
APPENDIX B

Hydrologic and Hydraulic Study





HYDROLOGIC AND HYDRAULIC STUDY SIX MILE CREEK ENVIRONMENTAL ASSESSMENT

Prepared for: **TOWN OF FORT ERIE**

Prepared by: **MONTROSE ENVIRONMENTAL SOLUTIONS CANADA INC.**

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HYDROLOGIC AND HYDRAULIC STUDY
SIX MILE CREEK ENVIRONMENTAL ASSESSMENT

Prepared for the Town of Fort Erie, April 2026



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TABLE OF CONTENTS

1	INTRODUCTION	1
1.1	Study Area	1
1.2	Background.....	1
1.3	Objectives	2
2	EXISTING CONDITIONS	2
2.1	Preliminary Assessment	2
2.1.1	Seasonal Flood Analysis.....	3
2.1.2	Compound Flood Analysis	3
2.1.3	Approach and Level of Service	3
2.2	Six Mile Creek Hydrology.....	4
2.2.1	Lake Erie Water Levels	4
2.3	Six Mile Creek Hydraulics	5
2.3.1	Updates to the HEC-RAS Model	5
2.3.2	Updated Model Comparison to NPCA's Model.....	6
2.3.3	Existing Conditions Model Simulations	8
2.3.4	Level of Service.....	10
3	ALTERNATIVE SOLUTION OVERVIEW AND ASSESSMENT	11
3.1	Assessment Methodology	12
3.1.1	Storm Surge Assessment.....	12
3.1.2	Upstream Storage Assessment	12
3.1.3	Riverine Flooding Assessment.....	13
3.2	Assessment Results	13
3.2.1	Do Nothing Alternative.....	13
3.2.2	Alternative Solution 1: Landform Barrier	14
3.2.3	Alternative Solution 2: Road Right-of-Way Barrier with Property Purchase	15
3.2.4	Alternative Solution 4: Thunder Bay Road Barrier and Backflow Prevention System ...	16
3.2.5	Alternative Solution 5: Lake Front Barrier and Backflow Prevention System.....	18
4	SUMMARY AND CONCLUSION	19
	REFERENCES	20

FIGURES

FIGURE 1.1	Example of the Seiche / Storm Surge Effect on Lake Erie (NPS 2018)
FIGURE 2.1	Lake Erie Water Levels Over Time
FIGURE 2.2	Comparison of the Montrose Updated Model to NPCA using 1:100-year Return Period Creek Flows with median lake level conditions
FIGURE 2.3	Comparison of the Montrose Updated Model to NPCA using 1:100-Year Return Period Creek Flows with 1:5-year storm surge lake level
FIGURE 2.4	Riverine Flood Levels (2-year through 100-year peak flows, median lake level)

FIGURE 2.5	Lake Flood Levels (2-year through 100-year Storm Surge Lake Level, 5-year Creek Flow)
FIGURE 3.1	Six Mile Creek 12-hour storm SWMHYMO Hydrograph
FIGURE 3.2	Alternative 1 HEC-RAS Model Profile Water Levels – 100-year (Regulatory) with Median Lake Level
FIGURE 3.3	Alternative 2 HEC-RAS Model Profile Water Levels – 100-year (Regulatory) with Median Lake Level
FIGURE 3.4	Alternative 4 – Upstream Storage Analysis
FIGURE 3.5	Alternative 4 HEC-RAS Model Profile Water Levels – 100-year (Regulatory) with Median Lake Level
FIGURE 3.6	Alternative 5 – Upstream Storage Analysis

TABLES

TABLE 2.1	Return Period Flows for Six Mile Creek
TABLE 2.2	Return Period Storm Surge Lake Levels for Fort Erie (masl)

APPENDICES

APPENDIX A	Existing Conditions Figures
	FIGURE A1 Study Area
	FIGURE A2 HEC-RAS Model Update Schematics
	FIGURE A3 Flood Extents 2- through 100-year Storm Surge
APPENDIX B	Alternative Solution Figures
	FIGURE B1 Do Nothing Alternative
	FIGURE B2 Alternative 1: Landform Barrier
	FIGURE B3 Alternative 2: Road Right-of-Way with Property Purchase
	FIGURE B4 Alternative 3: Property Purchase
	FIGURE B5 Alternative 4: Thunder Bay Road Barrier and Backflow Prevention System
	FIGURE B6 Alternative 5: Lake Front Barrier and Backflow Prevention System
APPENDIX C	Alternative Solutions Results Figures
	Figure C1 Do Nothing Alternative: Resulting Flood Depths During 5-year Storm Surge
	Figure C2 Alternative 1: Resulting Flood Depths During 5-year Storm Surge
	Figure C3 Alternative 2: Resulting Flood Depths During 5-year Storm Surge
	Figure C4 Alternative 4: Resulting Flood Depths During 5-year Storm Surge
	Figure C5 Alternative 5: Resulting Flood Depths During 5-year Storm Surge
APPENDIX D	Modelling Approach Technical Memorandum

1 INTRODUCTION

The Six Mile Creek watershed is in the Town of Fort Erie (The Town) and originates north of Highway 3, southeast of Teal Road and Bertie Street, and travels adjacent to several residential neighbourhoods on the east side of Centralia Avenue North before flowing into Lake Erie. The Town is undertaking a Schedule B Municipal Class Environmental Assessment (EA) for a portion of the Six Mile Creek watershed adjacent to Lake Erie. This community, locally known as Thunder Bay, has experienced localized flooding along Shirley Road and Bethune Avenue for decades, with incidents occurring as recently as April 2024. The area is vulnerable to both chronic coastal and riverine flooding. Coastal flooding is caused by high water levels in Lake Erie, while riverine flooding is caused by high stream flows in Six Mile Creek.

This report summarizes the hydrologic and hydraulic analysis conducted for the EA. The analysis forms the foundation for determining and evaluating potential flood mitigation alternatives, which aims to protect private properties and municipal infrastructure within the study area. These findings guide stakeholder engagement, establish acceptable levels of flood protection, and support long-term infrastructure planning.

1.1 Study Area

The study area representing the coastal and riverine flood-related issues in the community of Thunder Bay is generally bounded by Friendship Trail to the north, Neva Road to the west, Colony Road alignment to the east (500 m west of Windmill Point Road North), and Lake Erie to the south (Appendix A, Figure A1). The area is largely rural, with the primary land uses being swamp, treed, and undifferentiated/agricultural; the remaining portions are allocated to urban and rural residential land uses.

1.2 Background

For decades, the study area in the community of Thunder Bay has experienced several major storms, leading to localized flooding on private properties, as well as flooding along Shirley Road, Neva Road, and Bethune Avenue. Town staff have reported that high water levels in the creek have resulted in closures of Shirley Road nine times since February 2019. Recently, elevated lake level and wind gusts caused significant flooding on October 31, 2019, November 15, 2020, and December 2022 during Winter Storm Elliot (suspected cause was southwest wind gusts of 70 km/hr).

Although the study area is located within the documented NPCA 100-year riverine floodplain, it is suspected that the localized flooding occurs primarily due to the seiche effect or storm surge (see Figure 1.1) from Lake Erie.

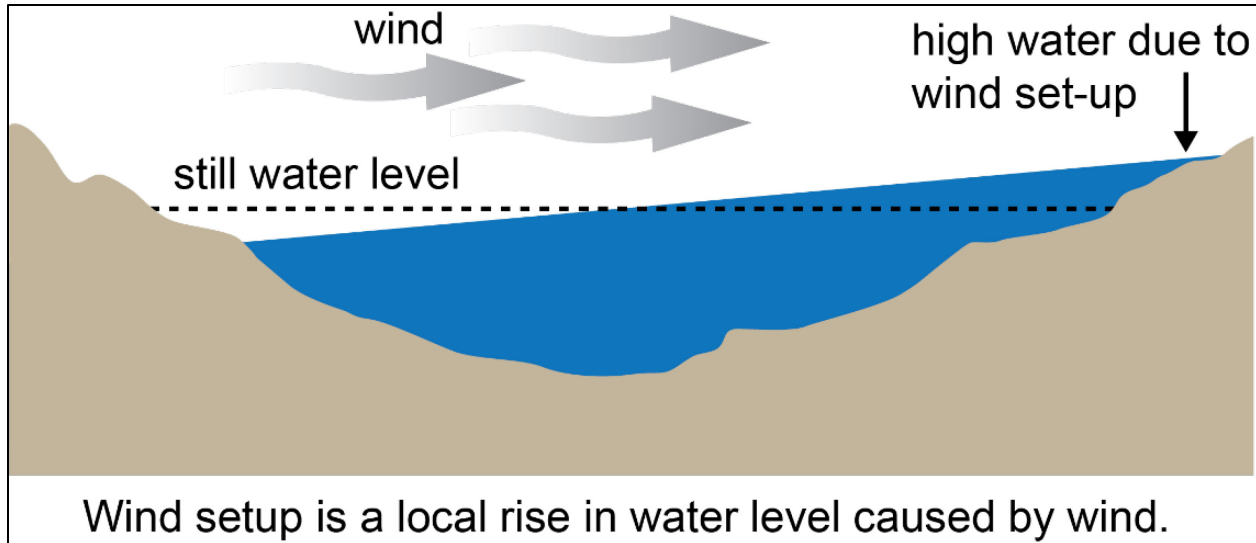


Figure 1.1 Example of the Seiche / Storm Surge Effect on Lake Erie (NPS 2018)

1.3 Objectives

The primary goal of this hydrologic and hydraulic study is to provide the technical information needed to support the EA for the Six Mile Creek flooding project. The specific objectives of this analysis are to:

- **Develop a Consistent Evaluation Tool:** Update and refine the hydraulic modelling for Six Mile Creek to accurately represent current topography and infrastructure. The model provides a consistent and reliable tool for simulating and comparing the performance of all proposed flood mitigation alternatives.
- **Establish Existing Flood Conditions:** Develop a baseline understanding of the current flood risk in the study area. This involves modelling the flood extent, depths, and water surface elevations for a range of design events that combine both Lake Erie water levels and Six Mile Creek flows.
- **Evaluate Flood Mitigation Alternatives:** Use the refined hydraulic model and supplementary analysis to assess the effectiveness and impacts of each proposed alternative. The technical outputs, such as flood inundation maps and water level data, will help determine and visually assess how each alternative solution performs in reducing flood levels and protecting the community and infrastructure.

2 EXISTING CONDITIONS

The following sections describe the study area's hydrologic and hydraulic current conditions, as well as the technical analyses used to better understand the study area's physical characteristics.

2.1 Preliminary Assessment

A preliminary assessment was conducted early in the project to evaluate the mechanism(s) of flooding in the area and determine a hydraulic modelling approach. A key component of the study was to determine the main cause of flooding in the area. The combination of riverine flooding from Six Mile Creek and lake level induced flooding from Lake Erie, often referred to as compound flooding, poses unique challenges for risk assessment and resilience planning. Compound flooding events occur when high river levels, driven by local precipitation, coincide with high

lake levels, which are driven by wind-induced storm surges and seasonal fluctuations in lake level. Determining if the flooding issues are a result of riverine flows, lake water levels or a combination thereof, focuses the assessment and helps determine practical solutions that can be implemented.

The preliminary assessment details and proposed modelling approach were compiled in a technical memorandum (Appendix D). A summary of the results is provided below.

2.1.1 Seasonal Flood Analysis

In southern Ontario, the largest rainfall events typically result from summer convective thunderstorms, which occur most frequently in July and August. However, in the months November to March, freshet and rain-on-snow events can also cause high riverine flood events, particularly in rural watersheds (such as the Six Mile Creek watershed).

A frequency analysis was completed to determine the seasonal patterns of rainfall against the occurrences of flooding in nearby gauged watersheds (Twenty Mile Creek, Twelve Mile Creek and Welland River). The results showed that the highest recorded river flows occur between November and March, rather than during the typical periods of high rainfall/convective thunderstorm events (July and August). This leads to the conclusion that high water levels in Six Mile Creek are typically driven by rain-on-snow events through the winter/early spring. The analysis also examined the occurrence of peak storm surge events, which typically occur from October to February. This temporal correlation suggests a potential for high river flow in Six Mile Creek to coincide with high surge levels in Lake Erie, which could result in compound flooding.

2.1.2 Compound Flood Analysis

The seasonal occurrence of riverine floods and storm surge events during the winter months suggests that there may be instances where compound flooding occurs in Six Mile Creek. A statistical analysis examined days when rainfall exceeding 20 mm was recorded, in relation to daily maximum storm surge lake levels. Over a period of 60 years, there was only one instance, on November 14, 1974, where a coinciding events could have occurred (58 mm of rainfall and a 1.7 m storm surge); however, large rainfall/melt events and peak storm surges were generally independent. This suggests that coinciding events are possible but are quite rare/weakly correlated. Furthermore, no significant rainfall occurred in the Six Mile Creek watershed during the periods when the Town reported flooding incidents between 2019 and 2023. Therefore, the analysis indicates that the main cause of flooding in the study area is lake-induced storm surges from Lake Erie, rather than Six Mile Creek flows.

2.1.3 Approach and Level of Service

The preliminary assessment memo also examined the resulting flood extents from a combination of riverine and lake-induced storm surges to inform the modelling approach. At the time of preparing the memo, the local survey had not yet been completed, and the assessment was conducted using the existing NPCA model prior to any refined data updates. After the data was collected, the hydraulic model (including a revision to the model datum) was completed. To avoid confusion with discrepancies in water levels presented in the May 2024 technical memo (due to model updates and changes in datum), the analysis was redone once the existing conditions model was updated and is described in Section 3.

2.2 Six Mile Creek Hydrology

The study area is bound within the 18 km² drainage area of the Six Mile Creek watershed (Appendix A, Figure A1). Six Mile Creek generally flows from north to south and from west to east within the study area. While there appear to have been some local changes to land use within the study area, much of the land use in the upstream portion of the watershed has remained unchanged since the 1950s. Land use in the study area is largely rural, with the primary land uses being swamp, treed, and undifferentiated/agricultural; the remaining portions are allocated to urban and rural residential land uses. Soils in the residential areas are largely disturbed and “unmapped” within the Soil Survey Complex. Soils surrounding Six Mile Creek and the adjacent wetland are classified as alluvium, which is described as a loose mix of clay, silt, sand and gravel sediments that are associated with floodplains. There is a small pocket between the residential area and the wetland that has been mapped as “Maplewood Soil - Red Phase,” which is characterized by a loamy texture over silty clay (Kingston and Presant 1989).

There are no flow monitoring gauges on Six Mile Creek; therefore, return period flows for the creek have been extracted from catchment ID=03 (044100) using the NPCA’s SWMHYMO model developed for the area by Philips Engineering Ltd. in 2008. An overview of the peak flows derived from 2- to 100-year events for the main branch of Six Mile Creek is outlined in Table 2.1. No updates to the watershed flows were completed as part of the project.

Table 2.1 Return Period Flows for Six Mile Creek

Return Period	2-year	5-year	10-year	25-year	50-year	100-year
Flow m ³ /s	4.82	13.15	20.10	30.46	38.81	47.40

2.2.1 Lake Erie Water Levels

Lake Erie water level data is the most critical factor influencing flooding in the study area. It acts as the downstream boundary for the hydraulic model. Lake levels, including the effects of storm surge, were determined from a calibrated hindcast model of Lake Erie developed by Prodanovic (2023) using the TELEMAC 2D coastal circulation model. This model provides the most accurate historical water levels for the study area. Lake level data were extracted at Buffalo (the closest port location), providing a slightly conservative surge level estimate as Buffalo is located further east of Fort Erie and experiences slightly higher storm surges.

Lake Erie’s geography makes it highly susceptible to storm surge (or seiche). Due to its shallow depth and east-west orientation, strong southwest winds can push large volumes of water to the eastern end of the lake. This effect can raise water levels by up to 2.4 m in the Fort Erie area in extreme cases. The storm surge effect leads to flooding in low-lying areas or near watercourse outlets, with the water oscillating in these areas for hours or even days (see Figure 2.1).

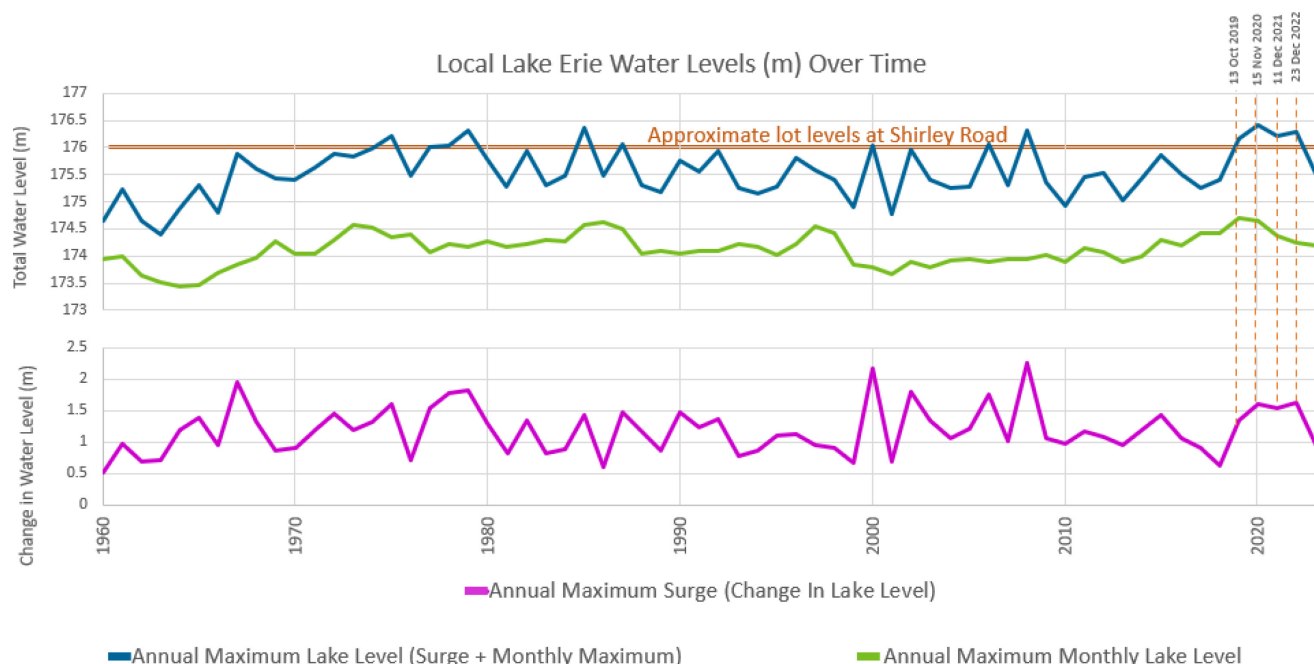


Figure 2.1 Lake Erie Water Levels Over Time

A probability analysis was completed using the hindcast results of the TELEMAC 2D coastal circulation model (Prodonovic, 2023). The analysis reviewed 64 years of storm surge data, with water levels ranging from 174.8 to 176.8 metres above sea level (masl). Generalized Extreme Value was the distribution found to best predict the data and was selected to derive the return period frequency of the combined lake level/storm surge level for Lake Erie. A summary of return period storm surge lake levels for Fort Erie is outlined in Table 2.2.

Table 2.2 Return Period Storm Surge Lake Levels for Fort Erie (masl)

Return Period	2-year	5-year	10-year	25-year	50-year	100-year
Combined Lake Level & Surge ¹	175.58	175.98	176.18	176.33	176.47	176.56

1. Datum is CGVD 2013

2.3 Six Mile Creek Hydraulics

To understand and assess the hydraulic characteristics of the study area, NPCA provided the existing HEC-RAS model (Phillips, 2006) for Six Mile Creek. The model was trimmed at the upstream extent (Dominion Road cross-section) to focus on the study area; other changes and model updates are described in Section 2.3.1.

2.3.1 Updates to the HEC-RAS Model

To accurately represent the existing conditions of the study area, NPCA's HEC-RAS model (Phillips, 2006) was updated with more recent topography and survey data. The model updates were conducted in HEC-RAS version 6.4.1, as follows:

- The model was georeferenced to the NAD 83 Zone 17N (CSRS) projection.

- The general topography was updated to the MNRF (2021, Vertical Datum: CGVD2013) LiDAR and survey data (collected and provided by the Town between November 2024 and January 2025). Surveyed structures included the Thunder Bay Road bridge and the two small bridges at Colony Road, as well as Dominion Road. Survey data was originally provided in the CGVD28 vertical datum, which was later converted to the CGVD2013 datum to align with the LiDAR data.
- Cross-sections were recut from the terrain and adjusted where required. New cross-sections were added to represent the areas of interest as well as conform to best modelling practices. The elevation profile for the general cross-sections was derived from the LiDAR data, while the topography for the cross-sections associated with bridges and roads of interest was assigned based on the survey points. Bridge ineffective areas were also updated (See Appendix A, Figure A2).
- The upstream boundary condition flow data was taken from the 1992 NPCA SWMHYMO model (Table 2.1), while the downstream boundary conditions were assigned from a coastal Flood Frequency Analysis (FFA) developed using the Prodanovic model (2023) (Table 2.2).
- Mannings n values were also adjusted to better reflect the boundary of the wetland and vegetation.
- Ineffective areas were added to appropriate locations based on best modelling practices. Buildings were also coded in as blocked obstructions.

2.3.2 Updated Model Comparison to NPCA's Model

Figure 2.2 shows a comparison of Montrose's updated hydraulic model with the NPCA model for the regulatory 1:100-year flood under mean lake level conditions. The updated model shows higher water levels in Six Mile Creek downstream of Friendship Trail bridge. In particular, water levels are approximately 0.3 m higher at Thunder Bay Road bridge and 0.5 m higher near the Access/Colony Road crossings (Figure 2.2). The increase in water levels is due to several factors:

- The recently surveyed bridge elevations are lower than the elevations specified in the NPCA model.
- The median lake level used in the updated model is slightly higher than the lake level used as a downstream boundary condition in the NPCA model.
- Additional cross-sections between the access bridge and Lake Erie, where the creek flow expands more gradually than in the NPCA model.
- Mannings roughness values were increased in some locations throughout the wetland area.
- Ineffective flow areas were added along the Six Mile Creek channel upstream and downstream of the Thunder Bay Road crossing.

The differences in the updated and NPCA model are most prominent when the lake level is at median or normal conditions. Under 1:5-year storm surge lake level, the difference in water levels between the two models is less than 0.1 m as higher lake levels dominate the differences in model configuration and bridge geometry (Figure 2.3).

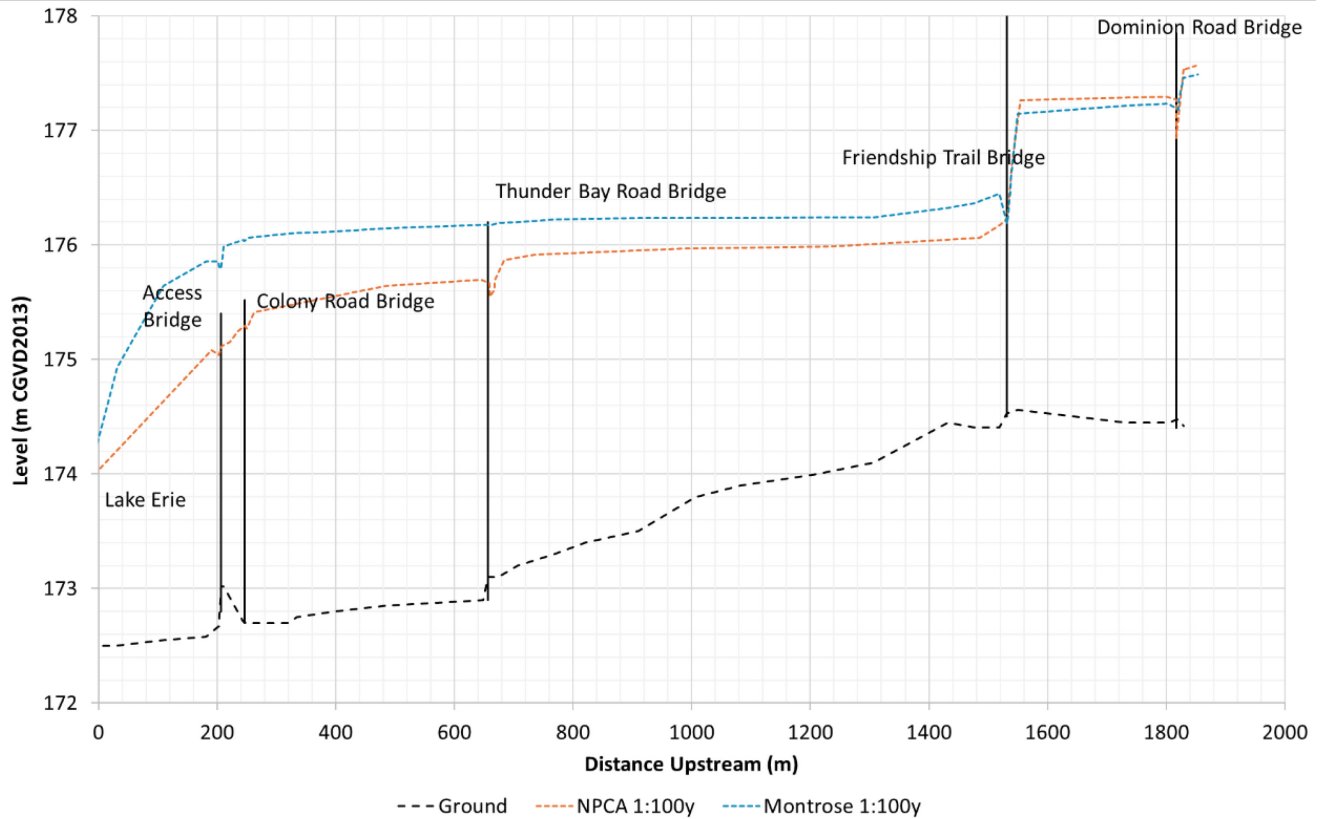


Figure 2.2 Comparison of the Montrose Updated Model to NPCA using 1:100-year Return Period Creek Flows with median lake level conditions

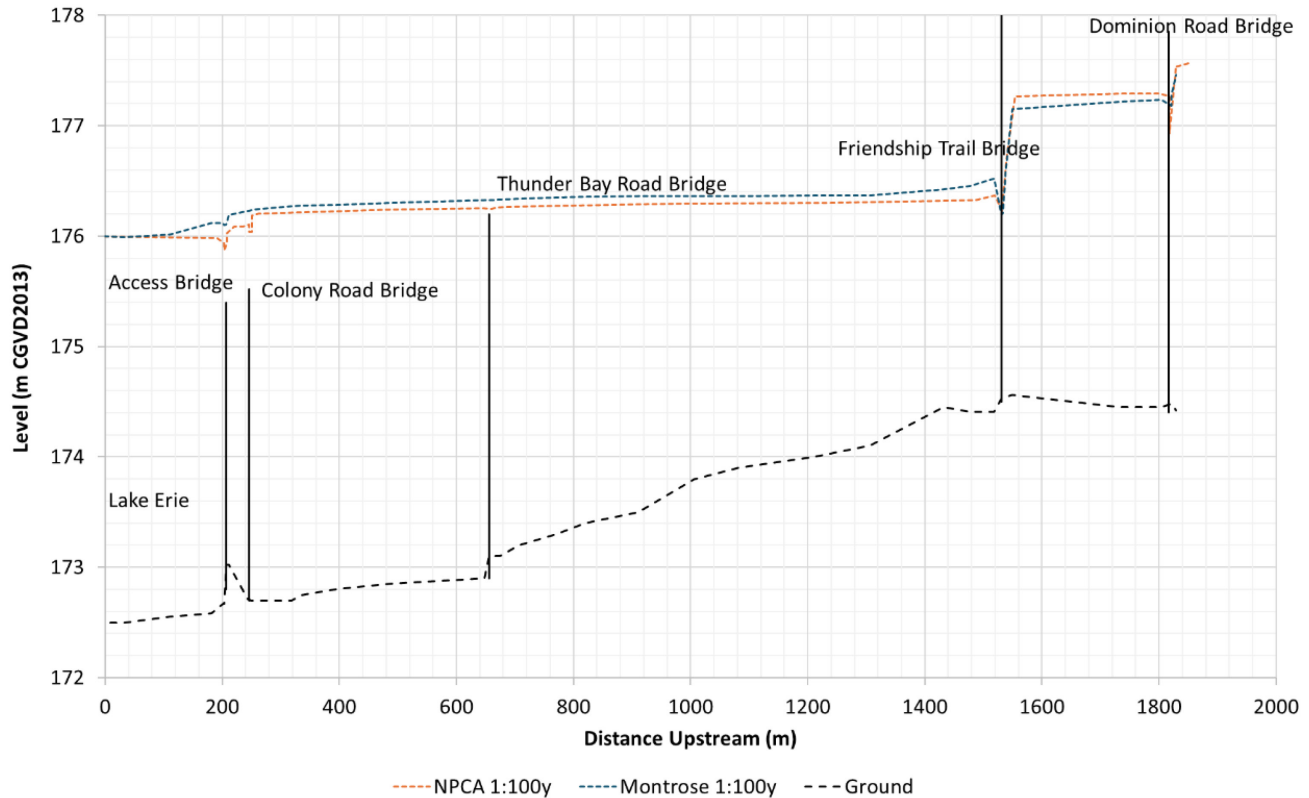


Figure 2.3 Comparison of the Montrose Updated Model to NPCA using 1:100-Year Return Period Creek Flows with 1:5-year storm surge lake level

2.3.3 Existing Conditions Model Simulations

2.3.3.1 Riverine Water Levels

A hydraulic analysis of the Six Mile Creek was performed using the updated existing conditions HEC-RAS model with data from the return period flows (Table 2.1), assuming a median lake level of 173.6 masl CVGD2013. The analysis found that average lot levels of the Shirley Road properties (176 masl CVGD2013) are within the 50-year riverine flood extent. Therefore, it would be expected that these properties would only flood from river flows (Six Mile Creek) once per 50 years on average. Figure 2.4 shows the result of the hydraulic analysis for the Six Mile Creek 2-year through 100-year return periods flows.

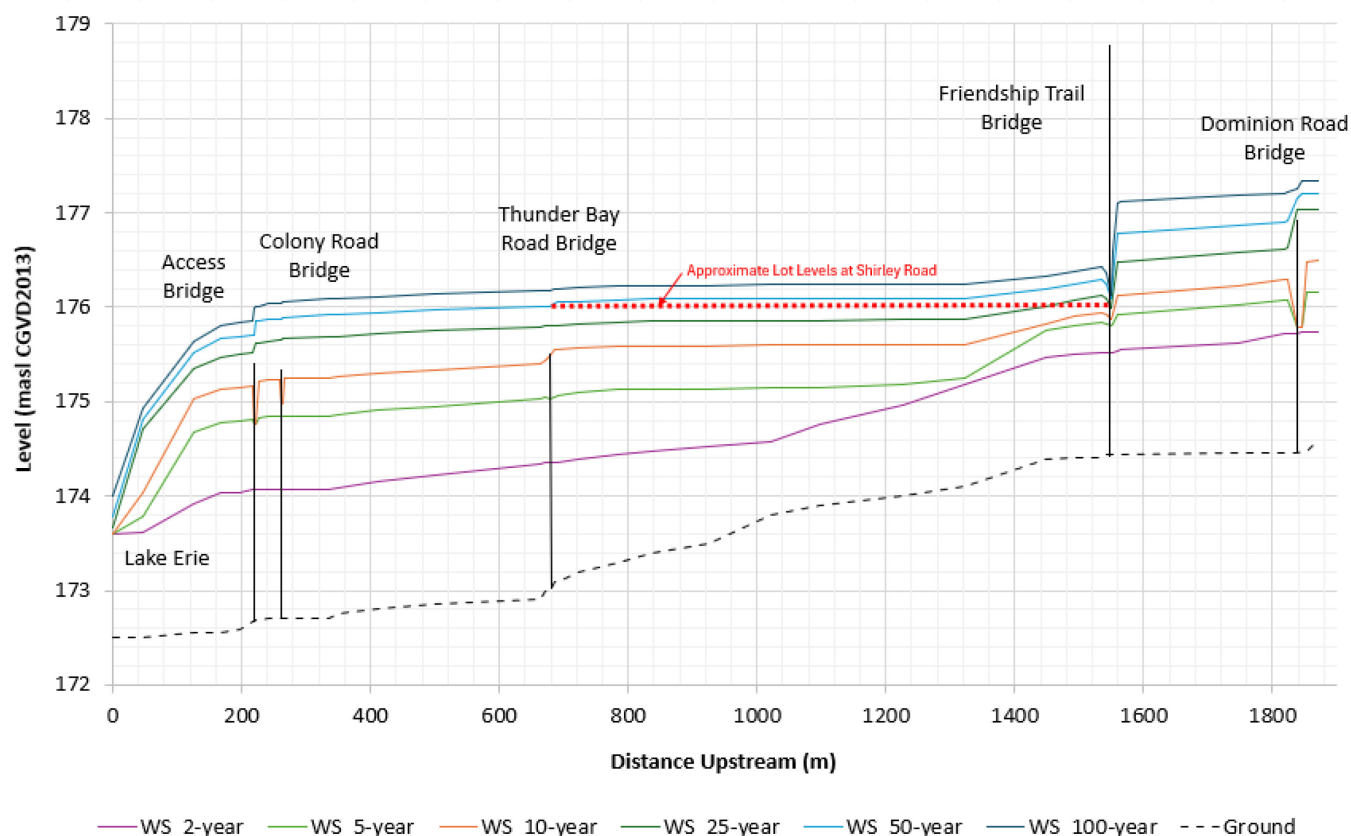


Figure 2.4 Riverine Flood Levels (2-year through 100-year peak flows, median lake level)

2.3.3.2 Lake Surge Water Levels

A hydraulic analysis of Six Mile Creek was performed using the updated existing conditions HEC-RAS model with data from the return period storm surge lake levels based on a combined lake level/storm surge analysis (Table 2.2). The analysis determined that return period surge lake levels produce higher water levels upstream than the equivalent riverine flood levels. Shirley Road properties are at approximately the 5-year storm surge water levels (Figure 2.5). Therefore, they would flood from storm surge lake levels once per 5 years on average.

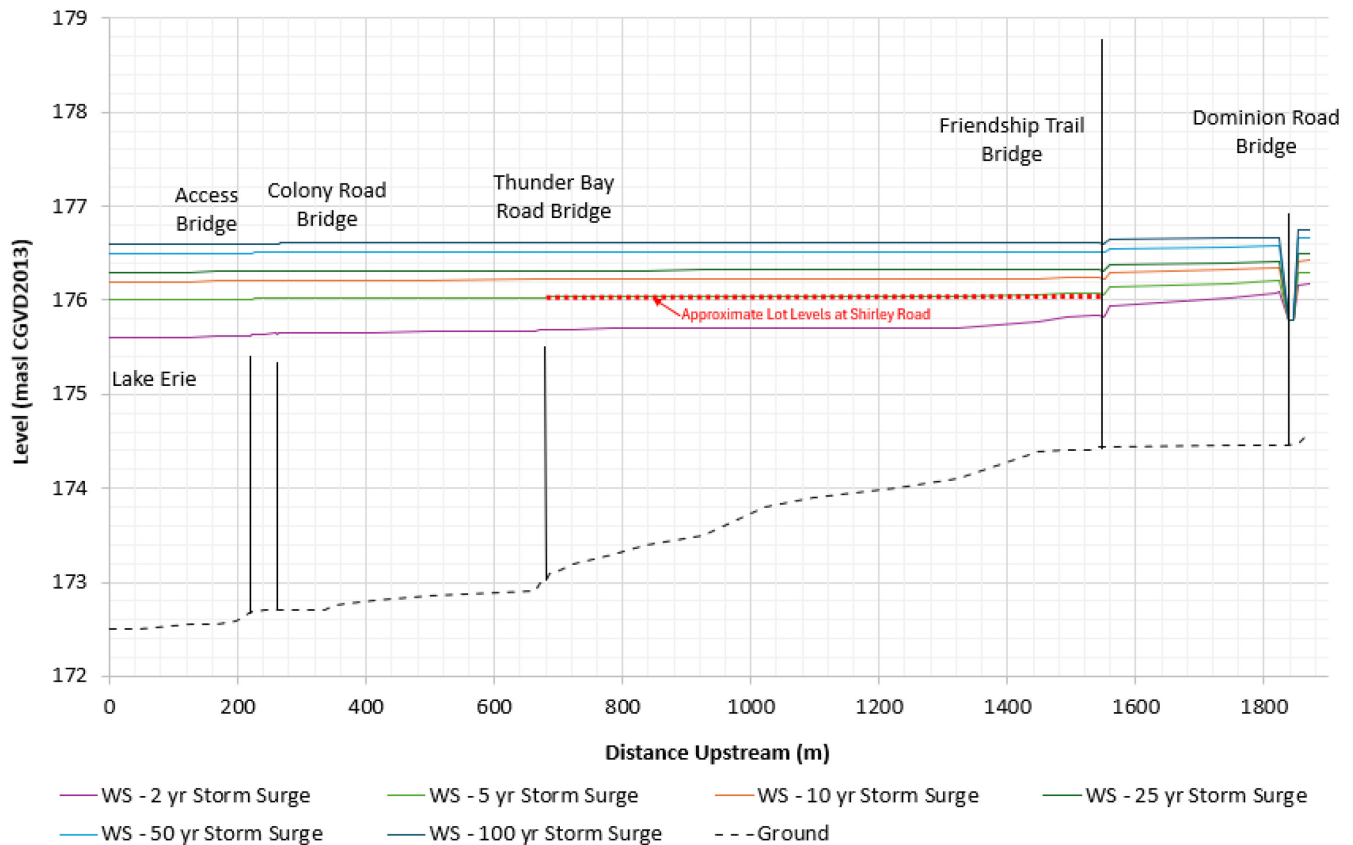


Figure 2.5 Lake Flood Levels (2-year through 100-year Storm Surge Lake Level, 5-year Creek Flow)

2.3.4 Level of Service

While removing the regulatory flood extents completely for the community of Thunder Bay would be the most beneficial, it ultimately is not practical due to the low-lying topography and proximity to the lake. Alternative solutions that remove the flooding extent entirely from properties (both lake and riverine flooding) would be too costly or too complex to construct.

The level of service needs to consider the flooding mechanism (lake levels), the frequency of occurrence (return period), protection of houses / buildings (as opposed to the entire property, or non-developed properties) as well as costs and constructability. Appendix A, Figure A3, shows inundations extents of the 2 through 100-year lake surge events, along with the regulatory riverine flood extent.

Based on discussions with agencies and stakeholders, a 5-year level of service related to lake surge flooding was selected to facilitate the alternative solutions development and evaluation process. This selection aligns with Town's design standards where lake flood risk within the study area would be consistent with the rest of Town design criteria: "storm sewers and ditches shall [convey] the runoff from the 5-year storm event with minimal inconvenience to activities of property owners and damage to properties (Town of Fort Erie Subdivision Control Guidelines for Development of New Subdivisions 2021)." Additional considerations for selecting the 5-year level of service include:

- Properties experiencing frequent storm surge induced flooding – the properties that experience the most frequent flooding are located with the 5-year storm surge flood extent.
- Feasible construction – barriers or control structures that address a higher level of service would be challenging or complicated to construct.
- Environmental impacts – a higher level of service would require larger and more extensive construction, potentially impacting the adjacent sensitive wetland and natural heritage features.
- Cost-effectiveness – larger or more complex flood mitigation solutions will come at a higher capital cost to implement as well as maintain.

All alternative solutions presented below achieve a reduction in flood risk within the 5-year storm surge flood extent for residential properties along Shirely Road, Neva Road, and Bethune Ave. The alternative solutions provide protection of residential dwelling structures, but do not eliminate the risk of property flooding.

Three properties south of Thunder Bay Road may have residential dwellings within the 5-year storm surge flood extent. Access to these properties was not granted prior to undertaking the required surveys, and therefore the structure elevations could not be confirmed. As such, these three properties have not been formally included in the evaluation of alternative solutions.

3 ALTERNATIVE SOLUTION OVERVIEW AND ASSESSMENT

A key step in the EA process is developing and evaluating a range of alternative solutions. Six alternatives (a “do nothing” alternative and 5 proposed alternatives) were assessed to mitigate and prevent flooding to the properties within the 5-year storm surge flood line. The alternative solution figures are shown in Appendix B and include:

- Do Nothing Alternative: This mandatory alternative provides a baseline for comparison. It assumes no new flood protection infrastructure is built, representing the existing level of flood risk.
- Structural Barriers: Alternatives 1, 2, 4, and 5 involve constructing physical barriers to block the lake surge. These vary by location and design and include:
 - Alternative 1: Landform barrier (or dyke) along rear property lines.
 - Alternative 2: Landform barrier along the municipal roadway.
 - Alternative 4: Landform barrier along Thunder Bay Road with backflow prevention system.
 - Alternative 5: Landform barrier (or dyke) along the Lake Erie shoreline with backflow prevention system.
- Non-Structural Solutions: Alternative 3 focus property-level actions rather than large-scale public works, with the Town acquiring properties within the 5-year storm surge to remove dwellings from the flood risk area.

Only Alternative Solutions 1, 2, 4, and 5 required hydraulic assessment. The following subsections describe each alternative in more detail, how each of the alternatives were assessed, and the main findings for the assessment.

3.1 Assessment Methodology

The Alternative Solutions were assessed using three specific design scenarios to evaluate the following:

- primary protection from 5-year storm surge (does the alternative meet the required level of service)
- secondary impacts from trapped local runoff (how much storage do the barriers and/or backflow prevention systems contain upstream, and is this acceptable)
- the potential to worsen existing riverine flooding (does the alternative improve lake level flooding but increase creek (riverine) flooding)

3.1.1 Storm Surge Assessment

The updated Six Mile Creek hydraulic model was used to evaluate the protection level from the lake induce storm surge. Water levels for the 5-year storm surge were combined with the 5-year creek flows to evaluate the resulting level of flood protection.

3.1.2 Upstream Storage Assessment

Alternatives involving physical barriers (Alternatives 1, 2, 4, and 5) can trap stormwater runoff or Six Mile Creek flow behind the barriers and prevent it from draining. During a lake surge event, backflow prevention on culverts or barriers would close, preventing the drainage. If a significant rainfall event occurs at the same time as a lake level surge, this trapped runoff, or flow can cause localized "inland" flooding.

It is assumed that Alternatives 1 and 2 would include passive backflow prevention culverts outfitted with a device such as flap gates or duckbills. These devices work via water pressure differences to control flow automatically without any power or manual operation. Under normal conditions (not storm surge conditions), water on the upstream side of the culvert flows toward the outlet, the internal pressure pushes the flap open, allowing water to discharge. When the downstream water level rises, such as during a storm surge, the higher downstream pressure forces the flap closed against the culvert outlet. This prevents water from flowing backward into the culvert and protects upstream areas from flooding. No local runoff assessment was completed for Alternatives 1 and 2 and the passive backflow prevention system would not exacerbate any flooding upstream.

For Alternatives 4 and 5, it is assumed that the backflow prevention measures would not be passive and would instead rely on manually operated gate systems. These alternatives introduce the potential for upstream runoff to become trapped if a flood event occurs at the same time as a storm surge that requires the gates to remain closed. To assess this secondary flood risk, the existing SWMHYMO model for Six Mile Creek (Philips, 2008) was used, specifically the 12-hour storm duration hydrograph from catchment ID 03 (044100), to evaluate the accumulation of stormwater behind the Alternative 4 and 5 barriers under closed-gate conditions. It should be noted that the peaks from the 12-hour hydrographs differ from those used in the NPCA Regulatory HEC-RAS model, which applies peak flows from 24-hour duration storms. Figure 3.1 presents the resulting Six Mile Creek hydrographs for the 2- through 100-year 12-hour design storms.

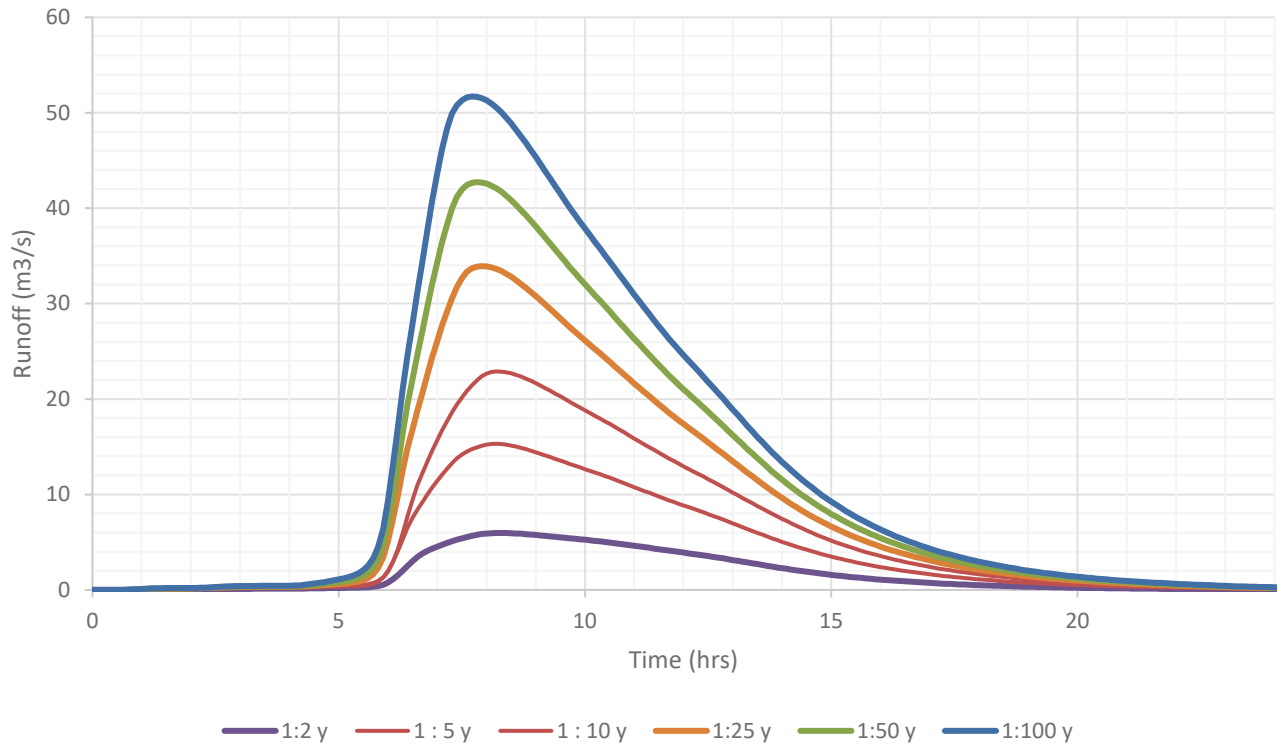


Figure 3.1 Six Mile Creek 12-hour storm SWMHYMO Hydrograph

To determine how much storage was available upstream of the barriers, a simple storage routing analysis was conducted using a spreadsheet. This analysis used the runoff volumes generated by the SWMHYMO model to calculate the water level that would build up behind each barrier alternative for the associated design storms. This method allowed for a clear assessment of the flood risk and was also used to evaluate the potential need of adding permanent or mobile pumping stations to the alternative solutions.

3.1.3 Riverine Flooding Assessment

The updated Six Mile Creek hydraulic model was used to assess whether the alternative solutions could contribute to increased riverine flooding. The analysis applied median lake levels as the downstream boundary condition and incorporated the 100-year Six Mile Creek flow to determine if any increase in Regulatory flood levels would result from the proposed solutions.

3.2 Assessment Results

3.2.1 Do Nothing Alternative

The 'do nothing' alternative must be considered as part of the EA process. In this alternative, no new infrastructure is built, there are no changes or improvements to existing infrastructure leading to no changes in flood risk to public and private properties.

Figure C1, in Appendix C, shows the 5-year storm surge and the properties and structures within (affected by) the resulting flood line.

3.2.2 Alternative Solution 1: Landform Barrier

Alternative 1 (Appendix B, Figure B2) creates a landform barrier (or dyke) along rear property lines adjacent to the wetland protecting residents along Shirley Road and Bethune Avenue from lake surge induced flooding up to the desired level of service.

The elevation of the landform is at the 5-year storm surge level (176 masl) plus 0.3 m of freeboard (additional height for resiliency). The barrier would extend approximately 425 m, at a height averaging 0.8 m (max height of 1.8 m), impacting 2,400 m² of area (rear properties and adjacent wetland/woodlands). Culverts with backflow prevention will be required through the barrier at each tributary (along Shirley Road and Bethune Avenue). An easement through the properties yard would be required for construction and maintenance access.

3.2.2.1 Performance During 5-Year Storm Surge

The hydraulic modelling indicates that the landform barrier effectively mitigates flooding upstream of the barrier, protecting the properties on Shirley Avenue and Bethune Avenue. The freeboard also provides some additional flood protection resiliency as it prevents flooding up to the 176.3 masl elevation (approximately the 25-year storm surge level). The resulting flood protection is illustrated in the flood-depth mapping provided in Figure C2, Appendix C.

3.2.2.2 Impact on Regulatory Riverine Flooding

The analysis of the 1:100-year regulatory riverine flood was conducted to ensure the alternative does not worsen existing flood conditions. The results in Figure 3.2 show that the barrier has no adverse impact on regulatory flood levels.

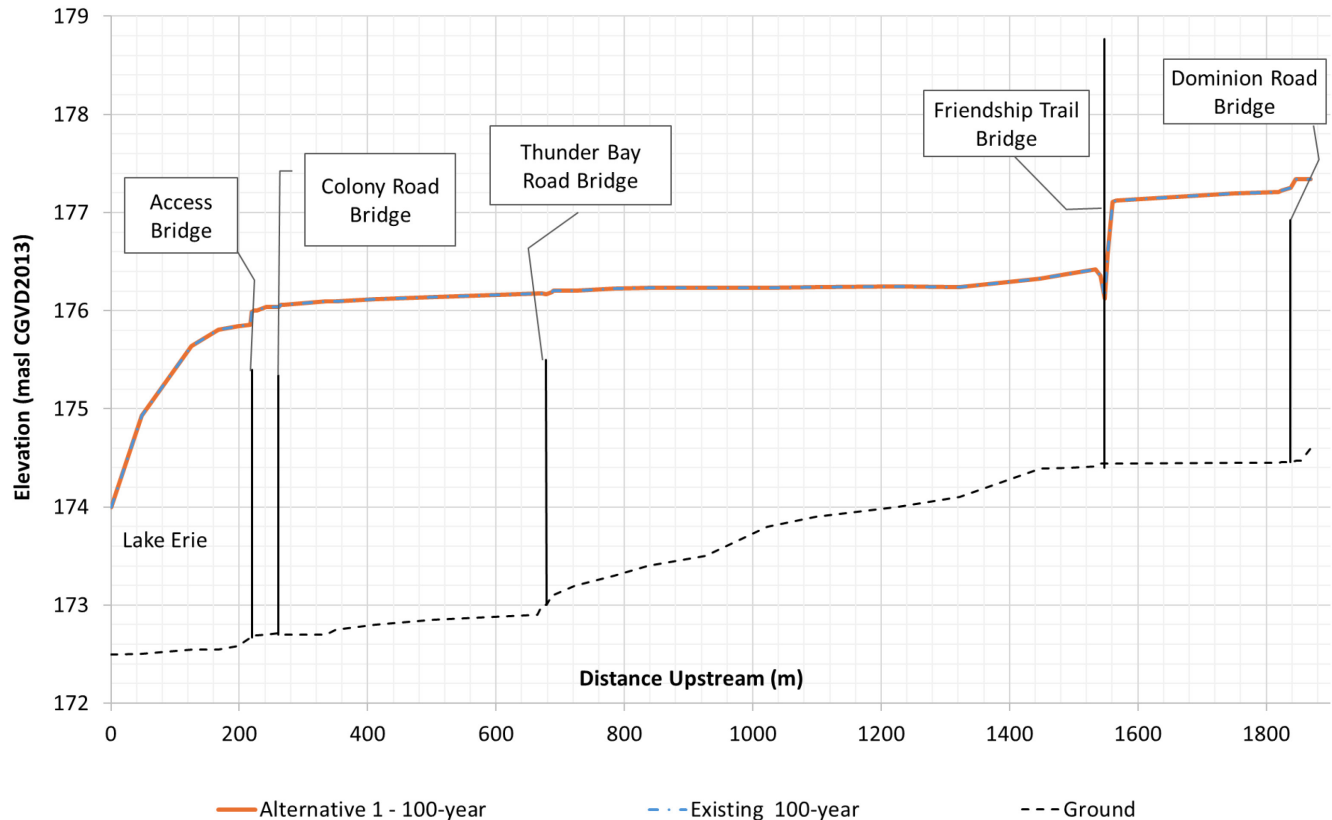


Figure 3.2 Alternative 1 HEC-RAS Model Profile Water Levels – 100-year (Regulatory) with Median Lake Level

3.2.3 Alternative Solution 2: Road Right-of-Way Barrier with Property Purchase

Alternative 2 raises the elevation of the municipal roadway to create a barrier, protecting residents on the west side of Shirley Road from lake surge induced flooding. Culverts sized to the 100-year upstream peak flow would need to be installed along the tributary draining toward Six Mile Creek. The culverts (2 x 1,200 mm diameters downstream of Shirley Road) require backflow prevention to stop flow backwater from entering upstream during a storm surge event. This alternative makes use of existing road infrastructure and corridor to form flood barriers removing the need to construct barriers outside the existing municipal corridor.

The ROW barrier does not alleviate flooding from all properties along Shirley Road. There are five residential properties with buildings falling within the 5-year storm surge area, east of Shirley Road and south of Bethune Avenue. These properties would need to be purchased to eliminate flood risk for the desired level of service.

3.2.3.1 Performance During 5-Year Storm Surge

The hydraulic modelling indicates that the landform barrier effectively mitigates flooding upstream of the barrier, protecting the property buildings on west side of Shirley Avenue. The freeboard also provides some additional flood protection resiliency as it prevents flooding up to the 176.3 masl elevation (approximately the 25-year storm surge level). The resulting flood protection is illustrated in the flood-depth mapping provided in Figure C3, Appendix C.

3.2.3.2 Impact on Regulatory Riverine Flooding

The analysis of the 1:100-year regulatory riverine flood was conducted to ensure the alternative does not worsen existing flood conditions. The results in Figure 3.3 show that the barrier has no adverse impact on regulatory flood levels.

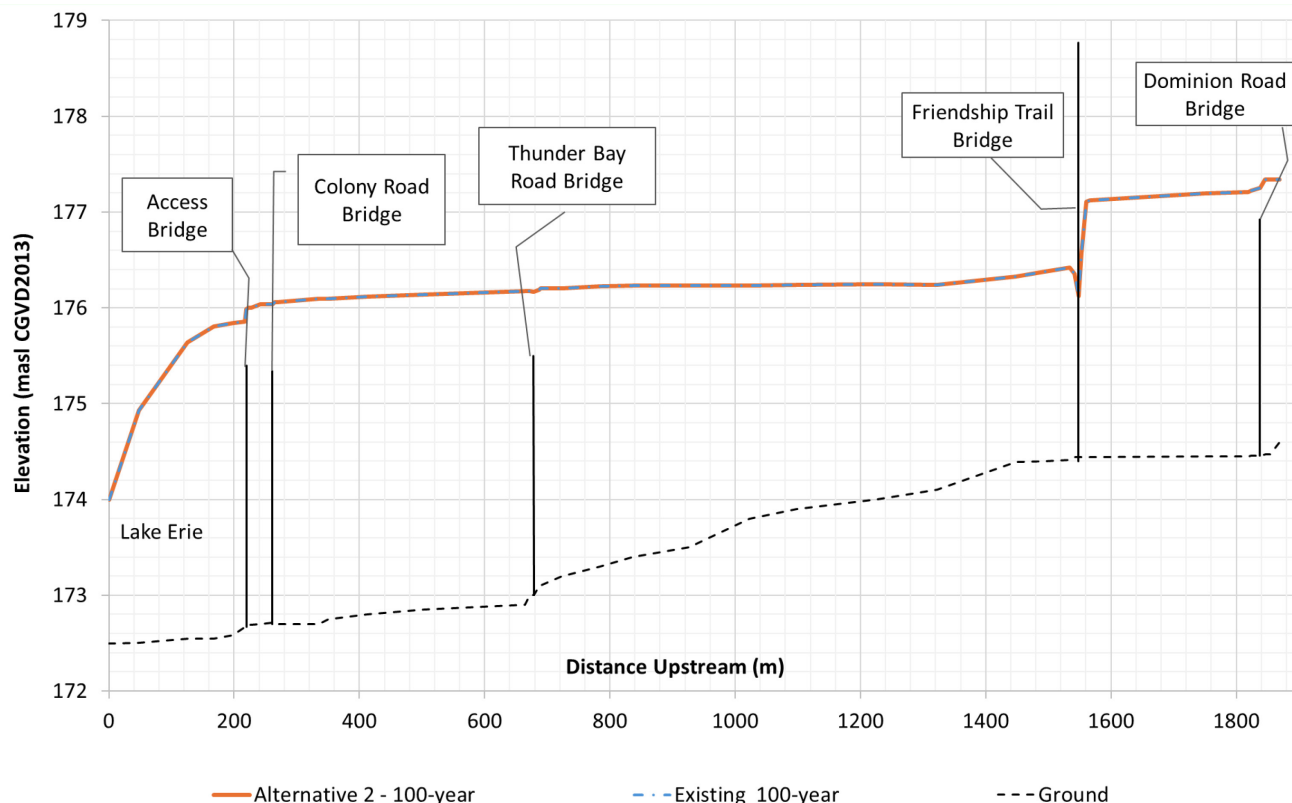


Figure 3.3 Alternative 2 HEC-RAS Model Profile Water Levels – 100-year (Regulatory) with Median Lake Level

3.2.4 Alternative Solution 4: Thunder Bay Road Barrier and Backflow Prevention System

Alternative 4 raises the elevation of Thunder Bay Road and incorporates a backflow prevention system (gates), protecting residents north of the road from surge flooding. The gates would have to be operated by the Town during storm surge events and closed once the event subsides (approximately 12 hours). The road would be raised approximately 0.6 m from the existing elevation; the existing bridge will likely need to be retrofitted. For this alternative evaluation it is assumed that the conveyance (opening of the bridge) would remain the same.

3.2.4.1 Performance During 5-Year Storm Surge

The hydraulic modelling indicates that the landform barrier effectively mitigates flooding upstream of the barrier, protecting the property buildings upstream of Thunder Bay Road. The freeboard also provides some additional flood protection resiliency as it prevents flooding up to the 176.3 masl elevation (approximately the 25-year storm surge level). The resulting flood protection is illustrated in the flood-depth mapping provided Figure C4, Appendix C.

3.2.4.2 Performance During a Coinciding Riverine Events

The upstream flow analysis shows that there is insufficient storage upstream of the Thunder Bay Road to contain the 2-year, 12-hour flood event. The total volume of storage required is approximately 150,000 m³, which would result in an elevation of 175.8 masl. From the provided survey, the lowest building elevation on Shirley Road was found to be 175.6 masl, indicating that the backwater would result in flooding of the upstream properties during a coinciding 2-year riverine event (Figure 3.4). As such, a pump station at Thunder Bay Road will be required during storm surge events to ensure that the upstream properties are adequately protected.

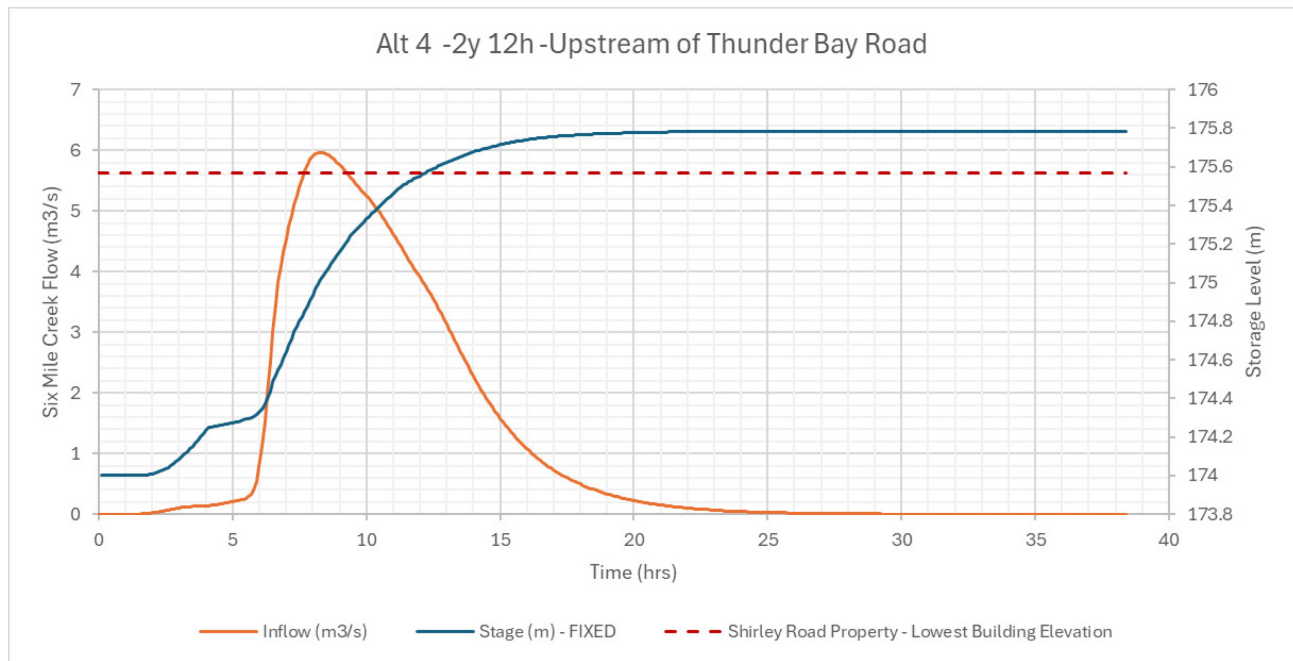


Figure 3.4 Alternative 4 – Upstream Storage Analysis

3.2.4.3 Impact on Regulatory Riverine Flooding

The existing, lower Thunder Bay Road elevation is overtopped during riverine events greater than the 10-year peak flow, and provides a secondary overflow path for floodwaters. Raising the road removes this path, causing water to back up and increases upstream flood elevations. The analysis of the 1:100-year regulatory riverine flood was conducted to determine if the alternative worsens existing flood conditions. The results in Figure 3.5 show that the barrier at Thunder Bay Road does lead to increase flood risk during the Regulatory (100-year) event. To mitigate this adverse impact, a significant enlargement of the bridge opening is required (which has not been including in the analysis).

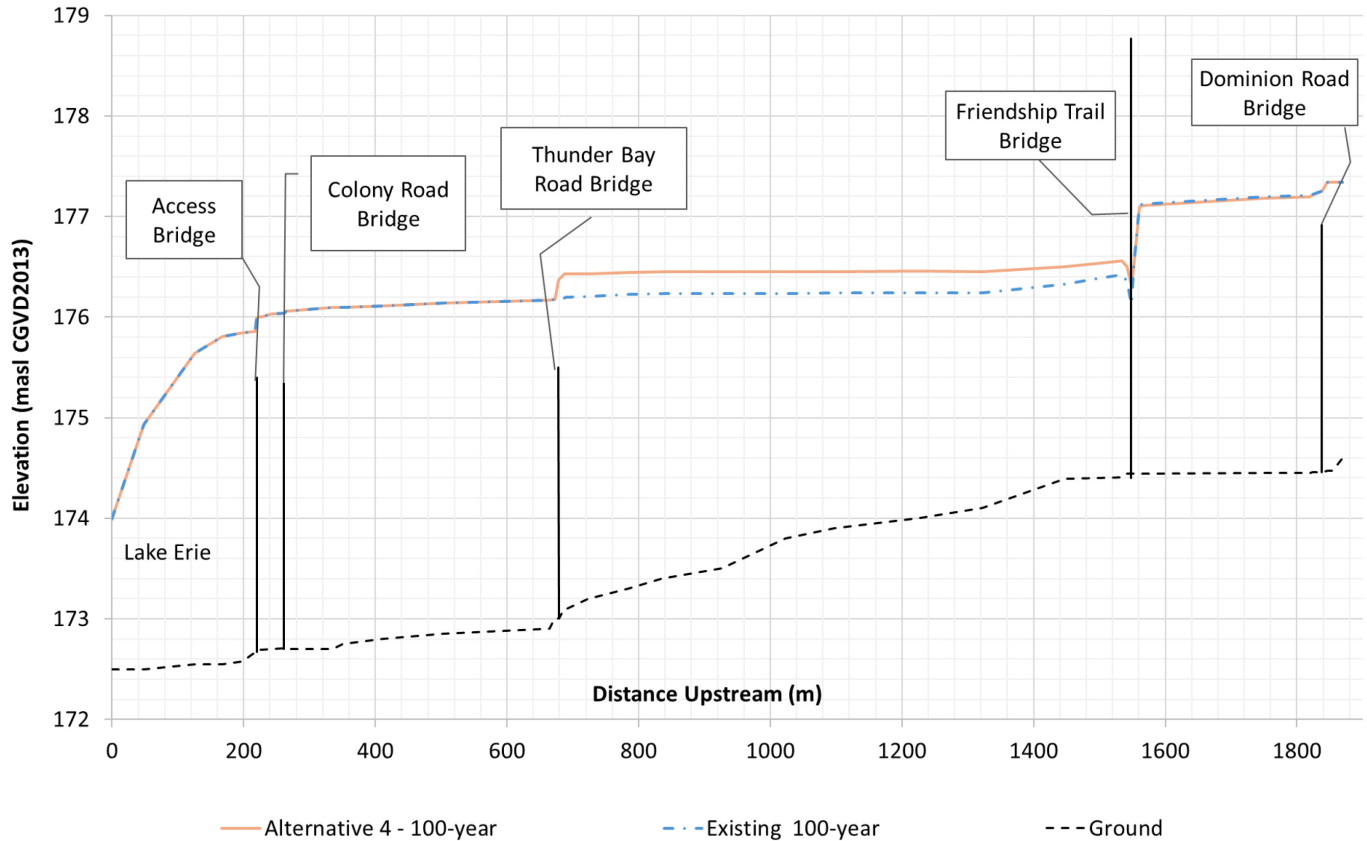


Figure 3.5 Alternative 4 HEC-RAS Model Profile Water Levels – 100-year (Regulatory) with Median Lake Level

3.2.5 Alternative Solution 5: Lake Front Barrier and Backflow Prevention System

Alternative 5 creates a barrier along the Lake Erie shoreline with operational gates for backflow prevention, protecting residents along Six Mile Creek from surge flooding. The barrier elevation equals the 5-year surge level plus freeboard. Road access would be required for maintenance.

3.2.5.1 Performance During 5-Year Storm Surge

The hydraulic modelling indicates that the landform barrier effectively mitigates flooding upstream of the barrier, protecting the property buildings upstream of Thunder Bay Road. The freeboard also provides some additional flood protection resiliency as it prevents flooding up to the 176.3 masl elevation (approximately the 25-year storm surge level). The resulting flood protection is illustrated in the flood-depth mapping provided in Figure C5, Appendix C.

3.2.5.2 Performance During a Coinciding Riverine Events

The upstream flow analysis shows that there is insufficient storage upstream of the Thunder Bay Road to contain the 2-year, 12-hour flood event. The total volume of storage required is approximately 150,000 m³, which would result in an elevation of 175.3 masl. From the DEM, the lowest building elevation on Colony Road was estimated at 175.4 masl, indicating that the backwater would result in flooding of this property during a coinciding

2-year riverine event (Figure 3.6). As such, a pump station at the lakefront barrier will be required during storm surge events to ensure that the upstream properties are adequately protected.

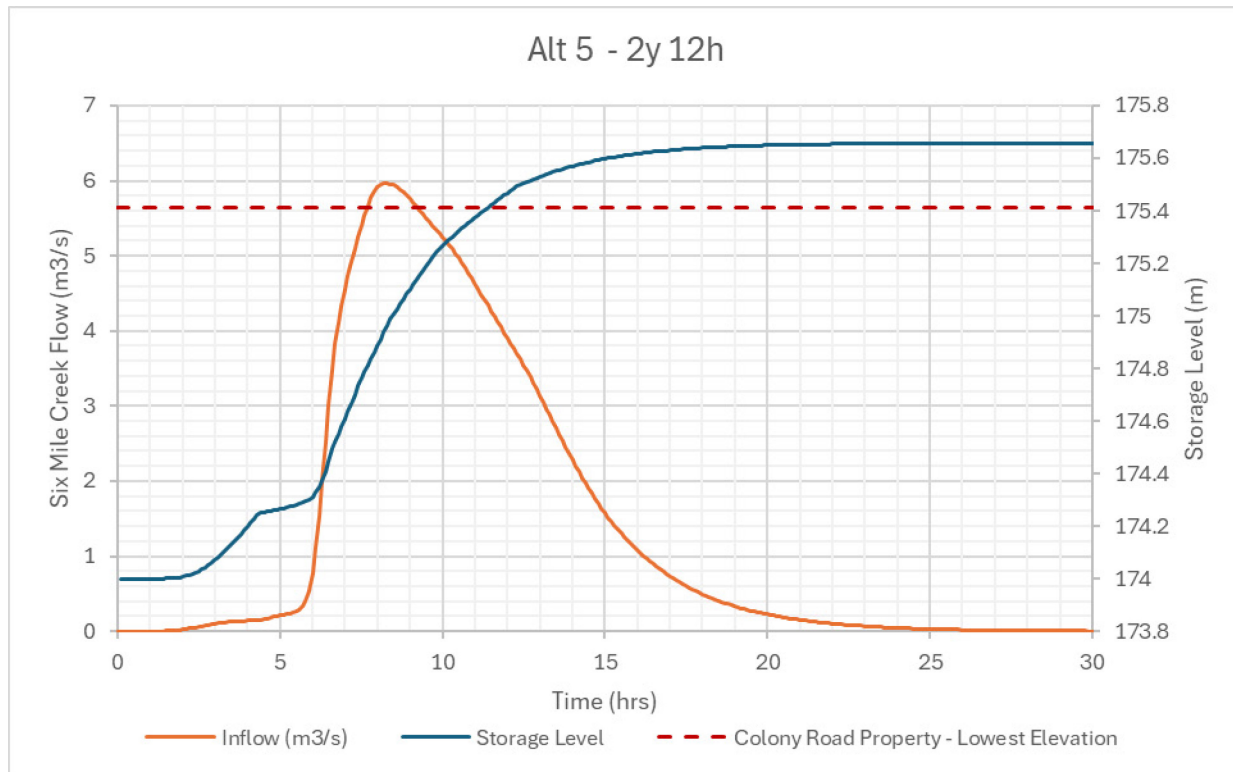


Figure 3.6 Alternative 5 – Upstream Storage Analysis

3.2.5.3 Impact on Regulatory Riverine Flooding

A continuous barrier at the interface of the Creek and Lake Erie could potentially obstruct riverine flows and worsen upstream flooding. To mitigate this, the design assumes the barrier would incorporate a structure with operable gates that open fully. These gates would only be closed to block lake surge. This structure would be effectively as wide as the 100-year riverine flood extent (approximately 35 m wide) at the river mouth to avoid impacts upstream. As the design would be required to convey the 100-year flow without upstream impacts, no adverse impact on regulatory flood levels would occur.

4 SUMMARY AND CONCLUSION

The updated hydrologic and hydraulic assessment for the Six Mile Creek EA study area (Thunder Bay community) refined existing conditions using an updated HEC-RAS model (v6.4.1) incorporating CGVD2013 LiDAR terrain, Town survey (converted from CGVD28), revised cross-sections/ineffective areas, updated roughness and obstruction representation, and boundary conditions defined by NPCA SWMHYMO-derived design flows and a Lake Erie storm-surge FFA based on a calibrated hindcast (TELEMAC 2D) dataset. The analyses indicate that flooding in the neighbourhood is primarily controlled by Lake Erie water levels (storm surge) rather than Six Mile Creek flow; observed flood incidents from 2019–2023 were not associated with significant rainfall, and compound surge/riverine coincidences are statistically rare. Existing-conditions simulations show that typical Shirley Road lot elevations (~176 m, CGVD2013) intersect approximately the 50-year riverine flood extent under median lake level,

but align closer to the 5-year storm-surge water level, confirming that surge events drive the frequent property flooding.

A 5-year storm-surge level of service was therefore adopted for alternative screening, consistent with Town drainage design criteria. Several alternative solutions (Do Nothing; structural barriers; and property acquisition) was evaluated against:

1. ability to mitigate 5-year surge inundation (with freeboard)
2. potential for trapped runoff/upstream storage impacts when backflow devices or gates are closed, and
3. risk of adverse effects on the regulatory (100-year) riverine profile under median lake levels.

Alternatives 1 (rear-lot landform barrier) and 2 (road right-of-way barrier with select property purchase) meet the 5-year surge protection target and do not increase regulatory riverine flood levels in the modelled condition. Alternatives 4 (Thunder Bay Road barrier with operable gates) and 5 (lakefront barrier with operable gates) also reduce surge inundation but introduce operational/secondary flood risks challenges. Alternative 4, raising Thunder Bay Road, removes an existing overflow pathway during larger riverine events and increases upstream water levels under the regulatory event unless major conveyance upgrades (bridge opening enlargement) are implemented. Alternative 5 required that the gate be built to span the 100-year water level, as to not increase flood risk upstream.

Overall, the updated modelling provides a consistent evaluation framework for the EA, demonstrating that practical flood risk reduction is achievable for the frequently affected structure areas, but that complete elimination of flood extents during the Regulatory storm is not feasible given the site's low-lying topography and lake influence. The full evaluation of the alternatives is provided in the accompany Project File Report.

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