Flood Hazard and Scoped Stormwater Management Assessment

Burlington GO Mobility Hub and Downtown
Burlington, Ontario
Project TPB178008

Prepared for:

City of Burlington
426 Brant Street, Burlington, ON L7R 3Z6

9/22/2020

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1.0 Introduction

The City of Burlington is undertaking a land use planning study for four (4) Mobility Hub areas. 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. In support of this planning effort (lead by Brook McIlroy Inc for the GO Station Mobility Hubs and SGL Planning for Downtown), Dillon Consulting Limited (Dillon) is preparing a series of Scoped Environmental Impact Studies (EIS) for each of the four (4) hubs. 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 in these areas.

In support of this effort, Wood Environment & Infrastructure Solutions (Wood) is preparing a series of flood hazard and scoped stormwater management assessments for each of the three (3) hubs and the Downtown area. These documents are intended to define existing flood hazards for areas of anticipated development, and to also develop preliminary stormwater management strategies, including reviewing drainage infrastructure service capacity, where feasible and required.

This report is focused upon two (2) of the four (4) areas, specifically the Downtown area and Burlington GO Mobility Hub. These two (2) areas are located directly adjacent to each other, and although these areas are separated by the Hager-Rambo Diversion Channel, potential floodwater spills from this feature (within the Burlington Mobility Hub) have the potential to impact the Downtown area hence these have been assessed jointly. Drawing 1 presents the boundaries of these two (2) Mobility Hub study areas along with the area watercourses and existing stormwater management (flood control) facilities.

The analyses documented within the current report are intended to provide context with respect to the overall flood risk to the Burlington GO Mobility Hub and Downtown area, 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 Environmental Impact Study (EIS) reporting. In addition, the current reporting also includes the Scoped Stormwater Management (SWM) criteria assessment for the respective areas. Further, the "Hager Rambo Flood Control Facilities Assessment" (September, 2020) is considered a companion document to this process to support the crediting of the facilities in the area's flood management.

2.0 Burlington GO Mobility Hub

2.1 Hydrology

2.1.1 Overall Modelling Updates

The currently approved hydrologic modelling for the Hager-Rambo system is the 1997 OTTHYMO model (ref. Philips Planning and Engineering, 1997). As part of the Urban Area Flood Vulnerability, Prioritization and Mitigation Study for the City of Burlington (in response to the August 4, 2014 storm event), Wood Environment & Infrastructure Solutions (Wood) updated the OTTHYMO model to a SWMHYMO format. As part of the current Mobility Hubs study, Wood has undertaken a more detailed review and refinement of the SWMHYMO version of the model, including making revisions and updates as required to more accurately represent current conditions. These updates include:

- Updating Roseland Creek drainage areas (i.e. diversion of Areas R-6, R-7, and R-8) to reflect the most current approved modelling (as per Class Environmental Assessment for Roseland Creek Flood Control, Philips Engineering, February 2009)
- Modification of channel routing elements (elements 532 and 583)
- Inclusion of a DUHYD split for subcatchment ER-1A based on the observed minor/major flow split
- Inclusion of an additional drainage area along Fairview Street not previously included (ER-1B, 10.2 ha)
- Correction of the drainage area for EH-3A2 (GIS measured area is 23.4 ha, listed as 15.0 ha in original 1997 hydrologic modelling)
- Drainage area (subcatchment) refinements and modifications for the Mobility Hub area
    - Sub-dividing of drainage areas around the East Rambo Pond and to the south of the QEW to better reflect drainage areas to key points of interest based on current mapping.
    - Re-parameterizing of these updated subcatchments using current land use data
    - Removal of drainage areas which drain directly to the Brant Road CNR underpass (these areas are drained by a storm sewer which is not connected to the Hager-Rambo Diversion channel, thus is included as part of the Downtown Area PCSWMM hydrologic modelling).
- A modification/update to the East Rambo Pond Flood Control Facility Rating Curve
    - Including a DUHYD split for the resultant spill flows between the West and East branches of Rambo Creek
- A modification/update to the Freeman Pond Flood Control Facility Rating Curve
- Use of current (2004) rainfall (intensity-duration-frequency or IDF data), as well as a sensitivity analysis to determine the critical design storm distribution

In addition to the preceding, a cursory review has been conducted to determine if any notable urbanization has occurred since the development of the preceding modelling (1997). Based on this review, no notable areas of change were noted within the tributary area.

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). 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™). Table 2.1 presents the resulting land use classifications and associated estimated imperviousness values.

Table 2.1 Estimated Land Use Characterization and Parameterization for Burlington GO Mobility Hub

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 above parameterization, an average overall impervious coverage of 74.6% +\- results for the existing drainage areas within the Burlington Mobility Hub Limit. The modelling updates have resulted in an increase of the impervious coverage from the original SWMHYMO modelling (which had an impervious coverage of approximately 70.6% +/-). Additional hydrologic parameters have been updated for the estimation of SCS Curve Number, slope, and flow lengths using the associated topographic contour data and soils information used for the Downtown area (discussed in Section 3).

Drawing 3 presents the drainage area boundaries for the Upper Hager, Upper Rambo, and Roseland Creek systems, and also depicts key hydrologic nodes (locations) of interest based on the flows generated from the updated hydrologic modelling. Drawing 4 presents the updated hydrologic modelling schematic, based on the previously completed 1997 Study (Philips Planning and Engineering Ltd.).

In addition to the preceding, it is noted that the previous (1997) modelling applied the 3-Hour Chicago Storm, using the then current IDF data. As part of this assessment, a more current City of Burlington IDF data (2004 update) has been applied, along with an analysis of a number of different design storm distributions to determine the most critical. Based on this analysis, the 24-Hour SCS Type II distribution has been selected based on the highest simulated flows within the receiving watercourse systems. The results of the hydrologic sensitivity analysis have been included in Appendix C. It should be noted however that the currently approved City IDF are based on the data (RBG Gauge) from 1964 to 1990 which were approved in 1999. The 2004 values represent approximately a 5% increase in rainfall depths as compared to the 1999 values.

Potential future changes in rainfall patterns (intensities and depths in particular) associated with climate change are beyond the scope of the current study. Notwithstanding, the potential impacts associated with climate change should be considered as part of future study.

It should be noted that there is some uncertainty with respect to the preceding hydrologic modelling, which should be understood and acknowledged in the interpretation of the modelling results and in developing

Official Plan/Land Use Policies. A key uncertainty with respect to hydrologic modelling is the estimation of imperviousness for different land uses. The values presented in Table 2.1, as applied for areas within the Burlington GO Mobility are generally considered reasonable and appropriate, however it is noted that impervious coverage assumptions for external areas have not been re-evaluated. A detailed review of these values is considered beyond the scope of current study. Notwithstanding, a future overall hydrologic modelling review and update for the entire watershed (i.e. the Hager-Rambo system) is likely warranted, in particular to update the modelling from the somewhat dated SWMHYMO platform, but also to re-assess and re-evaluate overall subcatchment parameterization. This effort would be best combined with a field monitoring and data collection program (ideally 1 year or more) to collect actual flow response data at key locations within the subwatershed, to adjust and calibrate any revised estimates of imperviousness and associated land use parameterization. Such a study would be expected to proceed independently of the current (Phase 1) or planned future (Phase 2) study works however, as it is not considered necessary to support the aims of the current focused study.

2.1.2 Flood Control Facilities

2.1.2.1 East Rambo Pond

Of particular note for the current area of interest is the assumptions regarding the performance of the East Rambo Pond. Based on the available documentation, this facility was designed to a 100-year level of flood control (using the 1997 3-hour Chicago storm distribution), with minimal freeboard (i.e. < 0.30 m). Above the design level, the facility would be expected to spill. Given the increase in flows associated with the application of current IDF data (and a longer duration design storm event), the facility would be expected to spill for the (current) 100-year storm event, as well as for the Regional Storm (Hurricane Hazel) event.

The Flood Control facility rating curve included in the 1997 modelling is understood to be a preliminary design curve; the facility underwent detailed design and construction by the MTO sometime between 1997 and 2004 (given that the facility is evident in historical aerial photography for that date). There are no available records within the City of Burlington's files which provide a detailed design summary or associated design rating curve. Attempts were made by Wood to obtain design information from the MTO, however these attempts were ultimately unsuccessful. As such, a new facility rating curve has been developed based on current (2017) information. Should the original detailed design information become available however, it is recommended that the information be compared against the rating curve developed as part of this report.

Low flow from the East Rambo Pond is drained by a 3 m wide by 1.5 m high concrete box at the western limits of the facility (field verified October 13, 2017). This conduit is ultimately directed to a 2.4 m x 1.8 m storm sewer beneath the QEW, which outlets to the East Rambo Creek at Queensway Drive at Brenda Crescent. The 1997 rating curve and modelling assumed that spill/overflow from the East Rambo Pond would continue to be directed towards the East Rambo Creek system. As alluded to in comments from Conservation Halton (ref. September 12, 2017 – copy included in Appendix B), based on a review of the East Rambo Pond area, it appears that spill above the maximum operating level would in fact be directed to the CNR underpass beneath the North Service Road and the QEW, and then ultimately drain into the West Rambo Creek system. The railway elevation (from the 2015 Region of Halton DEM) of 105.5 m +\- is the lowest point of potential spill. The 15 m +\- wide opening appears to have a continuous 0.9% grade to the south of the QEW. Secondary spill from the East Rambo Pond across the North Service Road would not occur until a higher elevation is reached, 106.4 m +\- (or some 0.9 m +\- higher).

An updated rating curve for the East Rambo Pond has been developed for the current study. The 2015 Region of Halton DEM has been used to develop 0.25 m elevation contours, and thus establish the stage-surface area relationship for the facility, and in turn the stage-storage relationship. This topographic information is considered the best available for the current study (and also reasonable given the scale of the facility). Pending the findings and recommendations of the Hager-Rambo Flood Control Storage Facilities Study (Wood, September 2020), the stage-surface area relationship may warrant further assessment as part of a future Phase 2 study .

The corresponding stage-discharge function has been determined by summing the three potential discharge outlets for the facility:

- Low flow discharge through the 3 m W x 1.5 m H box culvert has been estimated using an approximation of MTO Design Chart 5.39 (inlet control of a box culvert)
- Primary spill via the CNR has been estimated using Manning's equation for flow through the culvert structure
- Secondary spill via the NSR has been estimated using Manning's equation to approximate a weir type overflow

Figure 2.1 presents a comparison of the facility rating curve from the 1997 report, as well as the currently proposed rating curve. The developed rating curve ordinates are presented in Table 2.2.

As evident from Figure 2.1, the proposed rating curve indicates a lower rate of discharge at lower storage volumes, which would tend to result in a more rapid consumption of available storage volume. Both curves have a similar "break point" between low and high (spill flow), at approximately 11 to 12 ha-m (110,000 to 120,00 m^3). The spill portion of the proposed rating curve is further extended, which likely reflects the use of actual data (as compared to the approximations which were likely necessary for the preliminary 1997 curve).

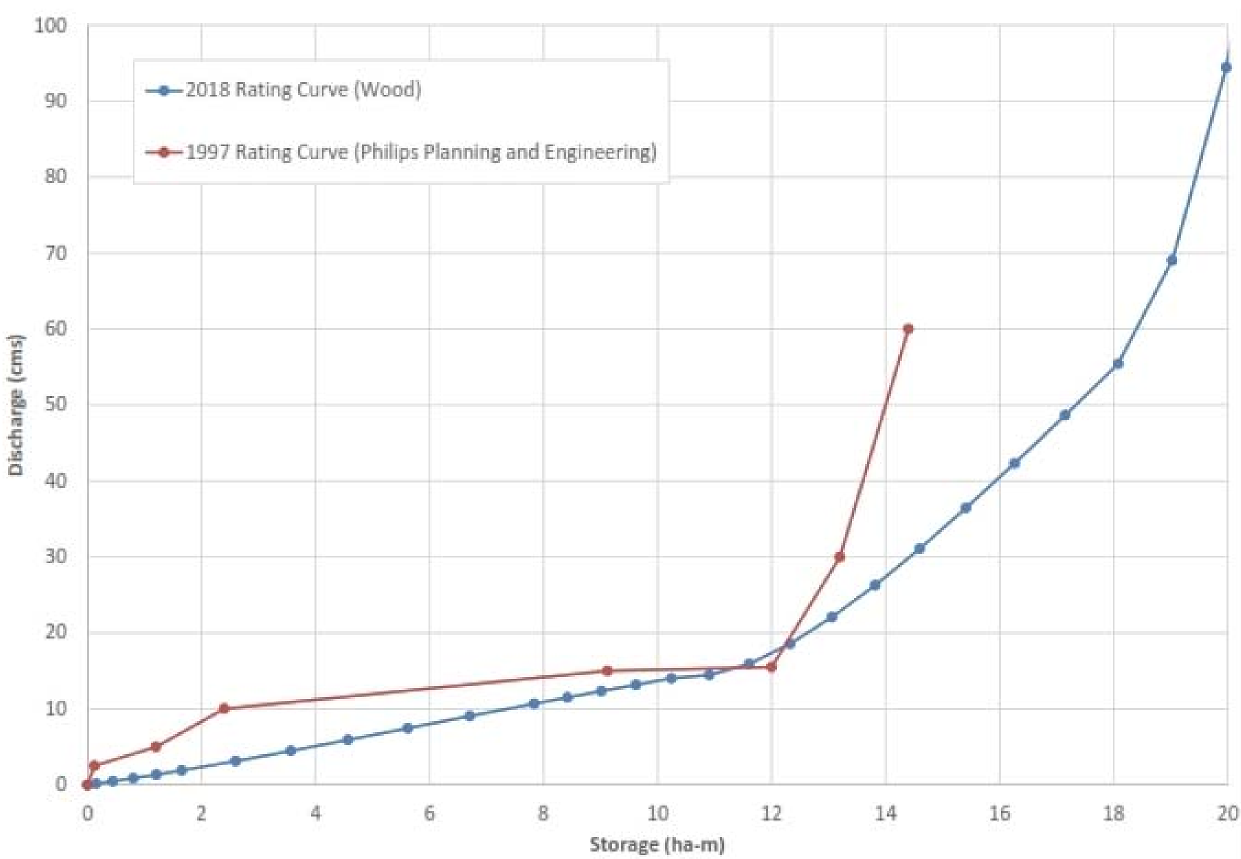

Figure 2.1: Rating Curve Comparison for East Rambo Pond

The proposed rating curve has been incorporated into the updated hydrologic modelling in SWMHYMO. A DIVERT HYD command has also been used to separate the combined discharge into its constituent components: culvert flow (to East Rambo Creek), CNR spill flow (to West Rambo Creek) and North Service Road spill flow (assumed to be ultimately directed to East Rambo Creek via culvert crossing of the QEW to the east).

Based on the results of the subsequent 2D hydraulic modelling (refer to Section 2.2.2), 5.1 m^3/s of the total Regional Storm Spill flow via the CNR (to the West Rambo Creek system – i.e. 39.4 m^3/s) would be returned to the East Rambo Creek at the CNR via the north ditch (if the backwater/tailwater impacts from the East Rambo Creek are not accounted for/included). Under the 100-year storm event, all of the spill would be retained within the West Rambo Creek. A DUHYD command has been incorporated into the Regional Storm event hydrologic modelling accordingly.

Updated modelling results incorporating the revised rating curve and flow division are presented in Section 2.1.3.

Table 2.2 Revised Rating Curve for East Rambo Pond

Stage (m)	Surface Area (m^2)	Storage (m^3)	Discharge from Culvert Outlet (m^3/s)	Spill Discharge to CNR (m^3/s)	Spill across NSR (m^3/s)	Total Flow (m^3/s)
103.3	4,033	0	0.00			0.00
103.4	25,762	1,490	0.15			0.15
103.5	33,069	4,431	0.46			0.46
103.6	38,899	8,030	0.87			0.87
103.7	42,367	12,093	1.35			1.35
103.8	46,706	16,547	1.90			1.90
104.0	47,806	25,998	3.12			3.12
104.2	48,871	35,666	4.48			4.48
104.4	51,442	45,697	5.93			5.93
104.6	53,427	56,184	7.45			7.45
104.8	55,329	67,059	9.04			9.04
105.0	57,736	78,366	10.66			10.66
105.1	58,878	84,197	11.49			11.49
105.2	60,114	90,146	12.33			12.33
105.3	61,529	96,228	13.17			13.17
105.4	62,899	102,450	14.02			14.02
105.5	69,051	109,047	14.45	0.00		14.45
105.6	71,059	116,053	14.89	1.02		15.91
105.7	72,694	123,240	15.36	3.20		18.57
105.8	74,576	130,604	15.82	6.24		22.06
105.9	76,640	138,165	16.27	10.00		26.27
106.0	79,592	145,976	16.70	14.38		31.08
106.1	83,282	154,120	17.12	19.33		36.45
106.2	87,028	162,635	17.54	24.79		42.33
106.3	90,534	171,514	17.94	30.72		48.66
106.4	94,855	180,783	18.33	37.09	0.00	55.42
106.5	94,855[1]	190,269	18.72	43.86	6.44	69.02
106.6	94,855[1]	199,754	19.10	51.01	24.33	94.44
106.7	94,855[1]	209,240	19.47	58.52	55.88	133.86

Note: 1. Surface Area assumed constant above NSR spill elevation of 106.4 m

As per discussion with CH staff (ref. Scheckenberger/Senior-Dearlove, August 20, 2018, e-mail response of September 11, 2018), it is understood that CH has requested updated floodplain mapping for East Rambo Creek based on the elimination of identified overflow pathway to the West Rambo Creek. This approach was confirmed as the other proposed options identified by CH could not be addressed:

- *Provide confirmation that the original design [of the East Rambo Pond] intended for overflow pathway to West Rambo Creek.* Both Wood and City staff have been unable to obtain any detailed design materials for the East Rambo Pond; nor does it appear that CH staff has this information.
- *Provide a flood risk assessment and mitigation study to identify the management approach with the best overall flood risk outcome.* This is beyond the scope of the current study.

Based on the preceding, an additional hypothetical hydrologic modelling scenario has been undertaken which uses the updated flood control rating curve presented in Table 2.2, however eliminates the DIVERT HYD command downstream to split flows between West and East Rambo Creeks (and routes all SWM outflow to the East Rambo Creek). The results of this additional scenario are presented in Section 2.1.3 with respect to simulated peak flows, and Section 2.2 with respect to the associated impacts to floodplains.

It should be noted that a scenario considering debris blockage of the outlet has not been considered as part of the current report. Pending the results of the Hager-Rambo Flood Control Storage Facilities Study (Wood), this additional modelling scenario may be required as part of a future Phase 2 Study.

2.1.2.2 Freeman Pond

The Freeman Pond is a large flood control facility located on the south side of the QEW/403 interchange. The facility attenuates flows to the East Hager Creek system. While East Hager Creek is outside of the limits of the Burlington Mobility Hub, previous floodplain mapping prepared by CH (ref. March 18, 2014 memorandum Lee/Harris-Brouwers) indicated that the Regional Storm Floodplain could potentially impact the subject Mobility Hub. As such, further assessment by Wood was required.

The Freeman Pond was designed by Philips Planning and Engineering; construction was completed in October 1995 (as per the Hager-Rambo Flood Control Works Operations & Maintenance Manual, Philips Planning and Engineering, December 17, 1998). A facility rating curve was included with the available modelling (the approved hydrologic modelling for the Hager-Rambo system is the 1997 OTTHYMO model, as noted previously). The Regional Storm modelling includes an overflow ordinate, which was noted previously by Wood to cause some model stability issues (given the minimal corresponding increase in storage and the difficulty of the model in interpolating intermediate values). The available documentation for the Freeman Pond does not indicate the corresponding expected stage/depth and surface area values which correspond to the available storage and discharge values. As such, it was considered inappropriate to estimate or assume a modified overflow function for the rating curve. A new facility rating curve has therefore been developed based on current (2018) information.

Low flow from the flood control facility is via a 1.75 m x 1.75 m concrete box culvert. These dimensions have been field verified, and match with record drawings. Notwithstanding, a low flow channel is also present below the primary box (approximately 0.25 m deep, 0.5 m wide at the base and 0.5 m wide at the top). Based on this additional conveyance area, an equivalent dimension of 1.85 m H by 1.75 m W would result. Available drawings also indicate an upstream invert of approximately 97.9 m; however available current topographic mapping data (2015 Region of Halton DEM) indicate the invert at this location is closer to 98.4 m. Detailed survey would be required to confirm the value definitively, however for the purposes of the development of an updated rating curve, the 98.4 m has been assumed to be correct, given that these data are more recent and will also be used to develop stage-surface area information.

There is conflicting information on the designed top of berm amongst available record drawings. One drawing indicates a spillway elevation of 105.15 m, while other drawings or portion of the O&M report indicate 105.4 m and 105.5 m (with a noted length of 107 m). Based on the previously noted DEM data, the low point along the berm is approximately 104.9 m. The elevation rises from this location, up to an elevation of approximately 105.6 m. The base spillway width varies, but is approximately 102 m +\- which is generally consistent with the value reported in the O&M manual.

It should be noted that based on the current topographic data (2015 DEM) there are two (2) locations where spill may occur at a lower elevation than noted in the O&M manual and other documentation. These locations are presented in Figure 2.2, and include:

- Along the north-east side of the primary Freeman Pond Berm (along Brant Street off-ramp, 125 m +\- west of Brant Street)
- From the smaller upstream ponding area on the north side of the Brant Street off-ramp

Figure 2.2: Potential Spill Locations from the Freeman Pond

Potential spill in these locations could occur at an elevation of 105.2 m +\- based on the 2015 Region of Halton DEM, which while higher than the estimated lowest spillway elevation of 104.9 m +\-, is below the typical top of berm elevation and previously reported berm heights. Other locations on the south side of the berm indicate low elevations of approximately 105.4 m +\-. A further topographic survey of these areas (and potentially the entire berm top, as well as adjacent high points) would be required to definitively confirm spill elevations, which is beyond the scope of the current study. Further, depending on the maximum operating level within the Freeman Pond, it is possible that these elevations would not be expected to be reached; this has been assessed as part of the modelling results in Section 2.1.3. Notwithstanding, for the purposes of the current assessment, it has been assumed that all spill from the

Freeman Pond would be via the primary spillway at the west limits of the pond, draining to East Hager Creek. This conservative approach assumes that any such low spots are mitigated or addressed such that the pond spill is directed to the primary outlet as originally intended.

An updated rating curve for the Freeman Pond has been developed for the current study based on the preceding. The 2015 Region of Halton DEM has been used to develop 0.25 m elevation contours, and thus establish the stage-surface area relationship for the facility, and in turn the stage-storage relationship. Surface areas for the facility reflect the primary Freeman Pond, as well as the two adjacent ponding areas upstream of the main pond and downstream of the QEW. As noted for the East Rambo Pond, while this topographic information is considered the best available for the current study (and also reasonable given the scale of the facility), pending the findings of the Hager-Rambo Flood Control Storage Facilities Study (Wood, September 2020), the stage-surface area relationship may warrant further assessment as part of a future Phase 2 study.

The corresponding stage-discharge function has been determined by summing the two potential discharge outlets for the facility:

- Low flow discharge through the equivalent 1.75 m W x 1.85 m H box culvert has been estimated using an approximation of MTO Design Chart 5.39 (inlet control of a box culvert)
- Primary spill via the overflow spillway has been estimated using Manning's Equation (given the irregular geometry) in order to estimate a weir type overflow

Figure 2.3 presents a comparison of the facility rating curve from previous hydrologic modelling (SWMHYMO), as well as the currently proposed rating curve. The developed rating curve ordinates are presented in Table 2.3.

As evident from Figure 2.3, the two rating curves are generally consistent for the majority of the operating range. The proposed rating curve indicates a slightly lower rate of discharge at lower storage volumes, which would tend to result in a slightly more rapid consumption of available storage volume. Both curves have a similar "break point" between low and high (spill flow), at approximately 31 to 32 ha-m (310,000 to 320,000 m^3). The spill portion of the proposed rating curve is further extended, which reflects the use of actual data (as compared to the approximation in the previous modelling which did not appear to account for the actual increase in storage volume with increasing depth).

Results from the hydrologic modelling applying the updated Freeman Pond rating curve are presented in Section 2.1.3.

It should be noted that a scenario considering debris blockage of the outlet has not been considered as part of the current report. Pending the findings of the Hager-Rambo Flood Control Storage Facilities Study (Wood, September 2020), this additional modelling scenario may be required as part of a future Phase 2 Study.

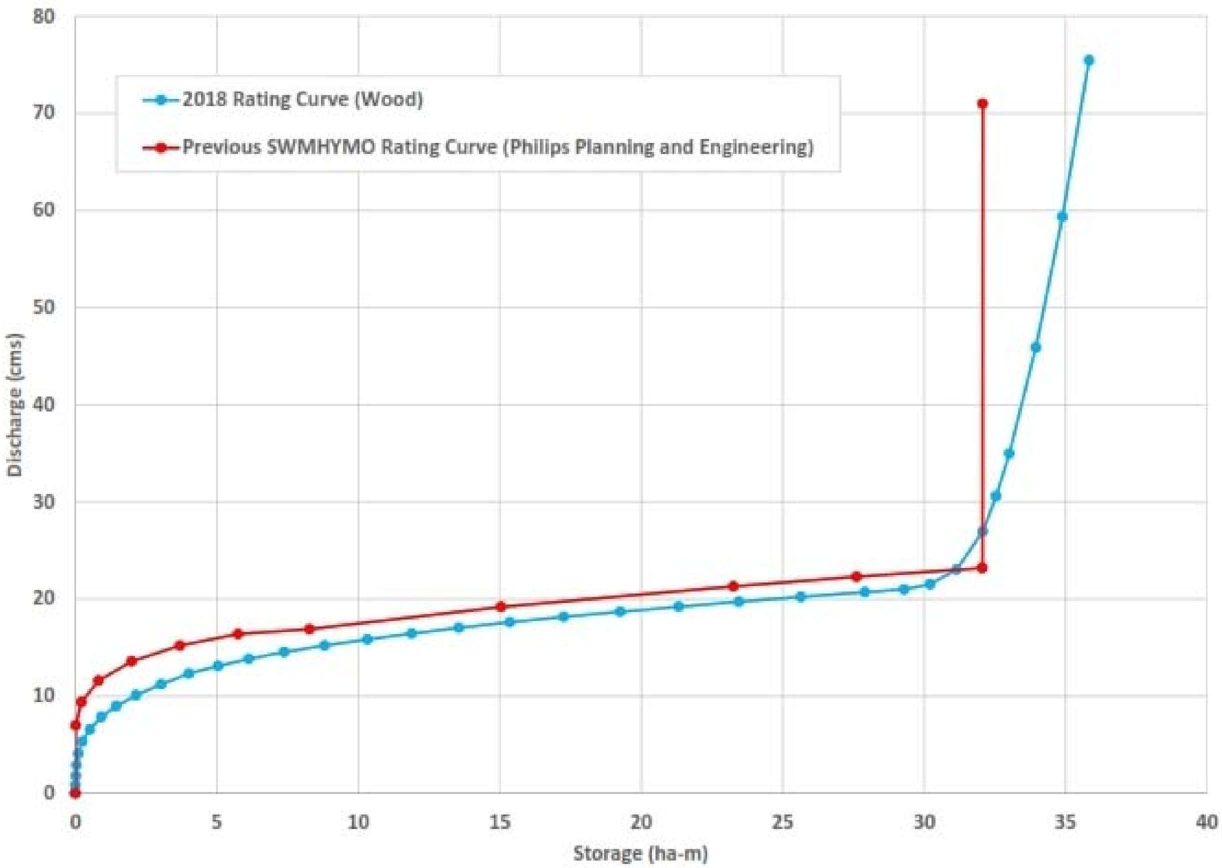

Figure 2.3: Rating Curve Comparison for Freeman Pond

Table 2.3 Revised Rating Curve for Freeman Pond

Stage (m)	Surface Area (m^2)	Storage (m^3)	Discharge from Culvert Outlet (m^3/s)	Berm Spill (m^3/s)	Total Flow (m^3/s)
98.40	0	0	0.00		0.00
98.75	251	34	0.84		0.84
99.00	776	163	1.81		1.81
99.25	1,369	431	2.92		2.92
99.50	3,464	1,035	4.10		4.10
99.75	8,192	2,492	5.33		5.33
100.00	12,811	5,117	6.59		6.59
100.25	19,336	9,136	7.87		7.87
100.50	23,224	14,456	8.99		8.99
100.75	32,725	21,449	10.10		10.10
101.00	38,314	30,329	11.22		11.22
101.25	40,449	40,175	12.34		12.34
101.50	42,009	50,482	13.11		13.11
101.75	44,789	61,332	13.85		13.85
102.00	55,119	73,820	14.54		14.54
102.25	59,491	88,146	15.21		15.21
102.50	61,073	103,217	15.84		15.84
102.75	64,311	118,890	16.45		16.45
103.00	69,085	135,564	17.04		17.04
103.25	74,557	153,519	17.61		17.61
103.50	78,291	172,626	18.17		18.17
103.75	81,342	192,580	18.70		18.70
104.00	83,940	213,240	19.22		19.22
104.25	86,344	234,525	19.73		19.73
104.50	89,166	256,464	20.23		20.23
104.75	91,701	279,073	20.71		20.71
104.90		292,913[1]	20.99	0.00	20.99
105.00	92,833	302,139	21.18	0.35	21.53
105.10		311,455[1]	21.37	1.68	23.05
105.20		320,770[1]	21.55	5.41	26.96
105.25	93,471	325,427	21.64	8.96	30.60
105.30		330,118[1]	21.73	13.25	34.98
105.40		339,501[1]	21.91	23.98	45.90
105.50	94,173	348,883	22.09	37.27	59.36
105.60	94,173	358,300	22.27	53.20	75.47

Note: 1. Interpolated storage based on calculated values/surface areas at 0.25 m depth increments.

2.1.3 Modelling Results

2.1.3.1 Flood Control Facilities In-Place

Updated simulated flows for key watercourse nodes are presented in Tables 2.4 and 2.5 for the 100-year storm event and Regional Storm respectively; refer to Drawing 3 and 4 for node locations. Note that for simulation of the Regional Storm, SCS Curve Numbers (CNs) have been updated to saturated (AMC-III) conditions to use the 12-hour version of Hurricane Hazel; depression storage values have also been set to zero.

Table 2.4 100-Year Storm Event Flows for Hager-Rambo Diversion Channel

Node	Current Drainage Area[1] (ha)	Location	100-Year Storm Peak Flow (m^3/s)			
			OTTTHYMO (1997 IDF, 3H Chicago)	SWMHYMO[2] (1997 IDF, 3H Chicago)	SWMHYMO[3] (2004 IDF, 24H SCS)	Difference (Current to 1997)
Q	642.6	East Rambo Pond Inlet	50.1	48.5	78.3	+56%
Q1	642.6	East Rambo Pond Box Culvert Outlet	15.1	15.1	17.2	+14%
Q2	642.6	East Rambo Pond Spill at CNR	0	0	21.1	NA
Q3	642.6	East Rambo Pond Spill at North Service Road	0	0	0	NA
J1	718.0	East Rambo Creek at CNR	NA	NA	21.2	NA
J	736.5	East Rambo Creek at H-R Diversion Channel Conf.	18.3	18.4	25.5	+39%
P	84.1	West Rambo Creek at QEW	11.3	11.1	18.6	+65%
P3	116.7	West Rambo at CNR (South of Plains Road East)	NA	NA	30.1	NA
P2	130.6	West Rambo at CNR (North of DePauls Lane)	NA	NA	30.9	NA
P1	140.9	West Rambo Creek at Fairview	15.1	14.9	31.2	+107%
K	886.4	H-R Diversion Channel D/S of West Rambo Creek	31.9	31.9	53.1	+66%
L	952.4	H-R Diversion Channel U/S of West Hager Conf.	35.1	37.1	58.8	+68%
G1	661.6	Freeman Pond Outlet	15.7	15.6	17.4	+11%
H	916.0	Freeman / West Hager Conf.	26.0	23.3	33.2	+28%
M	1,868.4	West Hager / H-R Diversion Channel Conf.	62.0	57.5	91.6	+48%
N	1,897.1	H-R Diversion Channel at Indian Creek	62.0	55.9	91.5	+48%

Notes:
1. Based on updated (2017) subcatchment boundaries; this differs somewhat from original 1997 modelling. Does not include areas due to spill flows.
2. Not including additional subcatchment boundary refinements and re-parameterization or revised rating curve for East Rambo Pond. Included to better document difference between SWMHYMO and OTTHYMO.
3. Includes all current modelling updates noted.

Table 2.5 Regional Storm Event Flows for Hager-Rambo Diversion Channel

Node	Current Drainage Area[1] (ha)	Location	Regional Storm Peak Flow (m^3/s)			
			OTTHYMO (1997)	SWMHYMO (Without Updates)[2]	SWMHYMO (With Updates)[3]	Difference (Current to 1997)
Q	642.6	East Rambo Pond Inlet	62.4	62.0	63.9	+2%
Q1	642.6	East Rambo Pond Box Culvert Outlet	62.4	62.1	18.5	-70%
Q2	642.6	East Rambo Pond Spill at CNR	0	0	39.4	NA
Q3	642.6	East Rambo Pond Spill at North Service Road	0	0	2.2	NA
J1	718.0	East Rambo Creek at CNR	NA	NA	32.8	NA
J	736.5	East Rambo Creek at H-R Diversion Channel Conf.	74.1	72.1	35.6	-52%
P	84.1	West Rambo Creek at QEW	11.8	11.9	11.9	+1%
P3	116.7	West Rambo at CNR (South of Plains Road East)	NA	NA	49.0	NA
P2	130.6	West Rambo at CNR (North of DePauls Lane)	NA	NA	50.6	NA
P1	140.9	West Rambo Creek at Fairview	18.6	18.8	51.6	+177%
K	886.4	H-R Diversion Channel D/S of West Rambo Creek	91.7	89.7	86.7	-5%
L	952.4	H-R Diversion Channel U/S of West Hager Conf.	99.4	98.6	95.3	-4%
G1	661.6	Freeman Pond Outlet	35.2	36.2	43.6	+24%
H	916.0	Freeman / West Hager Conf.	53.9	45.6	65.4	+21%
M	1,868.4	West Hager / H-R Diversion Channel Conf.	144.0	136.4	146.3	+2%
N	1,897.1	H-R Diversion Channel at Indian Creek	146.2	138.6	146.9	0%

Notes:
1. Based on updated (2017) subcatchment boundaries; this differs somewhat from original 1997 modelling.
2. Not including additional subcatchment boundary refinements and re-parameterization or revised rating curve for East Rambo Pond. Included to better document difference between SWMHYMO and OTTHYMO.
3. Includes all current modelling updates noted.

When comparing the results of the 1997 IDF 3 Hour 100-Year Chicago Storm, the simulated flows produced by SWMHYMO for the same event are generally within a rounding error of those produced by OTTHYMO, as evident in Table 2.4. As the flows are tracked downstream however, the differences trend larger due to the effects of the simulated routing elements. To understand the differences between the OTTHYMO and SWMHYMO modelling platforms, a comparison of the resulting output files was undertaken. The comparison revealed that OTTHYMO and SWMHYMO produce minor differences in the pervious segment of the STANDHYD command (SWMHYMO is a rounding difference lower). Although the differences are minor, they accumulate as the modelling continues downstream and accumulates flow. Further differences were noted in the results of the routing elements. In particular, a significant flow reduction was noted in the SWMHYMO results of routing element 583 which had been modelled as a STORE TRAVEL TIME command. The differences could not be resolved between the two models and therefore the routing element has been updated to a ROUTE CHANNEL command. The reduction in flow at Nodes H, M, and N are attributed to the change to routing element 583. The remaining STORE TRAVEL TIME commands were investigated and determined to not produce significant differences between inflows and outflows, therefore they remain unchanged within the model.

In general, the previous SWMHYMO modelling (prior to making more significant model changes) indicates good agreement with the currently approved 1997 OTTHYMO modelling, particularly in the area of interest (i.e. the Hager-Rambo Diversion channel upstream of the confluence of the West Hager Creek system (including the Freeman Pond). The base SWMHYMO modelling is therefore considered a reasonable and valid basis for the subsequent model modifications noted.

As would be expected, making additional modelling modifications (including updated subcatchment parameterization, more intense IDF data and a longer duration design storm, and modified rating curves for the East Rambo and Freeman Ponds) yields further differences. Overall, the 24-hour SCS Type-II design storm distribution yields the largest peak flows, and thus has been applied for the current assessment (refer to Appendix C).

Large simulated increases are indicated for the West Rambo Creek system, which is expected given the additional spill flow from the East Rambo Pond. Corresponding flow decreases are indicated for the East Rambo Creek system. Discharges from the Freeman Pond are also increased under the updated modelling, albeit much less than for the East Rambo Pond. These increases are considered attributable to modelling changes, including a revision to the drainage area surrounding the pond area, and more importantly, the revised rating curve (including spill portion) for the pond, which would somewhat decrease storage capacity as compared to the 1997 modelling.

For the Hager-Rambo Diversion channel between West Rambo Creek and West Hager Creek (nodes K and L), 100-year storm event results are increased as compared to the previous modelling, due primarily to the changes in the IDF parameters and use of a longer storm event, as noted previously. As evident from Table 2.5, changes for the Regional Storm Event for this portion of the channel are nominal, with the results actually indicating a slight decrease in flows. For the Hager-Rambo Diversion Channel downstream of the confluence with the West Hager (nodes M and N), results are similar; 100-year flow increases indicated (due to the revised IDF/design storm duration) and Regional Storm Flows which indicate only nominal change.

The performance of the updated flood control facilities relevant to the current assessment (i.e. East Rambo Pond, and to a lesser degree the Freeman Pond) for the 100-year and Regional Storm Events has also been reviewed; the modelling results are presented in Table 2.6.

Table 2.6 Simulated Performance of Flood Control Facilities within Burlington Mobility Hub (as per Existing Performance – Scenario 1)

Facility	Storm Event	Peak Operating Level (m)	Peak Storage (m^3)	Total Outflow (m^3/s)	Discharge via Primary Outlet (m^3/s)	Spill Flow (m^3/s)
East Rambo	100-Year	106.13	156,900	38.3	17.2	21.1 (CNR) 0.0 (NSR)
	Regional	106.43	184,100	60.0	18.5	39.4 (CNR) 2.2 (NSR)
Freeman	100-Year	103.16	146,800	17.4	17.4	0.0
	Regional	105.38	337,500	43.6	21.9	21.7

With respect to the East Rambo Pond, the pond indicates spill via the CNR for the 100-year storm event, as would be expected given the preceding discussion. For the 100-year storm event (2004 IDF data, 24 hour SCS Type II distribution), a maximum storage of 156,900 m3 is indicated, which equates to a maximum water surface elevation of 106.13 m (well above the CNR elevation of 105.5 m +\-). The maximum discharge via the CNR underpass would be 21.1 m^3/s. No spill across the North Service Road is indicated for the 100-year storm event (which would be expected to occur beginning approximately at 106.4 m +\-).

Based on the modified rating curve for the East Rambo Pond, and the revised hydrologic modelling (including updated design storms), modelling results indicate that spills from the East Rambo Pond to the CNR would be estimated to occur at the 10-year storm event (24 Hour SCS Type-II distribution) and greater. This suggests that spills would be a more frequent occurrence than originally intended, and may have more frequent impacts to downstream lands. It should be noted that the hydrologic modelling is not calibrated however. A flow monitoring program and subsequent modelling calibration effort would be beneficial to further confirm the flood risk for this system, however this is beyond the scope of the current study.

For the Regional Storm event, a maximum simulated storage of 184,100 m^3 is indicated for the East Rambo Pond, which equates to a maximum water surface elevation of 106.43 m +\- (or above the NSR spill elevation). This results in an estimated 2.2 m^3/s of spill across the North Service Road. The maximum simulated spill discharge via the CNR is 39.4 m^3/s, while 18.5 m^3/s would be discharged via the primary culvert outlet. The simulated CNR spill is substantial, and would be expected to have an impact to downstream receivers. The expected flooding extents from this spill flow (as well as other channel flows) is assessed further in Section 2.2.

The simulated results for the Freeman Pond (Table 2.6) indicate that the 100-year flow is easily contained by the facility (maximum operating level of 103.16 m), with all discharge via the primary outlet. For the Regional Storm Event, the revised modelling indicates a peak operating level of 105.38 m, which would be greater than the estimated spill elevation of 104.90 m. An estimated spill of 21.7 m^3/s over the berm therefore results, which is approximately equivalent to the simulated discharge from the primary culvert outlet (21.9 m^3/s). As noted with respect to the pond (Section 2.1.2.2), the currently available topographic data indicates that spill may occur at other locations (on the east side of the facility - beyond the primary spillway) beginning at approximately 105.2 m +\- (i.e. less than the simulated maximum Regional Storm operating level of 105.38 m). No further analyses of these potential secondary spills has been included in the current assessment. It is recommended that an additional topographic survey be completed to definitively confirm elevations in these areas (as well as the primary spillway) and the potential impacts of these spills, if they would in fact occur. Similarly to the observations with respect to the East Rambo Pond, it is noted that the hydrologic modelling is not calibrated, thus there may be benefit to undertaking such an effort as part of a follow-up study, to better assess the potential flood risk in this area.

2.1.3.2 Revised East Rambo Pond Spills

Based on discussions with Conservation Halton (July 27, 2018 memorandum Dearlove-Caldwell, and subsequent response of August 20, 2018 Scheckenberger-Dearlove – refer to Appendix B), it is understood that Conservation Halton (CH) has recommended three (3) different approaches to the flood management approach with respect to potential spills from the East Rambo Pond to West Rambo Creek. These approaches include:

a. Confirming that the original design intended for spills via the CNR culvert to West Rambo Creek;
b. Undertaking a flood risk assessment and mitigation study to identify the preferred management approach; or
c. Generating updated floodplain mapping for East Rambo Creek based on the assumption of all discharge from the East Rambo Pond being directed to East Rambo Creek.

As documented in Wood's response of August 20, 2018 (Scheckenberger-Dearlove), the City of Burlington's preferred approach is c). No information is available to confirm or deny a), and b) is considered well beyond the scope of the current study.

The previously updated hydrologic modelling (SWMHYMO) has been modified to simulate this alternate scenario (referred to as Scenario 2). Under Scenario 2, the East Rambo Pond is assumed to have the same rating curve as existing conditions (Scenario 1), however the spill flow to the CNR underpass (Q2) is instead directed to the East Rambo system rather than to the West Rambo Creek. All other components of the hydrologic modelling remain unchanged.

Following the preceding discussions with CH and City staff, it was ultimately determined that the preferred approach was to undertake a retrofit feasibility assessment for the East Rambo Flood Control Facility, to determine whether or not a retrofit to re-direct flows to East Rambo Creek (as per Scenario 2) was in fact feasible. A copy of this summary is included in Appendix E. It was ultimately concluded that such a retrofit was likely not physically, economically, or practically feasible, and further, would be undesirable given the potential flooding impacts and associated risks.

Notwithstanding, the results from Scenario 2 have been included in the reporting for comparison purposes. Simulated results for the 100-year storm event are presented in Table 2.7, along with the difference to the Scenario 1 results. A similar comparison has also been prepared for the Regional Storm Event, with the results presented in Table 2.8.

Table 2.7 100-Year Storm Event Flows for Hager-Rambo Diversion Channel (East Rambo Pond directed entirely to East Rambo Creek – Scenario 2)

Node	Current Drainage Area (ha)	Location	100-Year Storm Peak Flow (m^3/s)		
			Drainage Split in Place (Scenario 1)	All Flows to East Rambo Creek (Scenario 2)	Difference (%)
Q	642.6	East Rambo Pond Inlet	78.3	78.3	0%
Q1	642.6	East Rambo Pond Box Culvert Outlet	17.2	17.2	0%
Q2	642.6	East Rambo Pond Spill at CNR	21.1	21.1	0%
Q3	642.6	East Rambo Pond Spill at North Service Road	0	0	0%
J1	718.0	East Rambo Creek at CNR	21.2	40.9	+93%
J	736.5	East Rambo Creek at H-R Diversion Channel Conf.	25.5	42.8	+68%
P	84.1	West Rambo Creek at QEW	18.6	18.6	0%
P3	116.7	West Rambo at CNR (South of Plains Road East)	30.1	23.5	-22%
P2	130.6	West Rambo at CNR (North of DePauls Lane)	30.9	26.1	-16%
P1	140.9	West Rambo Creek at Fairview	31.2	26.8	-14%
K	886.4	H-R Diversion Channel D/S of West Rambo Creek	53.1	54.4	2%
L	952.4	H-R Diversion Channel U/S of West Hager Conf.	58.8	60.3	3%
G1	661.6	Freeman Pond Outlet	17.4	17.4	0%
H	916.0	Freeman / West Hager Conf.	33.2	33.2	0%
M	1,868.4	West Hager / H-R Diversion Channel Conf.	91.6	92.9	+1%
N	1,897.1	H-R Diversion Channel at Indian Creek	91.5	92.6	+1%

Table 2.8 Regional Storm Event Flows for Hager-Rambo Diversion Channel (East Rambo Pond directed entirely to East Rambo Creek – Scenario 2)

Node	Current Drainage Area[1] (ha)	Location	Regional Storm Peak Flow (m^3/s)		
			Drainage Split in Place (Scenario 1)	All Flows to East Rambo Creek (Scenario 2)	Difference (%)
Q	642.6	East Rambo Pond Inlet	63.9	63.9	0%
Q1	642.6	East Rambo Pond Box Culvert Outlet	18.5	18.5	0%
Q2	642.6	East Rambo Pond Spill at CNR	39.4	39.4	0%
Q3	642.6	East Rambo Pond Spill at North Service Road	2.2	2.2	0%
J1	718.0	East Rambo Creek at CNR	32.8	66.9	+104%
J	736.5	East Rambo Creek at H-R Diversion Channel Conf.	35.6	69.6	+96%
P	84.1	West Rambo Creek at QEW	11.9	11.9	0%
P3	116.7	West Rambo at CNR (South of Plains Road East)	49.0	16.2	-67%
P2	130.6	West Rambo at CNR (North of DePauls Lane)	50.6	18.1	-64%
P1	140.9	West Rambo Creek at Fairview	51.6	19.4	-62%
K	886.4	H-R Diversion Channel D/S of West Rambo Creek	86.7	86.9	0%
L	952.4	H-R Diversion Channel U/S of West Hager Conf.	95.3	95.6	0%
G1	661.6	Freeman Pond Outlet	43.6	43.6	0%
H	916.0	Freeman / West Hager Conf.	65.4	65.4	0%
M	1,868.4	West Hager / H-R Diversion Channel Conf.	146.3	146.0	0%
N	1,897.1	H-R Diversion Channel at Indian Creek	146.9	146.6	0%

As would be expected, the results indicate a large increase in flows to the East Rambo Creek, and a decrease in flows to the West Rambo Creek. Flows within East Rambo Creek would approximately double for both the 100-year and Regional Storm Events with the CNR spill flow re-directed to this location. The decreases in flows to West Rambo Creek are somewhat less however, which is considered attributable to timing effects given the combination of flows with the upstream West Rambo Creek area (which unlike the East Rambo Creek, does not pass through the East Rambo Pond). Along the Hager-Rambo Diversion Channel downstream of the confluence of both systems (i.e. west of Brant Street), differences are again negligible for both the 100-year and Regional Storm Events; 3% difference or less. The impacts of this hypothetical flow scenario have also been assessed using hydraulic modelling; this is discussed further in Section 2.2.

2.1.3.3 Flood Control Facilities Removed

At the request of Conservation Halton, an additional scenario has been considered which involves the removal of all flood control facilities from the modelling simulation for the Regulatory Storm Event (in this case, the Regional Storm, or Hurricane Hazel). The subject flood control facilities include:

- West Hager Pond (north of North Service Road, between Skyway Dr and Kerns Rd)
- Freeman Pond (south of QEW and west of Brant Street)
- East Rambo Pond (north of North Service Road, between CNR and Guelph Line)

Extensive dialogue between Conservation Halton, the City of Burlington, and Wood has occurred regarding the inclusion (or not) of the approved flood control facilities in the assessment of flood risk. Ultimately, the City of Burlington has stated that these facilities are to be included in any assessment which will establish the limits of regulated areas at risk of flooding for land use planning purposes. Conservation Halton has noted (July 27, 2018 memorandum – refer to Appendix B) that it would be in a position to support crediting of the flood control facilities, subject to receipt of additional information, including confirmation of the function of the ponds, identification of failure risks, confirmation of impacts of any future upstream development, and confirmation on ownership and maintenance.

Wood is currently supporting the City of Burlington to complete a technical analysis of the flood control facilities, including inspection, rating curve confirmation (through updated topographic data and site survey), structural/geotechnical stability analysis, sensitivity analysis (climate change impacts), and identification of any remedial measures. The study is currently underway, it is expected that the outcomes of this study will allow CH to support the inclusion of these facilities in establishing the associated regulatory flows, as per the position of the City of Burlington. Additional modelling refinements may be required as part of the Phase 2 works as a result of the outcome of the technical analysis of the Hager-Rambo Flood Control Storage Facilities Study (Wood, September 2020).

Notwithstanding, the City has agreed that as part of this study, an additional modelling scenario be conducted to assess the potential impact to simulated flows (and associated potential channel spills) from the removal of these facilities. An updated hydrologic modelling scenario including the removal of these facilities has been undertaken by Wood accordingly. Simulated results are presented in Table 2.9 (100-year) and 2.10 (Regional Storm) for Scenario 1 (East Rambo Pond spills as per existing conditions).

Table 2.9 Comparison of 100-Year Storm Event Flows (24-Hour SCS Type II) for Hager-Rambo Diversion Channel (Scenario 1) with and without Approved Flood Control Facilities in Place

Node	Current Drainage Area[1] (ha)	Location	100-Year Storm Peak Flow (m^3/s)		
			With Facilities	Without Facilities	Difference (%)
Q	642.6	East Rambo Pond Inlet	78.3	78.3	0%
Q1	642.6	East Rambo Pond Box Culvert Outlet	17.2	18.9	+10%
Q2	642.6	East Rambo Pond Spill at CNR	21.1	46.5	+120%
Q3	642.6	East Rambo Pond Spill at North Service Road	0	13.0	NA
J1	718.0	East Rambo Creek at CNR	21.2	35.1	+66%
J	736.5	East Rambo Creek at H-R Div Channel Conf.	25.5	37.5	+47%
P	84.1	West Rambo Creek at QEW	18.6	18.6	0%
P3	116.7	West Rambo at CNR (South of Plains Road East)	30.1	69.1	+130%
P2	130.6	West Rambo at CNR (North of DePauls Lane)	30.9	71.1	+130%
P1	140.9	West Rambo Creek at Fairview	31.2	71.9	+130%
K	886.4	H-R Diversion Channel D/S of West Rambo	53.1	109.8	+107%
L	952.4	H-R Diversion Channel U/S of West Hager Conf.	58.8	115.9	+97%
G1	661.6	Freeman Pond Outlet	17.4	77.2	+344%
H	916.0	Freeman / West Hager Conf.	33.2	82.1	+147%
M	1,868.4	West Hager / H-R Diversion Channel Conf.	91.6	195.8	+114%
N	1,897.1	H-R Diversion Channel at Indian Creek	91.5	190.4	+108%

Note: 1. Based on updated (2017) subcatchment boundaries; this differs somewhat from original 1997 modelling.

Table 2.10 Comparison of Regional Storm Event Flows for Hager-Rambo Diversion Channel (Scenario 1) with and without Approved Flood Control Facilities in Place

Node	Current Drainage Area[1] (ha)	Location	Regional Storm Peak Flow (m^3/s)		
			With Facilities	Without Facilities	Difference (%)
Q	642.6	East Rambo Pond Inlet	62.0	62.0	0%
Q1	642.6	East Rambo Pond Box Culvert Outlet	18.5	18.6	+1%
Q2	642.6	East Rambo Pond Spill at CNR	39.4	41.3	+5%
Q3	642.6	East Rambo Pond Spill at North Service Road	2.2	4.0	+82%
J1	718.0	East Rambo Creek at CNR	32.8	35.7	+9%
J	736.5	East Rambo Creek at H-R Div Channel Conf.	35.6	38.6	+8%
P	84.1	West Rambo Creek at QEW	11.9	11.9	0%
P3	116.7	West Rambo at CNR (South of Plains Road East)	49.0	52.4	+7%
P2	130.6	West Rambo at CNR (North of DePauls Lane)	50.6	54.1	+7%
P1	140.9	West Rambo Creek at Fairview	51.6	55.4	+7%
K	886.4	H-R Diversion Channel D/S of West Rambo	86.7	94.9	+9%
L	952.4	H-R Diversion Channel U/S of West Hager Conf.	95.3	102.8	+8%
G1	661.6	Freeman Pond Outlet	43.6	71.0	+63%
H	916.0	Freeman / West Hager Conf.	65.4	81.0	+24%
M	1,868.4	West Hager / H-R Diversion Channel Conf.	146.3	186.8	+28%
N	1,897.1	H-R Diversion Channel at Indian Creek	146.9	187.8	+28%

Note: [1] Based on updated (2017) subcatchment boundaries; this differs somewhat from original 1997 modelling.

With respect to the 100-year storm event (Table 2.9), notable increases in flows would be expected with the removal of the flood control facilities. Flows from the East Rambo Pond would increase, increasing discharges to both East and West Rambo Creeks, given the flow split in this case. Flows to the Hager-Rambo Diversion channel downstream of West Rambo Creek (Brant/Fairview) would more than double in magnitude. Discharges from the Freeman Pond would increase more than four-fold, which demonstrates the attenuation performance of the Freeman Pond for the 100-year storm event. Beyond the confluence of the diversion channel and Hager Creek system, peak flows are again more than double those for the with flood control scenario.

With respect to the Regional Storm event (Table 2.10), there would be a negligible impact from removing the East Rambo Pond from the simulation. Box culvert outflows would increase by 1%, and CNR spills by 5%. While the percentage of increase in spills across the North Service Road is notable (82%), this reflects only a 1.8 m^3/s absolute increase in flow. As noted previously, the facility was not designed to provide any attenuation for the Regional Storm (100-year storm event design only). The currently simulated results also appear to be generally consistent with the Regional Storm flows presented in the previous (1997) reporting, which indicated generally no change in peak flows from upstream to downstream of the pond (suggesting no attenuative function for this event).

Discharges from the Freeman Pond would however be increased with its removal (63%), leading to corresponding increases of between 24 and 28% in West Hager Creek and the Hager-Rambo Diversion Channel downstream of the confluence with Hager Creek. In general, given the limits of both the Burlington GO and Downtown areas, the increase in flows associated with the removal of both the West Hager Pond and the Freeman Pond, while notable, are expected to have a limited impact for the current assessment of flood risk in the Mobility Hub areas. Increased flows would lead to increased water levels in Hager Creek, which would likely lead to increased spills via the Plains Road underpass to Maple Street (spill mechanics in this area have been assessed separately using 2D modelling, as reviewed further in Section 2.2). The increase in flows associated with the removal of these facilities would also impact the Hager-Rambo Diversion Channel where it receives flows from these system (i.e. immediately east of Maple Street at Fairview Street). Any potential spills in this area would also likely be directed towards Maple Street. Any spills from the Maple Street area would be beyond the limits of the expected re-development for the Downtown area.

Based on the results presented in Tables 2.9 and 2.10, it is notable that with flood control facilities removed, the 100-year storm event would in fact be the "regulatory" storm (i.e. peak flows are higher than those from the Regional).

2.2 Hydraulics

2.2.1 Riverine (1-Dimensional Modelling)

2.2.1.1 Model Development

In order to determine the potential for spills from the Hager-Rambo Diversion Channel, and assess floodplain limits for the area watercourses (Hager-Rambo Diversion Channel and the West and East Rambo Creek branches upstream) updated hydraulic modelling has been undertaken. A hydraulic model of the channel was previously prepared using HEC-2 (Philips Planning and Engineering, 1984). More recently, Conservation Halton (CH) prepared a hydraulic model of the channel using HEC-GeoRAS, based on a 2002 digital elevation model (DEM). CH has further updated the model, including incorporating hydraulic structures based on data available from the 1984 HEC-2 model. A memorandum summarizing the model updates was provided to Wood by CH as part of the Urban Area Flood Study (March 18th, 2014 (2015)), including a number of disclaimers related to its use (provided in "as-is" condition). A copy of the memorandum has been included in Appendix B for reference.

Notwithstanding, given the vintage of the HEC-2 modelling, and for the purposes of this preliminary assessment, the HEC-GeoRAS model provided by CH has been employed as the base model for the current study. It is noted that the 2002 DEM source is somewhat dated; however there have been no known updates or channel modifications within the study area since that time with the exception of the West Rambo Creek (Walmart development), and in that case the more current modelling (or a new model based on a 2015 DEM source) has been employed.

In order to utilize the base modelling for the current study, a number of additional modelling updates have been considered necessary to ensure the suitability of the hydraulic modelling. Additional modelling updates have included:

- Updated SWMHYMO generated peak flows have been incorporated as steady state flow rates.
- Incorporating channel sections and structures for the West Rambo Creek (Leighland Road to the Hager-Rambo Diversion channel)
  - Includes the existing approved model for the section between the CNR and the Diversion Channel (Walmart development)
  - West Rambo Creek enclosure beneath Fairview Street modified to use Bridge Method rather than culvert routine, with spill elevation also adjusted based on 2015 Region of Halton DEM
  - New modelling created and added (HEC-GeoRAS) for the portion between Leighland Road and the CNR
- Refining overbank geometry for channel sections at expected spill points based on a more current elevation data source (Region of Halton 2015 DEM)

- Incorporating lateral structures at expected spill points, and truncating the overbank sections of the open channel cross-sections accordingly based on the spill point
  - **Lateral Structure 1** – along the south side of the Hager-Rambo Diversion Channel (parallel to Fairview Street), between East Rambo Creek and West Rambo Creek (i.e. east of Brant Street)
  - **Lateral Structure 2** - along the south side of the Hager-Rambo Diversion Channel (parallel to Fairview Street), downstream of the confluence with West Rambo Creek (i.e. west of Brant Street)
  - **Lateral Structure 3** – along the west bank East Rambo Creek upstream of CNR
- Verifying and updating hydraulic structure (bridge and culvert) sizes and details (including the Thorpe Road crossing and the CNR spill section along East Rambo Creek) as well as channel roughness values from field reconnaissance data.

Drawings 5A and 5B presents the general scope of the HEC-RAS modelling along with the cross-section locations.

The field inspection and verification of the West and East Rambo Creeks and the Hager-Rambo Diversion Channel was completed on September 6, 2017. As noted, the primary purpose of this inspection was to confirm all hydraulic structure sizes, including those along the West Rambo Creek, for which there was no information available from the City or CH (upstream of the CNR). In addition, the creek sections were photographed, to assist in assigning a representative channel roughness value.

Separately from the current study, Wood has been retained by the City of Burlington to undertake the inspection and design of four (4) stormwater railway crossings. One (1) of the four (4) crossings is the primary CNR tracks crossing of West Rambo Creek (referred to as WR6 in the current study). Based on the field work completed as part of this study, it was confirmed that the culvert is actually composed of three (3) distinct sections, rather than one (1) section which was assumed in previous versions of the current study, based on the limited field reconnaissance of the downstream face of the crossing (upstream face was not accessible). The most upstream section is a 2850 mm diameter circular CSP pipe 13.6 m in length, the middle section is a 3100 mm span by 2850 mm rise masonry arch 14.6 m in length with exposed concrete, and the most downstream section is a 3100 mm span by 2850 mm rise concrete arch 4 m in length. Based on the preceding, the upstream section (2850 mm diameter circular CSP pipe) would in fact be the critical conveyance section based on opening area and Manning's Roughness Coefficient (corrugated steel pipe as compared to concrete/masonry). The current version of the hydraulic modelling therefore assumes the crossing is as per this critical section; the associated updated flood hazard mapping reflects this modelling update.

For concrete channel sections, a roughness of 0.015 has been assigned, for other naturalized sections of channel a roughness of 0.045 has been employed, consistent with the approach applied for the West Rambo (Walmart) channel, and reflecting the more naturalized state of the channel. For overbank areas, a roughness of 0.02 has been applied for paved areas, 0.045 for grassed (urban) areas, and 0.08 for more forested/vegetated areas. These values are consistent with the values recommended by Conservation Halton in its November 2, 2017 correspondence. Subsequent comments from Conservation Halton (January 29, 2018) suggested the potential to lower the channel roughness value, however based on the preceding, Wood is of the opinion that the value of 0.045 is appropriate.

For floodplain delineation, riverine floodplains extents have been developed using the 1D HEC-GeoRAS modelling, without losses from potential spill flows, in order to conservatively account for the potential for future spill mitigation. Spill locations (lateral structures) outlined in the preceding section have been identified accordingly however.

All models utilize simulated peak flows that include crediting of flood control facilities, as discussed in previous sections. Notwithstanding, two (2) separate flow scenarios (with storage) have been assessed. Scenario 1 includes the East Rambo Pond as per the currently estimated rating curve (spills to the West Rambo Creek system), and Scenario 2 is a hypothetical scenario as requested by Conservation Halton, which assumes all discharge for the East Rambo Pond is directed to East Rambo Creek.

No 1-dimensional floodplain mapping has been presented directly for Hager Creek. This is discussed further in subsequent sections.

It should be noted that based on data availability at the time of the study, the Region of Halton's 2015 DEM is considered the best available topographic data to support additional floodplain mapping. Notwithstanding, additional, more accurate topographic mapping has subsequently become available from CH (2018 LiDAR data from Airborne Imaging). As part of the planned future Phase 2 works, the City of Burlington will update the modelling to use the more current (and accurate) information.

2.2.1.2 Floodplain Delineation (East Rambo Pond Existing Spills – Scenario 1)

The simulated floodplain extents for Scenario 1 (East Rambo Pond spill via CNR to West Rambo Creek – as per existing conditions, credit given to all flood control facilities) are presented in Drawing 5A. A discussion of the results for different sections of the system are outlined below.

Comparison is also made to the floodplain limits as generated from the base model prepared by CH (March 18, 2014 – copies included in Appendix B).

West Rambo Creek

Due to the significant spill flows to the West Rambo Creek system from the East Rambo Pond via the CNR underpass, floodplain limits (both 100-year and Regional Storm) are notably affected. 1-Dimensional (1D) hydraulic cross-sections cannot be reasonably extended to contain the magnitude of the simulated flows; nor would a 1D modelling approach appropriately represent the complex spill mechanisms occurring in this area. In particular, given the existing grade along Plains Road, the majority of any flows which overtop the West Rambo Creek enclosure at Plains Road would be expected to drain westerly towards Brant Street, rather than continue south back to West Rambo Creek. Based on the preceding, a 2-dimensional (2D) hydraulic modelling approach has been considered to be the preferable method of assessing floodplain limits. The results of this analysis are discussed further in the subsequent sections.

Notwithstanding, a modified 1D steady-state HEC-RAS approach has also been applied. The simulated results from the 2D modelling approach have been used to determine the simulated peak flow which drains back into the channel immediately downstream of Plains Road. Based on those modelling results (described further in subsequent sections), a 100-year peak flow of 17.5 m^3/s and a Regional Storm Event peak flow of 20.5 m^3/s result immediately downstream (prior to adding in flows for WR-1A2 at node P3). Revised peak flows are presented in Table 2.11 (100-year) and 2.12 (Regional Storm) respectively.

Table 2.11 Comparison of 100-Year Storm Event Flows (24-Hour SCS Type II) for West Rambo Creek (Scenario 1) accounting for 2D estimated spills at Plains Road

Node	Current Drainage Area (ha)	Location	100-Year Storm Peak Flow (m^3/s)		
			Full Flow	2D Spill Reduced Flows	Difference (%)
P	84.1	West Rambo Creek at QEW	18.6	18.6	0%
P3	116.7	West Rambo at CNR (South of Plains Road East)	30.1	17.6	-42%
P2	130.6	West Rambo at CNR (North of DePauls Lane)	30.9	19.6	-37%
P1	140.9	West Rambo Creek at Fairview	31.2	20.7	-34%

Table 2.12 Comparison of Regional Storm Flows for West Rambo Creek (Scenario 1) accounting for 2D estimated spills at Plains Road

Node	Current Drainage Area (ha)	Location	100-Year Storm Peak Flow (m^3/s)		
			Full Flow	2D Spill Reduced Flows	Difference (%)
P	84.1	West Rambo Creek at QEW	11.9	11.9	0%
P3	116.7	West Rambo at CNR (South of Plains Road East)	49.0	20.7	-58%
P2	130.6	West Rambo at CNR (North of DePauls Lane)	50.6	22.5	-56%
P1	140.9	West Rambo Creek at Fairview	51.6	23.7	-54%

These flow hydrographs have then been combined with simulated subcatchment peak flows to determine steady state flow inputs at downstream nodes along West Rambo Creek to its confluence with the Hager-Rambo Diversion channel. For the purposes of calculating floodplain extents for West Rambo Creek only, the reduced peak flows (accounting for spill to Plains Road/Brant Street) have also been applied to downstream locations within the Hager-Rambo Diversion Channel, in order to more reasonably represent tailwater conditions.

Given the confluence of spill flows immediately upstream of Plains Road, it is not considered feasible to present a 1D generated floodline for the section upstream of Plains Road (to Leighland Road). Reference is made to the 2D model generated results for this area.

Based on the spill-reduced peak flows for Scenario 1, floodplain extents for West Rambo Creek (Drawing 5A) are generally restricted to the channel block, with no expected overtopping of hydraulic structures with the exception of Fairview Street, where a spill conditions would be expected for the Regional Storm Event. The modelling results indicate that this spill is largely attributable to high backwater/tailwater conditions from the Hager-Rambo Diversion Channel on the west side of Brant Street. It is noteworthy that the 2D modelling results for this area (discussed further in subsequent sections) do not indicate a spill from the channel to Fairview Street for the Regional Storm Event, however that model assumes a normal depth boundary condition for the culvert, which would be expected to be lower than that generated from the HEC-RAS 1D modelling.

With respect to proposed development parcels, the simulated floodplain extents would affect a portion of the following properties:

- **2026 Plains Road East.** A minor portion of this site would lie within the regulated floodplain, specifically the ditch along the CNR spur line tracks.

- **2070 Queensway Drive.** A large portion of this site (between the CNR spur line and the primary CNR tracks) would lie within both the 100-year and Regional Floodplain extents, as the floodline exceeds the channel limits in this area.
- **2078 Queensway Drive.** The channel in this case forms part of the property limits, as such although the floodplain extents are not extensive to the east, this property would be within the Regulated limits.
- **2065 Fairview Street.** A portion of this site (the existing Walmart) would lie within the regulated floodplain limits, specifically the access roadway between West Rambo Creek and the building itself.
- **923 Brant Street.** A minor portion of the rear of this site, directly adjacent to the West Rambo Creek, would lie within the updated Regulatory Floodplain limits.
- **895 Brant Street**. Similarly to 923 Brant Street, a minor portion of the rear of this site, directly adjacent to West Rambo Creek, would lie within the updated Regulatory Floodplain limits.

In addition to the preceding, parcels between the CNR and West Rambo Creek at Plains Road would also be subjected to overland flow spills. This has been assessed further using 2D hydraulic modelling; refer to the discussion included as part of that section.

Based on comments from Conservation Halton (July 25, 2019), to address the potential for future culvert upgrades, an updated version of the flood hazard mapping has been prepared for the West Rambo Creek that combines the 1D and 2D hydraulic modelling results, as well as channel topography (i.e. top of bank). The results of this assessment are presented in Drawing 5C). Flood fringe areas have been estimated for areas downstream of the CNR tracks based on the results of the 1D hydraulic modelling for West Rambo Creek with full flows included (i.e. no reduction in flows due to upstream spill at Plains Road). The results presented in Drawing 5C are intended to provide interim guidance to planning policies in this area. It is expected that the flood hazard mapping for West Rambo Creek will be further updated as part of the Phase 2 modelling updates to be completed separately from the current study, which will primarily involve the application of updated (2018) LiDAR topography data acquired by CH/City for the area and analyses refinements.

East Rambo Creek

Given the revised rating curve for the East Rambo Pond (which diverts a large portion of spill flows via the CNR to the West Rambo Creek system), it would be expected that the updated 100-year and Regional Storm floodplains would be notably reduced as compared the previously generated extents prepared by CH (ref. March 18, 2014 summary plots – copies included in Appendix B). The updated floodplain extents, while reduced compared to the previously estimated limits by CH, still indicate generally similar overall trends.

The updated hydraulic modelling results (Drawing 5A) indicate that the floodplain extents would largely be contained in close proximity to the channel to the north of Fassel Avenue, although a number of adjacent residential properties would be located within the limits of the updated Regional Storm floodplain. The simulated flooding extents upstream of Glenwood School Drive are however notably reduced as compared to the previous CH generated results.

South of Fassel Avenue however, a much wider floodplain is indicated. For the Regional Storm Event, a potential spill is indicated to the west (towards the Burlington GO area and towards West Rambo Creek). As such, the floodplain limits in this area are considered to be better assessed using 2D modelling; this is presented in subsequent sections of the report.

There is a notably wide floodplain immediately upstream of the CNR. Based on the updated spill section for the CNR tracks (as extracted from the Region of Halton's 2015 DEM), a spill across the railway tracks would be expected for the Regional Storm Event at the railway low point, in the vicinity of the Burlington GO station. This spill would be based on the full flows within the HEC-RAS modelling (i.e. no consideration for the loss of flow associated with upstream spills at Lateral Structure 3). Similarly to the preceding discussion on Lateral Structure 3, this area is considered more appropriately assessed using 2D hydraulic modelling, as presented in subsequent sections. It is noted that the 2D hydraulic modelling results for the same area do not indicate a spill across the CNR tracks for the same scenario (which is attributable to the differences in steady-state and unsteady-state modelling, and explicitly assessing spills within the 2D modelling platform).

Downstream of the CNR, both the 100-year and Regional Storm floodplains are contained within the channel, and do not indicate any spills to adjacent properties (as was indicated on previous floodplain mapping generated by CH – refer to Appendix B). This is attributable to the reductions in flows due to the revised East Rambo Flood Control facility rating curve.

With respect to proposed development parcels, the simulated floodplain extents would affect a portion of the following properties:

- **2170 Queensway Drive.** A portion of this property abuts the CNR tracks directly adjacent to the East Rambo Creek, and thus is indicated as being partially within the estimated floodplain extents. Other portions of the site may be subjected to spill flows.

In addition to the preceding, parcels between the CNR and East Rambo Creek at Plains Road would also be subjected to overland flow spills. This has been assessed further using 2D hydraulic modelling; refer to the discussion included as part of that section.

Upper Hager-Rambo Diversion Channel

The Hager-Rambo Diversion Channel is the ultimate receiver of flows from both the East and West branches of Rambo Creek. The diversion channel parallels Fairview Street on the south side, crossing beneath Brant Street. Flows within the West Rambo Creek are conveyed via a separate, parallel enclosure, which outlets slightly downstream of the primary Brant Street crossing.

Lateral spills on the south side of the diversion channel have been identified both to the east and west of Brant Street (lateral structures 1 and 2; refer to Drawing 5A and the preceding section) for the Regional Storm Event. No spills from these areas would be expected for the 100-year storm event. Beyond these spill areas, floodplain extents on the north side are generally contained to the channel block to both the west and east of Brant Street. Overtopping would be expected both for the Hager-Rambo Diversion channel to Fairview Street (east of Brant Street), as well as from the West Rambo Creek to Fairview Street, as noted previously.

Based on the preceding, no potential development parcels in this area would be subject to direct floodplain encroachment, however those parcels directly south of the diversion channel to the west of Brant Street would be subjected to potential spill flows. This has been assessed separately using 2D modelling; refer to that section for a further discussion.

Hager Creek

Hager Creek generally parallels the east side of the QEW from the Freeman Pond to its confluence with the Hager-Rambo Diversion Channel at Fairview Street. This watercourse is located outside of the limits of the Burlington Mobility Hub. Notwithstanding, the HEC-GeoRAS modelling developed by Conservation Halton (March 18, 2014) indicates that estimated floodplain extents for this watercourse could potentially impact the Burlington Mobility Hub (refer to Appendix B). That modelling (by CH) indicated a Regional Storm flow of between 35.2 m^3/s (immediately downstream of the Freeman Pond) and 53.9 m^3/s (at Node H – confluence with West Hager Creek), and a corresponding water surface elevation of 100.47 m at the CNR (which would be expected to overtop the railway tracks and also impact areas in the Burlington Mobility Hub in the vicinity of Brant Street given the extensive floodplain extents.

The hydrology updates generated as part of the current study have resulted in revised Regional Storm flows (ref. Table 2.5), such that the flows at the Freeman Pond outlet (Node G1) and downstream of the confluence with West Hager Creek (Node H) would be 43.6 m^3/s and 65.4 m^3/s respectively. Based on these flows, and the updated HEC-GeoRAS modelling prepared for this study, a wide floodplain continues to be indicated for this area, with a simulated Regional Storm elevation of 100.75 m +\- and width of 400 m +\- directly upstream of the CNR, which would have the potential to impact the Burlington Mobility Hub (note that the updated floodplain limits have not been formally delineated/presented graphically). The elevated water levels appear to be largely attributable to the backwater/tailwater conditions, with a water surface elevation of 98.99 m indicated on the downstream side of the culverts.

Given the extensive floodplain extents predicted by the 1D modelling, and associated potential for storage and spills, a verification of these results has been undertaken using 2D modelling. This is assessed further in the subsequent section (2.2.2).

Lower Hager-Rambo Diversion Channel

Although beyond the limits of the current study, the estimated floodplain limits for the Lower Hager-Rambo Diversion Channel have also been generated (ref. Drawing 5D). As this area is beyond the current study limits, the hydraulic modelling is generally as per that prepared previously by CH staff (ref. Appendix B).

Overall, the results indicate that flows for both the 100-year and Regional Storm events would be expected to be contained to the diversion channel. The hydraulic structure at Thorpe Road is indicated as having sufficient capacity to convey both the 100-year and Regional Storm events without overtopping. A potential spill is however indicated for the Regional Storm Event at Maple Avenue, including the roadway and the area immediately upstream of Maple Avenue.

Spills from Maple Avenue may have the potential to impact areas within the Downtown area study limits. However, based on discussions with City staff, it is understood that the properties along Maple Avenue within the Mobility Hub are likely under less pressure for re-development at this time. Given the preceding, and the limits of the study area, no further assessment of this spill has been undertaken as part of the current study. Further study of this potential spill area is however warranted in the future prior to re-development.

2.2.1.3 Floodplain Delineation (East Rambo Pond Spills to East Rambo Creek – Scenario 2)

As discussed previously in Section 2.1.3.2, an additional scenario has been completed (referred to as Scenario 2) which is based on all flows from the East Rambo Pond being directed back to East Rambo Creek (i.e. including spills via the CNR). Updated peak flows from this scenario were presented previously in Tables 2.7 and 2.8. The previously described 1-dimensional hydraulic modelling has been re-run with these flows values; the resulting simulated floodplain extents are presented in Drawing 5B.

It is noted that Scenario 2 is a hypothetical scenario only, particularly given the findings of the East Rambo Flood Control Facility Retrofit Feasibility Assessment (ref. Appendix E. Thus the results are described more generally than for existing conditions (Scenario 1), and no individual listing of potential re-development parcels affected by floodplain extents is presented. In addition, the results for Hager Creek are not presented, as this system would be unaffected by any changes to the East Rambo Pond.

West Rambo Creek

The simulated floodplain extents for Scenario 2 differ from Scenario 1 in a few key areas. For the Section upstream of De Pauls Lane, the 100-year storm event is in fact the Regulatory Event (not the Regional Storm), and generates the most conservative floodline. Spill is also indicated from West Rambo Creek towards Brant Street upstream of the CNR tracks. Downstream of De Pauls Lane (to Fairview Street), the Regional Storm is again the Regulatory Floodplain, largely attributable to backwater/tailwater impacts form the main Hager-Rambo Diversion. In general, overall Regulatory Floodplain extents for this scenario are quite similar to those for Scenario 1. The results from Scenario 2 do indicate overtopping of De Pauls Lane upstream of Fairview Street, which was not indicated in Scenario 1. Overtopping at Fairview Street is again indicated for the Regulatory Event (Regional Storm).

East Rambo Creek

As would be expected, by diverting the full flow from the East Rambo Pond to East Rambo Creek, greater flows and thus more extensive floodplain extents results. To the north of the CNR, a much larger number of residential properties adjacent to the creek (outside of the Burlington GO Mobility Hub Boundary) would be placed within the Regulatory Floodplain limits, particularly along Fassel Avenue. An additional spill is also noted at the eastern limits (i.e. to the east of Hazel Street). Overtopping of the CNR is also noted, as well as spill to the Burlington GO station via Lateral Structure 3.

Although the low (spill) point along the CNR tracks is located to the west of East Rambo Creek (as per Drawing 5B), the applied hydraulic modelling methodology does not account for any loss of flows. Thus, to the south of the CNR, floodplain extents are indicated to the east of East Rambo Creek which would include several adjacent industrial/commercial properties. A spill would also be expected to the south, via Argon Court.

Upper Hager-Rambo Diversion Channel

Simulated floodplain extents for the Regulatory Event for the Hager-Rambo Diversion channel are generally similar to those for Scenario 1. Floodplain extents are generally confined to the eastern top of bank parallel to Fairview Street, however spills would be expected to the south (Lateral Structures 1 and 2). Overtopping of the enclosure would be again expected to Fairview Street, east of Brant Street.

2.2.1.4 Spill Analysis (Lateral Structures)

Modelling Approach

Further to the base 1D hydraulic model development described in the previous section, lateral structures have been implemented into the base hydraulic modelling based on identified spill locations. These lateral structures have been incorporated for expected spill locations in order to better quantify the magnitude of the expected spills, which have then been assessed separately using 2-dimensional (2D) hydraulic modelling (refer to Section 2.2.2).

For the current assessment, a total of three (3) primary lateral structures have been included in the modelling as follows (refer to Drawing 5A for lateral structure locations):

- **Potential Spill Area 1**: along the south bank of the Hager-Rambo Diversion Channel where it parallels Fairview Street (upstream (east) of the Brant Street enclosure).

- **Potential Spill Area 2:** along the south bank of the Hager-Rambo Diversion Channel where it parallels Fairview Street (downstream (west) of the Brant Street enclosure, between Brant Street and the CNR tracks (west of Brant Street). This area has been modelled as a combination of two lateral structures (2A and 2B) due to reach connectivity within the HEC-RAS modelling.
- **Potential Spill Area 3:** along the west bank of East Rambo Creek upstream of the CNR.

Lateral structures have been incorporated based on the estimated spill elevation (i.e. highest elevation on that bank). Open channel cross-sections have been truncated accordingly in these locations. A nominal weir (spill) width of 10 m has been assumed for all lateral structures.

A weir coefficient of 0.28 has been employed for the estimation of spill across lateral structures. The 1-dimensional (1D) modelling HEC-RAS User's Manual does not provide recommended values for the lateral structure weir coefficient, as such it has been considered appropriate to defer to the 2D modelling User's Manual. The 2-dimensional (2D) modelling HEC-RAS User's Manual specifies that an appropriate weir coefficient for an overland flow path should be within the range of "0.11 to 0.55, however the coefficient should be calibrated to produce reasonable results whenever possible." Given that calibration for a Regional Storm event is not possible, the value of 0.28 was selected, which represents the transition between "natural high ground barrier" and "non elevated overbank terrain" as per the recommended values in Table 3-1 of the HEC-RAS 5.0 2D Modelling User's Manual. The lateral structures have been inputted as zero-height weirs rather than the broad crested weirs as per the recommendations of CH (November 2, 2017 comments – refer to Appendix B). The change in weir type has resulted in a negligible change in the simulated flows from the lateral structures.

When calculating spill flows within HEC-RAS, there is an option to use flow optimization. When flow optimization is not selected, the program calculates the water surface profile as it would normally. The calculated water surface profile adjacent to the lateral structure is then used to determine the estimated spill flow, based on the water level and the lateral structure dimensions. This approach is considered to be overly conservative (i.e. generates unrealistically high spill flows), in that it does not account for the interaction between water levels and flow diversions. Once spill begins, upstream flows would be split between channel flows and spill flows, which would impact the water level in downstream locations. The flow optimization routine for lateral structures in HEC-RAS accounts for this by deducting calculated spill flows via the lateral structure from downstream channel flows in order to achieve an overall flow balance (i.e. upstream channel flow = spill flow + downstream channel flow). A number of model iterations are undertaken in order to balance the flows and calculate the representative water surface profile. This approach is considered to be more realistic, and generates more representative spill flows in these settings.

A typical concern with the flow optimization methodology is that by reducing downstream flows, floodplain extents may be underestimated if the spill is ever mitigated in the future. Similarly, if multiple lateral structures are included in the modelling and more than one uses the flow optimization routine, spills at downstream locations may be underestimated if these areas are similarly mitigated in the future. To address this concern, Wood has undertaken multiple model iterations, such that flow optimization is only employed for one lateral structure per simulation. Using this methodology, the spill from each lateral structure can be more realistically addressed individually, while also conservatively not including any potential flow loss from upstream areas. A combined flow optimization scenario has also been employed, to assess the combined spill impact to downstream areas.

It is understood from previous correspondence that CH staff has expressed concerns with the use of flow optimization (ref. November 2, 2017 correspondence, updated November 10, 2017). As requested, peak flow results from both the with, and without flow optimization scenarios have been generated for comparison purposes only. Based on the preceding discussion on the interpretation of the unrealistic basis of the no flow optimization routine, flow optimization results have ultimately been applied for subsequent

2D spill analyses (Section 2.2.2). Based on subsequent comments from Conservation Halton (July 27, 2018), it is understood that Conservation Halton now supports the application of this approach.

Scenario 1 (East Rambo Pond) Spill Results

Estimated spill flow are presented in Tables 2.13 and 2.14 for the 100-year and Regional Storm respectively (refer to Drawing 5A for cross-section locations). Presented results are for Scenario 1 (i.e. East Rambo Pond discharges as per existing conditions). For comparison purposes, the results of the no flow optimization scenario have also been presented as noted previously. The results are presented for the "with" and "without" flood control scenarios, however as per previous correspondence and discussions with CH, the City of Burlington has indicated that these facilities are to be credited in any assessment of regulatory and flood risk assessment impacts affecting land use planning.

In addition to spills from the three (3) lateral structures, estimated overtopping flows from the Hager-Rambo Diversion Channel Culvert at Fairview Street (east of Brant) are presented, based on the simulated weir flow in this location. Overtopping flows from the West Rambo Culvert at Fairview Street have similarly been presented in Tables 2.13 and 2.14.

Table 2.13 Estimated Spill Flows (100-Year Storm – 2004 IDF, 24H SCS Type-II) from East Rambo Creek and Hager-Rambo Diversion Channel in Area of Interest (East Rambo Pond Spill as per Existing Conditions – Scenario 1)

Spill Area	Cross-Section Range	Estimated Spill Flow (m^3/s)					
		Individual Flow Optimization		Combined Flow Optimization[4]		No Flow Optimization	
		With Flood Control	Without Flood Control	With Flood Control	Without Flood Control	With Flood Control	Without Flood Control
LS 3 (East Rambo – 2801)	2802.17 to 2699.39	0	0.34[5]	NA	NA	0	0.34
LS 1 (2400)	2401.66 to 1991.14	0	10.79[1]	0	6.63	0	16.63
H-R Culvert Spill at Fairview[3]	NA	0	8.06[1] 7.23[2]	0	1.73	0	17.96
West Rambo Culvert Spill at Fairview[3]	NA	0	31.35[1] 23.75[2]	0	22.40	0	34.22
LS 2A + 2B (1720 and 1668)	1721.669 to 1703.419 and 1667.58 to 1443.625	0	29.96[2]	0	25.02	0	81.48

Notes:
1. Based on optimization of Lateral Structure 1 only (2400).
2. Based on optimization of Lateral Structures 2A+2B only (1720+1668).
3. Based on weir flow for hydraulic structure in HEC-RAS modelling.
4. Optimization of Lateral Structures 1, 2A, and 2B combined to assess spill to the south.
5. Based on optimization of Lateral Structure 3 only (2801).

The results for the 100-year storm event (Table 2.13) indicate that with flood controls in place, no spills from the Hager-Rambo Diversion Channel would be expected, either along the channel itself or at culvert crossings. With flood control facilities removed, much more notable spills are indicated. This increase is logical, given that the attenuation provided by upstream flood control facilities, particularly for the 100-year event. This is evident in the results presented previously in Table 2.9. Notwithstanding as noted previously, this scenario has been provided for information purposes only, and will not be used for regulatory or further risk assessment purposes.

Table 2.14 Estimated Spill Flows (Regional Storm) from East Rambo Creek and Hager-Rambo Diversion Channel in Area of Interest (East Rambo Pond Spill as per Existing Conditions – Scenario 1)

Spill Area	Cross-Section Range	Estimated Spill Flow (m^3/s)					
		Individual Flow Optimization		Combined Flow Optimization[4]		No Flow Optimization	
		With Flood Control	Without Flood Control	With Flood Control	Without Flood Control	With Flood Control	Without Flood Control
LS 3 (East Rambo – 2801)	2802.17 to 2699.39	0.34[5]	0.35[5]	NA	NA	0.34	0.35
LS 1 (2400)	2401.66 to 1991.14	5.81[1]	8.13[1]	2.15	4.52	9.91	13.15
H-R Culvert Spill at Fairview[3]	NA	1.12[1] 0.48[2]	4.84[1] 4.06[2]	0	0.54	7.44	12.72
West Rambo Culvert Spill at Fairview[3]	NA	12.33[1] 7.69[2]	17.49[1] 11.55[2]	7.22	10.39	15.30	20.69
LS 2A + 2B (1720 and 1668)	1721.669 to 1703.419 and 1667.58 to 1443.625	10.81[2]	17.00[2]	9.46	13.46	40.28	56.63

Notes:
1. Based on optimization of Lateral Structure 1 only (2400).
2. Based on optimization of Lateral Structure 2A+2B only (1720+1668).
3. Based on weir flow for hydraulic structure in HEC-RAS modelling.
4. Optimization of Lateral Structures 1, 2A, and 2B combined to assess spill to the south.
5. Based on optimization of Lateral Structure 3 only (2801).

For the Regional Storm event spill flows are more consistent for the "With" and "Without" Flood Control scenarios than for the 100-year storm event, however the Without Flood Control scenario yields higher peak flows, as would be expected. The closer values in this case reflects the lack of Regional Storm attenuation provided by the East Rambo Pond, which was designed to only provide storage up to, and including, the 100-year storm event. The impact of flow optimization is also apparent, with notably higher (and as noted previously, overly conservative) flows from the no flow optimization scenario. For the purposes of assessing the impact of Hager-Rambo Diversion Channel spill flows on the Downtown area, the spill flows including flood control, and with flow optimization have been selected, given the preceding discussions.

It should be noted that any spills in areas further downstream (i.e. Maple Street) are not considered to be a focus of the current study. These spills would be expected to continue south on Maple Street, which would be beyond the limits of the expected re-development for the Downtown area (i.e. not an area of current focus). This was noted by the City of Burlington at the August 23, 2017 meeting; the Summary of Actions of this meeting (Wood, August 24, 2017) noted that the City can generate policy for any future infills in this area as a separate undertaking. In addition, as noted previously, these spill flows are generally considered to be nominal, particularly when flood control facilities are included in the analysis.

Scenario 2 (East Rambo Pond) Spill Results

The preceding analysis results were based on Scenario 1, which reflects existing conditions (i.e. East Rambo Pond spills split between West Rambo and East Rambo Creeks). In addition to this scenario, the resulting spills from Scenario 2 (all flows from East Rambo Pond directed to East Rambo Creek, as per CH requested scenario) have also been generated. Simulated spill flows from this scenario are presented in Table 2.15 (100-year Storm) and 2.16 (Regional Storm) respectively.

Table 2.15 Estimated Spill Flows (100-Year Storm – 2004 IDF, 24H SCS Type-II) from East Rambo Creek and Hager-Rambo Diversion Channel in Area of Interest (East Rambo Pond Spill all to East Rambo Creek – Scenario 2)

Spill Area	Cross-Section Range	Estimated Spill Flow (m^3/s)					
		Individual Flow Optimization		Combined Flow Optimization[4]		No Flow Optimization	
		With Flood Control	Without Flood Control	With Flood Control	Without Flood Control	With Flood Control	Without Flood Control
LS 3 (East Rambo – 2801)	2802.17 to 2699.39	0.35[5]	0.37[5]	NA	NA	0.35	0.37
LS 1 (2400)	2401.66 to 1991.14	0	17.82[1]	0	14.16	0	29.71
H-R Culvert Spill at Fairview[3]	NA	0	30.63[1] 41.28[2]	0	25.36	0	51.30
West Rambo Culvert Spill at Fairview[3]	NA	0	7.89[1] 3.83[2]	0	1.32	0	13.99
LS 2A + 2B (1720 and 1668)	1721.669 to 1703.419 and 1667.58 to 1443.625	0	30.02[2]	0	20.07	0	78.68

Notes:
1. Based on optimization of Lateral Structure 1 only (2400).
2. Based on optimization of Lateral Structure 2A+2B only (1720+1668).
3. Based on weir flow for hydraulic structure in HEC-RAS modelling.
4. Optimization of Lateral Structures 1, 2A, and 2B combined to assess spill to the south.
5. Based on optimization of Lateral Structure 3 only (2801).

For the 100-year storm event, the results for the "with flood control" scenario are nearly identical, namely zero flow. The exception is for Lateral Structure 3; under Scenario 2 there is a small discharge indicated (0.35 m^3/s), due to the increase in flows to East Rambo Creek. Under the "without flood control" scenario, discharges are similarly increased for Lateral Structure 3, Lateral Structure 1, and the Hager-Rambo Diversion Channel Culvert at Fairview Street, as these features are all directly downstream of the East Rambo Creek (and upstream of the West Rambo Creek). A decrease in simulated discharges is indicated for the West Rambo Creek under this scenario, which is expected given the corresponding decrease in flows. Simulated spills for Lateral Structures 2A and 2B (downstream of the confluence) are slightly reduced under Scenario 2 as compared to Scenario 1.

Table 2.16 Estimated Spill Flows (Regional Storm) from East Rambo Creek and Hager-Rambo Diversion Channel in Area of Interest (East Rambo Pond Spill all to East Rambo Creek – Scenario 2)

Spill Area	Cross-Section Range	Estimated Spill Flow (m^3/s)					
		Individual Flow Optimization		Combined Flow Optimization[4]		No Flow Optimization	
		With Flood Control	Without Flood Control	With Flood Control	Without Flood Control	With Flood Control	Without Flood Control
LS 3 (East Rambo – 2801)	2802.17 to 2699.39	2.02[5]	3.54[5]	NA	NA	2.84	5.88
LS 1 (2400)	2401.66 to 1991.14	10.68[1]	15.31[1]	9.19	11.92	18.72	24.87
H-R Culvert Spill at Fairview[3]	NA	15.08[1] 22.04[2]	23.49[1] 30.71[2]	13.21	18.75	30.00	40.86
West Rambo Culvert Spill at Fairview[3]	NA	0[1] 22.04[2]	0[1] 0.78[2]	0	0	3.29	9.31
LS 2A + 2B (1720 and 1668)	1721.669 to 1703.419 and 1667.58 to 1443.625	11.16[2]	23.70[2]	5.21	14.72	39.85	70.35

Notes:
1. Based on optimization of Lateral Structure 1 only (2400).
2. Based on optimization of Lateral Structure 2A+2B only (1720+1668).
3. Based on weir flow for hydraulic structure in HEC-RAS modelling.
4. Optimization of Lateral Structures 1, 2A, and 2B combined to assess spill to the south.
5. Based on optimization of Lateral Structure 3 only (2801).

For the Regional Storm Event, similar differences due to the re-distribution of spill flows from the East Rambo Pond are observed. Spills from features along the East Rambo Creek (i.e. Lateral Structure 3, Lateral Structure 1, and the Hager-Rambo Diversion Culvert at Fairview) indicate higher spill flows for Scenario 2, due to the increased discharges. Corresponding reduced flows are indicated for the West Rambo Creek Culvert at Fairview Street, due to the flow re-allocation. Spill flows from Lateral Structure 2 (i.e. along the Hager-Rambo Diversion channel downstream of the confluence of East and West Rambo Creeks) are increased slightly in Scenario 2 as compared to Scenario 1. Given that the peak flows at this combined point are generally equal for Scenario 1 and Scenario 2 (refer to Table 2.8), the reason for these differences in the simulated spill flows at this location is unclear.

It should be noted that as per Drawing 5B, an additional potential spill is indicated from the East Rambo Creek upstream of Fairview Street under Scenario 2, which would likely be directed to Argon Court. Given the location of the spill relative to the 1D hydraulic modelling cross-sections, an additional lateral structure cannot be readily incorporated into the modelling to quantify the spill in this location. Given the hypothetical nature of Scenario 2 and the expected upstream spill via the CNR to the west of East Rambo Creek, the likelihood of this potential spill is considered low, and thus does not warrant further assessment.

An additional potential spill is also indicated for the East Rambo Creek upstream of the CNR, near Fassel Avenue and Hazel Street. This spill location is far outside of the current study limits, and thus does not warrant further assessment. The area has been assessed further as part of the additional 2D hydraulic modelling; this is reviewed further in Section 2.2.2.

2.2.2 Spill Analyses (2-Dimensional Modelling)

2.2.2.1 East Rambo Pond Spill to West Rambo Creek via CNR (Scenario 1)

As noted in previous sections, based on the revised operating curve for the East Rambo Pond, an extensive spill flow would be expected to cross the QEW via the CNR culvert. Given the magnitude of the spill flow, and the capacity of the receiving drainage system (which would not have been designed to accept such flows), a 1-dimensional (1D) hydraulic analysis is considered to be inadequate to assess spill pathways. As such, a 2-dimensional (2D) hydraulic model has been developed in PCSWMM in order to assess the routing of flows, as well as to assess the resulting influence on the floodplain for the West Rambo Creek, given the inability of the 1D model to properly contain a full flow condition (including spills). Interactions between the West Rambo and East Rambo Creeks are also assessed by including both features within the modelling.

The 2D mesh developed for this assessment generally extends from the QEW to the north, and to Fairview Street to the south (and between Brant Street to the west and Glendale Court/Drury Lane to the east, respectively). The mesh encompasses an area of some 190 ha +\-. Mesh resolution and type has been varied depending on the location:

- Channel areas – 2 m to 3 m resolution, with a directional mesh (rectangular mesh elements which follow the specified centerline)
- Railway tracks – 3 m to 5 m resolution, with a directional mesh based on the centerline
- Roadways – 5m resolution, with a hexagonal mesh (six-sided) or rectangular mesh
- Other areas – 5 m to 10 m resolution, with a hexagonal mesh

Surface roughness values have been specified consistent with those mandated by the Toronto Region Conservation Authority for 2D modelling analyses. These values are noted below, and are in fact slightly more conservative than those requested by Conservation Halton (as per November 2, 2017 letter response). Documentation included with PCSWMM does not specify any specific roughness values for 2D modelling.

- Ditches and Channel – 0.05 (higher value than typical 0.035 to reflect heavier vegetation)
- Urban Pervious Area (grassed) – 0.05
- Naturalized Area (forested, well vegetated) – 0.08
- Urban Impervious Area (paved) – 0.025

Obstructions have been added based on the City of Burlington's Buildings GIS data layer, with some minor corrections and additional detail required in some cases where the polygons did not adequately match the extents of structures, as evident from current aerial photography. The high-rise residential building at 2089-2095 Fairview Street (directly west of the primary Burlington GO Station) has been added as an obstruction, as estimated from currently available aerial photography (which shows the construction footprint). Small buildings such as sheds (i.e. generally less than 50 m2) have not been included as these structures are not considered to be significant. A total of 426 obstructions have been included within the mesh area, with a large portion of these detached residential units.

The Region of Halton's 2015 DEM has been used to sample elevations for 2D cells. Since the DEM does not filter out underpasses (i.e. elevations reflect the top of the structure), 2D cell (and associated junction) elevations have manually been adjusted to reflect the estimated bottom (ground) elevations. Adjustments have been necessary at both the Plains Road/CNR crossing, as well as the Brant Street CNR crossings.

It should be noted that based on data availability at the time of the study, the Region of Halton's 2015 DEM is considered the best available topographic data to support additional floodplain mapping. Notwithstanding, additional, more accurate topographic mapping has subsequently become available from CH (2018 LiDAR data from Airborne Imaging). As part of the planned future Phase 2 works, the City of Burlington will update the modelling to use the more current (and accurate) information.

Culvert crossings for the West Rambo Creek tributary along the north side of Plains Road have been field verified. Two (2) 400 mm diameter CSP driveway culverts have been noted to the east of the CNR, with a 1200 mm diameter CSP crossing beneath the CNR itself. A 900 mm diameter CSP has been noted for the Courthouse Driveway Culvert immediately upstream of the West Rambo Creek. Other hydraulic structures along the East and West Rambo Creeks have been based on the corresponding sizes in the HEC-GeoRAS 1D modelling described previously (which in turn has also been based on a field verification). Smaller ditch culverts in inaccessible areas (i.e. along the CNR) have generally been assumed as 600 mm diameter CSP culverts as a default. Inlet and exit losses were included for all culverts, again consistent with the HEC-GeoRAS modelling or field checks.

The culvert outlet of the West Rambo Creek to the Hager-Rambo Diversion channel has also been included in the modelling, with a normal boundary condition set at the downstream limits. In addition, the Brant Street CNR underpass storm sewer system has been included in the modelling, with a normal boundary condition outfall set just south of Fairview Street. Typical storm sewer exit losses have been included based on the angle of the storm sewer bend. Bottom draw orifices have been included in the modelling at representative locations to represent catchbasin grates, with an assumed 0.125 m2 per catchbasin grate (consistent with OPSD details). 2D mesh outfalls (with a free boundary condition) have also been set at the southern limits of the mesh to allow for discharge, including generally:

- At the intersection of Brant Street and Fairview Street (including West Rambo Creek)
- In the vicinity of Maplewood Drive and Joyce Street

Flow hydrographs from the SWMHYMO modelling at key locations have been inputted as external time series to the PCSWMM modelling. This includes the CNR spill hydrographs (from the East Rambo Pond) and flows at the beginning of West Rambo Creek (just north of Plains Road). In addition, subcatchment flows from the West Rambo Creek area have also been manually inputted as external times series at appropriate nodes within the modelling. It should be noted that subcatchments from the Downtown PCSWMM hydrologic/hydraulic modelling (i.e. those areas which drain to the Brant Street/CNR underpass) have not been included in the 2D model given their relatively small contributing area, and the focus on the West Rambo Creek area.

As noted, both the 100-year storm event (24-hour SCS Type II distribution) and the Regional Storm Event have been simulated in PCSWMM. Simulated depth contour plots are presented in Figure 2.4 and 2.5 for the 100-year storm event and Regional Storm Event respectively for Scenario 1 (as per existing conditions – East Rambo Creek spills to both West Rambo and East Rambo Creeks). Maximum depth contours are indicated on the figures. Orange lines represent the Mobility Hubs study boundaries, the red lines indicate the limits of the 2D model. Velocity and depth x velocity product maps have been included in Appendix C.

For the 100-year storm event (Figure 2.4), the modelling results indicate high depths (0.3 m to 1.2 m) around the buildings located on the east side of the CNR to the north of Plains Road. This reflects the spill mechanics via the CNR, which primarily directs flows to the east side. A minor spill is noted from this area across Plains Road towards Queensway Drive, and then south through existing properties and west along Queensway Drive. Flow depths are typically lower however, 0.14 m or less. The majority of the flows would be directed westerly on the north side of Plains Road towards West Rambo Creek. Given the small (900 mm diameter) culvert at the Courthouse driveway, flows would spill onto either side, and would largely bypass the West Rambo Creek culvert crossing and continue west on Plains Road towards Brant Street and the CNR underpass where much more significant depths (1.50 to 1.99 m) are noted at the underpass. The modelling results indicate that the majority of the 100-year flows would be contained close to the West Rambo Channel blocks, with the most notable exception upstream of Leighland Road, where spills from the channel are indicated into the upstream residential area.

For the Regional Storm Event (Figure 2.5), the modelling results and flow paths are generally similar to those for the 100-year event, but more formative. Depths are higher throughout, including a larger spill across Plains Road towards the Queensway Drive area. Depths at the Brant Street underpass are also increased, and are noted to be in excess of 2 m. Given the significant depth accumulation in the underpass, the modelling indicates that a spill above the high point on Brant Street to the south (and the Downtown area) would be expected. Some of this accumulation is indicated as spilling back to the West Rambo Creek at De Pauls Lane, which in turn would be expected to accumulate partially against the Walmart building.

The PCSWMM 2D model predicts a total Regional Storm spill flow at Brant/Fairview of 18.33 m^3/s (via Brant Street). This compares reasonably well to the spill flow estimate from the 1D HEC-RAS model (via West Rambo Creek enclosure at Fairview Street; no flow optimization routine) of 22.74 m^3/s as presented in Table 2.14 (combination of 7.44 m^3/s from Hager-Rambo Diversion Channel Culvert and 15.30 m^3/s from West Rambo Creek). The 1D modelling would be expected to generate higher peak flows, due to the use of steady-state modelling and no flow optimization/spill losses.

In both cases (100-year and Regional Storm Events), it should be noted that the floodplain extents of West Rambo Creek downstream of Plains Road reflect the high amount of spill towards the Brant Street underpass. Should this area be re-graded in the future to divert further flows to West Rambo Creek, riverine floodplain extents would be expected to increase further. To assess this scenario, it would likely be necessarily to manually input flow to the channel on the south side of Plains Road and re-run the modelling. However, this additional assessment has not been conducted as part of the current assessment. Given the generally steep grades on Plains Road, it is considered unlikely that the spill mechanics indicated by the 2D modelling could be altered to any significant degree. Thus the currently generated floodplain extents are considered to be reasonable and appropriate. The results of the previously completed 1D hydraulic modelling and floodplain extents (Drawings 5A and 5B) should also be considered.

A version of the presented 2D model that does not include the East Rambo Creek portion has also been developed in order to assess the potential spill from the West Rambo Creek alone (i.e. including CNR spills) back to the East Rambo Creek. A peak flow of 5.1 m3/s is indicated as returning to the East Rambo Creek at the CNR due to this increased spill flow. This value has been used in the hydrologic modelling schematic accordingly.

The majority of the impacted development lands would be impacted by spill flows, rather than riverine floodplain limits. As such, these parcels would potentially be regulated differently by Conservation Halton based on its current guidelines. Notwithstanding, as evident from the prepared figures, properties along Plains Road in particular would be at risk of spills and flooding. The property at 2170 Queensway Drive, directly adjacent to the Burlington GO Station also appears to be a primary spill route and thus would require further consideration as part of any subsequent re-development design to ensure flows can be conveyed and the property suitably flood-proofed.

2.2.2.2 East Rambo Pond Discharge to East Rambo Creek (Scenario 2)

The 2D model of the West/East Rambo Creek area described in Section 2.2.2.1 has also been used to simulate the results for Scenario 2 (i.e. hypothetical scenario whereby all discharge from the East Rambo Pond (including CNR spill) is assumed to be directed to East Rambo Creek). This scenario is provided for information purposes only; as per the East Rambo Flood Control Facility Retrofit Feasibility Assessment (ref. Appendix E), a retrofit to re-direct a greater portion of flows to East Rambo Creek is considered neither feasible nor desirable.

Flow hydrographs at the upstream limits of the drainage system have been updated accordingly for the 100-year and Regional Storm events. Results are presented graphically in Figures 2.6 and 2.7 respectively. Maximum depth contours are indicated on the figures. Orange lines represent the Mobility Hubs study boundaries, the red lines indicate the limits of the 2D model. Velocity and depth x velocity product maps have been included in Appendix C.

As would be expected, the results for Scenario 2 indicate more extensive flooding extents for the East Rambo Creek than for the West Rambo Creek, and other related areas (including the Brant Street underpass). For the 100-year storm event (Figure 2.6), spill from the West Rambo Creek channel between Leighland Road and Plains Road is again indicated, resulting in spill both towards the residential area to the north, and along Plains Road to the Brant Street underpass (although maximum depths are notably less than Scenario 1). Flooding extents for the East Rambo Creek however increase, both in the vicinity of Glenwood School Drive, and directly upstream of the CNR, which would affect properties both along Fassel Avenue, but also result in impacts to the adjacent properties, such as 2170 Queensway Drive.

For the Regional Storm Event (Figure 2.7), the depth accumulation upstream of the CNR around East Rambo Creek is notably wide, and would extend to the industrial property at 860 Guelph Line, and impact the majority of the properties along Fassel Avenue. Spills from East Rambo Creek to the west would impact 2170 Queensway Drive as well as the Burlington GO Station property, and ultimately result in overtopping of the CNR tracks (which was not indicated for Scenario 1). This overtopping would impact the properties to the south, including the Burlington GO Station, the recent residential development at 2089-2095 Fairview Street, and the Walmart property. Results for West Rambo Creek would however be reduced as noted for the 100-year storm event, although impacts to Leighland Road and some minor spill to the Brant Street underpass would again be noted. The CNR spills are generally consistent with the results of the 1D modelling (Drawing 5B), which reflects the spill at the low point along the CNR tracks. Floodplain extents for East Rambo Creek downstream of the CNR are notably different however, as the 1D modelling conservatively assumes no loss of flow, whereas the 2D modelling accounts for the loss of flow associated with the spill/overtopping. Overall, the 2D modelling results for this area are considered more reasonable.

It should again be noted however, that Scenario 2 is a hypothetical scenario, and assumes that all flows and spills from the East Rambo Pond could be all directed to East Rambo Creek. The feasibility of such a scenario is considered very low, given that conveyance capacity across the QEW would need to be greatly increased, and that the existing CNR crossing would need to be blocked or water levels greatly reduced. Although the analyses completed for this study do not constitute a formal flood management plan, the flooding impacts from Scenario 2 appear to be greater than those for Scenario 1, both to residential properties along East Rambo Creek, and also to infrastructure by the overtopping of the CNR tracks. By contrast, the flooding impacts of Scenario 1 primarily involve industrial properties along Plains Road, and the Brant Street underpass. While these flooding impacts are notable, they are considered preferable to those of Scenario 2, and also reflect existing conditions (i.e. would not require the significant infrastructure upgrades which Scenario 2 would, to achieve a questionable benefit).

Figure 2.4: 2D Modelled Maximum Depth Contours for West Rambo and East Rambo Creek areas between the QEW and Fairview Street (100-Year Storm Event, Scenario 1)

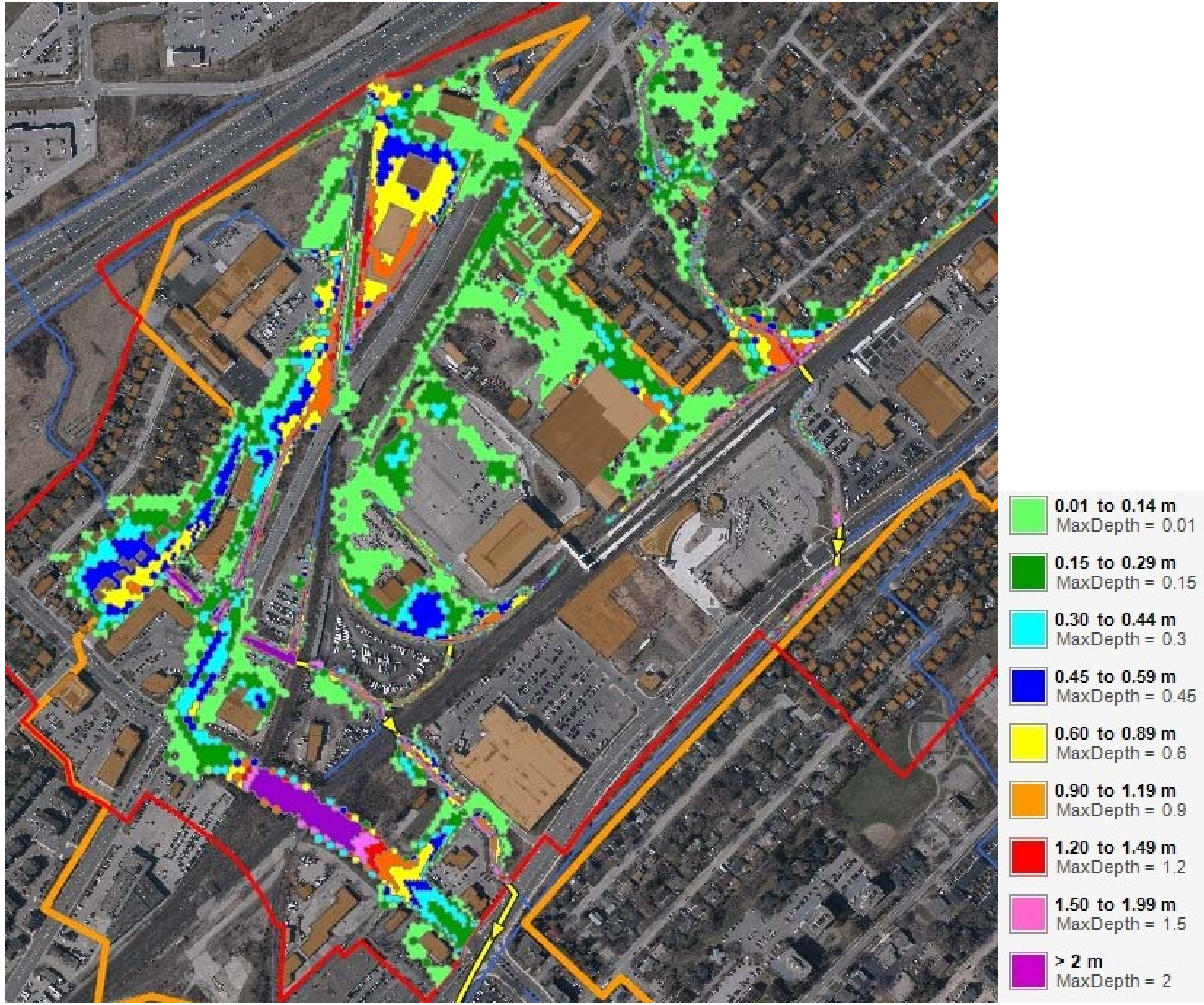

Figure 2.5: 2D Modelled Maximum Depth Contours for West Rambo and East Rambo Creek areas between the QEW and Fairview Street (Regional Storm Event, Scenario 1)

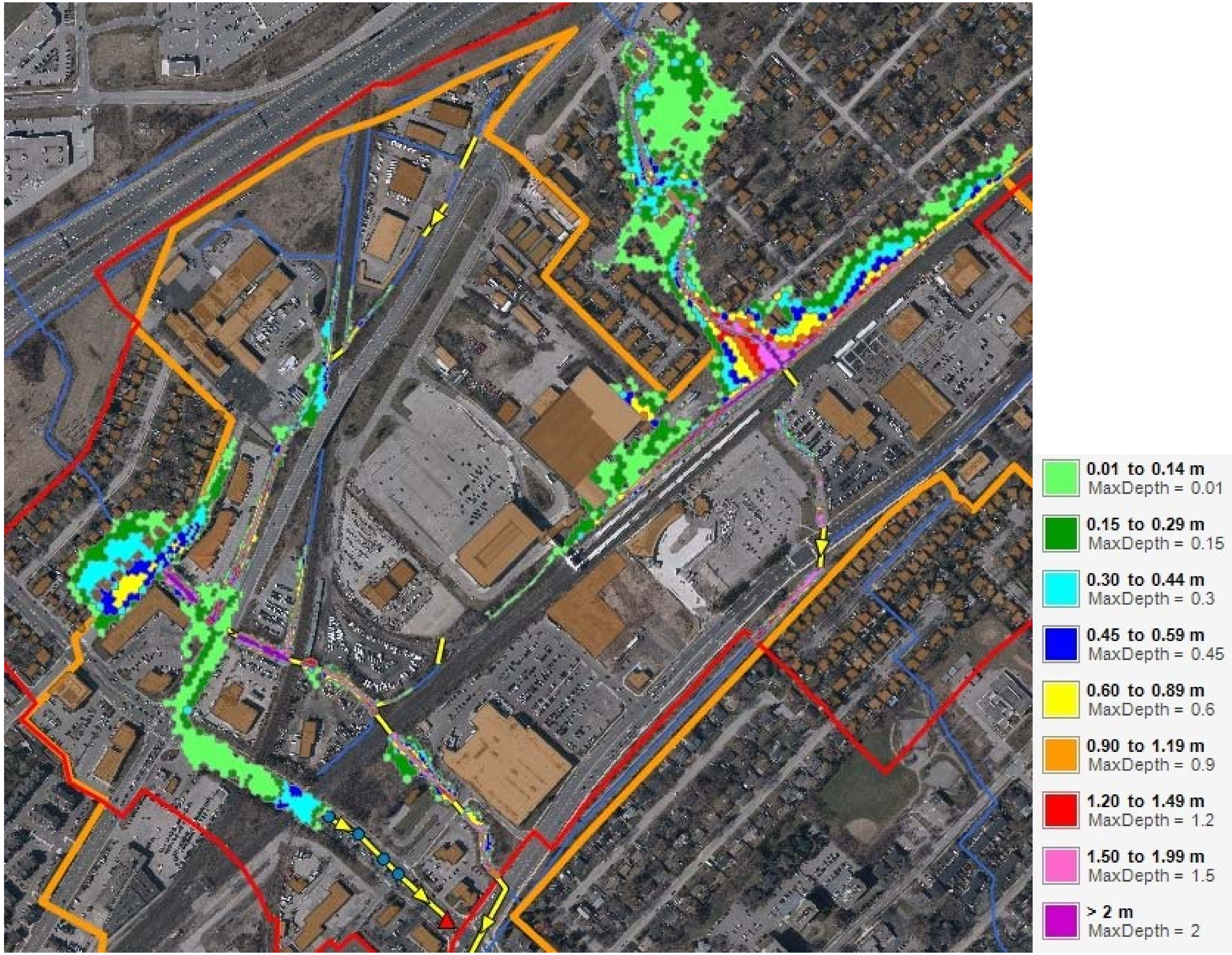

Figure 2.6: 2D Modelled Maximum Depth Contours for West Rambo and East Rambo Creek areas between the QEW and Fairview Street (100-Year Storm Event, Scenario 2)

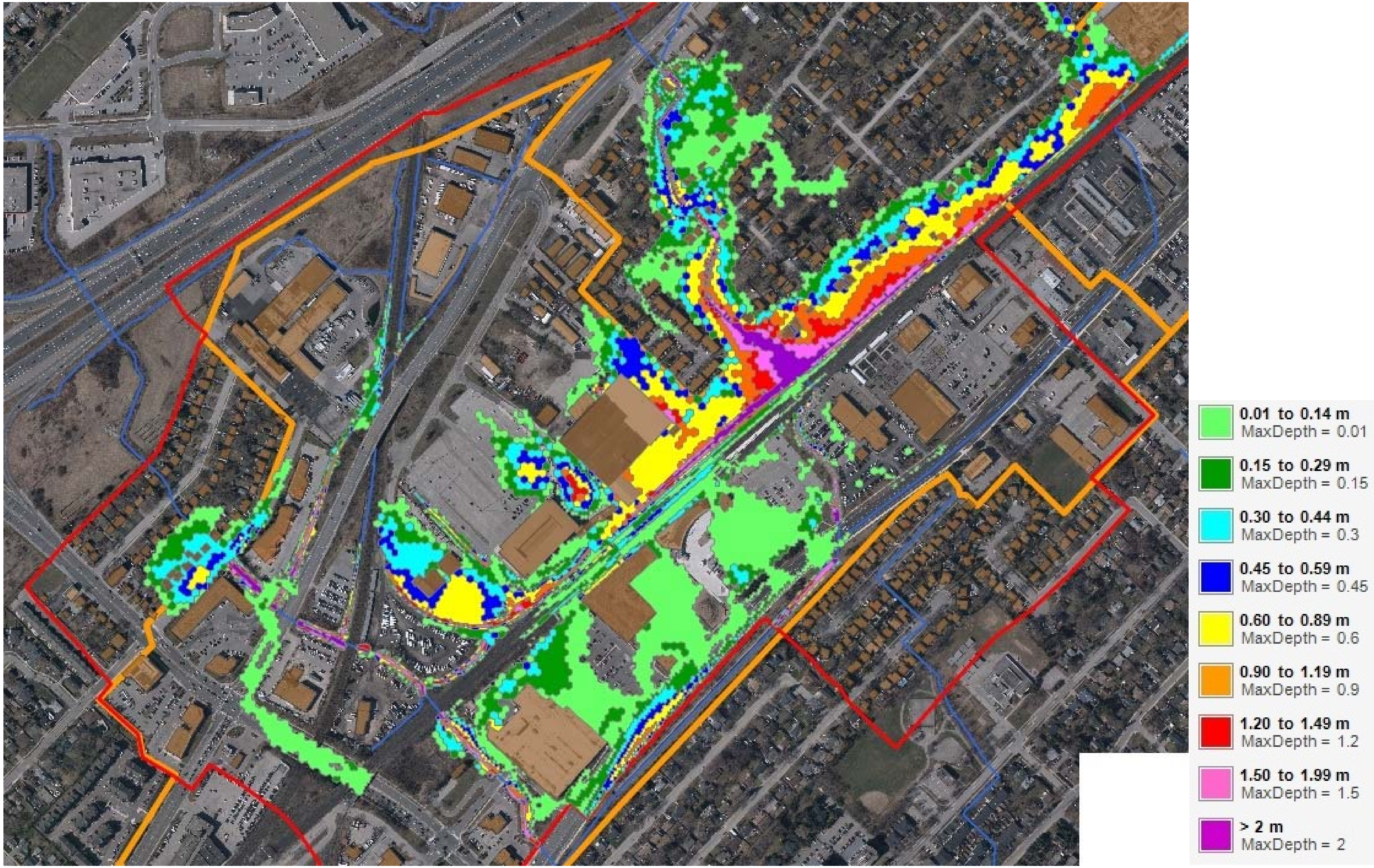

Figure 2.7: 2D Modelled Maximum Depth Contours for West Rambo and East Rambo Creek areas between the QEW and Fairview Street (Regional Storm Event, Scenario 2)

2.2.2.3 Hager-Rambo Diversion Channel Spills

In order to assess the potential impact of Regional Storm spills from the Hager-Rambo Diversion Channel to the areas downstream (including the southern portion of the Burlington GO Mobility Hub, as well as the Downtown area), it has been necessary to determine how those spill flows would be routed from the point of spill. An analysis is therefore necessary to confirm what areas would be impacted by channel spill, and ultimately where these spill flows are conveyed.

This additional analysis has been completed for the spill flow results for Scenario 1 only (i.e. East Rambo Pond performing as per existing conditions). Given the hypothetical nature of Scenario 2 (i.e. all flows from East Rambo Pond directed back to East Rambo Creek), a further assessment beyond the analyses previously completed, is not considered to be warranted. This spill assessment is also only completed for the Regional Storm Event (Hurricane Hazel), as the preceding modelling results do not indicate any expected spills for the 100-year storm event.

The preliminary proposed approach (as discussed with City and CH staff) was to generate a relatively coarse 2-dimensional (2D) hydraulic model, in order to be able to quantify spill directions and extents. A 2D model of this area has been generated using PCSWMM. The developed model generally extends from Fairview Street to Blairholm Avenue (north to south).

A 5 m hexagonal mesh has been applied throughout. The Region of Halton's 2015 DEM was used to sample elevations for 2D cells.

Surface roughness values have been specified consistent with those mandated by the Toronto Region Conservation Authority for 2D modelling analyses. These values as noted earlier, are in fact slightly more conservative than those requested by Conservation Halton (as per November 2, 2017 letter response).

- Urban Pervious Area (grassed) – 0.05
- Urban Impervious Area (paved) – 0.025

Obstructions have been added based on the City of Burlington's Buildings GIS data layer, with some minor corrections and additional required in some cases where the polygon did not adequately match the extents of structures as evident from current aerial photography. Small buildings such as sheds (i.e. generally less than 50 m2) have not been included as these structures are not considered to be significant and cannot be reasonably represented in the mesh.

Three (3) different outfall locations have been incorporated for the 2D mesh, with a free outfall condition assumed throughout. These locations are:

- Lower Rambo Creek (west branch);
- Brant Street (south of Blairholm Avenue) and
- Blairholm Avenue (at Lower Rambo Creek)

Based on the results of the updated spill analysis, channel spills inputs have been identified in four (4) different locations:

- From Lateral Structure 1 (south side of Hager-Rambo Diversion Channel east of Brant)
- From overtopping of the Hager-Rambo Diversion Culvert at Fairview Street (east of Brant)
- From overtopping of the West Rambo Creek Culvert at Fairview Street
- From Lateral Structure 2 (south side of Hager-Rambo Diversion Channel west of Brant)

Flow hydrographs for these locations have been inputted into the modelling as external time series data files. The estimated spill peak flows presented previously from the HEC-RAS lateral structures and weir flow from the Hager-Rambo Diversion Channel Culvert and West Rambo Culvert at Fairview Street (refer to Section 2.2.1.4 and Tables 2.13 and 2.14) have been used to split off the upper portion of flow from the complete flow hydrographs from the SWMHYMO hydrologic modelling.

In addition, to the preceding four (4) spill flow locations, the estimated spill flow hydrograph from the 2D modelling for the West Rambo Creek spill assessment (refer to Section 2.2.1.1) has also been included as a flow input (overflow from the Brant Street underpass). Under this scenario, it is assumed that no spill flows would occur from other locations.

Flow contributions from the Downtown area PCSWMM modelling (discussed further in Section 3) have not been included as part of the inputs to the 2D modelling. The 2D modelling is intended to primarily determine the routing of the spill flows, and the ultimate receivers of these flows. The resulting routed spill flow hydrographs are then added separately into the Downtown area PCSWMM modelling, as discussed further in Section 3. Overall, the magnitude of the channel spill flows are also considerably larger than the localized drainage contributions, thus there is likely only a minor difference between simulated results for the with, and without, these additional drainage areas (although further modelling would be required to confirm this definitively).

Based on the preceding, a total of five (5) different scenarios have been simulated based on the various diversion channel spill assessments noted previously:

- **Spill Scenario 0 (Base):** Full spill flow from West Rambo (Brant Street Underpass) only (no flow optimization for lateral structures or weir flow from Hager-Rambo Diversion Channel or West Rambo Culverts)
- **Spill Scenario 1**: Lateral Structure 1 (East of Brant) optimized
- **Spill Scenario 2**: Lateral Structure 2A+2B (West of Brant) optimized
- **Spill Scenario 3**: Lateral Structures 1 and 2A+2B combined optimization
- **Spill Scenario 4**: No flow optimization (weir flow from Hager-Rambo Diversion Channel Culvert only)

The peak inflows for the preceding scenarios are presented in Table 2.17, along with the simulated discharges (outflows) at the downstream outfalls. Graphical summaries of the 2D simulated maximum depths are presented in Figures 2.8 to 2.12 respectively for the previously noted spill scenarios. Velocity and depth x velocity product maps have been included in Appendix C.

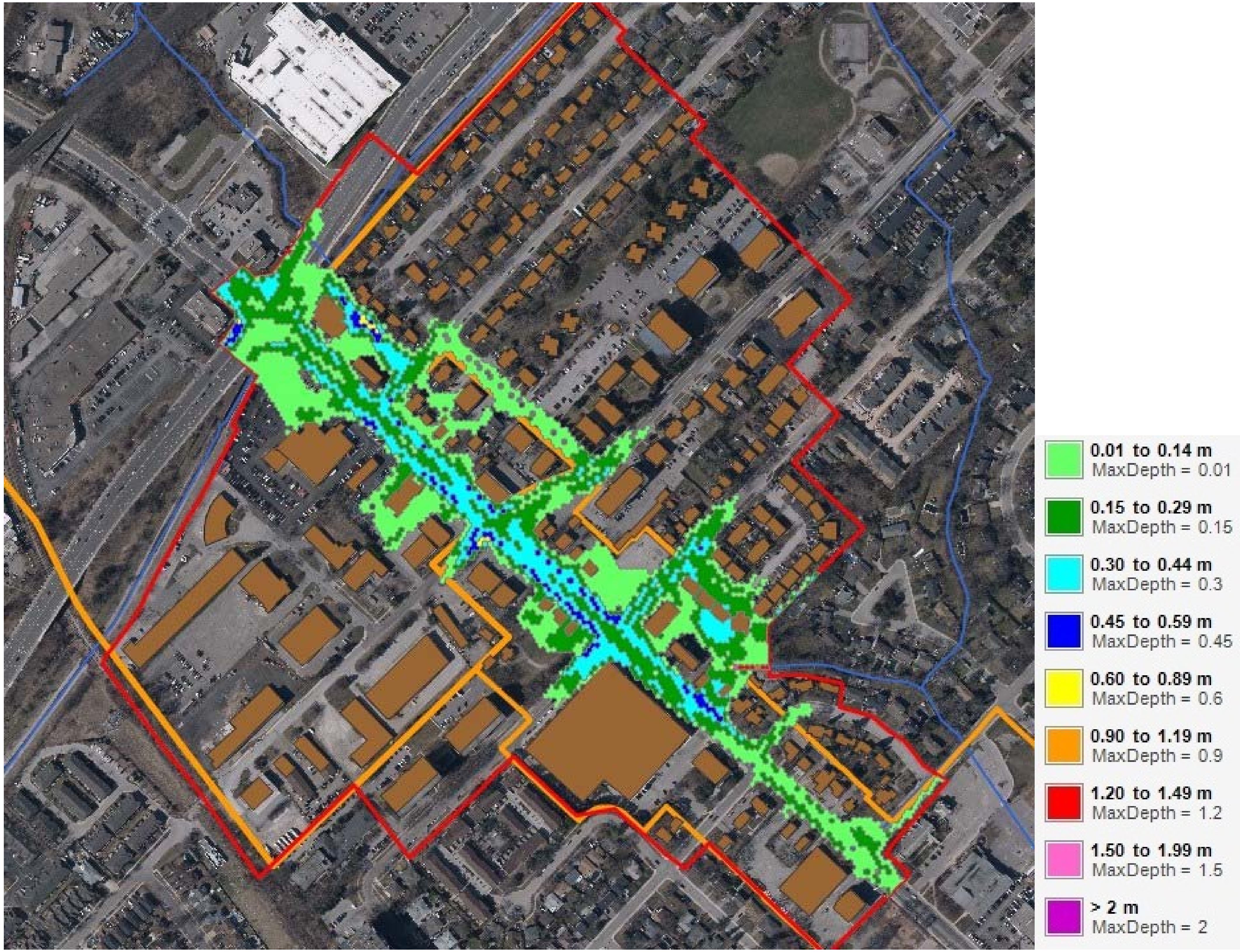

Figure 2.8: 2D Modelled Maximum Depth Contours for areas Downstream of Fairview Street (Spill Scenario 0 - Regional Storm Event, Scenario 1)

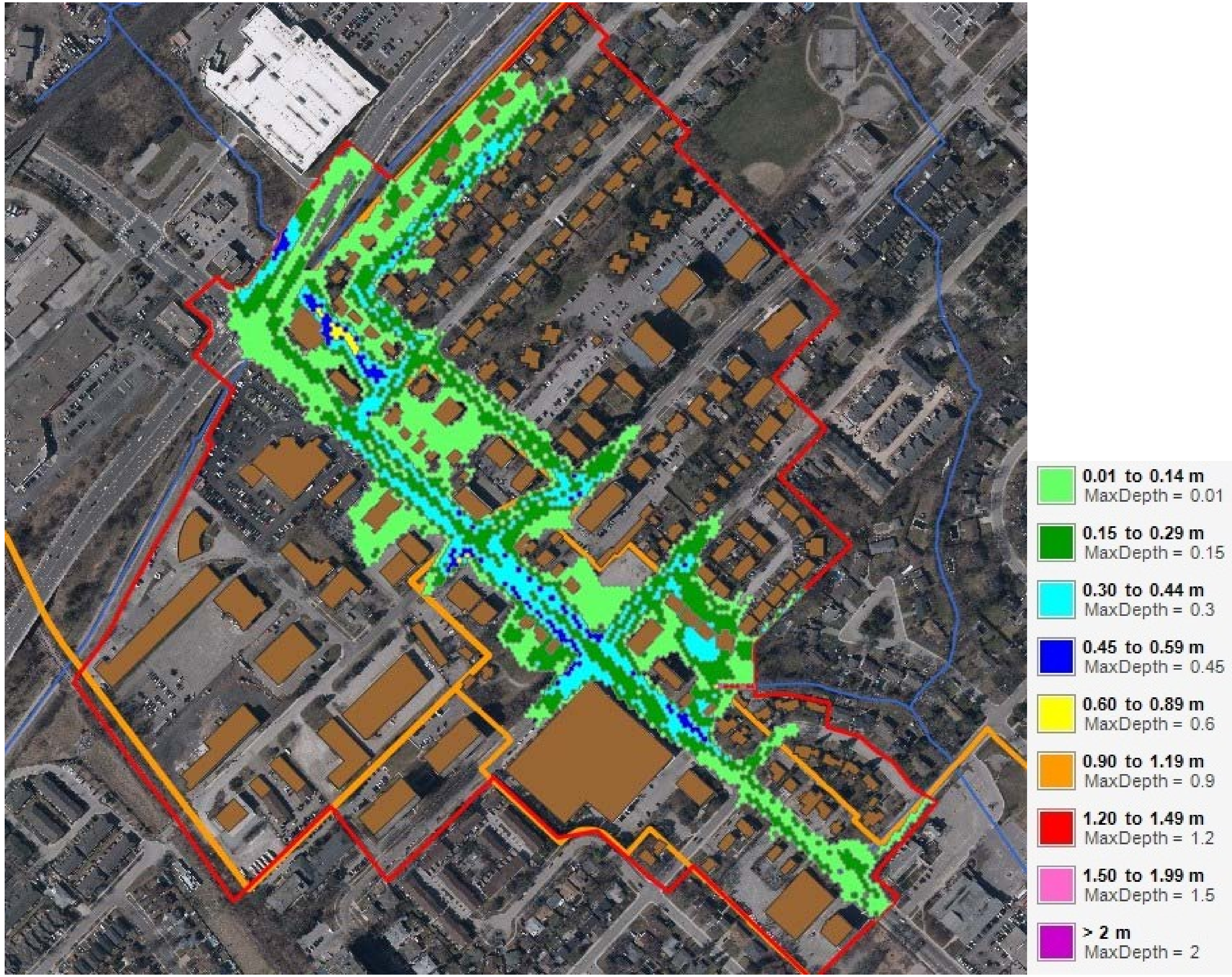

Figure 2.9: 2D Modelled Maximum Depth Contours for areas Downstream of Fairview Street (Spill Scenario 1 - Regional Storm Event, Scenario 1)

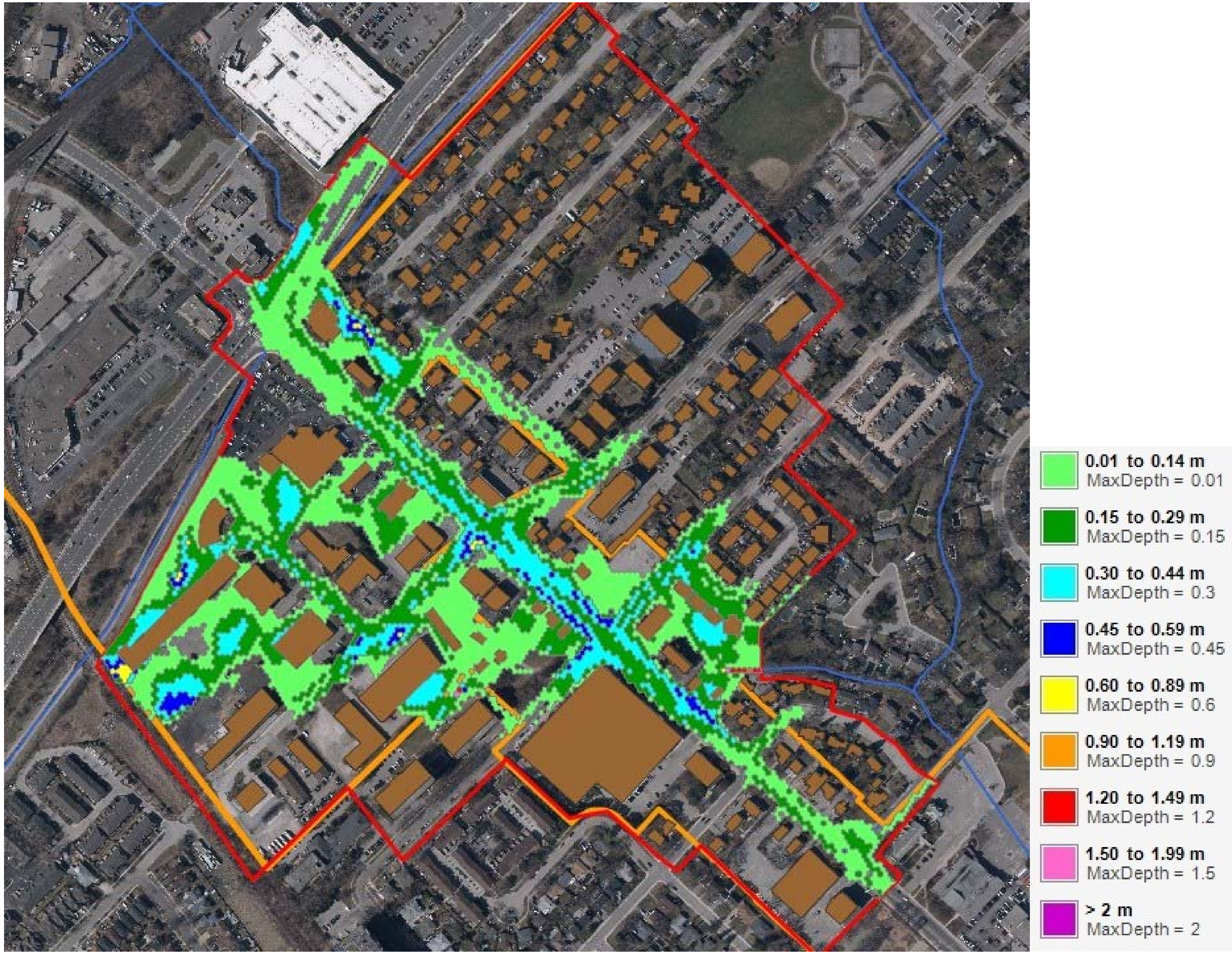

Figure 2.10: 2D Modelled Maximum Depth Contours for areas Downstream of Fairview Street (Spill Scenario 2 - Regional Storm Event, Scenario 1)

Figure 2.11: 2D Modelled Maximum Depth Contours for areas Downstream of Fairview Street (Spill Scenario 3 - Regional Storm Event, Scenario 1)

Figure 2.12: 2D Modelled Maximum Depth Contours for areas Downstream of Fairview Street (Spill Scenario 4 - Regional Storm Event, Scenario 1)

Table 2.17 Simulated Inflows and Outflows for Hager-Rambo Diversion Channel Spill Assessment (Regional Storm Event) – East Rambo Pond Spill as per Existing Conditions (East Rambo Scenario 1)

Spill Scenario	Simulated Peak Inflows (m^3/s)					Simulated Peak Outflows (m^3/s)		
	Lateral Structure 1 (East of Brant) Spill	HR Diversion Channel Culvert (Fairview) Spill	West Rambo Culvert (Fairview) Spill	Brant Street Underpass Spill[1]	Lateral Structure 2A+2B (West of Brant) Spill	West Branch of Lower Rambo Creek	Brant Street South of Blairholm	Blairholm Ave
0 (Base)	0	0	0	18.33	0	16.48	1.39	0.01
1	5.81	1.12	12.33	0	0	17.16	1.46	0.02
2	0	0.48	7.69	0	10.81	16.52	1.39	0.01
3	2.15	0	7.22	0	9.46	15.88	1.33	0.00
4	0	7.44	15.30	0	0	20.77	1.79	0.06

Note: 1. From 2D modelling (PCSWMM) for upstream area (as per Section 2.2.2.1). All other inflows generated from 1D modelling (HEC-RAS).

With respect to the simulated spill extents (Figures 2.8 to 2.12), varying results are indicated as would be expected.

Scenario 1 yields the largest impact to residential properties along Edinburgh Drive and Maplewood Drive (immediately downstream of lateral structure 1); the results from Scenario 3 are fairly similar however (less spill towards Maplewood Drive).

Scenarios 2 yields the largest impact to the industrial properties to the north of Grahams Lane (including Legion Road), due to the largest spill flow from Lateral Structure 2 (west of Brant Street); Scenario 3 however yields similar results as the spill flows are comparable. Depths of up to 0.45 to 0.59 m are indicated (dark blue shading).

All of the spill flow scenarios indicate impacts along Brant Street, as the primary drainage outlet for spill flows. Spill Scenario 4 generates the largest overall spill flow inputs (both from Hager-Rambo Diversion Channel Culvert at Fairview and West Rambo Culvert at Fairview), which results in the correspondingly highest simulated depths along Brant Street and adjacent side streets (including the rear-yard area between Brant Street and Edinburgh Road in particular). Depths along Brant Street range up to the 0.45 to 0.59 m range (dark blue shading). In general, flows would tend to accumulate at the roadway sag point near 736-750 Brant Street, and spill easterly towards the upstream limits of Upper Rambo Creek. The remaining spill flows would continue down Brant Street as noted, with a very minor portion being directed to Blairholm Avenue and back to the Lower Rambo Creek.

The results presented in Table 2.17 indicate that Scenario 4 (overtopping of both the Hager-Rambo Diversion Channel Culvert and West Rambo Culvert at Fairview Street) yields the highest overall spill flows to downstream receivers. Results for the other scenarios are generally comparable however, with spill flows returning to Lower Rambo Creek of between 16 and 17 m3/s. The resulting increased flows for this scenario will also be used to delineate a revised riverine floodplain map for the Lower Rambo Creek. Based on the direction of spill flows, it is not expected that flows to Lower Hager Creek will be affected by the Hager-Rambo Diversion channel spill flows.

Similar to the results for the assessment of spills from the East Rambo Pond, the additional simulated impacts reflect spill flows, rather than riverine floodplains. As such, these areas are not currently regulated by Conservation Halton (i.e. development could still potentially proceed, but should still incorporate best practices to minimize risk to life and property). This is considered further as part of the overall proposed stormwater management strategy, as discussed in Section 2.3.

2.2.2.4 Hager Creek at CNR

As presented in Section 2.2.1.2, the simulated Regional Storm Floodplain extents for the Hager Creek within the HEC-GeoRAS model (both the original modelling developed by CH, and the modelling updated as part of the current study) are considered to be questionable, given the extensive floodplain extents (400 m +\-) and associated volume involved, and the potential for other spills and re-direction of flows in the area to the east of the channel.

As further confirmation of this finding, an additional 2-dimensional (2D) hydraulic model of the Hager Creek area (between the Freeman Pond and the CNR crossing) has been developed using PCSWMM. A similar modelling methodology to that described in previous sections has been applied. A 3 m directional mesh has been applied for the primary channel area, with a roughness of 0.035 applied to reflect the straight and consistent nature of the channel (which also contains some segments of smoother concrete lining). Paved areas and roadways have used a slightly coarser 5 m hexagonal mesh, with an associated smoother roughness coefficient of 0.025. The balance of the pervious areas have used a coarser 10 m hexagonal mesh with a uniform roughness of 0.05 applied.

Building areas have been modeled as obstructions based on the City of Burlington's data layer. Grades for the CNR underpass at Plains Road have been manually adjusted to reflect the base elevations. The CNR culvert structure (triple 2.0 m circular concrete pipes) has been inputted to the 2D model, using the inverts specified in the HEC-GeoRAS modelling. A roughness coefficient of 0.013 has been applied, along with an inlet loss of 0.5 and an exit loss of 1.0.

In order to address Conservation Halton concerns regarding tailwater influences, the modelling also includes additional 1-dimensional (1D) channel elements downstream of the CNR. Channel sections immediately downstream have been included, as well as the downstream culvert crossing at Plains Road, and the section of open channel downstream of this crossing. An outfall with a normal depth boundary condition has been applied at that point of the modelling.

The Regional Storm hydrograph at node H (refer to Drawing 3 and Table 2.5) from the SWMHYMO modelling has been used as an external time series input to the modelling at the upstream limits of the 2D mesh within the channel. This timeseries (peak flow of 65.4 m3/s) has been conservatively applied, rather than applying the direct discharge from node G1 (Freeman Pond outlet) and adding in additional flows from incremental sources, including the West Hager Creek.

The results of this assessment (maximum simulated depths) are presented in Figure 2.13. Depth contours and the associated legend are presented on the figure. Red lines indicate the limits of the 2D modelling mesh. Velocity and depth x velocity product maps have been included in Appendix C.

As evident from Figure 2.13, simulated floodplain extents would encompass Leighland Park, and also spill along adjacent side streets such as Leighland Road, Coric Avenue, and Glendale Avenue, including around the townhouse complex in this area. The 2D modelling results however indicate that at this point spill would be directed to the CNR underpass, which would be the local low point. Once a sufficient volume accumulates in the underpass, spill would then be expected to be directed westward along Plains Road, and then ultimately spill south parallel to Maple Street towards Fairview Street.

No spills or flows are directed towards Brant Street, or would be expected to have any impact to the Burlington GO Mobility Hub. Spills towards Fairview Street would generally appear to be directed south towards Maple Street. Spills in this area would potentially therefore impact the Downtown area, given that Maple Avenue (south of Caroline Street) is included within this limit (refer to Drawing 1). Based on the currently proposed plans for the Downtown area however, re-development is not a priority in this area and can be addressed through Official Plan policies and/or the future Phase 2 study.

The simulated peak water surface elevation within the 2D modelling immediately upstream of the CNR of 99.52 m is approximately 1 m less than the 1D HEC-GeoRAS simulated elevation of 100.47 m +\-. The elevated levels predicted by the 1D modelling reflects the conservative assumptions inherent in steady-state modelling, and also that localized spill pathways are not accounted for, as they are inherently in a 2D model.

The results again suggest that the Regional Storm Floodplain for Hager Creek would have no impact on the Burlington GO or Downtown area lands.

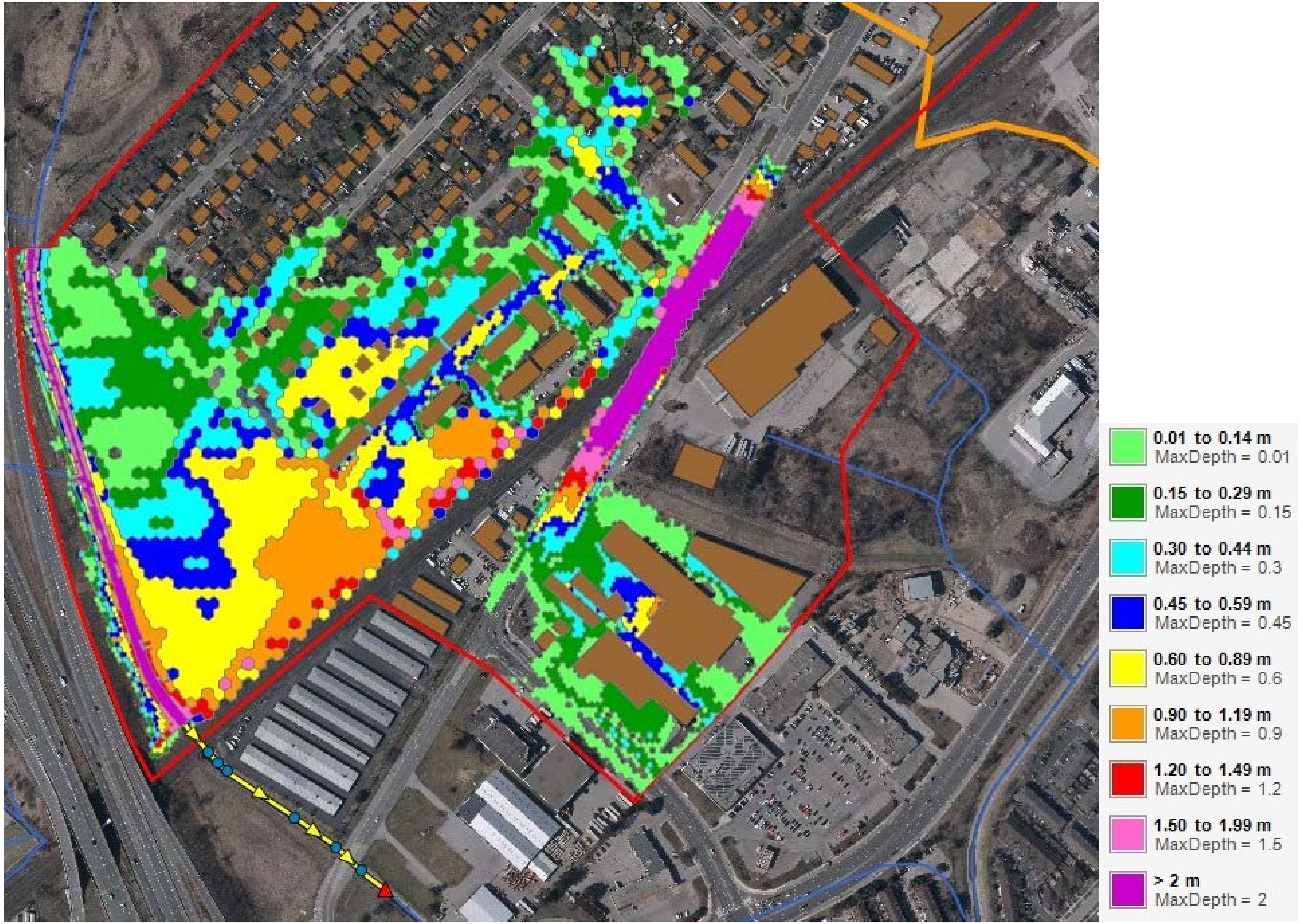

Figure 2.13: 2D Modelled Maximum Depth Contours for Hager Creek Spills (Regional Storm Event)

2.3 Stormwater Management

2.3.1 Anticipated Development Changes

The currently proposed land use plan for the Burlington GO Mobility Hub (revised May 2018) is included in Appendix A. Based on the proposed plan, land use precincts include:

- Urban Employment (industrial areas north of Plains Road East in the vicinity of the CNR)
- Burlington GO Central (assumed to be a mix of uses)
- Fairview/Brant Frequent Transit Corridor
- Leighland Node (near intersection of Plains Road and Brant Street, south of Leighland Road)
- Mid-Rise Residential (balance of areas, including currently industrial area along Graham's lane and Legion Road)
- Public Service (property at south-west corner of Fairview Street and Drury Lane – Halton Catholic School Board)

The preceding proposes to revise land use types and densities for the Burlington GO Mobility Hub, in particular, increasing the number of residential properties. From a hydrologic/impervious coverage perspective however, overall changes are expected to be relatively minor. As per Drawing 2, the majority of the existing area would be considered as "institutional" (assumed 60% impervious coverage). Impervious coverage for the preceding proposed land uses is not known definitively, however would not be expected to increase significantly from existing conditions. Existing greenspace areas are primarily restricted to areas adjacent to roadways, railways, and watercourses. Based on a review of existing coverage, there are only three (3) areas which are largely undeveloped, as presented in Figure 2.14 (in red).

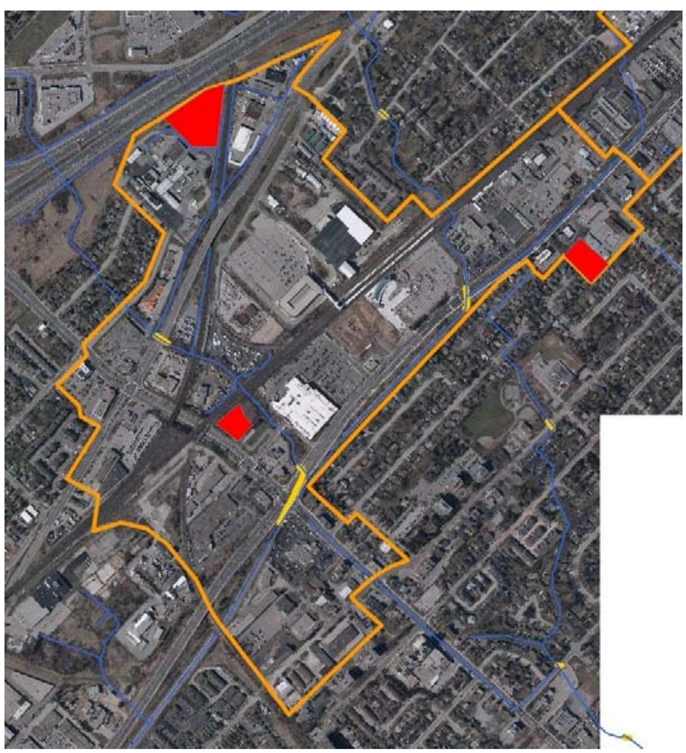

Figure 2.14: Burlington GO Mobility Hub and Existing Pervious Areas

The existing pervious areas presented in Figure 2.11 include:

- 933 Brant Street (0.39 ha)
- 1055 Truman (portion of Nalco Site – 1.30 ha)
- 820 Drury Lane (portion of Halton Catholic School Board Site - 0.55 ha)

As evident from Figure 2.11, these areas reflect only a minor portion of the overall study area limit. Overall, these changes should be considered as part of the proposed stormwater management (SWM) strategy, as discussed further in Section 2.3.4.

2.3.2 Floodplain and Spill Impacts

Floodplain Limits for the East Rambo Creek, West Rambo Creek, and Hager-Rambo Diversion Channel have been presented previously. Based on the supplementary Retrofit Feasibility Assessment of the East Rambo Flood Control Facility (refer to Appendix E), the focus is on the results for Flow Scenario 1 (i.e. East Rambo Pond spilling towards West Rambo Creek), given that this reflects existing conditions, and the expected conditions for the foreseeable future.

Drawing 5A presents the corresponding riverine floodplain limits from the 1-dimensional (1D) modelling, while results using 2-dimensional (2D) modelling are presented in Figures 2.1 and 2.2 (north of Fairview Street) and Figures 2.8 to 2.12 (spills to areas to the south).

Based on input from Conservation Halton (ref. Dearlove-Bustamante, July 25, 2019), the generated floodplain mapping for the West Rambo Creek has been used to prepare an updated flood hazard mapping limit to guide policy planning in the interim period. This mapping (ref. Drawing 5C) has been prepared to address CH concerns with respect to the implementation of Provincial Policies (MNRF, 2002) with respect to spill flows, specifically the simulated reduction of flows to West Rambo Creek based on the associated spill flow westerly along Plain Road towards Brant Street based on the completed 2D hydraulic modelling.

A number of properties have been identified which are expected to be subject to re-development, but would have existing floodplain or spill flow impacts. Reference is made to the previously noted Drawing and Figures, and sections of the report which identify these locations.

As noted previously, 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). With respect to riverine floodplain, Conservation Halton regulates 7.5 m from the greatest creek hazard (regulatory floodplain limit). Development must be in keeping with Conservation Halton policies, which allows for minor works associated with existing uses and limits intensification. (ref. Policies and Guidelines for the Administration of Ontario Regulation 162/06, Conservation Halton, Amended November 26, 2015). The latter (spill flows) have not been historically regulated by CH under O. Reg 162/06 (refer to Section 4.2.5 of the previous document).

The 2D hydraulic modelling completed as part of this study has confirmed that there are a number of spill areas where potential re-development sites would be subject to flood risk. It is expected that the planned subsequent (Phase 2) Flood Hazard Study discussed in previous sections will further confirm the extent of the spill areas, as well as provide recommendations for potential floodproofing or mitigation measures necessary to reduce flood hazard risk, as part of any future re-development in the study area. The City and CH will work together to develop special, area specific Official Plan policies for spill areas, informed by recommendations of the Phase 2 study. CH did not regulate spills in the past because it was not possible to map the extent of a spill and the nature of a spill (i.e., depth and velocity) was unknown. CH has indicated that its permission will be required prior to developing in spill areas.

The Ministry of Natural Resources and Forestry (MNRF) considers spills to be flood hazards. CH regulates flood hazards and, as such, CH has indicated that its permission is required to develop in spill areas. As noted previously, CH did not regulate spills in the past because it was not possible to map the limit or extent of a spill and the nature of a spill (i.e., depth and velocity) was unknown.

With respect to riverine floodplain regulation, all of the identified watercourses in the study area (East Rambo Creek, West Rambo Creek, Hager-Rambo Diversion Channel) and associated Regulatory Floodplains would be regulated by Conservation Halton, including a 7.5 m buffer, as noted previously. Floodplain limits in these cases could potentially be reduced through downstream infrastructure improvements (i.e. channel widening, re-grading, or more likely hydraulic structure (culvert) improvements) to reduce floodplain extents. This is discussed further in Section 2.3.3. Beyond these measures, development would be restricted to the extents noted.

As evident from the results of the completed 2D hydraulic modelling, there are a number of spill flow areas, where potential re-development properties would be subject to flood risk. As noted, these areas are not currently regulated by Conservation Halton (CH), thus development could still potentially proceed subject to review and discussion with CH. Notwithstanding, it is recommended that appropriate flood mitigation and management strategies be employed in these cases. This would 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, and where supported by CH (which typically does not support active floodproofing). 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 attempt to achieve a cut/fill balance, in order to avoid off-site impacts. Where filling is unavoidable, compensatory measures may be warranted. The hydraulic modelling tools developed as part of this study should be considered for application to assess re-developments as they occur, to confirm impacts and effectiveness.

Flooding spills for the Burlington GO Mobility Hub are primarily the result of spill flows from the East Rambo Pond, and the magnitude of peak flows from upstream contributing drainage areas. Although beyond the scope of the current study, opportunities to reduce flows (including spill flows) would also further reduce potential flooding impacts to the study area. As per the completed East Rambo Flood Control Facility Retrofit Assessment (ref. Appendix E), this is generally not considered feasible. The implementation of other upstream storage and flood control systems within the contributing drainage area could likewise be a potential solution, but would again be beyond the scope of the current study.

It should again be noted that the hydrologic modelling applied for the current study, while technically sound and appropriate, remains dated, and has not been calibrated (i.e. adjusted to reflect actual observed responses to storm events). Typically, uncalibrated hydrologic models are conservative (i.e. over-predict flows and volumes as compared to existing conditions). Thus, further study could potentially result in a reduction or refinement in flood risk. Given the estimated frequency of spill from the East Rambo Pond (i.e. 25-year storm event and greater) there would be value in undertaking such an assessment to more definitively confirm flood risk. In the absence of such information, the results generated by the current study are considered the best available data.

2.3.3 Potential Infrastructure Improvements

As noted in Section 2.3.2, one potential mitigation 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 Drawing 5A, primary locations where this could be beneficial include:

- West Rambo Creek
  a. Driveway Culvert in front of 2021 Plains Road (900 mm diameter CSP)
  b. Private road Culvert connecting separate components of 2021 Plains Road (2.5 m x 1.7 m horizontal elliptical CSP – approximately a 1950 mm circular equivalent)
  c. Private culvert at 2078 Queensway Drive (size unable to be field verified)
  d. At the main CNR (concrete arch 2.8 m x 3.0 m)
- East Rambo Creek
  a. At the main CNR (2.9 m x 2.7 m box)

With respect to West Rambo Creek, culvert a) would allow for a greater conveyance of spill flows from the CNR spill to the West Rambo Creek itself, and reduce overtopping and spills to Plains Road East. The culvert crossing of the CNR upstream of this location (north ditch parallel to Plains Road East) is a 1200 mm diameter CSP, which indicates under-sizing, even when spill flows are not considered.

The private road culvert at 2021 Plains Road (b) would again appear to be undersized (2.5 m x 1.7 m HE CSP) based solely on a comparison to the size of the crossing of Plains Road East immediately downstream (4.2 m x 1.6 m box), which has more than double the conveyance area of the upstream crossing. Upgrading of this culvert would primarily benefit upstream residential properties along Leighland Road (outside of the Burlington GO Mobility Hub boundary) but would also reduce spills through the 2021 Plains Road site.

The size of the private culvert at 2078 Queensway Drive is unknown, as it could not be accessed to be field verified. Thus, it is possible that this structure is also a hydraulic constraint. The size should be confirmed and reviewed as part of any future development plans for this area.

The West Rambo CNR culvert crossing (d) is a concrete arch structure. The overall opening/conveyance area is comparable to that of upstream crossings, however the structure is much narrower than upstream structures (2.8 m as compared to 4.2 m). The results from the 1-dimensional hydraulic modelling indicate a backwater condition behind the structure. The City of Burlington is currently reviewing the structural condition of this crossing and potential replacement structures as part of a separate study (ref. Stormwater Railway Crossing Inspection and Design); Wood has been retained separately by the City for this undertaking. The need and benefits of a modified crossing in this location will therefore be reviewed further as part of that study.

With respect to the East Rambo Creek, the CNR culvert crossing (2.9 m x 2.7 m box) clearly results in a notable backwater impact, as evident from the floodplain extents on Drawing 5A. It is also clearly undersized when compared to the next downstream structure at Fairview Street (twin 3.8 m x 2.3 m box culvert). As such, a wider culvert at this location would be expected to benefit upstream floodplain extents and flood levels.

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 (with the exception of those areas draining to the Brant Street underpass, which is reviewed further as part of the Downtown area modelling in Section 3). As such, an assessment or confirmation of storm sewer capacity for the Burlington GO Mobility Hub is beyond the scope of the current study.

2.3.4 Stormwater Management Strategy

As discussed in Section 2.3.1, the proposed re-development within the study area is not expected to result in a significant change in impervious coverage, given the existing urbanized/developed nature of the study area. Further, the study area is located towards the downstream limits of a larger drainage system (Hager-Rambo), and in many cases lands would be expected to drain directly to the watercourse (rather than via intermediary conveyance systems such as storm sewers).

Based on the preceding, the City of Burlington's typical quantity controls (post-development to pre-development peak flow controls for the 2 through 100-year storm events) are generally considered sufficient for development sites within the study area. Notwithstanding, given the lack of information with respect to the hydraulic capacity of existing storm sewer systems, and the similar lack of information on 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) is appropriate for those sites connecting to the City's storm sewer system. 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. Further, those areas outletting to trunk storm sewers with identified capacity constraints should potentially require further over-control to the simulated capacity of the storm sewer receiver.

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, best efforts should be implemented.

As re-developments proceed within the study area, there is an opportunity to improve stormwater quality of discharges to the receiving system. Although the area watercourses ultimately discharge to a concrete-lined channel system (i.e. the Hager-Rambo Diversion), this system in turn outlets to Indian Creek, and Hamilton Harbour. Thus an improvement in stormwater quality will benefit these receivers. 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 the City of Burlington has recently updated its Stormwater Management Design Policies and Guidelines, thus additional stormwater management requirements, particularly with respect to climate change, erosion control, and water balance/infiltration may also 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 Burlington GO Mobility Hub (revised May 2018 - Appendix A) indicate 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.

3.0 Downtown Area

3.1 Hydrology

3.1.1 Model Development

3.1.1.1 Hydrologic Elements

There is currently no hydrologic or hydraulic modelling available for the Downtown area (i.e. Lower Hager or Lower Rambo Creeks). As per the approved April 25, 2017 Work Plan for this study (ref. Appendix B), new hydrologic and hydraulic modelling are to be developed as part of the current study, using an integrated model in PCSWMM.

Subcatchment boundaries have been developed on the basis of the trunk storm sewer network (generally pipes 600 mm in diameter and greater), and topographic data supplied by the City of Burlington (2015 elevation data from the Region of Halton). Given the resolution of the hydraulic system, subcatchment resolution is also relatively resolute. A total of 182 subcatchments (440.8 ha) have been discretized for the current PCSWMM model, with an average drainage area of 2.4 ha +\-. Subcatchment boundaries for the Downtown area are presented in Drawing 6. As evident, the current study boundaries show generally good agreement with the drainage boundaries for adjacent watersheds (i.e. Upper Hager-Rambo system and Roseland Creek).

The City of Burlington has provided two different sources of existing 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 usable for hydrologic and water quality 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 applied for the current modelling work is presented in Drawing 3.

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 establish an average value. For detached residential areas, directly and indirectly connected areas have been estimated based on rooftop downspout connectivity (as evident from Google Street View™). Table 3.1 presents the resulting land use classifications and associated estimated imperviousness values. Based on this parameterization, the average overall impervious coverage for the Downtown area is approximately 60%.

As noted, given the urban nature of the Downtown area, surficial soils mapping from Agriculture Canada is not available. However, the City of Burlington maintains a database of previously completed geotechnical investigations (i.e. borehole logs). A selected number of boreholes (14 +\-) for the Downtown area have been reviewed to characterize local surficial soil conditions. While soils in the study area vary somewhat, a predominance of more permeable soils (Silty Sand and Sandy Silt) has been noted. Based on this information, an overall SCS Classification of "BC" has been assumed for the study area.

Table 3.1 Estimated Land Use Characterization and Parameterization for Downtown Area

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%

Infiltration for pervious areas has been simulated using the US SCS Curve Number Methodology. Based on the preceding characterization of area soils, and a typical grassed land use for pervious areas, a base Curve Number of 67 has been applied for the simulation of pervious areas (under AMC-II, or normal conditions). As PCSWMM does not distinguish between directly connected and total impervious areas, the directly connected area has been used, given that this value is the more critical (i.e. responds most directly to rainfall input). The remaining indirectly connected impervious area has been accounted for by area-weighting the Curve Number for pervious areas to also include non-directly connected impervious areas (Curve Number of 98).

Updated (2004 – RBG Gauge) intensity-duration-frequency (IDF) data has been used for the simulation of the 100-year storm event. Based on a sensitivity analysis, the 24-hour SCS Type-II distribution has been selected for the simulation of watercourse flows. Results from the sensitivity analysis are included in Appendix D. It should be noted however that the currently approved City IDF are those based on the data from 1964 to 1990 (RBG Gauge), which were approved in 1999. The 2004 values represent approximately a 5% increase in rainfall depths as compared to the 1999 values.

For the simulation of the Regional Storm Event (Hurricane Hazel), the 12-hour version of the storm has been employed, with SCS Curve Numbers adjusted to AMC-III (saturated) conditions as per current Provincial Policy.

Potential future changes in rainfall patterns (intensities and depths in particular) associated with climate change are beyond the scope of the current study. Notwithstanding, the potential impacts associated with climate change should be considered as part of future study.

It should be noted that while the hydrologic parameterization presented in Table 3.1 is considered reasonable (and likely conservative), the values are professional assumptions. As part of future study, should field monitoring data become available, a model calibration/validation effort should be considered to further refine assumed impervious coverages. However, typically in such uncalibrated modelling, monitoring data indicates that assumed impervious coverages should be reduced, leading to less conservative results.

3.1.1.2 Hydraulic Elements

As an integrated hydrologic/hydraulic model, PCSWMM also requires that routing and conveyance elements be included explicitly. Given the urbanized nature of the Downtown area, this generally includes urban drainage components (i.e. storm sewers and roadways), as well as some riverine components (open channels/creeks).

With respect to urban hydraulics, as per the approved April 25, 2017 Work Plan, the modelling has focused upon "trunk" storm sewers, which have been considered to be those sewers with a diameter of 600 mm or greater. It should be noted that some smaller storm sewer segments have also been included in the modelling in certain locations as required to ensure a reasonable representation of drainage conditions. The storm sewer database supplied by the City of Burlington does not contain any invert elevation information. As such, an extensive number of plan and profile drawings (350 +\-) have been reviewed to extract the invert elevation data (and associated maintenance hole rim elevation), and transfer this information into the PCSWMM model. In some cases, plan and profile drawings (and associated elevation data) were not available; in these cases alternative techniques have been employed to estimate these data, including interpolation between known elevations, use of DEM data (for rim elevations), and in other cases, assumed depths (i.e. storm sewer 2.5 m +\- below surface). In general however, the plan and profile drawings supplied by the City of Burlington have been sufficient to populate the majority of the required storm sewer system elevations. Ultimately, a total of 340 storm sewer segments have been incorporated into the PCSWMM model for the Downtown area.

The dual drainage creator tool within PCSWMM has been used to develop a major flow conveyance system, parallel to the storm sewer system and based on those elevations (gutter elevation assumed to be equal to the maintenance hole rim elevation). The major system has used typical roadway right-of-way sections for conveyance (both a typical 2-lane and 4-lane roadway section). Additional major system conduits have been added to the modelling to link adjacent areas as required (i.e. parallel streets with unconnected storm sewers).

The minor (storm sewer) and major (roadway overland flow) systems have been linked through bottom draw orifices at junction nodes. The orifices have been sized based on the number of connected catchbasins being represented, with an assumed opening area of 0.125 m^2 per catchbasin (consistent with OPSD details for catchbasin grates). Maintenance hole lids have also been included as required (i.e. junction node linkages where no catchbasins are present).

With respect to riverine (open channel/creek) sections within the Downtown Hub, there is currently no developed or approved hydraulic modelling available for the Lower Hager and Lower Rambo Creek Systems. As such, a new hydraulic model has been developed using HEC-GeoRAS, as described in greater detail in Section 3.2. This modelling has been completed based on elevation data supplied by the City of Burlington (2015 elevation data from the Region of Halton in geodatabase format; more recent than CH source). Ultimately, the modelling developed in HEC-GeoRAS has been imported into PCSWMM to represent the hydrologic routing of open channel areas, and connected to the hydraulic modelling for the urban areas (i.e. storm sewer outfalls, major overland flow route spills to watercourses).

Two different versions of the system hydraulics have been modelled in PCSWMM. One version excludes all hydraulic structures (i.e. roadway culverts and bridges), while the other includes these features. The first approach has been employed for the purposes of developing estimates of riverine peak flows (i.e. input to the HEC-GeoRAS modelling), in order to not include the storage available behind structures, and thus attenuate flows. This approach is consistent with current Provincial Policy and the comments received from Conservation Halton (ref. September 12, 2017 letter). The second scenario (including hydraulic structures) has been simulated in order to estimate more realistic upstream hydraulic boundary conditions (i.e. where the riverine systems enter long enclosures/sewers or other features not well modelled by HEC-RAS). While this scenario would result in slightly lower simulated peak flows, it generates higher/more conservative water levels due to the inclusion of hydraulic structures, which is the primary purpose of this scenario. The results of both scenarios have been compared in order to determine which yields the highest upstream water levels for use as a fixed boundary condition at the upstream face of longer enclosures.

Storm sewer outfalls to Lake Ontario (7 total) have been incorporated into the modelling, using a normal depth boundary condition. Overland flow route outfalls to Lake Ontario have similarly employed a normal depth boundary condition.

3.1.2 Modelling Results

Given the resolution and scope of the developed hydrologic/hydraulic modelling, a detailed summary of hydrologic modelling parameters have been presented in Appendix D. A summary of simulated flows at key riverine nodes (Lower Hager and Lower Rambo Creeks) is presented in Table 3.2. For comparison purposes, simulated flows using both modelling versions (with and without hydraulic structures) have been included; however as noted, the peak flows without hydraulic structures are used for floodplain mapping purposes (as per Section 3.2). The flows presented within Table 3.2 also do not include any spill flows from the Hager-Rambo Diversion Channel – these results are presented in Table 3.3.

Table 3.2 Simulated Peak Flows (m^3/s) at Riverine Nodes of Interest (Downtown Area) – Without Spill Flows from Hager-Rambo Diversion Channel

Watercourse	Location and Model ID	Drainage Area (ha)[1]	With Hydraulic Structures		Without Hydraulic Structures	
			100Y	Regional	100Y	Regional
Lower Hager Creek	Baldwin Street (J752.2523)	36.5	4.94	4.28	6.80	4.59
	Birch Avenue (J426.0621)	44.5	5.24	5.07	7.40	5.63
	Caroline Street (J306.062)	51.8	5.45	5.47	7.46	6.08
	Ontario Street (J97.03847)	76.4	6.90	6.52	9.07	7.42
Lower Rambo Creek	West Branch Upstream of Blairholm Ave (J114.8044)	22.7	3.00	1.19	3.00	1.14
	East Branch at Ghent Avenue (J387.8489)	25.5	4.84	3.56	5.25	3.67
	East Branch at Courtland Place (J39.16557)	30.0	4.98	4.17	5.74	4.30
	Blairholm Ave - Upstream (J8)	90.8	14.17	12.24	14.80	12.42
	Blairholm Ave - Downstream (J433.9925)	100.2	15.93	13.59	16.58	13.79
	Victoria Avenue (J314.0674)	109.7	17.38	14.33	18.56	14.60
	Caroline Street (J28)	141.5	20.31	16.34	22.01	16.63
	James Street (J552.0832)	151.5	22.66	19.61	25.89	20.23
	South of Waterfront Trail (J419.5095)	224.0	29.48	25.62	35.09	26.70
	Lakeshore Road – Upstream (J179.2253)	227.2	29.48	25.74	35.44	27.09
	Lakeshore Road Downstream / Lake Ontario (J59.22536)	259.1	31.39	29.23	44.86	31.95

Note: 1. As estimated from PCSWMM. Note that due to interconnectivity of minor and major systems, actual representative drainage area based on flow splits may differ somewhat.

In general, simulated 100-year and Regional Storm Event flows are relatively consistent in magnitude (with the exception of smaller upstream areas, such as West Branch of the Lower Rambo). The governing (i.e. Regulatory) flow depends on the location selected, and whether structures are included or removed from the model simulation. In general however, the 100-year storm event tends to be the Regulatory event.

As would be expected, removing hydraulic structures results in an increase in simulated flows, since this removes any associated storage or flow attenuation within PCSWMM's hydraulic routing routines. The relative increase in flows from the removal of hydraulic structures is notably more for the 100-Year storm event (average increase of 21% +\-), as compared to the Regional Storm (average increase of 5% +\-). This likely reflects the form of the hydrographs for the two storm events. The 100-Year storm event would be expected to have a sharper, more peaked shape and lower volume, as such it would be more sensitive to the effects of storage and flow attenuation than the Regional Storm Event, which would have a longer hydrograph shape and associated runoff volume (and thus less sensitive to the effects of storage and flow attenuation). As noted previously, hydraulic modelling (as per Section 3.2) is to use the more conservative flows generated by the without structures simulation run, which is also consistent with current Provincial Policy.

In addition to Table 3.2, consideration also needs to be given to the additional spill flows from the Hager-Rambo Diversion Channel (as discussed in Section 2.2). These additional flows have been added to the PCSWMM modelling as external time-varying hydrographs, at the spill locations discussed in Section 2.2 (Lower Rambo Creek – West Branch and at Brant Street south of Blairholm Avenue). The resultant peak flows incorporating spills are presented in Table 3.3, for the with and without structures scenarios. Note that results have been included for Lower Rambo Creek only, since all spill flows would be directed to this watercourse (none to Lower Hager Creek).

Table 3.3 Simulated Peak Flows (m^3/s) for Regional Storm Event at Riverine Nodes of Interest (Downtown Area) – With Spill Flows from Hager-Rambo Diversion Channel

Watercourse	Location and Model ID	Drainage Area (ha)[1]	With Hydraulic Structures		Without Hydraulic Structures	
			With Spill Flows	Difference	With Spill Flows	Difference
Lower Rambo Creek	West Branch Upstream of Blairholm Ave (J114.8044)	22.7	21.16	+19.97	21.14	+20.00
	East Branch at Ghent Avenue (J387.8489)	25.5	3.56	0	3.67	0
	East Branch at Courtland Place (J39.16557)	30.0	4.17	0	4.30	0
	Blairholm Ave (J8)	90.8	17.67	+5.43	18.24	+5.82
	Victoria Avenue (J314.0674)	109.7	23.37	+9.04	24.34	+9.74
	Caroline Street (J28)	141.5	25.33	+8.99	26.34	+9.71
	James Street (J552.0832)	151.5	28.02	+8.41	28.96	+8.73
	South of Waterfront Trail (J419.5095)	224.0	31.94	+6.32	34.25	+7.55
	Lakeshore Road – Upstream (J179.2253)	227.2	32.51	+6.77	34.43	+7.34
	Lakeshore Road Downstream / Lake Ontario (J59.22536)	259.1	33.92	+4.69	37.55	+5.60

Note: 1. As estimated from PCSWMM. Note that due to interconnectivity of minor and major systems, actual representative drainage area based on flow splits may differ somewhat.

The results indicate the most significant peak flow increases at the West Branch of the Upper Rambo Creek, as would be expected, as this is the primary receiver for spill flows from the Hager-Rambo Diversion Channel. Hydrograph timing and combination effects are such however that the magnitude of the increase due to the spill flows is reduced further downstream, generally to an increase of between 5 and 10 m^3/s +\- downstream of Blairholm Avenue. The timing effect is notable in this case as the spill flows from the Hager-Rambo Diversion Channel would be further delayed, given the large difference in contributing drainage area (i.e. 900 ha +\- at diversion channel spill point as compared to 90 ha +\- for Upper Rambo Creek at

Blairholm Avenue). The impacts of these additional spill flows for the Regional Storm Event have been assessed using the developed hydraulic modelling, both urban (roadway flooding depths from PCSWMM) and riverine (from HEC-GeoRAS), as presented in Section 3.2.

The preceding hydrologic modelling results have all included the Blairholm Avenue enclosure, which conveys flows from Lower Rambo Creek between Blairholm Avenue and an area upstream of Victoria Avenue (approximately 150 m in length). As per comments from CH (July 25, 2019), the potential impacts of removing this enclosure (i.e. should it be upgraded or replaced with a daylighted section of channel in the future) has been further assessed. The PCSWMM modelling has been updated accordingly, by replacing the enclosure with a typical open channel section (as per the section immediately upstream of the enclosure). The existing grades/elevations have been assumed to remain consistent. Exit loss coefficients have been replaced with an average loss coefficient for channels, consistent with the approach applied in other areas. Additional node surcharge height has been required in one (1) location along Caroline Street for the Regional Storm with spills scenario, in order to prevent loss of flow. The simulated modelling results are presented in Table 3.4.

Table 3.4 Simulated Peak Flows (m^3/s) for Various Storms at Nodes of Interest for Lower Rambo Creek - (Downtown Area) – Assessment of Impact of Blairholm Avenue Enclosure (Without Hydraulic Structures)

Location and Model ID	Drainage Area (ha)[1]	With Enclosure			Without Enclosure		
		100Y	Regional No Spills	Regional With Spills	100Y	Regional No Spills	Regional With Spills
West Branch Upstream of Blairholm Ave (J114.8044)	22.7	3.00	1.14	21.14	2.94	0.94	21.00
East Branch at Ghent Avenue (J387.8489)	25.5	5.25	3.67	3.67	5.25	3.67	3.67
East Branch at Courtland Place (J39.16557)	30.0	5.74	4.30	4.30	6.07	4.30	4.30
Blairholm Ave (Upstream) J8)	90.8	14.80	12.42	18.24	17.51	12.64	29.85
Blairholm Ave Downstream (J433.9925)	100.2	16.58	13.79	23.30	19.57	14.00	30.73
Victoria Avenue (J314.0674)	109.7	18.56	14.60	24.34	21.28	14.82	32.07
Caroline Street (J28)	141.5	22.01	16.63	26.34	23.79	16.88	32.79
James Street (J552.0832)	151.5	25.89	20.23	28.96	27.24	20.49	34.97
South of Waterfront Trail (J419.5095)	224.0	35.09	26.70	34.25	36.08	26.98	40.29
Lakeshore Road – Upstream (J179.2253)	227.2	35.44	27.09	34.43	36.35	27.38	40.59
Lakeshore Road Downstream / Lake Ontario (J59.22536)	259.1	44.86	31.95	37.55	45.09	32.25	43.82

The results indicate that there is a minimal difference in flows with, and without, the enclosure in place for the 100-Year storm and the Regional Storm Event (without spills). The exception is the area immediately around Blairholm Avenue for the 100-year storm event, which is considered attributable to the peaked nature of the hydrograph for this storm event. A more notable difference is evident for the Regional Storm (with spills) scenario. Peak flows below Blairholm Avenue indicate increases of between 20 to 30%, which suggest that the Blairholm enclosure provides a notable degree of storage and flow attenuation for this event.

The presented floodplain mapping for the "with spills" (ref. Drawing 12) has been developed conservatively by applying a different approach for areas north and south of the Blairholm Avenue enclosure respectively. For areas north of the enclosure, the existing condition flows (with the enclosure in place) have been applied. For areas south of the enclosure, the higher flow scenario assuming the potential future removal of the enclosure have been applied, consistent with Provincial Policy (MNRF, 2002).

3.2 Hydraulics

3.2.1 Urban Drainage Systems (PCSWMM)

3.2.1.1 Storm Sewers

The developed PCSWMM hydraulic modelling has been used to characterize the conveyance capacity of the existing trunk storm sewer system (i.e. those elements included in the modelling). The following characterization has been employed based on the simulated hydraulic gradeline (HGL – maximum expected water surface elevation) characterization for individual storm sewer segments:

- Unsurcharged - HGL is below pipe obverts at both upstream and downstream ends
- Surcharged – HGL is above pipe obvert at either or both of the upstream and downstream ends, but below the ground surface
- Flooded – HGL is above the ground surface at either or both of the upstream and downstream ends

Results have been generated for the 5-year storm event, as this is the City of Burlington's design standard for storm sewers. The 24-hour SCS Type-II Design Storm Distribution has been employed, consistent with the distribution employed for the assessment of the 100-year storm event. Results are presented graphically in Drawing 13.

The simulated results indicate a range of estimated storm sewer capacity. The trunk storm sewer along Brant Street (south of Caroline Street) is indicated as being unsurcharged along its entire length, as are storm sewers in close proximity to Lake Ontario, including along Lakeshore Road (west of Lower Rambo Creek). The remaining sections are indicated as surcharged, with a few sections indicated as flooded. Flooded sections tend to be located at the upstream limits of the simulated storm sewer extents, including Caroline Street and Ghent Avenue.

3.2.1.2 Overland Flow (Roadways)

Hydraulic modelling results for the major system of the urban drainage area (i.e. roadway overland flow routes) have been assessed as part of the current summary. In order to characterize areas of higher overland flow depths, the following characterization has been employed for nodes:

- Maximum depth between 0.15 m and 0.30 m (i.e. above curb height, but within the roadway right-of-way)
- Greater than 0.30 m (i.e. outside the limits of the right-of-way)

Actual street cross-sections could be used to better refine the preceding generic assumptions on right-of-way depths, particularly for the downtown Brant Street corridor where the edge of the right-of-way may be less than 0.3 m above the gutter elevation. Notwithstanding, for the current assessment the preceding assumptions are considered reasonable.

Results have been generated for both the 100-year storm event (Drawing 7) as well as the Regional Storm Event (Drawing 8). Both drawings also indicate the locations of identified roadway sag points. Both drawings also exclude spill flows from the Hager-Rambo Diversion Channel, which would impact flooding depths along Brant Street. A revised figure which includes the estimated spill flows to Brant Street for the Regional Storm Event is presented in Drawing 9. Note that for areas to the north of Blairholm Avenue (which is the limit of the 2-dimensional (2D) modelling described in Section 2.2.2.3) reference should be made to that section and associated Figures for more detailed flood depths summaries.

For the 100-year storm event (Drawing 7), the results indicate that some locations would be expected to experience overland flow depths in excess of 0.15 m (i.e. above curb height), and others would be expected to experience depths in excess of 0.30 m (i.e. outside of the roadway right-of-way). With respect to the expected areas of re-development within the Downtown area, the primary areas of concern would be:

- Baldwin Street (east of Brant Street)
- James Street (at Pearl Street)
- Martha Street (at James Street)
- Lakeshore Road (at Old Lakeshore Road)

These locations all indicate simulated 100-year surface depths in excess of 0.30 m. These locations also generally correlate with the areas of identified riverine flooding (as discussed further in Section 3.2.2), which is logical given the integrated hydraulics within the PCSWMM modelling (i.e. tailwater levels from the creek would impact upon storm sewer drainage capacity).

There are a number of areas along Brant Street where depths in excess of 0.15 m are indicated, however there are no locations along Brant Street with depths in excess of 0.30 m.

For the Regional Storm Event without spills (Drawing 8), the simulated results generally indicate a lesser degree of surface flooding than the 100-year storm event. In particular, no surface flooding depths in excess of curb height (0.15 m) along Brant Street are indicated with the exception of a sag point at Maplewood Drive. Of the previously noted areas of concern for the 100-year storm event, only those at Baldwin Street and Martha Street are also indicated in being in excess of 0.30 m for the Regional Storm Event.

For the Regional Storm Event with spills (Drawing 9), simulated overland flow depths in the vicinity of the spill (i.e. Brant Street south of Fairview Street) increase notably as compared to the without spills scenario (Drawing 8). The most significant increases are seen to the north of Blairholm Avenue, which is expected given that the majority of the Brant Street flows spill towards the Lower Rambo Creek to the north of this location (at the roadway sag point). Notwithstanding, overland flow depths along Brant Street are also increased, although still typically in the 150 mm to 300 mm range (above curb height, but likely still within the roadway right-of-way). Roadway depths are also increased at roadway sag points at Lower Rambo Creek (i.e. Blairholm Avenue, Baldwin Street, Caroline Street, Martha Street, and Lakeshore Road), which reflects the increased creek flows and higher associated tailwater conditions for storm sewer outlets. For a more detailed assessment of overland flow depths due to the spill flows, reference is made to the 2D hydraulic modelling work discussed previously in Section 2.2.2.3.

3.2.2 Riverine Drainage Systems (HEC-RAS)

3.2.2.1 Model Development

As noted previously, there is currently no hydraulic modelling available for either the Lower Hager or the Lower Rambo Creek systems. As such, new modelling (HEC-GeoRAS) has been developed as part of the current study in order to develop estimated floodplain mapping.

It should be noted that the integrated hydrologic/hydraulic modelling (PCSWMM, as per Section 3.1) is also capable of generating simulated floodplain elevations. However, as per the comments provided by Conservation Halton (ref. September 12, 2017 letter), it is understood that a preference is for the floodplain analysis to be completed in a steady-state HEC-RAS model, given concerns with respect to flow attenuation and storage, due to the more complex hydrodynamic modelling routines used in PCSWMM (full dynamic wave routing as compared to an energy equation approach). Notwithstanding, it is noted that HEC-RAS cannot properly model enclosures and sewers (short bridges and culverts only). As such, in areas where the creek systems are directed to these types of structures, the modelling has been truncated, with a fixed boundary condition applied based on the results from the PCSWMM modelling.

A new HEC-GeoRAS model has been developed for the open channel sections of both the Lower Hager and Lower Rambo Creeks. Consistent with the other analyses of the Downtown area, this modelling has been completed based on elevation data supplied by the City of Burlington (2015 elevation data from the Region of Halton in geodatabase format, which were found to be the most recent and most detailed of the elevation data provided). Hydraulic modelling cross sections have been implemented at approximately a 30 m spacing, in order to allow for reasonably detailed modelling results.

It should be noted that based on data availability at the time of the study, the Region of Halton's 2015 DEM is considered the best available topographic data to support additional floodplain mapping. Notwithstanding, additional, more accurate topographic mapping has subsequently become available from CH (2018 LiDAR data from Airborne Imaging). As part of the planned future Phase 2 works, the City of Burlington will update the modelling to use the more current (and accurate) information.

A field inspection of the Lower Hager and Lower Rambo Creeks was conducted on June 27 and 28, 2017. The purpose of this inspection was to confirm all hydraulic structure dimensions, as well as to document the condition of the channels (to assist in assigning an appropriate roughness value). Based on this review, and subsequent comments from CH (November 2, 2017), a Manning's Roughness Coefficient of 0.04 has been applied for channel areas. For overbank areas, roughness values range between 0.02 (paved areas) to 0.045 (grassed or urban pervious areas), to 0.08 (densely vegetated overbank areas). Typical values of expansion and contraction values have been applied, including modifications around hydraulic structures. Ineffective flow areas have been incorporated around hydraulic structures as per standard practice.

A normal depth boundary condition has been applied for the downstream limits of the modelling at Lake Ontario. In addition, fixed water surface elevations have been applied at the upstream limits of enclosures based on the results of the PCSWMM modelling (greater of the with and without structures modelling), given that long enclosures/sewers cannot be properly represented and modelled in HEC-RAS. For Lower Hager Creek, node J13.42342 has been applied, which is one node upstream of the actual enclosure (18.72 m upstream) in order to more conservatively estimate tailwater. Similarly for Lower Rambo Creek, the results have been extracted from node J2.929314, which is two nodes upstream of the actual enclosure (11.71 m upstream) in order to more conservatively estimate tailwater conditions based on a review of the simulated hydraulic gradeline in PCSWMM (which suggests a lowering at the enclosure). A summary of the resulting boundary condition levels at these enclosures is presented in Table 3.5. Peak flows for the 100-year and Regional Storm Event are as per Section 3.1.2 (ref. Tables 3.2, 3.3, and 3.4).

Table 3.5 Fixed Boundary Conditions for HEC-GeoRAS Modelling

Scenario	Watercourse	Location	Water Surface Elevation (m)	
			100-Year	Regional
Without Spills	Lower Hager	Elgin Street	83.31	83.24
	Lower Rambo	Caroline Street	85.47	85.20
With Spills	Lower Hager	Elgin Street	83.31	83.24
	Lower Rambo[1]	Caroline Street	85.47	85.91
	Lower Rambo[2]	Caroline Street	85.56	86.33

1. With Blairholm enclosure upstream in place
2. With Blairholm enclosure upstream removed (as per Section 3.1.2.1 – Table 3.4)

As discussed previously, the inclusion of spill flows would impact only the Lower Rambo Creek System, with an increased Regional Storm Water Surface boundary conditions (+0.71 m) indicated at the Caroline Street enclosure. A further increase in the simulated water surface boundary condition is indicated when the Blairholm Avenue enclosure is removed from the modelling (as per Section 3.1.2.1), with the water surface elevation indicating a further 0.42 m increase. This would be expected to also increase upstream floodplain extents, as discussed further in the subsequent section.

Based on a review of the preceding simulated water surface elevation and available record drawings, it is generally expected that a minor spill may occur upstream of the Caroline Street enclosure under this scenario (Regional Storm event with spills and with removal of upstream Blairholm Avenue enclosure). Available record drawings (ref. Drawing MCB-257 (Rambo Creek Culvert – Elizabeth Street Reconstruction) included in Appendix D) suggest the simulated water surface elevation of 86.33 m would be very close to the spill elevation indicated on the record drawing elevation profile. Further detailed site survey would therefore be required to definitively confirm the potential risk of spill in this area. The potential for a spill should be re-evaluated as part of the Phase 2 Study.

3.2.2.2 Floodplain Extents

Floodplain mapping extents for the Lower Hager Creek for the 100-year and Regional Storm Events are presented in Drawing 10. For the Lower Rambo Creek, results are presented in Drawing 11 (No Spills), and Drawing 12 (including spills from the Hager-Rambo Diversion Channel).

As noted in Section 3.1.2 (Tables 3.2 and 3.3), in general the 100-Year Storm and Regional Storm Event flows are similar (with the exception of the additional impact of spill flows from the Hager-Rambo Diversion Channel). As such, the 100-Year and Regional Storm Event (Without Spills) Floodplains are generally very similar to each other.

For the Lower Hager Creek (Drawing 10), in general it is unlikely that potential re-development sites (ref. Appendix A) would be impacted by the identified riverine flooding. A spill area has been identified between Birch Avenue and Caroline Street. Based on a review of topographic mapping information, it appears that this spill would likely be directed to the existing sag point on Burlington Avenue, between Caroline Street and Ontario Street. This spill area would not impact any parcels that are likely to redevelop within the Downtown area.

With respect to the Lower Rambo Creek (Drawing 11 – Without Spills from the Hager-Rambo Diversion Channel), no channel spills have been identified. Several parcels that could potentially re-develop have been identified as being within the limits of the riverine floodplain, and include:

- Brant Street and Baldwin Street (North-East Corner)
- James Street between Pearl Street and Martha Street (South Side)

- Martha Street at James Street (East Side)
- Martha Street at Pine Street (East Side)
- Lakeshore Road at Old Lakeshore Road (West Side)

In general, only a portion of the above-noted properties appear to be impacted by the identified riverine floodplain extents. The most vulnerable area appears to be the parcel south of James Street (between Pearl Street and Martha Street), where the majority of the site appears to be encompassed by the estimated floodplain. Particular attention and consideration will therefore be required for this location.

With the inclusion of spills for the Regional Storm Event (Drawing 12), the results indicate wider floodplain extents, particularly at the most upstream portions of Lower Rambo Creek. This reflect the direct impact of spill flows from the Hager-Rambo Diversion Channel. As noted in Section 3.1.2 (and Table 3.3) the simulated flow increase is higher at this point, but is reduced further downstream due to hydrograph timing and addition effects. For areas downstream of Blairholm Avenue, the mapping under this scenario also conservatively assume the potential future removal of the Blairholm enclosure, as per Provincial policy (MNRF, 2002) and as discussed in Section 3.1.2.

Two (2) additional areas that may potentially be re-develop and are impacted by riverine flood risk for the Regional Storm Event with spill included have been identified. These areas include:

- Brant Street and Ghent Avenue (South-East Corner)
- Elizabeth Street/Emerald Crescent at Caroline Street (North-West Corner)

As was noted for the other potential locations, not all of the properties noted above appear to be impacted by riverine floodplain impacts, but some portion of the site would be expected to be impacted. For the property at Brant Street and Ghent Avenue, reference should also be made to the previous 2D hydraulic modelling results which indicates the expected spill depths in this area.

As noted in previous sections, the simulated floodplain extents for the Regional Storm Event (with spills) conservatively assumes different conditions upstream and downstream of the Blairholm Avenue enclosure. Floodplain extents downstream of the enclosure apply the simulated higher flow rates assuming a future removal of this feature (thus removing any potential storage and flow attenuation benefit), consistent with Provincial policy (MNRF, 2002). Floodplain extents are therefore generally greater for this scenario than all other scenarios, given the combined impact of additional spill flows from the Hager-Rambo Diversion Channel and the removal of the Blairholm Avenue enclosure for this scenario.

3.3 Stormwater Management

3.3.1 Anticipated Development Changes

The currently proposed land use plans for the Downtown area are included in Appendix A. A precinct plan has been developed, which separates the overall Downtown area into several sub-areas with common features. Large sections of existing detached residential land uses are proposed to be maintained under proposed conditions, including the St. Luke's and Emerald Neighbourhood Precincts. Re-development is primarily anticipated along some portions of the Brant Street Corridor, as well as the Downtown East and Lakeshore Precincts (this includes some areas in the block bounded by James Street to Lakeshore Road along the north-south, and John Street to Martha Street along the east-west).

The preceding will result in revised land use types and densities for the Downtown area, in particular increasing the number of residential properties. From a hydrologic/impervious coverage perspective however, changes are relatively minor. As per Drawing 2, the majority of the existing area where re-development is anticipated would be considered as high impervious (90%). An impervious coverage has not been applied to the currently proposed revised land use plans, however it is considered unlikely that this value would exceed existing coverage and assumptions. This should be considered as part of the proposed stormwater management (SWM) strategy, as discussed further in Section 3.3.4.

Separate from the current study, the City of Burlington has retained SGL Consulting Ltd. to undertake a review of its planning and development policies for the Downtown area. In general, it is understood that this review has considered reduced densities and targets for this area, which would therefore suggest that the land use data employed for the current study is likely conservative. Reference is made to the work being completed as part of that separate study however, including a re-assessment of stormwater and flooding impacts (Wood, 2019).

3.3.2 Floodplain and Spill Impacts

Estimated floodplain limits for Lower Hager and Lower Rambo Creeks (1-dimensional (1D) modelling) were presented in Drawings 10-12, while results using 2-dimensional (2D) modelling have been presented in Figures 2.8 to 2.12 (spills from Fairview Street and Hager-Rambo Diversion Channel). Reference is made to the previously noted Drawing and Figures, and sections of the report which identify these locations.

As noted previously, 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). Typically, the former (riverine floodplains) are regulated by Conservation Authorities, and prevent any development within the floodplain limits (plus a suitable buffer), unless a Special Policy Area or other exception applies depending on the level of flood risk. Lower Hager and Lower Rambo Creeks are in a unique situation, as they are not currently formally regulated features by Conservation Halton. This is due to the historical implementation of the Hager-Rambo Diversion Channel, which diverted upstream flows away from these receivers, leaving only local flows. Since that time, these remnant channels have not been deemed to be regulated watercourses, however this policy may be reviewed further by Conservation Halton. The City of Burlington has historically applied a 6 m buffer from Lower Hager and Lower Rambo Creeks, it is recommended that this process be maintained in the future. As such, re-development of properties which contain identified floodplains could still proceed, subject to the previously noted 6 m buffer.

As noted with respect to the Burlington GO Mobility Hub (Section 2.3), spills are have not been historically regulated (refer to Section 4.2.5 of Policies and Guidelines for the Administration of Ontario Regulation 162/06, Conservation Halton, Amended November 26, 2015). As evident from the results of the completed 2D hydraulic modelling, there are a number of spill flow areas, where potential re-development properties would be subject to flood risk (primarily directly south of Fairview Street and along Brant Street). As noted, in Section 2.3.2, spill areas have not been historically regulated by Conservation Halton, however this is considered attributable to the fact that previously it was not possible to accurately map the extents and nature of spills. Notwithstanding, the Lower Hager and Lower Rambo Creeks are not currently formally regulated features by Conservation Halton, thus based on this understanding, development could still potentially proceed, subject to the implementation of suitable floodproofing measures. It is understood however that the City and CH will in the future work together to develop special, area specific Official Plan policies for spill areas, informed by the recommendations of the Phase 2 Study. It is recommended that any proposed re-developments in the subject areas seek updated direction from the City of Burlington at the time of development.

In both cases (riverine floodplain extents and spill areas), 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 does not typically support active flood proofing; notwithstanding, the subject reaches are not currently regulated by CH. 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. The hydraulic modelling tools developed as part of this study should be considered for application to assess re-developments as they occur, to confirm potential impacts and the effectiveness of mitigation measures.

In some cases, floodplain reduction can potentially be achieved through hydraulic structure upgrades; this would require review on a case by case basis to determine the cost-benefit. Similarly, spill flows can potentially be better managed through purposeful grading of overland flow routes (including roadways), and where feasible, storage systems (likely sub-surface).

It should again be noted that the hydrologic modelling applied for the current study, 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 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.

In addition to the preceding, it should be noted that the developed 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. The results generated by the current study are however still considered appropriate for the estimation of floodplain risk.

3.3.3 Potential Infrastructure Improvements

As noted in Section 3.3.2, one potential mitigation strategy for areas with riverine floodplain impacts is to review the feasibility of infrastructure improvements, specifically hydraulic structures (culverts). Based on a review of the hydraulic modelling results, and the limits of the expected re-development (i.e. Lower Rambo Creek – no re-development along Lower Hager Creek), the following locations would be suggested for potential hydraulic structure upgrades:

a. Enclosure downstream of Blairholm Avenue (existing 1.73 x 2.69 m vertical elliptical – 2.1 m circular equivalent)
b. Victoria Avenue (existing 3.0 x 1.5 m box)
c. Martha Street (existing 2.95 x 2.35 m concrete arch)
d. Waterfront Trail (existing 6.4 x 0.9 m open bottom concrete)
e. Lakeshore Road (existing 3.0 x 2.1 m concrete box)

Culverts a) and b) are in close proximity to one another and the upgrades would likely be completed together (upstream portion of Lower Rambo Creek); similarly culverts c), d) and e) would all likely be considered together (most downstream portion of Lower Rambo Creek).

With respect to culverts a) and b), the Blairholm enclosure is notably undersized, given upstream floodplain extents and the evident overtopping. The Blairholm enclosure also has a smaller conveyance area than the downstream box culvert at Victoria Avenue. The enclosure passes through private property; subsequent discussions with City staff (Malik-Senior, February 7, 2019) have indicated that the City does hold an easement over this feature to permit upgrading if required. The Victoria Avenue structure, while larger, has a more notable impact to expected re-development lands, and thus may be a higher priority for upgrade/replacement.

With respect to culverts c), d), and e), the hydraulic modelling results indicate that floodplain levels are most sensitive to hydraulic structure d) – the Waterfront Trail (existing 6.4 m x 0.9 m open bottom concrete), based on the extensive simulated backwater upstream of the structure. Although wide, this structure is fairly low, and thus results in a larger backwater impact. Notwithstanding, expected re-development areas would also benefit from a replacement of the Martha Street crossing (structure c) in conjunction with the upgrade to the Waterfront Trail structure, although the latter would have a greater overall impact, and a replacement of c) alone would have minimal benefit (as it would not address the tailwater constraint). The Lakeshore Road culvert crossing is indicated as being overtopped for both the 100-year and Regional Storm events. An upgrade in this location could eliminate the overtopping, which would benefit adjacent potential re-development lands.

Trunk storm sewer sections with deficient hydraulic capacity (i.e. less than the 5-year storm event) have been identified previously. These sections should therefore be considered for capacity upgrades where feasible, in conjunction with the City of Burlington's existing capital planning for road reconstructions, which will also include the recommendations of the City's Stormwater Quality Control Plan for the downtown area (Wood, November 2019).

3.3.4 Stormwater Management Strategy

As discussed in Section 3.3.1, the proposed re-development within the study area is not expected to result in any observable change in impervious coverage, given the existing urbanized/developed nature of the downtown study area. Further, in many cases lands would be expected to drain directly to the watercourse (rather than via intermediary conveyance systems such as storm sewers).

Based on the preceding, the City of Burlington's typical quantity controls (post-development to pre-development peak flow controls for the 2 through 100 year storm events) are generally considered sufficient for development sites within the study area. Notwithstanding, a number of areas have been identified with sub-standard storm sewer capacity (i.e. surcharging or flooding for the 5-year event – refer to Drawing 13) or overland flow conveyance capacity (i.e. roadway flooding depths greater than 0.30 m for the 100-year event – refer to Drawing 7). In these locations in particular, 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. Further, those areas outletting to trunk storm sewers with identified capacity constraints (refer to Drawing 13) should potentially require further over-control to the simulated capacity of the storm sewer receiver. The modelling tools developed as part of the current study may be applied to further assess and validate quantity control measures and storm sewer capacity in these areas. This will ensure that the proposed strategy functions as intended, particularly in areas with identified conveyance capacity restrictions.

Given the highly urbanized nature of the downtown area, 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, best efforts should be implemented.

As re-developments proceed within the study, area there is also an opportunity to 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.

The City of Burlington has completed a Stormwater Quality Control Plan for the Downtown Area (Wood, November 2019), which overlaps with a portion of the current Mobility Hub study area. The recommendations and proposed measures from that study should be considered as part of the overall quality control strategy for new developments in the Downtown area. In some cases, a cash-in-lieu approach may be warranted, to support the implementation of larger off-site measures. This includes the implementation of Low Impact Development Best Management Practices (LID BMPs) for roadway reconstructions, consistent with the "Green Streets" approach. LID BMPs can be implemented 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.

In addition, it should be noted that the City of Burlington has recently updated its Stormwater Management Design Policies and Guidelines, thus additional stormwater management requirements, particularly with respect to climate change, erosion control, and water balance/infiltration may also result for future developments, beyond the basic quantity and quality requirements noted previously.

4.0 Summary

4.1 Conclusions and Recommendations

The land use plans prepared for the Burlington GO Mobility Hub and Downtown area indicate that re-development and intensification are expected in these areas. This report has been prepared in support of this planning effort, in order to summarize the expected flood hazard limits for both areas, given the drainage system connections between the two areas. Both existing and new hydrologic and hydraulic models have been refined and developed in order to reasonablly assess expected flood hazards, due to both riverine floodplain extents, as well as spills, and urban overland flows.

For the Burlington GO Mobility Hub, overland spills are expected in a number of different areas, primarily within the West Rambo Creek area due to uncontrolled spills from the East Rambo Pond via the CNR underpass beneath the QEW. These spills have been mapped and assessed using 2-dimensional (2D) modelling given the complexity of the flow pathways. Conventional 1-dimensional (1D) hydraulic modelling has also been prepared for the area watercourses to confirm the floodplain extents. Spills from the Hager-Rambo Diversion Channel along Fairview Street for the Regional Storm event have the potential to impact a number of re-development areas in the subject Mobility Hub. The combination of these flood hazard maps will help inform the flood risk to future re-developments within the Burlington GO Mobility Hub. A general floodplain management strategy has been proposed, which necessarily distinguishes between riverine floodplain extents (regulated by Conservation Halton) and spills (not currently regulated by Conservation Halton). 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 Burlington GO Mobility Hub is outlined in Table 4.1.

For the Downtown area, the upper sections along Brant Street are expected to be impacted by potential spill flows from the Hager-Rambo Diversion Channel area. A new, integrated hydrologic/hydraulic dual-drainage model has been developed, which permits the assessment of trunk storm sewer capacity, overland flow capacity, as well as the establishment of flows within the watercourse receivers. A conventional 1D hydraulic model has been developed for the establishment of riverine floodplain extents. The preceding flood hazard maps and summaries of conveyance capacities (urban drainage systems) will help to inform the flood risk to future re-developments within the Downtown area. A general floodplain management strategy has again been proposed for this Hub; however as noted the Downtown area differs from the Burlington GO Mobility Hub in that riverine floodplain extents are not currently regulated by Conservation Halton, given the legacy of the upstream Hager-Rambo Diversion Channel. In addition to the general floodplain management strategy, potential hydraulic structure upgrades have been noted which may assist in further reducing floodplain extents. A SWM strategy, similar to that for the Burlington GO Mobility Hub, has been proposed with respect to stormwater quantity and quality. A summary of the proposed measures for the Downtown area is presented in Table 4.2.

Table 4.1 Summary of Flood Hazard and SWM Strategies for Burlington GO Mobility Hub

Management Area	Consideration	Recommendation
Development Area Flood Management	Riverine floodplain encroachment onto development sites	• Undertake a Phase 2 Flood Hazard Study using more detailed topographical survey data to facilitate future Zoning Bylaw Amendment and Site Plan applications. • Conservation Halton regulates 7.5 m from the greatest creek hazard (regulatory floodplain limit). Development must be in keeping with Conservation Halton policies, which allows for minor works associated with existing uses and limits intensification. • Consider opportunities to reduce floodplain extents through hydraulic structure upgrades or other potential improvements (channel widening/re-grading, or optimization of East Rambo Pond); refer to subsequent sections.
	Flood spills onto development sites	• Undertake a Phase 2 Flood Hazard Study using more detailed topographical survey data to facilitate future Zoning Bylaw Amendment and Site Plan applications. • Development can proceed subject to suitable flood management strategy on affected development sites. 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. Confirm safe ingress/egress from site (pedestrians and vehicles). • Attempt to achieve 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 West Rambo Creek, consider upsizing to: a) Driveway culvert in front of 2021 Plains Road b) Private road culvert at 2021 Plains Road c) Private culvert at 2078 Queensway Drive (no information – to be confirmed) d) Main CNR (currently being reviewed as part of a separate study) • For East Rambo Creek, consider upsizing to: a) Main CNR
	Storm Sewers	• Insufficient information to recommend specific upgrades. Consider further as part of future study (dual drainage modleling).
	Overland Flow Pathways	• Insufficient information to recommend specific upgrades. Consider further as part of future study, including identified spill pathways (dual drainage modelling).
	Flood Control Facilities	• Consider any recommendations stemming from the Hager-Rambo Flood Control Storage Facilities Study (Wood, September 2020).

Table 4.1 Summary of Flood Hazard and SWM Strategies for Burlington GO Mobility Hub

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) of peak flows for areas connecting to storm sewers or where major system is constrained; additional over control may be warranted where a known capacity constraint exists in the trunk storm sewer system • Confirm Regional Storm controls are not required through Phase 2 Flood Hazard Study. • 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. Best efforts to be considered where it can be demonstrated that the above cannot be reasonably be achieved.
	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")

Table 4.2 Summary of Flood Hazard and SWM Strategies for the Downtown Area

Management Area	Consideration	Recommendation
Development Area Flood Management	Riverine floodplain encroachment onto development sites	• Undertake a Phase 2 Flood Hazard Study using more detailed topographical survey data to facilitate future Zoning Bylaw Amendment and Site Plan applications. • Floodplain extents for Lower Hager and Lower Rambo Creek are not currently regulated features by Conservation Halton • Notwithstanding, City policy is to restrict development within a 6 m buffer beyond the limits of the identified floodplain limits; this process should continue to be applied
	Flood spills onto development sites	• Undertake a Phase 2 Flood Hazard Study using more detailed topographical survey data to facilitate future Zoning Bylaw Amendment and Site Plan applications. • Development can proceed subject to suitable flood management strategy on affected development sites. • 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. Confirm safe ingress/egress from site, including pedestrians and vehicles. • Attempt to achieve a cut/fill balance for flood storage volume to avoid off-site impacts.

Table 4.2	Summary of Flood Hazard and SWM Strategies for the Downtown Area	
Management Area	**Consideration**	**Recommendation**
		• 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 along Lower Rambo Creek to reduce floodplain extents for development lands: a) Enclosure downstream of Blairholm Avenue b) Victoria Avenue c) Martha Street (need to complete Waterfront Trail upgrade first) d) Waterfront Trail e) Lakeshore Road
	Storm Sewers	• Consider capacity upgrades for identified deficient storm sewers (those with surcharging or flooding for the 5-year storm event)
	Overland Flow Pathways	• Review opportunities for improvements in areas where 100-year and Regional Storm accumulation depths are > 0.30 m
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) of peak flows for areas connecting to storm sewers or where major system is constrained. Additional over-control may be warranted where the current modelling results indicate storm sewer capacity is less than 5-year storm event standard • Utilize existing hydrologic/hydraulic modelling tools to verify effectiveness of site quantity control strategies. Confirm Regional Storm controls are not required through Phase 2 Flood Hazard Study. • 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. Best efforts to be considered where it can be demonstrated that the above cannot be reasonably be achieved.
	Quality Control	• Enhanced (80% average annual TSS for all impervious areas • Review opportunities for synergies with other studies (Stormwater Quality Control Plan for Downtown) and road reconstruction projects in particular ("Green Streets")

4.2 Future Studies

The current study provides a basis for the estimation of existing flood hazards and a proposed SWM strategy for both the Burlington GO Mobility Hub and the Downtown area. 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 hydrologic and hydraulic modelling tools developed as part of the current study should be leveraged to the extent possible to support these future works, given the overall associated efficiency, and ability to assess the effectiveness of future SWM strategies for re-developments.

- 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. This would apply both to the drainage systems within the Burlington GO Mobility Hub and Downtown area. Notwithstanding, this effort would be considered independently of the current (Phase 1) or planned future (Phase 2) study works, as it is not considered necessary to support the aims of the current focused study.
- The preceding field monitoring effort could potentially be combined with an overall hydrologic modelling update for the Hager-Rambo system in particular, which would re-assess land use coverage/imperviousness and support model calibration/validation, and also potentially migrate the model to a more current tool (i.e. from SWMHYMO to Visual OTTHYMO or HEC-HMS, among others). Notwithstanding, this effort would be considered independently of the current (Phase 1) or planned future (Phase 2) study works, as it is not considered necessary to support the aims of the current focused study.
- Further field verification and topographic survey is also recommended in certain locations, including the Freeman Pond (to verify spill elevations and vulnerable locations), as well as hydraulic cross-sections and details for the Lower Hager and Lower Rambo Creeks, given the use of Digital Elevation Model (DEM) data for the current assessment. This effort is expected to be considered as part of the Hager-Rambo Flood Control Storage Facilities Study (Wood, September 2020).

The current study should also be considered in conjunction with other ongoing City of Burlington initiatives within the study area. For both areas 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. Opportunities for synergies with the City's Stormwater Quality Control Plan for the downtown area (Wood, November 2019) should likewise be reviewed and leveraged where feasible.

In addition to the preceding, Conservation Halton (CH) has identified a number of technical analyses and follow-up assessments that have been recommended to be completed by the City of Burlington following the completion of the current study (which is intended to support the drafting of Official Plan policies). The follow-up analyses (referred to as "Phase 2") are generally outlined in CH's comments of July 25, 2019 (Dearlove-Bustamante – refer to Appendix B). A preliminary Study Terms of Reference has also been developed and reviewed by CH (November 2019). The Phase 2 analyses are intended to provide a more resolute level of detail to support future site plan submissions, and also incorporate more current/resolute topographic data from CH/City, as well as any updated land use information from the City of Burlington.

In general, the following additional items are expected to be required as part of the Phase 2 analyses:

- Update both 1-dimensional (1D) and 2-dimensional (2D) hydraulic modelling with more recent LiDAR topographic data acquired by CH/City (Airborne Imaging, August 2018)
- Assess a "quasi-steady state" condition for 2D modelling to assess impact of storage volumes; also sensitivity/impact analysis for upsizing all hydraulic structures (such as Plains Road crossing of West Rambo Creek)
- Assess the impacts of infilling/development on spill zones using the 2D hydraulic modelling
- Review the potential for spills from the Hager-Rambo Diversion Channel at Thorpe Road and Maple Avenue in greater detail
- Confirm Regional Storm quantity controls are not required

It is expected that the additional results of the Phase 2 analyses will be used to further refine the recommendations of the current study, however the general guidance and principles outlined in the current study will remain consistent.

Lastly as noted earlier, CH has requested that in order to support crediting of the flood control/quantity control function of the existing facilities within the subject study area (i.e. the East Rambo Flood Control Facility, the West Hager Flood Control Facility, and the Freeman Pond), that a specific study be undertaken to assess the structural stability and functional condition of these facilities. (ref. Hager Rambo Flood Control Facilities Study, September 2020) This study includes:

- Visual Inspection
- Facility Capacity and Performance Verification
- Structural Stability Assessment (Structural and Geotechnical Engineering)
- Sensitivity Analysis (Climate Change Considerations)
- Remedial Works and Implementation Considerations

This report has been provided separately to CH and the City for review and comment. The final version (September 2020) addresses received CH comments of May 7 and August 27, 2020. In general, the study has confirmed that the flood control facilities are stable and can, in Wood's professional opinion, be appropriately credited in the flooding analyses and management, consistent with the position of the City of Burlington. Identified remedial works will be prioritized appropriately by the City.

Respectfully submitted,

Wood Environment & Infrastructure Solutions,
a division of Wood Canada Limited

Per: Ron Scheckenberger, M.Eng., P.Eng.
Principal, Water Resources

Per: Matthew Senior, M.A.Sc., P. Eng.
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Water Resources Engineer

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Water Resources Engineer

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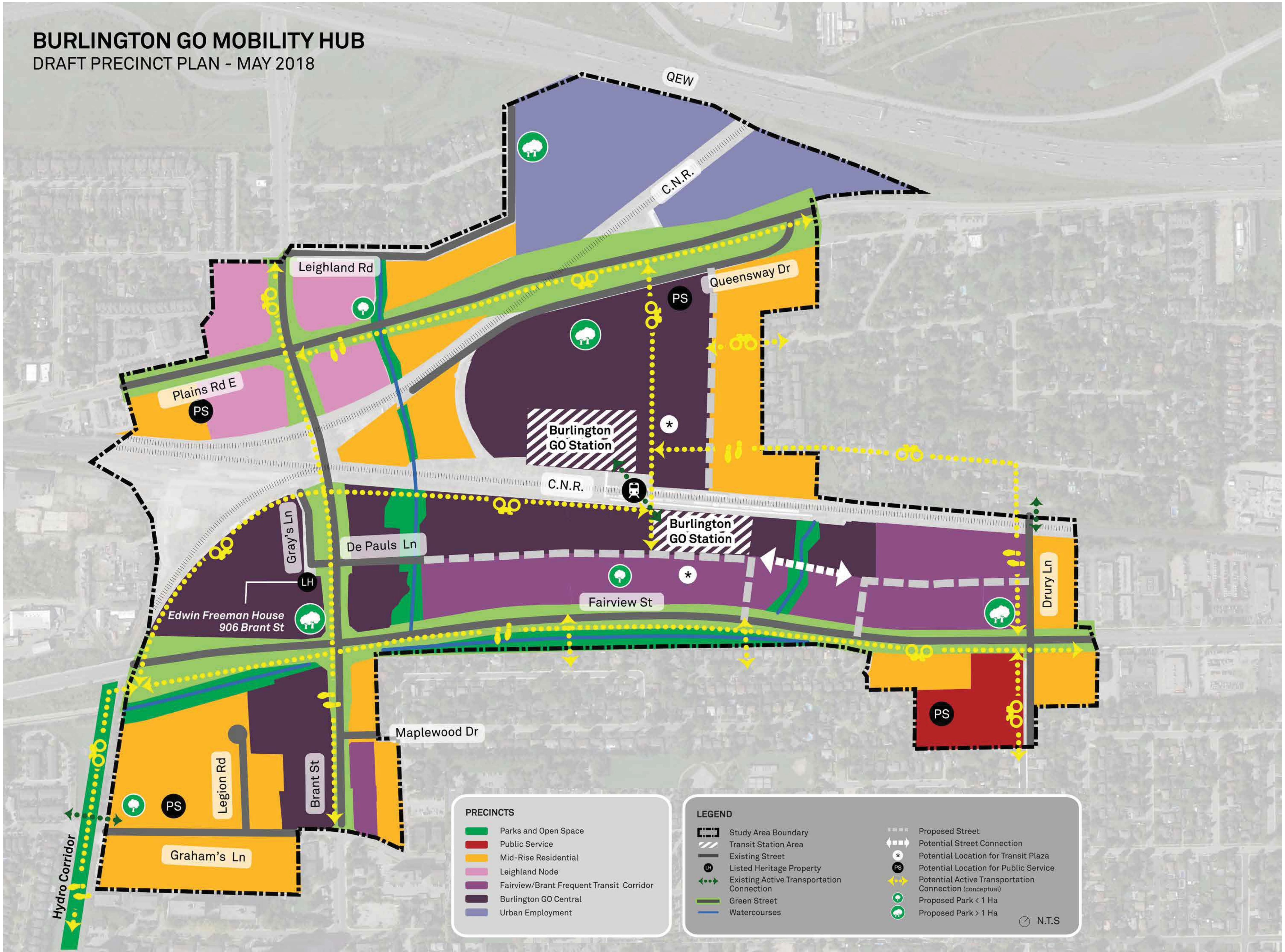
Appendix A

Mobility Hub Land Use Plans



GROW BOLD

City of Burlington

Please note that the draft precinct plan, precinct boundaries, associated intention statements and key directions are preliminary and subject to change as a result of on-going technical studies and community and stakeholder feedback.

Figure 5: Proposed Revised Precincts

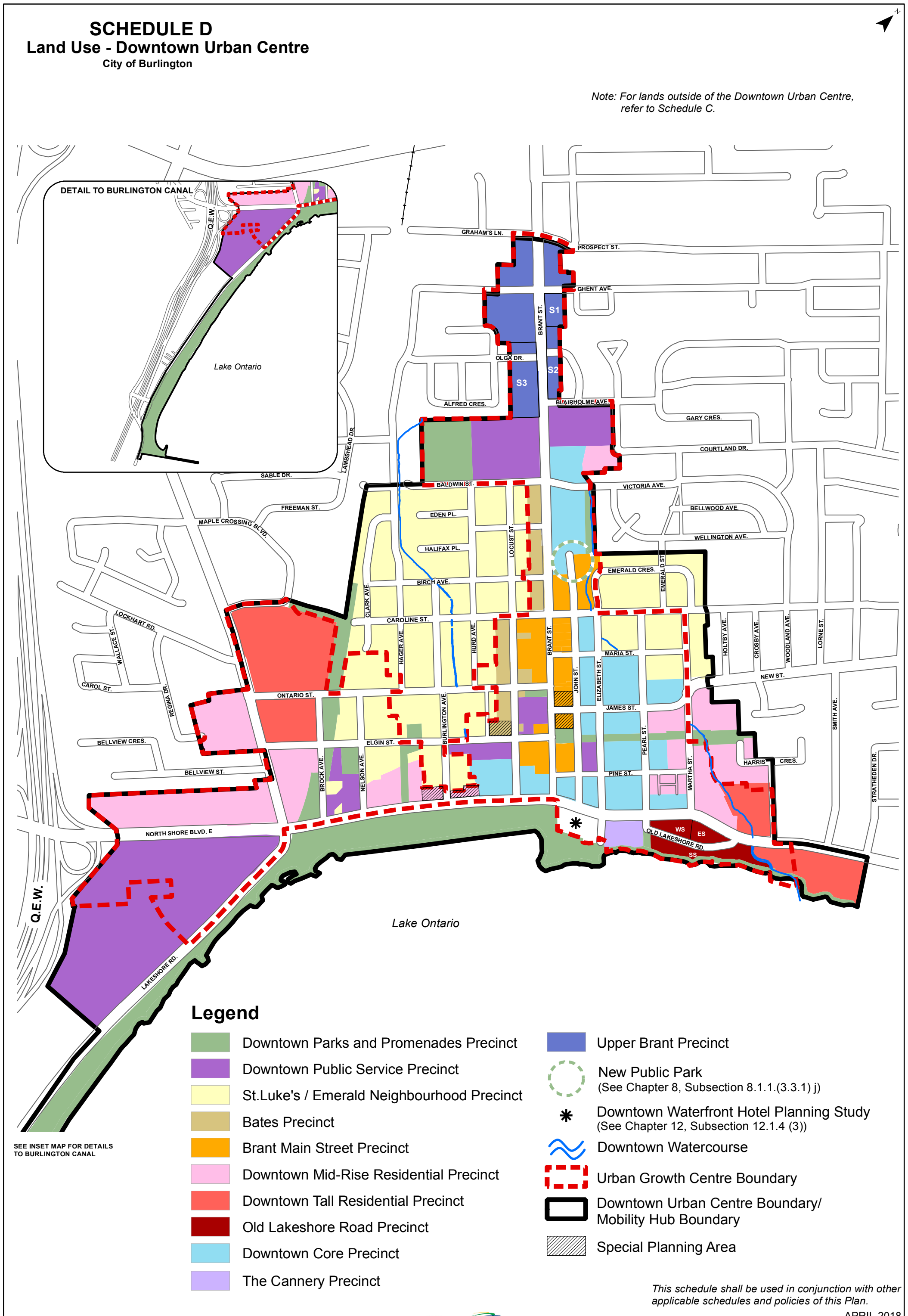


Figure 6: Adopted Official Plan Schedule D – Land Use – Downtown Urban Centre, 2018 showing the existing Precincts

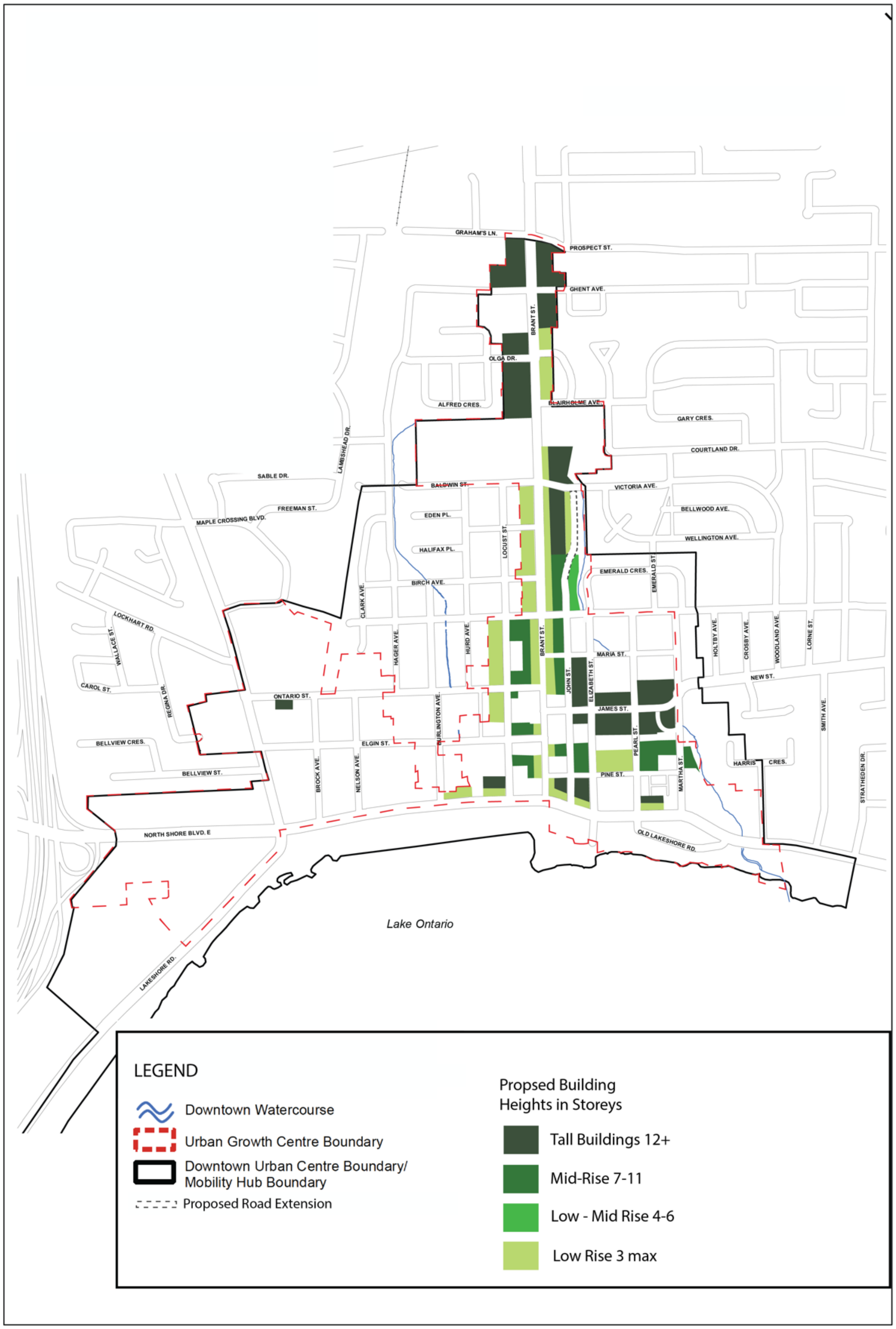


Figure 10: Concept 1 Building Heights

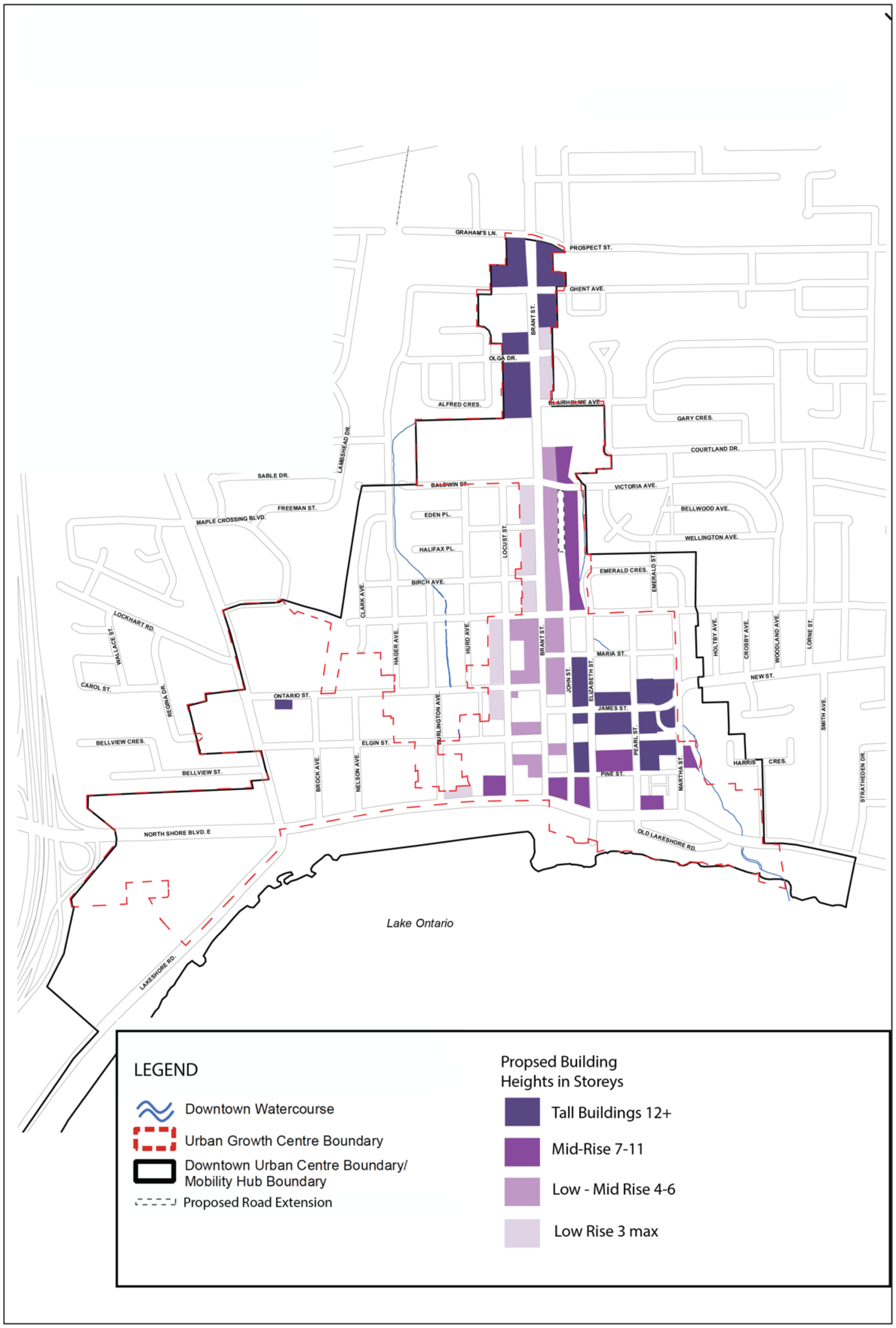


Figure 11: Concept 2 Building Heights

Appendix B

Background Information and Correspondence (Conservation Halton)

Memorandum

CONSERVATION HALTON – ENGINEER MEMO

Date: March 18th, 2014
To: Aaron Brouwers – AMEC Foster Wheeler
C.C.: Janette Brenner, Janelle Weppler
From: Jeff Lee and Cory Harris
Regarding: Hager Rambo Diversion Hydraulic Model Update

I am providing background information on the update to the generic regulations hydraulic model for the Hager Rambo diversion channel to be forwarded to AMEC Foster Wheeler for the August 4th, 2014 storm assessment for the City of Burlington. The model was originally developed in GIS using HEC-geoHMS and the 2002 terrain model. A cursory examination of the 2013 orthophoto imagery indicates very little change in land use in the flood plain since 2002. Therefore, the current update to the model was performed using the 2002 terrain data which is considered to have the highest vertical accuracy of the terrain models available. Design storm peak flows used in the model were obtained from Philips Planning and Engineering LTD (1997).

The model is comprised of three reaches:

a) **Main 1 diversion channel**: XS 3198.98 to XS 928.0883. Downstream from storm sewer draining storm water retention pond south of the CNR railway tracks and north of North Service Road to the confluence of the West Branch and the Main Branch diversion channel.

b) **Main 2 diversion channel:** XS 898.3339 to XS 54.645. Downstream from the confluence of the West Branch and Main Branch to immediately upstream of the culvert at the QEW.

c) **West branch diversion channel:** XS 1321.378 to XS 20.09473 Downstream from culvert outlet to the Freeman storm water retention pond to the confluence of the West Branch and Main Branch diversion channel

The original model did not have any structures. In the main branch, the dimensions for these were inputted into the model using the Bridge Data Sheets included in Phillips Planning and Engineering (1984). For the west branch, structure dimensions were obtained from engineering department pre-designed drawings. There may be discrepancies between these and actual values but staff who have walked these stretches of the channel are of the opinion that the actual values are very close to those from the pre-designed drawings. While the dimensions and shape of the structures are representative of what is observed in the field, all rectangular shaped culverts were assumed to be the following type:

Chart #: 10-90 degree headwall; Chamfered or beveled inlet:
Scale# 1- Inlet edges chamfered ¾ inch

Staff recommends that actual structure type be confirmed from report photographs or field reconnaissance. It should be noted that no dimension data were available for the bridge spanning Thorpe Road. Dimensions for this structure were assumed to be identical to that of the structure on Maple Avenue located roughly 250 m downstream. This information should be confirmed.

The bridge data sheets (Philips Planning and Engineering Ltd., 1984) included surveyed upstream structure invert elevations for the structures included in the model. The invert values were compared to the DEM derived channel inverts from the cross section immediately upstream from the structure to gain an understanding of the vertical accuracy of the DEM (Table 1).

Table 1. Comparison of DEM derived and surveyed channel invert elevations.

Location	**Surveyed Elevation (m)**	**DEM elevation (m)**	**Difference (m)**
Glenwood School Drive	99.74	99.18	0.56
CNR railway	96.69	96.59	0.10
Diversion Channel Inlet	94.06	94.38	0.32
Diversion Channel Brant / Fairview storm sewer	93.07	93.01	0.06
Diversion Channel CNR railway	90.51	90.94	0.43
Diversion Channel Maple Avenue	87.51	87.66	0.15
Mean			0.27
Standard Deviation			0.20

The average difference is roughly twice the MNRF recommended vertical accuracy value (± 12.5 cm) for DEM product used in flood plain modelling. Channel invert elevations between XS 1721 and 1412 should be checked for accuracy. Photographs from Philips Planning and Engineering (1984) suggest a more gradual grade transition between the bounding XS at the double circular culverts at the CNR tracks.

The DEM derived geometry is representative of what is observed in the main channel. However, at several locations in the West Branch, the geometry from the constructed channel depicts a V shaped cross section instead of the U shaped channel observed from photographs taken on site and field visits conducted by staff. When confirmed by photographs or staff, cross sectional geometry was modified to reflect a vertical drop in the channel walls at these locations.

At each cross section, channel widths were measured in a GIS using the digital orthophoto imagery to locate channel banks and bank stationing was adjusted where required.

Model output indicates that there are several spill areas where simulated flood waters are not contained within the DEM derived flood plain valley. An attempt was made to gain additional storage by extending cross sections lengths and by adjusting downstream lengths based on the center of mass of the flood plain between cross sections at areas of interest. Interestingly, these modifications had little impact on the extent of the floodplain or the spill. Spill areas were identified and are documented below for each modeled reach. These are identified on the maps based on the bulleted items label. The yellow arrows indicate the general flow direction of the spill.

Diversion Channel – Main 1 – Map 1 out of 2

A. Cul-de-sac at Glenwood school drive. Flowing south towards the CNR tracks.

B. CNR railway tracks: Flows south through the culvert at CNR tracks and may back up east in the ditch when culvert capacity is exceeded.

C. CNR railways spur line: Flows west through the culvert under railway spur line into a tributary draining to the diversion channel. Flows would also likely spill into the Cap-Brick property west of the Burlington GO Station.

D. CNR railway: water surface elevation from model output indicates that CNR railway tracks are overtopped (100.7m) with flow potentially flooding the car dealership and the Garden Centre / greenhouses.

E. Culvert at Fairview street: water surface elevation from model output indicates overtopping of Fairview with flow heading east on Fairview Street.

F. Diversion channel between XS: 2201 and 1991. Water surface elevation from model output indicates overtopping on the south side of the diversion channel. The spill is assumed to flow across the properties that back onto the diversion channel and front onto Edinburgh Drive. Flows would be conveyed within the Edinburgh Drive right of way in a westerly direction and south to Robinson Street. Model output indicates overtopping onto Fairview Street at the west end of the bermed section of the channel. Water is assumed to flow west to the Brant – Fairview intersection and flow south on Brant Street. Berm height on the south side of the channel is known to be higher than what is reflected on DEM. Berm elevation should be checked for accuracy where model output indicates flow spilling toward Edinburgh Drive.

Diversion Channel – Main 1 – Map 2 out of 2

G. Diversion channel between XS 1667 and 1443: Water surface elevation from model output indicates overtopping on the south side of the diversion channel. The spill is assumed to flow across the commercial properties to the catch basins on Grahams Lane. Overland flow is also assumed along the ditch on the east side of the CNR tracks

Diversion Channel – Main 2

H. Diversion channel between XS 554 and 454: Water surface elevation from model output indicates overtopping of the Maple Avenue Bridge. Intersecting the water surface with the DEM at the road surface suggests only partial overtopping of Maple Avenue. Water flow is assumed across the residential properties and on Lambs Court and to the catch basins at the intersection of Lambs Court and Stephenson Drive.

West Branch

I. CNR Track overpass on Plains Road: Water surface elevations from model output suggest that overland flow would spill to the east within the North ditch of Plains road to the catch basins on Plains Road within the CNR grade separation.

J. North CNR Ditch under QEW Niagara: Water surface elevation from model output suggest overland flow in a westerly direction within the north ditch of the CNR line to the Hydro substation west of the QEW and north of the CNR tracks. It should be noted that the spill at this location and at the CNR grade separation would probably mitigate the extent of the flooding in the residential neighborhood to the north east of the baseball diamonds.

K. West of Mapleview Mall Access Ramp: Water surface elevation from model output (between XS 485 and 508) suggests overland flow in a westerly direction onto Plains Road and into the Fairview intersection. Grades on the DEM indicate that flow would continue to spill to the east on Fairview.

Further modification of the model is recommended to further quantify and refine spill locations and boundaries.

Storm sewers are modelled as straight pipes. Roughness coefficients should be adjusted upwards to reflect friction losses due to the change of direction in the storm sewer alignment.

Disclaimer:

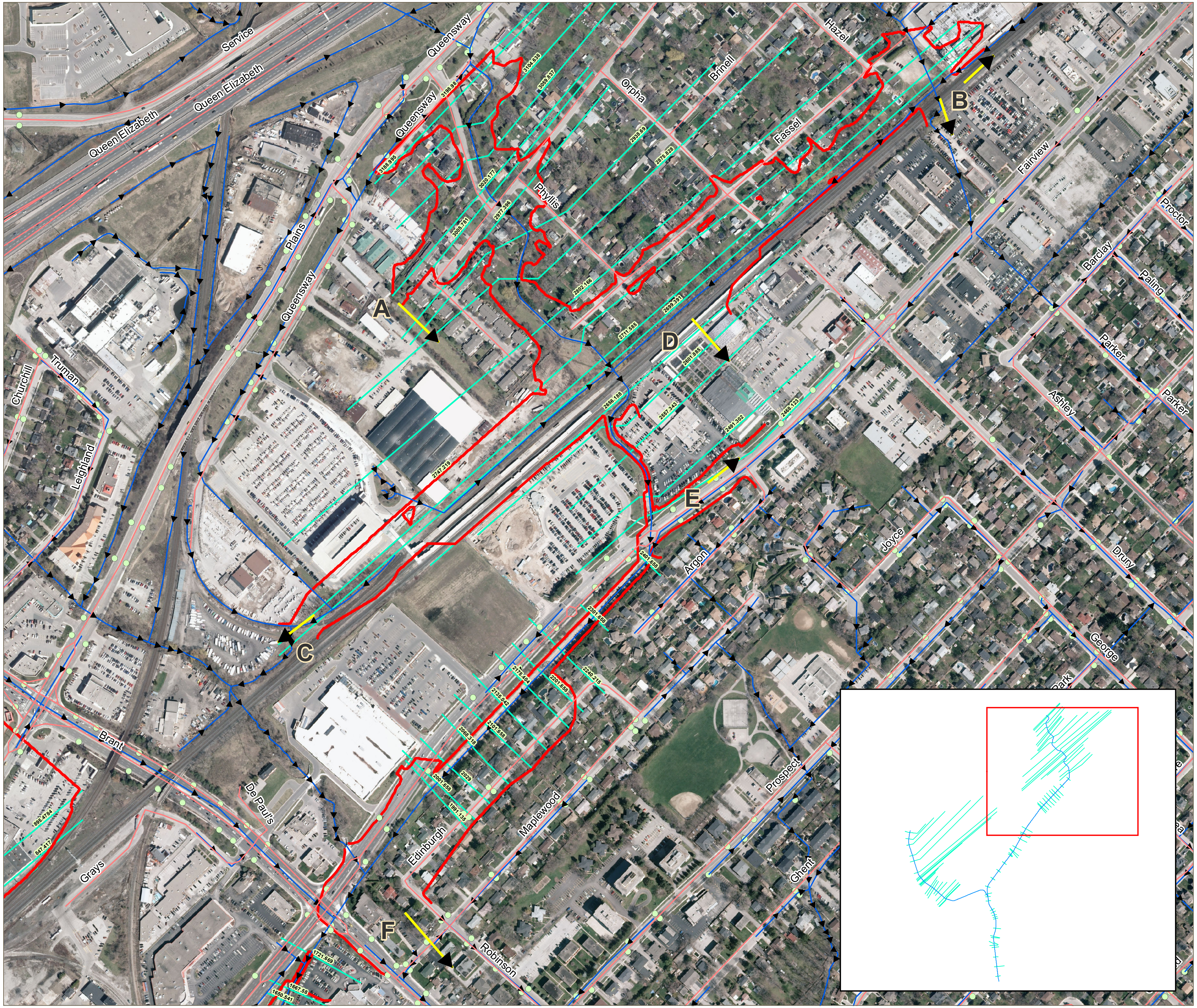
The preliminary generic regulation hydraulic models are being provided to AMEC Foster Wheeler ‘as is’ in order to assist with, and expedite analyses being completed on behalf of the City of Burlington relating to the Flood Vulnerability and Prioritization Study. Please be advised that the models provided are preliminary and have not been validated or approved by Conservation Halton staff at this time. Any refinements to the models must be properly documented at the relevant sections of the models and summarized for future reference. Once the revisions to the models have been made and the study has been completed, Conservation Halton staff requires that a digital copy of the updated models be returned for our records.

The models and any associated mapping were produced by Conservation Halton and should be used for information purposes only. Data sources used in its production are of varying quality and accuracy and all boundaries should be considered approximate.

References:

Philips Planning and Engineering, 1984 – Hager and Rambo Creeks Flood Control – Pre-Design Study – Volume 2: Appendices.

Philips Planning and Engineering, 1997 – Technical Summary Updated Hydrology – Indian Creek, Hager Rambo System, Roseland Creek



Hager-Rambo Diversion Channel Regional Floodplain

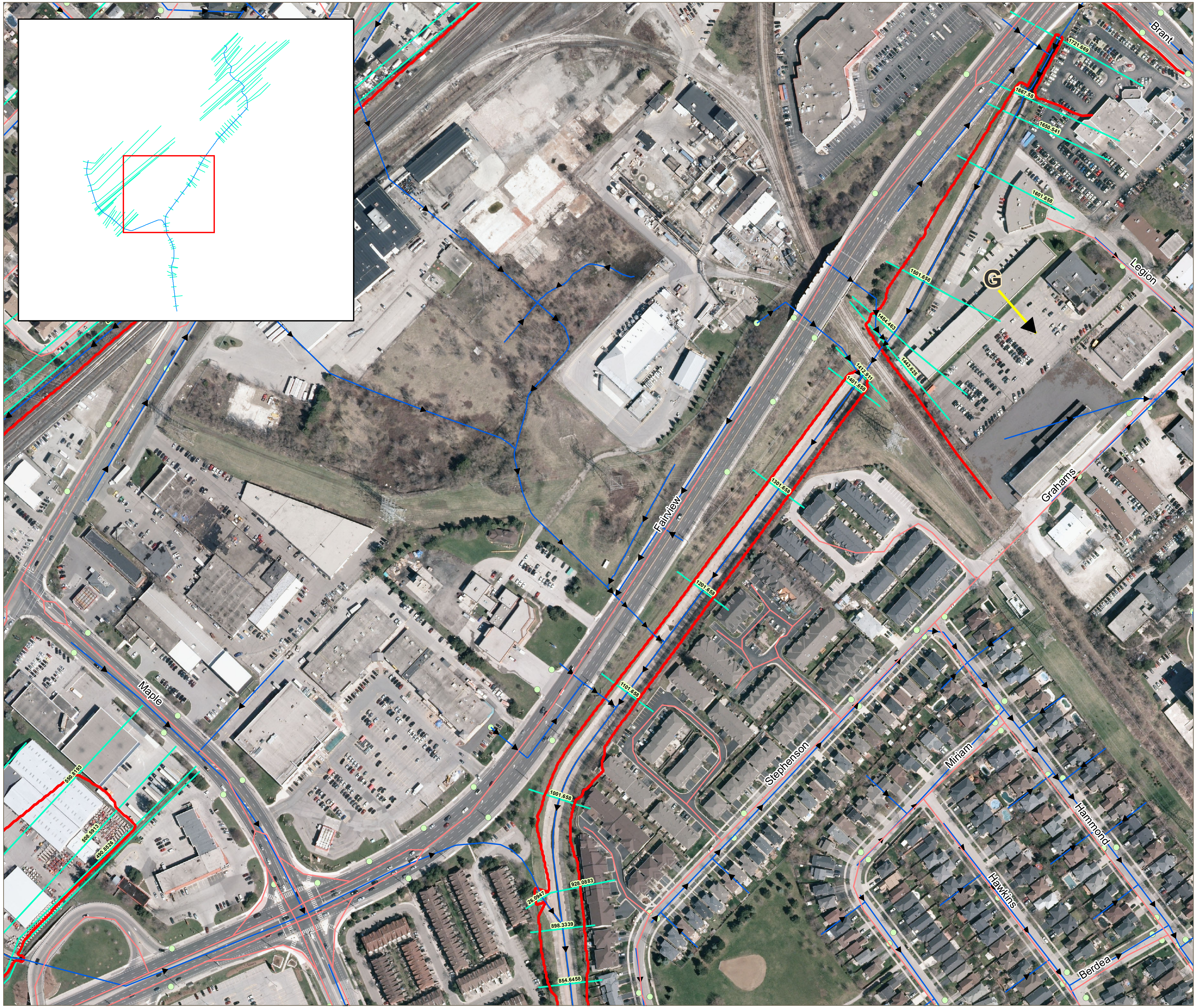
Diversion Channel - Main 1
1 Out of 2

Conservation Halton

Legend

- Roads
- Water Flow
- Catch Basin
- Modeled Regional Floodlines (Draft)
- Cross Sections

0 40 80 160 240 320 400 Metres



Hager-Rambo Diversion Channel Regional Floodplain

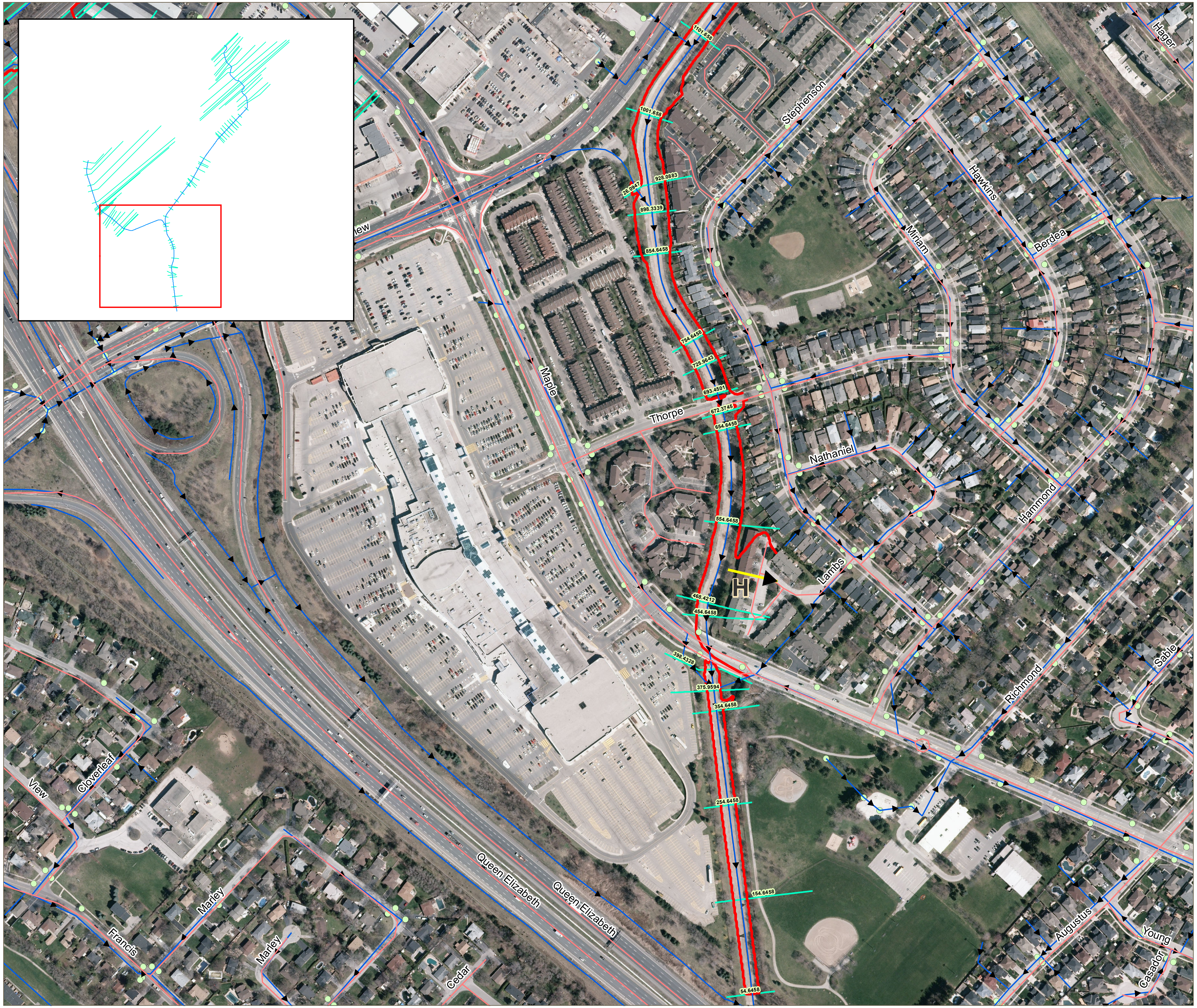
Diversion Channel - Main 1
2 Out of 2

Conservation Halton

Legend

- Roads
- Water Flow
- Catch Basin
- Modeled Regional Floodlines (Draft)
- Cross Sections

0 25 50 100 150 200 250 Metres



Hager-Rambo Diversion Channel Regional Floodplain

Diversion Channel - Main 2

Conservation Halton

Legend

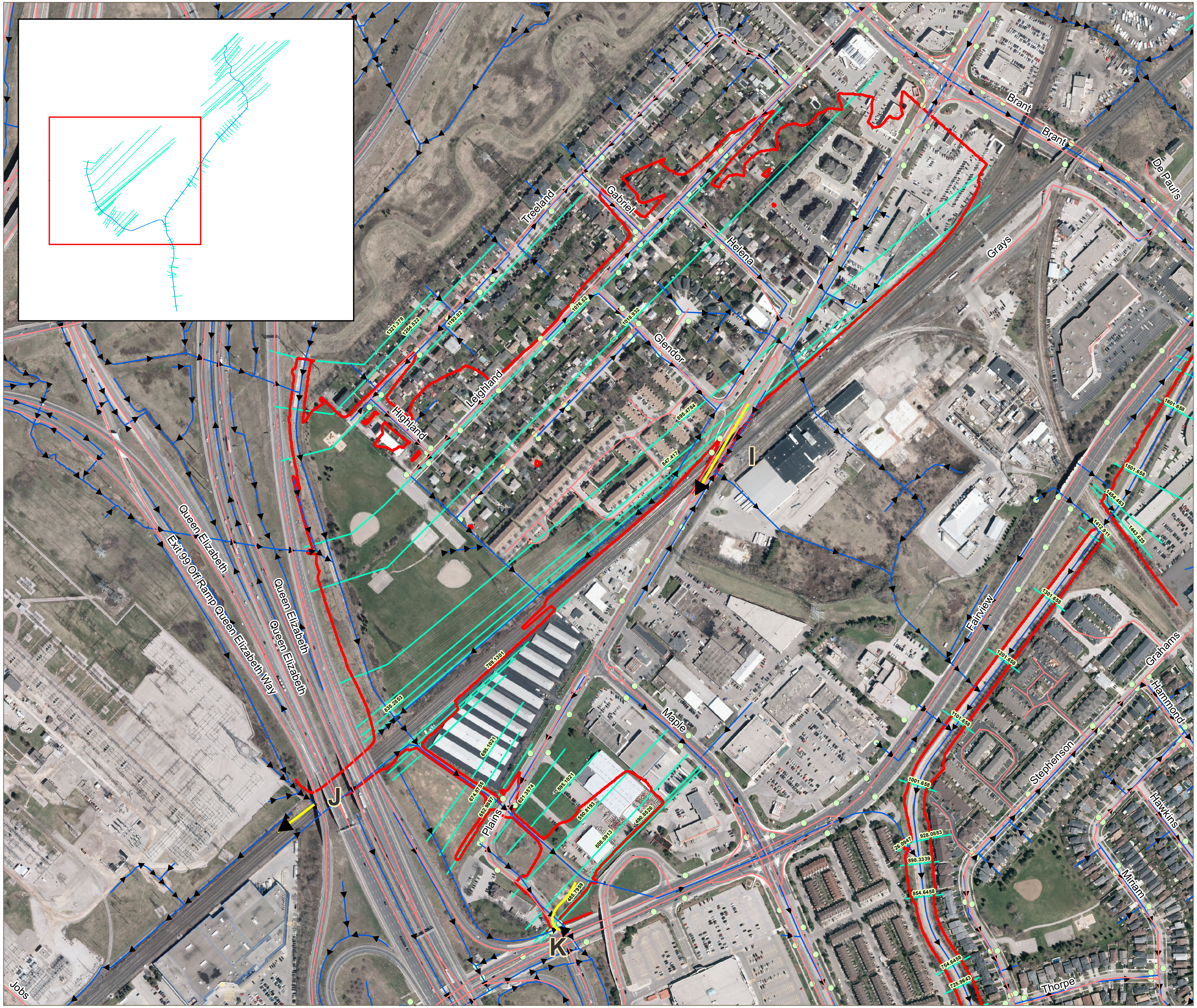
- Roads
- Water Flow
- Catch Basin
- Modeled Regional Floodlines (Draft)
- Cross Sections

0 30 60 120 180 240 300 Metres

Hager-Rambo Diversion Channel Regional Floodplain

Diversion Channel - West Branch

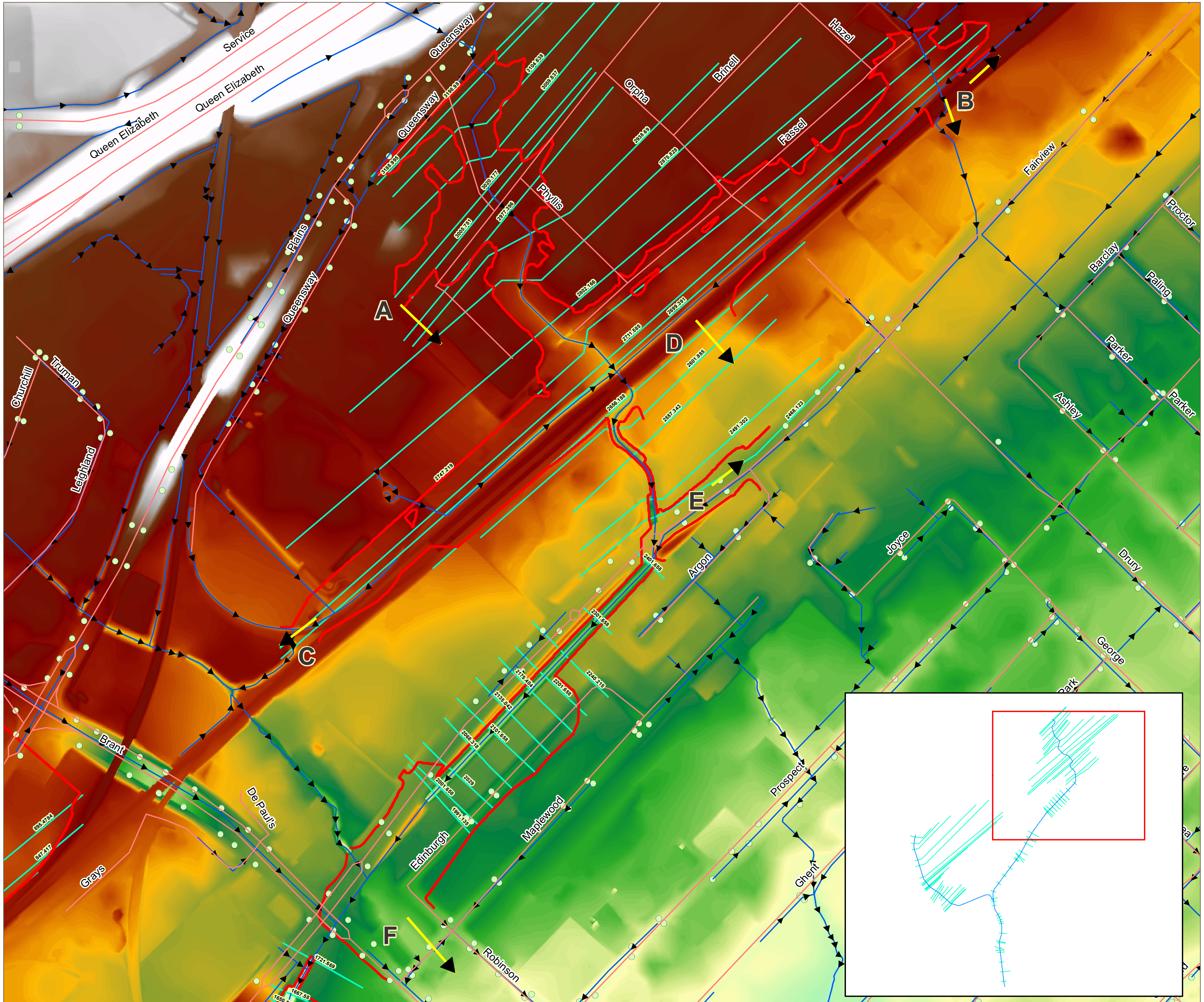
Conservation Halton



Legend

- Roads
- Water Flow
- Catch Basin
- Modeled Regional Floodlines (Draft)
- Cross Sections

0 40 80 160 240 320 400 Metres



Hager-Rambo Diversion Channel Regional Floodplain

Diversion Channel - Main 1
1 Out of 2

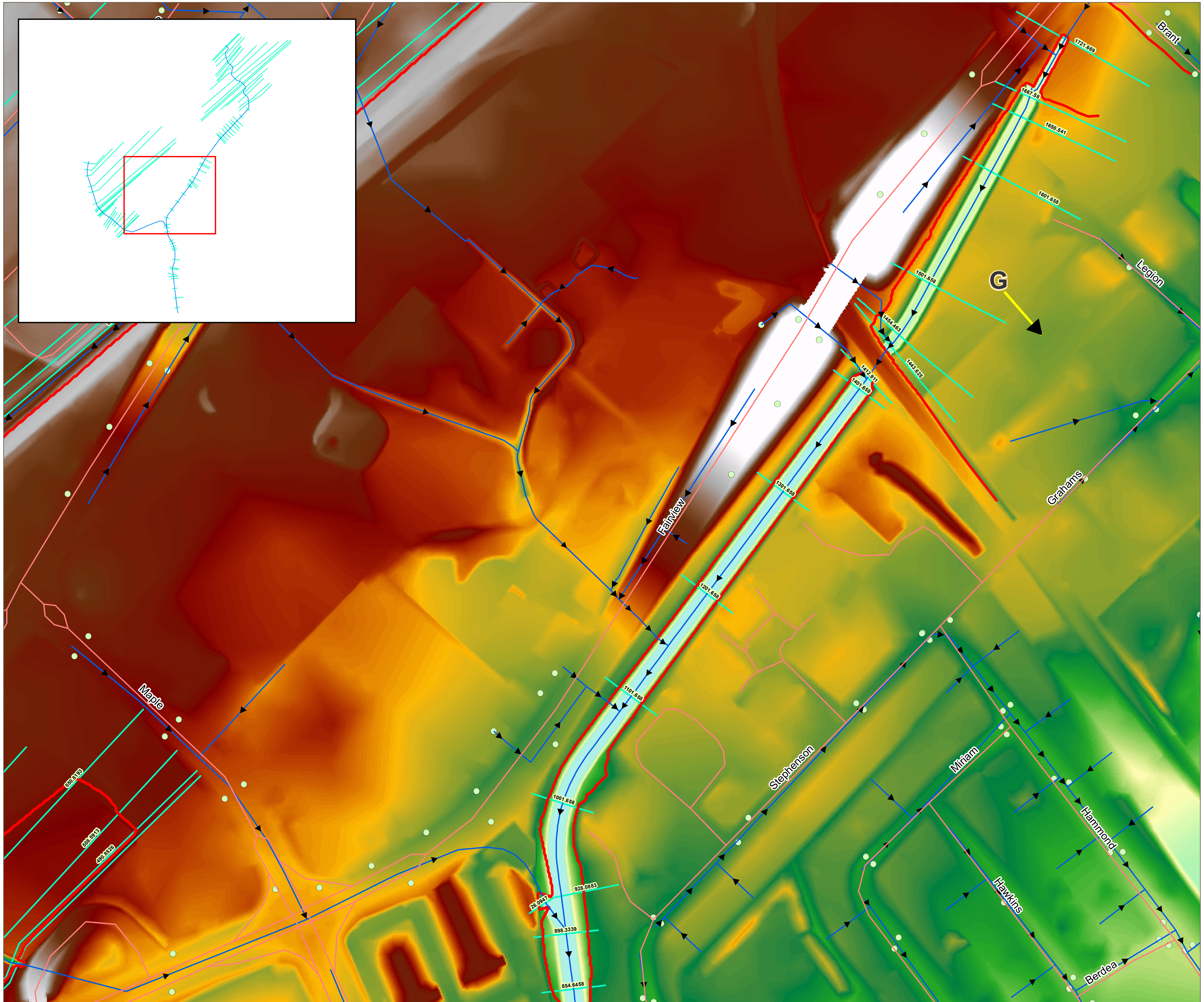
Conservation Halton

Legend

- Roads
- Water Flow
- Catch Basin
- Modeled Regional Floodlines (Draft)
- Cross Sections

Elevation (m)
High : 117.9
Low : 89.7

0 40 80 160 240 320 400 Metres



Hager-Rambo Diversion Channel Regional Floodplain

Diversion Channel - Main 1
2 Out of 2

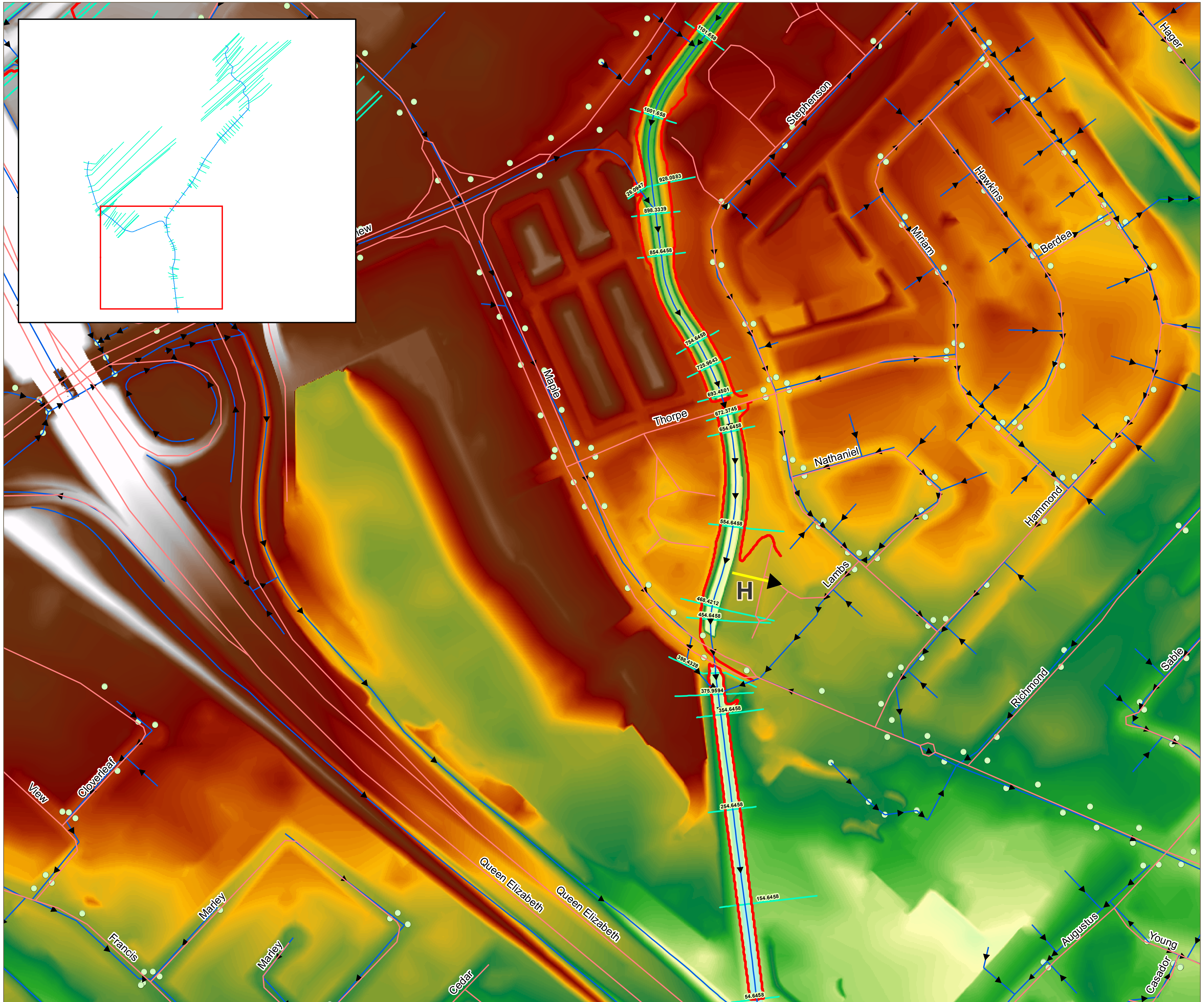
Conservation Halton

Legend

- Roads
- Water Flow
- Catch Basin
- Modeled Regional Floodlines (Draft)
- Cross Sections

Elevation (m)
High : 106.8
Low : 88.9

0 25 50 100 150 200 250 Metres



Hager-Rambo Diversion Channel Regional Floodplain

Diversion Channel - Main 2

Conservation Halton

Legend

- Roads
- Water Flow
- Catch Basin
- Modeled Regional Floodlines (Draft)
- Cross Sections

Elevation (m)

High : 108.1

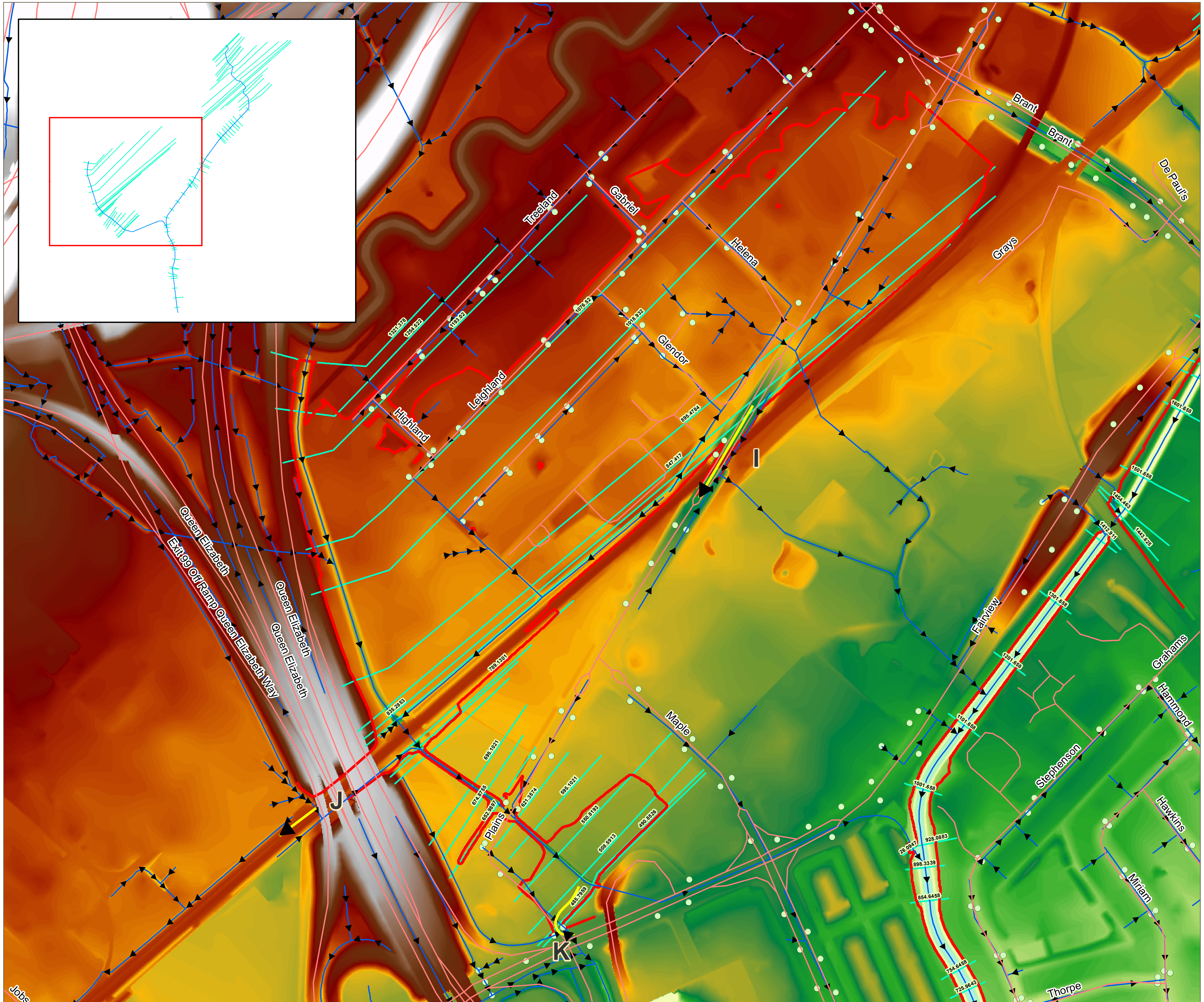
Low : 85.8

0 30 60 120 180 240 300 Metres

Hager-Rambo Diversion Channel Regional Floodplain

Diversion Channel - West Branch

Conservation Halton



Legend

- Roads
- Water Flow
- Catch Basin
- Modeled Regional Floodlines (Draft)
- Cross Sections

Elevation (m)

High : 121.2

Low : 88.5

0 40 80 160 240 320 400 Metres

March 6, 2017 (Updated April 25, 2017)
Our File: TPB178008-04

City of Burlington
426 Brant Street
Burlington, ON L7R 3Z6

Attention: Phillip Caldwell, MCIP RPP, Senior Planner

Dear Sir:

Re: Scoped Environmental Impact Studies Work Plan, Mobility Hubs Planning

Brook McIlroy Inc.'s (BMI) proposal for Consulting Services for the City of Burlington Mobility Hub Planning (December 12, 2016) outlined a Work Plan that included departures from the Terms of Reference (TOR) agreed to between the City and Conservation Halton and Region of Halton and outlined in RFP-239-16 (November 17, 2016). The changes to the TOR were proposed by Amec Foster Wheeler and Dillon Consulting in order to provide cost efficiencies to accommodate the City's project budget, and related specifically to the *Scoped Environmental Impact Studies* as defined in Appendix G *Environmental Impact Study Preliminary Guidance For Study Components and Technical Requirements* in the RFP. The intent of this letter is to more clearly communicate the changes to the TOR for the Environmental Impact Study presented in BMI's December 12, 2016 proposal. It is intended that this letter and attachments are read in conjunction with BMI's December 12, 2016 proposal.

On February 14, 2017 staff from the City of Burlington, Conservation Halton, Amec Foster Wheeler and Dillon Consulting met to discuss the Work Plan for the Scoped Environmental Impact Study. The discussion focused on identifying the changes proposed to the TOR and the objective was to obtain agreement between the City, Conservation Halton and the BMI Team on the proposed Work Plan such that there was a consensus moving forward. In an effort to clearly and concisely summarize the proposed changes to the TOR, the original TOR have been modified and changes have been tracked. The changes proposed by Amec Foster Wheeler to *Section 6.0 Stormwater Management and Riverine Hazards* and by Dillon Consulting to *Section 5.0 Environmental Studies and Analysis* and *Section 7.0 Supplementary Information* have been integrated in Attachment A. As noted above, it is intended that this letter and Attachment A are read in conjunction with BMI's December 12, 2016 proposal. Further, Attachment A is intended to clarify our original proposal, not replace it – if the City perceives an inconsistency between the December 12, 2016 proposal and Attachment A, please bring it to the attention of the BMI Team.

Five (5) key study gaps related to *Stormwater Management and Riverine Hazards* have been identified and are summarized below. The proposed gap-filling approaches and study-risks related to potential out-of-scope work are discussed in Attachment A to this letter.

1. Uncertainties remain on policy perspectives related to Regulatory flood control and specifically the Hager-Rambo Flood Control System. Conservation Halton agreed to review this matter further and advise on how the Authority will seek to apply policy. Background related to this issue is discussed in Section 6.3 a) x).

2. Flood risk in the Burlington and Downtown Mobility Hubs related to a potential breach of the Freeman Pond and/or West Hager Pond, two of the three flood control facilities that are part of the Hager-Rambo Flood Control System, is a potential gap. Amec Foster Wheeler has outlined preliminary assessments that are proposed and is expected to determine if additional study is required as part of the Mobility Hub Planning.

3. Flood spills have been identified in several locations along the Hager-Rambo Diversion Channel however the associated spill path(s) through the Burlington and Downtown Mobility Hubs and the potential impact on future development is a gap. Amec Foster Wheeler has outlined preliminary assessments that are proposed to be completed and are expected to provide 'high-level' guidance on the flood hazard associated with the spill(s). The level of flood risk prescription that can be obtained within the existing Work Plan scope is uncertain and additional study will be required. The limitations of the assessment are discussed in Section 6.3 a) x).

4. The Work Plan proposes a high-level risk assessment for erosion potential related to future development in the Mobility Hubs. Where erosion potential is determined to be 'low' and the Technical Advisory Committee (TAC) agrees that no further study is required, the proposed Work Plan will meet study objectives. If erosion potential cannot be satisfactorily screened by proposed Work Plan, study gaps may exist. Gaps relate to the potential need to establish erosion thresholds downstream of the Mobility Hubs, and the potential need to undertake continuous hydrologic simulations to complete an erosion duration analysis in support of establishing the criteria for future erosion control requirements. Section 6.2 e) (2) provides additional detail on the proposed approach.

5. Conservation Halton staff have noted they will consider regulating Lower Hager and Lower Rambo Creeks; staff to advise. No implications to the Work Plan are expected.

Additional comments from Conservation Halton (received via e-mail March 23, 2017, secondary comments received via e-mail April 20, 2017) have also been updated into the current revised work plan. To summarize the changes resulting from this additional round of comments:

1. Page 6 of PDF (5.0 - Table A) – Aldershot has been revised to a "Yes*", based on the qualifiers and conditions outlined under the "*".
2. Page 10 of PDF (5.0 – Water Quality/Benthic Invertebrates) – Asteriks added for Burlington and Appleby Line.
3. Page 11 of PDF (5.0 – Stream/Drainage Corridor and Storm Sewer Outfall Assessment) Falcon Creek and Glen Wood Creek have not been included in the Table. Falcon Creek is not located within the Aldershot Mobility hub area, and Glenwood Creek has only a minor amount within the area. Qualifying wording has been added to the text that an assessment may be required if it is determined that there is any expected hydrologic impact to these features; if necessary this work would be beyond the current scope. Table B within Section 6.0 (Hydrologic Modelling Requirements) has been similarly updated.

4. Page 17 of PDF (6.2 e) 3) – Proposed Hydrology/Stormwater Management) – Revised wording to include assessment of *preliminary potential* flood mitigation controls in the event of spill. Any detailed measures or assessments would be beyond the scope of the current study and are therefore not included.
5. Page 22 of PDF (6.3 a) x) – Hager-Rambo Diversion Channel & Flood Control System) – wording has been revised to clarify that the system to be assessed will include the channels between the ponds and the diversion channel (although spills will only be assessed at a high level, as noted in the revised terms of reference). This also assumes that the hydraulic models are readily available for these reaches in a usable state. Reference has also been included to the East Rambo Pond (it has been assumed that this is what was being referred to, rather than the East Hager Pond, as no such feature is known to exist beyond the QEW/North Service Road drop structure, which has no storage or attenuation function).

We trust the foregoing is consistent with our discussion on February 14, 2017 and provides an adequate basis upon which to advance the Work Plan for the Scoped Environmental Impact Studies.

Sincerely,

Amec Foster Wheeler Environment & Infrastructure
a Division of Amec Foster Wheeler Americas Limited

Per: Ron Scheckenberger, P.Eng.
Principal Consultant

Per: Matt Senior, M.A.Sc., P.Eng.
Project Engineer

AB/ls/MJS/RBS

c.c. David Sajecki, Brook McIlroy Inc.
Daniel Bourassa, Dillon Consulting
Allen Benson, Dillon Consulting
Justine Giancola, Dillon Consulting
Jeff Hirvonen, GeoProcess

APPENDIX G

ENVIRONMENTAL IMPACT STUDY
PRELIMINARY GUIDANCE FOR STUDY COMPONENTS AND TECHNICAL REQUIREMENTS

DISCLAIMER

Please note that information contained in this Appendix has been provided by partner agencies to the City of Burlington. Given the urban context of the Mobility Hub study areas, additional scoping/elimination of study requirements identified within this Appendix will be explored with the chosen project consultant to ensure study's focus is less on characterization of existing features and more on restoration and enhancement opportunities.

The chosen project consultant will be required to submit a work plan for the Environmental Impact Studies upon awarding of the project contract which will identify an environmental scope of work reflective of the existing urban context of the Mobility Hub study areas and based on the consultant's own past experience as well as other best practices for similar studies. The project consultant's proposed work plan will be evaluated by the City of Burlington and partner agencies through a technical advisory committee (TAC)

1.0 STUDY PURPOSE

The purpose of Environmental Impact Studies in each Mobility Hub area is generally to:

- Inventory, characterize, and assess existing environmental conditions including natural hazards, natural heritage and water resource features and areas;
- Provide recommendations for the protection, restoration, and enhancement, where feasible, of natural heritage, and water resource features and areas;
- Provide recommendations for management and mitigation of natural hazard and other constraints, where feasible;
- Provide sufficient detail to support the designation of the Natural Heritage System (NHS), through refinement of the Regional Natural Heritage System (RNHS), as well as identifying areas for future development;
- Refinement of the Regional Natural Heritage System for the Study Area and development of a Natural Heritage System Restoration and Enhancement Plan to be implemented through redevelopment and private and public land stewardship as part of an innovative Environmental Management Strategy for each study area;
- Conformity with applicable Provincial, Regional, and City land use planning policies, including Section 145(9) of the Regional Official Plan, and applicable Conservation Halton Policies;

- Establish procedures for monitoring water quality and quantity before, during and after development; and
- Other objectives and goals as proposed by the project consultant in their final work plan.

2.0 STUDY PROCESS/PHASING

The Environmental Impact Studies should be broken into the following phases to allow for feedback from relevant technical reviewers/agencies:

- Phase 1 – Background Review and Characterization
- Phase 2 – Analysis
- Phase 3 – Management Strategy Development
- Phase 4 – Implementation and Monitoring

The Environmental Impact Studies will both inform and be informed by the land use scenarios developed as part of the Area Specific Planning process. As a result, study phases should be prioritized based on the information required to inform the delivery of stage 1 and stage 2 project deliverables as established in the Terms of Reference and may include the undertaking certain phases concurrently.

The final Environmental Impact Studies should be completed prior to the approval of Area Specific Plans.

3.0 ADVISORY COMMITTEES/MEETINGS

Work undertaken as part of the Environmental Impact Studies will be reviewed by a technical advisory committee (tac) with representation from the project consultant, the City of Burlington, Region of Halton and Conservation Halton.

4.0 STUDY CONSIDERATIONS

Urban Context – Environmental Impact Studies/Sub-Watershed Studies such as those required within each Mobility Hub area are typically conducted in undeveloped greenfield settings. The existing urban nature of all four Mobility Hub study areas should be considered when undertaking the Environmental Impact Studies.

Innovative Implementation Strategy – Given the urban nature of the Mobility Hub study areas, the Environmental Management Strategy prepared at the conclusion of the Environmental Impact Studies should consider innovative implementation tools not typically considered in relation to Area Specific/Secondary Plans in greenfield areas. As greenfield development will not be the primary mechanism relied on for implementation, policies targeted primarily at guiding future development will not be the best way to fulfill the majority of the recommendations. Redevelopment, public land stewardship, public works relating to natural hazard mitigation and stormwater infrastructure “greening”, targeted ecological restoration projects and community education and stewardship may be more relevant tools in these studies. As a result, the studies should explore utilizing a broadened set of implementation tools to reflect the urban context of these areas.

5.0 ENVIRONMENTAL STUDIES AND ANALYSIS

Table A Environmental Studies and Analysis

Required Environmental Studies/Analysis	Aldershot	Burlington	Downtown	Appleby
Hydrogeologic Assessment following CH Requirements for Completion of hydrogeological studies to facilitate Conservation Halton's reviews http://www.conservationhalton.ca/policies-and-guidelines	Yes*	No*	No*	No*
Identification of the extent of Hazard lands within the hub study area in accordance with MNRF guidelines and Conservation Halton policy and guidelines http://www.conservationhalton.ca/policies-and-guidelines.	Yes*	Yes*	Yes*	Yes*
Flooding Hazard Assessment	Yes	Yes	Yes	Yes
Erosion Hazard Assessment	Yes	Yes	Yes	Yes
Coastal hazard assessment			Yes	
Natural Heritage Studies/ System (see Table D in 7.0)	Yes*	Yes*	Yes*	Yes*
Species at Risk Consultation with the Ministry of Natural Resources and Forestry (MNRF)	Yes	Yes	Yes	Yes
Hydrologic/hydrogeologic evaluation and water balance for the wetlands	Yes*			
Stream classification, fish community inventory and fish habitat assessment	Yes	Yes	Yes	Yes
Water quality evaluation (including water chemistry and benthic invertebrates)	Yes	Yes	Yes	Yes
Stormwater management mitigation plans	Yes	Yes	Yes	Yes

Please note that where **Yes*** is indicated please refer to the proceeding Notes section below.

<u>**Table A**</u> <u>Notes:</u>

- <u>Hydrogeologic Assessment:</u> For the Burlington Mobility Hub, Downtown Mobility Hub and Appleby Mobility Hub the hydrogeologic assessment will rely on available borehole information to screen for the feasibility and provide future design guideance (where proposed) for subsurface green infrastructure (LID's). The basic information collected from existing available borehole data would include groundwater levels, soils types, infiltration rates, etc. For the Aldershot Mobility Hub, the following is included in the Work Plan:

- Review CH information including regulations mapping
- Review 1200 King Road data (spring and summer)
- Conduct a field reconnaissance to observe any changes and possible points of water discharge (either surface and / or groundwater)
- Establish micro-topography to define surface water catchment zone
- Develop details of a future monitoring assessment program

With regard to the foregoing, it is expected that following the execution of this scoped investigation there would be a better understanding of the composition and function of the wetland including its possible zone of influence on surface water contribution. This understanding will then inform the potential extent of the constraint, while providing direction on water management strategies and also the form of future studies.

- Identification of Natural Hazard lands: To determine the hazard limit associated with valleys (defined and undefined), both the flooding and erosion hazards are to be considered. The hazard limit is set by the greater of the flood or erosion hazard, plus the applicable development setback based on the appropriate policy and regulatory requirements. It should be noted that additional buffers and/or corridor widths may be needed in consideration of other factors introduced by the study assessment including, but not limited to, the protection of ecological and hydrologic functions such as critical function zones and impacts to adjacent lands.

- Natural Heritage Studies/ System: Natural heritage studies are completed in order to identify and further delineate the existing Regional Natural Heritage System (RNHS). Natural heritage investigations/studies will be conducted while using the guiding policy framework of the RNHS within the Regional Official Plan Amendment No. 38 (ROPA 38). They will provide an appropriate level of detail for the planning analyses such that the components of the RNHS (Key Features; Enhancement Areas and Linkages) can be identified and associated functions characterized. Once the RNHS and its key features are identified and delineated potential impacts of the proposed Secondary Plan and restoration or enhancement opportunities can be presented. Standard field studies include, but are not limited to, Ecological Land Classification (ELC), wetland delineation (using ELC), vegetation surveys, breeding bird surveys, and amphibian breeding surveys. It is noted that for the next stage of study OWES will be required.

Understanding the urban nature of the Mobility Hub study areas and the importance of interconnecting the core areas and key features of the RNHS, there will be a focus on identifying opportunities to use a combination of ecological restoration, natural hazard mitigation (excluding structural technicques), stormwater infrastructure, parks, etc. to establish both active and passive City of Burlington - Mobility Hub Planning Brook McIlroy/ connections with the natural environment. Where this may not be possible, other options such as community education and stewardship programs will be proposed, to establish this connection between residents and the environment.

A Natural Heritage study for the Aldershot GO Train Station lands as well as those lands immediately adjacent has recently been initated. Therefore, the study requirements for those portions of the study area with the Aldershot Mobility Hub area may already be underway and could inform/suppliment additional environmental work required in the study area. Please note that there are additional natural areas within the study area that will need to be assessed using the same criteria.

Based on consultation with CH Planning Ecologists, the following terrestrial field studies will be required for each of the Mobility Hubs. The table below should be read concurrently with ***Attachment A***, Figures 1 through 4, which illustrate the portions within each of the Mobility Hub study areas where field studies will occur.

Terrestrial Field Studies	**Aldershot**	**Burlington**	**Downtown**	**Appleby**
Ecological Land Classification	✓	✓	✓	✓
Wetland Delineation	✓*			✓*
Vegetation Inventory	✓	✓	✓	✓
Breeding Bird Surveys	✓	✓	✓	✓

**Presence of wetlands to be confirmed through ELC.*

A more fulsome list of the terrestrial and aquatic natural heritage studies that may be considered has been included in Section 7.0, Table D of this Appendix.

- Species at Risk: Species at Risk (SAR) listed as Endangered or Threatened under *Ontario Regulation 242/08* are afforded both species and habitat protection under the Ontario *Endangered Species Act* (ESA), 2007. The MNRF will be consulted to request relevant SAR occurrence records pertaining to each of the four Mobility Hub study areas. This information will be used to help identify potential SAR and SAR habitat within each of the study areas. Although incidental observations of SAR and/or potential SAR habitat will be noted during field surveys, it is important to note that this work plan does not include any work that may be required under the ESA (i.e., additional surveys, permitting, etc.).

Should species-specific surveys or permitting be required by the MNRF, Dillon has qualified staff (e.g., qualified Butternut Health Assessors, etc.) that can provide the City with these services, as required (Note: SAR mapping will not be on any publicly available mapping).

- Stream Classification: For each of the four Mobility Hub study areas, stream classification of existing watercourses will be established to determine either the required and/or appropriate setbacks for protection from proposed development. Required setbacks are established by CH through a number of policies differentiating between major and minor valley systems. Appropriate setbacks are established by using all available information including sensitivity of features, background reports (i.e., Sustainable Halton reports, etc.), experience in similar situations and potential impacts of proposed adjacent land uses in order to protect the form and function of the watercourse features (Note: the greater of the required or appropriated setback will be identified as a development constraint). Potential restoration and enhancement opportunities will also be considered wherever possible. Stream classification will rely on existing information (e.g., fish community sampling etc.) where available to determine stream type (permanent, intermittent, ephemeral), thermal regime, and whether streams provide suitable fish habitat. Other parameters to consider when determining suitability for fish habitat include riparian and in-stream cover, stream morphology, nutrient inputs etc. Where no information is available site visits may be required to collect information on stream characteristics, fish community sampling, thermal regime, etc. TAC to be included on site walks involving consideration of classification of watercourses.

- Water Quality/Benthic Invertebrates: In two (2) recent/ongoing Secondary Plans (Halton Hills/Mississauga), Amec Foster Wheeler consultatively worked with CH and the area municipality to defer the water quality (chemistry) and benthic invertebrates investigations. The rationale, which was ultimately supported by CH, was based on the perspective that the information collected rarely, if ever, influences land use decisions. Stormwater Management practices need to (most often) meet the highest standards, therefore water chemistry/benthic invertebrates also does not drive the level of protection for the receiving systems (watercourses or Lake). On this basis, the main utility of these data comes forward during the monitoring phase following development. In order to determine the efficacy of the various management practices in mitigating the impacts of development, baseline monitoring (water chemistry/benthic invertebrates) is considered useful and important. Notwithstanding these data are most appropriately collected closer towards the period of planned land use change. Therefore, based on the foregoing, as part of this task, it is proposed to develop the scope of an appropriate water quality and benthics sampling program for each Mobility Hub to be executed as part of a future investigation.

Based on consultation with CH Planning Ecologists, the following aquatic field studies will be required for each of the Mobility Hubs. The table below should be read concurrently with ***Attachment A***, Figures 1 through 4 which illustrate the portions within each of the Mobility Hub study areas where aquatic studies will occur.

Aquatic Field Studies	**Aldershot**	**Burlington**	**Downtown**	**Appleby**
Stream Classification	✓	✓*	✓*	✓*

**Daylighted portions of the Lower Rambo Creek, north of the Centennial Pathway and isolated portions in the Burlington and Appleby Hubs to be included in assessment. Locations of daylighted portions to be confirmed by CH.*

- <u>Stream/Drainage Corridor and Storm Sewer Outfall Assessment:</u> The various open watercourse corridors in the respective study areas provide important functions for the natural environment, as "natural" conveyance infrastructure (drainage system), riparian habitat and socially by preserving and enhancing open space. In order to continue these functions in the long term, it is important to determine current functionality and from this establish means for enhancement/restoration in the context of future development concepts. The primary corridors proposed to be assessed as part of this study include:

Aldershot *	Grindstone Tributary, West Aldershot Creek, LaSalle Creek, Forest Glen Creek, Teal Creek
Burlington	East/ West Rambo Creek and Roseland Creek
Appleby	Appleby Creek, West Sheldon Creeks, and Shoreacres Creek
Downtown	Lower Hager and Rambo Creeks

* *Additional assessments <u>may</u> be required for Falcon Creek and Glenwood Creek if it is determined* that these receivers *will experience hydrologic change due to the proposed Mobility Hubs development. This additional work would be determined pending discussions through the Technical Advisory Committee and review of the sewershed mapping.*

The scope of this review will include field reconnaissance by a Drainage Engineer, Aquatic Ecologist and a Fluvial Geomorphologist. Based on the visual review, the following will be identified and mapped:

- Bank treatment/areas for stabilization
- Aquatic/riparian habitat
- Stream stability

- Vegetation
- Storm outfalls and neighbouring land uses.

The foregoing approximate mapping exercise will then be used as a base for developing a framework for a restoration/rehabilitation plan for each system. Each watercourse will also be investigated for mitigation or rehabilitation opportunities, with the objective of maximizing the remaining natural potential of the watercourse's form and function (where feasible). This will include a rapid investigation of reach-wide channel stability and identification of causes of instability, where present. For areas where opportunities for mitigation or improvement exist, high level recommendations will be proposed to address key imbalances between the conveyance of flow and sediment. In development of these recommendations the Study Team Fluvial Geomorphologists will work closely with the Study Team Water Resources Engineers to ensure conceptual plans are feasible and sustainable in the long term.

In addition, one of the considerations cited in the TOR relates to potential "day lighting" of enclosed watercourses. These opportunities and their implications on area infrastructure will be reviewed at a high-level as part of this task.

6.0 STORM WATER MANAGEMENT AND RIVERENE HAZARDS

The following sections are intended to provide an overview of select components that are to be assessed as part of the Environmental Impact Studies. It is also to identify the minimum requirements for the study. The project consultant will be required to prepare a final work plan to further detail and refine the information set out in the Request for Proposal and associated appendices. The background and characterization, analysis and reporting work must be completed to the satisfaction of the advisory committee.

It should be noted that although each study component has been discussed separately, all components are to be looked at comprehensively and in an integrated manner. This will also help to ensure that the objectives that have been established for the study area have been met. All of the work described below is to be completed by a licensed professional (Engineer and/or Geoscientist as appropriate. All final reports and maps are to be signed and sealed.

6.1 Existing Hydrology

The project consultant will be required to:

a) Undertake a review of previous subwatershed and stormwater management studies, aerial photos, topographic base maps, flow records, high water marks, precipitation records, and existing "Permits To Take Water" within and upstream of the study areas;

b) Develop and verify physical feature mapping of the subwatersheds, including subwatershed boundaries, upstream catchment areas, watercourses, drainage swales, wetland features, undrained depressions, other drainage improvements, land use, levels of directly and indirectly connected imperviousness, existing stormwater management features, etc. and ensure these are represented in the models;

c) Refine or develop (where required) hydrologic models to be used for each subwatershed area. Refer to Table 1.1 provided below, which summarizes the status of available modelling. The models should be deterministic hydrologic models, capable of continuous simulation (if required, see (i).) with strong physical representation of surface runoff and infiltration, channel storage, base flows, and for the Aldershot mobility hub, a more detailed understanding of the surface/groundwater interaction;

    i) Continuous simulation has not been included in the proposed Work Plan. See Section 6.2 e) (2) for implications to the erosion assessment.

d) Document and justify hydrologic modeling parameters;

e) Determine sub-basins to establish nodes at points of interest;

f) Model selection, parameterization, and extent are to be approved by the advisory committee;

   i) The Work Plan assumes the existing models identified in Table B are approved. Model parameterization will be reviewed to ensure previous assumptions are supportable. Adjustments to model discretization/parameterization are expected within Mobility Hub study areas, however watershed wide re-parametrization of existing models has not been included, nor is it expected to be required.

g) Calculate unitary discharge rates at each key node, complete comparisons to the previously calculated flows (where available) to validate modelled flow values;

h) Present the findings to the TAC and based on mutual discussions and agreements proceed to the next stage.

Table B Hydrologic Modeling Requirements

Mobility Hub	Hydrologic Modeling Required	Available Information
Aldershot Mobility Hub*	Grindstone Creek (refinement of 1995 GAWSER model, with expansion of 2007 Waterdown Road interchange SWMHYMO model)	Grindstone Creek Subwatershed Study (Cosburn Patterson Wardman Ltd, 1995) Indian Creek Grade Separation Design (AMEC 2013) Falcon Creek Hydrology and Hydraulics Study (Valdor, 2012)
	Creek West of LaSalle Park Road (Create new model)	Unavailable. New PCSWMM model proposed
	Teal Creek, Forest Glen Creek, LaSalle Creek, (refinement of PCSWMM model)	Class EA for Aldershot Community Stormwater Master Plan (AMEC, 2013)

Burlington Mobility Hub	West Rambo Creek and Diversion (OTTHYMO refinement)	Technical Summary Updated Hydrology: Indian Creek, Hager-Rambo System, Roseland Creek (Phillips, 1997)
	East Rambo Creek (OTTHYMO refinement)	Technical Summary Updated Hydrology: Indian Creek, Hager-Rambo System, Roseland Creek (Phillips, 1997)
	Roseland Creek (refinement of SWMHYMO)	TRoseland Creek Flood Control Class EA (Philips Engineering Ltd, 2009)
Downtown Mobility Hub	Lower Rambo Creek (create model)	Unavailable. New PCSWMM model proposed
	Lower Hager Creek (create model)	Unavailable. New PCSWMM model proposed
Appleby Mobility Hub	Appleby Creek (GAWSER refinement)	Appleby Creek Floodline Mapping Update (EWRG 1997)
	Shoreacres Creek (refinement of GAWSER)	Shoreacres Creek Floodplain Mapping Update (EWRG 1997)
	Sheldon Creek (refinement of HSPF model)	Sheldon Creek Hydrologic and Hydraulic Study (DRAFT, AMEC Foster Wheeler, 2016)

* *Additional hydrologic modelling* *<u>may</u>* *be required for Falcon Creek and Glenwood Creek if it is determined* that these receivers *will experience hydrologic change due to the proposed Mobility Hubs development. This additional work would be determined pending discussions through the Technical Advisory Committee and review of the sewershed mapping. An existing PCSWMM model is available for Glenwood Creek (Aldershot Community Stormwater Master Plan, AMEC 2013), while an existing GAWSER model is available for Falcon Creek (Falcon Creek Hydrology and Hydraulic Study, Valdor 2012).*

6.2 Proposed Hydrology / Stormwater Management

a) Develop model parameterization for the proposed condition hydrologic model based on the three land use scenarios. Obtain approval for model parameterization by the TAC.

b) Model future uncontrolled conditions for each of the three land use scenarios.

c) Identify downstream constrictions within the major and minor system drainage routes and assess the impact of the proposed development. See also Section 6.3 below.

d) Develop watercourse specific stormwater management strategies that achieve the following goals and objectives:

   (1) To ensure new development does not increase the frequency and intensity of flooding, the rate of natural stream erosion or increase slope instability;

      (i) See Section 6.2 e) (2) for considerations related to erosion control

   (2) To ensure natural heritage features and areas, including their ecological and hydrologic functions, are protected from potential adverse impacts of development;

   (3) To prevent accelerated enrichment and contamination of surface and groundwater resources from development activities;

   (4) To maintain linkages and related hydrologic and hydrogeologic functions among groundwater features, and surface water features, where required as determined through the scoped hydrologic and hydrogeologic study; and

   (5) To ensure that riparian rights of downstream landowners, specific to the use and enjoyment of water across their property is respected.

e) The effectiveness of stormwater management mitigation plans must be confirmed through model simulation results for peak flow control and erosion mitigation performance. The preferred plan must be tested relative to the municipal design storms and Hurricane Hazel Regional Storm Event, and two climate change hydrologic scenarios (as established in the Draft City-Wode Flood Vulnerability, Prioritization and Mitigation Study, Amec Foster Wheeler, November 2016), and the August 4th, 2014 flood event. The following tasks shall be included:

   (1) Utilize the results of the pre-development modeling to set targets and unitary discharge rates (paired storage and discharge values presented per impervious ha) at key locations. Provide preliminary sizing for stormwater management facilities;

   (2) Determine whether erosion controls are required and provide technical justification for the selected level of control, in consultation with the TAC;

      a) The Work Plan includes a preliminary assessment to identify the impacts on erosion potential related to the proposed land-use changes within the Mobility Hubs. 'Risk' will be established by:

         (i) Completing a runoff volume impact assessment for the future land use scenarios based on the 25 mm Chicago 3 hour design event. Existing and future condition peak flows and channel velocities will also be considered.

         (ii) Input from the fluvial geomorphologic assessment which will provide preliminary insight into the sensitivity of watercourse reaches within and downstream of the Mobility Hubs. (e.g. highly armoured reaches represent a ‘low’ risk receiver)

b) Where erosion risk is considered ‘low’ by the TAC, no additional study will be required. Erosion control requirements for these areas will be approved by the TAC and may include: no erosion control, LID BMPs, extended detention based on current requirements outlined in the Stormwater Management Planning and Design Manual, MOE, 2003. Any emerging guidance will also be considered in consultation with the TAC.

c) Where erosion risk is not ‘low’ and the TAC determines a more rigorous assessment will be required to establish erosion controls; the scope for this work will be established by the TAC. Key scope gaps to complete a more detailed erosion assessment are considered to be 1. Establishing critical erosion threshold shear/flow; 2. Continuous simulation. Detailed erosion assessment is not included in the Work Plan.

(3) Determine whether post to pre-quantity control should be required for the Regional storm. The SWS must investigate and evaluate the potential risks and determine what level of control will be required. The analysis shall include the increase in risk to life (see qualifiers below) as well as the potential for flood risk to private, Municipal, Regional, Provincial and Federal property under Regional Storm conditions;

a) Risk to life will not be characterized through a detailed evaluation of depth and velocity. Flood impacts will be characterized by changes in water surface elevations, extents of flooding and hydraulic structure performance (i.e. overtopping frequency and depth). In the instance that the extents of flooding are predicted to meaningfully change, the impact and preliminary required mitigation controls will be identified for consideration by TAC as part of this study. Detailed measures or assessments are beyond the scope of the current study.

(4) Hydrologic model parameterization for impervious coverage to apply maximum potential impervious coverage based on proposed and existing zoning, and as established through the land use planning process. Planning policies will be required to ensure future development does not exceed the assumed maximum zoning imperviousness

(5) Assess the impact of the stormwater management strategies relative to creek peak flows and flow duration based on a design storm methodology. Present the hydrologic impacts of the proposed stormwater management strategies.

(6) Present the recommended stormwater management strategy. The conceptual design for the stormwater management facilities should include storage rating curves, facility locations, and outlets.

f) Identify opportunities to utilize Low Impact Development methods (LIDs), assess/quantify their feasibility and demonstrate compliance with the forthcoming MOECC Guidelines (anticipated to be released in Winter 2016/2017). Storm runoff should be treated via a multi-barrier approach, incorporating onsite, conveyance, end of pipe controls and LIDs to acceptable standards as determined in the MOECC's Stormwater Management Planning and Design Manual (2003) or more recent standard.

i) The Work Plan does not include any specific analysis/assessment to meet the anticipated update to the MOECC SWM Guidelines where the analysis/assessment is beyond that described by other tasks outlined in the Work Plan. The updated MOECC guidelines will be reviewed once available to determine if there is any impact to the Work Plan.

g) Hydrologic analyses shall be conducted for existing and future development conditions to determine pre and post-development flows and investigate the impact of post-development conditions on: flows, volumes, flood levels, channel erosion [see i) below] and base flows [see ii) below]. The subwatershed plans shall recommend an array of runoff control measures to be carried out in Secondary Plan and Subdivision Plan level studies to ensure that downstream peak flows are not increased, downstream channel erosion is not increased and that stormwater runoff is appropriately treated to meet water quality targets. The recommendations must be defined in sufficient detail to support completion of the subsequent secondary planning level studies.

i) Section 6.2 e) (2) for description of the erosion assessment included in the Work Plan

ii) Continuous simulation is not included in the Work Plan and as such, post-development impacts to baseflow will not be determined.

6.3 Natural Hazards

The study shall identify the extent of flooding and the limits of the erosion hazard lands within the study areas, in accordance with the Ministry of Natural Resources and Forestry (MNRF)'s Provincial Technical Guidelines and Conservation Authority direction.

To determine the hazard limit associated with valleys (confined and unconfined), both the flooding and erosion hazards are to be considered. The hazard limit is set by the greater of the flood or erosion hazard, plus the applicable development setback based on policy and regulatory requirements. Additional buffers and/or corridor widths maybe needed for ecological and hydrologic purposes. The minimum setback is 15 metres from major valley systems such as Grindstone Creek, and 7.5 meters from minor valley systems.

a) Flood Hazards

Floodplain mapping refinements and/or generation (where watershed scale mapping and modeling is not available – as per the table below) are to be completed in accordance with MNRF recommendations based on the applicable Provincial Technical Guidelines (i.e., "Technical Guide – River & Stream Systems: Flooding Hazard Limit", Ministry of Natural Resources & Watershed Science Centre, 2002, "Technical Guide – Great Lakes, St. Lawrence River Shorelines, Flooding, Erosion and Dynamic Beaches", or updated current standard). Flood plain mapping must be refined/generated for the Mobility Hub study areas and for riverine flooding, a sufficient distance up and downstream to clearly characterize all hydraulic interactions and identify any future hydraulic impacts associated with development. The models should be detailed and flexible enough to evaluate modifications to the existing floodplains including realignment or changes to the corridor widths and profiles. The U.S. Army Corps of Engineers HEC RAS model is an acceptable tool for the hydraulic analyses.

Note: Provincial Technical Guidelines (i.e., "Technical Guide – River & Stream Systems: Flooding Hazard Limit", Ministry of Natural Resources & Watershed Science Centre, 2002 requirements/recommendations will be met with the following exceptions:

- Model calibration (Section F8 of the Technical Guide) will not be completed
- Testing and sensitivity analysis (Section F9 of the Technical Guide) will only be undertaken on the basis of peak flows where the Regulatory floodplain is not confined to a valley feature, or where the Regulatory floodplain is close to breaching a valley feature under future land use conditions

To establish/refine the existing riverine floodplain constraints to support a planning level study, the following steps must be completed:

i) Survey major watercourse crossing structures within the Mobility Hub study areas and a hydraulically relevant distance up and downstream, where existing data are not available or are not considered to be of a satisfactory level of accuracy, as approved by the TAC. A complete detailed survey of the low flow and bankfull channels (sufficient for floodplain mapping purposes) within municipal creek blocks along Appleby Creek is included in the Work Plan; opportunities to re-allocated the effort associated with this task will be considered by TAC on a priority basis. DEM data (0.5 m resolution) will be provided and may be applied to the floodplain throughout the remainder of the study areas where public access is unavailable. The project consultant is to ensure that the DEM and field survey data are properly integrated.

ii) As part of the refinement of the models, verify the hydrologic information, cross section locations and hydraulic parameters included in the hydraulic analyses and update as appropriate. Document the sources of information utilized within the hydraulic models. Alternatively, create and document a new hydraulic model where required. Hydraulic parameters utilized within the model are to be determined in consultation with the TAC.

iii) Establish reach boundary conditions based on the best available information, but ensure sufficient cross sections between the boundary conditions and study areas of interest to achieve model stability. Where Lake Ontario represents the starting water level, the mean monthly water level associated with Lake Ontario should be used as the boundary condition,

iv) The Lake Ontario's flood hazard limit (100 year high water level) must also be considered as it may govern in the establishment of the hazard within the Downtown Hub.

v) As part of the hydraulic modeling for the Aldershot mobility hub, the Floodplain delineation for Grindstone Creek must consider spill from the adjacent Falcon Creek. The spill values will be provided by the TAC.

vi) Validate the refined existing conditions models through comparison with original models (where available).

vii) Where the regulatory storm is defined by a 1:100 year design storm as opposed to Hurricane Hazel Regional storm event, climate change implications are to be assessed (three projected scenarios will be provided by the TAC) through modeling efforts and presented in a tabular form to inform the potential level of risk associated with anticipated climate change scenarios.

viii) Evaluate the extent of the future floodplains based on proposed hydrologic and hydraulic conditions as envisioned through the secondary planning process.

ix) Prepare full size copies of floodplain mapping (existing and proposed conditions) for the regulatory storm (greater of the 1:100 year or Regional Storm Event). The mapping shall be presented on a topographic contour base, overlain with property boundaries, structures, watercourse locations, and labeled hydraulic cross sections. Cross sections are to be labelled with cross section ID, the associated Regional and 1:100 year water levels, and the 'start' and 'end' of the modeled segments of the cross sections. Submit digital and hard copies of the mapping.

x) Hager-Rambo Diversion Channel & Flood Control System –

(1) The diversion channel is estimated to have capacity for the 50 year design storm based on the original design criteria and subsequent analyses. For larger design events (100 year and Regional Storm), the channel is expected to spill at several locations. A preliminary understanding of existing hydraulic conditions is available from Conservation Halton's draft HEC-RAS model for the channel. Spill paths are not known at this time, however spills are expected to impact the south end of the Burlington Mobility Hub and the Downtown Mobility Hub and may impact the location/nature of future development in these hubs. The magnitude of spill flow is also not known for any design event at this time.

(2) The Hager-Rambo flood control system consists of three (3) facilities including the Freeman Pond (QEW-Highway 403 interchange), West Hager Pond (North Service Road, west of Brant Street) and the East Rambo Pond (North Service Road, west of Guelph Line). The facilities were required to provide flood control (peak flow attenuation) for stormwater diversions related to the Highway 407 corridor (East/West Rambo Creek & East Hager Creek), and also accommodate a diversion from Roseland Creek. The flood control system was design and approved by the City of Burlington, Conservation Halton and the Province of Ontario to provide peak flow control for all events up to and including the Regional Storm.

Current Provincial policy (ref. MNR, 2002) does not allow modification of Regulatory peak flows through stormwater management in establishing the downstream Regulatory flood hazard. Current policy also does not allow implementation of flood control measures for the purpose of facilitating development downstream. These policies are key considerations for the Mobility Hub Study as development proposed within the Burlington and Downtown Mobility hubs is expected to be affected by a flood flows in excess of the capacity of the Hager-Rambo Diversion Channel including spills. The associated flood risk will significantly increase if the Hager-Rambo flood control system is not credited for reducing Regulatory peak flows. It has not been determined how current policy affects previous Provincial approvals granted to the Hager-Rambo flood control system. However, it has been identified that a Hager-Rambo flood risk assessment is required and must consider peak flows with and without the flood control system in-place. The spill assessment will involve use of simplified techniques and will not involve 2D modelling.

(3) The Freeman Pond and the West Hager Pond detain runoff using an engineered barrier above ground (i.e. berms and/or weirs) which may classify them as dams under the Lakes and Rivers Improvement Act. Current Provincial criteria requires that dam breach assessments be undertaken to inform the design process and

establish flood risk downstream related to a flood wave. A dam breach assessment has not been undertaken to date. Given that the influence the two flood control facilities is integral to the Hager-Rambo system, a preliminary review of dam breach, including spill paths is considered required to understand the potential for an increase to Regulatory peak flows in the system (between the ponds and the diversion channel), and potential increase in flood hazard risk downstream.

(4) Based on the foregoing, the following assessments can be accommodated within the existing Work Plan:

(a) Hydraulic modelling to estimate the order of magnitude of the spills from for the Hager-Rambo Diversion channel, as well as upstream connecting channels, under attenuated and unattenuated Regulatory peak flow based on a steady-state flow methodology. Other simplified estimation techniques will be considered. The preceding assumes that hydraulic models of the channels between the ponds and the diversion channel are readily available from Conservation Halton in a usable state.

(b) Review of potential Freeman Pond, West Hager Pond, and East Rambo Pond breach spill paths to the extent that a preliminary understanding of the potential for the breach to affect the Burlington or Downtown Mobility Hubs. Given that the facilities are generally west of the Hubs (with the exception of the East Rambo Pond which is a depressed feature and thus considered to be lower risk), direct impacts are expected to be limited. Calculation of breach (i.e. Dam Break) peak flows cannot be accommodated in the current Work Plan.

(c) Review of topographic mapping to identify potential Diversion channel spill paths through the Burlington and Downtown Mobility Hubs. The spill path, local topography and the estimated spill magnitude will be considered together to coarsely estimate the potential extents of flood impact within the Burlington and Downtown Mobility Hubs.

(d) DISCLAIMER. To generate a level of accuracy that can be reasonably relied upon to guide development and establish related policies, including garnering the necessary approvals from Conservation Halton and the Province would require detailed hydraulic modelling including unsteady state flow analysis and 2 dimensional flow routing and potential dam breach assessment. Amec Foster Wheeler's Work Plan identified the concern related to the spill, however no effort was included in the Work Plan to conduct the above noted assessments. Clearly the detailed analysis that would be required cannot be accommodated by the current Work Plan. That said, it is expected that above noted preliminary analyses can be accommodated within the existing scope. The assessments will necessarily be highly conservative and qualifiers regarding the accuracy will be applied. At best, the outcomes are generally expected to improve the understanding of the potential spatial impact of the spill, and inform the scope of additional future study. Given that there is very limited existing understanding of the hydraulics related to the spills, the level of effort required to establish meaningful parameters around the extent of flood risk in the Mobility Hubs is unknown. Therefore, Amec Foster Wheeler will make best efforts within the existing Work Plan to provide meaningful information around flood hazards related to the spill, however it cannot be guaranteed that outcomes of the spill assessment will meet the specific needs of the Mobility Hub Study. Amec Foster Wheeler will work with the engineering and planning teams such that potential gaps in the flood hazard assessment, as they relate to planning needs, can be identified as early as possible and options to re-assign or add additional scope can be considered by the City and TAC.

Table C Hydraulic Modeling Requirements

Mobility Hub	**Hydraulic Modeling Required**	**Available Information**
Aldershot Mobility Hub	Grindstone Creek (refinement of HEC-2 and conversion to HEC RAS)	Grindstone Creek Subwatershed Study (Cosburn Patterson Wardman Ltd, 1995)

Burlington Mobility Hub	West Rambo Creek and Diversion (review and refinement of Conservation Halton Hager-Rambo Diversion Channel Model, 2014)	Technical Summary Updated Hydrology: Indian Creek, Hager-Rambo System, Roseland Creek (Phillips, 1997)
	East Rambo Creek (existing Amec Foster Wheeler model)	Technical Summary Updated Hydrology: Indian Creek, Hager-Rambo System, Roseland Creek (Phillips, 1997)
Downtown Mobility Hub	Lower Rambo Creek (create model)	Unavailable
	Lower Hager Creek (create model)	Unavailable
Appleby Mobility Hub	Appleby Creek (HEC-RAS refinement)	Appleby Creek Floodline Mapping Update (EWRG 1997)
	Sheldon Creek (refinement of Hec Ras)	Sheldon Creek Hydrologic and Hydraulic Study (DRAFT, AMEC Foster Wheeler, 2016)

b) Erosion Hazards

The erosion hazard assessment must be completed in accordance with the most current version of MNRF's "Technical Guide – River & Stream Systems: Erosion Hazard Limit," (currently 2002), which is deemed to be inclusive of Parish Geomorphic's Belt Width Delineation Procedures" (currently Revised 2004). Conservation Halton staff in conjunction with the proponent's geomorphologist and/or geotechnical engineer will determine the status of the valley systems as either confined or unconfined. For confined systems, the erosion hazard is defined as the greater of the physical top of bank or long term stable top of bank. For unconfined systems, the erosion hazard limit is defined as the meander belt allowance. The 15m and 7.5m regulated setbacks are to be applied to governing erosion hazard (i.e. the meander belt, physical top of bank or stable top of bank).

The erosion hazard assessment must be completed by a licensed qualified professional Fluvial Geomorphologist, Geotechnical Engineer and/or Water Resources Engineer. Justification as to whether climate change impacts need to be considered as part of corridor sizing is required.

Recognizing that some of the Mobility Hub study areas are partially developed, it may be appropriate to analyze meander belt widths on the basis of empirical equations. Where the meander-belt width is determined on the basis of empirical equations, the results of multiple applicable equations are to be presented and justification is to be provided for the equation that is ultimately selected as most appropriate in this area.

At a minimum, the erosion hazard limit must be supported by documentation detailing: collected field data (if applicable), the methodologies applied, analysis and supporting calculations and text justifying the ultimate methodology selected to define the erosion hazard limit. Additionally, digital and hard copy figures must be submitted and shall include a signed and sealed, full size, scaled, plan view drawing showing:

i) Detailed topographic information (contour intervals of less than or equal to 0.5m) with a referenced source for all topographic information;

ii) The current locations of the watercourse centerlines and limits of bankfull channels;

iii) The erosion hazard limits ;

iv) The regulated allowance (15 metres for major valley systems and 7.5 metres for minor systems).

To support the assessments of the erosion hazards, the following must also be assessed:

<u>For unconfined systems:</u>

i) Reach break locations, overlain on an orthophoto complete with topographic mapping,

ii) Any noted areas of erosion concerns and any locations where the 100 year migration rate may have been determined;

iii) The watercourses' current central tendency (meander belt axis);

iv) Available historic watercourse centrelines (where available);

v) The calculated meander belts (preliminary meander belts);

vi) The analyzed 1:100 year erosion setbacks (100 year migration rate) or alternate setbacks using safety factors as required;

<u>For confined systems:</u>

i) Given that this study is intended to support secondary planning and not zoning or lotting, the project consultant is to apply conservative assumptions for stable slope inclinations (i.e. slope inclinations of 3:1 in soil) and toe erosion allowances (maximum tabulated values applicable to site soils) and forego the completion of a detailed geotechnical study at this time. The erosion hazards will need to be further refined through detailed studies at a later date, prior to site development. At that time, the physical top of bank must also be staked by Conservation Halton.

The following must be shown on a scaled sealed figure:

i) Slope cross section locations and I.D.'s

ii) Limit of the Toe Erosion Allowance; and

iii) Limit of the Stable Slope Allowance

6.4 Digital Data Requirements

The project consultant will be required to provide the following information to the City of Burlington, Halton Region, and/or Conservation Halton:

a) For modeling related data products, digital and executable copies of model input and output files, as well as licensed copies of any proprietary modeling software and PDF copies of key summary information (such as the model schematics, drainage area plans, hydraulic cross section locations, etc.) are to be provided to the City Region and Conservation Halton.

b) Digital copies of the written reports are to be provided in both MS Word 2010 and PDF format.

c) All mapping products produced for the study shall be geo-referenced to real world coordinates and have a standard UTM NAD 83, Zone 17 projection with NAD83 vertical datum.

d) New features captured by the project consultant using GPS or heads-up digitizing from air photography will have a capture accuracy rating for the feature included as an attribute (+/- 0.5 m accuracy).

e) A mapping layer index will be provided listing the layer name and providing a description/abstract of the layer's content. Also, FGDC compliant metadata shall be created for each layer produced by the project consultant.

f) Digital data will be delivered in one of the following formats: ESRI file geodatabase v10.2 feature classes or ESRI shape file format ensuring attribute names are not truncated in the shape files. Layers created by the project consultant shall be topologically correct (i.e. adjacent polygon features will be without gaps/overlaps and shall share vertices/nodes where appropriate).

g) If the project consultant utilizes ESRI ArcGIS to produce maps, the matching .mxd will be provided that corresponds to the mapping.

h) If software limitations prevent the project consultant from meeting these requirements, alternate formats may be considered (e.g., DGN) with the written agreement of the City. City GIS staff should be consulted if additional technical details are required to these requirements.

7.0 SUPPLEMENTORY INFORMATION

Table D Terrestrial & Aquatic Studies

Y/N	Survey	Optimal Inventory Period	Methodology and Protocols	Notes
☒	Ecological Land Classification (ELC)	• May to early June, July to September	• ELC System for Southern Ontario First Approximation (Lee et al., 1999) or as updated from time to time	• Classification to the Vegetation Type. • Should the community not be available within the Guide, please use the community series level and provide notation as to why this approach is used. • Include all data sheets (e.g., soils, disturbance, etc.). • Mapping should clearly differentiate between the polygons.
☐	Wetland Evaluation and Delineation	• Evaluation: variety of seasons to ensure the full evaluation occurs as per OWES • Delineation: Late spring to early fall, before the first hard frost with CH and potentially MNRF staff	• Ontario Wetland Evaluation System (OWES) for Southern Ontario (3rd Edition, 2014 or as updated from time to time)	• Detailed inventory and assessment including vegetation, mammals, birds, reptiles, amphibians, fish, insects, benthos etc., using specific protocol noted in this table. • Ensure sufficient time for MNRF to process. *Note: presence of wetlands to be confirmed through ELC surveys the next planning stage will require OWES delineation.*
☒	Vegetation Inventory	• Single-season: mid-June to August, to be completed concurrently with ELC	• Comprehensive vegetation species list to be provided, will be combined with ELC • Details on species including level of invasiveness, CoC, CoW, species rarity etc., should be recorded	Species rarity to be based on: • Species at Risk in Ontario list (MNRF) • S-Rank using the Natural Heritage Information Centre species lists • Local rarity using Halton Natural Areas Inventory (2006) and Hamilton Natural Areas Inventory (2014)
☒	Breeding Birds	• Breeding birds: May 24 to July 10	Habitat Dependent: • Ontario Breeding Bird Atlas protocols	• Point counts required for monitoring. • Generally consists of two survey visits spaced approximately 10 days apart,

Y/N	Survey	Optimal Inventory Period	Methodology and Protocols	Notes
			• Area searches and wandering transects	spread evenly over the season.
☐	Amphibians	• Early spring – summer (species dependent) • Active Visual Encounter Surveys (VES) on rainy late March – early April nights	• Bird Studies Canada Great Lakes Marsh Monitoring Program (including 3 separate spring/early summer seasonal survey timing windows). • Active Visual Encounter Searches (VES) for salamanders	• Trapping may be required for JESA, if known or suspected and as required and permitted by the MNRF. • If sampling in urban areas, point counts longer than three minutes may be recommended *Note: presence of potential amphibian breeding habitat to be confirmed through ELC surveys. Where necessary, recommendations to undertake amphibian breeding surveys will be made as part of the development application process.*
☐	Reptiles	• April – June • Late Summer/Fall: Late August to October for migration or congregating species • Weather dependent	• Species and habitat dependent • May include cover board surveys, spring emergence surveys etc. • Consultation recommended ahead of work	*Note: presence of potential reptile hibernacula or nesting areas to be confirmed through ELC surveys. Where necessary, recommendations to undertake additional surveys will be made as part of the development application process.*
☐	Butterflies	• June – August • July (peak) • Weather dependent	• Species and habitat dependent • Consultation recommended ahead of work	*Note: potential significant wildlife habitat for migratory butterflies to be confirmed through ELC surveys.*
☐	Dragonflies and damselflies	• June – August • July (peak) • Weather dependent	• Species and habitat dependent • Consultation recommended ahead of work	*Note: potential significant wildlife habitat for dragonflies and damselflies to be identified through incidental observations and other field studies (ELC, etc.).*

Y/N	Survey	Optimal Inventory Period	Methodology and Protocols	Notes
☐	Mammals	• Species dependent	• Sightings and tracking • Small mammal trapping depending on the site	*Note: potential significant wildlife habitat for mammals to be identified through incidental observations and other field studies (ELC, etc.). Where necessary, recommendations to undertake species specific surveys will be made as part of the development application process.*
☐	Bats	• During leaf off season for cavity tree surveys	• Species and habitat dependent • SAR Bats require different surveys than SWH bats. • MNRF Guidelines, where applicable • Consultation recommended ahead of work	*Note: potential for bat habitat to be identified through ELC. Where necessary, recommendations to undertake bat surveys will be made as part of the development process.*
☒	Stream Classification	• Summer (June- July)	• Ontario Stream Assessment Protocol (OSAP)	• Collect information on riparian and in-stream cover, stream morphology, nutrient input, etc.
☐	Benthic Invertebrate Sampling	• Spring (May)	• OSAP Section2, Module 3 • Travelling kick and sweep methods completed three times over the study period (May)	• Data to be collected includes % abundance, Family Richness, and % Taxa Richness Index *Note: to be completed during future investigations closer to construction, to set a baseline for monitoring purposes.*

Note: The surveys listed above were agreed to at the meeting with CH on February 14, 2017. Additional surveys may be required as identified through the preliminary field program, to be addressed through the development application and approvals process.

ATTACHMENT A:

Terrestrial and Aquatic Field Study Locations

Conservation
Halton

905.336.1158
Fax: 905.336.7014
2596 Britannia Road West
Burlington, Ontario L7P 0G3
conservationhalton.ca

Protecting the Natural Environment from Lake to Escarpment

July 7, 2017

BY EMAIL AND MAIL

Phil Caldwell
City of Burlington
Planning and Building Department
426 Brant Street, P.O. Box 5013
Burlington, Ontario L7R 3Z6

Dear Mr. Caldwell:

Re: Mobility Hubs Project – Final Work Plan
City of Burlington
CH File: MPR 653

Conservation Halton (CH) staff has reviewed the City of Burlington's Mobility Hubs Final Work Plan dated updated April 25th 2017 and Agreement dated March 9, 2017 and offer the following comments:

- The level of study provided for the Appleby and Aldershot Hubs will generally identify flooding and erosion hazards and is sufficient to support the Area Specific Plans. Additional technical studies will be required to support redevelopment and intensification at the site-specific level. Some of these studies require holistic evaluation on a subwatershed basis, and should be completed in advance of any Site Specific Application, while others can be included as part of a Site Specific Application (Table 1 summarizes study gaps and recommended timing for these submissions). The Area Specific Plan should specify the types, levels, and timing of studies required and who would be responsible for funding and undertaking these studies.

- The level of study for the Downtown and Burlington Hubs is insufficient to determine the general nature and extent of the flooding and erosion hazards. Identification of areas where redevelopment and intensification is appropriate is not possible. **Conservation Halton recommends that the City undertakes additional required comprehensive studies, outlined below, prior to the completion of the Area Specific Plans to determine the general nature and extent of the flooding hazard and to develop appropriate land use policies to minimize risk to life and property through redevelopment and**

intensification in keeping with Section 3.0 – Protecting Public Health and Safety of the Provincial Policy Statement (PPS) (Conservation Halton has delegated responsibility for commenting on Sections 3.1.1-3.1.7 of the PPS under the one-window approach).

Should the City proceed with finalizing the Area Specific Plan (ASP) for the Burlington and Downtown Hubs without this additional analysis and decision making, the ASP should clearly indicate that comprehensive studies to determine the nature and extent of the hazards are required, in conjunction with additional subwatershed level studies, before site-specific applications for redevelopment and intensification could be accepted. The ASP should specify that a Terms of Reference for these comprehensive studies would have to be completed to the satisfaction of the City and Conservation Halton and indicate who would be responsible for undertaking and funding the studies. The policy framework developed for the ASP should implement measure(s) to restrict advancement of development or re-development proposals within the entire Study Area before completion of all additional comprehensive studies and subsequent site specific studies (Table 1 summarizes study gaps and recommended timing for these submissions).

Conservation Halton prefers that the City complete the required technical studies rather than deferring them to a latter stage of the planning process, as this would provide certainty to residents and developers in the Burlington and Downtown Mobility Hubs. Further discussion regarding the preferred approach is requested by CH prior to signing the Agreement.

The technical studies required and the rationale for requesting these studies are outlined below.

<u>Additional Work Needed to Support Identification of the Flood Hazard at an Area Specific Plan Level for the Downtown and Burlington Mobility Hubs:</u>

As acknowledged in the Disclaimer associated with AMECFW's updated April 25, 2017 Work Plan, *"To generate a level of accuracy that can be reasonably relied upon to guide development and establish related polices ... would require detailed hydraulic modelling... Clearly the detailed analysis that would be required cannot be accommodated by the current Work Plan."* The proposed studies do not fully characterize and define the limits of natural hazards associated with the Downtown and Burlington Hubs. Determining the extent of the flooding hazard impacting these Hubs is reliant upon an understanding of potential spill associated with the upstream Hager Rambo Diversion Channel. This is further complicated for the Downtown Hub by the need to understand how potential spills from the diversion channel impact the flood and erosion risks associated with the remnant lower Hager and lower Rambo channels. While a precise delineation of the flood hazard is not necessary at this time, it would be prudent for the City and Conservation Halton to understand the general extent of the flood hazard to establish a basic understanding of the lands available for intensification.

The extent of spill from the Hager Rambo Diversion channel is dependent upon how flow attenuation associated with the upstream Freeman, West Hager and East Rambo ponds are credited in the calculation of the flood hazard. Since Conservation Halton, the City, and the

Province jointly constructed the above-mentioned flood control reservoirs the hazard management approach for this area has credited these facilities in the past. However, current MNRF Guidelines do not support crediting any attenuation associated with on-line flood control reservoirs. As such, existing Approximate Regulation Limit mapping within the Downtown and Burlington Hubs should not be relied upon to determine constraints for intensification. To finalize the floodplain delineation associated with the Burlington and Downtown Mobility Hubs, a decision must be made on whether, it is appropriate to continue to credit the Freeman Pond, West Hager and East Rambo ponds.

Per discussions with the City of Burlington (June 5th, 2017 involving Allan Magi, Cary Clark, Barb Veale, Janelle Weppler, Janette Brenner), the City committed to reviewing their files for historical documentation on the flood control reservoirs. This information is to be reviewed prior to further consultation on this issue. Key information the City was to look for included:

- written documentation regarding the decision(s) made by the City, Conservation Halton and the Province to credit attenuation within the SWM facilities,
- final design and construction details (embankment height, inclusion of design safety factors incorporated into the design, etc.), and,
- ownership and management information.

As the City, Region and Conservation Halton will be potentially accepting additional risk/liability should there be a decision to continue crediting these ponds, additional attributes that contribute to the level of risk, must also be considered, including:

- potential future changes in flow contributing to these ponds due to climate change or development,
- consistency in floodplain mapping approaches relative to other flood control facilities in Conservation Halton's jurisdiction, i.e., dams, regional control ponds, etc.,
- future management requirements for the structures (i.e., Do the ponds need to be managed as dams in future? How will this impact the required frequency of maintenance and inspection? Are remedial works required to meet safety standards?), and,
- other relevant factors as determined through ongoing discussions.

Once a decision on crediting attenuation within the upstream ponds is made, the hydraulic analysis associated with the diversion channel must:

a) be revised based on any flow change,
b) determine whether spills are significant (and cannot be eliminated), and,
c) how any significant spill is credited in reducing downstream flows within the diversion channel.

Should significant spills from the Diversion Channel be recognized and credited, a corresponding analysis determining how spill from the Diversion Channel impacts the flood hazard associated with any watercourse or drainage system receiving the spill flows will be required. The updated April 25, 2017 Work Plan commits the Mobility Hub Consulting Team and TAC to identifying study gaps as early as possible.

A joint decision on crediting the existing flood control reservoirs must be made before land use concept plans and the technical studies supporting the ASP are finalized for the Burlington and Downtown Hubs, as the limit of the Floodplain Hazard will determine which areas may intensify. While this decision making process is understood to be separate from the Mobility Hub Study, the final decision may rely, to some extent, on the findings of the modelling proposed as part of the Mobility Hub Work Plan.

The updated April 25, 2017 Work Plan addresses modeling related to the on-line flood control reservoirs and associated spill, but only in a preliminary way, including the following items:

- estimation of the order of magnitude of the spill from the diversion channel under attenuated and unattenuated peak flow conditions;
- review of potential pond breach spill paths to provide a preliminary understanding of spill path routes through the Burlington and Downtown Mobility Hubs.

This approach will allow only a coarse estimate of the potential flood impact. Insufficient detail will be available to fully characterize the flood hazard. The level of analysis will be less rigorous than the analysis completed for the Appleby and Aldershot Hubs. To achieve a similar level of analysis, the quantification of the spills, their locations and their flow paths would be required as well as a decision on the use of attenuated or unattenuated flows.

Additional Technical Studies Recommended for all Four ASPs Prior to Site Specific Development Applications:

Should the City proceed with Area Specific Plans, additional holistic subwatershed scale technical studies should be completed to support development. In drafting the original ToR for the Mobility Hub Study, Conservation Halton staff accepted the limitations of the Council-driven timelines and access issues associated with fractured property ownership, and scoped several elements typically required to support an Area Specific Plan out of the agreed ToR. This was based on an understanding that these elements would be further assessed through later studies that would holistically address subwatershed impacts. The original requirements of the ToR were further scoped through the Work Plan presented by the City's consultants. Following development of the consultant's Work Plan, the City identified an expectation that development would advance directly from the Area Specific Plan to individual site specific development applications. Conservation Halton staff are very concerned with the proposal to advance directly to individual site specific development applications.

The following technical deficiencies, while not required for the completion of an Area Specific Plan, are better suited to a higher level study rather than a site specific application:

- *Hydrologic Model Review*: The Work Plan included a review of hydrologic model parameterization, but noted watershed wide re-parameterization (outside of the Mobility Hubs) was not included. There is also no requirement for the models to be calibrated and validated. Watershed conditions associated with the planned development, particularly as described in the older hydrology studies (dated 1997 for Shoreacres, Appleby and the upper Hager Rambo Diversion System), may not fully correspond with actual development. Each Hydrologic model must be calibrated and validated following a watershed wide review, to ensure proposed stormwater management targets appropriately protect downstream residents from increased runoff generated by intensification. Following refinement of the existing condition model, the impact of the anticipated stormwater management controls should be tested to ensure that the shifted hydrographs associated with flow control will not negatively impact flooding or erosion when evaluated cumulatively.

- *Detailed Spill Assessment and 2-Dimensional Modelling:* The 1- Dimensional steady state modelling being created or refined may not be sufficient to assess the developed urban floodplain and/or the Falcon Creek Spill. 2-Dimensional modelling may be required to fully assess the flooding risks for site specific applications in some areas, such as the Downtown Hub, Aldershot Hub, and potentially the Burlington Hub.

- *Dam Break Analysis:* A dam break analysis is recommended to inform risk and for the purposes of emergency planning, downstream of the on-line ponds associated with the Hager Rambo Diversion Channel. (Note: Current MNRF Technical Guidelines recommends regulatory flows be assessed based on peak flow from a dam break conditions wherever public safety is the issue, but identifies a preferred approach of using unregulated flows to identify the flood hazard downstream of dams.) While it is not anticipated that the Dam Break Scenario would be used in establishing regulation limits, it is recommended that this work be completed to identify the level of risk posed by the upstream facilities. This would impact the Downtown and Burlington Hubs.

The current Work Plan is not sufficient for Conservation Halton to support site specific development applications or development adjacent to natural hazards without completion of the above technical studies. Completion of these studies as part of individual site development applications will not allow for comprehensive mitigation measures and will result in substantially more complex and costly submissions and delays. It is recommended that these studies be prepared by the City in advance of site development applications. Alternatively, a less preferable option could include identification within the policies of the Area Specific Plan that the above studies will need to be completed for the entire subwatershed area, by the first developer to advance redevelopment or intensification within each catchment area.

Work Required to Support Site Specific Development Applications:

Upon completion of the above studies, further site specific technical studies will be required to properly define and characterize natural hazards and features in order to satisfy Conservation Halton's regulatory requirements for future site specific development applications. Table 1 provides a summary of items required for site specific applications.

Summary of Future Works Required

Table 1 summarizes the studies required at different stages in the planning process. Additional comments related to individual study components are outlined in Appendix A. This list is not exhaustive and requirements may vary based on the individual sites.

Conservation Halton staff look forward to continue working with the City of Burlington through the review process for this Mobility Hubs Study. Further discussion regarding the points mentioned in this correspondence is recommended. If you have any questions please contact the undersigned at extension 2266.

Yours truly,

Barbara Veale

for Leah Chishimba, MAES
Environmental Planner

Cc: Jonathan Pounder, Conservation Halton, email
Rosa Bustamante, City of Burlington, email
Richard Clark, Region of Halton, email
Jason Elliot, Region of Halton, email
Mary Lou Tanner, City of Burlington, email
Allan Magi, City of Burlington, email
Cary Clark, City of Burlington, email

Table 1: Summary of Tasks/Analysis Requirements

Required Tasks/Analysis	Downtown	Aldershot	Burlington	Appleby
Tasks/Studies Preferably Completed Prior to Finalizing the ASP*				
Completion of all supporting studies identified in the Work Plan	✓	✓	✓	✓
Identification of future study requirements	✓	✓	✓	✓
Discussion and decision making on crediting attenuation associated with the Freeman, West Hager and East Rambo Ponds	✓		✓	
Quantification of spill flows and spill locations related to the Hager Rambo Diversion Channel	✓		✓	
Quantification of downstream flow paths from the Diversion Channel to the remnant channels (2-Dimensional modeling may be required)	✓		✓	
Studies Preferably Completed Prior to Site Specific Development Applications**				
Watershed-wide review and update to the hydrologic model, including calibration and validation	✓	✓	✓	✓
Watershed wide update to the hydraulic model, based on refined hydrology	✓	✓	✓	✓
Evaluate spill impacts associated with Falcon Creek		✓		
Dam break analysis is recommended to inform emergency planning and risk	✓		✓	
Detailed analysis of erosion potential and mitigation for all high risk watercourses	✓	✓	✓	✓
Re-evaluation of the proposed stormwater management strategy with due consideration for implications of timing of anticipated controls	✓	✓	✓	✓
Establish a monitoring framework	✓	✓	✓	✓
Note: Given the importance of assessing cumulative impacts, the above studies should be completed holistically, considering full future build out of catchment, including all development sites within the Mobility Hub.				
Studies Completed as Part of Site Specific Development Applications				
Flooding Hazard Assessment:				
Update hydraulic model based on detailed, accurate, site specific topographic information and map the regulated flooding hazard	✓	✓	✓	✓
Erosion Hazard Assessment:				
Determine and map the erosion hazard associated with confined valley systems and/or refine the unconfined hazard limit. Map the regulated erosion hazard.	✓	✓	✓	✓
Shoreline Hazard Assessment:				
Refine and map the flooding and erosion hazards associated with Lake Ontario	✓			
Stormwater Management (SWM) Assessment:				
Demonstration that all SWM Criteria (enhanced level of quality control, erosion and quantity control, water balance, etc.) required to mitigate development impacts is achieved in accordance with current guidelines.	✓	✓	✓	✓
Terrestrial and Aquatic:				
Additional field work may be required to address data gaps and uncertainties within the characterization of terrestrial and aquatic environments and hydrologic setting.	✓	✓	✓	✓
Hydrologic/hydrogeologic evaluation and water balance for wetlands (where applicable)	✓	✓	✓	✓
Monitoring	✓	✓	✓	✓

* These studies must be completed before acceptance of Site Specific Development Applications

** If these studies are deferred to a site specific development application, the first development to go forward would need to assess impacts associated with all development in the watershed within and adjacent to the Mobility Hub, similar to an EIR/FSS or SIS/EIR process applied in adjacent municipalities.

Detailed Requirements for Site Specific Development Applications for all the Mobility Hubs

APPENDIX A

1. **Erosion Hazard:**

The Mobility Hub Study Work Plan proposes to assess the extent of hazard associated with Confined Valley Systems through a desk top exercise considering conservative stable slope inclinations and toe erosion setbacks, based on available information. Future development applications on properties located adjacent to or containing a confined valley system will be required to complete the following:

- Top of bank staking in the field by Conservation Halton with an Ontario Land Surveyor (OLS);
- A Fluvial Geomorphic Assessment that assesses toe erosion (considering both current and anticipated future conditions);
- A slope stability assessment in accordance with current MNRF Guidelines, to the satisfaction of Conservation Halton. It is expected that the Geotechnical Assessment will require completion of site specific boreholes and survey of the slope.

Please note that for unconfined valley systems, the tasks associated with the work plan should be sufficient to assess the existing erosion hazard, however, additional works to clarify the extent of the development constraint associated with the meander belt component of the erosion hazard will be required for systems impacted by mitigation strategies (i.e., systems that may be 'day lighted' or otherwise altered), and for systems undergoing significant changes in hydrologic regime.

2. **Shoreline Erosion Hazard:**

For properties within the Downtown Hub impacted by the shoreline hazard the following will be required:

- A detailed topographic survey and geotechnical borehole analysis.
- Delineation of the erosion hazard and associated development setbacks.
- Assessment of shoreline protection works to ensure they meet current standards. The repair/ replacement/ reconstruction of shoreline protection works will be required if they do not meet current standards.
- A CH permit for the shoreline protection works.

Please note that Conservation Halton requires that the shoreline protection works meet current standards to ensure the erosion hazard is addressed, and to reduce development setbacks.

It is also recommended that pre-consultation be undertaken, as setbacks associated for Lake

Ontario can be significant and there are properties along this stretch where development would be restricted to replacement of no more than what currently exists.

3. **Floodplain Hazard:**

While the Area Specific Plan will provide some rough delineation of floodplain hazards, further refinement will be required in support of any site specific applications. The following analysis 'gaps' and associated study requirements will apply to each property containing or located adjacent to the floodplain hazard:

- The hydrologic and hydraulic models need to be validated through comparison with the measured and observed precipitation, runoff response, flows, and water levels. The validation process may trigger the need for further model calibration and refinement. Model sensitivity should also be assessed through this process.
- The available topographic data utilized in the hydraulic models is not sufficient for site specific property applications, and as such the model must be refined on the basis of detailed topographic survey or LiDAR data (of appropriate quality) to support individual property developments.
- Given the limited feasibility of eliminating the spill from Falcon Creek to the Grindstone Creek and Indian Creek Systems, detailed evaluation of the spill will be required to confirm appropriate downstream flood flows for each of the above listed watersheds. This will need to be assessed prior to any site specific development within the Grindstone Creek system.
- The 1- Dimensional steady-state modelling being refined and created may not be sufficient to assess the developed urban floodplain. 2-Dimensional modelling may be required to fully assess the flooding risks for site specific applications within the Aldershot, Burlington and Downtown Hubs (not anticipated for the Appleby Hub).
- While a preliminary investigation of potential downstream spill pathways has been considered, a full dam breach assessment has not been considered downstream of the Freeman and Triple Ponds or other on-line controls. Additional assessment may need to be undertaken pending the outcomes of the Mobility Hub Study's initial assessment

The above limitations will need to be addressed individually as each application advances, and will require additional effort to ensure data consistency. Gaps should be considered cumulatively and holistically for the entire development catchment to the extent feasible, by the first development to advance within each hub.

4. **Hydrologic Impacts to a Wetland:**

Specific hydrologic impacts to wetlands will need to be evaluated at a site specific stage as the existing models are not integrated groundwater/surface water models and the stormwater management strategies being advanced will be high level. To support development adjacent to a wetland, the following will be required:

- A hydrologic evaluation that demonstrates at minimum that there will be no negative impact to the hydrologic functions of the wetland as result of the proposed development.

5. **Stormwater Management Criteria:**

Significant gaps are noted with respect to the establishment of Stormwater Management Criteria for the subject lands:

- The hydrologic modeling work relies on a variety of existing models, resulting in the establishment of stormwater management criteria based on numerous different modelling platforms of various degrees of currency. The models are to be updated relative to each of the hubs, but a watershed wide update is not considered within the Work Plan. Therefore, the stormwater management requirements associated with each watershed may not be as 'equitable' as if they were modeled using a consistent modeling platform. It is possible that watershed conditions associated with the planned development, particularly as described in the older hydrology studies (dated 1997 for Shoreacres, Appleby and the upper Hager Rambo Diversion System), may not fully correspond with actual development.
- The Work Plan does not include a requirement to calibrate or validate models using existing information nor does it include requirements to collect and calibrate or validate the existing models utilizing new calibration data. Conservation Halton staff had previously indicated through our comments on the ToR the need for validation of each hydrologic model as part of a subsequent phase of the study. Where validation results in a significant revision to flows, the stormwater management strategy must be reassessed to confirm that the required extent of mitigation is maintained.
- The hydrologic modeling work does not require continuous modeling or the determination of a critical erosion threshold, resulting in less robust analysis tools to assess channel erosion impacts and effectiveness of the mitigation strategy. Where the potential for 'high' erosion risk is identified, more detailed analysis (that considers cumulative impacts associated with full build out of the Mobility Hub) will be required to support a site specific mitigation strategy at the site plan stage.
- The Stormwater Management Strategy is being defined based on the 2003 MOE Stormwater Management Planning and Design Guide. It is anticipated that the MOECC's forthcoming LID Design Guide may significantly alter stormwater management practices, and may require re-assessment or significant revision to the SWM Strategy, when this Design Guide comes into effect.
- The Stormwater Management Strategy is based on an expectation that planning policies will protect against increases in impervious coverage over and above the maximum allowable under current and proposed zoning. At the site specific development stage, updated hydrologic modelling may be required should intensification increase impervious coverage beyond what was considered at the time of the Mobility Hub Study.
- Fractured ownership within each of the hub areas are anticipated to result in a series of

on-site controls, as opposed to development of communal, municipally controlled infrastructure. Timing impacts associated with the development of numerous site specific controls will not be fully assessed through the Mobility Hub Study. Development of a municipal site control strategy to address intensification concerns regarding ensuring maintenance of on-site stormwater management controls is also recommended.

Given the importance of assessing cumulative impacts, additional study prior to initiation of development is to be completed holistically, and have due consideration for the full future build out of the watercourse catchment, including other sites within the Mobility Hub. This assessment may be submitted as part of an enhanced Stormwater Management Design Brief.

6. **Monitoring:**

Monitoring, such as detailed geomorphic monitoring, has not been included in the work plan. Determination and completion of necessary pre and post-construction monitoring has been deferred to future study, and therefore may result in the delay of future site specific development while the pre-construction monitoring program is confirmed and sufficient baseline monitoring is completed.

7. **Terrestrial and Aquatic:**

Once, initial characterization work is completed, and more is known in terms of proposed land uses and potential impacts, additional field work may be required to address data gaps and uncertainties within the characterization of terrestrial and aquatic environments and hydrologic setting.

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Protecting the Natural Environment from Lake to Escarpment

September 12, 2017

BY EMAIL AND MAIL

Phil Caldwell
City of Burlington
Planning and Building Department
426 Brant Street, P.O. Box 5013
Burlington, Ontario L7R 3Z6

Dear Mr. Caldwell:

**Re: Downtown Mobility Hub – Background Review and Preliminary Constraints Scoped Environmental Impacts Study and Scoped SWM Assessment
Mobility Hubs - City of Burlington
CH File: MPR 653**

Conservation Halton staff has had an opportunity to review the memorandum titled 'Downtown Mobility Hub – Background Review and Preliminary Constraints Scoped Environmental Impacts Study and Scoped SWM Assessment Mobility Hubs – City of Burlington, prepared by AMEC Foster Wheeler (August 23rd, 2017) that was presented at the August 23rd meeting. Comments provided below have focused on ***Flow Optimization***, ***Understanding Level of Uncertainty***, and ***Detailed Comments Specific to the August 23rd Memorandum***. Comments on the ***Summary of Actions Arising from the August 23rd Meeting*** have been included in Appendix A attached to this letter. We also want to thank AMEC Foster Wheeler for the Hager-Rambo Flood Control Works Operations and Maintenance Manual that was sent on August 29th, 2017. It has been forwarded to our Manager of Risk and Land for review and confirmation of ownership/access information.

Flow Optimization

During the August 23rd meeting, the City and its consultant AMEC Foster Wheeler were looking for direction from Conservation Halton on the scenario to be used in the analysis of spill flow magnitude and location. After considerable discussion, the following outlines the approach Conservation Halton is in agreement with:

1. Conduct analysis for spill flow magnitude and location using all four scenarios (Flow Optimization - with and without flood control and No Flow Optimization with and without flood control). This approach would allow us to better understand the level of risk, and gain an appreciation for the full costs and benefits associated with each scenario.
2. If unable to conduct analysis using all four scenarios (i.e. due to project constraints), Conservation Halton recommends the analysis be conducted based on No Flow Optimization Without Flood Control in accordance with the approach outlined in the 2002 MNR Document "Technical Guide – River & Stream Systems: Flooding Hazard Limit". This approach would be consistent with the approved provincial standard and protect the potential to eliminate spills through modifications to the diversion channel.

3. Pending the outcome of current or future studies, Conservation Halton would be willing to accept an analysis based on flow optimization, where it has been demonstrated that the spill may not be feasibly eliminated (and is larger than 10% of the total flow). Where it is deemed not feasible to eliminate the spill, we would request documentation on the alternative measures considered and how they were assessed. This approach would be consistent with the approved Provincial standard.

Understanding Level of Uncertainty
As acknowledged at the August 23, 2017 meeting, the provided Memorandum does not include a commitment to assess and document the degree of uncertainty associated with the modeled and mapped outcome. As agreed at the meeting, it is the expectation that AMEC Foster Wheeler will provide analysis and documentation with respect to the degree of uncertainty associated with the hydrologic and hydraulic model assumptions/output individually as well as when the models are integrated together. It was also agreed that the level of uncertainty will then be addressed by the agencies in conjunction with developing appropriate policies for the Downtown Mobility Hub, including the potential need for additional Factors of Safety, or additional study at the next stage in the planning process.

Detailed Comments Specific to the August 23rd Memorandum
The following comments are intended to provide additional guidance to the City and AMEC Foster Wheeler, as they move forward with the analysis outlined in the August 23rd Memorandum as well as the broader Mobility Hub study.

1. **Preliminary Spill Analysis, Page 3:** Further to the third bullet in the list provided, the potential for the spill along the railway underpass at the QEW/403 should be considered in conjunction with the study for the Burlington Mobility Hub. This may require inclusion of additional lateral structures upstream of Fairview in conjunction with the modeling for that study area.
2. **Flood Risk Assessment of Downstream Areas, Page 5:** It is expected that development limitations within all spill zones will comprehensively assess risk and include considerations of both flow velocity and depth. Ponding depths exceeding 0.2 m should not be looked upon as the sole constraining factor related to flood-risk in the spill areas.
3. **Routing and assessment of spill flows to downstream areas, page 6:** Conservation Halton is supportive of the limits of the proposed 2D mesh on the basis of an understood commitment from the City to address other growth areas within the Mobility Hub that may be subject to significant spill flow. Appropriate policies reflecting the level of potential flood risk and level of uncertainty associated with the stated potential flood risk will need to be developed. Please note that within the policies the need for additional study may be identified.
4. **Routing and assessment of spill flows to downstream areas, page 6:** The last bullet on page 6 indicates that a dual drainage PCSWMM hydrology/hydraulic model will be utilized to complete a combined impact assessment of flooding and spills downstream of the limits of the simplified 2D PCSWMM hydraulic model to assess spill. It is noted that due to the dynamic routing functions inherent in PCSWMM, separate modeling input scenarios (such as a hydrologic model that excludes all crossings) and hydrograph manipulation (extending the duration of peak flows to prevent routing effects behind culverts) may be required to ensure riverine flooding conditions are modelled in accordance with approved Provincial guidelines. This issue was touched upon during a brief discussion on the use of the PCSWMM model as part of the May 31st Mobility Hubs Meeting.
5. Modeling utilizing HEC-RAS may also be required to complete the flooding impact assessment once flows are returned to the floodplain proper associated with Lower Rambo and/or Lower Hager Creeks.

6. All figures identify a layer titled "Watercourse (Conservation Halton)" which appears to consolidate several Conservation Halton data layers. It is recommended line work be reviewed and refined, prior to public distribution of any figures.
7. Given the known limitations associated with the 'Regulatory Floodline' it is recommended that this layer be removed from Drawing 2.

Additional Comments

Conservation Halton provided comments (dated July 7th, 2017) to the City concerning the Mobility Hub Project – Final Work Plan (dated April 12, 2017). Since the release of the July 7th, 2017 letter, discussion between Conservation Halton, the City and AMEC Foster Wheeler has focused primarily on the Downtown Mobility Hub. Conservation Halton requests a response to the additional comments and concerns identified in the July 7th, 2017 letter.

We trust the above is of assistance and assist the City in moving through the Mobility Hub projects and in particular the Downtown Mobility Hub. Conservation Halton staff look forward to continue working with the City of Burlington through the review process for the Mobility Hubs Study. If you require additional information please contact the undersigned at extension 2231.

Yours truly,

Heather Dearlove, B.Sc.
Environmental Planner

Cc: Jonathan Pounder, Conservation Halton, email
Barb Veale, Conservation Halton, email
Rosa Bustamante, City of Burlington, email
Richard Clark, Region of Halton, email
Jason Elliot, Region of Halton, email

Appendix A:

Comments on Summary of Actions Arising from the August 23rd Meeting

1. **Bullet 5** – Barb Veale from Conservation Halton to forward a summary of information pertaining to ownership and operations of the Upper Hager – Rambo flood attenuation system as researched by the Risk and Land Management section of Conservation Halton. The summary will be forwarded to the City by September 22nd, 2017.
2. **Bullet 11** – Conservation Halton will accept the use of unsteady state flows within the proposed PCSWMM 2-D hydraulic model for the 2D mesh area shown in Drawing 3. The use of unsteady state flows for the assessment of the diversion channel and lower remnant channels, however, is not supported for floodplain mapping purposes.
3. **Bullet 12** – Conservation Halton understands the Burlington GO Station study limits to be inclusive of the entire Mobility Hub.
4. **Bullet 13** – This bullet indicates that AMEC Foster Wheeler will be completing a 'regulatory Spill Assessment' for the Downtown Mobility Hub. As the regulatory status of the spill was not discussed in any great detail, we have assumed the reference to 'regulatory' was meant to indicate the flow rate being analysed as part of the spill assessment as opposed to the regulatory status of the spill. Please confirm and update the Summary of Actions.
5. **Bullet 14** – Is this statement in relation to Conservation Halton's commenting role for future development and Planning Act applications in the area south of the diversion channel? Please clarify and update.
6. **Bullets 15 and 16** – Conservation Halton recommends that a meeting be set up to discuss the flood attenuation of the Upper Hager – Rambo system as the Province was a partner in funding system. Maintenance, Operation and Mitigation should be discussed with the Region, City, Conservation Halton and the Province.
7. **Bullet 20** – Please update this bullet with the following text: Phil Caldwell confirmed that any building heights, density targets, etc. presented to the public and at the Council workshop this Fall will be subject to any additional constraints that are identified through the flood risks analysis. The precinct plan being presented to the public will include disclaimers stating that this is a precinct plan and that constraints such as flooding have not been considered at this time. Similarly Phil advised that the target densities can be shifted between precincts if required once the flood risks are known.
8. Janette Brenner from Conservation Halton flagged the need for an uncertainty analysis to be presented in conjunction with the materials submitted, as per previous discussions (Brenner/Scheckenberger 18/08/17).

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Protecting the Natural
Environment from
Lake to Escarpment

November 10, 2017

BY EMAIL AND MAIL (REVISED)

Phil Caldwell
City of Burlington
Planning and Building Department
426 Brant Street, P.O. Box 5013
Burlington, Ontario L7R 3Z6

Dear Mr. Caldwell:

Re: Downtown Mobility Hub – Flood Hazard Assessment (Draft) Scoped Environmental Impact Study and Scoped SWM Assessment
Mobility Hubs - City of Burlington
CH File: MPR 653

Conservation Halton staff has reviewed the memorandum titled 'Flood Hazard Assessment (Draft) Scoped Environmental Impact Study and Scoped SWM Assessment – City of Burlington, prepared by AMEC Foster Wheeler (September 27, 2017) presented at the September 27, 2017 Technical Advisory Committee Meeting and offers the following comments.

Freeman Pond, West Hager and East Rambo Ponds

Conservation Halton recognizes that the Province, City and Conservation Halton jointly constructed the Freeman Pond, West Hager Pond and East Rambo Ponds and have historically credited these facilities. However, given current flood standards and the implications of climate change, there is a need to gain a better understanding of the risks associated with this approach as part of any studies supporting intensification. At this time, Conservation Halton has insufficient information to determine if the Freeman, West Hager and East Rambo Ponds are functioning as designed. Given this uncertainty and potential public safety risk, the following should be included as part of the assessment:

1. Confirmation and agreement on ownership maintenance/inspection of the ponds,
2. Determination as to whether the ponds were built and functioning as designed,
3. Consideration of potential future changes in flow contributing to these ponds due to anticipated development,
4. Identification of the need and opportunities for enhancement to the existing ponds to improve functionality to bring the ponds to current standards and to reduce the potential failure risk,
5. Consistency in floodplain mapping approaches relative to other flood control facilities in Conservation Halton's jurisdiction (i.e. dams, regional control ponds, etc.), and
6. Identification of any other relevant factors.

Flow Optimization

In our correspondence dated September 12, 2017, Conservation Halton requested a four-scenario approach for Flow Optimization analysis for the Downtown Mobility Hub Study. This approach is consistent with the Provincial standard and should be completed before land use concept plans and technical studies supporting the Area Specific Plans are finalized. An understanding of the extent and magnitude of the spill within the Downtown Mobility study area, including its impact on the Rambo Creek Flood flows, is needed to inform development policies for the Downtown Mobility hub including the potential need for additional 'Factors of Safety' or additional study requirements.

Comments Specific to the September 27th Memorandum

General comments in response to the September 27th memo are provided below with detailed comments provided in Appendix A.

- The hydrologic and hydraulic assessment of the Lower Rambo Creek (without consideration of spills from the diversion channel) may be conservative, however, the floodplain limits shown are likely to expand once spills and flow paths from the diversion channel are quantified.
- The HEC RAS model used to evaluate the floodplain associated with the Hager Rambo diversion channel is insufficient. Additional model revision will be required to quantify spill from the Hager Rambo diversion channel.
- Decisions related to flood risk must have due regard for the limitations associated with the analysis (including scope of work, physical data availability and quality, the need to build off of older, uncalibrated models, application of different models and modelling techniques, etc.). Risk management approaches should recognize the potential for future refinements and increased model accuracy to modify flood risk and associated development opportunities.
- Additional discussion as noted above will be required to determine the appropriateness of continual crediting of the ponds and the use of flow optimization.

Detailed technical comments related to the models for the following ***Hydrologic Assessment of Lower Rambo and Lower Hager Creeks (PCSWMM Analysis), Hydraulic Assessment of Lower Rambo Creek (HEC RAS) Hydrologic Assessment of the Upper Hager and Upper Rambo Systems, and Hydraulic Assessment of the Hager-Rambo Diversion Channel;*** are provided in Appendix A (attached). Conservation Halton would be happy to discuss these comments further if needed.

We trust the above is of assistance and assist the City in moving through the Mobility Hub projects and in particular the Downtown Mobility Hub. Conservation Halton staff look forward to continue working with the City of Burlington through the review process for the Mobility Hubs Study. If you require additional information please contact the undersigned at extension 2231.

Yours truly,

Heather Dearlove, B.Sc.
Environmental Planner

Cc: Ron Scheckenberger, Wood
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Appendix A: Detail Comments

Hydrologic Assessment of Lower Rambo and Lower Hager Creeks (PCSWMM Analysis)

1. ***2.1.1. Hydrology, page 3:***
   a. There is a discrepancy between total imperviousness and directly connected imperviousness for residential properties (as per Table 2.1 Estimated Land Use Classification and Parameterization for Downtown Mobility Hub). Please clarify.
   b. A figure should be provided to show how the selected land use classifications (given in Table 2.1) have been applied within the model including which areas were recognized as Downtown Low Density Residential vs. Low Density Residential and which areas were identified as high impervious.
   c. Conservation Halton is supportive of the selection of a base curve number and hydraulic conductivity associated with a more open textured soil. The selected base CN value of 67 (representative of Meadow in hydrologic soil group BC) and hydraulic conductivity of 0.5 is accepted, given the need for conservatism associated with data limitations related to the underlying soils.
   d. Please provide the details and output from the referenced sensitivity analysis, completed to select the 6 hour Chicago rainfall distribution as most appropriate. Given that the 1:100 year flows typically exceed flows generated based on the Hurricane Hazel rainfall distribution, the rainfall distribution applied will impact the extent of the flood risk being considered.
   e. As only the last 12 hours of the Hurricane Hazel rainfall distribution have been simulated, all depression storage (pervious and impervious) should be set to 0, as was done for the Upper Hager and Upper Rambo models.
   f. As part of the more detailed reporting provided at the completion of the project, please include a summary of key model parameters applied to each catchment.

2. ***2.1.2 Hydraulics, page 5:*** The identified seven storm sewer outfalls to Lake Ontario should be clearly shown on Drawing 1 in combination with a clear delineation of each separate outfall's upstream catchment area. The drainage area associated with each of the remaining outfalls should also be provided.

3. ***Additional comments associated with the provided PCSWMM model:*** Insufficient documentation was provided in the materials provided to support the following model inputs associated with Model DT_EX_Trunk_No_Structures_Regional.inp:
   a. Inclusion of hydraulic transects that define high cord of brides, including 119.8925_HC, 123.4355_HC, etc.
   b. Inclusion weirs
   c. Storage unit SU1

   Please provide additional documentation to clarify why these structures have been included in the model.

Hydraulic Assessment of Lower Rambo Creek (HEC RAS)

4. ***2.1.2 Hydraulics, page 5 and 2.2.1 Model Development, page 8:*** The fixed boundary condition elevation of 76.6 m (representing the Lower Rambo outfall to Lake Ontario) is considered overly conservative when establishing the flood hazard. In accordance with the MNRF Technical Guidelines, it would be appropriate to utilize a known water surface elevation equivalent to the mean annual lake level in conjunction with analysis of the regulatory flow. The reported maximum monthly mean average lake level reported by Water Survey Canada for the period of record from 1918 to 2016 is 75.2 masl. The hazard must be determined in accordance with MNRF guidelines as the greater of the mean annual lake level and the river and stream systems flooding hazard limit or Great Lakes St. Lawrence River System Flooding Hazard Limit (accepted as 76.0 masl plus a 15 m flood allowance for waver

uprush and other water related hazards).

5. ***2.1.4 Hydraulic Model Results, page 6:*** It is not apparent that the described approach of applying boundary conditions in HEC RAS based on the PCSWMM modeling that includes hydraulic structures was followed. The boundary condition applied at Rambo Reach R1-2 (at the commencement of the Piped section at Caroline Street) appears to have been based on the maximum hydraulic grade line associated with the 'with structures' scenario for Junction J28 for the 1:100 year flow, but not for the Regional Storm. Please review and revise as necessary.
6. The following additional concerns are flagged based upon a review of the Lower Rambo Creek System.
   a. The flow applied at Rambo 2 (R1_2) between the confluence of R1_1 and R1_3 and the downstream face of the enclosure between Blairholme and Victoria Street (Between River Stations 646.547 to RS 435.2496) underestimates flows conveyed through the enclosure. Based on the provided SWMM model output flows at the downstream limit of the enclosure (Junction 433.9925) are predicted to be 13.91 m^3/s under Regional storm conditions and 15.38 m^3/s under 1:100 year rainfall, assuming no structures. The provided hydraulic model was based on a regional and 1:100 year flows at the inlet of the enclosure (J8) which equaled 12.54 m^3/s and 13.99 m^3/s respectively. Additional justification will be required to support application of the lower inlet flows, particularly should the capacity of the conduit remain unchanged.
   b. Given the urbanized nature of the lower Rambo Creek, channel form is variable and ranges from hardened (with vertical concrete walls) to a more natural stream system with wooded corridors. Conservation Halton is not supportive of the universal application of a main channel manning's n value of 0.03, particularly where the main channel width exceeds the bankfull channel. Conservation Halton is supportive of using 0.08 for the overburden in the municipally owned blocks (consistent with Conservation Halton's floodplain mapping program) and the application of a reduced overbank Manning's n value (0.045 for residential lots or an alternate value if justified by Wood) outside of the municipally-owned creek blocks, recognizing that much of the overbank floodplain extends onto developed urban lots.
   c. The modelled crossing associated with the waterfront trail should be reviewed. The modelled top-of- road elevation is approximately 1 m lower than indicated by Conservation Halton's topographic information, and there appears to be poor correlation between the defining bridge high and low chords and the bounding hydraulic cross sections.
   d. Flow changes have been noted to occur within the four hydraulic cross sections defining culverts and bridges and their associated expansion and contraction zones. The flow change locations should be adjusted to ensure a consistent flow value is modelled across the bridge, or the flow change within the crossing structure should be justified. The impacts of the flow change location relative to HEC RAS's automated hydraulic calculations should be discussed.
   e. The expansion and contraction zones associated with crossing structures should be modelled consistently with HEC RAS Guidelines. It appears that the downstream bounding cross section (cross section 4) was not consistently applied. Placement of an additional boundary cross section will be required.
   f. Hydraulic cross –section 479.3439 has been extended by HEC RAS. The terminal right bank station should be coincident with the point of spill where flows would leave the Rambo Creek Channel.
   g. Ensure all road crossings are labelled within the model.
   h. Conservation Halton is supportive of updating this model to consider spill flows from the Hager Rambo Diversion Channel once the more detailed spill assessment has determined flows and locations where spill returns to Rambo Creek. This assessment should also consider the impact of

the related hydrology comments associated with both the upper and lower Hager Creek. Conservation Halton staff provided additional direction on crediting of upstream flood control facilities and flow optimization in the body of the letter. Previous Conservation Halton correspondence dated July 12, 2017 and September 12, 2017 also discuss this issue.

Hydrologic Assessment of the Upper Hager and Upper Rambo Systems

7. ***Updates to Base Modeling, page 10:***
   a. The text references a cursory review to determine if any notable development has occurred that was not anticipated by the 1997 modelling. While staff support the conclusion that no notable additional development has occurred, the modelled development intensity does not appear to be consistent with the built form. Low density residential was modelled as 35% total impervious with 9% directly connected impervious. Catchment WR-6, which appears to be 40% developed, is modelled based on NASHYD, with a CN value of 93, while adjacent natural catchments WR-9 and WH-5 are modelled with a CN value of 91. While it is recognized that the 1997 model is an approved model, and widescale revision of the impervious coverages extending beyond the mobility hub would go beyond the scope of the workplan, it is expected that concerns and limitations associated with the existing model will be highlighted within the final documentation, and that these limitations be considered and analyzed relative to risk. It is also noted that for two of the channel routing functions the travel time table was exceeded.
   b. Conservation Halton staff appreciate that the sensitivity analysis confirming the appropriateness of the 6 hour Chicago Storm distribution will be documented within the ultimate reporting.

8. ***3.1.3 Removal of SWM Facilities, page 14:*** The document states: "the City of Burlington is of the firm opinion that these facilities [East Rambo, Freeman and West Hager Ponds] are to be included in any assessment which will establish the limits of regulated areas". Additional comments on this approach are provided in the body of this letter.

9. ***Tables 3.2 3.3, 3.4, 3.5*** – The reported current SWMHYMO flow of 45.6 m^3/s at Node H is not consistent with the provided model, which indicates flows will be 54.5m^3/s. Please review and update accordingly.

10. ***Additional Comments on the SWMHYMO modeling:*** Does the City's storm sewer data confirm the minor system drainage split (between the East Rambo and Freeman ponds) for the catchments north of the 407? The modelled receiving outlets for catchments ER-5B, ER 4C, ER4B and ER4A differ from Conservation Halton's gis information. Do catchments north of the 407 contribute to the West Rambo Tributary south of the 407 – as they are modeled to do? Does catchment WR 9 connect through WR3B as indicated and modeled in the 1997 study or through EH3C? Please confirm.

Hydraulic Assessment of the Hager-Rambo Diversion Channel

11. ***3.2.1 Base Hydraulic Model, page 17:*** Please provide additional explanatory notes clarifying how spill locations were selected. Are there any additional spill locations that may impact development potential within the Downtown Hub, require consideration through policy development (i.e. spills would appear to be as likely or more likely upstream of Thorpe Road as at Maple Avenue)? Is there potential for a spill upstream of Thorpe Road to impact intensification within the Downtown Hub that would require policy considerations similar to the Maple Avenue spill? Please confirm.

12. ***3.2.2. Channel Spill Analysis, page 19:***
    a. Additional discussion with the Province, City and Conservation Halton is required to determine whether the upstream ponds should be credited. Therfore, 'Regulatory' limits as an outcome of this study should not be presented until these discussion have taken place.

    b. Conservation Halton staff could not replicate the following spill flows identified in Table 3.7

(Conservation Halton staff ran the model utilizing HEC RAS 4.1.0, as the model would not run in 5.0.3):

- Flow Optimization and no Flow Optimization without flood control for Spills 2 and 3
- All flows associated with Spill Area 4

Please confirm the listed values in Table 3.7.

13. Comments on HEC RAS for Hager Rambo Diversion Channel:
    a. The roughness coefficients contained in the current model are not consistent with roughness values currently being applied as part of Conservation Halton's floodplain mapping program. While a Manning's n value of 0.015 is accepted for the concrete slab portion of the channel, unless detailed justification is provided and accepted, overbank areas commencing at the top of the concrete channel should be modelled at 0.045 (representative of manicured lawn) within the overbank associated with the diversion channel and through private residential lots. Where the overbank extends across large commercial parking lots, a Mannings n value of 0.02 may be applied. Recognizing model sensitivity to roughness and the potential implications of spill relative to downstream flood risk, Conservation Halton would prefer to have the hydraulic model updated with discretized roughness values as part of the current study. Should the outcome of the current study remain at a high level and require subsequent more detailed modeling to address previously noted concerns and broadly define the regulated floodplain, it would be acceptable to define overbank areas based on significant landuse.
    b. Additional consideration must be given to how flow nodes are incorporated into the model. The current modelling approach would appear to underestimate flow at key crossing structures:
        i. Application of flow node J at hydraulic cross section 2401.66 underestimates the flow experienced at the CNR and Fairview St. Crossings. It is recommended that the additional flow contribution associated with catchment ER-1 be considered at both the CNR and Fairview Crossings.
        ii. Application of flow node K commencing at hydraulic cross section 1721.699 and 1721.6 underestimates flow crossing Brant Street and tailwater conditions that may affect the enclosure upstream of Brant Street opposite the Walmart.
        iii. The flow tables in the report reported a lower flow at Node H than was evident in the provided hydrologic model. Please revise the flow at Node H and at West Hager 1018.932.
        iv. For several structures, flow changes occurred within the limits of the four cross sections defining the hydraulic structure. Justification for the flow change and analysis of the potential impacts of the flow change location were not provided. Flow changes within the bounding hydraulic cross sections of a crossing structure are not generally supported.
    c. Please document the approach taken to define the top of the lateral structures.
    d. Lateral structures have been modelled as broad crested weirs, but the selected lateral weir co-efficient (0.28) is applicable to non-elevated overbank terrain or a natural high ground barrier, which is generally more in keeping with the available topographic information. Please consider using a zero height weir crest not selected for the model.
    e. Please investigate the hydraulic response at Thorpe Road as it was noted under some profiles water levels drop 1 m (within the 4 m upstream of the bridge).
    f. Hydraulic Crossings 1429.197, 107 and 5 all demonstrate flow dropping below the road deck across the road surface. Crossings should be reviewed and ineffective flow depths and locations should be adjusted for the hydraulic cross sections defining these structures.
    g. Justification is required for the non-standard culvert entrance loss coefficients selected for culverts 272, 169 and 38.
    h. The selected n value for culvert 304 should be reviewed and adjusted or justified within the report.
    i. There were several instances where CHECKRAS flagged non-standard distances had been selected

for the expansion and contraction zones associated with hydraulic structures, please review the CHECKRAS output and confirm that expansion and contraction zones have been appropriately considered within the model.

j. Issues with integration between the modelled top of road and ground profile were noted relative to the following stations: 805.3582, 169, 683.094, 107, 5.Please review and revise the data as required.
k. The height and/or placement of the ineffective flow areas should be reviewed relative to cross sections 106 R & L, 145.5228 L, 2656.188 R & L, 277.288 R & L, 1.18 R & L, 272.4874 R & L, 145.5228 R & L, and 672.3745 L. Please update accordingly.
l. The hydraulic model has extended numerous sections vertically to contain flows. Please confirm that all extended cross sections were terminated at the point of spill, where flow would not return to the channel.

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Protecting the Natural
Environment from
Lake to Escarpment

January 29, 2018

BY EMAIL AND MAIL

Phil Caldwell
City of Burlington, Planning and Building Department
426 Brant Street, P.O. Box 5013
Burlington, Ontario L7R 3Z6

Dear Mr. Caldwell:

Re: Downtown and Burlington Mobility Hub – Flood Hazard Assessment Scoped Environmental Impact Study and Scoped SWM Assessment
Mobility Hubs - City of Burlington
CH File: MPR 653

Conservation Halton staff has completed their review of the technical memorandum titled 'Downtown and Burlington Mobility Hub - Flood Hazard Assessment Scoped Environmental Impact Study and Scoped SWM Assessment – City of Burlington,' presented and prepared by AMEC Foster Wheeler on November 30, 2017. The models presented are generally now advanced enough to support a high level study which generally defines the flood hazard, with the exception of some important gaps in the information. For this reason, we recommend additional study be done to better understand the West Rambo floodplain and the potential interactions between Upper Hager and Upper West Rambo Creeks and to model the extent of the floodplain associated with piped sections of Lower Rambo Creek. In addition, an agreement on the assumptions regarding the effectiveness of upstream controls and the suitability of using flow optimization will be required. The following comments highlight why we feel additional study and agreement on assumptions at this level is required.

As has been stated throughout our discussions, further refinements will be required to increase the accuracy of the flood hazards at future planning/development stages for the Mobility Hubs prior to the approval of specific development applications.

General Comments

1. ***East Rambo Pond - Detailed Flood Risk Assessment and Mitigation Study:*** The memo indicates that the East Rambo Pond is expected to spill into the West Rambo Creek via the QEW/railway underpass. Previously, the spill was believed to be directed to the East Rambo tributary. The 2D modelling generated to support flood risk assessment indicates that existing drainage systems are unable to convey the overflow.

   Given the limited documentation available, it is unclear if this overflow pathway was the intended major system spillway within the original design. The memo does not address whether or not there may be an opportunity to decrease or eliminate the overflow connection to the West Rambo Tributary, or whether doing so could have a net positive outcome reducing downstream flood risk. There may be a need for more detailed flood risk assessment and mitigation study related to the local drainage feature.

Based on the above limitations, and given the magnitude and proportion of the overflow directed to the West Rambo Tributary under the regulatory event (slightly more than double what is directed through the main outfall to East Rambo Creek), the overland flow route connecting the East Rambo Pond and West Rambo channel may pose a flood hazard.

In the absence of a detailed flood risk assessment and mitigation, the floodplain associated with the downstream flow path from the East Rambo Pond normal outfall should be sized based on the elimination of the overflow pathway to the West Rambo Tributary. This approach allows for the potential to mitigate flood risk along the overland flow route, should it prove feasible.

2. ***Potential Floodplain Interaction between Hager Creek and West Rambo Creek – The Need for Additional Information:*** To support the conclusion that tailwater conditions will not impact flood elevations within the Hager Creek channel, and the resulting decision to rule out potential floodplain interactions from the East Hager floodplain to the West Rambo floodplain, additional information is required. More specific technical comments in this regard are provided in Appendix A.
3. ***Use of 2D Hydraulic Modelling for West Rambo Creek – Recommendations:*** The use of 2D hydraulic modelling gives us a rough estimate of the scope, magnitude and locale of the flood hazard. However, there are limitations to the use of the current modelling because:

   - there are significant data limitations related to the accuracy and resolution of the available topographic information, and
   - there are technical challenges in adapting 2D model inputs to generate floodplain limits consistent with MNRF guidelines related to attenuation and spills.

   In fact, the application of 2D modeling based on available data may exacerbate the potential for inaccurate flood risk estimation. Conservation Halton recommends that the 1D hydraulic assessment for West Rambo be refined to:
   a. review and update West Rambo Creek hydrology (as necessary – reference Technical Comment);
   b. incorporate additional major flow pathways between the East Rambo Pond and West Rambo Creek as identified within the 2D analysis;
   c. update inlet culvert losses, per standard approaches, and
   d. evaluate the impact of lowering the main channel Manning's n value for West Rambo Creek from 0.045 to 0.035, provided field reconnaissance confirms the appropriateness of the lower Manning's n value.
4. ***Lower Hager and Lower Rambo Channels – Further Identification of Flood Risk:*** When generating regulatory flows through the PCSWMM model for the Lower Hager and Lower Rambo channels, it appears that a conservative modelling approach was used involving: a) modelling of the full 285 mm of rainfall associated with the Hurricane Hazel Storm; and b) modelling AMC III conditions and 0 depression storage at the start of simulation; in addition to the selection of a boundary condition for Lake Ontario which represents an overly conservative scenario involving coincident 1:100 year lake levels and a regulatory riverine flood.

   When modelling the Regional storm event, Conservation Halton requires that either modelling or boundary conditions be used, but does not require both to be adopted. Conservation Halton supports model refinement to address this issue. The boundary condition should be adjusted (as indicated in our previous comments). Conversely, as only the open channel portion of the Lower Rambo channel was modelled and flows appear to exceed the capacity of the pipe network, the full extent of the flood risk does not appear to have been characterized.

5. ***Crediting Upstream Ponds- Further Technical Assessments:*** As noted in Conservation Halton's letter dated November 10, 2017, we would like to understand the risk associated with the continual crediting of the Freeman Pond, West Hagar Pond, and East Rambo Ponds. The most recent submission shows that there are significant differences in the flow values with and without crediting of these ponds. Further technical assessments to determine the flood attenuation effectiveness of these facilities and the risks associated with the downstream spill pathways is recommended.

6. ***Response Matrix:*** Please ensure that a detailed response matrix is included as part of any subsequent submission. The response matrix facilitates our ability to focus on key areas and reduce the time of review.

7. *Next Steps*
   Conservation Halton is pleased that the additional work carried out by AMEC Foster Wheeler (WOOD.) has really helped to describe the existing scope and magnitude of the potential hazard in downstream areas. The flow regime is very complex and the modelling provided to date has identified some additional gaps in information that should be addressed now. In addition, the models assume that the upstream flood control facilities and are functioning to design standards and that flows can be optimized. These assumptions represent the 'best case' scenario and have not been verified. For this reason, we recommend that a more conservative approach be used to define the flood hazard. Further discussion and agreement on this matter is needed.

   With the additional information noted above and an agreement on the assumptions related to upstream controls and flow optimization, Conservation Halton would be in a position to discuss appropriate planning policies and can advise the City regarding the nature and extent of further work which will be required to refine the hazard areas at a later date, prior to considering development proposals.

   We would like further dialogue with the City to discuss our comments and the next steps in the planning process. To this end, I will contact you to schedule a follow-up meeting. If you require additional information please contact the undersigned at extension 2231.

Yours truly,

Heather Dearlove, B.Sc.
Environmental Planner

Cc: Ron Scheckenberger, Amec Foster Wheeler, email
Jonathan Pounder, Conservation Halton, email
Barb Veale, Conservation Halton, email
Hassaan Basit, Conservation Halton, email
Rosa Bustamante, City of Burlington, email

Appendix A: Detail Comments

Detailed Comments from the Review of the November 30th Memo

1. ***Section 2.1.3 Simulated Flows (With Flood Control Facilities), page 7, and Section 2.1. 4 Simulated Flows (Removal of Flood Control Facilities), Page 12:*** The East Rambo Pond Inlet Flow, Q, given in Tables 2.4 and 2.6 differs from the provided model. The provided model indicates the inlet flow to be 63.95 m3/s. Please updated accordingly.

2. ***Section 2.1.3. Simulated Flows (With Flood Control Facilities), page 9:***
   a. Please elaborate on the implications of the noted sensitivity in the overflow portion of the Freeman Pond rating curve. Given that the significant increase in flow (from 36.2 m^3/s to 49.6 m^3/s per Table 2.4), has arisen primarily due to 8 ha increase in drainage area, is this indicative of flows accessing the emergency spillway, where the spillway was not previously accessed?
   b. Given the discharge change in the flow storage curve (from 23.2 m^3/s at 320,600 m^3 to 71.0 m^3/s at 320700 m^3), what are the implications of a partially blocked outlet? Based on the updated model, what is the freeboard height of the facility?

3. ***Section 2.2.2.1 Lateral Structures Spill Analysis (1D), page 15:*** It is unclear what flow plan was considered in the development of Drawing 5, as none of the listed Regional storm water levels indicated in Drawing 5 directly match any of the provided plan outputs. As part of the next submission, please ensure that all floodplain mapping clearly indicates the model version, and the plan (and associated flow and geometry files) relied upon to generate the floodplain mapping. A hard copy of the summary model run output should also be provided.

4. ***Section 2.2.2.1 Lateral Structures Spill Analysis (1D), pages 14 and 16:*** Values included in the following tables appear to have been switched. The Regional values appear to have been reported in the 1:100 year table, while the 1:100 year values appear to have been reported in the Regional Table:
   - Table 2.7: Estimated Spill Flows (100-Year Storm – 2004 IDF;
   - 24 hour SCS Type II) from Hager-Rambo Diversion Channel in Area of Interest (page 15), and
   - Table 2.8: Estimated Spill Flows (Regional Storm) from Hager-Rambo Diversion Channel in Area of Interest (page 16) for the Estimated Spill Flow With Losses from Channel (Combined Flow Optimization) for the Without Flood Control Scenario associated with LS1 (2202) and LS2 (1668)

5. ***Section 2.2.2.2 Floodplain Delineation (1D), page 17:*** Paragraph two indicates that a comparison between the base model prepared by Conservation Halton and the updated modelling completed by AMEC Foster Wheeler has been attached to the current memorandum, however the attached information appeared to be limited to the approximate floodplain limits determined through Conservation Halton's model. Is additional information forthcoming, highlighting the impact of the flow increase and model changes made by Wood?

6. ***Section 2.2.2.2 Floodplain Delineation (1D) West Rambo Creek, page 17:*** As outlined in the body of this letter, Conservation Halton is generally not supportive of the use of 2D hydraulic modelling to establish the limits of the regulated floodplain associated with the West Rambo Creek. Conservation Halton requires the 1D modelling be utilized to delineate the limits of the regulatory floodplain and refined accordingly:
   a. Review and revise (if necessary) the hydrology for Rambo Creek, addressing Conservation Halton's previous request for clarification - Does the City's storm sewer data confirm the minor system drainage split (between the East Rambo and Freeman ponds) for the catchments north of the 407? The modelled receiving outlets for catchments ER-5B, ER 4C, ER4B and ER4A differ from Conservation Halton's gis information. Do catchments north of the 407 contribute to the

West Rambo Tributary south of the 407 – as they are modeled to do? Does catchment WR 9 connect through WR3B as indicated and modeled in the 1997 study or through EH3C?

b. Incorporate additional major flow pathways between the East Rambo Pond and West Rambo Creek as identified within the 2D analysis;

c. Update culvert entrance losses, per standard approaches, and evaluate the impact of lowering the main channel Manning's n value for West Rambo Creek from 0.045 to 0.035, provided field reconnaissance confirms the appropriateness of the lower Manning's n value.

7. ***Section 2.2.2.2 Floodplain Delineation (1D), East Rambo Creek, page 17:*** Conservation Halton would be supportive of the City assessing flood risk and mitigation measures associated with non-regulated spill flow pathways (related to East Rambo Creek south of Fassel Avenue) through the use of 2D modelling.

8. ***Section 2.2.2.2 Floodplain Delineation (1D), Hager Creek, page 18:*** The stage-storage discharge analysis undertaken for Upper Hager Creek to evaluate potential for interactions between the Hager Creek floodplain and the West Rambo Creek floodplain is not supported as sufficiently robust to rule out interactions between the two floodplains at this time. The assumption that the culverts will function under inlet control needs to be verified. The geometry of the downstream system is believed to increase the likelihood of tailwater conditions controlling culvert hydraulics. It is also unclear whether or not the calculated storage area upstream of the railway considered 'bare earth' conditions, or whether storage losses associated with the numerous structures identified within the floodplain were accounted for in any way. It is noted that the modelled hydraulic cross sections associated with the Upper Hager channel are hundreds of metres shorter than those shown in the CH Figure - Hager-Rambo Diversion Channel Regional Floodplain – Diversion Channel – West Branch, that was attached to the November 30th Memo. It is unclear if these sections were shortened in recognition of the point of spill, and therefore appropriately represent the limits of the regulated floodplain, or whether the sections were terminated prematurely, and therefor result in an overly conservative estimate of the regulatory flood elevation. As Conservation Halton's topographic information indicates that the hydraulic cross sections have been terminated prematurely in the current model, the termination point of the hydraulic cross sections should be reviewed, and the model updated accordingly.

9. ***2.2.3.1 CNR Spill (West Rambo Creek), page 20:*** Please note, Conservation Halton has not established standardized Manning's n values to be considered for 2D modeling, and understands selection of appropriate Manning's n values may vary between models based on the model assumptions as well as anticipated flow depths. While higher Manning's n values outside of any 1D flow areas are expected (to account for the predominately shallow flow regime), the TRCA values indicated appear to be lower than the 2D values recommended for use in HEC RAS. It is therefore recommended that roughness values be applied consistent with documented recommendations for 2D modelling in PCSWMM, as opposed to based on TRCA's guidelines.

10. ***2.2.3.1 CNR Spill (West Rambo Creek), page 20:*** Based on output provided, it appears a full 2D model was generated for West Rambo Creek, however the provided text indicates entrance and exit losses were applied to culverts. Please verify whether or not when completing a full 2D model in PCSWMM, the calculation approach integrated into PCSWMM accounts for inlet and exit losses associated with culverts, as is the case with 2D model simulations in HEC RAS.

11. ***2.2.3.2 Hager-Rambo Diversion Channel Spills, page 22:*** As indicated above Conservation Halton is supportive of applying TRCA's values for 2D Manning's n where the values are consistent with the PCSWMM recommendations and anticipated flow depths.

12. ***2.2.3.3 Hager Creek, page 24:*** While the completion of a 2D model to provide an additional measure of analysis to explore potential interactions between the Hager and West Rambo Creek floodplains is

appreciated, the analysis terminated at the CNR line south of Leighland Park, and assumed a normal depth boundary condition. For these reasons, the analysis does not alleviate concern over how tailwater conditions impact discharge at the CNR culvert. It is noted that downstream of the CNR, the channel narrows to a vertical box approximately 4.5 m wide, resulting in a more limited downstream cross sectional area than the triple 2.0 m culverts at a depth of 2 m. The channel is further constrained downstream, when flows enter an approximately 400 m long box culvert connecting to the diversion channel. The capacity of this channel has the potential to be limiting and impact flow through the culvert.

13. ***3.1.1 Hydrology, page 27:*** Contrary to the provided description, the Time Series Hurricane Hazel storm file included in PCSWMM includes the full 285 mm of runoff associated with the Hurricane Hazel Storm, as well as maintaining SCS III soil parameters and 0 depression storage. Conservation Halton supports either modification of the Storm file to model only the last 12 hours of the Hurricane Hazel event, or modification of the input sub-catchment parameters to return soil to AMC II conditions and appropriate depression storage values.

14. ***3.1.3 Hydrology Model Results, page 29:*** The results provided in Table 3.2 indicate that the 1:100 year flows are expected to exceed the Regional Storm flows even where catchments have large contributing drainage areas. This is even noted to be the case at the outlet to Lake Ontario. The hydrology should be reviewed further, and should results remain unchanged, detailed justification should be provided as to why in this instance, there have been no transition to Hurricane Hazel storm as the regulatory storm event.

15. ***3.2.1 Model Development, Page 32:*** Should the enclosures not have sufficient capacity to convey the full extent of the regulatory flows, the overland component of the floodplain should be modelled through HEC RAS to establish the limits of the floodplain. There are multiple approaches that may be taken to address this. One such method, which has been previously adopted within the City of Burlington (in the Falcon Creek Study) is to apply the difference of the flow modelled at the downstream end of the enclosure and the peak capacity of the enclosure at the upstream limit of the enclosure as the flow for the reach, and model only the surface conveyance features. Please ensure that the extent of the flood risk is appropriately defined.

16. ***3.2.1 Model Development, Page 32:*** Conservation Halton's comments of November 2, 2017 appear to have been mis-understood. Conservation Halton is not supportive of applying a known water surface elevation of 76.0 for the Lake Ontario connection when modelling the 1:100 year and regional storm events, as this would represent the simultaneous occurrence of regulated lake based flooding and riverine based flooding. The MNRF technical guidelines require that the regulatory flood boundary be based on the greater of the two events happening independently. As such a lower water surface elevation may be supported as a boundary condition at Lake Ontario. Please review previous comments and revise accordingly.

<u>Additional Comments on the Hydraulic Models Received in Support of the November 30th 2017 TAC Memo:</u>

1. Flow changes have been noted to occur within the four hydraulic cross sections defining culverts and bridges and their associated expansion and contraction zones. The flow change locations should either be adjusted to ensure a consistent and appropriate flow values are modelled across the bridge, or the flow change within the crossing structure should be justified, and the impacts of the flow change location relative to HEC RAS's automated hydraulic calculations should be discussed.

2. The hydraulic models contain numerous cross sections that have been extended vertically to contain flows. Some of these cross sections have been shortened. Please confirm that all vertically extended

cross sections are terminated at the point of spill, i.e. where a raindrop falling on the ground would not be directed back to the channel.

3. Please ensure all flow nodes included in the hydraulic model are documented in tables. Flow changes for the following cross sections within the Upper Hager Diversion Channel model were not documented within the report:
   - Flow change at Cross Section 2699.391 (hydrograph 521)
   - Flow change at 1412.911 (hydrograph 531)
   - Flow change at cross section 220 (hydrograph 51714)
   - Flow change at cross section 355.12 (hydrograph 51717)
   - Flow change at cross section 272.4874 (hydrograph 51712)
   - Flow change at cross section 169.6089 (hydrograph 51713)
   - Flow change at cross section 38.481 (hydrograph 51714)

4. Please review the selected cross section flow changes to ensure that the appropriate flow change location has been selected:
   - Cross Section 2699.391 (hydrograph 521) - It would have been expected that major system flow at the CNR crossing would include major system flow contributions from catchment ER-1A. If flows at Cross Section 2699.391 are not updated, please indicate where major system flows from ER-1A access East Rambo Creek.
   - Cross Section 2401.658 –Why were flow contributions from ER-1A (minor), ER1B and ER1F not considered with respect to the Fairview Road Crossing?
   - Application of flow node K commencing at hydraulic cross section 1721.699 and 1721.6 underestimates flow within the Brant Street crossing, due to the additional flows from est Rambo Creek. Please discuss and support maintaining the flow contribution from West Rambo Creek at the downstream limit of the crossing.
   - The flow change at cross section 220 Rambo Creek West Branch would appear to be more appropriately applied at UR1 40.68162, upstream of the CNR Crossing.

5. It is recommended that overbank Manning's n values associated with the apartment and condominium blocks adjacent to Lower Rambo Creek between Martha Street and Lake Ontario be increased to 0.08 below the top of valley where there is more naturalized valley corridor. Additionally, parcel layer fabric appears to indicate creek blocks are in existence sporadically along the Lower Rambo channel. Where mucnicipal creek blocks exist, it is recommended that the Manning n value for the overbank area associated with the creek block be increased to 0.08.

6. The LOB Manning's N value at HR Diversion Main 1-2 cross section 1454.463 of 0.0245 should be reviewed and revised.

7. As part of the final submission, please ensure that all model limitations and sensitivities are flagged to set the framework of policy discussions moving forward. In addition to sensitivity documentation already identified as forthcoming with the final report, please also include sensitivity testing with respect to cell size and calculation time step considered as part of the 2D modelling.

Date: **July 27, 2018**
To: **Phil Caldwell, City of Burlington**
C.C.: **Rosa Bustamante, Leah Smith, Umar Malik, Allan Magi, City of Burlington**
Karyn Poad, Richard Clark, Region of Halton
Ron Scheckenberger, Wood.
From: **Heather Dearlove, Conservation Halton**
Regarding: **Mobility Hubs Flood Hazard Assessment**

Further to the July 18, 2018 meeting of City, Region and Conservation Halton staff, outlined below are Conservation Halton's key interests related to the Mobility Hubs Flood Hazard Assessment and future Secondary Plans for the area.

1. *Crediting of Freeman, West Hager and East Rambo Ponds*

Conservation Halton would be in a position to support the crediting of the Freeman, West Hager and East Rambo Ponds ponds once the following items have been addressed:

a) Written confirmation that the ponds are functioning as designed (prepared by a Professional Engineer)
b) Identification of any potential failure risks associated with the ponds and, as necessary, recommendations to reduce any potential risks based on current standards (prepared by a Professional Engineer)
c) Confirmation from City staff that future development upstream of the ponds can be managed, as necessary, to ensure that it would not have an impact on the ponds' functions

It is also critical that Conservation Halton and City staff have further discussion about pond ownership and that a formal agreement relating to on-going pond inspection and maintenance be developed. Please see additional comments on this matter below.

Conservation Halton staff would be pleased to meet City staff on-site to conduct an inspection of the facilities and to help to scope the report requirements for (a) and (b) above. Further, Conservation Halton is willing to partner with the City on this study/report and can provide some funding to assist with the associated study/report costs.

2. *Hager Creek and West Rambo Creek Interaction*

Please provide the technical information that confirms there is no spill from the Hager Creek floodplain to West Rambo Creek (see Appendix A of January 29, 2018 CH letter). This information would be used to finalize flood hazard limits for West Rambo Creek, the diversion channel, downtown spill area, and Lower Hager/Rambo channels.

3. *East Rambo Creek Pond Spill into West Rambo Creek*

Please clarify the preferred flood management approach for this area. To do this, we recommend that one of the following approaches be undertaken:

a) Provide confirmation that the original design intended for overflow pathway to West Rambo Creek
b) Provide a flood risk assessment and mitigation study to identify the management approach with the best overall flood risk outcome
c) Provide updated floodplain mapping for East Rambo Creek based on the elimination of the overflow pathway to the West Rambo Creek (i.e. assume all flows from East Rambo Pond discharge to East Rambo Creek)

This information would then be used to finalize flood hazard limits downstream of the East Rambo Pond.

The additional analysis/assessment noted above will have implications on the following areas, which will need to be refined at a later date:

- West Rambo Creek Floodplain Mapping (Refined 1-D hydraulic assessment for West Rambo Creek)
- East Rambo Creek Floodplain Mapping (Refined 1-D hydraulic assessment downstream of the East Rambo Creek)
- Diversion Channel Floodplain Mapping and Spills Analysis (including 2D mapping of areas downstream of Diversion Channel)
- Lower Hager and Lower Rambo Channels Floodplain Mapping (Refined 1-D hydraulic assessment)

4. *Flow Optimization*

Flow Optimization was discussed at our meeting and questions were raised about how it was being applied within the Downtown and Burlington Mobility Hub analysis. Conservation Halton staff has reviewed the November 2018 submission can confirm that we have no outstanding concerns with how the Flow Optimization has been applied for the Downtown Hub and that it should continue to be applied in this manner moving forward.

5. *Pond/Channel Ownership and Maintenance*

As noted above and further to our discussion at the meeting, ownership and maintenance of both the ponds and diversion channel warrants further discussion. Based on a review of our records, a number of parties may be owners of these facilities and could be responsible for ongoing maintenance. In order to clarify roles and responsibilities, it would be beneficial to have a focussed discussion on this matter and to develop a formal agreement moving forward. Conservation Halton's CAO will contact City staff to arrange a time to discuss this specific matter.

6. Secondary Plan(s)

As discussed at our meeting, Conservation Halton is willing to work with City staff to ensure that appropriate Secondary Plan policies are developed to address flood hazards and manage/mitigate any potential risk.

Wood Environment & Infrastructure Solutions
a Division of Wood Canada Limited
3450 Harvester Road, Suite 100
Burlington, ON L7N 3W5, Canada
T: 905-335-2353
www.woodplc.com

August 20,2018
Our File: TPB178008

Heather Dearlove
Environmental Planner

Conservation Halton
2596 Britannia Road West
Burlington, ON L7P 03G

Dear Ms. Dearlove,

RE: Response to Conservation Halton regarding Mobility Hubs Flood Hazard Assessment (CH Memorandum of July 27, 2018), City of Burlington

Further to the meeting between staff of Conservation Halton (CH), City of Burlington (City), Region of Halton (Region) and Wood Environment & Infrastructure Solutions (Wood) on July 18, 2018 related to the City of Burlington's Mobility Hubs Flood Hazard Assessment, and the subsequent summary of CH's key interests stemming from that meeting (ref. memorandum of July 27, 2018), we hereby provide you with a response to the identified items.

It should be noted that the Mobility Hub Study relates to four (4) hubs – Aldershot GO, Burlington GO, Downtown, and Appleby GO, however the focus of the current response (and CH's original memorandum) is related to the Burlington GO and Downtown hubs only. Reference is also made to CH's letter of January 29, 2018, which was previously the most recent correspondence and summary of CH's opinions regarding these areas (based on the technical memorandum prepared and submitted by wood on November 30, 2017). It is noted that specific technical comments provided as part of that correspondence will be incorporated into a pending updated submission by Wood, revised as necessary, based on the overall study direction outcomes indicated in this current correspondence.

For clarity, CH comments follow the original numbers and have been reproduced in italics with the response following:

1. Crediting of Freeman, West Hager, and East Rambo Ponds

Conservation Halton would be in a position to support the crediting of the Freeman, West Hager and East Rambo Ponds ponds once the following items have been addressed:

a) Written confirmation that the ponds are functioning as designed (prepared by a Professional Engineer)
b) Identification of any potential failure risks associated with the ponds and, as necessary, recommendations to reduce any potential risks based on current standards (prepared by a Professional Engineer)
c) Confirmation from City staff that future development upstream of the ponds can be managed, as necessary, to ensure that it would not have an impact on the ponds' functions

It is also critical that Conservation Halton and City staff have further discussion about pond ownership and that a formal agreement relating to on-going pond inspection and maintenance be developed. Please see additional comments on this matter below.

Conservation Halton staff would be pleased to meet City staff on-site to conduct an inspection of the facilities and to help to scope the report requirements for (a) and (b) above. Further, Conservation Halton is willing to partner with the City on this study/report and can provide some funding to assist with the associated study/report costs.

Wood and the City of Burlington are encouraged that CH will now consider formally crediting of the attenuative function of the Freeman, West Hager and East Rambo Ponds. As you are aware, the items cited are beyond the scope of the current Mobility Hubs Study. It is understood that City staff has indicated a willingness to undertake these works in partnership with CH staff; further discussion is required accordingly. For the purposes of the current Mobility Hubs Flood Hazard Assessment, as per the direction of the City of Burlington, these flood control facilities will be credited in the hydrologic modelling. Notwithstanding, as per previous requests from CH staff, hydrologic modelling results without these features in place will also be presented for reference purposes, however these flows will not be applied in any subsequent hydraulic analyses and the planning for risk mitigation.

2. Hager Creek and West Rambo Creek Interaction

Please provide the technical information that confirms there is no spill from the Hager Creek floodplain to West Rambo Creek (see Appendix A of January 29, 2018 CH letter). This information would be used to finalize flood hazard limits for West Rambo Creek, the diversion channel, downtown spill area, and Lower Hager/Rambo channels.

A scoped 2-dimensional (2D) hydraulic analysis was completed for this area (Hager Creek upstream of the railway tracks – Leighland Park) as part of the November 30, 2017 technical memorandum to validate Wood's opinion that the Regulatory Floodplain for Hager Creek would not be expected to have any spill to the West Rambo Creek (as suggested by CH's previously developed 1D hydraulic modelling – March 18, 2014 memorandum). As per CH's comments of January 29, 2018, we understand that CH has requested the analysis be expanded to include the downstream channel area, given concerns regarding capacity limitations of this reach, and the potential tailwater impact. Wood agrees that this modelling should be updated, and will include the revised analysis as part of the next technical submission to CH.

3. East Rambo Creek Pond Spill into West Rambo Creek

Please clarify the preferred flood management approach for this area. To do this, we recommend that one of the following approaches be undertaken:

a) Provide confirmation that the original design intended for overflow pathway to West Rambo Creek
b) Provide a flood risk assessment and mitigation study to identify the management approach with the best overall flood risk outcome
c) Provide updated floodplain mapping for East Rambo Creek based on the elimination of the overflow pathway to the West Rambo Creek (i.e. assume all flows from East Rambo Pond discharge to East Rambo Creek)

This information would then be used to finalize flood hazard limits downstream of the East Rambo Pond.

The additional analysis/assessment noted above will have implications on the following areas, which will need to be refined at a later date:

- *West Rambo Creek Floodplain Mapping (Refined 1-D hydraulic assessment for West Rambo Creek)*
- *East Rambo Creek Floodplain Mapping (Refined 1-D hydraulic assessment downstream of the East Rambo Creek)*
- *Diversion Channel Floodplain Mapping and Spills Analysis (including 2D mapping of areas downstream of Diversion Channel)*
- *Lower Hager and Lower Rambo Channels Floodplain Mapping (Refined 1-D hydraulic assessment)*

With respect to point a), both Wood and City staff have been unable to obtain any detailed design materials for the East Rambo Pond which would confirm the intended function for overflows. If CH has any such information available, Wood would be pleased to incorporate it into the documentation.

With respect to point b), such an assessment is considered beyond the scope of the current study. As such, we would suggest that point c) (updated floodplain mapping for East Rambo Creek (Queensway to the Hager-Rambo Diversion Channel)) be pursued for the current study.

The preceding would result in a revised floodplain for the East Rambo Creek. Given the considerably larger peak flows, it is suggested that the current 2D modelling for the West Rambo Creek area may need to be expanded to include spills from the East Rambo Creek, particularly along Queensway Drive and upstream of the railway tracks. Depending on the findings of this subsequent analysis, representative floodplain mapping (1D or 2D) will be prepared accordingly.

It is acknowledged that this higher flow within the East Rambo Creek will likely increase the potential spill from the Hager-Rambo Diversion Channel at Lateral Structure 1 (i.e. upstream of its confluence with the West Rambo Creek); however combined flows further downstream (and associated spills) should generally remain unchanged. As such, an additional 2D spill assessment will need to be completed. However, as the spill contribution to Lower Rambo Creek was previously assessed based on the most conservative of the four (4) assessed spill scenarios, it is not currently anticipated that any updates to the riverine floodplain mapping (1D) will be required; this will be confirmed.

With respect to West Rambo Creek (Leighland Road to Fairview Street), as per the November 30, 2017 technical memorandum, a 1D hydraulic model of the channel was determined to be incapable of adequately determining the floodplain extents, given the large spill flows. As such, flooding extents for this entire area were assessed using a 2D approach, which would, in our professional opinion, yield the most conservative results. If the overflow from the East Rambo Pond via the CNR/QEW underpass is eliminated, this would in turn reduce flows to West Rambo Creek and yield a much less conservative floodplain, and one that is not actually representative of the current flood and spill mechanics of this area. As such, we would suggest the previously developed West Rambo Creek floodplain mapping (using a 2D approach) should continue to govern, and that 1D floodplain mapping using decreased flows is not warranted.

4. Flow Optimization

Flow Optimization was discussed at our meeting and questions were raised about how it was being applied within the Downtown and Burlington Mobility Hub analysis. Conservation Halton staff has reviewed the November 2018 submission can confirm that we have no outstanding concerns with how the Flow Optimization has been applied for the Downtown Hub and that it should continue to be applied in this manner moving forward.

Wood and City staff are pleased that the approach advanced in the November 30, 2017 technical memorandum for spills from the Hager-Rambo Diversion channel to the Downtown area is now considered to be acceptable to CH staff. The documentation for the Mobility Hubs Flood Risk Assessment will proceed under this assumption.

5. Pond/Channel Ownership and Maintenance

As noted above and further to our discussion at the meeting, ownership and maintenance of both the ponds and diversion channel warrants further discussion. Based on a review of our records, a number of parties may be owners of these facilities and could be responsible for ongoing maintenance. In order to clarify roles and responsibilities, it would be beneficial to have a focussed discussion on this matter and to develop a formal agreement moving forward. Conservation Halton's CAO will contact City staff to arrange a time to discuss this specific matter.

Similar to Point 1, this item is beyond the scope of the current Mobility Hubs Flood Hazard Assessment, and should be discussed directly amongst City and CH staff, as well as any other affected stakeholders.

6. Secondary Plan(s)

As discussed at our meeting, Conservation Halton is willing to work with City staff to ensure that appropriate Secondary Plan policies are developed to address flood hazards and manage/mitigate any potential risk.

Understood. High-level flood mitigation approaches will be developed as part of the current study. Further, more refined policies may be developed as part of subsequent secondary plans, based on the overall direction of the current study.

We trust that the foregoing is clear and acceptable to CH; should you require any additional information please contact Wood or the City accordingly.

Sincerely,

Wood Environment & Infrastructure Solutions
a Division of Wood Canada Limited

Per: Ron Scheckenberger, M.Eng., P.Eng.
Principal Consultant

Per: Matt Senior, M.A.Sc., P.Eng.
Senior Project Engineer

MJS\RBS

cc: Phil Caldwell, Rosa Bustamante, Leah Smith, Umar Malik, Allan Magi, City of Burlington
Karyn Poad, Richard Clark, Region of Halton

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Senior, Matt

From: Caldwell, Phil <Phil.Caldwell@burlington.ca>
Sent: Tuesday, September 11, 2018 10:51 AM
To: Scheckenberger, Ron; Senior, Matt; Malik, Umar
Subject: FW: Mobility Hub - Follow-up from the July 18th, 2018 Meeting

FYI CH response to WOOD memo and site visit with City staff.

Ron/Matt, is it worth just following up with CH directly regarding #2 and their questions about the memo?

From: Heather Dearlove <hdearlove@hrca.on.ca>
Sent: Tuesday, September 11, 2018 9:19 AM
To: Caldwell, Phil <phil.caldwell@burlington.ca>; Bustamante, Rosa <Rosa.Bustamante@burlington.ca>
Cc: Kellie McCormack <kmcCormack@hrca.on.ca>; Clark, Cary <Cary.Clark@burlington.ca>
Subject: RE: Mobility Hub - Follow-up from the July 18th, 2018 Meeting

Good Morning,

Thank you for the response to our July 27, 2018 memo and the site visit on August 7, 2018. I wanted to send a quick follow-up email to provide an update to the next steps we see to move the project forward:

1. Conservation Halton will coordinate directly with Cary Clark's team to discuss the additional work requested to support the crediting of the Freeman, West Hager and East Rambo Ponds. As a follow-up to the discussion held during the site visit on August 7, 2018, Conservation Halton is pulling together key items to assist in this discussion.
2. With respect to the response provided by Wood in relation to the East Rambo Creek Pond Spill into West Rambo Creek, Conservation Halton is appreciative of the City's selection of the third option but note the following:
   - Conservation Halton is looking forward to the receipt of the updated floodplain mapping for East Rambo Creek.
   - West Rambo Creek Floodplain Mapping – It is not clear why flows would be decreased within a 1-D model for the West Rambo Creek system as suggested by the last paragraph. Nevertheless, Conservation Halton is supportive of updating the 2-D model first and then re-assessing the need/benefits for refining 1-D modeling for West Rambo Creek (including the flow pathway between East Rambo Creek and West Rambo Creek). To minimize delays, it is recommended that a technical meeting with Wood, City and Conservation Halton engineering staff be arranged to discuss the updated 2-D model results once they are available and to discuss next steps.
3. Conservation Halton would like to coordinate a meeting with City Planners, Regional Planners and Conservation Halton Planners to discuss the development of the Secondary Plan policies and in particular the policies to address flood hazards and to manage/mitigate any potential risk.
4. Conservation Halton CAO will engage with City officials and other affected stakeholders in the coming weeks to continue the discussion of ownership and maintenance of the ponds.

Conservation Halton staff are looking forward to continue the discussion and to continue to work with the City to move the Mobility Hub study forward. Please contact me at your earliest convenience to schedule the additional meetings mentioned above.

Sincerely,

Heather Dearlove, BSc.
Environmental Planner

Conservation Halton
2596 Britannia Road West, Burlington, ON L7P 0G3
905.336.1158 ext. 2231 | Fax 905.336.6684 | hdearlove@hrca.on.ca
conservationhalton.ca

From: Caldwell, Phil [mailto:Phil.Caldwell@burlington.ca]
Sent: August 27, 2018 2:15 PM
To: Heather Dearlove
Cc: Bustamante, Rosa; Smith, Leah; Magi, Allan; Malik, Umar; Poad, Karyn; Clark, Richard; Scheckenberger, Ron; Kellie McCormack; Clark, Cary; Plas, Kyle; Romlewski, Samantha
Subject: RE: Mobility Hub - Follow-up from the July 18th, 2018 Meeting

Hi Heather,

Please find attached a response to CH's matters of interest memo provided on July 27 as prepared by WOOD and reviewed by City staff. Please note that items 1a) and b) from CH's memo are continuing to be scoped and discussed following our joint field visit on Tuesday August 7th. If not already, please connect with Umar and/or Cary to finalize the scope of this work to be carried out.

On a side note, I will be out of the office for at least the next few weeks as my wife gave birth to our little daughter on Friday. If you need anything from the hubs team in the interim, please contact Rosa Bustamante.

Thanks,
Phil

From: Heather Dearlove <hdearlove@hrca.on.ca>
Sent: Friday, July 27, 2018 2:53 PM
To: Caldwell, Phil <phil.caldwell@burlington.ca>
Cc: Bustamante, Rosa <Rosa.Bustamante@burlington.ca>; Smith, Leah <Leah.Smith@burlington.ca>; Magi, Allan <Allan.Magi@burlington.ca>; Malik, Umar <Umar.Malik@burlington.ca>; Poad, Karyn <Karyn.Poad@halton.ca>; Clark, Richard <Richard.Clark@halton.ca>; Scheckenberger, Ron <ron.scheckenberger@woodplc.com>; Kellie McCormack <kmcCormack@hrca.on.ca>
Subject: Mobility Hub - Follow-up from the July 18th, 2018 Meeting

Phil,

Once again, thank you for the opportunity to meet and discuss the items Conservation Halton raised as part of the Mobility Hub study. As committed to during the July 18, 2018 meeting, we have pulled together the key matters that are of interest to Conservation Halton (please see the attached).

We trust that the attached provides clarity regarding Conservation Halton's interests. We look forward to receiving a response from the City and moving forward on these matters. Please do not hesitate to contact me at ext. 2231 if you would like to discuss further.

Sincerely,

Heather Dearlove, BSc.
Environmental Planner

Conservation Halton

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Protecting the Natural Environment from Lake to Escarpment

July 25, 2019

BY EMAIL AND MAIL

Rosa Bustamante
City of Burlington, Planning and Building Department
426 Brant Street, P.O. Box 5013
Burlington, Ontario L7R 3Z6

Dear Ms. Bustamante:

Re: Flood Hazard and Scoped Stormwater Management Assessment - Burlington GO and Downtown Mobility Hubs
Mobility Hubs - City of Burlington
CH File: MPR 653

Conservation Halton (CH) staff has reviewed the following documents prepared as part of the Downtown Mobility Hub and Burlington Mobility Hub study:

1. *Flood Hazard and Scoped Stormwater Management Assessment, Burlington GO and Downtown Mobility Hubs, City of Burlington, prepared by Wood Inc., dated February 25, 2019 (received March 11, 2019); and*
2. *Technical Comment Responses, prepared by Wood Inc., dated February 27, 2019 (received March 11, 2019).*

Conservation Halton's general comments are noted below and more detailed comments on the above documents can be found in **Appendix A** and **Appendix B** of this letter. Some of our comments were previously provided to City staff via email; however, they have been reorganized based on the discussion at the July 9, 2019 meeting with City of Burlington, Wood Inc. and Conservation Halton staff.

General Comments

1. Conservation Halton is committed to working with City staff on the Freeman, West Hager and East Rambo Ponds Study, in order to confirm that the flood control facilities are functioning as designed. Further discussions will be needed, once this study is complete, to determine if there are any implications for the modelling that is underway as part of the Mobility Hub study. Conservation Halton staff looks forward to working with the City of Burlington on this study and will follow-up separately with City staff on this matter.
2. Similar to the comments Conservation Halton provided on the City of Burlington Official Plan update, statements that suggest that the Lower Hager/Lower Rambo are not regulated watercourses should be removed. We also recommend that any statements that suggest that spills are 'not formally regulated by Conservation Halton' be removed.

3. Additional discussion and comments on the Flood Hazard and Stormwater Management Strategy (Section 4.0) will be provided once our outstanding technical comments are addressed.

Staff recommends that the comments in **Appendix A** and **Appendix B** be addressed based on the approach agreed to at the July 9, 2019 meeting. Conservation Halton is committed to working with the City to advance the Flood Hazard and Scoped SWM Assessment and staff is pleased to participate in scheduled technical committee meetings. If you require additional information or clarity on the attached comments, please do not hesitate to contact the undersigned at extension 2231.

Yours truly,

Heather Dearlove, B.Sc.
Environmental Planner

Cc: Ron Scheckenberger, Wood, email
Allison Enns and Leah Smith, City of Burlington, email
Karyn Poad, Region of Halton, Email
Kellie McCormack and Barb Veale, Conservation Halton, email

Appendix A: Follow-up Comments from Conservation Halton's January 29, 2018 Letter

The comments below build on Conservation Halton's letter dated January 29, 2019 and the response provided by Wood. Note that Conservation Halton's original comment is in italics and a follow-up comment is noted below.

As per the July 9, 2019 meeting, staff has identified whether our comment should be addressed as part of an update to the Flood Hazard and Scoped SWM Assessment or in later stages of the planning process (i.e., whether the comment should be addressed in Phase 1 or Phase 2).

- Phase 1: Updates to the Flood Hazard and Scoped SWM Assessment & supporting documentation to support the drafting of OP Policies.
- Phase 2: Model updates to be completed comprehensively by the City (e.g. updated hydraulic analysis with detailed topographical information, flood impact assessment of potential future development).

General Comments

3. ***Use of 2D Hydraulic Modelling for West Rambo Creek – Recommendations:*** *The use of 2D hydraulic modelling gives us a rough estimate of the scope, magnitude and locale of the flood hazard. However, there are limitations to the use of the current modelling because:*

   - *there are significant data limitations related to the accuracy and resolution of the available topographic information, and*
   - *there are technical challenges in adapting 2D model inputs to generate floodplain limits consistent with MNRF guidelines related to attenuation and spills.*

   In fact, the application of 2D modeling based on available data may exacerbate the potential for inaccurate flood risk estimation. Conservation Halton recommends that the 1D hydraulic assessment for West Rambo be refined to:

   a. *review and update West Rambo Creek hydrology (as necessary – reference Technical Comment);*
   b. *incorporate additional major flow pathways between the East Rambo Pond and West Rambo Creek as identified within the 2D analysis;*
   c. *update inlet culvert losses, per standard approaches, and*
   d. *evaluate the impact of lowering the main channel Manning's n value for West Rambo Creek from 0.045 to 0.035, provided field reconnaissance confirms the appropriateness of the lower Manning's n value.*

   Comment Partially Addressed: See Comments 1 and 2 in Appendix B regarding flood hazard delineation for West Rambo Creek. Complete as part of Phase 1 and Phase 2 works.

4. ***Lower Hager and Lower Rambo Channels – Further Identification of Flood Risk:*** *When generating regulatory flows through the PCSWMM model for the Lower Hager and Lower Rambo channels, it appears that a conservative modelling approach was used involving: a) modelling of the full 285 mm of rainfall associated with the Hurricane Hazel Storm; and b) modelling AMC III conditions and 0 depression storage at the start of simulation; in addition to the selection of a boundary condition for Lake Ontario which represents an overly conservative scenario involving coincident 1:100 year lake levels and a regulatory riverine flood.*

   When modelling the Regional storm event, Conservation Halton requires that either modelling or boundary conditions be used but does not require both to be adopted. Conservation Halton supports *model refinement to address this issue. The boundary condition should be adjusted (as indicated in our previous comments). Conversely, as only the open channel portion of the Lower Rambo channel was modelled and flows appear to exceed the capacity of the pipe network, the full extent of the flood risk does not appear to have been characterized.*

Comment Partially Addressed: See Comments 11, 12, 14 and 15 in Appendix B regarding confirmation of peak flow rates, boundary conditions and pipe capacity for Lower Rambo Creek. Complete as part of Phase 1 and Phase 2 works.

5. *Crediting Upstream Ponds- Further Technical Assessments: As noted in Conservation Halton's letter dated November 10, 2017, we would like to understand the risk associated with the continual crediting of the Freeman Pond, West Hagar Pond, and East Rambo Ponds. The most recent submission shows that there are significant differences in the flow values with and without crediting of these ponds. Further technical assessments to determine the flood attenuation effectiveness of these facilities and the risks associated with the downstream spill pathways is recommended.*

   Comment Partially Addressed: The decision on whether the flood control facilities should be credited within regulatory mapping is the responsibility of Conservation Halton. Conservation Halton is working with the City of Burlington on the Freeman, West Hager and East Rambo Ponds Study to determine whether the ponds are functioning as designed and whether they should continue to be credited as flood control facilities. Further discussions will be needed, once this study is complete, to determine if there are any implications for the analysis completed as part of the Mobility Hub study. It is Conservation Halton's preference that this work be completed as part of the Phase 1 works. If this is not resolved in Phase 1, then the Phase 1 documentation and the OP Policies will need to identify the uncertainty surrounding this issue and the potential implications on future development. This issue will need to be resolved in conjunction with Phase 2.

6. ***New General Comment:*** References to and illustration of planned re-development parcels should be refined to reflect the updated land use framework being considered at this time. Complete as part of Phase 1 works.

Detailed Comments from the Review of the November 30th Memo

1. ***Section 2.1.3 Simulated Flows (With Flood Control Facilities), page 7, and Section 2.1. 4 Simulated Flows (Removal of Flood Control Facilities), Page 12:*** *The East Rambo Pond Inlet Flow, Q, given in Tables 2.4 and 2.6 differs from the provided model. The provided model indicates the inlet flow to be 63.95 m3/s. Please updated accordingly.*
   Comment Partially Addressed: The Regional Storm East Rambo Pond Inlet Flow, Q, given in Tables 2.5 and 2.8 reflects Node 517 in the model and not Node 51700 as indicated in the response memo. The provided model indicates the inlet flow Q to be 63.9 m3/s. Revisit and update accordingly. Complete as part of Phase 1 works.

2. ***Section 2.1.3. Simulated Flows (With Flood Control Facilities), page 9:***
   a. *Please elaborate on the implications of the noted sensitivity in the overflow portion of the Freeman Pond rating curve. Given that the significant increase in flow (from 36.2 m^3/s to 49.6 m^3/s per Table 2.4), has arisen primarily due to 8 ha increase in drainage area, is this indicative of flows accessing the emergency spillway, where the spillway was not previously accessed?*
      Comment Addressed: Conservation Halton staff supports the proposal for a supplemental topographic survey to verify the spillway grades and other key elevations for the Freeman Pond (to refine the rating curve for this facility and update the modeling results accordingly as well as to assess the potential for additional spills from the pond). Complete survey as part of the Phase 1 works but at a minimum in conjunction with Phase 2 works. This work will be completed as part

of the additional study by the City of Burlington in partnership with Conservation Halton. Complete the recommended modelling updates as part of the Phase 2 works.

b. *Given the discharge change in the flow storage curve (from 23.2 m^3/s at 320,600 m^3 to 71.0 m^3/s at 320700 m^3), what are the implications of a partially blocked outlet? Based on the updated model, what is the freeboard height of the facility?*
Acknowledged: Implications of a partially blocked outlet and available freeboard within the Freeman Pond can be evaluated through the separate study proposed to support municipal and conservation authority decisions on crediting facilities within the flood hazard mapping. Complete as part of the Phase 1 works or, at a minimum, complete in conjunction with Phase 2 works. Complete the recommended modelling updates as part of the Phase 2 works.

7. ***Section 2.2.2.2 Floodplain Delineation (1D), East Rambo Creek, page 17:*** *Conservation Halton would be supportive of the City assessing flood risk and mitigation measures associated with non-regulated spill flow pathways (related to East Rambo Creek south of Fassel Avenue) through the use of 2D modelling.*
Comment Partially Addressed: See Comment 4 in Appendix B regarding the potential spill from East Rambo Creek at Fairview Street.

8. ***Section 2.2.2.2 Floodplain Delineation (1D), Hager Creek, page 18:*** *The stage-storage discharge analysis undertaken for Upper Hager Creek to evaluate potential for interactions between the Hager Creek floodplain and the West Rambo Creek floodplain is not supported as sufficiently robust to rule out interactions between the two floodplains at this time. The assumption that the culverts will function under inlet control needs to be verified. The geometry of the downstream system is believed to increase the likelihood of tailwater conditions controlling culvert hydraulics. It is also unclear whether or not the calculated storage area upstream of the railway considered 'bare earth' conditions, or whether storage losses associated with the numerous structures identified within the floodplain were accounted for in any way. It is noted that the modelled hydraulic cross sections associated with the Upper Hager channel are hundreds of metres shorter than those shown in the CH Figure - Hager-Rambo Diversion Channel Regional Floodplain – Diversion Channel – West Branch, that was attached to the November 30th Memo. It is unclear if these sections were shortened in recognition of the point of spill, and therefore appropriately represent the limits of the regulated floodplain, or whether the sections were terminated prematurely, and therefor result in an overly conservative estimate of the regulatory flood elevation. As Conservation Halton's topographic information indicates that the hydraulic cross sections have been terminated prematurely in the current model, the termination point of the hydraulic cross sections should be reviewed, and the model updated accordingly.*
Comment Addressed: As part of future updates, the model should be refined further, as necessary, to address the minor offsets observed between the alignment of the culverts and CNR rail embankment (XS 805). Complete as part of Phase 2 works.

15. ***3.2.1 Model Development, Page 32:*** *Should the enclosures not have sufficient capacity to convey the full extent of the regulatory flows, the overland component of the floodplain should be modelled through HEC RAS to establish the limits of the floodplain. There are multiple approaches that may be taken to address this. One such method, which has been previously adopted within the City of Burlington (in the Falcon Creek Study) is to apply the difference of the flow modelled at the downstream end of the enclosure and the peak capacity of the enclosure at the upstream limit of the enclosure as the flow for the reach, and model only the surface conveyance features. Please ensure that the extent of the flood risk is appropriately defined.*
Comment Partially Addressed: Different pipe capacity results were calculated for the Lower Rambo Creek enclosure downstream of Caroline Street (Conduit C12) when Conservation Halton staff ran the model within EPA SWMM 5.1.013. Pipe capacity should be re-confirmed in

conjunction with the model refinements noted in our detailed comments below. Additional comments on the Lower Hager may come at a later date or review deferred to the City of Burlington. Complete as part of Phase 1 works.

Additional Comments on the Hydraulic Models Received in Support of the November 30th, 2017 TAC Memo:

3. *Please ensure all flow nodes included in the hydraulic model are documented in tables. Flow changes for the following cross sections within the Upper Hager Diversion Channel model were not documented within the report:*
   - *Flow change at Cross Section 2699.391 (hydrograph 521)*
   - *Flow change at 1412.911 (hydrograph 531)*
   - *Flow change at cross section 220 (hydrograph 51714)*
   - *Flow change at cross section 355.12 (hydrograph 51717)*
   - *Flow change at cross section 272.4874 (hydrograph 51712)*
   - *Flow change at cross section 169.6089 (hydrograph 51713)*
   - *Flow change at cross section 38.481 (hydrograph 51714)*

   Comment Addressed: Note that all flow rate summary tables should include all flow node changes included within a hydraulic model. Complete as part of Phase 2 works.

4. *Please review the selected cross section flow changes to ensure that the appropriate flow change location has been selected:*
   - *Application of flow node K commencing at hydraulic cross section 1721.699 and 1721.6 underestimates flow within the Brant Street crossing, due to the additional flows from East Rambo Creek. Please discuss and support maintaining the flow contribution from West Rambo Creek at the downstream limit of the crossing.*

   Comment Partially Addressed: Based on the July 9, 2019 meeting, it is our understanding that Wood has sufficient information to state that the West Rambo Creek outlets to the open diversion channel downstream of Brant Street and not into the enclosure. Complete verification in the field if necessary, as part of Phase 2 works.

7. *As part of the final submission, please ensure that all model limitations and sensitivities are flagged to set the framework of policy discussions moving forward. In addition to sensitivity documentation already identified as forthcoming with the final report, please also include sensitivity testing with respect to cell size and calculation time step considered as part of the 2D modelling.*

   Comment Partially Addressed: The document does not discuss sufficiently the uncertainty associated with the various tools, assumptions and analysis to set the framework for future policy discussions and technical study requirements. Examples of uncertainties include the limited re-evaluation of external drainage area impervious coverages, the accuracy of the topographical survey data and unanalyzed scenarios. Complete as part of Phase 1 works.

Appendix B: Comments on the Updated Flood Hazard and Scoped Stormwater Management Assessment Report

The comments below are based Conservation Halton staff's review of the updated Flood Hazard and Scoped Stormwater Management Assessment, Burlington GO and Downtown Mobility Hubs, City of Burlington, prepared by Wood Inc., dated February 25, 2019.

Section 2.0 - Burlington GO Mobility Hub
Section 2.2 - Hydraulics
West Rambo Creek - Floodplain Delineation

1. **Sections 2.2.1.2 & Drawing No. 5A - Scenario 1 (Existing East Rambo Pond Spill to West Rambo Creek):** Since the spill near Plains Road could potentially be reduced through culvert improvements or other measures in this location Conservation Halton staff does not support the reduction of flow rates within the 1-D model. Staff acknowledges that modeling of the full flows within a 1-D model at this location would likely be overly conservative. An alternative was discussed with representatives from the City of Burlington and Wood at the July 9, 2019 meeting as follows:
   a. Between CNR Tracks and Leighland Road (appears to be both floodway and spill flood hazards):
      i. Map a line along the top of the "valley" on the west and east sides of the creek. Updated 1D modeling would not be required to support the mapping and specific flood elevations therefore should not be provided on the drawing to be used for Planning purposes. Complete as part of Phase 1 works.
      ii. Map the extent of the 'area requiring further study' based on existing conditions 2-D modeling (Sections 2.2.2.1 & 2.2.2.2). Complete as part of Phase 1 works.
      iii. Update the 2-D modeling and mapping to reflect the full range of potential spill conditions resulting from culvert conveyance improvements or other similar measures. While this could be addressed through removal of the culverts, etc. from the model in various combinations, another potential method would be to extend the duration of the peak flow to 'over-ride' the flow routing effects of the storage upstream of the culverts. Complete as part of Phase 2 works.

   b. Between the two CNR Track lines (appears to be floodway, flood fringe and spill flooding hazards):
      i. Refined mapping could take one of two approaches. A third category could be added and mapped between the top of the "valley" and the high point of ground adjacent to the Brant Street underpass called "area of potential limited development (no intensification of use) requiring further study' (or other appropriate terminology). Alternatively, the "flood fringe" areas can be mapped similar to the spill areas with sufficient notes on the drawing and sufficient documentation within the report to describe the different types of development that may be considered in the different types of flood hazard areas. See Section 2.3 comments below for more discussion in this regard. Complete as part of Phase 1 works.

   c. Between CNR Tracks and Fairview Street (appears to be both floodway and spill flood hazards):
      i. For those areas where a spill is suggested by the 1-D model with full flows, apply an approach similar to that outlined in (a) above. Complete as part of Phase 1 works.

   Additional discussion will need to be held with City staff to discuss how this information will be presented.

2. **Scenario 2 (Elimination of Spill from East Rambo Pond to West Rambo Creek) – Section 2.2.1.3 & Drawing No. 5B:** Once a decision is made regarding the modeling and mapping for Scenario 1, Scenario 2 modeling and mapping should also be updated accordingly. Complete as part of Phase 1 and Phase 2 works.

3. **Drawing No. 5A:** To facilitate future use, Conservation Halton staff recommends that a spill arrow from the East Rambo Pond be added at the top of the map near the CNR crossing. Complete as part of Phase 1 works.

East Rambo Creek, Floodplain Delineation

4. **Section 2.2.1.3, Section 2.2.1.4 & Drawing No. 5B - Scenario 2 (Elimination of Spill from East Rambo Pond to West Rambo Creek):**
   a. As discussed in more detail under our Section 2.3 comments, Scenario 2 should be used for Planning purposes and to establish regulatory floodplain limits for East Rambo Creek unless it can be demonstrated that reduction of the spill from the East Rambo Pond to West Rambo Creek is not feasible. Complete as part of Phase 1 works. If Scenario 2 is used for planning and regulatory purposes, further consideration should be given to the potential spill from East Rambo Creek at Fairview Street (immediately upstream of the diversion channel). Conservation Halton recommends that policy be developed in Phase 1 by City Planning staff that considers the possibility of a spill at this location. Phase 1 documentation/policies will need to identify whether additional modeling should be undertaken as part of Phase 2 or by the individual landowners on a site by site basis.
   b. Within the model several ineffective flow areas at crossings continue to be of concern. Complete as part of Phase 2 works.

5. **Scenario 1 (Existing East Rambo Pond Spill to West Rambo Creek):** In the event that Scenario 2 is not used for planning and regulatory purposes, the hydraulic modeling and mapping in the vicinity of Sections 3198 and 3188 as well on the south side of Glenwood School Drive should be revisited. Complete as part of Phase 1 works.

Hager-Rambo Diversion Channel & Associated Spills

6. **Section 2.2.2.3 - Analysed Scenarios:** As discussed in more detail under our Section 2.3 comments below, Conservation Halton staff recommend assessing the spills from the diversion channel based on Scenario 2 as well as Scenario 1 flows unless it can be demonstrated that reduction of the spill from the East Rambo Pond to West Rambo Creek is not feasible. Complete as part of Phase 1 works.

7. **Sections 2.2.1 & 2.2.2 - Maple Avenue Spills:** Conservation Halton staff concur that additional analysis of the potential spill at Maple Avenue is not necessary at this time; however, we disagree that it has no potential for impact on re-development blocks as stated in Section 2.2.2.4. The Downtown Mobility Hub Concept Plan provided in Appendix A illustrates two re-development blocks that could potentially be affected by spills along the road network near Maple Avenue south of Caroline Street. Conservation Halton notes that Policies developed for these areas should address the potential spill impacts. Complete as part of Phase 1 works.

8. **Thorpe Road Spill:** Conservation Halton staff could not locate discussion within the report that confirms there is no potential for the spill from the diversion channel at Thorpe Road to affect the Downtown Mobility Hub area. Complete as part of Phase 1 works. The hydraulic model also continues

to indicate a 1 m drop in flood elevations within the 4 m upstream of Thorpe Road, which should be revisited in conjunction with future model updates. Complete as part of Phase 2 works.

9. **Drawings:** Conservation Halton staff is concerned that the presence of spills at Thorpe Road and Maple Avenue are not reflected on any mapping and therefore may inadvertently be missed in the future. We recommend that an additional figure and/or drawing be included within the report that identifies these spill locations. Complete as part of Phase 1 works.

Section 2.0 - Burlington GO Mobility Hub
Section 2.3 - Stormwater Management
West Rambo, East Rambo, Hager-Rambo Diversion Channel & Associated Spills

10. **Section 2.3.1 - Anticipated Development Changes**: This section should be refined to reflect the updated land use framework being considered at this time. Complete as part of Phase 1 works.

11. **Section 2.3.2 - Floodplain and Spill Impacts**:
    a. As noted under General Comments above, please remove any statements that suggests that spills are 'not formally regulated by Conservation Halton' be removed.
    b. Remove the reference to 'no development is permitted within the Regulatory Floodplain limit'. The type of redevelopment or scale of intensification permitted within flood hazards, such as spills or the 'flood fringe', depends on a number of factors, including if there is an acceptable level of risk and if special policies can be developed for those areas.
    c. While Scenario 1 is more representative of existing conditions as well as representing the worse case scenario for West Rambo Creek, it does not represent the worse case scenario for East Rambo Creek, the Diversion Channel, or the spill flows from the Diversion Channel. For these reaches, Scenario 1 also does not meet Provincial Guidelines, which recommend that reduced flows should only be used after a review of alternatives proves that the spill cannot be prevented. On the other hand, use of Scenario 2 flows to map the flood hazard for East Rambo Creek, the Diversion Channel and the spills from the Diversion Channel will protect future opportunities to mitigate/reduce the overall flood risks in the area by reducing or eliminating the spill from the East Rambo Creek Pond to West Rambo Creek. As discussed at the July 9, 2019 meeting, Wood will submit a high-level analysis of the feasibility to reduce or eliminate the spill from the East Rambo Creek pond to West Rambo Creek, which will be evaluated by City and Conservation Halton staff. If this analysis does not demonstrate to the satisfaction of the agencies that there is no reasonable potential to reduce the spill, Conservation Halton will recommend that Scenario 2 be used to delineate the flood hazard area for these reaches for Regulatory and Planning purposes. Complete as part of Phase 1 works.
    d. Prior to construction, both 1-D and 2-D modeling and mapping of existing conditions must be updated with more detailed topographical information. Due to the nature of the flooding in the area, this update will need to be done comprehensively for the entire area as opposed to on a site by site basis. Complete as part of Phase 2 works.
    e. For spill areas, additional 2-D modeling and mapping is recommended to assess the potential impacts from cumulative development impacts (including grading/filling) within spill areas. This analysis would demonstrate where and how development can proceed without resulting in negative flooding impacts (flood levels on site, upstream and downstream) while protecting life (access/egress) and protecting property (floodproofing requirements). Complete as part of Phase 2 works.
    f. For spill areas, separate drawings showing velocity as well as the depth velocity product for the 1:100 year and Regional Storm will be necessary to support City and Conservation Halton staff decisions in the future. Complete as part of Phase 1 works.

g. The fourth paragraph of this section provides potential ideas for managing re-development in the subject area. Conservation Halton staff will provide comment on these ideas in conjunction with the pending City policy discussions. Complete as part of Phase 1 works.

Section 3.0, Downtown Mobility Hub
Section 3.1, Hydrology
Lower Rambo Creek, Floodplain Delineation

12. **Section 3.1.2.1, Hydrology:** Table 3.3, indicates that peak flows (when spills are included) will decrease between the upper end of the West Branch and the Lower Rambo Creek at Blairholm Avenue despite the addition of flows from the East Branch and local drainage. This suggests that the PCSWMM model is applying significant routing of flows within this area, potentially because of the backwater effect from the Blairholm Avenue culvert/enclosure. As there would appear to be an opportunity to upgrade or daylight the culvert/enclosure as part of future redevelopment, it is recommended that the enclosures (Conduits C11 and C31) be removed from the 'without hydraulic structures' model to assess the impacts on flows. If upon removal of the culvert/enclosure, the significant routing continues to be predicted by the modeling, this finding should be discussed with City and Conservation Halton staff prior to resubmission. Complete as part of Phase 1 works.

Section 3.2, Hydraulics

13. The legend on Drawing No. 12 incorrectly indicates that 100-year storm flood elevations are shown. Since the **Regulatory** Storm event flips back and forth between the 100 year and Regional Storm, it is recommended that both storm flood elevations be provided on the drawing and the composite **Regulatory** Storm floodline illustrated. The 100-year Lake Ontario flood level of 76.0 m should also be reflected, allowing the floodline to extend down to the Lake Ontario shoreline. Complete as part of Phase 1 works.

14. Pipe capacity at the Caroline Street enclosure should be reconfirmed in conjunction with addressing Comments 11 and 12 above. Complete as part of Phase 1 works.

15. Maximum HGL elevations for Junction J28 under Regional Storm conditions are different from that used as the known starting water surface boundary condition for Lower Rambo Creek upstream of Caroline Street. The boundary condition at this location should be revisited in conjunction with addressing Comments 11 and 12 above. Complete as part of Phase 1 works.

Section 3.0, Downtown Mobility Hub
Section 3.3, Stormwater Management
Lower Rambo Creek & Spills from Diversion Channel

16. **Section 3.3.1, Anticipated Development Changes:** This section should be refined to reflect updated land use framework being considered at this time. Complete as part of Phase 1 works.

17. **Section 3.3.2, Floodplain and Spill Impacts:**
    a. As noted under General Comments above, please remove any statements that suggests that spills are 'not formally regulated by Conservation Halton' be removed.
    b. As mentioned above, please revise reference to the regulatory status of the Lower Hager/Lower Rambo watercourses within the text of the report.
    c. Remove the reference to no development is permitted within the Regulatory Floodplain limit. The level of development and intensification permitted within the flood hazard (i.e. spills and 'flood

fringe') will be dependent on the level of risk and will been determined through discussion with Conservation Halton.

d. Further to the recommendation in the last paragraph, Conservation Halton staff will require delineation of precise 1-D floodplain limits with more detailed topographical information prior to re-development. While this could be provided as individual sites re-develop, since the 2-D modeling and mapping should be done in a comprehensive fashion, it is highly recommended that a comprehensive update to the 1-D mapping and modelling be completed at the same time. Complete as part of Phase 2 works.

e. 2-D modeling and mapping of existing spills must be updated with more detailed topographical information. Due to nature of the flooding in the area, this update will need to be done comprehensively for the entire area as opposed to on a site by site basis. Complete as part of Phase 2 works.

f. For spill areas, additional 2-D modeling and mapping is recommended to assess the potential impacts from cumulative development impacts (including grading/filling) within spill areas. This analysis would demonstrate where and how development can proceed without resulting in negative flooding impacts (flood levels on site, upstream and downstream) while protecting life (access/egress) and protecting property (floodproofing requirements). Complete as part of Phase 2 works.

g. For spill areas, separate drawings showing velocity as well as the depth velocity product for the 1:100 year and Regional Storm will be necessary to support City and Conservation Halton staff decisions in the future. Complete as part of Phase 1 works.

h. The fourth paragraph of this section provides potential ideas for managing re-development in the subject area. Conservation Halton staff will provide comment on these ideas in conjunction with the pending City policy discussions. Complete as part of Phase 1 works.

18. **Section 4.0, Conclusions and Recommendations:** This section should be updated as necessary in conjunction with resolving the above noted issues. The required next steps, including additional modeling and decision milestones, should be clearly outlined. Complete as part of Phase 1 works.

Conservation
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Protecting the Natural
Environment from
Lake to Escarpment

September 25, 2019

BY EMAIL AND MAIL

Umar Malik
City of Burlington, Capital Works Department
426 Brant Street, P.O. Box 5013
Burlington, Ontario L7R 3Z6

Dear Mr. Malik:

**Re: Downtown and Burlington GO Mobility Hub Flood Hazard and Scoped SWM Assessment
East Rambo Flood Control Facility - Retrofit Feasibility Assessment
Mobility Hubs - City of Burlington
CH File: MPR 653**

Conservation Halton (CH) staff has reviewed the memorandum titled '*East Rambo Flood Control Facility - Retrofit Feasibility Assessment*', prepared by Wood Inc., dated August 9, 2019 in response to the comments in Conservation Halton's July 25, 2019 letter. The memorandum provides an assessment of the feasibility of retrofitting the East Rambo Flood Control Facility to prevent the spill condition to the West Rambo Creek and concludes that a retrofit of the East Rambo Flood Control Facility is not desirable as a result of associated increase in flood damage/risk to residential properties and is not technically feasible. Conservation Halton staff finds merit in Wood's recommendation and appreciates that the final recommendation is based on the consideration of a variety of factors. We support this holistic approach to evaluation moving forward but have some comments which need to be addressed before Conservation Halton staff can support the recommendation.

1. ***Section B, Introduction, Page 2:*** The introduction paragraph makes reference to re-directing 'all flows'. As per staff's discussion with Matt Senior, Wood Inc. (August 14 and September 9, 2019), the assessment should also speak to redirection of a portion of the spill. See Comments 2 and 3 below for more details.
2. ***Section B.1, Flood Impacts to Residential Properties, Page 2:*** The following items should be updated/expanded to support the final recommendation:
    a. The impact assessment (i.e. public safety analysis) should be updated to fully document threats to those areas beyond residential properties. The assessment needs to confirm that there are no vulnerable populations, critical infrastructure (e.g., electrical substations, key telecommunication hub) or other hazards (e.g., toxic waste facilities) within the Study Area.
    b. Expand the discussion on the potential to increase downstream channel capacity to limit extent of the flooding along either flow pathway. For example, expand the discussion on the potential for

mitigating flood risks along Plains Road and Brant Street (near West Rambo Creek) as there is greater public land ownership and fewer private property owners along West Rambo Creek then East Rambo Creek. This may provide opportunities for future works along West Rambo to mitigate impacts of the inter-basin spill.

c. An assessment of potential impacts arising from a partial mitigation strategy should be included if deemed feasible.

3. ***Section B.2, Feasibility of Preventing Spill via CNR Crossing, Page 3:*** Conservation Halton is generally supportive of the findings of the assessment related to the feasibility of fully eliminating the spill; however, analysis of the feasibility of partial mitigation should also be addressed. Use of a permanent, passive flood control wall, instead of a berm, should be referenced.
4. ***Section B.2, Feasibility of Preventing Spill via CNR Crossing***: Revise 'North Spill Road' to read 'North Service Road'.
5. It is our understanding that neither the City of Burlington or Wood have discussed the findings of this assessment with CN representatives. Considering the predicted flooding along the CN tracks, CN may in the future wish to reduce the spill frequency along their tracks. Staff recommends that the City consider sharing this information with CN and obtain concurrence with the report findings. At a minimum, document the City's efforts to share this information with CN.

Recommendation

Once the above items are addressed, Conservation Halton will be in a position to formalize the existing spill from the East Rambo Creek at the Flood Control Facility/CN Tracks to West Rambo Creek, as well as support the recommendations of the memorandum and the updated flood hazard modeling and mapping, as per our July 25, 2019 letter.

Staff recommends the following next steps:

i. Revise 'East Rambo Flood Control Facility - Retrofit Feasibility Assessment' memorandum, incorporate into the Flood Hazard and Scoped Stormwater Management Assessment (Phase 1 Report) as part of the Burlington Mobility Hub Study (Comments 1, 2, 3, and 4 above).

ii. Document efforts made to engage with CN (can be completed as part of the Phase 2 Flood Hazard Study) (Comment 5 above).

iii. Update flood hazard modeling and mapping in both above listed reports.

Conservation Halton is committed to working with the City to advance the Flood Hazard and Scoped SWM Assessment as part of the Burlington Mobility Hub Study and staff is pleased to participate in upcoming technical working meetings. If you require additional information or clarity on the attached comments, please do not hesitate to contact the undersigned at extension 2231.

Yours truly,

Heather Dearlove, B.Sc.
Environmental Planner

Cc: Ron Scheckenberger and Matt Senior, Wood, email
Leah Smith, and Cary Clark, City of Burlington, email

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Protecting the Natural Environment from Lake to Escarpment

January 7, 2020

BY EMAIL AND MAIL

Leah Smith
City of Burlington, Planning and Building Department
426 Brant Street, P.O. Box 5013
Burlington, Ontario L7R 3Z6

Dear Ms. Smith:

Re: Flood Hazard and Scoped Stormwater Management Assessment - Burlington GO and Downtown Mobility Hubs – Revised Report and Response Matrix
Mobility Hubs - City of Burlington
CH File: MPR 653

Conservation Halton (CH) staff has reviewed the following documents prepared as part of the Downtown Mobility Hub and Burlington Mobility Hub study:

1. *Flood Hazard and Scoped Stormwater Management Assessment, Burlington GO and Downtown Mobility Hubs (tracked changes version), City of Burlington, prepared by Wood Inc., dated December 18, 2019 (received via email on December 18, 2019) and*
2. *Downtown and Burlington GO Mobility Hubs Flood Hazard Assessment and Scoped SWM Assessment Technical Comment Responses, prepared by Wood Inc., dated December 18, 2019 (received via email on December 18, 2019).*

Conservation Halton's general comments are noted below and more detailed comments on the above documents can be found in **Appendix A** of this letter.

General Comments

1. Conservation Halton is looking forward to continuing to work with the City of Burlington on the following additional studies associated with the Burlington Mobility Hub study:
   - Freeman, West Hager and East Rambo Pond Study
   - Ongoing Ownership and Maintenance Discussion, and
   - Burlington Mobility Hub Phase 2 work
2. Additional edits have been provided in the text of the report (track changes version) in relation to Conservation Halton's previous request to remove any statement that suggests that spills are 'not formally regulated by Conservation Halton'.

Staff recommends that the comments in **Appendix A** be addressed as part of the updates to the final reporting. Conservation Halton is committed to working with the City to advance the Flood Hazard and Scoped SWM Assessment and additional studies mentioned above. If you require additional information or clarity on the attached comments, please do not hesitate to contact the undersigned at extension 2231.

Yours truly,

Heather Dearlove, B.Sc.
Environmental Planner

Encl. Tracked changes version of the report with Conservation Halton edits (digital copy of letter only)

Cc: Ron Scheckenberger, and Matt Senior, Wood, email
Allison Enns, City of Burlington, email
Karyn Poad, Region of Halton, Email

Appendix A: Comments from Conservation Halton's Letter Dated July 25, 2019

The comments below are based Conservation Halton staff's review of the updated Flood Hazard and Scoped Stormwater Management Assessment, Burlington GO and Downtown Mobility Hubs, City of Burlington, prepared by Wood Inc., dated December 18, 2019 (Tracked Changes Version) and the discussion held at the December 18, 2019 meeting with the City of Burlington Staff and the consultants. Comments from Conservation Halton staff below have indicated where additional text edits are required (see attached version of the tracked changes copy of the report) and has indicated where additional information is required.

General Comments (body of July 25, 2019 letter)

1. Comment addressed: Conservation Halton staff are working with the City of Burlington on the Freeman, West Hager and East Rambo Pond Study.
2. Comment partially addressed: Edits have been provided on Pages 57, 62, and 81.
3. Comment addressed

Appendix A: Follow-up Comments from Conservation Halton's January 29, 2018 Letter

General Comments

3. Comment partially addressed: Please see Comment 1 below for additional edits to Drawing No.5C.
4. Comment partially addressed: Please see Comments 11, 12, 14 and 15 below.
5. Comment partially addressed: Edits have been provided on Pages 25 and 86.
6. Comment addressed

Detailed Comments from the Review of the November 30th Memo

1. Comment addressed
2. ***Section 2.1.3. Simulated Flows (With Flood Control Facilities), page 9:***
   a. Edits have been provided on Pages 11 and 15 regarding refined rating curves for these facilities during the future Phase 2 Study based on updated topographical information.
   b. Edits have been provided on Pages 13 and 16 regarding the potential for debris blockage at the pond outlets.
7. Comment addressed
8. To be addressed in Phase 2
15. Comment addressed

Additional Comments on the Hydraulic Models Received in Support of the November 30th, 2017 TAC Memo:

3. To be addressed in Phase 2
4. Comment addressed
7. Comment partially addressed: Edits have been provided on Pages 10, 11, 15, 28, 43, 74, and 85.

Appendix B: Comments on the Updated Flood Hazard and Scoped Stormwater Management Assessment Report

Section 2.0 - Burlington GO Mobility Hub

Section 2.2 - Hydraulics

West Rambo Creek - Floodplain Delineation

1. **Sections 2.2.1.2 & Drawing No. 5A - Scenario 1 (Existing East Rambo Pond Spill to West Rambo Creek):** Edits have been provided on Pages 29, 31, 85 and 86. As discussed at the December 19th meeting, please make the following edits to Drawing No. 5C:
   i. Add a 'no development area, floodway/top of bank' area between Plains Road East and Leighland Road.
   ii. Add an 'area requires further study, flood fringe' yellow on the east side of the floodway downstream of the CNR tracks.
   iii. Add a note indicating that further study will be required for all properties impacted by a flood fringe and spill area mapped on the drawing.
   iv. Illustrate the full extent of potential spills across and on the south side of Fairview Street in the vicinity of Brant Street. Alternatively, the Drawing could reference specifically the figures that illustrate the extent of the spills within this part of the Burlington GO Mobility Study Area.
   v. Illustrate the full extent of the spill areas from the East Rambo system within the Burlington GO Mobility Hub Study Area. Alternatively, the Drawing could reference specifically the figures that illustrate the extent of the spills.
2. No longer applicable to current study
3. Comment addressed

East Rambo Creek, Floodplain Delineation

4. **Section 2.2.1.3, Section 2.2.1.4 & Drawing No. 5B - Scenario 2 (Elimination of Spill from East Rambo Pond to West Rambo Creek):**
   a. Comment addressed
   b. No longer applicable to current study
5. **Scenario 1 (Existing East Rambo Pond Spill to West Rambo Creek):** Conservation Halton staff support the recommendation to remove the most upstream cross-section (XS 3198) from the Phase 1 reporting.

Hager-Rambo Diversion Channel & Associated Spills

6. No longer applicable to current study
7. **Sections 2.2.1 & 2.2.2 - Maple Avenue Spills:** Edits have been provided on Pages 34 and 59 regarding spill at Maple Avenue.
8. Comment addressed
9. Comment addressed

Section 2.0 - Burlington GO Mobility Hub

Section 2.3 - Stormwater Management

West Rambo, East Rambo, Hager-Rambo Diversion Channel & Associated Spills

10. Comment addressed

11. **Section 2.3.2 - Floodplain and Spill Impacts**:
    a. Comment partially addressed: Edits have been provided on Page 62.
    b. Comment partially addressed: Edits have been provided on Page 62.
    c. Comment addressed
    d. To be addressed in Phase 2
    e. To be addressed in Phase 2
    f. Comment addressed
    g. As note in the July 25, 2019 letter this section provides potential ideas for managing re-development in the subject area. Please note that Conservation Halton typically does not support active floodproofing and that safe ingress/egress must be considered for both pedestrians and vehicles. Conservation Halton staff will provide comment on these ideas in conjunction with the pending City policy discussions.

Section 3.0, Downtown Mobility Hub
Section 3.1, Hydrology
<u>Lower Rambo Creek, Floodplain Delineation</u>

12. **Section 3.1.2.1, Hydrology:** Conservation Halton staff are supportive of the Regional Floodplain Mapping with Spills presented on the updated Drawing No. 12 received December 19, 2019. We also support the recommendation to re-evaluate the potential for a spill at Caroline Street as part of the Phase 2 Study. Edits have been provided on Pages 72, 75 and 77.

Section 3.2, Hydraulics

13. Comment partially addressed: The two versions of Drawing No. 12 that we have received indicate only the Regional Storm flood elevations and floodline. It is our understanding from the December 19th meeting that a drawing has been prepared providing the 100-year and Regional Storm flood elevations and composite Regulatory floodline. Please forward the revised drawing for our review. On the drawing, including in the legend, the 100-year Lake Ontario flood level of 76.0 m should be illustrated as a different line type from the Regional/Regulatory Storm floodline. Also, remove the shoreline buffer line (15m) from the drawing.
14. Comment partially addressed: Edits have been provided on Page 75 (Section 3.2.2.1, Model Development) in light of the updated Drawing No. 12 received December 19th.
15. Comment addressed

Section 3.0, Downtown Mobility Hub
Section 3.3, Stormwater Management
<u>Lower Rambo Creek & Spills from Diversion Channel</u>

16. Comment Addressed
17. **Section 3.3.2, Floodplain and Spill Impacts:**
    a. Comment partially addressed: Edits have been provided on Pages 77 and 78.
    b. Comment partially addressed: Edits have been provided on Page 77.
    c. Comment partially addressed: Edits have been provided on Page 77.
    d. To be addressed in Phase 2
    e. To be addressed in Phase 2
    f. To be addressed in Phase 2
    g. Comment addressed
    h. As noted in the July 25, 2019 letter, this section provides potential ideas for managing re-development in the subject area. Please note that Conservation Halton typically does not support

active floodproofing and that safe ingress/egress must be considered for both pedestrians and vehicles. Conservation Halton staff will provide comment on these ideas in conjunction with the pending City policy discussions.

18. **Section 4.0, Conclusions and Recommendations:** Edits have been provided on Pages 81-86.

Appendix C

Hydrologic and Hydraulic Modelling Files (Burlington GO Mobility Hub)

Memorandum

December 10, 2004
104138-26

TO:	*Philip Kelly, P. Eng.*
FROM:	*Aaron Brouwers / Ron Scheckenberger*
RE:	*City of Burlington IDF Relationships and Design Storms*

As per our December 1, 2004 work plan, we have updated the IDF curves and the associated IDF parameters as well as regenerated the associated design storms based on the most current information.

SCS Design Storms

The 1994 Storm Drainage Design Manual (PPEL) developed the IDF relationships based on 27 years of rainfall intensity data (1964–1990) from the Royal Botanical Gardens gauge provided by the Atmospheric Environment Service (AES). The current assessment updates the previous and includes 35 years of data (1962–1996); most notably it includes the large events recorded in 1995. Table 1 compares AES 6 and 12 hour duration rainfall depths used in the 1994 and 2004 assessments; the depths have been used to develop the SCS Type II 6 and 12 hour design storms for the current assessment (ref. Tables 5 & 6, attached).

TABLE 1
COMPARISON OF AES RAINFALL DEPTHS (mm)

Duration (hours)	Frequency (Years)	1994	2004
6	100	85.9	92.4
6	5	48.7	51.3
12	100	92.1	103.6
12	5	55.2	58.9

The depths for the 100 year event show an 8 % and 12 % increase for the 6 and 12 hour durations, respectively. The 5 year event experiences lower relative increases of 5 % and 7 % for the 6 and 12 hour durations, respectively. The increases can largely be attributed to events experienced in 1995, which are the largest within the period of record. As would be expected, these large events have more influence on predicted rainfall depths for the less frequent events (i.e. 100 year).

IDF Parameters/Curve & Chicago Design Storms

Table 2 summarizes the AES IDF values for the subject gauge. Performing a three-parameter regression, using the SWMHYMO Chicago Storm function, provides initial A, B and C parameters, which define the IDF curve fit. These parameters have been refined through manual regression analysis and are presented in Table 3. The equation for the IDF curves is as follows:

$$i = \frac{A}{(t+B)^C}$$

where:
i = rainfall intensity (mm/hr)
t = storm duration (minutes)
A, B, C = defined in Table 2

The regression provides only a 'best fit' for the AES data, and when applying the IDF parameters provided, rainfall depths for a given frequency storm and duration will vary from actual statistically derived depths from

AES (ref. IDF curves attached). This is consistent with 1994 assessment and is necessary in order provide the standard set of three parameters (i.e. A, B &C). The ratio of the time to peak to the total storm duration, *r*, (used for calculating the Chicago distributions) has been set at 0.48, which is the recommended value for Ontario (Marsalek, 1978). This is consistent with the 1977 and 1994 assessments, which used a value of 0.46 for *r*. Table 4 presents a comparison of the current and previous IDF assessments; the 3 and 4 hour Chicago design storms are attached (ref. Table 7 & 8).

TABLE 2
INTENSITY-DURATION-FREQUENCY VALUES
ROYAL BOTANICAL GARDENS

Duration (min)	Rainfall Intensity (mm/hr)					
	2	5	10	25	50	100
5	94.6	122.2	140.6	163.7	180.9	198.0
10	68.3	89.2	103.2	120.8	133.8	146.7
15	55.7	74.3	86.7	102.2	113.8	125.2
30	36.2	47.2	54.5	63.7	70.5	77.3
60	22.1	27.6	31.2	35.7	39.1	42.5
120	14.3	18.6	21.4	25.0	27.7	30.4
360	6.0	8.5	10.2	12.3	13.9	15.4
720	3.5	4.9	5.8	7.0	7.8	8.6
1440	2.1	2.8	3.3	3.8	4.3	4.7

TABLE 3
IDF PARAMETERS – ROYAL BOTANICAL GARDENS

Parameter	2	5	10	25	50	100
A	595.5	688.2	748.0	867.0	947.3	1036.1
B	6.0	5.0	4.5	4.5	4.5	4.5
C	0.778	0.753	0.740	0.737	0.733	0.733

TABLE 4
COMPARISON OF IDF ASSESSMENTS

Item		1977	1994	2004
Source of Rainfall Data		Royal Botanical Gardens	Royal Botanical Gardens	Royal Botanical Gardens
Duration of Rainfall Record		12 Years	27 Years (1964-1990)	35 Years (1962-1996)
IDF Parameters				
5 Year	A B C	1111 7 0.857	697.4 5 0.764	688.2 5.0 0.753
100 Year	A B C	2377 9 0.886	1114.1 5 0.761	1036.1 4.5 0.733
Predicted Depth (mm)				
100 Year - 3 Hour Duration Depth		68.5	62.9	67.9
5 Year - 3 Hour Duration Depth		37.6	38.7	40.5
100 Year - 4 Hour Duration Depth		71.6	67.7	73.6
5 Year - 4 Hour Duration Depth		39.6	41.7	43.7

The results for the 100 year event show a 5 % and 6 % increase in rainfall depths for the 3 and 4 hour durations, respectively, when comparing the 2004 and 1994 assessments. The 5 year event experiences similar relative increases of 5 % for both the 3 and 4 hour durations, respectively.

We trust this satisfies your current requirements, should you require anything further please do not hesitate to contact our office. Once you have reviewed this information and are in agreement with its content, we will forward you digital copies of this memo and its attachments.

AB/RS/ab

Attach.

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SCENARIO 1 - SWM

Flow Node	Location	NHYD	001 3 Hr Chicago (1994 IDF)	002 24 Hr Chicago (1994 IDF)	003 Scaled 1981	004 Scaled 1982	005 3 Hr Chicago (2004 IDF)	006 6 Hr Chicago (2004 IDF)	007 6 Hour SCS (RBG)	008 12 Hour SCS (RBG)	009 24 Hour SCS (RBG)	010 Regional
Q	East Rambo Pond Inlet	51700	50.9	64.8	50.5	55.2	61.5	70.2	71.5	75.3	78.3	63.9
Q1	East Rambo Pond Box Culvert Outlet	519	14.9	16.3	16.0	16.8	16.0	16.9	16.5	17.0	17.2	18.5
Q2	East Rambo Pond Spill at CNR	51710	0.9	10.7	7.4	15.2	7.6	16.7	12.6	17.5	21.1	34.3
Q3	East Rambo Pond Spill at North Service Road	51703	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2
J1	East Rambo at CNR	9951	15.7	17.7	17.0	20.3	17.1	18.9	18.1	19.5	21.2	32.8
J	East Rambo Creek at H-R Diversion Channel Conf.	522	16.6	19.8	19.7	22.8	18.9	23.0	21.4	23.7	25.5	35.6
P	West Rambo Creek at QEW	526	11.1	14.9	10.2	12.9	14.4	16.5	16.7	17.6	18.6	11.9
P3	West Rambo at CNR (South of Plains Rd East)	51713	14.5	18.2	13.3	22.6	17.8	24.3	21.1	25.4	30.1	49.0
P2	West Rambo at CNR (North of De Pauls Ln)	51714	16.3	20.2	14.9	23.4	19.8	25.0	23.7	26.2	30.9	50.6
P1	West Rambo Creek at Fairview	528	17.0	21.0	15.4	23.8	20.6	25.4	24.4	26.5	31.2	51.6
K	Confluence of East and West Rambo Creeks	531	31.8	40.5	35.5	45.7	38.0	46.5	45.1	48.5	53.6	87.6
L	H-R Diversion Channel U/S of West Hager Conf.	537	36.6	46.1	40.9	49.3	43.5	51.2	51.6	55.3	58.8	95.3
G1	Freeman Pond Outlet	572	13.5	15.7	14.2	15.8	15.2	16.6	16.3	16.9	17.4	43.6
H3	West Hager at CNR	581	23.9	30.1	27.6	28.8	28.8	32.1	31.3	33.0	34.3	63.7
H	Freeman / West Hager Conf.	583	19.9	26.0	22.8	29.1	23.9	28.9	25.9	28.4	33.2	65.4
M	West Hager / H-R Diversion Channel Conf.	584	51.0	69.6	60.7	77.8	60.4	78.5	72.1	78.6	91.6	146.3
N	H-R Diversion Channel at Indian Creek	586	47.3	69.9	61.1	78.8	59.0	79.2	71.8	78.9	91.5	146.9

SCENARIO 1 - NS

Flow Node	Location	NHYD	001 3 Hr Chicago (1994 IDF)	002 24 Hr Chicago (1994 IDF)	003 Scaled 1981	004 Scaled 1982	005 3 Hr Chicago (2004 IDF)	006 6 Hr Chicago (2004 IDF)	007 6 Hour SCS (RBG)	008 12 Hour SCS (RBG)	009 24 Hour SCS (RBG)	010 Regional
Q	East Rambo Pond Inlet	51700	50.9	64.8	50.5	55.2	61.5	70.2	71.5	75.3	78.3	63.9
Q1	East Rambo Pond Box Culvert Outlet	519	18.1	18.6	18.0	18.3	18.5	18.7	18.8	18.8	18.9	18.6
Q2	East Rambo Pond Spill at CNR	51710	32.8	41.8	32.4	36.9	40.1	44.2	44.5	45.6	46.5	36.2
Q3	East Rambo Pond Spill at North Service Road	51703	0.0	4.5	0.0	0.0	2.9	7.3	8.2	10.8	13.0	4.0
J1	East Rambo at CNR	9951	22.5	27.2	23.9	21.5	25.5	29.8	30.4	32.9	35.1	35.7
J	East Rambo Creek at H-R Diversion Channel Conf.	522	25.3	30.0	26.8	24.0	29.1	32.4	33.5	35.5	37.5	38.6
P	West Rambo Creek at QEW	526	11.1	14.9	10.2	12.9	14.4	16.5	16.7	17.6	18.6	11.9
P3	West Rambo at CNR (South of Plains Rd East)	51713	47.2	59.5	45.1	51.8	57.8	63.8	65.1	67.1	69.1	52.4
P2	West Rambo at CNR (North of De Pauls Ln)	51714	47.5	61.3	46.0	52.1	59.4	65.6	66.9	69.0	71.1	54.1
P1	West Rambo Creek at Fairview	528	47.9	61.1	45.7	50.9	58.9	65.9	67.1	69.5	71.9	55.4
K	Confluence of East and West Rambo Creeks	531	73.3	91.6	71.5	73.5	87.8	98.8	101.2	105.8	109.8	94.9
L	H-R Diversion Channel U/S of West Hager Conf.	537	77.2	96.5	76.0	76.5	92.7	104.3	106.5	111.5	115.9	102.8
G1	Freeman Pond Outlet	571	36.1	55.8	41.0	39.8	50.1	64.6	63.7	71.4	77.2	71.0
H3	West Hager at CNR	581	48.0	65.1	49.6	54.0	62.0	75.2	77.2	83.3	89.0	81.0
H	Freeman / West Hager Conf.	583	40.7	58.5	39.2	44.4	53.5	34.7	64.5	76.6	82.1	83.9
M	West Hager / H-R Diversion Channel Conf.	584	113.9	153.5	111.9	118.1	144.4	128.6	167.5	186.1	195.8	186.8
N	H-R Diversion Channel at Indian Creek	586	111.5	142.2	109.2	112.8	139.7	125.8	163.3	178.5	190.4	187.8

SCENARIO 2 - SWM

Flow Node	Location	NHYD	001 3 Hr Chicago (1994 IDF)	002 24 Hr Chicago (1994 IDF)	003 Scaled 1981	004 Scaled 1982	005 3 Hr Chicago (2004 IDF)	006 6 Hr Chicago (2004 IDF)	007 6 Hour SCS (RBG)	008 12 Hour SCS (RBG)	009 24 Hour SCS (RBG)	010 Regional
Q	East Rambo Pond Inlet	51700	50.9	64.8	50.5	55.2	61.5	70.2	71.5	75.3	78.3	63.9
Q1	East Rambo Pond Box Culvert Outlet	519	14.9	16.3	16.0	16.8	16.0	16.9	16.5	17.0	17.2	18.5
Q2	East Rambo Pond Spill at CNR	51710	0.9	10.7	7.4	15.2	7.6	16.7	12.6	17.5	21.1	39.4
Q3	East Rambo Pond Spill at North Service Road	51703	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2
J1	East Rambo at CNR	9951	16.6	28.4	23.8	34.8	24.7	35.6	30.5	36.4	40.9	66.9
J	East Rambo Creek at H-R Diversion Channel Conf.	522	17.5	29.9	24.9	36.6	26.2	37.2	32.1	38.0	42.8	69.6
P	West Rambo Creek at QEW	526	11.1	14.9	10.2	12.9	14.4	16.5	16.7	17.6	18.6	11.9
P3	West Rambo at CNR (South of Plains Rd East)	51713	14.5	18.2	13.3	15.3	17.8	20.0	21.1	22.0	23.5	16.2
P2	West Rambo at CNR (North of De Pauls Ln)	51714	16.3	20.2	14.9	16.8	19.8	22.1	23.7	24.7	26.1	18.1
P1	West Rambo Creek at Fairview	528	17.0	21.0	15.4	16.6	20.6	23.0	24.4	25.4	26.8	19.4
K	Confluence of East and West Rambo Creeks	531	31.8	40.5	35.5	46.1	38.0	47.4	45.1	48.9	54.9	87.8
L	H-R Diversion Channel U/S of West Hager Conf.	537	36.6	46.1	40.9	49.7	43.5	51.9	51.6	55.3	60.3	95.6
G1	Freeman Pond Outlet	571	13.5	15.7	14.2	15.8	15.2	16.6	16.3	16.9	17.4	43.6
H3	West Hager at CNR	581	23.9	30.1	27.6	28.8	28.8	32.1	31.3	33.0	34.3	63.7
H	Freeman / West Hager Conf.	583	19.9	26.0	22.8	29.1	23.9	28.9	25.9	28.4	33.2	65.4
M	West Hager / H-R Diversion Channel Conf.	584	51.0	69.6	60.7	78.1	60.4	79.8	72.1	79.8	92.9	146.0
N	H-R Diversion Channel at Indian Creek	586	47.3	69.9	61.2	79.1	59.4	80.1	71.8	79.9	92.6	146.6

SCENARIO 2 - NS

Flow Node	Location	NHYD	001 3 Hr Chicago (1994 IDF)	002 24 Hr Chicago (1994 IDF)	003 Scaled 1981	004 Scaled 1982	005 3 Hr Chicago (2004 IDF)	006 6 Hr Chicago (2004 IDF)	007 6 Hour SCS (RBG)	008 12 Hour SCS (RBG)	009 24 Hour SCS (RBG)	010 Regional
Q	East Rambo Pond Inlet	51700	50.9	64.8	50.5	55.2	61.5	70.2	71.5	75.3	78.3	63.9
Q1	East Rambo Pond Box Culvert Outlet	519	18.1	18.6	18.0	18.3	18.5	18.7	18.8	18.8	18.9	18.6
Q2	East Rambo Pond Spill at CNR	51710	32.8	41.8	32.4	36.9	40.1	44.2	44.5	45.6	46.5	41.3
Q3	East Rambo Pond Spill at North Service Road	51703	0.0	4.5	0.0	0.0	2.9	7.3	8.2	10.8	13.0	4.0
J1	East Rambo at CNR	9951	55.3	68.5	55.7	56.8	65.6	73.8	74.9	78.4	81.2	71.9
J	East Rambo Creek at H-R Diversion Channel Conf.	522	57.8	71.4	58.0	59.1	68.3	76.4	77.5	81.1	83.8	74.7
P	West Rambo Creek at QEW	526	11.1	14.9	10.2	12.9	14.4	16.5	16.7	17.6	18.6	11.9
P3	West Rambo at CNR (South of Plains Rd East)	51713	14.5	18.2	13.3	15.3	17.8	20.0	21.1	22.0	23.5	16.2
P2	West Rambo at CNR (North of De Pauls Ln)	51714	16.3	20.2	14.9	16.8	19.8	22.1	23.7	24.7	26.1	18.1
P1	West Rambo Creek at Fairview	528	17.0	21.0	15.4	16.6	20.6	23.0	24.4	25.4	26.8	19.4
K	Confluence of East and West Rambo Creeks	531	74.9	93.0	73.6	75.8	89.7	100.1	103.3	107.0	110.8	99.8
L	H-R Diversion Channel U/S of West Hager Conf.	537	79.0	97.9	78.0	78.4	94.4	105.5	108.3	112.9	117.0	104.2
G1	Freeman Pond Outlet	571	36.1	55.8	41.0	39.8	50.1	64.6	63.7	71.4	77.2	71.0
H3	West Hager at CNR	581	50.3	75.3	56.7	55.4	68.3	86.3	85.2	94.8	101.9	96.9
H	Freeman / West Hager Conf.	583	41.6	67.0	42.2	48.0	57.9	86.8	71.8	82.3	90.9	99.8
M	West Hager / H-R Diversion Channel Conf.	584	115.4	160.6	114.4	123.5	145.8	192.1	175.5	188.8	206.4	202.4
N	H-R Diversion Channel at Indian Creek	586	111.9	155.7	109.5	113.3	142.4	157.6	170.9	186.6	193.3	199.6

HEC-RAS Plan: 2DTW1677

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Upper Rambo	UR1	355.1200	24 Hour SCS_SWM	17.57	98.22	101.346	99.503	101.362	0.000171	0.61	56.86	138.153	0.13
Upper Rambo	UR1	355.1200	REG_SWM	20.54	98.22	101.366	99.608	101.385	0.000220	0.70	59.61	144.177	0.15
Upper Rambo	UR1	355.1200	24 Hour SCS_NS	0.10	98.22	98.340	98.340	98.369	0.029220	0.75	0.13	2.228	0.97
Upper Rambo	UR1	355.1200	REG_NS	0.10	98.22	98.340	98.340	98.369	0.029220	0.75	0.13	2.228	0.97
Upper Rambo	UR1	355		Lat Struct									
Upper Rambo	UR1	333.1341	24 Hour SCS_SWM	17.57	98.05	101.349	99.504	101.357	0.000104	0.46	60.47	197.003	0.10
Upper Rambo	UR1	333.1341	REG_SWM	20.54	98.05	101.370	99.600	101.380	0.000127	0.51	64.59	203.963	0.11
Upper Rambo	UR1	333.1341	24 Hour SCS_NS	0.10	98.05	98.270	98.226	98.289	0.008938	0.60	0.17	1.511	0.58
Upper Rambo	UR1	333.1341	REG_NS	0.10	98.05	98.270	98.226	98.289	0.008938	0.60	0.17	1.511	0.58
Upper Rambo	UR1	318.4964	24 Hour SCS_SWM	17.57	97.89	101.340	99.268	101.355	0.000131	0.55	36.88	48.507	0.11
Upper Rambo	UR1	318.4964	REG_SWM	20.54	97.89	101.373	99.377	101.377	0.000046	0.33	83.27	138.251	0.07
Upper Rambo	UR1	318.4964	24 Hour SCS_NS	0.10	97.89	98.027	98.027	98.063	0.030984	0.84	0.12	1.742	1.02
Upper Rambo	UR1	318.4964	REG_NS	0.10	97.89	98.027	98.027	98.063	0.030984	0.84	0.12	1.742	1.02
Upper Rambo	UR1	304.6275	24 Hour SCS_SWM	17.57	97.63	101.337	99.463	101.353	0.000122	0.58	42.65	53.409	0.11
Upper Rambo	UR1	304.6275	REG_SWM	20.54	97.63	101.368	99.652	101.375	0.000078	0.47	87.69	188.377	0.09
Upper Rambo	UR1	304.6275	24 Hour SCS_NS	0.10	97.63	97.955	97.776	97.957	0.000391	0.19	0.51	3.718	0.14
Upper Rambo	UR1	304.6275	REG_NS	0.10	97.63	97.955	97.776	97.957	0.000391	0.19	0.51	3.718	0.14
Upper Rambo	UR1	304		Culvert									
Upper Rambo	UR1	277.2888	24 Hour SCS_SWM	17.57	97.43	99.856	99.160	100.289	0.005548	2.91	6.03	29.304	0.60
Upper Rambo	UR1	277.2888	REG_SWM	20.54	97.43	100.801	99.347	100.808	0.000165	0.41	55.92	41.215	0.08
Upper Rambo	UR1	277.2888	24 Hour SCS_NS	0.10	97.43	97.611	97.495	97.614	0.001324	0.24	0.42	2.624	0.19
Upper Rambo	UR1	277.2888	REG_NS	0.10	97.43	97.611	97.495	97.614	0.001324	0.24	0.42	2.624	0.19
Upper Rambo	UR1	277		Lat Struct									
Upper Rambo	UR1	272.4874	24 Hour SCS_SWM	17.57	97.40	99.976	98.839	100.138	0.002176	1.78	9.86	35.426	0.37
Upper Rambo	UR1	272.4874	REG_SWM	20.54	97.40	100.633	98.975	100.768	0.001307	1.63	12.62	41.483	0.30
Upper Rambo	UR1	272.4874	24 Hour SCS_NS	0.10	97.40	97.547	97.547	97.585	0.050650	0.87	0.12	1.579	1.02
Upper Rambo	UR1	272.4874	REG_NS	0.10	97.40	97.547	97.547	97.585	0.050650	0.87	0.12	1.579	1.02
Upper Rambo	UR1	272		Culvert									
Upper Rambo	UR1	232.4432	24 Hour SCS_SWM	17.57	97.20	99.482	98.626	99.691	0.001985	2.02	8.68	13.614	0.45
Upper Rambo	UR1	232.4432	REG_SWM	20.54	97.20	99.871	98.762	100.073	0.001526	1.99	10.32	15.459	0.41
Upper Rambo	UR1	232.4432	24 Hour SCS_NS	0.10	97.20	97.400	97.333	97.407	0.003667	0.39	0.26	2.389	0.38
Upper Rambo	UR1	232.4432	REG_NS	0.10	97.20	97.400	97.333	97.407	0.003667	0.39	0.26	2.389	0.38
Upper Rambo	UR1	232		Lat Struct									
Upper Rambo	UR1	222.4837	24 Hour SCS_SWM	17.57	97.16	99.547	98.414	99.605	0.000641	1.10	19.51	14.381	0.25
Upper Rambo	UR1	222.4837	REG_SWM	20.54	97.16	99.939	98.505	99.990	0.000452	1.04	25.74	17.501	0.22
Upper Rambo	UR1	222.4837	24 Hour SCS_NS	0.10	97.16	97.284	97.284	97.318	0.028449	0.82	0.12	1.732	0.98
Upper Rambo	UR1	222.4837	REG_NS	0.10	97.16	97.284	97.284	97.318	0.028449	0.82	0.12	1.732	0.98
Upper Rambo	UR1	202.1057	24 Hour SCS_SWM	17.61	96.90	99.540	98.220	99.586	0.000455	0.99	23.23	16.223	0.22
Upper Rambo	UR1	202.1057	REG_SWM	20.69	96.90	99.935	98.315	99.976	0.000338	0.96	30.24	19.143	0.19
Upper Rambo	UR1	202.1057	24 Hour SCS_NS	0.10	96.90	97.173	97.058	97.177	0.001488	0.29	0.34	2.389	0.25
Upper Rambo	UR1	202.1057	REG_NS	0.10	96.90	97.173	97.058	97.177	0.001488	0.29	0.34	2.389	0.25
Upper Rambo	UR1	174.6994	24 Hour SCS_SWM	17.61	96.73	99.560	97.941	99.569	0.000125	0.59	78.11	63.130	0.12
Upper Rambo	UR1	174.6994	REG_SWM	20.69	96.73	99.956	98.194	99.962	0.000084	0.53	104.68	70.694	0.10
Upper Rambo	UR1	174.6994	24 Hour SCS_NS	0.10	96.73	97.168	96.882	97.168	0.000112	0.11	0.93	4.277	0.07
Upper Rambo	UR1	174.6994	REG_NS	0.10	96.73	97.168	96.882	97.168	0.000112	0.11	0.93	4.277	0.07
Upper Rambo	UR1	169.6089	24 Hour SCS_SWM	17.61	96.76	99.357	98.235	99.521	0.001358	1.80	9.81	23.756	0.38
Upper Rambo	UR1	169.6089	REG_SWM	20.69	96.76	99.746	98.375	99.913	0.001121	1.81	11.44	38.772	0.35
Upper Rambo	UR1	169.6089	24 Hour SCS_NS	0.10	96.76	97.167	96.903	97.168	0.000156	0.13	0.74	3.099	0.09
Upper Rambo	UR1	169.6089	REG_NS	0.10	96.76	97.167	96.903	97.168	0.000156	0.13	0.74	3.099	0.09
Upper Rambo	UR1	169		Culvert									
Upper Rambo	UR1	145.5228	24 Hour SCS_SWM	17.61	96.74	98.961	98.281	99.211	0.002736	2.21	7.96	12.314	0.51
Upper Rambo	UR1	145.5228	REG_SWM	20.69	96.74	99.140	98.420	99.428	0.002795	2.38	8.71	13.449	0.53
Upper Rambo	UR1	145.5228	24 Hour SCS_NS	0.10	96.74	97.166	96.917	97.167	0.000269	0.17	0.60	2.747	0.11
Upper Rambo	UR1	145.5228	REG_NS	0.10	96.74	97.166	96.917	97.167	0.000269	0.17	0.60	2.747	0.11
Upper Rambo	UR1	145		Lat Struct									
Upper Rambo	UR1	141.4725	24 Hour SCS_SWM	17.61	96.85	99.001	98.326	99.157	0.002078	1.81	13.18	15.729	0.44
Upper Rambo	UR1	141.4725	REG_SWM	20.69	96.85	99.197	98.446	99.358	0.001912	1.86	16.79	23.337	0.43
Upper Rambo	UR1	141.4725	24 Hour SCS_NS	0.10	96.85	97.161	97.022	97.165	0.001137	0.28	0.36	2.179	0.22
Upper Rambo	UR1	141.4725	REG_NS	0.10	96.85	97.161	97.022	97.165	0.001137	0.28	0.36	2.179	0.22
Upper Rambo	UR1	135.4062	24 Hour SCS_SWM	19.60	96.96	98.838	98.512	99.104	0.005046	2.31	9.33	10.250	0.64
Upper Rambo	UR1	135.4062	REG_SWM	22.46	96.96	99.090	98.613	99.321	0.003551	2.17	12.92	18.343	0.55
Upper Rambo	UR1	135.4062	24 Hour SCS_NS	0.10	96.96	97.098	97.098	97.136	0.030238	0.86	0.12	1.571	1.01
Upper Rambo	UR1	135.4062	REG_NS	0.10	96.96	97.098	97.098	97.136	0.030238	0.86	0.12	1.571	1.01
Upper Rambo	UR1	119.4501	24 Hour SCS_SWM	19.60	96.75	98.859	98.248	99.020	0.002341	1.82	12.86	11.850	0.46
Upper Rambo	UR1	119.4501	REG_SWM	22.46	96.75	99.124	98.348	99.253	0.001629	1.68	18.85	39.485	0.39
Upper Rambo	UR1	119.4501	24 Hour SCS_NS	0.10	96.75	97.066	96.915	97.070	0.000896	0.26	0.39	2.271	0.20
Upper Rambo	UR1	119.4501	REG_NS	0.10	96.75	97.066	96.915	97.070	0.000896	0.26	0.39	2.271	0.20
Upper Rambo	UR1	89.15574	24 Hour SCS_SWM	19.60	96.81	98.849	98.175	98.944	0.001489	1.46	17.99	32.311	0.37
Upper Rambo	UR1	89.15574	REG_SWM	22.46	96.81	99.157	98.259	99.198	0.000613	1.05	31.92	61.179	0.24
Upper Rambo	UR1	89.15574	24 Hour SCS_NS	0.10	96.81	96.954	96.954	96.990	0.029421	0.84	0.12	1.632	1.00
Upper Rambo	UR1	89.15574	REG_NS	0.10	96.81	96.954	96.954	96.990	0.029421	0.84	0.12	1.632	1.00

HEC-RAS Plan: 2DTW1677 (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Upper Rambo	UR1	59.83022	24 Hour SCS_SWM	19.60	96.18	98.857	97.791	98.903	0.000605	1.07	28.48	62.754	0.24
Upper Rambo	UR1	59.83022	REG_SWM	22.46	96.18	99.167	97.881	99.181	0.000196	0.67	51.23	79.635	0.14
Upper Rambo	UR1	59.83022	24 Hour SCS_NS	0.10	96.18	96.410	96.377	96.435	0.011966	0.71	0.14	1.233	0.66
Upper Rambo	UR1	59.83022	REG_NS	0.10	96.18	96.410	96.377	96.435	0.011966	0.71	0.14	1.233	0.66
Upper Rambo	UR1	40.68162	24 Hour SCS_SWM	19.60	95.90	98.869	97.230	98.889	0.000201	0.66	40.39	71.204	0.14
Upper Rambo	UR1	40.68162	REG_SWM	22.46	95.90	99.167	97.310	99.176	0.000096	0.50	69.48	99.204	0.10
Upper Rambo	UR1	40.68162	24 Hour SCS_NS	0.10	95.90	96.059	96.059	96.098	0.028213	0.87	0.11	1.439	0.99
Upper Rambo	UR1	40.68162	REG_NS	0.10	95.90	96.059	96.059	96.098	0.028213	0.87	0.11	1.439	0.99
Upper Rambo	UR1	38.481	24 Hour SCS_SWM	19.60	95.82	98.162	97.762	98.725	0.005455	3.32	5.90	14.560	0.73
Upper Rambo	UR1	38.481	REG_SWM	22.46	95.82	98.409	97.929	99.001	0.004946	3.41	6.59	17.081	0.71
Upper Rambo	UR1	38.481	24 Hour SCS_NS	0.10	95.82	95.993	95.993	96.035	0.028080	0.91	0.11	1.273	0.99
Upper Rambo	UR1	38.481	REG_NS	0.10	95.82	95.993	95.993	96.035	0.028080	0.91	0.11	1.273	0.99
Upper Rambo	UR1	38		Culvert									
Upper Rambo	UR1	1.18	24 Hour SCS_SWM	19.60	94.70	97.142	96.452	97.577	0.003278	2.92	6.71	13.141	0.60
Upper Rambo	UR1	1.18	REG_SWM	22.46	94.70	97.189	96.617	97.738	0.004035	3.28	6.84	14.022	0.67
Upper Rambo	UR1	1.18	24 Hour SCS_NS	0.10	94.70	96.002	94.795	96.003	0.000001	0.03	3.52	7.338	0.01
Upper Rambo	UR1	1.18	REG_NS	0.10	94.70	96.002	94.795	96.003	0.000001	0.03	3.52	7.338	0.01
Upper Rambo	UR1	0.01	24 Hour SCS_SWM	19.60	95.82	97.146	97.099	97.509	0.012012	2.67	7.34	8.800	0.93
Upper Rambo	UR1	0.01	REG_SWM	22.46	95.82	97.233	97.190	97.622	0.012010	2.76	8.13	9.236	0.94
Upper Rambo	UR1	0.01	24 Hour SCS_NS	0.10	95.82	95.980	95.956	95.997	0.012005	0.58	0.17	2.158	0.65
Upper Rambo	UR1	0.01	REG_NS	0.10	95.82	95.980	95.956	95.997	0.012005	0.58	0.17	2.158	0.65
Rambo Creek	West Branch	220	24 Hour SCS_SWM	20.68	94.99	96.769		96.819	0.002279	1.08	26.44	42.152	0.34
Rambo Creek	West Branch	220	REG_SWM	23.60	94.99	96.850		96.903	0.002200	1.12	29.92	43.786	0.33
Rambo Creek	West Branch	220	24 Hour SCS_NS	0.10	94.99	95.367		95.368	0.000208	0.11	0.94	4.815	0.08
Rambo Creek	West Branch	220	REG_NS	0.10	94.99	95.367		95.368	0.000208	0.11	0.94	4.815	0.08
Rambo Creek	West Branch	210	24 Hour SCS_SWM	20.68	95.19	96.712		96.789	0.003537	1.53	25.97	43.983	0.42
Rambo Creek	West Branch	210	REG_SWM	23.60	95.19	96.800		96.874	0.003276	1.54	29.92	45.603	0.41
Rambo Creek	West Branch	210	24 Hour SCS_NS	0.10	95.19	95.356	95.299	95.361	0.005700	0.32	0.31	3.772	0.35
Rambo Creek	West Branch	210	REG_NS	0.10	95.19	95.356	95.299	95.361	0.005700	0.32	0.31	3.772	0.35
Rambo Creek	West Branch	200	24 Hour SCS_SWM	20.68	95.13	96.708		96.754	0.001933	1.11	30.95	47.734	0.31
Rambo Creek	West Branch	200	REG_SWM	23.60	95.13	96.795		96.842	0.001849	1.13	35.20	49.719	0.31
Rambo Creek	West Branch	200	24 Hour SCS_NS	0.10	95.13	95.198	95.198	95.219	0.072251	0.65	0.15	4.236	1.10
Rambo Creek	West Branch	200	REG_NS	0.10	95.13	95.198	95.198	95.219	0.072251	0.65	0.15	4.236	1.10
Rambo Creek	West Branch	190	24 Hour SCS_SWM	20.68	94.80	96.692		96.735	0.001629	1.12	33.77	48.390	0.30
Rambo Creek	West Branch	190	REG_SWM	23.60	94.80	96.780		96.824	0.001590	1.15	38.10	50.361	0.30
Rambo Creek	West Branch	190	24 Hour SCS_NS	0.10	94.80	95.126		95.128	0.000598	0.16	0.62	3.814	0.13
Rambo Creek	West Branch	190	REG_NS	0.10	94.80	95.126		95.128	0.000598	0.16	0.62	3.814	0.13
Rambo Creek	West Branch	180	24 Hour SCS_SWM	20.68	94.97	96.673		96.717	0.001946	1.03	28.81	42.888	0.31
Rambo Creek	West Branch	180	REG_SWM	23.60	94.97	96.761		96.806	0.001853	1.06	32.64	44.502	0.31
Rambo Creek	West Branch	180	24 Hour SCS_NS	0.10	94.97	95.077	95.077	95.106	0.057111	0.75	0.13	2.476	1.04
Rambo Creek	West Branch	180	REG_NS	0.10	94.97	95.078	95.078	95.106	0.054042	0.74	0.14	2.502	1.01
Rambo Creek	West Branch	166	24 Hour SCS_SWM	20.68	94.57	96.298	96.298	96.623	0.024646	2.54	8.40	13.517	0.99
Rambo Creek	West Branch	166	REG_SWM	23.60	94.57	96.361	96.361	96.712	0.023756	2.64	9.26	13.749	0.98
Rambo Creek	West Branch	166	24 Hour SCS_NS	0.10	94.57	94.730	94.695	94.745	0.013273	0.54	0.18	1.841	0.55
Rambo Creek	West Branch	166	REG_NS	0.10	94.57	94.741	94.695	94.753	0.009689	0.49	0.21	1.882	0.47
Rambo Creek	West Branch	160	24 Hour SCS_SWM	20.68	94.44	95.993	95.993	96.346	0.015306	2.89	10.18	14.888	0.85
Rambo Creek	West Branch	160	REG_SWM	23.60	94.44	96.064	96.064	96.443	0.015545	3.02	11.24	15.060	0.86
Rambo Creek	West Branch	160	24 Hour SCS_NS	0.10	94.44	94.631	94.601	94.651	0.017890	0.62	0.16	1.648	0.63
Rambo Creek	West Branch	160	REG_NS	0.10	94.44	94.601	94.601	94.640	0.046430	0.88	0.11	1.422	0.99
Rambo Creek	West Branch	150	24 Hour SCS_SWM	20.68	94.27	96.033		96.120	0.003972	1.34	17.21	21.607	0.43
Rambo Creek	West Branch	150	REG_SWM	23.60	94.27	96.100		96.197	0.004095	1.42	18.67	22.108	0.45
Rambo Creek	West Branch	150	24 Hour SCS_NS	0.10	94.27	94.636		94.637	0.000239	0.14	0.74	2.795	0.08
Rambo Creek	West Branch	150	REG_NS	0.10	94.27	94.455	94.371	94.461	0.003676	0.35	0.29	2.146	0.30
Rambo Creek	West Branch	140	24 Hour SCS_SWM	20.68	94.28	95.977		96.080	0.003683	1.69	20.67	26.015	0.44
Rambo Creek	West Branch	140	REG_SWM	23.60	94.28	96.039		96.155	0.003980	1.80	22.31	26.686	0.46
Rambo Creek	West Branch	140	24 Hour SCS_NS	0.10	94.28	94.636		94.636	0.000077	0.08	1.20	4.078	0.05
Rambo Creek	West Branch	140	REG_NS	0.10	94.28	94.339	94.339	94.363	0.055904	0.69	0.15	3.032	1.00
Rambo Creek	West Branch	130	24 Hour SCS_SWM	20.68	93.90	95.955		96.042	0.002973	1.38	18.85	22.605	0.39
Rambo Creek	West Branch	130	REG_SWM	23.60	93.90	96.013		96.115	0.003266	1.49	20.19	23.117	0.41
Rambo Creek	West Branch	130	24 Hour SCS_NS	0.10	93.90	94.635		94.636	0.000013	0.05	2.08	4.055	0.02
Rambo Creek	West Branch	130	REG_NS	0.10	93.90	94.262		94.263	0.000240	0.13	0.76	3.020	0.08
Rambo Creek	West Branch	122	24 Hour SCS_SWM	20.68	93.95	95.917	94.977	96.019	0.001872	1.42	14.57	19.176	0.34
Rambo Creek	West Branch	122	REG_SWM	23.60	93.95	95.957	95.056	96.085	0.002266	1.58	14.89	19.511	0.37
Rambo Creek	West Branch	122	24 Hour SCS_NS	0.10	93.95	94.635	94.026	94.635	0.000003	0.02	4.32	9.004	0.01
Rambo Creek	West Branch	122	REG_NS	0.10	93.95	94.262	94.026	94.262	0.000061	0.07	1.54	6.564	0.04
Rambo Creek	West Branch	107		Bridge									
Rambo Creek	West Branch	106	24 Hour SCS_SWM	20.68	94.00	95.211	95.211	95.671	0.019889	3.09	7.33	16.179	0.98
Rambo Creek	West Branch	106	REG_SWM	23.60	94.00	95.296	95.296	95.798	0.019576	3.23	8.01	17.471	0.98
Rambo Creek	West Branch	106	24 Hour SCS_NS	0.10	94.00	94.635	94.063	94.635	0.000008	0.04	2.76	7.328	0.02
Rambo Creek	West Branch	106	REG_NS	0.10	94.00	94.259	94.063	94.260	0.000245	0.12	0.84	4.057	0.08
Rambo Creek	West Branch	90	24 Hour SCS_SWM	20.68	93.38	94.896	94.870	95.232	0.017582	2.67	9.36	15.258	0.88
Rambo Creek	West Branch	90	REG_SWM	23.60	93.38	95.110		95.363	0.010483	2.36	12.96	18.420	0.71
Rambo Creek	West Branch	90	24 Hour SCS_NS	0.10	93.38	94.635		94.635	0.000001	0.02	5.85	11.964	0.01
Rambo Creek	West Branch	90	REG_NS	0.10	93.38	94.259		94.259	0.000015	0.04	2.34	6.165	0.02

HEC-RAS Plan: 2DTW1677 (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Rambo Creek	West Branch	80	24 Hour SCS_SWM	20.68	93.23	94.828		95.033	0.010446	2.33	12.68	14.727	0.69
Rambo Creek	West Branch	80	REG_SWM	23.60	93.23	95.060		95.238	0.007368	2.21	16.47	18.903	0.60
Rambo Creek	West Branch	80	24 Hour SCS_NS	0.10	93.23	94.635		94.635	0.000000	0.01	9.97	13.372	0.00
Rambo Creek	West Branch	80	REG_NS	0.10	93.23	94.259		94.259	0.000002	0.02	5.43	10.728	0.01
Rambo Creek	West Branch	70	24 Hour SCS_SWM	20.68	92.77	94.780		94.949	0.005387	1.85	12.44	13.191	0.52
Rambo Creek	West Branch	70	REG_SWM	23.60	92.77	95.032		95.177	0.003730	1.73	16.03	15.843	0.44
Rambo Creek	West Branch	70	24 Hour SCS_NS	0.10	92.77	94.635		94.635	0.000000	0.01	10.62	12.115	0.00
Rambo Creek	West Branch	70	REG_NS	0.10	92.77	94.259		94.259	0.000001	0.02	6.59	9.306	0.01
Rambo Creek	West Branch	60	24 Hour SCS_SWM	20.68	93.05	94.757		94.884	0.004953	1.61	14.29	16.685	0.49
Rambo Creek	West Branch	60	REG_SWM	23.60	93.05	95.029		95.131	0.003017	1.46	19.43	24.320	0.40
Rambo Creek	West Branch	60	24 Hour SCS_NS	0.10	93.05	94.635		94.635	0.000000	0.01	12.29	16.096	0.00
Rambo Creek	West Branch	60	REG_NS	0.10	93.05	94.259		94.259	0.000001	0.01	6.79	12.492	0.01
Rambo Creek	West Branch	50	24 Hour SCS_SWM	20.68	93.00	94.760		94.831	0.002788	1.18	18.35	20.062	0.37
Rambo Creek	West Branch	50	REG_SWM	23.60	93.00	95.040		95.095	0.001623	1.06	25.34	33.232	0.29
Rambo Creek	West Branch	50	24 Hour SCS_NS	0.10	93.00	94.635		94.635	0.000000	0.01	15.89	19.312	0.00
Rambo Creek	West Branch	50	REG_NS	0.10	93.00	94.259		94.259	0.000001	0.01	9.04	17.057	0.00
Rambo Creek	West Branch	40	24 Hour SCS_SWM	20.68	92.82	94.384	94.384	94.744	0.017952	2.69	8.69	16.429	0.89
Rambo Creek	West Branch	40	REG_SWM	23.60	92.82	94.945		95.065	0.003681	1.67	20.35	26.549	0.43
Rambo Creek	West Branch	40	24 Hour SCS_NS	0.10	92.82	94.635		94.635	0.000000	0.01	13.41	20.917	0.00
Rambo Creek	West Branch	40	REG_NS	0.10	92.82	94.259		94.259	0.000001	0.02	6.88	12.123	0.01
Rambo Creek	West Branch	30	24 Hour SCS_SWM	20.68	92.71	94.079	93.963	94.445	0.016947	2.68	7.72	7.764	0.86
Rambo Creek	West Branch	30	REG_SWM	23.60	92.71	94.915		95.033	0.002720	1.55	17.46	16.108	0.37
Rambo Creek	West Branch	30	24 Hour SCS_NS	0.10	92.71	94.635		94.635	0.000000	0.01	13.38	13.061	0.00
Rambo Creek	West Branch	30	REG_NS	0.10	92.71	94.259		94.259	0.000000	0.01	9.21	9.148	0.00
Rambo Creek	West Branch	20	24 Hour SCS_SWM	20.68	92.02	94.255		94.317	0.001520	1.10	18.95	12.876	0.28
Rambo Creek	West Branch	20	REG_SWM	23.60	92.02	94.961		94.999	0.000555	0.86	28.29	13.557	0.18
Rambo Creek	West Branch	20	24 Hour SCS_NS	0.10	92.02	94.635		94.635	0.000000	0.00	23.92	13.243	0.00
Rambo Creek	West Branch	20	REG_NS	0.10	92.02	94.259		94.259	0.000000	0.01	19.01	12.880	0.00
Rambo Creek	West Branch	10	24 Hour SCS_SWM	20.68	92.06	93.897	93.498	94.212	0.007729	2.49	8.32	7.727	0.64
Rambo Creek	West Branch	10	REG_SWM	23.60	92.06	94.785	93.605	94.950	0.002216	1.80	13.10	9.115	0.37
Rambo Creek	West Branch	10	24 Hour SCS_NS	0.10	92.06	94.635	92.178	94.635	0.000000	0.01	12.29	8.881	0.00
Rambo Creek	West Branch	10	REG_NS	0.10	92.06	94.259	92.178	94.259	0.000000	0.01	10.27	8.293	0.00
Rambo Creek	West Branch	5		Bridge									
Rambo Creek	West Branch	0	24 Hour SCS_SWM	20.68	91.77	93.855	93.000	94.070	0.003205	2.05	10.07	5.812	0.45
Rambo Creek	West Branch	0	REG_SWM	23.60	91.77	94.565	93.116	94.721	0.001572	1.75	13.50	6.146	0.33
Rambo Creek	West Branch	0	24 Hour SCS_NS	0.10	91.77	94.635	91.806	94.635	0.000000	0.01	13.84	6.179	0.00
Rambo Creek	West Branch	0	REG_NS	0.10	91.77	94.259	91.806	94.259	0.000000	0.01	12.02	6.002	0.00
HRFreemanPond	WestHager	1321.378	24 Hour SCS_SWM	17.39	97.32	99.633		99.709	0.000223	1.22	14.27	8.118	0.29
HRFreemanPond	WestHager	1321.378	REG_SWM	71.02	97.32	100.608	99.897	101.053	0.000844	3.00	32.03	57.129	0.60
HRFreemanPond	WestHager	1321.378	24 Hour SCS_NS	77.19	97.32	100.857	100.029	101.217	0.000640	2.78	47.19	64.393	0.54
HRFreemanPond	WestHager	1321.378	REG_NS	70.99	97.32	100.738	99.899	101.105	0.000670	2.77	39.71	61.003	0.54
HRFreemanPond	WestHager	1254.522	24 Hour SCS_SWM	17.39	97.39	99.546	98.992	99.667	0.002930	1.54	11.28	10.489	0.47
HRFreemanPond	WestHager	1254.522	REG_SWM	71.02	97.39	100.602	100.193	100.907	0.003716	2.61	39.08	65.153	0.59
HRFreemanPond	WestHager	1254.522	24 Hour SCS_NS	77.19	97.39	100.938	100.298	101.087	0.001738	1.98	61.48	67.818	0.42
HRFreemanPond	WestHager	1254.522	REG_NS	70.99	97.39	100.793	100.195	100.975	0.002163	2.12	51.71	66.893	0.46
HRFreemanPond	WestHager	1193.02	24 Hour SCS_SWM	17.39	97.28	99.438		99.522	0.001679	1.28	13.57	10.504	0.36
HRFreemanPond	WestHager	1193.02	REG_SWM	71.02	97.28	100.733		100.762	0.000460	1.04	122.27	218.409	0.21
HRFreemanPond	WestHager	1193.02	24 Hour SCS_NS	77.19	97.28	101.010		101.021	0.000178	0.69	193.33	293.720	0.13
HRFreemanPond	WestHager	1193.02	REG_NS	70.99	97.28	100.874		100.890	0.000263	0.81	155.53	259.278	0.16
HRFreemanPond	WestHager	1193		Lat Struct									
HRFreemanPond	WestHager	1076.52	24 Hour SCS_SWM	17.39	96.83	99.397	98.451	99.462	0.000214	1.13	15.48	12.286	0.31
HRFreemanPond	WestHager	1076.52	REG_SWM	71.02	96.83	100.747	99.639	100.750	0.000012	0.42	391.08	378.634	0.08
HRFreemanPond	WestHager	1076.52	24 Hour SCS_NS	77.19	96.83	101.014	99.729	101.016	0.000007	0.34	492.21	379.625	0.06
HRFreemanPond	WestHager	1076.52	REG_NS	70.99	96.83	100.881	99.635	100.883	0.000008	0.36	441.72	379.131	0.07
HRFreemanPond	WestHager	1018.932	24 Hour SCS_SWM	34.34	96.56	99.176	98.666	99.396	0.003833	2.08	16.70	14.221	0.57
HRFreemanPond	WestHager	1018.932	REG_SWM	63.71	96.56	100.748	99.252	100.749	0.000011	0.19	396.79	279.686	0.03
HRFreemanPond	WestHager	1018.932	24 Hour SCS_NS	101.91	96.56	101.013	99.510	101.015	0.000017	0.24	471.02	280.432	0.04
HRFreemanPond	WestHager	1018.932	REG_NS	81.04	96.56	100.880	99.510	100.882	0.000014	0.21	433.97	280.060	0.04
HRFreemanPond	WestHager	895.4784	24 Hour SCS_SWM	34.34	96.01	98.958	98.073	99.085	0.001529	1.60	23.92	22.857	0.38
HRFreemanPond	WestHager	895.4784	REG_SWM	63.71	96.01	100.747	98.648	100.747	0.000009	0.20	605.67	335.897	0.03
HRFreemanPond	WestHager	895.4784	24 Hour SCS_NS	101.91	96.01	101.011	99.290	101.013	0.000016	0.27	694.67	336.490	0.04
HRFreemanPond	WestHager	895.4784	REG_NS	81.04	96.01	100.879	98.958	100.880	0.000012	0.23	650.27	336.194	0.04
HRFreemanPond	WestHager	847.417	24 Hour SCS_SWM	34.34	94.95	99.012	97.379	99.048	0.000073	0.96	85.49	260.897	0.19
HRFreemanPond	WestHager	847.417	REG_SWM	63.71	94.95	100.747	98.045	100.747	0.000001	0.17	789.44	404.269	0.03
HRFreemanPond	WestHager	847.417	24 Hour SCS_NS	101.91	94.95	101.012	99.108	101.012	0.000002	0.23	896.57	404.931	0.03
HRFreemanPond	WestHager	847.417	REG_NS	81.04	94.95	100.880	98.338	100.880	0.000002	0.20	843.12	404.606	0.03
HRFreemanPond	WestHager	835.2853	24 Hour SCS_SWM	34.34	94.22	99.000	96.740	99.046	0.000078	1.00	81.91	268.097	0.19
HRFreemanPond	WestHager	835.2853	REG_SWM	63.71	94.22	100.746	97.410	100.747	0.000004	0.30	779.62	376.216	0.04
HRFreemanPond	WestHager	835.2853	24 Hour SCS_NS	101.91	94.22	101.010	98.271	101.012	0.000006	0.41	879.05	376.769	0.06
HRFreemanPond	WestHager	835.2853	REG_NS	81.04	94.22	100.878	97.750	100.880	0.000005	0.35	829.46	376.493	0.05
HRFreemanPond	WestHager	826.5759	24 Hour SCS_SWM	34.34	93.70	99.009	95.315	99.036	0.000019	0.72	47.54	410.018	0.11
HRFreemanPond	WestHager	826.5759	REG_SWM	63.71	93.70	100.746	95.875	100.747	0.000000	0.12	1089.96	449.764	0.02
HRFreemanPond	WestHager	826.5759	24 Hour SCS_NS	101.91	93.70	101.011	96.478	101.011	0.000001	0.17	1209.01	450.541	0.02
HRFreemanPond	WestHager	826.5759	REG_NS	81.04	93.70	100.879	96.161	100.879	0.000001	0.15	1149.62	450.154	0.02

HEC-RAS Plan: 2DTW1677 (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
HRFreemanPond	WestHager	805.3582		Culvert									
HRFreemanPond	WestHager	789.1301	24 Hour SCS_SWM	34.34	93.73	97.904	95.010	97.931	0.000035	0.73	47.30	13.051	0.12
HRFreemanPond	WestHager	789.1301	REG_SWM	63.71	93.73	98.987	95.571	99.008	0.000028	0.75	201.33	324.165	0.11
HRFreemanPond	WestHager	789.1301	24 Hour SCS_NS	101.91	93.73	99.025	96.182	99.073	0.000065	1.14	213.92	324.637	0.17
HRFreemanPond	WestHager	789.1301	REG_NS	81.04	93.73	99.013	95.862	99.045	0.000042	0.92	210.02	324.491	0.14
HRFreemanPond	WestHager	780.9492	24 Hour SCS_SWM	34.34	93.74	97.857	95.225	97.920	0.000104	1.11	30.96	8.616	0.19
HRFreemanPond	WestHager	780.9492	REG_SWM	63.71	93.74	98.951	95.888	98.999	0.000085	1.11	102.66	117.117	0.18
HRFreemanPond	WestHager	780.9492	24 Hour SCS_NS	101.91	93.74	98.914	96.605	99.046	0.000233	1.83	98.27	116.892	0.30
HRFreemanPond	WestHager	780.9492	REG_NS	81.04	93.74	98.953	96.229	99.030	0.000136	1.41	102.87	117.125	0.23
HRFreemanPond	WestHager	776.5764	24 Hour SCS_SWM	34.34	93.79	97.593	96.297	97.858	0.000736	2.28	15.06	5.947	0.46
HRFreemanPond	WestHager	776.5764	REG_SWM	63.71	93.79	98.941	97.268	98.996	0.000171	1.35	90.71	114.787	0.24
HRFreemanPond	WestHager	776.5764	24 Hour SCS_NS	101.91	93.79	98.751	98.694	99.007	0.000758	2.73	68.99	114.112	0.51
HRFreemanPond	WestHager	776.5764	REG_NS	81.04	93.79	98.933	97.766	99.025	0.000283	1.73	89.82	114.759	0.31
HRFreemanPond	WestHager	765.4565	24 Hour SCS_SWM	37.21	93.67	96.911	96.911	97.782	0.003514	4.14	9.00	5.159	1.00
HRFreemanPond	WestHager	765.4565	REG_SWM	65.45	93.67	97.797	97.797	98.888	0.003284	4.63	14.14	6.466	1.00
HRFreemanPond	WestHager	765.4565	24 Hour SCS_NS	105.00	93.67	98.702	98.702	98.993	0.000941	3.02	72.22	119.789	0.57
HRFreemanPond	WestHager	765.4565	REG_NS	83.94	93.67	98.932	98.583	99.021	0.000301	1.80	99.81	120.302	0.32
HRFreemanPond	WestHager	695.1021	24 Hour SCS_SWM	37.21	93.55	97.029	96.097	97.418	0.001150	2.76	13.47	5.722	0.57
HRFreemanPond	WestHager	695.1021	REG_SWM	65.45	93.55	97.769	97.049	98.430	0.001856	3.60	18.26	11.020	0.76
HRFreemanPond	WestHager	695.1021	24 Hour SCS_NS	105.00	93.55	98.426	98.426	98.707	0.000843	2.88	81.90	146.912	0.54
HRFreemanPond	WestHager	695.1021	REG_NS	83.94	93.55	97.556	97.556	98.850	0.003385	5.04	16.65	6.416	1.00
HRFreemanPond	WestHager	674.8755	24 Hour SCS_SWM	37.21	93.47	97.067	95.751	97.373	0.000866	2.45	15.18	5.842	0.49
HRFreemanPond	WestHager	674.8755	REG_SWM	65.45	93.47	97.836	96.743	98.357	0.001354	3.20	22.31	49.108	0.64
HRFreemanPond	WestHager	674.8755	24 Hour SCS_NS	105.00	93.47	98.376	98.376	98.662	0.000828	2.85	81.30	159.079	0.52
HRFreemanPond	WestHager	674.8755	REG_NS	83.94	93.47	97.627	97.263	98.653	0.002814	4.49	18.70	7.547	0.91
HRFreemanPond	WestHager	652.9897	24 Hour SCS_SWM	37.21	93.45	97.147	95.028	97.282	0.000111	1.63	22.83	6.612	0.27
HRFreemanPond	WestHager	652.9897	REG_SWM	65.45	93.45	97.987	95.732	98.175	0.000395	2.01	61.54	131.293	0.34
HRFreemanPond	WestHager	652.9897	24 Hour SCS_NS	105.00	93.45	97.464	96.555	98.376	0.000671	4.23	24.82	6.645	0.68
HRFreemanPond	WestHager	652.9897	REG_NS	83.94	93.45	97.947	96.133	98.279	0.000698	2.66	56.29	122.540	0.45
HRFreemanPond	WestHager	633.4816		Culvert									
HRFreemanPond	WestHager	621.3574	24 Hour SCS_SWM	37.21	93.33	96.511	95.803	97.050	0.001802	3.25	11.44	4.534	0.65
HRFreemanPond	WestHager	621.3574	REG_SWM	65.45	93.33	97.915	97.915	98.116	0.000704	2.39	58.19	157.254	0.40
HRFreemanPond	WestHager	621.3574	24 Hour SCS_NS	105.00	93.33	98.092	98.092	98.312	0.000899	2.79	86.11	158.362	0.46
HRFreemanPond	WestHager	621.3574	REG_NS	83.94	93.33	98.009	98.009	98.216	0.000795	2.58	72.92	158.117	0.43
HRFreemanPond	WestHager	595.1021	24 Hour SCS_SWM	37.21	93.26	96.009	96.009	96.885	0.003345	4.15	8.97	5.107	1.00
HRFreemanPond	WestHager	595.1021	REG_SWM	65.45	93.26	97.808	96.896	97.876	0.000264	1.57	101.46	205.247	0.31
HRFreemanPond	WestHager	595.1021	24 Hour SCS_NS	105.00	93.26	98.163	97.795	98.198	0.000154	1.30	193.79	269.942	0.24
HRFreemanPond	WestHager	595.1021	REG_NS	83.94	93.26	98.037	97.724	98.074	0.000161	1.29	159.82	269.580	0.24
HRFreemanPond	WestHager	550.8193	24 Hour SCS_SWM	37.21	93.19	96.216	95.248	96.535	0.000842	2.50	14.88	6.267	0.52
HRFreemanPond	WestHager	550.8193	REG_SWM	65.45	93.19	97.828	96.059	97.846	0.000062	0.87	176.26	161.026	0.16
HRFreemanPond	WestHager	550.8193	24 Hour SCS_NS	105.00	93.19	98.164	97.231	98.187	0.000076	1.03	232.18	166.520	0.18
HRFreemanPond	WestHager	550.8193	REG_NS	83.94	93.19	98.042	97.135	98.061	0.000063	0.91	211.86	166.520	0.16
HRFreemanPond	WestHager	508.5913	24 Hour SCS_SWM	37.21	93.02	96.014	95.427	96.475	0.001421	3.01	12.37	6.201	0.68
HRFreemanPond	WestHager	508.5913	REG_SWM	65.45	93.02	97.836	96.892	97.840	0.000017	0.46	301.22	264.700	0.08
HRFreemanPond	WestHager	508.5913	24 Hour SCS_NS	105.00	93.02	98.175	97.081	98.180	0.000019	0.53	390.95	264.700	0.09
HRFreemanPond	WestHager	508.5913	REG_NS	83.94	93.02	98.051	97.012	98.055	0.000016	0.48	358.06	264.700	0.08
HRFreemanPond	WestHager	490.8526	24 Hour SCS_SWM	37.21	92.79	95.564	95.564	96.402	0.003131	4.06	9.17	5.479	1.00
HRFreemanPond	WestHager	490.8526	REG_SWM	65.45	92.79	97.837	96.598	97.840	0.000010	0.38	363.06	248.230	0.07
HRFreemanPond	WestHager	490.8526	24 Hour SCS_NS	105.00	92.79	98.176	96.802	98.180	0.000014	0.47	447.17	248.230	0.08
HRFreemanPond	WestHager	490.8526	REG_NS	83.94	92.79	98.052	96.735	98.054	0.000011	0.41	416.32	248.230	0.07
HRFreemanPond	WestHager	485.7959	24 Hour SCS_SWM	37.21	92.76	95.470	95.238	96.203	0.002577	3.80	9.80	4.870	0.85
HRFreemanPond	WestHager	485.7959	REG_SWM	65.45	92.76	97.837	96.144	97.839	0.000011	0.37	426.94	312.810	0.06
HRFreemanPond	WestHager	485.7959	24 Hour SCS_NS	105.00	92.76	98.176	97.075	98.179	0.000014	0.45	532.99	312.810	0.07
HRFreemanPond	WestHager	485.7959	REG_NS	83.94	92.76	98.052	96.610	98.054	0.000011	0.39	494.08	312.810	0.06
HRFreemanPond	WestHager	249.2144		Culvert									
HRFreemanPond	WestHager	26.09473	24 Hour SCS_SWM	37.21	89.80	92.271	91.400	92.578	0.000503	2.45	15.17	8.292	0.51
HRFreemanPond	WestHager	26.09473	REG_SWM	65.45	89.80	93.243	92.099	93.586	0.000622	2.60	25.54	10.618	0.48
HRFreemanPond	WestHager	26.09473	24 Hour SCS_NS	105.00	89.80	94.251	92.880	94.721	0.000644	3.06	37.00	12.186	0.49
HRFreemanPond	WestHager	26.09473	REG_NS	83.94	89.80	93.931	92.498	94.292	0.000535	2.68	33.19	11.648	0.45
HRDiversion	Main1	3198.98	24 Hour SCS_SWM	19.04	100.70	103.162	103.162	103.234	0.000825	1.58	29.58	164.369	0.46
HRDiversion	Main1	3198.98	REG_SWM	30.54	100.70	103.229	103.229	103.306	0.001043	1.84	43.11	206.115	0.52
HRDiversion	Main1	3198.98	24 Hour SCS_NS	32.53	100.70	103.236	103.236	103.316	0.001090	1.89	44.69	207.585	0.54
HRDiversion	Main1	3198.98	REG_NS	32.94	100.70	103.239	103.239	103.318	0.001089	1.89	45.20	208.076	0.54
HRDiversion	Main1	3188.995	24 Hour SCS_SWM	19.04	100.66	102.185		102.499	0.001550	2.48	7.67	6.672	0.74
HRDiversion	Main1	3188.995	REG_SWM	30.54	100.66	102.473	102.331	102.984	0.002068	3.17	9.64	6.995	0.86
HRDiversion	Main1	3188.995	24 Hour SCS_NS	32.53	100.66	102.485	102.389	103.055	0.002288	3.35	9.72	7.009	0.91
HRDiversion	Main1	3188.995	REG_NS	32.94	100.66	102.469	102.401	103.067	0.002426	3.43	9.61	6.991	0.93
HRDiversion	Main1	3104.638	24 Hour SCS_SWM	19.04	99.96	101.760	101.760	102.301	0.002927	3.26	5.97	6.953	0.98
HRDiversion	Main1	3104.638	REG_SWM	30.54	99.96	102.418	102.418	102.813	0.001289	2.94	18.09	45.100	0.70
HRDiversion	Main1	3104.638	24 Hour SCS_NS	32.53	99.96	102.418	102.418	102.866	0.001463	3.14	18.09	45.100	0.75
HRDiversion	Main1	3104.638	REG_NS	32.94	99.96	102.616	102.616	102.851	0.000776	2.45	33.04	116.957	0.56
HRDiversion	Main1	3059.837	24 Hour SCS_SWM	19.04	99.61	101.426	101.267	101.887	0.002505	3.01	6.36	6.073	0.89
HRDiversion	Main1	3059.837	REG_SWM	30.54	99.61	102.000	102.000	102.390	0.001404	2.91	18.67	47.176	0.71
HRDiversion	Main1	3059.837	24 Hour SCS_NS	32.53	99.61	102.061	102.061	102.439	0.001337	2.90	21.73	53.638	0.70

HEC-RAS Plan: 2DTW1677 (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
HRDiversion	Main1	3059.837	REG_NS	32.94	99.61	102.074	102.074	102.449	0.001319	2.90	22.44	55.063	0.69
HRDiversion	Main1	3020.177	24 Hour SCS_SWM	19.04	99.27	101.567	100.863	101.763	0.000639	2.06	15.90	41.678	0.47
HRDiversion	Main1	3020.177	REG_SWM	30.54	99.27	101.753	101.753	102.026	0.000908	2.61	25.61	66.202	0.57
HRDiversion	Main1	3020.177	24 Hour SCS_NS	32.53	99.27	101.810	101.810	102.059	0.000846	2.56	29.69	77.581	0.55
HRDiversion	Main1	3020.177	REG_NS	32.94	99.27	101.810	101.810	102.065	0.000867	2.59	29.71	77.623	0.56
HRDiversion	Main1	3005.781	24 Hour SCS_SWM	19.04	99.18	101.581	100.756	101.731	0.000638	1.80	15.43	36.728	0.45
HRDiversion	Main1	3005.781	REG_SWM	30.54	99.18	101.619	101.619	101.964	0.001453	2.75	16.88	39.696	0.69
HRDiversion	Main1	3005.781	24 Hour SCS_NS	32.53	99.18	101.682	101.682	102.007	0.001348	2.72	19.59	46.182	0.67
HRDiversion	Main1	3005.781	REG_NS	32.94	99.18	101.688	101.688	102.015	0.001353	2.73	19.89	46.759	0.67
HRDiversion	Main1	2991.867		Culvert									
HRDiversion	Main1	2977.396	24 Hour SCS_SWM	19.04	98.83	101.417	101.417	101.655	0.001285	2.30	14.92	48.717	0.65
HRDiversion	Main1	2977.396	REG_SWM	30.54	98.83	101.665	101.665	101.869	0.001107	2.40	32.11	106.839	0.62
HRDiversion	Main1	2977.396	24 Hour SCS_NS	32.53	98.83	101.695	101.695	101.895	0.001094	2.42	35.39	112.621	0.62
HRDiversion	Main1	2977.396	REG_NS	32.94	98.83	101.698	101.698	101.900	0.001107	2.44	35.71	113.142	0.62
HRDiversion	Main1	2938.69	24 Hour SCS_SWM	19.04	98.71	100.934	100.934	101.299	0.002384	2.87	11.19	25.192	0.90
HRDiversion	Main1	2938.69	REG_SWM	30.54	98.71	101.279	101.279	101.533	0.001434	2.70	28.98	57.854	0.73
HRDiversion	Main1	2938.69	24 Hour SCS_NS	32.53	98.71	101.307	101.307	101.566	0.001452	2.75	30.61	58.615	0.74
HRDiversion	Main1	2938.69	REG_NS	32.94	98.71	101.313	101.313	101.572	0.001456	2.76	30.93	58.746	0.74
HRDiversion	Main1	2875.828	24 Hour SCS_SWM	19.04	97.96	99.798	99.798	100.272	0.003283	3.05	6.24	6.775	1.00
HRDiversion	Main1	2875.828	REG_SWM	30.54	97.96	100.260	100.260	100.761	0.002145	3.18	12.13	24.138	0.86
HRDiversion	Main1	2875.828	24 Hour SCS_NS	32.53	97.96	100.332	100.332	100.823	0.001997	3.17	14.04	29.193	0.84
HRDiversion	Main1	2875.828	REG_NS	32.94	97.96	100.571	100.336	100.870	0.001066	2.56	23.66	56.158	0.63
HRDiversion	Main1	2802.166	24 Hour SCS_SWM	19.04	97.42	99.585	99.445	99.940	0.001826	2.66	8.05	12.805	0.79
HRDiversion	Main1	2802.166	REG_SWM	30.54	97.42	100.299	99.885	100.520	0.000695	2.26	24.74	34.702	0.53
HRDiversion	Main1	2802.166	24 Hour SCS_NS	32.53	97.42	100.270	99.931	100.536	0.000845	2.47	23.75	33.769	0.58
HRDiversion	Main1	2802.166	REG_NS	32.94	97.42	100.644	99.946	100.776	0.000368	1.84	39.41	51.105	0.39
HRDiversion	Main1	2801		Lat Struct									
HRDiversion	Main1	2747.219	24 Hour SCS_SWM	21.23	97.02	99.776	99.035	99.825	0.000187	1.19	36.58	63.192	0.27
HRDiversion	Main1	2747.219	REG_SWM	32.83	97.02	100.432	99.378	100.450	0.000068	0.87	91.99	98.989	0.17
HRDiversion	Main1	2747.219	24 Hour SCS_NS	35.06	97.02	100.430	99.433	100.451	0.000078	0.93	91.83	98.935	0.19
HRDiversion	Main1	2747.219	REG_NS	35.71	97.02	100.727	99.442	100.735	0.000033	0.65	145.55	158.363	0.12
HRDiversion	Main1	2711.585	24 Hour SCS_SWM	21.23	96.81	99.787	98.903	99.814	0.000097	0.89	62.21	86.231	0.21
HRDiversion	Main1	2711.585	REG_SWM	32.83	96.81	100.442	99.146	100.445	0.000015	0.43	328.28	785.710	0.09
HRDiversion	Main1	2711.585	24 Hour SCS_NS	35.06	96.81	100.442	99.185	100.445	0.000017	0.46	328.13	785.669	0.09
HRDiversion	Main1	2711.585	REG_NS	35.71	96.81	100.732	99.197	100.732	0.000004	0.24	576.02	929.055	0.05
HRDiversion	Main1	2699.391	24 Hour SCS_SWM	21.23	96.68	99.270	98.871	99.692	0.001180	2.88	7.38	267.426	0.69
HRDiversion	Main1	2699.391	REG_SWM	32.83	96.68	100.443	99.343	100.443	0.000001	0.12	983.59	1098.338	0.02
HRDiversion	Main1	2699.391	24 Hour SCS_NS	35.06	96.68	100.443	99.425	100.443	0.000001	0.13	983.59	1098.338	0.03
HRDiversion	Main1	2699.391	REG_NS	35.71	96.68	99.451	99.451	100.437	0.002426	4.40	8.12	303.931	1.00
HRDiversion	Main1	2678.053		Culvert									
HRDiversion	Main1	2656.188	24 Hour SCS_SWM	21.23	96.30	98.061	97.899	98.662	0.001513	3.43	6.19	13.660	0.86
HRDiversion	Main1	2656.188	REG_SWM	32.83	96.30	98.399	98.399	99.385	0.001935	4.40	7.46	42.272	1.00
HRDiversion	Main1	2656.188	24 Hour SCS_NS	35.06	96.30	98.487	98.487	99.518	0.001910	4.50	7.79	44.030	1.00
HRDiversion	Main1	2656.188	REG_NS	35.71	96.30	98.514	98.514	99.556	0.001896	4.52	7.90	44.574	1.00
HRDiversion	Main1	2601.885	24 Hour SCS_SWM	21.23	95.79	98.211	97.615	98.406	0.000664	2.02	15.65	70.616	0.49
HRDiversion	Main1	2601.885	REG_SWM	32.83	95.79	98.360	98.360	98.422	0.000338	1.52	56.89	182.251	0.36
HRDiversion	Main1	2601.885	24 Hour SCS_NS	35.06	95.79	98.360	98.360	98.431	0.000386	1.63	56.89	182.250	0.38
HRDiversion	Main1	2601.885	REG_NS	35.71	95.79	98.360	98.360	98.433	0.000400	1.66	56.89	182.250	0.39
HRDiversion	Main1	2557.343	24 Hour SCS_SWM	25.45	95.42	97.699	97.699	98.247	0.002540	3.41	9.52	9.877	0.97
HRDiversion	Main1	2557.343	REG_SWM	35.55	95.42	98.060	98.060	98.125	0.000455	1.67	54.19	170.461	0.42
HRDiversion	Main1	2557.343	24 Hour SCS_NS	37.53	95.42	98.060	98.060	98.132	0.000507	1.76	54.19	170.461	0.45
HRDiversion	Main1	2557.343	REG_NS	38.56	95.42	98.060	98.060	98.136	0.000535	1.81	54.19	170.461	0.46
HRDiversion	Main1	2491.302	24 Hour SCS_SWM	25.45	94.91	96.671	96.671	97.119	0.002810	2.97	8.58	9.650	1.00
HRDiversion	Main1	2491.302	REG_SWM	35.55	94.91	96.905	96.905	97.450	0.002656	3.27	10.87	9.925	1.00
HRDiversion	Main1	2491.302	24 Hour SCS_NS	37.53	94.91	96.944	96.944	97.510	0.002660	3.33	11.26	9.972	1.00
HRDiversion	Main1	2491.302	REG_NS	38.56	94.91	96.968	96.968	97.541	0.002637	3.35	11.49	10.001	1.00
HRDiversion	Main1	2468.123	24 Hour SCS_SWM	25.45	94.39	96.005	95.515	96.219	0.000620	2.05	12.42	9.150	0.54
HRDiversion	Main1	2468.123	REG_SWM	35.55	94.39	96.423	95.757	96.676	0.000522	2.23	15.97	9.430	0.52
HRDiversion	Main1	2468.123	24 Hour SCS_NS	37.53	94.39	96.500	95.802	96.760	0.000509	2.26	16.63	9.481	0.52
HRDiversion	Main1	2468.123	REG_NS	38.56	94.39	96.540	95.823	96.803	0.000503	2.27	16.96	9.508	0.51
HRDiversion	Main1	2443.509		Culvert									
HRDiversion	Main1	2401.658	24 Hour SCS_SWM	25.45	93.98	95.326	95.147	95.676	0.001406	2.62	9.71	9.215	0.78
HRDiversion	Main1	2401.658	REG_SWM	35.55	93.98	95.551	95.392	96.030	0.001520	3.07	11.60	9.472	0.83
HRDiversion	Main1	2401.658	24 Hour SCS_NS	37.53	93.98	95.599	95.437	96.097	0.001510	3.13	12.00	9.527	0.83
HRDiversion	Main1	2401.658	REG_NS	38.56	93.98	95.634	95.461	96.135	0.001473	3.14	12.29	9.566	0.83
HRDiversion	Main1	2400		Lat Struct									
HRDiversion	Main1	2393.06	24 Hour SCS_SWM	25.45	93.86	95.357	95.086	95.621	0.001141	2.28	11.17	10.268	0.70
HRDiversion	Main1	2393.06	REG_SWM	35.55	93.86	95.612	95.337	95.945	0.001212	2.56	13.91	11.181	0.73
HRDiversion	Main1	2393.06	24 Hour SCS_NS	37.53	93.86	95.667	95.376	96.007	0.001200	2.58	14.52	11.395	0.73
HRDiversion	Main1	2393.06	REG_NS	38.56	93.86	95.704	95.403	96.043	0.001172	2.58	14.95	11.539	0.72
HRDiversion	Main1	2301.658	24 Hour SCS_SWM	25.45	93.68	95.030	94.978	95.440	0.002109	2.84	8.97	9.429	0.93
HRDiversion	Main1	2301.658	REG_SWM	35.55	93.68	95.414	95.228	95.806	0.001494	2.77	12.81	10.609	0.81

HEC-RAS Plan: 2DTW1677 (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
HRDiversion	Main1	2301.658	24 Hour SCS_NS	37.53	93.68	95.460	95.273	95.865	0.001496	2.82	13.31	10.752	0.81
HRDiversion	Main1	2301.658	REG_NS	38.56	93.68	95.534	95.292	95.914	0.001340	2.73	14.11	10.979	0.77
HRDiversion	Main1	2240.215	24 Hour SCS_SWM	25.45	93.45	94.953	94.806	95.292	0.001601	2.58	9.86	9.686	0.82
HRDiversion	Main1	2240.215	REG_SWM	35.55	93.45	95.371	95.052	95.691	0.001121	2.51	14.18	10.993	0.70
HRDiversion	Main1	2240.215	24 Hour SCS_NS	37.53	93.45	95.417	95.100	95.749	0.001131	2.55	14.69	11.138	0.71
HRDiversion	Main1	2240.215	REG_NS	38.56	93.45	95.497	95.122	95.809	0.001011	2.47	15.60	11.391	0.67
HRDiversion	Main1	2201.658	24 Hour SCS_SWM	25.45	93.39	94.921	94.716	95.225	0.001368	2.44	10.43	9.873	0.76
HRDiversion	Main1	2201.658	REG_SWM	35.55	93.39	95.355	94.969	95.641	0.000959	2.37	15.00	11.222	0.65
HRDiversion	Main1	2201.658	24 Hour SCS_NS	37.53	93.39	95.401	95.013	95.699	0.000971	2.42	15.52	11.366	0.66
HRDiversion	Main1	2201.658	REG_NS	38.56	93.39	95.484	95.035	95.763	0.000868	2.34	16.48	11.625	0.63
HRDiversion	Main1	2175.404	24 Hour SCS_SWM	25.45	93.34	94.898	94.665	95.185	0.001258	2.37	10.73	9.935	0.73
HRDiversion	Main1	2175.404	REG_SWM	35.55	93.34	95.341	94.914	95.612	0.000882	2.30	15.43	11.270	0.63
HRDiversion	Main1	2175.404	24 Hour SCS_NS	37.53	93.34	95.387	94.960	95.669	0.000896	2.35	15.95	11.408	0.64
HRDiversion	Main1	2175.404	REG_NS	38.56	93.34	95.472	94.981	95.737	0.000801	2.28	16.93	11.665	0.60
HRDiversion	Main1	2135.042	24 Hour SCS_SWM	25.45	93.29	94.860	94.596	95.132	0.001163	2.31	11.02	9.992	0.70
HRDiversion	Main1	2135.042	REG_SWM	35.55	93.29	95.319	94.846	95.573	0.000805	2.23	15.91	11.322	0.60
HRDiversion	Main1	2135.042	24 Hour SCS_NS	37.53	93.29	95.364	94.888	95.630	0.000820	2.28	16.43	11.454	0.61
HRDiversion	Main1	2135.042	REG_NS	38.56	93.29	95.452	94.912	95.701	0.000732	2.21	17.45	11.709	0.58
HRDiversion	Main1	2101.658	24 Hour SCS_SWM	25.45	93.25	94.818	94.556	95.093	0.001179	2.32	10.95	9.912	0.71
HRDiversion	Main1	2101.658	REG_SWM	35.55	93.25	95.294	94.806	95.546	0.000788	2.22	15.99	11.261	0.60
HRDiversion	Main1	2101.658	24 Hour SCS_NS	37.53	93.25	95.339	94.849	95.602	0.000805	2.28	16.50	11.387	0.60
HRDiversion	Main1	2101.658	REG_NS	38.56	93.25	95.430	94.871	95.676	0.000715	2.20	17.55	11.647	0.57
HRDiversion	Main1	2068.318	24 Hour SCS_SWM	25.45	93.21	94.782	94.509	95.052	0.001145	2.30	11.04	9.889	0.70
HRDiversion	Main1	2068.318	REG_SWM	35.55	93.21	95.274	94.756	95.518	0.000750	2.19	16.26	11.288	0.58
HRDiversion	Main1	2068.318	24 Hour SCS_NS	37.53	93.21	95.318	94.807	95.574	0.000769	2.24	16.75	11.413	0.59
HRDiversion	Main1	2068.318	REG_NS	38.56	93.21	95.413	94.826	95.651	0.000680	2.16	17.85	11.682	0.56
HRDiversion	Main1	2029	24 Hour SCS_SWM	25.45	93.11	94.754	94.423	95.004	0.001008	2.21	11.50	9.903	0.66
HRDiversion	Main1	2029	REG_SWM	35.55	93.11	95.258	94.682	95.485	0.000673	2.11	16.83	11.295	0.55
HRDiversion	Main1	2029	24 Hour SCS_NS	37.53	93.11	95.301	94.725	95.540	0.000692	2.17	17.32	11.414	0.56
HRDiversion	Main1	2029	REG_NS	38.56	93.11	95.399	94.750	95.621	0.000613	2.09	18.45	11.685	0.53
HRDiversion	Main1	2001.658	24 Hour SCS_SWM	25.45	93.04	94.738	94.374	94.974	0.000926	2.15	11.82	9.921	0.63
HRDiversion	Main1	2001.658	REG_SWM	35.55	93.04	95.247	94.629	95.465	0.000624	2.07	17.21	11.223	0.53
HRDiversion	Main1	2001.658	24 Hour SCS_NS	37.53	93.04	95.290	94.672	95.519	0.000644	2.12	17.70	11.332	0.54
HRDiversion	Main1	2001.658	REG_NS	38.56	93.04	95.389	94.694	95.603	0.000571	2.05	18.83	11.583	0.51
HRDiversion	Main1	1991.135	24 Hour SCS_SWM	25.45	93.01	94.630	94.337	94.940	0.001002	2.46	10.33	9.698	0.68
HRDiversion	Main1	1991.135	REG_SWM	35.55	93.01	95.091	94.592	95.423	0.000723	2.55	13.92	10.925	0.61
HRDiversion	Main1	1991.135	24 Hour SCS_NS	37.53	93.01	95.109	94.638	95.472	0.000780	2.67	14.06	10.973	0.63
HRDiversion	Main1	1991.135	REG_NS	38.56	93.01	95.217	94.658	95.558	0.000678	2.59	14.90	11.262	0.60
HRDiversion	Main1	1780.106		Culvert									
HRDiversion	Main1	1721.669	24 Hour SCS_SWM	25.45	91.47	93.874	92.959	94.091	0.000671	2.06	12.36	5.955	0.46
HRDiversion	Main1	1721.669	REG_SWM	35.55	91.47	94.537	93.292	94.776	0.000609	2.17	16.42	6.300	0.43
HRDiversion	Main1	1721.669	24 Hour SCS_NS	37.53	91.47	94.463	93.356	94.745	0.000732	2.35	15.96	6.261	0.47
HRDiversion	Main1	1721.669	REG_NS	38.56	91.47	93.991	93.390	94.435	0.001327	2.95	13.05	6.015	0.64
HRDiversion	Main1	1720		Lat Struct									
HRDiversion	Main1	1717.069	24 Hour SCS_SWM	25.45	91.55	93.897	92.894	94.063	0.000465	1.80	14.11	6.966	0.40
HRDiversion	Main1	1717.069	REG_SWM	35.55	91.55	94.564	93.203	94.744	0.000408	1.88	18.90	7.413	0.38
HRDiversion	Main1	1717.069	24 Hour SCS_NS	37.53	91.55	94.496	93.257	94.708	0.000489	2.04	18.40	7.367	0.41
HRDiversion	Main1	1717.069	REG_NS	38.56	91.55	94.043	93.287	94.374	0.000880	2.55	15.13	7.064	0.56
HRDiversion	Main1	1703.419	24 Hour SCS_SWM	25.45	91.54	93.899	92.851	94.053	0.000424	1.74	14.62	7.095	0.39
HRDiversion	Main1	1703.419	REG_SWM	35.55	91.54	94.566	93.153	94.736	0.000376	1.82	19.50	7.518	0.36
HRDiversion	Main1	1703.419	24 Hour SCS_NS	37.53	91.54	94.498	93.206	94.697	0.000450	1.98	18.99	7.475	0.40
HRDiversion	Main1	1703.419	REG_NS	38.56	91.54	94.047	93.236	94.355	0.000802	2.46	15.68	7.189	0.53
HRDiversion	Main1-2	1667.58	24 Hour SCS_SWM	43.07	91.48	93.896	92.808	94.029	0.000290	1.62	26.63	13.698	0.37
HRDiversion	Main1-2	1667.58	REG_SWM	59.62	91.48	94.576	93.095	94.710	0.000237	1.63	36.67	15.619	0.34
HRDiversion	Main1-2	1667.58	24 Hour SCS_NS	0.10	91.48	94.635	91.561	94.635	0.000000	0.00	37.60	15.737	0.00
HRDiversion	Main1-2	1667.58	REG_NS	0.10	91.48	94.259	91.561	94.259	0.000000	0.00	31.84	14.883	0.00
HRDiversion	Main1-2	1667		Lat Struct									
HRDiversion	Main1-2	1650.541	24 Hour SCS_SWM	43.07	91.46	93.901		94.020	0.000272	1.53	28.11	15.775	0.37
HRDiversion	Main1-2	1650.541	REG_SWM	59.62	91.46	94.586		94.701	0.000190	1.50	39.82	18.674	0.32
HRDiversion	Main1-2	1650.541	24 Hour SCS_NS	0.10	91.46	94.635		94.635	0.000000	0.00	40.75	18.914	0.00
HRDiversion	Main1-2	1650.541	REG_NS	0.10	91.46	94.259		94.259	0.000000	0.00	33.98	17.062	0.00
HRDiversion	Main1-2	1601.658	24 Hour SCS_SWM	43.07	91.35	93.907		94.002	0.000194	1.36	31.77	17.326	0.31
HRDiversion	Main1-2	1601.658	REG_SWM	59.62	91.35	94.591		94.688	0.000134	1.38	44.75	21.253	0.27
HRDiversion	Main1-2	1601.658	24 Hour SCS_NS	0.10	91.35	94.635		94.635	0.000000	0.00	45.71	21.624	0.00
HRDiversion	Main1-2	1601.658	REG_NS	0.10	91.35	94.259		94.259	0.000000	0.00	38.08	18.519	0.00
HRDiversion	Main1-2	1501.658	24 Hour SCS_SWM	43.07	91.13	93.894		93.981	0.000172	1.30	33.02	16.923	0.29
HRDiversion	Main1-2	1501.658	REG_SWM	59.62	91.13	94.583		94.673	0.000122	1.34	46.50	23.409	0.26
HRDiversion	Main1-2	1501.658	24 Hour SCS_NS	0.10	91.13	94.635		94.635	0.000000	0.00	47.75	24.165	0.00
HRDiversion	Main1-2	1501.658	REG_NS	0.10	91.13	94.259		94.259	0.000000	0.00	39.69	19.298	0.00
HRDiversion	Main1-2	1454.463	24 Hour SCS_SWM	43.07	91.07	93.896		93.970	0.000135	1.21	35.92	17.675	0.26
HRDiversion	Main1-2	1454.463	REG_SWM	59.62	91.07	94.585		94.665	0.000100	1.25	50.10	25.705	0.24
HRDiversion	Main1-2	1454.463	24 Hour SCS_NS	0.10	91.07	94.635		94.635	0.000000	0.00	51.42	26.611	0.00
HRDiversion	Main1-2	1454.463	REG_NS	0.10	91.07	94.259		94.259	0.000000	0.00	42.70	20.758	0.00

HEC-RAS Plan: 2DTW1677 (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
HRDiversion	Main1-2	1443.625	24 Hour SCS_SWM	43.07	90.72	93.810	92.157	93.949	0.000142	1.65	26.05	15.831	0.30
HRDiversion	Main1-2	1443.625	REG_SWM	59.62	90.72	94.451	92.485	94.633	0.000143	1.89	31.59	25.544	0.31
HRDiversion	Main1-2	1443.625	24 Hour SCS_NS	0.10	90.72	94.635	90.786	94.635	0.000000	0.00	33.18	28.431	0.00
HRDiversion	Main1-2	1443.625	REG_NS	0.10	90.72	94.259	90.786	94.259	0.000000	0.00	29.93	23.374	0.00
HRDiversion	Main1-2	1429.197		Culvert									
HRDiversion	Main1-2	1412.911	24 Hour SCS_SWM	43.07	90.13	92.328	91.650	92.639	0.000525	2.47	17.43	10.371	0.55
HRDiversion	Main1-2	1412.911	REG_SWM	59.62	90.13	93.373	91.985	93.636	0.000257	2.27	26.26	11.502	0.41
HRDiversion	Main1-2	1412.911	24 Hour SCS_NS	0.10	90.13	94.635	90.225	94.635	0.000000	0.00	48.47	20.815	0.00
HRDiversion	Main1-2	1412.911	REG_NS	0.10	90.13	94.259	90.225	94.259	0.000000	0.00	41.80	15.217	0.00
HRDiversion	Main1-2	1401.658	24 Hour SCS_SWM	43.07	90.10	92.403		92.554	0.000369	1.73	24.96	14.685	0.42
HRDiversion	Main1-2	1401.658	REG_SWM	59.62	90.10	93.450		93.554	0.000152	1.43	42.30	19.201	0.29
HRDiversion	Main1-2	1401.658	24 Hour SCS_NS	0.10	90.10	94.635		94.635	0.000000	0.00	69.69	27.275	0.00
HRDiversion	Main1-2	1401.658	REG_NS	0.10	90.10	94.259		94.259	0.000000	0.00	59.93	24.586	0.00
HRDiversion	Main1-2	1301.658	24 Hour SCS_SWM	58.81	89.88	92.206		92.471	0.000631	2.28	25.80	14.967	0.55
HRDiversion	Main1-2	1301.658	REG_SWM	95.29	89.88	93.223		93.482	0.000371	2.26	42.72	18.713	0.45
HRDiversion	Main1-2	1301.658	24 Hour SCS_NS	115.87	89.88	94.407		94.580	0.000151	1.85	68.54	25.667	0.31
HRDiversion	Main1-2	1301.658	REG_NS	102.84	89.88	94.033		94.203	0.000170	1.84	59.50	22.738	0.32
HRDiversion	Main1-2	1201.658	24 Hour SCS_SWM	58.81	89.69	92.170		92.405	0.000527	2.15	27.40	15.103	0.51
HRDiversion	Main1-2	1201.658	REG_SWM	95.29	89.69	93.208		93.439	0.000332	2.13	45.05	19.365	0.43
HRDiversion	Main1-2	1201.658	24 Hour SCS_NS	115.87	89.69	94.407		94.560	0.000133	1.74	72.89	28.290	0.29
HRDiversion	Main1-2	1201.658	REG_NS	102.84	89.69	94.030		94.182	0.000151	1.73	62.89	24.875	0.30
HRDiversion	Main1-2	1101.658	24 Hour SCS_SWM	58.81	89.52	92.159		92.345	0.000387	1.91	30.81	16.118	0.44
HRDiversion	Main1-2	1101.658	REG_SWM	95.29	89.52	93.204		93.400	0.000239	1.96	50.21	21.164	0.37
HRDiversion	Main1-2	1101.658	24 Hour SCS_NS	115.87	89.52	94.409		94.542	0.000105	1.64	86.22	40.548	0.26
HRDiversion	Main1-2	1101.658	REG_NS	102.84	89.52	94.030		94.163	0.000117	1.63	71.81	35.386	0.27
HRDiversion	Main1-2	1001.658	24 Hour SCS_SWM	58.81	89.43	92.131		92.304	0.000349	1.84	31.89	16.155	0.42
HRDiversion	Main1-2	1001.658	REG_SWM	95.29	89.43	93.189		93.374	0.000219	1.92	52.40	23.269	0.35
HRDiversion	Main1-2	1001.658	24 Hour SCS_NS	115.87	89.43	94.404		94.530	0.000097	1.60	90.81	44.871	0.25
HRDiversion	Main1-2	1001.658	REG_NS	102.84	89.43	94.024		94.149	0.000108	1.59	76.31	35.144	0.26
HRDiversion	Main1-2	928.0883	24 Hour SCS_SWM	58.81	89.14	92.109		92.279	0.000324	1.83	32.19	13.865	0.38
HRDiversion	Main1-2	928.0883	REG_SWM	95.29	89.14	93.151		93.354	0.000264	2.01	50.67	22.224	0.35
HRDiversion	Main1-2	928.0883	24 Hour SCS_NS	115.87	89.14	94.388		94.519	0.000129	1.66	93.38	50.810	0.25
HRDiversion	Main1-2	928.0883	REG_NS	102.84	89.14	94.001		94.138	0.000143	1.67	75.72	40.344	0.26
HRDiversion	Main2	898.3339	24 Hour SCS_SWM	91.56	88.95	91.860		92.240	0.000710	2.73	33.57	16.560	0.60
HRDiversion	Main2	898.3339	REG_SWM	146.26	88.95	92.912		93.321	0.000452	2.85	58.60	32.810	0.51
HRDiversion	Main2	898.3339	24 Hour SCS_NS	206.05	88.95	94.143		94.490	0.000263	2.71	108.93	47.262	0.41
HRDiversion	Main2	898.3339	REG_NS	186.78	88.95	93.731		94.106	0.000316	2.78	90.01	44.560	0.45
HRDiversion	Main2	854.6458	24 Hour SCS_SWM	91.56	88.94	91.845		92.203	0.000678	2.65	34.55	17.039	0.59
HRDiversion	Main2	854.6458	REG_SWM	146.26	88.94	92.908		93.295	0.000426	2.77	56.73	25.735	0.50
HRDiversion	Main2	854.6458	24 Hour SCS_NS	206.05	88.94	94.132		94.479	0.000257	2.68	111.38	72.700	0.41
HRDiversion	Main2	854.6458	REG_NS	186.78	88.94	93.717		94.093	0.000310	2.75	83.98	44.680	0.44
HRDiversion	Main2	754.6458	24 Hour SCS_SWM	91.56	88.68	91.842		92.126	0.000451	2.36	39.08	18.230	0.49
HRDiversion	Main2	754.6458	REG_SWM	146.26	88.68	92.910		93.242	0.000324	2.57	61.45	23.706	0.44
HRDiversion	Main2	754.6458	24 Hour SCS_NS	206.05	88.68	94.124		94.449	0.000218	2.58	105.38	58.426	0.38
HRDiversion	Main2	754.6458	REG_NS	186.78	88.68	93.711		94.055	0.000256	2.63	85.16	41.233	0.41
HRDiversion	Main2	725.9643	24 Hour SCS_SWM	91.56	88.50	91.851		92.105	0.000385	2.23	41.38	19.023	0.46
HRDiversion	Main2	725.9643	REG_SWM	146.26	88.50	92.922		93.224	0.000285	2.45	65.03	25.137	0.42
HRDiversion	Main2	725.9643	24 Hour SCS_NS	206.05	88.50	94.142		94.433	0.000192	2.46	113.12	59.888	0.36
HRDiversion	Main2	725.9643	REG_NS	186.78	88.50	93.727		94.039	0.000226	2.51	90.87	41.758	0.39
HRDiversion	Main2	693.4501	24 Hour SCS_SWM	91.56	88.51	91.623	90.640	92.042	0.000468	2.87	31.93	18.329	0.54
HRDiversion	Main2	693.4501	REG_SWM	146.26	88.51	92.470	91.341	93.111	0.000509	3.55	41.24	22.187	0.58
HRDiversion	Main2	693.4501	24 Hour SCS_NS	206.05	88.51	94.138	92.013	94.425	0.000179	2.43	115.10	52.978	0.35
HRDiversion	Main2	693.4501	REG_NS	186.78	88.51	93.726	91.807	94.026	0.000206	2.46	94.33	47.826	0.37
HRDiversion	Main2	683.0943		Bridge									
HRDiversion	Main2	672.3745	24 Hour SCS_SWM	91.56	88.48	90.851	90.571	91.561	0.001195	3.73	24.53	15.492	0.81
HRDiversion	Main2	672.3745	REG_SWM	146.26	88.48	91.979	91.256	92.760	0.000750	3.92	37.35	20.763	0.69
HRDiversion	Main2	672.3745	24 Hour SCS_NS	206.05	88.48	92.724	91.920	93.328	0.000576	3.46	64.56	24.979	0.59
HRDiversion	Main2	672.3745	REG_NS	186.78	88.48	92.663	91.716	93.178	0.000504	3.20	63.03	24.664	0.55
HRDiversion	Main2	654.6458	24 Hour SCS_SWM	91.56	88.46	90.857	90.675	91.508	0.001543	3.57	25.61	14.783	0.87
HRDiversion	Main2	654.6458	REG_SWM	146.26	88.46	92.095		92.619	0.000663	3.21	47.58	21.848	0.61
HRDiversion	Main2	654.6458	24 Hour SCS_NS	206.05	88.46	92.450		93.255	0.000875	4.00	55.77	24.362	0.72
HRDiversion	Main2	654.6458	REG_NS	186.78	88.46	92.479		93.127	0.000697	3.59	56.48	24.569	0.64
HRDiversion	Main2	636.8858	24 Hour SCS_SWM	91.51	88.42	90.926		91.393	0.001020	3.03	30.20	16.539	0.72
HRDiversion	Main2	636.8858	REG_SWM	146.89	88.42	92.151		92.542	0.000506	2.77	53.86	23.394	0.54
HRDiversion	Main2	636.8858	24 Hour SCS_NS	192.26	88.42	92.596		93.084	0.000518	3.10	66.31	33.201	0.56
HRDiversion	Main2	636.8858	REG_NS	187.80	88.42	92.553		93.032	0.000518	3.08	64.89	32.196	0.56
HRDiversion	Main2	554.6458	24 Hour SCS_SWM	91.51	87.98	90.947		91.291	0.000651	2.60	35.24	16.922	0.57
HRDiversion	Main2	554.6458	REG_SWM	146.89	87.98	92.156		92.490	0.000367	2.57	60.18	25.645	0.46
HRDiversion	Main2	554.6458	24 Hour SCS_NS	192.26	87.98	92.619		93.022	0.000379	2.86	88.15	69.396	0.48
HRDiversion	Main2	554.6458	REG_NS	187.80	87.98	92.572		92.972	0.000381	2.84	84.89	69.092	0.48
HRDiversion	Main2	468.4212	24 Hour SCS_SWM	91.51	87.64	90.963	89.830	91.221	0.000402	2.25	40.65	16.912	0.46
HRDiversion	Main2	468.4212	REG_SWM	146.89	87.64	92.163	90.463	92.448	0.000267	2.39	71.14	33.158	0.40
HRDiversion	Main2	468.4212	24 Hour SCS_NS	192.26	87.64	92.613	90.899	92.983	0.000302	2.74	86.48	37.733	0.43
HRDiversion	Main2	468.4212	REG_NS	187.80	87.64	92.570	90.859	92.932	0.000299	2.71	84.88	36.166	0.43

HEC-RAS Plan: 2DTW1677 (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
HRDiversion	Main2	454.6458	24 Hour SCS_SWM	91.51	87.66	90.641	89.964	91.136	0.006042	3.12	29.35	16.242	0.63
HRDiversion	Main2	454.6458	REG_SWM	146.89	87.66	91.740	90.649	92.343	0.006440	3.45	45.23	74.710	0.64
HRDiversion	Main2	454.6458	24 Hour SCS_NS	192.26	87.66	92.721	92.153	92.859	0.001594	1.87	127.23	113.128	0.33
HRDiversion	Main2	454.6458	REG_NS	187.80	87.66	92.671	92.135	92.814	0.001692	1.91	121.65	108.793	0.33
HRDiversion	Main2	420.9742		Culvert									
HRDiversion	Main2	398.4328	24 Hour SCS_SWM	91.51	87.29	89.756	89.756	90.735	0.002323	4.38	20.87	10.646	1.00
HRDiversion	Main2	398.4328	REG_SWM	146.89	87.29	90.506	90.506	91.792	0.002144	5.02	29.24	12.261	1.00
HRDiversion	Main2	398.4328	24 Hour SCS_NS	192.26	87.29	91.013	91.013	92.551	0.002019	5.50	34.99	15.765	1.00
HRDiversion	Main2	398.4328	REG_NS	187.80	87.29	90.962	90.962	92.480	0.002037	5.46	34.41	14.998	1.00
HRDiversion	Main2	375.9594	24 Hour SCS_SWM	91.51	87.05	89.484	89.484	90.318	0.002106	4.04	22.63	13.673	1.00
HRDiversion	Main2	375.9594	REG_SWM	146.89	87.05	90.147	90.147	91.198	0.001975	4.54	32.36	16.051	1.00
HRDiversion	Main2	375.9594	24 Hour SCS_NS	192.26	87.05	90.576	90.576	91.809	0.001807	4.92	39.94	19.442	0.99
HRDiversion	Main2	375.9594	REG_NS	187.80	87.05	90.538	90.538	91.752	0.001817	4.89	39.19	19.046	0.99
HRDiversion	Main2	354.6458	24 Hour SCS_SWM	91.51	86.91	89.414	89.414	90.238	0.002115	4.02	22.76	14.030	1.01
HRDiversion	Main2	354.6458	REG_SWM	146.89	86.91	90.053	90.053	91.107	0.001916	4.55	32.50	18.412	1.00
HRDiversion	Main2	354.6458	24 Hour SCS_NS	192.26	86.91	90.593	90.593	91.682	0.001487	4.66	48.09	36.245	0.91
HRDiversion	Main2	354.6458	REG_NS	187.80	86.91	90.548	90.548	91.631	0.001508	4.64	46.51	35.367	0.92
HRDiversion	Main2	254.6458	24 Hour SCS_SWM	91.51	86.57	89.105	89.105	89.911	0.002081	3.98	23.01	14.301	1.00
HRDiversion	Main2	254.6458	REG_SWM	146.89	86.57	89.765	89.765	90.767	0.001769	4.44	34.81	26.998	0.97
HRDiversion	Main2	254.6458	24 Hour SCS_NS	192.26	86.57	90.284	90.284	91.305	0.001392	4.55	52.92	39.183	0.89
HRDiversion	Main2	254.6458	REG_NS	187.80	86.57	90.248	90.248	91.257	0.001396	4.52	51.54	38.924	0.89
HRDiversion	Main2	154.6458	24 Hour SCS_SWM	91.51	86.12	88.705	88.705	89.537	0.002119	4.04	22.64	13.800	1.01
HRDiversion	Main2	154.6458	REG_SWM	146.89	86.12	89.656	89.656	90.266	0.001046	3.62	68.70	90.620	0.75
HRDiversion	Main2	154.6458	24 Hour SCS_NS	192.26	86.12	89.949	89.949	90.600	0.001034	3.89	95.73	93.970	0.76
HRDiversion	Main2	154.6458	REG_NS	187.80	86.12	89.918	89.918	90.570	0.001044	3.88	92.79	93.675	0.76
HRDiversion	Main2	54.64576	24 Hour SCS_SWM	91.51	85.80	88.189	88.189	89.016	0.002089	4.03	22.71	13.703	1.00
HRDiversion	Main2	54.64576	REG_SWM	146.89	85.80	88.888	88.888	89.887	0.001868	4.43	33.94	24.095	0.98
HRDiversion	Main2	54.64576	24 Hour SCS_NS	192.26	85.80	89.310	89.310	90.095	0.001314	4.20	76.45	67.984	0.85
HRDiversion	Main2	54.64576	REG_NS	187.80	85.80	89.286	89.286	90.059	0.001304	4.16	74.87	67.152	0.84

HEC-RAS Plan: Nov2018_sc2

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Upper Rambo	UR1	355.1200	24 Hour SCS_SWM	23.51	98.22	101.441	99.707	101.460	0.000223	0.72	70.87	156.059	0.15
Upper Rambo	UR1	355.1200	REG_SWM	16.23	98.22	101.344	99.451	101.358	0.000147	0.57	56.62	137.449	0.12
Upper Rambo	UR1	355.1200	24 Hour SCS_NS	23.51	98.22	101.441	99.707	101.460	0.000223	0.72	70.87	156.059	0.15
Upper Rambo	UR1	355.1200	REG_NS	16.23	98.22	101.344	99.451	101.358	0.000147	0.57	56.62	137.449	0.12
Upper Rambo	UR1	355		Lat Struct									
Upper Rambo	UR1	333.1341	24 Hour SCS_SWM	23.51	98.05	101.446	99.699	101.454	0.000105	0.47	80.50	212.906	0.10
Upper Rambo	UR1	333.1341	REG_SWM	16.23	98.05	101.347	99.455	101.354	0.000090	0.42	60.02	196.324	0.09
Upper Rambo	UR1	333.1341	24 Hour SCS_NS	23.51	98.05	101.446	99.699	101.454	0.000105	0.47	80.50	212.906	0.10
Upper Rambo	UR1	333.1341	REG_NS	16.23	98.05	101.347	99.455	101.354	0.000090	0.42	60.02	196.324	0.09
Upper Rambo	UR1	318.4964	24 Hour SCS_SWM	23.51	97.89	101.448	99.476	101.452	0.000045	0.33	93.63	139.418	0.07
Upper Rambo	UR1	318.4964	REG_SWM	16.23	97.89	101.339	99.219	101.352	0.000112	0.50	36.84	48.079	0.11
Upper Rambo	UR1	318.4964	24 Hour SCS_NS	23.51	97.89	101.448	99.476	101.452	0.000045	0.33	93.63	139.418	0.07
Upper Rambo	UR1	318.4964	REG_NS	16.23	97.89	101.339	99.219	101.352	0.000112	0.50	36.84	48.079	0.11
Upper Rambo	UR1	304.6275	24 Hour SCS_SWM	23.51	97.63	101.443	99.828	101.450	0.000075	0.47	102.08	190.953	0.09
Upper Rambo	UR1	304.6275	REG_SWM	16.23	97.63	101.337	99.374	101.350	0.000104	0.54	42.63	53.386	0.10
Upper Rambo	UR1	304.6275	24 Hour SCS_NS	23.51	97.63	101.443	99.828	101.450	0.000075	0.47	102.08	190.953	0.09
Upper Rambo	UR1	304.6275	REG_NS	16.23	97.63	101.337	99.374	101.350	0.000104	0.54	42.63	53.386	0.10
Upper Rambo	UR1	304		Culvert									
Upper Rambo	UR1	277.2888	24 Hour SCS_SWM	23.51	97.43	101.438	99.526	101.439	0.000009	0.11	225.51	172.085	0.02
Upper Rambo	UR1	277.2888	REG_SWM	16.23	97.43	99.555	99.067	100.037	0.007382	3.08	5.28	27.233	0.68
Upper Rambo	UR1	277.2888	24 Hour SCS_NS	23.51	97.43	101.438	99.526	101.439	0.000009	0.11	225.51	172.085	0.02
Upper Rambo	UR1	277.2888	REG_NS	16.23	97.43	99.555	99.067	100.037	0.007382	3.08	5.28	27.233	0.68
Upper Rambo	UR1	277		Lat Struct									
Upper Rambo	UR1	272.4874	24 Hour SCS_SWM	23.51	97.40	101.283	99.102	101.403	0.000891	1.53	15.35	184.835	0.26
Upper Rambo	UR1	272.4874	REG_SWM	16.23	97.40	99.685	98.780	99.865	0.002885	1.88	8.64	33.758	0.42
Upper Rambo	UR1	272.4874	24 Hour SCS_NS	23.51	97.40	101.283	99.102	101.403	0.000891	1.53	15.35	184.835	0.26
Upper Rambo	UR1	272.4874	REG_NS	16.23	97.40	99.685	98.780	99.865	0.002885	1.88	8.64	33.758	0.42
Upper Rambo	UR1	272		Culvert									
Upper Rambo	UR1	232.4432	24 Hour SCS_SWM	23.51	97.20	100.355	98.889	100.540	0.001098	1.90	12.35	19.938	0.35
Upper Rambo	UR1	232.4432	REG_SWM	16.23	97.20	99.305	98.565	99.518	0.002281	2.04	7.94	12.699	0.47
Upper Rambo	UR1	232.4432	24 Hour SCS_NS	23.51	97.20	100.355	98.889	100.540	0.001098	1.90	12.35	19.938	0.35
Upper Rambo	UR1	232.4432	REG_NS	16.23	97.20	99.305	98.565	99.518	0.002281	2.04	7.94	12.699	0.47
Upper Rambo	UR1	232		Lat Struct									
Upper Rambo	UR1	222.4837	24 Hour SCS_SWM	23.51	97.16	100.422	98.589	100.463	0.000295	0.96	35.16	21.816	0.18
Upper Rambo	UR1	222.4837	REG_SWM	16.23	97.16	99.368	98.372	99.431	0.000771	1.13	17.03	13.485	0.27
Upper Rambo	UR1	222.4837	24 Hour SCS_NS	23.51	97.16	100.422	98.589	100.463	0.000295	0.96	35.16	21.816	0.18
Upper Rambo	UR1	222.4837	REG_NS	16.23	97.16	99.368	98.372	99.431	0.000771	1.13	17.03	13.485	0.27
Upper Rambo	UR1	202.1057	24 Hour SCS_SWM	23.51	96.90	100.419	98.399	100.453	0.000227	0.88	40.40	23.399	0.16
Upper Rambo	UR1	202.1057	REG_SWM	16.23	96.90	99.361	98.176	99.409	0.000531	1.01	20.40	15.235	0.23
Upper Rambo	UR1	202.1057	24 Hour SCS_NS	23.51	96.90	100.419	98.399	100.453	0.000227	0.88	40.40	23.399	0.16
Upper Rambo	UR1	202.1057	REG_NS	16.23	96.90	99.361	98.176	99.409	0.000531	1.01	20.40	15.235	0.23
Upper Rambo	UR1	174.6994	24 Hour SCS_SWM	23.51	96.73	100.437	98.259	100.442	0.000054	0.47	141.54	87.532	0.08
Upper Rambo	UR1	174.6994	REG_SWM	16.23	96.73	99.380	97.938	99.390	0.000153	0.62	67.09	59.119	0.13
Upper Rambo	UR1	174.6994	24 Hour SCS_NS	23.51	96.73	100.437	98.259	100.442	0.000054	0.47	141.54	87.532	0.08
Upper Rambo	UR1	174.6994	REG_NS	16.23	96.73	99.380	97.938	99.390	0.000153	0.62	67.09	59.119	0.13
Upper Rambo	UR1	169.6089	24 Hour SCS_SWM	23.51	96.76	100.242	98.497	100.396	0.000828	1.74	13.53	55.431	0.31
Upper Rambo	UR1	169.6089	REG_SWM	16.23	96.76	99.179	98.173	99.342	0.001502	1.79	9.06	18.498	0.39
Upper Rambo	UR1	169.6089	24 Hour SCS_NS	23.51	96.76	100.242	98.497	100.396	0.000828	1.74	13.53	55.431	0.31
Upper Rambo	UR1	169.6089	REG_NS	16.23	96.76	99.179	98.173	99.342	0.001502	1.79	9.06	18.498	0.39
Upper Rambo	UR1	169		Culvert									
Upper Rambo	UR1	145.5228	24 Hour SCS_SWM	23.51	96.74	99.399	98.538	99.693	0.002439	2.40	9.80	19.686	0.50
Upper Rambo	UR1	145.5228	REG_SWM	16.23	96.74	98.867	98.217	99.102	0.002755	2.15	7.56	11.716	0.51
Upper Rambo	UR1	145.5228	24 Hour SCS_NS	23.51	96.74	99.399	98.538	99.693	0.002439	2.40	9.80	19.686	0.50
Upper Rambo	UR1	145.5228	REG_NS	16.23	96.74	98.867	98.217	99.102	0.002755	2.15	7.56	11.716	0.51
Upper Rambo	UR1	145		Lat Struct									
Upper Rambo	UR1	141.4725	24 Hour SCS_SWM	23.51	96.85	99.472	98.549	99.609	0.001432	1.76	24.30	41.958	0.38
Upper Rambo	UR1	141.4725	REG_SWM	16.23	96.85	98.901	98.272	99.053	0.002186	1.78	11.74	12.887	0.45
Upper Rambo	UR1	141.4725	24 Hour SCS_NS	23.51	96.85	99.472	98.549	99.609	0.001432	1.76	24.30	41.958	0.38
Upper Rambo	UR1	141.4725	REG_NS	16.23	96.85	98.901	98.272	99.053	0.002186	1.78	11.74	12.887	0.45
Upper Rambo	UR1	135.4062	24 Hour SCS_SWM	26.08	96.96	99.508	98.724	99.559	0.000840	1.24	35.84	76.123	0.28
Upper Rambo	UR1	135.4062	REG_SWM	18.12	96.96	98.713	98.462	98.994	0.006040	2.36	8.19	8.531	0.69
Upper Rambo	UR1	135.4062	24 Hour SCS_NS	26.08	96.96	99.508	98.724	99.559	0.000840	1.24	35.84	76.123	0.28
Upper Rambo	UR1	135.4062	REG_NS	18.12	96.96	98.713	98.462	98.994	0.006040	2.36	8.19	8.531	0.69
Upper Rambo	UR1	119.4501	24 Hour SCS_SWM	26.08	96.75	99.509	98.459	99.544	0.000474	1.03	40.83	71.920	0.22
Upper Rambo	UR1	119.4501	REG_SWM	18.12	96.75	98.731	98.201	98.898	0.002681	1.84	11.41	10.825	0.48
Upper Rambo	UR1	119.4501	24 Hour SCS_NS	26.08	96.75	99.509	98.459	99.544	0.000474	1.03	40.83	71.920	0.22
Upper Rambo	UR1	119.4501	REG_NS	18.12	96.75	98.731	98.201	98.898	0.002681	1.84	11.41	10.825	0.48
Upper Rambo	UR1	89.15574	24 Hour SCS_SWM	26.08	96.81	99.516	98.361	99.529	0.000182	0.64	55.79	72.452	0.14
Upper Rambo	UR1	89.15574	REG_SWM	18.12	96.81	98.685	98.128	98.814	0.002151	1.63	13.36	13.373	0.44
Upper Rambo	UR1	89.15574	24 Hour SCS_NS	26.08	96.81	99.516	98.361	99.529	0.000182	0.64	55.79	72.452	0.14
Upper Rambo	UR1	89.15574	REG_NS	18.12	96.81	98.685	98.128	98.814	0.002151	1.63	13.36	13.373	0.44

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River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Upper Rambo	UR1	59.83022	24 Hour SCS_SWM	26.08	96.18	99.518	97.986	99.524	0.000070	0.44	81.10	90.014	0.09
Upper Rambo	UR1	59.83022	REG_SWM	18.12	96.18	98.687	97.741	98.757	0.000919	1.25	20.26	35.438	0.29
Upper Rambo	UR1	59.83022	24 Hour SCS_NS	26.08	96.18	99.518	97.986	99.524	0.000070	0.44	81.10	90.014	0.09
Upper Rambo	UR1	59.83022	REG_NS	18.12	96.18	98.687	97.741	98.757	0.000919	1.25	20.26	35.438	0.29
Upper Rambo	UR1	40.68162	24 Hour SCS_SWM	26.08	95.90	99.518	97.410	99.522	0.000043	0.36	106.92	112.798	0.07
Upper Rambo	UR1	40.68162	REG_SWM	18.12	95.90	98.710	97.185	98.735	0.000259	0.71	30.50	46.950	0.16
Upper Rambo	UR1	40.68162	24 Hour SCS_NS	26.08	95.90	99.518	97.410	99.522	0.000043	0.36	106.92	112.798	0.07
Upper Rambo	UR1	40.68162	REG_NS	18.12	95.90	98.710	97.185	98.735	0.000259	0.71	30.50	46.950	0.16
Upper Rambo	UR1	38.481	24 Hour SCS_SWM	26.08	95.82	98.705	98.120	99.335	0.004497	3.52	7.42	45.813	0.69
Upper Rambo	UR1	38.481	REG_SWM	18.12	95.82	98.027	97.674	98.576	0.005809	3.28	5.52	13.649	0.75
Upper Rambo	UR1	38.481	24 Hour SCS_NS	26.08	95.82	98.705	98.120	99.335	0.004497	3.52	7.42	45.813	0.69
Upper Rambo	UR1	38.481	REG_NS	18.12	95.82	98.027	97.674	98.576	0.005809	3.28	5.52	13.649	0.75
Upper Rambo	UR1	38		Culvert									
Upper Rambo	UR1	1.18	24 Hour SCS_SWM	26.08	94.70	97.227	96.815	97.945	0.005167	3.75	6.95	14.272	0.76
Upper Rambo	UR1	1.18	REG_SWM	18.12	94.70	97.111	96.368	97.492	0.002927	2.74	6.62	12.068	0.57
Upper Rambo	UR1	1.18	24 Hour SCS_NS	26.08	94.70	97.227	96.815	97.945	0.005167	3.75	6.95	14.272	0.76
Upper Rambo	UR1	1.18	REG_NS	18.12	94.70	97.111	96.368	97.492	0.002927	2.74	6.62	12.068	0.57
Upper Rambo	UR1	0.01	24 Hour SCS_SWM	26.08	95.82	97.334	97.296	97.754	0.012007	2.87	9.08	9.742	0.95
Upper Rambo	UR1	0.01	REG_SWM	18.12	95.82	97.098	97.051	97.446	0.012014	2.62	6.93	8.560	0.93
Upper Rambo	UR1	0.01	24 Hour SCS_NS	26.08	95.82	97.334	97.296	97.754	0.012007	2.87	9.08	9.742	0.95
Upper Rambo	UR1	0.01	REG_NS	18.12	95.82	97.098	97.051	97.446	0.012014	2.62	6.93	8.560	0.93
Rambo Creek	West Branch	220	24 Hour SCS_SWM	26.76	94.99	96.935		96.990	0.002107	1.15	33.74	45.506	0.33
Rambo Creek	West Branch	220	REG_SWM	19.36	94.99	96.731		96.780	0.002316	1.07	24.86	41.520	0.34
Rambo Creek	West Branch	220	24 Hour SCS_NS	26.76	94.99	96.992		97.039	0.001752	1.08	36.35	46.648	0.30
Rambo Creek	West Branch	220	REG_NS	19.36	94.99	96.771		96.815	0.001975	1.01	26.56	42.209	0.31
Rambo Creek	West Branch	210	24 Hour SCS_SWM	26.76	95.19	96.892		96.963	0.003033	1.54	34.19	47.289	0.40
Rambo Creek	West Branch	210	REG_SWM	19.36	95.19	96.671		96.749	0.003672	1.53	24.17	43.223	0.43
Rambo Creek	West Branch	210	24 Hour SCS_NS	26.76	95.19	96.959		97.018	0.002422	1.42	37.42	48.602	0.36
Rambo Creek	West Branch	210	REG_NS	19.36	95.19	96.726		96.790	0.002934	1.41	26.58	44.235	0.39
Rambo Creek	West Branch	200	24 Hour SCS_SWM	26.76	95.13	96.886		96.933	0.001760	1.15	39.83	51.792	0.31
Rambo Creek	West Branch	200	REG_SWM	19.36	95.13	96.667		96.713	0.001973	1.09	29.02	46.807	0.32
Rambo Creek	West Branch	200	24 Hour SCS_NS	26.76	95.13	96.954		96.994	0.001424	1.07	43.42	53.344	0.28
Rambo Creek	West Branch	200	REG_NS	19.36	95.13	96.722		96.761	0.001608	1.02	31.64	48.062	0.29
Rambo Creek	West Branch	190	24 Hour SCS_SWM	26.76	94.80	96.871		96.915	0.001542	1.18	42.80	52.418	0.29
Rambo Creek	West Branch	190	REG_SWM	19.36	94.80	96.651		96.694	0.001647	1.10	31.80	47.579	0.30
Rambo Creek	West Branch	190	24 Hour SCS_NS	26.76	94.80	96.943		96.980	0.001252	1.09	46.59	54.018	0.27
Rambo Creek	West Branch	190	REG_NS	19.36	94.80	96.709		96.745	0.001348	1.03	34.60	48.773	0.27
Rambo Creek	West Branch	180	24 Hour SCS_SWM	26.76	94.97	96.852		96.899	0.001760	1.09	36.79	46.184	0.31
Rambo Creek	West Branch	180	REG_SWM	19.36	94.97	96.632		96.676	0.001991	1.02	27.07	42.136	0.32
Rambo Creek	West Branch	180	24 Hour SCS_NS	26.76	94.97	96.926		96.966	0.001415	1.01	40.30	48.800	0.28
Rambo Creek	West Branch	180	REG_NS	19.36	94.97	96.694		96.730	0.001579	0.94	29.71	43.272	0.28
Rambo Creek	West Branch	166	24 Hour SCS_SWM	26.76	94.57	96.421	96.421	96.804	0.023430	2.76	10.09	13.936	0.99
Rambo Creek	West Branch	166	REG_SWM	19.36	94.57	96.267	96.267	96.581	0.025010	2.49	7.99	13.279	0.99
Rambo Creek	West Branch	166	24 Hour SCS_NS	26.76	94.57	96.747	96.421	96.916	0.006814	1.87	17.45	29.492	0.56
Rambo Creek	West Branch	166	REG_NS	19.36	94.57	96.517	96.267	96.675	0.008317	1.78	11.64	17.397	0.60
Rambo Creek	West Branch	160	24 Hour SCS_SWM	26.76	94.44	96.134	96.134	96.542	0.015868	3.17	12.30	15.229	0.88
Rambo Creek	West Branch	160	REG_SWM	19.36	94.44	96.275	95.957	96.429	0.005425	1.98	14.47	15.569	0.52
Rambo Creek	West Branch	160	24 Hour SCS_NS	26.76	94.44	96.744	96.134	96.877	0.003474	1.91	22.58	20.517	0.44
Rambo Creek	West Branch	160	REG_NS	19.36	94.44	96.535	95.957	96.629	0.002763	1.58	18.70	17.186	0.38
Rambo Creek	West Branch	150	24 Hour SCS_SWM	26.76	94.27	96.182		96.287	0.004020	1.48	20.51	22.728	0.45
Rambo Creek	West Branch	150	REG_SWM	19.36	94.27	96.330		96.371	0.001354	0.93	23.95	23.843	0.27
Rambo Creek	West Branch	150	24 Hour SCS_NS	26.76	94.27	96.795		96.832	0.000832	0.90	37.78	32.610	0.22
Rambo Creek	West Branch	150	REG_NS	19.36	94.27	96.568		96.596	0.000746	0.78	30.56	30.796	0.20
Rambo Creek	West Branch	140	24 Hour SCS_SWM	26.76	94.28	96.123		96.245	0.004041	1.88	24.57	27.579	0.47
Rambo Creek	West Branch	140	REG_SWM	19.36	94.28	96.314		96.358	0.001307	1.15	30.08	30.577	0.27
Rambo Creek	West Branch	140	24 Hour SCS_NS	26.76	94.28	96.789		96.823	0.000856	1.08	47.30	38.130	0.23
Rambo Creek	West Branch	140	REG_NS	19.36	94.28	96.560		96.588	0.000769	0.96	38.57	37.579	0.21
Rambo Creek	West Branch	130	24 Hour SCS_SWM	26.76	93.90	96.093		96.205	0.003392	1.58	22.07	24.330	0.42
Rambo Creek	West Branch	130	REG_SWM	19.36	93.90	96.305		96.345	0.001046	0.96	27.58	27.570	0.24
Rambo Creek	West Branch	130	24 Hour SCS_NS	26.76	93.90	96.779		96.815	0.000714	0.94	41.65	31.612	0.21
Rambo Creek	West Branch	130	REG_NS	19.36	93.90	96.555		96.581	0.000589	0.79	34.77	29.676	0.18
Rambo Creek	West Branch	122	24 Hour SCS_SWM	26.76	93.95	96.013	95.138	96.168	0.002638	1.74	15.34	19.979	0.40
Rambo Creek	West Branch	122	REG_SWM	19.36	93.95	96.267	94.937	96.332	0.000912	1.11	17.37	22.054	0.24
Rambo Creek	West Branch	122	24 Hour SCS_NS	26.76	93.95	96.775	95.138	96.810	0.000478	0.91	41.14	23.477	0.18
Rambo Creek	West Branch	122	REG_NS	19.36	93.95	96.518	94.937	96.569	0.000634	1.00	19.38	22.756	0.20
Rambo Creek	West Branch	107		Bridge									
Rambo Creek	West Branch	106	24 Hour SCS_SWM	26.76	94.00	95.386	95.386	95.930	0.019133	3.37	8.74	18.241	0.98
Rambo Creek	West Branch	106	REG_SWM	19.36	94.00	96.123	95.172	96.224	0.001901	1.46	14.63	27.132	0.34
Rambo Creek	West Branch	106	24 Hour SCS_NS	26.76	94.00	96.460	95.386	96.597	0.002092	1.71	17.33	28.855	0.36
Rambo Creek	West Branch	106	REG_NS	19.36	94.00	96.361	95.172	96.440	0.001277	1.30	16.53	28.668	0.28
Rambo Creek	West Branch	90	24 Hour SCS_SWM	26.76	93.38	95.218		95.473	0.009529	2.39	15.06	20.494	0.68
Rambo Creek	West Branch	90	REG_SWM	19.36	93.38	96.148		96.171	0.000504	0.80	37.57	27.124	0.17
Rambo Creek	West Branch	90	24 Hour SCS_NS	26.76	93.38	96.500		96.528	0.000510	0.89	47.21	27.565	0.18
Rambo Creek	West Branch	90	REG_NS	19.36	93.38	96.382		96.399	0.000326	0.69	43.98	27.418	0.14

HEC-RAS Plan: Nov2018_sc2 (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Rambo Creek	West Branch	80	24 Hour SCS_SWM	26.76	93.23	95.165		95.359	0.007321	2.31	18.62	21.703	0.60
Rambo Creek	West Branch	80	REG_SWM	19.36	93.23	96.146		96.164	0.000416	0.77	43.56	28.182	0.16
Rambo Creek	West Branch	80	24 Hour SCS_NS	26.76	93.23	96.499		96.520	0.000438	0.86	53.60	28.768	0.16
Rambo Creek	West Branch	80	REG_NS	19.36	93.23	96.381		96.394	0.000277	0.67	50.24	28.573	0.13
Rambo Creek	West Branch	70	24 Hour SCS_SWM	26.76	92.77	95.137		95.297	0.003816	1.83	17.86	19.092	0.45
Rambo Creek	West Branch	70	REG_SWM	19.36	92.77	96.143		96.160	0.000262	0.66	48.55	37.992	0.13
Rambo Creek	West Branch	70	24 Hour SCS_NS	26.76	92.77	96.497		96.516	0.000274	0.73	62.15	38.969	0.13
Rambo Creek	West Branch	70	REG_NS	19.36	92.77	96.380		96.392	0.000174	0.57	57.62	38.646	0.11
Rambo Creek	West Branch	60	24 Hour SCS_SWM	26.76	93.05	95.141		95.248	0.002902	1.51	22.47	30.061	0.39
Rambo Creek	West Branch	60	REG_SWM	19.36	93.05	96.146		96.156	0.000163	0.50	61.08	43.525	0.10
Rambo Creek	West Branch	60	24 Hour SCS_NS	26.76	93.05	96.500		96.512	0.000171	0.56	76.63	44.060	0.11
Rambo Creek	West Branch	60	REG_NS	19.36	93.05	96.382		96.389	0.000108	0.44	71.43	44.060	0.08
Rambo Creek	West Branch	50	24 Hour SCS_SWM	26.76	93.00	95.155		95.213	0.001531	1.09	29.52	39.221	0.29
Rambo Creek	West Branch	50	REG_SWM	19.36	93.00	96.148		96.154	0.000091	0.38	76.63	53.488	0.08
Rambo Creek	West Branch	50	24 Hour SCS_NS	26.76	93.00	96.502		96.509	0.000099	0.43	96.46	59.105	0.08
Rambo Creek	West Branch	50	REG_NS	19.36	93.00	96.383		96.388	0.000062	0.33	89.57	56.527	0.06
Rambo Creek	West Branch	40	24 Hour SCS_SWM	26.76	92.82	95.055		95.183	0.003615	1.73	23.64	33.117	0.44
Rambo Creek	West Branch	40	REG_SWM	19.36	92.82	96.144		96.152	0.000161	0.52	67.00	44.518	0.10
Rambo Creek	West Branch	40	24 Hour SCS_NS	26.76	92.82	96.497		96.508	0.000175	0.58	83.84	48.563	0.11
Rambo Creek	West Branch	40	REG_NS	19.36	92.82	96.380		96.387	0.000111	0.45	78.18	48.314	0.08
Rambo Creek	West Branch	30	24 Hour SCS_SWM	26.76	92.71	95.021		95.151	0.002812	1.64	19.22	17.255	0.38
Rambo Creek	West Branch	30	REG_SWM	19.36	92.71	96.134		96.150	0.000215	0.62	48.53	34.375	0.11
Rambo Creek	West Branch	30	24 Hour SCS_NS	26.76	92.71	96.485		96.505	0.000240	0.71	60.71	34.943	0.12
Rambo Creek	West Branch	30	REG_NS	19.36	92.71	96.373		96.385	0.000148	0.54	56.80	34.761	0.10
Rambo Creek	West Branch	20	24 Hour SCS_SWM	26.76	92.02	95.070		95.114	0.000608	0.93	29.77	13.662	0.19
Rambo Creek	West Branch	20	REG_SWM	19.36	92.02	96.137		96.147	0.000085	0.45	52.80	30.310	0.08
Rambo Creek	West Branch	20	24 Hour SCS_NS	26.76	92.02	96.488		96.501	0.000110	0.54	64.16	32.860	0.09
Rambo Creek	West Branch	20	REG_NS	19.36	92.02	96.375		96.383	0.000065	0.41	60.46	32.860	0.07
Rambo Creek	West Branch	10	24 Hour SCS_SWM	26.76	92.06	94.854	93.711	95.056	0.002594	1.99	13.47	9.224	0.40
Rambo Creek	West Branch	10	REG_SWM	19.36	92.06	96.120	93.450	96.142	0.000271	0.67	33.36	21.273	0.12
Rambo Creek	West Branch	10	24 Hour SCS_NS	26.76	92.06	96.463	93.711	96.495	0.000351	0.81	41.89	28.370	0.13
Rambo Creek	West Branch	10	REG_NS	19.36	92.06	96.361	93.450	96.379	0.000207	0.61	38.98	28.370	0.10
Rambo Creek	West Branch	5		Bridge									
Rambo Creek	West Branch	0	24 Hour SCS_SWM	26.76	91.77	94.373	93.233	94.604	0.002563	2.13	12.57	6.056	0.42
Rambo Creek	West Branch	0	REG_SWM	19.36	91.77	95.996	92.947	96.039	0.000253	0.92	24.45	6.491	0.14
Rambo Creek	West Branch	0	24 Hour SCS_NS	26.76	91.77	96.403	93.233	96.471	0.000355	1.16	27.09	6.500	0.17
Rambo Creek	West Branch	0	REG_NS	19.36	91.77	96.323	92.947	96.359	0.000197	0.86	26.57	6.500	0.13
HRFreemanPond	WestHager	1321.378	24 Hour SCS_SWM	17.39	97.32	99.633		99.709	0.000223	1.22	14.27	8.118	0.29
HRFreemanPond	WestHager	1321.378	REG_SWM	43.56	97.32	100.700		100.847	0.000269	1.74	37.46	59.916	0.34
HRFreemanPond	WestHager	1321.378	24 Hour SCS_NS	77.19	97.32	100.857	100.029	101.217	0.000640	2.78	47.19	64.393	0.54
HRFreemanPond	WestHager	1321.378	REG_NS	70.99	97.32	100.854	99.898	101.160	0.000545	2.57	46.98	64.300	0.49
HRFreemanPond	WestHager	1254.522	24 Hour SCS_SWM	17.39	97.39	99.546	98.992	99.667	0.002930	1.54	11.28	10.489	0.47
HRFreemanPond	WestHager	1254.522	REG_SWM	43.56	97.39	100.712	99.697	100.797	0.001021	1.42	46.31	66.198	0.31
HRFreemanPond	WestHager	1254.522	24 Hour SCS_NS	77.19	97.39	100.938	100.298	101.087	0.001738	1.98	61.48	67.818	0.42
HRFreemanPond	WestHager	1254.522	REG_NS	70.99	97.39	100.917	100.195	101.050	0.001550	1.86	60.10	67.755	0.39
HRFreemanPond	WestHager	1193.02	24 Hour SCS_SWM	17.39	97.28	99.438		99.522	0.001679	1.28	13.57	10.504	0.36
HRFreemanPond	WestHager	1193.02	REG_SWM	43.56	97.28	100.743		100.754	0.000166	0.63	124.52	220.442	0.13
HRFreemanPond	WestHager	1193.02	24 Hour SCS_NS	77.19	97.28	101.010		101.021	0.000178	0.69	193.33	293.720	0.13
HRFreemanPond	WestHager	1193.02	REG_NS	70.99	97.28	100.980		100.990	0.000171	0.67	184.61	287.544	0.13
HRFreemanPond	WestHager	1193		Lat Struct									
HRFreemanPond	WestHager	1076.52	24 Hour SCS_SWM	17.39	96.83	99.397	98.451	99.462	0.000214	1.13	15.48	12.286	0.31
HRFreemanPond	WestHager	1076.52	REG_SWM	43.56	96.83	100.748	99.170	100.749	0.000004	0.26	391.50	378.638	0.05
HRFreemanPond	WestHager	1076.52	24 Hour SCS_NS	77.19	96.83	101.014	99.729	101.016	0.000007	0.34	492.21	379.625	0.06
HRFreemanPond	WestHager	1076.52	REG_NS	70.99	96.83	100.984	99.635	100.985	0.000006	0.32	480.76	379.513	0.06
HRFreemanPond	WestHager	1018.932	24 Hour SCS_SWM	34.34	96.56	99.176	98.666	99.396	0.003833	2.08	16.70	14.221	0.57
HRFreemanPond	WestHager	1018.932	REG_SWM	63.71	96.56	100.748	99.252	100.749	0.000011	0.19	396.79	279.686	0.03
HRFreemanPond	WestHager	1018.932	24 Hour SCS_NS	101.91	96.56	101.013	99.510	101.015	0.000017	0.24	471.02	280.432	0.04
HRFreemanPond	WestHager	1018.932	REG_NS	96.95	96.56	100.982	99.510	100.985	0.000016	0.24	462.57	280.347	0.04
HRFreemanPond	WestHager	895.4784	24 Hour SCS_SWM	34.34	96.01	98.958	98.073	99.085	0.001529	1.60	23.92	22.857	0.38
HRFreemanPond	WestHager	895.4784	REG_SWM	63.71	96.01	100.747	98.648	100.747	0.000009	0.20	605.67	335.897	0.03
HRFreemanPond	WestHager	895.4784	24 Hour SCS_NS	101.91	96.01	101.011	99.290	101.013	0.000016	0.27	694.67	336.490	0.04
HRFreemanPond	WestHager	895.4784	REG_NS	96.95	96.01	100.981	99.250	100.983	0.000015	0.26	684.54	336.422	0.04
HRFreemanPond	WestHager	847.417	24 Hour SCS_SWM	34.34	94.95	99.012	97.379	99.048	0.000073	0.96	85.49	260.897	0.19
HRFreemanPond	WestHager	847.417	REG_SWM	63.71	94.95	100.747	98.045	100.747	0.000001	0.17	789.44	404.269	0.03
HRFreemanPond	WestHager	847.417	24 Hour SCS_NS	101.91	94.95	101.012	99.108	101.012	0.000002	0.23	896.57	404.931	0.03
HRFreemanPond	WestHager	847.417	REG_NS	96.95	94.95	100.981	98.611	100.982	0.000002	0.22	884.37	404.859	0.03
HRFreemanPond	WestHager	835.2853	24 Hour SCS_SWM	34.34	94.22	99.000	96.740	99.046	0.000078	1.00	81.91	268.097	0.19
HRFreemanPond	WestHager	835.2853	REG_SWM	63.71	94.22	100.746	97.410	100.747	0.000004	0.30	779.62	376.216	0.04
HRFreemanPond	WestHager	835.2853	24 Hour SCS_NS	101.91	94.22	101.010	98.271	101.012	0.000006	0.41	879.05	376.769	0.06
HRFreemanPond	WestHager	835.2853	REG_NS	96.95	94.22	100.980	98.183	100.982	0.000006	0.40	867.74	376.706	0.06
HRFreemanPond	WestHager	826.5759	24 Hour SCS_SWM	34.34	93.70	99.009	95.315	99.036	0.000019	0.72	47.54	410.018	0.11
HRFreemanPond	WestHager	826.5759	REG_SWM	63.71	93.70	100.746	95.875	100.747	0.000000	0.12	1089.96	449.764	0.02
HRFreemanPond	WestHager	826.5759	24 Hour SCS_NS	101.91	93.70	101.011	96.478	101.011	0.000001	0.17	1209.01	450.541	0.02
HRFreemanPond	WestHager	826.5759	REG_NS	96.95	93.70	100.981	96.407	100.981	0.000001	0.17	1195.45	450.452	0.02

HEC-RAS Plan: Nov2018_sc2 (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
HRFreemanPond	WestHager	805.3582		Culvert									
HRFreemanPond	WestHager	789.1301	24 Hour SCS_SWM	34.34	93.73	97.904	95.010	97.931	0.000035	0.73	47.30	13.051	0.12
HRFreemanPond	WestHager	789.1301	REG_SWM	63.71	93.73	98.987	95.571	99.008	0.000028	0.75	201.33	324.165	0.11
HRFreemanPond	WestHager	789.1301	24 Hour SCS_NS	101.91	93.73	99.025	96.182	99.073	0.000065	1.14	213.92	324.637	0.17
HRFreemanPond	WestHager	789.1301	REG_NS	96.95	93.73	98.994	96.107	99.042	0.000063	1.13	203.82	324.258	0.17
HRFreemanPond	WestHager	780.9492	24 Hour SCS_SWM	34.34	93.74	97.857	95.225	97.920	0.000104	1.11	30.96	8.616	0.19
HRFreemanPond	WestHager	780.9492	REG_SWM	63.71	93.74	98.951	95.888	98.999	0.000085	1.11	102.66	117.117	0.18
HRFreemanPond	WestHager	780.9492	24 Hour SCS_NS	101.91	93.74	98.914	96.605	99.046	0.000233	1.83	98.27	116.892	0.30
HRFreemanPond	WestHager	780.9492	REG_NS	96.95	93.74	98.891	96.518	99.017	0.000221	1.78	95.65	116.739	0.29
HRFreemanPond	WestHager	776.5764	24 Hour SCS_SWM	34.34	93.79	97.593	96.297	97.858	0.000736	2.28	15.06	5.947	0.46
HRFreemanPond	WestHager	776.5764	REG_SWM	63.71	93.79	98.941	97.268	98.996	0.000171	1.35	90.71	114.787	0.24
HRFreemanPond	WestHager	776.5764	24 Hour SCS_NS	101.91	93.79	98.751	98.694	99.007	0.000758	2.73	68.99	114.112	0.51
HRFreemanPond	WestHager	776.5764	REG_NS	96.95	93.79	98.767	98.670	98.987	0.000654	2.54	70.81	114.168	0.47
HRFreemanPond	WestHager	765.4565	24 Hour SCS_SWM	37.21	93.67	96.911	96.911	97.782	0.003514	4.14	9.00	5.159	1.00
HRFreemanPond	WestHager	765.4565	REG_SWM	65.45	93.67	97.797	97.797	98.888	0.003284	4.63	14.14	6.466	1.00
HRFreemanPond	WestHager	765.4565	24 Hour SCS_NS	105.00	93.67	98.702	98.702	98.993	0.000941	3.02	72.22	119.789	0.57
HRFreemanPond	WestHager	765.4565	REG_NS	99.81	93.67	98.669	98.669	98.968	0.000953	3.02	64.88	92.797	0.57
HRFreemanPond	WestHager	695.1021	24 Hour SCS_SWM	37.21	93.55	97.029	96.097	97.418	0.001150	2.76	13.47	5.722	0.57
HRFreemanPond	WestHager	695.1021	REG_SWM	65.45	93.55	97.769	97.049	98.430	0.001856	3.60	18.26	11.020	0.76
HRFreemanPond	WestHager	695.1021	24 Hour SCS_NS	105.00	93.55	98.426	98.426	98.707	0.000843	2.88	81.90	146.912	0.54
HRFreemanPond	WestHager	695.1021	REG_NS	99.81	93.55	98.402	98.402	98.679	0.000823	2.83	78.37	145.530	0.53
HRFreemanPond	WestHager	674.8755	24 Hour SCS_SWM	37.21	93.47	97.067	95.751	97.373	0.000866	2.45	15.18	5.842	0.49
HRFreemanPond	WestHager	674.8755	REG_SWM	65.45	93.47	97.836	96.743	98.357	0.001354	3.20	22.31	49.108	0.64
HRFreemanPond	WestHager	674.8755	24 Hour SCS_NS	105.00	93.47	98.376	98.376	98.662	0.000828	2.85	81.30	159.079	0.52
HRFreemanPond	WestHager	674.8755	REG_NS	99.81	93.47	98.347	98.347	98.633	0.000817	2.81	76.82	155.395	0.51
HRFreemanPond	WestHager	652.9897	24 Hour SCS_SWM	37.21	93.45	97.147	95.028	97.282	0.000111	1.63	22.83	6.612	0.27
HRFreemanPond	WestHager	652.9897	REG_SWM	65.45	93.45	97.987	95.732	98.175	0.000395	2.01	61.54	131.293	0.34
HRFreemanPond	WestHager	652.9897	24 Hour SCS_NS	105.00	93.45	97.464	96.555	98.376	0.000671	4.23	24.82	6.645	0.68
HRFreemanPond	WestHager	652.9897	REG_NS	99.81	93.45	97.571	96.456	98.353	0.000555	3.92	25.48	16.163	0.62
HRFreemanPond	WestHager	633.4816		Culvert									
HRFreemanPond	WestHager	621.3574	24 Hour SCS_SWM	37.21	93.33	96.511	95.803	97.050	0.001802	3.25	11.44	4.534	0.65
HRFreemanPond	WestHager	621.3574	REG_SWM	65.45	93.33	97.915	97.915	98.116	0.000704	2.39	58.19	157.254	0.40
HRFreemanPond	WestHager	621.3574	24 Hour SCS_NS	105.00	93.33	98.092	98.092	98.312	0.000899	2.79	86.11	158.362	0.46
HRFreemanPond	WestHager	621.3574	REG_NS	99.81	93.33	98.072	98.072	98.290	0.000878	2.75	82.93	158.303	0.45
HRFreemanPond	WestHager	595.1021	24 Hour SCS_SWM	37.21	93.26	96.009	96.009	96.885	0.003345	4.15	8.97	5.107	1.00
HRFreemanPond	WestHager	595.1021	REG_SWM	65.45	93.26	97.808	96.896	97.876	0.000264	1.57	101.46	205.247	0.31
HRFreemanPond	WestHager	595.1021	24 Hour SCS_NS	105.00	93.26	98.149	97.795	98.186	0.000162	1.33	190.13	269.903	0.24
HRFreemanPond	WestHager	595.1021	REG_NS	99.81	93.26	98.118	97.779	98.155	0.000165	1.33	181.60	269.812	0.25
HRFreemanPond	WestHager	550.8193	24 Hour SCS_SWM	37.21	93.19	96.216	95.248	96.535	0.000842	2.50	14.88	6.267	0.52
HRFreemanPond	WestHager	550.8193	REG_SWM	65.45	93.19	97.828	96.059	97.846	0.000062	0.87	176.26	161.026	0.16
HRFreemanPond	WestHager	550.8193	24 Hour SCS_NS	105.00	93.19	98.151	97.231	98.175	0.000078	1.04	230.00	166.520	0.18
HRFreemanPond	WestHager	550.8193	REG_NS	99.81	93.19	98.120	97.211	98.143	0.000075	1.02	224.91	166.520	0.18
HRFreemanPond	WestHager	508.5913	24 Hour SCS_SWM	37.21	93.02	96.014	95.427	96.475	0.001421	3.01	12.37	6.201	0.68
HRFreemanPond	WestHager	508.5913	REG_SWM	65.45	93.02	97.836	96.892	97.840	0.000017	0.46	301.22	264.700	0.08
HRFreemanPond	WestHager	508.5913	24 Hour SCS_NS	105.00	93.02	98.163	97.081	98.168	0.000019	0.54	387.56	264.700	0.09
HRFreemanPond	WestHager	508.5913	REG_NS	99.81	93.02	98.131	97.068	98.136	0.000019	0.53	379.32	264.700	0.09
HRFreemanPond	WestHager	490.8526	24 Hour SCS_SWM	37.21	92.79	95.564	95.564	96.402	0.003131	4.06	9.17	5.479	1.00
HRFreemanPond	WestHager	490.8526	REG_SWM	65.45	92.79	97.837	96.598	97.840	0.000010	0.38	363.06	248.230	0.07
HRFreemanPond	WestHager	490.8526	24 Hour SCS_NS	105.00	92.79	98.163	96.802	98.167	0.000014	0.47	443.99	248.230	0.08
HRFreemanPond	WestHager	490.8526	REG_NS	99.81	92.79	98.132	96.786	98.136	0.000013	0.46	436.27	248.230	0.08
HRFreemanPond	WestHager	485.7959	24 Hour SCS_SWM	37.21	92.76	95.470	95.238	96.203	0.002577	3.80	9.80	4.870	0.85
HRFreemanPond	WestHager	485.7959	REG_SWM	65.45	92.76	97.837	96.144	97.839	0.000011	0.37	426.94	312.810	0.06
HRFreemanPond	WestHager	485.7959	24 Hour SCS_NS	105.00	92.76	98.164	97.075	98.166	0.000014	0.45	529.00	312.810	0.07
HRFreemanPond	WestHager	485.7959	REG_NS	99.81	92.76	98.132	96.966	98.135	0.000013	0.44	519.25	312.810	0.07
HRFreemanPond	WestHager	249.2144		Culvert									
HRFreemanPond	WestHager	26.09473	24 Hour SCS_SWM	37.21	89.80	92.304	91.400	92.602	0.000481	2.42	15.37	8.304	0.50
HRFreemanPond	WestHager	26.09473	REG_SWM	65.45	89.80	93.236	92.099	93.581	0.000627	2.60	25.47	10.609	0.49
HRFreemanPond	WestHager	26.09473	24 Hour SCS_NS	105.00	89.80	94.259	92.880	94.727	0.000640	3.05	37.10	12.199	0.49
HRFreemanPond	WestHager	26.09473	REG_NS	99.81	89.80	94.197	92.817	94.635	0.000607	2.95	36.35	12.096	0.48
HRDiversion	Main1	3198.98	24 Hour SCS_SWM	40.11	100.70	103.394	103.265	103.418	0.000381	1.21	78.73	221.149	0.32
HRDiversion	Main1	3198.98	REG_SWM	64.55	100.70	103.419	103.334	103.470	0.000812	1.79	84.36	222.439	0.47
HRDiversion	Main1	3198.98	24 Hour SCS_NS	77.75	100.70	103.461	103.364	103.516	0.000872	1.89	93.64	224.552	0.49
HRDiversion	Main1	3198.98	REG_NS	69.06	100.70	103.435	103.346	103.487	0.000830	1.82	87.74	223.211	0.48
HRDiversion	Main1	3188.995	24 Hour SCS_SWM	40.11	100.66	102.600	102.600	103.338	0.002771	3.81	10.54	7.137	1.00
HRDiversion	Main1	3188.995	REG_SWM	64.55	100.66	103.291	103.291	103.451	0.000659	2.32	68.68	208.297	0.51
HRDiversion	Main1	3188.995	24 Hour SCS_NS	77.75	100.66	103.356	103.356	103.500	0.000637	2.33	82.72	219.871	0.50
HRDiversion	Main1	3188.995	REG_NS	69.06	100.66	103.312	103.312	103.468	0.000660	2.34	73.10	211.509	0.51
HRDiversion	Main1	3104.638	24 Hour SCS_SWM	40.11	99.96	102.748	102.748	102.923	0.000634	2.31	50.50	145.299	0.51
HRDiversion	Main1	3104.638	REG_SWM	64.55	99.96	102.933	102.933	103.101	0.000704	2.58	81.65	188.913	0.54
HRDiversion	Main1	3104.638	24 Hour SCS_NS	77.75	99.96	102.986	102.986	103.166	0.000790	2.77	91.97	199.628	0.58
HRDiversion	Main1	3104.638	REG_NS	69.06	99.96	102.954	102.954	103.124	0.000729	2.64	85.62	193.562	0.55
HRDiversion	Main1	3059.837	24 Hour SCS_SWM	40.11	99.61	102.249	102.249	102.587	0.001162	2.90	33.70	72.864	0.66
HRDiversion	Main1	3059.837	REG_SWM	64.55	99.61	102.553	102.553	102.771	0.000886	2.78	92.95	203.063	0.59
HRDiversion	Main1	3059.837	24 Hour SCS_NS	77.75	99.61	102.672	102.672	102.855	0.000801	2.74	121.40	252.960	0.57

HEC-RAS Plan: Nov2018_sc2 (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
HRDiversion	Main1	3059.837	REG_NS	69.06	99.61	102.566	102.566	102.801	0.000963	2.91	95.58	205.577	0.62
HRDiversion	Main1	3020.177	24 Hour SCS_SWM	40.11	99.27	102.154	101.925	102.236	0.000341	1.79	69.82	143.445	0.36
HRDiversion	Main1	3020.177	REG_SWM	64.55	99.27	102.146	102.146	102.367	0.000910	2.92	68.66	142.575	0.58
HRDiversion	Main1	3020.177	24 Hour SCS_NS	77.75	99.27	102.222	102.222	102.452	0.000989	3.10	79.84	151.779	0.61
HRDiversion	Main1	3020.177	REG_NS	69.06	99.27	102.171	102.171	102.397	0.000945	2.99	72.29	145.297	0.60
HRDiversion	Main1	3005.781	24 Hour SCS_SWM	40.11	99.18	101.790	101.790	102.144	0.001445	2.93	25.26	68.211	0.70
HRDiversion	Main1	3005.781	REG_SWM	64.55	99.18	102.074	102.074	102.234	0.000856	2.49	86.55	234.332	0.55
HRDiversion	Main1	3005.781	24 Hour SCS_NS	77.75	99.18	102.130	102.130	102.294	0.000932	2.64	99.68	238.376	0.58
HRDiversion	Main1	3005.781	REG_NS	69.06	99.18	102.092	102.092	102.256	0.000894	2.56	90.68	236.013	0.56
HRDiversion	Main1	2991.867		Culvert									
HRDiversion	Main1	2977.396	24 Hour SCS_SWM	40.11	98.83	101.790	101.790	101.937	0.000901	2.28	61.14	206.181	0.57
HRDiversion	Main1	2977.396	REG_SWM	64.55	98.83	102.024	101.919	102.115	0.000671	2.15	110.94	220.365	0.50
HRDiversion	Main1	2977.396	24 Hour SCS_NS	77.75	98.83	102.094	101.972	102.186	0.000706	2.26	126.46	224.897	0.52
HRDiversion	Main1	2977.396	REG_NS	69.06	98.83	102.121	101.936	102.185	0.000494	1.91	132.56	226.664	0.43
HRDiversion	Main1	2938.69	24 Hour SCS_SWM	40.11	98.71	101.394	101.394	101.679	0.001580	2.99	35.76	60.800	0.78
HRDiversion	Main1	2938.69	REG_SWM	64.55	98.71	101.630	101.630	101.992	0.001882	3.59	52.37	86.486	0.87
HRDiversion	Main1	2938.69	24 Hour SCS_NS	77.75	98.71	101.835	101.835	102.098	0.001359	3.29	73.84	122.837	0.75
HRDiversion	Main1	2938.69	REG_NS	69.06	98.71	101.630	101.630	102.045	0.002157	3.84	52.33	86.422	0.93
HRDiversion	Main1	2875.828	24 Hour SCS_SWM	40.11	97.96	100.677	100.677	101.005	0.001144	2.77	30.63	69.735	0.66
HRDiversion	Main1	2875.828	REG_SWM	64.55	97.96	101.052	100.969	101.335	0.000970	2.89	59.80	85.531	0.62
HRDiversion	Main1	2875.828	24 Hour SCS_NS	77.75	97.96	101.080	101.080	101.461	0.001302	3.38	62.26	86.877	0.72
HRDiversion	Main1	2875.828	REG_NS	69.06	97.96	101.374	101.007	101.544	0.000549	2.38	93.00	136.292	0.48
HRDiversion	Main1	2802.166	24 Hour SCS_SWM	40.11	97.42	100.159	100.159	100.661	0.001684	3.34	20.20	30.201	0.81
HRDiversion	Main1	2802.166	REG_SWM	64.55	97.42	101.019	100.638	101.265	0.000634	2.68	62.06	70.013	0.53
HRDiversion	Main1	2802.166	24 Hour SCS_NS	77.75	97.42	100.844	100.844	101.341	0.001324	3.70	50.67	61.093	0.76
HRDiversion	Main1	2802.166	REG_NS	69.06	97.42	101.288	100.706	101.479	0.000461	2.44	83.19	95.073	0.46
HRDiversion	Main1	2801		Lat Struct									
HRDiversion	Main1	2747.219	24 Hour SCS_SWM	40.93	97.02	100.425	99.542	100.454	0.000108	1.09	91.30	98.756	0.22
HRDiversion	Main1	2747.219	REG_SWM	66.89	97.02	101.178	99.902	101.188	0.000040	0.79	223.76	184.901	0.14
HRDiversion	Main1	2747.219	24 Hour SCS_NS	81.17	97.02	100.530	100.018	100.620	0.000332	1.97	101.81	102.493	0.38
HRDiversion	Main1	2747.219	REG_NS	71.87	97.02	101.413	99.942	101.420	0.000028	0.69	267.79	188.010	0.12
HRDiversion	Main1	2711.585	24 Hour SCS_SWM	40.93	96.81	100.441	99.284	100.445	0.000023	0.54	327.33	785.444	0.11
HRDiversion	Main1	2711.585	REG_SWM	66.89	96.81	101.184	99.602	101.185	0.000002	0.20	999.03	934.940	0.04
HRDiversion	Main1	2711.585	24 Hour SCS_NS	81.17	96.81	100.585	99.680	100.592	0.000041	0.74	443.69	857.631	0.15
HRDiversion	Main1	2711.585	REG_NS	71.87	96.81	101.418	99.658	101.418	0.000001	0.16	1217.09	934.940	0.03
HRDiversion	Main1	2699.391	24 Hour SCS_SWM	40.93	96.68	100.443	99.641	100.443	0.000002	0.15	983.10	1098.033	0.03
HRDiversion	Main1	2699.391	REG_SWM	66.89	96.68	101.185	100.440	101.185	0.000001	0.12	1853.80	1181.660	0.02
HRDiversion	Main1	2699.391	24 Hour SCS_NS	81.17	96.68	100.588	100.440	100.588	0.000005	0.25	1149.78	1168.131	0.05
HRDiversion	Main1	2699.391	REG_NS	71.87	96.68	101.418	100.440	101.418	0.000001	0.10	2129.36	1181.660	0.02
HRDiversion	Main1	2678.053		Culvert									
HRDiversion	Main1	2656.188	24 Hour SCS_SWM	40.93	96.30	98.712	98.712	99.854	0.001843	4.74	8.64	55.738	1.00
HRDiversion	Main1	2656.188	REG_SWM	66.89	96.30	99.596	99.596	101.183	0.001655	5.58	11.99	369.544	1.00
HRDiversion	Main1	2656.188	24 Hour SCS_NS	81.17	96.30	99.860	99.860	99.864	0.000023	0.59	415.07	489.794	0.11
HRDiversion	Main1	2656.188	REG_NS	71.87	96.30	99.756	99.756	101.416	0.001623	5.71	12.59	480.106	1.00
HRDiversion	Main1	2601.885	24 Hour SCS_SWM	40.93	95.79	98.360	98.360	98.456	0.000526	1.90	56.89	182.249	0.44
HRDiversion	Main1	2601.885	REG_SWM	66.89	95.79	98.441	98.441	98.576	0.000810	2.42	71.90	187.074	0.55
HRDiversion	Main1	2601.885	24 Hour SCS_NS	81.17	95.79	98.485	98.485	98.630	0.000909	2.61	80.13	189.757	0.59
HRDiversion	Main1	2601.885	REG_NS	71.87	95.79	98.456	98.456	98.595	0.000853	2.50	74.62	187.941	0.57
HRDiversion	Main1	2557.343	24 Hour SCS_SWM	42.76	95.42	98.060	98.060	98.154	0.000658	2.00	54.19	170.461	0.51
HRDiversion	Main1	2557.343	REG_SWM	69.61	95.42	98.135	98.135	98.283	0.001089	2.66	67.71	188.066	0.66
HRDiversion	Main1	2557.343	24 Hour SCS_NS	83.83	95.42	98.287	98.193	98.368	0.000638	2.16	98.80	214.913	0.51
HRDiversion	Main1	2557.343	REG_NS	74.72	95.42	98.144	98.144	98.305	0.001191	2.79	69.35	190.339	0.69
HRDiversion	Main1	2491.302	24 Hour SCS_SWM	42.76	94.91	97.054	97.054	97.664	0.002602	3.46	12.36	10.104	1.00
HRDiversion	Main1	2491.302	REG_SWM	69.61	94.91	97.954	97.525	97.970	0.000087	0.87	166.44	253.255	0.20
HRDiversion	Main1	2491.302	24 Hour SCS_NS	83.83	94.91	98.333	97.566	98.339	0.000032	0.59	320.29	412.328	0.12
HRDiversion	Main1	2491.302	REG_NS	74.72	94.91	98.131	97.539	98.140	0.000050	0.70	239.34	388.470	0.15
HRDiversion	Main1	2468.123	24 Hour SCS_SWM	42.76	94.39	96.697	95.916	96.975	0.000480	2.34	18.30	9.613	0.51
HRDiversion	Main1	2468.123	REG_SWM	69.61	94.39	97.953	96.442	97.968	0.000052	0.81	195.05	266.142	0.15
HRDiversion	Main1	2468.123	24 Hour SCS_NS	83.83	94.39	98.331	96.691	98.338	0.000025	0.61	300.67	299.632	0.11
HRDiversion	Main1	2468.123	REG_NS	74.72	94.39	98.130	96.531	98.139	0.000034	0.68	242.78	274.489	0.12
HRDiversion	Main1	2443.509		Culvert									
HRDiversion	Main1	2401.658	24 Hour SCS_SWM	42.76	93.98	95.751	95.553	96.280	0.001403	3.22	13.27	9.700	0.82
HRDiversion	Main1	2401.658	REG_SWM	69.61	93.98	96.667	96.082	97.111	0.000943	2.95	23.57	10.835	0.64
HRDiversion	Main1	2401.658	24 Hour SCS_NS	83.83	93.98	96.883	96.339	97.408	0.001092	3.21	26.35	15.690	0.70
HRDiversion	Main1	2401.658	REG_NS	74.72	93.98	96.787	96.173	97.244	0.001008	2.99	24.97	13.100	0.66
HRDiversion	Main1	2400		Lat Struct									
HRDiversion	Main1	2393.06	24 Hour SCS_SWM	42.76	93.86	95.833	95.492	96.176	0.001107	2.60	16.47	12.044	0.71
HRDiversion	Main1	2393.06	REG_SWM	69.61	93.86	96.732	95.991	97.034	0.000562	2.44	29.86	20.048	0.54
HRDiversion	Main1	2393.06	24 Hour SCS_NS	83.83	93.86	96.976	96.209	97.300	0.000533	2.56	38.60	35.624	0.54
HRDiversion	Main1	2393.06	REG_NS	74.72	93.86	96.860	96.074	97.159	0.000519	2.44	34.51	34.998	0.52
HRDiversion	Main1	2301.658	24 Hour SCS_SWM	42.76	93.68	95.703	95.385	96.066	0.001158	2.67	16.01	11.499	0.72
HRDiversion	Main1	2301.658	REG_SWM	69.61	93.68	96.674	95.884	96.981	0.000542	2.46	29.38	17.218	0.53

HEC-RAS Plan: Nov2018_sc2 (Continued)

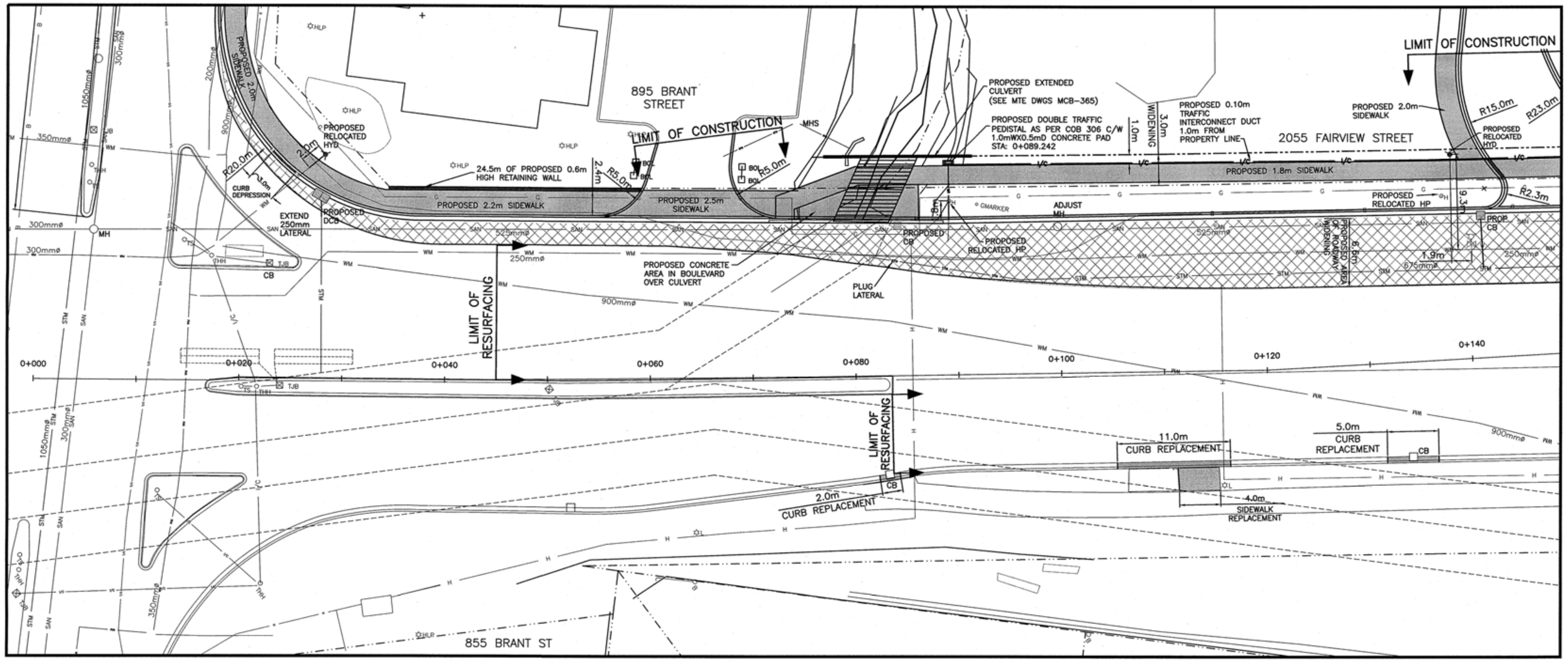
River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
HRDiversion	Main1	2301.658	24 Hour SCS_NS	83.83	93.68	96.856	96.105	97.232	0.000599	2.73	32.64	18.497	0.56
HRDiversion	Main1	2301.658	REG_NS	74.72	93.68	96.785	95.968	97.104	0.000528	2.51	31.34	18.084	0.53
HRDiversion	Main1	2240.215	24 Hour SCS_SWM	42.76	93.45	95.673	95.216	95.972	0.000882	2.42	17.65	11.943	0.64
HRDiversion	Main1	2240.215	REG_SWM	69.61	93.45	96.668	95.713	96.928	0.000426	2.27	32.42	18.586	0.48
HRDiversion	Main1	2240.215	24 Hour SCS_NS	83.83	93.45	96.851	95.945	97.172	0.000477	2.52	36.01	23.932	0.51
HRDiversion	Main1	2240.215	REG_NS	74.72	93.45	96.780	95.797	97.051	0.000417	2.32	34.54	19.262	0.47
HRDiversion	Main1	2201.658	24 Hour SCS_SWM	42.76	93.39	95.662	95.126	95.932	0.000762	2.30	18.60	12.172	0.59
HRDiversion	Main1	2201.658	REG_SWM	69.61	93.39	96.664	95.624	96.908	0.000377	2.20	33.83	18.889	0.45
HRDiversion	Main1	2201.658	24 Hour SCS_NS	83.83	93.39	96.847	95.843	97.149	0.000425	2.45	37.33	19.311	0.48
HRDiversion	Main1	2201.658	REG_NS	74.72	93.39	96.776	95.708	97.031	0.000372	2.25	35.96	19.147	0.45
HRDiversion	Main1	2175.404	24 Hour SCS_SWM	42.76	93.34	95.653	95.071	95.908	0.000706	2.24	19.08	12.207	0.57
HRDiversion	Main1	2175.404	REG_SWM	69.61	93.34	96.660	95.571	96.896	0.000354	2.16	34.57	18.606	0.44
HRDiversion	Main1	2175.404	24 Hour SCS_NS	83.83	93.34	96.842	95.794	97.136	0.000402	2.42	38.00	19.065	0.47
HRDiversion	Main1	2175.404	REG_NS	74.72	93.34	96.772	95.654	97.019	0.000350	2.22	36.66	18.888	0.44
HRDiversion	Main1	2135.042	24 Hour SCS_SWM	42.76	93.29	95.635	95.004	95.877	0.000647	2.18	19.64	12.239	0.55
HRDiversion	Main1	2135.042	REG_SWM	69.61	93.29	96.663	95.502	96.875	0.000330	2.05	36.50	22.463	0.42
HRDiversion	Main1	2135.042	24 Hour SCS_NS	83.83	93.29	96.849	95.729	97.111	0.000370	2.28	40.96	25.302	0.45
HRDiversion	Main1	2135.042	REG_NS	74.72	93.29	96.777	95.584	96.998	0.000324	2.10	39.16	24.269	0.42
HRDiversion	Main1	2101.658	24 Hour SCS_SWM	42.76	93.25	95.616	94.966	95.855	0.000631	2.16	19.77	12.174	0.54
HRDiversion	Main1	2101.658	REG_SWM	69.61	93.25	96.656	95.465	96.863	0.000313	2.04	38.72	22.497	0.41
HRDiversion	Main1	2101.658	24 Hour SCS_NS	83.83	93.25	96.842	95.705	97.097	0.000352	2.27	42.94	22.948	0.44
HRDiversion	Main1	2101.658	REG_NS	74.72	93.25	96.770	95.549	96.986	0.000308	2.08	41.31	22.774	0.41
HRDiversion	Main1	2068.318	24 Hour SCS_SWM	42.76	93.21	95.601	94.911	95.832	0.000601	2.13	20.10	12.216	0.53
HRDiversion	Main1	2068.318	REG_SWM	69.61	93.21	96.654	95.419	96.850	0.000290	1.99	41.93	25.351	0.40
HRDiversion	Main1	2068.318	24 Hour SCS_NS	83.83	93.21	96.841	95.651	97.081	0.000326	2.22	46.72	25.832	0.43
HRDiversion	Main1	2068.318	REG_NS	74.72	93.21	96.769	95.505	96.972	0.000285	2.04	44.86	25.647	0.40
HRDiversion	Main1	2029	24 Hour SCS_SWM	42.76	93.11	95.589	94.841	95.806	0.000546	2.06	20.73	12.211	0.51
HRDiversion	Main1	2029	REG_SWM	69.61	93.11	96.647	95.348	96.837	0.000269	1.97	43.35	25.571	0.38
HRDiversion	Main1	2029	24 Hour SCS_NS	83.83	93.11	96.833	95.576	97.067	0.000306	2.20	48.15	26.136	0.41
HRDiversion	Main1	2029	REG_NS	74.72	93.11	96.762	95.434	96.960	0.000266	2.01	46.31	25.921	0.38
HRDiversion	Main1	2001.658	24 Hour SCS_SWM	42.76	93.04	95.580	94.788	95.789	0.000513	2.03	21.09	12.066	0.49
HRDiversion	Main1	2001.658	REG_SWM	69.61	93.04	96.672	95.292	96.817	0.000225	1.77	57.09	56.988	0.35
HRDiversion	Main1	2001.658	24 Hour SCS_NS	83.83	93.04	96.882	95.529	97.036	0.000227	1.87	69.35	59.961	0.35
HRDiversion	Main1	2001.658	REG_NS	74.72	93.04	96.797	95.381	96.935	0.000208	1.76	64.32	58.751	0.34
HRDiversion	Main1	1991.135	24 Hour SCS_SWM	42.76	93.01	95.386	94.759	95.740	0.000628	2.64	16.22	11.719	0.58
HRDiversion	Main1	1991.135	REG_SWM	69.61	93.01	96.669	95.313	96.814	0.000221	1.77	56.84	56.383	0.35
HRDiversion	Main1	1991.135	24 Hour SCS_NS	83.83	93.01	96.877	95.584	97.032	0.000225	1.87	68.92	59.653	0.35
HRDiversion	Main1	1991.135	REG_NS	74.72	93.01	96.793	95.407	96.933	0.000206	1.76	63.98	58.433	0.34
HRDiversion	Main1	1780.106		Culvert									
HRDiversion	Main1	1721.669	24 Hour SCS_SWM	42.76	91.47	94.271	93.511	94.699	0.001171	2.90	14.76	6.161	0.60
HRDiversion	Main1	1721.669	REG_SWM	69.61	91.47	95.739	94.225	96.150	0.000815	2.84	24.51	9.391	0.53
HRDiversion	Main1	1721.669	24 Hour SCS_NS	83.83	91.47	96.139	94.551	96.585	0.000803	2.98	30.79	23.952	0.52
HRDiversion	Main1	1721.669	REG_NS	74.72	91.47	96.074	94.348	96.448	0.000682	2.72	29.29	22.058	0.48
HRDiversion	Main1	1720		Lat Struct									
HRDiversion	Main1	1717.069	24 Hour SCS_SWM	42.76	91.55	94.322	93.402	94.639	0.000771	2.50	17.13	7.251	0.52
HRDiversion	Main1	1717.069	REG_SWM	69.61	91.55	95.790	94.047	96.093	0.000505	2.44	29.01	12.057	0.42
HRDiversion	Main1	1717.069	24 Hour SCS_NS	83.83	91.55	96.191	94.349	96.528	0.000494	2.59	36.25	27.548	0.42
HRDiversion	Main1	1717.069	REG_NS	74.72	91.55	96.117	94.160	96.400	0.000423	2.37	34.31	25.084	0.39
HRDiversion	Main1	1703.419	24 Hour SCS_SWM	42.76	91.54	94.326	93.348	94.623	0.000706	2.41	17.71	7.366	0.50
HRDiversion	Main1	1703.419	REG_SWM	69.61	91.54	95.793	93.983	96.082	0.000476	2.38	29.66	12.942	0.40
HRDiversion	Main1	1703.419	24 Hour SCS_NS	83.83	91.54	96.194	94.282	96.517	0.000469	2.54	35.67	16.764	0.41
HRDiversion	Main1	1703.419	REG_NS	74.72	91.54	96.121	94.091	96.390	0.000399	2.31	34.46	16.213	0.37
HRDiversion	Main1-2	1667.58	24 Hour SCS_SWM	54.87	91.48	94.423	93.015	94.553	0.000242	1.60	34.31	15.254	0.34
HRDiversion	Main1-2	1667.58	REG_SWM	87.84	91.48	95.908	93.521	96.018	0.000111	1.49	67.16	28.811	0.25
HRDiversion	Main1-2	1667.58	24 Hour SCS_NS	110.83	91.48	96.315	93.830	96.450	0.000120	1.66	78.93	29.061	0.26
HRDiversion	Main1-2	1667.58	REG_NS	99.79	91.48	96.218	93.683	96.335	0.000106	1.54	76.14	29.001	0.25
HRDiversion	Main1-2	1667		Lat Struct									
HRDiversion	Main1-2	1650.541	24 Hour SCS_SWM	54.87	91.46	94.432		94.544	0.000203	1.48	37.01	17.905	0.32
HRDiversion	Main1-2	1650.541	REG_SWM	87.84	91.46	95.918		96.011	0.000085	1.37	73.12	30.105	0.23
HRDiversion	Main1-2	1650.541	24 Hour SCS_NS	110.83	91.46	96.327		96.442	0.000092	1.53	85.48	30.374	0.24
HRDiversion	Main1-2	1650.541	REG_NS	99.79	91.46	96.229		96.328	0.000081	1.41	82.52	30.309	0.23
HRDiversion	Main1-2	1601.658	24 Hour SCS_SWM	54.87	91.35	94.437		94.530	0.000140	1.36	41.56	20.347	0.28
HRDiversion	Main1-2	1601.658	REG_SWM	87.84	91.35	95.923		96.004	0.000067	1.29	88.41	38.456	0.21
HRDiversion	Main1-2	1601.658	24 Hour SCS_NS	110.83	91.35	96.334		96.433	0.000073	1.44	104.35	39.102	0.22
HRDiversion	Main1-2	1601.658	REG_NS	99.79	91.35	96.235		96.321	0.000065	1.33	100.48	38.946	0.21
HRDiversion	Main1-2	1501.658	24 Hour SCS_SWM	54.87	91.13	94.428		94.515	0.000127	1.31	43.06	21.131	0.26
HRDiversion	Main1-2	1501.658	REG_SWM	87.84	91.13	95.922		95.996	0.000061	1.24	90.53	38.767	0.20
HRDiversion	Main1-2	1501.658	24 Hour SCS_NS	110.83	91.13	96.333		96.424	0.000067	1.39	106.71	39.959	0.21
HRDiversion	Main1-2	1501.658	REG_NS	99.79	91.13	96.234		96.312	0.000060	1.28	102.76	39.648	0.20
HRDiversion	Main1-2	1454.463	24 Hour SCS_SWM	54.87	91.07	94.431		94.506	0.000103	1.22	46.43	22.526	0.24
HRDiversion	Main1-2	1454.463	REG_SWM	87.84	91.07	95.922		95.991	0.000054	1.20	98.00	48.795	0.19
HRDiversion	Main1-2	1454.463	24 Hour SCS_NS	110.83	91.07	96.334		96.419	0.000060	1.34	120.95	60.650	0.20
HRDiversion	Main1-2	1454.463	REG_NS	99.79	91.07	96.234		96.308	0.000053	1.24	115.02	58.837	0.19

HEC-RAS Plan: Nov2018_sc2 (Continued)

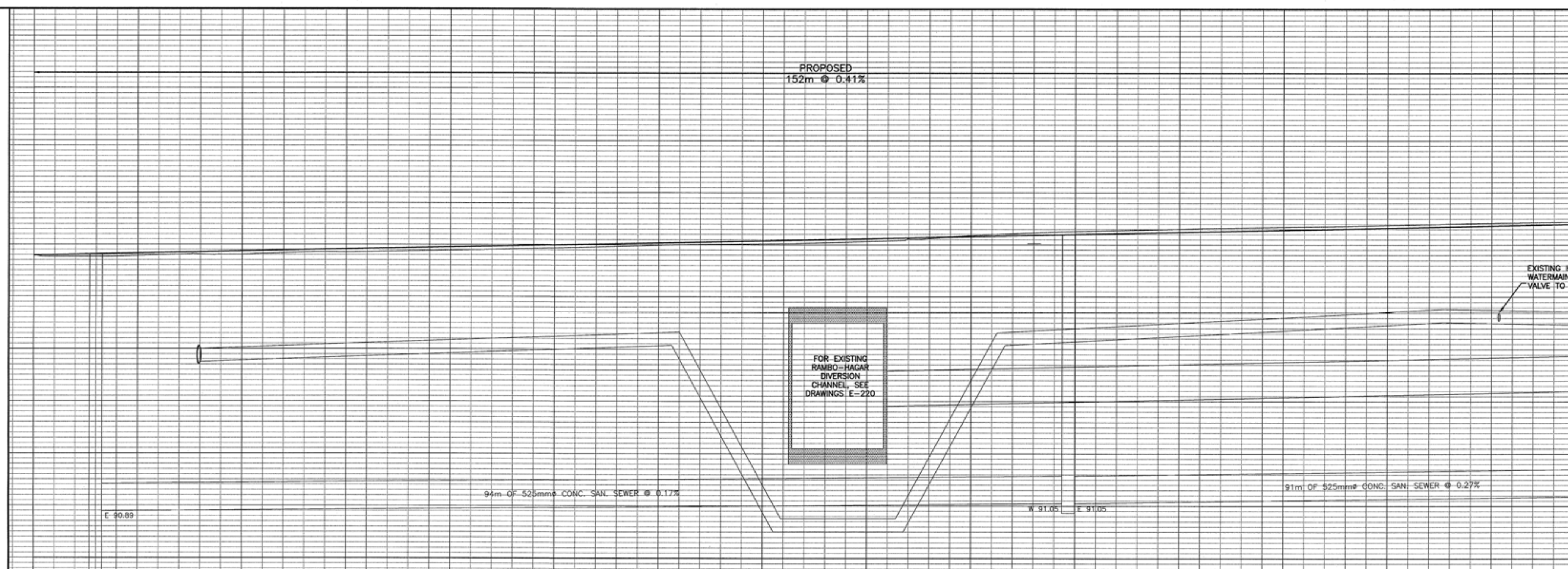
River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
HRDiversion	Main1-2	1443.625	24 Hour SCS_SWM	54.87	90.72	94.312	92.394	94.478	0.000138	1.81	30.38	23.973	0.31
HRDiversion	Main1-2	1443.625	REG_SWM	87.84	90.72	95.740	92.979	95.949	0.000197	2.03	48.57	84.397	0.34
HRDiversion	Main1-2	1443.625	24 Hour SCS_NS	110.83	90.72	96.126	93.349	96.370	0.000210	2.24	69.23	93.746	0.35
HRDiversion	Main1-2	1443.625	REG_NS	99.79	90.72	96.056	93.178	96.267	0.000183	2.06	65.52	92.940	0.33
HRDiversion	Main1-2	1429.197		Culvert									
HRDiversion	Main1-2	1412.911	24 Hour SCS_SWM	54.87	90.13	92.138	91.893	92.751	0.001176	3.47	15.82	10.188	0.81
HRDiversion	Main1-2	1412.911	REG_SWM	87.84	90.13	93.035	92.488	93.753	0.000817	3.75	23.41	11.055	0.72
HRDiversion	Main1-2	1412.911	24 Hour SCS_NS	110.83	90.13	94.347	92.865	94.691	0.000469	2.60	43.17	15.730	0.46
HRDiversion	Main1-2	1412.911	REG_NS	99.79	90.13	94.305	92.687	94.591	0.000395	2.37	42.52	15.487	0.42
HRDiversion	Main1-2	1401.658	24 Hour SCS_SWM	54.87	90.10	92.294		92.574	0.000720	2.35	23.39	14.358	0.59
HRDiversion	Main1-2	1401.658	REG_SWM	87.84	90.10	93.255		93.520	0.000432	2.28	38.67	17.989	0.48
HRDiversion	Main1-2	1401.658	24 Hour SCS_NS	110.83	90.10	94.426		94.606	0.000172	1.89	64.15	25.782	0.32
HRDiversion	Main1-2	1401.658	REG_NS	99.79	90.10	94.370		94.521	0.000147	1.73	62.72	25.383	0.30
HRDiversion	Main1-2	1301.658	24 Hour SCS_SWM	60.31	89.88	92.231		92.502	0.000637	2.30	26.18	15.042	0.56
HRDiversion	Main1-2	1301.658	REG_SWM	95.57	89.88	93.216		93.479	0.000377	2.27	42.60	18.680	0.45
HRDiversion	Main1-2	1301.658	24 Hour SCS_NS	117.00	89.88	94.412		94.588	0.000153	1.87	68.68	25.710	0.31
HRDiversion	Main1-2	1301.658	REG_NS	104.20	89.88	94.360		94.504	0.000127	1.69	67.35	25.292	0.28
HRDiversion	Main1-2	1201.658	24 Hour SCS_SWM	60.31	89.69	92.195		92.435	0.000533	2.17	27.77	15.175	0.51
HRDiversion	Main1-2	1201.658	REG_SWM	95.57	89.69	93.201		93.434	0.000338	2.14	44.91	19.330	0.43
HRDiversion	Main1-2	1201.658	24 Hour SCS_NS	117.00	89.69	94.412		94.567	0.000135	1.76	73.04	28.338	0.29
HRDiversion	Main1-2	1201.658	REG_NS	104.20	89.69	94.360		94.487	0.000112	1.59	71.58	27.866	0.26
HRDiversion	Main1-2	1101.658	24 Hour SCS_SWM	60.31	89.52	92.184		92.374	0.000393	1.93	31.22	16.207	0.44
HRDiversion	Main1-2	1101.658	REG_SWM	95.57	89.52	93.197		93.395	0.000242	1.97	50.05	21.128	0.37
HRDiversion	Main1-2	1101.658	24 Hour SCS_NS	117.00	89.52	94.414		94.549	0.000106	1.65	86.44	40.598	0.26
HRDiversion	Main1-2	1101.658	REG_NS	104.20	89.52	94.361		94.472	0.000088	1.50	84.31	40.037	0.24
HRDiversion	Main1-2	1001.658	24 Hour SCS_SWM	60.31	89.43	92.155		92.333	0.000355	1.87	32.29	16.252	0.42
HRDiversion	Main1-2	1001.658	REG_SWM	95.57	89.43	93.181		93.369	0.000222	1.93	52.23	23.211	0.36
HRDiversion	Main1-2	1001.658	24 Hour SCS_NS	117.00	89.43	94.409		94.537	0.000098	1.62	91.05	45.366	0.25
HRDiversion	Main1-2	1001.658	REG_NS	104.20	89.43	94.357		94.462	0.000082	1.46	88.82	40.532	0.23
HRDiversion	Main1-2	928.0883	24 Hour SCS_SWM	60.31	89.14	92.132		92.307	0.000332	1.85	32.52	13.949	0.39
HRDiversion	Main1-2	928.0883	REG_SWM	95.57	89.14	93.143		93.348	0.000267	2.02	50.50	22.160	0.36
HRDiversion	Main1-2	928.0883	24 Hour SCS_NS	117.00	89.14	94.393		94.526	0.000131	1.67	93.65	50.810	0.25
HRDiversion	Main1-2	928.0883	REG_NS	104.20	89.14	94.343		94.453	0.000108	1.52	91.11	50.466	0.23
HRDiversion	Main2	898.3339	24 Hour SCS_SWM	92.92	88.95	91.888		92.268	0.000700	2.73	34.02	16.872	0.60
HRDiversion	Main2	898.3339	REG_SWM	145.97	88.95	92.907		93.315	0.000453	2.85	58.42	32.764	0.51
HRDiversion	Main2	898.3339	24 Hour SCS_NS	206.39	88.95	94.152		94.498	0.000262	2.71	109.32	47.316	0.41
HRDiversion	Main2	898.3339	REG_NS	202.45	88.95	94.071		94.422	0.000271	2.72	105.54	46.787	0.42
HRDiversion	Main2	854.6458	24 Hour SCS_SWM	92.92	88.94	91.873		92.232	0.000669	2.65	35.03	17.213	0.59
HRDiversion	Main2	854.6458	REG_SWM	145.97	88.94	92.902		93.290	0.000427	2.77	56.59	25.594	0.50
HRDiversion	Main2	854.6458	24 Hour SCS_NS	206.39	88.94	94.141		94.486	0.000256	2.68	111.99	72.700	0.41
HRDiversion	Main2	854.6458	REG_NS	202.45	88.94	94.056		94.410	0.000267	2.70	105.80	72.700	0.42
HRDiversion	Main2	754.6458	24 Hour SCS_SWM	92.92	88.68	91.870		92.155	0.000446	2.37	39.59	18.368	0.49
HRDiversion	Main2	754.6458	REG_SWM	145.97	88.68	92.904		93.236	0.000324	2.57	61.32	23.677	0.44
HRDiversion	Main2	754.6458	24 Hour SCS_NS	206.39	88.68	94.133		94.456	0.000217	2.58	105.87	58.751	0.38
HRDiversion	Main2	754.6458	REG_NS	202.45	88.68	94.050		94.378	0.000224	2.59	101.14	55.087	0.39
HRDiversion	Main2	725.9643	24 Hour SCS_SWM	92.92	88.50	91.879		92.135	0.000382	2.24	41.91	19.184	0.46
HRDiversion	Main2	725.9643	REG_SWM	145.97	88.50	92.917		93.219	0.000285	2.45	64.89	25.105	0.42
HRDiversion	Main2	725.9643	24 Hour SCS_NS	206.39	88.50	94.150		94.441	0.000192	2.46	113.62	59.901	0.36
HRDiversion	Main2	725.9643	REG_NS	202.45	88.50	94.066		94.363	0.000198	2.47	108.62	59.574	0.37
HRDiversion	Main2	693.4501	24 Hour SCS_SWM	92.92	88.51	91.645	90.659	92.070	0.000470	2.89	32.17	18.444	0.54
HRDiversion	Main2	693.4501	REG_SWM	145.97	88.51	92.466	91.339	93.105	0.000509	3.54	41.19	22.169	0.58
HRDiversion	Main2	693.4501	24 Hour SCS_NS	206.39	88.51	94.146	92.020	94.433	0.000179	2.43	115.53	53.079	0.35
HRDiversion	Main2	693.4501	REG_NS	202.45	88.51	94.064	91.978	94.353	0.000184	2.43	111.20	52.049	0.35
HRDiversion	Main2	683.0943		Bridge									
HRDiversion	Main2	672.3745	24 Hour SCS_SWM	92.92	88.48	90.877	90.586	91.591	0.001182	3.74	24.82	15.571	0.81
HRDiversion	Main2	672.3745	REG_SWM	145.97	88.48	91.979	91.255	92.757	0.000747	3.91	37.35	20.764	0.69
HRDiversion	Main2	672.3745	24 Hour SCS_NS	206.39	88.48	92.734	91.922	93.335	0.000573	3.46	64.79	25.026	0.59
HRDiversion	Main2	672.3745	REG_NS	202.45	88.48	92.754	91.881	93.326	0.000540	3.37	65.31	25.132	0.57
HRDiversion	Main2	654.6458	24 Hour SCS_SWM	92.92	88.46	90.887	90.693	91.534	0.001515	3.57	26.06	14.875	0.86
HRDiversion	Main2	654.6458	REG_SWM	145.97	88.46	92.095		92.616	0.000661	3.21	47.57	21.845	0.61
HRDiversion	Main2	654.6458	24 Hour SCS_NS	206.39	88.46	92.463		93.264	0.000865	3.98	56.10	24.460	0.71
HRDiversion	Main2	654.6458	REG_NS	202.45	88.46	92.528		93.265	0.000777	3.83	57.69	24.916	0.68
HRDiversion	Main2	636.8858	24 Hour SCS_SWM	92.55	88.42	90.957		91.420	0.000995	3.01	30.72	16.647	0.71
HRDiversion	Main2	636.8858	REG_SWM	146.58	88.42	92.151		92.540	0.000504	2.77	53.85	23.384	0.54
HRDiversion	Main2	636.8858	24 Hour SCS_NS	193.29	88.42	92.607		93.096	0.000517	3.11	66.66	33.447	0.56
HRDiversion	Main2	636.8858	REG_NS	199.61	88.42	92.628		93.142	0.000539	3.19	67.36	33.928	0.57
HRDiversion	Main2	554.6458	24 Hour SCS_SWM	92.55	87.98	90.977		91.318	0.000641	2.59	35.74	17.041	0.57
HRDiversion	Main2	554.6458	REG_SWM	146.58	87.98	92.155		92.488	0.000366	2.56	60.16	25.638	0.46
HRDiversion	Main2	554.6458	24 Hour SCS_NS	193.29	87.98	92.630		93.034	0.000378	2.86	88.95	69.471	0.48
HRDiversion	Main2	554.6458	REG_NS	199.61	87.98	92.655		93.076	0.000392	2.93	90.63	69.628	0.49
HRDiversion	Main2	468.4212	24 Hour SCS_SWM	92.55	87.64	90.992	89.840	91.250	0.000396	2.25	41.14	17.006	0.45
HRDiversion	Main2	468.4212	REG_SWM	146.58	87.64	92.162	90.460	92.447	0.000266	2.38	71.12	33.156	0.40
HRDiversion	Main2	468.4212	24 Hour SCS_NS	193.29	87.64	92.624	90.906	92.995	0.000302	2.75	86.89	38.082	0.43
HRDiversion	Main2	468.4212	REG_NS	199.61	87.64	92.645	90.961	93.037	0.000316	2.82	87.73	38.805	0.44

HEC-RAS Plan: Nov2018_sc2 (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
HRDiversion	Main2	454.6458	24 Hour SCS_SWM	92.55	87.66	90.671	89.977	91.165	0.005949	3.12	29.69	16.327	0.62
HRDiversion	Main2	454.6458	REG_SWM	146.58	87.66	91.730	90.648	92.339	0.006522	3.47	44.29	66.195	0.65
HRDiversion	Main2	454.6458	24 Hour SCS_NS	193.29	87.66	92.733	92.159	92.870	0.001570	1.86	128.62	114.180	0.32
HRDiversion	Main2	454.6458	REG_NS	199.61	87.66	92.764	92.183	92.902	0.001571	1.87	132.15	116.816	0.32
HRDiversion	Main2	420.9742		Culvert									
HRDiversion	Main2	398.4328	24 Hour SCS_SWM	92.55	87.29	89.774	89.774	90.757	0.002315	4.39	21.07	10.678	1.00
HRDiversion	Main2	398.4328	REG_SWM	146.58	87.29	90.499	90.499	91.786	0.002153	5.03	29.16	12.245	1.00
HRDiversion	Main2	398.4328	24 Hour SCS_NS	193.29	87.29	91.020	91.020	92.568	0.002025	5.51	35.07	15.869	1.00
HRDiversion	Main2	398.4328	REG_NS	199.61	87.29	91.162	91.162	92.590	0.001954	5.30	38.67	17.497	0.97
HRDiversion	Main2	375.9594	24 Hour SCS_SWM	92.55	87.05	89.499	89.499	90.337	0.002104	4.06	22.82	13.716	1.00
HRDiversion	Main2	375.9594	REG_SWM	146.58	87.05	90.143	90.143	91.193	0.001976	4.54	32.31	16.028	1.00
HRDiversion	Main2	375.9594	24 Hour SCS_NS	193.29	87.05	90.585	90.585	91.822	0.001805	4.93	40.11	19.532	0.99
HRDiversion	Main2	375.9594	REG_NS	199.61	87.05	90.642	90.642	91.902	0.001785	4.98	41.23	20.097	0.99
HRDiversion	Main2	354.6458	24 Hour SCS_SWM	92.55	86.91	89.429	89.429	90.256	0.002112	4.03	22.96	14.078	1.01
HRDiversion	Main2	354.6458	REG_SWM	146.58	86.91	90.047	90.047	91.102	0.001926	4.55	32.39	18.089	1.00
HRDiversion	Main2	354.6458	24 Hour SCS_NS	193.29	86.91	90.601	90.601	91.694	0.001486	4.67	48.40	36.416	0.91
HRDiversion	Main2	354.6458	REG_NS	199.61	86.91	90.648	90.648	91.764	0.001486	4.73	50.14	37.353	0.92
HRDiversion	Main2	254.6458	24 Hour SCS_SWM	92.55	86.57	89.120	89.120	89.929	0.002076	3.99	23.22	14.354	1.00
HRDiversion	Main2	254.6458	REG_SWM	146.58	86.57	89.761	89.761	90.763	0.001772	4.44	34.71	26.875	0.97
HRDiversion	Main2	254.6458	24 Hour SCS_NS	193.29	86.57	90.293	90.293	91.316	0.001389	4.56	53.27	39.248	0.89
HRDiversion	Main2	254.6458	REG_NS	199.61	86.57	90.346	90.346	91.381	0.001376	4.59	55.37	39.638	0.89
HRDiversion	Main2	154.6458	24 Hour SCS_SWM	92.55	86.12	88.719	88.719	89.556	0.002116	4.05	22.84	13.848	1.01
HRDiversion	Main2	154.6458	REG_SWM	146.58	86.12	89.654	89.654	90.263	0.001046	3.62	68.47	90.590	0.75
HRDiversion	Main2	154.6458	24 Hour SCS_NS	193.29	86.12	89.955	89.955	90.607	0.001034	3.89	96.31	94.028	0.76
HRDiversion	Main2	154.6458	REG_NS	199.61	86.12	89.992	89.992	90.649	0.001032	3.93	99.80	94.377	0.76
HRDiversion	Main2	54.64576	24 Hour SCS_SWM	92.55	85.80	88.204	88.204	89.035	0.002084	4.04	22.91	13.745	1.00
HRDiversion	Main2	54.64576	REG_SWM	146.58	85.80	88.884	88.884	89.883	0.001871	4.43	33.85	23.930	0.98
HRDiversion	Main2	54.64576	24 Hour SCS_NS	193.29	85.80	89.310	89.310	90.104	0.001327	4.22	76.48	67.999	0.85
HRDiversion	Main2	54.64576	REG_NS	199.61	85.80	89.382	89.382	90.153	0.001257	4.19	81.50	70.290	0.83



FAIRVIEW STREET



	0+000	0+020	0+040	0+060	0+080	0+100	0+120	0+140
℄ ELEV'S	95.76 / 95.788	95.79 / 95.870	95.90 / 95.952	96.00 / 96.035	96.07 / 96.117	96.26 / 96.199	96.34 / 96.281	96.40 / 96.364
STORM SEWER					92.91 — 98m OF 675mmø CONC STM SEWER @ 0.44%			
CHAINAGE	0+000	0+020	0+040	0+060	0+080	0+100	0+120	0+140

No.	DATE	BY	REVISIONS
2	07/05/08	AXI	ISSUED FOR CONSTRUCTION
1	06/20/07	AXI	ISSUED FOR TENDER

DESIGN: A. IVANAJ — CHECKED
DRAWN: A. IVANAJ — CHECKED
DATE: JUNE 2007
SCALE: HORZ. 1:250 VERT 1:50
REFERENCES:
FIELD NOTES:
STAMP

APPROVALS
MUNICIPAL: MANAGER OF DESIGN AND CONSTRUCTION
DATE: May 6/2008
REGIONAL: COMMISSIONER OF PUBLIC WORKS
DIRECTOR OF DESIGN & CONSTRUCTION
CONSULTANT

CITY OF Burlington

TITLE
FAIRVIEW STREET
BRANT ST TO FUTURE WAL-MART ENTRANCE

MUNICIPAL DRAWING NO. MF-06
CAD FILENAME: M:\2007 CONTRACTS\FAIRVIEWCUNAGO-2\DWG\PHASE ONE.DWG
CONTRACT NO. 07-13
SHEET 1 OF 4

FAIRVIEW STREET WIDENING 07-13

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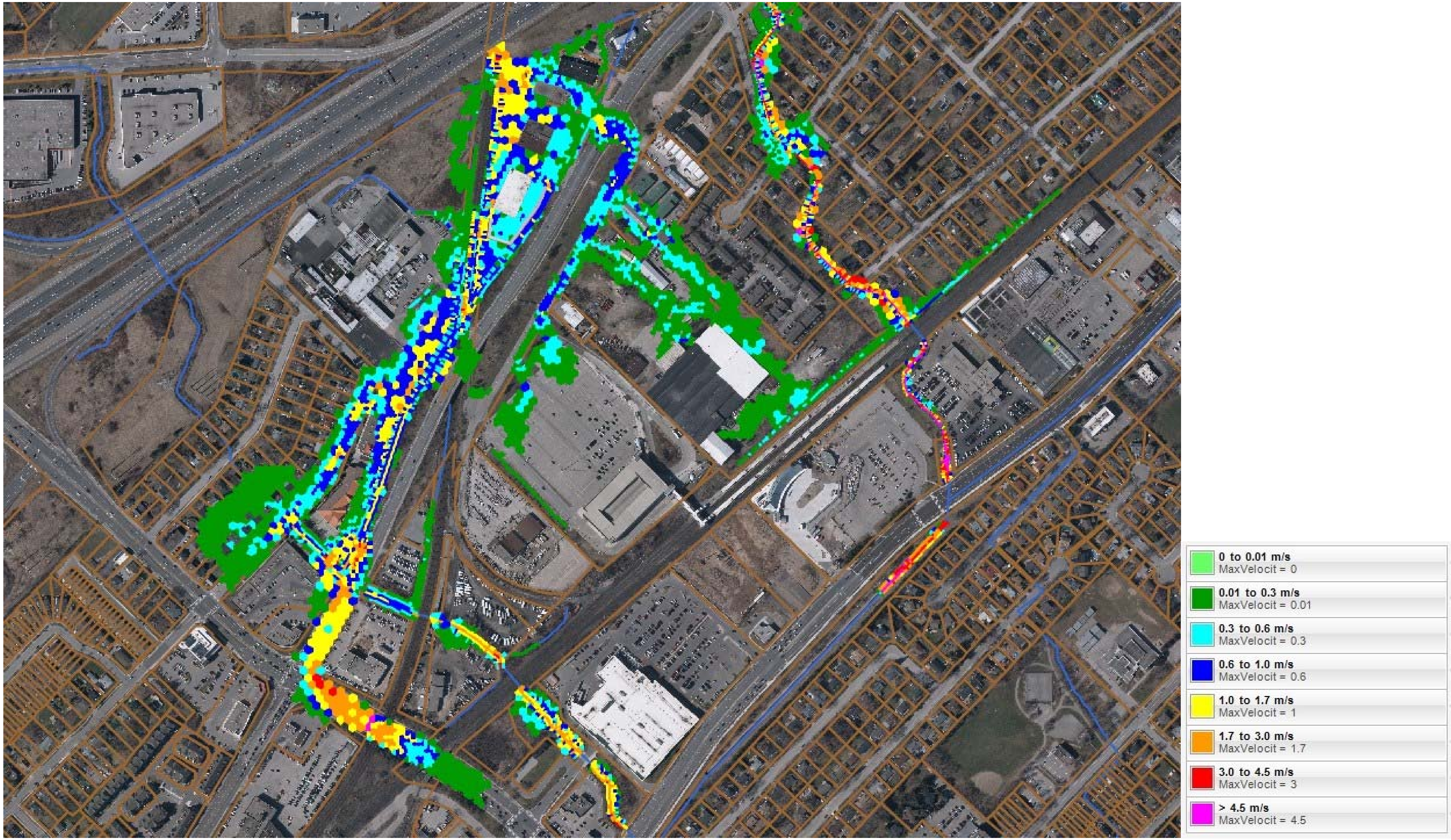

FIGURE C1-A: 2D MAXIMUM VELOCITY SUMMARY FOR EAST AND WEST RAMBO CREEKS – 100-YEAR STORM EVENT (ENTIRE AREA)

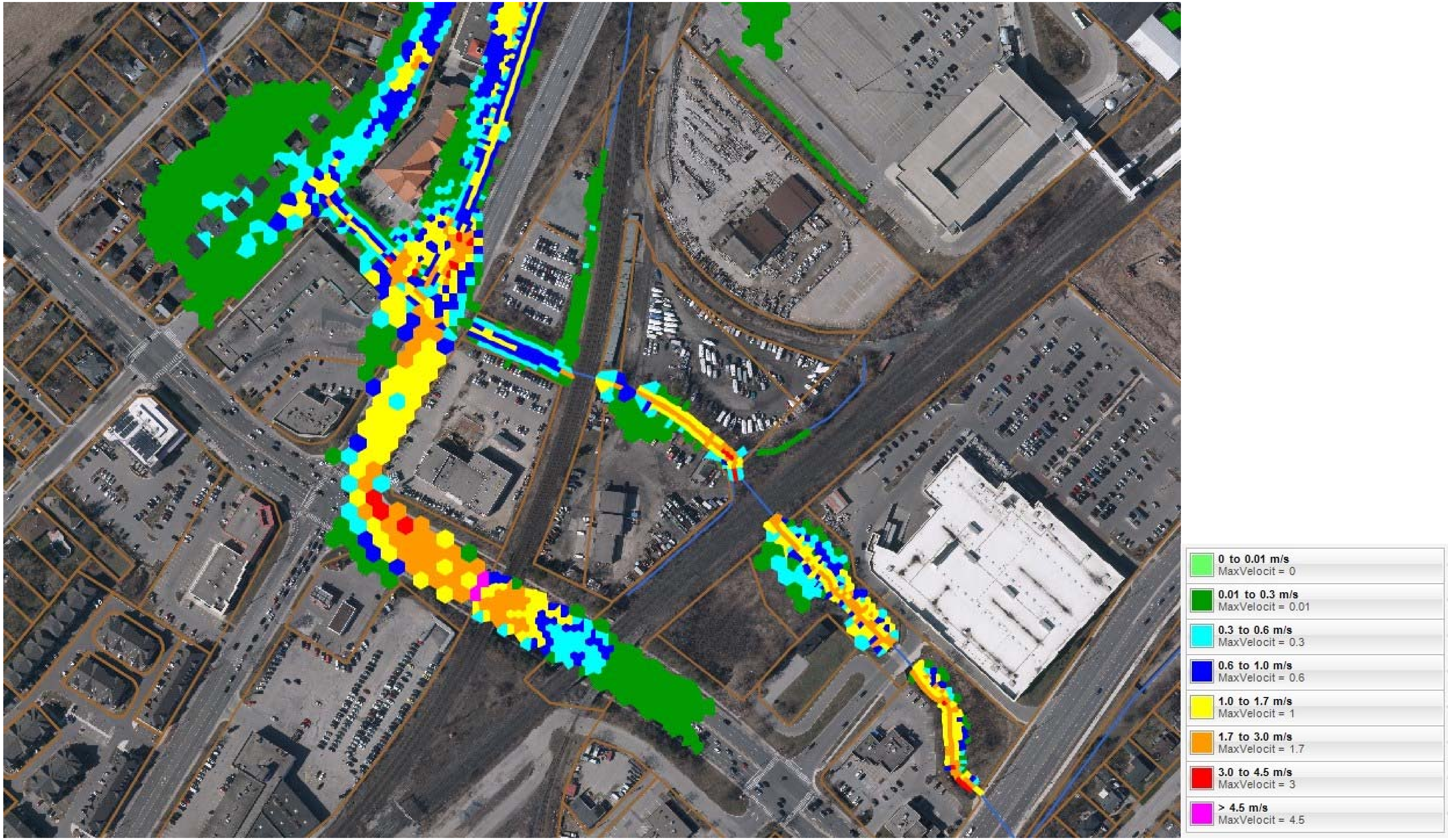

FIGURE C1-B: 2D MAXIMUM VELOCITY SUMMARY FOR EAST AND WEST RAMBO CREEKS – 100-YEAR STORM EVENT (BRANT STREET AREA)

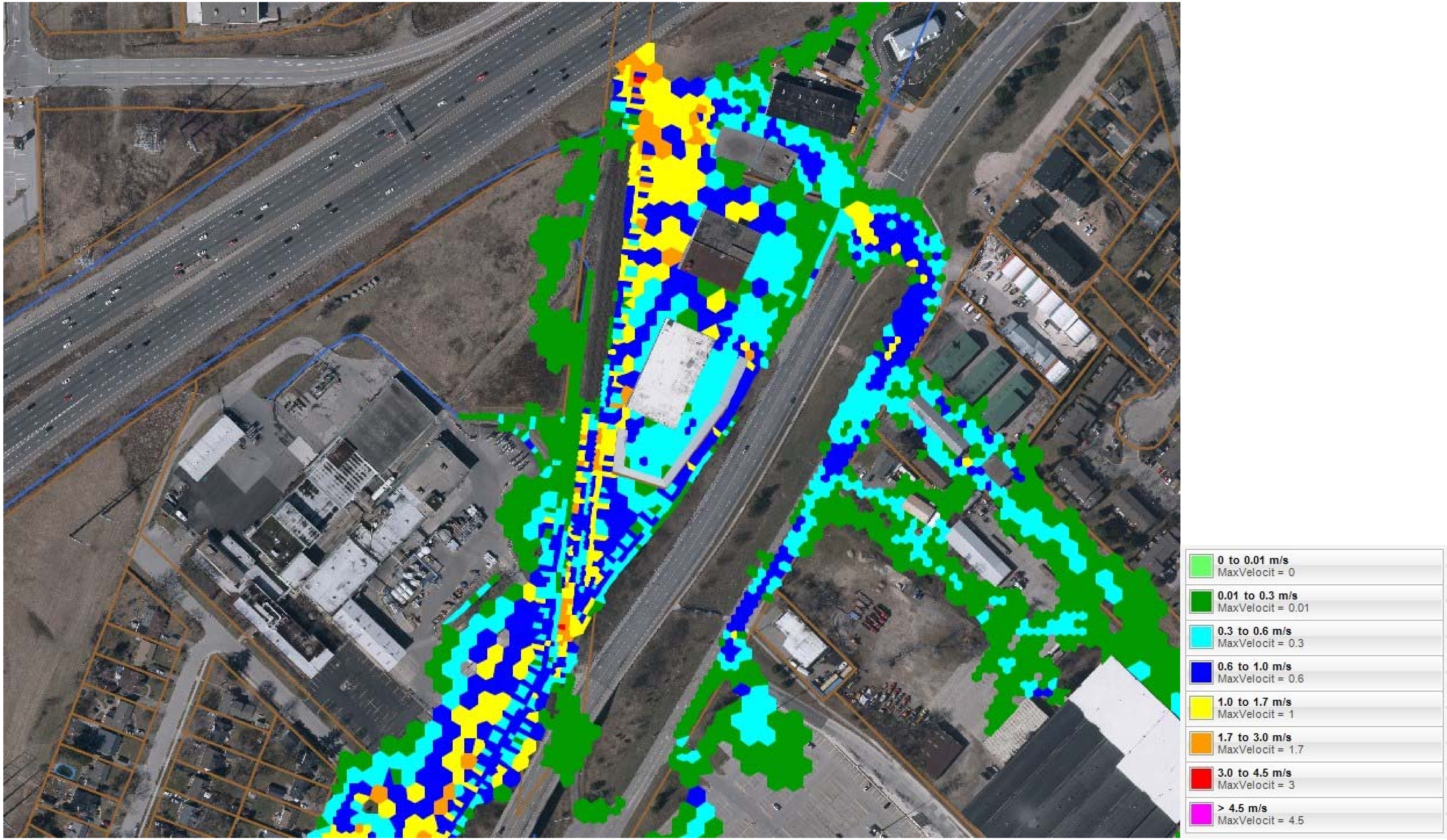

FIGURE C1-C: 2D MAXIMUM VELOCITY SUMMARY FOR EAST AND WEST RAMBO CREEKS – 100-YEAR STORM EVENT (CNR SPILL AREA)

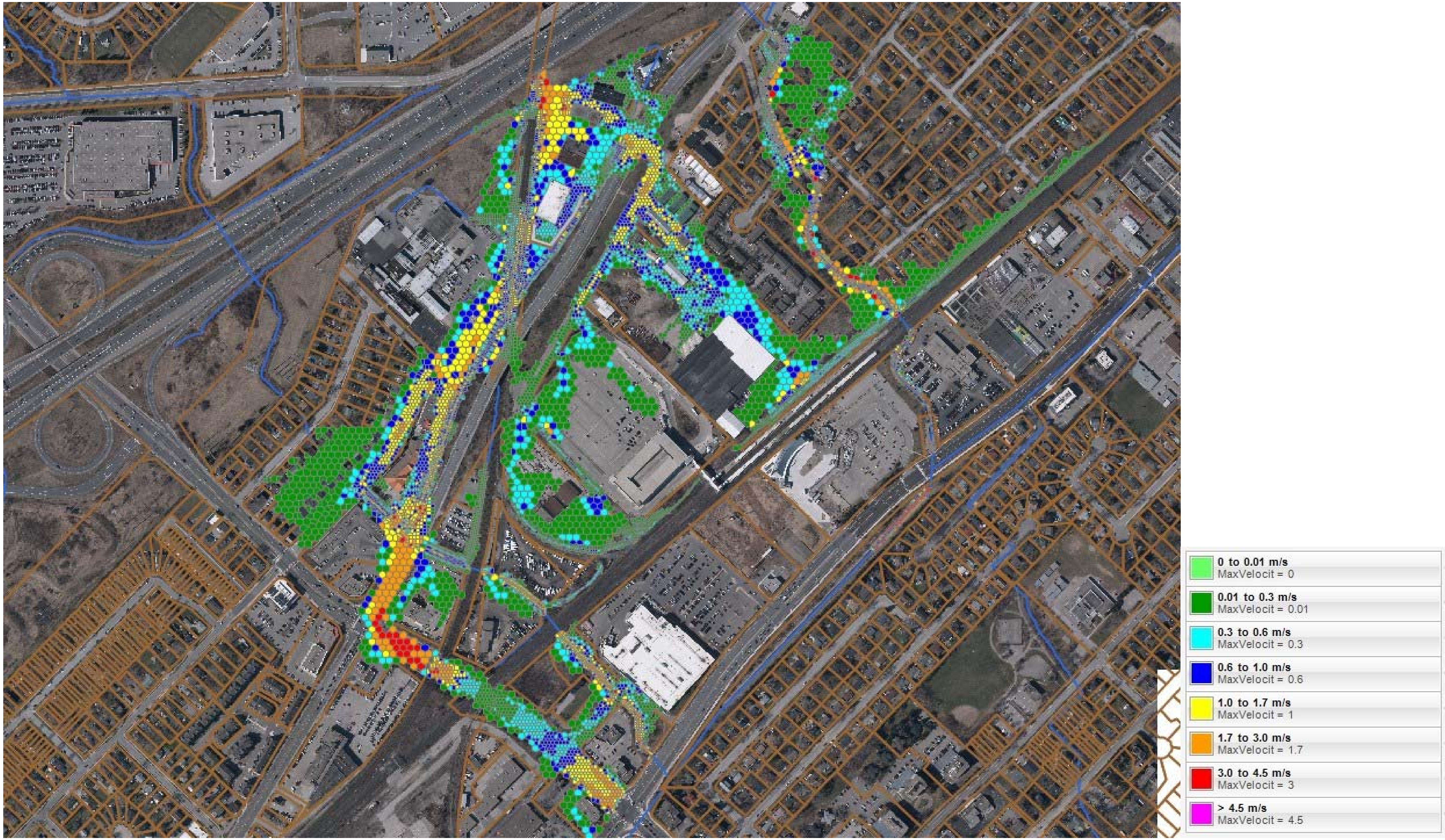

FIGURE C2-A: 2D MAXIMUM VELOCITY SUMMARY FOR EAST AND WEST RAMBO CREEKS – REGIONAL STORM EVENT (ENTIRE AREA)

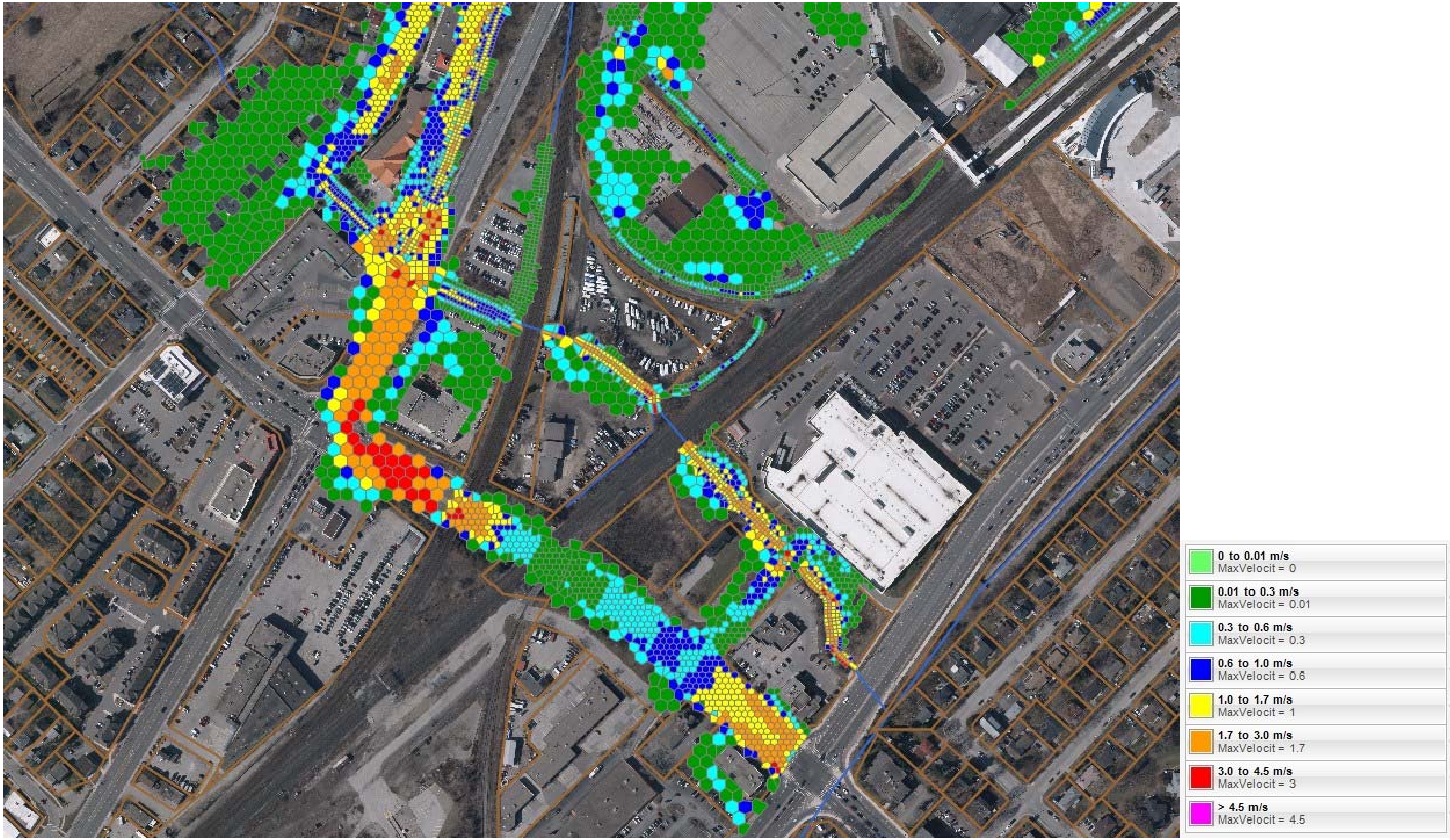

FIGURE C2-B: 2D MAXIMUM VELOCITY SUMMARY FOR EAST AND WEST RAMBO CREEKS – REGIONAL STORM EVENT (BRANT STREET AREA)

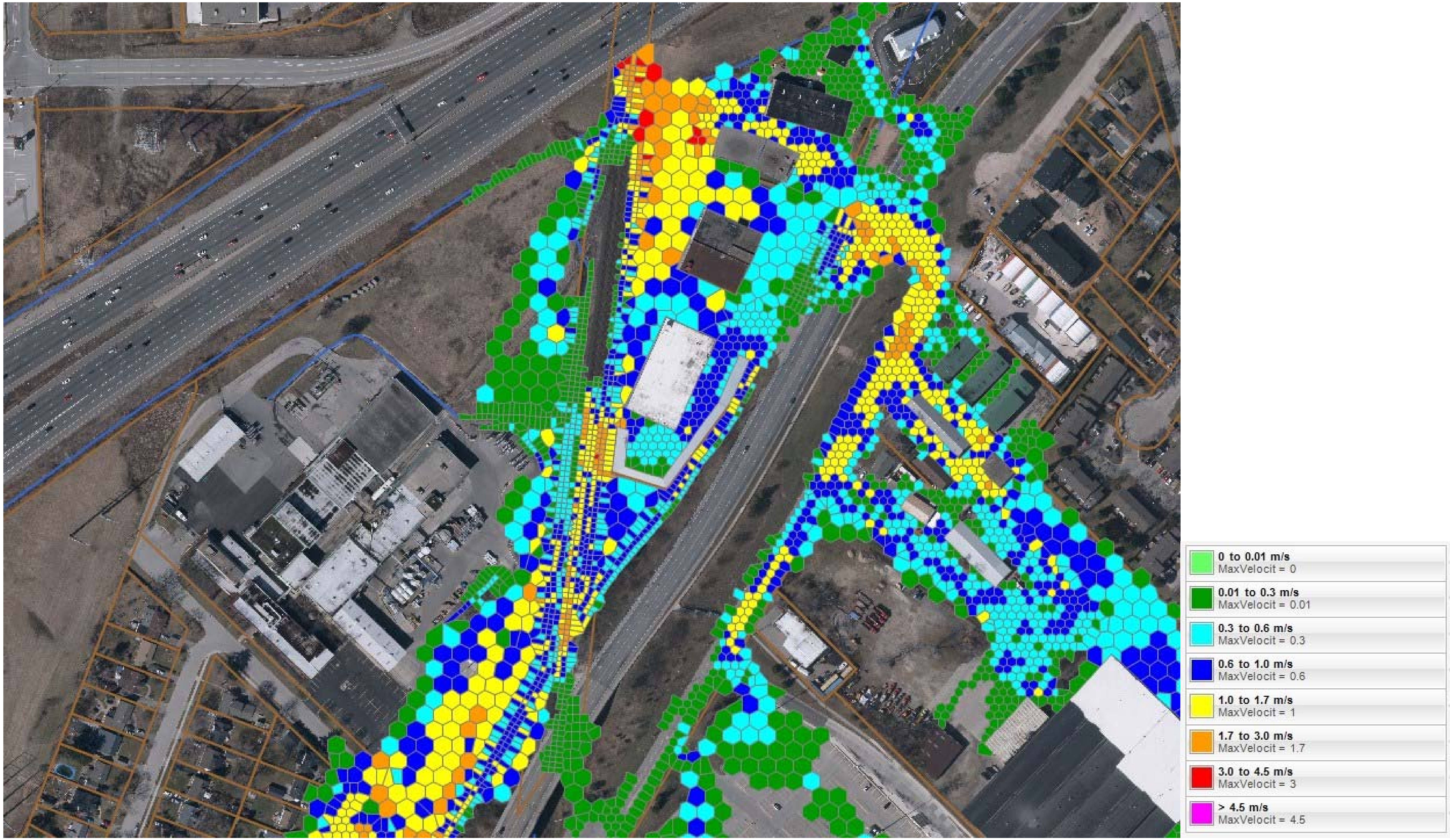

FIGURE C2-C: 2D MAXIMUM VELOCITY SUMMARY FOR EAST AND WEST RAMBO CREEKS – REGIONAL STORM EVENT (CNR SPILL AREA)

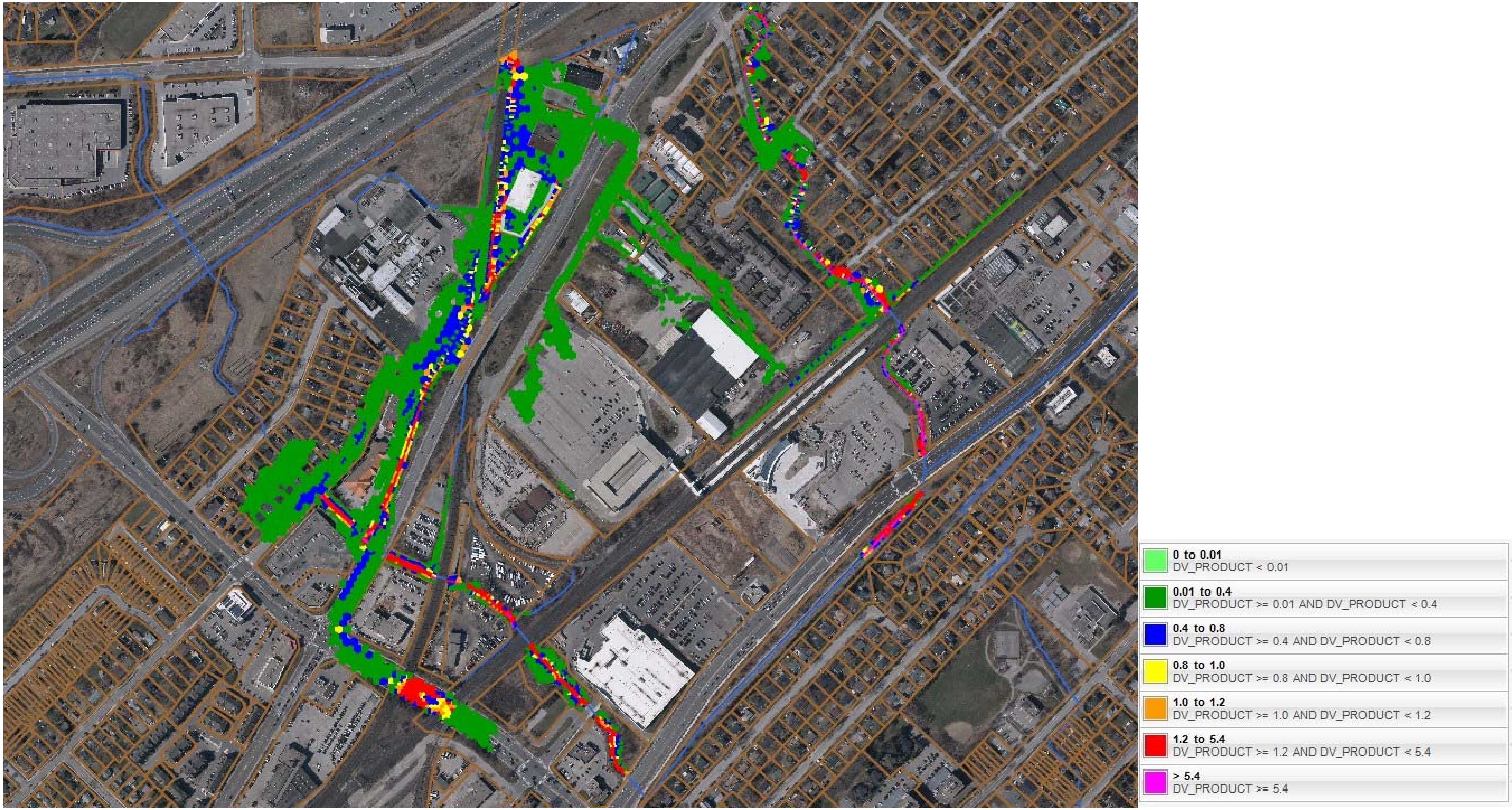

FIGURE C3-A: 2D MAXIMUM DEPTH X VELOCITY SUMMARY FOR EAST AND WEST RAMBO CREEKS – 100-YEAR STORM EVENT (ENTIRE AREA)

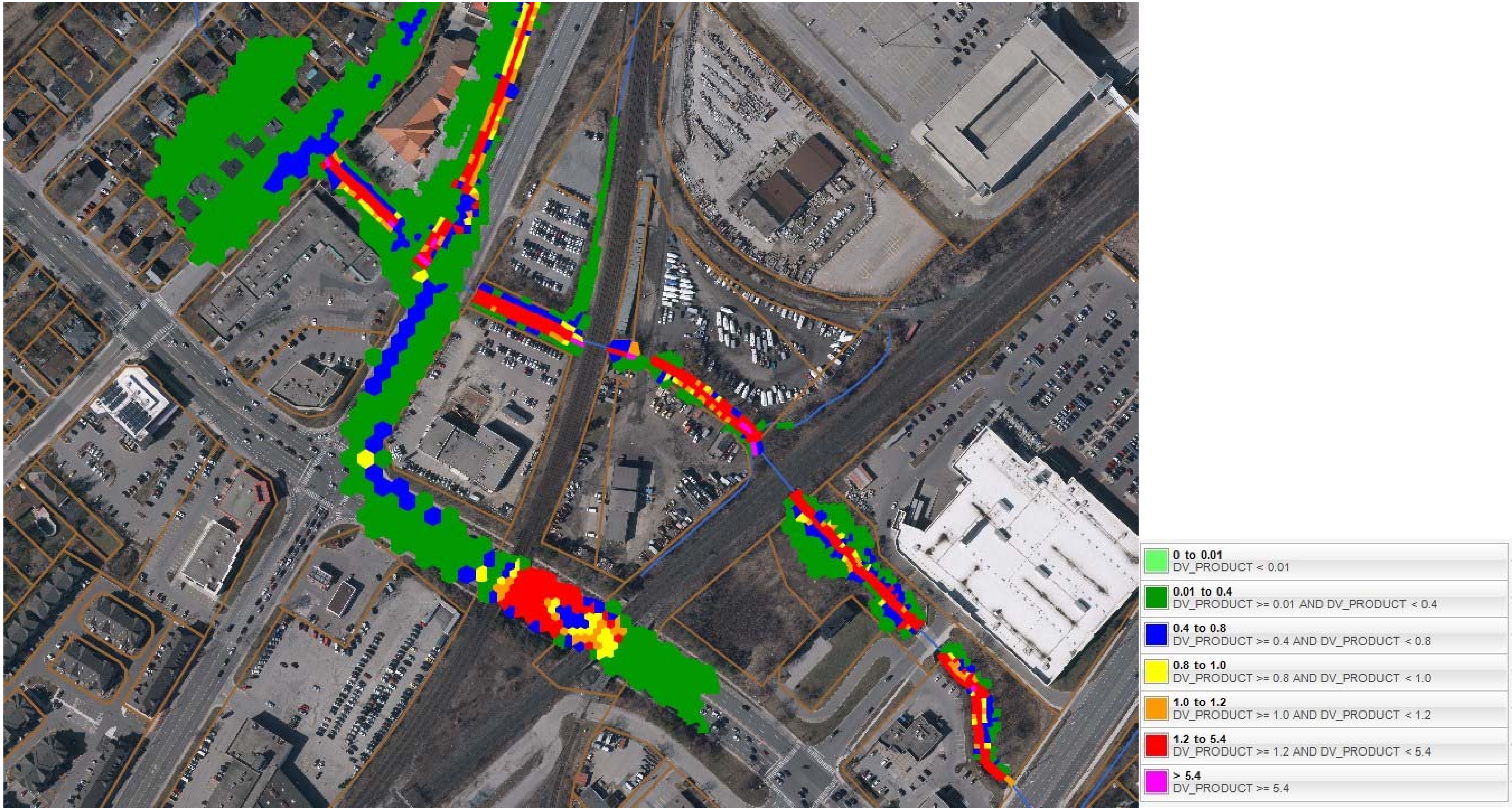

FIGURE C3-B: 2D MAXIMUM DEPTH X VELOCITY SUMMARY FOR EAST AND WEST RAMBO CREEKS – 100-YEAR STORM EVENT (BRANT STREET AREA)

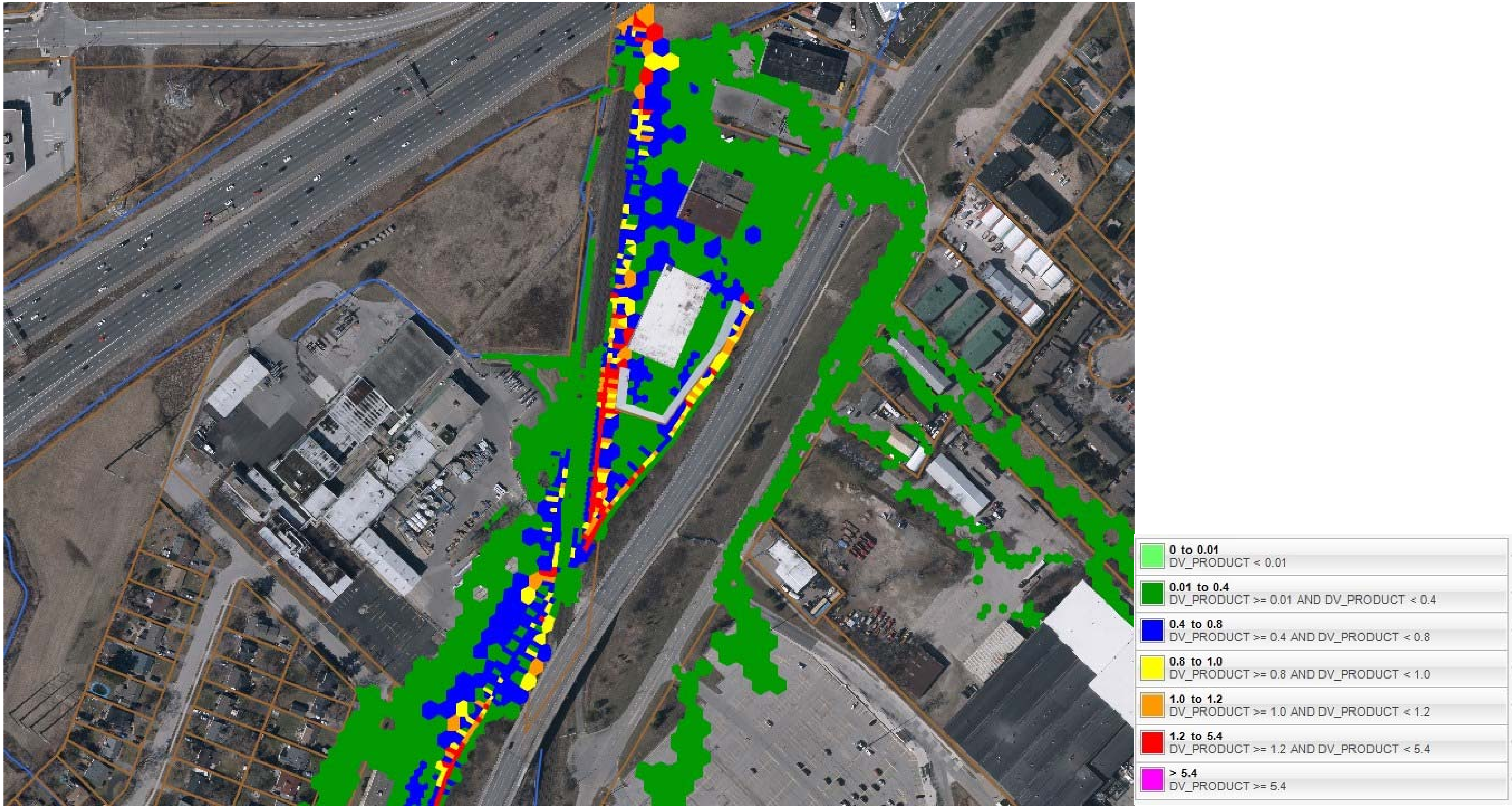

FIGURE C3-C: 2D MAXIMUM DEPTH X VELOCITY SUMMARY FOR EAST AND WEST RAMBO CREEKS – 100-YEAR STORM EVENT (CNR SPILL AREA)

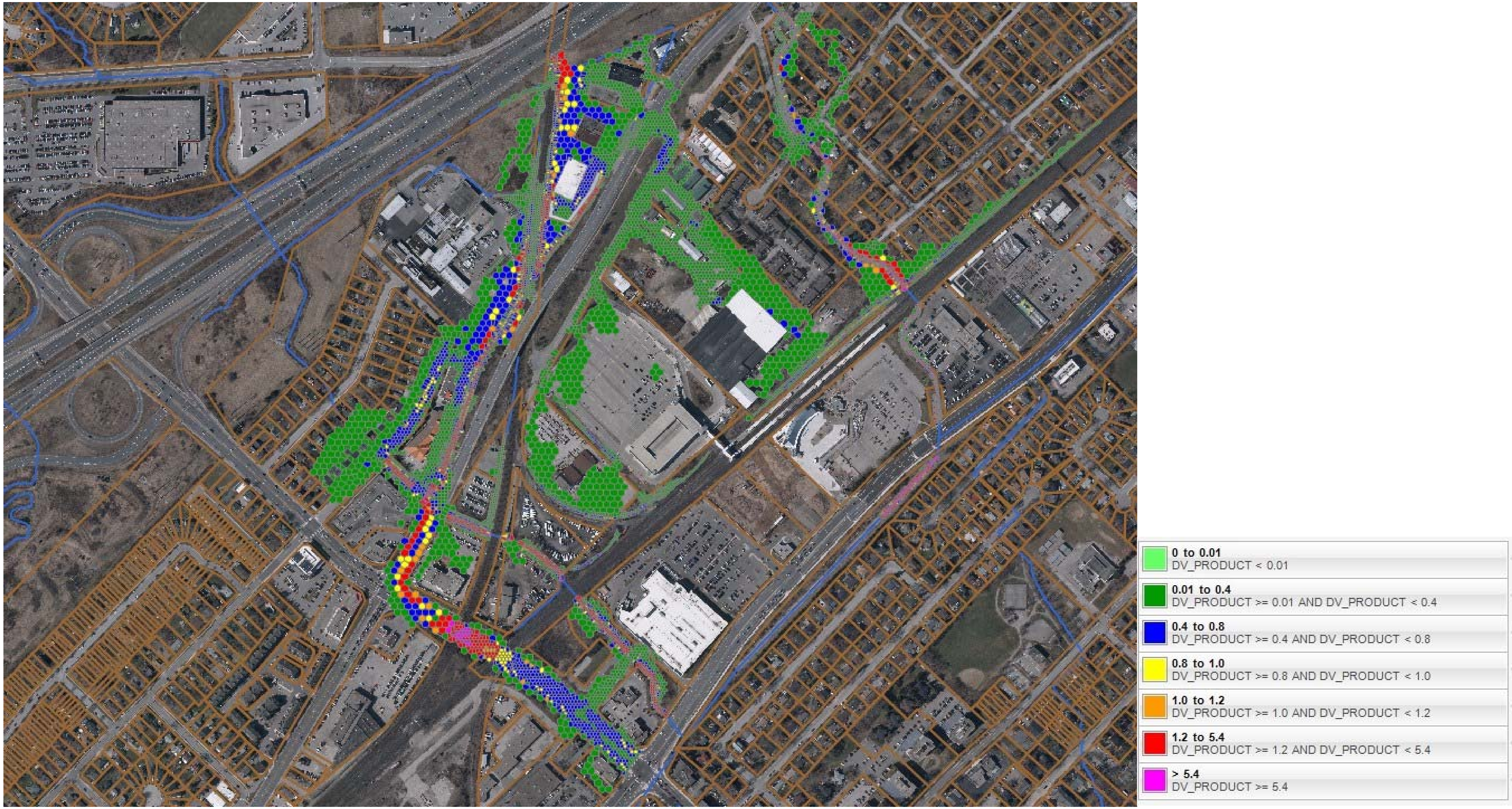

FIGURE C4-A: 2D MAXIMUM DEPTH X VELOCITY SUMMARY FOR EAST AND WEST RAMBO CREEKS – REGIONAL STORM EVENT (ENTIRE AREA)

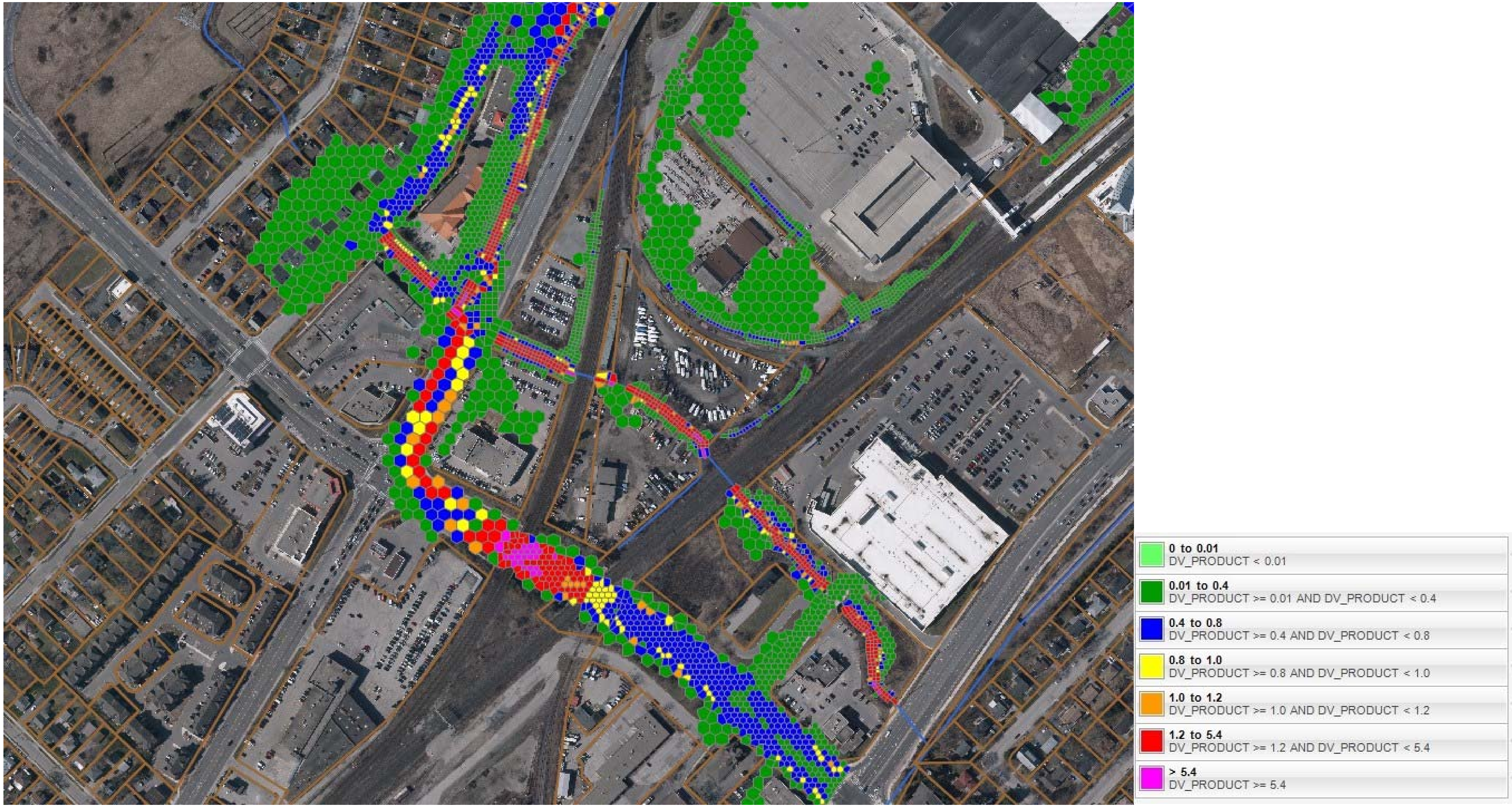

FIGURE C4-B: 2D MAXIMUM DEPTH X VELOCITY SUMMARY FOR EAST AND WEST RAMBO CREEKS – REGIONAL STORM EVENT (BRANT STREET AREA)

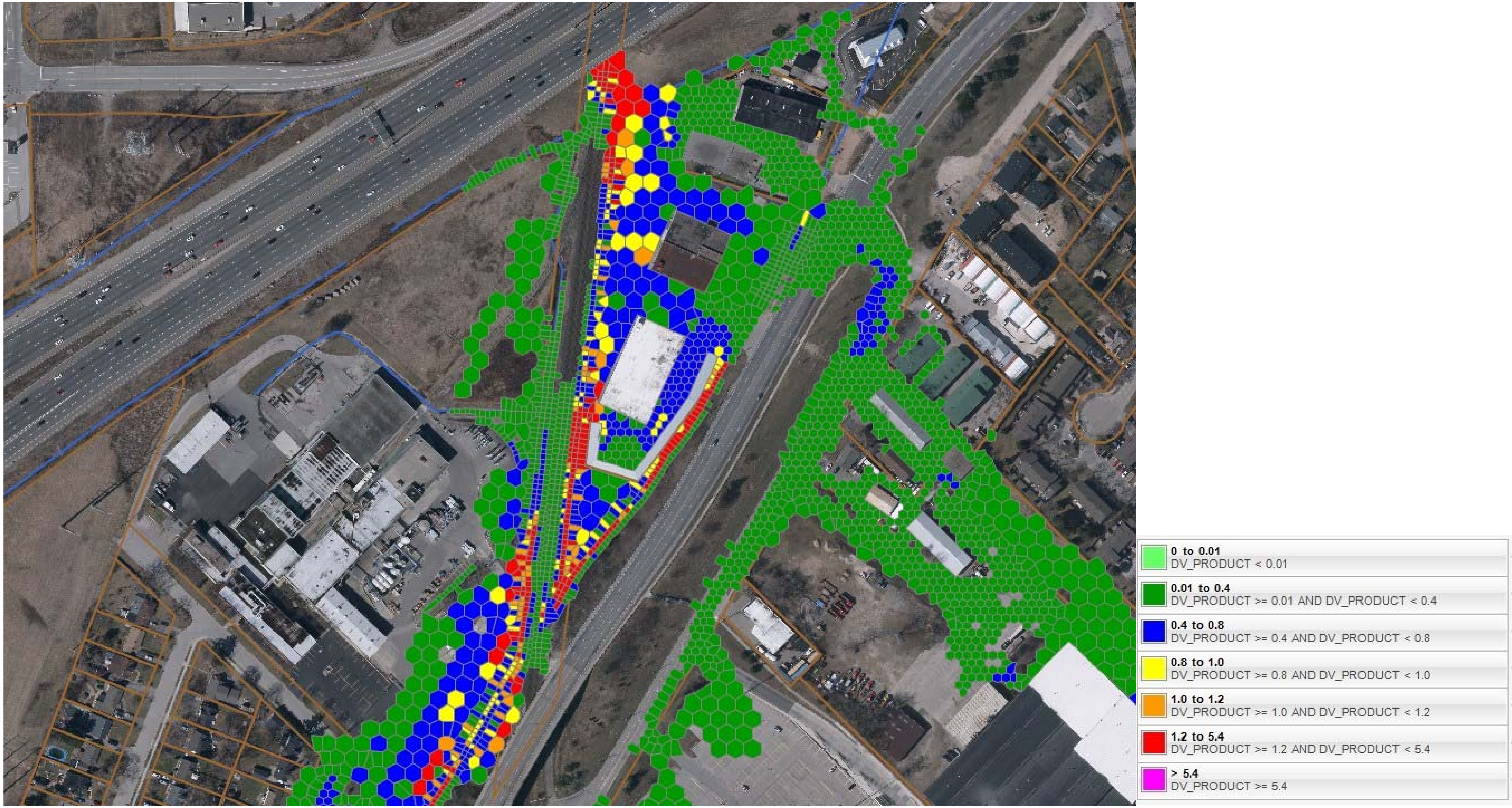

FIGURE C4-C: 2D MAXIMUM DEPTH X VELOCITY SUMMARY FOR EAST AND WEST RAMBO CREEKS – REGIONAL STORM EVENT (CNR SPILL AREA)

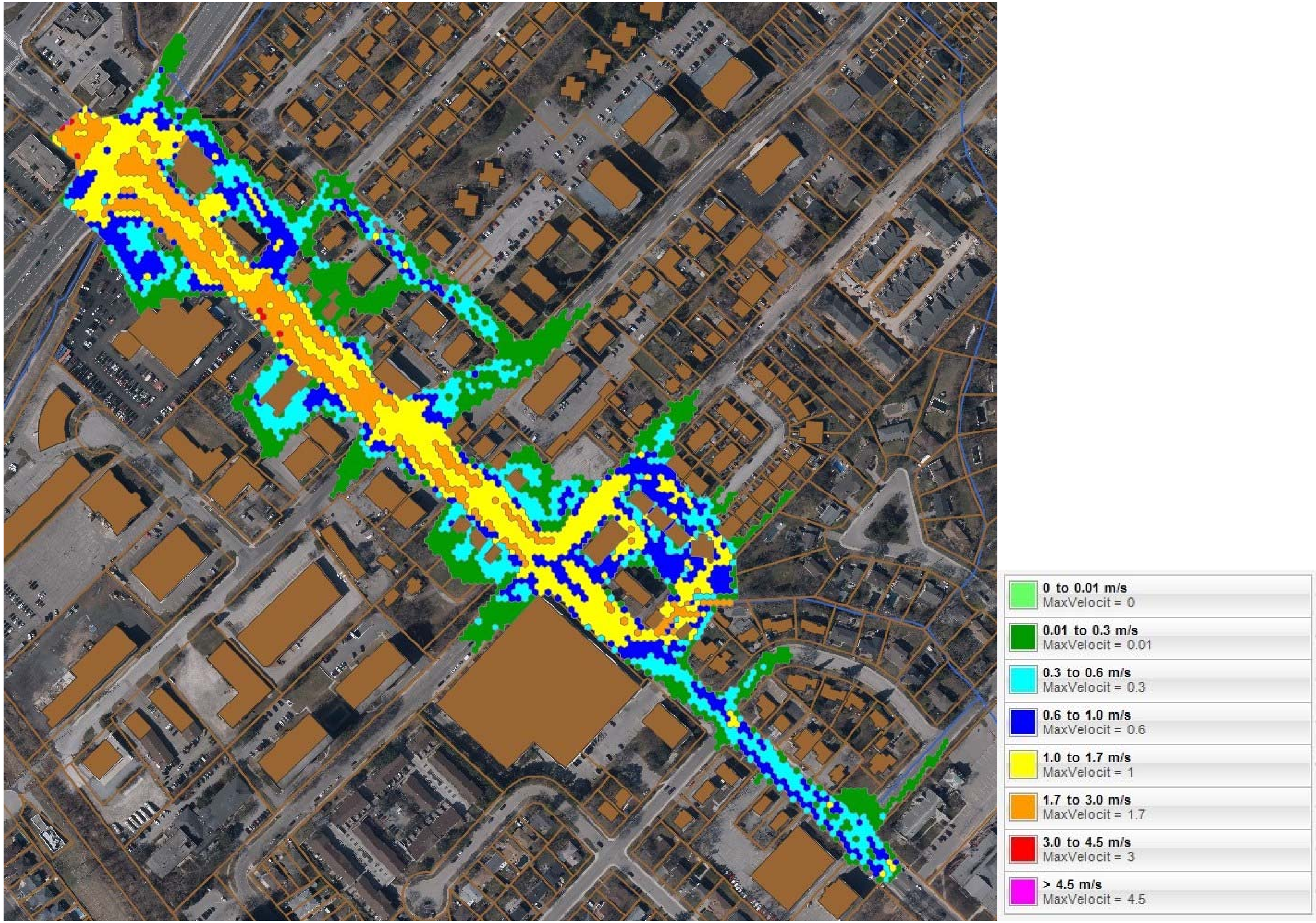

FIGURE C5: 2D MAXIMUM VELOCITY SUMMARY FOR HAGER-RAMBO DIVERSION CHANNEL SPILLS – REGIONAL STORM (SCENARIO 0)

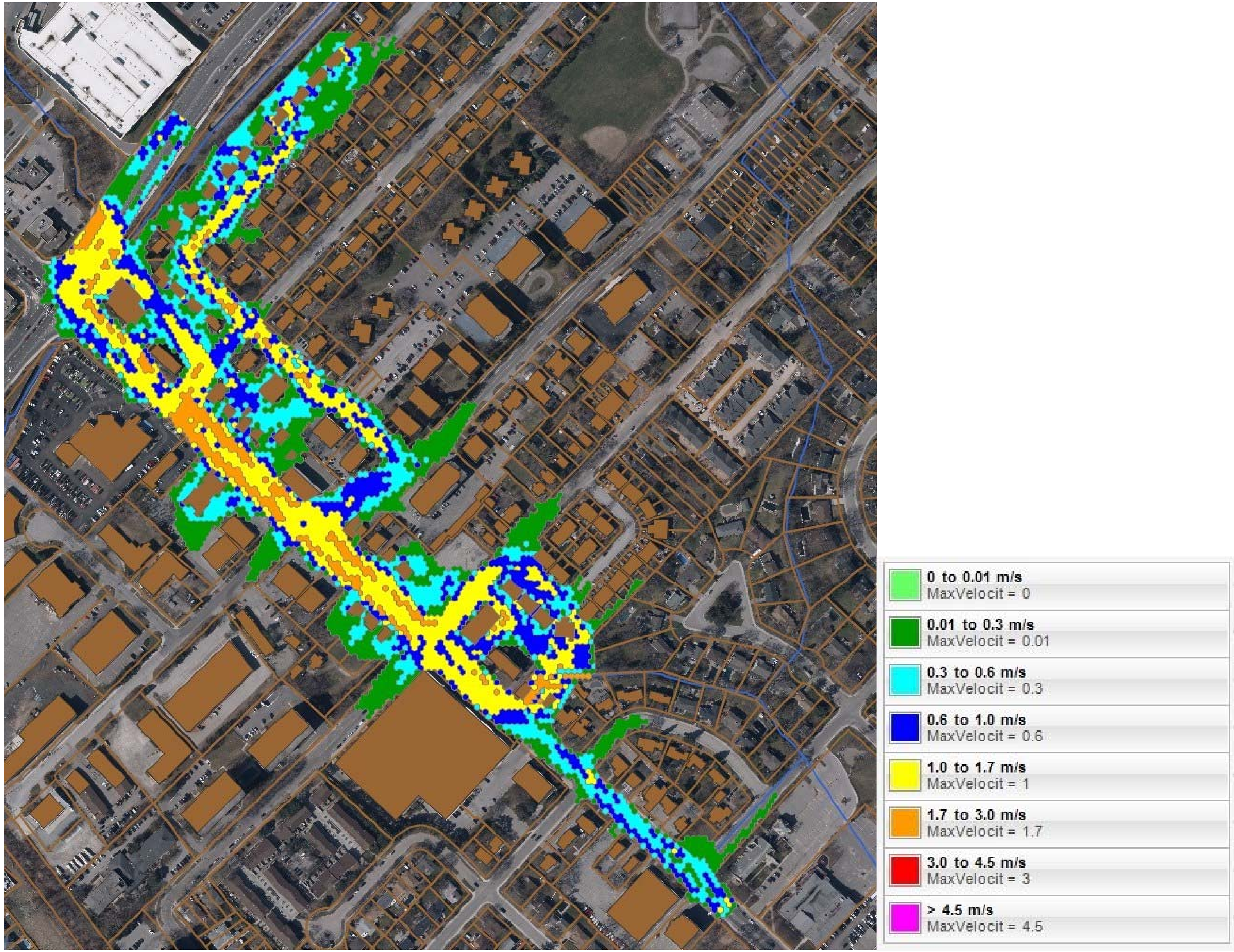

FIGURE C6: 2D MAXIMUM VELOCITY SUMMARY FOR HAGER-RAMBO DIVERSION CHANNEL SPILLS – REGIONAL STORM (SCENARIO 1)

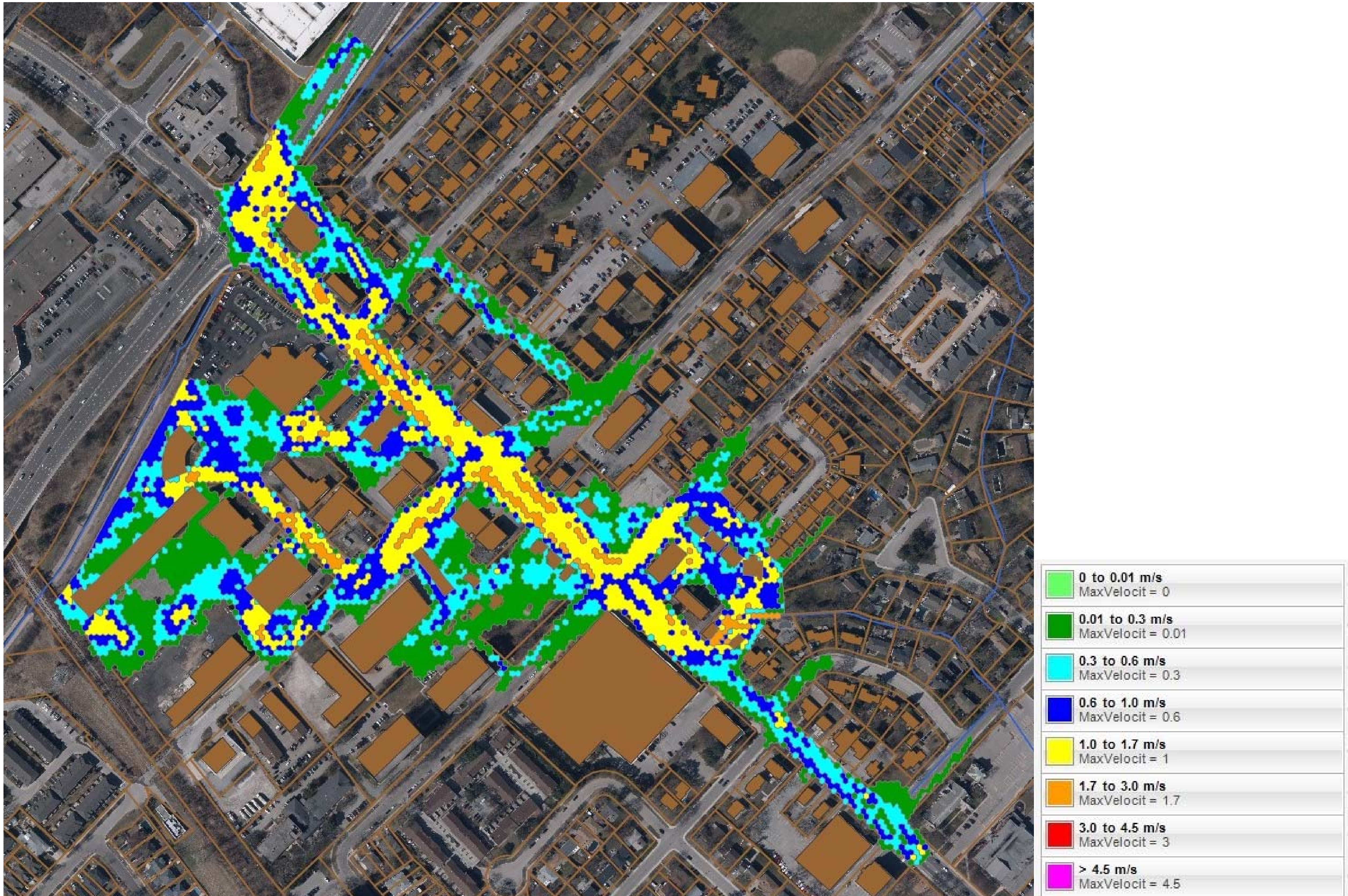

FIGURE C7: 2D MAXIMUM VELOCITY SUMMARY FOR HAGER-RAMBO DIVERSION CHANNEL SPILLS – REGIONAL STORM (SCENARIO 2)

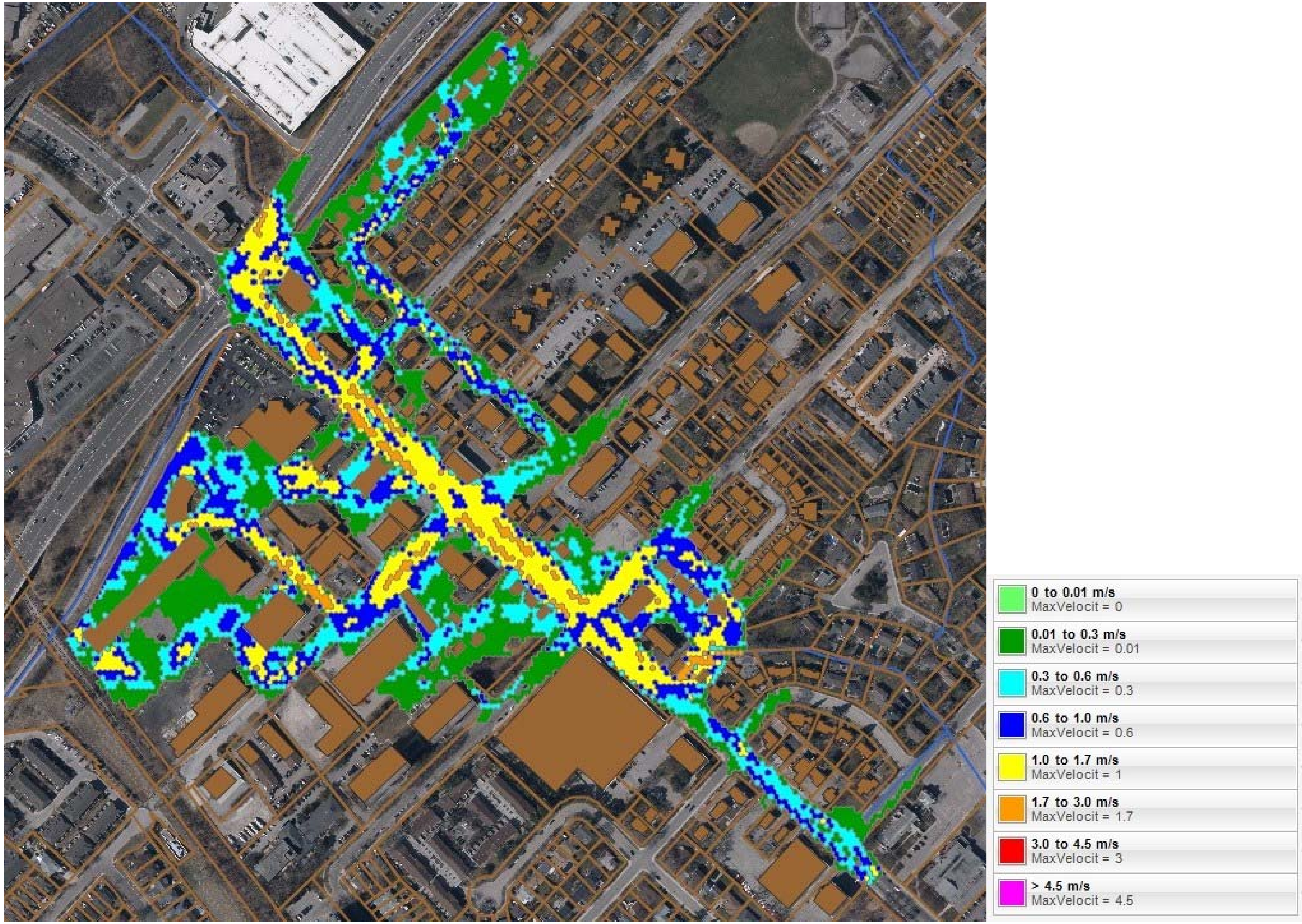

FIGURE C8: 2D MAXIMUM VELOCITY SUMMARY FOR HAGER-RAMBO DIVERSION CHANNEL SPILLS – REGIONAL STORM (SCENARIO 3)

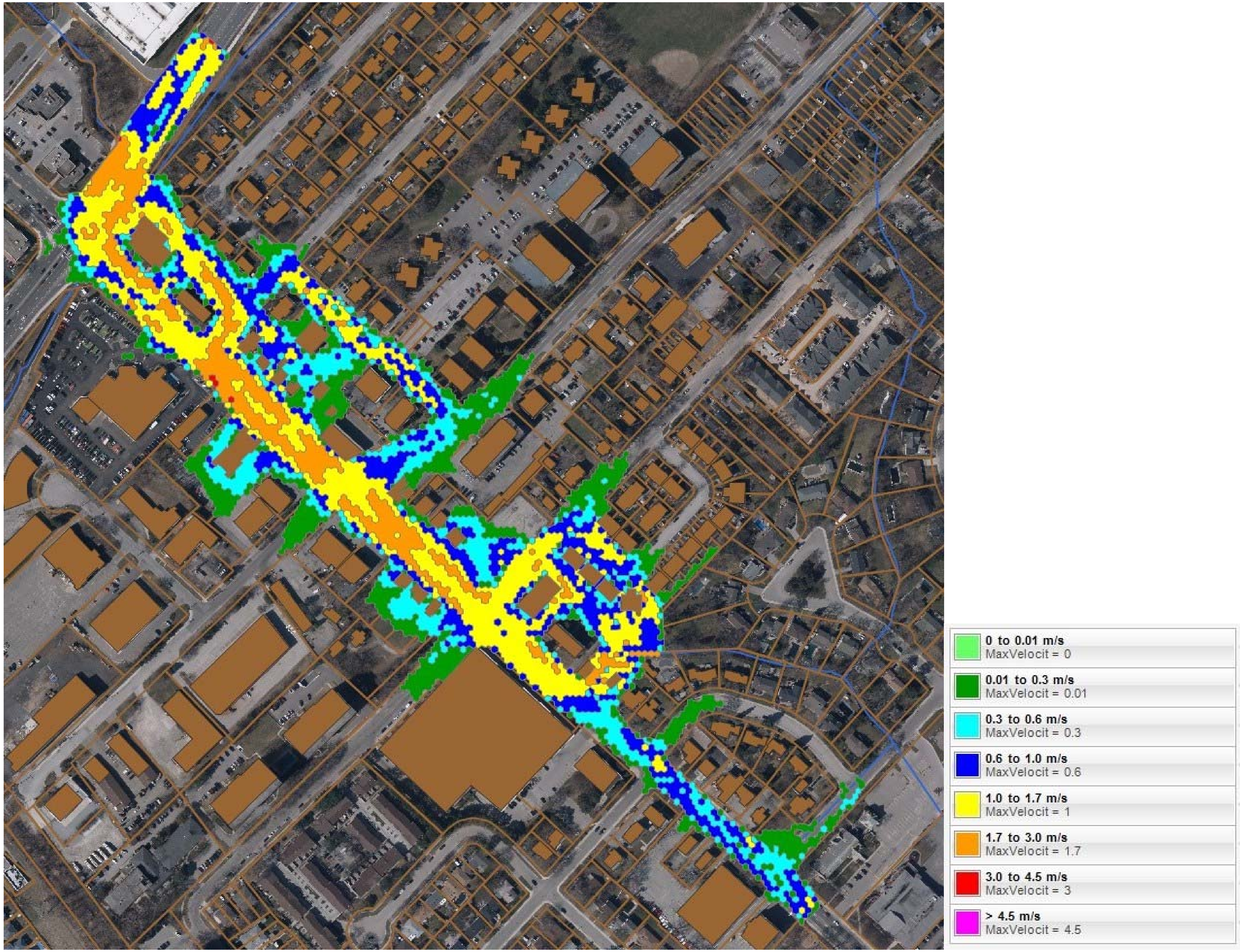

FIGURE C9: 2D MAXIMUM VELOCITY SUMMARY FOR HAGER-RAMBO DIVERSION CHANNEL SPILLS – REGIONAL STORM (SCENARIO 4)

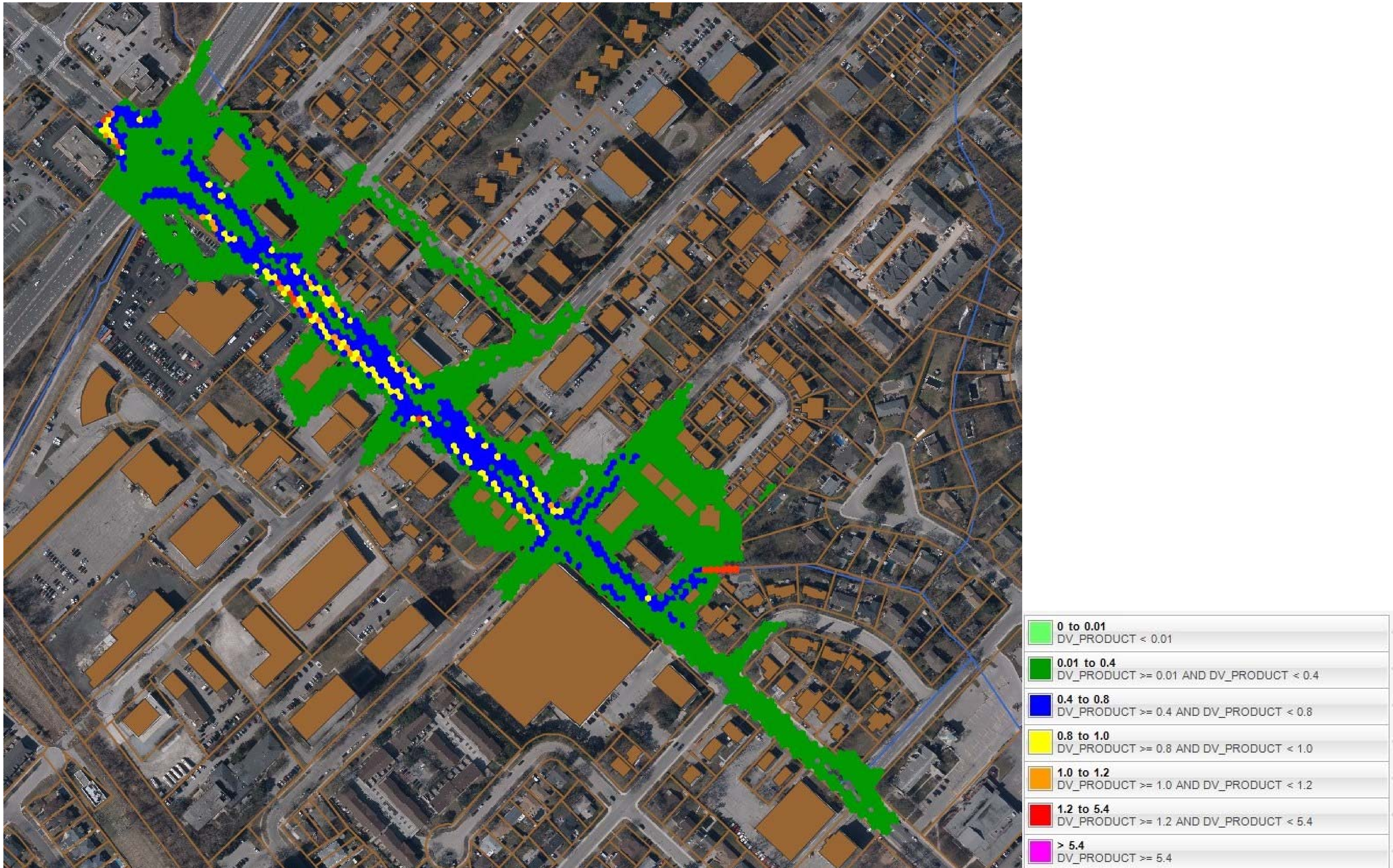

FIGURE C10: 2D MAXIMUM DEPTH X VELOCITY SUMMARY FOR HAGER-RAMBO DIVERSION CHANNEL SPILLS – REGIONAL STORM (SCENARIO 0)

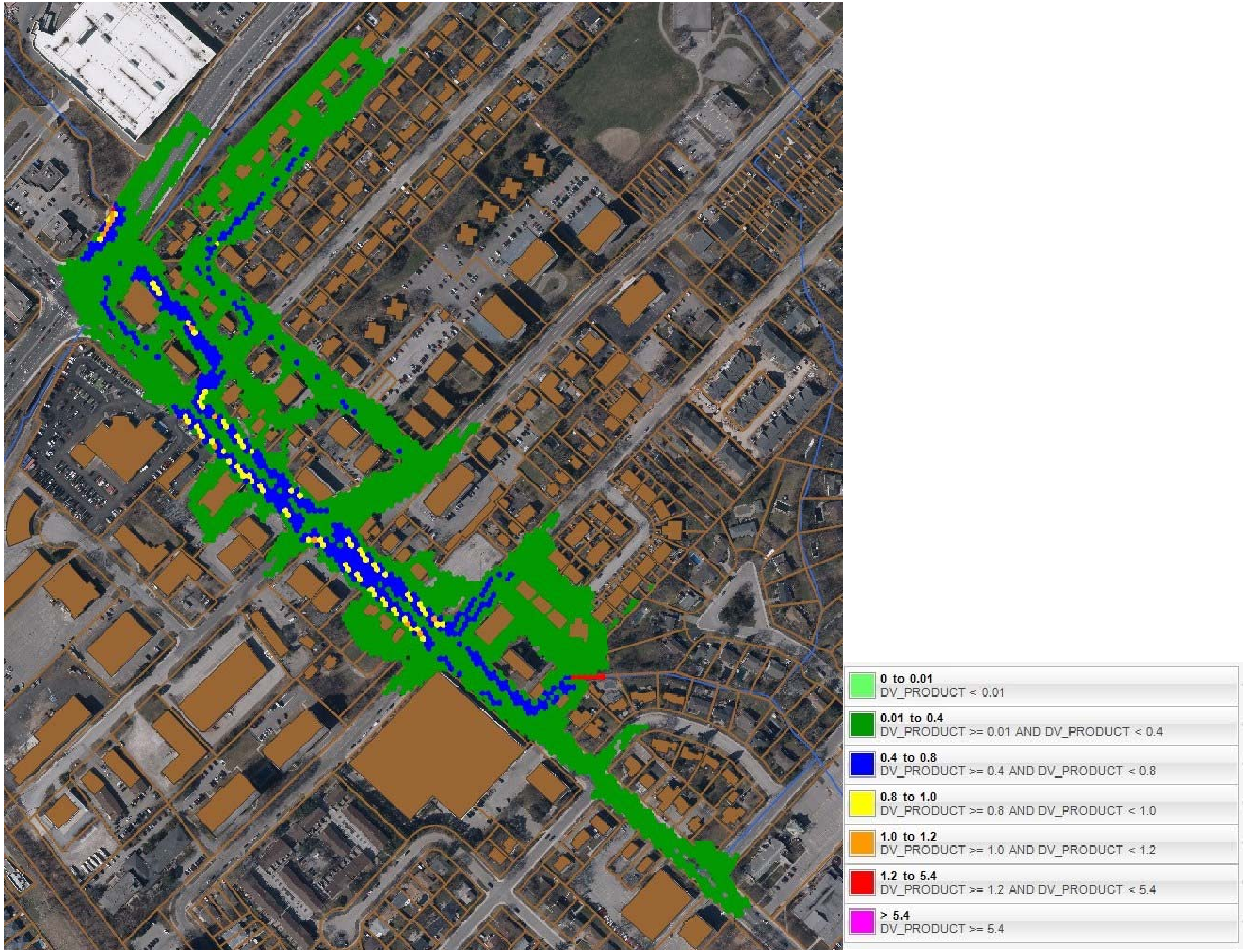

FIGURE C11: 2D MAXIMUM DEPTH X VELOCITY SUMMARY FOR HAGER-RAMBO DIVERSION CHANNEL SPILLS – REGIONAL STORM (SCENARIO 1)

FIGURE C12: 2D MAXIMUM DEPTH X VELOCITY SUMMARY FOR HAGER-RAMBO DIVERSION CHANNEL SPILLS – REGIONAL STORM (SCENARIO 2)

FIGURE C13: 2D MAXIMUM DEPTH X VELOCITY SUMMARY FOR HAGER-RAMBO DIVERSION CHANNEL SPILLS – REGIONAL STORM (SCENARIO 3)

FIGURE C14: 2D MAXIMUM DEPTH X VELOCITY SUMMARY FOR HAGER-RAMBO DIVERSION CHANNEL SPILLS – REGIONAL STORM (SCENARIO 4)

Appendix D

Hydrologic and Hydraulic Modelling Files (Downtown Area)

PHILIPS ENGINEERING

Memorandum

December 10, 2004
104138-26

TO: *Philip Kelly, P. Eng.*

FROM: *Aaron Brouwers / Ron Scheckenberger*

RE: *City of Burlington IDF Relationships and Design Storms*

As per our December 1, 2004 work plan, we have updated the IDF curves and the associated IDF parameters as well as regenerated the associated design storms based on the most current information.

SCS Design Storms

The 1994 Storm Drainage Design Manual (PPEL) developed the IDF relationships based on 27 years of rainfall intensity data (1964–1990) from the Royal Botanical Gardens gauge provided by the Atmospheric Environment Service (AES). The current assessment updates the previous and includes 35 years of data (1962–1996); most notably it includes the large events recorded in 1995. Table 1 compares AES 6 and 12 hour duration rainfall depths used in the 1994 and 2004 assessments; the depths have been used to develop the SCS Type II 6 and 12 hour design storms for the current assessment (ref. Tables 5 & 6, attached).

TABLE 1
COMPARISON OF AES RAINFALL DEPTHS (mm)

Duration (hours)	Frequency (Years)	1994	2004
6	100	85.9	92.4
6	5	48.7	51.3
12	100	92.1	103.6
12	5	55.2	58.9

The depths for the 100 year event show an 8 % and 12 % increase for the 6 and 12 hour durations, respectively. The 5 year event experiences lower relative increases of 5 % and 7 % for the 6 and 12 hour durations, respectively. The increases can largely be attributed to events experienced in 1995, which are the largest within the period of record. As would be expected, these large events have more influence on predicted rainfall depths for the less frequent events (i.e. 100 year).

IDF Parameters/Curve & Chicago Design Storms

Table 2 summarizes the AES IDF values for the subject gauge. Performing a three-parameter regression, using the SWMHYMO Chicago Storm function, provides initial A, B and C parameters, which define the IDF curve fit. These parameters have been refined through manual regression analysis and are presented in Table 3. The equation for the IDF curves is as follows:

$$i = \frac{A}{(t+B)^C}$$

where:
i = rainfall intensity (mm/hr)
t = storm duration (minutes)
A, B, C = defined in Table 2

The regression provides only a 'best fit' for the AES data, and when applying the IDF parameters provided, rainfall depths for a given frequency storm and duration will vary from actual statistically derived depths from

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E-mail address: admin@philipseng.com ♦ ♦ ♦ Website: www.philipseng.com

AES (ref. IDF curves attached). This is consistent with 1994 assessment and is necessary in order provide the standard set of three parameters (i.e. A, B &C). The ratio of the time to peak to the total storm duration, *r*, (used for calculating the Chicago distributions) has been set at 0.48, which is the recommended value for Ontario (Marsalek, 1978). This is consistent with the 1977 and 1994 assessments, which used a value of 0.46 for *r*. Table 4 presents a comparison of the current and previous IDF assessments; the 3 and 4 hour Chicago design storms are attached (ref. Table 7 & 8).

TABLE 2
INTENSITY-DURATION-FREQUENCY VALUES
ROYAL BOTANICAL GARDENS

Duration (min)	Rainfall Intensity (mm/hr)					
	2	5	10	25	50	100
5	94.6	122.2	140.6	163.7	180.9	198.0
10	68.3	89.2	103.2	120.8	133.8	146.7
15	55.7	74.3	86.7	102.2	113.8	125.2
30	36.2	47.2	54.5	63.7	70.5	77.3
60	22.1	27.6	31.2	35.7	39.1	42.5
120	14.3	18.6	21.4	25.0	27.7	30.4
360	6.0	8.5	10.2	12.3	13.9	15.4
720	3.5	4.9	5.8	7.0	7.8	8.6
1440	2.1	2.8	3.3	3.8	4.3	4.7

TABLE 3
IDF PARAMETERS – ROYAL BOTANICAL GARDENS

Parameter	2	5	10	25	50	100
A	595.5	688.2	748.0	867.0	947.3	1036.1
B	6.0	5.0	4.5	4.5	4.5	4.5
C	0.778	0.753	0.740	0.737	0.733	0.733

TABLE 4
COMPARISON OF IDF ASSESSMENTS

Item		1977	1994	2004
Source of Rainfall Data		Royal Botanical Gardens	Royal Botanical Gardens	Royal Botanical Gardens
Duration of Rainfall Record		12 Years	27 Years (1964-1990)	35 Years (1962-1996)
IDF Parameters				
5 Year	A B C	1111 7 0.857	697.4 5 0.764	688.2 5.0 0.753
100 Year	A B C	2377 9 0.886	1114.1 5 0.761	1036.1 4.5 0.733
Predicted Depth (mm)				
100 Year - 3 Hour Duration Depth		68.5	62.9	67.9
5 Year - 3 Hour Duration Depth		37.6	38.7	40.5
100 Year - 4 Hour Duration Depth		71.6	67.7	73.6
5 Year - 4 Hour Duration Depth		39.6	41.7	43.7

The results for the 100 year event show a 5 % and 6 % increase in rainfall depths for the 3 and 4 hour durations, respectively, when comparing the 2004 and 1994 assessments. The 5 year event experiences similar relative increases of 5 % for both the 3 and 4 hour durations, respectively.

We trust this satisfies your current requirements, should you require anything further please do not hesitate to contact our office. Once you have reviewed this information and are in agreement with its content, we will forward you digital copies of this memo and its attachments.

AB/RS/ab

Attach.

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PCSWMM model parameters

Subcatchment Name	Area (ha)	Flow Length (m)	Imperv. (%)	Curve Number	
				AMC II	AMC III
ST1	3.47	35.5	86.7	67	82.4
ST2	2.79	24.5	90.0	67	82.4
ST3	4.22	30.8	63.6	76.9	88.3
ST5	4.78	58.9	65.5	67	82.4
ST7	3.89	51.5	30.0	67	82.4
ST9	5.15	50.0	67.2	68.7	83.4
ST11	3.54	35.4	65.1	80.3	90.2
ST12	2.96	48.2	65.4	79.9	90
ST13	3.52	60.3	53.1	67	82.4
ST14	1.08	27.8	69.2	67	82.4
ST15	2.43	34.8	60.6	76.3	88
ST16	4.36	31.3	64.2	80.1	90.1
ST17	3.87	64.8	66.0	76.8	88.2
ST18	0.89	30.0	73.1	80.4	90.3
ST19	2.95	29.6	68.9	67	82.4
ST20	2.21	42.1	66.8	67	82.4
ST22	1.27	35.7	68.3	80.6	90.4
ST23	1.43	25.5	57.2	76.8	88.2
ST25	4.49	44.4	52.5	76	87.8
ST28	0.75	50.0	10.2	67	82.4
ST29	4.53	50.0	63.0	67	82.4
ST30	2.16	43.5	65.6	67	82.4
ST31	2.78	35.5	61.3	72.6	85.8
ST32	3.88	70.9	60.8	67	82.4
ST33	3.31	31.0	66.9	67	82.4
ST34	1.84	79.9	60.3	74.7	87
ST35	1.10	45.8	64.0	67	82.4
ST36	1.73	51.2	56.8	71.9	85.4
ST37	2.16	28.0	89.7	68.1	83.1
ST38	1.47	60.8	90.0	67	82.4
ST41	5.71	43.4	55.1	76.4	88
ST43	3.71	51.5	61.7	73.6	86.4
ST44	4.22	47.9	53.2	76.8	88.2
ST46	0.90	31.9	63.4	77.7	88.7
ST47	6.12	81.2	83.5	67	82.4
ST48	3.38	72.9	75.9	67	82.4
ST49	4.51	49.6	72.2	75.8	87.7
ST50	3.39	32.7	64.5	69.4	83.9
ST51	3.02	46.8	55.2	76.9	88.3
ST52	1.80	73.1	55.4	76.9	88.3
ST53	2.43	50.0	34.5	67	82.4
ST54	1.53	77.5	52.8	67.1	82.4
ST55	5.24	40.0	62.5	67.3	82.6
ST56	1.25	44.8	67.4	67.4	82.7
ST57	0.81	34.2	89.8	67	82.4
ST58	0.96	35.7	60.0	71.5	85.1
ST59	1.99	45.8	74.5	69.2	83.7
ST61	4.46	89.1	51.5	74.1	86.7
ST62	3.31	56.7	52.6	76.7	88.2
ST63	6.59	47.0	54.2	76.9	88.3
ST65	3.93	30.0	51.2	76.6	88.1
ST66	5.82	52.2	52.6	76.6	88.1
ST67	5.69	74.5	29.4	68.9	83.6
ST68	5.08	53.1	50.0	73.3	86.2
ST69	1.08	49.1	52.8	76.7	88.2
ST70	0.62	30.0	59.6	77.2	88.5
ST71	2.52	42.6	51.5	76.6	88.1
ST72	5.23	48.5	53.6	76.3	87.9
ST73	4.38	68.6	53.4	76.8	88.2
ST74	1.15	42.2	53.6	76.8	88.2
ST75	1.41	49.3	52.5	76.7	88.2
ST76	3.16	47.0	78.0	67.1	82.4
ST77	1.20	41.9	85.7	73.9	86.5
ST78	3.46	40.9	51.1	76.5	88.1
ST79	0.96	45.4	90.0	67	82.4
ST80	2.88	50.4	54.1	76.8	88.3
ST81	4.00	95.2	72.7	75	87.2
ST82	5.50	55.8	52.5	76	87.8
ST83	1.38	53.0	51.8	76.6	88.1
ST84	1.83	43.0	53.3	76.8	88.2
ST85	1.36	49.7	58.8	74.6	87
ST86	0.35	31.3	58.1	77.1	88.4
ST87	1.40	67.4	57.7	78.7	89.3
ST88	3.64	84.1	57.2	73.7	86.4
ST89	1.39	34.6	57.3	75.4	87.4
ST90	2.15	31.1	76.0	69.5	83.9
ST91	0.79	28.8	53.3	76.2	87.9
ST92	2.28	27.3	90.0	67	82.4
ST93	1.21	30.4	89.8	67	82.4
ST94	1.45	82.5	90.0	67	82.4
ST95	7.28	42.8	55.5	76.9	88.3

NOTE:
Depression storage of 1 mm for impervious areas and 5mm for pervious areas have been used in 100 Year and 5 year storms models.
Depression storage has been kept as 0mm for Regional storm models

Subcatchment Name	Area (ha)	Flow Length (m)	Imperv. (%)	Curve Number	
				AMC II	AMC III
ST96	2.74	41.3	48.6	76.3	88
ST97	3.82	33.3	57.1	76.9	88.3
ST98	0.81	50.0	10.1	67	82.4
ST99	4.11	55.5	50.8	76.1	87.8
ST100	0.70	48.5	10.8	67	82.4
ST101	2.75	30.9	62.8	75.6	87.6
ST102	2.35	40.0	40.0	75.3	87.4
ST103	1.27	25.6	61.6	77.4	88.6
ST104	2.17	30.0	82.8	67	82.4
ST105	3.17	63.4	56.8	67	82.4
ST106	1.30	30.0	88.2	67	82.4
ST107	1.69	27.1	90.0	67	82.4
ST109	0.75	25.2	90.0	67	82.4
ST110	3.40	58.9	66.2	67	82.4
ST111	5.41	160.0	34.1	67.2	82.5
ST112	0.81	37.5	53.9	72.3	85.6
ST113	1.32	40.3	69.1	77.5	88.6
ST114	1.17	40.0	47.5	76.2	87.9
ST115	2.62	39.6	51.5	76.6	88.1
ST116	1.11	50.0	55.0	76.9	88.3
ST118	0.84	40.0	48.5	76.3	87.9
ST119	1.72	37.1	89.9	67.3	82.6
ST120	0.94	29.3	63.8	77.4	88.6
ST121	1.00	30.0	70.8	70.8	84.7
ST122	2.99	34.9	54.2	75.3	87.4
ST123	3.07	35.4	65.0	69.4	83.9
ST124	1.98	42.5	68.5	73.7	86.5
ST125	1.03	27.9	72.1	77.1	88.4
ST126	1.13	30.5	66.1	80.5	90.3
ST127	2.16	30.9	68.5	80.6	90.4
ST128	2.14	26.0	65.8	80.5	90.3
ST129	2.76	29.1	61.5	71.1	84.9
ST130	2.16	38.5	64.1	69.5	84
ST131	2.79	33.4	48.5	69.4	83.9
ST132	2.91	88.2	52.1	76.7	88.2
ST133	2.95	72.3	50.3	76.5	88.1
ST135	3.70	65.2	36.1	67.6	82.8
ST136	4.95	77.9	20.8	67	82.4
ST137	4.01	80.1	60.0	67.1	82.5
ST138	0.99	26.0	65.8	76	87.8
ST139	3.60	30.0	60.4	70.4	84.5
ST140	1.94	39.5	64.5	67	82.4
ST141	1.77	30.0	51.9	70.3	84.4
ST142	1.31	24.7	54.4	67	82.4
ST143	2.15	33.4	59.5	72.2	85.6
ST144	0.98	33.9	70.8	67.2	82.5
ST145	0.89	27.4	60.9	77.3	88.5
ST146	3.79	37.0	53.8	76.7	88.2
ST147	1.77	43.0	47.5	75.9	87.7
ST148	1.41	27.3	56.1	76.9	88.3
ST149	2.15	50.9	10.1	67	82.4
ST150	1.61	44.6	56.4	74.7	87
ST151	2.35	32.0	86.9	67	82.4
ST152	4.22	50.0	90.0	67	82.4
ST153	1.65	36.4	63.1	77.4	88.6
ST154	0.56	50.0	39.3	75.1	87.3
ST155	1.94	25.5	52.3	76.6	88.1
ST156	1.65	88.8	52.5	76.6	88.1
ST158	0.40	30.0	64.2	77.4	88.6
ST159	1.06	50.0	37.1	74.9	87.1
ST160	1.54	37.3	67.7	74.8	87.1
ST161	1.31	45.2	69.6	67	82.4
ST162	2.05	98.3	54.3	76.9	88.3
ST163	2.41	30.4	77.5	76.9	88.3
ST166	1.56	71.7	90.0	67	82.4
ST167	0.75	30.0	56.4	72.4	85.7
ST169	1.08	31.5	90.0	67	82.4
ST170	1.14	50.0	53.7	76.7	88.2
ST172	0.66	36.3	69.2	67	82.4
ST173	1.34	68.0	67.7	67.1	82.4
ST174	2.99	40.0	63.8	67	82.4
ST177	0.39	30.0	89.3	67	82.4
ST178	0.75	30.0	73.7	77.3	88.5
ST60_2	4.04	47.2	74.1	67	82.4
ST60_4	2.85	30.0	89.9	67	82.4
ST8_1	1.34	32.4	63.4	70.3	84.4
ST8_2	7.59	32.4	58.3	73	86.1
ST10_1	2.50	31.2	56.3	77.7	88.8
ST10_3	3.08	31.2	57.9	76	87.8
ST10_2	5.18	31.2	54.8	77.6	88.7
ST10_5	1.86	31.2	67.7	80.6	90.4

NOTE:
Depression storage of 1 mm for impervious areas and 5mm for pervious areas have been used in 100 Year and 5 year storms models.
Depression storage has been kept as 0mm for Regional storm models

PCSWMM model parameters

Subcatchment Name	Area (ha)	Flow Length (m)	Imperv. (%)	Curve Number	
				AMC II	AMC III
ST21_1	0.90	28.3	60.8	77.3	88.5
ST21_3	1.08	28.3	59.9	77.3	88.5
ST21_4	0.53	28.3	58.2	77.2	88.4
ST4_1	0.95	36.0	28.9	67	82.4
ST4_2	2.51	36.0	54.3	69.5	83.9
ST108_1	0.98	32.7	90.0	67	82.4
ST108_2	2.20	32.7	89.5	67	82.4
ST134_1	0.96	31.4	67.0	77.2	88.4
ST134_2	0.53	31.4	40.0	75.3	87.4
ST64_1	0.20	39.0	85.7	73.2	86.2
ST64_2	2.12	39.0	73.6	67	82.4
S1	6.48	34.8	54.4	76.9	88.3
S2	3.97	52.2	46.7	72.5	85.8
ST60_1	2.08	25.6	64.4	79.6	89.8
ST60_5	0.31	25.6	90.0	67	82.4
ST26_2	1.85	200.0	10.1	67	82.4
S3	0.61	171.1	19.6	67	82.4
S4	1.95	177.3	10.3	67	82.4
ST6_1	0.77	36.3	44.6	67	82.4
ST6_2	1.51	36.3	76.4	67	82.4

NOTE:
Depression storage of 1 mm for impervious areas and 5mm for pervious areas have been used in 100 Year and 5 year storms models.
Depression storage has been kept as 0mm for Regional storm models

HEC-RAS Plan: Nov20

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Rambo5	R2_2	461.0511	100Y	5.25	90.94	92.14		92.20	0.003229	1.02	5.47	14.58	0.41
Rambo5	R2_2	461.0511	Regional	3.67	90.94	92.10		92.13	0.002107	0.78	4.82	11.96	0.33
Rambo5	R2_2	461.0511	Regional_WithSpi	3.67	90.94	92.10		92.13	0.002107	0.78	4.82	11.96	0.33
Rambo5	R2_2	453.63	100Y	5.25	90.68	92.16		92.18	0.000448	0.56	11.49	25.02	0.17
Rambo5	R2_2	453.63	Regional	3.67	90.68	92.11		92.12	0.000269	0.42	10.22	19.50	0.13
Rambo5	R2_2	453.63	Regional_WithSpi	3.67	90.68	92.11		92.12	0.000269	0.42	10.22	19.50	0.13
Rambo5	R2_2	446.2103	100Y	5.25	90.41	92.16	91.38	92.18	0.000374	0.56	13.76	49.48	0.15
Rambo5	R2_2	446.2103	Regional	3.67	90.41	92.11	91.18	92.11	0.000212	0.41	11.61	32.43	0.12
Rambo5	R2_2	446.2103	Regional_WithSpi	3.67	90.41	92.11	91.18	92.11	0.000212	0.41	11.61	32.43	0.12
Rambo5	R2_2	424.1243		Culvert									
Rambo5	R2_2	386.2102	100Y	5.25	90.31	91.84	91.36	92.05	0.004422	2.03	2.58	21.38	0.54
Rambo5	R2_2	386.2102	Regional	3.67	90.31	91.80	91.16	91.91	0.002333	1.46	2.52	19.58	0.39
Rambo5	R2_2	386.2102	Regional_WithSpi	3.67	90.31	91.80	91.16	91.91	0.002333	1.46	2.52	19.58	0.39
Rambo5	R2_2	376.210*	100Y	5.25	90.27	91.92		91.94	0.000753	0.67	10.30	24.40	0.21
Rambo5	R2_2	376.210*	Regional	3.67	90.27	91.84		91.86	0.000529	0.53	8.57	21.68	0.17
Rambo5	R2_2	376.210*	Regional_WithSpi	3.67	90.27	91.84		91.86	0.000529	0.53	8.57	21.68	0.17
Rambo5	R2_2	366.210*	100Y	5.25	90.22	91.89		91.92	0.001339	0.85	8.71	23.30	0.27
Rambo5	R2_2	366.210*	Regional	3.67	90.22	91.83		91.85	0.000951	0.69	7.20	20.70	0.22
Rambo5	R2_2	366.210*	Regional_WithSpi	3.67	90.22	91.83		91.85	0.000951	0.69	7.20	20.70	0.22
Rambo5	R2_2	356.2103	100Y	5.74	90.18	91.74	91.74	91.88	0.009697	1.83	4.54	17.93	0.62
Rambo5	R2_2	356.2103	Regional	4.30	90.18	91.46	91.46	91.79	0.028588	2.51	1.71	2.67	1.00
Rambo5	R2_2	356.2103	Regional_WithSpi	4.30	90.18	91.46	91.46	91.79	0.028588	2.51	1.71	2.67	1.00
Rambo5	R2_2	329.1303	100Y	5.74	89.94	91.18		91.24	0.002771	1.18	6.18	17.67	0.40
Rambo5	R2_2	329.1303	Regional	4.30	89.94	91.05		91.11	0.002744	1.06	4.59	9.22	0.39
Rambo5	R2_2	329.1303	Regional_WithSpi	4.30	89.94	91.06		91.11	0.002623	1.05	4.69	9.53	0.38
Rambo5	R2_2	299.1303	100Y	5.74	89.80	91.07		91.14	0.004677	1.19	4.82	7.87	0.49
Rambo5	R2_2	299.1303	Regional	4.30	89.80	90.94		91.00	0.004702	1.11	3.86	6.98	0.48
Rambo5	R2_2	299.1303	Regional_WithSpi	4.30	89.80	90.95		91.01	0.004292	1.08	3.99	7.11	0.46
Rambo5	R2_2	267.8488	100Y	5.74	89.62	90.86		90.97	0.006917	1.44	3.98	6.42	0.59
Rambo5	R2_2	267.8488	Regional	4.30	89.62	90.74		90.83	0.006586	1.32	3.26	5.81	0.56
Rambo5	R2_2	267.8488	Regional_WithSpi	4.30	89.62	90.80		90.87	0.004989	1.19	3.62	6.12	0.49
Rambo5	R2_2	237.8488	100Y	5.74	89.55	90.65		90.75	0.007319	1.40	4.11	7.45	0.60
Rambo5	R2_2	237.8488	Regional	4.30	89.55	90.53		90.62	0.007744	1.33	3.24	6.61	0.61
Rambo5	R2_2	237.8488	Regional_WithSpi	4.30	89.55	90.70		90.75	0.003135	0.95	4.56	9.80	0.40
Rambo5	R2_2	207.8487	100Y	5.74	89.10	90.45		90.54	0.006118	1.50	4.25	6.34	0.55
Rambo5	R2_2	207.8487	Regional	4.30	89.10	90.34		90.42	0.005274	1.33	3.61	5.83	0.51
Rambo5	R2_2	207.8487	Regional_WithSpi	4.30	89.10	90.63		90.67	0.002223	1.03	6.34	17.49	0.34
Rambo5	R2_2	177.8112	100Y	5.74	89.05	90.32		90.39	0.003774	1.28	5.24	10.03	0.46
Rambo5	R2_2	177.8112	Regional	4.30	89.05	90.24		90.29	0.003064	1.07	4.50	8.18	0.41
Rambo5	R2_2	177.8112	Regional_WithSpi	4.30	89.05	90.60		90.62	0.000927	0.78	10.05	31.07	0.24
Rambo5	R2_2	147.8487	100Y	5.74	88.91	90.18	89.87	90.27	0.003637	1.47	5.23	10.62	0.47
Rambo5	R2_2	147.8487	Regional	4.30	88.91	90.15	89.76	90.20	0.002390	1.16	4.86	9.86	0.38
Rambo5	R2_2	147.8487	Regional_WithSpi	4.30	88.91	90.59	89.76	90.60	0.000411	0.62	11.22	20.66	0.17
Rambo5	R2_2	117.8488	100Y	5.74	88.86	90.19	89.74	90.21	0.000782	0.75	15.02	42.57	0.22
Rambo5	R2_2	117.8488	Regional	4.30	88.86	90.15	89.64	90.16	0.000599	0.64	13.14	40.23	0.19
Rambo5	R2_2	117.8488	Regional_WithSpi	4.30	88.86	90.59	89.64	90.59	0.000048	0.23	35.80	59.08	0.06
Rambo5	R2_2	87.66842	100Y	5.74	88.62	90.18	89.48	90.19	0.000366	0.56	21.37	56.86	0.16
Rambo5	R2_2	87.66842	Regional	4.30	88.62	90.14	89.39	90.15	0.000271	0.47	18.99	54.77	0.13
Rambo5	R2_2	87.66842	Regional_WithSpi	4.30	88.62	90.59	89.39	90.59	0.000019	0.15	66.18	143.16	0.04
Rambo5	R2_2	58.71547	100Y	5.74	88.38	90.16	89.30	90.18	0.000451	0.68	16.91	46.14	0.18
Rambo5	R2_2	58.71547	Regional	4.30	88.38	90.13	89.19	90.14	0.000310	0.55	15.30	44.19	0.15
Rambo5	R2_2	58.71547	Regional_WithSpi	4.30	88.38	90.59	89.19	90.59	0.000016	0.15	81.30	207.60	0.03
Rambo5	R2_2	51.1528		Culvert									
Rambo5	R2_2	39.16559	100Y	5.74	88.35	90.13	89.36	90.17	0.000961	0.96	8.47	13.97	0.25
Rambo5	R2_2	39.16559	Regional	4.30	88.35	90.11	89.25	90.13	0.000567	0.73	8.15	12.83	0.19
Rambo5	R2_2	39.16559	Regional_WithSpi	4.30	88.35	90.59	89.25	90.59	0.000008	0.10	102.15	211.26	0.02
Rambo3	R1_3	612.0832	100Y	25.89	80.65	83.08	82.25	83.10	0.000194	0.48	38.98	35.95	0.10
Rambo3	R1_3	612.0832	Regional	20.23	80.65	82.98	82.19	83.00	0.000157	0.42	35.40	33.86	0.09
Rambo3	R1_3	612.0832	Regional_WithSpi	28.96	80.65	83.07	82.28	83.10	0.000252	0.54	38.47	35.58	0.12
Rambo3	R1_3	582.0831	100Y	25.89	80.43	83.09	82.06	83.10	0.000060	0.32	69.93	59.97	0.07
Rambo3	R1_3	582.0831	Regional	20.23	80.43	82.98	81.74	82.99	0.000049	0.28	63.67	58.41	0.06
Rambo3	R1_3	582.0831	Regional_WithSpi	28.96	80.43	83.08	82.09	83.09	0.000078	0.37	69.22	59.80	0.08

HEC-RAS Plan: Nov20 (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Rambo3	R1_3	552.0832	100Y	35.09	79.86	83.07		83.09	0.000170	0.58	55.49	46.06	0.11
Rambo3	R1_3	552.0832	Regional	26.70	79.86	82.97		82.99	0.000126	0.48	50.96	44.41	0.09
Rambo3	R1_3	552.0832	Regional_WithSpi	34.25	79.86	83.06		83.08	0.000165	0.57	55.06	45.91	0.11
Rambo3	R1_3	538.23	100Y	35.09	79.68	83.07		83.09	0.000179	0.66	54.87	51.95	0.12
Rambo3	R1_3	538.23	Regional	26.70	79.68	82.97		82.98	0.000129	0.54	50.02	46.26	0.10
Rambo3	R1_3	538.23	Regional_WithSpi	34.25	79.68	83.06		83.08	0.000174	0.65	54.40	51.41	0.12
Rambo3	R1_3	524.3676	100Y	35.09	79.50	83.06	82.35	83.09	0.000343	1.00	49.44	72.15	0.18
Rambo3	R1_3	524.3676	Regional	26.70	79.50	82.96	81.84	82.98	0.000254	0.85	42.99	59.16	0.15
Rambo3	R1_3	524.3676	Regional_WithSpi	34.25	79.50	83.05	82.35	83.08	0.000338	0.99	48.78	71.55	0.17
Rambo3	R1_3	506.4043		Culvert									
Rambo3	R1_3	498.3496	100Y	35.09	79.07	82.99	81.50	83.01	0.000319	0.73	61.01	105.08	0.13
Rambo3	R1_3	498.3496	Regional	26.70	79.07	82.89	81.10	82.91	0.000284	0.67	50.87	94.80	0.12
Rambo3	R1_3	498.3496	Regional_WithSpi	34.25	79.07	82.98	81.47	83.00	0.000315	0.72	60.05	103.73	0.13
Rambo3	R1_3	497.733	100Y	35.09	79.06	82.99		83.01	0.000310	0.72	60.91	101.78	0.12
Rambo3	R1_3	497.733	Regional	26.70	79.06	82.89		82.91	0.000273	0.66	51.00	92.96	0.12
Rambo3	R1_3	497.733	Regional_WithSpi	34.25	79.06	82.98		83.00	0.000307	0.72	59.98	100.60	0.12
Rambo3	R1_3	488.54*	100Y	35.09	78.90	82.98		83.01	0.000231	0.78	58.04	76.86	0.13
Rambo3	R1_3	488.54*	Regional	26.70	78.90	82.89		82.90	0.000174	0.67	50.90	69.44	0.11
Rambo3	R1_3	488.54*	Regional_WithSpi	34.25	78.90	82.97		83.00	0.000225	0.77	57.37	76.20	0.13
Rambo3	R1_3	479.3439	100Y	35.09	78.75	82.98	80.20	83.00	0.000193	0.71	61.75	73.79	0.11
Rambo3	R1_3	479.3439	Regional	26.70	78.75	82.88	79.96	82.90	0.000142	0.60	54.90	66.81	0.10
Rambo3	R1_3	479.3439	Regional_WithSpi	34.25	78.75	82.97	80.18	82.99	0.000188	0.70	61.11	73.19	0.11
Rambo3	R1_3	462.2752		Bridge									
Rambo3	R1_3	449.5095	100Y	35.09	78.25	79.77	79.70	80.43	0.011839	3.60	9.75	17.60	0.93
Rambo3	R1_3	449.5095	Regional	26.70	78.25	79.46	79.46	80.07	0.014663	3.44	7.76	15.28	1.00
Rambo3	R1_3	449.5095	Regional_WithSpi	34.25	78.25	79.68	79.68	80.39	0.013887	3.74	9.16	16.73	1.00
Rambo3	R1_3	419.5095	100Y	35.09	77.74	79.87		80.04	0.002662	1.93	25.03	23.66	0.45
Rambo3	R1_3	419.5095	Regional	26.70	77.74	79.38		79.60	0.004942	2.15	14.56	16.64	0.58
Rambo3	R1_3	419.5095	Regional_WithSpi	34.25	77.74	79.58		79.84	0.004988	2.36	18.28	20.88	0.59
Rambo3	R1_3	389.5095	100Y	35.44	77.24	79.84		79.96	0.001634	1.55	23.52	13.06	0.34
Rambo3	R1_3	389.5095	Regional	27.09	77.24	79.32		79.45	0.002495	1.58	17.21	11.69	0.41
Rambo3	R1_3	389.5095	Regional_WithSpi	34.43	77.24	79.52		79.68	0.002691	1.78	19.58	12.18	0.43
Rambo3	R1_3	359.2253	100Y	35.44	77.11	79.78		79.91	0.001523	1.67	26.79	17.04	0.35
Rambo3	R1_3	359.2253	Regional	27.09	77.11	79.23		79.38	0.002344	1.74	18.17	14.38	0.41
Rambo3	R1_3	359.2253	Regional_WithSpi	34.43	77.11	79.41		79.60	0.002672	1.98	20.87	15.26	0.45
Rambo3	R1_3	329.2253	100Y	35.44	76.97	79.74		79.86	0.001381	1.55	25.68	17.89	0.32
Rambo3	R1_3	329.2253	Regional	27.09	76.97	79.18		79.30	0.002080	1.58	17.78	11.78	0.38
Rambo3	R1_3	329.2253	Regional_WithSpi	34.43	76.97	79.35		79.52	0.002457	1.83	19.85	12.41	0.42
Rambo3	R1_3	299.2253	100Y	35.44	76.63	79.75		79.82	0.000644	1.18	39.30	22.86	0.23
Rambo3	R1_3	299.2253	Regional	27.09	76.63	79.17		79.25	0.000938	1.22	26.83	20.26	0.27
Rambo3	R1_3	299.2253	Regional_WithSpi	34.43	76.63	79.35		79.45	0.001120	1.40	30.50	21.06	0.29
Rambo3	R1_3	269.2253	100Y	35.44	76.23	79.75		79.80	0.000439	1.00	38.68	17.04	0.19
Rambo3	R1_3	269.2253	Regional	27.09	76.23	79.17		79.22	0.000565	0.97	29.20	15.64	0.21
Rambo3	R1_3	269.2253	Regional_WithSpi	34.43	76.23	79.35		79.41	0.000705	1.14	32.00	16.21	0.23
Rambo3	R1_3	239.2254	100Y	35.44	76.19	79.73		79.78	0.000509	1.07	38.16	17.62	0.20
Rambo3	R1_3	239.2254	Regional	27.09	76.19	79.14		79.20	0.000660	1.05	28.36	16.04	0.22
Rambo3	R1_3	239.2254	Regional_WithSpi	34.43	76.19	79.31		79.39	0.000832	1.24	31.09	16.48	0.25
Rambo3	R1_3	208.9721	100Y	44.86	75.99	79.75		79.76	0.000099	0.50	109.41	76.81	0.09
Rambo3	R1_3	208.9721	Regional	31.95	75.99	79.16		79.18	0.000222	0.64	65.11	70.09	0.13
Rambo3	R1_3	208.9721	Regional_WithSpi	37.55	75.99	79.34		79.36	0.000189	0.62	78.48	74.03	0.12
Rambo3	R1_3	179.2253	100Y	44.86	75.69	79.75		79.76	0.000072	0.44	126.96	101.78	0.08
Rambo3	R1_3	179.2253	Regional	31.95	75.69	79.16		79.17	0.000132	0.53	77.22	69.33	0.10
Rambo3	R1_3	179.2253	Regional_WithSpi	37.55	75.69	79.34		79.35	0.000119	0.52	90.27	76.20	0.10
Rambo3	R1_3	149.1544	100Y	44.86	75.52	79.75	78.44	79.76	0.000058	0.44	158.62	114.25	0.07
Rambo3	R1_3	149.1544	Regional	31.95	75.52	79.16	77.86	79.17	0.000109	0.53	99.76	87.48	0.10
Rambo3	R1_3	149.1544	Regional_WithSpi	37.55	75.52	79.34	78.11	79.35	0.000095	0.52	116.21	91.40	0.09
Rambo3	R1_3	120.4764		Culvert									
Rambo3	R1_3	89.22531	100Y	44.86	75.50	78.34	78.34	79.75	0.011070	5.27	8.51	19.82	1.00
Rambo3	R1_3	89.22531	Regional	31.95	75.50	77.76	77.76	78.89	0.011936	4.71	6.79	15.39	1.00
Rambo3	R1_3	89.22531	Regional_WithSpi	37.55	75.50	78.02	78.02	79.28	0.011498	4.97	7.56	16.94	1.00
Rambo3	R1_3	52.39929	100Y	44.86	75.06	76.91	76.91	77.50	0.017327	3.39	13.23	11.34	1.00
Rambo3	R1_3	52.39929	Regional	31.95	75.06	76.61	76.61	77.13	0.018237	3.19	10.02	9.80	1.01

HEC-RAS Plan: Nov20 (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Rambo3	R1_3	52.39929	Regional_WithSpi	37.55	75.06	76.75	76.75	77.30	0.017903	3.29	11.41	10.49	1.01
Rambo3	R1_3	29.22528	100Y	44.86	74.65	76.42	76.37	76.96	0.016014	3.26	13.74	11.57	0.96
Rambo3	R1_3	29.22528	Regional	31.95	74.65	76.13	76.08	76.59	0.016017	3.00	10.66	10.14	0.93
Rambo3	R1_3	29.22528	Regional_WithSpi	37.55	74.65	76.26	76.21	76.76	0.016006	3.13	12.01	10.74	0.94
Rambo2	R1_2	646.5477	100Y	16.58	87.76	90.13	89.14	90.14	0.000273	0.61	43.11	47.57	0.14
Rambo2	R1_2	646.5477	Regional	13.79	87.76	90.11	89.04	90.12	0.000205	0.52	41.87	47.20	0.12
Rambo2	R1_2	646.5477	Regional_WithSpi	23.30	87.76	90.58	89.43	90.59	0.000169	0.55	65.55	53.38	0.11
Rambo2	R1_2	631.28	100Y	16.58	87.47	90.12	88.97	90.14	0.000322	0.66	37.60	40.65	0.15
Rambo2	R1_2	631.28	Regional	13.79	87.47	90.10	88.86	90.11	0.000237	0.56	36.65	40.10	0.13
Rambo2	R1_2	631.28	Regional_WithSpi	23.30	87.47	90.58	89.35	90.58	0.000106	0.43	104.41	128.87	0.09
Rambo2	R1_2	616.0219	100Y	16.58	87.17	90.12	89.40	90.13	0.000336	0.68	36.00	40.35	0.15
Rambo2	R1_2	616.0219	Regional	13.79	87.17	90.10	89.15	90.11	0.000242	0.57	35.16	38.89	0.13
Rambo2	R1_2	616.0219	Regional_WithSpi	23.30	87.17	90.58	89.81	90.58	0.000104	0.43	99.90	115.90	0.09
Rambo2	R1_2	582.2874		Culvert									
Rambo2	R1_2	435.2496	100Y	16.58	86.40	88.69	88.69	89.76	0.013985	4.58	3.62	30.66	1.00
Rambo2	R1_2	435.2496	Regional	13.79	86.40	88.44	88.44	89.39	0.014537	4.31	3.20	23.54	1.00
Rambo2	R1_2	435.2496	Regional_WithSpi	23.30	86.40	89.24	89.24	90.58	0.012932	5.13	4.54	93.89	1.00
Rambo2	R1_2	420.46	100Y	16.58	86.32	88.45		88.50	0.001711	1.08	16.24	25.00	0.32
Rambo2	R1_2	420.46	Regional	13.79	86.32	88.36		88.41	0.001668	1.01	14.30	21.77	0.32
Rambo2	R1_2	420.46	Regional_WithSpi	23.30	86.32	88.57		88.65	0.002038	1.26	19.79	32.58	0.36
Rambo2	R1_2	405.6775	100Y	18.56	86.24	88.38		88.46	0.003297	1.27	14.75	19.69	0.43
Rambo2	R1_2	405.6775	Regional	14.60	86.24	88.32		88.38	0.002646	1.08	13.59	19.24	0.38
Rambo2	R1_2	405.6775	Regional_WithSpi	24.34	86.24	88.49		88.60	0.003678	1.45	17.19	26.66	0.47
Rambo2	R1_2	375.2496	100Y	18.56	86.15	88.33		88.38	0.001617	0.98	19.63	29.23	0.31
Rambo2	R1_2	375.2496	Regional	14.60	86.15	88.29		88.32	0.001208	0.82	18.26	26.78	0.27
Rambo2	R1_2	375.2496	Regional_WithSpi	24.34	86.15	88.44		88.51	0.001878	1.13	23.47	45.92	0.34
Rambo2	R1_2	348.247	100Y	18.56	86.08	88.30	87.85	88.35	0.001174	0.94	21.73	38.32	0.27
Rambo2	R1_2	348.247	Regional	14.60	86.08	88.26	87.75	88.29	0.000875	0.79	20.17	36.34	0.23
Rambo2	R1_2	348.247	Regional_WithSpi	24.34	86.08	88.41	87.84	88.46	0.001322	1.05	26.20	51.33	0.29
Rambo2	R1_2	334.5936		Culvert									
Rambo2	R1_2	313.3015	100Y	18.56	86.01	87.98	87.76	88.06	0.003297	1.23	15.97	33.33	0.43
Rambo2	R1_2	313.3015	Regional	14.60	86.01	87.53	87.53	88.20	0.016992	3.63	4.03	12.43	1.00
Rambo2	R1_2	313.3015	Regional_WithSpi	24.34	86.01	88.13	87.81	88.20	0.002791	1.26	21.57	43.08	0.41
Rambo2	R1_2	283.3015	100Y	18.56	85.98	87.95	87.21	87.99	0.001067	0.99	26.06	36.52	0.27
Rambo2	R1_2	283.3015	Regional	14.60	85.98	87.76	87.10	87.80	0.001165	0.93	20.05	28.48	0.27
Rambo2	R1_2	283.3015	Regional_WithSpi	24.34	85.98	88.08	87.34	88.14	0.001249	1.14	31.55	43.49	0.30
Rambo2	R1_2	253.3015	100Y	22.01	85.87	87.59	87.42	87.85	0.009343	2.27	10.16	14.79	0.74
Rambo2	R1_2	253.3015	Regional	16.63	85.87	87.49		87.68	0.007589	1.91	8.86	12.86	0.66
Rambo2	R1_2	253.3015	Regional_WithSpi	26.34	85.87	87.65	87.53	87.97	0.010867	2.55	11.06	16.00	0.81
Rambo2	R1_2	222.9477	100Y	22.01	85.78	87.43	87.24	87.57	0.006624	1.70	15.61	36.16	0.61
Rambo2	R1_2	222.9477	Regional	16.63	85.78	87.27	87.13	87.42	0.009180	1.71	9.85	18.02	0.70
Rambo2	R1_2	222.9477	Regional_WithSpi	26.34	85.78	87.56	87.35	87.69	0.005157	1.66	20.41	37.46	0.56
Rambo2	R1_2	193.3015	100Y	22.01	85.29	87.37		87.45	0.002296	1.36	22.77	30.23	0.39
Rambo2	R1_2	193.3015	Regional	16.63	85.29	87.19		87.27	0.002428	1.27	17.66	28.43	0.39
Rambo2	R1_2	193.3015	Regional_WithSpi	26.34	85.29	87.50		87.58	0.002160	1.41	26.90	31.60	0.38
Rambo2	R1_2	156.0717	100Y	22.01	85.25	87.01	86.86	87.28	0.008524	2.34	11.21	19.47	0.72
Rambo2	R1_2	156.0717	Regional	16.63	85.25	86.92		87.11	0.006772	1.96	9.55	16.96	0.63
Rambo2	R1_2	156.0717	Regional_WithSpi	26.34	85.25	87.02	86.98	87.40	0.011781	2.76	11.41	19.74	0.85
Rambo2	R1_2	120.5211	100Y	22.01	85.04	86.99		87.08	0.002525	1.77	22.88	50.70	0.43
Rambo2	R1_2	120.5211	Regional	16.63	85.04	86.77		86.92	0.004084	2.05	14.32	31.05	0.54
Rambo2	R1_2	120.5211	Regional_WithSpi	26.34	85.04	87.09		87.16	0.002072	1.66	28.40	58.64	0.39
Rambo2	R1_2	92.92934	100Y	22.01	84.76	86.76	86.43	86.97	0.005084	2.20	13.67	26.95	0.57
Rambo2	R1_2	92.92934	Regional	16.63	84.76	86.55	86.23	86.77	0.006016	2.16	9.16	15.68	0.61
Rambo2	R1_2	92.92934	Regional_WithSpi	26.34	84.76	86.86	86.80	87.07	0.004859	2.25	16.69	32.83	0.57
Rambo2	R1_2	62.92931	100Y	22.01	84.46	86.33	86.33	86.74	0.010530	3.05	10.13	13.75	0.82
Rambo2	R1_2	62.92931	Regional	16.63	84.46	86.06	86.06	86.49	0.013628	3.03	7.06	10.19	0.90
Rambo2	R1_2	62.92931	Regional_WithSpi	26.34	84.46	86.57	86.57	86.88	0.007108	2.79	14.33	23.51	0.69
Rambo2	R1_2	32.92926	100Y	22.01	84.16	85.72	85.57	86.06	0.009017	2.79	11.26	13.58	0.78
Rambo2	R1_2	32.92926	Regional	16.63	84.16	85.47	85.41	85.81	0.011300	2.72	8.17	11.57	0.84
Rambo2	R1_2	32.92926	Regional_WithSpi	26.34	84.16	85.92	85.72	86.23	0.007280	2.75	14.69	23.39	0.72
Rambo2	R1_2	2.929314	100Y	22.01	83.79	85.47	85.10	85.79	0.008656	2.50	8.95	7.43	0.65
Rambo2	R1_2	2.929314	Regional	16.63	83.79	85.20	84.91	85.48	0.009722	2.34	7.11	5.80	0.67

HEC-RAS Plan: Nov20 (Continued)

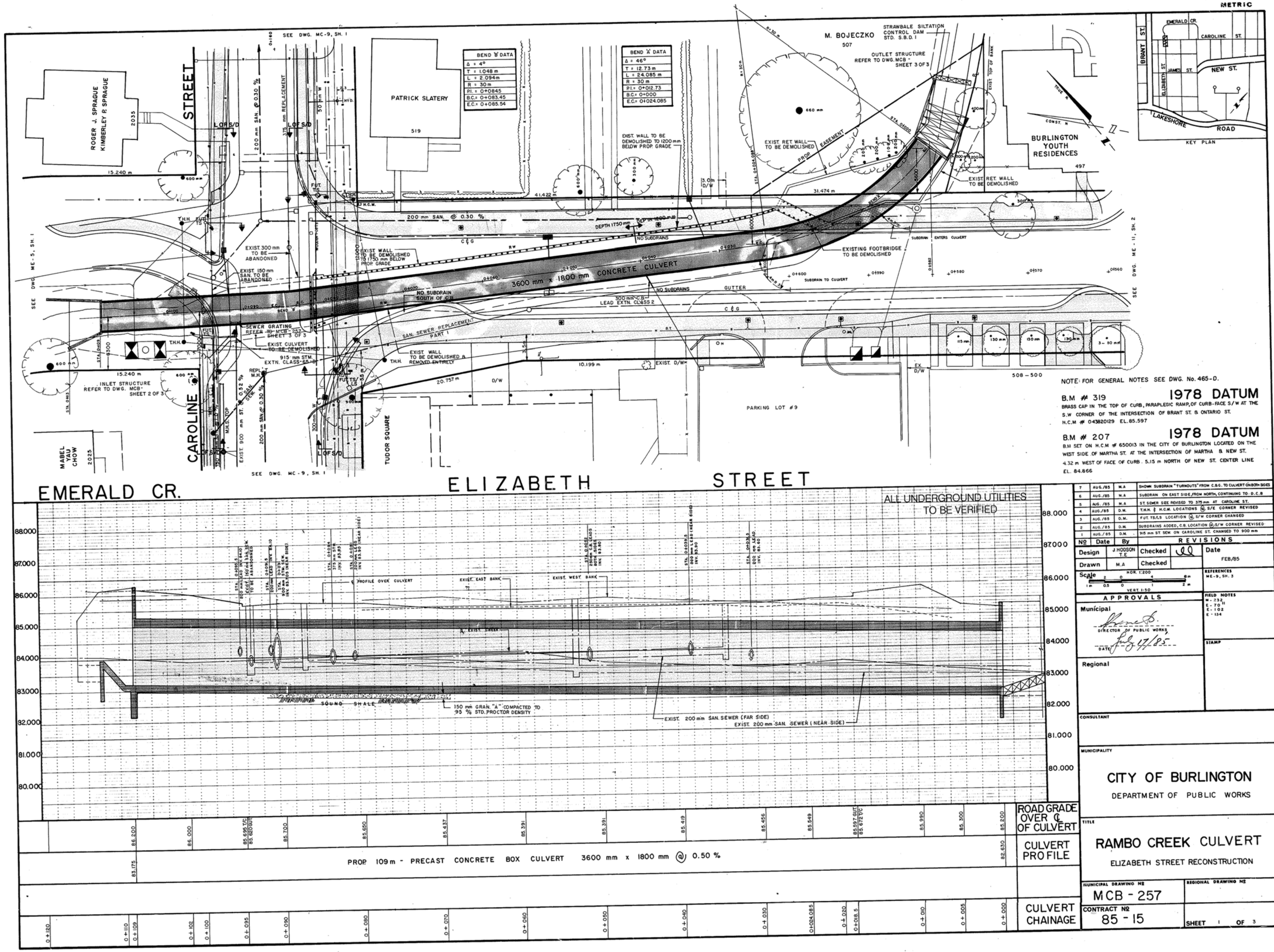
River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Rambo2	R1_2	2.929314	Regional_WithSpi	26.34	83.79	85.70	85.25	86.01	0.007262	2.51	10.90	10.42	0.61
Rambo1	R1_1	174.8044	100Y	3.00	89.02	90.20	89.83	90.25	0.002958	1.01	3.10	5.22	0.39
Rambo1	R1_1	174.8044	Regional	1.14	89.02	90.13	89.58	90.14	0.000620	0.43	2.74	4.92	0.17
Rambo1	R1_1	174.8044	Regional_WithSpi	21.14	89.02	90.93	90.93	91.07	0.004732	2.07	21.40	70.52	0.55
Rambo1	R1_1	144.8044	100Y	3.00	88.77	90.16		90.18	0.001267	0.66	4.54	6.52	0.25
Rambo1	R1_1	144.8044	Regional	1.14	88.77	90.12		90.12	0.000215	0.27	4.28	6.33	0.10
Rambo1	R1_1	144.8044	Regional_WithSpi	21.14	88.77	90.68		90.75	0.003334	1.51	22.15	47.48	0.45
Rambo1	R1_1	114.8044	100Y	3.00	88.54	90.15	89.31	90.16	0.000351	0.48	6.87	8.42	0.15
Rambo1	R1_1	114.8044	Regional	1.14	88.54	90.12	89.06	90.12	0.000057	0.19	6.59	8.26	0.06
Rambo1	R1_1	114.8044	Regional_WithSpi	21.14	88.54	90.66	90.23	90.69	0.001004	1.05	38.98	75.39	0.26
Rambo1	R1_1	84.80438	100Y	3.00	88.52	90.15	89.18	90.15	0.000144	0.32	11.88	19.98	0.09
Rambo1	R1_1	84.80438	Regional	1.14	88.52	90.12	88.96	90.12	0.000024	0.13	11.26	19.48	0.04
Rambo1	R1_1	84.80438	Regional_WithSpi	21.14	88.52	90.58	90.06	90.65	0.001624	1.31	21.85	26.53	0.34
Rambo1	R1_1	54.92922	100Y	3.00	88.41	90.15	89.14	90.15	0.000086	0.26	19.31	42.48	0.07
Rambo1	R1_1	54.92922	Regional	1.14	88.41	90.12	88.90	90.12	0.000015	0.10	18.05	41.20	0.03
Rambo1	R1_1	54.92922	Regional_WithSpi	21.14	88.41	90.59	90.04	90.61	0.000485	0.75	56.19	103.16	0.18
Rambo1	R1_1	24.60143	100Y	3.00	88.01	90.15	88.86	90.15	0.000035	0.17	19.57	27.67	0.05
Rambo1	R1_1	24.60143	Regional	1.14	88.01	90.12	88.60	90.12	0.000006	0.06	18.91	20.62	0.02
Rambo1	R1_1	24.60143	Regional_WithSpi	21.14	88.01	90.58	89.55	90.59	0.000334	0.62	57.89	121.52	0.16
Hager2	H1_2	943.1819	100Y	6.80	87.58	88.91		89.00	0.004653	1.39	5.51	10.52	0.49
Hager2	H1_2	943.1819	Regional	4.59	87.58	88.77		88.84	0.004257	1.17	4.19	8.61	0.45
Hager2	H1_2	943.1819	Regional_WithSpi	4.59	87.58	88.77		88.84	0.004257	1.17	4.19	8.61	0.45
Hager2	H1_2	902.2523	100Y	6.80	87.49	88.75	88.43	88.83	0.003506	1.33	7.64	39.22	0.43
Hager2	H1_2	902.2523	Regional	4.59	87.49	88.62		88.69	0.003090	1.14	4.62	11.73	0.40
Hager2	H1_2	902.2523	Regional_WithSpi	4.59	87.49	88.62		88.69	0.003090	1.14	4.62	11.73	0.40
Hager2	H1_2	871.6326	100Y	6.80	87.42	88.73		88.75	0.001320	0.75	10.59	33.72	0.27
Hager2	H1_2	871.6326	Regional	4.59	87.42	88.60		88.62	0.001182	0.63	7.27	10.99	0.25
Hager2	H1_2	871.6326	Regional_WithSpi	4.59	87.42	88.60		88.62	0.001182	0.63	7.27	10.99	0.25
Hager2	H1_2	842.2523	100Y	6.80	87.31	88.69		88.71	0.001318	0.78	11.74	39.64	0.27
Hager2	H1_2	842.2523	Regional	4.59	87.31	88.56		88.58	0.001313	0.70	7.50	25.60	0.27
Hager2	H1_2	842.2523	Regional_WithSpi	4.59	87.31	88.56		88.58	0.001313	0.70	7.50	25.60	0.27
Hager2	H1_2	812.2523	100Y	6.80	87.21	88.64		88.67	0.001347	0.88	11.18	32.10	0.28
Hager2	H1_2	812.2523	Regional	4.59	87.21	88.52		88.54	0.001181	0.75	7.81	22.88	0.25
Hager2	H1_2	812.2523	Regional_WithSpi	4.59	87.21	88.52		88.54	0.001181	0.75	7.81	22.88	0.25
Hager2	H1_2	768.2065	100Y	6.80	87.05	88.58	88.25	88.61	0.001298	0.87	11.20	31.72	0.27
Hager2	H1_2	768.2065	Regional	4.59	87.05	88.47	88.00	88.49	0.001110	0.75	7.92	26.28	0.25
Hager2	H1_2	768.2065	Regional_WithSpi	4.59	87.05	88.47	88.00	88.49	0.001110	0.75	7.92	26.28	0.25
Hager2	H1_2	755.2369		Culvert									
Hager2	H1_2	746.0177	100Y	6.80	86.96	88.52	88.16	88.57	0.002069	1.10	10.32	41.46	0.32
Hager2	H1_2	746.0177	Regional	4.59	86.96	88.26	87.89	88.33	0.003202	1.17	4.61	8.93	0.38
Hager2	H1_2	746.0177	Regional_WithSpi	4.59	86.96	88.26	87.89	88.33	0.003202	1.17	4.61	8.93	0.38
Hager2	H1_2	722.2523	100Y	6.80	86.78	88.10	88.01	88.38	0.019086	2.38	2.86	3.76	0.87
Hager2	H1_2	722.2523	Regional	4.59	86.78	87.97		88.15	0.013187	1.90	2.42	3.35	0.71
Hager2	H1_2	722.2523	Regional_WithSpi	4.59	86.78	87.97		88.15	0.013187	1.90	2.42	3.35	0.71
Hager2	H1_2	692.2523	100Y	7.40	86.60	87.89		88.03	0.005806	1.94	5.32	9.51	0.57
Hager2	H1_2	692.2523	Regional	5.63	86.60	87.74		87.87	0.006379	1.86	4.05	7.63	0.59
Hager2	H1_2	692.2523	Regional_WithSpi	5.63	86.60	87.74		87.87	0.006379	1.86	4.05	7.63	0.59
Hager2	H1_2	662.2523	100Y	7.40	86.43	87.75		87.87	0.004378	1.76	5.84	11.20	0.52
Hager2	H1_2	662.2523	Regional	5.63	86.43	87.59		87.71	0.004570	1.64	4.40	8.09	0.52
Hager2	H1_2	662.2523	Regional_WithSpi	5.63	86.43	87.59		87.71	0.004570	1.64	4.40	8.09	0.52
Hager2	H1_2	632.2524	100Y	7.40	86.25	87.63		87.75	0.003635	1.58	5.82	11.87	0.46
Hager2	H1_2	632.2524	Regional	5.63	86.25	87.49		87.58	0.003494	1.42	4.51	6.83	0.45
Hager2	H1_2	632.2524	Regional_WithSpi	5.63	86.25	87.49		87.58	0.003494	1.42	4.51	6.83	0.45
Hager2	H1_2	602.2523	100Y	7.40	86.08	87.52		87.63	0.004112	1.60	5.91	12.37	0.48
Hager2	H1_2	602.2523	Regional	5.63	86.08	87.37		87.47	0.003956	1.43	4.54	7.38	0.46
Hager2	H1_2	602.2523	Regional_WithSpi	5.63	86.08	87.37		87.47	0.003956	1.43	4.54	7.38	0.46
Hager2	H1_2	572.2523	100Y	7.40	85.90	87.38		87.50	0.004659	1.67	5.49	9.01	0.47
Hager2	H1_2	572.2523	Regional	5.63	85.90	87.26		87.35	0.004034	1.45	4.56	6.95	0.43
Hager2	H1_2	572.2523	Regional_WithSpi	5.63	85.90	87.26		87.35	0.004034	1.45	4.56	6.95	0.43
Hager2	H1_2	542.2523	100Y	7.40	85.78	87.20		87.35	0.005583	1.82	4.84	6.41	0.55
Hager2	H1_2	542.2523	Regional	5.63	85.78	87.12		87.23	0.004362	1.53	4.32	6.14	0.48
Hager2	H1_2	542.2523	Regional_WithSpi	5.63	85.78	87.12		87.23	0.004362	1.53	4.32	6.14	0.48

HEC-RAS Plan: Nov20 (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Hager2	H1_2	512.2524	100Y	7.40	85.69	87.07		87.18	0.005162	1.63	6.25	13.76	0.49
Hager2	H1_2	512.2524	Regional	5.63	85.69	87.02		87.09	0.003805	1.36	5.58	12.72	0.42
Hager2	H1_2	512.2524	Regional_WithSpi	5.63	85.69	87.02		87.09	0.003805	1.36	5.58	12.72	0.42
Hager2	H1_2	482.2522	100Y	7.40	85.62	87.12	86.67	87.13	0.000217	0.40	42.16	128.24	0.12
Hager2	H1_2	482.2522	Regional	5.63	85.62	87.05	86.58	87.05	0.000250	0.41	32.86	125.10	0.12
Hager2	H1_2	482.2522	Regional_WithSpi	5.63	85.62	87.05	86.58	87.05	0.000250	0.41	32.86	125.10	0.12
Hager2	H1_2	466.4048	100Y	7.40	85.59	87.12	86.62	87.12	0.000144	0.31	49.65	139.44	0.09
Hager2	H1_2	466.4048	Regional	5.63	85.59	87.05	86.50	87.05	0.000162	0.31	39.44	137.84	0.10
Hager2	H1_2	466.4048	Regional_WithSpi	5.63	85.59	87.05	86.50	87.05	0.000162	0.31	39.44	137.84	0.10
Hager2	H1_2	446.3873		Culvert									
Hager2	H1_2	426.0621	100Y	7.40	85.48	87.08	86.58	87.12	0.001648	1.13	11.03	34.52	0.31
Hager2	H1_2	426.0621	Regional	5.63	85.48	87.01	86.46	87.05	0.001369	0.99	8.85	30.53	0.28
Hager2	H1_2	426.0621	Regional_WithSpi	5.63	85.48	87.01	86.46	87.05	0.001369	0.99	8.85	30.53	0.28
Hager2	H1_2	426.06		Lat Struct									
Hager2	H1_2	396.0621	100Y	7.40	85.41	87.03		87.05	0.002362	0.96	12.63	36.36	0.30
Hager2	H1_2	396.0621	Regional	5.63	85.41	86.96		86.99	0.002387	0.92	10.30	35.70	0.30
Hager2	H1_2	396.0621	Regional_WithSpi	5.63	85.41	86.96		86.99	0.002387	0.92	10.30	35.70	0.30
Hager2	H1_2	380.98	100Y	7.46	85.37	86.99	86.85	87.02	0.002415	1.06	12.06	36.88	0.34
Hager2	H1_2	380.98	Regional	6.08	85.37	86.89	86.82	86.94	0.003460	1.19	8.79	34.76	0.40
Hager2	H1_2	380.98	Regional_WithSpi	6.08	85.37	86.89	86.82	86.94	0.003460	1.19	8.79	34.76	0.40
Hager2	H1_2	365.8991	100Y	7.46	85.33	86.68	86.68	86.93	0.013833	2.31	3.95	11.67	0.83
Hager2	H1_2	365.8991	Regional	6.08	85.33	86.60	86.60	86.83	0.014134	2.18	3.17	8.98	0.82
Hager2	H1_2	365.8991	Regional_WithSpi	6.08	85.33	86.60	86.60	86.83	0.014134	2.18	3.17	8.98	0.82
Hager2	H1_2	338.331	100Y	7.46	85.06	86.32	86.32	86.45	0.006351	1.76	7.05	31.13	0.57
Hager2	H1_2	338.331	Regional	6.08	85.06	86.24	86.24	86.39	0.007623	1.82	4.81	23.93	0.61
Hager2	H1_2	338.331	Regional_WithSpi	6.08	85.06	86.24	86.24	86.39	0.007623	1.82	4.81	23.93	0.61
Hager2	H1_2	331.3203		Culvert									
Hager2	H1_2	306.0621	100Y	7.46	84.68	85.86	85.69	86.15	0.012290	2.42	3.09	3.31	0.76
Hager2	H1_2	306.0621	Regional	6.08	84.68	85.85	85.58	86.05	0.008221	1.97	3.08	3.31	0.62
Hager2	H1_2	306.0621	Regional_WithSpi	6.08	84.68	85.85	85.58	86.05	0.008221	1.97	3.08	3.31	0.62
Hager2	H1_2	296.062*	100Y	7.46	84.63	85.90	85.76	85.96	0.004924	1.27	9.14	32.27	0.45
Hager2	H1_2	296.062*	Regional	6.08	84.63	85.87	85.66	85.92	0.004467	1.18	8.03	31.80	0.43
Hager2	H1_2	296.062*	Regional_WithSpi	6.08	84.63	85.87	85.66	85.92	0.004467	1.18	8.03	31.80	0.43
Hager2	H1_2	286.062*	100Y	7.46	84.59	85.86		85.90	0.004710	1.12	10.91	50.88	0.44
Hager2	H1_2	286.062*	Regional	6.08	84.59	85.83		85.87	0.004629	1.07	9.23	48.72	0.44
Hager2	H1_2	286.062*	Regional_WithSpi	6.08	84.59	85.83		85.87	0.004629	1.07	9.23	48.72	0.44
Hager2	H1_2	276.062	100Y	9.07	84.54	85.81		85.85	0.006590	1.12	12.37	54.03	0.51
Hager2	H1_2	276.062	Regional	7.42	84.54	85.78		85.81	0.006628	1.08	10.63	51.47	0.50
Hager2	H1_2	276.062	Regional_WithSpi	7.42	84.54	85.78		85.81	0.006628	1.08	10.63	51.47	0.50
Hager2	H1_2	266.062*	100Y	9.07	84.44	85.69	85.68	85.76	0.009301	1.54	9.96	52.13	0.63
Hager2	H1_2	266.062*	Regional	7.42	84.44	85.66	85.65	85.73	0.008827	1.45	8.49	48.79	0.61
Hager2	H1_2	266.062*	Regional_WithSpi	7.42	84.44	85.66	85.65	85.73	0.008827	1.45	8.49	48.79	0.61
Hager2	H1_2	256.062*	100Y	9.07	84.34	85.62	85.62	85.69	0.005751	1.41	12.59	81.59	0.52
Hager2	H1_2	256.062*	Regional	7.42	84.34	85.62	85.56	85.67	0.003787	1.15	12.69	81.70	0.42
Hager2	H1_2	256.062*	Regional_WithSpi	7.42	84.34	85.62	85.56	85.67	0.003787	1.15	12.69	81.70	0.42
Hager2	H1_2	246.0621	100Y	9.07	84.24	85.52	85.52	85.60	0.005173	1.44	12.11	78.03	0.50
Hager2	H1_2	246.0621	Regional	7.42	84.24	85.20	85.20	85.56	0.022971	2.66	2.79	3.85	1.00
Hager2	H1_2	246.0621	Regional_WithSpi	7.42	84.24	85.20	85.20	85.56	0.022971	2.66	2.79	3.85	1.00
Hager2	H1_2	216.062	100Y	9.07	84.03	85.39		85.40	0.000881	0.59	26.87	85.61	0.21
Hager2	H1_2	216.062	Regional	7.42	84.03	85.25		85.26	0.001334	0.64	17.91	56.07	0.25
Hager2	H1_2	216.062	Regional_WithSpi	7.42	84.03	85.25		85.26	0.001334	0.64	17.91	56.07	0.25
Hager2	H1_2	186.6753	100Y	9.07	83.86	85.37		85.38	0.000442	0.54	28.27	53.96	0.16
Hager2	H1_2	186.6753	Regional	7.42	83.86	85.23		85.23	0.000661	0.61	20.89	47.32	0.19
Hager2	H1_2	186.6753	Regional_WithSpi	7.42	83.86	85.23		85.23	0.000661	0.61	20.89	47.32	0.19
Hager2	H1_2	156.0621	100Y	9.07	83.20	85.35	85.08	85.36	0.000683	0.56	26.89	67.15	0.17
Hager2	H1_2	156.0621	Regional	7.42	83.20	85.18	85.05	85.20	0.001988	0.86	15.63	61.02	0.28
Hager2	H1_2	156.0621	Regional_WithSpi	7.42	83.20	85.18	85.05	85.20	0.001988	0.86	15.63	61.02	0.28
Hager2	H1_2	132.4355		Culvert									
Hager2	H1_2	97.03838	100Y	9.07	83.00	84.67	84.67	85.36	0.022890	3.67	2.47	7.76	1.00
Hager2	H1_2	97.03838	Regional	7.42	83.00	84.57	84.50	85.11	0.019824	3.24	2.29	4.38	0.92
Hager2	H1_2	97.03838	Regional_WithSpi	7.42	83.00	84.57	84.50	85.11	0.019824	3.24	2.29	4.38	0.92

HEC-RAS Plan: Nov20 (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Hager2	H1_2	74.1437*	100Y	9.07	82.85	84.49	84.46	84.69	0.009723	2.25	5.61	12.38	0.67
Hager2	H1_2	74.1437*	Regional	7.42	82.85	84.38	84.38	84.60	0.011461	2.28	4.30	10.66	0.71
Hager2	H1_2	74.1437*	Regional_WithSpi	7.42	82.85	84.38	84.38	84.60	0.011461	2.28	4.30	10.66	0.71
Hager2	H1_2	51.2490*	100Y	9.07	82.71	84.05	84.05	84.36	0.017042	2.86	4.39	9.97	0.91
Hager2	H1_2	51.2490*	Regional	7.42	82.71	84.03	84.03	84.25	0.012589	2.43	4.21	9.34	0.78
Hager2	H1_2	51.2490*	Regional_WithSpi	7.42	82.71	84.03	84.03	84.25	0.012589	2.43	4.21	9.34	0.78
Hager2	H1_2	28.35437	100Y	9.07	82.56	84.13		84.17	0.001521	1.14	12.88	19.64	0.31
Hager2	H1_2	28.35437	Regional	7.42	82.56	84.03		84.06	0.001590	1.11	10.86	18.09	0.31
Hager2	H1_2	28.35437	Regional_WithSpi	7.42	82.56	84.03		84.06	0.001590	1.11	10.86	18.09	0.31
Hager2	H1_2	13.42432	100Y	9.07	82.07	83.89	83.89	84.10	0.009181	2.21	5.49	15.88	0.66
Hager2	H1_2	13.42432	Regional	7.42	82.07	83.61	83.61	83.97	0.019469	2.68	2.95	4.66	0.91
Hager2	H1_2	13.42432	Regional_WithSpi	7.42	82.07	83.61	83.61	83.97	0.019469	2.68	2.95	4.66	0.91



METRIC
MCB-257
SH. 1 OF 3
RAMBO CREEK CULVERT
ELIZABETH STREET RECONSTRUCTION
CITY OF BURLINGTON
DEPARTMENT OF PUBLIC WORKS
MUNICIPAL DRAWING № MCB - 257
CONTRACT № 85 - 15
SHEET 1 OF 3
EMERALD CR.
ELIZABETH STREET
CAROLINE STREET
TUDOR SQUARE
PATRICK SLATERY 519
M. BOJECZKO 507
BURLINGTON YOUTH RESIDENCES 497
ROGER J. SPRAGUE KIMBERLEY P. SPRAGUE 2035
MABEL YAU CHOW 2025
PARKING LOT #9
3600 mm x 1800 mm CONCRETE CULVERT
EXISTING FOOTBRIDGE TO BE DEMOLISHED
INLET STRUCTURE REFER TO DWG. MCB-257 SHEET 2 OF 3
OUTLET STRUCTURE REFER TO DWG. MCB-257 SHEET 3 OF 3
STRAWBALE SILTATION CONTROL DAM STD. S.B.D. I
BEND 'B' DATA
Δ = 4°
T = 1.048 m
L = 2.094 m
R = 30 m
P.I. = 0+0845
B.C.= 0+083.45
E.C.= 0+085.54
BEND 'A' DATA
Δ = 46°
T = 12.73 m
L = 24.085 m
R = 30 m
P.I.= 0+012.73
B.C.= 0+000
E.C.= 0+024.085
NOTE: FOR GENERAL NOTES SEE DWG. No. 465-D.
B.M # 319 1978 DATUM
BRASS CAP IN THE TOP OF CURB, PARAPLEGIC RAMP, OF CURB-FACE S/W AT THE S.W CORNER OF THE INTERSECTION OF BRANT ST. & ONTARIO ST. H.C.M # 043820129 EL.85.597
B.M # 207 1978 DATUM
B.M SET ON H.C.M # 650013 IN THE CITY OF BURLINGTON LOCATED ON THE WEST SIDE OF MARTHA ST. AT THE INTERSECTION OF MARTHA & NEW ST. 4.32 m WEST OF FACE OF CURB. 5.15 m NORTH OF NEW ST. CENTER LINE EL. 84.866
ALL UNDERGROUND UTILITIES TO BE VERIFIED
150 mm GRAN. "A" COMPACTED TO 95 % STD. PROCTOR DENSITY
SOUND SHALE
EXIST. 200 mm SAN. SEWER (FAR SIDE)
EXIST. 200 mm SAN. SEWER (NEAR SIDE)
PROP. 109 m - PRECAST CONCRETE BOX CULVERT 3600 mm x 1800 mm @ 0.50 %
ROAD GRADE OVER ℄ OF CULVERT
CULVERT PROFILE
CULVERT CHAINAGE
REVISIONS
7 AUG./85 M.A SHOWN SUBDRAIN "TURNOUTS" FROM C.&G. TO CULVERT ON BOTH SIDES
6 AUG./85 M.A SUBDRAIN ON EAST SIDE, FROM NORTH, CONTINUING TO D.C.B
5 AUG./85 M.A ST. SEWER SIZE REVISED TO 375 mm AT CAROLINE ST.
4 AUG./85 D.M. T.H.H. & H.C.M. LOCATIONS @ S/E CORNER REVISED
3 AUG./85 D.M. FUT. TS/LS LOCATION @ S/W CORNER CHANGED
2 AUG./85 D.M. SUBDRAINS ADDED, C.B. LOCATION @ S/W CORNER REVISED
1 AUG./85 D.M. 915 mm ST SEW. ON CAROLINE ST. CHANGED TO 900 mm
Design J. HODSON T.E.
Drawn M.A
Date FEB/85
Scale HOR. 1:200 VERT 1:50
REFERENCES ME-9, SH. 3
FIELD NOTES M-232 E-70 II E-102 E-134
APPROVALS
Municipal
DIRECTOR OF PUBLIC WORKS
DATE July 17/85
Regional
KEY PLAN
LAKESHORE ROAD
CAROLINE ST.
NEW ST.
BRANT ST.

Appendix E

East Rambo Flood Control Facility Retrofit Feasibility Assessment

Memo

To: Heather Dearlove and Jannette Brenner, Conservation Halton

From: Ron Scheckenberger and Matt Senior, Wood

Date: August 9, 2019 (Revised December 18, 2019)

File: TPB178008

cc: Leah Smith, Cary Clark, and Umar Malik, City of Burlington

Re: **Downtown and Burlington GO Mobility Hubs**
Flood Hazard and Scoped SWM Assessment
East Rambo Flood Control Facility – Retrofit Feasibility Assessment
City of Burlington

A. Introduction and Background

Further to Wood's submission of the updated "Flood Hazard and Scoped Stormwater Management Assessment, Burlington GO and Downtown Mobility Hubs" Report (February 25, 2019), and the receipt of comments from Conservation Halton (ref. e-mail Dearlove-Enns, June 27, 2019 and written comments ref. Dearlove-Bustamante, July 25, 2019), as well as the meeting of July 9, 2019, we hereby provide a summary outlining Wood's professional opinion on the potential feasibility of a retrofit of the East Rambo Flood Control Facility, to prevent the spill condition to the West Rambo Creek. The text herein also reflects comments provided by Conservation Halton (CH) in its correspondence of September 25, 2019 (Dearlove-Malik).

As you are aware, the results of the previously noted assessment have indicated that under sufficiently high flows (approximately the 1 in 10-year storm event) the East Rambo Flood Control Facility (FCF) would generate uncontrolled spills via the CNR crossing under the QEW, which would direct flows to the West Rambo Creek system, south of the QEW (rather than the controlled discharge from the East Rambo FCF, which is directed to the East Rambo Creek at Plains Road/Brenda Crescent). This condition results in flows from the East Rambo FCF being split between the East and West Rambo Creek systems, contrary to the previously understood design performance (with all flows being directed to the East Rambo Creek system).

Based on the preceding, CH has previously requested that two (2) modelling scenarios be assessed: with the division of flows as estimated based on actual existing conditions (Scenario 1) and with all flows being directed to East Rambo Creek, as originally intended (Scenario 2). Peak flows for both scenarios were generated and included in the previously noted report, as well as estimated floodplain mapping for both scenarios.

In its comments of July 5, 2019 ref. (e-mail Dearlove-Enns), CH has noted that while Scenario 1 is more representative of existing conditions, it does not represent the worst case scenario for East Rambo Creek and the eventual receiver of East Rambo Creek flows, namely the Hager-Rambo Diversion Channel. Further, CH has suggested that Scenario 1 does not meet Provincial Guidelines, which recommend that reduced flows (i.e. to East Rambo Creek) should only be used after a review of alternatives proves that the spill cannot reasonably be prevented. CH has therefore recommended that Scenario 2 be used to delineate the flood hazard for the East Rambo Creek, as well as the Hager-Rambo Diversion Channel. Under Scenario 2, the generated floodplain mapping (refer to Drawing 5B from the previously noted report) indicates the potential for spill flows from East Rambo Creek in the vicinity of Fairview Street and Argon Court, as well as from the Hager-Rambo Diversion Channel itself, along Fairview Street, between the East and West Rambo Creeks. CH has suggested that these spill flows require additional assessment to better understand the impacts of these flows to the Burlington GO Mobility Hub, as well as the impact of routed flows to the downstream receivers (i.e. Lower Rambo Creek) within the Downtown Mobility Hub.

As discussed at the meeting of July 9, 2019 (and in Comment 11c of its July 25, 2019 comments), CH staff has indicated they may be in a position to support the application of the current condition and more representative flows associated with Scenario 1 (which would then eliminate the need for further hydraulic modelling and floodplain mapping for Scenario 2), if a sufficiently robust alternative/feasibility assessment is undertaken to demonstrate that it is not considered reasonably feasible or likely that the East Rambo FCF could ever be retrofitted or altered to address the previously noted spill. This memorandum is intended to document this assessment.

B. Potential Retrofitting East Rambo FCF – Review of Considerations

Wood is of the professional opinion that a retrofit of the East Rambo FCF to re-direct flood flows towards the East Rambo Creek is both undesirable (given the potential impacts) and also infeasible (given the technical and financial burdens associated with such works). This would apply both to a complete or partial re-direction of flows, given that similar challenges would occur in both instances. A summary of the rationale for this opinion is outlined herein.

1. ***Flood Impacts to Residential Properties.*** As evident from previously prepared floodplain mapping for Scenarios 1 (as per existing conditions) and 2 (all flows from the East Rambo FCF re-directed to East Rambo Creek), Scenario 2 results in a much more extensive floodplain for the East Rambo Creek between the QEW and Fairview Street (ref. Drawings 5A and 5B from the previously noted report). Based on a preliminary estimate, approximately 40 +\- additional detached residential homes between Plains Road and the CNR tracks would be placed within the Regulatory Floodplain under Scenario 2 as compared to Scenario 1, which would notably increase flood risk and damage potential. Further, a large number of additional residential homes would be placed at risk south of Fairview Street due to spill flows from East Rambo Creek and the Hager-Rambo Diversion

Channel under Scenario 2 as compared to Scenario 1. Based on a high-level review with staff from the City of Burlington, it is understood that there are no other critical infrastructure installations that should be considered in either spill area (i.e. electrical substations, telecommunications hub, waste management sites, etcetera). It is further understood that there are no critical vulnerable populations in either area (nursing homes, retirement homes, hospitals, etcetera). Thus, the primary differentiator between the flood risks in the two (2) areas relates to the presence (or absence) of residential units.

Under Scenario 1, spill flows to West Rambo Creek via the CNR would primarily impact industrial/commercial properties only, which would be expected to have a correspondingly lower risk to public life and public property as noted previously. The exception would be high surface flows along Plains Road and the Brant Street underpass, which would be expected to flood due to spill flows and would correspondingly pose a safety risk to drivers.

These flood risks could potentially be practically mitigated through additional measures however, such as increased culvert capacity of West Rambo Creek at Plains Road, grading modifications, and storage. This could also potentially include channel improvements to increase capacity.

With respect to Scenario 1, based on a review of property limits and grading, opportunities are generally considered limited along West Rambo Creek, downstream of Plains Road (subject to acquiring private property) and would also necessitate co-ordination to upgrade three (3) hydraulic structures (two (2) railway lines and one (1) private crossing).

With respect to Scenario 2, channel improvements would be further constrained by the larger number of private properties crossed by East Rambo Creek, and the greater complexities associated with acquiring private residential properties (as opposed to commercial/industrial properties). Although opportunities along both watercourses are considered limited/constrained, improvements to West Rambo Creek would generally be more feasible.

Overall, it is considered that the flood impacts and risks under Scenario 2 are greater than under Scenario 1, given the direct impact to residential properties and residents which involve overnight uses. Channel improvements along East Rambo Creek (which would receive more of the flow under Scenario 2) would also be more complex.

The preceding suggests that a retrofit of the East Rambo FCF to re-direct spill flows to East Rambo Creek (either partially or wholly) would be counter-productive in terms of risk management, and ultimately counter to the overall goals of both the City of Burlington and Conservation Halton.

2. ***Feasibility of Preventing Spill via CNR Crossing.*** As noted previously, based on the hydrologic modelling conducted for the Mobility Hub Study, the East Rambo FCF would be expected to spill to the West Rambo Creek system via the CNR crossing at approximately the 1 in 10-year storm event. The spill elevation of the railway tracks in this location has been estimated as 105.5 m, as compared to the base facility elevation of 103.3 m (active depth of 2.2 m at spill point). By contrast, the maximum simulated water level within the facility for the Regional Storm Event (Scenario 1) is estimated as 106.43 m (or some 0.93 m higher), or just above the secondary North Service Road spill elevation of 106.40 m.

   Given the grade constraints associated with railway tracks, it is considered unlikely that the railway tracks could be practically raised to address the spill; further this would have impacts on the vertical clearance within the CNR enclosure itself, which would suggest that the structure would need to be altered and replaced to meet CNR clearance requirements. Even a partial adjustment of rail geometry would be complex and costly, and ultimately only partially effective.

   A stand-alone automated active flood barrier could potentially be implemented on the CNR QEW crossing (to be enabled once flood levels within the pond reached a certain critical level), however this would require active ongoing monitoring of pond levels and associated automated controls for the barrier. It is unclear who would be responsible for the long-term capital, and operation and maintenance costs for such a system. It is also unclear whether or not both CNR and MTO would agree to the implementation of such a system within their jurisdiction. Such a flood barrier would also likely not be fully watertight, given the nature of railway tracks (i.e. irregular granular bedding and elevated tracks), although it would likely reduce flood spills, if it could be feasibly implemented.

   A passive flood barrier (i.e. a berm or wall) could also potentially be considered to prevent spill from entering the CNR QEW crossing. Notwithstanding, the barrier would need to be completed on both sides of the CNR tracks, given the potential for backwater and flooding on the upstream side of the CNR tracks via East Rambo Creek and the associated culvert crossing of the CNR. This would also require re-alignment of East Rambo Creek on the downstream side of the FCF and would also reduce the available flood storage volume within the FCF due to the barrier (notably there would be a reduced impact associated with a wall as compared to a sloped berm however). A barrier on the upstream side of the CNR would be constrained by available space and the numerous landowner interests in this area. Alternatively, a backwater prevention system could potentially be implemented and fitted to the East Rambo Creek culvert, however further detailed hydraulic modelling would need to be completed to confirm to assess effectiveness and feasibility at this scale.

With respect to both active and passive flood barriers to prevent spill via the CNR crossing, the local impacts of implementing such a flood barrier have also not been assessed. Increased operating levels in the FCF have the potential to result in additional flooding of the surrounding area unless additional flow relief was implemented in combination with the flood barrier. In particular, flood encroachment on the properties at 2220, 2250 and 2260 Industrial Street is estimated to occur at an elevation of approximately 106.0 m; this could potentially be worsened by berming off relief flow via the CNR QEW crossing and increasing operating levels within the facility.

Re-grading/expansion of the pond to reduce operating levels is also considered infeasible given surrounding infrastructure (roadways and railways). It is understood that available storage in the facility was maximized at the time of design and also further extended as part of the Area 8 Roseland Creek Diversion, hence potential for additional storage is not considered available. If the North Service Road were theoretically to be shifted closer to the QEW, there would be the potential to increase the facility footprint area, however this would be subject to the acquisition of additional land and agreement with the MTO, both of which may not be forthcoming given active uses in the area. In addition, such an expansion in storage in and of itself would likely not be effective; this storage expansion would likely need to be combined with additional relief flow, necessitating additional infrastructure upgrades (assessed further as part of the subsequent review point).

Based on the preceding, the direct elimination of spill flows through physical works via raising of the CNR tracks, implementation of a flood barrier, or re-grading/expansion of the existing FCF are all considered unlikely or infeasible. Spill flows via the CNR QEW crossing could also potentially be reduced/prevented if additional relief flow could be incorporated to re-direct flows towards East Rambo Creek; this is considered further as part of the subsequent review point.

3. ***Feasibility of Re-Directing Flows to East Rambo Creek.*** As a final consideration, the feasibility of re-directing overflows from the East Rambo FCF to East Rambo Creek has also been reviewed. Based on the currently estimated facility operating curve (stage-storage-discharge), the existing low flow outlet (3.0 m wide x 1.5 m high box culvert) has a limited capacity, which restricts discharge and ultimately results in spill via the first relief point (i.e. the CNR QEW crossing). As such, in order to re-direct flows to the East Rambo Creek, the FCF outlet would either need to be upgraded/upsized, or potentially twinned with a secondary relief crossing of the QEW to the East Rambo Creek. Such an undertaking would be expected to be extremely complex and costly. The crossing would need to cross not only the North Service Road but the QEW, with a combined 12 lanes of active traffic. Construction would therefore need to utilize trenchless methods, such as microtunnelling or jack and bore to avoid disruption to the roadways, and clearly require agreement with the MTO. The cost of the construction (including implementation of large diameter piping)

would be expected to be high. Additional reconstruction on Plains Road and Brenda Crescent/Queensway Drive would also be required to re-direct the additional storm flows to East Rambo Creek.

Further, the estimated Regional Storm inflow to the East Rambo FCF is 62.0 m^3/s. As per the simulated results for Scenario 2, the existing box culvert has been estimated to convey some 18.5 m^3/s, leaving a residual peak flow to be conveyed of some 43.5 m^3/s. Assuming a concrete box culvert structure at a 0.5% grade, and a similar rise to the existing structure (1.5 m), an additional width of some 7.5 m would be required. This large geometry would further increase construction costs, potentially necessitating two (2) separate relief lines.

A less costly alternative could potentially be to re-direct spill flow from the CNR at the downstream side of the QEW, via the existing grassed area in the QEW right-of-way between the CNR and Plains Road/Brenda Crescent. The feasibility of completely blocking and re-directing uncontrolled spill flows at this magnitude is considered low however; the potential for practically constructing a flow bypass in the noted area is unknown without further detailed assessment. Such a system would further require agreement with MTO (and could potentially limit its use of the corridor including any potential future widening), and would also need to assess any potential impacts to the existing industrial properties fronting on Plains Road in this area.

All of the preceding measures also assume no additional flow restrictor controls within the East Rambo FCF. Ultimately, the FCF was originally approved to provide flow controls up to and including the 100-year storm event. Any potential retrofit would need to consider what, if any, potential measures could be incorporated into the design to achieve a greater degree of flow control to ensure compatibility with the originally approved intent and mitigate downstream impacts associated with legacy works. The feasibility of this approach would require further consideration and assessment.

Overall, the re-direction of spill flows from West Rambo Creek to East Rambo Creek would be a highly complex and costly undertaking, and would necessarily involve partnership and agreement with the MTO given the works in proximity to the QEW.

C. Summary

Based on the preceding, Wood is of the professional opinion that a retrofit of the East Rambo Flood Control Facility to re-direct predicted spill flows towards East Rambo Creek is neither desirable (given the associated increase in flood damages and risk to residential properties and residents themselves) nor technically feasible (given the technical complexities and associated costs in preventing and re-directing the aforementioned spill flows).

Wood further notes that the City of Burlington is also of the same opinion with respect to the preceding; City staff will provide separate written confirmation of same.

It is recommended that the findings of the preceding be reviewed with CN rail staff, given the potential implications to CN rail infrastructure, and its potential interest in reducing the spill frequency associated with its infrastructure. It is recommended that the City of Burlington share this memorandum and associated reporting information with CN rail staff, and document any associated correspondence accordingly.

We trust the preceding to be satisfactory; please do not hesitate to contact Wood should you wish to discuss the matter further.

LEGEND

- WATERCOURSE
- CONTOUR (1m)
- PARCEL FABRIC
- STORM SEWER SYSTEM
- FLOOD CONTROL FACILITY SPILL

SCALE VALID ONLY FOR 24"x36" VERSION

MOBILITY HUB PLANNING STUDY CITY OF BURLINGTON	EAST RAMBO FLOOD CONTROL FACILITY OVERVIEW	wood.	Scale 1:1750 (0 20 40 60) Consultant File No. TPB178008 Drawing No.

Path: P:\2017\Projects\TPB178008S – Mobility Hub Planning Consulting Services\06_DES-ENG\01_CAD\02_DWGS\05_WR\01_PROJ\2019-08 (EastRambo)\Dwg ER-Overview.dwg

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