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MIKE Flood 1D-2D Model Development and Regulatory Floodplain Mapping Pickering / Ajax SPA

Toronto and Region Conservation Authority
City of Toronto

March 2018 (FINAL)

Prepared By:

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Prepared For:

The Toronto and Region Conservation Authority

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Toronto and Region Conservation for The Living City

VALDOR WATER RESOURCES

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Executive Summary

As part of the overall Pickering/Ajax Special Policy Area (SPA) 2D Hydraulic Model and Dykes Assessment project, Valdor Engineering Inc. was retained by the TRCA to develop a 1D-2D hydraulic model using MIKE Flood for the Study Area that includes the Pickering and Ajax Dykes and to prepare Regulatory Floodplain Mapping. The dykes were constructed in the 1980's to provide the 500-yr level of flood protection for the Pickering (Village East) and Notion Road/Pickering Village Special Policy Areas (SPA's) located within the Duffins Creek watershed.

An existing conditions hydraulic model was developed using MIKE Flood using a high resolution (0.5m X 0.5m) raster surface derived from the LiDAR Survey (2015), 2016 topographic survey related to channel cross sections and dyke elevations, 2016 digital orthophotos, GIS data layers for land use, building polygons, road polygons, street network, river network and edge of water lines, flow data from the 2012 hydrology update, and hydraulic structure design drawings from the City of Pickering, Town of Ajax, Durham Region and the Ministry of Transportation.

Eleven (11) scenarios were investigated for the Pickering (Village East) and Notion Road/Pickering Village SPA hydraulic analysis based on actual storms and return period storm events combined with dyke conditions with and without flood protection (*i.e.* dykes) in place. The results of the MIKE Flood model using the steady flow hydrographs provided by the TRCA were used to delineate the extent of flooding for the Regional, 500-yr, 350-yr and 2-yr through 100-yr storms within the Pickering (Village East) and Notion Road/Pickering Village SPA's. The extent of flooding using the steady flow input hydrographs is generally similar but greater than the results using the unsteady flow input hydrographs. Based on discussions with the TRCA, it was determined that the steady flow input hydrographs would be applied to all model runs for this study.

With assistance from the TRCA, three (3) updated map sheets were prepared based on the flood depth maps calculated with the MIKE Flood model. These updated map sheets will replace the existing Duffins Creek floodplain Map Sheets 4, 5 and 6.

Based on the results of the MIKE Flood model, it was determined that the requisite level of flood protection regarding the existing flood control infrastructure for the 500-yr storm is not provided for all areas within the Pickering (Village East) and Notion Road/Pickering Village SPA's. The Pickering Dyke provides flood protection for the 100-yr storm flow and the Ajax Dyke provides flood protection for the 50-yr storm flow. Factors contributing to the reduced level of flood protection afforded by the Pickering and Ajax Dykes include reduced dyke elevations compared to the design elevations and less sophisticated hydraulic modeling methods previously available.

Options to rehabilitate the existing dykes and reinstate the 500-yr level of flood protection should be investigated for future consideration and implementation. Recommended mitigation options including bridge or culvert conveyance capacity improvements, channel conveyance capacity improvements, spill containment and grade adjustments should be considered.

As a minimum requirement, it is important that the TRCA in association with the City of Pickering, Town of Ajax and Region of Durham reinstate the existing level of flood protection within the Pickering (Village East) and Notion Road/Pickering Village SPA's to ensure the area remains flood free for events up to and including the 500-yr storm and to minimize the risk to life and property.

Opportunities to improve the level of flood protection beyond the 500-yr storm should be investigated at a high level of assessment to confirm if such an undertaking is practical.

1.0 INTRODUCTION

As part of the overall Pickering/Ajax Special Policy Area (SPA) 2D Hydraulic Model and Dykes Assessment project, Valdor Engineering Inc. was retained by the TRCA to develop a 1D-2D hydraulic model using MIKE Flood for the Study Area that includes the Pickering and Ajax Dykes and to prepare Regulatory Floodplain Mapping. The dykes were constructed in the 1980's to provide the 500-yr level of flood protection for the Pickering (Village East) and Notion Road/Pickering Village Special Policy Areas (SPA's) located within the Duffins Creek watershed.

1.1 Study Area

The study area consists of the entire Pickering (Village East) and Notion Road/Pickering Village Special Policy Areas (SPA's) which lie between Valley Farm Road at the upstream end to downstream of Bayly Street West. **Figure 1.1** illustrates the general location of the study area, including the approximate location of the Pickering and Ajax Dykes.

1.2 Project Background

The flood control works implemented for the Pickering/Ajax SPA area were constructed in the mid 1980's to alleviate flooding within the identified Flood Damage Centre as a top priority and consisted of two flood protection dykes, one in each municipality. The Pickering Dyke constructed in 1985 extends for approximately 1,100 m north of Kingston Road West and west to Brock Road. The Ajax Dyke constructed in 1984 extends for approximately 600 m west of Church Street South near Mill Street and north to an apartment building located on the west side of Church Street South in the vicinity of Christena Crescent (see **Figures 1.1**). The design of the flood control infrastructure was completed by Simcoe Engineering Group and was intended to provide flood protection up to and including the 500-yr storm flow.

In June 2009, Geomorphic Solutions was retained by the TRCA to complete an interim report to determine the level of flood protection the dykes provide, summarize the fluvial geomorphic assessment and assess the structural condition of the dykes. The Geomorphic Solutions report concluded that the majority of the Pickering dyke provides 500-year flood protection, however, the Ajax dyke only provides the 100-year flood protection. The Interim Report also documented detailed deficiencies and concerns observed that were utilized to facilitate Valdor's field assessment.

Subsequent to the *Hydrologic Model Study Humber, Don and Rouge Rivers, Highland, Duffin, Petticoat and Carruther's Creeks* completed by James F. MacLaren in 1979 using a hydrologic model based on HYMO, a number of hydrology updates for the Duffins Creek Watershed have been completed. Hydrology updates were completed by Aquafor Beech Ltd. in 1991 using the INTERHYMO/OTTHYMO model and in 2002 using the Visual OTTHYMO model. The most recent update is contained in the *2012 Duffins Creek Hydrology Update* using Visual OTTHYMO (Aquafor, 2013).

1.3 Purpose of Study

The purpose of the study is to develop a coupled 1D-2D hydraulic model to define existing flood conditions for the 2-yr to 100-yr design storms and the 350-yr, 500-yr and Regional storms and to prepare updated floodplain mapping for the Regional storm within the Pickering (Village East) and Notion Road/Pickering Village SPA's along with a supporting technical report.

1.4 Study Scope and Approach

The scope and the key steps of this report are as follows:

- Review of background information and documents
    - Review of all the historic information.
    - Review of all the previously completed studies.

- Develop a 1D-2D hydraulic model using MIKE Flood for the study area including the Pickering (Village East) and Notion Road/Pickering Village SPA's.
    - Identify model data needs and gaps.
    - Complete field surveys to verify the drainage network, topographic features (spill points, flood walls, dykes, retaining walls, dams, and any other hydraulic barriers, etc.), and prepare an inventory of the structures.
    - Identify a 2D model domain and 1D model extent, and prepare all the data layers corresponding to this model domain.
    - For the entire model domain, create a high resolution (0.50m X 0.50m) DEM surface integrating elevation survey data for the (low flow and underwater) channel area and the LiDAR DEM data with the help of ArcGIS 3D Digital Terrain Modelling (DTM) toolsets. The modified DEM surface is used to create MIKE 21 2D bathymetry and MIKE 11 1D channel cross-sections.
    - Prepare a base map that identifies the main topographic features to be considered in various modelled scenarios and flood depth mapping.
    - Develop an existing condition model for the study area using MIKE Flood 1D/2D coupled model approach.
    - Run the existing condition MIKE Flood model using the steady and unsteady inflow hydrographs for Hurricane Hazel and the 500-yr design storm and determine the preferred hydrograph type with which to proceed.
    - Prepare flood depth, velocity, flow direction maps and animations corresponding to Regional, 500-yr, 350-yr and 2-yr through 100-yr model runs.

- Prepare signed and stamped updated floodplain mapping for Duffins Creek Map Sheets 4, 5 and 6.

1.5 Previously Completed Available Studies and Information

A review of the following studies and key design drawings provided by the TRCA was completed in preparing the *MIKE Flood 1D-2D Development and Regulatory Floodplain Mapping, Pickering / Ajax SPA* report:

- Aquafor Beech Limited, *2012 Duffins Creek Hydrology Update*, 11 February 2013.
- Geomorphic Solutions, *Duffins Creek Flood Protection Dyke Erosion Risk, Level of Service Assessment and Maintenance and Improvement Study, Interim Report*, June 2009
- Greck and Associates, *Flood Plain Map Sheets,* Duf-04 (TRCA, 2004), Duf-05 (TRCA, 2004), Duf-06 (TRCA, 2004).Geomorphic Solutions, *Interim Report*, June 2009.
- MMM, *Flood Plain Map Sheets,* Duf-01 (TRCA, 2004), Duf-02 (TRCA, 2004), Duf-03 (TRCA, 2004), Duf-07 (TRCA, 2004), Duf-10 (TRCA, 2004).
- Simcoe Engineering, *Preliminary Engineering Report for Flood Protection on the Duffin Creek in the Pickering Ajax Area*, 1982.
- Simcoe Engineering, *Ajax Flood Protection Dyke Plan*, August 1984.
- Simcoe Engineering, *Pickering Flood Protection Dyke Plan*, July 1985.

- James F. Maclaren, *Hydrologic Model Study Humber, Don and Rouge Rivers, Highland, Duffin, Petticoat and Carruther's Creeks*, 1979.

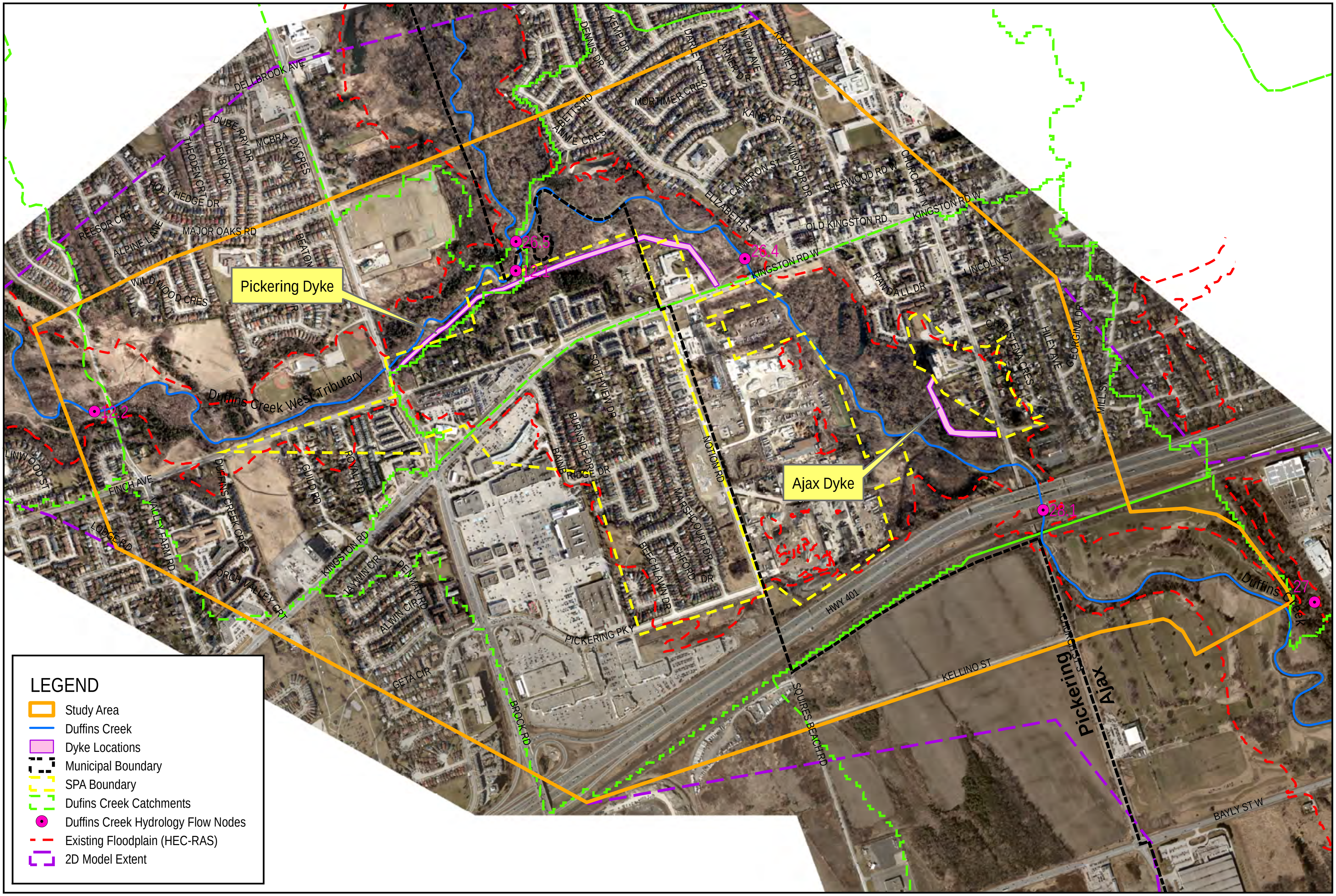

Figure 1.1
STUDY AREA

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TORONTO AND REGION CONSERVATION
PICKERING-AJAX DYKE ASSESSMENT AND FLOOD REMEDIATION STUDY

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2.0 EXISTING CONDITIONS HYDRAULIC MODEL DEVELOPMENT (USING MIKE FLOOD)

2.1 Data Review and Preparation

2.1.1 Available Data and Information

The following data sets were provided by the TRCA:

- High resolution (0.5m X 0.5m) raster surface derived from the LiDAR Survey (2015)
- 2016 digital orthophotos
- GIS data layers for land use, building polygons, road polygons, street network, river network and edge of water lines
- Existing TRCA approved floodline map sheets: Duf-01, Duf-02, Duf-03, Duf-04, Duf-05, Duf-06, Duf-07, Duf-10
- Current TRCA floodplain model (HEC-RAS, 2004)
- Flow data: 2-yr through 100-yr, 350-yr, 500-yr and Hurricane Hazel storm event inflow hydrographs at seven inflow nodes and one Q-H curve at downstream boundary location in the Duffin Creek
- 2016 survey data related to channel cross-sections, dyke elevations, structure dimensions including culvert openings, bridge piers, weir sections, road decks, railings and storm outfall information.
- Hydraulic structure design drawings from the City of Pickering, Town of Ajax, Durham Region and the Ministry of Transportation

2.1.2 Additional Site Survey and Hydraulic Structure Inventory

Valdor Engineering Inc. conducted site visits and field surveys on 26 July 2017, 15 August 2017, 16 August 2017 and 14 November 2017 along the dykes and adjacent areas within the study area. The purpose of the site visits and field surveys was to observe the condition of important features such as the extent and dimensions of the dykes, dams/weirs, any other flood barriers or the presence of any visible hydraulic connectivity between the channel and floodplain areas across/through the dykes.

Table 2.1: Hydraulic Structure Locations

Structure ID	Structure Location	Structure Type
S1	Valley Farm Road	Concrete Bridge
S2	Brock Road	Concrete Bridge
S3	D/S of Brock Road	Steel Pedestrian Bridge
S4	U/S of Kingston Rd. W.	Steel Pedestrian Bridge
S5	Kingston Rd. W.	Concrete Bridge
S6	U/S of Church St.	Dam (Weir)
S7	Church St. S.	Concrete Bridge

S8	HWY 401	Concrete Bridge
S9	GO Transit Bridge	Railway Bridge
S10	CN Railway	Railway Bridge
S11	D/S of CN Rail	Steel Pedestrian Bridge
S12	Bayly St. W.	Concrete Bridge

The surveys confirmed the number of crossings, dimensions and elevations of all openings, road decks, bridge railings, bridge alignments and skew angles, dam/weir alignments and dimensions. Photos were obtained for all the inline hydraulic structures (see **Table 2.1**) and the culvert crossings associated with the dykes. An inventory of key hydraulic structures is provided in **Appendix A.** Details of the hydraulic structures (*i.e.* bridges and culverts) are provided in **Table A.1** in **Appendix A**.

2.1.3 Base Mapping Data Layers and Land Use for Roughness Map

The TRCA provided topographic mapping, which included all buildings, roads, river network lines, edge of water, and other information typically shown on the TRCA's floodplain map sheets. The planimetric data used to update the base mapping were compiled using aerial photographs flown in 1977 and 2002. The TRCA updated the land use data layers such as buildings, roads, parking lots, other various urban land uses including natural and overbank areas using available digital orthophotos (2016). Valdor digitized and finalized the 1D channel centre line based on the LiDAR DEM data, 2016 orthophoto, existing floodplain map sheets and the existing HEC-RAS model. The 1D cross-section cut-lines were created based on the 1D channel centre line. Various spatial data layers used to develop the MIKE 11 channel and the MIKE 21 overland models are shown in **Figure 2.1**. Using the TRCA's base mapping data layers, a land use map was prepared using ArcGIS (see **Figure 2.2**) which was ultimately used to generate the 2D roughness map. Each roughness polygon was assigned with a roughness value based on the appropriate category in the TRCA's roughness table (See **Table B.1** in **Appendix B**).

2.1.4 Preparation of Digital Elevation Model

Two main sources of elevation data were integrated to create a base digital elevation model in GIS. These data sources were the LiDAR elevation surface (2015) and the topographic survey data (**Figure A.1a** and **Figure A.1b** in **Appendix A**). The information extracted from the survey data (by the TRCA and Valdor) and the available drawings (by the City, Town, Region and MTO) were used to upgrade, update and eventually transform the base digital elevation model into a 2D overland area bathymetry and 1D channel cross-sections. This step was necessary to accurately represent various localized elevation features such as the inline weir structure area, drop structures including abrupt changes in the river bed slope, bridge road deck surfaces, solid railings, channel cross-sections immediately upstream and downstream of culverts and bridges, low flow channel cross-sections, etc. **Figure 2.1** illustrates the data layers that were used to update the model bathymetry.

LiDAR Elevation Surface

The TRCA acquired high-resolution digital elevation data using LiDAR for the study area. The collected LiDAR mass point elevation data were processed into a hydro-enforced DEM using break lines for rivers and streams. Valdor received this hydro-DEM data that was converted into a 0.50 m x 0.50 m raster surface for the study area. Road deck surfaces at all bridge and culvert locations were removed to ensure appropriate water flow paths at those locations. **Figure 2.3** shows the LiDAR based 0.50m x 0.50m raster digital elevation model (DEM).

It is important to note that the elevation in the LiDAR DEM for the low flow channel area does not represent the bathymetry of the low flow channel, rather it corresponds to the elevation of the water surface at the time the LiDAR data was obtained. Several cross-sections were cut using the LiDAR DEM and were compared with the survey data at the same locations to show the difference between LiDAR low flow channel elevations and surveyed cross-section elevations (See **Figures 2.4a** and **2.4b**). The road surface elevations at the culverts and bridges were removed and replaced by the low flow WSEL's. Verification of the LiDAR for the dyke area was completed using a number of points selected randomly from the TRCA's topographic survey on the dyke. Based on this verification, the LiDAR was found to be within about 7 cm of the surveyed data (see **Table B.3** in **Appendix B**). Valdor digitized georeferenced polylines for the edge of water on both sides of the river using high resolution (15cm X 15 cm) orthophotos, 50 cm contours and the available map sheet data layers from the TRCA. It was observed that outside the edge of water, the LiDAR data is highly accurate and contains detailed elevations in both the x and y directions, whereas the survey data has measured elevation data only along a cross-section survey line. Based on these findings, it was decided that a high resolution digital elevation model for the area inside the two edge of water lines would be created using the available survey and LiDAR data. The digital elevation model was then integrated with the original LiDAR DEM to prepare a combined 0.50 m x 0.50 m DEM with corrected ground elevations below water.

To create an accurate elevation surface for the water area using appropriate controls during the interpolation process, an adequate number of 3D breaklines including a polygon shape boundary (*i.e.* soft breakline) defining the interpolation extent were introduced in the ArcGIS DTM (Digital Terrain Model) environment. 3D edge of water lines were created using LiDAR elevations at the land-water interface. At least three longitudinal 3D break lines including 3D river network lines were generated using the available survey data. An adequate number of (about 100) 3D elevation cross-section lines were generated based on the survey data. At least two 3D breaklines were created upstream and downstream of each structure including inline weir structures to correctly represent the changes in the adjacent US and DS 2D bathymetry. An example of the 3D breaklines created is shown in **Figure B.1** in **Appendix B.** The TIN based digital terrain model (DTM) created for the water area and the participating data layers is shown in **Figure B.2** in **Appendix B**. A digital elevation raster surface with 0.50 m grid resolution was created using the bilinear interpolation method and then combined with the original LiDAR DEM surface. For verification, several cross-sections were cut using the corrected DEM (*i.e. DEM corrected for the water area*) and compared with the surveyed cross-section. The comparison shows that the combined DEM correctly represents the channel and over bank area (See **Figures 2.5a** and **2.5b**). The TRCA survey data was available between Valley Farm Road and upstream of Bayly St. W. within the study area extents that were used in the corrected DEM generation process. For the remaining segments of the river network (*i.e.* upstream of Valley Farm Road and downstream of Bayly St. W.), the DEM correction process included data from Valdor field measurements for low flow water depths, channel inverts, bridge openings, the existing HEC-RAS model and the available design drawings from the City and the Region. As a result, the modified DEM for the MIKE Flood 1D-2D model extents contains corrected elevations for the water area along the entire river network (See **Figure B.3** in **Appendix B**). The final channel bottom corrected raster DEM is shown in **Figure B.4** (in **Appendix B**), which was used to create the MIKE 21 mesh-based 2D overland area bathymetry as well as to cut approximately 900 MIKE 11 1D channel cross sections.

2.2 Hydraulic Model Development Using MIKE Flood

The Pickering-Ajax study area was modelled using the MIKE Flood interface that integrates the dynamic coupling of the MIKE 11 hydrodynamic and MIKE 21 hydrodynamic modules. The rivers and channels of the study area were modelled using the one-dimensional MIKE 11 modelling system and the overland surfaces were modelled using the two-dimensional MIKE 21 modelling system. MIKE Flood integrates these two models into a single dynamically coupled model. The coupling approach allows one to avoid important limitations of resolution and accuracy encountered when the modelling is done using any of these individual modelling systems. MIKE Flood's ability to simulate overbank flows is based on the lateral link that enables the coupled model to dynamically exchange flow between 1D river and 2D flood plain areas.

2.3 MIKE 11 1D River Model

The MIKE 11 Hydrodynamic (HD) module was used to model the Duffins Creek channel network through the study area. The main elements of the MIKE 11 model setup are:

- Establishing the channel network and creating cross-sections
- Structure modelling
- Roughness parameters
- Boundary conditions and flow input hydrographs
- Simulation settings

2.3.1 Establish Channel Network and Creating Cross Sections

Since accurate representation of the channel geometry is critical to represent flows in the channel, a high resolution digital elevation model was created (Section 2.1.4) by combining the survey information for the low flow channel in order to cut the MIKE 11 1D channel cross sections. Flood calculations using the two-dimensional MIKE 21 engine are more detailed and accurate compared to calculations using the uni-directional MIKE 11 1D engine. In MIKE 11, the 1D flow direction for the entire channel section is determined by the user-approximated straight cutline, while the flow directions in the MIKE 21 individual cells are different and are calculated based on individual cell elevation, slope, slope direction and vector summation of the momentum force. As a result, the flow direction at each cell varies with each time step which is a more accurate representation. Therefore, we extended the 1D channel cross-sections up to approximately the bankfull discharge location (approximately 2 to 5-yr flow level) in the MIKE 11 1D model. Using this approach basically allows the MIKE 21 2D engine to perform computations for the majority of the flow area above the 2 to 5-yr flow that occurs in the river valley or flood plain. High resolution bathymetry (using LiDAR) is more detailed and accurate for detailed computations using MIKE 21 in these overbank areas beyond the 2 to 5-yr or bankfull limits. Therefore, the 1D channel cross section cut lengths are usually shorter than the width of the valley channel. This approach allowed the Pickering dyke area to be included as a part of the 2D bathymetry, which makes it possible to complete accurate flooding computations over and adjacent to the dyke area. It also facilitates the relatively quick development of flood remediation scenarios involving dyke grade alterations. Approximately 900 cross sections were cut. The cross-sections were cut at an interval of 10 m to 15 m. Higher density cross sections were located near the areas of high interest as well as close to the bend areas in the 1D channel to define them more accurately. MIKE Hydro, which is a map-based graphical user interface for MIKE products, was used to extract the cross-section data. The river network line was digitized using ArcGIS and the corrected high resolution LiDAR DEM data (**Figure B.4** in **Appendix B**), the existing floodplain map sheets, and the Duffins Creek hydrology river network shape file. Examples of the ArcGIS based river network, the 1D river banklines and the cross section cut lines created for MIKE 11 are shown in **Figures B.5a, B.5b** and **B.5c (Appendix B)**. The river network line and cross section cut marks as represented in the MIKE 11 model are shown in **Figure 2.10**.

2.3.2 Structure Modelling

The structure information obtained from the TRCA survey and existing drawings were confirmed through field measurements completed by Valdor. The existing HEC-RAS model was used to obtain structure information for the channel downstream of the study area only. All the structures except structures at Highway 401, GO Transit and CN Railway were manually inserted into the MIKE 11 model. There are a total of 12 culvert/bridge structures (S1 through S12) (see **Table 2.2**) along the main Duffins Creek and the west tributary reach within the model domain extents. The structure details are provided in **Table A.1** in **Appendix A.** The structure locations are shown in **Figure 2.1** and the inventory sheets (S1 through S12) are provided in **Appendix A**.

Table 2.2 Structures in MIKE the Flood Model

Structure Identifier, ID	River/Branch Name	Location	M11 Cross-Section		Modelled As
			ID	Chainage	
S1	Duffins Creek - West Tributary	Valley Farm Road	690	687.0354	Culvert and Weir in M11
S2	Duffins Creek - West Tributary	Brock Road	802	1756.4266	Culvert and Weir in M11
S3	Duffins Creek - West Tributary	D/S of Brock Road	111	1262.3731	Bridge in M11
S4	Duffins Creek - West Tributary	U/S of Kingston Rd. W.	168A	1803.3758	Bridge in M11
S5	Duffins Creek - West Tributary	Kingston Rd. W.	175	1852.7788	Culvert and Weir in M11
S6	Duffins Creek - West Tributary	U/S of Church St.	248	2585.5288	Weir in M11
S7	Duffins Creek - West Tributary	Church St. S.	284	2926.9990	Culvert and Weir in M11
S8	Duffins Creek - West Tributary	HWY 401	-	-	Piers in M21 2D
S9	Duffins Creek - West Tributary	GO Transit Bridge	-	-	Piers in M21 2D
S10	Duffins Creek - West Tributary	CN Railway	314	3176.8293	Piers in M21 2D
S11	Duffins Creek - West Tributary	D/S of CN Rail	315	3182.2404	Piers in M21 2D
S12	Duffins Creek - West Tributary	Bayly St. W.	326	3253.0818	Culvert and Weir in M11

Hydraulic structures S1, S2, S5, S7, and S12 were incorporated into the model using the typical culvert structure approach in MIKE 11. The road decks were incorporated using the typical weir modelling approach. Hydraulic structures S3, S4 and S11 were incorporated into the model using the typical bridge structure approach in MIKE 11. Energy equations were used to compute flow through typical structures including computations for submergence and overflow. The bridge/culvert opening curves were derived using a spreadsheet based on the survey data and the LiDAR data. Examples of spreadsheet based opening curves are provided in **Figures B.6a** and **B.6b** (see **Appendix B**). The skewed opening curves were projected on a cross-section cutline perpendicular to the river network line to adjust for the skewed angle. Structure S6 is included as a weir in the MIKE 11 model. The cross-sections immediately upstream and downstream of the weir structure were generated using survey data and incorporated in the MIKE 11 channel section. Structures at Highway 401, GO Transit and CN Railway were inserted into the MIKE 21 bathymetry as piers in the 2D overland area. The pier shape file was added into the mesh polygon layers. Pier polygon areas were defined and excluded from the mesh generation. Some of the pier polygons were small and would create very small angles and tiny triangular mesh units, which would cause model instability and require a very small time step interval. To avoid this instability, the 95 piers at Hwy. 401 were aggregated into 20 approximately equivalent rectangular shaped piers (see **Figure B.7** in **Appendix B**). A comparative analysis was completed that showed the overall length of the aggregated piers along the flow direction was increased by 7 percent and the width perpendicular to flow direction was increased by about 18 percent. It was concluded that this increase in width and length of the pier shape will have a very insignificant impact on the flow and water level computations over the very wide wet area at the Hwy. 401 crossing.

2.3.3 Roughness Parameters

The TRCA standard Manning's roughness coefficients were used for the channel sections and the structures as follows:

- Natural channel (low flow): 0.035
- Overbank area: 0.08
- Concrete bridge and culvert: 0.013

Most of the culverts and bridges have varying internal surface properties corresponding to the presence of multiple surface types such as natural channel, concrete and wood in a single structure. As a result, a single roughness value was not applicable to these culverts and a weighted average roughness was calculated (see **Table B.2** in **Appendix B**).

2.3.4 Boundary Conditions and Flow Input Hydrographs

Two main boundaries are specified for the MIKE 11 river model. The upstream boundary is typically a constant or time series discharge, while the downstream boundary is usually a constant or time series water level or a rating curve representing the Q-H relationship. The point source or distributed source incremental inflow boundaries for all intermediate locations are defined, usually, in the MIKE 11 channel network within the 2D model domain. The MIKE 11 downstream boundary at Chainage 7151.7790 m was assigned with a Q-H relationship curve. The TRCA derived the Q-H relationship as a boundary at HEC-RAS Chainage 28.12 corresponding to the MIKE 11 channel location (i.e. Node N8). The inflow input boundaries including the Q-H boundary locations are shown in **Figure C.1** in **Appendix C**. The inflow and downstream boundaries used in the model simulation scenarios are provided in **Table 2.3.**

The inflow hydrographs for all the return period events (2-yr through 100-yr) including the 350-yr, 500-yr and the Hurricane Hazel were used as the MIKE 11 inflow boundaries at six different locations in the 1D channel and at one location in the 2D overland area. The upstream boundary location in the Duffins Creek west tributary is the first upstream flow node N1, which is an open boundary location for inflow from the upstream catchment area. The upstream boundary location in the Duffins Creek main branch is the upstream flow node N3, which is also an open boundary location for inflow from the upstream catchment area. The flow node locations (*i.e.* N2, N4, N5 and N6) corresponding to the four MIKE 11 inflow boundaries have incremental inflows. The incremental inflow at any boundary location is distributed (as a distributed source) between the MIKE 11 chainage of the two flow node locations (such as between this and the upstream node). The distributed source chainages are shown in **Table 2.3**. The inflow hydrograph for the catchment flow at hydrology node 27 was directly input into the MIKE 21 bathymetry (at flow node 7) using the Source and Sink method.

Table 2.3: MIKE 11/21 Model Boundaries

In MIKE Flood		Boundary Type	Boundary Description	From		To		Regional Peak Flows (cms)
River/Branch name	Node			M11 XSec. ID/M21	M11 Chainage (m)	M11 XSec. ID	M11 Chainage (m)	
Duffins Creek - West Tributary	N1	Open	Inflow (M11 us)	629	0.00	-	-	312.014
Duffins Creek - West Tributary	N2	Distributed Source	Inflow (Along M11 Channel)	693	710.0428	872	2407.8728	20.385
Duffins Creek - Main River	N3	Open	Inflow (M11 us)	1	0.00	-	-	371.327
Duffins Creek - Main River	N4	Distributed Source	Inflow (Along M11 Channel)	70	859.3413	172	1828.7342	19.258
Duffins Creek - Main River	N5	Distributed Source	Inflow (Along M11 Channel)	177	1870.52	312	3168.1890	29.097
Duffins Creek - Main River	N6	Distributed Source	Inflow (Along M11 Channel)	317	3190.4404	627	7132.9598	64.522
M21 Bathymetry (CA 27)	N7	Open	Inflow (M21 Boundary)	Code 2	-	-	-	140.884
Duffins Creek - Main River	N8	Open	Q-H (M11 ds)	628	7151.7790			-

The TRCA provided the inflow hydrographs (see **Figures C.2** to **C.10** in **Appendix C**) for the 2-yr though 100-yr, 350-yr, 500-yr return period and the Regional storm events corresponding to the seven inflow nodes (*i.e.* N1, N2, N3, N4, N5, N6, and N7).

Table 2.4 Peak Flow at Different Hydrology Flow Nodes

Existing Conditions							
Node ID	**12.2**	**12.1**	**26.5**	**26.4**	**28.1**	**28**	**27**
2yr	22.200	1.817	24.729	2.278	5.731	9.480	12.534
5yr	36.374	3.122	39.342	3.866	7.888	12.814	19.359
10yr	44.841	4.336	49.801	5.181	9.383	15.105	25.404
25yr	57.485	5.594	64.874	6.646	11.363	18.077	33.387
50yr	67.325	6.595	76.819	7.771	13.516	20.904	40.002
100yr	77.575	7.599	89.424	8.910	15.109	23.233	46.147
Future Conditions							
Node ID	**12.2**	**12.1**	**26.5**	**26.4**	**28.1**	**28**	**27**
350yr	122.245	17.501	138.536	17.373	27.028	58.001	112.708
500yr	131.810	18.626	150.991	18.442	28.637	61.332	120.488
Regional	312.014	20.385	371.327	19.258	29.097	64.522	140.884

The inflow hydrographs for the 350-yr, 500-yr and the Regional storm events correspond to the future land use conditions, while the 2-yr through 100-yr storm flows correspond to the existing land use hydrological conditions. The peak flows at different hydrologic flow nodes are provided in **Table 2.4**. The peak flows and flow hydrographs at each of the flow nodes 12.1, 26.4, 28.1 and 28 are incremental flows which were calculated based on the corresponding individual sub-catchments. The MIKE Flood inflow boundary locations and the related hydrologic flow nodes and the corresponding type of flow (*i.e.* total flow or incremental flow) regarding the MIKE Flood input are provided in **Table 2.5.**

Table 2.5 Hydrology Flow Nodes and Corresponding Model Boundary Locations

Hydrology Flow Node ID	Total/Incremental Flow	MIKE11/MIKE21 Inflow Boundary Locations
12.2	Total flow	N1
12.1	Incremental flow	N2
26.5	Total flow	N3
26.4	Incremental flow	N4
28.1	Incremental flow	N5
28	Incremental flow	N6
27	Total flow	N7

2.3.5 Simulation Settings

The MIKE 111D Model setup contains descriptions of a number of parameters. The main items to include in the model setup are simulation period with start and end date and time, time step interval and output saving details including information on 2D mapping within MIKE 11 1D channel area.

While some of the parameter settings (such as simulation period) will be assumed by the MIKE 21 model settings and specific scenario simulation settings in Section 2.5.2, a general description of parameters related to the MIKE 11 model settings is provided as follows:

- A simulation period of 15 hours was used indicating a start and end date and time.
- The adaptive time step was used, however, the description parameter file option was selected for initial conditions.
- The global parameters such as roughness, initial discharge, etc. defined in the HD parameter file will be assumed by the specific parameters defined in the MIKE 11 cross section editor or in the simulation settings.
- In the HD parameter settings, 2mX2m 2D raster mapping (for 1D channel area) options were used to generate dynamic (h, p, q), water depth, water level files and maximum water depth, water surface and velocity output files.
- The MIKE 11 results file was saved for water level, discharge including additional output for flow widths, lateral inflows, flooded areas at H and Q points and at structures at five (5) minute intervals.

2.4 MIKE 21 2D Overland Flow Model

The 2D overland area was modelled using MIKE 21 FM HD, which is a fully dynamic modelling system for 2D free-surface flows. The MIKE 21 editors were used to construct and store various basic and hydrodynamic data layers. The following are the main elements of the MIKE 21 model setup:

- Mesh Design
- Bathymetry creation
- Roughness parameters for 2D overland surface
- Boundary and initial conditions
- Model settings

2.4.1 Mesh Design

The MIKE 21 FM model uses a mesh-based bathymetry for hydrodynamic computations. The details and the desired accuracy of the model results depends on how the mesh has been designed. In addition, the mesh resolution has a significant impact on the accuracy of the results. A high resolution mesh is required to retain higher variability of the ground elevation surface. High resolution is also required to represent in detail topographic features (such as buildings, paved roads, walkways, retaining walls, flood walls, etc.). A high uniform mesh resolution for the entire model domain may be preferred. At the same time it is important to keep the number of mesh elements not too high to avoid very long computer processing time and very large file sizes. As such, the mesh was designed as follows:

- A high resolution mesh was used in areas of greatest concern or interest.
- Triangulation was completed as much as possible using smooth boundaries.
- The number of small area triangles was minimized.
- The number of small angle triangles was minimized (the use of equilateral triangles is the best choice for a perfect mesh).

A high resolution mesh will create small angles and small area triangulation which causes instability issues and requires shorter simulation time step intervals, resulting in very long run times and large file sizes. It is challenging to identify a compromise between these factors. As such, the entire area within the 2D model domain extents was divided into several mesh resolution zones (see **Figure 2.6**). In order to maintain a reasonable output file size and runtime for a wide range of model simulations, it was decided that the high resolution area would include the dyke areas as well as the existing floodplain and a reasonable buffer around the floodplain. The remaining outside areas adjacent to the high resolution polygons were included in the medium and low resolution zones. Mesh resolution varies from 4.0 m^2 triangulation to 50.0 m^2 triangulation. In general, the high resolution areas were assigned with 10 m^2, except the dyke area where 4.0 m^2 triangulation was used. The area immediately adjacent the high resolution area was assigned with 25 m^2 triangulation while the downstream area beyond the study area boundary was assigned with 50 m^2 triangulation resolution. The building polygons were adjusted by the TRCA to avoid small angles and small area in triangle generation during the mesh construction process, and the process of adjusting building polygons is done in ArcGIS using Building Simplify (removing points that are too close within a bulding outline but still maintain general outline of a building) and Polygon Agregation functions (merging buildings with gaps less than or equal to 1m).

The Pickering-Ajax 2D model mesh was created using the MIKE Zero Mesh Generator editor tool. In the mesh generator editor, GIS data layers corresponding to 2D model domain extent, building shapes and river polygon were imported. The building polygons and the river polygons were excluded from the mesh generation to avoid computational mesh triangulation from occurring within these polygons. Based on the above resolution zone map, a mesh was created (see **Figure 2.7**), refined, smoothened and finalized through an iterative process to eliminate small areas and small angle triangles as well as to avoid an excessively large number of nodes and elements. For the final mesh, the minimum angle used was 20 degrees while the total number of mesh elements and nodes was less than 700,000 and 400,000, respectively.

2.4.2 Bathymetry Creation

The bathymetry is, in general, a digital elevation surface representing the entire 2D modelled area in the MIKE 21 modelling system. All computations (such as velocities v_x, v_y, flow fluxes q_x, q_y, etc.) in the MIKE 21 overland flow model are based on the bathymetry. An accurate bathymetry is crucial to achieving accurate model computations. Despite using a proper mesh design approach (described in Section 2.4.1 above), the accuracy of the bathymetry is highly reliant on the spatial resolution and accuracy of the topographic information. In addition, the extent of the bathymetry may have significant influences on the study area model results.

The extent of the bathymetry, which is the same as the 2D model extent as shown in **Figure 2.1,** was defined with consideration of the following issues:

- Study area extent – the 2D model bathymetry was extended beyond the study area (see **Figure 2.1**). An adequate "buffer" reach upstream and downstream of the study area was maintained to avoid any undesirable boundary influences on the model results within the study area.
- The extent of the available LiDAR data was adequate and was utilized as much as required in building the model bathymetry.
- The availability of important land use data layers such as buildings, roads and paved parking areas, structure information and survey data (*e.g.* dyke and other flood barriers).

High resolution LiDAR elevation data was used to prepare a digital elevation model. The survey data for the low flow channel, dykes and the structures were integrated to correct the DEM surface using the most accurate ArcGIS Digital Terrain Modelling approach (as described in Section 2.1.4). The corrected DEM had a spatial resolution of 0.50mX0.50m, which was then resampled into a 1.0mX1.0m resolution scatter data file. Using the MIKE Zero Mesh Generator editor tool, the 2D model bathymetry (see **Figure 2.8**) was created using the mesh generated in Section 2.4.1 above. The 'Natural Neighbour' interpolation method was used to complete interpolations based on the 1.0mX1.0m resampled scatter data sets.

2.4.3 Roughness Parameters for 2D Overland Surface

The MIKE 21 overland flow solver uses roughness parameters for each grid cell when completing computations. The land use map (see **Figure 2.2**) prepared using the TRCA's available land use/land cover information was converted into a MIKE 21 roughness map. In MIKE 21, the roughness was defined in terms of the MIKE system's Manning's resistance number (M), which is effectively the inverse (*i.e.* 1/n) of the Manning's roughness coefficient value (see **Figure 2.9**). The Manning's resistance number (M-value) map was prepared based on the TRCA's roughness land use table (**Table B.1 in Appendix B**). The roughness values and corresponding Resistance numbers used in MIKE 21 are as follows:

- Overbank areas: 0.08 (M = 12.50)
- Roads and large parking areas: 0.025 (M = 40)
- Urban large pervious areas: 0.05 (M = 20)
- Natural areas: 0.08 (M = 12.50)

2.4.4 Boundary and Initial Conditions

Boundary conditions for the MIKE 21 model define how the flow and water levels will be controlled at the peripheral edges of the 2D model domain defined by the bathymetry limits. In MIKE Flood, the 2D boundary is typically a condition at the outer edges to specify how the edges of the model domain will behave during the model run. In a 1D and 2D coupled model, the upstream inflow boundary is typically defined in the MIKE 11 model, while a link in the upstream area between MIKE 11 and MIKE 21 needs to be specified. Similarly, another link between MIKE 11 and MIKE 21 at the downstream boundary is required to specify the location where the MIKE 11 channel is discharging its routed flow into the 2D model domain. In addition, the 2D initial surface needs to be provided as an initial surface from which the 2D overland flow solver begins computations. Typically, in MIKE 21, the boundaries are specified using the following approaches:

- One single or multiple boundaries, as appropriate, for all open edges of the MIKE 21 model domain to be defined
- The type of boundaries commonly used are specified discharges, water levels or velocities
- The format of the boundary input can be constant or time varying or space varying or a rating curve or a combination of these, as appropriate
- The land type boundary may be used to specify model domain edges, which are defined as closed

Based on the availability of the upstream and downstream hydrotechnical data (such as flow and flow nodes, existing floodplain map sheets and HEC-RAS models), the MIKE 21 2D model domain extents compared to current study area extents, we explored various possibilities regarding the upstream and downstream boundary conditions of the MIKE Flood model. The MIKE 21 upstream boundaries associated with the Duffins Creek main branch to the north and the Duffins Creek tributary to the west were assumed to be closed. At these two upstream locations, inflow boundaries were defined in the MIKE 11 channel as described above in Section 2.3.4. The MIKE 21 open boundary was introduced for the inflow input locations immediately south of Highway 401. This inflow is generated from the catchment at hydrologic flow node 27. In MIKE 21, this inflow input boundary location is designated by inflow input node N7 (see inflow input and boundary locations in **Figure C.1**), where the total flow corresponding to hydrology flow node 27 were distributed directly on the MIKE 21 bathymetry.

The downstream MIKE 21 boundary was assumed to be closed. The downstream limit of the MIKE 21 bathymetry is located over 2.50 km (measured along the channel centre line) from the study area boundary. The 1D-2D coupled model extends up to the downstream end of the 2D model domain. Wider cross-sections were created using MIKE Hydro for the downstream segment of the 1D channel. All the cross-sections were extended beyond the existing floodplain so that various storm event flows were contained within the 1D channel. Therefore, it was concluded that a boundary defined at the downstream end of the MIKE 11 channel would be appropriate. A brief description of this MIKE 11 downstream boundary was provided in Section 2.3.4 above. In order to begin computations, the MIKE 21 2D overland flow solver requires an initial water surface condition, which was set at the arbitrary water surface elevation of 74.0 m, a value close to the low flow water level in the downstream area.

2.4.5 Model Settings

The MIKE 21 FM Flow Model setup contains descriptions of a number of parameters. The key parameters are simulation period, start and end time, time step interval, flooding and drying depths, output saving duration and saving interval details.

While some of the parameters specific to various scenario simulations are provided in Section 2.5.2, a general description of the parameters related to the MIKE 21 model settings is provided as follows:

- A 15 hour simulation period was used for the steady peak inflow hydrograph simulation. The simulation period was entered using an arbitrary start and end date and time with a specified total number of time steps and time step interval. In this case, the total number of time steps was 270,000 with a time step interval of 0.20 seconds.
- The drying, flooding and wetting depths used were 0.005 m, 0.01 m and 0.02 m, respectively.
- The dynamic output range started from time step 0 to time step 270,000 with a saving time interval of 1,500.
- The saving output variables were surface elevation, still water depth, total water depth, U velocity (x-direction), V velocity (y-direction), flow flux (qx, qy), current speed and current direction.
- The dynamic output file type used was "2D (horizontal)" while the output format was selected as "Area Series" with only wet areas that ensures the saving of specified information at every computational point.

2.5 MIKE Flood – Model Simulation and Output

2.5.1 Coupling the 1D and 2D Models

The final steps for the Pickering-Ajax 2D model setup was the integration of the 1D MIKE 11 channel model with the 2D overland area MIKE 21 model using the MIKE Flood model interface. Lateral links were used to connect the Duffins branches 1D MIKE 11 model with the corresponding mesh elements of the 2D MIKE 21 model as shown in **Figure 2.11**. This integration in MIKE Flood allows a seamless flow exchange between the 1D river and the 2D overland areas thereby enabling the space and time-dependent dynamic simulation of flows as occurs physically in real-world hydraulic systems. This integration is facilitated by coupling together the 1D MIKE 11 model and the 2D MIKE 21 model in two ways as follows:

- A lateral link is set up that enables the coupling along the left bank and right bank of the 1D channel with the 2D overland areas. The model allows for a dynamic exchange internally in both directions between the 1D channel and 2D floodplain flow components. Flow through the link is dependent on a weir-structure equation and the water levels in MIKE 11 and MIKE 21. Flow through the link is distributed among several MIKE 11 water level points and several MIKE 21 grid cells.
- A standard link is set up that enables the coupling at the upstream or downstream end of the 1D channel with the 2D overland area

Figure 2.11 also shows the bathymetry of the Pickering-Ajax 1D and 2D coupled model, where the 1D river and the building areas were represented as blocked white cells and the link line between 1D and 2D models is shown as a series of red cells.

2.5.2 Simulation Parameters

The simulation parameters of the 1D and 2D coupled model were specified in each of the individual models. The total duration of the MIKE Flood model simulation was 15 hours for the steady peak inflow and 30 hours for the unsteady peak inflow hydrograph simulations. The simulation durations specified in the MIKE 21 model supersede the ones specified in the MIKE 11 setup. Regarding the 15 hour steady peak hydrograph simulations, the first two (2) hours were used to create a mild rising limb in the hydrograph and the remaining 13 hours was used to run the simulation with the steady peak inflow. A rising limb with a mild slope was used to avoid the generation of any undesirable momentum that could result from a steeper rising limb in the hydrograph. It was determined that 15 hours of simulation time was adequate to allow the model to convey the peak flows throughout the 1D and 2D model and accounting for the effect of storage elements within the floodplain area, such as depression storage, and sinks. The intent of the study is to map maximum water levels – the additional run time is not necessary as the water level does not increase beyond that point. Time series output (see **Figure B.8** in **Appendix B**) corresponding to flooding depth at different locations south of Hwy. 401 and around Notion Road and Church street were generated based on the 15 hour steady peak simulation results. Video animation was created and analysed. It was confirmed that all the areas north of Hwy 401 achieved a steady state condition at around 13 hours of simulation. In general, the total number of time steps used for a steady peak flow simulation was 270,000 as specified with the MIKE 21 model setup. A time step interval of 0.20 second was used for every simulation, which ensured adequate capture of the peak flow response by each of the smallest 2D meshes and the 1D channel computational points.

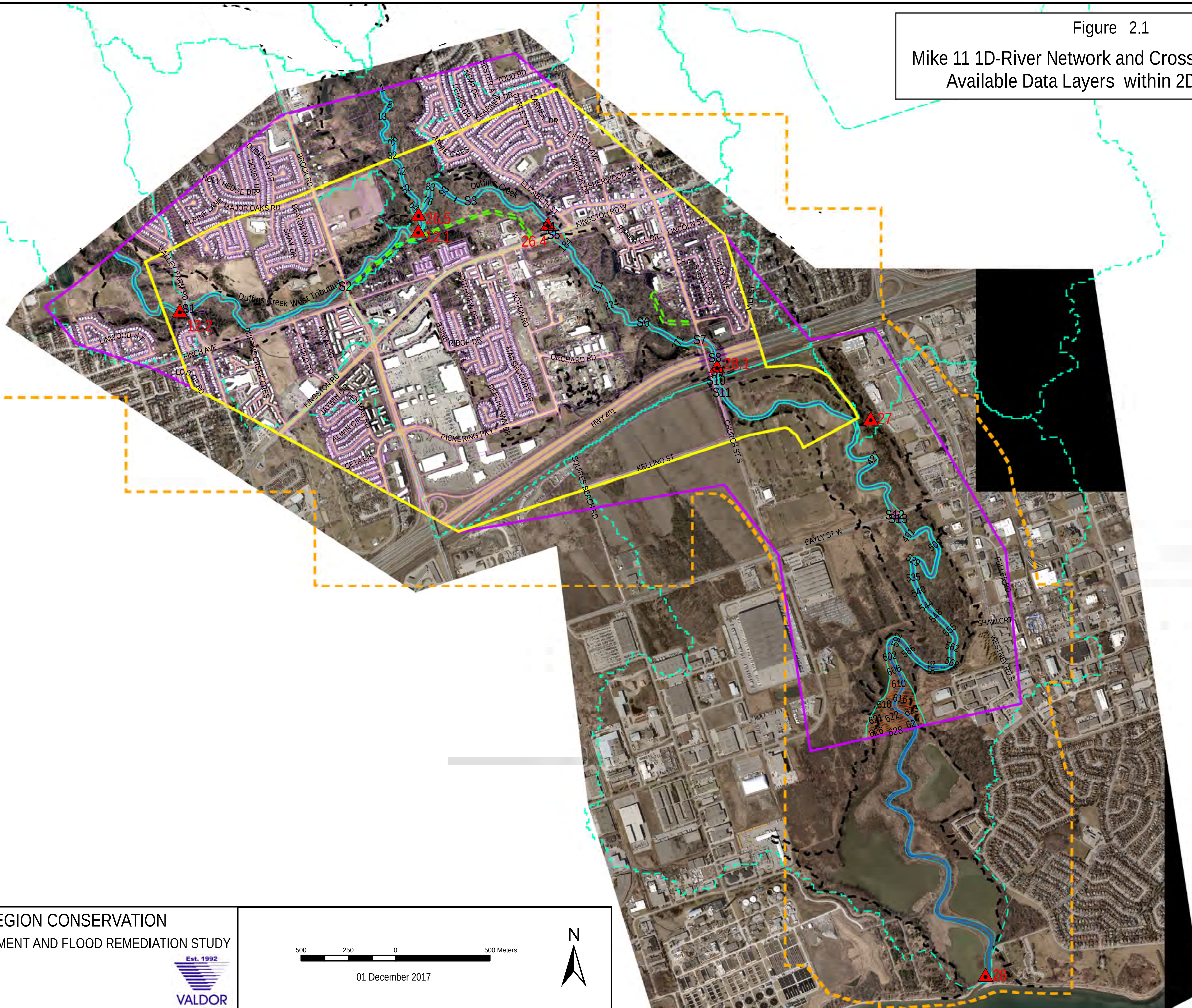
The total duration of the unsteady hydrograph simulation was 30 hours. The actual duration of the full unsteady hydrograph included in the MIKE 11 setup was longer than 30 hours. The unsteady simulation started at 3:00 hours from the beginning of the hydrograph and ended at 33:00 hours as specified in the MIKE 21 model setup. Running the full hydrograph requires over one hundred hours of computer time. It was decided that a shorter period would be selected that includes the peak as well as a portion from the rising and falling limbs of the hydrograph so that the model can convey the peak flows throughout all the 1D and 2D model area. It was observed that the first three (3) hours are not contributing much flow into the system and the hydrograph peaks occur in between 10:00 to 16:00 hours. Therefore, a simulation starting from 3:00 hours and ending at 33:00 hours was adequate to generate the maximum flooding impacts over the entire study area.

2.5.3 Model Output

The key MIKE Flood model outputs are dynamic flood depth (H) and flow flux in the x-direction (q_x) and the y-direction (q_y). Post-processing was completed within the MIKE system to create resultant flood velocity (V_r) and 2D WSEL's for each of the model run scenarios. The outputs were converted into ArcGIS format. ArcGIS was used to process the output layers to prepare the Regional flood depth maps which show the extent and depth of flooding. Velocity maps, depth-velocity product maps and flow direction maps were created using ArcGIS. Flood animations were created using V_x, V_y velocity vector components with the dynamic flood depth in the background that shows the flow path and flow direction. The flood animations provide a better understanding of how the flood waters propagate over the study area in space and time with any changes in the basic and hydro-dynamic parameters. Section 3.0 describes all the return period simulation results corresponding to various scenarios (see **Table 3.1**).

Figure 2.1

Mike 11 1D-River Network and Cross-Section Location, Available Data Layers within 2D Model Extent



LEGEND

- Study Area
- Duffins Creek
- 2D Model Domain
- TRCA LiDAR Data Extent
- Dyke Locations
- Roads
- Structure S1, S2, S3
- Buildings
- Parcel
- Catchments
- Hydrology Flow Nodes
- Existing FloodLine (HEC-RAS)
- River Bank
- Water Edge
- Mike Hydro Cross-Section Line

TORONTO AND REGION CONSERVATION

PICKERING-AJAX DYKE ASSESSMENT AND FLOOD REMEDIATION STUDY

Toronto and Region Conservation for The Living City

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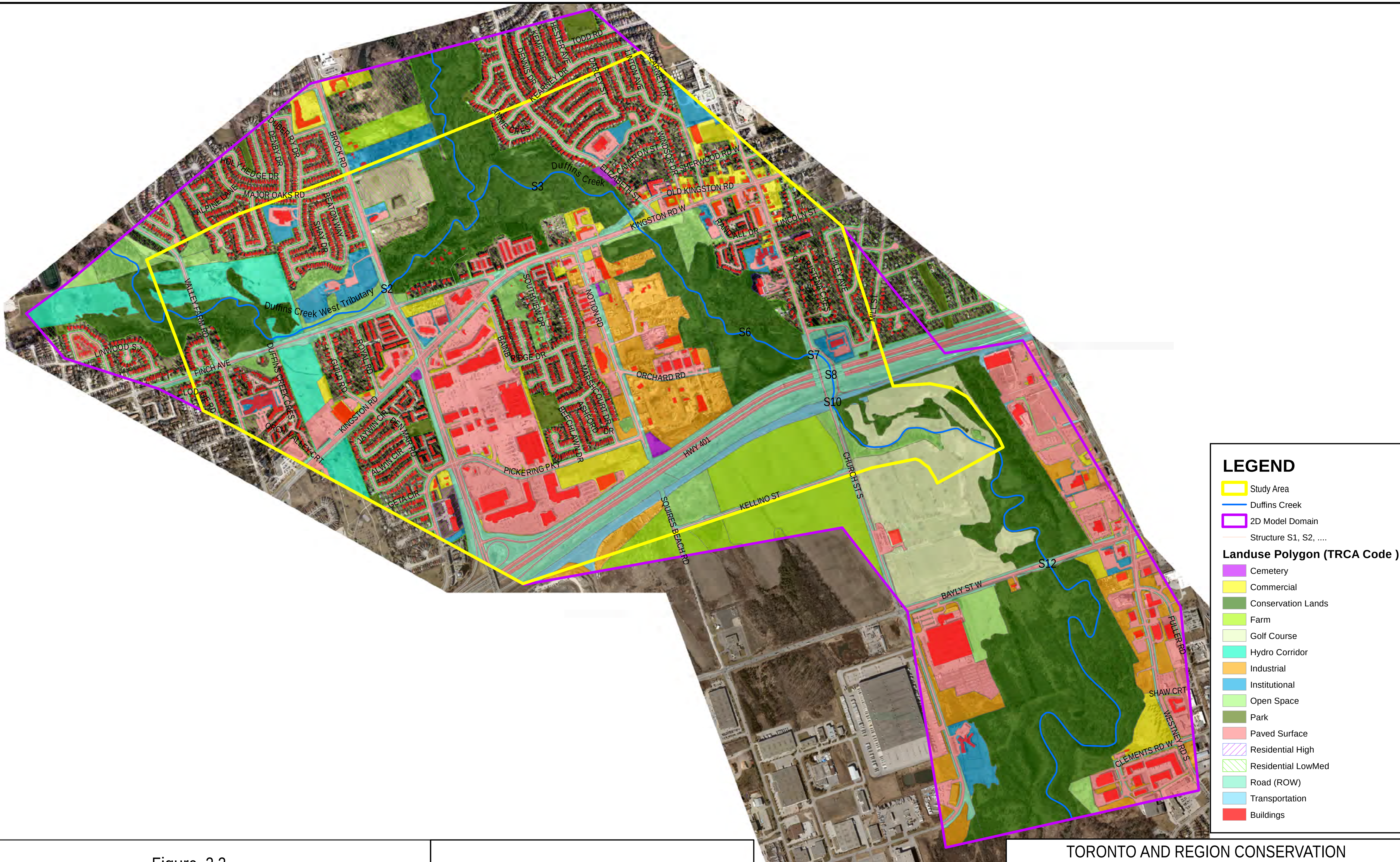

Figure 2.2

TRCA LANDUSE POLYGON USED FOR 2D ROUGHNESS MAP

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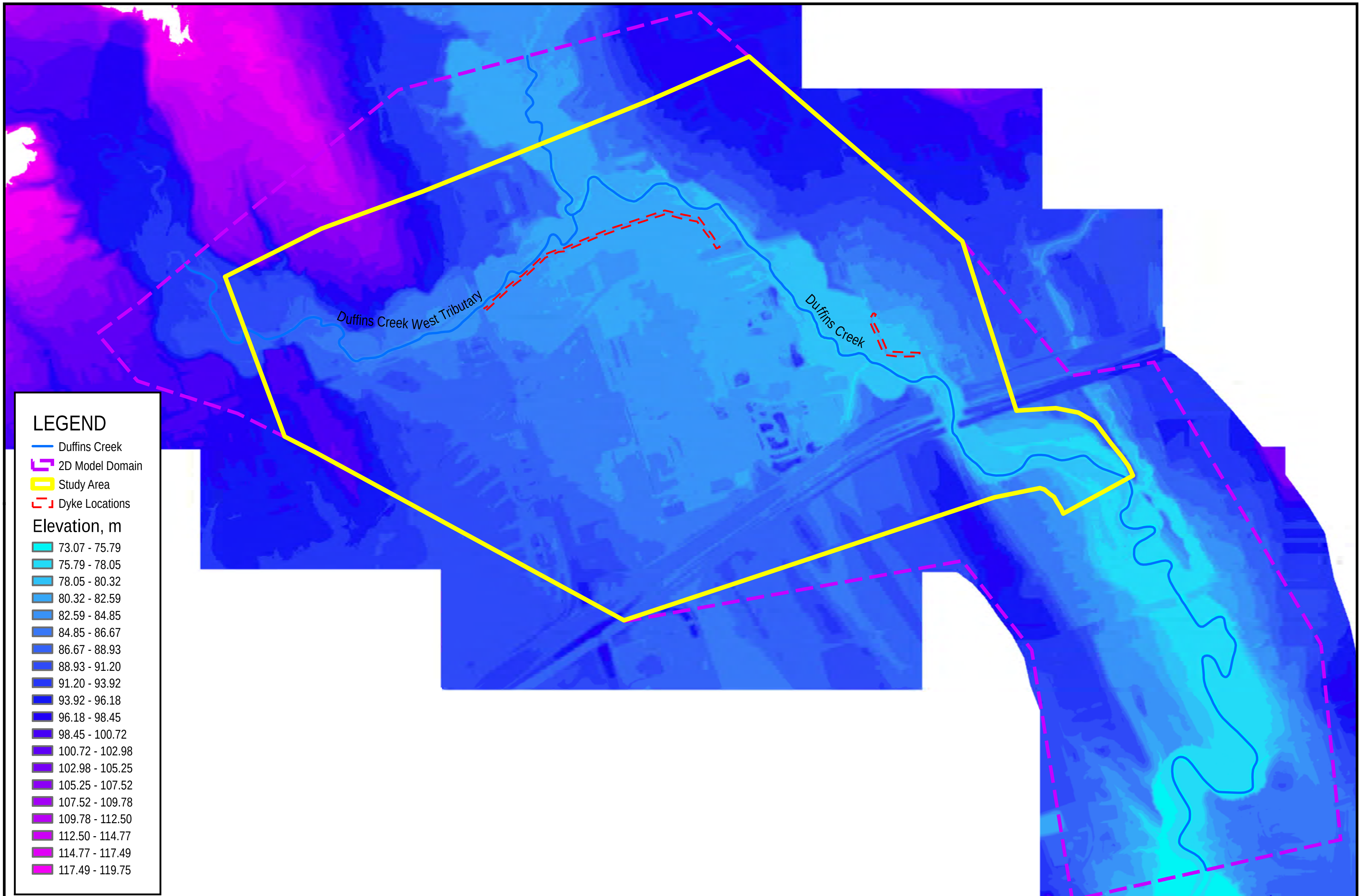

Figure 2.3

DIGITAL ELEVATION MODEL (LiDAR)

23 November 2017

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PICKERING-AJAX DYKE ASSESSMENT AND FLOOD REMEDIATION STUDY

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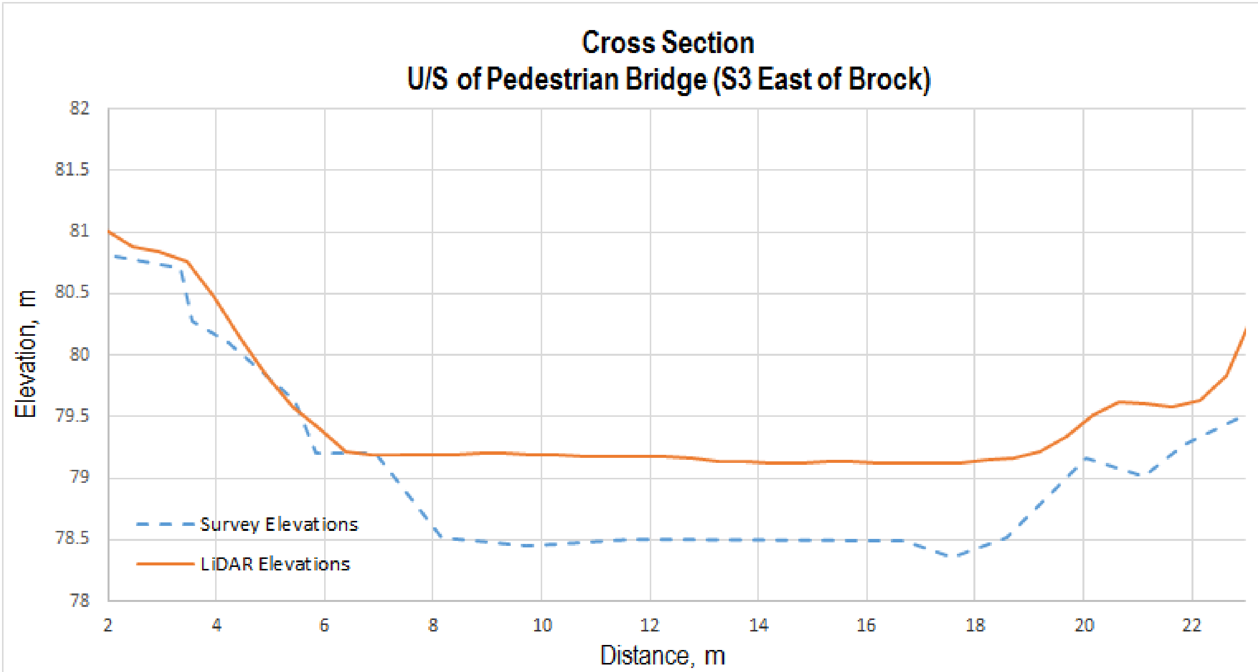

Figure 2.4a LiDAR DEM vs Survey

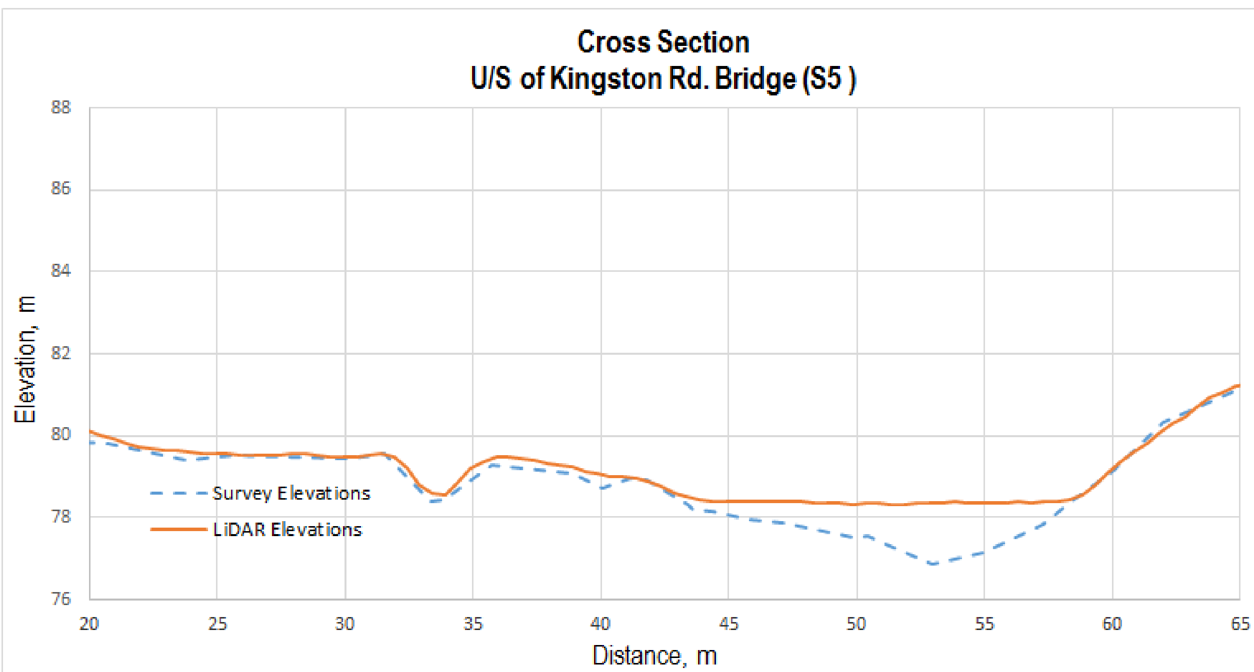

Figure 2.4b LiDAR DEM vs Survey

Figure 2.4 LiDAR DEM vs Survey	N 1 December 2017	TORONTO AND REGION CONSERVATION AJAX / PICKERING DYKE STUDY

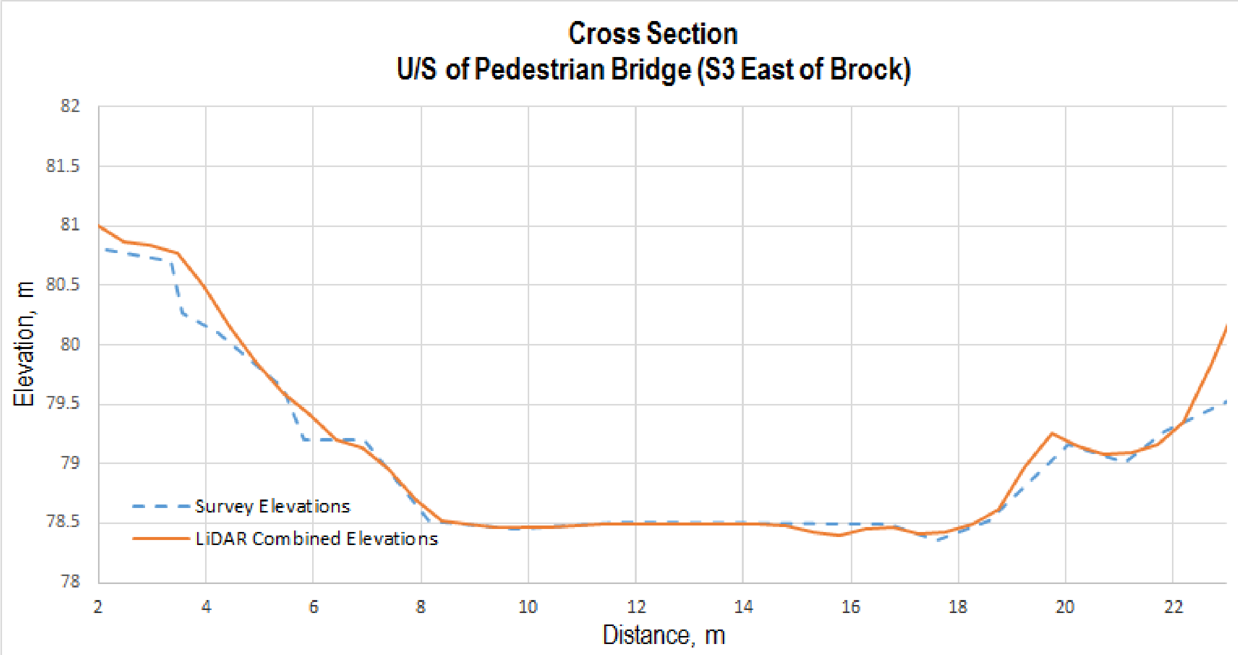

Figure 2.5a Corrected LiDAR DEM vs Survey

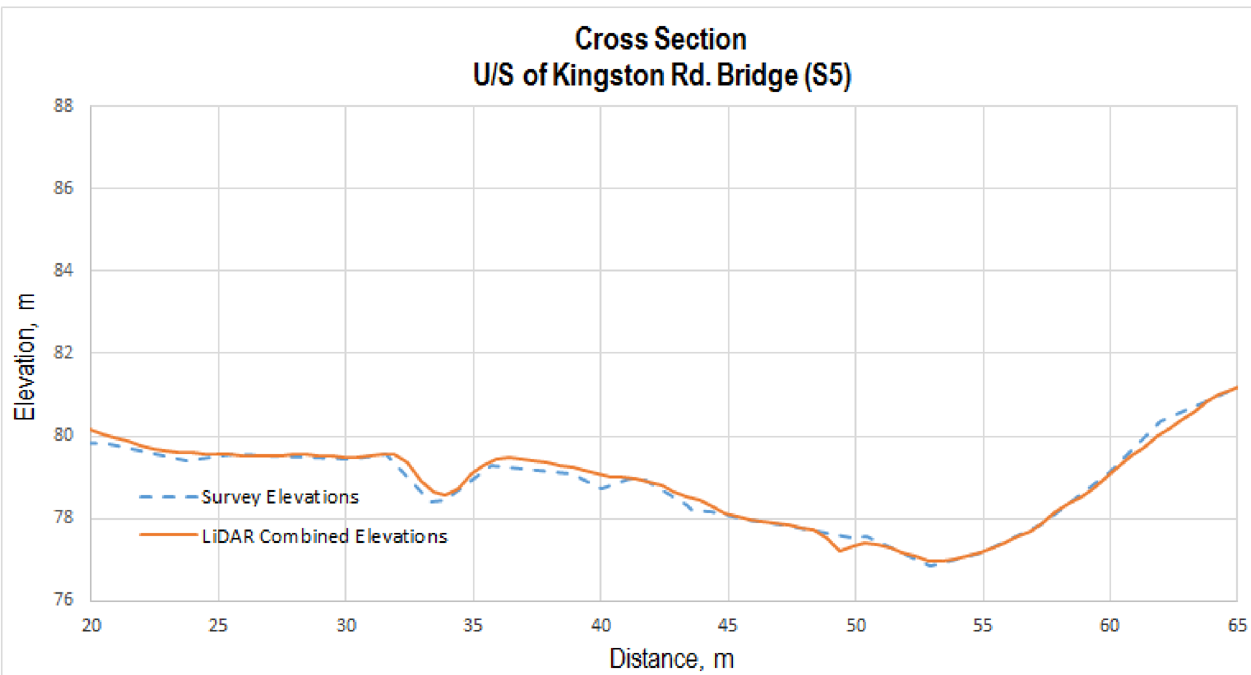

Figure 2.5b Corrected LiDAR DEM vs Survey

Figure 2.5 Corrected LiDAR DEM vs Survey

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1 December 2017

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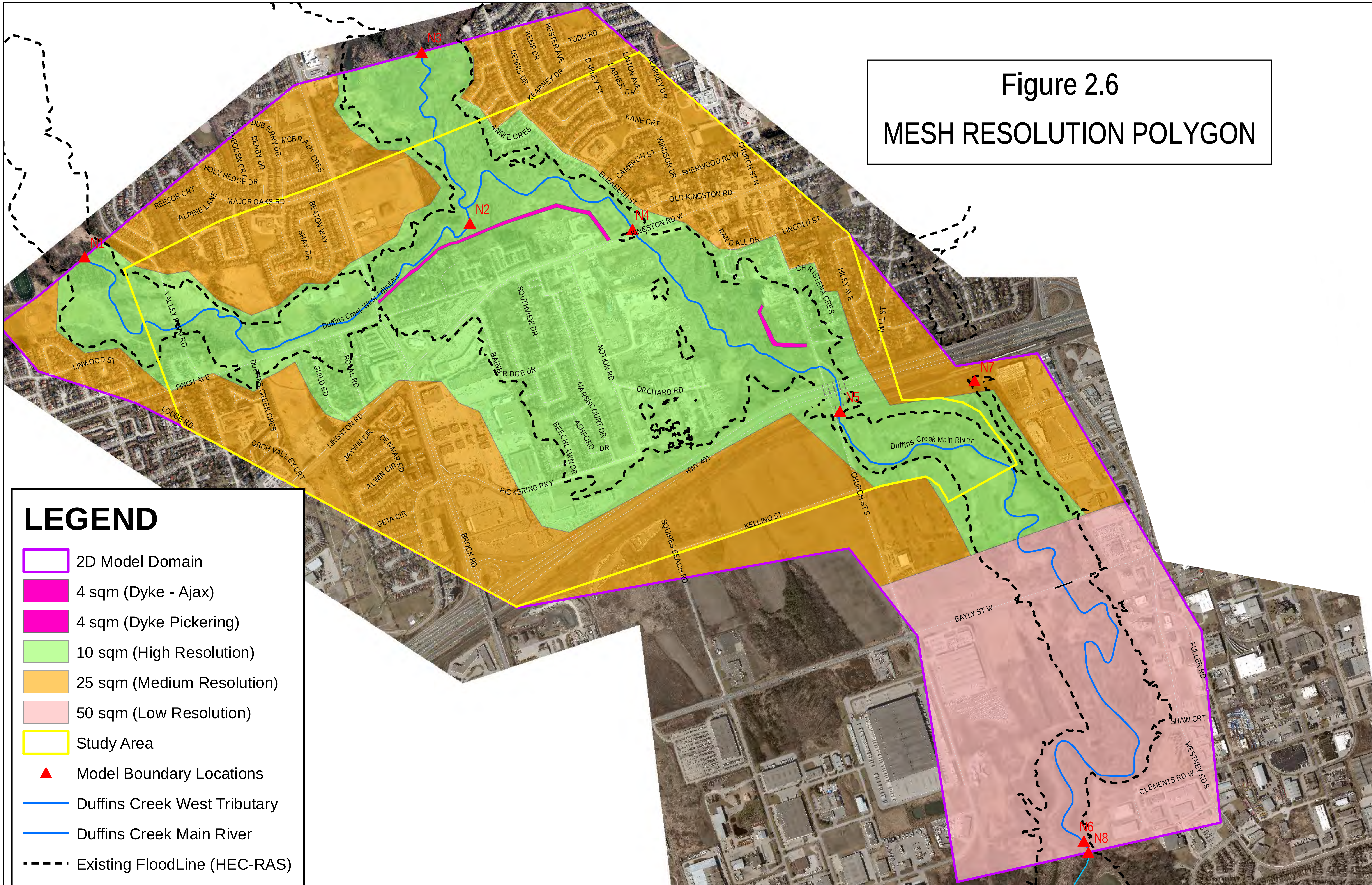

Figure 2.6

MESH RESOLUTION POLYGON

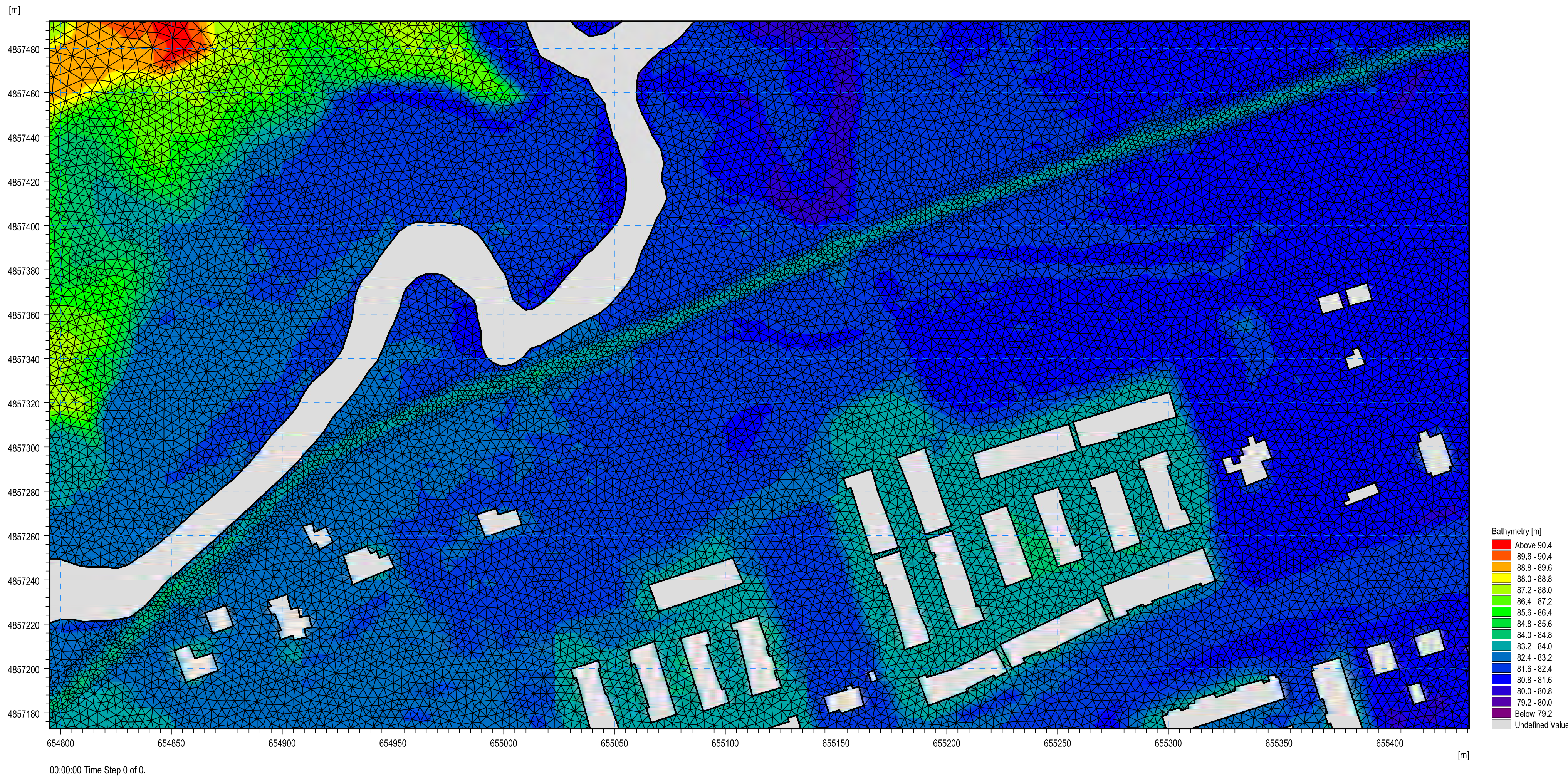

Figure 2.7
Flexible Mesh Used to Create Bathymetry

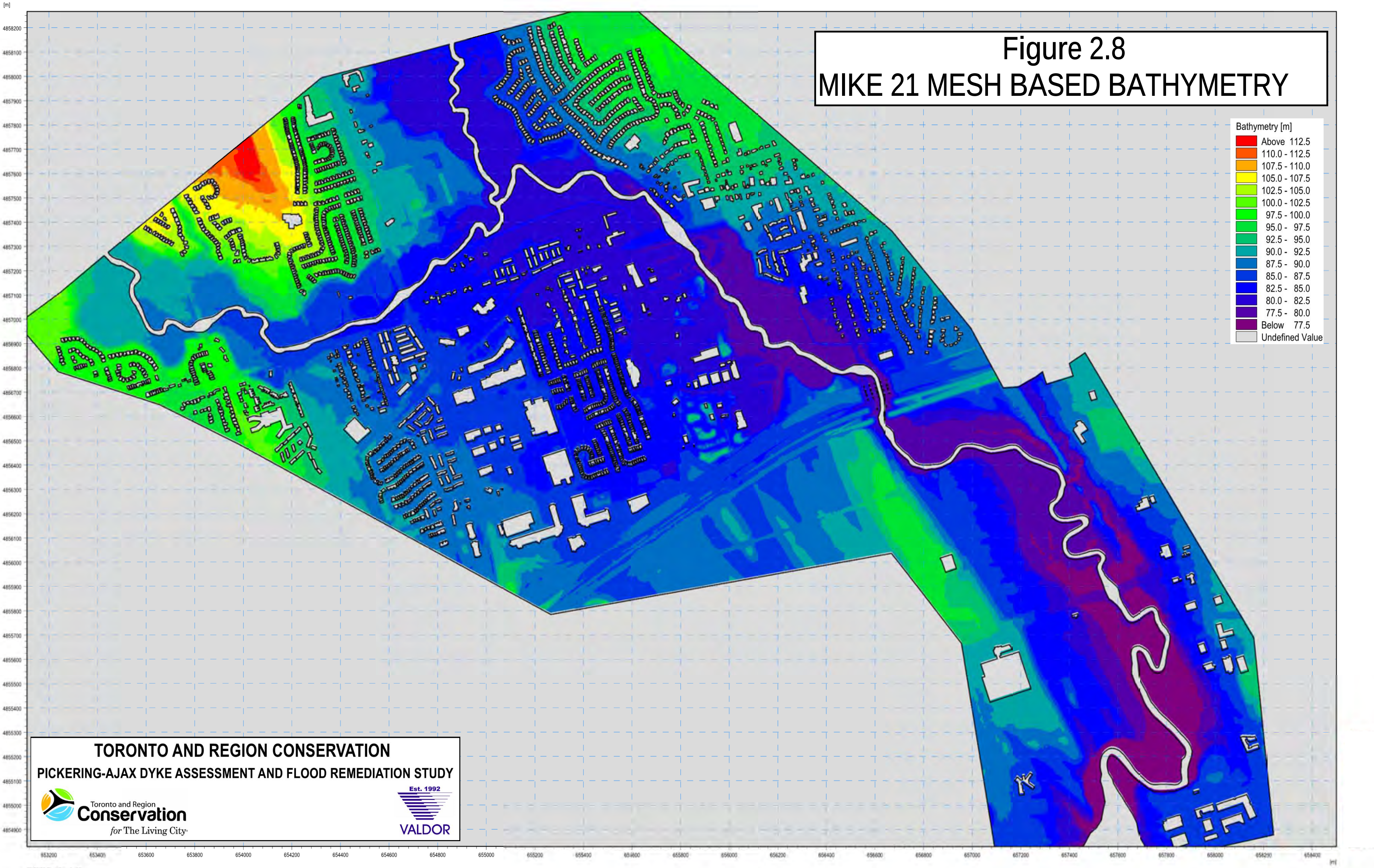

Figure 2.8
MIKE 21 MESH BASED BATHYMETRY

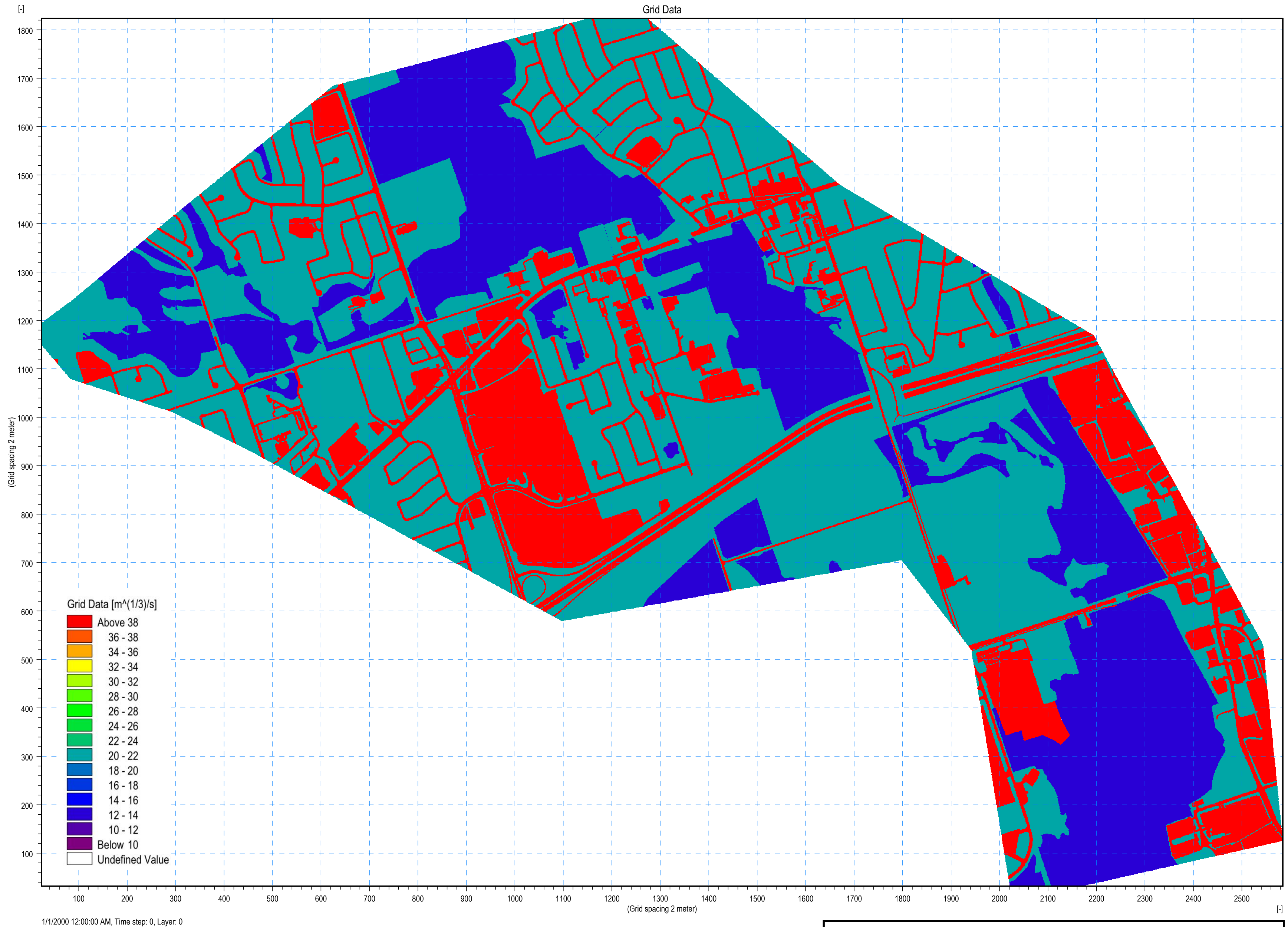

Figure 2.9
Mike Flood Resistance Map (M-value)

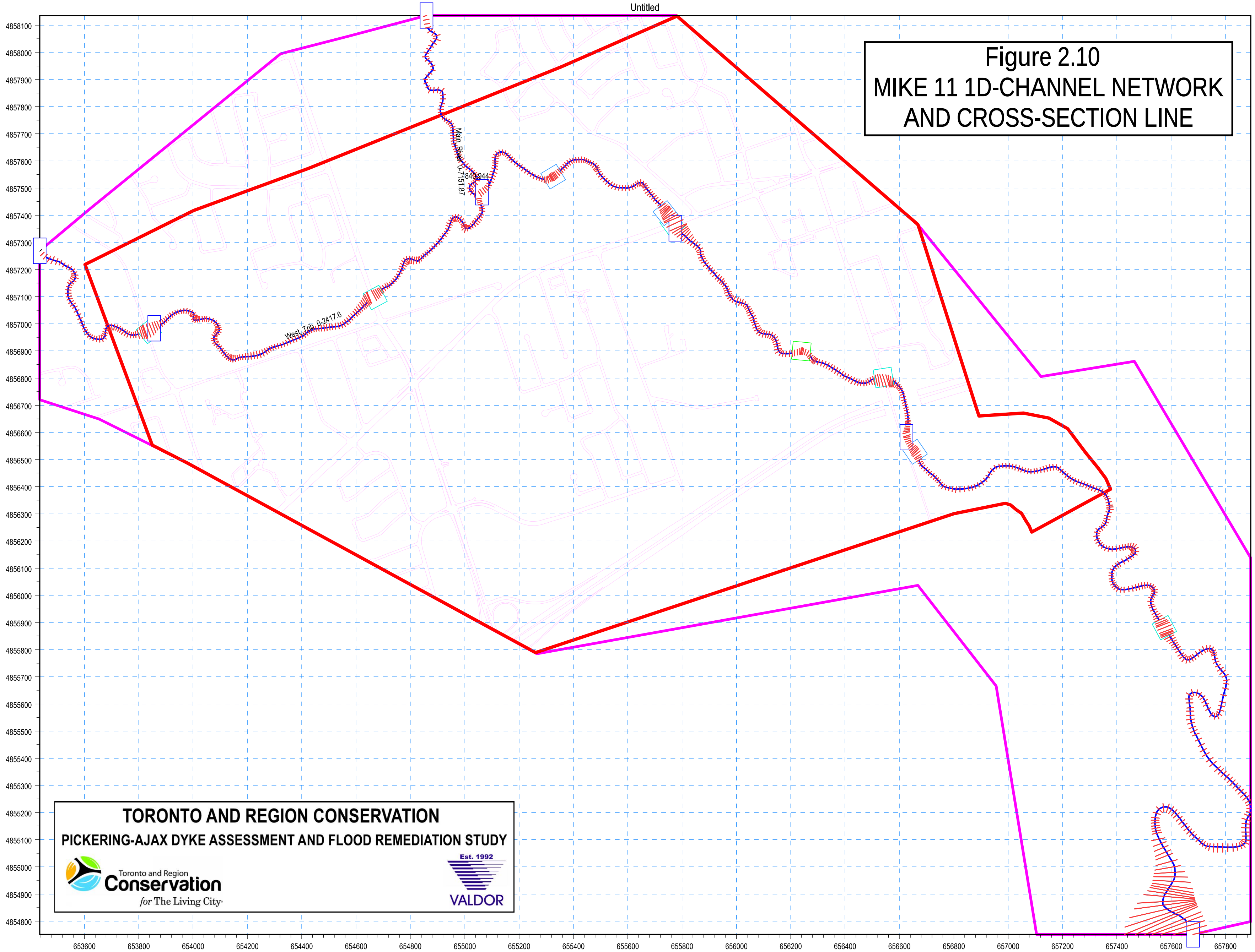

Figure 2.10
MIKE 11 1D-CHANNEL NETWORK AND CROSS-SECTION LINE

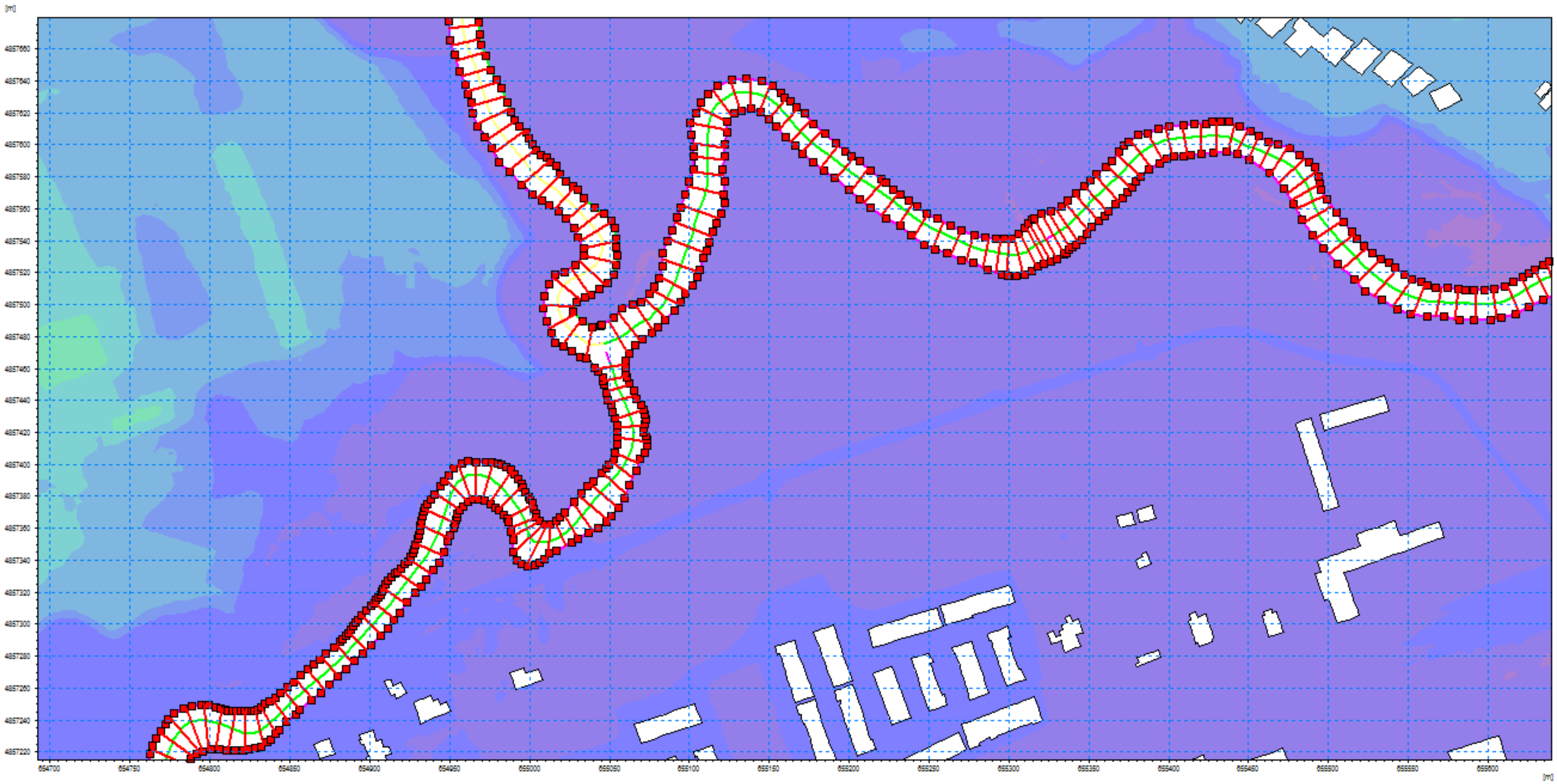

Figure 2.11
Mike Flood 1D-2D Linkage and Blocked White Cells

3.0 FLOOD ASSESSMENT & RESULTS (USING MIKE FLOOD MODEL)

3.1 Model Run Scenarios

Eleven (11) scenarios were investigated for the Pickering (Village East) and Notion Road/Pickering Village SPA hydraulic analysis based on actual storms and return period storm events combined with dyke conditions with and without flood protection (*i.e.* dykes) in place. A list of model run scenarios including key information for each scenario is provided in **Table 3.1**.

Table 3.1: List of Model Runs and Key Features for each Scenario

Scenario No. in Model Setup	Dyke Condition	Storm Events/ Inflow Hydrographs	Hydrograph Type	Flow Land Use Condition	Simulation Period
S01	Ex. Dykes in Place	Hurricane Hazel	Steady Peak	Future	15 hours
S02	Ex. Dykes in Place	Hurricane Hazel	Unsteady	Future	30 hours
S03	Ex. Dykes in Place	2-yr Inflow hydrograph	Steady Peak	Existing	15 hours
S04	Ex. Dykes in Place	5-yr Inflow hydrograph	Steady	Existing	15 hours
S05	Ex. Dykes in Place	10-yr Inflow hydrograph	Steady	Existing	15 hours
S06	Ex. Dykes in Place	25-yr Inflow hydrograph	Steady	Existing	15 hours
S07	Ex. Dykes in Place	50-yr Inflow hydrograph	Steady	Existing	15 hours
S08	Ex. Dykes in Place	100-yr Inflow hydrograph	Steady	Existing	15 hours
S09	Ex. Dykes in Place	350-yr Inflow hydrograph	Steady	Future	15 hours
S10	Dykes Removed	500-yr Inflow hydrograph	Steady	Future	15 hours
S11	Ex. Dykes in Place	500-yr Inflow hydrograph	Steady	Future	15 hours

The scenario model runs and corresponding results are described in the following sections.

3.2 Comparison of MIKE Flood Results for Steady and Unsteady Input Hydrographs – Regional Storm

The MIKE Flood model was run using both steady and unsteady flow input hydrographs. The results using the steady flow input hydrograph for the Regional storm is provided in **Figure 3.1** and the results using the unsteady flow input hydrograph is provided in **Figure 3.2**. A comparison of unsteady and steady flow input hydrograph results is provided in **Figure 3.3**. The current approved floodline based on HEC-RAS modeling completed in 2004 and based on peak flows from the *2002 Duffins Creek Hydrology Update* (Aquafor, 2002) is included on each figure for reference. The extent of flooding using the steady flow input hydrograph is generally similar but greater than the results using the unsteady flow input hydrograph. Based on discussions with the TRCA, it was determined that the steady flow input hydrographs would be applied to all model runs for this study.

3.2.1 Understanding the MIKE Flood Results – Points to Consider

MIKE 11 (or MIKE 21) flow simulation, using either steady peak or unsteady hydrographs, is based on the fully dynamic wave description (using St. Venant Equations: conservation of mass and conservation of momentum), where flow conditions change over time and space. All the governing forces (*i.e.* gravitational, frictional and static) causing water movement are changing from point to point over space and time based on the water surface slope, bed slope, and roughness characteristics. As a result, the MIKE Flood model simulated flow conditions (*i.e.* velocity, depth, flow and flow direction) change from one point to another and with time at every point. This flow type is referred to as unsteady non-uniform flow. The simulation is called unsteady (and non-uniform) flow simulation or fully dynamic flow simulation.

In contrast, steady uniform flow simulation is based on the conservation of mass only, where the flow condition does not change over time and space. Computations are completed step by step for each time step assuming WSEL and velocity are constant between two sections within each time step interval. Unlike unsteady non-uniform flow simulation, there is no consideration of change in momentum, a consideration that results in acceleration to water movement in unsteady simulation.

In MIKE Flood, we may have a constant inflow (such as the Hazel peak inflow) input to the MIKE 11 model at any upstream location in the channel while simulation results show flow conditions change from point to point and with time at every point as the governing forces are changing at any point over space and time. However, if the steady peak flow input is used for a very long simulation period, any location over a 2D surface or in the channel may achieve a steady state flow condition provided that no other new forces start acting at any location (for example such forces could be due to tidal flow or wall effect at any location). The reason for this steady state condition is that after a long steady input duration, the governing forces at that particular location remain unchanged.

3.3 Existing Flood Assessment Results – Regional Storm (Steady Flow Input)

The model run for the Regional flood simulation was carried out using the steady Regional inflow hydrographs with dykes in place. The inflow input locations are shown in **Figure C.1** in **Appendix C** and the corresponding MIKE 11 inflow boundary locations are provided in **Table 2.3.** All Regional storm inflow hydrographs are provided in **Figure C.2 (Appendix C).** The Regional flood depth and extent map is included in **Figure 3.1**. A full size flood depth map prepared in GIS is provided in **Map D.1** in **Appendix D**. Model results were post-processed by MIKE View and GIS to prepare velocity, flow direction and depth-velocity product (*i.e.* preliminary flood risk mapping) maps as shown in **Figure E.1, Figures E.4** through **E.7** and **E.17** (in **Appendix E**), respectively. The existing conditions model results show that both the Pickering and Ajax Dykes are entirely overtopped and most of the Pickering (Village East) and Notion Road/Pickering Village SPA's are flooded due to spilling over the dykes as well as spilling from areas upstream of the Pickering Dyke in the vicinity of the intersection of Brock Road and

Finch Avenue and areas upstream of the Ajax Dyke west of Church Street South. Within the Pickering (Village East) SPA, the road network including Kingston Road West and Notion Road are flooded with a general range in depth of 0.30 m to over 2.40 m. In general, the depth of flooding in the Pickering (Village East) SPA varies between 0.30 m to over 3.60 m. Within the Notion Road/Pickering Village SPA, Church Street South is flooded with a general range in depth of 0.30 m to over 3.60 m. The depth of flooding in the Notion Road/Pickering Village varies predominantly between 2.40 m to over 3.60 m.

3.4 Existing Flood Assessment Results – 500-yr Storm (Steady Flow Input)

The model run for the 500-yr storm flood simulation was carried out using the steady 500-yr inflow hydrographs with dykes in place. The inflow input locations are shown in **Figure C.1** in **Appendix C** and the corresponding MIKE 11 inflow boundary locations are provided in **Table 2.3.** All 500-yr storm inflow hydrographs are provided in **Figure C.3 (Appendix C).** The model results in terms of flood depth and extent is included in **Figure 3.4**. A full size 500-yr flood depth map prepared in GIS is provided in **Map D.2** in **Appendix D**. Model results were post-processed using MIKE View and GIS to prepare velocity, flow direction and depth-velocity product (*i.e.* preliminary flood risk mapping) maps as shown in **Figure E.2**, **Figure E.8** and **Figure E.18** (in **Appendix E**), respectively. The existing conditions model results show that both the Pickering and Ajax Dykes are almost entirely overtopped and sizeable areas within the Pickering (Village East) and Notion Road/Pickering Village SPA's are flooded due to spilling over the dykes. It is noted that there is no spill upstream of the Pickering Dyke in the vicinity of the intersection of Brock Road and Finch Avenue as occurs for the Regional storm flow. Similarly, there is no spill upstream of the Ajax Dyke west of Church Street South as occurs for the Regional storm flow. A large residential area generally located west of Notion Road, east of Bainbridge Drive, north of Pickering Parkway and south of Kingston Road West that is inundated for the Regional storm flow is flood free for the 500-yr storm flow. Similarly, a residential development located north of the intersection of Kingston Road West and Finch Avenue and a residential area located north of the Ajax Dyke west of Church Street South that is flooded for the Regional storm flow is flood free for the 500-yr storm flow. Within the Pickering (Village East) SPA, flooding of the road network is much less extensive for the 500-yr storm flow than for the Regional storm flow. Portions of Finch Avenue, Kingston Road West, Southview Drive, Notion Road and Orchard Road are flooded with a general range in depth of 0.30 m to over 1.20 m. In general, the depth of flooding in the Pickering (Village East) SPA varies between 0.30 m to over 1.80 m. Within the Notion Road/Pickering Village SPA, Church Street South is flooded with a general range in depth of 0.30 m to over 1.20 m. The depth of flooding in the Notion Road/Pickering Village varies predominantly between 1.20 m to over 2.40 m.

3.5 Existing Flood Assessment Results – 500-yr Storm with Dyke Removed (Steady Flow Input)

As part of the study, a flood simulation was completed for a hypothetical situation assuming complete failure of the existing flood dyke. The model run for this 500-yr storm flood simulation was carried out using the steady 500-yr inflow hydrographs with the dyke removed. The inflow input locations are shown in **Figure C.1** in **Appendix C** and the corresponding MIKE 11 inflow boundary locations are provided in **Table 2.3.** All 500-yr storm inflow hydrographs are provided in **Figure C.3 (Appendix C).** The model results in terms of flood depth and extent assuming full dyke breach is included in **Figure 3.5** and flow direction mapping is shown in **Figure E.9** (in **Appendix E**). It is interesting to note that the extent of flooding based on the existing conditions model results assuming full dyke breach is only marginally greater than that with the dyke in place. This is most likely due to the fact that under existing conditions with the dykes in place for the 500-yr storm flow, the spill is so extensive that the extent of flooding is not much different than with the dykes removed. The depth of flooding in some areas is greater under conditions with the dykes removed than when the dykes are left in place. The notable differences between the scenario assuming dyke removed compared to the scenario assuming dyke in place are summarized as follows:

1. The depth and extent of flooding north of Kingston Road West is greater for the scenario with dykes removed.
2. The depth of flooding west of Southview Drive is greater for the scenario with dykes removed.
3. The depth and extent of flooding along Notion Road south of Kingston Road West is greater for the scenario with dykes removed.
4. The depth of flooding west of Church Street South near the Ajax Dyke is greater for the scenario with dykes removed.

Based on the hypothetical scenario assuming full dyke breach, it is concluded that the existing flood dyke provides only a marginal increase in flood protection for the 500-yr storm flow than having no dykes at all.

3.6 Existing Flood Assessment Results – 350-yr Storm (Steady Flow Input)

The model run for the 350-yr storm flood simulation was carried out using the steady 350-yr inflow hydrographs with dykes in place. The inflow input locations are shown in **Figure C.1** in **Appendix C** and the corresponding MIKE 11 inflow boundary locations are provided in **Table 2.3.** All 350-yr storm inflow hydrographs are provided in **Figure C.4 (Appendix C).** The model results in terms of flood depth and extent is included in **Figure 3.6**. Model results were post-processed using MIKE View and GIS to prepare velocity, flow direction and depth-velocity product (*i.e.* preliminary flood risk mapping) maps as shown in **Figure E.3**, **Figure E.10** and **Figure E.19** (in **Appendix E**), respectively. The existing conditions model results for the 350-yr storm are similar to those for the 500-yr storm although flow depths and the extent of flooding is slightly reduced. Both the Pickering and Ajax Dykes are overtopped for the 350-yr storm flow. There are some small areas east of Southview Drive and east of Notion Road that are flood free for the 350-storm flow that are flooded for the 500-yr storm flow. Within the Pickering (Village East) SPA, portions of Finch Avenue, Kingston Road West, Southview Drive, Notion Road and Orchard Road are flooded with a general range in depth of 0.30 m to over 0.80 m. In general, the depth of flooding in the Pickering (Village East) SPA varies between 0.30 m to over 1.20 m. Within the Notion Road/Pickering Village SPA, Church Street South is flooded with a general range in depth of 0.30 m to over 0.80 m. The depth of flooding in the Notion Road/Pickering Village varies predominantly between 1.20 m to over 2.40 m.

3.7 Existing Flood Assessment Results – 2-yr to 100-yr Storms (Steady Flow Input)

Additional model runs were completed using the MIKE Flood program for the 2-yr to 100-yr design storms and a summary of the extent of flooding for the various design storms is summarized below.

3.7.1 100-yr Storm

The model run for the 100-yr storm flood simulation was carried out using the steady 100-yr inflow hydrographs with dykes in place. The inflow input locations are shown in **Figure C.1** in **Appendix C** and the corresponding MIKE 11 inflow boundary locations are provided in **Table 2.3.** All 100-yr storm inflow hydrographs are provided in **Figure C.5 (Appendix C).** Model results were post-processed using MIKE View and GIS to prepare flow direction and depth-velocity product (*i.e.* preliminary flood risk mapping) maps as shown in **Figure E.11**, **Figure E.20** (in **Appendix E**), respectively. The extent of flooding based on the existing conditions model results for the 100-yr storm is noticeably less than for the 350-yr design storm. The existing conditions model results for the 100-yr storm flow show that the Pickering Dyke is not overtopped, however, the Ajax Dyke is overtopped. Most areas within the Pickering (Village East) SPA are flood free while flooding within the Notion Road/Pickering Village SPA is generally limited to areas off private property and west of Church Street South. Within the Pickering (Village East) SPA, flooding of the road network is virtually nonexistent while flooding of the road network within the Notion Road/Pickering Village SPA is limited to a low area along Church Street

South in the vicinity of Highway 401 with a depth of flooding of approximately 0.10 m to 0.30 m. The depth of flooding in the Pickering (Village East) SPA is limited to areas adjacent the watercourse and varies predominantly between 0.60 m to over 1.20 m. The depth of flooding in the Notion Road/Pickering Village varies predominantly between 0.30 m to over 1.80 m.

3.7.2 2-yr to 50-yr Storms

The model runs for the 2-yr to 50-yr storm flood simulations were carried out using the steady 2-yr through 50-yr inflow hydrographs with dykes in place. The inflow input locations are shown in **Figure C.1** in **Appendix C** and the corresponding MIKE 11 inflow boundary locations are provided in **Table 2.3.** The inflow hydrographs are provided in **Figures C.6** through **C.10** **(Appendix C).** Model results were post-processed using MIKE View and GIS to prepare flow direction maps as shown in **Figures E.12** through **E.16** (in **Appendix E**). The extent of flooding based on the existing conditions model results for the 2-yr to 50-yr storms is generally confined to the watercourse that traverses the study area. The existing conditions model results show that both the Pickering and Ajax Dykes are not overtopped and areas within the Pickering (Village East) and Notion Road/Pickering Village SPA's are generally flood free.

3.8 Discussion of Results – Current Study vs. 1984/1985 Dyke Design

Based on the results for the updated flows using the MIKE Flood model, the level of flood protection afforded by the Pickering Dyke is the 100-yr storm flow while the level of flood protection afforded by the Ajax Dyke is the 50-yr storm flow. Both dykes were designed in the 1980's to provide flood protection for the 500-yr storm flow. A comparison of the peak flows used in the original design of the Pickering and Ajax Dykes and the peak flows used in the current assessment is provided in **Table 3.2**. As shown, the peak flows used in the original design by Simcoe Engineering are slightly higher than the updated peak flows provided in *2012 Duffins Creek Hydrology Update* (Aquafor, 2013).

Table 3.2: Comparison of 1982 Peak Flows and 2012 Peak Flows

Return Period	Peak Flow at HWY 401 (Node 28.1)		Peak Flow in West Branch of Confluence (Node 12.1)	
	Simcoe Engineering Dyke Report (1982)	Aquafor Hydrology Update (2012)	Simcoe Engineering Dyke Report (1982)	Aquafor Hydrology Update (2012)
350-yr	342 cms	323 cms	145 cms	140 cms
500-yr	360 cms	349 cms	150 cms	150 cms

The following observations are provided to better understand why the 500-yr design level of flood protection is not provided:

- We reviewed the *Preliminary Engineering Report for Flood Protection on the Duffin Creek in the Pickering Ajax Area* (Simcoe Engineering, 1982) and completed a brief comparison of results to better understand the reduced level of flood protection calculated based on the MIKE Flood model. In completing our investigations, it was noted that the 500-yr water levels downstream of HWY 401 and the railroad crossings (*i.e.* near the bottom end of the study area) are lower in the Simcoe Engineering HEC-2 model than in the current MIKE Flood model by approximately 0.8 m to 0.9 m. It is suspected that the lower tailwater conditions in the Simcoe Engineering HEC-2 model are reflected in water surface elevation calculations upstream through the relatively flat area between HWY 401 and Kingston Rd. The 500-yr water levels in the Simcoe Engineering HEC-2 model near the Ajax Dyke are approx. 1.1 m lower than in the MIKE Flood model. The

500-yr water levels in the Simcoe Engineering HEC-2 model near the Pickering Dyke are approximately 0.2 m to 0.5 m lower than in the MIKE Flood model. The 500-yr water levels upstream of Brock Rd are nearly the same in the Simcoe Engineering HEC-2 model compared with the MIKE Flood model. As a result of the lower tailwater conditions in the Simcoe Engineering HEC-2 model, the level of flood protection appears to have been over-estimated in comparison with the level of flood protection estimated using the MIKE Flood model using higher tailwater conditions.

- The most recent topographic survey and LiDAR revealed that the top elevations of the Pickering Dyke and the Ajax Dyke are lower than the design elevations at many locations by up to approximately 0.10 m and 0.33 m, respectively. As a result of the lower top of dyke elevations, spill from Duffins Creek is enabled at a reduced level of protection below the 500-yr storm flow.
- The MIKE Flood hydraulic model is a two-dimensional model based on detailed topographic survey and LiDAR data that is more sophisticated and more accurate than the one-dimensional HEC-2 model utilized in the design of the Pickering and Ajax Dykes in the 1980's. As such, spill areas are much better defined and far less likely to be missed than when using HEC-2 with less detailed topographic information.

Figure 3.1

REGIONAL FLOOD DEPTH MAP

(EXISTING CONDITION)

STEADY INFLOW HYDROGRAPH (HURRICANE HAZEL)

250 125 0 250 Meters

01 December 2017

N

Note:

Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain study. Any other use of this information by a third party requires verification and is at the sole risk of that party

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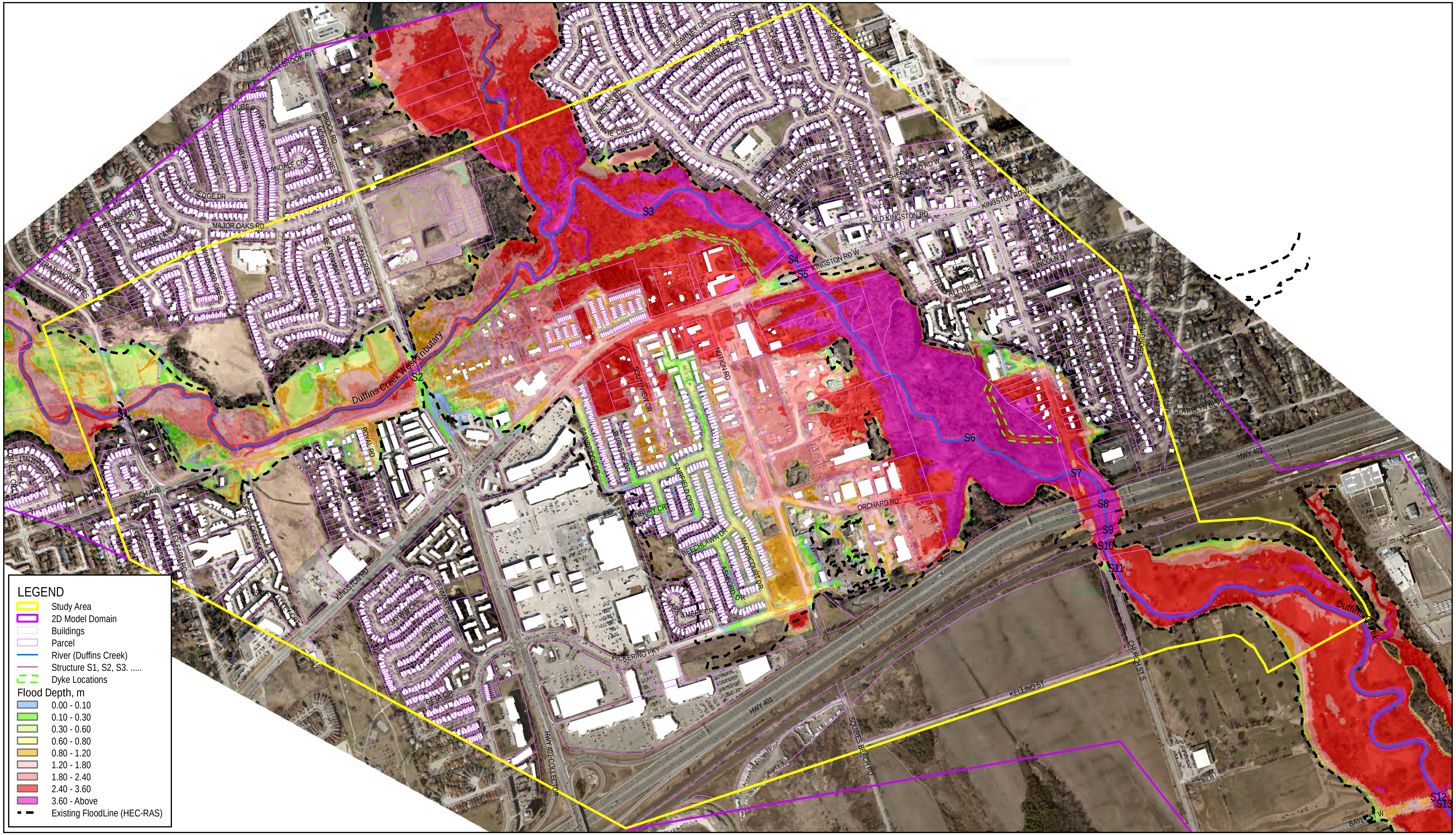

Figure 3.2
REGIONAL FLOOD DEPTH MAP
(EXISTING CONDITION)
UNSTEADY INFLOW HYDROGRAPH (HURRICANE HAZEL)

250 125 0 250 Meters

03 December 2017

N

Note:

Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain study. Any other use of this information by a third party requires verification and is at the sole risk of that party

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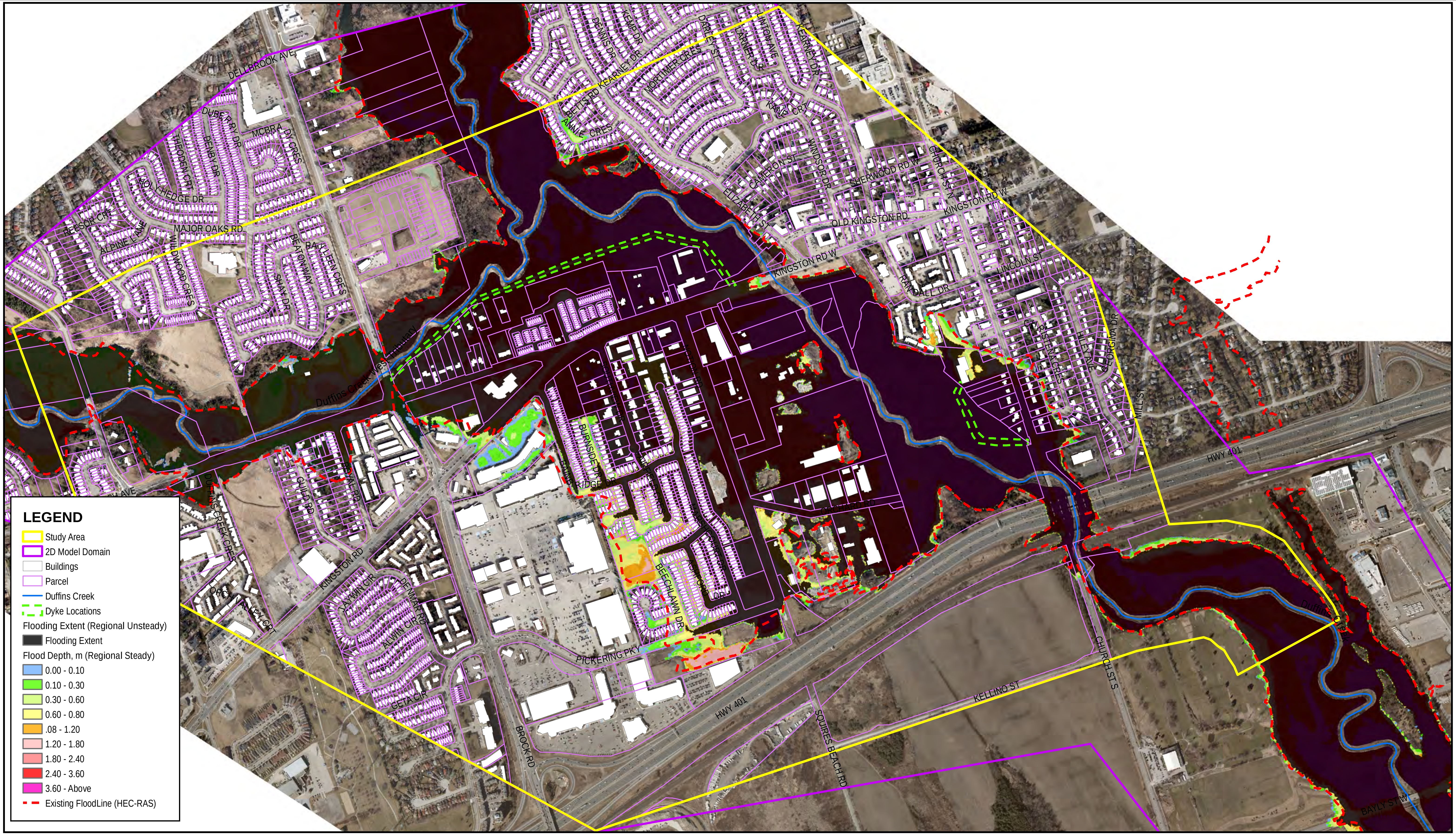

Figure 3.3

COMPARISON OF REGIONAL FLOOD EXTENTS MAP

(EXISTING CONDITION)

STEADY AND UNSTEADY INFLOW HYDROGRAPH (HURRICANE HAZEL)

250 125 0 250 Meters

N

03 December 2017

Note:

Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain study. Any other use of this information by a third party requires verification and is at the sole risk of that party

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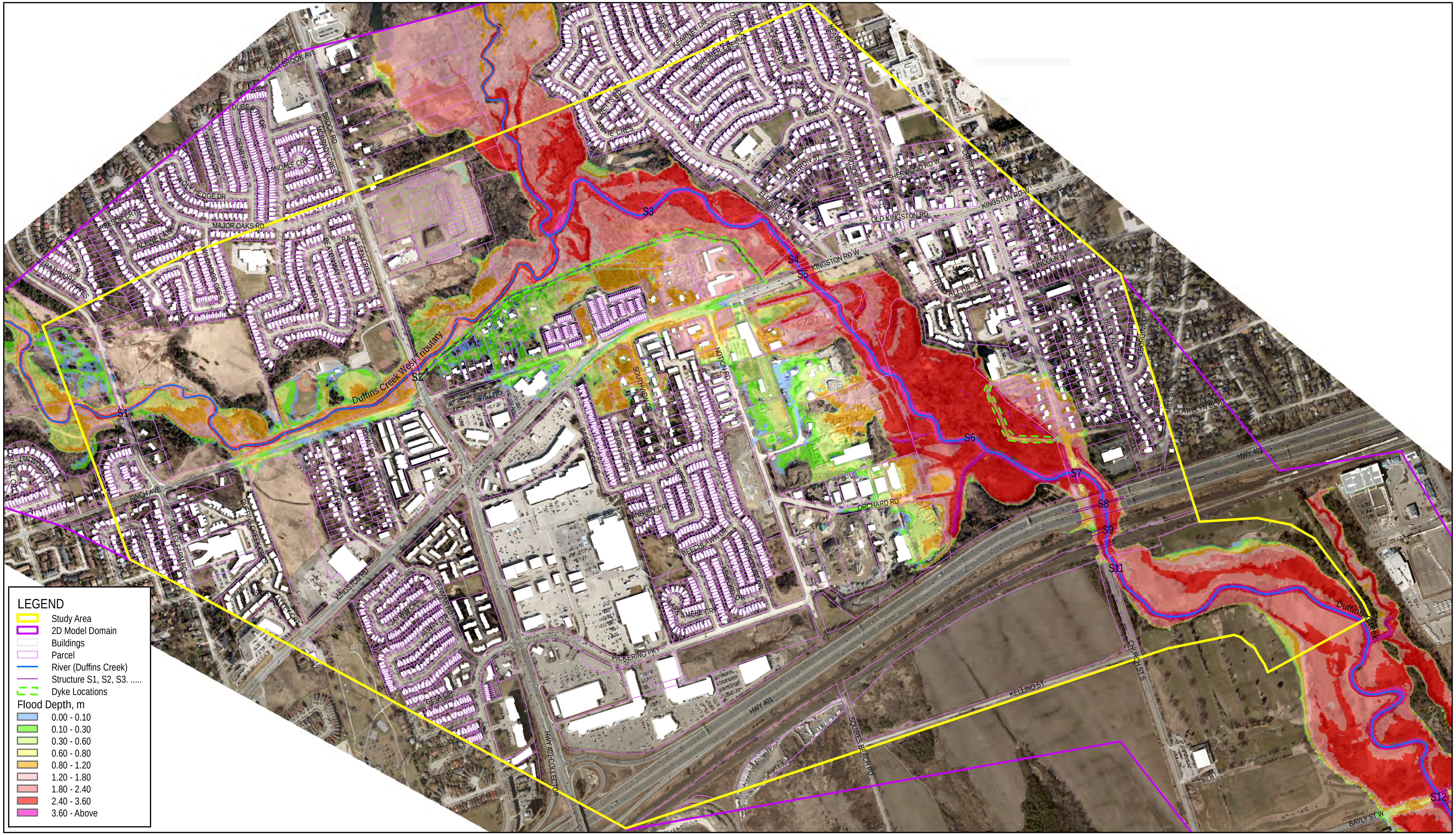

Figure 3.4
500-YR FLOOD DEPTH MAP
(EXISTING CONDITION)

STEADY INFLOW HYDROGRAPH (500-YR STORM)

250 125 0 250 Meters

N

01 December 2017

Note:

Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain study. Any other use of this information by a third party requires verification and is at the sole risk of that party

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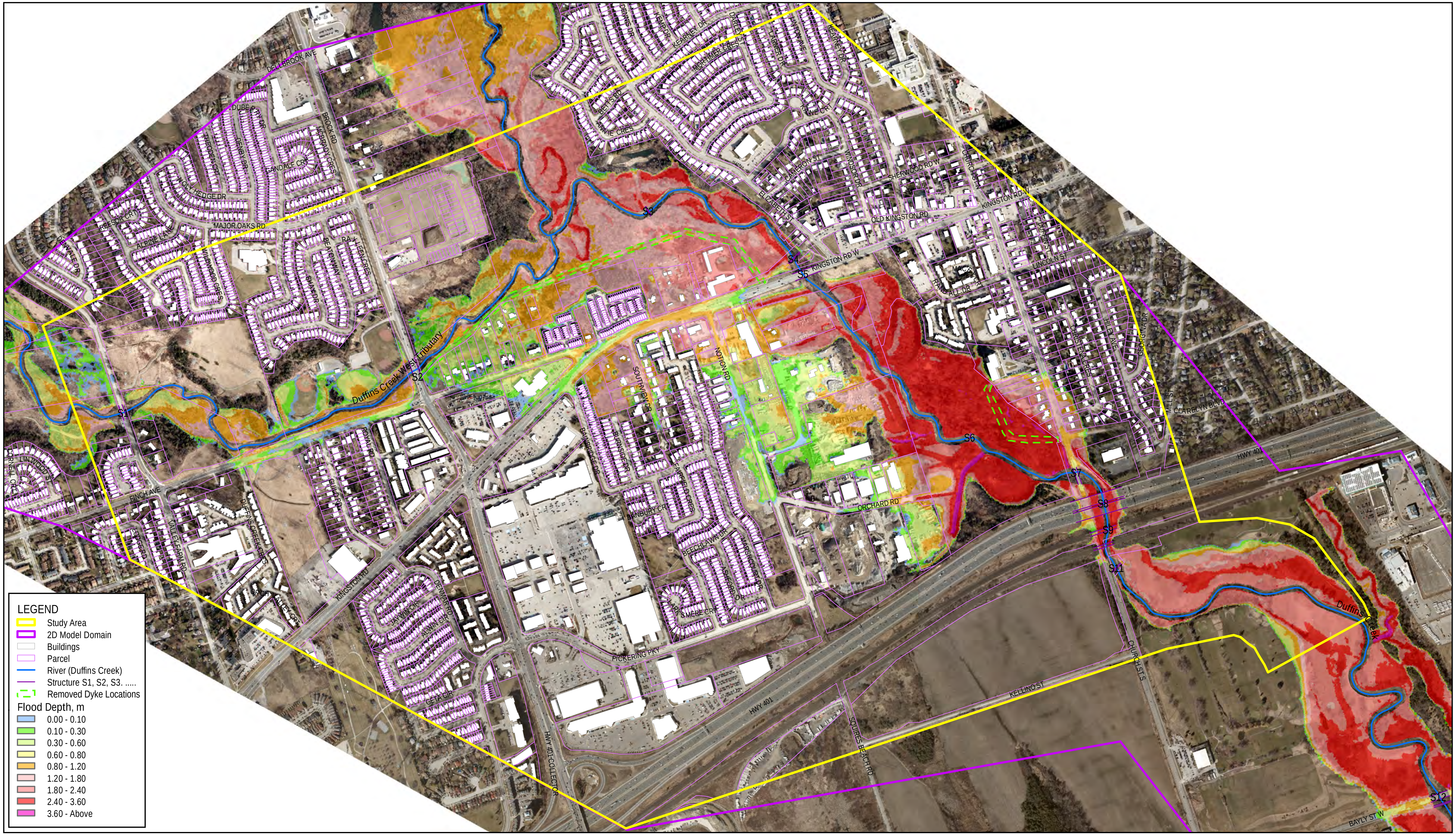

Figure 3.5

500-YR FLOOD DEPTH MAP

(DYKE REMOVED)

STEADY INFLOW HYDROGRAPH (500-YR STORM)

250 125 0 250 Meters

01 December 2017

N

Note:

Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain study. Any other use of this information by a third party requires verification and is at the sole risk of that party

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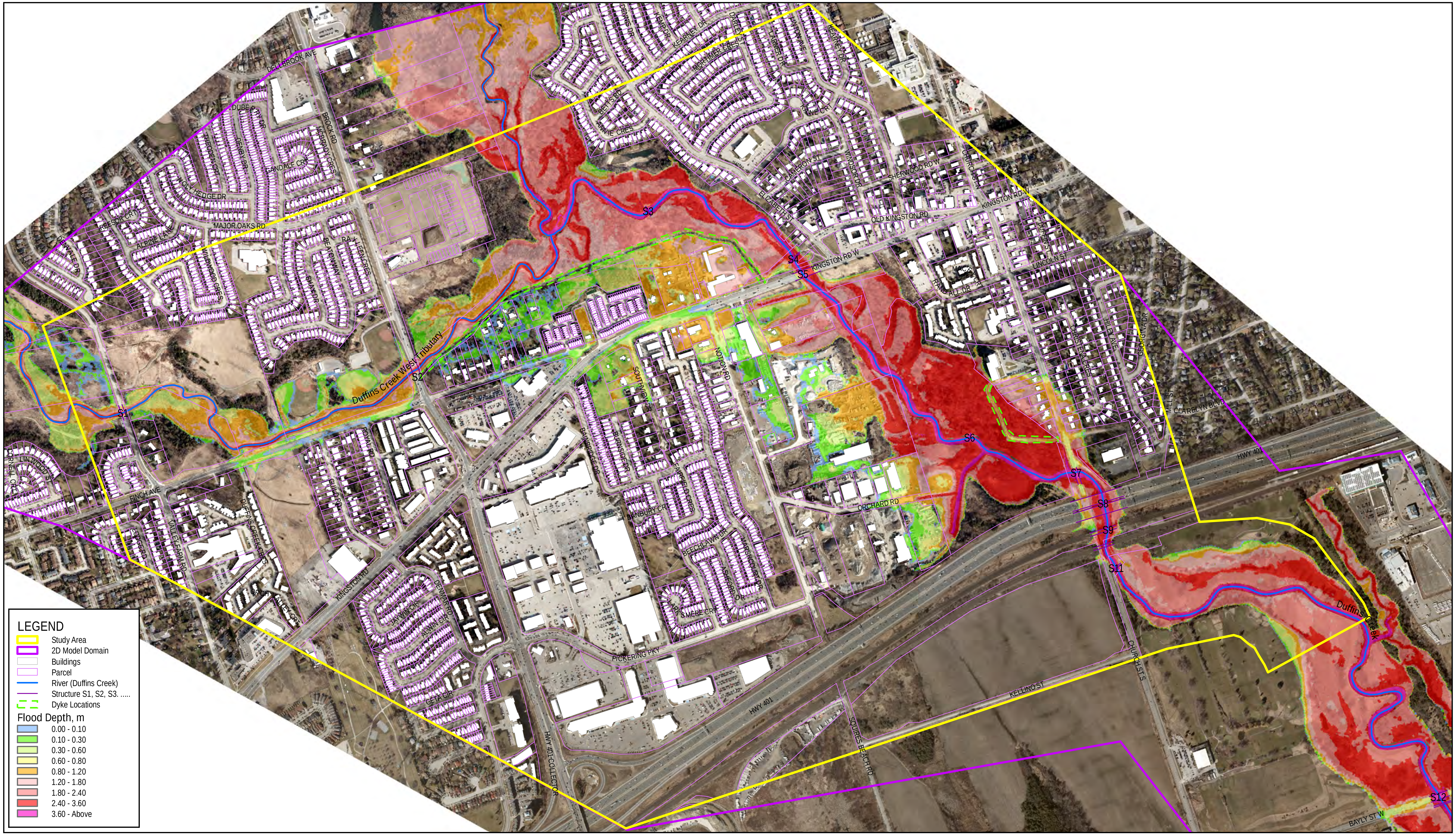

Figure 3.6

350-YR FLOOD DEPTH MAP

(EXISTING CONDITION)

STEADY INFLOW HYDROGRAPH (350-YR STORM)

250 125 0 250 Meters

01 December 2017

N

Note:

Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain study. Any other use of this information by a third party requires verification and is at the sole risk of that party

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4.0 FLOODPLAIN MAPPING

In Section 3, flood simulation results were compared based on the steady Hurricane Hazel peak flow hydrograph and unsteady Hurricane Hazel hydrograph. Based on the comparative analysis and discussions with the TRCA, in order not to account for the effect of storage elements within the floodplain area and to generate a conservative floodplain, it was determined that the steady Hurricane Hazel input hydrograph was more appropriate to use for floodplain mapping than the unsteady flow hydrograph. In addition, this is the approach currently supported by the MNRF when completing hydraulic modeling using a fully dynamic 1D/2D program such as MIKE Flood.

With assistance from the TRCA, three (3) updated map sheets were prepared based on the flood depth maps calculated with the MIKE Flood model. These updated map sheets will replace the existing Duffins Creek floodplain Map Sheets 4, 5 and 6. The floodline was created by digitizing the extent of the flood depth map prepared in ArcGIS. The flood depth map in ArcGIS was prepared using the MIKE Flood results obtained from the 15-hr steady Hurricane Hazel hydrograph simulation converted and resampled into a 0.5 m x 0.5 m GIS raster surface. The contours used to prepare the base map were created using the LiDAR digital elevation surface by the TRCA. The updated Duffins Creek engineered floodplain Map Sheets 4, 5 and 6 are provided in **Appendix F**.

5.0 SUMMARY AND CONCLUSIONS

Under the direction of the Toronto and Region Conservation Authority, Valdor Engineering has completed the *MIKE Flood 1D-2D Development and Regulatory Floodplain Mapping, Pickering / Ajax SPA* report. The key findings and results of the study are summarized as follows:

1. Using the updated digital elevation model (DEM) derived from recently obtained LiDAR data supplemented with the completed topographic survey for channel sections and hydraulic structures, updated land use data, and updated flow data, an integrated 1D/2D hydraulic model was prepared using MIKE Flood for the Pickering (Village East) and Notion Road/Pickering Village SPA's. The results of the MIKE Flood model were found to be similar to the current approved extents of flooding for the Regional storm based on HEC-RAS in many areas, however, the spill areas including overland floodplain areas were much better defined and additional areas of flooding were found west of Bainbridge Drive and south of Kingston Road West, in the vicinity of Betts Road and Annie Crescent, and at the intersection of Finch Avenue and Brock Road.

2. The results of the MIKE Flood model using the steady flow hydrographs provided by the TRCA were used to delineate the extent of flooding for the Regional, 500-yr, 350-yr and 2-yr through 100-yr storms within the Pickering (Village East) and Notion Road/Pickering Village SPA's.

3. The Duffins Creek Map Sheets 4, 5 and 6 were updated using the integrated 1D/2D hydraulic model MIKE Flood and steady inflow hydrographs for the Regional storm.

4. Based on the results of the MIKE Flood model, it was determined that the requisite level of flood protection regarding the existing flood control infrastructure for the 500-yr storm is not provided for all areas within the Pickering (Village East) and Notion Road/Pickering Village SPA's. The Pickering Dyke provides flood protection for the 100-yr storm flow and the Ajax Dyke provides flood protection for the 50-yr storm flow. Factors contributing to the reduced level of flood protection afforded by the Pickering and Ajax Dykes include reduced dyke elevations compared to the design elevations and less sophisticated hydraulic modeling methods previously available.

6.0 RECOMMENDATIONS

The following summarizes the report recommendations:

1. The revised Duffins Creek Floodplain Map Sheets 4, 5 and 6 based on the 1D/2D integrated hydraulic model (MIKE Flood) should be used to replace the existing floodplain map sheets completed previously for the study area.
2. A characterization and risk assessment of the floodplain should be undertaken to identify the flood processes and to identify low and high risk areas within the floodplain associated with the Pickering (Village East) and Notion Road/Pickering Village SPA's.
3. An analysis of flood flows and the flooding process should be undertaken to determine the key hydraulic constraints contributing to the flooding within the Pickering (Village East) and Notion Road/Pickering Village SPA's. Any hydraulic constraints including undersized hydraulic structures (*e.g.* bridges with poor conveyance capacity), undersized channels (*e.g.* watercourse with poor conveyance capacity) and constraints due to topography (*e.g.* spill points, low lying or flat, poorly drained topography) should be investigated.
4. Options to rehabilitate the existing dykes and reinstate the 500-yr level of flood protection should be investigated for future consideration and implementation. Recommended mitigation options including bridge or culvert conveyance capacity improvements, channel conveyance capacity improvements, spill containment and grade adjustments should be considered.
5. As a minimum requirement, it is important that the TRCA in association with the City of Pickering, Town of Ajax and Region of Durham reinstate the existing level of flood protection within the Pickering (Village East) and Notion Road/Pickering Village SPA's to ensure the area remains flood free for events up to and including the 500-yr storm and to minimize the risk to life and property.
6. Opportunities to improve the level of flood protection beyond the 500-yr storm should be investigated at a high level of assessment to confirm if such an undertaking is practical.

7.0 REFERENCES

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Respectfully Submitted,

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APPENDIX 'A'

Completed Survey and Structure Inventory

Pickering/Ajax Mike Flood
1D-2D Model Development and Regulatory Floodplain Mapping

Toronto and Region Conservation Authority

Appendix 'A' Contents:

- **Figure A.1a & 1b** Topographic Field Survey by TRCA
- **Figure A.2** Existing Flood Control Infrastructure Location Map
- **Table A.1** Hydraulic Structure Details (Pickering/Ajax SPA)
- **Structure Inventory Sheets** (Structures S1-S12)

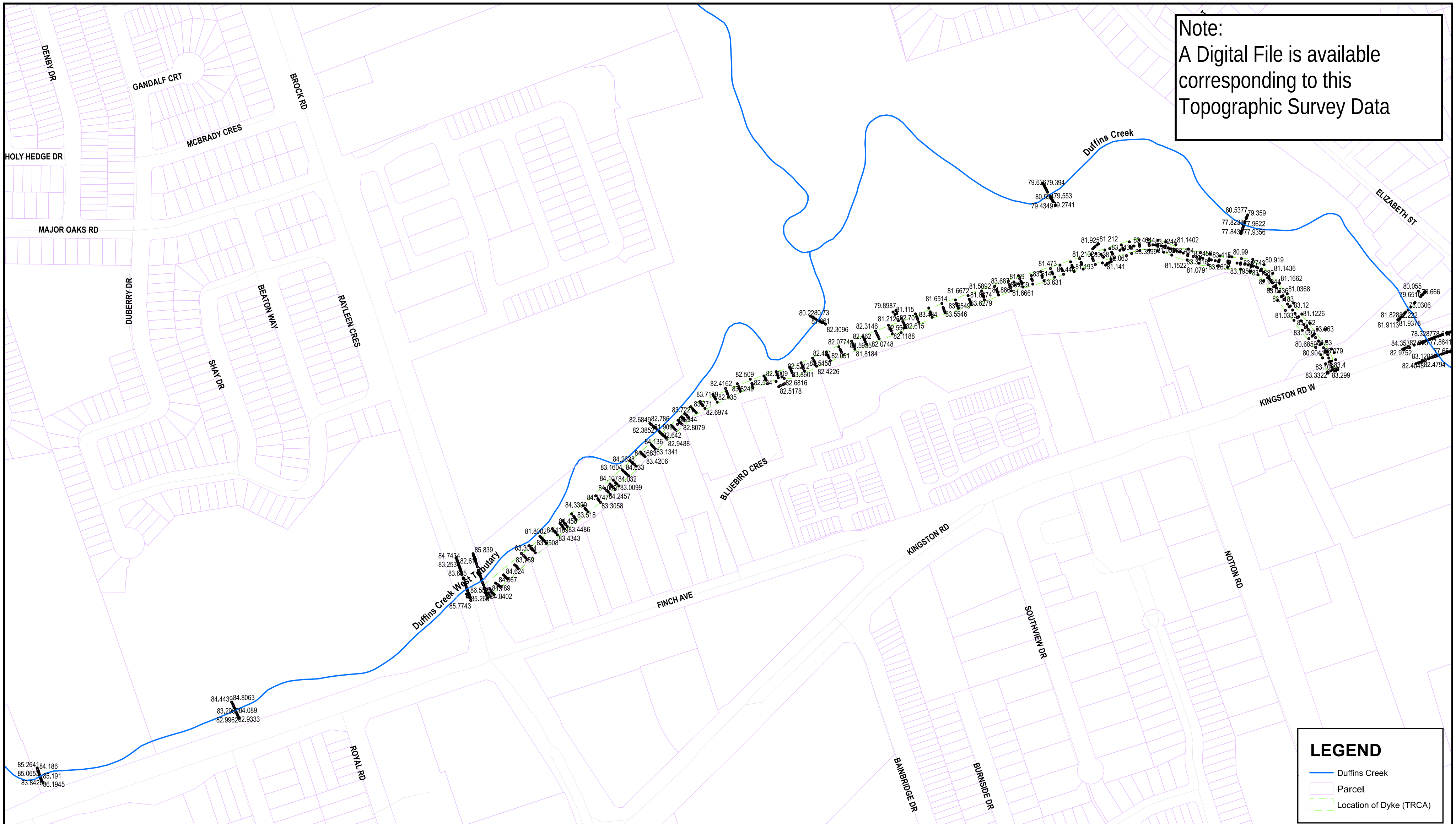

Figure A.1a

TOPOGRAPHIC FIELD SURVEY BY TRCA
(PICKERING DYKE)

130 65 0 130 Meters

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01 December 2017

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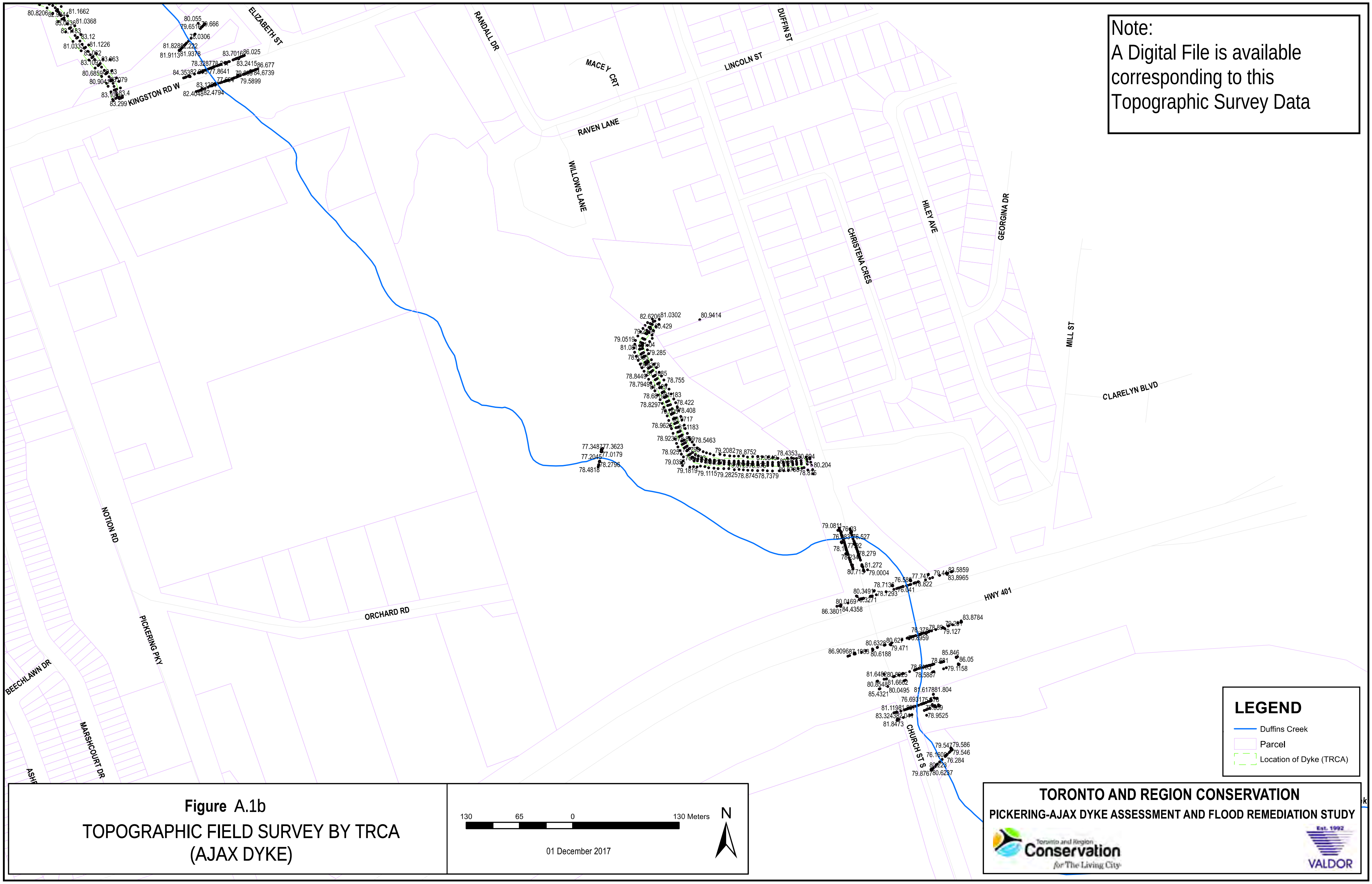


Figure A.1b
TOPOGRAPHIC FIELD SURVEY BY TRCA
(AJAX DYKE)

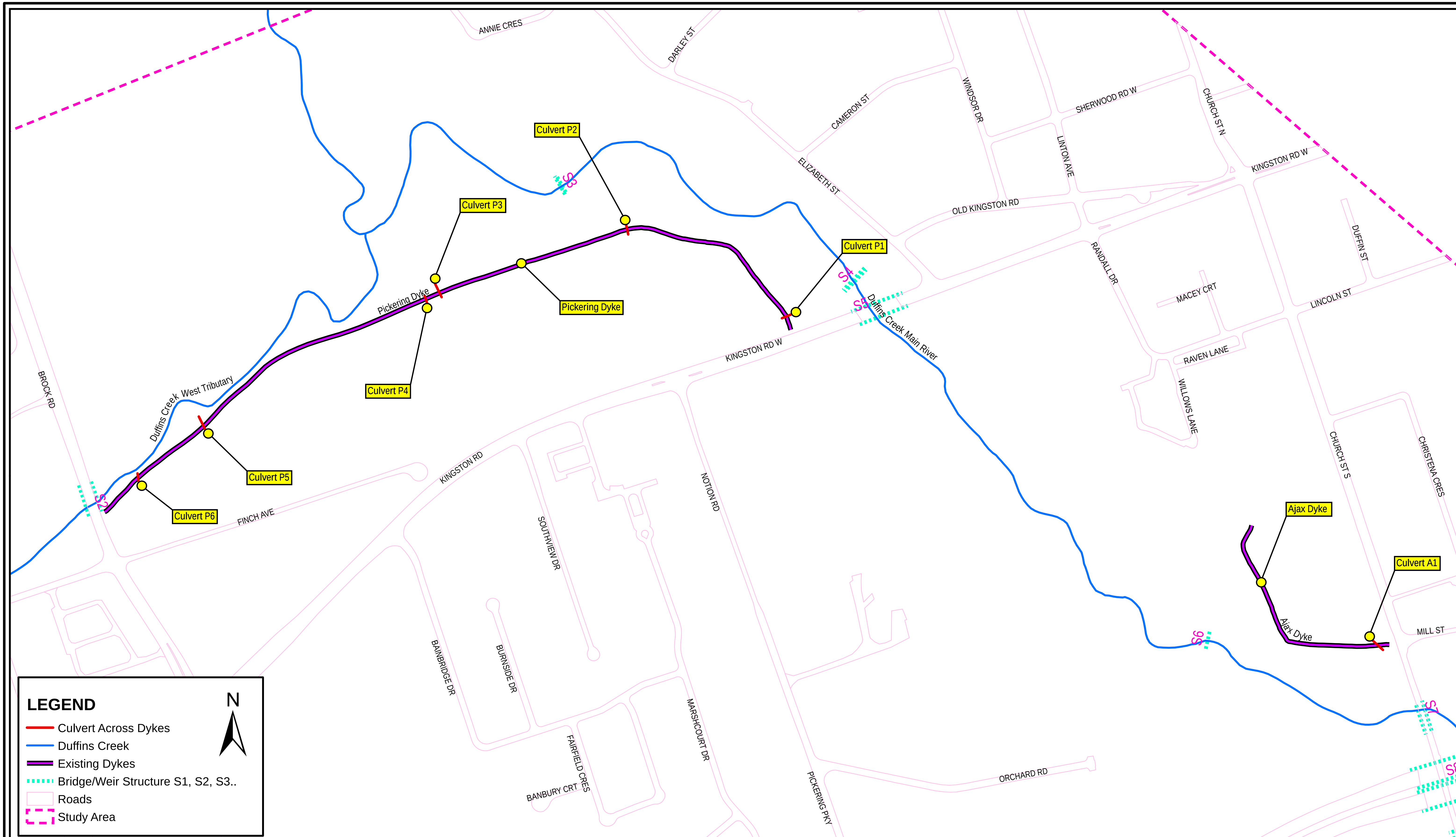


Figure A.2

EXISTING FLOOD CONTROL INFRASTRUCTURE LOCATION MAP

29 November 2017

TORONTO AND REGION CONSERVATION

PICKERING-AJAX DYKE ASSESSMENT AND FLOOD REMEDIATION STUDY

Valdor Engineering Inc.

File:17134

Date: December 2017

Table A.1 Hydraulic Structure Details (Pickering/Ajax SPA)

Identifier	Location	Opening Size Width (m)	Opening Size Height (m)	Bridge/ Culvert Length Along Channel (m)	U/S Invert (m)	D/S Invert (m)	Type of Structure	Remarks
S1	Valley Farm Road	Max. 48.20	Max. 4.20	13.62	86.60	86.60	Concrete Bridge	
S2	Brock Road	Max. 34.67	Max. 3.22	18.50	81.77	81.98	Concrete Bridge	
S3	D/S of Brock Road	Max. 28.57	Max. 3.045	3.50	78.325	78.395	Steel Pedestrian Bridge	
S4	U/S of Kingston Rd. W.	Max. 44.16	Max. 4.245	3.40	77.830	77.844	Steel Pedestrian Bridge	
S5	Kingston Rd. W.	Max. 60.6	Max. 7.50	20.44	77.350	77.455	Concrete Bridge	
S6	U/S of Church St.	-	-	-	-	-	Dam (Weir)	Modelled as weir
S7	Church St. S.	Max. 39.892	Max. 4.63	11.32	76.080	76.104	Concrete Bridge	
S8	HWY 401	-	-	-	-	-	Concrete Bridge	Piers in 2D Bathymetry
S9	GO Transit Bridge	-	-	-	-	-	Railway Bridge	Piers in 2D Bathymetry
S10	CN Railway	-	-	-	-	-	Railway Bridge	Piers in 2D Bathymetry
S11	D/S of CN Rail	Max. 34.55	Max. 5.30	3.40	75.859	75.865	Steel Pedestrian Bridge	
S12	Bayly St. W.	Max. 47.41	Max. 3.50	10.00	74.70	74.60	Concrete Bridge	

HYDRAULIC STRUCTURE INVENTORY SHEET (S-1)

Watershed and Location Information	Structure Configuration and Dimensions		Current Flow Information
Date : August 16th, 2017	Structure Type : Concrete Bridge		Flow Present (Y/N): Y
Field Crew: Valdor Engineering Inc Staffs	No. of Openings/Culverts: 1	Footing: Open Bottom with Abutments	Approx. Depth (m):0.3m
Watershed Name: Duffins	Materials: Concrete Deck with Open Concrete Railings		Approximate Velocity(m/s):
Subcatchment Area No.:	Opening Height 4.2 m (maximum); Width 48.20 m (maximum)		Upstream Erosion (Y/N):N
Tributary Name: Duffins Creek	Pier Dimension: NA		Downstream Erosion (Y/N):N
Floodplain Map Sheet No.: 06	Length: 13.62 m	Total bridge span: 48.20 m	Additional Flow Information:
Cross-section Range:	Road Deck: Concrete walkway surface elevation varies in both (x & y) directions between the highest 93.2 m to the lowest 92.0 m		
Municipality: City of Pickering			
Location: Duffins Creek at Valley Farm Road, North of Finch Avenue	Low chord/obvert: Elevation varies from 89.45 to 90.0 m		
	Invert: Elevations on the irregular natural channel vary across and along the bridge section around 86.60 m		

Additional Field Notes:

Site Sketch:

Downstream of Concrete Bridge

Downstream of Concrete Bridge

Description of Photograph:

HYDRAULIC STRUCTURE INVENTORY SHEET (S-2)

Watershed and Location Information	Structure Configuration and Dimensions		Current Flow Information
Date : August 15th, 2017	Structure Type : Concrete Bridge		Flow Present (Y/N): Y
Field Crew: Valdor Engineering Inc Staffs	No. of Openings/Culverts: 2	Footing: Open Bottom with Pier	Approx. Depth (m): 0.63 m
Watershed Name: Duffins	Materials: Concrete Deck with Solid Concrete Railings and Open Steel Railings		Approximate Velocity(m/s):
Subcatchment Area No.:	Opening Height 3.22 m (maximum); Width 34.67 m excluding pier		Upstream Erosion (Y/N): N
Tributary Name: Duffins Creek	Pier Dimension: Pier width of 1.082 m		Downstream Erosion (Y/N): N
Floodplain Map Sheet No.: 06	Length: 18.50 m	Total bridge span: 35.752 m	Additional Flow Information:
Cross-section Range:	Road Deck: Concrete walkway surface elevation varies in both (x & y) directions between the highest 86.184 m to the lowest 85.696 m		
Municipality: City of Pickering			
Location: Duffins Creek at Brock Road, North of Finch Avenue	Low chord/obvert: Elevation varies between 84.244 m to 84.920 m		
	Invert: Elevations on the irregular natural channel vary across and along the bridge section having a u/s inv. of 81.77 m; d/s inv. of 81.98 m		

Additional Field Notes:

Site Sketch:

Upstream of Concrete Bridge

Downstream of Concrete Bridge

Description of Photograph:

HYDRAULIC STRUCTURE INVENTORY SHEET (S-3)

Watershed and Location Information	Structure Configuration and Dimensions		Current Flow Information
Date : August 15th, 2017	Structure Type : Pedestrian Bridge		Flow Present (Y/N): Y
Field Crew: Valdor Engineering Inc Staffs	No. of Openings/Culverts: 1	Footing: Open Bottom	Approx. Depth (m): 0.55m
Watershed Name: Duffins	Materials: Wooden Deck with Steel Beam Support, Open Steel Railings		Approximate Velocity(m/s):
Subcatchment Area No.:	Opening Height 3.045 m (maximum); Width 28.57 m		Upstream Erosion (Y/N):Y
Tributary Name: Duffins Creek	Pier Dimension: NA		Downstream Erosion (Y/N):Y
Floodplain Map Sheet No.: 05	Length: 3.50 m	Total bridge span: 28.57 m	Additional Flow Information:
Cross-section Range:	Road Deck: Wooden walkway surface elevation varies in both (x & y) directions between the highest 82.3 m to the lowest 82.0 m		
Municipality: City of Pickering			
Location: Duffins Creek D/S of Brock Road, North of Notion Road	Low chord/obvert: Elevation varies between 82.0 m to 81.7 m		
	Invert: Elevations on the irregular natural channel vary across and along the bridge section having an u/s inv. of 78.325 m, a d/s inv. of 78.395 m		

Additional Field Notes:

Site Sketch:

Upstream of Pedestrian Bridge

Downstream of Pedestrian Bridge

Description of Photograph:

HYDRAULIC STRUCTURE INVENTORY SHEET (S-4)

Watershed and Location Information	Structure Configuration and Dimensions	Current Flow Information
Date : August 15th, 2017	Structure Type : Pedestrian Bridge	Flow Present (Y/N): Y
Field Crew: Valdor Engineering Inc Staffs	No. of Openings/Culverts: 1 — Footing: Open Bottom	Approx. Depth (m):0.44m
Watershed Name: Duffins	Materials: Steel Deck with Steel Beam Support, Open Steel Railings	Approximate Velocity(m/s):
Subcatchment Area No.:	Opening Height 4.245 m (maximum); Width 44.16 m	Upstream Erosion (Y/N):Y
Tributary Name: Duffins Creek	Pier Dimension: NA	Downstream Erosion (Y/N):Y
Floodplain Map Sheet No.: 05	Length: 3.40 m — Total bridge span: 44.16 m	Additional Flow Information:
Cross-section Range:	Road Deck: Steel walkway surface elevation varies in both (x & y) directions between the highest 83.4 m to the lowest 83.1 m	
Municipality: Town of Ajax		
Location: Duffins Creek at U/S of Kingston Road West, West of Old Kingston Road	Low chord/obvert: Elevation varies between 81.828 m to 82.082 m	
	Invert: Elevations on the irregular natural channel vary across and along the bridge section having an u/s inv. of 77.830 m, a d/s inv. of 77.844 m	

Additional Field Notes:

Site Sketch:

Upstream of Pedestrian Bridge

Downstream of Pedestrian Bridge

Description of Photograph:

HYDRAULIC STRUCTURE INVENTORY SHEET (S-5)

Watershed and Location Information	Structure Configuration and Dimensions		Current Flow Information
Date : August 15th, 2017	Structure Type : Concrete Bridge		Flow Present (Y/N): Y
Field Crew: Valdor Engineering Inc Staffs	No. of Openings/Culverts: 3	Footing: Open Bottom with Piers	Approx. Depth (m):0.81m
Watershed Name: Duffins	Materials: Concrete Deck with Solid Concrete Railings		Approximate Velocity(m/s):
Subcatchment Area No.:	Opening Height 7.50 m (maximum); Width 60.6 m excluding piers		Upstream Erosion (Y/N):N
Tributary Name: Duffins Creek	Pier Dimension: Pier width of 0.71 m; length of 21.12 m		Downstream Erosion (Y/N):N
Floodplain Map Sheet No.: 05	Length: 20.44 m	Total bridge span: 62.02 m	Additional Flow Information:
Cross-section Range:	Road Deck: Concrete walkway surface elevation varies in both (x & y) directions between the highest 86.10 m to the lowest 85.25 m		
Municipality: Town of Ajax			
Location: Duffins Creek at Kingston Road West, West of Church Street North	Low chord/obvert: Elevation varies with maximum of 84.90 m		
	Invert: Elevations on the irregular natural channel vary across and along the bridge section having a u/s inv. of 77.350 m; d/s inv. of 77.455 m		

Additional Field Notes:

Site Sketch:

Upstream of Concrete Bridge

Downstream of Concrete Bridge

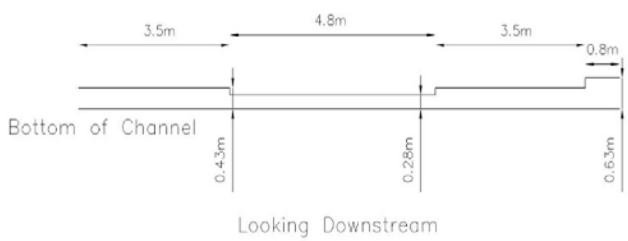
Description of Photograph:

HYDRAULIC STRUCTURE INVENTORY SHEET (S-6)

Watershed and Location Information	Structure Configuration and Dimensions		Current Flow Information
Date : August 16th, 2017	Structure Type : Concrete Weir with Metal Lip		Flow Present (Y/N): Y
Field Crew: Valdor Engineering Inc Staffs	No. of Openings/Culverts: 1	Footing: NA	Approx. Depth (m):0.45m
Watershed Name: Duffins	Materials: Concrete Weir		Approximate Velocity(m/s):
Subcatchment Area No.:	Max. opening width is 4.8 m		Upstream Erosion (Y/N):
Tributary Name: Duffins Creek	Pier Dimension: NA		Downstream Erosion (Y/N):
Floodplain Map Sheet No.: 05	Length: NA	Total bridge span: NA	Additional Flow Information:
Cross-section Range:			
Municipality: Town of Ajax	Road Deck: NA		
Location: Duffins Creek U/S of Church Street South, West of Mill Street	Low chord/obvert: NA		
	Invert: NA		

Additional Field Notes:

Site Sketch:



Upstream of Concrete Weir

Downstream of Concrete Weir

Description of Photograph:

HYDRAULIC STRUCTURE INVENTORY SHEET (S-7)

Watershed and Location Information	Structure Configuration and Dimensions		Current Flow Information
Date : August 15th, 2017	Structure Type : Concrete Bridge		Flow Present (Y/N): Y
Field Crew: Valdor Engineering Inc Staffs	No. of Openings/Culverts: 3	Footing: Open Bottom with Piers	Approx. Depth (m):0.29m
Watershed Name: Duffins	Materials: Concrete Deck with Solid Concrete Railings		Approximate Velocity(m/s):
Subcatchment Area No.:	Opening Height 4.63 m (maximum); Width of 39.892 m excluding piers		Upstream Erosion (Y/N):Y
Tributary Name: Duffins Creek	Pier Dimension: Pier width of 1.2 m; length varies from 17.12 m to 16.06 m		Downstream Erosion (Y/N):N
Floodplain Map Sheet No.: 04	Length: 11.32 m	Total bridge span: 42.292 m	Additional Flow Information:
Cross-section Range:	Road Deck: Concrete walkway surface elevation varies in both (x & y) directions between the highest 81.483 m to the lowest 81.062 m		
Municipality: Town of Ajax			
Location: Duffins Creek at Church Street South, North of Hwy 401	Low chord/obvert: Elevation varies with maximum of 80.72 m		
	Invert: Elevations on the irregular natural channel vary across and along the bridge section having an u/s inv. of 76.080 m; d/s inv. of 76.104 m		

Additional Field Notes:

Site Sketch:

Upstream of Concrete Bridge

Downstream of Concrete Bridge

Description of Photograph:

HYDRAULIC STRUCTURE INVENTORY SHEET (S-8)

Watershed and Location Information	Structure Configuration and Dimensions		Current Flow Information
Date : August 15th, 2017	Structure Type : Concrete Bridge		Flow Present (Y/N): Y
Field Crew: Valdor Engineering Inc Staffs	No. of Openings/Culverts: 6	Footing: Open Bottom with Piers	Approx. Depth (m):0.62m
Watershed Name: Duffins	Materials: Concrete Deck with Solid Concrete Railings		Approximate Velocity(m/s):
Subcatchment Area No.:	Opening Height 10.6 m (maximum); Width 135.70 m including piers		Upstream Erosion (Y/N):Y
Tributary Name: Duffins Creek	Pier Dimension: Pier dimension varies, Details in additional field notes column		Downstream Erosion (Y/N):N
Floodplain Map Sheet No.: 04	Length: 59.26 m	Total bridge span: 135.70 m	Additional Flow Information:
Cross-section Range:	Road Deck: Concrete deck surface elevation varies in both (x & y) directions around 87.31 m		
Municipality: Town of Ajax			
Location: Duffins Creek at Hwy 401, East of Church Street South	Low chord/obvert: Elevation varies between 85.329 m to 86.092 m		
	Invert: Elevations on the irregular natural channel vary across and along the bridge section having a u/s inv. of 75.492 m; d/s inv. of 75.812 m		

Additional Field Notes: Five rows of piers each consists of 8 rectangular piers with length range from 1.84m to 1.92m, width range from 1.37m to 1.69m and 11 circular piers with diameter range from 762mm to 1200mm

Upstream of HWY 401 Bridge

Downstream of HWY 401 Bridge

Description of Photograph:

HYDRAULIC STRUCTURE INVENTORY SHEET (S-9)

Watershed and Location Information	Structure Configuration and Dimensions		Current Flow Information
Date : August 15th, 2017	Structure Type : Steel Bridge with Open Railings		Flow Present (Y/N): Y
Field Crew: Valdor Engineering Inc Staffs	No. of Openings/Culverts: 3	Footing: Open Bottom with Piers	Approx. Depth (m):0.51m
Watershed Name: Duffins	Materials: Steel Deck with Open Steel Railings and Steel Deck		Approximate Velocity(m/s):
Subcatchment Area No.:	Opening Height 11.859 m (maximum); Width 97.12 m excluding two piers		Upstream Erosion (Y/N):Y
Tributary Name: Duffins Creek	Pier Dimension: Pier width of 1.5 m, length of 8.53 m		Downstream Erosion (Y/N):Y
Floodplain Map Sheet No.: 04	Length: 8.06 m	Total bridge span: 100.12 m	Additional Flow Information:
Cross-section Range:	Road Deck: Steel deck surface elevation varies in both (x & y) directions between the highest 90.75 m to the lowest 90.27 m		
Municipality: Town of Ajax			
Location: Duffins Creek at Go Transit Bridge, South of Hwy 401	Low chord/obvert: Elevation varies between 87.096 m to 87.579 m		
	Invert: Elevations on the irregular natural channel vary across and along the bridge section having a u/s inv. of 75.72 m; d/s inv. of 75.79 m		

Additional Field Notes:

Site Sketch:

Upstream of Go Transit Bridge

Downstream of Go Transit Bridge

Description of Photograph:

HYDRAULIC STRUCTURE INVENTORY SHEET (S-10)

Watershed and Location Information

Date : August 15th, 2017

Field Crew: Valdor Engineering Inc Staffs

Watershed Name: Duffins

Subcatchment Area No.:

Tributary Name: Duffins Creek

Floodplain Map Sheet No.: 03

Cross-section Range:

Municipality: Town of Ajax

Location: Duffins Creek at CN Rail, South of Hwy 401

Structure Configuration and Dimensions

Structure Type : Steel Bridge

No. of Openings/Culverts: 3 | Footing: Open Bottom with Piers

Materials: Wooden Deck with Open Steel Railings and Concrete Piers

Opening Height 12.897 m (maximum); Width of 48.27 m excluding two pier

Pier Dimension: Pier width of 2.5 m; Pier length of 8.4 m

Length: 6.51 m | Total bridge span: 53.27 m

Road Deck: Wooden deck surface elevation varies in both (x & y) directions around 90.5 m

Low chord/obvert: Elevation varies between 88.432 m to 88.191 m

Invert: Elevations on the irregular natural channel vary across and along the bridge section having a u/s inv. of 75.535 m

Current Flow Information

Flow Present (Y/N): Y

Approx. Depth (m):

Approximate Velocity(m/s):

Upstream Erosion (Y/N):Y

Downstream Erosion (Y/N):N

Additional Flow Information:

Additional Field Notes:

Site Sketch:

Upstream of CN Rail Bridge

Downstream of CN Rail Bridge

Description of Photograph:

HYDRAULIC STRUCTURE INVENTORY SHEET (S-11)

Watershed and Location Information	Structure Configuration and Dimensions		Current Flow Information
Date : August 16th, 2017	Structure Type : Pedestrian Bridge		Flow Present (Y/N): Y
Field Crew: Valdor Engineering Inc Staffs	No. of Openings/Culverts: 1	Footing: Open Bottom	Approx. Depth (m):0.6m
Watershed Name: Duffins	Materials: Wooden Deck, Steel Beam to support Walkway, Open Steel Railings		Approximate Velocity(m/s):
Subcatchment Area No.:	Opening Height 5.30 m (maximum); Width 34.55 m (maximum)		Upstream Erosion (Y/N):N
Tributary Name: Duffins Creek	Pier Dimension: NA		Downstream Erosion (Y/N):Y
Floodplain Map Sheet No.: 03	Length: 3.40 m	Total bridge span: 34.55 m	Additional Flow Information:
Cross-section Range:	Road Deck: Wooden deck walkway surface elevation varies in both (x & y) directions between the highest 81.45 m to the lowest 81.15 m		
Municipality: Town of Ajax			
Location: Duffins Creek at D/S of CN Railway Bridge, East of Church Street South	Low chord/obvert: Elevation varies between 79.79 m to 81.16 m		
	Invert: Elevations on the irregular natural channel vary across and along the bridge section having an u/s inv. of 75.859 m, a d/s inv. of 75.865 m		

Additional Field Notes:

Site Sketch:

Upstream of Pedestrian Bridge

Downstream of Pedestrian Bridge

Description of Photograph:

HYDRAULIC STRUCTURE INVENTORY SHEET (S-12)

Watershed and Location Information	Structure Configuration and Dimensions	Current Flow Information
Date : August 16th, 2017	Structure Type : Concrete Bridge	Flow Present (Y/N): Y
Field Crew: Valdor Engineering Inc Staffs	No. of Openings/Culverts: 3 — Footing: Open Bottom with Piers	Approx. Depth (m):
Watershed Name: Duffins	Materials: Concrete Deck with Solid Concrete Railings and Open Steel Railings	Approximate Velocity(m/s):
Subcatchment Area No.:	Opening Height 3.5 m (maximum); Width 47.41 m excluding two piers' width	Upstream Erosion (Y/N):Y
Tributary Name: Duffins Creek	Pier Dimension: Pier Width 1.0 m each	Downstream Erosion (Y/N):N
Floodplain Map Sheet No.: 03	Length: 10.0 m — Total bridge span: 49.41 m	Additional Flow Information:
Cross-section Range:	Road Deck: Concrete walkway surface elevation varies in both (x & y) directions around 79.20 m	
Municipality: Town of Ajax		
Location: Duffins Creek at Bayly Street West, West of Westney Road South	Low chord/obvert: Elevation varies around 78.00 m	
	Invert: Elevations on the irregular natural channel vary across and along the bridge section with an u/s inv. of 74.70 m and a d/s inv. of 74.60 m	

Additional Field Notes:

Site Sketch:

Upstream of Concrete Bridge

Downstream of Concrete Bridge

Description of Photograph:

APPENDIX 'B'

Supporting Technical Information - Bathymetry and Roughness

Pickering/Ajax Mike Flood
1D-2D Model Development and Regulatory Floodplain Mapping

Toronto and Region Conservation Authority

Appendix 'B' Contents:

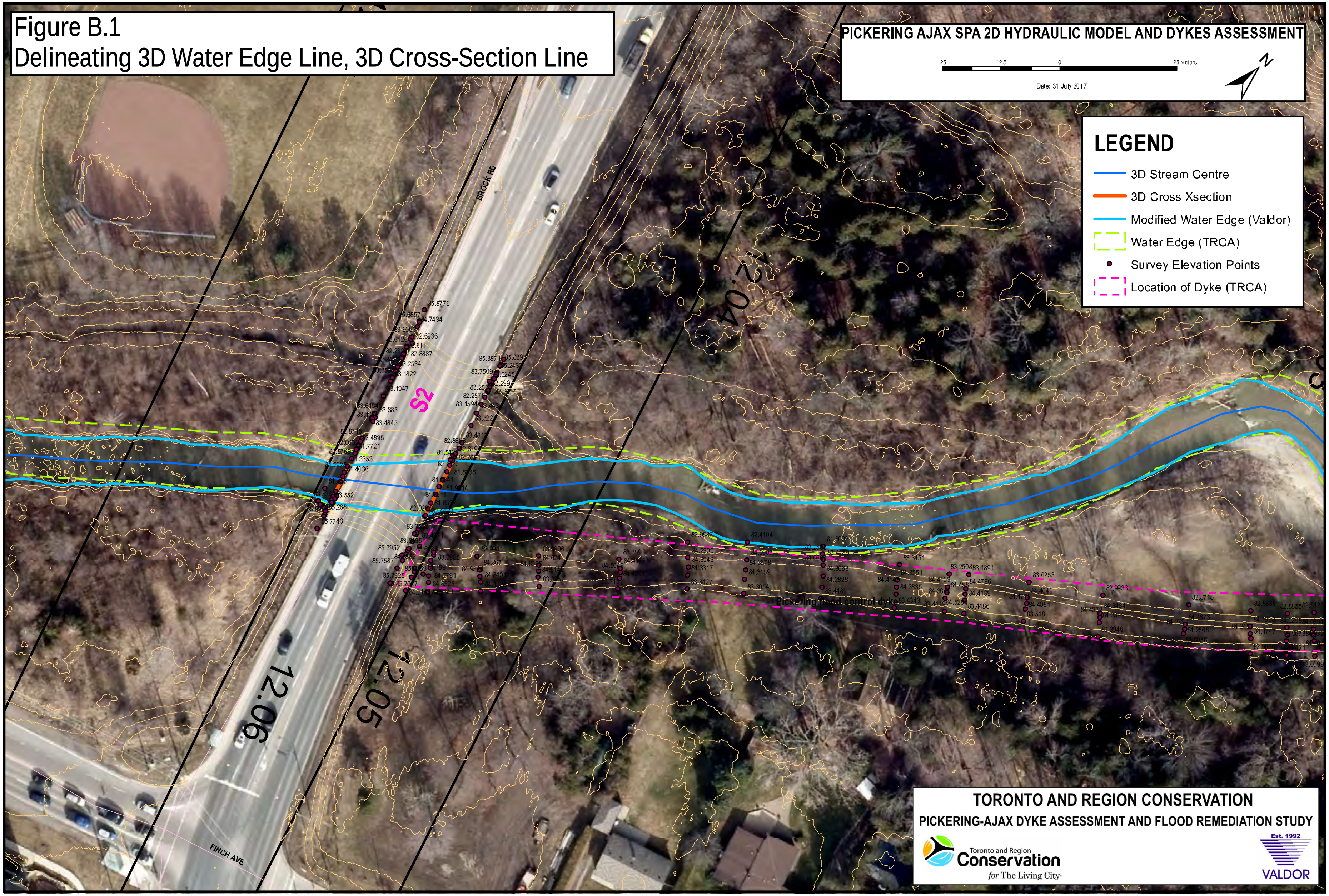
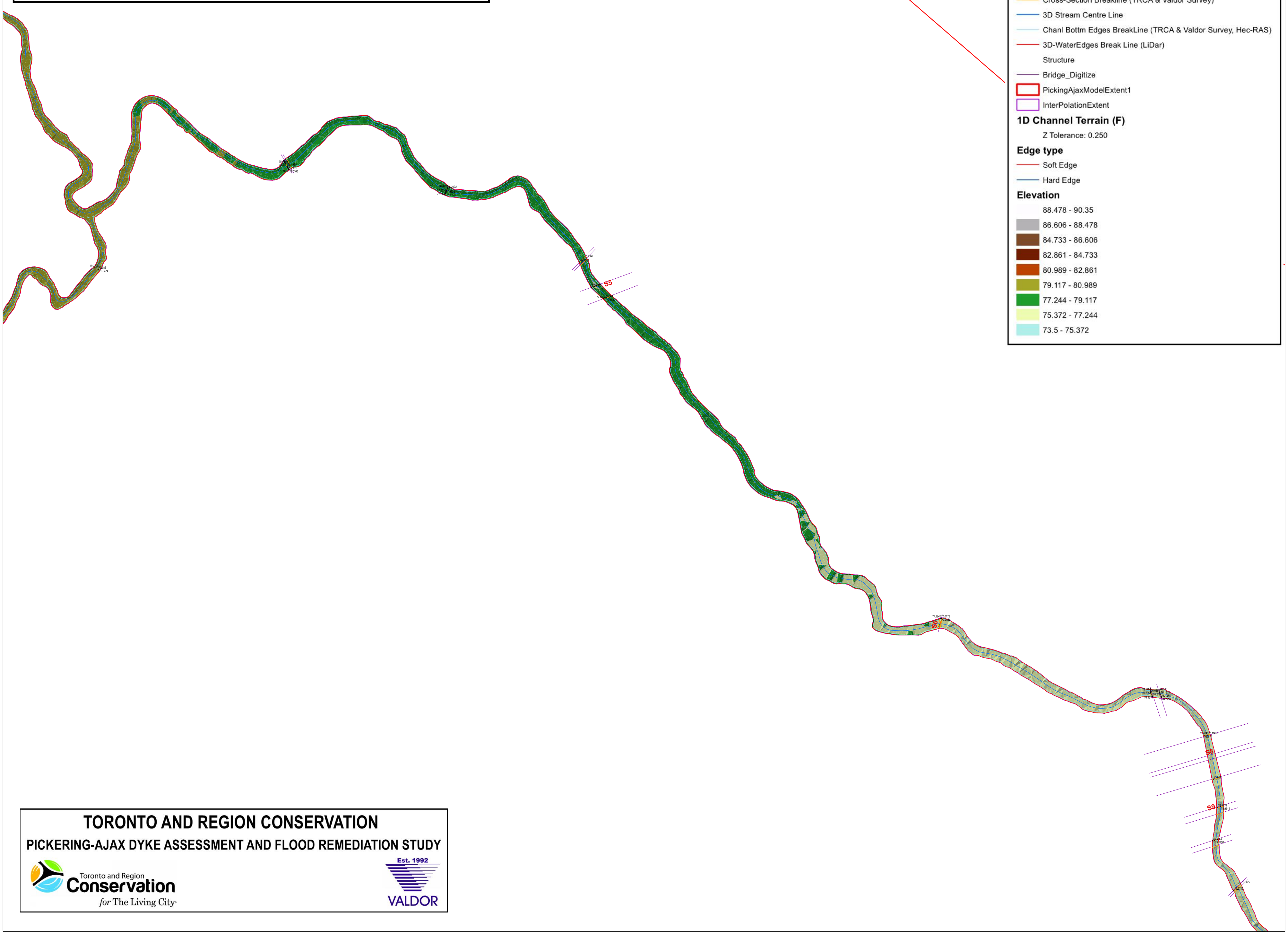


Figure B.1
Delineating 3D Water Edge Line, 3D Cross-Section Line

Figure B.2 DTM - TIN Surface for Water Covered Area and Participating Data Layers



TORONTO AND REGION CONSERVATION

PICKERING-AJAX DYKE ASSESSMENT AND FLOOD REMEDIATION STUDY

Toronto and Region Conservation *for* The Living City

Est. 1992 VALDOR

Figure B.3 Corrected Raster DEM for Underwater Ground Surface

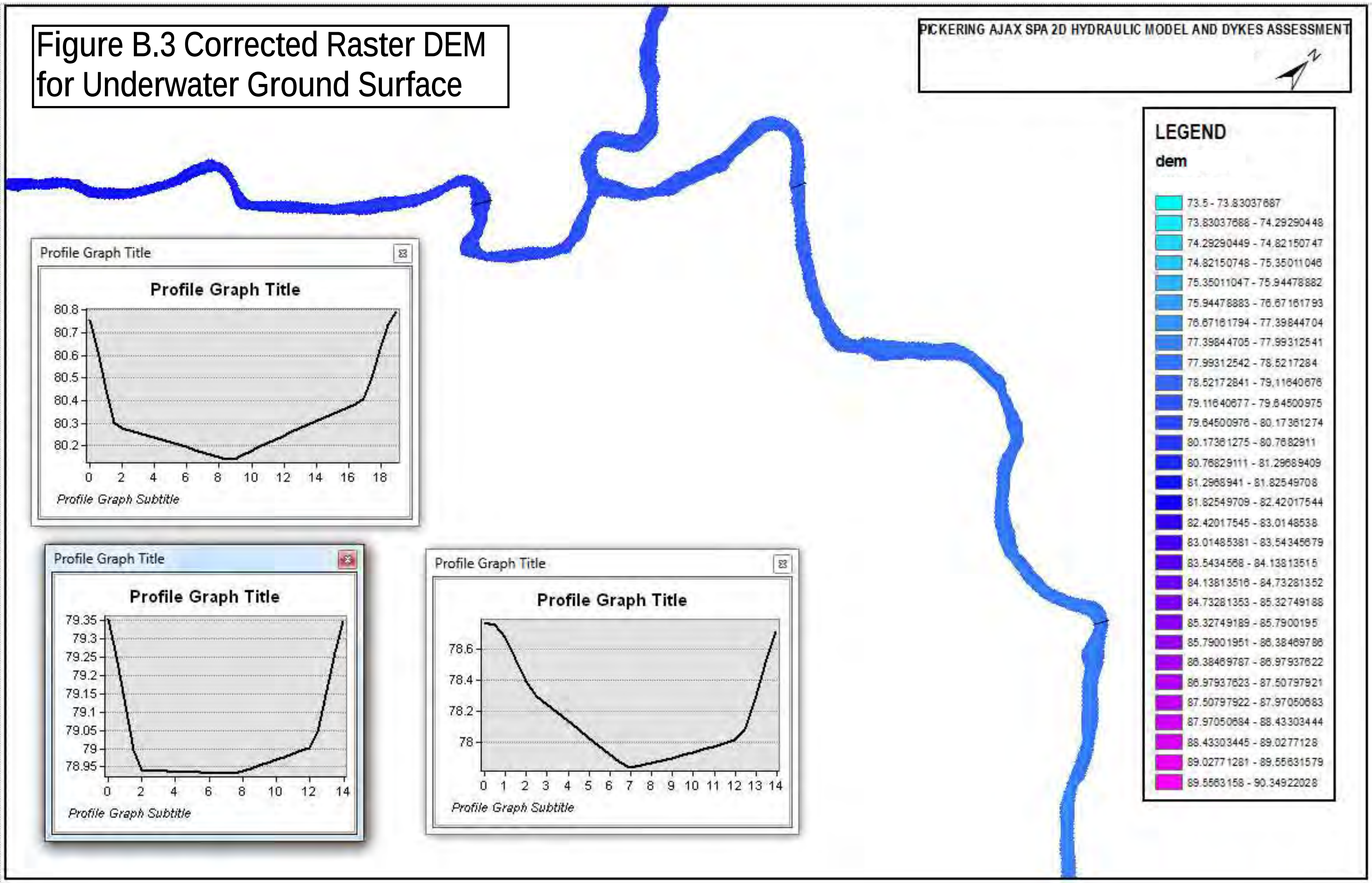
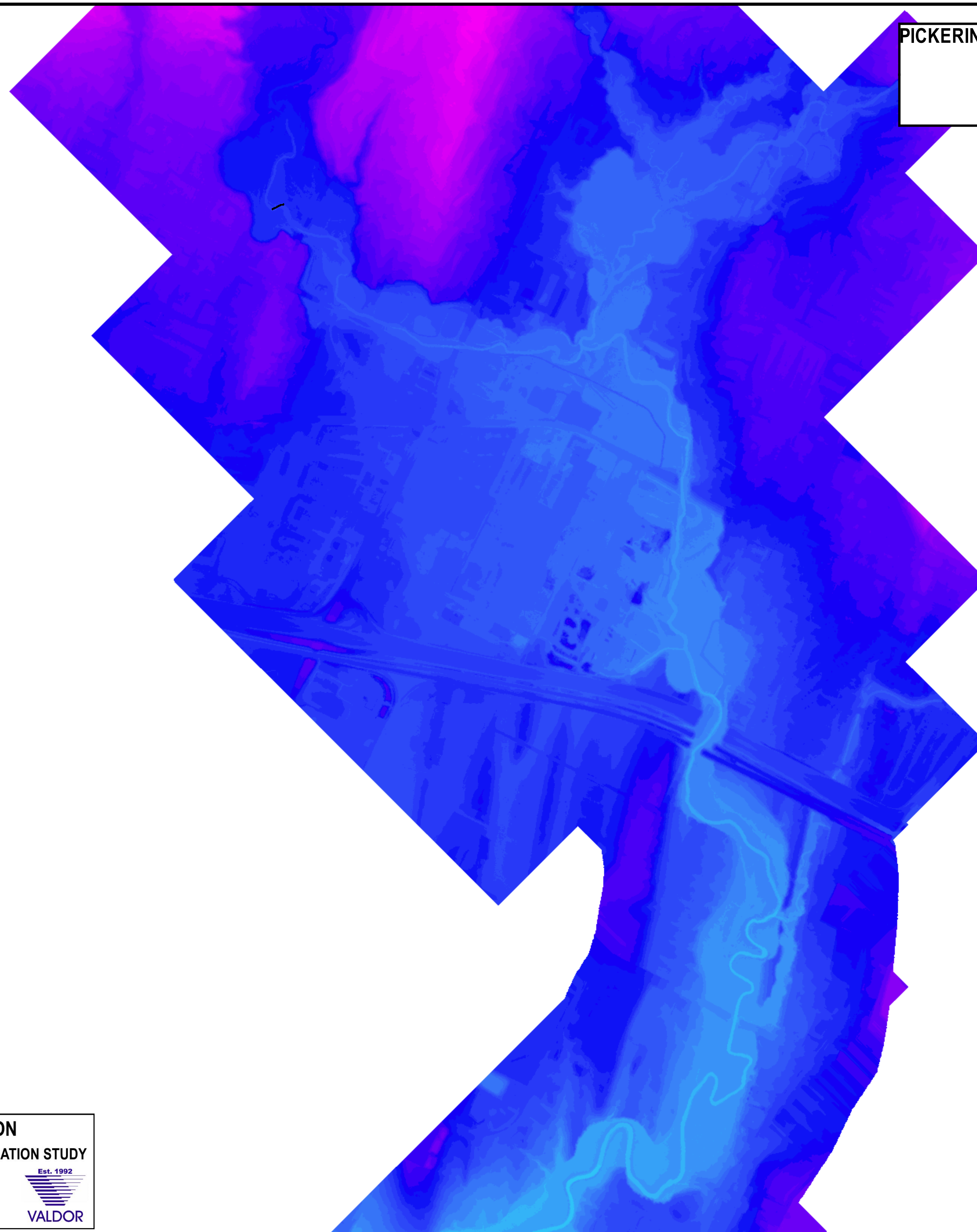


Figure B.4
50cm 1D-2D Combined
Corrected Raster DEM



PICKERING AJAX SPA 2D HYDRAULIC MODEL AND DYKES ASSESSMENT

N

LEGEND

Raster DEM Corrected

- 65.36733446 - 66.72710431
- 66.72710432 - 68.99338738
- 68.99338739 - 71.71292707
- 71.71292708 - 73.97921014
- 73.97921015 - 74.88572337
- 74.88572338 - 76.24549321
- 76.24549322 - 78.05851967
- 78.05851968 - 79.87154613
- 79.87154614 - 81.68457259
- 81.6845726 - 83.04434243
- 83.04434244 - 84.85736889
- 84.8573689 - 86.67039535
- 86.67039536 - 88.4834218
- 88.48342181 - 90.29644826
- 90.29644827 - 92.10947472
- 92.10947473 - 93.92250118
- 93.92250119 - 95.73552764
- 95.73552765 - 97.5485541
- 97.54855411 - 99.36158055
- 99.36158056 - 101.174607
- 101.1746071 - 102.9876335
- 102.9876336 - 104.8006599
- 104.80066 - 106.6136864
- 106.6136865 - 108.4267128
- 108.4267129 - 110.2397393
- 110.2397394 - 112.0527658
- 112.0527659 - 113.8657922
- 113.8657923 - 115.6788187
- 115.6788188 - 117.4918451
- 117.4918452 - 119.7581282

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Figure B.5a Mike 11 1D-River Network, Banklines and Cross-Section Cutlines

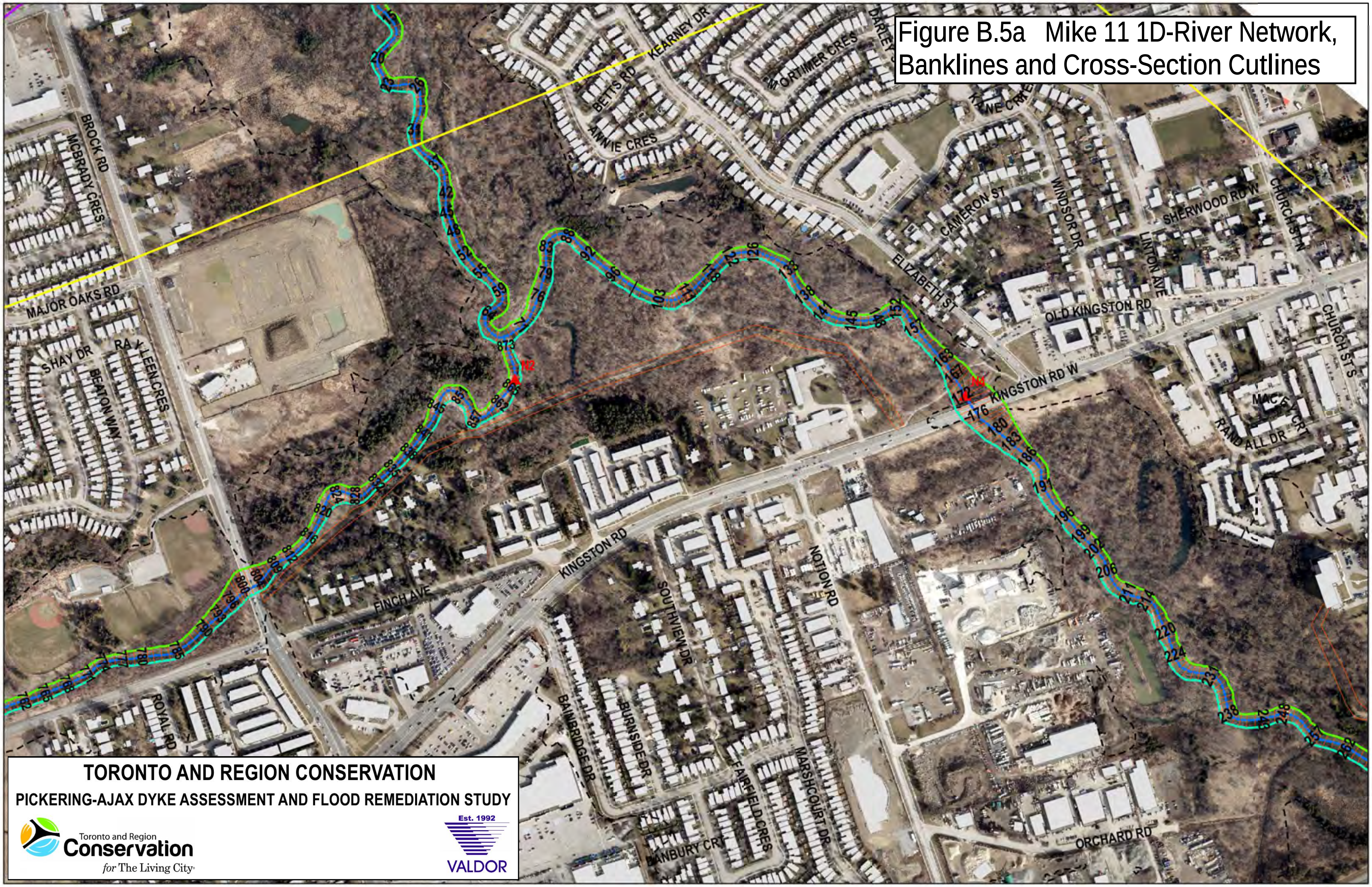

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Figure B.5b Mike 11 1D-River Network, Banklines and Cross-Section Cutlines

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Figure B.5c Mike 11 1D-River Network, Banklines and Cross-Section Cutlines

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Figure B.6a Example Showing Survey Data as Converted into Mike 11 Structure Opening

S5

AVG **17134 - Pickering**

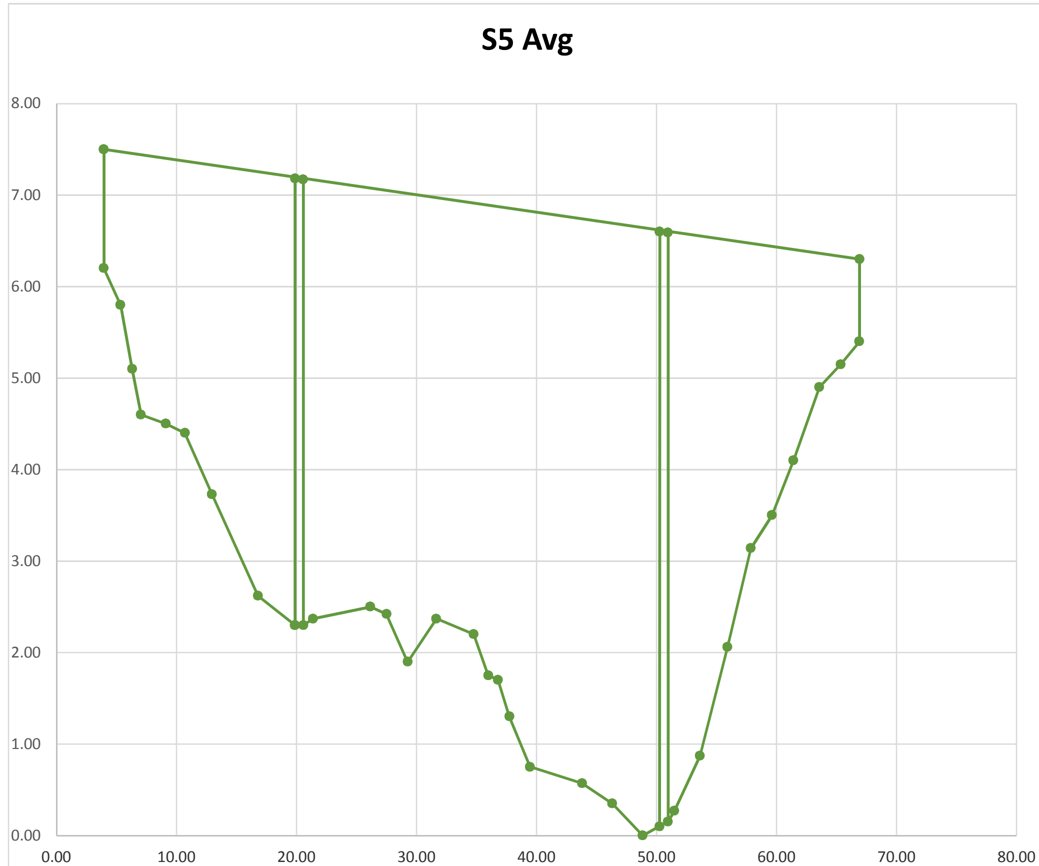
Location: Kingston Rd

Survey Data

Point #	Adjusted Horizontal Distance (m)	Elevation (m)	
1	3.95	84.70	
2	3.95	83.40	
3	5.33	83.00	
4	6.30	82.30	
5	7.04	81.80	
6	9.10	81.70	
7	10.70	81.60	
8	12.96	80.93	
9	16.80	79.82	
10	19.87	79.50	
11	19.88	79.50	
12	19.88	84.38	
13	20.56	84.37	
14	20.57	79.50	
15	21.37	79.57	
16	26.16	79.70	
17	27.50	79.62	
18	29.26	79.10	
19	31.65	79.57	
20	34.77	79.40	
21	35.98	78.95	
22	36.80	78.90	
23	37.74	78.50	
24	39.47	77.95	
25	43.81	77.77	
26	46.32	77.55	
27	48.84	77.20	Lowes
28	50.25	77.30	
29	50.26	83.80	
30	50.95	83.79	
31	50.96	77.35	
32	51.487	77.47	
33	53.63	78.07	
34	55.92	79.26	
35	57.86	80.34	
36	59.62	80.7	
37	61.4	81.3	
38	63.56	82.1	
39	65.36	82.35	
40	66.9	82.6	
41	66.92	83.5	
42	3.952	84.7	

Adjusted Horizontal Distance (m)	Corrected Vertical Distance (m)
3.95	7.50
3.95	6.20
5.33	5.80
6.30	5.10
7.04	4.60
9.10	4.50
10.70	4.40
12.96	3.73
16.80	2.62
19.87	2.30
19.88	2.30
19.88	7.18
20.56	7.17
20.57	2.30
21.37	2.37
26.16	2.50
27.50	2.42
29.26	1.90
31.65	2.37
34.77	2.20
35.98	1.75
36.80	1.70
37.74	1.30
39.47	0.75
43.81	0.57
46.32	0.35
48.84	0.00
50.25	0.10
50.26	6.60
50.95	6.59
50.96	0.15
51.49	0.27
53.63	0.87
55.92	2.06
57.86	3.14
59.62	3.50
61.40	4.10
63.56	4.90
65.36	5.15
66.90	5.40
66.92	6.30
3.95	7.50

Depth	Width
0	0
0.35	3.94
0.57	7.28
0.75	12.28
1.7	16.94
1.75	17.94
1.9	18.62
2.2	22.94
2.37	26.28
2.5	36.6
3.14	40.6
3.5	43.28
4.4	49.28
4.6	53.28
4.9	54.6
5.4	58.94
6.2	60.6
6.3	60.6
7.184	16
7.5	0



TORONTO AND REGION CONSERVATION

PICKERING-AJAX DYKE ASSESSMENT AND FLOOD REMEDIATION STUDY

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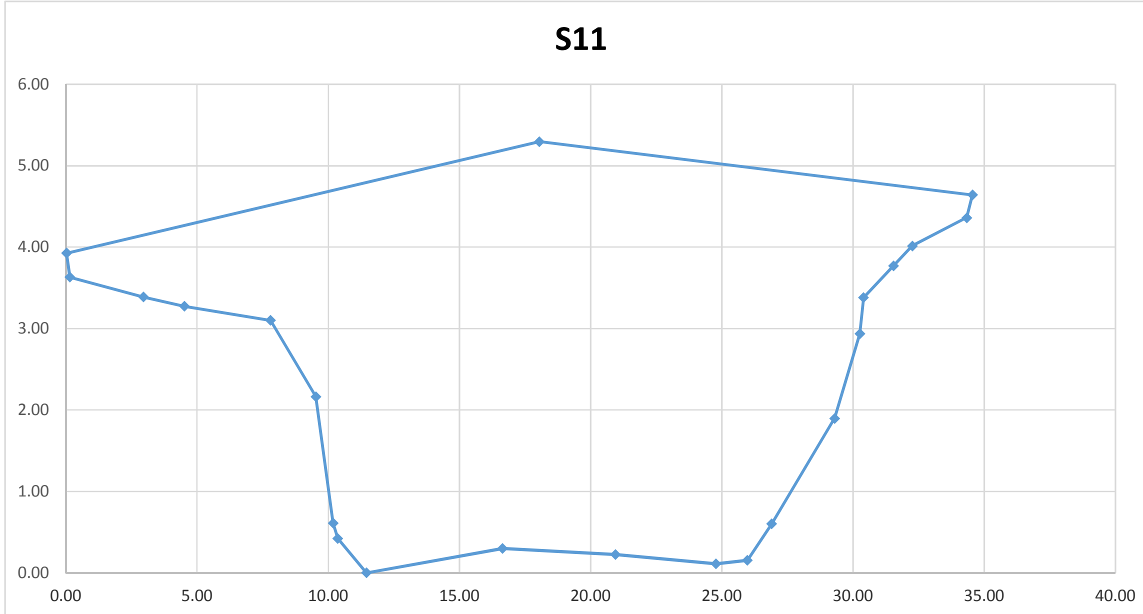
Point #	Horizontal Distance (m)	Elevation (m)		Adjusted Horizontal Distance (m)	Corrected Vertical Distance (m)
1	0.00	79.79		0.03	3.93
2	0.13	79.49		0.16	3.63
3	2.93	79.25		2.96	3.39
4	4.49	79.14		4.52	3.27
5	7.77	78.96		7.79	3.10
6	9.50	78.03		9.53	2.16
7	10.16	76.47		10.18	0.61
8	10.34	76.28		10.37	0.42
9	11.43	75.86	Lowest	11.46	0.00
10	16.62	76.16		16.65	0.30
11	20.92	76.09		20.95	0.23
12	24.75	75.97		24.78	0.11
13	25.94	76.02		25.97	0.15
14	26.87	76.46		26.90	0.60
15	29.27	77.76		29.30	1.90
16	30.23	78.80		30.26	2.94
17	30.37	79.24		30.40	3.38
18	31.51	79.63		31.54	3.77
19	32.23	79.88		32.26	4.01
20	34.30	80.22		34.33	4.36
21	34.53	80.50		34.55	4.64
22	18.02	81.16		18.05	5.30
23	0.00	79.79		0.03	3.93



S11

Deck TRCA and Valdor Survey

Point	Distance (m)	Elevation (m)
1	0.03	80.09
2	18.05	81.458
3	34.55	80.803

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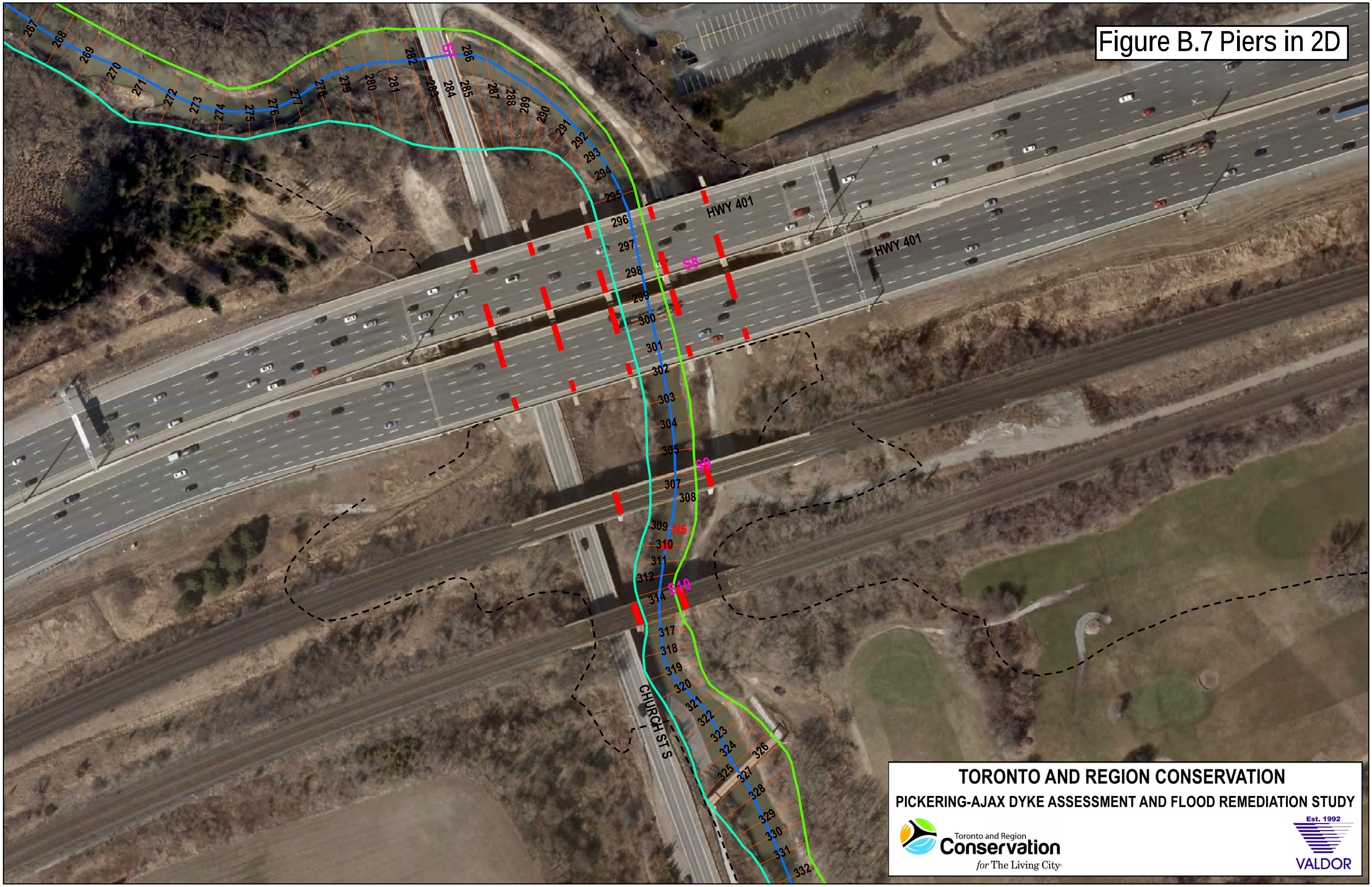
Figure B.6b Example Showing Survey Data as Converted into Mike 11 Structure Opening

Figure B.7 Piers in 2D



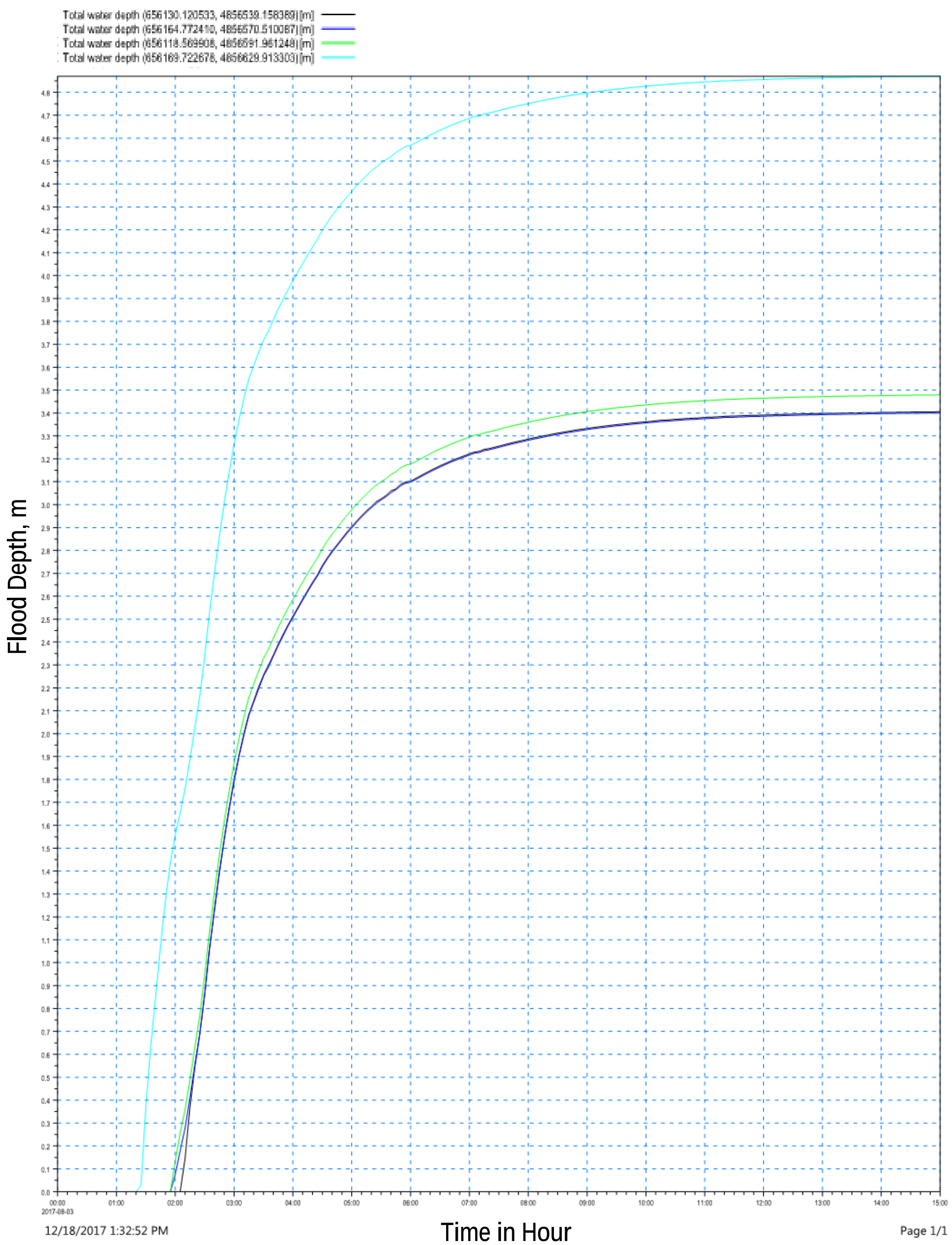


Figure B.8a Time Series Regional Flood Depth at Different Locations North of 401 near Notion Road

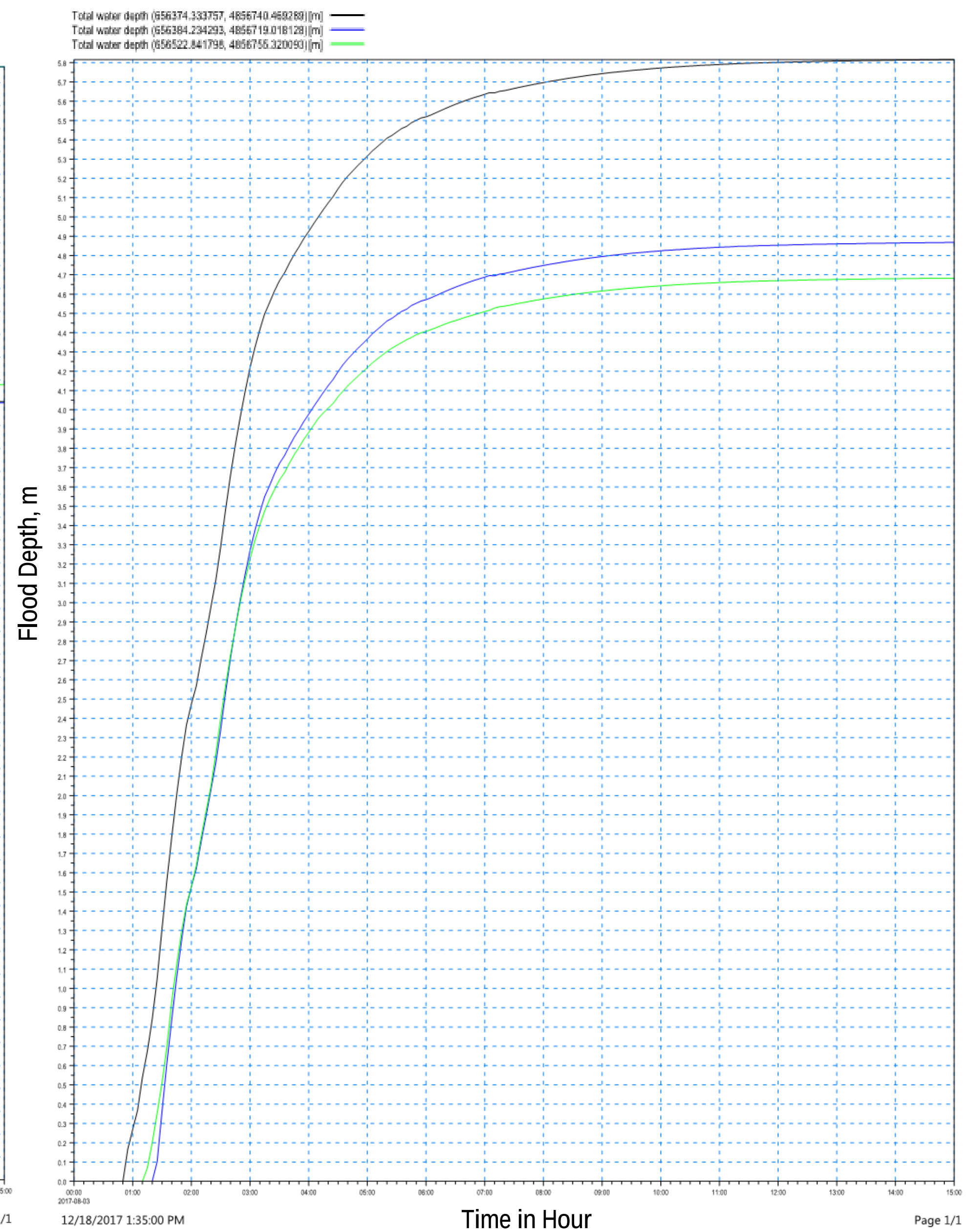


Figure B.8b Time Series Regional Flood Depth at Different Locations North of 401 near Church Street South

Table B.1 Land Use and Mike Flood Roughness

Available TRCA Code	Surface	Roughness (n-value)	Roughness (M-value)	GIS Map Unit
Road (Paved Surface)	Paved Surface	0.025	40	1
Parking Lot (Paved Surface)	Paved Surface	0.025	40	2
Road (ROW)	Urban Pervious	0.05	20	3
Residential Low Medium	Urban Pervious	0.05	20	4
	Natural Area	0.08	12.5	5
Residential High	Urban Pervious	0.05	20	6
Commercial	Paved Surface	0.025	40	7
	Urban Pervious	0.05	20	8
Industrial	Urban Pervious	0.05	20	9
	Natural Area	0.08	12.5	10
Institutional	Urban Pervious	0.05	20	11
	Natural Area	0.08	12.5	12
Park	Urban Pervious	0.05	20	13
	Natural Area	0.08	12.5	14
Conservation Lands	Urban Pervious	0.05	20	15
	Natural Area	0.08	12.5	16
Cemetery	Urban Pervious	0.05	20	17
	Natural Area	0.08	12.5	18
Farm	Urban Pervious	0.05	20	19
	Natural Area	0.08	12.5	20
Open Space	Urban Pervious	0.05	20	21
	Natural Area	0.08	12.5	22
Golf Course	Urban Pervious	0.05	20	23
Hydro Corridor	Urban Pervious	0.05	20	24
Transportation	Urban Pervious	0.05	20	25
Building	Building	0.0001	10000	26

Table B.2 Roughness for Bridge, Culvert & Weir

Bridge / Culvert	n Value for Opening	Remarks
S1	0.024	0.013 (Concrete) 0.035 (Natural)
S2	0.024	0.013 (Concrete) 0.035 (Natural)
S3	0.025	0.015 (Wood) 0.035 (Natural)
S4	0.025	0.015 (Steel) 0.035 (Natural)
S5	0.024	0.013 (Concrete) 0.035 (Natural)
S6	0.013	0.013 (Concrete Weir)
S7	0.024	0.013 (Concrete) 0.035 (Natural)
S8	NA	Concrete Piers in 2D
S9	NA	
S10	0.013	Concrete Piers in 1D
S11	0.025	0.015 (Wood) 0.035 (Natural)
S12	0.024	0.013 (Concrete) 0.035 (Natural)

Detailed Calculation

$$nC1 = \frac{(0.80+49.00+1.35)\times 0.013+48.35\times 0.035}{0.80+49.00+1.35+48.35} = 0.024$$

$$nC2 = \frac{(1.82+1.72+36.26)\times 0.013+36.57\times 0.035}{1.82+1.72+36.26+36.57} = 0.024$$

$$nC3 = \frac{28.68\times 0.015+30.30\times 0.035}{28.68+30.30} = 0.025$$

$$nC4 = \frac{44.25\times 0.015+48.03\times 0.035}{44.25+48.03} = 0.025$$

$$nC5 = \frac{(1.39+0.91+62.48)\times 0.013+64.80\times 0.035}{1.39+0.91+62.48+64.80} = 0.024$$

$$nC7 = \frac{(2.87+1.30+41.73)\times 0.013+42.81\times 0.035}{2.87+1.30+41.73+42.81} = 0.024$$

$$nC11 = \frac{(0.29+0.37+34.77)\times 0.015+37.24\times 0.035}{0.29+0.37+34.77+37.24} = 0.025$$

$$nC12 = \frac{(2.90+0.84+47.39)\times 0.013+47.81\times 0.035}{2.90+0.84+47.39+47.81} = 0.024$$

Road Deck, n = 0.015

Table B.3

Pickering 2D: Comparison of Dyke Survey Point Elevations vs LiDAR Elevations

Checking Point	Locations	Berm Survey Elevations (m)	LiDAR Elevations (m)	Differences (m)
1	At Brock Rd Bridge	85.70	85.718	0.018
2	East of Brock Road	85.7587	85.760597	0.002
3	East of Brock Road	84.783	84.833290	0.050
4	East of Brock Road	84.2791	84.224289	-0.055
5	Near Confluence	83.934	83.996628	0.062
6	Near Confluence	83.977	83.964973	-0.013
7	Near Pedestrian Bridge S3	82.0509	82.045624	-0.005
8	Near Pedestrian Bridge S3	81.339	81.329582	-0.010
9	At Kingston W	83.604	83.675110	0.071

APPENDIX ‘C’

Flow Data and Mike Flood Boundaries

Pickering/Ajax Mike Flood
1D-2D Model Development and Regulatory Floodplain Mapping

Toronto and Region Conservation Authority

Appendix ‘C’ Contents:

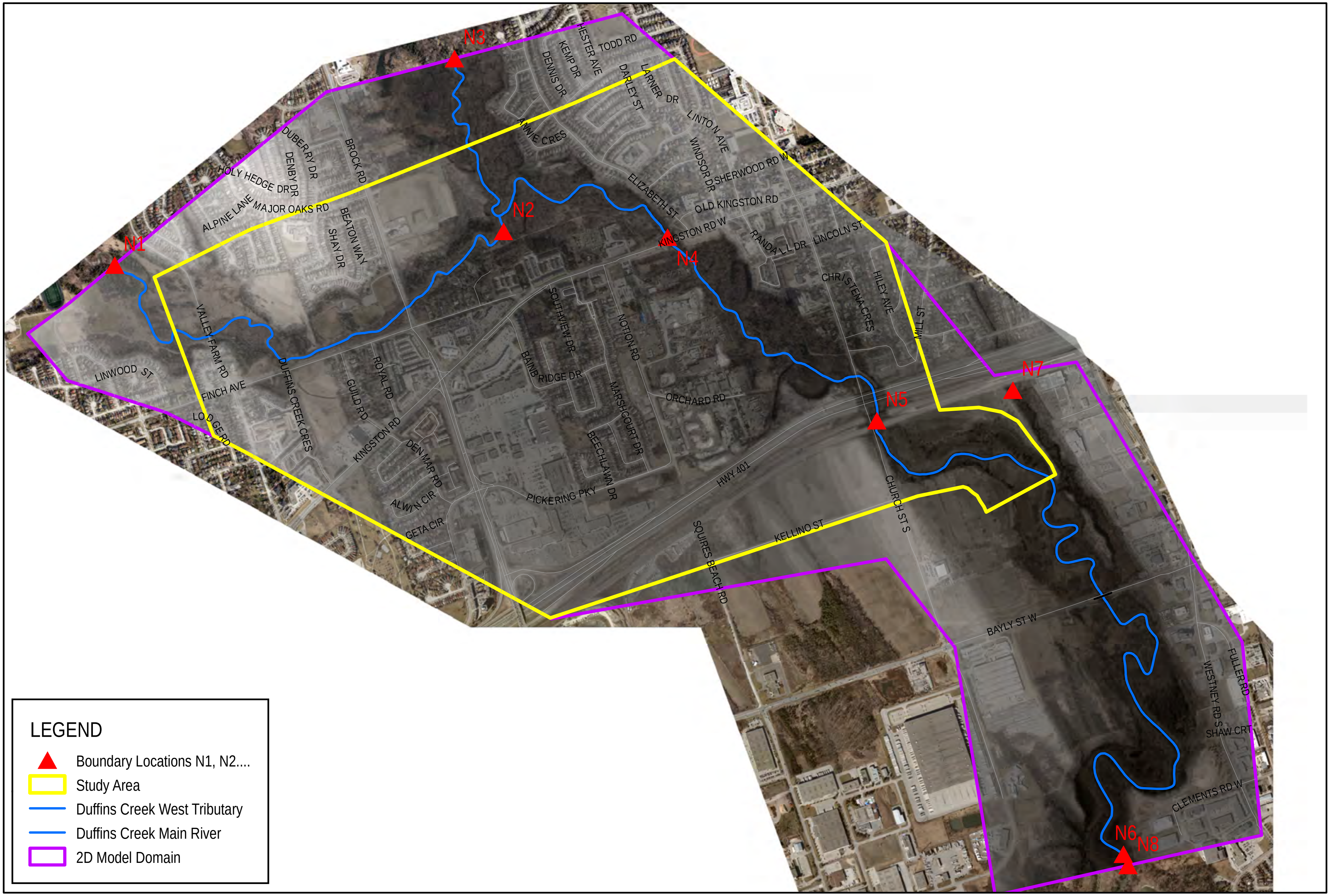


Figure C.1

MIKE FLOOD INFLOW INPUT AND BOUNDARY LOCATIONS

400 200 0 400 Meters

N

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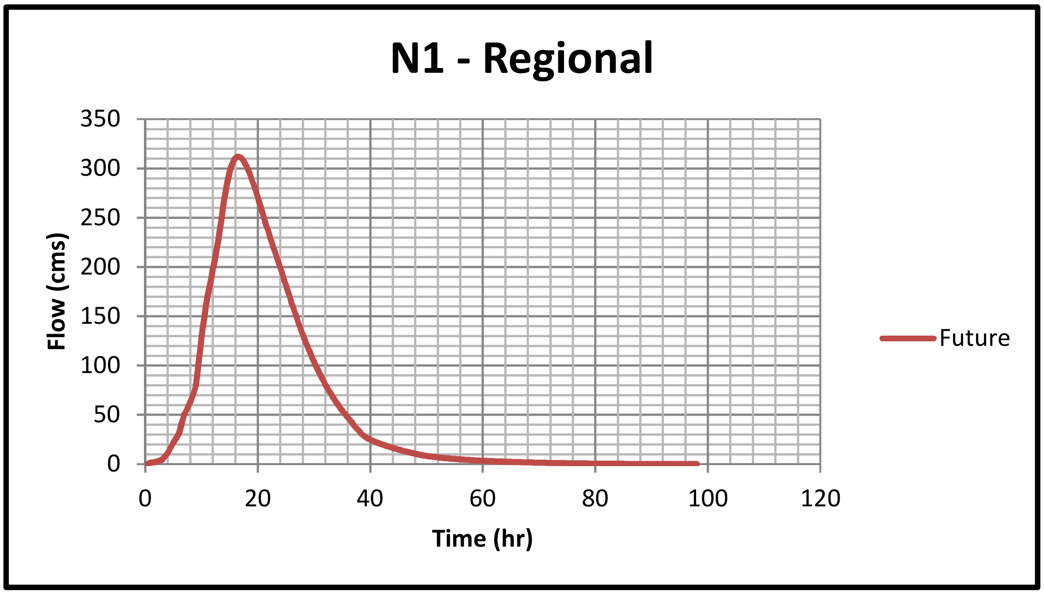
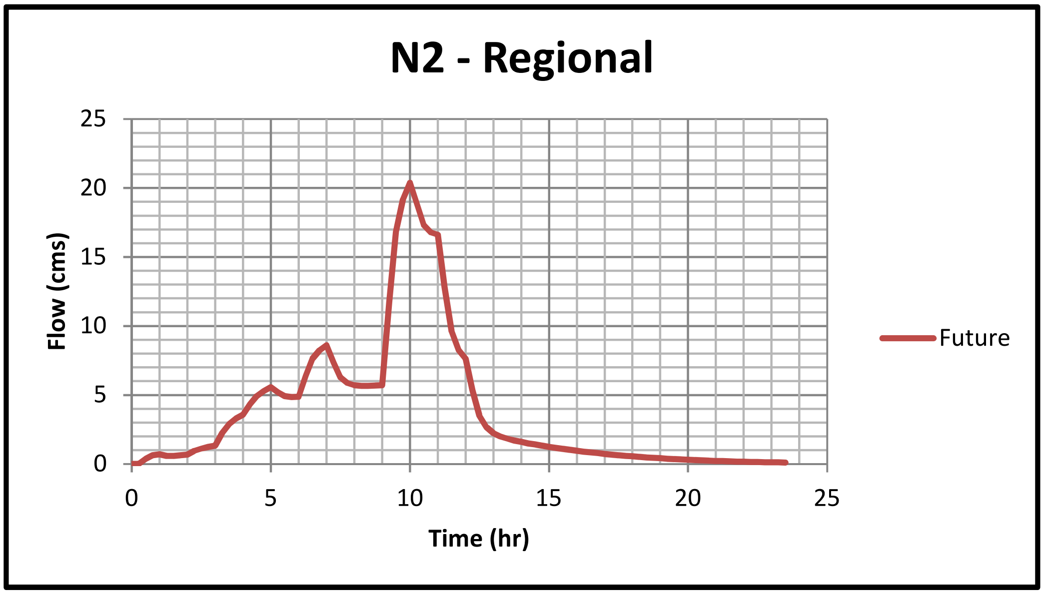
Figure C.2 - Regional Inflow Hydrographs (Pickering/Ajax SPA)





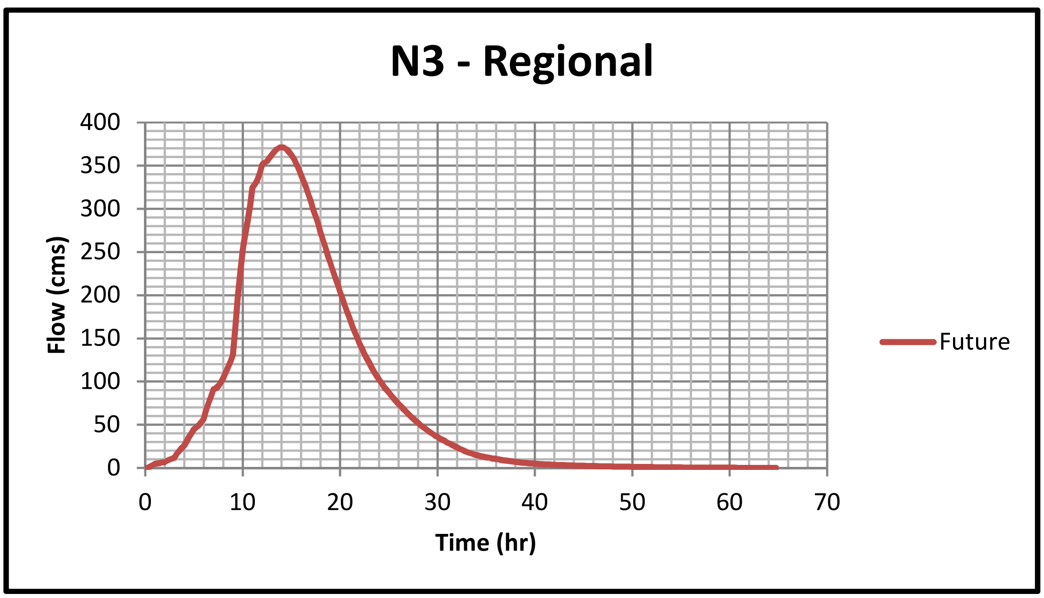
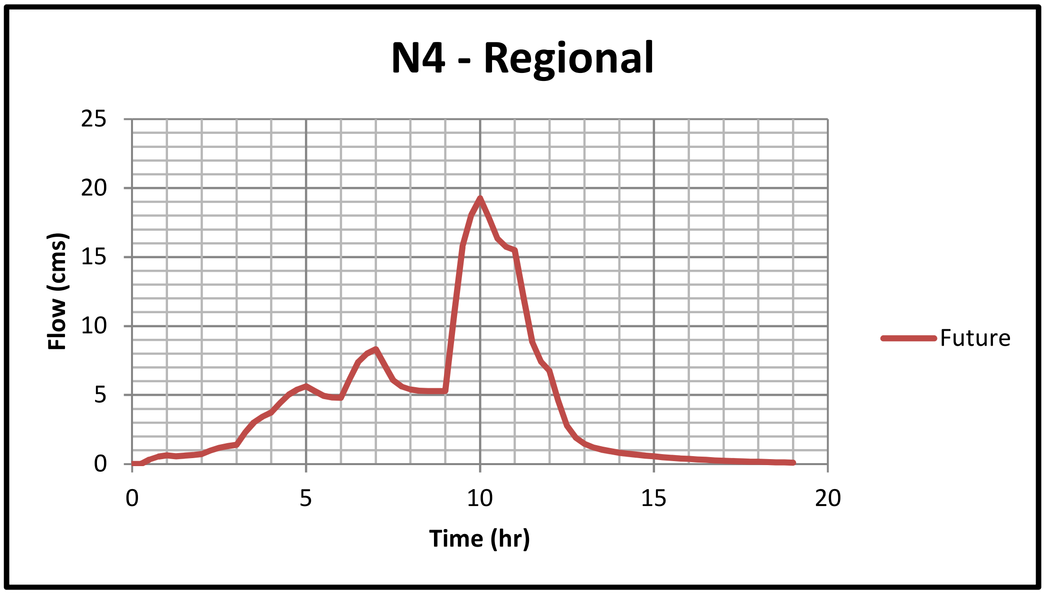
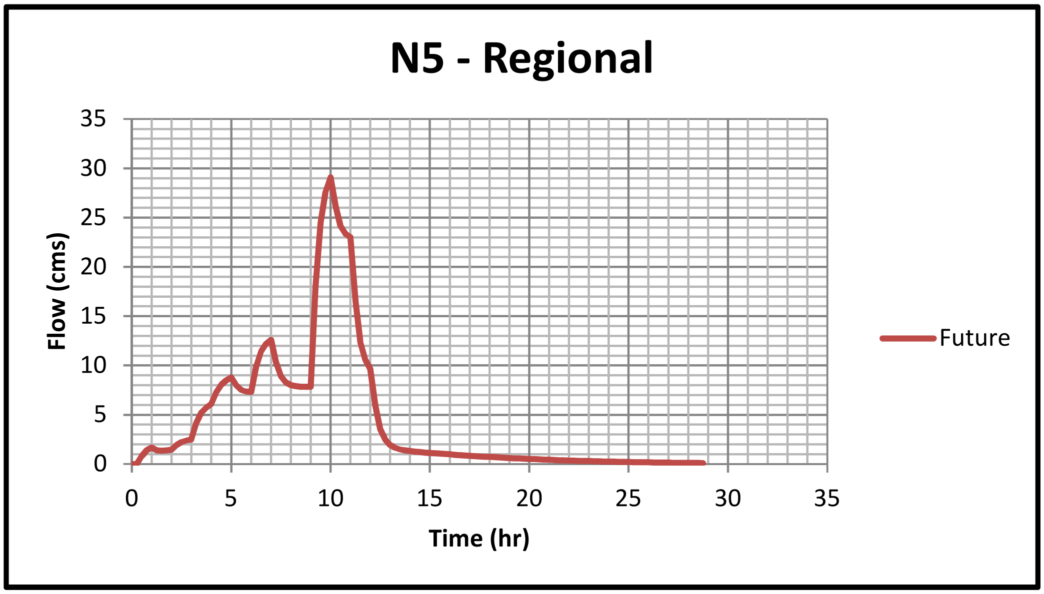
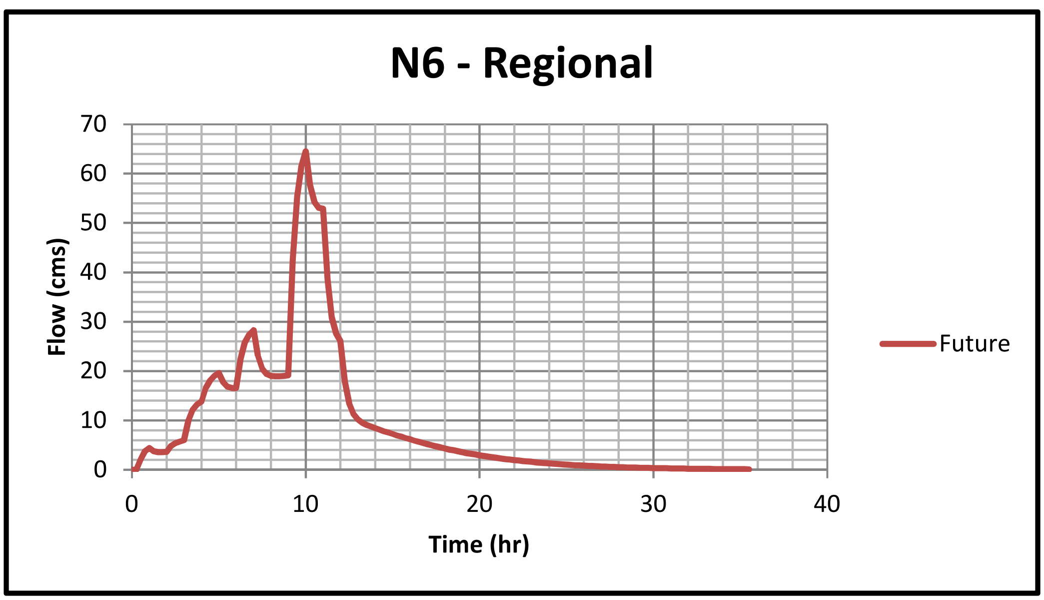


Figure C.2 (Cont'd.)







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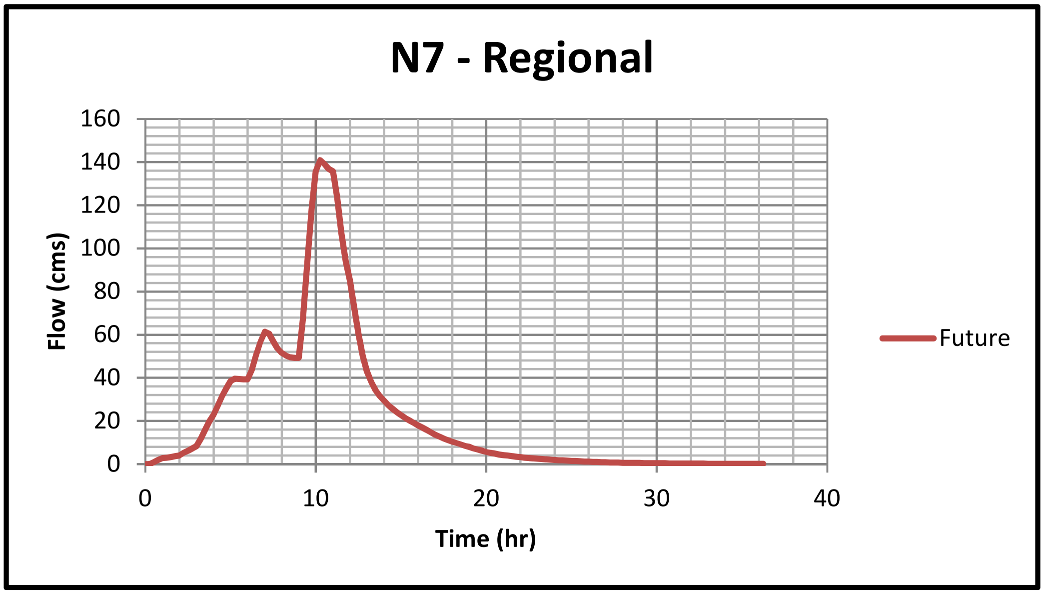
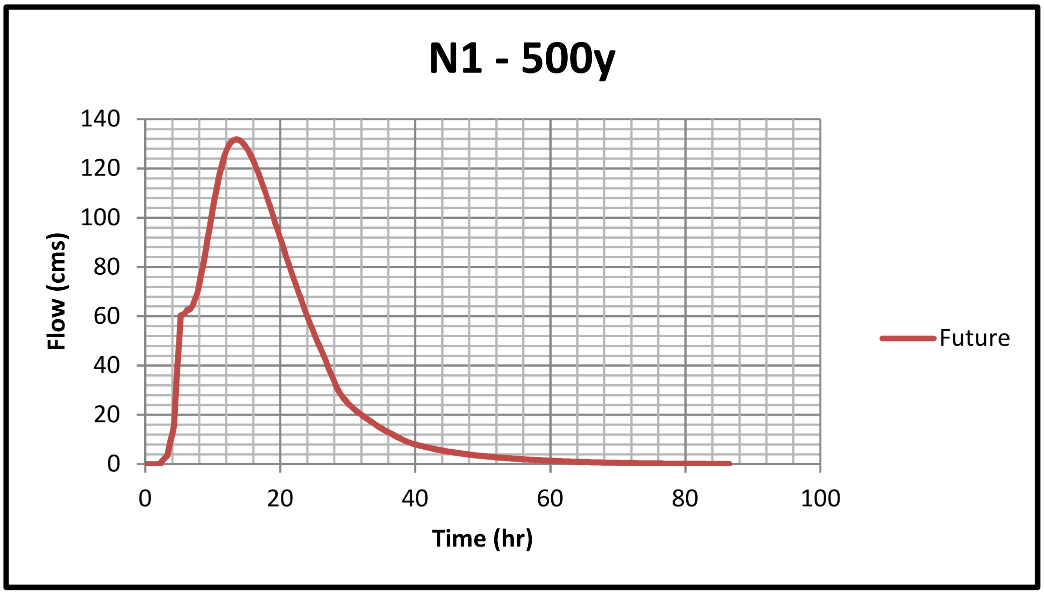
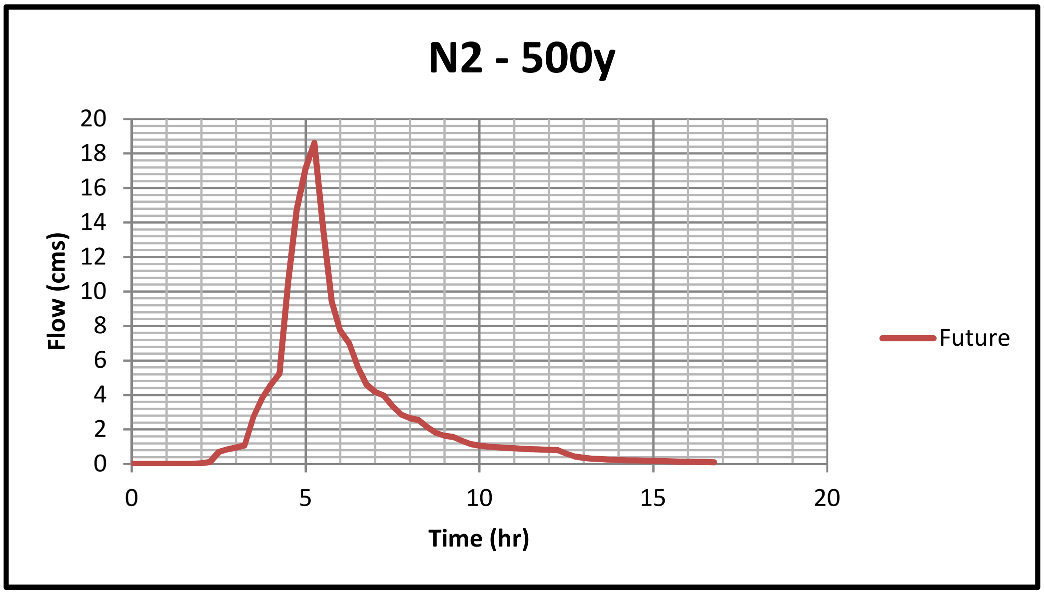
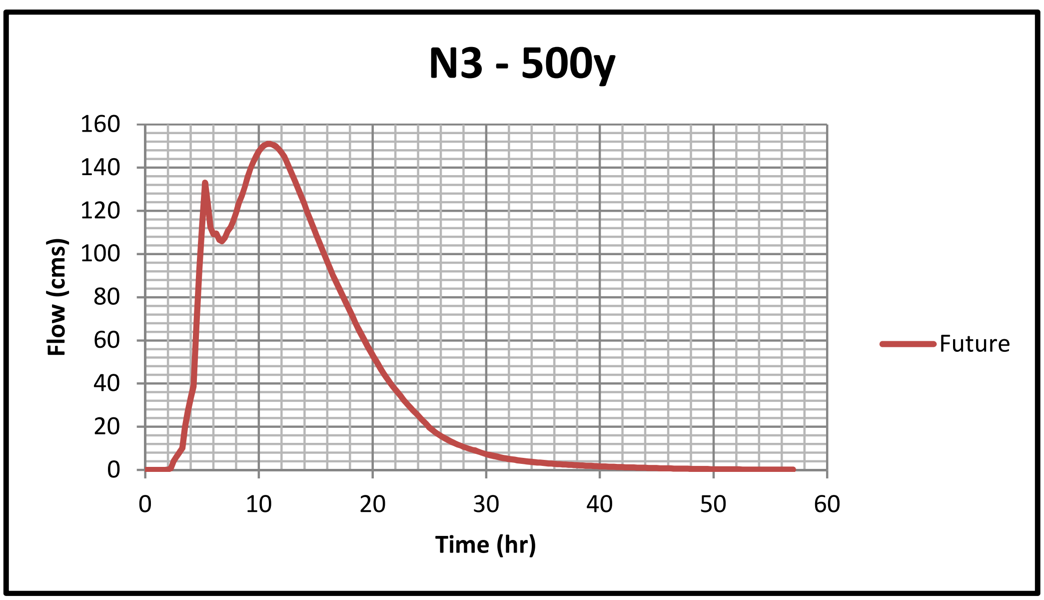


Figure C.3 - 500-yr Inflow Hydrographs (Pickering/Ajax SPA)







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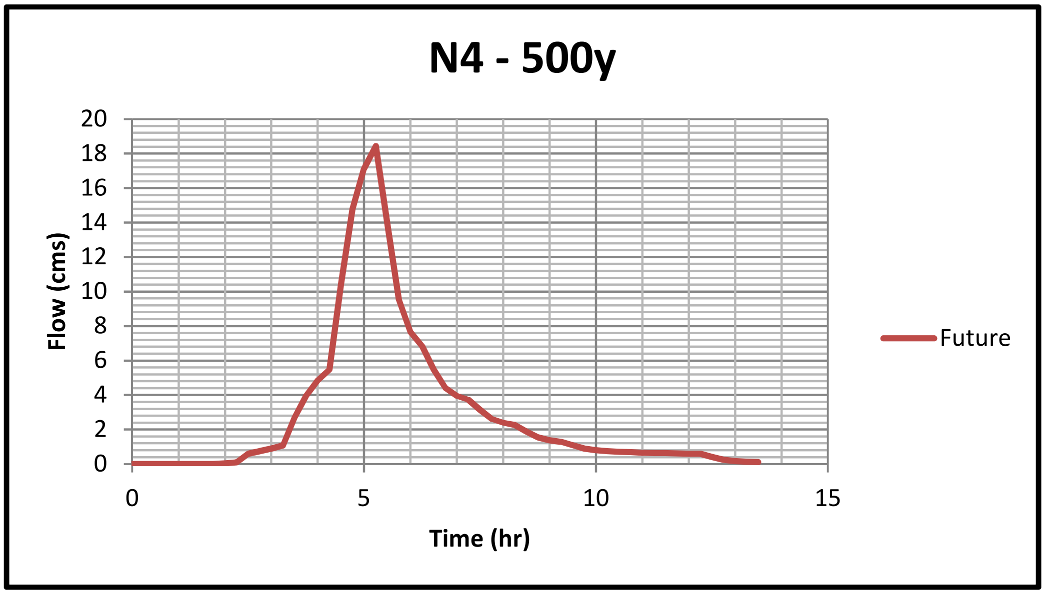

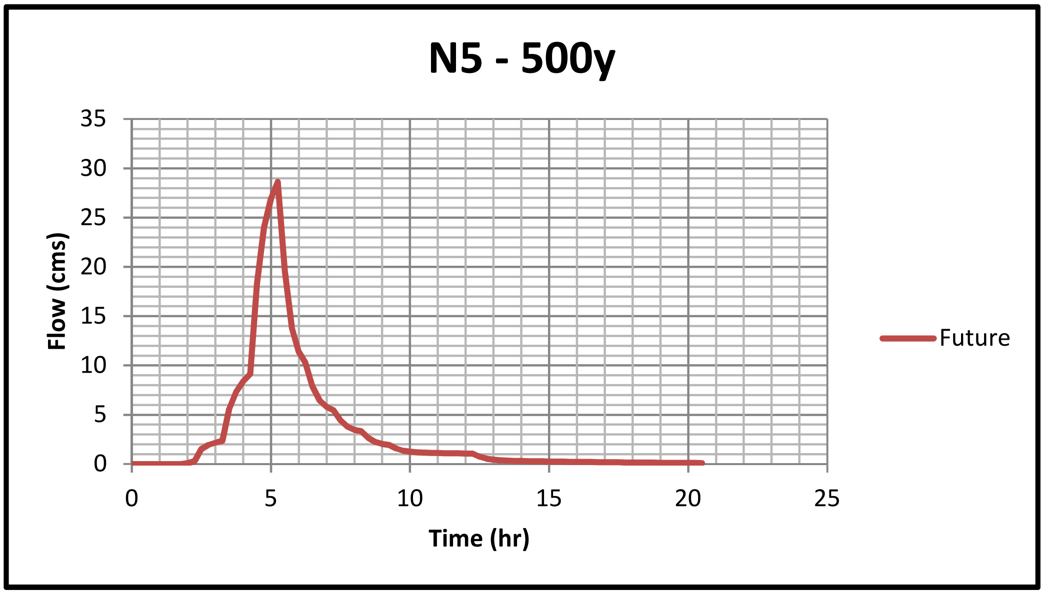

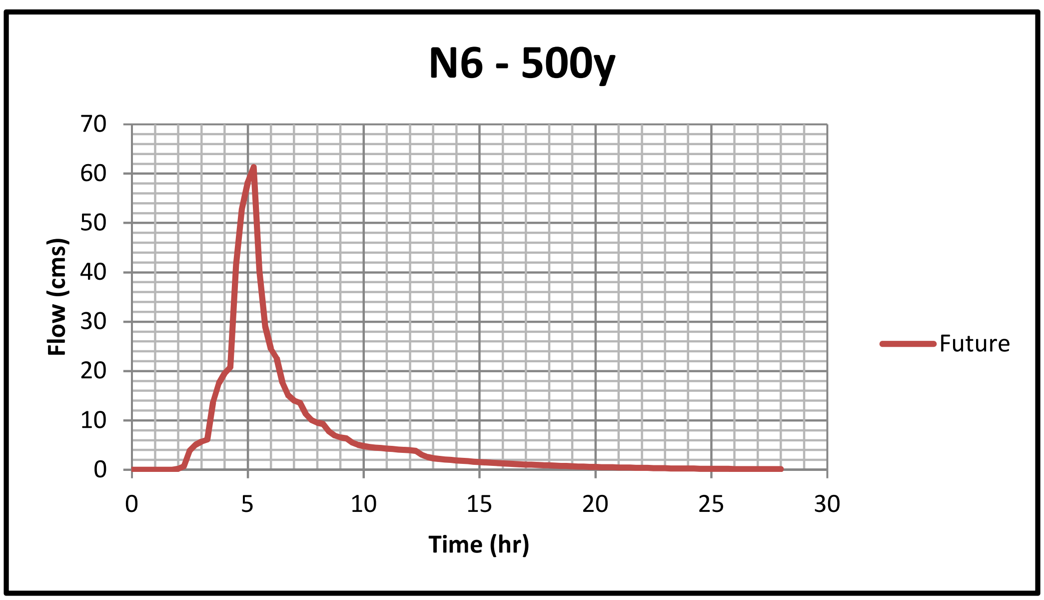

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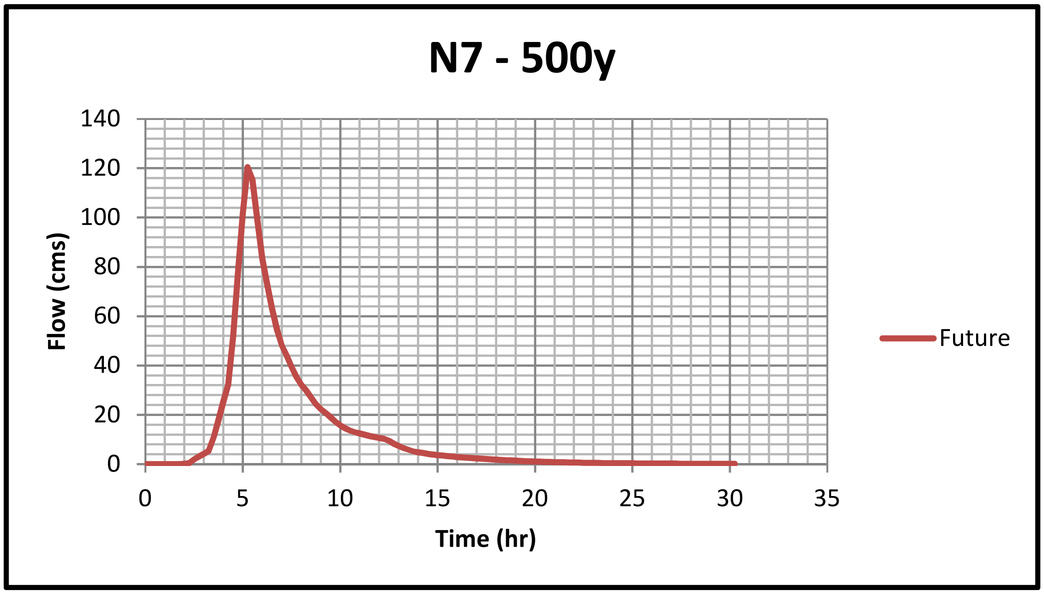
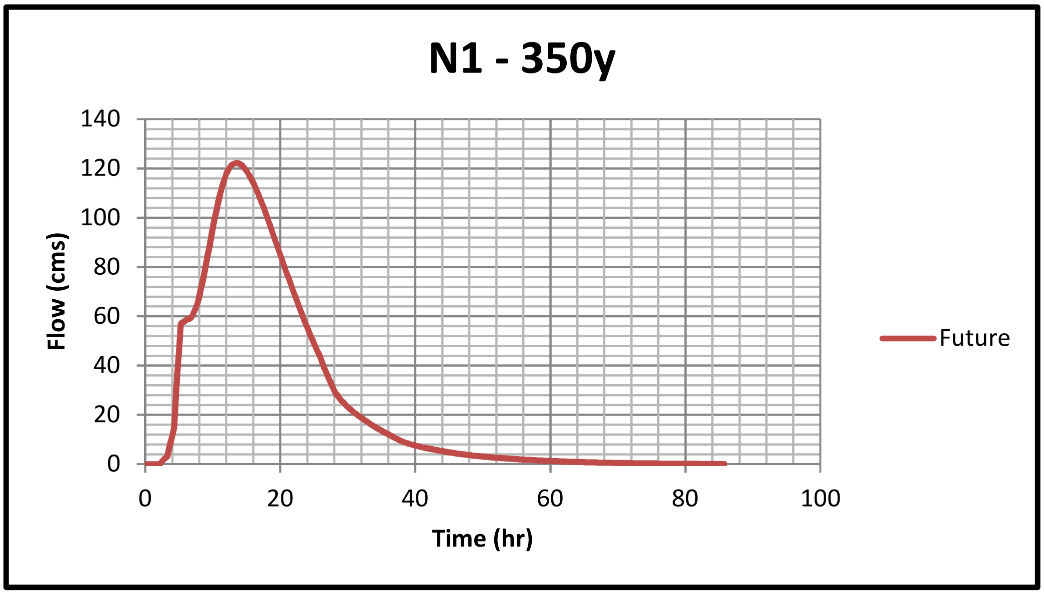
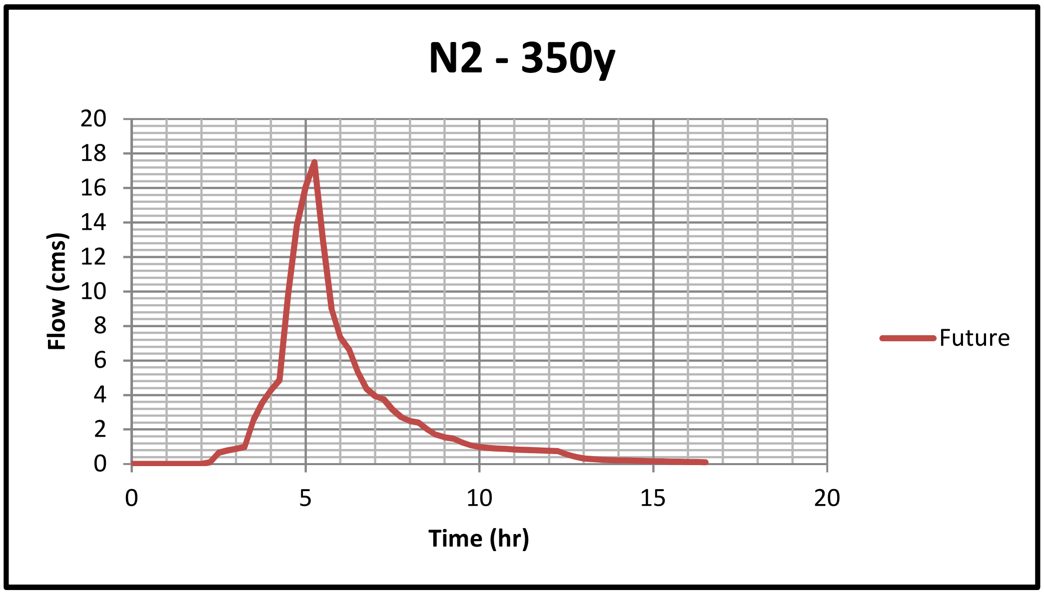
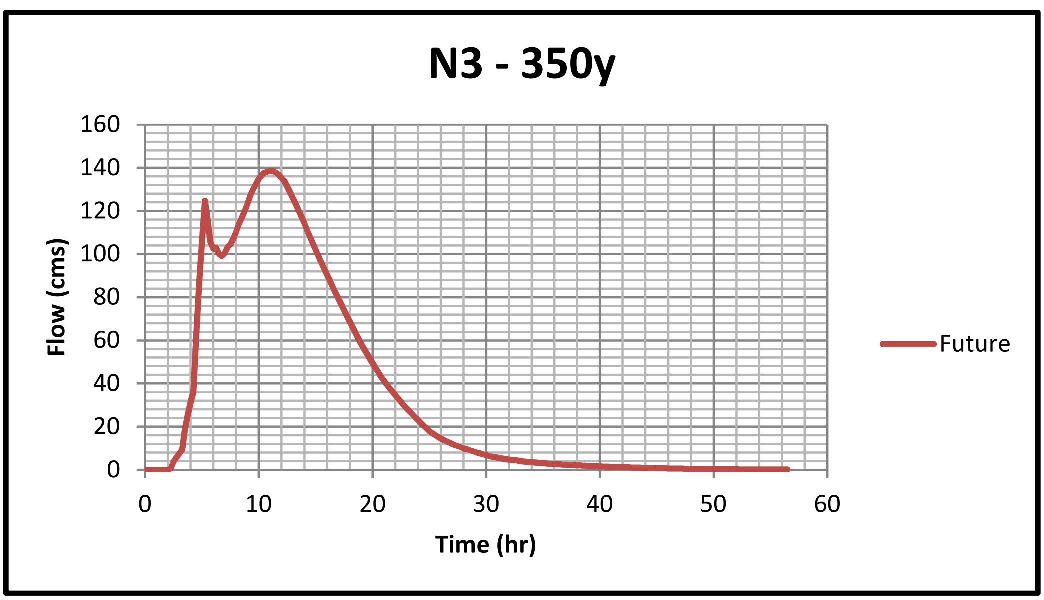


Figure C.4 - 350-yr Inflow Hydrographs (Pickering/Ajax SPA)







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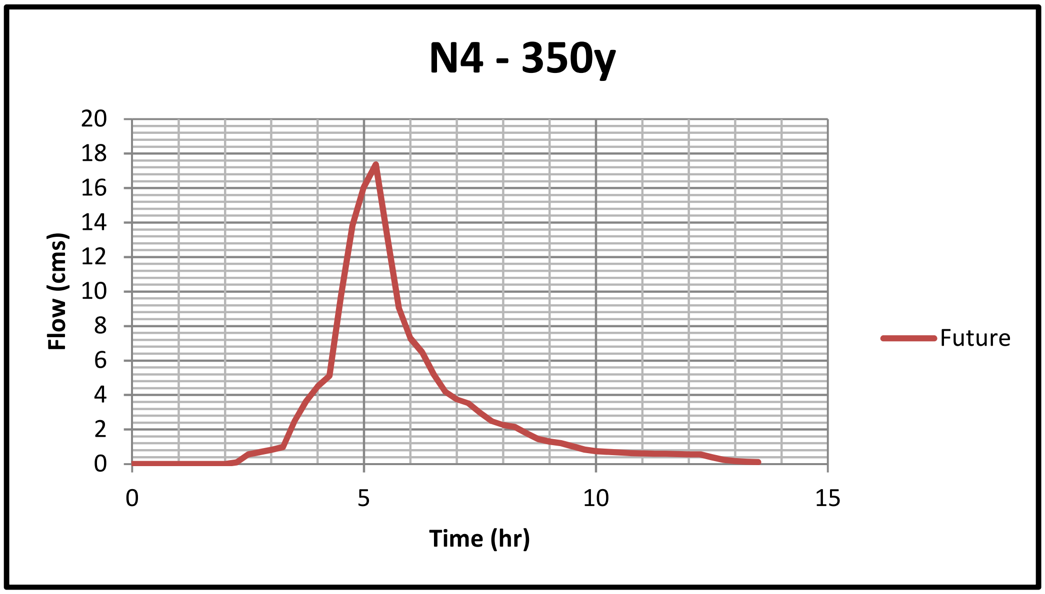

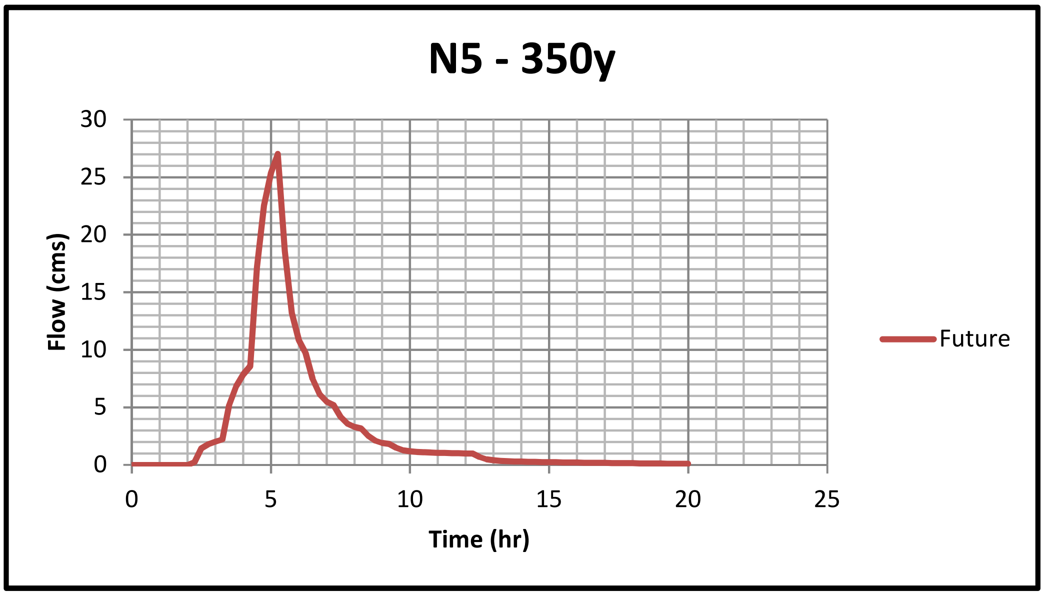

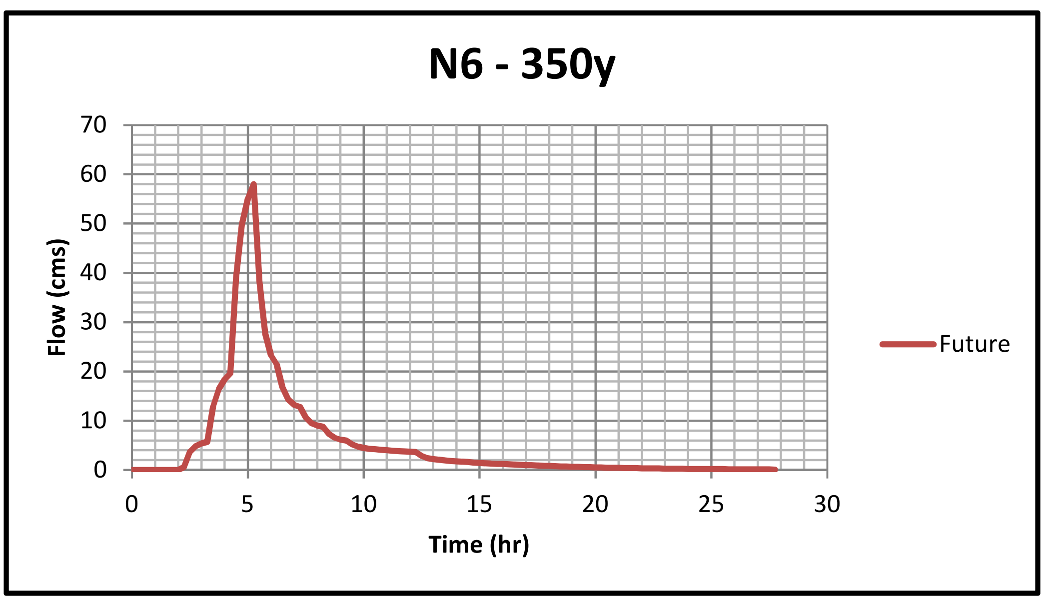

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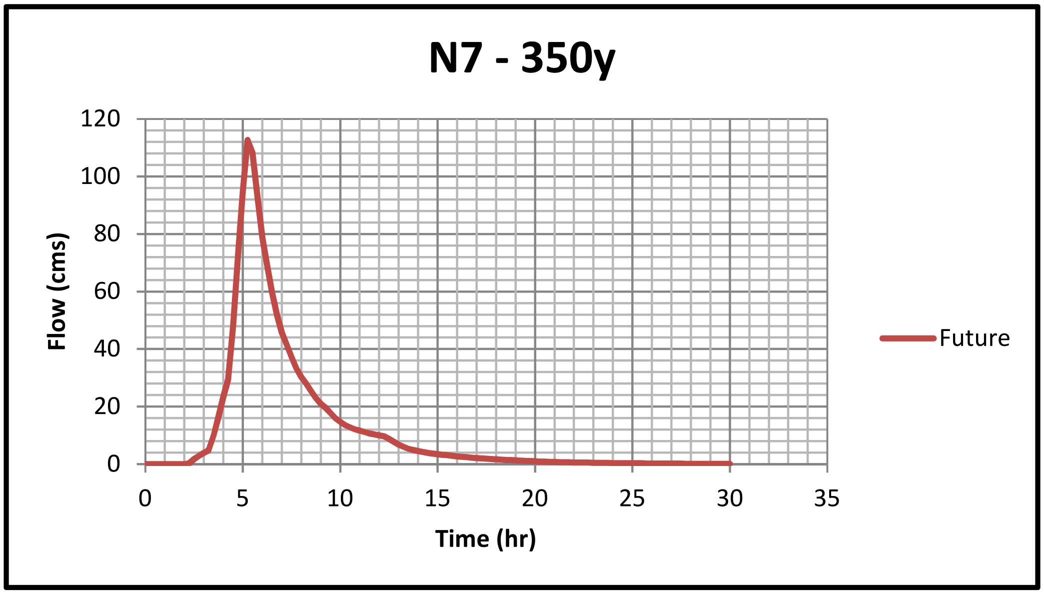
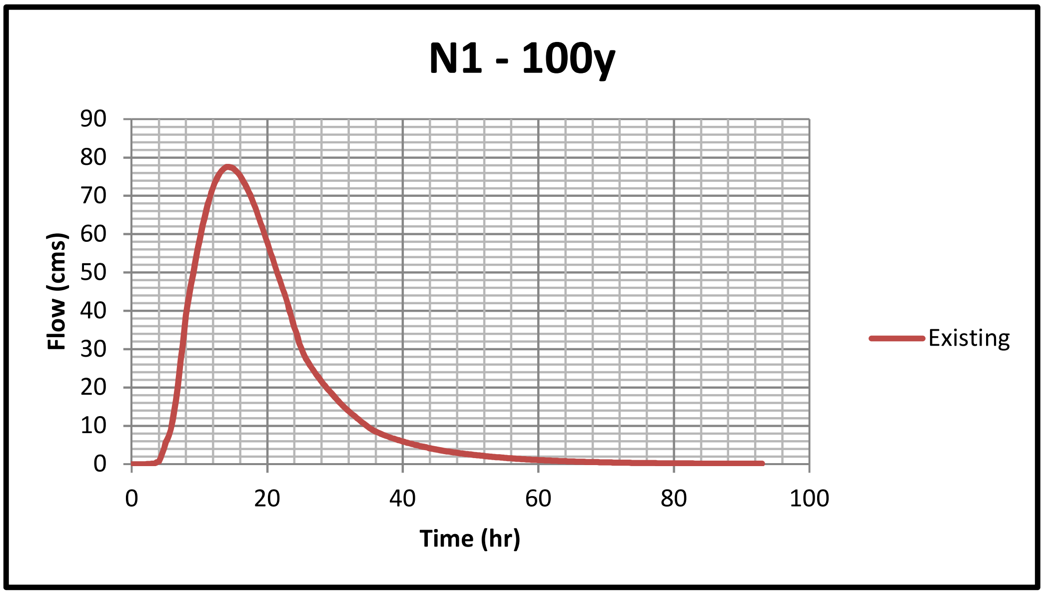
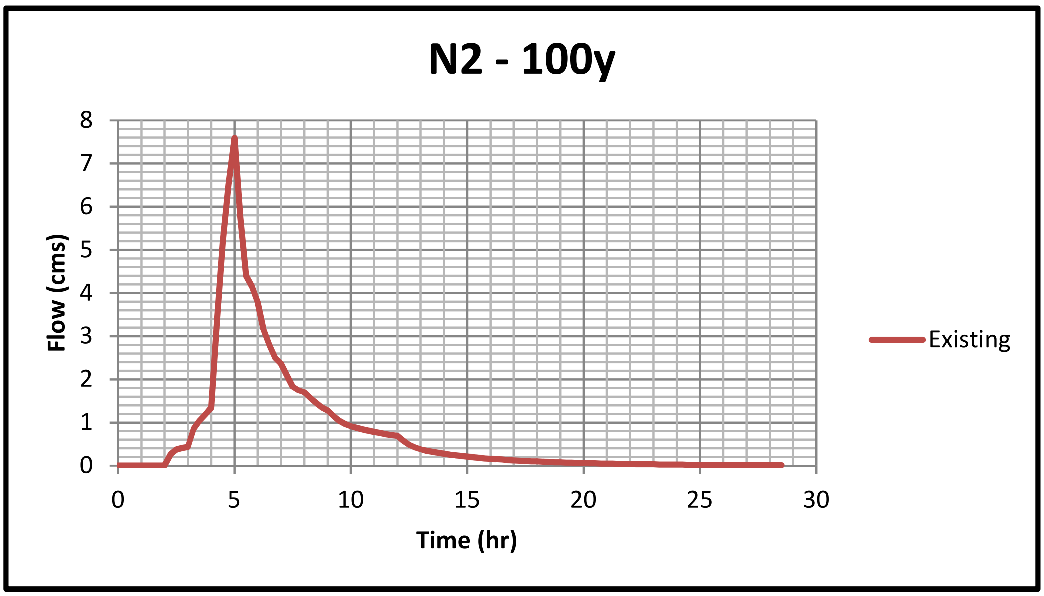
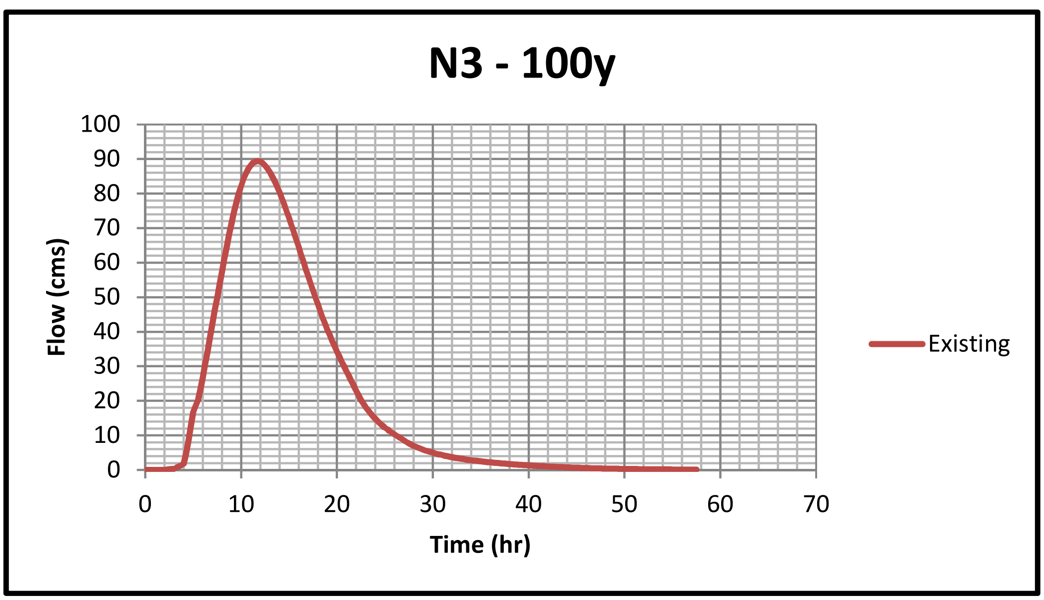


Figure C.5 - 100-yr Inflow Hydrographs (Pickering/Ajax SPA)







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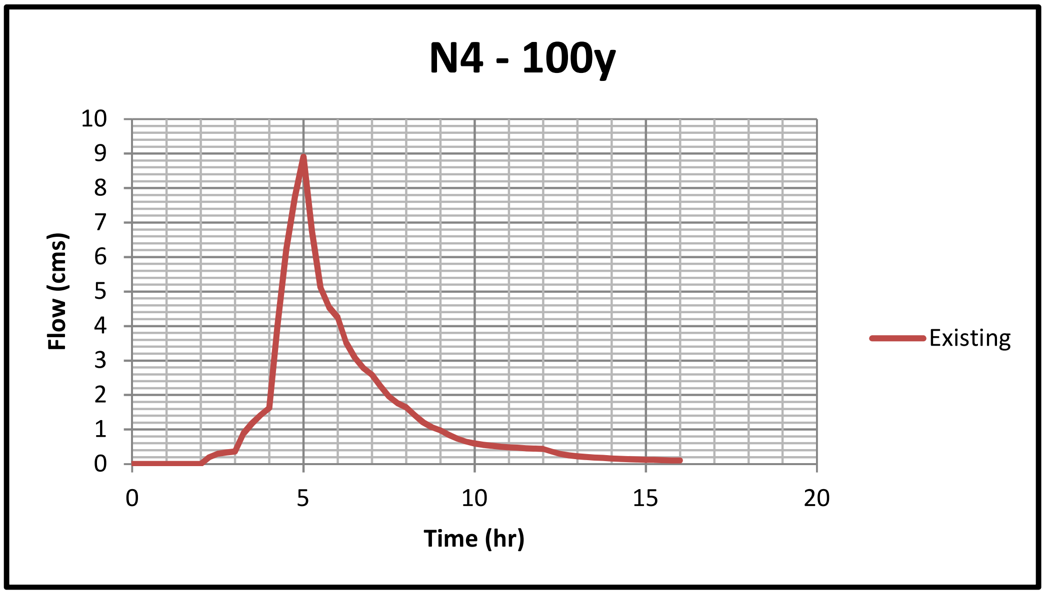

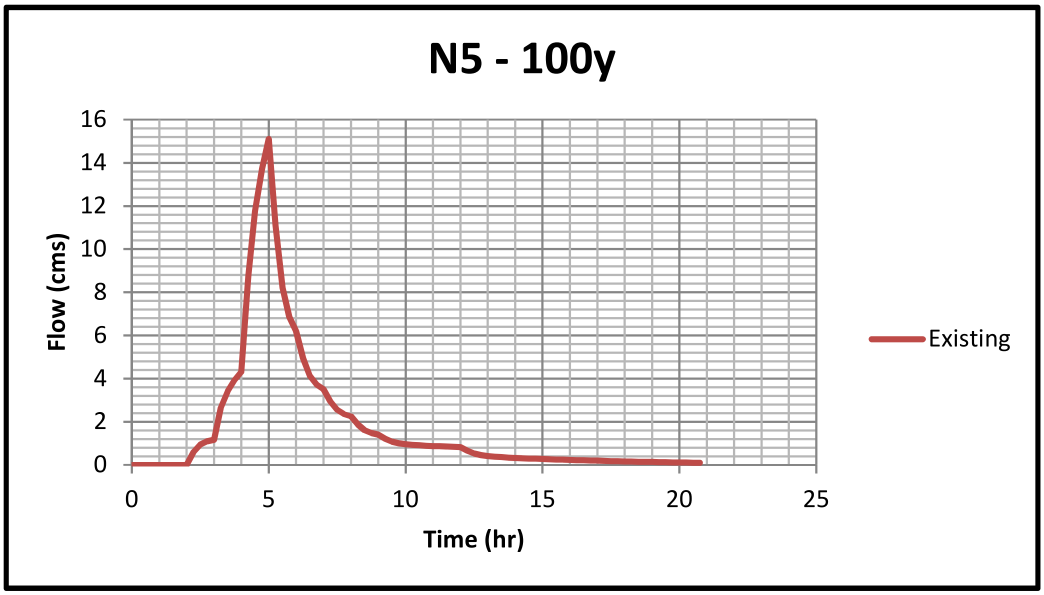

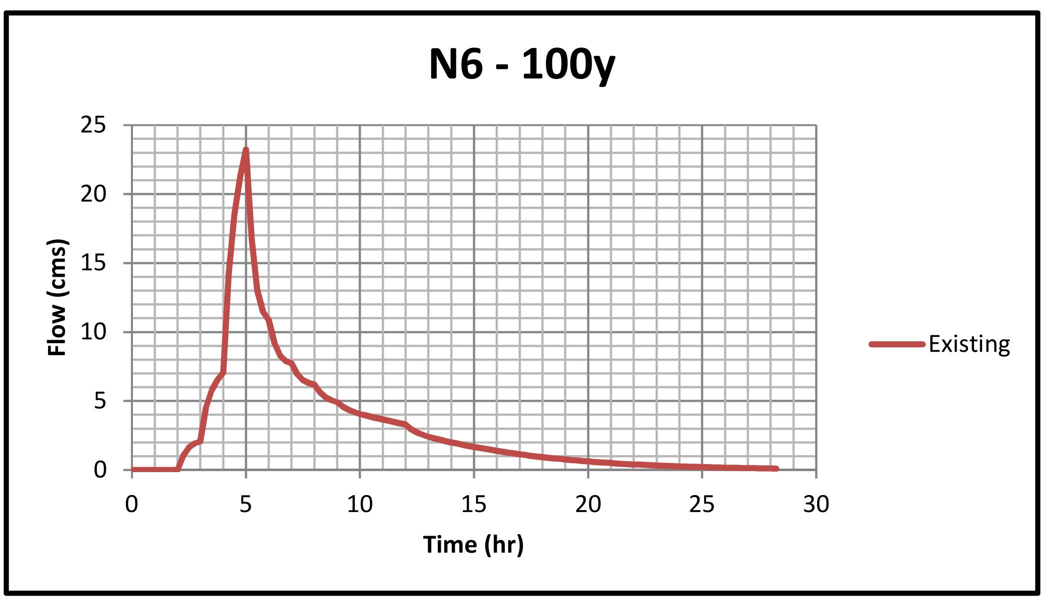

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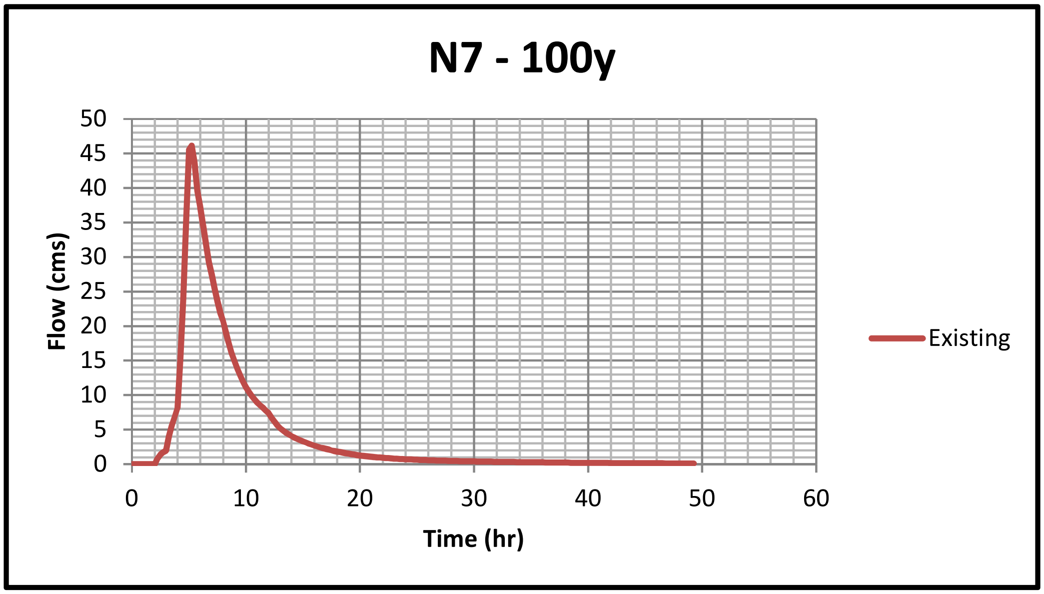
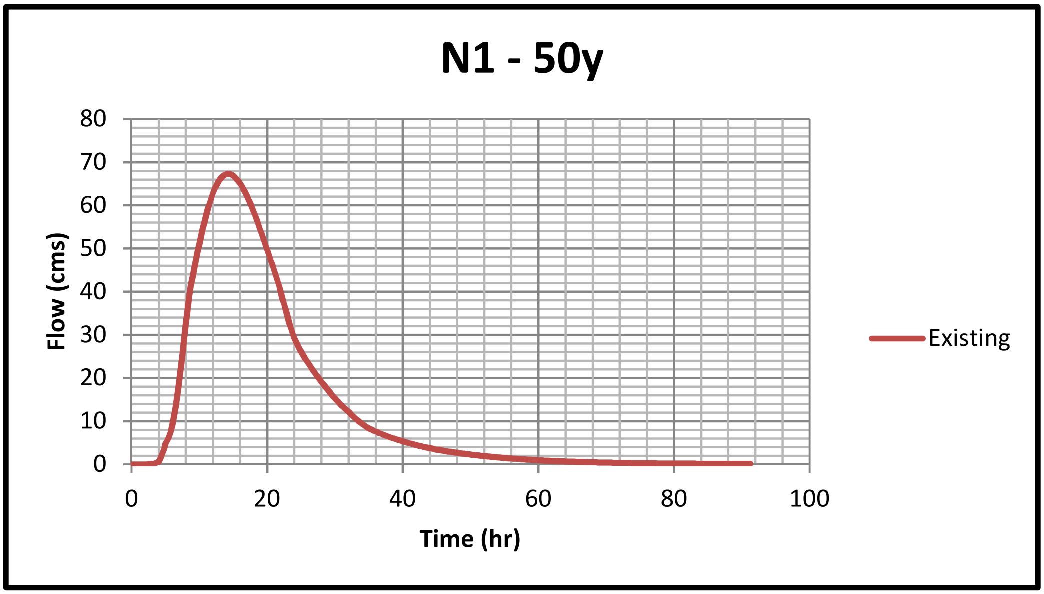
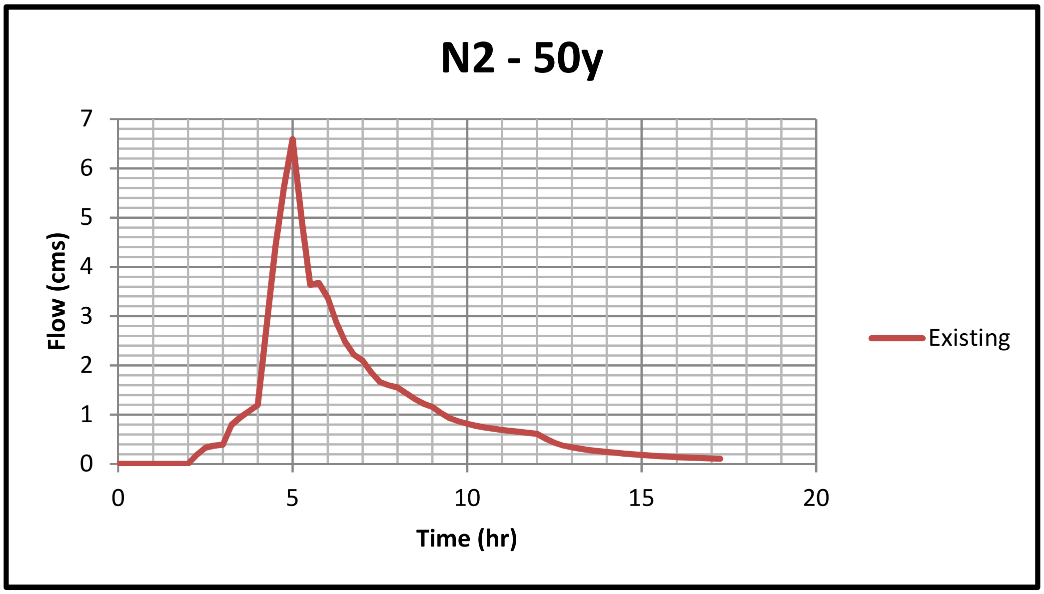
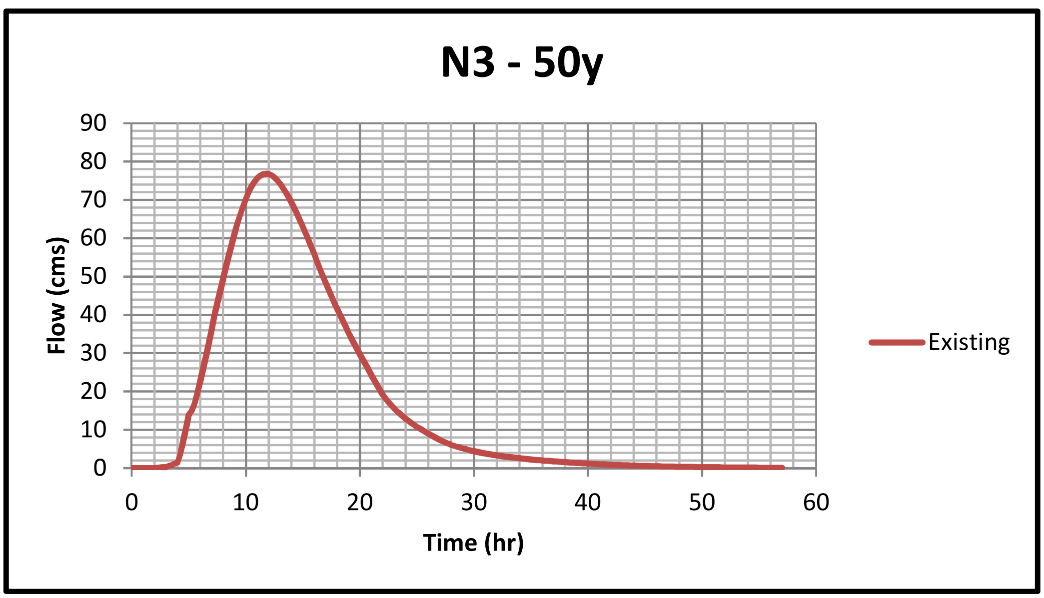


Figure C.6 - 50-yr Inflow Hydrographs (Pickering/Ajax SPA)







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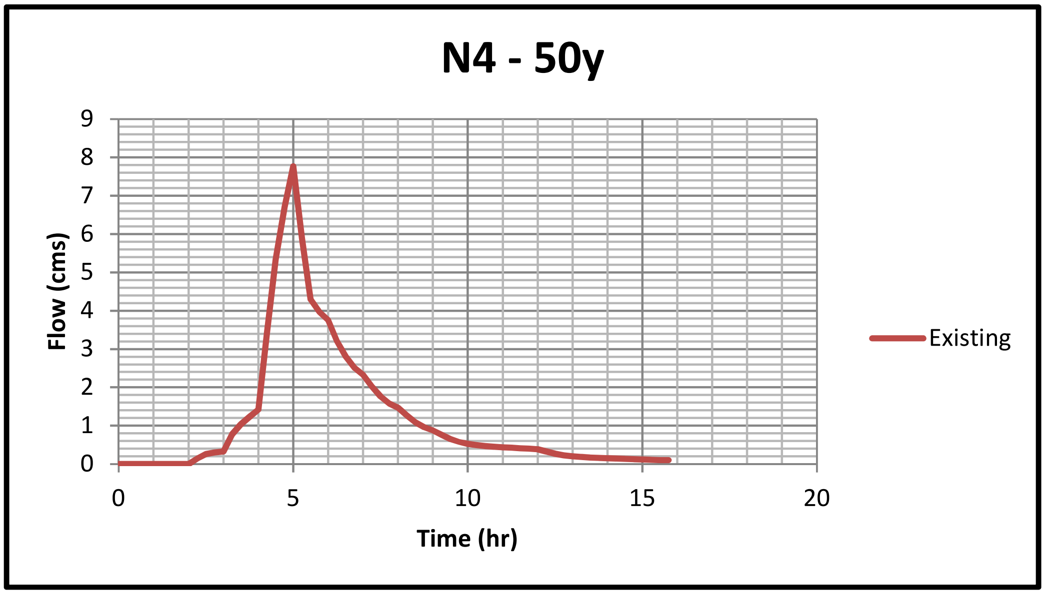

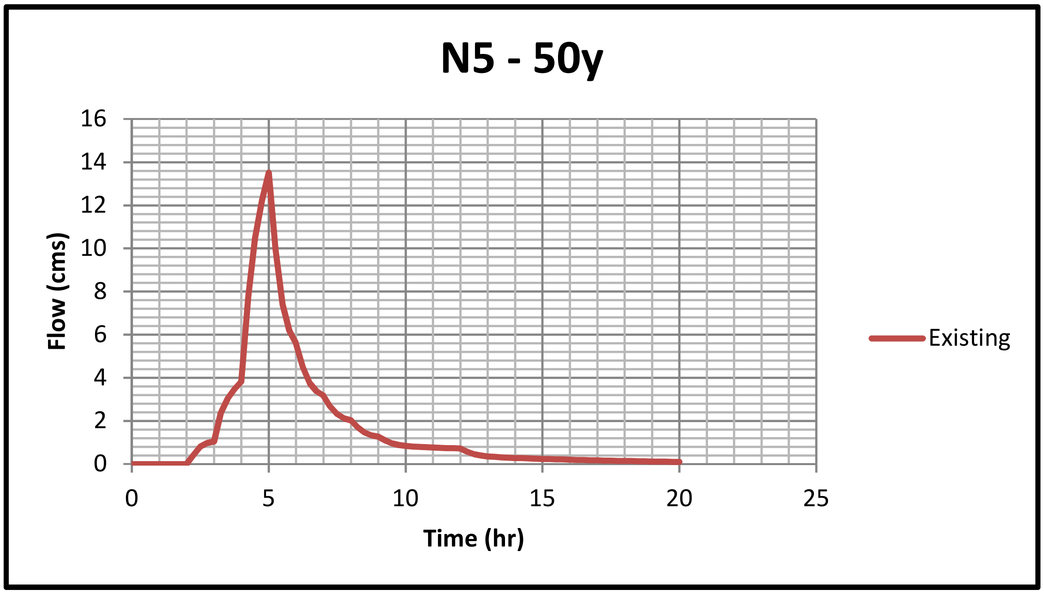

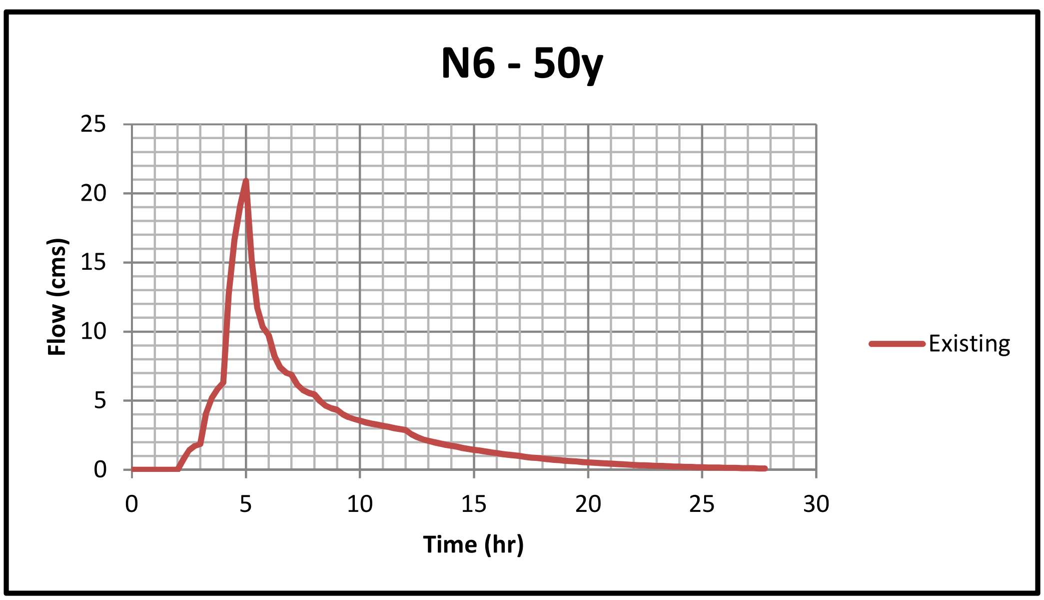

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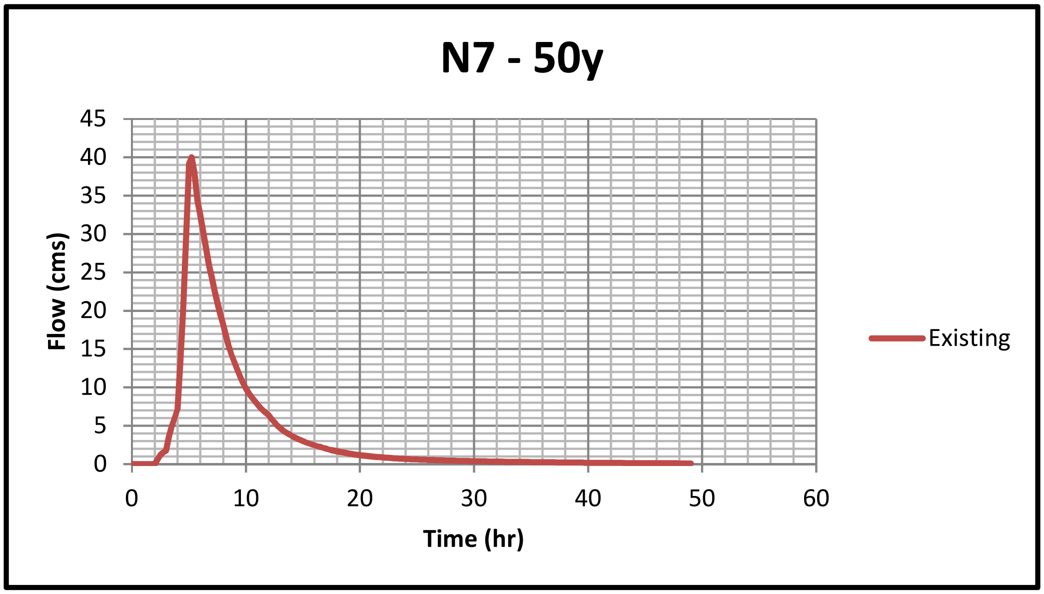
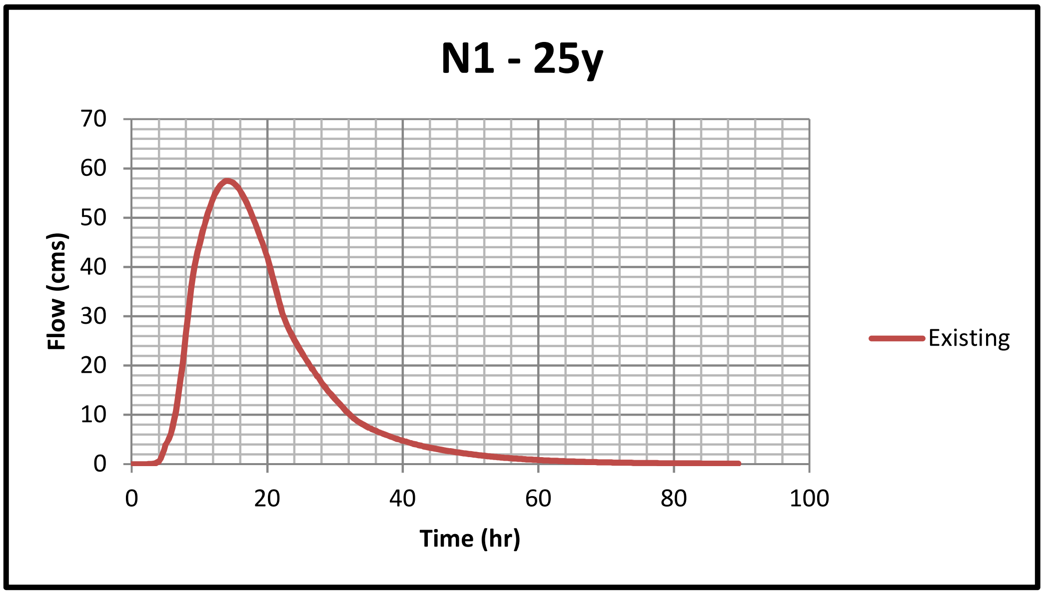
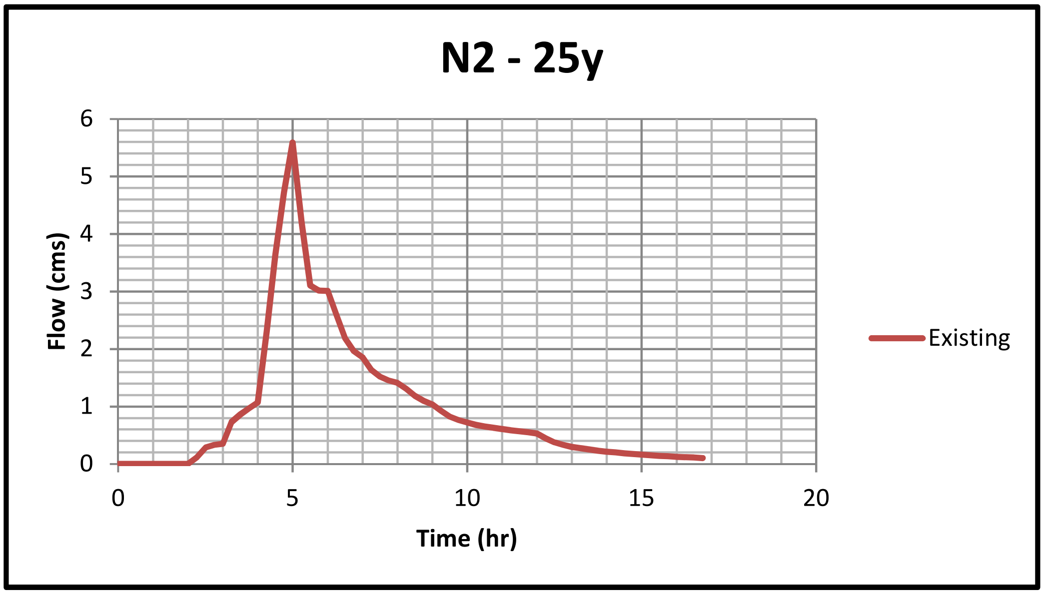
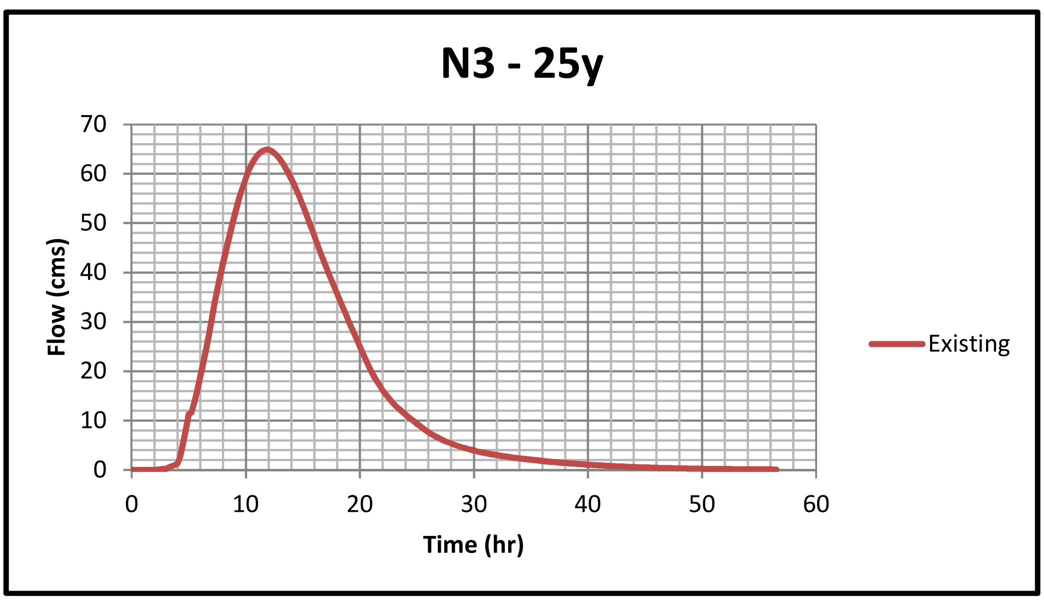


Figure C.7 - 25-yr Inflow Hydrographs (Pickering/Ajax SPA)







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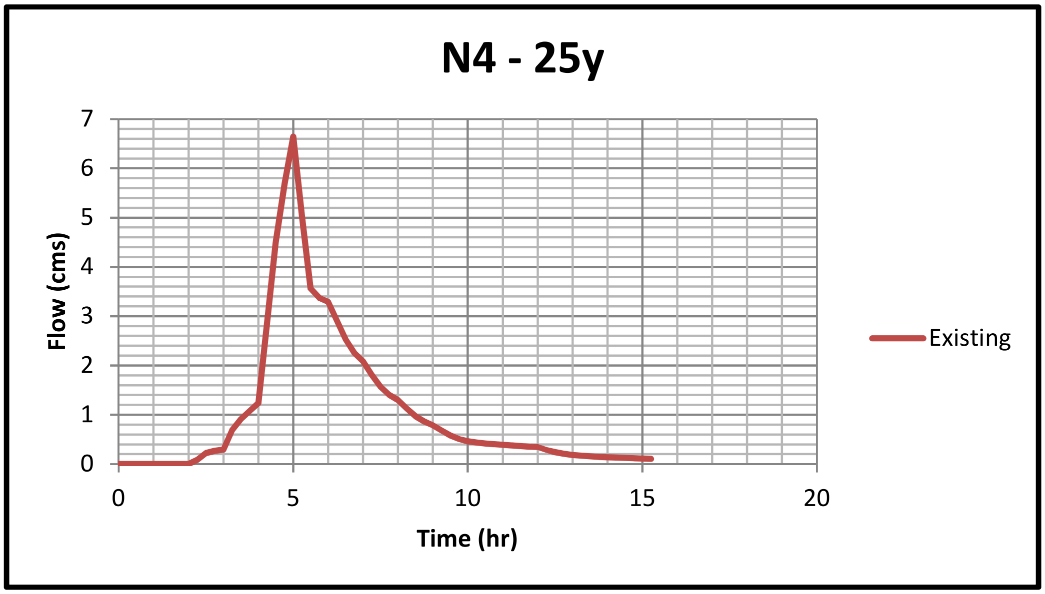

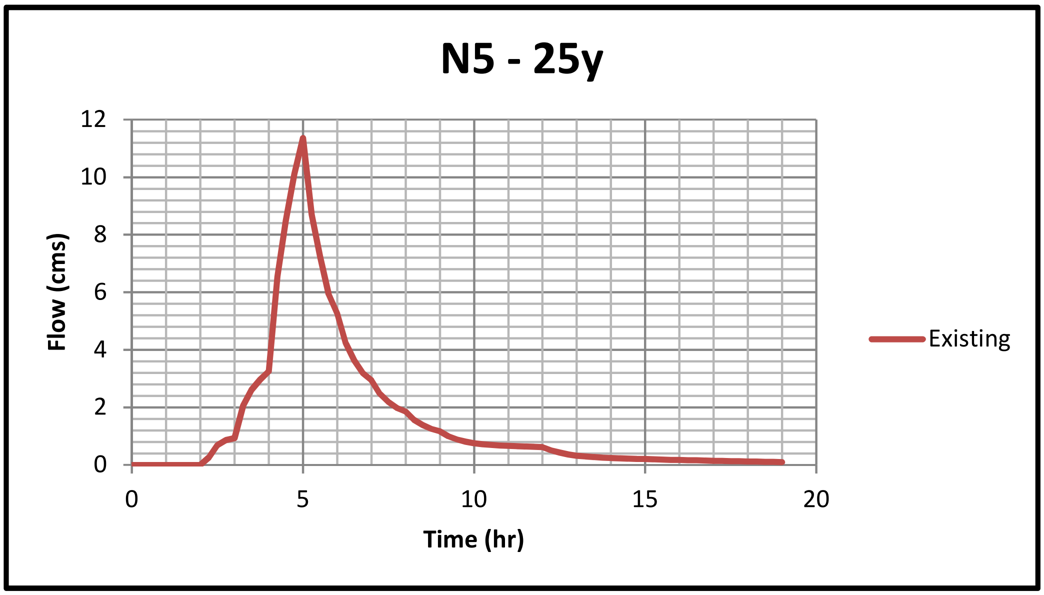

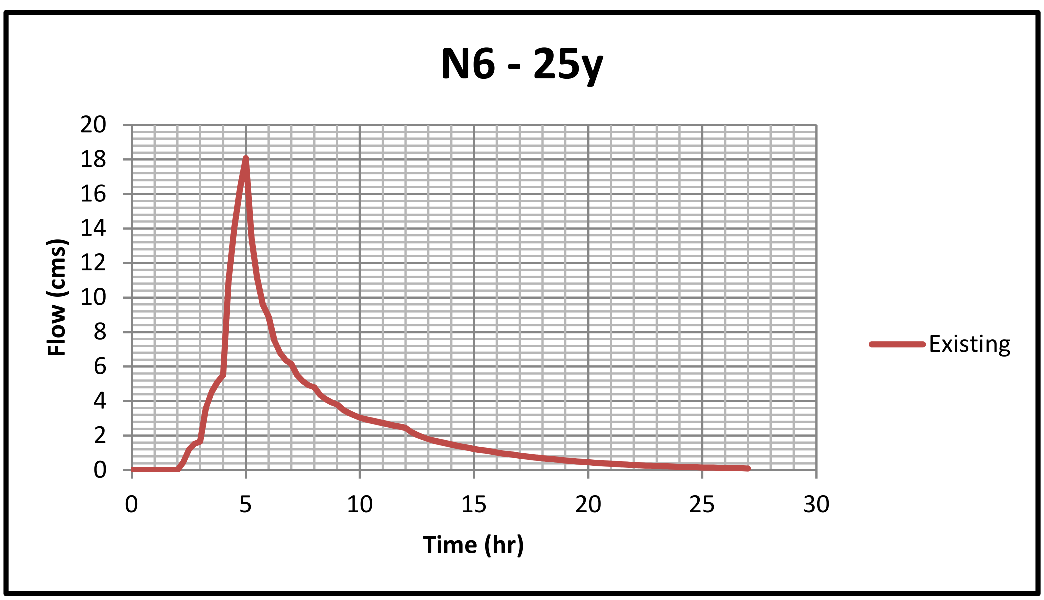

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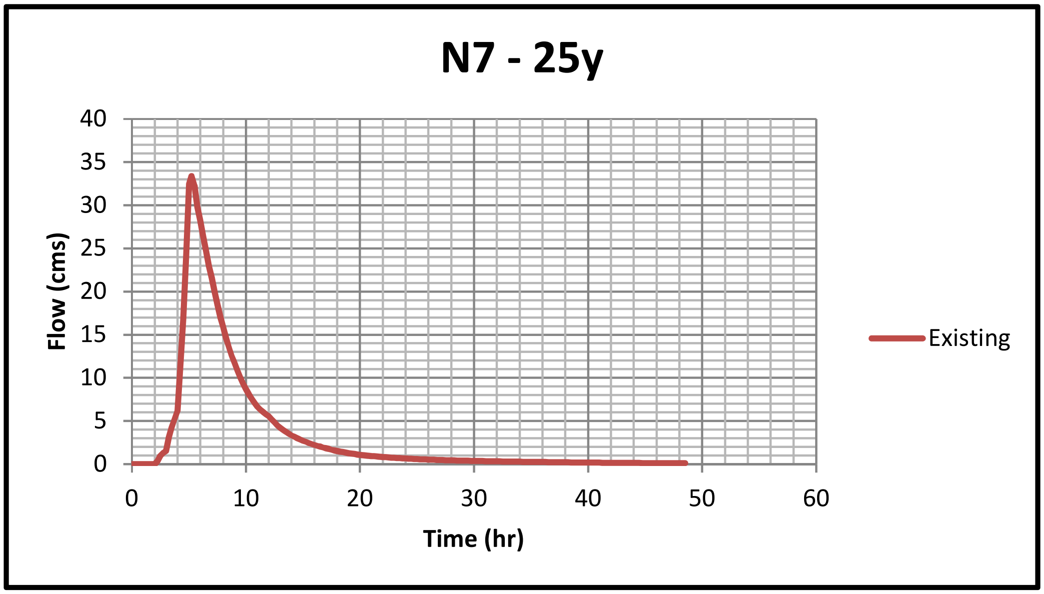
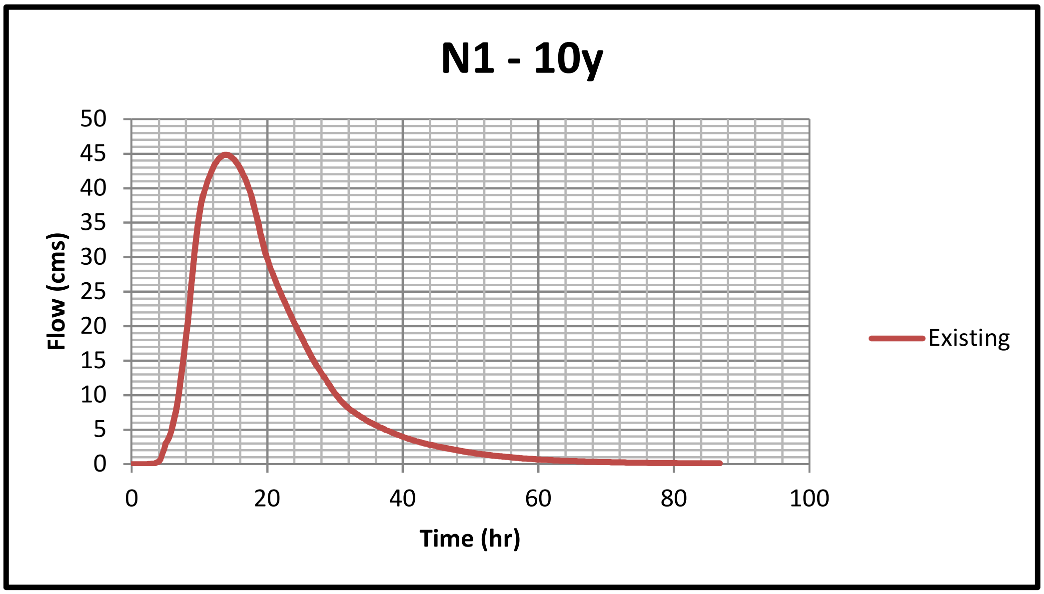
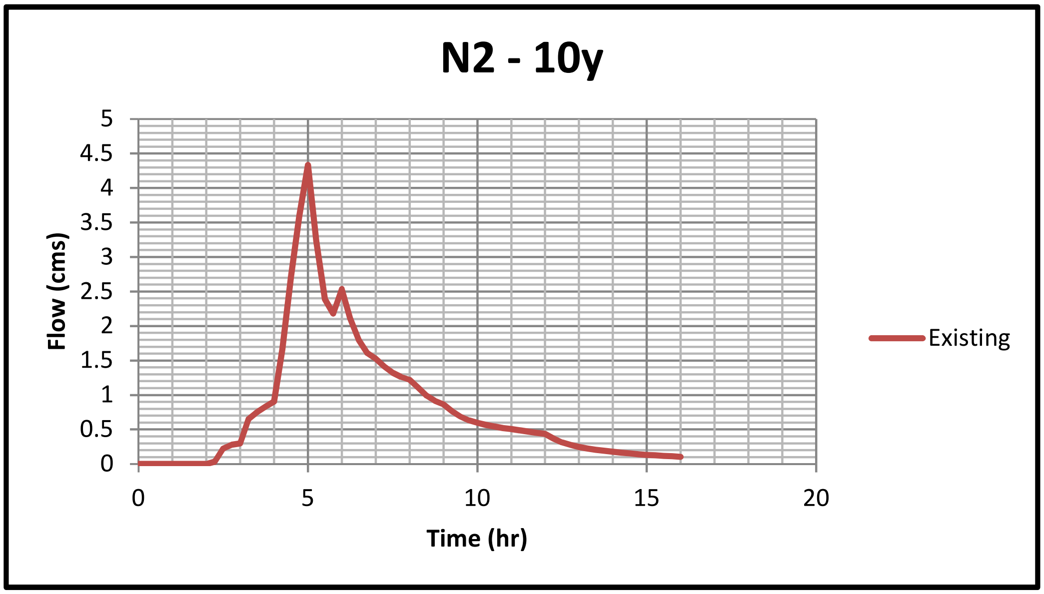
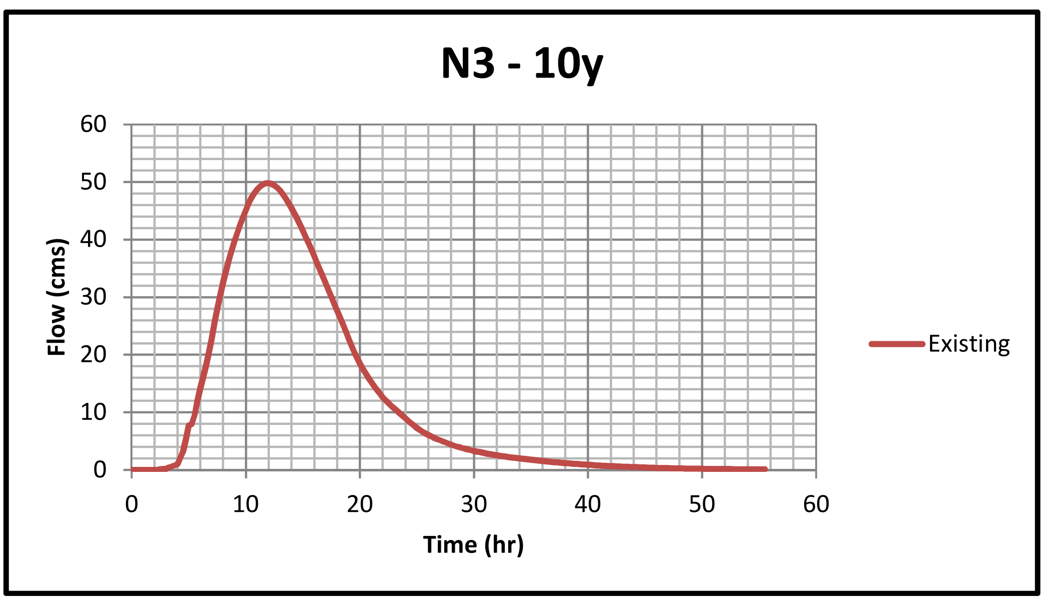


Figure C.8 - 10-yr Inflow Hydrographs (Pickering/Ajax SPA)







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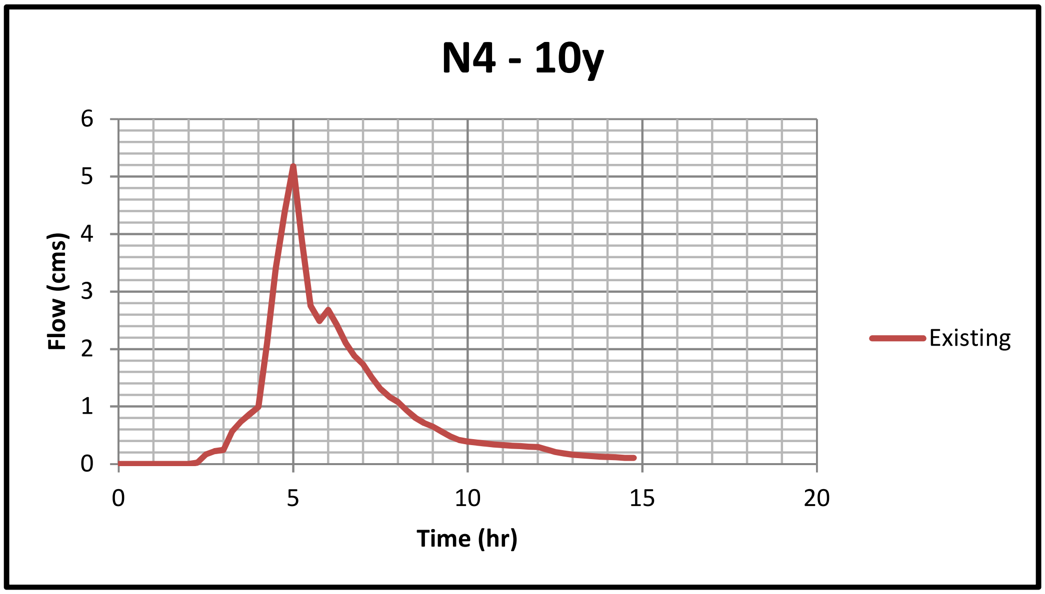

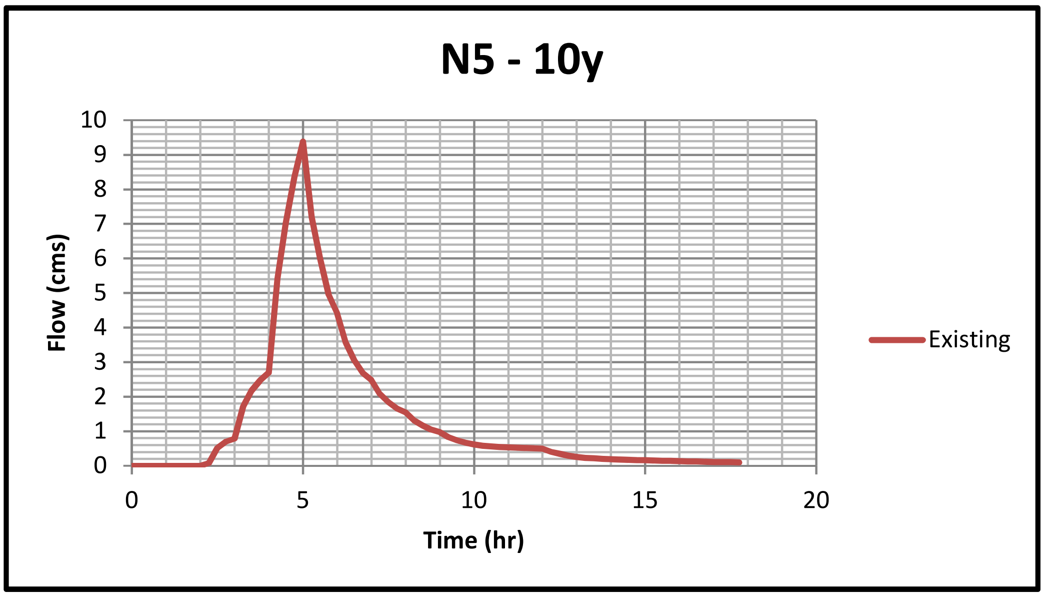

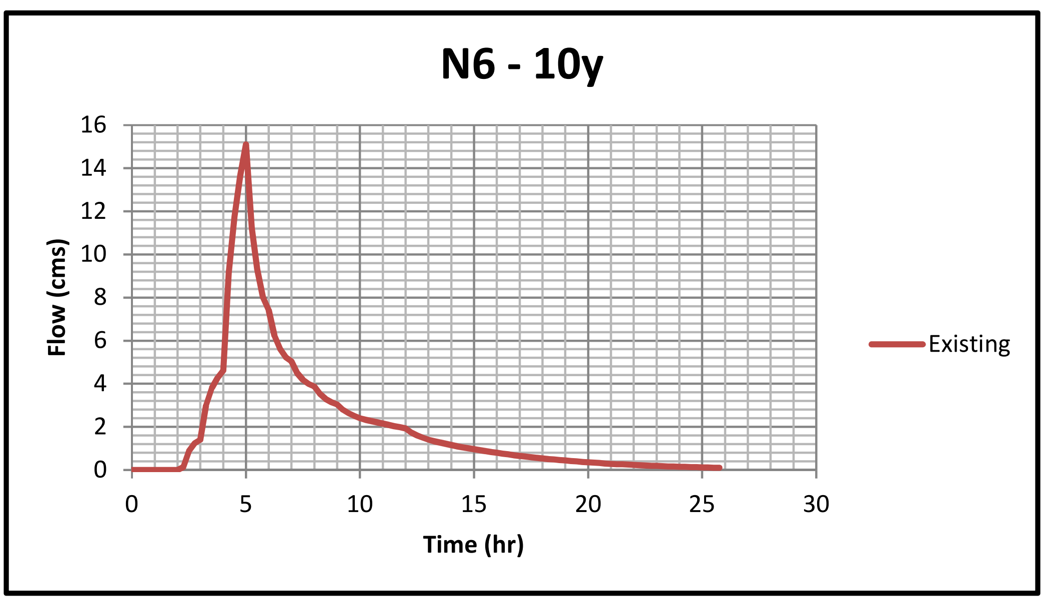

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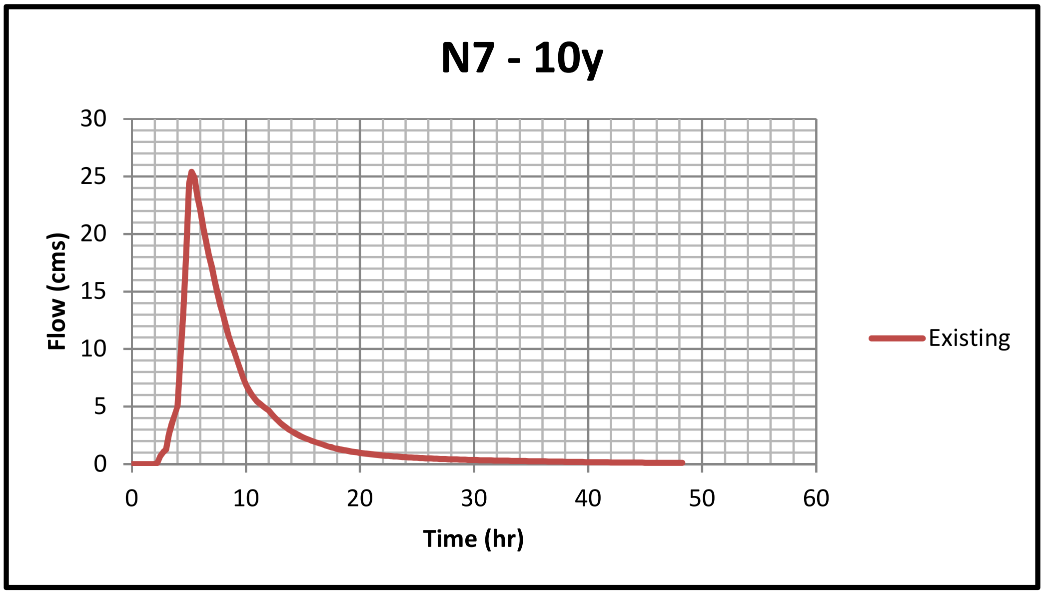
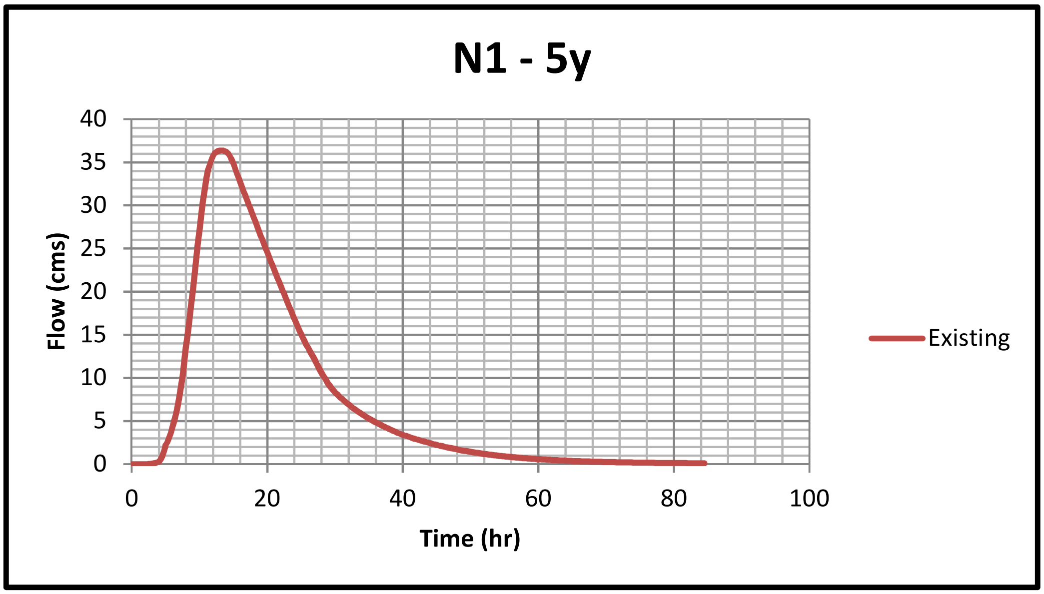
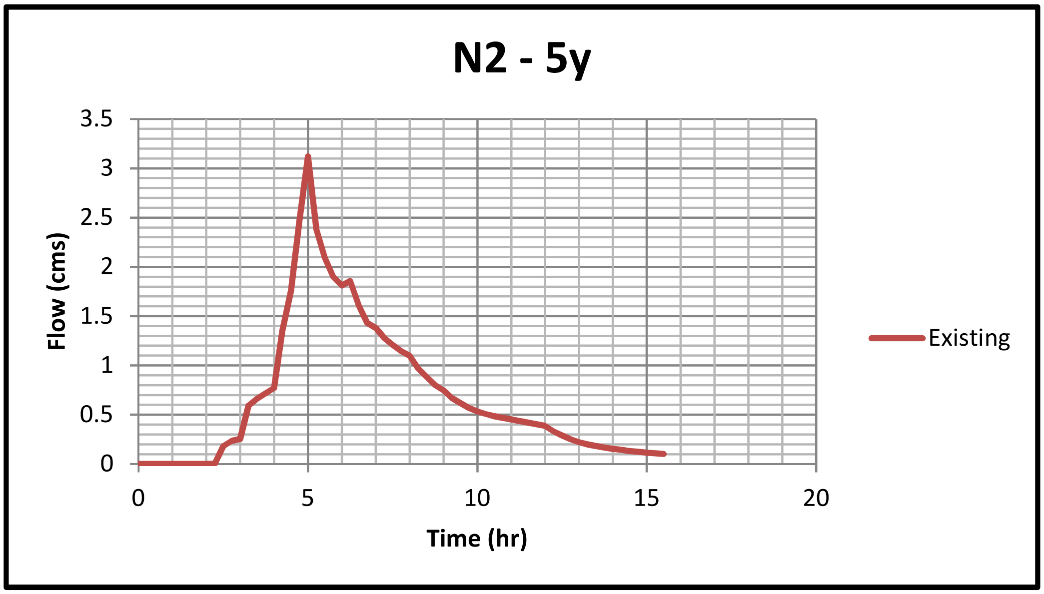


Figure C.9- 5-yr Inflow Hydrographs (Pickering/Ajax SPA)





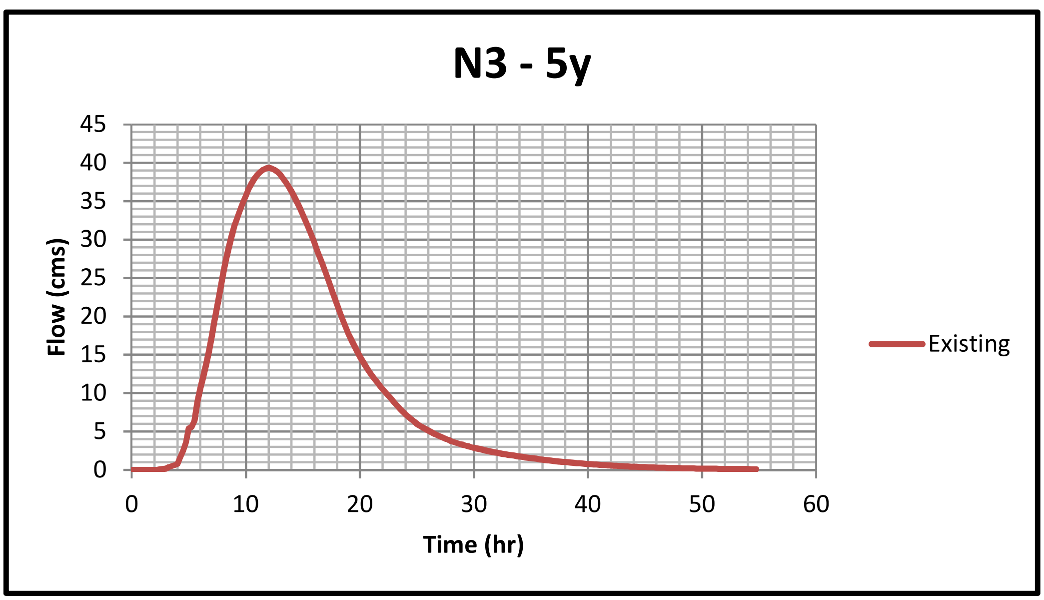
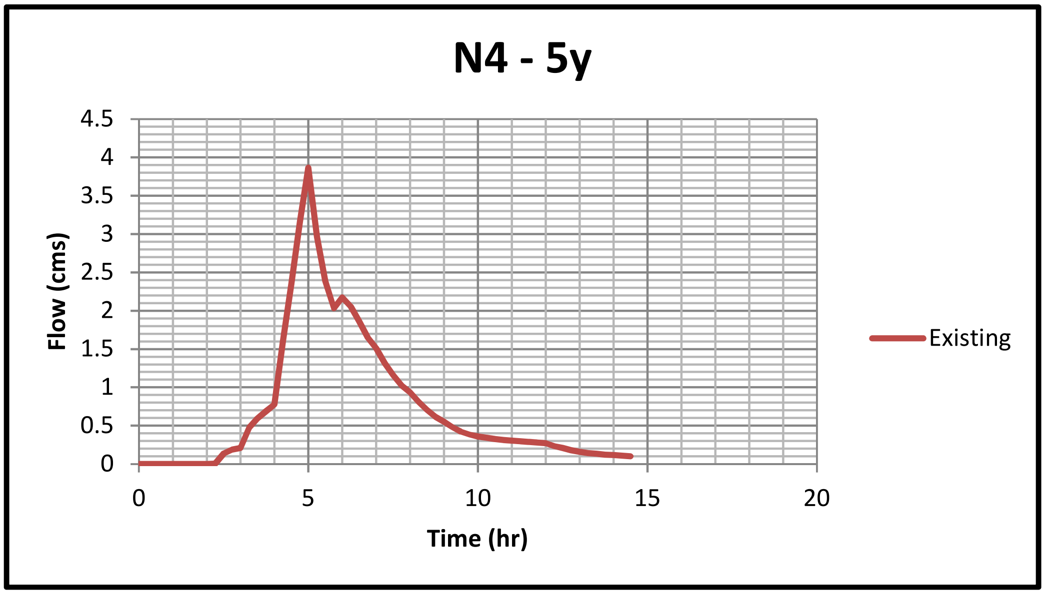
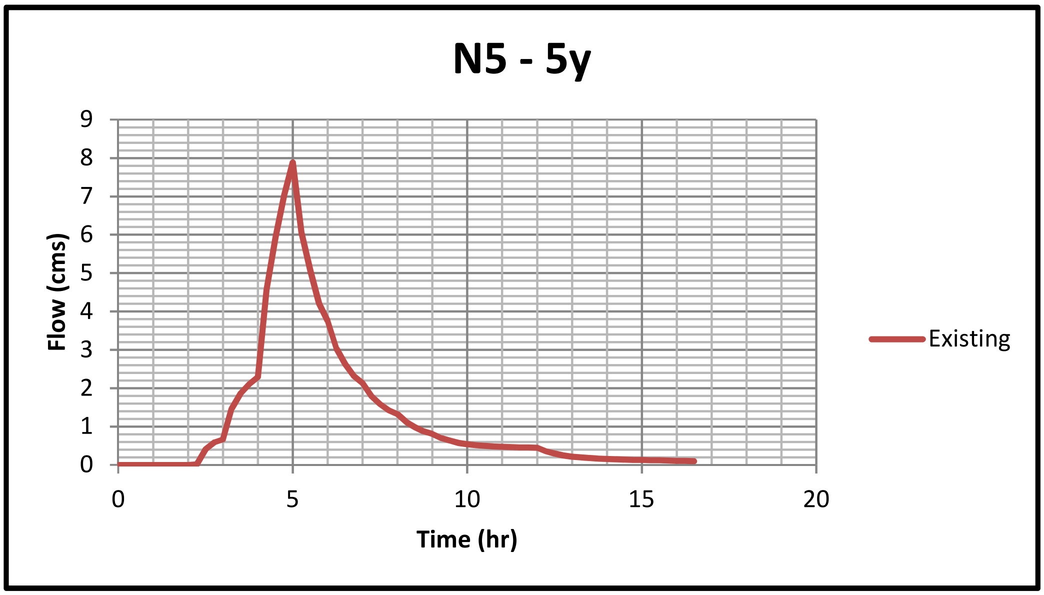


Figure C.9 (Cont'd.)





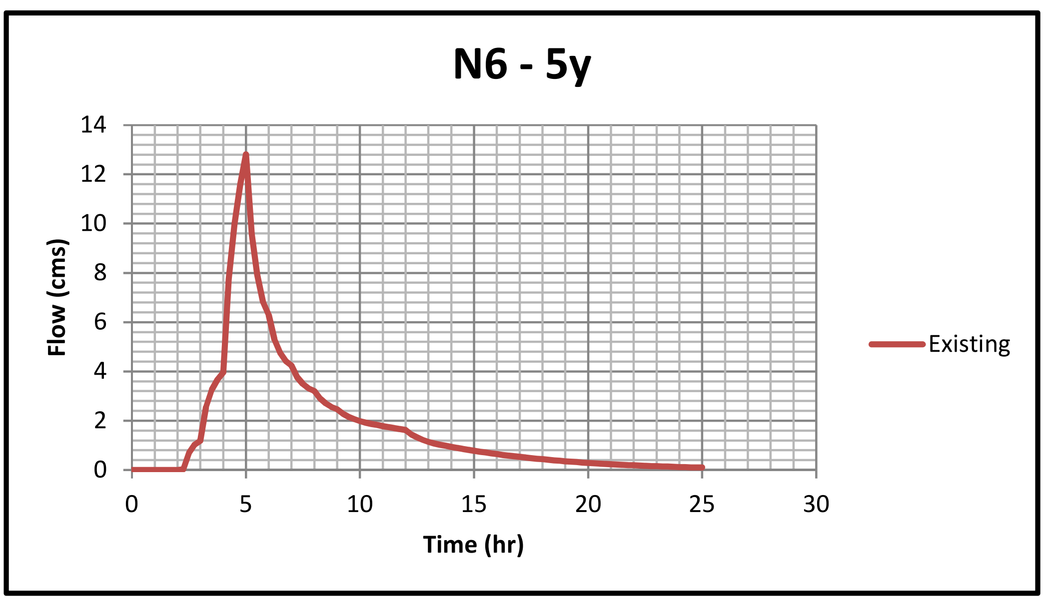


Figure C.9 (Cont'd.)

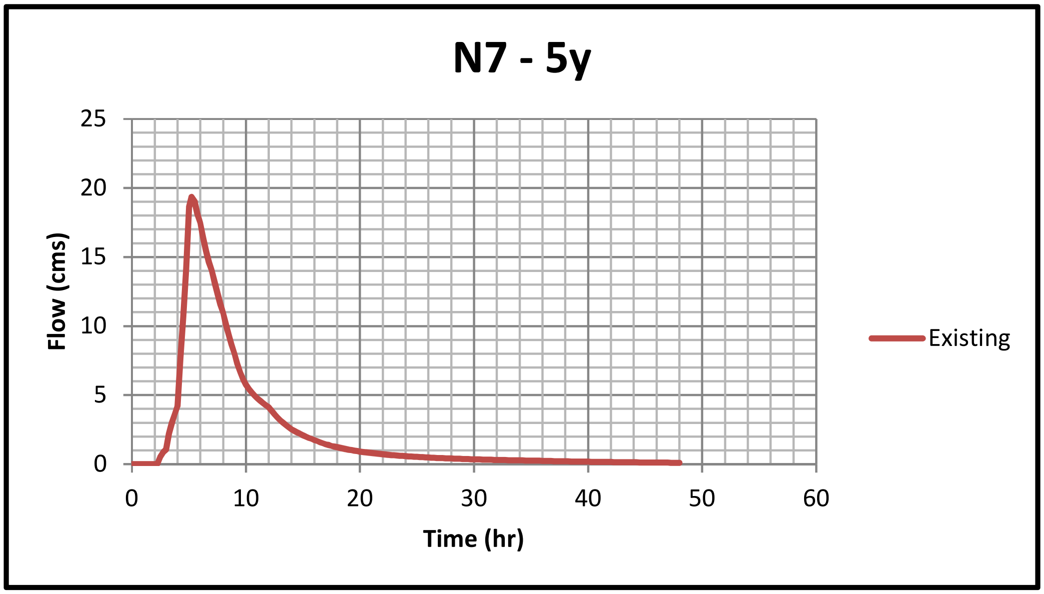
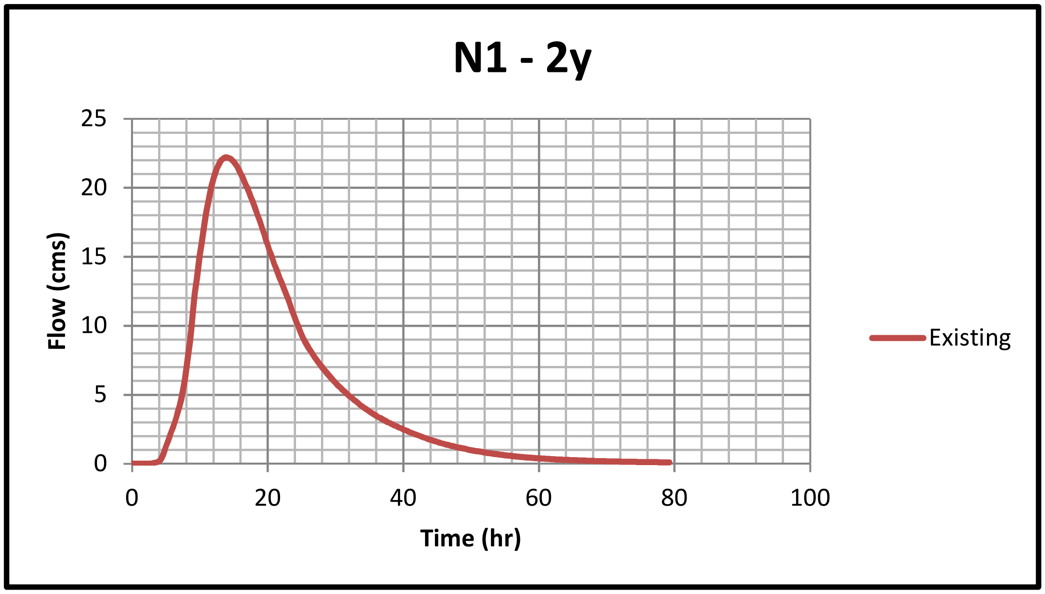
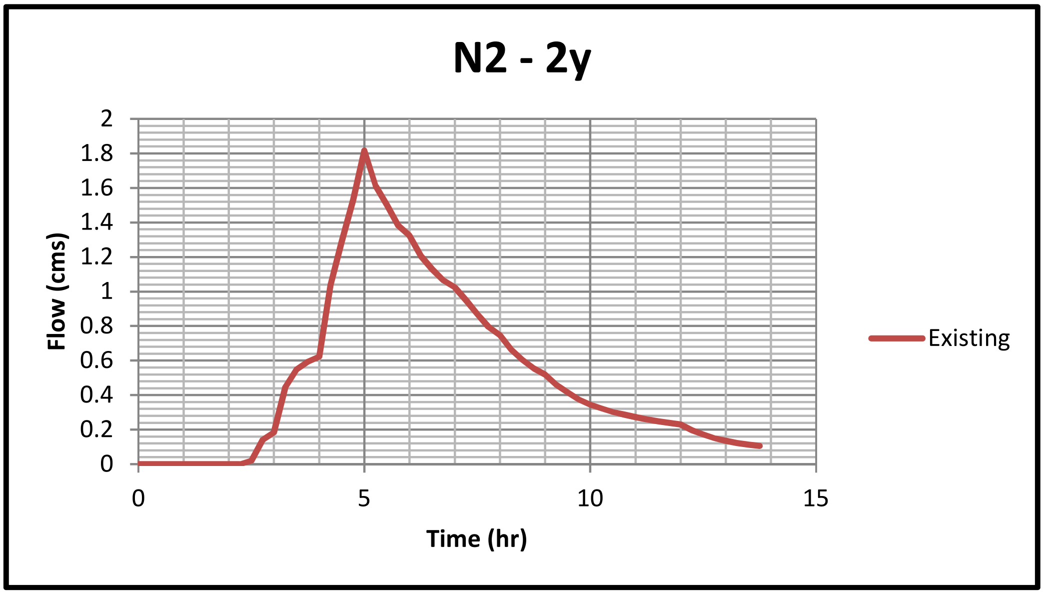


Figure C.10 - 2-yr Inflow Hydrographs (Pickering/Ajax SPA)





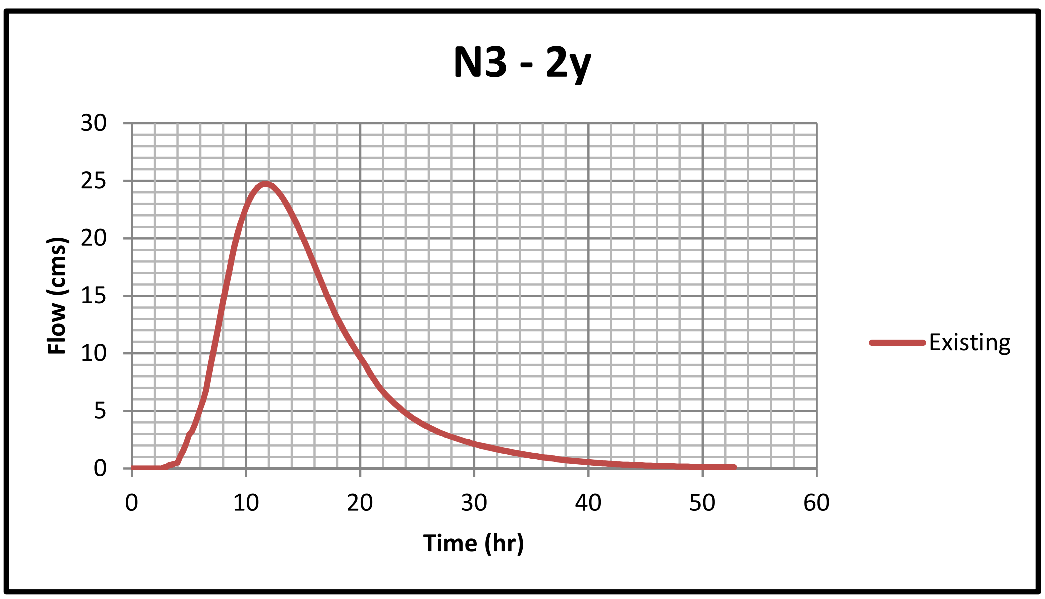
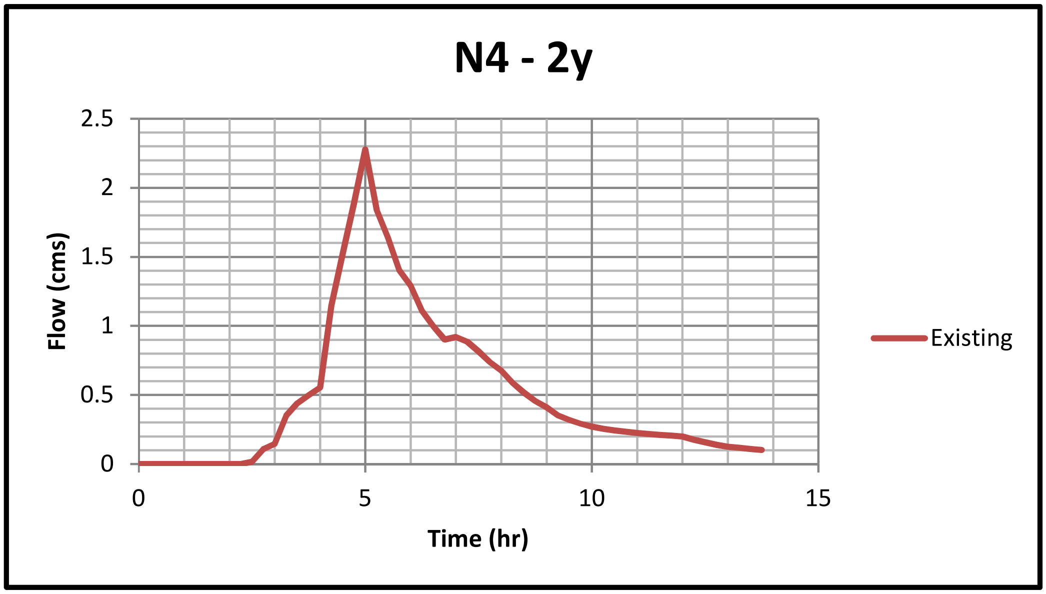
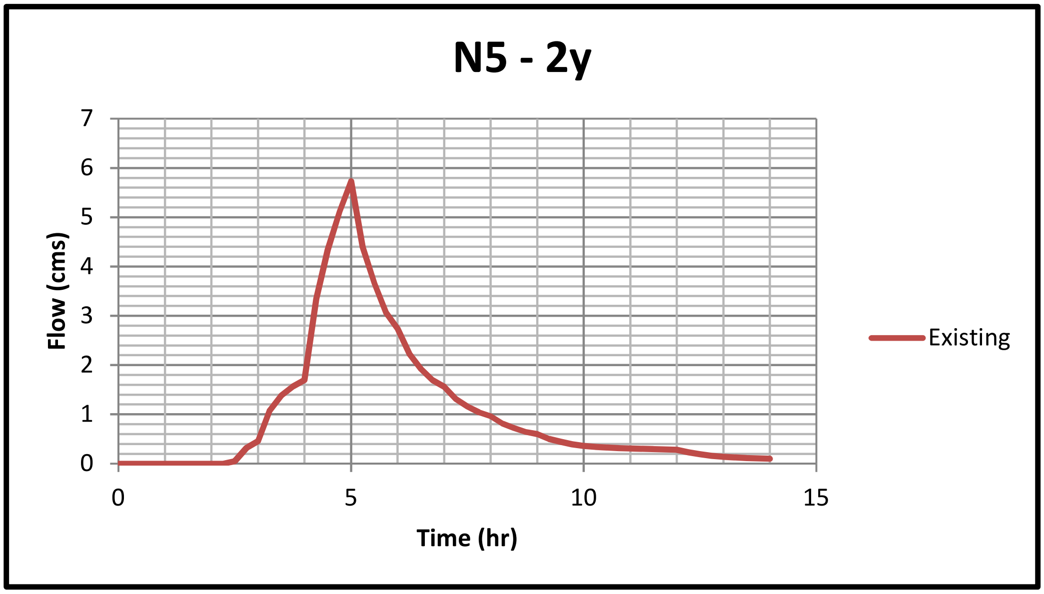


Figure C.10 (Cont'd.)





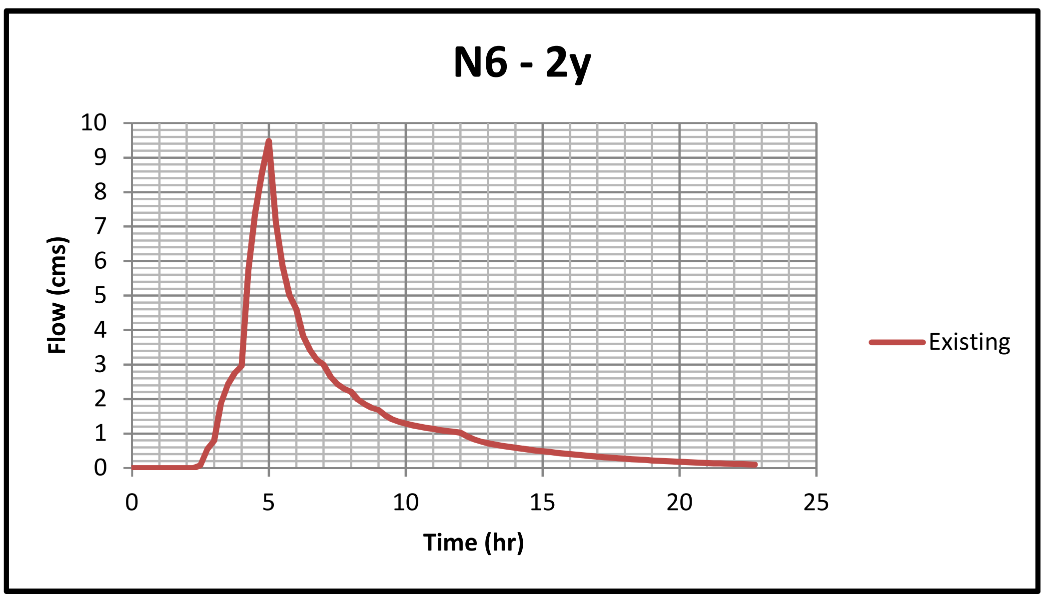


Figure C.10 (Cont'd.)

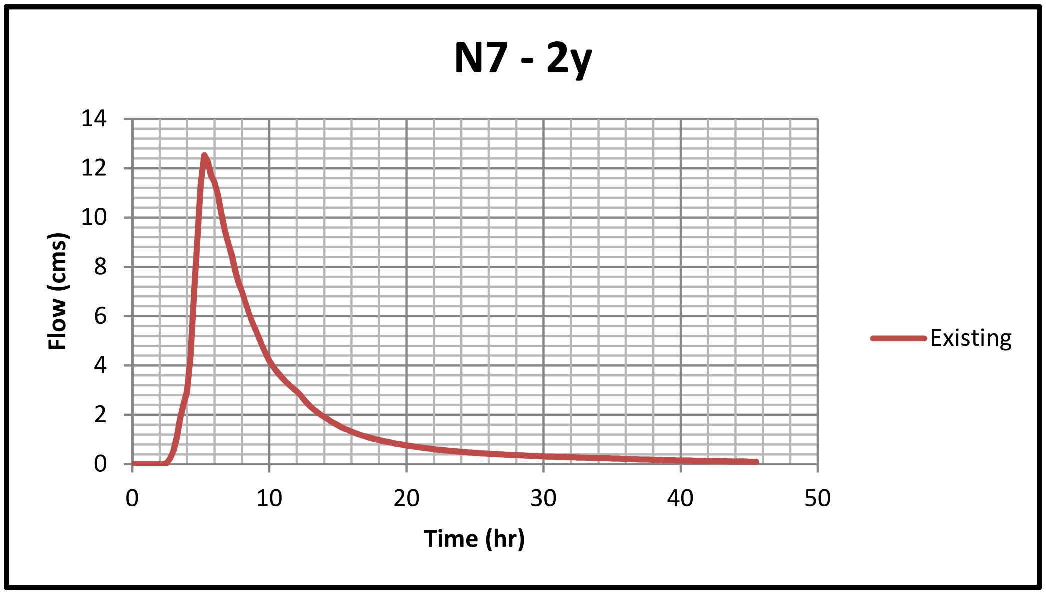


Table C.1 Q-H boundary (Extracted from HEC-RAS station 28.12, TRCA) as shown in table below

Q (cms)	H (m)
0	73.9
65.5	76.39
104.1	76.7
131.9	76.91
171.6	77.02
201.8	77.17
232.3	77.34
276	77.66
862.5	78.78
900	78.83
950	78.87

APPENDIX ‘D’

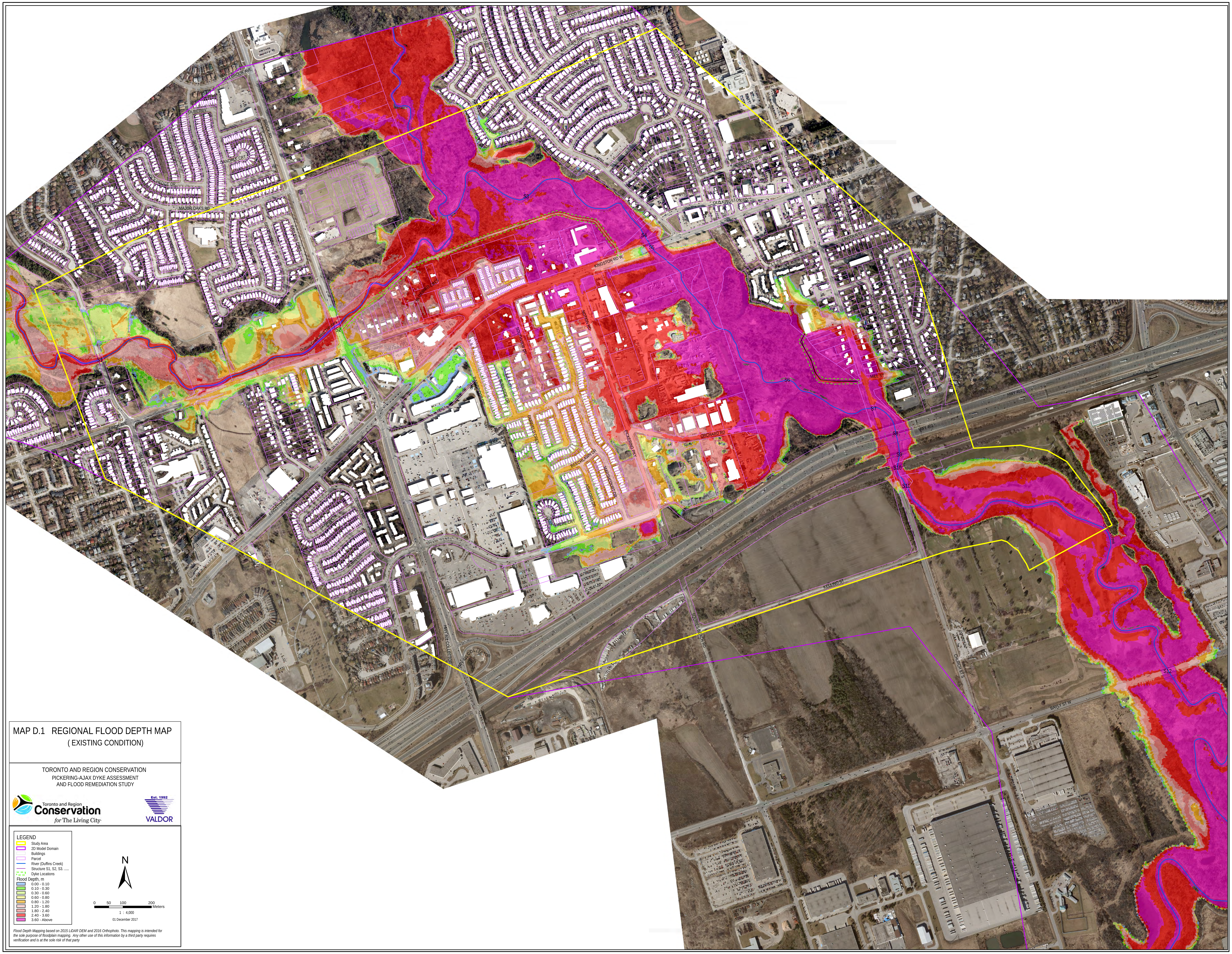
Full Size Maps for Flood Depth (500-yr and Hurricane Hazel)

Pickering/Ajax Mike Flood
1D-2D Model Development and Regulatory Floodplain Mapping

Toronto and Region Conservation Authority

Appendix ‘D’ Contents:

- **Map D.1** Existing Condition Regional Flood Depth Map (full size drawing)
- **Map D.2** Existing Condition 500-yr Flood Depth Map (full size drawing)



MAP D.1 REGIONAL FLOOD DEPTH MAP
(EXISTING CONDITION)

TORONTO AND REGION CONSERVATION
PICKERING-AJAX DYKE ASSESSMENT
AND FLOOD REMEDIATION STUDY

Toronto and Region Conservation *for* The Living City

Est. 1992 VALDOR

LEGEND
- Study Area
- 2D Model Domain
- Buildings
- Parcel
- River (Duffins Creek)
- Structure S1, S2, S3. .....
- Dyke Locations

Flood Depth, m
- 0.00 - 0.10
- 0.10 - 0.30
- 0.30 - 0.60
- 0.60 - 0.80
- 0.80 - 1.20
- 1.20 - 1.80
- 1.80 - 2.40
- 2.40 - 3.60
- 3.60 - Above

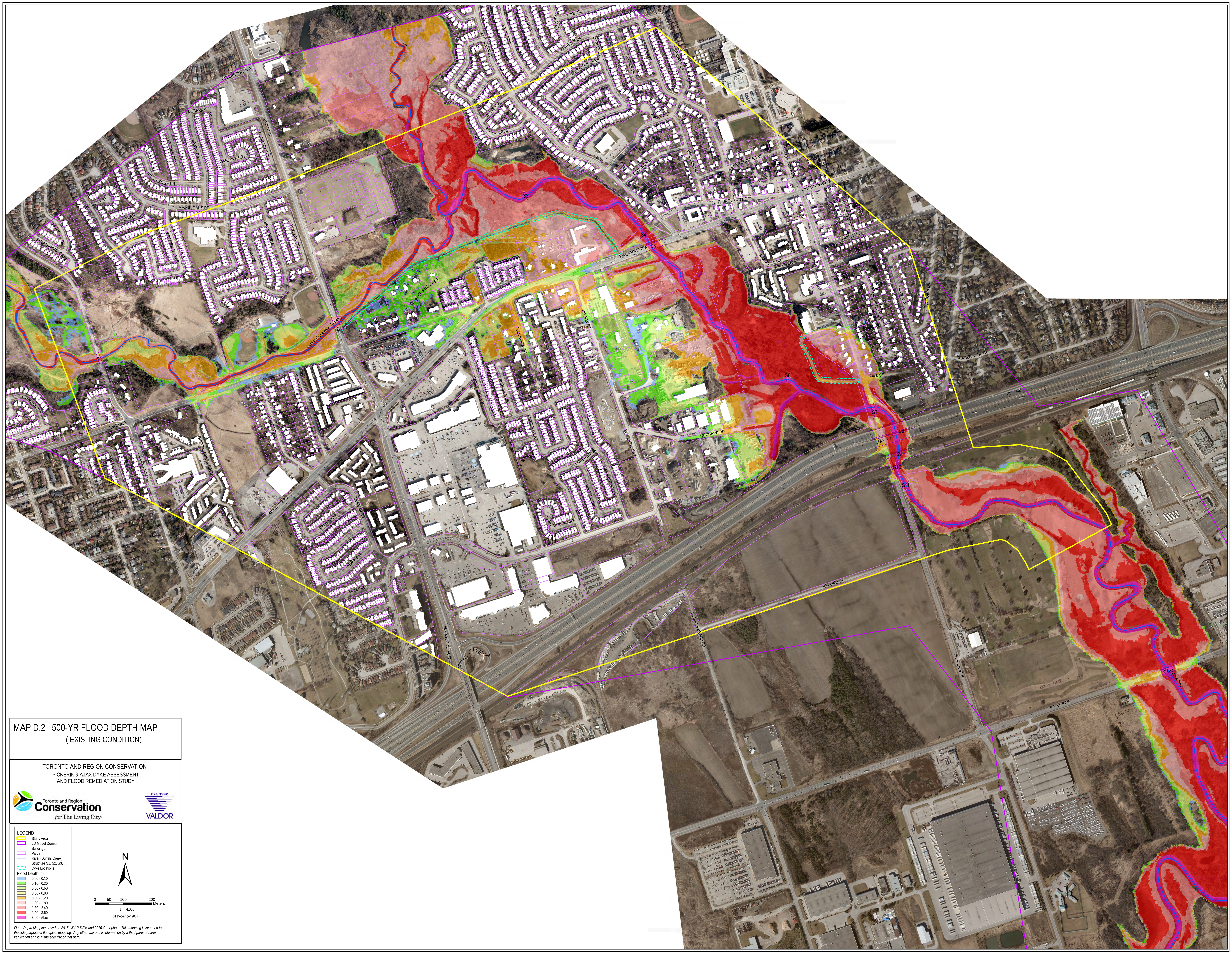
N

0 50 100 200 Meters

1 : 4,000

01 December 2017

Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain mapping. Any other use of this information by a third party requires verification and is at the sole risk of that party


MAP D.2 500-YR FLOOD DEPTH MAP
(EXISTING CONDITION)
TORONTO AND REGION CONSERVATION
PICKERING-AJAX DYKE ASSESSMENT
AND FLOOD REMEDIATION STUDY
Toronto and Region Conservation for The Living City
Est. 1992
VALDOR
LEGEND
Study Area
2D Model Domain
Buildings
Parcel
River (Duffins Creek)
Structure S1, S2, S3. .....
Dyke Locations
Flood Depth, m
0.00 - 0.10
0.10 - 0.30
0.30 - 0.60
0.60 - 0.80
0.80 - 1.20
1.20 - 1.80
1.80 - 2.40
2.40 - 3.60
3.60 - Above
N
0 50 100 200 Meters
1 : 4,000
01 December 2017
Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain mapping. Any other use of this information by a third party requires verification and is at the sole risk of that party

APPENDIX 'E'

Figures for Flood Velocity,
Flow Direction and Depth x Velocity

Pickering/Ajax Mike Flood
1D-2D Model Development and Regulatory Floodplain Mapping

Toronto and Region Conservation Authority

Appendix 'E' Contents:

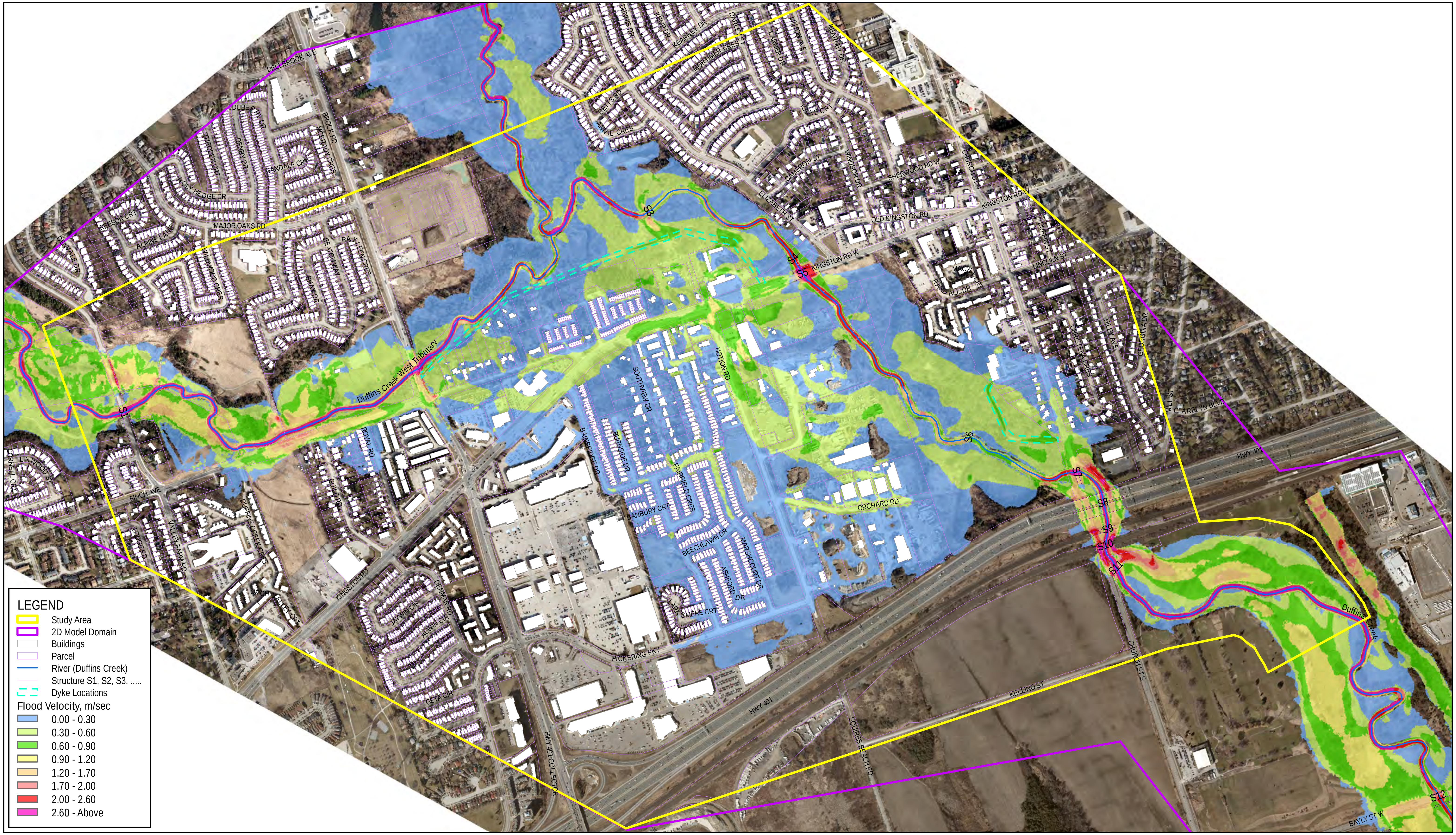


Figure E.1

REGIONAL FLOOD VELOCITY MAP

(EXISTING CONDITION)

STEADY INFLOW HYDROGRAPH (HURRICANE HAZEL)

250 125 0 250 Meters

01 December 2017

N

Note:

Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain study. Any other use of this information by a third party requires verification and is at the sole risk of that party

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PICKERING-AJAX DYKE ASSESSMENT AND FLOOD REMEDIATION STUDY

Toronto and Region Conservation for The Living City

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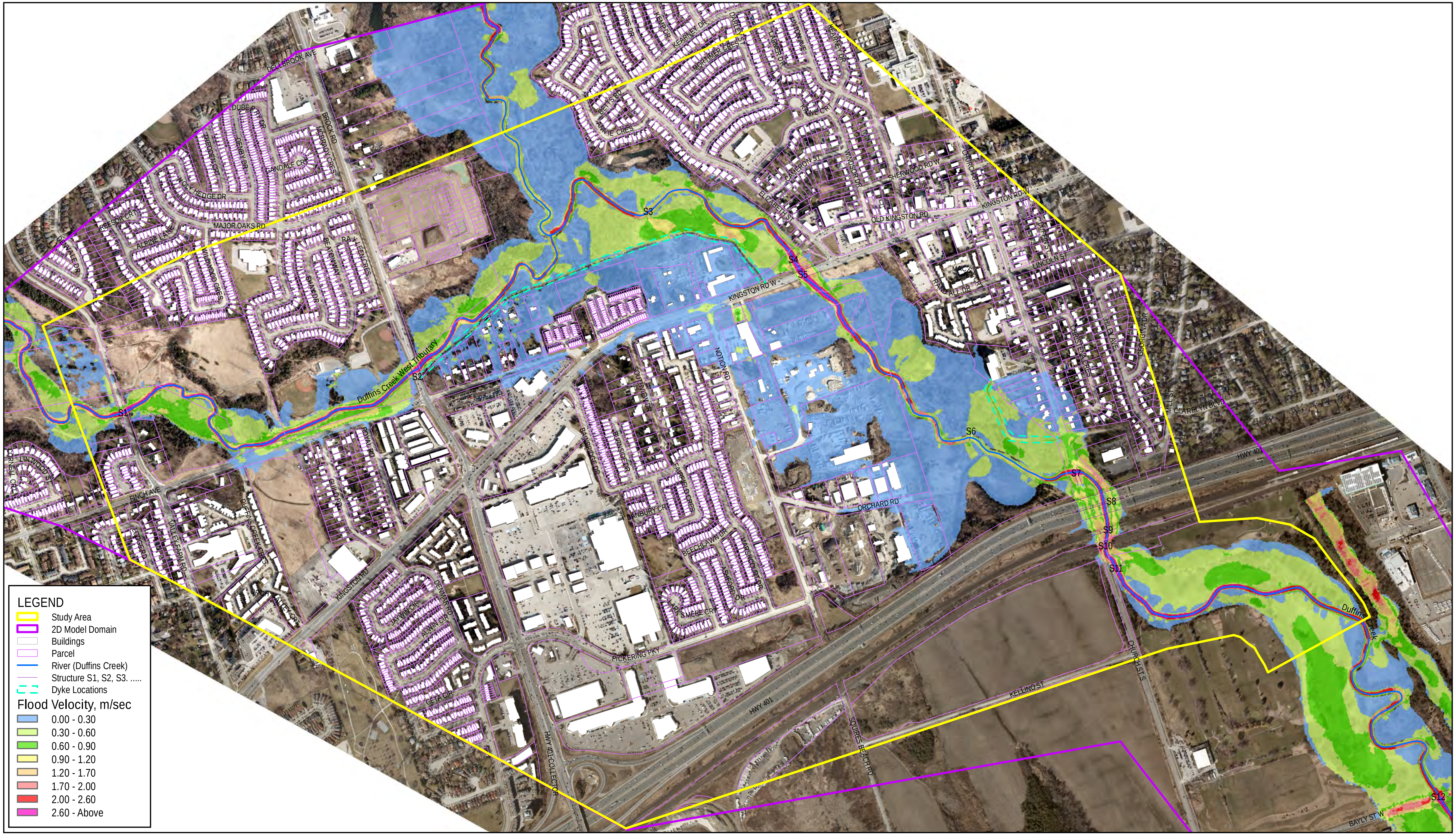

Figure E.2

500-YR FLOOD VELOCITY MAP

(EXISTING CONDITION)

STEADY INFLOW HYDROGRAPH (500-YR STORM)

250 125 0 250 Meters

01 December 2017

N

Note:

Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain study. Any other use of this information by a third party requires verification and is at the sole risk of that party

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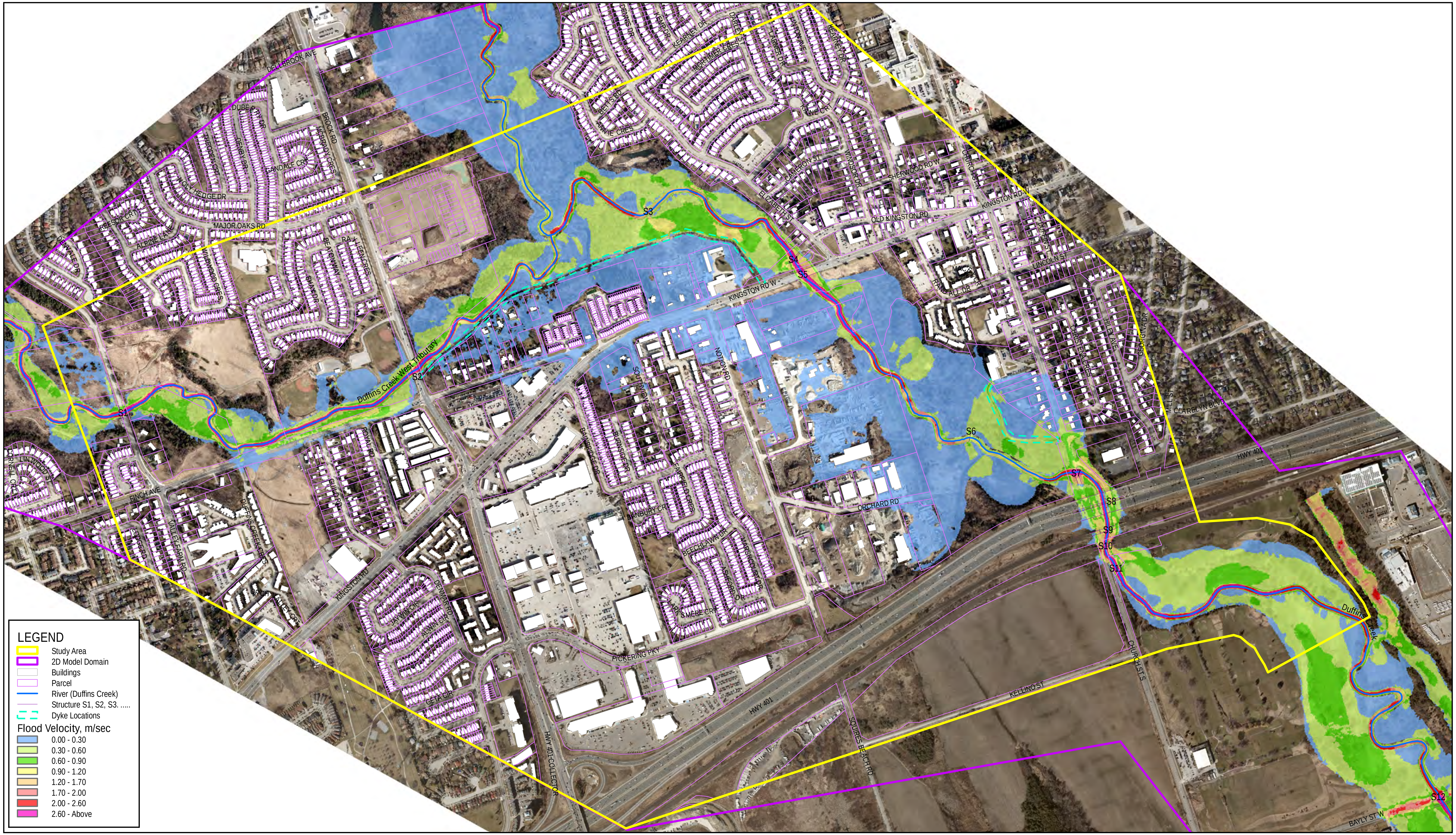

Figure E.3

350-YR FLOOD VELOCITY MAP

(EXISTING CONDITION)

STEADY INFLOW HYDROGRAPH (350-YR STORM)

250 125 0 250 Meters

01 December 2017

N

Note:

Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain study. Any other use of this information by a third party requires verification and is at the sole risk of that party

TORONTO AND REGION CONSERVATION

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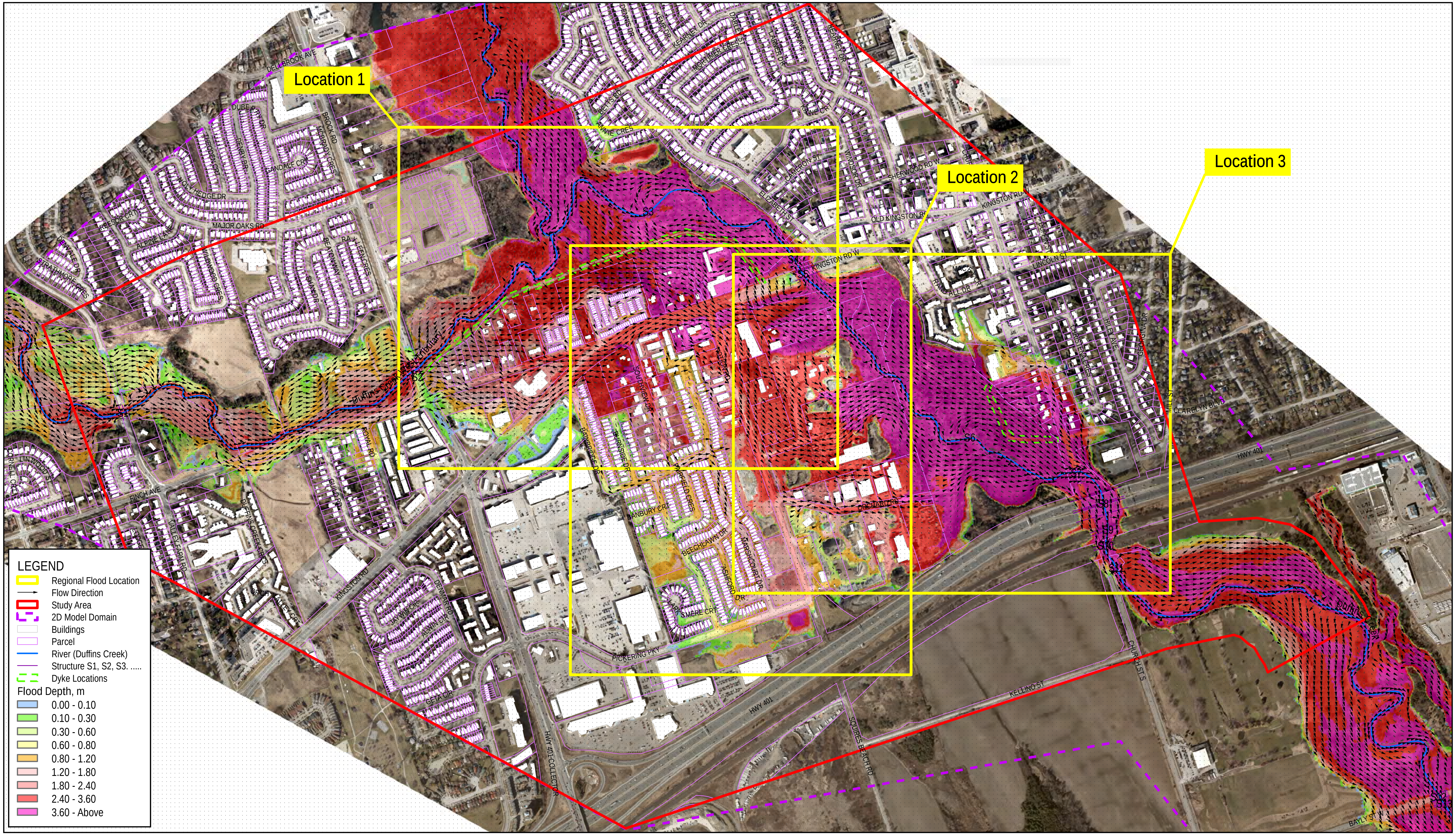

Figure E.4

REGIONAL FLOOD FLOW DIRECTION AND LOCATION MAP

(EXISTING CONDITION)

STEADY INFLOW HYDROGRAPH (HURRICANE HAZEL)

01 December 2017

Note:

Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain study. Any other use of this information by a third party requires verification and is at the sole risk of that party

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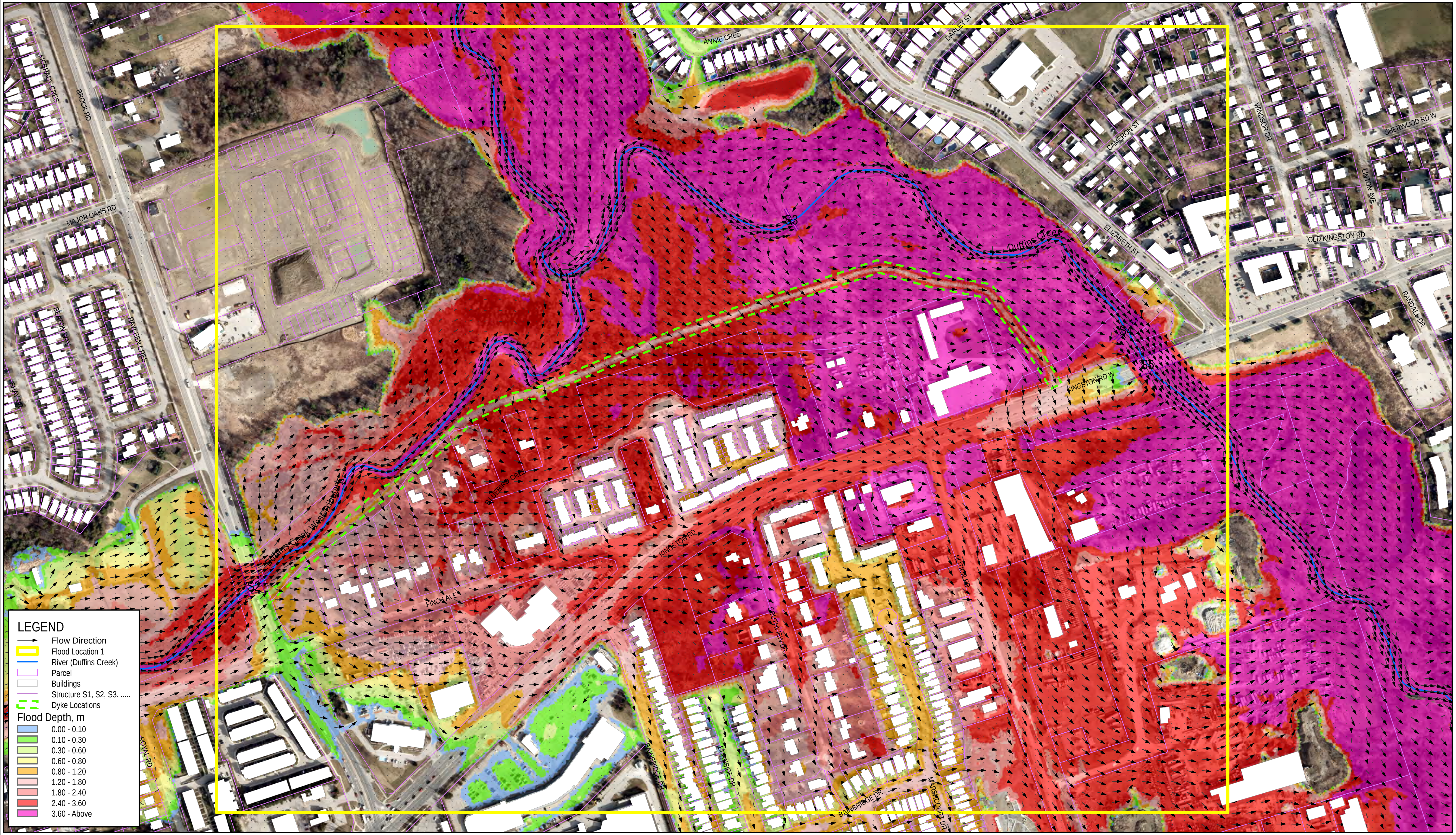

Figure E.5

REGIONAL FLOOD FLOW

(Location 1 - Ref. Figure E.4)

(EXISTING CONDITION)

STEADY INFLOW HYDROGRAPH (HURRICANE HAZEL)

100 50 0 100 Meters

01 December 2017

N

Note:

Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain study. Any other use of this information by a third party requires verification and is at the sole risk of that party

TORONTO AND REGION CONSERVATION

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Figure E.6

REGIONAL FLOOD FLOW
(Location 2 - Ref. Figure E.4)

(EXISTING CONDITION)
STEADY INFLOW HYDROGRAPH (HURRICANE HAZEL)

0 37.5 75 150 Meters

N

01 December 2017

Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain study. Any other use of this information by a third party requires verification and is at the sole risk of that party

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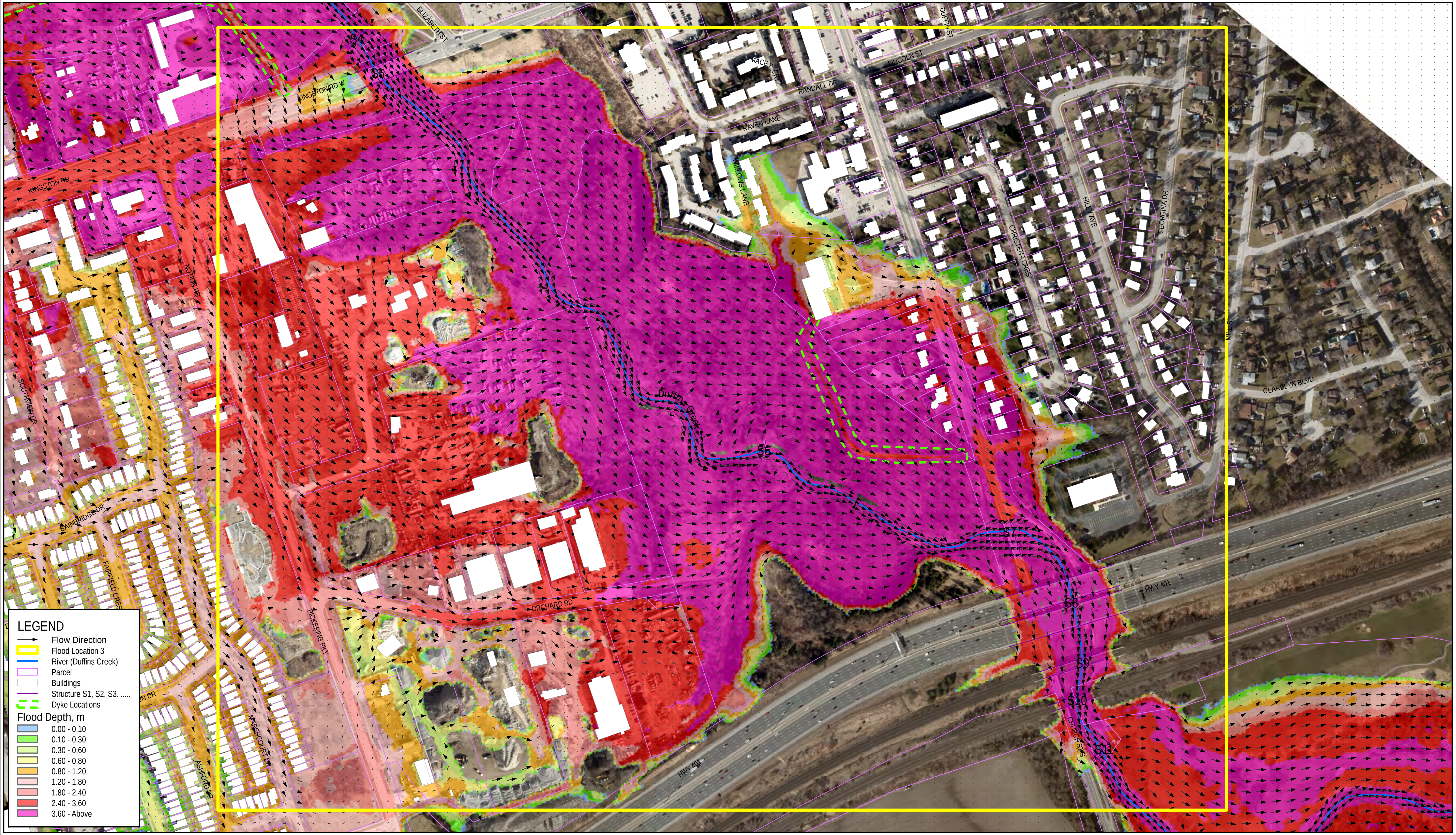

Figure E.7

REGIONAL FLOOD FLOW

(Location 3 - Ref. Figure E.4)

(EXISTING CONDITION)

STEADY INFLOW HYDROGRAPH (HURRICANE HAZEL)

01 December 2017

Note:

Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain study. Any other use of this information by a third party requires verification and is at the sole risk of that party

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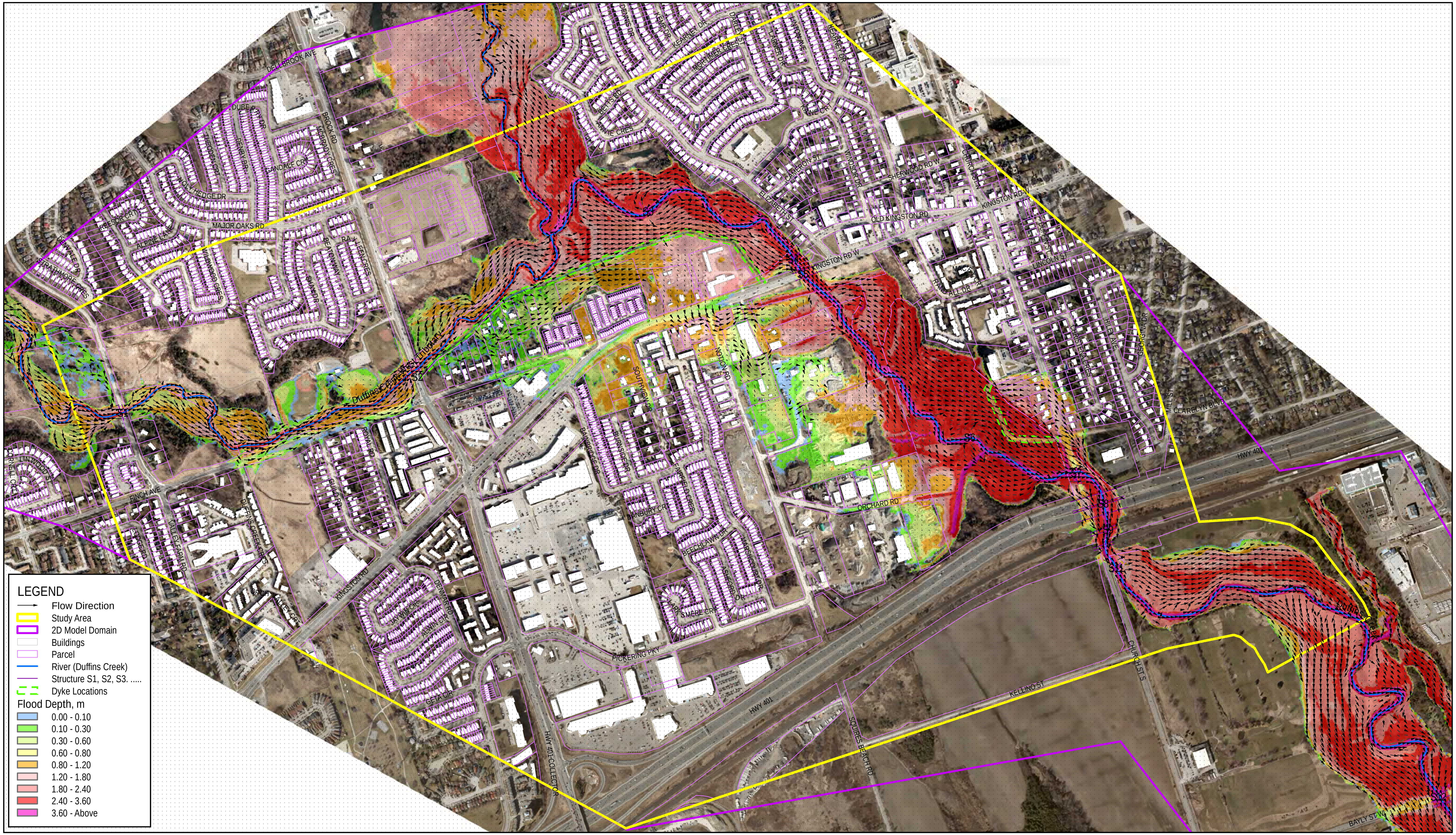

Figure E.8
500-YR FLOOD FLOW DIRECTION MAP
(EXISTING CONDITION)

STEADY INFLOW HYDROGRAPH (500-YR STORM)

01 December 2017

Note:

Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain study. Any other use of this information by a third party requires verification and is at the sole risk of that party

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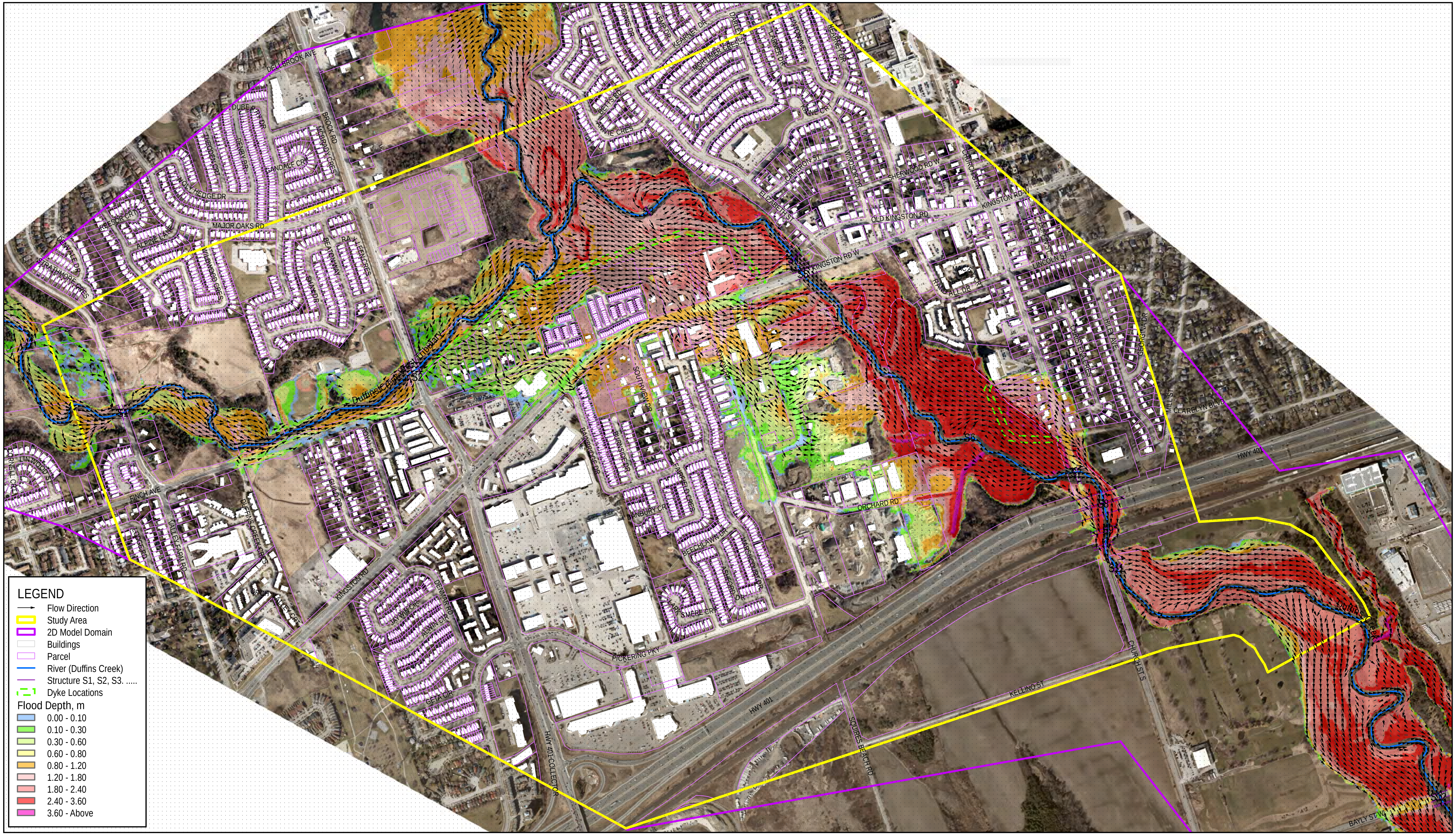

Figure E.9

500-YR FLOOD FLOW DIRECTION MAP

(DYKE REMOVED)

STEADY INFLOW HYDROGRAPH (500-YR STORM)

01 December 2017

Note:

Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain study. Any other use of this information by a third party requires verification and is at the sole risk of that party

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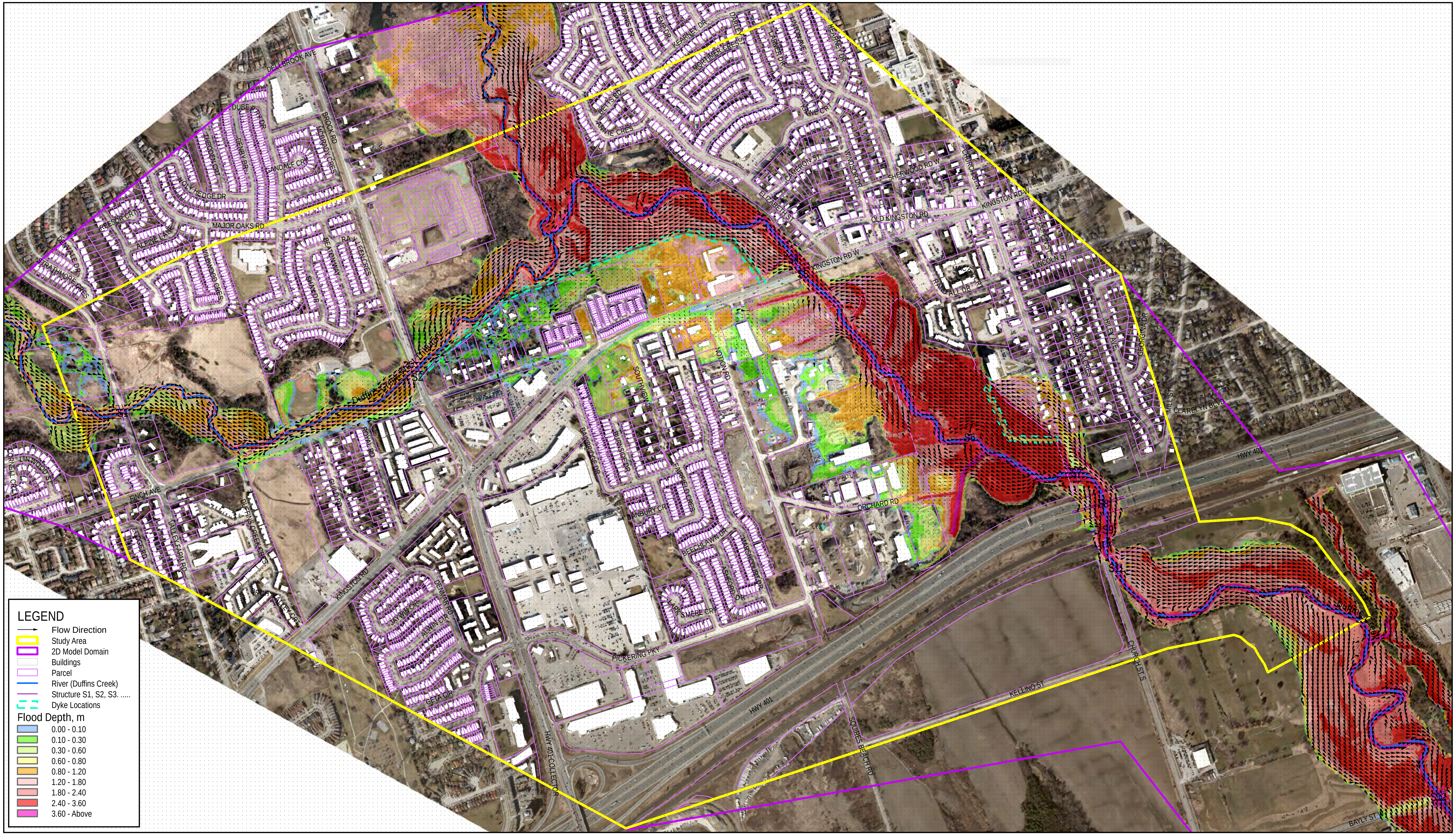

Figure E.10

350-YR FLOOD FLOW DIRECTION MAP

(EXISTING CONDITION)

STEADY INFLOW HYDROGRAPH (350-YR STORM)

250 125 0 250 Meters

01 December 2017

N

Note:

Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain study. Any other use of this information by a third party requires verification and is at the sole risk of that party

TORONTO AND REGION CONSERVATION

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Toronto and Region Conservation for The Living City

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Figure E.11
100-YR FLOOD FLOW DIRECTION MAP
(EXISTING CONDITION)

STEADY INFLOW HYDROGRAPH (100-YR STORM)

250 125 0 250 Meters

01 December 2017

N

Note:

Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain study. Any other use of this information by a third party requires verification and is at the sole risk of that party

TORONTO AND REGION CONSERVATION

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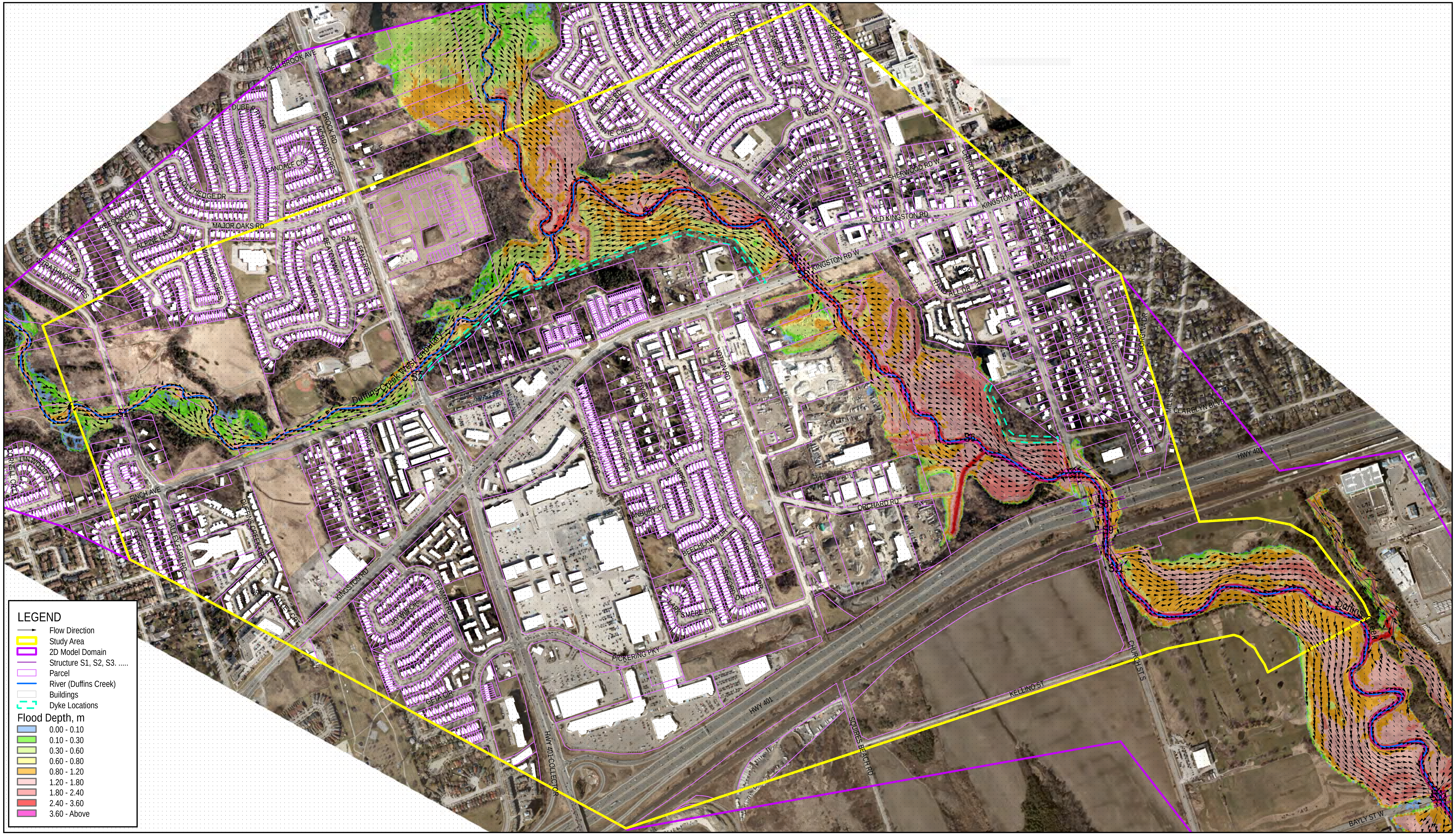

Figure E.12

50-YR FLOOD FLOW DIRECTION MAP

(EXISTING CONDITION)

STEADY INFLOW HYDROGRAPH (50-YR STORM)

250 125 0 250 Meters

01 December 2017

N

Note:

Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain study. Any other use of this information by a third party requires verification and is at the sole risk of that party

TORONTO AND REGION CONSERVATION

PICKERING-AJAX DYKE ASSESSMENT AND FLOOD REMEDIATION STUDY

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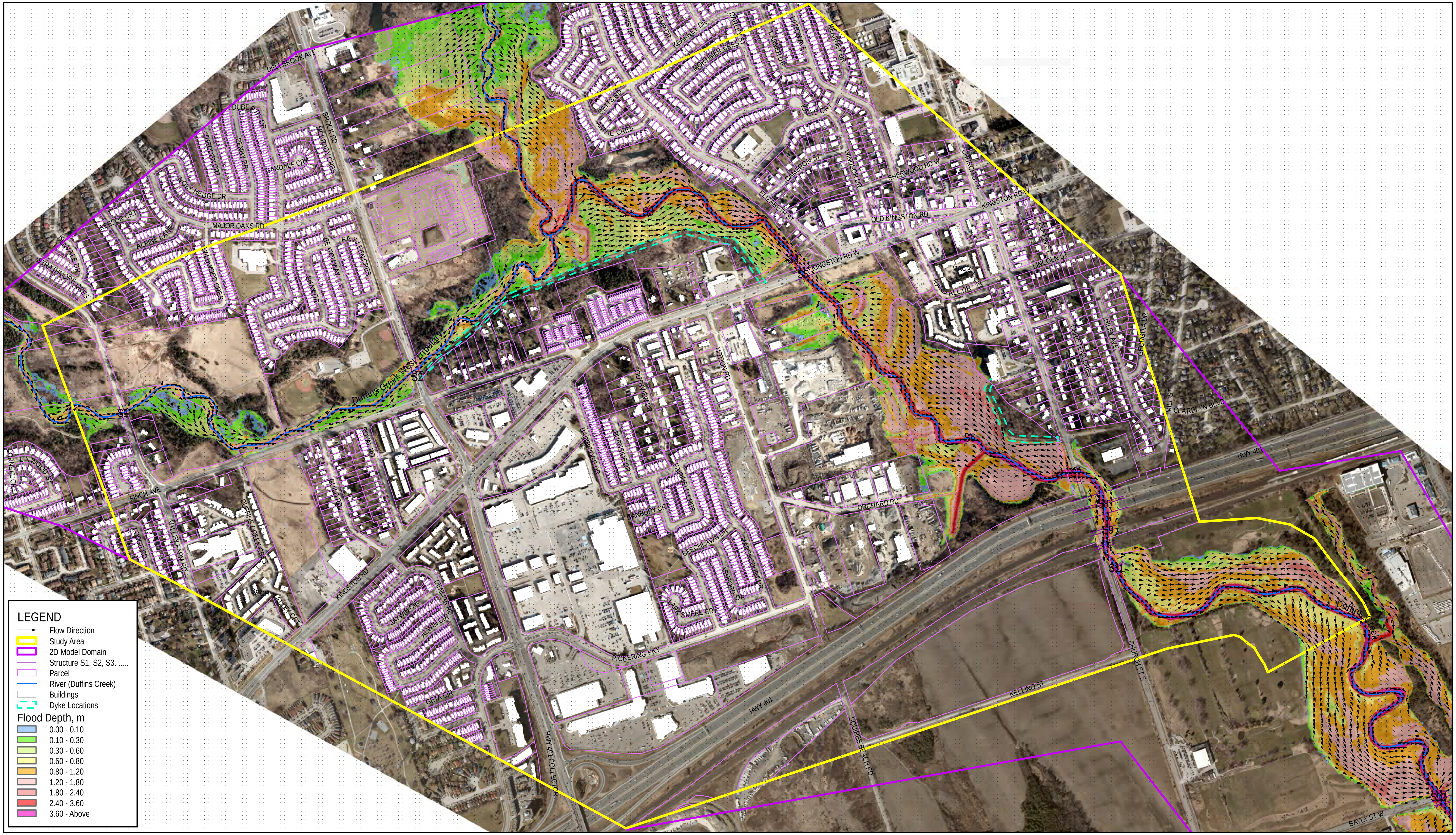

Figure E.13
25-YR FLOOD FLOW DIRECTION MAP
(EXISTING CONDITION)

STEADY INFLOW HYDROGRAPH (25-YR STORM)

01 December 2017

Note:

Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain study. Any other use of this information by a third party requires verification and is at the sole risk of that party

TORONTO AND REGION CONSERVATION

PICKERING-AJAX DYKE ASSESSMENT AND FLOOD REMEDIATION STUDY

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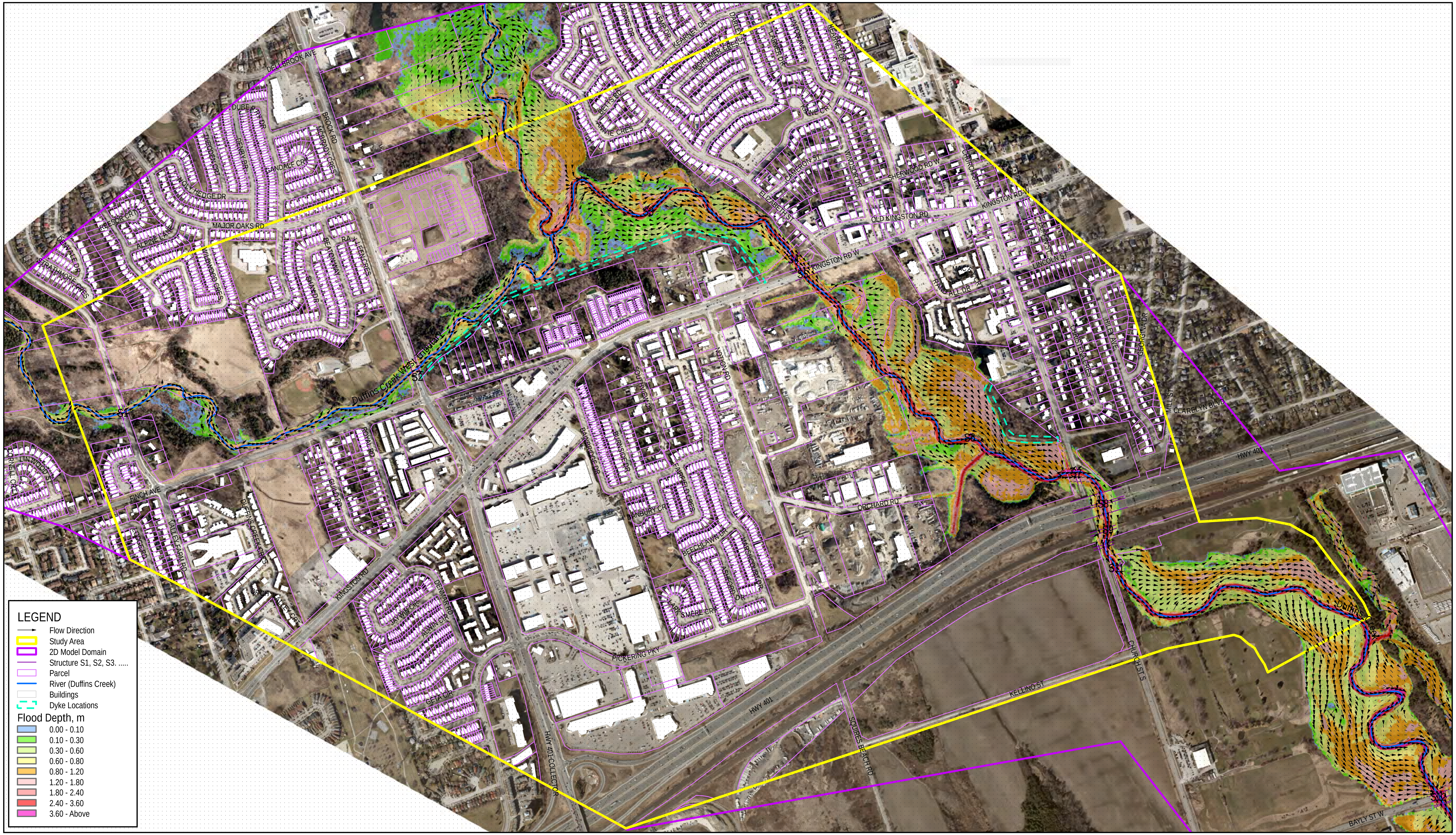

Figure E.14
10-YR FLOOD FLOW DIRECTION MAP
(EXISTING CONDITION)

STEADY INFLOW HYDROGRAPH (10-YR STORM)

Note:

Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain study. Any other use of this information by a third party requires verification and is at the sole risk of that party

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PICKERING-AJAX DYKE ASSESSMENT AND FLOOD REMEDIATION STUDY

Toronto and Region Conservation for The Living City

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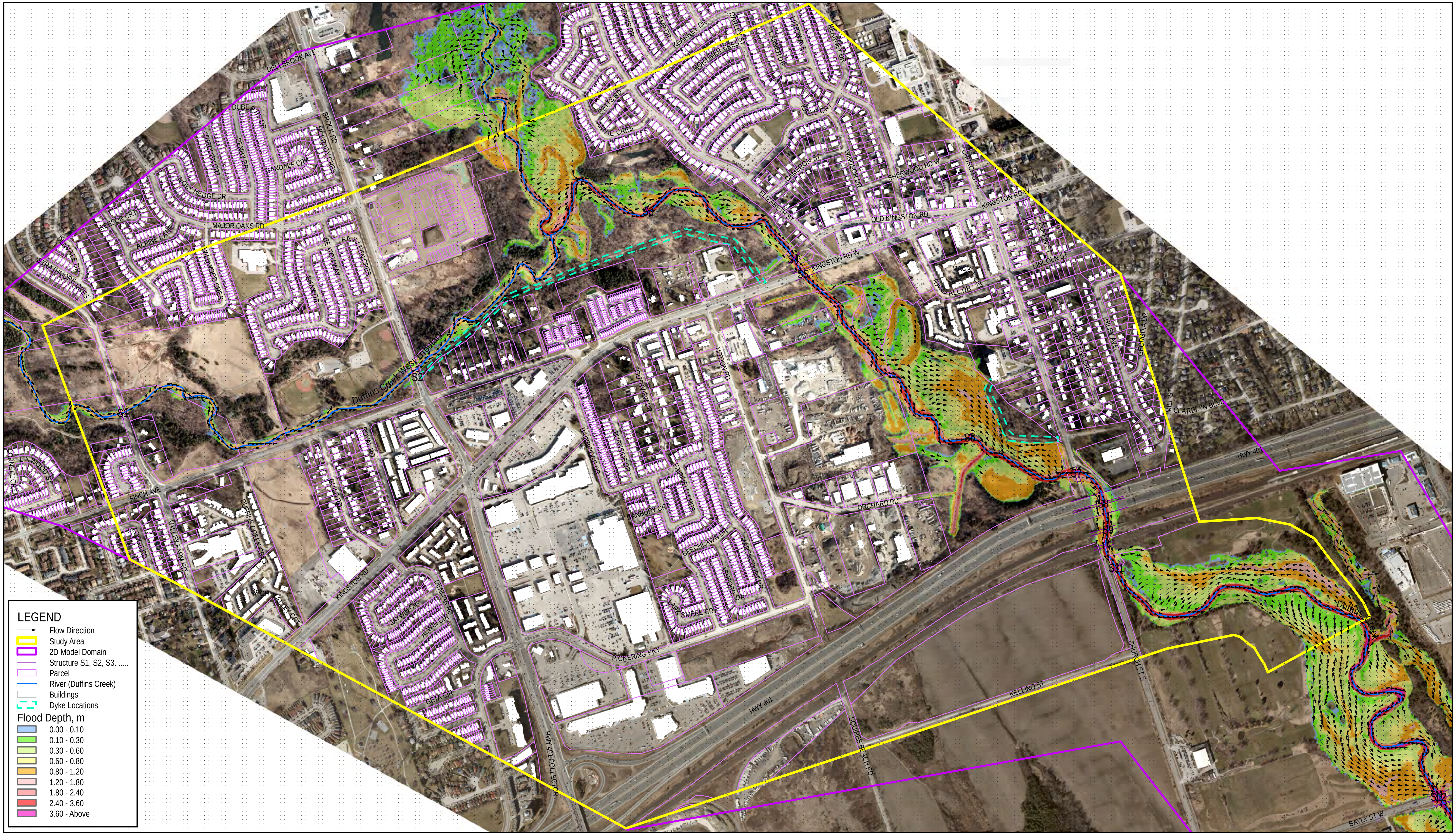

Figure E.15
5-YR FLOOD FLOW DIRECTION MAP
(EXISTING CONDITION)

STEADY INFLOW HYDROGRAPH (5-YR STORM)

250 125 0 250 Meters

01 December 2017

N

Note:

Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain study. Any other use of this information by a third party requires verification and is at the sole risk of that party

TORONTO AND REGION CONSERVATION

PICKERING-AJAX DYKE ASSESSMENT AND FLOOD REMEDIATION STUDY

Toronto and Region Conservation for The Living City

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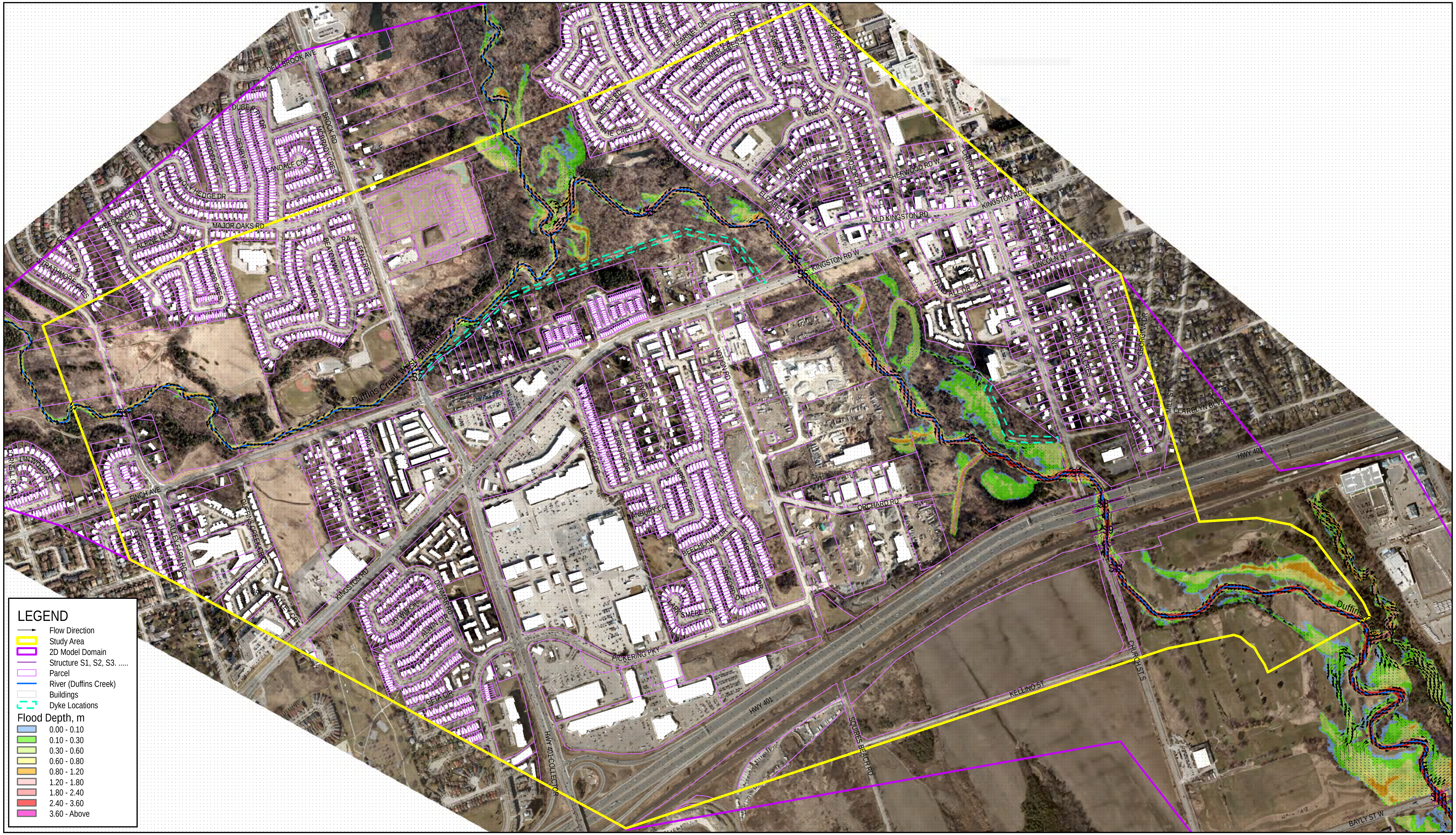

Figure E.16

2-YR FLOOD FLOW DIRECTION MAP

(EXISTING CONDITION)

STEADY INFLOW HYDROGRAPH (2-YR STORM)

05 December 2017

Note:

Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain study. Any other use of this information by a third party requires verification and is at the sole risk of that party

TORONTO AND REGION CONSERVATION

PICKERING-AJAX DYKE ASSESSMENT AND FLOOD REMEDIATION STUDY

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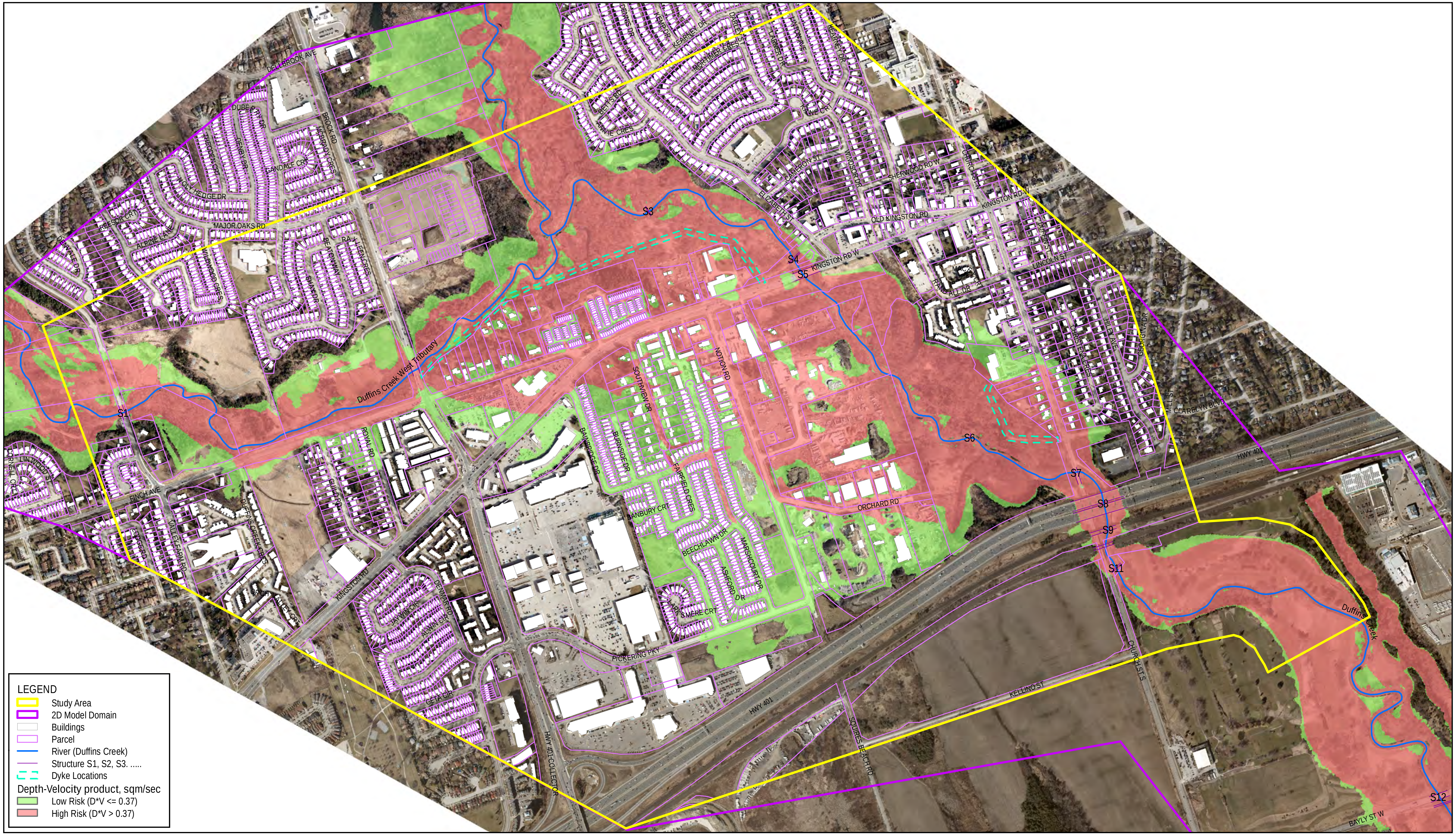

Figure E.17
REGIONAL DEPTH-VELOCITY PRODUCT MAP
(EXISTING CONDITION)
STEADY INFLOW HYDROGRAPH (HURRICANE HAZEL)

Note:

Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain study. Any other use of this information by a third party requires verification and is at the sole risk of that party

TORONTO AND REGION CONSERVATION
PICKERING-AJAX DYKE ASSESSMENT AND FLOOD REMEDIATION STUDY

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Figure E.18

500-YR DEPTH-VELOCITY PRODUCT MAP

(EXISTING CONDITION)

STEADY INFLOW HYDROGRAPH (500-YR STORM)

250 125 0 250 Meters

01 December 2017

N

Note:

Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain study. Any other use of this information by a third party requires verification and is at the sole risk of that party

TORONTO AND REGION CONSERVATION

PICKERING-AJAX DYKE ASSESSMENT AND FLOOD REMEDIATION STUDY

Toronto and Region Conservation for The Living City

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Figure E.19

350-YR DEPTH-VELOCITY PRODUCT MAP

(EXISTING CONDITION)

STEADY INFLOW HYDROGRAPH (350-YR STORM)

250 125 0 250 Meters

01 December 2017

N

Note:

Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain study. Any other use of this information by a third party requires verification and is at the sole risk of that party

TORONTO AND REGION CONSERVATION

PICKERING-AJAX DYKE ASSESSMENT AND FLOOD REMEDIATION STUDY

Toronto and Region Conservation for The Living City

Est. 1992 VALDOR

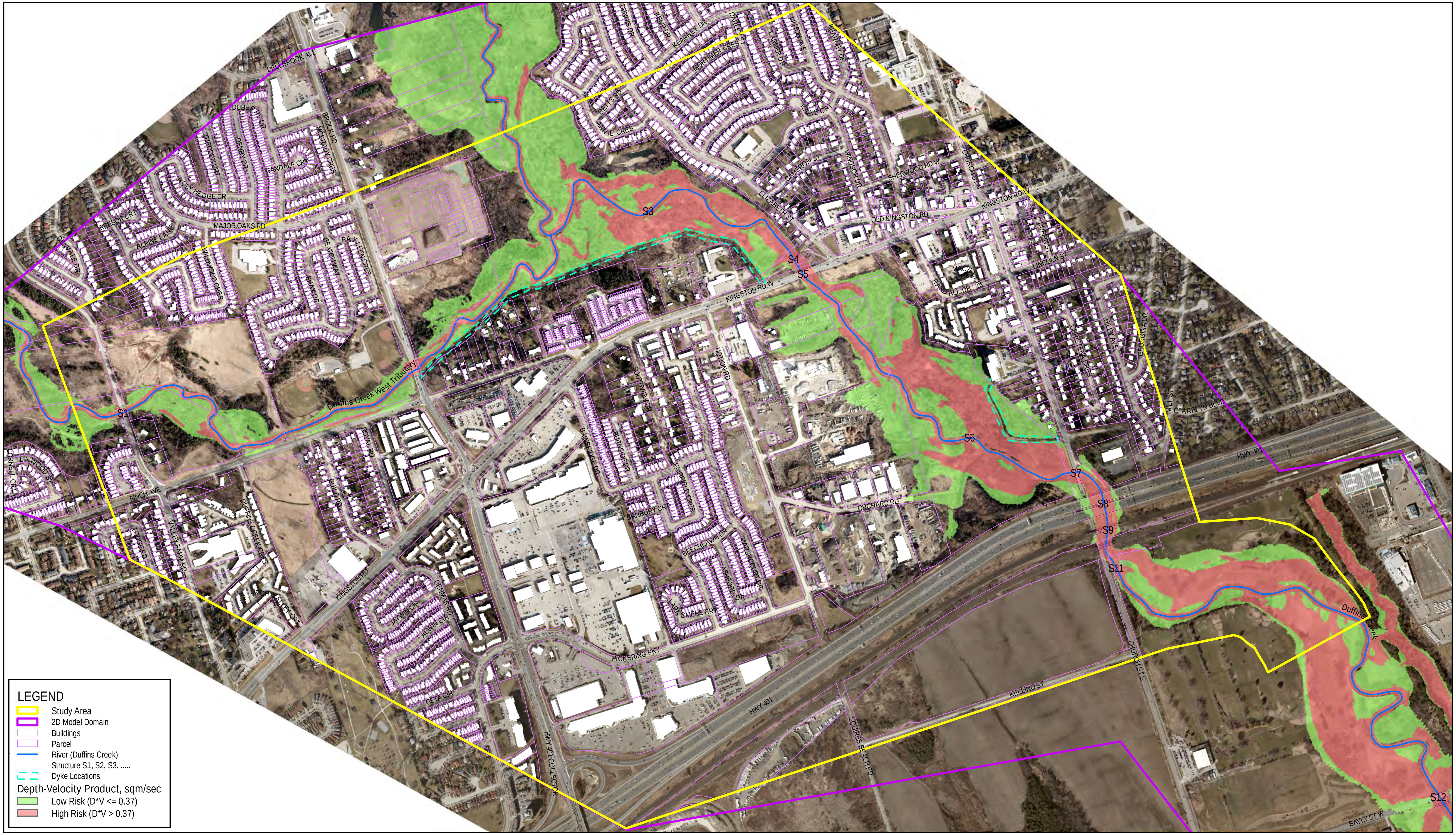

Figure E.20

100-YR DEPTH-VELOCITY PRODUCT MAP

(EXISTING CONDITION)

STEADY INFLOW HYDROGRAPH (100-YR STORM)

250 125 0 250 Meters

01 December 2017

N

Note:

Flood Depth Mapping based on 2015 LiDAR DEM and 2016 Orthophoto. This mapping is intended for the sole purpose of floodplain study. Any other use of this information by a third party requires verification and is at the sole risk of that party

TORONTO AND REGION CONSERVATION

PICKERING-AJAX DYKE ASSESSMENT AND FLOOD REMEDIATION STUDY

Toronto and Region Conservation for The Living City

Est. 1992 VALDOR

APPENDIX ‘F’

Updated Floodplain Map Sheets

Pickering/Ajax Mike Flood
1D-2D Model Development and Regulatory Floodplain Mapping

Toronto and Region Conservation Authority

Appendix ‘F’ Contents:

- **Sheet 4** Duffins Creek Floodplain Map Sheet (full size drawing)
- **Sheet 5** Duffins Creek Floodplain Map Sheet (full size drawing)
- **Sheet 6** Duffins Creek Floodplain Map Sheet (full size drawing)

REVISIONS			
NO.	DESCRIPTION	BY	DATE

NOTE:
Flood line derived using 2D modelling software.
Water surface elevations available - please contact TRCA Engineering Services for further information: 416-661-6600.

LEGEND

Contour Index	Trail
Contour Intermediate	Bridge
Contour Auxiliary	Fence
Contour Text (100)	Water Feature
Spot Height	Building
Road	Regulatory Flood Line
Parking Lot	
Rail Line	
Hydro Tower	

The elevation data on this map was produced by TRCA from a DEM with 0.5 m grid resolution. The DEM was created using mass points with a vertical accuracy tolerance of +/- 0.10m RMSE on hard flat surfaces. The mass points were collected using LiDAR flown in 2015 by Airborne Imaging.

The planimetric data on this map was compiled from a variety of sources of different vintage and may not match with the elevation dataset. This data is for reference only.

The vertical datum is mean sea level as established by the Geodetic Survey of Canada.
CGVD 1928-1978 Ontario Adjusted Version

The horizontal datum is North American Datum 1983, U.T.M. 6° projection Zone 17, Central Meridian 81° W

Grid Interval 100 metres.

PLEASE NOTE:
FLOODLINE ELEVATIONS ARE SUBJECT TO CHANGE DUE TO REVISED INFORMATION.

Elevation Data provided by:

AIRBORNE IMAGING

VALDOR ENGINEERING INC.
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PLEASE NOTE:
THE PROFESSIONAL ENGINEER'S STAMP VERIFIES THE FLOOD LINE AND ASSOCIATED DATA NOT THE MAP DATA UNLESS OTHERWISE NOTED

LICENSED PROFESSIONAL ENGINEER
06 Feb 18
W. L. R. COFFEY
PROVINCE OF ONTARIO

FLOOD PLAIN MAPPING PROGRAM

FLOODLINE APPROVED DATE: ____________

Toronto and Region Conservation for The Living City
5 Shoreham Drive Downsview Ontario M3N 1S4 (416) 661-6600

Scale 1:2000

CONTOUR INTERVAL 1.0 METRE

DUFFINS CREEK

SHEET No. 4

REVISIONS			
NO.	DESCRIPTION	BY	DATE

NOTE:
Flood line derived using 2D modelling software.
Water surface elevations available – please contact
TRCA Engineering Services for further information: 416–661–6600.

LEGEND

Contour Index		Trail	
Contour Intermediate		Bridge	
Contour Auxiliary		Fence	
Contour Text	100	Water Feature	
Spot Height	100.10	Building	
Road		Regulatory Flood Line	• • • • •
Parking Lot			
Rail Line			
Hydro Tower	⊠		

The elevation data on this map was produced by TRCA from a DEM with 0.5 m grid resolution. The DEM was created using mass points with a vertical accuracy tolerance of +/- 0.10m RMSE on hard flat surfaces. The mass points were collected using LiDAR flown in 2015 by Airborne Imaging.

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The vertical datum is mean sea level as established by the Geodetic Survey of Canada.
CGVD 1928-1978 Ontario Adjusted Version

The horizontal datum is North American Datum 1983, U.T.M. 6° projection Zone 17, Central Meridian 81° W

Grid Interval 100 metres.

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Elevation Data provided by:

AIRBORNE IMAGING

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LICENSED PROFESSIONAL ENGINEER
06 Feb 18
W. L. P. COFFEY
PROVINCE OF ONTARIO

FLOOD PLAIN MAPPING PROGRAM

FLOODLINE APPROVED DATE: ____________________

Toronto and Region Conservation for The Living City
5 Shoreham Drive Downsview Ontario M3N 1S4 (416) 661-6600

Scale 1:2000
Metres 100 0 100 200
Feet 200 0 200 400 600 800 1000
CONTOUR INTERVAL 1.0 METRE

DUFFINS CREEK

SHEET No. 5

REVISIONS			
NO.	DESCRIPTION	BY	DATE

NOTE:
Flood line derived using 2D modelling software.
Water surface elevations available – please contact
TRCA Engineering Services for further information: 416-661-6600.

LEGEND

Contour Index		Trail	
Contour Intermediate		Bridge	
Contour Auxiliary		Fence	
Contour Text	100	Water Feature	
Spot Height	100.10	Building	
Road		Regulatory Flood Line	• • • • •
Parking Lot			
Rail Line			
Hydro Tower	⊠		

The elevation data on this map was produced by TRCA from a DEM with 0.5 m grid resolution. The DEM was created using mass points with a vertical accuracy tolerance of +/- 0.10m RMSE on hard flat surfaces. The mass points were collected using LiDAR flown in 2015 by Airborne Imaging.
The planimetric data on this map was compiled from a variety of sources of different vintage and may not match with the elevation dataset. This data is for reference only.
The vertical datum is mean sea level as established by the Geodetic Survey of Canada.
CGVD 1928-1978 Ontario Adjusted Version
The horizontal datum is North American Datum 1983, U.T.M. 6° projection Zone 17, Central Meridian 81° W
Grid Interval 100 metres.

PLEASE NOTE:
FLOODLINE ELEVATIONS ARE SUBJECT TO CHANGE DUE TO REVISED INFORMATION.

Elevation Data provided by:

AIRBORNE IMAGING

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LICENSED PROFESSIONAL ENGINEER
06 Feb 18
W. L. P. COFFEY
PROVINCE OF ONTARIO

FLOOD PLAIN MAPPING PROGRAM

FLOODLINE APPROVED DATE: ____________

Toronto and Region Conservation
for The Living City
5 Shoreham Drive Downsview Ontario M3N 1S4 (416) 661-6600

Scale 1:2000
100 Metres 0 100 200 Metres
200 Feet 0 200 400 600 800 1000 Feet
CONTOUR INTERVAL 1.0 METRE

DUFFINS CREEK

SHEET No. 6

APPENDIX 'G'

TRCA Correspondence, Meeting Minutes

Pickering/Ajax Mike Flood
1D-2D Model Development and Regulatory Floodplain Mapping

Toronto and Region Conservation Authority

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10 August 2017
File: **17134**

Hydrotechnical Meeting #1
Pickering / Ajax SPA 2D Hydraulic Model and Dyke Assessment
TRCA

NOTES OF MEETING

Location:	Meeting via teleconference	
Date of Meeting:	09 August 2017 (14h30 – 15h00)	
Attendees:	Nick Lorrain	Toronto and Region Conservation Authority (TRCA)
	Qiao Ying	Toronto and Region Conservation Authority (TRCA)
	Abdul Baten	Valdor Engineering (Valdor)
	Bill Coffey	Valdor Engineering (Valdor)

Introductions

1. The purpose of the meeting was to discuss any questions/issues regarding the hydrotechnical components of the project (*i.e.* Mike Flood model).

Project Discussions – Summary of Key Items

The following is a brief summary of the key items discussed at the meeting, including any required action items:

2. A progress update was provided by Valdor regarding the review of background information and data pre-processing.

3. Some data gaps were discussed, including the following:

   a. Valdor has identified missing information for many structures including deck elevations, piers, bridge obvert, railing details, etc. **Valdor to confirm whether additional geodetic survey is required or if local field measurements will suffice**. **The TRCA to clarify survey shots and provide sections for surveyed structures as shots are not all labelled clearly.**

   b. It was noted that Valdor does not have as-constructed drawings for the following: (1) Bayly St. Bridge; (2) Pedestrian Bridge d/s of Bayly St. Bridge; (3) CN Railroad Bridge; and, (4) Church St. Bridge. The TRCA indicated that some of this information was not available but they will confirm and provide, if possible. The TRCA confirmed that the HEC-RAS coding of the Bayly St. Bridge can be used and should be reliable. The pedestrian bridge d/s of Bayly St. need not be coded in the Mike Flood model since it is much larger than the Bayly St. Bridge and will not govern in terms of conveyance capacity.

   c. The survey of the Lamprey Weir is missing drop elevations. Qiao indicated that the survey of this information was not possible due to depth/velocity of flow during the survey. Valdor will use the drop provided in the HEC-RAS model.

4. The Mike Flood modelling was discussed, including the following items:

   a. It was noted that the surveyed channel sections are sparsely located. The procedure to proceed with channel interpolations based on surveyed sections provided was discussed.
   b. It was noted that the location of the flow nodes seem to be shifted. The TRCA clarified that the catchment delineations are correct and that the flow nodes correspond to the catchment outlets. Valdor to adjust the flow node locations accordingly.
   c. It was confirmed by the TRCA that the tributary d/s of Brock Road is to be modelled using Mike 11 and that Flow Node 26.5 is the total flow input from this tributary.
   d. Abdul to discuss separately with Qiao the preparation of the building layer for mesh generation.

5. Valdor to prepare and submit the DEM for TRCA review prior to mesh generation.

6. The meeting was adjourned.

Notes Prepared By*:

VALDOR ENGINEERING INC.

Bill Coffey, M.Sc., P.Eng.
Head of Water Resources

c: All Attendees and project team

*Any errors or omissions should be reported to the author in writing as soon as possible.

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24 August 2017
File: **17134**

Hydrotechnical Meeting #2

Pickering / Ajax SPA 2D Hydraulic Model and Dyke Assessment
TRCA

NOTES OF MEETING

Location:	Meeting via teleconference	
Date of Meeting:	23 August 2017 (14h30 – 15h00)	
Attendees:	Nick Lorrain	Toronto and Region Conservation Authority (TRCA)
	Qiao Ying	Toronto and Region Conservation Authority (TRCA)
	Abdul Baten	Valdor Engineering (Valdor)
	Bill Coffey	Valdor Engineering (Valdor)

Introductions

1. The purpose of the meeting was to discuss any questions/issues regarding the hydrotechnical components of the project (*i.e.* Mike Flood model).

Project Discussions – Summary of Key Items

The following is a brief summary of the key items discussed at the meeting, including any required action items:

2. A progress update was provided by Valdor regarding the field survey of hydraulic structures.

    a. It was noted that the Bayly St. Bridge is currently under construction creating access issues to obtain measurements. It was agreed that the Bayly St. Bridge will be coded in the Mike Flood model based the drawings provided by the TRCA and the HEC-RAS structure details.
    b. Similarly, the Valley Farms Rd. Bridge is currently under construction creating access issues. It was agreed that the Valley Farms Rd. Bridge will be coded in the Mike Flood model based the drawings provided by the TRCA and the HEC-RAS structure details.
    c. It was noted that the HEC-RAS model does not indicate any drop at the Lamprey Weir and the TRCA survey does not include information regarding the drop. Based on the Valdor field visit, there is a drop that was measured and the LiDAR also indicates a drop. It was agreed that the drop will be based on the Valdor field measurements.

3. An update was provided by Valdor regarding the Mike Flood model preparation. The detailed delineations for edge of water, bank lines and creek centre line have been completed.

4. The limits of the study area and the model domain extents were discussed and it was agreed that

"engineered" floodlines would be provided within Map Sheets DUF-03, 04, 05 and 06 to the limits of the revised study area. It was proposed that the current identified study area limits at the north end be shifted slightly to the south matching the north limits of Map Sheets DUF-05 and 06 to allow a suitable reach length to ensure model stability and confidence in the flood line results within the map sheet limits. It was agreed that the current study area limit to the north would become the model domain extent and the study area would be revised slightly south, as noted. It was also agreed that an integrated Mike 11/21 model would be prepared for the reaches between the newly established model domain extents to the north to just downstream of Bayly Street. The model domain extents were discussed for the downstream area near the lake and it was agreed that this can be set approx. 1.7 km upstream of the lake (d/s of area near Clements Rd.). Based on the LiDAR, the lake elevation is higher than the water levels in the watercourse to this point including surround lands (*i.e.* very flat and influenced by the lake level). Flows will be applied appropriately. A figure is attached illustrating the proposed adjustments and modelling approach agreed to.

5. It was noted that the HEC-RAS section geometry would be used to supplement the LiDAR data where lands are submerged. **Qiao to confirm if the current HEC-RAS geometry is satisfactory to use for areas modelled in Mike 21 downstream of Bayly Street to the revised model domain extents.**

6. **Valdor to prepare and submit the DEM for TRCA review prior to mesh generation.**

7. **Valdor to follow up with GeoPro regarding the quotation for revised drilling methodology to minimize tree cutting along the flood control berms.**

8. The meeting was adjourned.

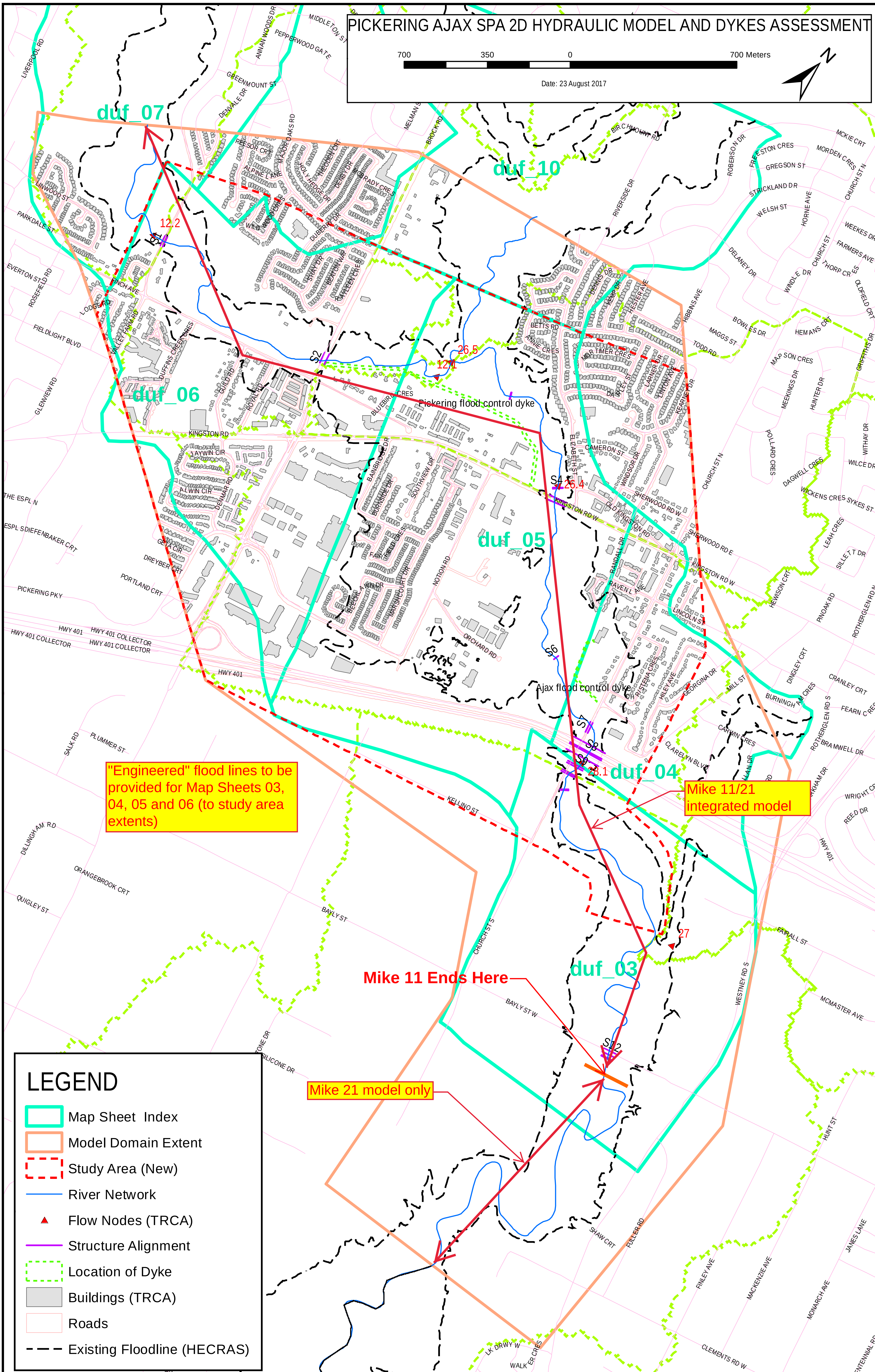
Notes Prepared By*:

VALDOR ENGINEERING INC.

Bill Coffey, M.Sc., P.Eng.
Head of Water Resources

c: All Attendees and project team

*Any errors or omissions should be reported to the author in writing as soon as possible.


PICKERING AJAX SPA 2D HYDRAULIC MODEL AND DYKES ASSESSMENT
700 350 0 700 Meters
N
Date: 23 August 2017
duf_07
duf_10
duf_06
duf_05
duf_04
duf_03
Pickering flood control dyke
Ajax flood control dyke
"Engineered" flood lines to be provided for Map Sheets 03, 04, 05 and 06 (to study area extents)
Mike 11/21 integrated model
Mike 11 Ends Here
Mike 21 model only
S1
S2
S4
S6
S7
S8
S9
S12
12.2
26.5
12.1
26.4
23.1
27
LEGEND
Map Sheet Index
Model Domain Extent
Study Area (New)
River Network
Flow Nodes (TRCA)
Structure Alignment
Location of Dyke
Buildings (TRCA)
Roads
Existing Floodline (HECRAS)

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06 September 2017
File: **17134**

Hydrotechnical Meeting #3

Pickering / Ajax SPA 2D Hydraulic Model and Dyke Assessment
TRCA

NOTES OF MEETING

Location:	Meeting via teleconference	
Date of Meeting:	06 September 2017 (14h30 – 15h00)	
Attendees:	Nick Lorrain	Toronto and Region Conservation Authority (TRCA)
	Qiao Ying	Toronto and Region Conservation Authority (TRCA)
	Abdul Baten	Valdor Engineering (Valdor)
	Bill Coffey	Valdor Engineering (Valdor)

Introductions

1. The purpose of the meeting was to discuss any questions/issues regarding the hydrotechnical components of the project (*i.e.* Mike Flood model).

Project Discussions – Summary of Key Items

The following is a brief summary of the key items discussed at the meeting, including any required action items:

2. An update was provided by Valdor regarding the Mike Flood model preparation. The surface was prepared and submitted recently to the TRCA for review (DTM with participating terrain data sets, DEM in GIS and dfs2 file in Mike Flood). **Valdor to send the channel component raster GIS file to the TRCA (Qiao), as requested, along with a description of the methodology employed regarding the surface preparation.** Once the surface is approved, Valdor to proceed with cutting cross sections and the preparation of the M11 model bathymetry.

3. The land use mapping was discussed regarding the new model domain extent. **Valdor to provide a mask to the TRCA (Qiao) and the TRCA to clip the land use map based on the new model domain extent.**

4. The building polygon layer was discussed. **The TRCA (Qiao) to provide the smoothened building data layer as per earlier discussions.**

5. Discussions were had regarding mesh preparation. **Valdor to provide a figure to the TRCA (Qiao) with the proposed mesh polygon extent with different mesh resolutions for review.**

6. The TRCA indicated they would like to review the mesh once it is prepared. **Valdor to prepare and submit the mesh for review by the TRCA.**

7. Valdor indicated some questions/concerns regarding the proposed Q-H relationship to be used at the

downstream boundary that was based on HEC-RAS. It was agreed that further discussions would be had regarding this to ensure the most appropriate boundary condition is used. **The TRCA (Qiao) to review and confirm based on the preparation of another Q-H relationship using M11.**

8. The meeting was adjourned.

Notes Prepared By*:

VALDOR ENGINEERING INC.

Bill Coffey, M.Sc., P.Eng.
Head of Water Resources

c: All Attendees and project team

*Any errors or omissions should be reported to the author in writing as soon as possible.

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31 October 2017
File: **17134**

Hydrotechnical Meeting #4

Pickering / Ajax SPA 2D Hydraulic Model and Dyke Assessment
TRCA

NOTES OF MEETING

Location:	Meeting via teleconference	
Date of Meeting:	04 October 2017 (14h30 – 15h00)	
Attendees:	Nick Lorrain	Toronto and Region Conservation Authority (TRCA)
	Qiao Ying	Toronto and Region Conservation Authority (TRCA)
	Abdul Baten	Valdor Engineering (Valdor)
	Bill Coffey	Valdor Engineering (Valdor)

Introductions

1. The purpose of the meeting was to discuss any questions/issues regarding the hydrotechnical components of the project (*i.e.* Mike Flood model).

Project Discussions – Summary of Key Items

The following is a brief summary of the key items discussed at the meeting, including any required action items:

2. An update was provided by Valdor regarding the Mike Flood model preparation. Discussions were had regarding the modelling of the Hwy 401 crossing. **Valdor to include a discussion on how the crossings in this area were modelled in the report.**

3. The bathymetry was discussed and final comments were provided by the TRCA. **Valdor to finalize the bathymetry based on these comments and to proceed with the coupling of the M11 and M21 models and run the existing conditions model for the Regional storm.**

4. An update was provided regarding the geotechnical investigations. GeoPro is finalizing the lab work and will be preparing the geotechnical report.

5. The meeting was adjourned.

Notes Prepared By*:

VALDOR ENGINEERING INC.

Bill Coffey, M.Sc., P.Eng.
Head of Water Resources

c: All Attendees and project team

*Any errors or omissions should be reported to the author in writing as soon as possible.

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31 October 2017
File: **17134**

Hydrotechnical Meeting #5

Pickering / Ajax SPA 2D Hydraulic Model and Dyke Assessment
TRCA

NOTES OF MEETING

Location: TRCA Offices - Moraine Room

Date of Meeting: 24 October 2017 (14h30 – 15h30)

Attendees:	Nick Lorrain	Toronto and Region Conservation Authority (TRCA)
	Qiao Ying	Toronto and Region Conservation Authority (TRCA)
	Abdul Baten	Valdor Engineering (Valdor)
	Bill Coffey	Valdor Engineering (Valdor)

Introductions

1. The purpose of the meeting was to discuss any questions/issues regarding the hydrotechnical components of the project (*i.e.* Mike Flood model).

Project Discussions – Summary of Key Items

The following is a brief summary of the key items discussed at the meeting, including any required action items:

2. An update was provided by Valdor regarding the Mike Flood model preparation and a summary review was provided to the TRCA regarding the modified DEM creation, the 1D (M11) model, the 2D (M21) model and mesh and the Mike Flood boundaries.

3. Preliminary results were presented (Flood Depth Mapping and animations) for the Regional storm. The results were discussed and it was agreed that Valdor would proceed with modelling the Regional model using steady flows only and the 500-yr model would be prepared for both steady and unsteady flows. The results of the 500-yr model will be reviewed by the TRCA and discussed prior to proceeding with the return period model runs (either steady or unsteady flows will be used for the return period runs – to be determined). **Valdor to submit a digital copy of the steady flow Regional storm Mike Flood model for TRCA review and to be followed by the steady and unsteady flow 500-yr Mike Flood model for TRCA review prior to proceeding with final return period model runs.**

4. An update was provided regarding the geotechnical investigations. GeoPro is finalizing the geotechnical report and has indicated it will be completed next week. **Valdor to submit to the TRCA for review.**

5. The meeting was adjourned.

Notes Prepared By*:

VALDOR ENGINEERING INC.

Bill Coffey, M.Sc., P.Eng.
Head of Water Resources

c: All Attendees and project team

*Any errors or omissions should be reported to the author in writing as soon as possible.

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29 November 2017
File: **17134**

Hydrotechnical Meeting #6

Pickering / Ajax SPA 2D Hydraulic Model and Dyke Assessment
TRCA

NOTES OF MEETING

Location:	via teleconference	
Date of Meeting:	29 November 2017 (14h30 – 15h00)	
Attendees:	Nick Lorrain	Toronto and Region Conservation Authority (TRCA)
	Qiao Ying	Toronto and Region Conservation Authority (TRCA)
	Mike Todd	Toronto and Region Conservation Authority (TRCA)
	Abdul Baten	Valdor Engineering (Valdor)
	Bill Coffey	Valdor Engineering (Valdor)

Introductions

1. The purpose of the meeting was to provide a project status update and to clarify and confirm the reporting format related to the 1D-2D modelling and flood characterization.

Project Discussions – Summary of Key Items

The following is a brief summary of the key items discussed at the meeting, including any required action items:

2. An update was provided by Valdor regarding the *Dyke Safety Report*. **It was noted that figures were being finalized and hard copies of the report will be printed and delivered to the TRCA tomorrow.** The TRCA indicated that 4 copies of the report were required.

3. An update was provided by Valdor regarding the Mike Flood model runs. It was indicated that 8 of the 11 runs were completed, however, post-processing needs to be done. The TRCA confirmed that all model runs will be completed using the steady inflow hydrographs and that the Regional storm simulation will also include a run using the unsteady inflow hydrographs. In addition, it was confirmed that Scenarios 9, 10 and 11 in Table 1 of the RFP are to be run using the future conditions flows (not Existing conditions flows) and Scenario 10 with the dyke removed is to be completed using the 500-yr storm (not 350-yr storm). Qiao and Abdul to discuss the best approach for removing the berm in the mesh. The TRCA noted that a scenario is not required with topsoil removed from the top of berm.

4. The coordination of activities associated with the preparation of the floodplain map sheets was discussed. It was agreed to use the following approach (similar to previous approach on other TRCA projects):

   a. Valdor to provide the TRCA with the combined DEM surface (combined LiDAR and watercourse survey data).
   b. The TRCA (Mike Todd) to prepare the floodplain map sheet contours using the combined DEM

surface provided by Valdor and return to Valdor a shp file with the contours.

c. Valdor to delineate the Regional floodline using the contour information in conjunction with the depth mapping prepared using Mike Flood (this will avoid any 'visual discrepancies' on the floodplain map sheets).
d. Valdor to provide the TRCA (Mike T.) with a digital copy of the Regional floodline delineations.
e. The TRCA to overlay the floodlines on the base mapping for the floodplain map sheets and return a digital copy to Valdor for review.
f. Valdor to review and provide any comments, if necessary, to the TRCA (Mike T.).
g. The TRCA (Mike T.) to print off a final hard copy for pick-up by Valdor from TRCA Reception.
h. Valdor to complete final check and sign/seal drawings, make copies for report and return signed/sealed original to TRCA reception (Attn. Mike Todd).

5. Clarification was requested by Valdor regarding the total number and organization of reports for the project. Valdor asked if it was acceptable to combine the 1D-2D model development, regulatory floodplain mapping and flood characterization in one report (similar to the approach for the Bolton project – excl. info to be included in the separate *Dyke Safety Report*). **The TRCA (Nick L.) to review/clarify/confirm if this is acceptable and how the TRCA would like the project reports separated or combined. If that is acceptable, Valdor will complete the *2D Modelling and Flood Characterization Report* and deliver to the TRCA by 22 December 2017.**

6. The TRCA requested a meeting be held on 18 or 19 December with Ali S. and Craig M. to discuss any comments regarding the *Dyke Safety Report*. **The TRCA to confirm dates internally and send out meeting invitation.**

7. The meeting was adjourned.

Notes Prepared By*:

VALDOR ENGINEERING INC.

Bill Coffey, M.Sc., P.Eng.
Head of Water Resources

c: All Attendees and project team

*Any errors or omissions should be reported to the author in writing as soon as possible.

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25 July 2017
File: **17134**

Steering Committee Meeting #1

Pickering / Ajax SPA 2D Hydraulic Model and Dyke Assessment
TRCA

NOTES OF MEETING

Location:	TRCA – Duffins Room	
Date of Meeting:	20 July 2017 (14h30 – 16h30)	
Attendees:	Nick Lorrain	Toronto and Region Conservation Authority (TRCA)
	Qiao Ying	Toronto and Region Conservation Authority (TRCA)
	Robert Chan	Toronto and Region Conservation Authority (TRCA)
	Abdul Baten	Valdor Engineering (Valdor)
	Bill Coffey	Valdor Engineering (Valdor)

Introductions

1. Introductions were made.

2. The purpose of the meeting was to "kick-off" the project with the TRCA and to review the work plan, schedule and available background information.

Project Discussions – Summary of Key Items

The following is a brief summary of the key items discussed at the meeting, including any required action items:

3. *Administrative Items:* The engineering agreement and data sharing agreements were signed previously. Valdor provided previously the TRCA with the required WSIB Clearance Certificate and insurance certificates for professional liability, commercial general liability and automobile liability. Valdor will record and distribute minutes from the project meetings.

4. *The Project Team:* The project lead consultant will be Valdor Engineering. Also included on the project team is GeoPro Consulting Limited for geotechnical / structural work and Water's Edge for provisional survey work.

5. The TRCA will setup a project using Basecamp which is a web based project management tool to enable organized communications, file sharing, etc. between members of the project team.

6. The project work plan and schedule were reviewed.

7. *Transfer of Information:* The TRCA provided Valdor with a USB drive with various files, reports and information (see attached list). Valdor will review the information provided and identify any data gaps.

8. Valdor requested a copy of the legal fabric, if available. The TRCA will try to obtain.

9. Ali Shirazi will be the contact at the TRCA regarding geotechnical issues and review.

10. The TRCA (Nick) re-iterated the importance to have the project completed within the allocated schedule as the funding is time sensitive.

11. It was indicated by the TRCA that some sites are under construction (e.g. Church site) that may need to be reviewed to confirm consistent with the assigned roughness values.

12. If using the Highway 401 drawings, an adjustment of 10 cm is required to account for the historical vertical datum adjustment.

13. If Valdor runs the model down to Lake Ontario, it was agreed that a lake water surface elevation of 75.70 m is to be used.

14. Discussed pros and cons of mesh vs. grid usage when completing 2D studies.

15. Discussed the triangulation issue with mesh in the vicinity of buildings. Valdor to work with TRCA (Qiao) to simplify.

16. Edge of water line was discussed. The current line indicated on the plan is an offset from the centerline and may be closer to a bank line although it does not match very well in many areas with the orthophoto. Valdor will delineate edge of water based on the orthophoto.

17. Unsteady flows will be provided by the TRCA for the identified flow nodes. It was discussed and agreed to distribute flows between the flow nodes.

18. There is a weir structure that was identified by the TRCA that has been surveyed. This information will be provided to Valdor.

19. It was agreed that Valdor will provide the TRCA with the bathymetry for TRCA review once it is complete. Similarly, Valdor to provide the MF model to the TRCA for review at key development stages. It is anticipated this will streamline the model review process.

20. It was agreed that Mike Flood 2016 using M11 'Classic' will be used to model this study. It was discussed there are some issues/limitations with Mike Hydro (MF 2016) and some uncertainty with Mike Hydro (MF 2017) possibly when used with the mesh (?).

21. Valdor to sign the TRCA's data sharing agreement.

22. A tentative date was set for 27 July (11h00) to meet to discuss the geotechnical work plan and methodology. Valdor to confirm with GeoPro that they are available.

23. It was agreed that bi-weekly 'technical' meetings would be beneficial, at least during the initial stages of data review and model development, to help streamline the process. The TRCA will set this up.

24. The meeting was adjourned.

Notes Prepared By*:

VALDOR ENGINEERING INC.

Bill Coffey, M.Sc., P.Eng.
Head of Water Resources

c: All Attendees and project team

*Any errors or omissions should be reported to the author in writing as soon as possible.

Pickering Ajax 2D Model Project
Data Transfer List

Last Edited: July 25, 2017 by Qiao

	Data	Notes	Status	Folder
1	Study area GIS shapefile		In hard drive	\Background\Study Area
2	2012 Hydrology Study	Report	In hard drive	\Background\Hydrology
3	Flow Nodes GIS shapefile		In hard drive	\Background\Hydrology\Basemaps
4	Catchments GIS shapefile		In hard drive	\Background\HydrologyBasemaps
5	Watercourse GIS shapefile		In hard drive	\Background\Hydrology\Basemaps
6	Landuse GIS shapefile		In hard drive	\Background\Hydrology\Basemaps
7	Location of existing HEC-RAS cross-section	From HWY 401 to the lake	In hard drive	\Background\Hydrology\Basemaps
8	Existing HEC-RAS models	Not geo-referenced	In hard drive	\Background\Existing HEC-RAS
9	LiDAR data	0.5-m (study area) and 1m (from HWY 401 to the lake) ESRI Grid format	In hard drive	\Background\PickeringAjaxLidar
10	Aerial Imagery (2016)	15-cm Orthographic image (study area) and 1m Orthographic image (from HWY 401 to the lake)	In hard drive	\Background\Ortho Image
11	Building footprint GIS shapefile		In hard drive	\Background\Hydrology\Basemaps
12	Roads GIS shapefile		In hard drive	\Background\Hydrology\Basemaps
12	TRCA Standard Manning's n (pdf)	Manning's Roughness	In hard drive	\Background
14	Existing Mapping Sheets index GIS shapefile		In hard drive	\Background\Mapsheets
15	Existing Mapping Sheets (dwg, dgn and pdf format)	8 mapping sheets	In hard drive	\Background\Mapsheets

16	Floodline polygon		In hard drive	\Background\Mapsheets
17	Hydraulic Structure Inventory Sheet	template	In hard drive	\Background
18	Flow data (in excel)	Peak flows and 15-minutes hydrographs	In hard drive	\Background\Hydrology\Flow data
19	Dyke Design Drawings in TIFF		In hard drive	\Background\Dyke Design Drawings
20	Location of Dykes GIS shapefile		In hard drive	\Background\Dyke Design Drawings
21	Pickering Ajax Dyke study report (2009) (pdf)		In hard drive	\Background
22	Bridge Drawings (pdf)		In hard drive	\Background\Bridge Drawings
23	Survey Data		In progress	\Background\Survey Data
24	Contour		In progress	\Background\Contour Data

Abdul Baten

From: Qiao Ying <qiao.ying@trca.on.ca>
Sent: Friday, September 08, 2017 4:25 PM
To: Abdul Baten
Cc: Bill Coffey; Nick Lorrain
Subject: RE: DEM review and Q-H boundary

Hi Abdul,

I think it will be easier to do adjustment in MIKE 11 cross-sections. Regarding the building and landuse polygons, Mike has finished but we have not got time to QA/QC, so I think it would be better I send them early next week.

Qiao

Regards,

Qiao Ying M.Sc., P.Eng. | Capital Projects | Restoration & Infrastructure
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416-661-6898 | qiao.ying@trca.on.ca | www.trca.on.ca | Follow us on Twitter @TRCA_Flood
Office Location and Courier Address |101 Exchange Avenue | Vaughan, Ontario L4K 5R6

Mailing Address | 5 Shoreham Drive | Toronto, Ontario M3N 1S46

From: Abdul Baten <ABaten@Valdor-Engineering.com>
To: Qiao Ying <qiao.ying@trca.on.ca>
Cc: Bill Coffey <BCoffey@Valdor-Engineering.com>, Nick Lorrain <nlorrain@trca.on.ca>
Date: 09/08/2017 12:39 PM
Subject: RE: DEM review and Q-H boundary

Hi Qiao,

Thanks for your review and feedback on the modified DEM for low flow water area. I have gone through the indicated three areas to check and verify underwater ground surface. I cut several cross-sections and longitudinal sections through those areas and check with the available data. In general, the cross-section's cut extending between the two low flow water edges show consistent. I also cut longitudinal profiles following thalweg and this thalweg-profile seem ok in general.

The long section shown in your first figure is a longitudinal creek profile near 401. This long-profile shows low point immediate upstream side of the 401 and high point spike immediate downstream side of the 401 (see the arrows marked in yellow in the attached file no.1). These two low and high elevation points in the longitudinal profile seem real, which are due to the contribution of the surveyed elevation points in the interpolated surface. In the attached file no.2, you can see the survey elevation points in red, which show agreement to the interpolated values. Profile (see file no.2) through the thalweg looks a bit better, which is 20 - 25 cm lower than the high point shown in the 1st figure of file no.1.

In conclusion, if we really need adjustment to resolve any unrealistic situation in geometry for this area we can do it directly in the Mike 11 cross-sections, which should work fine as well. Another approach could be to create a surface again, where we can exclude those high and low survey points. But that may not be realistic for this area.

Let me know your thoughts.

Regards,

Abdul Baten

From: Qiao Ying [mailto:qiao.ying@trca.on.ca]
Sent: Thursday, September 07, 2017 3:27 PM
To: Abdul Baten <ABaten@Valdor-Engineering.com>
Cc: Bill Coffey <BCoffey@Valdor-Engineering.com>; Nick Lorrain <nlorrain@trca.on.ca>
Subject: DEM review and Q-H boundary

Hi Abdul,

As we discussed on the phone, we all agreed the Q-H boundary I provided earlier works reasonably for this project. I have reviewed the 1D DTM, and found 3 areas where the interpolation seemed off, please see attached document. I also reviewed the two dykes in the final DEM, and did spot check and they look good to me. Mike is finalizing the building footprint and landuse map, and they will be ready tomorrow.

Qiao

Regards,

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[attachment "1 - DEM Review_PickeringAjax - TRCA.docx" deleted by Qiao Ying/TRCA] [attachment "2 - Longitudinal profile of Duffin Creek at 401 - Valdor.docx" deleted by Qiao Ying/TRCA]

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Thank you."

Abdul Baten

From: Qiao Ying <qiao.ying@trca.on.ca>
Sent: Thursday, September 07, 2017 11:47 AM
To: Abdul Baten
Cc: Bill Coffey; Nick Lorrain
Subject: Q-H boundary - Pickering Ajax 2D model
Attachments: Comparison of Steady and Unsteady.xlsx

Hi Abdul,

I converted the existing HEC-RAS model for Catchment 28 from steady to unsteady, and ran few events (50yr, 100yr, 350yr plus regional). The comparisons between steady and unsteady results for selected events show that results are very similar within the final 2D model domain (upstream of Station 28.13), and diversion of difference in results starts downstream of 2D model downstream boundary. The tests also demonstrate that using 75.7m Lake Level as 2D model downstream boundary will significantly under-estimate water surface elevations. The conclusion is the Q-H relation extracted from the existing HEC-RAS model is reasonable. I have attached excel spreadsheet of my analysis.

Qiao

Regards,

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Mailing Address | 5 Shoreham Drive | Toronto, Ontario M3N 1S46

From:	Bill Coffey
To:	"Qiao Ying"
Cc:	Nick Lorrain; Abdul Baten
Subject:	RE: TRCA"s comments on the DRAFT Report - Pickering Ajax 2D Modeling
Date:	Friday, March 09, 2018 5:01:00 PM

Hi Qiao,

This is to confirm that we have addressed all comments, as requested per the TRCA's Memorandum dated 18 January 2018.

Regarding Comment #14, discussions were had between you and Abdul Baten (Valdor) and it was agreed that Table C.2 would be moved from Appendix C and added as two tables (Tables 2.4 and 2.5) to Section 2.3.4 in the main body of the report. Thank you.

Regards,

Bill Coffey, M.Sc., P.Eng.
Head of Water Resources
Valdor Engineering Inc.

From: Qiao Ying [mailto:qiao.ying@trca.on.ca]
Sent: Thursday, January 18, 2018 3:10 PM
To: Bill Coffey <BCoffey@Valdor-Engineering.com>
Cc: Nick Lorrain <nlorrain@trca.on.ca>; Abdul Baten <ABaten@Valdor-Engineering.com>
Subject: TRCA's comments on the DRAFT Report - Pickering Ajax 2D Modeling

Hi Bill,

Attached please find the our comments on the draft report. I also include SPA polygon file to be included in Figure 1.1.

Qiao

Regards,

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TORONTO AND REGION Conservation for The Living City

MEMORANDUM

TO:	Bill Coffey, Valdor Engineering Inc.	DATE:	January 18, 2018
FROM:	Qiao Ying, Nick Lorrain	CFN:	57370
RE:	Pickering Ajax 2D Modeling and Dyke Assessment Study – DRAFT Existing Conditions Report		
CC:	Sameer Dhalla, Abdule Baten		

Engineering Services staff has had the opportunity to review the DRAFT report titled "Mike Flood 1D-2D Model Development and Regulatory Floodplain Mapping Pickering/Ajax SPA (DRAFT)" dated December 2017 as prepared by Valdor Engineering Ltd. and offer the following comments:

Capital Projects Comments

1. Please review the report in detail and address grammar and spelling errors as required.

2. Please ensure the Table of Content (ToC) is consistent with the sections, sub-sections referenced in the report.

3. Further, please ensure the Figure labels and titles are consistent between the ToC and the figures in the report.

4. Please note the report references figures 2.4a and 2.4b, however these figures were not provided. Further, figure 2.5 is also missing (2.4 and 2.5 seem to have been combined).

5. Please revise the "Follows Section" column in the ToC for the figure listings.

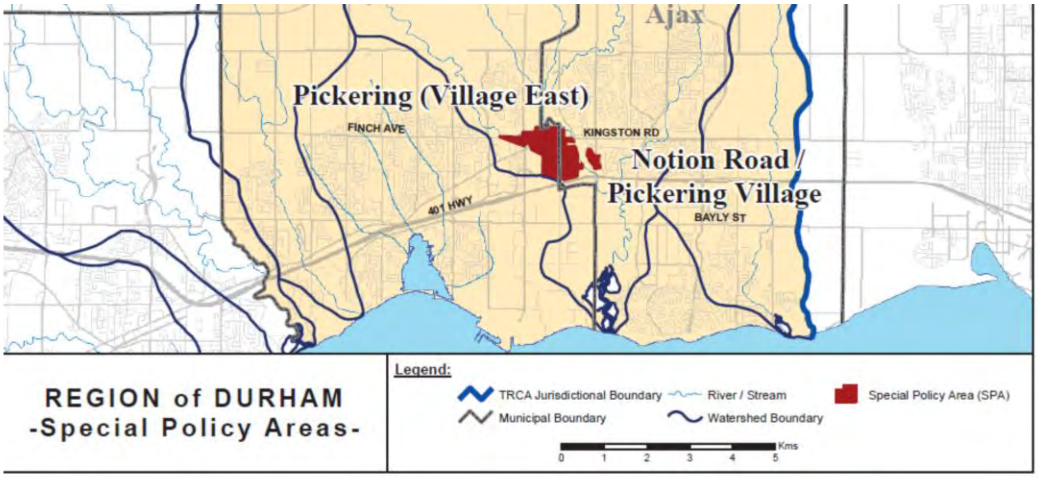
6. Section 1.5, Previously Completed Available Studies and Information, the Geomorphic Solutions study should be a separate bullet point.

7. In the Context section, please replace "berm" with "dyke".

8. A number of the figure titles reference Mike hydro or Mike 11. In order to avoid confusion, please use only one term (this happens in Figure 2.1, Figure 2.10, Figure B.5a-B.5c).

9. For figure titles, please use full words (e.g. existing condition) instead of abbreviations (e.g. ex cond) (this occurs in Figure 2.11, Figure 3.1, Figure 3.2, Figure B.6a, Figure B.6b, and Figure B.8).

10. In Figure 1.1, please include the SPA polygons and municipal boundaries for the City of Pickering and Town of Ajax (see image below).



11. In Section 1.4, we only need to produce Map Sheets 4, 5 and 6. Map sheet 3 is not required. Please revise this section as required.

12. In Section 2.1.1, for bullet #7 "2016 survey data" please provide further details related to the type of available survey data (i.e. Channel or Dyke surveys).

13. In Section 2.1.4, the last sentence "The final 1D - 2D combined and corrected raster DEM….." please revise to read "The final channel bottom corrected raster DEM…."

14. Please prepare a figure for Section 2.4.3 Boundary Conditions Setup and Flow Input Hydrographs which correlate the flow nodes used in the MIKE Flood model with the flow nodes from the hydrology model.

15. Further, please update Table 2.3: Mike 11/21 Model Boundaries to include a column with the Regional Storm peak flow values used at each of the flow nodes.

16. Please provide a note for Table C.2 in Appendix C to highlight that the flows for Nodes 12.1, 26.4, 28.1, and 28 are peak flows from the sub-catchments, and not the flow nodes referenced in the hydrology model.

17. For a coupled model, creation of the 1D portion of model is normally completed first, then followed by creation of 2D portion, therefore please switch Section 2.3 and Section 2.4 to reflect the proper sequence of the model build. Further please revise the sub-section numbering as required.

18. Section 2.3 MIKE 11 1D River Model references the Humber River Watershed, please revise to reference the Duffins Creek, and proper tributary. In addition, please revise the main elements of the MIKE 11 model setup as follows:

    - Establish channel network and creating cross-section
    - Structure modeling
    - Roughness parameters
    - Boundary and initial conditions
    - Simulation settings

19. Figure 2.10 Channel Network and Cross Sections, please remove red rectangular cross-sections and red cross-section correction line from the figure and only keep the cross-section width lines.

20. Table 2.2 Structure Modelling, the last three rows need to be updated to reflect the latest revision, i.e. both S10 and S11 were represented as Piers in M21 2D, and S12 was represented as a Culvert and Weir in M11.

21. Section 2.3.4 Boundary Conditions Setup and Flow Input Hydrographs, please revise the sentence "…, while the downstream boundary is usually a constant or time series water level" by adding "or a rating curve representing Q-H relationship" at the end of the sentence.

22. Please add a section discussing simulation settings in 1D model: timestep, simulation period, initial condition, results saving settings (1D results, and 2D mapping output within the channel) etc.

23. Section 2.3 MIKE 21 2D Overland Flow, please revise the main elements of the MIKE 21 model setup as follows:
    - Mesh design
    - Bathymetry creation
    - Roughness parameters
    - Boundary and initial conditions
    - Model settings

24. Please separate the discussion related to mesh design from the bathymetry creation discussion and provide a separate section.

25. Section 2.3.2 Boundary Conditions, please add the following text "In a 1D and 2D coupled model," before the sentence "The upstream inflow boundary is typically defined in the MIKE 11 mode". In addition, please change "Typically, in MIKE Flood…" to "Typically, in MIKE 21". This section is intended to discuss boundary and initial conditions specifically for the 2D MIKE 21 model, as such please provide discussions related to what type of 2D boundary condition and initial condition were defined in the 2D model.

26. Please add a section related to "Model settings". This new sections should discuss items such as simulation period, timestep, flooding and drying, eddy viscosity and outputs etc.

27. Section 2.5 (i.e. coupled model), please add the following sentence "For the Duffins branches, lateral links were used to connect the 1D MIKE 11 model with the corresponding mesh elements of the 2D MIKE 21 model, as shown on Figure 2.11".

28. In Table 3.1, for S02 please change 3-33 hours to 30 hours.

Please revise the report at your earliest convenience, and feel free to contact me should you have any questions or concerns.

Regards,
Qiao