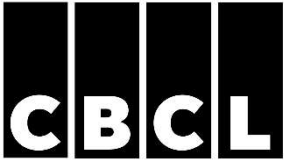


# Town of Windsor Stormwater Plan

Final Draft Report



221101.00 • December 2023

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December 15, 2023

Todd Richard  
Director of Public Works  
West Hants Regional Municipality  
PO Box 3000  
100 King Street  
Windsor, NS B0N 2T0

Dear Mr. Richard,

*RE: WHRM Windsor Stormwater Plan – DRAFT REPORT*

CBCL Limited (CBCL) is pleased to submit the Draft Stormwater Plan Report for the West Hants Regional Municipality (WHRM) in Windsor, Nova Scotia.

Please do not hesitate to contact the undersigned if you have any questions regarding this report.

Yours very truly,

CBCL Limited

*Draft*

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Project No.: 221101.00

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# 1 Project Overview

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CBCL Limited (CBCL) was engaged by the West Hants Regional Municipality (WHRM) to complete an assessment of the Town of Windsor's (Windsor) major and minor stormwater infrastructure. On July 27, 2021, an intense rainfall event, estimated at 45mm of rain in less than an hour, caused the Town's stormwater conveyance system to be overwhelmed, resulting in localized flooding. This assessment provides an overview of the results of the stormwater capacity analysis and outlines recommendations for a phased approach to separating the existing combined sewer system. The report also includes options that could provide some immediate relief to the most affected areas. Opinions of probable cost have been generated to allow for comparisons of costs between the options.



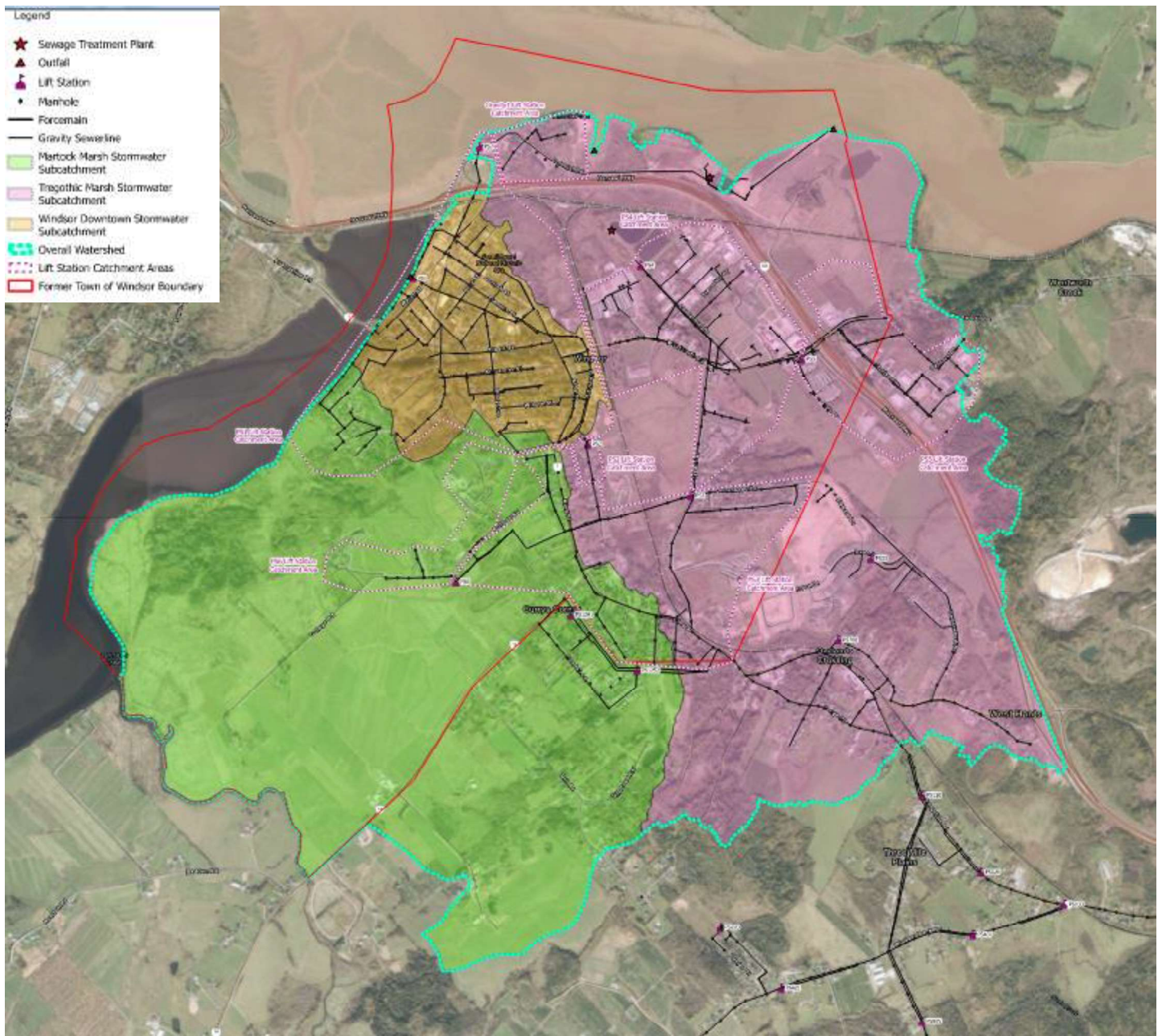
A July 2021 rain event overwhelmed Town infrastructure, causing localized flooding.

## 1.1 Background

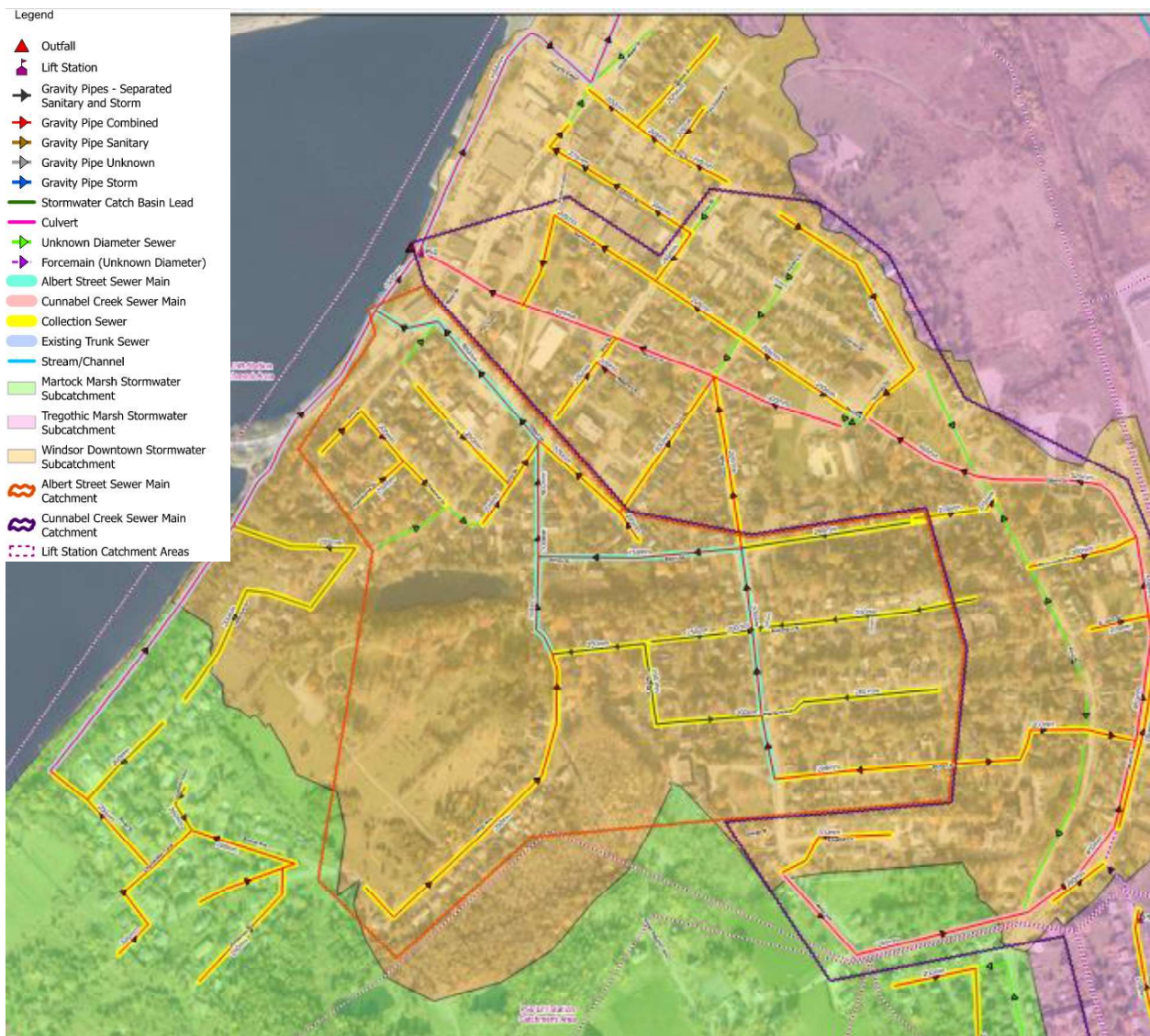
Stormwater in Windsor is managed by a combination of above and below ground (i.e., sewer collection system) infrastructure. There are three stormwater sheds within Windsor referred to as Martock Marsh, Windsor Downtown, and Tregothic Marsh. Refer to Figure 1.1, reduced version below and full size in Appendix A, for the location of each stormwater shed.

The existing Windsor Downtown system consists of both combined and separated sewers. The land use in this watershed consists primarily of low-medium density residential with some commercial development. Locations with separated storm and sanitary sewer include Alexander Street, Highland Avenue, and Churchill Street; however, the separated sewers on Alexander and Highland Streets re-enter the combined system on Wiley Avenue, therefore the benefits of sewer separation on these streets are not realized downstream.

There are two main trunk sewers that collect and convey combined sewer in the Windsor Core, these trunk sewers are referred to as the "Cunnabel Creek Sewer" and the "Albert Street Sewer". Each sewer flows towards the Avon River. Along the Avon River, a large diameter trunk sewer collects the flow from the sewer mains, where it discharges to the lift station 7 north of Highway 101 and is then pumped to a new Wastewater Treatment Plant (WWTP). Refer to Figure 1.2, reduced version below and full size in Appendix A, for map of the existing collection system for the Windsor Downtown.



**Figure 1.1: Study Area and Stormwater Catchment Areas**



**Figure 1.2: Existing Main and Collection System**

The Tregothic Marsh watershed consists of two main creeks, Tregothic Creek and Wentworth Creek, which collects stormwater within the Tregothic Marsh area (Wentworth Road and Creek, Payzant Drive, Underwood, Nesbitt Street area) and discharge to Avon River. The land use in the area is largely agricultural, with some light industrial/commercial and low-density residential developments. Stormwater east of the Windsor Downtown area collects and discharges through Tregothic Creek to the Avon River, north of Highway 101. Stormwater in the industrial area at Wentworth Road, that crosses Highway 101, collects in a storm sewer system and discharges to the Avon River. Stormwater piping is limited to a section on Termain Crescent, Wentworth Road, and some areas within the Agricultural grounds. Figure 1.3, reduced version below and full size in Appendix A, presents an overview of the existing storm sewer system.



**Figure 1.3: Tregothic Marsh Existing Conditions**

The Martock Marsh watershed consists mostly of open ditches and drains to the Avon River. The land uses consist mostly of agricultural and some residential. A storm sewer system was installed on College Road in 2023.

## 1.2 Project Objectives

The objective of the project was to evaluate the capacity of the existing stormwater system and make recommendations to improve the existing system's capacity to accommodate design storm events.

CBCL developed two stormwater models for this project, one for the Windsor Downtown catchment areas and a second for the Tregothic Marsh watershed. Capacity analysis for both of these watersheds are presented in this report. The Martock Marsh watershed was not included in this scope of work; however, portions of this watershed are collected and discharged into the Windsor Downtown system and the Tregothic Marsh system.

The development of these models required significant field data collection, collaboration with Municipal Staff, and data analysis to support an assessment of the existing system capacity. The methodology associated with the model construction, calibration, and analysis is described in the following sections.

## 2 Data Collection and Analysis

WHRM representatives provided information on the location of storm, sanitary, and combined sewers, via Geographic Information System (GIS) mapping, throughout the study area. CBCL reviewed the GIS and compiled data maps. The GIS was found to have information on some, but not all, of the sewer pipe diameters, but was missing pipe elevations which is critical in calculating pipe capacity.

To develop the model, information on pipe material, depth to inverts, flow direction, and type of sewer (combined, storm, sanitary) was required to be collected in the field by CBCL and WHRM staff. In addition, to confirm the information provided in the GIS database was correct, sewer diameter was also checked and recorded in the field during the data collection phase. This level of data collection was not anticipated as it was originally understood that the GIS contained the required all essential information to develop a fully functional model. The field data collection program was intensive and executed by both WHRM and CBCL representatives and focused on the main sewers within the Windsor Core, as well as areas of known flooding. The data collected supported a more accurate representation of the main collector pipes in the existing combined sewer system. Data collection efforts were only completed for main sewer lines and trunk sewers; survey of combined sewers on the side streets was not completed.

In addition to the field data collection program, CBCL also collected data from the following sources for the project:

- ▶ Provincial topographic and LiDAR Data.
- ▶ Soil mapping from Agriculture and Agri-Food Canada.
- ▶ Intensity-Duration-Frequency curves for the Kentville climate change station from Environment Canada.
- ▶ Anecdotal information on historical flooding events in the Town.
- ▶ Anecdotal information on the municipal infrastructure collected from Town from operators.
- ▶ Record drawings.

### 2.1 Field Data Collection

To support modeling of the combined sewer system, approximately 180 manholes were surveyed and information on pipe material, depth to inverts, flow direction, type of sewer

(combined, storm, sanitary) and diameter were collected. CBCL completed the topographic survey work, collecting elevation information for the manholes on the main sewers within the Windsor Downtown, as well as areas of known flooding. WHRM representatives collected information on the pipe material, depth to invert, flow direction, structure type, and pipe diameter for each manhole. This data was compiled for CBCL to input into the model.

Smaller diameter combined sewers, mainly in residential areas, were not included in the field data collection program. The field data collection program focused on collecting information on the main collector pipes within the combined sewer, as well as areas of known flooding. The theoretical flows from areas that were not included in the field data collection program were still included in the model, however the model does not contain information on the pipes. The flow from non-modeled areas of the collection system were assigned to a receiving trunk sewer to address their contribution to the main collection system. Figure 2.1 and Figure 2.2 in Appendix A, shows the combined sewer system sections that received additional data collection. Additional data collection would be required to assess sewer capacity in the areas not included in the field data collection program.

To support modeling of the Tregothic Marsh, approximately 30 culverts were surveyed. At each culvert, one cross section of the watercourse was surveyed upstream and downstream of the culvert. A survey shot at the top and bottom of the watercourse bank on each side of the channel, as well as the centreline of the channel were also collected. The invert (bottom of the structure) and obvert (top of the structure) at each end of each culvert was surveyed, and a cross section of the road, railroad, landscape above the culvert was also collected.

For culverts not included in the field data collection program, assumptions were made regarding their slopes and/or sizes based on the information available. If the model needs to be used for the design of culvert upgrades, additional site surveys would be recommended to confirm if their inverts and sizes can be further collected, and the model would need to be updated with more information available for the detailed design. Figure 2.2, presents the culverts that were included in the field data collection program.

## 2.2 Lift Stations

Drawings and pump information for two sewage lift stations (PS1 Lake Piziquid, PS2 Tremain Crescent), were requested to support modelling efforts within the Windsor Core area. Information on the configuration of the pump system (duplex/triplex system), dimensions of the wet wells, and pump curves were collected for PS1 and incorporated in the model, unfortunately, pump curves for PS2 were not available. To include the flow from PS2 in the existing conditions model, the theoretical flow was assigned to a manhole on O'Brien Street as a direct inflow. Pump curves used to model PS1 are provided in Appendix B.

## 2.3 Plans and Drawings

To develop the model of the Downtown and Tregothic Marsh areas, WHRM representatives provided drawings of the following assets and areas:

- ▶ Stormwater retention pond at Cole Drive.
- ▶ Storm sewer plan along Wentworth Road from near Payzant Drive to Highway 101 Exit 5A.
- ▶ Replacement plan for the Centennial Drive culvert.
- ▶ CBCL Record Drawings for the Trunk Sewer along Avon River.
- ▶ Various Street Upgrade Projects completed in the Windsor Core Area:
  - Alexander Street.
  - Albert Street.
  - Churchill Street.
  - Highland Avenue.
  - Highway 101 Trunk Sewer Crossing.

Relevant data from these plans were included in the model. There are some storm sewers with missing inverts and/or sizes in the plans. For those sewers, assumptions were made regarding their slopes and/or sizes based on the information available. In addition, it was assumed that the plans reflect current conditions.

## 2.4 Rainfall Monitoring

Two notable flood events have occurred within the Town over the past decade that have resulted in significant damage to private and public properties. For the July 27, 2021 rainfall event, there are no Environment Canada operated rainfall gauges within the study area. However, there are five Environment Canada climate stations within relatively close proximity to the study area including Kentville, Kejimikujik, Greenwood, Parsborro, and Debert. The closest Environment Canada operated climate station is located in Kentville, approximately 35km from Windsor.

For the July 27, 2021 rainfall event, the community of Kentville did not report any rain or flooding. Therefore, an investigation into nearby private rain gauges was completed to determine the rainfall intensities recorded in Windsor. One private rain gauging station (INSWESTH2) is located directly in the Town near the intersection of Wentworth Road and Payzant Drive. INSWESTH2 recorded approximately 59mm of rain for the July 27 storm event. Another private rain gauging station (IGARLA2) that is located near Avon View High School on Merriweather Crescent recorded approximately 48mm of rain for the July 27 storm event. Both private rain gauges are within the watershed extents of the study area.

Private rain gauges can be an excellent source of rainfall data to supplement Environment Canada data; however, private rain gauges do not typically go through any type of quality assurance or quality control checks (QA/QC). Because there is no QA/QC for private gauges,

Based on anecdotal evidence from WHRM staff, the IGARLA2 weather station most closely represented the rainfall volume reported locally. For this reason, this gauge was selected for model calibration.

## 2.5 Flow Monitoring

Flow metering within the sewershed was completed at six different locations from April – June 2022, five of which were placed in the Windsor Core area, and one placed on Centennial Drive. Flow metering was completed to record sanitary flows throughout the sewershed during a dry weather event, and record combined sewer flows during a wet weather event. Unfortunately, a large rain event did not occur within the metering period.

Metered data quality is influenced by both site set-up and site maintenance. Site set-up conditions which may impact data quality include pipe slope and sewage velocity. Site maintenance includes keeping sensors free of accumulated debris; however, it is not possible to keep the sensors clean at all times. A check of the meters was completed approximately halfway through the recording period. It was observed that each of the five meters in the Windsor Downtown were recording data. The meter installed on Centennial Drive had failed. A replacement sensor was ordered and installed to finish the flow monitoring work on Centennial Drive.

The flow meter sensors were placed in the upstream sewers at each manhole, and the data loggers recorded water depths, velocities, and flows at five-minute intervals. Figure 2.1 shows the location of the installed flow meters.

Table 2.1 below summarizes the placement of the flow meters throughout the Windsor Core Sewershed.

**Table 2.1: Upstream and Downstream Meter Placement**

Meter Number	Downstream Flow Meters	Upstream Flow Meters
Meter 1	N/A	N/A
Meter 2	N/A	Meter 4
Meter 3	N/A	Meter 5
Meter 4	Meter 2	N/A
Meter 5	Meter 3	N/A

## 2.6 Theoretical Sanitary Flows

Theoretical flows were used to validate the measured flows. As the sewer system in the Windsor Downtown is a combined storm and sanitary sewer system, sanitary flows were included to calibrate the model for the July 2021 event. Utilizing information collected

during the data collection phase, existing sanitary sewer drawings provided by WHRM representatives, and ground surface elevation, existing sanitary sewersheds for each flowmeter were delineated. To determine the average and peak dry weather residential flow to each flow meter, the number of persons per household was determined. The average household size is approximately 2.1 persons (Statistics Canada 2016 Census). To determine the total population within the sewershed, the number of buildings were counted utilizing aerial imagery.

Average and peak dry weather theoretical flows for each flowmeter sewershed were developed. Criteria used for developing the theoretical flows was obtained from *Atlantic Canada Wastewater Systems Guidelines, May 2022*. The parameters obtained from the guidelines include:

- ▶ Estimated Wastewater Generation:
  - Residence – 380L/day/person.
  - Hotels – 380 per bedroom (Motels – 300L per bedroom) (tourist home – 270L per bedroom).
  - Industrial and Commercial Buildings – 45L per employee.
  - Restaurants – 160L per seat.
  - Hospitals – 950L per bed.
  - Schools – 90L per person (Boarding school – 380L per person).
  - Theatres – 25L per seat.
  - Stores/shopping centres/office buildings – 6L per m<sup>2</sup>.
  - Churches – 25L per seat.
  - Beauty parlors – 200L per seat.
  - Senior Citizen Home – 600L per apartment.
  - Swimming pools – 70L per person.
  - Daycare Centre – 115L per child.
  - Automobile services no car washing – 20L per car served (With car washing – 340L per car washed).
  - Park with flush toilets – 50L per person.
  - Bowling arena – 900L per alley.
  - Assembly halls – 35L per seat.
- ▶ Peaking Factor:
  - Residential (Population Generated) – Harmon’s Peaking Factor.
  - Peaking Factor of 1.5 for sewage flow generated from Commercial Buildings.
- ▶ Infiltration Allowance:
  - 0.28 L/s/Ha.

The average residential flow was determined using the following formula:

$$Q_{avg} = \frac{G * P}{86.4}$$

Where:

$Q_{avg}$  = Average flow (L/s).

G = Per capita average daily design flow (380 L/P/D).

P = Contributing population in thousands.

The peak residential flow was determined using the following formula:

$$Q_{pdw} = \frac{G * P * Pf}{86.4}$$

Where:

$Q_{pdw}$  = Peak dry weather flow (L/s).

G = Per capita average daily design flow (380 L/P/D).

P = Contributing population in thousands.

Pf = Peaking factor.

The peaking factor was the larger of 2.5 or Harmon's Peaking Factor:

$$\text{Harmon's Peaking Factor} = 1 + \frac{14}{4 + P^{0.5}}$$

Where:

P = Contributing population in thousands.

Commercial sewage flow rates within each sewershed were developed using the information listed above. To determine the number of commercial flow generators within the sewershed, aerial and street imagery were checked, with background information gathered online and through conversations with WHRM representatives. To account for inflow and infiltration (I&I) into the wastewater collection system, an allowance of 0.28L/s/Ha was included.

Theoretical average dry weather flow (ADF) and peak dry weather flow (PDF) expected at each flowmeter throughout the Windsor Downtown Sewershed are summarized in Table 2.2 and compared to the measured flows. Graphs showing recorded data are provided in Appendix H.

**Table 2.2: Sewage Flows**

	Meter 1	Meter 2	Meter 3	Meter 4	Meter 5
Theoretical ADF (L/s)	5.1	10.4	18.4	7.7	9.4
Measured ADF (L/s)	3.0	14.0	21.0	7.0	N/A**
Theoretical PDF (L/s)	7.2	18.2	32.2	13.7	18.0
Measured PDF (L/s)	5.0	18.0	N/A*	12.0	N/A**

\*Large spikes in recorded data do not allow measured peak dry weather flow to be determined.

\*\* Recorded flows are significantly lower than expected, indicating a potential issue with the sensor during the recording period

The theoretical flows were compared to the recorded flows during a dry weather period in mid-May 2022. Flow monitoring data underwent an analysis to determine the validity of the results obtained and to determine if the theoretical flows developed are representative of the sewershed.

As sanitary flows are not the cause of system surcharges or backups and represent a small cross sectional flow area within the large diameter combined sewer mains, a comparison of the results of the meter analysis is presented below. To confirm that the recorded depths of sanitary flow during a dry weather event were accurate prior to inputting the information into the model, CBCL reviewed the depth of flow data with WHRM representatives, who indicated that the results were representative of typical dry weather flows.

### Meter 1 (From West Catchment Area Along Avon River)

Average recorded flow trends compared well to theoretical average flow. The recorded depth of flow in the 600mm (24") pipe averages approximately 50mm during the recording period.

### Meter 2 (Albert Street)

Average recorded flow is approximately 35% higher than theoretical average flow. The recorded depth of flow in the 900mm (36") pipe averages approximately 100mm during the recording period. This recorded depth is the largest as this location is furthest downstream.

### Meter 3 (Cunnabel Creek near Water Street)

There are large spikes in the recorded flow and depth measurements, however, with the large spikes removed, the average recorded flow trends well when compared to theoretical average flow. The recorded depth of flow in the 1000mm pipe averages approximately 220mm during the recording period, which is significantly higher than other meters, but this is reasonable as this meter was placed in a section of pipe farthest down Cunnabel Creek where most flow would be collected.

#### Meter 4 (Albert Street)

Average recorded flow trends well when compared to theoretical flow. The recorded depth of flow in the 750mm (30") pipe is slightly less than the level recorded downstream at Meter 2 throughout the recording period, which is to be expected.

#### Meter 5 (O'Brien & Stannus Street Intersection)

The recorded flow at Meter 5 is significantly lower than the theoretical flow. The recorded depth measurements are significantly lower than the depth recorded at Meter 3 downstream, indicating a potential issue with the sensor during the recording period.

## 3 Climate Change

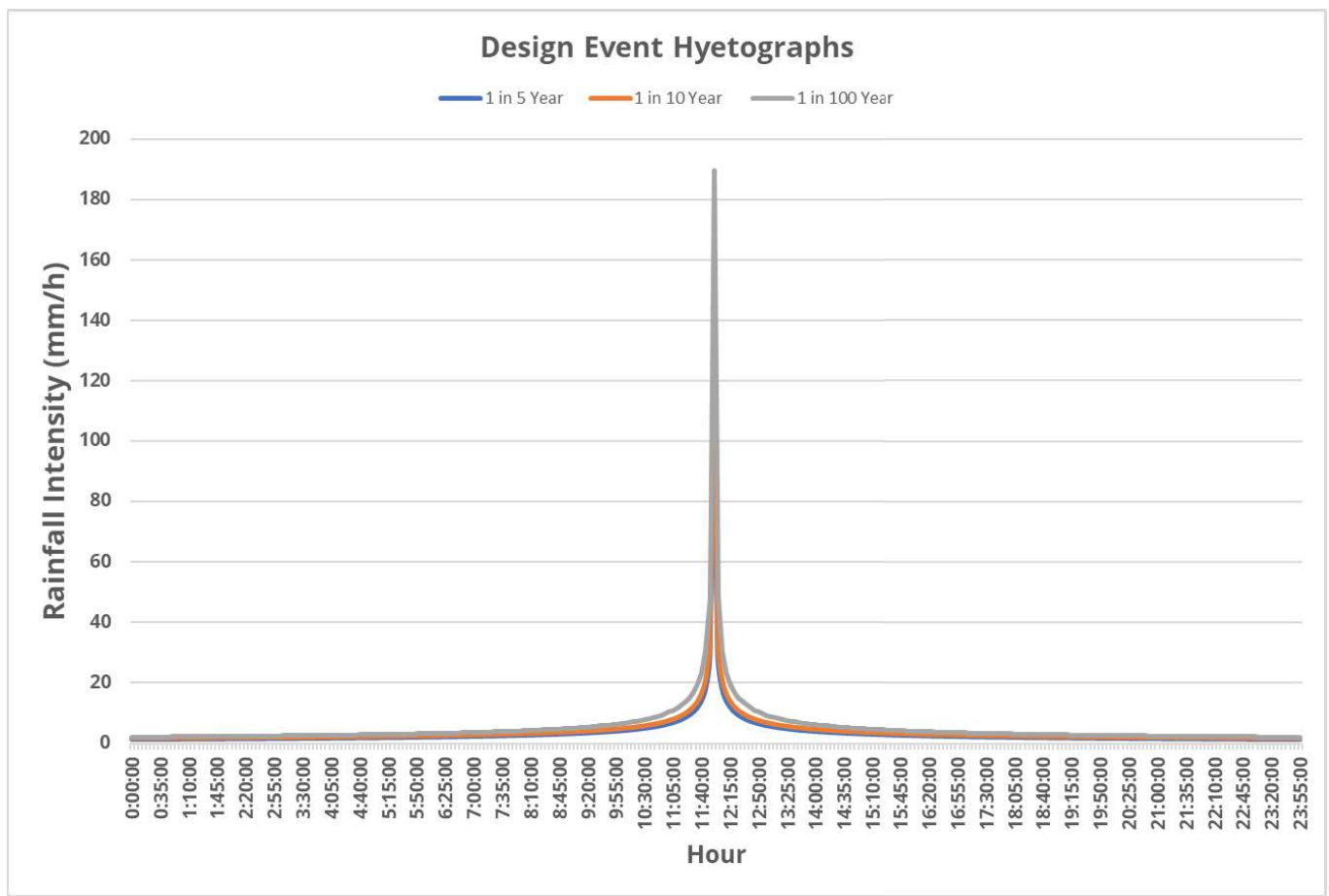
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Climate change, and particularly the increase in precipitation intensity resulting from climate change, is one of several factors expected to affect flooding vulnerabilities in the future. Other factors that may contribute to flood risk include uncertainties in development, population growth, infrastructure condition and performance, among others. Climate change impacts to rainfall and coastal water levels in 2090 were investigated in this Chapter, and the results were used as inputs in the hydrologic and hydraulic models to assess the flooding in 2090.

### 3.1 Rainfall

The existing storm drainage system was assessed to determine the locations of undersized major infrastructure during the design storm events. The WHRM municipal services specification manual, issued in September 2022, prescribes storm sewer systems be designed based on a storm frequency of 1 in 5 years, except in areas designated for commercial or industrial development where a design storm frequency of 1 in 10 years should be used. Roadways, road cross culverts, watercourse crossings, and other major drainage systems should have a capacity to convey stormwater from a design storm frequency of 1 in 100 years.

Intensity Duration Frequency (IDF) curves for the Kentville station are available and are based on years of historical rainfall data. A Chicago distribution was used to produce 24-hour design rainfall events at 5-minute increments using the IDF curves for the Kentville CDA station for 1 in 5 year, 1 in 10 year, and 1 in 100 year storm events. The design event hyetographs in present-day (2023) are presented in Figure 3.1, and they were used in the Windsor Downtown model and Tregothic Marsh model to assess the drainage system capacity and flood extents under the existing condition.



**Figure 3.1: Design Event Hyetographs in Present-Day (2023)**

There are several approaches to estimating increases in precipitation intensity, those include:

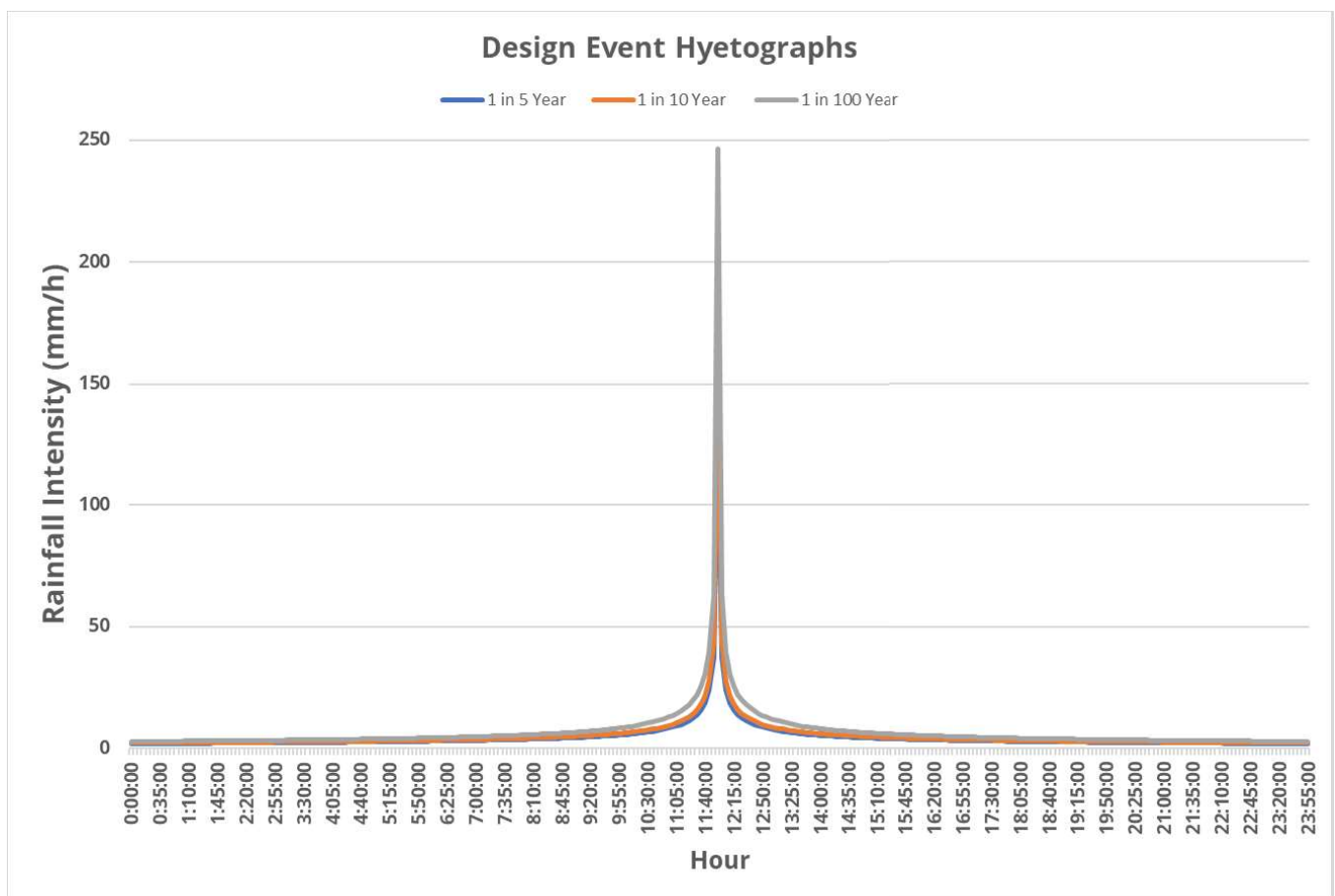
- ▶ **The Lines et al. (2009) report**, published by the Meteorological Service of Canada (Atlantic Region), downscaled rainfall amounts for Atlantic Canada using two General Circulation Models (GCMs) and emissions scenario B2. This was the commonly used reference before the IDF-CC tool.
- ▶ **The Western University Intensity Duration Frequency Climate Change tool (IDF-CC tool)** downscales Environment and Climate Change Canada rain stations using quantile matching (method described in Srivastav et al., 2014). This tool is gaining popularity in engineering applications.
- ▶ **The Clausius-Clapeyron equation** governs the capacity of the atmosphere to hold water as a function of temperature (Westra et al., 2014). Use of this theoretical method was recommended by Environment and Climate Change Canada Scientists (*pers. Comm.* Dr. Xuebin Zhang and Dr. Alex Cannon, Senior Research Scientists at Environment Canada).

These tools have various strengths and limitations in terms of ensembles of the GCMs used, the choice of emission scenarios, as well as process-based assumptions. For example, although the IDF-CC tool is gaining popularity, it assumes that the relationship

between sub-daily and daily precipitation will be unchanged in the future. According to the Pacific Climate Impacts Consortium (2015), this is likely to be an invalid assumption. Therefore, no single climate change projection method should be used in isolation.

Instead, it is important to consider and compare all available tools as well as their assumptions and obtain a range of possible climate change outcomes. CBCL's experience applying these methods throughout Atlantic Canada has shown that the range of possible outcomes tends to center around a 30% increase in precipitation intensity for the year 2090, which can thus be considered a reasonable climate change factor for 2090 conditions.

Therefore, the hyetograph prepared for this project were increased by 30% and simulated in the models to estimate projected flows. The resulting design event hyetographs in 2090 are presented in Figure 3.2 and they were used in the Windsor Downtown model and the Tregothic Marsh model to assess the drainage system capacity and flood extents for 2090 conditions.



**Figure 3.2: Design Event Hyetographs in 2090**

A comparison between the current and 2090 precipitation events is provided in Figure 3.3.

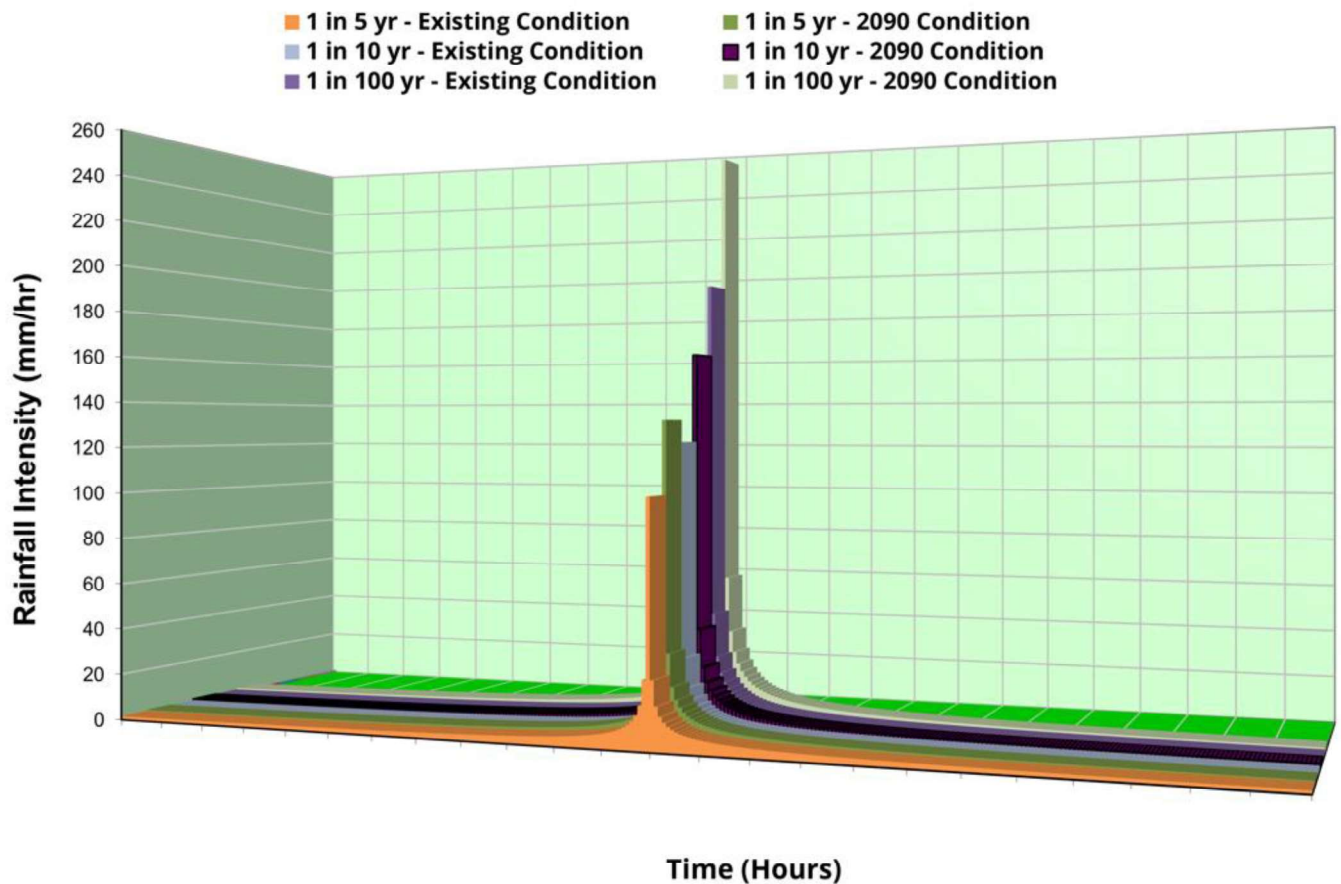


Figure 3.3: Comparison between Current and Design Event Hyetographs (2090)

## 3.2 Coastal Water Levels

### 3.2.1 Background

Since the Tregothic Marsh discharges to the Avon River, extreme static water levels and time series of tidal signals were derived for Windsor, NS to be used as the boundary conditions of the model. The **extreme static water levels** included in this analysis include contributions from the following parameters:

- ▶ **Tide** – Tides are the periodic rise and fall of the surface of oceans, bays, etc., due principally to the gravitational interactions between the moon, sun, and earth. The characteristics of tides such as amplitude and frequency vary depending on a variety of factors including but not limited to geographical position, dimensions, and depth of the body of water.
- ▶ **Storm Surge** – Storm surges are created by meteorological effects on sea level, such as wind set-up (shoreward wind stresses causing an increase in water level) and low atmospheric pressure. Storm surge can be defined as the difference between the observed water level during a storm and the predicted astronomical tide. Regional

storm surge trends can be inferred from large-scale models and nearby tide gauge observations if available.

- ▶ **Sea Level Rise (SLR)** – SLR is an increase in the ocean’s water levels due to the effects of climate change. Global Mean SLR is caused primarily by two factors: (1) expansion of water from increasing ocean temperatures, and (2) the melting of polar ice sheets and mountain glaciers. Global Mean SLR will accelerate due to climate change, causing increased risks of coastal erosion and flooding. Relative sea level rise (RSLR) represents Global Mean SLR corrected with local factors including but not limited to vertical land motion, or changes in local oceanic circulation.

The extreme static water levels calculated in this analysis are for present-day and in 2090 under normal conditions and a 2-yr RP storm event. The analysis includes a total of four timeseries. The tidal signals were derived based on a harmonic analysis of tidal constituents.

### 3.2.2 Results

To develop the water level time series, first static coastal water levels were derived for the site. Various relevant sources for the tidal levels, the extreme water levels, and SLR were used. The lower low water large tide (LLWLT) was based on the tidal elevations provided at the Hantsport Tide Station (DFO, 2023). The higher high water large tide (HHWLT) was based on a previously CBCL study in the Avon River, that used numerical modelling to determine the HHWLT. The 2-yr RP extreme water levels were calculated by adding the 2-yr RP storm surge residual (0.6m) to the HHWLT, which was derived from a storm surge hindcast for Atlantic Canada Bernier & Thompson (2006). The SLR values for 2090 was sourced from Climate Data Canada, which listed a SLR value of 0.7m in 2090 under the RCP8.5 median projection in the Minas Basin (James et al., 2014). A summary of the extreme static water levels for the various scenarios are presented in Table 3.1.

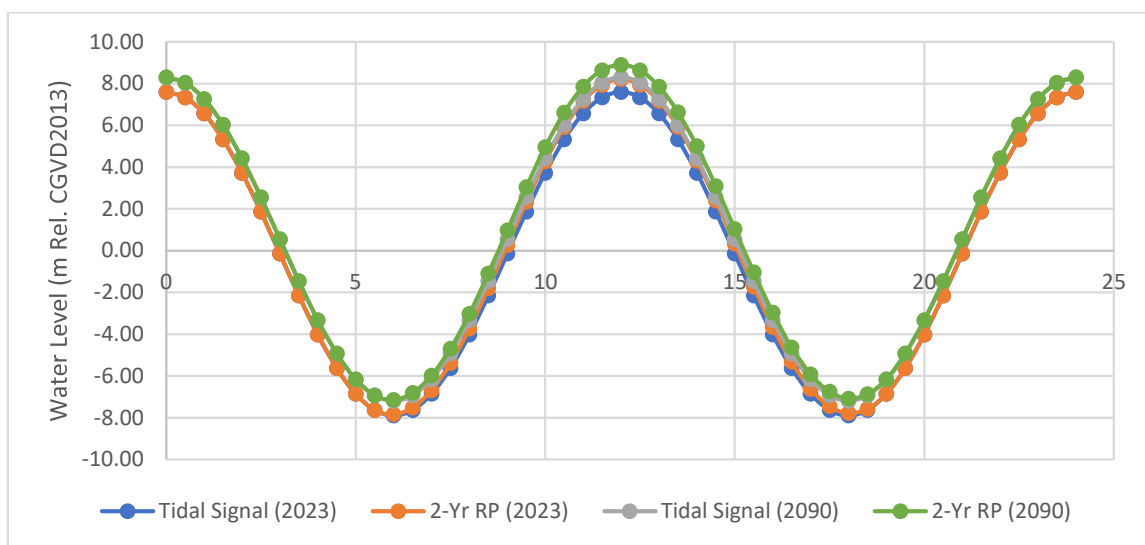
**Table 3.1: Extreme Static Water Levels**

Water Level Type	Parameter	Water Level (m CGVD2013)	Source
<b>Tidal Levels</b>	<b>LLWLT (2023)</b>	-7.9	<a href="https://tides.gc.ca">https://tides.gc.ca</a>
	<b>HHWLT (2023)</b>	7.6	Previously completed study <a href="https://tides.gc.ca/en/stations/00282">https://tides.gc.ca/en/stations/00282</a>
<b>Present Day Extreme Static Water Levels due to Storm Surge</b>	<b>2-Yr RP (2023)</b>	8.2	Bernier & Thompson (2006)
<b>2090 Extreme Water Levels due to SLR and Storm Surge</b>	<b>HHWLT (2090)</b>	8.3	<a href="https://climatedata.ca/">https://climatedata.ca/</a>
	<b>2-Yr RP (2090)</b>	8.9	

Using the calculated extreme static water levels, four time series of the tidal signals under various conditions were developed as below. Among the four scenarios, 2-yr RP storm event in present-day (2023) and in 2090 were used as coastal boundary conditions of the Tregothic Marsh model to assess the 2023 and 2090 conditions, respectively.

- ▶ Typical tidal signal in present-day (2023).
- ▶ 2-yr RP storm event in present-day (2023).
- ▶ Typical tidal signal in 2090.
- ▶ 2-yr RP storm event in 2090.

A time series is calculated using a tidal signal formula (harmonic analysis) and applying the relevant storm surge or SLR. For the extreme storm events, the storm surge residual is added in increments by applying a multiplier from 10% to 100%, to mimic the reality of a storm. The various tidal signals are shown in Figure 3.4.



**Figure 3.4: Tidal Signals for Various Extreme Water Levels**

### 3.2.3 Limitations

The extreme static water levels derived in this report only include the combination of tides, storm surges, and SLR. Increased water levels due to wave set-up, wave run-up, storm water runoff, and fluvial contributions are not included in the coastal extreme water levels provided in this report. These values were derived using a high-level analysis, meant to be used as inputs for hydrologic and hydraulic models. The water levels presented in this report should not be used for the design of coastal structures as this would require a more detailed study.

Results should be interpreted with caution and actual conditions encountered in the future may vary from predictions. There are uncertainties relating to SLR projections due to modelling capabilities in addition to the unknowns surrounding future anthropogenic emissions. We recommend that results be revisited regularly as new information becomes available (i.e., SLR projections, water level measurements, tidal elevations, etc.).

## 3.2.4 References

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Bernier, N.B., Thompson, K.R. (2006). Predicting the frequency of storm surges and extreme sea levels in the northwest Atlantic. J. Geophys. Research Vol 111 C10009.

Fisheries and Ocean Canada (DFO). (2023). Tide and water level stations.  
<https://tides.gc.ca/en/stations/00282>.

James, T.S., Henton, J. A., Leonard, L. J., Darlington, A., Forbes, D. L., Craymer, M. (2014). Relative sea-level projections in Canada and the adjacent mainland United States; Geological Survey of Canada, Open file 7737, 72pp. <https://doi.org/10.4095/295574>.

# 4 Model Development and Calibration

Models of both the Windsor Downtown and Tregothic Marsh were developed using PCSWMM, a modelling program developed by Computational Hydraulics International (CHI) that integrates Version 5 of the Storm Water Management Model (SWMM) with a GIS engine. SWMM is a hydrologic and 1D-2D hydraulic model produced by the United States Environmental Protection Agency to study urban drainage systems. This software can perform unsteady flow calculations to simulate water backup, pooling, and pipe and culvert hydraulics.

## 4.1 Hydrology

Subcatchments were delineated using a digital elevation model (DEM) and the watershed delineation tool in PCSWMM. The DEM consisted of LiDAR data downloaded from the provincial GeoNova site. Subcatchment characteristics were determined from the DEM and the 2015 land cover mapping from Agriculture and Agri-food Canada, which includes:

- ▶ Area.
- ▶ Width.
- ▶ Flow length.
- ▶ Basin slope.
- ▶ Imperviousness.
- ▶ Roughness for pervious and impervious areas.

The Green-Ampt Infiltration method was selected for infiltration calculations. Soil information for the study area was obtained from the National Soil Data Base available through Agriculture and Agri-Foods Canada in shapefile format. The *Soil Survey of Hants County Nova Scotia* report and shapefile were used to determine soil characteristics for the subcatchment areas. Original soil characteristics modelled for the soil include:

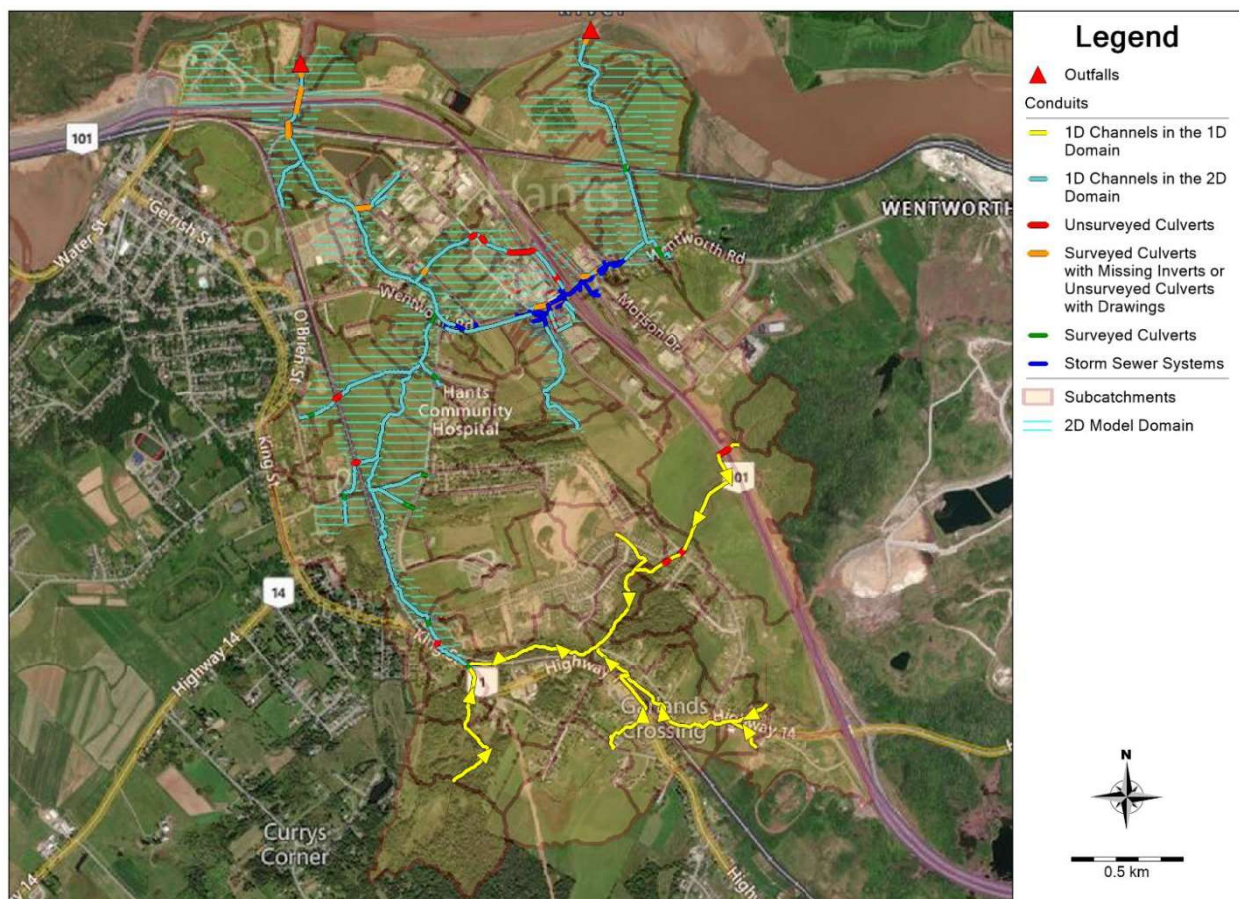
- ▶ Suction head: 210.06mm.
- ▶ Hydraulic Conductivity: 1.02mm/hr.
- ▶ Initial Deficit: 0.277.



Photos and videos of the July flooding event were provided by WHRM representatives and were used to calibrate the model. After the model was calibrated, the model was used to develop conceptual sewer upgrade options for a 1 in 5 year design storm, including the impacts of climate change. Smaller diameter collector sewers and associated manholes, mainly in residential areas, were not included in the model.

## 4.2.2 Tregothic Marsh

The Tregothic Marsh model is a combined 1D-2D model. Upstream of the Tregothic Marsh area is modelled as 1D domain, while the Tregothic Marsh area is modelled with 1D channels and 2D floodplains. The model domain is presented in Figure 4.2, below and in Appendix C.



**Figure 4.2: Tregothic Marsh Model Domain**

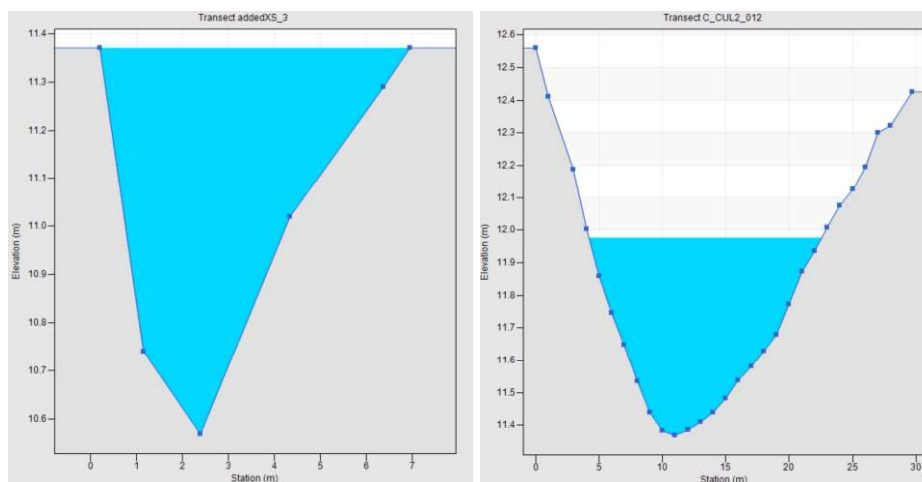
There are a total of forty-three culverts included in the model:

- ▶ Eighteen of them were surveyed with sizes and upstream and downstream inverts.
- ▶ Seven of them were surveyed with sizes and only upstream or downstream inverts.
- ▶ Five of them were not surveyed but had details from the drawing.
- ▶ Thirteen of them were neither surveyed nor having available drawings. Inverts and sizes for the culverts in the model were from survey or drawings (when survey is not available).

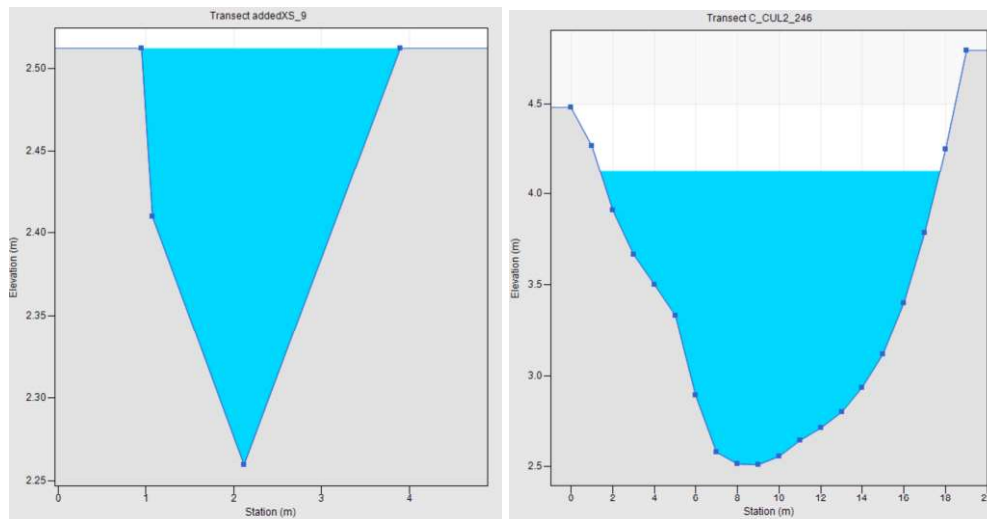
For those unsurveyed culverts upstream of the Tregothic Marsh area, inverts were estimated from the LiDAR DEM and a diameter of 1.8m was assigned to them to ensure all flows getting through to downstream. For those culverts without drawing and with missing survey information within the Tregothic Marsh area, inverts were estimated from the LiDAR DEM, and sizes were either from the immediate upstream/downstream surveyed culvert or assumed to be 0.6m. Additional survey information would be required for culvert upgrades in the detail design phase.

There are drawings for the storm sewers along Wentworth Road between the two creeks, and they were included in the model. Some of the sewers did not have inverts in the drawings, for which a slope of 0.5% was assumed and assigned. Additional survey information would be required for sewer upgrades in the detail design phase.

One cross section of the watercourse was surveyed upstream and/or downstream of each surveyed culvert. Comparing the surveyed cross section with the cross section from the LiDAR DEM, it was determined that the DEM did not capture the bathymetry under the water surface at the time of LiDAR detection. Therefore, aside from the transect derived from the LiDAR DEM, the cross sectional area under the water surface was added as an additional transect in the 1D channel and assumed to remain the same between the downstream of one surveyed cross section and upstream of next surveyed cross section, thus leading to two transects to represent the 1D channel within the 2D domain. Figure 4.3 shows an example taken from the upstream of Tregothic Creek, and Figure 4.4 shows an example taken from the downstream of Tregothic Creek.



**Figure 4.3: Transect Representing the Cross Sectional Area under the Water Surface at the time of LiDAR Detection (Left) and Transect to Represent the Cross Sectional Area above the Water Surface within the Watercourse Banks (Right)**

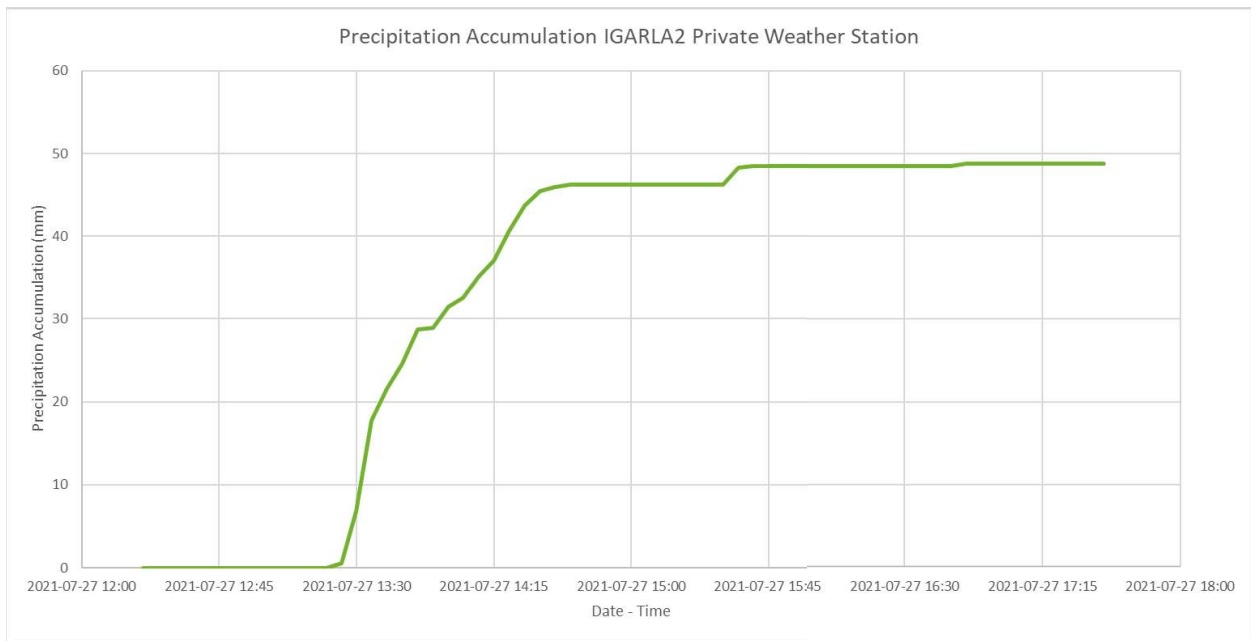


**Figure 4.4: Transect Representing the Cross Sectional Area under the Water Surface at the time of LiDAR Detection (Left) and Transect to Represent the Cross Sectional Area above the Water Surface within the Watercourse Banks (Right)**

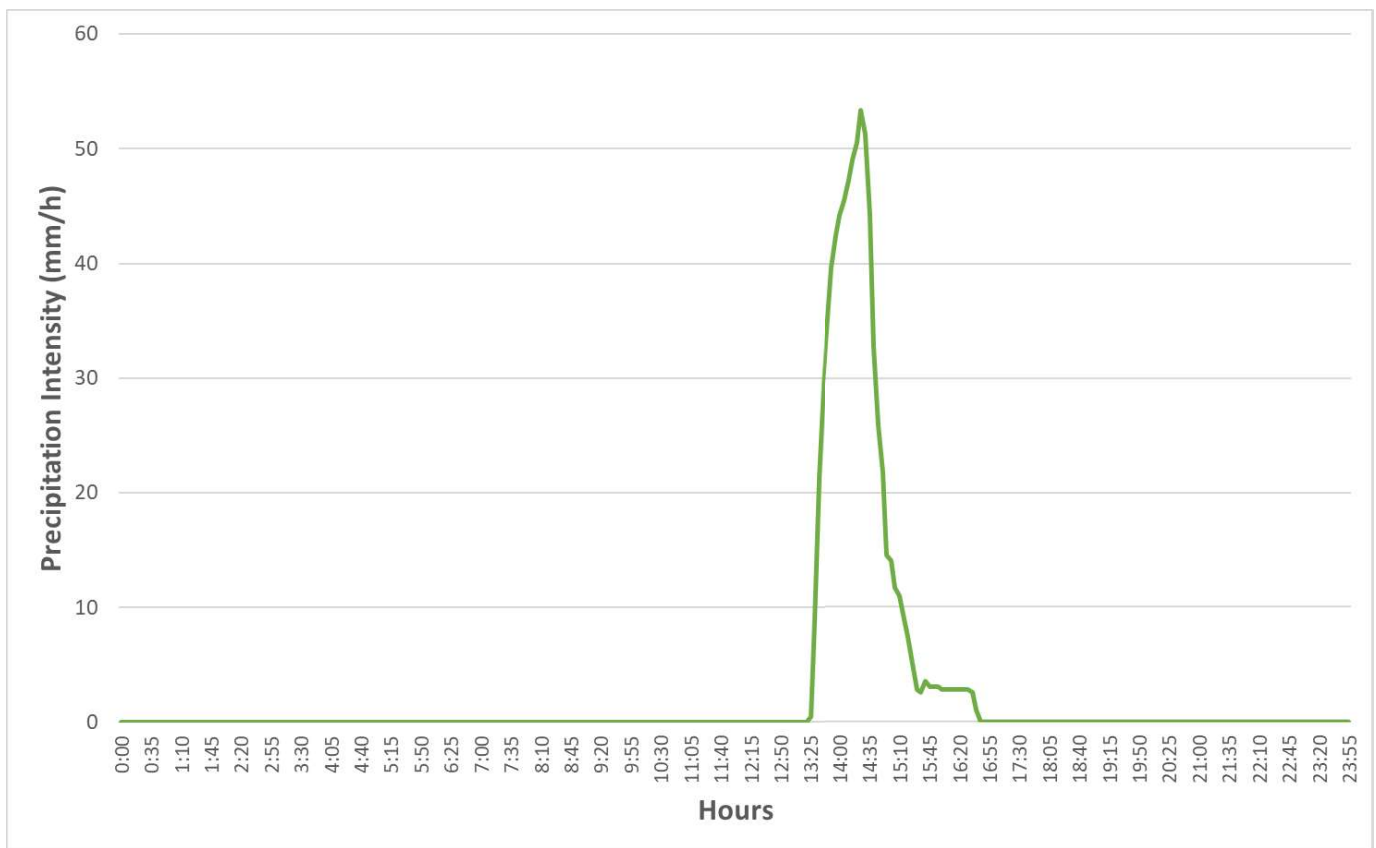
Coastal water levels discussed in Chapter 3.2, were used as the boundary conditions at the outfalls from Tregothic Marsh. Flap gates were included in the model for the culverts under the aboiteau at the outlets of both creeks.

### 4.3 Model Calibration

Rainfall data is often one of the largest uncertainties during the calibration process. This uncertainty is amplified when the watershed is large and the available rain gauges are very sparse. The rainfall intensity and total rainfall volume can vary significantly according to the location within the watershed. As the watershed size becomes larger, using a single point to estimate the rainfall across the entire watershed becomes less and less representative. The other uncertainty with using an isolated rainfall gauge is that the peak flow can be significantly affected by how the storm travels over the watershed. Figure 4.5 below shows the precipitation accumulation and Figure 4.6 shows the rainfall intensity at the IGARLA2 private weather station.



**Figure 4.5: Design Event Rainfall Accumulation**



**Figure 4.6: Design Event Rainfall Intensity**

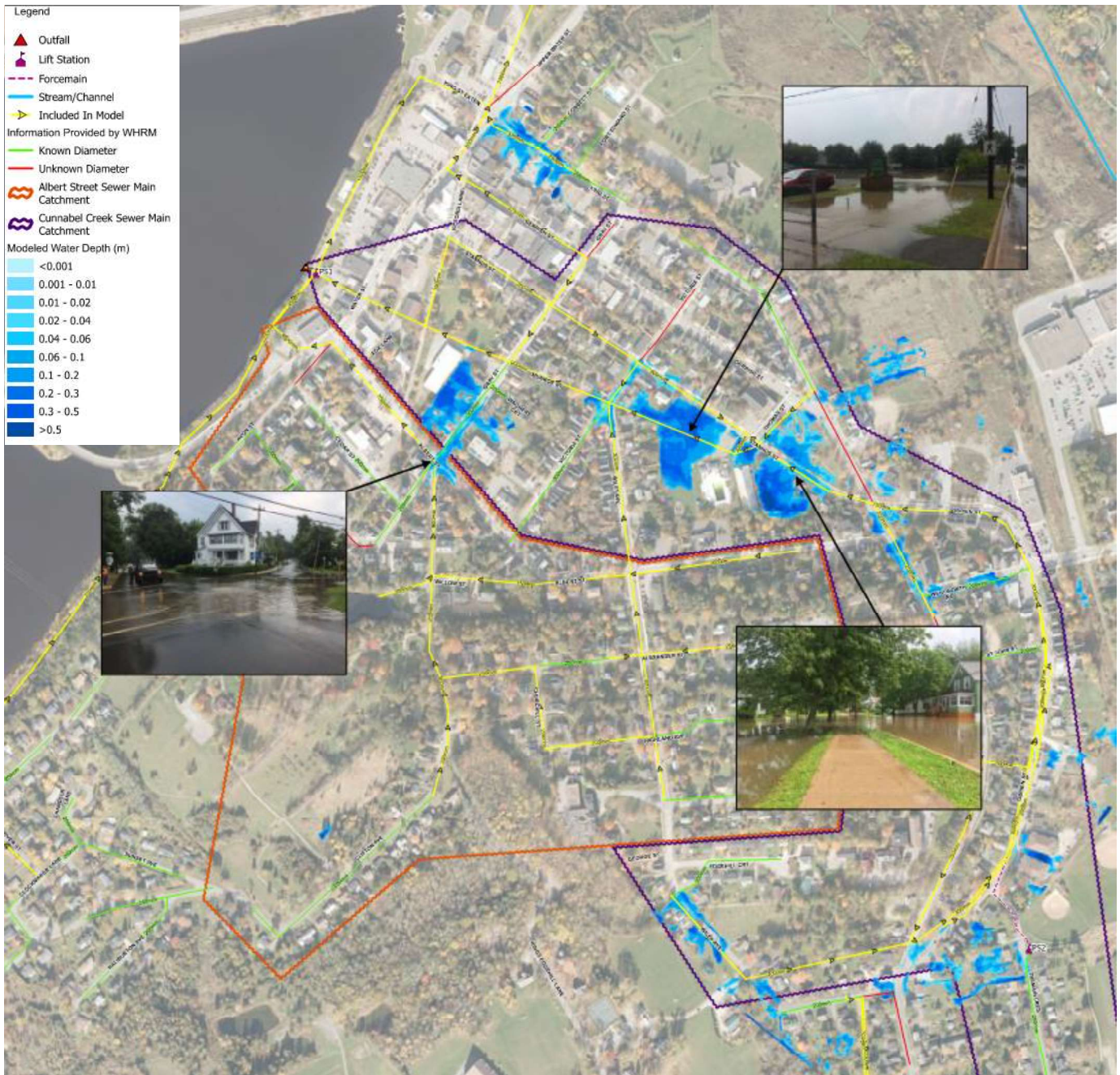
### 4.3.1 Windsor Downtown

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Significant flooding and sewer system surcharging was experienced at multiple locations throughout Town during the July 2021 event. Photos and videos provided by WHRM staff were reviewed and utilized to calibrate the hydraulic model. Locations where flooding occurred include:

- ▶ Albert Street and Gray Street Intersection.
- ▶ Elmcroft Park.
- ▶ Cunnabel Creek Storm Sewer Corridor.
- ▶ Stannus Street.
- ▶ King Street.

Multiple iterations and different scenarios were run where model parameters such as hydraulic conductivity, impervious and pervious surface percentages, surface water storage depth, subcatchment flow length, and runoff coefficients were manipulated to replicate flooding that occurred in the Town. Once satisfactory results were achieved, the depth of flooding at Elmcroft Park, Victoria Park, Stannus Street, Albert/Gray Street intersection, and King Street was discussed with WHRM. It was noted that the flooding locations and depths modelled were representative of on-site conditions during the rain event. In addition, photos provided of the flooding were consistent with the modelled results. Figure 4.7 presented on the following page, and in Appendix C, illustrates the depth of flooding modelled for the July 2021 event and includes photos of flooding and surcharging provided by WHRM.



**Figure 4.7: July 2021 Model Calibration Windsor Downtown**

### 4.3.2 Tregothic Marsh

Significant flooding and sewer system surcharging was experienced at multiple locations throughout Tregothic Marsh area during the July 2021 event. Photos and videos provided by WHRM staff are available for following locations:

- ▶ Empire Lane and the parking lot nearby.
- ▶ Exhibition Arena area.

The July 2021 storm was modelled for calibration, with the 1 in 2 year coastal water levels in present-day (2023) included at the outlets of the two creeks. Model parameters such as

hydraulic conductivity, impervious and pervious surface percentages, surface water storage depth, subcatchment flow length, and runoff coefficients were adjusted within the reasonable ranges, by comparing the resulting flood extents to the available photos and videos at the above two locations. The resulting flooding in the other locations were also discussed with WHRM, and it was noted that the flooding locations and depths modelled were representative of on-site conditions during the rain event, except for the parking lot area of Tim Hortons and McDonald's (i.e., to the east of the intersection of Cole Drive and Wentworth Road). WHRM staff stated that the parking lot area has never be flooded but the model showed some flooding in the area. Additional survey information would be required for the drainage systems at the parking lot and for the sewer system along Cole Drive to refine the model results in this area. Figure 4.8 below, and in Appendix C, illustrates the depth and extent of flooding modelled for the July 2021 event in the Tregothic Marsh area, with photos of flooding and surcharging provided by WHRM.



**Figure 4.8: July 2021 Model Calibration for Tregothic Marsh**

## 5 Existing System Capacity

The following Chapter provides modeling results the following return period rainfall events:

- ▶ 1 in 5 year design event (i.e. 1 in 5 year climate change adjusted rainfall) in the Windsor Core Downtown with free outfall from PS1 overflow pipe to lake behind aboiteau structure.
- ▶ 1 in 10 year design event (i.e., 1 in 10 year climate change adjusted rainfall with 1 in 2 year coastal water levels in 2090) in the Tregothic Marsh Area.
- ▶ 1 in 100 year design event (i.e., 1 in 100 year climate change adjusted rainfall with 1 in 2 year coastal water levels in 2090) in the Tregothic Marsh Area.

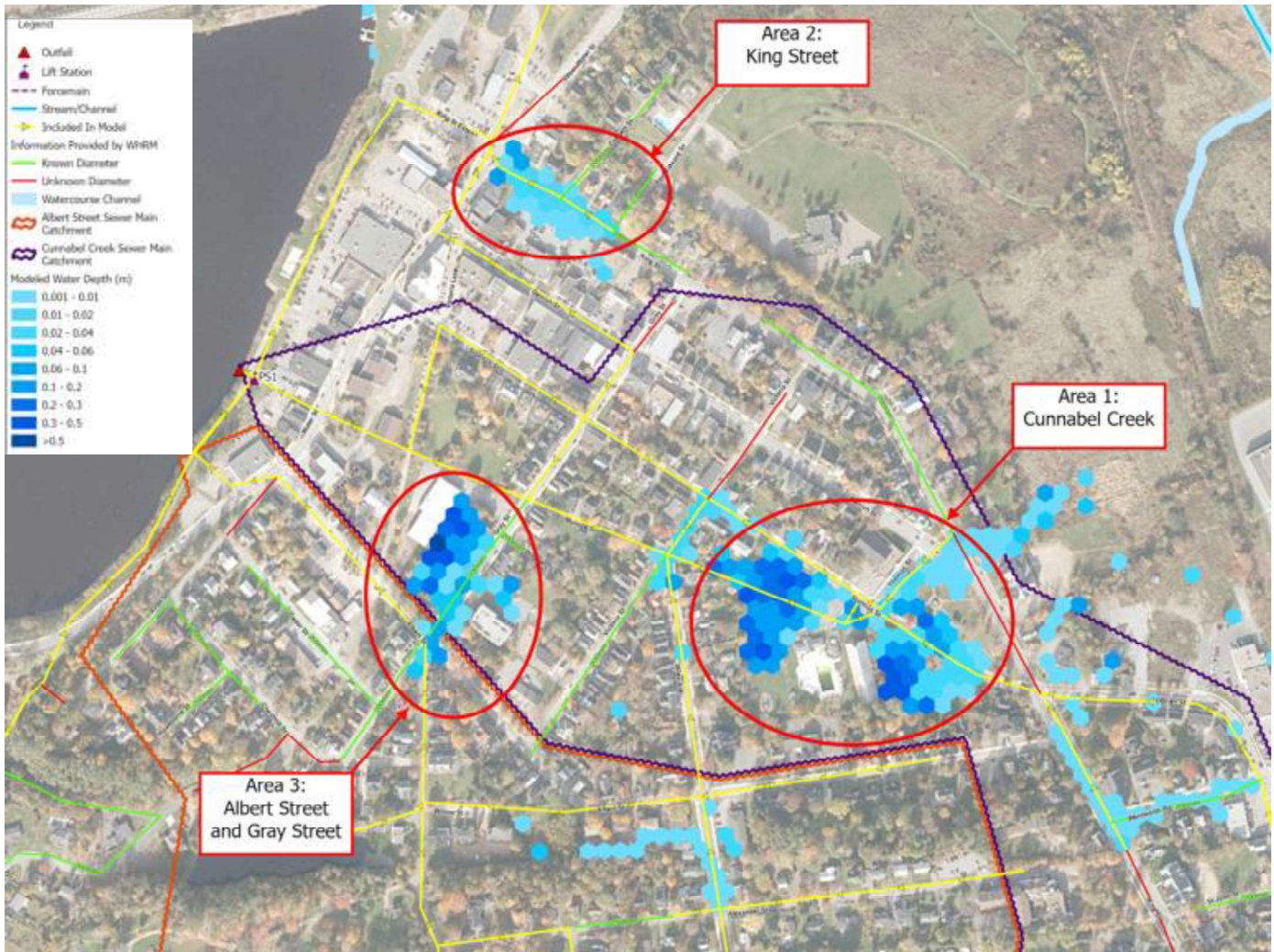
### 5.1 Windsor Downtown

Using the calibrated model discussed above, the existing combined system in the Windsor Core area was modelled with a 1 in 5 year design storm. While surcharging of the existing combined sewer system does not occur throughout the entire system, notable surcharging and flooding does occur at the intersection of Gray and Albert Street, throughout Stannus Street, Elmcroft Park, and King Street for the 1 in 5 year design storm. The extents of surcharging and flooding for a 1 in 5 year storm are similar to the flooding and surcharging which occurred during the July 2021 event.

Model results for the 1 in 5 year design storm in the Windsor Downtown model are presented in Figure 5.1 on the following page as well as in Appendix C. Flooding can occur as result of many factors, some of which include:

- ▶ Undercapacity sewers for the selected design storm (i.e., insufficient slope or diameter of pipe).
- ▶ Back-graded pipes.
- ▶ Low topographic elevations with respect to the tidal level.
- ▶ Among others.

Multiple simulations have been run to investigate the potential factors resulting in flood risk at various locations within the Windsor Downtown area. The results of the 1 in 5 year design rainfall event on the existing system are summarized in the sections below at key locations of flooding across the downtown area.

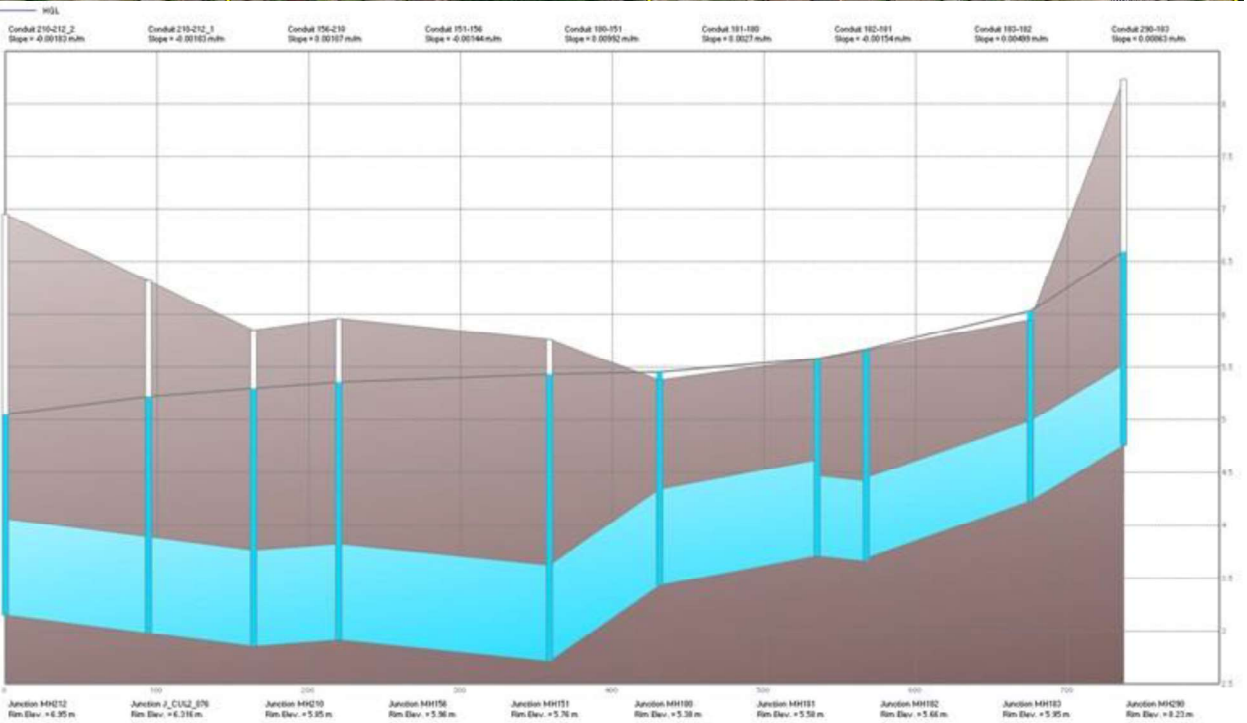
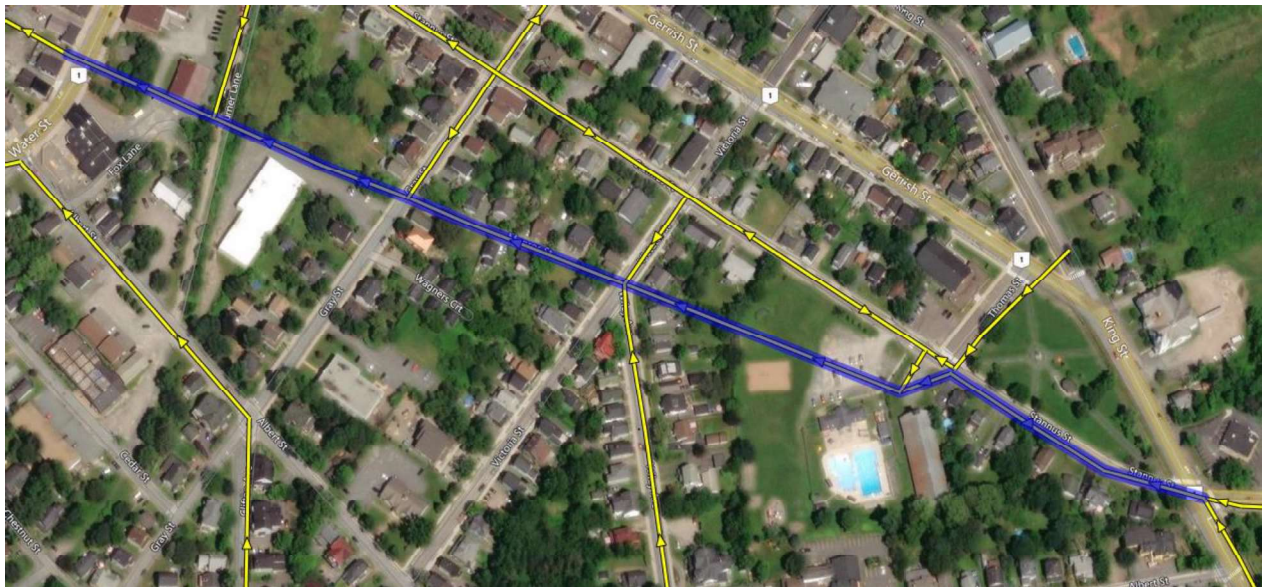


**Figure 5.1: Simulated Surface Flooding during the 1 in 5 year Design Storm**

### 5.1.1 Cunnabel Creek

The Cunnabel Creek area is flat and is a large natural floodplain for the Downtown area. This is caused by the surrounding streets, such as on Water Street, Stannus Street, O'Brien Street, all being at a higher elevation than Cunnabel Creek and not allowing any collected water to discharge. In addition to the back-graded sewers along Cunnabel Creek, the lowest manhole in Cunnabel Creek system is also located in Elmcroft Park.

The underground sewer system through Cunnabel Creek does not have the required capacity to convey a 1 in 5 year design storm, resulting in flooding throughout Elmcroft Park and Stannus Street. A profile view of the combined sewer currently installed in Cunnabel Creek, from Water Street to the intersection of O'Brien and King Street during a 1 in 5 year storm is shown in Figure 5.2 on the following page.

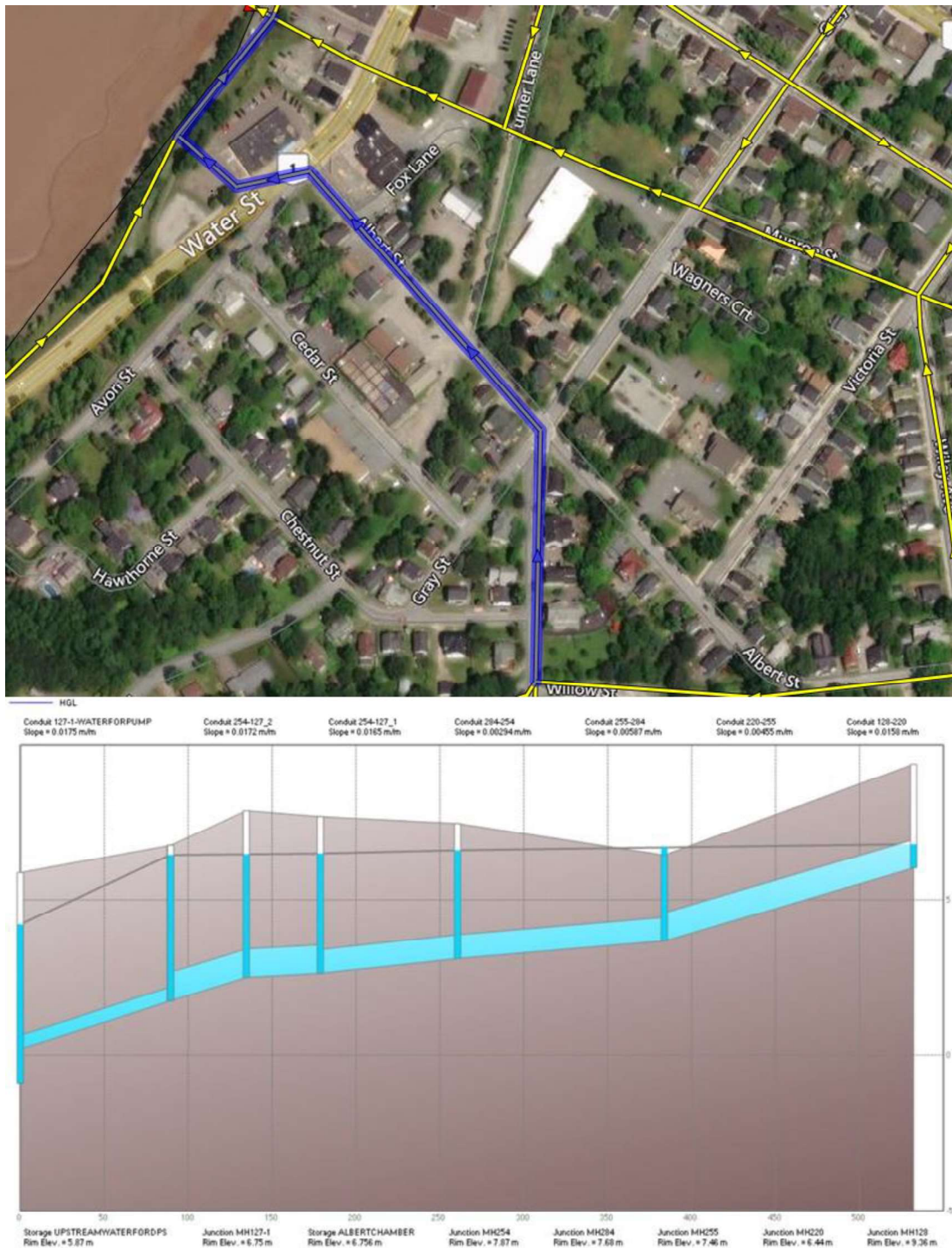


**Figure 5.2: Plan and Profile View of the Cunnabel Creek Area during the Existing Conditions 1 in 5 Year Design Storm**

### 5.1.2 Albert/Gray Street Intersection

There is simulated flooding at the Albert Street/Gray Street intersection due to stormwater flooding out to the surface through the manhole cover. Stormwater that leaves the sewer through the manhole cover flows into the parking lot on Gray Street, following the surface topography. Flooding is occurring at the intersection of Albert and Gray street as this location is the lowest top elevation along the Albert Street sewer main.

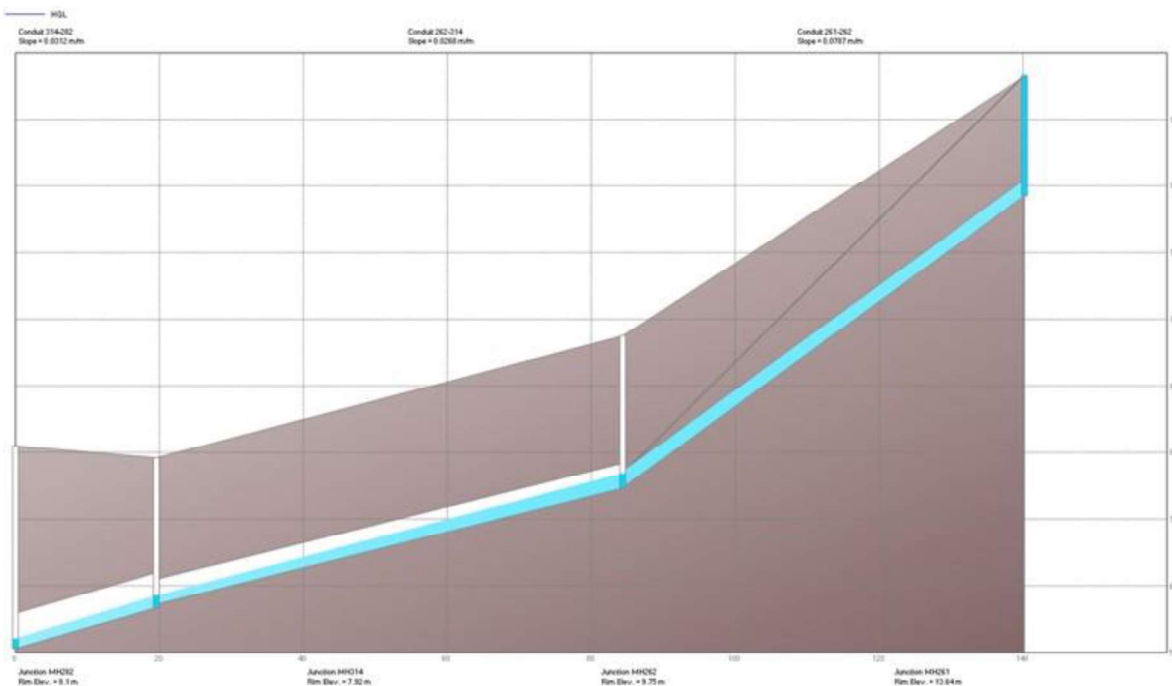
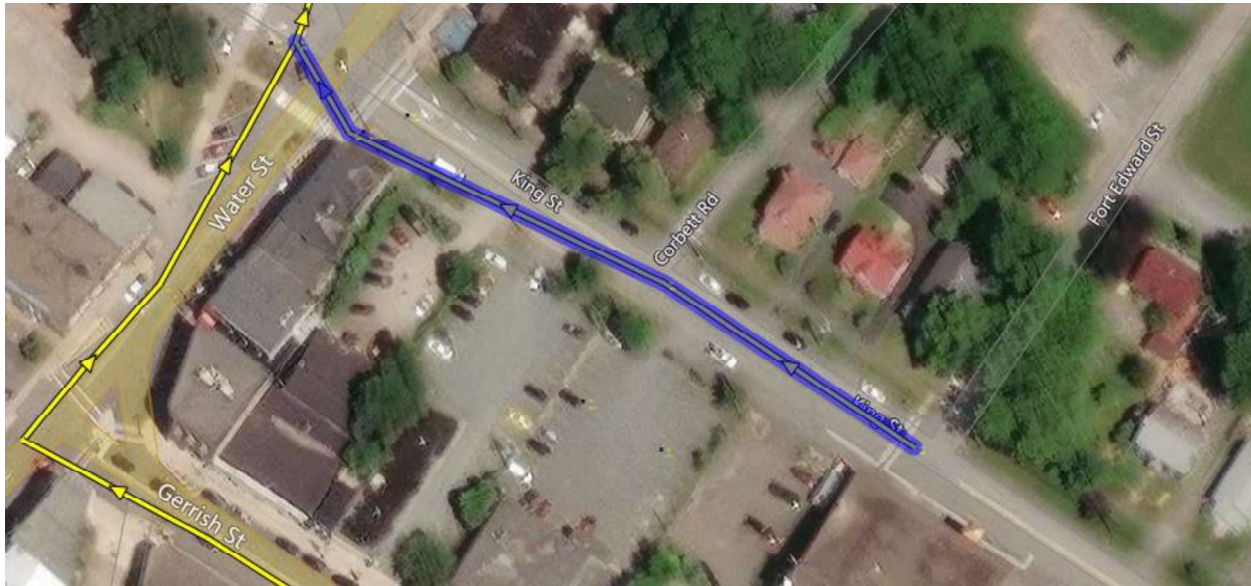
In addition to the surface elevation being low, surcharging is due to a downstream sewer with limited capacity. A plan and profile view of the combined sewer currently installed in Albert Street, from Water Street to the intersection of Willow Street and Clifton Avenue, during a 1 in 5 year design storm is shown in Figure 5.3.



**Figure 5.3: Plan and Profile View of the Sewer on Albert Street during the Existing Conditions 1 in 5 Year Design Storm**

### 5.1.3 King Street

Based on model results, there are storm sewers on King Street that do not have sufficient capacity to convey the 1 in 5 year design storm. A plan and profile view of the combined sewer currently installed on King Street, from Fort Edward Street To Water Street, during a 1 in 5 year design storm is shown below in Figure 5.4.



**Figure 5.4: Plan and Profile View of the King Street Sewer during the Existing Conditions 1 in 5 Design Year Storm**

## 5.2 Tregothic Marsh

Using the calibrated model, the existing watercourse channels and drainage systems in the Tregothic Marsh area was modelled with a 1 in 10 year and a 1 in 100 year design events. The resulting flood extents in the Tregothic Marsh area and the culverts/sewers capacity assessment were presented in Figure 5.5 and Figure 5.6 below, as well as in Appendix C.

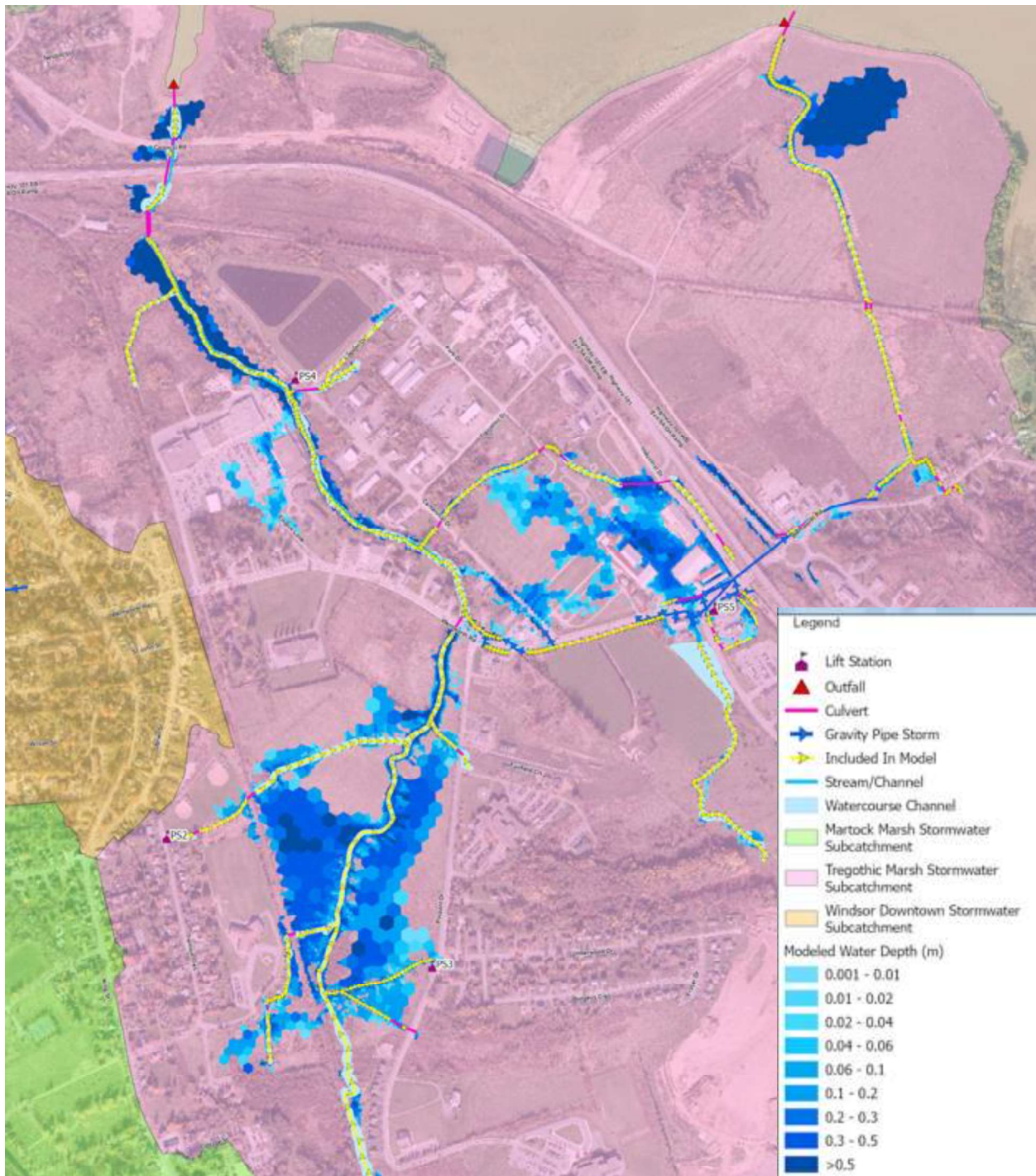
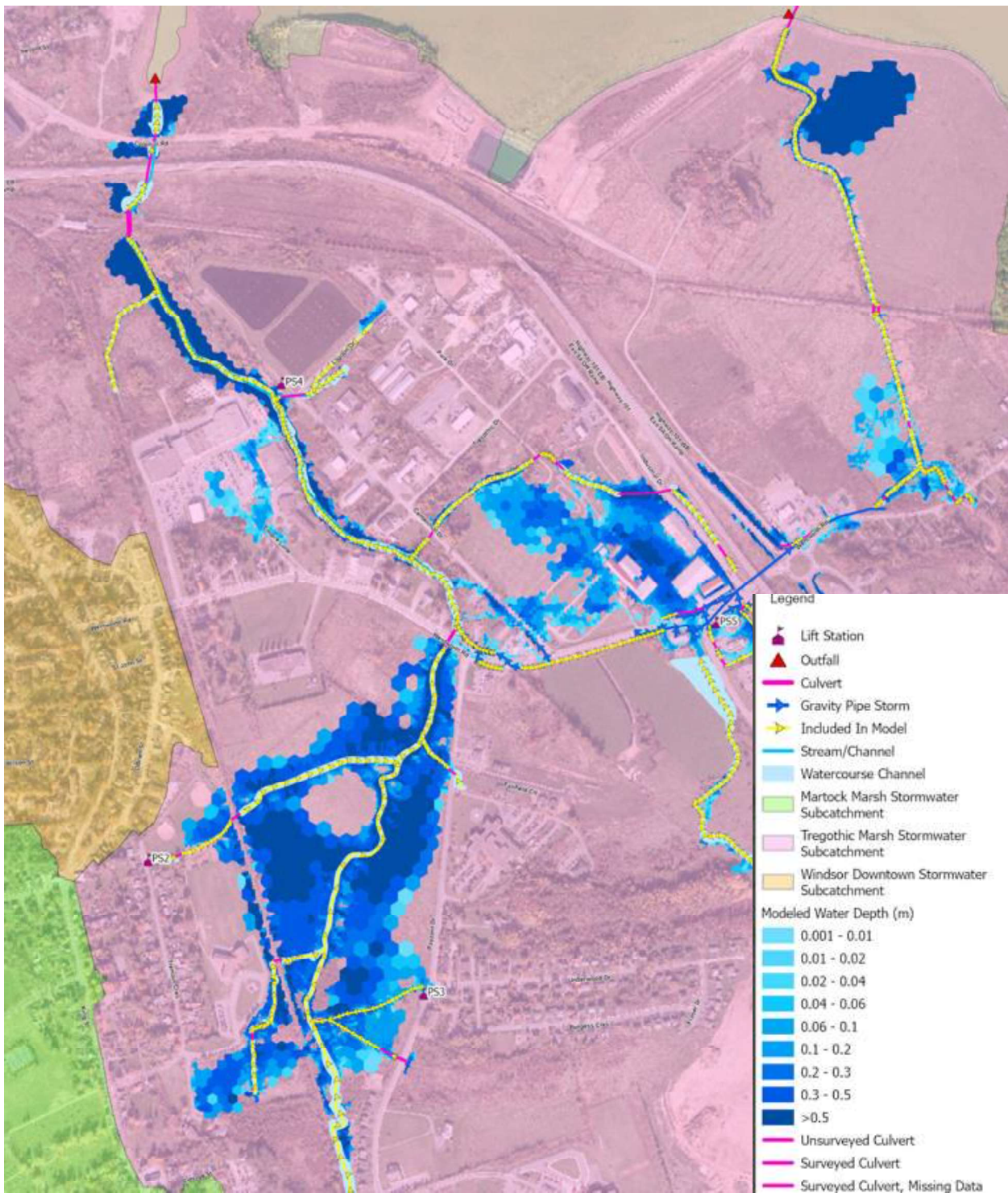


Figure 5.5: Flood Extents 1:10 Year Design Event with CC for Tregothic Marsh Area

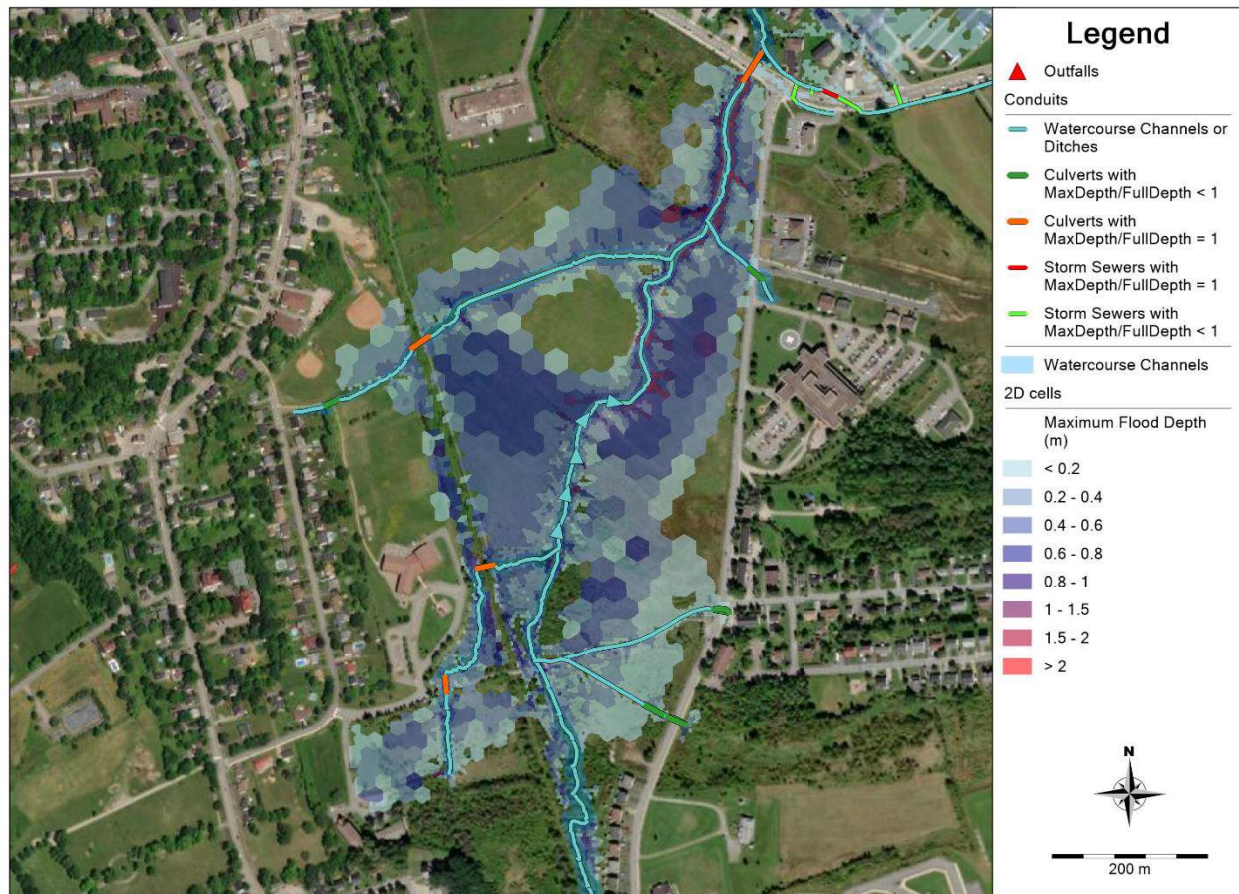


**Figure 5.6: Flood Extents 1:100 Event with CC of Tregothic Marsh**

Multiple simulations have been run to investigate the potential factors that are causing flooding in different locations within the Tregothic Marsh Area. The analysis for the flood extents and existing drainage systems in the 1 in 100 year and 1 in 10 year design events are presented below and in the following figures.

## 5.2.1 Agricultural Area South of Wentworth Road

Flood extents for the 1 in 100 year design event and potential causes of flooding are presented in Figure 5.7. There are culverts along the watercourse channels that do not have enough capacity (orange lines in Figure 5.5) and are restricting the flows, but the main reason for the flooding is that this area is flat and is a large natural floodplain for Tregothic Creek. Additional survey would be required to assess the potential flooding at Tremain Crescent which is being completed under a separate project.

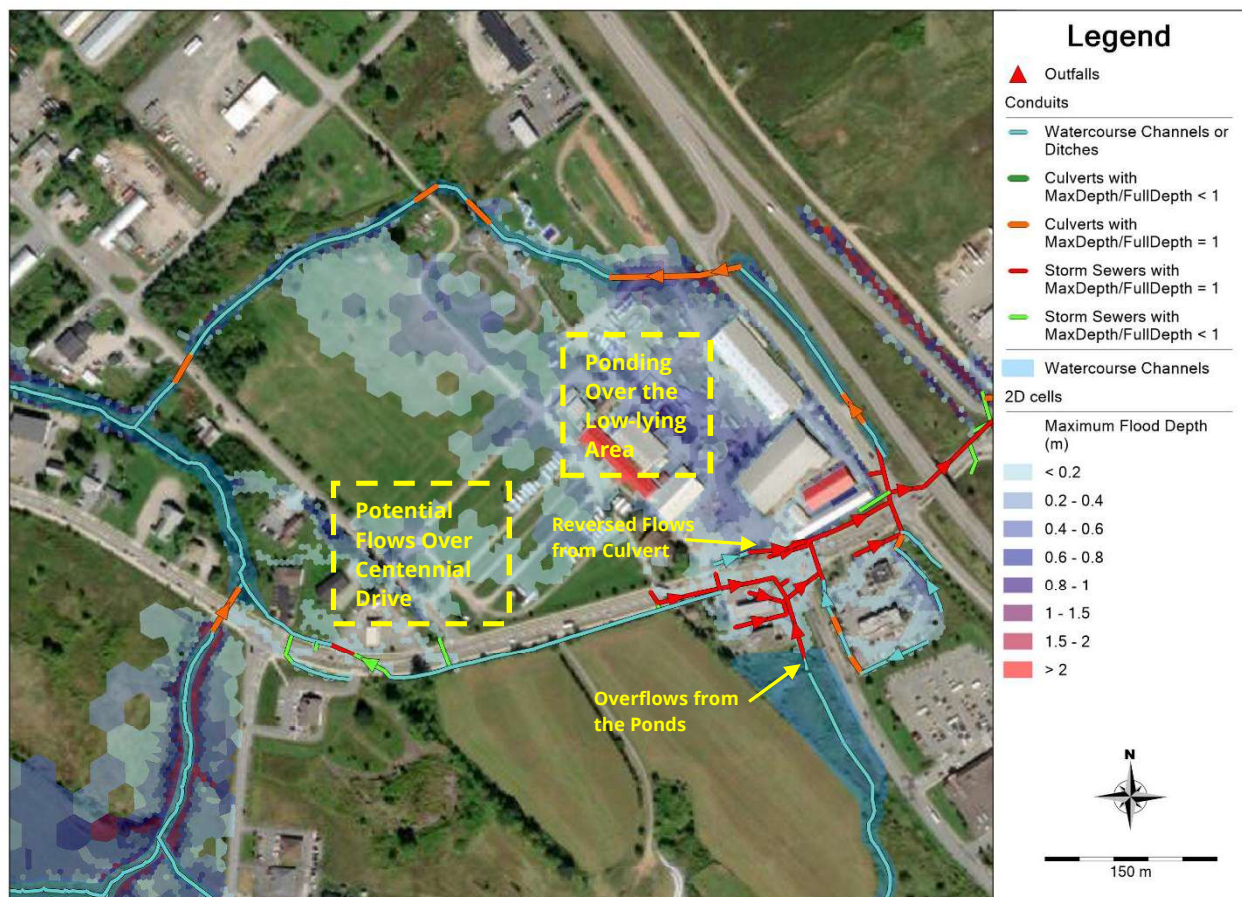


**Figure 5.7: Flood Extents 1:100 Year Design Event – Agricultural Area South of Wentworth Road**

## 5.2.2 Industrial Area near the Intersection of Wentworth Road and Industrial Drive

The parking lot area west of Industrial Drive & north of Wentworth Road is low-lying and stormwater tends to pond in this area during rainfall events before flowing towards the watercourse channels. Flood extents for the 1 in 100 year design event and potential causes of flooding are presented in Figure 5.8. The main contributions of stormwater to the parking lot include overflows from the existing detention ponds, reversed flows from the existing sewer systems through a culvert, and potential overflows from Centennial Drive.

Culverts along the ditches that are surrounding the parking lot have an assumed diameter of 0.6m, which were found to not have enough capacity which is causing overland flows. Additional survey would be required for those unsurveyed culverts and the recent constructions north of Centennial Drive as noted by WHRM staff, to refine the model in the area. As to the parking lot area west of Industrial Drive and south of Wentworth Road, flooding is expected in the area from the model results. There are overflows from the ditches and culverts surrounding the parking lot. Culverts along the ditches were assumed to have a diameter of 0.381m, and these culverts were found to not have enough capacity. Additional survey would be required for those unsurveyed ditches and culverts, as well as the sewer system along Cole Drive, to refine the model in the area.

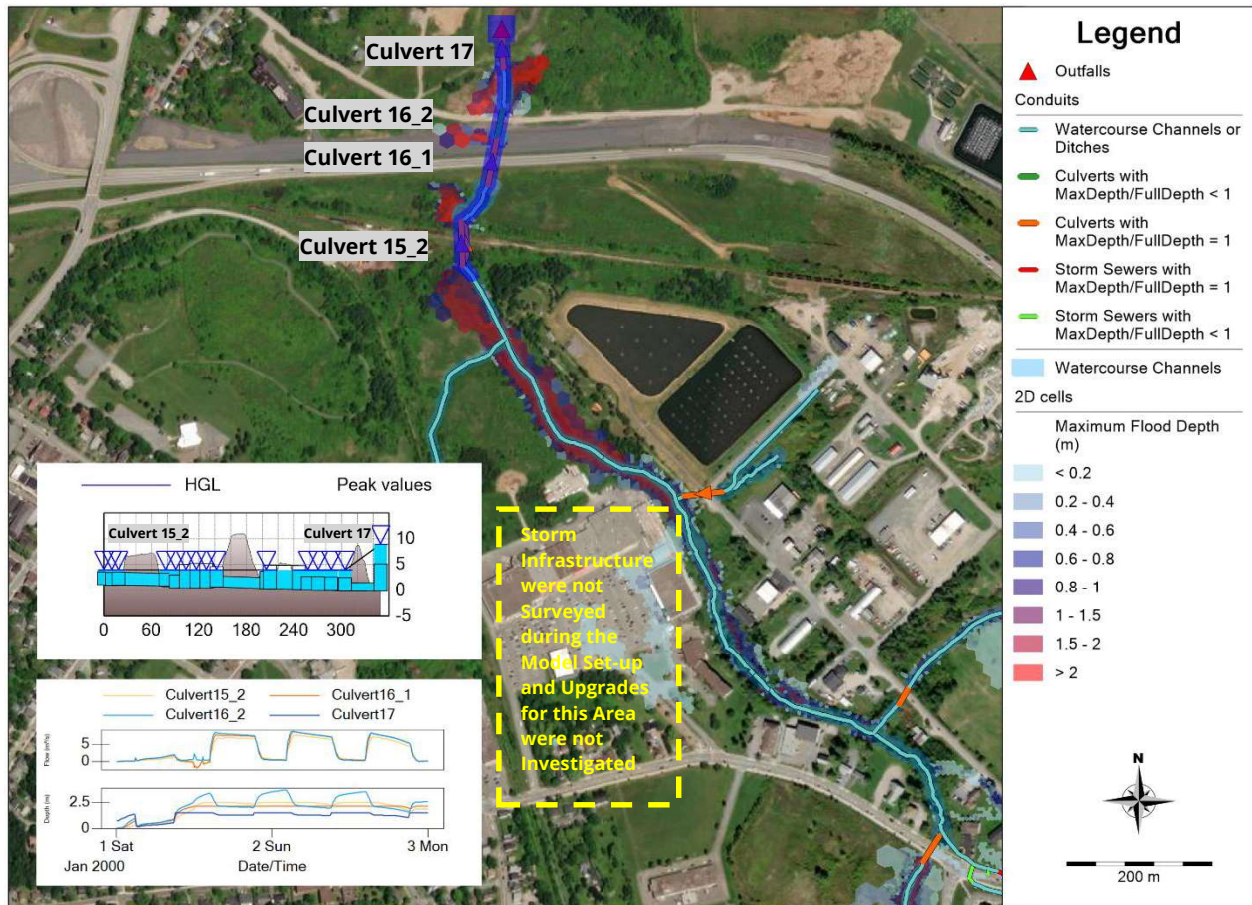


**Figure 5.8: Flood Extents for 1:100 Event for Tregothic Marsh Area - Industrial Area near the Intersection of Wentworth Road and Industrial Drive**

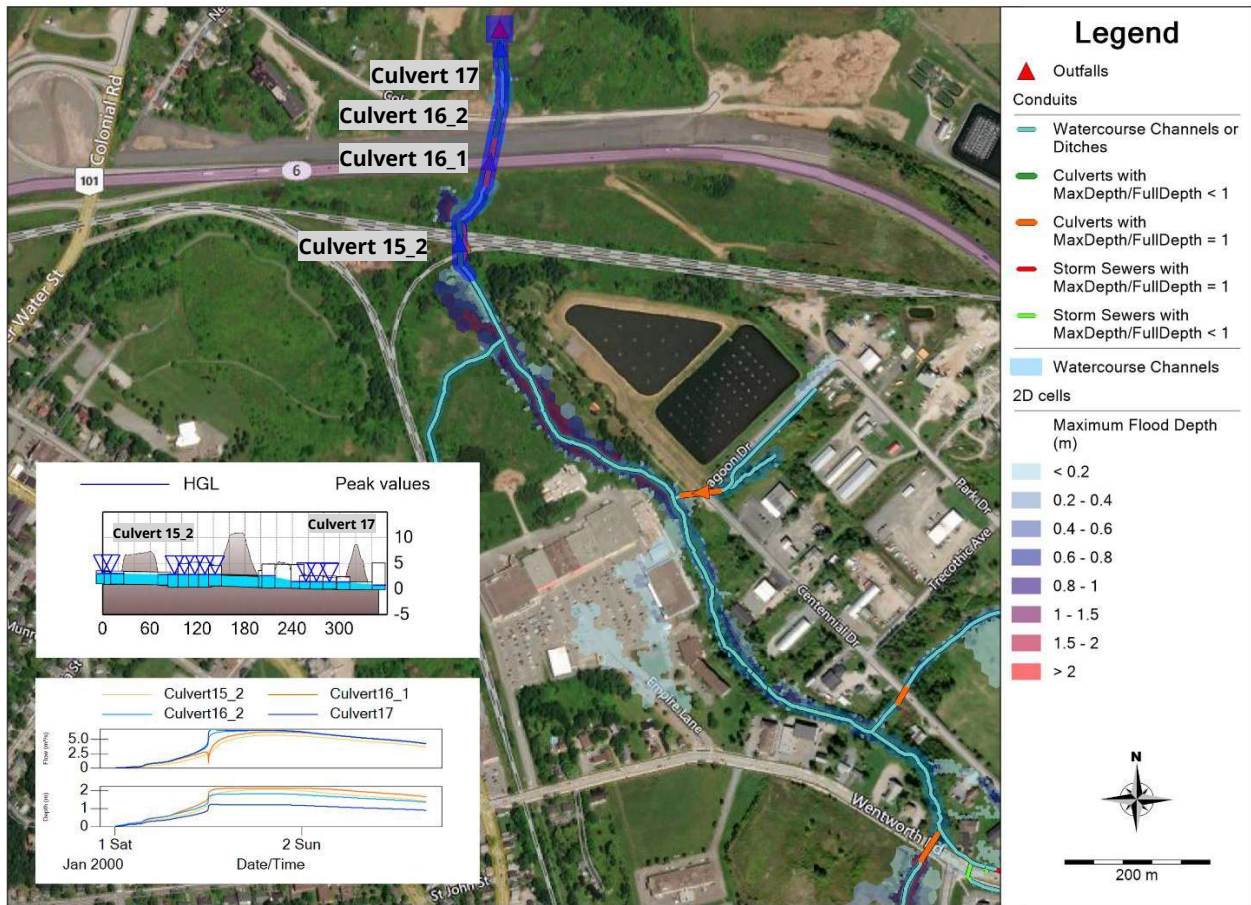
### 5.2.3 Downstream of Tregothic Creek from Wentworth Road to the Outlet

There is flooding at Empire Lane and the parking lot nearby, as the stormwater is discharging freely at Empire Lane and flows over the parking lot following the surface topography. Information to confirm if there are any stormwater structures on site for drainage were not available during the model set-up and not included in the model.

Overland flooding is expected along the Tregothic Creek, especially in the downstream area near the culvert under the train track. Flood extents for the 1 in 100 year design event and potential causes of flooding are presented in Figure 5.9. Flap Gate would be in place during high tide, and when the gate opens, the culverts (culvert 15\_2, culvert 16\_1, culvert 16\_2, and culvert 17) are still full during low tides in the 24-h rainfall event. A free outfall has been tested in the model to investigate the resulting flood extents for the 1 in 100 year design event without influences of coastal water levels, as presented in Figure 5.10. It was noted that the tidal water does restrict the outflows, but the influence was not significant enough to impact the areas beyond 700m upstream from the outlet of Tregothic Creek.



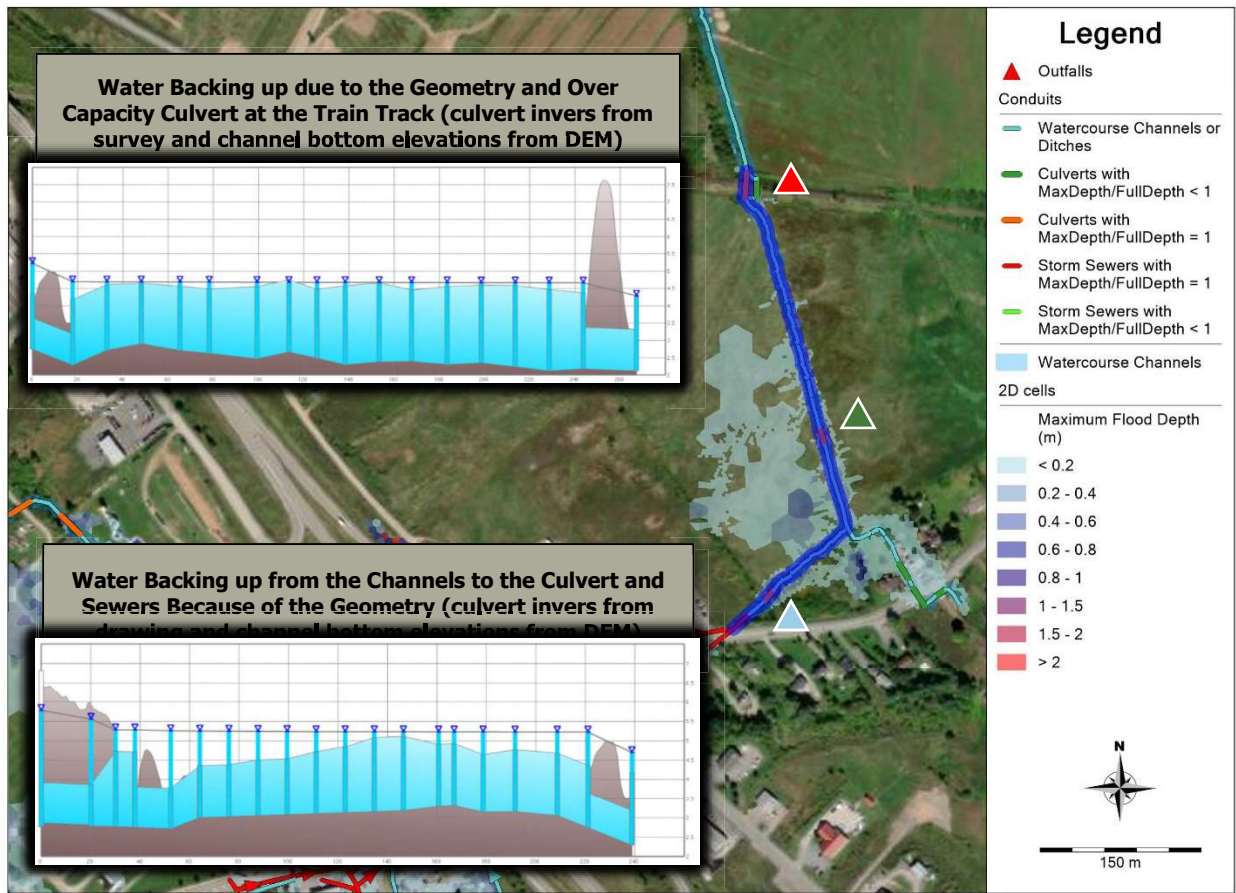
**Figure 5.9: Flood Extents 1 :100 Year Design Event of Tregothic Marsh - Downstream of Tregothic Creek from Wentworth Road to the Outlet (1 in 2 Year Coastal Water Levels at the Outlet)**



**Figure 5.10: Flood Extents 1:100 Year Design Event of Tregothic Marsh – Downstream of Tregothic Creek from Wentworth Road to the Outlet (Free Outfall at the Outlet)**

## 5.2.4 Open Ditch Area

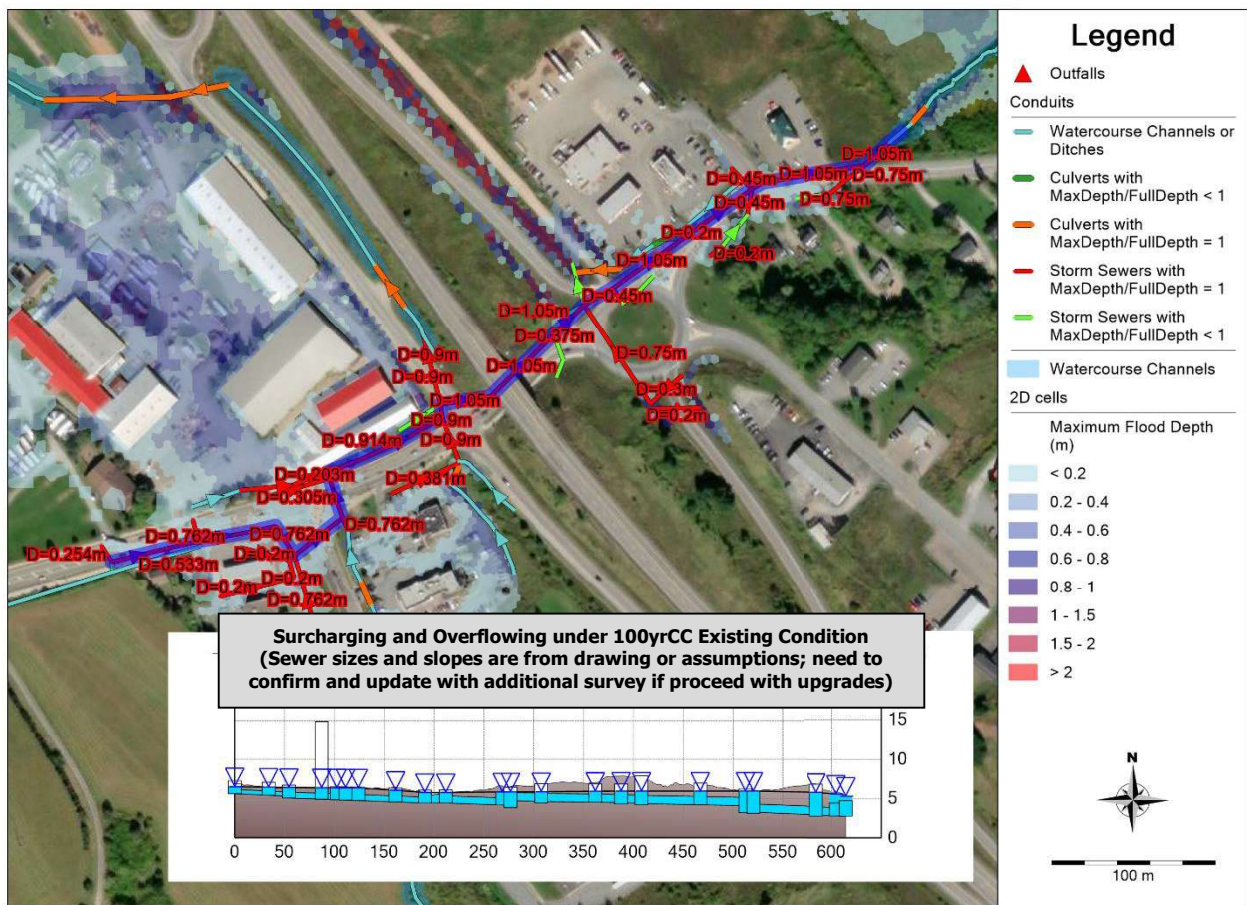
There are culverts along the watercourse channels that do not have enough capacity. Flood extents for the 1 in 100 year design event and potential causes of flooding are presented in Figure 5.11. The channel bottom elevations are from the LiDAR DEM and it was noted that the water is backing up from the channels because of the channel bottom geometry. Additional survey would be required to have cross sections for the ditch at a certain increment to refine the model in the area.



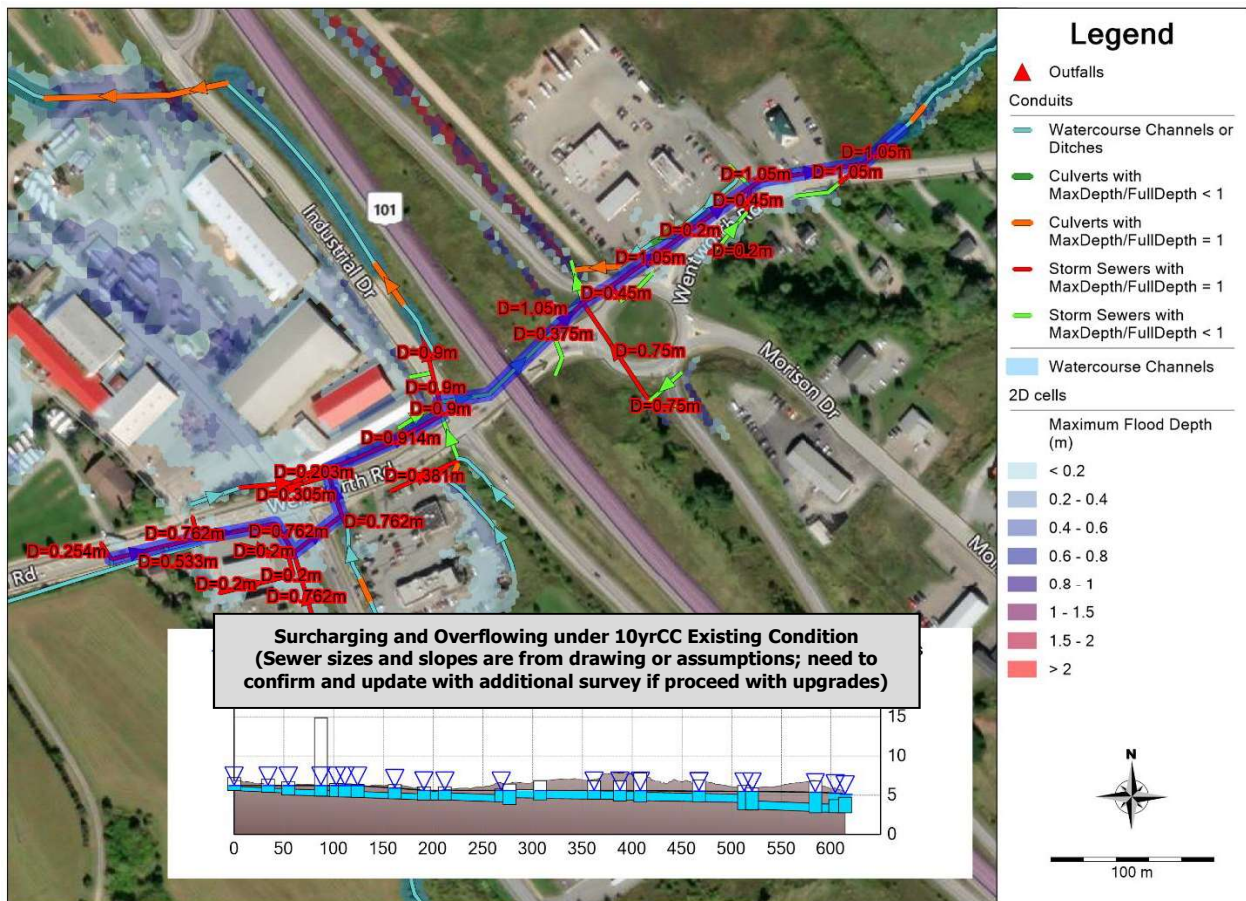
**Figure 5.11: Flood Extents 1:100 Year Event for Tregothic Marsh Area – Open Ditch Area**

### 5.2.5 Storm Sewer Systems along Wentworth Road

It was noted that surcharging and overflowing are expected for the storm sewer systems along Wentworth Road in the 1 in 100 year design event (Figure 5.12) and 1 in 10 year design event (Figure 5.13). Additional survey would be required for the sewer system for any upgrades on the sewers in the detailed design phase.



**Figure 5.12: Flood Extents 1:100 Year Design Event of the Tregothic Marsh Area – Storm Sewer Systems along Wentworth Road**



**Figure 5.13: Flood Extents 1:10 Event of Tregothic Marsh area – Storm Sewer Systems along Wentworth Road**

## 6 Windsor Downtown Proposed Stormwater Upgrades

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CBCL developed multiple concepts for upgrades to the existing minor drainage system in Windsor for the 1 in 5 and 1 in 10 year design events with climate change impacts considered, and to the major drainage system for the 1 in 100 year design event with climate change impacts. The concepts were discussed with WHRM staff, where suggestions and changes were modelled and feasibility determined. Upgrades options for the Windsor Downtown and Tregothic Marsh area are summarized below.

As noted in the Planning Strategy document, Council intends to focus the Commercial Development District in the Commercial Core areas in the Three Mile Plains and Falmouth Growth Centre. Therefore, the Windsor Core upgrades were based of a design storm frequency of 1 in 5 years, and the upgrade options for the two creeks areas were developed based of a design storm frequency of 1 in 10 years for the minor drainage systems, and based of a design storm frequency of 1 in 100 years for the major systems.

### 6.1 Windsor Downtown Full Separation Options

It should be noted that due to the relatively flat topography in the Windsor Downtown area, many of the new proposed storm sewer pipes have minimal slope (less than 1%) requiring the diameter of the storm sewer to be larger relative to storm sewer pipe on a more conventional slope of 2% or greater. In addition, a fixed elevation of 2.1m was modeled for the stormwater outfalls which outlet to the lake upstream of the aboiteau structure. To achieve the minimal slope outlined above on the new storm sewer, the outlet invert elevation of the system is set below 2.1m, meaning at some points, the outlet of the storm sewer may be under water.

The Cunnabel Creek Right-of-Way (ROW) is the existing main corridor for combined sewer through the Windsor Downtown. CBCL reviewed drawings provided by WHRM for the Cunnabel Creek ROW from Water Street to Elmcroft Park. A drawing dated in 1915, provided in Appendix D, showed a variable width ROW, ranging from 9.15m wide at Water Street, to 3.05m near Elmcroft Park. A review of Nova Scotia property mapping information, aerial imagery, and on-site photos taken by WHRM staff, show that there are houses near

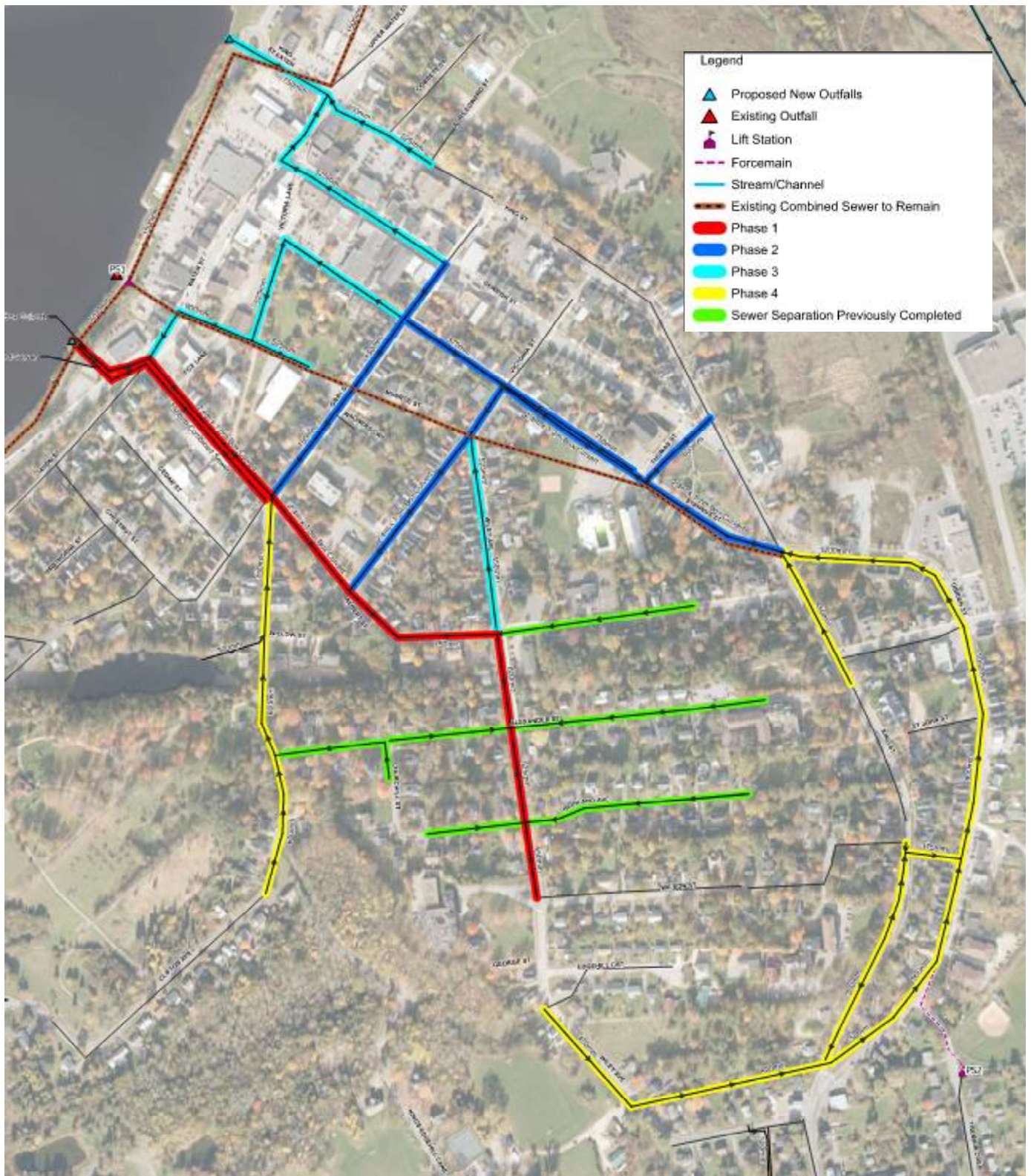
the 6.10m ROW on Munroe Street. It appears that one house is infringing on the ROW along Munroe Street, and there are multiple sheds/small buildings on the ROW east of Victoria Street. In addition, the drawing from 1915 did not show a ROW from Water Street to the Avon River, and there are currently two commercial properties approximately 6.0m apart that would make constructing a large diameter structure to the outfall difficult. Any option reusing this corridor will need to take this in consideration. Alternatively, an alternate route would be needed to direct stormwater to the Avon River, in this case the topography will result in sections of deep storm pipe that can be very difficult and expensive to construct. Considerable time was spent evaluating options and trying to optimize the stormwater system path.

Each option below describes the core drainage pathway and does not discuss the sub catchments upgrades that discharge into the core drainage pathway. It is intended that the sub catchments will be separated and connected to the new separated core stormwater and sanitary sewers discussed below. Profiles of the major drainage pathways have been developed as part of this study to confirm slope and capacities. Prior to implementing any plan, the main drainage pathway should be surveyed and designed to a level sufficient to confirm that all sub catchments can connect and there are no conflicts affecting the alignment that could impact the proposed slopes used in this report to calculate capacity and pipe size.

### 6.1.1 Full Separation Option 1: Remove Flow from Cunnabel Creek

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To avoid having to structurally support houses during construction along Cunnabel Creek, or acquire property to facilitate the installation of a large storm sewer, Option 1 proposes that storm water be diverted away from the existing Cunnabel Creek ROW, towards Albert Street in a large diameter box culvert along Stannus and Victoria Street. This will avoid installing large diameter sewers in close proximity to houses and businesses along the existing ROW, but will increase the sewer depth as Albert Street is at a higher elevation than Cunnabel Creek. Proposed upgrades for Option 1 are discussed below, refer to Figure 6.1 on the following page, as well as in Appendix E. A description of the main flow paths for this option are presented on the following page.

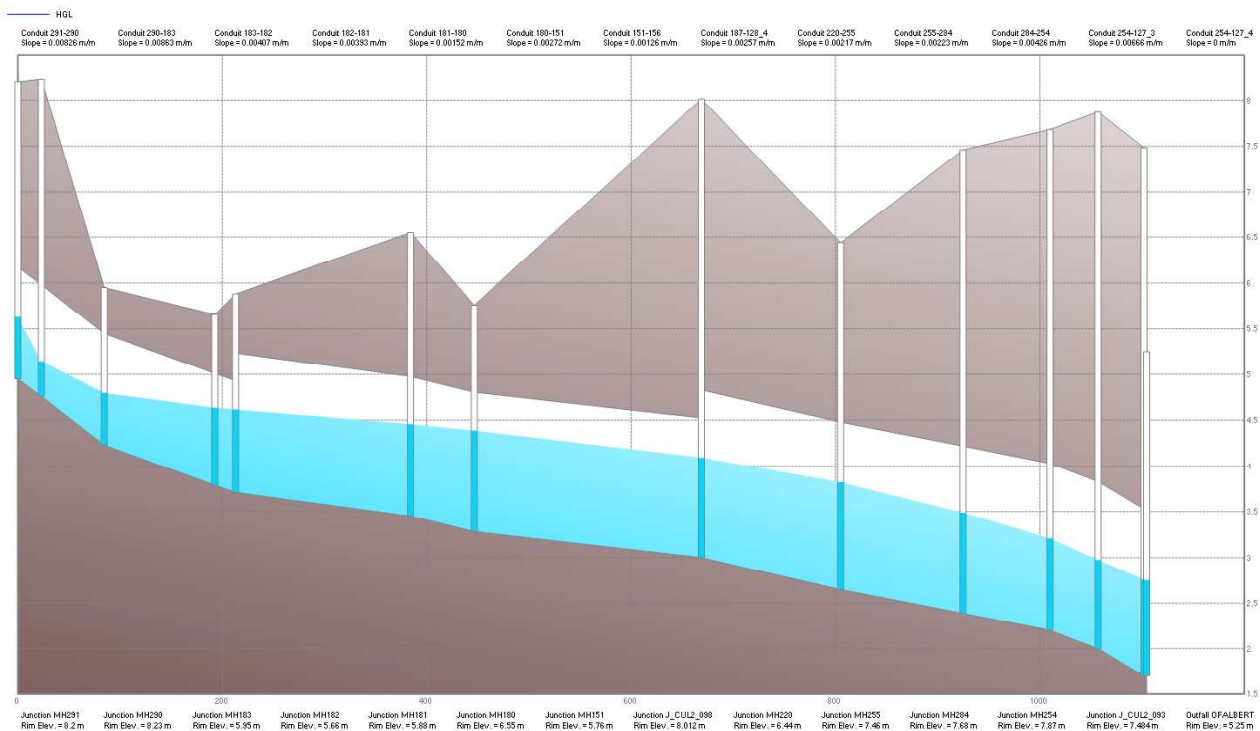


**Figure 6.1: Full Separation Option 1**

## Albert Street Storm Sewer

The Albert Street storm sewer in this option is proposed as the main sewer for Windsor. Flow from all areas of the Town, except for the northern area of Gerrish and King Street, is proposed to outlet through a new outfall northeast of the Albert and Water Street intersection. This option avoids the requirement to install a large diameter storm sewer in the existing Cunnabel Creek ROW, and the existing combined sewer can remain as a dedicated sanitary sewer, or be upgraded and replaced as required during detailed design.

A 2.4m x 1.8m concrete box culvert from the outfall to Victoria Street is proposed through Albert Street. Due to the unique topography of Windsor, to collect the stormwater east of Albert Street, the proposed storm sewer must be significantly deeper than the following options, nearly 6m deep at Water Street, and 5m deep at the intersection of Victoria Street, to allow stormwater to drain through the outfall. From Victoria-Albert Street intersection, a 2.4m x 1.5m concrete box culvert is proposed through Victoria Street to Stannus Street, continuing to the intersection of Thomas Street. From Thomas Street, a 2.4m x 1.2m box culvert is proposed to the intersection of King Street due to the low elevation in the area. A profile of the proposed box culverts from the outfall to O'Brien-King Intersection is provided below.



**Figure 6.2: Proposed Box Culverts from Albert Street Outfall to King-O'Brien Intersection**

Circular storm sewer throughout O'Brien Street from O'Brien-King Street intersection to the southern section of Wiley Avenue is proposed ranging from 1200mm to 450mm diameter.

To connect the existing streets that have already been separated, such as Highland and Alexander, a storm sewer system from the intersection of Albert/Victoria Street to Wiley/Wilson Street, ranging in diameter from 750mm to 450mm, is also proposed.

### Albert Street Combined Sewer

To aid in flushing the existing combined trunk sewer along the Avon River, it is proposed that the Albert Street sewer system is not completely separated. It is proposed that a 750mm combined sewer be installed along Albert Street from the intersection of Albert and Gray Street, parallel to the proposed storm sewer. The combined sewer would collect stormwater and sanitary flow West of Albert Street from the Cedar Street, Chestnut Street, and Gray Street area, and outlet to the existing combined sewer along the Avon River.

### King Street Storm Sewer

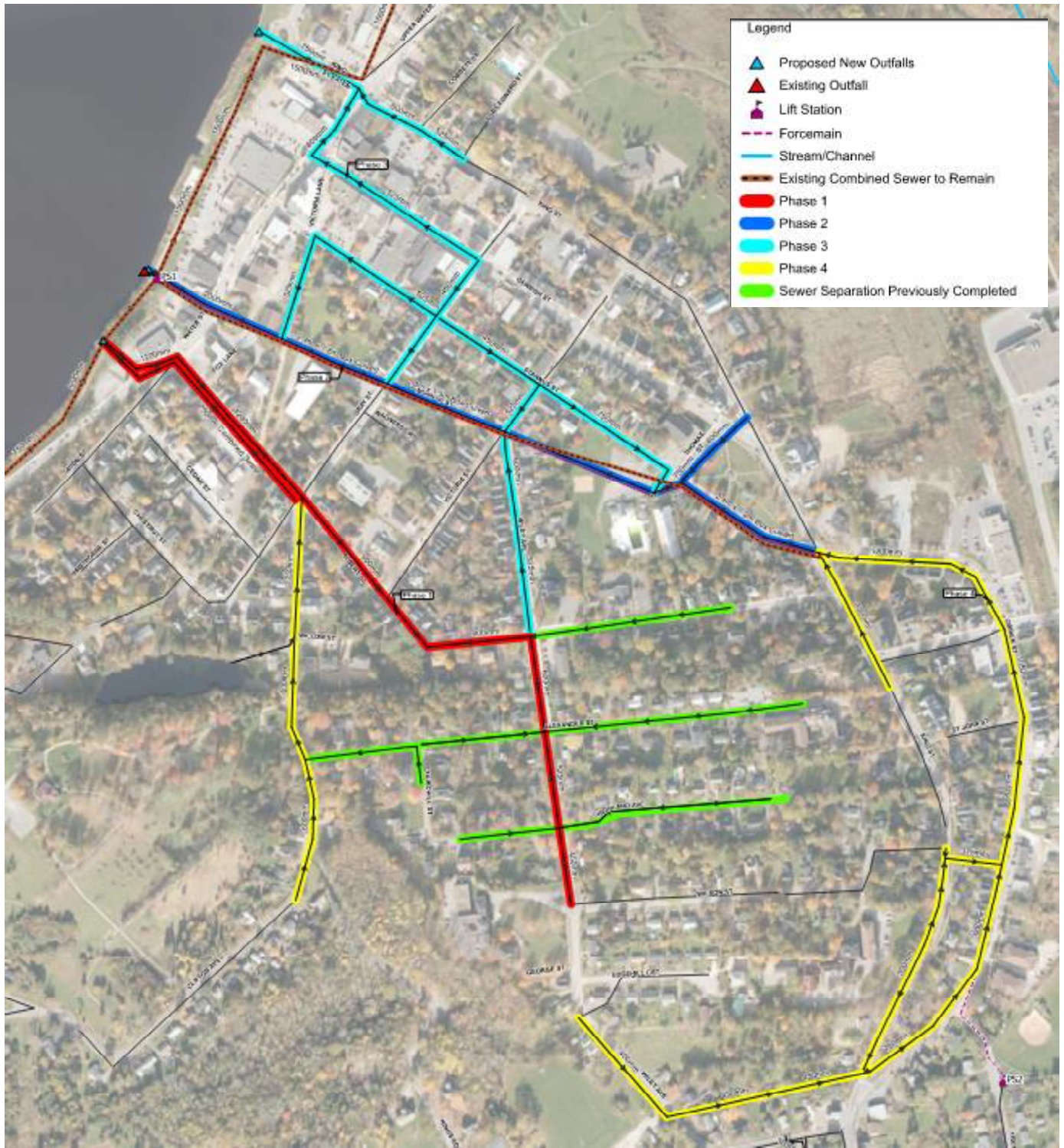
The King Street east storm sewer would discharge flow collected on King Street and Gerrish Street to the Avon River. A new stormwater outfall at King Street east is proposed. Diameters of storm sewers for the King Street east storm Sewer range from 525mm to 750mm.

### Optional Storage

Due to the large size of the box culverts in this option, a preliminary assessment was made into whether adding detention storage to the system would allow for a smaller size. Findings indicate that a 4,330m<sup>3</sup> storage unit (pond, underground chamber, etc.) located at Victoria Park on Stannus Street could intercept enough flow to allow the box culvert width to be reduced from 2.4m to 1.2m. A more detailed design process would need to be completed in order to fully assess the viability of this storage option.

## 6.1.2 Full Separation Option 2: Replacement of Existing System

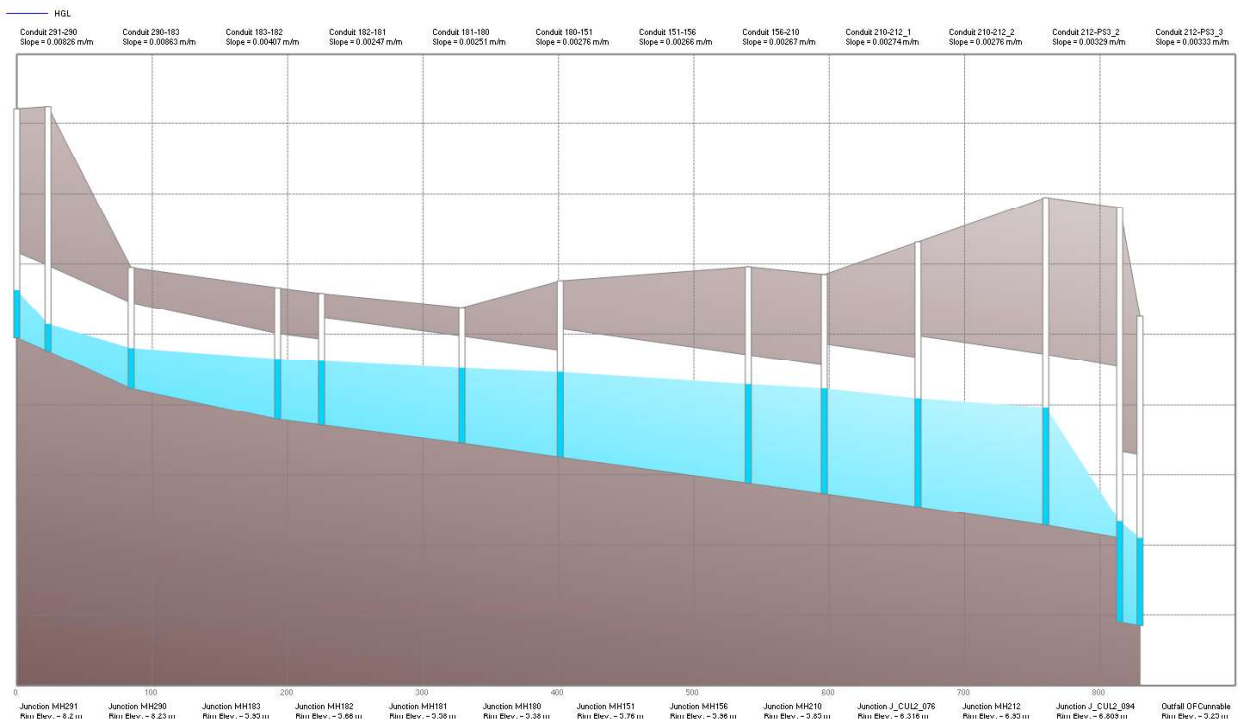
This option mimics how the system currently operates with the current drainage pathways maintained. A description of the main flow paths for this option are below. Figure 6.3 on the following page and in Appendix E.



**Figure 6.3: Full Separation Option 2**

## Cunnabel Creek Storm Sewer

The proposed Cunnabel Creek storm sewer collects stormwater runoff following a similar layout as the existing system, however, storm sewer pipe sizes are significantly increased through the Cunnabel Creek ROW. Flow is collected on Stannus Street, Wiley Avenue from Victoria Street to Albert Street, Gray Street, Munroe Street, Victoria Street, King Street, O'Brien Street, Wentworth Road, and the southern section of Wiley Avenue. The main trunk storm sewer would remain through the Cunnabel Creek ROW and outlet at a new stormwater outfall near the existing lift station (PS1). Due to the low elevation through Elmcroft Park, a large diameter circular storm sewer would not have the required cover through the park. Alternatively, a 2.4m wide box culvert, starting at the intersection of Stannus and King Street to the intersection of Cunnabel Creek and Turner Lane, is proposed. The height of the box culvert would range from 1.2m at Stannus/King Street to 1.8m at Turner/Cunnabel Creek. A 2m circular pipe is proposed downstream of Turner Lane as there is adequate cover to transition back to a circular pipe. To cross the existing 1.5m diameter combined sewer, a drop manhole would be required before the combined sewer. Upstream of the proposed box culverts, the proposed diameters range from 1200mm to 300mm. A profile of the proposed storm sewer from the new outfall near PS1 to King-O'Brien intersection through the existing Cunnabel Creek ROW is shown below.



**Figure 6.4: Proposed Storm Sewer along Existing Cunnabel Creek ROW**

## Cunnabel Creek Sanitary Sewer

A new sanitary sewer is proposed parallel to the new Cunnabel Creek storm sewer system described above from the lift station (PS1) near the Avon River to the intersection of King and O'Brien Street. The new sanitary sewer would replace the existing combined sewer and

be significantly smaller in size. The proposed pipe diameter is 300mm, however, sizing, location, and tie-ins of the new sanitary sewer would be completed during the detailed design phase of the system upgrades. Future separation projects upstream of the King and O'Brien intersection would tie into this sewer as separation projects are completed.

### Albert Street Storm Sewer

The proposed Albert Street storm sewer collects flow on Highland Avenue, Alexander Street, Wilson Street, Wiley Avenue from Albert to Wilson Street, Albert Street, Clifton Avenue, and Gray Street and discharges the flow to a new outfall at the Avon River northeast of the Albert Street – Water Street intersection. To cross the existing combined sewer near the outfall, a drop manhole would be required before the combined sewer. Diameters of storm sewers for the Albert Street storm sewer range from 450mm to 1.2m.

### Albert Street Combined Sewer

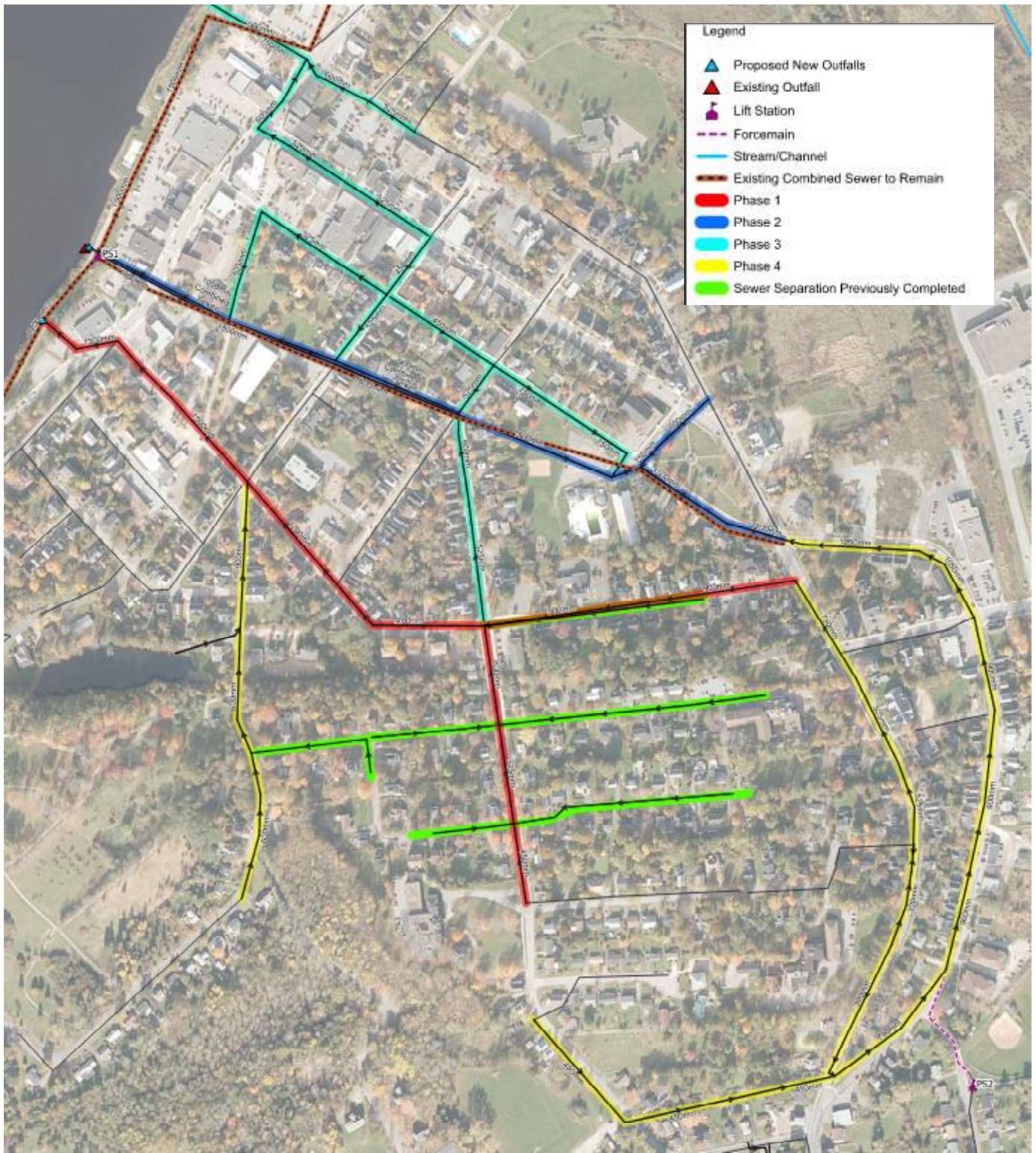
Similar to Option 1, to aid in flushing the existing combined trunk sewer along the bank of the Avon River, it is proposed that the Albert Street sewer system not be completely separated. To allow stormwater to enter the existing combined system, it is proposed that a 750mm combined sewer be installed along Albert Street from the existing combined sewer to the intersection of Albert and Gray Street, parallel to the proposed storm sewer. The combined sewer would collect stormwater and sanitary flow West of Albert Street from the Cedar Street, Chestnut Street, and Gray Street area, and outlet to the existing combined sewer along the Avon River.

### King Street Storm Sewer

Similar to Option 1, the King Street east storm sewer would discharge flows collected on King Street and Gerrish Street to the Avon River. A new stormwater outfall at King Street east is proposed. Diameters of storm sewers for the King Street east storm Sewer range from 525mm to 750mm.

## 6.1.3 Full Separation Option 3: Spilt Flow Between Albert St and Cunnabel Creek

This option balances the stormwater flow between Albert St and Cunnabel Creek drainage areas to minimize pipes sizes. A description of the main flow paths for this option are below. Figure 6.5 presented on the following page, and in Appendix E, outlines this option. Phase 1 and 2 could be switched to allow for quicker benefits to be seen in the Cunnabel Creek Sewershed.



**Figure 6.5: Full Separation Option 3**

## Cunnabel Creek Twinned Storm and Combined Sewer

The proposed Cunnabel Creek storm sewer collects stormwater runoff following a similar route as described in Option 2. However, this option directs some stormwater flow away from Cunnabel Creek, therefore reducing the required diameter of if the storm sewer in Cunnabel Creek. A new storm sewer from King Street to Wiley Avenue is proposed. This new storm sewer would take flow on King Street and Wilson Street through Albert Street to Wiley Avenue. The sewer inverts will be deep and minimally sloped due to the existing elevations along Albert Street. Diameters of storm sewer would range from 300mm to 900mm. As design upgrades for this this section of Albert Street have been completed and intend on being tendered and constructed in the summer of 2023, it may not be feasible to complete the proposed upgrades through Albert Street. Additionally, as the 2023 project would be completed before design could be finished on the proposed storm sewer, digging up and reinstating work recently complete would not be economical.

Similar to Option 2, flow collected on O'Brien Street and the southern section of Wiley Avenue would connect and outlet to Cunnabel Creek near Elmcroft Park. Diameters of this section of storm sewer range from 300mm to 1500mm.

To aid in flushing the existing combined trunk sewer along the bank of the Avon River, and to reduce the diameter of the proposed storm sewer in Cunnabel Creek, a parallel storm and combined sewer is proposed. To allow stormwater to enter the existing combined system, it is proposed that a new combined sewer, ranging in diameter from 900mm to 1050mm, be installed parallel to the new Cunnabel Creek storm sewer (1.5m to 2m circular diameter). This combined sewer would collect stormwater and sanitary flow from the northern side of Cunnabel Creek and discharge to the existing combined trunk sewer, while stormwater and sanitary flow south of Cunnabel Creek would flow into separated Cunnabel Creek storm and sanitary sewers, which would outlet to the Avon River through a new outfall, and which outlets to PS1, respectively.

## Albert Street Storm Sewer

The proposed Albert Street storm sewer collects flow on Highland Avenue, Alexander Street, Albert Street, Wiley Avenue from Albert to Wilson Street, Gray Street, Clifton Street and King Street is proposed to outlet to the Avon River. To cross the existing combined sewer near the Avon River, a drop manhole would be required before the combined sewer. Diameters of storm sewers for the Albert Street storm sewer range from 450mm to 1.5m.

## King Street Storm Sewer

The proposed King Street east storm sewer would discharge flow collected on King Street and Gerrish Street to the Avon River. A new stormwater outfall at King Street east is proposed. Diameters of storm sewers for the King Street east storm Sewer range from 525mm to 750mm.

## 6.1.4 Flow Control

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A phased approach to upgrade the existing combined sewer with the proposed upgrades in any of the options will be required. The proposed phasing plan starts at the river and goes uphill. As a result, new sanitary pipe will be connected to the discharge of an existing combined sewer pipe. The new sanitary pipe will be smaller than the existing combined sewer pipe and therefore care will be needed during design to develop a flow control/diversion strategy to divert excess flows from the existing combined system to the new stormwater system. If care is not taken the existing combined system could surcharge resulting in flooding of basements.

## 6.2 Cunnabel Creek Focused Options

The Cunnabel Creek drainage area contains most of the deficiencies and as such we explored options that would improve stormwater capacity in this area prior to full separation. The options analyzed in this context may not be the most efficient or effective long term option for the entire Windsor Downtown system, but they could provide quicker benefits to the highest impacted areas. Some of these options do not require separation and as a result if those options are selected the entire approach to separation and stormwater management may need to be re-examined.

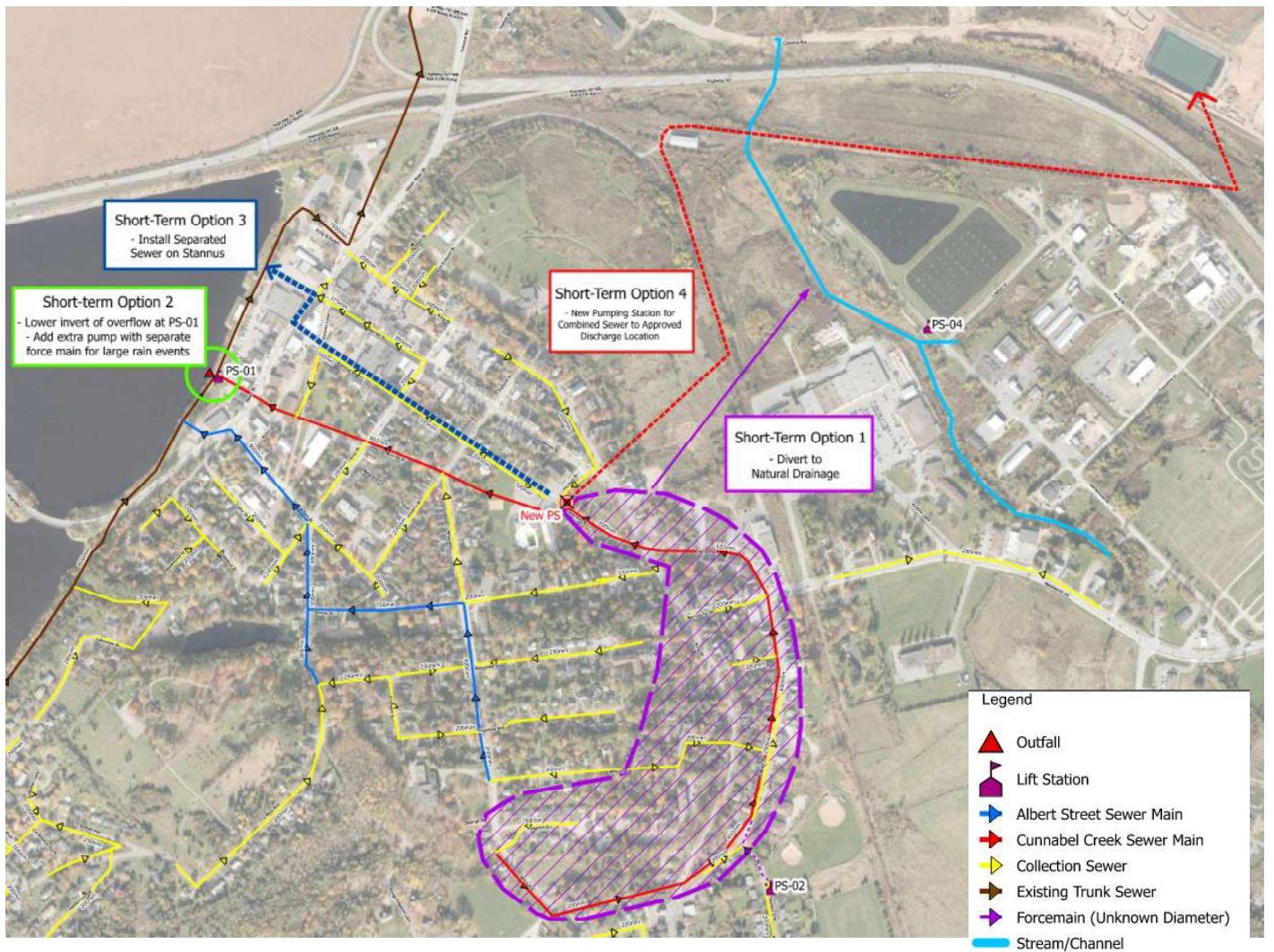
Five options were evaluated. These options are discussed below and presented in Figure 6.6. refer to Appendix E for full size drawing. Figure 6.7 shows a profile view of the combined sewer from just upstream of Stannus Street to PS-01 with the hydraulic grade line for each option.

### 6.2.1 Cunnabel Creek Option 1 – Upstream Separation

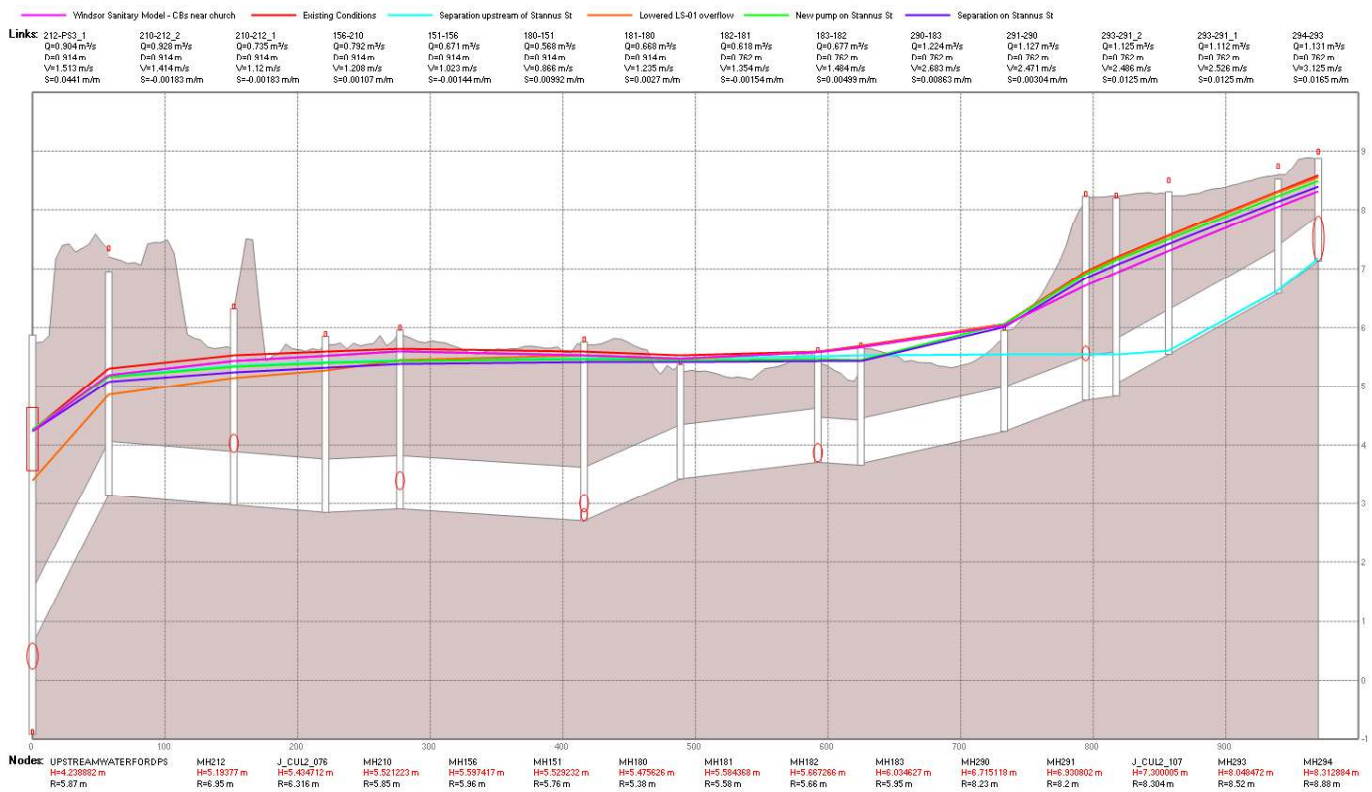
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This option investigated separating the combined sewer upstream of Stannus Street which would include O'Brian Street, Wentworth Road, St. John Street, Edgehill Court, and parts of Wilson Street and Wiley Avenue. The objective of this option would be to remove the upstream stormwater flows from the Stannus Street area and divert it to Tregothic Marsh behind Sobeys. This would reduce the stormwater flows to Cunnabel Creek and provide some relief under smaller storms, provide some improvement in the short term until full separation is completed.

This option significantly reduced the hydraulic grade line (HGL) in the upstream separated area. The model showed that even with this flow diversion the Cunnabel Creek combined sewer would still surcharge, meaning that limited improvements would be achieved for the design storm. The diversion of flows to the Tregothic Marsh would have impacts on that system and those impacts would need to be understood prior to moving forward with this option.



**Figure 6.6: Cunnabel Creek Options**



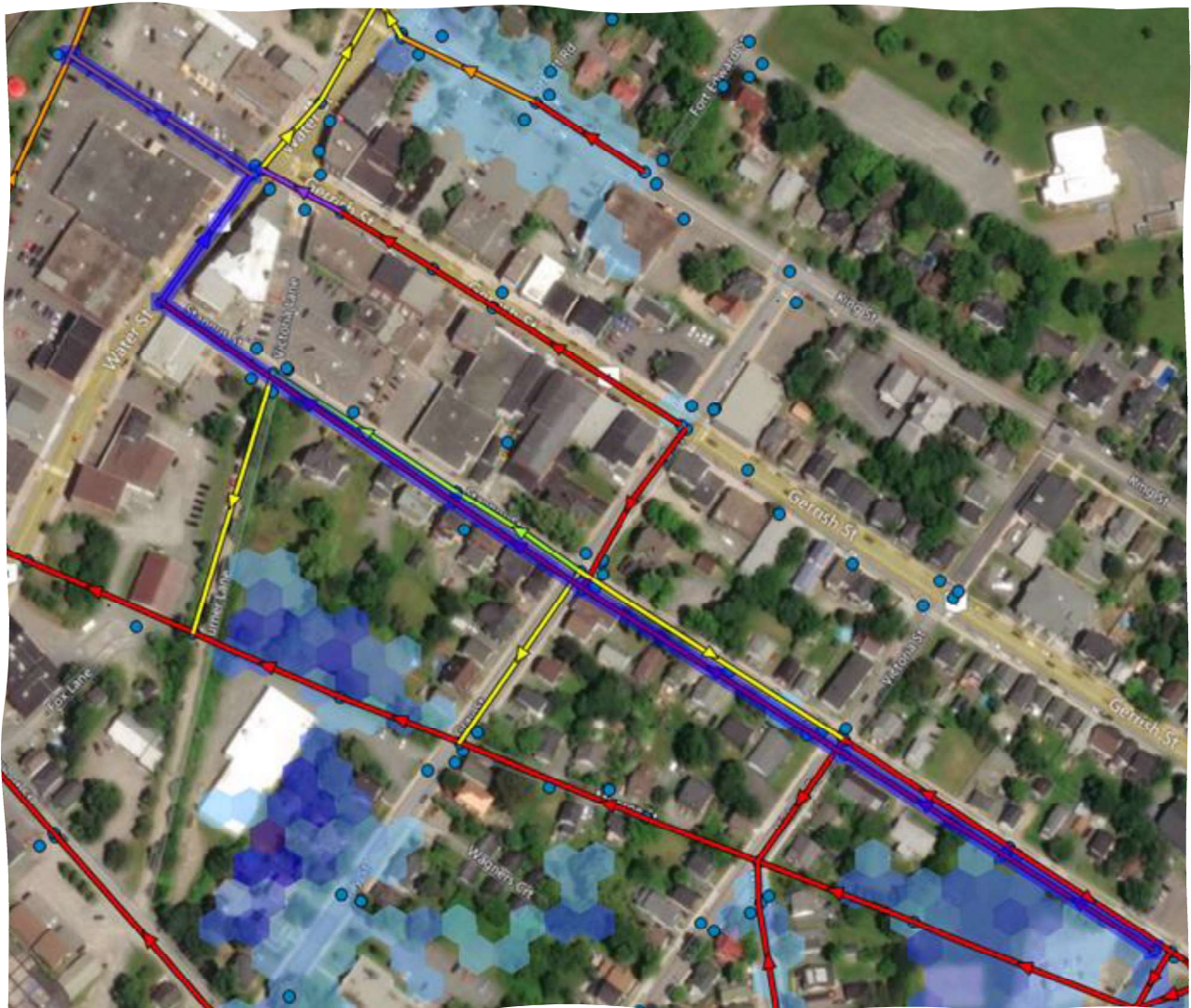
**Figure 6.7: Sewer Profile with HGL Along Cunnabel Creek**

## 6.2.2 Cunnabel Creek Option 2 – Lower the Overflow at PS1

This option investigated lowering the invert of the overflow at PS-01 from elevation 3.57m to elevation 2.57m, and adding an extra pump at PS-01 with a separate force main for use during large rain events. The objective of this option was to increase the downstream conveyance to see if this would allow more stormwater to enter the system. Model results showed no noticeable change in system performance. This is because the Cunnabel Creek combined sewer is already flowing at capacity and does not have the ability to transport additional flows to the pump station.

## 6.2.3 Cunnabel Creek Option 3 – Separating Stannus Street

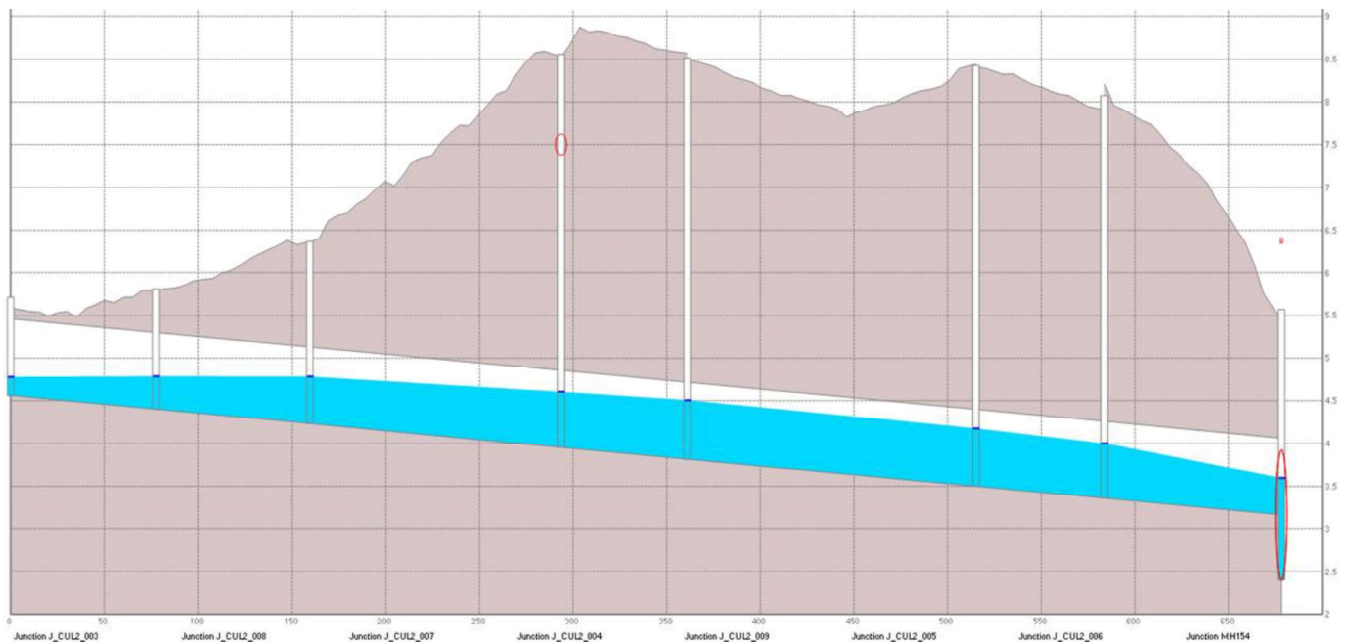
This option investigated the benefit of separating Stannus Street as the first phase. Under this option we assumed a new sewer and stormsewer would be installed on Stannus Street with sewer pipe connected to the existing truck sewer next to Avon River and the stormwater pipe discharging directly to the Avon River. The dark blue line in Figure 6.8 represents the proposed Stannus Street separation.



**Figure 6.8: Stannus Street Separation**

Under this option the upstream combined sewer would be connected to the new sewer with a flow control structure to allow combined sewer to be discharged to the new stormsewer when the flows in the sewer system reach a predetermined rate and flows above that rate are discharged to the stormsewer. The new sewer and stormsewers would be sized to accommodate all future flows that could enter the system as upstream separation advances. The upstream separation would be as noted in Cunnabel Creek Option 1. As the upstream stream system is separated the sewer and storm pipes would be connected to the correct pipes. This approach is a common approach but would need approval from regulatory agencies as it has the potential to increase combined sewer discharges until separation is completed.

The installation of the storm sewer and sanitary sewer would be very deep, see Figure 6.9, in some locations. Construction options such as tunneling open trench would need to be evaluated to determine how to best construct this option.



**Figure 6.9: Stormsewer on Stannus Street**

This option did identify some improvements in local flooding, see reduced flooding in Figure 6.8, and the new piping would be designed to not surcharge to prevent basement flooding to homes connect to the new system.

## 6.2.4 Cunnabel Creek Option 4 – Installation of a Stormwater Pump on Stannus Street

Option 1 identified that local improvements were not realized by downstream pumping because the Cunnabel Creek combined sewer is at capacity. This option looked at installing a combined sewer pump system in the Stannus Street area that would pump combined sewer to the Avon River or the existing sewage treatment plant once the combined sewer flows reached a certain elevation. This option was evaluated with based on a maximum pumping rate of 1,000lps (13,000 lgal/m).

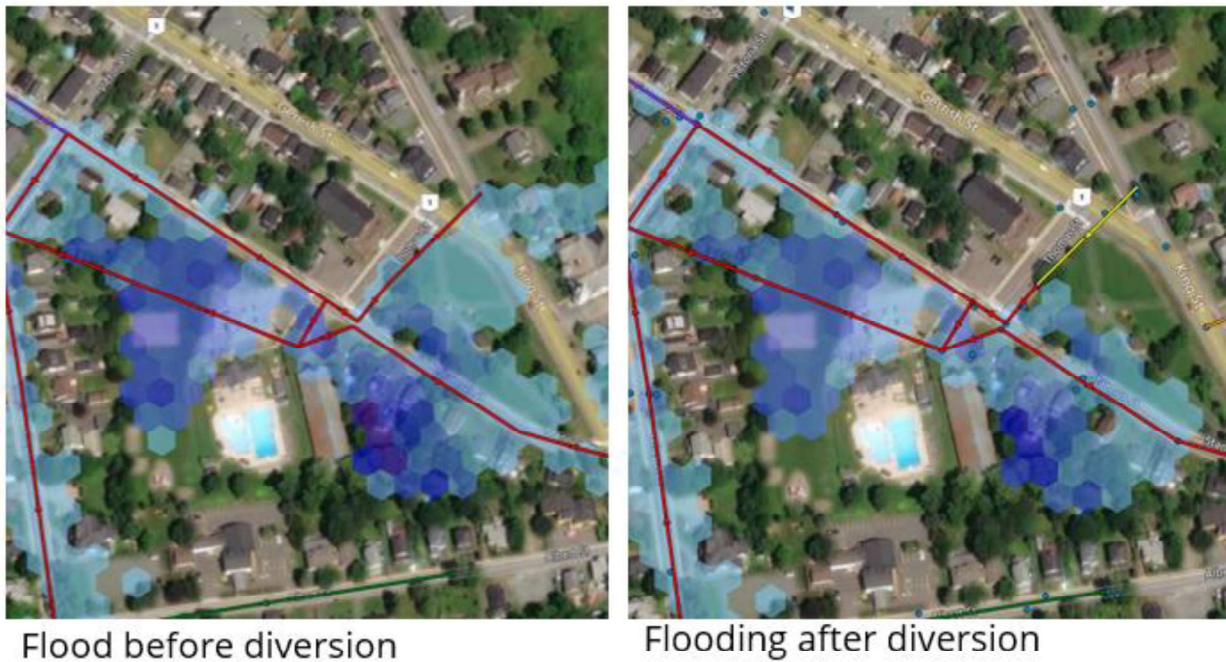
This option showed that removing flows from the system in this area did improve the performance of the Cunnabel Creek combined sewer. With this option the Cunnabel Creek combined sewer still surcharges but the combined sewer does not surface and flow overland. Local surface flood is improved some as there is more capacity in the system to allow surface water to enter. The combined sewer level was not reduced in the system enough to prevent backups into homes and backflow preventors would still be required.

There would need to be discussion with regulatory agencies on how this option could be implemented, what would be an acceptable level of treatment, etc.

A modified version of this option would be to design a large gravity sewer (similar to Option 3) and direct the flow to Avon River or to an existing pump station and upgrade the existing pumpstation installed or building a new one.

## 6.2.5 Cunnabel Creek Option 5 – Local Stormwater Collection and Discharge to Tregothic Marsh

This option looked at collecting and diverting surface water in the Stannus Street area to Tregothic Marsh. This would require the installation of a local sewer collection systems and a stormwater pipe that would cross King Street and discharge to Tregothic Marsh. This option reduced the surface water levels but did not improve levels in the combined sewer system and therefore sewer backups would not be prevented. Refer to Figure 6.10 for comparison of surface flooding with no system changes and flood after this option is implemented.



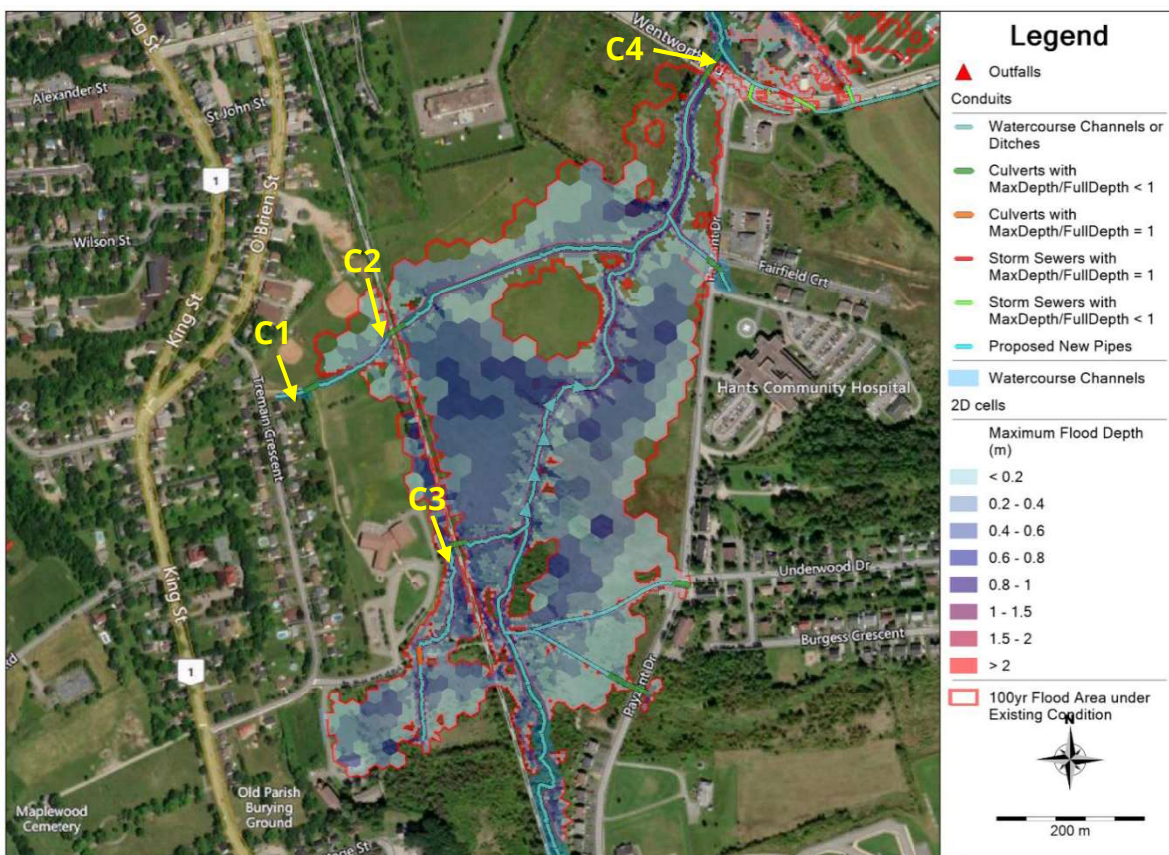
**Figure 6.10: Flood Comparison**

## 6.3 Proposed Tregothic Marsh Stormwater Upgrades

The following section provides proposed stormwater upgrades for the various areas of Tregothic Marsh.

### 6.3.1 Agricultural Area South of Wentworth Road

Proposed upgrades in the area are mainly on the culverts along the watercourse channels. The flood extents with proposed upgrades are presented in Figure 6.11, and the details for the culverts with proposed upgrades are summarised in Table 6.1. Additional survey would be required to confirm the sizes of unsurveyed culverts for culvert upgrades in the detailed design phase and to assess the local flooding at Tremain Crescent. The upgrades of the culverts decreased the flood extents to an extent, but since the area is a large natural floodplain for Tregothic Creek, it was found that there are no efficient mitigation measures for the area. Local areas that discharge into this area, and that are at higher elevations, should be evaluated on a case by case bases to determine how to best manage local stormwater in these areas.



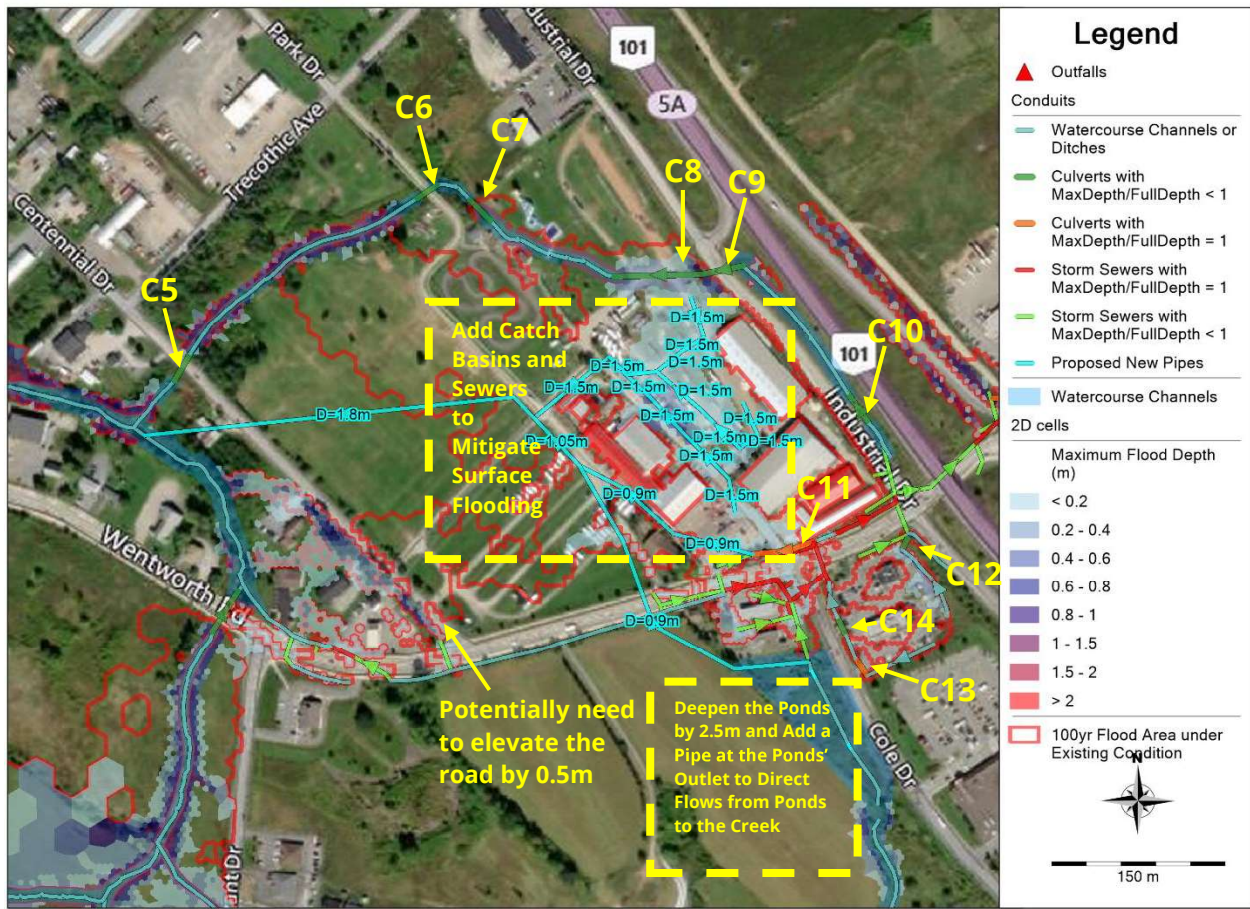
**Figure 6.11: 1:100 Flood Tregothic Marsh Area with Proposed Upgrades – Agricultural Area South of Wentworth Road**

**Table 6.1: Proposed Upgrades on Culverts in the Area**

Culvert Name	Location	Survey Condition	Culvert Sizes in the Model for Existing Condition with Upstream (U/S) H/D	Culvert Sizes in the Model for Proposed Upgrades with Upstream (U/S) H/D
C1	Outlet of the ditch and across the road	Surveyed	Circular culvert with a diameter of 0.6m with U/S H/D at 1.23	Circular culvert with a diameter of 0.75m with U/S H/D at 0.88
C2	Outlet of the ditch and across the train track	Unsurveyed	Circular culvert with a diameter of 0.6m with U/S H/D at 1.8	Circular culvert with a diameter of 0.9m with U/S H/D at 0.78
C3	Outlet of the ditch and across the train track	Unsurveyed	Circular culvert with a diameter of 0.6m with U/S H/D at 1.47	Circular culvert with a diameter of 0.9m with U/S H/D at 0.88
C4	Along Tregothic Creek and across Wentworth Road	Surveyed	Circular culvert with a diameter of 1.2m with U/S H/D at 2.32	Rectangular culvert with the height and width at 2.438m with U/S H/D at 0.79

### 6.3.2 Industrial Area Near the Intersection of Wentworth Road and Industrial Drive

Proposed upgrades in the area are mainly on deepening the existing detention ponds by 2.5m, adding a sewer system in the area to direct flows from the industrial area to Tregothic Creek, upgrading the culverts along the ditches, as well as elevating one section of Centennial Drive by 0.5m to prevent overflows to the parking lot from the road. The proposed new sewer system would include an outflow pipe with a diameter of 0.9m to direct flows from the existing detention ponds, a pipe with a diameter of 0.9m to collect flows from the reversed Culvert C11, catchbasins and underground pipes with a diameter of 1.5m in the parking lot area to mitigate the surface flooding, and a pipe with a diameter of 1.8m across the field for all the directed flows above to discharge into Tregothic Creek. In addition, it has been tested that a ditch with 2m width, 1m depth, and 2:1 slope would likely be required to remove all stormwater remaining on the surface in the parking lot. Note that the pipe diameters, slopes, and layout of the proposed new sewer system are subject to further investigation on the local geometry, and since there was not much survey information in the area but only record drawings, any upgrades regarding the existing detention ponds, culverts, sewers, and roads would require further survey information in the detailed design phase to ensure all the elements in the model are in line with the existing conditions. The flood extents with proposed upgrades are presented in Figure 6.12, and the details for the culverts with proposed upgrades are summarised in Table 6.2.



**Figure 6.12: Flood Extents 1:100 Event Tregothic Marsh Area with Proposed Upgrades – Industrial area near the Intersection of Wentworth Road and Industrial Drive**

**Table 6.2: Proposed Upgrades on Culverts in the Area**

Culvert Name	Location	Survey Condition	Culvert Sizes in the Model for Existing Condition with Upstream (U/S) H/D	Culvert Sizes in the Model for Proposed Upgrades with Upstream (U/S) H/D
C5	Outlet of the channel and across Centennial Drive	Unsurveyed, drawing available	Rectangular culvert with the height at 1.219m and width at 3.353m with U/S H/D at 1.85	Rectangular culvert with the height at 3.353m and width at 3.353m with U/S H/D at 0.81
C6	Along the ditches and across the road	Unsurveyed	Circular culverts with a diameter of 0.6m with U/S H/D at 2.85 with U/S H/D at 2.08	Circular culverts with a diameter of 1.35m with U/S H/D at 0.77 with U/S H/D at 0.77

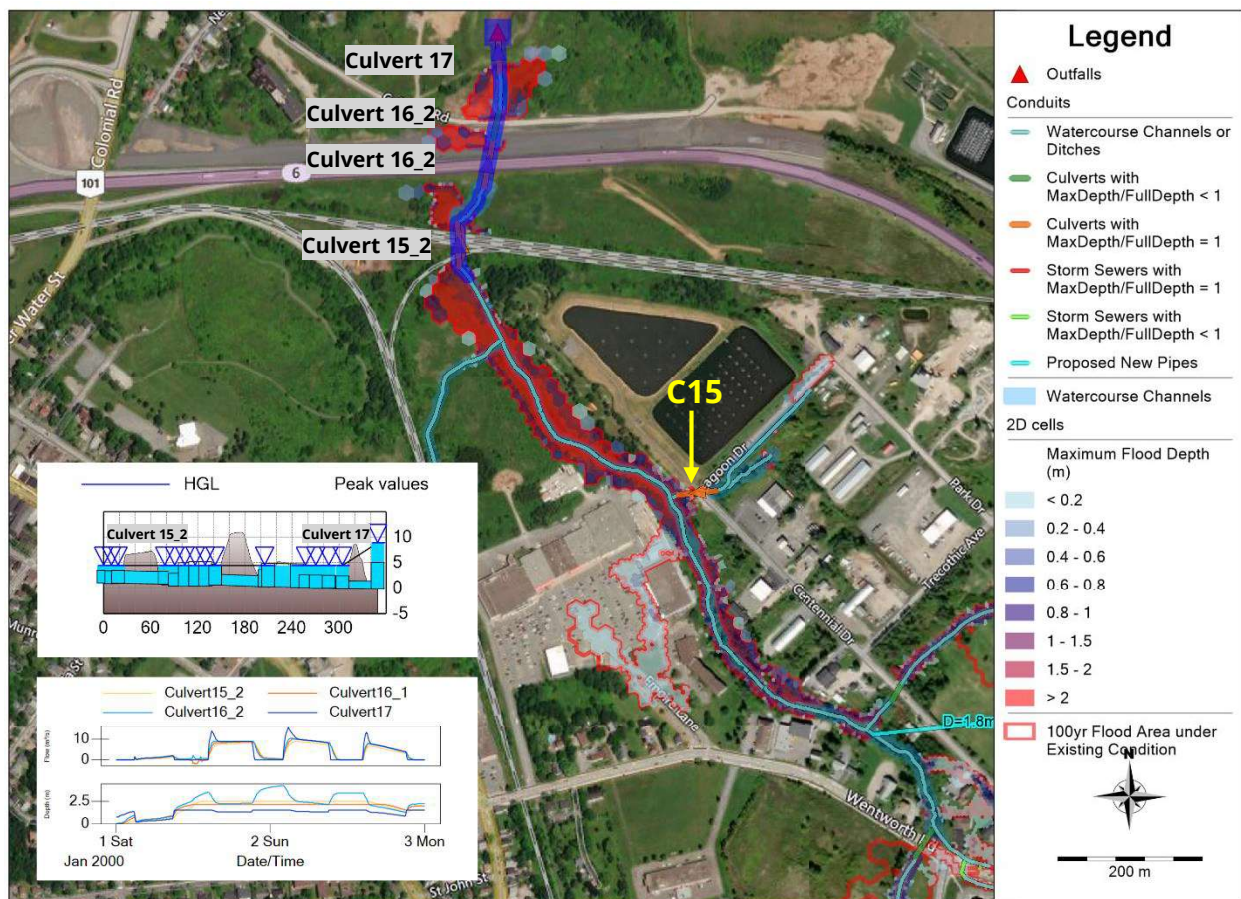
Culvert Name	Location	Survey Condition	Culvert Sizes in the Model for Existing Condition with Upstream (U/S) H/D	Culvert Sizes in the Model for Proposed Upgrades with Upstream (U/S) H/D
C7	Along the ditches and across the road	Unsurveyed	Circular culverts with a diameter of 0.6m with U/S H/D at 2.85 with U/S H/D at 3.02	Circular culverts with a diameter of 1.35m with U/S H/D at 0.77 with U/S H/D at 0.81
C8	Along the ditches and across the road	Unsurveyed	Circular culverts with a diameter of 0.6m with U/S H/D at 2.9	Circular culverts with a diameter of 1.35m with U/S H/D at 0.87
C9	Along the ditches and across the road	Unsurveyed	Circular culverts with a diameter of 0.6m with U/S H/D at 3.03	Circular culverts with a diameter of 1.35m with U/S H/D at 0.94
C10	Along the ditch and across the road	Unsurveyed	Circular culvert with a diameter of 0.6m with U/S H/D at 2.92	Circular culvert with a diameter of 1.2m with U/S H/D at 1.03
C11	Outlet of the ditch and across the road	Unsurveyed, drawing available	Circular culvert with a diameter of 0.381m with U/S H/D at 1.92	Circular culvert with a diameter of 0.9m with U/S H/D at 1.1 (Note: need to reverse the culvert direction)
C12	Outlet of the ditch and across the vegetated land	Unsurveyed, drawing available	Circular culvert with a diameter of 0.381m with U/S H/D at 2.39	Circular culvert with a diameter of 0.9m with U/S H/D at 0.74
C13	Along the ditches and across the road	Unsurveyed	Circular culverts with a diameter of 0.381m with U/S H/D at 4.36	Circular culverts with a diameter of 0.9m with U/S H/D at 1.36
C14	Along the ditches and across the road	Unsurveyed	Circular culverts with a diameter of 0.381m with U/S H/D at 3.99	Circular culverts with a diameter of 0.9m with U/S H/D at 1.23

### 6.3.3 Downstream of Tregothic Creek from Wentworth Road to the Outlet

Culvert upgrades and the option of adding a pump near the outlet of Tregothic Creek were investigated. Based on the modelling results, the culvert located near Lagoon Drive crossing Centennial Drive do not have capacity for the 1 in 100 year design event, and the proposed upgrade is as shown in **Table 6.3** Table 6.3. The upgrades mentioned in the Chapter 6.3.1 and Chapter 6.3.2 as well as the upgraded culvert C15 would lead to more water directed to Tregothic Creek, and the resulting flood extents for the 1 in 100 year design event is presented in Figure 6.13. Flap Gate would be in place during high tide, and when the gate opens, the culverts (culvert 15\_2, culvert 16\_1, culvert 16\_2, and culvert 17) are still full during low tides in the 24-h rainfall event. It was noted that the increase of flood extents and depths in the downstream of Tregothic Creek as a result of the proposed upgrades upstream is not significant, and there are no increasing risks on the existing buildings along the Creek from the proposed upgrades upstream.

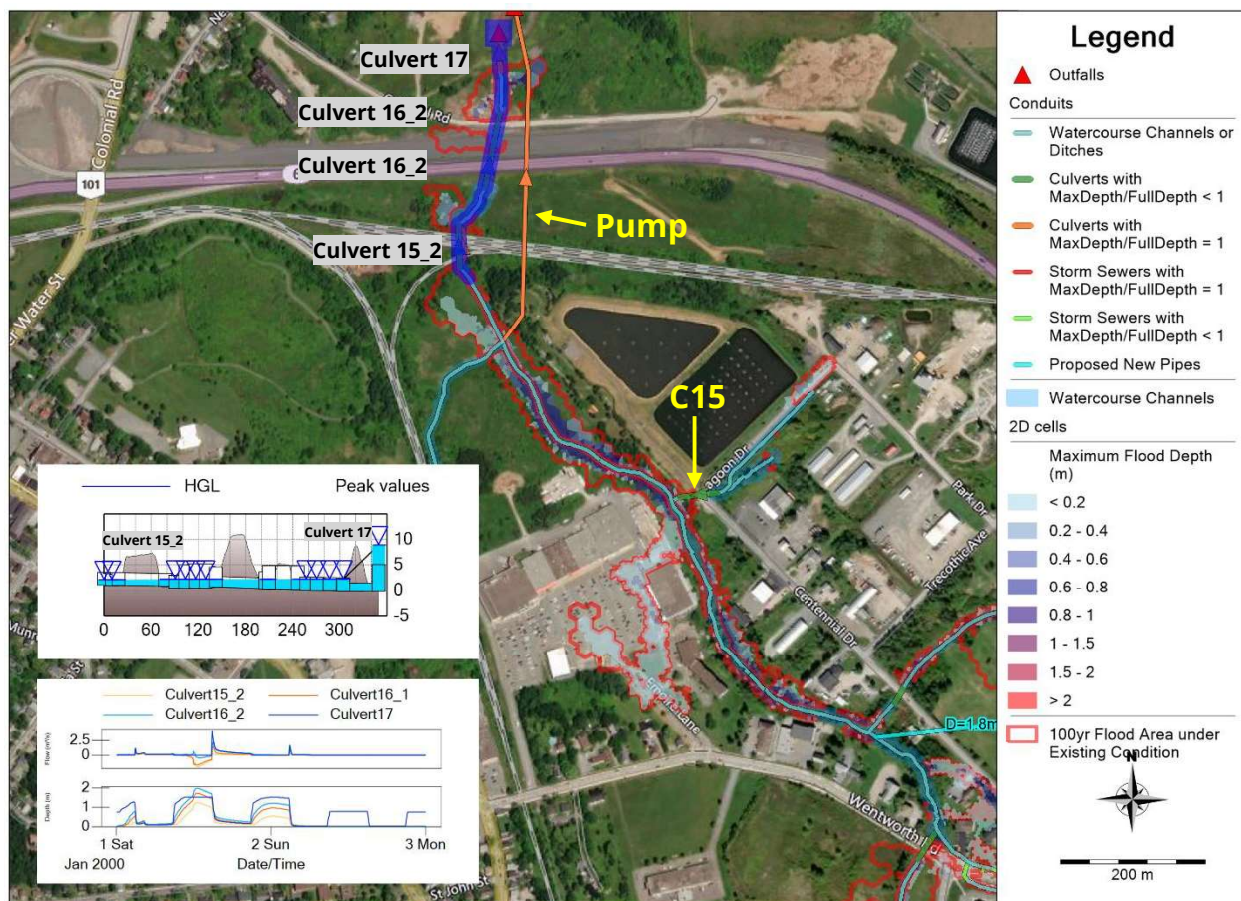
**Table 6.3: Proposed Upgrades on Culverts in the Area**

Culvert Name	Location	Survey Condition	Culvert Sizes in the Model for Existing Condition with Upstream (U/S) H/D	Culvert Sizes in the Model for Proposed Upgrades with Upstream (U/S) H/D
C15	Outlet of the ditch and across Centennial Drive	Surveyed	Circular culverts with a diameter of 0.25m with U/S H/D at 6.96	Circular culverts with a diameter of 1.2m with U/S H/D at 1.06



**Figure 6.13: Flood Extents 1:100 Event of the Tregothic Marsh Area with Proposed Upgrades – Downstream of Tregothic Creek from Wentworth Road to the Outlet (without the Pumping Station)**

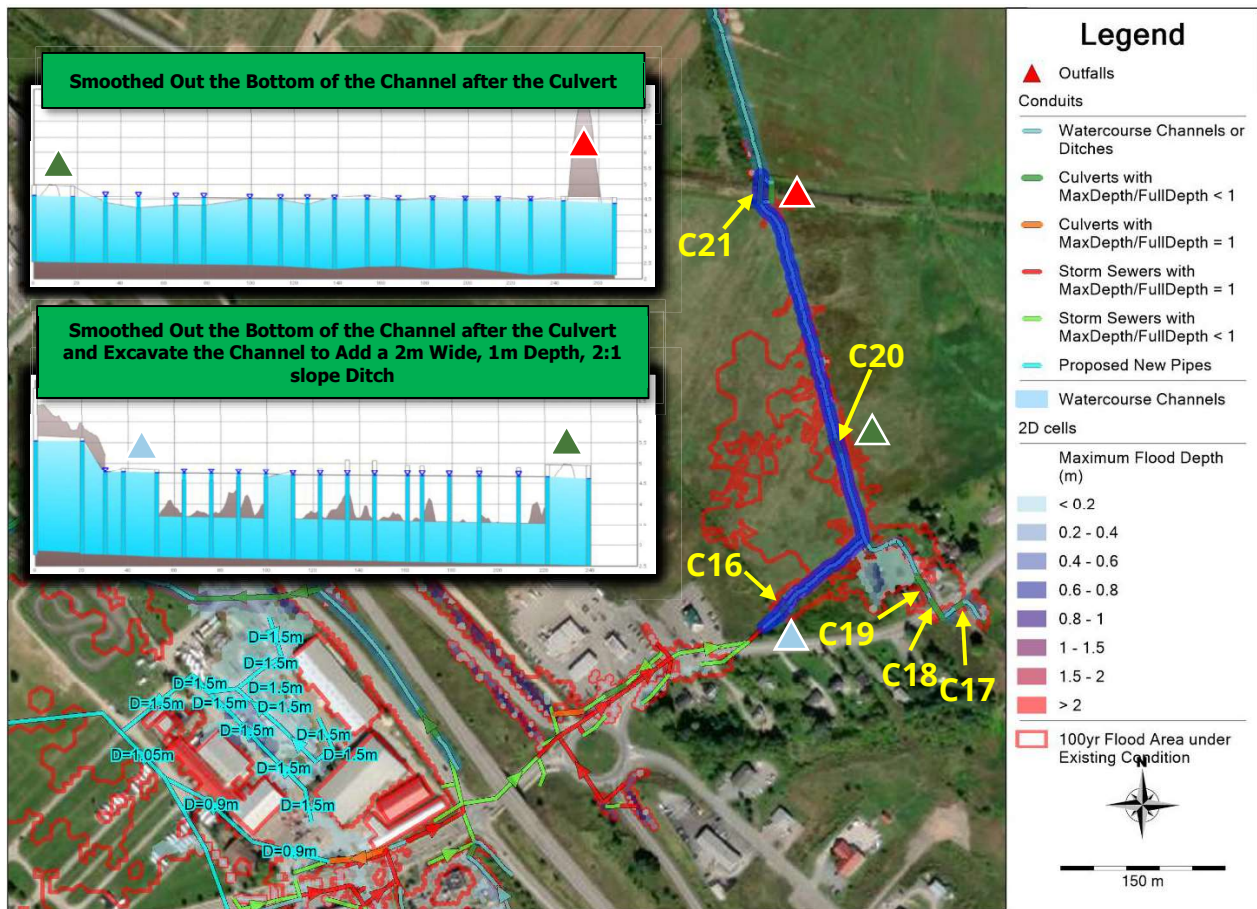
The option of adding a pump near the outlet of Tregothic Creek was tested to investigate the resulting reduction in flood extents. The pumping station was modelled to start when the water depth reaches 0.5m, with the maximum flow rate at  $\sim 12\text{m}^3/\text{s}$ , and total pumped water volume at  $687 \times 10^6$  ltr. The flood extents for the 1 in 100 year design event with proposed upgrades (including the upgrades mentioned in the Chapter 6.3.1 and Chapter 6.3.2, as well as the upgraded culvert C15) are presented in Figure 6.14. Flap Gate would be in place during high tide, and when the gate opens, the culverts (culvert 15\_2, culvert 16\_1, culvert 16\_2, and culvert 17) are not full during low tides in the 24-h rainfall event. It was noted that the pumping station does help reducing the restrictions on the outflows and decreasing the flood extents, especially in the downstream area near the multiple culverts at the outlet, but the influence was not significant to impact areas beyond 700m upstream from the outlet of Tregothic Creek, and does not help reducing the risks to the existing buildings along the Creek.



**Figure 6.14: Flood Extents 1:100 Event of Tregothic Marsh Area with Proposed Upgrades – Downstream of Tregothic Creek from Wentworth Road to the Outlet (with the Pumping Station)**

### 6.3.4 Open Ditch Area

Proposed upgrades in the area are including adding a ditch with 2m width, 1m depth, and 2:1 slope to the existing ditch and upgrading the culverts along the watercourse channels. The ditch bottom geometry also requires adjustments to prevent water backing up from the ditch to Culvert C17 and Culvert C21. Note that the additional survey of the cross sections of ditch would be required for related upgrades in this area. The flood extents for the 1 in 100 year design event with proposed upgrades are presented in Figure 6.15, and the details for the culverts with proposed upgrades are summarised in Table 6.4.



**Figure 6.15: Flood Extents 1:100 Event for the Tregothic Marsh Area with Proposed Upgrades - Open Ditch Area**

**Table 6.4: Proposed Upgrades on Culverts in the Area**

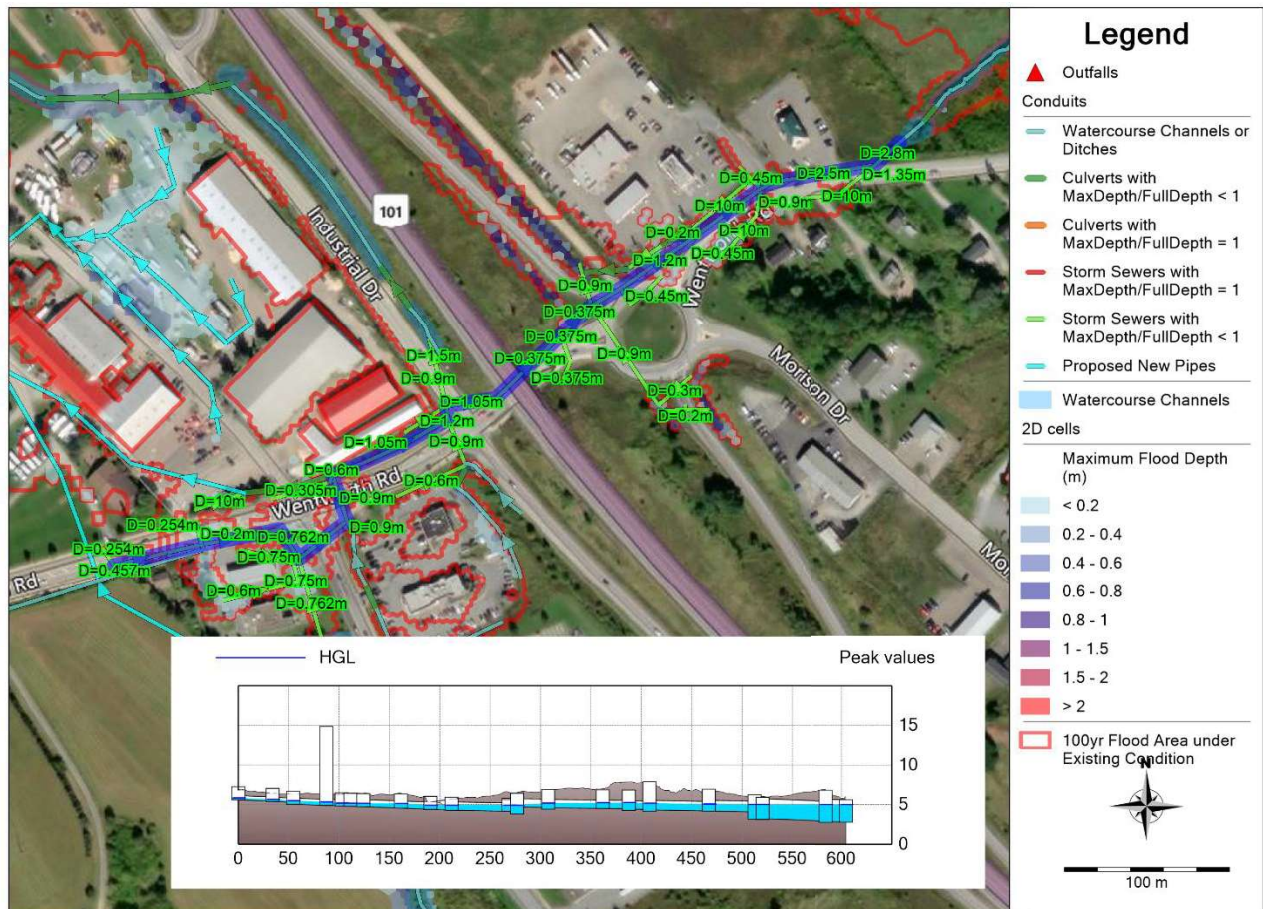
Culvert Name	Location	Survey Condition	Culvert Sizes in the Model for Existing Condition with Upstream (U/S) H/D	Culvert Sizes in the Model for Proposed Upgrades with Upstream (U/S) H/D
C16	In the vegetated land	Surveyed, and drawing available	Circular culvert with a diameter of 0.75m (based on survey); Circular culvert with a diameter of 1.05m (based on drawing) with U/S H/D at 2.41	Rectangular culvert with the height at 2.134m and width at 2.743m with U/S H/D at 0.95

Culvert Name	Location	Survey Condition	Culvert Sizes in the Model for Existing Condition with Upstream (U/S) H/D	Culvert Sizes in the Model for Proposed Upgrades with Upstream (U/S) H/D
C17	Outlet of the ditch and across the road	Surveyed	Circular culvert with a diameter of 0.6m with U/S H/D at 1.5	Circular culvert with a diameter of 1.05m, with invert adjustments and U/S H/D at 1.01
C18	Outlet of the ditch and across Wentworth Road	Surveyed	Circular culvert with a diameter of 0.6m with U/S H/D at 1.67	Circular culvert with a diameter of 1.05m, with invert adjustments and U/S H/D at 0.88
C19	In the vegetated land	Surveyed	Circular culvert with a diameter of 0.75m with U/S H/D at 1.08	Circular culvert with a diameter of 1.2m, with invert adjustments and U/S H/D at 0.88
C20	In the vegetated land	Surveyed	Circular culvert with a diameter of 0.9m with U/S H/D at 2.76	Rectangular culvert with the height and width at 2.438m with U/S H/D at 0.87
C21	Along open ditch and Across the train track	Surveyed	Circular culvert with a diameter of 1.2m with U/S H/D at 2.08	Rectangular culvert with the height and width at 2.438m with U/S H/D at 0.93

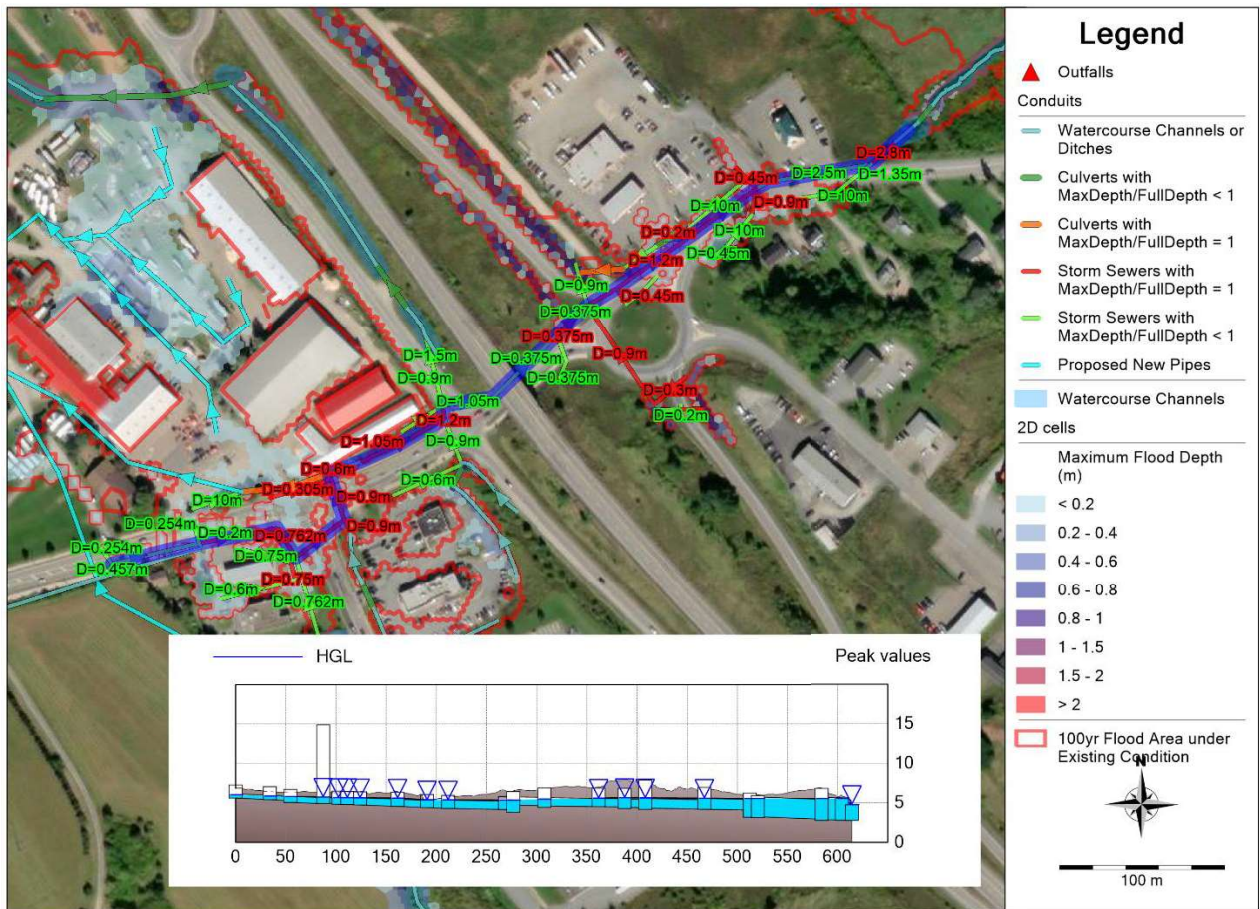
### 6.3.5 Storm Sewer Systems along Wentworth Road

Surcharging and overflowing were noted from the existing storm sewer system along Wentworth Road under the 1 in 10 year and 1 in 100 year design events. Proposed upgrades to the sewers were modelled to have the ratio of the 1 in 10 year design flow to full flow pipe capacity less than 80%. The resulting upgraded sewers also have the capacity for the 1 in 100 year design flow. The flood extents and sewer profiles with proposed upgrades for the 1 in 10 year and 1 in 100 year design events are presented in Figure 6.16 and Figure 6.17 respectively, with proposed sizes labelled in each sewer. Note that the proposed pipe diameters are subject to further investigation on the existing sewer system along Wentworth Road and Cole Drive since there was no survey information of the sewer system in the area but only record drawings. The proposed upgrades selected for the

existing detention ponds and for the industrial area near the intersection of Wentworth Road and Industrial Drive could also affect the sizing of the proposed upgrades on the existing sewer system along Wentworth Road.



**Figure 6.16: Flood Extents for 1:10 Year Event for Tregothic Marsh Area with Proposed Upgrades – Storm Sewer Systems along Wentworth Road**

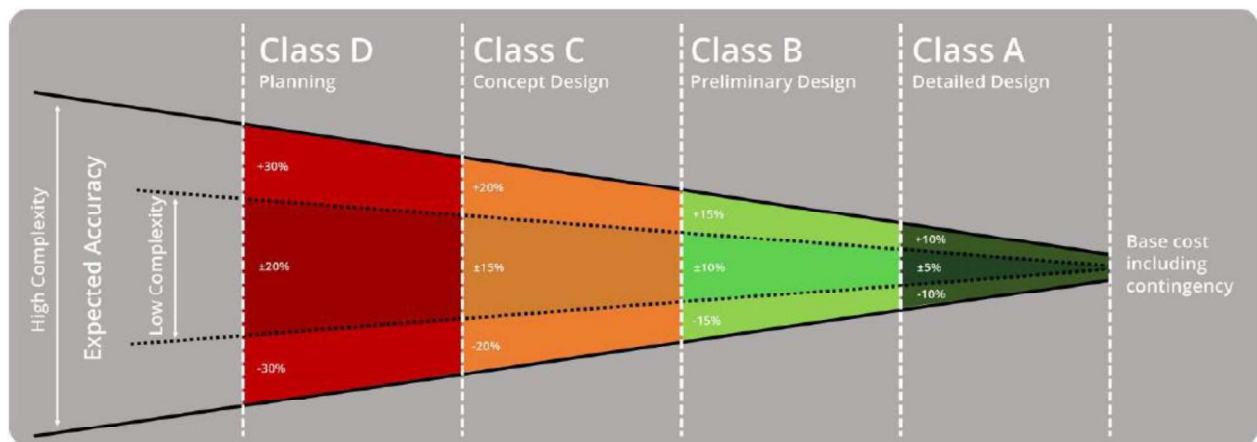


**Figure 6.17: Flood Extents 1:100 Year Event for Tregothic Marsh Area with Proposed Upgrades – Storm Sewer Systems along Wentworth Road**

## 7 Opinion of Probable Costs and Discussion

Costs were developed as part of the project to allow for comparison of options, not to set project budgets. In order to set actual project budgets Concept Design will be required to confirm routing, exact sizing of new infrastructure, existing infrastructure conflicts (that may result in the need to relocate or replace existing works), construction methods, property impacts, environmental requirements, and numerous other issues.

The estimates prepared as part of this project are considered Class D Cost (Planning Level) Estimates for a complex project. The typical range of accuracy of an estimate at this stage in project development is +/-30%. As the projects become more defined and developed the costs will be better defined. We have included a figure below that helps to illustrate this general concept. As more information is obtained and more engineering work carried out , cost certainty increases.



Costs presented below were developed based on a combination of measured units (typically linear length) with estimated unit rates (\$/meter for example) and numerous allowances. Units were calculated from the model for existing combined sewer and new stormwater sewers.

The estimates contain contingencies for design development, construction, and engineering. A brief description of each follows.

**Design development** contingency is used to account for items that have not been investigated or known to be part of the project at this stage. A value of 40% was used for these estimates.

**Construction contingency** is to account for items that may come up during construction as unforeseen conditions during the project design phase. A value of 10% was used for these estimates.

**Engineering contingency** is used to estimate design services that may be required in the design and construction phase of the project. These could include items such as engineering services, geotechnical investigation, survey, and approvals. A value of 12% was used for these estimates.

Note that items such as land purchases, legal services, staff time, and complex environmental assessment, are not included in the estimate.

## 7.1 Windsor Downtown – Long Term Options

Costs are presented for the Windsor Downtown study area. A more detailed presentation of costs is included in Appendix F.

Description	Option 1 Remove Flor from Cunnabel Creek	Option 2 Replace Existing System	Option 3 Split Flow between Cunnabel Creek and Albert Street
Construction Estimate	\$92,410,000	\$88,800,000	\$85,340,000
Design Development Allowance	\$36,970,000	\$35,520,000	\$34,140,000
Construction Contingency	\$12,938,000	\$12,432,000	\$11,948,000
Engineering	\$1,553,000	\$1,492,000	\$1,434,000
Costs with Construction Contingency Excl. HST	\$144,000,000	\$139,000,000	\$132,900,000

All of the above options will result in a new stormwater system that will accommodate the future 1:5 year storm with no surcharging. The sanitary would also provide reliable service and not surcharge preventing sewer backups.

Based on the accuracy of costing at this phase of a project all options would be considered equal in cost.

Option 3 would provide the quickest benefit to the Cunnabel Creek sewershed.

## 7.2 Cunnabel Creek Focused Option

This option used the same approach as the full separation option.

Description	Option 1 Separate Upstream of Stannus and Discharge Storm into Field Bedside Sobey's	Option 2 Lower the Invert of Overflow at PS1 Add Extra Pump with Added Separate	Option 3 Install Separate Sewer on Stannus Street	Option 4 Install Large Storm Pump Station on Stannus Street Pump Combined to Approved Discharge
Construction Estimate	\$27,555,240	\$17,172,000	\$9,826,620	\$20,950,000
Design Development Allowance	\$11,030,000	\$6,870,000	\$3,940,000	\$8,380,000
Construction Contingency	\$3,859,000	\$2,405,000	\$1,377,000	\$2,933,000
Engineering	\$4,630,320	\$2,885,040	\$1,652,040	\$3,519,600
Costs with Construction Contingency Excl. HST	\$47,080,000	\$29,340,000	\$16,800,000	\$35,790,000

As noted previously in the report Option 3 provides initial benefit and is a project that could be implemented in one large phase or 2 smaller phases. This followed by Option 1 would result in a large portion of the Cunnabel Creek watershed being separated and provide improvements in drainage.

Option 2 did not provide any benefit.

Option 4 provided benefit but could have high operational costs associated with a new pump station.

## 7.3 Tregothic Marsh

The Tregothic Marsh area needs 21 culvert replacement, upgrades to some existing stormwater system as well as new stormwater system. A summary is provided below with the detailed cost estimated provided in Appendix F. This includes the same contingencies as noted above.

Description	Tregothic Creek
Construction Estimate	\$10,110,000
Design Development Allowance	\$4,050,000
Construction Contingency	\$1,020,000
Engineering	\$1,220,000
Costs with Construction Contingency Excl. HST	\$16,400,000

# APPENDIX A

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## Existing System Configuration and Field Data Collection



- Legend**
- ★ Sewage Treatment Plant
  - ▲ Outfall
  - LIFT Station
  - Rainfall
  - Storm Sewerline
  - Manurep Marsh Stormwater Subcatchment
  - Singlep Marsh Stormwater Subcatchment
  - Windsor Downtown Stormwater Subcatchment
  - Overall Watershed
  - LIFT Station Catchment Area
  - Storm Water of Windsor Boundary

**Revision of Issue**

No	Date	Description
3	December 2023	ISSUED FOR - Final Report
2	November 2023	ISSUED FOR - Draft Report
1	April 2023	ISSUED FOR - Draft Report



Project: **MWH WINDSOR STORMWATER PLAN**

Figure 1  
Study area and Stormwater Subcatchments

**NOTE:**  
Stormwater Subcatchment delineations based on over-land surface water flow

Date	Issue	Scale
December 2023	Final Report	1:2,500
November 2023	Draft Report	---
April 2023	Draft Report	---

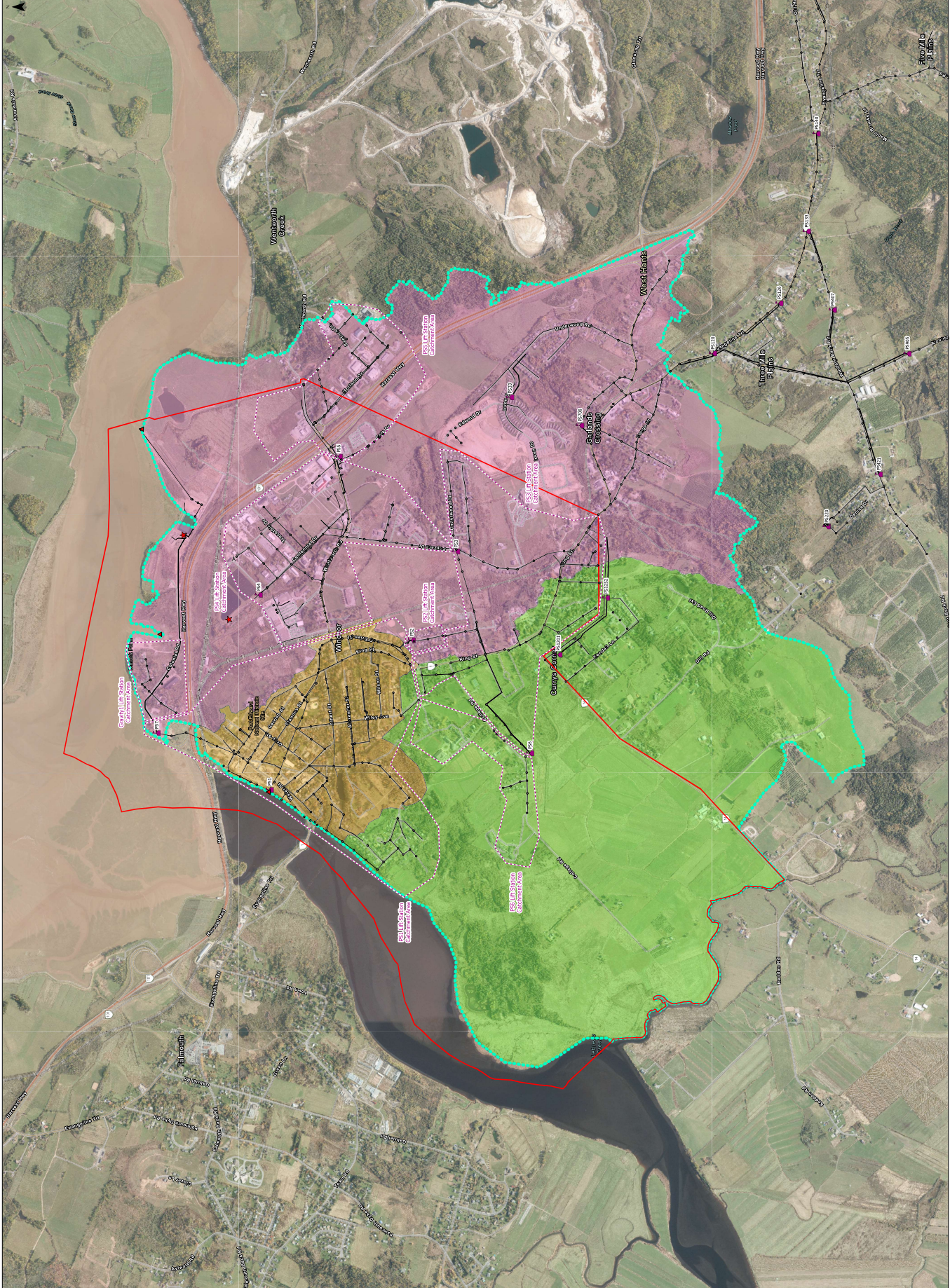
No	Date	Description
3	December 2023	ISSUED FOR - Final Report
2	November 2023	ISSUED FOR - Draft Report
1	April 2023	ISSUED FOR - Draft Report

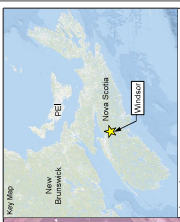
Project: **MWH WINDSOR STORMWATER PLAN**

Figure 1  
Study area and Stormwater Subcatchments



Date	Issue	Scale
December 2023	Final Report	1:2,500
November 2023	Draft Report	---
April 2023	Draft Report	---





- Legend**
- ▲ Outfall
  - ▲ LIFT Station
  - ▲ Gravity Pipe - Separated
  - ▲ Gravity Pipe Combined
  - ▲ Gravity Pipe Sanitary
  - ▲ Gravity Pipe Unknown
  - ▲ Gravity Pipe Storm
  - ▲ Stormwater Catch Basin Lead
  - ▲ Catchment
  - ▲ Dewatered Sewer
  - ▲ Unknown (Unknown Diameter)
  - ▲ Albert Street Sewer Main
  - ▲ Dumbell Creek Sewer Main
  - ▲ Collection Sewer
  - ▲ Existing Trunk Sewer
  - ▲ Stream/Channel
  - ▲ Subcatchment
  - ▲ Tripathic Head Stormwater Subcatchment
  - ▲ Subcatchment Stormwater
  - ▲ Subcatchment Stormwater
  - ▲ Subcatchment Stormwater
  - ▲ Albert Street Sewer Main Catchment
  - ▲ Dumbell Creek Sewer Main Catchment
  - ▲ LIFT Station Catchment Areas

**NOTE:**  
Stormwater Subcatchment delineations based on over-land surface water flow

No	Date	Description
3	December 2023	ISSUED FOR - Final Report
2	November 2023	ISSUED FOR - Draft Report
1	April 2023	ISSUED FOR - Draft Report

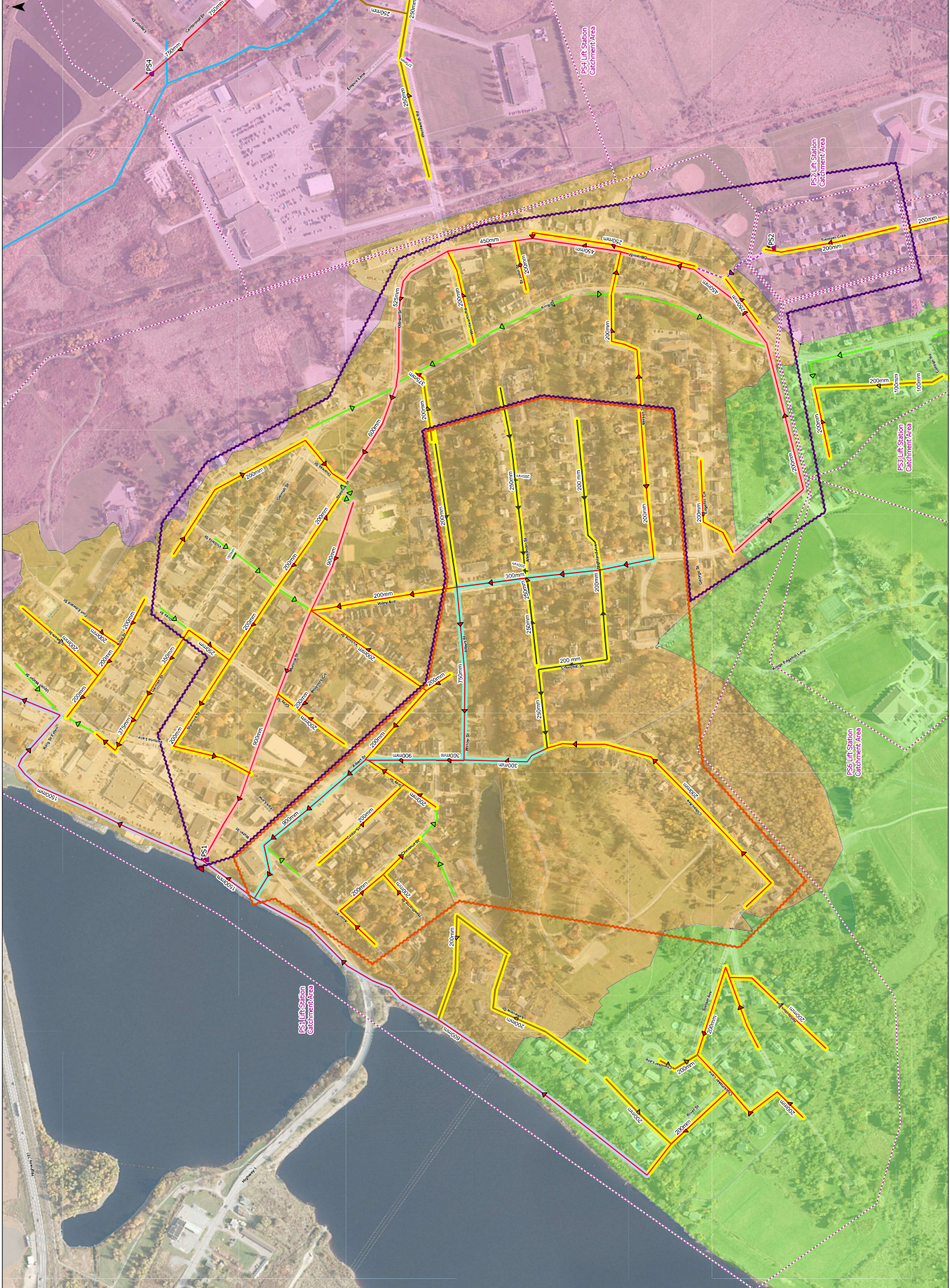
Revision or Issue	
No	Description

West Hants  
Engineering & Planning Inc.

**CBCL**

Figure 1.2  
Existing Main and  
Collection Sewers

Date	December 2023	Scale	1:3,500
Drawn	CH	Designed	---
Checked	---	Approved	---
Project No.	221101.00	Figure No.	1.2





- Legend**
- ▲ Outfall
  - ▲ Lift Station
  - ▲ Stormy Pipe Combined
  - ▲ Stormy Pipe Sanitary
  - ▲ Stormy Pipe Storm
  - ▲ Stormy Pipe Storm
  - ▲ Stormwater Catch Basin Lead
  - ▲ Culvert
  - ▲ Unknown Diameter Sewer
  - ▲ Roseman (Unknown Diameter)
  - ▲ Abert Street Sewer Main
  - ▲ Colwell Creek Sewer Main
  - ▲ Existing Trunk Sewer
  - ▲ Stream/Channel
  - ▲ Windsor Downtown Stormwater Subcatchment
  - ▲ Windsor Downtown Stormwater Subcatchment
  - ▲ Lift Station Catchment Area
  - ▲ Unsurveyed Culvert
  - ▲ Surveyed Culvert, Missing Data

**NOTE:**  
Stormwater Subcatchment delineations based on overland surface water flow

No	Date	Description
3	December 2023	ISSUED FOR - Final Report
2	November 2023	ISSUED FOR - Draft Report
1	April 2023	ISSUED FOR - Draft Report

Revision of Issue	
No	Description



Project: **MWH WINDSOR STORMWATER PLAN**

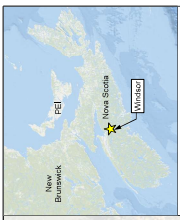
Figure 1.3  
Tregohic Marsh  
Existing Conditions

**CBCL**

Date:	December 2023	Scale:	1:2,500
Drawn:	CH	Designed:	---
Checked:	---	Approved:	---
Project No.:	221101.00	Figure No.:	1.3







- Legend**
- Flow Meter Location
  - Outfall
  - Lift Station
  - Manhole - Combined
  - Manhole - Sanitary
  - Manhole - Storm
  - Manhole - Unknown
  - Grassy Pipe - Combined
  - Grassy Pipe - Sanitary
  - Grassy Pipe - Unknown
  - Grassy Pipe - Storm
  - Stormwater Catch Basin Lead
  - Culvert
  - Accession
  - Stormwater Subcatchment
  - Stormwater Subcatchment
  - Windsor Downtown Stormwater Subcatchment
  - Tregeothic Creek Stormwater Subcatchment

**NOTE:**  
Stormwater Subcatchment delineations based on overland surface water flow

No	Date	Description
3	December 2023	ISSUED FOR - Final Report
2	November 2023	ISSUED FOR - Draft Report
1	April 2023	ISSUED FOR - Draft Report

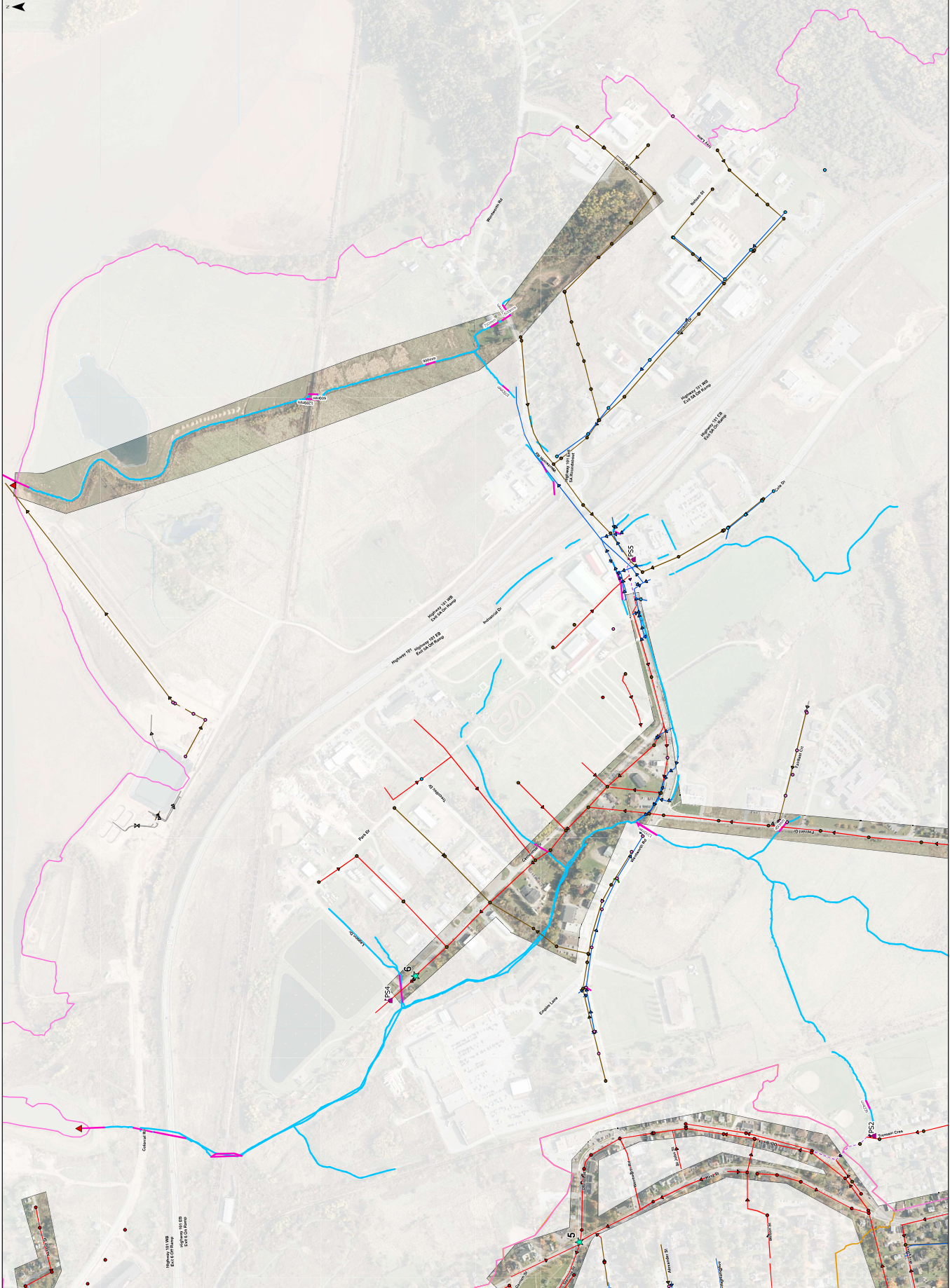
No	Date	Description
Revision or Issue		



Project  
**MWH WINDSOR STORMWATER PLAN**

Figure 2.2  
Tregeothic Marsh Field Data

Date	December 2023	Status	1-4-2020
Drawn	CH	Designed	---
Checked	---	Approved	---
Project No.	221101.00	Figure No.	2.2



# APPENDIX B

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## Lift Station Pumping Curves

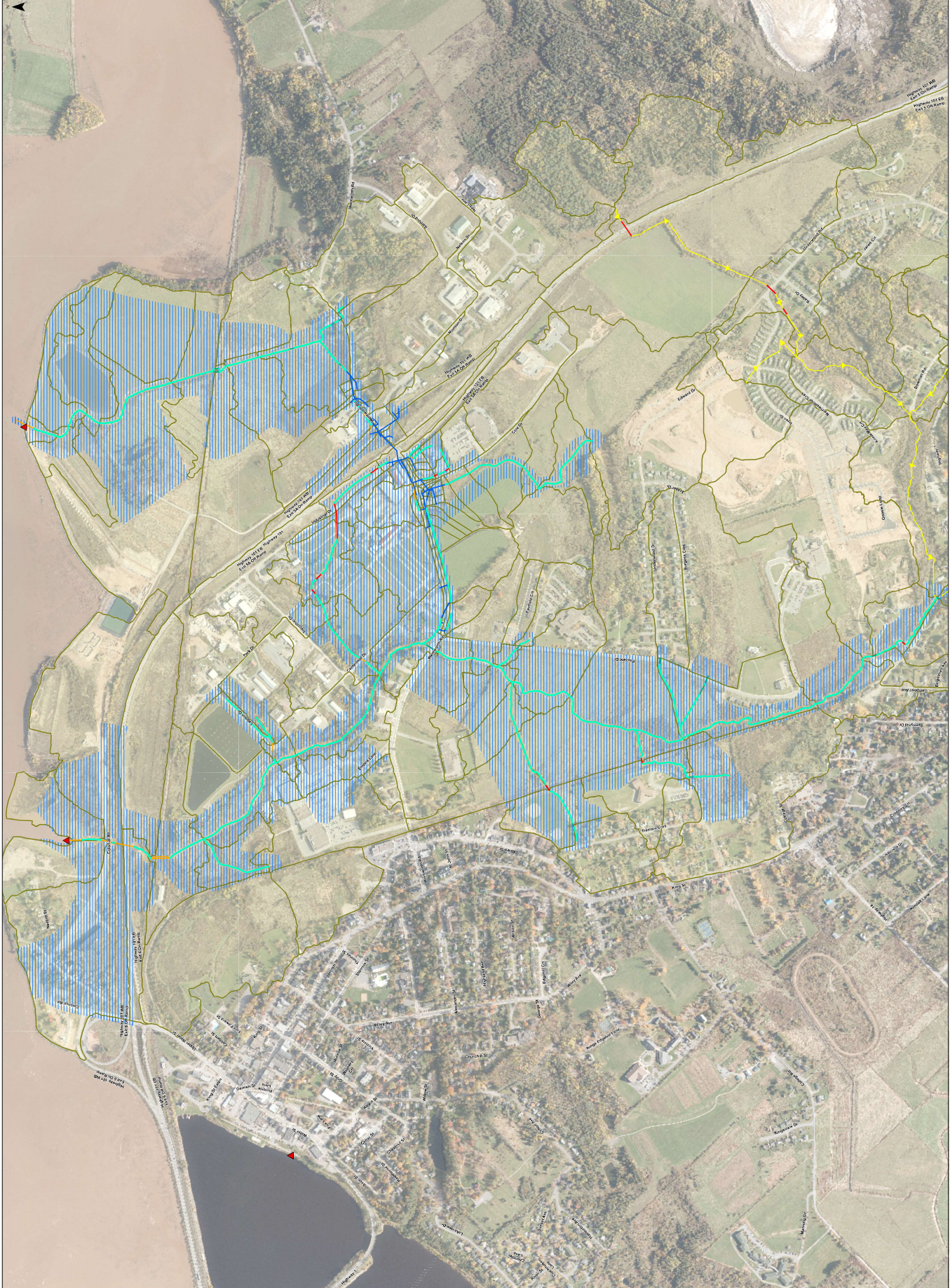


# APPENDIX C

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## Figures of Model Limits, Flooding July 2021, and Design Storm Flooding





Key Map

New Brunswick  
PEI  
Nova Scotia  
Windsor

**Legend**

- ▲ Outfall
- ▬ 1D Channels in the 1D Domain
- ▬ 2D Channels in the 2D Domain
- ▬ Subcatchment
- ▬ Street or Unserviced Culverts with Downpipes
- ▬ Street or Unserviced Culverts
- ▬ Unserviced Culverts
- ▬ Subcatchments
- ▬ 2D Domain

**NOTE:**  
Stormwater Subcatchment delineations based on over-land surface water flow

No	Date	Description
3	December 2023	ISSUED FOR - Final Report
2	November 2023	ISSUED FOR - Draft Report
1	April 2023	ISSUED FOR - Draft Report

Revision or Issue	
No	Description



Project  
**MWH WINDSOR STORMWATER PLAN**

Figure Title  
**Figure 4.2  
Tregothic Marsh Model Domain**



Date:	December 2023	Scale:	1:7,500
Drawn:	CH	Designed:	---
Checked:	---	Approved:	---
Project No.:	221101.00	Figure No.:	4.2



- Legend**
- Outfall
  - Lift Station
  - Force Main
  - Stormwater Head
  - Information Provided by WPRM
  - Known Diameter
  - Unknown Diameter
  - Alert Street Sewer Main
  - Cancelled Creek Sewer Main
  - Outfall
  - Manhole Water Depth (m)

Manhole Water Depth (m)
<0.021
0.01 - 0.01
0.01 - 0.01
0.02 - 0.04
0.04 - 0.06
0.06 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.5
>0.5

No	Date	Description
3	December 2023	ISSUED FOR - Final Report
2	November 2023	ISSUED FOR - Draft Report
1	April 2023	ISSUED FOR - Draft Report

Revision of Issue	
No	Description

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improving healthy lives

Project: **MWH WINDSOR STORMWATER PLAN**

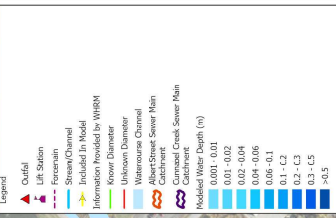
Figure 4.7  
 July 21 Storm Event  
 Water Depth in  
 Windsor Downtown

**CBCL**

Date:	December 2023	Scale:	1:2,500
Drawn:	CH	Designed:	---
Checked:	---	Approved:	---
Project No.:	221101.00	Figure No.:	4.7







No.	Date	Description
3	December 2023	ISSUED FOR - Final Report
2	November 2023	ISSUED FOR - Draft Report
1	April 2023	ISSUED FOR - Draft Report

Revision of Issue	
No.	Description

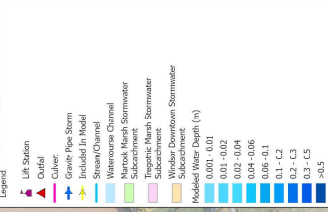


Project: MWH WINDSOR STORMWATER PLAN

Figure 5.1  
Windsor Downtown Storm Flood Risk with Climate Change

Date: December 2023 Scale: 1:2,500  
 Drawn: City Prepared: ---  
 Checked: --- Approved: ---  
 Project No.: 22101.00 Figure No.: 5.1





**NOTE:**  
Stormwater Subcatchment delineations based on overlaid surface water flow

No.	Date	Description
3	December 2023	ISSUED FOR - Final Report
2	November 2023	ISSUED FOR - Draft Report
1	April 2023	ISSUED FOR - Draft Report

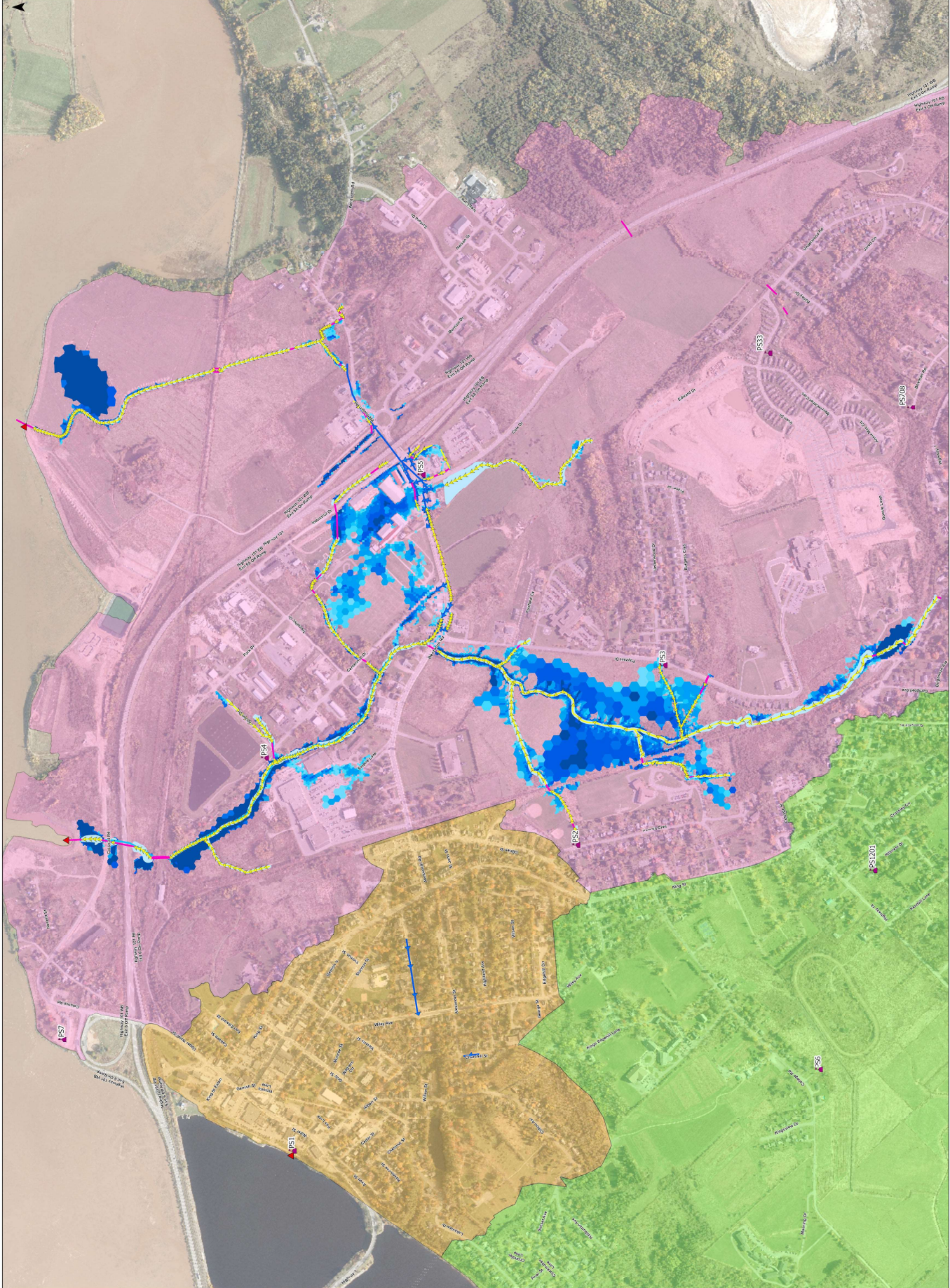
Revision or Issue	
No.	Description



Project: MWH WINDSOR STORMWATER PLAN

Figure 5.5  
Tregothic Marsh  
Flood Hazard for 10  
Year Storm with Climate Change

Date:	November 2023	Scale:	1:7,000
Drawn:		City:	Windsor
Checked:		Approved:	
Project No.:	22101.00	Figure No.:	5.3





- Legend**
- Lift Station
  - Culvert
  - Orange Pipe Storm
  - Green Pipe Storm
  - Stream/Channel
  - Watercourse Channel
  - Harlock Marsh Stormwater
  - Subcatchment
  - Subcatchment Stormwater
  - Windsor Downtown Stormwater
  - Marsh/Forest Stormwater
  - Municipal Stormwater (%)
  - 0.01 - 0.02
  - 0.02 - 0.04
  - 0.04 - 0.06
  - 0.06 - 0.1
  - 0.1 - 0.2
  - 0.2 - 0.3
  - 0.3 - 0.5
  - Unserved Culvert
  - Served Culvert, Missing Data

**NOTE:**  
Stormwater Subcatchment delineations based on overlaid surface water flow

No.	Date	Description
3	December 2023	ISSUED FOR - Final Report
2	November 2023	ISSUED FOR - Draft Report
1	April 2023	ISSUED FOR - Draft Report

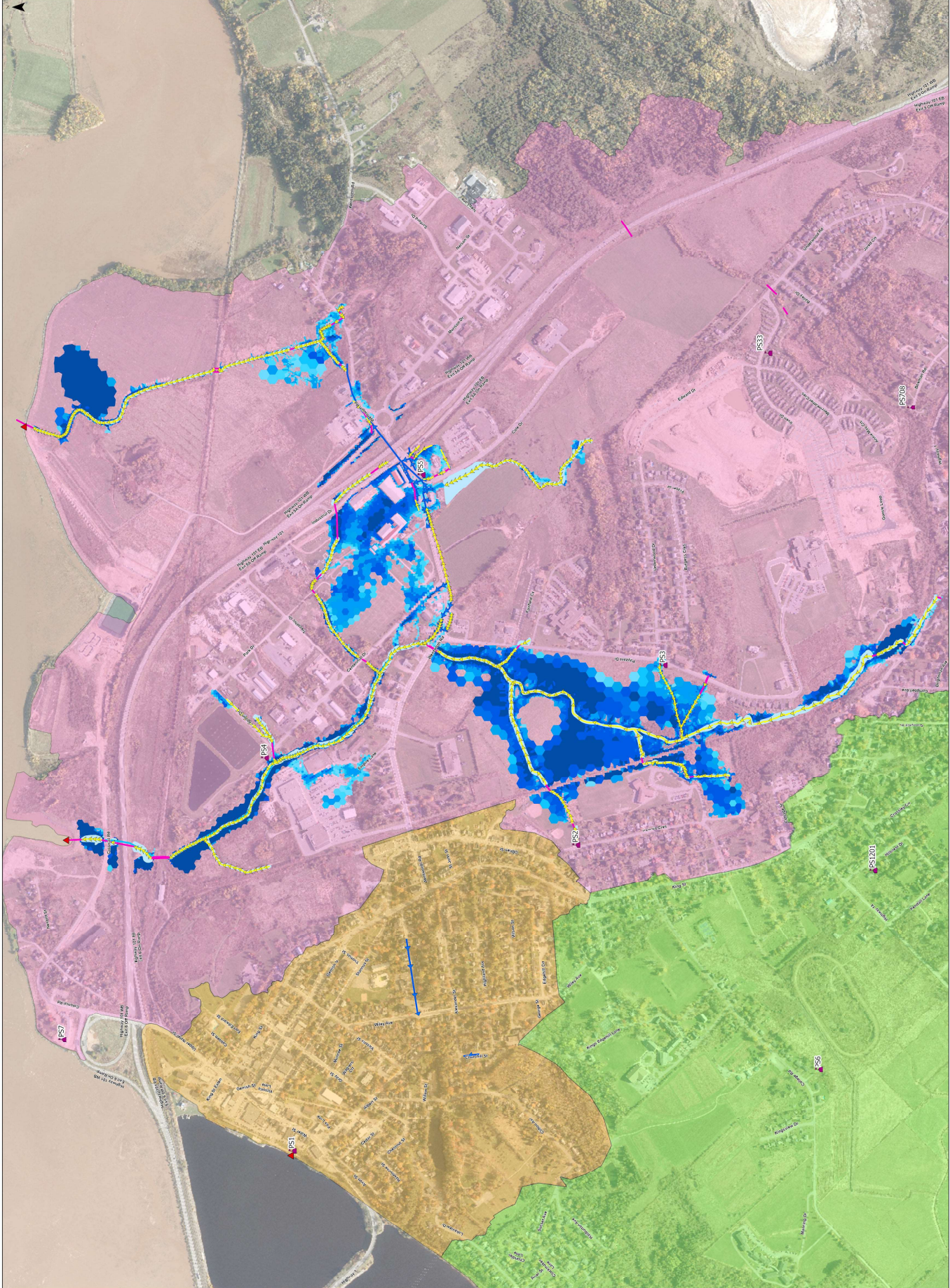
Revision or Issue	
No.	Description



Project: **MWH WINDSOR STORMWATER PLAN**

Figure 5.6  
Tregothic Marsh  
Flood in 100  
Year Storm with Climate Change

Date:	December 2023	Scale:	1:7,000
Drawn:	City	Approved:	---
Checked:	---	Project No.:	22101.00
		Figure No.:	5.3



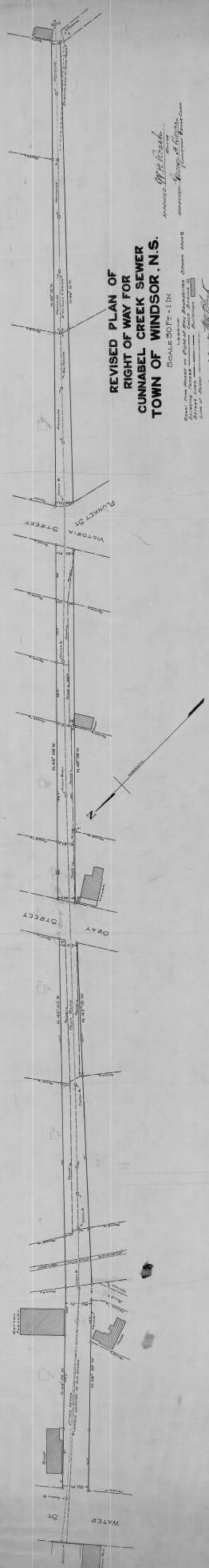
# APPENDIX D

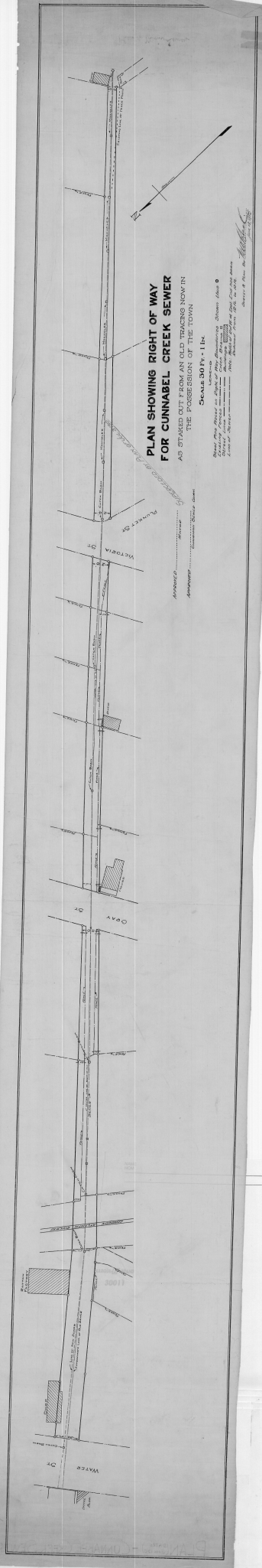
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## Existing ROW Drawings

**REVISED PLAN OF  
RIGHT OF WAY FOR  
GUNNABEL CREEK SEWER  
TOWN OF WINDSOR, N.S.**

SCALE: 1" = 20' - 0"  
DRAWN BY: [Signature]  
CHECKED BY: [Signature]  
DATE: [Date]





**PLAN SHOWING RIGHT OF WAY  
FOR CUNNABEL CREEK SEWER**  
AS STAKED OUT FROM AN OLD TRACKING NOW IN  
THE POSSESSION OF THE TOWN.

Scale 50 Ft. = 1 In.  
 Checked by [Name] on [Date]  
 Drawn by [Name] on [Date]  
 Approved by [Name] on [Date]  
 City Engineer

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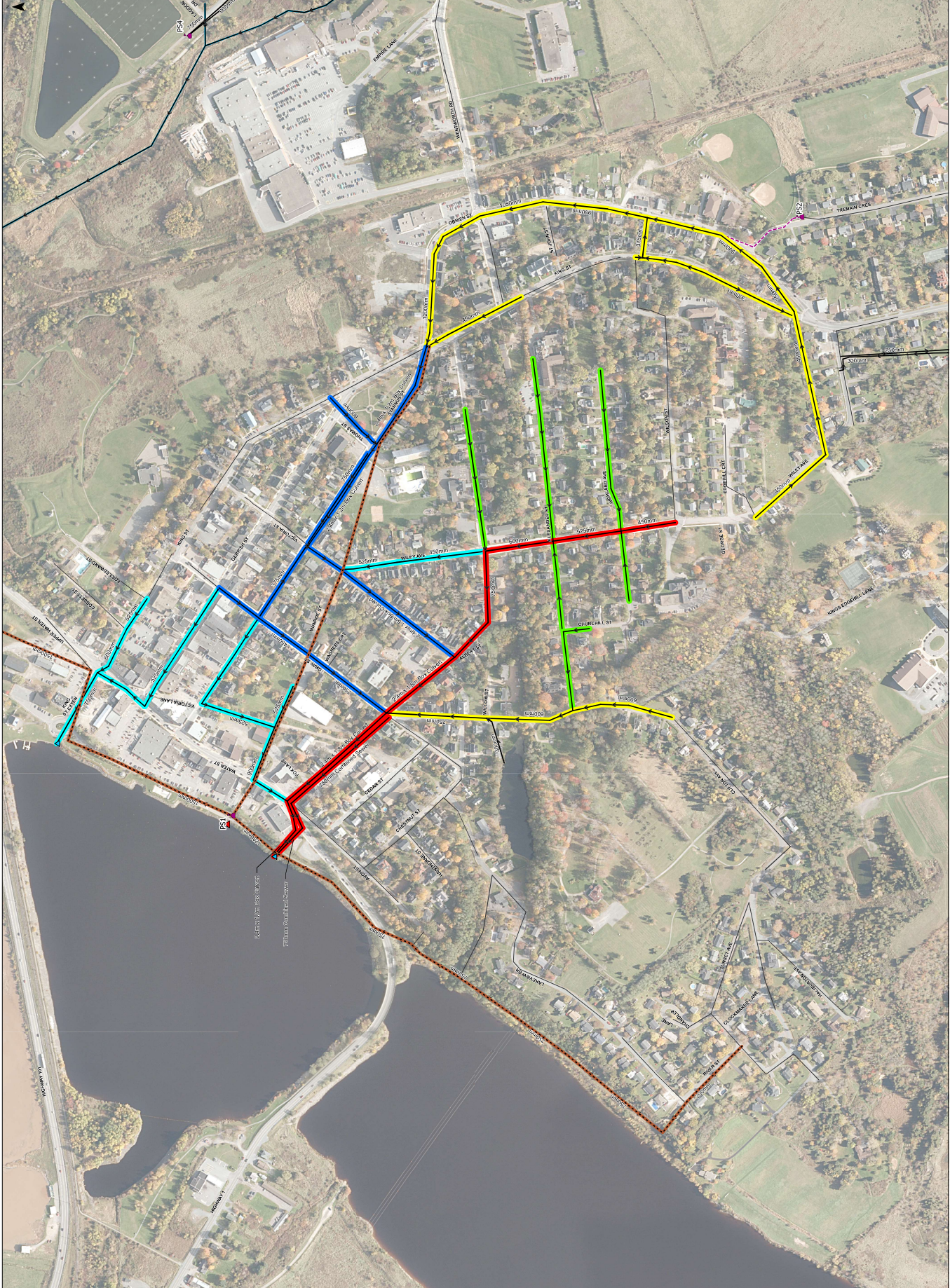
# APPENDIX E

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## Full Separation Options Plans



- Legend**
- Proposed New Outfalls
  - Existing Outfall
  - Lift Station
  - Facilities to be Relocated
  - Existing Combined Sewer to Remain
  - Phase 1
  - Phase 2
  - Phase 3
  - Phase 4
  - Sewer Separation Previously Completed



No	Date	Description
3	December 2023	ISSUED FOR - Final Report
2	November 2023	ISSUED FOR - Draft Report
1	April 2023	ISSUED FOR - Draft Report

Revision of Issue	
No	Description



Project: **MWH WINDSOR STORMWATER PLAN**

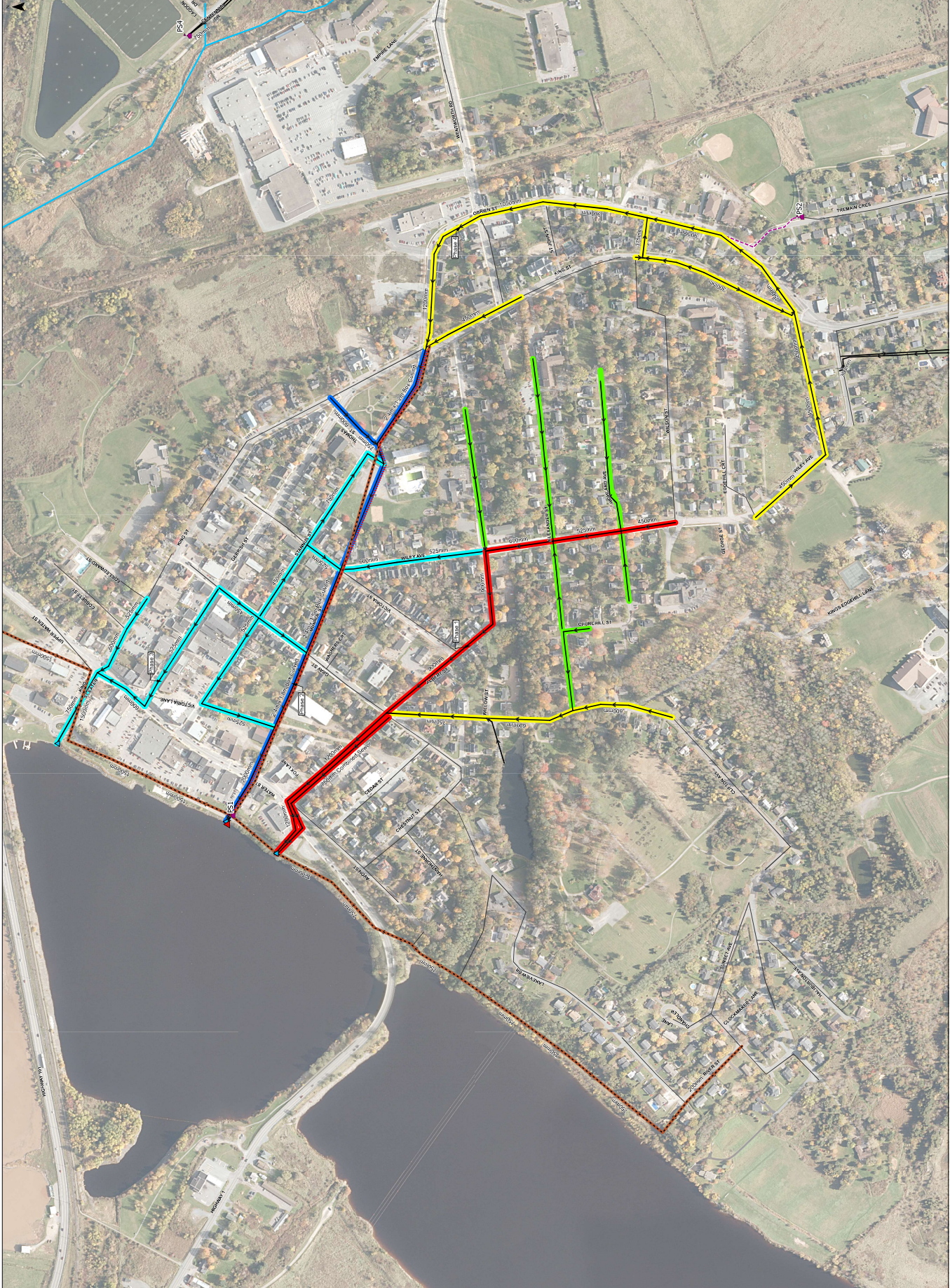
Figure 6.1  
Option 1

Date:	December 2023	Scale:	1:2,500
Drawn:		Checked:	
Project No.:	221101.00	Figure No.:	6.1





- Legend**
- Existing Outfall
  - Proposed New Outfall
  - Lift Station
  - Facilities
  - Facilities to be Relocated
  - Sanitary
  - Existing Combined Sewer to Remain
  - Phase 1
  - Phase 2
  - Phase 3
  - Phase 4
  - Sewer Separation Previously Completed



No	Date	Description
3	December 2023	ISSUED FOR - Final Report
2	November 2023	ISSUED FOR - Draft Report
1	April 2023	ISSUED FOR - Draft Report

Revision of Issue	
No	Description



Project  
**MWH WINDSOR STORMWATER PLAN**

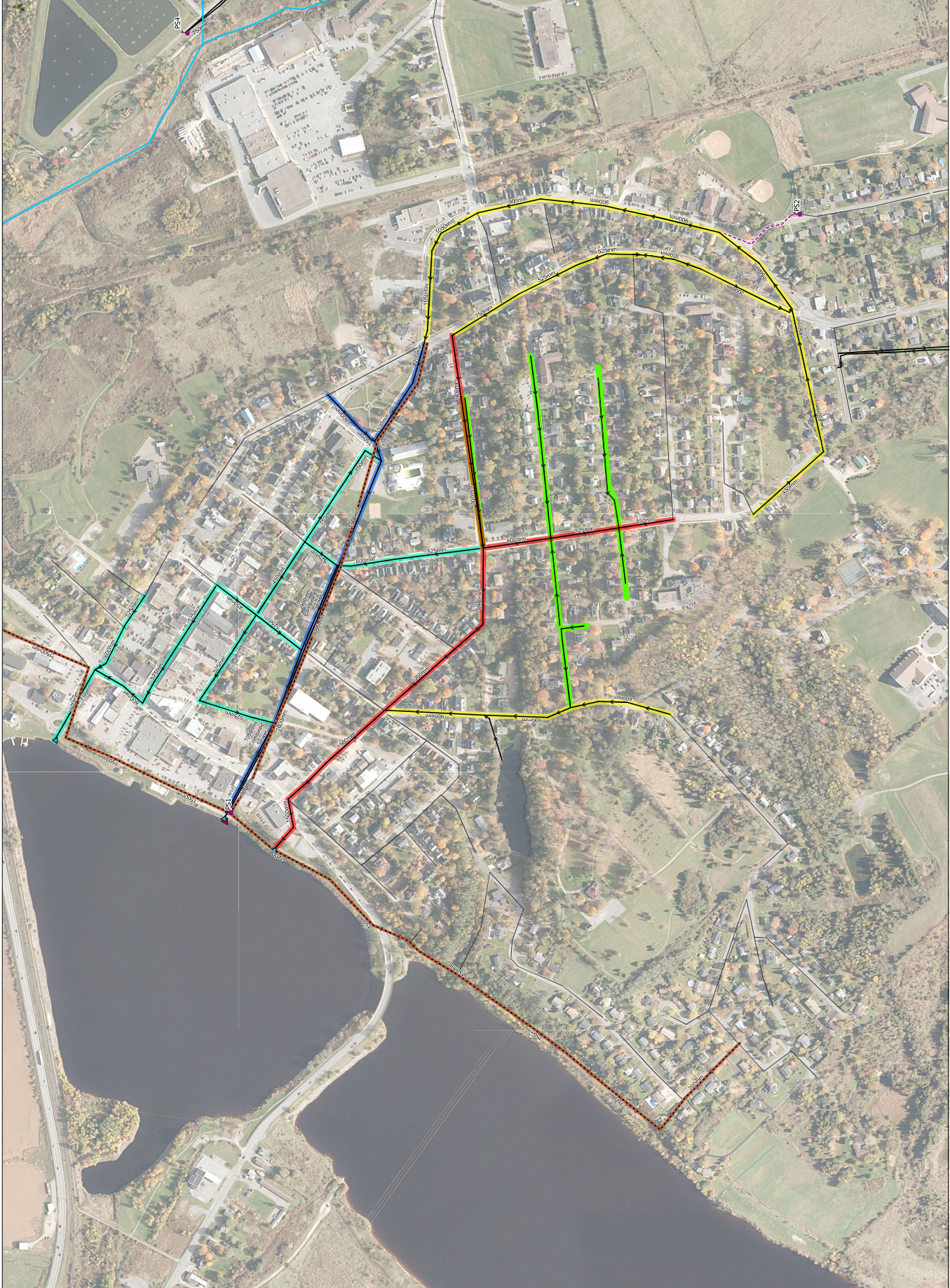
Figure No: **Figure 6.3**  
Option 2

Date:	December 2023	Scale:	1:2,500
Drawn:	CH	Designed:	---
Checked:	---	Approved:	---
Project No:	221101.00	Figure No:	6.3





- Legend**
- Existing Outfall
  - Proposed New Outfalls
  - U/I Station
  - Stations to be Replaced
  - Existing Combined Sewer to Remain
  - Phase 1
  - Phase 2
  - Phase 3
  - Phase 4
  - Sewer Separation Previously Completed



No	Date	Description
3	December 2023	ISSUED FOR - Final Report
2	November 2023	ISSUED FOR - Draft Report
1	April 2023	ISSUED FOR - Draft Report

Revision of Issue	
No	Description



Project: **MWH WINDSOR STORMWATER PLAN**

Figure Title: **Figure 6.5  
Option 3**

Date:	December 2023	Scale:	1:2,500
Drawn:	CH	Designed:	---
Checked:	---	Approved:	---
Project No.:	221101.00	Figure No.:	6.5

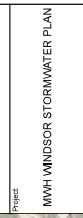




- Legend**
- ▲ Outfall
  - ▲ Lift Station
  - ▲ Street Sewer Main
  - ▲ Combined Sewer Main
  - ▲ Collection Sewer
  - ▲ Existing Trunk Sewer
  - ▲ Foreman (Unknown Diameter)
  - ▲ Stream/Channel
  - ▲ Option 1

No.	Date	Description
1	November 2023	ISSUED FOR - Presentation

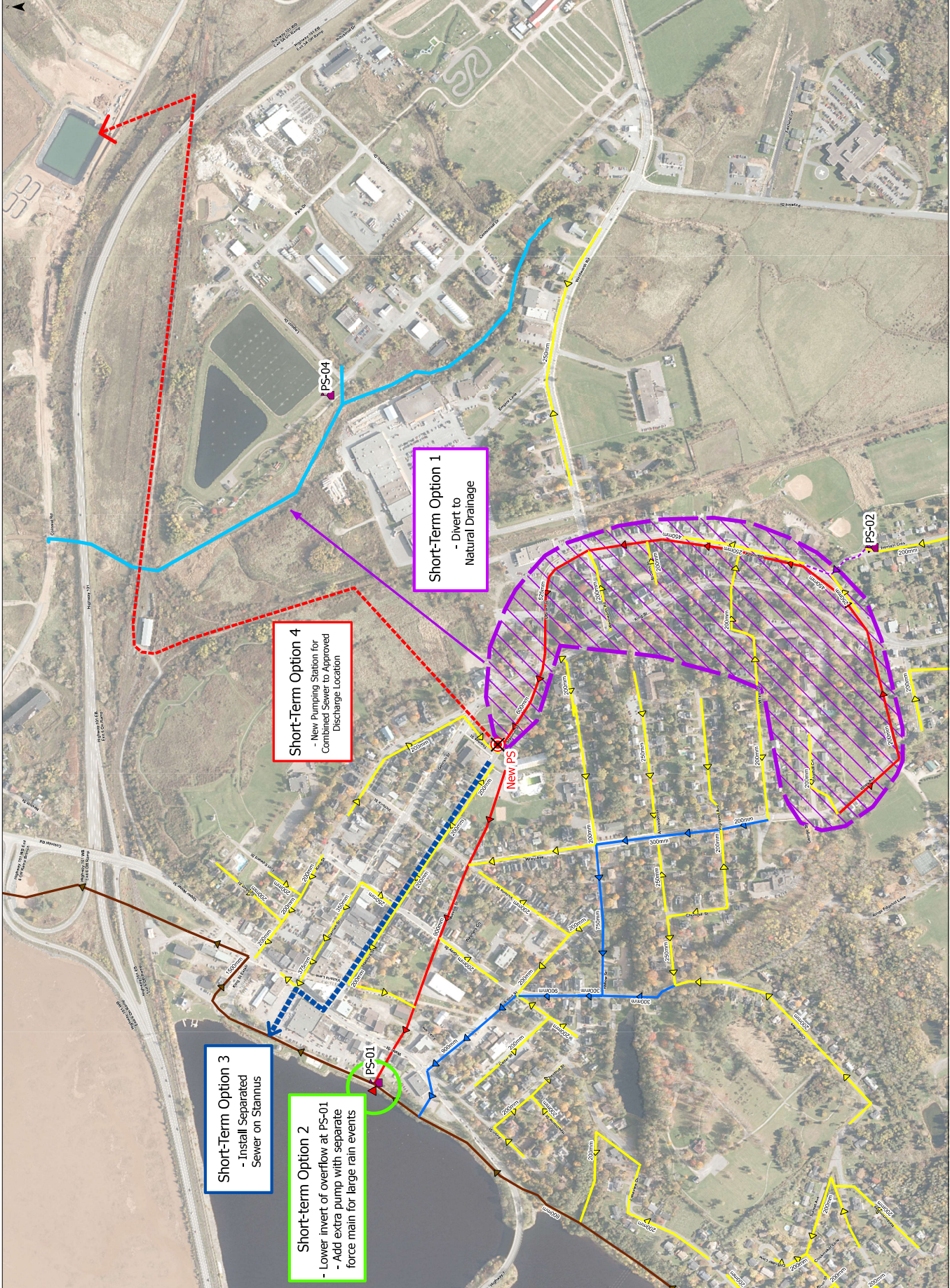
Revision of Issue



Project  
MWH WINDSOR STORMWATER PLAN

Figure 6.6  
Cumabel Creek Options

Date	November 2023	Scale	1:4,000
Drawn	CH	Designed	---
Checked	---	Approved	---
Project No.	221101.00	Figure No.	6.6



**Short-Term Option 1**  
- Divert to Natural Drainage

**Short-Term Option 4**  
- New Pumping Station for Combined Sewer to Approved Discharge Location

**Short-Term Option 3**  
- Install Separated Sewer on Stannus

**Short-term Option 2**  
- Lower invert of overflow at PS-01  
- Add extra pump with separate force main for large rain events

# APPENDIX F

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## Opinion of Probable Cost



**OPINION of PROBABLE CONSTRUCTION COSTS**  
**MWH Town of Windsor, NS - Long Term Sепation Options**  
**Town of Windsor, NS**  
*(Based on CBCL Report titled WHRM Town of Windsor Stormwater plan - dated Dec 15, 2023)*

Date:	12-14-2023
Project No.:	221101.00
Prepared & Reviewed by:	AT / AB
Budget Class:	Class D

**SUMMARY**

**SCHEDULE OF QUANTITIES AND UNIT PRICES**

Description	Option 1			Option 2			Option 3		
	Remove flow from Cunnabel Creek			Replace Existing System			Split flow Between Cunnabel Creek and Albert St		
<b>MOBILIZATION, BONDS, INSURANCE, PCM</b>		\$	3,650,000	\$	3,300,000	\$	3,200,000		
<b>DEMOLITIONS &amp; DISPOSAL ALLOWANCE</b>		\$	500,000	\$	500,000	\$	500,000		
<b>REMOVAL of UNDERGROUND UTILITIES</b>		\$	3,354,000	\$	3,192,800	\$	1,596,400		
<b>SSP, Soldier Walls, Coffe Dam Allowance</b>		\$	6,100,000	\$	6,850,000	\$	6,450,000		
<b>MANHOLES</b>		\$	4,940,000	\$	4,940,000	\$	4,290,000		
<b>STORM &amp; SANITARY LINES c/w Street Sidewalk Reinstatements</b>		\$	52,513,383	\$	57,224,019	\$	67,011,620		
<b>Box Culverts</b>		\$	19,191,000	\$	10,495,000	\$	-		
<b>CATCH BASINS</b>		\$	2,080,000	\$	2,080,000	\$	2,080,000		
<b>OUTFALLS</b>		\$	80,000	\$	210,000	\$	210,000		
<b>Subtotal</b>		\$	92,408,383	\$	88,791,819	\$	85,338,020		
<b>DESIGN DEVELOPMENT ALLOWANCE - Note 1</b>	40%	\$	36,970,000	\$	35,520,000	\$	34,140,000		
<b>OPINION of PROBABLE COSTS without CONSTRUCTION CONTINGENCY</b>		\$	<b>129,379,000</b>	\$	<b>124,312,000</b>	\$	<b>119,479,000</b>		
<b>CONSTRUCTION CONTINGENCY - Note 2</b>	10%	\$	12,938,000	\$	12,432,000	\$	11,948,000		
<b>LOCATION FACTOR - Note 3</b>	0%		<i>Included</i>		<i>Included</i>		<i>Included</i>		
<b>ESCALATION / INFLATION (Based on 2023 Dollars) - Note 4</b>	0%		<i>Not Included</i>		<i>Not Included</i>		<i>Not Included</i>		
<b>Engineering (Based on 2023 Dollars) - Note 4</b>	12%	\$	1,553,000	\$	1,492,000	\$	1,434,000		
<b>OPINION of PROBABLE COSTS with CONSTRUCTION CONTINGENCY Excl. HST</b>		\$	<b>144,000,000</b>	\$	<b>139,000,000</b>	\$	<b>132,900,000</b>		

THIS OPINION OF PROBABLE COSTS IS PRESENTED ON THE BASIS OF EXPERIENCE, QUALIFICATIONS, AND BEST JUDGEMENT. IT HAS BEEN PREPARED IN ACCORDANCE WITH ACCEPTABLE PRINCIPLES AND PRACTICES. SUDDEN MARKET TREND CHANGES, NON-COMPETITIVE BIDDING SITUATIONS, UNFORESEEN LABOUR AND MATERIAL ADJUSTMENTS, UNFORESEEN SITE CONDITIONS, AND THE LIKE ARE BEYOND THE CONTROL OF CBCL LIMITED. IT IS NOT A PREDICTION OF LOW PRICE. AS SUCH WE CANNOT WARRANT OR GUARANTEE THAT ACTUAL COSTS WILL NOT VARY FROM THE OPINION PROVIDED. IT IS BASED ON THE DATE OF THIS BUDGET.

- Note 1** This Design Developmnt Allowance is to account for uncertainty in construction cost due to undefined design scope.
- Note 2** The Construction Contingency is to factor in potential post tender Change Orders.
- Note 3** This Location Factor is for variances between construction costs at the location of the project & historical costs data.
- Note 4** This Escalation / Inflation Allowance is for increases in construction costs from the time of budget development to Tender Call.

**Budget Definitions**

A Class "D" Budget is an order of magnitude conceptual budget to screen various alternative solutions. Project documents are in the initial stages but sufficient information is available to provide an indication of probable cost and allow ranking of the various options being considered. Design development is typically in the concept stage.



**OPINION of PROBABLE CONSTRUCTION COSTS**  
**MWH Town of Windsor, Short Term Stormwater Plan - Storm Frequency 1-**  
**Town of Windsor, NS**

*1 of Windsor Stormwater plan - dated Dec 15, 2023)*

Date:	12-14-2023
Project No.	221101.00
Prepared & Reviewed by:	AT / AB
Budget Class	Class D

**SUMMARY**

**SCHEDULE OF QUANTITIES AND UNIT PRICES**

Item	Description	Option 1 Separate upstream of Stannus and Discharge Storm into field beside Sobey's	Option 2 Lower the Invert of Overflow at PS1 add Extra Pump with added Separate Forcemain	Option 3 Install Separate Sewer on Stannus St.	Option 4 Install Large Storm Pump Sta. on Stannus St. Pump Combined to Approved Discharge
	<b>Construction Estimate</b>	\$ 27,555,240	\$ 17,172,000	\$ 9,826,620	\$ 20,950,000
	<b>DESIGN DEVELOPMENT ALLOWANCE - Note 1</b>	\$ 11,030,000	\$ 6,870,000	\$ 3,940,000	\$ 8,380,000
	<b>STS without CONSTRUCTION CONTINGENCY</b>	<b>\$ 38,586,000</b>	<b>\$ 24,042,000</b>	<b>\$ 13,767,000</b>	<b>\$ 29,330,000</b>
	<b>CONSTRUCTION CONTINGENCY - Note 2</b>	\$ 3,859,000	\$ 2,405,000	\$ 1,377,000	\$ 2,933,000
	<b>LOCATION FACTOR - Note 3</b>	<i>Included</i>	<i>Included</i>	<i>Included</i>	<i>Included</i>
	<b>ESCALATION / INFLATION - Note 4</b>	<i>Not Included</i>	<i>Not Included</i>	<i>Not Included</i>	<i>Not Included</i>
	Engineering	\$ 4,630,320	\$ 2,885,040	\$ 1,652,040	\$ 3,519,600
	<b>with CONSTRUCTION CONTINGENCY w/o HST</b>	<b>\$ 47,080,000</b>	<b>\$ 29,340,000</b>	<b>\$ 16,800,000</b>	<b>\$ 35,790,000</b>

THIS OPINION OF PROBABLE COSTS IS PRESENTED ON THE BASIS OF EXPERIENCE, QUALIFICATIONS, AND BEST JUDGEMENT. IT HAS BEEN PREPARED IN ACCORDANCE WITH ACCEPTABLE PRINCIPLES AND PRACTICES. SUDDEN MARKET TREND CHANGES, NON-COMPETITIVE BIDDING SITUATIONS, UNFORESEEN LABOUR AND MATERIAL ADJUSTMENTS, UNFORESEEN SITE CONDITIONS, AND THE LIKE ARE BEYOND THE CONTROL OF CBCL LIMITED. IT IS NOT A PREDICTION OF LOW PRICE. AS SUCH WE CANNOT WARRANT OR GUARANTEE THAT ACTUAL COSTS WILL NOT VARY FROM THE OPINION PROVIDED. IT IS BASED ON THE DATE OF THIS BUDGET.

**Note 1** This Design Development Allowance is to account for uncertainty in construction cost due to undefined design scope.

**Note 2** The Construction Contingency is to factor in potential post tender Change Orders.

**Note 3** This Location Factor is for variances between construction costs at the location of the project & historical costs data.

**Note 4** This Escalation / Inflation Allowance is for increases in construction costs from the time of budget development to Tender Call. Based on 2023 Dollars.

**Budget Definitions**

A **Class "D" Budget** is an order of magnitude conceptual budget to screen various alternative solutions. Project documents are in the initial stages but sufficient information is available to provide an indication of probable cost and allow ranking of the various options being considered. Design development is typically in the concept stage.



**MWH Town of Windsor Wentworth - Tregothic Creek  
Town of Windsor, NS**

Date: 12-15-2023

Project No. 221101.00

Prepared & Reviewed by: AT / AB

Budget Class Class D

Description			
<b>Mobilization</b>		\$	1,100,000
<b>Demolition</b>		\$	200,000
<b>Culverts and Stormpipe (by Area)</b>			
Agricultural Area South of Wentworth Road			
C1	750mm Pipe	\$	37,000
C2	900mm Pipe	\$	42,000
C3	900mm Pipe	\$	42,000
C4	2.4 x 2.4 Box Culvert	\$	300,000
<b>Subtotal</b>		<b>\$</b>	<b>421,000</b>
Industrial Area			
C5	3.5 x 3.5 Box Culvert	\$	980,000
C6	1.35mm Pipe	\$	99,750
C7	1.35mm Pipe	\$	123,500
C8	1.35mm Pipe	\$	361,000
C9	1.35mm Pipe	\$	171,000
C10	1200mm Pipe	\$	45,000
C11	900mm Pipe	\$	42,000
C12	900mm Pipe	\$	42,000
C13	900mm Pipe	\$	42,000
C14	900mm Pipe	\$	75,600
New Storm System		\$	5,500,000
<b>Subtotal</b>		<b>\$</b>	<b>7,481,850</b>
Downstream of Tregothic Creek from Wentworth Drive			
C15	1200mm Pipe	\$	45,000
<b>Subtotal</b>		<b>\$</b>	<b>45,000</b>
Open Ditch			
C16	2.75 x 2.14 Box Culvert	\$	200,000
C17	1050mm Pipe	\$	44,000
C18	1050mm Pipe	\$	44,000
C19	1200mm Pipe	\$	45,000
C20	2.4 x 2.4 Box Culvert	\$	200,000
C21	2.4 x 2.4 Box Culvert	\$	320,000
<b>Subtotal</b>		<b>\$</b>	<b>853,000</b>
<b>Construction Total</b>		<b>\$</b>	<b>10,110,000</b>
	<b>DESIGN DEVELOPMENT ALLOWANCE - Note 1</b>	40%	\$ 4,050,000
	<b>CONSTRUCTION CONTINGENCY - Note 2</b>	10%	\$ 1,020,000
	<b>LOCATION FACTOR - Note 3</b>	0%	<i>Included</i>
	<b>ESCALATION / INFLATION - Note 4</b>	0%	<i>Not Included</i>
	<b>Engineering</b>	12%	\$ 1,220,000
	<b>OPINION of PROBABLE COSTS with CONSTRUCTION CONTINGENCY w/o HST</b>		<b>\$ 16,400,000</b>

**Note 1** This Design Developmnt Allowance is to account for uncertainty in construction cost due to undefined design scope.

**Note 2** The Construction Contingency is to factor in potential post tender Change Orders.

**Note 3** This Location Factor is for variances between construction costs at the location of the project & historical costs data.

**Note 4** This Escalation / Inflation Allowance is for increases in construction costs from the time of budget development to Tender Call. Based on 2023 dollars.

**Budget Definitions**

A **Class "D" Budget** is an order of magnitude conceptual budget to screen various alternative solutions. Project documents are in the initial stages but sufficient information is available to provide an indication of probable cost and allow ranking of the various options being considered. Design development is typically in the concept stage.

A **Class "C" Budget** is based on a full description of the preferred option, construction/design experience and market conditions. This estimate should be sufficient for making correct investment decisions and obtaining preliminary project approval. Design development is typically in the order of 25% complete.

A **Class "B" Budget** is based on preliminary detailed design drawings and outline specifications or performance criteria, which includes design of all major systems and subsystems. The result of all site/installation investigations have been incorporated. This budget should provide for the establishment of realistic prediction of cost and be sufficient to obtain effective project approval. Design development is typically in the order of 50% complete.

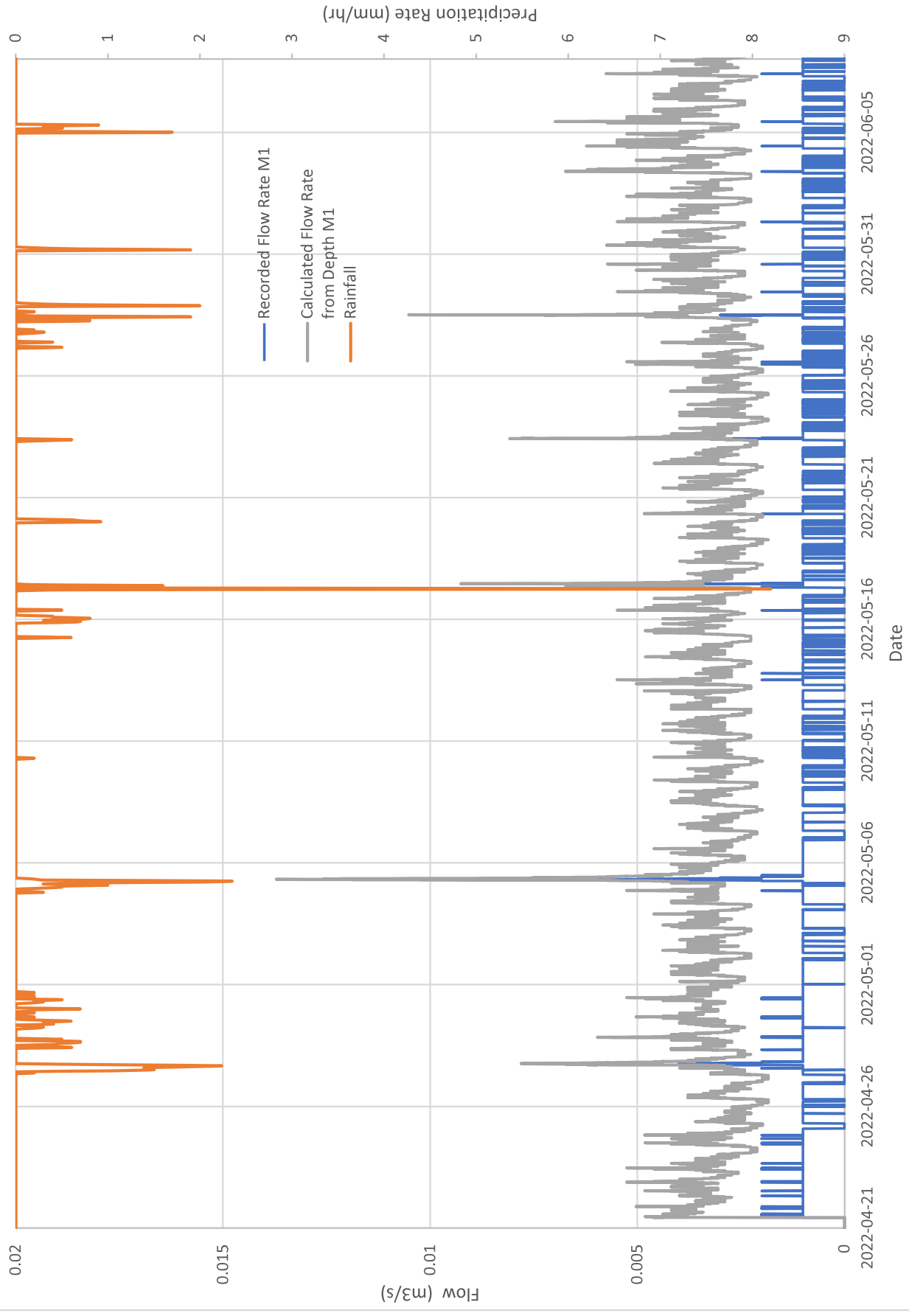
A **Class "A" Budget** is based on complete or substantially complete working drawings and specifications prior to calling for competitive bids. This estimate should be sufficient to allow a detailed reconciliation/negotiation with bidding contractors after tender. This estimate will contain only those cash allowances called for in the tender documents and will not allow for design contingencies, but include a post award construction

# APPENDIX G

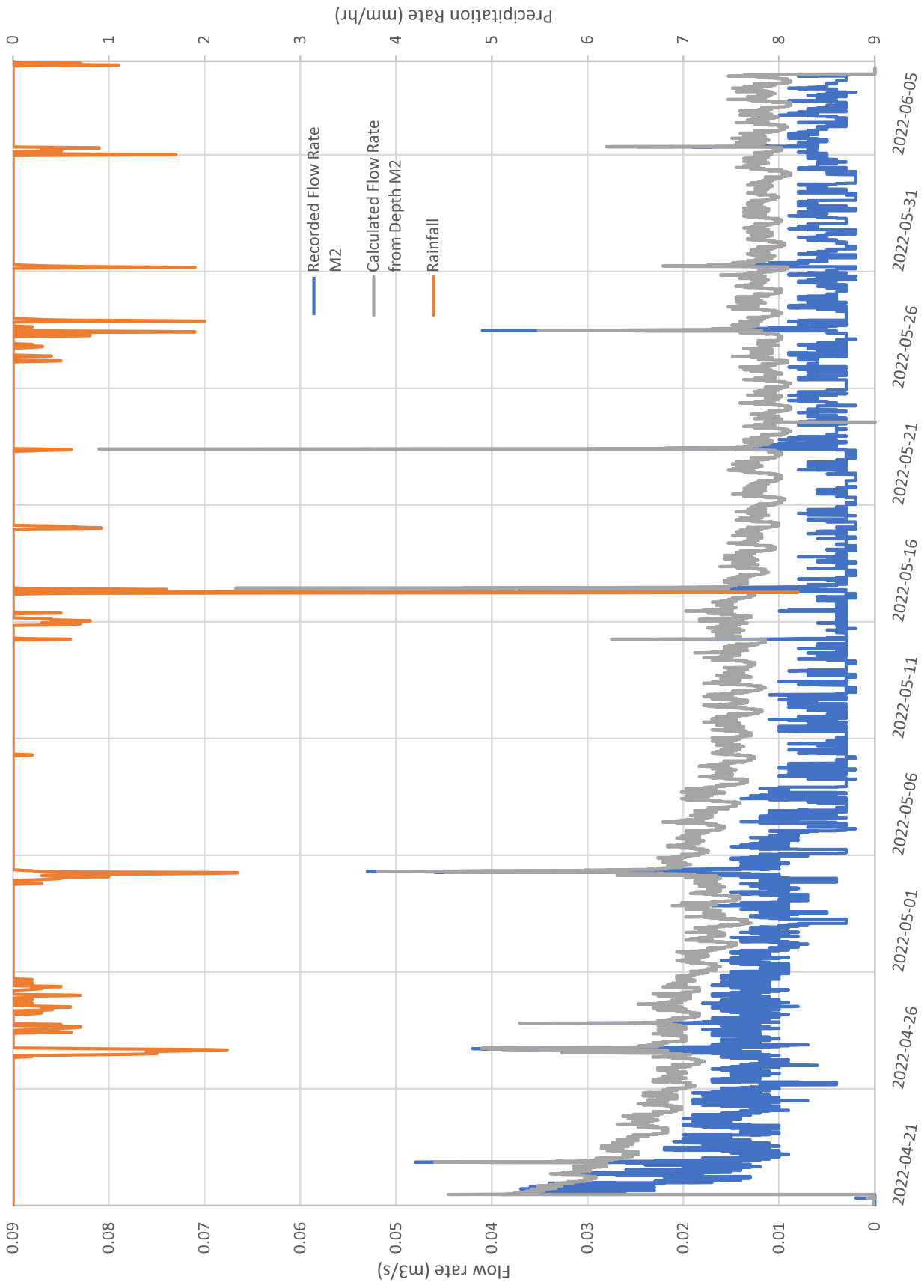
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## Flow Monitoring Data Plots

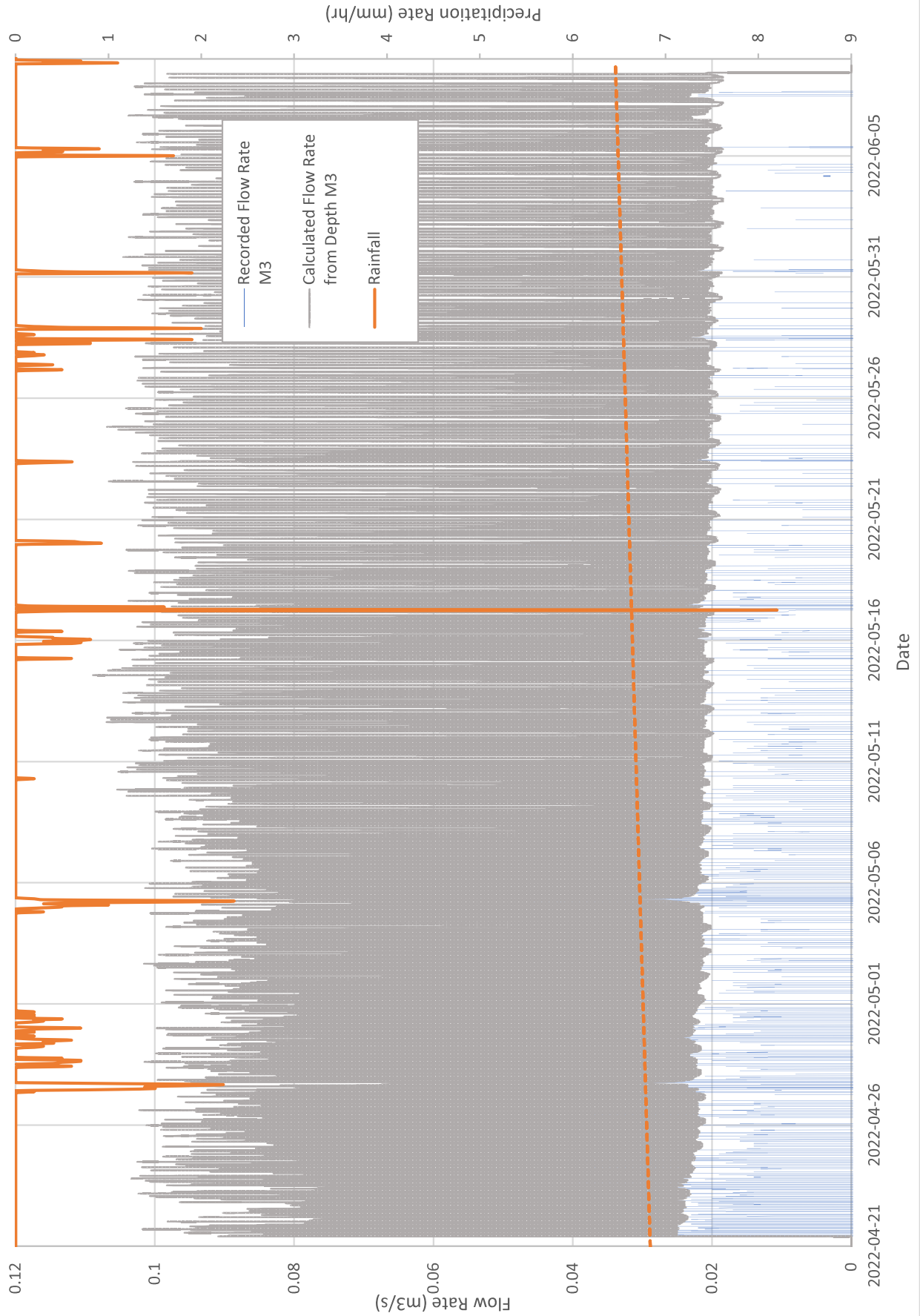
# Flow Rate and Rainfall Meter 1



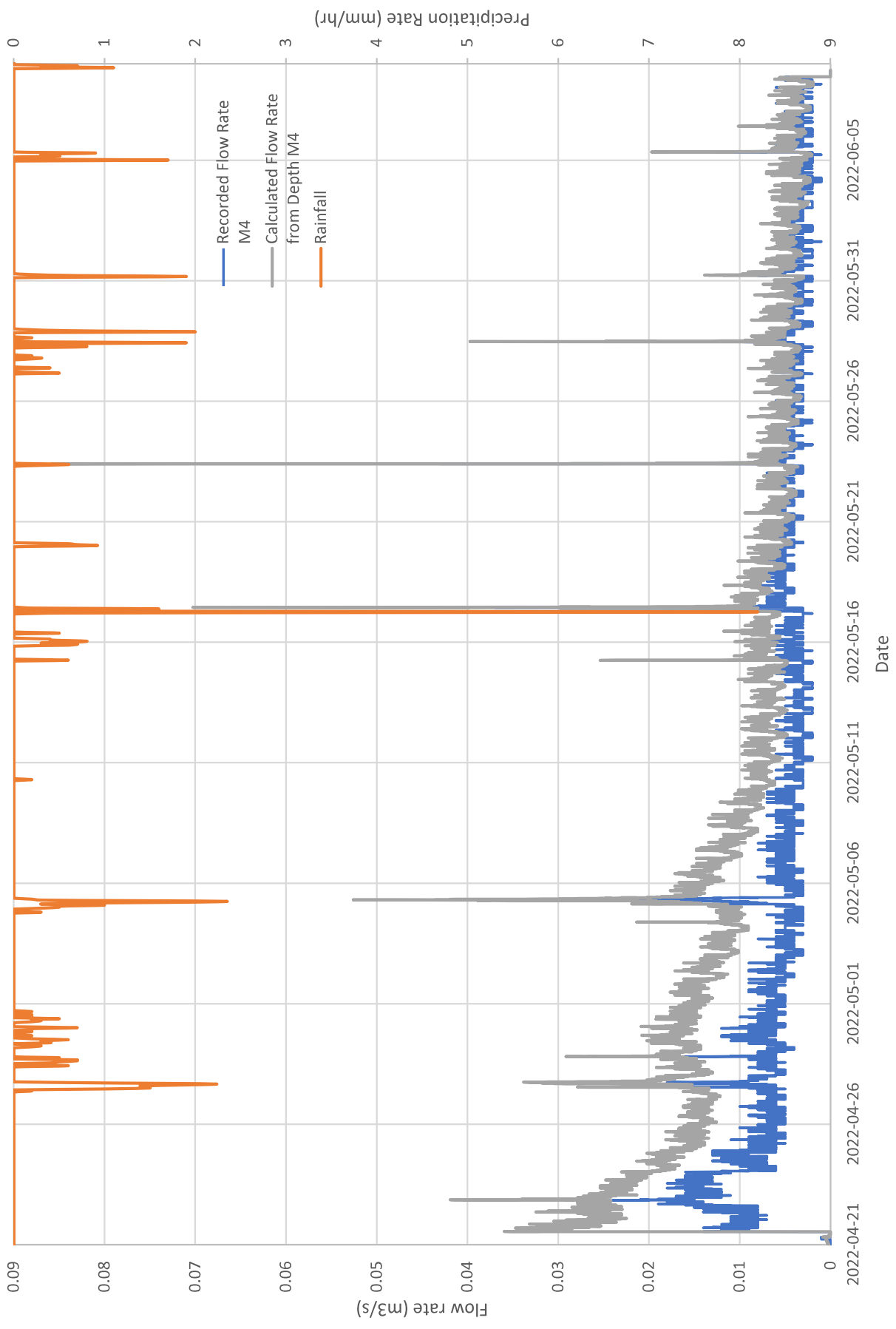
# Flow Rate and Rainfall Meter 2



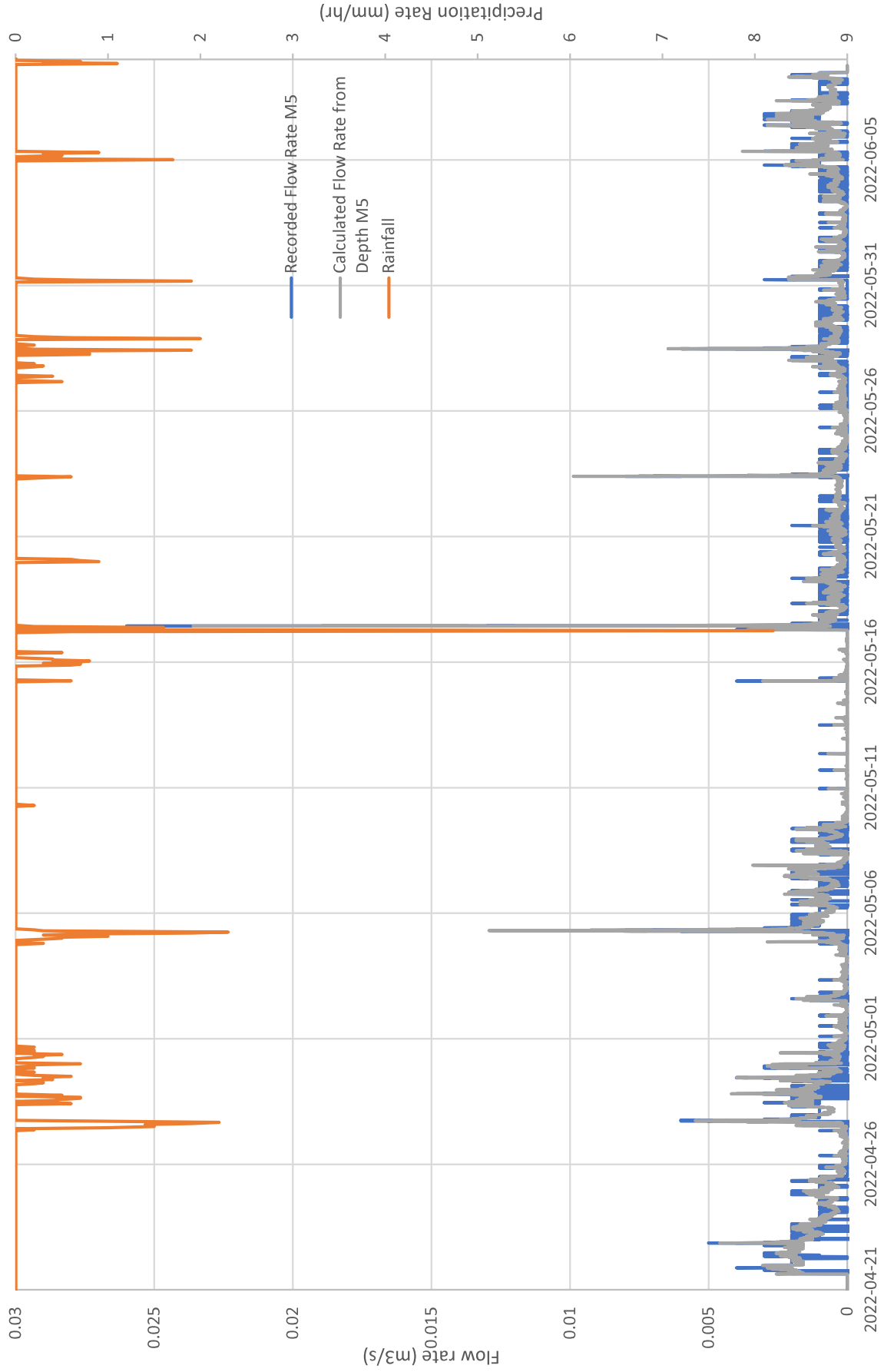
### Flow Rate and Rainfall Meter 3



# Flow Rate and Rainfall Meter 4



# Flow Rate and Rainfall Meter 5





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