Point Abino Drain Watershed Hydrology and Hydraulics Report

City of Port Colborne / Town of Fort Erie

April 8, 2022

Project No: EWB-199998

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Notice:
This report is based on information and data that was available for review as provided. The analysis undertaken is for the purpose stated in the report and is not for use elsewhere.

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1 Introduction

The City of Port Colborne retained Paul Marsh, P.Eng of EWA Engineers Inc. to prepare a Drainage Report under the Drainage Act R.S.O. 1990 for the Point Abino formerly called Point Abino Marsh (PAM) Drain. The Drain Engineer's Report is prepared as follows:

- Point Abino Drain Baseline Report; provides an assessment of current drainage problems and identifies the extent of the drainage area to be serviced by the municipal drain.

- Point Abino Watershed Report; provides a capacity assessment of existing capacity through the use of hydrologic and hydraulic modelling and assessing existing conditions and design for future conditions. The modelling will be used to identify the options for resolving problems and recommends the preferred options to improve drainage.

The final Engineer's Report is composed of the two previous reports along with supporting documentation, drainage cost estimates and assessment schedules.

This report is the Point Abino Watershed Report and provides a summary assessment of the existing drainage capacity for the Municipal Drain. The analysis conducted uses a computer model to assess the existing flow capacity of the drain segments and the overall function of the drain as a watershed drainage system.

The Baseline Drainage Report for the drain presents the current, as of 2021, baseline or reference conditions. In some cases, a drainage issue may be identified in the Baseline Report but deferred from implementation in the Drain Engineer's report. The Baseline Report identifies the total needs of the drain works but does not provide specific recommendations on implementation.

1.1 Point Abino Drain Watershed

Figure 1 Point Abino Drain - Boundary

The Point Abino Drain Watershed is composed of distinct channels or drainage flow paths:

1. **Point Abino Outlet** with flap gate
   64m –@ Point Abino Rd. to the Lake. STA 0+000 to 0+250 including the triple CSP culvert access lane.

2. **Point Abino Main Drain**; from STA 0+250 to STA 1+900 lower reach west of Point Abino Road.
3. **Point Abino Main West**; STA 1+900 to 3+420 this portion ends at the municipal boundary between Fort Erie and Port Colborne, Holloway Bay Rd. S.
4. **Point Abino Sherkston Shores**; STA 3+420 to the end of the drain at 4+700 with a slope of 0.8%.
5. **Point Abino Branch #1**; to culvert crossing @ Michener Rd. which connects to drain at 0+475
6. **Point Abino East Branch**; is 350m starting a point west of #393 Point Abino Rd and ending at the confluence with the Point Abino main Drain. East Branch has a positive slope of 0.04% (0.00044 m/m)

There is a significant role played in the drain to serve roadside swales along north / south roadways; Pleasant Beach Rd. Holloway Bay Rd. S and Mathews Rd. S. Drainage service along Point Abino Rd is presumed to be largely from the Point Abino Rd. Pumping Station and the Point Abino Rd PS drainage study. This was confirmed by correspondence received.

The Point Abino Drain serves an area of 792 hectares based on the defined drain boundary, refer to Figure 1.

- Watershed average fall (slope) is given 0.26% or 2.6m per 1000m
- Drain average fall (slope) is given as 0.14% or 1.4m per 1000m

The Point Abino Drain would be characterized as a split slope watershed, relatively high slope in the upper portion of the watershed and very low slope in the lower portion of the watershed. In particular, the lower portion of the drain is highly influenced by the Lake water elevation with a littoral sand influenced outlet. Along the western edge of the watershed is a dune area adjacent to Lake Erie and this is known to be hydraulically connected to the drain water elevation.

The Point Abino Drain, was last maintained by the Town of Fort Erie in 2011 from Holloway Bay Rd. to the outlet on Point Abino Rd. The Port Colborne sections were maintained in 2018. The last known drain report prepared under the act that was implemented was the works constructed by report prepared by CJ Clarke in 1983. Subsequent reports were prepared in 1996 but after Tribunal hearings no works were constructed.

The drain can be segregated into distinct geographic areas.

- **Point Abino Outlet environment**; this area starts at the triple CSP culvert access lane and goes to the lake. Predominately sand soil and is the interface with the Lake for the drain outlet, which is a constructed twin chamber concrete structure with passive flap gates on the face of the outlet. The invert is lower than the average lake level.

- **From 0+250 to 1+900 Point Abino Main Drain North and Point Abino Main Drain West Stn 3+420**; this area is west of Point Abino Rd and is west to Holloway Bay Rd S. Significant as almost the entire length is identified as a wetland. Includes the East Branch. Much of this area is low and the Point Abino Drain from the east side of Holloway Bay Rd. to the 3 CSP culverts has only 0.592m of fall over 3170m, which is a calculated grade slope of 0.0000187 m/m which is a barely perceptible grade slope to the outlet.

- **West Point Abino Drain to Sherkston Shores** STA 3+420 to 4+700
  This area is a heavily urbanized and depends on the drain for sufficient outlet to the East. The Catchment boundary extends west to the Turtle Pond Rd. which is a constructed boundary.

- **Point Abino Branch #1**; Upland drainage with the best grade or bed slope. This section original was design to progress north 250m further upstream north of Michener Rd. but was only constructed to the north side ROW for Michener Rd.

2 Study Approach

The analysis of the Point Abino Watershed is based on Hydrologic and Hydraulic Scientific analysis. Water monitoring, gauge measurements, have not been practiced in the past and thus calibration or validation of the computer based model results is limited to historical anecdotal comparisons.

2.1 Methodology

There are two engineering analysis methods that are key to the analysis of municipal drainage.

1. The prediction of runoff flow based on a hydrologic analysis.

2. The calculation of ditch and culvert capacity (ability to contain water flow) using hydraulic formulae.

2.1.1 Hydrologic techniques

Figure 2 and Figure 3 illustrates the modelling and design process for sizing a ditch, channel or stream. The computer model predicts a peak flow (hydrograph) based on a mathematic model of runoff from a specific land use. The ditch is sized to convey the peak flow based on design parameters but significantly influenced by the available grade, slope m/m, for the ditch, channel or stream.

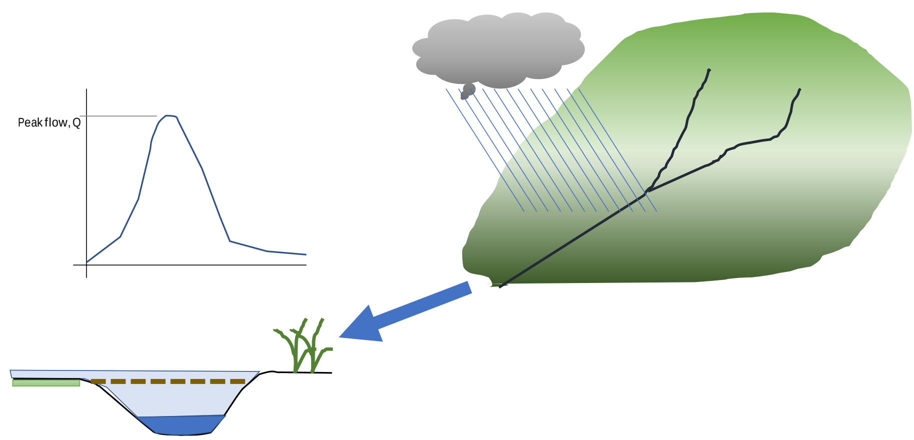


Figure 2 Watershed Predicted Runoff Peak Flow

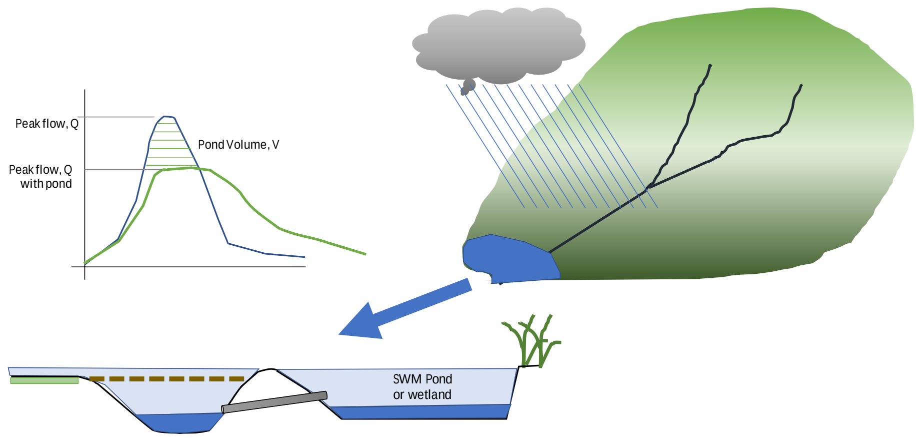


Figure 3 Watershed SWM Pond Runoff Peak Flow

The software selected for modelling is the US Environmental Protection Agency (EPA) Storm Water Management Model (SWMM) Version 5.1

www.epa.gov/swmm

The following is provided as a description of the software and function.

> The EPA Storm Water Management Model (SWMM) is a dynamic rainfall-runoff-routing simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas. The runoff component of SWMM operates on a collection of subcatchment areas that receive precipitation and generate runoff and pollutant loads. The routing portion of SWMM transports this runoff through a system of pipes, channels, storage/treatment devices, pumps, and regulators. SWMM tracks the quantity and quality of runoff generated within each subcatchment, and the flow rate, flow depth, and quality of water in each pipe and channel during a simulation period comprised of multiple time steps.

This software was selected as being freely available, accessible and for the variety of techniques that are implemented and available. Specifically, the two techniques of interest are:

- Historically, runoff methods used for watershed modelling often implement the SCS Curve Number Method. The SCS curve number (CN) method is a simple, widely used and efficient method for determining the approximant amount of runoff from a rainfall event in a particular area.

- EPA SWMM is also used for Low Impact Development (LID) assessments. This is relevant to analysis of runoff function rather than the characterization available with the CN method.

2.1.2 Hydraulic techniques

The EPA SWMM computer based hydrology modelling implements dynamic routing in addition to the runoff methods, there is a characterization of the existing drainage system using simple hydraulic analysis. This is limited in assessing specific aspects of the existing system but provides a segment by segment and element by element comparison of previous design and current function.

The predominate analytical technique used is Manning's Equation (developed by Gauckler in 1867 and Manning in 1890) for fluid flow in open channels.

$$V = \frac{k}{n} {R_h}^{2/3} \, S^{1/2}$$

From this equation a prediction can be made of the existing capacity of the ditch or the maximum fluid flow for a culvert that is flowing full.

For a culvert operating in inlet control, where the head water is higher than the tail water, a different formula is used and based on MTO requirements can predict the maximum design capacity for the culvert or bridge crossing.

These hydraulic analysis techniques provide a means to compare current capacities from the upstream limit of the drainage system to the downstream outlet for the existing conditions.

The use of the hydrologic model allows a more detailed examination of the range of drainage performance conditions including the analysis of storage within the system.

These second analytical technique is used to assess the existing and potential use of additional storage elements within the drainage area such as ponds, wetlands and other runoff detection features.

2.2 Design Storm

There are in fact three primary scenarios that are proposed for investigation using EPA SWMM computer based analysis of the Point Abino Watershed. They are as follows:

1. A 24 hour duration precipitation event with a range of frequency of occurrence from the likely (1:2 year) to the less probable events (1:50 year or 1:100 year). This event is characterized or described as a major precipitation event associated with a significant weather event.

2. A short duration highly intense summertime convective storm with a duration of 1 hour and a low frequency or probability of occurrence ranging to a higher probability of occurrence.

3. A winter time precipitation event. This is related to the event described in #1 but specifically occurs during the winter when the ground is frozen

and limited infiltration occurs. There may also be melting contributing to the runoff but in this specific case, we are only considering the impact of rain on frozen ground as a worse case consideration for drainage performance.

These three types of scenarios will be investigated using EPA SWMM for the full range of IDF predicted storms; 1:2, 1:5, 1:10, 1:25, 1:50 and 1:100. There is a recognized risk of a Hurricane Hazel type of storm (referred to often as the Regional flood event) occurring that is not considered in this analysis other than the similarity that occurs within the rain on frozen ground case.

The storm probability analysis for Port Colborne is provided by a recording gauge and is reported at the web site:

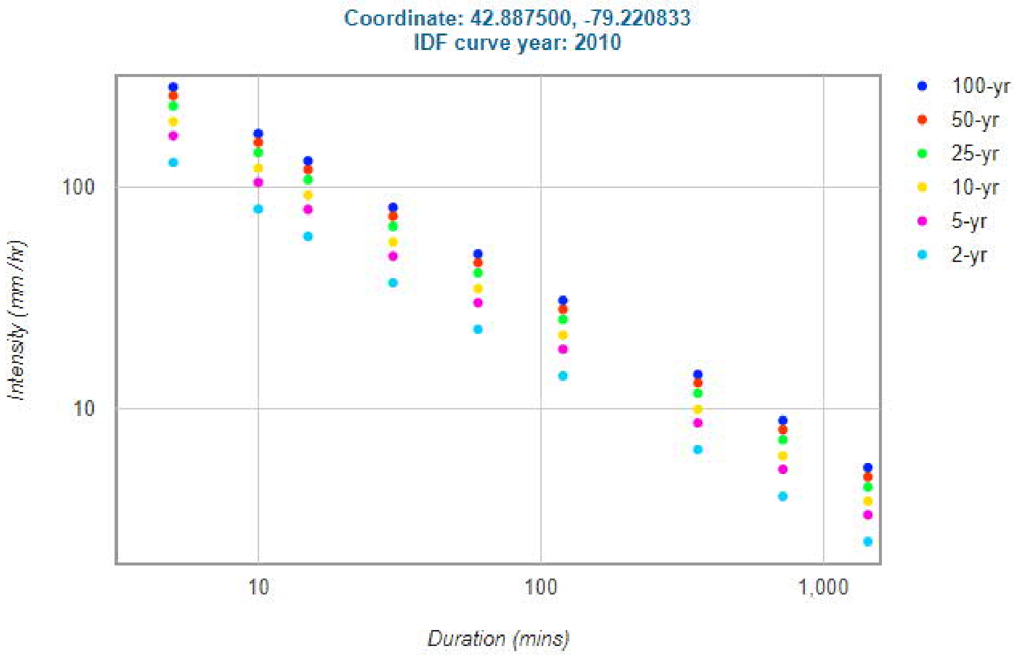


Figure 4 Port Colborne IDF Curve chart

From: http://www.eng.uwaterloo.ca/~dprincz/mto_site/results_out.shtml?coords=42.890648,-79.223098

The tables of intensity, volume values are provided in Appendix A.

From these tables two design storms are prepared for use within the Hydrologic analysis;

- As described in the Canada Flood Guide a SCS type storm is used for the longer duration event, 24 hour storms.

- The short duration intense storm is represented with the Chicago storm distribution to characterize the intense type of sudden storm.

The design storms are implemented and provided in Appendix A for reference.

The precipitation events used in the design storms for each of the probability occurrence is as follows in the Design Storm Table.

Table 1 Hydrologic Model Design Storm Events

Design Storm	Probability return period	Volume, mm
SCS Type – 24 hour	1:2	49.8
	1:5	68.9
	1:10	81.5
	1:25	97.5
	1:50	109.3
	1:100	121.1
Chicago – 1 hour	1:5	48.2

2.2.1 Historical Precipitation Events

There are storms indicated in the precipitation record; 1979 and 1991 that are in excess of the 100 year storm and would provide historical context for field verification of model results. This is not a gauged watershed verification but using historical anecdotal observations to confirm runoff values is a reasonable basis for validating model results.

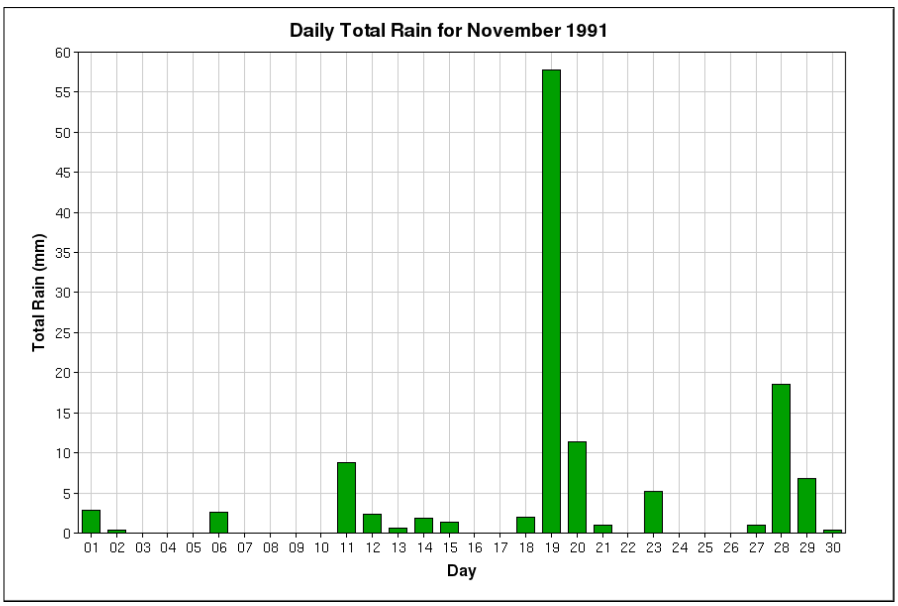


Figure 5 Precipitation data for Nov 1991

Year 1991 had a value greater than the 100 year storm. Data 64.2mm
100 year = 63.1 - 2 hour storm comparable event

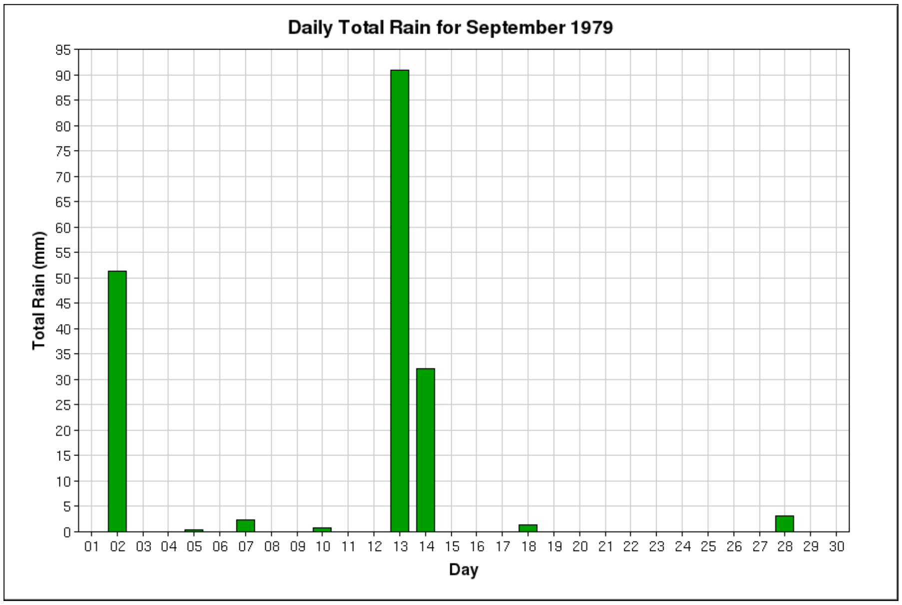


Figure 6 Precipitation data for Sept. 1979

Year 1979 had a value greater than the 100 year storm. Data 116.4mm
100 year = 105.9 - 12 hour storm comparable value.

2.2.2 August 2018 Storms

Environment Canada maintains a Metrological station in Port Colborne, which is located at or near the lighthouse along the waterfront. The Figure 7is the daily rainfall for that location.

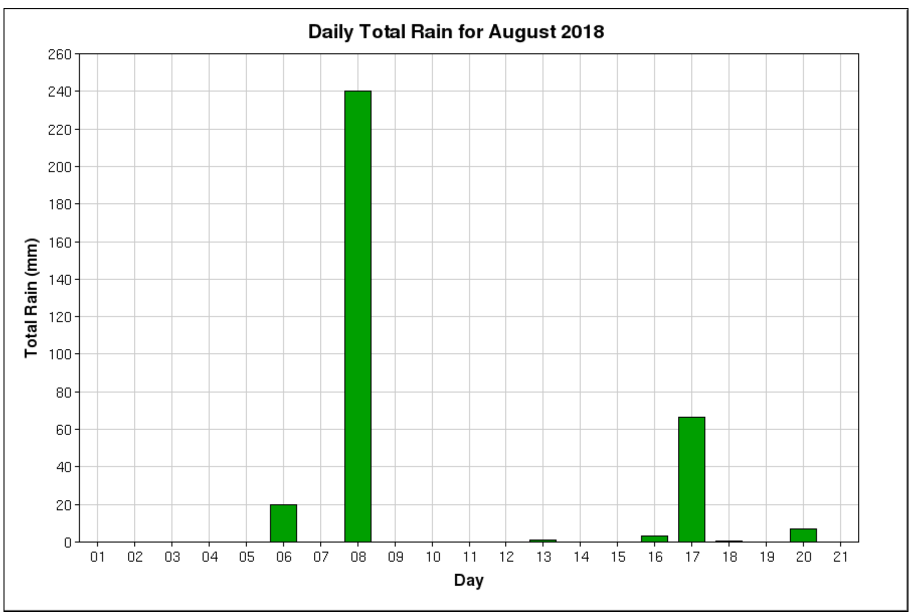


Figure 7 Env Canada Port Colborne Rain August 2018

The Regional Municipality of Niagara maintains a precipitation station on the Seaway WWTP grounds and provided data on precipitation measured at the station in 5 minute intervals for the period of August, 2018. Figure 8 shows the rainstorm events for both the August 7th morning event and the August 8 morning event.

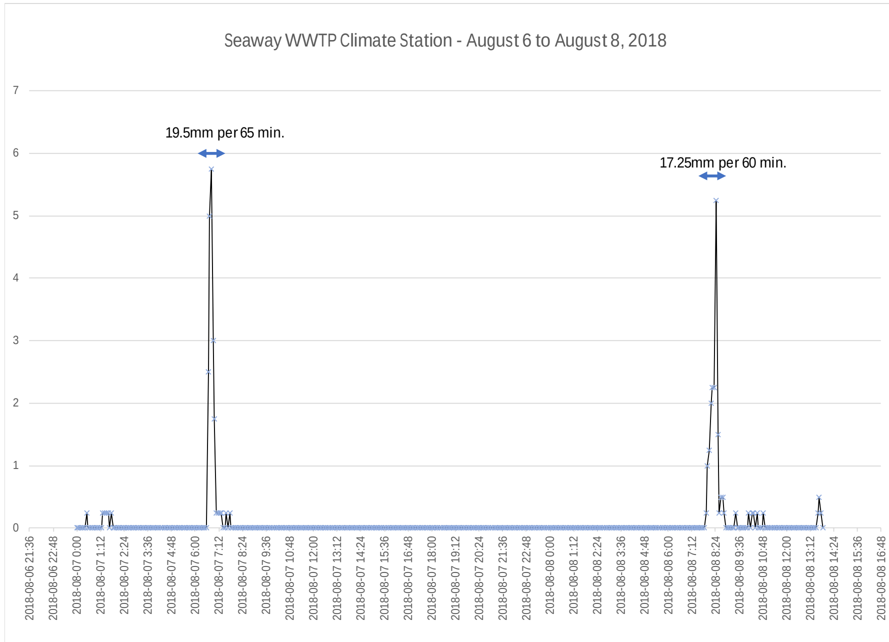


Figure 8 August 2018 Precipitation Events

Both events are characteristic of summer convective storms with short duration intense events that are not widespread but very localized. There were significant reports of flooding in localized portions of Port Colborne but no documented reports of flooding within the drains. The distance between the two gauges is 2km. The one day reported total of 240mm exceeds by a significant margin the IDF intensity for a 1:100 year event while the Seaway WWTP station reported storm is below a 1:2 year event.

From this historical event, we can conclude that sudden intense rainfall events are happening but are not widely distributed. The impacts are very localized.

2.2.3 July 17 2021 Storm

A storm occurred on July 17th, 2021 that had widespread impacts across Port Colborne including the Point Abino Watershed.

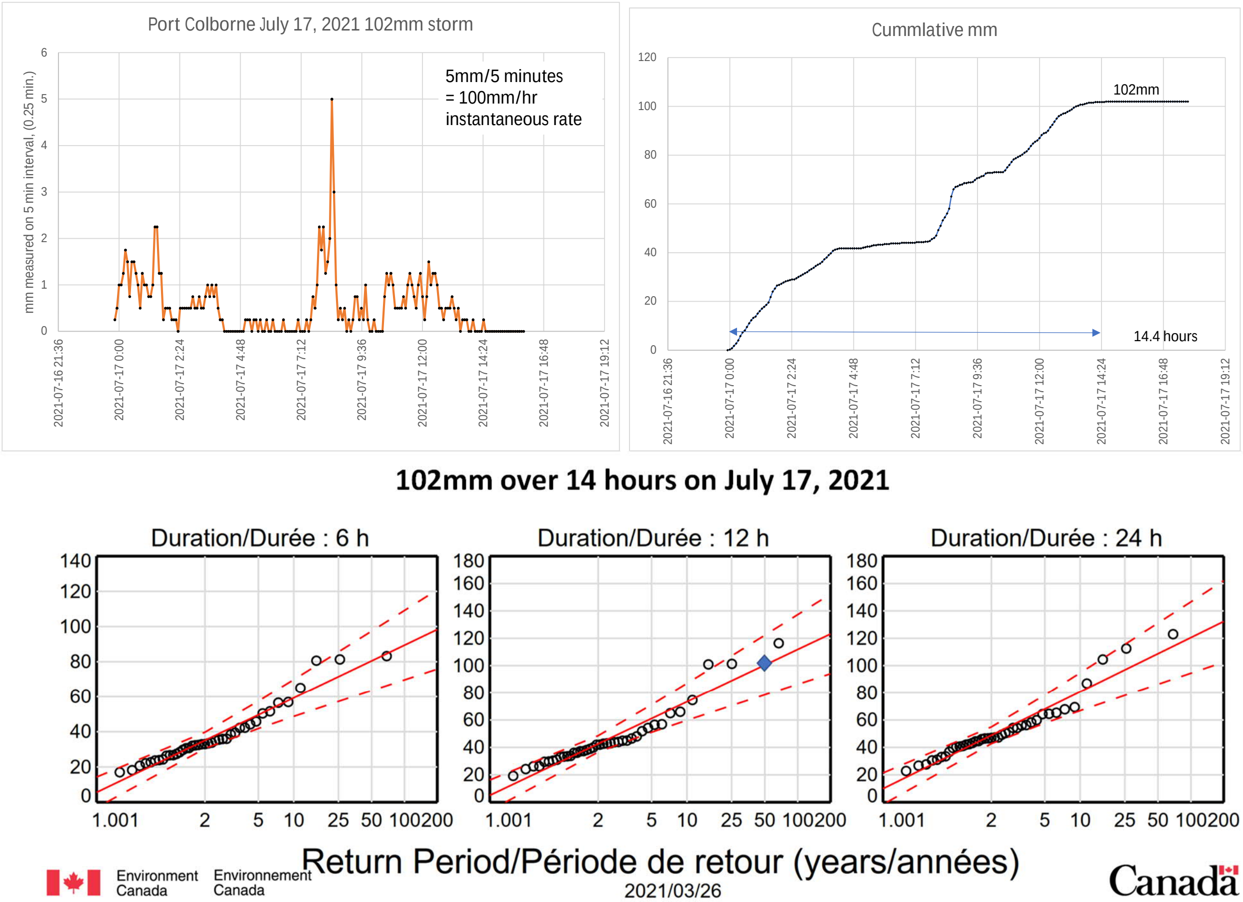


Figure 9 July 17 Storm Records

Graphs show the size of the storm over a 12 hour period, actual is closer to 14 hours, suggests that the storm was a 1:50 year return period storm. Reports indicate that flooding did occur in several areas of Port Colborne. No high level marks were recorded on the Point Abino Drain and the storm was limited in distribution with Welland recording a small amount of precipitation.

2.3 Historical Seiche Storms

This area is influenced by both upstream runoff that exceeds the available channel capacity, but also backwater effects from Lake Erie that inundate the near shore area.

Seiche - A seiche (/ˈseɪʃ/ SAYSH) is a standing wave in an enclosed or partially enclosed body of water.

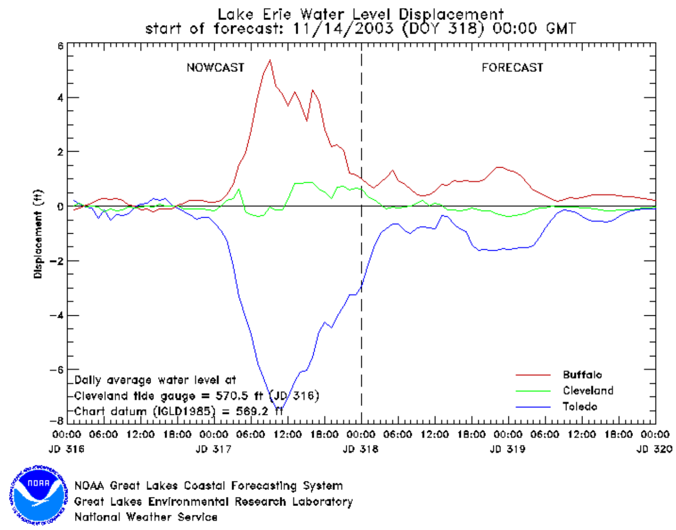


Figure 10 NOAA Seiche Chart

Differences in water level caused by a seiche on Lake Erie, recorded between Buffalo, New York (red) and Toledo, Ohio (blue) on November 14, 2003: Source: https://en.wikipedia.org/wiki/Seiche

Surge

A storm surge, storm flood, tidal surge or storm tide is a coastal flood or tsunami-like phenomenon of rising water commonly associated with low-pressure weather systems, such as tropical cyclones. It is measured as the rise in water level above the normal tidal level, and does not include waves.

For our purposes in this report we will use the terms seiche and surge together and reference the same phenomena, which is a rise in Lake water surface level that causes water to back up from the lake into the local streams and drainage systems.

There's a distinction made in surge level as a static water level influence on the drain and the dynamic impact of waves on the outlet as distinct and different impacts.

2.3.1 October 31, 2019 Storm

This sudden storm caused widespread flooding along the Lake Erie North Shore and was both an intense precipitation event and a high wind lake surge or seiche event. In additional to very high winds driving up lake levels, there was a recorded 29.4mm of precipitation, which is not a significant amount (5 days prior there was 36.6mm without flooding). Using Environment Canada reporting for Port Colborne station.

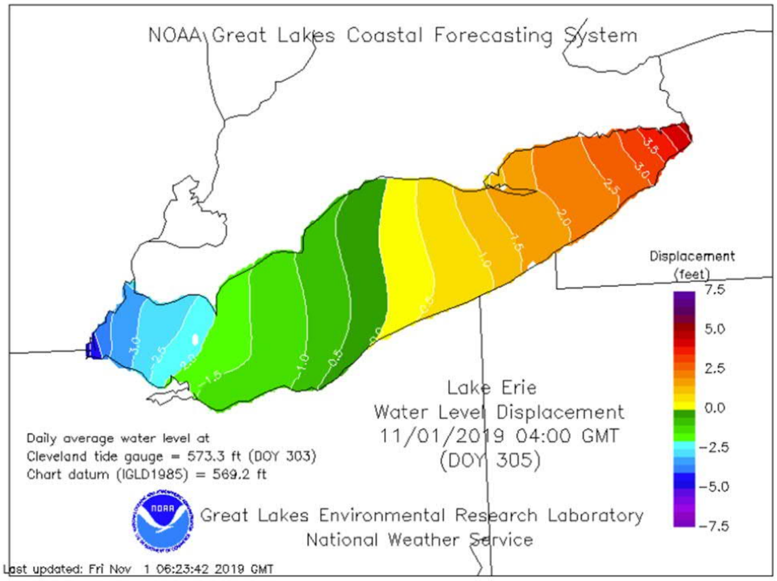


Figure 11 NOAA Lake Erie Seiche Conditions

The level that the water had risen was subsequently surveyed and reported to be 176.45m using UTM NAD 83 datum.

2.3.2 November 15, 2020 Storm

This storm surge caused a similar flood as the previous year's storm. Post-storm, the Town of Fort Erie surveyed the debris highwater mark left on the fence for #137 Shirley Rd. This storm is relevant to the Point Abino watershed as it exemplifies the surge/seiche that can be experienced by the east and north shore of Lake Erie. The measured impact indicates direct storm static surge level on a nearby watershed without a surge control.

Precipitation report from Environment Canada for the Port Colborne station showed that a total day recorded rainfall was 6.6mm of precipitation. This was confirmed by precipitation reports for two stations in Fort Erie operated by RMON.

- 500 Ridgeway Road, Crystal Beach precipitation station: 6.75mm
- 660 Industrial Drive, Industrial Park precipitation station: 7.75mm

(Data provided by email from Mr. Glenn Fulton dated January 8th, 2021.)

This confirms that the event was from Lake effect flooding and not from precipitation induced stormwater runoff. This storm flood elevation was recorded as 176.46m, nearly the same as the previous year.

This sudden storm caused widespread flooding along the Lake Erie North Shore and was predominately a high wind lake surge or seiche event. The following chart shows the average hourly results for lake levels as recorded at Port Colborne, (note that these values are recorded as height above the International Great Lakes Datum (IGLD which is not the same datum as used by the survey).

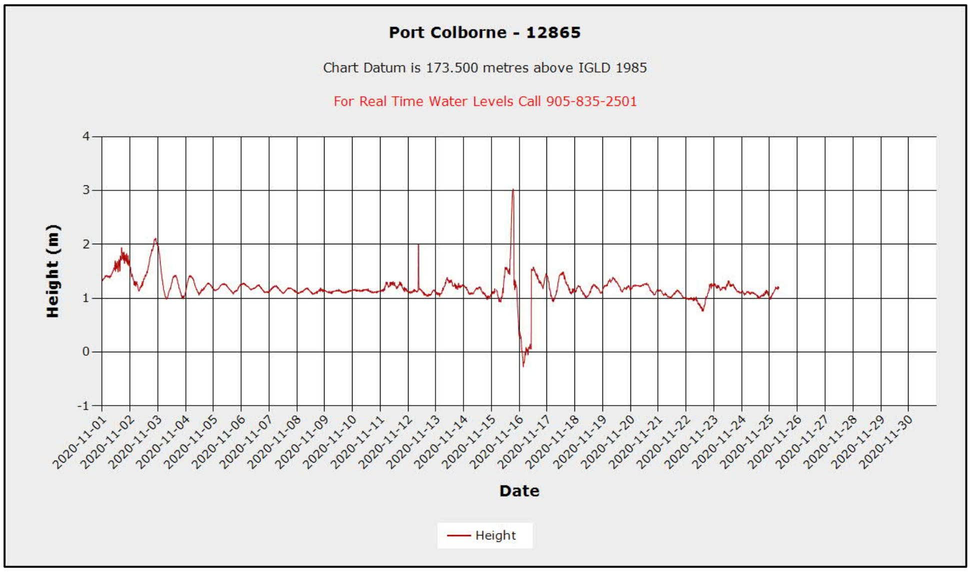


Figure 12 Great Lakes Water Level at Port Colborne

A recent presentation titled, "Vulnerability Assessment and Climate Change Adaptation Options for the Great Lakes Coastline – The Chatham-Kent Lake Erie Example" by Pete Zuzek and Linda Mortsch hosted by Climate Risk Institute identified that as winter temperatures change with climate change, we expect to have more winter storms with open water in Lake Erie. The prediction is for fewer winters with lake ice acting to dampen the effects of storm surge and seiche impacts.

The conclusion is that the risk of wintertime events on the lakes will be greater in the future than the past. Risk of these events is a combination of high lake levels and storm surge/seiche. A storm event when the lake levels are low poses less risk.

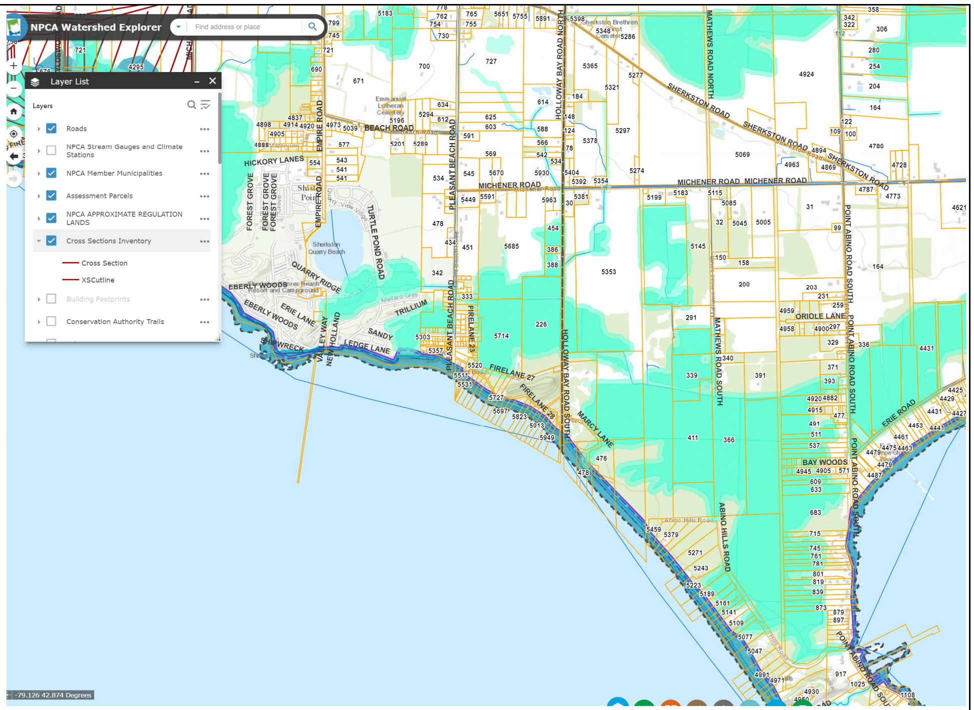
2.4 Previous Reports and Studies

The Point Abino watershed does not appear to have previous stormwater modelling prepared as part of a flood line study or water quality report.

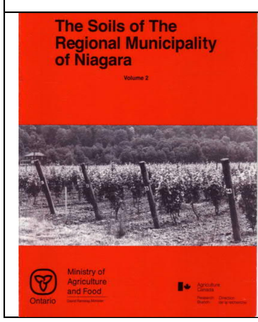
Wetlands are identified.

NPCA regulated lands are shown based on buffer.

Reference Documents:



NPCA Watershed explorer does not show any previous stormwater flood studies completed for the Point Abino Drain.
Light green shading is indicative of approximate regulated limits.



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3 Hydrology

The Point Abino Drainage system was composed into a computer-based model to analyze the hydrology and hydraulics of the existing drain. The model was created using PC-SWMM software to complete an EPA SWM v5.4 model. Considerations for the landform were given in the creation of the model.

The predominate soil through the Point Abino Watershed is clay with poorly drained conditions. Figure 13 is colour coded for the predominate soil types.

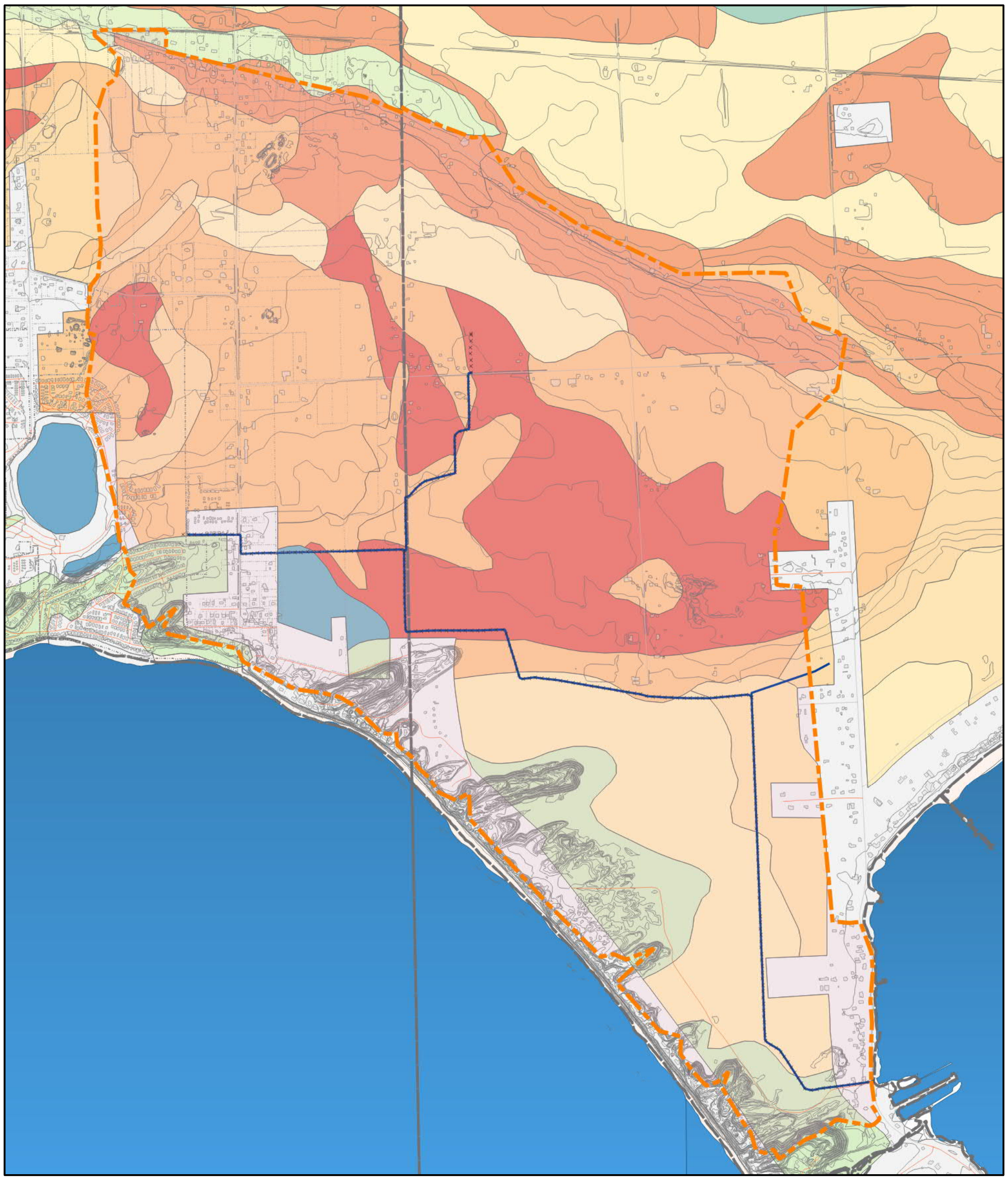

Figure 13 Point Abino Watershed Soil Classifications

The two predominate soils within the catchment are Welland Clay (blue) to the west and Bok (red) predominately a clay soil to the east with lobes of Chinguacousy, Farmington and Franktown (lighter shades). The grey is a series labeled 'not mapped' and is generally representative of the sand dunes Erie shoreline, which was deemed unsuitable for farming and thus not mapped. However, the light green areas are mapped as eolian fine sand indicating the extent of the dune soil feature.

The lower reach is shown as HOY or Holly soil series an organic soil associated with swamp conditions.

Table 2 Point Abino Soils Table

BOK	Brooke Soil, 50 to100cm variable textures over mainly limestone and dolostone bedrock.
CHINGUACOUSY	Mainly clay loam till. Imperfectly drained.
FARMINGTON Loam	10 to 20cm variable textures over mainly limestone and dolostone bedrock. Drainage is rapid. Brunisolic Gray Brown Luvisol
FRANKTOWN	20 to 50 cm variable textures over mainly limestone and dolostone bedrock. Imperfectly drain. Gleyed Melanci Brunisol
HOY Holly	Holly Soil – Organic soil, swamp associated, 40 to 160 cm deep over loamy mineral soil materials.
WAM Walsingham	Walsingham is mostly eolian fine sand at least 1m thick identified as imperfectly drained.
NM	Not Mapped, covers all of the urban area, sand dune area.

From The Soils of Regional Municipality of Niagara, volume 2, dated 1989, from which the GIS data is shown.

From The Soils of Regional Municipality of Niagara, volume 2, dated 1989, from which the GIS data is shown in Figure 13 as a map with the Point Abino Drain, boundary overlaid, we can see that the predominate feature is poor drainage above (North) of the Friendship Trail. Predominately land grades throughout the Watershed are low, with almost very low land slopes below the Friendship Trail.

From this information, we can choose our soil groups for CN values within the Watershed. Group D soils are those for the upper watershed, Brooke, Chinguacousy, Welland and Franktown. The lower areas consisting of land not mapped adjacent to the lake are considered Group C or B because of the presence of major sand deposits.

Table 3 CN Hydrologic Soil Groups

Land Use Description on Input Screen	Description and Curve Numbers from TR-55					
	Cover Description		Curve Number for Hydrologic Soil Group			
	Cover Type and Hydrologic Condition	% Impervious Areas	A	B	C	D
Agricultural	Row Crops - Straight Rows + Crop Residue Cover-Good Condition (1)		64	75	82	85
Commercial	Urban Districts: Commercial and Business	85	89	92	94	95
Forest	Woods(2) - Good Condition		30	55	70	77

Grass/Pasture	Pasture, Grassland, or Range[3] - Good Condition		39	61	74	80
High Density Residential	Residential districts by average lot size: 1/8 acre or less	65	77	85	90	92
Industrial	Urban district: Industrial	72	81	88	91	93
Low Density Residential	Residential districts by average lot size: 1/2 acre lot	25	54	70	80	85
Open Spaces	Open Space (lawns, parks, golf courses, cemeteries, etc.)[4] Fair Condition (grass cover 50% to 70%)		49	69	79	84
Parking and Paved Spaces	Impervious areas: Paved parking lots, roofs, driveways, etc. (excluding right-of-way)	100	98	98	98	98
Residential 1/8 acre	Residential districts by average lot size: 1/8 acre or less	65	77	85	90	92
Residential 1/4 acre	Residential districts by average lot size: 1/4 acre	38	61	75	83	87
Residential 1/3 acre	Residential districts by average lot size: 1/3 acre	30	57	72	81	86
Residential 1/2 acre	Residential districts by average lot size: 1/2 acre	25	54	70	80	85
Residential 1 acre	Residential districts by average lot size: 1 acre	20	51	68	79	84
Residential 2 acres	Residential districts by average lot size: 2 acre	12	46	65	77	82
Water/ Wetlands		0	0	0	0	0

Color Key

CN #XX	Point Abino subject value	Model implemented

Notes
(1) Hydraulic condition is based on combination factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes, (d) percent of residue on the land surface (good>=20%), and (e) degree of surface roughness.
(2) Good: Woods are protected form grazing, and litter and brush adequately cover the soil.
(3) Good: >75% ground cover and lightly or only occasionally grazed.
(4) CN's shown sre equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.

Information on soil permeability was found online for grape growers within Niagara Region and published in the following form.

WATER INFILTRATION INTO SOIL

		WATER INFILTRATION INTO SOIL		SOIL WATER HOLDING CAPACITY				DRAINAGE - WATER MOVEMENT THROUGH ENTIRE PROFILE			
SOIL SERIES	SURFACE SOIL TEXTURE	RATE OF WATER INFILTRATION (based on surface soil texture)	RATE OF WATER INFILTRATION (in/hr)	SOIL WATER HOLDING CAPACITY	AVERAGE INCHES OF WATER/ INCH OF SOIL AT FIELD CAPACITY	GRAPE ROOTING DEPTH (36 inches or max of A and B soil profile depth) inches	AVAILABLE WATER WITHIN ROOTING DEPTH (inches)	HYDRO-LOGIC SOIL GROUP	RATE OF WATER FLOW THROUGH THE SOIL PROFILE (in/hr)	LEACHING RISK	DRAINAGE CLASS
Morley	Silty Clay	Slow	0.08-0.2	Medium	0.13	27	3.60	D	0-0.04	Very Low	Poorly drained
Toldeo	Silty Clay	Slow	0.08-0.2	Medium	0.13	22	2.93	D	0-0.04	Very Low	Poorly drained
Jeddo	Clay Loam	Medium	0.15-0.3	High	0.17	19	3.17	D	0-0.04	Very Low	Poorly drained
Beverly	Silty Clay Loam	Medium	0.15-0.3	High	0.17	26	4.33	C	0.04-0.16	Low	Imperfectly drained
Chingua-cousy	Clay Loam	Medium	0.15-0.3	High	0.19	16	3.00	C	0.04-0.16	Low	Imperfectly drained
Tavistock	Loam	Fast	0.3-0.5	Medium	0.15	28	4.08	C	0.04-0.16	Low	Imperfectly drained
Vineland	Very Fine Sandy Loam	Fast	0.3-0.5	Low	0.10	33	3.44	B	0.16-0.32	Medium	Imperfectly drained
Grimsby	Very Fine Sandy Loam	Fast	0.3-0.5	Low	0.10	36	3.75	A	0.3-0.5	High	Well drained

Sarah Krick and Donna Speranzini AAFC 2013

Figure 14 Soil Drainage Permeability Factors

This shows a low rate of infiltration of 3.8 mm/hr to 7.62 mm/hr for both Chinguacousy Clay loam and Jeddo Clay Loam within the Point Abino Watershed. From this a setting of Ia = 5mm was selected.

3.1 Existing Conditions Drain Model

An EPA SWMM v5.1 model was setup based on a sub-catchment discretization and channel segregation using GIS data as the based for model determinations. A GIS map of the data used for model set up is included in Appendix B. The Catchment definitions are shown in Figure 15 and Table 4 with runoff parameters for the CN runoff model. Consideration was given in the catchment definitions to major roads and culvert crossings along with drainage junctions for branch drains.

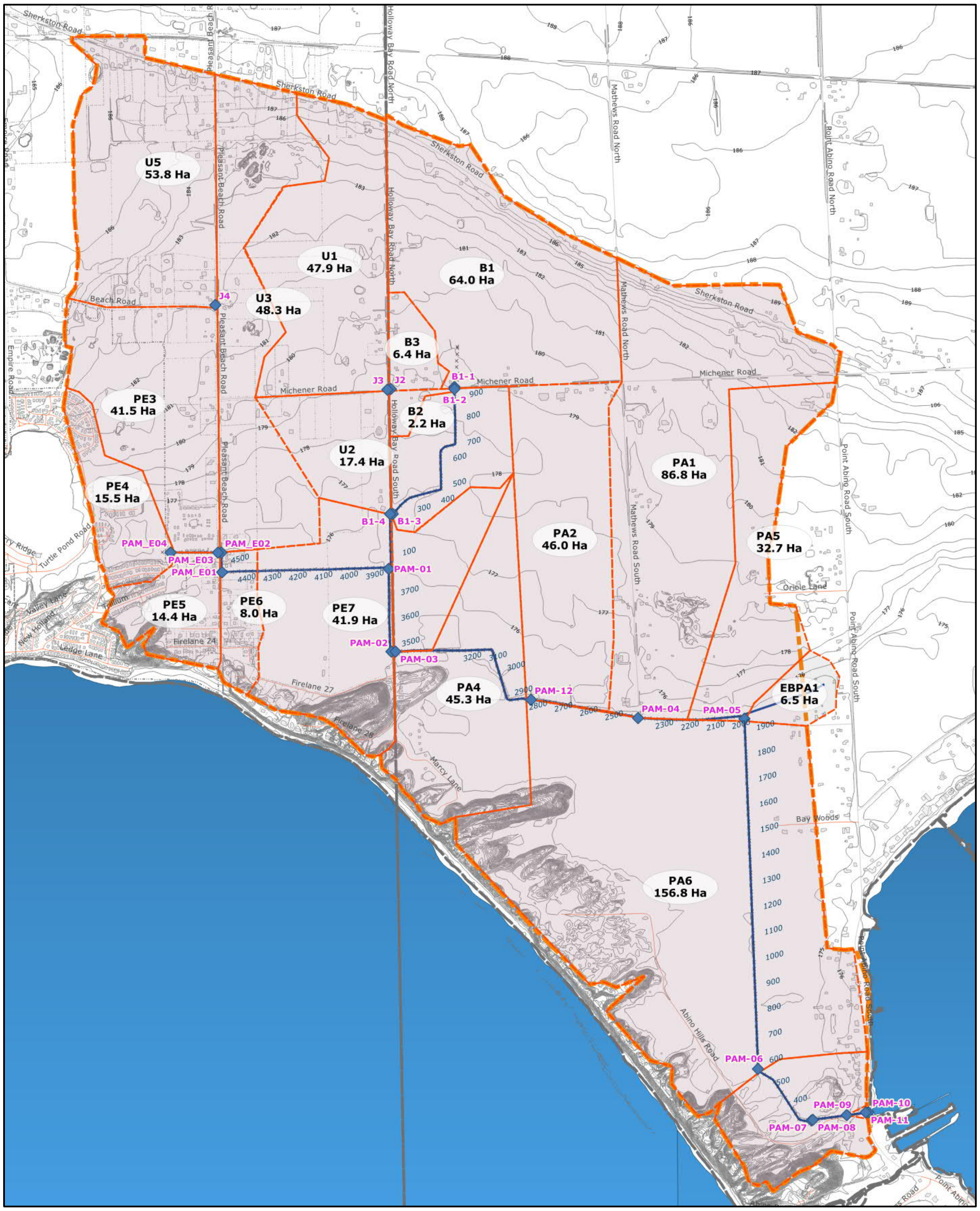

Figure 15: SWMM Model view

Catchment areas:

The Catchments were defined in GIS and specific areas calculated and runoff characteristics were selected based on landforms, land use and other factors for each catchment, those variables are listed in the following table.

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Table 4 Point Abino Watershed Catchment Variables

Name	Outlet	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	Imperv. (%)	Curve Number	Peak Runoff (m^3/s)	Runoff Coefficient
B1	B1-1	64.0	713	898	0.1	8	74	0.73	0.252
B2	B1-2	2.2	135	166	0.1	5	80	0.07	0.453
B3	J2	6.4	188	341	0.1	8	80	0.16	0.45
B4	B1-3	19.4	317	612	0.1	5	80	0.25	0.388
EBPA1	EB1	6.5	205	317	0.05	4.5	80	0.1	0.418
PA1	PAM-04	86.8	484	1794	0.1	5	74	0.66	0.205
PA2	PAM-12	46.0	362	1271	0.1	7	74	0.55	0.266
PA3	PAM-03	15.9	279	571	0.1	5	80	0.22	0.398
PA4	PAM-12	45.3	529	856	0.1	5	80	0.46	0.337
PA5	PAM-05	32.7	373	877	0.1	10	78	0.57	0.364
PA6	PAM-06	156.8	1123	1396	0.1	5	70	0.89	0.131
PA7	PAM-09	22.5	410	549	0.1	10	72	0.43	0.308
PE3	PAM_E03	41.5	355	1169	0.15	10	80	0.72	0.392
PE4	PAM_E04	15.5	275	563	0.15	30	85	0.8	0.632
PE5	PAM_E03	14.4	368	392	0.15	25	85	0.69	0.607
PE6	PAM_E01	8.0	166	483	0.15	25	85	0.48	0.619
PE7	PAM-02	41.9	563	743	0.1	10	80	0.67	0.379
U1	J3	47.9	498	962	0.2	8	76	0.71	0.319
U2	B1-4	17.4	370	471	0.1	8	80	0.33	0.414
U3	PAM_E02	48.3	427	1131	0.05	8	76	0.54	0.272
U5	J4	53.8	546	985	0.15	10	76	0.82	0.318

The model was set up as a Junction (node) and conduit (link) model in EPA SWMM software as shown in the GIS depicted in Figure 15.

A Logical Model Diagram is included in the report Appendix B. The logical Diagram represents the organization of the specific nodes and links irrespective of the geographic representation shown in Figure 15.

Idealized Channels are used to represent flows without surcharging conditions. Channels are typically designed to a lower capacity than the 1:100 year design storm and thus an idealized version is required unless a 2D or dual drainage model is implemented.

The model has surcharge points as shown in the following profile view of the 1:5 year model result, see Figure 16 Design Runoff Event Profiles .

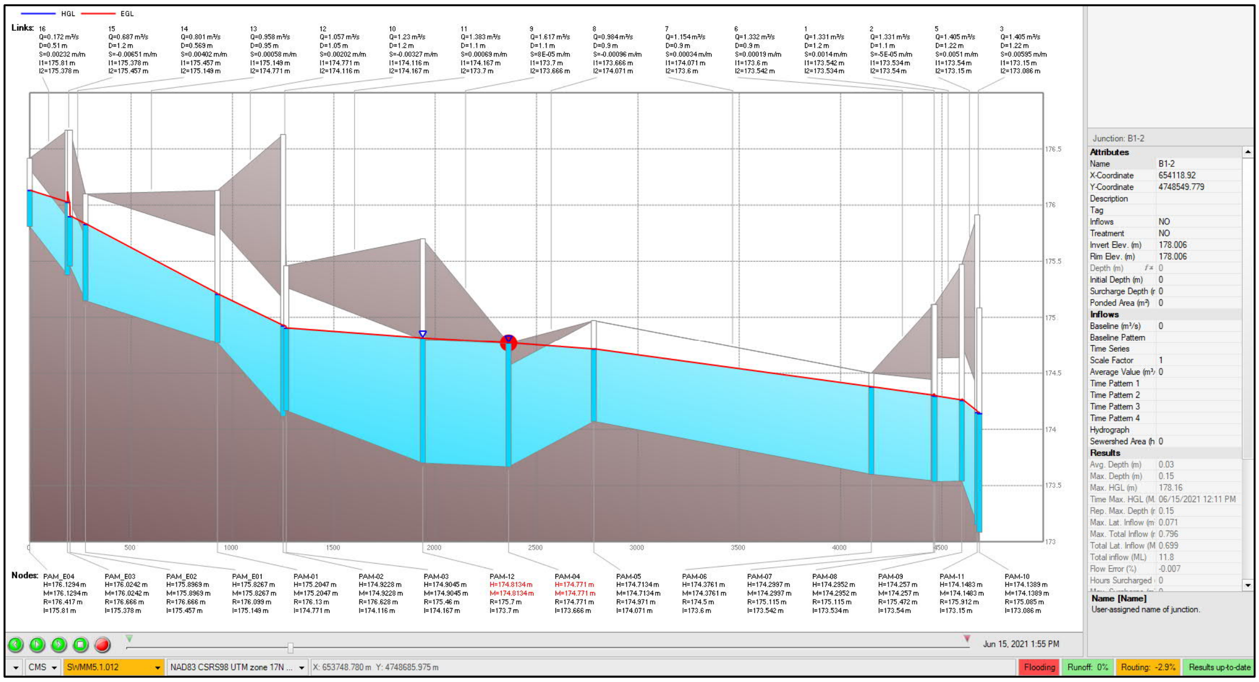

Figure 16 Design Runoff Event Profiles

The right portion of Figure 16 shows the outlet of the Point Abino Drain to Lake Erie.

From the flooded junction, PAM-04 (red circle highlight), to the invert of the box culvert outlet is a distance of 2.4km with a total fall of only 0.1m, which is similar to the Wignell Drain in Port Colborne. The function of this outlet is compromised by the low grade and ‘runs’ when the runoff above this point pushes higher water to the outlet. Changing the grade is not an option to make an improvement to gain an increase in flow performance.

The outlet is considered for the purposes of the model to be a fixed flowing outlet, which means that the elevation shown for the outlet has a specific fixed static Lake water surface elevation that is higher than the water’s edge elevation. For the purposes of the model, the average annual elevation is used 174.14m.

What we can appreciate is that the outlet is impacted by the Lake surface elevation. For most of the time the drain has a consistent slow and steady flow to Lake Erie but this is not the case during seiche storm event. Standing water upstream of the gate outlet is common as the lake levels vary.

Figure 17 Point Abino Outlet Flap gate

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The steel gate operate on the basis of an elevated level in the lake, higher than the level in the drain pushing the gate closed against the frame. Gate opens when the flow from the drain with a higher elevation than the lake pushes the gate open.

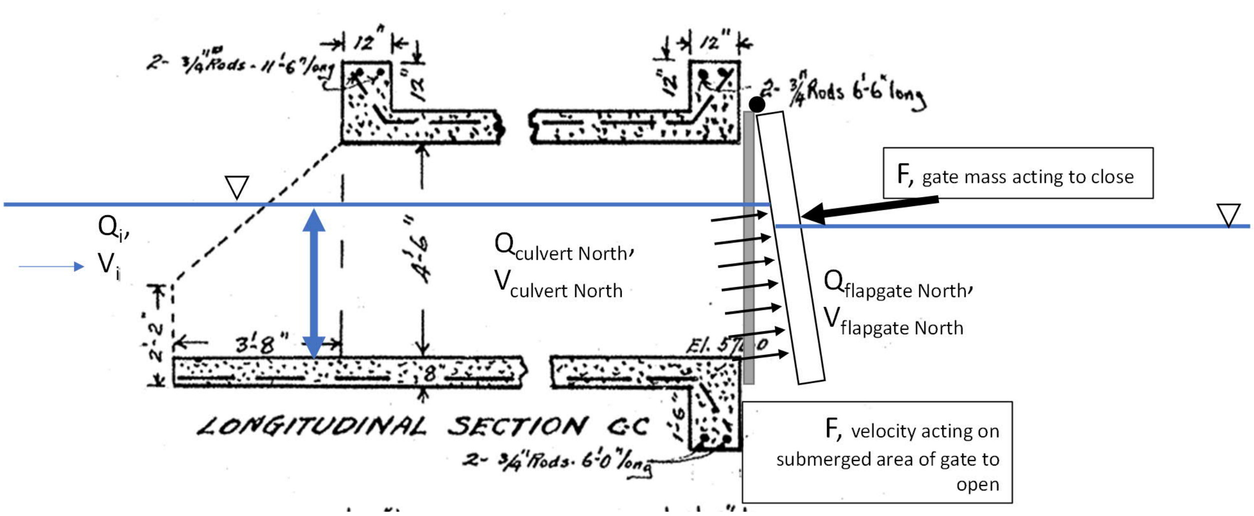


Figure 18 Point Abino Flap gate forces to open

There are some key functional impacts of the passive flap gate structure, and they are as follows:

1. The gate reduces the flow from the Lake into the drain at the outlet to near zero when the gate achieves an effective seal against the face of the outlet structure. Any gaps allow seepage to flow backwards but back flow is greatly reduced by the gate.

2. Once the gate is slack closed from the outside pressure of a higher water level on lake side, it opens when the lake drops below the existing water

elevation in the drain. The pressure from the height differential between lake side and drain side pushes the weight of the gate open.

3. The outlet is not ever a free flowing outlet as the gate weight always impacts the available opening.

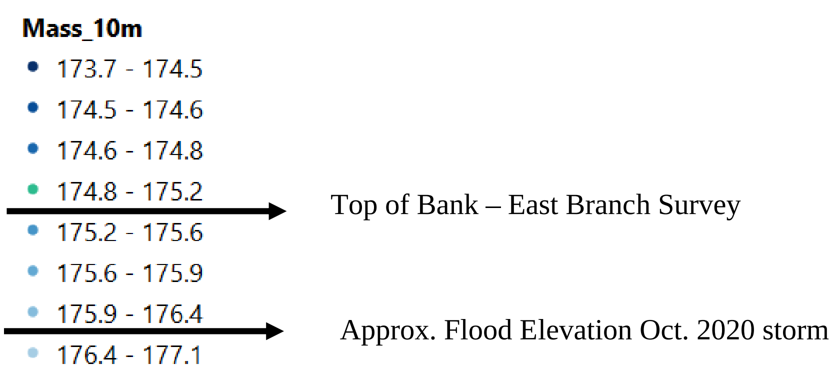
4. With an outlet invert elevation of 172.8m (NAD83) and an average annual Lake Erie surface elevation of 172.14m (IGLD), the outlet is submerged most of the time.

The performance of the outlet impacts the stormwater model.

3.1.1 Point Abino Flood Storage

Hydrologic models are based on a runoff catchment that is routed to an outlet using a channel or pipe conveyance with junctions (or model nodes). The conveyance structure is based on consistent regular geometry and for the channel to be modified or changed then it is required for a model node or junction be used to make such a transition. This is very often used to model the performance of culverts within a hydrologic model with an upstream node and a downstream node connecting to traditional trapezoidal open channels with a pipe conveyance or box conveyance for the culvert crossing the roadway.

This figure is prepared using the data from the NPCA (Niagara Peninsula CA) Orthophoto digital mapping prepared and published in 2012. The orthophoto (plane based survey method) was digitized into a 10m Digital Elevation Model (DEM) which gives a dot covering the surface of the watershed. A subset of that data was used with GIS software to colour code each dot based on the elevation recorded in the DEM. The colour coding using GIS is configured to show elevation by colour.



The transition from blue to green is intended to correspond with the top of bank surveyed at the confluence of the East Branch and Main Branch.

Figure 19 Point Abino Main Channel looking South from East Branch

The sand dunes to the west of Point Abino protect the area behind the dunes from storms. The dunes stop water from flowing in directly but as the dunes are sand, water will seep through them and seek a level behind the dunes. That level depends on the relationship between the driving height of the Lake and the rate of seepage through the dunes. Similarly, the height of Point Abino Rd offers a barrier to the Lake but at the point where the drain outlets to the Lake, from survey the centreline road elevation is 175.912m. Contour lines from NPCA are colour coded:

- 175.0 is light brown (almost yellow)
- 176.0 is bright pink
- 177.0 is orange.

The surge/seiche from the Lake pushes back into the drain and pushes the main Point Abino Drain backwards up to the East Branch, which can then flow backwards as far as the Point Abino Rd. This figure shows that the water may be able to cross the road and seek a path back to the lake or add to flooding. The risk is that the water could back all the way to the Point Abino PS and cause a circular flow with the lake, where this amount of water may exceed the capacity of the Point Abino Road pumping station.

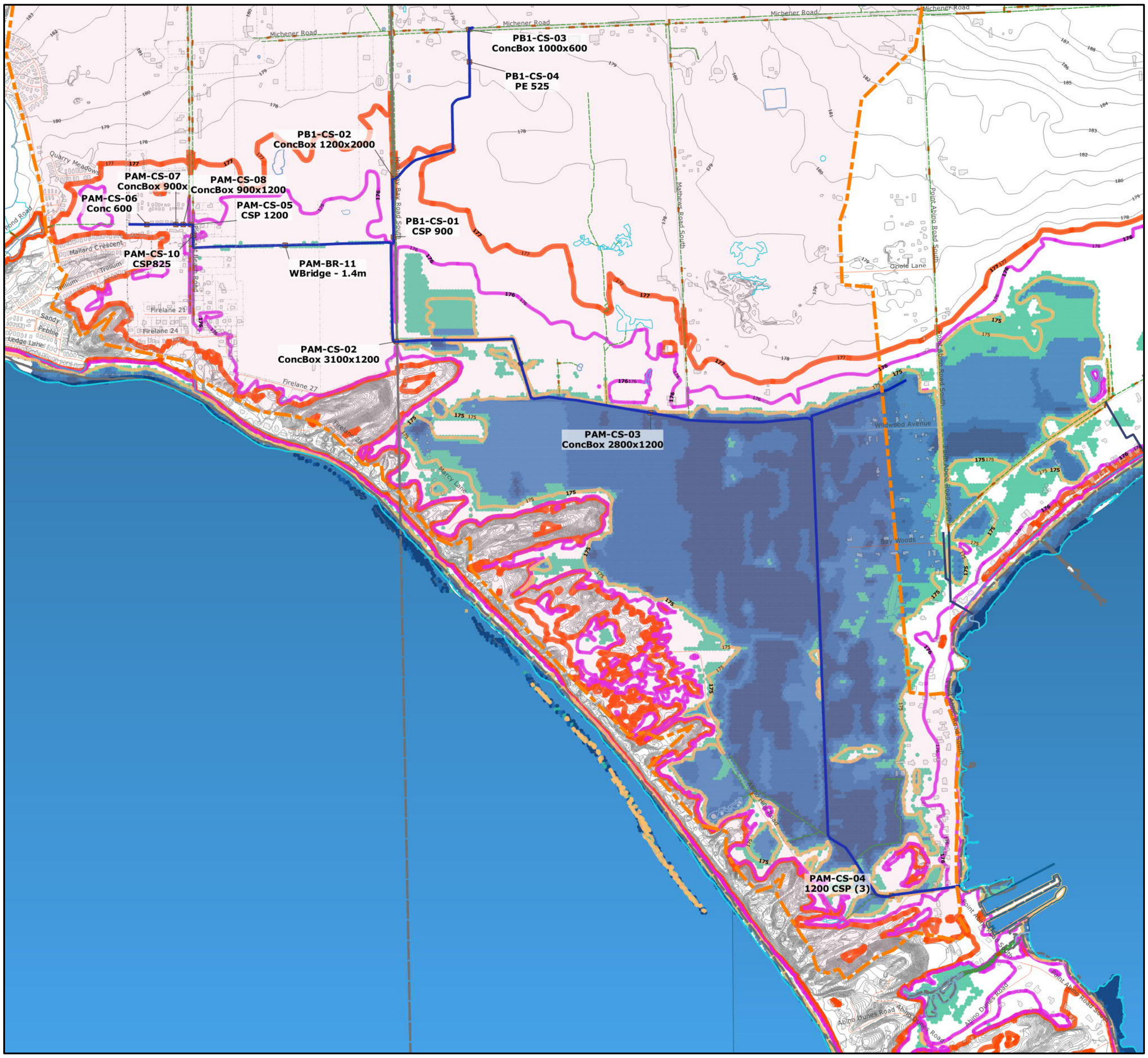


Figure 20 Point Abino Flood Zone Elevations

3.1.2 Hydrologic Model Results

The model was prepared using best available information and configured with accepted input variables representative of the areas and land uses occurring in the watershed. The model was run based on input files and the output files were reviewed using the graphic interface provided by the software. Additional analysis was prepared using GIS to graphically display results. The 1D model results are shown in the following model output tables and discussed with recommended actions to support the Drainage design process.

Table 5 Point Abino Junction 1:2 Yr Flood Results

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**********************
  Node Surcharge Summary
  **********************
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Surcharging occurs when water rises above the top of the highest conduit.

Node	Type	Hours Surcharged	Max. Height Above Crown Meters	Min. Depth Below Rim Meters
PAM_E04	JUNCTION	0.50	0.097	0.000
PAM-04	JUNCTION	5.29	0.005	0.000
PAM-12	JUNCTION	1.25	0.066	0.834

****
Node Flooding Summary
****

Flooding refers to all water that overflows a node, whether it ponds or not.

Node	Hours Flooded	Maximum Rate CMS	Time of Max Occurrence days hr:min	Total Flood Volume 10^6 ltr	Maximum Ponded Depth Meters
PAM_E04	0.35	0.215	0 12:10	0.161	0.000
PAM-04	4.34	1.112	0 13:02	4.675	0.000

****
Outfall Loading Summary
****

Outfall Node	Flow Freq Pcnt	Avg Flow CMS	Max Flow CMS	Total Volume 10^6 ltr
pam - Outlet	93.36	0.760	50.556	85.432
System	93.36	0.760	50.556	85.432

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CMS	Time of Max Occurrence days hr:min	Maximum |Veloc| m/sec	Max/ Full Flow	Max/ Full Depth
PAM-0+100	CONDUIT	1.248	0 17:31	0.28	1.16	0.66
PAM-0+220	CONDUIT	1.247	0 17:27	0.27	0.81	0.83
PAM-0+550	CONDUIT	1.129	0 14:10	0.27	0.54	0.77
PAM-1+910	CONDUIT	1.524	0 12:48	0.36	0.44	0.85
PAM-2+400	CONDUIT	2.365	0 12:57	0.32	1.65	1.00
PAM-2+800	CONDUIT	2.365	0 12:43	0.39	0.56	0.90
PAM-3+450	CONDUIT	2.524	0 12:34	0.66	0.50	0.78
PAM-3+800	CONDUIT	1.680	0 12:25	0.52	0.85	0.83
PAM-4+450	CONDUIT	1.628	0 12:14	0.74	0.82	1.00
PAM-4+520	CONDUIT	0.408	0 12:07	0.45	0.80	1.00
PAM-CS-02	CONDUIT	2.570	0 12:36	1.01	0.85	0.77
PAM-CS-04	CONDUIT	1.248	0 17:25	0.57	0.53	0.62
PAM-CS-05	CONDUIT	1.316	0 12:15	1.91	0.74	0.71
PAM-CS-20a	CONDUIT	3.916	2 02:05	2.69	1.12	0.87
PAM-CS-20b	CONDUIT	1.289	0 16:10	0.60	0.40	0.70
PA-Outlet	CONDUIT	50.556	2 02:10	7.64	0.46	0.68
PB1-0+000	CONDUIT	1.127	0 12:23	0.84	0.85	0.90
PB1-0+225	CONDUIT	0.636	0 12:13	0.54	0.51	0.85
PB1-CS-02	CONDUIT	0.664	0 12:23	0.42	0.38	0.68
PB1-CS-03	CONDUIT	0.721	0 12:10	1.57	1.23	0.76
PEB1	CONDUIT	0.045	0 12:12	0.08	0.04	0.86
RS-Holloway-W	CONDUIT	0.512	0 12:11	0.70	0.57	0.88
RS-Michener-S	CONDUIT	0.078	0 12:11	0.25	0.15	0.48
RS-Pleasant-W	CONDUIT	0.468	0 12:16	0.46	0.76	0.94

Table 6 Point Abino Junction 1:5 Yr Flood Results

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Node Surcharge Summary
****

Surcharging occurs when water rises above the top of the highest conduit.

Node	Type	Hours Surcharged	Max. Height Above Crown Meters	Min. Depth Below Rim Meters
B1-1	JUNCTION	0.16	0.262	0.338
J4	JUNCTION	0.21	0.000	0.000
PAM_E01	JUNCTION	0.23	0.000	0.000
PAM_E04	JUNCTION	1.16	0.097	0.000
PAM-02	JUNCTION	0.62	0.050	1.262
PAM-04	JUNCTION	14.28	0.005	0.000
PAM-12	JUNCTION	11.25	0.212	0.688

****
Node Flooding Summary
****

Flooding refers to all water that overflows a node, whether it ponds or not.

Node	Hours Flooded	Maximum Rate CMS	Time of Max Occurrence days hr:min	Total Flood Volume 10^6 ltr	Maximum Ponded Depth Meters
J4	0.21	0.602	0 12:10	0.202	0.000
PAM_E01	0.22	0.674	0 12:12	0.268	0.000
PAM_E04	0.88	1.049	0 12:11	1.364	0.000
PAM-04	13.88	3.044	0 12:59	56.781	0.000

****
Outfall Loading Summary
****

Outfall Node	Flow Freq Pcnt	Avg Flow CMS	Max Flow CMS	Total Volume 10^6 ltr
pam - Outlet	94.84	0.965	31.328	124.712
System	94.84	0.965	31.328	124.712

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CMS	Time of Max Occurrence days hr:min	Maximum |Veloc| m/sec	Max/ Full Flow	Max/ Full Depth
PAM-0+100	CONDUIT	1.495	0 14:14	0.32	1.39	0.70
PAM-0+220	CONDUIT	1.495	0 15:42	0.30	0.97	0.89
PAM-0+550	CONDUIT	1.167	0 13:13	0.26	0.56	0.81
PAM-1+910	CONDUIT	1.490	0 12:24	0.34	0.43	0.86
PAM-2+400	CONDUIT	3.806	0 12:54	0.52	2.66	1.00
PAM-2+800	CONDUIT	3.411	0 12:56	0.47	0.81	1.00
PAM-3+450	CONDUIT	3.229	0 12:27	0.68	0.64	0.93
PAM-3+800	CONDUIT	2.001	0 12:25	0.56	1.02	0.95
PAM-4+450	CONDUIT	2.142	0 12:13	0.98	1.07	1.00

PAM-4+520	CONDUIT	0.412	0	12:01	0.45	0.81	1.00
PAM-CS-02	CONDUIT	3.443	0	12:39	1.07	1.13	0.98
PAM-CS-04	CONDUIT	1.495	0	14:14	0.63	0.63	0.66
PAM-CS-05	CONDUIT	1.590	0	12:15	1.91	0.89	0.90
PAM-CS-20a	CONDUIT	3.987	2	07:22	2.86	1.14	0.87
PAM-CS-20b	CONDUIT	1.609	0	14:00	0.60	0.50	0.72
PA-Outlet	CONDUIT	31.328	2	07:11	4.77	0.29	0.67
PB1-0+000	CONDUIT	1.621	0	12:24	1.00	1.22	1.00
PB1-0+225	CONDUIT	1.031	0	12:12	0.75	0.83	0.96
PB1-CS-02	CONDUIT	0.958	0	12:24	0.42	0.55	0.98
PB1-CS-03	CONDUIT	1.119	0	12:10	2.00	1.91	0.96
PEB1	CONDUIT	0.061	0	12:06	0.07	0.05	0.88
RS-Holloway-W	CONDUIT	0.820	0	12:11	0.93	0.91	0.98
RS-Michener-S	CONDUIT	0.137	0	12:11	0.30	0.26	0.64
RS-Pleasant-W	CONDUIT	0.564	0	12:09	0.50	0.92	1.00

The model results are shown as visual map-based results in the following figure.

Figure 21 Design Storms and Hours Flooded

These model results indicate that the drain or portions thereof are not meeting the minimum standards for conveyance without flooding occurring.

The model provides runoff results for channels, which are represented in the model as links with pipe shapes and dimensions or trapezoidal channels with a depth consistent with survey results. The results are shown for the 5 year precipitation event indicate system challenges with the current arrangement.

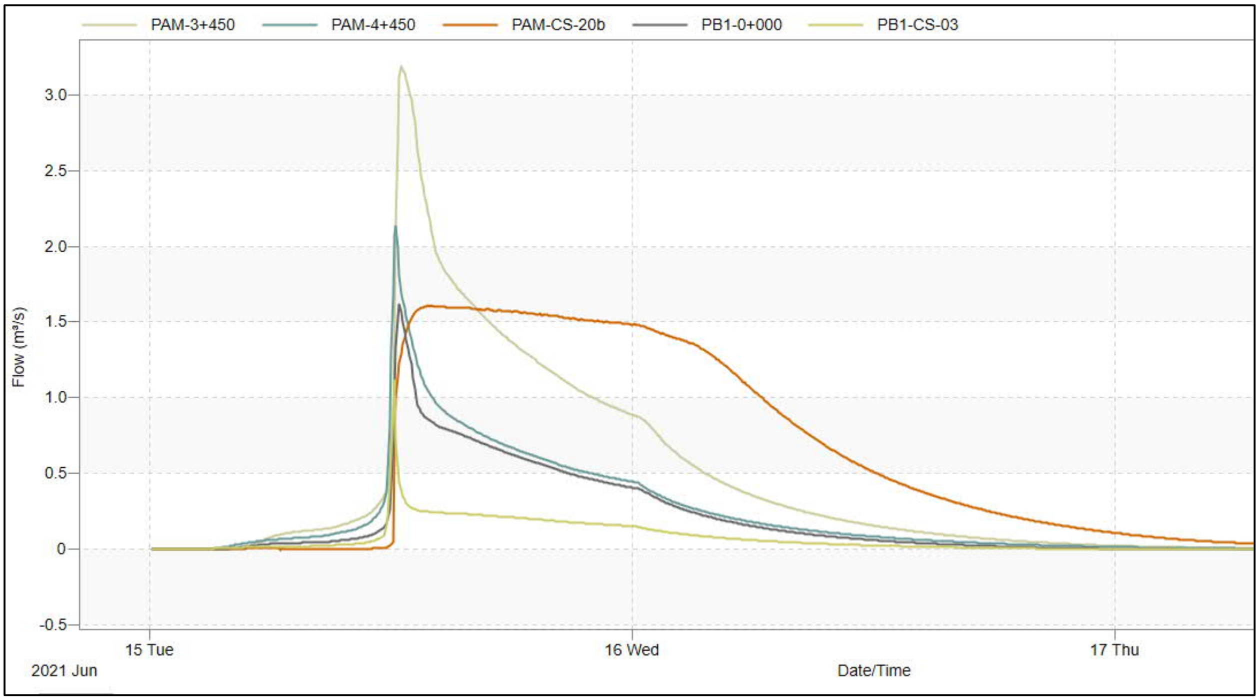

Figure 22 Model Hydrograph Results 1:5 year Design Storm

Base Model Observations

The following are observations about the existing system resulting from the modelling performed to date.

1. The model identifies flooding occurs for the design storm standard test for 68.9mm of precipitation in 24 hours (5 yr storm).
2. Flooding (red boxes) occurs in the upper portion of the drain adjacent to Pleasant Beach Road.

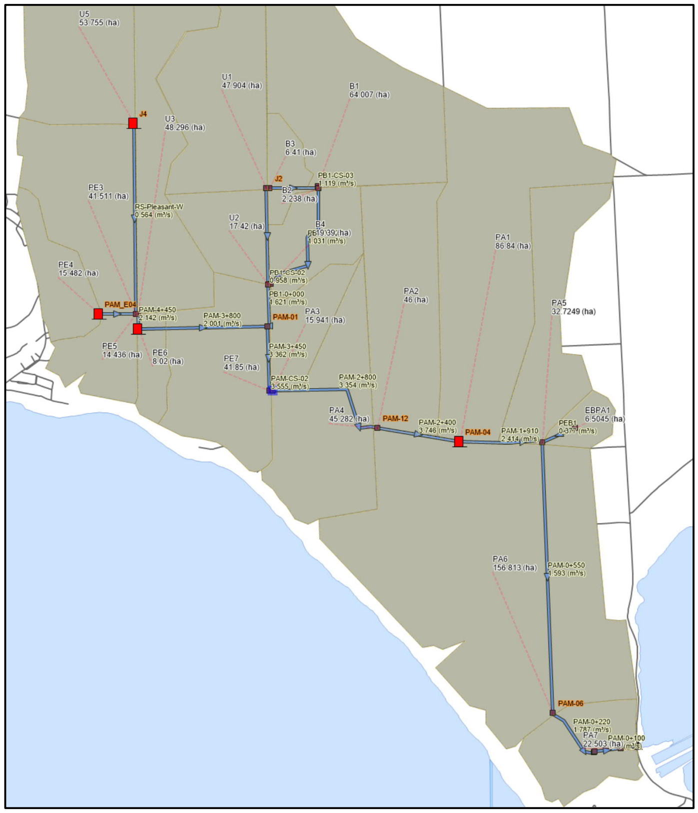

Figure 23 Design Storm Flooding Indicators

3. Flooding is shown at the node south of Mathews Rd S and this may be due to the lack of invert data for the drain in the lower reach or reflects the low gradient to the outlet.

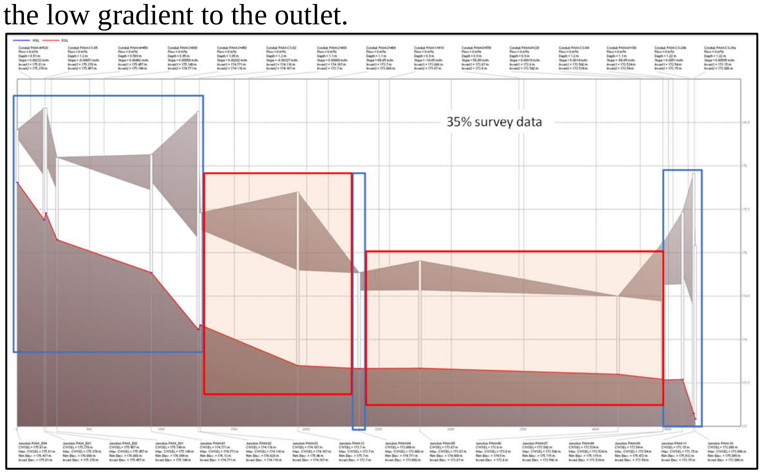

Figure 24 Drain Grade line Missing Data

4. The red box is indicative of missing survey data and the grade line has been adjusted to a positive grade to outlet for modelling purposes. Only

35% of the Point Abino Drain has been surveyed, 100% of the Point Abino Branch #1 Drain was surveyed.

5. The missing data for the lower reach of the model, East of Holloway Bay Rd compromises the model in those channel sections; however, with known surveyed inverts at Holloway Bay Rd and the outlet the general grade for the lower 3420m of the drain can be represented but without cross-sections or other physical data for confirmation of input parameters.

6. The outlet is modelled as a controlled flap gate with outlet discharged into a fixed elevation at 174.16m for Lake Erie (average monthly).

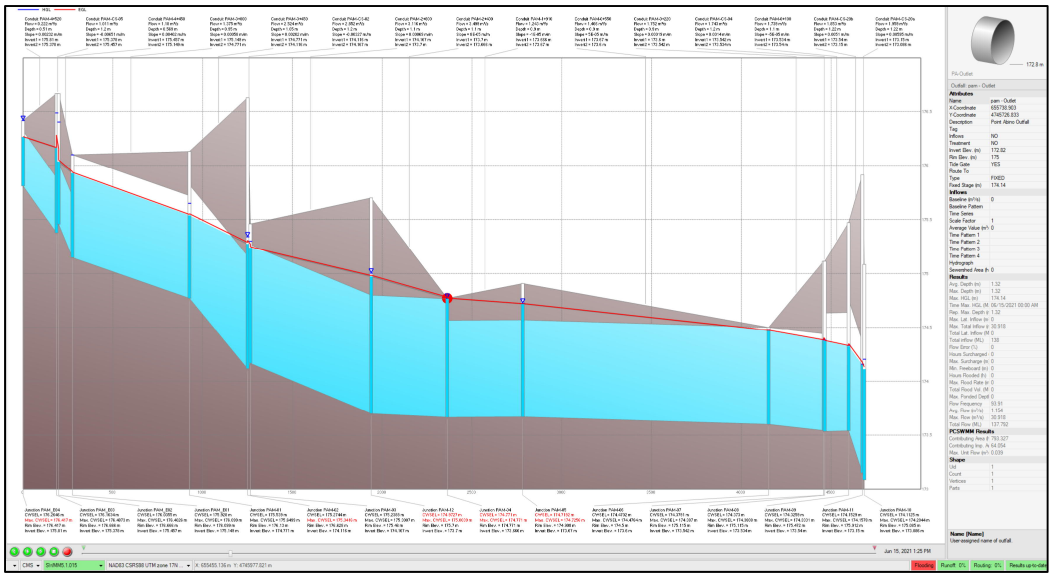

Figure 25 PC-SWMM Model Profile View

Notes:

The model is prepared based on best available information.

The model used survey data where available and assumptions about the missing channel information was made consistent with model practices.

Flow monitoring has not been performed and the model is unverified.

3.2 Proposed Design Model

After the 50% design review to consider options for improvement and design profiles for 75% are composed then a final model to assess performance improvements and limitations will be performed and those results will be documented in the final report.

4 Drain Hydraulics

The following presents the existing grades based on the survey. These are the actual grades from the survey of inverts at road crossings, and along the drain as the survey collected drain channel grades for a selected set of cross-sections, 35% of Point Abino and 100% of Branch #1. Those are represented in the Baseline Drawings included in Appendix B of the Baseline Report.

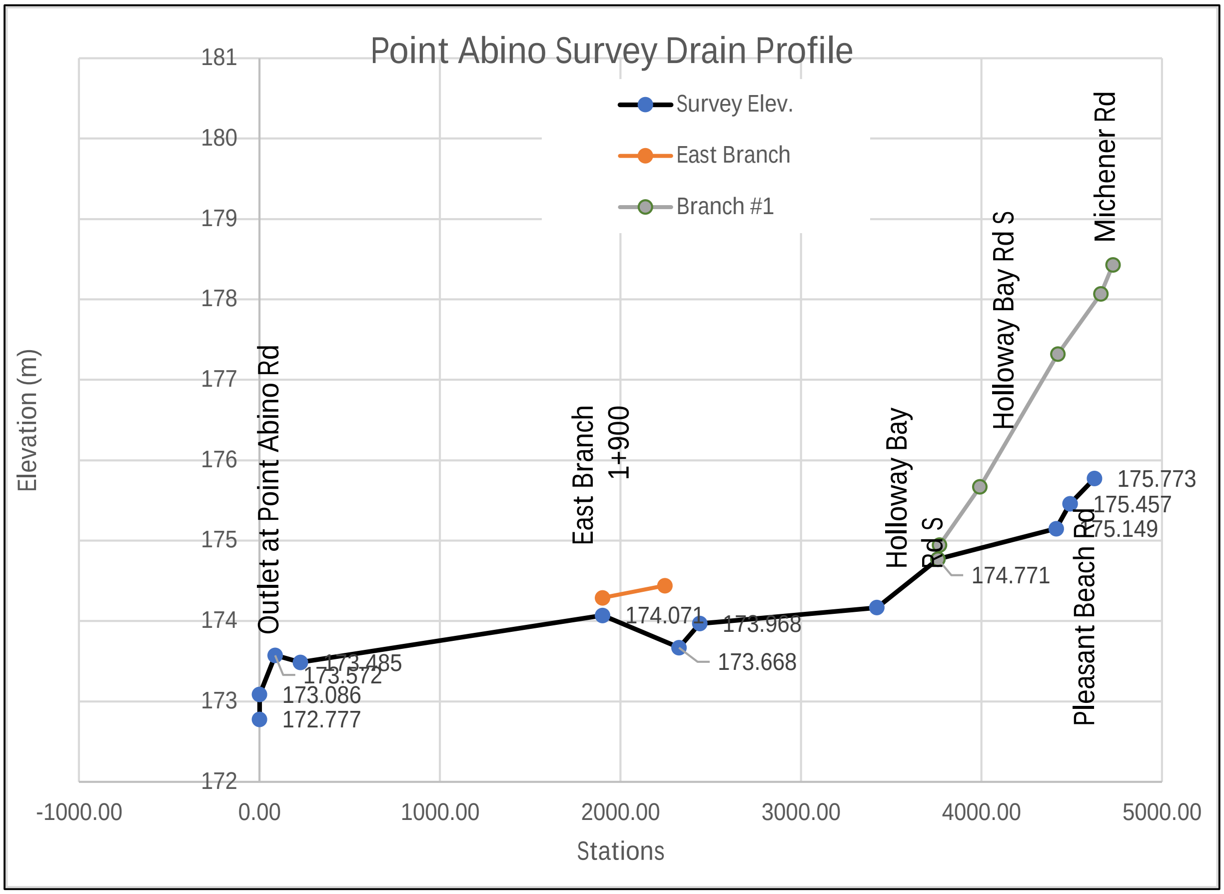

Figure 26 Point Abino Drain Profile

Detailed drawings are included in the Baseline report and show the existing static water level. The static water is undesirable but constricted by the outlet elevation and past over excavation of the channel during maintenance or by design.

4.1 Drain Channel Capacity Analysis

The cross-section of each drain channel, where drain channels are defined by the model set up with specific junctions as shown in the Model Map Diagrams in Appendix B was used to calculate a top of bank channel flow capacity.

Manning's n values were used from the US DOT reference, included in Appendix D. Where a top bank on either side of the channel has different heights then the lowest height, providing the least capacity, is used in the calculation.

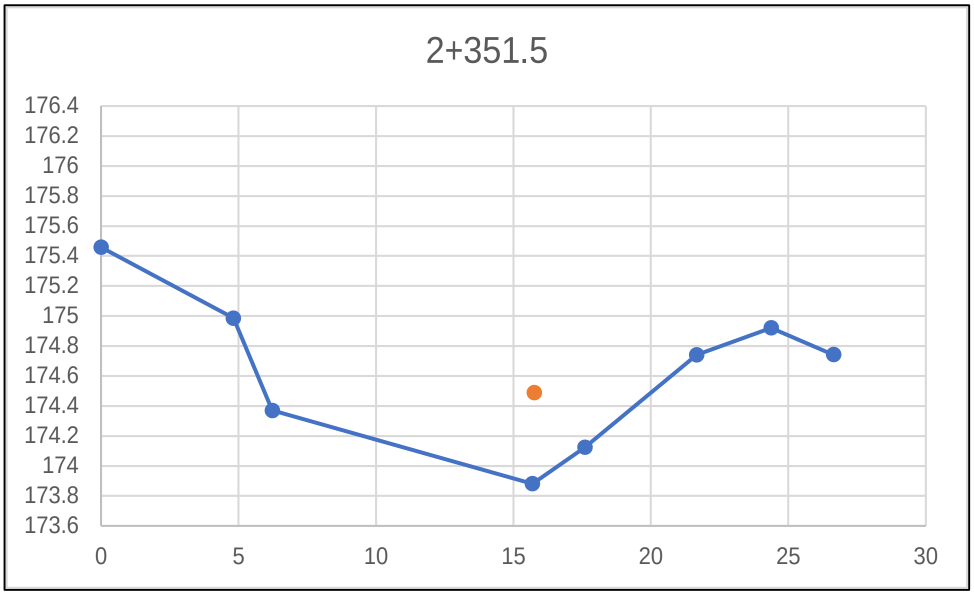

Figure 27 Channel Capacity Cross Sectional Analysis Stn 2+351.5

The orange dot is the surveyed static water elevation, or standing water in the drain.

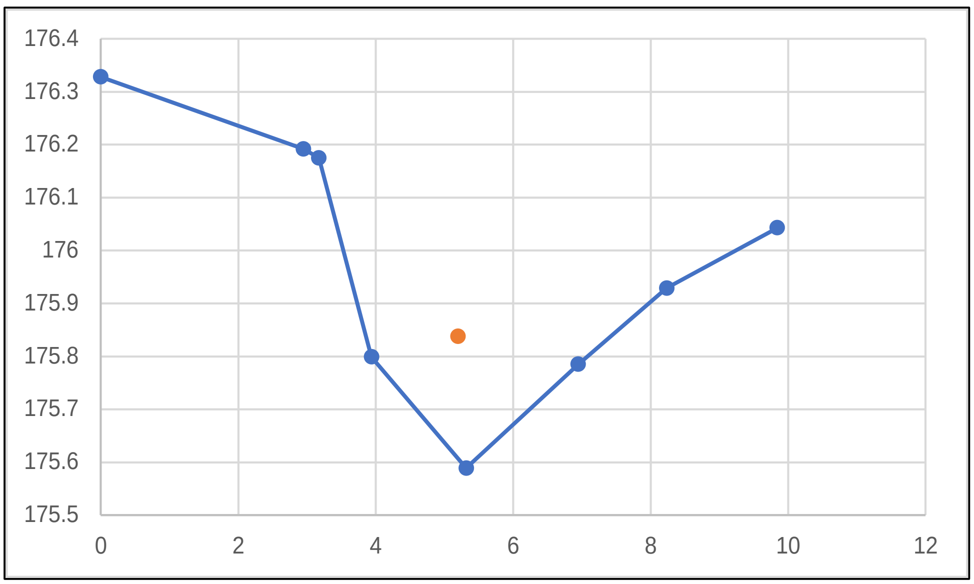

Figure 28 Station 4+469.4 Cross-section capacity flow calculation

The depth for this section is only 0.59m with a bottom width of only 1m

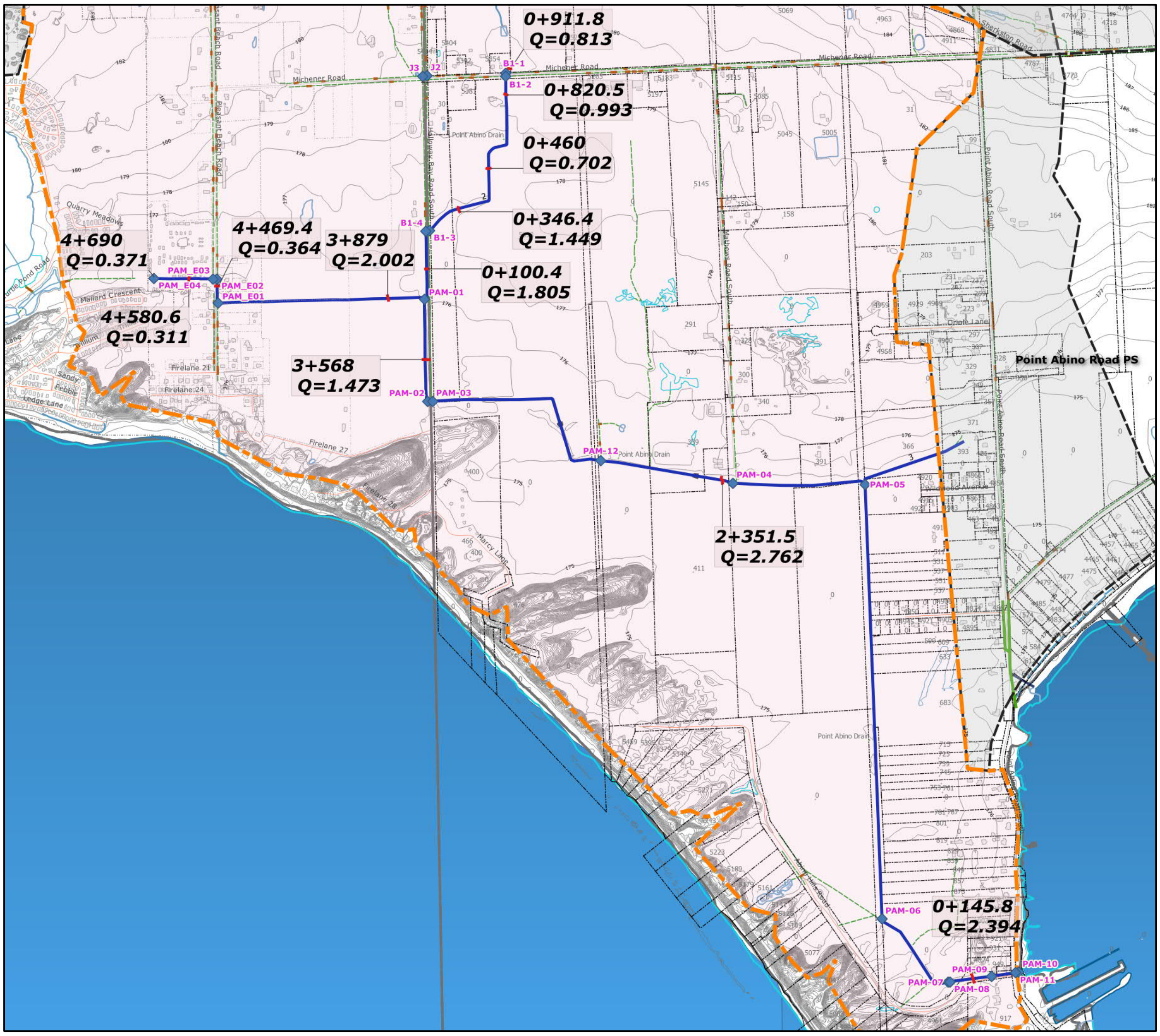

Figure 29 Plan View of Cross-Section Locations

Table 7 Hydraulic Drain Channel Capacity Analysis

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The result of the analysis is as follows:

- Cross-sections are available for each and every segment of the Point Abino Drain.

- The Grade line or lack of a positive grade is the greatest influence on capacity.

Table 8 Cross - Section Existing Capacities

Point Abino Marsh Drain (PAM)				Point Abino Branch 1			
STA	Model Junction	Upstream Area	Capacity Q, cms	STA		Upstream Area	Capacity Q, cms
0+145	PAM-06	771	2.394	0+100.4	B1-4	157	1.805
2+351.5	PAM-12	488	2.762	0+346.4	B1-2	73	1.449
3+568	PAM-01	339	1.473	0+460	B1-2	73	0.702
3+879	PAM_E01	181	2.002	0+820.5	B1-2	73	0.993
4+469.4	PAM_E02	173	0.364	0+911.8	B1-1	64	0.813
4+580.6	PAM_E04	15.5	0.311				
4+690	PAM_E04	15.5	0.371				

4.2 Point Abino Bridge and Culvert Structures

There are a total of 14 identified crossings, 13 culvert crossings, that are part of the Point Abino Drain. There are additional culverts that connect to the drain as a road outlet or Right of Way (ROW) crossing. The ROW culverts use the drain as an outlet either directly or by roadway drainage swales.

The culvert capacity analysis was conducted using HY-8 software for each culvert. Software Output reports are available in Appendix E. The design performance targets are 1:5 year for local roads, 1:2 year for private crossings. Each culvert has design flow based on the hydrologic model implemented for the design flows given for each node.

Crossings, bridges, gate structure and culverts are shown in Figure 30.

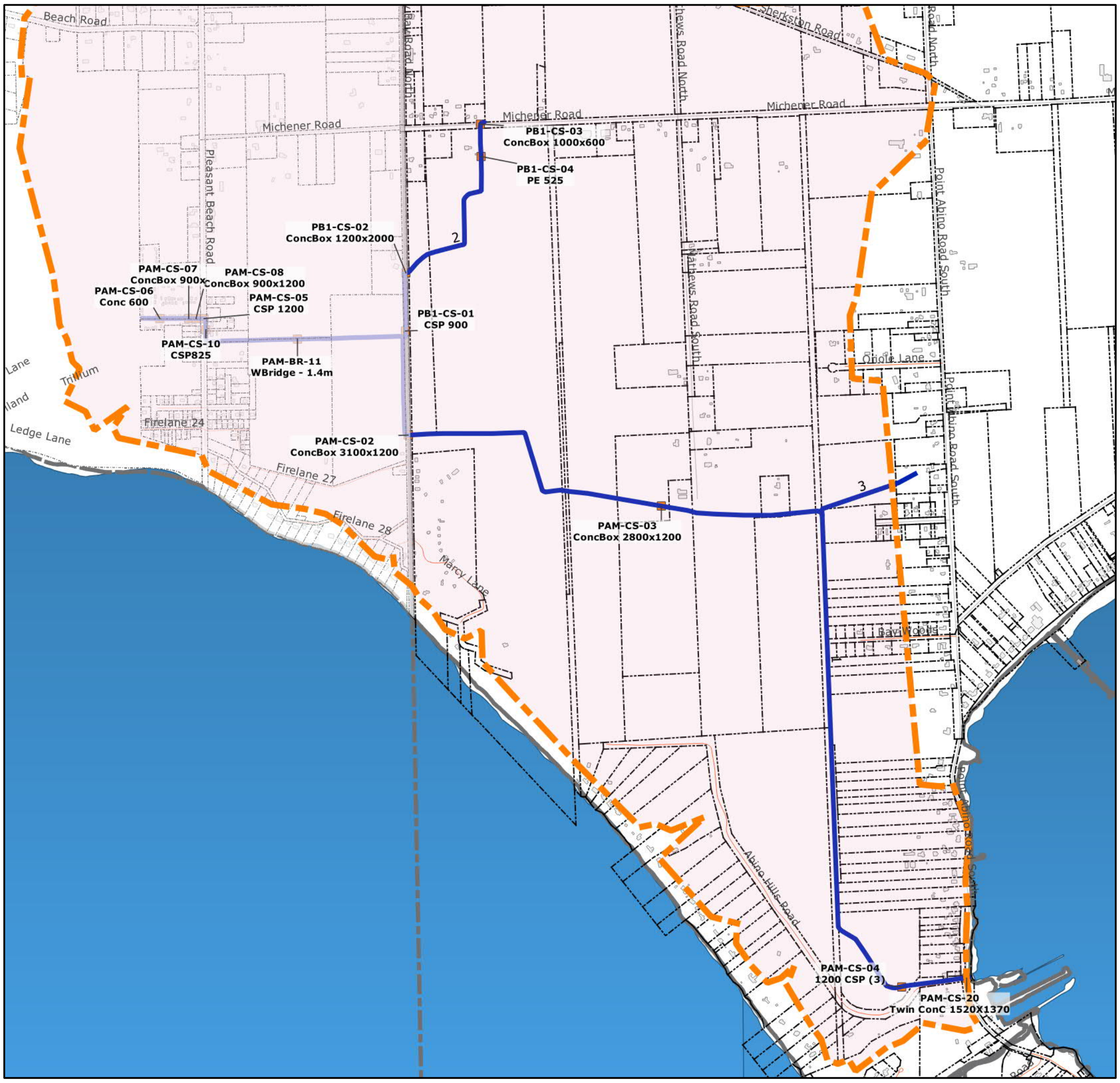


Figure 30 Point Abino Drain Crossings

A map with a plan view of the culverts is included in Appendix A. The existing culverts were assessed for capacity. Culvert integrity is to be assessed by inspection yet to be performed but for inclusion with the final report.

Table 9 Point Abino Drain Crossings

Name ID	Crossing	INSP Status	Drain	Diam	Material	Culvert desc	Length, m
PB1-CS-01	Private	Not insp	Branch #1	900	CSP	CSP 900	5.8
PB1-CS-02	Holloway Bay Road	Not insp	Branch #1		CONC	ConcBox 1200x2000	10.7
PB1-CS-04	Private	Not insp	Branch #1	525	PE	PE 525	5.2
PB1-CS-03	Michener Road	Not insp	Branch #1		CONC	ConcBox 1000x600	7
PAM-CS-06	Private	Not insp	Point Abino Drain	600	CONC	Conc 600	6
PAM-CS-07	Private	Not insp	Point Abino Drain		CONC	ConcBox 900x	2
PAM-CS-08	Private	Not insp	Point Abino Drain		CONC	ConcBox 900x1200	7
PAM-CS-05	Pleasant Beach Road	Not insp	Point Abino Drain	1200	CSP	CSP 1200	14

PAM-CS-10	Private	Not insp	Point Abino Drain	825	CSP	CSP825	6
PAM-CS-02	Holloway Bay Road	Not insp	Point Abino Drain		Concrete footings	ConcBox 3100x1200	15.5
PAM-CS-03	Private	Not insp	Point Abino Drain		CONC	ConcBox 2800x1200	2.7
PAM-CS-04	Private	Not insp	Point Abino Drain	1200	CSP	1200 CSP (3)	5.6
PAM-CS-20	Point Abino Rd	Not insp	Point Abino Drain		CIP	Twin ConC 1520X1370	86.44
Bridges							
PAM-BR-11	Private	Not insp	Point Abino Drain			WBridge - 1.4m	1.4

4.2.1 Culvert Analysis

Culverts have two forms of analysis on their capacity.

- The first is the PC-SWMM Model of runoff and has two nodes, one node for the upstream side of the culvert and the second for the downstream side of the culvert. The result is a prediction of flow capacity through an existing culvert using the PC-SWMM dynamic analysis to solve higher order flow equations through the node-link model. Smaller culverts, such as those serving private laneway crossings, are not modelled in this manner and only those large road crossing culverts are analyzed in this manner.

- The second is analysis of the existing culverts using HY-8 to perform the traditional inlet condition vs. outlet condition analysis of predicted design flows.

This distinction of two differing measures for culvert performance is important when considering the actual design deployment of culverts.

The following culverts are identified as not meeting the capacity target, (highlighted in yellow with Status set to Fail). Culverts are shown in the order from upstream to downstream with confluences, where Branch Drain No 1 joins, as empty rows.

Table 10 Culvert Capacity Assessment

Name ID	Drain	Sta	Crossing	DS Junction	Culv desc	Model-Q cms	Hy-8 Q	Design Ratio	Capacity Assessment
PAM-CS-06	Point Abino	4+640	Private	PAM_E03	Conc 600	1.049	0.53	0.51	Fail
PAM-CS-07	Point Abino	4+550	Private	PAM_E03	ConcBox 900x	1.049	0.86	0.82	Margin
PAM-CS-08	Point Abino	4+525	Private	PAM_E03	ConcBox 900x1200	1.049	0.9	0.86	Margin
PAM-CS-05	Point Abino	4+500	Pleasant Beach Road	PAM_E02	CSP 1200	2.348	1.27	0.54	Fail
PAM-CS-10	Point Abino	4+480	Private	PAM_E01	CSP825	2.216	0.85	0.38	Fail
PB1-CS-03	Branch #1	20+890	Michener Road	B1-2	ConcBox 1000x600	1.119	1.12	1.00	Pass
PB1-CS-04	Branch #1	20+775	Private	B1-3	PE 525	1.308	0.37	0.28	Fail
PB1-CS-02	Branch #1	20+225	Holloway Bay Road	B1-4	ConcBox 1200x2000	1.276	1.28	1.00	Pass
PB1-CS-01	Branch #1	20+010	Private	PAM-01	CSP 900	1.713	1.39	0.81	Margin
PAM-CS-02	Point Abino	3+340	Holloway Bay Road	PAM-03	ConcBox 3100x1200	3.734	3.73	1.00	Pass
PAM-CS-03	Point Abino	2+435	Private	PAM-04	ConcBox 2800x1200	3.669	3.67	1.00	Pass
PAM-CS-04	Point Abino	0+225	Private	PAM-09	1200 CSP (3)	3.963	3.96	1.00	Pass
PAM-CS-20	Point Abino	0+005	Point Abino Rd	PAM-10	Twin ConC 1520X1370	1.892/3.963	3.96	1.00	Pass

The analysis indicates that 4 of the 13 culverts are smaller than the target design storm. However, each of those are for private access crossings which are not required to meet the same design standards as are local roads. Except for the Pleasant Beach Road crossing which fails to pass the capacity target

3 of the 13 culverts are marginally passing the design standard. The predicted design flow and the calculated overtopping capacity are within 80% and thus within a range of tolerance based on the analysis.

The outlet is analyzed with the Lake at or below the gate bottom and the effects of high lake level is not considered within the HY-8 software analysis. The analysis does show that the twin box culvert is able to pass the projected design flow out to the lake when the lake level is low. However, this not the typical occurrence and that is modelled effectively in the Hydrologic model, PC-SWMM (EPA SWM v5.1.015)

4.3 Outlet

The Point Abino Drain outlet is one of the lowest surface water outlets on the Eastern Lake Erie shore between Town of Fort Erie and City of Port Colborne based on drain reports assigned to EWA.

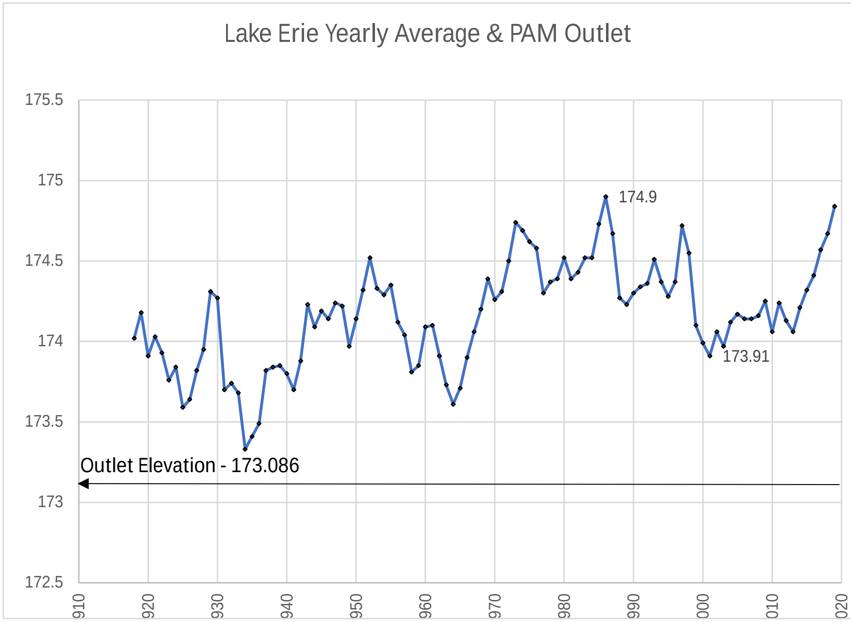


Figure 31 Lake Erie Annual Elevations compared to Point Abino Outlet

The outlet elevation shown is indicating that the existing outlet is submerged on average relative to the monthly average elevations of Lake Erie.

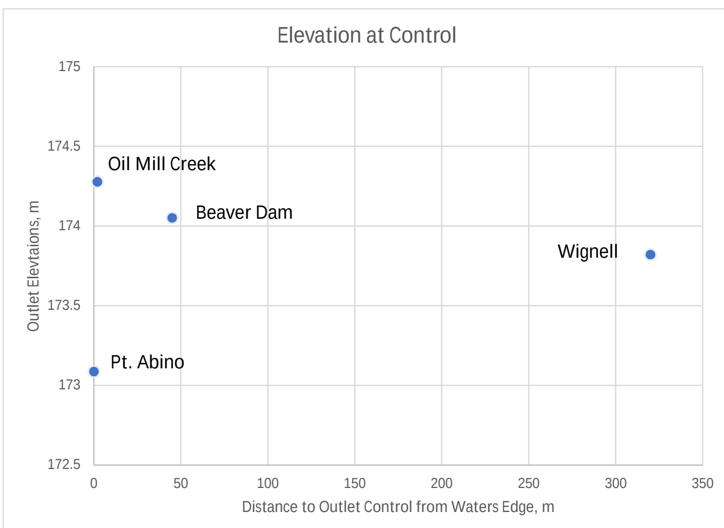


Figure 32 Lake Erie East Drain Outlet Elevations

From these two figures, we can see that Point Abino Outlet is generally lower than the Lake Erie elevation, the outlet is on average submerged. Point Abino Outlet is the lowest outlet of the 4 drains surveyed.

4.3.1 Point Abino Pumping System

Point Abino Drain included a report for a pumping system that was abandoned and not built on the direction of the Ontario Drainage Tribunal.

The original report identified a preliminary design including site and general arrangement.

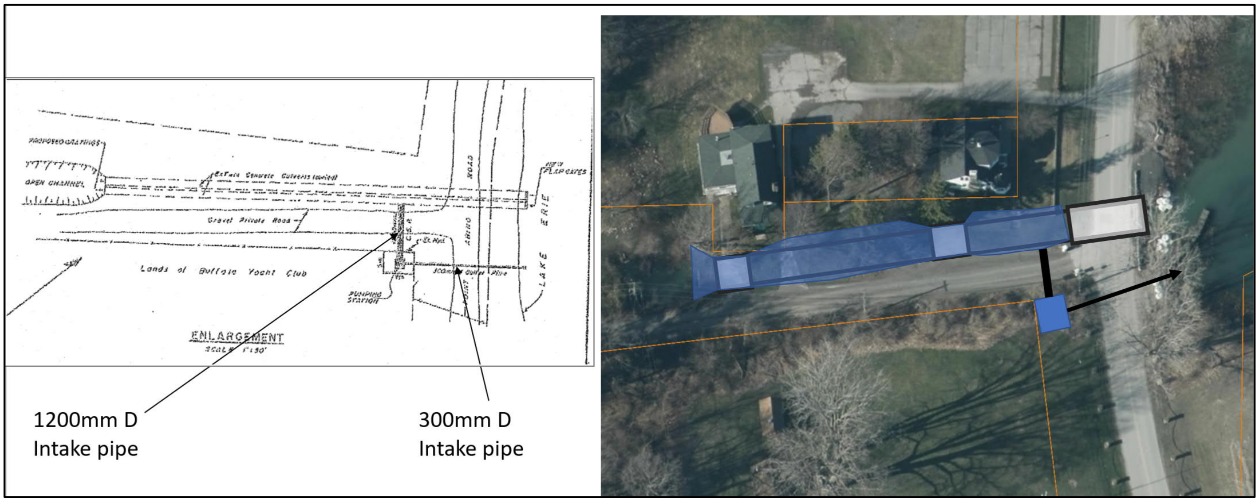


Figure 33 Pumping Station Site Option

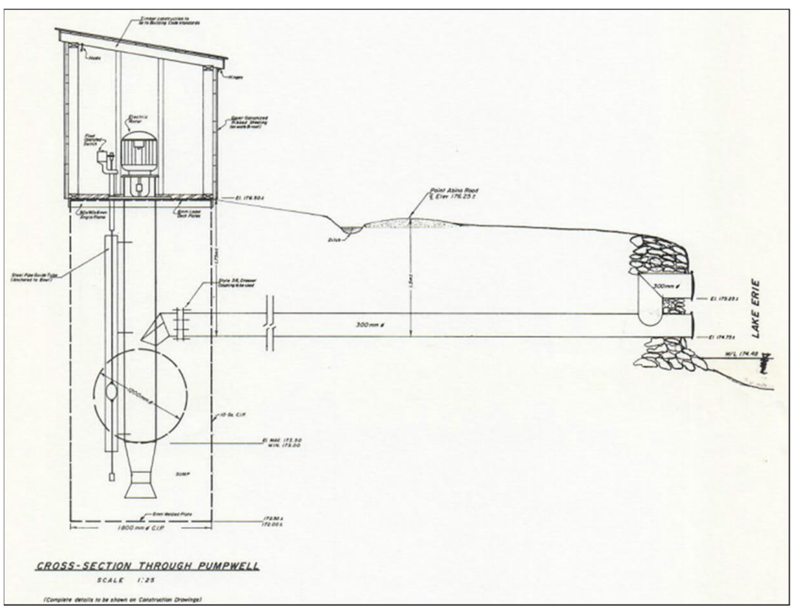


Figure 34 Preliminary Pumping Station General Arrangement

If pumping is to be implemented, then a new pumping station based on standard accepted rates for a watershed the size of Point Abino at 752Ha should require a pump operating at 582.1 lps (9,000 USGPM) to 1164.2 lps (18,000 USGPM).

In addition to the refinement of pumping rate targets, additional design and environmental compliance requirements are anticipated. Design options to consider submersible pumping would decrease the surface disruption within the road allowance.

5 Point Abino Watershed Summary

The following summarizes the results of the hydrology and hydraulic analysis.

1. Overall Point Abino has some flooding points for the design storm, 68.9mm of precipitation in 24 hours.
    a. The model indicates that the grade line to the lake is compromised.

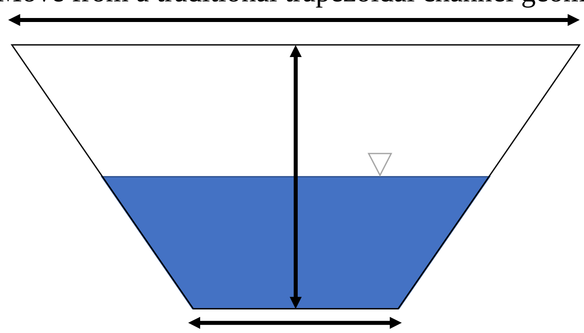
    b. The existing twin box culvert conveying runoff to the lake is assessed in the model as having adequate capacity when considering a free flowing outlet. However, with the invert below the average lake level this is almost never the actual operating condition.

2. The Point Abino Branch #1 portion of the drain is functioning and has positive slope such that a sufficient working drain is achieved.

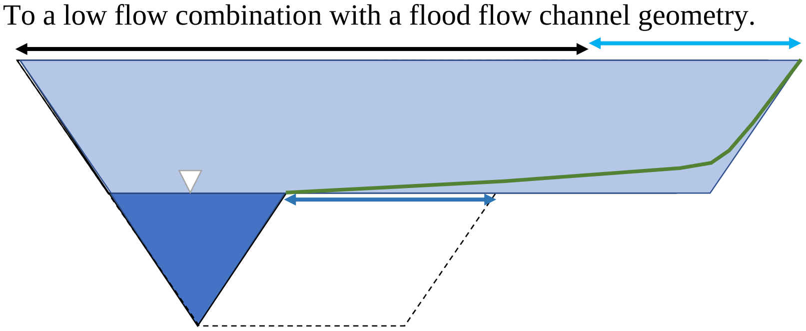
3. The existing Point Abino Drain from Holloway Bay Rd. S to the outlet is grade compromised at 0.00187% positive slope. There is no opportunity to make an improvement in this grade line by deepening the existing channel.

4. Investigate conversion of the existing Point Abino Drain segment into a naturalized flood channel.

    a. Move from a traditional trapezoidal channel geometry.



    b. To a low flow combination with a flood flow channel geometry.



    c. As an additional part of the naturalization investigate a pond / riffle arrangement for consideration instead of introduction of any sinuosity.

5. Most existing culverts convey the flow required to meet the minimum standard. However, culvert improvements/replacements are needed to address deficiencies in the following two categories:

    a. Structural condition of the culvert is compromised,

    b. Existing design capacity and/or upstream/downstream capacity is compromised.

6. Investigate a concept design for a pumping station with a wet well with intake screen and pumping system to discharge into Lake Erie across Point Abino Road.
    a. Determine the cost to design, seek environmental approvals, construction and long-term operational costs. Prepare a Preliminary Design Report to present cost estimate and preliminary assessment.

    b. A cost verses benefit analysis for a pumping option should be assessed in the final report. This would allow a Petition 4 test of support for the watershed based on an assessment table of costs just for the pumping station alone.

7. The existing Point Abino outlet control structure is functional but is structurally compromised based on the most recent assessment, (inspection report prepared by Ellis Engineering in March of 2021).
    a. Investigate options to improve the flow capacity through the existing outlet structure or through replacement.

    b. Replacement of the structure but only for the Point Abino Road crossing.

    c. Conversion of existing to open channel with possible culvert access to private property.

8. The following deficiencies of the existing Point Abino Drain are noted for inclusion in the Final Report.

    a. Existing channels do not meet the target design standard for capacity leading to localized flooding as indicated by the hydrologic model.

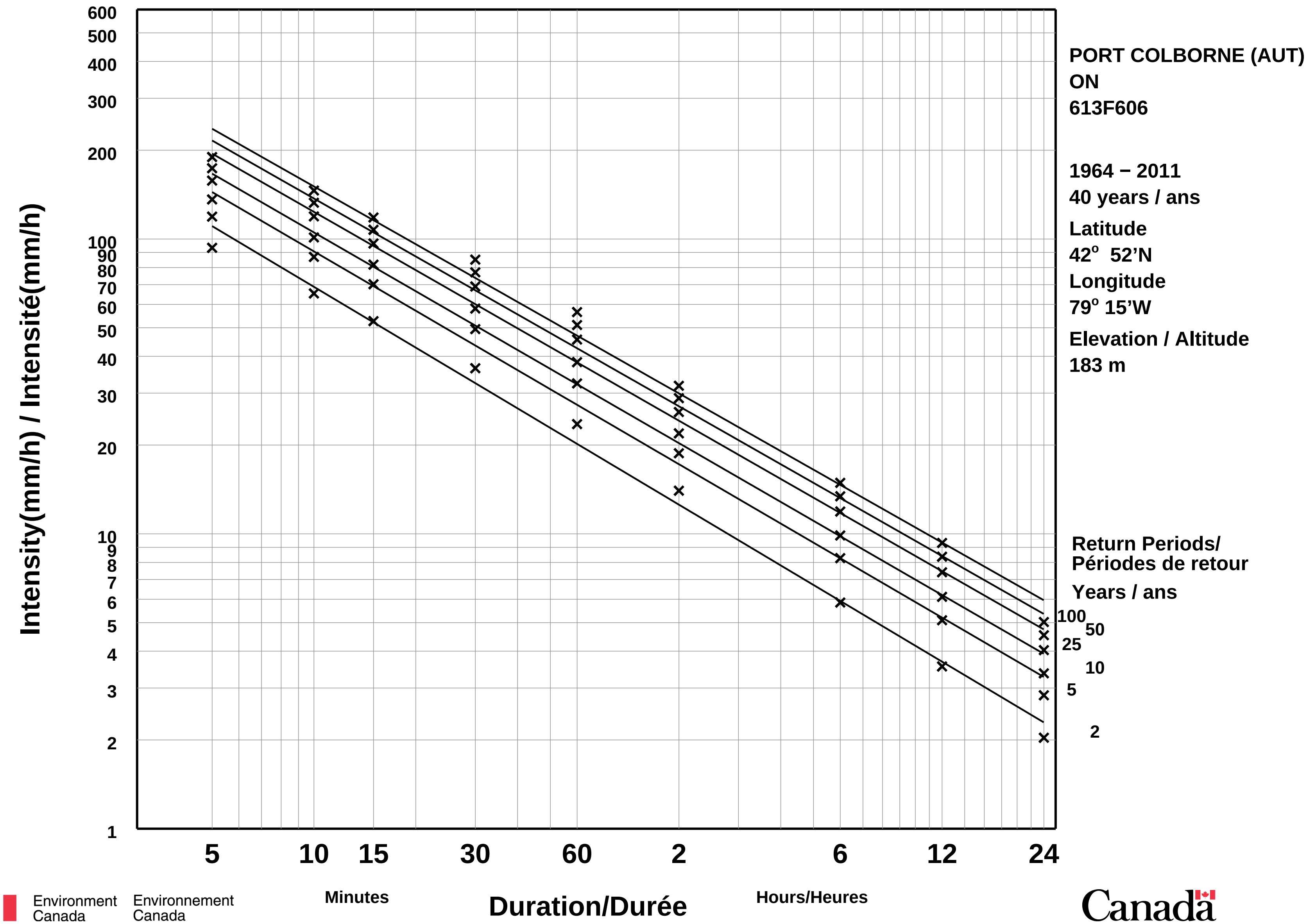
    b. The lower reach is compromised for grade based on available information; however, improving the grade as discussed in previous reports is not an option. Refinements in use and additional flood plain allocations are recommended approaches.

Appendix A:
Design Storm Data

Short Duration Rainfall Intensity−Duration−Frequency Data

2021/03/26

Données sur l'intensité, la durée et la fréquence des chutes de pluie de courte durée



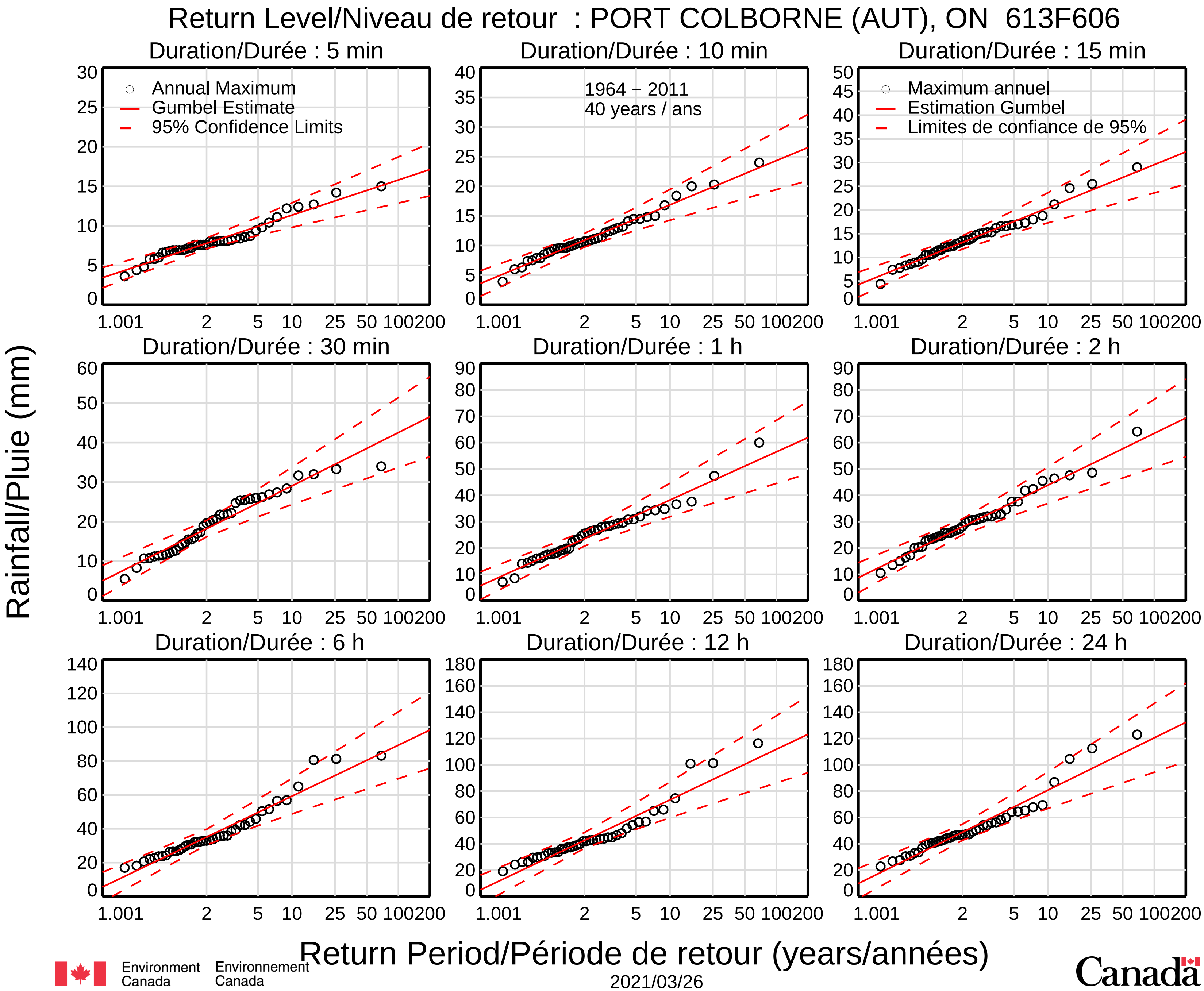
PORT COLBORNE (AUT)
ON
613F606

1964 − 2011
40 years / ans

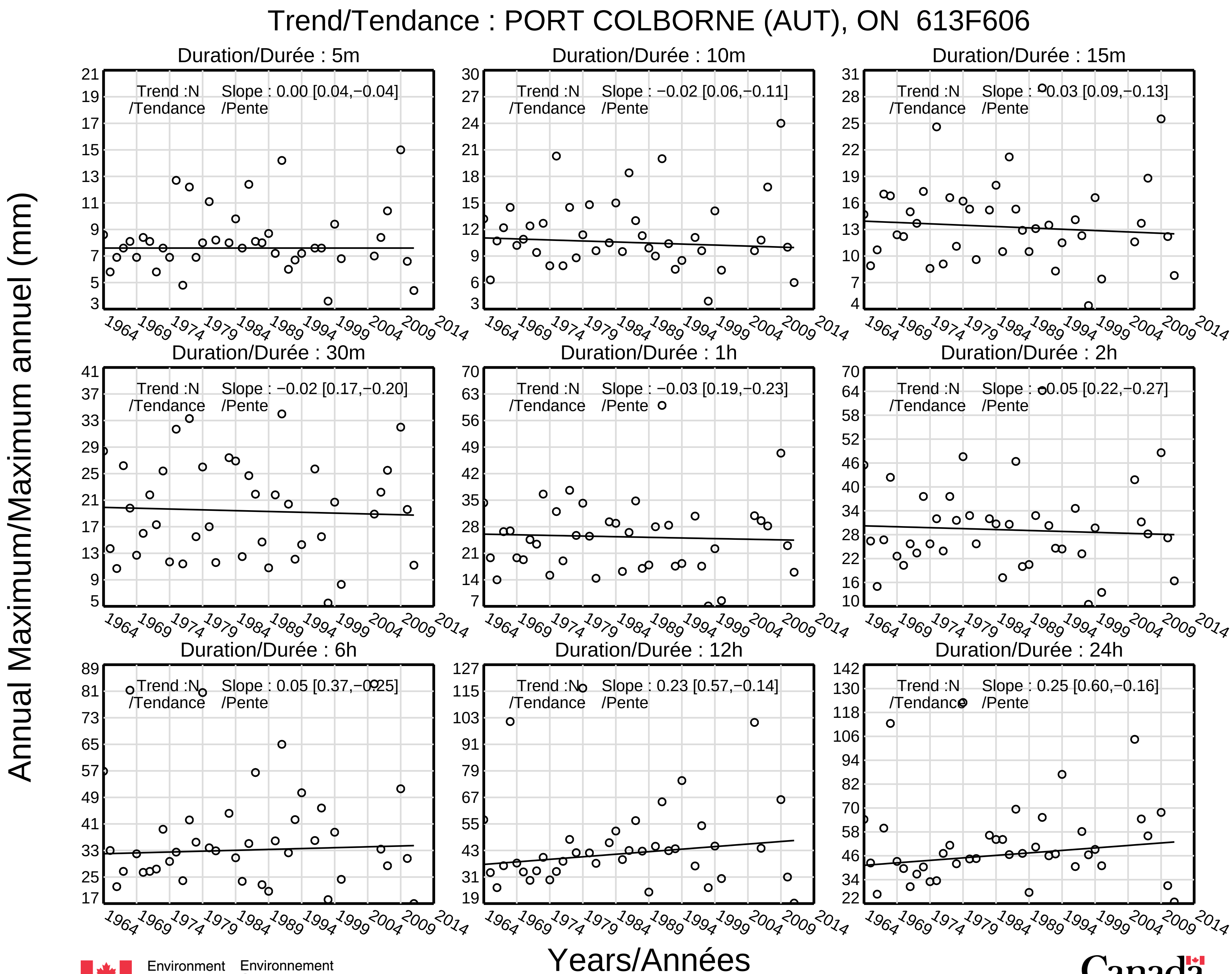
Latitude
42° 52'N
Longitude
79° 15'W
Elevation / Altitude
183 m

Environment Canada Environnement Canada

Canada



Return Level/Niveau de retour : PORT COLBORNE (AUT), ON 613F606
Duration/Durée : 5 min
Duration/Durée : 10 min
Duration/Durée : 15 min
Duration/Durée : 30 min
Duration/Durée : 1 h
Duration/Durée : 2 h
Duration/Durée : 6 h
Duration/Durée : 12 h
Duration/Durée : 24 h
Annual Maximum
Gumbel Estimate
95% Confidence Limits
1964 – 2011
40 years / ans
Maximum annuel
Estimation Gumbel
Limites de confiance de 95%
Rainfall/Pluie (mm)
Return Period/Période de retour (years/années)
1.001 2 5 10 25 50 100 200
Environment Canada
Environnement Canada
2021/03/26
Canada



Environment Canada Environnement Canada

Canada

;;EPA SWMM Time Series Data
;;5-year cumulative storm with a total rainfall amount of 68.90 mm using a SCS Type II 24-hr storm distribution.

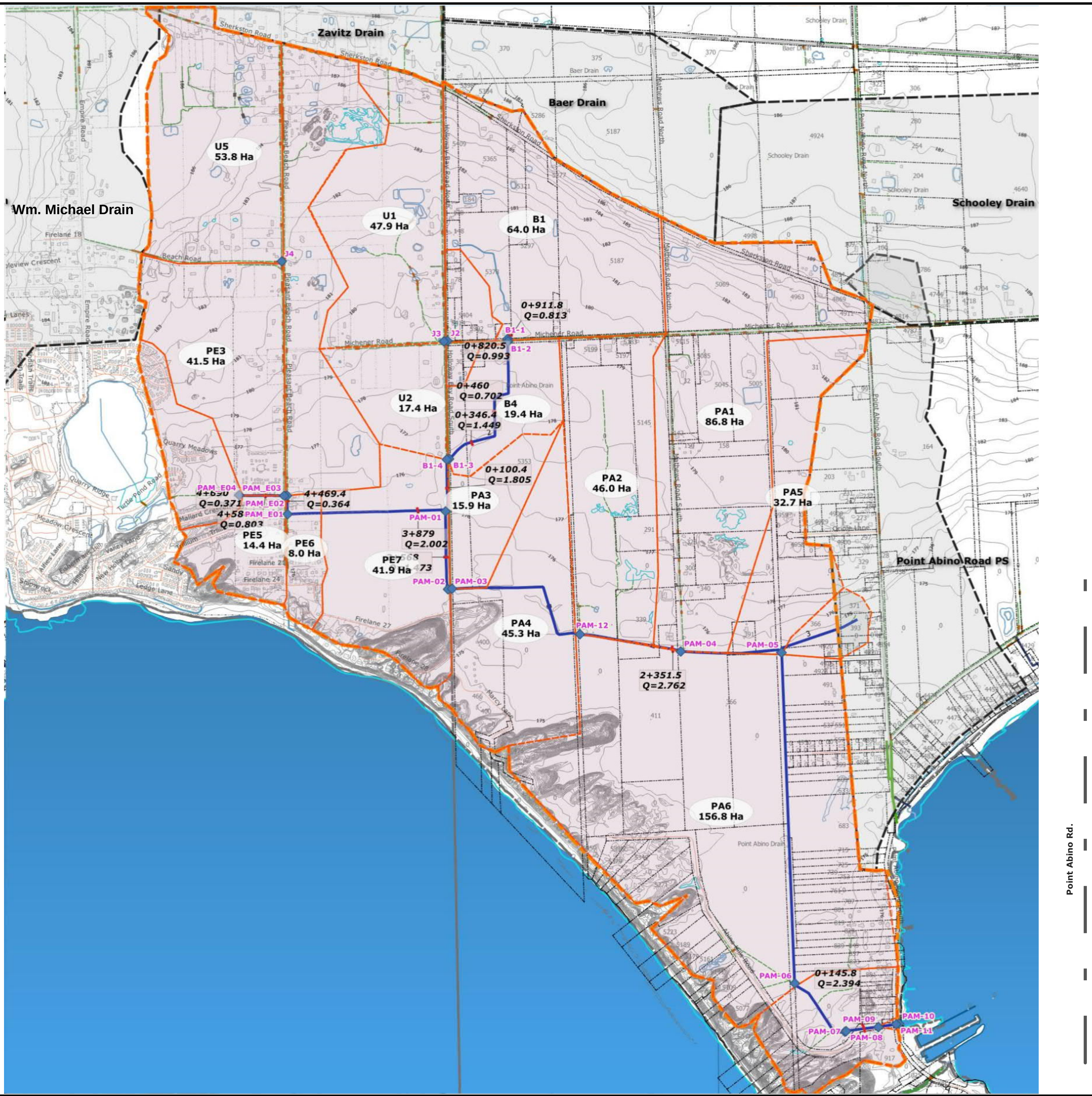
0:00	0.00000
0:10	0.11580
0:20	0.23350
0:30	0.35311
0:40	0.47465
0:50	0.59810
1:00	0.72345
1:10	0.85073
1:20	0.97992
1:30	1.11101
1:40	1.24404
1:50	1.37896
2:00	1.51580
2:10	1.65456
2:20	1.79524
2:30	1.93781
2:40	2.08232
2:50	2.22873
3:00	2.37705
3:10	2.52730
3:20	2.67945
3:30	2.83351
3:40	2.98950
3:50	3.14740
4:00	3.30720
4:10	3.46994
4:20	3.63645
4:30	3.80673
4:40	3.98095
4:50	4.15894
5:00	4.34070
5:10	4.52636
5:20	4.71588
5:30	4.90912
5:40	5.10627
5:50	5.30728
6:00	5.51200
6:10	5.72068
6:20	5.93307
6:30	6.14933
6:40	6.36944
6:50	6.59336
7:00	6.82110
7:10	7.05274
7:20	7.28815
7:30	7.52733
7:40	7.77045

7:50	8.01734
8:00	8.26800
8:10	8.53037
8:20	8.81171
8:30	9.11203
8:40	9.43181
8:50	9.77057
9:00	10.12830
9:10	10.49577
9:20	10.86323
9:30	11.23070
9:40	11.61378
9:50	12.02718
10:00	12.47090
10:10	12.95366
10:20	13.48189
10:30	14.05560
10:40	14.69178
10:50	15.40374
11:00	16.19150
11:10	17.11200
11:20	18.21440
11:30	19.49870
11:40	23.18807
11:50	32.45142
12:00	45.68070
12:10	47.76630
12:20	49.41990
12:30	50.64150
12:40	51.58979
12:50	52.43956
13:00	53.19080
13:10	53.86395
13:20	54.48405
13:30	55.05110
13:40	55.57130
13:50	56.05360
14:00	56.49800
14:10	56.91604
14:20	57.32083
14:30	57.71236
14:40	58.09021
14:50	58.45481
15:00	58.80615
15:10	59.14381
15:20	59.46821
15:30	59.77936
15:40	60.07683
15:50	60.36104
16:00	60.63200

16:10	60.89368
16:20	61.15061
16:30	61.40285
16:40	61.65014
16:50	61.89273
17:00	62.13058
17:10	62.36355
17:20	62.59177
17:30	62.81523
17:40	63.03390
17:50	63.24777
18:00	63.45690
18:10	63.66117
18:20	63.86070
18:30	64.05550
18:40	64.24537
18:50	64.43055
19:00	64.61098
19:10	64.78653
19:20	64.95736
19:30	65.12338
19:40	65.28461
19:50	65.44108
20:00	65.59280
20:10	65.74158
20:20	65.88941
20:30	66.03631
20:40	66.18224
20:50	66.32723
21:00	66.47128
21:10	66.61431
21:20	66.75641
21:30	66.89763
21:40	67.03777
21:50	67.17699
22:00	67.31530
22:10	67.45259
22:20	67.58895
22:30	67.72436
22:40	67.85881
22:50	67.99231
23:00	68.12488
23:10	68.25643
23:20	68.38704
23:30	68.51671
23:40	68.64541
23:50	68.77318
24:00	68.90000

Appendix B:

Point Abino Watershed Model & Figures



Point Abino Drain

Plan View

Hydrologic Model

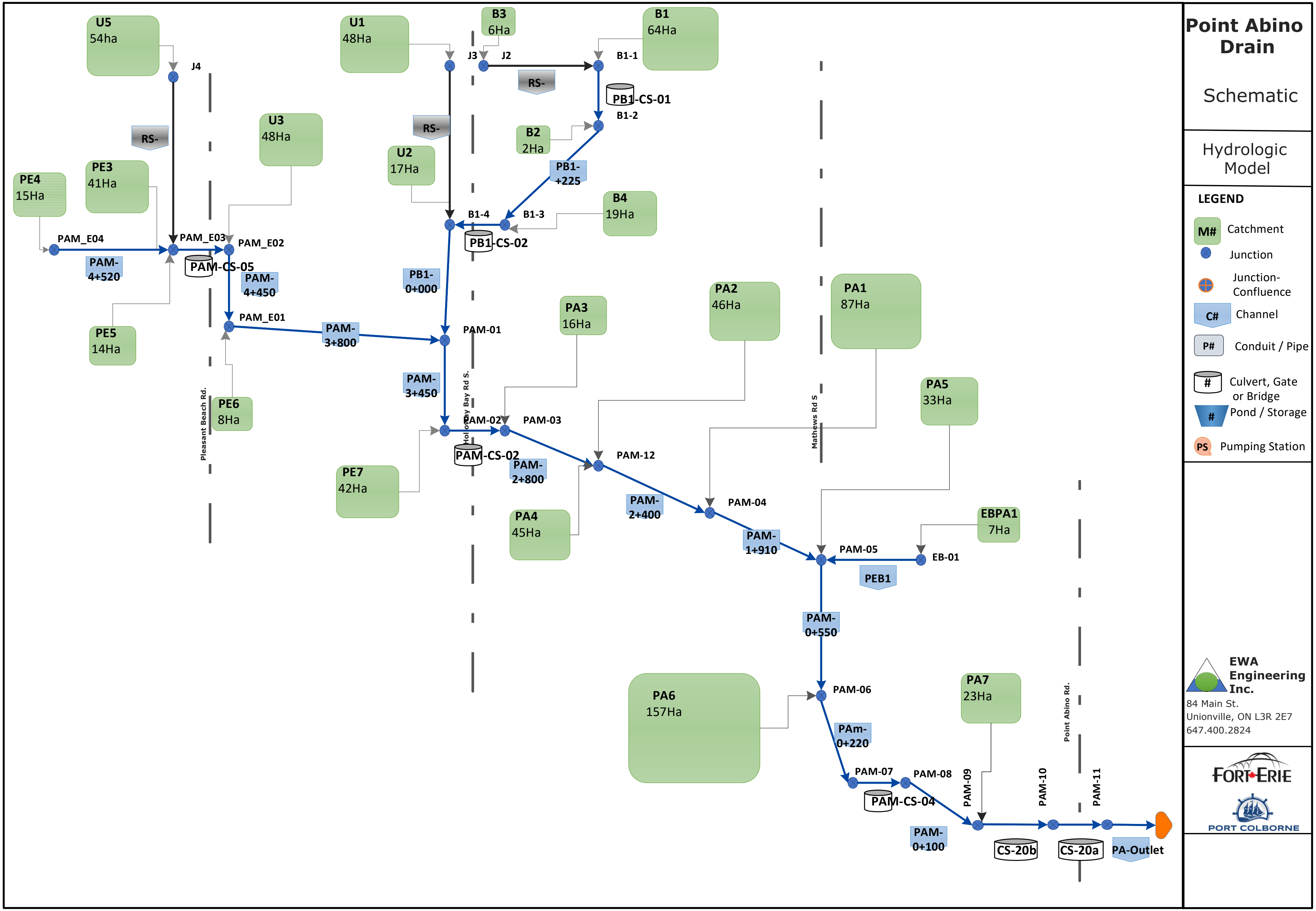
LEGEND

- M# Catchment
- Junction
- Junction-Confluence
- C# Channel
- P# Conduit / Pipe
- # Culvert, Gate or Bridge
- # Pond / Storage
- PS Pumping Station

EWA Engineering Inc.
84 Main St.
Unionville, ON L3R 2E7
647.400.2824

FORT ERIE

PORT COLBORNE


Point Abino Drain
Schematic
Hydrologic Model
LEGEND
M# Catchment
Junction
Junction-Confluence
C# Channel
P# Conduit / Pipe
Culvert, Gate or Bridge
Pond / Storage
PS Pumping Station
EWA Engineering Inc.
84 Main St.
Unionville, ON L3R 2E7
647.400.2824
FORT ERIE
PORT COLBORNE
U5 54ha
U1 48Ha
B3 6Ha
B1 64Ha
J4
J3
J2
B1-1
RS-
PB1-CS-01
B1-2
U3 48Ha
B2 2Ha
U2 17Ha
PB1- +225
PE4 15Ha
PE3 41Ha
B4 19Ha
B1-4
B1-3
PB1-CS-02
PAM_E04
PAM_E03
PAM_E02
PAM- 4+520
PAM-CS-05
PAM- 4+450
PB1- 0+000
PAM_E01
PE5 14Ha
PAM- 3+800
PAM-01
PA3 16Ha
PA2 46Ha
PA1 87Ha
PAM- 3+450
PA5 33Ha
PE6 8Ha
Pleasant Beach Rd.
Holloway Bay Rd S.
Mathews Rd S
PAM-02
PAM-03
PAM-CS-02
PAM-12
PE7 42Ha
PAM- 2+800
PA4 45Ha
PAM- 2+400
PAM-04
EBPA1 7Ha
PAM- 1+910
PAM-05
EB-01
PEB1
PAM- 0+550
PA6 157Ha
PAM-06
PA7 23Ha
PAm- 0+220
Point Abino Rd.
PAM-07
PAM-08
PAM-09
PAM-10
PAM-11
PAM-CS-04
PAM- 0+100
CS-20b
CS-20a
PA-Outlet

Appendix C:

Model Output Files

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.1 (Build 5.1.015)

WARNING 02: maximum depth increased for Node EB1
WARNING 02: maximum depth increased for Node J4
WARNING 02: maximum depth increased for Node PAM_E01
WARNING 02: maximum depth increased for Node PAM-06

****
Element Count
****
Number of rain gages 2
Number of subcatchments ... 21
Number of nodes 25
Number of links 24
Number of pollutants 0
Number of land uses 0

****
Raingage Summary
****

Name	Data Source	Data Type	Recording Interval
Chicago_1h	Chicago_1h	INTENSITY	5 min.
Rain Gage-01	24hr-SCS-5yr	CUMULATIVE	10 min.

****
Subcatchment Summary
****

Name	Area	Width	%Imperv	%Slope	Rain Gage	Outlet
B1	64.01	713.00	8.00	0.1000	Rain Gage-01	B1-1
B2	2.24	135.00	5.00	0.1000	Rain Gage-01	B1-2
B3	6.41	188.00	8.00	0.1000	Rain Gage-01	J2
B4	19.39	317.00	5.00	0.1000	Rain Gage-01	B1-3
EBPA1	6.50	205.00	4.50	0.0500	Rain Gage-01	EB1
PA1	86.84	484.00	5.00	0.1000	Rain Gage-01	PAM-04
PA2	46.00	362.00	7.00	0.1000	Rain Gage-01	PAM-12
PA3	15.94	279.00	5.00	0.1000	Rain Gage-01	PAM-03
PA4	45.28	529.00	5.00	0.1000	Rain Gage-01	PAM-12
PA5	32.72	373.00	10.00	0.1000	Rain Gage-01	PAM-05
PA6	156.81	1123.00	5.00	0.1000	Rain Gage-01	PAM-06

PA7	22.50	410.00	10.00	0.1000	Rain Gage-01
PAM-09					
PE3	41.51	355.00	10.00	0.1500	Rain Gage-01
PAM_E03					
PE4	15.48	275.00	30.00	0.1500	Rain Gage-01
PAM_E04					
PE5	14.44	368.00	25.00	0.1500	Rain Gage-01
PAM_E03					
PE6	8.02	166.00	25.00	0.1500	Rain Gage-01
PAM_E01					
PE7	41.85	563.00	10.00	0.1000	Rain Gage-01
PAM-02					
U1	47.90	498.00	8.00	0.2000	Rain Gage-01
J3					
U2	17.42	370.00	8.00	0.1000	Rain Gage-01
B1-4					
U3	48.30	427.00	8.00	0.0500	Rain Gage-01
PAM_E02					
U5	53.76	546.00	10.00	0.1500	Rain Gage-01
J4					

****
Node Summary
****

Name	Type	Invert Elev.	Max. Depth	Ponded Area	External Inflow
B1-1	JUNCTION	178.14	1.20	0.0	
B1-2	JUNCTION	178.01	1.12	0.0	
B1-3	JUNCTION	175.44	1.79	0.0	
B1-4	JUNCTION	175.47	1.20	0.0	
EB1	JUNCTION	174.34	0.50	0.0	
J2	JUNCTION	178.55	0.75	0.0	
J3	JUNCTION	178.55	0.75	0.0	
J4	JUNCTION	177.00	0.80	0.0	
PAM_E01	JUNCTION	175.15	0.95	0.0	
PAM_E02	JUNCTION	175.46	1.21	0.0	
PAM_E03	JUNCTION	175.38	1.29	0.0	
PAM_E04	JUNCTION	175.81	0.61	0.0	
PAM-01	JUNCTION	174.77	1.36	0.0	
PAM-02	JUNCTION	174.12	2.51	0.0	
PAM-03	JUNCTION	174.17	1.29	0.0	
PAM-04	JUNCTION	173.67	1.10	0.0	
PAM-05	JUNCTION	173.67	1.24	0.0	
PAM-06	JUNCTION	173.60	0.90	0.0	
PAM-07	JUNCTION	173.54	1.57	0.0	
PAM-08	JUNCTION	173.53	1.58	0.0	
PAM-09	JUNCTION	173.54	1.93	0.0	
PAM-10	JUNCTION	173.09	2.00	0.0	
PAM-11	JUNCTION	173.15	2.76	0.0	
PAM-12	JUNCTION	173.70	2.00	0.0	
pam - Outlet	OUTFALL	172.82	1.95	0.0	

****
Link Summary
****

Name	From Node	To Node	Type	Length	% Slope	Roughness
PAM-0+100	PAM-08	PAM-09	CONDUIT	133.2	-0.0045	0.0400
PAM-0+220	PAM-06	PAM-07	CONDUIT	307.1	0.0189	0.0400
PAM-0+550	PAM-05	PAM-06	CONDUIT	1369.1	0.0051	0.0400
PAM-1+910	PAM-04	PAM-05	CONDUIT	420.6	-0.0010	0.0400
PAM-2+400	PAM-12	PAM-04	CONDUIT	423.5	0.0080	0.0400
PAM-2+800	PAM-03	PAM-12	CONDUIT	672.9	0.0694	0.0400
PAM-3+450	PAM-01	PAM-02	CONDUIT	324.0	0.2021	0.0400
PAM-3+800	PAM_E01	PAM-01	CONDUIT	651.4	0.0580	0.0400
PAM-4+450	PAM_E02	PAM_E01	CONDUIT	76.5	0.4024	0.0400
PAM-4+520	PAM_E04	PAM_E03	CONDUIT	186.0	0.2322	0.0400
PAM-CS-02	PAM-02	PAM-03	CONDUIT	15.6	-0.3267	0.0400
PAM-CS-04	PAM-07	PAM-08	CONDUIT	5.7	0.1397	0.0240
PAM-CS-05	PAM_E03	PAM_E02	CONDUIT	12.1	-0.6514	0.0230
PAM-CS-20a	PAM-11	PAM-10	CONDUIT	10.8	0.5952	0.0400
PAM-CS-20b	PAM-09	PAM-11	CONDUIT	76.4	0.5105	0.0400
PA-Outlet	PAM-10	pam - Outlet	CONDUIT	2.6	10.1157	0.0300
PB1-0+000	B1-4	PAM-01	CONDUIT	219.9	0.3201	0.0400
PB1-0+225	B1-2	B1-3	CONDUIT	648.1	0.3958	0.0400
PB1-CS-02	B1-3	B1-4	CONDUIT	10.7	-0.3166	0.0400
PB1-CS-03	B1-1	B1-2	CONDUIT	9.4	1.4164	0.0400
PEB1	EB1	PAM-05	CONDUIT	182.7	0.3672	0.0360
RS-Holloway-W	J3	B1-4	CONDUIT	488.4	0.6296	0.0400
RS-Michener-S	J2	B1-2	CONDUIT	248.3	0.2191	0.0400
RS-Pleasant-W	J4	PAM_E03	CONDUIT	968.6	0.1675	0.0400

****
Cross Section Summary
****

Conduit	Shape	Full Depth	Full Area	Hyd. Rad.	Max. Width	No. of Barrels	Full

PAM-0+100	TRAPEZOIDAL	1.10	7.32	0.82	8.30	1	1.07
PAM-0+220	TRAPEZOIDAL	0.90	5.72	0.69	7.70	1	1.54
PAM-0+550	TRAPEZOIDAL	0.90	5.72	0.69	7.70	1	0.80
PAM-1+910	TRAPEZOIDAL	0.90	5.72	0.69	7.70	1	0.35
PAM-2+400	TRAPEZOIDAL	1.10	7.32	0.82	8.30	1	1.43
PAM-2+800	TRAPEZOIDAL	1.10	7.32	0.82	8.30	1	4.21
PAM-3+450	TRAPEZOIDAL	1.05	5.49	0.74	6.80	1	5.04
PAM-3+800	TRAPEZOIDAL	0.95	4.32	0.66	5.97	1	1.97
PAM-4+450	TRAPEZOIDAL	0.57	2.19	0.43	4.71	1	1.99
PAM-4+520	TRAPEZOIDAL	0.51	0.91	0.32	2.54	1	0.51
PAM-CS-02	RECT_CLOSED	1.20	3.72	0.43	3.10	1	3.04
PAM-CS-04	CIRCULAR	1.20	1.13	0.30	1.20	3	0.79
PAM-CS-05	CIRCULAR	1.20	1.13	0.30	1.20	1	1.78
PAM-CS-20a	RECT_CLOSED	1.22	1.86	0.34	1.52	2	1.74
PAM-CS-20b	RECT_CLOSED	1.22	1.86	0.34	1.52	2	1.61
PA-Outlet	RECT_OPEN	1.95	9.75	1.10	5.00	1	109.87
PB1-0+000	TRAPEZOIDAL	0.80	1.62	0.44	3.23	1	1.32
PB1-0+225	TRAPEZOIDAL	0.60	1.47	0.40	3.35	1	1.25
PB1-CS-02	RECT_CLOSED	1.20	2.40	0.37	2.00	1	1.76
PB1-CS-03	RECT_CLOSED	0.60	0.60	0.19	1.00	1	0.58
PEB1	TRAPEZOIDAL	0.50	2.12	0.40	5.00	1	1.94
RS-Holloway-W	TRAPEZOIDAL	0.70	0.91	0.35	2.00	1	0.90
RS-Michener-S	TRAPEZOIDAL	0.70	0.91	0.35	2.00	1	0.53
RS-Pleasant-W	TRAPEZOIDAL	0.80	1.12	0.39	2.20	1	0.61

```
*********************************************************
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
*********************************************************
```

```
****************
Analysis Options
****************
Flow Units ............... CMS
Process Models:
  Rainfall/Runoff ........ YES
  RDII ................... NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Ponding Allowed ........ YES
  Water Quality .......... NO
Infiltration Method ...... CURVE_NUMBER
Flow Routing Method ...... DYNWAVE
Surcharge Method ......... EXTRAN
Starting Date ............ 06/15/2021 00:00:00
Ending Date .............. 06/18/2021 00:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:05:00
Wet Time Step ............ 00:05:00
Dry Time Step ............ 00:10:00
Routing Time Step ........ 30.00 sec
Variable Time Step ....... YES
Maximum Trials ........... 8
Number of Threads ........ 4
Head Tolerance ........... 0.001500 m


*********************
Control Actions Taken
*********************


**************************        Volume         Depth
Runoff Quantity Continuity     hectare-m            mm
**************************     ---------       -------
Total Precipitation ......        54.660        68.900
Evaporation Loss .........         0.000         0.000
Infiltration Loss ........        34.403        43.366
Surface Runoff ...........        18.902        23.827
Final Storage ............         1.366         1.721
Continuity Error (%) .....        -0.020


**************************        Volume        Volume
Flow Routing Continuity        hectare-m      10^6 ltr
**************************     ---------     ---------
Dry Weather Inflow .......         0.000         0.000
Wet Weather Inflow .......        18.900       189.003
Groundwater Inflow .......         0.000         0.000
RDII Inflow ..............         0.000         0.000
External Inflow ..........         0.000         0.000
External Outflow .........        13.779       137.793
Flooding Loss ............         4.249        42.486
Evaporation Loss .........         0.000         0.000
Exfiltration Loss ........         0.000         0.000
Initial Stored Volume ....         0.001         0.009
```

```
  Final Stored Volume ......         0.878         8.785
  Continuity Error (%) .....        -0.028


  ************************
  Highest Continuity Errors
  ************************
  Node PAM-05 (2.21%)
  Node PAM-06 (1.84%)
  Node PAM-12 (1.05%)


  ***************************
  Time-Step Critical Elements
  ***************************
  Link PA-Outlet (85.99%)
  Link PAM-CS-04 (10.79%)
  Link PAM-CS-02 (1.52%)


  ********************************
  Highest Flow Instability Indexes
  ********************************
  Link PA-Outlet (26)
  Link PAM-CS-20a (25)
  Link PAM-CS-20b (15)


  *************************
  Routing Time Step Summary
  *************************
  Minimum Time Step           :     0.50 sec
  Average Time Step           :     1.13 sec
  Maximum Time Step           :    30.00 sec
  Percent in Steady State     :     0.00
  Average Iterations per Step :     2.08
  Percent Not Converging      :     0.02
  Time Step Frequencies       :
     30.000 - 13.228 sec      :     1.83 %
     13.228 -  5.833 sec      :     0.98 %
      5.833 -  2.572 sec      :     2.10 %
      2.572 -  1.134 sec      :     9.11 %
      1.134 -  0.500 sec      :    85.99 %


  ***************************
  Subcatchment Runoff Summary
  ***************************

  ---------------------------------------------------------------------------------
---------------------------------------------
                            Total      Total      Total      Total     Imperv
Perv      Total       Total     Peak  Runoff
                           Precip      Runon       Evap      Infil     Runoff
Runoff     Runoff      Runoff   Runoff   Coeff
  Subcatchment                 mm         mm         mm         mm         mm
mm         mm    10^6 ltr      CMS
```

B1	68.90	0.00	0.00	45.06	5.40	17.17	22.57	14.45	1.12	0.328
B2	68.90	0.00	0.00	36.87	3.38	27.39	30.78	0.69	0.06	0.447
B3	68.90	0.00	0.00	36.78	5.41	25.46	30.87	1.98	0.16	0.448
B4	68.90	0.00	0.00	39.35	3.38	24.82	28.20	5.47	0.29	0.409
EBPA1	68.90	0.00	0.00	38.86	3.04	25.74	28.79	1.87	0.10	0.418
PA1	68.90	0.00	0.00	47.95	3.38	14.88	18.25	15.85	0.90	0.265
PA2	68.90	0.00	0.00	46.85	4.73	16.05	20.78	9.56	0.67	0.302
PA3	68.90	0.00	0.00	39.25	3.38	25.01	28.39	4.53	0.24	0.412
PA4	68.90	0.00	0.00	39.35	3.38	23.80	27.17	12.31	0.61	0.394
PA5	68.90	0.00	0.00	40.13	6.75	20.58	27.33	8.94	0.70	0.397
PA6	68.90	0.00	0.00	51.54	3.38	12.72	16.10	25.24	1.67	0.234
PA7	68.90	0.00	0.00	44.18	6.76	16.71	23.47	5.28	0.51	0.341
PE3	68.90	0.00	0.00	37.28	6.75	22.37	29.12	12.09	0.89	0.423
PE4	68.90	0.00	0.00	22.97	20.25	23.76	44.01	6.81	0.91	0.639
PE5	68.90	0.00	0.00	24.61	16.88	25.82	42.70	6.16	0.86	0.620
PE6	68.90	0.00	0.00	24.61	16.88	25.57	42.45	3.40	0.45	0.616
PE7	68.90	0.00	0.00	37.28	6.75	23.13	29.88	12.50	0.96	0.434
U1	68.90	0.00	0.00	42.41	5.40	19.83	25.23	12.09	0.91	0.366
U2	68.90	0.00	0.00	37.46	5.41	24.77	30.18	5.26	0.39	0.438
U3	68.90	0.00	0.00	43.79	5.40	16.79	22.19	10.72	0.73	0.322
U5	68.90	0.00	0.00	41.91	6.75	18.96	25.71	13.82	1.16	0.373

****
Node Depth Summary
****

Node	Type	Average Depth Meters	Maximum Depth Meters	Maximum HGL Meters	Time of Max Occurrence days	hr:min	Reported Max Depth Meters
B1-1	JUNCTION	0.14	0.86	179.00	0	12:10	0.86
B1-2	JUNCTION	0.14	0.55	178.55	0	12:13	0.54
B1-3	JUNCTION	0.39	1.20	176.64	0	12:22	1.19
B1-4	JUNCTION	0.35	1.16	176.63	0	12:22	1.15

EB1	JUNCTION	0.18	0.41	174.75	0	12:42	0.38
J2	JUNCTION	0.08	0.35	178.90	0	12:11	0.34
J3	JUNCTION	0.18	0.67	179.22	0	12:11	0.66
J4	JUNCTION	0.27	0.80	177.80	0	12:08	0.80
PAM_E01	JUNCTION	0.34	0.95	176.10	0	12:12	0.95
PAM_E02	JUNCTION	0.20	1.00	176.45	0	12:13	0.99
PAM_E03	JUNCTION	0.38	1.15	176.53	0	12:14	1.15
PAM_E04	JUNCTION	0.11	0.61	176.42	0	12:01	0.61
PAM-01	JUNCTION	0.30	0.88	175.65	0	12:50	0.88
PAM-02	JUNCTION	0.53	1.23	175.34	0	12:57	1.23
PAM-03	JUNCTION	0.46	1.13	175.30	0	12:58	1.13
PAM-04	JUNCTION	0.83	1.10	174.77	0	12:36	1.11
PAM-05	JUNCTION	0.79	1.08	174.75	0	12:43	1.06
PAM-06	JUNCTION	0.71	0.88	174.48	0	15:26	0.88
PAM-07	JUNCTION	0.71	0.85	174.39	0	14:17	0.85
PAM-08	JUNCTION	0.71	0.85	174.38	0	14:17	0.85
PAM-09	JUNCTION	0.68	0.79	174.33	0	14:19	0.79
PAM-10	JUNCTION	1.04	1.76	174.84	2	23:39	1.52
PAM-11	JUNCTION	0.98	1.01	174.16	2	02:53	1.01
PAM-12	JUNCTION	0.83	1.30	175.00	0	12:58	1.30
pam - Outlet	OUTFALL	1.32	1.32	174.14	0	00:00	1.32

****

Node Inflow Summary

****

Node	Type	Maximum Lateral Inflow CMS	Maximum Total Inflow CMS	Time of Max Occurrence days	hr:min	Lateral Inflow Volume 10^6 ltr	Total Inflow Volume 10^6 ltr	Flow Balance Error Percent
B1-1	JUNCTION	1.119	1.119	0	12:10	14.4	14.4	-0.002
B1-2	JUNCTION	0.057	1.308	0	12:10	0.689	17.1	-0.029
B1-3	JUNCTION	0.289	1.276	0	12:11	5.47	22.6	0.204
B1-4	JUNCTION	0.389	1.713	0	12:12	5.26	39.9	0.019
EB1	JUNCTION	0.101	0.431	0	12:40	1.87	1.95	-0.029
J2	JUNCTION	0.158	0.158	0	12:10	1.98	1.98	-0.031
J3	JUNCTION	0.914	0.914	0	12:10	12.1	12.1	-0.071
J4	JUNCTION	1.161	1.161	0	12:10	13.8	13.8	0.027
PAM_E01	JUNCTION	0.446	2.531	0	12:10	3.4	51.4	-0.069
PAM_E02	JUNCTION	0.725	2.216	0	12:10	10.7	48	-0.001

PAM_E03	JUNCTION	1.747	2.348	0	12:08	18.3	37.5	0.102
PAM_E04	JUNCTION	0.913	1.049	0	12:11	6.81	7.02	-0.052
PAM-01	JUNCTION	0.000	3.620	0	12:24	0	91.1	0.045
PAM-02	JUNCTION	0.963	3.734	0	12:30	12.5	104	0.049
PAM-03	JUNCTION	0.243	3.669	0	12:31	4.52	108	-0.042
PAM-04	JUNCTION	0.896	3.963	0	12:57	15.9	144	0.774
PAM-05	JUNCTION	0.702	2.649	0	12:36	8.94	114	2.259
PAM-06	JUNCTION	1.675	2.008	0	12:43	25.2	136	1.875
PAM-07	JUNCTION	0.000	1.787	0	15:53	0	134	0.385
PAM-08	JUNCTION	0.000	1.789	0	16:04	0	134	0.171
PAM-09	JUNCTION	0.514	1.892	0	14:35	5.28	139	0.214
PAM-10	JUNCTION	0.000	3.780	2	03:11	0	138	0.039
PAM-11	JUNCTION	0.000	1.899	0	14:12	0	138	0.038
PAM-12	JUNCTION	1.277	3.746	0	12:58	21.9	130	1.059
pam - Outlet	OUTFALL	0.000	30.918	2	03:30	0	138	0.000

****
Node Surcharge Summary
****

Surcharging occurs when water rises above the top of the highest conduit.

Node	Type	Hours Surcharged	Max. Height Above Crown Meters	Min. Depth Below Rim Meters
B1-1	JUNCTION	0.16	0.262	0.338
J4	JUNCTION	0.21	0.000	0.000
PAM_E01	JUNCTION	0.22	0.000	0.000
PAM_E04	JUNCTION	1.16	0.097	0.000
PAM-02	JUNCTION	0.45	0.026	1.286
PAM-04	JUNCTION	12.46	0.005	0.000
PAM-05	JUNCTION	15.06	0.180	0.158
PAM-12	JUNCTION	11.09	0.204	0.696

****
Node Flooding Summary
****

Flooding refers to all water that overflows a node, whether it ponds or not.

Node	Hours Flooded	Maximum Rate CMS	Time of Max Occurrence days hr:min	Total Flood Volume 10^6 ltr	Maximum Ponded Depth Meters
J4	0.21	0.602	0 12:10	0.202	0.000
PAM_E01	0.22	0.675	0 12:12	0.268	0.000
PAM_E04	0.88	1.049	0 12:11	1.364	0.000
PAM-04	12.18	2.721	0 12:44	40.653	0.000

****
Outfall Loading Summary
****

Outfall Node	Flow Freq Pcnt	Avg Flow CMS	Max Flow CMS	Total Volume 10^6 ltr
pam - Outlet	93.91	1.154	30.918	137.792
System	93.91	1.154	30.918	137.792

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CMS	Time of Max Occurrence days hr:min	Maximum |Veloc| m/sec	Max/ Full Flow	Max/ Full Depth
PAM-0+100	CONDUIT	1.790	0 16:23	0.35	1.67	0.75
PAM-0+220	CONDUIT	1.787	0 15:53	0.33	1.16	0.96
PAM-0+550	CONDUIT	1.593	0 12:43	0.30	1.99	0.99
PAM-1+910	CONDUIT	2.414	0 12:36	0.42	6.99	1.00
PAM-2+400	CONDUIT	3.746	0 12:59	0.51	2.62	1.00
PAM-2+800	CONDUIT	3.354	0 12:59	0.47	0.80	1.00
PAM-3+450	CONDUIT	3.362	0 12:31	0.70	0.67	0.92
PAM-3+800	CONDUIT	2.001	0 12:25	0.56	1.02	0.94
PAM-4+450	CONDUIT	2.142	0 12:13	0.98	1.07	1.00
PAM-4+520	CONDUIT	0.412	0 12:01	0.46	0.81	1.00
PAM-CS-02	CONDUIT	3.555	0 12:31	1.13	1.17	0.97
PAM-CS-04	CONDUIT	1.789	0 16:04	0.70	0.76	0.71
PAM-CS-05	CONDUIT	1.590	0 12:15	1.91	0.89	0.90
PAM-CS-20a	CONDUIT	3.780	2 03:11	2.71	1.08	0.87
PAM-CS-20b	CONDUIT	1.899	0 14:12	0.69	0.59	0.74
PA-Outlet	CONDUIT	30.918	2 03:30	4.73	0.28	0.67
PB1-0+000	CONDUIT	1.621	0 12:24	1.00	1.22	1.00
PB1-0+225	CONDUIT	1.031	0 12:12	0.75	0.83	0.96
PB1-CS-02	CONDUIT	0.958	0 12:24	0.43	0.55	0.98
PB1-CS-03	CONDUIT	1.119	0 12:10	2.00	1.91	0.96
PEB1	CONDUIT	0.377	0 12:40	0.22	0.19	0.91
RS-Holloway-W	CONDUIT	0.820	0 12:11	0.93	0.91	0.98
RS-Michener-S	CONDUIT	0.137	0 12:11	0.30	0.26	0.64

RS-Pleasant-W	CONDUIT	0.564	0	12:09	0.50	0.92	1.00

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**************************
Flow Classification Summary
**************************
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	Adjusted	---------- Fraction of Time in Flow Class ----------								
	/Actual		Up	Down	Sub	Sup	Up	Down	Norm	Inlet
Conduit	Length	Dry	Dry	Dry	Crit	Crit	Crit	Crit	Ltd	Ctrl
PAM-0+100	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
PAM-0+220	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.01	0.00
PAM-0+550	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.10	0.00
PAM-1+910	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.03	0.00
PAM-2+400	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.03	0.00
PAM-2+800	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.67	0.00
PAM-3+450	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.96	0.00
PAM-3+800	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.02	0.00
PAM-4+450	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.84	0.00
PAM-4+520	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.92	0.00
PAM-CS-02	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.05	0.00
PAM-CS-04	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.05	0.00
PAM-CS-05	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.04	0.00
PAM-CS-20a	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.01
PAM-CS-20b	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.06	0.00
PA-Outlet	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
PB1-0+000	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.41	0.00
PB1-0+225	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.97	0.00
PB1-CS-02	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.02	0.00
PB1-CS-03	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.85	0.00
PEB1	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.68	0.00

RS-Holloway-W 1.00 0.00 0.00 0.00 1.00 0.00 0.00 0.00 0.95
0.00
RS-Michener-S 1.00 0.00 0.00 0.00 1.00 0.00 0.00 0.00 0.98
0.00
RS-Pleasant-W 1.00 0.00 0.00 0.00 1.00 0.00 0.00 0.00 0.99
0.00

****
Conduit Surcharge Summary
****

Conduit	Hours Full Both Ends	Hours Full Upstream	Hours Full Dnstream	Hours Above Full Normal Flow	Hours Capacity Limited
PAM-0+100	0.01	0.01	0.01	17.44	0.01
PAM-0+220	0.01	0.01	0.01	13.87	0.01
PAM-0+550	0.01	15.06	0.01	18.19	0.01
PAM-1+910	15.06	15.06	16.02	24.20	0.01
PAM-2+400	11.00	11.08	12.46	10.08	9.69
PAM-2+800	0.53	0.53	11.08	0.01	0.01
PAM-3+450	0.01	0.01	1.56	0.01	0.01
PAM-3+800	0.01	0.01	0.01	0.19	0.01
PAM-4+450	1.41	1.41	5.27	0.18	0.18
PAM-4+520	1.16	1.16	7.82	0.01	0.01
PAM-CS-02	0.01	0.01	0.45	0.86	0.01
PAM-CS-20a	0.01	0.01	0.01	0.01	0.01
PB1-0+000	0.56	0.84	0.89	0.60	0.44
PB1-0+225	0.01	0.01	7.39	0.01	0.01
PB1-CS-03	0.01	0.16	0.01	0.33	0.01
PEB1	0.01	0.01	30.05	0.01	0.01
RS-Holloway-W	0.01	0.01	1.14	0.01	0.01
RS-Pleasant-W	0.01	0.01	1.30	0.01	0.01

Analysis begun on: Tue Mar 8 09:42:14 2022
Analysis ended on: Tue Mar 8 09:42:20 2022
Total elapsed time: 00:00:06

Appendix D:

Channel Analysis

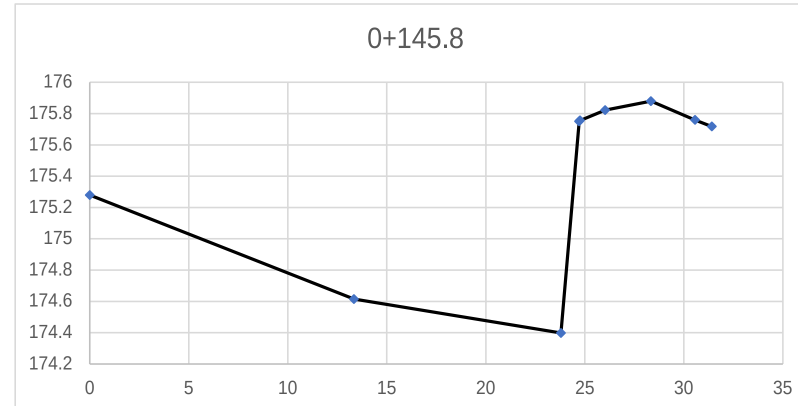
Point Abino Marsh Drain (PAM)

Capacity analysis using Mannings formula

0+145

Design		
0.0002	Slope	0.00014
	Depth	0.12
1.5	BW	10.45
	TW	24.71
1	SS1	20.1
1	SS2	0.7

	field_1	field_2	field_3	field_4	field_5	Distance	Length
1	1721	4745724	655584.5	175.279	OG	0	0
2	1722	4745712	655590.3	174.615	BS	13.346	13.346
3	1668	4745702	655593	174.398	BS	10.451	23.797
4	1670	4745701	655593.3	175.75	TS	0.915	24.712
5	1669	4745701	655593.3	175.756	GR	0.051	24.764
6	1671	4745700	655593.7	175.822	ER	1.270	26.034
7	1672	4745698	655594.2	175.879	CL	2.308	28.342
8	1673	4745696	655594.8	175.759	ER	2.226	30.568
9	1674	4745695	655595.2	175.717	OG	0.849	31.417

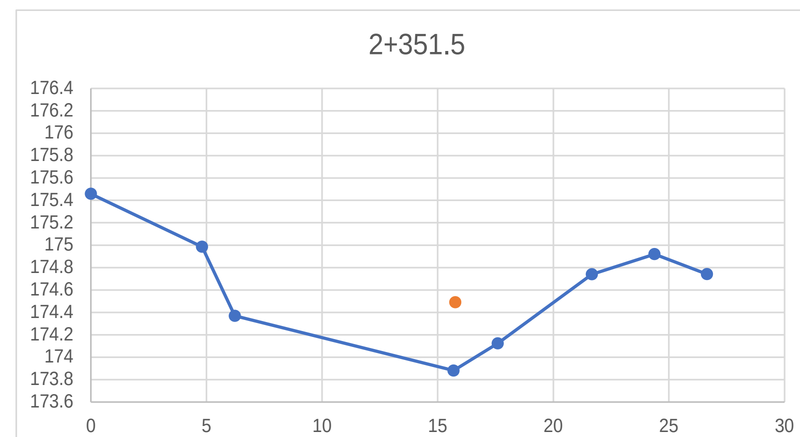


Full height	Perimeter	Area	Rh	n	Velocity	Flow, Q
175.27	0.00					
175.27	13.36	4.31				
175.27	10.49	7.98				
175.27	0.00	0.18				
175.27	0.00					
175.27	0.00					
175.27	0.00					
175.27	0.00					
175.27	0.00					
	23.85	12.47	0.52	0.04	0.192	2.394

2+351.5

0.0006	Slope	0.00014
	Depth	1.10
	BW	11.37
	TW	16.86
	SS1	2.3
	SS2	6.6

field_1	field_2	field_3	field_4	field_5	Distance	Length
1648	4747284	654798.6	175.459	OG	0	0
1649	4747280	654797.4	174.986	TS	4.811	4.811
1650	4747278	654797.8	174.37	BS	1.415	6.226
1651	4747274	654806.3	173.881	D	9.463	15.690
1653	4747273	654804.9	174.124	BS	1.906	17.596
1654	4747269	654802.5	174.741	TS	4.070	21.666
1655	4747267	654800.6	174.921	OG	2.711	24.378
1656	4747265	654801.3	174.742	OG	2.270	26.648
1652	4747274	654806.2	174.49	WL	0.073	15.763

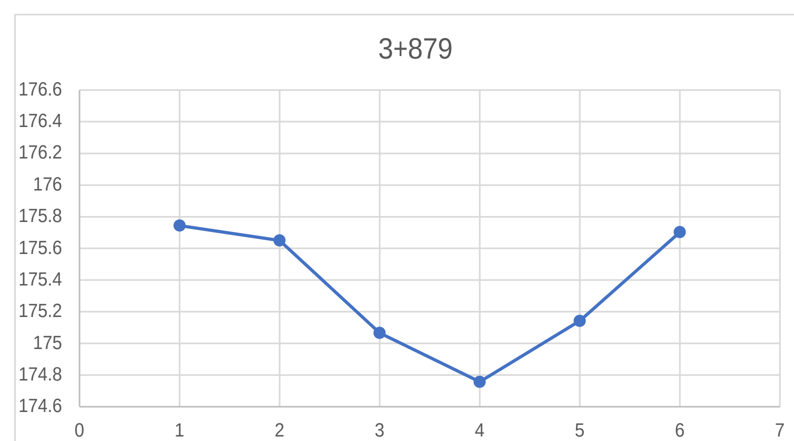


Full height	Perimeter	Area	Rh	n	Velocity	Flow, Q
174.92	0.00					
174.92	0.00					
174.92	1.52	0.34				
174.92	9.52	7.52				
174.92	0.44	1.75				
174.92	2.07	1.98				
174.92	4.07	0.24				
174.92	0.00	0.20				
174.92						
	17.61	12.04	0.68	0.04	0.229	2.762

3+568

0.0011	Slope	0.00014
	Depth	1.05
	BW	3.65
	TW	7.36
	SS1	1.3
	SS2	1.9

	field_1	field_2	field_3	field_4	field_5	Distance	Length
1	1549	4747655	653857.8	175.752	OG	0	0
2	1548	4747655	653860.5	175.632	TS	2.734	2.734
3	1547	4747655	653861.9	174.47	BS	1.492	4.226
4	1546	4747655	653863.7	174.601	D	1.812	6.038
5	1545	4747655	653865.5	174.459	BS	1.837	7.875
6	1544	4747656	653867.6	175.654	TS	2.217	10.092
7	1543	4747655	653870.8	175.894	OG	3.521	13.613
8	1542	4747655	653874.3	175.869	ER	3.575	17.188
9	1541	4747655	653876.7	176.012	CL	2.407	19.595

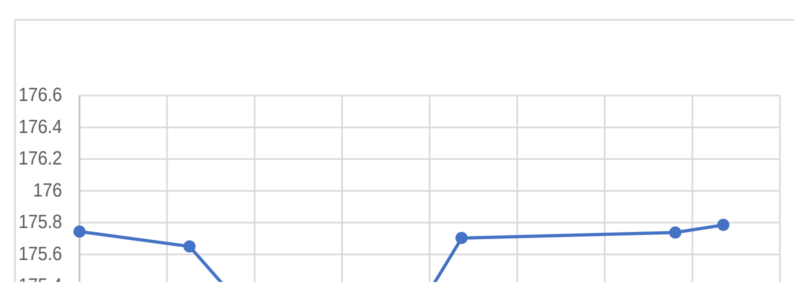


Full height	Perimeter	Area	Rh	n	Velocity	Flow, Q
175.65	0.00					
175.65	2.73					
175.65	1.90	0.89				
175.65	2.09	2.02				
175.65	2.19	2.06				
175.65	0.00	1.32				
175.65	0.00					
175.65	0.00					
175.65	0.00					
	8.92	6.29	0.70	0.04	0.234	1.473

3+879

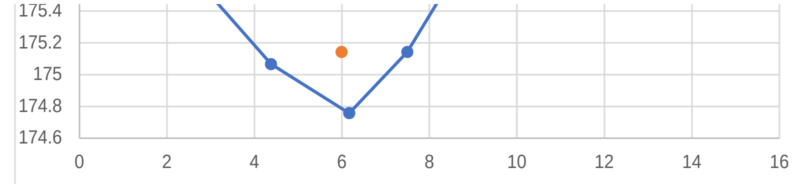
0.0011	Slope	0.0018
	Depth	0.95
	BW	3.12
	TW	6.22
	SS1	3.2
	SS2	2.2

	field_1	field_2	field_3	field_4	field_5	Distance	Length
1	1257	4747843	653748.7	175.744	OG	0	0
2	1255	4747846	653748.6	175.65	TS	2.513	2.513
3	1254	4747848	653748.1	175.066	BS	1.868	4.381
4	1252	4747849	653747.1	174.757	D	1.787	6.168
5	1251	4747850	653747.2	175.142	BS	1.329	7.497
6	1250	4747852	653747.1	175.703	TS	1.233	8.730



Full height	Perimeter	Area	Rh	n	Velocity	Flow, Q
175.65	0.00					
175.65	2.51					
175.65	1.96	0.55				
175.65	2.00	1.32				
175.65	1.42	0.93				
175.65	1.69	0.82				

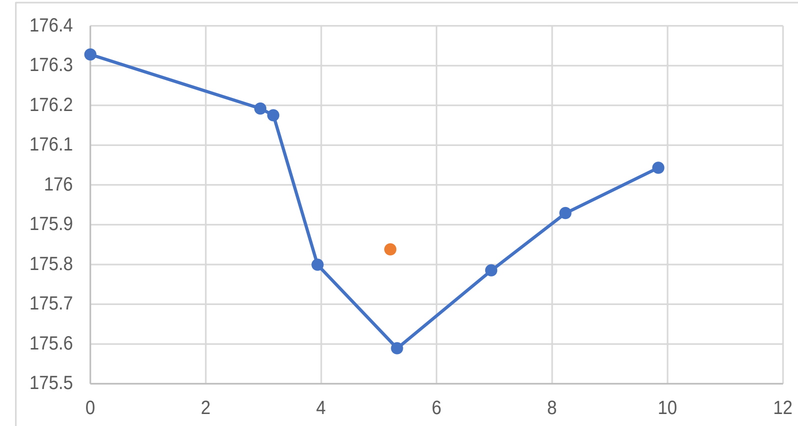
				field_1	field_2	field_3	field_4	field_5	Distance	Length
			7	1249	4747856	653745.7	175.738	OG	4.883	13.613
			8	1248	4747857	653745.4	175.785	BUSH	1.096	14.709
				1253	4747849	653747.2	175.142	WL	1.612	5.992



Full height	Perimeter	Area	Rh	n	Velocity	Flow, Q
175.65	0.00	0.00				
175.65	0.00					
175.65	0.00					
	9.58	3.61	0.38	0.04	0.554	2.002

4+469.4

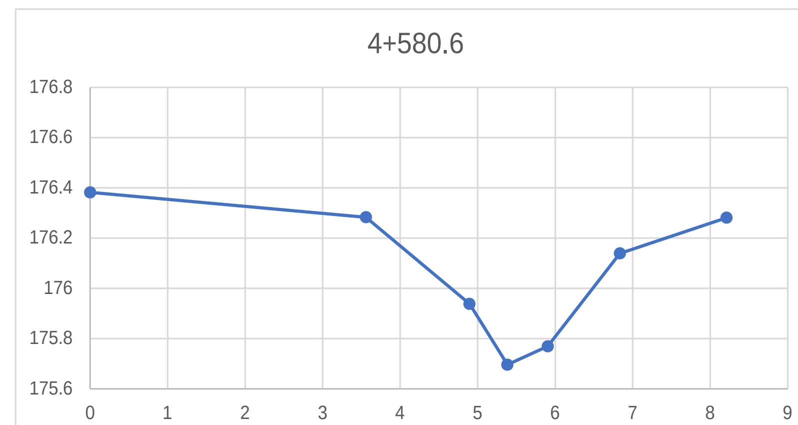
0.0041	Slope	0.0006		field_1	field_2	field_3	field_4	field_5	Distance	Length
	Depth	0.59	1	1156	4747888	653203.2	176.328	CL	0	0
	BW	3.01	2	1155	4747888	653206.2	176.192	EP	2.946	2.946
	TW	5.20	3	1154	4747888	653206.4	176.175	TS	0.226	3.172
	SS1	21.7	4	1153	4747888	653207.2	175.799	BS	0.766	3.937
	SS2	33.0	5	1151	4747888	653208.5	175.589	D	1.379	5.316
			6	1150	4747888	653210.2	175.785	BS	1.630	6.946
			4	1149	4747888	653211.4	175.929	TS	1.286	8.233
			8	1148	4747889	653213.1	176.043	OG	1.610	9.842
				1152	4747888	653208.4	175.838	WL	1.262	5.199



Full height	Perimeter	Area	Rh	n	Velocity	Flow, Q
176.04	0.00					
176.04	0.00					
176.04	0.00					
176.04	0.80	0.04				
176.04	1.45	0.48				
176.04	1.65	0.58				
176.04	1.29	0.24				
176.04	0.00	0.09				
	5.19	1.42	0.27	0.04	0.257	0.364

4+580.6

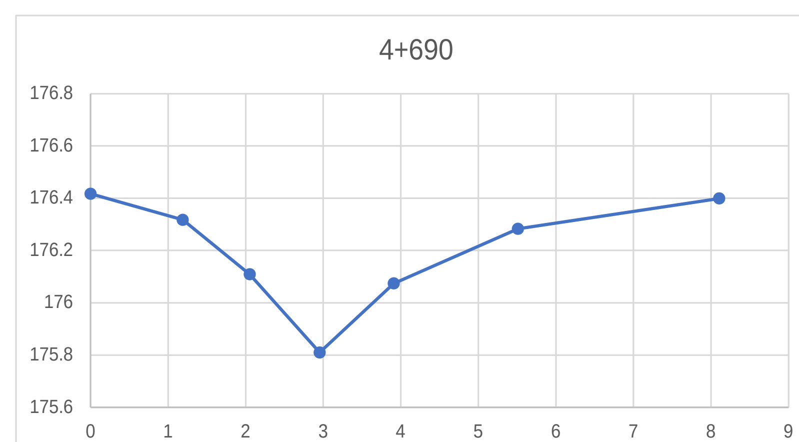
0.001	Slope	0.0006	field_1	field_2	field_3	field_4	field_5	Distance	Length
	Depth	0.59	1056	4747906	653118.9	176.382	OG	0	0
	BW	1.01	1057	4747910	653119	176.283	TS	3.559	3.559
	TW	3.28	1058	4747911	653119.2	175.938	BS	1.336	4.895
	SS1	3.9	1059	4747911	653119.3	175.696	D	0.489	5.383
	SS2	2.5	1060	4747912	653119.3	175.769	BS	0.521	5.904
			1061	4747913	653119.2	176.139	TS	0.930	6.835
			1062	4747914	653119.6	176.281	OG	1.377	8.211



Full height	Perimeter	Area	Rh	n	Velocity	Flow, Q
176.28	0.00					
176.28	0.00					
176.28	1.38	0.23				
176.28	0.76	0.23				
176.28	0.73	0.29				
176.28	0.94	0.30				
176.28	0.00	0.10				
	3.81	1.14	0.30	0.04	0.273	0.311

4+690

Slope	0.0023	wkt_geom	field_1	field_2	field_3	field_4	field_5	Distance	Length
Depth	0.51	PointZ (65	1000	4747909	653010.2	176.417	OG	0	0
BW	1.86	PointZ (65	1001	4747910	653010	176.317	TS	1.190	1.190
TW	4.32	PointZ (65	1002	4747911	653009.8	176.109	BS	0.862	2.053
SS1	4.1	PointZ (65	1003	4747912	653009.7	175.81	D	0.903	2.955
SS2	7.7	PointZ (65	1004	4747913	653009.8	176.074	BS	0.955	3.911
		PointZ (65	1005	4747914	653009.8	176.283	TS	1.601	5.512
		PointZ (65	1006	4747917	653010	176.399	OG	2.594	8.106

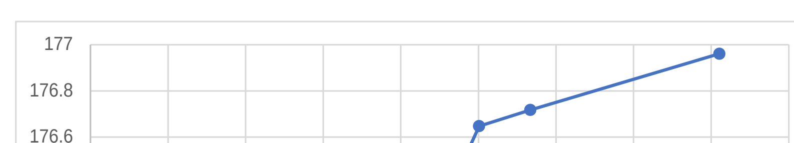


Full height	Perimeter	Area	Rh	n	Velocity	Flow, Q
176.317	0.00					
176.317	1.19					
176.317	0.89	0.09				
176.317	1.04	0.32				
176.317	0.99	0.36				
176.317	1.60	0.22				
176.317	0.00					
176.317						
	5.70	0.99	0.17	0.04	0.374	0.371

Point Abino Branch 1

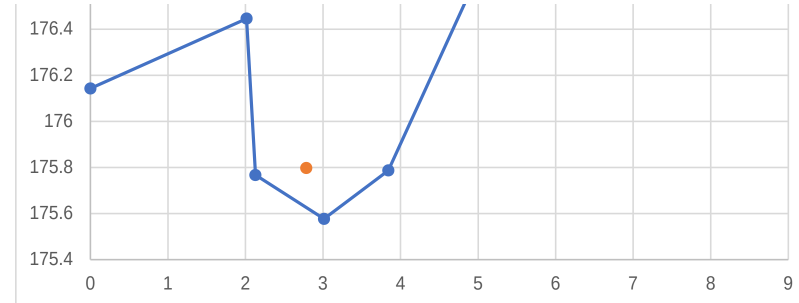
0+100.4

Slope	0.003		field_1	field_2	field_3	field_4	field_5	Distance	Length
Depth	0.22	1	1950	4747942	653865.8	176.143	TS	0	0



Full height	Perimeter	Area	Rh	n	Velocity	Flow, Q
176.446						

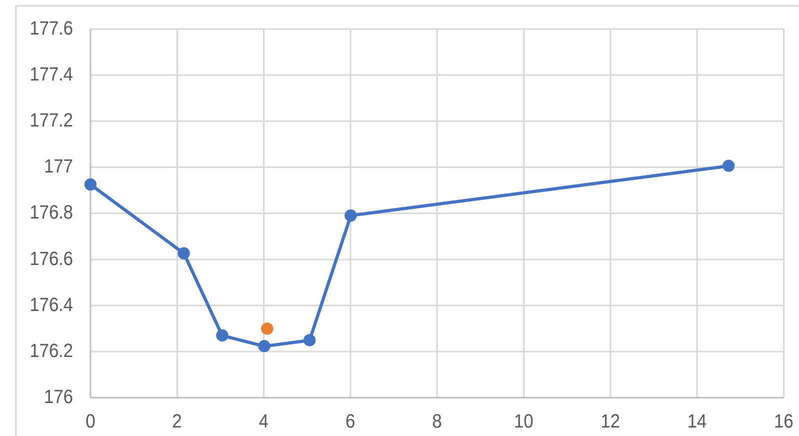
			field_1	field_2	field_3	field_4	field_5	Distance	Length
BW	0.83	2	1949	4747942	653867.8	176.446	TS	2.014	2.014
TW	2.88	3	1948	4747942	653867.8	175.767	BS	0.114	2.129
SS1	4.7	4	1946	4747943	653868.7	175.577	D	0.885	3.014
SS2	106.1	5	1945	4747943	653869.5	175.787	BS	0.829	3.842
		6	1944	4747943	653870.7	176.647	TS	1.167	5.009
		7	1943	4747943	653871.3	176.717	EP	0.659	5.669
		8	1942	4747943	653873.7	176.961	CL	2.438	8.107
			1947	4747942	653868.5	175.798	WL	0.656	2.785



Full height	Perimeter	Area	Rh	n	Velocity	Flow, Q
176.446	0.00					
176.446	0.69	0.04				
176.446	1.24	0.69				
176.446	1.06	0.63				
176.446	1.33	0.76				
176.446	0.00					
	4.32	2.12	0.49	0.04	0.851	1.805

0+346.4

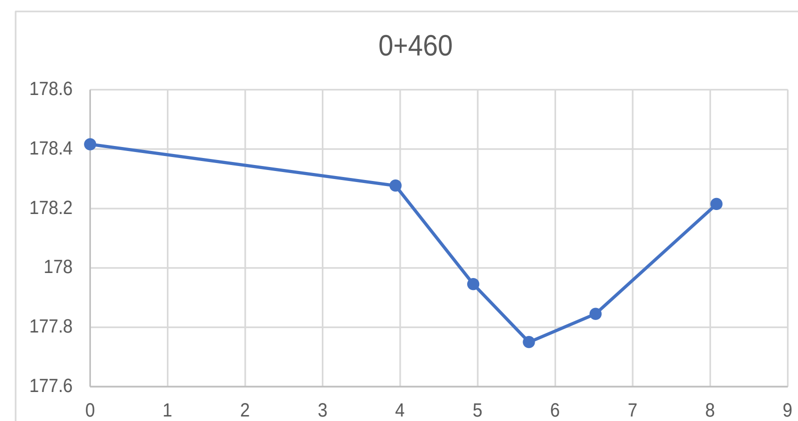
Slope	0.003		field_1	field_2	field_3	field_4	field_5	Distance	Length
Depth	0.03	1	2251	4748136	653968.1	176.925	OG	0	0
BW	1.04	2	2250	4748134	653967.7	176.626	TS	2.154	2.154
TW	2.90	3	2249	4748133	653967.7	176.27	BS	0.885	3.040
SS1	2.5	5	2247	4748132	653967.9	176.223	D	0.971	4.011
SS2	-19.5	6	2246	4748131	653968.3	176.249	BS	1.045	5.056
		7	2245	4748130	653968.7	176.79	TS	0.952	6.008
		8	2244	4748122	653972.7	177.006	OG	8.723	14.731
		6	2248	4748132	653967.8	176.299	WL	1.040	4.080



Full height	Perimeter	Area	Rh	n	Velocity	Flow, Q
176.78	0.00					
176.78	0.00					
176.78	1.02	0.29				
176.78	1.12	0.52				
176.78	1.15	0.54				
176.78	1.17	0.53				
176.78	0.00					
	4.46	1.88	0.42	0.04	0.770	1.449

0+460

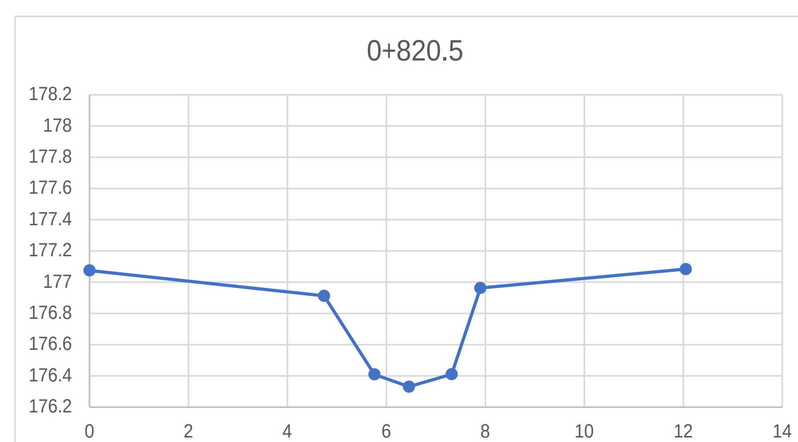
Slope	0.003	field_1	field_2	field_3	field_4	field_5	Distance	Length
Depth	0.47	1461	4748493	654115	178.416	OG	0	0
BW	1.58	1464	4748492	654118.8	178.277	TS	3.941	3.941
TW	4.14	1465	4748492	654119.8	177.945	BS	1.003	4.944
SS1	3.0	1466	4748492	654120.4	177.75	D	0.717	5.662
SS2	4.2	1467	4748491	654121.3	177.845	BS	0.860	6.522
		1468	4748490	654122.4	178.215	TS	1.560	8.082



Full height	Perimeter	Area	Rh	n	Velocity	Flow, Q
178.215	0.00					
178.215	0.00					
178.215	1.04	0.10				
178.215	0.85	0.26				
178.215	0.94	0.36				
178.215	0.00	0.29				
	2.83	1.02	0.36	0.04	0.692	0.702

0+820.5

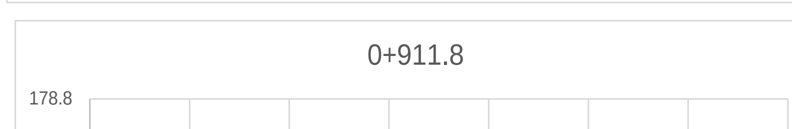
Slope	0.003	field_1	field_2	field_3	field_4	field_5	Distance	Length
Depth	0.63	3063	4749351	648648.9	177.075	OG	0	0
BW	1.56	3064	4749352	648653.7	176.912	TS	4.741	4.741
TW	3.16	3065	4749352	648654.7	176.41	BS	1.019	5.759
SS1	2.0	3066	4749352	648655.3	176.331	D	0.699	6.458
SS2	1.0	3067	4749352	648656.2	176.411	BS	0.862	7.321
		3068	4749352	648656.8	176.963	TS	0.578	7.899
		3069	4749353	648660.9	177.084	OG	4.152	12.051



Full height	Perimeter	Area	Rh	n	Velocity	Flow, Q
176.963	0.00					
176.963	0.00					
176.963	1.16	0.31				
176.963	0.94	0.41				
176.963	1.02	0.51				
176.963	0.58	0.16				
176.963	0.00					
	3.70	1.39	0.38	0.04	0.713	0.993

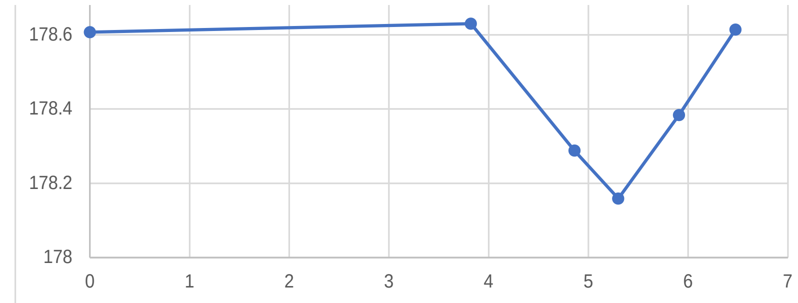
0+911.8

Slope	0.003		field_1	field_2	field_3	field_4	field_5	Distance	Length
Depth	0.47	1	2085	4748574	654125.7	178.607	OG	0	0



Full height	Perimeter	Area	Rh	n	Velocity	Flow, Q
178.7						

BW	1.05	2	2086	4748573	654129.5	178.63	TS	3.821	3.821	178.7	0.00	0.31				
TW	2.65	3	2088	4748573	654130.5	178.288	BS	1.039	4.860	178.7	1.12	0.25				
SS1	3.0	4	2087	4748573	654130.9	178.159	D	0.440	5.300	178.7	0.70	0.21				
SS2	2.5	5	2089	4748573	654131.5	178.384	BS	0.609	5.909	178.7	0.69	0.26				
		6	2090	4748573	654132.1	178.614	TS	0.566	6.474	178.7	0.57	0.11				
		7	2091	4748573	654134.2	178.776	OG	2.106	8.581							
											3.07	1.15	0.37	0.04	0.709	0.813

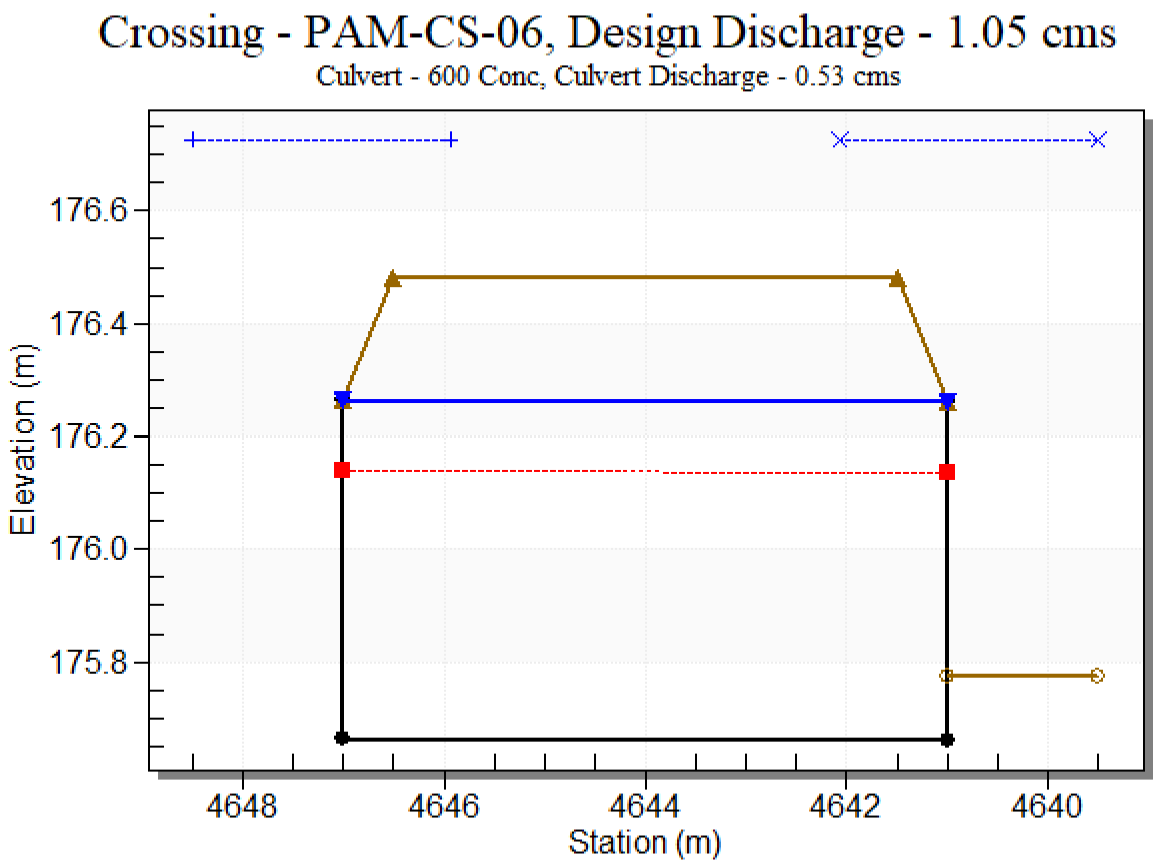


Appendix E:

HY-8 Analysis

HY-8 Culvert Analysis Report

Water Surface Profile Plot for Culvert: 600 Conc



Culvert Performance Curve Plot: 600 Conc

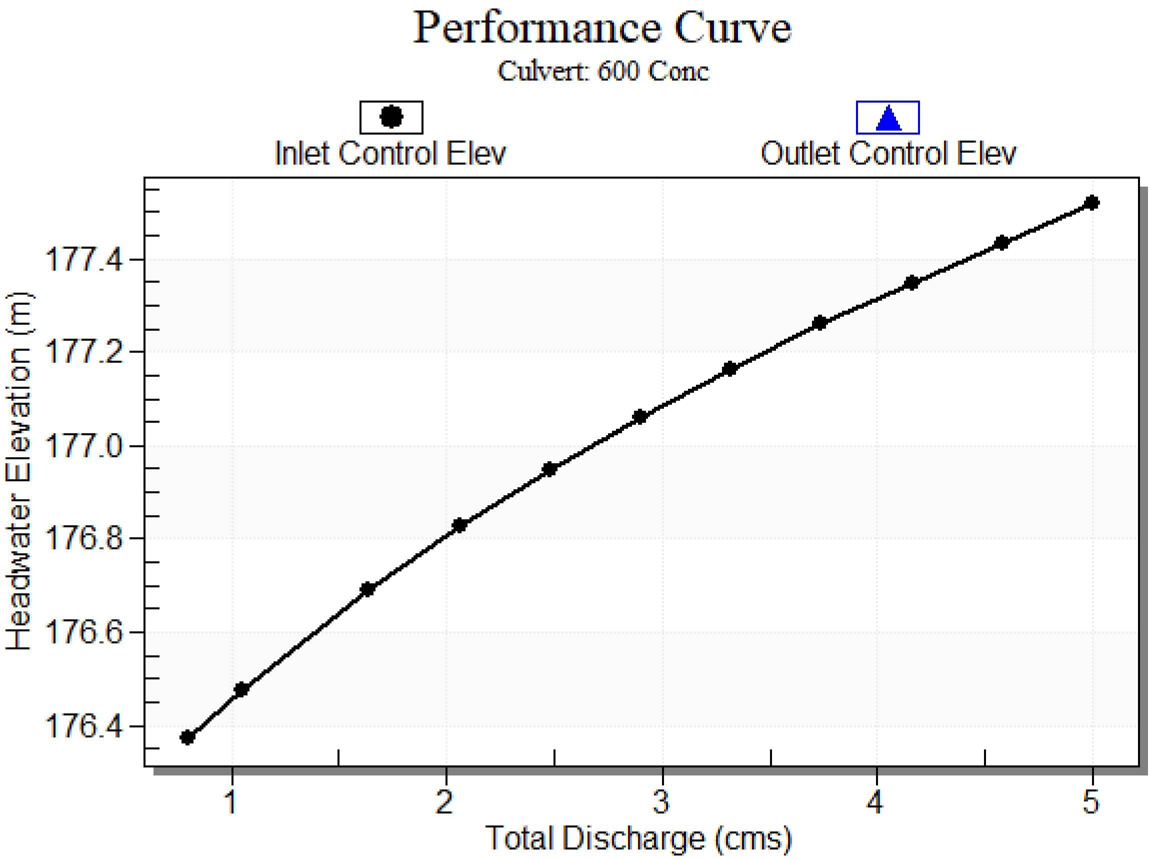


Table 1 - Culvert Summary Table: 600 Conc

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
0.80	0.46	176.62	0.709	1.145	4-FFf	-0.305	0.443	0.600	0.846	1.622	0.506
1.05	0.53	176.73	0.811	1.316	4-FFf	-0.305	0.475	0.600	0.954	1.873	0.542
1.64	0.66	176.93	1.027	1.654	4-FFf	-0.305	0.521	0.600	1.159	2.317	0.606
2.06	0.72	177.05	1.163	1.857	4-FFf	-0.305	0.540	0.600	1.277	2.556	0.641
2.48	0.78	177.16	1.286	2.039	4-FFf	-0.305	0.552	0.600	1.382	2.758	0.671
2.90	0.83	177.25	1.398	2.205	4-FFf	-0.305	0.561	0.600	1.476	2.932	0.698
3.32	0.87	177.34	1.501	2.357	4-FFf	-0.305	0.568	0.600	1.563	3.086	0.722
3.74	0.91	177.42	1.596	2.499	4-FFf	-0.305	0.573	0.600	1.642	3.224	0.744
4.16	0.95	177.49	1.686	2.633	4-FFf	-0.305	0.556	0.600	1.716	3.349	0.763
4.58	0.98	177.56	1.769	2.759	4-FFf	-0.305	0.542	0.600	1.786	3.463	0.782
5.00	1.01	177.63	1.856	2.878	4-FFf	-0.305	0.582	0.600	1.852	3.570	0.799

****

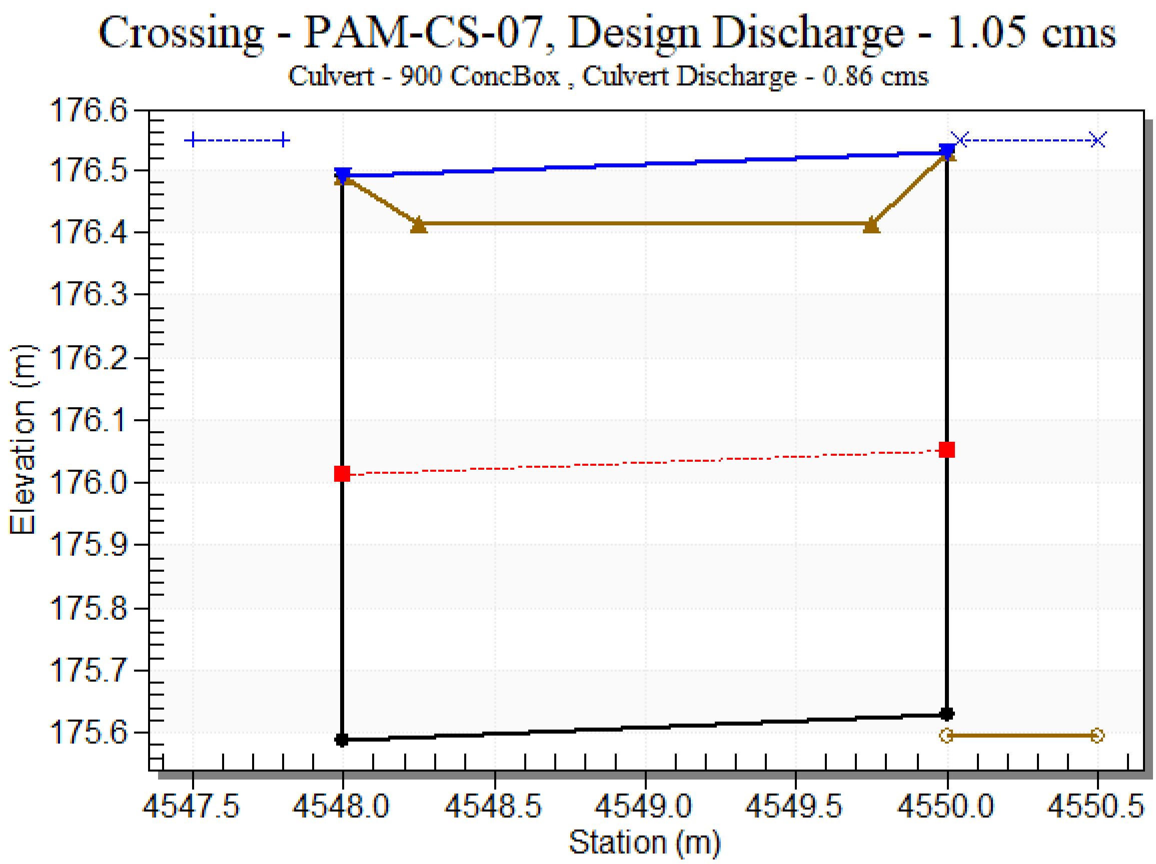
Straight Culvert

Inlet Elevation (invert): 175.66 m,   Outlet Elevation (invert): 175.66 m

Culvert Length: 6.00 m,   Culvert Slope: 0.0002

****

Water Surface Profile Plot for Culvert: 900 ConcBox



Culvert Performance Curve Plot: 900 ConcBox

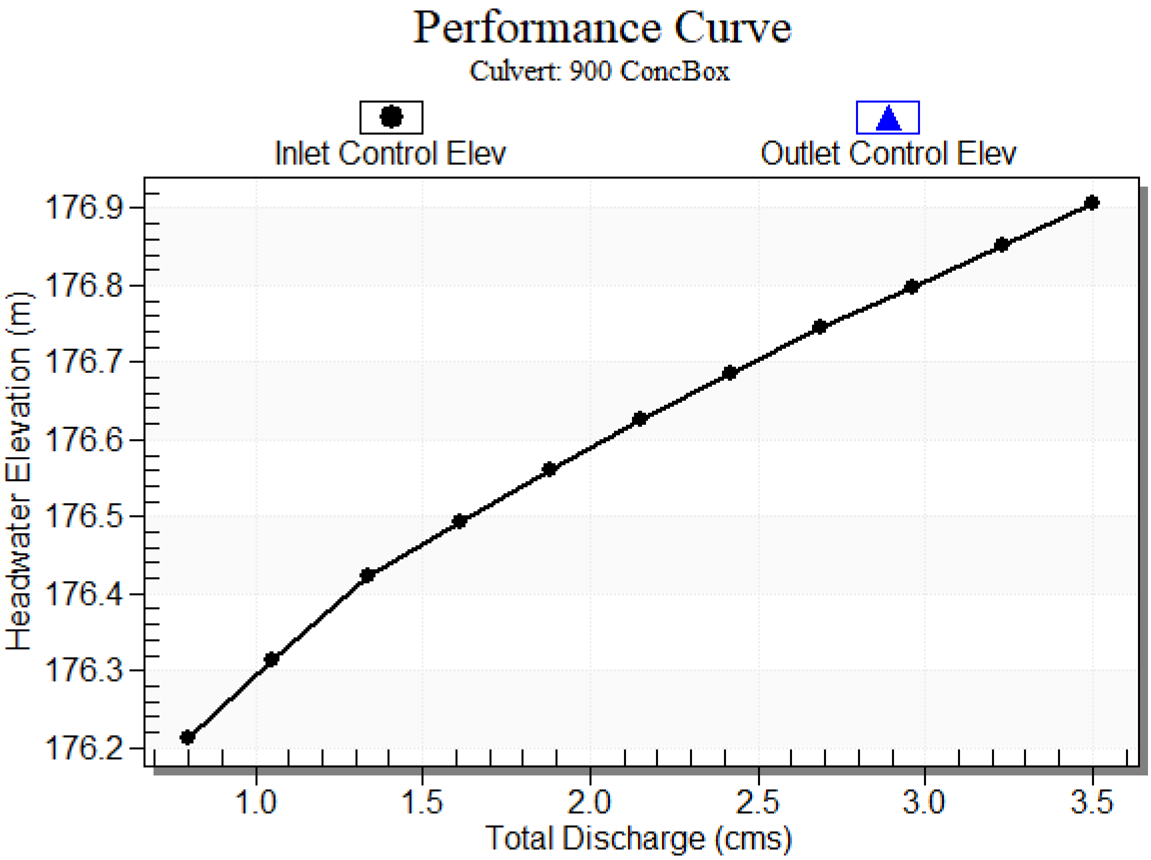


Table 2 - Culvert Summary Table: 900 ConcBox

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
0.80	0.68	176.44	0.623	0.905	7-A2t	-0.305	0.361	0.812	0.846	0.838	0.506
1.05	0.86	176.55	0.726	1.032	4-FFf	-0.305	0.423	0.900	0.954	0.959	0.542
1.34	1.07	176.66	0.835	1.178	4-FFf	-0.305	0.488	0.900	1.062	1.186	0.576
1.61	1.20	176.74	0.903	1.294	4-FFf	-0.305	0.527	0.900	1.149	1.332	0.603
1.88	1.33	176.82	0.972	1.406	4-FFf	-0.305	0.565	0.900	1.228	1.478	0.626
2.15	1.45	176.90	1.036	1.510	4-FFf	-0.305	0.598	0.900	1.301	1.611	0.648
2.42	1.56	176.96	1.097	1.609	4-FFf	-0.305	0.628	0.900	1.368	1.733	0.667
2.69	1.67	177.03	1.157	1.705	4-FFf	-0.305	0.656	0.900	1.430	1.850	0.685
2.96	1.75	177.09	1.209	1.793	4-FFf	-0.305	0.679	0.900	1.489	1.949	0.701
3.23	1.84	177.14	1.262	1.879	4-FFf	-0.305	0.702	0.900	1.545	2.047	0.717
3.50	1.93	177.19	1.318	1.964	4-FFf	-0.305	0.724	0.900	1.597	2.146	0.731

****

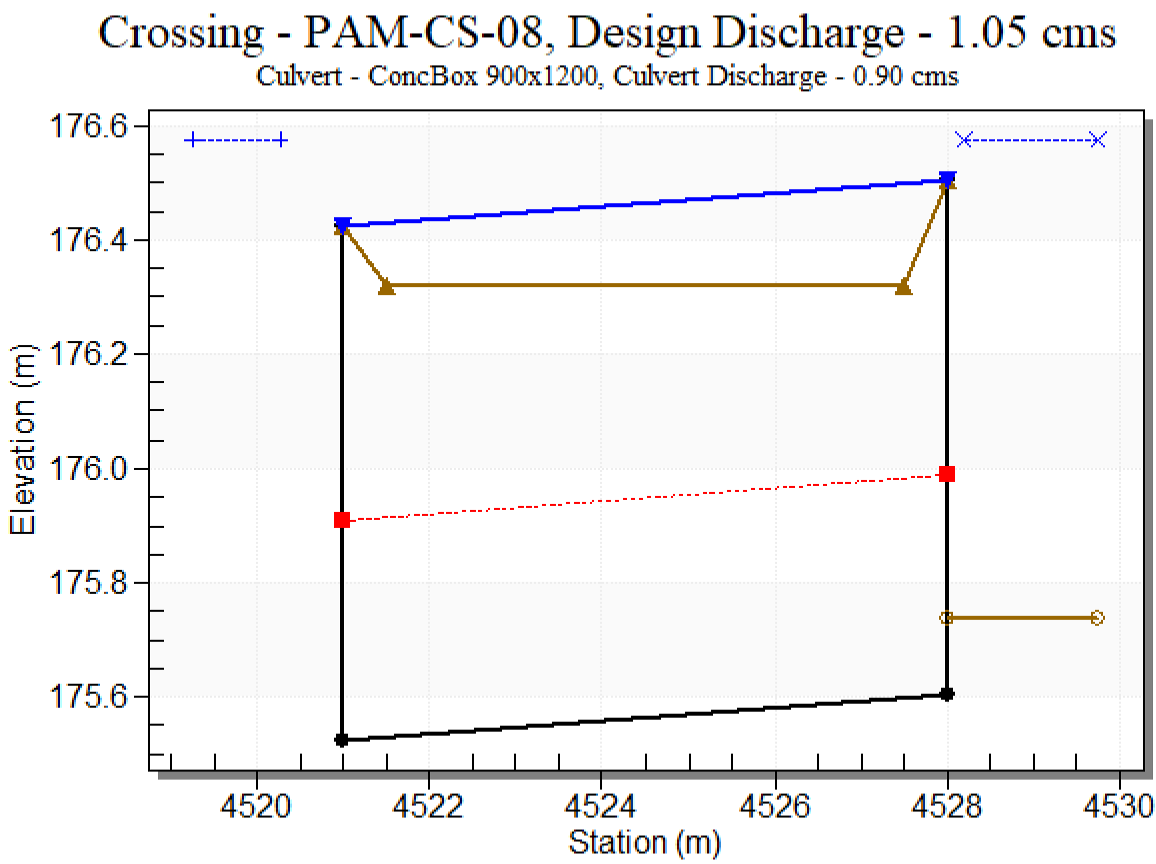
Straight Culvert

Inlet Elevation (invert): 175.59 m,   Outlet Elevation (invert): 175.63 m

Culvert Length: 2.00 m,   Culvert Slope: -0.0200

****

Water Surface Profile Plot for Culvert: ConcBox 900x1200



Culvert Performance Curve Plot: ConcBox 900x1200

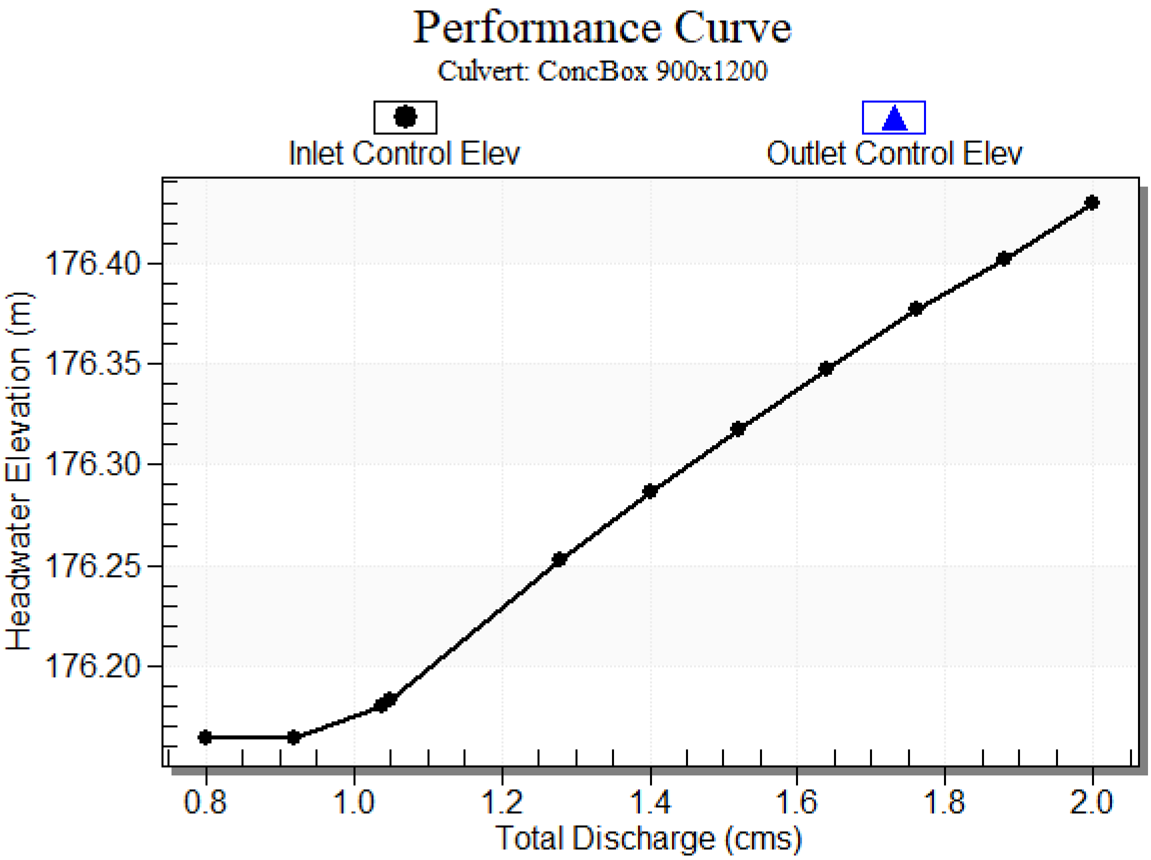


Table 3 - Culvert Summary Table: ConcBox 900x1200

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
0.80	0.86	176.48	0.639	0.948	7-A2t	-0.305	0.373	0.876	0.743	0.815	0.628
0.92	0.86	176.53	0.639	1.056	4-FFf	-0.305	0.373	0.900	0.792	0.794	0.650
1.04	0.89	176.57	0.655	1.105	4-FFf	-0.305	0.383	0.900	0.836	0.825	0.670
1.05	0.90	176.58	0.658	1.109	4-FFf	-0.305	0.385	0.900	0.840	0.831	0.672
1.28	1.05	176.65	0.728	1.207	4-FFf	-0.305	0.427	0.900	0.917	0.971	0.706
1.40	1.12	176.69	0.762	1.256	4-FFf	-0.305	0.447	0.900	0.954	1.041	0.722
1.52	1.19	176.73	0.792	1.302	4-FFf	-0.305	0.465	0.900	0.989	1.105	0.737
1.64	1.26	176.76	0.822	1.347	4-FFf	-0.305	0.483	0.900	1.023	1.167	0.751
1.76	1.33	176.79	0.852	1.392	4-FFf	-0.305	0.500	0.900	1.055	1.231	0.765
1.88	1.39	176.82	0.877	1.433	4-FFf	-0.305	0.514	0.900	1.085	1.283	0.777
2.00	1.45	176.85	0.905	1.476	4-FFf	-0.305	0.530	0.900	1.115	1.343	0.790

****

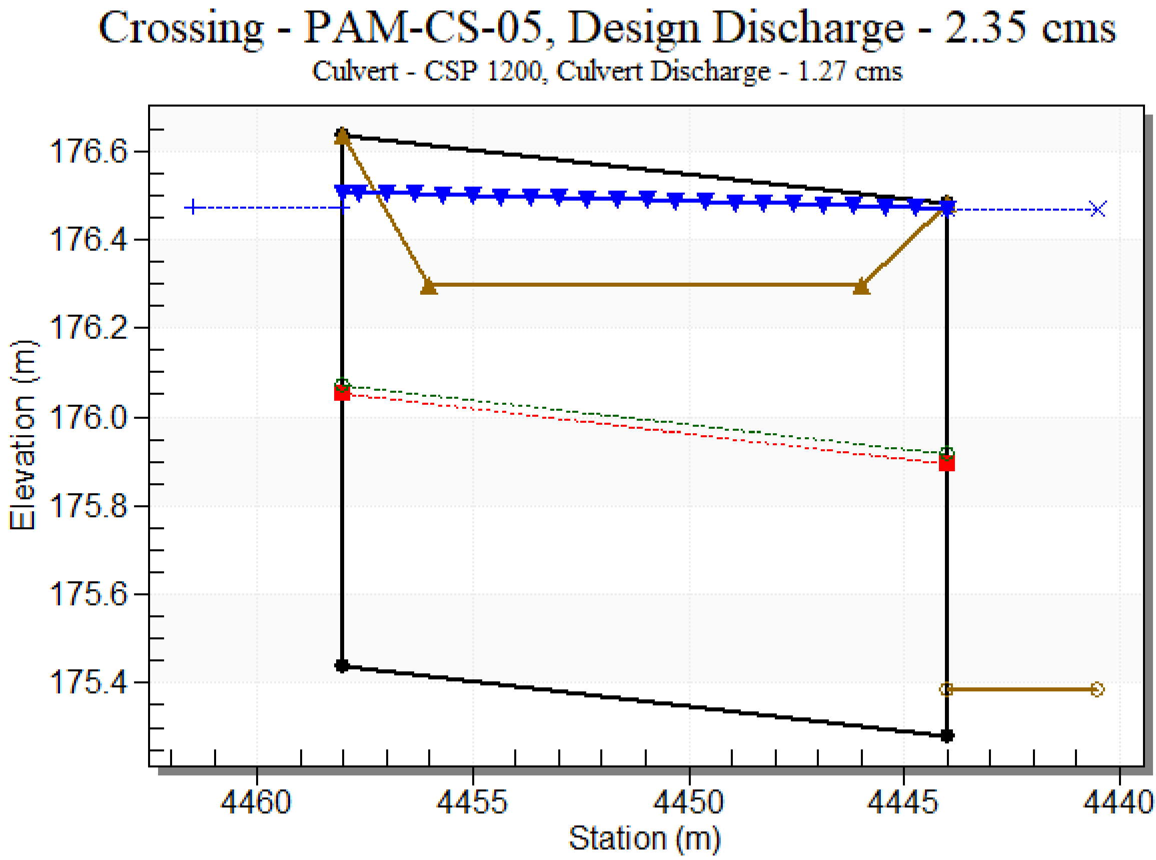
Straight Culvert

Inlet Elevation (invert): 175.53 m,   Outlet Elevation (invert): 175.60 m

Culvert Length: 7.00 m,   Culvert Slope: -0.0113

****

Water Surface Profile Plot for Culvert: CSP 1200



Culvert Performance Curve Plot: CSP 1200

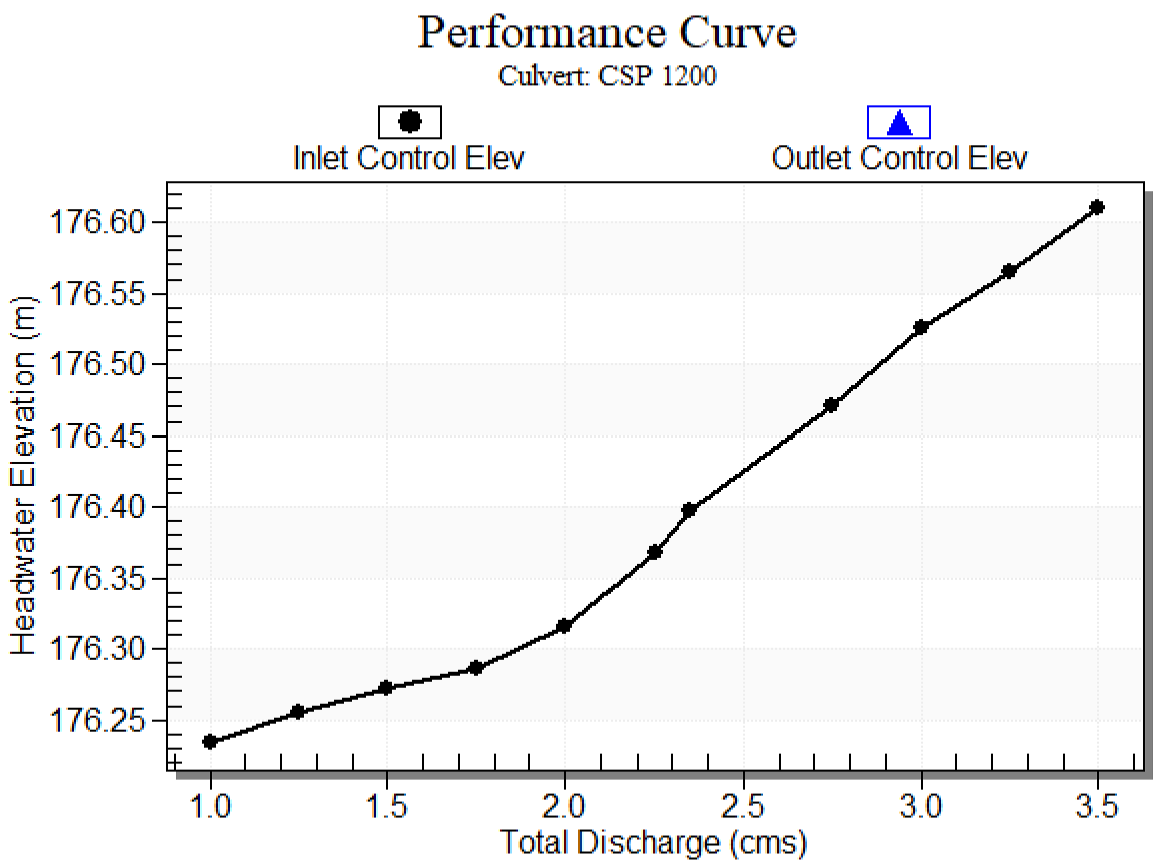


Table 4 - Culvert Summary Table: CSP 1200

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
1.00	0.94	176.31	0.797	0.879	3-M1t	0.530	0.524	0.826	0.726	1.134	0.660
1.25	0.98	176.33	0.818	0.930	3-M1t	0.544	0.536	0.908	0.808	1.070	0.699
1.50	1.02	176.35	0.835	0.983	3-M1t	0.554	0.546	0.982	0.882	1.025	0.733
1.75	1.04	176.36	0.848	1.037	3-M1t	0.563	0.554	1.048	0.948	0.995	0.762
2.00	1.10	176.40	0.878	1.099	3-M1t	0.581	0.570	1.109	1.009	1.010	0.788
2.25	1.21	176.45	0.931	1.173	3-M1t	0.614	0.599	1.166	1.066	1.079	0.812
2.35	1.27	176.47	0.961	1.207	7-M1t	0.633	0.614	1.187	1.087	1.126	0.821
2.75	1.42	176.55	1.034	1.329	3-M1f	0.678	0.649	1.200	1.169	1.255	0.854
3.00	1.53	176.60	1.089	1.412	4-FFf	0.712	0.676	1.200	1.216	1.354	0.873
3.25	1.61	176.64	1.128	1.483	4-FFf	0.737	0.693	1.200	1.261	1.423	0.891
3.50	1.70	176.69	1.173	1.557	4-FFf	0.764	0.714	1.200	1.304	1.501	0.908

****

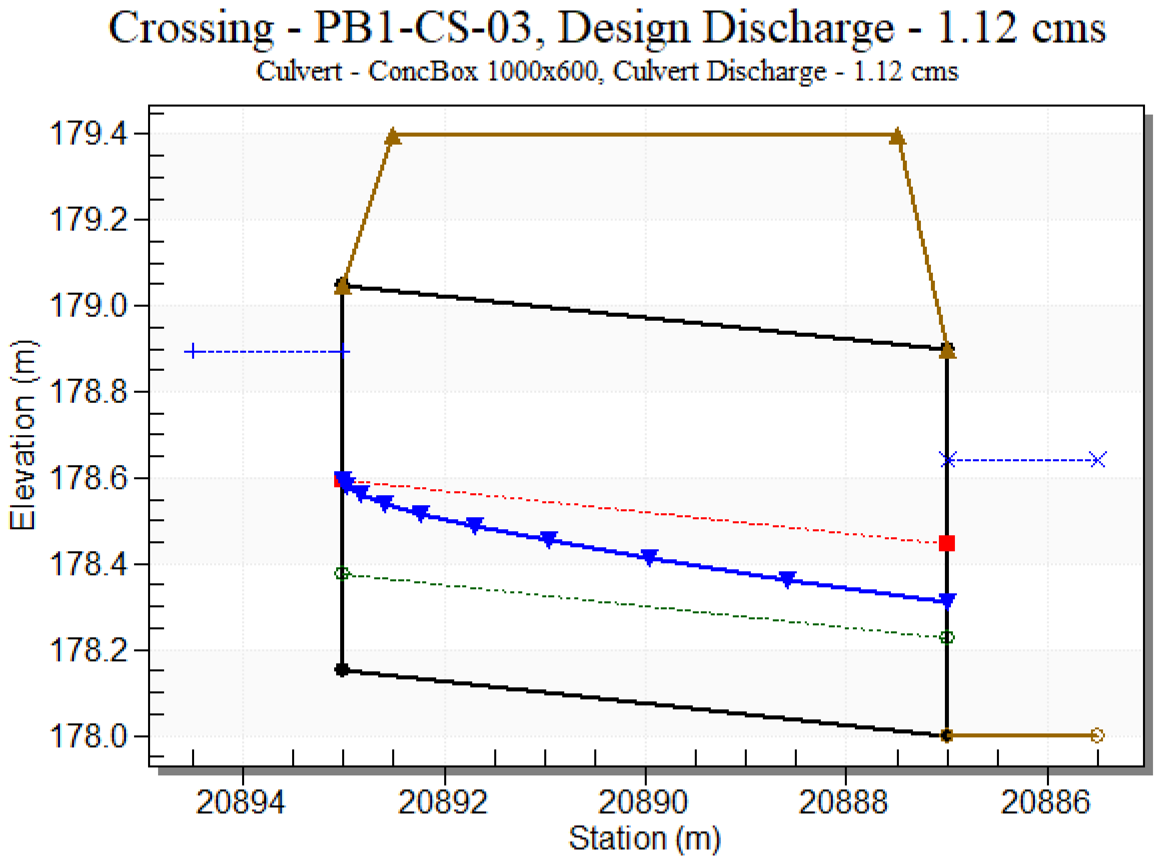
Straight Culvert

Inlet Elevation (invert): 175.44 m,   Outlet Elevation (invert): 175.28 m

Culvert Length: 14.00 m,   Culvert Slope: 0.0111

****

Water Surface Profile Plot for Culvert: ConcBox 1000x600



Culvert Performance Curve Plot: ConcBox 1000x600

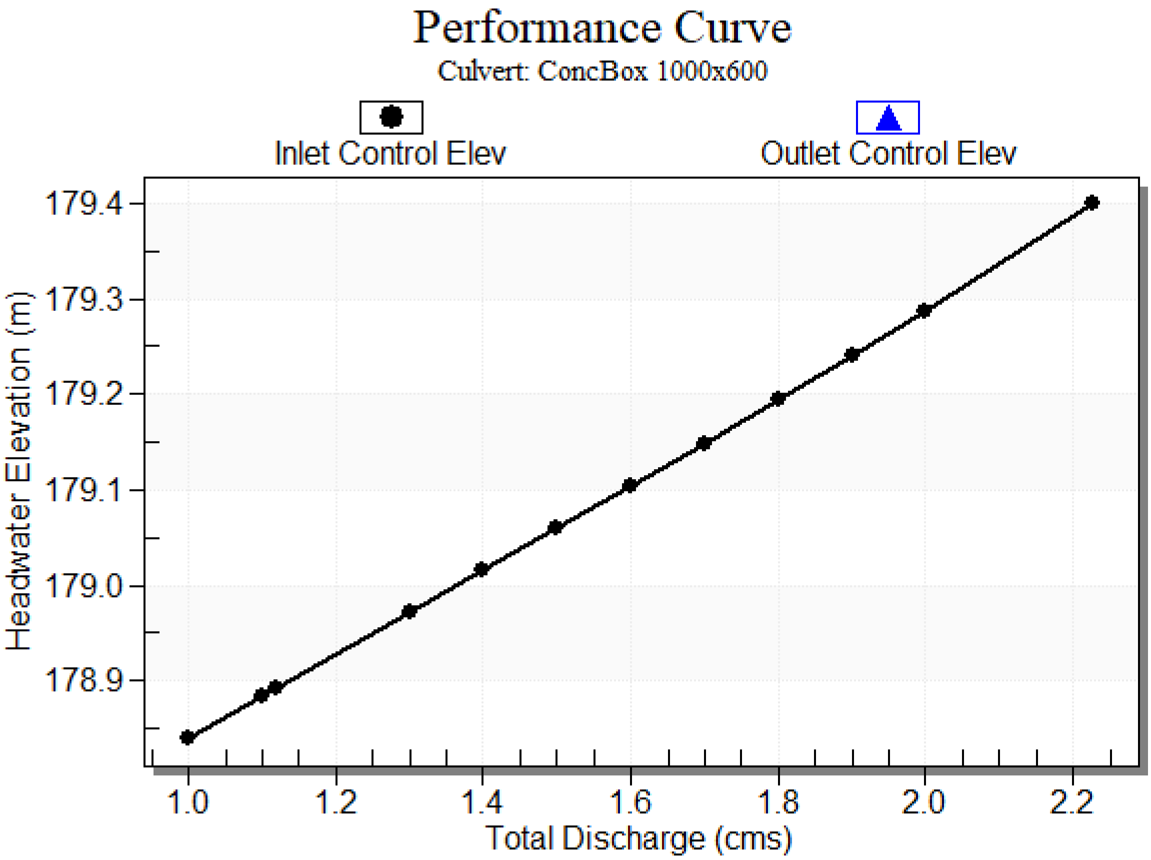


Table 5 - Culvert Summary Table: ConcBox 1000x600

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
1.00	1.00	178.84	0.689	0.528	1-S2n	0.210	0.414	0.286	0.608	2.918	1.088
1.10	1.10	178.88	0.735	0.570	1-S2n	0.224	0.441	0.307	0.635	2.987	1.115
1.12	1.12	178.89	0.743	0.578	1-S2n	0.226	0.446	0.311	0.640	3.000	1.120
1.30	1.30	178.97	0.823	0.655	1-S2n	0.251	0.493	0.349	0.686	3.104	1.163
1.40	1.40	179.02	0.866	0.697	1-S2n	0.264	0.518	0.369	0.710	3.161	1.185
1.50	1.50	179.06	0.910	0.740	5-S2n	0.277	0.542	0.389	0.732	3.215	1.206
1.60	1.60	179.10	0.954	0.783	5-S2n	0.289	0.566	0.409	0.754	3.261	1.225
1.70	1.70	179.15	0.998	0.828	5-S2n	0.302	0.589	0.428	0.775	3.308	1.244
1.80	1.80	179.19	1.043	0.872	5-S2n	0.314	0.612	0.447	0.795	3.355	1.262
1.90	1.90	179.24	1.090	0.918	5-S2n	0.326	0.634	0.466	0.815	3.400	1.279
2.00	2.00	179.29	1.137	0.964	5-S2n	0.338	0.657	0.485	0.834	3.440	1.296

****

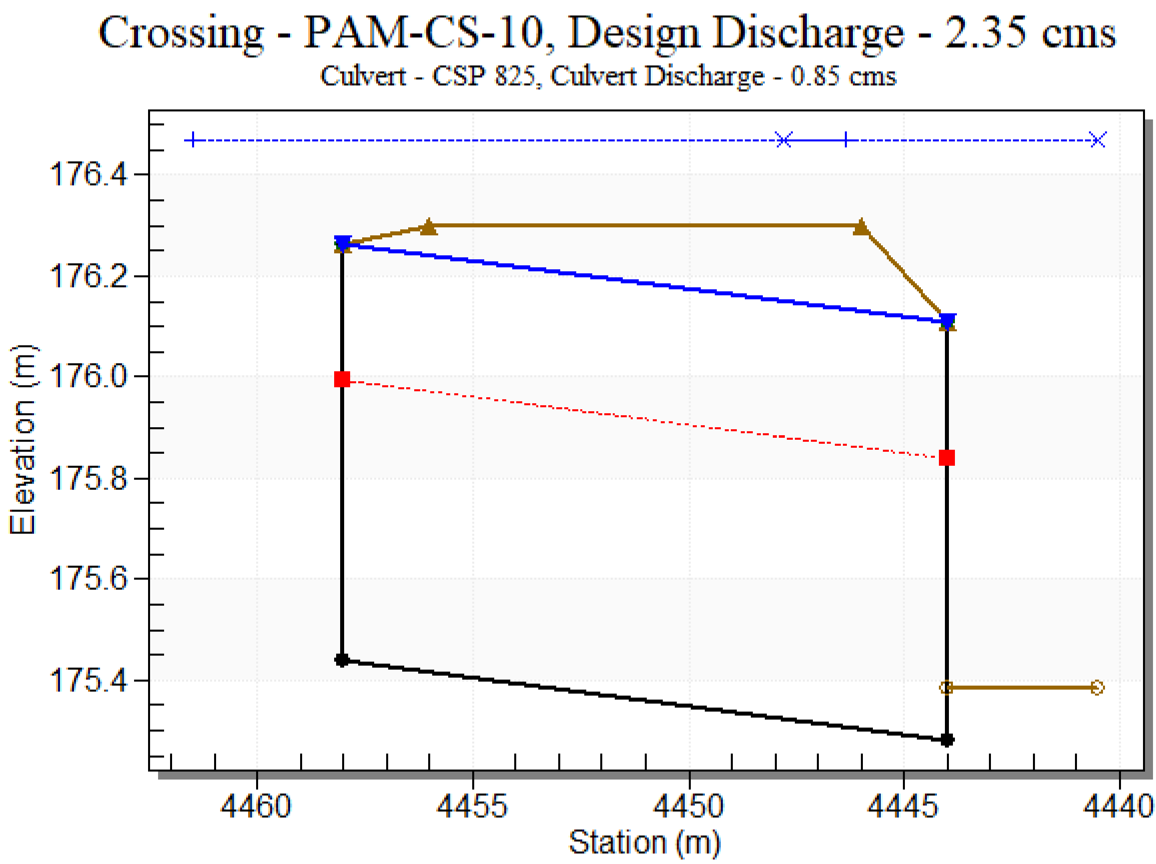
Straight Culvert

Inlet Elevation (invert): 178.15 m,   Outlet Elevation (invert): 178.00 m

Culvert Length: 6.00 m,   Culvert Slope: 0.0250

****

Water Surface Profile Plot for Culvert: CSP 825



Culvert Performance Curve Plot: CSP 825

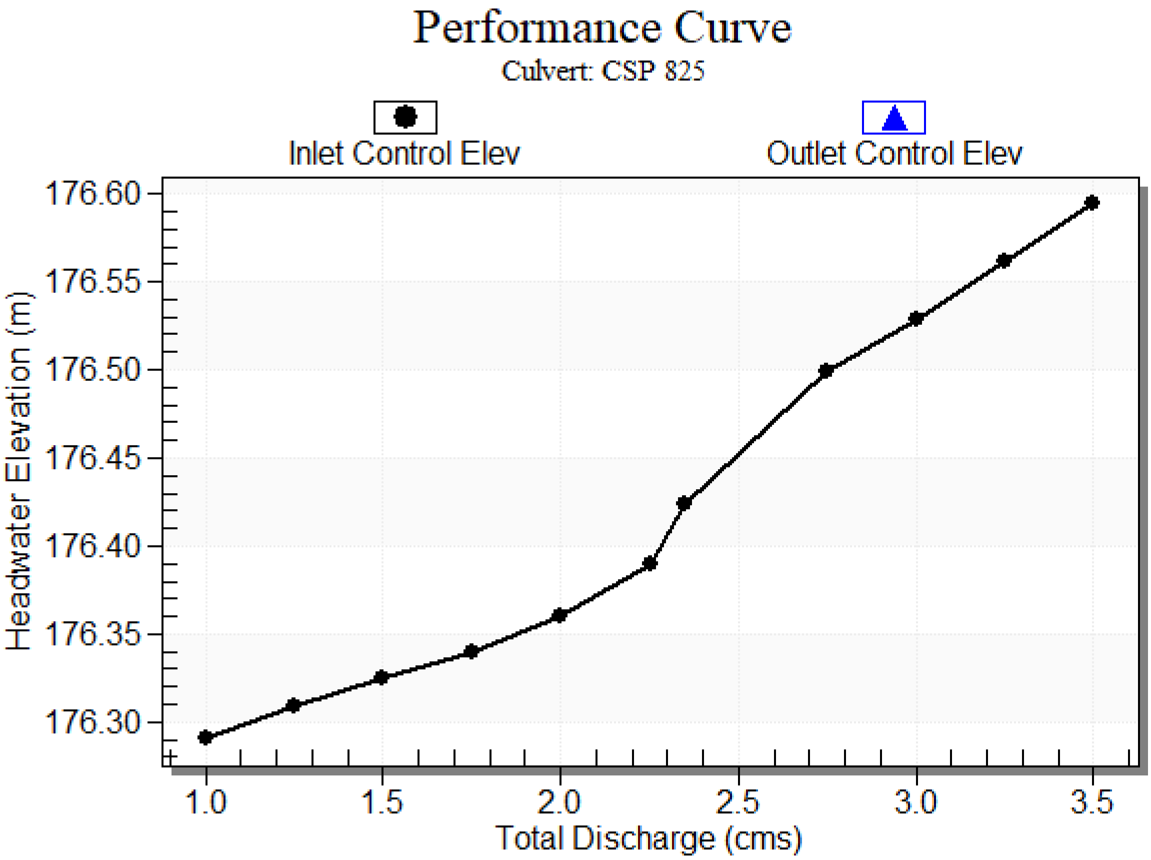


Table 6 - Culvert Summary Table: CSP 825

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
1.00	0.72	176.33	0.854	0.956	3-M1f	0.582	0.510	0.825	0.726	1.341	0.660
1.25	0.74	176.35	0.872	1.062	4-FFf	0.595	0.517	0.825	0.808	1.378	0.699
1.50	0.75	176.37	0.888	1.150	4-FFf	0.607	0.523	0.825	0.882	1.409	0.733
1.75	0.77	176.38	0.902	1.229	4-FFf	0.618	0.528	0.825	0.948	1.438	0.762
2.00	0.79	176.40	0.923	1.309	4-FFf	0.634	0.536	0.825	1.009	1.478	0.788
2.25	0.82	176.45	0.953	1.394	4-FFf	0.659	0.546	0.825	1.066	1.534	0.812
2.35	0.85	176.47	0.987	1.447	4-FFf	0.825	0.557	0.825	1.087	1.597	0.821
2.75	0.92	176.55	1.062	1.600	4-FFf	0.825	0.581	0.825	1.169	1.730	0.854
3.00	0.95	176.60	1.092	1.676	4-FFf	0.825	0.590	0.825	1.216	1.779	0.873
3.25	0.98	176.65	1.124	1.752	4-FFf	0.825	0.598	0.825	1.261	1.832	0.891
3.50	1.01	176.69	1.158	1.827	4-FFf	0.825	0.607	0.825	1.304	1.885	0.908

****

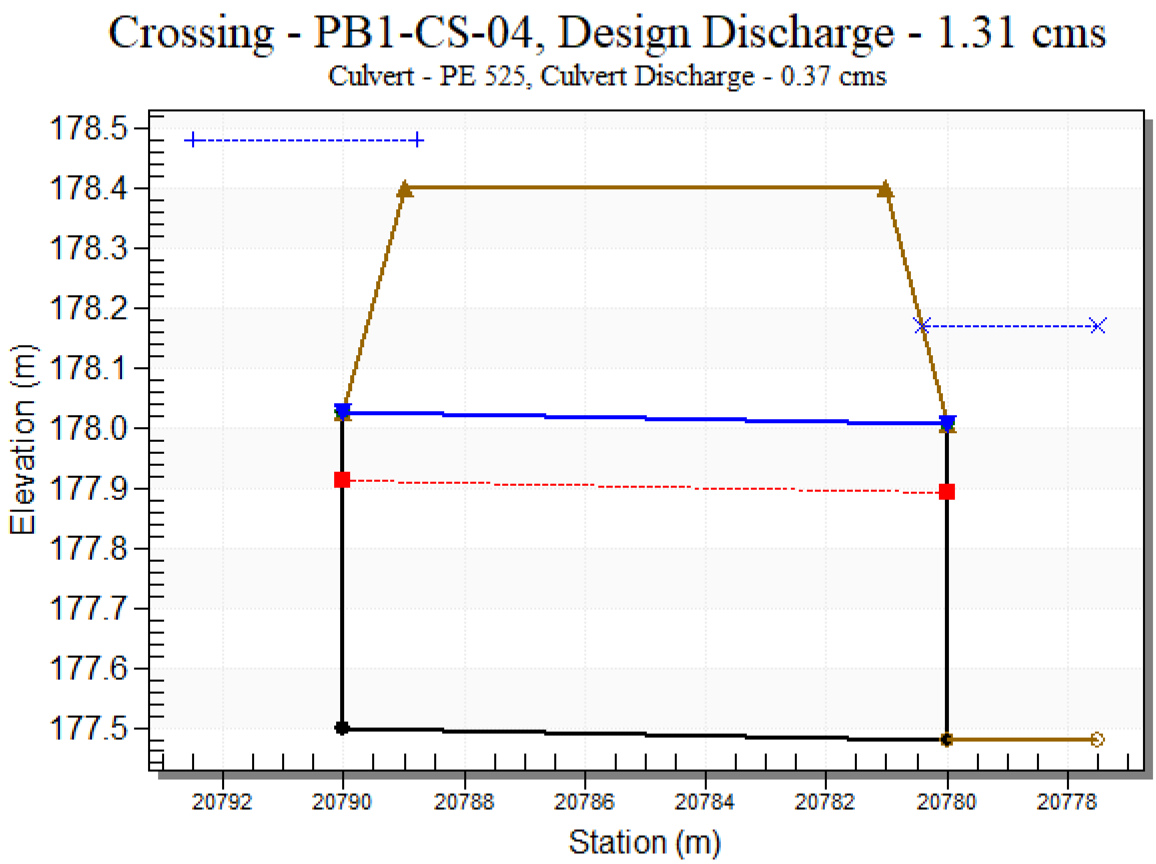
Straight Culvert

Inlet Elevation (invert): 175.44 m,   Outlet Elevation (invert): 175.28 m

Culvert Length: 14.00 m,   Culvert Slope: 0.0111

****

Water Surface Profile Plot for Culvert: PE 525



Culvert Performance Curve Plot: PE 525

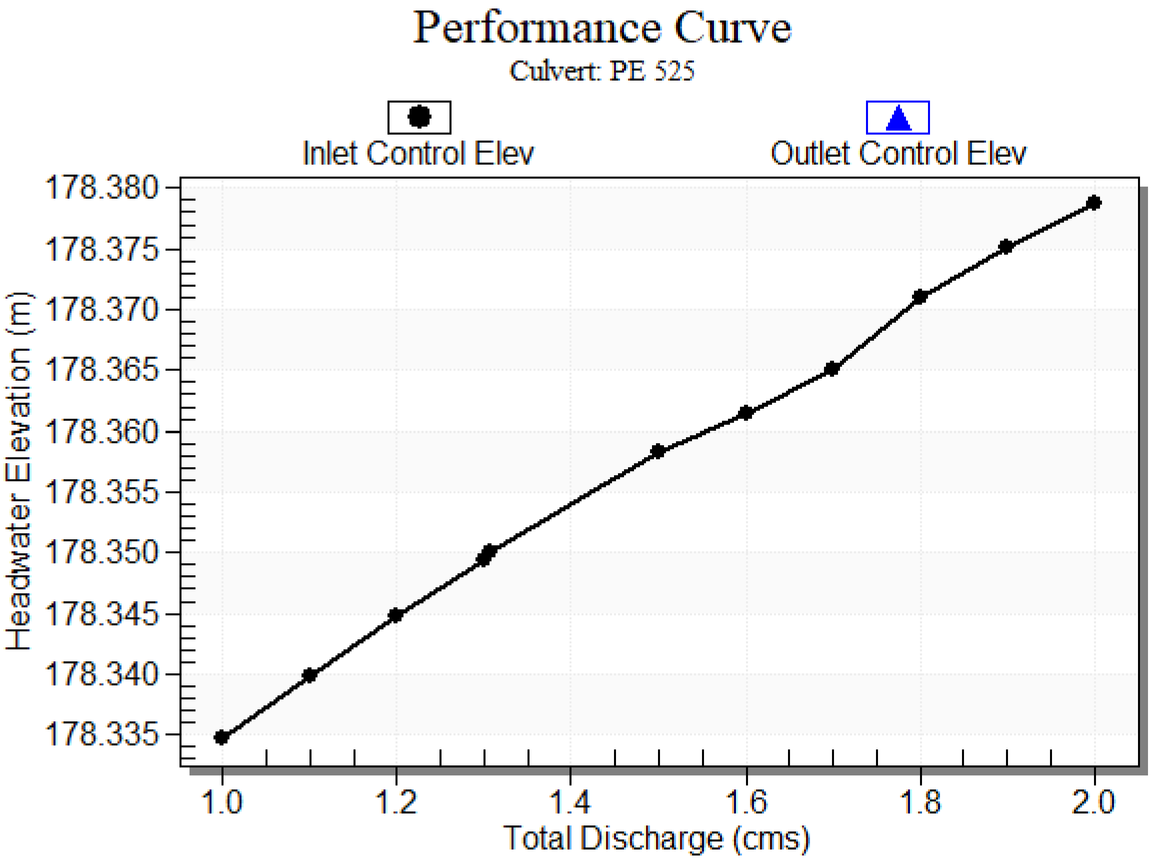


Table 7 - Culvert Summary Table: PE 525

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
1.00	0.36	178.46	0.835	1.104	4-FFf	0.525	0.408	0.525	0.608	1.681	1.088
1.10	0.37	178.47	0.840	1.137	4-FFf	0.525	0.409	0.525	0.635	1.690	1.115
1.20	0.37	178.47	0.845	1.169	4-FFf	0.525	0.410	0.525	0.661	1.699	1.140
1.30	0.37	178.48	0.849	1.198	4-FFf	0.525	0.411	0.525	0.686	1.707	1.163
1.31	0.37	178.48	0.850	1.201	4-FFf	0.525	0.411	0.525	0.688	1.708	1.165
1.50	0.37	178.49	0.858	1.254	4-FFf	0.525	0.412	0.525	0.732	1.722	1.206
1.60	0.37	178.50	0.861	1.279	4-FFf	0.525	0.413	0.525	0.754	1.728	1.225
1.70	0.38	178.50	0.865	1.304	4-FFf	0.525	0.414	0.525	0.775	1.734	1.244
1.80	0.38	178.51	0.871	1.331	4-FFf	0.525	0.415	0.525	0.795	1.744	1.262
1.90	0.38	178.51	0.875	1.355	4-FFf	0.525	0.416	0.525	0.815	1.751	1.279
2.00	0.38	178.51	0.879	1.377	4-FFf	0.525	0.416	0.525	0.834	1.757	1.296

****

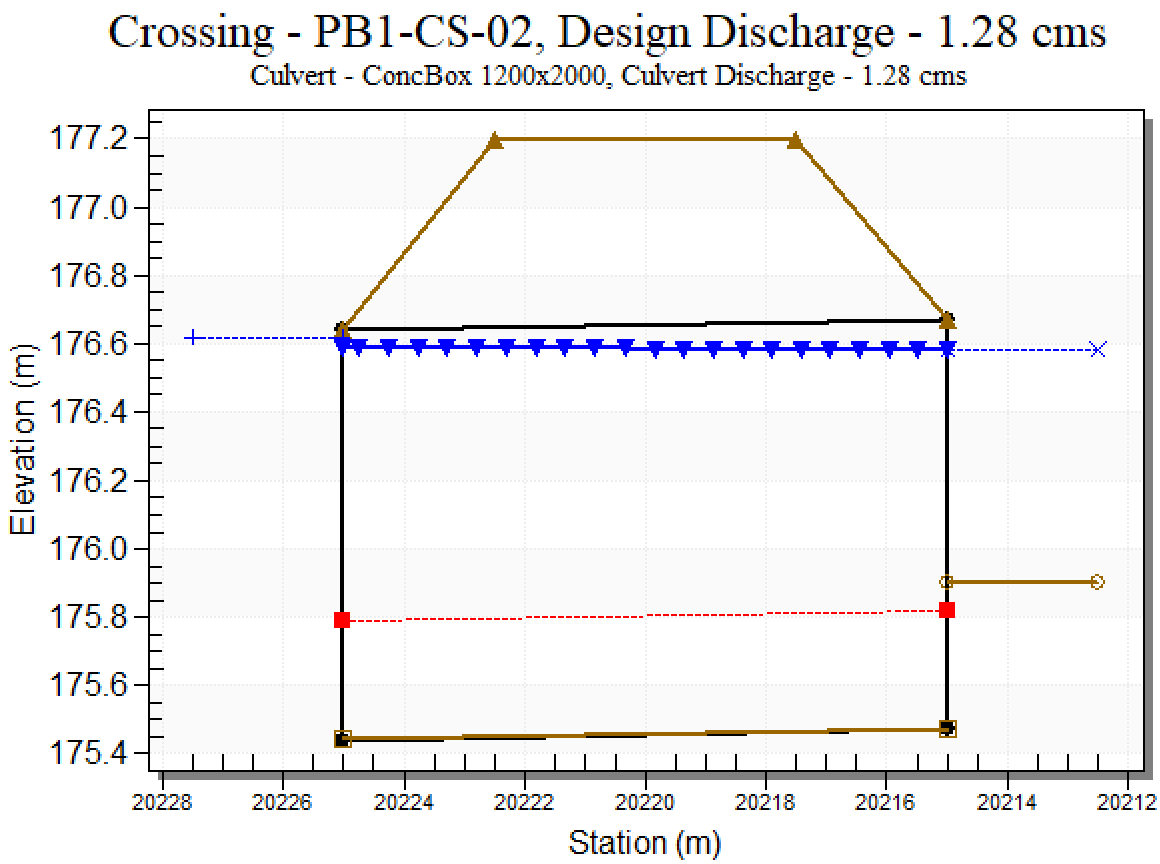
Straight Culvert

Inlet Elevation (invert): 177.50 m,   Outlet Elevation (invert): 177.48 m

Culvert Length: 10.00 m,   Culvert Slope: 0.0020

****

Water Surface Profile Plot for Culvert: ConcBox 1200x2000



Culvert Performance Curve Plot: ConcBox 1200x2000

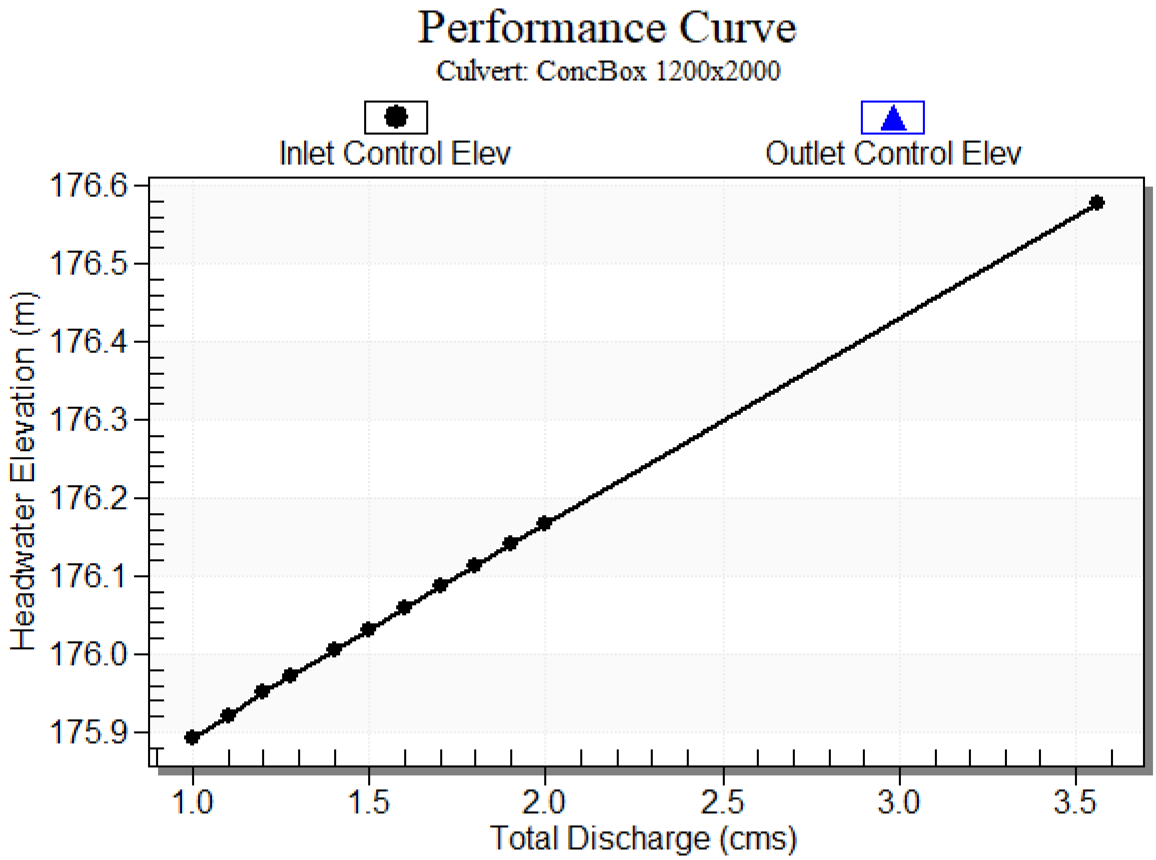


Table 8 - Culvert Summary Table: ConcBox 1200x2000

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
1.00	1.00	176.53	0.451	1.094	7-A2t	-0.305	0.296	1.037	0.608	0.482	1.088
1.10	1.10	176.57	0.481	1.125	7-A2t	-0.305	0.315	1.065	0.635	0.516	1.115
1.20	1.20	176.60	0.510	1.155	7-A2t	-0.305	0.334	1.091	0.661	0.550	1.140
1.28	1.28	176.62	0.531	1.177	7-A2t	-0.305	0.348	1.110	0.680	0.575	1.157
1.40	1.40	176.65	0.565	1.212	7-A2t	-0.305	0.371	1.139	0.710	0.614	1.185
1.50	1.50	176.68	0.591	1.237	7-A2t	-0.305	0.388	1.162	0.732	0.645	1.206
1.60	1.60	176.68	0.618	1.243	7-A2t	-0.305	0.405	1.184	0.754	0.676	1.225
1.70	1.70	176.73	0.646	1.286	4-FFf	-0.305	0.422	1.200	0.775	0.709	1.244
1.80	1.80	176.75	0.673	1.312	4-FFf	-0.305	0.438	1.200	0.795	0.750	1.262
1.90	1.90	176.78	0.700	1.339	4-FFf	-0.305	0.454	1.200	0.815	0.792	1.279
2.00	2.00	176.80	0.727	1.364	4-FFf	-0.305	0.470	1.200	0.834	0.834	1.296

****

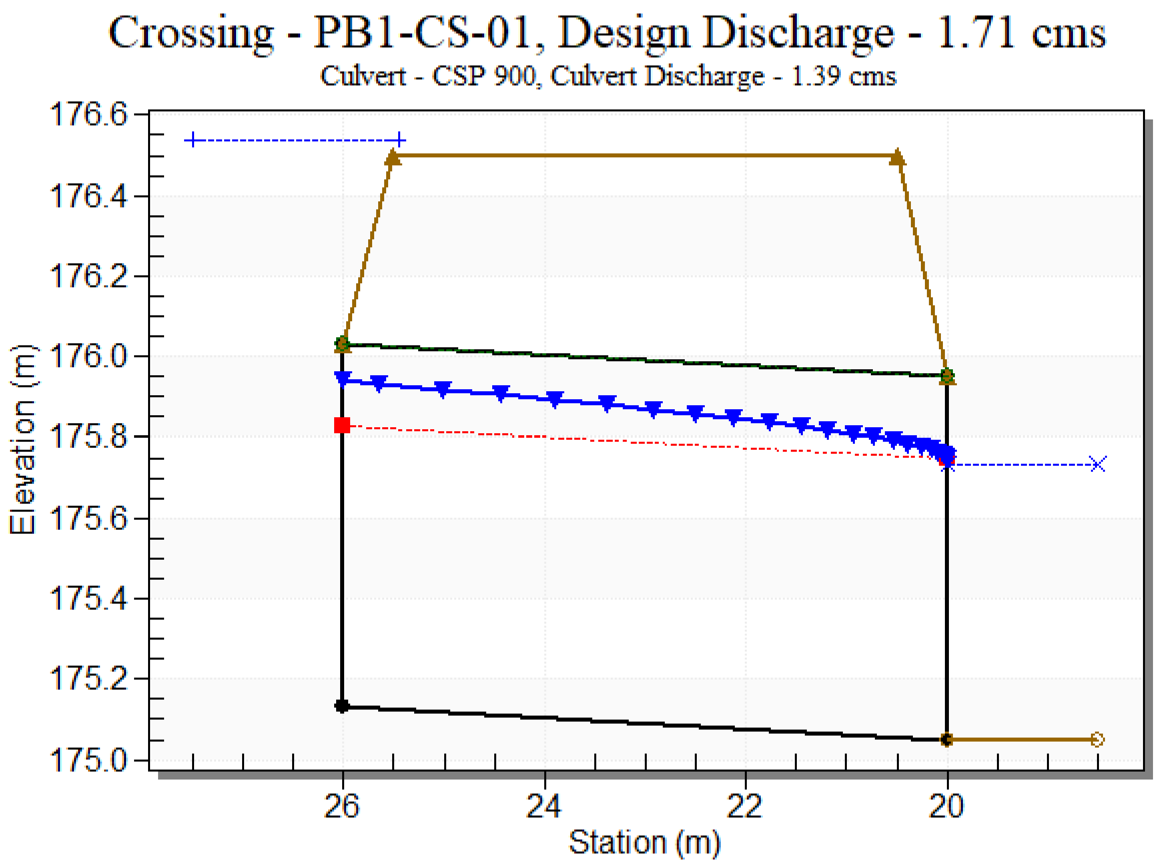
Straight Culvert

Inlet Elevation (invert): 175.44 m,   Outlet Elevation (invert): 175.47 m

Culvert Length: 10.00 m,   Culvert Slope: -0.0030

****

Water Surface Profile Plot for Culvert: CSP 900



Culvert Performance Curve Plot: CSP 900

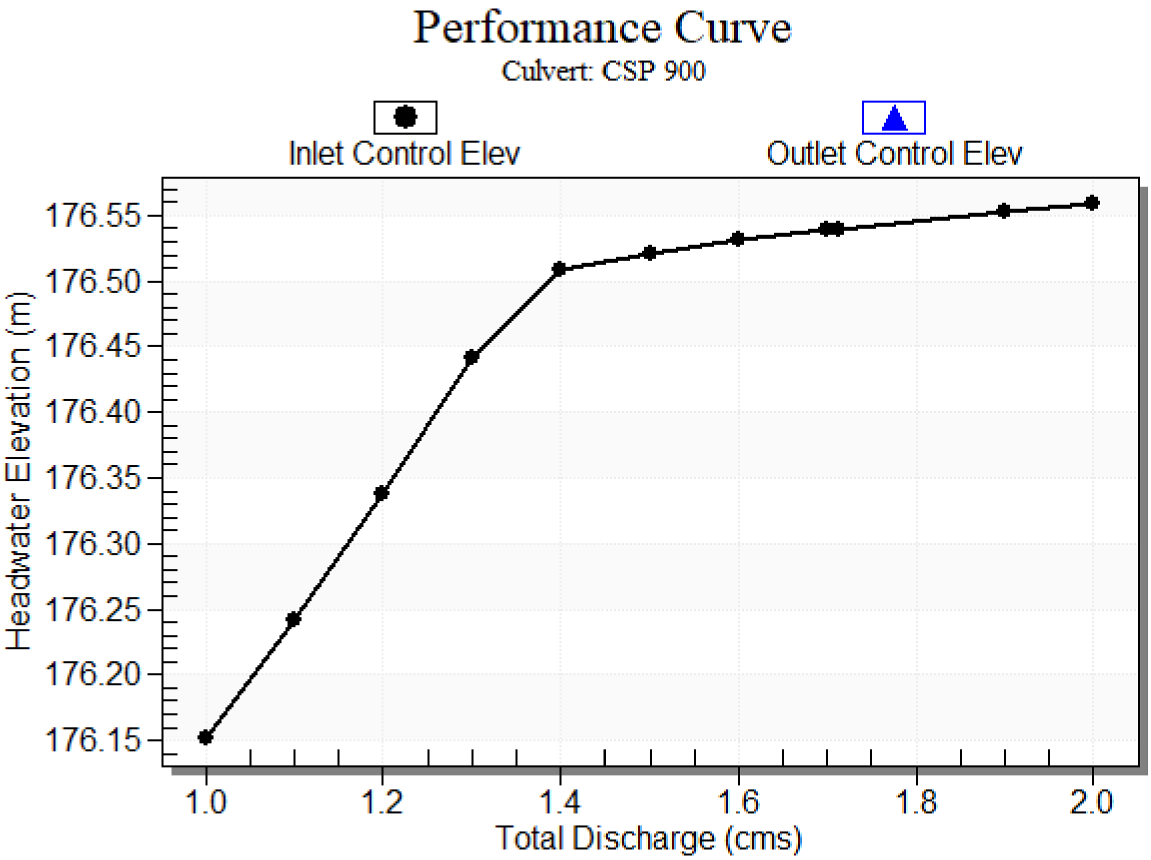


Table 9 - Culvert Summary Table: CSP 900

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
1.00	1.00	176.18	1.021	1.054	7-M2c	0.639	0.590	0.590	0.522	2.262	1.074
1.10	1.10	176.25	1.111	1.118	7-M2c	0.696	0.620	0.620	0.548	2.352	1.102
1.20	1.20	176.34	1.208	1.186	7-M2c	0.900	0.648	0.648	0.573	2.446	1.128
1.30	1.30	176.44	1.312	1.257	7-M2c	0.900	0.674	0.674	0.596	2.542	1.152
1.40	1.36	176.51	1.379	1.302	7-M2c	0.900	0.689	0.689	0.618	2.601	1.174
1.50	1.37	176.52	1.391	1.310	7-M2c	0.900	0.692	0.692	0.640	2.612	1.196
1.60	1.38	176.53	1.401	1.316	7-M2c	0.900	0.694	0.694	0.661	2.620	1.216
1.70	1.39	176.54	1.409	1.322	7-M2c	0.900	0.696	0.696	0.681	2.627	1.236
1.71	1.39	176.54	1.410	1.322	7-M2c	0.900	0.696	0.696	0.683	2.628	1.238
1.90	1.40	176.55	1.423	1.331	3-M2t	0.900	0.699	0.719	0.719	2.566	1.272
2.00	1.40	176.56	1.429	1.336	3-M2t	0.900	0.700	0.737	0.737	2.517	1.289

****

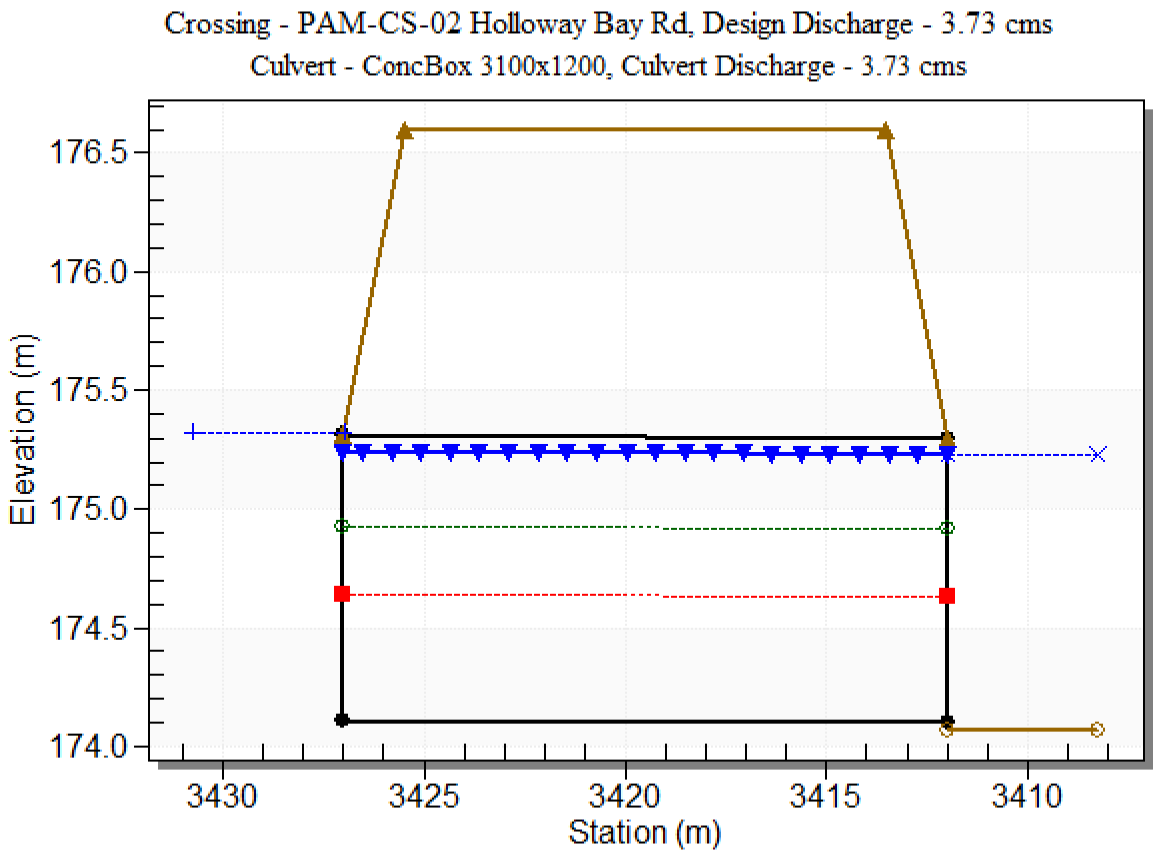
Straight Culvert

Inlet Elevation (invert): 175.13 m,   Outlet Elevation (invert): 175.05 m

Culvert Length: 6.00 m,   Culvert Slope: 0.0133

****

Water Surface Profile Plot for Culvert: ConcBox 3100x1200



Culvert Performance Curve Plot: ConcBox 3100x1200

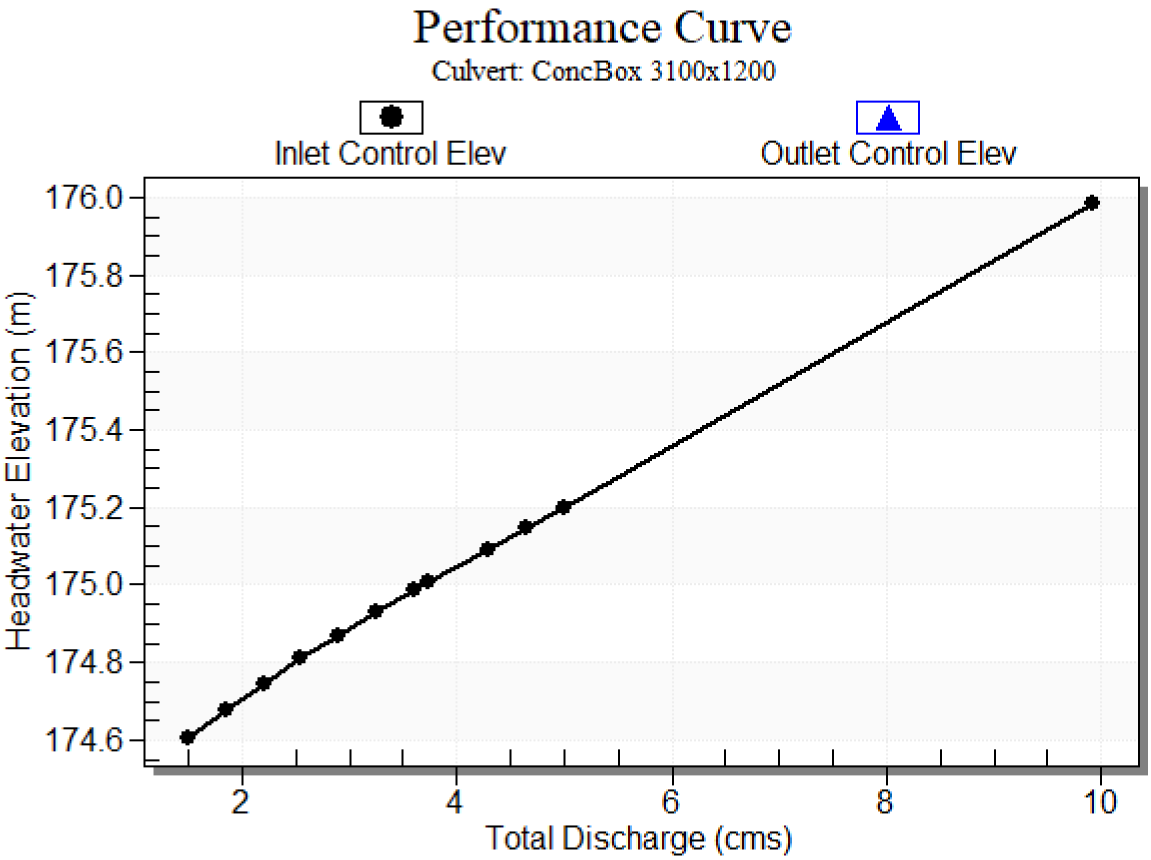


Table 10 - Culvert Summary Table: ConcBox 3100x1200

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
1.50	1.50	174.82	0.494	0.705	3-M1t	0.440	0.288	0.672	0.702	0.720	0.459
1.85	1.85	174.91	0.568	0.801	3-M1t	0.506	0.331	0.760	0.790	0.785	0.489
2.20	2.20	175.00	0.637	0.889	3-M1t	0.568	0.372	0.840	0.870	0.845	0.515
2.55	2.55	175.08	0.700	0.970	3-M1t	0.628	0.410	0.914	0.944	0.900	0.538
2.90	2.90	175.16	0.761	1.047	3-M1t	0.686	0.447	0.983	1.013	0.951	0.559
3.25	3.25	175.23	0.819	1.119	3-M1t	0.742	0.482	1.048	1.078	1.000	0.578
3.60	3.60	175.30	0.875	1.188	3-M1t	0.796	0.516	1.110	1.140	1.046	0.595
3.73	3.73	175.32	0.896	1.214	7-M1t	0.817	0.529	1.133	1.163	1.063	0.601
4.30	4.30	175.44	0.983	1.325	4-FFf	0.902	0.581	1.200	1.254	1.156	0.625
4.65	4.65	175.51	1.035	1.398	4-FFf	0.953	0.612	1.200	1.308	1.250	0.639
5.00	5.00	175.58	1.087	1.469	4-FFf	1.004	0.642	1.200	1.359	1.344	0.652

****

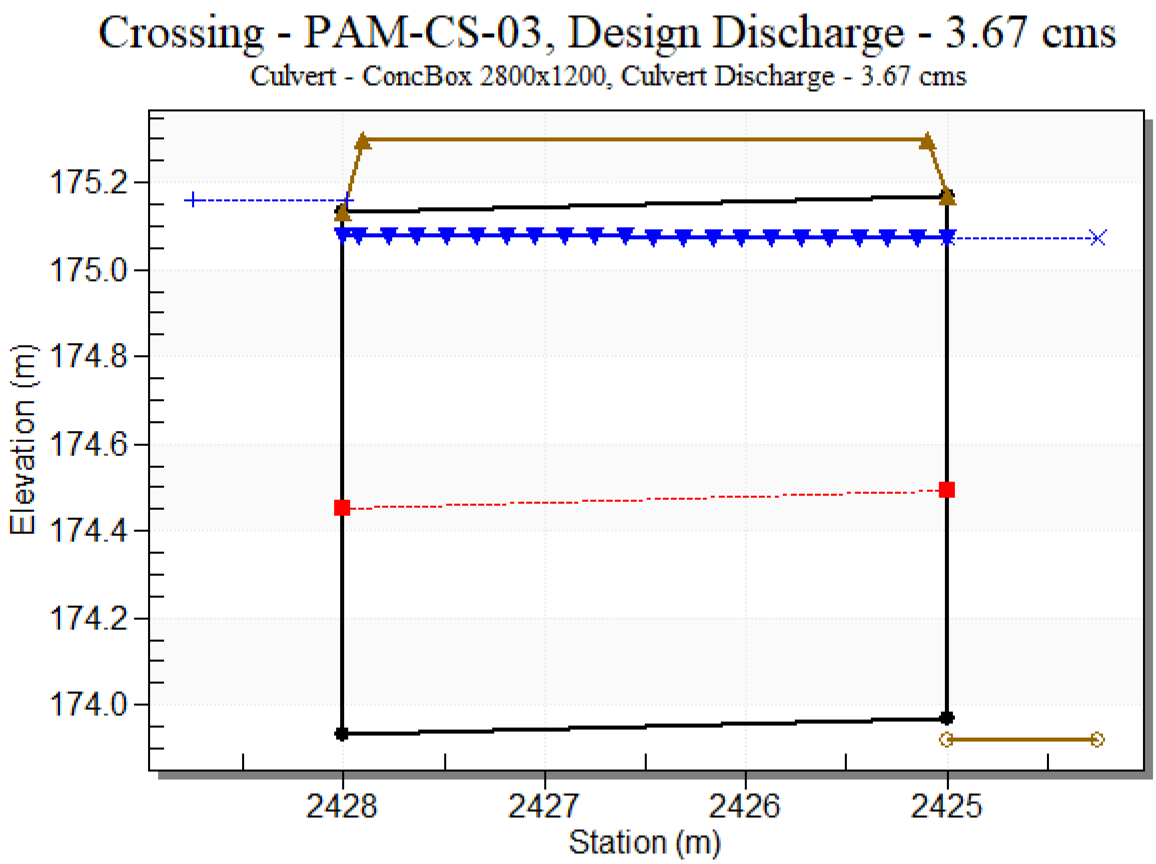
Straight Culvert

Inlet Elevation (invert): 174.11 m,   Outlet Elevation (invert): 174.10 m

Culvert Length: 15.00 m,   Culvert Slope: 0.0007

****

Water Surface Profile Plot for Culvert: ConcBox 2800x1200



Culvert Performance Curve Plot: ConcBox 2800x1200

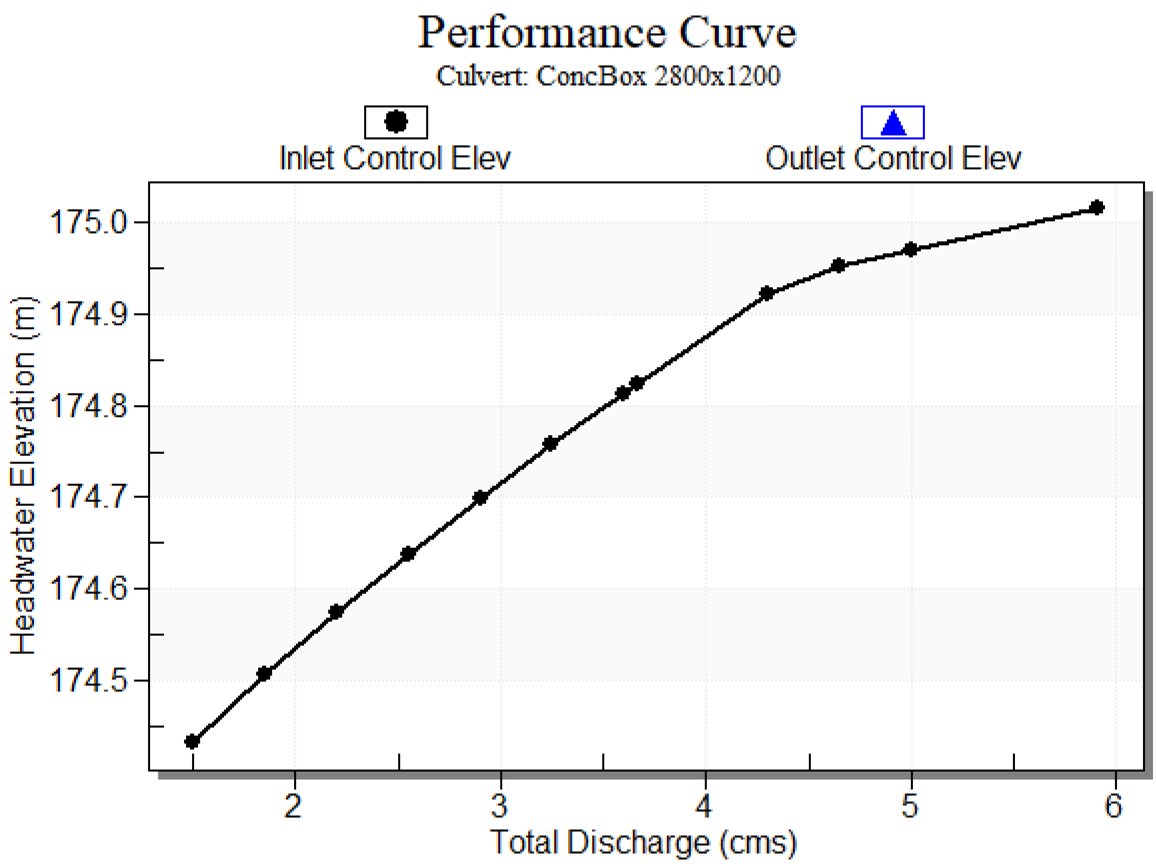


Table 11 - Culvert Summary Table: ConcBox 2800x1200

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
1.50	1.50	174.66	0.501	0.733	7-A2t	-0.305	0.288	0.652	0.702	0.742	0.459
1.85	1.85	174.76	0.577	0.829	7-A2t	-0.305	0.331	0.740	0.790	0.807	0.489
2.20	2.20	174.85	0.645	0.916	7-A2t	-0.305	0.372	0.820	0.870	0.865	0.515
2.55	2.55	174.93	0.708	0.998	7-A2t	-0.305	0.410	0.894	0.944	0.920	0.538
2.90	2.90	175.00	0.769	1.074	7-A2t	-0.305	0.447	0.963	1.013	0.971	0.559
3.25	3.25	175.08	0.827	1.147	7-A2t	-0.305	0.482	1.028	1.078	1.019	0.578
3.60	3.60	175.15	0.883	1.215	7-A2t	-0.305	0.516	1.090	1.140	1.065	0.595
3.67	3.67	175.16	0.894	1.229	7-A2t	-0.305	0.523	1.102	1.152	1.074	0.598
4.30	4.30	175.28	0.991	1.348	4-FFf	-0.305	0.581	1.200	1.254	1.156	0.625
4.65	4.52	175.32	1.024	1.413	4-FFf	-0.305	0.600	1.200	1.308	1.214	0.639
5.00	4.62	175.34	1.040	1.469	4-FFf	-0.305	0.610	1.200	1.359	1.243	0.652

****

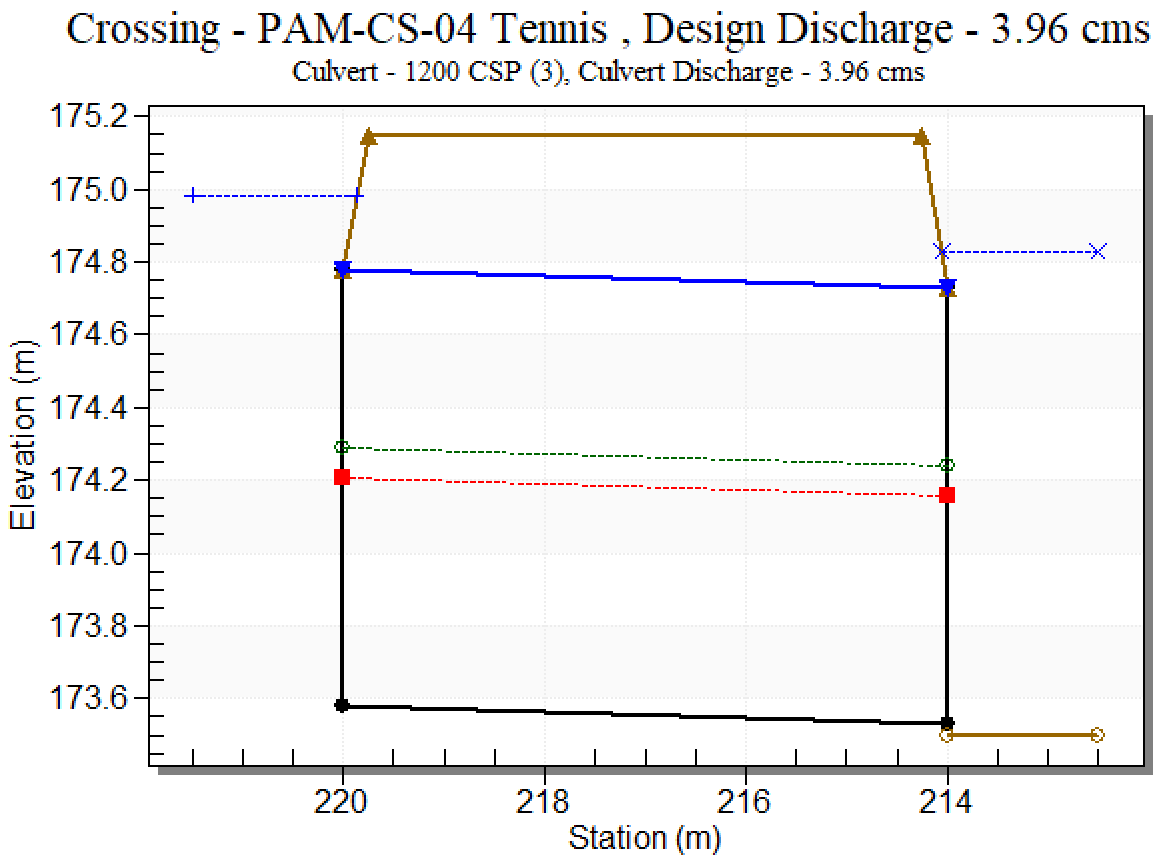
Straight Culvert

Inlet Elevation (invert): 173.93 m,   Outlet Elevation (invert): 173.97 m

Culvert Length: 3.00 m,   Culvert Slope: -0.0133

****

Water Surface Profile Plot for Culvert: 1200 CSP (3)



Culvert Performance Curve Plot: 1200 CSP (3)

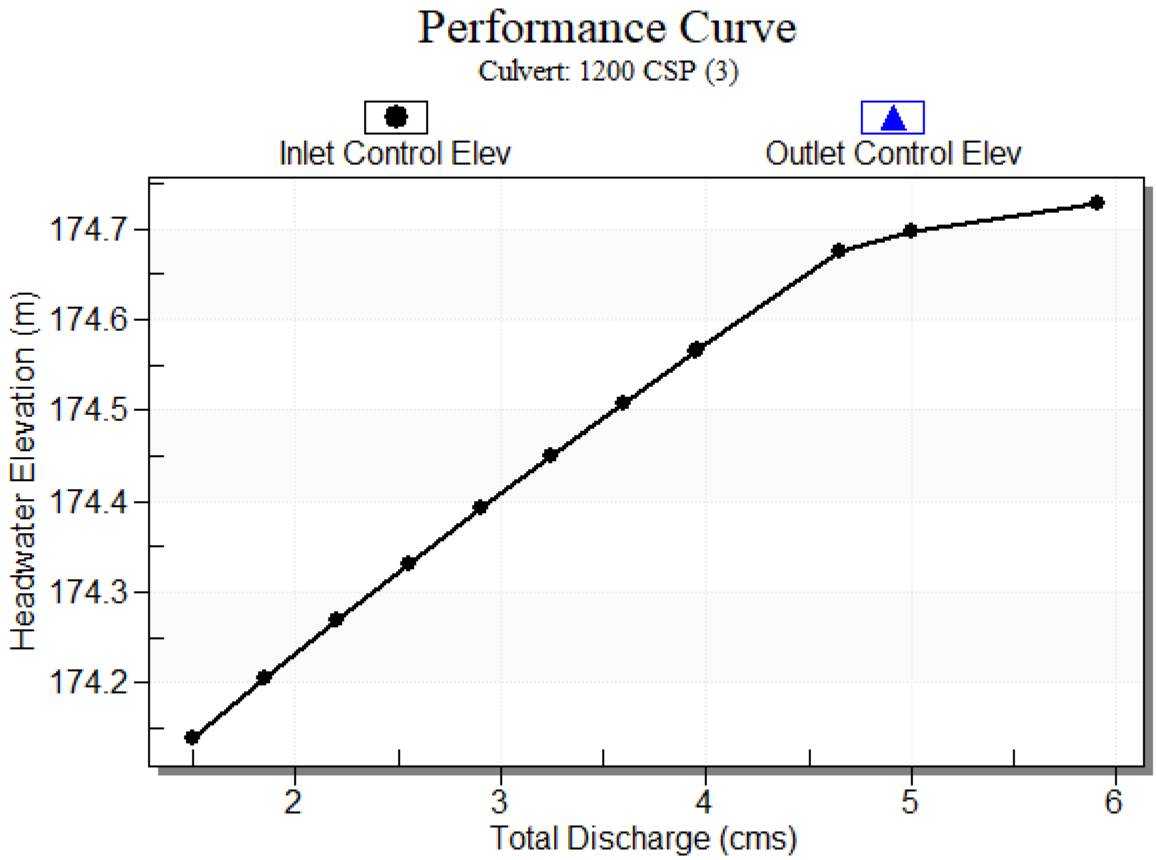


Table 12 - Culvert Summary Table: 1200 CSP (3)

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
1.50	1.50	174.33	0.559	0.745	3-M1t	0.406	0.376	0.738	0.768	0.685	0.317
1.85	1.85	174.43	0.626	0.850	3-M1t	0.454	0.420	0.836	0.866	0.733	0.339
2.20	2.20	174.53	0.690	0.947	3-M1t	0.499	0.460	0.926	0.956	0.783	0.358
2.55	2.55	174.62	0.752	1.039	3-M1t	0.543	0.496	1.009	1.039	0.837	0.374
2.90	2.90	174.71	0.812	1.128	3-M1t	0.585	0.532	1.087	1.117	0.898	0.389
3.25	3.25	174.80	0.870	1.216	7-M1t	0.626	0.565	1.160	1.190	0.968	0.402
3.60	3.60	174.89	0.928	1.308	3-M1f	0.667	0.596	1.200	1.260	1.061	0.415
3.95	3.95	174.98	0.985	1.400	4-FFf	0.708	0.625	1.200	1.326	1.164	0.426
3.96	3.96	174.98	0.987	1.404	4-FFf	0.710	0.626	1.200	1.328	1.168	0.427
4.65	4.62	175.16	1.096	1.582	4-FFf	0.790	0.678	1.200	1.450	1.363	0.447
5.00	4.75	175.19	1.118	1.652	4-FFf	0.806	0.688	1.200	1.508	1.401	0.456

****

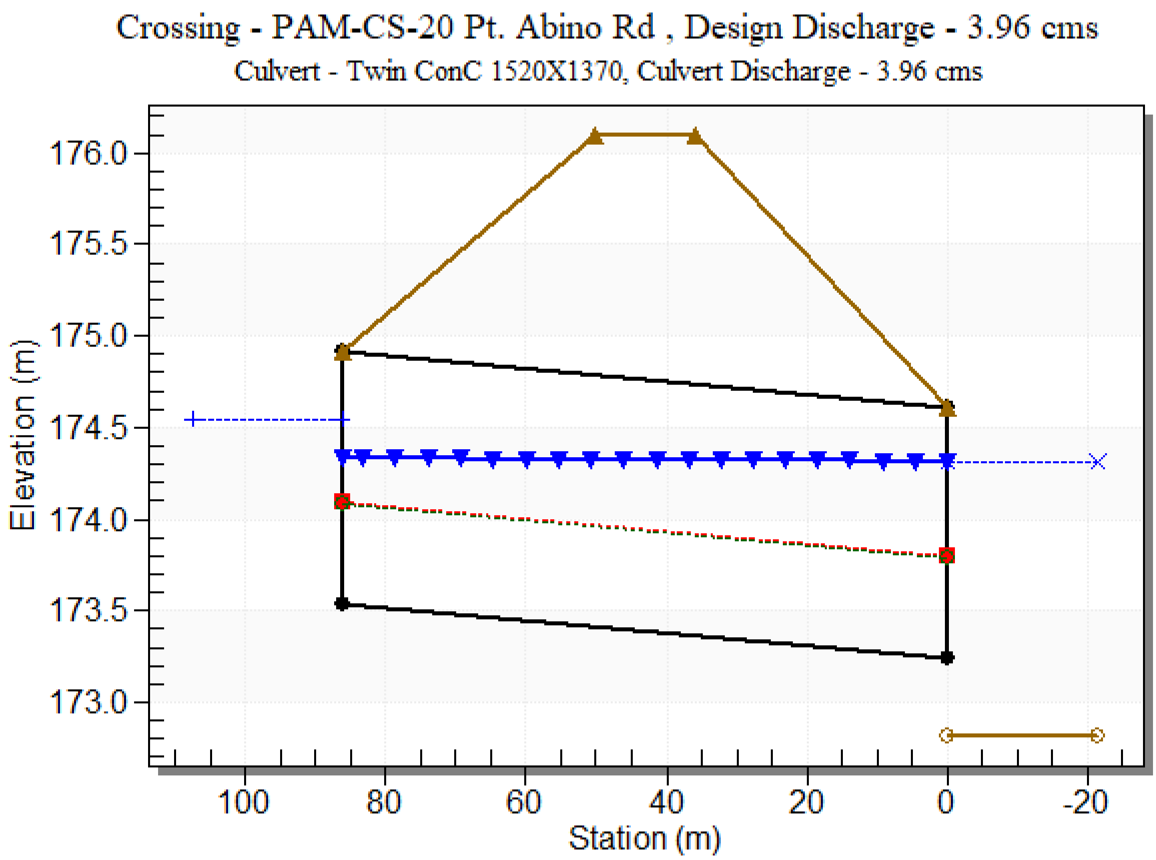
Straight Culvert

Inlet Elevation (invert): 173.58 m,   Outlet Elevation (invert): 173.53 m

Culvert Length: 6.00 m,   Culvert Slope: 0.0083

****

Water Surface Profile Plot for Culvert: Twin ConC 1520X1370



Culvert Performance Curve Plot: Twin ConC 1520X1370

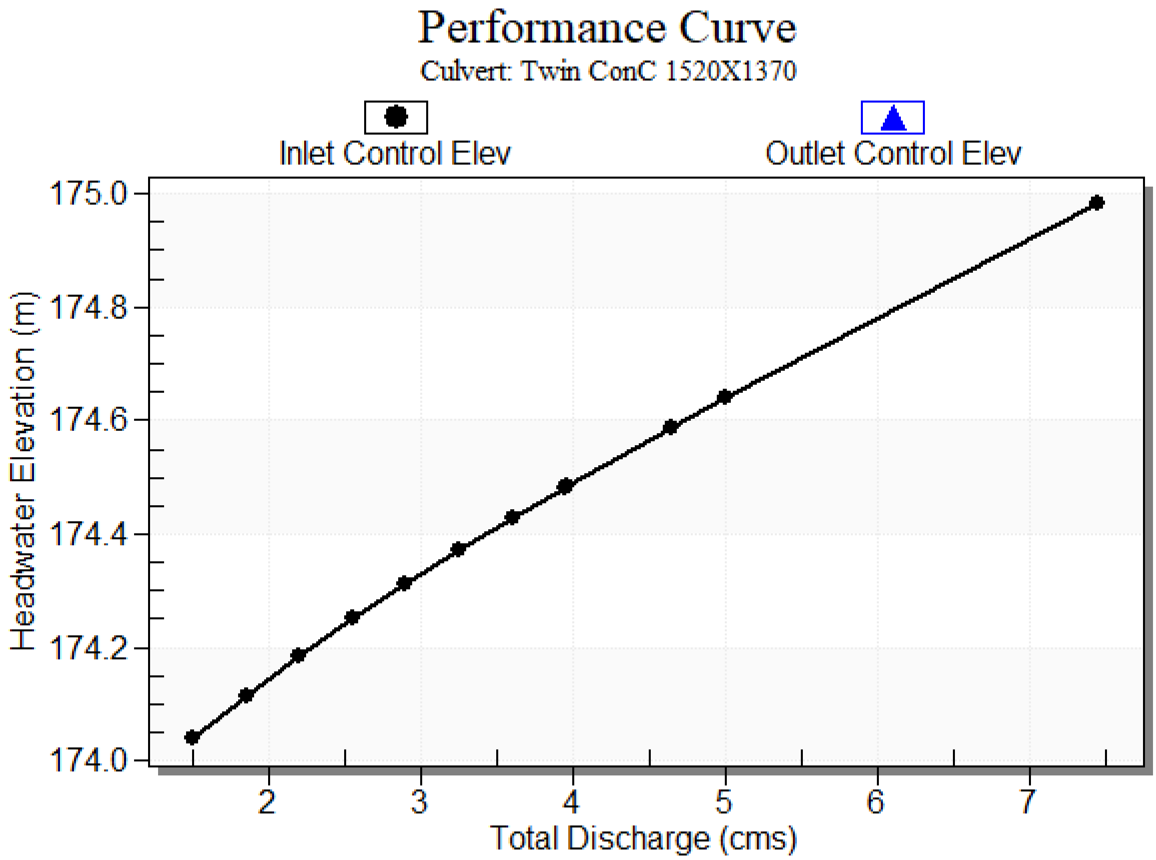


Table 13 - Culvert Summary Table: Twin ConC 1520X1370

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth (m)	Outlet Control Depth (m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
1.50	1.50	174.04	0.499	0.075	1-JS1t	0.278	0.292	0.359	0.779	1.374	0.321
1.85	1.85	174.11	0.574	0.199	1-JS1t	0.321	0.335	0.474	0.894	1.283	0.345
2.20	2.20	174.18	0.644	0.318	1-S2n	0.361	0.376	0.361	1.003	2.005	0.365
2.55	2.55	174.25	0.710	0.434	1-S2n	0.400	0.415	0.400	1.108	2.097	0.384
2.90	2.90	174.32	0.772	0.779	1-S1t	0.438	0.453	0.788	1.208	1.210	0.400
3.25	3.25	174.38	0.830	0.843	1-S1t	0.475	0.488	0.885	1.305	1.207	0.415
3.60	3.60	174.46	0.887	0.917	1-S1t	0.510	0.523	0.980	1.400	1.208	0.429
3.95	3.95	174.54	0.942	0.997	1-S1t	0.546	0.556	1.073	1.493	1.211	0.441
3.96	3.96	174.54	0.944	1.000	1-S1t	0.547	0.557	1.076	1.496	1.211	0.441
4.65	4.65	174.70	1.048	1.161	1-S1t	0.615	0.620	1.252	1.672	1.221	0.463
5.00	5.00	174.78	1.099	1.244	1-S1t	0.648	0.651	1.340	1.760	1.228	0.474

****

Straight Culvert

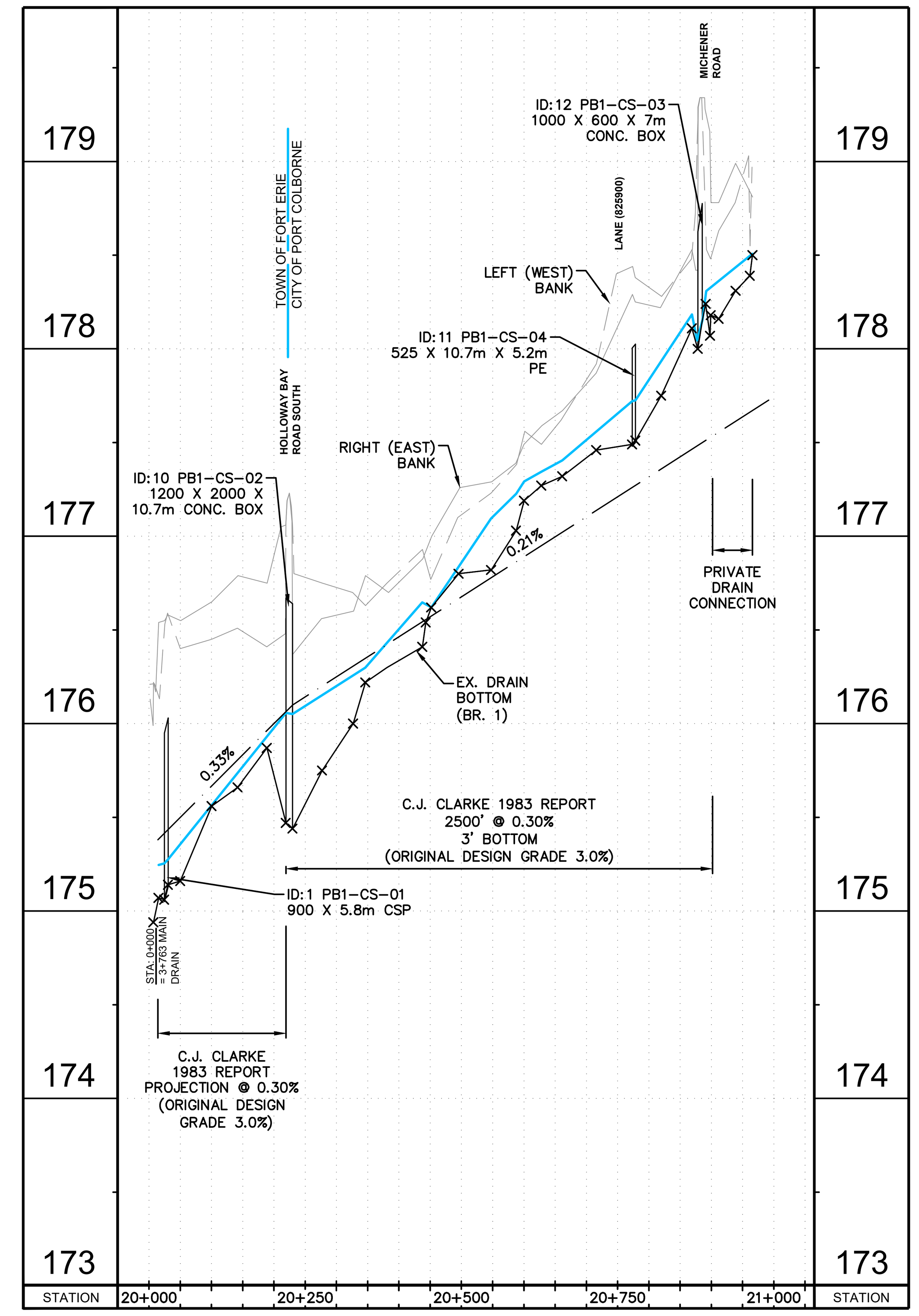
Inlet Elevation (invert): 173.54 m,   Outlet Elevation (invert): 173.24 m

Culvert Length: 86.00 m,   Culvert Slope: 0.0035

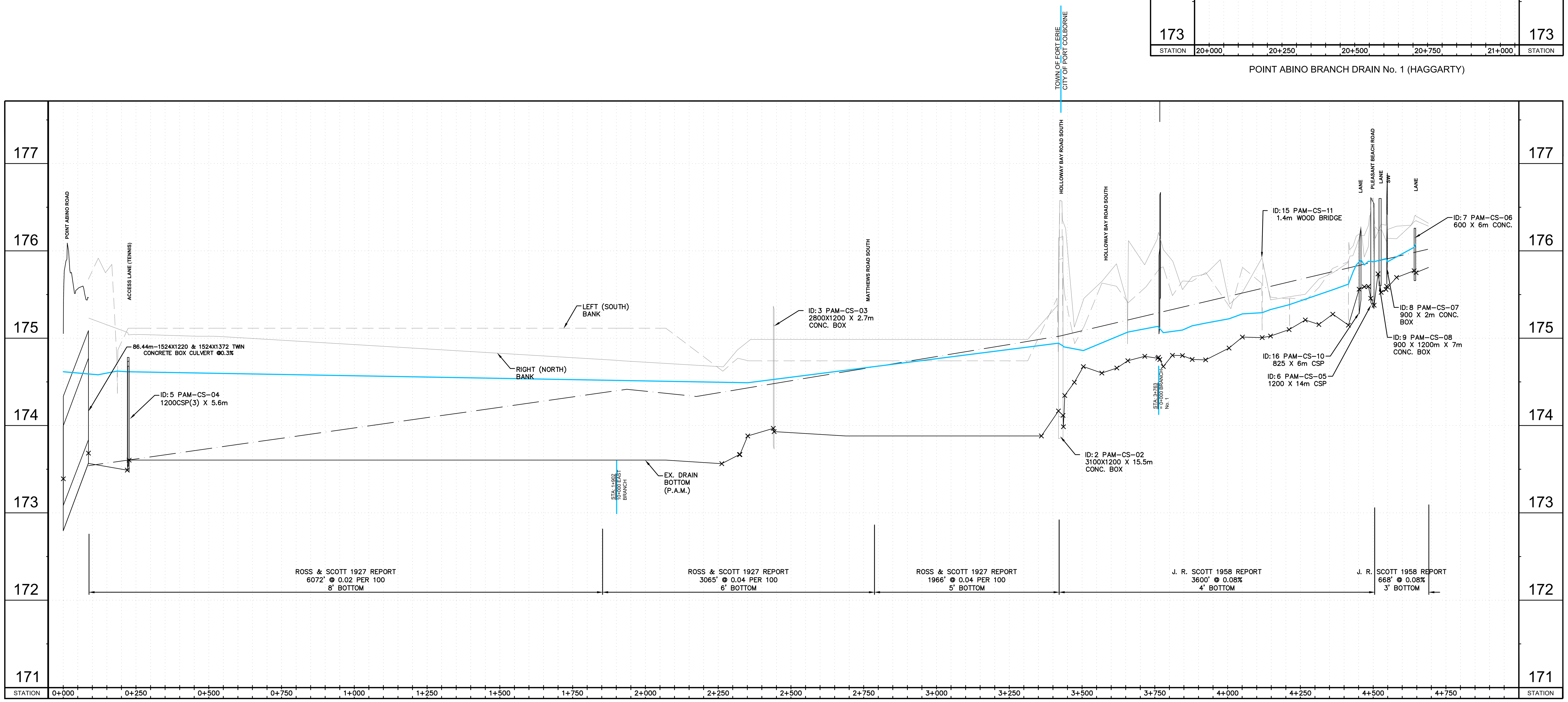
****

Appendix F:

Calculations and Supporting Documents



POINT ABINO BRANCH DRAIN No. 1 (HAGGARTY)



POINT ABINO MARSH DRAIN

PORT COLBORNE
66 Charlotte St, Port Colborne ON, L3K 3C8
905-835-2900

LEGEND

- EX. WATER LEVEL
- EX. DESIGN BOTTOM
- EX. DITCH BOTTOM
- EX. TOP OF BANK

NOTES

DRAWINGS ARE BASED ON INFORMATION PROVIDED BY THE CITY OF PORT COLBORNE, TOWN OF FORT ERIE AND OPEN DATA FROM ONTARIO, NIAGARA PENINSULA CONSERVATION AUTHORITY, REGIONAL MUNICIPALITY OF NIAGARA AND OTHER ACCESSIBLE DATA. ALL OTHER INFORMATION IS PROVIDED FOR PROJECT REFERENCE BUT IS NOT TO BE RELIED ON FOR CONSTRUCTION OR ANY OTHER PURPOSE OTHER THAN INCLUSION IN THE BASELINE REPORT.

FINAL BASELINE REPORT	01	2021/12/20	PM
ISSUED FOR/REVISIONS	No.	YYYY/MM/DD	BY

CONTROL POINTS:

CONSULTANT:

EWA Engineering Inc.
647.400.2824
www.ewaeng.com

DESIGN BY:
DRAWN BY: AVAL
CHECKED BY: P.M.
APPROVED BY: P.M.
DATE:
STAMP:

POINT ABINO DRAIN

POINT ABINO DRAIN OVERALL PROFILE

HOR. SCALE - 1:7500 VERT. SCALE - 1:50
STN: N/A TO: N/A
PROJECT NO: 19-9997
DWG NO: DWG-003

Nº	NAME	ACRE ±	LOT	CON
1	VIRGINIA ROBERTS		32	BF L.E.
2	VIRGINIA ROBERTS		32	BF L.E.
3	CLARENCE STRAUBINGER		32	BF L.E.
4	ANITA SIMONDS		32	BF L.E.
5	EUGENE LESLIE		32	BF L.E.
6	EUGENE LESLIE		32	BF L.E.
7	PETER MARTIN		32	BF L.E.
8	" "		32	BF L.E.
9	LILLIAN HARDESTY		32	BF L.E.
10	RICHARD POTTS		32	BF L.E.
11	ANITA HUGHES		32	BF L.E.
12	HERBERT HEIMERL		32	BF L.E.
13	EVELYN EWART		32	BF L.E.
14	JULIA BAUER		32	BF L.E.
15	MICHAEL MARKARIAN		32	BF L.E.
16	MICHAEL MARKARIAN		32	BF L.E.
17	RICHARD BENNETT		32	BF L.E.
18	ROCCO TERMINI		32	BF L.E.
19	IRENE REP OF HYLANT		32	BF L.E.
20	" " " "		32	BF L.E.
21	RICHARD FERRICK		32	BF L.E.
22	ROBERT CANE		32	BF L.E.
23	JOHN NELSON		32	BF L.E.
24	ROBERTS DOBMEIER		32	BF L.E.
25	VIRGINIA ROBERTS		32	BF L.E.
26	WILLIAM HUGHES		32	BF L.E.
27	BLANCH MAYER		32	BF L.E.
28	FLO FOREMAN	.480	32	"
29	ROBERT WEBER	.190	32	BF L.E.
30	MARGARET PAYNE	.390	32	BF L.E.
31	VIOLET FYKE	.300	32	BF L.E.
32	MARC PAYNE	.150	32	"
33	MILDRED CURTIS	.150	32	"
34	MATTHEW MASTERSON	.450	32	"
35	NANE FALLON	.600	32	"
36	RUSSEL CRAWFORD	.150	32	"
37	ERWIN McINDO	.450	32	"
38	LAVERNE KOABEL	.800	32	"
39	MATTHEW MASTERSON	.300	32	"
40	MURIEL CRAWFORD	.300	32	"
41	AUSTIN LOGAN	.300	32	"
42	JIMMY PAGE	.300	32	"
43	DONALD MITCHEL	.300	32	"
		.800	32	BF L.E.

Nº	NAME	Ac. ±
1	SIMON ESHAK	.120
2	JOSEPH BARTO	.120
3	SHEILA CIFFA	.200
4	CHARLES MINKEL	.150
5	LESTER THUERSAM	.170
6a	A. PUNTORIERO	.140
6b	D. PUNTORIERO	.140
7	ANGELO VISCO	.140
8	FRANK SULINO	.140
9	THOMAS TIFFNEY	.140
10	MICHAEL PASCO	.140
11	DONNA LEGROS	.240
12	DANNY POTTER	.073
13	EDWIN GRANGER	.073
14	JOSEPH MORELLO	.073
15	DWEEK SALICO	.073
16	FRANCIS McCLINTOCK	.073
17	F. McLINTOCK	.073
18	F. McLINTOCK	.073
19	BESSIE BATES	.110
20	FRED SACCO	.110
21	NORMAN PAOLINI	.140
22	JOHN ARMAO	.073
23	GASPER RUSSO	.073

REVISION DATE	REMARKS	REVISION DATE	REMARKS
MAY 12, 1980	REVISE OWNERS	MAY 21, 1982	DRAINAGE AREA FOR HAGGERTY DRAIN
SEPT. 17, 1980	DRAINAGE AREA CORRECTED	DEC. 23, 1982	REVISE OWNERS
FEB. 10, 1982	PUMPING STATION SITE SHOWN		

C.J. CLARKE, NIAGARA, LIMITED
CONSULTING ENGINEERS
ONTARIO LAND SURVEYORS
WELLAND ONTARIO

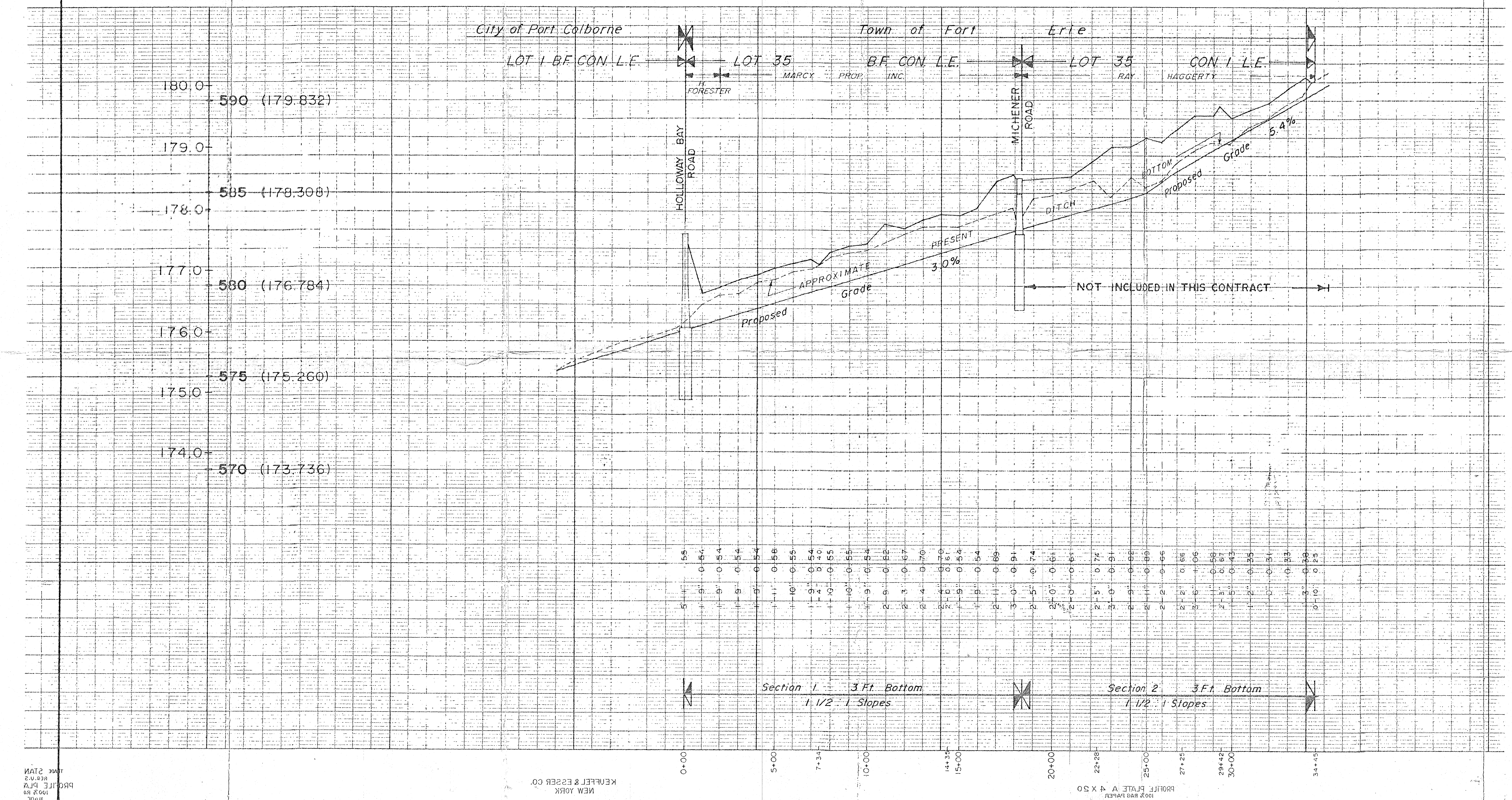
REGISTERED PROFESSIONAL ENGINEER
A. PLUHAR
PROVINCE OF ONTARIO

CITY OF PORT COLBORNE
AND
TOWN OF FORT ERIE

PLAN SHOWING
LANDS DRAINED BY THE

POINT ABINO DRAIN

SCALE: HOR. - 1"=500'
VERT. -
DESIGN - A. PLUHAR
DRAWN - J.C. LUNDY
CHECKED - A. PLUHAR
DATE - OCT. 1978
PROJECT Nº - 77-66
DWG. Nº 2



—NOTES—

1) Wooden stakes numbered consecutively 0+0, 1+0, 2+0, etc are set at 100' intervals along the drain

2) The drain is to be excavated to the depth, widths, grade line and side slopes shown on this profile. Side slopes are to be neatly dressed off straight

3) All trees and brush are to be completely removed from the bottom and side slopes of the drain Trees and brush so removed are to be deposited clear of the excavated earth No excavated material is to be deposited within six (6) feet of the upper edges of the new channel and is to be spread and levelled to a maximum of six (6) inches, unless written instructions to permit piling of the same are received from the owner Branch drains are not to be obstructed.

4) All fences are to be replaced in conditions as found, likewise with wooden farm bridges Excavate to grade under all bridges Carefully preserve all grade stakes

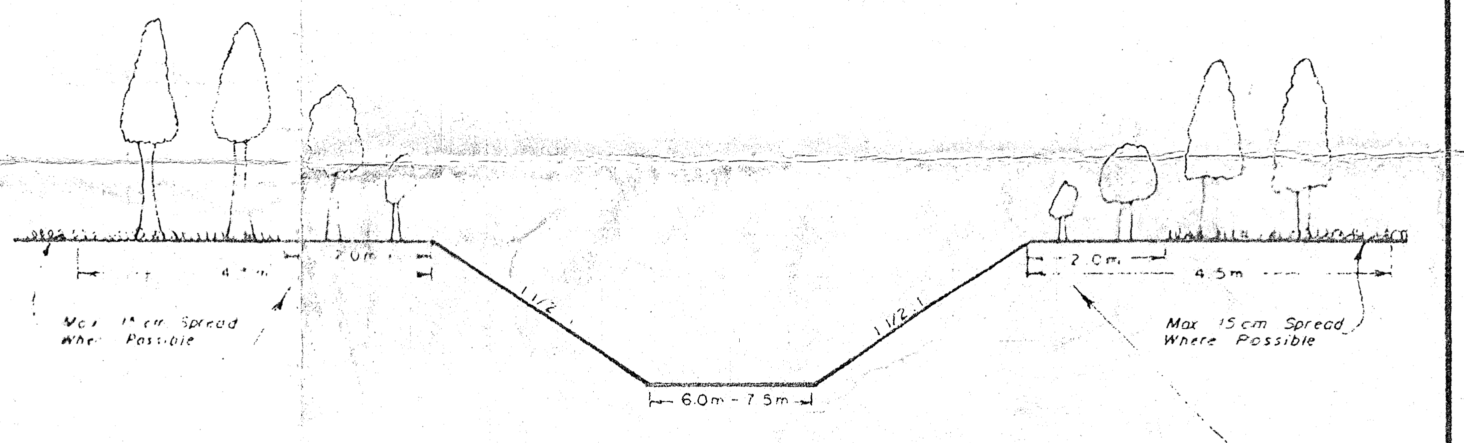
5) Excavated earth is to be deposited on road allowances only with the expressed consent of the Road Superintendent

6) All work is to be completed to the entire satisfaction of the Engineer incharge for the Municipality

7) Conversion Factors

	1 ft. = 0.3048 metre	1 acre = 0.4047 hectors
	1 m. = 3.2808 feet	1 hector = 2.4710 acres

8) No trees over 100mm (4") trunk diameter shall be removed without written permission of the property owner



ALL SHRUBS AND BRUSH ARE TO BE COMPLETELY REMOVED WITHIN 2m ON EACH SIDE

REVISION DATE	REMARKS	REVISION DATE	REMARKS
OCTOBER 19, 1983	REVISED NAME BRANCH Nº 1 DRAIN		

C.J. CLARKE, NIAGARA, LIMITED

CONSULTING ENGINEERS
ONTARIO LAND SURVEYORS
WELLAND ONTARIO

A. PLUHAR

TOWN OF FORT ERIE

BRANCH Nº 1 DRAIN

NEW BRANCH OF THE POINT ABINO DRAIN.

FROM HOLLOWAY BAY ROAD STA. 0+00
TO END OF DRAIN STA. 34+45

SCALE: HOR - 1" = 400'
VERT. - 1" = 4'
DESIGN - A. PLUHAR
DRAWN - M. ROY
CHECKED - A. PLUHAR
DATE - MAY 14, 1982
PROJECT Nº - 77-66
DWG Nº 3