Appendix B
Technical Studies

Technical Memorandum

June 9, 2021

To:	Ms. Diana Friesen	Ref. No.:	11211778
From:	J.C. Janusz Czuj, P.Eng.	Tel:	519-340-4269
CC:	Pat Prodanovic, Ph.D., P.Eng.		

Subject: 2D Hydraulic Modelling of Joshua Creek

1. Introduction

The Town of Oakville initiated the Joshua's Creek Flood Mitigation Study Municipal Class Environmental Assessment (MCEA). The purpose of the study is to identify and evaluate feasible flood mitigation options to alleviate flood risk along Joshua's Creek within the Town's jurisdiction. GHD Limited (GHD) has been retained to execute the MCEA study.

As part of the study, GHD has developed a two dimensional (2D) unsteady hydraulic model to evaluate flood hydraulics along flood-prone regions of Joshua's Creek. The intent of the 2D modelling is to evaluate the possibility of inter-watershed flows (or spills) occurring in two areas within the Joshua Creek watershed: i) near the Highway 403 crossing, and ii) at the area in the vicinity of the Royal Windsor Drive and Metrolinx Railway crossings. The purpose of this memorandum is to document the development and the results of the 2D hydraulic model of the creek system.

1.1 Definitions and Conventions

This document adopts the naming convention that assumes the observer is standing in the middle of the creek and looks in the direction of flow. For example, references are made to left and right banks, which relate to what a person would see standing in the middle of the creek and looking downstream.

1.2 Background

Joshua's Creek is located in the Town of Oakville within the jurisdiction of the Halton Region Conservation Authority. It spans approximately 11 kilometers (km) from its headwaters near Lower Baseline Road between Trafalgar Road and Ninth Road to Lake Ontario, south of Lakeshore Road East, and just east of the Oakville-Mississauga municipal border. The Joshua's Creek watershed is long and narrow with a total contributing drainage area of approximately 21 km^2. Highway 403/Queen Elizabeth Way (QEW) intersects the watershed approximately 7 km downstream from the headwaters. The land use upstream of Highway 403 is mostly agricultural with some residential pockets. The land use downstream of Highway 403 is mostly residential, commercial and industrial, including the Ford Motor Company (Ford) industrial plant on the south side of the creek. Figure 1.1 presents a site location map of the study area and Figure 1.2 shows the Joshua's Creek watershed boundary.

GHD previously completed hydraulic modelling of Joshua's Creek as part of the Joshua's Creek Flood Mitigation Opportunities Study (GHD, 2020). The purpose of the 2020 study was to perform a hydrotechnical analysis of the creek system from Upper Middle Road to Lake Ontario to identify flood risk sites and develop flood mitigation options. The hydraulic analysis was performed using a one-dimensional (1D) steady state HEC-RAS model. The 1D model results showed flooding of a residential area located in the right overbank area of Joshua's Creek between Constance Drive and Brookmill Road during the Regional storm event. The results also revealed flooding at the Ford industrial plant and overtopping of Royal Windsor Drive. Figure 1.3 shows the 100-year, 100-year with climate change and Regional flood inundation boundaries from the 1D model. Based on these results the following flood mitigation options were identified in the 2020 study:

- Construction of a berm along the right creek bank between Cornwall Road and Ford Drive to provide flood protection of the residential area;
- Construction of berms on the north and south creek banks through the Ford property to provide flood protection of the Ford industrial area; and
- Installation of an overflow culvert through Royal Windsor Drive to lower the upstream floodplain elevation.

In addition, the analysis identified potential inter-watershed flows (spills) from the creek system upstream of Highway 403, and near the Royal Windsor Drive and Metrolinx railway crossings. However, the occurrence of the spills could not be confirmed due to the limitations of the 1D steady state modelling approach.

One-dimensional steady state hydraulic models use instantaneous peak flow rates to compute maximum water surface elevations along the watercourse. One-dimensional hydraulic models are not capable of representing complex overland flow patterns that move in two dimensions outside of the linear channel system. In addition, steady state models conservatively assume the peak flow rates persist for an infinite amount of time, and ignore the finite flood volume of the runoff hydrograph. To address these limitations, the current study employs a 2D unsteady hydraulic model of Joshua's Creek in flood-prone areas to provide a more realistic representation of flood hydraulics, assess the effectiveness of the flood mitigation alternatives and confirm the potential spill locations identified in the 1D study.

1.3 Organization of the Memorandum

The remainder of this memorandum is organized as follows:

- Section 2 – Data Collection
- Section 3 – Model Setup
- Section 4 – Model Output
- Section 5 - Conclusions

2. Data Collection

The following datasets were used to establish the 2D hydraulic model input parameters:

2.1 Topographic Data

The terrain model was generated from the Lidar-Derived Ontario Digital Terrain Model (DTM) Land Information Ontario Dataset, which is publicly available from Ontario GeoHub (https://geohub.lio.gov.on.ca/datasets/776819a7a0de42f3b75e40527cc36a0a, last accessed 7 September 2020)

The Lidar-Derived Ontario DTM is comprised of numerous datasets collected during several acquisition projects. The Joshua's Creek study area is captured in the Greater Toronto Area (GTA) Halton Lidar that was collected between March – June 2018. This dataset has a spatial resolution of 0.5 metres (m) and a vertical accuracy of 5 centimetres (cm). The horizontal coordinate system is the Universal Transverse Mercator Zone 17 North and the horizontal datum is the North American Datum of 1983 Canadian Spatial Reference System (NAD83 CSRS), epoch 2010. The vertical coordinate system is the Canadian Geodetic Vertical Datum (CGVD) 2013.

2.2 Aerial Data

Orthoimagery for the study area was provided by the Town to GHD at the commencement of the project. The data was collected in 2019 and has a horizontal resolution of 0.1 m.

2.3 Hydrology

The present study uses the latest hydrologic information available for the project site, documented in the GHD (2020) study. Hydrographs for the 2- to 100-year design flow events, the 100-year climate change adjusted design flow event and Hurricane Hazel were derived from the hydrologic model developed as part of the GHD (2020) study.

The hydrologic model was created using the PCSWMM software (Computational Hydraulics International, 2017), which uses the U.S. Environmental Protection Agency (USEPA) Storm Water Management Model 5 (SWMM5) engine. More detailed information on the hydrologic model development is provided in the hydrotechnical report for the 1D study (GHD, 2020).

The 2- to 100-year hyetographs in the GHD (2020) study were generated using the Town's 24-hour Kiefer and Chu (Chicago) synthetic design storm distributions with a time step of 10 minutes and a 0.33 ratio of the time of the maximum intensity to the storm duration.

The 100-year climate change adjusted hyetograph in the GHD (2020) study was also represented by a 24-hour Chicago synthetic design storm distribution. Wood derived the Chicago distribution parameters for the Town from projected intensity-duration-frequency (IDF) values. The IDF values were originally developed for the City of Toronto under the 2080 – 2100 Intergovernmental Panel on Climate Change (IPCC) Scenario RCP 8.5 using the IDF-CC Tool (Version 2).

The 12-hour duration Hurricane Hazel rainfall distribution was obtained from the MNRF Flood Hazard Limit Guidelines (MNRF, 2002), and used to model the Regional event hydrograph (GHD, 2020). Since this distribution represents the last 12-hours of the 48-hour historical storm event, the infiltration parameters of the hydrologic model were adjusted to characterize the saturated ground conditions at the beginning of the simulation.

Table 2.1 summarizes the peak flow rates at various locations along Joshua's Creek for all design storm events. Figure 2.1 presents the location of the creek sections where the peak flow rates are calculated and reported.

Table 2.1 Summary of Peak Flow Rates at Various Locations along Joshua's Creek

Return Period	Peak Flow Rate at Various Locations (m^3/s)		
	Highway 403	Metrolinx Railway	Ford Drive
2-year	15.14	16.34	16.45
5-year	24.65	26.46	26.81
10-year	31.54	33.94	34.50
25-year	41.32	44.48	45.46
50-year	48.37	52.08	53.38
100-year	53.50	57.82	59.95
100-year Climate Change	67.75	72.37	74.47
Hurricane Hazel	135.5	150.4	159.7

2.4 Hydraulic Structures

The Town retained Calder Engineering to complete a detailed topographic survey of the watercourse crossings within the study area along Joshua's Creek. The survey was performed in 2017. The topographic survey was compared against available background data for the hydraulic structures including the Joshua's Creek Flood Plain Mapping Study Technical Report (July 1988), which includes an inventory of hydraulic structures along the creek. These datasets were used to model the hydraulic structures in the 1D study. The 2017 survey references the CGVD1928 vertical datum. GHD overlaid the 2017 survey with the 2018 Lidar-derived Ontario DTM (noting the datasets have different vertical datums), and were not able to determine a consistent vertical shift between the elevations. As such, GHD decided to conduct a supplemental site visit to verify/confirm key structure elevations within the study area.

GHD performed the supplemental topographic survey of the key hydraulic structures located in the vicinity of the spill at Royal Windsor Drive and the Metrolinx Railway crossings on September 28, 2020 (GHD September 2020 survey). The survey included the following crossings: Old Ford Drive (accessible through the Gate 3 Ford plant entrance), an Unnamed Service Road (accessible from Royal Windsor Drive and Ford Drive), Royal Windsor Drive, the Metrolinx Railway, Cornwall Road and Constance Drive. The survey was performed in the CGVD1928 vertical datum, referenced to Benchmark No. 88 of the Town of Oakville Benchmark System, and corrected to the CGVD2013 vertical datum using the Natural Resources Canada 65U015 Station. The relevant benchmark information is provided in Attachment A. GHD overlaid the GHD

September 2020 survey with the 2018 Lidar data and obtained consistency in the elevations, which provided confidence in using the Lidar data to represent the geometry of the river and floodplain.

A photo log of the surveyed structures is provided in Attachment B.

3. Model Setup

3.1 Terrain Model

The terrain model was generated from the Lidar-Derived Ontario DTM for the study area. The study area was defined to capture flow through Joshua's Creek from upstream of Highway 403 to the Ford Drive crossing and from Wedgewood Creek to Clearview Creek along the Royal Windsor Drive and CN Railway crossings.

The Lidar-Derived Ontario DTM product consists of bare earth terrain, where non-ground features such as structures and road crossings have been removed, resulting in smooth artificial terrain surfaces at these locations. As such, GHD modified the DTM to create a more representative terrain surface of the creek system at the road crossings. River reach segments were drawn along Joshua's Creek at each crossing and cross sections were cut through the Lidar terrain on either side of the smooth/artificial terrain surfaces. Surveyed cross sections from the GHD September 2020 survey were used to characterize or verify the terrain upstream and downstream of the crossings where available. Interpolation surfaces were generated between the cross sections of each river reach. The final modified terrain model was created by combining the interpolation surfaces with the Lidar-Derived Ontario DTM with priority given to the interpolation surfaces. Comparisons of the surveyed cross sections and Lidar are provided in Attachment A.

3.2 2D Flow Area

In the 2D model, a computational mesh overlays the terrain data, and together the computational mesh and the terrain data determine the direction of flow through the model domain. The mesh was created by drawing a 2D Flow Area polygon over the study area and specifying the mesh cell sizes. A cell size of 4 m was assigned to the channel using a refinement region, and a cell size of 10 m was assigned elsewhere.

The mesh was further refined by enforcing break lines along critical elevation boundaries such as road crests, berms, and buildings. The outer boundary of the refinement region was also enforced as a break line. Mesh cell faces are snapped to break lines to ensure critical elevations are captured in the computational mesh, and to ensure water will not flow across the cell face until the water surface elevation exceeds the terrain elevation along the break line (USACE, 2016).

A sample of the resultant computational mesh is shown on Figure 3.1.

![GHD logo]

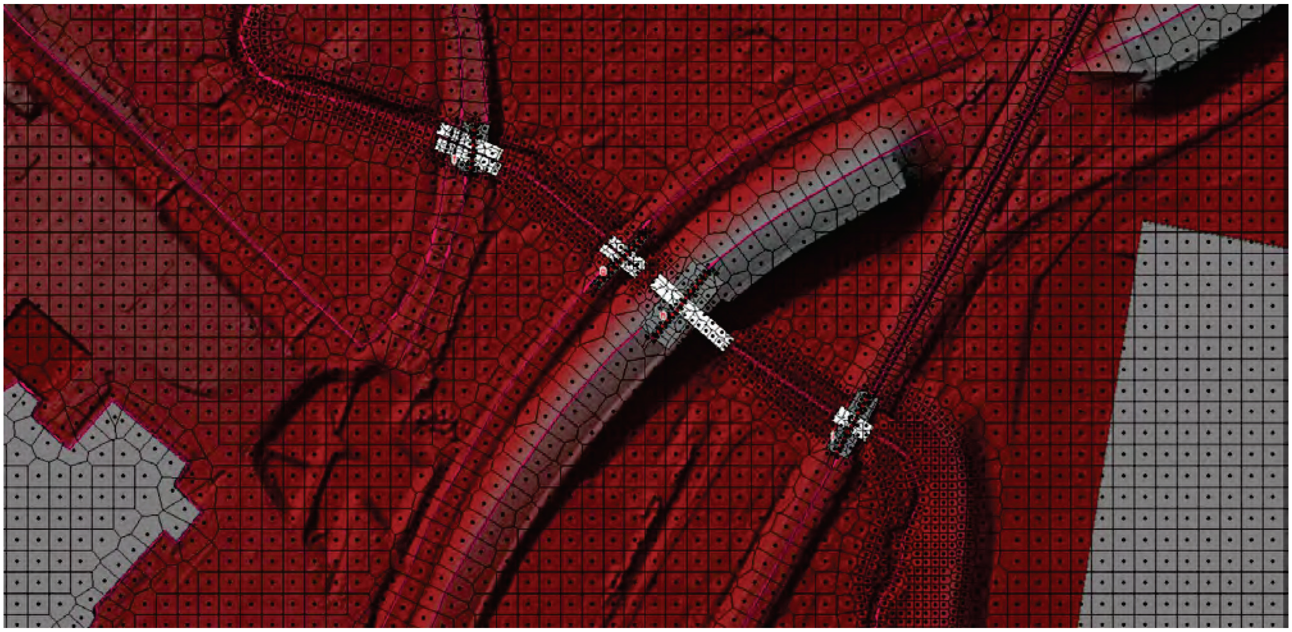


Figure 3.1 Computational Mesh of the 2D Study Area

3.3 Manning's 'n' Layer

Manning's 'n' values are used to represent friction losses in the hydraulic model due to surface roughness. Manning's 'n' values were assigned to the study area based on the land cover type. A spatially varying land cover shapefile was created in a GIS environment and imported to the hydraulic model. The land cover layer is shown on Figure 3.2. The land cover classifications and corresponding Manning's 'n' values are summarized in Table 3.1.

Table 3.1 Manning's 'n' Values Based on Land Cover Classification

Land Cover Classification	Manning's 'n' Value
Channel	0.035
Grassland	0.055
Woods (along channel banks)	0.080
Woods (in overbank areas)	0.120
Residential (buildings not included in terrain)	0.120
Industrial (buildings included in terrain)	0.020
Roads	0.013

3.4 Hydraulic Structures

The study area includes fifteen watercourse crossings as listed below:

1. Crossing at 1720 North Service Road
2. Highway 403 N-W Ramp

3. Highway 403/Queen Elizabeth Way (QEW)
4. Highway 403 W-N/S Ramp
5. South Service Road
6. Railway Crossing, East of QEW, South of Ford Drive (Ford Property)
7. Private Road Crossing 1 (Ford Property)
8. Private Road Crossing 2 (Old Ford Drive)
9. Unnamed Service Road
10. Royal Windsor Drive
11. Metrolinx Railway
12. Cornwall Road
13. Constance Drive
14. Brookmill Road
15. Ford Drive

The watercourse crossings are shown on Figure 3.3.

The study area of the 2D model was split into two parts to assess the potential spill locations. In the upstream section, the hydraulic structures at the North Service Road, Highway 403 N-W Ramp, Highway 403, Highway 403 W-N/S Ramp and the South Service Road crossings were incorporated in the 2D model to assess the spill area upstream of Highway 403. In the downstream section, Private Road Crossing 2, the Unnamed Service Road, Royal Windsor Drive, the Metrolinx Railway, Cornwall Road, Constance Drive and Brookmill Road crossings were included in the model to evaluate the 1D flood mitigation alternatives and potential spill areas at the Royal Windsor Drive and Metrolinx Railway crossings. The Railway Crossing and Private Road Crossing 1 on the Ford property were not included in the model as they do not have a significant impact on the flood inundation boundaries in the areas of the spill.

Table 3.2 includes a summary of the geometric properties of the hydraulic structures included in the 2D model. Culverts and all hydraulic structures that have potential to be overtopped during the Regional storm event (Crossings A-I) were modelled using culverts within the SA/2D Connections component of the geometry editor. There is currently no method for modelling bridge hydraulics in 2D Flow Areas; therefore, these hydraulic structures were modelled as either box or arch culverts. Manning's 'n' values of 0.035 and 0.013 were assigned to the bottom and top/sides of the structures, respectively. Culvert invert elevations were selected based on the thalweg of the channel as determined from the modified terrain layer. Photos 1-7 in Attachment B show a significant amount of sediment accumulation in the Private Road Crossing 2 and Unnamed Service Road culverts. Sediment accumulation was represented in the model by entering a "depth blocked" value into the culvert editor.

The hydraulic structures at Cornwall Road, Constance Drive, Brookmill Road and Ford Drive are wide bridge spans. Preliminary model output shows that the Regional water surface elevations do not overtop these crossings; therefore, these bridges were represented in the model using the terrain without the bridge structure in place.

Table 3.2 Geometric Properties of Hydraulic Structures in the 2D Model Study Area

2D Model Crossing ID	Street Crossing	Structure Type	Span	Rise	No. Barrels
A	Crossing at 1720 NSR	Bridge	24.7	3.2	1
B	QEW N-W Ramp	Bridge	16.1	4.2	1
C	QEW/Highway 403	Reinforced Concrete Arch Culvert	9.1	4.6	1
D	QEW W-N/S Road	Bridge	12.5	5.0	1
E	South Service Road	Reinforced Concrete Box Culvert	5.4	3.6	3
	Railway Crossing, East of QEW, South of Ford Drive	Reinforced Concrete Box Culvert	5.7	1.6	4
			12.6	1.5	1
			5.3	1.5	1
	Private Road Crossing 1	Reinforced Concrete Box Culvert	6.1	1.5	4
			6.3	1.5	2
			6.5	1.5	2
F	Private Road Crossing 2	Reinforced Concrete Box Culvert	6.2	1.8	2
G	Unnamed Service Road	Reinforced Concrete Box Culvert	4.5	1.8	2
H	Royal Windsor Drive	Reinforced Concrete Arch Culvert	8.3	3.8	1
I	CN Railway	Bridge	8.3	2.6	1
	Cornwall Road	Bridge	16.0	3.6	1
	Constance Drive	Bridge	15.0	3.5	1
	Brookmill Road	Bridge	26.0	3.1	1
	Ford Drive	Bridge	75.0	5.6	1

3.5 Boundary conditions

Boundary conditions were assigned at the upstream and downstream extents of the 2D Flow Area at Joshua's Creek. The upstream boundary condition was defined as a flow hydrograph.

The coordinates of the hydrograph vary based on the design flow event and the location where the hydrographs were extracted from the hydrologic model. Model simulations were performed for the 2- to 100-year design flow events, the 100-year design flow event adjusted for climate change and Hurricane Hazel for each location. The first set of design flow hydrographs were extracted at Joshua's Creek and Highway 403 to assess the potential spill at this location. The second and third sets of hydrographs were extracted from the hydrologic model at Joshua's Creek and the Metrolinx Railway and Ford Drive, respectively. The Metrolinx Railway location was selected to assess the potential spill and evaluate the flood mitigation options from the Ford Property to Ford Drive from the 2D modelling perspective. The Ford Drive location was selected to provide input for a conservative run. All flow hydrograph inputs have a 5 minute time step and 72-hour duration.

The downstream boundary condition was defined as the normal depth. The friction slope was assumed to equal to the average longitudinal slope of Joshua's Creek downstream of Ford Drive, which was estimated to be 0.006 from the Lidar terrain data.

3.6 Simulation settings

The default *Unsteady Computation Options and Tolerances* options were used except for the 2D Flow Equation Set and Advanced Time Step Controls. HEC-RAS includes two shallow water equation sets for 2D flow including the Diffusive Wave (default) and the Full Momentum equations. The Diffusive Wave equation is a simplification of the Full Momentum equation, which allows for faster run times. Both equation sets were implemented to determine their impact on the results. The results revealed a significant difference with the Full Momentum equations yielding more conservative results; therefore, the Full Momentum equations were used to complete the study.

The simulation time window was set to 72 hours and a variable time step was employed through the Advanced Time Step Control tab. The time step was automatically adjusted to ensure the Courant Number was between 0.5 to 3 as a Courant Number of less than three (3) should be targeted when applying the Full Momentum equation set (USACE, 2016). The Courant Number equation is provided below:

$$C = \frac{V \times \Delta T}{\Delta X}$$

Where, C is the Courant Number, V is the maximum velocity, ΔT is the time step and ΔX is the average mesh size.

3.7 Sensitivity Analysis

A finer mesh resolution was used to assess the impact of the computational mesh on the model output. A mesh size of 3 m was used in the refinement region and 5 m was used elsewhere.

4. Model Output

This section presents the results of the sensitivity analyses as well as the maximum flood inundation boundaries generated by the 1D and 2D hydraulic models for a range of design flow events. The 2D flood inundation boundaries are more reliable due to the limitations of the 1D steady state modelling approach as discussed above.

4.1 Sensitivity Analysis Results

Firstly, Figure 4.1 – 4.2 show a comparison of the 2D flood inundation boundaries generated using the hydrographs computed within Joshua's Creek at the Metrolinx Railway and Ford Drive for the 100-year and Regional design flow events, respectively. The results show that the choice between these hydrograph locations has little to no impact on the flood inundation boundaries.

Secondly, Figure 4.3 – 4.4 show a comparison of the 2D flood inundation boundaries using the fine and coarse mesh sizes for the 100-year and Regional design flow events, respectively. Overall, there are no significant differences in the pattern of behavior of the flood inundation. As such, the coarser mesh comprised of 4 m and 10 m cell sizes can be used to produce adequate results in support of the MCEA study. This is preferred due to the significantly lower computational time required to run the simulations compared to the finer mesh option.

4.2 Flood Inundation Boundaries

Figure 4.5 – 4.6 show the Joshua's Creek flood inundation boundaries for the 2- and 5-year design flow events through Ford property to Ford Drive. The 1D and 2D model outputs are comparable.

Figure 4.7 – 4.8 show Joshua's Creek flood inundation boundaries for the 10 and 25-year design flow events through the Ford property to Ford Drive. The differences between the model outputs can be summarized as follows: The 2D model output shows smaller flood extents on the Ford property upstream of the Royal Windsor Drive and Metrolinx Railway crossings compared to the 1D model output. Flood inundation occurs in the pond and parking lot areas at the south end of the Ford industrial area, which is located within the CH regulatory limit, with some inundation along the northeast end of the property. In addition, the 2D model output shows overtopping of the right bank immediately downstream of the Metrolinx Railway causing an inundation of the wetland area, which is not captured in the 1D model output. Both models show that the water is confined to the channel from the wetland at the Metrolinx Railway crossing to Ford Drive.

Figure 4.9 – 4.10 show the flood inundation boundaries for the 50-year and 100-year design flow events, respectively. Similar to the results presented above, the 2D model output shows a smaller flood extent on the Ford property. In addition, the 1D results indicate a potential spill to the Wedgewood Creek catchment; however, the 2D model output shows there is no spill during the 50- and 100-year design flow events. Lastly, both 1D and 2D model results show overtopping of Royal Windsor Drive; however, the extent of the overtopping is much less in the 2D model output compared to the 1D results. The maximum 100-year flood depth over Royal Windsor Drive is less than 0.3 m.

Figure 4.11 shows the flood extents for the climate change adjusted 100-year design flow rate. The 2D flood inundation boundary indicates that there is an inter-watershed spill to the Wedgewood Creek catchment.

Figure 4.12 shows the Regional flood inundation boundary generated by the 1D and 2D models. Overall, the 1D and 2D inundation boundaries are comparable upstream of the Royal Windsor Drive. The 1D results indicate potential spills between the Metrolinx Railway and the Royal Windsor Drive crossings toward the

Wedgwood Creek catchment as well as the Clearview Creek catchment; however, the 2D results show the spill occurs to the Wedgewood Creek system only.

The 2D results displayed on Figure 4.12 also show a much larger flood extent downstream of the Metrolinx Railway on the southwest side of Joshua's Creek. The 1D model failed to capture the flood extent in the right overbank area from Maple Grove Drive to Joshua's Creek (including some inundation of the development on the northwest corner of the Maple Grove Drive and Cornwall Road intersection). Both the 1D and 2D model results show overtopping of the right creek bank between Constance Drive and Brookmill Road, causing inundation of the residential neighbourhood. An animation of the unsteady 2D simulation presents the progression of Regional flood inundation downstream of the Metrolinx Railway. The animation shows the flood wave originates from overtopping of the Metrolinx Railway and overtopping of the right creek bank between Constance Drive and Brookmill Road. The maximum Regional water level exceeds 1.5 m in the roadways and swales of the inundated residential area. The highest water levels are observed along Devon Road, Brook Place, Donnybrook Road, and in the swale between the houses on Brook Place and Donnybrook Road. The maximum Regional water levels over Royal Windsor Drive are approximately 0.3 – 0.4 m.

Figure 4.13 shows the flood extent for the 100-year design flow event adjusted for climate change and Hurricane Hazel at Highway 403 generated by the 2D model. These results were generated to confirm the occurrence of a spill upstream of Highway 403. The results show there is a spill from the creek system upstream of Highway 403 during the Regional storm event. Flows are confined within the creek system during the 100-year climate change events at this location.

5. Conclusion

In conclusion, the 2D hydraulic model identified the following potential flood risk sites along Joshua's Creek:

- The wetland, commercial/industrial and residential areas downstream of the Metrolinx Railway to Brookmill Road and west (to approximately Maple Grove Drive) in the right overbank area of Joshua's Creek during the Regional storm event. This floodwater originates from overtopping of the Metrolinx Railway and overtopping of the right creek bank between Constance Drive and Brookmill Road.
- The 100-year climate change flood event is contained within the channel system from the wetland immediately downstream of the Metrolinx Railway to the downstream model limit at Ford Drive.
- The low point on Royal Windsor Drive is in the right overbank area of Joshua's Creek crossing. The model output shows that the depth of flooding over Royal Windsor Drive is less than 0.3 m and less than 0.4 m during the 100-year climate change and Regional events, respectively.
- Flood inundation of the parking lot on the south side of the Ford industrial area, within the existing CH regulatory limit, with minor flooding along the northeast side of the industrial area during the 10-year event.
- Inter-watershed flows to the Wedgewood Creek system during the climate change adjusted 100-year design flow event and the Regional event. The spill location immediately upstream of Highway 403

during the Regional event has also been confirmed; however, improvements to Highway 403 are considered outside the scope of this study.

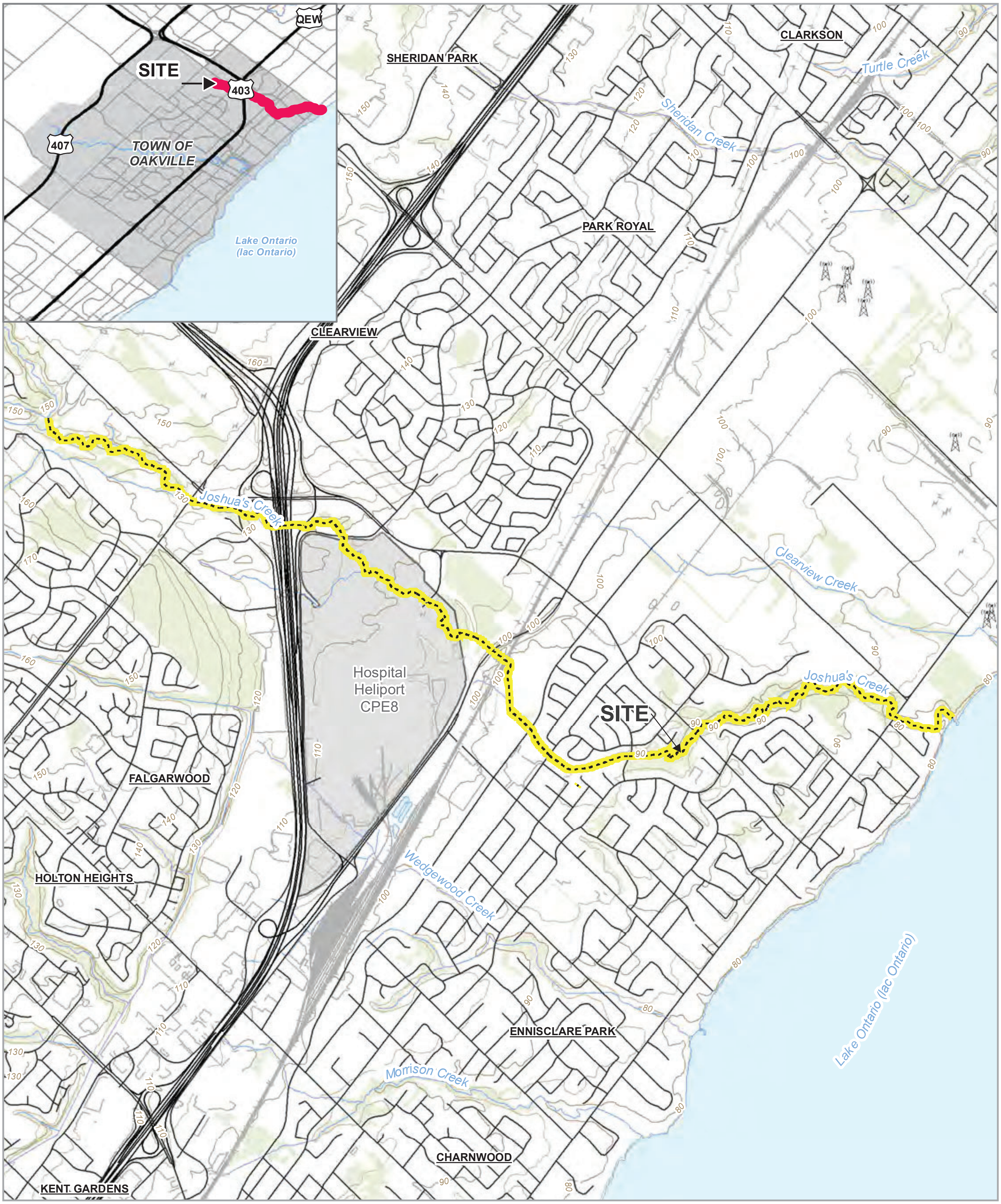
6. References

GHD, 2020, Joshua's Creek Flood Mitigation Opportunities Study Hydrotechnical Modelling Report

Dillon, 1988, Joshua's Creek Flood Plain Mapping Study Technical Report, Halton Region Conservation Authority

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

US Army Corps of Engineers, 2016, HEC-RAS River Analysis System 2D Modeling User's Manual Version 5



Paper Size ANSI A

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Meters

Map Projection: Transverse Mercator
Horizontal Datum: North American 1983
Grid: NAD 1983 UTM Zone 17N

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TOWN OF OAKVILLE
2D HYDRAULIC MODELLING OF JOSHUA'S CREEK

SITE LOCATION MAP

Project No. 11211778
Revision No. -
Date Oct 1, 2020

FIGURE 1.1

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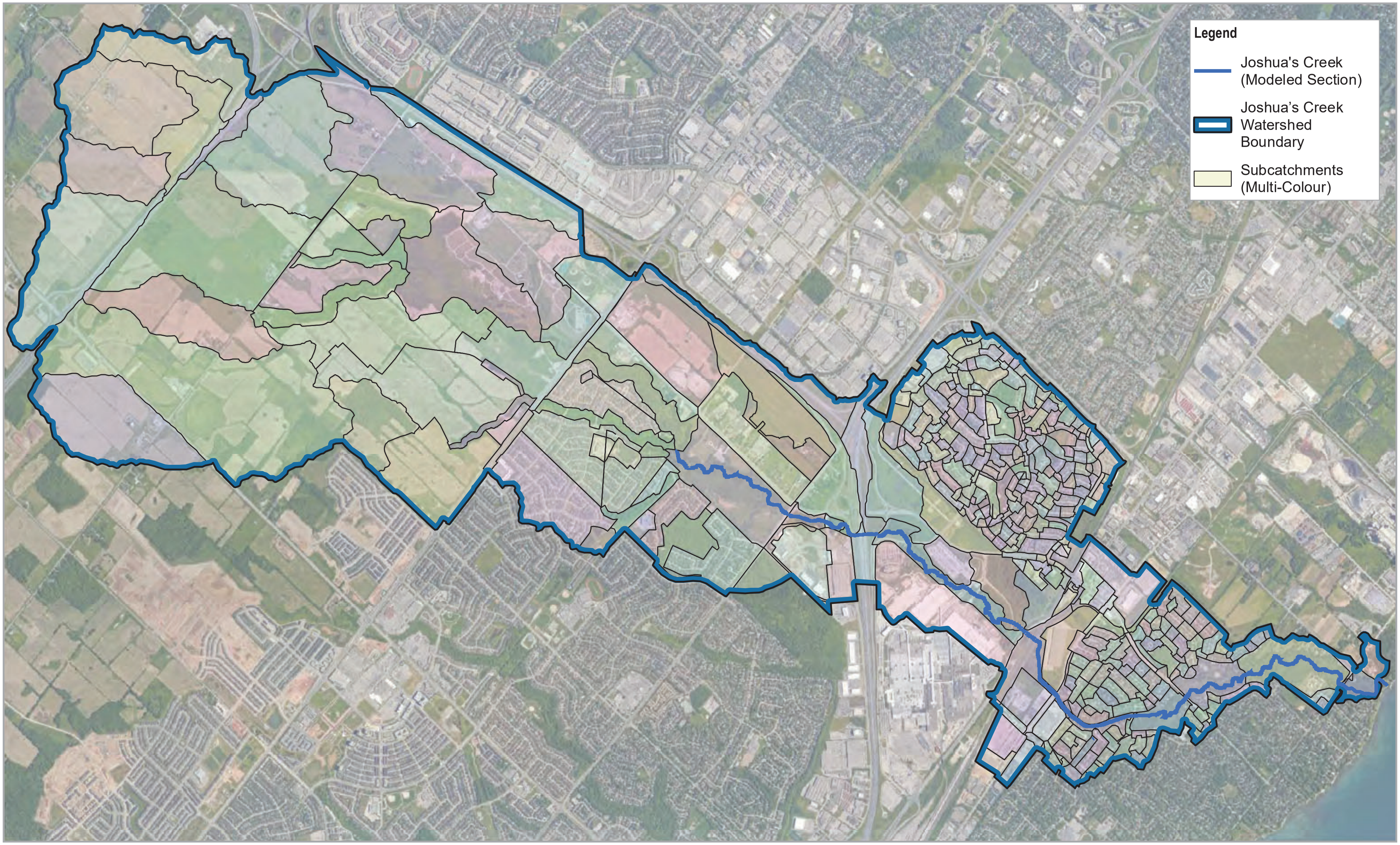

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GHD

TOWN OF OAKVILLE
2D HYDRAULIC MODELLING OF JOSHUA'S CREEK

JOSHUA'S CREEK WATERSHED

Project No. **11211778**
Revision No. **-**
Date **Oct 1, 2020**

FIGURE 1.2

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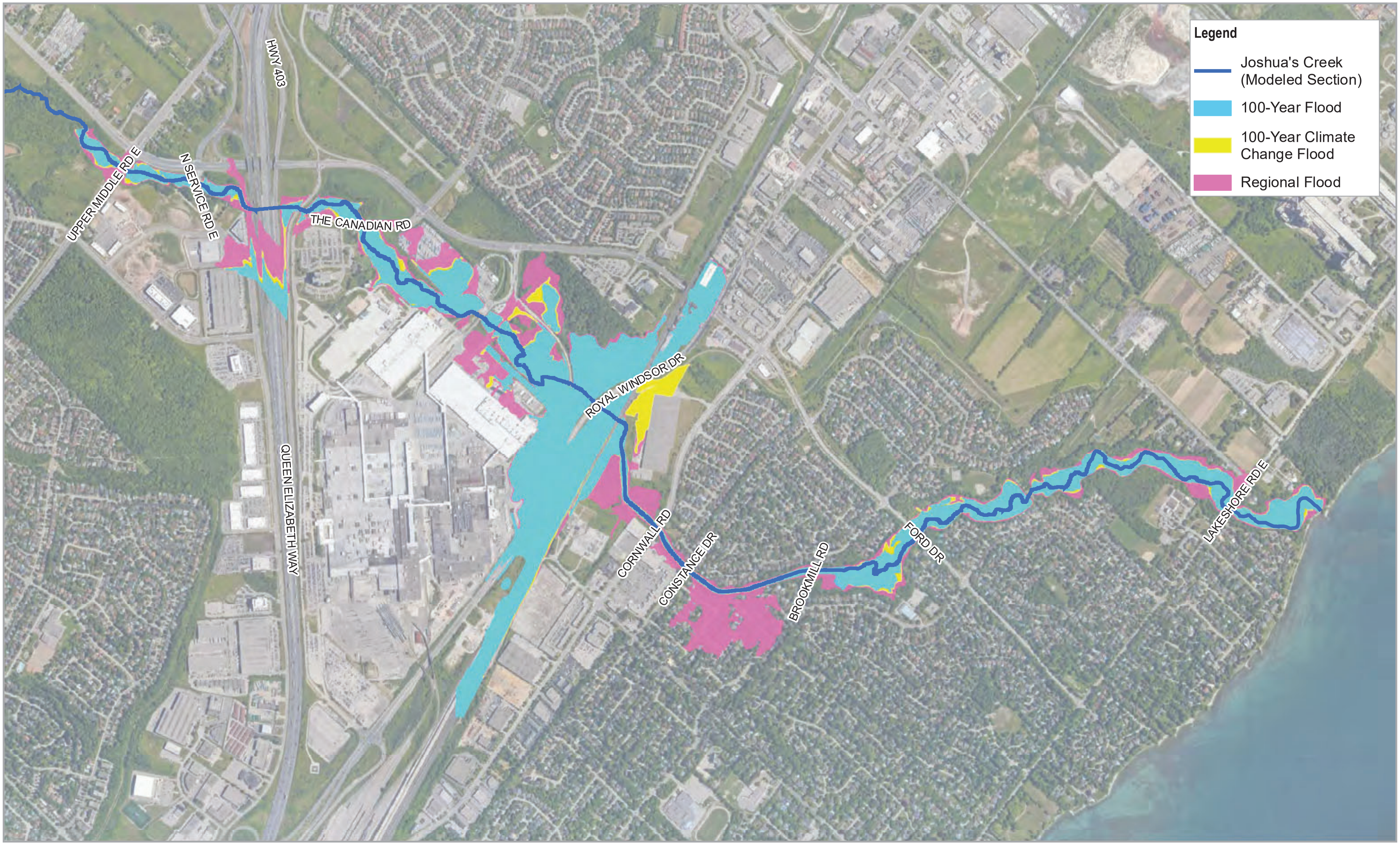

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Grid: NAD 1983 UTM Zone 17N

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GHD

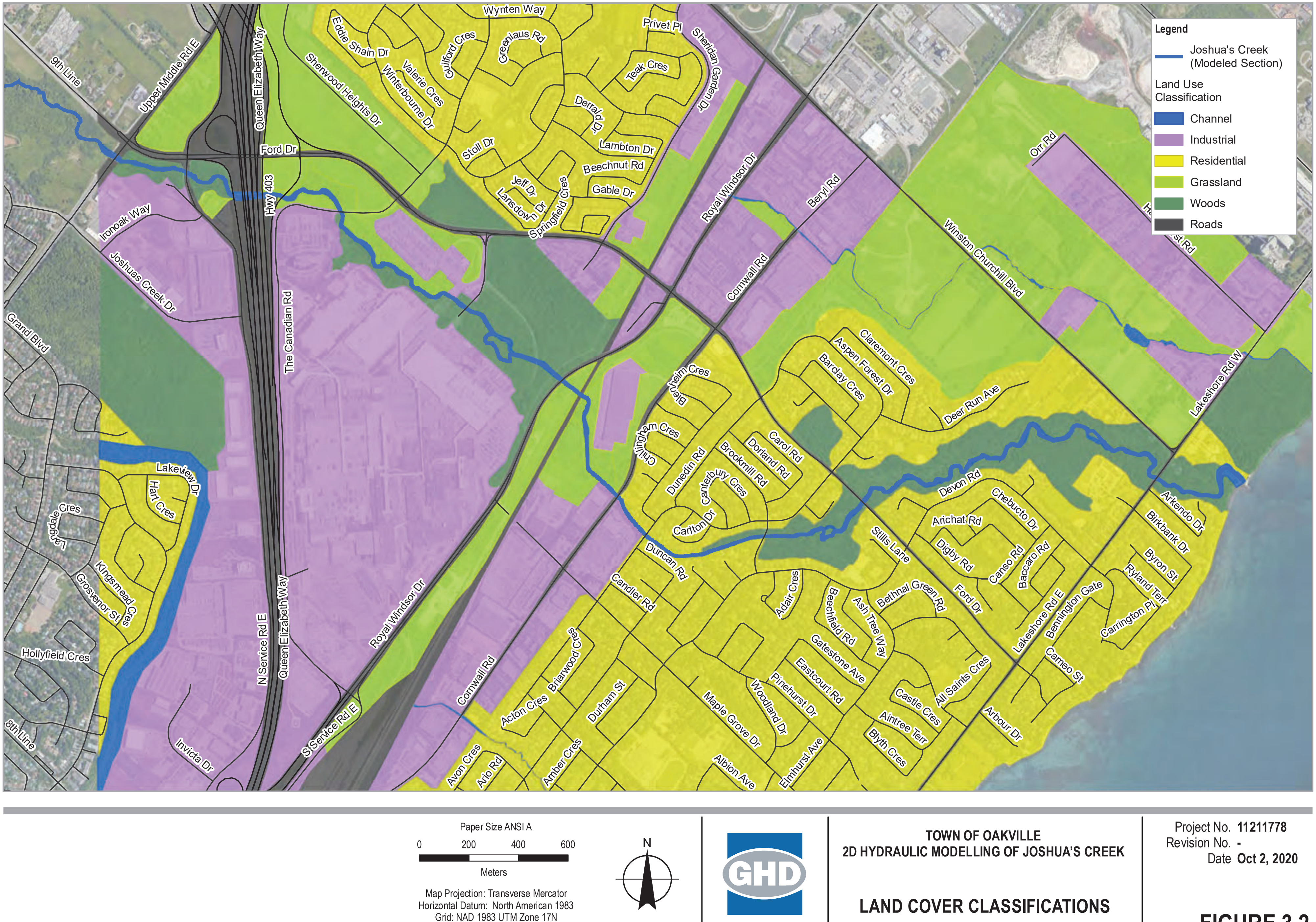
TOWN OF OAKVILLE
2D HYDRAULIC MODELLING OF JOSHUA'S CREEK

1D FLOOD INUNDATION BOUNDARIES

Project No. 11211778
Revision No. -
Date Oct 1, 2020

FIGURE 1.3

Data source: Image ©2019 Google, Imagery date



Map Projection: Transverse Mercator
Horizontal Datum: North American 1983
Grid: NAD 1983 UTM Zone 17N

TOWN OF OAKVILLE
2D HYDRAULIC MODELLING OF JOSHUA'S CREEK

LAND COVER CLASSIFICATIONS

Project No. 11211778
Revision No. -
Date Oct 2, 2020

FIGURE 3.2

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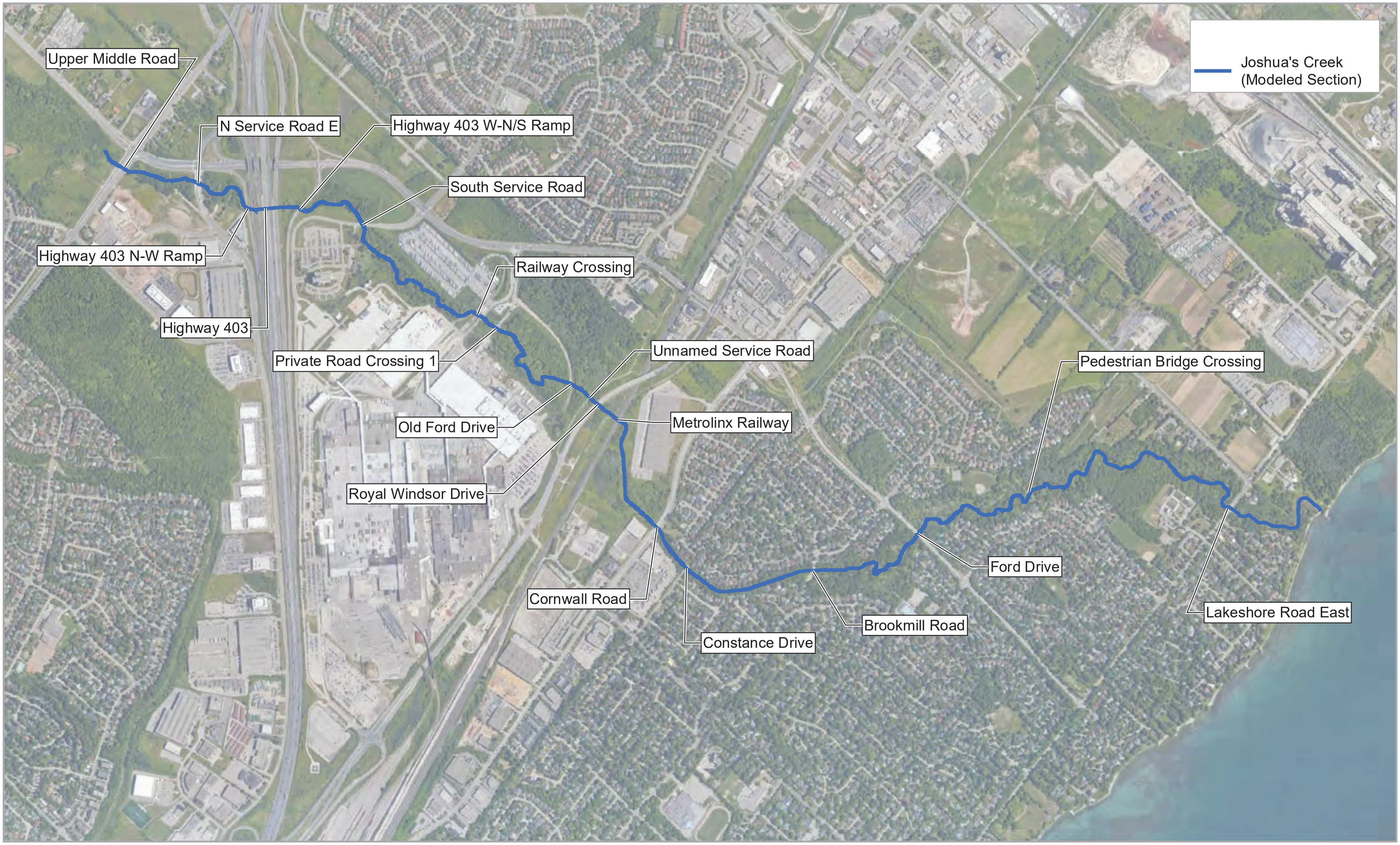

Map Projection: Transverse Mercator
Horizontal Datum: North American 1983
Grid: NAD 1983 UTM Zone 17N

TOWN OF OAKVILLE
2D HYDRAULIC MODELLING OF JOSHUA'S CREEK

JOSHUA'S CREEK CROSSINGS

Project No. **11211778**
Revision No. **-**
Date **Jun 9, 2021**

FIGURE 3.3

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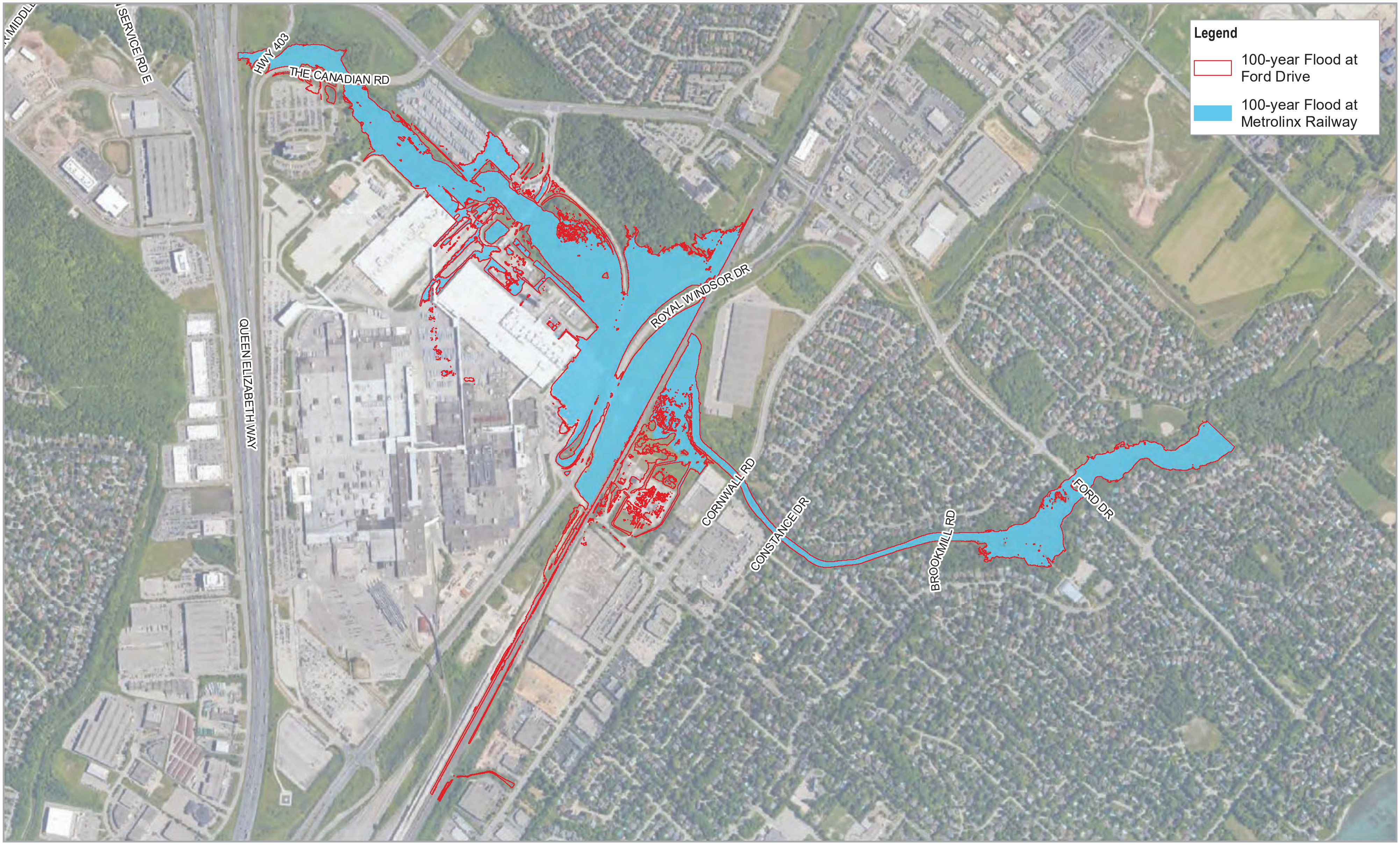

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Meters

Map Projection: Transverse Mercator
Horizontal Datum: North American 1983
Grid: NAD 1983 UTM Zone 17N

N

TOWN OF OAKVILLE
2D HYDRAULIC MODELLING OF JOSHUA'S CREEK

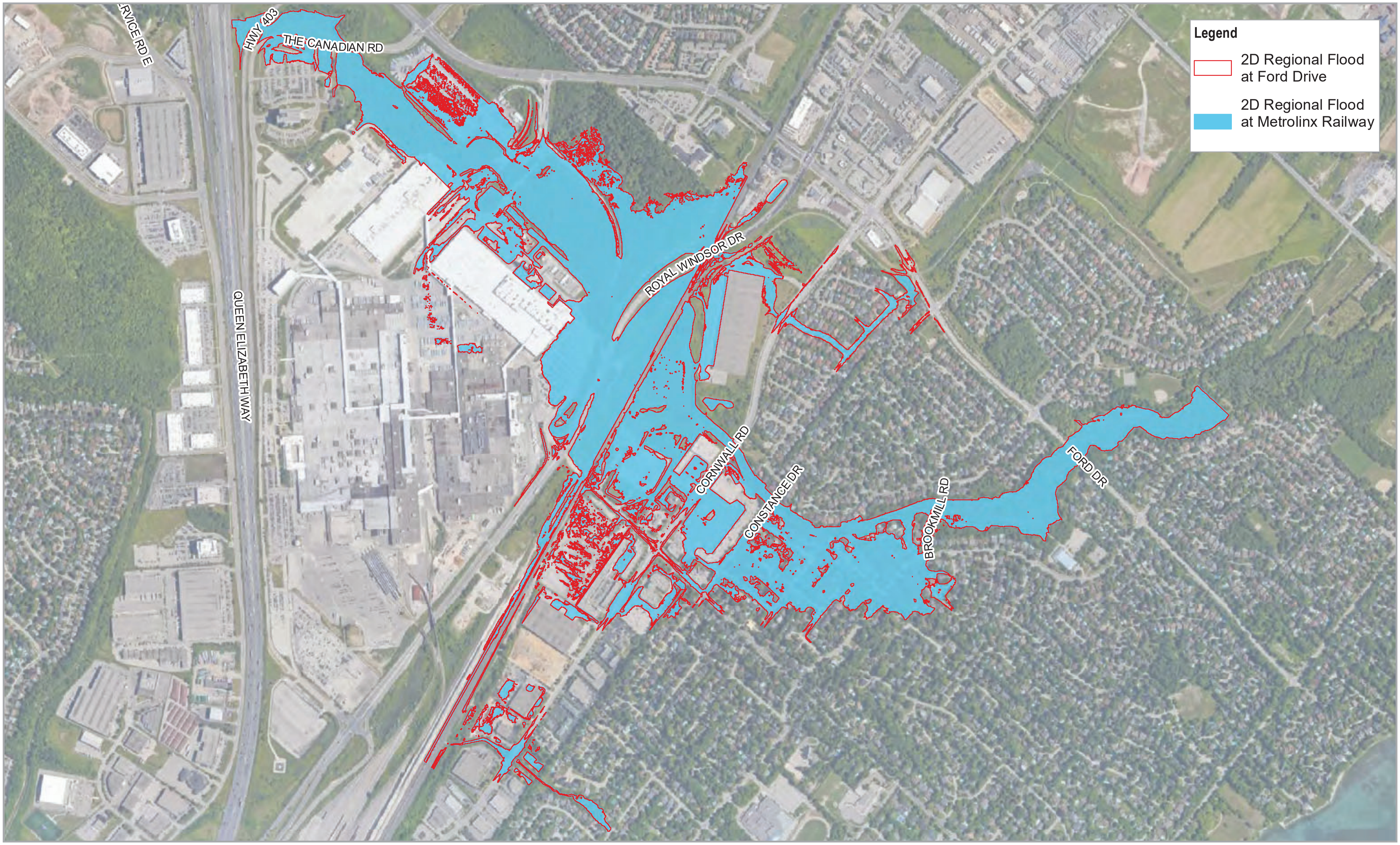
100-YEAR INUNDATION BOUNDARY-HYDROGRAPH COMPARISON

Project No. **11211778**
Revision No. **-**
Date **Jun 9, 2021**

FIGURE 4.1

Q:\GIS\PROJECTS\11211000s\11211778\Layouts\20210604_MEMO001\11211778_20210604_MEMO001_GIS010.mxd
Print date: 09 Jun 2021 - 10:44

Data source: Image ©2020 Google, Imagery date: 8/Jun/2018



Paper Size ANSI A

0 100 200 300

Meters

Map Projection: Transverse Mercator
Horizontal Datum: North American 1983
Grid: NAD 1983 UTM Zone 17N

N

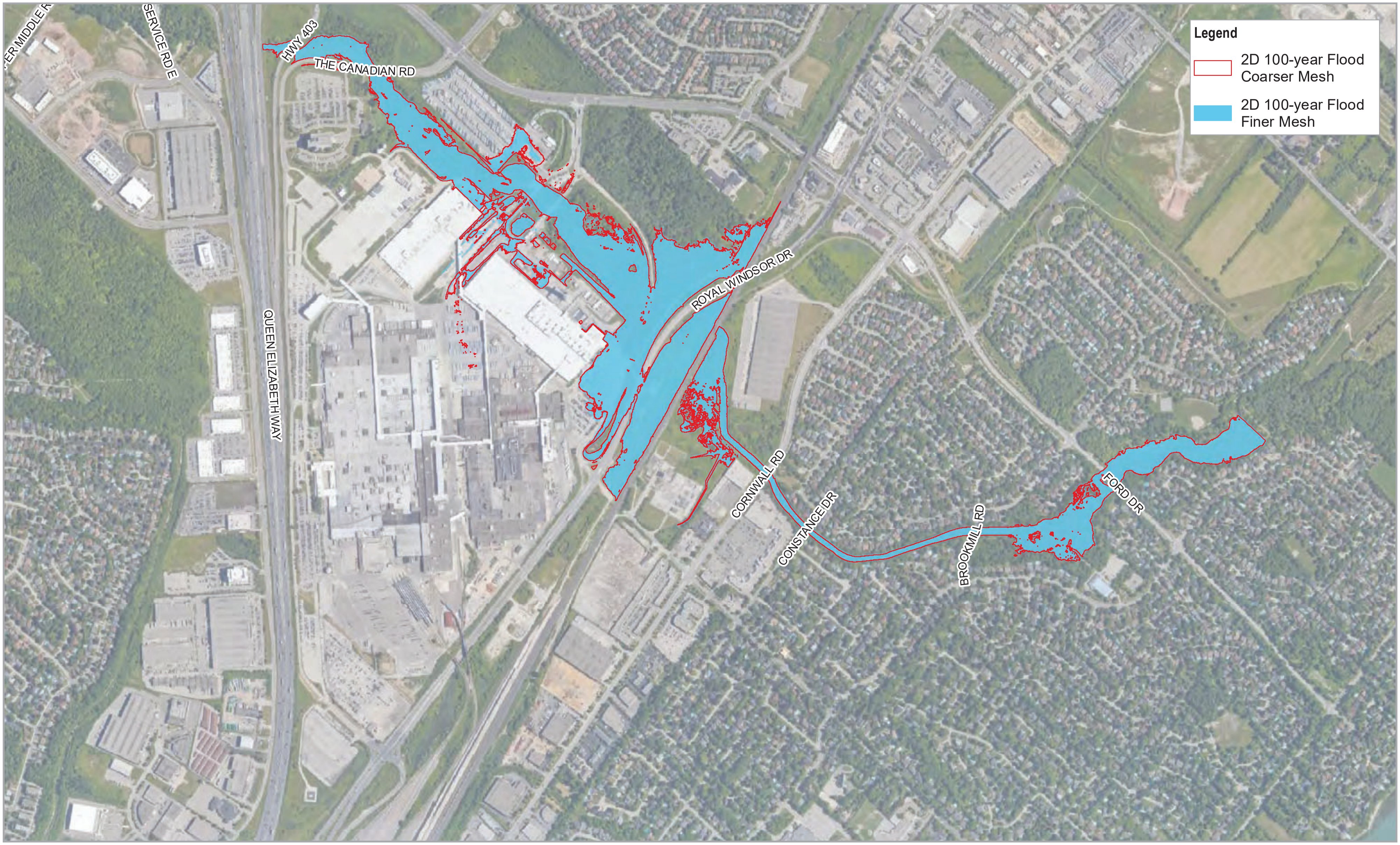
TOWN OF OAKVILLE
2D HYDRAULIC MODELLING OF JOSHUA'S CREEK

REGIONAL INUNDATION BOUNDARY-HYDROGRAPH COMPARISON

Project No. **11211778**
Revision No. **-**
Date **Jun 9, 2021**

FIGURE 4.2

Q:\GIS\PROJECTS\11211000s\11211778\Layouts\20210604_MEMO001\11211778_20210604_MEMO001_GIS011.mxd
Print date: 09 Jun 2021 - 10:47



Paper Size ANSI A

0 100 200 300

Meters

Map Projection: Transverse Mercator
Horizontal Datum: North American 1983
Grid: NAD 1983 UTM Zone 17N

N

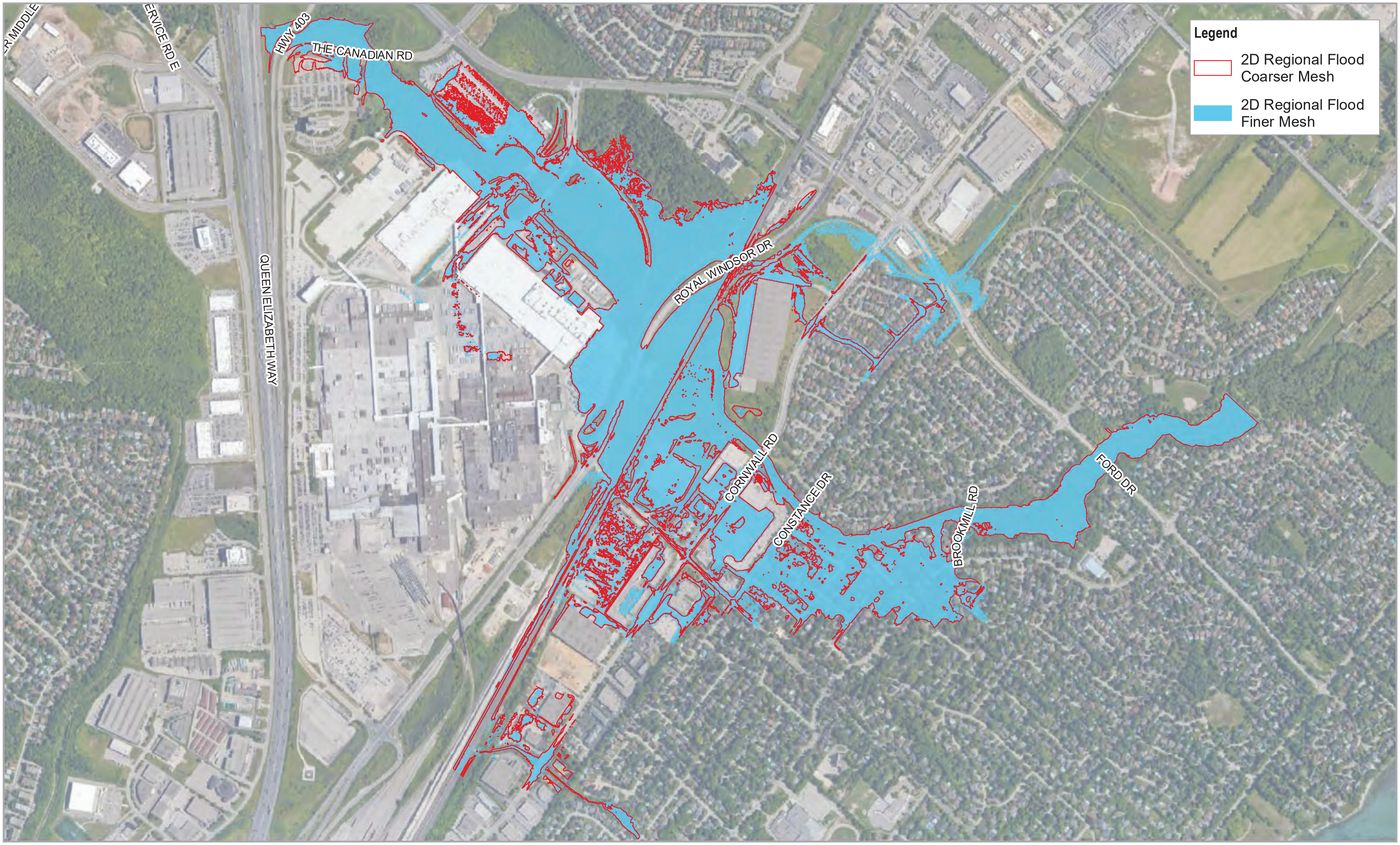
TOWN OF OAKVILLE
2D HYDRAULIC MODELLING OF JOSHUA'S CREEK

100-YEAR INUNDATION BOUNDARY-MESH RESOLUTION COMPARISON

Project No. **11211778**
Revision No. **-**
Date **Jun 9, 2021**

FIGURE 4.3

Q:\GIS\PROJECTS\11211000s\11211778\Layouts\20210604_MEMO001\11211778_20210604_MEMO001_GIS012.mxd
Print date: 09 Jun 2021 - 10:46



Paper Size ANSI A

0 100 200 300

Meters

Map Projection: Transverse Mercator
Horizontal Datum: North American 1983
Grid: NAD 1983 UTM Zone 17N

N

GHD

TOWN OF OAKVILLE
2D HYDRAULIC MODELLING OF JOSHUA'S CREEK

REGIONAL INUNDATION BOUNDARY-MESH RESOLUTION COMPARISON

Project No. **11211778**
Revision No. **-**
Date **Jun 9, 2021**

FIGURE 4.4

Q:\GIS\PROJECTS\11211000s\11211778\Layouts\20210604_MEMO001\11211778_20210604_MEMO001_GIS013.mxd
Print date: 09 Jun 2021 - 10:45

Data source: Image ©2020 Google, Imagery date: 8/Jun/2018

Paper Size ANSI A

0 100 200 300

Meters

Map Projection: Transverse Mercator
Horizontal Datum: North American 1983
Grid: NAD 1983 UTM Zone 17N

N

TOWN OF OAKVILLE
2D HYDRAULIC MODELLING OF JOSHUA'S CREEK

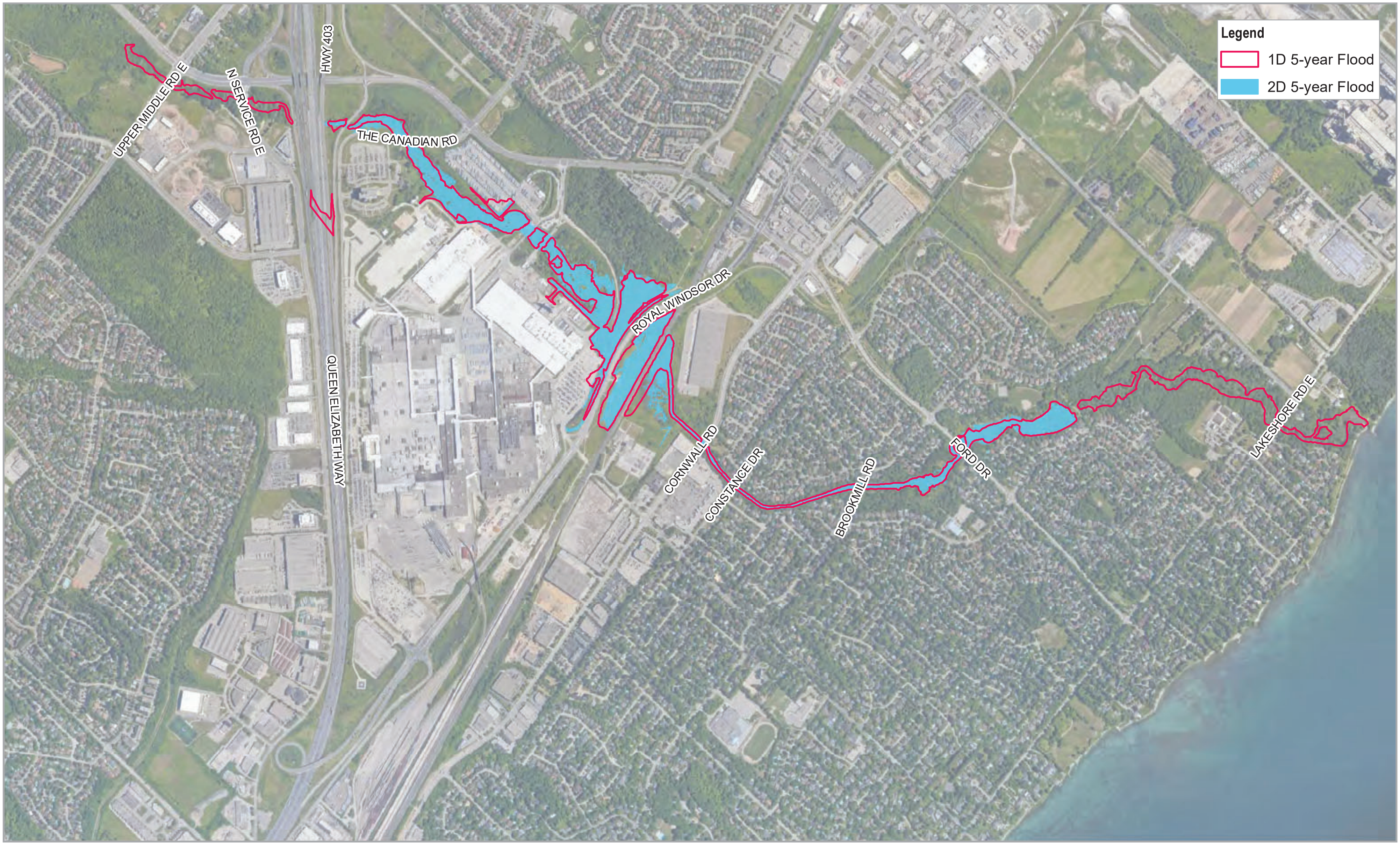
2-YEAR INUNDATION BOUNDARIES

Project No. **11211778**
Revision No. **-**
Date **Jun 4, 2021**

FIGURE 4.5

Q:\GIS\PROJECTS\11211000s\11211778\Layouts\20210604_MEMO001\11211778_20210604_MEMO001_GIS004.mxd
Print date: 04 Jun 2021 - 09:48

Data source: Image ©2020 Google, Imagery date: 8/Jun/2018



Paper Size ANSI A

0 100 200 300

Meters

Map Projection: Transverse Mercator
Horizontal Datum: North American 1983
Grid: NAD 1983 UTM Zone 17N

N

GHD

TOWN OF OAKVILLE
2D HYDRAULIC MODELLING OF JOSHUA'S CREEK

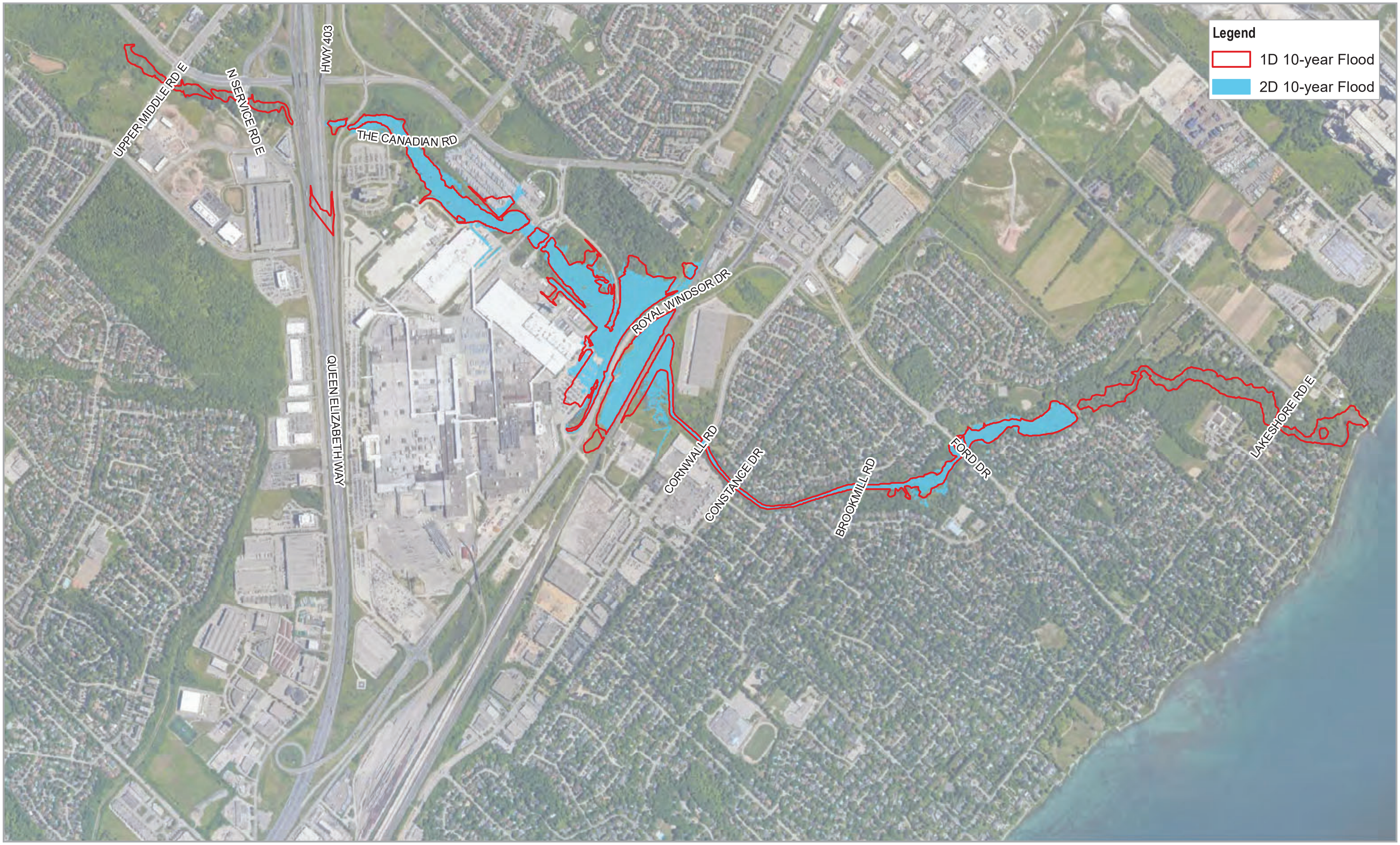
5-YEAR INUNDATION BOUNDARIES

Project No. **11211778**
Revision No. **-**
Date **Jun 4, 2021**

FIGURE 4.6

Q:\GIS\PROJECTS\11211000s\11211778\Layouts\20210604_MEMO001\11211778_20210604_MEMO001_GIS005.mxd
Print date: 04 Jun 2021 - 09:51

Data source: Image ©2020 Google, Imagery date: 8/Jun/2018



Paper Size ANSI A

0 100 200 300

Meters

Map Projection: Transverse Mercator
Horizontal Datum: North American 1983
Grid: NAD 1983 UTM Zone 17N

N

GHD

TOWN OF OAKVILLE
2D HYDRAULIC MODELLING OF JOSHUA'S CREEK

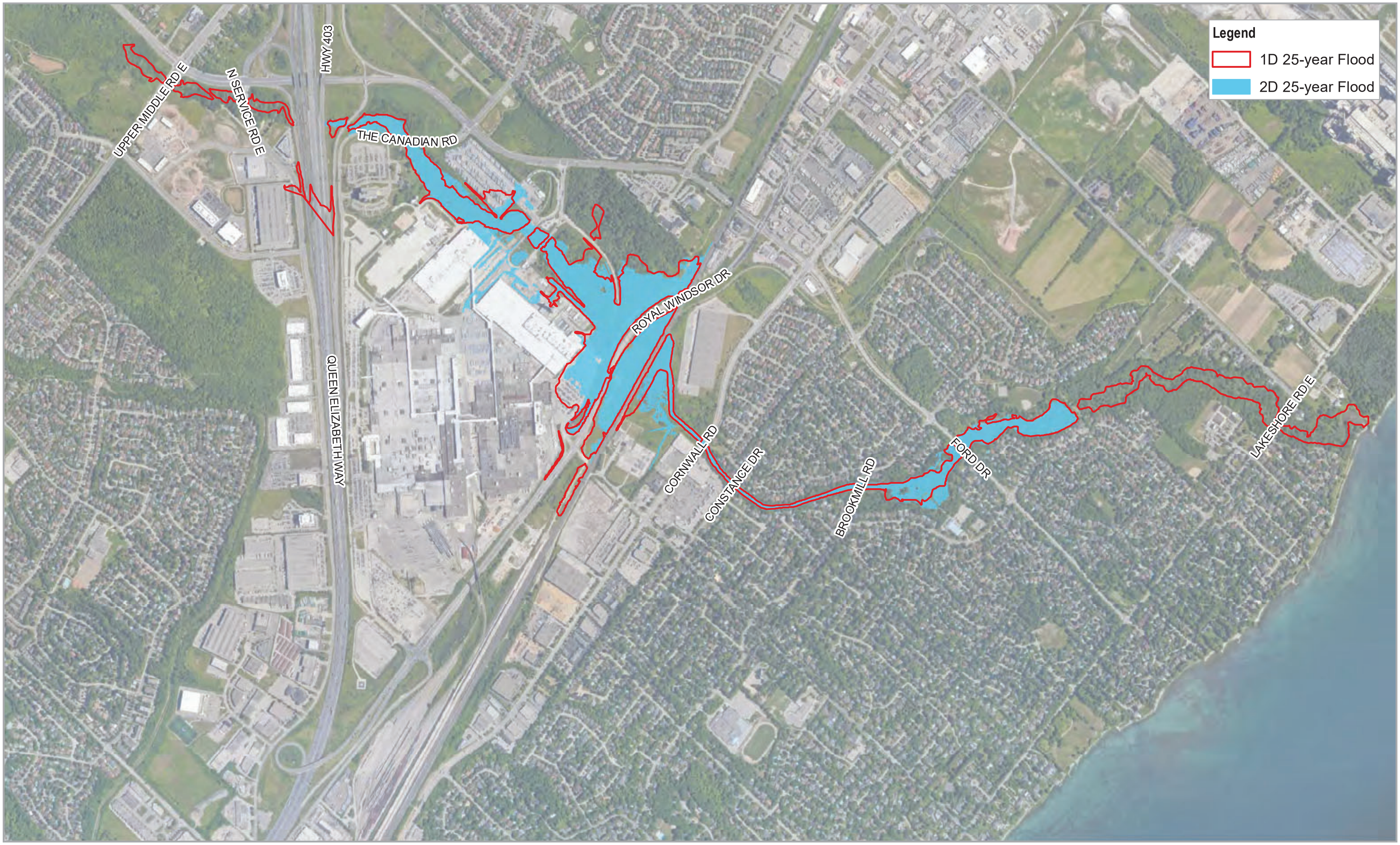
10-YEAR INUNDATION BOUNDARIES

Project No. **11211778**
Revision No. **-**
Date **Jun 4, 2021**

FIGURE 4.7

Q:\GIS\PROJECTS\11211000s\11211778\Layouts\20210604_MEMO001\11211778_20210604_MEMO001_GIS006.mxd
Print date: 04 Jun 2021 - 09:53

Data source: Image ©2020 Google, Imagery date: 8/Jun/2018



Paper Size ANSI A

0 100 200 300

Meters

Map Projection: Transverse Mercator
Horizontal Datum: North American 1983
Grid: NAD 1983 UTM Zone 17N

N

TOWN OF OAKVILLE
2D HYDRAULIC MODELLING OF JOSHUA'S CREEK

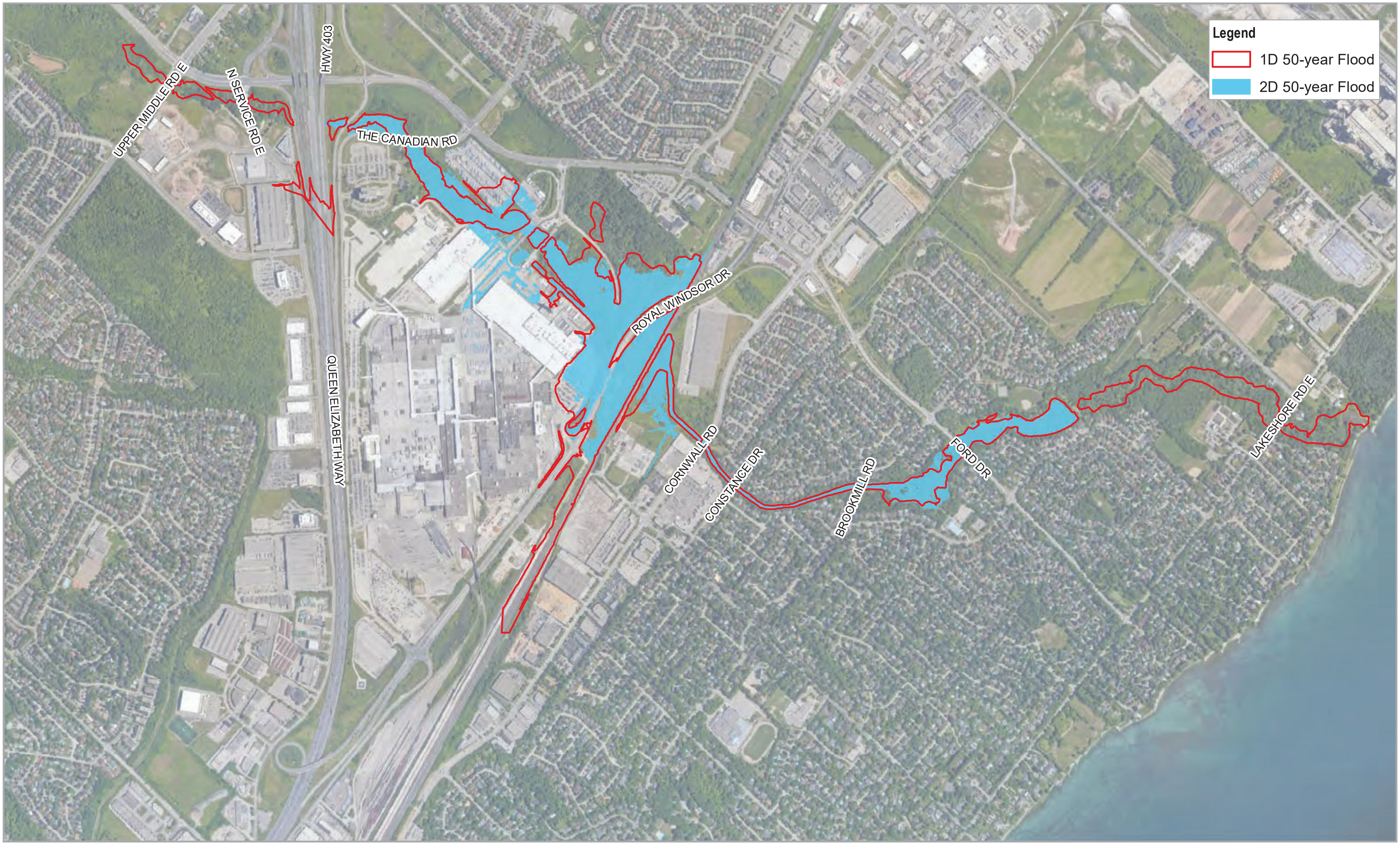
25-YEAR INUNDATION BOUNDARIES

Project No. **11211778**
Revision No. **-**
Date **Jun 4, 2021**

FIGURE 4.8

Q:\GIS\PROJECTS\11211000s\11211778\Layouts\20210604_MEMO001\11211778_20210604_MEMO001_GIS007.mxd
Print date: 04 Jun 2021 - 09:55

Data source: Image ©2020 Google, Imagery date: 8/Jun/2018



Paper Size ANSI A

0 100 200 300

Meters

Map Projection: Transverse Mercator
Horizontal Datum: North American 1983
Grid: NAD 1983 UTM Zone 17N

N

TOWN OF OAKVILLE
2D HYDRAULIC MODELLING OF JOSHUA'S CREEK

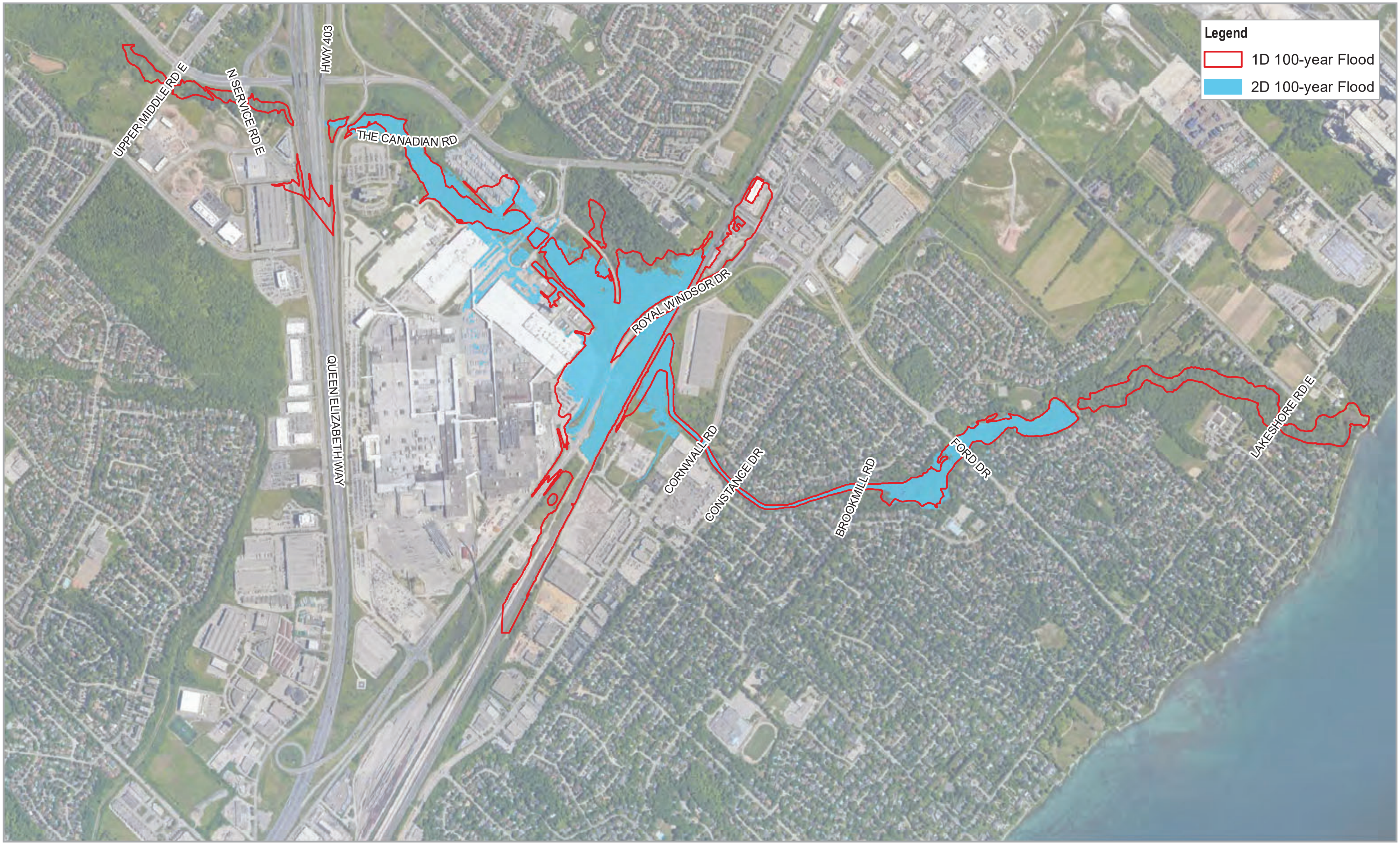
50-YEAR INUNDATION BOUNDARIES

Project No. **11211778**
Revision No. **-**
Date **Jun 4, 2021**

FIGURE 4.9

Q:\GIS\PROJECTS\11211000s\11211778\Layouts\20210604_MEMO001\11211778_20210604_MEMO001_GIS008.mxd
Print date: 04 Jun 2021 - 09:57

Data source: Image ©2020 Google, Imagery date: 8/Jun/2018



Paper Size ANSI A

0 100 200 300

Meters

Map Projection: Transverse Mercator
Horizontal Datum: North American 1983
Grid: NAD 1983 UTM Zone 17N

N

TOWN OF OAKVILLE
2D HYDRAULIC MODELLING OF JOSHUA'S CREEK

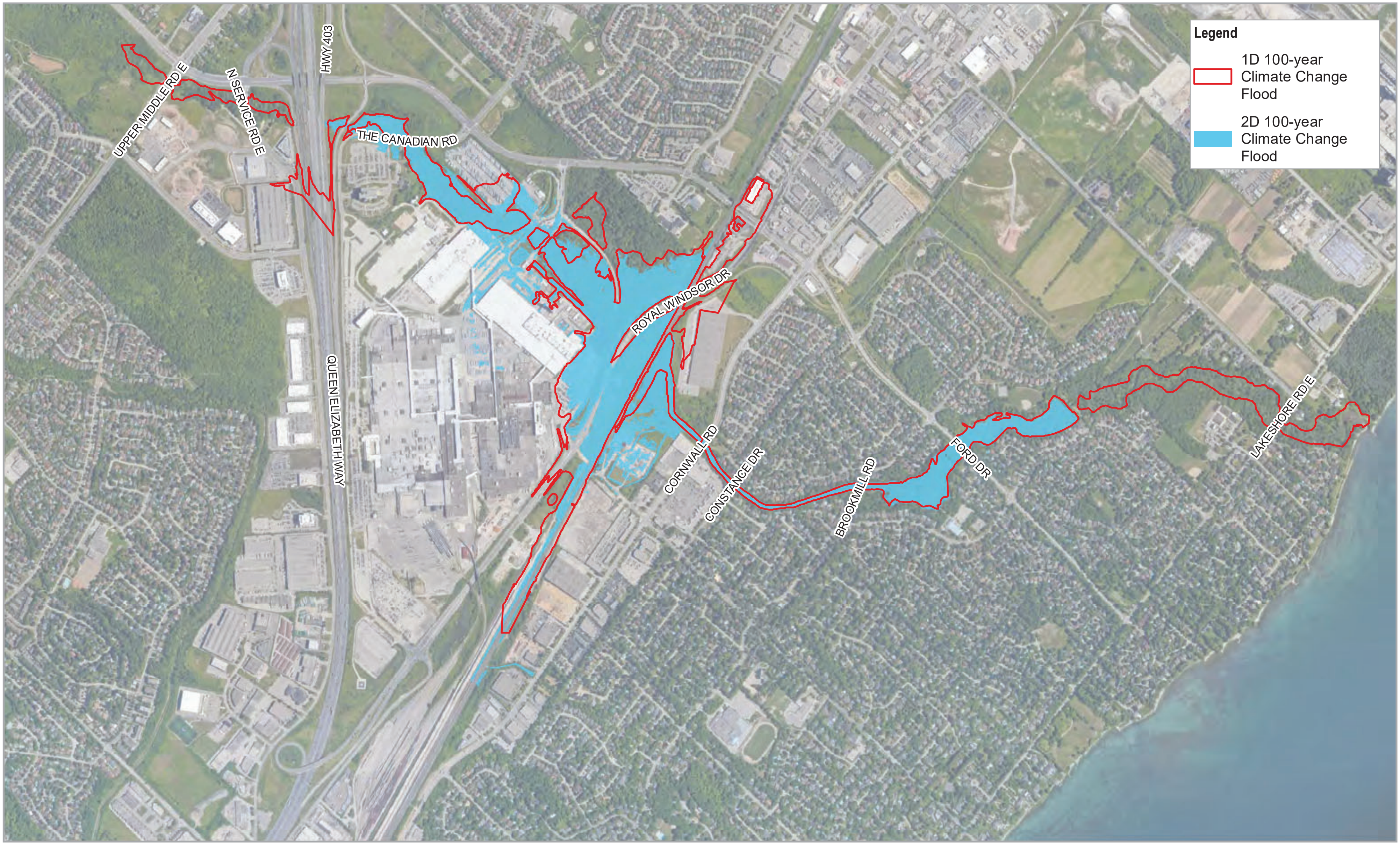
100-YEAR INUNDATION BOUNDARIES

Project No. **11211778**
Revision No. **-**
Date **Jun 4, 2021**

FIGURE 4.10

Q:\GIS\PROJECTS\11211000s\11211778\Layouts\20210604_MEMO001\11211778_20210604_MEMO001_GIS001.mxd
Print date: 04 Jun 2021 - 09:40

Data source: Image ©2020 Google, Imagery date: 8/Jun/2018



Paper Size ANSI A

0 100 200 300

Meters

Map Projection: Transverse Mercator
Horizontal Datum: North American 1983
Grid: NAD 1983 UTM Zone 17N

N

TOWN OF OAKVILLE
2D HYDRAULIC MODELLING OF JOSHUA'S CREEK

100-YEAR CLIMATE CHANGE INUNDATION BOUNDARIES

Project No. **11211778**
Revision No. **-**
Date **Jun 4, 2021**

FIGURE 4.11

Q:\GIS\PROJECTS\11211000s\11211778\Layouts\20210604_MEMO001\11211778_20210604_MEMO001_GIS002.mxd
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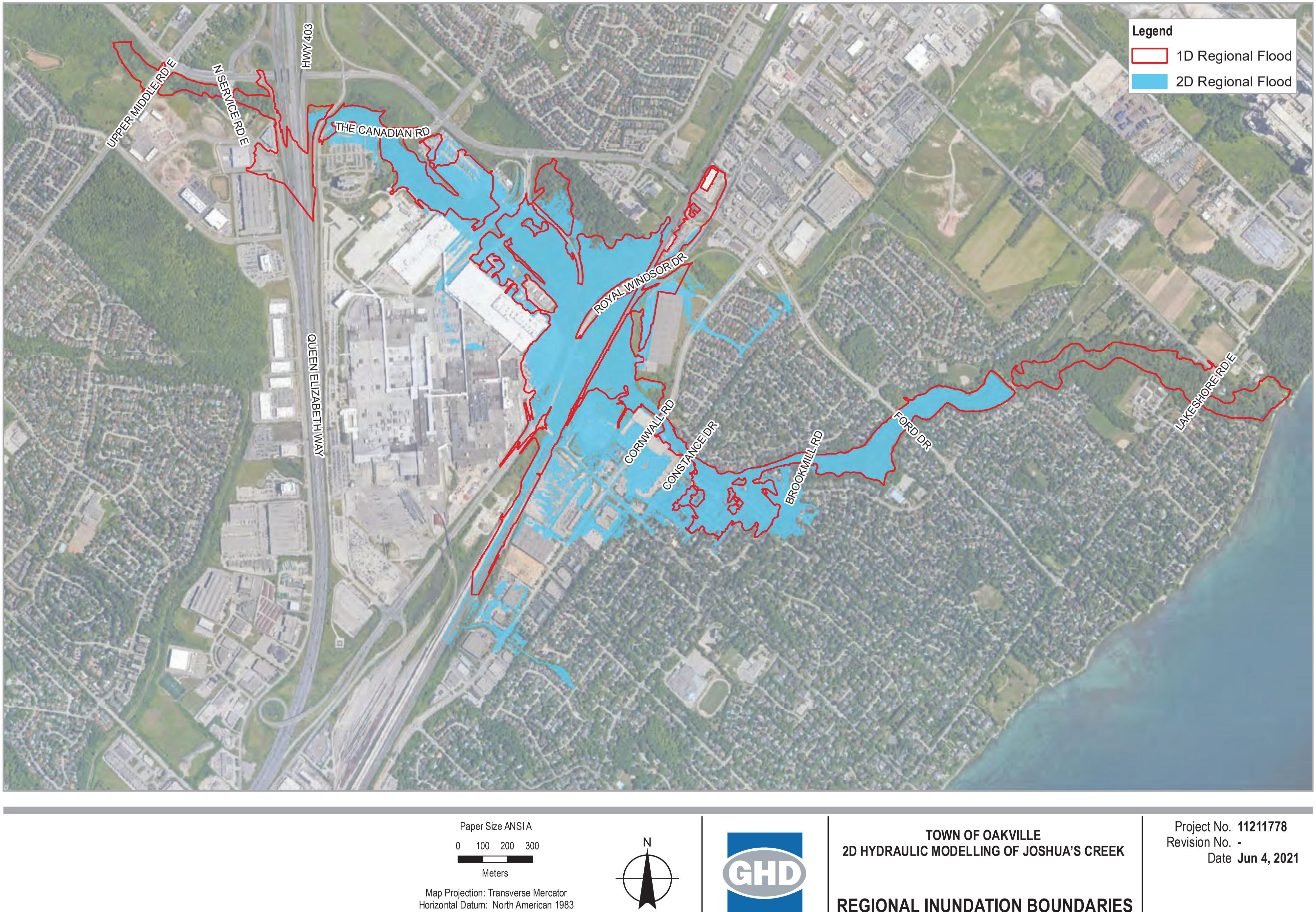
Data source: Image ©2020 Google, Imagery date: 8/Jun/2018



TOWN OF OAKVILLE
2D HYDRAULIC MODELLING OF JOSHUA'S CREEK

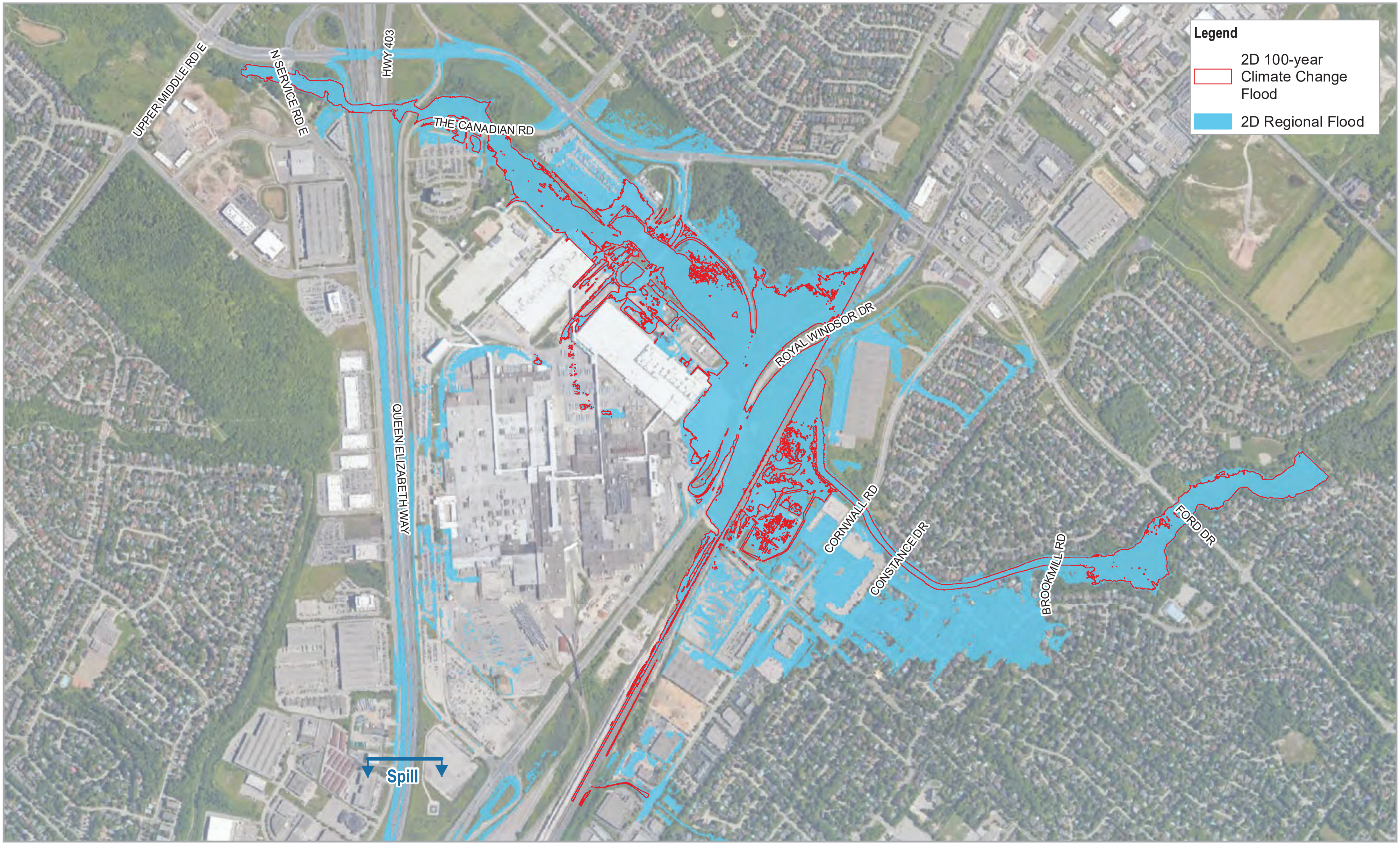
REGIONAL INUNDATION BOUNDARIES

Project No. 11211778
Revision No. -
Date Jun 4, 2021

FIGURE 4.12

Q:\GIS\PROJECTS\11211000s\11211778\Layouts\20210604_MEMO001\11211778_20210604_MEMO001_GIS003.mxd
Print date: 04 Jun 2021 - 09:45

Data source: Image ©2020 Google, Imagery date: 8/Jun/2018



Paper Size ANSI A

0 100 200 300

Meters

Map Projection: Transverse Mercator
Horizontal Datum: North American 1983
Grid: NAD 1983 UTM Zone 17N

N

GHD

TOWN OF OAKVILLE
2D HYDRAULIC MODELLING OF JOSHUA'S CREEK

SPILL ASSESSMENT
UPSTREAM OF HIGHWAY 403

Project No. 11211778
Revision No. -
Date Jun 4, 2021

FIGURE 4.13

Q:\GIS\PROJECTS\11211000s\11211778\Layouts\20210604_MEMO001\11211778_20210604_MEMO001_GIS009.mxd
Print date: 04 Jun 2021 - 10:00

Data source: Image ©2020 Google, Imagery date: 8/Jun/2018

Attachment A

TOWN OF OAKVILLE
BENCHMARK SYSTEM

O.B.M. #88 ELEVATION 142.996

DESCRIPTION -
The southerly end of the concrete door sill at the main entrance to Firehall #7. The entrance is on the Joshuas Creek Dr. (east) side of the building.

DATE	BY	SOURCE	ELEVATION
Aug 1998	Jim Clark	J.C. #102	143.1361

REVISIONS –

June 2011	Bob Mathers (Town of Oakville)		142.996

Elevation established from Geodetic Surveys Canada plate
001 1965 U593
CGVD 1928 (1978 Adjustment)

Station Report - 65U015

Station 1 of 1

Site Identification

Name	Province	NTS map sheet	Unique Number	Provincial Identifier	Network
65U015	Ontario	030M05	65U015		43079SW

Horizontal Data

Coordinates scaled from map

Geographic

Latitude	Longitude
43° 29' 16.8"	79° 40' 30.0"

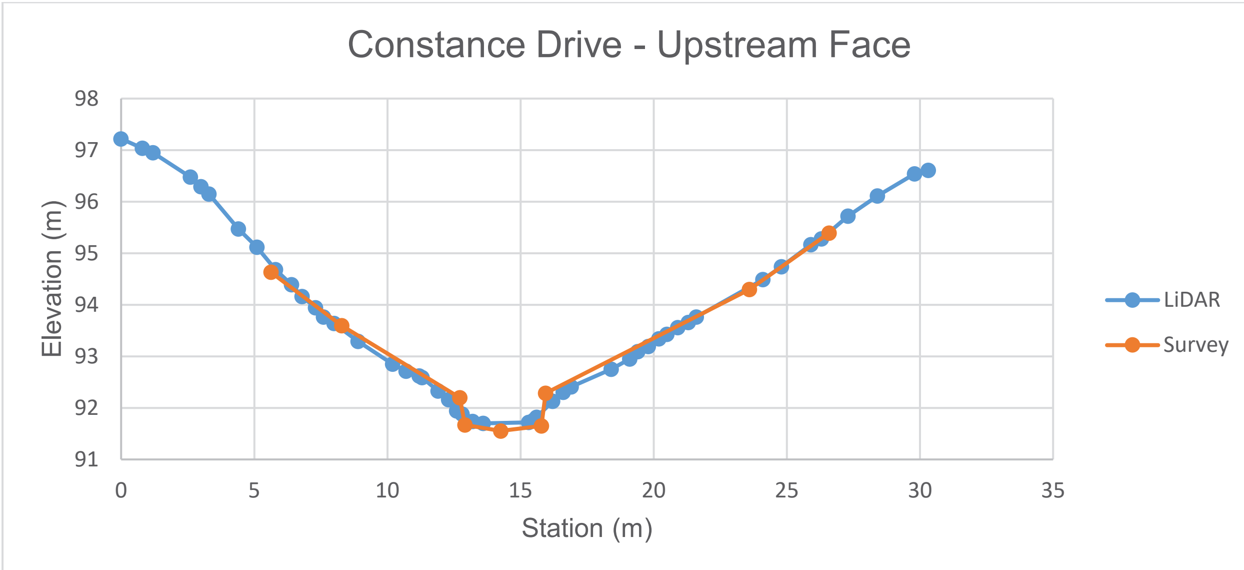
UTM

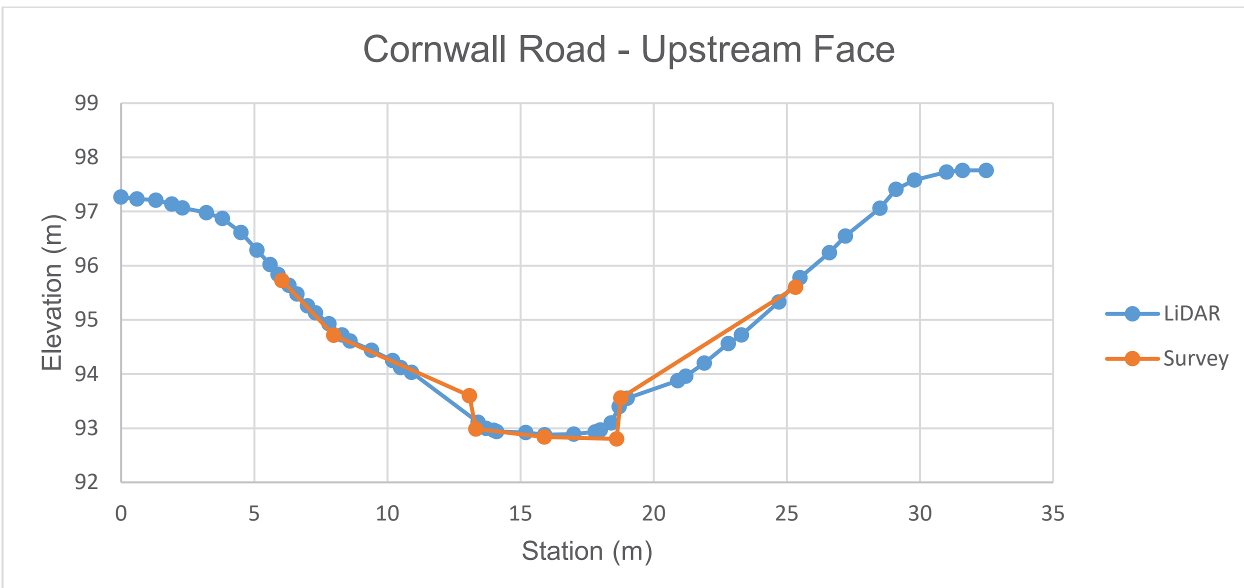
Zone	Easting (metres)	Northing (metres)	Scale
17	607140.467	4815861.34	0.99974

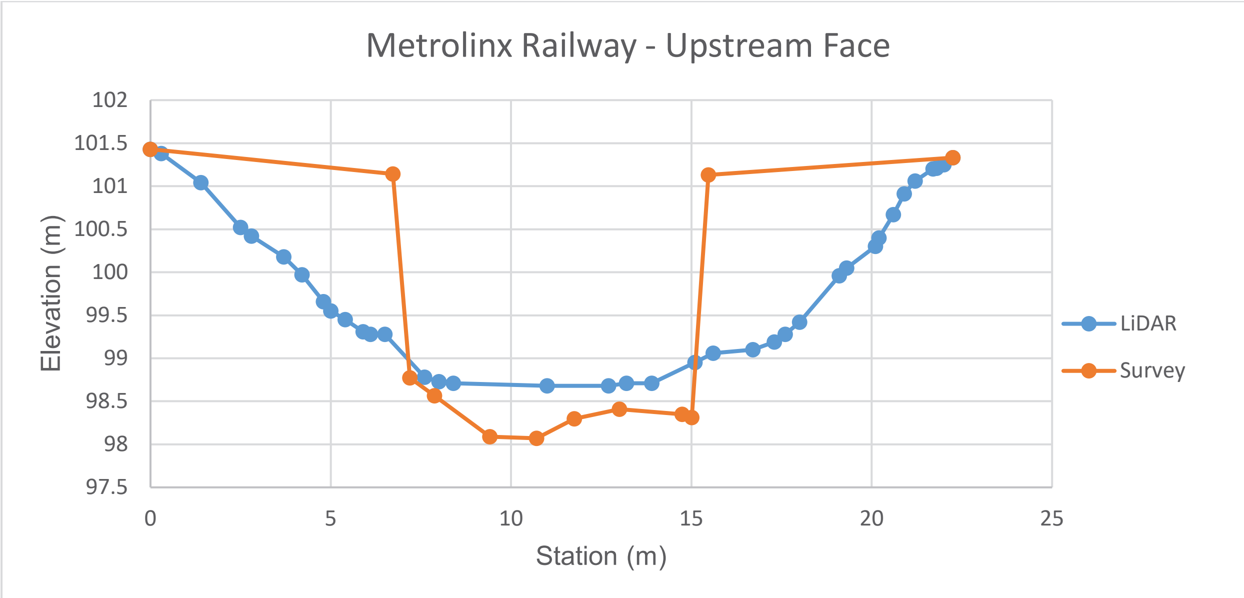
Vertical Data

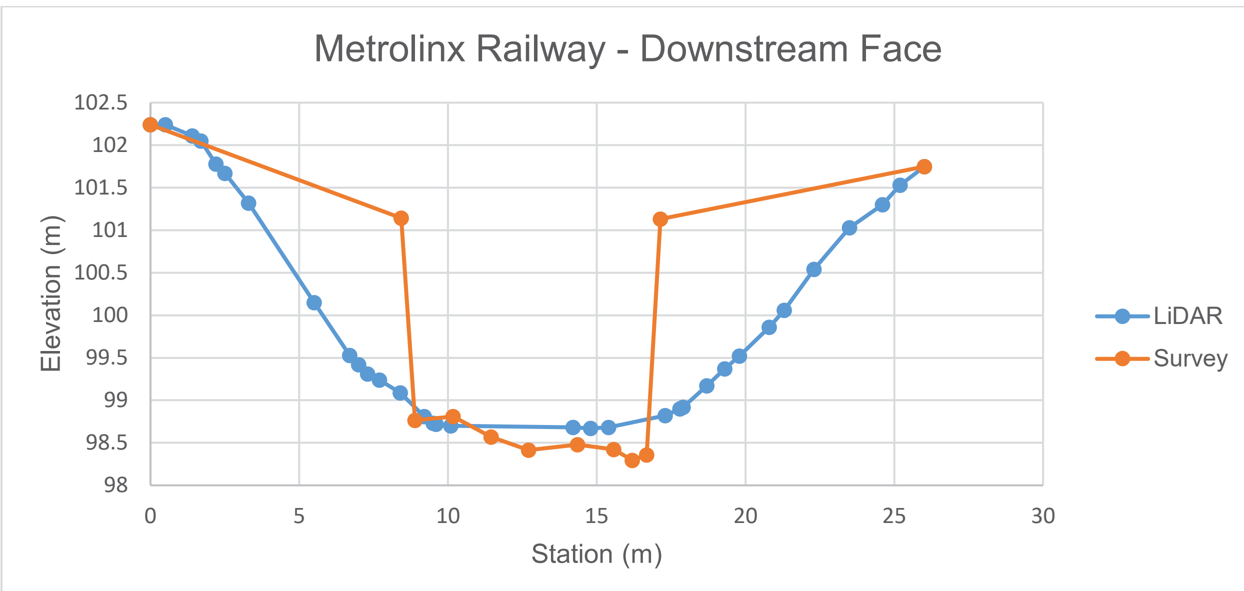
Vertical Datum	Elevation (m)	Order	Gravity (mGal)	Published	Project ID
CGVD2013 (2010.0)	124.256	1st	980410.81	2013	H13ML1311
CGVD28	124.670	1st	980480.89	1965	VA331
IGLD85	124.760	1st	980619.90	1992	IGLD85AP92

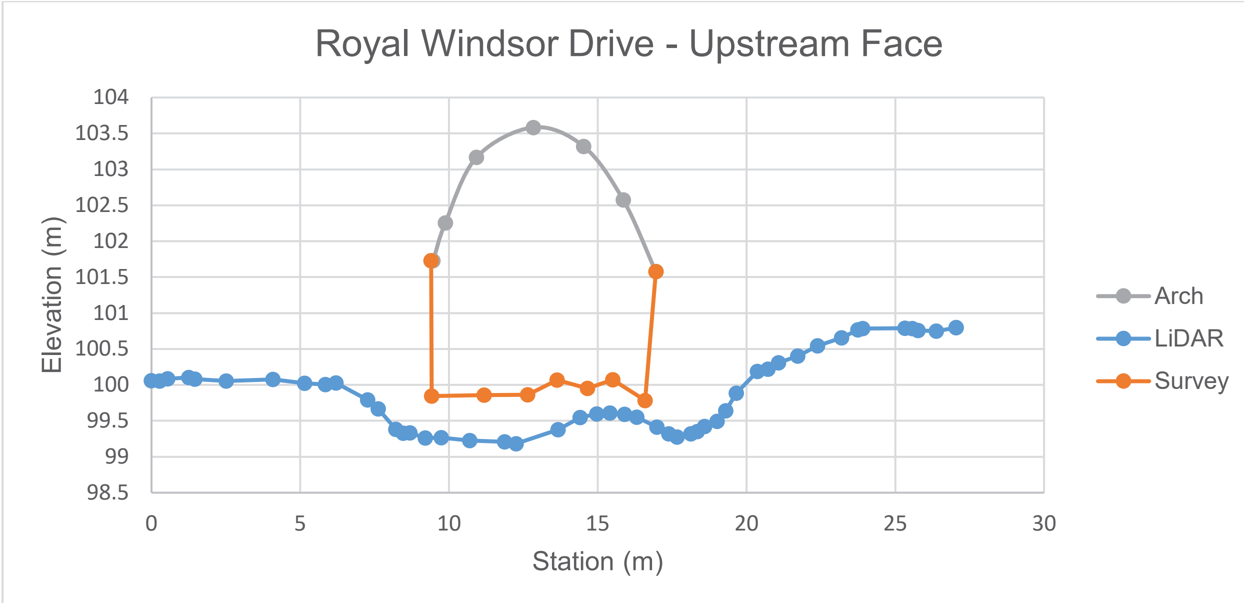
Station Marker				
Marker Type	Inspected in	Established by	Status	Comments
Permanent agency marker	1965	Canadian geodetic survey - nrcan	Good	None


Constance Drive - Upstream Face
Elevation (m)
98
97
96
95
94
93
92
91
0
5
10
15
20
25
30
35
Station (m)
LiDAR
Survey

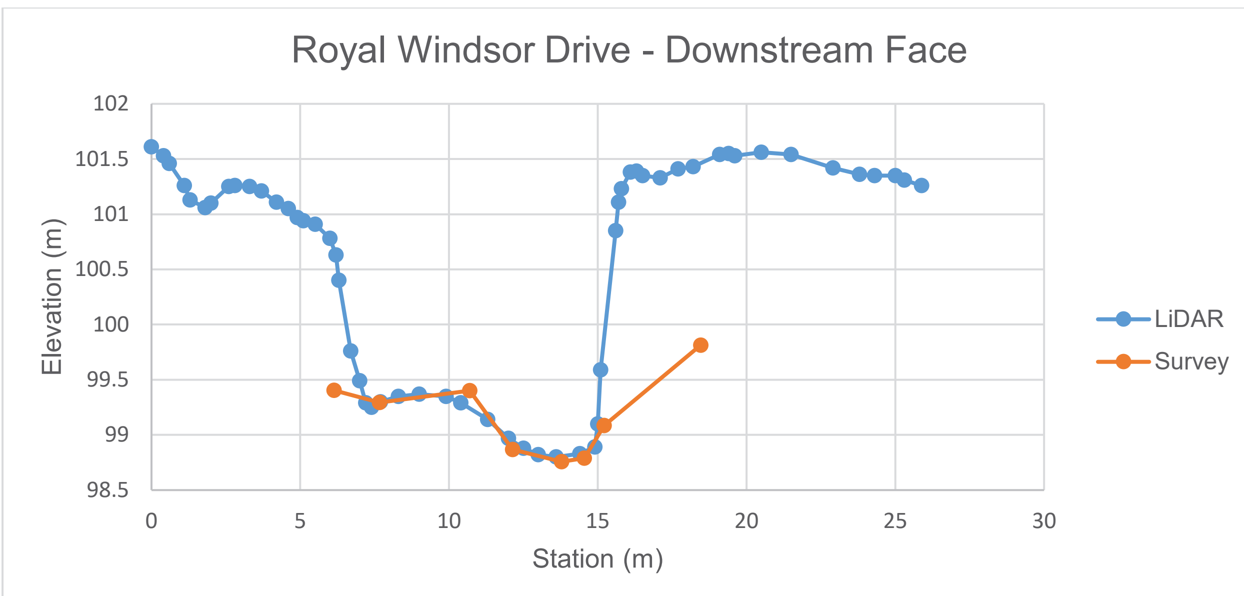

Cornwall Road - Upstream Face
Elevation (m)
99
98
97
96
95
94
93
92
0
5
10
15
20
25
30
35
Station (m)
LiDAR
Survey


Metrolinx Railway - Upstream Face
Elevation (m)
Station (m)
LiDAR
Survey
102
101.5
101
100.5
100
99.5
99
98.5
98
97.5
0
5
10
15
20
25

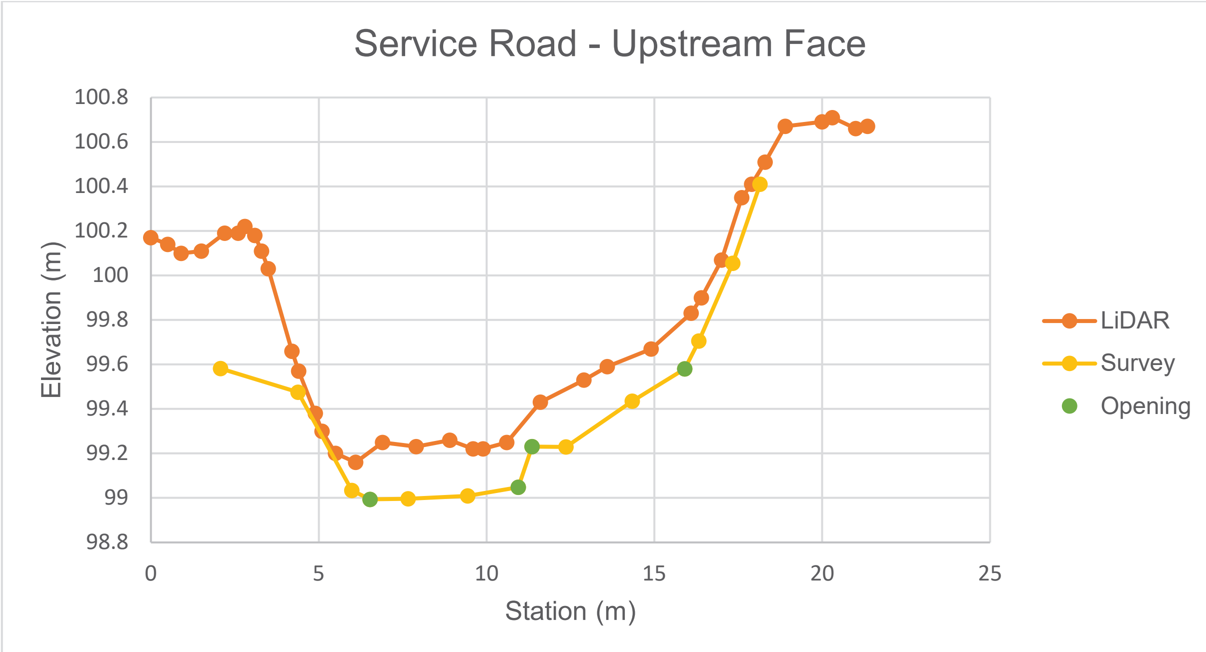

Metrolinx Railway - Downstream Face
Elevation (m)
Station (m)
LiDAR
Survey
102.5
102
101.5
101
100.5
100
99.5
99
98.5
98
0
5
10
15
20
25
30

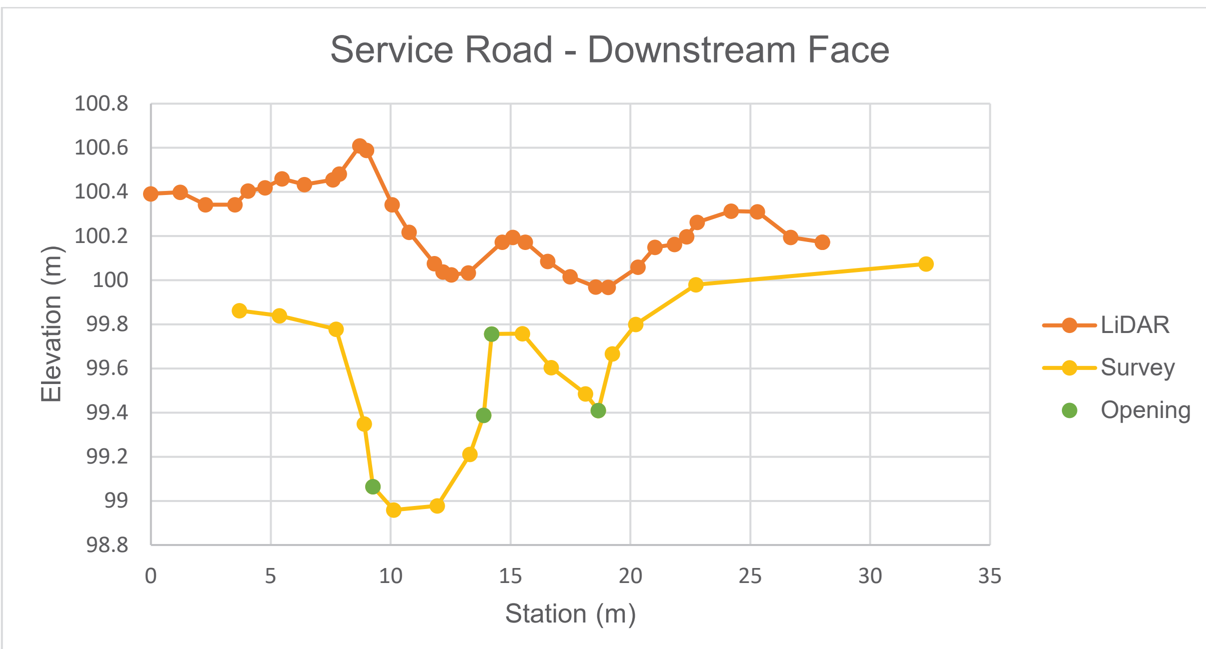


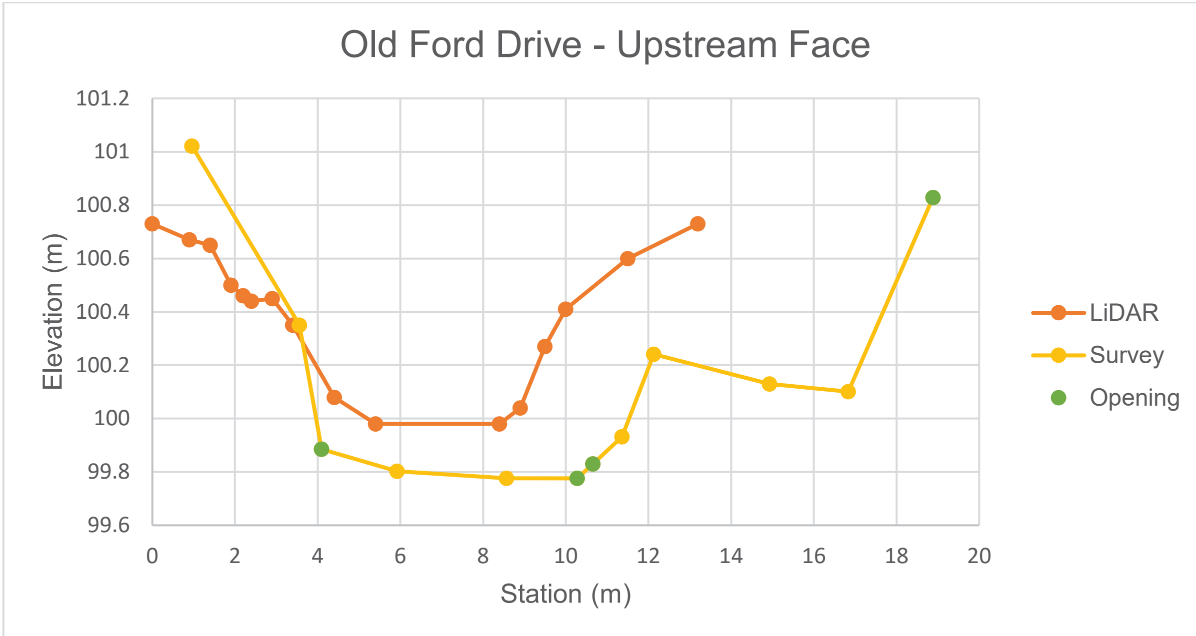
Royal Windsor Drive - Upstream Face
Elevation (m)
Station (m)
104
103.5
103
102.5
102
101.5
101
100.5
100
99.5
99
98.5
0
5
10
15
20
25
30
Arch
LiDAR
Survey



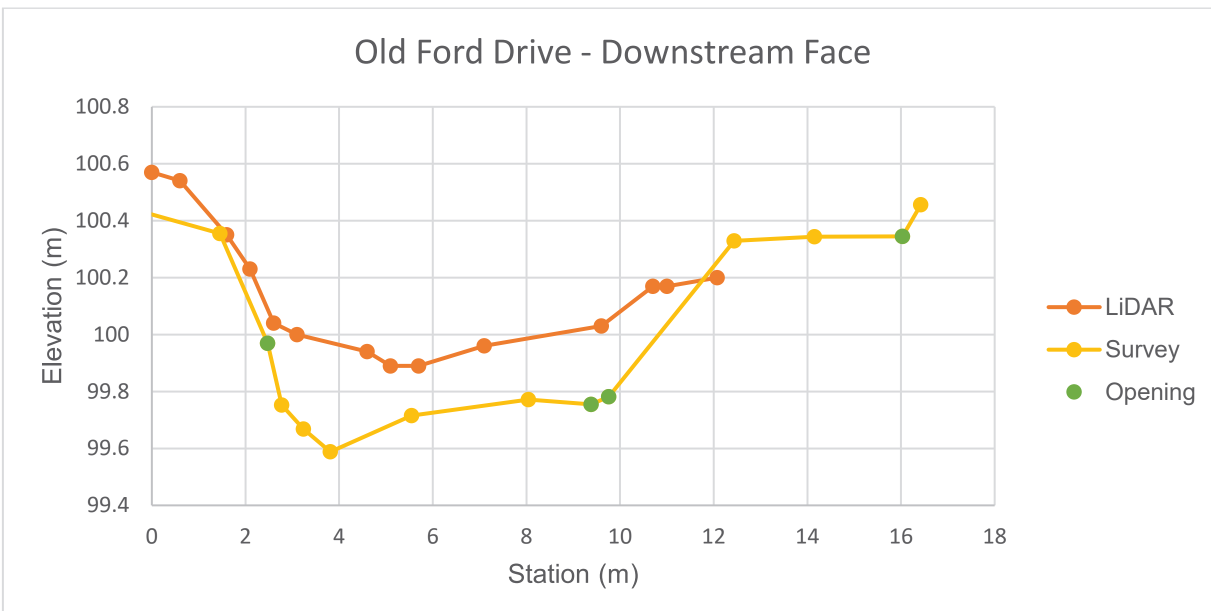
Royal Windsor Drive - Downstream Face
Elevation (m)
Station (m)
102
101.5
101
100.5
100
99.5
99
98.5
0
5
10
15
20
25
30
LiDAR
Survey


Service Road - Upstream Face
Elevation (m)
100.8
100.6
100.4
100.2
100
99.8
99.6
99.4
99.2
99
98.8
0
5
10
15
20
25
Station (m)
LiDAR
Survey
Opening


Service Road - Downstream Face
Elevation (m)
100.8
100.6
100.4
100.2
100
99.8
99.6
99.4
99.2
99
98.8
0
5
10
15
20
25
30
35
Station (m)
LiDAR
Survey
Opening



Old Ford Drive - Upstream Face
Elevation (m)
101.2
101
100.8
100.6
100.4
100.2
100
99.8
99.6
0
2
4
6
8
10
12
14
16
18
20
Station (m)
LiDAR
Survey
Opening



Old Ford Drive - Downstream Face
Elevation (m)
100.8
100.6
100.4
100.2
100
99.8
99.6
99.4
0
2
4
6
8
10
12
14
16
18
Station (m)
LiDAR
Survey
Opening

Attachment B

Photo 1 - Downstream Face of Private Road 2 Culvert Looking Upstream

Photo 2 - Left* Barrel of the Private Road 2 Culvert

Notes:
1. Direction (left and right) are defined if you were standing in a channel looking downstream

Site Photographs

Photo 3 - Right Barrel of the Private Road 2 Culvert

Photo 4 - Sediment Deposition Through the Private Road 2 Culvert

Site Photographs

Photo 5 - Downstream Face of Unnamed Service Road Culvert Looking Upstream

Photo 6 - Left Barrel of the Unnamed Service Road Culvert

Photo 7 - Right Barrel of the Unnamed Service Road Culvert

Photo 8 - Upstream Face of Royal Windsor Drive Culvert

Site Photographs

Photo 9 - Inside Barrel of Royal Windsor Drive Culvert

Photo 10 - Upstream Face of CN Rail Bridge

Site Photographs

Photo 11 - Under the CN Rail Bridge Looking Downstream

Photo 12 - Under Cornwall Road Bridge Looking Downstream

Site Photographs

Photo 13 - Joshua's Creek Downstream of the Cornwall Road Bridge

Photo 14 - Downstream Face of Constance Drive Bridge Looking Upstream