Carruthers Creek Watershed Plan

Hydrological Assessment

Prepared for the Region of Durham

November 2019

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FOREWORD

The Region of Durham recognizes watershed plans as an effective tool to inform the management of Durham's water resources, natural heritage, and natural hazards, such as flooding. In 2015, the Region retained the Toronto and Region Conservation Authority (TRCA) to update the watershed plan for Carruthers Creek.

This four-year study will build upon the goals, objectives, and management recommendations established in the 2003 *Watershed Plan for Duffins Creek and Carruthers Creek*.

The following report is one of a series of scenario analysis technical reports that follow the watershed characterization studies (completed in 2017). Information contained in these technical reports will examine potential impacts of future growth and land use changes in combination with other influences such as climate change. Additionally, these technical reports provide the knowledge base necessary to develop the plan's management recommendations. Any recommendations contained in the scenario analysis technical reports are consolidated in the Carruthers Creek Watershed Plan's management framework. The Watershed Plan is the final source for goals, objectives, indicators and management recommendations related to Carruthers Creek. Readers are encouraged to refer to the technical reports for more detailed implementation suggestions.

INTRODUCTION

This report summarizes the analysis carried out by the Toronto and Region Conservation Authority (TRCA) for the land use and land cover scenarios as developed through the Carruthers Creek Watershed Plan (CCWP). Herein, TRCA describes the work completed and the assumptions made with respect to the hydrologic modelling for the Carruthers Creek watershed using the Visual OTTHYMO (VO) hydrologic modelling platform, version VO5.1. The work undertaken included model development and the comparison of the peak flow estimates for four (4) land use and land cover scenarios (Figure 1):

1. **Current** - Existing land use conditions from 2015 based on aerial photo interpretation.

2. **Scenario 1** (+OP) - Refines current by assuming all lands south of the Greenbelt are now developed as approved up to 2031 in the Official Plans. Only minor changes from 2015 have resulted as most of the urban area was already developed in 2015.

3. **Scenario 2** (+NHS) – Refines future Scenario 1 by adding an enhanced Natural Heritage System (NHS) compared to the NHS in the approved Official Plans and using updated information on terrestrial habitat connectivity, habitat configurations, and climate vulnerabilities.

4. **Scenario 3** (+Potential Urban) - Illustrates prospective development post-2031 in the headwaters area outside of the enhanced Natural Heritage System identified in Scenario 2. There is no change in the existing urban area south of the Greenbelt from the current Official Plans.

This report will provide a high-level description of the hydrology model set up and parameterization for each of the four land use and land cover scenarios, comparison of peak flows estimates for all scenarios, and a preliminary list of high-level management objectives for consideration through the watershed plan.

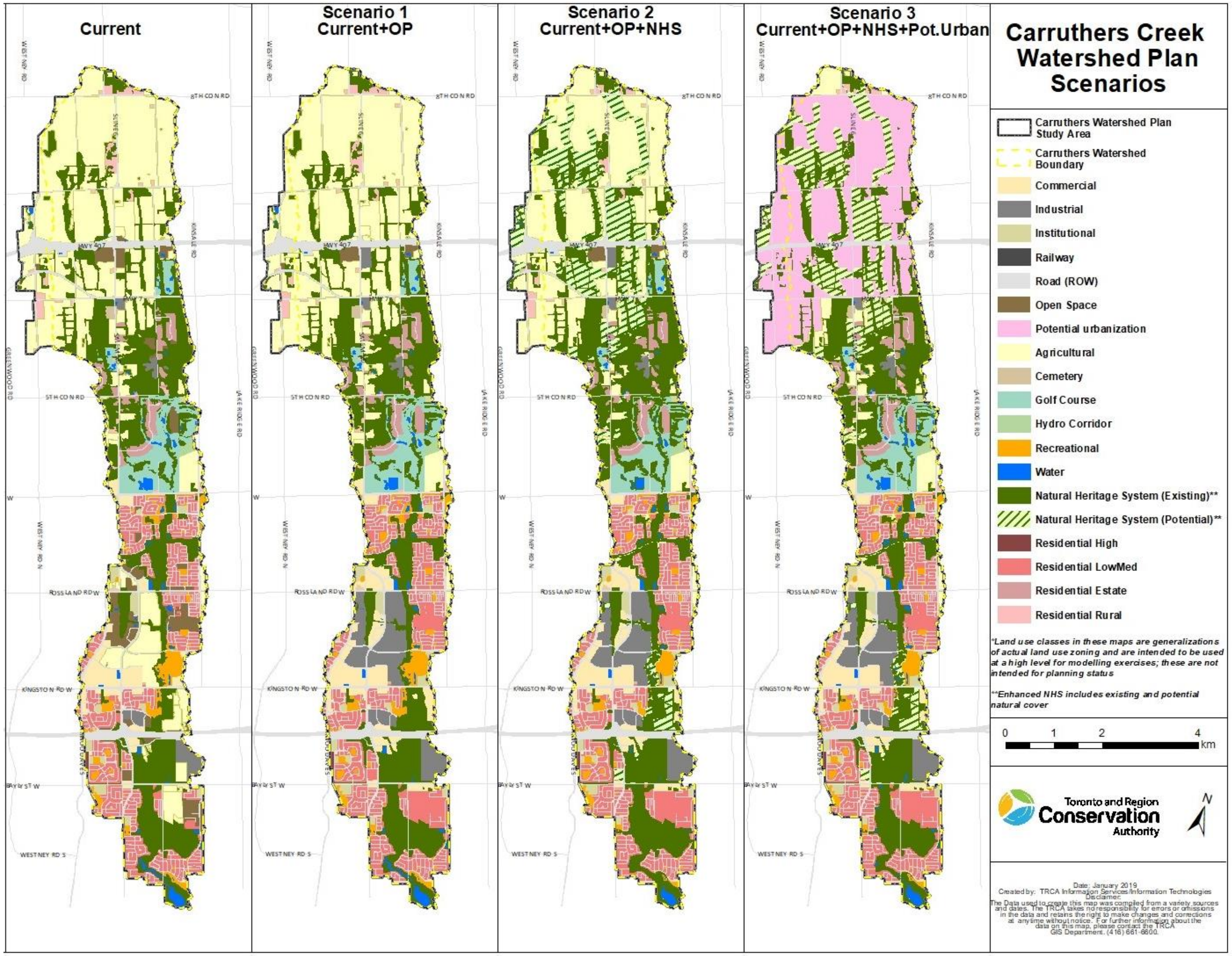


FIGURE 1 FOUR LAND USE SCENARIOS FOR THE CARRUTHERS CREEK WATERSHED PLAN HYDROLOGICAL ASSESSMENT DEPICTING CURRENT, SCENARIO 1, SCENARIO 2, AND SCENARIO 3. POTENTIAL NATURAL HERITAGE SYSTEM AREAS ARE PROPOSED FOR NHS ENHANCEMENT.

BACKGROUND

As per standard TRCA modelling procedures the modelling work completed for the CCWP meets or exceeds industry standards. Furthermore, the hydrology model developed by Cole Engineering Inc. (Cole), for TRCA and the Town of Ajax in 2011, form the base models for land use scenario testing. The models developed by Cole in 2011 have been reviewed for completeness and consistency by both TRCA and municipal staff and has been used successfully for Floodplain and Stormwater Management assessments, by various consulting firms, since 2011.

The models developed by Cole in 2011 undertook a comprehensive calibration and validation process and reflect watershed conditions, provide reasonable and justifiable peak flow estimates, and are appropriate for use as part of the CCWP.

It is important to note that the discussion provided below relates to the work completed in support of the CCWP initiative and is not a detailed summary of the work completed by Cole in 2011. Further information related to the 2011 Carruthers Creek Hydrology Update can be obtained through *Hydrology Update Report Carruthers Creek Watershed, Carruthers Creek Flood Management & Analysis Municipal Class EA*, Cole Engineering, *October 2011*.

MODELLING METHODOLOGY

Land use mapping developed by TRCA form the base of the model adjustments for each of the land use scenarios. Particular attention was made to ensure the land use categories (i.e. low, medium and high density residential) were consistent between the land use mapping developed by TRCA and those used by Cole in 2011. It should be noted that several minor refinements were made to the 2011 Existing Conditions model to ensure land categories were consistent between the land use mapping used in 2011, and the land use mapping developed for the CCWP. It should also be noted that the minor adjustments in land categories do not significantly impact the 2011 Existing Conditions results and were completed to ensure consistency between models for comparison purposes. Flow node locations used for the purpose of this hydrology assessment can be seen in Appendix 1.

To ensure model consistency, parameters have been kept consistent with the 2011 Cole Engineering report (Table 1). For further details related to the overall model build and parameterization process, including calibration and validation please refer to Cole Engineering 2011 report titled *Hydrology Update Report Carruthers Creek Watershed, Carruthers Creek Flood Management & Analysis Municipal Class EA*, October 2011.

TABLE 1 INPUT PARAMETERS FOR CCWP SCENARIO ANALYSIS AND 2011 COLE ENGINEERING HYDROLOGY UPDATE MODELLING

Land Use Code	Carruthers Creek Watershed Plan		2011 Cole Engineering Hydrology Update	
	Total Imperviousness (TIMP)	Directly Connected Imperviousness (XIMP)	Total Imperviousness (TIMP)	Directly Connected Imperviousness (XIMP)
Estate Residential	0.14	0.09	0.14	0.09
Residential LowMed	0.55	0.35	-	-
Residential Low	-	-	0.45	0.24
Residential Medium	-	-	0.55	0.35
Residential High	0.64	0.35	0.64	0.35
Institutional	0.55	0.3	0.55	0.3
Industrial	0.9	0.9	0.9	0.9
Commercial	0.9	0.9	0.9	0.9
Agricultural	0	0	0	0
Natural Cover	0	0	0	0
Open Space	0.01	0.01	0.01	0.01
Cemetery	0.01	0.01	0.01	0.01
Recreational	0.2	0.2	0.2	0.2
Open Water	1	1	1	1
Railway	0.5	0.5	0.5	0.5
Road (ROW)	1	1	1	1
Golf Course	0.01	0.01	0.01	0.01
Hydro Corridor	0.01	0.01	-	-
Rural Residential	0.1	0	-	-
Natural Cover (Potential)	0	0	-	-
Future Urban (Commercial)	0.9	0.9	-	-

Once the land use categories were standardized, model adjustments were made to reflect the proposed land use and land cover. Generally, these adjustments consisted of the following:

- Catchment adjustments - Leveraging GIS and the tools available in VO2 undertook conversions of rural catchments to urban catchments (NASHYDs to STANDHYDs). As per standard modelling procedures catchments with impervious values of 20% or greater were modelled as STANHYDs (Urban), while catchments with impervious values less than 20% were modelled as NASHYDs (Rural);
- Where rural catchments were changed to urban catchments, Percent Impervious (%imp) and Directly Connected Impervious (XIMP) values were consistent with the values for land use categories established 2011;
- Urban catchment slope, surface Mannings “n” are consistent with the values used in 2011 for urban areas and industry practice;
- Curve Number (CN) and Initial Abstraction (IA) values for pervious surfaces within urban catchments were consistent with the values for each land use category from the 2011 model;

- CN and IA values for the recommended enhanced NHS were used to reflect the proposed NHS and assumed 50% would be wooded and 50% meadow. CN and IA values for the proposed enhanced NHS were prorated based on land use and cover from the parent catchment.

A detailed description of the work completed, and assumptions made for each land use scenario is described in below.

Current

Notes and Assumptions:

- The Current scenario was based on Cole 2011 “2008 Existing Conditions” Scenario;
- Catchments that appear to have the same land use in the Cole 2011 “2008 Existing Conditions” land use scenario were left untouched in the model;
- Catchments that were developed post 2008 were converted from NASHYDs (rural catchments) to STANDHYDs (urban catchments);
- Route reservoirs which represent stormwater management (SWM) ponds were added to the model where NASHYDs were converted to STANDHYDs. SWM pond functions were added to the model based on their operational configurations derived from detailed design reports obtained from the Town of Ajax, City of Pickering, and MTO;
- Percent Impervious (%imp) and Directly Connected Impervious (XIMP) values remained consistent with the values used by Cole.

Scenario 1

Notes and Assumptions:

- Scenario 1 was based on the Current scenario;
- Land use was updated based on Region of Durham, Town of Ajax, and City of Pickering OP’s.
- Catchments where the OP proposes a change from rural to urban conditions were converted from NASHYDs (rural catchments) to STANDHYDs (urban catchments);
- Route reservoirs which represent stormwater management (SWM) ponds were added to the model where NASHYDs were converted to STANDHYDs. SWM pond functions were added to the model by estimating operational function based on current Carruthers Creek stormwater management quantity control requirements;
- Percent Impervious (%imp) and Directly Connected Impervious (XIMP) values remained consistent with the values used by Cole.

Scenario 2

Notes and Assumptions:

- Scenario 2 was based on Scenario 1;
- Areas of enhanced NHS opportunities were developed by TRCA;
- Land cover for the enhanced NHS were represented in the model as 50% meadow, and 50% forest;
- The enhanced NHS land use and land cover were consolidated to a single value for each catchment based on a spatial relationship;
- For rural catchments CN and IA values were modified based on a spatial relationship to reflect the inclusion of the enhanced NHS;

- For urban catchments CN and IA values were modified based on a spatial relationship for the pervious component of the catchments;
- Areas where the enhanced NHS proposes water features (wetlands/marshes) were excluded from consideration due to the lack of information and were modelled as 50% meadow and 50% forest;
- It should be noted that CN and IA values for the natural areas were calibrated in 2011 by Cole. The CN and IA values for meadow and forest areas within proposed NHS areas varied substantially from the calibrated values established in 2011 but were used to maintain a similar methodology to the approach applied through the SWAT water quality modelling component of the CCWP.

Scenario 3

Notes and Assumptions:

- Scenario 3 was based on Scenario 2;
- Preliminary land use plans for potential development area within the Whitebelt areas were provided by TRCA;
- Catchments where the potential urban build out proposes a change from rural to urban conditions were converted from NASHYDs (rural catchments) to STANDHYDs (urban catchments);
- %imp and XIMP values for urban areas remain consistent with the values for each land type (i.e. residential, commercial, industrial) from the Cole model;
- The enhanced NHS remains the same as Scenario 2;
- Where the enhanced NHS parent catchment was changed from a rural catchment to an urban catchment the NHS was represented in the pervious component of the updated parent catchment;
- The assessment of Scenario 3 excluded consideration of SWM, including potential ponds within the Whitebelt lands.

Regional Storm Simulation

Once the 2- through 100-year models were completed, each scenario was duplicated for the Regional Storm (Hurricane Hazel) simulation. As per standard modelling practice, CN values were converted to reflect antecedent moisture conditions for saturated soils (AMC III). Also, all SWM facilities were removed from the model to account for the system failing or being at capacity during a Regional event. Once the model was adjusted to AMC III and all SWM facilities removed, the model was then run with the Hurricane Hazel event.

RESULTS AND DISCUSSION

As noted above, a comparison of Regional Storm peak flows at multiple locations through the watershed is provided in Table 2. In addition to the Regional Storm simulations, Appendix 2 includes results for the design storm simulations for Scenarios 1, 2 and 3. Please see Appendix 3 for the hydrographs associated with the Regional Storm.

Although the text below refers mainly to the results from the Regional Storm simulations, the trends observed for the Regional Storm are also observed for the design storm simulations. As such, the description and rationale provided below are also applicable for the design storm simulations.

Please note that the peak flow values differ slightly between the 2011 update and current study for Scenario 1; this is due to the reclassification of residential land use between the two models. Specifically, Scenario 1 combined low- and medium-density residential land use, which resulted in a higher impervious value than what was used by Cole in 2011. The increased impervious value affects the %Imp and XIMP parameters in the model, resulting in slightly increased peak flow values over those established by Cole in 2011.

Although the modelling completed as part of this scenario analysis only looked at land use as a future stressor, climate change is expected to increase precipitation, annual average temperatures and the frequency of extreme weather events, which will impact watersheds within the Region of Durham. Some of the anticipated implications of a changing climate include localized flooding, violent storm damage, changes to ecosystem composition, and changes to agricultural conditions and production.

Scenarios 1 and 2

Generally, there is a slight reduction in peak flow values when comparing Scenario 1 and 2 (see Table 2). This reflects the impacts associated with the enhanced NHS. From a flood mitigation and management perspective, the proposed NHS has negligible impacts on flood flows however there are several ecological and temperature mitigation benefits which have been documented within the CCWP.

Scenarios 1 and 3

Results at a catchment scale for Scenarios 1 and 3 indicate significant changes in peak flow values. In one instance, peak flow values are reduced while an increase in peak flow is observed for most of the watershed. It is important to note that the reduction in peak flow values for the East Tributary downstream of Highway 7 is the result of changes to catchment timing under Scenario 3, where the location of the potential development area and increases in impervious surfaces results in runoff reaching the catchment outlet faster than the land use assumptions used for Scenario 1.

TABLE 2 REGIONAL STORM SIMULATION RESULTS

Regional Storm	VO2 Sub-catchment IDs	2011 Update	Scenario 1 (+OP)		Scenario 2 (+NHS)		Scenario 3 (+Potential Urban)	
Location		Peak Flows (m^3/s)	Peak Flows (m^3/s)	% Change from 2011 Update	Peak Flows (m^3/s)	% Change from Scenario 1	Peak Flows (m^3/s)	% Change from Scenario 1
U/S Hwy. 7 (W. Tributary)	3096	12.98	11.012	-15.2%	10.713	-2.7%	47.347	330.0%
	1175	7.6	7.601	0.0%	7.394	-2.7%	31.893	319.6%
	3095	20.49	18.612	-9.2%	18.107	-2.7%	78.605	322.3%
D/S Hwy. 7 (E. Tributary)	1181	5.73	5.725	-0.1%	5.539	-3.2%	3.345	-41.6%
	1182	7.21	7.205	-0.1%	7.005	-2.8%	30.395	321.9%
	1183	7.01	7.011	0.0%	6.91	-1.4%	19.927	184.2%
	3103	18.57	18.572	0.0%	18.114	-2.5%	62.462	236.3%
D/S 5th Concession (E. Tributary)	1179	3.68	3.678	-0.1%	3.691	0.4%	3.691	0.4%
	3102	23.42	23.423	0.0%	22.916	-2.2%	61.279	161.6%
	3101	26.99	26.992	0.0%	26.505	-1.8%	62.965	133.3%
U/S Taunton Rd. (Confluence)	3094	35.13	32.702	-6.9%	31.944	-2.3%	78.623	140.4%
	3098	33.76	34.465	2.1%	33.924	-1.6%	67.896	97.0%
	3093	68.89	67.153	-2.5%	65.855	-1.9%	146.519	118.2%
Taunton Rd.	3092	71.61	69.897	-2.4%	68.593	-1.9%	148.839	112.9%
CPR	3087	70.66	68.988	-2.4%	67.689	-1.9%	156.109	126.3%
U/S Rossland Rd.	3082	70.51	68.863	-2.3%	67.941	-1.3%	160.888	133.6%
Hwy. 2 E.	1044	94.07	99.6	5.9%	96.468	-3.1%	193.789	94.6%
D/S Bayly St.	1033	105.74	114.651	8.4%	112.25	-2.1%	190.371	66.0%
Shoal Point Rd.	1005	140.52	149.498	6.4%	147.189	-1.5%	210.632	40.9%
Lake Ontario	1000	146.92	155.952	6.1%	153.714	-1.4%	213.973	37.2%

At a sub-watershed scale, significant increases in peak flows are also observed. This is also a reflection of the location and scale of the potential development area used in Scenario 3. The significant increase in impervious surfaces associated with the potential development will impact runoff volume and watershed timing, increasing peak flow values at and downstream of confluence points.

At a watershed scale the change in peak flow values are not as pronounced as those at a catchment and sub-watershed scale. This reflects the magnitude of the peak flow values being compared to one another, and the effects of routing flows through significant downstream valley corridors.

Without proper mitigation, the increase in peak flow values observed through Scenario 3 would have significant impacts to flood levels throughout the watershed. Of concern is the impact to flooding for the Lower Carruthers Flood Vulnerable Cluster within the Town of Ajax. Past studies completed by the Town and TRCA have indicated the need to implement flood remediation solutions in the form of an identified Flood Protection Landform and improved conveyance through the valley to reduce existing flood risk.

As per TRCA's Flood Protection Land Forming Technical Guidelines, AECOM 2019:

> *A flood protection landform is generally defined as a non-structural measure made of earth that provides permanent flood protection. Landforms are similar to dykes and berms, since they are man-made barriers placed adjacent to river corridors to provide passive protection from flooding. Unlike traditional dykes and berms, however, landforms are built on a much larger scale with very gentle slopes. Furthermore, landforms are designed to generally require less maintenance and provide a significantly higher lever of protection in terms of typical models of failure*.

Should development within the Carruthers Creek headwaters proceed, the flood remediation solutions proposed for the Lower Carruthers Flood Vulnerable Cluster would not meet the original design requirements established through the EA process (i.e. provide permanent flood control for Lower Carruthers to the Regional Storm). As such, a thorough reassessment of the Carruthers Creek Flood Management & Analysis Municipal Class EA would be required should a Settlement Area Boundary Expansion be justified following the Municipal Comprehensive Review process. This reassessment would involve initiating a new environmental assessment to investigate a more comprehensive list of alternate solutions to offset any impacts associated with potential development in the headwaters of Carruthers Creek following a Settlement Area Boundary Expansion.

It should be noted that the intent of this assignment was to simulate the hydrologic response of several land use scenarios to inform the CCWP. Completing a detailed hydraulic assessment to quantify the impacts to flood levels within the watershed was outside the scope of work. Given the observed increase in peak flow values for Scenario 3 it is recommended that, following a Settlement Area Boundary Expansion, in accordance with the Growth Plan, and prior to municipal approval of a development proposal, a thorough hydraulic assessment be undertaken to quantify the potential changes to flood levels prior to development proceeding. Further, if current urban areas are susceptible to flooding under Scenario 3, then further flood remediation assessments in the form of feasibility assessments and Environmental Assessments would need to be undertaken by TRCA or its municipal partners in Durham.

Scenario 3 and ROPA 128, 2012

The Cole report entitled *Carruthers Creek Flood Management & Analysis Municipal Class EA: Regional Official Plan Amendment No. 128 Impact Report, May 2012*, simulated hydrological impacts from potential future build-out conditions using the Natural Heritage System delineated in the current City of Pickering Official Plan. This scenario is herein referred to as ROPA 128, 2012. There was interest amongst CCWP stakeholders to compare the results of the ROPA 128, 2012 scenario with Scenario 3 to examine the benefits of the Enhanced Natural Heritage System for various design storms if potential future build-out should proceed.

Because the Enhanced NHS is likely to have limited hydrologic benefit during a storm event with a magnitude such as the Regional Storm, it is not surprising that there is no significant difference in Regional Storm flow values between Scenario 3 and the ROPA 128, 2012 modelling results. However, benefits of the Enhanced NHS can be observed for the smaller storms as peak flows are up to 25% higher for the ROPA 128, 2012 scenario compared to Scenario 3 (e.g. for 2-year storm). It should be noted that TRCA did not develop a new modelling scenario for ROPA 128. Flow values presented in Appendix 4 for the ROPA 128, 2012 scenario were taken directly from the 2012 hydrology summary report by Cole. Please see Appendix 4 for details.

MANAGEMENT/MITIGATION RECOMMENDATIONS

The following section provides a high-level list and description of potential management recommendations related to flood impacts for Region of Durham, Town of Ajax, and City of Pickering consideration. The management recommendations provided are preliminary and should be confirmed and validated through additional hydrologic and hydraulic modelling, in compliance with the Growth Plan. This will ensure that the recommendations remain applicable should a Settlement Area Boundary Expansion in the headwaters of the Carruthers Creek watershed be required following the Municipal Comprehensive Review and Land Needs Assessment processes. The management recommendations will need to be reassessed at the appropriate time (i.e. secondary planning, subwatershed planning) prior to any development being approved.

Land Use Planning

Should a Settlement Area Boundary Expansion be justified in the headwaters of Carruthers Creek watershed, in accordance with the Growth Plan, then it must be demonstrated through subwatershed planning (or equivalent through a secondary plan process) that the proposed expansion would be planned to avoid, or minimize and mitigate, any potential negative impacts on watershed conditions and the Water Resource System, including the quality and quantity of water. This approach would utilize land use planning approaches to minimize imperviousness and maintain hydrologic processes and downstream flows. For example, focusing potential development in smaller, higher-density development areas could maintain larger natural areas that would limit downstream flows.

Implementation of Downstream Flood Remediation Alternatives

In combination with land use planning, a thorough reassessment of the Carruthers Creek Flood Management & Analysis Municipal Class EA would be required should a Settlement Area Boundary Expansion be justified following the Municipal Comprehensive Review process. This reassessment would involve initiating a new environmental assessment to investigate a more comprehensive list of alternative solutions to offset any impacts associated with potential development in the headwaters of Carruthers Creek following a Settlement Area Boundary Expansion. Any reassessment of flood mitigation measures developed for the Lower

Carruthers Flood Vulnerable Cluster should consider future impacts of climate change using the most up to date climate modelling data for Durham Region in addition to a detailed analysis related to the impact on flooding as a result of record Lake Ontario levels in 2017 and 2019.

Future Studies

As noted above, potential changes to flood levels across the watershed should be assessed following a Settlement Area Boundary Expansion and prior to municipal approval of any development proposals (i.e. at the Secondary Plan stage). If this assessment identifies that new areas of the watershed are susceptible to flooding, then further flood remediation assessments, in the form of feasibility assessments and/or environmental assessments would need to be undertaken to mitigate any potential impacts.

Regional Storm Stormwater Management Quantity Control

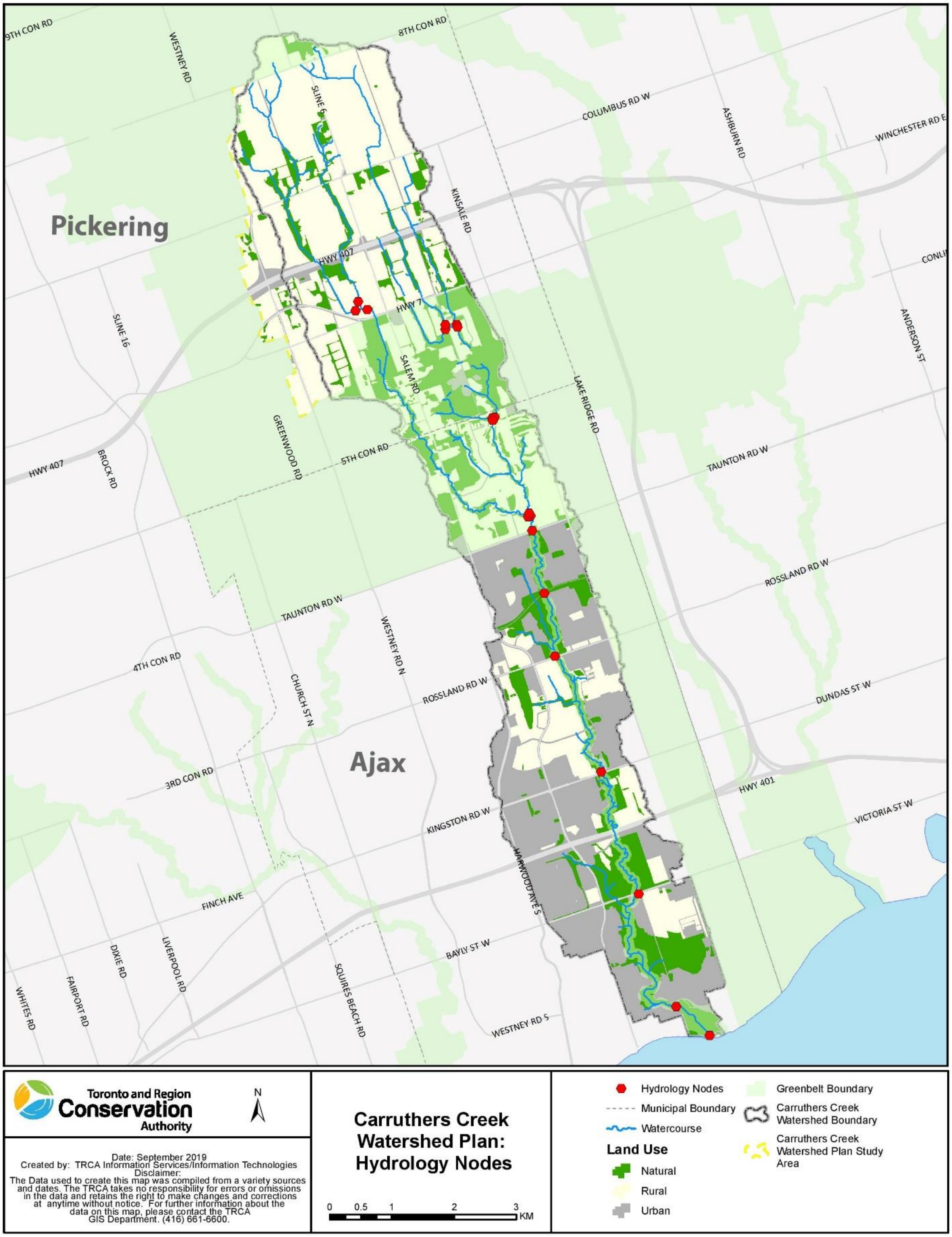
The application of Regional Control in the headwaters of Carruthers Creek is recommended should development be proposed following a Settlement Area Boundary Expansion. The Ministry of Natural Resources and Forestry (MNRF) has not accepted this approach in TRCA's jurisdiction and further consultation including support from the MNRF would be required to apply Regional Control. Land use needs to accommodate the required runoff volume may not comply with land use targets due to pond size.

Municipal Infrastructure Upgrades

Existing water crossings overtopped during a Regional Storm event should be upgraded to ensure safe public and emergency response passage. Furthermore, watercourse crossings where upstream flood levels result from insufficient crossing capacity should be replaced[1].

[1] A list of these structures has been provided under a separate cover and will be included in the CCWP.

APPENDIX 1


9TH CON RD
8TH CON RD
WESTNEY RD
SLINE 6
COLUMBUS RD W
ASHBURN RD
WINCHESTER RD E
KINSALE RD
Pickering
HWY 407
HWY 7
SLINE 16
SALEM RD
LAKE RIDGE RD
ANDERSON ST
GREENWOOD RD
5TH CON RD
HWY 407
BROCK RD
TAUNTON RD W
ROSSLAND RD W
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WESTNEY RD N
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CHURCH ST N
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Ajax
3RD CON RD
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VICTORIA ST W
KINGSTON RD W
HARWOOD AVE S
FINCH AVE
BAYLY ST W
DIXIE RD
LIVERPOOL RD
SQUIRES BEACH RD
WHITES RD
FAIRPORT RD
WESTNEY RD S
Toronto and Region Conservation Authority
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Date: September 2019
Created by: TRCA Information Services/Information Technologies
Disclaimer:
The Data used to create this map was compiled from a variety sources and dates. The TRCA takes no responsibility for errors or omissions in the data and retains the right to make changes and corrections at anytime without notice. For further information about the data on this map, please contact the TRCA GIS Department. (416) 661-6600.
Carruthers Creek Watershed Plan: Hydrology Nodes
0 0.5 1 2 3 KM
Hydrology Nodes
Municipal Boundary
Watercourse
Land Use
Natural
Rural
Urban
Greenbelt Boundary
Carruthers Creek Watershed Boundary
Carruthers Creek Watershed Plan Study Area

APPENDIX 2

2-year	VO2 Subcatchment IDs	Scenario 1 (+OP)	Scenario 2 (+NHS)		Scenario 3 (+Potential Urban)	
Location		Peak Flows (m^3/s)	Peak Flows (m^3/s)	% Change from Scenario 1	Peak Flows (m^3/s)	% Change from Scenario 1
U/S Hwy. 7 (W. Tributary)	3096	0.946	0.822	-13.1%	0.883	-7%
	1175	0.575	0.505	-12.2%	3.854	570%
	3095	1.52	1.326	-12.8%	1.424	-6%
D/S Hwy. 7 (E. Tributary)	1181	0.409	0.337	-17.6%	0.186	-55%
	1182	0.57	0.493	-13.5%	3.053	436%
	1183	0.539	0.498	-7.6%	2.425	350%
	3103	1.398	1.226	-12.3%	1.274	-9%
D/S 5th Concession (E. Tributary)	1179	0.159	0.158	-0.6%	0.158	-1%
	3102	1.626	1.446	-11.1%	1.56	-4%
	3101	1.777	1.596	-10.2%	1.714	-4%
U/S Taunton Rd. (Confluence)	3094	2.202	1.973	-10.4%	2.013	-9%
	3098	2.136	1.947	-8.8%	2.136	0%
	3093	4.338	3.92	-9.6%	4.066	-6%
Taunton Rd.	3092	4.542	4.128	-9.1%	4.306	-5%
CPR	3087	4.671	4.254	-8.9%	4.439	-5%
U/S Rossland Rd.	3082	4.815	4.399	-8.6%	4.6	-4%
Hwy. 2 E.	1044	5.718	5.254	-8.1%	5.559	-3%
D/S Bayly St.	1033	6.25	5.771	-7.7%	6.144	-2%
Shoal Point Rd.	1005	7.387	7.262	-1.7%	7.498	2%
Lake Ontario	1000	7.993	7.896	-1.2%	7.983	0%

5-year	VO2 Subcatchment IDs	Scenario 1 (+OP)	Scenario 2 (+NHS)	Scenario 3 (+Potential Urban)		
Location		Peak Flows (m^3/s)	Peak Flows (m^3/s)	% Change from Scenario 1	Peak Flows (m^3/s)	% Change from Scenario 1
U/S Hwy. 7 (W. Tributary)	3096	1.458	1.296	-11.1%	1.439	-1%
	1175	0.89	0.794	-10.8%	5.346	501%
	3095	2.346	2.088	-11.0%	2.256	-4%
D/S Hwy. 7 (E. Tributary)	1181	0.637	0.537	-15.7%	0.3	-53%
	1182	0.879	0.774	-11.9%	4.368	397%
	1183	0.829	0.774	-6.6%	3.356	305%
	3103	2.16	1.925	-10.9%	1.988	-8%
D/S 5th Concession (E. Tributary)	1179	0.26	0.259	-0.4%	0.259	0%
	3102	2.529	2.283	-9.7%	2.448	-3%
	3101	2.775	2.529	-8.9%	2.703	-3%
U/S Taunton Rd. (Confluence)	3094	3.51	3.167	-9.8%	3.124	-11%
	3098	3.354	3.096	-7.7%	3.371	1%
	3093	6.865	6.263	-8.8%	6.427	-6%
Taunton Rd.	3092	7.179	6.577	-8.4%	6.796	-5%
CPR	3087	7.462	6.859	-8.1%	7.087	-5%
U/S Rossland Rd.	3082	7.724	7.115	-7.9%	7.374	-5%
Hwy. 2 E.	1044	9.346	8.685	-7.1%	9.075	-3%
D/S Bayly St.	1033	10.095	9.433	-6.6%	9.916	-2%
Shoal Point Rd.	1005	11.708	11.112	-5.1%	11.832	1%
Lake Ontario	1000	11.9	11.529	-3.1%	12.07	1%

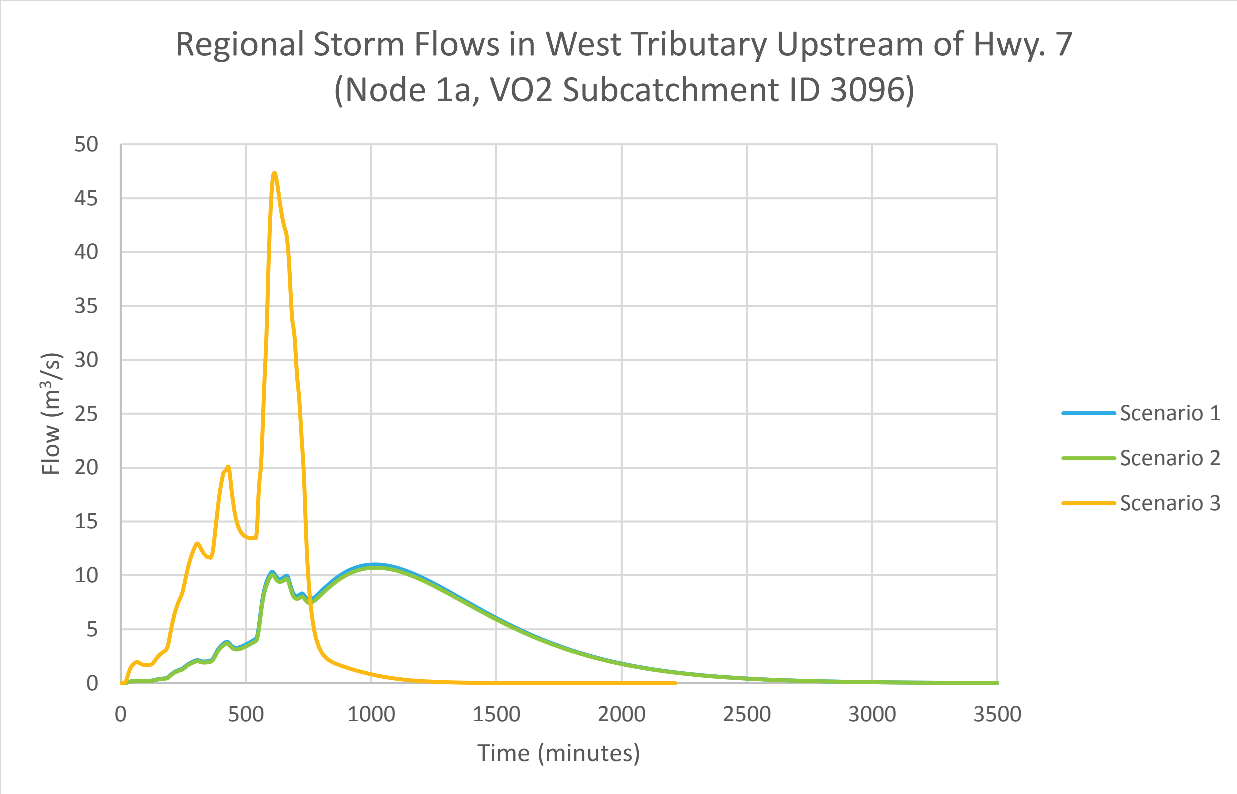
10-year	VO2 Subcatchment IDs	Scenario 1 (+OP)	Scenario 2 (+NHS)		Scenario 3 (+Potential Urban)	
Location		Peak Flows (m^3/s)	Peak Flows (m^3/s)	% Change from Scenario 1	Peak Flows (m^3/s)	% Change from Scenario 1
U/S Hwy. 7 (W. Tributary)	3096	1.815	1.625	-10.5%	2.011	11%
	1175	1.121	1.008	-10.1%	6.406	471%
	3095	2.932	2.631	-10.3%	3.168	8%
D/S Hwy. 7 (E. Tributary)	1181	0.804	0.686	-14.7%	0.387	-52%
	1182	1.105	0.982	-11.1%	5.35	384%
	1183	1.041	0.977	-6.1%	4.002	284%
	3103	2.717	2.441	-10.2%	2.845	5%
D/S 5th Concession (E. Tributary)	1179	0.337	0.337	0.0%	0.337	0%
	3102	3.194	2.905	-9.0%	3.428	7%
	3101	3.515	3.225	-8.3%	3.756	7%
U/S Taunton Rd. (Confluence)	3094	4.516	4.102	-9.2%	4.294	-5%
	3098	4.263	3.957	-7.2%	4.626	9%
	3093	8.779	8.058	-8.2%	8.837	1%
Taunton Rd.	3092	9.175	8.458	-7.8%	9.308	1%
CPR	3087	9.556	8.841	-7.5%	9.706	2%
U/S Rossland Rd.	3082	9.894	9.178	-7.2%	10.05	2%
Hwy. 2 E.	1044	11.94	11.185	-6.3%	12.253	3%
D/S Bayly St.	1033	12.942	12.16	-6.0%	13.418	4%
Shoal Point Rd.	1005	14.943	14.169	-5.2%	15.563	4%
Lake Ontario	1000	15.154	14.388	-5.1%	15.8	4%

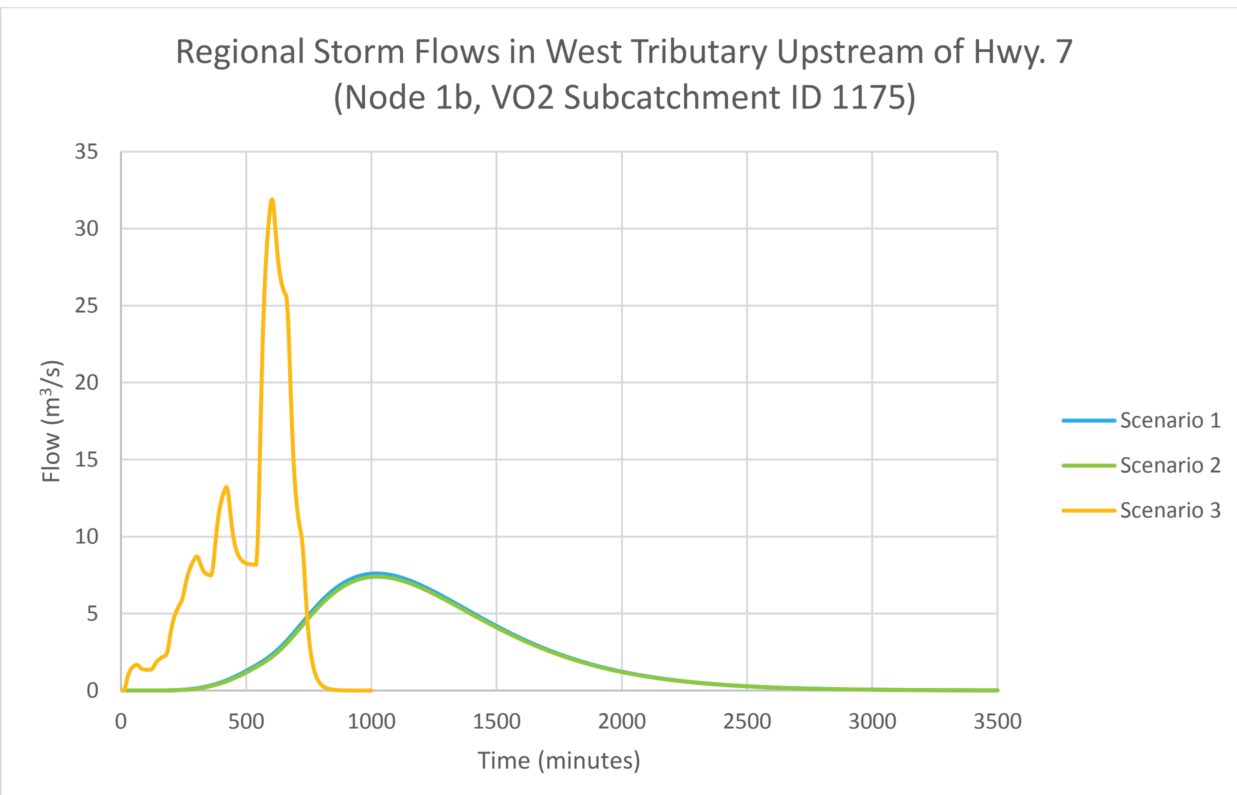
25-year	VO2 Subcatchment IDs	Scenario 1 (+OP)	Scenario 2 (+NHS)		Scenario 3 (+Potential Urban)	
Location		Peak Flows (m^3/s)	Peak Flows (m^3/s)	% Change from Scenario 1	Peak Flows (m^3/s)	% Change from Scenario 1
U/S Hwy. 7 (W. Tributary)	3096	2.312	2.085	-9.8%	3.165	37%
	1175	1.429	1.296	-9.3%	7.757	443%
	3095	3.731	3.371	-9.6%	4.955	33%
D/S Hwy. 7 (E. Tributary)	1181	1.03	0.89	-13.6%	0.505	-51%
	1182	1.406	1.262	-10.2%	6.603	370%
	1183	1.325	1.249	-5.7%	4.885	269%
	3103	3.461	3.137	-9.4%	4.295	24%
D/S 5th Concession (E. Tributary)	1179	0.445	0.445	0.0%	0.445	0%
	3102	4.088	3.748	-8.3%	5.005	22%
	3101	4.512	4.172	-7.5%	5.427	20%
U/S Taunton Rd. (Confluence)	3094	5.815	5.375	-7.6%	6.16	6%
	3098	5.497	5.137	-6.5%	6.563	19%
	3093	11.305	10.511	-7.0%	12.7	12%
Taunton Rd.	3092	11.824	11.019	-6.8%	13.324	13%
CPR	3087	12.328	11.518	-6.6%	13.847	12%
U/S Rossland Rd.	3082	12.738	11.931	-6.3%	14.263	12%
Hwy. 2 E.	1044	15.396	14.493	-5.9%	17.205	12%
D/S Bayly St.	1033	16.871	15.928	-5.6%	18.748	11%
Shoal Point Rd.	1005	19.329	18.386	-4.9%	21.423	11%
Lake Ontario	1000	19.617	18.686	-4.7%	21.741	11%

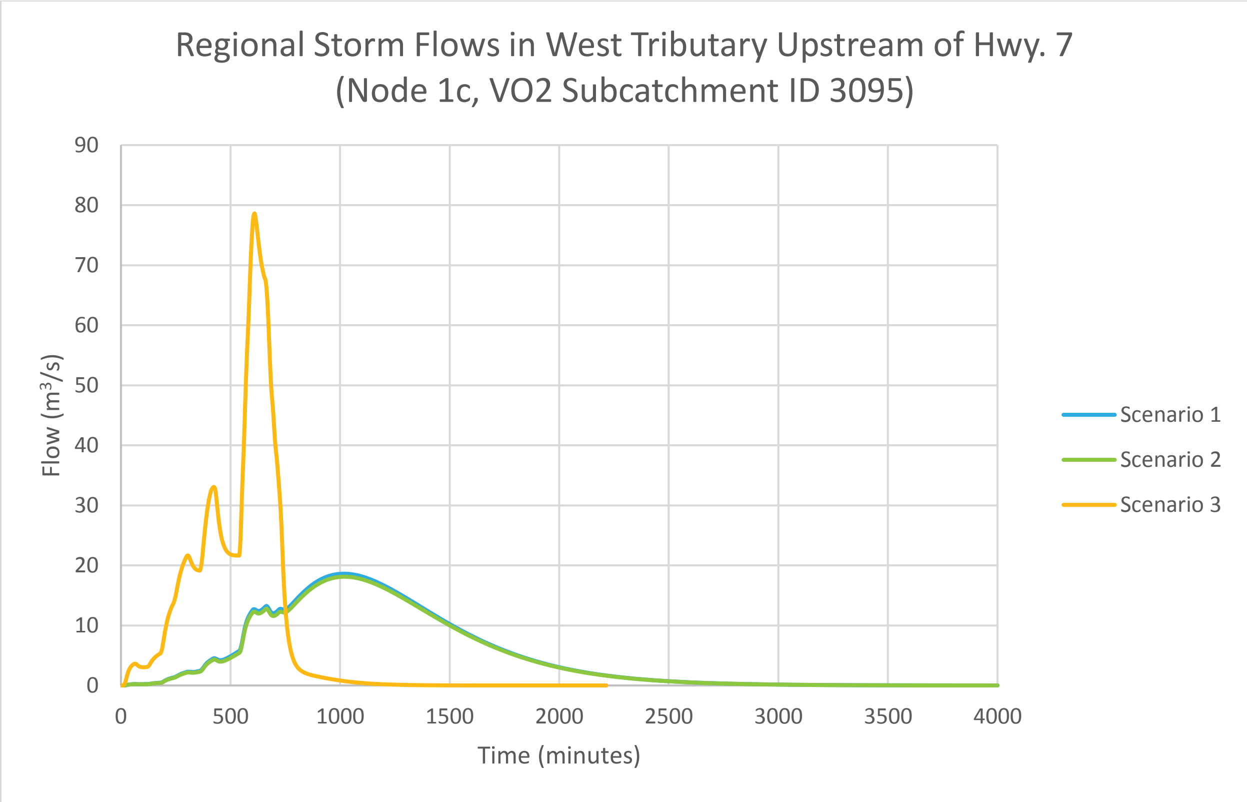
50-year	VO2 Subcatchment IDs	Scenario 1 (+OP)	Scenario 2 (+NHS)		Scenario 3 (+Potential Urban)	
Location		Peak Flows (m^3/s)	Peak Flows (m^3/s)	% Change from Scenario 1	Peak Flows (m^3/s)	% Change from Scenario 1
U/S Hwy. 7 (W. Tributary)	3096	2.696	2.447	-9.2%	4.096	52%
	1175	1.669	1.522	-8.8%	8.857	431%
	3095	4.353	3.957	-9.1%	6.479	49%
D/S Hwy. 7 (E. Tributary)	1181	1.205	1.049	-12.9%	0.599	-50%
	1182	1.64	1.481	-9.7%	7.642	366%
	1183	1.545	1.461	-5.4%	5.541	259%
	3103	4.041	3.681	-8.9%	5.589	38%
D/S 5th Concession (E. Tributary)	1179	0.532	0.533	0.2%	0.533	0%
	3102	4.787	4.41	-7.9%	6.374	33%
	3101	5.295	4.918	-7.1%	6.862	30%
U/S Taunton Rd. (Confluence)	3094	6.82	6.319	-7.3%	7.84	15%
	3098	6.447	6.053	-6.1%	8.215	27%
	3093	13.263	12.367	-6.8%	16.031	21%
Taunton Rd.	3092	13.857	12.968	-6.4%	16.774	21%
CPR	3087	14.443	13.559	-6.1%	17.401	20%
U/S Rossland Rd.	3082	14.906	14.032	-5.9%	17.893	20%
Hwy. 2 E.	1044	17.983	17.075	-5.0%	21.501	20%
D/S Bayly St.	1033	19.756	18.784	-4.9%	23.195	17%
Shoal Point Rd.	1005	22.728	21.704	-4.5%	26.447	16%
Lake Ontario	1000	23.109	22.063	-4.5%	26.856	16%

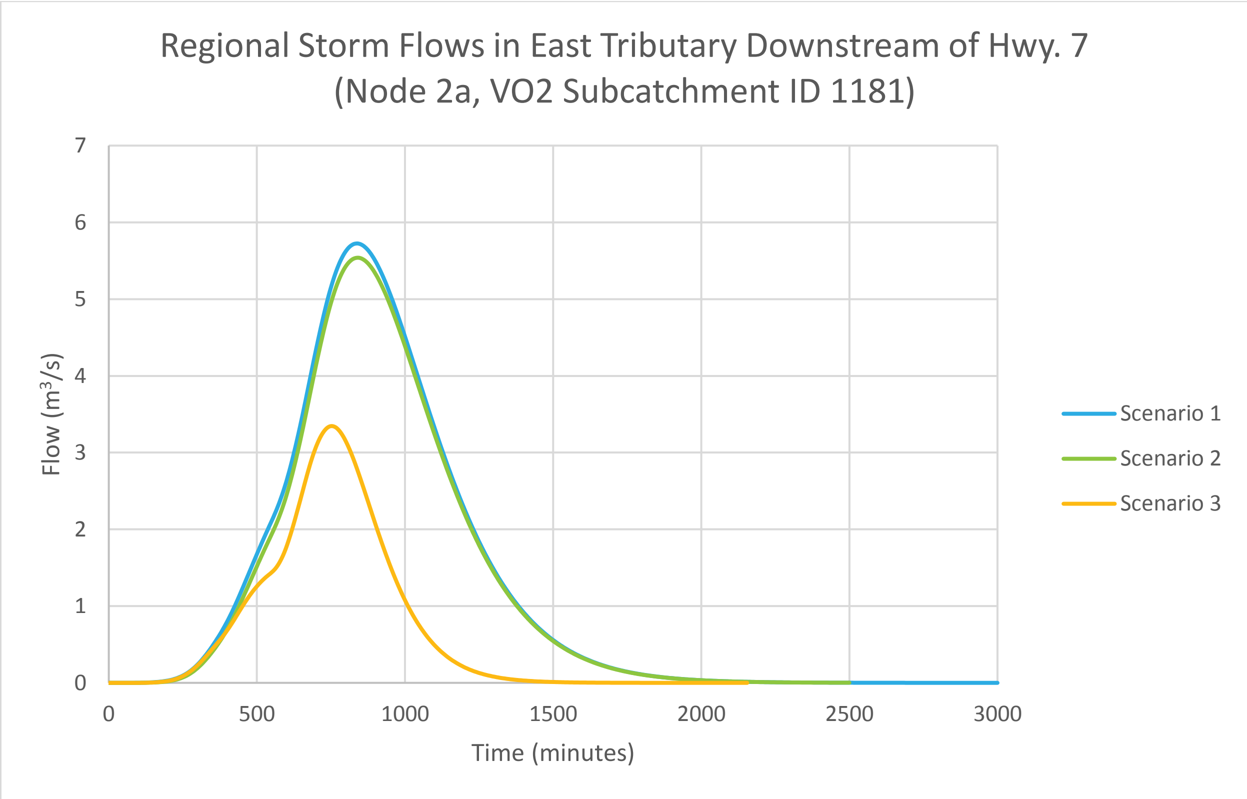
100-year	VO2 Subcatchment IDs	Scenario 1 (+OP)	Scenario 2 (+NHS)		Scenario 3 (+Potential Urban)	
Location		Peak Flows (m^3/s)	Peak Flows (m^3/s)	% Change from Scenario 1	Peak Flows (m^3/s)	% Change from Scenario 1
U/S Hwy. 7 (W. Tributary)	3096	3.095	2.821	-8.9%	5.027	62%
	1175	1.918	1.757	-8.4%	9.936	418%
	3095	4.999	4.565	-8.7%	7.994	60%
D/S Hwy. 7 (E. Tributary)	1181	1.388	1.217	-12.3%	0.697	-50%
	1182	1.883	1.709	-9.2%	8.663	360%
	1183	1.773	1.682	-5.1%	6.259	253%
	3103	4.642	4.249	-8.5%	6.889	48%
D/S 5th Concession (E. Tributary)	1179	0.625	0.626	0.2%	0.626	0%
	3102	5.515	5.103	-7.5%	7.774	41%
	3101	6.112	5.7	-6.7%	8.329	36%
U/S Taunton Rd. (Confluence)	3094	7.894	7.327	-7.2%	9.511	20%
	3098	7.456	7.024	-5.8%	9.91	33%
	3093	15.347	14.345	-6.5%	19.405	26%
Taunton Rd.	3092	16.023	15.027	-6.2%	20.268	26%
CPR	3087	16.688	15.685	-6.0%	20.978	26%
U/S Rossland Rd.	3082	17.23	16.234	-5.8%	21.559	25%
Hwy. 2 E.	1044	20.663	19.63	-5.0%	25.656	24%
D/S Bayly St.	1033	22.639	21.575	-4.7%	27.705	22%
Shoal Point Rd.	1005	26.127	25.106	-3.9%	31.553	21%
Lake Ontario	1000	26.607	25.575	-3.9%	32.003	20%

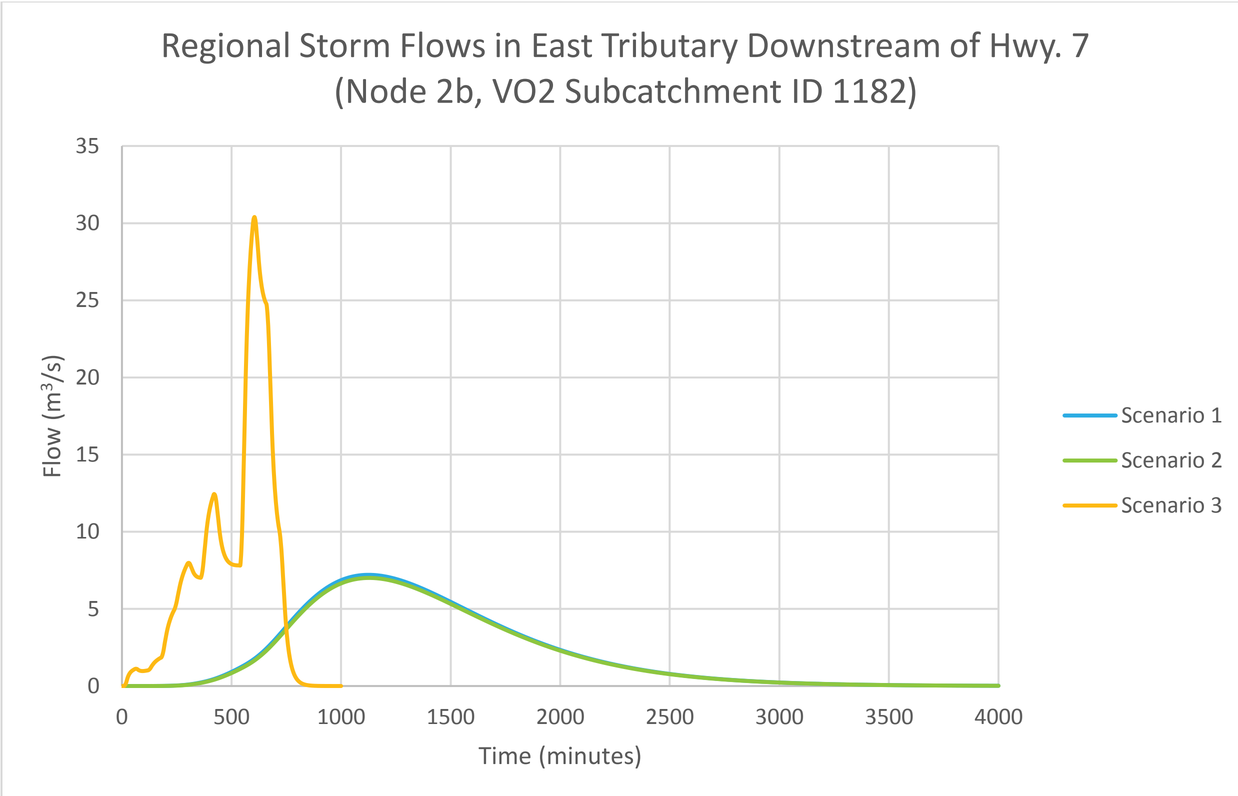
APPENDIX 3

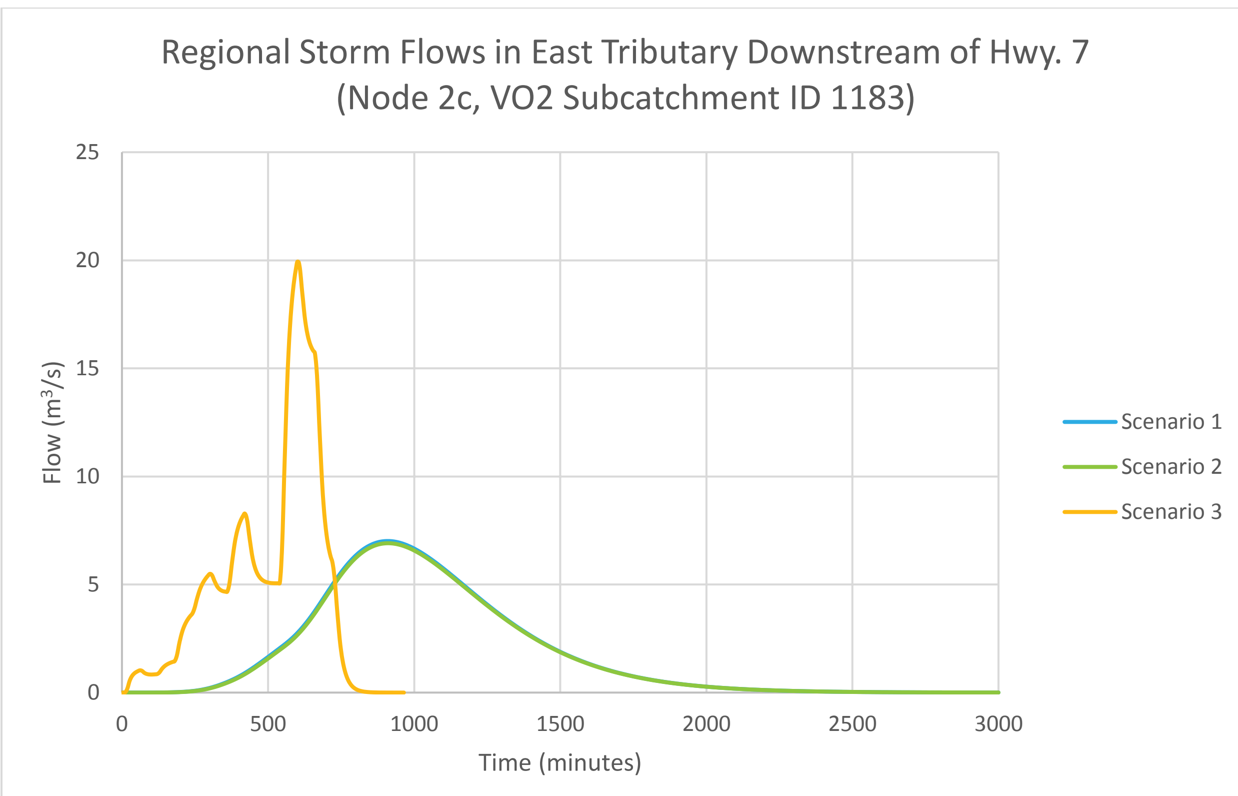

Regional Storm Flows in West Tributary Upstream of Hwy. 7
(Node 1a, VO2 Subcatchment ID 3096)
Flow (m3/s)
Time (minutes)
0
5
10
15
20
25
30
35
40
45
50
0
500
1000
1500
2000
2500
3000
3500
Scenario 1
Scenario 2
Scenario 3

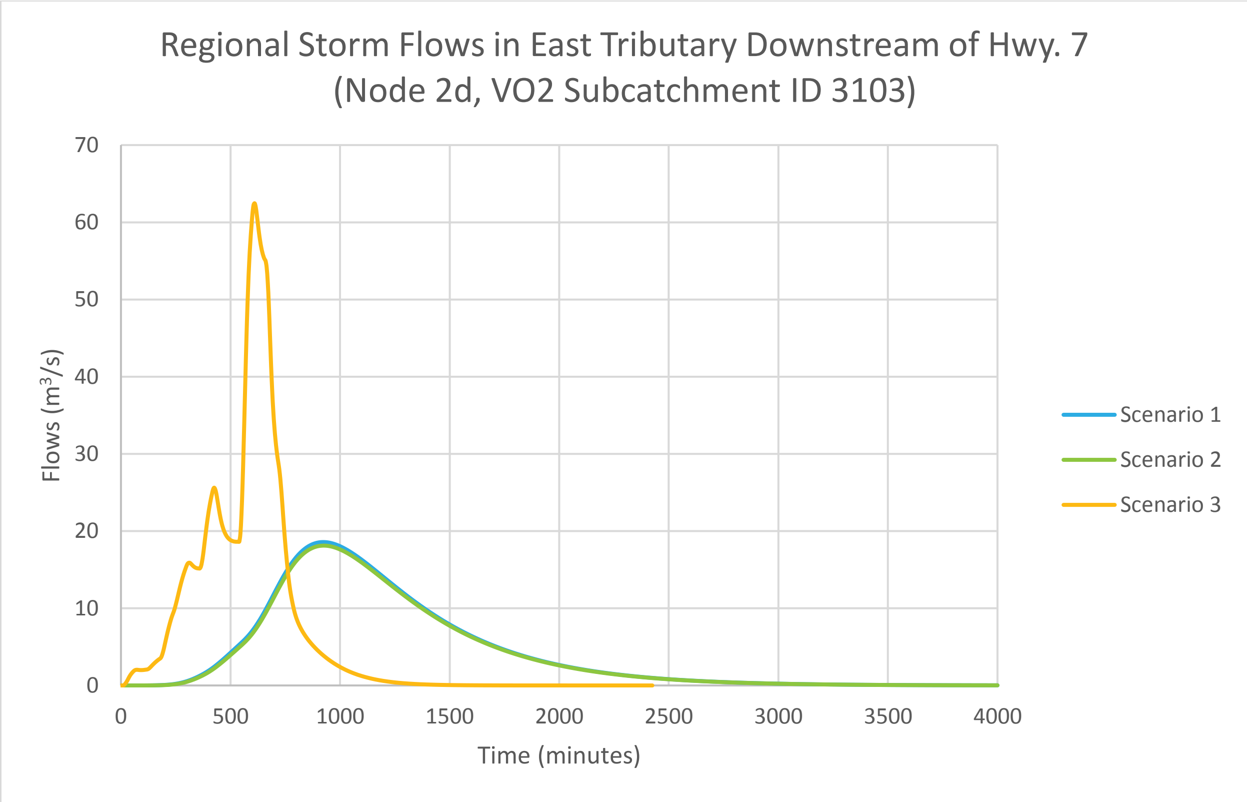

Regional Storm Flows in West Tributary Upstream of Hwy. 7
(Node 1b, VO2 Subcatchment ID 1175)
Flow (m3/s)
Time (minutes)
0
5
10
15
20
25
30
35
0
500
1000
1500
2000
2500
3000
3500
Scenario 1
Scenario 2
Scenario 3

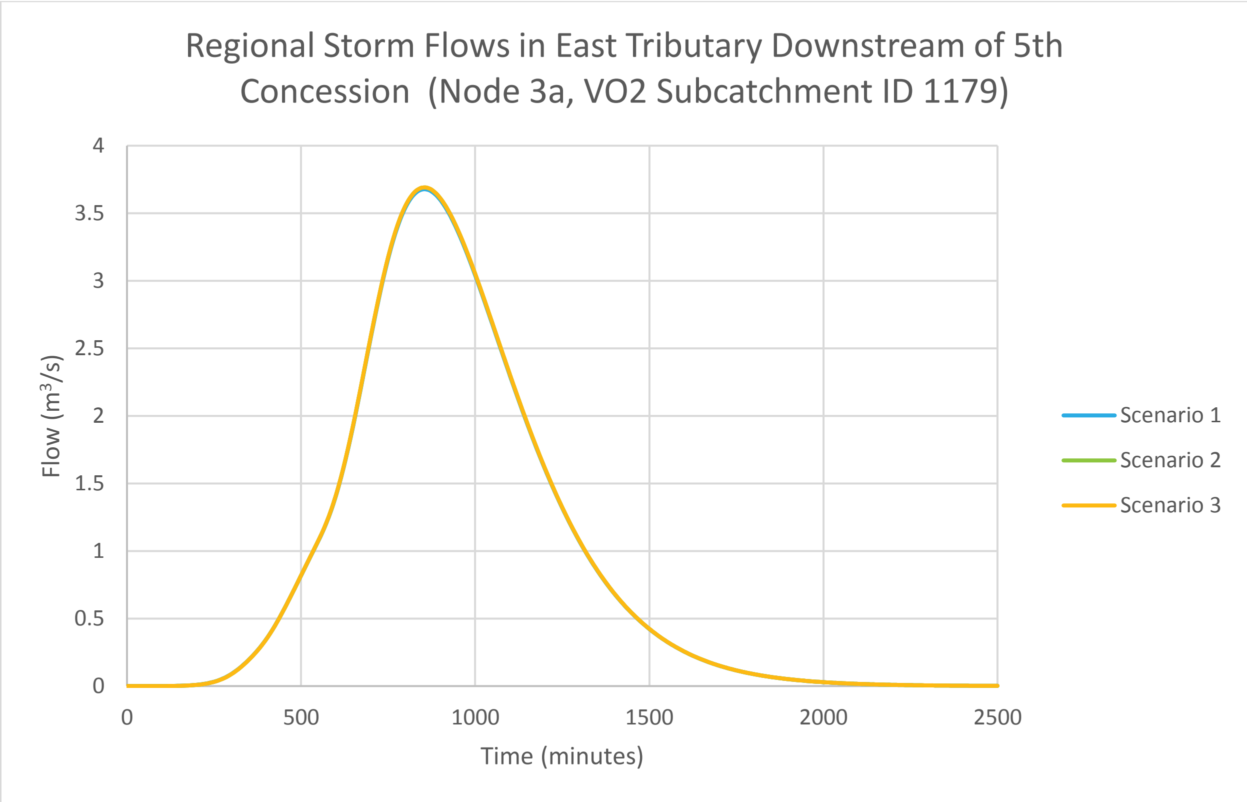

Regional Storm Flows in West Tributary Upstream of Hwy. 7
(Node 1c, VO2 Subcatchment ID 3095)
Flow (m3/s)
0
10
20
30
40
50
60
70
80
90
0
500
1000
1500
2000
2500
3000
3500
4000
Time (minutes)
Scenario 1
Scenario 2
Scenario 3

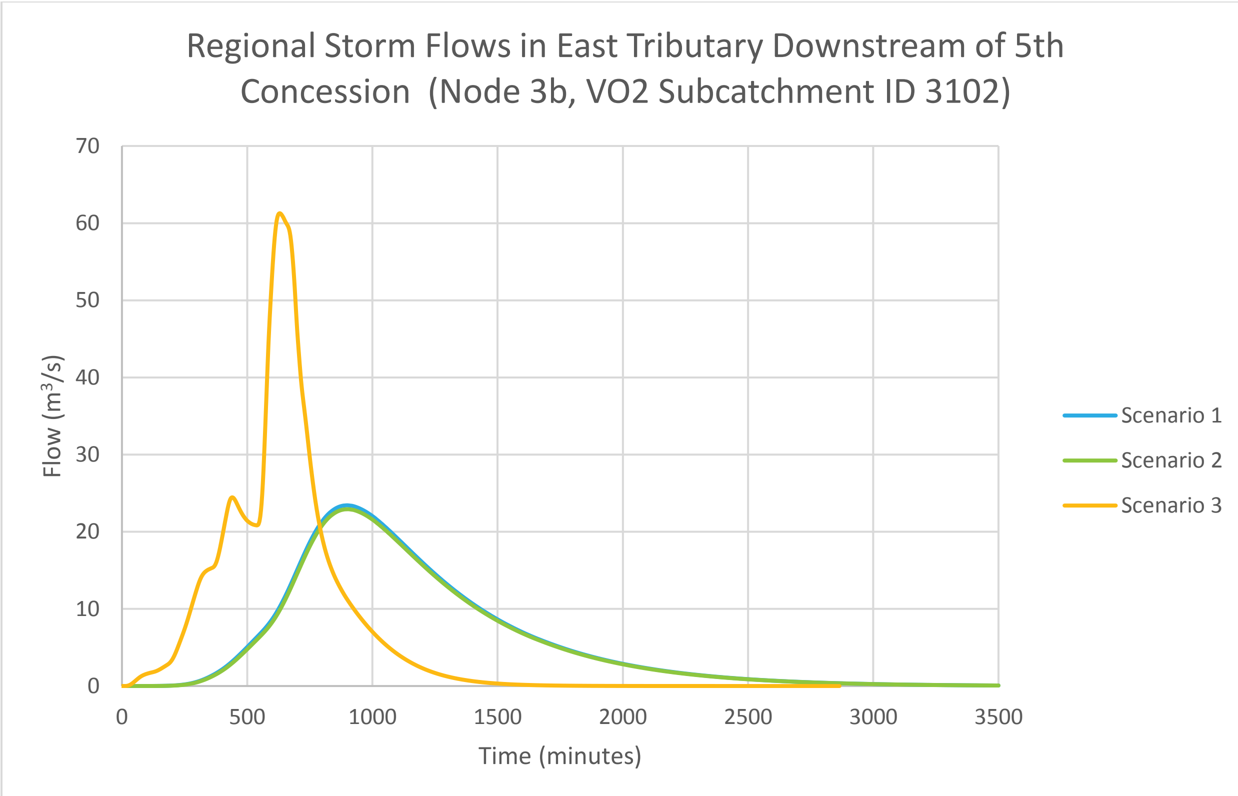

Regional Storm Flows in East Tributary Downstream of Hwy. 7
(Node 2a, VO2 Subcatchment ID 1181)
Flow (m3/s)
0
1
2
3
4
5
6
7
0
500
1000
1500
2000
2500
3000
Time (minutes)
Scenario 1
Scenario 2
Scenario 3

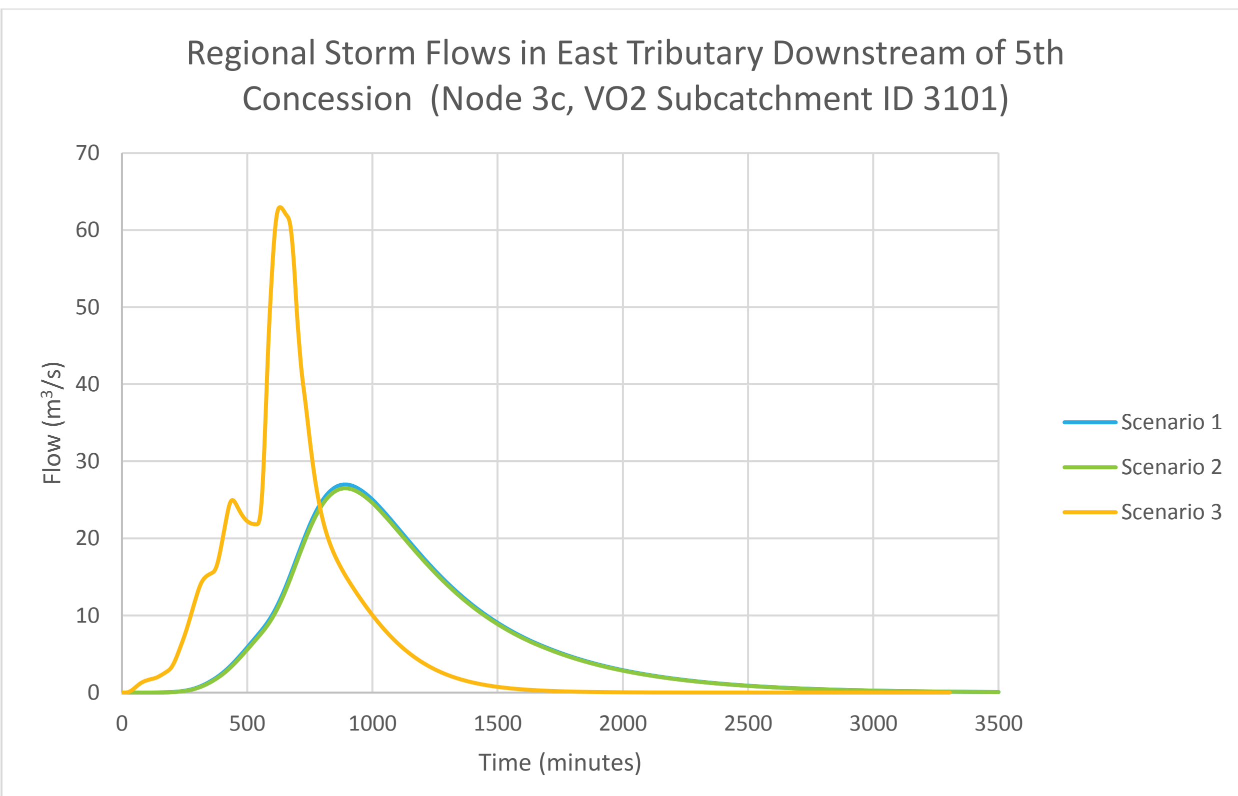

Regional Storm Flows in East Tributary Downstream of Hwy. 7
(Node 2b, VO2 Subcatchment ID 1182)
35
30
25
20
15
10
5
0
Flow (m3/s)
0
500
1000
1500
2000
2500
3000
3500
4000
Time (minutes)
Scenario 1
Scenario 2
Scenario 3

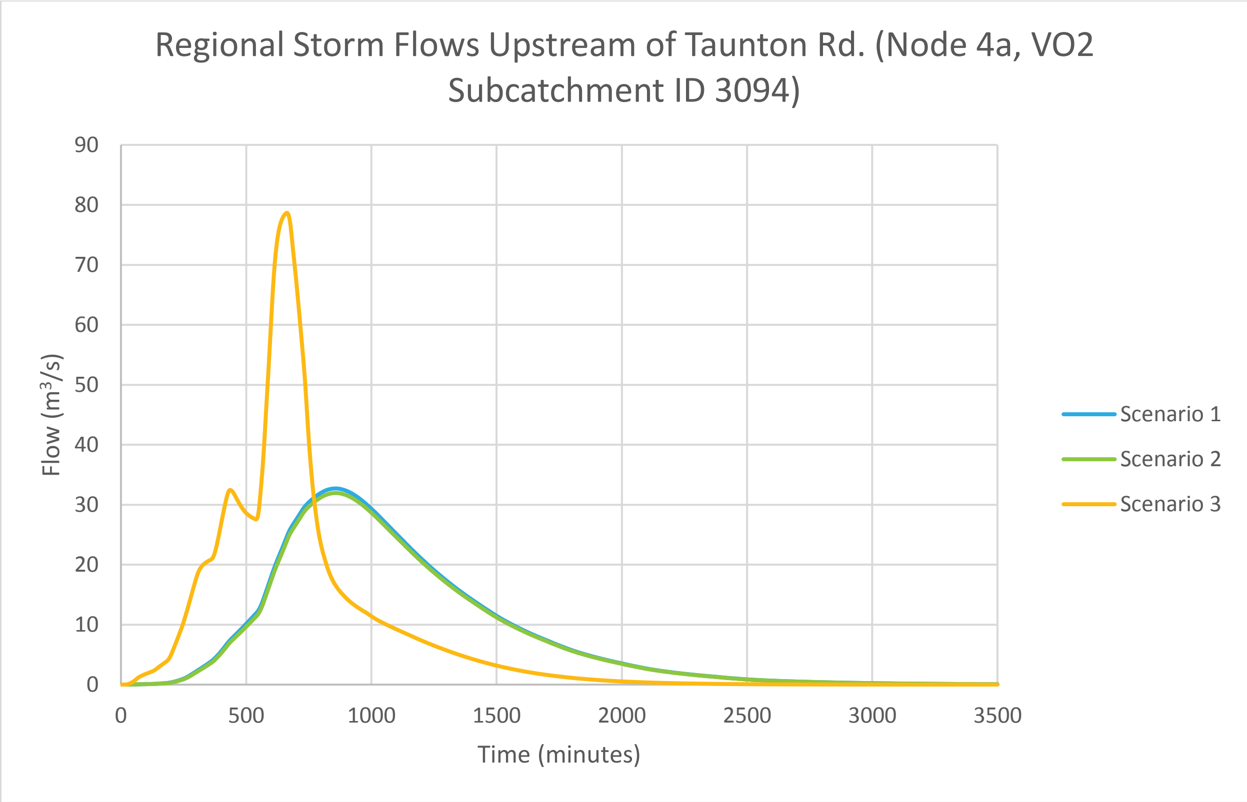

Regional Storm Flows in East Tributary Downstream of Hwy. 7
(Node 2c, VO2 Subcatchment ID 1183)
25
20
15
10
5
0
Flow (m3/s)
0
500
1000
1500
2000
2500
3000
Time (minutes)
Scenario 1
Scenario 2
Scenario 3

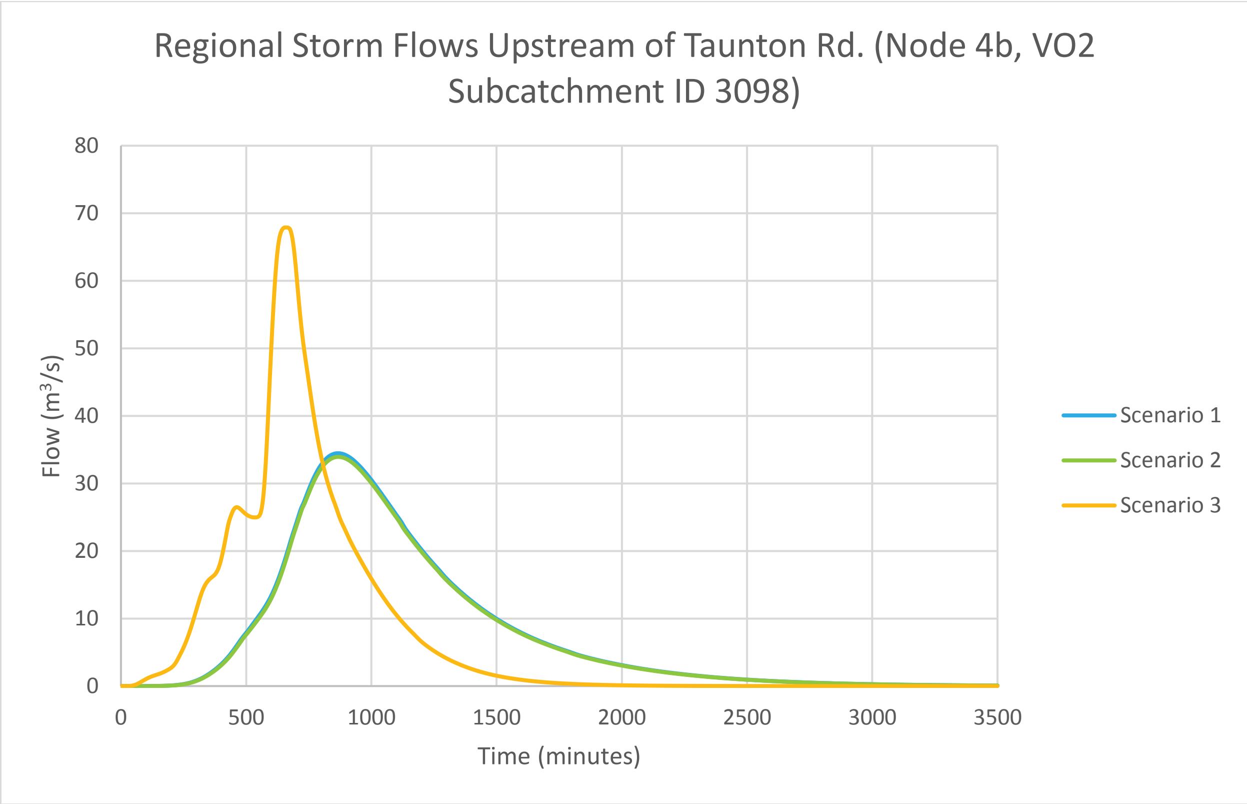

Regional Storm Flows in East Tributary Downstream of Hwy. 7
(Node 2d, VO2 Subcatchment ID 3103)
Flows (m3/s)
70
60
50
40
30
20
10
0
0
500
1000
1500
2000
2500
3000
3500
4000
Time (minutes)
Scenario 1
Scenario 2
Scenario 3

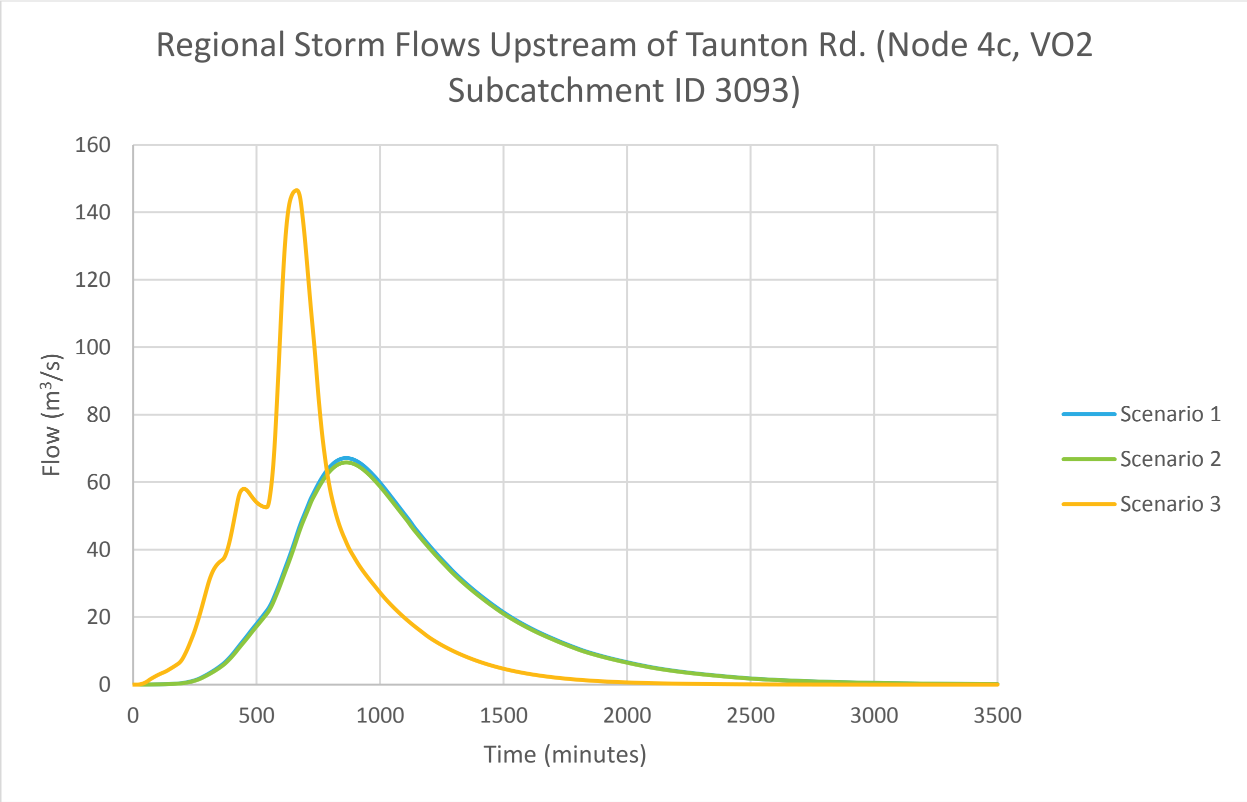

Regional Storm Flows in East Tributary Downstream of 5th Concession (Node 3a, VO2 Subcatchment ID 1179)
Flow (m3/s)
4
3.5
3
2.5
2
1.5
1
0.5
0
0
500
1000
1500
2000
2500
Time (minutes)
Scenario 1
Scenario 2
Scenario 3

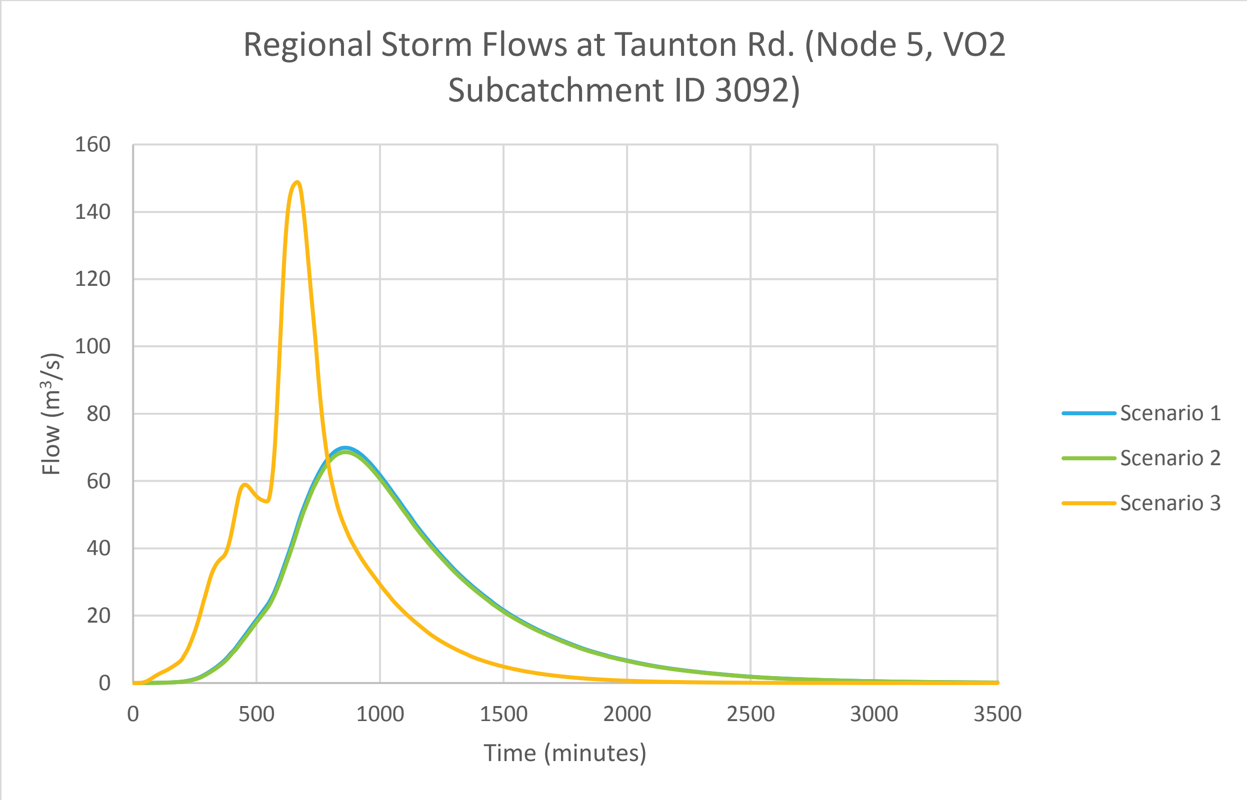

Regional Storm Flows in East Tributary Downstream of 5th Concession (Node 3b, VO2 Subcatchment ID 3102)
Flow (m3/s)
0
10
20
30
40
50
60
70
0
500
1000
1500
2000
2500
3000
3500
Time (minutes)
Scenario 1
Scenario 2
Scenario 3

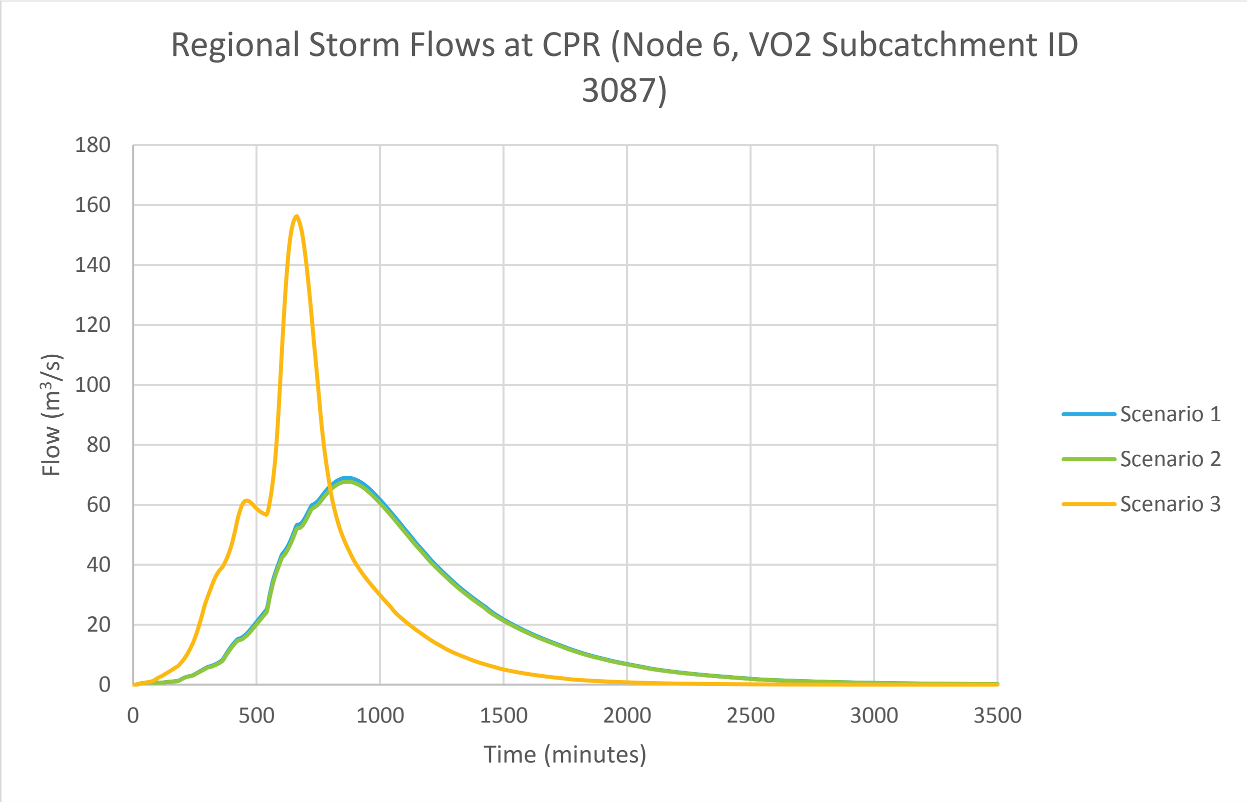

Regional Storm Flows in East Tributary Downstream of 5th Concession (Node 3c, VO2 Subcatchment ID 3101)
Flow (m3/s)
0
10
20
30
40
50
60
70
0
500
1000
1500
2000
2500
3000
3500
Time (minutes)
Scenario 1
Scenario 2
Scenario 3

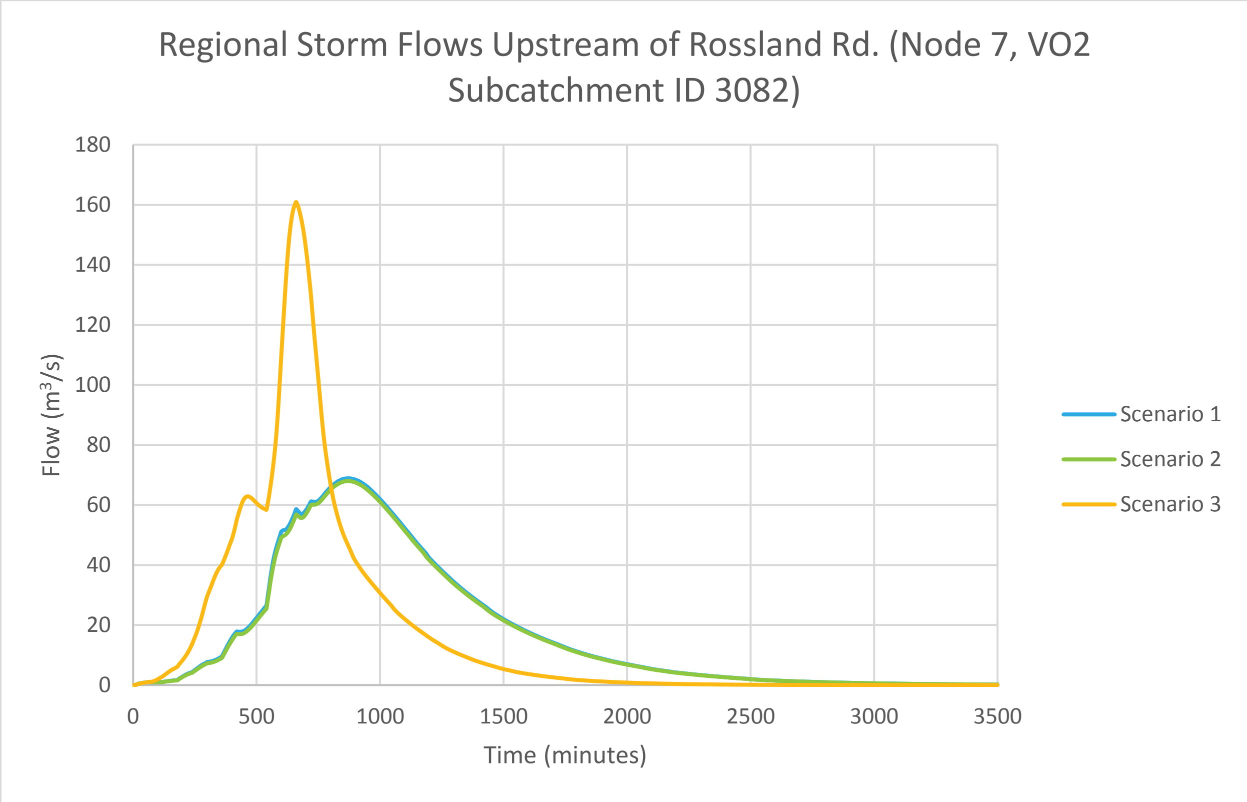

Regional Storm Flows Upstream of Taunton Rd. (Node 4a, VO2 Subcatchment ID 3094)
Flow (m3/s)
90
80
70
60
50
40
30
20
10
0
0
500
1000
1500
2000
2500
3000
3500
Time (minutes)
Scenario 1
Scenario 2
Scenario 3

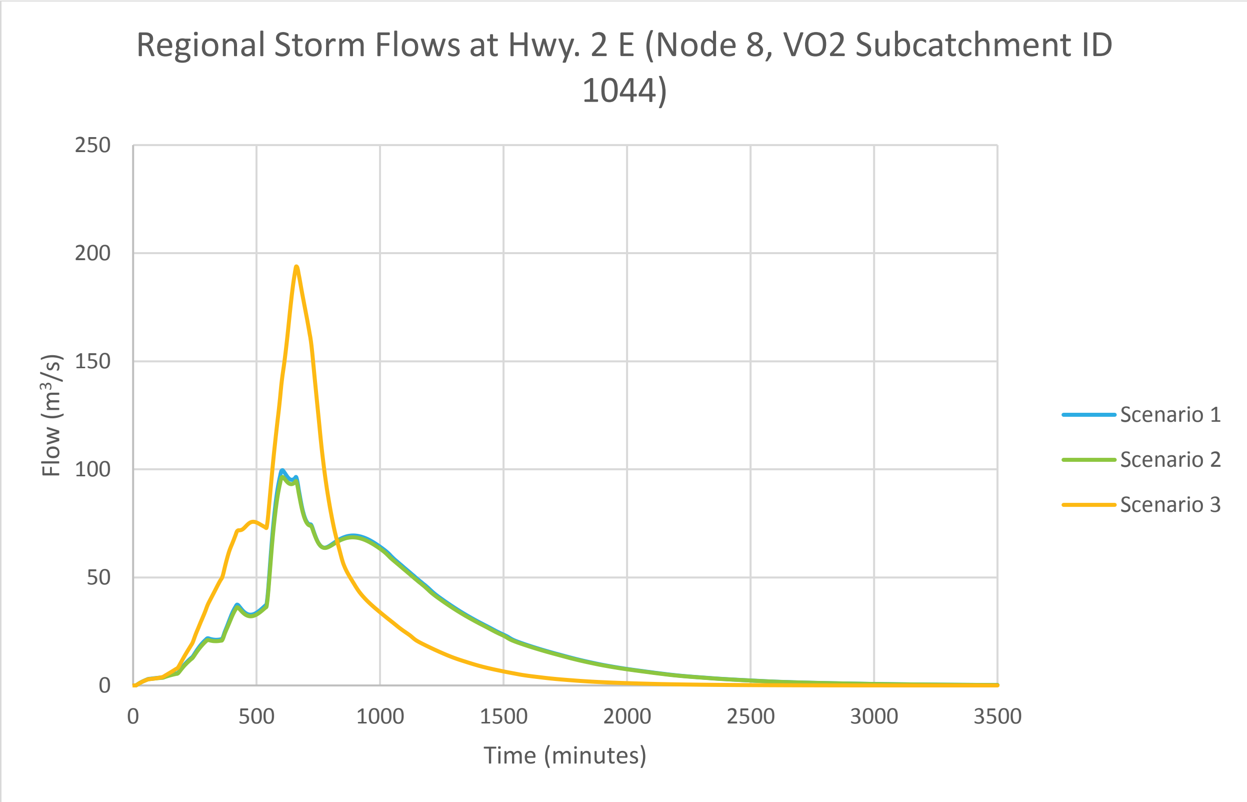

Regional Storm Flows Upstream of Taunton Rd. (Node 4b, VO2 Subcatchment ID 3098)
Flow (m3/s)
80
70
60
50
40
30
20
10
0
0
500
1000
1500
2000
2500
3000
3500
Time (minutes)
Scenario 1
Scenario 2
Scenario 3

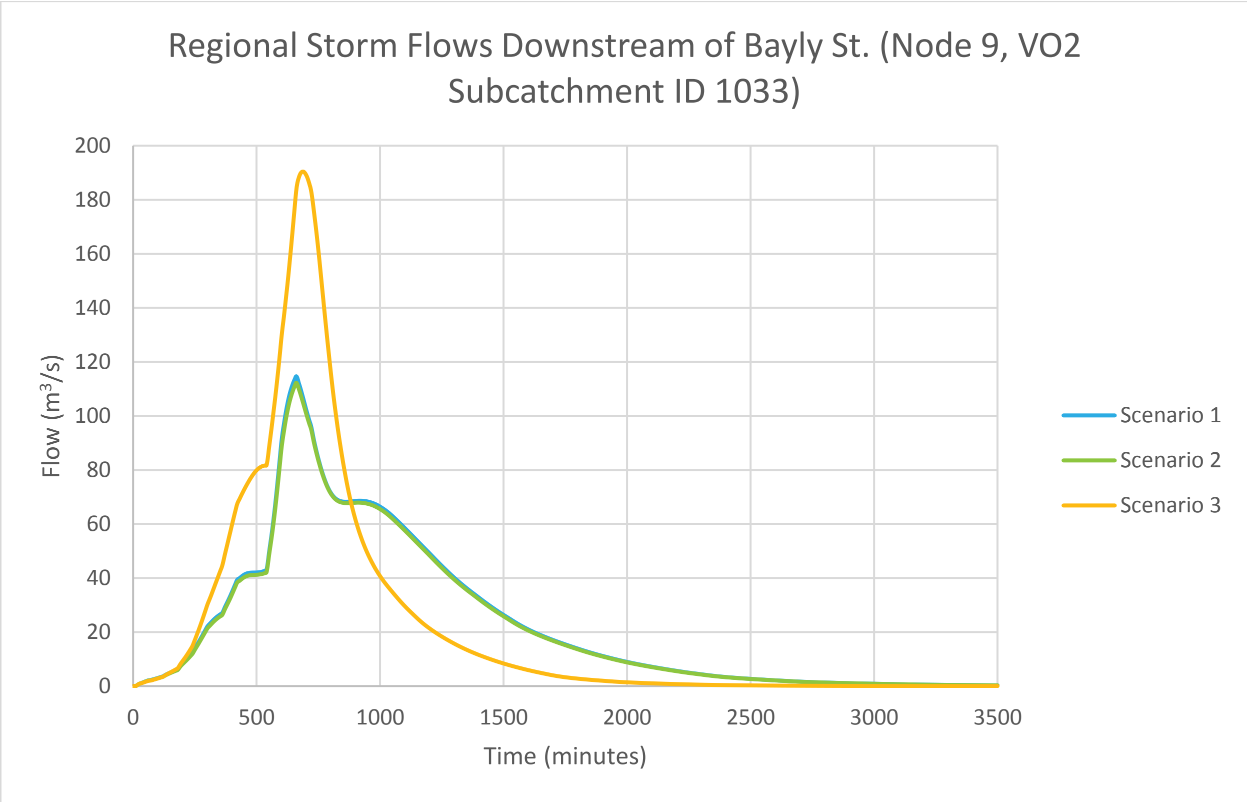

Regional Storm Flows Upstream of Taunton Rd. (Node 4c, VO2 Subcatchment ID 3093)
Flow (m3/s)
160
140
120
100
80
60
40
20
0
0
500
1000
1500
2000
2500
3000
3500
Time (minutes)
Scenario 1
Scenario 2
Scenario 3

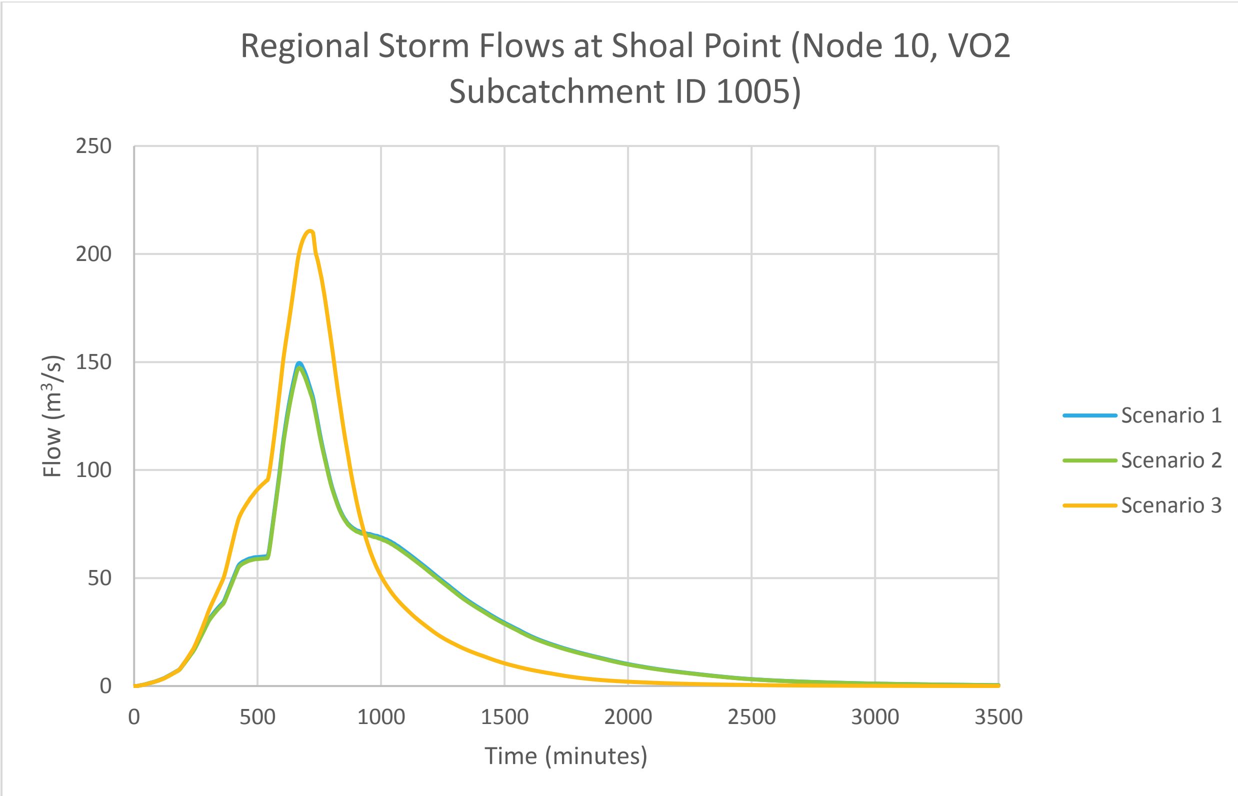

Regional Storm Flows at Taunton Rd. (Node 5, VO2 Subcatchment ID 3092)
Flow (m3/s)
160
140
120
100
80
60
40
20
0
0
500
1000
1500
2000
2500
3000
3500
Time (minutes)
Scenario 1
Scenario 2
Scenario 3

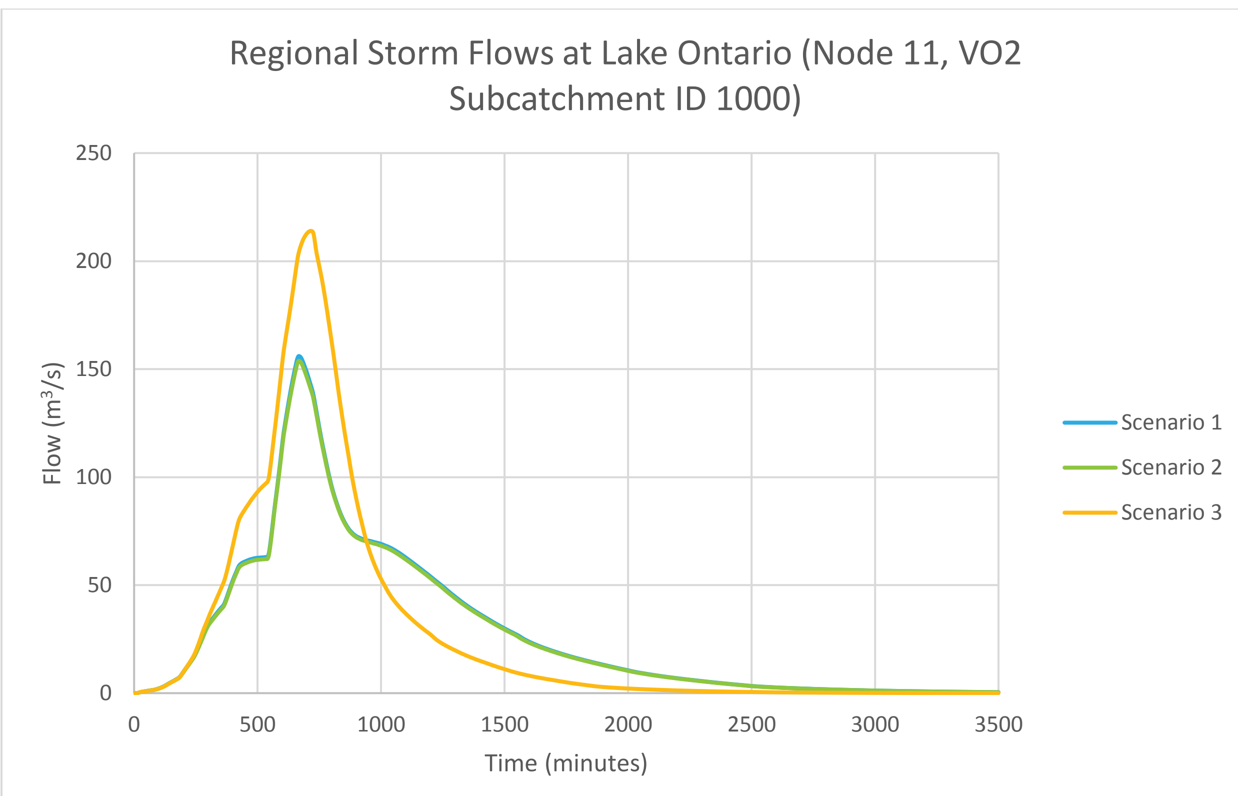

Regional Storm Flows at CPR (Node 6, VO2 Subcatchment ID 3087)
Flow (m3/s)
0
20
40
60
80
100
120
140
160
180
0
500
1000
1500
2000
2500
3000
3500
Time (minutes)
Scenario 1
Scenario 2
Scenario 3


Regional Storm Flows Upstream of Rossland Rd. (Node 7, VO2 Subcatchment ID 3082)
Flow (m3/s)
0
20
40
60
80
100
120
140
160
180
0
500
1000
1500
2000
2500
3000
3500
Time (minutes)
Scenario 1
Scenario 2
Scenario 3


Regional Storm Flows at Hwy. 2 E (Node 8, VO2 Subcatchment ID 1044)
250
200
150
100
50
0
Flow (m3/s)
0
500
1000
1500
2000
2500
3000
3500
Time (minutes)
Scenario 1
Scenario 2
Scenario 3


Regional Storm Flows Downstream of Bayly St. (Node 9, VO2 Subcatchment ID 1033)
200
180
160
140
120
100
80
60
40
20
0
Flow (m3/s)
0
500
1000
1500
2000
2500
3000
3500
Time (minutes)
Scenario 1
Scenario 2
Scenario 3


Regional Storm Flows at Shoal Point (Node 10, VO2 Subcatchment ID 1005)
Flow (m3/s)
250
200
150
100
50
0
0
500
1000
1500
2000
2500
3000
3500
Time (minutes)
Scenario 1
Scenario 2
Scenario 3


Regional Storm Flows at Lake Ontario (Node 11, VO2 Subcatchment ID 1000)
Flow (m3/s)
250
200
150
100
50
0
0
500
1000
1500
2000
2500
3000
3500
Time (minutes)
Scenario 1
Scenario 2
Scenario 3

APPENDIX 4

Regional Storm	VO2 Subcatchment IDs	2011 Update	Scenario 1 (+OP)		Scenario 2 (+NHS)		Scenario 3 (+Potential Urban)		ROPA 128, 2012	
Location		Peak Flows (m^3/s)	Peak Flows (m^3/s)	% Change from 2011 Update	Peak Flows (m^3/s)	% Change from Scenario 1	Peak Flows (m^3/s)	% Change from Scenario 1	Peak Flows (m^3/s)	% Change from Scenario 1
U/S Hwy. 7 (W. Tributary)	3096	12.98	11.012	-15.2%	10.713	-2.7%	47.347	330.0%	48.80	330%
	1175	7.6	7.601	0.0%	7.394	-2.7%	31.893	319.6%	32.71	320%
	3095	20.49	18.612	-9.2%	18.107	-2.7%	78.605	322.3%	80.99	322%
D/S Hwy. 7 (E. Tributary)	1181	5.73	5.725	-0.1%	5.539	-3.2%	3.345	-41.6%	3.44	-42%
	1182	7.21	7.205	-0.1%	7.005	-2.8%	30.395	321.9%	30.69	322%
	1183	7.01	7.011	0.0%	6.91	-1.4%	19.927	184.2%	20.62	184%
	3103	18.57	18.572	0.0%	18.114	-2.5%	62.462	236.3%	61.05	236%
D/S 5th Concession (E. Tributary)	1179	3.68	3.678	-0.1%	3.691	0.4%	3.691	0.4%	3.68	0%
	3102	23.42	23.423	0.0%	22.916	-2.2%	61.279	161.6%	60.88	162%
	3101	26.99	26.992	0.0%	26.505	-1.8%	62.965	133.3%	62.74	133%
U/S Taunton Rd. (Confluence)	3094	35.13	32.702	-6.9%	31.944	-2.3%	78.623	140.4%	79.74	140%
	3098	33.76	34.465	2.1%	33.924	-1.6%	67.896	97.0%	69.34	97%
	3093	68.89	67.153	-2.5%	65.855	-1.9%	146.519	118.2%	148.79	118%
Taunton Rd.	3092	71.61	69.897	-2.4%	68.593	-1.9%	148.839	112.9%	151.31	113%
CPR	3087	70.66	68.988	-2.4%	67.689	-1.9%	156.109	126.3%	158.38	126%

U/S Rossland Rd.	3082	70.51	68.863	-2.3%	67.941	-1.3%	160.888	133.6%	163.38	134%
Hwy. 2 E.	1044	94.07	99.6	5.9%	96.468	-3.1%	193.789	94.6%	195.02	95%
D/S Bayly St.	1033	105.74	114.651	8.4%	112.25	-2.1%	190.371	66.0%	189.95	66%
Shoal Point Rd.	1005	140.52	149.498	6.4%	147.189	-1.5%	210.632	40.9%	210.35	41%
Lake Ontario	1000	146.92	155.952	6.1%	153.714	-1.4%	213.973	37.2%	213.60	37%

Design Storm (at Shoal Point Rd)	ROPA 128, 2012 Peak Flows (m^3/s)	Scenario 3 (+Potential Urban) Peak Flows (m^3/s)	Change in Peak Flows (m^3/s)	% Change from Scenario 3
2-year	9.4	7.498	1.902	25.37
5-year	13.76	11.832	1.928	16.29
10-year	17.26	15.563	1.697	10.90
25-year	23.44	21.423	2.017	9.42
50-year	28.21	26.447	1.763	6.67
100-year	33.46	31.553	1.907	6.04

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