8	S	165.50	165.00	166.70	166.20	1.11	1.34	2.01	100%	0.0	1.34	2.01	165.72	167.50	167.50	166.45	166.70	0.79	1.00	Yes	1.05	0.80	0.25	Yes	Yes	Yes
16+390	CV-0401-001912	000904010037	Haldimand	Centreline	CSP	Arch	1	1630	1120	58.8	12.5	S	169.50	169.25	170.62	170.37	0.42	1.10	1.63	100%	0.0	1.10	1.63	169.92	170.50	171.00	170.21	170.40	0.63	0.80	Yes	0.29	0.10	0.41	No	No	Yes
16+620	CV-0401-001908/880	000904010080/35	Haldimand	Centreline	CSP	Arch	1	1390	970	63.0	9.8	S	172.50	172.00	173.47	172.97	0.79	0.91	1.35	100%	0.0	0.91	1.35	172.58	174.00	174.00	173.14	173.33	0.66	0.86	Yes	0.86	0.67	0.33	Yes	No	Yes
20+930	CV-0401-001906	000904010085	Haldimand	Centreline	CSP	Circular	1		900	68.2	14.6	S	151.00	148.50	151.90	149.40	3.66	0.78	1.17	100%	0.0	0.78	1.17	149.04	158.00	158.00	151.91	152.18	1.01	1.31	Yes	6.09	5.82	-0.01	Yes	Yes	Yes
21+030	CV-0401-001907	000904010086	Haldimand	Centreline	Concrete	Box	1	1500	1200	155.0	41.0	S	151.00	148.50	152.20	149.70	1.61	2.33	3.54	100%	0.0	2.33	3.54	149.22	158.00	158.00	152.08	152.42	0.90	1.18	Yes	5.92	5.58	0.12	Yes	Yes	Yes
	CV-0401-001906+CV-0401-001907	000904010086 + 000904010085	Haldimand	Centreline	Concrete	Box	1	1500	1200	86.8	41.0	S	151.00	148.50	152.20	149.70	2.88	1.57	2.39	100%	0.0	1.57	2.39	149.22	158.00	158.00	152.08	152.43	0.90	1.19	Yes	5.92	5.57	0.12	Yes	Yes	Yes
21+615	CV-0401-001854	000904010015	Haldimand	Centreline	Smooth or Rough	Circular	1		900	48.0	4.7	S	143.50	142.00	144.40	142.90	3.13	0.50	0.74	100%	0.0	0.50	0.74	142.54	145.00	145.00	144.16	144.32	0.73	0.91	Yes	0.84	0.68	0.24	Yes	No	Yes
22+480	CV-0401-001914	000904010007	Haldimand	Centreline	CSP	Circular	1		900	65.2	10.1	S	130.00	127.50	130.90	128.40	3.84	0.38	0.59	77%	0.00	0.29	0.46	128.04	135.00	136.00	130.48	130.62	0.53	0.69	Yes	4.52	4.38	0.42	Yes	Yes	Yes
24+940	CV-0401-001850	000904010001	Haldimand	Centreline	Smooth or Rough	Circular	1		1200	55.2	28.6	S	169.50	169.00	170.70	170.20	0.91	1.65	2.50	75%	0.00	1.24	1.87	169.72	171.00	171.00	170.47	170.73	0.81	1.02	Yes	0.53	0.27	0.23	Yes	No	Yes
Highway 401 - Cramahe Township																																					
Centrelines																																					
10+396	CV-0401-001837	001004010032	Cramahe	Centreline	CSP	Circular	1		900	49.5	14.5	S	171.50	171.00	172.40	171.90	1.01	0.98	1.45	100%	0.0	0.98	1.45	171.54	173.25	173.25	172.42	172.86	1.02	1.51	Yes	0.83	0.39	-0.02	Yes	No	Yes
11+143	CV-0401-001835	001004010030	Cramahe	Centreline	Concrete	Box	1	1800	1500	52.4	110.6	S	165.00	164.00	166.50	165.50	1.91	3.98	5.92	100%	0.0	3.98	5.92	164.90	167.00	167.00	166.34	166.75	0.89	1.17	Yes	0.66	0.25	0.16	Yes	No	Yes
11+478	CV-0401-001910	001004010041	Cramahe	Centreline	CSP	Circular	1		900	54.9	47.5	S	171.00	170.50	171.90	171.40	0.91	2.38	3.53	100%	0.0	2.38	3.53	171.04	172.50	172.50	175.60	180.69	5.11	10.77	No	-3.10	-8.19	-3.70	No	No	No

Proposed Conditions

Station	DAID	Catchment ID	Geographic Township	Culvert Description	Material	Shape	Number of Barrels	Hydraulic Dimensions (mm)		Length	Total Drainage Area	Flow Direction	Upstream Invert	Downstream Invert	Upstream Obvert	Downstream Obvert	Slope	Unadjusted Flows (m3/s)		Lake / Wetland Reduction Factor	Lake/ Wetland Reduction Area	Adjusted Flows (m3/s)		Tail water Elev.	Spill Elev.	Road Elev. At Culvert	Required Headwater Elev. (m)	Required Headwater Elev. (m)	Depth of Headwater / Height of Opening (HW/D)	Depth of Headwater / Height of Opening (HW/D)	HW/D <1.5 (Design Storm)	Freeboard From Spill Point (m)	Freeboard From Spill Point (m)	Clearance (m)	Freeboard > 0.3 m (Design Storm)	Freeboard > 1.0 m (Design Storm)	HW<Spill point (Check Storm)
								Span	Height/ Diam.	(m)	(ha)		(m)	(m)	(m)	(m)	(%)	Design	Check	(%)	(%)	Design	Check	(m)	(m)	(m)	Design	Check	Design	Check	(Yes/No)	Design	Check	Design	(Yes/No)	(Yes/No)	(Yes/No)
Highway 401 - Hamilton Township																																					
23+330	CV-0401-001882	000804010053	Hamilton	Centreline	Smooth or Rough	Circular	1		900	53.7	18.6	S	166.00	165.00	166.90	165.90	1.86	0.60	0.90	1.00	0.00	0.60	0.90	165.54	168.50	169.00	166.74	166.95	0.82	1.06	Yes	1.76	1.55	0.16	Yes	Yes	Yes
	CV-0401-001882+CV-0401-002059	000804010053 + 000804010044	Hamilton	Centreline	Smooth or Rough	Circular	1		1200	53.7	29.0	S	166.00	165.00	167.20	166.20	1.86	1.28	1.92	1.00	0.00	1.28	1.92	165.72	168.50	169.00	167.03	167.32	0.86	1.10	Yes	Yes	Yes	Yes	Yes	Yes	Yes
23+605	CV-0401-002059	000804010044	Hamilton	Centreline	CSP - Plastic Lined	Circular	1		900	56.9	10.5	S	167.00	165.50	167.90	166.40	2.64	0.68	1.02	1.00	0.00	0.68	1.02	166.04	169.50	170.00	167.83	168.07	0.92	1.19	Yes	1.67	1.43	0.07	Yes	Yes	Yes
Highway 401 - Haldimand Township																																					
Lyle Street Interchange																																					
10+230 (W-N/S)	-	-	Haldimand	Ramp	CSP	Circular	1		800	25.0	2.5	S	0.13	0.00	0.93	0.8	0.50	0.26	0.40	100%	0.0	0.26	0.40	0.48	1.93	1.93	0.63	0.76	0.63	0.79	Yes	1.30	1.17	0.30	Yes	Yes	Yes
9+780 (N-E)	-	-	Haldimand	Ramp	CSP	Circular	1		800	20.0	2.0	S	0.10	0.00	0.90	0.8	0.50	0.22	0.34	100%	0.0	0.22	0.34	0.48	1.90	1.90	0.58	0.68	0.60	0.73	Yes	1.32	1.22	0.32	Yes	Yes	Yes
9+975 (S-W)	-	-	Haldimand	Ramp	CSP	Circular	1		800	45.0	2.0	E	0.23	0.00	1.03	0.8	0.50	0.28	0.41	100%	0.0	0.28	0.41	0.48	2.03	2.03	0.74	0.87	0.64	0.81	Yes	1.29	1.16	0.29	Yes	Yes	Yes
10+350 (W-N/S)	-	-	Haldimand	Ramp	CSP	Circular	1		800	35.0	2.0	S	0.18	0.00	0.98	0.8	0.50	0.22	0.34	100%	0.0	0.22	0.34	0.48	1.98	1.98	0.64	0.75	0.58	0.72	Yes	1.34	1.23	0.34	Yes	Yes	Yes
10+450 (E-N/S)	-	-	Haldimand	Ramp	CSP	Circular	1		800	25.0	3.5	S	0.13	0.00	0.93	0.8	0.50	0.42	0.63	100%	0.0	0.42	0.63	0.48	1.93	1.93	0.78	0.96	0.82	1.04	Yes	1.15	0.97	0.15	Yes	Yes	Yes
9+800 (Lyle)	-	-	Haldimand	Entrance	CSP	Circular	1		800	50.0	2.0	S	0.25	0.00	1.05	0.8	0.50	0.22	0.34	100%	0.0	0.22	0.34	0.48	2.05	2.05	0.71	0.83	0.58	0.73	Yes	1.34	1.22	0.34	Yes	Yes	Yes
10+200 (Lyle)	-	-	Haldimand	Entrance	CSP	Circular	1		800	35.0	2.0	S	0.18	0.00	0.98	0.8	0.50	0.28	0.41	100%	0.0	0.28	0.41	0.48	1.98	1.98	0.70	0.82	0.66	0.81	Yes	1.28	1.16	0.28	Yes	Yes	Yes
10+200b (Lyle - Carpool)	-	-	Haldimand	Entrance	CSP	Circular	1		800	25.0	2.0	W	0.13	0.00	0.93	0.8	0.50	0.28	0.41	100%	0.0	0.28	0.41	0.48	1.93	1.93	0.65	0.77	0.66	0.81	Yes	1.28	1.16	0.28	Yes	Yes	Yes
10+300 (Lyle)	-	-	Haldimand	Entrance	CSP	Circular	1		800	25.0	1.0	S	0.13	0.00	0.93	0.8	0.50	0.13	0.20	100%	0.0	0.13	0.20	0.48	1.93	1.93	0.53	0.58	0.51	0.57	Yes	1.40	1.35	0.40	Yes	Yes	Yes
Centrelines																																					
11+705	CV-0401-001858	000904010054	Haldimand	Centreline	Smooth or Rough	Circular	1		1500	51.5	54.8	S	162.50	162.00	164.00	163.50	0.97	2.67	4.01	100%	0.0	2.67	4.01	162.90	165.00	165.00	163.93	164.33	0.95	1.22	Yes	1.07	0.67	0.07	Yes	Yes	Yes
12+090	CV-0401-001857	000904010052	Haldimand	Centreline	Smooth or Rough	Circular	1		1200	52.8	10.1	S	152.50	150.00	153.70	151.20	4.74	0.88	1.30	100%	0.0	0.88	1.30	150.72	154.00	155.00	153.26	153.45	0.63	0.79	Yes	0.74	0.55	0.44	Yes	No	Yes
12+420	21-468/C+CV-0401-001855	21-468/C + 000904010048	Haldimand	Centreline	Concrete	Box	1	1540	1570	60.9	23.6	S	136.00	132.50	137.57	134.07	5.74	0.48	0.80	72%	0.0	0.35	0.57	133.44	140.50	140.50	141.73	142.30	1.15	1.53	Yes	2.27	1.70	-0.23	Yes	Yes	Yes
12+720	CV-0401-001855	000904010048	Haldimand	Centreline	Concrete	Box	1	1540	1570	60.9	23.6	S	136.00	132.50	137.57	134.07	5.74	0.48	0.80	72%	0.0	0.35	0.57	133.44	140.50	140.50	136.26	136.38	0.17	0.24	Yes	4.24	4.12	1.31	Yes	Yes	Yes
13+030	CV-0401-001873	000904010047	Haldimand	Centreline	Concrete	Box	1	1200	1200	73.8	38.3	S	139.50	138.50	140.70	139.70	1.35	1.10	1.75	100%	0.0	1.10	1.75	139.22	149.50	149.50	139.74	140.01	0.20	0.42	Yes	9.76	9.49	0.96	Yes	Yes	Yes
14+135	21-469/C	21-469/C	Haldimand	Centreline	Concrete	Circular	1	3100	1500	91.5	45.1	S	142.50	140.30	144.00	141.80	2.40			62%	0.0	1.92	0.00	141.20	155.00	155.50	143.23	143.45	0.49	0.63	Yes	11.77	11.55	0.77	Yes	Yes	Yes
14+200	21-270/C+CV-0401-001791	21-270/C + 000904010065/46	Haldimand	Centreline	Concrete	Arch	1	7200	4150	85.0	1923.2	S	143.15	140.45	147.30	144.60	3.18			67%	0.0	33.06	0.76	142.94	155.00	156.00	144.77	145.01	0.39	0.45	Yes	10.23	9.99	2.53	Yes	Yes	Yes
14+660	CV-0401-001791/825	000904010065/46	Haldimand	Centreline	Smooth	Circular	1		900	48.0	11.7	S	165.00	164.50	165.90	165.40	1.04	0.49	0.76	100%	0.0	0.49	0.76	165.04	166.50	166.50	165.59	165.76	0.66	0.84	Yes	0.91	0.74	0.31	Yes	No	Yes
15+150	CV-0401-001721	000904010068	Haldimand	Centreline	Smooth or Rough	Circular	1		900	48.3	5.3	S	165.50	165.00	166.40	165.90	1.04	0.38	0.56	67%	0.0	0.25	0.38	165.54	167.50	167.50	165.93	166.04	0.48	0.60	Yes	1.57	1.46	0.47	Yes	Yes	Yes
	V-0401-001721 + CV-0401-001885/82	000904010068 +	Haldimand	Centreline	Smooth or Rough	Circular	1		1200	48.3	27.1	S	165.50	165.00	166.70	166.20	1.04	1.72	2.57	88%	0.00	1.51	2.27	165.72	167.50	167.50	166.50	166.79	0.83	1.07	Yes	1.00	0.71	0.20	Yes	Yes	Yes
15+480	CV-0401-001885/824	000904010071/44	Haldimand	Centreline	Smooth or Rough	Circular	1		1200	45.0	21.8	S	165.50	165.00	166.70	166.20	1.11	1.34	2.01	100%	0.0	1.34	2.01	165.72	167.50	167.50	166.45	166.70	0.79	1.00	Yes	1.05	0.80	0.25	Yes	Yes	Yes
16+390	CV-0401-001912	000904010037	Haldimand	Centreline	CSP	Arch	1	1630	1120	58.8	12.5	S	169.50	169.25	170.62	170.37	0.42	1.10	1.63	100%	0.0	1.10	1.63	169.92	170.50	171.00	170.21	170.40	0.63	0.80	Yes	0.29	0.10	0.41	No	No	Yes
16+620	CV-0401-001908/880	000904010080/35	Haldimand	Centreline	CSP	Arch	1	1390	970	63.0	9.8	S	172.50	172.00	173.47	172.97	0.79	0.91	1.35	100%	0.0	0.91	1.35	172.58	174.00	174.00	173.14	173.33	0.66	0.86	Yes	0.86	0.67	0.33	Yes	No	Yes
20+930	CV-0401-001906	000904010085	Haldimand	Centreline	CSP	Circular	1		900	68.2	14.6	S	151.00	148.50	151.90	149.40	3.66	0.78	1.17	100%	0.0	0.78	1.17	149.04	158.00	158.00	151.91	152.18	1.01	1.31	Yes	6.09	5.82	-0.01	Yes	Yes	Yes
21+030	CV-0401-001907	000904010086	Haldimand	Centreline	Concrete	Box	1	1500	1200	155.0	41.0	S	151.00	148.50	152.20	149.70	1.61	2.33	3.54	100%	0.0	2.33	3.54	149.22	158.00	158.00	152.08	152.42	0.90	1.18	Yes	5.92	5.58	0.12	Yes	Yes	Yes
	CV-0401-001906+CV-0401-001907	000904010086 + 000904010085	Haldimand	Centreline	Concrete	Box	1	1500	1200	86.8	41.0	S	151.00	148.50	152.20	149.70	2.88	1.57	2.39	100%	0.0	1.57	2.39	149.22	158.00	158.00	152.08	152.43	0.90	1.19	Yes	5.92	5.57	0.12	Yes	Yes	Yes
21+615	CV-0401-001854	000904010015	Haldimand	Centreline	Smooth or Rough	Circular	1		900	48.0	4.7	S	143.50	142.00	144.40	142.90	3.13	0.50	0.74	100%	0.0	0.50	0.74	142.54	145.00	145.00	144.16	144.32	0.73	0.91	Yes	0.84	0.68	0.24	Yes	No	Yes
22+480	CV-0401-001914	000904010007	Haldimand	Centreline	CSP	Circular	1		900	65.2	10.1	S	130.00	127.50	130.90	128.40	3.84	0.38	0.59	0.77	0.00	0.29	0.46	128.04	135.00	136.00	130.48	130.62	0.53	0.69	Yes	4.52	4.38	0.42	Yes	Yes	Yes
24+940	CV-0401-001850	000904010001	Haldimand	Centreline	Smooth or Rough	Circular	1		1200	55.2	28.6	S	169.50	169.00	170.70	170.20	0.91	1.65	2.50	0.75	0.00	1.24	1.87	169.72	171.00	171.00	170.47	170.73	0.81	1.02	Yes	0.53	0.27	0.23	Yes	No	Yes
Highway 401 - Cramahe Township																																					
Percy Street Interchange																																					
9+460 (S-E)	-	-	Cramahe	Ramp	CSP	Circular	1		800	35.0	1.0	S	0.18	0.00	0.98	0.80	0.50	0.12	0.17	100%	0.0	0.12	0.17	0.48	1.98	1.98	0.54	0.59	0.46	0.52	Yes	1.44	1.39	0.44	Yes	Yes	Yes
10+510 (W-N/S)	-	-	Cramahe	Ramp	CSP	Circular	1		900	40.0	5.0	S	0.20	0.00	1.10	0.90	0.50	0.39	0.58	100%	0.0	0.39	0.58	0.54	2.10	2.10	0.80	0.96	0.67	0.84	Yes	1.30	1.14	0.30	Yes	Yes	Yes
10+610 (W-N/S)	-	-	Cramahe	Ramp	Concrete	Box	1	2400	1500	80.0	158.1	S	161.16	160.34	162.66	161.84	1.03	5.21	7.73	100%	0.0	5.21	7.73	161.24	163.66	163.66	162.40	162.77	0.83	1.07	Yes	1.26	0.89	0.26	Yes	Yes	Yes
9+975 (Percy)	-	-	Cramahe	Sideroad	CSP	Circular	1		800	60.0	1.5	W	0.30	0.00	1.10	0.80	0.50	0.16	0.24	100%	0.0	0.16	0.24	0.48	2.10	2.10	0.68	0.77	0.48	0.59	Yes	1.42	1.33	0.42	Yes	Yes	Yes
10+025 (Percy)	-	-	Cramahe	Sideroad	CSP	Box	1	1800	900	60.0	47.5	W	0.30	0.00	1.20	0.90	0.50	2.38	3.53	100%	0.0	2.38	3.53	0.54	2.20	2.20	1.12	1.54	0.91	1.38	Yes	1.08	0.66	0.08	Yes	Yes	Yes
9+790 (Percy)	-	-	Cramahe	Sideroad	CSP	Circular	1		800	40.0	4.0	W	0.20	0.00	1.00	0.80	0.50	0.33	0.49	100%	0.0	0.33	0.49	0.48	2.00	2.00	0.77	0.92	0.71	0.90	Yes	1.23	1.08	0.23	Yes	Yes	Yes
10+130 (E-N/S)	-	-	Cramahe	Ramp	CSP	Box	1	1800	900	30.0	47.5	W	0.15	0.00	1.05	0.90	0.50	2.38	3.53	100%	0.0	2.38	3.53	0.54	2.05	2.05	0.97	1.39	0.91	1.38	Yes	1.08	0.66	0.08	Yes	Yes	Yes
9+525 (Percy)	-	-	Cramahe	Entrance	CSP	Circular	1		800	25.0	2.0	S	0.13	0.00	0.93	0.80	0.50	0.20	0.29	100%	0.0	0.20	0.29	0.48	1.93	1.93	0.58	0.66	0.57	0.67	Yes	1.35	1.27	0.35	Yes	Yes	Yes
9+525b (Percy)	-	-	Cramahe	Entrance	CSP	Circular	1		1200	25.0	30.0	S	0.13	0.00	1.33	1.20	0.50	1.50	2.22	100%	0.0	1.50	2.22	0.72	2.33	2.33	1.27	1.62	0.95	1.25	Yes	1.06	0.71	0.05	Yes	Yes	Yes
9+650 (Percy)	-	-	Cramahe	Entrance	CSP	Circular	1		1200	20.0	20.0	S	0.10	0.00	1.30	1.20	0.50	1.10	1.64	100%	0.0	1.10	1.64	0.72	2.30	2.30	1.05	1.30	0.79	1.00	Yes	1.25	1.00	0.25	Yes	Yes	Yes
9+675 (Percy)	-	-	Cramahe	Sideroad	CSP	Circular	1		1500	30.0	40.0	W	0.15	0.00	1.65	1.50	0.50	1.86	2.76	100%	0.0	1.86	2.76	0.90	2.65	2.65	1.31	1.62

Culvert Design Report
Cramahe - 10+396

Peak Discharge Method: User-Specified			
Design Discharge	0.9800 m³/s	Check Discharge	1.4500 m³/s

Grades Model: Inverts			
Invert Upstream	171.50 m	Invert Downstream	171.00 m
Length	49.50 m	Slope	0.010101 m/m
Drop	0.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	171.54 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-900 mm Circular	0.9800 m³/s	172.52 m	2.22 m/s
	Trial-2	1-900 mm Circular	1.4500 m³/s	173.27 m	2.65 m/s

Culvert Design Report
Cramahe - 10+396

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	172.52 m	Discharge	0.9800 m³/s
Headwater Depth/Height	1.12	Tailwater Elevation	171.54 m
Inlet Control HW Elev.	172.48 m	Control Type	Outlet Control
Outlet Control HW Elev.	172.52 m		

Grades			
Upstream Invert	171.50 m	Downstream Invert	171.00 m
Length	49.50 m	Constructed Slope	0.010101 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.58 m
Slope Type	Mild	Normal Depth	0.71 m
Flow Regime	Subcritical	Critical Depth	0.58 m
Velocity Downstream	2.22 m/s	Critical Slope	0.016985 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	172.52 m	Upstream Velocity Head	0.16 m
Ke	0.90	Entrance Loss	0.15 m

Inlet Control Properties			
Inlet Control HW Elev.	172.48 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Cramahe - 10+396 (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	172.44 m	Discharge	0.9800 m³/s
Headwater Depth/Height	0.88	Tailwater Elevation	171.63 m
Inlet Control HW Elev.	172.37 m	Control Type	Outlet Control
Outlet Control HW Elev.	172.44 m		

Grades			
Upstream Invert	171.50 m	Downstream Invert	171.00 m
Length	49.50 m	Constructed Slope	0.010101 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.63 m
Slope Type	Mild	Normal Depth	0.62 m
Flow Regime	Subcritical	Critical Depth	0.56 m
Velocity Downstream	1.78 m/s	Critical Slope	0.014047 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	1.07 m
Section Size	1050 mm	Rise	1.07 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	172.44 m	Upstream Velocity Head	0.17 m
Ke	0.90	Entrance Loss	0.15 m

Inlet Control Properties			
Inlet Control HW Elev.	172.37 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.9 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Cramahe - 10+396 (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	172.69 m	Discharge	1.4500 m³/s
Headwater Depth/Height	1.12	Tailwater Elevation	171.63 m
Inlet Control HW Elev.	172.65 m	Control Type	Outlet Control
Outlet Control HW Elev.	172.69 m		

Grades			
Upstream Invert	171.50 m	Downstream Invert	171.00 m
Length	49.50 m	Constructed Slope	0.010101 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.68 m
Slope Type	Mild	Normal Depth	0.82 m
Flow Regime	Subcritical	Critical Depth	0.68 m
Velocity Downstream	2.40 m/s	Critical Slope	0.016187 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	1.07 m
Section Size	1050 mm	Rise	1.07 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	172.69 m	Upstream Velocity Head	0.20 m
Ke	0.90	Entrance Loss	0.18 m

Inlet Control Properties			
Inlet Control HW Elev.	172.65 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.9 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Cramahe - 10+396

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	173.27 m	Discharge	1.4500 m³/s
Headwater Depth/Height	1.93	Tailwater Elevation	171.54 m
Inlet Control HW Elev.	172.87 m	Control Type	Outlet Control
Outlet Control HW Elev.	173.27 m		

Grades			
Upstream Invert	171.50 m	Downstream Invert	171.00 m
Length	49.50 m	Constructed Slope	0.010101 m/m

Hydraulic Profile			
Profile	CompositeM2PressureProfile	Depth, Downstream	0.71 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.71 m
Velocity Downstream	2.65 m/s	Critical Slope	0.022387 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	173.27 m	Upstream Velocity Head	0.25 m
Ke	0.90	Entrance Loss	0.22 m

Inlet Control Properties			
Inlet Control HW Elev.	172.87 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Cramahe - 10+396 (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	0.9800 m³/s	Check Discharge	1.4500 m³/s

Grades Model: Inverts			
Invert Upstream	171.50 m	Invert Downstream	171.00 m
Length	49.50 m	Slope	0.010101 m/m
Drop	0.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	171.63 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-1050 mm Circular	0.9800 m³/s	172.44 m	1.78 m/s
	Trial-2	1-1050 mm Circular	1.4500 m³/s	172.69 m	2.40 m/s

Culvert Design Report
Cramahe - 11+143

Peak Discharge Method: User-Specified			
Design Discharge	3.9800 m³/s	Check Discharge	5.9200 m³/s

Grades Model: Inverts			
Invert Upstream	165.00 m	Invert Downstream	164.00 m
Length	52.40 m	Slope	0.019084 m/m
Drop	1.00 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	164.90 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-1830 x 1520 mm Box	3.9800 m³/s	166.37 m	2.42 m/s
	Trial-2	1-1830 x 1520 mm Box	5.9200 m³/s	166.79 m	5.00 m/s

Culvert Design Report
Cramahe - 11+143

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	166.37 m	Discharge	3.9800 m³/s
Headwater Depth/Height	0.90	Tailwater Elevation	164.90 m
Inlet Control HW Elev.	166.21 m	Control Type	Entrance Control
Outlet Control HW Elev.	166.37 m		

Grades			
Upstream Invert	165.00 m	Downstream Invert	164.00 m
Length	52.40 m	Constructed Slope	0.019084 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.90 m
Slope Type	Steep	Normal Depth	0.45 m
Flow Regime	N/A	Critical Depth	0.78 m
Velocity Downstream	2.42 m/s	Critical Slope	0.004105 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.83 m
Section Size	1830 x 1520 mm	Rise	1.52 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	166.37 m	Upstream Velocity Head	0.39 m
Ke	0.50	Entrance Loss	0.20 m

Inlet Control Properties			
Inlet Control HW Elev.	166.21 m	Flow Control	N/A
Inlet Type	18 to 33.7° wingwall flare, d=0.0830	Area Full	2.8 m²
K	0.48600	HDS 5 Chart	9
M	0.66700	HDS 5 Scale	2
C	0.02490	Equation Form	2
Y	0.83000		

Culvert Design Report
Cramahe - 11+143

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	166.79 m	Discharge	5.9200 m³/s
Headwater Depth/Height	1.17	Tailwater Elevation	164.90 m
Inlet Control HW Elev.	166.58 m	Control Type	Entrance Control
Outlet Control HW Elev.	166.79 m		

Grades			
Upstream Invert	165.00 m	Downstream Invert	164.00 m
Length	52.40 m	Constructed Slope	0.019084 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.65 m
Slope Type	Steep	Normal Depth	0.60 m
Flow Regime	Supercritical	Critical Depth	1.02 m
Velocity Downstream	5.00 m/s	Critical Slope	0.004475 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.83 m
Section Size	1830 x 1520 mm	Rise	1.52 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	166.79 m	Upstream Velocity Head	0.51 m
Ke	0.50	Entrance Loss	0.26 m

Inlet Control Properties			
Inlet Control HW Elev.	166.58 m	Flow Control	N/A
Inlet Type	18 to 33.7° wingwall flare, d=0.0830	Area Full	2.8 m²
K	0.48600	HDS 5 Chart	9
M	0.66700	HDS 5 Scale	2
C	0.02490	Equation Form	2
Y	0.83000		

Culvert Design Report
Cramahe - 11+143 (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	3.9800 m³/s	Check Discharge	5.9200 m³/s

Grades Model: Inverts			
Invert Upstream	165.00 m	Invert Downstream	164.00 m
Length	52.40 m	Slope	0.019084 m/m
Drop	1.00 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater			
Tailwater Elevation	164.90 m		

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-2440 x 1520 mm Box	3.9800 m³/s	166.13 m	1.81 m/s
	Trial-2	1-2440 x 1520 mm Box	5.9200 m³/s	166.48 m	2.70 m/s

Culvert Design Report
Cramahe - 11+478

Peak Discharge Method: User-Specified			
Design Discharge	2.3800 m³/s	Check Discharge	3.5300 m³/s

Grades Model: Inverts			
Invert Upstream	171.00 m	Invert Downstream	170.50 m
Length	54.90 m	Slope	0.009107 m/m
Drop	0.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater			
Tailwater Elevation	171.04 m		

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-900 mm Circular	2.3800 m³/s	175.64 m	3.73 m/s
	Trial-2	1-900 mm Circular	3.5300 m³/s	180.75 m	5.39 m/s

Culvert Design Report
Cramahe - 11+478

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	175.64 m	Discharge	2.3800 m³/s
Headwater Depth/Height	5.07	Tailwater Elevation	171.04 m
Inlet Control HW Elev.	173.87 m	Control Type	Outlet Control
Outlet Control HW Elev.	175.64 m		

Grades			
Upstream Invert	171.00 m	Downstream Invert	170.50 m
Length	54.90 m	Constructed Slope	0.009107 m/m

Hydraulic Profile			
Profile	CompositeM2PressureProfile	Depth, Downstream	0.85 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.85 m
Velocity Downstream	3.73 m/s	Critical Slope	0.046784 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	175.64 m	Upstream Velocity Head	0.67 m
Ke	0.90	Entrance Loss	0.60 m

Inlet Control Properties			
Inlet Control HW Elev.	173.87 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Cramahe - 11+143 (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	166.13 m	Discharge	3.9800 m³/s
Headwater Depth/Height	0.74	Tailwater Elevation	164.90 m
Inlet Control HW Elev.	166.00 m	Control Type	Entrance Control
Outlet Control HW Elev.	166.13 m		

Grades			
Upstream Invert	165.00 m	Downstream Invert	164.00 m
Length	52.40 m	Constructed Slope	0.019084 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.90 m
Slope Type	Steep	Normal Depth	0.36 m
Flow Regime	N/A	Critical Depth	0.65 m
Velocity Downstream	1.81 m/s	Critical Slope	0.003381 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	2.44 m
Section Size	2440 x 1520 mm	Rise	1.52 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	166.13 m	Upstream Velocity Head	0.32 m
Ke	0.50	Entrance Loss	0.16 m

Inlet Control Properties			
Inlet Control HW Elev.	166.00 m	Flow Control	N/A
Inlet Type	18 to 33.7° wingwall flare, d=0.0830	Area Full	3.7 m²
K	0.48600	HDS 5 Chart	9
M	0.66700	HDS 5 Scale	2
C	0.02490	Equation Form	2
Y	0.83000		

Culvert Design Report
Cramahe - 11+143 (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	166.48 m	Discharge	5.9200 m³/s
Headwater Depth/Height	0.97	Tailwater Elevation	164.90 m
Inlet Control HW Elev.	166.30 m	Control Type	Entrance Control
Outlet Control HW Elev.	166.48 m		

Grades			
Upstream Invert	165.00 m	Downstream Invert	164.00 m
Length	52.40 m	Constructed Slope	0.019084 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.90 m
Slope Type	Steep	Normal Depth	0.47 m
Flow Regime	N/A	Critical Depth	0.84 m
Velocity Downstream	2.70 m/s	Critical Slope	0.003536 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	2.44 m
Section Size	2440 x 1520 mm	Rise	1.52 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	166.48 m	Upstream Velocity Head	0.42 m
Ke	0.50	Entrance Loss	0.21 m

Inlet Control Properties			
Inlet Control HW Elev.	166.30 m	Flow Control	N/A
Inlet Type	18 to 33.7° wingwall flare, d=0.0830	Area Full	3.7 m²
K	0.48600	HDS 5 Chart	9
M	0.66700	HDS 5 Scale	2
C	0.02490	Equation Form	2
Y	0.83000		

Culvert Design Report
Cramahe - 11+478

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	180.75 m	Discharge	3.5300 m³/s
Headwater Depth/Height	10.66	Tailwater Elevation	171.04 m
Inlet Control HW Elev.	176.73 m	Control Type	Outlet Control
Outlet Control HW Elev.	180.75 m		

Grades			
Upstream Invert	171.00 m	Downstream Invert	170.50 m
Length	54.90 m	Constructed Slope	0.009107 m/m

Hydraulic Profile			
Profile	CompositeM2PressureProfile	Depth, Downstream	0.90 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.90 m
Velocity Downstream	5.39 m/s	Critical Slope	0.107999 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	180.75 m	Upstream Velocity Head	1.47 m
Ke	0.90	Entrance Loss	1.33 m

Inlet Control Properties			
Inlet Control HW Elev.	176.73 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Cramahe - 11+478 (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	2.3800 m³/s	Check Discharge	3.5300 m³/s

Grades Model: Inverts			
Invert Upstream	171.00 m	Invert Downstream	170.50 m
Length	54.90 m	Slope	0.009107 m/m
Drop	0.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater			
Tailwater Elevation	171.04 m		

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-1830 x 910 mm Box	2.3800 m³/s	171.97 m	3.15 m/s
	Trial-2	1-1830 x 910 mm Box	3.5300 m³/s	172.29 m	3.52 m/s

Culvert Design Report
Cramahe - 11+478 (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	171.97 m	Discharge	2.3800 m³/s
Headwater Depth/Height	1.07	Tailwater Elevation	171.04 m
Inlet Control HW Elev.	171.90 m	Control Type	Entrance Control
Outlet Control HW Elev.	171.97 m		

Grades			
Upstream Invert	171.00 m	Downstream Invert	170.50 m
Length	54.90 m	Constructed Slope	0.009107 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.41 m
Slope Type	Steep	Normal Depth	0.41 m
Flow Regime	Supercritical	Critical Depth	0.56 m
Velocity Downstream	3.15 m/s	Critical Slope	0.003798 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.83 m
Section Size	1830 x 910 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	171.97 m	Upstream Velocity Head	0.28 m
Ke	0.50	Entrance Loss	0.14 m

Inlet Control Properties			
Inlet Control HW Elev.	171.90 m	Flow Control	N/A
Inlet Type	30 to 75° wingwall flares	Area Full	1.7 m²
K	0.02600	HDS 5 Chart	8
M	1.00000	HDS 5 Scale	1
C	0.03470	Equation Form	1
Y	0.86000		

Culvert Design Report
Cramahe - 11+478 (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	172.29 m	Discharge	3.5300 m³/s
Headwater Depth/Height	1.41	Tailwater Elevation	171.04 m
Inlet Control HW Elev.	172.29 m	Control Type	Inlet Control
Outlet Control HW Elev.	172.27 m		

Grades			
Upstream Invert	171.00 m	Downstream Invert	170.50 m
Length	54.90 m	Constructed Slope	0.009107 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.55 m
Slope Type	Steep	Normal Depth	0.54 m
Flow Regime	Supercritical	Critical Depth	0.72 m
Velocity Downstream	3.52 m/s	Critical Slope	0.004017 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.83 m
Section Size	1830 x 910 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	172.27 m	Upstream Velocity Head	0.36 m
Ke	0.50	Entrance Loss	0.18 m

Inlet Control Properties			
Inlet Control HW Elev.	172.29 m	Flow Control	N/A
Inlet Type	30 to 75° wingwall flares	Area Full	1.7 m²
K	0.02600	HDS 5 Chart	8
M	1.00000	HDS 5 Scale	1
C	0.03470	Equation Form	1
Y	0.86000		

Culvert Design Report
Haldimand - 11+705

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	174.44 m	Discharge	4.0100 m³/s
Headwater Depth/Height	13.05	Tailwater Elevation	162.54 m
Inlet Control HW Elev.	169.75 m	Control Type	Outlet Control
Outlet Control HW Elev.	174.44 m		

Grades			
Upstream Invert	162.50 m	Downstream Invert	162.00 m
Length	51.50 m	Constructed Slope	0.009709 m/m

Hydraulic Profile			
Profile	CompositeM2PressureProfile	Depth, Downstream	0.91 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.91 m
Velocity Downstream	6.12 m/s	Critical Slope	0.142117 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	174.44 m	Upstream Velocity Head	1.90 m
Ke	0.90	Entrance Loss	1.71 m

Inlet Control Properties			
Inlet Control HW Elev.	169.75 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 11+705 (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	2.6700 m³/s	Check Discharge	4.0100 m³/s

Grades Model: Inverts			
Invert Upstream	162.50 m	Invert Downstream	162.00 m
Length	51.50 m	Slope	0.009709 m/m
Drop	0.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater

Tailwater Elevation	162.90 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-1500 mm Circular	2.6700 m³/s	163.94 m	2.38 m/s
	Trial-2	1-1500 mm Circular	4.0100 m³/s	164.36 m	3.03 m/s

Culvert Design Report
Haldimand - 11+705

Peak Discharge Method: User-Specified			
Design Discharge	2.6700 m³/s	Check Discharge	4.0100 m³/s

Grades Model: Inverts			
Invert Upstream	162.50 m	Invert Downstream	162.00 m
Length	51.50 m	Slope	0.009709 m/m
Drop	0.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater

Tailwater Elevation	162.54 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-900 mm Circular	2.6700 m³/s	168.01 m	4.13 m/s
	Trial-2	1-900 mm Circular	4.0100 m³/s	174.44 m	6.12 m/s

Culvert Design Report
Haldimand - 11+705

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	168.01 m	Discharge	2.6700 m³/s
Headwater Depth/Height	6.02	Tailwater Elevation	162.54 m
Inlet Control HW Elev.	165.99 m	Control Type	Outlet Control
Outlet Control HW Elev.	168.01 m		

Grades			
Upstream Invert	162.50 m	Downstream Invert	162.00 m
Length	51.50 m	Constructed Slope	0.009709 m/m

Hydraulic Profile			
Profile	CompositeM2PressureProfile	Depth, Downstream	0.87 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.87 m
Velocity Downstream	4.13 m/s	Critical Slope	0.059206 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	168.01 m	Upstream Velocity Head	0.84 m
Ke	0.90	Entrance Loss	0.76 m

Inlet Control Properties			
Inlet Control HW Elev.	165.99 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 11+705 (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	163.94 m	Discharge	2.6700 m³/s
Headwater Depth/Height	0.95	Tailwater Elevation	162.90 m
Inlet Control HW Elev.	163.84 m	Control Type	Outlet Control
Outlet Control HW Elev.	163.94 m		

Grades			
Upstream Invert	162.50 m	Downstream Invert	162.00 m
Length	51.50 m	Constructed Slope	0.009709 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.90 m
Slope Type	Mild	Normal Depth	0.92 m
Flow Regime	Subcritical	Critical Depth	0.84 m
Velocity Downstream	2.38 m/s	Critical Slope	0.012860 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	1.52 m
Section Size	1500 mm	Rise	1.52 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	163.94 m	Upstream Velocity Head	0.27 m
Ke	0.90	Entrance Loss	0.25 m

Inlet Control Properties			
Inlet Control HW Elev.	163.84 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	1.8 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 11+705 (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	164.36 m	Discharge	4.0100 m³/s
Headwater Depth/Height	1.22	Tailwater Elevation	162.90 m
Inlet Control HW Elev.	164.30 m	Control Type	Outlet Control
Outlet Control HW Elev.	164.36 m		

Grades			
Upstream Invert	162.50 m	Downstream Invert	162.00 m
Length	51.50 m	Constructed Slope	0.009709 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	1.04 m
Slope Type	Mild	Normal Depth	1.28 m
Flow Regime	Subcritical	Critical Depth	1.04 m
Velocity Downstream	3.03 m/s	Critical Slope	0.015409 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	1.52 m
Section Size	1500 mm	Rise	1.52 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	164.36 m	Upstream Velocity Head	0.32 m
Ke	0.90	Entrance Loss	0.29 m

Inlet Control Properties			
Inlet Control HW Elev.	164.30 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	1.8 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 12+090

Peak Discharge Method: User-Specified			
Design Discharge	0.8800 m³/s	Check Discharge	1.3000 m³/s

Grades Model: Inverts			
Invert Upstream	152.50 m	Invert Downstream	150.00 m
Length	52.80 m	Slope	0.047348 m/m
Drop	2.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	150.54 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-900 mm Circular	0.8800 m³/s	153.49 m	3.19 m/s
	Trial-2	1-900 mm Circular	1.3000 m³/s	153.78 m	3.52 m/s

Culvert Design Report
Haldimand - 12+090

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	153.49 m	Discharge	0.8800 m³/s
Headwater Depth/Height	1.08	Tailwater Elevation	150.54 m
Inlet Control HW Elev.	153.39 m	Control Type	Entrance Control
Outlet Control HW Elev.	153.49 m		

Grades			
Upstream Invert	152.50 m	Downstream Invert	150.00 m
Length	52.80 m	Constructed Slope	0.047348 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.40 m
Slope Type	Steep	Normal Depth	0.40 m
Flow Regime	Supercritical	Critical Depth	0.55 m
Velocity Downstream	3.19 m/s	Critical Slope	0.016183 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	153.49 m	Upstream Velocity Head	0.23 m
Ke	0.90	Entrance Loss	0.21 m

Inlet Control Properties			
Inlet Control HW Elev.	153.39 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 12+090 (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	153.29 m	Discharge	0.8800 m³/s
Headwater Depth/Height	0.65	Tailwater Elevation	150.72 m
Inlet Control HW Elev.	153.18 m	Control Type	Entrance Control
Outlet Control HW Elev.	153.29 m		

Grades			
Upstream Invert	152.50 m	Downstream Invert	150.00 m
Length	52.80 m	Constructed Slope	0.047348 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.72 m
Slope Type	Steep	Normal Depth	0.26 m
Flow Regime	N/A	Critical Depth	0.50 m
Velocity Downstream	1.23 m/s	Critical Slope	0.003648 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.22 m
Section Size	1200 mm	Rise	1.22 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	153.29 m	Upstream Velocity Head	0.19 m
Ke	0.50	Entrance Loss	0.09 m

Inlet Control Properties			
Inlet Control HW Elev.	153.18 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	1.2 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Design Report
Haldimand - 12+090 (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	153.48 m	Discharge	1.3000 m³/s
Headwater Depth/Height	0.81	Tailwater Elevation	150.72 m
Inlet Control HW Elev.	153.37 m	Control Type	Entrance Control
Outlet Control HW Elev.	153.48 m		

Grades			
Upstream Invert	152.50 m	Downstream Invert	150.00 m
Length	52.80 m	Constructed Slope	0.047348 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.72 m
Slope Type	Steep	Normal Depth	0.32 m
Flow Regime	N/A	Critical Depth	0.62 m
Velocity Downstream	1.81 m/s	Critical Slope	0.003893 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.22 m
Section Size	1200 mm	Rise	1.22 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	153.48 m	Upstream Velocity Head	0.24 m
Ke	0.50	Entrance Loss	0.12 m

Inlet Control Properties			
Inlet Control HW Elev.	153.37 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	1.2 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Design Report
Haldimand - 12+090

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	153.78 m	Discharge	1.3000 m³/s
Headwater Depth/Height	1.40	Tailwater Elevation	150.54 m
Inlet Control HW Elev.	153.71 m	Control Type	Entrance Control
Outlet Control HW Elev.	153.78 m		

Grades			
Upstream Invert	152.50 m	Downstream Invert	150.00 m
Length	52.80 m	Constructed Slope	0.047348 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.50 m
Slope Type	Steep	Normal Depth	0.50 m
Flow Regime	Supercritical	Critical Depth	0.67 m
Velocity Downstream	3.52 m/s	Critical Slope	0.020319 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	153.78 m	Upstream Velocity Head	0.32 m
Ke	0.90	Entrance Loss	0.29 m

Inlet Control Properties			
Inlet Control HW Elev.	153.71 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 12+090 (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	0.8800 m³/s	Check Discharge	1.3000 m³/s

Grades Model: Inverts			
Invert Upstream	152.50 m	Invert Downstream	150.00 m
Length	52.80 m	Slope	0.047348 m/m
Drop	2.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	150.72 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-1200 mm Circular	0.8800 m³/s	153.29 m	1.23 m/s
	Trial-2	1-1200 mm Circular	1.3000 m³/s	153.48 m	1.81 m/s

Culvert Design Report
Haldimand - 12+720

Peak Discharge Method: User-Specified			
Design Discharge	0.3500 m³/s	Check Discharge	0.5700 m³/s

Grades Model: Inverts			
Invert Upstream	136.00 m	Invert Downstream	132.50 m
Length	60.90 m	Slope	0.057471 m/m
Drop	3.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	133.44 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-1520 x 1520 mm Box	0.3500 m³/s	136.31 m	0.24 m/s
	Trial-2	1-1520 x 1520 mm Box	0.5700 m³/s	136.42 m	0.40 m/s

Culvert Design Report
Haldimand - 12+720

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	136.31 m	Discharge	0.3500 m³/s
Headwater Depth/Height	0.20	Tailwater Elevation	133.44 m
Inlet Control HW Elev.	136.27 m	Control Type	Entrance Control
Outlet Control HW Elev.	136.31 m		

Grades			
Upstream Invert	136.00 m	Downstream Invert	132.50 m
Length	60.90 m	Constructed Slope	0.057471 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.94 m
Slope Type	Steep	Normal Depth	0.07 m
Flow Regime	N/A	Critical Depth	0.18 m
Velocity Downstream	0.24 m/s	Critical Slope	0.003903 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.52 m
Section Size	1520 x 1520 mm	Rise	1.52 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	136.31 m	Upstream Velocity Head	0.09 m
Ke	0.50	Entrance Loss	0.04 m

Inlet Control Properties			
Inlet Control HW Elev.	136.27 m	Flow Control	N/A
Inlet Type	18 to 33.7° wingwall flare, d=0.083D	Area Full	2.3 m²
K	0.48600	HDS 5 Chart	9
M	0.66700	HDS 5 Scale	2
C	0.02490	Equation Form	2
Y	0.83000		

Culvert Design Report
Haldimand - 12+720

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	136.42 m	Discharge	0.5700 m³/s
Headwater Depth/Height	0.28	Tailwater Elevation	133.44 m
Inlet Control HW Elev.	136.37 m	Control Type	Entrance Control
Outlet Control HW Elev.	136.42 m		

Grades			
Upstream Invert	136.00 m	Downstream Invert	132.50 m
Length	60.90 m	Constructed Slope	0.057471 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.94 m
Slope Type	Steep	Normal Depth	0.10 m
Flow Regime	N/A	Critical Depth	0.24 m
Velocity Downstream	0.40 m/s	Critical Slope	0.003841 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.52 m
Section Size	1520 x 1520 mm	Rise	1.52 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	136.42 m	Upstream Velocity Head	0.12 m
Ke	0.50	Entrance Loss	0.06 m

Inlet Control Properties			
Inlet Control HW Elev.	136.37 m	Flow Control	N/A
Inlet Type	18 to 33.7° wingwall flare, d=0.0830	Area Full	2.3 m²
K	0.48600	HDS 5 Chart	9
M	0.66700	HDS 5 Scale	2
C	0.02490	Equation Form	2
Y	0.83000		

Culvert Design Report
Haldimand - 13+030

Peak Discharge Method: User-Specified			
Design Discharge	1.1000 m³/s	Check Discharge	1.7500 m³/s

Grades Model: Inverts			
Invert Upstream	139.00 m	Invert Downstream	138.50 m
Length	38.26 m	Slope	0.013068 m/m
Drop	0.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater			
Tailwater Elevation	139.22 m		

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-1220 x 1220 mm Box	1.1000 m³/s	139.76 m	1.25 m/s
	Trial-2	1-1220 x 1220 mm Box	1.7500 m³/s	140.04 m	1.99 m/s

Culvert Design Report
Haldimand - 14+660

Peak Discharge Method: User-Specified			
Design Discharge	0.4900 m³/s	Check Discharge	0.7600 m³/s

Grades Model: Inverts			
Invert Upstream	165.00 m	Invert Downstream	164.50 m
Length	45.00 m	Slope	0.011111 m/m
Drop	0.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater			
Tailwater Elevation	165.98 m		

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-825 mm Circular	0.4900 m³/s	166.10 m	0.89 m/s
	Trial-2	1-825 mm Circular	0.7600 m³/s	166.28 m	1.38 m/s

Culvert Design Report
Haldimand - 14+660

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	166.10 m	Discharge	0.4900 m³/s
Headwater Depth/Height	1.32	Tailwater Elevation	165.98 m
Inlet Control HW Elev.	165.98 m	Control Type	Outlet Control
Outlet Control HW Elev.	166.10 m		

Grades			
Upstream Invert	165.00 m	Downstream Invert	164.50 m
Length	45.00 m	Constructed Slope	0.011111 m/m

Hydraulic Profile			
Profile	PressureProfile	Depth, Downstream	1.48 m
Slope Type	N/A	Normal Depth	0.32 m
Flow Regime	N/A	Critical Depth	0.42 m
Velocity Downstream	0.89 m/s	Critical Slope	0.004372 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	166.10 m	Upstream Velocity Head	0.04 m
Ke	0.90	Entrance Loss	0.04 m

Inlet Control Properties			
Inlet Control HW Elev.	165.98 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 13+030

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	139.76 m	Discharge	1.1000 m³/s
Headwater Depth/Height	0.63	Tailwater Elevation	139.22 m
Inlet Control HW Elev.	139.67 m	Control Type	Entrance Control
Outlet Control HW Elev.	139.76 m		

Grades			
Upstream Invert	139.00 m	Downstream Invert	138.50 m
Length	38.26 m	Constructed Slope	0.013068 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.72 m
Slope Type	Steep	Normal Depth	0.30 m
Flow Regime	N/A	Critical Depth	0.44 m
Velocity Downstream	1.25 m/s	Critical Slope	0.004489 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.22 m
Section Size	1220 x 1220 mm	Rise	1.22 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	139.76 m	Upstream Velocity Head	0.22 m
Ke	0.50	Entrance Loss	0.11 m

Inlet Control Properties			
Inlet Control HW Elev.	139.67 m	Flow Control	N/A
Inlet Type	18 to 33.7° wingwall flare, d=0.0830	Area Full	1.5 m²
K	0.48600	HDS 5 Chart	9
M	0.66700	HDS 5 Scale	2
C	0.02490	Equation Form	2
Y	0.83000		

Culvert Design Report
Haldimand - 13+030

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	140.04 m	Discharge	1.7500 m³/s
Headwater Depth/Height	0.85	Tailwater Elevation	139.22 m
Inlet Control HW Elev.	139.92 m	Control Type	Entrance Control
Outlet Control HW Elev.	140.04 m		

Grades			
Upstream Invert	139.00 m	Downstream Invert	138.50 m
Length	38.26 m	Constructed Slope	0.013068 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.72 m
Slope Type	Steep	Normal Depth	0.41 m
Flow Regime	N/A	Critical Depth	0.59 m
Velocity Downstream	1.99 m/s	Critical Slope	0.004885 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.22 m
Section Size	1220 x 1220 mm	Rise	1.22 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	140.04 m	Upstream Velocity Head	0.30 m
Ke	0.50	Entrance Loss	0.15 m

Inlet Control Properties			
Inlet Control HW Elev.	139.92 m	Flow Control	N/A
Inlet Type	18 to 33.7° wingwall flare, d=0.0830	Area Full	1.5 m²
K	0.48600	HDS 5 Chart	9
M	0.66700	HDS 5 Scale	2
C	0.02490	Equation Form	2
Y	0.83000		

Culvert Design Report
Haldimand - 14+660

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	166.28 m	Discharge	0.7600 m³/s
Headwater Depth/Height	1.53	Tailwater Elevation	165.98 m
Inlet Control HW Elev.	165.98 m	Control Type	Outlet Control
Outlet Control HW Elev.	166.28 m		

Grades			
Upstream Invert	165.00 m	Downstream Invert	164.50 m
Length	45.00 m	Constructed Slope	0.011111 m/m

Hydraulic Profile			
Profile	PressureProfile	Depth, Downstream	1.48 m
Slope Type	N/A	Normal Depth	0.41 m
Flow Regime	N/A	Critical Depth	0.52 m
Velocity Downstream	1.38 m/s	Critical Slope	0.005041 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	166.28 m	Upstream Velocity Head	0.10 m
Ke	0.90	Entrance Loss	0.09 m

Inlet Control Properties			
Inlet Control HW Elev.	165.98 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 14+660 (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	0.4900 m³/s	Check Discharge	0.7600 m³/s

Grades Model: Inverts			
Invert Upstream	165.00 m	Invert Downstream	164.50 m
Length	45.00 m	Slope	0.011111 m/m
Drop	0.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater			
Tailwater Elevation	165.04 m		

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-900 mm Circular	0.4900 m³/s	165.64 m	1.21 m/s
	Trial-2	1-900 mm Circular	0.7600 m³/s	165.82 m	1.88 m/s

Culvert Design Report
Haldimand - 14+660 (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	165.64 m	Discharge	0.4900 m³/s
Headwater Depth/Height	0.70	Tailwater Elevation	165.04 m
Inlet Control HW Elev.	165.57 m	Control Type	Entrance Control
Outlet Control HW Elev.	165.64 m		

Grades			
Upstream Invert	165.00 m	Downstream Invert	164.50 m
Length	45.00 m	Constructed Slope	0.011111 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.54 m
Slope Type	Steep	Normal Depth	0.31 m
Flow Regime	N/A	Critical Depth	0.41 m
Velocity Downstream	1.21 m/s	Critical Slope	0.004085 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	165.64 m	Upstream Velocity Head	0.15 m
Ke	0.50	Entrance Loss	0.08 m

Inlet Control Properties			
Inlet Control HW Elev.	165.57 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	0.7 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Design Report
Haldimand - 14+660 (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	165.82 m	Discharge	0.7600 m³/s
Headwater Depth/Height	0.90	Tailwater Elevation	165.04 m
Inlet Control HW Elev.	165.76 m	Control Type	Entrance Control
Outlet Control HW Elev.	165.82 m		

Grades			
Upstream Invert	165.00 m	Downstream Invert	164.50 m
Length	45.00 m	Constructed Slope	0.011111 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.54 m
Slope Type	Steep	Normal Depth	0.39 m
Flow Regime	N/A	Critical Depth	0.51 m
Velocity Downstream	1.88 m/s	Critical Slope	0.004505 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	165.82 m	Upstream Velocity Head	0.21 m
Ke	0.50	Entrance Loss	0.10 m

Inlet Control Properties			
Inlet Control HW Elev.	165.76 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	0.7 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Design Report
Haldimand - 15+150

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	166.09 m	Discharge	0.3800 m³/s
Headwater Depth/Height	0.64	Tailwater Elevation	165.54 m
Inlet Control HW Elev.	166.02 m	Control Type	Outlet Control
Outlet Control HW Elev.	166.09 m		

Grades			
Upstream Invert	165.50 m	Downstream Invert	165.00 m
Length	48.30 m	Constructed Slope	0.010352 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.54 m
Slope Type	Mild	Normal Depth	0.38 m
Flow Regime	Subcritical	Critical Depth	0.36 m
Velocity Downstream	0.94 m/s	Critical Slope	0.013526 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	166.09 m	Upstream Velocity Head	0.11 m
Ke	0.90	Entrance Loss	0.10 m

Inlet Control Properties			
Inlet Control HW Elev.	166.02 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 15+150 (proposed with 15+480)

Peak Discharge Method: User-Specified			
Design Discharge	1.5100 m³/s	Check Discharge	2.2700 m³/s

Grades Model: Inverts			
Invert Upstream	165.50 m	Invert Downstream	165.00 m
Length	48.30 m	Slope	0.010352 m/m
Drop	0.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater

Tailwater Elevation	165.72 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-1200 mm Circular	1.5100 m³/s	166.64 m	2.10 m/s
	Trial-2	1-1200 mm Circular	2.2700 m³/s	166.98 m	2.69 m/s

Culvert Design Report
Haldimand - 15+150

Peak Discharge Method: User-Specified			
Design Discharge	0.2800 m³/s	Check Discharge	0.3800 m³/s

Grades Model: Inverts			
Invert Upstream	165.50 m	Invert Downstream	165.00 m
Length	48.30 m	Slope	0.010352 m/m
Drop	0.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater

Tailwater Elevation	165.54 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-900 mm Circular	0.2800 m³/s	166.00 m	0.69 m/s
	Trial-2	1-900 mm Circular	0.3800 m³/s	166.09 m	0.94 m/s

Culvert Design Report
Haldimand - 15+150

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	166.00 m	Discharge	0.2800 m³/s
Headwater Depth/Height	0.55	Tailwater Elevation	165.54 m
Inlet Control HW Elev.	165.93 m	Control Type	Outlet Control
Outlet Control HW Elev.	166.00 m		

Grades			
Upstream Invert	165.50 m	Downstream Invert	165.00 m
Length	48.30 m	Constructed Slope	0.010352 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.54 m
Slope Type	Mild	Normal Depth	0.32 m
Flow Regime	Subcritical	Critical Depth	0.30 m
Velocity Downstream	0.69 m/s	Critical Slope	0.013305 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	166.00 m	Upstream Velocity Head	0.09 m
Ke	0.90	Entrance Loss	0.08 m

Inlet Control Properties			
Inlet Control HW Elev.	165.93 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 15+150 (proposed with 15+480)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	166.64 m	Discharge	1.5100 m³/s
Headwater Depth/Height	0.94	Tailwater Elevation	165.72 m
Inlet Control HW Elev.	166.56 m	Control Type	Outlet Control
Outlet Control HW Elev.	166.64 m		

Grades			
Upstream Invert	165.50 m	Downstream Invert	165.00 m
Length	48.30 m	Constructed Slope	0.010352 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.72 m
Slope Type	Mild	Normal Depth	0.73 m
Flow Regime	Subcritical	Critical Depth	0.67 m
Velocity Downstream	2.10 m/s	Critical Slope	0.013810 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	1.22 m
Section Size	1200 mm	Rise	1.22 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	166.64 m	Upstream Velocity Head	0.22 m
Ke	0.90	Entrance Loss	0.19 m

Inlet Control Properties			
Inlet Control HW Elev.	166.56 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	1.2 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 15+150 (proposed with 15+480)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	166.98 m	Discharge	2.2700 m³/s
Headwater Depth/Height	1.21	Tailwater Elevation	165.72 m
Inlet Control HW Elev.	166.93 m	Control Type	Outlet Control
Outlet Control HW Elev.	166.98 m		

Grades			
Upstream Invert	165.50 m	Downstream Invert	165.00 m
Length	48.30 m	Constructed Slope	0.010352 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.83 m
Slope Type	Mild	Normal Depth	1.01 m
Flow Regime	Subcritical	Critical Depth	0.83 m
Velocity Downstream	2.69 m/s	Critical Slope	0.016485 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	1.22 m
Section Size	1200 mm	Rise	1.22 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	166.98 m	Upstream Velocity Head	0.25 m
Ke	0.90	Entrance Loss	0.22 m

Inlet Control Properties			
Inlet Control HW Elev.	166.93 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	1.2 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 15+150 (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	0.2500 m³/s	Check Discharge	0.3800 m³/s

Grades Model: Inverts			
Invert Upstream	165.50 m	Invert Downstream	165.00 m
Length	48.30 m	Slope	0.010352 m/m
Drop	0.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	165.54 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-900 mm Circular	0.2500 m³/s	165.94 m	0.62 m/s
	Trial-2	1-900 mm Circular	0.3800 m³/s	166.05 m	0.94 m/s

Culvert Design Report
Haldimand - 15+150 (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	165.94 m	Discharge	0.2500 m³/s
Headwater Depth/Height	0.48	Tailwater Elevation	165.54 m
Inlet Control HW Elev.	165.89 m	Control Type	Entrance Control
Outlet Control HW Elev.	165.94 m		

Grades			
Upstream Invert	165.50 m	Downstream Invert	165.00 m
Length	48.30 m	Constructed Slope	0.010352 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.54 m
Slope Type	Steep	Normal Depth	0.22 m
Flow Regime	N/A	Critical Depth	0.29 m
Velocity Downstream	0.62 m/s	Critical Slope	0.003895 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	165.94 m	Upstream Velocity Head	0.10 m
Ke	0.50	Entrance Loss	0.05 m

Inlet Control Properties			
Inlet Control HW Elev.	165.89 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	0.7 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Design Report
Haldimand - 15+480

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	166.95 m	Discharge	1.3400 m³/s
Headwater Depth/Height	1.58	Tailwater Elevation	165.54 m
Inlet Control HW Elev.	166.76 m	Control Type	Outlet Control
Outlet Control HW Elev.	166.95 m		

Grades			
Upstream Invert	165.50 m	Downstream Invert	165.00 m
Length	45.00 m	Constructed Slope	0.011111 m/m

Hydraulic Profile			
Profile	CompositeM2PressureProfile	Depth, Downstream	0.68 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.68 m
Velocity Downstream	2.55 m/s	Critical Slope	0.020839 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	166.95 m	Upstream Velocity Head	0.21 m
Ke	0.90	Entrance Loss	0.19 m

Inlet Control Properties			
Inlet Control HW Elev.	166.76 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 15+480

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	168.52 m	Discharge	2.0100 m³/s
Headwater Depth/Height	3.30	Tailwater Elevation	165.54 m
Inlet Control HW Elev.	167.69 m	Control Type	Outlet Control
Outlet Control HW Elev.	168.52 m		

Grades			
Upstream Invert	165.50 m	Downstream Invert	165.00 m
Length	45.00 m	Constructed Slope	0.011111 m/m

Hydraulic Profile			
Profile	CompositeM2PressureProfile	Depth, Downstream	0.81 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.81 m
Velocity Downstream	3.25 m/s	Critical Slope	0.034319 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	168.52 m	Upstream Velocity Head	0.48 m
Ke	0.90	Entrance Loss	0.43 m

Inlet Control Properties			
Inlet Control HW Elev.	167.69 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 15+150 (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	166.05 m	Discharge	0.3800 m³/s
Headwater Depth/Height	0.61	Tailwater Elevation	165.54 m
Inlet Control HW Elev.	165.99 m	Control Type	Entrance Control
Outlet Control HW Elev.	166.05 m		

Grades			
Upstream Invert	165.50 m	Downstream Invert	165.00 m
Length	48.30 m	Constructed Slope	0.010352 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.54 m
Slope Type	Steep	Normal Depth	0.28 m
Flow Regime	N/A	Critical Depth	0.36 m
Velocity Downstream	0.94 m/s	Critical Slope	0.003969 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	166.05 m	Upstream Velocity Head	0.13 m
Ke	0.50	Entrance Loss	0.07 m

Inlet Control Properties			
Inlet Control HW Elev.	165.99 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	0.7 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Design Report
Haldimand - 15+480

Peak Discharge Method: User-Specified			
Design Discharge	1.3400 m³/s	Check Discharge	2.0100 m³/s

Grades Model: Inverts			
Invert Upstream	165.50 m	Invert Downstream	165.00 m
Length	45.00 m	Slope	0.011111 m/m
Drop	0.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	165.54 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-900 mm Circular	1.3400 m³/s	166.95 m	2.55 m/s
	Trial-2	1-900 mm Circular	2.0100 m³/s	168.52 m	3.25 m/s

Culvert Design Report
Haldimand - 15+480 (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	1.3400 m³/s	Check Discharge	2.0100 m³/s

Grades Model: Inverts			
Invert Upstream	165.50 m	Invert Downstream	165.00 m
Length	45.00 m	Slope	0.011111 m/m
Drop	0.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	165.72 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-1200 mm Circular	1.3400 m³/s	166.58 m	1.87 m/s
	Trial-2	1-1200 mm Circular	2.0100 m³/s	166.86 m	2.56 m/s

Culvert Design Report
Haldimand - 15+480 (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	166.58 m	Discharge	1.3400 m³/s
Headwater Depth/Height	0.88	Tailwater Elevation	165.72 m
Inlet Control HW Elev.	166.48 m	Control Type	Outlet Control
Outlet Control HW Elev.	166.58 m		

Grades			
Upstream Invert	165.50 m	Downstream Invert	165.00 m
Length	45.00 m	Constructed Slope	0.011111 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.72 m
Slope Type	Mild	Normal Depth	0.66 m
Flow Regime	Subcritical	Critical Depth	0.63 m
Velocity Downstream	1.87 m/s	Critical Slope	0.013364 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	1.22 m
Section Size	1200 mm	Rise	1.22 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	166.58 m	Upstream Velocity Head	0.22 m
Ke	0.90	Entrance Loss	0.19 m

Inlet Control Properties			
Inlet Control HW Elev.	166.48 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	1.2 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 15+480 (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	166.86 m	Discharge	2.0100 m³/s
Headwater Depth/Height	1.12	Tailwater Elevation	165.72 m
Inlet Control HW Elev.	166.80 m	Control Type	Outlet Control
Outlet Control HW Elev.	166.86 m		

Grades			
Upstream Invert	165.50 m	Downstream Invert	165.00 m
Length	45.00 m	Constructed Slope	0.011111 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.78 m
Slope Type	Mild	Normal Depth	0.88 m
Flow Regime	Subcritical	Critical Depth	0.78 m
Velocity Downstream	2.56 m/s	Critical Slope	0.015428 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	1.22 m
Section Size	1200 mm	Rise	1.22 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	166.86 m	Upstream Velocity Head	0.26 m
Ke	0.90	Entrance Loss	0.23 m

Inlet Control Properties			
Inlet Control HW Elev.	166.80 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	1.2 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 16+390

Peak Discharge Method: User-Specified			
Design Discharge	1.1000 m³/s	Check Discharge	1.6300 m³/s

Grades Model: Inverts			
Invert Upstream	169.50 m	Invert Downstream	169.25 m
Length	58.80 m	Slope	0.004252 m/m
Drop	0.25 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater			
Tailwater Elevation	169.67 m		

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-1090 x 690 mm Arch	1.1000 m³/s	171.15 m	2.33 m/s
	Trial-2	1-1090 x 690 mm Arch	1.6300 m³/s	172.81 m	2.97 m/s

Culvert Design Report
Haldimand - 16+390 (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	1.1000 m³/s	Check Discharge	1.6300 m³/s

Grades Model: Inverts			
Invert Upstream	169.50 m	Invert Downstream	169.25 m
Length	58.80 m	Slope	0.004252 m/m
Drop	0.25 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater			
Tailwater Elevation	169.92 m		

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-1630 x 1120 mm Arch	1.1000 m³/s	170.26 m	1.13 m/s
	Trial-2	1-1630 x 1120 mm Arch	1.6300 m³/s	170.48 m	1.68 m/s

Culvert Design Report
Haldimand - 16+390 (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	170.26 m	Discharge	1.1000 m³/s
Headwater Depth/Height	0.70	Tailwater Elevation	169.92 m
Inlet Control HW Elev.	170.16 m	Control Type	Outlet Control
Outlet Control HW Elev.	170.26 m		

Grades			
Upstream Invert	169.50 m	Downstream Invert	169.25 m
Length	58.80 m	Constructed Slope	0.004252 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.67 m
Slope Type	Mild	Normal Depth	0.59 m
Flow Regime	Subcritical	Critical Depth	0.42 m
Velocity Downstream	1.13 m/s	Critical Slope	0.012079 m/m

Section			
Section Shape	Arch	Mannings Coefficient	0.025
Section Material	Steel and Aluminum Var CR	Span	1.63 m
Section Size	1630 x 1120 mm	Rise	1.09 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	170.26 m	Upstream Velocity Head	0.08 m
Ke	0.90	Entrance Loss	0.07 m

Inlet Control Properties			
Inlet Control HW Elev.	170.16 m	Flow Control	N/A
Inlet Type	Thin wall projecting	Area Full	1.4 m²
K	0.03400	HDS 5 Chart	34
M	1.50000	HDS 5 Scale	3
C	0.04960	Equation Form	1
Y	0.57000		

Culvert Design Report
Haldimand - 16+390

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	171.15 m	Discharge	1.1000 m³/s
Headwater Depth/Height	2.41	Tailwater Elevation	169.67 m
Inlet Control HW Elev.	170.46 m	Control Type	Outlet Control
Outlet Control HW Elev.	171.15 m		

Grades			
Upstream Invert	169.50 m	Downstream Invert	169.25 m
Length	58.80 m	Constructed Slope	0.004252 m/m

Hydraulic Profile			
Profile	CompositeM2PressureProfile	Depth, Downstream	0.49 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.49 m
Velocity Downstream	2.33 m/s	Critical Slope	0.019697 m/m

Section			
Section Shape	Arch	Mannings Coefficient	0.024
Section Material	Steel and Aluminum Var CR 3x1 Corrugations Historic	Span	1.09 m
Section Size	1090 x 690 mm	Rise	0.69 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	171.15 m	Upstream Velocity Head	0.18 m
Ke	0.90	Entrance Loss	0.16 m

Inlet Control Properties			
Inlet Control HW Elev.	170.46 m	Flow Control	N/A
Inlet Type	18 inch CR structural plate, projecting	Area Full	0.6 m²
K	0.03000	HDS 5 Chart	35
M	1.50000	HDS 5 Scale	1
C	0.04960	Equation Form	1
Y	0.57000		

Culvert Design Report
Haldimand - 16+390

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	172.81 m	Discharge	1.6300 m³/s
Headwater Depth/Height	4.82	Tailwater Elevation	169.67 m
Inlet Control HW Elev.	171.15 m	Control Type	Outlet Control
Outlet Control HW Elev.	172.81 m		

Grades			
Upstream Invert	169.50 m	Downstream Invert	169.25 m
Length	58.80 m	Constructed Slope	0.004252 m/m

Hydraulic Profile			
Profile	CompositeM2PressureProfile	Depth, Downstream	0.60 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.60 m
Velocity Downstream	2.97 m/s	Critical Slope	0.032322 m/m

Section			
Section Shape	Arch	Mannings Coefficient	0.024
Section Material	Steel and Aluminum Var CR 3x1 Corrugations Historic	Span	1.09 m
Section Size	1090 x 690 mm	Rise	0.69 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	172.81 m	Upstream Velocity Head	0.40 m
Ke	0.90	Entrance Loss	0.36 m

Inlet Control Properties			
Inlet Control HW Elev.	171.15 m	Flow Control	N/A
Inlet Type	18 inch CR structural plate, projecting	Area Full	0.6 m²
K	0.03000	HDS 5 Chart	35
M	1.50000	HDS 5 Scale	1
C	0.04960	Equation Form	1
Y	0.57000		

Culvert Design Report
Haldimand - 16+390 (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	170.48 m	Discharge	1.6300 m³/s
Headwater Depth/Height	0.90	Tailwater Elevation	169.92 m
Inlet Control HW Elev.	170.37 m	Control Type	Outlet Control
Outlet Control HW Elev.	170.48 m		

Grades			
Upstream Invert	169.50 m	Downstream Invert	169.25 m
Length	58.80 m	Constructed Slope	0.004252 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.67 m
Slope Type	Mild	Normal Depth	0.82 m
Flow Regime	Subcritical	Critical Depth	0.52 m
Velocity Downstream	1.68 m/s	Critical Slope	0.013140 m/m

Section			
Section Shape	Arch	Mannings Coefficient	0.025
Section Material	Steel and Aluminum Var CR	Span	1.63 m
Section Size	1630 x 1120 mm	Rise	1.09 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	170.48 m	Upstream Velocity Head	0.11 m
Ke	0.90	Entrance Loss	0.10 m

Inlet Control Properties			
Inlet Control HW Elev.	170.37 m	Flow Control	N/A
Inlet Type	Thin wall projecting	Area Full	1.4 m²
K	0.03400	HDS 5 Chart	34
M	1.50000	HDS 5 Scale	3
C	0.04960	Equation Form	1
Y	0.57000		

Culvert Design Report
Haldimand - 16+620

Peak Discharge Method: User-Specified			
Design Discharge	0.9100 m³/s	Check Discharge	1.3500 m³/s

Grades Model: Inverts			
Invert Upstream	172.50 m	Invert Downstream	172.00 m
Length	63.00 m	Slope	0.007937 m/m
Drop	0.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater			
Tailwater Elevation	172.41 m		

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-1090 x 690 mm Arch	0.9100 m³/s	173.47 m	2.12 m/s
	Trial-2	1-1090 x 690 mm Arch	1.3500 m³/s	174.72 m	2.61 m/s

Culvert Design Report
Haldimand - 16+620

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	173.47 m	Discharge	0.9100 m³/s
Headwater Depth/Height	1.42	Tailwater Elevation	172.41 m
Inlet Control HW Elev.	173.30 m	Control Type	Outlet Control
Outlet Control HW Elev.	173.47 m		

Grades			
Upstream Invert	172.50 m	Downstream Invert	172.00 m
Length	63.00 m	Constructed Slope	0.007937 m/m

Hydraulic Profile			
Profile	CompositeM2PressureProfile	Depth, Downstream	0.45 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.45 m
Velocity Downstream	2.12 m/s	Critical Slope	0.017001 m/m

Section			
Section Shape	Arch	Mannings Coefficient	0.024
Section Material	Steel and Aluminum Var CR 3x1 Corrugations Historic	Span	1.09 m
Section Size	1090 x 690 mm	Rise	0.69 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	173.47 m	Upstream Velocity Head	0.12 m
Ke	0.90	Entrance Loss	0.11 m

Inlet Control Properties			
Inlet Control HW Elev.	173.30 m	Flow Control	N/A
Inlet Type	18 inch CR structural plate, projecting	Area Full	0.6 m²
K	0.03000	HDS 5 Chart	35
M	1.50000	HDS 5 Scale	1
C	0.04960	Equation Form	1
Y	0.57000		

Culvert Design Report
Haldimand - 16+620

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	174.72 m	Discharge	1.3500 m³/s
Headwater Depth/Height	3.23	Tailwater Elevation	172.41 m
Inlet Control HW Elev.	173.75 m	Control Type	Outlet Control
Outlet Control HW Elev.	174.72 m		

Grades			
Upstream Invert	172.50 m	Downstream Invert	172.00 m
Length	63.00 m	Constructed Slope	0.007937 m/m

Hydraulic Profile			
Profile	CompositeM2PressureProfile	Depth, Downstream	0.55 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.55 m
Velocity Downstream	2.61 m/s	Critical Slope	0.024534 m/m

Section			
Section Shape	Arch	Mannings Coefficient	0.024
Section Material	Steel and Aluminum Var CR 3x1 Corrugations Historic	Span	1.09 m
Section Size	1090 x 690 mm	Rise	0.69 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	174.72 m	Upstream Velocity Head	0.27 m
Ke	0.90	Entrance Loss	0.24 m

Inlet Control Properties			
Inlet Control HW Elev.	173.75 m	Flow Control	N/A
Inlet Type	18 inch CR structural plate, projecting	Area Full	0.6 m²
K	0.03000	HDS 5 Chart	35
M	1.50000	HDS 5 Scale	1
C	0.04960	Equation Form	1
Y	0.57000		

Culvert Design Report
Haldimand - 16+620 (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	173.40 m	Discharge	1.3500 m³/s
Headwater Depth/Height	0.93	Tailwater Elevation	172.58 m
Inlet Control HW Elev.	173.34 m	Control Type	Outlet Control
Outlet Control HW Elev.	173.40 m		

Grades			
Upstream Invert	172.50 m	Downstream Invert	172.00 m
Length	63.00 m	Constructed Slope	0.007937 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.58 m
Slope Type	Mild	Normal Depth	0.61 m
Flow Regime	Subcritical	Critical Depth	0.49 m
Velocity Downstream	1.80 m/s	Critical Slope	0.014158 m/m

Section			
Section Shape	Arch	Mannings Coefficient	0.025
Section Material	Steel and Aluminum Var CR	Span	1.45 m
Section Size	1390 x 970 mm	Rise	0.97 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	173.40 m	Upstream Velocity Head	0.15 m
Ke	0.90	Entrance Loss	0.13 m

Inlet Control Properties			
Inlet Control HW Elev.	173.34 m	Flow Control	N/A
Inlet Type	Thin wall projecting	Area Full	1.1 m²
K	0.03400	HDS 5 Chart	34
M	1.50000	HDS 5 Scale	3
C	0.04960	Equation Form	1
Y	0.57000		

Culvert Design Report
Haldimand - 17+640

Peak Discharge Method: User-Specified			
Design Discharge	0.8400 m³/s	Check Discharge	1.2700 m³/s

Grades Model: Inverts			
Invert Upstream	168.00 m	Invert Downstream	167.50 m
Length	50.20 m	Slope	0.009960 m/m
Drop	0.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater

Tailwater Elevation	168.04 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-900 mm Circular	0.8400 m³/s	168.92 m	2.08 m/s
	Trial-2	1-900 mm Circular	1.2700 m³/s	169.39 m	2.48 m/s

Culvert Design Report
Haldimand - 16+620 (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	0.9100 m³/s	Check Discharge	1.3500 m³/s

Grades Model: Inverts			
Invert Upstream	172.50 m	Invert Downstream	172.00 m
Length	63.00 m	Slope	0.007937 m/m
Drop	0.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater

Tailwater Elevation	172.58 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-1390 x 970 mm Arch	0.9100 m³/s	173.19 m	1.22 m/s
	Trial-2	1-1390 x 970 mm Arch	1.3500 m³/s	173.40 m	1.80 m/s

Culvert Design Report
Haldimand - 16+620 (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	173.19 m	Discharge	0.9100 m³/s
Headwater Depth/Height	0.72	Tailwater Elevation	172.58 m
Inlet Control HW Elev.	173.13 m	Control Type	Outlet Control
Outlet Control HW Elev.	173.19 m		

Grades			
Upstream Invert	172.50 m	Downstream Invert	172.00 m
Length	63.00 m	Constructed Slope	0.007937 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.58 m
Slope Type	Mild	Normal Depth	0.46 m
Flow Regime	Subcritical	Critical Depth	0.39 m
Velocity Downstream	1.22 m/s	Critical Slope	0.012834 m/m

Section			
Section Shape	Arch	Mannings Coefficient	0.025
Section Material	Steel and Aluminum Var CR	Span	1.45 m
Section Size	1390 x 970 mm	Rise	0.97 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	173.19 m	Upstream Velocity Head	0.12 m
Ke	0.90	Entrance Loss	0.11 m

Inlet Control Properties			
Inlet Control HW Elev.	173.13 m	Flow Control	N/A
Inlet Type	Thin wall projecting	Area Full	1.1 m²
K	0.03400	HDS 5 Chart	34
M	1.50000	HDS 5 Scale	3
C	0.04960	Equation Form	1
Y	0.57000		

Culvert Design Report
Haldimand - 17+640

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	168.92 m	Discharge	0.8400 m³/s
Headwater Depth/Height	1.01	Tailwater Elevation	168.04 m
Inlet Control HW Elev.	168.87 m	Control Type	Outlet Control
Outlet Control HW Elev.	168.92 m		

Grades			
Upstream Invert	168.00 m	Downstream Invert	167.50 m
Length	50.20 m	Constructed Slope	0.009960 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.54 m
Slope Type	Mild	Normal Depth	0.63 m
Flow Regime	Subcritical	Critical Depth	0.54 m
Velocity Downstream	2.08 m/s	Critical Slope	0.015888 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	168.92 m	Upstream Velocity Head	0.15 m
Ke	0.90	Entrance Loss	0.14 m

Inlet Control Properties			
Inlet Control HW Elev.	168.87 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 17+640

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	169.39 m	Discharge	1.2700 m³/s
Headwater Depth/Height	1.52	Tailwater Elevation	168.04 m
Inlet Control HW Elev.	169.20 m	Control Type	Outlet Control
Outlet Control HW Elev.	169.39 m		

Grades			
Upstream Invert	168.00 m	Downstream Invert	167.50 m
Length	50.20 m	Constructed Slope	0.009960 m/m

Hydraulic Profile			
Profile	CompositeM2PressureProfile	Depth, Downstream	0.67 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.67 m
Velocity Downstream	2.48 m/s	Critical Slope	0.019949 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	169.39 m	Upstream Velocity Head	0.19 m
Ke	0.90	Entrance Loss	0.17 m

Inlet Control Properties			
Inlet Control HW Elev.	169.20 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 20+590

Peak Discharge Method: User-Specified			
Design Discharge	2.3500 m³/s	Check Discharge	3.6100 m³/s

Grades Model: Inverts			
Invert Upstream	144.00 m	Invert Downstream	142.00 m
Length	79.50 m	Slope	0.025157 m/m
Drop	2.00 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	142.93 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-1830 x 1520 mm Box	2.3500 m³/s	144.97 m	1.38 m/s
	Trial-2	1-1830 x 1520 mm Box	3.6100 m³/s	145.29 m	2.12 m/s

Culvert Design Report
Haldimand - 20+590

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	144.97 m	Discharge	2.3500 m³/s
Headwater Depth/Height	0.63	Tailwater Elevation	142.93 m
Inlet Control HW Elev.	144.85 m	Control Type	Entrance Control
Outlet Control HW Elev.	144.97 m		

Grades			
Upstream Invert	144.00 m	Downstream Invert	142.00 m
Length	79.50 m	Constructed Slope	0.025157 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.93 m
Slope Type	Steep	Normal Depth	0.29 m
Flow Regime	N/A	Critical Depth	0.55 m
Velocity Downstream	1.38 m/s	Critical Slope	0.003793 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.83 m
Section Size	1830 x 1520 mm	Rise	1.52 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	144.97 m	Upstream Velocity Head	0.28 m
Ke	0.50	Entrance Loss	0.14 m

Inlet Control Properties			
Inlet Control HW Elev.	144.85 m	Flow Control	N/A
Inlet Type	18 to 33.7° wingwall flare, d=0.0830	Area Full	2.8 m²
K	0.48600	HDS 5 Chart	9
M	0.66700	HDS 5 Scale	2
C	0.02490	Equation Form	2
Y	0.83000		

Culvert Design Report
Haldimand - 20+930

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	151.92 m	Discharge	0.7800 m³/s
Headwater Depth/Height	1.00	Tailwater Elevation	149.04 m
Inlet Control HW Elev.	151.82 m	Control Type	Entrance Control
Outlet Control HW Elev.	151.92 m		

Grades			
Upstream Invert	151.00 m	Downstream Invert	148.50 m
Length	68.20 m	Constructed Slope	0.036657 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.54 m
Slope Type	Steep	Normal Depth	0.40 m
Flow Regime	N/A	Critical Depth	0.52 m
Velocity Downstream	1.93 m/s	Critical Slope	0.015487 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	151.92 m	Upstream Velocity Head	0.21 m
Ke	0.90	Entrance Loss	0.19 m

Inlet Control Properties			
Inlet Control HW Elev.	151.82 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 20+930

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	152.19 m	Discharge	1.1700 m³/s
Headwater Depth/Height	1.30	Tailwater Elevation	149.04 m
Inlet Control HW Elev.	152.11 m	Control Type	Entrance Control
Outlet Control HW Elev.	152.19 m		

Grades			
Upstream Invert	151.00 m	Downstream Invert	148.50 m
Length	68.20 m	Constructed Slope	0.036657 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.51 m
Slope Type	Steep	Normal Depth	0.51 m
Flow Regime	Supercritical	Critical Depth	0.64 m
Velocity Downstream	3.11 m/s	Critical Slope	0.018808 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	152.19 m	Upstream Velocity Head	0.29 m
Ke	0.90	Entrance Loss	0.26 m

Inlet Control Properties			
Inlet Control HW Elev.	152.11 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 20+590

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	145.29 m	Discharge	3.6100 m³/s
Headwater Depth/Height	0.84	Tailwater Elevation	142.93 m
Inlet Control HW Elev.	145.14 m	Control Type	Entrance Control
Outlet Control HW Elev.	145.29 m		

Grades			
Upstream Invert	144.00 m	Downstream Invert	142.00 m
Length	79.50 m	Constructed Slope	0.025157 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.93 m
Slope Type	Steep	Normal Depth	0.39 m
Flow Regime	N/A	Critical Depth	0.74 m
Velocity Downstream	2.12 m/s	Critical Slope	0.004033 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.83 m
Section Size	1830 x 1520 mm	Rise	1.52 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	145.29 m	Upstream Velocity Head	0.37 m
Ke	0.50	Entrance Loss	0.18 m

Inlet Control Properties			
Inlet Control HW Elev.	145.14 m	Flow Control	N/A
Inlet Type	18 to 33.7° wingwall flare, d=0.0830	Area Full	2.8 m²
K	0.48600	HDS 5 Chart	9
M	0.66700	HDS 5 Scale	2
C	0.02490	Equation Form	2
Y	0.83000		

Culvert Design Report
Haldimand - 20+930

Peak Discharge Method: User-Specified			
Design Discharge	0.7800 m³/s	Check Discharge	1.1700 m³/s

Grades Model: Inverts			
Invert Upstream	151.00 m	Invert Downstream	148.50 m
Length	68.20 m	Slope	0.036657 m/m
Drop	2.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	149.04 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-900 mm Circular	0.7800 m³/s	151.92 m	1.93 m/s
	Trial-2	1-900 mm Circular	1.1700 m³/s	152.19 m	3.11 m/s

Culvert Design Report
Haldimand - 20+930 (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	0.7800 m³/s	Check Discharge	1.1700 m³/s

Grades Model: Inverts			
Invert Upstream	151.00 m	Invert Downstream	148.50 m
Length	68.20 m	Slope	0.036657 m/m
Drop	2.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	149.04 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-900 mm Circular	0.7800 m³/s	151.92 m	1.93 m/s
	Trial-2	1-900 mm Circular	1.1700 m³/s	152.19 m	3.11 m/s

Culvert Design Report
Haldimand - 20+930 (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	151.92 m	Discharge	0.7800 m³/s
Headwater Depth/Height	1.00	Tailwater Elevation	149.04 m
Inlet Control HW Elev.	151.82 m	Control Type	Entrance Control
Outlet Control HW Elev.	151.92 m		

Grades			
Upstream Invert	151.00 m	Downstream Invert	148.50 m
Length	68.20 m	Constructed Slope	0.036657 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.54 m
Slope Type	Steep	Normal Depth	0.40 m
Flow Regime	N/A	Critical Depth	0.52 m
Velocity Downstream	1.93 m/s	Critical Slope	0.015487 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.52 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	151.92 m	Upstream Velocity Head	0.21 m
Ke	0.90	Entrance Loss	0.19 m

Inlet Control Properties			
Inlet Control HW Elev.	151.82 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 20+930 (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	152.19 m	Discharge	1.1700 m³/s
Headwater Depth/Height	1.30	Tailwater Elevation	149.04 m
Inlet Control HW Elev.	152.11 m	Control Type	Entrance Control
Outlet Control HW Elev.	152.19 m		

Grades			
Upstream Invert	151.00 m	Downstream Invert	148.50 m
Length	68.20 m	Constructed Slope	0.036657 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.51 m
Slope Type	Steep	Normal Depth	0.51 m
Flow Regime	Supercritical	Critical Depth	0.64 m
Velocity Downstream	3.11 m/s	Critical Slope	0.018808 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	152.19 m	Upstream Velocity Head	0.29 m
Ke	0.90	Entrance Loss	0.26 m

Inlet Control Properties			
Inlet Control HW Elev.	152.11 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 21+030

Peak Discharge Method: User-Specified			
Design Discharge	1.5700 m³/s	Check Discharge	2.3900 m³/s

Grades Model: Inverts			
Invert Upstream	151.00 m	Invert Downstream	148.50 m
Length	86.80 m	Slope	0.028802 m/m
Drop	2.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater			
Tailwater Elevation	149.22 m		

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-1220 x 1220 mm Box	1.5700 m³/s	151.97 m	1.79 m/s
	Trial-2	1-1220 x 1220 mm Box	2.3900 m³/s	152.28 m	5.02 m/s

Culvert Design Report
Haldimand - 21+030 (proposed with 20+930)

Peak Discharge Method: User-Specified			
Design Discharge	2.3300 m³/s	Check Discharge	3.5400 m³/s

Grades Model: Inverts			
Invert Upstream	151.00 m	Invert Downstream	148.50 m
Length	86.80 m	Slope	0.028802 m/m
Drop	2.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater			
Tailwater Elevation	149.22 m		

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-1220 x 1220 mm Box	2.3300 m³/s	152.26 m	2.65 m/s
	Trial-2	1-1220 x 1220 mm Box	3.5400 m³/s	152.66 m	5.56 m/s

Culvert Design Report
Haldimand - 21+030 (proposed with 20+930)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	152.26 m	Discharge	2.3300 m³/s
Headwater Depth/Height	1.03	Tailwater Elevation	149.22 m
Inlet Control HW Elev.	152.11 m	Control Type	Entrance Control
Outlet Control HW Elev.	152.26 m		

Grades			
Upstream Invert	151.00 m	Downstream Invert	148.50 m
Length	86.80 m	Constructed Slope	0.028802 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.72 m
Slope Type	Steep	Normal Depth	0.38 m
Flow Regime	N/A	Critical Depth	0.72 m
Velocity Downstream	2.65 m/s	Critical Slope	0.005230 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.22 m
Section Size	1220 x 1220 mm	Rise	1.22 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	152.26 m	Upstream Velocity Head	0.36 m
Ke	0.50	Entrance Loss	0.18 m

Inlet Control Properties			
Inlet Control HW Elev.	152.11 m	Flow Control	N/A
Inlet Type	18 to 33.7° wingwall flare, d=0.0830	Area Full	1.5 m²
K	0.48600	HDS 5 Chart	9
M	0.66700	HDS 5 Scale	2
C	0.02490	Equation Form	2
Y	0.83000		

Culvert Design Report
Haldimand - 21+030

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	151.97 m	Discharge	1.5700 m³/s
Headwater Depth/Height	0.79	Tailwater Elevation	149.22 m
Inlet Control HW Elev.	151.86 m	Control Type	Entrance Control
Outlet Control HW Elev.	151.97 m		

Grades			
Upstream Invert	151.00 m	Downstream Invert	148.50 m
Length	86.80 m	Constructed Slope	0.028802 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.72 m
Slope Type	Steep	Normal Depth	0.29 m
Flow Regime	N/A	Critical Depth	0.55 m
Velocity Downstream	1.79 m/s	Critical Slope	0.004776 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.22 m
Section Size	1220 x 1220 mm	Rise	1.22 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	151.97 m	Upstream Velocity Head	0.28 m
Ke	0.50	Entrance Loss	0.14 m

Inlet Control Properties			
Inlet Control HW Elev.	151.86 m	Flow Control	N/A
Inlet Type	18 to 33.7° wingwall flare, d=0.0830	Area Full	1.5 m²
K	0.48600	HDS 5 Chart	9
M	0.66700	HDS 5 Scale	2
C	0.02490	Equation Form	2
Y	0.83000		

Culvert Design Report
Haldimand - 21+030

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	152.28 m	Discharge	2.3900 m³/s
Headwater Depth/Height	1.05	Tailwater Elevation	149.22 m
Inlet Control HW Elev.	152.13 m	Control Type	Entrance Control
Outlet Control HW Elev.	152.28 m		

Grades			
Upstream Invert	151.00 m	Downstream Invert	148.50 m
Length	86.80 m	Constructed Slope	0.028802 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.39 m
Slope Type	Steep	Normal Depth	0.39 m
Flow Regime	Supercritical	Critical Depth	0.73 m
Velocity Downstream	5.02 m/s	Critical Slope	0.005265 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.22 m
Section Size	1220 x 1220 mm	Rise	1.22 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	152.28 m	Upstream Velocity Head	0.37 m
Ke	0.50	Entrance Loss	0.18 m

Inlet Control Properties			
Inlet Control HW Elev.	152.13 m	Flow Control	N/A
Inlet Type	18 to 33.7° wingwall flare, d=0.0830	Area Full	1.5 m²
K	0.48600	HDS 5 Chart	9
M	0.66700	HDS 5 Scale	2
C	0.02490	Equation Form	2
Y	0.83000		

Culvert Design Report
Haldimand - 21+030 (proposed with 20+930)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	152.66 m	Discharge	3.5400 m³/s
Headwater Depth/Height	1.37	Tailwater Elevation	149.22 m
Inlet Control HW Elev.	152.46 m	Control Type	Entrance Control
Outlet Control HW Elev.	152.66 m		

Grades			
Upstream Invert	151.00 m	Downstream Invert	148.50 m
Length	86.80 m	Constructed Slope	0.028802 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.52 m
Slope Type	Steep	Normal Depth	0.52 m
Flow Regime	Supercritical	Critical Depth	0.95 m
Velocity Downstream	5.56 m/s	Critical Slope	0.005903 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.22 m
Section Size	1220 x 1220 mm	Rise	1.22 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	152.66 m	Upstream Velocity Head	0.48 m
Ke	0.50	Entrance Loss	0.24 m

Inlet Control Properties			
Inlet Control HW Elev.	152.46 m	Flow Control	N/A
Inlet Type	18 to 33.7° wingwall flare, d=0.0830	Area Full	1.5 m²
K	0.48600	HDS 5 Chart	9
M	0.66700	HDS 5 Scale	2
C	0.02490	Equation Form	2
Y	0.83000		

Culvert Design Report
Haldimand - 21+615

Peak Discharge Method: User-Specified			
Design Discharge	0.5000 m³/s	Check Discharge	0.7400 m³/s

Grades Model: Inverts			
Invert Upstream	143.50 m	Invert Downstream	142.00 m
Length	48.00 m	Slope	0.031250 m/m
Drop	1.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater			
Tailwater Elevation	142.54 m		

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-900 mm Circular	0.5000 m³/s	144.21 m	1.24 m/s
	Trial-2	1-900 mm Circular	0.7400 m³/s	144.39 m	1.83 m/s

Culvert Design Report
Haldimand - 21+615

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	144.21 m	Discharge	0.5000 m³/s
Headwater Depth/Height	0.77	Tailwater Elevation	142.54 m
Inlet Control HW Elev.	144.11 m	Control Type	Entrance Control
Outlet Control HW Elev.	144.21 m		

Grades			
Upstream Invert	143.50 m	Downstream Invert	142.00 m
Length	48.00 m	Constructed Slope	0.031250 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.54 m
Slope Type	Steep	Normal Depth	0.33 m
Flow Regime	N/A	Critical Depth	0.41 m
Velocity Downstream	1.24 m/s	Critical Slope	0.013967 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	144.21 m	Upstream Velocity Head	0.16 m
Ke	0.90	Entrance Loss	0.14 m

Inlet Control Properties			
Inlet Control HW Elev.	144.11 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 21+615

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	144.39 m	Discharge	0.7400 m³/s
Headwater Depth/Height	0.97	Tailwater Elevation	142.54 m
Inlet Control HW Elev.	144.29 m	Control Type	Entrance Control
Outlet Control HW Elev.	144.39 m		

Grades			
Upstream Invert	143.50 m	Downstream Invert	142.00 m
Length	48.00 m	Constructed Slope	0.031250 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.54 m
Slope Type	Steep	Normal Depth	0.41 m
Flow Regime	N/A	Critical Depth	0.50 m
Velocity Downstream	1.83 m/s	Critical Slope	0.015228 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	144.39 m	Upstream Velocity Head	0.20 m
Ke	0.90	Entrance Loss	0.18 m

Inlet Control Properties			
Inlet Control HW Elev.	144.29 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 21+615 (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	144.39 m	Discharge	0.7400 m³/s
Headwater Depth/Height	0.97	Tailwater Elevation	142.54 m
Inlet Control HW Elev.	144.29 m	Control Type	Entrance Control
Outlet Control HW Elev.	144.39 m		

Grades			
Upstream Invert	143.50 m	Downstream Invert	142.00 m
Length	48.00 m	Constructed Slope	0.031250 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.54 m
Slope Type	Steep	Normal Depth	0.41 m
Flow Regime	N/A	Critical Depth	0.50 m
Velocity Downstream	1.83 m/s	Critical Slope	0.015228 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	144.39 m	Upstream Velocity Head	0.20 m
Ke	0.90	Entrance Loss	0.18 m

Inlet Control Properties			
Inlet Control HW Elev.	144.29 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 22+315

Peak Discharge Method: User-Specified			
Design Discharge	0.6100 m³/s	Check Discharge	0.9600 m³/s

Grades Model: Inverts			
Invert Upstream	128.00 m	Invert Downstream	127.50 m
Length	60.30 m	Slope	0.008292 m/m
Drop	0.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater

Tailwater Elevation	128.22 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-1220 x 1220 mm Box	0.6100 m³/s	128.52 m	0.70 m/s
	Trial-2	1-1220 x 1220 mm Box	0.9600 m³/s	128.70 m	1.09 m/s

Culvert Design Report
Haldimand - 21+615 (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	0.5000 m³/s	Check Discharge	0.7400 m³/s

Grades Model: Inverts			
Invert Upstream	143.50 m	Invert Downstream	142.00 m
Length	48.00 m	Slope	0.031250 m/m
Drop	1.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater

Tailwater Elevation	142.54 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-900 mm Circular	0.5000 m³/s	144.21 m	1.24 m/s
	Trial-2	1-900 mm Circular	0.7400 m³/s	144.39 m	1.83 m/s

Culvert Design Report
Haldimand - 21+615 (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	144.21 m	Discharge	0.5000 m³/s
Headwater Depth/Height	0.77	Tailwater Elevation	142.54 m
Inlet Control HW Elev.	144.11 m	Control Type	Entrance Control
Outlet Control HW Elev.	144.21 m		

Grades			
Upstream Invert	143.50 m	Downstream Invert	142.00 m
Length	48.00 m	Constructed Slope	0.031250 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.54 m
Slope Type	Steep	Normal Depth	0.33 m
Flow Regime	N/A	Critical Depth	0.41 m
Velocity Downstream	1.24 m/s	Critical Slope	0.013967 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	144.21 m	Upstream Velocity Head	0.16 m
Ke	0.90	Entrance Loss	0.14 m

Inlet Control Properties			
Inlet Control HW Elev.	144.11 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 22+315

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	128.52 m	Discharge	0.6100 m³/s
Headwater Depth/Height	0.42	Tailwater Elevation	128.22 m
Inlet Control HW Elev.	128.46 m	Control Type	Entrance Control
Outlet Control HW Elev.	128.52 m		

Grades			
Upstream Invert	128.00 m	Downstream Invert	127.50 m
Length	60.30 m	Constructed Slope	0.008292 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.72 m
Slope Type	Steep	Normal Depth	0.23 m
Flow Regime	N/A	Critical Depth	0.29 m
Velocity Downstream	0.70 m/s	Critical Slope	0.004213 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.22 m
Section Size	1220 x 1220 mm	Rise	1.22 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	128.52 m	Upstream Velocity Head	0.15 m
Ke	0.50	Entrance Loss	0.07 m

Inlet Control Properties			
Inlet Control HW Elev.	128.46 m	Flow Control	N/A
Inlet Type	18 to 33.7° wingwall flare, d=0.0830	Area Full	1.5 m²
K	0.48600	HDS 5 Chart	9
M	0.66700	HDS 5 Scale	2
C	0.02490	Equation Form	2
Y	0.83000		

Culvert Design Report
Haldimand - 22+315

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	128.70 m	Discharge	0.9600 m³/s
Headwater Depth/Height	0.57	Tailwater Elevation	128.22 m
Inlet Control HW Elev.	128.62 m	Control Type	Entrance Control
Outlet Control HW Elev.	128.70 m		

Grades			
Upstream Invert	128.00 m	Downstream Invert	127.50 m
Length	60.30 m	Constructed Slope	0.008292 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.72 m
Slope Type	Steep	Normal Depth	0.32 m
Flow Regime	N/A	Critical Depth	0.40 m
Velocity Downstream	1.09 m/s	Critical Slope	0.004404 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.22 m
Section Size	1220 x 1220 mm	Rise	1.22 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	128.70 m	Upstream Velocity Head	0.20 m
Ke	0.50	Entrance Loss	0.10 m

Inlet Control Properties			
Inlet Control HW Elev.	128.62 m	Flow Control	N/A
Inlet Type	18 to 33.7° wingwall flare, d=0.0830	Area Full	1.5 m²
K	0.48600	HDS 5 Chart	9
M	0.66700	HDS 5 Scale	2
C	0.02490	Equation Form	2
Y	0.83000		

Culvert Design Report
Haldimand - 22+480

Peak Discharge Method: User-Specified			
Design Discharge	0.2900 m³/s	Check Discharge	0.4600 m³/s

Grades Model: Inverts			
Invert Upstream	130.00 m	Invert Downstream	127.50 m
Length	65.20 m	Slope	0.038344 m/m
Drop	2.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	128.04 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-900 mm Circular	0.2900 m³/s	130.52 m	0.72 m/s
	Trial-2	1-900 mm Circular	0.4600 m³/s	130.68 m	1.14 m/s

Culvert Design Report
Haldimand - 22+480

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	130.52 m	Discharge	0.2900 m³/s
Headwater Depth/Height	0.57	Tailwater Elevation	128.04 m
Inlet Control HW Elev.	130.43 m	Control Type	Entrance Control
Outlet Control HW Elev.	130.52 m		

Grades			
Upstream Invert	130.00 m	Downstream Invert	127.50 m
Length	65.20 m	Constructed Slope	0.038344 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.54 m
Slope Type	Steep	Normal Depth	0.24 m
Flow Regime	N/A	Critical Depth	0.31 m
Velocity Downstream	0.72 m/s	Critical Slope	0.013319 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	130.52 m	Upstream Velocity Head	0.11 m
Ke	0.90	Entrance Loss	0.10 m

Inlet Control Properties			
Inlet Control HW Elev.	130.43 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 22+480 (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	130.52 m	Discharge	0.2900 m³/s
Headwater Depth/Height	0.57	Tailwater Elevation	128.04 m
Inlet Control HW Elev.	130.43 m	Control Type	Entrance Control
Outlet Control HW Elev.	130.52 m		

Grades			
Upstream Invert	130.00 m	Downstream Invert	127.50 m
Length	65.20 m	Constructed Slope	0.038344 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.54 m
Slope Type	Steep	Normal Depth	0.24 m
Flow Regime	N/A	Critical Depth	0.31 m
Velocity Downstream	0.72 m/s	Critical Slope	0.013319 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	130.52 m	Upstream Velocity Head	0.11 m
Ke	0.90	Entrance Loss	0.10 m

Inlet Control Properties			
Inlet Control HW Elev.	130.43 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 22+480 (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	130.68 m	Discharge	0.4600 m³/s
Headwater Depth/Height	0.74	Tailwater Elevation	128.04 m
Inlet Control HW Elev.	130.57 m	Control Type	Entrance Control
Outlet Control HW Elev.	130.68 m		

Grades			
Upstream Invert	130.00 m	Downstream Invert	127.50 m
Length	65.20 m	Constructed Slope	0.038344 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.54 m
Slope Type	Steep	Normal Depth	0.30 m
Flow Regime	N/A	Critical Depth	0.39 m
Velocity Downstream	1.14 m/s	Critical Slope	0.013800 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	130.68 m	Upstream Velocity Head	0.15 m
Ke	0.90	Entrance Loss	0.13 m

Inlet Control Properties			
Inlet Control HW Elev.	130.57 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 22+480

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	130.68 m	Discharge	0.4600 m³/s
Headwater Depth/Height	0.74	Tailwater Elevation	128.04 m
Inlet Control HW Elev.	130.57 m	Control Type	Entrance Control
Outlet Control HW Elev.	130.68 m		

Grades			
Upstream Invert	130.00 m	Downstream Invert	127.50 m
Length	65.20 m	Constructed Slope	0.038344 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.54 m
Slope Type	Steep	Normal Depth	0.30 m
Flow Regime	N/A	Critical Depth	0.39 m
Velocity Downstream	1.14 m/s	Critical Slope	0.013800 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	130.68 m	Upstream Velocity Head	0.15 m
Ke	0.90	Entrance Loss	0.13 m

Inlet Control Properties			
Inlet Control HW Elev.	130.57 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 22+480 (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	0.2900 m³/s	Check Discharge	0.4600 m³/s

Grades Model: Inverts			
Invert Upstream	130.00 m	Invert Downstream	127.50 m
Length	65.20 m	Slope	0.038344 m/m
Drop	2.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	128.04 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-900 mm Circular	0.2900 m³/s	130.52 m	0.72 m/s
	Trial-2	1-900 mm Circular	0.4600 m³/s	130.68 m	1.14 m/s

Culvert Design Report
Haldimand - 22+700

Peak Discharge Method: User-Specified			
Design Discharge	1.9400 m³/s	Check Discharge	2.9900 m³/s

Grades Model: Inverts			
Invert Upstream	136.50 m	Invert Downstream	135.00 m
Length	62.90 m	Slope	0.023847 m/m
Drop	1.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	135.72 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-1220 x 1220 mm Box	1.9400 m³/s	137.61 m	2.21 m/s
	Trial-2	1-1220 x 1220 mm Box	2.9900 m³/s	137.99 m	4.87 m/s

Culvert Design Report
Haldimand - 22+700

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	137.61 m	Discharge	1.9400 m³/s
Headwater Depth/Height	0.91	Tailwater Elevation	135.72 m
Inlet Control HW Elev.	137.48 m	Control Type	Entrance Control
Outlet Control HW Elev.	137.61 m		

Grades			
Upstream Invert	136.50 m	Downstream Invert	135.00 m
Length	62.90 m	Constructed Slope	0.023847 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.72 m
Slope Type	Steep	Normal Depth	0.36 m
Flow Regime	N/A	Critical Depth	0.64 m
Velocity Downstream	2.21 m/s	Critical Slope	0.005000 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.22 m
Section Size	1220 x 1220 mm	Rise	1.22 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	137.61 m	Upstream Velocity Head	0.32 m
Ke	0.50	Entrance Loss	0.16 m

Inlet Control Properties			
Inlet Control HW Elev.	137.48 m	Flow Control	N/A
Inlet Type	18 to 33.7° wingwall flare, d=0.0830	Area Full	1.5 m²
K	0.48600	HDS 5 Chart	9
M	0.66700	HDS 5 Scale	2
C	0.02490	Equation Form	2
Y	0.83000		

Culvert Design Report
Haldimand - 22+700

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	137.99 m	Discharge	2.9900 m³/s
Headwater Depth/Height	1.22	Tailwater Elevation	135.72 m
Inlet Control HW Elev.	137.81 m	Control Type	Entrance Control
Outlet Control HW Elev.	137.99 m		

Grades			
Upstream Invert	136.50 m	Downstream Invert	135.00 m
Length	62.90 m	Constructed Slope	0.023847 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.50 m
Slope Type	Steep	Normal Depth	0.49 m
Flow Regime	Supercritical	Critical Depth	0.85 m
Velocity Downstream	4.87 m/s	Critical Slope	0.005604 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.22 m
Section Size	1220 x 1220 mm	Rise	1.22 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	137.99 m	Upstream Velocity Head	0.42 m
Ke	0.50	Entrance Loss	0.21 m

Inlet Control Properties			
Inlet Control HW Elev.	137.81 m	Flow Control	N/A
Inlet Type	18 to 33.7° wingwall flare, d=0.0830	Area Full	1.5 m²
K	0.48600	HDS 5 Chart	9
M	0.66700	HDS 5 Scale	2
C	0.02490	Equation Form	2
Y	0.83000		

Culvert Design Report
Haldimand - 23+770

Peak Discharge Method: User-Specified			
Design Discharge	3.7800 m³/s	Check Discharge	5.6900 m³/s

Grades Model: Inverts			
Invert Upstream	153.00 m	Invert Downstream	149.00 m
Length	70.10 m	Slope	0.057061 m/m
Drop	4.00 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater			
Tailwater Elevation	150.08 m		

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-1830 x 1830 mm Box	3.7800 m³/s	154.33 m	1.91 m/s
	Trial-2	1-1830 x 1830 mm Box	5.6900 m³/s	154.74 m	2.88 m/s

Culvert Design Report
Haldimand - 24+940

Peak Discharge Method: User-Specified			
Design Discharge	1.2400 m³/s	Check Discharge	1.8700 m³/s

Grades Model: Inverts			
Invert Upstream	169.50 m	Invert Downstream	169.00 m
Length	55.20 m	Slope	0.009058 m/m
Drop	0.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater			
Tailwater Elevation	169.54 m		

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-900 mm Circular	1.2400 m³/s	170.91 m	2.45 m/s
	Trial-2	1-900 mm Circular	1.8700 m³/s	172.49 m	3.09 m/s

Culvert Design Report
Haldimand - 24+940

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	170.91 m	Discharge	1.2400 m³/s
Headwater Depth/Height	1.54	Tailwater Elevation	169.54 m
Inlet Control HW Elev.	170.67 m	Control Type	Outlet Control
Outlet Control HW Elev.	170.91 m		

Grades			
Upstream Invert	169.50 m	Downstream Invert	169.00 m
Length	55.20 m	Constructed Slope	0.009058 m/m

Hydraulic Profile			
Profile	CompositeM2PressureProfile	Depth, Downstream	0.66 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.66 m
Velocity Downstream	2.45 m/s	Critical Slope	0.019592 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	170.91 m	Upstream Velocity Head	0.18 m
Ke	0.90	Entrance Loss	0.16 m

Inlet Control Properties			
Inlet Control HW Elev.	170.67 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 23+770

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	154.33 m	Discharge	3.7800 m³/s
Headwater Depth/Height	0.73	Tailwater Elevation	150.08 m
Inlet Control HW Elev.	154.17 m	Control Type	Entrance Control
Outlet Control HW Elev.	154.33 m		

Grades			
Upstream Invert	153.00 m	Downstream Invert	149.00 m
Length	70.10 m	Constructed Slope	0.057061 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	1.08 m
Slope Type	Steep	Normal Depth	0.30 m
Flow Regime	N/A	Critical Depth	0.76 m
Velocity Downstream	1.91 m/s	Critical Slope	0.004066 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.83 m
Section Size	1830 x 1830 mm	Rise	1.83 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	154.33 m	Upstream Velocity Head	0.38 m
Ke	0.50	Entrance Loss	0.19 m

Inlet Control Properties			
Inlet Control HW Elev.	154.17 m	Flow Control	N/A
Inlet Type	18 to 33.7° wingwall flare, d=0.0830	Area Full	3.3 m²
K	0.48600	HDS 5 Chart	9
M	0.66700	HDS 5 Scale	2
C	0.02490	Equation Form	2
Y	0.83000		

Culvert Design Report
Haldimand - 23+770

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	154.74 m	Discharge	5.6900 m³/s
Headwater Depth/Height	0.95	Tailwater Elevation	150.08 m
Inlet Control HW Elev.	154.54 m	Control Type	Entrance Control
Outlet Control HW Elev.	154.74 m		

Grades			
Upstream Invert	153.00 m	Downstream Invert	149.00 m
Length	70.10 m	Constructed Slope	0.057061 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	1.08 m
Slope Type	Steep	Normal Depth	0.40 m
Flow Regime	N/A	Critical Depth	1.00 m
Velocity Downstream	2.88 m/s	Critical Slope	0.004432 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.83 m
Section Size	1830 x 1830 mm	Rise	1.83 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	154.74 m	Upstream Velocity Head	0.50 m
Ke	0.50	Entrance Loss	0.25 m

Inlet Control Properties			
Inlet Control HW Elev.	154.54 m	Flow Control	N/A
Inlet Type	18 to 33.7° wingwall flare, d=0.0830	Area Full	3.3 m²
K	0.48600	HDS 5 Chart	9
M	0.66700	HDS 5 Scale	2
C	0.02490	Equation Form	2
Y	0.83000		

Culvert Design Report
Haldimand - 24+940

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	172.49 m	Discharge	1.8700 m³/s
Headwater Depth/Height	3.27	Tailwater Elevation	169.54 m
Inlet Control HW Elev.	171.46 m	Control Type	Outlet Control
Outlet Control HW Elev.	172.49 m		

Grades			
Upstream Invert	169.50 m	Downstream Invert	169.00 m
Length	55.20 m	Constructed Slope	0.009058 m/m

Hydraulic Profile			
Profile	CompositeM2PressureProfile	Depth, Downstream	0.79 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.79 m
Velocity Downstream	3.09 m/s	Critical Slope	0.030607 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	172.49 m	Upstream Velocity Head	0.41 m
Ke	0.90	Entrance Loss	0.37 m

Inlet Control Properties			
Inlet Control HW Elev.	171.46 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 24+940 (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	1.2400 m³/s	Check Discharge	1.8700 m³/s

Grades Model: Inverts			
Invert Upstream	169.50 m	Invert Downstream	169.00 m
Length	55.20 m	Slope	0.009058 m/m
Drop	0.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater			
Tailwater Elevation	169.72 m		

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-1200 mm Circular	1.2400 m³/s	170.51 m	1.73 m/s
	Trial-2	1-1200 mm Circular	1.8700 m³/s	170.80 m	2.49 m/s

Culvert Design Report
Haldimand - 24+940 (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	170.51 m	Discharge	1.2400 m³/s
Headwater Depth/Height	0.83	Tailwater Elevation	169.72 m
Inlet Control HW Elev.	170.43 m	Control Type	Outlet Control
Outlet Control HW Elev.	170.51 m		

Grades			
Upstream Invert	169.50 m	Downstream Invert	169.00 m
Length	55.20 m	Constructed Slope	0.009058 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.72 m
Slope Type	Mild	Normal Depth	0.67 m
Flow Regime	Subcritical	Critical Depth	0.60 m
Velocity Downstream	1.73 m/s	Critical Slope	0.013127 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	1.22 m
Section Size	1200 mm	Rise	1.22 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	170.51 m	Upstream Velocity Head	0.18 m
Ke	0.90	Entrance Loss	0.16 m

Inlet Control Properties			
Inlet Control HW Elev.	170.43 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	1.2 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Haldimand - 24+940 (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	170.80 m	Discharge	1.8700 m³/s
Headwater Depth/Height	1.06	Tailwater Elevation	169.72 m
Inlet Control HW Elev.	170.74 m	Control Type	Outlet Control
Outlet Control HW Elev.	170.80 m		

Grades			
Upstream Invert	169.50 m	Downstream Invert	169.00 m
Length	55.20 m	Constructed Slope	0.009058 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.75 m
Slope Type	Mild	Normal Depth	0.90 m
Flow Regime	Subcritical	Critical Depth	0.75 m
Velocity Downstream	2.49 m/s	Critical Slope	0.014923 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	1.22 m
Section Size	1200 mm	Rise	1.22 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	170.80 m	Upstream Velocity Head	0.21 m
Ke	0.90	Entrance Loss	0.19 m

Inlet Control Properties			
Inlet Control HW Elev.	170.74 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	1.2 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Hamilton - 23+330

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	167.00 m	Discharge	0.9000 m³/s
Headwater Depth/Height	1.10	Tailwater Elevation	165.54 m
Inlet Control HW Elev.	166.91 m	Control Type	Entrance Control
Outlet Control HW Elev.	167.00 m		

Grades			
Upstream Invert	166.00 m	Downstream Invert	165.00 m
Length	53.70 m	Constructed Slope	0.018622 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.37 m
Slope Type	Steep	Normal Depth	0.37 m
Flow Regime	Supercritical	Critical Depth	0.56 m
Velocity Downstream	3.57 m/s	Critical Slope	0.004793 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	167.00 m	Upstream Velocity Head	0.23 m
Ke	0.90	Entrance Loss	0.21 m

Inlet Control Properties			
Inlet Control HW Elev.	166.91 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Hamilton - 23+330 (proposed with 23+605)

Peak Discharge Method: User-Specified			
Design Discharge	1.2800 m³/s	Check Discharge	1.9200 m³/s

Grades Model: Inverts			
Invert Upstream	166.00 m	Invert Downstream	165.00 m
Length	53.70 m	Slope	0.018622 m/m
Drop	1.00 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater

Tailwater Elevation	165.72 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-1200 mm Circular	1.2800 m³/s	167.07 m	1.78 m/s
	Trial-2	1-1200 mm Circular	1.9200 m³/s	167.37 m	2.73 m/s

Culvert Design Report
Hamilton - 23+330

Peak Discharge Method: User-Specified			
Design Discharge	0.6000 m³/s	Check Discharge	0.9000 m³/s

Grades Model: Inverts			
Invert Upstream	166.00 m	Invert Downstream	165.00 m
Length	53.70 m	Slope	0.018622 m/m
Drop	1.00 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater

Tailwater Elevation	165.54 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-900 mm Circular	0.6000 m³/s	166.79 m	1.49 m/s
	Trial-2	1-900 mm Circular	0.9000 m³/s	167.00 m	3.57 m/s

Culvert Design Report
Hamilton - 23+330

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	166.79 m	Discharge	0.6000 m³/s
Headwater Depth/Height	0.86	Tailwater Elevation	165.54 m
Inlet Control HW Elev.	166.69 m	Control Type	Entrance Control
Outlet Control HW Elev.	166.79 m		

Grades			
Upstream Invert	166.00 m	Downstream Invert	165.00 m
Length	53.70 m	Constructed Slope	0.018622 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.54 m
Slope Type	Steep	Normal Depth	0.30 m
Flow Regime	N/A	Critical Depth	0.45 m
Velocity Downstream	1.49 m/s	Critical Slope	0.004234 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	166.79 m	Upstream Velocity Head	0.18 m
Ke	0.90	Entrance Loss	0.16 m

Inlet Control Properties			
Inlet Control HW Elev.	166.69 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Hamilton - 23+330 (proposed with 23+605)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	167.07 m	Discharge	1.2800 m³/s
Headwater Depth/Height	0.88	Tailwater Elevation	165.72 m
Inlet Control HW Elev.	166.94 m	Control Type	Entrance Control
Outlet Control HW Elev.	167.07 m		

Grades			
Upstream Invert	166.00 m	Downstream Invert	165.00 m
Length	53.70 m	Constructed Slope	0.018622 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.72 m
Slope Type	Steep	Normal Depth	0.56 m
Flow Regime	N/A	Critical Depth	0.61 m
Velocity Downstream	1.78 m/s	Critical Slope	0.013220 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	1.22 m
Section Size	1200 mm	Rise	1.22 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	167.07 m	Upstream Velocity Head	0.24 m
Ke	0.90	Entrance Loss	0.22 m

Inlet Control Properties			
Inlet Control HW Elev.	166.94 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	1.2 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Hamilton - 23+330 (proposed with 23+605)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	167.37 m	Discharge	1.9200 m³/s
Headwater Depth/Height	1.12	Tailwater Elevation	165.72 m
Inlet Control HW Elev.	167.25 m	Control Type	Entrance Control
Outlet Control HW Elev.	167.37 m		

Grades			
Upstream Invert	166.00 m	Downstream Invert	165.00 m
Length	53.70 m	Constructed Slope	0.018622 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.71 m
Slope Type	Steep	Normal Depth	0.71 m
Flow Regime	Supercritical	Critical Depth	0.76 m
Velocity Downstream	2.73 m/s	Critical Slope	0.015098 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	1.22 m
Section Size	1200 mm	Rise	1.22 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	167.37 m	Upstream Velocity Head	0.32 m
Ke	0.90	Entrance Loss	0.29 m

Inlet Control Properties			
Inlet Control HW Elev.	167.25 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	1.2 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Hamilton - 23+330 (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	0.6000 m³/s	Check Discharge	0.9000 m³/s

Grades Model: Inverts			
Invert Upstream	166.00 m	Invert Downstream	165.00 m
Length	53.70 m	Slope	0.018622 m/m
Drop	1.00 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	165.54 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-900 mm Circular	0.6000 m³/s	166.79 m	1.49 m/s
	Trial-2	1-900 mm Circular	0.9000 m³/s	167.00 m	3.57 m/s

Culvert Design Report
Hamilton - 23+330 (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	166.79 m	Discharge	0.6000 m³/s
Headwater Depth/Height	0.86	Tailwater Elevation	165.54 m
Inlet Control HW Elev.	166.69 m	Control Type	Entrance Control
Outlet Control HW Elev.	166.79 m		

Grades			
Upstream Invert	166.00 m	Downstream Invert	165.00 m
Length	53.70 m	Constructed Slope	0.018622 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.54 m
Slope Type	Steep	Normal Depth	0.30 m
Flow Regime	N/A	Critical Depth	0.45 m
Velocity Downstream	1.49 m/s	Critical Slope	0.004234 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	166.79 m	Upstream Velocity Head	0.18 m
Ke	0.90	Entrance Loss	0.16 m

Inlet Control Properties			
Inlet Control HW Elev.	166.69 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Hamilton - 23+605

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	167.85 m	Discharge	0.6800 m³/s
Headwater Depth/Height	0.93	Tailwater Elevation	166.04 m
Inlet Control HW Elev.	167.75 m	Control Type	Entrance Control
Outlet Control HW Elev.	167.85 m		

Grades			
Upstream Invert	167.00 m	Downstream Invert	165.50 m
Length	56.90 m	Constructed Slope	0.026362 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.54 m
Slope Type	Steep	Normal Depth	0.29 m
Flow Regime	N/A	Critical Depth	0.48 m
Velocity Downstream	1.68 m/s	Critical Slope	0.004361 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	167.85 m	Upstream Velocity Head	0.19 m
Ke	0.90	Entrance Loss	0.17 m

Inlet Control Properties			
Inlet Control HW Elev.	167.75 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Hamilton - 23+605

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	168.09 m	Discharge	1.0200 m³/s
Headwater Depth/Height	1.19	Tailwater Elevation	166.04 m
Inlet Control HW Elev.	168.00 m	Control Type	Entrance Control
Outlet Control HW Elev.	168.09 m		

Grades			
Upstream Invert	167.00 m	Downstream Invert	165.50 m
Length	56.90 m	Constructed Slope	0.026362 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.36 m
Slope Type	Steep	Normal Depth	0.36 m
Flow Regime	Supercritical	Critical Depth	0.59 m
Velocity Downstream	4.19 m/s	Critical Slope	0.005086 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	168.09 m	Upstream Velocity Head	0.26 m
Ke	0.90	Entrance Loss	0.23 m

Inlet Control Properties			
Inlet Control HW Elev.	168.00 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Hamilton - 23+330 (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	167.00 m	Discharge	0.9000 m³/s
Headwater Depth/Height	1.10	Tailwater Elevation	165.54 m
Inlet Control HW Elev.	166.91 m	Control Type	Entrance Control
Outlet Control HW Elev.	167.00 m		

Grades			
Upstream Invert	166.00 m	Downstream Invert	165.00 m
Length	53.70 m	Constructed Slope	0.018622 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.37 m
Slope Type	Steep	Normal Depth	0.37 m
Flow Regime	Supercritical	Critical Depth	0.56 m
Velocity Downstream	3.57 m/s	Critical Slope	0.004793 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	167.00 m	Upstream Velocity Head	0.23 m
Ke	0.90	Entrance Loss	0.21 m

Inlet Control Properties			
Inlet Control HW Elev.	166.91 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Hamilton - 23+605

Peak Discharge Method: User-Specified			
Design Discharge	0.6800 m³/s	Check Discharge	1.0200 m³/s

Grades Model: Inverts			
Invert Upstream	167.00 m	Invert Downstream	165.50 m
Length	56.90 m	Slope	0.026362 m/m
Drop	1.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	166.04 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-900 mm Circular	0.6800 m³/s	167.85 m	1.68 m/s
	Trial-2	1-900 mm Circular	1.0200 m³/s	168.09 m	4.19 m/s

Culvert Design Report
Hamilton - 23+605 (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	0.6800 m³/s	Check Discharge	1.0200 m³/s

Grades Model: Inverts			
Invert Upstream	167.00 m	Invert Downstream	165.50 m
Length	56.90 m	Slope	0.026362 m/m
Drop	1.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	166.04 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-900 mm Circular	0.6800 m³/s	167.85 m	1.68 m/s
	Trial-2	1-900 mm Circular	1.0200 m³/s	168.09 m	4.19 m/s

Culvert Design Report
Hamilton - 23+605 (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	167.85 m	Discharge	0.6800 m³/s
Headwater Depth/Height	0.93	Tailwater Elevation	166.04 m
Inlet Control HW Elev.	167.75 m	Control Type	Entrance Control
Outlet Control HW Elev.	167.85 m		

Grades			
Upstream Invert	167.00 m	Downstream Invert	165.50 m
Length	56.90 m	Constructed Slope	0.026362 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.54 m
Slope Type	Steep	Normal Depth	0.29 m
Flow Regime	N/A	Critical Depth	0.48 m
Velocity Downstream	1.68 m/s	Critical Slope	0.004361 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	167.85 m	Upstream Velocity Head	0.19 m
Ke	0.90	Entrance Loss	0.17 m

Inlet Control Properties			
Inlet Control HW Elev.	167.75 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Hamilton - 23+605 (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	168.09 m	Discharge	1.0200 m³/s
Headwater Depth/Height	1.19	Tailwater Elevation	166.04 m
Inlet Control HW Elev.	168.00 m	Control Type	Entrance Control
Outlet Control HW Elev.	168.09 m		

Grades			
Upstream Invert	167.00 m	Downstream Invert	165.50 m
Length	56.90 m	Constructed Slope	0.026362 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.36 m
Slope Type	Steep	Normal Depth	0.36 m
Flow Regime	Supercritical	Critical Depth	0.59 m
Velocity Downstream	4.19 m/s	Critical Slope	0.005086 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	168.09 m	Upstream Velocity Head	0.26 m
Ke	0.90	Entrance Loss	0.23 m

Inlet Control Properties			
Inlet Control HW Elev.	168.00 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Hamilton - 24+810

Peak Discharge Method: User-Specified			
Design Discharge	5.2900 m³/s	Check Discharge	8.0700 m³/s

Grades Model: Inverts			
Invert Upstream	156.50 m	Invert Downstream	153.50 m
Length	73.10 m	Slope	0.041040 m/m
Drop	3.00 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	154.61 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-2440 x 1830 mm Box	5.2900 m³/s	157.87 m	1.95 m/s
	Trial-2	1-2440 x 1830 mm Box	8.0700 m³/s	158.32 m	2.98 m/s

Culvert Design Report
21-467/C

Peak Discharge Method: User-Specified			
Design Discharge	10.8400 m³/s	Check Discharge	16.4300 m³/s

Grades Model: Inverts			
Invert Upstream	147.50 m	Invert Downstream	140.75 m
Length	147.10 m	Slope	0.045887 m/m
Drop	6.75 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	141.83 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-3050 x 1830 mm Box	10.8400 m³/s	149.40 m	8.06 m/s
	Trial-2	1-3050 x 1830 mm Box	16.4300 m³/s	150.01 m	9.10 m/s

Culvert Design Report
21-467/C

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	149.40 m	Discharge	10.8400 m³/s
Headwater Depth/Height	1.04	Tailwater Elevation	141.83 m
Inlet Control HW Elev.	149.31 m	Control Type	Entrance Control
Outlet Control HW Elev.	149.40 m		

Grades			
Upstream Invert	147.50 m	Downstream Invert	140.75 m
Length	147.10 m	Constructed Slope	0.045887 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.44 m
Slope Type	Steep	Normal Depth	0.44 m
Flow Regime	Supercritical	Critical Depth	1.09 m
Velocity Downstream	8.06 m/s	Critical Slope	0.003305 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	3.05 m
Section Size	3050 x 1830 mm	Rise	1.83 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	149.40 m	Upstream Velocity Head	0.54 m
Ke	0.50	Entrance Loss	0.27 m

Inlet Control Properties			
Inlet Control HW Elev.	149.31 m	Flow Control	Unsubmerged
Inlet Type	3/4 inch chamfers; 15° skewed headwall	Area Full	5.6 m²
K	0.52200	HDS 5 Chart	11
M	0.66700	HDS 5 Scale	3
C	0.04020	Equation Form	2
Y	0.73000		

Culvert Design Report
Hamilton - 24+810

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	157.87 m	Discharge	5.2900 m³/s
Headwater Depth/Height	0.75	Tailwater Elevation	154.61 m
Inlet Control HW Elev.	157.73 m	Control Type	Entrance Control
Outlet Control HW Elev.	157.87 m		

Grades			
Upstream Invert	156.50 m	Downstream Invert	153.50 m
Length	73.10 m	Constructed Slope	0.041040 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	1.11 m
Slope Type	Steep	Normal Depth	0.34 m
Flow Regime	N/A	Critical Depth	0.78 m
Velocity Downstream	1.95 m/s	Critical Slope	0.003484 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	2.44 m
Section Size	2440 x 1830 mm	Rise	1.83 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	157.87 m	Upstream Velocity Head	0.39 m
Ke	0.50	Entrance Loss	0.20 m

Inlet Control Properties			
Inlet Control HW Elev.	157.73 m	Flow Control	N/A
Inlet Type	18.4° wingwall flares - offset	Area Full	4.5 m²
K	0.49300	HDS 5 Chart	13
M	0.66700	HDS 5 Scale	3
C	0.02270	Equation Form	2
Y	0.89700		

Culvert Design Report
Hamilton - 24+810

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	158.32 m	Discharge	8.0700 m³/s
Headwater Depth/Height	0.99	Tailwater Elevation	154.61 m
Inlet Control HW Elev.	158.10 m	Control Type	Entrance Control
Outlet Control HW Elev.	158.32 m		

Grades			
Upstream Invert	156.50 m	Downstream Invert	153.50 m
Length	73.10 m	Constructed Slope	0.041040 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	1.11 m
Slope Type	Steep	Normal Depth	0.45 m
Flow Regime	N/A	Critical Depth	1.04 m
Velocity Downstream	2.98 m/s	Critical Slope	0.003721 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	2.44 m
Section Size	2440 x 1830 mm	Rise	1.83 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	158.32 m	Upstream Velocity Head	0.52 m
Ke	0.50	Entrance Loss	0.26 m

Inlet Control Properties			
Inlet Control HW Elev.	158.10 m	Flow Control	N/A
Inlet Type	18 to 33.7° wingwall flare, d=0.0830	Area Full	4.5 m²
K	0.48600	HDS 5 Chart	9
M	0.66700	HDS 5 Scale	2
C	0.02490	Equation Form	2
Y	0.83000		

Culvert Design Report
21-467/C

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	150.01 m	Discharge	16.4300 m³/s
Headwater Depth/Height	1.37	Tailwater Elevation	141.83 m
Inlet Control HW Elev.	149.94 m	Control Type	Entrance Control
Outlet Control HW Elev.	150.01 m		

Grades			
Upstream Invert	147.50 m	Downstream Invert	140.75 m
Length	147.10 m	Constructed Slope	0.045887 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.59 m
Slope Type	Steep	Normal Depth	0.58 m
Flow Regime	Supercritical	Critical Depth	1.44 m
Velocity Downstream	9.10 m/s	Critical Slope	0.003560 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	3.05 m
Section Size	3050 x 1830 mm	Rise	1.83 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	150.01 m	Upstream Velocity Head	0.72 m
Ke	0.50	Entrance Loss	0.36 m

Inlet Control Properties			
Inlet Control HW Elev.	149.94 m	Flow Control	Transition
Inlet Type	3/4 inch chamfers; 15° skewed headwall	Area Full	5.6 m²
K	0.52200	HDS 5 Chart	11
M	0.66700	HDS 5 Scale	3
C	0.04020	Equation Form	2
Y	0.73000		

Culvert Design Report
21-467/C (Regional)

Peak Discharge Method: User-Specified			
Design Discharge	15.8150 m³/s	Check Discharge	0.0000 m³/s

Grades Model: Inverts			
Invert Upstream	147.50 m	Invert Downstream	140.75 m
Length	147.10 m	Slope	0.045887 m/m
Drop	6.75 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	141.83 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-3050 x 1830 mm Box	15.8150 m³/s	149.95 m	9.02 m/s

Culvert Design Report
21-467/C (Regional)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	149.95 m	Discharge	15.8150 m³/s
Headwater Depth/Height	1.34	Tailwater Elevation	141.83 m
Inlet Control HW Elev.	149.86 m	Control Type	Entrance Control
Outlet Control HW Elev.	149.95 m		

Grades			
Upstream Invert	147.50 m	Downstream Invert	140.75 m
Length	147.10 m	Constructed Slope	0.045887 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.58 m
Slope Type	Steep	Normal Depth	0.57 m
Flow Regime	Supercritical	Critical Depth	1.40 m
Velocity Downstream	9.02 m/s	Critical Slope	0.003532 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	3.05 m
Section Size	3050 x 1830 mm	Rise	1.83 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	149.95 m	Upstream Velocity Head	0.70 m
Ke	0.50	Entrance Loss	0.35 m

Inlet Control Properties			
Inlet Control HW Elev.	149.86 m	Flow Control	Transition
Inlet Type	3/4 inch chamfers; 15° skewed headwall	Area Full	5.6 m²
K	0.52200	HDS 5 Chart	11
M	0.66700	HDS 5 Scale	3
C	0.04020	Equation Form	2
Y	0.73000		

Culvert Design Report
21-468/C

Peak Discharge Method: User-Specified			
Design Discharge	9.1400 m³/s	Check Discharge	13.6500 m³/s

Grades Model: Inverts			
Invert Upstream	140.00 m	Invert Downstream	138.50 m
Length	71.70 m	Slope	0.020921 m/m
Drop	1.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater			
Tailwater Elevation	139.40 m		

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-3050 x 1520 mm Box	9.1400 m³/s	141.70 m	5.50 m/s
	Trial-2	1-3050 x 1520 mm Box	13.6500 m³/s	142.24 m	6.05 m/s

Culvert Design Report
21-468/C (Regional)

Peak Discharge Method: User-Specified			
Design Discharge	11.3300 m³/s	Check Discharge	0.0000 m³/s

Grades Model: Inverts			
Invert Upstream	140.00 m	Invert Downstream	138.50 m
Length	71.70 m	Slope	0.020921 m/m
Drop	1.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater			
Tailwater Elevation	139.40 m		

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-3050 x 1520 mm Box	11.3300 m³/s	141.96 m	5.79 m/s

Culvert Design Report
21-468/C (Regional)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	141.96 m	Discharge	11.3300 m³/s
Headwater Depth/Height	1.29	Tailwater Elevation	139.40 m
Inlet Control HW Elev.	141.87 m	Control Type	Entrance Control
Outlet Control HW Elev.	141.96 m		

Grades			
Upstream Invert	140.00 m	Downstream Invert	138.50 m
Length	71.70 m	Constructed Slope	0.020921 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.64 m
Slope Type	Steep	Normal Depth	0.59 m
Flow Regime	Supercritical	Critical Depth	1.12 m
Velocity Downstream	5.79 m/s	Critical Slope	0.003328 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	3.05 m
Section Size	3050 x 1520 mm	Rise	1.52 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	141.96 m	Upstream Velocity Head	0.56 m
Ke	0.50	Entrance Loss	0.28 m

Inlet Control Properties			
Inlet Control HW Elev.	141.87 m	Flow Control	Transition
Inlet Type	3/4 inch chamfers; 15° skewed headwall	Area Full	4.6 m²
K	0.52200	HDS 5 Chart	11
M	0.66700	HDS 5 Scale	3
C	0.04020	Equation Form	2
Y	0.73000		

Culvert Design Report
21-468/C

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	141.70 m	Discharge	9.1400 m³/s
Headwater Depth/Height	1.12	Tailwater Elevation	139.40 m
Inlet Control HW Elev.	141.61 m	Control Type	Entrance Control
Outlet Control HW Elev.	141.70 m		

Grades			
Upstream Invert	140.00 m	Downstream Invert	138.50 m
Length	71.70 m	Constructed Slope	0.020921 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.55 m
Slope Type	Steep	Normal Depth	0.51 m
Flow Regime	Supercritical	Critical Depth	0.97 m
Velocity Downstream	5.50 m/s	Critical Slope	0.003230 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	3.05 m
Section Size	3050 x 1520 mm	Rise	1.52 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	141.70 m	Upstream Velocity Head	0.49 m
Ke	0.50	Entrance Loss	0.24 m

Inlet Control Properties			
Inlet Control HW Elev.	141.61 m	Flow Control	Unsubmerged
Inlet Type	3/4 inch chamfers; 15° skewed headwall	Area Full	4.6 m²
K	0.52200	HDS 5 Chart	11
M	0.66700	HDS 5 Scale	3
C	0.04020	Equation Form	2
Y	0.73000		

Culvert Design Report
21-468/C

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	142.24 m	Discharge	13.6500 m³/s
Headwater Depth/Height	1.47	Tailwater Elevation	139.40 m
Inlet Control HW Elev.	142.24 m	Control Type	Inlet Control
Outlet Control HW Elev.	142.22 m		

Grades			
Upstream Invert	140.00 m	Downstream Invert	138.50 m
Length	71.70 m	Constructed Slope	0.020921 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.74 m
Slope Type	Steep	Normal Depth	0.67 m
Flow Regime	Supercritical	Critical Depth	1.27 m
Velocity Downstream	6.05 m/s	Critical Slope	0.003433 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	3.05 m
Section Size	3050 x 1520 mm	Rise	1.52 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	142.22 m	Upstream Velocity Head	0.63 m
Ke	0.50	Entrance Loss	0.32 m

Inlet Control Properties			
Inlet Control HW Elev.	142.24 m	Flow Control	Submerged
Inlet Type	3/4 inch chamfers; 15° skewed headwall	Area Full	4.6 m²
K	0.52200	HDS 5 Chart	11
M	0.66700	HDS 5 Scale	3
C	0.04020	Equation Form	2
Y	0.73000		

Culvert Design Report
21-468/C + 000904010048

Peak Discharge Method: User-Specified			
Design Discharge	9.4000 m³/s	Check Discharge	14.0300 m³/s

Grades Model: Inverts			
Invert Upstream	140.00 m	Invert Downstream	138.50 m
Length	71.70 m	Slope	0.020921 m/m
Drop	1.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater			
Tailwater Elevation	139.40 m		

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-3050 x 1520 mm Box	9.4000 m³/s	141.73 m	5.53 m/s
	Trial-2	1-3050 x 1520 mm Box	14.0300 m³/s	142.30 m	6.09 m/s

Culvert Design Report
21-468/C + 000904010048

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	141.73 m	Discharge	9.4000 m³/s
Headwater Depth/Height	1.14	Tailwater Elevation	139.40 m
Inlet Control HW Elev.	141.64 m	Control Type	Entrance Control
Outlet Control HW Elev.	141.73 m		

Grades			
Upstream Invert	140.00 m	Downstream Invert	138.50 m
Length	71.70 m	Constructed Slope	0.020921 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.56 m
Slope Type	Steep	Normal Depth	0.52 m
Flow Regime	Supercritical	Critical Depth	0.99 m
Velocity Downstream	5.53 m/s	Critical Slope	0.003241 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	3.05 m
Section Size	3050 x 1520 mm	Rise	1.52 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	141.73 m	Upstream Velocity Head	0.49 m
Ke	0.50	Entrance Loss	0.25 m

Inlet Control Properties			
Inlet Control HW Elev.	141.64 m	Flow Control	Unsubmerged
Inlet Type	3/4 inch chamfers; 15° skewed headwall	Area Full	4.6 m²
K	0.52200	HDS 5 Chart	11
M	0.66700	HDS 5 Scale	3
C	0.04020	Equation Form	2
Y	0.73000		

Culvert Design Report
21-468/C + 000904010048

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	142.30 m	Discharge	14.0300 m³/s
Headwater Depth/Height	1.51	Tailwater Elevation	139.40 m
Inlet Control HW Elev.	142.30 m	Control Type	Inlet Control
Outlet Control HW Elev.	142.26 m		

Grades			
Upstream Invert	140.00 m	Downstream Invert	138.50 m
Length	71.70 m	Constructed Slope	0.020921 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.76 m
Slope Type	Steep	Normal Depth	0.68 m
Flow Regime	Supercritical	Critical Depth	1.29 m
Velocity Downstream	6.09 m/s	Critical Slope	0.003451 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	3.05 m
Section Size	3050 x 1520 mm	Rise	1.52 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	142.26 m	Upstream Velocity Head	0.65 m
Ke	0.50	Entrance Loss	0.32 m

Inlet Control Properties			
Inlet Control HW Elev.	142.30 m	Flow Control	Submerged
Inlet Type	3/4 inch chamfers; 15° skewed headwall	Area Full	4.6 m²
K	0.52200	HDS 5 Chart	11
M	0.66700	HDS 5 Scale	3
C	0.04020	Equation Form	2
Y	0.73000		

Culvert Design Report
21-469/C

Peak Discharge Method: User-Specified			
Design Discharge	2.3700 m³/s	Check Discharge	3.5700 m³/s

Grades Model: Inverts			
Invert Upstream	142.50 m	Invert Downstream	140.30 m
Length	91.50 m	Slope	0.024044 m/m
Drop	2.20 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater			
Tailwater Elevation	141.38 m		

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-3660 x 1830 mm Box	2.3700 m³/s	143.11 m	0.60 m/s
	Trial-2	1-3660 x 1830 mm Box	3.5700 m³/s	143.30 m	0.90 m/s

Culvert Design Report
21-469/C - proposed (lined)

Peak Discharge Method: User-Specified			
Design Discharge	2.3700 m³/s	Check Discharge	3.5700 m³/s

Grades Model: Inverts			
Invert Upstream	142.50 m	Invert Downstream	140.30 m
Length	91.50 m	Slope	0.024044 m/m
Drop	2.20 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater			
Tailwater Elevation	141.08 m		

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-3400 x 1300 mm Arch	2.3700 m³/s	143.23 m	1.09 m/s
	Trial-2	1-3400 x 1300 mm Arch	3.5700 m³/s	143.45 m	1.65 m/s

Culvert Design Report
21-469/C - proposed (lined)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	143.23 m	Discharge	2.3700 m³/s
Headwater Depth/Height	0.56	Tailwater Elevation	141.08 m
Inlet Control HW Elev.	143.13 m	Control Type	Entrance Control
Outlet Control HW Elev.	143.23 m		

Grades			
Upstream Invert	142.50 m	Downstream Invert	140.30 m
Length	91.50 m	Constructed Slope	0.024044 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.78 m
Slope Type	Steep	Normal Depth	0.33 m
Flow Regime	N/A	Critical Depth	0.42 m
Velocity Downstream	1.09 m/s	Critical Slope	0.010939 m/m

Section			
Section Shape	Arch	Mannings Coefficient	0.024
Section Material	Steel structural plate 18 In CR	Span	3.40 m
Section Size	3400 x 1300 mm	Rise	1.30 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	143.23 m	Upstream Velocity Head	0.20 m
Ke	0.50	Entrance Loss	0.10 m

Inlet Control Properties			
Inlet Control HW Elev.	143.13 m	Flow Control	Unsubmerged
Inlet Type	18 inch CR structural plate, No bevels	Area Full	3.2 m²
K	0.00880	HDS 5 Chart	35
M	2.00000	HDS 5 Scale	2
C	0.03680	Equation Form	1
Y	0.68000		

Culvert Design Report
21-469/C

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	143.11 m	Discharge	2.3700 m³/s
Headwater Depth/Height	0.33	Tailwater Elevation	141.38 m
Inlet Control HW Elev.	143.08 m	Control Type	Entrance Control
Outlet Control HW Elev.	143.11 m		

Grades			
Upstream Invert	142.50 m	Downstream Invert	140.30 m
Length	91.50 m	Constructed Slope	0.024044 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	1.08 m
Slope Type	Steep	Normal Depth	0.18 m
Flow Regime	N/A	Critical Depth	0.35 m
Velocity Downstream	0.60 m/s	Critical Slope	0.002970 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	3.66 m
Section Size	3660 x 1830 mm	Rise	1.83 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	143.11 m	Upstream Velocity Head	0.17 m
Ke	0.50	Entrance Loss	0.09 m

Inlet Control Properties			
Inlet Control HW Elev.	143.08 m	Flow Control	Unsubmerged
Inlet Type	3/4 inch chamfers; 15° skewed headwall	Area Full	6.7 m²
K	0.52200	HDS 5 Chart	11
M	0.66700	HDS 5 Scale	3
C	0.04020	Equation Form	2
Y	0.73000		

Culvert Design Report
21-469/C

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	143.30 m	Discharge	3.5700 m³/s
Headwater Depth/Height	0.44	Tailwater Elevation	141.38 m
Inlet Control HW Elev.	143.26 m	Control Type	Entrance Control
Outlet Control HW Elev.	143.30 m		

Grades			
Upstream Invert	142.50 m	Downstream Invert	140.30 m
Length	91.50 m	Constructed Slope	0.024044 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	1.08 m
Slope Type	Steep	Normal Depth	0.23 m
Flow Regime	N/A	Critical Depth	0.46 m
Velocity Downstream	0.90 m/s	Critical Slope	0.002896 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	3.66 m
Section Size	3660 x 1830 mm	Rise	1.83 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	143.30 m	Upstream Velocity Head	0.23 m
Ke	0.50	Entrance Loss	0.11 m

Inlet Control Properties			
Inlet Control HW Elev.	143.26 m	Flow Control	Unsubmerged
Inlet Type	3/4 inch chamfers; 15° skewed headwall	Area Full	6.7 m²
K	0.52200	HDS 5 Chart	11
M	0.66700	HDS 5 Scale	3
C	0.04020	Equation Form	2
Y	0.73000		

Culvert Design Report
21-469/C - proposed (lined)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	143.45 m	Discharge	3.5700 m³/s
Headwater Depth/Height	0.73	Tailwater Elevation	141.08 m
Inlet Control HW Elev.	143.34 m	Control Type	Entrance Control
Outlet Control HW Elev.	143.45 m		

Grades			
Upstream Invert	142.50 m	Downstream Invert	140.30 m
Length	91.50 m	Constructed Slope	0.024044 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.78 m
Slope Type	Steep	Normal Depth	0.43 m
Flow Regime	N/A	Critical Depth	0.54 m
Velocity Downstream	1.65 m/s	Critical Slope	0.011597 m/m

Section			
Section Shape	Arch	Mannings Coefficient	0.024
Section Material	Steel structural plate 18 In CR	Span	3.40 m
Section Size	3400 x 1300 mm	Rise	1.30 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	143.45 m	Upstream Velocity Head	0.27 m
Ke	0.50	Entrance Loss	0.14 m

Inlet Control Properties			
Inlet Control HW Elev.	143.34 m	Flow Control	Unsubmerged
Inlet Type	18 inch CR structural plate, No bevels	Area Full	3.2 m²
K	0.00880	HDS 5 Chart	35
M	2.00000	HDS 5 Scale	2
C	0.03680	Equation Form	1
Y	0.68000		

Culvert Design Report
21-469/C - proposed (lined) (Regional)

Peak Discharge Method: User-Specified			
Design Discharge	2.0300 m³/s	Check Discharge	0.0000 m³/s

Grades Model: Inverts			
Invert Upstream	142.50 m	Invert Downstream	140.30 m
Length	91.50 m	Slope	0.024044 m/m
Drop	2.20 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater			
Tailwater Elevation	141.08 m		

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-3400 x 1300 mm Arch	2.0300 m³/s	143.16 m	0.94 m/s

Culvert Design Report
21-469/C - proposed (lined) (Regional)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	143.16 m	Discharge	2.0300 m³/s
Headwater Depth/Height	0.50	Tailwater Elevation	141.08 m
Inlet Control HW Elev.	143.06 m	Control Type	Entrance Control
Outlet Control HW Elev.	143.16 m		

Grades			
Upstream Invert	142.50 m	Downstream Invert	140.30 m
Length	91.50 m	Constructed Slope	0.024044 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.78 m
Slope Type	Steep	Normal Depth	0.31 m
Flow Regime	N/A	Critical Depth	0.39 m
Velocity Downstream	0.94 m/s	Critical Slope	0.010831 m/m

Section			
Section Shape	Arch	Mannings Coefficient	0.024
Section Material	Steel structural plate 18 In CR	Span	3.40 m
Section Size	3400 x 1300 mm	Rise	1.30 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	143.16 m	Upstream Velocity Head	0.18 m
Ke	0.50	Entrance Loss	0.09 m

Inlet Control Properties			
Inlet Control HW Elev.	143.06 m	Flow Control	Unsubmerged
Inlet Type	18 inch CR structural plate, No bevels	Area Full	3.2 m²
K	0.00880	HDS 5 Chart	35
M	2.00000	HDS 5 Scale	2
C	0.03680	Equation Form	1
Y	0.68000		

Culvert Design Report
21-469/C (Regional)

Peak Discharge Method: User-Specified			
Design Discharge	2.0300 m³/s	Check Discharge	0.0000 m³/s

Grades Model: Inverts			
Invert Upstream	142.50 m	Invert Downstream	140.30 m
Length	91.50 m	Slope	0.024044 m/m
Drop	2.20 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater			
Tailwater Elevation	141.38 m		

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-3660 x 1830 mm Box	2.0300 m³/s	143.05 m	0.51 m/s

Culvert Design Report
21-470/C

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	153.83 m	Discharge	6.3500 m³/s
Headwater Depth/Height	0.73	Tailwater Elevation	151.08 m
Inlet Control HW Elev.	153.77 m	Control Type	Entrance Control
Outlet Control HW Elev.	153.83 m		

Grades			
Upstream Invert	152.50 m	Downstream Invert	150.00 m
Length	91.60 m	Constructed Slope	0.027293 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	1.08 m
Slope Type	Steep	Normal Depth	0.37 m
Flow Regime	N/A	Critical Depth	0.76 m
Velocity Downstream	1.93 m/s	Critical Slope	0.003116 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	3.05 m
Section Size	3050 x 1830 mm	Rise	1.83 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	153.83 m	Upstream Velocity Head	0.38 m
Ke	0.50	Entrance Loss	0.19 m

Inlet Control Properties			
Inlet Control HW Elev.	153.77 m	Flow Control	Unsubmerged
Inlet Type	4 inch chamfers; 15° skewed headwall	Area Full	5.6 m²
K	0.52200	HDS 5 Chart	11
M	0.66700	HDS 5 Scale	3
C	0.04020	Equation Form	2
Y	0.73000		

Culvert Design Report
21-470/C

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	154.60 m	Discharge	12.5100 m³/s
Headwater Depth/Height	1.15	Tailwater Elevation	151.08 m
Inlet Control HW Elev.	154.49 m	Control Type	Entrance Control
Outlet Control HW Elev.	154.60 m		

Grades			
Upstream Invert	152.50 m	Downstream Invert	150.00 m
Length	91.60 m	Constructed Slope	0.027293 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.62 m
Slope Type	Steep	Normal Depth	0.58 m
Flow Regime	Supercritical	Critical Depth	1.20 m
Velocity Downstream	6.67 m/s	Critical Slope	0.003381 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	3.05 m
Section Size	3050 x 1830 mm	Rise	1.83 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	154.60 m	Upstream Velocity Head	0.60 m
Ke	0.50	Entrance Loss	0.30 m

Inlet Control Properties			
Inlet Control HW Elev.	154.49 m	Flow Control	Unsubmerged
Inlet Type	4 inch chamfers; 15° skewed headwall	Area Full	5.6 m²
K	0.52200	HDS 5 Chart	11
M	0.66700	HDS 5 Scale	3
C	0.04020	Equation Form	2
Y	0.73000		

Culvert Design Report
21-469/C (Regional)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	143.05 m	Discharge	2.0300 m³/s
Headwater Depth/Height	0.30	Tailwater Elevation	141.38 m
Inlet Control HW Elev.	143.02 m	Control Type	Entrance Control
Outlet Control HW Elev.	143.05 m		

Grades			
Upstream Invert	142.50 m	Downstream Invert	140.30 m
Length	91.50 m	Constructed Slope	0.024044 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	1.08 m
Slope Type	Steep	Normal Depth	0.16 m
Flow Regime	N/A	Critical Depth	0.32 m
Velocity Downstream	0.51 m/s	Critical Slope	0.003010 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	3.66 m
Section Size	3660 x 1830 mm	Rise	1.83 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	143.05 m	Upstream Velocity Head	0.16 m
Ke	0.50	Entrance Loss	0.08 m

Inlet Control Properties			
Inlet Control HW Elev.	143.02 m	Flow Control	Unsubmerged
Inlet Type	4 inch chamfers; 15° skewed headwall	Area Full	6.7 m²
K	0.52200	HDS 5 Chart	11
M	0.66700	HDS 5 Scale	3
C	0.04020	Equation Form	2
Y	0.73000		

Culvert Design Report
21-470/C

Peak Discharge Method: User-Specified			
Design Discharge	6.3500 m³/s	Check Discharge	12.5100 m³/s

Grades Model: Inverts			
Invert Upstream	152.50 m	Invert Downstream	150.00 m
Length	91.60 m	Slope	0.027293 m/m
Drop	2.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater			
Tailwater Elevation	151.08 m		

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-3050 x 1830 mm Box	6.3500 m³/s	153.83 m	1.93 m/s
	Trial-2	1-3050 x 1830 mm Box	12.5100 m³/s	154.60 m	6.67 m/s

Culvert Design Report
21-470/C (Regional)

Peak Discharge Method: User-Specified			
Design Discharge	10.2600 m³/s	Check Discharge	0.0000 m³/s

Grades Model: Inverts			
Invert Upstream	152.50 m	Invert Downstream	150.00 m
Length	91.60 m	Slope	0.027293 m/m
Drop	2.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater			
Tailwater Elevation	151.08 m		

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-3050 x 1830 mm Box	10.2600 m³/s	154.34 m	3.12 m/s

Culvert Design Report
21-470/C (Regional)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	154.34 m	Discharge	10.2600 m³/s
Headwater Depth/Height	1.00	Tailwater Elevation	151.08 m
Inlet Control HW Elev.	154.24 m	Control Type	Entrance Control
Outlet Control HW Elev.	154.34 m		

Grades			
Upstream Invert	152.50 m	Downstream Invert	150.00 m
Length	91.60 m	Constructed Slope	0.027293 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	1.08 m
Slope Type	Steep	Normal Depth	0.51 m
Flow Regime	N/A	Critical Depth	1.05 m
Velocity Downstream	3.12 m/s	Critical Slope	0.003279 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	3.05 m
Section Size	3050 x 1830 mm	Rise	1.83 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	154.34 m	Upstream Velocity Head	0.52 m
Ke	0.50	Entrance Loss	0.26 m

Inlet Control Properties			
Inlet Control HW Elev.	154.24 m	Flow Control	Unsubmerged
Inlet Type	4 inch chamfers; 15° skewed headwall	Area Full	5.6 m²
K	0.52200	HDS 5 Chart	11
M	0.66700	HDS 5 Scale	3
C	0.04020	Equation Form	2
Y	0.73000		

Culvert Design Report
21-576/C

Peak Discharge Method: User-Specified			
Design Discharge	10.7000 m³/s	Check Discharge	16.8500 m³/s

Grades Model: Inverts			
Invert Upstream	120.50 m	Invert Downstream	119.70 m
Length	81.00 m	Slope	0.009877 m/m
Drop	0.80 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	121.20 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-3050 x 2440 mm Box	10.7000 m³/s	122.39 m	2.34 m/s
	Trial-2	1-3050 x 2130 mm Box	16.8500 m³/s	123.06 m	3.69 m/s

Culvert Design Report
21-576/C

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	122.39 m	Discharge	10.7000 m³/s
Headwater Depth/Height	0.77	Tailwater Elevation	121.20 m
Inlet Control HW Elev.	122.29 m	Control Type	Entrance Control
Outlet Control HW Elev.	122.39 m		

Grades			
Upstream Invert	120.50 m	Downstream Invert	119.70 m
Length	81.00 m	Constructed Slope	0.009877 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	1.50 m
Slope Type	Steep	Normal Depth	0.73 m
Flow Regime	N/A	Critical Depth	1.08 m
Velocity Downstream	2.34 m/s	Critical Slope	0.003299 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	3.05 m
Section Size	3050 x 2440 mm	Rise	2.44 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	122.39 m	Upstream Velocity Head	0.54 m
Ke	0.50	Entrance Loss	0.27 m

Inlet Control Properties			
Inlet Control HW Elev.	122.29 m	Flow Control	Unsubmerged
Inlet Type	3/4 inch chamfers; 15° skewed headwall	Area Full	7.4 m²
K	0.52200	HDS 5 Chart	11
M	0.66700	HDS 5 Scale	3
C	0.04020	Equation Form	2
Y	0.73000		

Culvert Design Report
21-576/C (Regional)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	123.27 m	Discharge	18.9600 m³/s
Headwater Depth/Height	1.13	Tailwater Elevation	121.20 m
Inlet Control HW Elev.	123.12 m	Control Type	Entrance Control
Outlet Control HW Elev.	123.27 m		

Grades			
Upstream Invert	120.50 m	Downstream Invert	119.70 m
Length	81.00 m	Constructed Slope	0.009877 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	1.17 m
Slope Type	Steep	Normal Depth	1.10 m
Flow Regime	Supercritical	Critical Depth	1.58 m
Velocity Downstream	5.33 m/s	Critical Slope	0.003674 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	3.05 m
Section Size	3050 x 2440 mm	Rise	2.44 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	123.27 m	Upstream Velocity Head	0.79 m
Ke	0.50	Entrance Loss	0.40 m

Inlet Control Properties			
Inlet Control HW Elev.	123.12 m	Flow Control	Unsubmerged
Inlet Type	3/4 inch chamfers; 15° skewed headwall	Area Full	7.4 m²
K	0.52200	HDS 5 Chart	11
M	0.66700	HDS 5 Scale	3
C	0.04020	Equation Form	2
Y	0.73000		

Culvert Design Report
21-576/C

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	123.06 m	Discharge	16.8500 m³/s
Headwater Depth/Height	1.20	Tailwater Elevation	121.20 m
Inlet Control HW Elev.	122.93 m	Control Type	Entrance Control
Outlet Control HW Elev.	123.06 m		

Grades			
Upstream Invert	120.50 m	Downstream Invert	119.70 m
Length	81.00 m	Constructed Slope	0.009877 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	1.50 m
Slope Type	Steep	Normal Depth	1.01 m
Flow Regime	N/A	Critical Depth	1.46 m
Velocity Downstream	3.69 m/s	Critical Slope	0.003579 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	3.05 m
Section Size	3050 x 2130 mm	Rise	2.13 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	123.06 m	Upstream Velocity Head	0.73 m
Ke	0.50	Entrance Loss	0.37 m

Inlet Control Properties			
Inlet Control HW Elev.	122.93 m	Flow Control	Unsubmerged
Inlet Type	3/4 inch chamfers; 15° skewed headwall	Area Full	6.5 m²
K	0.52200	HDS 5 Chart	11
M	0.66700	HDS 5 Scale	3
C	0.04020	Equation Form	2
Y	0.73000		

Culvert Design Report
21-576/C (Regional)

Peak Discharge Method: User-Specified			
Design Discharge	18.9600 m³/s	Check Discharge	0.0000 m³/s

Grades Model: Inverts			
Invert Upstream	120.50 m	Invert Downstream	119.70 m
Length	81.00 m	Slope	0.009877 m/m
Drop	0.80 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	121.20 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-3050 x 2440 mm Box	18.9600 m³/s	123.27 m	5.33 m/s

Culvert Design Report
Lyle - IC - 10+200 (Lyle) (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	0.2800 m³/s	Check Discharge	0.4100 m³/s

Grades Model: Inverts			
Invert Upstream	0.18 m	Invert Downstream	0.00 m
Length	35.00 m	Slope	0.005000 m/m
Drop	0.18 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	0.48 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-825 mm Circular	0.2800 m³/s	0.70 m	0.86 m/s
	Trial-2	1-825 mm Circular	0.4100 m³/s	0.82 m	1.25 m/s

Culvert Design Report
Lyle - IC - 10+200 (Lyle) (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	0.70 m	Discharge	0.2800 m³/s
Headwater Depth/Height	0.62	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	0.63 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.70 m		

Grades			
Upstream Invert	0.18 m	Downstream Invert	0.00 m
Length	35.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.48 m
Slope Type	Mild	Normal Depth	0.41 m
Flow Regime	Subcritical	Critical Depth	0.31 m
Velocity Downstream	0.86 m/s	Critical Slope	0.013834 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.70 m	Upstream Velocity Head	0.05 m
Ke	0.90	Entrance Loss	0.05 m

Inlet Control Properties			
Inlet Control HW Elev.	0.63 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Lyle - IC - 10+200b (Lyle) (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	0.65 m	Discharge	0.2800 m³/s
Headwater Depth/Height	0.63	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	0.58 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.65 m		

Grades			
Upstream Invert	0.13 m	Downstream Invert	0.00 m
Length	25.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.48 m
Slope Type	Mild	Normal Depth	0.41 m
Flow Regime	Subcritical	Critical Depth	0.31 m
Velocity Downstream	0.86 m/s	Critical Slope	0.013834 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.65 m	Upstream Velocity Head	0.05 m
Ke	0.90	Entrance Loss	0.04 m

Inlet Control Properties			
Inlet Control HW Elev.	0.58 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Lyle - IC - 10+200b (Lyle) (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	0.77 m	Discharge	0.4100 m³/s
Headwater Depth/Height	0.77	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	0.70 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.77 m		

Grades			
Upstream Invert	0.13 m	Downstream Invert	0.00 m
Length	25.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.48 m
Slope Type	Mild	Normal Depth	0.52 m
Flow Regime	Subcritical	Critical Depth	0.38 m
Velocity Downstream	1.25 m/s	Critical Slope	0.014404 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.77 m	Upstream Velocity Head	0.07 m
Ke	0.90	Entrance Loss	0.06 m

Inlet Control Properties			
Inlet Control HW Elev.	0.70 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Lyle - IC - 10+200 (Lyle) (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	0.82 m	Discharge	0.4100 m³/s
Headwater Depth/Height	0.77	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	0.75 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.82 m		

Grades			
Upstream Invert	0.18 m	Downstream Invert	0.00 m
Length	35.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.48 m
Slope Type	Mild	Normal Depth	0.52 m
Flow Regime	Subcritical	Critical Depth	0.38 m
Velocity Downstream	1.25 m/s	Critical Slope	0.014404 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.82 m	Upstream Velocity Head	0.07 m
Ke	0.90	Entrance Loss	0.06 m

Inlet Control Properties			
Inlet Control HW Elev.	0.75 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Lyle - IC - 10+200b (Lyle) (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	0.2800 m³/s	Check Discharge	0.4100 m³/s

Grades Model: Inverts			
Invert Upstream	0.13 m	Invert Downstream	0.00 m
Length	25.00 m	Slope	0.005000 m/m
Drop	0.13 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	0.48 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-825 mm Circular	0.2800 m³/s	0.65 m	0.86 m/s
	Trial-2	1-825 mm Circular	0.4100 m³/s	0.77 m	1.25 m/s

Culvert Design Report
Lyle - IC - 10+230 (W-N/S) (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	0.2600 m³/s	Check Discharge	0.4000 m³/s

Grades Model: Inverts			
Invert Upstream	0.13 m	Invert Downstream	0.00 m
Length	25.00 m	Slope	0.005000 m/m
Drop	0.13 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	0.48 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-825 mm Circular	0.2600 m³/s	0.63 m	0.80 m/s
	Trial-2	1-825 mm Circular	0.4000 m³/s	0.76 m	1.22 m/s

Culvert Design Report
Lyle - IC - 10+230 (W-N/S) (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	0.63 m	Discharge	0.2600 m³/s
Headwater Depth/Height	0.61	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	0.56 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.63 m		

Grades			
Upstream Invert	0.13 m	Downstream Invert	0.00 m
Length	25.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.48 m
Slope Type	Mild	Normal Depth	0.40 m
Flow Regime	Subcritical	Critical Depth	0.30 m
Velocity Downstream	0.80 m/s	Critical Slope	0.013774 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.63 m	Upstream Velocity Head	0.04 m
Ke	0.90	Entrance Loss	0.04 m

Inlet Control Properties			
Inlet Control HW Elev.	0.56 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Lyle - IC - 10+230 (W-N/S) (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	0.76 m	Discharge	0.4000 m³/s
Headwater Depth/Height	0.76	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	0.69 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.76 m		

Grades			
Upstream Invert	0.13 m	Downstream Invert	0.00 m
Length	25.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.48 m
Slope Type	Mild	Normal Depth	0.52 m
Flow Regime	Subcritical	Critical Depth	0.37 m
Velocity Downstream	1.22 m/s	Critical Slope	0.014367 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.76 m	Upstream Velocity Head	0.07 m
Ke	0.90	Entrance Loss	0.06 m

Inlet Control Properties			
Inlet Control HW Elev.	0.69 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Lyle - IC - 10+300 (Lyle) (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	0.1300 m³/s	Check Discharge	0.2000 m³/s

Grades Model: Inverts			
Invert Upstream	0.13 m	Invert Downstream	0.00 m
Length	25.00 m	Slope	0.005000 m/m
Drop	0.13 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater

Tailwater Elevation	0.48 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-825 mm Circular	0.1300 m³/s	0.53 m	0.40 m/s
	Trial-2	1-825 mm Circular	0.2000 m³/s	0.58 m	0.61 m/s

Culvert Design Report
Lyle - IC - 10+350 (W-N/S)

Peak Discharge Method: User-Specified			
Design Discharge	0.3000 m³/s	Check Discharge	0.4500 m³/s

Grades Model: Inverts			
Invert Upstream	164.25 m	Invert Downstream	164.00 m
Length	19.90 m	Slope	0.012563 m/m
Drop	0.25 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater

Tailwater Elevation	164.36 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-600 mm Circular	0.3000 m³/s	164.86 m	1.67 m/s
	Trial-2	1-600 mm Circular	0.4500 m³/s	165.07 m	2.00 m/s

Culvert Design Report
Lyle - IC - 10+350 (W-N/S)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	164.86 m	Discharge	0.3000 m³/s
Headwater Depth/Height	1.00	Tailwater Elevation	164.36 m
Inlet Control HW Elev.	164.82 m	Control Type	Outlet Control
Outlet Control HW Elev.	164.86 m		

Grades			
Upstream Invert	164.25 m	Downstream Invert	164.00 m
Length	19.90 m	Constructed Slope	0.012563 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.36 m
Slope Type	Mild	Normal Depth	0.40 m
Flow Regime	Subcritical	Critical Depth	0.36 m
Velocity Downstream	1.67 m/s	Critical Slope	0.018095 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.61 m
Section Size	600 mm	Rise	0.61 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	164.86 m	Upstream Velocity Head	0.11 m
Ke	0.90	Entrance Loss	0.10 m

Inlet Control Properties			
Inlet Control HW Elev.	164.82 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.3 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Lyle - IC - 10+300 (Lyle) (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	0.53 m	Discharge	0.1300 m³/s
Headwater Depth/Height	0.48	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	0.48 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.53 m		

Grades			
Upstream Invert	0.13 m	Downstream Invert	0.00 m
Length	25.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.48 m
Slope Type	Mild	Normal Depth	0.27 m
Flow Regime	Subcritical	Critical Depth	0.21 m
Velocity Downstream	0.40 m/s	Critical Slope	0.013746 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.53 m	Upstream Velocity Head	0.02 m
Ke	0.90	Entrance Loss	0.01 m

Inlet Control Properties			
Inlet Control HW Elev.	0.48 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Lyle - IC - 10+300 (Lyle) (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	0.58 m	Discharge	0.2000 m³/s
Headwater Depth/Height	0.54	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	0.50 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.58 m		

Grades			
Upstream Invert	0.13 m	Downstream Invert	0.00 m
Length	25.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.48 m
Slope Type	Mild	Normal Depth	0.34 m
Flow Regime	Subcritical	Critical Depth	0.26 m
Velocity Downstream	0.61 m/s	Critical Slope	0.013665 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.58 m	Upstream Velocity Head	0.03 m
Ke	0.90	Entrance Loss	0.03 m

Inlet Control Properties			
Inlet Control HW Elev.	0.50 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Lyle - IC - 10+350 (W-N/S)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	165.07 m	Discharge	0.4500 m³/s
Headwater Depth/Height	1.34	Tailwater Elevation	164.36 m
Inlet Control HW Elev.	165.03 m	Control Type	Outlet Control
Outlet Control HW Elev.	165.07 m		

Grades			
Upstream Invert	164.25 m	Downstream Invert	164.00 m
Length	19.90 m	Constructed Slope	0.012563 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.44 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.44 m
Velocity Downstream	2.00 m/s	Critical Slope	0.022428 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.61 m
Section Size	600 mm	Rise	0.61 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	165.07 m	Upstream Velocity Head	0.13 m
Ke	0.90	Entrance Loss	0.11 m

Inlet Control Properties			
Inlet Control HW Elev.	165.03 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.3 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Lyle - IC - 10+350 (W-N/S) (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	0.2200 m³/s	Check Discharge	0.3400 m³/s

Grades Model: Inverts			
Invert Upstream	0.18 m	Invert Downstream	0.00 m
Length	35.00 m	Slope	0.005000 m/m
Drop	0.18 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater

Tailwater Elevation	0.48 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-825 mm Circular	0.2200 m³/s	0.64 m	0.67 m/s
	Trial-2	1-825 mm Circular	0.3400 m³/s	0.75 m	1.04 m/s

Culvert Design Report
Lyle - IC - 10+350 (W-N/S) (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	0.64 m	Discharge	0.2200 m³/s
Headwater Depth/Height	0.55	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	0.57 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.64 m		

Grades			
Upstream Invert	0.18 m	Downstream Invert	0.00 m
Length	35.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.48 m
Slope Type	Mild	Normal Depth	0.36 m
Flow Regime	Subcritical	Critical Depth	0.27 m
Velocity Downstream	0.67 m/s	Critical Slope	0.013688 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.64 m	Upstream Velocity Head	0.04 m
Ke	0.90	Entrance Loss	0.04 m

Inlet Control Properties			
Inlet Control HW Elev.	0.57 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Lyle - IC - 10+350 (W-N/S) (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	0.75 m	Discharge	0.3400 m³/s
Headwater Depth/Height	0.69	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	0.68 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.75 m		

Grades			
Upstream Invert	0.18 m	Downstream Invert	0.00 m
Length	35.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.48 m
Slope Type	Mild	Normal Depth	0.46 m
Flow Regime	Subcritical	Critical Depth	0.34 m
Velocity Downstream	1.04 m/s	Critical Slope	0.014065 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.75 m	Upstream Velocity Head	0.06 m
Ke	0.90	Entrance Loss	0.05 m

Inlet Control Properties			
Inlet Control HW Elev.	0.68 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Lyle - IC - 10+450 (E-N/S)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	171.33 m	Discharge	0.6300 m³/s
Headwater Depth/Height	2.19	Tailwater Elevation	170.11 m
Inlet Control HW Elev.	171.17 m	Control Type	Outlet Control
Outlet Control HW Elev.	171.33 m		

Grades			
Upstream Invert	170.00 m	Downstream Invert	169.75 m
Length	17.30 m	Constructed Slope	0.014451 m/m

Hydraulic Profile			
Profile	CompositeM2PressureProfile	Depth, Downstream	0.51 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.51 m
Velocity Downstream	2.40 m/s	Critical Slope	0.031526 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.61 m
Section Size	600 mm	Rise	0.61 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	171.33 m	Upstream Velocity Head	0.24 m
Ke	0.90	Entrance Loss	0.21 m

Inlet Control Properties			
Inlet Control HW Elev.	171.17 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.3 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Lyle - IC - 10+450 (E-N/S) (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	0.4200 m³/s	Check Discharge	0.6300 m³/s

Grades Model: Inverts			
Invert Upstream	0.13 m	Invert Downstream	0.00 m
Length	25.00 m	Slope	0.005000 m/m
Drop	0.13 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	0.48 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-825 mm Circular	0.4200 m³/s	0.78 m	1.29 m/s
	Trial-2	1-825 mm Circular	0.6300 m³/s	0.96 m	1.93 m/s

Culvert Design Report
Lyle - IC - 10+450 (E-N/S)

Peak Discharge Method: User-Specified			
Design Discharge	0.4200 m³/s	Check Discharge	0.6300 m³/s

Grades Model: Inverts			
Invert Upstream	170.00 m	Invert Downstream	169.75 m
Length	17.30 m	Slope	0.014451 m/m
Drop	0.25 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	170.11 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-600 mm Circular	0.4200 m³/s	170.76 m	1.94 m/s
	Trial-2	1-600 mm Circular	0.6300 m³/s	171.33 m	2.40 m/s

Culvert Design Report
Lyle - IC - 10+450 (E-N/S)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	170.76 m	Discharge	0.4200 m³/s
Headwater Depth/Height	1.25	Tailwater Elevation	170.11 m
Inlet Control HW Elev.	170.74 m	Control Type	Outlet Control
Outlet Control HW Elev.	170.76 m		

Grades			
Upstream Invert	170.00 m	Downstream Invert	169.75 m
Length	17.30 m	Constructed Slope	0.014451 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.42 m
Slope Type	Mild	Normal Depth	0.50 m
Flow Regime	Subcritical	Critical Depth	0.42 m
Velocity Downstream	1.94 m/s	Critical Slope	0.021376 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.61 m
Section Size	600 mm	Rise	0.61 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	170.76 m	Upstream Velocity Head	0.14 m
Ke	0.90	Entrance Loss	0.12 m

Inlet Control Properties			
Inlet Control HW Elev.	170.74 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.3 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Lyle - IC - 10+450 (E-N/S) (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	0.78 m	Discharge	0.4200 m³/s
Headwater Depth/Height	0.78	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	0.71 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.78 m		

Grades			
Upstream Invert	0.13 m	Downstream Invert	0.00 m
Length	25.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.48 m
Slope Type	Mild	Normal Depth	0.53 m
Flow Regime	Subcritical	Critical Depth	0.38 m
Velocity Downstream	1.29 m/s	Critical Slope	0.014463 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.78 m	Upstream Velocity Head	0.07 m
Ke	0.90	Entrance Loss	0.06 m

Inlet Control Properties			
Inlet Control HW Elev.	0.71 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Lyle - IC - 10+450 (E-N/S) (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	0.96 m	Discharge	0.6300 m³/s
Headwater Depth/Height	1.00	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	0.89 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.96 m		

Grades			
Upstream Invert	0.13 m	Downstream Invert	0.00 m
Length	25.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.48 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.48 m
Velocity Downstream	1.93 m/s	Critical Slope	0.015964 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.96 m	Upstream Velocity Head	0.09 m
Ke	0.90	Entrance Loss	0.08 m

Inlet Control Properties			
Inlet Control HW Elev.	0.89 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Lyle - IC - 2012

Peak Discharge Method: User-Specified			
Design Discharge	0.4400 m³/s	Check Discharge	0.6600 m³/s

Grades Model: Inverts			
Invert Upstream	167.50 m	Invert Downstream	167.25 m
Length	17.90 m	Slope	0.013966 m/m
Drop	0.25 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	167.61 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-600 mm Circular	0.4400 m³/s	168.29 m	1.98 m/s
	Trial-2	1-600 mm Circular	0.6600 m³/s	168.96 m	2.48 m/s

Culvert Design Report
Lyle - IC - 2012

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	168.29 m	Discharge	0.4400 m³/s
Headwater Depth/Height	1.29	Tailwater Elevation	167.61 m
Inlet Control HW Elev.	168.27 m	Control Type	Outlet Control
Outlet Control HW Elev.	168.29 m		

Grades			
Upstream Invert	167.50 m	Downstream Invert	167.25 m
Length	17.90 m	Constructed Slope	0.013966 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.43 m
Slope Type	Mild	Normal Depth	0.56 m
Flow Regime	Subcritical	Critical Depth	0.43 m
Velocity Downstream	1.98 m/s	Critical Slope	0.022065 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.61 m
Section Size	600 mm	Rise	0.61 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	168.29 m	Upstream Velocity Head	0.14 m
Ke	0.90	Entrance Loss	0.12 m

Inlet Control Properties			
Inlet Control HW Elev.	168.27 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.3 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Lyle - IC - 2050/51/54

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	163.94 m	Discharge	0.4700 m³/s
Headwater Depth/Height	0.82	Tailwater Elevation	162.48 m
Inlet Control HW Elev.	163.88 m	Control Type	Outlet Control
Outlet Control HW Elev.	163.94 m		

Grades			
Upstream Invert	163.25 m	Downstream Invert	162.00 m
Length	203.00 m	Constructed Slope	0.006158 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.48 m
Slope Type	Mild	Normal Depth	0.54 m
Flow Regime	Subcritical	Critical Depth	0.41 m
Velocity Downstream	1.44 m/s	Critical Slope	0.014770 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	163.94 m	Upstream Velocity Head	0.08 m
Ke	0.90	Entrance Loss	0.07 m

Inlet Control Properties			
Inlet Control HW Elev.	163.88 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Lyle - IC - 2050/51/54

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	164.19 m	Discharge	0.6900 m³/s
Headwater Depth/Height	1.12	Tailwater Elevation	162.48 m
Inlet Control HW Elev.	164.06 m	Control Type	Outlet Control
Outlet Control HW Elev.	164.19 m		

Grades			
Upstream Invert	163.25 m	Downstream Invert	162.00 m
Length	203.00 m	Constructed Slope	0.006158 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.50 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.50 m
Velocity Downstream	2.02 m/s	Critical Slope	0.016487 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	164.19 m	Upstream Velocity Head	0.09 m
Ke	0.90	Entrance Loss	0.08 m

Inlet Control Properties			
Inlet Control HW Elev.	164.06 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Lyle - IC - 2012

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	168.96 m	Discharge	0.6600 m³/s
Headwater Depth/Height	2.40	Tailwater Elevation	167.61 m
Inlet Control HW Elev.	168.75 m	Control Type	Outlet Control
Outlet Control HW Elev.	168.96 m		

Grades			
Upstream Invert	167.50 m	Downstream Invert	167.25 m
Length	17.90 m	Constructed Slope	0.013966 m/m

Hydraulic Profile			
Profile	CompositeM2PressureProfile	Depth, Downstream	0.52 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.52 m
Velocity Downstream	2.48 m/s	Critical Slope	0.033631 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.61 m
Section Size	600 mm	Rise	0.61 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	168.96 m	Upstream Velocity Head	0.26 m
Ke	0.90	Entrance Loss	0.23 m

Inlet Control Properties			
Inlet Control HW Elev.	168.75 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.3 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Lyle - IC - 2050/51/54

Peak Discharge Method: User-Specified			
Design Discharge	0.4700 m³/s	Check Discharge	0.6900 m³/s

Grades Model: Inverts			
Invert Upstream	163.25 m	Invert Downstream	162.00 m
Length	203.00 m	Slope	0.006158 m/m
Drop	1.25 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	162.48 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-825 mm Circular	0.4700 m³/s	163.94 m	1.44 m/s
	Trial-2	1-825 mm Circular	0.6900 m³/s	164.19 m	2.02 m/s

Culvert Design Report
Lyle - IC - 9+780 (N-E) (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	0.2200 m³/s	Check Discharge	0.3400 m³/s

Grades Model: Inverts			
Invert Upstream	0.10 m	Invert Downstream	0.00 m
Length	20.00 m	Slope	0.005000 m/m
Drop	0.10 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	0.48 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-825 mm Circular	0.2200 m³/s	0.58 m	0.67 m/s
	Trial-2	1-825 mm Circular	0.3400 m³/s	0.68 m	1.04 m/s

Culvert Design Report
Lyle - IC - 9+780 (N-E) (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	0.58 m	Discharge	0.2200 m³/s
Headwater Depth/Height	0.57	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	0.49 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.58 m		

Grades			
Upstream Invert	0.10 m	Downstream Invert	0.00 m
Length	20.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.48 m
Slope Type	Mild	Normal Depth	0.36 m
Flow Regime	Subcritical	Critical Depth	0.27 m
Velocity Downstream	0.67 m/s	Critical Slope	0.013688 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.58 m	Upstream Velocity Head	0.03 m
Ke	0.90	Entrance Loss	0.03 m

Inlet Control Properties			
Inlet Control HW Elev.	0.49 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Lyle - IC - 9+780 (N-E) (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	0.68 m	Discharge	0.3400 m³/s
Headwater Depth/Height	0.69	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	0.61 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.68 m		

Grades			
Upstream Invert	0.10 m	Downstream Invert	0.00 m
Length	20.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.48 m
Slope Type	Mild	Normal Depth	0.46 m
Flow Regime	Subcritical	Critical Depth	0.34 m
Velocity Downstream	1.04 m/s	Critical Slope	0.014065 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.68 m	Upstream Velocity Head	0.06 m
Ke	0.90	Entrance Loss	0.05 m

Inlet Control Properties			
Inlet Control HW Elev.	0.61 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Lyle - IC - 9+800 (Lyle) (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	0.71 m	Discharge	0.2200 m³/s
Headwater Depth/Height	0.54	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	0.64 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.71 m		

Grades			
Upstream Invert	0.25 m	Downstream Invert	0.00 m
Length	50.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.48 m
Slope Type	Mild	Normal Depth	0.36 m
Flow Regime	Subcritical	Critical Depth	0.27 m
Velocity Downstream	0.67 m/s	Critical Slope	0.013688 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.71 m	Upstream Velocity Head	0.04 m
Ke	0.90	Entrance Loss	0.04 m

Inlet Control Properties			
Inlet Control HW Elev.	0.64 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Lyle - IC - 9+800 (Lyle) (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	0.2200 m³/s	Check Discharge	0.3400 m³/s

Grades Model: Inverts			
Invert Upstream	0.25 m	Invert Downstream	0.00 m
Length	50.00 m	Slope	0.005000 m/m
Drop	0.25 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater

Tailwater Elevation	0.48 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-825 mm Circular	0.2200 m³/s	0.71 m	0.67 m/s
	Trial-2	1-825 mm Circular	0.3400 m³/s	0.83 m	1.04 m/s

Culvert Design Report
Lyle - IC - 9+800 (Lyle) (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	0.83 m	Discharge	0.3400 m³/s
Headwater Depth/Height	0.69	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	0.76 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.83 m		

Grades			
Upstream Invert	0.25 m	Downstream Invert	0.00 m
Length	50.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.48 m
Slope Type	Mild	Normal Depth	0.46 m
Flow Regime	Subcritical	Critical Depth	0.34 m
Velocity Downstream	1.04 m/s	Critical Slope	0.014065 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.83 m	Upstream Velocity Head	0.06 m
Ke	0.90	Entrance Loss	0.05 m

Inlet Control Properties			
Inlet Control HW Elev.	0.76 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Lyle - IC - 9+975 (S-W) (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	0.2800 m³/s	Check Discharge	0.4100 m³/s

Grades Model: Inverts			
Invert Upstream	0.23 m	Invert Downstream	0.00 m
Length	45.00 m	Slope	0.005000 m/m
Drop	0.23 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater

Tailwater Elevation	0.48 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-825 mm Circular	0.2800 m³/s	0.74 m	0.86 m/s
	Trial-2	1-825 mm Circular	0.4100 m³/s	0.87 m	1.25 m/s

Culvert Design Report
Lyle - IC - 9+975 (S-W) (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	0.87 m	Discharge	0.4100 m³/s
Headwater Depth/Height	0.77	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	0.80 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.87 m		

Grades			
Upstream Invert	0.23 m	Downstream Invert	0.00 m
Length	45.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.48 m
Slope Type	Mild	Normal Depth	0.52 m
Flow Regime	Subcritical	Critical Depth	0.38 m
Velocity Downstream	1.25 m/s	Critical Slope	0.014404 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.87 m	Upstream Velocity Head	0.07 m
Ke	0.90	Entrance Loss	0.06 m

Inlet Control Properties			
Inlet Control HW Elev.	0.80 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Lyle - IC - 9+975 (S-W) (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	0.74 m	Discharge	0.2800 m³/s
Headwater Depth/Height	0.62	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	0.68 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.74 m		

Grades			
Upstream Invert	0.23 m	Downstream Invert	0.00 m
Length	45.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.48 m
Slope Type	Mild	Normal Depth	0.41 m
Flow Regime	Subcritical	Critical Depth	0.31 m
Velocity Downstream	0.86 m/s	Critical Slope	0.013834 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.74 m	Upstream Velocity Head	0.05 m
Ke	0.90	Entrance Loss	0.05 m

Inlet Control Properties			
Inlet Control HW Elev.	0.68 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Percy - IC - 10+025 (Percy)

Peak Discharge Method: User-Specified			
Design Discharge	0.2300 m³/s	Check Discharge	0.3400 m³/s

Grades Model: Inverts			
Invert Upstream	166.50 m	Invert Downstream	166.25 m
Length	29.90 m	Slope	0.008361 m/m
Drop	0.25 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater

Tailwater Elevation	166.79 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-900 mm Circular	0.2300 m³/s	166.94 m	0.57 m/s
	Trial-2	1-900 mm Circular	0.3400 m³/s	167.05 m	0.84 m/s

Culvert Design Report
Percy - IC - 10+025 (Percy)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	166.94 m	Discharge	0.2300 m³/s
Headwater Depth/Height	0.48	Tailwater Elevation	166.79 m
Inlet Control HW Elev.	166.89 m	Control Type	Outlet Control
Outlet Control HW Elev.	166.94 m		

Grades			
Upstream Invert	166.50 m	Downstream Invert	166.25 m
Length	29.90 m	Constructed Slope	0.008361 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.54 m
Slope Type	Mild	Normal Depth	0.31 m
Flow Regime	Subcritical	Critical Depth	0.27 m
Velocity Downstream	0.57 m/s	Critical Slope	0.013268 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	166.94 m	Upstream Velocity Head	0.06 m
Ke	0.90	Entrance Loss	0.05 m

Inlet Control Properties			
Inlet Control HW Elev.	166.89 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Percy - IC - 10+025 (Percy)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	167.05 m	Discharge	0.3400 m³/s
Headwater Depth/Height	0.60	Tailwater Elevation	166.79 m
Inlet Control HW Elev.	166.99 m	Control Type	Outlet Control
Outlet Control HW Elev.	167.05 m		

Grades			
Upstream Invert	166.50 m	Downstream Invert	166.25 m
Length	29.90 m	Constructed Slope	0.008361 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.54 m
Slope Type	Mild	Normal Depth	0.38 m
Flow Regime	Subcritical	Critical Depth	0.34 m
Velocity Downstream	0.84 m/s	Critical Slope	0.013419 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	167.05 m	Upstream Velocity Head	0.08 m
Ke	0.90	Entrance Loss	0.07 m

Inlet Control Properties			
Inlet Control HW Elev.	166.99 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Percy - IC - 10+025 (Percy) (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	2.1100 m³/s	Check Discharge	3.1400 m³/s

Grades Model: Inverts			
Invert Upstream	0.30 m	Invert Downstream	0.00 m
Length	60.00 m	Slope	0.005000 m/m
Drop	0.30 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater			
Tailwater Elevation	0.54 m		

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-1830 x 910 mm Box	2.1100 m³/s	1.12 m	2.14 m/s
	Trial-2	1-1830 x 910 mm Box	3.1400 m³/s	1.54 m	2.79 m/s

Culvert Design Report
Percy - IC - 10+025 (Percy) (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	1.12 m	Discharge	2.1100 m³/s
Headwater Depth/Height	0.90	Tailwater Elevation	0.54 m
Inlet Control HW Elev.	1.11 m	Control Type	Entrance Control
Outlet Control HW Elev.	1.12 m		

Grades			
Upstream Invert	0.30 m	Downstream Invert	0.00 m
Length	60.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.54 m
Slope Type	Steep	Normal Depth	0.46 m
Flow Regime	N/A	Critical Depth	0.51 m
Velocity Downstream	2.14 m/s	Critical Slope	0.003750 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.83 m
Section Size	1830 x 910 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	1.12 m	Upstream Velocity Head	0.26 m
Ke	0.20	Entrance Loss	0.05 m

Inlet Control Properties			
Inlet Control HW Elev.	1.11 m	Flow Control	N/A
Inlet Type	90° headwall w 45° bevels	Area Full	1.7 m²
K	0.49500	HDS 5 Chart	10
M	0.66700	HDS 5 Scale	2
C	0.03140	Equation Form	2
Y	0.82000		

Culvert Design Report
Percy - IC - 10+025 (Percy) (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	1.54 m	Discharge	3.1400 m³/s
Headwater Depth/Height	1.36	Tailwater Elevation	0.54 m
Inlet Control HW Elev.	1.46 m	Control Type	Entrance Control
Outlet Control HW Elev.	1.54 m		

Grades			
Upstream Invert	0.30 m	Downstream Invert	0.00 m
Length	60.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.62 m
Slope Type	Steep	Normal Depth	0.62 m
Flow Regime	Supercritical	Critical Depth	0.67 m
Velocity Downstream	2.79 m/s	Critical Slope	0.003942 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.83 m
Section Size	1830 x 910 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	1.54 m	Upstream Velocity Head	0.33 m
Ke	0.70	Entrance Loss	0.23 m

Inlet Control Properties			
Inlet Control HW Elev.	1.46 m	Flow Control	N/A
Inlet Type	0° wingwall flares	Area Full	1.7 m²
K	0.06100	HDS 5 Chart	8
M	0.75000	HDS 5 Scale	3
C	0.04230	Equation Form	1
Y	0.82000		

Culvert Design Report
Percy - IC - 10+130 (E-N/S)

Peak Discharge Method: User-Specified			
Design Discharge	0.2000 m³/s	Check Discharge	0.2900 m³/s

Grades Model: Inverts			
Invert Upstream	170.75 m	Invert Downstream	170.50 m
Length	16.80 m	Slope	0.014881 m/m
Drop	0.25 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater			
Tailwater Elevation	170.77 m		

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-600 mm Circular	0.2000 m³/s	171.24 m	1.48 m/s
	Trial-2	1-600 mm Circular	0.2900 m³/s	171.36 m	1.68 m/s

Culvert Design Report
Percy - IC - 10+130 (E-N/S)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	171.24 m	Discharge	0.2000 m³/s
Headwater Depth/Height	0.81	Tailwater Elevation	170.77 m
Inlet Control HW Elev.	171.19 m	Control Type	Outlet Control
Outlet Control HW Elev.	171.24 m		

Grades			
Upstream Invert	170.75 m	Downstream Invert	170.50 m
Length	16.80 m	Constructed Slope	0.014881 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.29 m
Slope Type	Mild	Normal Depth	0.29 m
Flow Regime	Subcritical	Critical Depth	0.29 m
Velocity Downstream	1.48 m/s	Critical Slope	0.016239 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.61 m
Section Size	600 mm	Rise	0.61 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	171.24 m	Upstream Velocity Head	0.10 m
Ke	0.90	Entrance Loss	0.09 m

Inlet Control Properties			
Inlet Control HW Elev.	171.19 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.3 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Percy - IC - 10+130 (E-N/S)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	171.36 m	Discharge	0.2900 m³/s
Headwater Depth/Height	1.00	Tailwater Elevation	170.77 m
Inlet Control HW Elev.	171.31 m	Control Type	Outlet Control
Outlet Control HW Elev.	171.36 m		

Grades			
Upstream Invert	170.75 m	Downstream Invert	170.50 m
Length	16.80 m	Constructed Slope	0.014881 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.35 m
Slope Type	Mild	Normal Depth	0.37 m
Flow Regime	Subcritical	Critical Depth	0.35 m
Velocity Downstream	1.68 m/s	Critical Slope	0.017876 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.61 m
Section Size	600 mm	Rise	0.61 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	171.36 m	Upstream Velocity Head	0.12 m
Ke	0.90	Entrance Loss	0.11 m

Inlet Control Properties			
Inlet Control HW Elev.	171.31 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.3 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Percy - IC - 10+130 (E-N/S) (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	2.1100 m³/s	Check Discharge	3.1400 m³/s

Grades Model: Inverts			
Invert Upstream	0.15 m	Invert Downstream	0.00 m
Length	30.00 m	Slope	0.005000 m/m
Drop	0.15 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	0.54 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-1830 x 910 mm Box	2.1100 m³/s	0.97 m	2.14 m/s
	Trial-2	1-1830 x 910 mm Box	3.1400 m³/s	1.39 m	2.79 m/s

Culvert Design Report
Percy - IC - 10+130 (E-N/S) (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	0.97 m	Discharge	2.1100 m³/s
Headwater Depth/Height	0.90	Tailwater Elevation	0.54 m
Inlet Control HW Elev.	0.96 m	Control Type	Entrance Control
Outlet Control HW Elev.	0.97 m		

Grades			
Upstream Invert	0.15 m	Downstream Invert	0.00 m
Length	30.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.54 m
Slope Type	Steep	Normal Depth	0.46 m
Flow Regime	N/A	Critical Depth	0.51 m
Velocity Downstream	2.14 m/s	Critical Slope	0.003750 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.83 m
Section Size	1830 x 910 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.97 m	Upstream Velocity Head	0.26 m
Ke	0.20	Entrance Loss	0.05 m

Inlet Control Properties			
Inlet Control HW Elev.	0.96 m	Flow Control	N/A
Inlet Type	90° headwall w 45° bevels	Area Full	1.7 m²
K	0.49500	HDS 5 Chart	10
M	0.66700	HDS 5 Scale	2
C	0.03140	Equation Form	2
Y	0.82000		

Culvert Design Report
Percy - IC - 10+510 (W-N/S)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	165.59 m	Discharge	0.3900 m³/s
Headwater Depth/Height	0.65	Tailwater Elevation	165.29 m
Inlet Control HW Elev.	165.53 m	Control Type	Outlet Control
Outlet Control HW Elev.	165.59 m		

Grades			
Upstream Invert	165.00 m	Downstream Invert	164.75 m
Length	28.00 m	Constructed Slope	0.008929 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.54 m
Slope Type	Mild	Normal Depth	0.40 m
Flow Regime	Subcritical	Critical Depth	0.36 m
Velocity Downstream	0.97 m/s	Critical Slope	0.013557 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	165.59 m	Upstream Velocity Head	0.10 m
Ke	0.90	Entrance Loss	0.09 m

Inlet Control Properties			
Inlet Control HW Elev.	165.53 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Percy - IC - 10+510 (W-N/S)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	165.74 m	Discharge	0.5800 m³/s
Headwater Depth/Height	0.81	Tailwater Elevation	165.29 m
Inlet Control HW Elev.	165.68 m	Control Type	Outlet Control
Outlet Control HW Elev.	165.74 m		

Grades			
Upstream Invert	165.00 m	Downstream Invert	164.75 m
Length	28.00 m	Constructed Slope	0.008929 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.54 m
Slope Type	Mild	Normal Depth	0.51 m
Flow Regime	Subcritical	Critical Depth	0.44 m
Velocity Downstream	1.44 m/s	Critical Slope	0.014327 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	165.74 m	Upstream Velocity Head	0.12 m
Ke	0.90	Entrance Loss	0.11 m

Inlet Control Properties			
Inlet Control HW Elev.	165.68 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Percy - IC - 10+130 (E-N/S) (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	1.39 m	Discharge	3.1400 m³/s
Headwater Depth/Height	1.36	Tailwater Elevation	0.54 m
Inlet Control HW Elev.	1.31 m	Control Type	Entrance Control
Outlet Control HW Elev.	1.39 m		

Grades			
Upstream Invert	0.15 m	Downstream Invert	0.00 m
Length	30.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.62 m
Slope Type	Steep	Normal Depth	0.62 m
Flow Regime	Supercritical	Critical Depth	0.67 m
Velocity Downstream	2.79 m/s	Critical Slope	0.003942 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.83 m
Section Size	1830 x 910 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	1.39 m	Upstream Velocity Head	0.33 m
Ke	0.70	Entrance Loss	0.23 m

Inlet Control Properties			
Inlet Control HW Elev.	1.31 m	Flow Control	N/A
Inlet Type	0° wingwall flares	Area Full	1.7 m²
K	0.06100	HDS 5 Chart	8
M	0.75000	HDS 5 Scale	3
C	0.04230	Equation Form	1
Y	0.82000		

Culvert Design Report
Percy - IC - 10+510 (W-N/S)

Peak Discharge Method: User-Specified			
Design Discharge	0.3900 m³/s	Check Discharge	0.5800 m³/s

Grades Model: Inverts			
Invert Upstream	165.00 m	Invert Downstream	164.75 m
Length	28.00 m	Slope	0.008929 m/m
Drop	0.25 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	165.29 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-900 mm Circular	0.3900 m³/s	165.59 m	0.97 m/s
	Trial-2	1-900 mm Circular	0.5800 m³/s	165.74 m	1.44 m/s

Culvert Design Report
Percy - IC - 10+510 (W-N/S) (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	0.3900 m³/s	Check Discharge	0.5800 m³/s

Grades Model: Inverts			
Invert Upstream	0.20 m	Invert Downstream	0.00 m
Length	40.00 m	Slope	0.005000 m/m
Drop	0.20 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	0.54 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-900 mm Circular	0.3900 m³/s	0.80 m	0.97 m/s
	Trial-2	1-900 mm Circular	0.5800 m³/s	0.96 m	1.44 m/s

Culvert Design Report
Percy - IC - 10+510 (W-N/S) (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	0.80 m	Discharge	0.3900 m³/s
Headwater Depth/Height	0.66	Tailwater Elevation	0.54 m
Inlet Control HW Elev.	0.73 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.80 m		

Grades			
Upstream Invert	0.20 m	Downstream Invert	0.00 m
Length	40.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.54 m
Slope Type	Mild	Normal Depth	0.48 m
Flow Regime	Subcritical	Critical Depth	0.36 m
Velocity Downstream	0.97 m/s	Critical Slope	0.013557 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.80 m	Upstream Velocity Head	0.06 m
Ke	0.90	Entrance Loss	0.05 m

Inlet Control Properties			
Inlet Control HW Elev.	0.73 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Percy - IC - 10+510 (W-N/S) (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	0.96 m	Discharge	0.5800 m³/s
Headwater Depth/Height	0.83	Tailwater Elevation	0.54 m
Inlet Control HW Elev.	0.88 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.96 m		

Grades			
Upstream Invert	0.20 m	Downstream Invert	0.00 m
Length	40.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.54 m
Slope Type	Mild	Normal Depth	0.62 m
Flow Regime	Subcritical	Critical Depth	0.44 m
Velocity Downstream	1.44 m/s	Critical Slope	0.014327 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.96 m	Upstream Velocity Head	0.08 m
Ke	0.90	Entrance Loss	0.07 m

Inlet Control Properties			
Inlet Control HW Elev.	0.88 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Percy - IC - 10+610 (W-N/S)

Peak Discharge Method: User-Specified			
Design Discharge	3.9800 m³/s	Check Discharge	5.9200 m³/s

Grades Model: Inverts			
Invert Upstream	161.00 m	Invert Downstream	160.50 m
Length	48.60 m	Slope	0.010288 m/m
Drop	0.50 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater

Tailwater Elevation	161.40 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-1830 x 1520 mm Box	3.9800 m³/s	162.26 m	2.42 m/s
	Trial-2	1-1830 x 1520 mm Box	5.9200 m³/s	162.64 m	4.14 m/s

Culvert Design Report
Percy - IC - 10+610 (W-N/S) (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	5.2100 m³/s	Check Discharge	7.7300 m³/s

Grades Model: Inverts			
Invert Upstream	161.16 m	Invert Downstream	160.34 m
Length	80.00 m	Slope	0.010250 m/m
Drop	0.82 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater

Tailwater Elevation	161.24 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-2440 x 1520 mm Box	5.2100 m³/s	162.40 m	2.37 m/s
	Trial-2	1-2440 x 1520 mm Box	7.7300 m³/s	162.77 m	4.41 m/s

Culvert Design Report
Percy - IC - 10+610 (W-N/S) (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	162.40 m	Discharge	5.2100 m³/s
Headwater Depth/Height	0.81	Tailwater Elevation	161.24 m
Inlet Control HW Elev.	162.38 m	Control Type	Entrance Control
Outlet Control HW Elev.	162.40 m		

Grades			
Upstream Invert	161.16 m	Downstream Invert	160.34 m
Length	80.00 m	Constructed Slope	0.010250 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.90 m
Slope Type	Steep	Normal Depth	0.53 m
Flow Regime	N/A	Critical Depth	0.78 m
Velocity Downstream	2.37 m/s	Critical Slope	0.003477 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	2.44 m
Section Size	2440 x 1520 mm	Rise	1.52 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	162.40 m	Upstream Velocity Head	0.39 m
Ke	0.20	Entrance Loss	0.08 m

Inlet Control Properties			
Inlet Control HW Elev.	162.38 m	Flow Control	N/A
Inlet Type	90° headwall w 45° bevels	Area Full	3.7 m²
K	0.49500	HDS 5 Chart	10
M	0.66700	HDS 5 Scale	2
C	0.03140	Equation Form	2
Y	0.82000		

Culvert Design Report
Percy - IC - 10+610 (W-N/S)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	162.26 m	Discharge	3.9800 m³/s
Headwater Depth/Height	0.82	Tailwater Elevation	161.40 m
Inlet Control HW Elev.	162.24 m	Control Type	Entrance Control
Outlet Control HW Elev.	162.26 m		

Grades			
Upstream Invert	161.00 m	Downstream Invert	160.50 m
Length	48.60 m	Constructed Slope	0.010288 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.90 m
Slope Type	Steep	Normal Depth	0.56 m
Flow Regime	N/A	Critical Depth	0.78 m
Velocity Downstream	2.42 m/s	Critical Slope	0.004105 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.83 m
Section Size	1830 x 1520 mm	Rise	1.52 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	162.26 m	Upstream Velocity Head	0.39 m
Ke	0.20	Entrance Loss	0.08 m

Inlet Control Properties			
Inlet Control HW Elev.	162.24 m	Flow Control	N/A
Inlet Type	90° headwall w 45° bevels	Area Full	2.8 m²
K	0.49500	HDS 5 Chart	10
M	0.66700	HDS 5 Scale	2
C	0.03140	Equation Form	2
Y	0.82000		

Culvert Design Report
Percy - IC - 10+610 (W-N/S)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	162.64 m	Discharge	5.9200 m³/s
Headwater Depth/Height	1.07	Tailwater Elevation	161.40 m
Inlet Control HW Elev.	162.61 m	Control Type	Entrance Control
Outlet Control HW Elev.	162.64 m		

Grades			
Upstream Invert	161.00 m	Downstream Invert	160.50 m
Length	48.60 m	Constructed Slope	0.010288 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.78 m
Slope Type	Steep	Normal Depth	0.75 m
Flow Regime	Supercritical	Critical Depth	1.02 m
Velocity Downstream	4.14 m/s	Critical Slope	0.004475 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.83 m
Section Size	1830 x 1520 mm	Rise	1.52 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	162.64 m	Upstream Velocity Head	0.51 m
Ke	0.20	Entrance Loss	0.10 m

Inlet Control Properties			
Inlet Control HW Elev.	162.61 m	Flow Control	N/A
Inlet Type	90° headwall w 45° bevels	Area Full	2.8 m²
K	0.49500	HDS 5 Chart	10
M	0.66700	HDS 5 Scale	2
C	0.03140	Equation Form	2
Y	0.82000		

Culvert Design Report
Percy - IC - 10+610 (W-N/S) (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	162.77 m	Discharge	7.7300 m³/s
Headwater Depth/Height	1.06	Tailwater Elevation	161.24 m
Inlet Control HW Elev.	162.75 m	Control Type	Entrance Control
Outlet Control HW Elev.	162.77 m		

Grades			
Upstream Invert	161.16 m	Downstream Invert	160.34 m
Length	80.00 m	Constructed Slope	0.010250 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.72 m
Slope Type	Steep	Normal Depth	0.70 m
Flow Regime	Supercritical	Critical Depth	1.01 m
Velocity Downstream	4.41 m/s	Critical Slope	0.003691 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	2.44 m
Section Size	2440 x 1520 mm	Rise	1.52 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	162.77 m	Upstream Velocity Head	0.50 m
Ke	0.20	Entrance Loss	0.10 m

Inlet Control Properties			
Inlet Control HW Elev.	162.75 m	Flow Control	N/A
Inlet Type	90° headwall w 45° bevels	Area Full	3.7 m²
K	0.49500	HDS 5 Chart	10
M	0.66700	HDS 5 Scale	2
C	0.03140	Equation Form	2
Y	0.82000		

Culvert Design Report
Percy - IC - 9+460 (S-E) (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	0.1200 m³/s	Check Discharge	0.1700 m³/s

Grades Model: Inverts			
Invert Upstream	0.18 m	Invert Downstream	0.00 m
Length	35.00 m	Slope	0.005000 m/m
Drop	0.18 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater

Tailwater Elevation	0.48 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-825 mm Circular	0.1200 m³/s	0.54 m	0.37 m/s
	Trial-2	1-825 mm Circular	0.1700 m³/s	0.59 m	0.52 m/s

Culvert Design Report
Percy - IC - 9+460 (S-E) (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	0.54 m	Discharge	0.1200 m³/s
Headwater Depth/Height	0.44	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	0.48 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.54 m		

Grades			
Upstream Invert	0.18 m	Downstream Invert	0.00 m
Length	35.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.48 m
Slope Type	Mild	Normal Depth	0.26 m
Flow Regime	Subcritical	Critical Depth	0.20 m
Velocity Downstream	0.37 m/s	Critical Slope	0.013785 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.54 m	Upstream Velocity Head	0.02 m
Ke	0.90	Entrance Loss	0.02 m

Inlet Control Properties			
Inlet Control HW Elev.	0.48 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Percy - IC - 9+460 (S-E) (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	0.59 m	Discharge	0.1700 m³/s
Headwater Depth/Height	0.49	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	0.51 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.59 m		

Grades			
Upstream Invert	0.18 m	Downstream Invert	0.00 m
Length	35.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.48 m
Slope Type	Mild	Normal Depth	0.31 m
Flow Regime	Subcritical	Critical Depth	0.24 m
Velocity Downstream	0.52 m/s	Critical Slope	0.013664 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.59 m	Upstream Velocity Head	0.03 m
Ke	0.90	Entrance Loss	0.03 m

Inlet Control Properties			
Inlet Control HW Elev.	0.51 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Percy - IC - 9+525 (Percy) (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	0.66 m	Discharge	0.2900 m³/s
Headwater Depth/Height	0.64	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	0.59 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.66 m		

Grades			
Upstream Invert	0.13 m	Downstream Invert	0.00 m
Length	25.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.48 m
Slope Type	Mild	Normal Depth	0.42 m
Flow Regime	Subcritical	Critical Depth	0.32 m
Velocity Downstream	0.89 m/s	Critical Slope	0.013868 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.66 m	Upstream Velocity Head	0.05 m
Ke	0.90	Entrance Loss	0.04 m

Inlet Control Properties			
Inlet Control HW Elev.	0.59 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Percy - IC - 9+525b (Percy) (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	1.5000 m³/s	Check Discharge	2.2200 m³/s

Grades Model: Inverts			
Invert Upstream	0.13 m	Invert Downstream	0.00 m
Length	25.00 m	Slope	0.005000 m/m
Drop	0.13 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	0.48 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-1200 mm Circular	1.5000 m³/s	1.27 m	2.30 m/s
	Trial-2	1-1200 mm Circular	2.2200 m³/s	1.62 m	2.67 m/s

Culvert Design Report
Percy - IC - 9+525 (Percy) (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	0.2000 m³/s	Check Discharge	0.2900 m³/s

Grades Model: Inverts			
Invert Upstream	0.13 m	Invert Downstream	0.00 m
Length	25.00 m	Slope	0.005000 m/m
Drop	0.13 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	0.48 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-825 mm Circular	0.2000 m³/s	0.58 m	0.61 m/s
	Trial-2	1-825 mm Circular	0.2900 m³/s	0.66 m	0.89 m/s

Culvert Design Report
Percy - IC - 9+525 (Percy) (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	0.58 m	Discharge	0.2000 m³/s
Headwater Depth/Height	0.54	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	0.50 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.58 m		

Grades			
Upstream Invert	0.13 m	Downstream Invert	0.00 m
Length	25.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.48 m
Slope Type	Mild	Normal Depth	0.34 m
Flow Regime	Subcritical	Critical Depth	0.26 m
Velocity Downstream	0.61 m/s	Critical Slope	0.013665 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.58 m	Upstream Velocity Head	0.03 m
Ke	0.90	Entrance Loss	0.03 m

Inlet Control Properties			
Inlet Control HW Elev.	0.50 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Percy - IC - 9+525b (Percy) (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	1.27 m	Discharge	1.5000 m³/s
Headwater Depth/Height	0.94	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	1.18 m	Control Type	Outlet Control
Outlet Control HW Elev.	1.27 m		

Grades			
Upstream Invert	0.13 m	Downstream Invert	0.00 m
Length	25.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.67 m
Slope Type	Mild	Normal Depth	0.96 m
Flow Regime	Subcritical	Critical Depth	0.67 m
Velocity Downstream	2.30 m/s	Critical Slope	0.013782 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	1.22 m
Section Size	1200 mm	Rise	1.22 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	1.27 m	Upstream Velocity Head	0.15 m
Ke	0.90	Entrance Loss	0.13 m

Inlet Control Properties			
Inlet Control HW Elev.	1.18 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	1.2 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Percy - IC - 9+525b (Percy) (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	1.62 m	Discharge	2.2200 m³/s
Headwater Depth/Height	1.22	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	1.53 m	Control Type	Outlet Control
Outlet Control HW Elev.	1.62 m		

Grades			
Upstream Invert	0.13 m	Downstream Invert	0.00 m
Length	25.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.82 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.82 m
Velocity Downstream	2.67 m/s	Critical Slope	0.016269 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	1.22 m
Section Size	1200 mm	Rise	1.22 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	1.62 m	Upstream Velocity Head	0.20 m
Ke	0.90	Entrance Loss	0.18 m

Inlet Control Properties			
Inlet Control HW Elev.	1.53 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	1.2 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Percy - IC - 9+650 (Percy) (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	1.1000 m³/s	Check Discharge	1.6400 m³/s

Grades Model: Inverts			
Invert Upstream	0.10 m	Invert Downstream	0.00 m
Length	20.00 m	Slope	0.005000 m/m
Drop	0.10 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	0.72 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-1200 mm Circular	1.1000 m³/s	1.05 m	1.53 m/s
	Trial-2	1-1200 mm Circular	1.6400 m³/s	1.30 m	2.29 m/s

Culvert Design Report
Percy - IC - 9+650 (Percy) (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	1.05 m	Discharge	1.1000 m³/s
Headwater Depth/Height	0.78	Tailwater Elevation	0.72 m
Inlet Control HW Elev.	0.96 m	Control Type	Outlet Control
Outlet Control HW Elev.	1.05 m		

Grades			
Upstream Invert	0.10 m	Downstream Invert	0.00 m
Length	20.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.72 m
Slope Type	Mild	Normal Depth	0.76 m
Flow Regime	Subcritical	Critical Depth	0.57 m
Velocity Downstream	1.53 m/s	Critical Slope	0.012823 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	1.22 m
Section Size	1200 mm	Rise	1.22 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	1.05 m	Upstream Velocity Head	0.11 m
Ke	0.90	Entrance Loss	0.10 m

Inlet Control Properties			
Inlet Control HW Elev.	0.96 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	1.2 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Percy - IC - 9+675 (Percy) (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	1.31 m	Discharge	1.8600 m³/s
Headwater Depth/Height	0.76	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	1.20 m	Control Type	Outlet Control
Outlet Control HW Elev.	1.31 m		

Grades			
Upstream Invert	0.15 m	Downstream Invert	0.00 m
Length	30.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.70 m
Slope Type	Mild	Normal Depth	0.90 m
Flow Regime	Subcritical	Critical Depth	0.70 m
Velocity Downstream	2.29 m/s	Critical Slope	0.011846 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	1.52 m
Section Size	1500 mm	Rise	1.52 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	1.31 m	Upstream Velocity Head	0.15 m
Ke	0.90	Entrance Loss	0.14 m

Inlet Control Properties			
Inlet Control HW Elev.	1.20 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	1.8 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Percy - IC - 9+675 (Percy) (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	1.62 m	Discharge	2.7600 m³/s
Headwater Depth/Height	0.96	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	1.52 m	Control Type	Outlet Control
Outlet Control HW Elev.	1.62 m		

Grades			
Upstream Invert	0.15 m	Downstream Invert	0.00 m
Length	30.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.86 m
Slope Type	Mild	Normal Depth	1.22 m
Flow Regime	Subcritical	Critical Depth	0.86 m
Velocity Downstream	2.62 m/s	Critical Slope	0.012997 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	1.52 m
Section Size	1500 mm	Rise	1.52 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	1.62 m	Upstream Velocity Head	0.20 m
Ke	0.90	Entrance Loss	0.18 m

Inlet Control Properties			
Inlet Control HW Elev.	1.52 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	1.8 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Percy - IC - 9+650 (Percy) (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	1.30 m	Discharge	1.6400 m³/s
Headwater Depth/Height	0.99	Tailwater Elevation	0.72 m
Inlet Control HW Elev.	1.23 m	Control Type	Outlet Control
Outlet Control HW Elev.	1.30 m		

Grades			
Upstream Invert	0.10 m	Downstream Invert	0.00 m
Length	20.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.72 m
Slope Type	Mild	Normal Depth	1.07 m
Flow Regime	Subcritical	Critical Depth	0.70 m
Velocity Downstream	2.29 m/s	Critical Slope	0.014177 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	1.22 m
Section Size	1200 mm	Rise	1.22 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	1.30 m	Upstream Velocity Head	0.16 m
Ke	0.90	Entrance Loss	0.15 m

Inlet Control Properties			
Inlet Control HW Elev.	1.23 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	1.2 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Percy - IC - 9+675 (Percy) (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	1.8600 m³/s	Check Discharge	2.7600 m³/s

Grades Model: Inverts			
Invert Upstream	0.15 m	Invert Downstream	0.00 m
Length	30.00 m	Slope	0.005000 m/m
Drop	0.15 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	0.48 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-1500 mm Circular	1.8600 m³/s	1.31 m	2.29 m/s
	Trial-2	1-1500 mm Circular	2.7600 m³/s	1.62 m	2.62 m/s

Culvert Design Report
Percy - IC - 9+790 (Percy)

Peak Discharge Method: User-Specified			
Design Discharge	0.3300 m³/s	Check Discharge	0.4900 m³/s

Grades Model: Inverts			
Invert Upstream	175.00 m	Invert Downstream	174.75 m
Length	25.10 m	Slope	0.009960 m/m
Drop	0.25 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	175.11 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-600 mm Circular	0.3300 m³/s	175.65 m	1.76 m/s
	Trial-2	1-600 mm Circular	0.4900 m³/s	176.05 m	2.09 m/s

Culvert Design Report
Percy - IC - 9+790 (Percy)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	175.65 m	Discharge	0.3300 m³/s
Headwater Depth/Height	1.07	Tailwater Elevation	175.11 m
Inlet Control HW Elev.	175.62 m	Control Type	Outlet Control
Outlet Control HW Elev.	175.65 m		

Grades			
Upstream Invert	175.00 m	Downstream Invert	174.75 m
Length	25.10 m	Constructed Slope	0.009960 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.37 m
Slope Type	Mild	Normal Depth	0.48 m
Flow Regime	Subcritical	Critical Depth	0.37 m
Velocity Downstream	1.76 m/s	Critical Slope	0.018799 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.61 m
Section Size	600 mm	Rise	0.61 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	175.65 m	Upstream Velocity Head	0.09 m
Ke	0.90	Entrance Loss	0.09 m

Inlet Control Properties			
Inlet Control HW Elev.	175.62 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.3 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Percy - IC - 9+790 (Percy)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	176.05 m	Discharge	0.4900 m³/s
Headwater Depth/Height	1.72	Tailwater Elevation	175.11 m
Inlet Control HW Elev.	175.84 m	Control Type	Outlet Control
Outlet Control HW Elev.	176.05 m		

Grades			
Upstream Invert	175.00 m	Downstream Invert	174.75 m
Length	25.10 m	Constructed Slope	0.009960 m/m

Hydraulic Profile			
Profile	CompositeM2PressureProfile	Depth, Downstream	0.46 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	0.46 m
Velocity Downstream	2.09 m/s	Critical Slope	0.024000 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.61 m
Section Size	600 mm	Rise	0.61 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	176.05 m	Upstream Velocity Head	0.14 m
Ke	0.90	Entrance Loss	0.13 m

Inlet Control Properties			
Inlet Control HW Elev.	175.84 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.3 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Percy - IC - 9+790 (Percy) (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	0.77 m	Discharge	0.3300 m³/s
Headwater Depth/Height	0.68	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	0.70 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.77 m		

Grades			
Upstream Invert	0.20 m	Downstream Invert	0.00 m
Length	40.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.48 m
Slope Type	Mild	Normal Depth	0.46 m
Flow Regime	Subcritical	Critical Depth	0.34 m
Velocity Downstream	1.01 m/s	Critical Slope	0.014022 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.77 m	Upstream Velocity Head	0.06 m
Ke	0.90	Entrance Loss	0.05 m

Inlet Control Properties			
Inlet Control HW Elev.	0.70 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Percy - IC - 9+790 (Percy) (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	0.3300 m³/s	Check Discharge	0.4900 m³/s

Grades Model: Inverts			
Invert Upstream	0.20 m	Invert Downstream	0.00 m
Length	40.00 m	Slope	0.005000 m/m
Drop	0.20 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater

Tailwater Elevation	0.48 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-825 mm Circular	0.3300 m³/s	0.77 m	1.01 m/s
	Trial-2	1-825 mm Circular	0.4900 m³/s	0.92 m	1.50 m/s

Culvert Design Report
Percy - IC - 9+790 (Percy) (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	0.92 m	Discharge	0.4900 m³/s
Headwater Depth/Height	0.86	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	0.84 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.92 m		

Grades			
Upstream Invert	0.20 m	Downstream Invert	0.00 m
Length	40.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M2	Depth, Downstream	0.48 m
Slope Type	Mild	Normal Depth	0.60 m
Flow Regime	Subcritical	Critical Depth	0.42 m
Velocity Downstream	1.50 m/s	Critical Slope	0.014900 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.92 m	Upstream Velocity Head	0.07 m
Ke	0.90	Entrance Loss	0.07 m

Inlet Control Properties			
Inlet Control HW Elev.	0.84 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Percy - IC - 9+975 (Percy)

Peak Discharge Method: User-Specified			
Design Discharge	0.1600 m³/s	Check Discharge	0.2400 m³/s

Grades Model: Inverts			
Invert Upstream	166.50 m	Invert Downstream	166.25 m
Length	29.80 m	Slope	0.008389 m/m
Drop	0.25 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater

Tailwater Elevation	166.79 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-900 mm Circular	0.1600 m³/s	166.88 m	0.40 m/s
	Trial-2	1-900 mm Circular	0.2400 m³/s	166.95 m	0.59 m/s

Culvert Design Report
Percy - IC - 9+975 (Percy)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	166.95 m	Discharge	0.2400 m³/s
Headwater Depth/Height	0.50	Tailwater Elevation	166.79 m
Inlet Control HW Elev.	166.90 m	Control Type	Outlet Control
Outlet Control HW Elev.	166.95 m		

Grades			
Upstream Invert	166.50 m	Downstream Invert	166.25 m
Length	29.80 m	Constructed Slope	0.008389 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.54 m
Slope Type	Mild	Normal Depth	0.32 m
Flow Regime	Subcritical	Critical Depth	0.28 m
Velocity Downstream	0.59 m/s	Critical Slope	0.013270 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	166.95 m	Upstream Velocity Head	0.06 m
Ke	0.90	Entrance Loss	0.05 m

Inlet Control Properties			
Inlet Control HW Elev.	166.90 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Percy - IC - 9+975 (Percy)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	166.88 m	Discharge	0.1600 m³/s
Headwater Depth/Height	0.41	Tailwater Elevation	166.79 m
Inlet Control HW Elev.	166.81 m	Control Type	Outlet Control
Outlet Control HW Elev.	166.88 m		

Grades			
Upstream Invert	166.50 m	Downstream Invert	166.25 m
Length	29.80 m	Constructed Slope	0.008389 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.54 m
Slope Type	Mild	Normal Depth	0.26 m
Flow Regime	Subcritical	Critical Depth	0.23 m
Velocity Downstream	0.40 m/s	Critical Slope	0.013357 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.91 m
Section Size	900 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	166.88 m	Upstream Velocity Head	0.03 m
Ke	0.90	Entrance Loss	0.03 m

Inlet Control Properties			
Inlet Control HW Elev.	166.81 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.7 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Percy - IC - 9+975 (Percy) (proposed)

Peak Discharge Method: User-Specified			
Design Discharge	0.1600 m³/s	Check Discharge	0.2400 m³/s

Grades Model: Inverts			
Invert Upstream	0.30 m	Invert Downstream	0.00 m
Length	60.00 m	Slope	0.005000 m/m
Drop	0.30 m		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater

Tailwater Elevation	0.48 m

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-825 mm Circular	0.1600 m³/s	0.68 m	0.49 m/s
	Trial-2	1-825 mm Circular	0.2400 m³/s	0.77 m	0.73 m/s

Culvert Design Report
Percy - IC - 9+975 (Percy) (proposed)

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Design
Computed Headwater Elevation	0.68 m	Discharge	0.1600 m³/s
Headwater Depth/Height	0.46	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	0.63 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.68 m		

Grades			
Upstream Invert	0.30 m	Downstream Invert	0.00 m
Length	60.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.48 m
Slope Type	Mild	Normal Depth	0.30 m
Flow Regime	Subcritical	Critical Depth	0.23 m
Velocity Downstream	0.49 m/s	Critical Slope	0.013675 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	0.68 m	Upstream Velocity Head	0.04 m
Ke	0.90	Entrance Loss	0.03 m

Inlet Control Properties			
Inlet Control HW Elev.	0.63 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Percy - IC - 9+975 (Percy) (proposed)

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A m	Storm Event	Check
Computed Headwater Elevation	0.77 m	Discharge	0.2400 m³/s
Headwater Depth/Height	0.57	Tailwater Elevation	0.48 m
Inlet Control HW Elev.	0.71 m	Control Type	Outlet Control
Outlet Control HW Elev.	0.77 m		

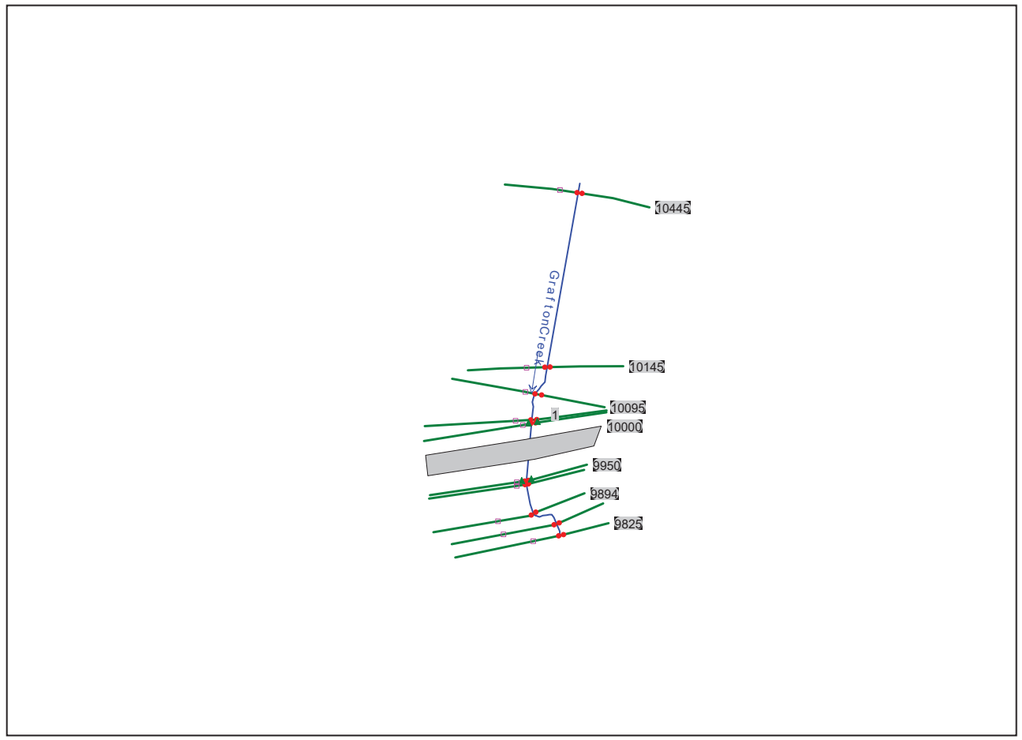
Grades			
Upstream Invert	0.30 m	Downstream Invert	0.00 m
Length	60.00 m	Constructed Slope	0.005000 m/m

Hydraulic Profile			
Profile	M1	Depth, Downstream	0.48 m
Slope Type	Mild	Normal Depth	0.38 m
Flow Regime	Subcritical	Critical Depth	0.29 m
Velocity Downstream	0.73 m/s	Critical Slope	0.013725 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	0.84 m
Section Size	825 mm	Rise	0.84 m
Number Sections	1		

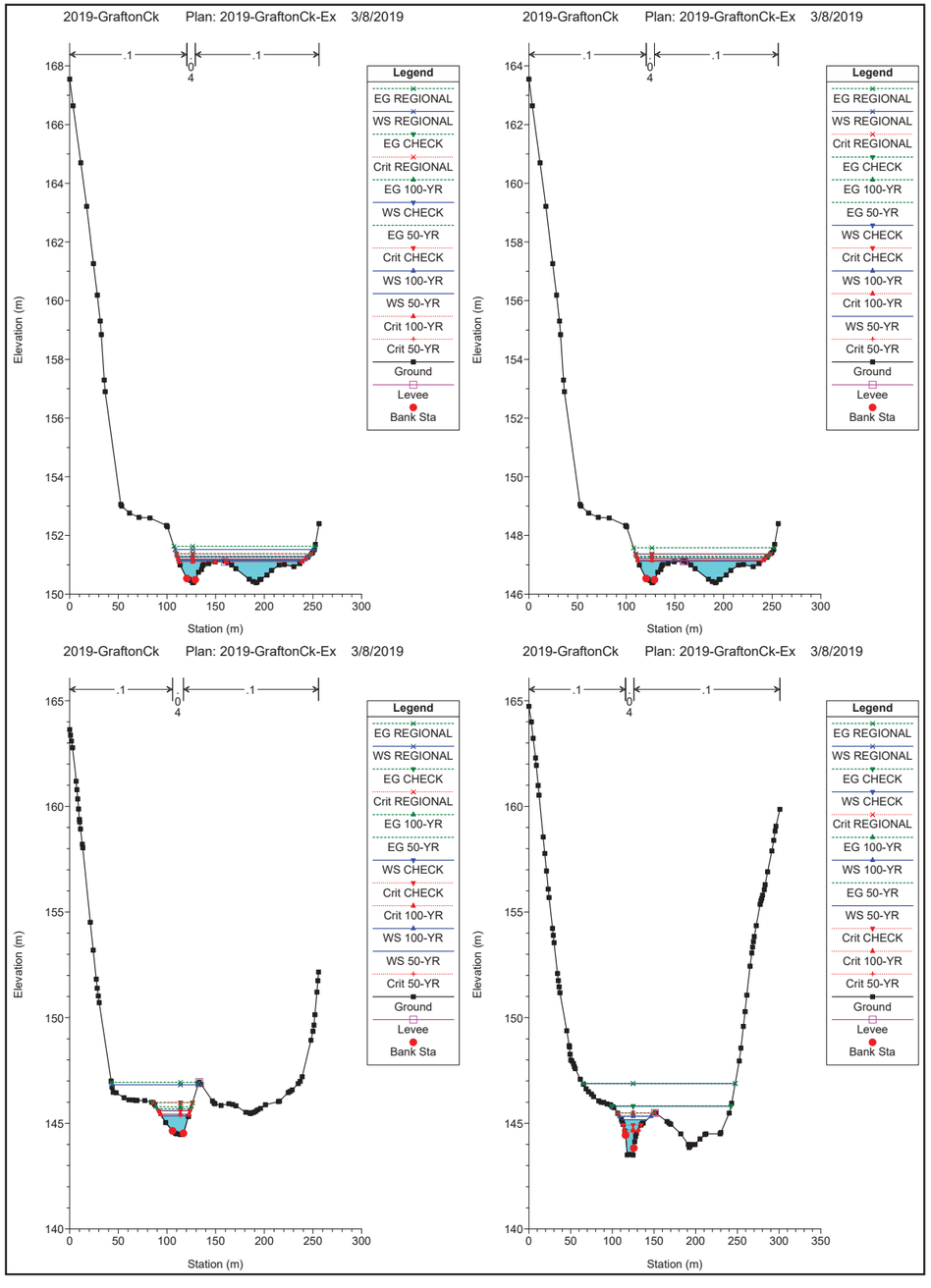
Outlet Control Properties			
Outlet Control HW Elev.	0.77 m	Upstream Velocity Head	0.05 m
Ke	0.90	Entrance Loss	0.04 m

Inlet Control Properties			
Inlet Control HW Elev.	0.71 m	Flow Control	N/A
Inlet Type	Projecting	Area Full	0.6 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		



HEC-RAS Plan: Ex River: GraftonCreek Reach: 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
1	10445	50-YR	29.17	150.39	151.14	151.10	151.25	0.012713	2.17	39.71	128.09	0.84
1	10445	100-YR	34.05	150.39	151.18	151.10	151.29	0.011997	2.20	45.58	130.23	0.83
1	10445	CHECK	44.38	150.39	151.27	151.21	151.37	0.010921	2.27	57.25	134.29	0.81
1	10445	REGIONAL	53.89	150.39	151.34	151.25	151.45	0.010428	2.34	66.83	137.23	0.80
1	10145	50-YR	29.17	146.39	147.13	147.13	147.25	0.014019	2.25	38.25	127.56	0.88
1	10145	100-YR	34.05	146.39	147.15	147.15	147.29	0.014912	2.39	42.03	128.94	0.92
1	10145	CHECK	44.38	146.39	147.21	147.21	147.36	0.016709	2.66	49.06	131.48	0.98
1	10145	REGIONAL	53.89	146.39	147.25	147.25	147.42	0.017825	2.86	55.20	133.65	1.03
1	10095	50-YR	29.17	144.47	145.34	145.34	145.67	0.015509	2.73	15.47	27.49	0.96
1	10095	100-YR	34.05	144.47	145.42	145.42	145.78	0.014883	2.85	17.80	29.12	0.96
1	10095	CHECK	44.38	144.47	145.58	145.57	145.98	0.013862	3.07	22.66	32.27	0.95
1	10095	REGIONAL	53.89	144.47	145.90	145.70	146.19	0.007505	2.69	34.09	38.72	0.73
1	10051	50-YR	29.17	143.50	145.14	144.57	145.29	0.003003	1.78	22.39	29.49	0.46
1	10051	100-YR	34.05	143.50	145.31	144.69	145.47	0.002711	1.82	28.07	36.88	0.45
1	10051	CHECK	44.38	143.50	145.79	144.91	145.81	0.000401	0.82	152.27	142.12	0.18
1	10051	REGIONAL	53.89	143.50	146.05	145.08	146.07	0.000325	0.80	191.51	159.53	0.16
1	10045	50-YR	29.17	143.52	144.66	144.66	145.15	0.014776	3.19	10.60	12.34	0.98
1	10045	100-YR	34.05	143.52	144.77	144.77	145.32	0.014405	3.36	12.00	13.10	0.98
1	10045	CHECK	44.38	143.52	145.01	145.01	145.62	0.012531	3.56	15.53	17.21	0.95
1	10045	REGIONAL	53.89	143.52	145.20	145.20	145.86	0.011769	3.74	18.37	19.12	0.94
1	10000		Culvert									
1	9950	50-YR	29.17	140.50	142.08	141.75	142.40	0.006221	2.64	14.82	13.78	0.67
1	9950	100-YR	34.05	140.50	142.18	141.88	142.56	0.006796	2.88	16.27	15.15	0.71
1	9950	CHECK	44.38	140.50	142.25	142.13	142.83	0.009971	3.58	17.30	16.08	0.87
1	9950	REGIONAL	53.89	140.50	142.37	142.37	143.09	0.011287	3.99	19.28	17.58	0.93
1	9944	50-YR	29.17	140.48	141.78	141.78	142.29	0.013028	3.37	12.84	16.54	0.95
1	9944	100-YR	34.05	140.48	141.93	141.93	142.46	0.012142	3.48	15.44	20.36	0.93
1	9944	CHECK	44.38	140.48	142.22	142.22	142.74	0.009774	3.54	22.36	26.44	0.86
1	9944	REGIONAL	53.89	140.48	142.38	142.38	142.95	0.009745	3.76	26.94	28.69	0.87
1	9894	50-YR	29.17	139.50	140.46	140.40	140.68	0.010344	2.46	24.32	52.99	0.80
1	9894	100-YR	34.05	139.50	140.54	140.49	140.77	0.009728	2.52	29.01	59.58	0.79
1	9894	CHECK	44.38	139.50	140.72	140.62	140.94	0.008027	2.55	41.68	84.02	0.74
1	9894	REGIONAL	53.89	139.50	140.84	140.75	140.96	0.005176	2.18	75.92	154.36	0.60
1	9844	50-YR	29.17	138.59	139.69	139.69	140.11	0.013840	2.97	12.94	21.85	0.94
1	9844	100-YR	34.05	138.59	139.81	139.81	140.24	0.012615	3.05	15.77	26.66	0.91
1	9844	CHECK	44.38	138.59	139.99	139.99	140.48	0.012130	3.29	21.26	34.66	0.92
1	9844	REGIONAL	53.89	138.59	140.19	140.19	140.64	0.009928	3.27	33.41	76.26	0.85
1	9825	50-YR	29.17	138.00	139.15	139.15	139.61	0.014956	3.12	12.13	16.10	0.98
1	9825	100-YR	34.05	138.00	139.26	139.26	139.76	0.014280	3.26	14.01	17.89	0.97
1	9825	CHECK	44.38	138.00	139.45	139.45	140.03	0.013917	3.57	17.71	21.02	0.99
1	9825	REGIONAL	53.89	138.00	139.74	139.74	140.27	0.010001	3.45	26.09	36.43	0.86


2019-GraftonCk Plan: 2019-GraftonCk-Ex 3/8/2019
Elevation (m)
Station (m)
Legend
EG REGIONAL
WS REGIONAL
EG CHECK
Crit REGIONAL
EG 100-YR
WS CHECK
EG 50-YR
Crit CHECK
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2019-GraftonCk Plan: 2019-GraftonCk-Ex 3/8/2019
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2019-GraftonCk Plan: 2019-GraftonCk-Ex 3/8/2019
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2019-GraftonCk Plan: 2019-GraftonCk-Ex 3/8/2019
Elevation (m)
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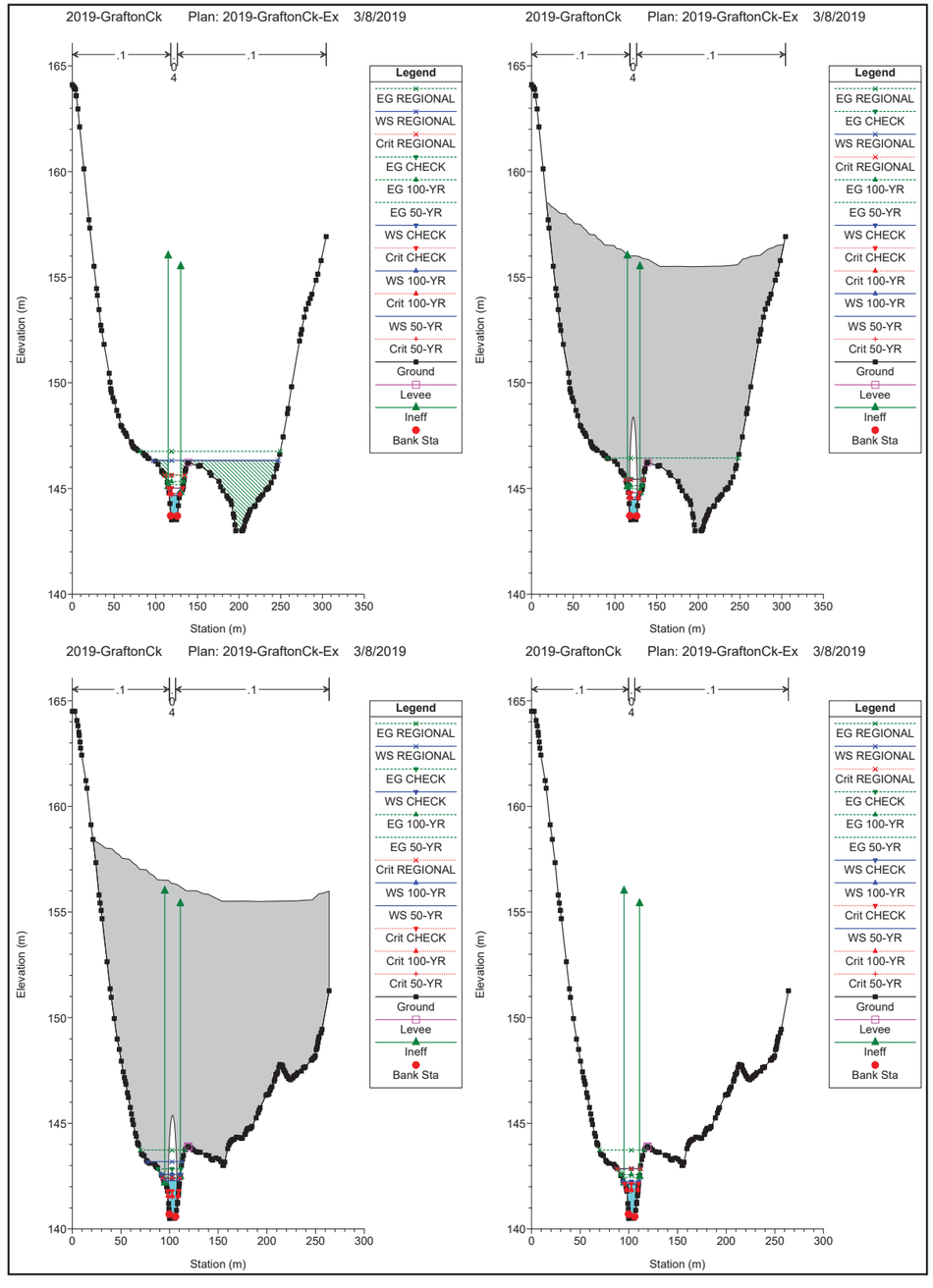
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2019-GraftonCk Plan: 2019-GraftonCk-Ex 3/8/2019
Elevation (m)
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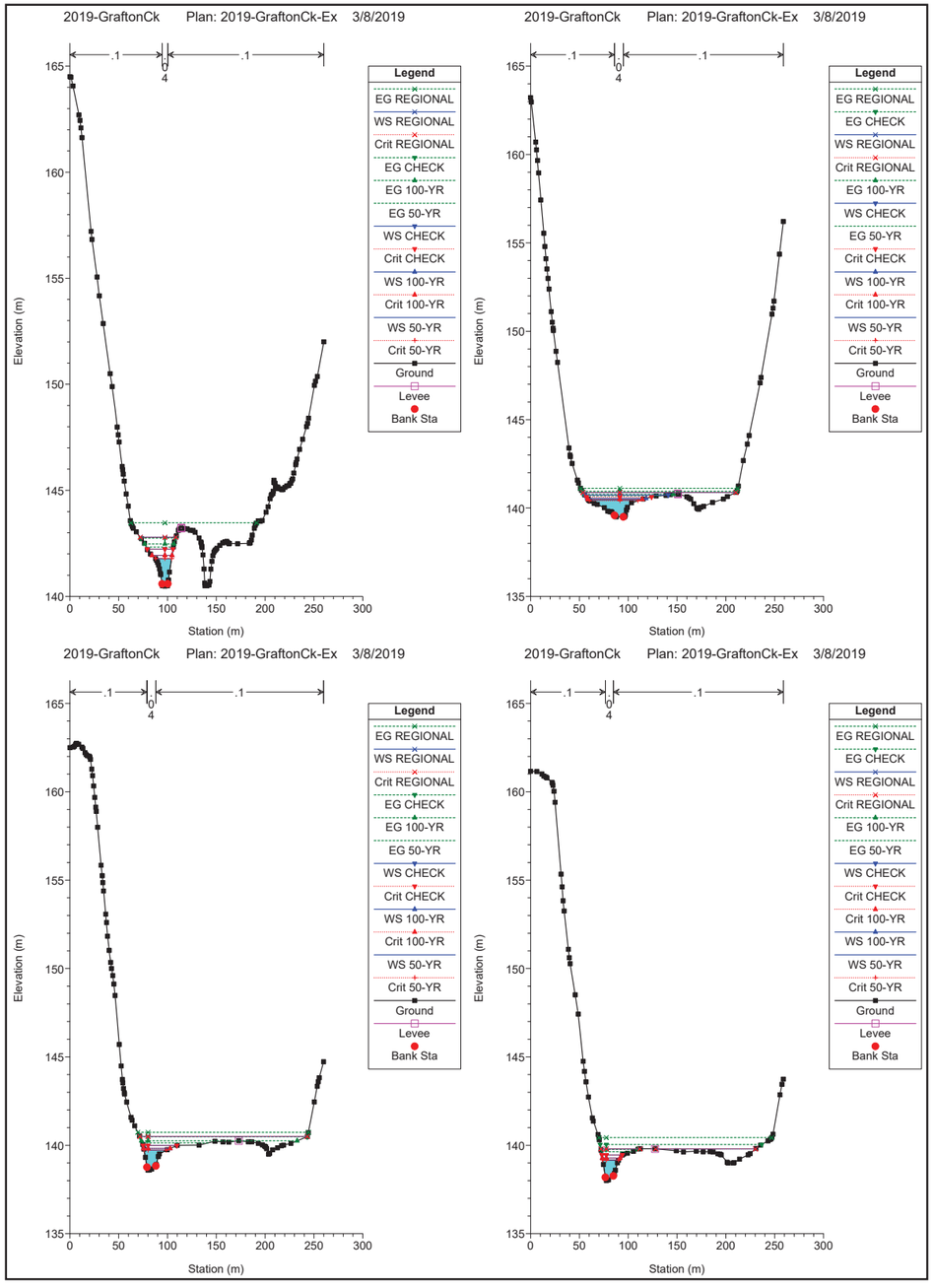
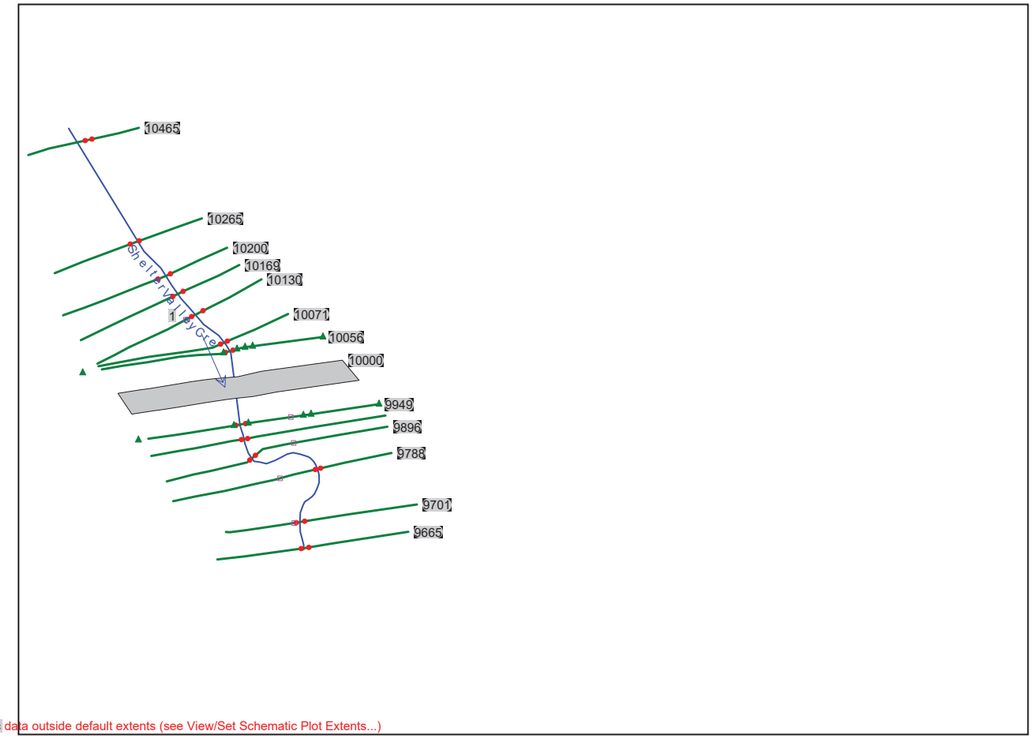
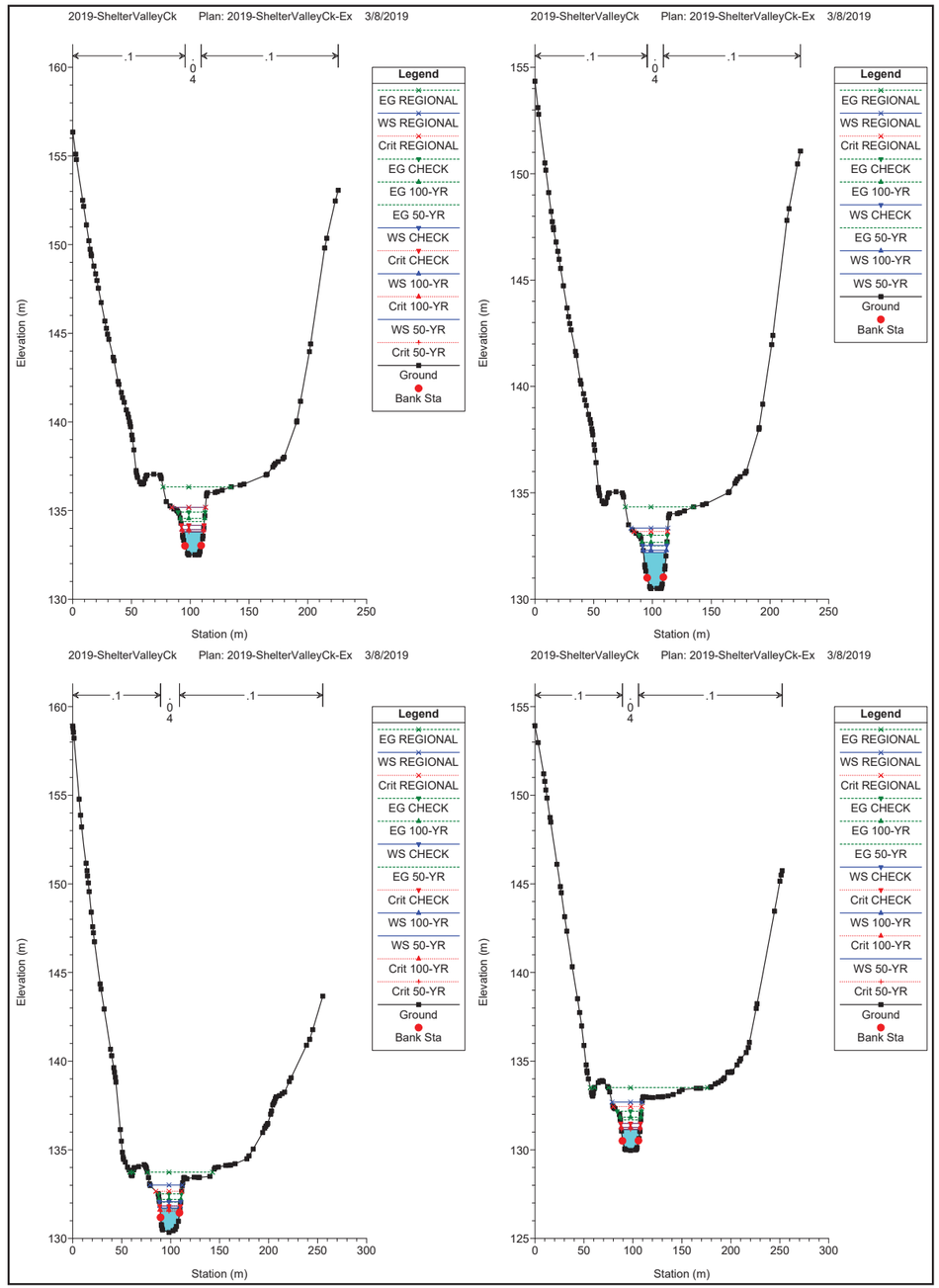


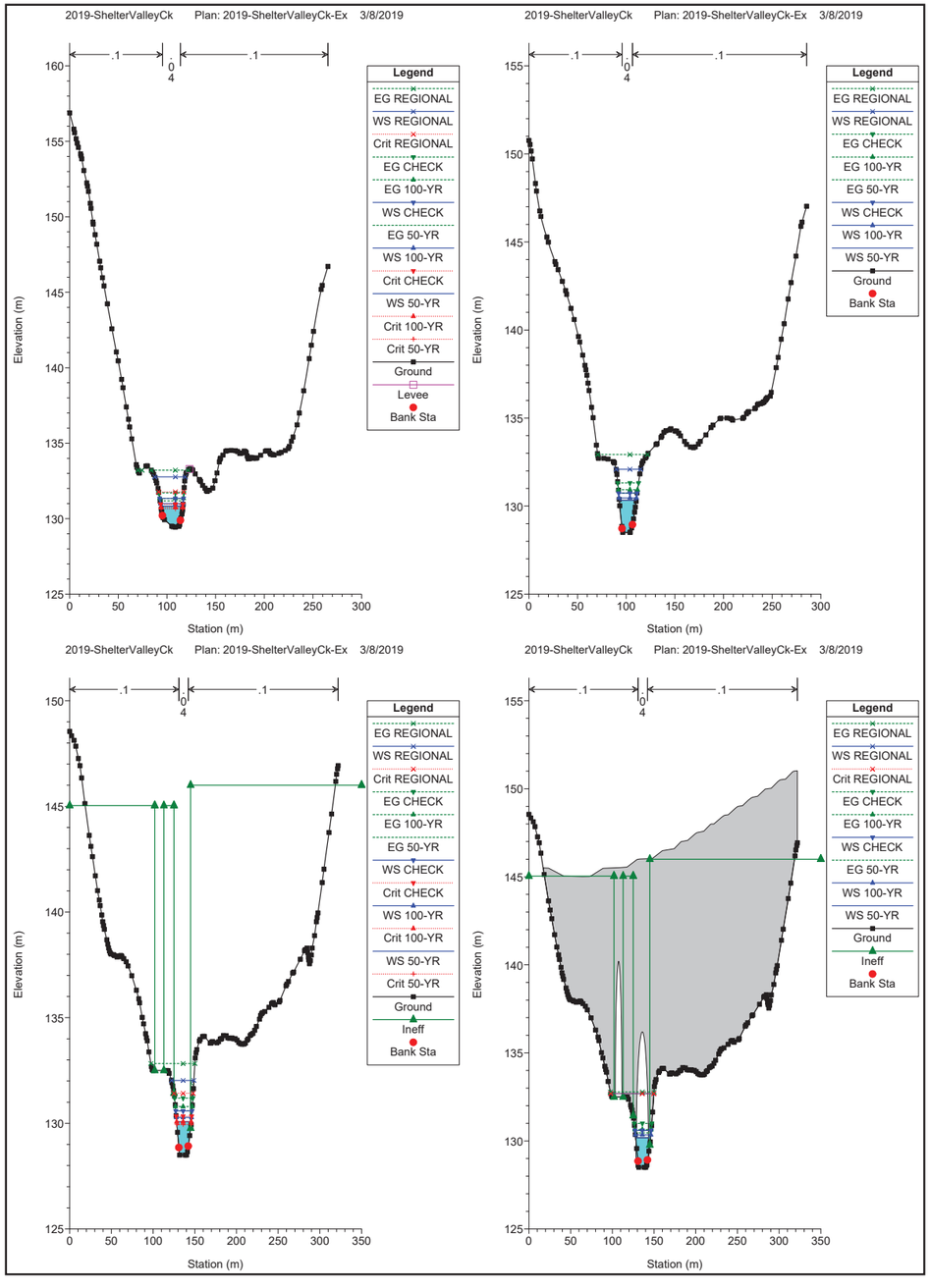


Some schematic data outside default extents (see View/Set Schematic Plot Extents...)

HEC-RAS Plan: Ex River: ShelterValleyCre Reach: 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
1	10465	50-YR	58.60	132.50	133.81	133.81	134.38	0.014302	3.41	18.83	18.14	0.98
1	10465	100-YR	67.57	132.50	133.93	133.93	134.56	0.013726	3.55	21.07	18.57	0.98
1	10465	CHECK	87.84	132.50	134.17	134.17	134.91	0.013081	3.88	25.70	19.38	0.98
1	10465	REGIONAL	185.69	132.50	135.18	135.18	136.33	0.010788	4.89	48.09	28.63	0.97
1	10265	50-YR	58.60	130.50	132.20		132.51	0.005550	2.55	26.13	19.45	0.64
1	10265	100-YR	67.57	130.50	132.30		132.67	0.005911	2.75	28.23	19.80	0.67
1	10265	CHECK	87.84	130.50	132.53		133.00	0.006539	3.13	32.79	20.67	0.72
1	10265	REGIONAL	185.69	130.50	133.34	133.18	134.34	0.008763	4.58	52.78	31.36	0.88
1	10200	50-YR	58.60	130.34	131.71	131.53	132.06	0.008954	2.59	22.83	20.69	0.77
1	10200	100-YR	67.57	130.34	131.83	131.62	132.21	0.008703	2.72	25.22	21.06	0.77
1	10200	CHECK	87.84	130.34	132.07	131.83	132.52	0.008241	2.97	30.38	21.84	0.77
1	10200	REGIONAL	185.69	130.34	133.02	132.66	133.74	0.007103	3.81	54.69	33.04	0.77
1	10169	50-YR	58.60	129.96	131.15	131.15	131.68	0.015094	3.24	18.88	19.24	0.99
1	10169	100-YR	67.57	129.96	131.26	131.26	131.84	0.014629	3.40	20.95	19.56	0.99
1	10169	CHECK	87.84	129.96	131.49	131.49	132.17	0.013649	3.69	25.51	20.25	0.99
1	10169	REGIONAL	185.69	129.96	132.69	132.44	133.51	0.007455	4.10	55.11	30.76	0.81
1	10130	50-YR	58.60	129.43	130.84	130.65	131.18	0.008724	2.62	23.99	22.68	0.77
1	10130	100-YR	67.57	129.43	131.00	130.75	131.35	0.007525	2.65	27.70	23.21	0.73
1	10130	CHECK	87.84	129.43	131.34	130.96	131.71	0.005905	2.72	35.81	24.35	0.67
1	10130	REGIONAL	185.69	129.43	132.77	131.78	133.21	0.003223	3.03	74.96	31.41	0.55
1	10071	50-YR	58.60	128.50	130.33		130.74	0.006423	2.92	24.24	17.46	0.70
1	10071	100-YR	67.57	128.50	130.46		130.93	0.006620	3.11	26.60	17.94	0.72
1	10071	CHECK	87.84	128.50	130.74		131.31	0.006978	3.49	31.65	18.92	0.76
1	10071	REGIONAL	185.69	128.50	132.09		132.93	0.005595	4.32	61.33	25.31	0.73
1	10056	50-YR	58.60	128.50	130.07	129.95	130.59	0.009765	3.25	20.91	17.50	0.84
1	10056	100-YR	67.57	128.50	130.28	130.08	130.80	0.008336	3.27	24.41	18.30	0.79
1	10056	CHECK	87.84	128.50	130.58	130.34	131.19	0.008000	3.57	29.73	19.45	0.80
1	10056	REGIONAL	185.69	128.50	132.03	131.42	132.83	0.005389	4.19	57.60	26.87	0.72
1	10000		Culvert									
1	9949	50-YR	58.60	127.98	129.90	129.22	130.10	0.002903	2.04	34.17	29.21	0.48
1	9949	100-YR	67.57	127.98	130.07	129.35	130.29	0.002849	2.14	37.74	30.77	0.48
1	9949	CHECK	87.84	127.98	130.23	129.57	130.54	0.003702	2.56	41.11	32.34	0.55
1	9949	REGIONAL	185.69	127.98	130.69	130.46	131.60	0.008536	4.42	50.83	38.58	0.86
1	9927	50-YR	58.60	127.50	129.31	129.31	129.88	0.010864	3.53	25.35	31.40	0.89
1	9927	100-YR	67.57	127.50	129.40	129.40	130.05	0.011653	3.79	28.39	34.95	0.93
1	9927	CHECK	87.84	127.50	129.77	129.77	130.34	0.008723	3.73	43.61	46.38	0.83
1	9927	REGIONAL	185.69	127.50	130.56	130.56	131.35	0.009188	4.76	87.86	66.87	0.90
1	9896	50-YR	58.60	127.50	129.01	129.01	129.45	0.010052	3.21	30.57	41.27	0.85
1	9896	100-YR	67.57	127.50	129.11	129.11	129.58	0.010036	3.36	34.88	42.91	0.86
1	9896	CHECK	87.84	127.50	129.31	129.31	129.85	0.010298	3.68	43.67	46.56	0.89
1	9896	REGIONAL	185.69	127.50	130.26	130.26	130.79	0.006908	4.03	116.84	102.87	0.78
1	9788	50-YR	58.60	126.49	128.12	128.12	128.49	0.009120	3.23	39.58	52.81	0.82
1	9788	100-YR	67.57	126.49	128.20	128.20	128.60	0.009410	3.40	44.08	53.55	0.84
1	9788	CHECK	87.84	126.49	128.36	128.36	128.82	0.010155	3.76	52.98	55.02	0.88
1	9788	REGIONAL	185.69	126.49	128.91	128.91	129.67	0.013638	5.18	84.74	60.84	1.07
1	9701	50-YR	58.60	124.98	126.50	126.40	126.98	0.009828	3.15	23.51	26.01	0.84
1	9701	100-YR	67.57	124.98	126.62	126.54	127.14	0.009821	3.31	26.67	27.96	0.85
1	9701	CHECK	87.84	124.98	126.83	126.79	127.47	0.010399	3.71	32.89	31.56	0.89
1	9701	REGIONAL	185.69	124.98	127.94	127.82	128.45	0.005480	3.73	109.29	92.07	0.70
1	9665	50-YR	58.60	124.50	126.00	126.00	126.57	0.011446	3.42	21.81	26.10	0.90
1	9665	100-YR	67.57	124.50	126.12	126.12	126.73	0.011309	3.58	25.01	27.34	0.91
1	9665	CHECK	87.84	124.50	126.39	126.39	127.07	0.010492	3.83	32.79	30.40	0.90
1	9665	REGIONAL	185.69	124.50	127.36	127.36	128.17	0.008302	4.52	78.59	57.39	0.86

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Legend
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2019-ShelterValleyCk Plan: 2019-ShelterValleyCk-Ex 3/8/2019
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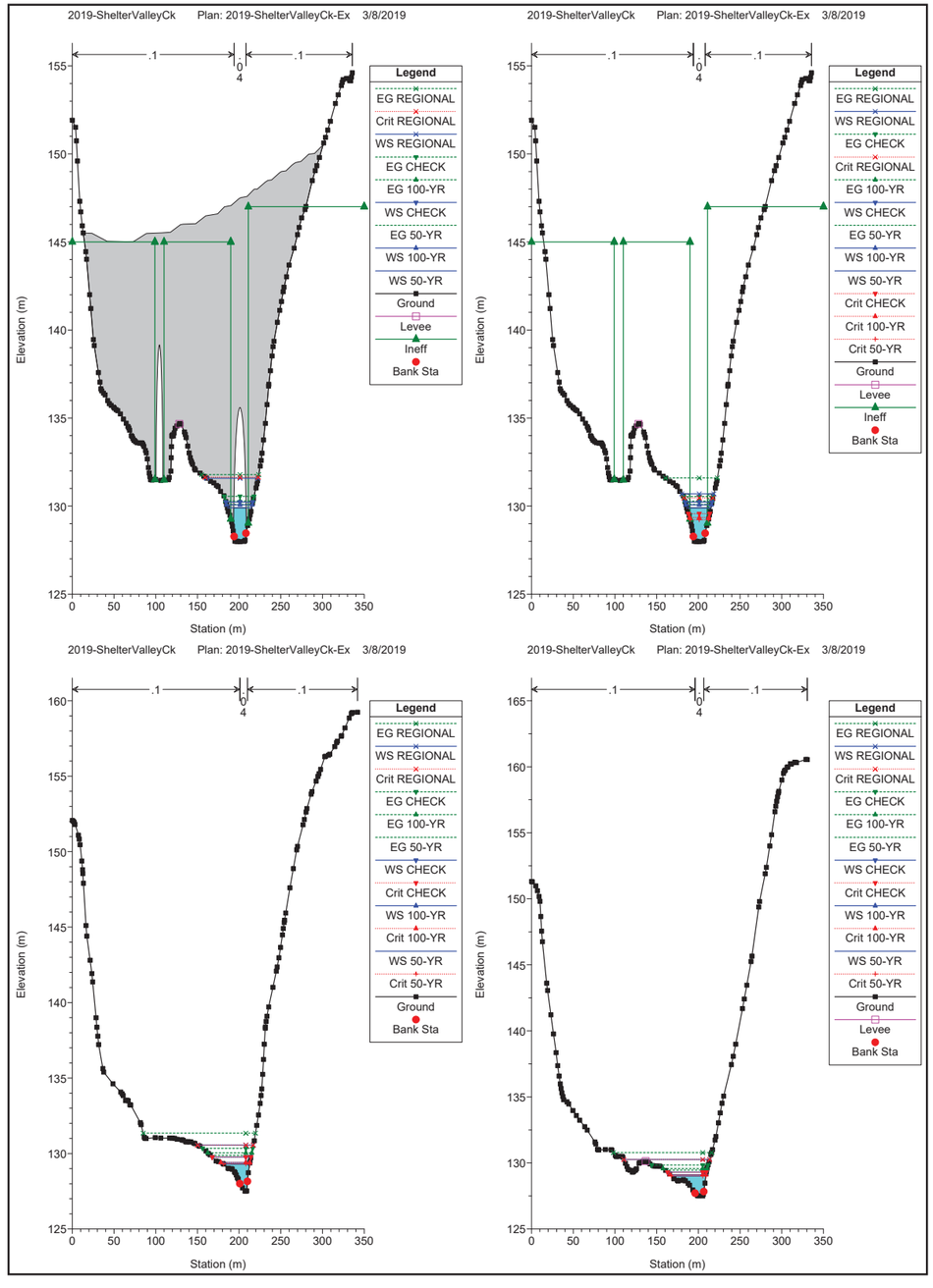
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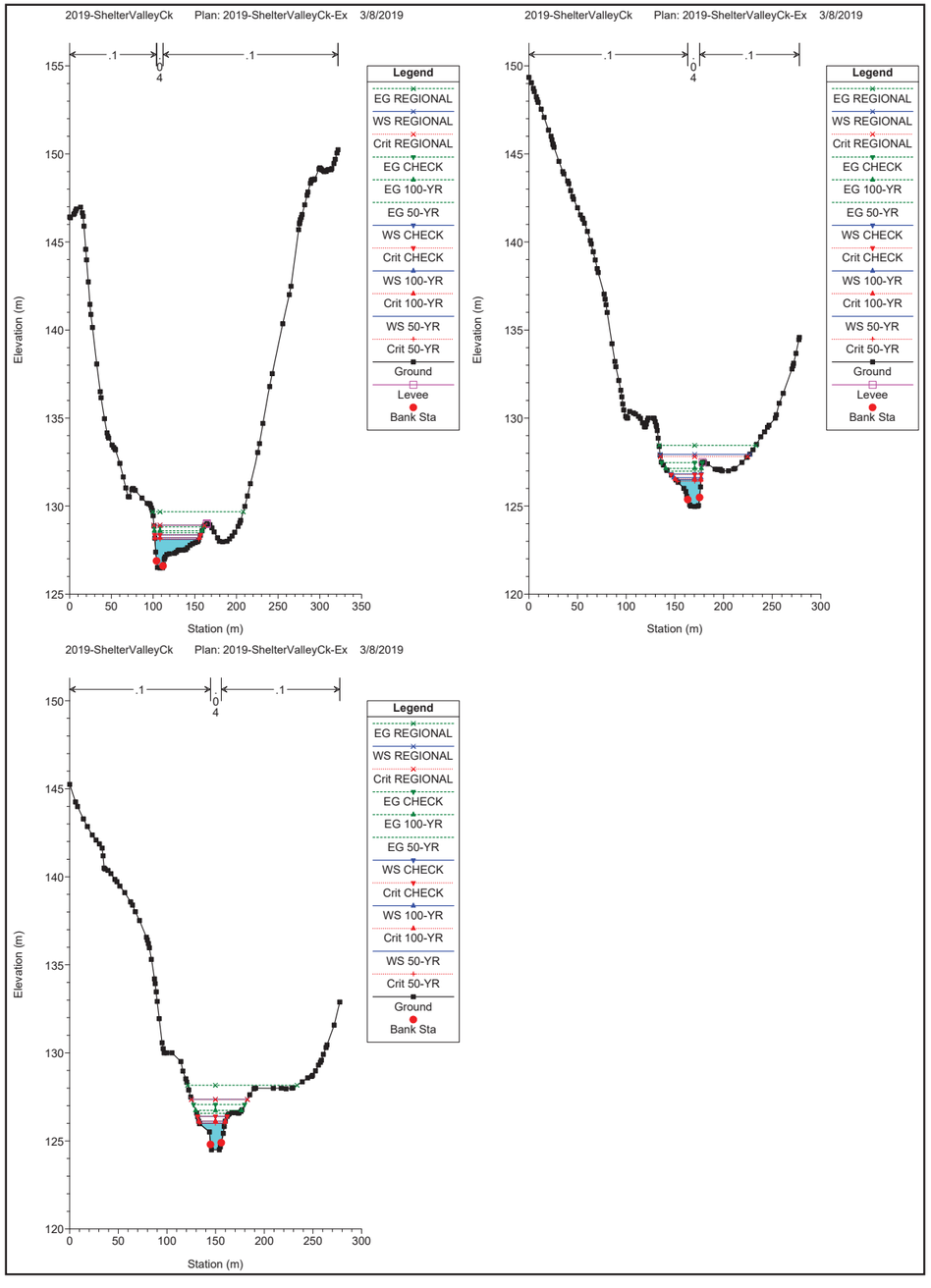
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2019-ShelterValleyCk Plan: 2019-ShelterValleyCk-Ex 3/8/2019
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2019-ShelterValleyCk Plan: 2019-ShelterValleyCk-Ex 3/8/2019
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