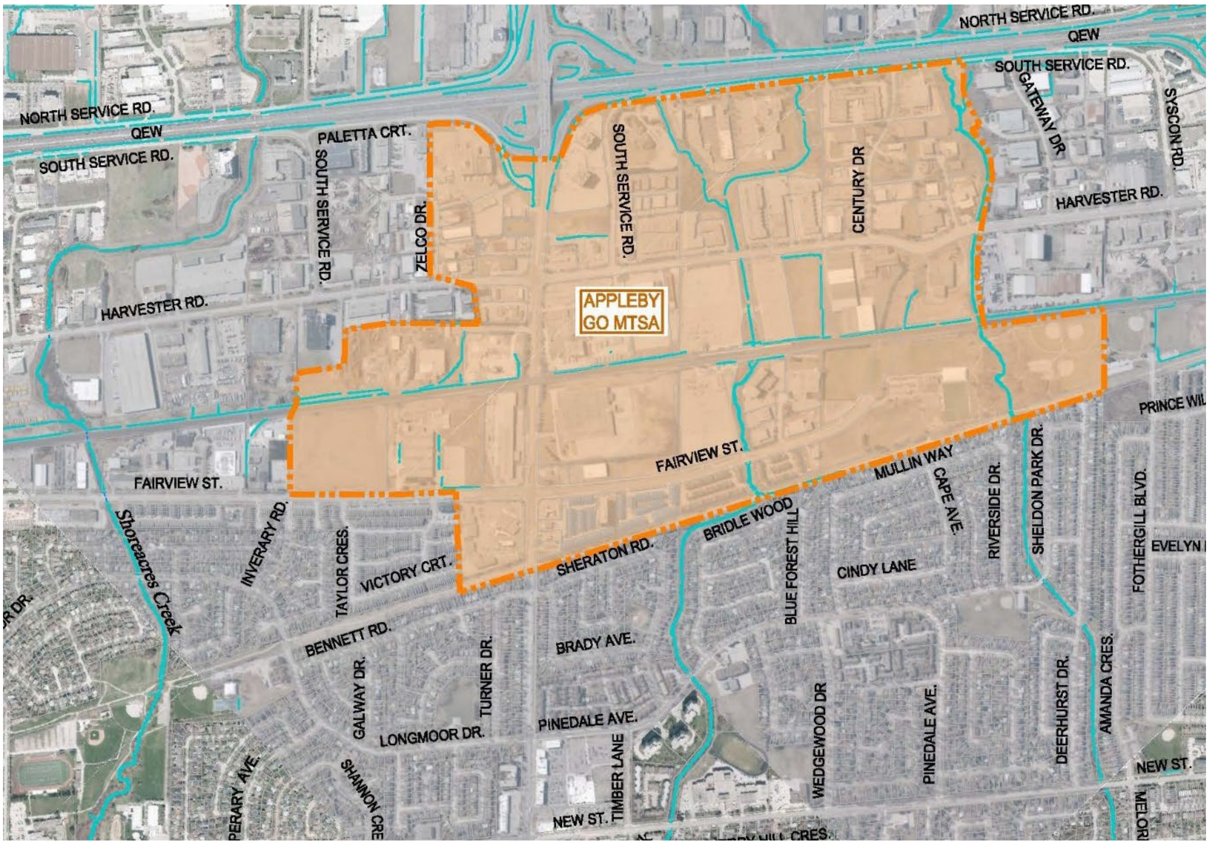
CITY OF BURLINGTON

FLOOD HAZARD AND SCOPED STORMWATER MANAGEMENT ASSESSMENT

APPLEBY GO MAJOR TRANSIT STATION AREA

JUNE 05, 2023



FLOOD HAZARD AND SCOPED STORMWATER MANAGEMENT ASSESSMENT

APPLEBY GO MAJOR TRANSIT STATION AREA

CITY OF BURLINGTON

PROJECT NO.: TPB178008
DATE: JUNE 05, 2023

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QUALITY MANAGEMENT

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APPROVED[1] BY *(must be reviewed for technical accuracy prior to approval)*

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1 INTRODUCTION

The City of Burlington (City) is undertaking a land use planning study for three (3) Major Transit Station Areas (MTSAs), previously referred to as Mobility Hubs. These are areas as located around the City's GO stations including Appleby GO, Burlington GO, Aldershot GO, and also includes the Downtown area where re-development and intensification are expected.

A planning study was undertaken commening in 2017 (lead by Brook McIlroy Inc.). This work included the preparation of a series of Scoped Environmental Impact Studies (EIS) for each of the four (4) areas cited above. The purpose of the Scoped EIS is to document existing environmental conditions and assess potential environmental impacts and mitigation strategies related to the expected development and re-development in these areas. Note that SGL Planning subsequently undertook a scoped review of the Downtown area ("Taking a Closer Look at the Downtown: Themes, Principles and Land Use Concepts", October 2019).

In support of this effort, WSP E&I Canada Limited (WSP; formerly Wood Environment & Infrastrucutre Solutions Canada Limited) prepared a series of flood hazard and scoped stormwater management assessments for each of these areas. Note that a combined report was prepared for the Burlington GO and Downtown area and assessed through a subsequent report update ("Major Transit Station Area (MTSA) Phase 2 Flood Hazard Assessmemnt, Burlington GO and Downtown" WSP, March 2023). Separate reporting was prepared for the Aldershot GO and Appleby GO MTSAs.

These documents aummarize existing flood hazards for areas of anticipated development, and to also develop preliminary stormwater management strategies, including consideraton for drainage infrastructure service capacity and associated improvements, where feasible and required.

The current report is focused specifically upon the Appleby GO MTSA. Drawing 1 presents the boundaries of the MTSA study area along with the area watercourses.

Ultimately, the analyses documented within the current report are intended to provide context with respect to the overall flood risk to the Appleby GO MTSA, and the potential implications to the proposed intensification development in these areas.

This report is intended to serve as a primary component of the overall Scoped EIS reporting. In addition, the current reporting also includes the Scoped Stormwater Management (SWM) criteria assessment.

The current reporting was largely finalized in February, 2019. The current version of the reporting has been updated to include minor additional comments from Conservation Halton (CH), as per its comment summaries of April 16 and November 26, 2021. Since that time updated hydrologic and hydraulic modelling has been completed by CH specifically for the Grindstone Creek watershed ("Grindstone Creek Floodplain Mapping Update", Matrix, March 2020). Reference should be made to the most current flood hazard mapping as available from CH. It is also recognized that CH has deferred the requirements for some supplementary analyses to a future phase of work; reference is made to those comments accordingly (refer to Appendix B).

2 HYDROLOGY

2.1 AVAILABLE MODELLING

The Appleby GO MTSA Area (Drawing 1) intersects a number of different watersheds (ref. Drawing 3). These watersheds and available sources of hydrologic modelling are summarized in Table 2.1 (as per Table B, Scoped EIS Work Plan (updated April 25, 2017).

Table 2.1. Available Hydrologic Modelling – Appleby GO MTSA

WATERSHED	STUDY DATE AND REFERENCE	MODELLING PLATFORM
Shoreacres Creek	Shoreacres Creek Floodplain Mapping Updates (EWRG, 1997)	GAWSER
Appleby Creek	Appleby Creek Floodline Mapping Updates (EWRG, 1997)	GAWSER
Sheldon Creek	Sheldon Creek Hydrologic and Hydraulic Study – DRAFT (Amec Foster Wheeler, 2016)	HSP-F

As evident from Table 2.1, the available hydrologic modelling is a mixture of GAWSER (Shoreacres and Appleby Creeks) and HSP-F (Sheldon Creek). It is also noted that the most current hydrologic modelling for Sheldon Creek remains in "Draft" form (as of the time of writing), as it is has not been formally approved by Conservation Halton. Nevertheless, as the most current available hydrologic modelling (and the one proposed as part of the Work Plan Terms of Reference), this modelling has been employed for the current assessment.

It should also be noted that Conservation Halton (CH) has undertaken a study to update the hydrologic and hydraulic modelling and floodplain mapping for the East Burlington Creeks, which includes Tuck Creek, Shoreacres Creek, Appleby Creek, and Sheldon Creek. This work (being completed by WSP) is nearing completion at the time of this version of the report, with a Public Information Centre (#2) planned for June 6, 2023. Once finalized and approved, this modelling should be applied for subsequent analyses. Notwithstanding as this modelling was not available at the time of the preparation of this study report, it could not reasonably be included.

2.2 HYDROLOGIC MODELLING UPDATES

2.2.1 EXISTING LAND USE PARAMETERIZATION

In order to develop a consistent approach to the estimation of flows under existing land use conditions, a consistent land use layer has been employed for all hydrologic models.

The City of Burlington has provided two different sources of land use mapping (Official Plan Mapping and Zoning Bylaw mapping). These mapping data have been reviewed, and ultimately the Zoning Bylaw mapping has been considered to be most representative of current conditions, and more readily useable for hydrologic modelling purposes. This mapping has been updated as required, including merging certain land use classifications, and adding separate distinctions as required (in particular, differentiating between more recent and intense detached residential areas, as opposed to older, less intense residential areas). The resulting land use mapping is presented in Drawing 2.

Imperviousness for these land use areas has been estimated using current aerial photography, with spot checks for three (3) different sub-areas for each land use classification, in order to estimate an average value. For detached residential areas, directly and indirectly connected areas have been estimated based on rooftop downspout connectivity (as evident from Google Earth™ and field review). Table 2.2 presents the resulting land use classifications and associated estimated imperviousness values.

Table 2.2. Estimated Land Use Characterization and Parameterization for Appleby GO MTSA

LAND USE CLASSIFICATION	TOTAL IMPERVIOUSNESS (%)	DIRECTLY CONNECTED IMPERVIOUSNESS (%)
Apartment Buildings	60%	60%
High Density Detached	60%	30%
Low Density Detached	40%	20%
Downtown High Density	60%	60%
Downtown Low Density Residential	35%	15%
High Impervious	90%	90%
Institutional	60%	60%
Park/Corridor	10%	10%
Semi Detached and Town Homes	60%	60%
Roadways	90%	90%

Based on the foregoing parameterization, an average overall impervious coverage of 69% +\- results for the existing drainage areas within the Appleby MTSA Limit. The modelling updates have resulted in an increase of the impervious coverage from the original modelling (which had an average impervious coverage of approximately 35% +/-). This likely reflects less conservative imperviousness assumptions associated with older vintage hydrologic modelling.

Drawings 3 and 4 present the drainage area boundaries for the Appleby MTSA area, and also depict key hydrologic nodes (locations) of interest based on the flows generated from the updated hydrologic modelling.

In addition to the preceding, it is noted that the older previously completed hydrologic assessments (Shoreacres and Appleby Creek – 1997) used the available IDF data of that time (to generate 3-Hour Chicago Design storms), which has generally since been superseded by more current/extensive datasets (GAWSER is capable of continuous hydrologic simulation, but this is beyond the current scope of work). As part of this assessment, the data from the 2004 IDF update completed by WSP (then Philips Engineering; December 10, 2004) has been applied; refer to Appendix C for details. It should be noted however that the currently approved City IDF are those specified in the 1994 Storm Drainage Design Manual (based on data from 1964 to 1990). The 2004 values represent approximately a 5% increase in rainfall depths as compared to the 1994 values.

A number of different design storm distributions have been assessed to determine the most critical. Based on this analysis (completed for the Burlington GO MTSA and Downtown area), the 24-Hour SCS Type II distribution has been selected based on the highest simulated flows within the receiving watercourse systems, and for consistency with the analyses completed for the other MTSAs. Sensitivity analysis results have been included in Appendix C.

The Sheldon Creek watershed was previously modelled using a continuous simulation methodology. The Sheldon Creek HSP-F model has hence been updated to simulate the 24-Hour SCS Type II design storm distribution as per the Scoped EIS Work Plan, and for consistency with the other completed watershed analyses.

2.2.2 GAWSER MODELLING (SHOREACRES AND APPLEBY CREEKS)

2.2.2.1 OVERVIEW

The Guelph All-Weather Sequential-Events Runoff (GAWSER) modelling program has been applied historically in the Shoreacres Creek and Appleby Creek watersheds. The GAWSER model has multiple methods for calculating subcatchment runoff, which apply variations of main channel and off channel routing of runoff through the subcatchment. The main channel section represents the overall hydraulic routing through the subcatchment, while the off channel represents the smaller drainage paths which lead to the main channel. The subcatchment length and width parameters are based on the length of the main channel and off channels, respectively.

A review of the lengths and width parameters applied in the 1997 EWRG models determined that for Appleby Creek the subcatchments have a length to width ratio of 7:1 or 3:1. Subcatchment Length (L), Width (W), and Main Channel Travel Time (TMC) have been revised for the discretized subcatchments using the methodology described in the GAWSER User Manual. The GAWSER User Manual Appendix A describes TMC as a linear function of length and flow velocity. The TMC has been estimated based on length weighting assuming the flow velocities within the discretized subcatchments remain the same from the parent catchments.

The Environmental Water Resources Group (EWRG) models have applied 'Model 4' which was been built for urban subcatchment modelling using two off channels to represent the pervious component and the impervious components of the subcatchment. The 'Model 4' parameter requires time of concentration for the main channel (TMCI) and both of the off channels (TOCi and TOCp). A review of the EWRG model parameterization determined that, other than imperviousness and soil composition, the remaining subcatchment parameters can be defined as follows:

- Time of Concentration Impervious Off Channel (TOCi) is set to 0.067 hours
- Time of Concentration Pervious Off Channel (TOCp) is set to:
  - 0.25 hours for urban subcatchments
  - 0.42 for rural subcatchments
  - And 0.48 for subcatchments A7, A7.1 and A7.2 in Appleby Creek
- Base Time (FTB) and Base Time Impervious (FTBi) are set to:
  - 1.2 for urban subcatchments
  - 2.0 for rural subcatchments

The subcatchment area discretization for Appleby Creek and Shoreacres Creek was updated in 2007 by the City of Burlington and utilized in the Urban-Area Flood Vulnerability, Prioritization and Mitigation Study completed by Amec Foster Wheeler (now WSP) in July 2017 (Burlington City-Wide Flood Study). The subcatchment areas were compared with the reported and modelled values from the 1997 EWRG Studies using GIS tools. The review determined that several areas no longer matched the local topography and adjustments to the subcatchment delineation were made to conform to the current topographic contour mapping. For example, West Appleby Creek has been realigned through subcatchment A18 (refer to Drawings 3 and 4). Furthermore, the updated 2007 subcatchment delineation showed area differences when compared to the 1997 reported values. The modelled subcatchments within the Appleby GO MTSA boundary have been updated to match the GIS areas, as well as subcatchments where area differences are greater than 5% (+/-). In order to maintain flows which are comparable to the approved hydrologic models, subcatchments with area changes of less than 5% have retained the original 1997 drainage areas.

The runoff procedures in GAWSER utilize a subcatchment discretization method which considers impervious area as an alternative soil type. The EWRG model divided the soils into hydrologic soil groups A, B, C, and D which is typical of the SCS methodology, however the soil groups have been further discretized into 'high vegetative cover' and 'low vegetative cover'. A review of the available soils mapping (Soil Survey Complex, MNRF 2012) determined that the soils throughout the Appleby MTSA are similar in composition to the soils used for the 1997 Study. Therefore, in order to maintain consistency with the approved model, the relative soil compositions from the pervious component of the parent subcatchments have been retained for the updated modelling.

For example, if the parent catchment was fifty percent (50 %) impervious thirty percent (30 %) Soil Group A and twenty percent (20 %) Soil Group B; then the updated subcatchment with sixty percent (60 %) impervious coverage would have a soil composition of twenty four percent (24 %) for Soil Group A and sixteen percent (16 %) for Soil Group B, i.e.:

Parent Subcatchment:	50 % Impervious	30 % Soil Group A	20 % Soil Group B
Pervious Component:		60 % Soil Group A	40 % Soil Group B
Updated Subcatchment:	60 % Impervious	24 % Soil Group A	16 % Soil Group B

The impervious coverages for the study area subcatchments have been calculated by applying the land use classifications discussed in Section 2.2.1. The subcatchment main channel time of concentration parameter was determined through 'length' weighting of the parent subcatchments to provide a reasonable comparison of flows to the approved modelling.

2.2.2.2 SHOREACRES CREEK

As noted previously, drainage areas have been updated based on more currently available data. A comparison of the modelled drainage areas for Shoreacres Creek is presented in Table 2.3.

Table 2.3. Shoreacres Creek – Subcatchment Drainage Area Comparison

Subcatchment[1]	Previously Reported Drainage Area (EWRG, 1997) (ha)	Previously Modelled Drainage Area (EWRG, 1997) (ha)	Updated Drainage Area (WSP, 2018) (ha)	Difference versus Model (ha)	Difference versus Model (%)
S22	26.0	26.0	26.0	0.0	0.0
S21	43.0	43.0	-	-	-
S22.1	8.1	8.1	8.1	0.0	0.0
S20	57.0	57.0	-	-	-
S19	138.0	138.0	138.0	0.0	0.0
S18	86.0	86.0	86.0	0.0	0.0
S17	31.0	31.0	31.0	0.0	0.0
S15	56.0	56.0	56.0	0.0	0.0
S14	9.6	9.6	9.6	0.0	0.0
S13	88.0	88.0	88.0	0.0	0.0
S12	-	-	29.6	-	-
S12.1	-	-	24.7	-	-
S12	**48.0**	**56.0**	**54.3**	**-1.7**	**-3.0**
S11	27.0	27.0	27.0	0.0	0.0

Subcatchment[1]	Previously Reported Drainage Area (EWRG, 1997) (ha)	Previously Modelled Drainage Area (EWRG, 1997) (ha)	Updated Drainage Area (WSP, 2018) (ha)	Difference versus Model (ha)	Difference versus Model (%)
S10	16.0	16.0	16.0	0.0	0.0
S9	21.0	21.0	21.0	0.0	0.0
S8	37.0	37.0	37.0	0.0	0.0
S7	91.0	91.0	91.0	0.0	0.0
EX5	23.0	23.0	23.0	0.0	0.0
EX4	19.0	19.0	15.0	-4.0	-21
EX3	8.6	8.6	8.6	0.0	0.0
S6	20.0	20.0	35.8	+15.8	+79
S5.3	18.0	18.0	24.0	6.0	33
S5.2	5.4	5.4	5.4	0.0	0.0
S5.1	28.0	28.0	28.0	0.0	0.0
S5	12.0	12.0	12.0	0.0	0.0
S4	33.0	33.0	33.0	0.0	0.0
S4.4	-	-	22.1	-	-
S4.5	-	-	10.4	-	-
S4.6	-	-	9.7	-	-
S4.7	-	-	26.8	-	-
S4.4	**69.0**	**69.0**	**69.0**	**0.0**	**0.0**
S4.3	10.0	10.0	13.7	+3.7	+37
S3.2	26.0	26.0	26.0	0.0	0.0
S3.1	2.3	2.3	2.3	0.0	0.0
S3	86.0	86.0	86.0	0.0	0.0
S2	15.0	15.0	15.0	0.0	0.0
S1.3	14.0	14.0	14.0	0.0	0.0
S1.1	5.7	5.7	5.7	0.0	0.0
S1.	53.0	53.0	53.0	0.0	0.0
A6.1	-	-	20.0	-	-
A6.2	-	-	10.3	-	-
A6	**42.0**	**42.0**	**45.3**	**+3.3**	**+7.9**
TOTAL	**1,230.7**	**1,238.7**	**1,258.4**	**+19.8**	**+1.6**

Note: 1. Subcatchments denoted using underlines have been split in the updated modelling and area comparisons are noted in the following row of bolded values.

In addition to the preceding, a review completed by WSP noted that updates were also required to reflect an area currently under construction in Shoreacres Creek (subcatchment S12). Subcatchments S12 and S12.1 within Shoreacres Creek were updated based on "Alton West Subdivision Pond Stormwater Management Report Draft Plan of Subdivision 24T-03003/B Sundial Homes" (Counterpoint Engineering Inc, October 5, 2016). The model has been updated using a lumped catchment approach with subcatchment S12.1 modelled as 29.6 ha at 73 %

impervious coverage and S12 modelled as 24.7 ha at 30% impervious coverage. The residential areas (S12.1) were routed through the Alton West Pond which has a storage-discharge relationship as presented in Table 2.4.

Updated subcatchment parameterization, using the methodology described in Section 2.2.2.1, is presented in Table 2.5.

Table 2.4. Alton West Pond Storage Discharge Relationships

STORAGE (m^3)	DISCHARGE (m^3/s)
0	0
8,042	0.10
10,922	0.13
12,167	0.23
13,272	0.45
14,144	0.63
15,045	0.83
15,276[1]	0.88
16,804[2]	11.18

1. Storage and flow values from appendix C of Counterpoint Engineering 2016 Report
2. Flow value is referenced in Appendix C of Counterpoint Engineering 2016 Report, storage volume has been assumed as 10% greater than 100-year storage.

Table 2.5. Shoreacres Creek Updated Subcatchment Parameters

Updated Subcatchment (WSP, 2018)			Parent Subcatchment (EWRG, 1997)	
Subcatchment	TMCi	Imperviousness (%)	Subcatchment	Imperviousness (%)
S4.3	0.053	65.5	S4.3	53.0
S4.4	0.029	58.1	S4.4	42.0
S4.5	0.013	30.6		
S4.6	0.012	50.7		
S4.7	0.031	62.0		
S12	0.090	73.0	S12.1	2.0
S12.1	0.076	30.2		

2.2.2.3 APPLEBY CREEK

As noted previously, drainage areas have been updated based on more currently available data. A comparison of the modelled drainage areas for Appleby Creek is presented in Table 2.6.

Table 2.6. Appleby Creek – Subcatchment Drainage Area Comparison

SUBCATCHMENT[1]	PREVIOUSLY REPORTED DRAINAGE AREA (EWRG, 1997) (ha)	PREVIOUSLY MODELLED DRAINAGE AREA (EWRG, 1997) (ha)	UPDATED DRAINAGE AREA (WSP, 2018) (ha)	DIFFERENCE VERSUS MODEL (ha)	DIFFERENCE VERSUS MODEL (%)
A24	1.60	1.60	1.60	0.00	0.0
A23	55.00	55.00	62.03	+7.03	+12.8
A22	47.00	47.00	47.00	0.00	0.0
A21	14.00	14.00	14.00	0.00	0.0
A20	18.00	18.00	22.79	+4.79	+26.6
A18	44.00	44.00	50.67	+6.67	+15.1
A17.1	25.00	25.00	23.21	-1.79	-7.2
A17	-	-	25.9	-	-
A17.2	-	-	5.87	-	-
A17	**36.00**	**36.00**	**31.77**	**-4.23**	**-11.8**
A16	197.00	197.00	197.00	0.00	0.0
A15	68.00	68.00	68.00	0.00	0.0
A13.0	4.20	4.20	43.00	-	-
A13.1	58.00	58.00	16.69	-	-
A13.5	-	-	0.61	-	-
A13	**62.20**	**62.20**	**60.30**	**-1.90**	**-3.1**
A12	49.00	49.00	49.00	0.00	0.0
A11	55.00	55.00	66.17	+11.17	+20.3
A10	37.00	37.00	37.00	0.00	0.0
A9	38.00	38.00	39.00	+1.00	+2.6
A8	13.00	13.00	13.00	0.00	0.0
A7	29.00	29.00	15.54	-	-
A7.1	31.00	31.00	51.66	-	-
A7.2	36.00	36.00	36.69	-	-
A7	**96.00**	**96.00**	**103.9**	**+7.90**	**+8.2**
A6	-	-	20.85	-	-
A6.3	-	-	0.90	-	-
A6.4	-	-	10.36	-	-
A6.5	-	-	13.21	-	-
A6	**42.00**	**42.00**	**45.32**	**+3.32**	**+7.9**
A6.1	-	-	19.99	-	-
A6.2	-	-	10.28	-	-
A6.1	**34.00**	**34.00**	**30.27**	**-3.73**	**-11.0**
A4.1	27.00	27.00	26.99	-0.01	0.0
A5	-	-	6.34	-	-
A5.1	-	-	30.34	-	-
A5.2	-	-	22.50	-	-

SUBCATCHMENT[1]	PREVIOUSLY REPORTED DRAINAGE AREA (EWRG, 1997) (ha)	PREVIOUSLY MODELLED DRAINAGE AREA (EWRG, 1997) (ha)	UPDATED DRAINAGE AREA (WSP, 2018) (ha)	DIFFERENCE VERSUS MODEL (ha)	DIFFERENCE VERSUS MODEL (%)
A5	**55.00**	**55.00**	**59.18**	**+4.18**	**+7.6**
A3	47.00	36.00	36.00	0.00	0.0
A2.1	35.00	35.00	35.00	0.00	0.0
A2	38.00	38.00	38.00	0.00	0.0
A1.2	18.00	18.00	18.00	0.00	0.0
EX1	2.50	2.50	2.50	0.00	0.0
A1.3	5.10	5.10	5.10	0.00	0.0
A1.0	31.00	31.00	31.00	0.00	0.0
TOTAL	**1190.4**	**1179.4**	**1212.7**	**+33.3**	**+2.8**

1. Subcatchments denoted using underlines have been split in the updated modelling and area comparisons are noted in the following row of bolded values

In addition to the preceding, a review completed by WSP noted that subcatchments representing Alton Village required updating to match the as-built conditions in Appleby Creek (subcatchment A13). The Appleby Creek subcatchment A13 in the EWRG model (1997) has been updated to include the Alton Village development from the "Rotary Pond Stormwater Management Pond Detailed Design Brief" (Counterpoint Engineering Inc. March, 2005). The stormwater management applied in the SWMHYMO modelling completed by Counterpoint included lot level controls for the employment lands which control the 100-year post development flows to the 5-year pre-development peak flow. The residential drainage areas are controlled by a stormwater management facility (Rotary Pond) located upstream of Dundas Street. The Appleby Creek model has been updated with a 43 ha subcatchment (A13) at 61% impervious coverage to represent the residential developments, which is then routed through the Rotary Pond. The storage-discharge relationship for the Rotary Pond is presented in Table 2.7. The portions of subcatchment A13 which do not contribute to the Rotary Pond have been lumped by their outlets at Dundas Street into subcatchments A13.1 and A13.5 (ref. Drawing 3). The routing effect of the Rotary Pond and other storage features have been removed from the modelling of the Regional Storm as required by Provincial Guidelines.

Table 2.7. Rotary Pond Storage Discharge Relationship

Storage (m^3)	Discharge (m^3/s)
0	0
3,656	0.115
18,202	0.264
20,402	0.278
24,000[1]	5.5

1. Overflow storage and flow values were contained in the SWMHYMO model inputs in Appendix A of Counterpoint Engineering Design Brief.

Updated subcatchment parameterization, using the methodology described in Section 2.2.2.1, is presented in Table 2.8.

Table 2.8. Appleby Creek Updated Subcatchment Parameters

Updated Subcatchment (WSP, 2018)			Parent Subcatchment (EWRG, 1997)	
Subcatchment	TMCi	Imperviousness (%)	Subcatchment	Imperviousness (%)
A24	0.054	78.0	A24	0.0
A17	0.151	66.6	A17	56.0
A17.2	0.071	56.3		
A13.0	0.089	61.0	A13	0.0
A13.1	0.097	25.0		
A13.5	0.022	78.0		
A7	0.122	56.5	A7	30.0
A7.1	0.565	48.1		4.0
A7.2	0.407	59.2		4.0
A6	0.032	60.6	A6	51.0
A6.3	0.018	34.7		
A6.4	0.045	54.6		
A6.5	0.058	47.5		
A6.1	0.063	66.1	A6.1	54.0
A6.2	0.048	79.5		
A5	0.009	45.8	A5	54.0
A5.1	0.042	54.0		
A5.2	0.027	49.4		

2.2.3 HSP-F MODELLING (SHELDON CREEK)

As noted in Table 2.1, a hydrologic modelling update for Sheldon Creek was conducted recently (2016) by Amec Foster Wheeler (WSP), using the HSP-F modelling platform. The study, and associated modelling remain in "draft" form (as of the time of writing), pending approval by Conservation Halton. Notwithstanding, as the most current available hydrologic modelling (and the one proposed as part of the Work Plan Terms of Reference), this modelling has been employed for the current assessment.

Reference is made to "Sheldon Creek Hydrologic and Hydraulic Study – DRAFT" (Amec Foster Wheeler, 2016) for further details on model development. Given the recent updates to the modelling, additional updates have been limited to adjustments to the existing land use imperviousness for the study area in order to ensure consistency with other areas.

The drainage boundaries for Sheldon Creek were updated as part of the Sheldon Creek Hydrologic and Hydraulic Study and where applicable were matched with the watershed boundary as defined by Conservation Halton. It is understood that although the overall Sheldon Creek Study remains in "draft" form, the subcatchment and watershed boundaries have been accepted by Conservation Halton and have therefore been used to match the watershed boundary of the eastern Appleby Creek subcatchments.

The uncalibrated subcatchment parameters have been applied for the Regional Storm Event as per the direction of Conservation Halton [ref. December 21, 2017 meeting with Amec Foster Wheeler (WSP) and the City and Burlington for the Sheldon Creek Hydrologic and Hydraulic Study (ref. Meeting Summary by WSP, January 30, 2018)]. The model revisions do not incorporate any drainage boundary changes discussed with Conservation

Halton as part of the Sheldon Creek Hydrologic and Hydraulic Study. In order to maintain consistency in the analyses the design storm event has been simulated using the uncalibrated subcatchment parameters.

The subcatchment boundaries for the Sheldon Creek watershed were retained from the June 2016 Study and the impervious coverage values were updated for subcatchments 104 and 105 which are within the Appleby MTSA boundary. Subcatchment 105 increased from 80.0 % impervious coverage to 82.9 % impervious coverage. Subcatchment 104 increased from 31.3 % impervious coverage to 42.4 % impervious coverage. The increases in impervious percentage are attributed to the separation of roads from the surrounding land use types as well as the 10 % impervious coverage assumed for park lands in the MTSA study. The Appleby MTSA is located within approximately 42.3 ha of the Sheldon Creek watershed with a total impervious coverage of 49.0 %.

2.3 HYDROLOGIC MODELLING RESULTS

2.3.1 GAWSER MODELLING (SHOREACRES AND APPLEBY CREEKS)

2.3.1.1 SHOREACRES CREEK

Updated simulated flows for key watercourse nodes in Shoreacres Creek are presented in Tables 2.9 and 2.10 for the 100-year storm event and for the Regional Storm, respectively; refer to Drawings 3 and 4 for node locations.

Table 2.9. Shoreacres Creek - 100-Year 24-Hour SCS Type II Storm Event Flows

NODE	CURRENT DRAINAGE AREA[1] (ha)	LOCATION	100-YEAR STORM PEAK FLOW (m^3/s)		
			ORIGINAL (EWRG, 1997)	UPDATED[2] (WSP, 2018)	DIFFERENCE
619	255	Headon Road -West Tributary	17.2	17.2	0.0
615	311	Walker's Line - West Tributary	21.0	21.0	0.0
611	169	Walker's Line - East Tributary	10.1	11.0	+0.9
609	561	Upper Middle Rd - East Tributary	35.0	35.3	+0.3
608	598	CNR - East Tributary	35.9	36.3	+0.4
607	689	QEW	38.0	38.4	+0.4
651	824	Harvester Rd.	44.1	44.1	0.0
6101	31.7	Fairview Street	-	3.3	-
642	1,044	Centennial Bikeway	55.2	55.0	-0.2
601	1,246	Lake Ontario	71.6	71.8	+0.2

Notes: 1. Based on updated (2018) subcatchment boundaries; may differ from previous modelling
2. Includes all current modelling updates noted

Table 2.10. Shoreacres Creek - Regional Storm Event Flows

NODE	CURRENT DRAINAGE AREA[1] (ha)	LOCATION	REGIONAL STORM PEAK FLOW (m^3/s)		
			ORIGINAL	UPDATED[2] (WSP, 2018)	DIFFERENCE
619	255	Headon Road -West Tributary	24.5	24.5	0.0
615	311	Walker's Line - West Tributary	30.4	30.4	0.0
611	169	Walker's Line - East Tributary	16.2	16.8	+0.6
609	561	Upper Middle Rd - East Tributary	54.7	55.7	+1.0
608	598	CNR - East Tributary	57.8	59.1	+1.3
607	689	QEW	66.2	68.2	+2.0
651	824	Harvester Rd.	79.5	81.7	+2.2
6101	31.7	Fairview Street	-	4.44	-
642	1,044	Centennial Bikeway	99.6	102.0	+2.4
601	1,246	Lake Ontario	118.0	120.0	+2.0

Notes: 1 Based on updated (2018) subcatchment boundaries; may differ from previous modelling
2. Includes all current modelling updates noted

The results for the 100-year storm event (Table 2.9) include SWM facilities in place; results for the Regional Storm Event (Table 2.10) also include SWM facilities, as the SWM facilities are not required to be removed (as per comments from CH, April 20, 2018) as updated floodplain mapping for Shoreacres Creek is not required.

A sensitivity test was performed for the Regional Storm Event to determine whether the 12-hour event (using zero depression storage) or the 48-hour event (allowing depression storage) produced the greater flow at the outlet. The results of the sensitivity test indicated that the 48-hour storm event produced the higher outflow and therefore the results from this scenario have been presented for Shoreacres Creek.

Both the 100-year storm event results presented in Table 2.9 and the Regional Storm Event results presented in Table 2.10 indicate generally consistency with earlier modelling with relatively minor increases in simulated peak flows for the locations presented under the updated (2018) modelling. This primarily reflects the increased imperviousness for the MTSA study area associated with the updated land use (Drawing 2). In addition, as noted previously, both watersheds also indicate a small increase in overall drainage area based on the hydrologic modelling updates. Overall, the updated peak flow results are generally comparable to those from the previous studies.

2.3.1.2 APPLEBY CREEK

Updated simulated flows for key watercourse nodes in Appleby Creek are presented in Tables 2.11 and 2.12 for the 100-year storm event and for the Regional Storm, respectively; refer to Drawings 3 and 4 for node locations.

Table 2.11. Appleby Creek – 100-Year 24-Hour SCS Type-II Storm Event Flows

NODE	CURRENT DRAINAGE AREA[1] (ha)	LOCATION	100-YEAR STORM PEAK FLOW (m^3/s)		
			ORIGINAL (EWRG, 1997)	UPDATED[2] (WSP, 2018)	DIFFERENCE
West Branch					
820	139.6	CN (Halton) - West Branch	17.5	18	+0.5
818	190.3	Appleby Line - West Branch	19.8	20.7	+0.9
857	239.4	U/S QEW -West Branch	21.4	24.1	+2.7
817	245.3	West Branch U/S Confluence with East Branch	22.8	24.5	+1.7
East Branch					
813	325.2	Dundas - East Branch	19.6	19.1	-0.5
810	483.3	CN (Halton) - East Branch	25.2	24.8	-0.4
808	534.3	Appleby Line North of Mainway- East Branch	26.9	28.3	+1.4
507	51.4	U/S QEW - East Branch	2.7	4.31	+1.6
807	637.9	East Branch Appleby Ck u/s confluence with West Branch	31.9	34.4	+2.5
Main Branch					
8101	904.1	Harvester Rd.	-	59.7	-
8102	905.0	Between Harvester Rd and Appleby Rd	-	59.7	-
826	928.6	CN (Oakville)	57	61.1	+4.1
8105	965.2	U/S Fairview Street	-	62.4	-
8106	995.5	D/S Fairview Street	-	64.1	-
8107	1018.0	Centennial Bikeway	-	65.1	-
828	1018.0	U/S Pinedale Avenue	61.5	65.0	+3.5
805	1045.0	D/S Pinedale Avenue	63.0	66.8	+3.8
801	1219.4	Lake Ontario	71.3	74.5	+3.2

1. Based on updated (2018) subcatchment boundaries; this may differ slightly from previous modelling.
2. Includes all current modelling updates noted.

Table 2.12. Appleby Creek – Regional Storm Event Flows

NODE	CURRENT DRAINAGE AREA[1] (ha)	LOCATION	REGIONAL STORM PEAK FLOW (m^3/s)		
			ORIGINAL (EWRG, 1997)	UPDATED[2] (WSP, 2018)	DIFFERENCE
WEST BRANCH					
820	139.6	CN (Halton) - West Branch	17.2	17.8	+0.6
818	190.3	Appleby Line - West Branch	22.1	23.4	+1.3
857	239.4	U/S QEW -West Branch	24.9	29.2	+4.3
817	245.3	West Branch U/S Confluence with East Branch	28.8	29.9	+1.1
EAST BRANCH					
813	325.2	Dundas - East Branch	30.5	50.5	+20.0
810	483.3	CN (Halton) - East Branch	43.6	63.7	+20.1
808	534.3	Appleby Line North of Mainway- East Branch	48.5	68.3	+19.8
507	51.4	U/S QEW - East Branch	3.2	5.7	+2.5
807	637.9	East Branch Appleby Ck u/s confluence with West Branch	57.4	73.3	+15.9
MAIN BRANCH					
8101	904.1	Harvester Rd.	-	97.9	-
8102	905.0	Between Harvester Rd and Appleby Rd	-	98.0	-
826	928.6	CN (Oakville)	86.4	100.0	+13.6
8105	965.2	U/S Fairview Street	-	103.0	-
8106	995.5	D/S Fairview Street	-	106.0	-
8107	1018.0	Centennial Bikeway	-	109.0	-
828	1018.0	U/S Pinedale Avenue	95.5	109.0	+13.5
805	1045.0	D/S Pinedale Avenue	97.3	111.0	+13.7
801	1219.4	Lake Ontario	112.0	125.0	+13.0

1. Based on updated (2018) subcatchment boundaries; this may differ slightly from previous modelling.
2. Includes all current modelling updates noted.

The results for the 100-year storm event (Table 2.11) include SWM facilities in place; the results for the Regional Storm Event (Table 2.12) have SWM facilities removed, as per Provincial Policy for floodplain mapping (Section 3.3.1).

A sensitivity test was performed for the Regional Storm Event to determine whether the 12-hour event (using zero depression storage) or the 48-hour event (allowing depression storage) produced the greater flow at the outlet. The results of the sensitivity test indicated that the 48-hour storm event produced the higher outflow and therefore the results from this scenario have been presented for Shoreacres Creek.

The 100-year storm event results presented in Table 2.11 indicate generally consistency with previous modelling with relatively minor increases in simulated peak flows for the locations presented under the updated (2018) modelling. This primarily reflects the increased imperviousness for the MTSA study area associated with the updated land use (Drawing 2). The Regional Storm Event results presented in Table 2.12 indicate larger increases (>10%) in the simulated flow which is considered attributable to the removal of stormwater management facilities from the model. In addition, as noted previously both watersheds also indicate a small increase in overall drainage area based on the hydrologic modelling updates. Overall, the updated peak flow results are generally comparable to those from the previous studies.

2.3.2 HSP-F MODELLING (SHELDON CREEK)

Updated simulated flows for key watercourse nodes in Sheldon Creek are presented in Tables 2.13 and 2.14 for the 100-year storm event and for the Regional Storm, respectively; refer to Drawings 3 and 4 for node locations.

The SCS Curve number methodology does not apply to HSP-F modelling and therefore the soil conditions were maintained for the Regional Storm Event. Furthermore, the HSP-F modelling platform does not use a depression storage parameter which can be altered for simulating the 12-hour Regional Storm Event. Therefore, the 48-hour event has been simulated for the Sheldon Creek watershed. SWM facilities have also been removed from the Regional Storm Event simulation (both the original and updated modelling).

Table 2.13. Sheldon Creek – 100-Year Continuous Simulation and 24-Hour SCS Type-II Design Storm Event Flows

NODE	CURRENT DRAINAGE AREA[1] (ha)	LOCATION	100-YEAR STORM PEAK FLOW (m^3/s)		
			CALIBRATED CONTINUOUS	UNCALIBRATED DESIGN STORM[2]	DIFFERENCE
106.1	879	QEW / Highway #403	28.0	30.9	+2.9
105.1	953	CN Railway	34.5	43.3	+8.8
104.1	1,073	New Street	35.3	45.5	+10.2
103.1	1,140	Burloak Drive	37.7	47.9	+10.2
102.1	1,166	Upstream of Confluence with East Branch	33.8	47.2	+13.4
101.1	1,771	Lake Ontario	54.0	70.5	+16.5

1. Based on updated (2018) subcatchment parameterization; this may differ slightly from previous modelling. Does not include drainage boundary changes discussed with Conservation halton as part of the Sheldon Creek Hydrology and Hydraulics Study.
2. Includes all current modelling updates noted.

Table 2.14. Sheldon Creek – Regional Storm Event Flows

NODE	CURRENT DRAINAGE AREA[1] (ha)	LOCATION	REGIONAL STORM PEAK FLOW (m^3/s)		
			ORIGINAL	UPDATED[2]	DIFFERENCE
106.1	879	QEW / Highway #403	87.5	87.5	0
105.1	953	CN Railway	95.7	95.7	0
104.1	1,073	New Street	105.3	105.5	+0.2
103.1	1,140	Burloak Drive	108.9	109.1	+0.2
102.1	1,166	Upstream of Confluence with East Branch	109.0	109.2	+0.2
101.1	1,771	Lake Ontario	166.3	166.6	+0.3

1. Based on updated (2018) subcatchment parameterization; this may differ slightly from previous modelling. Does not include drainage boundary changes discussed with Conservation halton as part of the Sheldon Creek Hydrology and Hydraulics Study.
2. Includes all current modelling updates noted.

As discussed in Section 2.2.3, the Regional Storm Event and 100-year design storm event have been simulated using the uncalibrated subcatchment parameterization. Given that the previous simulation of the 100-year event (continuous simulation) employed calibrated modelling, an increase in peak flows is to be expected, as presented in Table 2.13. The use of a design storm (as opposed to continuous simulation) may also yield some flow increases, although further assessment would be required to confirm this finding.

The results of the Regional Storm simulation by contrast yield very little difference, given the use of the uncalibrated modelling in both cases. The results indicate that the hydrologic modelling updates for the Appleby GO MTSA (existing conditions) have minimal impact on the flows through the Sheldon Creek watershed.

3 HYDRAULICS

3.1 AVAILABLE HYDRAULIC MODELLING

As noted previously, the Appleby GO MTSA Area (Drawing 1) intersects three (3) watersheds (Drawing 3). Notwithstanding, while a portion of the Shoreacres Creek watershed lies within the study area, the creek itself does not. As such, hydraulic modelling (HEC-RAS) is required only for the remaining two (2) watercourses, as summarized in Table 3.1. This is also consistent with the Scoped EIS Work Plan (updated April 25, 2017 – ref. Table C).

Table 3.1. Available Hydraulic Modelling – Appleby GO MTSA

WATERSHED	STUDY DATE AND REFERENCE	MODELLING PLATFORM
Appleby Creek	Floodline Mapping Update (EWRG, 1997)	HEC-2
	Appleby Creek Flood Study EA (Aquafor Beech, 2018)	HEC-RAS
Sheldon Creek	Hydrologic and Hydraulic Study – DRAFT (Amec Foster Wheeler, 2016)	HEC-RAS

Subsequent to the completion of the current study, it is understood that additional hydraulic modelling and floodplain mapping was completed for Appleby Creek through the City-led Appleby Creek Erosion Control Class EA (August 2020).

It should also be noted that Conservation Halton (CH) has undertaken a study to update the hydrologic and hydraulic modelling and floodplain mapping for the East Burlington Creeks, which includes Tuck Creek, Shoreacres Creek, Appleby Creek, and Sheldon Creek. This work (being completed by WSP) is nearing completion at the time of this version of the report, with a Public Information Centre (#2) planned for June 6, 2023. Once finalized and approved, this modelling should be applied for subsequent analyses. Notwithstanding as this modelling was not available at the time of the preparation of this study report, it could not reasonably be included.

3.2 HYDRAULIC MODELLING UPDATES

3.2.1 APPLEBY CREEK

As part of the Appleby Creek Floodplain Mapping Update Study (EWRG, 1997) a HEC-2 hydraulic model was developed. The Appleby Creek HEC-RAS model was subsequently updated as part of "Urban-Area Flood Vulnerability, Prioritization and Mitigation Study" (Amec Foster Wheeler, July 2017). This modelling has been applied for the current study and includes recent updates to the modelling beyond the Appleby GO MTSA study limit along Bridle Wood (ref. Flood Vulnerable Area 7). Furthermore, the modelling along Bridle Wood has been superseded by the HEC-RAS modelling completed recently as part of the City of Burlington's Flood Study EA for Appleby Creek (Aquafor Beech, 2018).

As part of this study, the Appleby Creek hydraulic model has been further refined through the Appleby GO MTSA study area to reflect the existing topography and hydraulic structures. The cross sections in the Appleby Creek HEC-RAS model have been compared to the City of Burlington's 2015 DEM for consistency. The comparison determined that the cross sections upstream of Harvester Road adequately matched the current topography and therefore updates have been limited to adding additional cross sections for hydraulic structures and adjusting Manning's roughness coefficients where applicable. The cross sections downstream of the railway tracks have been determined to no longer match the current topography and therefore cross sections 3100, 3010, 2960, 2860, 2842, 2839, 2810, and 2780 have been updated to match the City of Burlington's 2015 DEM (refer to Drawing 5).

The original Appleby Creek model did not incorporate the two northern most railway tracks as part of the hydraulic structure. As such, additional sections have been incorporated at the upstream face of the CN Railway tracks and the twin box culverts have been extended in the model. It has been noted that there is also a pedestrian foot bridge parallel with the railway tracks connecting the overflow parking lot for the Appleby GO Station. The footbridge has not been modelled, as the twin box culverts represent the more constraining structure through this reach.

A new hydraulic structure between cross sections 3298 and 3296 on (Drawing 5) has been incorporated into the model which reflects the roadway crossing which connects the Appleby GO Station parking lot to the overflow parking lot. A field investigation determined that the hydraulic structure is an 11.0 m x 3.4 m concrete arch. In addition, cross sections have been added to the HEC-RAS model to support the HEC-RAS methodology of defining hydraulic structures with four (4) cross sections (two (2) upstream and two (2) downstream). Flow change locations have been placed outside of the four cross sections which define the hydraulic structures.

As noted, the of City of Burlington has recently undertaken a Flood Study EA for Appleby Creek (Aquafor Beech, 2018) to further investigate potential flooding in the area of Bridle Wood identified in the 2017 Burlington City-Wide Flood Study. The existing conditions HEC-RAS model has been provided by the City of Burlington to incorporate into the hydraulic modelling for the current study (ref. Appendix D). The HEC-RAS model has been updated by inserting the EA model downstream of Fairview Street (i.e. downstream of cross section 2809). The first cross section representing the EA model is cross section 2787.644. All cross sections downstream of this location have been maintained from the EA modelling. The flow change locations have been updated to incorporate the flows from the GAWSER modelling as described in Section 2. Updated flow change locations and values are presented in Table 3.2. Regional Storm Peak Flows have SWM facilities removed, as per Provincial Policy.

The cross sections through the Appleby GO MTSA study area were required to be reversed to match the orientation of the EA cross sections (due to HEC-2 methodology being maintained in the previous version). The cross sections upstream of the QEW have been maintained as per the original HEC-2 orientation as they are beyond the limits of the current study. The cross sections upstream of the QEW should however be revised in future studies to match standard HEC-RAS cross-section orientation, which has been employed within the study limits.

Table 3.2. Appleby Creek – Flow Change Locations

NODE	HEC-RAS STATION	REACH	100 YEAR STORM PEAK FLOW (m^3/s)	REGIONAL STORM PEAK FLOW (m^3/s)
East Branch				
817	4589	East Tributary at Appleby Line	24.5	29.9
West Branch				
807	15710	West Tributary at Appleby Line	34.4	73.3
Main Branch				
8101	3590	Confluence of East and West Tributary	59.7	97.9
8102	3370	Main Branch D/S of Harvester Rd	59.7	98
826	3290	Main Branch U/S of CNR Track	61.1	100
8105	3100	Main Branch D/S of CNR Track	62.4	103
8107	2787.644	Main Branch D/S of Fairview St	65.1	109
803	1979.323	Main Branch D/S of Pinedale Ave	68.5	115
802	1533.912	Main Branch D/S of New St	72.4	121
801	759.6343	Main Branch D/S of Spruce Ave	74.5	125

Drawing 5 presents the hydraulic modelling cross-sections for the study area, which extend from north of the North Service Road to Bridle Wood at the south and covers the extents of Appleby Creek within the Appleby GO MTSA boundary.

3.2.2 SHELDON CREEK

An updated hydraulic model (HEC-RAS) for Sheldon Creek was most recently developed as part of "Sheldon Creek Hydrologic and Hydraulic Study – DRAFT" (Amec Foster Wheeler, 2016). This report remains in draft as of the time of writing; the hydraulic modelling developed for this study has not been formally approved or endorsed by Conservation Halton. Notwithstanding, as per the Scoped EIS Work Plan, this modelling is the most currently available and is to be applied for the development of estimated floodplains for the current study. Given the recent vintage of the modelling, no modifications have been required to support the current study.

Drawing 6 presents the hydraulic modelling cross-sections for the study area, which extend from the North Service Road to Riverside Drive and covers the extents of Sheldon Creek within the Appleby GO MTSA boundary.

The flow change locations (Table 3.3) have been updated, and uncalibrated flows have been simulated from Lake Ontario to upstream of the QEW for both the Main Branch and East Branch to establish a hydraulic profile through the study area. As noted previously, the 100-year (design storm) results include SWM facilities, while the Regional Storm Event results exclude them, as per Provincial Policy. The next upstream flow change locations (beyond the study limits) have been set as a duplicate of the most upstream values presented in Table 3.3, in order to provide a conservative upstream hydraulic profile. Beyond these limits all other flow change locations have been set to a value of 1 m3/s to indicate the values have not been updated. Based on WSP's review, these locations are sufficiently distant from the study area so as not to impact results.

Table 3.3. Sheldon Creek – Flow Change Locations

NODE	HEC-RAS STATION	REACH	100 YEAR STORM PEAK FLOW (m^3/s)	REGIONAL STORM PEAK FLOW (m^3/s)
East Branch				
203.1	4100	QEW to CN Railway	18.4	34.3
202.1	2699.999	CN Railway to New Street	46.8	48.0
201.1	1000	New Street to Confluence	35.5	53.9
Main Branch				
106.1	6342.364	Mainway to QEW	30.9	87.5
105.1	4929.197	QEW to CN Railway	43.3	95.7
104.1	4100	CN Railway to New Street	45.5	105.5
103.1	2681.999	New Street to Burloak Drive	47.9	109.1
102.1	1764.328	Burloak Drive to Confluence	47.2	109.2
101.1	1010.096	Confluence to Lake Ontario	70.5	166.6

3.3 HYDRAULIC MODELLING RESULTS

3.3.1 APPLEBY CREEK

Flood hazard limits generated by the previously noted HEC-RAS model for Appleby Creek are presented in Drawing 5. As noted on Drawing 5, it should be understood that the flood hazard limits presented are based on the information available at the time of the study commencement (2017) and the preparation of the primary report (April 2019). Flood hazard limits are expected to be superseded by the information from the East Burlington Creeks Flood Hazard Mapping Study (WSP, 2023). Reference should be made to current Flood Hazard Mapping as available from Conservation Halton. Notwithstanding, the results from the HEC-RAS modelling applied as part of the current study are detailed herein.

As noted in Section 2.3.1.1 (Table 2.9), in general the 100-Year Storm flows have increased slightly compared to the original modelling for the Appleby Creek watershed through the study area, whereas the Regional Storm Event flows (Table 2.10) have increased by approximately 10% through the study area. The simulated flooding extents for the 100-year storm event and the Regional Storm Event are depicted on Drawing 5.

The Appleby Creek HEC-RAS model indicates overtopping of the hydraulic structures at Harvester Road and Fairview Street for the Regional Storm Event, and spill to the east and west of the CNR crossing (but not overtopping) for the Regional Storm Event. The extents of the CN Railway spill have increased from those predicted in the original modelling due to the increased flows, and the topographic updates incorporated into the current model. A review of the City's 2015 DEM determined that a higher elevation exists for the top of rail elevation than was employed in the previous hydraulic modelling. Based on the updated modelling, two areas of spill are indicated upstream of the railway crossing, both east and west of the Appleby GO station. Further assessment, potentially including 2-dimensional (2D) modelling would be required to more definitively confirm the spill extents in this area.

The developed floodplain mapping of Appleby Creek has identified several parcels as being within the limits of the riverine floodplain. These areas are indicated on Drawing 5, and include:

- 5050 South Service Road on the Appleby Creek West Branch
- 952 Century Drive on the Appleby Creek East Branch
- 5155 Harvester Road on the Appleby Creek Main Branch
- 5195 Harvester Road on the Appleby Creek Main Branch
- 5150 and 5180 Harvester Road (North Appleby GO Station Parking Lots)
- 740 Oval Court on the Appleby Creek Main Branch
- 720 Oval Court on the Appleby Creek Main Branch
- 5135 Fairview Street on the Appleby Creek Main Branch
- 5111 Fairview Street (South Appleby GO Station Parking Lot)

In general, only a portion of the above-noted properties appear to be impacted by the identified riverine floodplain extents. Notwithstanding, as per Provincial and Conservation Halton policies, no re-development would be permitted within identified riverine floodplain limits.

In addition to the preceding, spill upstream of the CNR has the potential to impact parcels adjacent to the Appleby GO parking areas; these parcels would potentially include the following (although as noted, further assessment would be required to definitively confirm the limits of spill):

- 821 Appleby Line
- 5100 Harvester Road
- 5110 Harvester Road
- 5200 Harvester Road
- 5230 Harvester Road

The most vulnerable area appears to be the Appleby GO Station north parking lots, where the majority of the southern portion of the site is encompassed by the estimated floodplain. The lots are impacted by both the Regional Storm Event and the 100-year storm event. Spill from this area under both events (but primarily the Regional Storm Event), does have the potential to impact adjacent properties as noted above. Further hydraulic assessment (likely 2D modelling) would be required to confirm the flood risk limits from spills more definitively.

Although beyond the limits of the Appleby GO MTSA, it is noted that there is a flood risk to the houses along Bridle Wood, which was identified in the "Urban-Area Flood Vulnerability, Prioritization and Mitigation Study" (Amec Foster Wheeler, July 2017). Although this area is outside of the study area, it is understood that it is a known flood risk to the City of Burlington and has been included in the floodplain mapping on Drawing 5 to reinforce the downstream constraints. It is the understanding of WSP that the hydraulic modelling completed as part of the Appleby Creek Flood Study EA (Aquafor Beech, 2018) has determined the extents of the spill at Bridle Wood. Notwithstanding, the updated GAWSER generated Regional Storm Flows in the current study are approximately 10% higher than those used in the EA modelling. Furthermore, the EA modelling was generated using Conservation Halton's 2002 DEM, and therefore the cross-section topography in the model is inconsistent with the Region of Halton's 2015 DEM, which has been applied for the floodline mapping in this study.

3.3.2 SHELDON CREEK

Flood hazard limits generated by the previously noted HEC-RAS model for Sheldon Creek are presented in Drawing 6. As noted on Drawing 6, it should be understood that the flood hazard limits presented are based on the information available at the time of the study commencement (2017) and the preparation of the primary report (April 2019). Flood hazard limits are expected to be superseded by the information from the East Burlington Creeks Flood Hazard Mapping Study (WSP, 2023). Reference should be made to current Flood Hazard Mapping as available from Conservation Halton. Notwithstanding, the results from the HEC-RAS modelling applied as part of the current study are detailed herein.

As noted in Section 2.3.2 (Tables 2.13 and 2.14), in general the Regional Storm Event flows have increased slightly compared to the original modelling for the Sheldon Creek watershed through the study area.

The 100-year return period flows from the updated design storm modelling have been utilized for floodplain mapping to be consistent with the remainder of the study. The 100-year floodlines depicted on Drawing 6 will differ from those presented in the "Sheldon Creek Hydrologic and Hydraulic Study – DRAFT" (Amec Foster Wheeler, 2016) which was prepared using continuous simulation frequency flows for the 100-year storm event.

The simulated flooding extents for the 100-year frequency flows and the Regional Storm Event are depicted on Drawing 6. The Sheldon Creek HEC-RAS model indicates that the Regional Storm Floodplain is generally confined to the channel block area. Notwithstanding, some existing parcels are indicated as being within the limits of the estimated riverine floodplain (refer to Drawing 6):

- 5355 Harvester Road
- 5300 Harvester Road

Only a portion of the above-noted properties appear to be impacted by the identified riverine floodplain extents. Notwithstanding, as per Provincial and Conservation Halton policies, no re-development would be permitted within identified riverine floodplain limits.

Harvester Road is also indicated as being overtopped for the Regional Storm Event based on the updated hydraulic modelling. The cross sections upstream and downstream of the structure however indicate confinement to the channel, however current topographic data for the roadway suggest that the road elevation is somewhat lower and would be overtopped and that flow over the road would re-enter the channel to the south and west of the crossing at Harvester Road. Notwithstanding, a review of the topographic contours at Harvester Road suggests that any spill at this location would likely be directed back towards the channel. It is possible that the overtopping of Harvester Road could impact the property of 5300 Harvester Road; however, a further assessment (and likely through 2D modelling) would be required to confirm this definitively, which is beyond the scope of the current study.

4 STORMWATER MANAGEMENT

4.1 PLANNED DEVELOPMENT

The currently proposed land use plans for the Appleby GO MTSA are included in Appendix A. A precinct plan has been developed (May 2018), which separates the overall Appleby MTSA into several sub-areas with common features. The Appleby MTSA precincts are largely Urban Employment or General Employment lands with an area denoted as Appleby GO Central and Fairview Frequent Transit Corridor located south of the CNR Tracks. The area south of Fairview Street will remain Mid-Rise Residential and Sherwood Forest Park is to be maintained as open space.

The preceding is unlikely to result in significant revised land use types for the Appleby GO MTSA. The northern portion of the study area currently consists of employment lands, while the southern limits include existing residential development. The ultimate land uses expected under "Fairview Frequent Transit Corridor" and "Appleby GO Corridor" may potentially result in revised land usage, however from a hydrologic perspective, significant changes to impervious coverage would not be expected. Figure 4.1 presents the identified remaining greenspace/undeveloped areas (>0.5 ha +\-) within the Appleby GO MTSA (not including creek corridors and Sherwood Forest Park, which would not be expected to change based on the precinct plan).

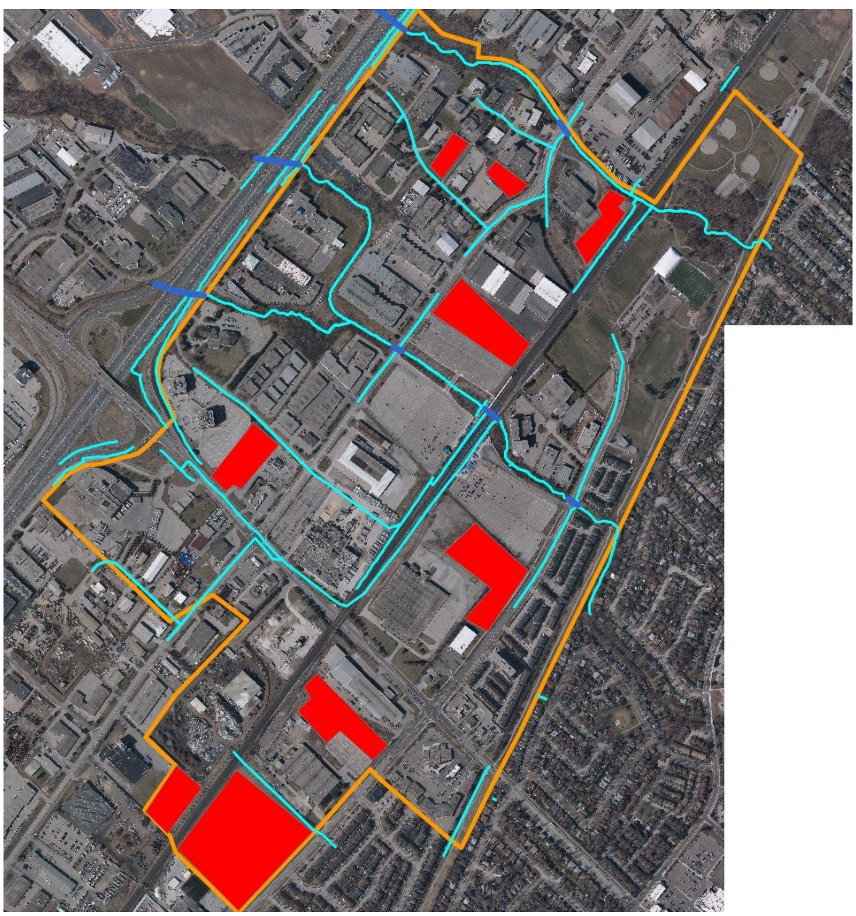

Figure 4.1. Appleby GO MTSA and Existing Pervious Areas

A total of 16.62 ha of such pervious/undeveloped areas has been identified (out of the total Appleby GO MTSA area of 207.4 ha).

- Shoreacres Creek (8.82 ha)
  - 834 Appleby Line (1.11 ha)
  - 4415 Fairview Street (5.85 Ha)
  - 4445 Fairview Street (1.86 ha)
- Appleby Creek (5.92 ha)
  - 5051 Fairview Street (1.32 ha)
  - 747 Appleby Line and 5091 Fairview Street (2.38 ha)
  - 5200 Harvester Road (2.22 ha)
- Sheldon Creek (1.88 ha)
  - 955 Century Drive (0.49 ha)
  - 905 Century Drive (0.45 ha)
  - 5300 Harvester Road (0.94 ha)

In general, the preceding areas reflect undeveloped portions of existing employment land sites. There are two parcels (4415 Fairview Street and 5200 Harvester Road) which are entirely currently open space/undeveloped. The property at 4415 Fairview Street is generally noted as "Fairview Frequent Transit Corridor", however the precinct plan also indicates a Proposed Park (> 1 ha). The property at 5200 Harvester Road is noted as "Urban Employment", however has a similar notation regarding a Proposed Park (> 1 ha). It is therefore uncertain how much of these sites would potentially urbanize, and what portion would remain greenspace/parkland. These two (2) sites represent approximately half of the identified remaining greenspace/pervious area within the Appleby GO MTSA, as such opportunities to maintain greenspace and pervious areas, potentially in conjunction with an overall SWM strategy, should be further explored at the next stages of planning and design.

From a hydrologic/impervious coverage perspective, the changes, if these parcels were to become fully impervious, are relatively minor. As per Drawing 2, the majority of the existing area where re-development is anticipated, have been assessed as high impervious (90%) or institutional-industrial (60%). The exception is the two previously noted undeveloped sites, which have been assessed as park-natural corridor; however as noted larger proposed parks are currently proposed for these areas. The remaining identified pervious areas represent a minority (4% +\-) of the overall MTSA area. Given existing impervious coverages, it is further considered unlikely that estimated values would be notably altered by re-development.

It should be noted that the preceding has focused on existing undeveloped areas. As noted in CH's comments of April 16, 2021, there is also the potential for other areas to experience notable increase in imperviousness, including potential development of existing parklands. Notwithstanding, It is considered reasonable to assume that existing City parklands will remain as is for the foreseeable future (i.e. assumed nominal imperviousness of 10% as per Table 2.2).

Overall, additional and updated hydrologic modelling are expected to be required through a future site-specific planning application should intensification increase impervious coverage beyond the limits of what has been considered as part of the current study. Additional hydrologic modelling and sizing of quantity controls would be required accordingly. Such modelling work would necessarily consider site specific soils and land use information. The potential need for Regional Storm controls should also be considered.

Future modelling work may also in turn require an additional review of hydraulic modelling and floodplain impacts, as discussed further in Section 4.2.

Notwithstanding the preceding, expected changes in land coverage should be considered as part of the proposed stormwater management (SWM) strategy, as discussed further in Section 4.4.

4.2 FLOODPLAIN AND SPILL IMPACTS

Riverine Floodplain Limits for Appleby Creek and Sheldon Creek (based on the information used in this study) are presented in Drawings 5 and 6 respectively. A number of properties have been identified which are expected to be subject to re-development (based on the understanding at the time of the original preparation of this report) but would have existing floodplain impacts (Section 3.3). Potential spill impacts have also been identified for Appleby Creek immediately upstream of the CNR.

A distinction must be made between flood risk due to a riverine floodplain (i.e. floodplain directly along/adjacent to the watercourse) and due to spills (i.e. excess flow draining in an uncontrolled manner, potentially no longer following the path of the watercourse). The former (riverine floodplains) are regulated by Conservation Authorities and prevent any development within the floodplain limits (plus a 7.5 m buffer for both Appleby and Sheldon Creeks, given their classifications as Minor Valley Systems), unless a Special Policy Area or other exception applies. This would therefore apply to those parcels noted as being impacted by riverine floodplain limits along both Appleby and Sheldon Creeks. Floodplain limits in these cases could potentially be reduced through infrastructure improvements (i.e. channel widening, re-grading, or more likely hydraulic structure (culvert) improvements where appropriate) to reduce floodplain extents, as discussed in Section 4.3. Beyond such measures, development would be restricted to the extents noted. It should also be re-iterated that any such works within a regulated area would require a permit and approval from CH.

Spills have not been historically regulated due to the inability to accurately map spills. Notwithstanding, in CH's "Policies and Guidelines for the Administration of Ontario Regulation 162/06" (Amended November 26, 2020), Section 2.29 (Spills), CH notes that spills are considered flood hazards and regulated as such; development or re-development may be considered on a case-by-case basis where the site is low risk. It is understood that CH is in the process of developing a formal spills policy. CH is currently operating under an interim spills policy; however, the future formal policy may further elaborate on requirements.

As evident from the results of the hydraulic analyses, there is a significant spill flow area within the Appleby GO Station north parking lot area, which is considered attributable to the capacity of the CNR crossing. This spill flow area could likely be mitigated through upsizing of the culverts crossing the CNR tracks; this is considered further in Section 4.3. There is a lesser spill flow area identified on Sheldon Creek at Harvester Road due to the Regional Storm event overtopping the road, however a review of the topographic contours at Harvester Road suggests that any spill would be directed back towards the channel. Spill results in this area are based on the modelling applied; reference should be made to the most current results which are expected to be from the East Burlington Creeks Flood Hazard Mapping Update study (WSP, 2023).

For locations subject to spill impacts (where other mitigation measures are not feasible), it is recommended that appropriate flood mitigation and management strategies be employed. This would primarily include floodproofing of buildings. Passive floodproofing (i.e. floodproofing that does not require human intervention) is preferred, which would be expected to focus on grading of both the site and building, to ensure that openings are greater than spill elevations (typically a 0.30 m freeboard is applied). Active floodproofing (measures that require human intervention) may be warranted in locations where passive floodproofing cannot reasonably be achieved. CH has clarified (comments of November 26, 2021) that is does not support active floodproofing for intensification of use, but is supportive for the protection of existing development, although passive measures are recommended.

In conjunction with the preceding, site grading should allow for the safe conveyance and routing of flood spill flows and consider the safe ingress and egress of vehicles from the site. Site grading in these locations should also work towards achieving a cut/fill balance, in order to avoid the potential for off-site impacts. This should be more strongly enforced for riverine floodplain areas, where a cut/fill can more easily be achieved. For re-developments in spill areas where filling is unavoidable, other compensatory measures may be warranted. Further hydraulic modelling (beyond the scope of the current study) is considered required to better assess and map spill flow impacts. Such hydraulic modelling could also be applied to better determine the potential impacts of any future developments and the most appropriate floodproofing/flood mitigation strategies.

It should again be noted that the hydrologic modelling applied for Shoreacres and Appleby Creeks, while technically sound and appropriate, has not been calibrated (i.e. adjusted to reflect actual observed responses to storm events). Typically, uncalibrated hydrologic models are considered conservative (i.e. over-predict flows and volumes as compared to existing conditions). Thus, further study could potentially result in a reduction in flood risk. In the absence of such information, the results generated by the current study are considered the best available data. The hydrologic modelling for Sheldon Creek has been calibrated to observed flows as part of the "Sheldon Creek Hydrologic and Hydraulic Study – DRAFT" (Amec Foster Wheeler, 2016), however it is noted that the uncalibrated modelling has conservatively been applied for the generation of Regional Storm Flows at the direction of Conservation Halton as part of the 2016 Study. Furthermore, in order to maintain consistency in the reported results presented herein, the 100-year return period design storm flows have been simulated based upon the uncalibrated model, consistent with the Regional Storm Flows. The results generated by the current study are considered to be the best available data at the time of the completion of this study.

Notwithstanding, it is noted that updated hydrologic modelling for the Tuck, Shoreacres, Appleby and Sheldon Creek watersheds will be available from the East Burlington Creeks Floodplain Mapping Update study (WSP, 2023) and should be applied as the basis for any subsequent watershed-based hydrologic assessments, following formal approval by CH.

In addition to the preceding, it should be noted that the riverine hydraulic modelling (open channel – HEC-GeoRAS) has been developed using a digital elevation model (DEM) from the Region of Halton (2015). Hydraulic structures have been included based on elevations from this source, along with corrections from record drawings, and data from field observations/measurements. Notwithstanding, a further validation should be considered in the future using topographic survey data, to better confirm precise floodplain limits. It is expected that this may occur as specific sites (particularly those identified as being within the floodplain) re-develop and proponents design appropriate mitigation measures. As per CH's comments of April 16, 2021, additional detailed floodplain mapping may be required prior to proposed land use changes The results generated by the current study are however still considered appropriate for the estimation of floodplain risk.

It should also be noted that the Region of Halton 2015 DEM was the best available dataset at the time of the preparation of that report. More current topographic data (i.e. 2018 LiDAR data based DEM; or other most current dataset) should be used for any subsequent assessment or site-specific studies. Considerations for differences in vertical datums between datasets would also be required.

Any future assessments should employ the most currently approved hydraulic modelling tools as available from Conservation Halton. As noted, it is expected that once approved this will be the East Burlington Creeks Flood Hazard Mapping Update Study (WSP, 2023).

4.3 POTENTIAL INFRASTRUCTURE IMPROVEMENTS

As noted in Section 4.2, one potential strategy for areas with riverine floodplain impacts is to review the feasibility of infrastructure improvements, which would most likely take the form of hydraulic structure (culvert) improvements. Based on the results presented in Drawings 5 and 6, the primary locations where this could be beneficial include:

- Appleby Creek
  a. Harvester Road (5.5 m W x 2.1 m H concrete box)
  b. CNR (twin 4.2 m W x 3.7 m H concrete boxes)
  c. Fairview Street (twin 3.3 m W x 2.0 m and 2.3 m H concrete boxes)
- Sheldon Creek
  a. Harvester Road (twin 3.4 m W x 2.4 m H concrete boxes)

The greatest benefit in flood reduction would occur through an upgrade to the CNR crossing of Appleby Creek, since as noted previously, this structure results in an extensive backwater effect and spills both to the east and west of the Appleby GO station parking area. Based on a preliminary review, a substantial structure upgrade (approximately doubling of the existing width to 20 m +\-) would be required in this location to prevent upstream spills, which given the span involved, would likely necessitate a bridge (column and girder) type structure which would be more costly and difficult to construct, along with associated channel transition modifications.

More localized benefits could potentially be realized by upgrades to the other noted hydraulic structures, including Harvester Road and Fairview Street along Appleby Creek, which indicate overtopping for the Regional Storm Event, and floodplain impacts to immediately upstream properties. Based on a hydraulic modelling assessment, an upgrade to the hydraulic structure at Harvester Street would need to be a similar width to that of the CNR, approximately 20 m +\-. This would again likely necessitate a bridge (column and girder) type structure which would be more costly and difficult to construct, along with associated channel transition modifications. Based on a further hydraulic modelling assessment, the hydraulic structure at Fairview Street was found to be relatively insensitive to increased spans; thus a hydraulic upgrade of this structure is not currently recommended.

Sheldon Creek is also noted as overtopping at Harvester Road, however a more minimal impact to upstream floodplains is noted, thus this structure would likely be of a lesser benefit overall; no specific hydraulic structure size is currently recommended.

As per CH's comments of April 16, 2021, it is noted that hydraulic structure improvements are typically evaluated with respect to access and ingress/egress for emergency services and the public. Currently, the floodplain mapping prepared for the current study does not show this as a constraint. Notwithstanding, any future evaluation of hydraulic structure upgrades should take into account the impact to ingress/egress and safe passage by emergency vehicles for overtopped roadways (i.e. Harvester Road) as part of an overall cost/benefit analysis. Such upgrades would also likely require evaluation through the Class Environmental Assessment process.

As part of further CH comments (November 26, 2021) it has been noted that there may be at least one (1) location where a future assessment of ingress/egress requirements should be undertaken to support intensifications of use. This location is at Fairview Street, given that it is currently a dead-end roadway with only one point of access. Given the preceding, and the planned intensification in this area (i.e. Oval Court), this should be considered further as part of any subsequent detailed development proposals in this area.

The currently available/developed hydraulic modelling is focused on overland and channel flows only; currently there is no hydraulic modelling available for trunk or local storm sewer systems. As such, an assessment or confirmation of storm sewer capacity for the Appleby GO MTSA is beyond the scope of the current study but should be considered as part of future study.

4.4 STORMWATER MANAGEMENT STRATEGY

As discussed in Section 4.1, the proposed re-development within the study area is not expected to result in large overall changes in impervious coverage, given the existing urbanized/developed nature of the study area. Notwithstanding, some potential re-development sites do include larger sections of existing pervious land, and a general strategy for quantity control is still required.

The largest, currently undeveloped parcels of land (pervious areas) are also indicated as possibly including larger (> 1 ha) parklands, which may preserve the overall, primarily pervious land use characteristics. These areas could also potentially be used to provide stormwater management (SWM) controls for adjacent developments, through the implementation of properly landscaped and designed features, including LID BMPs. Notwithstanding, given the complexities of shared-use agreements, on site controls for these areas may be preferred. Similarly, Sherwood Forest Park is indicated as being preserved as parklands; however, it may offer an opportunity for the provision of communal SWM features, either an above-ground SWM facility or sub-surface measures. However, given the park's location, grading, the preceding complexities of shared-used agreements, and the potential loss of useable park land, it is considered unlikely that this opportunity would be advanced further or supported by the City.

Potential re-development sites within the Appleby GO MTSA are a mixture of those which likely outlet directly to area watercourses (Appleby and Sheldon Creeks), and are drained by municipal services within the roadways (i.e. storm sewers). As noted in Section 4.3, the capacity of the existing storm sewer network in the Appleby GO MTSA is unknown, as there are no available hydraulic models for these systems. Consistent with current City practices for quantity control, it is recommended that requirements distinguish between these two types of outlets.

Where sites have an existing approved outfall directly to a watercourse system, post-development to pre-development peak flow for the 2 through 100-year storm events are generally considered sufficient. Given the relatively minor change in land use in the area, and the location (towards the downstream limits of the watershed) it is considered unlikely that further overcontrol to reduce any downstream riverine impacts would be of any benefit and may in fact result in an adverse synchronizing of peak flows.

Given the lack of information on storm sewer capacity (and overland flow routes), it is recommended that the City of Burlington's current informal policy of over-control (100-year post-development peak flow controlled to the 5-year pre-development peak flow) be applied as a minimum for those sites connecting to the City's storm sewer system unless the receiver can be demonstrated to have a greater capacity, in which case that identified capacity would govern. CH has noted in its comments of April 16, 2021 that post to pre peak flow control should still be required for the 2-year storm event in this case. In some areas the storm sewer system may have a capacity below the 5-year storm event; this reduced criterion should also govern in those areas. This policy ensures that discharges are adequately controlled to the conveyance capacity of the interim drainage system receiver (i.e. the storm sewer) and no overland flow impacts would result from the conversion of area land uses.

Should the City develop more detailed hydraulic modelling of the minor (storm sewer) and major (overland flow/roadway) urban drainage systems in this area, such modelling could potentially be used to confirm whether a lesser degree of quantity control would be acceptable (and potentially a greater degree of quantity control if greater constraints are identified). In the absence of such information, the informal policy of over-control is considered warranted for those sites connecting to the City's storm sewer network.

As per CH's comments of April 16, 2021, SWM quantity control requirements should also be revisited as necessary as the result of any future updated hydrologic and hydraulic modelling analyses (in particular CH's pending modelling updates to the East Burlington Creek Systems).

The necessity for on-site Regional Storm quantity controls has not been confirmed or assessed as part of the current study. Future assessments may be required as part of site plan development applications on a "case by case" basis. If Regional Storm controls are determined to be warranted, a further policy review will be required to confirm the necessary requirements to allow CH to support formal crediting, including consideration of ownership and operation and maintenance considerations.

Given the fragmented nature of the pervious areas within the study area, and the study areas location towards the downstream limits of watercourse systems, erosion control requirements are not considered as critical as in more undeveloped, greenfield areas. Notwithstanding, consistent with the City's current approach to site developments, erosion control should be implemented through the 24-hour extended detention of the 4-hour 25 mm storm event. This could potentially also be achieved through the provision of LID BMPs, as part of the overall site SWM strategy (including quality control). In cases where the proponent can demonstrate that the preceding requirement cannot be reasonably achieved for the site, further discussions with CH and City staff may be required. Any additional requirements stemming from the City's Appleby Creek Erosion Control Class EA (August 2020) should also be taken into account as part of any future erosion control measures.

As re-developments proceed within the study, area there is also an opportunity to holistically improve stormwater quality of discharges to the receiving system. The City of Burlington's current informal policy is to require "Enhanced" Water Quality treatment (80% average annual removal of Total Suspended Solids). This requirement accounts for the entire proposed impervious coverage, not only the "new" impervious coverage. It is recommended that this policy continue to be applied for re-developments within the study area, given the retroactive stormwater quality improvement to receivers.

It should be noted that over the course of this study, the City of Burlington updated its Stormwater Management Design Policies and Guidelines (these were finalized in May 2020), thus additional stormwater management requirements, particularly with respect to climate change, erosion control, and water balance/infiltration would result for future developments, beyond the basic quantity and quality requirements noted previously.

In addition to the preceding, the currently proposed land use plan for the Appleby GO MTSA (Draft Precinct Plan – May 2018) indicates the use of "Green Streets" for area roadways. Green Streets provide the opportunity to incorporate Low Impact Development Best Management Practices (LID BMPs) as part of the overall streetscaping design, including surface features (bioswales and bioretention areas, soil retention cells/tree planters) and sub-surface features (exfiltration pipes and storage chambers). These measures would benefit both water quantity, quality, and water budget/infiltration/erosion.

5 CONCLUSIONS AND RECOMMENDATIONS

The land use plans prepared for the Appleby GO MTSA indicate that re-development and intensification are expected in this area. This report has been prepared in support of this planning effort, in order to summarize the expected flood hazard limits for the MTSA. Existing hydrologic and hydraulic models have been refined in order to reasonably assess expected flood hazards, due to riverine floodplain extents, and potential spill areas.

Conventional 1-dimensional (1D) hydraulic modelling has been prepared for the area watercourses to confirm the riverine floodplain limits, and those locations where floodplain extents would limit any potential re-development. Spills from Appleby Creek at the CNR tracks have the potential to impact a number of re-development areas in the subject MTSA due to its uncontained nature.

A general floodplain management strategy has been proposed, which necessarily distinguishes between riverine floodplain extents (regulated by Conservation Halton) and spills (which are now considered to be regulated by CH and require assessment of re-development potential on a case-by-case basis). A general strategy has been proposed, as well as potential hydraulic structure upgrades in areas which may assist in reducing currently estimated floodplain extents. An overall stormwater management (SWM) strategy has also been proposed, including quantity and quality control measures to mitigate the impacts of future development. A summary of the proposed measures for the Appleby GO MTSA is outlined in Table 5.1.

The current study provides a basis for the estimation of existing flood hazards and a proposed SWM strategy for the Appleby GO MTSA. As noted, further study may be warranted as future refined land use planning and development studies. The following additional recommendations are noted in this regard:

- The City of Burlington may wish to consider undertaking further field monitoring and data collection efforts to support hydrologic model calibration, which will allow for a more informed estimate of flood risk.
- Further field verification and topographic survey is also recommended in certain locations, including potential spill locations such as the vicinity of the CNR tracks (to verify spill elevations and vulnerable locations). More current topographic data is now available (2018 LiDAR-based DEM) and should be applied for future studies (or more currently available data), notwithstanding consideration of vertical datum differences.
- More refined hydrologic and hydraulic modelling tools should potentially be considered for future development for the study area, including:
  - Dual drainage hydraulic modelling to confirm the capacity of area storm sewer and overland flow routes
  - Scoped 2D hydraulic modelling to confirm impacts of identified spill flows from Appleby Creek (potentially combined with an update to the 1D hydraulic modelling using available topographic survey)
  - Pending hydrologic and hydraulic modelling updates for the East Burlington Creeks by CH are expected to address some of these additional requirements.

Table 5.1. Summary of Flood Hazard and SWM Strategies for Appleby GO MTSA

MANAGEMENT AREA	CONSIDERATION	RECOMMENDATION
Development Area Flood Management	Riverine floodplain encroachment onto development sites	— No development can occur within 7.5 m buffer of identified floodplain extents (Appleby and Sheldon Creeks identified as Minor Valley System) — Consider opportunities to reduce floodplain extents through hydraulic structure upgrades or channel improvements where feasible (limited opportunity within the study area)
	Flood spills onto development sites	— Development may be able to proceed subject to suitable flood management strategy on affected development sites and confirmation based on current CH limits and policies. — Focus on passive floodproofing (re-grading of land and buildings to 0.30 m above identified flood level); consider active floodproofing (measures that require human intervention) where passive floodproofing not feasible, and where supported by CH (active floodproofing is not supported for intensification of use but supported for protection of existing development). Confirm safe ingress/egress from site. — Achievement a cut/fill balance for flood storage volume to avoid off-site impacts. — Assess proposed site management strategies through application of developed modelling tools to confirm no off-site impacts and safe conveyance of spill flows.
Area Infrastructure Improvements	Hydraulic Structures (Culverts)	— Consider benefit of hydraulic structure upgrades to reduce floodplain extents for development lands. — For Appleby Creek, consider upsizing to: a. Harvester Road (more limited benefit than CNR; would need a larger bridge structure of similar span – 20 m +\- with associated channel modifications) b. CNR (identified as the most deficient hydraulic structure; would require creation of a bridge structure with a width of 20 m +\- and associated channel modifications)
	Storm Sewers	— Insufficient information to recommend specific upgrades. Consider further as part of future study (dual drainage modelling).
	Overland Flow Pathways	— Insufficient information to recommend specific upgrades. Consider further as part of future study, including spill pathways (dual drainage modelling).
	SWM Facilities	— Consider implementation of SWM facilities (for local or external lands) within proposed future park areas (4415 Fairview Street and 5200 Harvester Road) and Sherwood Park as part of future re-development plans, however these may not ultimately be feasible

MANAGEMENT AREA	CONSIDERATION	RECOMMENDATION
Stormwater Management Criteria	Quantity Control	— Post to pre peak flow control (2-year through 100-year) for areas discharging directly to creek systems. — Over-control (100-year post to 5-year pre or demonstrated capacity) of peak flows for areas connecting to storm sewers or where major system is constrained. Ensure post to pre peak flow control is maintained for the 2-year storm event. Additional over-control may also be warranted where modelling results indicate storm sewer capacity is less than 5-year storm event standard. — Implement standard erosion control measures (24-hour extended detention of 4-hour 25 mm storm event), potentially in combination with LID BMPs for the overall SWM strategy. Where it can be demonstrated that the above cannot be reasonably be achieved, further discussion with CH and City staff may be required. — Requirements for Regional Storm control to be confirmed.
	Quality Control	— Enhanced (80% average annual TSS for all impervious areas — Review opportunities for synergies with other studies and road reconstruction projects in particular ("Green Streets")

The current study should also be considered in conjunction with other ongoing City of Burlington initiatives within the study area (i.e. Appleby Creek Flood Study EA). For the MTSA assessed herein, updated direction from the City's revised Stormwater Management Policies and Design Guidelines should be taken into account in the development of future SWM strategies for re-developments.