

TORONTO AND REGION CONSERVATION
AUTHORITY

Don River Floodplain Mapping Update (Phase I) and G. Ross Lord Dam's Operation Rule Optimization and Risks Study – Phase I Report

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Prepared by:



Ryan Weise, MEng,
Water Resources EIT

Approved by:



Fuad Curi, P.Eng.
Water Resources Department Head



EXECUTIVE SUMMARY

KGS Group was retained by TRCA to conduct a two-phase study which included the Don River Floodplain Mapping Update (Phase I) and the G. Ross Lord Dam's Operation Rule Optimization and Risk's Study (Phase II). This report documents Phase I of the study. The objective of Phase I was to update the Regulatory Floodplain and also provide raster data files (including velocity, depth, velocity*depth product, water surface elevation, and inundation boundary) for the Regional Flood, the 350-Year, 100-Year, 50-Year, 25-Year, 10-Year, 5-Year, and 2-Year storm events.

The Don River watershed is a highly urbanized watershed, located within the jurisdiction of the Toronto and Region Conservation Authority (TRCA). It includes two main branches of the river: The West Don River, the East Don River, and a large tributary: the Taylor/Massey Creek, which flows into the East Don. These three water courses join to form the Lower Don River, which, in turn, flows into Lake Ontario. For this project, only a portion of the Don River watershed was studied. This area extended from Steeles Ave to a location near Pottery Road. The study was also limited to hydraulic conditions in the river branches and tributaries. Hydrologic inputs were obtained from the recently completed Don River Hydrology Update study (AECOM, 2018).

KGS Group developed a One-dimensional, steady state hydraulic model of the study area using the USACE software package HEC-RAS 5.0.7. The hydraulic model geometry was extracted from LiDAR data captured in 2015 as well as bathymetry surveys, with in both cases were provided by TRCA. Manning's N values used in the model were assigned based on land use characteristics identified from aerial imagery and site reconnaissance, and in accordance with the table of TRCA's Standard Manning's Values.

The model includes 166 structures (bridges, culverts, and weirs). KGS Group and TRCA visited these crossings and developed for all of them watercourse crossing data sheets in accordance with TRCA's standards. As-built drawings were also obtained for many of these crossings. After comparing the data from the data sheets, as-built drawings and previous HEC-RAS models, the best data to be used in the model was selected.

Model boundary conditions included the peak flow values obtained from the Don River Hydrology Update (AECOM, 2018) and the water levels at the downstream end that were obtained from a model of the Lower Don River and provided by TRCA.

A sensitivity analysis was performed on the Manning's roughness coefficients, downstream boundary condition, and the flow regime (either fully subcritical or combination of sub and supercritical flow). The sensitivity analysis indicated that the model results were moderately sensitive to the overbank Manning's values; but were not sensitive to the downstream boundary condition. The sensitivity analysis demonstrated that the model results could be confidently used, within the range of uncertainty that is typically acceptable for model studies of this type.

KGS simulated the flow conditions for recurrent flows ranging from the 2 to 350-year storm events and for the Regional Storm flood (Hurricane Hazel). The latter corresponds to the Regulatory Flood in this watershed and was used to prepare floodplain maps that show the flood hazard delineation in accordance with Provincial guidelines (Technical Guide River & Stream Systems: Flooding Hazard Limit). It was also used to prepare raster

shapefiles showing flow velocity, flood depth, velocity-depth product, and water surface elevation for all the simulated events.

Six areas were identified within the study area, where flow would spill from the model domain and more detailed analysis, potentially with a Two-dimensional model, are recommended. Using the naming conventions adopted in this study, these correspond to:

- the left bank of Taylor Massey Creek, immediately upstream of the TTC crossing
- the West Don River over the left river bank, near the intersection at York Mills Rd. and Yonge St
- the crossing at Finch Ave. W over Tributary 6 of the West Don River
- the crossing of the Don Valley Parkway on Deerlick Creek 1 on the East Don River
- the area near the conduit under Woodsworth Rd. and Stubbs Dr, on Tributary 2 of the East Don River
- the crossing of Lawrence Ave. on Tributary 1 of the West Don River

The updated Regulatory Floodplain, obtained in this study, was compared to the one that had been previously developed and adopted for the area defined by the study domain. Differences found with respect to the previous floodplain maps for the study area were due to various factors including: the use of updated input flows, updated and more detailed topographic data and data at crossings, inclusion of additional crossings that were not in previous studies, extension of the study area to reaches of the river system that had not been previously modelled. The most notable differences were found upstream of the G. Ross Lord Dam, the crossing of Bayview Ave and Blythwood Rd over Burke Brook and the crossing of Woodfern Drive and Chelwood Rd over Taylor Massey Creek. At these locations, the new study indicates higher water levels and more extensive backwater effects that include flooding of areas and impacting properties that had not been previously identified as such.

ACKNOWLEDGEMENTS

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Ryan Weise, MEng., EIT.	KGS Group
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STATEMENT OF LIMITATIONS AND CONDITIONS

Limitations

This report has been prepared for The Toronto and Region Conservation Authority “TRCA” in accordance with the agreement between KGS Group TRCA (the “Agreement”). This report represents KGS Group’s professional judgment and exercising due care consistent with the preparation of similar reports. The information, data, recommendations and conclusions in this report are subject to the constraints and limitations in the Agreement and the qualifications in this report. This report must be read as a whole, and sections or parts should not be read out of context.

This report is based on information made available to KGS Group by TRCA. Unless stated otherwise, KGS Group has not verified the accuracy, completeness or validity of such information, makes no representation regarding its accuracy and hereby disclaims any liability in connection therewith. KGS Group shall not be responsible for conditions/issues it was not authorized or able to investigate or which were beyond the scope of its work. The information and conclusions provided in this report apply only as they existed at the time of KGS Group’s work.

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1.0 INTRODUCTION

1.1 Work Scope and Report Structure

This report corresponds to the first phase of a two-phase project entitled *Don River Floodplain Mapping Update (Phase I)* and *G. Ross Lord Dam's Operation Rule Optimization and Risk Study (Phase II)*. The second phase is documented in a separate report.

The objective of Phase I of the study was to update the floodplain maps for the study area described in Section 1.1 (Don River watershed from Steeles Ave to a location 222 m upstream of Pottery Rd). This scope included developing a One-dimensional steady state hydraulic model with the program HEC-RAS. The model was developed by KGS with various data sources including data provided by TRCA, as well as data gathered by KGS Group, as described in Section 2.1. The hydraulic model results were used to develop the updated floodplain maps.

This report is structured into six sections. Section 1 is the Introduction of the report. Section 2 describes the background review and a site reconnaissance. Section 3 describes the HEC-RAS model and Section 4, the Floodplain Mapping. Section 5 outlines recommendations and Section 6 includes the references used in the study.

1.2 Overview of the Don River Watershed

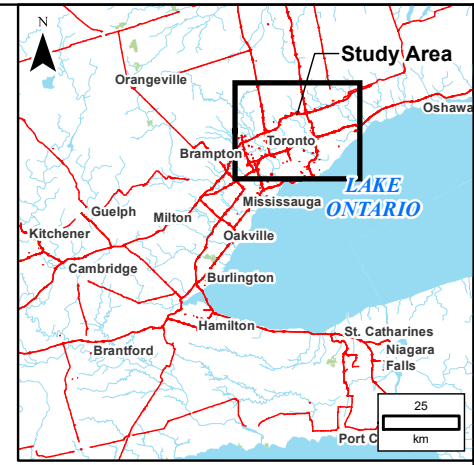
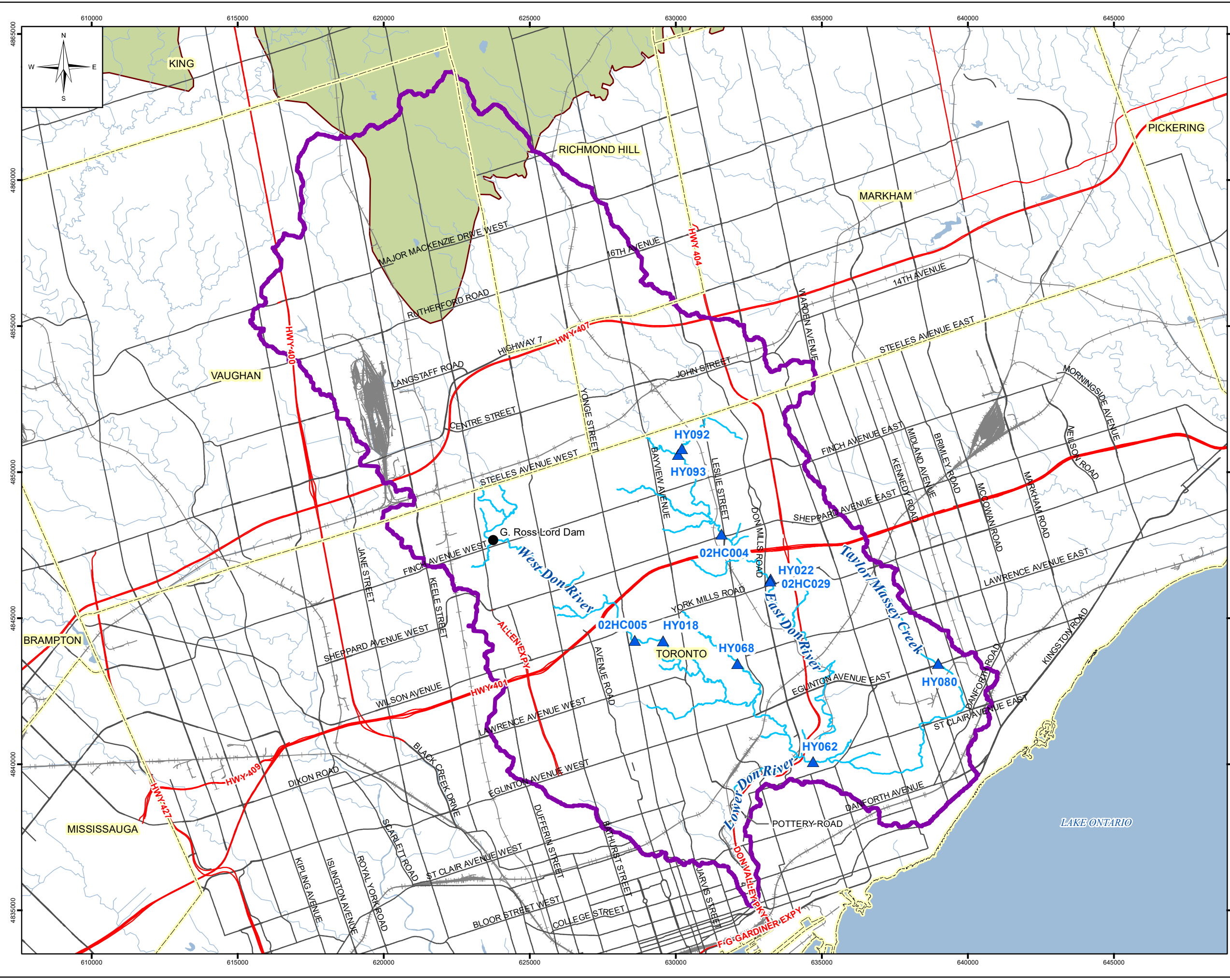
The Don River Watershed is a highly urbanized watershed, that extends through the City of Vaughan, Town of Richmond Hill, and the City of Toronto. The watershed includes three main water courses (branches and tributaries): The West Don River, the East Don River, and Taylor/Massey Creek. The East and West Don Rivers originate at the south slope of the Oak Ridges Moraine, in the City of Vaughan and the Town of Richmond Hill, and run in the southeasterly direction to join at Don Mills Rd. in the E.T. Seton Park. The length of the West Don River is approximately 22.7 km, while the East Don River is approximately 22.3 km long. From the confluence of these river branches the Lower Don River runs west and south to flow into Lake Ontario. Taylor Massey Creek originates near Highway 401 and the Don Valley Parkway. It runs for approximately 15.6 km, east of the East Don and joins the East Don River 200 m upstream of the confluence with the West Don.

The total area of the Don River watershed is approximately 350 km², of which 123 km² correspond to the West Don, 151 km² to the East Don, 35 km² to Taylor Massey Creek, and 41 km² to the Lower Don River. The West Don River is regulated by the G. Ross Lord Dam, located at the intersection of Finch Avenue and Dufferin Street.

Figure 1 shows the Don River watershed with key locations including the G Ross Lord Dam. The area of study for this project extends from just south of Steeles Avenue to a location 222 m north of Pottery Road.

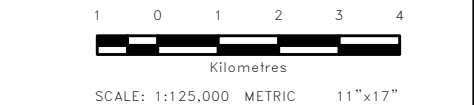
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- LEGEND:**
- Stream Gauges
 - Arterial Road
 - Highway
 - Watercourse (Don River Phase I)
 - Railway
 - Watercourse (Outside Project Limits)
 - Municipal Boundary
 - Oak Ridges Moraine
 - Don River Watershed

NOTES:
1. Topographic data shown provided by TRCA and/or Land Information Ontario (LIO).



All units are metric and in metres unless otherwise specified. Transverse Mercator Projection, NAD 1983, Zone 17 Elevations are in metres above sea level (MSL).

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DON RIVER FLOODPLAIN MAPPING UPDATES (PHASE I) AND G ROSS LORD DAM'S OPERATION (PHASE II)

DON RIVER WATERSHED	
APRIL 2020	FIGURE 01
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There have been several hydrologic studies of the Don River watershed. The most recent study, *The Don River Hydrology Update*, was completed by AECOM in 2018. In that study an updated hydrologic model was developed, using the software platform PCSWMM. The results of that study were used in this project to define inflow flows along the various river branches and tributaries.

2.0 DATA COLLECTION AND BACKGROUND REVIEW

2.1 Background Data Review

KGS performed a background review of the data provided by TRCA which included:

- Previous Studies
 - Don River Hydrology Update (AECOM, 2018)
 - Don River Watershed Plan, Surface Water Hydrology/Hydraulics and Stormwater Management (TRCA, 2009)
 - Don River Hydrology Update (MMM Group, 2004)
 - G. Ross Lord Dam OMS (IBI/TRCA, 2018)
 - G. Ross Lord Dam Dam Safety Review (Sanchez Engineering, 2013)
- Previous HEC-RAS Models and Regulatory Floodplain
 - MacViro, 2006 – Includes Regulatory Floodplain Maps
 - EarthTech, 2008 – Includes Regulatory Floodplain Maps
 - MMM Group, 2009 – Includes Regulatory Floodplain Maps
 - R.J. Burnside, 2011 – Includes Regulatory Floodplain Maps
- Bathymetry surveys at various locations provided by TRCA. These surveys are identified by TRCA with the following references: F1374, F776-2-3, F966, F807, F698-2, F914
- 2018 PCSWMM Hydrologic Model (AECOM, 2018)
- Hydrometric Data at Stations: WSC 02HC005, TRCA's HY018, HY027, HY017
- DEM developed from 2015 LiDAR Capture
- Ortho-imagery provided by TRCA (dated 2017)

This background data was reviewed by KGS for the purpose of obtaining information useful for the development of the new hydraulic model of the Don River branches and tributaries.

As part of the data review, a list of hydraulically significant water crossing structures was compiled with TRCA's input, and using the information available in the previous HEC-RAS model, the ortho-imagery provided by TRCA, as well as aerial imagery obtained from Google Earth. A comparison of the information on crossings from these various data sources was carried out to decide which structures warranted inclusion in the new hydraulic model.

In total, 275 crossings were identified in the study area. Many of these crossings were small pedestrian bridges. KGS and TRCA screened these structures using aerial photography and previous HEC-RAS models to determine which crossings were hydraulically significant to the Regional Flood. Small crossings that were completely submerged, such as golf course pedestrian bridges, were deemed hydraulically insignificant if the

previous HEC-RAS model results indicated that the water surface profiles did not change at the crossing. In some cases, KGS removed the crossing from the previous model to test if there was any change to the model results. Using this process, 109 crossings were deemed hydraulically insignificant and 166 were deemed hydraulically significant.

2.2 Site Reconnaissance

After selecting, in conjunction with TRCA, the water crossing structures to be included in the model, KGS carried out a site reconnaissance of the crossings. During this reconnaissance, data was collected to complete TRCA's standard crossing data sheets. The information was compiled on site using the ESRI123 software package and later formatted to meet TRCA's crossing sheet template. The crossing sheets are included in Appendix A of this report. The data that was collected included:

- Depth of Water at the Crossing
- Height from Obvert to Bottom of Channel
- Width of Opening (Perpendicular to Flow)
- Length of Crossing (Parallel to Flow)
- Height from Obvert to Top of Road
- Pier Widths and Locations
- Entrance and Exit Type

Measurements of these crossing dimensions were obtained with either a tape or a handheld laser. The depth of water in some cases was estimated by visual inspection where measurement with these tools was not possible or practical.

At each crossing, four photos were taken: one located upstream facing the structure, one at the structure facing upstream, one at the structure facing downstream, and one located downstream facing the structure. A site sketch was also prepared to show the dimensions and any other details considered important for the model development. The photos and the sketches were included in the Standard Data Sheets.

During the site visit, observations and photos were taken at intermediate locations in-between crossings to obtain a general knowledge of the river reaches. This was used, in conjunction with other data sources available, to assess model elements such as the appropriate values to represent surface roughness.

2.3 Collection of Water Crossing As-Built Information

After the Crossing Sheets were completed, the dimensions of each structure were compiled into a summary table. The dimensions obtained in the field were compared with other data sources, including the previous HEC-RAS model and As-Built drawings that TRCA obtained from various organizations, including CPR, Metrolinx, MTO, TTC, and the Region of York. During this comparison process, structures for which the dimensions from the various data sources did not match, and those for which data was not available or considered uncertain were flagged for further investigation.

For a selected number of structures, as-built drawings were requested from the City of Toronto Drawings Department and the City of Toronto Parks Department. In cases in which the as-built drawings requested

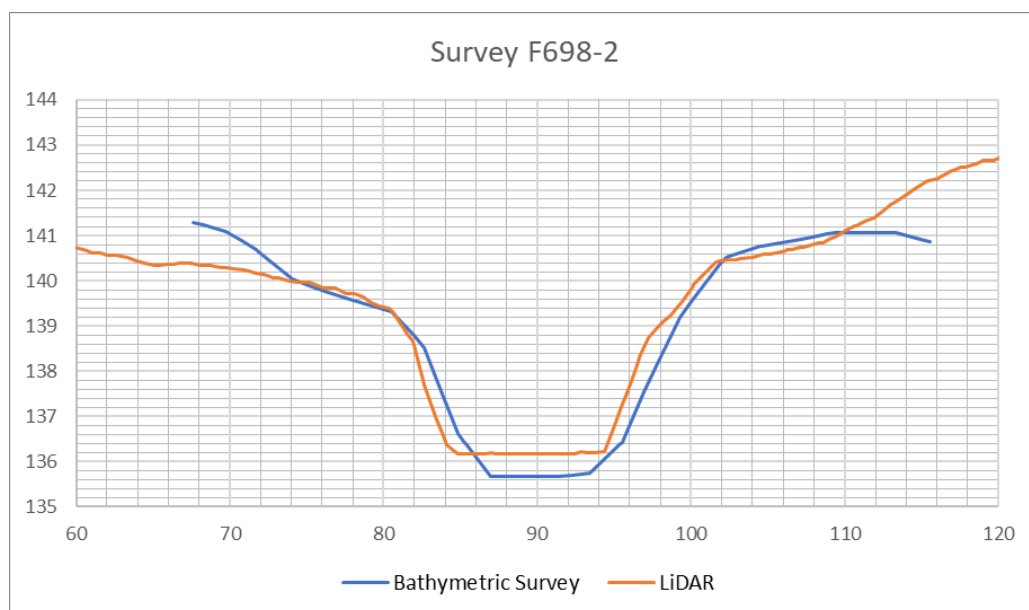
were not available, a decision was made to use either the dimensions from the site visit or the previous HEC-RAS model, whichever was considered to be the more reasonable or accurate. Appendix F summarizes the data sources adopted to define each crossing included in the hydraulic model.

2.4 Preparation of the Digital Elevation Model (DEM)

A Digital Elevation Model (DEM) was provided to KGS Group by TRCA. This DEM was developed from LiDAR captured in 2015, and includes bathymetric survey data captured at the location of the G. Ross Lord Dam's reservoir.

KGS compared the channel cross sections obtained from the DEM with cross sections obtained from bathymetric surveys that TRCA had carried out at the selected locations, as indicated in Section 2.1. It was found that in the downstream reaches of the main river branches (East Don, West Don and Taylor Massey Creek) the LiDAR generated DEM needed to be supplemented with the underwater channel shape derived from the bathymetric surveys, to properly represent the low flow channel depth. Figure 2 shows an example of such a cross section.

FIGURE 2 GEOMETRY COMPARISON



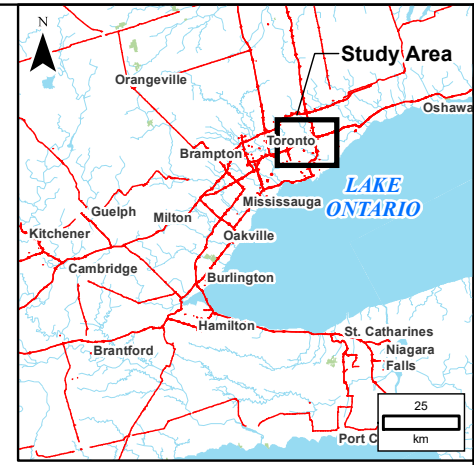
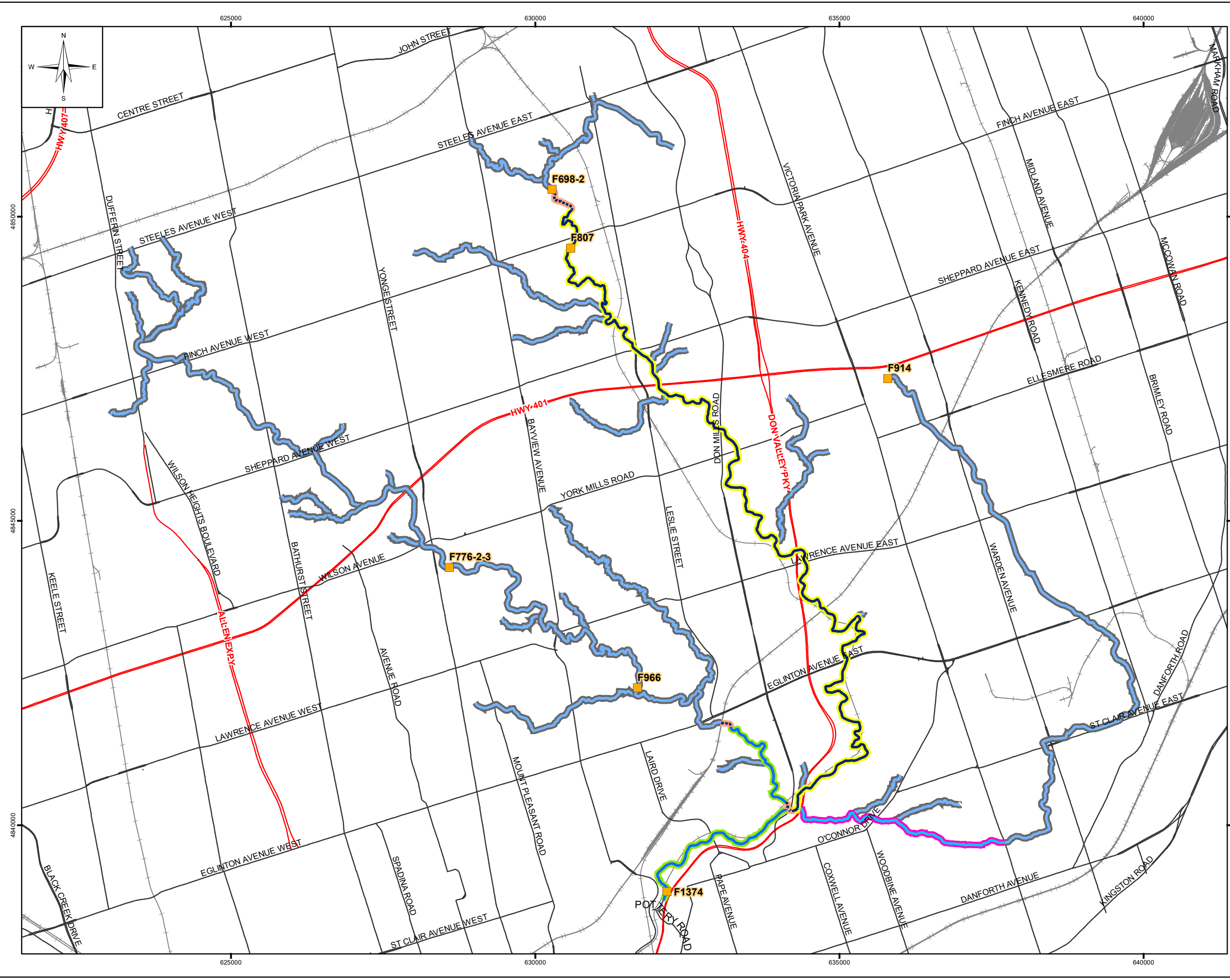
The DEM was adjusted to represent this additional depth. Lines were digitized on the GeoHEC-RAS platform to define the limits of the low flow channel, based on the DEM and orthoimagery, and the DEM elevations within the low flow channel were lowered to match the bathymetric data. Figure 3 shows the reaches that were adjusted and the corresponding depths of the low flow channels derived from the bathymetric survey data.

In the upstream reaches, on the other hand, the river branches and tributaries are shallower and it was considered that the DEM provided an appropriate representation of the cross sections. In those cases, the cross sections obtained directly from the DEM were not modified. In between those reaches where the

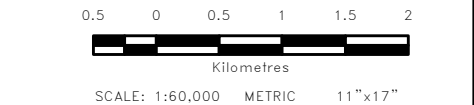
comparison indicated no need to adjust the DEM and those where the bathymetric surveys revealed a lower low flow channel than the DEM, there were reaches where a low flow channel was expected but there was no data available to properly assess its depth. In those cases, a low flow channel was included, with a depth corresponding to a linear transition from zero, at the upstream locations where the DEM was not adjusted, to the value identified from the bathymetric data, where it existed. The areas where the low flow channel was defined as a linear transition from zero depth to the depth obtained from bathymetric data are also shown in Figure 3.

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- LEGEND:**
- Bathymetric Survey Location
 - DEM Lowered by 0.3 m
 - DEM Lowered by 0.4 m
 - DEM Lowered by 0.48 m
 - No Adjustment Applied
 - Linear Interpolation
 - Major Road
 - Highways
 - Railway



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Transverse Mercator Projection, NAD 1983, Zone 17
Elevations are in metres above sea level (MSL7)

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DON RIVER FLOODPLAIN MAPPING UPDATES (PHASE I) AND G. ROSS LORD DAM'S OPERATION (PHASE II)

LOCATIONS OF BATHYMETRIC ADJUSTMENTS

APRIL 2020	FIGURE 03	REV: 0
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3.0 HYDRAULIC MODEL DEVELOPMENT

3.1 HEC-RAS Software

A One-dimensional steady state hydraulic model of the Don River from Steeles Ave to 222 m upstream of Pottery Rd was developed with the United States Army Core of Engineers (USACE) program HEC-RAS Version 5.0.7. At the request of TRCA, the model was used to perform steady-state subcritical flow simulations for various runoff events, with the objective of developing floodplain mapping for this extent of the Don River watershed.

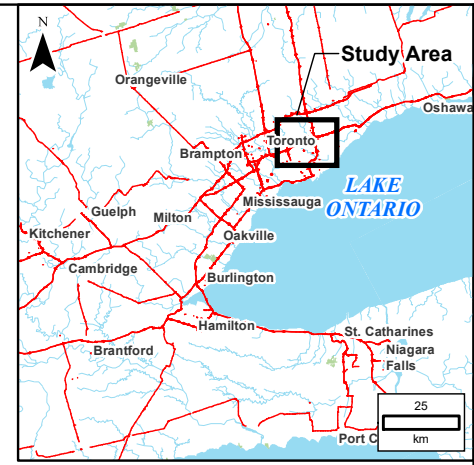
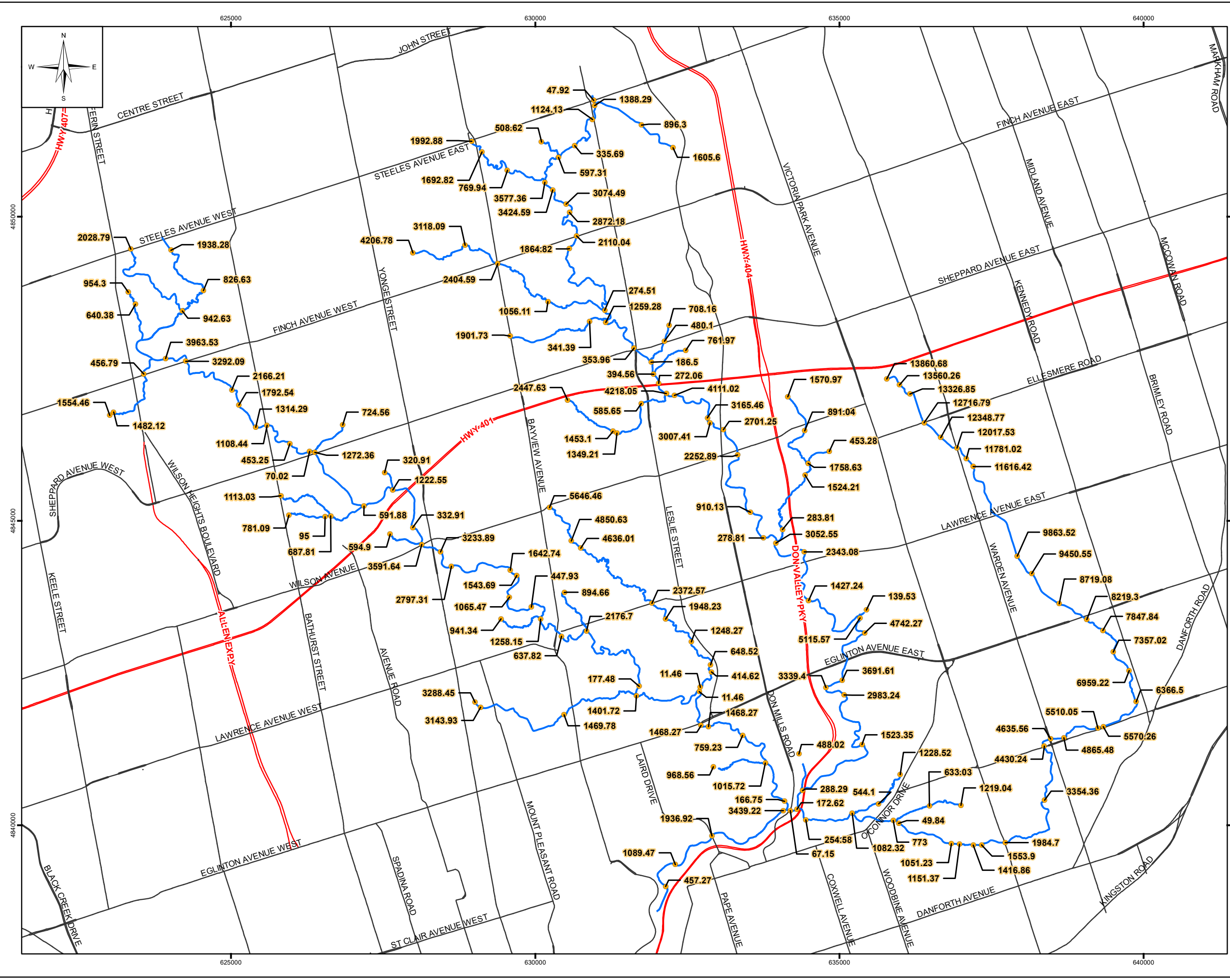
The Civil3D software package GeoHEC-RAS was used to assist in the model development. GeoHEC-RAS is a GIS based software package that utilizes the HEC-RAS API controller. GeoHEC-RAS also includes a mapping tool.

3.2 Development of Steady-State Input Flows

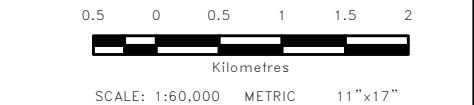
The 2018 PCSWMM hydrologic model of the Don River Watershed was used by TRCA to simulate the runoff generated by the 2-Yr, 5-Yr, 10-Yr, 25-Yr, 50-Yr, 100-Yr, 350-Yr recurrent storm events and the Regional Storm. For each event, peak flow values were extracted at selected locations (i.e. hydrologic model nodes) along each river reach. These constituted input flow locations for the hydraulic model, and were spaced so that flow changes between consecutive nodes were not greater than 10%. The peak flows were input to the hydraulic model as steady-state flow values, located at the cross sections nearest to each hydrologic model node. Figure 4 shows the peak flow values for each return period event and the cross section at which each flow value was input to the hydraulic model.

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- LEGEND:
- Flow Node Locations
 - River Reaches
 - Major Road
 - Highways



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Elevations are in metres above sea level (MSL)

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FLOW NODE LOCATIONS FOR THE DEVELOPMENT OF THE HEC-RAS STEADY FLOW DATA TABLE	
MARCH 2020	FIGURE 04
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3.3 Downstream Boundary Conditions

The downstream boundary condition for the hydraulic model was located at the furthest downstream cross section of the Lower Don River reach, which corresponds to a location 222 m upstream of the crossing at Pottery Road. To define this boundary condition, a set of water levels for this location, associated with each simulated event, was defined. These water levels were obtained by TRCA using a Two-dimensional model of the Lower Don River, prepared with the DHI software MIKE FLOOD. The details of this model are documented in the report *Lower Don River Subwatershed 1D-2D Modelling Project Final Report*. The values used as downstream boundary condition for the HEC-RAS model used in this study are shown in Table 1.

TABLE 1 DOWNSTREAM BOUNDARY CONDITION – RATING CURVE

Flood Event	Flow (m ³ /s)	Water Surface Elevation (m)
2-Yr	75.39	80.14
5-Yr	141.36	80.94
10-Yr	190.28	81.40
25-Yr	251.25	81.95
50-Yr	318.63	82.54
100-Yr	390.18	83.12
350-Yr	595.86	83.95
Regional	1509.65	86.04

3.4 Model Geometry and Parameters

3.4.1 RIVER REACHES AND CROSS SECTIONS

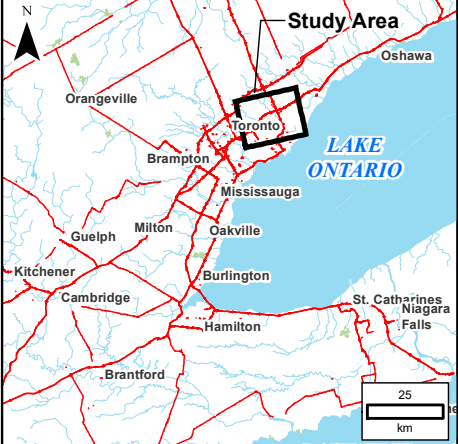
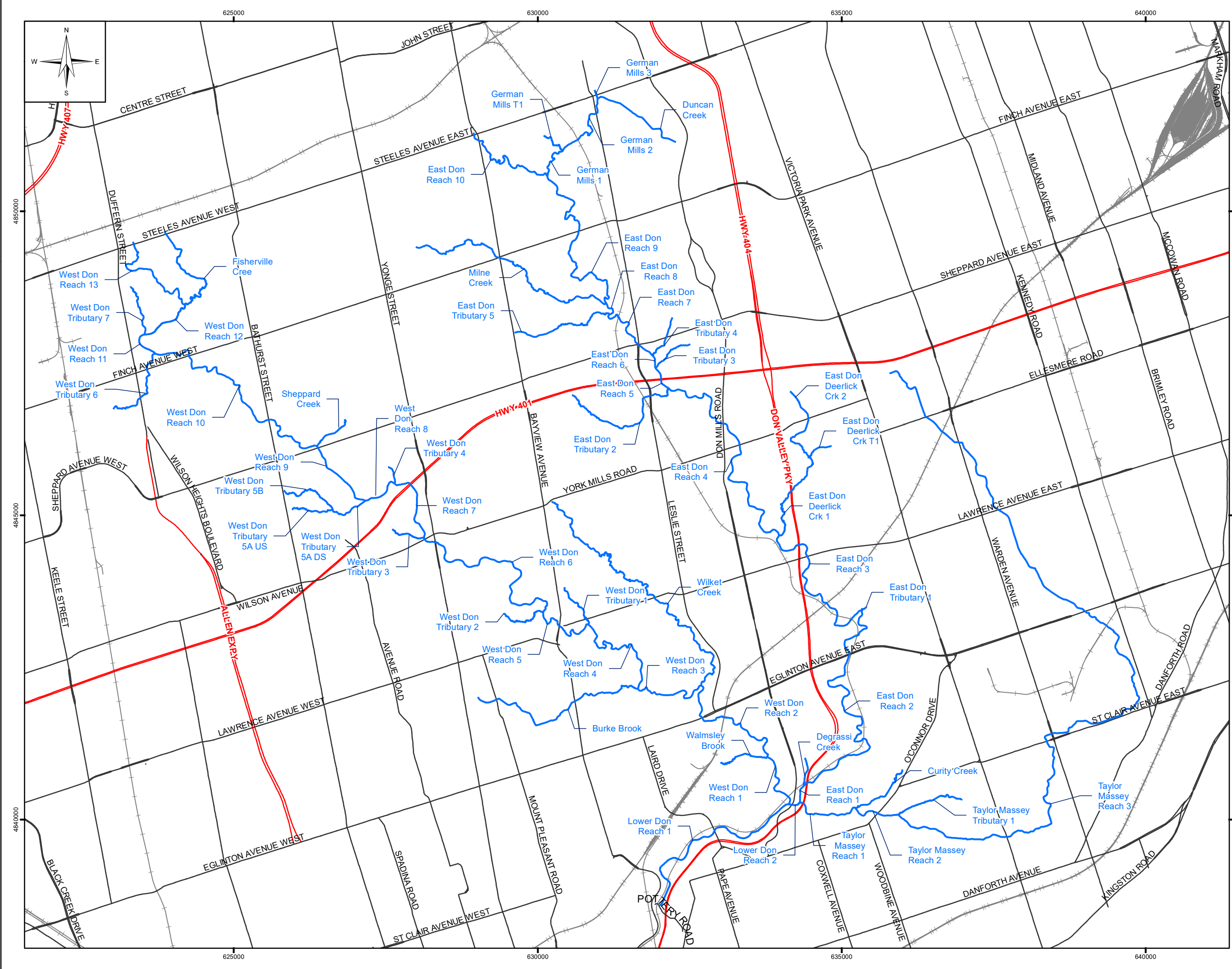
The Don River was divided into four main branches (East Don River, West Don River, Taylor/Massey Creek, and Lower Don River) and each branch was further subdivided into smaller reaches to allow the incorporation of tributaries. Figure 5 shows the location and the name assigned in the model to each river reach.

In a HEC-RAS model, the terrain is represented by cross sections of the river channel and overbanks placed at discrete locations. The cross sections for the Don River model were spaced at an interval of no more than 100 meters. Each cross section was drawn perpendicular to the flow path lines, which in turn were visually estimated using the flooding extents for the Regional Flood event available from previous studies. The geometry for each cross section was extracted from the DEM (adjusted as described in Section 2.4) within the GeoHEC-RAS software suite. The cross sections were labelled with their corresponding stationing in meters, beginning at the downstream end of the reach and increasing in the upstream direction.

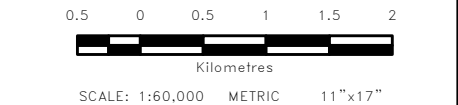
At each cross section, the bank stations were manually set based on site observations and aerial imagery, and with consideration of the observed shape of the cross sections. Reference lines were manually digitized on GeoHEC-RAS along the main channel alignment, as well as for the left and right overbank conveyance areas, for all river and tributary reaches. The channel centerline was based on the location of the thalweg as it could be interpreted based on the terrain DEM and the available ortho-imagery. The lines for the overbank conveyances were drawn approximately at one-third of the distance from that centerline to the edge of the floodlines defined in the previous floodplain maps. These reference lines were used to measure the distance between cross sections at the channel, left and right overbank areas, which were then input to HEC-RAS.

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11"x17" PLOT SCALE 1:1



- LEGEND:
- River Reaches
 - Major Road
 - Highways
 - Railway



All units are metric and in metres unless otherwise specified.
Transverse Mercator Projection, NAD 1983, Zone 17
Elevations are in metres above sea level (MSL7)

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DON RIVER FLOODPLAIN MAPPING UPDATES (PHASE I) AND G ROSS LORD DAM'S OPERATION (PHASE II)		
DON RIVER REACHES		
APRIL 2020	FIGURE 05	REV: 0

The Manning's roughness values adopted for the model, were based on TRCA's Standard Manning's Roughness Coefficients Table. A GIS layer was uploaded to the GeoHEC-RAS platform using the GIS shapefile of land uses provided by TRCA. It was used to assign the Manning's values corresponding to each land use in the table, to each cross section in the model. During the site visits, concrete lined channels were identified and noted. This information was used, with the aid of ortho-imagery and georeferenced site photos, to manually adjust the Manning's values in the model. Appendix B shows the table of TRCA's Standard Manning's Roughness Coefficients.

Levees were input to the cross sections at those locations in which streamwise high ground features, that could prevent water from entering portions of the overbank areas, were identified. It must be noted that not all high-ground features would operate as levees, so this required consideration of the general conditions in the river reaches. If the terrain (either upstream or downstream of the area of interest) allows connections between the channel and the overbank areas behind a potential levee, then these areas could become part of the flow conveyance and the use of levees in the model would be incorrect. Because one-dimensional models, which represent the geometry of the channel with discrete cross sections, cannot identify those connections, it is then up to the modeller to correctly discern the instances when levees should be used. For that purpose, the terrain was carefully reviewed to ensure that the conditions at those cross sections and in the channel reach in general were consistent with the proper use of levees in the model. In some cases, ineffective areas were used instead of levees, if the areas behind high ground could be flooded but without allowing continuous flow passage.

Ineffective areas were also used in areas of expansion or contraction of the channel or flood plain to separate zones of recirculation and ensure that the areas of actual flow conveyance were properly modelled. The definition of these ineffective areas was based on estimation of the flow path lines, using engineering judgment.

It is important to note, when it comes to modelling ineffective areas as well as levees, that these do not necessarily occur at the same locations for different flow magnitudes. High ground features that act as levees for a given flood could become flooded or circumvented by an even larger flood. Given that the model was intended to simulate a number of floods of different magnitudes, it was decided, in conjunction with TRCA, that, in defining these model elements, priority would be given to the proper representation of the hydraulic conditions during the Regional Storm Flood. It was, therefore, accepted that these conditions could in some cases not match those occurring during other floods of lesser magnitude, that were also simulated with the model.

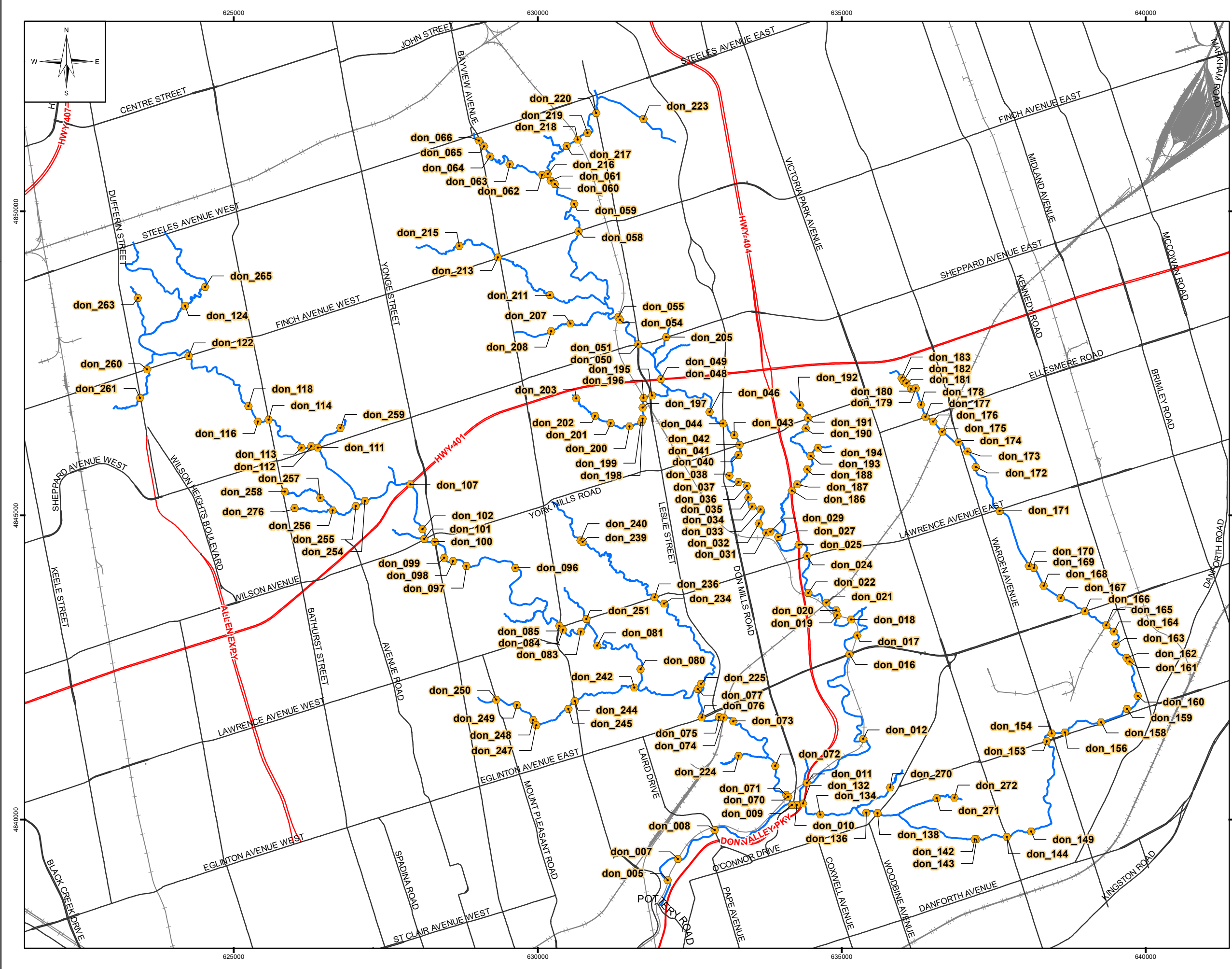
The cross sections input data also included head loss coefficients for contraction and expansion, that the model uses to calculate localized energy losses. For general cross sections the default values of these coefficients in HEC-RAS (0.1 for contraction and 0.3 for expansion) were used. A different set of values was used for these coefficients at crossings and other structures, which is discussed in Section 3.4.2.4.

3.4.2 HYDRAULIC STRUCTURES

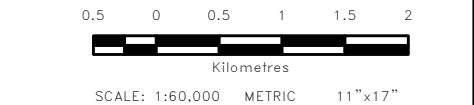
166 structures were identified as hydraulically significant for the definition of the regulatory floodplain and were included in the model; the location of these crossings can be seen in Figure 6. The various types of structures included in the model are listed below:

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- LEGEND:
- Crossing Location
 - River Reaches
 - Major Road
 - Highways
 - Railway



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Transverse Mercator Projection, NAD 1983, Zone 17
Elevations are in metres above sea level (MSL7)

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DON RIVER FLOODPLAIN MAPPING
UPDATES (PHASE I) AND G. ROSS
LORD DAM'S OPERATION (PHASE II)

DON RIVER CROSSING LOCATIONS	
APRIL 2020	FIGURE 06
	REV: 0

- 54 Culverts
- 43 Vehicle Bridges
- 39 Pedestrian Bridges
- 14 Railway Bridges
- 8 Weirs
- 7 Long Conduits (minimum length of 100 m)

Crossings were modelled with the best data available, among the sources listed in Section 2.3. The modelling approach to simulate these structures is described in the following subsections, except for the long conduits, which are discussed in Section 3.4.6.

3.4.2.1 Bridge Modelling Methodology

The culverts, bridges, and weirs were modelled in accordance with the HEC-RAS Hydraulic Reference Manual. HEC-RAS has different methodologies to model bridges and culverts in high flow and in low flow conditions. These are listed below.

High Flow:

- Energy Only (Standard Step)
- Pressure and/or Weir Flow

Low Flow:

- Energy (Standard Step)
- Momentum
- Yarnell (Class A Flow)

In high flow scenarios, the water surface level at the upstream face of the structure could be above or below the structure deck. An initial model run was used to identify which condition applied to each structure. If the initial results indicated that the water level was below the girder, then the Energy Only (standard step) Method was selected. If, otherwise, the water level was above the deck, and the flow through the bridge opening was relevant, then the Pressure and/or Weir Flow Method was selected. In some cases, when a bridge was completely submerged and the majority of the flow conveyance occurred in the overbanks, the Energy Only Method was selected.

In low flow scenarios, the model was run using the methods listed above for low flow. For bridges without piers, both the Energy Only (standard step) and the Momentum Methods were tested and the highest energy loss was selected. For bridges with piers, the Energy Only (standard step), Momentum Methods, and Yarnell (Class A Flow) were tested and the highest energy loss was selected.

3.4.2.2 Cross Sections for Bridge Modelling

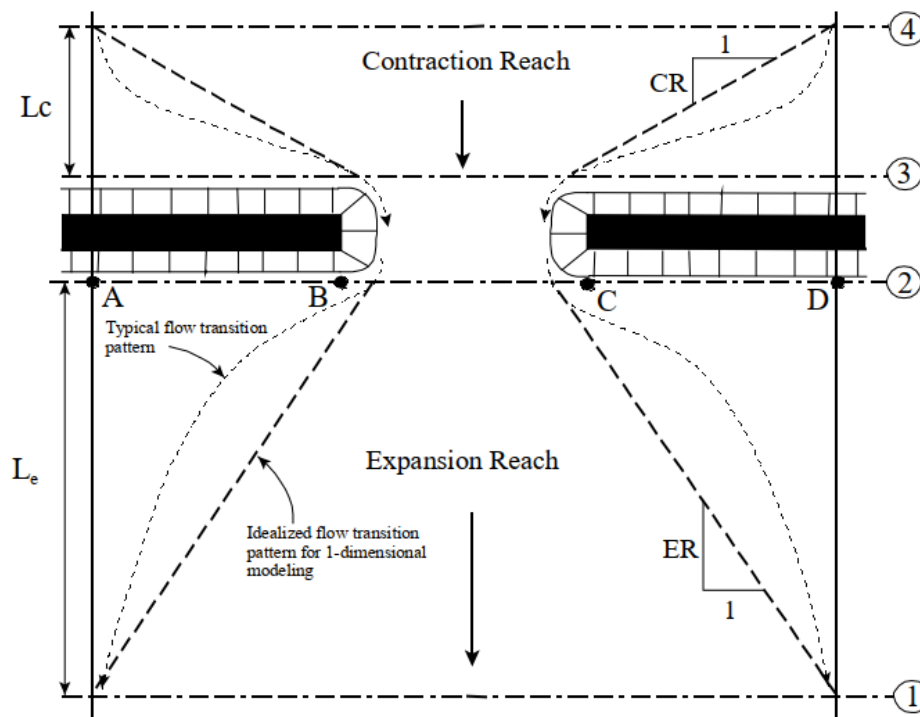
HEC-RAS requires four cross sections to be input to model a river crossing. These are numbered from downstream to upstream, as follows, and are shown in Figure 7:

- Cross section number 4 is the one located the most upstream of the crossing, where the flow lines are not affected by contraction effects;

- Cross section number 3 is located immediately upstream of the bridge/culvert inlet where the flow would almost entirely be contracted to the size of the opening;
- Cross section number 2 is located immediately downstream of the bridge/culvert outlet, where the flow has not yet expanded to the width of the channel;
- Cross section number 1 is located downstream where the flow lines are fully expanded to the width of the channel.

The contraction reach length (L_c in Figure 5) was estimated by taking the average embankment width (Average of the length between A-B and C-D in Figure 5) and applying a 1:1 ratio, which is a generally appropriate estimate for flow line contraction ratios. Typically, the expansion of the flow lines downstream of crossings occurs more gradually than their contraction upstream. Therefore, and in accordance with the HEC-RAS Hydraulic Reference Manual and general modelling practice, the expansion reach length (L_e in Figure 5) was estimated by taking the average embankment width and applying a 1.5:1 to 2:1 expansion ratio.

**FIGURE 7 CROSS SECTION LOCATIONS FOR BRIDGES AND CULVERTS
(TAKEN FROM HEC-RAS HYDRAULIC REFERENCE MANUAL)**



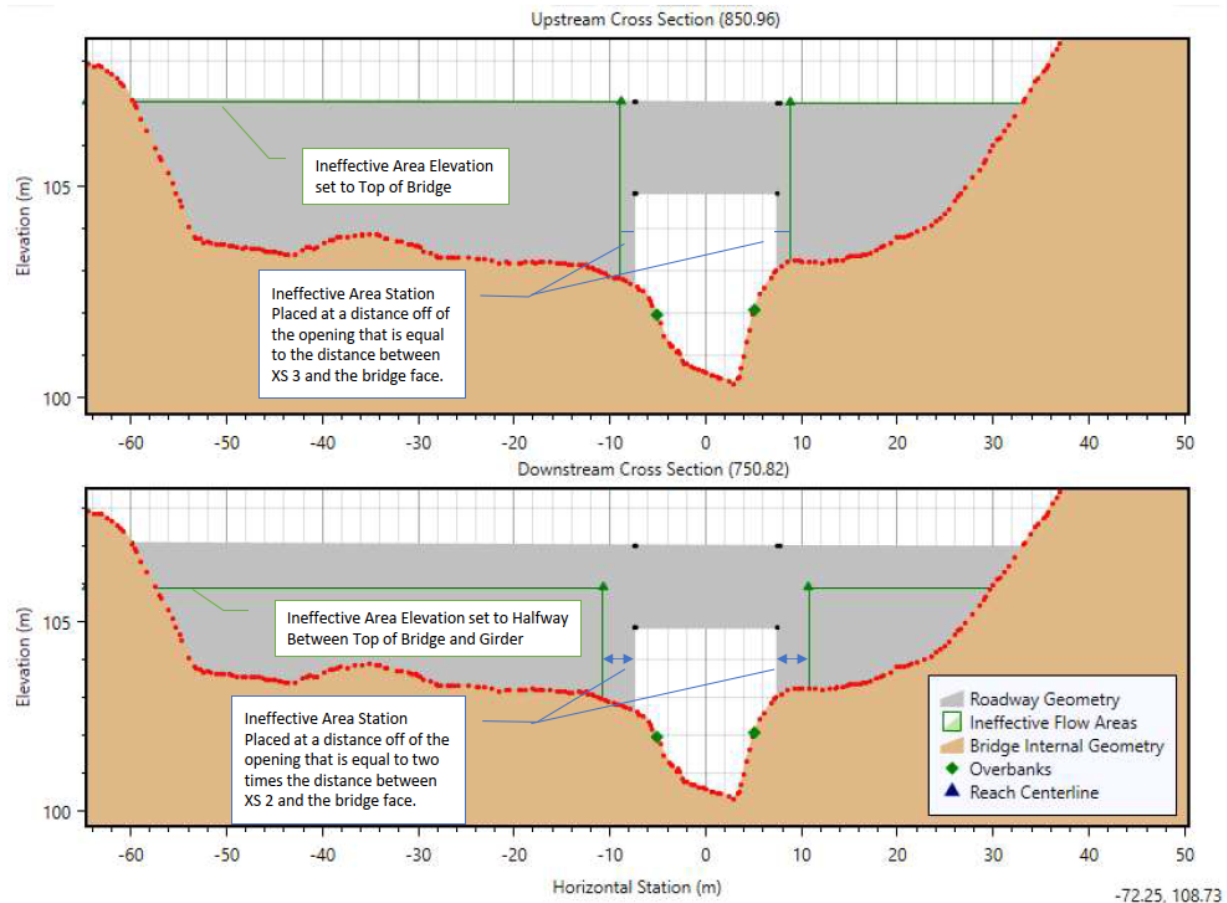
3.4.2.3 Ineffective Flow Areas for Bridges and Culverts

Ineffective flow areas were set to represent the contraction and expansion of flow lines indicated in Section 3.4.2.2, and in accordance with the HEC-RAS Hydraulic Reference Manual and general modelling practice. In general, the definition of the height of the ineffective areas was based on an assessment of what would be the effect of the obstruction posed locally by the bridge, culvert and the road. Typically, upstream of the structures, the ineffective flow areas were set up to the level of the road, while downstream of the structure, these were set lower than the road to acknowledge that flow tends to expand vertically down past the

obstruction. In some cases, where the road has a depression lower than the top of the structure, the ineffective areas were adjusted accordingly, to represent as close as possible the contraction and expansion of the flow pattern on the vertical direction. This required in many cases the use of multiple blocks of ineffective areas.

Figure 8 shows cross sections upstream and downstream of a sample crossing, with the ineffective areas as they were set in the model.

FIGURE 8 INEFFECTIVE FLOW AREAS FOR BRIDGES AND CULVERTS



3.4.2.4 Energy Loss Coefficients at Crossing

Local loss coefficients for modelling bridges and culverts were 0.3 for contraction and 0.5 for expansion. They were applied to the cross sections labeled 4, 3, and 2 in Section 3.4.2.2, where contraction and expansion effects related to the opening through the crossing would occur.

At culverts, there is also localized energy loss at the entrance and exit of the culvert opening. The corresponding head loss coefficients were input based on the configuration of the structures' inlet and outlet, and using standard values defined in the HEC-RAS Hydraulic Reference Manual. At bridge piers, head loss coefficients were also input to the model based on the pier geometry.

3.4.3 INPUT WATER SURFACE ELEVATIONS

At the location of dams, for which the operation of the water passages determines the upstream water level for any given flows, it is necessary to provide the model with the water level at the forebay. Input water levels were provided to the Don River model at the location of the G. Ross Lord Dam. TRCA independently performed a routing analysis for the Regional Flood event at the G. Ross Lord Dam, and the results of this analysis was used to define the input forebay water level for the model at that location. The maximum water level obtained in the Regional event for the G. Ross Lord Dam was El. 179.3 m.

A routing analysis was also carried out by TRCA upstream of the crossing of Burke Brook at Bayview Ave, to refine the estimate of water levels upstream of this crossing, by incorporating flood flow attenuation. The location of this crossing can be seen in Figure 9. At this crossing, referred to in the model as don_244, the limited conveyance at the entrance and the high embankment resulted in a large impoundment upstream. A hydrodynamic analysis, including the use of unsteady flow simulations, was used to refine initial estimates of the water level upstream of this crossing. The methodology and results for these analyses are described in detail in separate memorandums, which are provided in Appendix C. From that analysis, the maximum water level obtained in the Regional event for the don_244 crossing was El. 141.61 m.

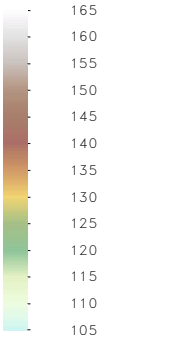
It must be noted that while the flow magnitudes input to the model downstream of the G. Ross Lord Dam included the attenuating effect of flood routing at the dam, the flows downstream of Crossing don_244 were those obtained directly from the hydrologic model discussed in Section 2.5 and did not include flood routing attenuation.



LEGEND:

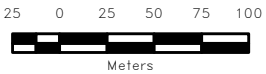
- Crossing Location
- River Centerline

Digital Elevation Model



NOTES:

1. Topographic data shown provided by TRCA and/or Land Information Ontario (LIO).
2. Imagery provided by TRCA.



SCALE: 1:4,000 METRIC 11"x17"

All units are metric and in metres unless otherwise specified.
Transverse Mercator Projection, NAD 1983, Zone 17
Elevations are in metres above sea level (MSL).

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DON RIVER FLOODPLAIN MAPPING
UPDATES (PHASE I) AND G ROSS
LORD DAM'S OPERATION (PHASE II)

LOCATION OF DON_244 CROSSING

APRIL 2020	FIGURE 09	REV: 0
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3.4.4 INEFFECTIVE FLOW AREAS

Ineffective flow areas were used to represent locations where the flow lines did not expand through the entire cross section, so that only part of the available cross-sectional area effectively passes flow. This could occur in bays, large river bends and in general those areas that while being flooded do not convey flow downstream.

3.4.5 BLOCKED OBSTRUCTIONS

Blocked obstructions were added to the cross-section geometry to represent any feature that would obstruct flow, such as buildings located within the floodplain. The GIS shapefile of building footprints provided by TRCA was used to define the extent of these obstructions within the cross sections. The elevation of the obstruction was then set as the value from the DEM provided by TRCA, at the centroid of the building, plus five metres. Obstructions were assigned at locations where buildings would interrupt the flow lines, whether those buildings were located within the alignment of the cross section or nearby. In general, engineering judgement was used to interpret the flow patterns and input obstructions to the model where appropriate, recognizing that the geometric input for one-dimensional models is only provided at discrete cross section locations.

3.4.6 LONG CONDUITS

Seven long conduits were identified within the model domain. These are culverts that range in length from 110 m to 914 m, and in many cases pass under multiple roads or houses. The location of these seven long conduits can be seen in Figure 10. Since HEC-RAS does not have specific routines to model pressurized flow conditions, a methodology was devised to model geometries that are not constant by which these conduits and their overland areas were modelled using PCSWMM in conjunction with HEC-RAS. The results of the two models were combined in an iterative process as described below. This process was performed for each long conduit and for each simulated flow condition.

1. HEC-RAS simulation was performed ignoring the flow through the conduit and water levels were obtained at the conduit inlet and outlet, to be used in the PCSWMM model.
2. The conduit was modelled in PSWMM, with the upstream and downstream water levels obtained from HEC-RAS during Step 1, to obtain the pipe flow through the conduit.
3. The pipe flow obtained with PCSWMM was subtracted from the total flow at that location to obtain the corresponding overland flow, when applicable.
 - a. If the results indicated that there was no overland flow, then the process ended, and the upstream water level obtained with PCSWMM was used in HEC-RAS as internal water level boundary condition for the reach upstream of the long conduit.
 - b. If there was overland flow, then the process continued in Step 4.
4. HEC-RAS simulation was performed again as in Step 1, but only with the overland flow obtained in Step 3, to update the water level upstream of the conduit.
5. Steps 2 to 4 were repeated until the solution converged when the assumed upstream water level in Step 2 matched the result in Step 4. Then the process ended and the resulting water level upstream of the conduit, that converged as the same value in the two models, was used in HEC-RAS as downstream boundary condition for the reach upstream of the conduit.



Table 2 shows the results obtained for the seven long conduits included in the model.

TABLE 2 CONDUIT FLOW RESULTS

Conduit Name	River Reach	Location	Results	Flood Event							
				Regional	350-Yr	100-Yr	50-Yr	25-Yr	10-Yr	5-Yr	2-Yr
don_171/172	Taylor Massey Reach 3	Manhattan Dr. to Lawrence Ave. East	Total Flow (m ³ /s)	41.6	11.98	8.77	7.85	6.82	5.73	4.89	3.64
			Overland Flow (m ³ /s)	0	0	0	0	0	0	0	0
			Conduit Flow (m ³ /s)	41.6	11.98	8.77	7.85	6.82	5.73	4.89	3.64
			Upstream W.L. (m)	165.47	162.66	162.41	162.33	162.24	162.14	162.06	161.92
don_195	East Don Tributary 2	Leslie St. and Lesmill Rd.	Total Flow (m ³ /s)	29.5	13.15	9.59	7.95	6.03	4.45	3.25	1.09
			Overland Flow (m ³ /s)	2.15	0	0	0	0	0	0	0
			Conduit Flow (m ³ /s)	27.35	13.15	9.59	7.95	6.03	4.45	3.25	1.09
			Upstream W.L. (m)	137.74	134.65	134.22	133.99	133.72	133.48	133.29	132.81
don_198/199	East Don Tributary 2	Woodsworth Rd. to Stubbs Dr.	Total Flow (m ³ /s)	27.06	12.04	8.76	7.25	5.49	4.1	0.99	1.04
			Overland Flow (m ³ /s)	4.34	0	0	0	0	0	0	0
			Conduit Flow (m ³ /s)	22.72	12.04	8.76	7.25	5.49	4.1	0.99	1.04
			Upstream W.L. (m)	142.35	138.86	138.48	138.3	138.12	138.06	138.03	138.04
don_247	West Don Burke Brook	Mt. Hope Catholic Cemetary	Total Flow (m ³ /s)	111.3	49.52	35.8	30.43	24.73	19.3	14.83	7.52
			Overland Flow (m ³ /s)	91.83	13.81	1.25	0	0	0	0	0
			Conduit Flow (m ³ /s)	19.47	35.71	34.55	30.43	24.73	19.3	14.83	7.52
			Upstream W.L. (m)	144.22	143.4	142.91	141.45	139.75	138.45	137.65	136.56
don_250	West Don Burke Brook	Blythwood Ravine Park Under Mt. Pleasant Rd.	Total Flow (m ³ /s)	111.3	49.52	35.8	30.43	24.73	19.3	14.83	7.52
			Overland Flow (m ³ /s)	89.7	27.04	13.15	9.06	0	0	0	0
			Conduit Flow (m ³ /s)	21.6	22.48	22.65	21.37	24.73	19.3	14.83	7.52
			Upstream W.L. (m)	148.37	147.64	147.38	147.13	145.74	145.83	145.48	144.82
don_254/255	West Don Tributary 5A	Earl Bales Lake / Don Valley Golf Course	Total Flow (m ³ /s)	110	39.08	26.53	20.23	14.87	10.08	8.46	6.2
			Overland Flow (m ³ /s)	99.51	28.76	20.28	15.2	10.87	6.3	4.68	4.26
			Conduit Flow (m ³ /s)	10.49	10.32	6.25	5.03	4	3.78	3.78	1.94
			Upstream W.L. (m)	142.94	141.36	141.06	140.84	140.63	140.35	140.3	140.19
don_257	West Don Tributary 5B	Northeast of Timberlane Dr.	Total Flow (m ³ /s)	19.27	6.41	5.23	4.17	2.27	1.81	1.62	1.25
			Overland Flow (m ³ /s)	17.39	5.2	4.11	3.05	1.68	1.29	1.17	0.86
			Conduit Flow (m ³ /s)	1.88	1.21	1.12	1.12	0.59	0.52	0.45	0.39
			Upstream W.L. (m)	163.71	163.43	163.38	163.29	163.11	163.05	163.03	162.98

3.5 Model Validation

There was not sufficient data available to fully calibrate or validate the model. The study area included 10 hydrometric gauges, owned by TRCA and the Water Survey of Canada (WSC), which can be seen in Figure 1. Of these 10 gauges, only 3 gauges had sufficient data to develop a rating curve. The available data for the 10 gauges are described below:

- WSC 02HC005 – Sufficient data was available to develop rating curve up to the 50-Yr event.
- WSC 02HC029 – Only includes flow data from 1964 to 1996.
- WSC 02HC004 – Only includes flow data from 1945 to 1965.
- TRCA HY018 – Sufficient data was available to develop a rating curve up to the 100-Yr event.
- TRCA HY022 – Only includes water level data.
- TRCA HY062 – Sufficient data available to develop a rating curve up to the 2-Yr event.
- TRCA HY068 – No data available for this gauge. The Don River Hydrology Update (AECOM, 2018) indicates that this rating curve is not maintained.

- TRCA HY080 – No data available for this gauge. The Don River Hydrology Update (AECOM, 2018) indicates that this gauge has no usable data.
- TRCA HY092 and HY093 – No data available for these sites.

The three gauges that had sufficient data were used to develop rating curves. These rating curves were compared to the results obtained from the hydraulic model at the corresponding cross section. The results can be seen in Figures 11, 12, and 13.

- **WSC Gauge 02HC005** is located at West Don Reach 6, just upstream of the Donino Ave. Crossing (don_098). This gauge is upstream of a weir and is more representative of the hydraulics of that structure than of the overall adequacy of the model parameters (i.e. Manning's N values). The sensitivity analysis described in Section 3.6 indicated that the Manning's roughness coefficients had little to no impact on the rating curve at this gauge. No attempt was made to alter the crossing geometry to better fit the gauge data, as the hydraulic model results provide a more conservative result.
- **TRCA Gauge HY018** is also located on the West Don Reach 6, at cross section 1750.09. The Don River Hydrology Update (AECOM, 2018) indicated that channel clearing may have artificially increased the flows recorded at this gauge. The hydraulic model results at cross section 1750.09 were compared with the gauge data and it was found that the hydraulic model provided a more conservative solution. This could be a result of a difference in elevation datums.
- **TRCA Gauge HY062** is located on the Taylor Massey Creek Reach 1, at cross section 496.87. Only a limited amount of data was available to develop a rating curve. The maximum flow observed corresponds approximately to the 2-Yr event. This data does not allow validating model results but a visual extrapolation of the data seems to be in the range of the hydraulic model results.

FIGURE 11 RATING CURVE VALIDATION AT WSC 02HC005

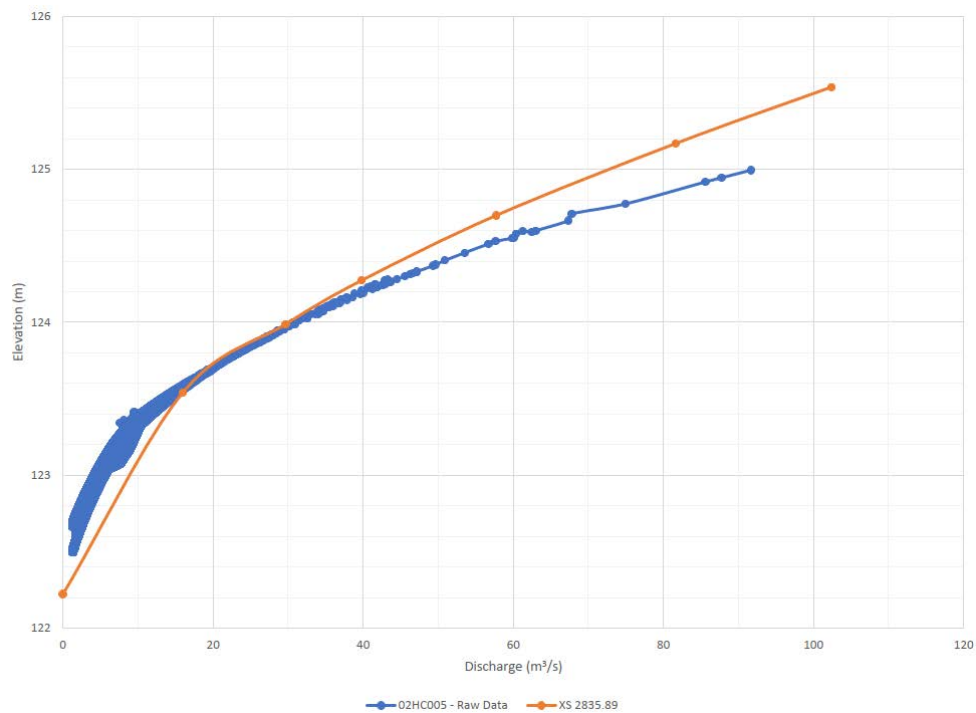


FIGURE 12 RATING CURVE VALIDATION AT TRCA HY018

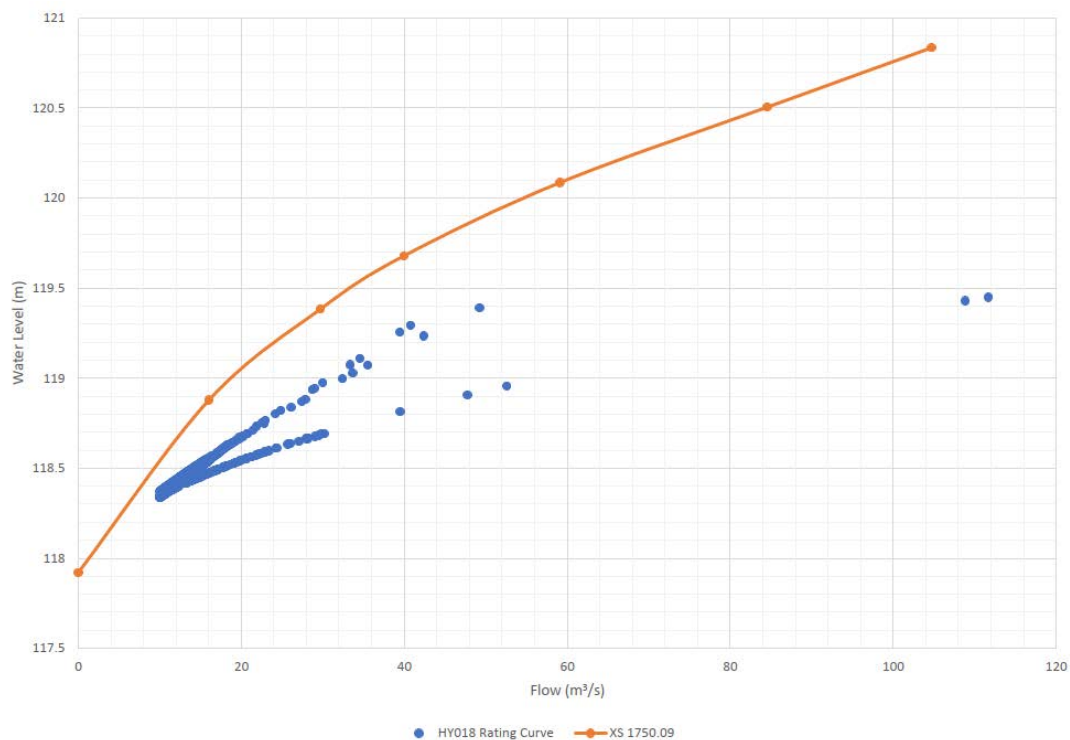
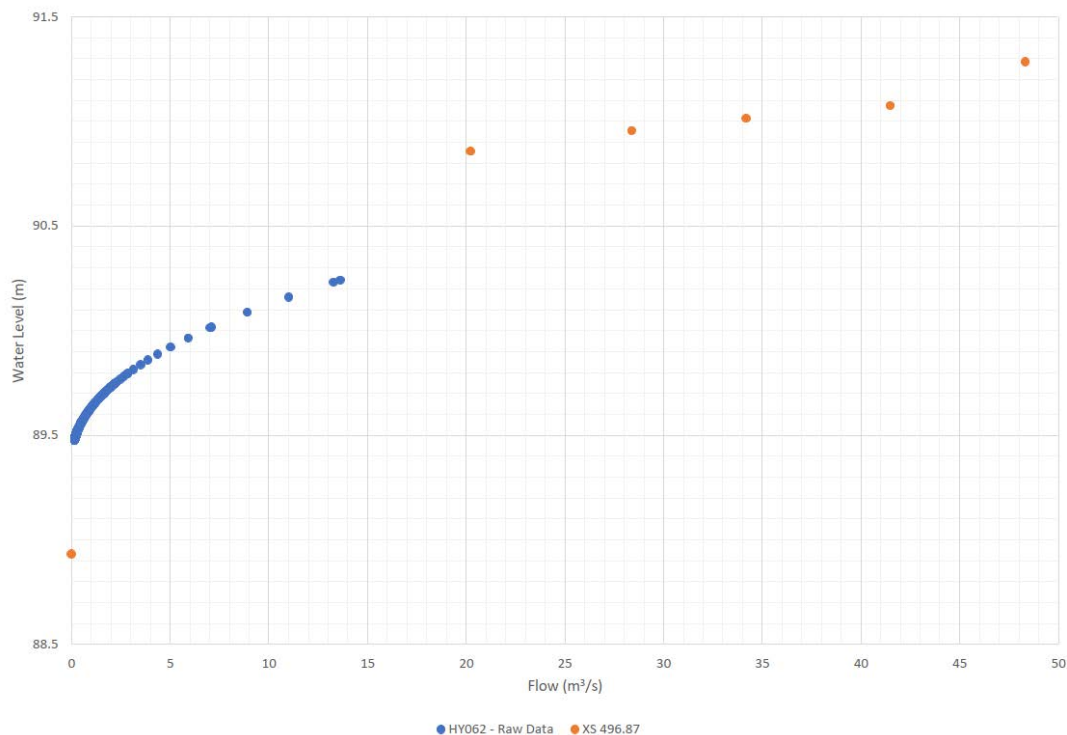


FIGURE 13 RATING CURVE VALIDATION AT TRCA HY062

The hydraulic model relies on the use of the detailed geometric data available and the selection of roughness coefficients that are in line with the observed land uses and types of surfaces, to represent the resistance to flow along the channel and floodplain, as well as the detailed data obtained at the locations of hydraulic structures. Although the available data was not sufficient to validate the model, it suggests that the model results are in the proper range and potentially slightly conservative. The confidence on the model results, given the inherent uncertainty in the selection of modelling parameters, was further evaluated with the sensitivity analyses described in Section 3.6.

3.6 Sensitivity Analyses

Sensitivity analyses were performed on all branches of the model. These analyses were used to evaluate the effect on the result of the selection of Manning's roughness coefficients, the downstream boundary condition, and the assumed flow regime (sub-critical flow only vs. mixed sub-critical/super-critical flow).

3.6.1 MODEL SENSITIVITY TO MANNING ROUGHNESS COEFFICIENTS

The Manning's roughness coefficients selected for the model were based on the table of Standard Manning's Roughness Coefficients that was provided by TRCA. These values are best estimates roughness parameters associated with given land uses and surface types, and have an inherent level of uncertainty. To test the sensitivity of the model results to changes in the Manning's roughness coefficients, the following cases were simulated:

- Standard Manning's Roughness Coefficients (Baseline)

- Increase of 15% in Manning values for the channel and the overbank areas
- Decrease of 15% in Manning values for the channel and the overbank areas
- Increase of 15% in Manning values for the channel
- Decrease of 15% in Manning values for the channel
- Increase of 15% in Manning values for the overbank areas
- Decrease of 15% in Manning values for the overbank areas

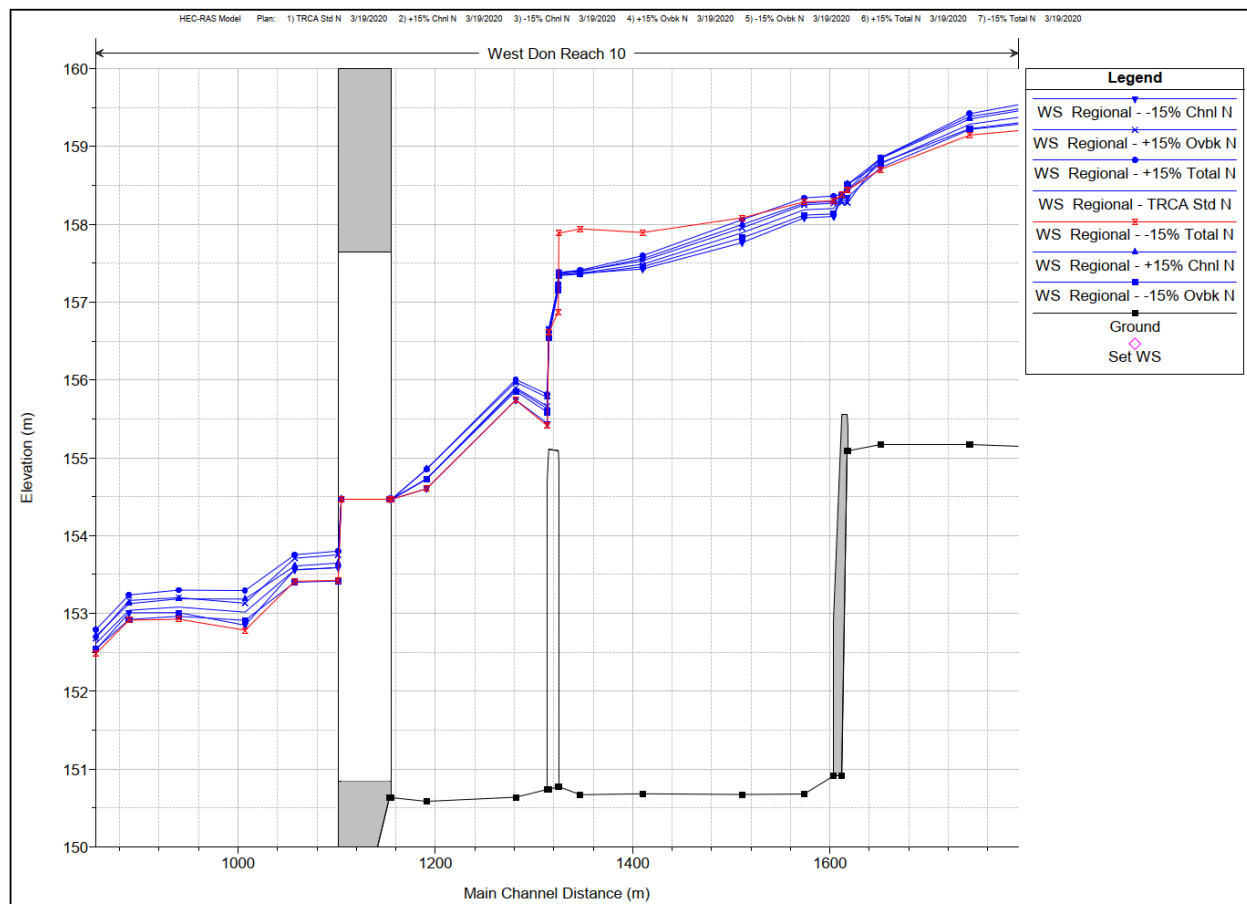
The results of the sensitivity analysis are shown in Table 3. The average differences obtained with respect to the base case is relatively small (less than 0.1 m) and within the precision expected from the model. This indicates that in general, the model results are not very sensitive to the changes on the roughness coefficient, within the reasonable values applicable to this parameter. For the Regional Storm flood event, the results also show that this small sensitivity to the Manning numbers is stronger for the overbank roughness coefficients than the channel roughness coefficients. This is expected because for that flood event a large portion on the conveyance occurred in the overbank areas.

There were some locations, where the sensitivity analysis to the Manning values showed large differences with respect to the base case. However, those conditions were consistently related to small differences associated to the changes in the Manning values that were amplified at crossing locations. As such, they are not reflective of the effect of the roughness parameter per se; but rather of the sensitivity of the HEC-RAS routines for crossings to small changes in downstream conditions. It was also identified that this could be related to the type of flow regime, which is discussed in Section 3.6.3.

Examples of crossing locations where the various models used to evaluate sensitivity to the roughness parameter resulted in local high differences are: the crossing on the Taylor Massey Creek Reach 3 at (don_144), the crossing on the West Don Reach 10 at (don_116), and the crossing on the Lower Don Reach 2 at (don_009). A careful review of these locations revealed that the cases that showed large differences with respect to the base case correspond to simulations in which the model could not converge on a solution. Figure 14 shows the results obtained for the various cases at the crossing labeled don_116. The figure shows that the results for all cases, except the 15% decrease on “total” (channel and overbank) N value, are very close to the base case. It was, therefore, concluded that those localized large differences were outliers and that, since the base case was invariably within a few centimetres from all other sensitivity scenarios, it can be confidently adopted for the purpose of preparation of the floodplain maps.

TABLE 3 MANNING'S SENSITIVITY ANALYSIS – COMPARISON TABLE

Sensitivity Case	Average Difference (m)	Max Difference (m)	Std. Dev of Difference	% of XS that are Different
Total Increase 15%	-0.08	1.04	0.09	73%
Channel Increase 15%	-0.02	1.04	0.08	76%
Overbank Increase 15%	-0.07	-0.42	0.08	73%
Total Decrease 15%	0.08	-0.57	0.09	72%
Channel Decrease 15%	0.01	0.48	0.09	78%
Overbank Decrease 15%	0.05	-1.00	0.12	75%

FIGURE 14 MANNING'S SENSITIVITY ANALYSIS – OUTLIER CASE

3.6.2 MODEL SENSITIVITY TO DOWNSTREAM BOUNDARY CONDITION

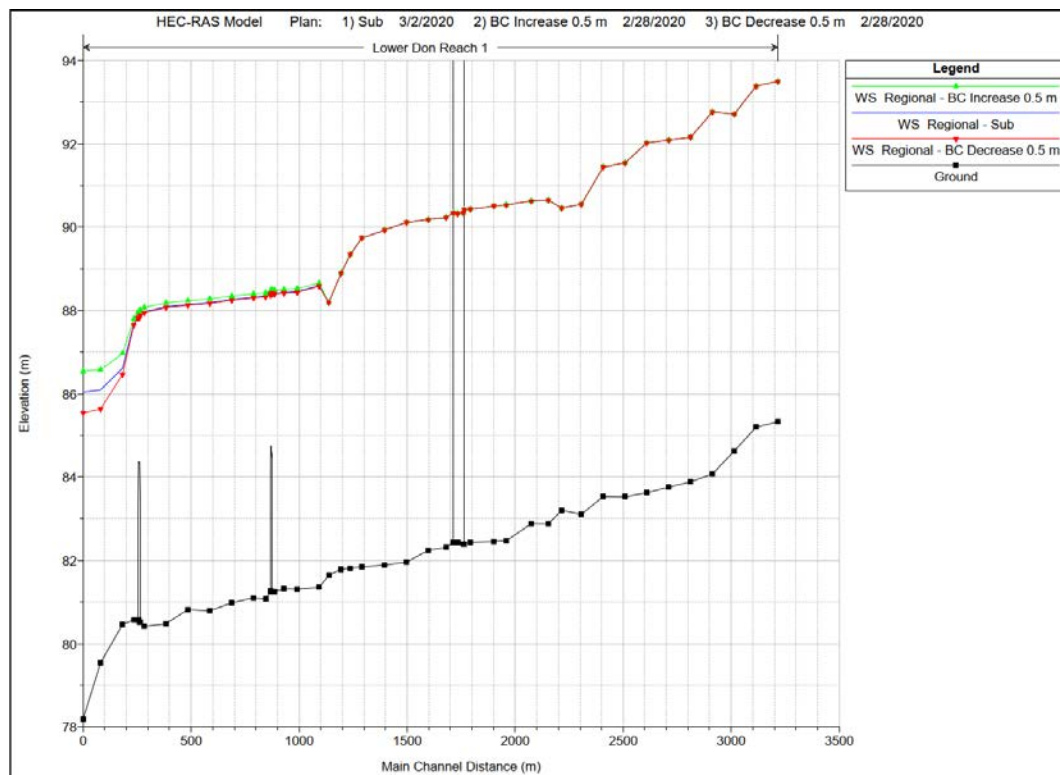
The downstream boundary condition used in the study is a rating curve developed from the Two-Dimensional model of the Lower Don River, as discussed in Section 2.6. To test the sensitivity of model results to this boundary condition, simulations of the Regional Storm flood were carried out for two additional scenarios: with the water level increased by 0.5 m with respect to the base case and with the water level decreased by 0.5 m.

The results of the sensitivity analysis are shown in Table 4 and the corresponding water surface profiles of the Lower Don River are shown in Figure 15. The results showed that the effect on changes to the assumed downstream water levels would mostly be limited to the last 250 m of the model domain (up to station don_005). Upstream of this location, the effect of the changes in the downstream water level were 0.10 m or less for up to 1 km upstream from the downstream boundary, and ceased beyond that point. It was concluded that the results with the base case could be confidently adopted knowing that any uncertainties in the model downstream boundary condition would only reflect on a very limited length of river.

TABLE 4 DOWNSTREAM BOUNDARY CONDITION SENSITIVITY ANALYSIS

Distance from Boundary Condition (m)	Difference in Water Surface Profile (m)		
	Decrease Boundary Condition 0.5 m	Normal Boundary Condition	Increase Boundary Condition 0.5 m
0	-0.50	0.00	0.50
80	-0.46	0.00	0.48
180	-0.14	0.00	0.35
280	-0.02	0.00	0.10
990	-0.01	0.00	0.07
1140	0.00	0.00	0.00

FIGURE 15 DOWNSTREAM BOUNDARY CONDITION SENSITIVITY ANALYSIS – LOWER DON



3.6.3 MODEL SENSITIVITY TO THE FLOW REGIME

At the request of TRCA the simulations carried out as part of this study were done assuming subcritical flow regime. Generally, this results in the most conservative estimate of the water levels; but there are areas of the river that could feature faster flows and in which localized supercritical flow could occur. KGS tested the sensitivity of the model results to the assumption made of flow regime by comparing the results of assuming subcritical flow regime with those obtained using mixed flow (i.e. allowing the model to simulate supercritical flow). When the simulations are done assuming mixed flow regime, HEC-RAS can carry out computations for both subcritical flow and supercritical flow, and applies the correct solution where appropriate, based on the estimated Froude Number. To carry out simulations with “mixed flow” regime, HEC-RAS requires an upstream boundary condition. In this case, the upstream boundary condition given to the model was to assume critical flow at the upstream end of all reaches. This condition only serves the purpose of allowing the model to start a simulation and it is often overwritten if the model obtains a higher water level than that corresponding to critical flow.

The results showed that the subcritical flow regime simulations yielded a water surface level that was on average 0.03 m higher than with mixed flow regime. A detailed review indicated that the results with these two scenarios were nearly identical for a large portion of the model, with the exception of reaches of steep channel slope, where the flow would most likely be supercritical. Large differences between the two simulations occurred only locally, immediately downstream of some crossings, where velocities are high. In

these areas where the two models differed, it is likely that supercritical flow would occur; and that the results assuming subcritical flow provide a conservative estimate of the water surface profile. The subcritical flow results were therefore adopted.

3.7 Model Results

The HEC-RAS model was used to simulate the hydraulic conditions with the flows representing runoff for the 2-Yr, 5-Yr, 10-Yr, 25-Yr, 50-Yr, 100-Yr and 350-Yr recurrent storms and the Regional Storm event. The input flows to the model for each of these scenarios are shown in Appendix E. The results from HEC-RAS, obtained assuming subcritical flow regime, are provided in Appendix D. Also included in Appendix D there is a table that summarizes, for each flow event, the structures identified in the model results as being overtopped as well as the depth of overtopping.

4.0 FLOODPLAIN MAPPING

The results of the simulations with the hydraulic model, described in Section 3.0, were used to prepare a map showing the Regulatory Floodplain. The results were also used to identify potential spill zones in which the flood could extent to outside of the model domain, and to generate flood extent polygons and raster files for the various flood events simulated.

The MNRF's Technical Guide River & Stream Systems: Flooding Hazard Limit (2002) (ref. Section 4.13 of the guidelines) defines a spill as occurring when flood levels overtop the banks of a watercourse and spill overland away from the watercourse channel. Frequently, this spill will move into another watershed or join the originating watercourse at a distance downstream. Further, the guidelines states that:

"The effect of spills moving into another watershed should be assessed to determine the potential flood risks. Alternative measures should be investigated to prevent the spill moving into the adjacent watershed. If the amount of spill is relatively small, less than 10% of the peak flow, the flood plain mapping for the watercourse should be based on the original flow, without any deduction for the spill. For larger spills, allowance for the reduced flow should only be made where the review of alternatives proves that the spill cannot be prevented, either because there are no feasible alternatives or the costs, when compared to the potential benefits, are too high. Where the spill re-joins the watercourse further downstream, the route of the spill should be examined to determine the potential harmful effects of overland flow. No reduction should be made for the spill in the downstream flood plain computations."

The initial simulations of the Regional Storm flood with the hydraulic model were used to identify potential spill zones within the study area. For this purpose, all the locations where the water surface extended laterally beyond the limits of the cross sections were identified. At each of these locations, the cross sections were the extended to try to include all the areas flooded, and the model was run again. The results were examined once again, and it was found that even with the extended cross sections there were six remaining locations, within the study area, where the model indicated that water could flow outside of the model domain during the Regional Storm flood. These locations were identified as "spill areas" that require more detailed evaluation, possibly using two-dimensional hydraulic models, to properly assess the flow patterns and the extent of the flooding. They are described in the following sections.

4.1.1 SPILL AREA #1 – ST. CLAIRE AVE. E. AND TTC STATION

A spill area was found along the left bank of Taylor Massey Creek, immediately upstream of the TTC crossing. This corresponds in the model to Crossing don_156 on Taylor Massey Creek Reach 3. The model results indicate that flow would exit the system and flow towards the west on St. Claire Ave. E. Figure 16 shows the location of this spill area.

4.1.2 SPILL AREA #2 – YORK MILLS RD AND YONGE ST.

A spill area was found at on the West Don River over the left river bank, near the intersection at York Mills Rd. and Yonge St. This corresponds in the model to Station 70.5 at the downstream end of Reach 7. The

model results indicate that excess flows would spill outside of the model domain along York Mills Road towards the east. Figure 17 shows the location of this spill area.

4.1.3 SPILL AREA #3 – FINCH AVENUE W AND WILMINGTON AVE.

A spill area was found at the crossing at Finch Ave. W. This corresponds in the model to Crossing don_260 on Tributary 6 of the West Don River. The model results indicate that the flow would exit the system and flow east on Finch Ave. W towards Wilmington Ave. Figure 18 shows the location of this spill area.

4.1.4 SPILL AREA #4 – DON VALLEY PARKWAY

A spill area was found at the crossing of the Don Valley Parkway on Deerlick Creek 1 on the East Don River. This corresponds in the model to Crossing don_186. The flow exits the system and flows south on the Don Valley Parkway. Figure 19 shows the location of this spill area.

4.1.5 SPILL AREA #5 – WOODSWORTH RD. AND STUBBS DR.

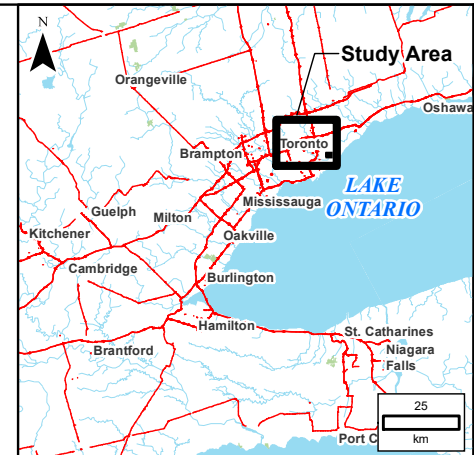
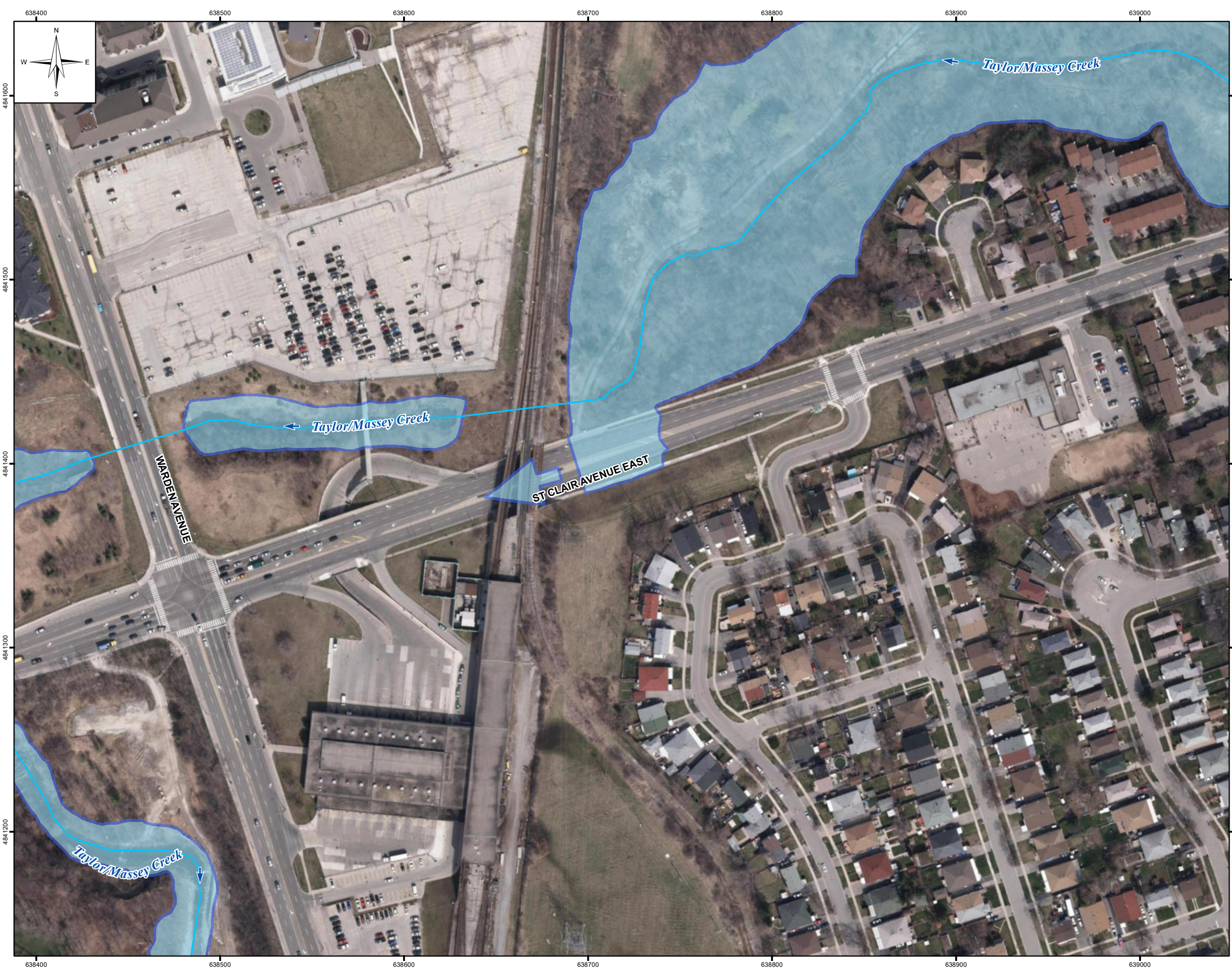
A spill area was found in the area near the conduit under Woodsworth Rd. and Stubbs Dr. This corresponds in the model to Crossing don_198/199 on Tributary 2 of the East Don River. The model results indicate that flow would exit the system and flow in the southeast direction along Woodsworth Drive. Figure 20 shows the location of this spill area.

4.1.6 SPILL AREA #6 – LAWRENCE AVE.

A spill area was found at the crossing of Lawrence Ave. on Tributary 1 of the West Don River. This corresponds in the model to crossing don_251 the flow exits the system at the right overbank and flows southwest. Figure 21 shows the location of this spill area.

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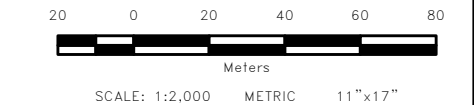


LEGEND:

- River Centerline
- Regional Flood Line

NOTES:

- Topographic data shown provided by TRCA and/or Land Information Ontario (LIO).
- Imagery provided by TRCA.

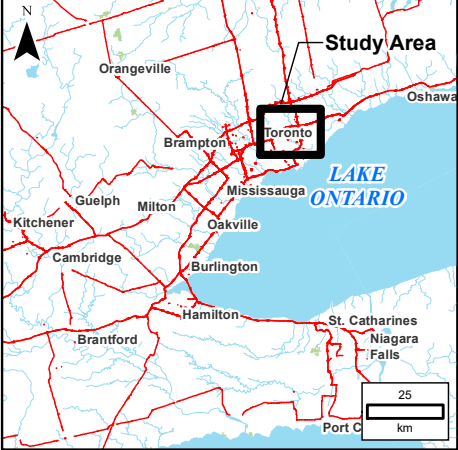
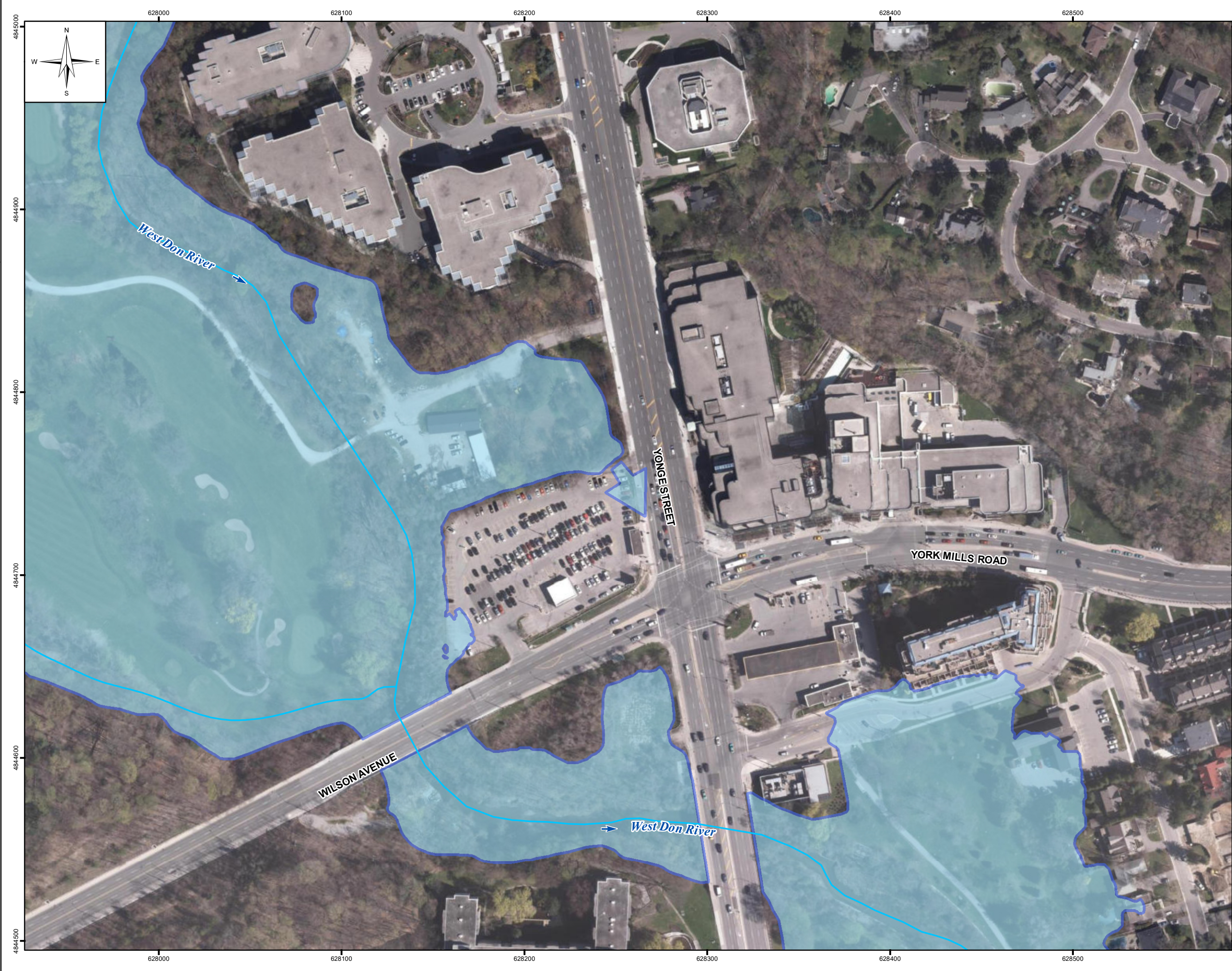


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UPDATES (PHASE I) AND G ROSS
LORD DAM'S OPERATION (PHASE II)

SPILL AREA #1		
APRIL 2020	FIGURE 16	REV: 0

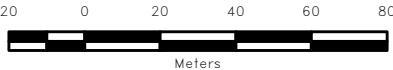


LEGEND:

- River Centerline
- Regional Flood Line

NOTES:

1. Topographic data shown provided by TRCA and/or Land Information Ontario (LIO).
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Elevations are in metres above sea level (MSL).

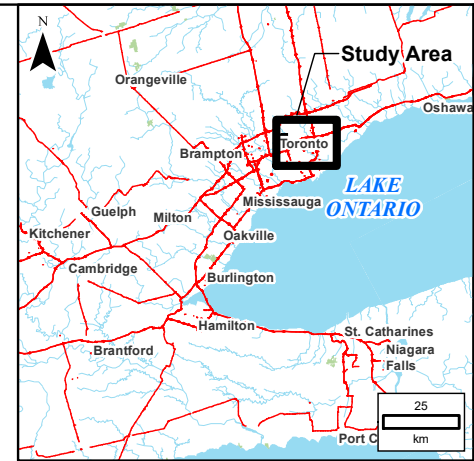
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DON RIVER FLOODPLAIN MAPPING
UPDATES (PHASE I) AND G ROSS
LORD DAM'S OPERATION (PHASE II)

SPILL AREA #2	
APRIL 2020	FIGURE 17
	REV: 0

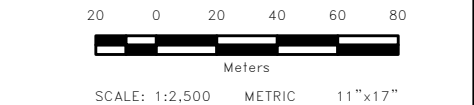
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- LEGEND:
- River Centerline
 - Regional Flood Line

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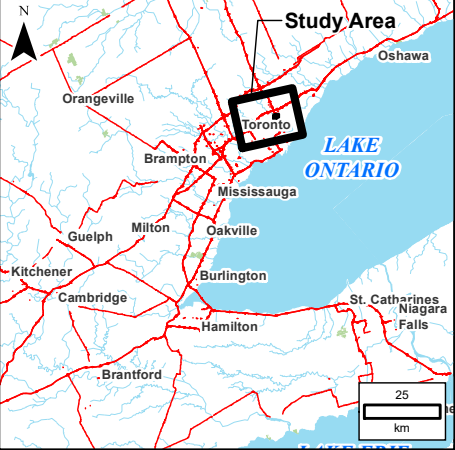
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LORD DAM'S OPERATION (PHASE II)

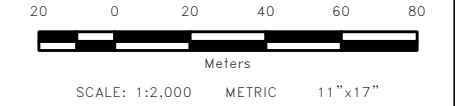
SPILL AREA #3		REV:
APRIL 2020	FIGURE 18	0



LEGEND:

- River Centerline
- Regional Flood Line

- NOTES:**
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DON RIVER FLOODPLAIN MAPPING
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LORD DAM'S OPERATION (PHASE II)

SPILL AREA #4		REV:
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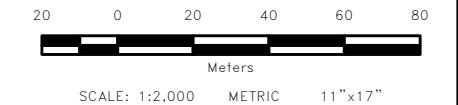


LEGEND:

- River Centerline
- Regional Flood Line

NOTES:

1. Topographic data shown provided by TRCA and/or Land Information Ontario (LIO).
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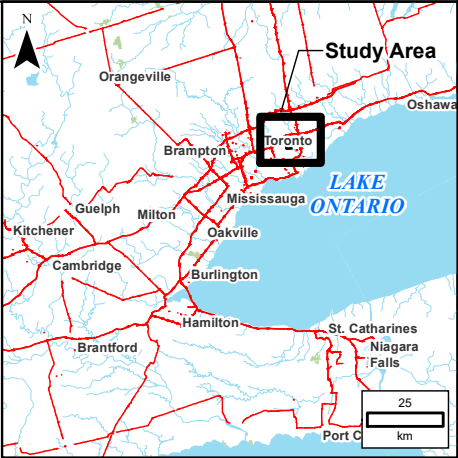
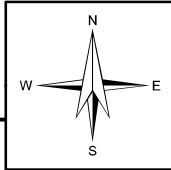
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DON RIVER FLOODPLAIN MAPPING
UPDATES (PHASE I) AND G ROSS
LORD DAM'S OPERATION (PHASE II)

SPILL AREA #5		
APRIL 2020	FIGURE 20	REV: 0



LEGEND:

- River Centerline
- Regional Flood Line

NOTES:

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UPDATES (PHASE I) AND G ROSS
LORD DAM'S OPERATION (PHASE II)

SPILL AREA #6

APRIL 2020	FIGURE 21	REV: 0
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4.2 Development of Flood Extent Polygons and Rasters

Version 5.0.7. of HEC-RAS has the capability to generate flood extent polygons and raster files representing model results using the RASMapper tool. This capability was used to prepare raster polygons for flow velocity, flood depth, velocity-depth product, and water surface elevation for all the simulated events: 2-Yr, 5-Yr, 10-Yr, 25-Yr, 50-Yr, 100-Yr, 350-Yr recurrent storm floods, and the Regional Storm flood.

HEC-RAS automatically generates these raster files based on the steady flow simulation results. In order to generate the files for velocity and velocity-depth product, the model requires that flow distribution subsections be set. In this project, the model was set to have up to 15 subsections in each of the left overbank, channel, and right overbank areas.

4.3 Mapping of the Regulatory Floodplain

The Regulatory Floodplain (i.e. flooding hazard limit, OMNR, 2002) in this area is defined as the greater of the flooding generated from the 100-Yr Flood Event or the Regional Storm Flood (Hurricane Hazel). In all locations of the model domain, the Regional Storm Flood resulted in the higher water surface elevations, and as such, it was used to define the flood hazard limit indicated in the Regulatory Floodplain maps.

The extent of the Regulatory Floodplain was generated using flood surfaces obtained with the GeoHEC-RAS mapping tool and the HEC-RAS RASMapper tool. Both of these tools generate continuous flood surfaces based on the results obtained with HEC-RAS at the discrete locations where cross sections are defined. They use slightly different algorithms and their results could differ, with varying quality among them. The following three surfaces were generated:

- Regional Storm flood extent obtained with the GeoHEC-RAS mapping tool with no extension beyond the width of the model cross sections
- Regional Storm flood extent obtained with the GeoHEC-RAS mapping tool extending up to 30 metres beyond the width of the model cross sections
- Regional Storm flood extent obtained with the RASMapper tool and with no extension

The three surfaces obtained with these mapping tools were visually compared, to discern, with consideration of the terrain features and the water level values, which one was the most appropriate at specific areas of the model domain. The resulting surface representing the Regulatory Floodplain was subsequently manually edited to correct any identified inconsistencies generated by the mapping algorithms. The instances that required manual editing included removing a few areas that although shown initially as flooded were separated from the river by a high terrain feature, as well as adjusting model results are overtopped crossings.

Since the mapping tools previously discussed do not accurately map the inundation that occurs where crossings are overtopped, at those locations, the Regulatory Floodline was manually edited to tie into the terrain upstream and downstream of the crossing.

Another location that required manual adjustment was at the conduit at Taylor Massey Reach 3 (don_172/171). There the study results showed that the conduit would pass all the flow and that no overland flow would occur. However, to allow continuity of the HEC-RAS model at that location, a nominal flow value

of 0.0001 m³/s was input as overland flow. It was then necessary to manually remove the associated overland flooding that the automatic algorithms generated.

A GIS polygon shape file was prepared, showing the Regulatory Floodplain refined and corrected as previously described. The surface was reviewed by KGS Group and also by TRCA. The mapping of this surface is provided in Appendix G.

4.4 Changes to the Regulatory Floodplain

The updated Regulatory Floodplain differs at various locations from the previously adopted one. The differences are a result of several changes with respect to the previous mapping work including: the use on this study of a more accurate Digital Elevation Model, changes in the input flows used in this study with respect to those used before, additional data on crossings, and the use of a new hydraulic model independently prepared for this project. The new model prepared as part of this study also extends beyond the limits of the model previously used to delineate the flooding hazard limits. There are, therefore, areas where the previous flood lines had been only estimated; but this time have been mapped with the use of model results.

A comparative review of the previous and the proposed flood lines shows that new areas of inundation were identified for the Regional Flood that had not been detected before. This is likely due to the use of greater flow input values (obtained from the AECOM 2018 study) than those used before. Additionally, many crossings that were not previously modelled are now included in the model. These generally cause local increases in the water surface level associated with localized flow restriction. The Regulatory Floodplain is shown in Appendix G. The following are the locations that show most notable differences between the previous and the new floodlines.

- **G. Ross Lord Dam:** On the West Don River, the water level set at G. Ross Lord Dam, obtained from the routing exercise described in Section 3.4.3, results in a larger inundation area upstream of the dam. This affects the reaches labelled in the model as Tributary 6, Reach 11, Tributary 7, and Reach 12.
- **Bayview Ave and Blythwood Rd:** On the West Don River, along Burke Brook, the water level set at the Bayview crossing (don_244), obtained from the routing exercise described in Section 3.2.5, resulted in a larger inundation area upstream of the crossing than what is shown in the previous floodlines. The newly identified inundation area includes some houses that exist along Sunnydane Crescent.
- **Woodfern Drive and Chelwood Rd:** On the Taylor Massey Creek, Reach 3 of the model, the railway crossing (don_165) causes a significant impoundment of water and causes additional flooding upstream of the crossing. This additional flooding extends approximately 1.6 km upstream of the crossing, and includes houses in the left overbank far upstream from the crossing, as well as houses near the crossing in both the right and left overbank areas.

5.0 SUMMARY AND RECOMMENDATIONS

5.1 Summary

This study (Phase I) consisted on evaluating hydraulic conditions for the Don River watershed from Steeles Ave to a location 222 m upstream of Pottery Rd. It included preparation of a new hydraulic model, using the program HEC-RAS Version 5.0.7 and use of the results of a hydrologic analysis conducted by AECOM for TRCA in 2018.

The study scope included a review of all pertinent background information provided by TRCA. A screening of the structures in the Don River system, within the study area, was carried out and over 166 structures, considered to affect the hydraulic conditions in the study area, were visited. The characteristics of these structures were documented using TRCA's standard crossing data sheets. The various data sources, including the site visit, previous models and available as-built drawings were evaluated and the most appropriate data source was selected for the preparation of the hydraulic model.

The hydraulic model developed as part of this study included the East Don River, West Don River, Taylor Massey Creek, and their main tributaries. The model cross sections were developed with the use of TRCA's LiDAR data and DEM (circa 2015), and additional bathymetric data obtained by TRCA. The model was prepared in accordance with standard modelling practices, HEC-RAS manual guidelines and TRCA requirements, including the use of TRCA's standard roughness coefficients. It was prepared by KGS Group and reviewed by TRCA.

The hydraulic model was used to simulate the flood events corresponding to the 2-Yr, 5-Yr, 10-Yr, 25-Yr, 50-Yr, 100-Yr, 350-Yr recurrent storm floods, and the Regional Storm flood. A sensitivity analysis indicated that the model could be confidently used for defining hydraulic conditions for the simulated events and for the preparation of floodplain maps showing the flooding hazard limits in accordance with provincial guidelines. The model results were then used to develop the updated Regulatory Floodplain Maps for the study area of the Don River watershed, using the flooding obtained for the Regional Storm flood. It was also used to prepare raster shapefiles showing flow velocity, flood depth, velocity-depth product, and water surface elevation for all the simulated events. Six spill areas, where the model showed that flows would exit the limits of the model domain were identified for further evaluation. These are at:

- the left bank of Taylor Massey Creek, immediately upstream of the TTC crossing
- the West Don River over the left river bank, near the intersection at York Mills Rd. and Yonge St
- the crossing at Finch Ave. W over Tributary 6 of the West Don River
- the crossing of the Don Valley Parkway on Deerlick Creek 1 on the East Don River
- the area near the conduit under Woodsworth Rd. and Stubbs Dr, on Tributary 2 of the East Don River
- the crossing of Lawrence Ave. on Tributary 1 of the West Don River

Differences found with respect to the previous floodplain maps for the study area were due to various factors including: the use of updated input flows, updated and more detailed topographic data and data at crossings, inclusion of additional crossings that were not in previous studies, extension of the study area to reaches of the river system that had not been previously modelled. The most notable differences were found upstream

of the G. Ross Lord Dam, the crossing of Bayview Ave and Blythwood Rd over Burke Brook and the crossing of Woodfern Drive and Chelwood Rd over Taylor Massey Creek. At this location, the new study indicates higher water levels and more extensive backwater effects that include flooding of areas and impacting properties that had not been previously identified as such.

5.2 Recommendations

It is recommended to adopt the model results and the updated Regulatory Floodplain Maps developed in this study for the Don River watershed from Steeles Avenue to upstream of Pottery Rd.

It is recommended to use the provided model results as reference for identification of infrastructure that could be affected during flood events as well as potential infrastructure improvements.

It is recommended that the six spill zones identified in the study be further investigated, potentially with the use of two-dimensional models.

6.0 REFERENCES

AECOM, 2018. Don River Hydrology Update. December 2018.

MNRF, 2002. Technical Guide River & Stream Systems: Flooding Hazard Limit. 2002.

USACE, 2016. HEC-RAS Hydraulic Reference Manual. February 2016.

APPENDIX A

Watercourse Crossing Data Sheets

APPENDIX B

TRCA's Standard Manning's Roughness for
Hydraulics Modelling

APPENDIX C

Additional Modelling

APPENDIX D

HEC – RAS Output

APPENDIX E

Flow Nodes Used for Development of the HEC-RAS
Steady Flow Data Table

APPENDIX F

Modelling Approach by Crossing Structure

APPENDIX G

Update Regulatory Floodplain Mapping of Don River



Experience in Action