TOWN OF OAKVILLE

FLOOD MITIGATION OPPORTUNITIES STUDY LOWER MORRISON AND LOWER WEDGEWOOD CREEKS

JUNE 19, 2024

FLOOD MITIGATION OPPORUNITIES STUDY LOWER MORRISON AND LOWER WEDGEWOOD CREEKS

TOWN OF OAKVILLE

Project No.: CA-EI-TPB168040
Date: June 19, 2024

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6/19/2024

Diana Michalakos,
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Town of Oakville
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Dear Madam,

RE: Technical Report
Flood Mitigation Opportunities Study Lower Morrison and Lower Wedgewood Creeks

The WSP Team is pleased to submit the Final Report for the Flood Mitigation Opportunities Study of Lower Morrison and Lower Wedgewood Creeks. This report has been compiled based upon the consultation and analyses completed over the course of this study, the comments provided by Conservation Halton and the Town during the various working meetings, and the input provided by the public and agency stakeholders during the Public Information Centres.

On behalf of the WSP Team, we thank the Town for the opportunity to work on this study and look forward to future opportunities to support the Town accordingly.

Yours truly,

Sincerely,

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WSP Canada Inc

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Manager, Water Resources
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QUALITY MANAGEMENT

ISSUE/REVISION	FIRST ISSUE	REVISION 1	REVISION 2	REVISION 3
Remarks	Revised Draft	Final Report		
Date	May 18, 2023	June19, 2024		
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Signature				
Authorised by		Matt Senior		
Signature				
Project number	TPB168040	CA-EI-TPB168040		

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[1] Approval of this document is an administrative function indicating readiness for release and does not impart legal liability on to the Approver for any technical content contained herein. Technical accuracy and fit-for-purpose of this content is obtained through the review process. The Approver shall ensure the applicable review process has occurred prior to signing the document.

EXECUTIVE SUMMARY

Introduction

The Town of Oakville initiated an assessment of the existing flooding conditions, within the older parts of the town, through the Town-Wide Flood Study, April 2008. The Town-wide Flood Study determined flood prone sites and a priority-based work program, including conducting Flood Mitigation Opportunities Studies to further assess flooding conditions and develop flood mitigation actions to be implemented to reduce flood risk.

In response, the Town of Oakville has initiated this Flood Mitigation Opportunities Study to formalize the understanding of flood risks within the Lower Morrison and Lower Wedgewood Creeks systems which would help in reducing flood risks to the public, property, buildings and infrastructure. It would also provide guidance for future development areas (i.e. Midtown Area) to improve stormwater management planning practices, incorporate green infrastructure, and to build climate change resilient stormwater infrastructure.

WSP E&I Canada Limited (WSP), formerly Wood Environment & Infrastructure Solutions Canada Limited (Wood); has been retained by the Town of Oakville (Town) to assess the Lower Morrison and Lower Wedgewood Creeks existing level of flood risk and to develop flood mitigation alternative recommendations to reduce flood risk. In addition, the study has assessed local drainage improvements within the Invicta Drive area to reduce and prevent overland flooding. The study has also assessed stormwater management requirements for future development within the Midtown Area. The study is intended to develop a comprehensive flood risk reduction plan for both creek systems.

The project limits, herein referred to as the Study Area, include 376.99 ha +/- draining to Lower Wedgwood Creek and 314.83 ha +/- draining to Lower Morrison Creek (ref. Drawing 1). The watersheds are located primarily south of the QEW, with a mixture of industrial, commercial, and residential land uses. The lower reaches of the Morrison Creek, as well as the lower reaches of the Wedgewood Creek, are conveyed through the Town of Oakville to the outlets at Lake Ontario.

Class Environmental Assessment Process

This study has been completed as a Schedule B undertaking of the Municipal Engineers Association (MEA) Class Environmental Assessment Process (ref. Municipal Engineers Association's Municipal Class Environmental Assessment October 2000, as amended in 2007, 2011, 2015 & 2023). The approved MEA Class Environmental Assessment (Class EA) document describes the process that a proponent must follow for a class or group of undertakings in order to satisfy the requirements of the Environmental Assessment Act. Additionally, it represents a method of obtaining an approval under the provincial Environmental Assessment Act and provides alternatives to carrying out individual environmental assessments for each separate undertaking or project within the class. This study has been developed, based upon the following Phased approach:

Phase 1: Problem Definition
Phase 2: Develop and Review Alternatives
Phase 3: Preferred Alternatives Selection and Preliminary Design
Phase 4: Preparation of Environmental Study Report

Consultation

Public Information Centres (PIC) have been held at planned intervals during the Flood Mitigation Opportunities Study process to inform the public of the study progress and seek input. The first PIC for the Flood Mitigation Opportunity Study was held on June 18, 2019, at the Town of Oakville Trafalgar Park Community Centre, while the second PIC was held online on December 17, 2020, due to Covid-19 restrictions. Notifications of the two (2) PICs

were sent to stakeholders, local residents, agencies and municipal staff by mail and email, as well as notices within the local newspaper.

Consultation has also been conducted with indigenous groups, namely the Six Nations of Grand River Territory, Mississaugas of the New Credit First Nation, Haudenosaunee Confederacy Council and Metis Nations of Ontario. In addition to notices being sent out to the four indigenous groups, a meeting to discuss the project was held in January 2021 with the Mississaugas of the Credit First Nation, with no further action arising out of the meeting.

The Class EA has been completed under the oversight of a Technical Steering Committee which included representatives from the Town of Oakville and Conservation Halton. Meetings have been held at key milestones throughout the study to review data needs and findings while providing input and guidance to achieve the study objectives.

Baseline Assessment

A PCSWMM hydrologic/ hydraulic model originally developed as part of the Town of Oakville Stormwater Master Plan by Amec Foster Wheeler has been used as the base model to determine peak flows for the 2 year to 100 year and Regional Storm events for both creek systems. The PCSWMM model has been refined and calibrated based on observed flows and rainfall.

Hydraulic (HEC-RAS) modelling for both the Lower Morrison Creek and Lower Wedgewood Creek has been conducted by Conservation Halton. For this study, the detailed hydraulic models for Lower Morrison Creek and Lower Wedgewood Creek, have been updated, based on field reconnaissance and topographic survey by WSP (to provide updated details of the road crossings and the associated immediate upstream and downstream creek reaches). The updated existing HEC-RAS hydraulic modelling has been used to determine flood elevations for the 2 to 100 year and Regional Storm events. Floodplain plans have been prepared for both creeks based on the foregoing modelling. Based on peak flows for all storm events, the 100 year storm would be the Regulatory Storm for both creek systems.

For Lower Morrison Creek approximately 98 properties and 43 buildings (buildings located on the flood risk properties) have been determined to be at flood risk, while for Lower Wedgewood Creek, 168 properties and 76 buildings (buildings located on the flood risk properties) are at flood risk. The identified flood risk primarily stems from inadequate flow conveyance capacity at crossings and/or historical land use encroachment into natural hazard lands

Alternative Assessment

Detailed analyses have been completed to evaluate alternative solutions to mitigate the flood risk within the subject focus area under existing and future land uses. Included in the assessment are two (2) sub areas, Invicta Drive and the Midtown Area.

For the Invicta Drive area to determine the preferred alternative, a long-list of alternatives were considered including conveyance improvements, stormwater management and drainage diversions. The preferred alternative is Alternative D2 Invicta Drive to Eighth Line Diversion. The Alternative includes a proposed diversion from Invicta Drive to a new stormwater management facility (wet pond) at Eighth Line and North Service Road. The alternative will mitigate the water quality, quantity, erosion and water budget impacts associated with the proposed North Service Road widening, while providing additional green space and benefits to the receiving Lower Wedgewood Creek.

For the Midtown Area assessment, two (2) stormwater management scenarios have been considered, one (1) with a diversion to the Sixteen Mile Creek from Lower Morrison Creek and the other without. The preferred alternative is the non-diversion scenario with the requirement that 25 mm capture, with an emphasis on green infrastructure in mind, be implemented for erosion control and stormwater quantity controls. Above the 25mm capture, further peak flow control will be required to mitigate proposed increases in peak flows resulting from development.

For the remaining Lower Morrison Creek and Lower Wedgewood Creek, a long-list of flood mitigation alternatives has been assessed through the use of evaluation criteria and scoring of the results, with the resulting short-list of alternatives undergoing a detailed assessment using the hydrologic and hydraulic modelling, and a cost/ benefit assessment. The preferred alternatives for both creeks consist of crossing upgrades and for Lower Morrison Creek an offline storage tank to be located within the Cornwall Road Park.

Non-structural alternatives were also evaluated, including creek maintenance, emergency preparedness, flood forecasting/warning, and regulation. These programs are currently in effect and help to reduce the threat to life and property, but do not reduce existing flood conditions. Land acquisition of flood-risk properties and buildings could take place if it is determined that the benefits of purchasing the property outweigh the mitigation costs; however, there are significant social and economic considerations that reduce its viability.

The potential flood risk reduction benefits for more frequent storm events for both Lower Morrison and Lower Wedgewood Creeks for the preferred alternatives have been provided in Tables EX-1 and EX-2. The tables summarize the benefits from the combined alternative (culvert upgrades and flood storage/diversion set at an inlet based upon the 5-year WSEL) for the 10-year and 25-year events, respectively.

Table EX-1. Summary of Flood Risk Reduction Benefits Resulting from Alternatives (10 Year)

LOWER MORRISON CREEK						
ALTERNATIVE	EXISTING NUMBER OF AT RISK PROPERTIES	EXISTING NUMBER OF AT RISK BUILDINGS	PROPERTIES WITH REDUCED FLOOD RISK	BUILDINGS WITH REDUCED FLOOD RISK	PROPERTIES REMOVED FROM FLOODPLAIN	BUILDINGS REMOVED FROM FLOODPLAIN
Combined	88	21	55	3	20	5
LOWER WEDGEWOOD CREEK						
Alternative	EXISTING NUMBER OF AT RISK PROPERTIES	EXISTING NUMBER OF AT RISK BUILDINGS	PROPERTIES WITH REDUCED FLOOD RISK	BUILDINGS WITH REDUCED FLOOD RISK	PROPERTIES REMOVED FROM FLOODPLAIN	BUILDINGS REMOVED FROM FLOODPLAIN
Combined	151	46	11	8	0	1

Table EX-2. Summary of Flood Risk Reduction Benefits Resulting from Alternatives (25 Year)

LOWER MORRISON CREEK						
ALTERNATIVE	EXISTING NUMBER OF AT RISK PROPERTIES	EXISTING NUMBER OF AT RISK BUILDINGS	PROPERTIES WITH REDUCED FLOOD RISK	BUILDINGS WITH REDUCED FLOOD RISK	PROPERTIES REMOVED FROM FLOODPLAIN	BUILDINGS REMOVED FROM FLOODPLAIN
Combined	118	28	50	10	13	12
LOWER WEDGEWOOD CREEK						
Alternative	EXISTING NUMBER OF AT RISK PROPERTIES	EXISTING NUMBER OF AT RISK BUILDINGS	PROPERTIES WITH REDUCED FLOOD RISK	BUILDINGS WITH REDUCED FLOOD RISK	PROPERTIES REMOVED FROM FLOODPLAIN	BUILDINGS REMOVED FROM FLOODPLAIN
Combined	161	60	11	8	1	1

The results in Tables EX-1 and EX-2, indicate the largest benefit is provided for the 25 year storm event, which has a total benefit of 106 properties and buildings with either reduced flood risk, or are removed from flood risk for both Lower Morrison and Lower Wedgewood Creeks combined. The floodlines generated for the 10-year and 25-year events are included in Appendix H (ref. Drawings 6 to 9).

Costing has been prepared for the preferred alternatives as indicated in Tables EX-3 and EX-4 for Lower Morrison and Lower Wedgewood Creeks, respectively.

Table EX-3. Summary of Preliminary Costs Associated with Proposed System Upgrades (Lower Morrison Creek)

SYSTEM	TOTAL COST ($M)	TOTAL COST WITH 15% CONTINGENCY ($M)
Culvert Upgrades	$ 2.24 M	$ 2.58 M
Flood Storage	$ 6.25 M	$ 7.19 M
Total	$ 8.49 M[1]	$ 9.77 M

1. Cost of Diversion has not been included as it would be either the diversion or flood storage to be implemented, not both, with flood storage providing similar benefits for reduced cost.

Table EX-4. Summary of Preliminary Costs Associated with Proposed System Upgrades (Lower Wedgewood Creek)

SYSTEM	TOTAL COST ($M)	TOTAL COST WITH 15% CONTINGENCY ($M)
Culvert Upgrades	$ 4.22 M	$ 4.85 M
Total	$ 4.22 M	$ 4.85 M

The cost benefit assessment for the alternatives proposed for both Creek Systems has been based upon the improvements that would be implemented for each alternative for the 100-year event (ref. Table 5.61). The total number of properties and buildings which benefit for each alternative (i.e. reduced flood risk based on lower flood elevations), per Creek, along with the associated cost (without contingency) is shown in Table EX-5 with the floodlines indicated on Figures EX-1 and EX-2. Alternatives would provide flood risk reduction for more frequent storm events than the 100 year storm, e.g. 10 year – 25 (ref. Tables EX-1 and EX-2).

Table EX-5. Summary of Flood Risk Reduction Benefits Resulting from Alternatives (100 Year)

LOWER MORRISON CREEK (98 PROPERTIES AND 28 EXISTING BUILDINGS AT FLOOD RISK)					
ALTERNATIVE	TOTAL COST ($M)	PROPERTIES WITH REDUCED RISK	PROPERTIES REMOVED FROM FLOODPLAIN	BUILDINGS WITH REDUCED FLOOD RISK	BUILDINGS REMOVED FROM FLOODPLAIN
Culvert Upgrades	$ 2.58 M	0	0	6	0
Flood Storage	$ 7.19 M	59	13	16	18
Combined	$ 9.77 M	59	13	16	18
LOWER WEDGEWOOD CREEK (151 PROPERTIES AND 46 EXISTING BUILDINGS AT FLOOD RISK)					
ALTERNATIVE	TOTAL COST ($M)	PROPERTIES WITH REDUCED RISK	PROPERTIES REMOVED FROM FLOODPLAIN	BUILDINGS WITH REDUCED FLOOD RISK	BUILDINGS REMOVED FROM FLOODPLAIN
Culvert Upgrades	$ 4.85 M	1	0	3	0
Combined	$ 4.85 M	1	0	3	0

The flood risk reduction benefits resulting from the preferred alternatives, indicates that alternatives recommended for Lower Morrison Creek would be more effective in lowering flood risk, than the alternatives for Lower Wedgewood Creek, with the main reason for the difference being the Flood Storage that could be implemented for Lower Morrison Creek and the reduced flows. Flood Storage was determined not be a feasible alternative for Lower Wedgewood Creek.

Implementation

Subject to town and Council approval, the preferred alternatives for mitigating the flood risk at various identified sites on Lower Morrison and Lower Wedgewood Creeks, as presented herein, can be advanced to the next stages of planning and design. Prioritization of the alternatives would be established by the Town as part of overall flood risk mitigation works being considered for the Town.

Implementation of each of the alternatives has been considered based on the Municipal Class EA process and associated project schedules (ref. Table EX-5) and whether each alternative will or will not require a more detailed Class Environmental Assessment. For the recommended culvert upgrades and the Lower Morrison offline flood storage tank, this Class EA has fulfilled the Municipal Class EA process and associated assessment requirements. For the Invicta Drive drainage improvements, future study requirements are to be determined through the North Service Road Improvements Project. Municipal Class EA project requirements for the Midtown Area stormwater management measures will be dependent upon the scope of work, public versus private ownership and any property purchase requirements for the Town.

Table EX-5. Summary of Preferred Alternatives and Implementation Considerations

LOCATION	MUNCIPAL CLASS EA SCHEDULE	EA STATUS	OTHER CONSIDERATIONS
• Invicta Drive Alternative D2	• Schedule B for stormwater management pond (fulfilled by this Class EA)	• *A Schedule B EA based on Project Classification 40b: Establish new or replace or expand existing stormwater detention/retention ponds or tanks and appurtenances including outfall to receiving water body where all such facilities are not located in an existing utility corridor, or an existing road allowance or where property acquisition is required.*	• To be integrated with the North Service Road reconstruction project with the understanding that the Town will own lands for the proposed Stormwater management facility. • Consultation with MTO required throughout the project regarding all project aspects including stormwater management. • - design requirements to be finalized through the North Service Road Improvements Project.
• Midtown Area	• Depends on type of stormwater management project and associated road works. Refer to Town of Oakville Commitment Letter to Conservation Halton (May 24, 2024) regarding additional assessment requirements for stormwater management within the Midtown Area.	o For consideration, projects are exempt based on: o *Project Classification 37: Roadside ditches, culverts and other such incidental stormwater works constructed solely for the purpose of servicing municipal road works.* o *Project Classification 40a: Establish new or replace or expand existing stormwater detention/retention ponds or tanks and appurtenances including outfall to receiving water body provided all such facilities are in either an existing utility corridor or an existing road allowance where no additional property is required.* o *Project Classification 44: Construction of stormwater management facilities which are required as a condition of approval on a consent, site plan, plan of subdivision or condominium which will come into effect under the Planning Act prior to the construction of the facility. This includes LID features.* • For consideration, projects require a Schedule B based on: o *Project Classification 38a: Establish new or modify, retrofit or improve LID features within an existing road allowance or an existing utility corridor.* o *Project Classification 38b: Establish new or modify, retrofit or improve LID features where property acquisition is required.* o *Project Classification 40b: Establish new or replace or expand existing stormwater detention/retention ponds or tanks and appurtenances including outfall to receiving water body where all such facilities are not located in an existing utility corridor, or an existing road allowance or where property acquisition is required.*	• Stormwater management works to be determined for each project within the Midtown Area. • Consultation required with MTO with its' jurisdiction along the highway corridor. • Design requirements will vary depending on each project scope. • Consultation with Conservation Halton within regulated areas. • Stormwater management works to consider Stormwater Master Plan recommendations.
• Culvert Crossings (Various Crossings on both Lower Morrison Creek and Lower Wedgewood Creek.	• Exempt	• Culvert Crossings upgrades are exempt under the 2023 Municipal Class EA Guidelines, based on Table C – Municipal Transit Projects: o Project Classification 8b: *Culvert repair or replacement where the capacity of the culvert or drainage area is changed.* • Should culverts be replaced solely for the purpose of flood control, then under Table B Municipal Water and Wastewater Projects (Shoreline/ In Water Works): o Project *Classification 50: Modify existing water crossings for the purposes of flood control* a Schedule B is required.	• Conservation Halton to be consulted for each culvert crossing. May require Department of Fisheries and Oceans (DFO) consultation. • Design to consider: o property o construction access o road design, o structural design o utilities, o geotechnical conditions, o excess soils

LOCATION	MUNCIPAL CLASS EA SCHEDULE	EA STATUS	OTHER CONSIDERATIONS
			o hydraulics, including Lower Morrison Lower Wedgewood Channel spill conditions o erosion conditions o stream morphology o fisheries passage and habitat o terrestrial vegetation assessment o wildlife and species at risk. o construction timing restrictions
• Lower Morrison Creek Offline Flood Storage Tank	• Schedule B (fulfilled by this Class EA)	• *As per Table B Municipal Water and Wastewater Projects (Shoreline/ In Water Works) stormwater tanks are Exempt based on:* o *Project Classification 40a : Establish new or replace or expand existing stormwater detention/retention ponds or tanks and appurtenances including outfall to receiving water body provided all such facilities are in either an existing utility corridor or an existing road allowance where no additional property is required* • *A Schedule B Class EA is required for:* o *Project Classification 51: Works undertaken in a watercourse for the purposes of flood control or erosion control, which may include:* o *bank or slope regrading, • deepening the watercourse, relocation,* o *realignment or channelization of watercourse* o *revetment including soil bio-engineering techniques* o *reconstruction of a weir or dam*	• Conservation Halton, DFO and Ministry of Environment Conservation and Parks (MECP) to be consulted. • Stage 1 Archaeological Assessment in area of the tank (ref. Appendix J) • Town of Oakville Parks, Recreation &. Culture to be consulted prior to project. • Design to consider: o park features and usage o construction access for creek inlet and outlet o tank configuration o structural design o utilities, o geotechnical and hydrogeological conditions, o excess soils o hydraulics, including Lower Morrison Lower Wedgewood Channel spill conditions o erosion conditions o stream morphology o fisheries habitat protection o terrestrial vegetation assessment o wildlife and species at risk o construction timing restrictions o post construction monitoring and adaptive measures o long-term maintenance

Figure EX-1. Lower Wedgewood Creek (100 Year Floodlines) with Culvert Upgrades

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1 INTRODUCTION

1.1 STUDY PURPOSE AND OBJECTIVES

The Town of Oakville initiated an assessment of the existing flooding conditions, within older part of the town, through the Town-Wide Flood Study, April 2008. The Town-wide Flood Study determined flood prone sites and a priority-based work program, including conducting Flood Mitigation Opportunities Studies to further assess flooding conditions and develop flood mitigation actions to be implemented to reduce flood risk.

In response, the Town of Oakville has initiated this Flood Mitigation Opportunities Study to formalize the understanding of flood risks within the Lower Morrison and Lower Wedgewood Creeks systems which would help in reducing flood risks to the public, property, buildings and infrastructure. It would also provide some guidance to improve stormwater management planning practices and to build climate change resilient stormwater infrastructure. This report summarizes the methods and findings of this study, as well as the recommendations for future works.

The project limits, herein referred to as the Study Area, include 376.99 ha +/- draining to Lower Wedgwood Creek and 314.83 ha +/- draining to Lower Morrison Creek (ref. Drawing 1). The watersheds are located primarily south of the QEW, with a mixture of industrial, commercial and residential land uses. The lower reaches of the Morrison Creek, as well as the lower reaches of the Wedgewood Creek, are conveyed through the Town of Oakville to the outlets at Lake Ontario. Most of the existing development within both watersheds is of an age that occurred prior to modern day stormwater management best management practices. That said there are a few stormwater management facilities such as the existing stormwater management (SWM) facility located on the Ontario Ministry of Transportation (MTO) property within the QEW / Royal Windsor Drive interchange, and the SWM facilities located south of the QEW, north of the CNR track and within Cornwall Woods, providing flow attenuation within Lower Wedgewood Creek.

1.2 CLASS ENVIRONMENTAL ASSESSMENT PROCESS

This study has been completed as a Schedule B undertaking of the Municipal Engineers Association (MEA) Class Environmental Assessment Process (ref. Municipal Engineers Association's Municipal Class Environmental Assessment October 2000, as amended in 2007, 2011, 2015 & 2023). The Ontario Environmental Assessment Act provides for *"…the betterment of the people of the whole or any part of Ontario by providing for the protection, conservation and wise management in Ontario of the environment."* The approved MEA Class Environmental Assessment (Class EA) document describes the process that a proponent must follow for a class or group of undertakings in order to satisfy the requirements of the Environmental Assessment Act. Additionally, it represents a method of obtaining an approval under the provincial Environmental Assessment Act and provides alternatives to carrying out individual environmental assessments for each separate undertaking or project within the class.

The Work Plan for this study has been developed, based upon the following Phased approach:

Phase 1: Problem Definition
Phase 2: Develop and Review of Alternatives
Phase 3: Preferred Alternatives Selection and Preliminary Design
Phase 4: Preparation of Environmental Study Report

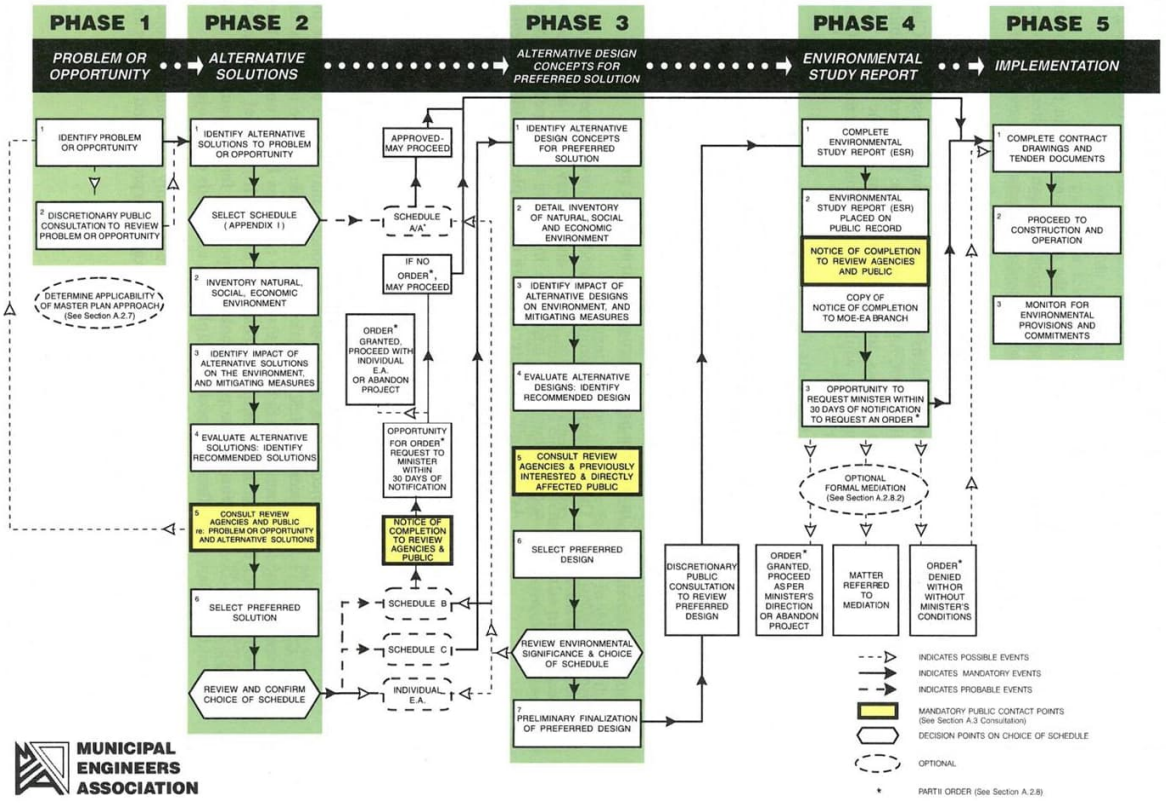

Figure 1.1 Municipal Class EA Process

1.3 CONSULTATION

1.3.1 PUBLIC CONSULTATION

Public Information Centres (PIC) have been held at planned intervals during the Flood Mitigation Opportunities Study process to inform the public of the study progress. The first PIC for the Flood Mitigation Opportunities Study was held on June 18, 2019, at the Town of Oakville Trafalgar Park Community Centre, while the second PIC was held online on December 17, 2020, due to Covid-19 restrictions. Notifications of the two (2) PICs were sent to stakeholders, local residents, agencies and municipal staff by mail and email, as well as notices within the local newspaper.

The PICs were attended by representatives from the Town of Oakville and from the WSP (formerly Wood) Team. An Information Session format was used for the PICs with display boards and maps detailing the project objectives, progress, and next steps within the context of the Class Environmental Assessment requirements. Copies of the display material presented at the PICs were uploaded to the town's website for public review and are provided in Appendix A. Comment forms were made available to members of the public to provide input/comments by

submitting their comments on site, via mail, fax or email, and received comments have also been included in Appendix A.

1.3.2 AGENCY CONSULTATION

The Class EA has been completed under the oversight of a Technical Steering Committee which included representatives from the Town of Oakville and Conservation Halton. Meetings have been held at key milestones throughout the study to review data needs and findings while providing input and guidance to achieve the study objectives. The meetings have been conducted as working sessions, to develop a consensus understanding of the flood risk issues within the subject area and to provide discussion of the potential mitigation opportunities. Minutes from the meetings are included in Appendix A.

1.3.3 INDEGENOUS GROUP CONSULTATION

Consultation has also been conducted with indigenous groups, namely the Six Nations of Grand River Territory, Mississaugas of the New Credit First Nation, Haudenosaunee Confederacy Council and Metis Nations of Ontario. In addition to notices being sent out to the four indigenous groups, a meeting to discuss the project was held in January 2021 with the Mississaugas of the Credit First Nation, with no further action arising out of the meeting.

2 BACKGROUND INFORMATION

Background information has been provided by the Town of Oakville and Conservation Halton for this study. This information has consisted of Geographic Information Systems (GIS) mapping, reports, drawings and modelling data. A summary description of the information used for this study has been provided in the following. A data tracking chart, with detailed information regarding each data element, is provided in Appendix B.

2.1 REPORTS

The following reports have been reviewed for this study:

- Flood Risk Mapping and Spill Quantification – Morrison-Wedgewood Diversion Channel Volume 1 – Hydrology Modelling Report, and Volume II – Hydraulic Modelling Report, Morrison Hershfield Ltd., March 31, 2020
- Reconstruction of the North Service Road, Draft Stormwater Management Report, CIMA, April 2020,
- Town of Oakville, Stormwater Master Plan Study, Wood, October 2019
- Cornwall Road Detailed Design, Amec Foster Wheeler, 2017
- Final Drainage and Stormwater Management Report of the Highway 403 QEW Widening, MRC, 2014
- Midtown Oakville Transportation and Stormwater Class Environmental Assessment, Cole Engineering, June 2014
- Town of Oakville Town-Wide Flood Study, Philips Engineering Ltd. (2008)
- Lower Morrison/Wedgewood Creeks Flood Erosion and Master Drainage Plan Study Technical Report by R.V. Anderson Associates Limited, 1993

2.2 MAPPING, DRAWINGS AND DOCUMENTS

- Town of Oakville GIS data includes shapefiles for topography and storm water management infrastructure such as storm sewers, maintenance holes, catch basins, laterals, outfalls, as well as aerial imagery (2015) for the study area. Additional data provided includes various creek cross section locations, road network, land use mapping, building footprints, property parcels, and Oakville property parcels.
- Town of Oakville Development Engineering Procedures and Guidelines Manual, undated
- Town of Oakville Zoning Bylaw 2014-014

2.3 MODELING DATA

- The following modelling data have been provided by the Town of Oakville and Conservation Halton (CH):
  - HEC-2 and HEC-RAS hydraulic models for Lower Morrison Creek and Lower Wedgewood Creeks (Conservation Halton).
  - PCSWMM model developed as part of the Stormwater Master Plan, Interim Model 2016

2.4 FIELD RECONNAISSANCE

In addition to the afore-mentioned information from the Town and Conservation Halton, field reconnaissance by WSP (former and Amec Foster Wheeler) staff was conducted on October 5th and 26th, 2016 (ref. Appendix B). The field reconnaissance was conducted with Town and Conservation Halton staff.

3 BASELINE ASSESSMENT

3.1 HYDROLOGY

3.1.1 PREVIOUS MODELLING

The original PCSWMM model was developed as part of the Town of Oakville Stormwater Master Plan by Amec Foster Wheeler and was designed to assess the storm sewer system within southern Oakville. For this study, a dual drainage assessment has been conducted using the PCSWMM methodology in order to evaluate the performance of the major system (overland, roads) and the minor system (sewers, ditches) within the focus area under different storms and various land use. The PCSWMM models developed for this study include hydraulic elements and junctions representing the minor system, such as maintenance holes and storm sewer pipes, as well as components of the major system and the road right-of-way including curb and gutter in urban areas and roadside ditches in rural sections. The following summarizes the approach and information applied to discretize the focus area and to parameterize the key hydrologic and hydraulic elements represented within the parent PCSWMM model.

3.1.2 SUBCATCHMENTS

The subcatchments within all sewersheds in the Oakville Stormwater Master Plan focus area had been initially established based on the preliminary drainage area boundaries advanced as part of the Phase 1 Stormwater Master Plan. The subcatchment boundaries had been further refined and revised based on topographic data (contours/spot elevations) provided by the Town and field investigations, in order to reflect the drainage system geometry.

Based on the subcatchment delineation, subcatchment parametrization had been established based upon the mapping and GIS data provided for the Oakville Stormwater Master Plan study and has been refined for this study, using available tools and techniques within the PCSWMM modelling software and ESRI ArcGIS™ package. The following provides further details regarding the initial parameterization of the subcatchments within the PCSWMM hydrologic model. Figure 3.1 shows the existing conditions drainage plan along with subcatchments.

Imperviousness

Imperviousness represents the amount of hard surfaces (buildings, roads, driveways, sidewalks) within a given subcatchment. The impervious coverage applied for hydrologic analyses is recognized to represent a central and sensitive parameter for modelling, whereby small changes in the parameter value may result in relatively high changes in simulated peak flow and runoff volume, compared to adjustments to other model parameters (i.e. soil parameters, shape parameters, etc.). Consequently, it has been recognized that the approach used to establish impervious coverage for the model subcatchments would need to satisfy the following criteria:

— Impervious coverages are to consider variation in land uses across the focus area.

— Impervious coverages are to consider differences in zoning within residential areas.

— Impervious coverages within residential areas are to distinguish between coverage on the lot versus coverage within the road right-of-way in order to accommodate assessing increased imperviousness on private residential properties for future conditions.

— Impervious coverages are to be consistent with manual measurements.

— Impervious coverages are to account for hard surfaces attributable to residential rooftops, as well as urban amenities (i.e. patios, gazebos, driveway expansions, hardscaping) which would be anticipated to be implemented by residents over time.

Various alternatives for establishing impervious coverage had been explored over the course of the Stormwater Management Master Plan in consultation with Town staff, to represent the extent of hard surfaces within the focus area. The conventional practice of applying a standard impervious coverage based upon land use (i.e. "low density residential", "medium density residential", high density residential") was screened from consideration, as this approach would not account for variations in coverage by zoning, and would not distinguish between coverage from roads and coverage from lots, nor would it account for changes to coverage over time resulting from implementing amenity surfaces.

An alternative approach was investigated, whereby the impervious coverages for existing land use conditions would be established through aerial image processing of aerial photography and GIS screening using ArcGIS, to identify the hard surfaces representing total impervious coverage (TIMP) within the area. Although this approach was noted to account for the variation in coverage by residential zone, as well as the influence of amenity surfaces, the coverages generated using the image processing technique for test areas were noted to differ from hard measured values by as much as 10 %, with no consistency in the variation between the image processed and measured values. The variation and magnitude of the discrepancy was noted to be attributable to the influence of shading in the aerial imagery, which varies according to the density of canopy cover, height of structures, as well as the time of day and season during which the aerial image was taken. Consequently, the approach of applying the image processing technique was not considered a viable and reliable technique for establishing existing impervious coverage for the Stormwater Master Plan.

Following further consultation with Town staff, an alternative approach was advanced and assessed for establishing the existing impervious coverage within the focus area for the Oakville Stormwater Master Plan, whereby a "standard" impervious coverage was established by land use or zone classification, using the aerial imagery, property ownership, and land classification shapefile provided for use in this study. This method permitted for a more distributed sampling area, particularly for the residential zones, based on the Town's Official Plan zoning classification (i.e. RL-1, RL-2, RL-3, etc.), rather than applying a single (i.e. uniform) impervious coverage based upon density (i.e. "low density", "medium density", etc.). Furthermore, the information generated under this approach maintains consistency with the Town's GIS and zoning data.

The Town's GIS land use zoning database was screened to identify the different zoning designations within the focus area, for which impervious coverages are required. The 2015 aerial imagery was visually inspected to identify the variability in impervious coverage across the focus area for each land use zone designation/classification (zone). Individual properties corresponding to each zone have been selected to develop a stratified sampling, which would capture the variability in impervious coverage noted from the visual inspection of the aerial imagery, and the impervious coverage for each individual property has been determined based upon manual measurement of the hard surfaces on the properties (i.e. building roofs, driveways, decks, pools, gazebos, sheds, parking lots). The areally-weighted impervious coverage has been calculated for each zone classification, in order to establish the corresponding imperviousness for use in hydrologic modelling of existing land use conditions. For residential areas, separate impervious coverages have been established for the residential lots and the municipal right-of-way using the above approach.

The locations of the properties used to establish the impervious coverages for each zone classification are provided in The Oakville Stormwater Master Plan final report, and the resulting impervious coverages for each zone classification are presented in Tables 3.1 and 3.2. Detailed calculations are also provided in The Oakville Stormwater Master Plan final report.

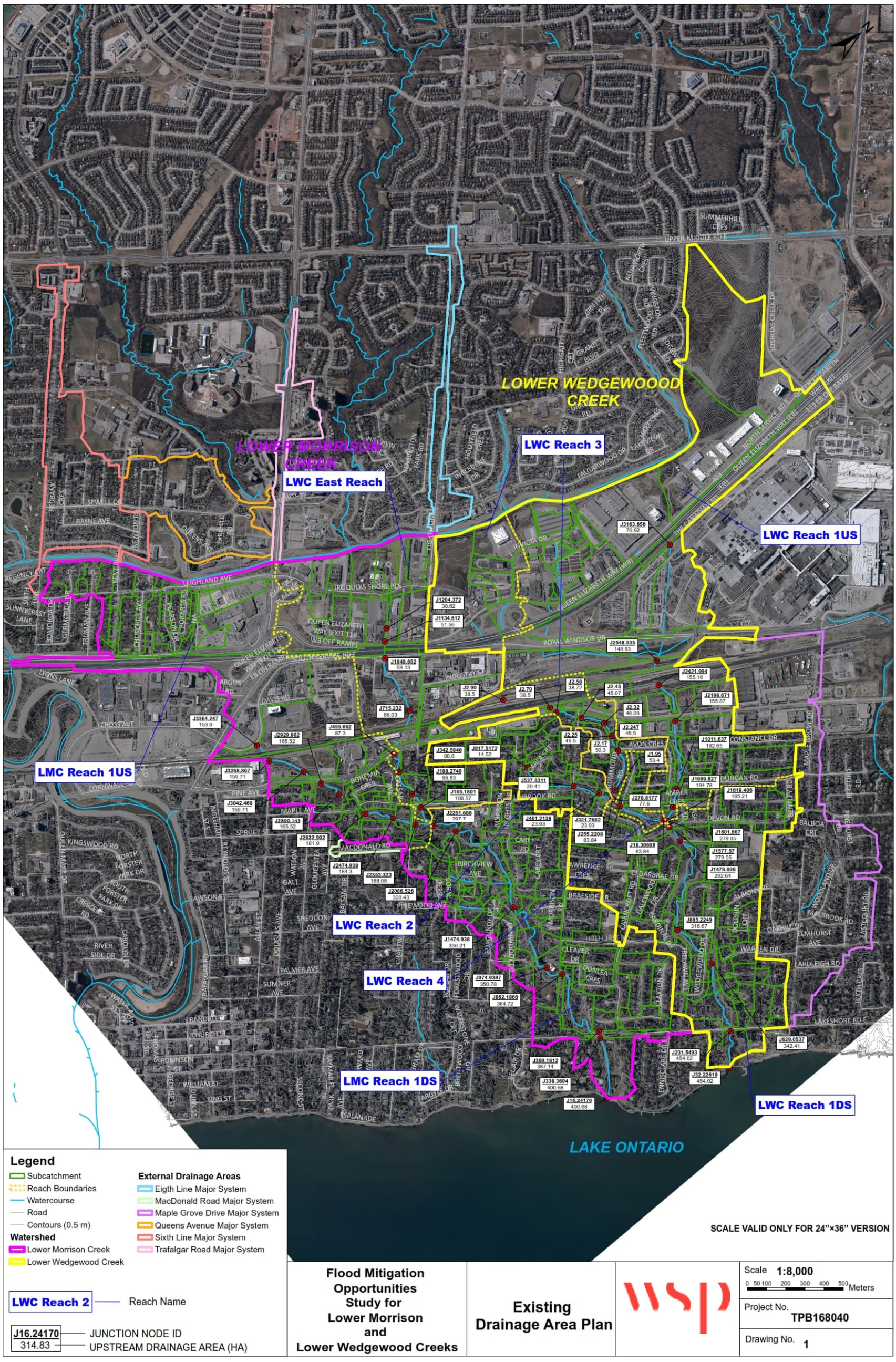

Figure 3.1 Existing Conditions Drainage Area Plan

Table 3.1 Impervious Coverages for Residential Zones and Municipal Rights of Way (%)

ZONE CLASSIFICATION	TYPE	IMPERVIOUSNESS
Residential Low (RL1)	ROW	60.1
	Lot	44.5
Residential Low (RL1-0)	ROW	64.0
	Lot	34.0
Residential Low (RL2)	ROW	NA[1]
	Lot	55.0
Residential Low (RL2-0)	ROW	64.1
	Lot	39.1
Residential Low (RL3)	ROW	70.8
	Lot	47.4
Residential Low (RL3-0)	ROW	58.8
	Lot	43.2
Residential Low (RL4)	ROW	NA[2]
	Lot	NA[2]
Residential Low (RL4-0)	ROW	58.4
	Lot	40.4
Residential Low (RL5)	ROW	70.8
	Lot	58.3
Residential Low (RL5-0)	ROW	70.5
	Lot	49.1
Residential Low (RL6)	ROW	63.6
	Lot	62.9
Residential Low (RL7)	ROW	65.1
	Lot	62.5
Residential Low (RL7-0)	ROW	59.0
	Lot	58.3
Residential Low (RL8)	ROW	76.1
	Lot	58.9
Residential Low (RL8-0)	ROW	73.4
	Lot	49.4
Residential Low (RL9)	ROW	76.4
	Lot	61.5
Residential Low (RL10)	ROW	NA[1]
	Lot	46.7
Residential Low (RL10-0)	ROW	NA[1]
	Lot	47.0
Residential Low (RL11)	ROW	79.0
	Lot	51.4
Residential Medium (RM1)	ROW	80.5
	Lot	61.5
Residential Medium (RM2)	ROW	NA[2]
	Lot	NA[2]
Residential Medium (RM3)	ROW	NA[2]
	Lot	NA[2]

ZONE CLASSIFICATION	TYPE	IMPERVIOUSNESS
Residential Medium (RM4)	ROW	63.9
	Lot	80.4
Residential High	ROW	60.4
	Lot	68.3
Residential Uptown Core	ROW	NA[2]
	Lot	NA[2]

Notes:
[1] No road right-of-ways are associated with the residential zones based on the zoning information and property parcel data provided by the Town
[2] The residential zone or right-of way is not found within the focus area based on the zoning information and property parcel data provided by the Town

Table 3.2: Impervious Coverages for Non-Residential Zones (%)

CLASS	IMPERVIOUSNESS
Neighbourhood Commercial	82.9
Community Commercial	85.2
Core Commercial	89.3
Central Business District	100.0
Cemetery	8.7
Community Use	30.1
Office Employment	84.0
Business Employment	93.4
Industrial	77.8
Institutional	75.1
Business Commercial	87.9
Existing Development	62.7
Greenbelt	5.0
Midtown Transitional Commercial	92.2
Midtown Transitional Employment	82.8
Main Street 1	100.0
Main Street 2	95.0
Urban Centre	90.0
Urban Core	95.0
Natural Area	5.0
Park	10.0
Private Open Space	5.0
Parkway Belt Public Use	25.0
Parkway Belt Complementary Use	10.0
Utility	26.6

Based upon the foregoing assessment of impervious coverages for each of the Town's land use zoning classifications, the impervious coverages developed using the above approach have been applied to determine the imperviousness at the subcatchment scale.

Flow Length and Slope

The maximum overland flow length, as defined in the EPA SWMM 5 manual, represents the length of the flow path from the inlet to the furthest drainage point of the subcatchment. The subcatchment slope represents the average gradient across the subcatchment surface. For the Oakville Stormwater Master Plan, flow length had been explicitly measured for each subcatchment, as the average length for sheet flow, before becoming channelized. Slope for each subcatchment has been determined using the topographic contour data. The same method has been applied for Flood Mitigation Opportunities Study for Lower Morrison and Lower Wedgewood Creeks.

Manning Roughness Coefficients

Manning's roughness coefficients represent the type of surface for the subcatchment, and the associated friction applied to the flow across the subcatchment surface. Manning's roughness coefficients have been determined for the pervious and impervious portions of each subcatchment. Consistent with previous studies and literature recommended values, a value of 0.014 has been assigned to the impervious segment of each subcatchment and a value of 0.25 has been assigned to the pervious segment of each subcatchment.

Depression Storage

Depression storage represents the depth of rainfall which would be captured and detained in surface depressions within the subcatchment. Depression Storage values have been assigned to the impervious and pervious segments of each subcatchment. 1 mm of depression storage has been assigned to impervious segments of subcatchments, while 5 mm of depression storage has been assigned to pervious segments of subcatchments based on standard conventions applied across North America.

Soil Parameters

The Green and Ampt approach for parameterization of soil moisture and recovery has been selected to model the infiltration properties of subcatchment soils. The soil parameters for the Green and Ampt approach include saturated hydraulic conductivity, suction head and initial moisture deficit. Based on a review of the available soil classification within the focus area, as previously discussed under Section 3.1, no soils classification is available for the western portion of the focus area. As such, the infiltration parameters for the subcatchments in that area have been established to be consistent with soil parameters as per the PCSWMM model developed as part of the Fourteen Mile Creek/McCraney Creek Flood Management Alternative Assessment, 2013, Town of Oakville. For the balance of the subcatchments located in areas with defined soil classification, soil infiltration parameters have been selected as per recommended values in the literature (ref. Table 3.3).

Table 3.3 Soil Parameters for Green and Ampt Infiltration Methodology

SOIL TYPE	CONDUCTIVITY mm/hr	SUCTION HEAD mm	INITIAL MOISTURE DEFICIT
Sand	120.4	49.02	0.024
Loamy Sand	29.97	60.96	0.047
Sandy Loam	10.92	109.98	0.085
Loam	3.3	88.9	0.116
Silt Loam	6.6	169.93	0.135
Sandy Clay Loam	1.52	219.96	0.136
Clay Loam	1.02	210.06	0.187
Silty Clay Loam	1.02	270	0.21
Sandy Clay	0.51	240.03	0.221
Silty Clay	0.51	290.07	0.251
Clay	0.25	320.04	0.265

3.1.3 MINOR SYSTEM

The minor system has been parameterized based on the information extracted from the Town's GIS database for the storm sewer network, which includes shapefiles for the sewer pipes and maintenance holes, as well as the information collected as part of the detailed survey of the storm sewer network and associated gap filling, as described earlier. Storm sewer pipes have been represented as conduits in the PCSWMM model, while maintenance holes have been represented using junctions.

The PCSWMM model has been developed such that the runoff generated from each subcatchment is initially conveyed to the major system components and then routed to the minor system through orifices representing catch basins, catch basin leads and maintenance hole leads, which have all been modelled explicitly in order to allow for the analysis of inlet control devices as part of the remediation alternatives. The sizes of the openings of orifices within the PCSWMM model have been determined to be equivalent to the sum of the open area of the inlet elements. The number of catch basins within each model subcatchment have been counted, and an equivalent size opening has been determined based upon assuming a uniform size for each catch basin. In addition, a value of 0.013 has been selected for Manning's coefficient for all the sewer pipes within the focus area.

3.1.4 MAJOR SYSTEM

The major system components in the model have been established based on the various road right-of-way (ROW) sections within the Town. The ROW cross sections are generally comprised of either, urban cross sections with curb and gutters, or rural cross sections with roadside ditches. Routing elements representing the urban cross sections have been developed based on standard Town ROW cross sections with an additional 2 % cross-fall for the portion of the cross-section beyond the ROW, extending to the front of adjacent buildings or structures. Various cross sections have been developed to represent the various road classifications and corresponding variation in the number of lanes within the ROW, as determined using the Town's GIS layers for roads and aerial imagery.

The major systems and minor systems generally have coincident locations and have largely been modelled as such. However, several networks have been identified with major-minor splits where a major system is conveyed in a direction that is not coincident with the minor system and has been modelled accordingly where appropriate.

In addition to the ROW cross sections, local open water features have been incorporated into the PCSWMM model to represent the remnant channels, or in areas where the major system ROW discharges to a primary swale for conveyance to a larger natural watercourse. In these cases, cross sections have been developed for the PCSWMM model to represent overland flow in swales running between houses on adjacent lots.

Weir elements have also been incorporated into the model to simulate low points in the ROW where the water would be conveyed to a natural water course. These have only been used where swales were not present and where a conveyance barrier existed. The weir height was dependent on the barrier which often corresponds to the curb height or the height at the front of a house as defined in the ROW cross sections.

3.1.5 OTHER REFINEMENTS

The observations from the field reconnaissance for rurally serviced areas have, as expected, noted the presence of driveway culverts crossing the roadside ditches. In order to account for the hydraulic impact of driveway culverts and embankments of varying size and condition, a sensitivity analysis of the hydraulic performance of this form of drainage system has been conducted to establish surrogate techniques to represent the combined hydraulic influence of the driveway culverts in the model, without explicitly incorporating each individual driveway culvert in the PCSWMM model. For these analyses, a typical road profile including the drainage ditches on both sides has been modelled in HEC-RAS with driveway culverts in-place. The model has been executed for a range of flows, from low flows contained within the drainage ditches, to high flows overtopping the road crown. Subsequently, as part of the sensitivity analysis, the driveway culverts have been removed from the road profile geometry and the profile of the drainage ditches has been modified such that the computed water surface elevation under each flow

profile would match the computed water surface elevation under corresponding flow profile for the original scenario, with driveway culverts in-place. Through this assessment, an equivalent cross-section for the drainage ditch has been developed which has a reduced conveyance capacity, comparable to the original drainage ditch cross-section. This equivalent cross-section has thus been used to simulate the impacts of driveway culverts versus incorporating the culverts individually in the PCSWMM model. The original drainage ditch sections along with the equivalent cross-sections are presented in Appendix E.

In order to characterize the baseline condition of the Lower Morrison Creek and Lower Wedgewood Creek Study Area and thereby identify and quantify the area's drainage problems, the PCSWMM Version 7.0 hydrologic model discussed above has been updated and refined. It should be noted that even though PCSWMM hydrologic model for this study was built upon the hydrologic model for Oakville Stormwater Master Plan study, the final models might be somewhat different since both the studies were under development concurrently. The PCSWMM model generates runoff from subcatchments within the Study Area which are then routed along major flow paths to determine peak flows, velocities, and hydraulic capacities at locations throughout the drainage system.

The PCSWMM modelling has been updated for the hydrologic/hydraulic assessment of Lower Morrison and Lower Wedgewood Creeks to assess the hydraulic performance of the creek systems. The manning's values within each watercourse has been set to minimum 0.035 within the low flow channel and a minimum value of 0.08 for the overbanks.

Surficial soils data for the study area (as available from Agriculture Canada – Ontario Soil Survey Reports) is generally lacking; mapping for the study area indicates an urbanized land use and therefore does not provide more detailed information. Based on the soils information determined within Southern Oakville from the Stormwater Master Plan the surficial geology within southern Oakville is predominantly characterized by coarse-textured glaciolacustrine deposits (sand, gravel, silt and clay).

The following items in relation to the selected parameters are important to note:

Subcatchments

- Impervious coverages as per the Stormwater Master Plan (ref. Appendix 'B')
- The Manning's 'n' value assigned to impervious surfaces is 0.013;
- The Manning's 'n' value assigned to pervious surfaces is 0.25;
- The depression storage assigned to impervious surfaces is 1 mm and 5 mm for the pervious surfaces;
- Based upon review of Table 24.2 within the User's guide to SWMM5, 13th Edition, the initial deficit fraction assigned for soils described herein is 0.25
- The hydraulic conductivity for the soils has been set to 3.5 mm/hr;
- The suction head for the soil has been assigned 50 mm;
- Subcatchment routing has been assigned to convey 40 % of the runoff to the pervious area, prior to conveyance to the subcatchment outlet.

Storm Sewers

- The entrance and exit loss coefficients assigned to storm sewers are 0.15 to 1 respectively (reference U.S. Department of Transportation Federal Highway Administration Hydraulic Engineering Circular 22 – Urban Drainage Design Manual, September 2009);
- The Manning's 'n' value assigned to road surfaces is 0.014. Typical industry standard for this parameter is 0.013; and
- The Manning's 'n' value assigned to ditches is 0.04. Typical industry standard for this parameter is 0.25.

The PCSWMM model developed for existing conditions models the drainage boundaries presented in Drawing 1. Land use for the existing conditions modelling has been based on Town of Oakville GIS zoning data and aerial measurements which has been used to develop the imperviousness for each subcatchment, in conjunction with the Oakville Stormwater Master Plan (ref. Appendix B).

Existing Stormwater Management Quantity Control Facilities

The existing stormwater management (SWM) quantity facilities have been incorporated into the PCSWMM model. Two (2) Town assumed dry SWM facilities have been identified near the Lower Wedgewood crossing of Cornwall Road between Morrison Road and Maple Grove Drive (Cornwall Woods). The stage storage relationships have been developed for these two (2) from the SWM facilities drawings provided by the Town. Additionally, five (5) private onsite SWM quantity facilities have been incorporated from the Invicta Drive Class EA study area and one (1) private onsite facility has been incorporated from the Cornwall Road Class EA.

A SWM quantity control facility has been identified east of the intersection of Royal Windsor Drive and South Service Road, adjacent to the CN Rail corridor. However, due to the inaccessibility of the corridor and the confidentiality of the CN Rail property, stage-storage-discharge information for the SWM facility could not be obtained. A transect representing the SWM facility has been incorporated into the PCSWMM model.

SWM facilities are not provided in the residential portion of the study area as it was largely developed during the 1950-60's and prior to the implementation of SWM quantity controls. Similarly, the commercial/industrial area adjacent to the QEW corridor likely does not have SWM facilities for the older developments whereas information was not provided for the newer developments and therefore were not incorporated into the model.

The PCSWMM model has been executed using the Town of Oakville 24-hour Chicago design storms for the 2-100 year storm events, with the simulated peak flow results in Tables 3.4 and 3.5 for Lower Morrison Creek and Lower Wedgewood Creek respectively.

Table 3.4 Lower Morrison Creek Existing Peak Flow Rates (m^3/s)

JUNCTION NAME/ LOCATION	CUMULATIVE DRAINAGE AREA (HA)	STORM EVENT						
		2	5	10	25	50	100	REGIONAL
J1204.372	20.99	1.95	2.68	3.20	4.17	5.23	6.17	2.56
J1134.612 - North Service Road	33.93	3.22	4.86	6.01	7.77	9.09	10.44	3.91
J1048.652	41.50	5.20	7.02	11.92	11.88	12.62	14.15	6.60
J715.232 - CN Rail Tracks	68.40	7.59	11.12	12.86	15.99	19.34	21.22	10.47
J455.662	69.67	7.86	10.97	12.77	16.95	19.10	21.12	10.58
J342.5846	71.17	7.96	11.16	12.94	17.09	19.48	21.54	10.78
J188.2748 - Chartwell Road	79.20	8.71	12.37	14.61	18.38	21.14	23.41	11.92
J105.1801 - Linbrook Road	88.94	9.09	13.07	15.52	15.23	21.83	23.88	12.83
J3364.247 - South Service Road	87.83	7.89	12.47	15.57	19.88	22.86	25.94	11.19
J3268.867	93.64	7.79	12.17	15.19	19.42	22.34	25.82	11.99
J3042.468	93.64	7.51	10.76	13.24	16.65	18.98	22.79	11.90
J2929.902 - Cornwall Road	99.45	7.53	10.65	12.67	16.64	19.39	22.84	12.86
J2800.143	99.45	7.35	10.35	14.50	16.32	18.62	21.04	13.66
J2632.902	115.83	8.57	11.71	14.51	17.61	19.80	21.96	14.73
J2474.938	118.23	8.71	11.84	14.37	17.61	19.70	21.74	15.00
J2353.323 - Chartwell Road	119.86	8.68	11.93	14.58	18.03	20.53	23.09	15.47

JUNCTION NAME/ LOCATION	CUMULATIVE DRAINAGE AREA (HA)	STORM EVENT						
		2	5	10	25	50	100	REGIONAL
J2251.686 - Confluence	211.85	17.16	24.01	27.51	33.03	38.77	43.06	28.42
J2086.526	214.58	17.37	24.14	27.76	33.22	38.72	42.99	28.73
J1474.938	250.36	18.11	25.51	29.52	35.39	40.54	45.74	32.28
J974.9387	264.93	17.61	25.28	29.74	35.50	40.57	45.56	33.78
J862.1866 - Morrison Road	278.87	18.05	25.67	29.73	35.64	40.44	45.99	35.14
J369.1612	301.29	17.84	25.89	30.18	36.23	40.63	45.47	37.30
J336.3604 - Lakeshore Road	314.83	18.09	26.25	30.56	36.71	41.15	46.05	38.70
J16.24170 - Lake Ontario	314.83	17.79	25.99	30.44	36.50	40.93	45.72	38.67

Table 3.5 Lower Wedgewood Creek Peak Flow Rates (m^3/s)

JUNCTION NAME/ LOCATION	CUMULATIVE DRAINAGE AREA (HA)	STORM EVENT						
		2	5	10	25	50	100	REGIONAL
J2.90 - CN Rail Tracks	38.50	3.47	5.43	6.69	8.39	9.49	10.68	3.47
J2.70	38.50	3.31	4.92	6.15	7.81	8.99	10.07	2.68
J2.58 - Cornwall Road	38.72	3.28	4.84	5.82	7.07	7.93	8.70	2.69
J2.45 - Morrison Road	45.07	3.69	5.38	6.37	7.83	8.83	9.71	3.30
J2.32	46.06	3.73	5.39	6.45	7.94	8.93	9.80	3.39
J2.25	46.50	3.72	5.21	6.66	7.76	8.81	9.70	3.41
J2.247	46.50	3.66	5.30	6.24	7.81	8.83	9.68	3.42
J2.17 - Avon Crescent	50.30	4.03	5.72	6.73	8.34	9.39	10.35	4.09
J1.95	53.40	4.23	6.42	6.91	8.41	9.46	10.43	6.33
J817.5172 - Chamberlain Lane	14.52	1.03	1.70	2.02	2.52	2.77	3.11	1.98
J537.8311 - Morrison Road	20.41	1.35	2.22	2.70	3.33	3.80	4.25	2.78
J401.2138 - Cumnock Crescent	23.93	1.50	2.40	2.94	3.69	4.20	4.70	3.18
J321.7682	23.93	1.71	2.43	2.96	3.60	4.07	4.58	3.39
J278.8177 - Confluence	77.60	5.33	8.00	8.91	10.95	12.55	13.76	8.60
J255.2208 - Drummond Road	83.84	5.00	7.50	9.10	11.35	12.91	14.26	8.39
J18.30608 - U/S of Devon Road Confluence	83.84	4.81	7.35	8.81	10.94	12.44	14.09	8.33
J3163.656 - The Canadian Road	70.92	7.87	12.30	15.41	19.70	22.83	25.94	9.98

JUNCTION NAME/ LOCATION	CUMULATIVE DRAINAGE AREA (HA)	STORM EVENT						
		2	5	10	25	50	100	REGIONAL
J2548.535 - CN Rail Tracks	148.53	11.56	19.46	24.48	29.27	33.22	37.02	21.23
J2421.994	155.16	10.94	18.07	22.64	27.59	31.32	35.27	22.03
J2198.671 - Cornwall Road	155.87	10.72	17.91	22.51	27.50	31.16	35.08	22.15
J1811.637 - Duncan Road	192.65	11.73	19.16	23.46	29.00	33.63	38.09	26.90
J1699.827 - Amber Crescent	194.78	11.69	19.02	23.62	28.60	33.98	38.38	27.03
J1619.406 - U/S of Devon Road Confluence	195.21	11.68	19.04	23.18	28.42	32.93	37.57	26.57
J1601.667 - Confluence	279.05	16.53	26.18	31.46	38.59	44.16	49.46	34.70
J1577.57 - Devon Road	279.05	16.54	26.19	31.43	38.56	44.14	49.41	34.71
J1478.696	292.64	18.80	31.93	44.51	59.62	43.51	48.19	45.24
J885.2249	316.67	17.45	27.43	33.26	40.68	46.15	51.81	38.70
J629.0537 - Wedgewood Drive	342.41	17.86	29.47	33.86	40.54	46.00	50.39	39.41
J231.5493 - Lakeshore Road	376.99	17.28	27.87	34.52	42.09	47.92	53.56	44.66
J32.22618 - Lake Ontario	376.99	17.24	27.90	34.29	41.79	47.95	53.79	44.64

Model Calibration/Validation

Water level monitoring data was collected in 10 min intervals by Calder Engineering during 2014 to 2016, at the Morrison Road culvert for Lower Morrison Creek and the Lakeshore Road culvert for Lower Wedgewood Creek. Flow data was also obtained by Calder Engineering during 2014 to 2017 which was used to develop rating curves for the respective monitoring locations which were ultimately used to convert the water level monitoring data to flow data. Precipitation data, provided by the Town, was collected in 5 min intervals at the Southeast Depot rain gauge, at 1100 Cornwall Road, which is 1.3 km (+/-) northwest of the Lower Morrison monitoring station and 1.9 km (+/-) east of the Lower Wedgewood monitoring station.

The observed flow data has been used during the calibration process for comparison to the simulated data by best fitting three (3) traits; the volume, the peak flows, and the timing. During this assessment, the base flow has been subtracted from the observed data to assist in producing comparable simulated runoff volumes. Twelve (12) storm events were initially selected for the calibration process, however five (5) of those storms have been screened due to data anomalies specific to the simulated volumes. The remaining seven (7) storms are provided in Table 3.6.

Table 3.6 Summary of Observed Precipitation Events Used for Calibration

YEAR	DATE	VOLUME (MM)	DURATION (MIN)	DURATION (HR)	PEAK INTENSITY (MM/HR)	AVERAGE INTENSITY (MM/HR)
2014	7-Oct	20.2	1005	16.8	5.4	1.2
	24-Nov	22.0	850	14.2	10	1.6
2015	29-Sep	33.0	455	7.6	19	4.4
	28-Oct	57.2	970	16.2	11.6	3.5
2016	31-Mar	30.2	1195	19.9	14.2	1.5
	29-Sep	21.4	885	14.8	7.8	1.5
	3-Nov	21.2	330	5.5	9	3.9

Concerns have been encountered during the calibration process regarding the Calder Engineering rating curves for both Lower Morrison and Lower Wedgewood Creeks. The peak flows and hydrographs results determined during the calibration process were considered suspect when comparing the simulated and observed flow data. The first issue that has been noted was the creek sections were not surveyed at the monitoring locations. It has been understood that the creek sections have been measured by hand, which may result in less accurate stage/area relationships for the two (2) flow monitoring stations. Secondly, no analytical hydraulic verification has been conducted for the subject rating curves such as a HEC-RAS hydraulic model or alternate method. Based on the foregoing, it was determined the observed flow data would be used to calibrate the simulated runoff volumes, however, the peak flows would need to be validated using an alternate method. The volumetric calibration chart of the PCSWMM model is provided in Appendix D.

A unitary peak flow analysis has been undertaken to validate the peak flow results obtained from the PCSWMM hydrologic model. The results from the 100 year storm event have been used for a unitary peak flow analysis in comparison to the unitary flow results determined from calibrated models for hydrologic assessments within southern Ontario (ref. Appendix D). The results indicate that the Lower Morrison Creek unitary flows appear to be high in comparison to the previously calibrated data of the alternate projects while the Lower Wedgewood unitary flows are comparable to the calibrated data. It has been noted that the unitary flows obtained for the calibrated comparison are primarily from rural areas with low imperviousness while the Lower Morrison/Wedgewood study area contains high impervious areas adjacent to the Highway QEW corridor. Selected subcatchments in this area were not modelled with routing elements (storm sewers) due to insufficient information. As such, these high impervious subcatchments are directly connected to the channels which is likely contributing to the higher than expected flow rates. Therefore, a comparison of the subcatchment peak runoff rates has been undertaken to validate the peak flows from the high impervious areas.

Two (2) calibrated models were selected for the high imperviousness comparison process; the Guelph Stormwater Master Plan existing conditions PCSWMM model and the Markham Future Urban Area existing conditions PCSWMM model. The comparison of the calibrated models high impervious (>70 % imperviousness) subcatchment unitary flows and the Lower Morrison/Wedgewood unitary flows are provided in Appendix D. The chart indicates the high impervious subcatchments unitary flows have a coefficient of determination of 0.79 (+/-) which reasonably fits the trendline for all the unitary flow data.

The Regional Storm was simulated in the PCSWMM hydrologic model as the Regulatory Event. The results were validated with unitary flows from multiple hydrologic assessments within southern Ontario (ref. Appendix D). The unitary flows obtained from the Lower Morrison/Wedgewood PSCWMM model are within the data range of the sample projects.

The Regional Storm peak flows at the selected junctions are shown to be lower than the peak flows of several design storms. This is primarily due to the small contributing drainage areas, high impervious areas adjacent to the QEW corridor that are more sensitive to the design storms with greater precipitation intensity than the Regional

Storm and the timing of flows. The greater precipitation intensity design storms generate a quicker runoff response which ultimately results in greater channel flows.

3.2 HYDRAULIC MODELLING AND FLOOD RISK ASSESSMENT

Hydraulic (HEC-RAS) modelling for both the Lower Morrison Creek and Lower Wedgewood Creek has been conducted by Conservation Halton. As part of the current project, the detailed hydraulic models for Lower Morrison Creek and Lower Wedgewood Creek, have been updated, based on field reconnaissance and topographic survey by WSP (former Wood and Amec Foster Wheeler) in 2016 to provide updated details of the road crossings and the associated immediate upstream and downstream creek reaches (ref. Appendix E). WSP's (former (Wood and Amec Foster Wheeler) survey scope for the subject area culverts included:

1. Review mapping and set controls and benchmarks
2. Conduct survey of culverts (dimensioning, upstream and downstream inverts and sections at culvert faces)
3. Conduct survey of watercourses upstream and downstream of culverts

The updated existing HEC-RAS hydraulic modelling has been used to determine flood elevations for the 2 to 100 year and Regional Storm events (ref. Figure 3.2 for the 100 year floodline). Spill conditions have also been indicated on Figures 3.2 and 3.3, where the watercourse systems have inadequate capacity to fully contain the 100 year storm. 100 year storm event peak flows were determined to be greater then Regional Storm event peak flows, thus 100 year peak flows govern the Regulatory event for both creek systems.

The MTO Highway Drainage Design Standard, dated January 2008, section SD-13 Design Flows and Freeboards, provides the design flow return period for culverts and bridges crossing roads within the Lower Morrison and Lower Wedgewood Creeks (ref. Table 3.7).

Table 3.7 Design Flow Return Period for Bridges and Culverts – Standard Road Classifications (Sources: MTO Highway Drainage Design Standard)

FUNCTIONAL ROAD CLASSIFICATION	RETURN PERIOD OF DESIGN FLOWS (YEAR)[1,2,3]	
	TOTAL SPAN LESS THAN OR EQUAL TO 6.0 M	TOTAL SPAN GREATER THAN 6.0 M
Freeway, Urban Arterial	50	100
Rural Arterial, Collector Road	25	50
Local Road	10	25

Note: [1] The listed design flow applies to roads under the jurisdiction of the Ministry of Transportation.
[2] The Fish Passage Design Flow for culverts is defined in standard WC-12 Fish Passage Requirements through Culverts.
[3] Sometimes referred to as Normal Design Flow

Table 3.7 provides the details of the hydraulic crossings (culverts and bridges) including the hydraulic capacity based on the results of the HEC-RAS hydraulic modelling. The 2008 Ministry of Transportation (MTO) Highway Drainage Design Standards, require hydraulic structures less than 6 m span to convey the 10 year storm peak flow with an appropriate freeboard and clearance and all structures greater than 6 m span to similarly convey the 25 year storm peak flow. As indicated in Table 8 (highlighted cells), fifteen (15) structures do not meet the 2008 MTO Highway Drainage Design Standards. In addition to the MTO hydraulic crossing criteria, MNRF has vehicle ingress and egress criteria. Table 3.8 indicates when vehicle ingress and egress would not be feasible due to flood depths great than 0.3 m. Pedestrian and CNR crossings have not been flagged based on the MTO and MNRF hydraulic criteria.

To potentially mitigate all, or part, of the existing flood risks, an assessment of the number of properties and buildings at risk of flooding for storm frequencies (10, 100 year and Regional Storm) for each reach has been determined. Property flooding does not include the low flow channel within the channel banks. Based on the results in Tables 3.9 and 3.10 the flood risk for the 100 year storm event, which occurs primarily as a result of inadequate flow conveyance capacity at crossings and/or historical development encroachment into natural hazard lands, has been determined for each creek as follows:

Lower Morrison Creek:

- 6 commercial properties
- 89 residential properties
- 3 public space properties
- 41 residential buildings
- 2 commercial buildings

Lower Wedgewood Creek:

- 1 industrial property
- 164 residential properties
- 3 public space properties
- 2 commercial buildings
- 74 residential buildings

It should be noted that various criteria for culvert and bridge crossing will be discussed in further detail during the discussion of hydraulic assessment of structural alternatives (ref. Section 5). Figures 3.2 and 3.3 provide the existing conditions flood line mapping for lower Morrison and lower Wedgewood creek.

Figure 3.2 Existing Conditions Floodplain Mapping for Lower Morrison Creek

Figure 3.3 Existing Conditions Floodplain Mapping for Lower Wedgewood Creek

Table 3.8 Hydraulic Crossing Summary

CULVERT LOCATION			CULVERT TYPE		CULVERT DIMENSIONS			OVER TOPPING				ACTUAL CAPACITY / (FREQUENCY)$_1$	ADDITIONAL NOTES
ID#	Creek	Road Crossing	Material	Shape	Span (m)	Rise (m)	Width (m)	Frequency (yr)	Flow (m^3/s)	Depth (m)	Velocity (m/s)	(m^3/s) / (yr)	
Lower Morrison Creek													
1	Morrison Creek US Reach	CNR Rail Crossing	Conc.	Box	3.30	1.50	31.00	100	6.47	99.87 (0.07 m)	3.98	15.57 / (10)	
2	Morrison Creek US Reach	Downstream of Railway	Corrugated Metal Pipe	Twin Circular	1.80	1.80	27.00	100	12.35	89.59 (0.29 m)	2.67	12.47 / (5)	
3	Morrison Creek US Reach	Cornwall Road	Conc.	Box	1.28	1.75	37.00	NA	NA	NA	NA	22.79 / (100)	Cornwall Road - CH - From Permit Application A/94/O/03
4	Morrison Creek US Reach	Maple Ave	Conc.	Box	3.00	1.20	159.90	100	11.15	96.01 (0.21 m)	2.67	7.53 / (2)	
5	Morrison Creek US Reach	Chartwell Road	Conc.	Box	3.00	1.60	16.30	100	10.76	93.54 (0.47 m)	2.29	8.71 / (2)	
6	Morrison East Creek	QEW	Conc.	Box	5.97	1.50	85.00	NA	NA	NA	NA	6.17 / (100)	
7	Morrison East Creek	Under CNR	Conc.	Box	1.80	1.50	19.00	100	16.32	100.68 (0.17 m)	1.86	7.59 / (2)	
8	Morrison East Creek	East Longo's Parking Lot	Conc.	Box	3.50	1.30	90.00	100	4.63	100.62 (0.12 m)	3.67	15.99 / (25)	
9	Morrison East Creek	Cornwall	Conc.	Twin Box	3.25	1.20	52.65	100	0.45	99.02 (0.02 m)	2.66	19.34 / (50)	
10	Morrison East Creek	Chartwell Road	Conc.	Twin Box	3.00	2.10	15.00	NA	NA	NA	NA	23.41 / (100)	
11	Morrison East Creek	Linbrook Road	Conc.	Conspan Arch	7.30	1.50	9.50	100	1.65	94.27 (0.25 m)	3.07	18.38 / (25)	
12	Morrison Creek DS Reach	Morrison Road	Conc.	Box	3.70	2.05	18.10	100	29.84	82.80 (0.40 m)	2.07	17.61 / (2)	
13	Morrison Creek DS Reach	Lakeshore Road	Corrugated Metal Pipe	Arch	7.90	3.20	20.00	NA	NA	NA	NA	45.99 / (100)	
Lower Wedgewood Creek													
1	Wedgewood US Reach	CN Railway	Conc.	Box	3.10	2.00	4.00	100	24.79	103.09 (0.88 m)	0.19	12.3 / (5)	
2	Wedgewood US Reach	CN Railway	Conc.	Box	3.10	2.00	92.60	100	7.30	103.09 (1.14 m)	3.95	21.23 / (Reg)	
3	Wedgewood US Reach	Cornwall Rd.	Conc.	Box	1.75	1.20	33.60	100	26.28	98.52 (0.59 m)	2.14	5.29 / (2)	2 Year flow is overtopping with Q weir = 0.36 m^3/s
4	Wedgewood US Reach	Duncan Road -	Conc.	Ellipse	2.45	1.80	15.80	100	25.16	94.36 (0.58 m)	2.87	10.72 / (2)	
5	Wedgewood US Reach	Amber Crescent	Conc.	Ellipse	2.10	2.60	17.00	100	26.69	92.90 (0.52 m)	2.66	5.29 / (2)	2 Year flow is overtopping with Q weir = 0.31 m^3/s
6	Wedgewood Creek Reach 2	Morrison Road	Corrugated Metal Pipe	Circular	1.20	1.20	12.00	100	1.25	95.14 (0.14 m)	1.94	1.7 / (5)	

CULVERT LOCATION			CULVERT TYPE		CULVERT DIMENSIONS			OVER TOPPING				ACTUAL CAPACITY / (FREQUENCY)[1]	ADDITIONAL NOTES
ID#	Creek	Road Crossing	Material	Shape	Span (m)	Rise (m)	Width (m)	Frequency (yr)	Flow (m^3/s)	Depth (m)	Velocity (m/s)	(m^3/s) / (yr)	
7	Wedgewood Creek Reach 2	Cumnock Crescent	Corrugated Metal Pipe	Circular	0.60	0.60	16.00	100	3.66	94.67 (0.30 m)	2.12	0.55 / (2)	2 Year flow is overtopping with Q weir = 0.8 m^3/s
8	Wedgewood Creek Reach 3	CN Railway	Corrugated Metal Pipe	Circular	1.20	1.20	57.00	100	7.62	101.25 (0.15 m)	2.66	3.29 / (2)	2 Year flow is overtopping with Q weir = 0.18 m^3/s
9	Wedgewood Creek Reach 3	Cornwall Road	Corrugated Metal Pipe	Arch	1.80	1.27	30.00	100	515	99.72 (0.41 m)	1.22	2.68 / (Reg)	
10	Wedgewood Creek Reach 3	Morrison Road	Corrugated Metal Pipe	Arch	1.80	1.26	31.5	100	0.34	98.77 (0.01 m)	2.08	7.93 / (50)	Bridge #3 Morrison Road CSPA 1.8 x 1.26
11	Wedgewood Creek Reach 3	Pedestrian	Wooden Structure	Plank Bridge	5.14	0.75	1.50	100	7.06	97.10 (0.85 m)	1.06	1.69 / (2)	2 Year flow is overtopping with Q weir = 2.00 m^3/s
12	Wedgewood Creek Reach 3	Pedestrian	Wooden Structure	Plank Bridge	7.14	1.00	1.50	100	5.94	97.03 (0.53 m)	1.46	3.39 / (Reg)	Pedestrian
13	Wedgewood Creek Reach 3	Pedestrian	Wooden Structure	Plank Bridge	7.89	1.03	1.50	100	6.05	96.26 (0.50 m)	1.23	3.66 / (2)	Pedestrian
14	Wedgewood Creek Reach 3	Pedestrian	Conc.	Box	1.40	1.20	1.20	100	7.06	95.05 (0.17 m)	1.60	6.24 / (10)	Bridge #2 Pedestrian Bridge in Park
15	Wedgewood Creek Reach 4	Drummond Rd	Corrugated Metal Pipe	Arch	1.70	1.15	7.50	100	8.55	93.73 (0.35 m)	0.66	4.55 / (2)	2 Year flow is overtopping with Q weir = 0.78 m^3/s
16	Wedgewood DS Reach	Devon Road	Conc.	Twin Conspan Arch	4.30	2.00	16.00	100	49.46	90.59 (0.01 m)	3.21	44.16 / (50)	Twin Conspan Arch 4.3 m x 2.0 m
17	Wedgewood DS Reach	Weaver Ave.	Metal Structure	Bridge	14.10	2.29	3.00	NA	NA	NA	NA	49.41 / (100)	
19	Wedgewood DS Reach	Wedgewood Drive	Corrugated Metal Pipe	Arch	5.50	1.50	21.20	100	50.61	83.86 (1.47 m)	0.19	0.92 / (2)	2 Year flow is overtopping with Q weir = 16.53 m^3/s
20	Wedgewood DS Reach	Warren Dr Park	Corrugated Metal Pipe	Arch	4.20	1.50	29.53	100	47.27	82.90 (0.51 m)	0.92	13.40 / (2)	2 Year flow is overtopping with Q weir = 0.75 m^3/s
21	Wedgewood DS Reach	Lakeshore Road	Corrugated Metal Pipe	Arch	3.80	1.90	21.30	100	31.48	80.52 (0.58 m)	3.33	17.86 / (2)	

1. Number in brackets represents the storm frequency or return period that a hydraulic crossing is able to convey without overtopping

Table 3.9 Lower Morrison Creek Flood Risk

	STORM EVENT:	10 YEAR	100 YEAR	REGIONAL STORM
Morrison US CN Railway / Cornwall Rd.	Flow (m^3/s):	15.57	25.94	11.19
Property Type	Commercial	1	1	1
	Public/Open Space		1	1
Building Type	Commercial			
Roadway	CN Railway	1	1	1
	Cornwall Rd.	1	1	1
Morrison US Cornwall Rd. / Perkin`s Passage Trial	Flow (m^3/s):	12.67	22.84	12.86
Property Type	Residential	3	17	15
	Public/Open Space	1	1	1
Building Type	Residential	5	11	9
Roadway	Cornwall Rd.	1	1	1
	Perkin`s Passage Trial	1	1	1
Morrison US Perkin`s Passage Trial / Chartwell Rd.	Flow (m^3/s):	14.51	21.96	14.73
Property Type	Residential	6	16	14
	Public/Open Space			
Building Type	Residential		1	
Roadway	Perkin`s Passage Trial		1	1
	Chartwell Rd.		1	
Morrison East Creek South Service Rd. / CN Railway	Flow (m^3/s):	3.20	6.17	2.56
Property Type	Commercial	1	4	3
	Public/Open Space		1	1
Building Type	Commercial		2	2
Roadway	South Service Rd.			
	CN Railway			
Morrison East Creek CN Railway / Cornwall Rd.	Flow (m^3/s):	12.86	21.22	10.47
Property Type	Residential		1	
	Public/Open Space			
Building Type	Residential			
Roadway	CN Railway			
	Cornwall Rd.		1	
Morrison East Creek Cornwall Rd. / Chartwell Rd.	Flow (m^3/s):	14.61	23.41	11.92
Property Type	Residential	4	14	12
	Public/Open Space			
Building Type	Residential	2	7	4

	STORM EVENT:	10 YEAR	100 YEAR	REGIONAL STORM
Roadway	Cornwall Rd.		1	
	Chartwell Rd.			
Morrison East Creek Chartwell Rd. / Linbrook Rd.	Flow (m^3/s):	15.52	23.88	12.83
Property Type	Residential		2	1
	Public/Open Space			
Building Type	Residential		1	
Roadway	Chartwell Rd.			
	Linbrook Rd.		1	
Morrison DS Chartwell Rd. / Morrison Rd.	Flow (m^3/s):	27.51	43.06	28.42
Property Type	Residential	8	21	17
	Public/Open Space			
Building Type	Residential	3	10	8
Roadway	Chartwell Rd.			
	Morrison Rd.		1	1
Morrison DS Morrison Rd. / Lakeshore Rd.	Flow (m^3/s):	29.73	45.99	35.14
Property Type	Residential	8	17	15
	Public/Open Space			
Building Type	Residential	3	9	9
Roadway	Morrison Rd.		1	1
	Lakeshore Rd.			
Morrison DS Lakeshore Rd. / Lake	Flow (m^3/s):	30.56	46.05	38.07
Property Type	Residential		1	
	Public/Open Space			
Building Type	Residential		2	1
Roadway	Lakeshore Rd.			
	Lake			

Table 3.10 Lower Wedgewood Creek Flood Risk

	STORM EVENT:	10 YEAR	100 YEAR	REGIONAL STORM
Wedgewood US QEW / Royal Windsor Dr.	Flow (m^3/s):	15.41	25.94	9.98
Property Type	Industrial	1	1	1
	Public/Open Space			
Building Type	Industrial/Commercial			
Roadway	QEW			
	Royal Windsor Dr.	1	1	1
Wedgewood US Royal Windsor Dr. / Cornwall Rd.	Flow (m^3/s):	24.48	37.02	21.23
Property Type	Business/Commercial	1	3	3
	Public/Open Space			
Building Type	Commercial		2	2
Roadway	Royal Windsor Dr.	1	1	1
	Cornwall Rd	1	1	1
Wedgewood US Cornwall Rd. / Duncan Rd.	Flow (m^3/s):	22.51	35.08	22.15
Property Type	Residential	11	21	21
	Public/Open Space			
Building Type	Residential		3	3
Roadway	Cornwall Rd.	1	1	1
	Duncan Rd.	1	1	1
Wedgewood US Duncan Rd. / Amber Cres.	Flow (m^3/s):	23.46	38.09	22.15
Property Type	Residential	3	7	6
	Public/Open Space			
Building Type	Residential		3	2
Roadway	Duncan Rd.	1	1	1
	Amber Cres.	1	1	1
Wedgewood US Amber Cres. / Devon Rd.	Flow (m^3/s):	23.62	38.38	27.03
Property Type	Residential	3	7	7
	Public/Open Space			
Building Type	Residential		5	3
Roadway	Amber Cres.	1	1	1
	Devon Rd.			
Wedgewood Creek Reach 2 Cynthia Lane/ Morrison Rd.	Flow (m^3/s):	2.02	3.11	1.98
Property Type	Residential	4	11	11
	Public/Open Space			
Building Type	Residential		3	3

	STORM EVENT:	10 YEAR	100 YEAR	REGIONAL STORM
Roadway	Cynthia Lane	1	1	1
	Morrison Rd.	1	1	1
Wedgewood Creek Reach 2 Morrison Rd./ Cumnock Cres.	Flow (m^3/s):	2.70	4.25	2.78
Property Type	Residential	3	5	5
	Public/Open Space			
Building Type	Residential		2	2
Roadway	Morrison Rd.	1	1	1
	Cumnock Cres.	1	1	1
Wedgewood Creek Reach 2 Cumnock Cres./ Drummond Rd.	Flow (m^3/s):	2.96	4.58	3.39
Property Type	Residential	5	8	8
	Public/Open Space			
Building Type	Residential		6	6
Roadway	Cumnock Cres.	1	1	1
	Drummond Rd.	1	1	1
Wedgewood Creek Reach 3 CN Railway / Morrison Rd.	Flow (m^3/s):	6.69	10.68	3.47
Property Type	Residential		5	
	Public/Open Space			
Building Type	Residential		5	
Roadway	CN Railway		1	
	Morrison Rd			
Wedgewood Creek Reach 3 Morrison Rd. / Drummond Rd.	Flow (m^3/s):	6.15	10.07	2.68
Property Type	Residential	12	28	28
	Public/Open Space			
Building Type	Residential/Commercial	4	15	12
Roadway	Morrison Rd.			
	Drummond Rd.			
Wedgewood Creek Reach 4 Drummond Rd. / Devon Rd.	Flow (m^3/s):	8.91	13.76	8.60
Property Type	Residential	8	16	16
	Public/Open Space			
Building Type	Residential	3	8	6
Roadway	Drummond Rd.	1	1	1
	Devon Rd.	1	1	1
Wedgewood DS Devon Rd. / Wedgewood Dr.	Flow (m^3/s):	31.43	49.41	34.71
Property Type	Residential	22	38	38

	STORM EVENT:	10 YEAR	100 YEAR	REGIONAL STORM
	Public/Open Space			
Building Type	Residential	9	17	17
Roadway	Devon Rd.	1	1	1
	Wedgewood Dr.	1	1	1
Wedgewood DS Wedgewood Dr. / Lakeshore Rd..	Flow (m^3/s):	33.86	50.39	39.41
Property Type	Residential	12	15	15
	Public/Open Space			
Building Type	Residential	5	6	6
Roadway	Wedgewood Dr.	1	1	1
	Lakeshore Rd.	1	1	1
Wedgewood DS Lakeshore Rd. / Lake	Flow (m^3/s):	34.29	53.79	44.64
Property Type	Residential	3	3	3
	Public/Open Space			
Building Type	Residential	1	1	1
Roadway	Lakeshore Rd.	1	1	1
	Lake			

3.3 NATURAL HERITAGE ASSESSMENT

Natural heritage consists of features either physical or biological which have universal value from a scientific, conservation, or aesthetic perspective. Natural heritage features reviewed for this report include policy plan areas, provincial parks and conservation areas, land use designations, natural area designations (e.g., Areas of Natural and Scientific Interest (ANSIs), environmental sensitive areas), wetlands, woodlands, and wildlife habitat, species of conservation concern (SoCC) and Species at Risk (SAR). The natural heritage features present within Lower Morrison and Wedgewood Creek are described for both the terrestrial and aquatic environment and are presented in more detail in Appendix C.

3.3.1 TERRESTRIAL ENVIRONMENT

Terrestrial ecology is the study of flora and fauna species and their habitats as well as the interactions and relationships between organisms. The objective of the terrestrial study is to identify the types of landforms present as well as the flora and fauna associated with these landforms. The evaluation allows for the identification of any rare or sensitive species present as well as their critical habitat. Terrestrial information can then be used to complete an evaluation of the impacts of various project alternatives and develop mitigation and compensation measures. Available background data has been summarized in order to provide an understanding of the terrestrial natural heritage characteristics of the study area.

Flora

The Midtown Oakville EA (2014) identified flora species located within the northern limits of the study area. A total of 145 plant species were identified and included 59 native Ontario plant species and 86 introduced and non-native plant species (Town of Oakville, 2014). Of the 59 species recorded within the EA only two were considered rare or uncommon within Halton Region and included common juniper (Juniperus communis) and eastern redcedar (Juniperus virginiana) (Town of Oakville, 2014). No provincially rare or SAR were recorded within the EA (Town of Oakville, 2014). Since the Midtown Oakville EA study area only overlapped with the most northern section of the Lower Morrison and Wedgewood Creek Study area, many flora species have yet to be identified within the southern limits of the study area.

During an October 2016 visit at Site 33 (ref. Appendix C), a potential Butternut was observed by Matrix staff. This observation may indicate that there could be additional Butternut trees within the study area. This species is considered endangered under the Provincial ESA and the Federal SARA as a result of rapid decline from the Butternut Canker disease. A full Butternut Health Assessment will need to be conduct on this tree to determine whether it has been affected by Butternut Canker, and if it can be retained.

Wildlife Habitat

The significant wildlife habitat assessment was based on the Significant Wildlife Habitat Criteria Schedules for Ecoregion 7E (MNRF, 2015).

The Provincial databases (identified species that had the potential to be present within the study area. The database indicated the potential for ten species of amphibians, ten species of reptiles, 38 species of mammal, and 71 species of birds to be present within the study area.

Of the 129 potential species identified within the background review, 14 were identified as SAR with an additional 21 species identified as SoCC.

3.3.2 AQUATIC ENVIRONMENT

Aquatic ecology is the study of water based ecosystems and the interactions and relationships between aquatic organisms and habitat parameters. The objective of an aquatic assessment is to identify the fisheries/aquatic community and the types of aquatic habitat available within Lower Morrison and Wedgewood Creeks. The assessment allows for the identification of any rare or sensitive species present as well as their critical habitat. The species information can then be used to assess project impacts, mitigation and compensation measures.

Fisheries

Lower Morrison Creek and Lower Wedgewood Creek are located within the Oakville East Urban Creeks watershed. Conservation Halton staff has conducted various fisheries assessments within the study area Conservation Halton's Long-term Environmental Monitoring Program (LEMP) has established multiple monitoring stations within the Lower Morrison and Wedgewood Creeks. These assessments were conducted over multiple years and include data from 2001 until 2014.

Conservation Halton's LEMP Report (2012) indicated that Lower Wedgewood Creek had an Index of Biotic Integrity (IBI) of the fish community indicating "fair" conditions. Lower Morrison Creek could not be measured because no fish were captured in 2012, however the 2008 study indicated that this creek was also considered to have "fair" conditions(Conservation Halton, 2008, 2012). The IBI uses indices such as indicator species, trophic composition, fish abundance and health to measure the general health of a stream ecosystem based on its upstream drainage area.

A total of four species were identified in Morrison Creek including, Creek Chub, White Sucker, Blacknose Dace, and Fathead Minnow. In Wedgewood Creek two species were identified including Blacknose Dace and Creek Chub. The species with the greatest number of individuals found at both sites was Creek Chub (Conservation Halton, 2016.

Morrison Creek is considered to be historical Redside Dace (endangered) habitat which was last noted in 1960 according to NHIC and Conservation Halton records (Conservation Halton, 2016). The MNRF have stated that there appears to be more recent evidence indicating the presence of this species within Lower Morrison Creek. Redside Dace prefer small, cool, clear streams which are less than 10m wide with slower current velocities (<0.08 m/s), greater depths (0.33-0.84m), and lots of overhanging vegetation (COSEWIC, 2007). The greatest limiting factor for Redside Dace is habitat degradation and loss which may result from changes in stream structure, such as channel widening, reservoir construction and decreased pool depth (COSEWIC, 2007).

Species at Risk

Based on the desktop assessment a total of six (6) SAR identified within the background review have the potential to be within the study area. These include Butternut (*Juglans cinerea*), Eastern Small-footed Myotis (*Myotis leibii*), Little Brown Myotis (*Myotis lucifugus*), Tri-coloured Bat (*Perimyotis subflavus*), Barn Swallow (*Hirundo rustica*) and Redside Dace (*Clinostomus* elongatus).

4 PROBLEM DEFINITION

The Town of Oakville Town-wide Flood Study identified seventeen (17) creek reaches on Lower Morrison Creek and Lower Wedgewood Creek where flooding of both private and public has been determined to occur. Flooding mitigation opportunities have been developed within this Municipal Class EA process to protect public safety, private property and municipal infrastructure on Lower Morrison Creek and Lower Wedgewood Creek McCraney Creek.

Alternative solutions to the identified problems should also consider the opportunity to integrate stormwater management for the planned urbanization of North Service Road, Invicta Drive and the Midtown Area.

5 ALTERNATIVE ASSESSMENT

Detailed analyses have been completed to evaluate alternative solutions to mitigate the flood risk within the subject focus area under existing and future land use. It should be noted that the alternative assessment for the mitigation associated with the projected impacts of land use change in regard to certain areas have been discussed separately in the following sections.

In addition to assessment of flood risk reduction within the overall study area, area focused assessments have been conducted for Invicta Drive and the Midtown growth area. The area assessments are integrated within the overall study area assessment. The following sections summarize the results of these analyses.

5.1 INVICTA DRIVE DRAINAGE ASSESSMENT

5.1.1 INVICTA DRIVE STUDY AREA

Invicta Drive is a two (2) lane local road, approximately 500 m long, located immediately north of the QEW and east of Eighth Line, within the Town of Oakville. The majority of the land use along Invicta Drive is made up of commercial and industrial applications, corresponding to a high impervious ground coverage and corresponding by high stormwater runoff potential. Given its predominantly rural cross-section, drainage along Invicta Drive is provided by roadside ditches and driveway culverts.

Stormwater drainage from Invicta Drive is directed south to North Service Road and subsequently drains across the QEW right-of-way. Three (3) Town easements have been identified within the area as providing drainage from Invicta Drive to North Service Road: [ref. Instrument H-231173, Instrument (R)550572, and Instrument (R)712001]. These easements convey stormwater to the North Service Road via drainage swales, storm sewers, and an isolated reach of rectangular concrete channel.

The Invicta Drive area is located within the Lower Wedgewood Creek watershed and runoff from the area is conveyed to the western tributary of Wedgewood Creek via two (2) culverts crossing the QEW. Approximately 9.9 hectares of the Invicta Drive study area, north of the North Service Road, contributes flow to the QEW culvert (i.e. 93.7 m long, 3050 mm x 1220 mm concrete box culvert) located nearest the intersection of North Service Road and Invicta Drive (i.e. conveyance link #16, ref. Figure 1) and approximately 21.4 hectares of the Invicta Drive study area, north of the North Service Road, contributes flow to the QEW culvert (i.e. 74.3 m long, 2440 mm x 1220 mm concrete box culvert) located nearest the aforementioned Town easements (i.e. conveyance link #12, ref. Figure 5.1). The combined 31.3 hectare Invicta Drive drainage area has an approximate average impervious coverage of 68%. Figure 3.1 illustrates subwatershed delineation and highlights the municipal easements within the Study Area.

Overall, the Invicta Drive area has a lack of existing municipal stormwater management controls (quality and quantity). Notwithstanding, based on the available site servicing and drainage plans, four (4) private properties employ on-site controls (i.e. 1132 Invicta Drive, 1170 Invicta Drive, 1177 Invicta Drive, and 1209 North Service Road).

An existing stormwater management (SWM) facility has been identified on MTO property within the QEW / Royal Windsor Drive interchange (ref. Final Drainage and Stormwater Management Report of the Highway 403-QEW Widening, MRC, 2014) downstream of Invicta Drive. The details of the function of this SWM facility are unknown however based on a review of aerial mapping and the available drawings, the SWM facility includes a permanent pool and extended detention storage so it can be assumed to provide water quality treatment for the QEW ramp loop at a minimum, and may also provide some erosion and/or flood control functions. There appears to be an inlet from the ditch that conveys Invicta Drive drainage entering the SWM facility on the west side of the QEW

ramp loop (ref. Appendix 'A,' MRC 2014), however its function is also unknown, and it is considered unlikely the facility provides any stormwater management for Invicta Drive.

The North Service Road is planned to be widened and realigned in a phased implementation plan proposed as part of the preferred alternative recommended in the *Midtown Oakville Transportation and Stormwater Class EA*.

The alternative evaluation as documented herein, identifies where there may be opportunities to integrate stormwater management needs for North Service Road (and Invicta Drive) with stormwater opportunities identified to address the existing problems in the Invicta Drive Study Area.

5.1.2 INVICTA DRIVE HYDROLOGY AND HYDRAULICS

A PCSWMM hydrologic and hydraulic model has been developed in order to characterize the baseline condition of the Invicta Drive Study Area and thereby identify and quantify the area's drainage problems. The PCSWMM model generates runoff from subcatchments within the Invicta Drive Study Area (i.e. between the Morrison/Wedgewood Diversion Channel and the QEW) which are then routed along major flow paths to determine peak flows, velocities, and hydraulic capacities at locations throughout the drainage system. Existing land use conditions have been represented in the parameterization of the model based on 2012 aerial photography. This is considered appropriate so that the analysis can represent land use conditions relatively consistent with conditions at the time of recent flood reports (i.e. June 17, 2014). It is noted that the Invicta Drive Study Area is close to ultimate build-out conditions regardless, and that any future development would require post- to pre-development flood controls.

Subcatchments in the Invicta Drive area have been delineated based on Town contour information, as well as information from available background reports, primarily the *Final Drainage and Stormwater Management Report of the Highway 403-QEW Widening* (MRC, 2014) and *Draft Detailed Design Report of the Midtown Core Road Network Improvements Phase II* (MRC, 2010).

Open channel conveyance has been incorporated into the model based on Town of Oakville survey data (April, 2013) of the easements and North Service Road ditch system. Select site plans were also provided by the Town and used to define details regarding the storm sewer conveyance in the Town's easement. A site visit was performed on October 14, 2016 to verify conveyance infrastructure and size where accessible. Hydraulic boundary conditions have been established at the downstream outlets of the two (2) QEW culverts using 100 year storm water surface elevations established in the *Final Drainage and Stormwater Management Report of the Highway 403-QEW Widening* by MRC (MTO, 2014). A detailed summary of the model parameterization will be provided in future reporting.

The existing land-use condition PCSWMM model has been verified against simulated peak flows for the 50 and 100 year return periods reported in the *Final Drainage and Stormwater Management Report of the Highway 403-QEW Widening* (MRC, 2014). Table 5.1 compares drainage area, average subwatershed imperviousness and peak flows.

Table 5.1: Invicta Drive Model Verification – Comparison of Peak Flows, Contributing Drainage Areas and Impervious Coverages

ITEM (UNIT)	MRC 2014[1] (MODEL: SWMHYMO)	PCSWMM	DIFFERENCE
Westerly QEW Culvert (Conveyance Link #16)			
Contributing Drainage Area (ha)	11.50	12.60	+ 1.10 ha / + 10%
Impervious Percentage (%)	34%	58%	+ 24%
50 Year Peak Flow (m^3/s)	1.80	2.48	+ 0.68 m^3/s / + 38%
100 Year Peak Flow (m^3/s)	2.09	2.68	+ 0.59 m^3/s / + 28%
Easterly QEW Culvert (Conveyance Link #12)			
Contributing Drainage Area (ha)	28.10	24.84	- 3.26 ha / - 12%
Impervious Percentage (%)	66%	69%	+ 3%
50 Year Peak Flow (m^3/s)	6.35	6.31	- 0.04 m^3/s / - 1%
100 Year Peak Flow (m^3/s)	7.17	7.29	+ 0.12 m^3/s / + 2%

Note: [1] Final Drainage and Stormwater Management Report of the Highway 403-QEW Widening (MRC, 2014)

As presented in Table 5.1, drainage areas contributing to the westerly outlet (Link #16, ref. Figure 1, Appendix H) remain similar between the two studies (within 10%), however average imperviousness is considerably higher in the current study (34% versus 58%). Part of the reason for the difference is likely the recent development of the Toronto Rock Practice Facility along the north side of Invicta Drive, which may not have been captured by the 2014 MRC study. As a result of the difference in imperviousness, increased catchment discretization, as well as other inherent changes in the modelling platform, peak flows for the 50 and 100 year events are 38% and 28% higher in the current study, respectively.

The drainage area and imperviousness contributing to the easterly outlet (Link #12, ref. Figure 1, Appendix H) remain similar, within 12% and 3%, respectively. Accordingly, peak flows for the 50 and 100 year events are also similar, within 1 to 2%. Based on the foregoing discussion, differences in simulated peak flow rates between the two models are considered reasonable and the current model is considered suitably verified against the results of the *Final Drainage and Stormwater Management Report of the Highway 403-QEW Widening* (MRC, 2014).

The 2 to 100 year 24 hour Chicago design storms have been simulated in the PCSWMM model (per Town of Oakville Development Engineering Procedures and Guidelines Manual), the results are summarized in Table 5.2. Refer to Figure 1 for flow node locations.

Table 5.2 Invicta Drive Existing Condition Peak Flows (m^3/s)

LOCATION	NODE #	CONTRIBUTING DRAINAGE AREA (HA)	RETURN PERIOD (YEARS)					
			2	5	10	25	50	100
Westerly QEW Culvert (Conveyance Link #16)								
Invicta Drive Culvert	1	1.17	0.22	0.35	0.43	0.54	0.62	0.70
North Service Rd Culvert	2	9.89	0.70	1.00	1.21	1.43	1.50	1.61
Easterly QEW Culvert (Conveyance Link #12)								
Easement	3	12.00	0.84	1.22	1.49	1.88	2.27	2.82
	4	13.19	0.99	1.45	1.79	2.24	2.60	3.16
North Service Rd	5	4.37	0.76	1.12	1.36	1.68	2.18	2.68
	6	17.56	1.50	2.03	2.31	2.51	2.64	2.75
	7	21.381	2.07	2.86	3.14	3.35	3.42	3.47
QEW	8	24.84	2.35	3.18	4.03	5.33	6.31	7.29

Table 5.3 summarizes the capacity of the conveyance infrastructure (modelled as links) in the Invicta Drive Study Area, provides contemporary design criteria, specific to the criteria by which the actual capacity has been established, and describes any relevant flooding mechanism.

Based on the results summarized in Table 5.3, the majority of Town conveyance infrastructure within the Invicta Drive drainage area has a capacity less than the contemporary design criteria, as does the North Service Road ditch downstream. As noted previously, flooding within the easement is predicted to impact private property. While reduced levels of service on Invicta Drive may not impact ingress/egress for a significant number of persons or businesses, the capacity of the North Service Road drainage infrastructure is considered to warrant improvement based on its existing substandard performance.

Property flooding was reported by Invicta Drive property owners (specifically Le Dome, 1173 North Service Road East) for the June 17, 2014 storm event which had 22.6 mm of rainfall in 25 minutes based on the Southeast Depot Rain Gauge (roughly 5 year return period based on Oakville IDF data). This corresponds reasonably well with the simulated capacity presented in Table 2.3 (i.e. 2 year frequency at Link #6), however it is noted that other variables could have been a factor during the June 17, 2014 event (i.e. debris blockage). It is further noted that simulated peak flows would be expected to be conservative due to modelling assumptions which would partly explain the difference in predicted flooding versus historical observed flooding.

Table 5.3 Invicta Drive Existing Condition Hydraulic Conveyance Capacity

LINK #	CONVEYANCE LINK	CONTEMPORARY DESIGN CRITERIA	SIMULATED CAPACITY	CRITERIA USED TO MEASURE CAPACITY	FLOOD MECHANISM[1]
Easterly QEW Culvert (Conveyance Link #12)					
1	Invicta Drive Road Crossing Culvert (Bulb) (1.20 m x 0.75 m Elliptical)	25 year	10 year	No spill across road	Spill east across Invicta Dr.
2	Storm sewer in easement 1177 Invicta Drive (250 mm Pipe)	5 year	10 year	No surcharge to surface	Spill southeast across private property
3	Easement Ditch	100 year	< 2 year	Conveyance within easement. No spill onto private property	Conveyance on private property
			25 year	Conveyance on private property but not impacting building	Conveyance impacts buildings
4	Easement Ditch	100 year	100 year	Conveyance within easement. No spill onto private property	Conveyance on private property
5	Easement Culvert (Shurguard Storage) (2130 mm x 1000 mm Open Box)	100 year	50 year	Conveyance within easement. No spill onto private property	Spills northeast to Shurguard Storage property
6	Easement Ditch	100 year	2 year	Conveyance within easement. No spill onto private property	Spills west to 'Le Dome' property.
7	Le Dome East Driveway Culvert (600 mm CSP)	10 year	< 2 year	No spill across driveway	Spills west along North Service Road
8	Easement-North Service Road Confluence	50 Year	2 year	No spill across road	Spills east across North Service Road
12	QEW Culvert - (2440 mm x 1220 mm Box)	50 Year	50 year	Greater than 1 m freeboard[2]	Less than 1 m freeboard[2]
Westerly QEW Culvert (Conveyance Link #16)					
13	Invicta Drive Road Culvert – North Service Road Intersection (450 mm CSP)	25 year	100 year	No spill across road	Spill east along ditch North Service Rd to easterly outlet
14	North Service Road Culvert (1.30 m x 0.70 m Elliptical)	50 Year	100 year	No spill across road	Spill east along ditch North Service Rd to easterly outlet
16	QEW Culvert (3050 mm x 1220 mm Box)	50 Year	100 year	Greater than 1 m freeboard[2]	Less than 1 m freeboard[2]

Notes: [1] 'Flood Mechanism' describes the type of flooding that occurs above the 'Simulated Capacity.'
[2] 'Based on the MTO's desirable freeboard criteria as per the *Final Drainage and Stormwater Management Report of the Highway 403-QEW Widening* (MRC, 2014.)

5.1.3 INVICTA DRIVE UNDERSTANDING OF THE PROBLEM

Based on discussions with Town of Oakville staff and the assessment of baseline drainage conditions, the following summarizes the drainage problems in the Invicta Drive Study Area:

i. Under-sized conveyance infrastructure including ditches in easements and Invicta Drive and North Service Road cross culverts and driveway culverts;

ii. Absence of stormwater management, both on individual sites and servicing the public right-of-way (only 4 out of 13 properties in the Study Area have some level of on-site quantity controls); and

iii. Re-occurring erosion leading to partial washout of the North Service Road ditch and shoulder where it confluences with the Invicta Drive drainage easement.

Alternative solutions have been identified to integrate stormwater management warrants for the planned improvement to North Service Road, and Invicta Drive.

5.1.4 INVICTA DRIVE ALTERNATIVE ASSESSMENT

5.1.4.1 LONG-LIST OF ALTERNATIVES

Based upon the results of the baseline hydrologic/hydraulic modelling and discussion with Town of Oakville staff on October 25, 2016, the following 'long-list' of potential alternatives has been prepared to address the under-sized conveyance infrastructure, absence of stormwater management infrastructure and issues related to erosion. Where the opportunity to integrate stormwater management warrants for the future widening and expansion of North Service Road into an alternative, it has been identified in the discussion for that alternative (i.e. reference Alternatives C1, C4, D2).

A. Do Nothing

B. Conveyance Improvements

1. Easement Cross Section Improvements
2. Easement System Lowering
3. Culvert Upgrades
4. Link #3 Conveyance Improvements
5. Shurguard Culvert Upgrade

C. Stormwater Management

1. MTO SWM Facility Retrofit
2. Subsurface Flood Control
3. Online Flood Control
4. Retrofit Source Control

D. Diversion

1. North Invicta Drive Diversion
2. Invicta Drive to Eighth Line Diversion

As part of the long-list screening, each alternative has been reviewed for feasibility from an implementation perspective and also screened at a high-level for effectiveness. Alternatives that have been screened from the long-list are discussed in the following; alternatives that have been advanced to the short-list are discussed in Section 5. On the basis of the long-list assessment, the following alternatives have been screened from further consideration:

Alternative B3 Culvert Upgrades: This alternative proposes to increase conveyance capacity across Invicta Drive and North Service Road and thereby potentially reduce the risk of flooding over roads and/or on private property. In particular, baseline modelling has indicated that the 600 mm diameter CSP Le Dome driveway culvert (Link #7) creates backwater which impacts the capacity of the easement ditch (Link #6), ultimately increasing flood risk for the Le Dome property. However, the future improvements to North Service Road proposes to eliminate all Study Area culverts with the exception of the Invicta Drive culvert at the bulb (Link #1, ref. Figure 1.) Although this culvert's capacity (10 year) is below contemporary design criteria (25 year), no flood impacts are understood to occur (as per model results and discussion with Town staff), with the exception of potentially nuisance impacts to ingress/egress. Consequently, with few opportunities for culvert improvements and limited negative impacts, this alternative is anticipated to provide minimal benefit and has therefore been screened from further consideration.

Alternative B5 Shurguard Culvert Upgrade: The Shurguard culvert (Link #5) is predicted to provide capacity for the 50 year storm event before spill would potentially impact the Shurguard property. Amec Foster Wheeler recently assessed the condition and capacity of the structure for the Town of Oakville Shurguard Culvert Assessment Report (AFW, 2013) and recommended rehabilitation of the structure rather than replacement due to capital cost and capacity considerations (estimated to have 100 year capacity based on a simple Manning's assessment) conducted at that time. The culvert was rehabilitated in 2015. Sensitivity analyses completed for the current assessment have determined that the reduced capacity predicted by the current model (i.e. 50 year capacity) is due primarily to backwater conditions along the North Service Road right-of-way and suggest that a 100 year capacity could be reached for the existing structure, if system capacity is upgraded along the North Service Road. Given that the existing ditch system along North Service Road will be eliminated as part of the urbanization, it has been assumed that the capacity of the system (major / minor) will be upgraded to some extent (ideally the 100 year). Given the recent rehabilitation, and the reasonable expectation of improvements downstream, this alternative has been screened.

Alternative C1 MTO SWM Facility Retrofit: Conceptually, this alternative would direct discharge from the ditch downstream of North Service Road (Link #15, ref. Figure 1, Appendix H) into the existing MTO SWM facility within the QEW / Royal Windsor Drive on-ramp loop. Given the location of the existing SWM facility (i.e. downstream of Invicta Drive), this opportunity would not directly benefit the flooding problems along the Invicta Drive easement. However, this alternative may provide an opportunity to reduce peak flows to the flood susceptible reaches of Wedgewood Creek downstream of the Invicta Drive Study Area, provide retroactive quality / erosion control for Invicta Drive, or be utilized to provide stormwater management for the proposed widening of North Service Road.

Retrofit of the existing facility outlet control structure would be required to accommodate the desired retrofit function (i.e. stormwater management for Invicta Area, or for North Service Road widening) and additional unused volume would need to be available to ensure that the existing function of the facility is not compromised. A review of the existing footprint of the facility (2,250 m^2 +/-) in combination with the estimated available vertical grade between a potential new inlet and the invert of the existing overflow outlet (0.5 m +/-) has determined that sufficient storage volume may be available within the ramp loop (1,125 m^3 +/-, assuming re-grading of the ramp loop embankments is not feasible) to provide a meaningful opportunity for retrofit stormwater management (for perspective, the 100 year runoff volume from the Invicta Drive area to this location is 10,500 m^3 +/-).

Coordination with MTO would be required for any modifications of the facility. Based on review of the Final Drainage and Stormwater Management Report of the Highway 403-QEW Widening (MRC, 2014), it appears MTO plans to modify the facility as part of the proposed future QEW widening, which may present the opportunity for partnership, however stormwater management warrants for the QEW widening may reduce the opportunity for joint use.

Given the lack of direct benefit to the Invicta Drive Study Area, and the uncertainties around the existing and future function of the facility, this alternative has been screened from the current assessment. However further consultation with MTO may be warranted as part of the North Service Road widening study to identify opportunities to develop an integrated stormwater management system to retroactively treat Invicta Drive and meet the future needs for North Service Road and QEW associated with the proposed widening.

Alternative C2 Subsurface Flood Control : This alternative would provide subsurface storage volume within the Invicta Drive cul-de-sac to attenuate runoff from upstream private properties and the road right-of-way to reduce existing peak flows and associated flooding downstream within the easement between Invicta Drive and North Service Road. Existing private stormwater infrastructure and grades in the easement downstream have been reviewed to determine feasibility. The Stormwater Management Report for 1170 Invicta Drive (A.M. Candaras Associates Inc., 2001) indicates a control orifice invert elevation of 109.38 m (immediately north of Invicta Drive) and available Site Plan drawings for 1171 Invicta Drive (D. Greenfield Associates Ltd., 1989) indicate the easement elevation on the south of Invicta Drive is 109.41 m. Based on the grades of constraining drainage infrastructure on the north and south side of Invicta Drive, a vertical grade of -0.03 m is available across the right-of-way [negative grade is likely due to differences in datum for the two (2) Site Plans], indicating that implementation of underground storage would not be feasible. This alternative has therefore been screened from further consideration.

Alternative C3 Online Flood Control : This alternative would involve the addition of a control structure to utilize existing available storage volume within the easement between Invicta Drive and Node 3 (Link #4, ref. Figure 1, Appendix H) in order to reduce flows downstream. Based on available drainage plans for the adjacent private property (1171 Invicta Drive), a storm sewer outlets into the easement at an elevation of 109.0 m and an overflow weir (stainless steel notch within the retaining wall) outlets at an invert elevation of approximately 110.0 m. In the baseline condition, the 10 year and 100 year storm events have flow elevations within this easement of 108.78 m and 109.01 m, respectively, indicating that appreciable storage volume would not be available within the easement without impacting the operating function of adjacent SWM controls. Accordingly, this alternative has been screened from further consideration.

Alternative C4 Retrofit Source Control : This alternative would include the implementation of Low Impact Development (LID) Best Management Practices (BMPs) within the Invicta Drive right-of-way. LID BMPs are designed to reduce runoff volume, promote infiltration and/or provide water quality controls, however, typically have limited utility for flood control, especially for larger storm events. Considering typical soils across the Town of Oakville (i.e. low permeability Type C and D), soil infiltration rates are expected to be moderate to low, which would reduce the potential storage volume (assuming typical drawdown targets of 24-48 hours are met) which would further reduce flood control utility. As such, this alternative is not considered an effective stand-alone flood control solution, however LID BMPs could be considered as complementary to other alternatives, by providing supplementary flood storage, erosion and water quality control, and/or water balance. This alternative would also provide an opportunity to provide offsetting water quality treatment for the proposed North Service Road urbanization and widening. Given the aforementioned factors, this alternative has been screened as a standalone alternative from further consideration for the current assessment, however, should be considered further as part of future roadway urbanization studies.

5.1.4.2 *SHORT-LISTED ALTERNATIVES*

Further to the long-list of alternatives screening, the remaining alternatives are considered to warrant further consideration as part of the short-list. The short-listed alternatives have been modelled in PCSWMM to provide a quantitative assessment of their effectiveness through comparison with the baseline condition. The short-listed alternatives are described in more detail in the following sections. Table 14 presents the results of the assessment by comparing the conveyance capacity of Study Area infrastructure under each short-listed alternative and the baseline condition.

Alternative A Do-nothing : This alternative proposes no changes to baseline conditions. Although this alternative does not address the identified problems, in certain cases it can be advanced as the preferred alternative where there is limited benefit, or unacceptable impacts associated with the other alternatives under consideration. This alternative is carried forward to the short-list evaluation primarily as a requirement of the Class Environmental Assessment process.

Alternative B1 Easement Cross Section (Hydraulic) Improvements : Under this alternative, conveyance capacity in the southern reach of the easement (ref. Figure 2) is proposed to be improved through cross section modifications, specifically the flow area would be increased by implementing vertical retaining walls to maximize hydraulic effectiveness. A maximum bottom width of 4 m has been estimated in order to allow sufficient space to accommodate the proposed retaining walls within the existing 6.0 m easement at 1173 North Service Road (Le Dome property). The improvements would result in the loss of 1.7 to 2.3 m of the parking area and impact 33 spaces. It is likely the 21 spaces could be saved through re-painting the lot, the remaining 12 are alongside the building where there is limited available space.

It has been assumed that the proposed North Service Road widening will not provide sufficient space to maintain a ditch on the north side of the road based on a preliminary layout presented in Figure ES-3 of the Midtown Oakville Transportation and Stormwater Class EA (Cole, 2014). Therefore, the proposed urbanization of North Service Road would require new drainage works to maintain the outlet for the easement. These works are likely to take the form of a new storm sewer within the right-of-way, however existing ditch and road grades provide limited vertical grade and lowering of the downstream receiving ditch (Link #11) would be required on MTO lands (approximately 1 m). Lowering of this system is considered further under Option B2. The option of a new North Service Road cross culvert at the terminus of the easement may also be possible. There is no existing ditch on the south side of the road though and a preliminary review of existing grades has indicated that there would be insufficient cover to install a culvert without additional complementary works. It would be feasible to cut a receiving ditch on MTO land directly south to the north QEW ditch, allowing a cross culvert to be installed at a lower elevation, in combination with a drop inlet structure on the north side of North Service Road (or localized lowering). In either case, works on the south side of the North Service Road would need to be coordinated with MTO and consider the proposed QEW widening. For the purposes of the assessment of this alternative, it has been assumed that drainage works associated with the urbanization of North Service Road will maintain (at minimum) existing conveyance capacity through the North Service Road right-of-way and that the functional solution will be determined as part of the North Service Road urbanization design and in consultation with MTO. This assumption provides a conservative 'book-end' for this alternative as improvements to drainage conditions are expected as part of the urbanization and will improve the performance of this alternative further.

The new outlet works have been represented in the PCSWMM modelling conceptually assuming the culvert option is advanced (expected to represent a lower capital cost). The results in Table 14 demonstrate that Alternative B1 would increase the easement conveyance capacity from the 2 year to the 10 year storm event. Benefits would also be realized at the Shurguard Storage culvert for this alternative, which would be able to convey the 100 year event (versus the 50 year event in the baseline condition) achieving the assumed contemporary conveyance criteria (i.e. 100 year.) Due to the improved conveyance of flows at North Service Road, however, small increases in peak flows and water surface elevations at the QEW culvert (Link #12, ref. Figure 1) reduce its conveyance capacity, from the 50 year to the 25 year storm event. This alternative could potentially be combined with other alternatives to mitigate the loss in capacity at the QEW culvert as the MTO would traditionally not accept impacts to drainage systems along the highway corridor. It is noted that conveyance capacity of MTO culvert is proposed to be increased as part of the Final Drainage and Stormwater Management Report of the Highway 403-QEW Widening (MRC, 2014.)

Alternative B2 Easement Drainage System Lowering : This alternative would build on Alternative B1 by combining cross section improvements with lowering of the easement system and its outlet. As discussed for Alternative B1, new conveyance works are required to maintain the easement outlet after urbanization of North Service Road. For Alternative B2, lowering the system will provide additional grade such that the storm sewer option is more feasible. The storm sewer option (versus the cross culvert, see discussion in Alternative B1) has been assumed for

Alternative B2 given the improved feasibility of the storm sewer, and that the storm sewer reduces the scope of work on MTO lands. More specifically, Alternative B2 proposes to lower the ditch invert elevations within the Town's easement (Link #6, ref. Figure 1, Appendix H) a maximum of 1.8 m at the North Service Road and lower the ditch invert elevations on MTO property (Link #11, ref. Figure 1, Appendix H) a maximum of 1.5 m at North Service Road, and connect the two systems with a dedicated storm sewer (ref. Figure 3, Appendix H). Similar to Alternative B1, the available flow area in the easement would be increased using retaining walls. The proposed storm sewer (1200 mm diameter storm sewer with an approximate slope of 0.3%) has been conservatively sized under this alternative to convey the 100 year storm event without overtopping the North Service Road. It has been assumed that the proposed sewer would convey flow from the easement only, and drainage associated with the North Service Road would be conveyed by a separate storm sewer system, such that stormwater management for the future widening and urbanization of the North Service Road can be implemented without complication from the external Invicta Drive drainage area (i.e. external drainage area would impact oil-grit separators sizing and performance if implemented and online quantity control volumes). The existing road grades have been assumed to be approximately equal to the proposed road grades for the purposes of the assessment.

As presented in Table 5.4, the ditch within the easement (Link #6, ref. Figure 1, Appendix H) would be able to convey the 100 year storm event (i.e. no spill onto private property). Peak flows from the easement would not overtop North Service Road (Link #8, ref. Figure 1, Appendix H) for storm events up to and including the 100 year event, both of which would satisfy their respective design criteria. Benefits are also noted at the Shurguard Storage culvert (Link #5, ref. Figure 1), which would be able to convey the 100 year event (versus the 50 year event in the baseline condition). Due to the improved conveyance of flows at North Service Road, however, small increases in peak flows and water surface elevations at the QEW culvert (Link #12, ref. Figure 1, Appendix H) reduce its conveyance capacity, from the 50 year to the 25 year storm event. This alternative could potentially be combined with other alternatives to mitigate the loss in capacity at the QEW culvert as the MTO would traditionally not accept impacts to drainage systems along the highway corridor. It is noted that conveyance capacity of MTO culvert (Link #12) is proposed to be increased as part of the *Final Drainage and Stormwater Management Report of the Highway 403-QEW Widening* (MRC, 2014).

Alternative B4 Link #3 Conveyance Improvements : This alternative proposes improvements to the portion of the swale located within the Town's easement on properties 1171 and 1177 Invicta Drive, adjacent to Shurguard Storage (Link #3, ref. Figure 1, Appendix H) The swale's width in this location is limited to approximately 1 m to 2 m and is bound by development on both sides: retaining walls to the north (located within the boundaries of the Town easement) and paved laneways on the Shurguard Storage property to the south. Field reconnaissance performed on October 14, 2016 noted that the swale is overgrown with tall grass and brush.

It may be possible to improve conveyance capacity by implementing retaining walls along both sides of the easement, however the increase in flow area would be minor. Lowering the easement ditch system has not been considered as the open culvert through Shurguard Storage (i.e. Link #5, ref. Figure 1, Appendix H) has recently (i.e. < 5 years) undergone rehabilitation work (ref. Section 5.1.4.1, Alternative B5). Furthermore, flooding is not understood to have historically been reported along this reach, and given the aforementioned constraints, no physical works are recommended at this time. However, clearing and maintenance of vegetation in the swale would reduce roughness and offer improved conveyance capacity. This option has been evaluated assuming a decrease in the Manning's roughness coefficient (i.e. 0.070 to 0.030). The option to line the ditch with concrete would also be available. The results indicate that the frequency with which risk of flooding would occur on adjacent, private property would decrease from less than the 2 year to the 10 year storm event and the frequency that adjacent buildings at Shurguard Storage would be at risk of flooding would decrease from the 25 year to the 100 year storm event with this form of maintenance. It is noted that conveyance on private property would still be predicted at the 2 year event under this alternative (ref. Table 5.5).

It is noted that available Site Plans for 1177 Invicta Drive suggest the 100 year flow is contained within the limits of the swale (Link #3, ref. Figure 1, Appendix H)

Alternative D1 North Invicta Drive Diversion: This alternative proposes the installation of a storm sewer which would divert the north Invicta Drive drainage area to the western study area outlet, consistent with the balance of the Invicta Drive ROW. The proposed sewer would divert flows from 7.28 ha +/- of drainage area, with an average imperviousness of 55% (i.e. subcatchments SLWC-17-3, SLWC-17-11, SLWC-17-12, SLWC-17-13, ref. Figure 2, Appendix H), away from the Town easement (ultimately QEW culvert at Link #12) and toward the QEW culvert at Link #16. The proposed sewer would also prevent flows from the west side of Invicta Drive (i.e. subcatchments SLWC-17-17, SLWC-17-18, SLWC-17-19, SLWC-17-20, SLWC-17-21, ref. Figure 2, Appendix H) from spilling overland to Link 10, as it does in the baseline condition. This alternative assumes an urban or semi-urban cross-section for Invicta Drive and sufficient inlet capacity such that the diversion sewer acts as the major flow route for the diverted area (within the PCSWMM model, runoff has been directed into manholes, assuming ample inlet capacity). In order to convey the 100 year peak flow without surcharge, 550 m of storm sewer (1200 mm, 1350 mm, and 1500 mm diameter pipes) at a minimum slope of 0.25% would be required.

Alternative D1 would improve the capacity of the Shurguard culvert (Link #5) from the 50 year to the 100 year event. Improvements to conveyance versus the baseline condition are also noted at North Service Road (Link #8) and the MTO culvert (Link #12). However, capacity in the Town easement (Link #6) would not improve and the Le Dome property would remain at risk to flooding for all simulated storm events. Table 5.4 presents an impact assessment for the diversion by comparing the peak flow rates at both QEW culverts (Links #12 and #16) under the baseline condition and Alternative D1.

Table 5.4 Existing Condition and Alternative D1 Comparison of Maximum Simulated Peak Flows for the 2 to 100 Year Storm Events at QEW Culverts (m^3/s)

LOCATION	RETURN PERIOD (YEARS)					
	2	5	10	25	50	100
Westerly QEW Culvert (Conveyance Link #16)						
Baseline	1.27	1.57	1.87	2.24	2.48	2.68
Alternative D1	1.74	2.58	3.14	3.86	4.43	5.19
Difference (m^3/s)	+ 0.47	+ 1.01	+ 1.27	+ 1.62	+ 1.95	+ 2.51
Difference (%)	+ 37%	+ 64%	+ 68%	+ 72%	+ 79%	+ 94%
Easterly QEW Culvert (Conveyance Link #12)						
Baseline	2.35	3.19	4.03	5.33	6.31	7.29
Alternative D1	2.21	3.12	3.58	4.64	5.51	6.32
Difference (m^3/s)	- 0.14	- 0.07	- 0.45	- 0.69	- 0.80	- 0.97
Difference (%)	- 6%	- 2%	- 11%	- 13%	- 13%	- 13%

As demonstrated in Table 5.4, peak flows at the QEW Culvert (Link #16, ref. Figure 2, Appendix H) would increase for all simulated storm events with increases ranging from approximately +37% to +94% above baseline conditions. Peak flows at the QEW Culvert (Link #12) would decrease for all simulated storm events with reductions ranging from approximately -2% to -13% compared to baseline conditions.

It is noted that if this alternative is advanced, a more fulsome impact assessment would be required for both Wedgewood Creek tributaries downstream of the QEW. If impacts are determined to be unacceptable, flood control would be required to offset predicted peak flow increases and may limit the feasibility of this alternative. It is noted that MTO would traditionally not accept impacts to drainage systems along the highway corridor, however in this case the diversion would improve the level of service at one MTO culvert (Link #12) without reducing level of service at the receiver (Link #16). It is noted that conveyance capacity of MTO culvert (Link #12) is proposed to be increased as part of the *Final Drainage and Stormwater Management Report of the Highway 403-QEW Widening* (MRC, 2014.) This assessment could be completed as part of the modelling to be undertaken for the balance of the Lower Morrison and Lower Wedgewood Creek Class Environmental Assessment.

Alternative D2 Invicta Drive to Eighth Line Diversion (Preliminary Preferred Alternative): This alternative proposes the installation of a storm sewer which could divert the entire Invicta Drive ROW area to a QEW culvert outside the Invicta Drive catchment area near Eighth Line (ref. Figure 3, Appendix H). A stormwater management facility would likely be required to offset peak flow impacts to the receiving system (the receiving system is smaller than under Alternative D1, and the QEW culvert has not been modelled). It is understood from Town staff that Town-owned vacant lands may become available as part of the North Service Road realignment near Eighth Line which is expected to create an opportunity for a potential future SWM facility. In addition to reducing flood risk along the Town's easement, an opportunity for retroactive flood (and possibly quality) control for a significant portion of the Invicta Drive area would therefore be available. It is noted that a sub-option of this alternative would be diversion of a smaller area common with Alternative B1.

The proposed storm sewer would divert 15.99 ha +/- of drainage area, with an average imperviousness of 59% (i.e. subcatchments SLWC-17-3, SLWC-17-11, SLWC-17-12, SLWC-17-13, SLWC-17-17, SLWC-17-18, SLWC-17-19, SLWC-17-20, SLWC-17-21, ref. Figure 3, Appendix H). This alternative would require similar storm sewer infrastructure as for Alternative D1, however the length of sewer required would increase from 550 m to approximately 850 m.

Alternative D2 generates the same reduction in flood risk along the easement and downstream as Alternative D1 (ref. Table 4.2). The key benefit Alternative D2 offers over D1, is the potential to provide stormwater management to offset impacts of the diversion, as well as provide retroactive flood control and quality control to the overall benefit of Wedgewood Creek downstream. The extent of these benefits would require further assessment. Furthermore, the opportunity to integrate the required water quality and/or quantity controls for the future urbanization of the North Service Road and Invicta Road may also exist.

Alternative D2 was considered the preliminary preferred alternative prior to completion of the North Service Road Drainage and Stormwater Management Assessment.

Table 5.5 Alternative Assessment of System Hydraulic Conveyance Capacity

LINK #	CONVEYANCE LINK	CRITERIA USED TO MEASURE CAPACITY	FLOOD MECHANISM[2]	CONTEMPORARY DESIGN CRITERIA	CAPACITY[1]					
					ALTERNATIVE A (DO NOTHING /BASELINE)	ALTERNATIVE B1 (CONSTRUCT RETAINING WALLS WITHIN EASEMENT)	ALTERNATIVE B2 (SEWER, EASEMENT LOWERING, RETAINING WALLS)	ALTERNATIVE B4 (LINK #3 CONVEYANCE IMPROVEMENTS)	ALTERNATIVE D1 (DIVERSION TO NORTH SERVICE ROAD)	ALTERNATIVE D2 (DIVERSION TO EIGHTH LINE)
Easterly QEW Culvert (Conveyance Link #12)										
1	Invicta Drive Road Crossing Culvert (Bulb)	No spill across road	Spill east across Invicta Dr.	25 year	10 year	10 year	10 year	10 year	*100 year*	*100 year*
2	Storm sewer in easement 1177 Invicta Drive	No surcharge to ground surface	Spill southeast across private property	5 year	10 year	10 year	10 year	10 year	10 year	10 year
3	Easement Ditch	Conveyance within easement. No spill onto private property	Conveyance on private property	100 year	< 2 year	< 2 year	< 2 year	*10 year*	< 2 year	< 2 year
		Conveyance on private property but not impacting building	Conveyance impacts buildings		25 year	25 year	25 year	*100 year*	25 year	25 year
4	Easement Ditch	Flooding extent within easement. No spill onto private	N/A (Conveyance on private property)	100 year	100 year	100 year	100 year	100 year	100 year	100 year
5	Easement Culvert (Shurguard Storage)	Flooding extent within easement. No spill onto private property	Spills northeast to Shurguard Storage property	100 year	50 year	*100 year*	*100 year*	50 year	*100 year*	*100 year*
6	Easement Ditch	Flooding extent within easement. No spill onto private	Spills west to Le Dome and/or east to Lakeside	100 year	2 year	*10 year*	*100 year*	2 year	2 year	2 year
7	Le Dome East Driveway Culvert	No spill across driveway	Spills west along North Service Road	10 year	< 2 year	Removed under urbanization of North Service Road				
8	Easement-North Service Road Confluence	No spill across road	Spills east across road	50 Year	2 year	2 year	*100 year*	2 year	*5 year*	*5 year*
12	QEW Culvert	Greater than 1 m freeboard[3]	Less than 1 m freeboard[3]	50 Year	50 year	*25 year*	*25 year*	50 year	*100 year*	*100 year*
13	Invicta Drive Road Culvert – North Service Road Intersection	No spill across road	N/A (Flows are directed east along ditch to Lower Wedgewood Creek).	25 year	100 year	Removed under urbanization of North Service Road				
14	North Service Road Culvert	No spill across road	N/A (Flows are directed east along ditch to Lower	50 Year	100 year	Removed under urbanization of North Service Road				
16	QEW Culvert	Greater than 1 m freeboard[3]	N/A (Less than 1 m freeboard)[3]	50 Year	100 year	100 year	100 year	100 year	100 year	100 year

Notes:
1 Capacity values written in bold/italic indicate a difference versus the baseline condition.
2 Flood Mechanism' describes the type of flooding that occurs above the 'Simulated Capacity.'
3 Based on the MTO's desirable freeboard criteria as per the *Final Drainage and Stormwater Management Report of the Highway 403-QEW Widening* (MRC, 2014.)

5.1.4.3 *NORTH SERVICE ROAD STORMWATER MANAGEMENT REPORT*

All of preliminary short alternatives at the time of the original assessment required the following:

1. Integration with the North Service Road Project (completed after initial Invicta Drive Assessment);
2. Consultation and collaboration with the MTO due to potential impacts to the QEW right-of-way (grading) or to QEW drainage infrastructure with consideration of the future widening of the QEW; and/or
3. Further assessment of downstream impacts as part of the ongoing Lower Morrison and Lower Wedgewood Creek Class Environmental Assessment.

The Town of Oakville retained CIMA+ to complete the detailed design of North Service Road Widening and Realignment between Eighth Line and 1.0 kilometers east of Invicta Road. The Drainage and SWM Report assessed existing drainage conditions in the study area and provided an evaluation and assessment of roadway drainage and stormwater management for the proposed roadway realignment. The report also documented the background information, existing conditions, proposed road realignment and recommended stormwater management strategy water quality and quantity controls. The study area is bound by Queen Elizabeth Way (QEW) on the south and existing commercial/industrial buildings to the north.

~~The Midtown Class EA study identified the need for SWM improvements for water quantity and quality control for the study limits based on quantity control release rates, enhanced water quality treatment and 5 mm retention for drainage to the Wedgewood Creek watershed. Improvements to the roadway drainage including storm sewer construction, oil-grit separator implementation and culvert replacements were identified as part of the Midtown EA Drainage and SWM report. However, a SWM strategy for addressing quantity control, and preliminary design of SWM, storm sewer and culvert conveyance systems was not completed during the Midtown EA study.~~

The North Service Road Stormwater Management Report concluded the following:

1. No SWM quality controls currently exist along North Service Road right-of-way.
2. Six (6) existing culverts were identified to be generally in poor condition.
3. Existing flooding has been identified at the La Dome and North Service Road.
4. Existing culverts 2 and 5 are considerably undersized for the existing condition flows and culvert capacity.
5. Wood's Invicta Drive Assessment preliminary preferred was Alternative D2 which included diverting drainage from Invicta Drive west to a proposed SWM facility at Eighth Line and North Service Road.
6. Based on the updated PCSWMM assessment the preliminary preferred solution (Invicta Drive Assessment Alternative D2) integrated with the widening of North Service Road will provide an overall reduction in flows to all the outlets.
7. The proposed diversion from Invicta Drive to a new stormwater management facility at Eighth Line and North Service Road will mitigate the water quality, quantity, erosion and water budget impacts associated with the proposed roadway widening, while providing significant benefits to the receiving Wedgewood Creek.

~~The North Service Road Stormwater Management Report recommended the following:~~

~~1. The Invicta Drive diversion to a stormwater management facility (wet pond) at Eighth Line and North Service Road (alternative D2 as presented by Wood) is recommended as the preferred stormwater management strategy to mitigate the impacts to both water quality and quantity for the North Service Road widening project.~~

A summary of the stormwater management controls that are required versus the provided controls for the North Service Road area is provided within Table 5.6. The recommended stormwater management facility will exceed the stormwater management water quality, quantity, erosion and water budget volumes.

Table 5.1: Comparison of Required and Proposed North Service

	EXTENDED DETENTION (M^3)	PERMEANT POOL (M^3)	WATER BUDGET (M^3)	EROSION CONTROL (M^3)	EA MINIMUM QUANTITY CRITERIA (M^3)	TOTAL REQUIRED STORAGE VOLUME (M^3)
Total Required	167	686	103	514	1,057	2,526
Total Recommended	1,168	2,774	230	4,745	12,000	20,917

5.2 MIDTOWN ALTERNATIVE ASSESSMENT

5.2.1 INTRODUCTION

As part of the Lower Morrison Creek (LMC) and Lower Wedgewood Creek (LWC) watersheds, the Midtown Area (ref. Appendix 'A'), is planned to undergo significant redevelopment, infill and intensification and improvements to the existing road network. The Midtown Oakville Transportation and Stormwater Municipal Class Environmental Assessment (EA), Cole Engineering, June 2014, built off hydrology and stormwater management requirements established in the Lower Morrison/Wedgewood Creeks Flood, Erosion and Master Drainage Plan (MDP) Study, R.V. Anderson, January 1993. The Class EA assessed drainage and stormwater management (SWM) requirements for servicing the planned road improvements and future development up to the year 2031.

The Town of Oakville as part of this study, has requested that the SWM criteria established in the 2014 Class EA be reviewed and reassessed, based on concerns that Class EA storage volume requirements are considered high, erosion thresholds were not determined to establish unitary erosion storage volumes and release rates, and that there were inconsistencies in comparison to pre-development flows determined from the 1993 MDP.

This area specific assessment provides an overview of the existing conditions hydrologic assessment for both watersheds for the Midtown Area and provides the SWM criteria for erosion and quantity control under a future conditions land use scenario. The assessment reviews and compares the SWM criteria established through the Class EA to storage criteria requirements established herein. The SWM criteria assessment as requested by the Town, has determined SWM quantity controls with and without a flow diversion from the Lower Morrison Creek drainage area in Midtown to Sixteen Mile Creek.

5.2.2 BACKGROUND STUDIES

To assess erosion and quantity SWM criteria for the Midtown study area, background reports, mapping, drawings and other documents have been obtained from the Town of Oakville and reviewed. A summary of the background information has been provided in Appendix 'A'.

5.3 LOWER MORRISON/WEDGEWOOD CREEKS FLOOD, EROSION AND MASTER DRAINAGE PLAN STUDY (R.V. ANDERSON, JANUARY 1993)

The R.V. Anderson (RVA) MDP was initiated by the Town to provide direction in managing existing and future drainage, creek erosion and flooding within the Lower Morrison/Wedgewood Creek's watersheds. The study established SWM criteria and sizing to facilitate future development and prevent flooding and erosion within the respective watersheds. Regional Storm (Hurricane Hazel) floodplain mapping was also prepared as part of the MDP and was used to identity flood susceptible areas.

The MDP used OTHYMO as the hydrologic modelling platform for determining the runoff response and peak flow rates for the 2 to 100 year storm events and Regional Storm, resulting from both existing (1993) and a future land use condition abstracted from Town of Oakville's Official Plan (1985). The OTTHYMO urban runoff calculation method (URBHYD) was applied to all areas of the Lower Morrison/Wedgewood Creeks. Design storms for return periods ranging from 2 to 100 years were developed using the Keifer & Chu (Chicago Distribution) method which was and still used by the Town of Oakville as the required storm distribution. A time step of 15 minutes and a storm duration of 24 hours were used in the simulations. The existing conditions peak flows resulting from the OTTHYMO hydrologic modelling were reported at various locations as indicated in Table 5.6.

Table 5.6 MDP Existing Conditions Peak Flows (m^3/s)

CREEK SYSTEM	LOCATION	RVA DRAINAGE AREA (HA)	DESIGN STORMS						REGIONAL
			2 YEAR	5 YEAR	10 YEAR	25 YEAR	50 YEAR	100 YEAR	
LWC - EAST BRANCH	QEW	60	3.5	4.7	5.7	7.4	8.6	9.9	6.8
	CN RAILWAY	170	10.3	13.3	16.1	20.2	23.4	26.7	20.8
	CONSTANCE DRIVE	200	10.3	13.3	16.1	20.2	23.4	26.7	22.6
	AMBER CRESCENT	220	10.3	13.3	16.1	20.2	23.4	26.7	24.8
LWC - EAST BRANCH - WESTERN TRIBUTARY	QEW	30	1.9	2.5	3.1	4.0	4.7	5.4	4.0
LWC - WEST BRANCH	QEW	30	1.9	2.5	3.1	4.0	4.7	5.4	3.9
	CN RAILWAY	45	1.9	2.6	3.3	4.2	4.9	5.7	5.5
	DRUMMOND ROAD	90	3.0	3.9	4.9	6.4	7.5	8.7	10.4
LOWER WEDGEWOOD CREEK	ALSCOT CRESCENT	360	10.6	13.6	17.0	21.9	25.8	30.1	39.0
	LAKE ONTARIO	420	10.9	14.0	17.6	22.7	26.6	31.6	44.9
LMC - EAST BRANCH	QEW	40	5.7	7.3	8.6	10.5	11.9	13.3	5.3
	LINBROOK ROAD	75	6.7	8.5	10.1	12.4	14.1	15.9	9.9
	CN RAILWAY	130	7.6	10.6	13.2	17.0	20.0	23.0	12.9

CREEK SYSTEM	LOCATION	RVA DRAINAGE AREA (HA)	DESIGN STORMS						REGIONAL
			2 YEAR	5 YEAR	10 YEAR	25 YEAR	50 YEAR	100 YEAR	
LMC - WEST BRANCH	MAPLE AVENUE	160	7.6	10.6	13.2	17.0	20.0	23.0	15.3
	CHARTWELL ROAD	170	7.6	10.6	13.2	17.0	20.0	23.0	17.0
LOWER MORRISON CREEK	MORRISON ROAD	320	11.2	14.6	18.2	23.5	27.4	31.5	32.7
	LAKE ONTARIO	360	11.2	14.6	18.2	23.5	27.4	32.0	37.0

The OTTHYMO hydrologic model for Lower Morrison Creek and Lower Wedgewood Creek was not calibrated due to the unavailability of rainfall and runoff gauges within the watersheds. However, the study notes that "Mimico Creek Study" was reviewed to abstract calibrated parameters which were considered representative of conditions within the Lower Morrison/Wedgewood Creeks.

The MDP determined the following regarding SWM controls:

- Any new development which increases downstream peak flow rates should have runoff controls.
- Applying post-pre-development criteria to the undeveloped sites in the LMC/LWC basins would generate higher than existing downstream peak flow rates.
- Literature reviews and past experience indicated that post-development runoff rates should be controlled to 50% of pre-development levels in the case where erosion is a concern. If erosion is not a concern, then downstream peak flow rates should be controlled to 70% of predevelopment peak flow rates to maintain existing flood levels along the Lower Morrison Creek and Lower Wedgewood Creek.

The recommended storage requirements for SWM quantity controls for Lower Morrison Creek and Lower Wedgewood Creek as per this study have been provided in Section 5.2.

5.4 MIDTOWN OAKVILLE TRANSPORTATION AND STORMWATER MUNICIPAL CLASS EA (COLE ENGINEERING, JUNE 2014)

The main purpose of the report was to determine the hydrologic and hydraulic impacts of the preferred future land use and transportation network alternative and to advise on preliminary watercourse crossing requirements for the proposed transportation improvements within the study area.

The Midtown Class EA existing and future land use conditions were assessed using a Visual OTTHYMO (VO2) hydrologic model. Based on downstream hydraulic capacity constraints (i.e. Channel geometry, channel depth and channel slope), the VO2 hydrologic model was used to develop allowable discharge rates for both the Lower Morrison Creek and Lower Wedgewood Creek watersheds, which were then used to establish unitary storage volume rates for all future (2031) development. Alternative road networks included as part of future development were also assessed, with the preferred transportation network (ref. Appendix 'A') including:

- A new north-south crossing of the QEW;
- Improvements to Royal Windsor Drive;
- Improvements to Trafalgar Road QEW interchange;
- Extension of Cross Avenue; and

— Pedestrian, cycling and transit facility improvements.

Preliminary SWM sizing criteria were recommended as part of the Class EA, with a focus on setting peak flow targets for each watershed within the Midtown Oakville study area. The Class EA also included a preliminary assessment of water quality and erosion controls and water balance.

The VO2 model was executed using the 24-hour Chicago storm distribution as per Town's design criteria. No calibration or validation was conducted for the hydrologic model. SWM criteria for erosion controls were not assessed as part of the Class EA, as it was anticipated that the water balance criteria would provide inherent reductions in the runoff response, thus ensuring that downstream erosion conditions would not be increased through Midtown development.

The following SWM recommendations were provided by the Class EA:

— Peak runoff rates from all new developments within the Lower Morrison Creek and Lower Wedgewood Creek watersheds are to be controlled to 50% of the Class EA's pre-development flows in order to mitigate potential erosion and flooding (as per RVA recommendation).
— The target flows for Lower Wedgewood Creek will remain at 50% of existing flows, as per the R.V. Anderson Study. The existing flows from the R.V. Anderson Study will be applied as the target flows for Lower Morrison Creek.
— Future development within the Midtown Study Area, including the development of the proposed transportation improvements, is to use the Midtown Class EA Study hydrologic model, demonstrating that the target flows are met.

The design storm event peak flows for existing and future land use conditions along with final target flows (2 year to 100 year) have been provided in Tables 5.7, 5.8 and 5.9.

Table 5.7 Midtown Class EA Existing Conditions Peak Flows (m^3/s)

CREEK SYSTEM	DRAINAGE AREA (HA)	DESIGN STORMS						REG. STORM
		2 YEAR	5 YEAR	10 YEAR	25 YEAR	50 YEAR	100 YEAR	
Lower Morrison Creek	197.8	29.1	43.0	52.1	64.9	74.3	84.0	28.9
Wedgewood Creek	107.6	15.0	22.2	29.7	37.1	42.4	47.5	15.7
Morrison/Wedgewood Diversion channel	42.9	4.9	8.2	10.0	12.4	14.9	16.8	6.2
16 Mile Creek	73.0	11.4	16.6	20.0	24.7	28.2	31.7	10.7

Table 5.8 Midtown Class EA Future Conditions Peak Flows (m^3/s)

CREEK SYSTEM	DRAINAGE AREA (HA)	DESIGN STORMS					
		2 YEAR	5 YEAR	10 YEAR	25 YEAR	50 YEAR	100 YEAR
Lower Morrison Creek	197.8	29.2	43.1	52.3	65.1	74.4	84.2
Wedgewood Creek	107.6	15.3	22.6	30.6	37.8	43.2	48.3
Morrison/Wedgewood Diversion channel	42.9	4.9	8.2	10	12.4	14.9	16.8
16 Mile Creek	73.0	11.5	16.7	20.1	24.8	28.3	31.9

Table 5.9 Midtown Class EA Existing Conditions Target Flows (m^3/s)

CREEK SYSTEM	DRAINAGE AREA (HA)	DESIGN STORMS					
		2 YEAR	5 YEAR	10 YEAR	25 YEAR	50 YEAR	100 YEAR
Lower Morrison Creek	197.8	11.2	14.6	18.2	23.5	27.4	31.5
Wedgewood Creek	107.6	7.5	11.1	14.8	18.6	21.2	23.8
Morrison/Wedgewood Diversion channel	42.9	4.9	8.2	10	12.4	14.9	16.8
16 Mile Creek	73.0	11.4	16.6	20	24.7	28.2	31.7

The RVA MDP recommended provision of extended detention within future SWM facilities based on the high erosion sensitivity of the watercourse within the study area. The RVA MDP recommended that post development peak flows be controlled to 50% of pre-development peak flow rates, in order to control downstream bed and bank erosion (ref. Appendix 'A'). Based on the highly erosive systems as determined by RVA, the COLE Class EA also recommended that the post development with SWM target flows be considered at 50% of their existing peak flows.

5.4.1 HYDROLOGIC ASSESSMENT

A PCSWMM hydrologic/ hydraulic model has been developed to characterize the baseline condition of the Lower Morrison Creek and Lower Wedgewood Creek Watersheds. The PCSWMM model has been prepared using the model submitted as part of the Town of Oakville Stormwater Master Plan by Wood. The model has been updated for the hydrologic/hydraulic assessment of Lower Morrison and Lower Wedgewood Creeks.

As opposed to the previous hydrologic models of the study area (i.e. OTTHYMO models developed by R.V.A and Cole), the PCSWMM model consists of the dual drainage system to model the study area with more resolution. Since the major system upstream of Morrison-Wedgewood diversion channel also contributes to flows within Lower Morrison Creek and Lower Wedgewood Creek downstream of the study area, the drainage areas determined based on this model for various key junctions are different than previous studies.

Surficial soils data for the study area (as available from Agriculture Canada – Ontario Soil Survey Reports) is generally lacking; mapping for the study area indicates an urbanized land use and therefore does not provide more detailed information. Based on the soils information determined within Midtown from the Stormwater Master Plan, Fourteen Mile Creek and McCraney Creek Flood Mitigation Opportunities Study and the Natural Capital Project, the surficial geology within Midtown is predominantly characterized by coarse-textured glaciolacustrine deposits (sand, gravel, silt and clay).

The following hydrologic and hydraulic parameters and coefficients are in keeping with the overall Lower Morrison Creek and Lower Wedgewood Creek PCSWMM Model:

Subcatchments

- Impervious coverages as per the Stormwater Master Plan (ref. Appendix 'B')
- The Manning's 'n' value assigned to impervious surfaces is 0.013;
- The Manning's 'n' value assigned to pervious surfaces is 0.25;
- The depression storage assigned to impervious surfaces is 1 mm and 5 mm for the pervious surfaces;
- Based upon review of Table 24.2 within the User's guide to SWMM5, 13th Edition, the initial deficit fraction assigned for soils described herein is 0.25
- The hydraulic conductivity for the soils has been set to 3.5 mm/hr;
- The suction head for the soil has been assigned 50 mm;

— Subcatchment routing has been assigned to convey 40 % of the runoff to the pervious area, prior to conveyance to the subcatchment outlet.

Storm Sewers

— The entrance and exit loss coefficients assigned to storm sewers are 0.15 to 1 respectively (reference U.S. Department of Transportation Federal Highway Administration Hydraulic Engineering Circular 22 – Urban Drainage Design Manual, September 2009);
— The Manning's 'n' value assigned to road surfaces is 0.014. Typical industry standard for this parameter is 0.013; and
— The Manning's 'n' value assigned to ditches is 0.04. Typical industry standard for this parameter is 0.25.

5.4.2 EXISTING CONDITIONS

The existing conditions PCSWMM model consists of subcatchment parameters reflecting the existing land use condition (ref. Appendix 'B'). A drainage area plan for the Midtown area has been provided in Appendix 'B'. The model has been executed for the 2 to 100 year return period design storms using the Town of Oakville IDF parameters and the 24 hour Chicago distribution, to determine peak flow values at key locations. A comparison of the peak flows reported within the MDP and Midtown Class EA versus the existing conditions peak flows determined using the PCSWMM is provided in Tables 5.10 and 5.11.

As indicated in Tables 5.10 and 5.11, for Lower Wedgewood Creek, the existing land use conditions peak flows determined using the PCSWMM model are reasonably close to the flows reported in the Midtown MDP, which is to be expected based on the similar total drainage areas and low increases in the subcatchments' imperviousness coverages. However, for Lower Morrison Creek, the peak flows reported by the Midtown Class EA, are almost double compared to the peak flows determined by the PCSWMM model. Based on the information available in the Midtown Class EA, the difference in the peak flows is attributed to the collective effect of various factors.

The drainage area for Lower Morrison Creek (at Morrison Road) is smaller in the Midtown Class EA (197.75 ha) compared to the PCSWMM model (364.7 ha). The average imperviousness coverage is significantly higher in the Midtown Class EA VO2 model compared to the PCSWMM model (20% ± higher). For an urban setting like Midtown, the design storm event peak flows are sensitive to imperviousness coverages.

The Midtown Class EA VO2 model used the SCS Curve Number method for infiltration which is different from the Green-Ampt method used in the PCSWMM model. Moreover, the CN values used (ref. Appendix 'A') were high (on average 81 and 91 for AMC II and AMC III conditions respectively) which led to higher peak flows. Most of subcatchment parameters used for the VO2 modelling in the Midtown Class EA were not optimized by any model calibration/validation.

There are no routing elements in VO2 model which would impact the timing of runoff response hydrograph; whereas the PCSWMM model includes highly detailed routing elements. The lack of routing elements in the VO2 model would also result in no flow attenuation, leading to higher peak flows.

Table 5.10 Comparison of MDP and Midtown

CREEK SYSTEM	LOCATION	MDP DRAINAGE AREA (HA)	PCSWWM DRAINAGE AREA (HA)	PCSWMM ID	2 YEAR			5 YEAR			10 YEAR		
					MDP EXISTING (M^3/S)	CLASS EA EXISTING (M^3/S)	PCSWMM EXISTING (M^3/S)	MDP EXISTING (M^3/S)	CLASS EA EXISTING (M^3/S)	PCSWMM EXISTING (M^3/S)	MDP EXISTING (M^3/S)	CLASS EA EXISTING (M^3/S)	PCSWMM EXISTING (M^3/S)
LWC East Branch	QEW	60	70.9	J3163.656	3.5		7.0	4.7		10.9	5.7		13.5
	CN Railway	170	148.5	J2548.535	10.3		10.9	13.3		16.1	16.1		21.1
	Constance Drive	200	187.4	J2000	10.3		11.3	13.3		17.8	16.1		22.2
	Amber Crescent	220	194.8	J1699.827	10.3		11.3	13.3		17.5	16.1		23.8
LWC East Branch - Western Tributary	QEW	30	27	J14_Inv	1.9		2.8	2.5		3.9	3.1		5.2
LWC - West Branch	QEW	30	12.6	J17_Inv	1.9		0.9	2.5		1.3	3.1		1.5
	CN Railway	45	38.5	J2.90	1.9		3.0	2.6		4.6	3.3		5.7
	Drummond Road	90	83.8	J255.2208	3.0		4.6	3.9		7.2	4.9		8.8
Lower Wedgewood Creek	Confluence north of Devon Road		279.1	J1601.667			15.9			23.8			30.14
	Alscot Crescent	360	316.7	J885.2249	10.6	14.97	16.89	13.6	22.17	25.80	17.0	29.67	32.83
	Wedgewood Drive		342.4	J629.0537			17.1			26.3			32.51
	Lake Ontario	420	454.0	J32.22618	10.9		17.0	14.0		26.1	17.6		33.08
LMC East Branch	QEW	40	59.1	J1048.652	5.7		4.1	7.3		5.8	8.6		6.9
	Linbrook Road	75	106.6	J105.1801	6.7		7.63	8.5		11.2	10.1		13.3
	Cornwall Road		87.3	J455.662			6.29			9.74			11.55
LMC West Branch	CN Railway	130	159.7	J3268.867	7.6		6.3	10.6		9.9	13.2		12.5
	Maple Avenue	160	181.9		7.6			10.6			13.2		
	Chartwell Road	170	188.1	J2353.323	7.6		8.2	10.6		11.4	13.2		13.1
Lower Morrison Creek	Confluence east of Chartwell Road and south of Linbrook Road		297.7	J2251.686			15.7			22.4			25.8
	Morrison Road	320	364.7	J862.1866	11.2	29.09	16.28	14.6	42.99	24.10	18.2	52.12	27.83
	Lake Ontario	360	400.7	J16.24170	11.2		16.3	14.6		24.4	18.2		28.8

Note: Table cells that are empty, do not have data available

Table 5.11 Comparison of MDP, Midtown Class EA Versus Existing Conditions Peak Flows Determined using PCSWMM

CREEK SYSTEM	LOCATION	MDP DRAINAGE AREA (HA)	PCSWMM DRAINAGE AREA (HA)	PCSWMM ID	25 YEAR			50 YEAR			100 YEAR		
					MDP (M^3/S)	CLASS EA (M^3/S)	PCSWMM (M^3/S)	MDP (M^3/S)	CLASS EA (M^3/S)	PCSWMM (M^3/S)	MDP (M^3/S)	CLASS EA (M^3/S)	PCSWMM (M^3/S)
LWC East Branch	QEW	60	70.9	J3163.656	7.4		17.2	8.6		19.8	9.9		22.4
	CN Railway	170	148.5	J2548.535	20.2		28.76	23.4		32.43	26.7		36.22
	Constance Drive	200	187.4	J2000	20.2		26.8	23.4		30.3	26.7		33.9
	Amber Crescent	220	194.8	J1699.827	20.2		29.45	23.4		33.01	26.7		38.28
LWC East Branch - Western Tributary	QEW	30	27	J14_Inv	4.0		5.5	4.7		6	5.4		6.6
LWC - West Branch	QEW	30	12.6	J17_Inv	4.0		1.9	4.7		2.1	5.4		2.3
	CN Railway	45	38.5	J2.90	4.2		7.13	4.9		8.13	5.7		9.06
	Drummond Road	90	83.8	J255.2208	6.4		10.82	7.5		12.22	8.7		13.71
Lower Wedgewood Creek	Confluence north of Devon Road		279.1	J1601.667			37.3			42.76			48.3
	Alscot Crescent	360	316.7	J885.2249	21.9	37.13	40.23	25.8	42.44	45.99	30.1	47.49	51.46
	Wedgewood Drive		342.4	J629.0537			39.3			44.41			49.5
	Lake Ontario	420	454.0	J32.22618	22.7		40.5	26.6		46.76	31.6		53.0
LMC East Branch	QEW	40	59.1	J1048.652	10.5		7.8	11.9		10.7	13.3		12.0
	Linbrook Road	75	106.6	J105.1801	12.4		16.4	14.1		22.3	15.9		23.3
	Cornwall Road		87.3	J455.662			14.04			15.71			18.44
LMC West Branch	CN Railway	130	159.7	J3268.867	17.0		15.9	20.0		18.4	23.0		21.2
	Maple Avenue	160	181.9		17.0			20.0			23.0		
	Chartwell Road	170	188.1	J2353.323	17.0		17.0	20.0		19.5	23.0		21.8
Lower Morrison Creek	Confluence east of Chartwell Road and south of Linbrook Road		297.7	J2251.686			30.12			34.49			39.89
	Morrison Road	320	364.7	J862.1866	23.5	64.91	33.55	27.4	74.26	37.81	31.5	83.98	42.71
	Lake Ontario	360	400.7	J16.24170	23.5		34.56	27.4		38.84	32.0		43.17

Note: Table cells that are empty, do not have data available

5.4.3 FUTURE CONDITIONS WITHOUT SWM

The future land use conditions PCSWMM model has been prepared by using the existing conditions model as a base and updating the subcatchment imperviousness parameters to reflect the proposed future land use plan including the improved road network (ref. Appendix 'B'). The PCSWMM model has been executed for the 24 hr - Chicago Distribution 2-100 Year design storms, with peak flows determined at key locations. The peak flow results for the future land use conditions are provided in Table 5.12, with a comparison to existing conditions peak flows in Table 5.13 and percentage differences in Table 5.14.

Table 5.12 Future Conditions Peak Flows Without SWM (m^3/s)

CREEK SYSTEM	LOCATION	DRAINAGE AREA (HA)	DESIGN STORM EVENT					
			2 YEAR	5 YEAR	10 YEAR	25 YEAR	50 YEAR	100 YEAR
LWC - East Branch	CN Railway	148.5	10.9	16.1	21.1	28.76	32.43	36.22
	Amber Crescent	194.8	11.3	17.5	23.8	29.45	33.01	38.28
LWC - West Branch	CN Railway	38.5	3.0	4.6	5.7	7.13	8.13	9.06
	Drummond Road	83.8	4.6	7.2	8.8	10.82	12.22	13.71
Lower Wedgewood Creek	Confluence north of Devon Road	279.1	15.9	23.8	30.14	37.3	42.76	48.3
	Alscot Crescent	316.7	16.89	25.80	32.83	40.23	45.99	51.46
	Wedgewood Drive	342.4	17.1	26.3	32.51	39.3	44.41	49.5
	Lake Ontario	454.0	17.0	26.1	33.08	40.5	46.76	53.0
LMC - East Branch	QEW	59.1	4.1	5.8	6.9	7.8	10.7	12.0
	Linbrook Road	106.6	7.63	11.2	13.3	16.4	22.3	23.3
	Cornwall Road	87.3	6.29	9.74	11.55	14.04	15.71	18.44
LMC - West Branch	CN Railway	159.7	6.3	9.9	12.5	15.9	18.4	21.2
	Chartwell Road	188.1	8.2	11.4	13.1	17.0	19.5	21.8
Lower Morrison Creek	Confluence east of Chartwell Rd & south of Linbrook Rd	297.7	15.7	22.4	25.8	30.12	34.49	39.89
	Morrison Road	364.7	16.28	24.10	27.83	33.55	37.81	42.71
	Lake Ontario	400.7	16.3	24.4	28.8	34.56	38.84	43.17

Table 5.13 Difference of Future Conditions Peak Flows Without SWM to Existing Conditions (m^3/s)

CREEK SYSTEM	LOCATION	DRAINAGE AREA (HA)	DESIGN STORM EVENT					
			2 YEAR	5 YEAR	10 YEAR	25 YEAR	50 YEAR	100 YEAR
LWC - East Branch	CN Railway	148.5	0.5	0.5	0.2	0.6	0.7	0.7
	Amber Crescent	194.8	0.4	0.4	0.5	0.9	1.6	-0.4
LWC - West Branch	CN Railway	38.5	0.3	0.5	0.6	0.7	0.8	0.8
	Drummond Road	83.8	0.3	0.5	0.5	0.6	0.8	0.6
Lower Wedgewood Creek	Confluence north of Devon Road	279.1	0.6	0.7	0.8	0.9	1.1	1.0
	Alscot Crescent	316.7	0.8	0.8	0.9	1.0	1.1	1.1
	Wedgewood Drive	342.4	0.6	1.8	0.9	0.7	1.3	0.7

CREEK SYSTEM	LOCATION	DRAINAGE AREA (HA)	DESIGN STORM EVENT					
			2 YEAR	5 YEAR	10 YEAR	25 YEAR	50 YEAR	100 YEAR
	Lake Ontario	454.0	0.6	0.7	0.9	0.8	1.2	1.1
LMC - East Branch	QEW	59.1	0.6	0.7	0.4	3.5	0.7	0.6
	Linbrook Road	106.6	0.7	0.8	0.7	-0.5	-2.9	-0.1
	Cornwall Road	87.3	1.1	0.7	0.8	0.6	1.3	1.1
LMC - West Branch	CN Railway	159.7	0.8	1.2	1.2	1.2	1.6	1.3
	Chartwell Road	188.1	0.8	0.5	1.0	1.0	0.9	0.9
Lower Morrison Creek	Confluence east of Chartwell Rd & south of Linbrook Rd	297.7	1.5	1.2	0.9	1.9	1.6	1.6
	Morrison Road	364.7	1.5	1.2	1.4	1.5	1.5	1.9
	Lake Ontario	400.7	1.2	1.1	1.3	1.5	1.3	1.6

Table 5.14 Percentage Difference of Future Conditions Peak Flows Without SWM to Existing Conditions (%)

CREEK SYSTEM	LOCATION	DRAINAGE AREA (HA)	DESIGN STORM EVENT					
			2 YEAR	5 YEAR	10 YEAR	25 YEAR	50 YEAR	100 YEAR
LWC - East Branch	CN Railway	148.5	4.3%	3.3%	0.9%	2.0%	2.2%	1.8%
	Amber Crescent	194.8	3.6%	2.2%	2.1%	3.2%	4.8%	-1.0%
LWC - West Branch	CN Railway	38.5	11.0%	10.0%	10.1%	9.3%	9.4%	8.4%
	Drummond Road	83.8	6.3%	6.4%	6.0%	5.4%	6.3%	4.5%
Lower Wedgewood Creek	Confluence north of Devon Road	279.1	3.5%	3.0%	2.6%	2.5%	2.5%	2.1%
	Alscot Crescent	316.7	4.5%	3.0%	2.8%	2.5%	2.4%	2.1%
	Wedgewood Drive	342.4	3.3%	6.8%	2.7%	1.8%	2.8%	1.4%
	Lake Ontario	454.0	3.3%	2.8%	2.8%	1.9%	2.6%	2.1%
LMC - East Branch	QEW	59.1	15.7%	11.9%	5.9%	45.0%	6.2%	5.2%
	Linbrook Road	106.6	9.4%	7.1%	5.5%	-3.0%	-13.1%	-0.6%
	Cornwall Road	87.3	16.9%	7.3%	6.8%	4.3%	8.5%	6.0%
LMC - West Branch	CN Railway	159.7	13.3%	12.4%	9.8%	7.7%	8.7%	6.3%
	Chartwell Road	188.1	9.2%	4.4%	7.7%	5.9%	4.6%	4.1%
Lower Morrison Creek	Confluence east of Chartwell Rd & south of Linbrook Rd	297.7	9.8%	5.2%	3.5%	6.4%	4.7%	3.9%
	Morrison Road	364.7	9.5%	4.8%	4.9%	4.4%	4.0%	4.4%
	Lake Ontario	400.7	7.3%	4.4%	4.5%	4.3%	3.5%	3.6%

As anticipated, the future land use conditions without SWM predominantly result in higher peak flows than existing conditions at key locations within study area. Typically, the increase in the peak flows is the highest for frequent storm events (i.e. 2 year, 5 year) and is the lowest for less frequent storm events (i.e. 50 year, 100 year). The increase in the peak flows is the highest near the upstream end of the study area, where the proposed development will occur, and is lowest near the downstream end of the study area (i.e. Lake Ontario).

The peak flow percentage increases resulting from the PCSWMM model is slightly higher than the percentage increase determined in the Midtown Class EA, but significantly smaller than the percentage increase determined in the MDP. From the above peak flow tables, it is evident that stormwater management needs to be implemented to control future condition peak flows to existing conditions.

5.4.4 EROSION THRESHOLD ANALYSIS

Aqualogic Consultants have been retained by the Town to conduct an erosion threshold analysis for Lower Morrison Creek and Lower Wedgewood Creek in support of determining erosion control criteria for the Midtown area. Three (3) creek reaches have been selected for determining erosion critical flows (ref. Appendix 'A') in consultation with the Town of Oakville. Two (2) locations are on Lower Morrison Creek, while the remaining one (1) is on lower Wedgewood Creek. The drainage area for each location is as follows:

- Lower Morrison Creek Upstream Reach: 70 ha
- Lower Morrison Creek Downstream Reach: 180 ha
- Lower Wedgewood Creek: 260 ha

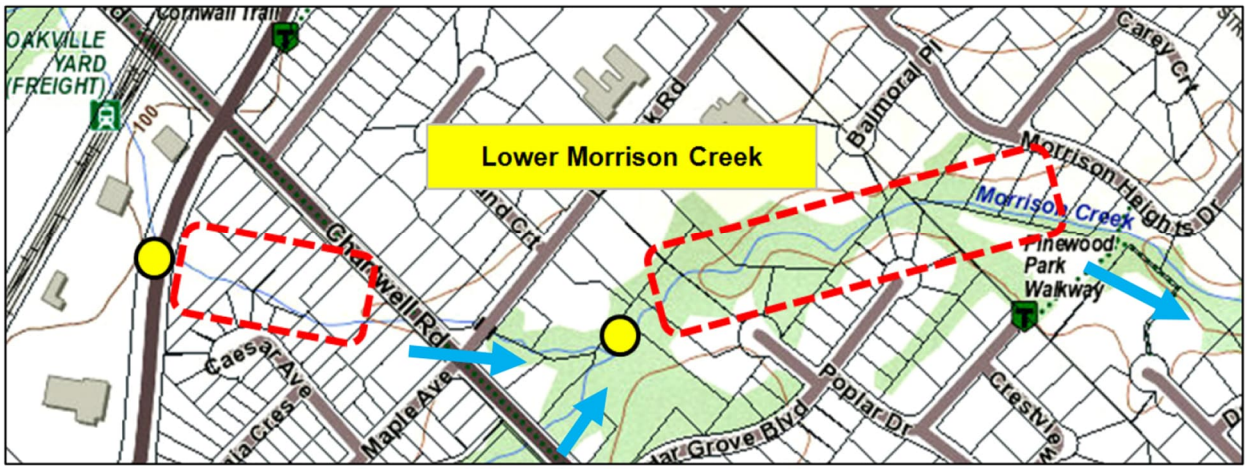

Figure 5.1 Lower Morrison Creek Erosion Sites

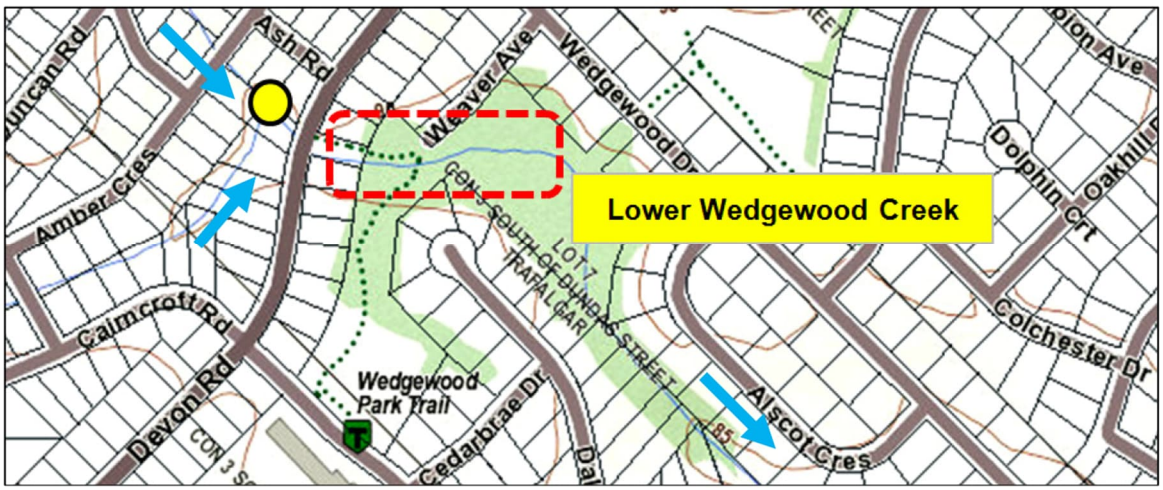

Figure 5.2 Lower Wedgewood Creek Erosion Sites

Erosion threshold analysis has been conducted using the five representative cross-sections over approximately 50 m of channel length for each location. Channel geometry has been measured laterally at each cross-section and the creek reaches longitudinal profiles have been surveyed and subsequently verified and compared to topographic mapping. Cross-section results as indicated in Table 5.15 have been obtained using the standard critical stability threshold criteria and specific iterations in cross-section models (ref. Appendix 'A').

Table 5.15 Creek Reach Critical Erosion Flows

LOCATIONS/ CREEK REACH	BANKFULL Q (M^3/S)	CRITICAL Q (M^3/S)
Lower Morrison Creek (Upstream Reach)	0.89	0.24
Lower Morrison Creek (Downstream Reach)	1.41	1.41
Lower Wedgewood Creek	1.70	1.47

Based on the erosion threshold analysis, the downstream reach of Lower Morrison Creek is deemed stable under existing bankfull flows, while each of the upstream reaches of Lower Morrison Creek and Lower Wedgewood Creek require adjustment to achieve stability.

5.4.5 STORMWATER MANAGEMENT ASSESSMENT

To address the impact of the future land use condition on peak flows and erosion conditions immediately downstream of the Midtown area, stormwater management erosion and quantity controls will be required.

The MDP provided stormwater management criteria (e.g. post development to pre-development peak flows), but did not provide recommended unitary storage volumes and discharge rates for each of the watersheds in the Midtown area.

The Midtown Class EA determined quantity (2 year to 100 year) unitary storage requirements and discharge rates for all development within the Midtown area. The Class EA did not differentiate between future development (infill/ intensification/ re-development and road improvements) and existing development. As such all-development areas were recommended to provide stormwater management controls to offset the impacts from future development. The Midtown Class EA did not provide unitary storage rates for erosion controls, it used the criteria that post development peak flows be controlled to 50% of pre-development peak flows (as per the MDP's recommendations), as such the erosion control volumes were incorporated into the quantity control storages.

Unitary quantity control storage rates for the Midtown area were provided in the Class EA as (m^3/ha), which for the purposes of this assessment have been converted to (m^3/imp.ha). The Midtown Class EA stormwater management requirements are provided in Tables 5.12 and Table 5.13 for comparison to the unitary storages determined from the PCSWMM modelling.

5.4.5.1 EROSION CONTROL ASSESSMENT

The future land use conditions PCSWMM model has been used to conduct an erosion assessment for each creek reach, by quantifying the hourly durational exceedances above the critical flows for a 42-year meteorological data set (1962 to 2003). The meteorological data set consists of recorded rainfall depth data at hourly interval.

The erosion assessment for the future land use conditions with SWM has been conducted under two separate scenarios, with and without a minor system (5 year) flow diversion from Lower Morrison Creek to Sixteen Mile Creek. The diversion was originally assessed by RVA in the MDP and subsequently by Cole Engineering in the Midtown Class EA, and has been assessed herein as requested by the Town.

5.4.5.2 EROSION ASSESSMENT WITH SWM (NO DIVERSION)

Under this scenario, the future land use conditions PCSWMM model, has been modified with storage elements representing various forms of stormwater management measures, located just downstream of the study area for each creek. Each storage element corresponded to either the West Branch or the East Branch of its corresponding creek.

The objective of the assessment has been to determine unitary storage requirements to maintain the hourly flow duration exceedances equal or below durations for existing land use conditions. Multiple assessment iterations with various unitary storage values of 150, 175, 200 and 300 m^3/imp. Ha have been conducted. A unitary storage of 160 m^3/imp. ha has been determined to be more than sufficient to provide erosion control for each creek. To establish erosion control requirements for each Midtown drainage outlet/creek, unitary flow rates have been determined based on the critical flow values at each location and the corresponding drainage area. Unitary storage volumes and discharge rates for each creek have been provided within Table 5.16. The unitary storage value of 160 m^3/imp.ha results in a slight overcontrol of erosion durations, that said, a storage value 150 m^3/imp.ha has been determined to not provide adequate erosion control. Tables 5.17 and 5.18 provide the duration exceedances and percentage differences for each creek for the various land use and SWM conditions.

Table 5.16 Unitary and Total Storage Volumes and Discharge Rates for Erosion Control Table

CREEK SYSTEM	BRANCH	DURATION EXCEEDANCES (HOURS)			
		UNITARY STORAGE (M^3/IMP. HA)	UNITARY DISCHARGE (M^3/S/HA)	TOTAL STORAGE (M^3)	DISCHARGE (M^3/S)
Lower Morrison Creek	West Branch	160	0.0078	6,587	1.027
	East Branch		0.0034	9,312	0.340
Lower Wedgewood Creek	West Branch		0.0057	5,458	0.211
	East Branch		0.0057	17,214	0.884

Table 5.17 Erosion Assessment Duration Exceedances (No Diversion)

LOCATIONS/CREEKS	PCSWMM JUNCTION ID	DURATION EXCEEDANCES (HOURS)		
		EXISTING	FUTURE WITH NO SWM	FUTURE WITH SWM
Lower Morrison Creek Upstream	J455.662	2,236	2,808	1,217
Lower Morrison Creek Downstream	J2251.686	590	729	312
Lower Wedgewood Creek	J1601.667	827	886	343

Table 5.18 Erosion Assessment Duration Exceedances Percentage Change (No Diversion)

LOCATIONS/CREEKS	PCSWMM JUNCTION ID	PERCENTAGE CHANGE IN DURATION EXCEEDANCES (HOURS)		
		EXISTING	FUTURE WITH NO SWM	FUTURE WITH SWM
Lower Morrison Creek (Upstream Reach)	J455.662	N.A.	+25.6%	-45.6%
Lower Morrison Creek (Downstream Reach)	J2251.686	N.A.	+23.5 %	-47.1%
Lower Wedgewood Creek	J1601.667	N.A.	+7.1%	-58.5%

5.4.5.3 *EROSION ASSESSMENT WITH SWM (WITH DIVERSION)*

As discussed in the MDP and the Midtown Class EA, there is an opportunity to divert flow from the West Branch of Lower Morrison Creek to the Sixteen Mile Creek along the newly proposed alignment of Cross Avenue from Trafalgar Road to west of Lyons Lane (ref. Appendix 'A'). For this assessment, similar to the approach within the Midtown Class EA, a storm sewer pipe has been added to the PCSWMM model, and has been configured to convey drainage from a subcatchment area of 20.7 ha (ref. Appendix 'A').

The main purpose of the flow diversion within the Class EA was to provide erosion control and hence, the design storms equal to or below 5-year return periods were considered to establish the pipe sizing. For less frequent storm events (i.e. 10, 25, 50 and 100 year design storms), the diversion pipe and appurtenances were not sized to capture and convey additional drainage. The storm sewer has been sized to be an 1800 mm diameter pipe at an average slope of 1%.

It was anticipated that the diversion of the Lower Morrison Creek West Branch toward the Sixteen Mile Creek for design storms of frequency 5 years or below, would help offset the increase in erosion exceedances durations in the watercourse. With the diversion in place, the future with SWM 25 year peak flow (11.1m^3/s) is below the existing conditions peak flow (15.9m^3/s). As such, no erosion control is required on the West branch of the Lower Morrison Creek due to the diversion. The full set of the results has been provided in Tables 5.19 and 5.20.

Table 5.19 Lower Morrison Duration Exceedances (With Diversion)

PCSWMM JUNCTION ID	DURATION EXCEEDANCES (HOURS)		
	EXISTING	FUTURE WITH NO SWM	FUTURE WITH SWM AND DIVERSION
J2251.686	590	729	109

Table 5.20 Erosion Assessment Duration Exceedances Percentage Change (With Diversion)

PCSWMM JUNCTION ID	PERCENTAGE CHANGE IN DURATION EXCEEDANCES (HOURS)		
	EXISTING	FUTURE WITH NO SWM	FUTURE WITH SWM
J2251.686	N.A.	+7.1%	-81.5%

5.4.5.4 *QUANTITY CONTROL ASSESSMENT*

To offset the impacts to peak flows resulting from the proposed future development and road improvements in the Midtown area, quantity controls for the 2 year to 100 year storm events will be required. The quantity controls have been determined using the design event methodology, as such the unitary storage volume requirements are to be considered above the erosion control unitary storage requirements. The same approach should be used for quantity unitary discharge release rates.

5.4.5.5 *QUANTITY CONTROL ASSESSMENT (NO DIVERSION)*

Stormwater quantity controls within Midtown have been assessed for each watershed to offset the peak flow impacts resulting from the future conditions land use. For this quantity control scenario, diversion of the Lower Morrison Creek West Branch has not been considered.

The PCSWMM hydrologic/ hydraulic model has been modified from the future land use model to include four (4) storage elements, with one (1) storage element for each of the East and West Branches of Lower Morrison Creek and Lower Wedgewood Creek. The discharge rates (target flows) for both the 25 year storm and 100 year storms have been set to either the lowest of the existing PCSWMM peak flows or the prorated pre-development 25 year and 100 year peak flows from the 1993 MDP, as discussed with the Town. A similar approach was used within the Midtown Class EA, where post development flows were controlled to lessor of either 50% of the Class EA existing peak flows or the 1993 MDP existing peak flows. As the PCSWMM existing land use condition is representative of 2017 land use conditions and the 1993 MDP existing land use was representative of a 1988 land use condition, controlling flows to the lessor of the PCSWMM existing land use condition or the MDP existing land use condition, would be a conservative approach.

Reducing the PCSWMM existing peak flows by 50%, has not been conducted, as the flow reduction approach within the 1993 MDP was to address erosion conditions, which have been addressed herein using an erosion threshold analysis and duration exceedance assessment. A comparison of existing peak flows/ unitary target flows from the MDP, Class EA and the PCSWMM modelling have been provided in Tables 5.21 and 5.22. The target flows used in the SWM quantity control assessment have been highlighted in Tables 5.21 and 5.22.

Table 5.21 Comparison of MDP and Midtown Class EA Versus the Existing Conditions PCSWMM Peak Flows

CREEK SYSTEM	LOCATION	2 YEAR				5 YEAR				10 YEAR			
		MDP (M^3/S)	CLASS EA (M^3/S)	CLASS EA 50% EXISTING (M^3/S)	PCSWMM (M^3/S)	MDP (M^3/S)	CLASS EA (M^3/S)	CLASS EA 50% EXISTING (M^3/S)	PCSWMM (M^3/S)	MDP (M^3/S)	CLASS EA (M^3/S)	CLASS EA 50% EXISTING (M^3/S)	PCSWMM (M^3/S)
LWC - East Branch	QEW	3.5			7.0	4.7			10.9	5.7			13.5
	CN Railway	10.3			10.9	13.3			16.1	16.1			21.1
	Constance Drive	10.3			11.3	13.3			17.8	16.1			22.2
	Amber Crescent	10.3			11.3	13.3			17.5	16.1			23.8
LWC - East Branch - Western Tributary	QEW	1.9			2.8	2.5			3.9	3.1			5.2
LWC - West Branch	QEW	1.9			0.9	2.5			1.3	3.1			1.5
	CN Railway	1.9			3.0	2.6			4.6	3.3			5.7
	Drummond Road	3.0			4.6	3.9			7.2	4.9			8.8
Lower Wedgewood Creek	Confluence north of Devon Road				15.9				23.8				30.14
	Alscot Crescent	10.6	15.0	7.5	16.89	13.6	22.2	11.1	25.80	17.0	29.7	14.8	32.83
	Wedgewood Drive				17.1				26.3				32.51
	Lake Ontario	10.9			17.0	14.0			26.1	17.6			33.08
LMC - East Branch	QEW	5.7			4.1	7.3			5.8	8.6			6.9
	Linbrook Road	6.7			7.63	8.5			11.2	10.1			13.3
	Cornwall Road				6.29				9.74				11.55
LMC - West Branch	CN Railway	7.6			6.3	10.6			9.9	13.2			12.5
	Maple Avenue	7.6				10.6				13.2			
	Chartwell Road	7.6			8.2	10.6			11.4	13.2			13.1
Lower Morrison Creek	Confluence east of Chartwell Road and south of Linbrook Road				15.7				22.4				25.8
	Morrison Road	11.2	29.1	14.5	16.28	14.6	43.0	21.5	24.10	18.2	52.1	26.1	27.83
	Lake Ontario	11.2			16.3	14.6			24.4	18.2			28.8

NOTE: empty cells in the above table represents unavailability of data.

The Values highlighted in this colour indicates Target flows set up by COLE by considering minimum of RVA Existing flows and Cole 50% Existing flows.

Table 5.22 Comparison of MDP and Midtown Class EA Versus Existing Conditions PCSWMM Peak Flows

CREEK SYSTEM	LOCATION	25 YEAR				50 YEAR				100 YEAR			
		MDP (M^3/S)	CLASS EA (M^3/S)	CLASS EA 50% EXISTING (M^3/S)	PCSWMM (M^3/S)	MDP (M^3/S)	CLASS EA (M^3/S)	CLASS EA 50% EXISTING (M^3/S)	PCSWMM (M^3/S)	MDP (M^3/S)	CLASS EA (M^3/S)	CLASS EA 50% EXISTING (M^3/S)	PCSWMM (M^3/S)
LWC - East Branch	QEW	7.4			17.2	8.6			19.8	9.9			22.4
	CN Railway	20.2			28.76	23.4			32.43	26.7			36.22
	Constance Drive	20.2			26.8	23.4			30.3	26.7			33.9
	Amber Crescent	20.2			29.45	23.4			33.01	26.7			38.28
LWC - East Branch - Western Tributary	QEW	4.0			5.5	4.7			6.0	5.4			6.6
LWC - West Branch	QEW	4.0			1.9	4.7			2.1	5.4			2.3
	CN Railway	4.2			7.13	4.9			8.13	5.7			9.06
	Drummond Road	6.4			10.82	7.5			12.22	8.7			13.71
Lower Wedgewood Creek	Confluence north of Devon Road				37.3				42.76				48.3
	Alscot Crescent	21.9	37.1	18.6	40.23	25.8	42.4	21.2	45.99	30.1	47.5	23.7	51.46
	Wedgewood Drive				39.3				44.41				49.5
	Lake Ontario	22.7			40.5	26.6			46.76	31.6			53.0
LMC - East Branch	QEW	10.5			7.8	11.9			10.7	13.3			12.0
	Linbrook Road	12.4			16.4	14.1			22.3	15.9			23.3
	Cornwall Road				14.04				15.71				18.44
LMC - West Branch	CN Railway	17.0			15.9	20.0			18.4	23.0			21.2
	Maple Avenue	17.0				20.0				23.0			
	Chartwell Road	17.0			17.0	20.0			19.5	23.0			21.8
Lower Morrison Creek	Confluence east of Chartwell Road and south of Linbrook Road				30.12				34.49				39.89
	Morrison Road	23.5	64.9	32.5	33.55	27.4	74.3	37.1	37.81	31.5	84.0	42.0	42.71
	Lake Ontario	23.5			34.56	27.4			38.84	32.0			43.17

NOTE: empty cells in the above table represents unavailability of data.

The Values highlighted in this colour indicates Target flows set up by COLE by considering minimum of RVA Existing flows and Cole 50% Existing flows.

The Values highlighted in this colour indicate Target flows set up by WSP by considering minimum of RVA Existing flows and WSP Existing flows (for the 25 year and 100 year storm events at the four storage elements).

The 25 year and 100 year storage volumes for each watershed branch have been iteratively assessed to meet the target flows. After multiple iterations, the unitary 25 year and 100 year storm event storages required for flood control have been determined and are provided in Table 5.23, along with the associated release rates, with a comparison of target flows versus actual flows in Table 5.24.

Table 5.23 Unitary and Total Storage Volumes and Discharge Rates for Quantity Control

CREEK SYSTEM	BRANCH	25 - YEAR			100 - YEAR		
		UNITARY STORAGE (M^3/IMP. HA)	TOTAL STORAGE (M^3)	DIS-CHARGE (M^3/S)	UNITARY STORAGE (M^3/IMP. HA)	TOTAL STORAGE (M^3)	DIS-CHARGE (M^3/S)
Lower Morrison Creek	West Branch	150	6,176	15.9	180	7,411	21.2
	East Branch	170	9,894	12.4	210	12,222	15.9
Lower Wedgewood Creek	West Branch	185	6,310	4.2	205	6,993	5.7
	East Branch	200	21,518	20.2	230	24,746	26.7

Table 5.24 Comparison of Target Flows with Simulated Flows for Quantity Control

CREEK SYSTEM	BRANCH	25 - YEAR		100 - YEAR	
		SIMULATED FLOW (M^3/S)	TARGET FLOW (M^3/S)	SIMULATED FLOW (M^3/S)	TARGET FLOW (M^3/S)
Lower Morrison Creek	West Branch	15.4	15.9	20.3	21.2
	East Branch	12.1	12.4	15.8	15.9
Lower Wedgewood Creek	West Branch	4.2	4.2	5.7	5.7
	East Branch	20.1	20.2	26.1	26.7

The total storages required for Lower Morrison Creek and Lower Wedgewood Creek as determined within the MDP, Midtown Class EA have been compared to the storage volumes determined from the PCSSWMM modelling in the Table 5.25. Total storage determined for the quantity control has incorporated the erosion control storage volumes.

Table 5.25 Comparison of Unitary and Total 100 Year Storage Required per MDP, Class EA and PCSWMM Modelling

CREEK SYSTEM	UNITARY STORAGE (M^3/IMP. HA)			TOTAL STORAGE (M^3)		
	MDP	CLASS EA	PCSWMM	MDP	CLASS EA	PCSWMM
Lower Morrison Creek	318	386	358	48,000	55,552	35,532
Lower Wedgewood Creek	352	287	384	51,000	26,934	54,410

The resulting 100 year peak flows have been provided in Table 5.26. It should be noted that the quantity controls have been determined to meet the target flows at the outlets of the Midtown area for their respective watercourse. Hence the suggested unitary storage for the quantity controls are sufficient to meet the existing flows downstream of the study area. The peak flows at locations upstream of the four (4) storage elements have been italicized in Table 5.26 for the Future with SWM Scenario, to indicate area-rated values, as flow values upstream of the storage elements are not representative of the SWM condition.

Table 5.26 Comparison of Existing, Future and Future with SWM PCSWMM Peak Flows

CREEK SYSTEM	LOCATION	EXISTING (M^3/S)	FUTURE (M^3/S)	FUTURE SWM (M^3/S)
LWC - East Branch	CN Railway	36.2	36.9	*24.8**
	Amber Crescent	38.3	37.9	30.0
LWC - West Branch	CN Railway	9.1	9.8	*5.3**
	Drummond Road	13.7	14.3	9.4
Lower Wedgewood Creek	Alscot Crescent	51.5	52.5	38.9
	Lake Ontario	53.0	54.1	42.8
LMC - East Branch	QEW	12.0	12.6	*9.4**
	Linbrook Road	23.3	23.2	20.3
LMC - West Branch	CN Railway	21.2	22.5	21.7
	Chartwell Road	21.8	22.7	21.8
Lower Morrison Creek	Morrison Road	42.7	44.6	39.4
	Lake Ontario	43.2	44.7	39.7

Note: * indicates peak flows upstream of storage elements and their values are area-rated.

5.4.5.6 *QUANTITY CONTROL ASSESSMENT (WITH DIVERSION)*

The diversion from the West Branch of Lower Morrison Creek to the Sixteen Mile Creek along the newly proposed alignment of Cross Avenue has been discussed in Section 5.4.5.3. The diversion has been sized to capture and convey the five year storm event. With the diversion incorporated into the PCSWMM model the Lower Morrison Creek unitary 25 year and 100 year storm event storages required for flood control have been determined and are provided in Table 5.27, along with the associated release rates. A comparison of target flows versus actual flows has been provided in Table 5.28. The total storages have been provided in Table 5.29 and the resulting peak flows downstream of Midtown have been provided in Table 5.30. As indicated in Section 5.4.5.3. and for the same reasons, the future with SWM peak flows downstream of the Midtown area do not match the existing peak flows. The peak flows at the locations upstream of the SWM facilities have been italicized in Table 5.30 to indicate the area-rated values.

Table 5.27 Unitary and total Storage Volumes and Discharge Rates for Quantity Control with Diversion Scenario

CREEK SYSTEM	BRANCH	25 - YEAR			100 - YEAR		
		UNITARY STORAGE (M^3/IMP. HA)	TOTAL STORAGE (M^3)	DIS-CHARGE (M^3/S)	UNITARY STORAGE (M^3/IMP. HA)	TOTAL STORAGE (M^3)	DIS-CHARGE (M^3/S)
Lower Morrison Creek	West Branch	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
	East Branch	170	9,894	12.4	210	12,222	15.9
Lower Wedgewood Creek	West Branch	185	6,310	4.2	205	6,993	5.7
	East Branch	200	21,518	20.2	230	24,746	26.7

Table 5.28 Comparison of Target Flows with Simulated Flows for Quantity Control with Diversion Scenario

CREEK SYSTEM	BRANCH	25 - YEAR		100 - YEAR	
		SIMULATED FLOW (M^3/S)	TARGET FLOW (M^3/S)	SIMULATED FLOW (M^3/S)	TARGET FLOW (M^3/S)
Lower Morrison Creek	West Branch	15.4	15.9	20.4	21.2
	East Branch	12.1	12.4	15.8	15.9
Lower Wedgewood Creek	West Branch	4.2	4.2	5.7	5.7
	East Branch	20.1	20.2	26.1	26.7

Table 5.29 Comparison of Unitary and Total 100-Year Storages Required per MDP, Class EA and PCSWMM Modelling for Quantity Control with Diversion Scenario

CREEK SYSTEM	100-YEAR UNITARY STORAGE (M^3/IMP. HA)			100 – YEAR TOTAL STORAGE (M^3)		
	MDP	CLASS EA	PCSWMM	MDP	CLASS EA	PCSWMM
Lower Morrison Creek	318	386	217	48,000	55,552	21,534
Lower Wedgewood Creek	352	287	384	51,000	26,934	54,410

Table 5.30 Comparison of PCSWMM Peak Flows with Diversion Scenario

CREEK SYSTEM	LOCATION	EXISTING (M^3/S)	FUTURE (M^3/S)	FUTURE SWM (M^3/S)
LWC - East Branch	CN Railway	36.2	36.9	*24.8**
	Amber Crescent	38.3	37.9	29.5
LWC - West Branch	CN Railway	9.1	9.8	*5.3**
	Drummond Road	13.7	14.3	9.4
Lower Wedgewood Creek	Alscot Crescent	51.5	52.5	38.9
	Lake Ontario	53.0	54.1	42.7
LMC - East Branch	QEW	12.0	12.6	*9.4**
	Linbrook Road	23.3	23.2	15.5
LMC - West Branch	CN Railway	21.2	22.5	20.1
	Chartwell Road	21.8	22.7	18.9
Lower Morrison Creek	Morrison Road	42.7	44.6	35.6
	Lake Ontario	43.2	44.7	36.5

Note: * indicates peak flows upstream of storage elements and their values are area-rated.

5.4.5.7 *COMPARISON OF DIVERSION VERSUS NON- DIVERSION SCENARIOS*

A comparison of the diversion versus non-diversion scenarios has been conducted to determine which scenario would be preferred with a comparison of storage being required provided in Table 5.31. As background to the results in Table 5.32 the following has been provided:

— Erosion control storages are based on erosive critical flows using a continuous model, with controls applied to at least maintain existing duration exceedances.

— 25 year and 100 year storm quantity storage control rates have been established based on target flows, which in the Midtown Assessment are based on the lower of the MDP, and PCSWMM existing peak flows as requested by the Town.

— For Diversion the unitary storage rates (m3/ imp.ha) are as per the following, with the 100 year storage including the 25 year storage value.

— The storage values have to been established based on the total impervious coverage for the Midtown area, as such unitary storage rates are to be applied to the entire site impervious coverage, therefore if there is no increase in impervious coverage for a site, the total storage rates would still be applied when it develops.

Table 5.31 Comparison of Storage Requirement

CREEK SYSTEM	BRANCH	NO DIVERSION				DIVERSION			
		EROSION	25 YR	100 YR	TOTAL	EROSION	25 YR	100 YR	TOTAL
Lower Morrison Creek	West Branch	160	150	180	340 (160+180)	0	0	0	0
	East Branch	160	170	210	370 (160+210)	160	170	210	370 (160+210)
Lower Wedgewood Creek	West Branch	160	185	205	365 (160+205)	160	185	205	365 (160+205)
	East Branch	160	200	230	390 (160+230)	160	200	230	390 (160+230)

In addition to the storage requirements, capital costs have been determined for each scenario. The Non-Diversion Scenario capital cost has been estimated at $7.19 M, while the Diversion Scenario would have a cost of $7.40 M (ref. Appendix I). Based on the significant different cost difference the Non-Diversion Scenario is the preferred scenario. The following section on low impact development has used the Non-Diversion Scenario.

5.4.5.8 *LOW IMPACT DEVELOPMENT*

The Town of Oakville Stormwater Master Plan through an iterative process of applying source controls in 5 mm increments to offset the impacts due to climate change and land use intensification, determined that source control ranging between 20-25 mm of capture would be required. Due to the variation in capture required to achieve the equivalent targets, the minimum capture of 25 mm was selected for low impact development (LID) best management practices.

To assess the benefit of applying 25 mm capture for the impervious surfaces within Midtown for the future land use condition with SWM, the PCSWMM model has been modified to include 25 mm of capture (i.e. detention of runoff through infiltration and/or evaporation). The 25mm capture would provide adequate control for the erosion critical flows as indicated in Tables 5.32 and 5.33 below, as such erosion control storage would not be required for Midtown development.

Table 5.32 Erosion Assessment Duration Exceedances (No Diversion)

LOCATIONS/CREEKS	PCSWMM JUNCTION ID	DURATION EXCEEDANCES (HOURS)			
		EXISTING	FUTURE WITH NO SWM	FUTURE WITH SWM	FUTURE WITH LID
Lower Morrison Creek (Upstream Reach)	J455.662	2,236	2,808	1,217	1,265

LOCATIONS/CREEKS	PCSWMM JUNCTION ID	DURATION EXCEEDANCES (HOURS)			
		EXISTING	FUTURE WITH NO SWM	FUTURE WITH SWM	FUTURE WITH LID
Lower Morrison Creek Downstream	J2251.686	590	729	312	376
Lower Wedgewood Creek	J1601.667	827	886	343	475

Table 5.33 Erosion Assessment Duration Exceedances Percentage Change (No Diversion)

LOCATIONS/CREEKS	PCSWMM JUNCTION ID	PERCENTAGE CHANGE IN DURATION EXCEEDANCES (HOURS)			
		EXISTING	FUTURE WITH NO SWM	FUTURE WITH SWM	FUTURE WITH LID
Lower Morrison Creek (Upstream Reach)	J455.662	N.A.	+25.6%	-45.6%	-43.4%
Lower Morrison Creek (Downstream Reach)	J2251.686	N.A.	+23.5 %	-47.1%	-36.2%
Lower Wedgewood Creek	J1601.667	N.A.	+7.1%	-58.5%	-42.6%

The following table indicates the total drainage areas for each tributary including areas upstream of Midtown and the “equivalent” storage provided by 25mm capture. Being consistent with the Oakville Masterplan, the 25mm capture has only been applied to the impervious area.

Table 5.34 Comparison of Storage Volume Requirements for Flood Control With and Without LID

CREEK SYSTEM	BRANCH	TOTAL DRAINAGE AREA (HA)	IMPERVIOUS AREA (HA)	STORAGE VOLUME PROVIDED BY 25MM CAPTURE USING LID BMPS (M^3)	ED VOLUME REQUIRED – NO LID (M^3) (PER160 M^3/IMP. HA[1])	VOLUME REQUIRED FOR QUANTITY CONTROL -NO LID (M^3) (VARIES)	BALANCE OF VOLUME (M^3)
Lower Morrison Creek	West Branch	131.06	75.97	18,993	6,587	7,411	-4,995
	East Branch	99.25	75.11	18,778	9,312	12,222	2,757
Lower Wedgewood Creek	West Branch	37.33	30.64	7,660	5,458	6,993	4,790
	East Branch	156.37	107.59	26,898	17,214	24,746	15,063

1: The unitary criteria is based on total impervious area within Midtown only and not the overall total drainage area.

As shown in Table 5.35, for Lower Morrison Creek West Branch the total required volume for erosion and flood control is less than the volume provided by 25mm capture which explains the negative value for the balance of volume. Please note that balance of volume does not provide the actual volume required for flood control but only a sense of what could be anticipated in terms of storage requirement for flood control. The following tables indicate the actual storage volumes required for flood control with 25mm capture using LID BMPs and their performance.

Table 5.35 Unitary and Total Storage Volumes and Discharge Rates for Quantity Controls

CREEK SYSTEM	BRANCH	25 - YEAR		100 - YEAR	
		UNITARY STORAGE – NO LID (M^3/IMP. HA)	UNITARY STORAGE – WITH LID (M^3/IMP. HA)	UNITARY STORAGE – NO LID (M^3/IMP. HA)	UNITARY STORAGE WITH LID (M^3/IMP. HA)
Lower Morrison Creek	West Branch	150	N.A.	180	N.A.
	East Branch	170	85	210	125
Lower Wedgewood Creek	West Branch	185	115	205	150
	East Branch	200	75	230	130

As indicated in Table 5.35 Lower Morrison Creek West Branch would not require any quantity control with 25 mm capture. The 25 mm capture provides sufficient storage to reduce future peak flows to target peak flows. Table 5.36 illustrates the revised unitary volumes with LID 25mm capture provided, and target flows, while Table 5.37 provides a comparison of target peak flows versus simulated peak flows, demonstrating that simulated peak flows are at or below target peak flows.

Table 5.36 Unitary and Total Storage Volumes and Discharge Rates for Quantity Control (With LID)

CREEK SYSTEM	BRANCH	25 - YEAR			100 - YEAR		
		UNITARY STORAGE (M^3/IMP. HA)	TOTAL STORAGE (M^3)	DISCHARGE (M^3/S)	UNITARY STORAGE (M^3/IMP. HA)	TOTAL STORAGE (M^3)	DISCHARGE (M^3/S)
Lower Morrison Creek	West Branch	N.A.	-	15.9	N.A.	-	21.2
	East Branch	85	4947	12.4	125	7275	15.9
Lower Wedgewood Creek	West Branch	115	3923	4.2	150	5117	5.7
	East Branch	75	8069	20.2	130	13987	26.7

Table 5.37 Comparison of Target Flows with Simulated Flows for Quantity Control (With LID)

CREEK SYSTEM	BRANCH	25 – YEAR		100 – YEAR	
		SIMULATED FLOW (M^3/S)	TARGET FLOW (M^3/S)	SIMULATED FLOW (M^3/S)	TARGET FLOW (M^3/S)
Lower Morrison Creek	West Branch	15.3	15.9	19.0	21.2
	East Branch	12.4	12.4	15.7	15.9
Lower Wedgewood Creek	West Branch	4.2	4.2	5.6	5.7
	East Branch	20.6	20.2	26.2	26.7

The total storages required for Lower Morrison Creek and Lower Wedgewood Creek as determined within the MDP, Midtown Class EA have been compared to the storage volumes determined from the PCSWMM modelling in the Table 5.38. Total storage determined for the quantity control has incorporated the erosion control storage volumes (which with the implemented 25mm capture are 0).

Table 5.38 Comparison of Unitary and Total 100 Year Storage Required per MDP, Class EA and PCSWMM Modelling

CREEK SYSTEM	UNITARY STORAGE (M^3/IMP. HA)				TOTAL STORAGE (M^3)			
	MDP	CLASS EA	PCSWMM – NO LID	PCSWMM – WITH LID	MDP	CLASS EA	PCSWMM – NO LID	PCSWMM – WITH LID
Lower Morrison Creek	318	386	358	73	48,000	55,552	35,532	7,275
Lower Wedgewood Creek	352	287	384	135	51,000	26,934	54,410	19,103

5.4.5.9 *CLIMATE CHANGE*

Based upon the results of the climate change assessment conducted as part of the Town of Oakville Stormwater Master Plan, it was recommended that the Town maintain the Environment and Climate Change Canada Toronto City station as the basis for the Town's design IDF relationship as part of its stormwater management guidelines and policies. Climate change scenarios were assessed through the Master Plan based upon projections for 2050 and 2080. The Stormwater Master Plan used the IDF relationship for the 5 year 2080 climate change scenario (given that any infrastructure planned under the Master Plan would be expected to have an engineered life of 50 to 100 years) to assess future land use conditions and impacts to infrastructure. In keeping with the Master Plan, the projected 2080 IDF relationship has been used to assess the impacts to future land use condition with SWM peak flows at the outlets of the Midtown area and to the Lake. Table 5.39 compares peak flows resulting from the existing land use condition (non climate change IDF relationship) to the future land use condition with SWM, SWM sized with the benefit of LID and SWM sized without the benefit of LID but with LID applied (with and without the climate change IDF relationship). Results indicate that future with SWM (SWM sized without the benefit of LID but with LID applied) peak flows would not increase at the Lake, for the climate change scenario with SWM storages and LID applied, but there would be slight increases upstream on Lower Morrison Creek.

Table 5.39 Comparison of 100 Year Design Storm Event Peak Flows Under Various Scenarios

CREEK SYSTEM	LOCATION	EXISTING (M^3/S)	FUTURE SWM WITHOUT LID_1 (M^3/S)/ % DIFFERENCE	FUTURE SWM WITH LID_2 (M^3/S)/ % DIFFERENCE	FUTURE Full SWM WITH LID_3 (M^3/S)/ % DIFFERENCE	FUTURE 2080 SWM WITHOUT LID_1 (M^3/S)/ % DIFFERENCE	FUTURE 2080 SWM WITH LID_2 (M^3/S)/ % DIFFERENCE	FUTURE 2080 Full SWM WITH LID_3 (M^3/S)/ % DIFFERENCE
LWC - East Branch	Amber Crescent	38.3	30.0 / -22	29.8 / -22	30.4 / -21	38.0 / -1	37.0 / -3	37.0 / -3
LWC - West Branch	Drummond Road	13.7	9.4 / -32	8.9 / -35	8.9 / -35	11.7 / -15	10.9 / -20	10.9 / -21
Lower Wedgewood Creek	Alscot Crescent	51.5	38.9 / -24	38.5 / -25	38.6 / -25	48.3 / -6	46.8 / -9	46.8 / -9
	Lake Ontario	53.0	42.8 / -19	42.7 / -19	42.7 / -19	52.0 / -2	50.9 / -4	50.9 / -4
LMC - East Branch	Linbrook Road	23.3	20.3 / -13	15.7 / -33	14.6 / -37	21.9 / -6	20.8 / -11	19.4 / -17
LMC - West Branch	Chartwell Road	21.8	21.8 / 0	22.6 / +4	20.6 / -6	24.7 / +13	25.4 / +16	23.4 / +7
Lower Morrison Creek	Morrison Road	42.7	39.4 / -8	40.8 / -5	36.3 / -15	46.3 / +8	46.4 / +9	43.0 / +1
	Lake Ontario	43.2	39.7 / -8	41.0 / -5	38.6 / -11	47.0 / +9	47.1 / +9	43.2 / 0

1. Refers to the SWM volumes as determined with no LID (ref. Table 5.38: SWM volumes of 35,532 m^3 and 54,410 m^3)
2. Refers to the SWM volumes determined with LID (ref. Table 5.38: SWM volumes of 7,275 m^3 and 19,103 m^3)
3. Refers to the SWM volumes as determined with no LID, but with LID applied (ref. Table 5.38: SWM volumes of 35,532 m^3 and 54,410 m^3)

5.4.6 MIDTOWN ASSESSMENT FINDINGS

The following findings have been made based on Midtown SWM assessment and review of the MDP and Class EA SWM requirements.

1. The Lower Morrison Creek and Lower Wedgewood Creek watersheds would incur increases in peak flows for all design storm events (i.e. 2-100 year) under future land use conditions (i.e. Midtown land development, Ref. Appendix 'B').
2. An erosion threshold analysis has been conducted by Aqualogic Consulting which defines the bankfull and critical flows for three (3) locations within the Lower Morrison Creek and Lower Wedgewood Creek watersheds.
3. The Lower Morrison Creek and Lower Wedgewood Creek watersheds would incur an increase in erosive hourly durations under future land use conditions (i.e. Midtown land development, Ref. Appendix 'B').
4. Sizing the stormwater management quantity control using the unitary sizing criteria determined using the PCSWMM modelling would provide the requisite flood control for the future Midtown land use condition, as per Table 5.38 and Table 5.39.
5. Erosion controls based on the erosion unitary storages and discharges would address requirements for maintaining or reducing erosive flow durations downstream of Midtown for the future land use conditions.
6. Flow diversion of the West Branch of Lower Morrison Creek up to 5-year design storm peak flow to Sixteen Mile Creek, is not considered preferred based on the cost and limited benefit. future conditions land use scenario, but is not required or recommended based on the level of control that would be provided by the stormwater management controls.
7. Implementation of 25 mm capture (i.e. detention through infiltration and/or evaporation) within LID BMPs would assist in achieving erosion and flood control targets within Midtown for the future land use condition. Should 25 mm capture not be achieved, additional quantity control would be required as indicated in Table 5.35, prorated based on the reduced amount of capture, with unitary discharge rates based on Table 5.36.
8. Peak flows for the Midtown future land use condition with SWM would increase at Lower Morrison Creek at certain locations under the 2080 RCP4.5 climate change scenario for the 100-year design storm (ref. Table 5.39). To prevent peak flow increases under the 2080 RCP4.5 climate change scenario, 25 mm capture should be implemented for Lower Morrison Creek, with the unitary quantity control storages based on Table 5.35 and 5.40 (without LID). For Lower Wedgewood Creek, SWM sizing with the benefit of LID could be used for the climate change scenario.
9. Based upon the PCSWMM hydrologic analysis conducted of the Midtown existing and future land use conditions, it is recommended that sizing of the stormwater management controls using the sizing criteria (ref. Table 5.40), be implemented to provide erosion and flood control for the Midtown area, with the consideration of climate change. .

Table 5.40 Unitary and Total Storage Volumes and Discharge Rates for Quantity Control (Climate Change Considered)

CREEK SYSTEM	BRANCH	TOTAL DRAINAGE AREA (HA)	IMPERVIOUS AREA (HA)	STORAGE VOLUME PROVIDED BY 25MM CAPTURE USING LID BMPS (M^3)	25 - YEAR			100 - YEAR			TOTAL STORAGE
					UNITARY STORAGE (M^3/IMP. HA)	TOTAL STORAGE (M^3)	DISCHARGE (M^3/S)	UNITARY STORAGE (M^3/IMP. HA)	TOTAL STORAGE (M^3)	DISCHARGE (M^3/S)	
Lower Morrison Creek	West Branch	131.06	75.97	18,993	150	6,176	15.9	180.	7,411	21.2	26,404
	East Branch	99.25	75.11	18,778	170	9,894	12.4	210	12,222	15.9	31,000
Lower Wedgewood Creek	West Branch	37.33	30.64	7,660	115	3,923	4.2	150	5,117	5.7	12,777
	East Branch	156.37	107.59	26,898	75	8,069	20.2	130	13,987	26.7	40,885

The following points/info has been provided for clarification regarding Table 5.40:

- Erosion control storages will be provided by the 25 mm capture(i.e. detention of runoff through infiltration and/or evaporation). Infrastructure for each tributary including the area upstream of Midtown, or if 25 mm capture is not possible, the "equivalent" storage provided by 25mm capture will be required. Being consistent with the Oakville Masterplan, the 25mm capture (i.e. retention) has only been applied to the impervious area.
- 25 year and 100 year storm quantity storage control rates have been established based on target flows for future land conditions, which are less than the existing peak flows.
- The storage values have been established based on the total impervious coverage for the Midtown area, as such unitary storage rates are to be applied to the entire site impervious coverage, therefore if there is no increase in impervious coverage for a site, the total storage rates would still be applied when it develops.
- Examples of applying the unitary storage rates are provided.

    1. Site 1: 1 ha within West Branch of Lower Wedgewood Creek. Current Site has 0% impervious coverage and proposes 70%. Total storage required is the 25mm capture ((i.e. detention of runoff through infiltration and/or evaporation).) for the site's impervious area, and 0.7 *150 m^3
    2. Site 2: 1 ha within East Branch of Lower Wedgewood Creek. Current Site has 50% impervious coverage and proposes 50%. Total storage is 25mm capture ((i.e. detention of runoff through infiltration and/or evaporation).) and 0.5*130 m^3
    3. Site 3: 1 ha within West Branch of Lower Morrison Creek. Current Site has 75% impervious coverage and proposes 100%. Total storage is 25 mm capture ((i.e. detention of runoff through infiltration and/or evaporation).) and 1*180 m^3
    4. For sites which cannot implement the 25 mm capture ((i.e. detention of runoff through infiltration the 25m as and/or evaporation).), the 25 year and 100 year storage volumes would increase as indicated in Table 5.31 (No Diversion) for erosion control and flood control. As an example, for a proposed 1 ha site at 50% impervious contributing to the West Branch of Lower Morrison Creek that is able to apply 50% (or 25% impervious coverage) of the 25mm retention volume, storage would be the following:

        - 25 mm capture * 0.5 imp.ha* 0.5 = 62.5m^3;
        - remaining erosion control volume at 160 m^3/ imp.ha * 0.5 imp.ha *0.50 = 40 m^3,
        - 25 year at 150m^3/imp.ha *0.5 imp.ha *0.5 = 37.5m^3 and;
        - 100 year at 180 m^3/imp.ha *0.5 imp.ha * 0.5= 45 m^3 (includes 25 year).
        - Total storage onsite = 62.5 + 40 + 45 m^3 = 147.5 m^3

5.5 STUDY AREA ALTERNATIVE ASSESSMENT

In order to address the identified riverine-based flooding potential within the Lower Morrison Creek and Lower Wedgewood Creeks, a long list of potential flood mitigation alternatives has been established. The long-list of flood mitigation measures has been screened based on functional aspects and based on engineering principles related to the effectiveness of improving flood protection and reducing flood risk. Short-listed alternatives have been assessed in more detail using functional performance criteria as determined through both hydrologic and hydraulic modelling. Flood protection benefits have been determined based on the number of properties and buildings with a proposed reduction in flood risk and the number of hydraulic crossings that have a proposed improvement in hydraulic performance.

The flood mitigation alternatives are to address the existing flooding potential along Lower Morrison Creek and Lower Wedgewood Creek, which occurs due to the following mechanisms:

i) Inadequate Channel (Conveyance System) Capacity

ii) Inadequate Floodplain Capacity

iii) Spill-Prone Areas where flow exceeds capacity and moves away from the watercourse

iv) Limited Culvert/Bridge Flow Capacity

v) Lack of Stormwater Control (Considered to be a flooding cause not a mechanism)

vi) Creek blockages due to debris or ice

5.5.1 LONG LIST OF ALTERNATIVES

The following long list of alternatives has been developed to reduce the flood risk potential along both Lower Morrison Creek and Lower Wedgewood Creek. The long list of alternatives for reducing flood risk has been subdivided into three main categories: "Do-Nothing", Structural/Capital Alternatives and Non-Structural Alternatives, plus a fourth category of "Combinations" of the sub-alternatives, as follows:

i. Do Nothing

ii. Structural/Capital Alternatives

   i. Culvert/Bridge upgrades
   ii. Eliminate/Reduce potential culvert blockages
   iii. Floodplain/Channel improvements
   iv. Flood proofing buildings
   v. Flow diversion
   vi. Online storage
   vii. Offline storage
   viii. Roadway longitudinal profile modification
   ix. Low Impact Development (LID) Best Management Practices (BMPS)

iii. Combinations of Structural Alternatives

iv. Non-Structural Alternatives

   i. Creek maintenance plan
   ii. Emergency preparedness
   iii. Flood forecasting/warning
   iv. Land acquisition
   v. Regulation

The long list of alternatives has been screened at a high-level based upon feasibility and anticipated effectiveness in reducing flood risk, to develop a short list of alternatives for further consideration. The screening of alternatives has considered the functionality of each alternative, with the objective of reducing the long list and advancing a short list of alternatives accordingly. The following summarizes the screening assessment of the long list of alternatives, and provides recommendations as to whether alternatives should be advanced or screened from further consideration.

1. Do Nothing: A do nothing approach is often selected if a suitable mitigation alternative cannot be achieved for a site and provides a benchmark comparison to other alternatives as required by the Municipal Class EA process Under a do nothing approach, the existing hydraulic capacity constraints and associated flood risk to the susceptible sites would continue and would not achieve the objectives of this

study. This alternative has been maintained should all other alternatives prove to be inadequate or incapable of mitigating the flood risk.

Advanced for Further Consideration

2. Structural Alternatives

i. Culvert/Bridge Upgrades: Culvert and/or bridge upgrades can increase the conveyance capacity of the existing crossing structures, and potentially mitigate upstream flood conditions or the overtopping of the structures. Of the thirteen (13) Lower Morrison Creek crossings within the subject area, there are total of four (4) bridges and/or culvert crossings (ref. Table 2.1) which have been reviewed as potential candidates for hydraulic upgrades. Of the fourteen (14) Lower Wedgewood Creek crossings within the subject area, there are total of four (4) bridges and/or culvert crossings (ref. attached) which have been reviewed as potential candidates for hydraulic upgrades. The crossings that are not considered as candidates for hydraulic upgrades by the town, either meet hydraulic criteria or cannot be upgraded due to property spatial constraints.

Advanced for Further Consideration

ii. Eliminate/Reduce Potential Culvert Blockages: Culvert blockages such as debris accumulation can cause a reduction in the flow conveyance through the hydraulic structures and could increase the likelihood of flooding conditions upstream of the blockage and/or overtopping of the culvert. Removing the potential blockages from the culverts can be achieved with debris management. The removal of debris could be accomplished at each culvert located within the municipal right-of-way. No historic information has been provided for the culverts along Lower Morrison Creek and Lower Wedgewood Creek, which would suggest severe or frequent blockage, as such this alternative has been screened from further consideration. Nevertheless, regular inspection and maintenance of hydraulic structures is already carried out by town staff and will help to reduce the risk of potential future blockages from occurring and resulting in increased flood potential.
Screened from Further Consideration

iii. Floodplain/Channel Improvements: Floodplain or channel improvements through channel widening works, lowering, implementing berms, or regrading of side slopes can increase the conveyance capacity of the channel and potentially mitigate flooding at the floodplain fringe to protect affected properties. This type of mitigation effort could be strategically implemented to mitigate the flooding of at-risk properties adjacent to the creek system, particularly in the developed residential areas. This alternative would be less feasible in confined creek systems. The widening of long reaches of Lower Morrison Creek and Lower Wedgewood Creek may not be feasible due to the confined nature of the creek system from existing development and existing dense vegetation, and lack of public ownership, however there may be some creek reaches where flow conveyance improvements are feasible.
Advanced for Further Consideration

iv. Flood Proofing Buildings: Isolated instances of property flooding from riverine systems are often not easily mitigated with larger reach-based alternatives and typically require more site specific considerations and solutions. As such, buildings may be flood proofed individually (e.g. by sealing low openings, implementing local berming and/or flood walls, establishing sill elevations for new openings, etc.). This alternative could be undertaken at select residential properties where other advanced alternatives do not demonstrate significant flood risk improvement. Initial considerations are summarized as follows:

- The hydraulic impact would likely be limited to isolated locations and would not likely demonstrate significant impact to the upstream or downstream properties.
- The estimated cost of this alternative is to be determined, as it would be calculated based on the number of properties requiring implementation, and also depend on numerous factors such as house type, construction, amenity area use etc.

- Permitting and consultation with the individual property owners would be required as the recommended works would be implemented on private property.
- The effectiveness of this alternative would be restricted to the identified properties where it would be implemented.

Advanced for Further Consideration

v. Flow Diversion: A flow diversion involves the use of a channel or pipe to convey flow/drainage away from high flood risk areas to locations further downstream within the same creek, or to another creek system, which has capacity. This alternative would require careful consideration of the hydraulic capacity of the receiving watercourse. A piped flow diversion has been considered within the Midtown Stormwater Management Assessment.
Advanced for Further Consideration

vi. Online Storage: Detention storage of creek flows which exceed the dry weather base flow could be provided online within the channel system or the floodplain where sufficient area and depth is available, provided it would not cause an increase in flood risk to other properties. This alternative could most effectively be implemented on public property where the flow is contained within the floodplain and there is a flood risk condition downstream of the storage facility. There are limited opportunities for online storage within Lower Morrison Creek and Lower Wedgewood Creek due to the confined nature of the creek system and the urbanized land use. As discussed with the town on April 15, 2020, potential locations that meet these criteria have been reviewed and determined to be unavailable.

Screened from Further Consideration

vii. Offline Storage (Convey Excess Flow to off-line Storage Facilities): Channel flows above frequent flows (i.e. 5 year to 10 year storm events), can be directed to offline storage facilities by implementing detention storage. There are no existing municipal SWM facilities that could be upgraded to provide additional flow control, as such offline storage would have to be implemented within new storage facilities to be located within suitable and available public lands.

Advanced for Further Consideration

viii. Roadway Longitudinal Profile Modification: The modification of a road's longitudinal profile could be undertaken to reduce flooding or overtopping from adjacent creek systems while maintaining road design within municipal standards and provincial performance criteria and allowing vehicle passage and emergency access during flood conditions.

Advanced for Further Consideration

ix. LID BMPS: Low Impact Development Best Management Practices (LID BMPs) represent the application of a suite of BMPs normally related to source and conveyance stormwater management controls to promote infiltration and pollutant removal on a local site-by-site basis. These measures rely on eliminating the direct connection between impervious surfaces such as roads and the storm drainage system, as well as the promotion of infiltration drainage. General design guidelines and considerations for source and conveyance controls have been advanced since the early 1990's as part of the MMAH "Making Choices" and in 1994 as part of the Ministry of the Environment's original Best Management Practices Guidelines.

Subsequent to the 1994 MOE Guidelines, technologies and standards have been developed further for the application of source and conveyance controls. These have evolved into a class of Best Management Practices (BMPs) referred to as Low Impact Development (LID) practices, which have advanced as an integrated form of site planning and storm servicing to maintain water balance and providing stormwater quality control for urban developments. LID BMPs provide benefits by way of reducing the erosion potential within receiving watercourses and thereby reducing the total volume of end-of-pipe stormwater erosion control requirements. In addition, due to volumetric controls afforded by LID BMP's, water quality is also improved through a reduction in mass loading. The benefits from LID stormwater management practices

are generally focused on the more frequent storm events (e.g., 2-year storm) of lower volumes as opposed to the less frequent storm events (e.g., 100-year storm) with higher volumes. Based on LID BMPs typically not providing peak flow control for infrequent storm events and therefore not reducing flooding within riverine systems, LID BMPs are not considered as an alternative to be further considered.

Screened from Further Consideration

3. Combinations of Structural Alternatives:
Combinations of the foregoing alternatives could be used strategically should individual alternatives be fully ineffective at mitigating the flooding conditions. Alternative combinations can at times be more effective than individual alternatives, as their influence can be heightened and used to target specific locations of the channel for more impactful results.
Advanced for Further Consideration

4. Non-Structural Alternatives:

The flood risk within the identified areas may also be addressed in part through non-structural solutions. This alternative encompasses a variety of options related to existing and/or new practices or policies, rather than capital works (structural). Although each alternative has not been evaluated explicitly, the following summarizes the options available for the non-structural alternative and their potential influence on the subject flood risk areas:

i. Creek Maintenance Plan: A creek maintenance plan involves municipal works to clear the channel and floodplain of debris. Pertaining to this study, the primary goal of this alternative would be for debris removal in the floodplain, to prevent obstructions from developing and increasing the likelihood of flood conditions in the vicinity of the creeks. This alternative could be implemented strategically throughout Lower Morrison Creek and Lower Wedgwood Creek, particularly in the residential areas, to reduce the resistance to flood flows and ultimately reduce the potential for flooding conditions at the properties on the floodplain fringe.

Advanced for Further Consideration

ii. Emergency Preparedness: Emergency preparedness is the planned response to an emergency situation to quickly protect people and property from unexpected, and often hazardous, events. While this alternative will not prevent hazardous events such as flooding from occurring, it assists in the preparation of identifying vulnerable residences and properties so they may undertake appropriate preparations in addition to mitigating the impact from the event. Emergency events include severe/extreme weather which can lead to riverine flooding in watercourses such as Lower Morrison Creek and Lower Wedgewood Creek. For this study, the at-risk areas of flooding can be identified, providing the Town and the Region of Halton with the ability to pro-actively address potential flood issues, and notify the public of flooding potential, so they may develop their own emergency preparedness plans in addition to the town's emergency preparedness plans.

Advanced for Further Consideration

iii. Flood Forecasting/Warning: Flood forecasting involves the prediction of flow rates and water surface elevations in channels and floodplains based on anticipated precipitation. The warning component of this alternative is the communication of the predicted rainfall and potential water surface elevations to those in flood susceptible areas for disaster prevention. The requirements for this alternative include the development of forecasting hydrologic and hydraulic models in addition to the investment of real-time flow monitoring equipment and software. A flood forecasting/warning program such as this would need to be developed with training for town staff in consultation with Conservation Halton. It is understood a flood forecasting/warning program is part of Conservation Halton's mandate.

Advanced for Further Consideration

iv. Land Acquisition: Land acquisition, in the form of land expropriation or through a *floodplain buyout program*, involves municipal, provincial, and/or federal government purchase of the flood susceptible properties to allow the property owners to relocate to a lower-risk area. Similar to the emergency preparedness and flood forecasting alternatives, land acquisition does not prevent flooding from occurring, but rather is intended to decrease the future financial burden/impacts of re-building in flood-prone areas. The cost of this alternative would likely be high; however, this type of approach has been implemented in high-risk areas, including in Calgary following the flood of 2013, and in Ottawa, following the second flood event in two (2) years (2017-2018).

Advanced for Further Consideration

v. Regulation: Establishing regulations for the extent and form of allowable development within the floodplain of Lower Wedgewood Creek and Lower Morrison Creek is carried out by the local Conservation Authority, (i.e. Conservation Halton). . Conservation Halton applies a one-zone floodplain management approach within its jurisdiction, which means that the entire floodplain (including flood fringe) is considered the floodway and all new development in the floodplain is prohibited with few exceptions.

Screened from Further Consideration

Short List of Alternatives

Based on the screening of the long list of alternatives, based on functionality and potential level of flood mitigation, the following short-list of alternatives has been prepared:

1. Do Nothing (Required as per Municipal Class Environmental Assessment Process)
2. Structural Alternatives

i. Culvert/Bridge upgrades
ii. Floodplain/Channel improvements
iii. Flood proofing buildings
iv. Flow diversion
v. Offline storage
vi. Roadway longitudinal profile modification

3. Combinations of Structural Alternatives
4. Non-Structural Alternatives (All alternatives are short listed, with exception of Regulation)

5.5.2 SHORT LIST ALTERNATIVE EVALUATION CRITERIA

In order to evaluate the short-listed alternatives, a qualitative evaluation system using negative, negative/neutral, neutral, neutral/positive and positive results, has been advanced to assess the suitability of each alternative against appropriate “evaluation factors”. The evaluation factors consist of considerations related to a two-tier hierarchy of potential impacts/issues organized by Evaluation Category, which have been supplemented by more detailed and specific Evaluation Criteria. Alternatives that are considered to not improve flooding conditions or are considered infeasible have been screened from further consideration. Alternatives that should be combined with other alternatives have been noted as such.

Evaluation Category

A broad description of the type of impacts and issues under consideration includes:

(i) Functional – Impacts that the alternative may have on how a system is intended to work as related to flood (and erosion) mitigation.

(ii) Environmental – Potential impacts or benefits that alternatives may have on terrestrial and aquatic habitat.

(iii) Social – Impacts/issues relating to the interaction of the community/neighbourhood with the implementation of the proposed alternative

(iv) Economic – Immediate and future costs and cost-benefit of the alternative including operations and maintenance.

Specific evaluation criteria relevant to each Evaluation Category has been summarized in Table 5.41.

Table 5.41 Evaluation Criteria per Municipal Class EA

EVALUATION CATEGORY	EVALUATION CRITERIA	CRITERIA DESCRIPTION
Functional	Effective (Provides Flood Protection for Properties)	The extent to which the alternative reduces or eliminates flood risk to properties and buildings.
	Ease of Implementation	Are there minimal or significant considerations required to implement the alternative.
Environmental	Impacts to Aquatic Systems	The extent to which the alternative results in a negative or positive aquatic resource impact or benefit.
	Impacts to Terrestrial Systems	The extent to which the alternative results in a negative or positive terrestrial resource impact or benefit.
Social	Private Property	The extent to which the alternative results in a negative or positive private property impacts or benefits (e.g. improved use of property based on reduced flood risk).
	Recreational Activities	The extent to which the alternative results in a negative or positive recreational activity impacts or benefits (e.g. improved use of park space or open lands).
	Public Safety	The extent to which the alternative results in a negative or positive public safety impact or benefit.
	Public Acceptance	The extent to which the public will or will not accept the recommended alternative.
Economic	Capital Costs	High capital costs are negative, while low capital costs are positive.
	Operation and Maintenance Costs	High operation and maintenance costs are negative, while low operation and maintenance costs are positive.

Shortlisted alternatives have been assessed per Municipal Class Environmental Assessment (EA) criteria, with Tables 5.42 and 5.43 providing a high-level assessment of functional, environmental, social, and economic criteria with overall ranking included.

Table 5.42 Evaluation of Short-Listed Structural Alternatives

CRITERIA	FACTOR	CULVERT/ BRIDGE UPGRADES		FLOODPLAIN/CHANNEL IMPROVEMENTS		FLOOD PROOFING BUILDINGS		FLOW DIVERSION		OFFLINE FLOOD STORAGE		ROADWAY LONGITUDINAL PROFILE MODIFICATION		COMBINATIONS	
		COMMENT	GRADE	COMMENT	GRADE	COMMENT	GRADE	COMMENT	GRADE	COMMENT	GRADE	COMMENT	GRADE	COMMENT	GRADE
Functional	Effective (Provides Flood Protection for Properties)	• Reduces potential spill depth and flow velocity across roadway • Reduces flood depths immediately upstream of the crossing, and depending on the creek slope, improvements can extend far upstream	●	• Floodplain/ channel improvements would improve flood protection to the creek reach and potentially reduce flood elevations upstream	●	• Suspected at risk properties adjacent to the creeks may be able to be protected. • Localized flood protection depends on flood elevations and private property elevations and configuration	○	• Flow diversion to Sixteen Mile Creek at Cornwall Road would reduce flood risk on Lower Morrison Creek, downstream of Cornwall Road • Flow diversion from Lower Wedgewood Creek does not appear possible	●	• Offline flood storage at Cornwall Road would reduce flood risk on Lower Morrison Creek, downstream of Cornwall Road • Offline flood storage on Lower Wedgewood Creek does not appear possible	●	• Raising road profiles would mitigate roadway spill conditions, but would increase upstream flood elevations.	◑	• Implement alternatives dependent upon property access and flood mitigation results. Roadway profile modifications are not considered probable in the shallow valley systems.	●
	Ease of Implementation	• Conservation Halton permit would be required to implement • May require temporary access on local properties • Would require input from stream morphologist, aquatic biologist and terrestrial specialist in addition to engineering disciplines. • Would require partial or full closure of the roadway.	◕	• Coordination and approval would be required from private property owners for works on their property. • Construction access would be difficult based on most creek reaches being private. • Permitting required from Conservation Halton. • Would require input from stream morphologist, aquatic biologist and terrestrial specialist in addition to engineering disciplines.	◑	• Conservation Halton permit would not be required for properties outside regulated area, that said, most properties would be within the regulated area. • Consultation with and approval from property owners required.	◑	• CH permit would be required. • Study to ensure there are no impact to downstream creeks would be required. Studies needed may include Environmental Flow Needs Assessment, Fluvial Geomorphological Studies, Fish community and fish habitat impact assessment • Flow diversion pipe(s) would be over 800 m length from Lower Morrison Creek to Sixteen Mile Creek. • Assessment required to determine potential impacts to 16 Mile Creek (less frequent storm events)	◑	• CH permit would be required. • Study to ensure there are no impact to downstream creeks would be required. Studies needed may include Environmental Flow Needs Assessment, Fluvial Geomorphological Studies, Fish community and fish habitat impact assessment	◕	• CH permit would be required as regrading would likely extend into floodplain and regulated setback. Increase in flood elevations upstream would not be permitted by CH • Impacts to existing utilities within the ROW to be further considered. • Driveway entrances would need to be raised to accommodate the modified road profiles.	◑	• Permitting required and to be confirmed by Conservation Halton. • Coordination and approval would be required from property owners for works on their property. Construction access would depend on location.	◕
Environmental	Impacts to Aquatic Systems	• In creek works will be required to facilitate culvert/ bridge upgrades, therefore	◑	• All floodplain works would be outside the bankful channel with no impact to aquatic	◑	• All building flood proofing works would be outside the channel with	○	• Assessment required to determine potential impacts to Sixteen Mile	◑	• No anticipated impacts to fish community and fish habitat along Lower Morrison Creek due to diversion of higher	○	• All roadway profile modification works would be outside the channel with	○	• All floodplain works would be outside the bankful channel with no impact to	◑

CRITERIA	FACTOR	CULVERT/ BRIDGE UPGRADES		FLOODPLAIN/CHANNEL IMPROVEMENTS		FLOOD PROOFING BUILDINGS		FLOW DIVERSION		OFFLINE FLOOD STORAGE		ROADWAY LONGITUDINAL PROFILE MODIFICATION		COMBINATIONS	
		COMMENT	GRADE	COMMENT	GRADE	COMMENT	GRADE	COMMENT	GRADE	COMMENT	GRADE	COMMENT	GRADE	COMMENT	GRADE
		temporary impacts to aquatic systems would result. • Potential impacts to riparian vegetation anticipated; any riparian vegetation removed would be replaced.		systems, but channel improvements would result in temporary impacts to aquatic systems • Potential impacts to riparian vegetation anticipated; any riparian vegetation removed would be replaced.		no impacts to aquatic systems.		Creek at proposed new outlet. • No anticipated impacts to fish community and fish habitat along Lower Morrison Creek due to diversion of higher flows only and maintenance of lower and more frequent flows within system.		flows only and maintenance of lower and more frequent flows within system.		no impacts to aquatic systems.		the aquatic systems • In creek works for crossings or flow channel flow conveyance improvements would have temporary impacts on aquatic habitat.	
	Impacts to Terrestrial Systems	• Local established vegetation could be impacted, such as tree removals for construction, however, areas could be replanted with appropriate vegetation following all earth works. • The vegetation impacted may be acting as a wildlife corridor. Replanting with some larger caliper trees would help to re-establish this function more quickly post construction. • Larger span culverts could provide for better wildlife connectivity.		• Established vegetation could be impacted, such as tree removals for construction, however, areas could be replanted with appropriate vegetation following all earth works. • The vegetation impacted may be acting as a wildlife corridor. Replanting with some larger caliper trees would help to re-establish this function more quickly post construction.		• Potential impacts to terrestrial systems within rear yards. • Replanting would occur with appropriate vegetation following all earth works.		• Anticipated impacts to terrestrial systems in Lower Morrison Creek due area disturbed at inlet structure to flow diversion. • Potential impact at outlet to Sixteen Mile Creek. • Replanting would occur with appropriate vegetation following all earth works.		• Anticipated impacts to terrestrial systems in Lower Morrison Creek due area disturbed at inlet structure to flow diversion. • Replanting would occur with appropriate vegetation following all earth works.		• No impacts to terrestrial systems.		• Established vegetation could be impacted, such as tree removals for construction, however, could be replanted with appropriate vegetation following all earth works.	
Social	Private Property	• Potential for temporary work on private properties.		• Consultation with private property owners required for implementation of a floodplain/		• Implementation on private property would be voluntary.		• Improved flood protection and reduced flood risk for private properties.		• Improved flood protection and reduced flood risk for private properties.		• Driveway entrances may need to be raised or lowered to accommodate		• Consultation with private property owners required for implementation of works located	

CRITERIA	FACTOR	CULVERT/ BRIDGE UPGRADES		FLOODPLAIN/CHANNEL IMPROVEMENTS		FLOOD PROOFING BUILDINGS		FLOW DIVERSION		OFFLINE FLOOD STORAGE		ROADWAY LONGITUDINAL PROFILE MODIFICATION		COMBINATIONS	
		COMMENT	GRADE	COMMENT	GRADE	COMMENT	GRADE	COMMENT	GRADE	COMMENT	GRADE	COMMENT	GRADE	COMMENT	GRADE
		• Consultation with private property and approval from private property owners may be required.		channel improvements required. • Would require multiple property owners to agree to floodplain/ channel improvements for alternative to be effective.								modified road profiles • Road runoff may enter the sites if driveway entrance elevations are not raised to be greater than the road elevation.		on private property. • All berming would be on private property. • Local drainage to the ROW would have to be maintained.	
	Recreational Activities	• No impact to recreational activities.	●	• Impacts will occur where recreational activities coincide with floodplain improvements	◐	• Impacts to the use of existing private property developments.	◐	• No impact to recreational activities.	○	• Temporary impacts to the Cornwall Road Park	◐	• Temporary impacts to the Cornwall Road Park	◐	• Temporary impacts to the Cornwall Road Park. • Impacts will occur where recreational activities coincide with floodplain improvements	◐
	Public Safety	• Culvert/ bridge upgrades would improve public safety based on reduced flood risk and reduced overtopping of roadways.	●	• Floodplain/ channel improvement would improve public safety based on reduced flood risk.	●	• Improved public safety for private properties.	◐	• Reduced flood risk for storm events up to the 100 year	●	• Reduced flood risk for storm events up to the 100 year	●	• Minimal improvement to public safety based on existing road profiles and flood elevations.	◐	• Reduced flood risk for storm events up to the 100 year with offline flood storage or flood diversion. Culvert upgrades, floodplain/ channel improvements and flood proofing buildings would reduce flood risk.	●
	Public Acceptance	• Favourable as this alternative should not impact private property to any great extent.	◐	• Likely unfavourable due to impacts to private property.	◐	• Likely unfavourable due to impacts to private property.	◐	• Likely favourable as there are no impacts to private property.	◐	• Likely favourable as there are no impacts to private property.	◐	• Major road reconstruction may not be seen as favorable due to traffic delays and potential detours.	◐	• Favourable for flow diversion/ offline flood storage. Unfavourable for work on private property.	○
Economic	Capital Costs	• Moderate capital costs for culvert/ bridge upgrades, but less than flow diversion or offline flood storage.	◐	• Costs include grading works and revegetation. • Relatively low capital cost in comparison to other structural alternatives.	◐	• Relatively low cost to the town for public engagement program, cost for implementation on properties is comparatively low and could be shared by landowners	◐	• Substantial cost in comparison to other structural alternatives.	●	• Substantial cost in comparison to other structural alternatives.	●	• Moderate capital costs due to the amount of fill material and grading required dependent on the road profile adjustments	◐	• Cost would likely include flow diversion/ flood storage and other alternatives, therefore significant cost.	●

CRITERIA	FACTOR	CULVERT/ BRIDGE UPGRADES		FLOODPLAIN/CHANNEL IMPROVEMENTS		FLOOD PROOFING BUILDINGS		FLOW DIVERSION		OFFLINE FLOOD STORAGE		ROADWAY LONGITUDINAL PROFILE MODIFICATION		COMBINATIONS	
		COMMENT	GRADE	COMMENT	GRADE	COMMENT	GRADE	COMMENT	GRADE	COMMENT	GRADE	COMMENT	GRADE	COMMENT	GRADE
	Operation and Maintenance Costs	• Medium cost in maintaining and repairing structures		• Potential costs include landscape maintenance. • Relatively low operations and maintenance cost in comparison to other structural alternatives.		• Relatively lower maintenance costs due to informal nature of floodproofing protection. Maintenance cost would be paid by the landowner		• Medium; clearing of inlet and outlet debris and occasional inspection and repair of infrastructure.		• Medium, clearing of inlet debris, occasional inspection of infrastructure and cleaning of tank.		• Comparable to existing road maintenance costs.		• Potential costs include landscape maintenance. • Relatively low operations and maintenance cost in comparison to other structural alternatives.	
Overall Ranking		Carry Forward		Carry Forward		Carry Forward		Carry Forward		Carry Forward		May not be feasible		Preliminary Preferred	

Legend				
Positive	Neutral/Positive	Neutral	Neutral/Negative	Negative

Table 5.43 Evaluation of Short-Listed Non-Structural Alternatives

CRITERIA	FACTOR	DO NOTHING		CREEK MAINTENANCE PLAN		EMERGENCY PREPAREDNESS/ FLOOD FORECASTING AND WARNING		LAND ACQUISITION	
		COMMENT	GRADE	COMMENT	GRADE	COMMENT	GRADE	COMMENT	GRADE
Functional	Effective (Provides Flood Protection for Properties)	• Does not mitigate the flooding condition.		• Does not mitigate the spill or flooding condition.		• Does not mitigate the spill or flooding condition on private property.		• Does not mitigate flooding condition • Would allow for easier implementation of alternatives, such as berming, for flood mitigation.	
	Ease of Implementation	• N/A		• Brush, tree, and debris removal would need to be coordinated with the Town of Oakville Roads and Works Department staff as well as town arborists.		• Develop a site-specific emergency preparedness plan with the town's emergency management coordinator with coordination with Conservation Halton and the Region of Halton. • Advise private property owners of the risk properties and recommend developing their own emergency preparedness plans.		• Purchase of lands would need Town Council approval following a negotiated purchase price.	
Environmental	Impacts to Aquatic Systems	• No impacts to aquatic systems.		• All creek maintenance (floodplain) works would be outside the channel; strategic replanting with smaller vegetation would mitigate potential loss of shading proximate to the watercourse; no anticipated impacts to aquatic systems.		• No impacts to aquatic systems.		• No impacts to aquatic systems.	
	Impacts to Terrestrial Systems	• No impacts to terrestrial systems.		• Impacts to terrestrial systems (tree removal)		• No impacts to terrestrial systems.		• No impacts to terrestrial systems.	
Social	Private Property	• Private properties continue to be at risk of flooding.		• Impacts to private property are likely unfavourable, as such all creek maintenance would need to be within the ROW or on town property.		• No impacts to private property from town implementation. • Private property implementation would be voluntary.		• Private property owners would not prefer lands to be purchased, instead the flood risk to be reduced.	
	Recreational Activities	• No impacts to recreational activities.		• No impact to recreational activities		• No impact to recreational activities.		• No impact to recreational activities.	
	Public Safety	• Risk of public safety due to ongoing flood potential.		• Minor reduction in flood potential anticipated.		• Increased awareness for the properties at-risk of flooding with encouragement to development individual emergency preparedness plans.		• At-risk properties would be acquired and managed by public agency to mitigate risk to public safety.	
	Public Acceptance	• Unfavourable		• Likely unfavourable due to the reduction in natural vegetation and potential vegetative privacy screening.		• Unfavourable as this does not mitigate the flood risk. • Puts the onus on the property owners to be prepared for infrequent storm events.		• Not favourable	

CRITERIA	FACTOR	DO NOTHING		CREEK MAINTENANCE PLAN		EMERGENCY PREPAREDNESS/ FLOOD FORECASTING AND WARNING		LAND ACQUISITION	
		COMMENT	GRADE	COMMENT	GRADE	COMMENT	GRADE	COMMENT	GRADE
Economic	Capital Costs	• Ongoing potential capital costs associated with ongoing flood risk.		• Low capital costs; identifying locations where floodplain maintenance would be required.		• Low capital cost; staff time to develop emergency preparedness plan and individual private property owners to develop their own plans. • Town to work with CH on flood forecasting and warning system. • CH to continue regulating		• Substantial initial capital costs for the purchase of the property.	
	Operation and Maintenance Costs	• Ongoing operation and maintenance costs associated with ongoing flood risk.		• Moderate-High operation and maintenance costs. • Town of Oakville Roads and Works Department would be required to perform landscape maintenance on the identified floodplain sections on a continuous basis.		• Low costs to update plan when necessary and provide updates to the at-risk property owners. • Costs to CH of flood forecasting and warning system and regulation.		• Dependent on preferred land use of the acquired property.	
Overall Ranking		• No improvement to overall system. Alternative not carried forward.		• Minimal performance improvements and does not alleviate spills or flooding conditions. Required to prevent additional flooding conditions. Do not carry alternative forward		• Flood risk not mitigated. Alternative provides public methods of reducing flood damages by education and warning of pending potential flood conditions. Alternative carried forward.		• Significant costs to purchase property in the flood plain. Little to no improvements expected for flood conditions. Alternative not carried forward.	

Legend									
	Positive		Neutral/Positive		Neutral		Neutral/Negative		Negative	

5.5.3 DETAILED EVALUATION OF THE SHORT LIST ALTERNATIVES

5.5.3.1 HYDROLOGIC AND HYDRAULIC ASSESSMENT OF STRUCTURAL ALTERNATIVES

Culvert/ Bridge Upgrades

The hydraulic performance of potential culvert and bridge upgrades has been assessed using the Ministry of Transportation (MTO) hydraulic criteria, and Ministry of Natural Resources and Forestry (MNRF) vehicle ingress and egress criteria for the calculations, and an assessment of the potential to reduce flooding conditions upstream of the crossing. Table 3.8 provides the hydraulic performance of existing crossings on Morrison and Wedgewood Creeks, respectively and, with the exception of one crossing, how each crossing fails to meet the MTO and MNRF hydraulic criteria.

Hydraulic performance standards have been established using the MTO Highway Drainage Design Standard (HDDS) (January 2008), which incorporates the hydraulic standards for watercourse crossings from the Canadian Highway Bridge Design Code. The following references the MTO document (in brackets) related to the hydraulic criteria:

i. Design storms used to calculate flood elevations (WC-1)

ii. Minimum top of road freeboard (WC-7)

iii. Desired top of road freeboard (WC-7)

iv. Maximum depth of relief flow over the road (WC-13)

v. Maximum product of depth and velocity of relief flow over the road (WC-13)

vi. Clearance for open-footing culverts (WC-7)

Culvert and bridge crossings are classified based upon WC-1 from the MTO HDDS. As such, the following design criteria apply:

- Design flow as per the MTO's 2008 Highway Design Standards for freeways and urban arterials would be the 50-year event for structures less than or equal to 6 m in span. Structures with a span exceeding 6 m should be designed to convey a minimum of the 100-year storm event.
- Top of Road Freeboard as per the MTO's 2008 Highway Design Standards should be a minimum of 1.0 m measured from the design flow hydraulic grade line elevation to the edge of the travelled lane. The desirable freeboard is 1.0 m measured vertically from the energy grade line for the design flow.
- Relief Flow as per the MTO's 2008 Highway Design Standards should be a maximum depth of flow on the roadway of 0.3 m, while the product of the velocity and depth on the roadway shall not exceed 0.8 m^2/s.
- Clearance for open footing culverts as per MTO HDDS WC-7 shall be 0.3 m (measured from the water surface elevation to the crossing's soffit). Flood depth for open footing culverts should be as follows:
  - Culverts with a diameter or rise <3.0 m will maintain a HW/D less than or equal to 1.5
  - Culverts with a diameter or rise of 3.0 m to 4.5 m will maintain a HW/D less than or equal to 4.5
  - Culverts with a diameter or rise >4.5 m will maintain a HW/D less than or equal to 1.0

In addition to the foregoing, the following Ministry of Natural Resources and Forestry (MNRF) vehicle ingress and egress criteria would also apply should any overtopping of roadway occur:

- Pedestrian passage criteria:
  - Depth of less than 0.8 m
  - Velocity of less than 1.7 m/s

    - Depth x Velocity of less than 0.4 m^2/s
- Private vehicle passage criteria:
    - Depth of less than 0.4 m
    - Velocity of less than 3 m/s
    - Depth x Velocity of less than 1.2 m^2/s
- Emergency vehicle passage criteria:
    - Depth of less than 1.2 m
    - Velocity of less than 4.5 m/s
    - Depth x Velocity of less than 5.4 m^2/s

For rail crossings, in the absence of Canadian standards, hydraulic criteria for rail crossings can be found in the American Railway Engineering and Maintenance-of-Way Association (AREMA) Manual (2008) Guidelines. AREMA recommends that culverts be designed to discharge: a 25-year flood without static head at the entrance [(.e., a maximum headwater to culvert diameter/rise ratio (HW/D) of 1.0]; and, a 100-year flood using the available head at entrance – the head is to be 0.6 m below the base of rail (i.e., 0.6 m minimum freeboard), or results in a HW/D not exceeding 1.5, whichever is less.

Hydraulic crossings that are considered to be undersized based on not meeting the provincial criteria, rail hydraulic criteria, or provide poor hydraulic performance, where there is adequate right-of-way space available for crossing upgrades, have been assessed within the HEC-RAS hydraulic modelling, and the preliminary crossing upgrade sizing provided in Tables 5.44 and 5.45. Figures 5.3 and 5.4 provide the locations of the hydraulic crossings (red icons) considered to be upgraded; green coloured creek reaches represent potential reaches for flow conveyance improvements which are discussed under floodplain/ channel improvements.

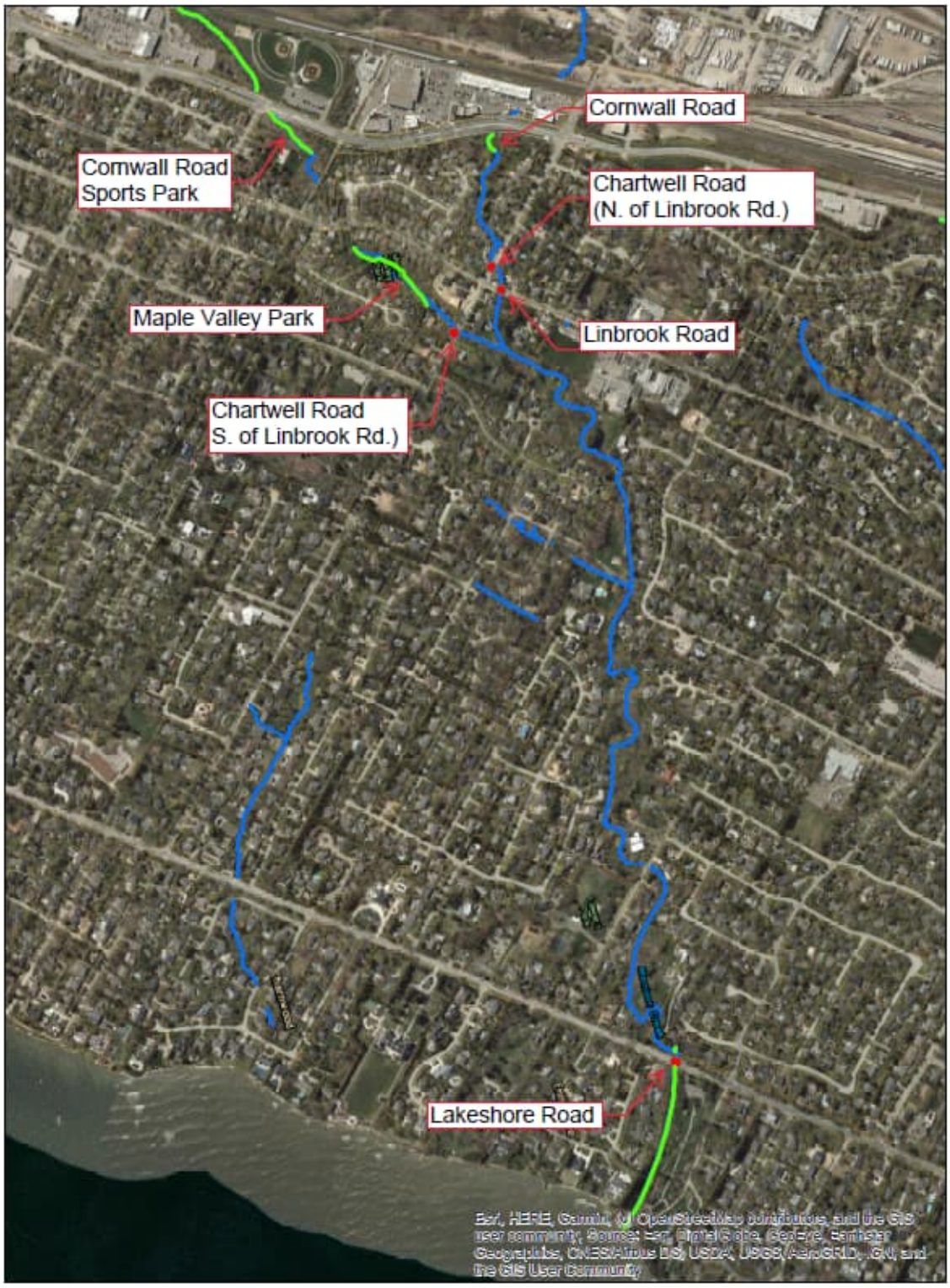

Figure 5.3 Lower Morrison Creek Flow Potential Conveyance Improvement Locations

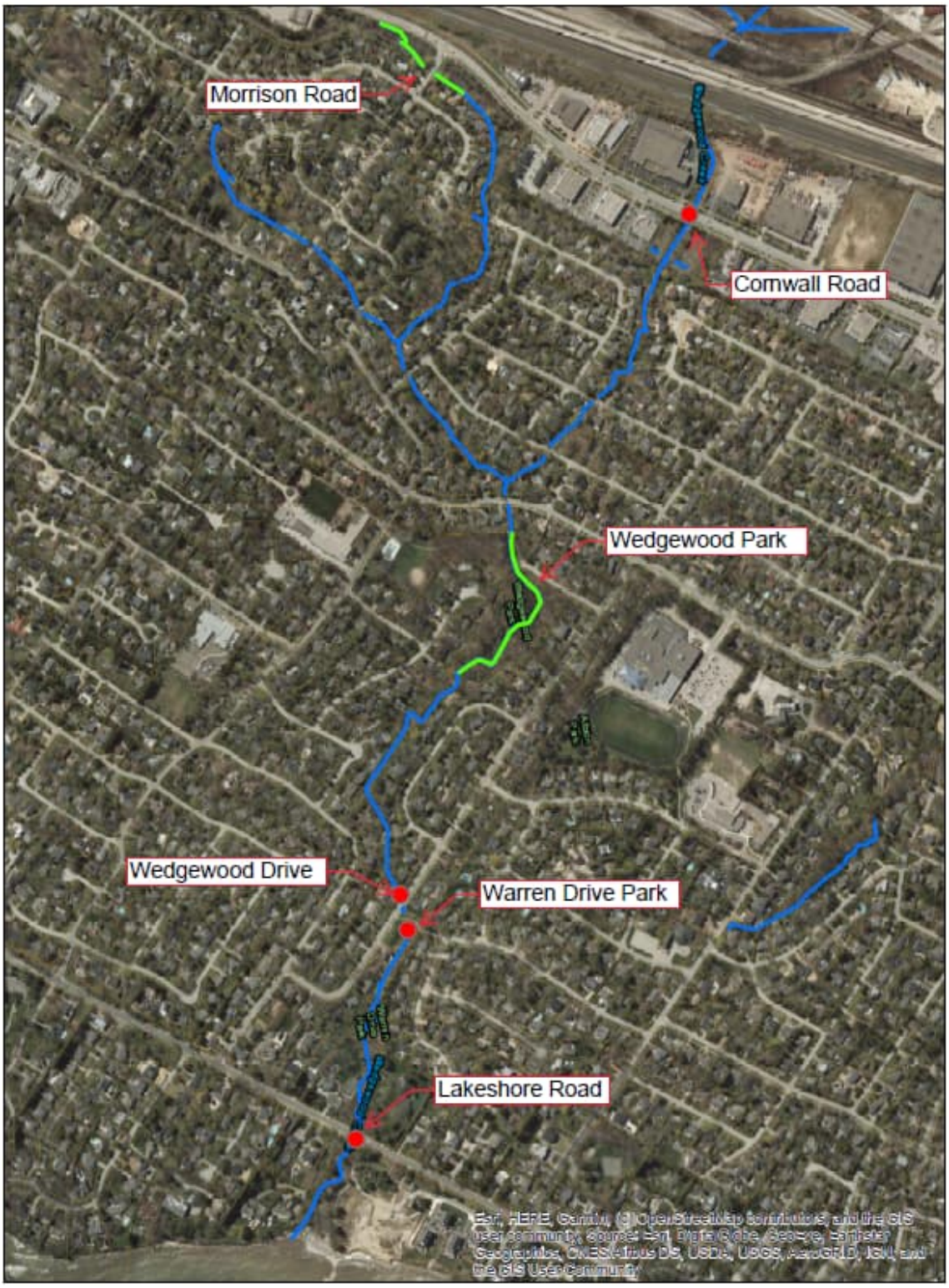

Figure 5.4 Lower Wedgewood Creek Flow Potential Conveyance Improvement Locations

Table 5.44 Lower Morrison Creek Hydraulic Crossing Performance

MORRISON CREEK	POTENTIAL CHANNEL/STRUCTURAL IMPROVEMENTS		MTO/AREMA CRITERIA									MNRF CRITERIA							
	EXISTING	PROPOSED	EXISTING					PROPOSED				EXISTING				PROPOSED			
LOCATION	EXISTING STRUCTURE (SPAN X RISE)	POTENTIAL UPGRADED STRUCTURE (SPAN X RISE)	LARGEST STORM CONVEYED WITHOUT OVERTOPPING	DESIGN STORM (MTO CRITERIA)	CLEARANCE (M)	FB (M)	PASS MTO CRITERIA (Y/N)	LARGEST STORM CONVEYED	CLEARANCE (M)	FB (M)	PASS MTO CRITERIA (Y/N)	OVERTOPPING DEPTH (M)	VELOCITY	DEPTH X VELOCITY	PASS MNRF CRITERIA (Y/N)	OVERTOPPING DEPTH (M)	VELOCITY	DEPTH X VELOCITY	PASS MNRF CRITERIA (Y/N)
Lakeshore Rd	7.9 x 3.2 CONSPAN Arch	14.6 x 3.35 CONSPAN Arch	100	100	0.13	1.51	N	100	0.16	1.54	N	N/A	N/A	N/A	Y	N/A	N/A	N/A	Y
Morrison Rd	3.7 x 2.05 Box	N/A	2	50	-1.00	-0.30	N	N/A	N/A	N/A	N/A	0.36	0.87	0.31	Y	N/A	N/A	N/A	N/A
Linbrook Rd	7.3 x 1.5 CONSPAN Arch	7.32 x 2.13 CONSPAN Arch	25	100	-0.39	-0.15	N	100	0.40	0.64	N	0.15	0.50	0.08	Y	N/A	N/A	N/A	Y
Chartwell Rd (N. of Linbrook)	Twin 3 x 2.1 Box	6.4 x 2.13 Box	100	100	0.13	0.55	N	N/A	N/A	N/A	N	N/A	N/A	N/A	Y	N/A	N/A	N/A	Y
Cornwall Rd	Twin 3.25 x 1.2 Box	N/A	50	100	-1.31	0.02	N	N/A	N/A	N/A	N/A	0.02	0.46	0.01	Y	N/A	N/A	N/A	N/A
East Longo's Parking Lot	3.5 x 1.3 Box	N/A	10	50	-1.30	-0.06	N	N/A	N/A	N/A	N/A	0.06	0.41	0.02	Y	N/A	N/A	N/A	N/A
Under CNR	1.8 x 1.5 Box	N/A	2	N/A	0.1	0.7	N	N/A	N/A	N/A	N/A	0.15	0.86	0.13	NA	N/A	N/A	N/A	N/A
Hwy 403	5.97 x 1.5 Box	N/A	100	50	0.30	1.52	Y	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Y	N/A	N/A	N/A	N/A
Chartwell Rd (S. of Linbrook)	3 x 1.6 Box	6.4 x 1.5 Box	2	50	-0.58	-0.40	N	10	-0.42	-0.24	N	0.40	0.44	0.18	Y	0.35	0.81	0.28	Y
Maple Ave	3 x 1.2 Box	N/A	2	50	-0.80	-0.01	N	N/A	N/A	N/A	N/A	0.01	0.54	0.01	Y	N/A	N/A	N/A	N/A
Cornwall Rd	8 x 1.75 Box	N/A	50	100	-0.58	0.06	N	N/A	N/A	N/A	N/A	0.06	0.46	0.03	Y	N/A	N/A	N/A	N/A
DS of CNR Crossing	Twin 1.8 m diameter CSP	N/A	5	50	-2.38	-0.02	N	N/A	N/A	N/A	N/A	0.02	0.72	0.01	Y	N/A	N/A	N/A	N/A
CNR Crossing	3.3 x 1.5 Box	6.4 x 2.4 Box	<2	N/A	-1.46	-0.07	N	100	0	1.39	Y	0.02	0.44	0.01	N/A	N/A	N/A	N/A	N/A

Table 5.45 Lower Wedgewood Creek Hydraulic Structure Performance

Wedgewood Creek	Potential Channel/Structural Improvements		MTO/AREMA Criteria									MNRF Criteria							
	Existing	Proposed	Existing					Proposed				Existing				Proposed			
Location	Existing Structure (Span x Rise)	Potential Upgraded Structure (Span x Rise)	Largest Storm Conveyed Without Overtopping	Design Storm (MTO Criteria)	Clearance (m)	FB (m)	Pass MTO Criteria (Y/N)	Largest Storm Conveyed	Clearance (m)	FB (m)	Pass MTO Criteria (Y/N)	Overtopping Depth (m)	Velocity	Depth x Velocity	Pass MNRF Criteria (Y/N)	Overtopping Depth (m)	Velocity	Depth x Velocity	Pass MNRF Criteria (Y/N)
Lakeshore Rd	3.8 x 1.9 CONSPAN Arch	14.6 x 3.05 CONSPAN Arch	2	50	-1.58	-0.54	N	25	-1.19	-0.15	N	0.54	1.00	0.54	N	0.27	1.32	0.36	Y
Warren Dr. Park	4.2 x 1.5 CSP Arch	7.3 x 1.52 CONSPAN Arch	<2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N	0.44	0.80	0.35	Y	0.38	0.83	0.32	Y
Wedgewood Dr	5.5 x 1.5 CSP Arch	7.3 x 1.52 CONSPAN Arch	<2	50	-0.37	-0.49	N	2	-0.32	-0.44	N	0.49	0.78	0.38	Y	0.44	0.80	0.35	Y
Devon Rd	Twin 4.3 x 2 CONSPAN Arch	N/A	50	100	-0.71	-0.01	N	N/A	N/A	N/A	N/A	0.01	0.22	0.00	Y	N/A	N/A	N/A	N/A
Drummond Rd	1.7 x 1.15 CONSPAN Arch	N/A	<2	50	-2.07	-0.32	N	N/A	N/A	N/A	N/A	0.32	0.69	0.22	Y	N/A	N/A	N/A	N/A
Cumnock Crescent	0.6 m diameter CSP	N/A	<2	50	-1.76	-0.31	N	N/A	N/A	N/A	N/A	0.31	0.62	0.19	Y	N/A	N/A	N/A	N/A
Morrison Rd	1.2 m diameter CSP	N/A	5	50	-0.77	-0.13	N	N/A	N/A	N/A	N/A	0.13	0.41	0.05	Y	N/A	N/A	N/A	N/A
Morrison Rd Conc. Bridge	5.7 x 1.5 Box	N/A	100	50	0.06	1.04	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Y	N/A	N/A	N/A	N/A
Cornwall Road	5.7 x 1.5 Box	N/A	100	50	0.00	0.45	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Y	N/A	N/A	N/A	N/A
Duncan Rd	2.45 x 1.8 CONSPAN Arch	N/A	<2	50	-1.67	-0.57	N	N/A	N/A	N/A	N/A	0.57	0.99	0.56	N	N/A	N/A	N/A	N/A
Amber Cres	6 x 2.24 Box	N/A	2	100	-1.66	-0.86	N	N/A	N/A	N/A	N/A	0.86	0.82	0.71	Y	N/A	N/A	N/A	N/A
Rd. N of Pond (Cornwall Rd)	Twin 1.75 x 1.2 Box	7.3 x 1.52 CONSPAN Arch	<2	50	-1.08	-0.58	N	5	-0.92	-0.42	N	0.58	0.95	0.55	N	0.46	0.98	0.45	Y
CN Railway	3.1 x 2 Box	6.4 x 2.4 Box	2	N/A	-1.65	1.89	N	100	0	3.44	Y	1.04	1.17	1.22	NA	N/A	N/A	N/A	N/A
CN Railway 1993 Culvert	3.1 x 2 Box	6.4 x 2.4 Box	2	N/A	-0.63	1.39	N	100	0.31	2.31	Y	0.43	1.25	0.54	NA	N/A	N/A	N/A	N/A
Royal Windsor Dr	1.9 x 1.1 Box	N/A	<2	50	-1.04	-0.94	N	N/A	N/A	N/A	N/A	0.94	1.25	1.18	N	N/A	N/A	N/A	N/A

Structures denoted by "<2" under the "Largest Storm Conveyed without Overtopping" column within Tables 5.44 and 5.45 indicate structures where storm events less than the 2 year event are expected to pass, whereas larger storms than this are expected to overtop. Rail culverts which pass underneath railway lines cannot be compared to MTO design criteria. Railway culverts follow the American Railway Engineering and Maintenance-of-Way Association (AREMA, 2008) recommendations that culverts be designed to discharge a 25-year flood event with a maximum HW/D ratio of 1.0, and also the 100-year flood event with a minimum of 0.6 m of freeboard, or a HW/D not exceeding 1.5. There are three railway culverts, as follows:

- CNR Culvert, on Lower Morrison Creek
- CN Railway 1993, Culvert on Lower Wedgewood Creek
- CN Railway, on Lower Wedgewood Creek

All three culverts do not meet the AREMA design criteria, due to either the existence of static head for the 25-year event, and/or insufficient freeboard for the 100-year storm event. As such, Wood has performed a hydraulic assessment on these structures to determine potential sizing in an effort to improve flow capacity. The proposed sizes and passing limits of the AREMA criteria for each culvert has been shown in Tables 5.43 and 5.44 for Lower Morrison Creek, and Lower Wedgewood Creek, respectively.

As per Table 5.45, the CNR culvert on Lower Morrison Creek is proposed to be upgraded from a 3.3 m span x 1.5 m rise concrete box culvert to that of a 6 m span x 2.44 m rise concrete box culvert. Implementing this upgrade would allow the AREMA criteria to be met for the 25-year event, as well as the freeboard limit for the 100-year event. Based upon Wood's assessment, there are no benefits to any localized properties or buildings as a result of this upgrade, though there is an overall net positive hydraulic benefit due to a lowering of WSELs and improvement of conveyance.

As per Table 5.45, the two CNR culverts on Lower Wedgewood Creek are proposed to be upgraded from 3.1 m span x 2 m rise concrete box culverts to 6 m span x 2.44 m rise concrete box culverts. Implementing this upgrade would allow the AREMA criteria to be met for the 25-year event, as well as the freeboard limit for the 100-year event. Based upon Wood's assessment, there are minor benefits as a result of these upgrades for local properties given a net positive hydraulic benefit due to a lowering of WSELs and improvement of overall conveyance. Should these upgrades be made, a benefit of 2 (two) properties having reduced floodlines in the vicinity of these upgrades can be expected for the 100-year event.

Culvert/bridge upgrades have been recommended for four (4) locations on Lower Morrison Creek, and four (4) locations on Lower Wedgewood Creek, as per Table 5.44 and Table 5.45. The town owned area of the channel and municipal right-of-way has been used to determine the largest structure size that could be provided. In determining the potential upgraded crossing sizing, the available depth of cover at each crossing was established by maintain a minimum depth of cover of 0.4 m, with a target of 0.6 m. Structures denoted by "N/A" within Table 5.44 and 5.45 were determined not to be feasible for upgrades based on property and municipal ROW constraints. Upgrading these structures would either require permission from neighbouring private property owners to allow channel works on their lands, or would require revising the roadway profile such that the minimum depth of cover above the structure be achieved.

The following structures for Lower Morrison and Lower Wedgewood Creeks may not be upgraded without permission from neighbouring private property owners based on either temporary or permanent creek works being required on private property(s), and will therefore require temporary or permanent easements to install, should they be considered for any future upgrades. These structure locations have been assessed based upon Town of Oakville parcel mapping, and have been determined to be spatially constricted based upon this mapping.

Lower Morrison Creek:

- Morrison Road 3.7 m x 2.05 m Box Culvert
- Cornwall Road Twin 3.25 m x 1.2 m Box Culvert
- East Longo's Parking Lot 3.5 m x 1.3 m Box Culvert

- Under CNR 1.8 m x 1.5 m Box Culvert
- Maple Avenue 3 m x 1.2 m Box Culvert
- Cornwall Road 8 m x 1.75 m Box Culvert
- D/S of CNR Crossing Twin 1.8 m Diameter CSP Culvert
- CNR Crossing 3.3 m x 1.5 m Box Culvert

Lower Wedgewood Creek:

- Devon Road Twin 4.3 m x 2 m CONSPAN Arch
- Drummond Road 1.7 m x 1.15 m CONSPAN Arch
- Cumnock Crescent 0.6 m Diameter CSP Culvert
- Morrison Road 1.2 m Diameter CSP Culvert
- Morrison Road Concrete Bridge 5.7 m x 1.5 m Box Culvert
- Cornwall Road 5.7 m x 1.5 m Box Culvert
- Duncan Road 2.45 m x 1.8 m CONSPAN Arch
- CN Railway 3.1 m x 2 m Box Culvert
- CN Railway 1993 Culvert 3.1 m x 2 m Box Culvert
- Royal Windsor Drive 1.9 m x 1.1 m Box Culvert

The sizing of the proposed upgraded structures has been based upon standard manufacturer sizes. The proposed upgraded structures for Lower Morrison and Lower Wedgewood Creeks are expected to provide varying degrees of hydraulic performance benefit and improvement, as indicated in the following:

Lower Morrison Creek:

- *Lakeshore Road:* The existing Lakeshore Road crossing on Lower Morrison Creek is a 7.9 m span by 3.2 m rise CONSPAN Arch. The existing structure does not meet MTO clearance criteria as it has a clearance of 0.13 m. The upgraded structure is proposed to be a 14.6 m span by 3.35 m rise CONSPAN™ Arch would improve upon the existing clearance value, by increasing it to 0.16 m. The proposed structure will also improve upon the freeboard available, by increasing it to 1.54 m under proposed conditions, compared to 1.51 m under existing.

The installation of this upgraded structure will also result in reductions in upstream water surface elevations (WSELs), with the revised 100-year flood line indicated on Drawing 1 (ref. Appendix H).

- *Linbrook Road:* The existing Linbrook Road structure is a 7.3 m span by 1.5 m rise CONSPAN™ Arch and does not meet MTO hydraulic criteria as it does not convey the 100-year design storm. The roadway is overtopped by approximately 0.15 m under the 100-year design storm condition, and therefore does not meet clearance or freeboard requirements. It is capable of conveying storms up to the 25-year event.

The upgraded structure at this location is proposed to be a 7.3 m span by 2.13 m rise CONSPAN™ Arch, that will be countersunk approximately 1.0 m on the upstream side. This will allow the proposed structure to convey the 100-year design storm without overtopping the roadway and will allow a clearance and freeboard of 0.4 m and 0.64 m, respectively. While the proposed structure does not meet MTO criteria for clearance and freeboard, it allows the conveyance of the design storm event without overtopping, and results in a significant reduction in upstream WSEL of approximately 0.79 m. As the proposed structure would not be overtopped, it will also meet the necessary MNRF criteria.

- *Chartwell Road (North of Linbrook Road):* The existing Chartwell Road structure, north of Linbrook Road, is a twin 3 m span by 2.1 m rise concrete box. While this structure can convey up to the 100-year storm event, it does not meet MTO clearance and freeboard criteria. Where possible, the opportunity to upgrade existing twin box structures to a single structure (either a concrete box or a CONSPAN™ Arch) of equivalent or greater

hydraulic capacity has been assessed. A single structure versus a twin structure is preferred from a stream morphology perspective.

As such, the proposed upgraded structure at this crossing consists of a 6.4 m span by 2.13 m concrete box culvert. The proposed structure would result in a minor reduction in upstream WSELs, including the 100-year design storm.

— *Chartwell Road (South of Linbrook Road):* The existing Chartwell Road structure, south of Linbrook Road, is a 3 m span by 1.6 m rise concrete box. The existing structure does not meet MTO criteria and is able to convey a 2-year storm event without overtopping the roadway.

The upgraded structure is proposed to be a 6.4 m span by 1.5 m rise concrete box. While this structure will not be able to meet MTO criteria, it will result in an overall hydraulic improvement by reducing the upstream 100 year flood elevation by 0.15 m, and would also be able to convey storms up to and including, the 10 year storm event.

Lower Wedgewood Creek:

— *Lakeshore Road:* The existing Lakeshore Road crossing on Lower Wedgewood Creek is a 3.8 m span by 1.9 m rise CONSPAN™ Arch. The existing structure does not meet MTO clearance or freeboard criteria and can only convey a 2-year storm event without overtopping the roadway. Due to the depth of overtopping of 0.54 m (and an equivalent depth x velocity of 0.54 m.m/s), the existing structure does not meet MNRF criteria.

Under proposed conditions, the upgraded structure would consist of a 14.6 m span x 3.05 m rise .CONSPAN™ Arch, which would improve the structure's hydraulic capacity. This proposed structure will be able to convey storm events up to, and including the 25-year storm. While this still does not meet the MTO criteria for clearance or freeboard, there would be a reduction in upstream 100-year flood elevation of 0.39 m.

The overtopping depth will also be reduced to 0.27 m from 0.54 m, resulting in a depth x velocity of 0.36 m.m/s, with the MNRF criteria being subsequently met under the proposed conditions.

— *Warren Drive Park:* The existing Warren Drive Park structure is a trail crossing that is sized as a 4.2 m span by 1.5 m rise CSP Arch. The proposed upgraded structure will consist of a 7.3 m span by 1.52 m rise CONSPAN™ Arch, which will reduce the 100-year flood elevation by 0.06 m (+/-).

The structure upgrade would also allow for improvement to the overtopping depth x velocity product (from an initial 0.35 m·m/s, to 0.32 m·m/s).

— *Wedgewood Drive:* The existing Wedgewood Drive structure is a 5.5 m span by 1.5 m rise CSP Arch. The existing structure does not meet MTO or MNRF criteria and does not convey any storm event without overtopping the roadway. The proposed upgraded structure would consist of a 7.3 m span by 1.52 m rise CONSPAN™ Arch, which would reduce the 100-year flood elevation by 0.05 m (+/-) and would convey the 2 year event.

While this hydraulic improvement is not enough to meet the MTO criteria for clearance or freeboard, it would reduce the overtopping depth x velocity product (from an initial 0.38 m·m/s, to 0.35 m·m/s). While this is a minor improvement in hydraulic conveyance, it will still provide some benefit with a marginal reduction in the upstream floodline.

— *Cornwall Road (North of Existing SWM Facility):* The existing structure at Cornwall Road is a twin 1.75 m span by 1.5 m rise box culvert. Under existing conditions, it does not meet MTO or MNRF criteria, and does not allow any the conveyance of any storm event without overtopping the roadway.

This structure is proposed to be replaced with a 7.3 m span by 1.52 m rise CONSPAN™ Arch which will be required to be countersunk onsite to allow for adequate cover. The larger crossing size will result in a 0.16 m (+/-) reduction in the 100-year flood elevation on the upstream side of the proposed structure (ref. Drawing 2). While this will not meet MTO criteria, it will allow the proposed structure to be able to meet MNRF criteria due to the reduction in overtopping depth, and subsequent reduction of depth x velocity product from 0.55 m·m/s, to 0.45 m·m/s.

Upgraded Hydraulic Structures Flood Risk Benefit

Based on the improved hydraulic conveyance of the proposed upgraded structures, there would be a reduction in flood elevations upstream of structures for both Lower Morrison Creek and Lower Wedgewood Creek. The resultant flood risk benefit for properties and buildings has been determined and has been summarized in Table 5.46. The structure improvements at Lower Morrison Creek will result in a total benefit of six (6) properties with reduced flood elevations, and six (6) buildings with reduced flood elevations. No property parcels or buildings are expected to be entirely removed from the existing 100-year floodplain. The structure improvements at Lower Wedgewood Creek will result in a total benefit of four (4) properties with reduced flood elevations, and three (3) buildings with reduced flood elevations. No property parcels or buildings are expected to be entirely removed from the existing 100-year floodplain.

Table 5.46 Resultant Hydraulic Structure Flood Risk Benefits (100 Year)

LOCATION	PROPERTIES WITH REDUCED FLOOD RISK	BUILDINGS WITH REDUCED FLOOD RISK	PROPERTIES REMOVED FROM FLOODPLAIN	BUILDINGS REMOVED FROM FLOODPLAIN
Lakeshore Road	0	1	0	0
Warren Drive Park	0	1	0	0
Rd. N of Pond (Cornwall Rd)	1	1	0	0
LOWER MORRISON CREEK				
LOCATION	PROPERTIES WITH REDUCED FLOOD RISK	BUILDINGS WITH REDUCED FLOOD RISK	PROPERTIES REMOVED FROM FLOODPLAIN	BUILDINGS REMOVED FROM FLOODPLAIN
Lakeshore Road	0	3	0	0
Chartwell Rd (S. of Linbrook Rd)	0	1	0	0
Chartwell Rd (N. of Linbrook Rd)	0	2	0	0

Based upon the foregoing, additional structures have been selected to be assessed in order to improve overall conveyance in the system. A backwater assessment has been performed throughout both Creek systems, with potential improvements on Lower Wedgewood Creek on Warren Drive Park and Wedgewood Drive.

Backwater Assessment

As per WSP's alternative assessment, there are a significant number of structures across both Creek systems that are not able to be upgraded further due to private property spatial constraints limiting the crossing span. In order to assess the potential benefits along both Lower Morrison Creek and Wedgewood Creek resulting from additional crossing upgrades requiring works on private property, the Town of Oakville requested Wood to perform a desktop analysis of existing structures and the potential flood risk benefit, should permanent easements or private property acquisition be considered. Considering creek works on existing private property would facilitate the use

of larger span structures than currently is feasible within town lands. As a minimum, a formal agreement from the property owner for the proposed creek works would be necessary for any of these works to begin.

WSP has assessed the 100-year event existing conditions flood elevations for both creek systems and has prepared 100-year flood line mapping. WSP has based this assessment on areas of backwater upstream of hydraulic crossings, where the upstream flood depths are moderately to significantly more than the downstream flood depths. Crossings may be in a backwater condition due to the hydraulic performance of downstream crossings, therefore by removing downstream crossings in the hydraulic model it is possible to determine the hydraulic performance of individual culverts and the potential backwater effect that may result from each crossing. The results of this assessment are provided in Table 5.48 for both creek systems.

Hydraulic crossings have been assessed based upon available property and topographic mapping, with the proposed upgraded structure sizing based upon the largest reasonable structure that could be installed should a permanent easements or property acquisition occur.

The upgraded crossings would require creek widening both upstream and downstream of the crossing. The length of the creek widening works indicated in Table 5.48 is based upon the difference between the upgraded culvert span and the existing top of bank width, with a 5:1 length/width ratio which to taper the widened creek to the existing top of bank width. The overall length of creek work to has been used to determine the number of properties that either a permanent easement and/or property acquisition would have to occur.

Based upon the 100 year event floodline mapping and HEC-RAS river profiles, WSP has determined the number of buildings that are currently within a backwater area, as well as the number of properties which would require creek widening at each crossing location via a permanent easement or property purchase (ref. Table 5.47).

Based upon the backwater assessment, it has been determined that the highest potential flood risk reduction benefit from upgraded crossings and creek widening on private property(s) may be observed at two locations on Wedgewood Creek. There are 6 (six) buildings affected by backwater conditions at Warren Drive Park, and 7 (seven) buildings affected by backwater conditions at Wedgewood Drive (ref. Table 5.47). Wedgewood Drive would require a permanent easement or property acquisition on 2 (two) properties for a potential crossing upgrade, which would maximize the potential flood risk reduction benefit versus the acquisition cost of property, or the requirement of a permanent easement.

As per a meeting with the Town of Oakville (September 11, 2020), WSP has been requested to further assess the crossings at Warren Drive Park and Wedgewood Drive in order to ascertain the potential flood risk reduction benefit that may result from upgrading the crossings, by either implementing permanent easements or by property acquisition. For this localized hydraulic assessment, WSP has considered three (3) potential scenarios, as per the following:

- Scenario 1 – Upgrade existing 4.2 m span x 1.5 m rise CSP arch at Warren Drive Park to an Eagle span bridge with span at least that of the 7m+/- channel width.
- Scenario 2 - Upgrade the existing 4.2 m span x 1.5 m rise CSP arch at Warren Drive Park to an Eagle span bridge, and upgrade the existing 5.5 m span x 1.5 m rise CSP arch on Wedgewood Drive to a 7.32 m span x 1.5 m rise CONSPAN culvert.
- Scenario 3 – Upgrade the existing 4.2 m span x 1.5 m rise CSP arch at Warren Drive Park to an Eagle span bridge, and upgrade the existing 5.5 m span x 1.5 m rise CSP arch on Wedgewood Drive to a 10.0 m span x 2.44 m rise embedded CONSPAN culvert.

The objective of this localized hydraulic assessment is to determine if a flood risk reduction benefit can be provided to the buildings within the 100-year floodplain, based upon the crossing and watercourse improvements for each scenario. The hydraulic conditions resulting for each scenario have been compared to the 100-year event existing conditions flood elevations to determine the flood risk reduction benefit.

Table 5.47 Buildings Affected by Backwater and Potential Structure Upgrade Sizing with Permanent Easement or Property Purchase

LOWER MORRISON CREEK							
STREET NAME	UPSTREAM BACKWATER?	NUMBER OF BUILDINGS AFFECTED BY BACKWATER	NUMBER OF PROPERTIES INCURRING CREEK WIDENING (WITH PERMANENT EASEMENT OR PROPERTY PURCHASE)	LENGTH OF CREEK WIDENING (WITH PERMANENT EASEMENT OR PROPERTY PURCHASE)	EXISTING STRUCTURE SIZE (SPAN X RISE)	POTENTIAL UPGRADED STRUCTURE SIZE (WITH PERMANENT EASEMENT OR PROPERTY PURCHASE)	ORIGINAL UPGRADED STRUCTURE RECOMMENDATION (ALTERNATIVE ASSESSMENT - MAY 2020)
Lakeshore	N	N/A	N/A	N/A	7.9 x 3.2 CONSPAN Arch	N/A	14.6 x 3.35 CONSPAN Arch
Morrison Rd	Y	8	4	13.5	3.7 x 2.05 Box	6.4 x 2.43 Box	N/A - Property Constraints
Linbrook Rd	Y	2	4	13.5	7.3 x 1.5 CONSPAN Arch	10 x 2.44 CONSPAN Arch Embedded	7.3 x 2.1 CONSPAN Arch
Chartwell Rd	N	N/A	N/A	N/A	Twin 3 x 2.1 Box	N/A	6.4 x 2.43 Box
Cornwall Rd	N	N/A	N/A	N/A	Twin 3.25 x 1.2 Box	N/A	N/A - Property Constraints
East Longo's Parking Lot	N	N/A	N/A	N/A	3.5 x 1.3 Box	N/A	N/A - Property Constraints
Under CNR	N	N/A	N/A	N/A	1.8 x 1.5 Box	N/A	N/A - Property Constraints
Hwy 403	N	N/A	N/A	N/A	5.97 x 1.5 Box	N/A	N/A - Property Constraints
Chartwell Rd	Y	3	4	20	3 x 1.6 Box	10 x 2.44 CONSPAN Arch Embedded	6.1 x 1.5 Box
Maple Ave	N	N/A	N/A	N/A	3 x 1.2 Box	N/A	N/A - Property Constraints
Cornwall Rd	N	N/A	N/A	N/A	8 x 1.75 Box	N/A	N/A - Property Constraints
DS of CNR Crossing	N	N/A	N/A	N/A	Twin 1.8 m Diameter CSP	N/A	N/A - Property Constraints
CNR Crossing	N	N/A	N/A	N/A	3.3 x 1.5 Box	N/A	N/A - Property Constraints
LOWER WEDGEWOOD CREEK							
STREET NAME	UPSTREAM BACKWATER?	NUMBER OF BUILDINGS AFFECTED BY BACKWATER	NUMBER OF PROPERTIES INCURRING CREEK WIDENING (WITH PERMANENT EASEMENT OR PROPERTY PURCHASE)	LENGTH OF CREEK WIDENING (WITH PERMANENT EASEMENT OR PROPERTY PURCHASE)	EXISTING STRUCTURE SIZE (SPAN X RISE)	POTENTIAL UPGRADED STRUCTURE SIZE (WITH PERMANENT EASEMENT OR PROPERTY PURCHASE)	ORIGINAL UPGRADED STRUCTURE RECOMMENDATION (ALTERNATIVE ASSESSMENT - MAY 2020)
Lakeshore	Y	2	3	40	3.8 x 1.9 CONSPAN Arch	21.9 x 3.35 Arch (Decast)	14.6 x 3.05 CONSPAN Arch
Warren Dr. Park	Y	6	2	22.5	4.2 x 1.5 CONSPAN Arch	10 x 2.44 CONSPAN Arch Embedded	7.3 x 1.5 CONSPAN Arch
Wedgewood Dr	Y	7	2	29	5.5 x 1.5 CONSPAN Arch	10 x 2.44 CONSPAN Arch Embedded	7.3 x 1.5 CONSPAN Arch
Devon Rd	Y	8	4	17	Twin 4.3 x 2 CONSPAN Arch	10 x 2.44 CONSPAN Arch	N/A - Property Constraints
Drummond Rd	Y	6	4	28	1.7 x 1.15 CONSPAN Arch	7.3 x 1.5 CONSPAN Arch	N/A - Property Constraints
Cumnock Crescent	Y*	N/A	N/A	N/A	0.6 m Diameter CSP	N/A	N/A - Property Constraints
Morrison Rd	N	N/A	N/A	N/A	1.2 m Diameter CSP	N/A	N/A - Property Constraints
Morrison Rd Conc. Bridge	N	N/A	N/A	N/A	5.7 x 1.5 Box	N/A	N/A - Property Constraints
Cornwall Road	N	N/A	N/A	N/A	5.7 x 1.5 Box	N/A	N/A - Property Constraints
Duncan Rd	Y	3	4	16.25	2.45 x 1.8 CONSPAN Arch	5.7 x 1.5 Box	N/A - Property Constraints
Rd. N of Pond (Cornwall Rd)	N	N/A	N/A	N/A	Twin 1.75 x 1.2 Box	N/A	7.3 x 1.5 CONSPAN Arch
CN Railway	N	N/A	N/A	N/A	3.1 x 2 Box	N/A	N/A - Property Constraints
CN Railway 1993 Culv	N	N/A	N/A	N/A	3.1 x 2 Box	N/A	N/A - Property Constraints

WSP initially hydraulically modelled the proposed Eagle span bridge at Warren Drive Park using the bridge modelling methodology in HEC-RAS hydraulic model platform. As HEC-RAS uses a different computation scheme to determine water conveyance and flow for the Bridge Method vs. the Culvert Method, the change in modelling approach from Culvert Method for the existing crossing to Bridge Method for the Eagle bridge, results in an increase in the 100 year WSEL for proposed crossings, which is not a realistic hydraulic result. Based upon the foregoing, to assess the Eagle bridge, a box culvert with dimensions of 9.86 m span x 1.5 m rise at Warren Drive Park has been used to represent the equivalent flow conveyance area of the Eagle bridge (at 14.78 m^2).

The 100-year flood elevations for the various hydraulic scenarios have been provided in Table 5.48.

Table 5.48 100 Year WSELs at Warren Drive Park for Scenarios 1, 2, and 3 with Upgraded Warren Drive Park Bridge (using Equivalent Culvert)

WARREN DRIVE PARK (UPSTREAM)		
SCENARIO	WSEL (M)	WSEL DIFFERENCE FROM EXISTING (M)
Existing Conditions	82.459	N/A
Scenario 1	82.404	-0.055
Scenario 2	82.404	-0.055
Scenario 3	82.396	-0.063
WEDGEWOOD DRIVE (UPSTREAM)		
SCENARIO	WSEL (M)	WSEL DIFFERENCE FROM EXISTING (M)
Existing Conditions	82.506	N/A
Scenario 1	82.477	-0.029
Scenario 2	82.471	-0.035
Scenario 3	82.439	-0.067

As per the hydraulic results indicated in Table 5.48, there would be minor reductions in the 100-year WSEL for each proposed condition scenario compared to existing conditions. While Scenario 3 provides the largest reduction (0.063 m) in the 100 year WSEL at Warren Drive Park, and a 0.067 m WSEL reduction at Wedgewood Drive, these reductions are insignificant and indicate that upgrading either of the two (2) crossings and requiring creek works on private property would not provide a flood risk reduction benefit to the buildings in proximity to the crossings. The 100-year floodlines prepared for this localized hydraulic assessment are indicated in Drawing 10 (ref. Appendix H), which compares the existing conditions floodlines to floodlines generated for each Scenario.

Based on the poor flood risk reduction results of this localized assessment, it is not recommended that crossing upgrades at Warren Drive Park and/or Wedgewood Drive be implemented that require works on private property. It is instead recommended to maintain the recommended culvert upgrades for Warren Drive Park and Wedgewood Drive, both of which are proposed to be 7.3 m span x 1.52 m rise CONSPAN arches. While the implementation of these structures will not result in any significant localized benefits, there will be a net hydraulic benefit to the overall system. The following summarizes the culvert upgrades based on the hydraulic assessment.

- Lower Morrison Creek:
  - Lakeshore Road (14.6 m span by 3.35 m rise CONSPANTM Arch) – Implementing this upgrade will result in 3 (three) buildings with a reduced flood risk.
  - Linbrook Road (7.3 m span by 2.13 m rise CONSPANTM Arch) – Will reduce flood elevations, but minimal reduction in flood risk to properties.
  - Chartwell Road (North of Linbrook Road) (6.4m span by 2.13m rise box) – Implementing this upgrade will result in 2 (two) buildings with a reduced flood risk.
  - Chartwell Road (South of Linbrook Road) (6.4m span by 1.5m rise box) – Implementing this upgrade will result in 1 (one) building with a reduced flood risk.

— Lower Wedgewood Creek:
  — Lakeshore Road (14.6m span by 3.05m rise Decast™ Arch) – Implementing this upgrade will result in 1 (one building with a reduced flood risk.
  — Warren Drive Park (7.3m span by 1.52m rise CONSPANTM Arch) – Implementing this upgrade will result in 1 (one) building with a reduced flood risk.
  — Wedgewood Drive Park (7.3m span by 1.52m rise CONSPANTM Arche) – Will reduce flood elevations, but minimal reduction in flood risk to properties.

Cornwall Road (North of Existing SWM Facility) (7.3m span by 1.52m rise CONSPANTM Arch) – Implementing this upgrade will result in 1 (one) property and 1 (one) building with a reduced flood risk.

Floodplain/Channel Improvements

Floodplain and/or low flow channel hydraulic improvements have been assessed for creek reaches located within Town of Oakville Property as discussed at the April 15, 2020 meeting. Conducting channel improvements on private property, requires the consent of the property owner, temporary work or permanent maintenance and access easements to be placed on creek reaches, as such it is considered impractical to implement floodplain or channel improvements on private property.

The following provides a summary of assessment the potential floodplain/channel locations considered along Lower Morrison Creek and Lower Wedgewood Creek, as indicated in Figures 5.5 to 5.8.

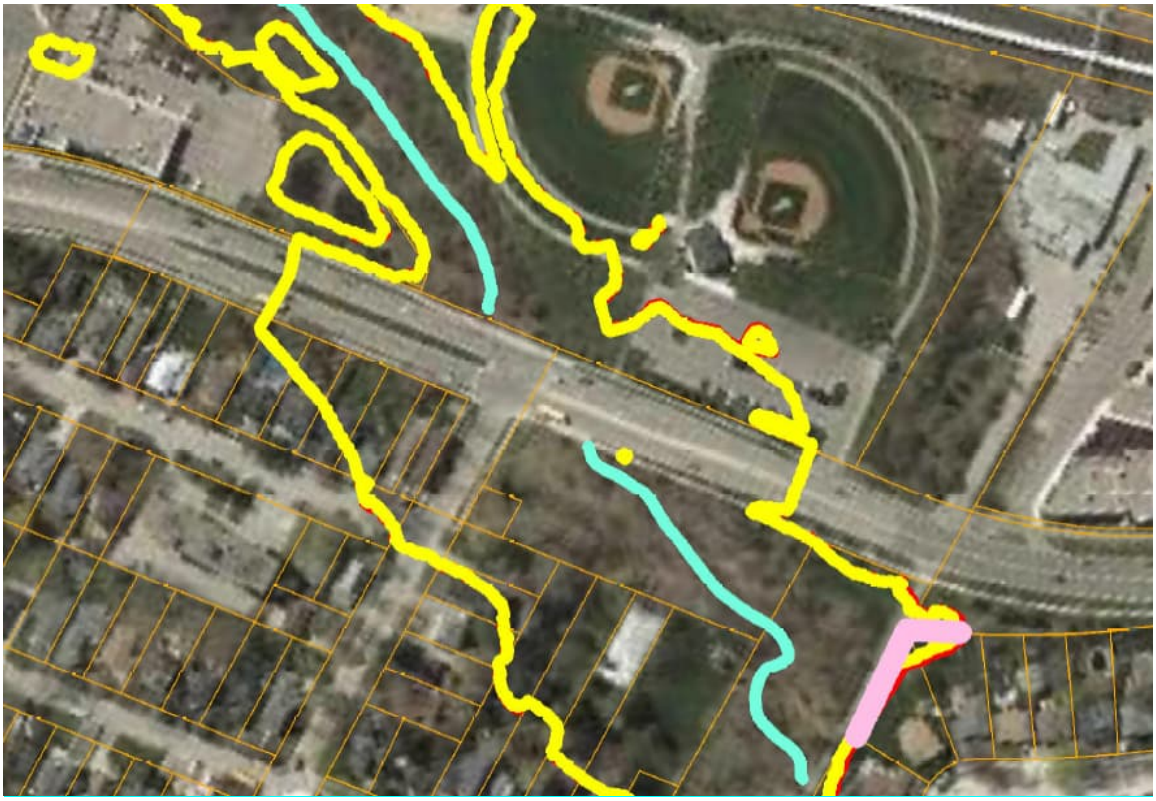

Figure 5.5 Location of Bohemia Crescent Flood Proofing Properties

Figure 5.6 Location of Morrison Road Flood Proofing Property

Figure 5.7 Location of Wedgewood Drive Flood Proofing Properties

Figure 5.8 Location of Cynthia Lane Flood Proofing Properties

Lower Morrison Creek:

- *Cornwall Road Park*: Located immediately north of Cornwall Road, the town owns the creek reach and the lands immediately east of the creek. The lands east of the creek are baseball diamonds and a play structure. The park area has been graded relatively flat within the overbank area along the east side of the creek to facilitate public use of the park. The creek is lined on either side with significant mature vegetation. Upstream of the creek reach, is the CNR rail corridor, crosses the creek, with only a 40 m section of open watercourse existing north of tracks, with the remaining system being enclosed. Based on the park lands already being graded effectively for flow conveyance, significant mature vegetation along the creek reach and limited open watercourse system upstream of the park, this creek reach has been screened from further consideration for flow conveyance improvements.
- Downstream of Cornwall Road Park: The town owns a 180 m section of creek located immediately downstream of Cornwall Road Park, south of Cornwall Road and east of Watson Avenue, entitled Perkin's Passage. The creek reach abuts private property on the west, south and east sides, with Cornwall Road on the north side of the creek. The land owned by the town is narrow, approximately 42 m in width, is relatively flat, and has significant mature vegetation along the creek reach. Based on the limited opportunity to improve the floodplain hydraulic performance due to existing grading and removal of significant vegetation, this creek reach has not been considered for flow conveyance improvements.
- Maple Valley Park: Lower Morrison Creek traverses Maple Valley Park for approximately 142 m. similar to the creek reach immediately downstream of Cornwall Road Park, the park is heavily treed and narrow (50 m +/-). The floodplain could not be regraded without impacting the significant mature vegetation, as such this creek reach has been screened from further consideration.
- East Branch Downstream of Cornwall Road: Approximately 50 m of open creek is owned by the town, located west of Chartwell Road and immediately downstream of Cornwall Road. The section is heavily treed and does not present a good opportunity for flow conveyance improvements.

— Gairloch Gardens: This park is located between Lakeshore Rod and the lake, as such it is at the downstream limit of Lower Morrison Creek. The creek reach is approximately 325 m long, with the creek located along the west side of the park. The park consists of formal gardens, ponds, mature trees and wide open landscaped areas. The park grounds above the creek top of bank are considered to be relatively flat, providing limited opportunity for flow conveyance improvements. Areas of the park which could be graded are used by gardens, or have mature trees. Based on the site restrictions, Gairloch Gardens has not been considered for flow conveyance improvements.

Lower Wedgewood Creek:

— West Branch West and East of Morrison Road. The Morrison Road culvert has recently been replaced as part of the Cornwall Road widening in 2018, designed in part by Wood. Creek works immediately either side of the culvert crossing were conducted to facilitate construction of the crossing. As part of the culvert design, Wood became aware that a local significant wetland exists immediately upstream of Morrison Road. Wood staff also walked the creek reach downstream of Morrison Road along the first two properties. The creek overbank is this area is flat, along the south side of the creek, while on the north side includes the heavily vegetated noise embankment along Cornwall Road. As such, opportunities to provide flow conveyance improvements either side of Morrison Road are severely restricted, therefore, this location has been screened from further consideration.
— Wedgewood Park: Wedgewood Park is located south of Devon Road. The park is narrow and mostly vegetated with large mature trees, either side of the creek. At the access to the park off Weaver Avenue, there is an open space area on the east overbank, which could be regraded to provide limited flow conveyance benefit. Wood has currently not assessed creek reach this within the HEC-RAS hydraulic model, based on the anticipated lack of flow conveyance improvement.

Flood Proofing Buildings

Localized flood proofing of buildings can occur through various methods such as flood protection berms and walls and modifications to buildings (i.e. remove or flood proof lower openings). WSP has conducted a review of properties and buildings currently located within the 100 year floodline, that could be protected by flood protection berming or walls, preferably up to 0.30 m height, but have considered locations that a 0.5 m high berm/ wall could be used. Flood protection berms/ walls would typically be located near the rear of back yards as to not impact use of residential properties. Locations which are heavily vegetated or have swimming pools that would obstruct implementation of flood protection berms/walls have not been considered due to the infeasibility of a flood berm or wall on private property and that implementing a berm on adjacent public lands would require higher berms, which become difficult to implement.

Local grading on public lands would be required to offset the hydraulic impact from implementing flood protection berms/walls; this would have to be assessed in a detailed local hydraulic model. The following summarizes locations (ref. Figures 5.4 – 5.7) where localized flood protection walls/berms (represented by pink lines) could be considered:

— Lower Morrison Creek:
  — 481 Bohemia Crescent (ref. Figure 5.54)
  — 489 Bohemia Crescent (ref. Figure 5.5)
  — 1190 Botany Hill (ref. Figure 5.6)
— Lower Morrison Creek:
  — 318 Wedgewood Drive (ref. Figure 5.7)
  — 330 Wedgewood Drive (ref. Figure 5.7)
  — 1193 Cynthia Lane (ref. Figure 5.8)
  — 1197 Cynthia Lane (ref. Figure 5.8)
  — 1203 Cynthia Lane (ref. Figure 5.8)

Flow Diversion

Opportunities for flow diversions from one creek system to another have been assessed as discussed at the April 15, 2020 meeting. Flow diversions allow for a reduction in flow in one creek system, but an increase in flow within the receiving system. For a flow diversion to be implemented, the receiving system has to have adequate capacity to incorporate the additional flow, and there are potential impacts to the creek system, properties, buildings or infrastructure which can occur as a result of the diversion. Should the diverted flow result in impacts to the receiving creek system, then the additional peak flows need to be offset through flow reductions upstream of the diversion. In addition, a flow diversion requires adequate grade difference between the two creek systems, with no impediment to the alignment or grade of the proposed diversion.

Based on the foregoing, Wood has assessed the potential for flow diversions from both Lower Wedgewood Creek and Lower Morrison Creek. For Lower Morrison Creek, Wood has determined that a flow diversion would not be feasible, as either Lower Wedgewood Creek or Joshua's Creek would not be able to convey additional flow and as both creek systems are at approximately the same profile as Lower Morrison Creek and have existing flooding conditions.

A flow diversion from Lower Wedgewood Creek to Sixteen Mile Creek has been discussed with the town and CH at the April 15, 2020 meeting. A flow diversion from the Lower Wedgewood Creek West Branch at Cornwall Road to Sixteen Mile Creek was indicated as possible, with additional hydrologic and hydraulic assessment required.

At the April 15, 2020 meeting, the Town also asked about a flow diversion from Lower Wedgewood Creek East Branch at Cornwall Road to Sixteen Mile Creek. The East and West Branch crossings of Cornwall Road are of similar grades, while the East Branch crossing of Cornwall Road is approximately 485 m east of the West Branch crossing of Cornwall Road. For a flow diversion to exist from the Lower Wedgewood Creek East Branch to Sixteen Mile Creek, it would have to be placed under the Lower Wedgewood Creek West Branch crossing of Cornwall Road. This is considered impractical and has been screened from further consideration.

A flow diversion from Lower Wedgewood Creek West Branch at Cornwall Road to Sixteen Mile Creek has been assessed using the PCSWMM hydrologic model. The flow diversion would occur from immediately upstream of Cornwall Road. In establishing the preferred piped flow diversion location (ref. Figure 5.8) several factors have been considered:

- Minimize length of the diversion between Lower Morrison Creek and Sixteen Mile Creek.
- Look for opportunities to site the intake in order to minimize the need to create an online valley structure to increase backwater within the creek at the diversion inlet, thereby selecting a location with maximum attainable head.
- Place the diversion inlet at/ or above the 5-year flood elevation to eliminate any potential for natural system impacts.
- Align the diversion conduit to reduce tree removal within both Lower Morrison Creek and Sixteen Mile Creek. The diversion outlet to Sixteen Mile Creek would also have to be aligned to minimize stream morphological impacts.

Figure 5.9 indicates the flow diversion route along Cornwall Road and Trafalgar Road to Sixteen Mile Creek.

Figure 5.9 Potential Lower Morrison Creek Flow Diversion Route

In an effort to eliminate the need for an online structure to create increased backwater and head at the diversion inlet on Lower Morrison Creek, while maximizing the available inlet flow area, an inlet capture system (notionally sized as two (2) 3 m by 2.4 m box culverts or equivalent such as a Morning Glory inlet) has been adopted as the diversion system inlet. The 3 m culvert span has been selected due to the low flow depths within the creek valley. Through refined modelling, there may be an opportunity to reduce the rise from 2.4 m to 1.5m.

The box culvert would transition to an 800 m (+/-) long 1.5 m diameter pipe, which through a drop structure would outlet to Six-teen Mile Creek via a 40 m long 1.5 m diameter pipe. The box culvert length has been minimized by transitioning to a 1.5 m diameter pipe just beyond the Lower Morrison Creek top of bank.

To increase the available head at the inlets to the flow diversion, as there is minimal head (<0.10 m for the 100 year with the inlet at the 10 year event flood elevation) the overbank areas would have to be regraded to create a localized increase in flood elevations and depths. The proposed grading (ref. Figure 5.10) would result in a head of 0.28 m during the 100-year storm, in which case two (2) 3 m span inlets would be required to capture the flow.

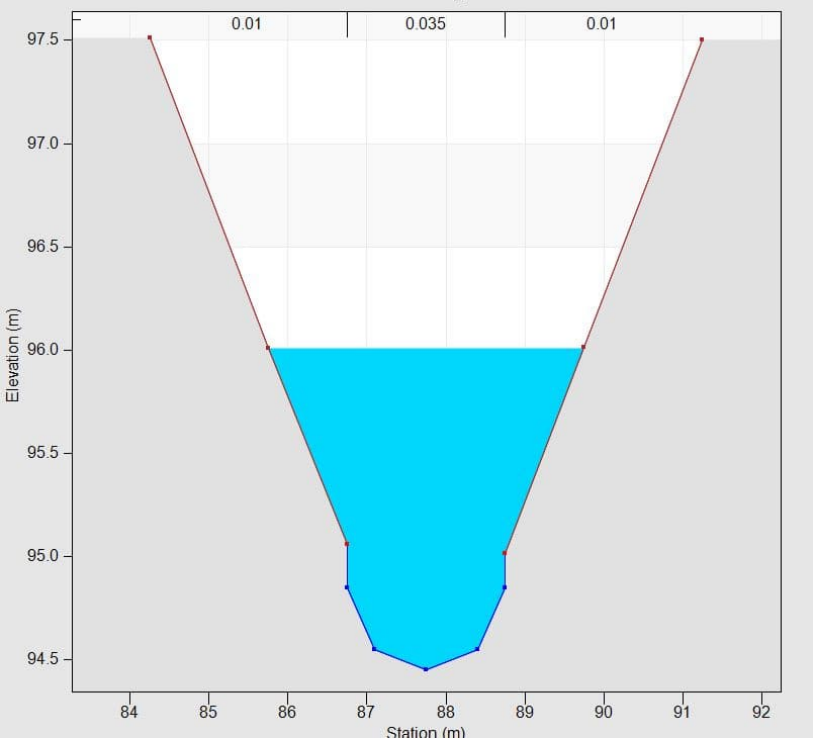

Figure 5.10 Proposed Channel Cross-section upstream of Cornwall Road

The flow diversion inlet configuration has been assessed at two elevations, to divert flows commencing at either the 5 year or 10-year storm frequencies. The reason for considering the 5 year storm frequency for the diversion assessment is there is limited available head (i.e. 28 cm or less) for more formative events (i.e. 10 year or above) within Lower Morrison Creek upstream of the Cornwall Road with the proposed grading. The flow diversion has been modelled in PCSWMM, with the diverted peak flows and downstream peak flow results provided in Table 5.49.

Based on the limited head within Lower Morrison Creek at the flow diversion inlet, the Lower Morrison Creek to Sixteen Mile Creek diversion would still reduce the flooding potential or risk for the 2 to 100 year storm events as indicated by the peak flows in Tables 5.49 and 5.50. The results in the Tables 5.49 and 5.50 are based on the inlet being set to the 5-year water surface elevation to obtain the maximum possible flood risk reduction from the diversion.

Table 5.49 Lower Morrison Creek Diversion to Sixteen Mile Creek Peak Flows (m^3/s)

LOCATION	25 Year	50 Year	100 Year
Creek Flow at Inlet	17.3	19.9	22.1
Diversion Flow:	4.2	6.0	7.8
Downstream Flow of Diversion	13.1	13.9	14.3

Table 5.50 Resulting Peak Flows (Existing/Proposed) in Lower Morrison Creek with Flow Diversion (m^3/s)

LOCATION	25 Year	50 Year	100 Year
Cornwall Road	15.18/13.1	17.75/13.9	20.62/14.3
Lake Ontario	34.68/30.4	38.87/33.1	43.31/36.9

Offline Storage

Offline storage can take various forms, whether above or below ground or receiving local drainage or diverted creek flows. Storage systems typically require open space and publicly owned lands to be implemented. Wood has conducted a review of open spaces, ownership and potential underground storage capacities, within Lower Morrison Creek and Lower Wedgewood Creek, with results in Table 5.51.

A review of available open spaces determined that above ground storage systems would not be feasible within town lands, due to the existing land uses (i.e. parks with designated uses) not providing adequate space. The drainage catchments contributing to Lower Morrison Creek and Lower Wedgewood Creek are typically small and do not convey through town owned open spaces. Based on the foregoing, an assessment of underground tanks with depth up to 5m, that would receive diverted drainage from creeks has been conducted.

Table 5.51 Potential Offline Storage (Underground) Facilities Locations

LOCATION	CREEK SYSTEM	OWNERSHIP	ESTIMATED FACILITY AREA (M^2)	ESTIMATED VOLUME CAPACITY[1] (M^3)
Cornwall Road Park	LM	Town of Oakville	12,000	60,000
Post Park	LM	Privately owned	-	-
St Mildred's-Lightbourn School	LM	Privately owned	-	-
St Mildred's-Lightbourn School	LM	Privately owned	-	-
Morrison Heights Drive Park	LM	Town of Oakville	2250	11,250
Lawson Park	LM	Town of Oakville	3,000	15,000
Wedgewood Park	LW	Town of Oakville	5,000	25,000
1441 Lakeshore Road	LW	Privately owned	-	-
E.J. James Public School	LW	Privately owned	-	-
Albion Park (Oakville Trafalgar High School)	LW	Privately owned	-	-
Maple Grove Public school	LW	Privately owned	-	-
St. Vincent Catholic Elementary School	LW	Privately owned	-	-

1. 5 m Depth

The feasibility of flow capture from a creek reach to a flood storage facility (ref. Figures 5.11 to 5.14) has been assessed commencing between the 5-year and 10-year storm events flood elevations. Flows below the 5-year or 10-year flood elevations would continue to flow as per existing conditions, with no anticipated impacts to the natural system functions (i.e. aquatic habitat and stream morphology).

In an effort to increase hydraulic head at each flood storage location to improve flow capture and increase the storage volumes, overbank grading (valley forming) has been proposed where possible. The grading would be located on town lands, immediately downstream of the inlet, with the objective of no impacts to adjacent properties, resulting from the localized increase in flood elevations. The available head for the 25 year and 100-year storm events has been provided in Table 5.52, with the modified head condition representing the condition assessed for the flood storage facilities.

For the Morrison Heights Drive Park and Lawson Park (Lower Morrison Creek) flood storage locations, due the locations being adjacent to residential areas, grading modifications to the channel overbanks to increase head would not be feasible as the localized increase in flood elevations may increase the flood risk to the neighboring properties. The peak inflows into each flood storage facility and the flood storage for the 25 year and 100-year storm events have been summarized within Table 5.52.

Local supplemental drainage capture opportunities have also been considered for the flood storage facility locations in Table 5.52, however due to the size of the drainage areas and the configuration of the local drainage systems in each area, drainage capture is either not considered feasible or beneficial.

Figure 5.11 Lower Morrison Creek Potential Locations for Offline Flood Storage

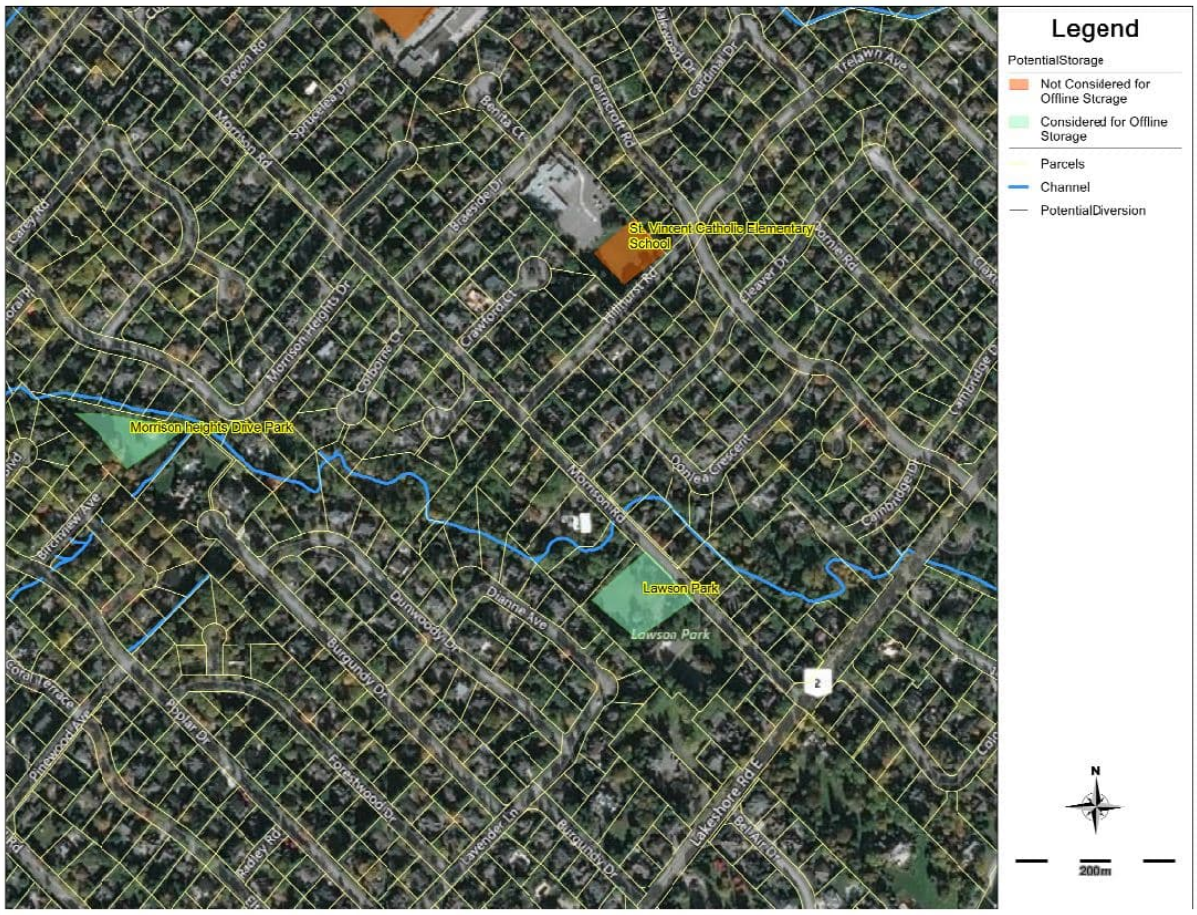

Figure 5.12 Lower Morrison Creek Potential Locations for Offline Flood Storage

Figure 5.13 Lower Wedgewood Creek Potential Locations for Offline Flood Storage

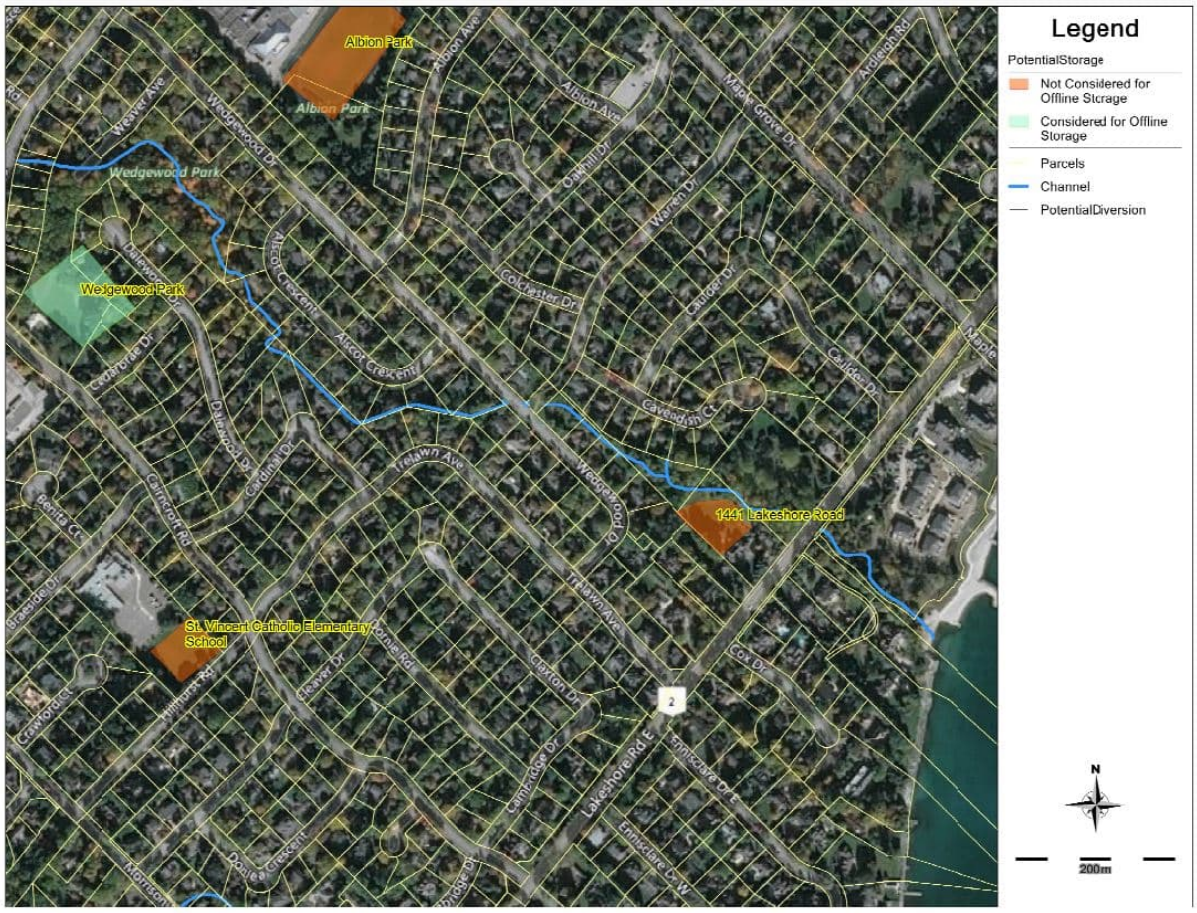

Figure 5.14 Potential Lower Wedgewood Creek Locations for Offline Flood Storage

Table 5.52 Available Hydraulic Head/ Modified Head at Flood Storage Facility Inlets Based on 5 year and 10 Year Water Surface Elevations (m)

STORAGE FACILITY (CREEK)	INLET INVERT SET TO ELEVATION OF 5 YEAR/ 10 YEAR WSEL	25 YEAR HEAD/ MODIFIED HEAD	100 YEAR HEAD/ MODIFIED HEAD
Cornwall Road Park (Lower Morrison Creek)	5 Year	0.21/0.45	0.32/0.65
	10 Year	0.09/0.13	0.20/0.28
Morrison Heights Drive Park (Lower Morrison Creek)	5 Year	0.15/0.15	0.29/0.29
	10 Year	0.09/0.09	0.23/0.23
Lawson Park (Lower Morrison Creek)	5 Year	0.27/0.27	0.48/0.48
	10 Year	0.15/0.15	0.36/0.36
Wedgewood Park (Lower Wedgewood Creek)	5 Year	0.32/0.48	0.53/0.75
	10 Year	0.14/0.26	0.35/0.53

Table 5.53 Flood Storage Facility Inflow (m^3/s)/ Utilized Storage/ Available Storage[1] (m^3)

STORAGE FACILITY. (CREEK)	INLET INVERT SET TO ELEVATION OF 5 YEAR/ 10 YEAR WSEL	25 YEAR	100 YEAR[1,2]
Cornwall Road Park (Lower Morrison Creek)	5 Year	5.23/6449	8.17/10800 (60,000)
	10 Year	1.01/712	3.41/3088 (60,000)
Morrison Heights Drive Park (Lower Morrison Creek)	5 Year	<0.1/ <100	<0.1/<100 (11,250)
	10 Year	<0.1/ <100	<0.1/<100 (11,250)
Lawson Park (Lower Morrison Creek)3	5 Year	<0.1/ <100	<0.1/<100 (15,000)
	10 Year	<0.1/ <100	<0.1/<100 (15,000)
Wedgewood Park (Lower Wedgewood Creek)	5 Year	0.41/493	1.8/2396 (25,000)
	10 Year	0.18/186	0.73/645 (25,000)

1. Available storage provided in brackets (Objective to use full tank capacity for the 100-year storm event +/-)
2. Total number of inlets considered – two (Objective to use full tank capacity for the 100-year storm event +/-)

The following provides a summary of the assessment results for the offline flood storage facilities listed in Tables 5.52 to Table 5.53 commencing with the locations that have been screened from further consideration.

Morrison Heights Drive Park: The park is located immediately west of Morrison Heights Drive, with available space to place a storage system. A review of the hydraulic modelling of Lower Morrison Creek indicates that there is inadequate head above either a five year or ten-year storm event for an inlet to capture adequate flow from the creek. Implementing local grading to increase flood elevations for an inlet would be problematic as the creek is also located next to residential properties, which could not incur any localized increase in flood elevations, therefore this location has been screened from further consideration.

Lawson Park: The park is located immediately north of Lakeshore Road and is south of Morrison Creek by 70 m, with a storage system not being feasible within at least 100 m of the creek. The park is also located near the outlet of Lower Morrison Creek, just upstream of the lake, therefore providing limited flood reduction benefit, as such this location has been screened from further consideration.

Wedgewood Park: Similar to Lawson Park, the open space within Wedgwood Park, is not close to the creek, being over 170 m west of the creek. The distance would require a lengthy inlet and outlet, to and from the underground flood storage facility. In addition, similar to Morrison Heights Drive, there is limited hydraulic head within the creek to facilitate an inlet and with residential properties located adjacent to the creek, increasing localized flood elevations would not be feasible. Based on the hydraulic/ hydrologic performance of the Wedgewood Park flood storage facility, flood elevations downstream of facility have been updated within the HEC-RAS hydraulic model and the resulting flood risk reduction benefit for private properties and buildings along Lower Wedgewood Creek has been determined and summarized in the Table 5.52. Based on the limited flood risk reduction, this offline flood storage facility has been screened from further consideration.

Cornwall Road Park: The results provided in Tables 5.54 and 5.55 for this flood storage facility location indicate that an off-line storage tank could significantly reduce peak flows for more formative events (i.e. 25 year and above). As anticipated, the inlet set at the five-year event water surface elevation would provide the highest flow capture and associated flood storage in comparison to the inlet set at the 10-year flood elevation. The flood risk reduction benefit resulting from this facility for Lower Morrison Creek has been provided in Table 5.54.

Table 5.54 Flood Risk Reduction Benefit Resulting from Flood Storage Facilities (100 Year Event)

LOWER MORRISON CREEK	PROPERTIES WITH REDUCED FLOOD RISK	BUILDINGS WITH REDUCED FLOOD RISK	PROPERTIES REMOVED FROM FLOODPLAIN	BUILDINGS REMOVED FROM FLOODPLAIN
5yr, 1 Inlet	59	16	13	18
5 yr, 2 Inlet	59	16	13	18
10 yr, 1 Inlet	54	9	13	5
10 yr, 2 Inlet	54	9	13	5
LOWER WEDGEWOOD CREEK	PROPERTIES WITH REDUCED FLOOD RISK	BUILDINGS WITH REDUCED FLOOD RISK	PROPERTIES REMOVED FROM FLOODPLAIN	BUILDINGS REMOVED FROM FLOODPLAIN
5yr, 1 Inlet	2	1	0	0
5 yr, 2 Inlet	1	1	0	0
10 yr, 1 Inlet	0	2	0	0
10 yr, 2 Inlet	0	2	0	0

As Table 5.54 indicates, the flood risk reduction benefit resulting from the off-line flood storage facility at Cornwall Road Park would be same with two (2) inlets versus one (1) inlet set to the five year storm event flood elevation. That said, there is a benefit to using two (2) inlets versus one (1) inlet based on the resulting peak flows downstream of flood storage facility as indicated in Table 5.55.

Table 5.55 Lower Morrison Creek Peak Flows with Flood Storage Facility (m^3/s)

LOCATION	25	50	100
Creek Flow	17.3	19.9	22.1
Flow to Flood Storage Facility (1 Inlet / 2 Inlets)	2.3/ 4.2	3.1/ 6.0	4.0/ 7.8
Downstream Flow of Flood Storage Facility (1 Inlet / 2 Inlets)	15.0/ 13.1	16.8/ 13.9	18.1/ 14.3

Roadway Longitudinal Profile Modification

Wood has assessed the potential to modify roadway profiles to reduce flood conditions upstream of crossings. This alternative is typically not feasible, since lowering road profiles leads to roadway existing overtopping depths increasing, or overtopping commencing. Raising road profiles, while protecting the road from overtopping or reducing overtopping depth, increases upstream flood elevations, which may be acceptable within defined deep valley settings, but typically not within shallow watercourse systems. Through an initial review of the road profiles within the HEC-RAS hydraulic modelling, the only location that indicated potential for further assessment was the Lower Morrison Creek crossing located at the intersection of Maple Avenue and Bohemia Crescent.

Modifying the HEC-RAS hydraulic modelling by reducing of the road profile along Maple Avenue from 95.8 m to 95.5 m across a 140 m long length would result in the 100 year storm event overtopping the road and would marginally reduce upstream flood elevations. In addition to the roadway profile being lowered, private property grades would also need to be reduced by 0.3 m to facilitate the roadway overtopping. Based on private property

grading being required to result in minimal flood elevations reduction, this alternative has been screened from further consideration.

5.5.4 COMBINATIONS

A combination of alternatives can provide increased flood mitigation compared to just a single alternative, as such the flood mitigation resulting from combined alternatives has been assessed and the results are provided in Table 5.56. A combination of alternatives would include the following:

- Culvert Upgrades – Consists of upgrades to existing culverts/structures on both Creek systems to provide an overall hydraulic improvement, either locally, or to the overall system.
- Localized Flood Protection (Berms) – Consists of localized flood protection via berms for certain properties to prevent the encroachment of floodwaters for the 100-year storm event. The benefits of localized flood protection are reduced or eliminated for smaller storm events due to an overall reduction in WSEL. Based on discussions with the Town, this alternative has been removed from further consideration, due to the difficulty to implement and the limited flood risk reduction benefit for only properties and no benefit to buildings.
- Flow Diversion – Consists of a flow diversion from Lower Morrison Creek to Sixteen Mile Creek, mitigating the conveyance of floodwater downstream of diversion location.
- Flood Storage – Consists of flood storage from Lower Morrison Creek to mitigate the conveyance of floodwater downstream of diversion location.

5.5.5 FLOOD RISK REDUCTION BENEFITS

As discussed in Section titled “Combinations”, the flood risk reduction benefits for the combined alternatives of culvert upgrades, localized flood protection, flow diversion, and flood storage have been assessed.

The combination of the Lower Morrison Creek flow diversion to Sixteen Mile Creek and the Lower Morrison Creek offline flood storage located at the same location would not be feasible, as the inlet for each alternative would be within the same creek reach and would reduce the effectiveness of each alternative. As each alternative provides basically the same flow reduction and flood mitigation benefit, the two (2) alternatives are noted in Table 5.56 as a single alternative with the two (2) scenarios of inlets set at the five year and 10 year event elevations. Based upon the hydrologic and hydraulic assessment of alternatives for Lower Morrison and Wedgewood Creeks, the benefits associated with each alternative have been summarized in the Table 5.56.

Table 5.56 Summary of Flood Risk Reduction Benefits Resulting from Alternatives (100 Year)

LOWER MORRISON CREEK (98 PROPERTIES AND 28 EXISTING BUILDINGS AT FLOOD RISK)				
ALTERNATIVE	PROPERTIES WITH REDUCED FLOOD RISK	BUILDINGS WITH REDUCED FLOOD RISK	PROPERTIES REMOVED FROM FLOODPLAIN	BUILDINGS REMOVED FROM FLOODPLAIN
Culvert Upgrades	0	6	0	0
5 year WSEL, 1/ 2 Inlets	59	16	13	18
10 year WSEL, 1/ 2 Inlets	54	9	13	5
Combined	59	16	13	18
LOWER WEDGEWOOD CREEK (151 PROPERTIES AND 46 EXISTING BUILDINGS AT FLOOD RISK)				

ALTERNATIVE	PROPERTIES WITH REDUCED FLOOD RISK	BUILDINGS WITH REDUCED FLOOD RISK	PROPERTIES REMOVED FROM FLOODPLAIN	BUILDINGS REMOVED FROM FLOODPLAIN
Culvert Upgrades	1	3	0	0
Combined	1	3	0	0

Based upon the results presented in Table 5.56 crossing upgrades and localized floodproofing (berming/walls) provide little overall flood reduction benefit for both Lower Morrison and Lower Wedgewood Creeks. It has determined that there would be limited opportunity to upsize existing structures without encroaching upon private properties. As such, while the upgraded structures do provide a net hydraulic improvement to the creek systems, the benefit from just crossing upgrades is low, as indicated in Table 5.56.

Localized floodproofing has also been considered. Due to constraints on most private property, the flood protection berm sizing would be considered too large for most backyards and would obstruct existing treed areas and/or pools and other backyard structures. As such, limited benefits would result from floodproofing with the flood risk reduction of only three (3) property parcels on Lower Morrison Creek and six (6) properties on Lower Wedgewood Creek. This alternative has not been further considered based on the limited flood risk reduction benefit and Tables 5.56 onwards do not including the alternative.

Of the two (2) scenarios for inlets to either an offline flood storage facility or a flow diversion at Cornwall Road Park, the largest overall benefit could be obtained using the inlet set at the 5-year flood elevation. The flood reduction benefit would be a total of 59 properties, and 16 buildings with reduced flood risk. This alternative would also remove 13 properties, and 18 buildings from the 100-year floodplain. For the offline flood storage facility at Cornwall Road, it would have to meet Regulatory Control Facility requirements, for flood line mapping. Flood line mapping for this alternative is provided in Drawing 3 (ref. Appendix H).

However, should the Town decide to use the scenario with inlet set at the 10 year flood elevation for an offline flood storage facility or a flow diversion at Cornwall Road Park, the flood risk reduction benefit would be 54 properties and 9 buildings with reduced flood risk. This alternative would also remove 13 properties and 5 buildings from the 100-year floodplain. Flood line mapping for this alternative is provided in Drawing 4 (ref. Appendix H).

The combined alternative considers that the recommended hydraulic crossing upgrades and an offline flood storage facility or a flow diversion at Cornwall Road park with an inlet set to the 5-year flood elevation be implemented. The combined alternative provides the highest flood risk reduction benefit, with 60 properties and 19 buildings with reduced flood risk, and 13 properties and 18 buildings removed from the 100-year floodplain.

This alternative may be further refined with localized flood protection be achievable for additional properties based on the proposed 100-year flood lines presented in Drawing 5 (ref. Appendix).

Based upon further discussion with the Town of Oakville (ref. email: Parker-Chipps June 21, 2020), WSP has assessed the potential flood risk reduction benefits for more frequent storm events for both Lower Morrison and Lower Wedgewood Creeks. Tables 5.58 and 5.59 summarize the benefits from the combined alternative (culvert upgrades and flood storage/diversion set at an inlet based upon the 5-year WSEL) for the 10-year and 25-year events, respectively.

Table 5.57 Summary of Flood Risk Reduction Benefits Resulting from Alternatives (10 Year)

ALTERNATIVE	EXISTING NUMBER OF AT RISK PROPERTIES	EXISTING NUMBER OF AT RISK BUILDINGS	PROPERTIES WITH REDUCED FLOOD RISK	BUILDINGS WITH REDUCED FLOOD RISK	PROPERTIES REMOVED FROM FLOODPLAIN	BUILDINGS REMOVED FROM FLOODPLAIN
Combined	88	21	55	3	20	5
LOWER WEDGEWOOD CREEK						
Alternative	EXISTING NUMBER OF AT RISK PROPERTIES	EXISTING NUMBER OF AT RISK BUILDINGS	PROPERTIES WITH REDUCED FLOOD RISK	BUILDINGS WITH REDUCED FLOOD RISK	PROPERTIES REMOVED FROM FLOODPLAIN	BUILDINGS REMOVED FROM FLOODPLAIN
Combined	151	46	11	8	0	1

Table 5.58 Summary of Flood Risk Reduction Benefits Resulting from Alternatives (25 Year)

ALTERNATIVE	EXISTING NUMBER OF AT RISK PROPERTIES	EXISTING NUMBER OF AT RISK BUILDINGS	PROPERTIES WITH REDUCED FLOOD RISK	BUILDINGS WITH REDUCED FLOOD RISK	PROPERTIES REMOVED FROM FLOODPLAIN	BUILDINGS REMOVED FROM FLOODPLAIN
Combined	118	28	50	10	13	12
LOWER WEDGEWOOD CREEK						
Alternative	EXISTING NUMBER OF AT RISK PROPERTIES	EXISTING NUMBER OF AT RISK BUILDINGS	PROPERTIES WITH REDUCED FLOOD RISK	BUILDINGS WITH REDUCED FLOOD RISK	PROPERTIES REMOVED FROM FLOODPLAIN	BUILDINGS REMOVED FROM FLOODPLAIN
Combined	161	60	11	8	1	1

Based upon the results in Tables 5.57 and 5.58, the largest benefit is provided for the 25 year storm event, which has a total benefit of 106 properties and buildings with either reduced flood risk, or are removed from flood risk for both Lower Morrison and Lower Wedgewood Creeks combined. The floodlines generated for the 10-year and 25-year events are included in Appendix H.

5.5.6 COST-BENEFIT SUMMARY

WSP has completed draft preliminary costing for the for each short-listed alternative. Cost estimates for culvert upgrades, , storage tank, and diversion have been included in Appendix I. Contingency costs have been rounded up to the nearest $100,000 within the subsequent tables, though consist of 15% of the total cost associated with each system. Table 5.59 and 5.60 provide a summary of the total costs associated with each system that may be implemented across Lower Morrison and Wedgewood Creeks, respectively.

Table 5.59 Summary of Preliminary Costs Associated with Proposed System Upgrades (Lower Morrison Creek)

SYSTEM	TOTAL COST ($M)	TOTAL COST WITH 15% CONTINGENCY ($M)
Culvert Upgrades	$ 2.24 M	$ 2.58 M
Flow Diversions	$ 6.25 M	$ 7.19 M
Flood Storage	$ 6.43 M	$ 7.40 M
Total	$ 8.490 M[1]	$ 9.771 M

1. Cost of Diversion has not been included as it would be either the diversion or flood storage to be implemented, not both, with flood storage providing similar benefits for reduced cost.

The total cost for Lower Morrison Creek as per Table 5.59 consists of the use of flood storage overflow diversion, as this is a more conservative cost estimate (flow diversion costs approximately $210,000 more than flood storage).

Table 5.60 Summary of Preliminary Costs Associated with Proposed System Upgrades (Lower Wedgewood Creek)

SYSTEM	TOTAL COST ($M)	TOTAL COST WITH 15% CONTINGENCY ($M)
Culvert Upgrades	$ 4.22 M	$ 4.85 M
Total	$ 4.22 M	$ 4.85 M

The costs associated with flood storage or flow diversions is applied to Lower Morrison Creek only, as the inlet level for both of these systems is the same and use of either system would result in similar benefits across both Creek systems. Given this, the costs for the alternatives which consider the 5 year WSEL with 1 or 2 inlets uses that of the flow diversion, as this cost is more conservative in comparison to that of flood storage (implementing flood diversions will cost approximately $210,000 more than flood storage). Table 5.61 outlines the summary of the preliminary total costs for the proposed system upgrades, should all upgrades be implemented.

Table 5.61 Summary of Preliminary Costs Associated with Proposed System Upgrades

SYSTEM	TOTAL COST ($M)	TOTAL COST WITH 15% CONTINGENCY ($M)
Culvert Upgrades	$ 6.46 M	$ 7.43 M
Flow Diversions	$ 6.43 M	$ 7.40 M
Flood Storage	$ 6.25 M	$ 7.19 M
Total	$ 12.71 M	$ 14.62 M

The total costs presented in Table 5.62 consider a combination of all system upgrades, including culvert upgrades on both Lower Morrison and Lower Wedgewood Creeks, but does not include the flow diversion on Lower Morrison Creek, which is not preferred

The cost benefit assessment for the alternatives proposed for both Creek Systems has been based upon the improvements that would be implemented for each alternative for the 100-year event (ref. Table 5.60). The total number of properties and buildings which benefit for each alternative, per Creek, along with the associated cost (without contingency) is shown in Table 5.62.

Table 5.62 Summary of Flood Risk Reduction Benefits Resulting from Alternatives (100 Year)

LOWER MORRISON CREEK			
ALTERNATIVE	TOTAL COST ($M)	TOTAL NUMBER OF PROPERTIES BENEFITTING	TOTAL NUMBER OF BUILDINGS BENEFITTING
Culvert Upgrades	$ 2.58 M	0	6
Flow Diversion/ Flood Storage – 5 Year Inlet	$ 7.19 M*	72	34
Combined	$ 9.77 M*	72	34
LOWER WEDGEWOOD CREEK			
ALTERNATIVE	TOTAL COST ($M)	TOTAL NUMBER OF PROPERTIES BENEFITTING	TOTAL NUMBER OF BUILDINGS BENEFITTING
Culvert Upgrades	$ 4.22 M	1	3
Combined	$ 4.22 M	1	3

Note*: The cost for the flow diversion has not been applied here, as the associated costs are larger in comparison to flood storage, while the storage provides similar performance, with reduced cost

Based upon the cost benefit summary in Table 5.62, the implementation of culvert upgrades will result in a minimal amount of properties and buildings benefitting as a result of these improvements. Culvert upgrades for Lower Morrison Creek will cost approximately $2.58 M, and will benefit 6 (six) buildings. Culvert upgrades on Lower Wedgewood Creek would cost approximately $4.85 M, and result in a benefit to 1 (one) property and 3 (three) buildings.

The largest benefit from a single alternative would result from setting the inlet to a 5-year WSEL with either 1 or 2 inlets to the flood storage, resulting in a total benefit of 72 properties, and 34 buildings. For this alternative, the cost of the flood storage has been selected at approximately $7.19 M. It should be noted that flood diversion can also be implemented here at a cost of $7.40 M.

The greatest overall benefit that can be observed is by implementing the combined alternative, which consists of culvert upgrades on both creeks, and the inlet set at the 5-year WSEL with either 1 or 2 inlets to the offline flood storage at Lower Morrison Creek. The total cost for this alternative Is $14.62 M, which includes the $7.19 M for flood storage. The total benefits with this alternative are a reduction or removal of floodlines for a total of 73 properties and 37 buildings.

5.5.7 NON-STRUCTURAL ALTERNATIVES

Non-structural alternatives such as Regulation, Flood Forecasting, Warning and Emergency Preparedness and a Creek Maintenance Plans are required to reduce the threat to life and property, but would not reduce existing flooding conditions and risk within the study area. As such these alternatives should be considered as potential areas for operational improvement in conjunction with the preferred structural solutions.

i. Creek Maintenance Plan: A creek maintenance plan involves municipal works to clear the channel and floodplain of debris. The Town of Oakville Staff already regularly observe conditions within town owned reaches of both Lower Morrison Creek and Lower Wedgwood Creek, to determine potentially obstruction to flow, and to schedule removal of potential obstructions. Removal of obstructions requiring machinery would require consultation and approval from Conservation Halton. In addition, the Town should continue to educate residents on clearing obstructions by hand on privately owned creek reaches.

ii. Emergency Preparedness: Based on the existing conditions flood potential, the at-risk areas of flooding should be identified by municipal address, if public allow by automated messaging system, providing

Town staff the ability to notify property owners and the public of potential flood conditions. The system would also allow Town staff to develop an emergency preparedness plan by knowing which areas to observe during significant storm events.

iii. Flood Forecasting/Warning: Conservation Halton provides a flood forecasting system that is supported by the Ministry of Natural Resources and Forestry at a provincial level, which also provides support to local municipalities. The Town of Oakville and the Region of Halton has the primary responsibility to provide flood emergency response, while Conservation Halton provide a flood forecasting and warning system. Conservation Halton provides the following:

- Monitor watershed and weather conditions and operate a flood forecasting system to provide a warning of anticipated or actual flood conditions.
- Issue flood alert and flood warning bulletins to municipalities and other appropriate agencies to advise of the potential for flooding.
- Operate conservation authority dams and flood control structures to reduce the effects of flooding.
- Provide advice to municipalities for preventing or reducing the effects of flooding.
- Maintain communications with municipalities and the Ontario Ministry of Natural Resources and Forestry during a flood event.

Land Acquisition: Land acquisition is typically considered to be one of the last alternatives for reducing flood risk of property and buildings, due to social, political and economic ramifications. That said, increased flood risk, due to climate change, has prompted consideration of property buy outs, by various levels of government. Therefore, this alternative must be considered, when financially viable, and when it is determined that the benefit of property purchase is greater than the repair costs. Potential for national action plan to help property owners with relocation, by the Federal Government, could in the future provide funding for land acquisition by the town.

5.6 PREFERRED ALTERNATIVES

5.6.1 INVICTA DRIVE

The preferred solution for Invicta Drive is Invicta Drive Assessment Alternative D2, which has been integrated with the widening of North Service Road and will provide an overall reduction in flows to all the outlets. The Alternative includes a proposed diversion from Invicta Drive to a new stormwater management facility at Eighth Line and North Service Road. The alternative will mitigate the water quality, quantity, erosion and water budget impacts associated with the proposed North Service Road widening, while providing significant benefits to the receiving Wedgewood Creek.

5.6.2 MIDTOWN AREA

The Non-Diversion Scenario has been selected as the preferred alternative for the Midtown Area based on storage requirements and costing. The minimum capture of 25 mm was selected for low impact development (LID) best management practices as per the Oakville Stormwater Master Plan. The Non-Diversion Scenario capital cost has been estimated at $4,981,535 (ref. Appendix I).

5.6.3 STUDY AREA ALTERNATIVES

The preferred alternatives based upon the short-listed alternative assessment include recommended crossing upgrades and either the Lower Morrison Creek Diversion to Sixteen Mile Creek or the Offline Flood Storage. The following summarizes the culvert upgrades and the approximated potential flood risk reduction benefit.

Crossing Upgrades

- Lower Morrison Creek:
  - Lakeshore Road (14.6 m span by 3.35 m rise CONSPANTM Arch) – Implementing this upgrade will result in 3 (three) buildings with a reduced flood risk.
  - Linbrook Road (7.3 m span by 2.13 m rise CONSPANTM Arch) – Will reduce flood elevations, but minimal reduction in flood risk to properties.
  - Chartwell Road (North of Linbrook Road) (6.4m span by 2.13m rise box) – Implementing this upgrade will result in 2 (two) buildings with a reduced flood risk.
  - Chartwell Road (South of Linbrook Road) (6.4m span by 1.5m rise box) – Implementing this upgrade will result in 1 (one) building with a reduced flood risk.
- Lower Wedgewood Creek:
  - Lakeshore Road (14.6m span by 3.05m rise Decast^{TM} Arch) – Implementing this upgrade will result in 1 (one building with a reduced flood risk.
  - Warren Drive Park (7.3m span by 1.52m rise CONSPANTM Arch) – Implementing this upgrade will result in 1 (one) building with a reduced flood risk.
  - Wedgewood Drive Park (7.3m span by 1.52m rise CONSPANTM Arche) – Will reduce flood elevations, but minimal reduction in flood risk to properties.
  - Cornwall Road (North of Existing SWM Facility) (7.3m span by 1.52m rise CONSPANTM Arch) – Implementing this upgrade will result in 1 (one) property and 1 (one) building with a reduced flood risk.

Three (3) CNR culverts upgrades have also been assessed to improve conveyance capacity and meet AREMA hydraulic performance guidelines. Upgrading these existing structures would reduce the flood risk to 2 (two) properties in the localized area for Lower Wedgewood Creek. A hydraulic benefit would be observed by upgrading the existing CNR culvert on Lower Morrison Creek, though there would be no noticeable change to the flood risk to properties.

The recommended culvert upgrades, in general, should be implemented in a downstream to upstream manner, to prevent the reduced flow attenuation resulting from upgraded culverts acting on existing crossings downstream.

Lower Morrison Creek Offline Flood Storage versus Flow Diversion to Sixteen Mile Creek

The flow diversion from Lower Morrison Creek to Sixteen Mile Creek could be implemented by constructing 840 m of 1.5 m diameter storm sewer from Cornwall Road Park along Cornwall Road and Trafalgar Road to Sixteen Mile Creek west of Ingelhart Street North, reducing the overall flood levels for Lower Morrison Creek and providing a flood risk reduction benefit to 72 properties and 34 buildings.

As an alternative to the flow diversion, a 10,800 m^3 flood storage tank could be built underneath the existing baseball diamond at Cornwall Road Park, with the ability to reduce downstream flooding due to its flow attenuating capacity. This alternative will provide a similar benefit to the flow diversion in providing a flood risk reduction benefit to 72 properties and 34 buildings.

A combined alternative on Lower Morrison Creek consisting of culvert upgrades, and either the flow diversion or flood storage may be implemented, providing a benefit to 72 properties and 34 buildings.

The flood mitigation benefit of the Lower Morrison Creek offline flood storage versus the Lower Morrison Creek flow diversion is the same based on using two (2) inlets, as such the preferred alternative needs to be selected based on other factors. Table 5.63 provides an assessment of each alternative:

Table 5.63 Evaluation of Lower Morrison Creek Alternatives

EVALUATION CRITERIA	LOWER MORRISON CREEK OFFLINE FLOOD STORAGE	LOWER MORRISON CREEK FLOW DIVERSION TO SIXTEEN MILE CREEK	COMMENTS
Functional	• Requires modification to either the creek reach and/or Cornwall Road crossing to improve hydraulic head at inlet. • Inlet to be set at the 5-year water surface elevation • Requires a 10,800 m^3 tank to be placed under the baseball diamond • Requires a pump system to discharge to the creek at a controlled rate after flood flows subside	• Requires modification to either the creek reach and/or Cornwall Road crossing to improve hydraulic head at inlet. • Inlet to be set at the 5-year water surface elevation • Requires an 840 m of 1.5 m diameter pipe to be placed along Cornwall Road and Trafalgar Road • An outlet to Sixteen Mile Creek would require a drop structure before discharging to the creek.	• Both alternatives require modifying the creek reach and/or Cornwall Road to improve hydraulic head • Inlet set at same level for both alternatives • The flow diversion will require additional drainage infrastructure • Drop structure may have a larger capital cost associated with it, compared to potentially higher operating costs for the pump needed for the flood storage
Environmental	• Impacts to Lower Morrison Creek would also be anticipated to be minor, with frequent flows not being altered.	• Would have potential impacts to both Lower Morrison Creek and Sixteen Mile Creek. Impacts to Sixteen Mile Creek would be anticipated to be minor based on the creek's flow capacity and significant valley formation. Impacts to Lower Morrison Creek would also be anticipated to be minor, with frequent flows not being altered.	• Flood storage would result in significantly lower environmental impacts compared to flow diversion, as there would be no impacts to Sixteen Mile Creek, as such, the flood storage alternative should be easier to approve by Conservation Halton.
Social	• Temporary disruption within Cornwall Road Park during construction	• Temporary disruption within Cornwall Road Park and along Cornwall Road and Trafalgar Road during construction	• The flood storage alternative will not provide as significant a social

EVALUATION CRITERIA	LOWER MORRISON CREEK OFFLINE FLOOD STORAGE	LOWER MORRISON CREEK FLOW DIVERSION TO SIXTEEN MILE CREEK	COMMENTS
			disruption as the flow diversion
Economic	• Preliminary costs have been determined as $6.85M	• Preliminary costs have been determined as $7.05 M, therefore slightly higher than the offline storage alternative	• Based upon preliminary costing, the flow diversion costs approximately $210,000 more than flood storage

Based upon the assessment, the preferred alternative is Offline Flood Storage. Implementing the Offline Flood Storage would alleviate flooding concerns and provide the same flood risk reduction benefit as Flow Diversion, while being more economically feasible. Due to the Offline Flood Storage being only located at the existing baseball diamond, versus that and Cornwall Road and Trafalgar Road for the Flow Diversion, less existing infrastructure will likely be affected or need to be upgraded. As the Flow Diversion would require approximately 840 m of new storm sewer piping to be installed along Cornwall Road and Trafalgar Road, the disruption to public activities would be significant in comparison to the localized disruption resulting from implementing the Offline Flood Storage alternative.

The environmental impacts for the Offline Flood Storage would be less than the Flow Diversion, which would have result on environmental impacts on Lower Morrison Creek, and Sixteen Mile Creek, although the impacts would be considered minor based on the peak flows that would be diverted. As such, the Offline Flood Storage alternative should be easier to receive approval for from Conservation Halton vs the Flow Diversion alternative.

Based upon the foregoing, the preliminary preferred alternative for Lower Morrison and Wedgewood Creeks is the implementation of Offline Flood Storage, with an inlet set to the 5-year WSEL with either 1 or 2 inlets (2 inlets preferred), while also implementing culvert upgrades and localized flood protection.

Preferred Alternatives Costing

Costing for the preferred alternatives has been included in Appendix H. Contingency costs have been rounded up to the nearest $100,000 within the subsequent tables, though consist of 15% of the total cost associated with each system. Tables 5.64 and 5.65 provide a summary of the total costs associated with each system that may be implemented across Lower Morrison and Wedgewood Creeks, respectively.

Table 5.64 Preferred Alternatives Summary of Costs (Lower Morrison Creek)

System	Total Cost ($M)	Total Cost with 15% Contingency ($M)
Culvert Upgrades	$ 2.24 M	$ 2.58 M
Flood Storage	$ 6.25 M	$ 7.19 M
Total	**$ .8.49 M**	**$ 9.77 M**

Table 5.65 Preferred Alternatives Summary of Costs (Lower Wedgewood Creek)

System	Total Cost ($M)	Total Cost with 15% Contingency ($M)
Culvert Upgrades	$ 4.22M	$ 4.85 M
Total	**$ 4.22 M**	**$ 4.85 M**

Figure 5.15 Comparison of Floodlines Between Existing Conditions and Preferred Alternative for Lower Morrison Creek

Figure 5.16 Comparison of Floodlines Between Existing Conditions and Preferred Alternative for Lower Wedgewood Creek

6 NEXT STEPS AND IMPLEMENTATION

6.1 PRIORITZATION

Subject to town and Council approval, the preferred alternatives for mitigating the flood risk at various identified sites on lower Morrison and lower Wedgewood creeks, as presented herein, can be advanced to the next stages of planning and design. Prioritization of the alternatives would be established by the Town as part of overall flood risk mitigation works being considered for the Town. Several riverine flood mitigation studies either have been completed or are nearing completion, which will have recommendations that will also have budgetary demands on the capital flood mitigation program. These studies include Munn's Creek, Fourteen Mile /McCraney Creek, Sheldon Creek and Joshua's Creek. Once all studies are completed, a prioritization of flood mitigation works will be carried out and implemented with consideration of level of risk, return on investment and funding availability.

6.2 IMPLEMENTATION

Implementation of each of the alternatives has been considered based on the Municipal Class EA process and associated project schedules (ref. Table 6.2) and whether each alternative will or will not require a more detailed Class Environmental Assessment. For the recommended culvert upgrades and the Lower Morrison offline flood storage tank, this Class EA has fulfilled the Municipal Class EA process and associated assessment requirements. For the Invicta Drive drainage improvements have been determined through the North Service Road Improvements Project. Municipal Class EA project requirements for the Midtown Area stormwater management measures will be dependent upon the scope of work, public versus private ownership and any property purchase requirements for the Town.

Although the preferred alternatives may not have further assessment requirements through the Municipal Class EA process, each alternative or project will have various assessment requirements through the design, approval construction and post construction phases (ref. Table 6.2).

Conservation Halton as part of the implementation of the Class EA recommendations, has required a Commitment Letter from the Town (ref. Appendix A). The Town has committed to various tasks in the development of recommendations, such as revised hydrologic/ hydraulic modelling, assessment of Regional Storm peak flows and other tasks, including revising the assessment for stormwater management for Midtown to incorporate spill conditions from the Lower Morrison Lower Wedgewood Channel.

It is recommended that pre-consultation with Conservation Halton be conducted to verify approval requirements, including consultation with other agencies such Department of Fisheries and Oceans. Conservation Halton will be able to provide, initial construction timing windows, which would be validated through detailed ecological field surveys at each of the respective sites, therefore ensuring wildlife and species at risk are not negatively impacted.

Site monitoring requirements for each project stage, pre-construction, construction and post construction should be determined in consultation with Conservation Halton and any other required approval agencies. It is anticipated that post construction monitoring for the Lower Morrison Creek Offline Flood Storage Tank will be required to confirm the operation of the facility. Table 6.2 provides a non-exhaustive summary of preferred alternative project assessment requirements to be considered by the Town.

Table 6.1 Summary of Preferred Alternatives and Implementation Considerations

LOCATION	MUNCIPAL CLASS EA SCHEDULE	EA STATUS	OTHER CONSIDERATIONS
• Invicta Drive Alternative D2	• Schedule B for stormwater management pond (fulfilled by this Class EA)	• *A Schedule B EA based on Project Classification 40b: Establish new or replace or expand existing stormwater detention/retention ponds or tanks and appurtenances including outfall to receiving water body where all such facilities are not located in an existing utility corridor, or an existing road allowance or where property acquisition is required.*	• To be integrated with the North Service Road reconstruction project with the understanding that the Town will own lands for the proposed Stormwater management facility. • Consultation with MTO required throughout the project regarding all project aspects including stormwater management. • - design requirements to be finalized through the North Service Road Improvements Project.
• Midtown Area	• Depends on type of stormwater management project and associated road works. Refer to Town of Oakville Commitment Letter to Conservation Halton (May 24, 2024) regarding additional assessment requirements for stormwater	o For consideration, projects are exempt based on: o *Project Classification 37: Roadside ditches, culverts and other such incidental stormwater works constructed solely for the purpose of servicing municipal road works.* o *Project Classification 40a: Establish new or replace or expand existing stormwater detention/retention ponds or tanks and appurtenances including outfall to receiving water body provided all such facilities are in either an existing utility corridor or an existing road allowance where no additional property is required.* o *Project Classification 44: Construction of stormwater*	• Stormwater management works to be determined for each project within the Midtown Area. • Consultation required with MTO with its' jurisdiction along the highway corridor. • Design requirements will vary depending on each project scope. • Consultation with Conservation Halton within regulated areas. • Stormwater management works to consider Stormwater Master Plan recommendations.

LOCATION	MUNCIPAL CLASS EA SCHEDULE	EA STATUS	OTHER CONSIDERATIONS
	management within the Midtown Area.	*management facilities which are required as a condition of approval on a consent, site plan, plan of subdivision or condominium which will come into effect under the Planning Act prior to the construction of the facility. This includes LID features.* • For consideration, projects require a Schedule B based on: o *Project Classification 38a: Establish new or modify, retrofit or improve LID features within an existing road allowance or an existing utility corridor.* o *Project Classification 38b: Establish new or modify, retrofit or improve LID features where property acquisition is required.* o *Project Classification 40b: Establish new or replace or expand existing stormwater detention/retention ponds or tanks and appurtenances including outfall to receiving water body where all such facilities are not located in an existing utility corridor, or an existing road allowance or where property acquisition is required.*	
• Culvert Crossings (Various	• Exempt	• Culvert Crossings upgrades are exempt under the 2023 Municipal	• Conservation Halton to be consulted for each culvert crossing. May require Department of Fisheries and Oceans (DFO) consultation.

LOCATION	MUNCIPAL CLASS EA SCHEDULE	EA STATUS	OTHER CONSIDERATIONS
Crossings on both Lower Morrison Creek and Lower Wedgewood Creek.		Class EA Guidelines, based on Table C – Municipal Transit Projects: o Project Classification 8b: *Culvert repair or replacement where the capacity of the culvert or drainage area is changed.* • Should culverts be replaced solely for the purpose of flood control, then under Table B Municipal Water and Wastewater Projects (Shoreline/ In Water Works): o Project *Classification 50: Modify existing water crossings for the purposes of flood control* a Schedule B is required.	• Design to consider: o property o construction access o road design, o structural design o utilities, o geotechnical conditions, o excess soils o hydraulics, including Lower Morrison Lower Wedgewood Channel spill conditions o erosion conditions o stream morphology o fisheries passage and habitat o terrestrial vegetation assessment o wildlife and species at risk. o construction timing restrictions
• Lower Morrison Creek Offline Flood Storage Tank	• Schedule B (fulfilled by this Class EA)	• *As per Table B Municipal Water and Wastewater Projects (Shoreline/ In Water Works) stormwater tanks are Exempt based on:* o *Project Classification 40a : Establish new or replace or expand existing stormwater detention/retention ponds or tanks and appurtenances including outfall to receiving water body provided all such facilities are in either an existing utility corridor or an existing road allowance where no additional property is required* • *A Schedule B Class EA is required for:*	• Conservation Halton, DFO and Ministry of Environment Conservation and Parks (MECP) to be consulted. • Stage 1 Archaeological Assessment in area of the tank (ref. Appendix J). • Town of Oakville Parks, Recreation & Culture to be consulted prior to project. • Design to consider: o park features and usage o construction access for creek inlet and outlet o tank configuration o structural design o utilities, o geotechnical and hydrogeological conditions, o excess soils o hydraulics, including Lower Morrison Lower Wedgewood Channel spill conditions

LOCATION	MUNCIPAL CLASS EA SCHEDULE	EA STATUS	OTHER CONSIDERATIONS
		o *Project Classification 51: Works undertaken in a watercourse for the purposes of flood control or erosion control, which may include:* o *bank or slope regrading, • deepening the watercourse, relocation,* o *realignment or channelization of watercourse* o *revetment including soil bio-engineering techniques* o *reconstruction of a weir or dam*	o erosion conditions o stream morphology o fisheries habitat protection o terrestrial vegetation assessment o wildlife and species at risk o construction timing restrictions o post construction monitoring and adaptive measures o long-term maintenance

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

The following conclusions have been prepared based on the findings of this study:

1. A calibrated PCSWMM hydrologic/hydraulic model has been developed using the modelling from the Town of Oakville Stormwater Master Plan modelling, with calibration to the modelling based on observed rainfall and observed flow data.
2. HEC-Ras hydraulic modelling has prepared for both Lower Morrison Creek and Lower Wedgewood Creek. The modelling has been validated based on observed flows and highwater levels.
3. The PCSWMM hydrologic modelling has been used to assess local drainage improvements and stormwater management measures to prevent flooding within the Invicta Drive study area.
4. The hydrologic and hydraulic modelling has been used to assess various short-listed flood mitigation alternatives with the objective of reducing flood risk along both creek systems.
5. A critical flow assessment for both creek systems at the downstream creek reaches of the Midtown Area has been conducted to determine stormwater erosion control requirements for future development within Midtown. Stormwater quantity controls have been assessed to offset future development impacts on both Lower Morrison and Lower Wedgewood Creeks.
6. A high-level climate change assessment has been conducted to provide guidance to the Town on future stormwater management impacts.

7.2 RECOMMENDATIONS

The following conclusions have been prepared based on the findings of this study:

1. The recommended flood risk mitigation alternatives for both Lower Morrison Creek and Lower Wedgewood Creek be considered and implemented by the Town in the context of the recommended flood mitigation projects resulting from each of the Town's Flood Mitigation studies.
2. The Town implement the recommended Alternative D2, with the diversion of drainage from Invicta Drive to a new stormwater management facility at Eighth Line and the North Service Road.
3. As per the recommendations of the Stormwater Master Plan, 25 mm capture should be applied for all future development, including the Midtown Area. The 25 mm capture will provide erosion control, with supplemental stormwater quantity control required to mitigate the predicted increase in peak flows to both creek systems, including consideration for climate change.
4. In implementing the preferred alternatives, that the tasks indicated in the Commitment Letter from the Town of Oakville to Conservation Halton be conducted, with consultation throughout the alternative implementation process.