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Hamilton Conservation Authority
Healthy Streams...Healthy Communities!

Class EA Flood Remediation Project- Watercourse 11, Fifty Point Conservation Area

Prepared for:
Hamilton Conservation Authority, Hamilton, Ontario

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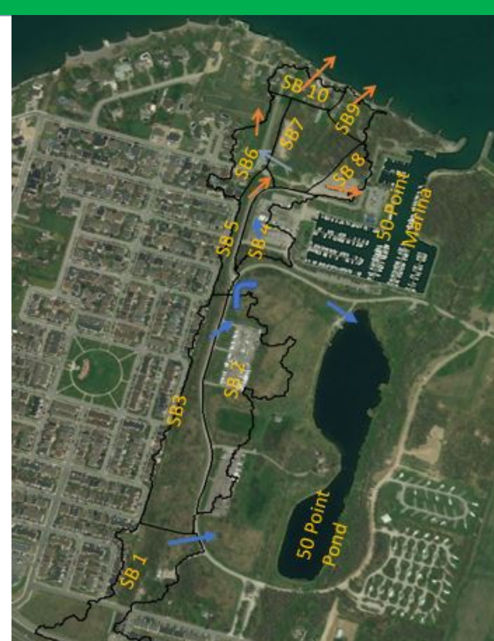

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Executive Summary

This report contains detailed description of all required components of the **CLASS EA Flood Remediation Project — Watercourse 11, Fifty Point Conservation Area,** completed by AHYDTECH Geomorphic Ltd. The steps of this project that have been completed and the professional work that have been carried out closely adhered to the Class Environmental Assessment for Remedial Flood and Erosion Control Projects (January 2002, as amended in 2009) document from Conservation Ontario.

The issue addressed by this Class EA is flooding that has been occurring in 50 Point Conservation Area, located north of the QEW and east of Fifty Rd in Stoney Creek, Ontario. The residential area along the western border of the conservation area, particularly on Windemere Rd along the shore of Lake Ontario, has been experiencing flooding as well. **The purpose of this study is to investigate the causes of the flooding and provide an evaluation of alternative solutions to the flooding issue, as well as finalize the preliminary design for the preferred alternative for flood remediation.** It is predicted that flooding is due to contributions from both Watercourse 11 and wave uprush from Lake Ontario. Landowners requested that the issue be addressed. Interested parties and the general public were invited to participate and provide comments at different stages of the EA process. The project team collected data and information of the existing environmental conditions, including natural, social, economic, and cultural factors, and analyzed them. A review and inventory of environmental features were performed to support the evaluation of potential project impacts.

AHYDTECH has created five preliminary alternatives solutions to the issue. They are as follows:

Alternative 1: **Do Nothing:** Maintain the existing channels, culverts, and drainage features including the existing shoreline structures. This alternative does not solve the problem.

Alternative 2: **Divert Subbasins SB1, SB2 & SB3 to the 50 Point Pond:** This alternative proposes diversion of 67% of the total runoff volume at a minimum cost ensuring least negative impact on the environment.

Alternative 3: **Divert Subbasin SB4 to the 50 Point Pond:** This alternative proposes diversion of almost 12% of the total runoff volume, this percentage of diversion is not enough to protect the area from flood damages.

Alternative 4: **Divert Subbasin SB4, SB5 & SB7 to the Storm Sewers at Shippee and McCollum:** This alternative proposes diversion of only 25% of the total runoff volume but implementation of this alternative is complex and confronts several significant physical and logistical issues. This alternative also requires high cost of construction and operation.

Alternative 5: **Combination of Alternative 2 and 4:** This alternative proposes diversion of 100% of the runoff volume but requires a very high construction and operation cost along with requirement for recurrent maintenance. However, the flood water from SB7 will remain in the water course.

After completing background research, field data collection, gathering input from stakeholders and the public, and performing hydrologic and hydraulic analysis of the area, AHYDTECH suggests the preferred alternative solution is Alternative 2, which is diverting subbasins SB1, SB2 and SB3 to the 50 Point Pond. Upon evaluation considering physical, social, technical and economic factors, it was found by AHYDTECH that if alternative 2 is undertaken, there will be no negative impacts and most impacts can be mitigated. Alternative 2 also provides feasibility of construction and implementation, and construction and operational cost of this alternative solution is comparatively very low. Alternative 5 requires construction of drainage system, sewer system, channels and roads to ensure complete diversion of the flow resulting in significantly high construction costs and requirement for tedious maintenance. On the other hand, alternative 2 proposes diversion of a significant portion of the total runoff with a cost very low compared to other alternatives. AHYDTECH have prepared the preliminary design and is ready to submit an Environmental Study Report (ESR) in accordance with provincial requirements to HCA and the necessary offices. The public will be notified of the ESR submittal and informed of the bump-up process and how to provide final comments.

1.0 INTRODUCTION

AHYDTECH Geomorphic Ltd. is retained to provide Environmental Assessment of the study area (as shown in figure 1), which has been experiencing localized flooding.

AHYDTECH has undertaken the Environmental Assessment (EA) process outlined in the Class Environmental Assessment for Remedial Flood and Erosion Control Projects (January 2002, as amended in 2009) approved under the Ontario Environmental Assessment Act (1990). This study has investigated the causes of the flooding and provide an evaluation of alternative solutions to the flooding issue, as well as finalize the preliminary design for the preferred alternative for flood remediation AHYDTECH has prepared the preliminary design of the preferred alternative based on the ecological, coastal engineering, hydrologic, hydraulic, and flooding hazard analysis.

1.1 PURPOSE AND OBJECTIVE

Occurrence of flooding has been identified by the local residents, located north of the QEW and east of Fifty Rd in Stoney Creek, Ontario. The residential area along the western border of the conservation area, particularly on Windemere Rd along the shore of Lake Ontario, has been experiencing flooding. The purpose of this study is to investigate the causes of the flooding and provide an evaluation of alternative solutions to the flooding issue, as well as finalize the preliminary design for the preferred alternative for flood remediation. It is predicted that flooding is due to contributions from Watercourse 11, groundwater and wave uprush from Lake Ontario. Landowners have requested that the issue be addressed. Interested parties and the general public and local residents were invited to participate and provide comments at different stages of the EA process.

1.2 DESCRIPTION OF STUDY AREA

The Fifty Point Conservation Area is an 80 hectare (197 acre) conservation area located north of the QEW and east of Fifty Road. The conservation area is an active recreation area containing marina, campground, trails, frontage on Lake Ontario and passive recreation amenities. The western boundary of the conservation area is bounded by subdivision development that is serviced by an existing storm water management system that drains to Lake Ontario via a storm water management pond. To the immediate east of the neighbouring storm water management pond, there is a watercourse which is the focus of this study (Figure 2). This watercourse drains along the western boundary of the conservation area through a forested section and drains to Lake Ontario via privately held lands and lands owned by the City of Hamilton. Flooding has occurred within the conservation area as well as on the property of the private residences along Windemere Road to the west. While this flooding in the conservation area is not problematic, the residents of the affected area face the risk of reoccurring property damage. AHYDTECH members conducted several site visits for coastal data collection and assessment purpose. A visual shoreline characteristics assessment was performed during the site visits and the assessment form is attached in Appendix C.

The Watercourse 11 watershed has gone through urban development, which has contributed to reduction and modification of the conservation drainage area. According a Hamilton Conservation Authority (HCA) contour site plan, the pre-development catchment area for the channel was approximately 12ha.

The Stoney Creek Urban Boundary Expansion (SCUBE) East - sub watershed study (Aquafor Beech, 2013) was undertaken for the City of Hamilton Secondary Plan. The study showed that the major part of the Watercourse 11 drainage area has also been replaced by an urban storm sewer, which is draining north to Lake Ontario through Storm Sewer system instead though the concrete channel (Watercourse 11). The existing drainage system as developed for SCUBE – 2013 is shown

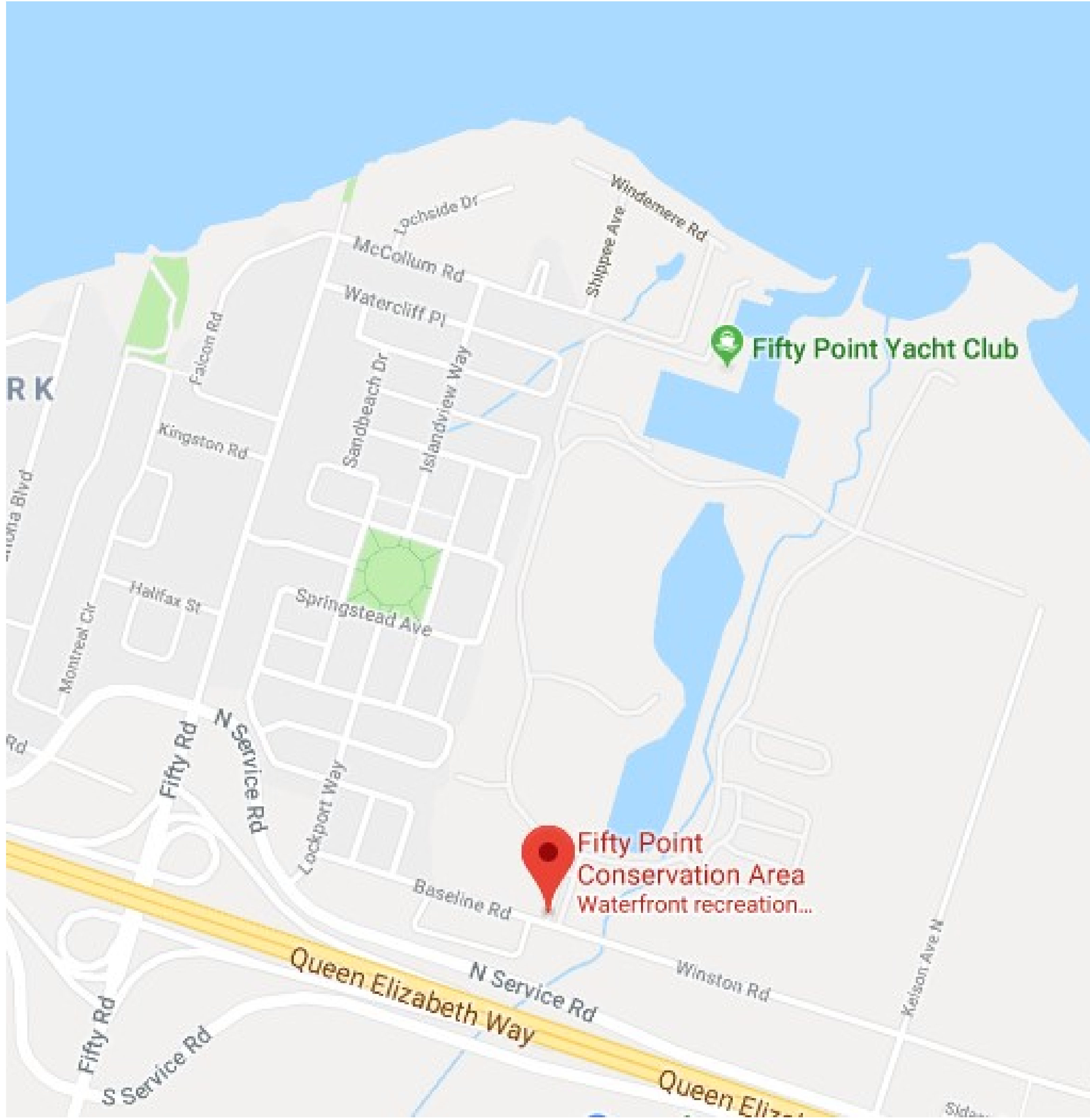


Figure 1: Study Area

Figure 2: Watercourse 11 Subwatershed of the Study Area

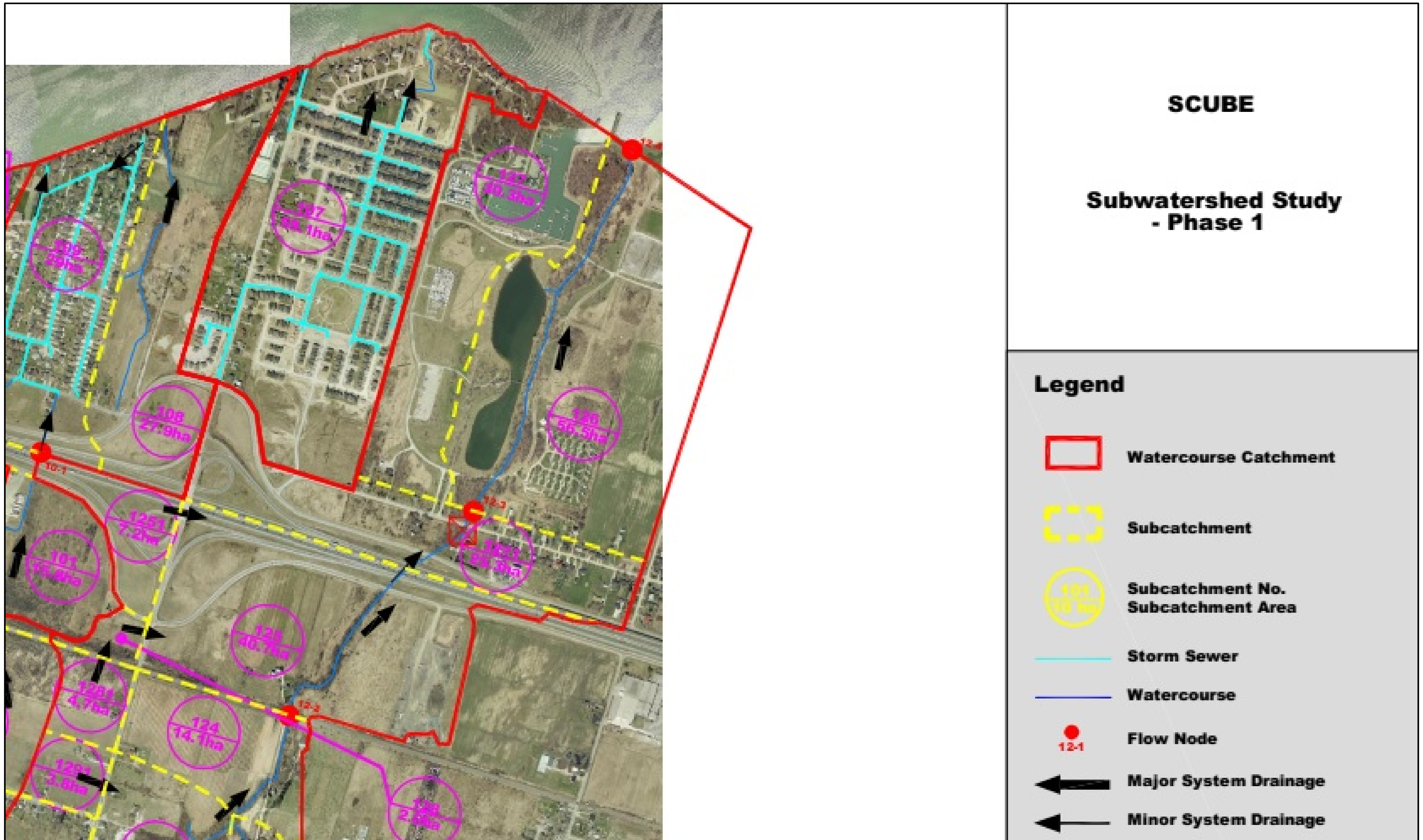


Figure 3: Stoney Creek Urban Boundary Expansion (SCUBE) East - subwatershed study

in Figure 3. The figure shows that the catchment 107 (SCUBE), which also covers a major area of the original catchment of Watercourse 11, now drains to Lake Ontario through the Storm Sewer and SWM pond system. Only small area around Windemere Road and east of Shippee Avenue drains to the concrete channel.

Figure 3 also shows that south eastern part of the Watercourse 11 watershed drains through the Watercourse 12 (Fifty Creek) drainage system.

1.3 PROBLEM STATEMENT

The residential area along the western border of the conservation area, particularly on Windemere Rd along the shore of Lake Ontario, has been experiencing flooding. This floodwater is generated from Watercourse 11, groundwater and the lake. Flooding takes places on the private lands and City of Hamilton lands located to the north. Specifically, the privately held lands contain residential dwellings that may be impacted by this flooding and the landowners have requested that this flooding issue be addressed. Flooding has occurred within the conservation area as well as on the property of the private residences along Windermere Road to the west. While this flooding in the conservation area is not problematic, the residents of the affected area face the risk of reoccurring property damage. The flooding that takes place is assumed to be impacted by riverine, groundwater flooding and Lake Ontario (wave uprush) flooding issues.

1.4 CLASS ENVIRONMENTAL ASSESSMENT

AHYDTECH Geomorphic and its project team has followed the “Class Environmental Assessment for Remedial Flood and Erosion Control Projects”, Conservation Ontario, January 2002, Amended June 2013, process. The Class EA document has identified four problem situations. These problem situations are: I) Riverine Flooding, II) Riverine and valley slope erosion, III) Shoreline Flooding, and IV) Shoreline Erosion.

I) Riverine Flooding

Flooding in the riverine system can occur due to two major reasons. These are an increase in water level from a storm event or rapid snow melt, and a result of the formation of ice jams, frazil ice, or other debris in watercourses. In order to protect areas from flooding, alternative remedial measures can be taken which include preventing the entry of floodwater to a specific site, or altering the flows through the channel during flood events. Flows can be altered by diverting water from flood vulnerable areas, increasing the hydraulic capacity of the watercourse and increasing upstream storage.

II) Riverine and Valley Slope Erosion

Watercourses flow and the sediment mixture of the watercourses bed and banks determine the fluvial processes which result in riverine erosion. Due to weathering, internal drainage problems, or the removal of stabilizing vegetation and soil material from the surface of the slope bluff/bank instability problems can also occur along river or stream banks. To address channel/riverbank erosion alternative remedial measures include reducing the erosive energy of the channel flows at the toe of the slope or protecting the toe or channel from this erosive energy. Stabilization of the face of the slope can be achieved through the use of drainage or grading improvements.

III) Shoreline Flooding

Riverine flooding and shoreline flooding are different from one another. In case of shoreline flooding wave action must be considered in addition to increases in water levels. The still water level plus the wave action (wave uprush/runup, overtopping, and ice accumulation) result in a final storm elevation. To protect an area from shoreline flooding alternative measures include preventing entry of floodwaters at a particular site, or reducing the wave uprush elevations by reducing wave energy offshore.

IV) Shoreline Erosion

Shoreline erosion is caused by waves, currents, shore geomorphology, ice and changes in water levels. As a result shoreline erosion is different from erosion in a river system. Deterioration of bluffs/banks, dunes, berms and beaches can occur as a result of shoreline erosion. In order to stop erosion of the backshore and coast area protection of natural features such as beaches, berms and dunes are necessary. Alternative remedial measures suitable to address shoreline erosion include reducing wave energy and enhancing natural processes, protecting from wave energy or stabilizing the slope through drainage or grading improvements.

For the Watercourse 11 and Fifty Point Conservation Area, Riverine Flooding and Shoreline Flooding situations are applicable. Hamilton Conservation Authority will be the proponent for the Class Environmental Assessment.

1.4.1 CONSERVATION AUTHORITY PLANNING PROCESS

Figure 1A and 1B describe the Class EA process.

FIGURE 1A
PLANNING AND DESIGN PROCESS
SELECTION OF A PROGRAM OPTION

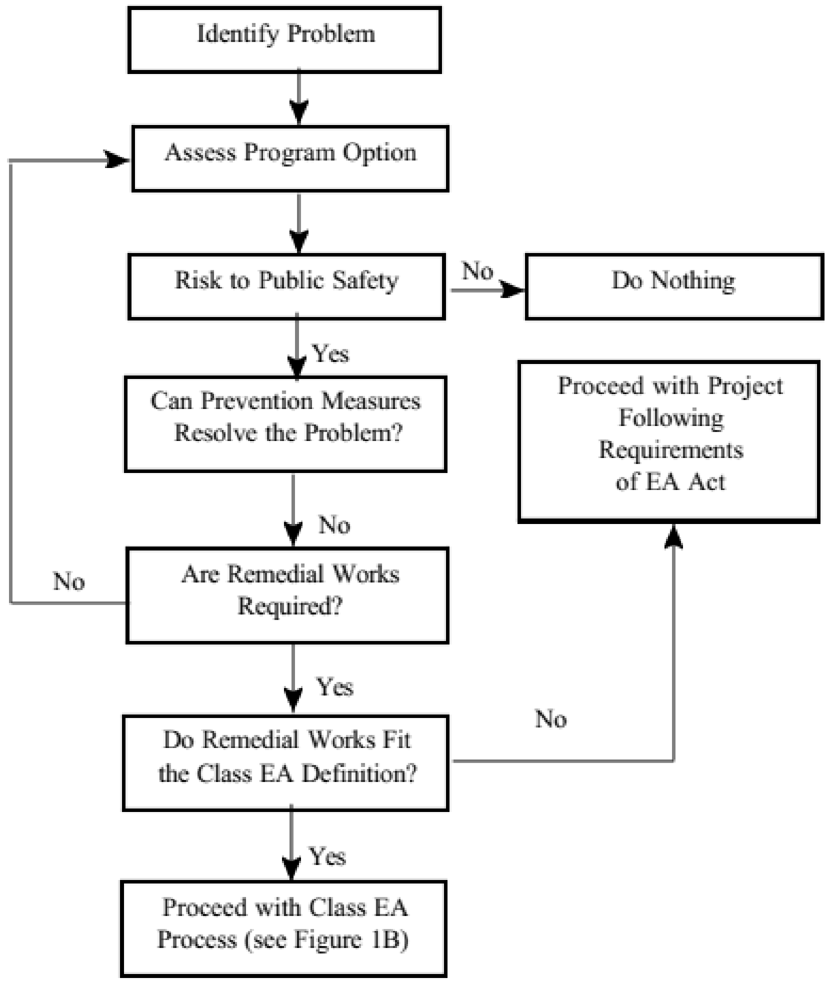
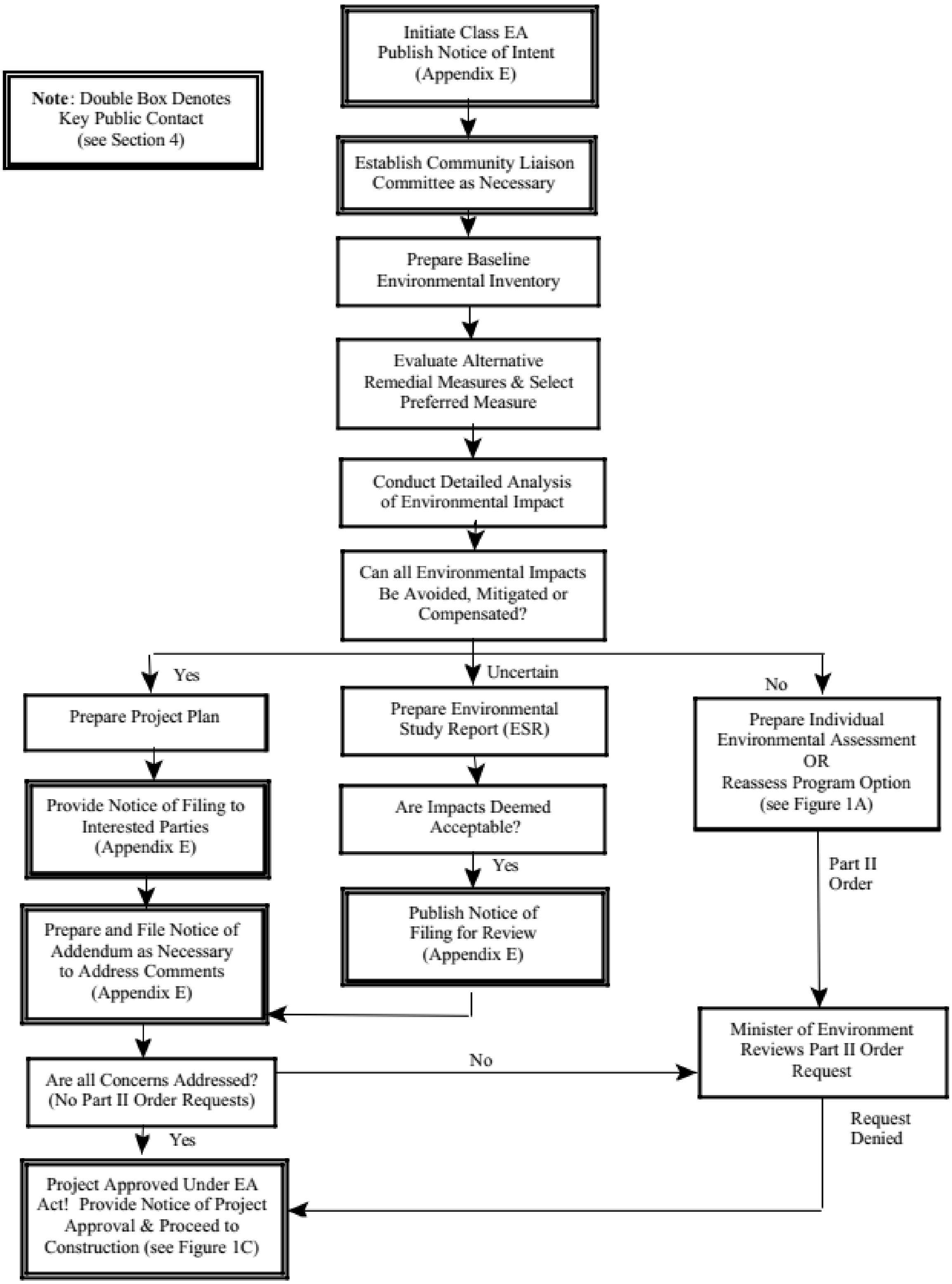


FIGURE 1B
PLANNING AND DESIGN PROCESS
CLASS ENVIRONMENTAL ASSESSMENT



1.4.2 INITIATION OF THE CLASS ENVIRONMENTAL ASSESSMENT PROCESS

The planning process outlined in the previous section, is one which occurs in Conservation Authorities' day to day activities. When it was determined that flooding situation in 50 Point Conservation Area potentially requires a flood or erosion control project, which meets the definition of this class, the Conservation Authority initiated the planning and design process as outlined in the following sections, and illustrated in Figure 1B. Landowners in the area and those who have been involved in the project's initiation were encouraged to participate in planning with the Conservation Authority throughout the project's duration. The process includes all steps which are necessary to plan, design, evaluate, implement, and monitor a project. Documentation occurs at each step since the decision making in this process must be traceable.

2.0 BACKGROUND

2.1 NEED FOR REMEDIAL FLOOD CONTROL PROJECTS

The Conservation Ontario addressed the following problems that can result from flooding and bank erosion:

- Risk to human life
- Property damage
- Damage or disruption of various corridors including roads, highways, bridges, pipelines, storm and sanitary sewers, telephone and hydro lines, etc.
- Sedimentation of watercourses and coastal wetland areas,
- Degradation of aquatic habitats, such as fish spawning grounds
- Loss of fertile soil, and the destruction of terrestrial vegetation and associated habitat resources
- Loss of natural shoreline protective features such as beaches, berms and dunes
- Imbalances in natural processes which provide aquatic and terrestrial habitat
- Personal hardship and severe social disruption
- Loss of cultural features such as bridges, mills, and houses

2.2 JUSTIFICATION OF THE CLASS ENVIRONMENTAL ASSESSMENT APPROACH

The Class EA approach has a common process of planning, design, approval, construction, operation and monitoring. This approach also has a predictable range of effects which are generally responsive to standard mitigation measures. As a result, Class EA approach is considered a suitable means for the planning of remedial flood and erosion control projects.

For planning and implementing flood and erosion control projects, the Class EA process is a consistent, streamlined, easily understood process. The process also provides the flexibility to be tailored to the activity, taking into account the environmental setting, public interest, and unique situation requirements.

2.3 DESCRIPTION OF UNDERTAKINGS WITHIN THE CLASS EA

Remedial flood and erosion control projects may be undertaken in case of four situations. These situations are:

I. Riverine Flooding
II. Riverine and Valley Slope Erosion
III. Shoreline Flooding

IV. Shoreline Erosion

After a problem is identified it is tested whether the nonstructural Conservation Authority program options prove effective in addressing the problem. If the nonstructural program options prove ineffective, some alternative methods may be considered for carrying out a specific remedial undertaking. This section describes the alternative methods. The alternatives are not necessarily interchangeable. In some cases one or more of the alternatives may be inadequate and several of the alternatives may be required in combination to solve the problem.

For Watercourse 11 and Fifty Point Conservation area, the identified problems are Riverine Flooding and Shoreline Flooding. The alternative solutions for these two problems are discussed in detail.

RIVERINE FLOODING

In a riverine situation where flooding is occurring, there are several alternatives to address the problem. These include, but are not limited to:

i) Prevent Entry of Floodwater

To prevent floodwater from entering a specific area, berms (dikes) may be installed. Berms act as a barrier to the entry of floodwater on a property. Berms are generally constructed by mounding earth, and seeding or planting to promote soil stabilization. The height is selected to resist the design storm.

ii) Modify River Ice Formation and/or Break-up Processes

Risk of damages due to flood can be presented by high water due to the formation and deposition of frazil ice or ice jams. In order to reduce this risk, modifying the ice formation and break-up process can be effective.

iii) Increase Hydraulic Capacity of Waterway

Through increasing the hydraulic capacity of waterway, lower levels of water can be allowed to overflow onto the floodplain. In this way the flow can be altered through the channel during flood events. This may be accomplished using the following methods:

- Bridge and Culvert Alterations
- Bank Regrading
- Increase Bank Height
- Revetments
- Channel Realignment
- Dredging

iv) Divert Water From Area

Diverting water from a flood prone area involves intercepting potentially damaging floodwater at a point upstream of the flood prone reach and routing to a point remote from the flood prone area. This may be accomplished by construction of a:

Bypass Channel

A bypass channel is created which normally contains water only when the capacity of the natural waterway is breached. This channel then carries water away from the floodprone area.

v) Increase Upstream Storage

Detaining flood water upstream can be an effective way to reduce damages due to flooding when flooding occurs in a river reach. This may be accomplished by using one of the following methods.

- Bridge and Culvert Alterations

- Dry Dams
- Weirs
- Wet Dams

SHORELINE FLOODING
In order to protect an area from shoreline flooding, there are a few alternative remedial measures that are of great necessity. Preventing entry of flood waters at a particular site is a primary concern. Besides, reducing wave energy offshore and reducing uprush elevations are also included in the alternative remedial measures.

i) Prevent Entry of Floodwaters
To prevent entry of floodwaters the main concern should be designing a structure with an elevation that is provided considering the increase in the water level and the wave action during an extreme storm event. These structural protections may include an impermeable dike, seawall or revetment. The following methods can be used to prevent the inundation of floodwaters.
Artificial Nourishment (Beach, Berm and Dune)
Artificial nourishment proves successful in flood control when effective wave energy dissipates and it is mandatory to ensure that the natural features remain as they were. In case of a deficiency in the sediment supply, artificial nourishment or strengthening provides natural material to those areas. The artificial nourishment process should be combined with other erosion protection methods. Otherwise, it would require continuous applications.
Dikes
Dikes generally provide protection during extreme events. They prevent inundation of flood water in a low lying area and hold the land and water boundary. Dikes do not provide protection to the neighbouring shoreline.
Seawalls
Seawall is built parallel to the shore and used for flood protection of the upland area. It is designed to withstand extreme wave action. Seawalls protect the area behind the structure and not the adjacent areas.
Revetments
Revetment provides protection to the embankment and shoreline behind the structure from waves or currents. They are typically built at the land/water interface and are usually sloped structures built of armour stone or rip rap. Revetments protect the upland area behind the structure and not the adjacent areas.

ii) Reduce Wave Energy
The wave action and wave energy should be considered differently than riverine systems. Coastal structures can provide protection again the wave action reaching the shoreline but they fail to reduce the still water level. Therefore, the structures must be designed for a combination of both the extreme water elevation and the wave action rather than just the high water level. The following list contains some of the common methods used to reduce the incoming wave energy. One or a combination of these may be used.
Offshore (Detached and Continuous) Breakwaters
Offshore breakwaters are continuous or detached structures built parallel to the shore. They promote a wave energy dissipating beach system and protect the area behind the structure. They reduce but do not eliminate the wave action and create a calm area behind the structure.
Offshore Low-Crested Breakwaters

Low-crested rock structures are built offshore, parallel to the shoreline. Energy is lost on the front side as waves overtop the structure. The top and backside of the structure must be designed to withstand the energy of the overtopping waves. There are three main types of structures; the reef, statically stable low-crested and submerged breakwater. The reef breakwater consists of a pile of stones that are dumped leaving the waves to shape the material. The statically stable low-crested breakwater is not designed for constant overtopping, but does allow energy to dissipate and pass over the top of the breakwater. The submerged breakwater is designed for waves to constantly overtop the structure.

From all these alternatives, diversion of water from the flood prone area by constructing a bypass channel is chosen as a remedial action for flooding in Watercourse 11 and Fifty Point Conservation area. The remedial action includes diverting water from sub-basins to the 50 point pond. It was also suggested that water from subbasins should be diverted to Storm Sewers at Shippee and McCollum. Environmental assessment of these alternatives were performed and the most suitable alternative has been chosen.

2.4 JUSTIFICATION OF CONSERVATION AUTHORITY INVOLVEMENT

The Fifty Point Conservation area is owned and operated by the Hamilton Conservation Authority, and Watercourse 11 is regulated by the Hamilton Conservation Authority. As a result, HCA is involved in this project addressing the residential flooding.

3.0 BASELINE INVENTORY

3.1 FIELD INVESTIGATION

AHYDTECH performed field visits and completed investigations for the site. The field data collection and investigation included topographic survey, bathymetry survey and shoreline characterization done by RTK /GPS and sonar survey techniques. AHYDTECH has collected cross-section data of Watercourse 11, existing culvert and of four cross shore profiles of the lake and near the shoreline in the study area. The shoreline of the study area can be categorized as natural, artificial with concrete retaining wall or revetment structure.

3.1.1 TOPOGRAPHIC SURVEY

A bench mark for the topographic survey was determined by the combination of a reference elevation from the MNRF Control Survey Information Exchange (COSINE) control database benchmark station located at Glover Road Bridge over QEW in Stoney Creek and AHYDTECH's RTK/GPS unit. AHYDTECH used the GPS to determine UTM coordinates (Zone 17, NAD83 horizontal datum projection). AHYDTECH used the X, Y, Z coordinates to determine the reference coordinates for our topographic and bathymetry survey of the site. There are several culverts in the project study area. AHYDTECH has measured the dimensions of the culvert including their length, width, height and diameter. As shown in Figure 4, four (4) cross-shore profiles were measured across the 50 Point Conservation Area. The measurements for each profile line started from the nearshore to about 5m depth in Lake Ontario. The survey provided complete topographic data of ground surface and all site features including the water level, shoreline boundary and other site feature locations. The collected data was in the format of the Zone 17, NAD83 horizontal datum projection with X, Y, Z coordinates.

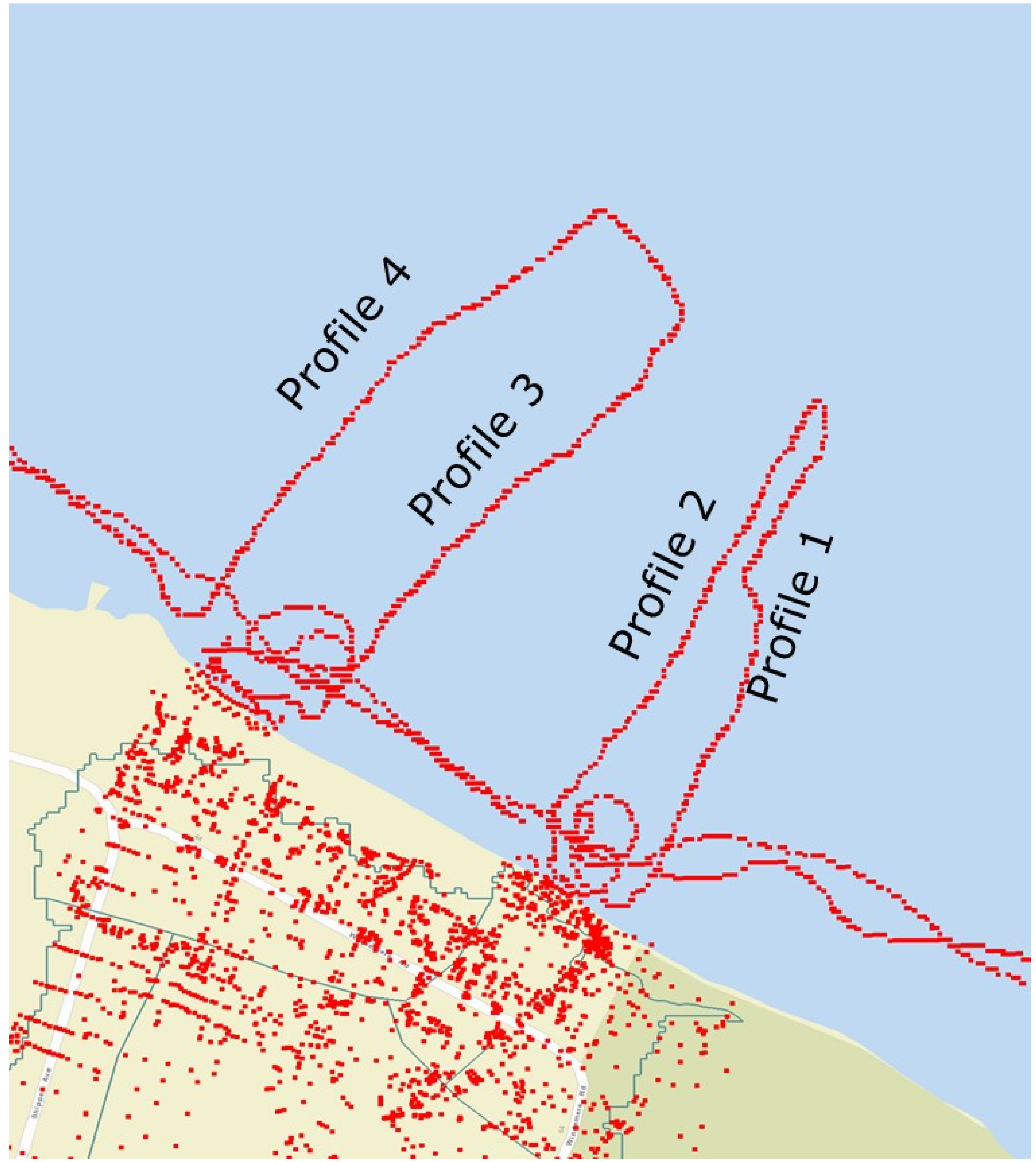


Figure 4: Cross Shore Profiles from field investigations

3.1.2 BATHYMETRIC SURVEY

A bathymetric survey was conducted to acquire data of four (4) cross shore profiles and near the shoreline as illustrated on Figure 4. The survey started in the lake from approximately 1m depth to 5m depth using a boat and a bathymetric survey unit. AHYDTECH has an aluminum boat which is 12ft long with motor propeller. AHYDTECH used a Lowrance Elite-4 CHIRP bathymetric survey unit, which has recording sonar to measure depth and GPS to provide geo-reference coordinates for bathymetric sounding conduction. The bathymetric survey unit has capabilities to determine point position and water depth. The sonar depth-sounder was attached on the tail of the boat close to the bottom and the mapping CHIRP was attached on the seat of the boat, which allows the field crew to see the sonar image in lake while operating the boat. Four profiles (Profile # 1, # 2, #3 and #4) were established perpendicular to the shoreline as reference for the boat travel direction to create a straight line for each cross shore bathymetric sounding profile. The bathymetric soundings used very refined intervals to capture variations of the lake bed and bed near shoreline. The collected data used the Zone 17, NAD83 horizontal datum projection format for surface and contour generation, site layout, shoreline structure, and stability analysis.

3.1.3 CROSS SHORE BATHYMETRIC PROFILE

During the field investigation, a single point water surface elevation was measured using the RTK/GPS close to the shoreline. The measured lake water surface elevation was compared and corrected with the Burlington Station water level above 74.2m IGLD chart datum. The Lake Ontario Water Level at the Burlington station on September 29, 2017, was 75.017m. The bathymetric survey unit recorded water depth for the four cross- shore profiles from water depth of approximately 1m up to a depth of 5 m offshore. Using the single point water surface elevation as the reference point, the sounding depths were subtracted to get the elevation of the lake bed at the associated points. Figure 5 illustrates the 4 cross shore profiles for a total length of about 200m from offshore to the onshore revetment.

3.1.4 SHORELINE CHARACTERIZATION

Observed from the field visit, that shoreline of the study area can be categorized as natural and artificial shoreline with concrete retaining wall or revetment structure. It has been observed that Profile # 1 has natural shoreline. The shoreline of Profile # 2 composed of broken concrete walls floors. Profile # 3 shore is slope revetment structure, and Profile # 4 is vertical retaining wall. In Profile #1 natural shoreline has mix of cobbles and gravels. There are two groins in both sides of the profile. Observed from the site visits, the shoreline Profile #1 can be categorized as natural beach with sand, cobble, boulders, rock, and some vegetation. Boulders and rocks presented in low plain beach and near shore provides roughness, which dissipates the wave energy, hence reduces the wave height. The upper natural beach area consisted of coarse sand and cobble provides more porosity for wave dissipation by infiltration, which also reduces wave height. Thus, the rock, boulder, coarse sand, and cobble composition of shoreline creates wave energy dissipation, where less wave energy can alter the shoreline, hence maintaining shoreline stability.
Profile # 2 shoreline located near 62B Windemere has broken concrete walls and floors. There are large boulders ranging diameter from 0.5m to 1m in the nearshore. Profile # 3 of slope revetment is categorized as artificial concrete block revetment, which was also the controlling structure for the shoreline. At the top of the revetment a concrete platform lined the edge of the shore. Some concrete

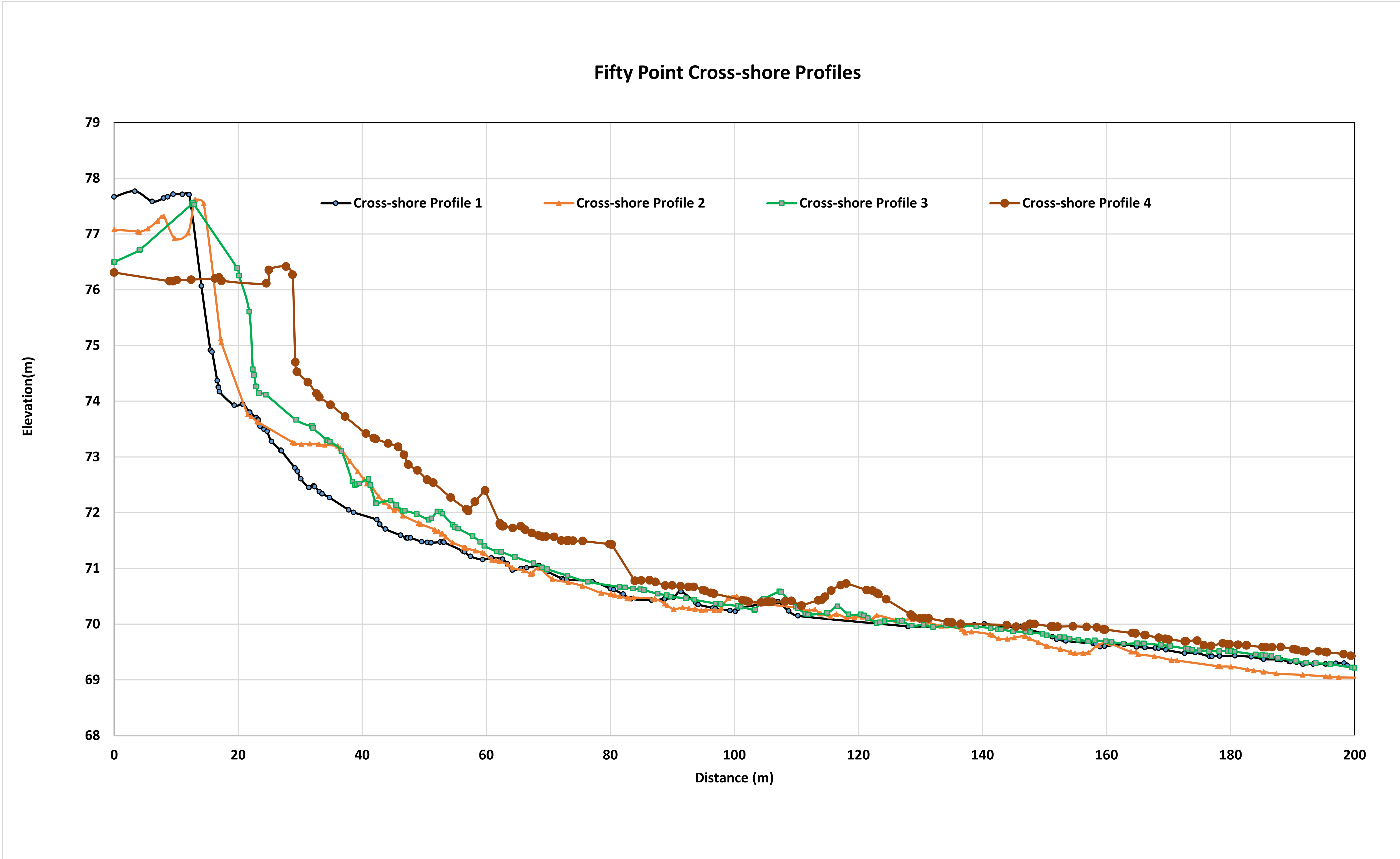


Figure 5: Cross Shore Profiles of Fifty Point Conservation Area

blocks in the revetment have fallen apart due to toe scour and structure failure. The space below the concrete platform is filled with artificial fill material majorly composed of gravel, rocks and concrete. A pipe passed through the broken side of revetment which drains out the water from back to the lake. Behind the concrete platform large size armour stones were seen and which are followed by concrete cast floor. A concrete wall of about 1m separates the floor from the backyard. The backyard of 45 Windemere Road is mostly covered by grass. Few trees were also observed at the backyard and the floor. Soil behind the revetment and concrete platform is stable and no erosion was observed.

Profile # 4 has vertical retaining wall with large boulders/concrete blocks. Boulders/concrete blocks are present at some locations near shore within approximately 20m-30m range from the shoreline. These boulders are providing stability to the lake bed in the shoreline against breaking waves and circulation. The western retaining wall is closer to water than the eastern portion but both are almost vertical to the surface. There is evidence of lake bed scour near toe of the western retaining wall due to breaking wave actions. The vertical retaining walls are generally in good condition. However, there are toe scours at the vertical wall due to wave actions. In one area of the shoreline has metal railings with supporting pillars on top of the concrete retaining walls.

Heights of most of the shoreline structures in the study area are lower than the wave uprush height. During strong wind-wave conditions from the north and north-east direction, water is overtopping the shoreline structures and flooding the residential areas.

3.1.5 DRAINAGE AREA DELINEATION

This study has used the field investigation information, AHYDTECH survey and A. T. McLaren survey data, and DEM data to delineate the Watercourse 11 boundary and its catchments. It was identified, based on our field investigation and study, that there are 10 subbasins existing in the Fifty point conservation area. These subbasins are denoted as SB1, SB2, SB3, SB4, SB5, SB6, SB7, SB8, SB9 and SB10. Among all these subbasins, it was found that SB6, SB8 and SB10 do not drain to Watercourse 11 and hence SB6, SB8 and SB10 are not part of Watercourse 11. Figure 6 depicts the subbasins of the watercourse 11 and their existing flow directions. Since SB10 is not a part of Watercourse 11, any floodwater that enters into SB10 from Watercourse 11 is treated as spill to the sub-catchment. SB10 is also not considered as true floodplain. Among all these subbasins, it was found that SB6, SB8 and SB10 do not drain to Watercourse 11. There are drainage ditches that runs along the road in west side of Fifty Point Conservation. Subbasins 5 and 6 are located along the west side road within Fifty Point Conservation area. From Figure 6, it can be seen from the existing flow directions that all the Subbasins pass their floodwater through SB9 and SB10 and eventually drain them to the Lake Ontario. The aim of this study is to ensure safe drainage of the flood water without causing any negative impact on the environment. Peak flows from the WC-11 can be safely accommodated by the lake. The 100 year water level of the lake and flow from the creek do not cause an issue of flooding in the residential area. However, when wind action causes wave uprush in the lake, the existing preventive structures are overtopped and flooding occurs. Additionally, the storm runoff from Watercourse 11 do not cause any significant change in the water levels of Lake Ontario. The wave uprush resulting from wind action in Lake Ontario, is also considered as an obstruction for the drainage of Watercourse 11.

Figure 7 shows contour lines created from the survey and DEM data. Observing Figure 7 and Figure 6 it can be seen that among all the subbasins SB1 is situated in the highest elevation and the elevation gradually decreases from SB1 to SB9. Figure 6 also ensures that the flow directions of the subbasins follow this elevation gradation.

Figure 6: Watercourse 11 basin delineation and existing flow direction

Figure 7: Watercourse 11 Digital Elevation Model Contour lines

3.2 HYDROLOGY

This study has followed the MNRF Natural Hazard Guidelines. A hydrologic analysis of the Watercourse 11 catchments was performed using SWMHYMO software to determine peak flows.

3.2.1 HYDROLOGIC MODEL PARAMETERS

This study followed Schedule 1. O. Reg. 161/06, s. 11 (1), which is applicable for HCA. The applicable flood event standard used to determine the maximum susceptibility to flooding of lands or areas within the watersheds in the area of jurisdiction of the HCA is the 100 Year Flood Event Standard as described in Schedule 1. O. Reg. 161/06, s. 11 (1).

This study has used the City of Hamilton Comprehensive Development Guidelines and Financial Policies Manual (2016) for determination of the 100 Year Flood Event. The SWMHYMO model used the 4 hour Chicago storm (25 mm), 100 Year Chicago storm (4 hour, 91.39 mm) and 100 year SCS 24 hour storm (122.89 mm) derived based on the City of Hamilton IDF curves at Mount Hope.

Table 1 below shows land use classification applied for the hydrologic analysis of the Watercourse 11 drainage catchments/basins.

Table 1: Land Use Classification

LU	Land use for Uplands Method
1	Forest with heavy ground litter
1	Hay meadow
2	Trash fallow or
2	Minimum tillage cultivation
2	Contour or strip cropped
2	Woodland
3	Short grass pasture
4	Cultivated straight row
6	Nearly bare and untilled
7	Grassed waterway
8	Paved
8	Small upland gullies

Table 2: Hydrologic Input Parameters

	SB 1	SB 2	SB 3	SB 4	SB 5	SB 7	SB 9
Runoff coefficient	0.22	0.37	0.16	0.35	0.18	0.17	0.17
Catchment length	379.89	473.99	528.02	234.48	264.1	167.58	122.85
Catchment slope	0.007	0.005	0.0061	0.0095	0.0071	0.0053	0.0079
Catchment area	3.1527	4.0095	3.4389	1.2025	0.7372	2.17	0.5743
Land use for Uplands Method	3	2	3	2	3	3	3
Catchment width	106.5	162.05	109.07	94.698	33.46	135.06	75.38

Table 2 presents hydrologic input parameters applied to compute time to peak of the seven basins. These parameters are runoff coefficient, catchment length, catchment slope, catchment area, land use and catchment width.

For the hydrologic modeling, this study applied six methods to estimate time to peak. These methods are: Airport Method, William's Equation (1977), Williams-Hann - Rural Recession Constant, Hymo/Otthymo (MTO Manual), Bransby – Williams and Uplands Method. Table 3 shows summary and average of time to peak computed by the six methods. The SWMHYMO model used the average value of time to peak of the six methods. The land use pattern of the catchments indicates that all the catchments are composed of a combination of rural and urban land use pattern. The land use of any of the catchments cannot be identified as completely rural or completely urban, and as a result, a single method cannot be selected for a catchment. The average of all 6 methods comply with the mixed land use pattern of the catchments.

Table 3: Methods applied to Compute Time to Peak

	Basin Time to Peak (hrs)						
METHOD	**1**	**2**	**3**	**4**	**5**	**7**	**9**
Airport Method	**0.69**	**0.75**	**0.93**	**0.43**	**0.61**	**0.54**	**0.41**
William's Equation (1977)	**0.20**	**0.28**	**0.23**	**0.12**	**0.11**	**0.20**	**0.10**
Williams-Hann - Rural Recession Constant	**0.16**	**0.21**	**0.19**	**0.09**	**0.10**	**0.14**	**0.07**
Hymo/Otthymo (MTO Manual)	**0.27**	**0.36**	**0.30**	**0.17**	**0.17**	**0.28**	**0.15**
Bransby - Williams	**0.23**	**0.31**	**0.33**	**0.15**	**0.19**	**0.11**	**0.09**
Uplands Method	**0.39**	**0.86**	**0.59**	**0.30**	**0.27**	**0.20**	**0.12**
Average	**0.32**	**0.46**	**0.43**	**0.21**	**0.24**	**0.25**	**0.15**

Sub-basin 1 consists mostly cultivated lands and lawns with sandy loam soil. In sub-basin 2, there are two parking lots with short grass on sides. Sub-basin 3 has very flat slope with meadows. Sub-basin 4 consists parking lot for boats and has 35% imperviousness. In sub-basin 5 there exist only grasslands. Sub-basin 7 has high density wooded area.

The SWMHYMO model used NASHYD unit hydrograph for Sub-basin 1, 2, 3, 4, 5 and 7 because of dominant rural land uses in these basins. The model applied STANDHYD unit hydrograph for Sub-basin 9 to simulate surface runoff. For this basin, a weighted SCS curved number (CN) was estimated based on soil, perviousness and land use.

Figure 8 shows soil characteristics in the Stoney Creek Watercourses. Both the Watercourse 11 and Watercourse 12 (Fifty Creek) watersheds have sandy loam (SL) indicating high infiltration capacity of soils and less surface runoff during storm events.

3.2.2 HYDROLOGICAL MODEL RESULTS

As explained earlier, the SWMHYMO model applied the 25mm 4 hour Chicago storm, 100 Year Chicago storm and 100 year SCS 24 hour storm events. In order to determine peak flows of the Watercourse 11 subbasin, this study analyzed the storm events' computed flows.

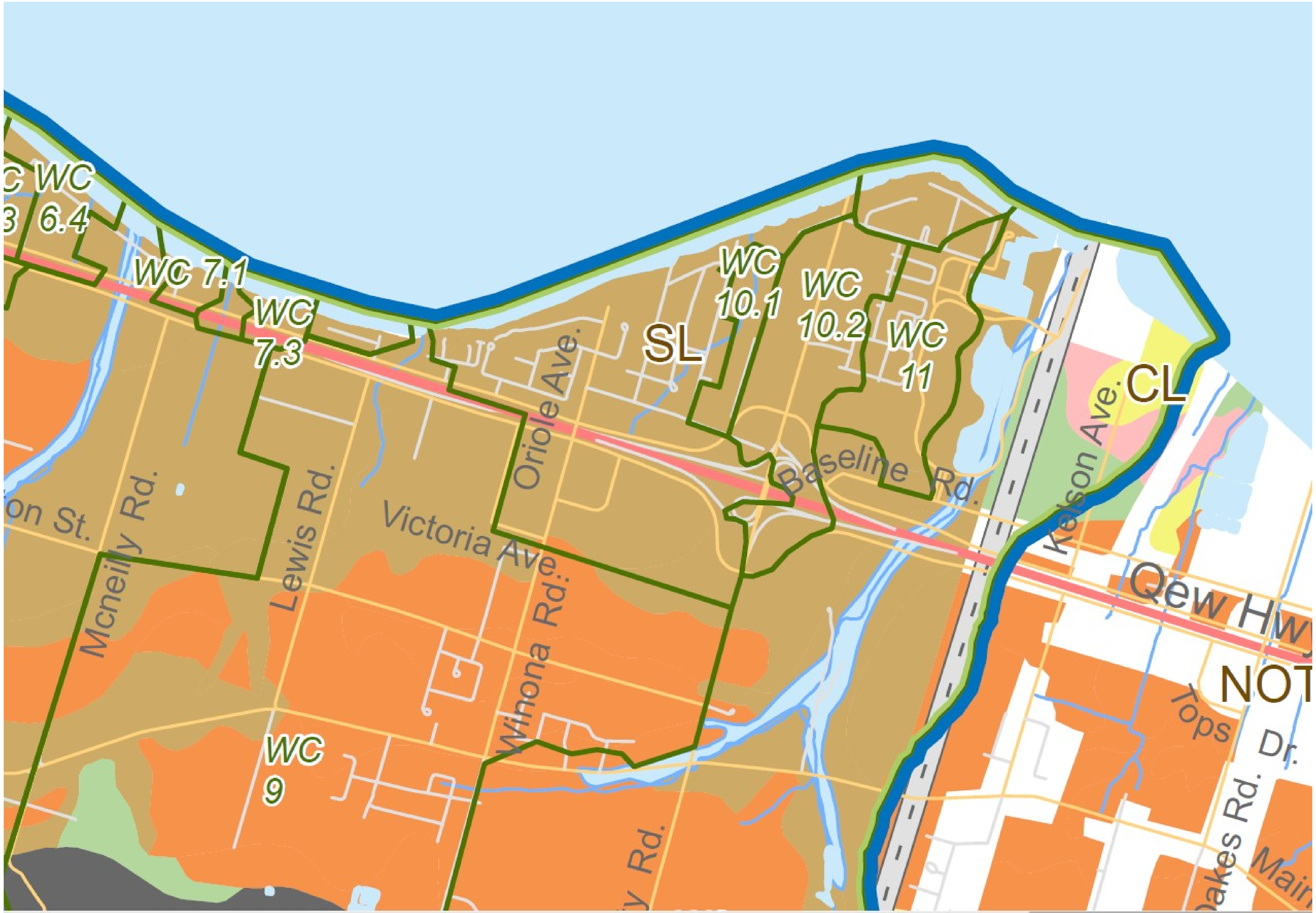


Figure 8: Soil Characteristics in Stoney Creek Watercourses (Source: Halton-Hamilton Source Water Protection, 2005)

The runoff volume resulting from the sub basin SB9 in 25 mm 4 hour Chicago storm event can be safely accommodated by the channel. Hence, although SB9 is a part of Watercourse 11, it is removed from the hydrologic analysis for 25 mm storm event.

Table 4: Basin and Channel Peak Flows for 25 mm 4 hour Chicago Storm

Storm Event	Results	SB1	SB2	SB3	SB4	SB5	SB7
25 mm 4 hour Chicago Storm	Peak Flow (cms)	0.038	0.065	0.022	0.034	0.008	0.022
	Area (ha)	3.15	4.01	3.44	1.2	0.74	2.17
	Runoff Volume (mm)	4.08	7.14	2.74	6.878	3.19	2.97
	Runoff Volume (m^3)	128.52	286.314	94.256	82.536	23.606	64.449

Table 5: Basin and Channel Peak Flows for 100 Year Chicago storm and 100 year SCS 24 hour storm

Storm Event	Results	SB1	SB2	SB3	SB4	SB5	SB7	SB9
100 year Chicago Storm	Peak Flow (cms)	0.159	0.268	0.102	0.125	0.036	0.098	0.156
	Area (ha)	3.15	4.01	3.44	1.2	0.74	2.17	0.57
	Runoff Volume (mm)	18.69	31.71	13.36	30.11	15.15	14.26	59.3
	Runoff Volume (m^3)	588.735	1271.571	459.584	361.32	112.11	309.442	338.01
100 year SCS 24 hour storm	Peak Flow (cms)	0.14	0.235	0.092	0.107	0.032	0.087	0.12
	Area (ha)	3.15	4.01	3.44	1.2	0.74	2.17	0.57
	Runoff Volume (mm)	25.62	43.36	18.4	41.14	20.81	19.62	85.59
	Runoff Volume (m^3)	807.03	1738.736	632.96	493.68	153.994	425.754	487.863

Peak flows of the basins, ditch and concrete channel are presented in Table 4 and Table 5. It can be seen from the table that the peak flows for the 100 Year Chicago storm are higher than those for the 25mm 4 hour Chicago storm and 100 year SCS 24 hour storm events. The SWMHYMO model and its summary results are presented in Appendix B.

The subdivision development study applied Level 1 Wetlands for the water quality control at the SWM facility. The facility has a total design storage capacity of 4,916 m^3. If Level 2 Wetland quality control is required, then the volume for the subdivision development area is 3,075.8 m^3 based on the MOE guideline Table 3.1 (70 m^3/ha). That means the SWM facility can handle an additional 1,840 m^3 flow volume from the diversion. Though reduction of wetland water quality control from level 1 to level 2 proposes utilization of storage capacity to accommodate diverted flow, HCA remains uncomfortable to recommend this reduction. The SWM facility was originally designed for Level 1 water quality treatment and HCA opines to conform to the original design.

From the SWMHYO model it can be seen that for 25mm 4 hour Chicago storm, if SB1, SB2 and SB3 subbasins are diverted to the 50 Point Pond, the combined flow from SB4, SB5 and SB7 is 170 m^3. If SB4 is also diverted to the 50 Point Pond, the combined flow from SB5 and SB7 will be 88 m^3. Both the diversion options can be applied if the SWM facility requires Level 2 Water Quality Control.

If SB5 and SB7 is diverted to the SWM facility then the new imperviousness of the subdivision becomes 54.4% of the combined area of SB5, SB7 and previous SWM drainage area. As Level 1 water quality control is applied in the subdivision development then the total storage volume for 54.4% imperviousness becomes 4,891 m^3 based on MOE guidelines. This total storage is smaller than the design storage capacity.

3.3 HYDRAULICS

3.3.1 DEVELOPMENT OF 1D HYDRAULIC MODEL

1D HEC-RAS hydraulic modeling has been used to determine flood elevations for 100 year Chicago storm event for three different conditions – existing condition and two proposed conditions. HEC-RAS is a software for one-dimensional or two-dimensional simulations of the evolution of a flood, which could have a steady or an unsteady flow rate, sediment transport, change of the river bed etc. The name 'HEC-RAS' derived from the creators of the software: Hydrologic Engineering Center, which stands as a subdivision of the Institute of Water Resources, U.S Army Corps of Engineers (HEC), and "RAS" is an acronym from "River Analysis System". The software itself, has four main river analysis possibilities: the constant flow rate at the surface of a considered river profile; simulation of an unsteady flow of water; calculations of the sediment transport and modifications of the river bed; and analysis of the water quality (U.S. Corps of Engineers, 2003, Tate et al. 1999). It is widely used tools to model 1D flow simulation and provides graphical results. Inundation mapping is accomplished in the HEC-RAS Mapper portion of the software and Tabular output is available is also available. When the length-to-width ratio is larger than 3:1, a 1D hydraulic model can provide fairly good results. (UK Environment Agency, 2009).
As explained in the section "Field Investigation", this study collected the refined survey data of the Watercourse 11 of Fifty Point conservation area. A combined topography data-set was created using SMS Scatter Module from the 5m contour DEM and the refined topography data surveyed by AHYDTECH. This data-set was used to generate new cross sections. Figure 9 shows the newly generated cross sections data that were directly imported to HEC-RAS geometric editor. AHYDTECH staff measured dimensions of the structures during the field visits. All these structures were included in the HEC-RAS model.
Manning's roughness coefficient n value for left and right bank is taken 0.045 where there exists woodlot in the area and 0.035 where there is grass in the area. The roughness coefficient for the reach is taken 0.025. In case of new cross sections, the value of nearest stations was used in the model. Manning's n coefficient reflects hydraulic resistance for flow in a river and flood plain. In reality, Manning's n value in the main channel is usually lower than that in the flood plain. It also varies in the flood plain depending on the type of land use/land cover.

Boundary Conditions
This study has completed the hydraulic and flooding analysis of the channel for the following storm event peak flows:

- 100 Year Chicago
- 100 Year 24 Hour SCS Type II

Upstream boundary condition: The flow of the 100-year Chicago storm at the upstream boundary is 0.159 m^3/s. As upstream boundary condition normal depth with slope S= 0.005 is provided for the flow.
Downstream boundary condition: The model used known water surface elevation of 76 m for downstream boundary condition.

Watercourse and Existing Structures
The project site, Watercourse 11 is bound by Baseline Rd in the south, Windemere Rd in the north, and Shippee Avenue in the west. There are 10 subbasins delineated in this watercourse, and these subbasins are denoted as SB1, SB2, SB3, SB4, SB5, SB6, SB7, SB8, SB9 and SB10. Among these subbasins, SB6, SB8 and SB10 drain their flows directly to Lake Ontario. Hence, in the model, main focus is given to the remaining seven sub basins. Figure 10 shows the subbasins of the Watercourse 11 and their existing flow direction.

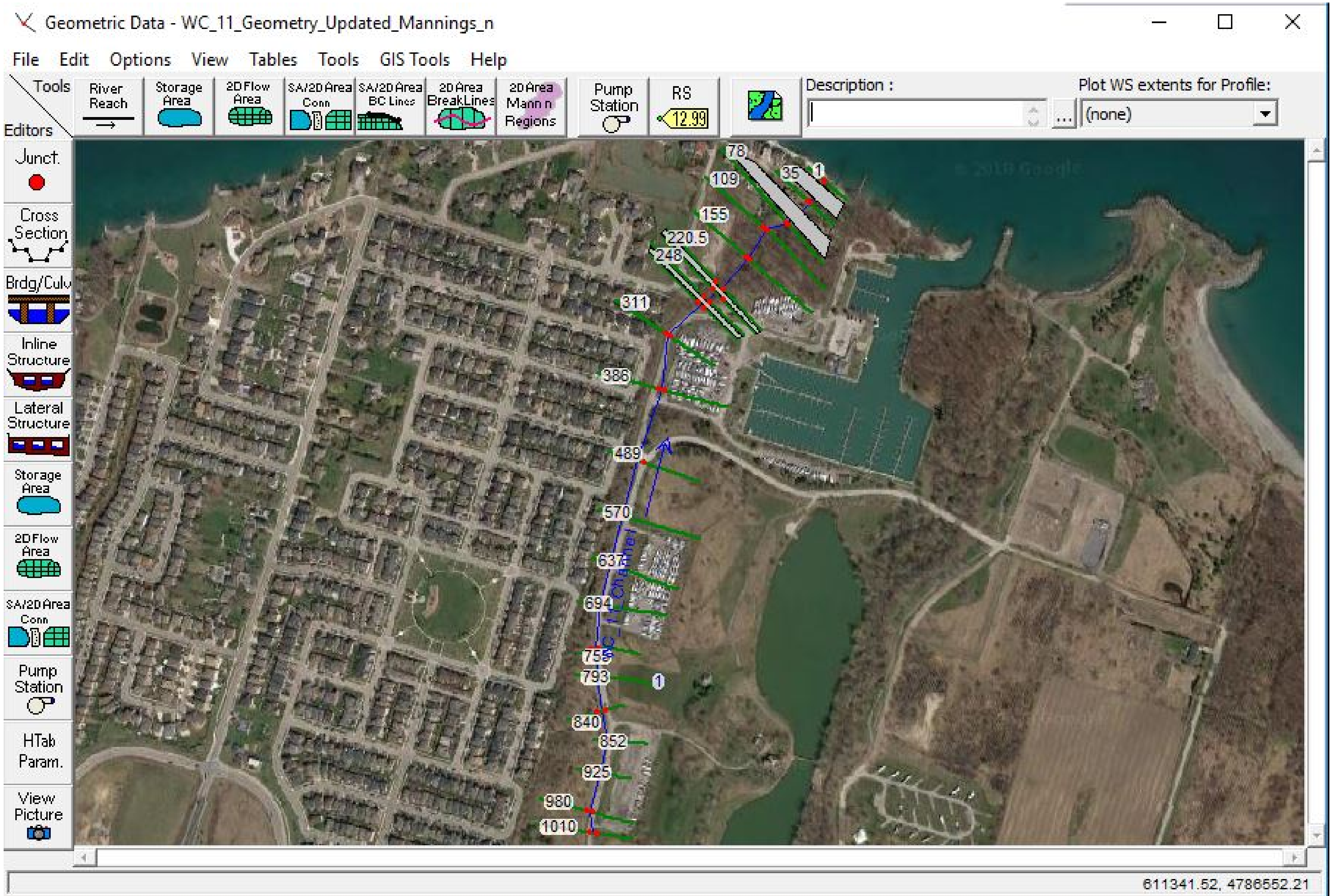


Figure 9: Geometry Data Input in HEC-RAS

Figure 10: Subbasins of Watercourse 11 and existing flow direction

Figure 11: Location of existing culverts

There are a total number of 16 culverts in the 50 Point Conservation area. For modeling purposes, four culverts are included in the model geometry data. These culverts are located in the river stations 246.5, 218.5, 72 and 27. The lengths of the culvert located in RS 246.5, 218.5, 72 and 27 are respectively 7 m, 6 m, 20.75 m and 20.75 m. The culverts at the downstream have span of 1.25 m and rise of 0.65 m. The other two culverts are circular, the opening of one culvert is 800 mm and other culvert has three cells of 600 mm diameter. Figure 11 shows the location of all the existing culverts.

3.3.2 RESULTS OF 1D HEC-RAS MODEL

Steady flow HEC-RAS simulations were performed for three different conditions: one existing condition and two proposed conditions. These two proposed conditions are alternative 2 and alternative 5. Alternative 2 suggests diversion of SB1, SB2 and SB3 to the Fifty Point pond and alternative 5 suggests diversion of SB1, SB2 and SB3 to the Fifty Point pond and diversion of SB4, SB5 and SB7 to the storm sewers at Shippee and McCollum. The simulation results include water surface elevations (WSE) at different river stations for 100 Year Chicago storm. These WSEs depict the level of flood water for different conditions and enable comparison of effectiveness in reducing flood levels for the different alternative solutions.

Table 6 shows the WSEs obtained from HEC-RAS model at river stations 78, 109, 155, 220.5 respectively for the existing condition, Alternative 2 and Alternative 5.

Table 6: HEC-RAS simulated WSE at river stations 78, 109, 155, 220.5 and 248

River Station	Storm	Existing Condition W.S. Elevation (m)	Alternative 2 W.S. Elevation (m)	Alternative 5 W.S. Elevation (m)
78	100 Yr Chicago	76.14	76.03	76.00
109	100 Yr Chicago	76.15	76.04	76.01
155	100 Yr Chicago	76.38	76.26	76.23
220.5	100 Yr Chicago	76.48	76.32	76.27
248	100 Yr Chicago	76.76	76.38	76.28

Table 7: Reduction in flooding between alternative 2 and alternative 5 and existing condition

River Station	Storm	Alternative 2: Reduction in W.S. Elevation (m)	Alternative 5: Reduction in W.S. Elevation (m)
78	100 Yr Chicago	0.11	0.14
109	100 Yr Chicago	0.11	0.14
155	100 Yr Chicago	0.12	0.15
220.5	100 Yr Chicago	0.16	0.21
248	100 Yr Chicago	0.38	0.48

From the table, it can be seen that HEC-RAS simulation was performed for the two proposed conditions, Alternative 2 and Alternative 5. Alternative 2 proposes diversion of flows from SB1, SB2 and SB3 to 50 Point Pond. Alternative 5 is actually the combination of Alternative 2 and Alternative 4. It can be observed from Table 7 that WSEs at the stations are minimum for Alternative 5. However, it does not eliminate flood water in the creek as flow from SB7 will remain in Watercourse 11. Alternative 2 diverts 67% of the total flow. As a result, it ensures significant reduction of flooding

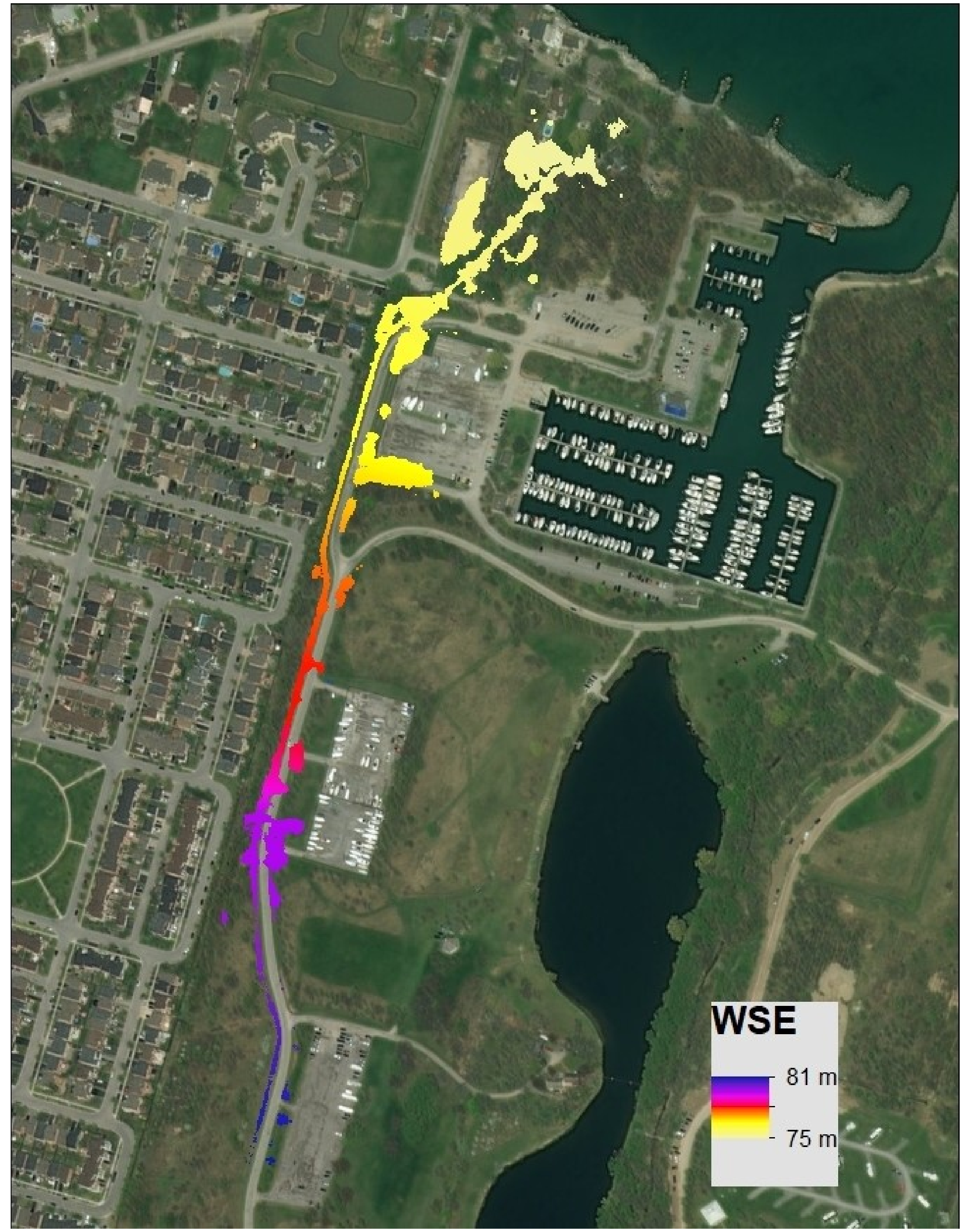


Figure 12: Flood Inundation Map for 100 Year Chicago Storm (existing condition)

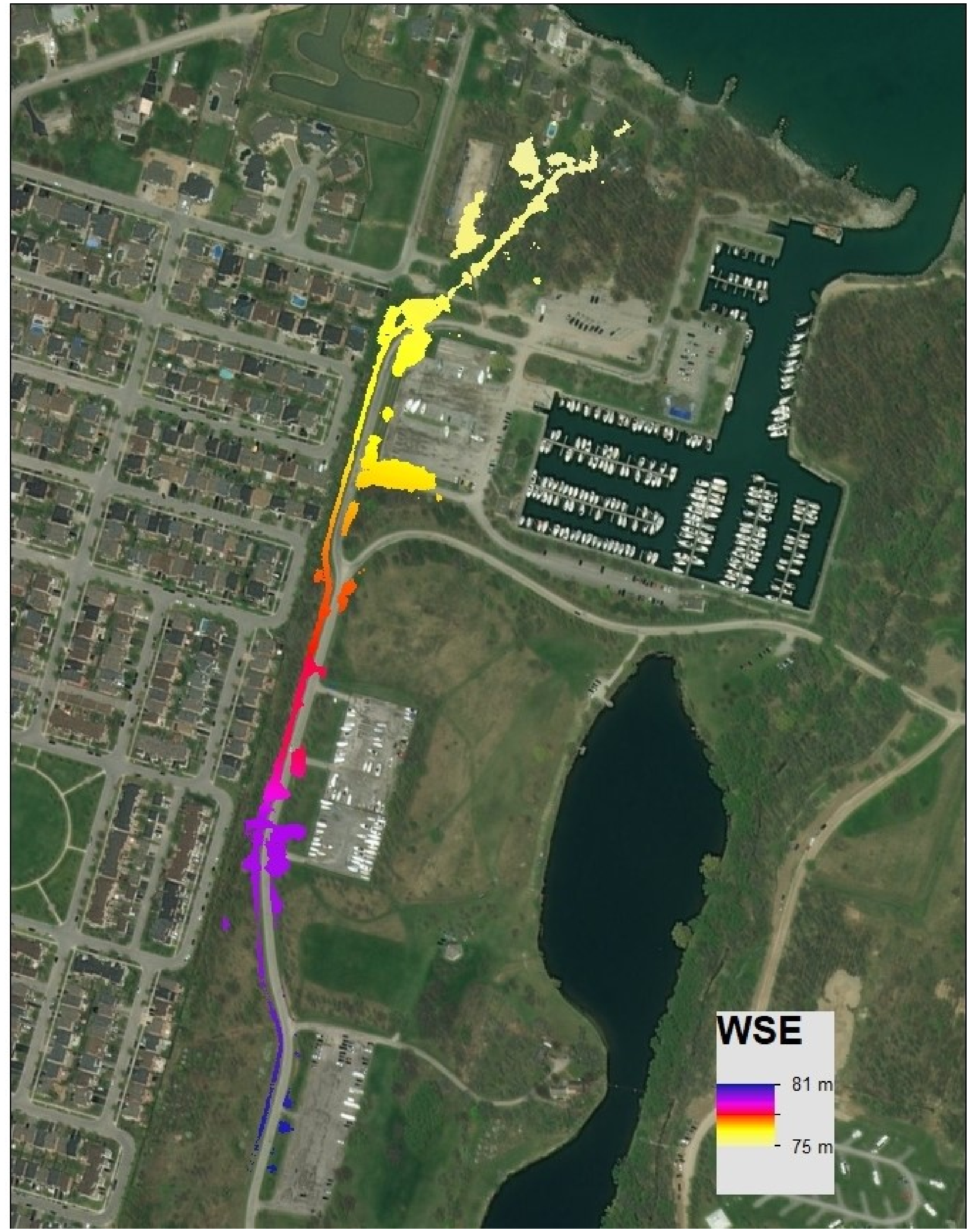


Figure 13: Flood Inundation Map for 100 year Chicago Storm (Proposed Condition: Alternate 2)

Figure 14: Flood Inundation Map for 100 Year Chicago Storm (Proposed Condition: Alternate 5)

in the study area, especially in the residential area. WSE for Alternative 2 is lower than that of the existing condition.

Flow conditions at different locations can also be observed for existing and proposed conditions. From the simulation results it can be observed that at the key locations, total flow is reduced when the alternatives are applied. Table 8 shows the flow conditions at different key locations obtained from HEC-RAS simulation for existing condition and two proposed conditions.

Table 8: HEC-RAS simulated Total Flow at river stations 78, 109, 155, 220.5 and 248

River Station	Storm	Existing Condition	Alternative 2	Alternative 5
		Q Total (m³/s)	Q Total (m³/s)	Q Total (m³/s)
78	100 Yr Chicago	0.63	0.26	0.1
109	100 Yr Chicago	0.59	0.16	0.1
155	100 Yr Chicago	0.59	0.16	0.1
220.5	100 Yr Chicago	0.59	0.16	0.04
248	100 Yr Chicago	0.59	0.16	0.04

After performing the steady flow analysis, flood inundation maps for existing condition are generated using a raster of 10 m spatial resolution. Figure 12 shows inundation map of the existing condition for 100 Year Chicago storm.

As shown in Figure 12, the flooding prevails in the existing condition. The intensity of flood inundation is high for 100 Year Chicago storm. During the storm event, the residential properties are inundated.

Inundation map of the 100 Year Chicago storm obtained for alternative 2 is shown in Figure 13. It can be observed that Alternative 2 will reduce the extent of flooding significantly in the residential area. Most of the flood water will remain in the creek.

Similar to the flood inundation maps generated for Alternative 2, flood inundation maps of Alternative 5 are generated using a raster of 10 m spatial resolution. Figure 14 shows inundation map of Alternative 5 for the 100 Year Chicago storm. Application of Alternative 5 significantly reduces flooding in the residential area.

3.4 COASTAL ANALYSIS

According to the MNR Technical Guidelines (2001), the regulated 100-year flood level for the Western Lake Ontario is 76m GSC (Geodetic Survey of Canada). As the project site is located on the Western Lake Ontario shoreline, we have also analyzed wind-wave data of the Western Lake Ontario.

3.4.1 ANALYSIS OF WIND-WAVE ENVIRONMENT

The Wave Information Studies (WIS) data collected by the United States Army Corps of Engineers (USACE) were used for the wind and wave frequency analysis. The project site is located on north of the QEW and east of Fifty Road. The site is closed to Lake Ontario WIS station 91133. Therefore, the data with record period from 1979 to 2014 of this station were used for this project. Figure 15 illustrates the wave rose graph generated by the USACE WIS for the significant wave height from all directions. It is observed from Figure 15 that most of the waves are coming from the west, northwest and northeast directions, and a minority of waves come from all the other directions. As mentioned earlier, the shoreline at the project site is facing northeast. Figure 16 shows the wind speed from all the directions at the WIS station. Most of winds and higher wind speed are coming from the west, southwest, and northwest directions. Any wind-wave coming from the northeast direction will have the greatest influence on the study area shoreline.

Table 9: Wind Speed Frequency Analysis

Wind Speed (m/s)			
Return Period	10	20	25
all directions	22.00	24.07	24.74
N	14.72	17.01	17.75
NE	15.53	17.78	18.50
E	15.52	17.73	18.45
SE	11.64	13.00	13.44
S	15.69	18.55	19.47
SW	20.65	23.37	23.37
W	20.84	21.62	22.23
NW	17.81	18.50	19.03

Table 10: Significant Wave Height Frequency Analysis.

Return Period	10		20		25	
	HMO (m)	TP (s)	HMO (m)	TP (s)	HMO (m)	TP (s)
all directions	3.11	6.30	3.61	8.39	3.78	6.93
N	2.00	5.21	2.42	5.73	2.55	5.73
NE	2.98	7.63	3.56	7.63	3.74	6.93
E	1.61	5.73	2.11	5.21	2.27	6.30
SE	0.98	3.56	1.28	3.56	1.37	3.91
S	1.64	3.91	1.82	4.31	1.87	4.31
SW	1.68	4.31	2.01	4.31	2.12	4.31
W	2.27	4.74	2.47	5.21	2.54	5.21
NW	2.00	4.74	2.30	5.21	2.39	5.21

Note:

HMO is the significant wave height in metres

TP is the associated wave period for the HMO in seconds

A frequency analysis for the wind speed and significant wave height was conducted and analyzed using the WIS data. It can be seen in Table 10 that there are 9 direction categories, one all directions category and 8 individual direction categories. The raw data from WIS has specific degree angles measured from true north rather than just stating the direction range. However, for the analysis in this study, 8 direction categories were adopted. The 8 direction categories, formed by dividing the 360 degree angle into 8 equal angles by 8 lines from the center, starting from the true north. Then the degree angles within the ±22.5 degree range from the true north were considered to be the north direction. All other directions were categorized in a similar way. The maximum annual wind and wave data categorized by 8 different directions and all directions was obtained by inputting the raw data into a programming code developed by Dr. Bahar SM. There are 36 years of data available. Each of the processed data sets for all the 9 direction categories were ranked from smallest to largest then distributed and extended to 100 years using lognormal,

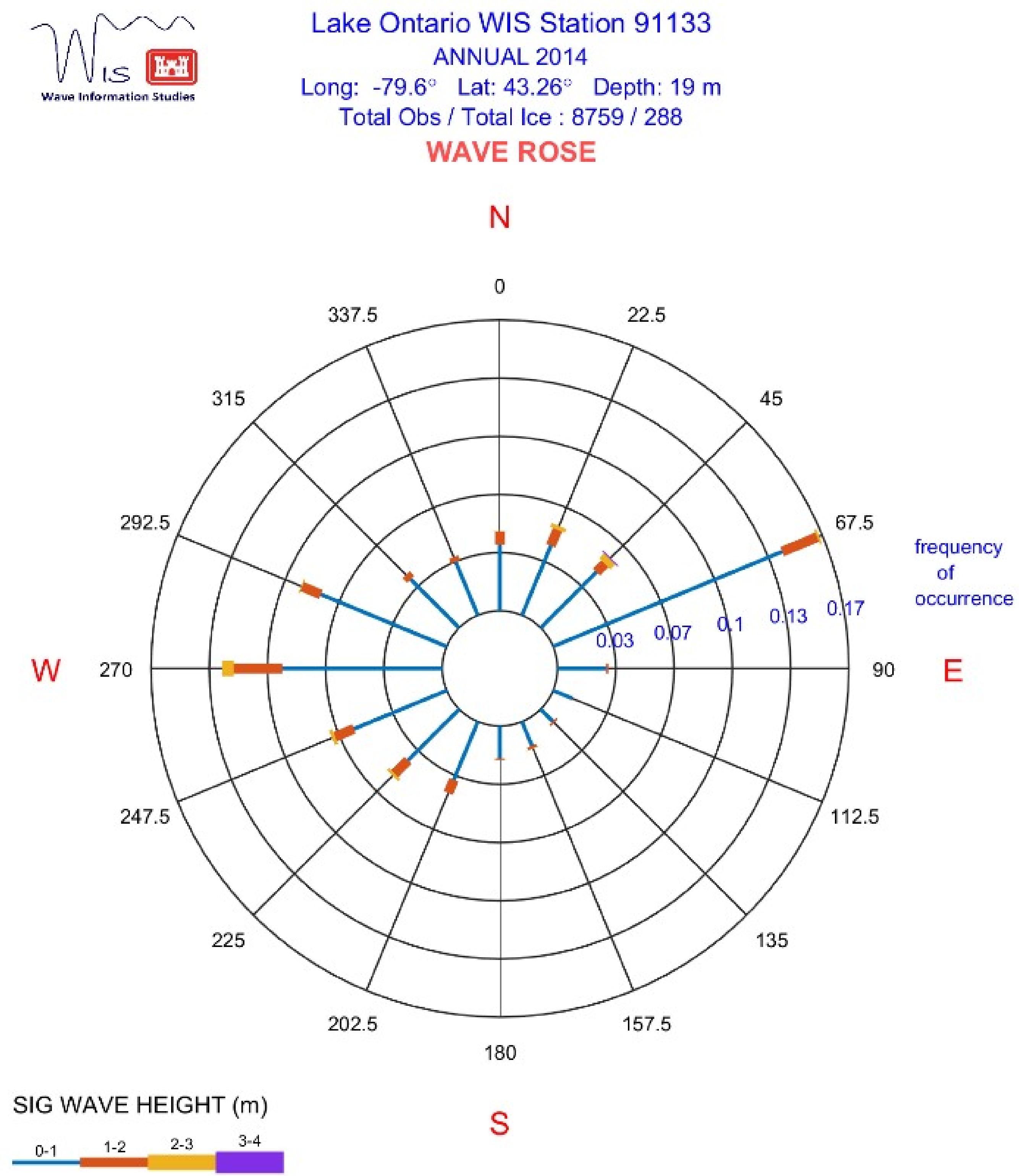


Figure 15: Wave Rise Graph for Significant Wave Height (USACE, 2017)

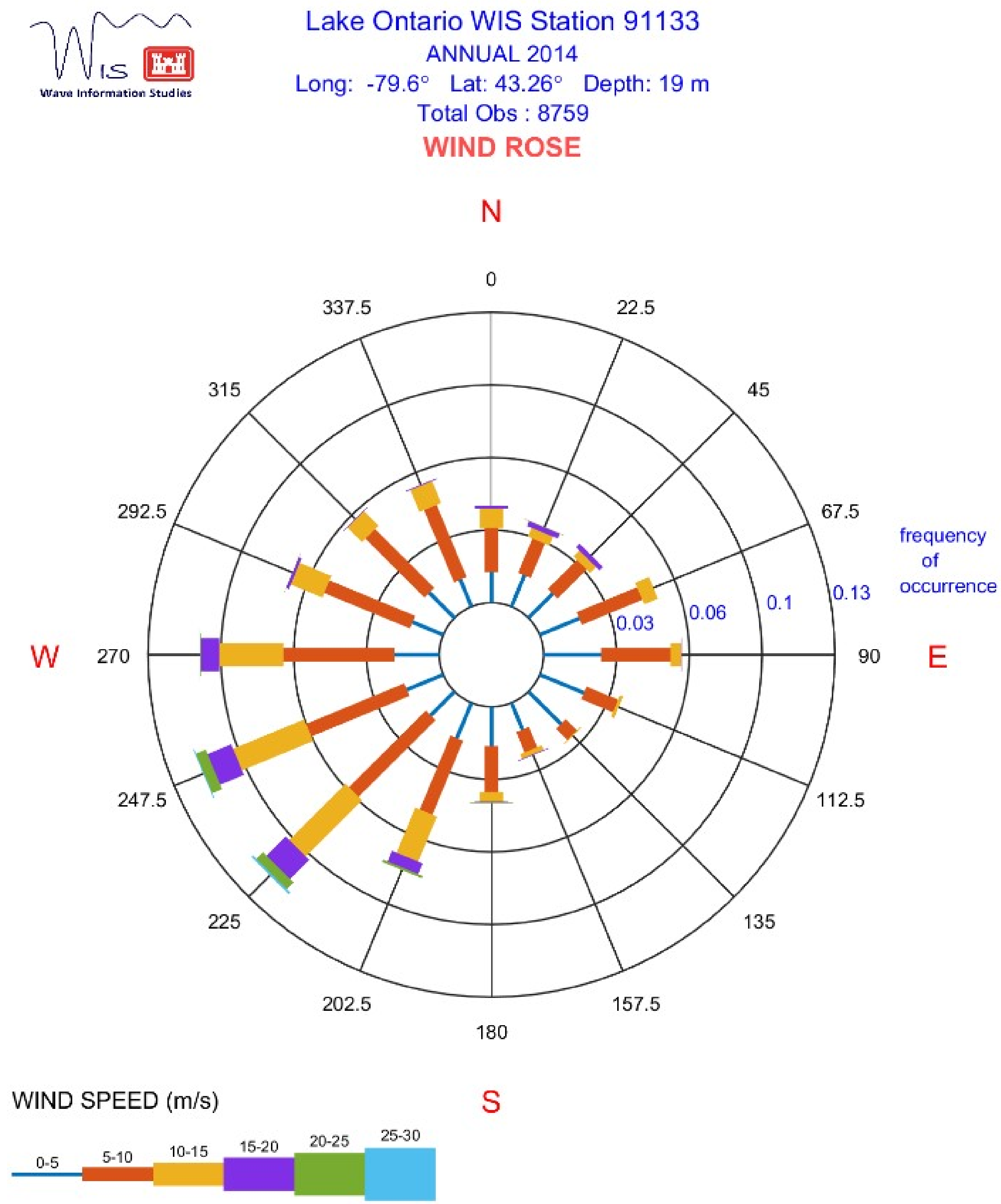
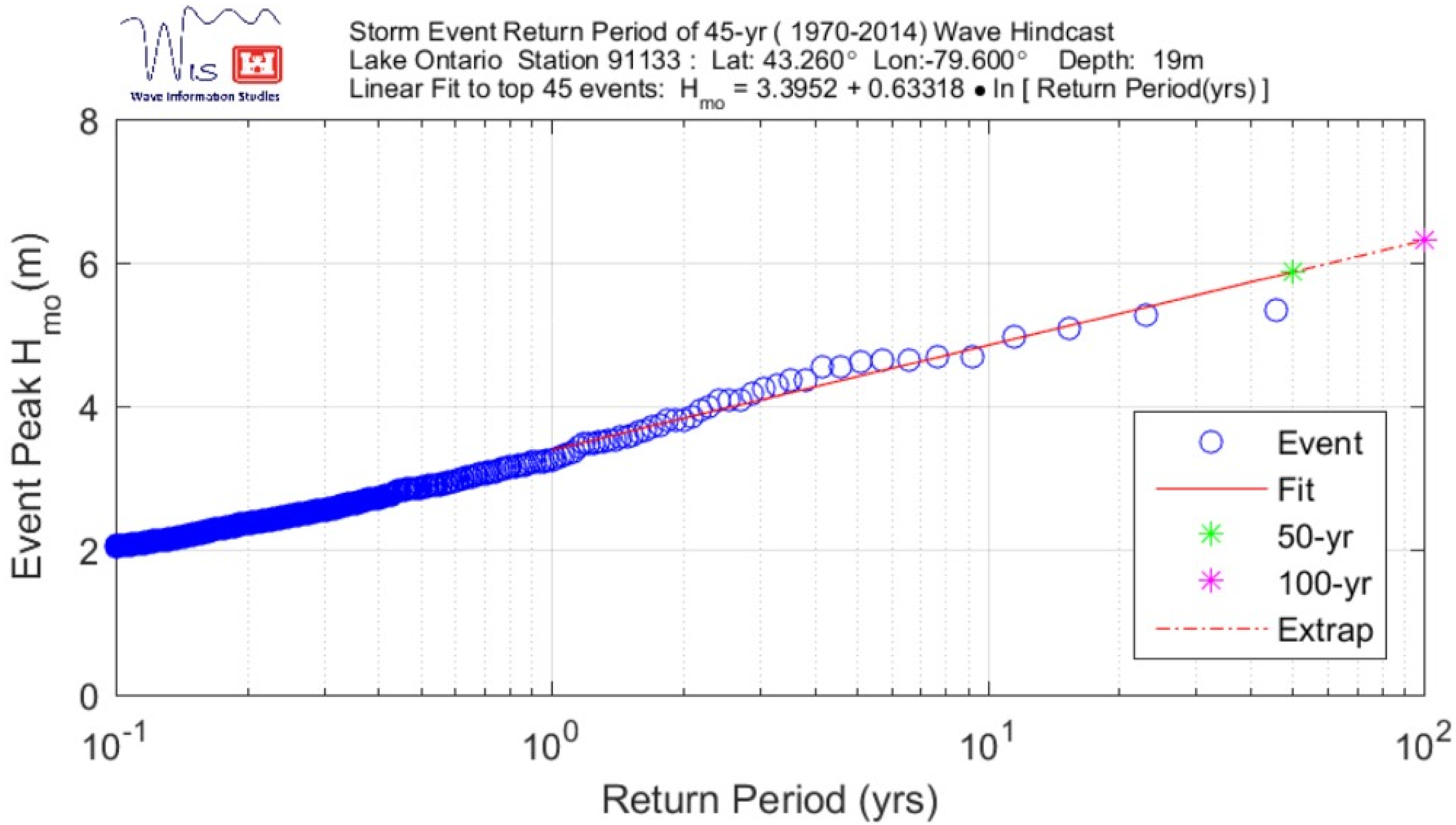


Figure 16: Wind Rise Graph for Wind Speed (USACE, 2017)



Top 10 events based on Peak H_{mo}

Event	Date/Time(UTC)	H_{mo}	T_p	θ_{mean}	Event	Date/Time(UTC)	H_{mo}	T_p	θ_{mean}
1	2012/10/30 06:00	5.35	8.94	32.0	6	1978/01/20 18:00	4.70	9.19	63.0
2	2011/02/02 09:00	5.28	9.09	63.0	7	1978/01/14 16:00	4.64	9.26	61.0
3	2011/10/20 02:00	5.09	9.08	61.0	8	1978/01/14 16:00	4.64	9.26	61.0
4	2013/04/12 08:00	4.97	9.13	64.0	9	2011/11/23 06:00	4.62	8.49	59.0
5	1978/01/20 18:00	4.70	9.19	63.0	10	1977/12/06 04:00	4.56	9.19	70.0

An event is defined as any period when $H_{mo} > 2.00$m θ_{mean} is direction that waves are arriving from

ERDC US Army Engineer Research & Development Center   ST91133_v01

Figure 17: Frequency Analysis of Wave Hindcast (WSI 91133)

linear, or exponential distribution where appropriate. Then the values for the 10, 20, and 25 years return periods were estimated from the data trend line calculated by the distribution methods.

Table 9 and 10 represent the frequency analysis for wind speed and significant wave height for all directions and each individual direction for return periods 10, 20, and 25 years. As shown in Table 9, the wind speeds are the largest coming from the southwest direction among all the direction categories other than the all directions category. It also should be noted that the wind speeds from the southwest direction is much greater than the wind speeds from the southeast direction. Table 10 shows that the significant wave heights are the largest from the northeast direction among all direction categories other than the all directions category. The shoreline at the project site is facing northeast, and wind-wave from that direction is the highest (Table 10) compared to all other directional wind-waves.

3.4.2 WAVE UPRUSH ANALYSIS

In order to determine a proper flood hazard limit, a few traditional theories and methods were applied to estimate wave run-up and the results of these methods were compared. A few methods were applied to determine the natural beach slope and the offshore deep-water wind-wave conditions were applied. A wave uprush computation was carried out. Deep water wave parameters, significant wave height and wave period, as well as local shoreline geometry were applied in the computation. Shoaling of deep water waves can cause destructive force on the shoreline structures because of wave breaking and energy dissipation.

The primary controlling parameters of wave uprush include still water level (SWL), incident wave climate (wave height, H, and wave period, *T*); slope of beach or protection work (tan α); slope of lake bottom (tan *α*); water depth at toe of the protection work or beach (*d*); surface roughness (*r*), and protection work permeability (*P*). Other factors that may also impact the magnitude of wave uprush includes bathymetry (e.g., offshore bars and composite slopes), berms in front of protection work, and oblique wave attack. The wave uprush can also be affected by the ice cover of shore. The ice covers turn the rough permeable slope into a smooth impermeable slope, which limits the depth of water, hence limiting the wave action.

AHYDTECH analyzed wave uprush for the study area shoreline. As mentioned earlier, this study followed the MNR Technical Guidelines (2001) and available coastal engineering protocols for the wave uprush analysis. AHYDTECH conducted wave uprush computation using several methods which are applicable to the project site. These methods are U.S. Army Corps of Engineers (1990), Upper Limit Method (MNR, 2001), Ahrens and Heimbaugh (1988a), Hunt (1959) and Battjes (1974) & Lorang (2000).

For four type of cross shore profiles AHYDTECH has computed wave uprush for 10 and 20 year return period. In the following Table results of different methods are shown.

Table 11: 10 Year Wave Uprush of Natural Shoreline

10 YEAR WAVE UPRUSH

METHOD	PROFILE # 1	PROFILE # 2	PROFILE # 3	PROFILE # 4
Hunt (1959)	**0.65**	**0.39**	**0.76**	**0.73**
Battjes (1974) & Lorang (2000)	**0.34**	**0.31**	**0.39**	**0.38**
Maximum Wave Uprush (m)	**0.65**	**0.39**	**0.76**	**0.73**
Maximum Wave Uprush Elevation (m)	**76.65**	**76.39**	**76.76**	**76.73**

Table 12: 20 Year Wave Uprush of Natural Shoreline

20 YEAR WAVE UPRUSH

METHOD	PROFILE # 1	PROFILE # 2	PROFILE # 3	PROFILE # 4
Hunt (1959)	**0.84**	**0.79**	**0.99**	**0.95**
Battjes (1974) & Lorang (2000)	**0.44**	**0.41**	**0.51**	**0.50**
Maximum Wave Uprush (m)	**0.84**	**0.79**	**0.99**	**0.95**
Maximum Wave Uprush Elevation (m)	**76.84**	**76.79**	**76.99**	**76.95**

Table 13: Wave Uprush of Vertical Wall

	Wave Uprush R (m)		
METHOD	10 Year	20 Year	MEAN
ACES (USACE 1990) & Goda (1985)	1.05	3.19	2.12
Upper Limit Method (MNR, 2001)	2.34	2.72	2.53
AVERAGE WAVE UPRUSH (m)	1.69	2.96	2.33

Table 14: Wave Uprush of Slope Revetment

	PROFILE # 2 WAVE UPRUSH (m)			PROFILE #3 WAVE UPRUSH (m)		
METHOD	10 Year	20 Year	MEAN	10 Year	20 Year	MEAN
ACES (usace 1990) & Goda (1985)	2.44	2.95	2.70	2.51	3.04	2.77
Ahrens and Heimbaugh (1988a) & Goda (1985)	2.61	2.88	2.74	1.85	2.05	1.95
AVERAGE WAVE UPRUSH (m)	2.53	2.91	2.72	2.18	2.55	2.36

It can be observed from the analysis above, the watercourse 11 in Fifty Point conservation area experiences flooding due to wave uprush. If designing a vertical sea wall is considered, the average wave uprush is found to be 2.33m. If designing a slope revetment is considered, values of average wave uprush for Profile #2 and Profile #3 are respectively 2.72 m and 2.36 m. In case of designing a slope revetment, the average wave uprush should be taken as 2.54 m which is the average of 2.72 m and 2.36 m. In this study, shoreline flooding is addressed in the Fifty Point conservation area. It can be concluded that one of the causes of shoreline flooding is wave uprush which is calculated to be in the range of 2.33 m to 2.72 m. The preliminary design of the alternative is proposed so that the damages of flooding caused by the wave uprush are also reduced.

3.5 NATURAL ENVIRONMENTAL ASSESSMENT

The upper reaches of the Watercourse 11 subwatershed are comprised of roadside swales with herbaceous vegetation along the north portion of the ring access road within the 50 Point Conservation Area. The swale system outlets via a culvert underneath a trail at the south end of a relatively small woodland located near the shore of Lake Ontario. The watercourse traverses the woodland flowing in a northerly direction. Within the woodland the channel is relatively wide until the downstream end where it narrows as it bends to the east along a property line. The watercourse soon bends to the north again and traverses the yards of private residences before flowing under Windemere Road. The downstream reach of the creek on both sides of Windemere Road is comprised of a concrete channel which outlets into the Lake.

Deciduous swamp is present along the watercourse in the southern portion of the woodland that transitions to Dogwood thicket swamp in the north. The wetland transitions into moist deciduous forest in the northeast and upland deciduous forest in the southeast. While wildlife surveys were not completed, the woodland likely provides habitat for songbirds and common mammals. One occupied raptor stick nest was observed in the tree canopy along the watercourse. The watercourse appears to provide suitable habitat for breeding anurans due to the presence of pools with minimal flow after the freshet. Being so close to the lake, the woodland likely provides some migratory bird habitat. Due to the relatively long concrete channel at its downstream end, it is unlikely that the watercourse supports direct fish habitat. The proposed alternatives will maintain the health of the existing woodlot.

4.0 LIST AND EXAMINATION OF ALTERNATIVES

The project team has worked on analyzing and identifying alternative solutions to the existing problem of flooding in the project area. Below are the tentative alternative solutions that are considered in addressing the problems and opportunities:

Table 15: List of Alternatives

Alternatives	Description of the Alternatives
Alternative 1	Do Nothing
Alternative 2	Divert Subbasins SB1, SB2 & SB3 to the 50 Point Pond
Alternative 3	Divert Subbasin SB4 to the 50 Point Pond
Alternative 4	Divert Subbasin SB4, SB5 & SB7 to the Storm Sewers at Shippee and McCollum
Alternative 5	Combination of Alternative 2 and 4

- **Alternative 1:** Alternative 1 involves maintaining the existing conditions in the study area. This includes maintaining the channels, drainage features, culverts and shoreline structures. This does not solve the flooding problem. The existing drainage features and structures have failed to prevent flooding damages. Maintaining these structures will not result in any solution for the flooding issue.
- **Alternative 2:** Alternative 2 involves diverting the flood water from SB1, SB2 and SB3 to the 50 point pond. From hydrological model analysis, it is found that total runoff volume which is causing flooding in Watercourse 11 is 3102.76 m^3. Alternative 2 suggests diversion of 2319.89 m^3 of runoff volume which is 67% of the total flow. Therefore, Alternative 2 ensures diversion of major portion of the flood flow with almost no negative impacts on the environment at a reasonable cost.
- **Alternative 3:** Alternative 3 suggests only diversion of subbasin SB4 to the 50 Point Pond. This ensures diversion of only 361.32 m^3 of flood water which is only 12% of the total flow. As a result, the flooding damages cannot be fully mitigated if this alternative is undertaken.

- **Alternative 4:** Alternative 4 involves diversion of subbasins SB4, SB5 and SB7 to the Storm Sewers at Shippee and McCollum. This ensures diversion of 782.87 m^3 of flood water which is about 25% of the total flow. Therefore, Alternative 4 ensures diversion of flood water less than the diversion proposed by alternative 2. It also requires high cost of construction and operation.
- **Alternative 5:** Alternative 5 suggests a combination of Alternative 2 and 4. This means diversion of flood water of subbasins SB1, SB2, SB3, SB4, SB5 and SB7. This ensures diversion of 100% of the flood water, but it requires very high construction and operation cost. Besides the construction process offers very low feasibility.

The alternatives do not address groundwater and wave uprush as flooding mechanisms.

4.1 EVALUATION OF ALTERNATIVE METHODS

The alternative methods are evaluated considering the following evaluation categories-

- **Physical/ Natural Environment:** Hydrology, Hydraulic & Flooding, Coastal Process, Acquisition of Private Property, Integration with Existing Environment, Integration with Existing Infrastructure, Groundwater/ Hydrogeological, Natural Heritage, Wild life and Vegetation, Aquatic Species, Habitat.
- **Social/Cultural Environment:** Landowner acceptance, Public Health & Safety, Utility Lines.
- **Technical/Engineering Factors:** Ease of Implementation and Construction, Agency Acceptance, Official Policy, Secondary Policies and Bylaw Requirements, & Technical Feasibility.
- **Economic Environment:** Timing Constraints, Operation & Maintenance, Capital Cost & Lifecycle Cost.

The alternative Evaluation Table is provided in Table 16 where impacts resulted from undertaking each alternative is evaluated for the mentioned categories. It is checked whether the impacts are positive or negative, if these impacts are significant and if these impacts can be fully or partially mitigated. Firstly, Alternative 1 which involves doing nothing, is evaluated. This alternative does not contribute any improvement in local hydrology and channel capacity. In case of reducing flooding impact in the upstream, conservation area and residential area, this alternative proposes no impact. Alternative 1 also does not improve the stream form and coastal function. Moreover, this alternative creates negative impact in case of bank stability. Since this alternative involves doing nothing, construction related impacts and property damage or acquisition are not applicable for this alternative. Impact on existing infrastructure is also not applicable for this alternative. It proposes no improvement or impact in case of groundwater quality, hydrogeology, natural heritage, wildlife corridor, vegetation population, aquatic habitat, terrestrial habitat and natural habitat. There will be no significant impacts in case of landowner acceptance and suggestions. There will be no benefit for public health and safety and no improvement to traffic conditions. In conclusion, for the riverine flooding and shoreline flooding issue of Fifty Point Conservation area, doing nothing cannot be chosen as an effective option.

Secondly, Alternative 2 is evaluated, which includes diverting subbasins SB1, SB2 & SB3 to the 50 Point Pond. This alternative successfully reduces the damages caused from conservation area flooding and residential area flooding. In case of upstream flooding issue, Alternative 2 provides no significant impacts. It proposes no significant impact on local hydrology, high flows within channel, stream, channel or shoreline stability, coastal function, short term erosion protection and long term erosion protection. There will be no significant construction impacts due to this alternative. If this alternative is undertaken, construction related impacts like noise, dust and traffic can be fully

Physical/Natural Environment

CATEGORY		Physical/Natural Environment																									
ISSUE		Hydrology, Hydraulic & Flooding					Coastal/Stream Process			Shoreline Erosion and Sedimentation		Protection/Acquisition of Private Property			Integration with Existing Environment		Integration with Existing Infrastructure		Groundwater/ Hydrogeological		Natural Heritage	Wild life and Vegetation		Aquatic Species, Habitat			
EVALUATION CRITERIA		Improvement to local hydrology	Improvement/decrease to high flows within channe carridor	Upstream flooding impact	Conservation Area flooding impact	Residential Flooding Impact	Improvement to stream form	Improvement to stream/channel/shoreline stability	Improvement to stream/Coastal function	Improvement to short-term erosion protection	Improvement to long-term erosion protection	Construction impact mitigation	Construction-related impacts-noise, dust, traffic	Potential long term effects for property damage/property acquisition due to the Alternative	Potential long-term effects on the existing environme	Available mitigation measures to mitigate the impac due to construction of alternative	Impact on existing infrastructure	Ease of integration with existing infrastructure	Improvement on groundwater quality	Impact on local hydrogeology	Impact on natural heritage/area	Improvement to wildlife carridor function	Improvement to vegetation population	Short-term improvement to aquatic habitat	Short-term improvement to terrestrial habitat	Long-term improvement to aquatic habitat	Long-term improvement to terrestrial habitat
A1	Do Nothing	N/A	N/A	*	*	*	N/A	×	N/A	▲	▲	N/A	N/A	N/A	▲	▲	N/A	N/A	N/A	N/A	N/A	N/A	N/A	▲	▲	▲	▲
A2	Divert Subbasins SB1, SB2 & SB3 to the 50 Point Pond	*	*	*	✓	✓	N/A	*	*	*	*	*	♦	*	✓	♦	*	*	*	*	*	*	*	♦	*	♦	♦
A3	Divert Subbasin SB4 to the 50 Point Pond	*	*	*	✓	✓	N/A	*	*	*	*	*	♦	*	✓	♦	*	*	*	*	*	*	*	♦	*	♦	♦
A4	Divert Subbasin SB4, SB5 & SB7 to the Storm Sewers at Shippee and McCollum	*	▲	*	✓	✓	N/A	▲	*	*	▲	×	*	▲	✓	▲	♦	▲	*	*	*	N/A	▲	▲	*	*	*
A5	Combination of Alternative 2 and 4	*	*	✓	♦	✓	▲	▲	*	▲	*	▲	*	▲	✓	♦	▲	×	*	✓	♦	*	♦	▲	*	✓	*

Social/Cultural Environment

CATEGORY		Social/Cultural Environment					
ISSUE		Landowner Acceptance		Public Health & Safety	Traffic		Utility Lines
EVALUATION CRITERIA		Ease of landowner acceptance	Potential probability of landowner suggestions/comments	Benefit for public health and safety	Improvements to current and future traffic condition	Potential traffic risk (e.g. collision tendency) associat with each alternative and mitigation measures	Conflict with existing utility lines under each alternat and avilability of mitigation measures (e.g. relocatio
A1	Do Nothing	*	*	N/A	N/A	×	N/A
A2	Divert Subbasins SB1, SB2 & SB3 to the 50 Point Pond	*	♦	✓	*	*	♦
A3	Divert Subbasin SB4 to the 50 Point Pond	*	♦	*	*	*	♦
A4	Divert Subbasin SB4, SB5 & SB7 to the Storm Sewers at Shippee and McCollum	▲	♦	*	*	*	♦
A5	Combination of Alternative 2 and 4	▲	▲	*	*	*	♦

Technical/Engineering Factors

CATEGORY		Technical/Engineering Factors										
ISSUE		Ease of Implementation and Construction		Agency Acceptance					Official Policy, Secondary Policies and Bylaw Requirements	Technical Feasibility		
EVALUATION CRITERIA		Complexity	Mitigation to construction failure/issues	City of Hamilton	HCA	MNRF	DFO	Utility Companies	Compliance issues	Improvement to infrastructure existing condition	Feasibility of construction	Feasibility of implementation
A1	Do Nothing	N/A	N/A	×	N/A	N/A	N/A	N/A	N/A	×	N/A	N/A
A2	Divert Subbasins SB1, SB2 & SB3 to the 50 Point Pond	♦	♦	♦	♦	♦	♦	*	♦	✓	✓	✓
A3	Divert Subbasin SB4 to the 50 Point Pond	♦	♦	♦	♦	♦	♦	*	♦	✓	♦	♦
A4	Divert Subbasin SB4, SB5 & SB7 to the Storm Sewers at Shippee and McCollum	▲	♦	♦	♦	♦	♦	*	♦	▲	*	*
A5	Combination of Alternative 2 and 4	×	♦	♦	♦	♦	♦	♦	♦	▲	♦	▲

Economic Environment

CATEGORY		Economic Environment							
ISSUE		Timing Constraints		Operation & Maintenance			Capital Cost	Lifecycle Cost	
EVALUATION CRITERIA		Impact of duration of cold water fish mating season o construction	Impact of duration of warm water fish mating seaso on construction	Requirements for maintenance	Frequency of maintenance and inspection required	Operational Cost	Cost to construct	Anticipated longevity of constructed Alternative	Overall Ranking
A1	Do Nothing	*	*	×	N/A	N/A	N/A	×	
A2	Divert Subbasins SB1, SB2 & SB3 to the 50 Point Pond	*	*	♦	▲	✓	✓	✓	1
A3	Divert Subbasin SB4 to the 50 Point Pond	*	*	♦	▲	▲	▲	✓	2
A4	Divert Subbasin SB4, SB5 & SB7 to the Storm Sewers at Shippee and McCollum	*	*	▲	▲	×	×	▲	4
A5	Combination of Alternative 2 and 4	*	*	♦	▲	×	×	♦	3

Method The alternatives were brought forward for detailed evaluation using the scoring system outlined

Scoring symbols

× negative impact; ▲ some impacts will remin; ♦ most impacts can be mitigated

✓ positive impact; * no significant impacts; N/A not applicable

Table 16: The Alternative Evaluation Table

mitigated. Due to this alternative there will be no significant potential long term effects on property damage or property acquisition. This also provides positive potential long term effects on the existing environment and no significant impact on the existing infrastructure. This alternative can be easily integrated with the existing infrastructure. No significant impact on groundwater quality and local hydrogeology is imposed from this alternative. There will be no significant impact on natural heritage area, wildlife and vegetation population due to this alternative. Most of the impacts on aquatic and terrestrial habitat due to this alternative can be mitigated. Landowner acceptance and suggestions can easily be taken in this alternative. This alternative also provides benefit for public health and safety. There will be no significant impact in current and future conditions and no potential traffic risk due to this alternative. The impacts in existing utility lines can mostly be mitigated. The anticipated longevity of this alternative is also promising. Considering all these evaluation components, it can be concluded that alternative 2 can be selected as the preferred alternative solution for this flooding issue of Fifty Point Conservation area.

Alternative 3 includes diverting subbasin SB4 to the 50 Point Pond. This alternative is also evaluated in all the mentioned categories. This alternative proposes no significant impact in case of improvement to local hydrology and channel capacity. Similar to Alternative 2, this alternative also successfully reduces the flooding damages of conservation area and residential area. It also proposes no significant impact on upstream flooding. All the impacts of this alternative is quite similar to alternative 2, except the feasibility of construction and implementation of this alternative is not positive because of negative grading in the SB4 ditch. Besides the frequency of maintenance and inspection cannot be maintained in case of this alternative. The construction and operational costs of this alternative also fail to reduce the impacts. Therefore, though Alternative 3 reduces the flooding damages, it is not preferred over Alternative 2.

Alternative 4 includes diverting Subbasin SB4, SB5 & SB7 to the storm sewers at Shippee and McCollum. This alternative provides almost similar impacts as provided by alternative 2 and 3, but some impacts are estimated to remain in case of high flows within channel corridor. Some impacts are also found to be prevailing in case of stream/channel/shoreline stability, long term erosion protection, long term effects on property, ease of integration with existing infrastructure, vegetation population, and short term improvement to aquatic habitat. Improvement to wildlife corridor function is not applicable in case of this alternative. This alternative does not propose any significant impact on long-term or short-term improvement on natural habitat. On the other hand, implementation of this alternative is comparatively complex, with requirement for frequent maintenance and inspection. There prevails grade constraints which impose difficulty in connecting subbasin SB7 to a SWM facility. The flooding issue in Fifty Point Joint Venture subdivision cannot be solved by diversion of the stormwater from SB7 since the grade constraints do not allow the water to be removed by gravity. Besides, there is an issue with agreement as HCA does not hold the authority to drain to this SWM facility. In order to implement alternative 4, agreement from the owner and regulating agencies will be required. The SWM facility was originally designed with Level 1 wetland water quality control. From the calculations it has been found that to safely accommodate the diverted flows in the SWM facility, reduction of wetland water quality control from Level 1 to Level 2 is required in the SWM facility. However, HCA prefers to adhere to the original Level 1 quality control. The cost of construction and operation is also found to be very high in case of this alternative. Due to the all the above mentioned complexity, high cost and requirement for recurrent maintenance, Alternative 4 is not preferred.

Alternative 5 is the combination of Alternative 2 and 4. This alternative successfully reduces the impacts of upstream flooding and residential flooding but some impacts still remain for some cases. In case of conservation area flooding, most of the impacts can be mitigated. It is found that some impacts will still remain in case of improvement to stream form, stream/channel/shoreline stability, short term erosion protection, construction impact mitigation, long term effect to property damage, existing infrastructure, and landowner acceptance. There will be some impacts on natural heritage and vegetation population due to this alternative. Implementation of this alternative is complex along with requirement for frequent maintenance and inspection similar to alternative 4. Compared to alternative 4, the operational and constructional cost of this alternative is higher. Therefore, Alternative 5 is in third preference.

Considering all the impacts and the possibility of mitigating the impacts, Alternative 2 is prioritized as the preferred alternative.

4.2 SELECTION OF A PREFERRED ALTERNATIVE

Based on the evaluations described in the previous section, Alternative 2 is selected as the preferred alternative. Detailed explanation of the reasons for choosing Alternative 2 as the preferred solution is as follows. From the hydrologic model, the subbasin flows are simulated. The simulated flows are shown in the following table:

Table 17: Simulated peak flows

Storm Event	Results	SB1	SB2	SB3	SB4	SB5	SB7	SB9
100 year Chicago Storm	Peak Flow (cms)	**0.159**	**0.268**	**0.102**	**0.125**	**0.036**	**0.098**	**0.156**
	Area (ha)	3.15	4.01	3.44	1.2	0.74	2.17	0.57
	Runoff Volume (mm)	18.69	31.71	13.36	30.11	15.15	14.26	59.3
	Runoff Volume (m^3)	588.74	1271.57	459.58	361.32	112.11	309.44	338.01
Regional 48 hour Hurricane Hazel Storm	Peak Flow (cms)	**0.099**	**0.197**	**0.074**	**0.062**	**0.019**	**0.054**	**0.075**
	Area (ha)	3.15	4.01	3.44	1.2	0.74	2.17	0.57
	Runoff Volume (mm)	61.28	103.34	44.34	97.88	49.99	47.17	234
	Runoff Volume (m^3)	1930.32	4143.93	1525.30	1174.56	369.93	1023.59	1333.80

- In case of 100 Year Chicago storm, the total runoff volume of SB1, SB2, SB3, SB4, SB5 and SB7 is 3102.76 m^3. Alternative 2 involves diverting runoff flow of SB1, SB2 and SB3 to the 50 Point Pond. Therefore, it ensures diversion of 2319.89 m^3 of flow which is two third of the total runoff volume. Since most of the flow are diverted, flooding damages from the Water Course 11 will be significantly mitigated.
- Figure 13 shows the result of hydraulic analysis if Alternative 2 is applied in case of a 100 Year Chicago storm. From the figure it can be seen that most flows are remaining in creek and not a single property is impacted by the flooding.
- In Alternative 2, the preliminary design will include creation of a wetland. The SB1, SB2 and SB3 will be connected to the wetland before discharging flow to the 50 Point Pond. This wetland will not only help in diversion but also improve the environmental condition. Alternative 2 and wetland creation can be performed at a very low cost.
- After the application of Alternative 2, it is likely to observe that the flow of SB7 will remain in SB7. Because of the presence of deciduous swamp and wooded area in SB7, eliminating the flows from SB7 will not be favourable to the environment. As a result, alternative 2 proves effective.
- Alternative 4 and alternative 5 may prove effective in reducing some flood damages but in spite of that, a portion of the flow will remain in the area and both of these alternatives require high construction and operational cost.

Therefore, considering all the above mentioned issues, Alternative 2 is found to be the preferred solution.

5.0 PRELIMINARY DESIGN AND APPROVAL PROCESS

Based on impact evaluation and effectiveness in reducing the flood damages, Alternative 2 is found to be the most effective solution. Alternative 2 suggests diversion of flows from SB1, SB2 and SB3 to the 50 Point Pond. Rest of the flow from SB4, SB5 and SB7 are discharged in Watercourse 11. Amount of flow diverted and discharged for three different storms are tabulated below.

Figure 18: Existing subbasins and proposed diversion process

Figure 19: Location of existing culverts

Figure 20: Flow Direction in Proposed Design Condition

Table 18: Flows in m³/s diverted to the Fifty Point Pond and discharged in Watercourse 11 from different subbasins

		25 mm 4 hour Chicago Storm		100 year Chicago Storm		100 year SCS 24 hour storm	
Alternative 2: Diversion of Flow	Subbasins	Stormwater Flow (m³/s)	Total Stormwater Flow (m³/s)	Stormwater Flow (m³/s)	Total Stormwater Flow (m³/s)	Stormwater Flow (m³/s)	Total Stormwater Flow (m³/s)
Diverted to the 50 Point Pond	SB1	0.038	0.125	0.159	0.529	0.14	0.467
	SB2	0.065		0.268		0.235	
	SB3	0.022		0.102		0.092	
Discharged in WC 11	SB4	0.034	0.064	0.125	0.259	0.107	0.226
	SB5	0.008		0.036		0.032	
	SB7	0.022		0.098		0.087	

The preliminary design of Alternative 2 aims at diversion of runoff volume of 2319.89 m^3 from the subbasins SB1, SB2 and SB3 to the Fifty Point Pond. Figure 18 shows the existing Sub-basins and proposed diversion process.

Figure 19 depicts that culvert C8 is located at the downstream of subbasins SB2 and SB3. The invert elevation of the existing culvert C8 allows transmission of water away from the Fifty Point pond. The prime concern of this design is to ensure successful diversion of flows from subbasins SB1, SB2 and SB3 to the Fifty Point Pond. The existing culvert C1 diverts flow of subbasin SB1 to subbasin SB3. To divert flows from subbasins SB2 and SB3 to the Fifty Point Pond, it is necessary to construct a ditch along the driveway towards the 50 Point Pond. In course of that action, construction of a berm with a height equal to the height of the road is designed. Construction of the berm will ensure diversion of flows from the subbasins SB2 and SB3 to the Fifty Point Pond. Before discharging the flow to the Fifty Point Pond, a drainage ditch and a wetland are constructed. Flood water will be obstructed by the berm and transferred to the new drainage ditch towards the 50 Point Pond. Then, the flood water will be transmitted to the wetland and finally to the Fifty Point Pond. This designed wetland ensures diversion and creates positive impact on the environment. The design of the wetland includes construction of an inlet and an outlet structure respectively at the inlet and outlet point of the wetland. The inlet and outlet structure consists of rip raps and the outlet point has a stabilized slope of 3:1. The direction of flows from the subbasins through the culverts to the wetland and Fifty Point Pond are shown in Figure 20. Storage capacity of Fifty Point Pond is significantly large compared to the flood discharge coming from the preferred option Alternative 2. The Pond releases flows to Fifty Point Creek, which eventually discharges to Lake Ontario. Therefore, Alternative 2 will not increase flood hazard within and downstream the 50 Point Pond.

The preliminary design for the preferred option, Alternative 2, will require approval from various governmental agencies. MNRF will be required to provide approvals for each storage facility and the process will be investigated.

6.0 SUMMARY AND RECOMMENDATIONS

6.1 SUMMARY

i. A Class EA has been conducted to design preventive measures for the flooding problems occurring in 50 Point Conservation Area. As a part of this Class EA project, 5 alternatives were evaluated following the guidelines of the authority.

ii. This study focuses on eliminating the flooding from Watercourse 11. Flooding also occurs from groundwater and the lake, but eliminating flooding damages from groundwater and lake is not a part of this study.

iii. Background research and field investigation and data collection were performed, gathering input from stakeholders and the public. The field investigation included topographic survey, bathymetric survey and shoreline characterization.

iv. A hydrological model was developed using SWMHYMO modeling software. The SWMHYMO model applied the 25mm 4 hour Chicago storm, 100 Year Chicago storm and 100 year SCS 24 hour storm in order to determine peak flows. The peak flows for the 100 Year Chicago storm are found higher than those for the 4 hour Chicago storm and 100 year SCS 24 hour storm events.

v. A HEC-RAS model was developed to prepare floodplain maps and to assess the response of the area against different alternatives. The floodplain maps provide a basis for better understanding and comparison of results from implementing different alternatives.

vi. The alternative methods are evaluated considering the following evaluation categories: Hydrology, Hydraulic & Flooding, Coastal Process, Acquisition of Private Property, Integration with Existing Environment, Integration with Existing Infrastructure, Groundwater/ Hydrogeological, Natural Heritage, Wild life and Vegetation, Aquatic Species, Habitat, Landowner acceptance, Public Health & Safety, Utility Lines, Ease of Implementation and Construction, Agency Acceptance, Official Policy, Secondary Policies and Bylaw Requirements, & Technical Feasibility, Timing Constraints, Operation & Maintenance, Capital Cost & Lifecycle Cost.

vii. Analyzing the HEC-RAS model results and the impact evaluations, Alternative 2 is chosen to be the most effective alternative that allows diversion of two third of the flood water with least negative impacts on the environment and minimum cost.

6.2 RECOMMENDATIONS

i. Diversion of flow from subbasins SB1, SB2 and SB3 is recommended, which is addressed as Alternative 2. This diversion ensures removal of two third of the total flood water from the Fifty Point Conservation area and ensures positive impact on the environment.

ii. A berm should be constructed at downstream of culvert C8. A drainage ditch and wetland should follow the berm to ensure safe flowing of flood water from SB2 and SB3 to the 50 Point Pond.

7.0 REFERENCES

Aquafor Beech Limited., May 15, 2013. Stoney Creek Urban Boundary Expansion (SCUBE) East – Subwatershed Study.

Aquafor Beech Limited., June, 2004. Stormwater Quality Management Strategy Community of Stoney Creek – Master Plan.

City of Hamilton, 2016. Comprehensive Development Guidelines and Financial Policies Manual.

Hamilton Conservation Authority, 2015. Floodplain Mapping Standard.

APPENDIX A: PUBLIC CONSULTATION

APPENDIX B: HYDROLOGY AND HYDRAULICS

APPENDIX C: SHORELINE CHARACTERIZATION