

OSWEGO CREEK FLOODPLAIN MAPPING

HYDRAULIC REPORT

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PROJECT 22-925



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OSWEGO CREEK FLOODPLAIN MAPPING HYDRAULIC REPORT

EXECUTIVE SUMMARY

Greck and Associates Limited (Greck) was retained by Niagara Peninsula Conservation Authority (NPCA) to generate floodplain mapping for the 50-year, 100-year, and 200-year floodplains for the Oswego Creek watershed. This report presents the work completed to provide Regulatory flood hazard mapping within NPCA identified reaches of the Oswego Creek watershed.

The study was completed following a process that included guidance and review by NPCA and public consultation. Public consultation was provided through three (3) Public Information Centres (PIC).

The key deliverables of this study include:

1. A new hydrologic model
2. A new hydraulic model
3. Inventory and hydraulic details for all major watercourse crossings
4. 107 digitally georeferenced flood hazard map sheets
5. Hydrology report
6. Hydraulic report

The flood hazard mapping prepared as part of this study will be used to establish regulation limits within the study area in accordance with provincial standards enforced by NPCA. In addition to informing regulation, the models developed as part of this study may be used for many purposes, including flood forecasting and warning, emergency planning and response, prioritization of flood mitigation efforts, etc. Note that due to the overall low gradient which results in poor drainage conditions of the Oswego Creek watershed, pluvial flooding is also a common occurrence, however, this report only focuses on fluvial flooding.

Hydrologic analyses were completed for the Oswego Creek watershed to determine peak flow rates for the 50-year, 100-year, and 200-year event. The aforementioned return frequency events are used to represent flow events which have a 2%, 1% and 0.5% probability of occurring respectively in a given year. The hydrologic analyses were completed through the development of a new deterministic hydrologic simulation model. Hydrologic analyses were prepared for existing land-use conditions and calibrated to observed flow data.

For the purposes of this study, the 100-year storm event flows were used in the hydraulic model to establish the Regulatory flood hazard limits. At select locations, due to the significant potential for flood storage, unsteady flood storage analyses were completed.

A new detailed, one-dimensional hydraulic computer simulation model was prepared for the study area. In total, approximately 224 kilometers of watercourse was modelled. To set up the model an extensive field program was completed to survey all pertinent watercourse crossings throughout the area to be mapped. The survey recorded culvert, bridge and road surface geometries to determine conveyance capacity via watercourse crossing structures and roadway overflow. A total of 110 watercourse crossings were investigated.

The results of the hydraulic analyses were mapped on 107 full size (610mm x 914mm) drawing sheets. The final maps show the 100-year floodlines. Separate mapping for the 50-year and 200-year storm events was also prepared for the NPCA to interpret local flood vulnerability due to climate change and for other considerations.

Draft reports and flood hazard mapping was presented at the public information center (PIC) #3 in February 2024.

Notable findings of the mapping include the following:

1. The backwater effects from the Welland River to Oswego Creek are significant. During a 100-year flood event, the floodwater elevations in the main branch of Oswego Creek, from its confluence with the Welland River to Indiana Road East (approximately 23km), is directly associated with water levels in the Welland River.
2. Due to the level topography of the Oswego landscape, changes in flood flow rate between the 50- and 200-year flood bring about greater change in the areas prone to flooding than changes in the depth of flooding.
3. Currently 44 buildings have been identified in the designated flood hazard area defined by the 100-year flood event. The buildings identified include residential homes, barns, industrial structures, sheds, and garages. The most significant flood prone area affecting residential lots is along Oswego Park Road.

This study has been prepared specifically for Regulatory floodline mapping purposes and not for the use in establishing or evaluating stormwater management criteria and system performance. This study received support through the National Disaster Mitigation Program. The views expressed in this material are the views of Greck and do not necessarily reflect the views of the Province of Ontario or the Government of Canada.

OSWEGO CREEK FLOODPLAIN MAPPING HYDRAULIC REPORT

1.0 INTRODUCTION

Greck and Associates Limited (Greck) was retained by Niagara Peninsula Conservation Authority (NPCA) to generate floodplain mapping for the 50-year, 100-year, and 200-year floodplains for approximately 224 kilometres (km) of Oswego Creek (including its major tributaries) located in rural Haldimand County. This report outlines the methodology and results of the hydraulic assessment undertaken to generate the Regulatory floodplain maps. It is currently NPCA's intention to use the 100-year storm flood conditions for regulatory purposes.

1.1 SCOPE OF WORK

The goals of this study are to prepare the following key deliverables:

1. New, fully georeferenced hydraulic model in HEC-RAS to identify flood hazards associated with Oswego Creek.
2. Detailed technical report of work completed.
3. Georeferenced flood hazard mapping.

The scope of work and input data used in this study was somewhat guided by the modelling procedures, data and findings used for preparation of the floodplain mapping for the Welland River watershed.

1.2 LIMITATIONS OF THIS STUDY

This study has been prepared specifically for Regulatory floodplain mapping purposes and not for the use in establishing or evaluating stormwater management criteria and system performance. Results of this study are an estimate of anticipated Regulatory flood hazards. Regulatory flood elevations can be further refined using site specific studies, topographic survey etc.

The flood hazards identified are associated with only with conveyance of flood flows within Oswego Creek and its tributaries. The mapping does not identify flood hazards arising from the operation of municipal sewer drainage infrastructure or the ponding of water on runoff surfaces.

As there are many small private watercourse crossings throughout the study area which have not been documented nor examined in detail by this study, minor localized differences may exist with the flood elevations reported in this study.

1.3 STUDY METHODOLOGY

Several steps were involved to complete the flood hazard mapping within the Oswego Creek watershed. The overall study methodology is described briefly below:

1. Review of Background Information: Review previous studies to gain a better understanding of watershed hydrology and hydraulics.
2. Data Collection and Processing: Survey hydraulic structures to confirm culvert and bridge geometries throughout the mapping study area & LiDAR validation.
3. Hydrologic Modelling: Develop a hydrologic model to quantify peak flows through the study area.
4. Model Calibration: Calibrate the hydrologic model to known, monitored events through the study area.
5. Hydraulic Modeling: Develop a hydraulic model to determine flood elevations throughout the study area.
6. Flood Hazard Mapping: Results of the hydraulic and hydrologic model were incorporated into digital flood hazard mapping, overlaying the overall floodline to identify flood hazards associated with major tributaries of Oswego Creek.

All technical analyses were completed by specialized water resources engineers at Greck. As part of Greck's QA/QC process, the project manager was responsible for overseeing and reviewing all analyses completed by the study team to ensure a quality and defensible product is completed. The NPCA provided additional peer review from external sources for the modelling, mapping and report products. This peer review was provided by a qualified water resources engineer who was not directly involved in the analysis and development of deliverables.

This report outlines the summary of analyses, calculations and modelling procedures completed in an effort to meet the study goals of establishing Regulatory Flood Hazard mapping for the Oswego Creek watershed.

1.4 STUDY AREA

The study area consists of the entire Oswego Creek watershed and is located in the southeastern portion of Haldimand County. Oswego Creek is a subwatershed of the Welland River watershed and has a drainage area of 187 square kilometers (km²). This represents 19% of the Welland River watershed, see **Figure 1.1**.

The majority of the watershed consists of undeveloped rural land, primarily with agricultural and forested uses, see **Figure 1.2**. There are some areas of urbanization located near small communities namely Canborough, Attercliffe Station, Oswego Park

and Canfield Junction. These areas consist of low intensity residential, industrial, and commercial land uses.

East of the Grand River, there is a geological feature referred to as the Onondaga escarpment and the strike of this bedrock causes the drainage waters to flow eastward to the Welland River including Oswego Creek. The low slope and lack of gradient create some very poorly drained sections in this area (OMAFRA, 1984). The upstream portion of the watershed has a typical elevation of 206 metres (m) and at the confluence with the Welland River 177m (based on a CGVD2013 vertical datum). This is an elevation difference of 29m over a distance of 28km. This results in an average land grade of 0.1%.

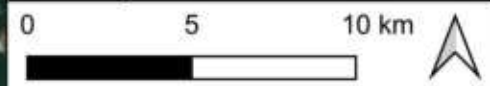
The soils are predominantly silty clay and silty clay loam. The majority of Oswego Creek is allowed to function as a natural channel system throughout the watershed. Both the topographic relief and soil characteristics results in a watercourse that is wide and very sinuous in nature. As such, channel grades are typically less than 0.1%.

The riparian lands adjacent to the watercourse are typically left natural and are well vegetated. Evidence of historic meander scars and oxbows are located throughout the shallow valley lands of this watercourse. These historical river channel alignments are generally easily flooded. As such, these areas are generally not used for agricultural purposes and have naturally revegetated as woodlots or wetland type features.

The greatest potential impacts to the natural conveyance of flood flows throughout the watershed are at watercourse crossings required for roadways and railways.



Figure 1.1:
Oswego Creek, Welland
River, and Twenty Mile
Creek Watershed Map
Oswego Creek
Floodplain Mapping
Project #: 22-925



- Legend**
- 02HA024 Canborough Flow Gauge
 - 02HA007 Welland River Below Caistor Corners Flow Gauge
 - 02HA006 Twenty Mile Creek at Balls Falls Flow Gauge
 - 6139449 Welland-Pelham Station
 - 6153194 Hamilton Airport Station
 - Oswego Creek Watershed
 - Welland River Watershed
 - Twenty Mile Creek Watershed

Oswego Creek Watershed Delineation:
via PCSWMM using LIDAR DTM by Greck and
Associates, February 2024

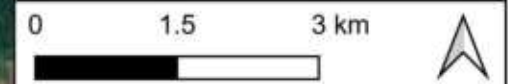
Welland River and Twenty Mile Creek
Watershed Delineation:
via OWIT

Basemap Image:
Google Maps 2024

Figure 1.2:
Oswego Creek Study Area

Oswego Creek Floodplain
Mapping

Project #: 22-925



Legend

- River Reaches
- Oswego Creek Watershed

DEM Source: LiDAR DTM
Hamilton-Niagara 2021 Package F
from Land Information Ontario
Basemap Image: Google Maps 2024

1.5 PREVIOUS STUDIES

Previous technical hydraulic studies completed for the Oswego Creek watershed were reviewed and are listed below with a brief description and summary of key elements relative to the work completed as part of this report.

Welland River Floodplain Mapping Update, WSP, November 2018.

A floodplain mapping study was completed to support the Regulatory floodplain mapping updates for the Welland River in November 2018. The study included the development of a MIKE 11 hydraulic model of the Welland River.

The report describes the methodology and presents the results of hydraulic model development, calibration, and validation. Only the 100-year flow event was assessed.

The developed MIKE 11 hydrologic model was calibrated using two NPCA water level monitoring stations at Caistors Corners Gauge and Old Siphon West during the February 10 to 14 2009 storm event. The surface water level calibration results were well reproduced with a 2% and 12% difference in water levels at the Caistors Corners gauge and Old Siphon West gauge respectively.

The Oswego Creek outlets into the Welland River, which is shown in Figure A20 in the WSP report. The 100-year water level is reported to be 175.4m at the Oswego Creek outlet, which is reported in the CGVD28 vertical datum. This equates to a 100-year water level of 175.02m under the CGVD2013 vertical datum.

Canada-Ontario Flood Damages Reduction Study, Watershed Flood Damage Assessment Study, Cumming Cockburn Limited, 1988

In 1988, the NPCA undertook a flood damage reduction study under the auspices of the federal-provincial Flood Damages Reduction Program. As part of the study a hydrology and hydraulic analysis was completed for Oswego Creek. This report was reviewed to obtain information that would support the hydraulic analyses required by the current study.

The 2-year, 5-year, 10-year, 25-year, 50-year, 100-year, and Regional storm event were estimated using OTTHYMO. The Oswego Creek hydraulic analysis utilized existing hydraulic information, and the HEC-2 hydraulic model developed from the 1976 study by Kilborn Ltd.

The study recommends a flood damage centre near Oswego Creek's outlet to the Welland River immediately upstream of the Toronto Hamilton Buffalo Railway and that

the potential for flood damage is low for events equal to or less than the 100-year storm. It also reports that the implementation of a floodplain management policy which utilizes the Regional storm floodline as criteria for the regulation of development was not considered to be a feasible approach due to the large size of the area being impacted on.

Flood Plain Mapping of Oswego Creek, Kilborn Ltd., March 1976

In 1976, the NPCA undertook a floodplain mapping study of Oswego Creek from Canborough to the Oswego Creek outlet into Welland River. The study was completed for the purposes of establishing acceptable development limits regarding the urbanization of the watershed and institute land use practices consistent with its environmental limitations. This report was reviewed to obtain information that would support the hydraulic analyses required by the current study.

The study established 25-year, 50-year, 100-year, and Regional peak flows using unit hydrograph methodology and water surface profiles were computed using HEC-2 hydraulic modelling software. The Regional storm floodline was plotted on floodplain map sheets.

The study reports that there is flooding at Regional Road 45 during the Hurricane Hazel event that is attributed to backwater from the Welland River.

1.6 PROJECT COMMUNICATION AND PUBLIC ENGAGEMENT

Public consultation was an important process throughout the study, as it allowed for the study team to receive feedback from local residents and business owners regarding the watershed.

Public feedback was sought through three (3) Public Information Centres (PICs). The first PIC was held shortly after project initiation on April 13th, 2023, to notify the public of the on-going study, share the Study Team's understanding of the watershed, solicit public input and local knowledge to support technical analysis. The second PIC was held on November 14th, 2023, to share the status of the field program, present draft results from the hydrology analysis, provide an update on-going works, and receive public feedback. The third was held on February 15th, 2024, to present draft results from the hydraulic analysis including the draft flood plain map sheets and receive public feedback.

To maximize study awareness among the general public, NPCA applied multiple notification methods including:

- Advertisements in the local newspapers
- Social media posts
- Mail letters to local residents residing in the Oswego Creek watershed.
- An update on the NPCA website

2.0 FIELD PROGRAM AND DATA COLLECTION

The following section details the methodology utilized in the collection and processing of data from the field to validate the LiDAR topography data and build the hydraulic model of Oswego Creek. The topographic survey is essential in hydraulic modelling, as watercourse crossing details need to be field verified via site visit to confirm culvert and bridge information, such as geometry, inlet/outlet configuration, etc. The use of LiDAR elevation data alone cannot capture specific items that may restrict the conveyance capacity across a bridge or culvert, such as concrete barriers.

The roadway or abandoned railway profile associated with the crossing structures was also surveyed. The survey of these features was used to accurately identify flood spill elevations and or validate data provided from site LIDAR.

The collection of data involved a field inspection of watercourse crossing structures and a GPS survey of channel cross-sections and inverts at selected locations. Inspection and survey methodology, equipment used, and the scope of the field program are detailed below.

Most of the field work was completed from May through to the end of September 2023 by a two-person team. This work involved collecting data for watercourse crossings and at selected channel cross-sections as predetermined by NPCA, and through a desktop review of the study area. A total of 110 crossing structures were surveyed, 107 of which were identified by NPCA, with three additional crossings of importance identified by Greck.

At each crossing site, access to the crossing was gained by walking down the bank adjacent to the crossing. Structural measurements were taken and recorded by one person, while the survey was completed by the other person. The respective methodology and equipment used for each task is outlined below.

Crossing Measurements

Measurement and recording equipment included a Bosch laser distance measurement tool with +/-1.5mm accuracy within 50m, tape measure, survey rod and tablet with a built-in camera. For distance measurements, the laser measuring tool was used wherever possible, as it provided the greatest accuracy.

Photos and measurements taken at each crossing were recorded via the tablet and placed on crossing specific field sheets. The "Stream Crossing Field Inventory Sheet" for each structure was identified using a naming convention described in **Section 4.1** below.

Measurements differed depending on the type of structure; however, a brief explanation of the fields on the crossing inventory forms and their modes of inspection are provided below. Inventory Sheets are provided in **Appendix A**.

Inlet Type – Shape and classification of structure, i.e., arch bridge, box culvert, etc.

of Spans – Number of openings for water to pass through. Two for twin culverts, four for bridges with three sets of piers, etc.

Span or Diameter – Width of the structure's opening(s). Multiple spans are provided for bridges with two or more piers. Measurements were primarily obtained with a hand laser measuring tool.

Rise – Vertical measurement of the structure's opening from invert to obvert (or the lowest point on a bridge profile). This does not include sediment accumulation for closed bottom footings. The survey rod was held vertically to clear the water and the laser measuring tool was held at the 1m mark, pointing upwards to measure to the obvert. The total rise recorded included the laser reading added to the 1m survey rod. Two measurements were taken, one at the upstream inlet and one at the downstream outlet.

Length – Horizontal measurements from inlet to outlet of structure. Measured by hand laser measuring tool for short distances and derived from GPS survey data for longer distances.

Material – The primary material(s) composing the structure, in most cases concrete or galvanized corrugated steel.

Open Footing – “No” if the structure has a floor, “Yes” if it does not have a floor, but rather a natural channel bottom.

Skew Angle – The plan view angle of the structure from a reference line perpendicular to the road centre. Approximated from pictures and aerial imagery.

Sediment Depth – Depth of accumulated sediment if the channel does not have an open footing. Measured with survey rod or derived from two GPS readings at the top and bottom of sediment.

Road Barrier – Height and type of the barrier reaching the highest elevation on the structure. Measured with hand laser measuring tool.

Upstream (US) / Downstream (DS) Invert Elevation – The elevation of either the footing or the bottom of the channel at the inlet and outlet of the structure. Recorded by GPS survey.

US/DS Obvert Elevation – Derived from the rise added to the invert elevation or measured via measuring tape from deck and a point of reference recorded by GPS survey.

Inlet/Outlet Type – In the case of culverts, an indication of wingwalls, retaining walls or headwalls.

High Water Mark Depth – Height of a visible watermark line from thalweg of channel. "Not Observed" if a watermark line was not visible. Measured with a survey rod.

Piers – An indication if the structure had piers (only for bridges).

Pier Width – Width of pier face to incoming flow. A diameter is provided for round-nose piers. Measured by measuring tape.

Low Point in Deck Elevation – Lowest elevation of deck profile, or the location where overtopping would first occur. Note that for roads with curbs, this is a curb elevation instead of a road elevation since the space between the top of curb and top of road is ineffective flow area. Recorded by GPS survey.

Water Depth – Upstream water depth from channel bottom to water surface. Measured by survey rod.

Additional Notes – Provided if there are notable or unusual elements to the structure.

Topographic Survey

Equipment used for the topographic survey included a Trimble R2 RTK Rover GPS with +/-1cm accuracy under a clear signal. To monitor the consistency of the equipment, a survey point of a benchmark was taken at the northwest corner of the Canboro Community Centre Parking Lot each day at the same time before visiting any sites, see **Figure 2.1**.



FIGURE 2.1: BENCHMARK SETUP AT NORTHWEST CORNER OF THE CANBORO COMMUNITY CENTRE PARKING LOT

Table 2.1 summarizes the elevations recorded at the control point each day of the survey.

TABLE 2.1: SURVEYED CONTROL POINT ELEVATIONS AT BENCHMARK

Date	Benchmark Surveyed Elevation (m above MSL)
May 5, 2023	179.115
May 10, 2023	179.097
May 18, 2023	179.099
May 25, 2023	179.115
May 31, 2023	179.100
June 7, 2023	179.099
July 26, 2023	179.059
August 3, 2023	179.080
August 9, 2023	179.108
September 22, 2023	179.075
September 26, 2023	179.125

Note: Elevations reported in vertical datum CGG2013.

This benchmark survey point was used as the control point for the survey for the entire day. The consistency proved to be within 7 centimetres (cm) over the course of the entire surveying period. In addition to the local benchmark, a permanent Ontario Ministry of Natural Resources and Forestry (MNR) benchmark was surveyed and compared to the published elevations. See **Figure 2.2** for a photograph of the benchmark and see **Table 2.2** for the elevation comparison.



FIGURE 2.2: MNR BENCHMARK 00819698351

TABLE 2.2: PERMANENT BENCHMARK ELEVATIONS

Benchmark	Benchmark Location	Benchmark Elevation (m)	Surveyed Elevation (m)
MNR Station No. 00819698351	608726.38 E 4759679.07 N	177.726	177.769

Note: All elevations in table are reported in vertical datum CGG2013. Benchmarks retrieved from Ontario Ministry of Natural Resources. Surveyed elevations from May 18, 2023.

As per **Table 2.2**, excellent accuracy was obtained with the survey equipment. As such, the surveyed benchmarks were not used to adjust daily surveyed values.

The points surveyed at each site included the road edges or curbs on the deck of both the upstream and downstream sides, the upstream and downstream inverts, the ends of each headwall and parapet wall, the top of any retaining or wingwalls, and some ground points to characterize any slopes or tapers around the inlet/outlet. Cross-sections were surveyed upstream or downstream of the crossing as needed to further characterize the channel.

Additional points were taken on either side of the deck, either close to the railing or on the headwall/top of culvert to serve as points of reference. These reference points were used to derive the obvert elevations, as some locations had excessive tree cover that prevented a clear GPS signal at the invert. Instead of adding the rise to the invert for these locations, the distance between the reference point and the obvert was measured and subtracted from the point of reference. The rise was then subtracted from the obvert to obtain an invert elevation. This method was also used if the invert elevation proved to have significant inaccuracy ($\pm 10\text{cm}$), again due to a weak GPS signal from excessive tree cover.

3.0 LIDAR DIGITAL TERRAIN MODEL

A Light Detection and Ranging (LiDAR) Digital Terrain Model (DTM) of the Oswego Creek watershed was key in developing the hydrologic and hydraulic models for this study. This technology provides high resolution digital topographic information, which was essential to the definition of drainage areas, watercourses and identifying areas inundated by flood water.

A 0.5m grid generated DTM referred to as "LiDAR DTM Hamilton-Niagara 2021 Package F", made available from Land Information Ontario, was used. The DTM contains information licensed under Open Government License – Ontario. A DTM is defined as a bare-earth Digital Elevation Model (DEM), where vegetation and buildings are filtered out. The DTM uses the CGVD2013 vertical datum and NAD83 CSRS Horizontal Datum, UTM Zone 17.

The DTM was used to extract cross-section and roadway geometry in the hydraulic model where topographic survey was not available. LiDAR data was compared with the deck centerline topographic survey points and was found to be consistent throughout the watershed, providing confidence in the accuracy of the LiDAR data.

4.0 DEVELOPMENT OF HYDRAULIC MODEL

The water surface elevations that will be used to define the flood elevations and limits of flooding within the Oswego Creek watershed were determined using CivilGEO's GeoHEC-RAS software (Version 4.1). GeoHEC-RAS utilizes the United States Army Corps of Engineers, Hydraulic Engineering Centre's River Analysis System, HEC-RAS software. This version of GeoHEC-RAS uses Version 6.4.1 of HEC-RAS.

HEC-RAS has the ability to perform one-dimensional (1-D) hydraulic calculations on a range of natural and constructed channels. It also has the ability to conduct a variety of analyses for structures at watercourse crossings. The newly created hydraulic model was used to determine the water surface elevations using the program's steady state analytical methods which are based on gradually varied flow within a subcritical flow regime.

All results provided in this section are based on existing land-use flow conditions. Note that based on the GIS land cover information provided by the NPCA, there has been very little change in land use of the watershed over the past couple decades.

The resultant water surface profiles are considered an accurate representation of the flood elevations during the 100-year storm event and appropriate for the purpose of Regulatory flood hazard mapping for Niagara Peninsula Conservation Authority.

The following sections present details of the model setup, flood results and discussion at critical locations. This study has fulfilled the project scope and developed flood hazard mapping in accordance with the Provincial Technical Guide - River and Stream Systems: Flooding Hazard Limit (MNRF, 2002).

4.1 HYDRAULIC MODEL ELEMENTS NAMING CONVENTION

The watershed was subdivided into distinct reaches based on the NPCA identified reaches that require floodplain mapping. Note for this study, floodplain mapping was not to be completed to the full extent of all tributaries within the Oswego Creek watershed.

Each reach as assigned a prefix of "34_" if located in the lower Oswego Creek watershed, or "17_" if located in the upper Oswego Creek watershed to be consistent with the Welland River Regulatory Flood Plain Mapping by MMM Group Limited dated May 2017. This approach also facilitated future comparison and analysis of the data generated to this previous study.

The lower Oswego Creek watershed had a total of forty-eight (48) modelled reaches and the upper Oswego Creek watershed had a total of twenty-nine (29) modelled reaches for a grand total of seventy-seven (77) reaches for the entire watershed.

The NPCA identified eighty-six (86) hydraulic crossing structures and twenty-one (21) abandoned railway crossing structures to be surveyed. The structures located on the main branch of the Oswego Creek were assigned a prefix "M" and the abandoned railway structures were assigned a prefix "RR". The remaining structures were numbered consecutively from downstream to upstream. This numbering system was also used in the field program crossing inventory sheets for consistency.

4.2 HYDRAULIC MODEL INPUT PARAMETERS

4.2.1 STREAM NETWORK

The delineated stream network was provided by the NPCA identifying which Oswego Creek watercourses to model. This stream network was further refined using the 2021 LiDAR DTM, field survey data and aerial orthophotography. A total of 77 reaches were defined as significant tributaries within the area for flood hazard mapping. In total, mapping was prepared for ~224km of watercourse.

4.2.2 FLOW INPUT

Peak flows determined by the PCSWMM hydrologic model were input directly into GeoHEC-RAS at select locations along each reach. A new flow was added where there was a significant flow change; flow changes would occur due to the addition of more drainage area. While all flow information for the 50-year, 100-year and 200-year design storms were included, the Regulatory floodline is defined by the 100-year storm. In all instances, flows recorded at a downstream point of interest would be inserted through the upstream section of the reach. For example, in **Figure 4.1**, flows derived at the road crossing 7306 would be inserted through the reach at cross section 8558. Flows at points of confluence between major reaches are incorporated directly at the point of confluence, as it would not be appropriate to convey flows at point of confluence further upstream.



FIGURE 4.1: INCORPORATION OF FLOWS INTO HYDRAULIC MODEL

Best efforts were made to ensure flow node changes were less than 10% throughout the study reach, however, this is not always achievable at specific areas of confluences between reaches.

Provided in **Figure 4.2** is a layout of the reaches through the study area. The steady flow data contained in the model is presented in **Table 4.1** below, with the corresponding river station where the flow change occurs.

Figure 4.2:
**Oswego Creek Hydraulic
Model Reach Layout**

Oswego Creek Floodplain
Mapping

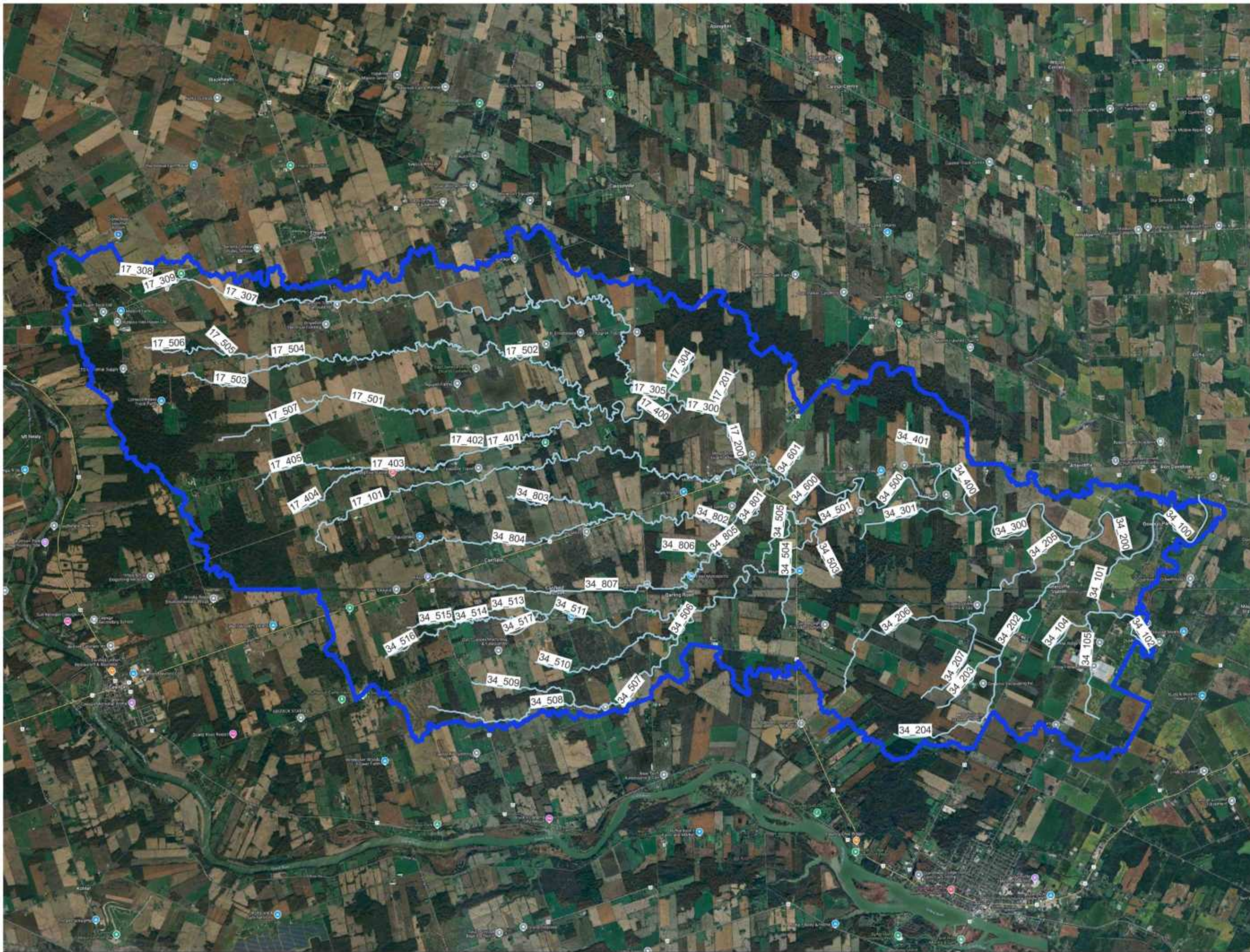
Project #: 22-925

0 1.5 3 km



Legend

- River Reaches
- ▭ Oswego Creek Watershed



DEM Source: LiDAR DTM
Hamilton-Niagara 2021 Package F
from Land Information Ontario

Basemap Image: Google Maps 2024

TABLE 4.1: OSWEGO CREEK PEAK FLOWS WITHIN HYDRAULIC MODEL

Reach	Location	HEC-RAS Section	200-year (m ³ /s)	100-year (m ³ /s)	50-year (m ³ /s)
34_100	Welland River and Chick-Hartnett Drain Confluence	3687	133.53	115.41	105.94
34_101	Carter Road	1041	15.61	13.89	12.97
34_101	North Abandoned Railway	1209	14.64	12.99	12.09
34_101	South Abandoned Railway	1820	14.35	12.74	11.87
34_102	Diltz Road	418	2.63	2.17	1.95
34_102	Upstream end of Tributary	1923	2.86	2.39	2.15
34_103	Chick-Hartnett Drain Confluence upstream of Abandoned Railway	544	11.02	9.78	9.11
34_104	Upstream end of Chick-Hartnett Drain	1467	9.12	7.59	6.82
34_105	Diltz Road	1018	4.77	4.13	3.98
34_105	Comfort Road	1284	4.64	3.80	3.46
34_105	Railway	2234	4.46	3.73	3.35
34_200	Robinson Road	2335	128.17	111.10	102.08
34_201	Welland River and Sugar Creek Drain Confluence	283	126.08	109.46	100.67
34_202	Abandoned Railway	1465	8.68	7.70	7.18
34_202	Abandoned Railway	2090	8.25	7.25	6.70
34_202	Stringer Road	3334	7.96	6.99	6.40
34_202	Waines Drain and James Drain Confluence	3567	8.14	7.02	6.41
34_203	Upstream end of James Drain	1249	5.73	4.76	4.27
34-204	Upstream end of Waines Drain	3833	4.69	3.91	3.52
34_205	Moote Road	3694	33.53	27.89	25.04
34_206	Upstream end of Sugar Creek Drain	4403	20.26	16.86	15.14
34_207	Upstream end of Tributary and James Road	1612	4.84	4.03	3.63
34_300	Welland River and Tributary Confluence near Moote Road	4259	121.07	105.32	97.01
34_301	Melick Road	2985	9.58	7.96	7.14
34_400	Welland River and tributary confluence	1426	119.07	103.67	95.58
34_401	Private Driveway	1803	10.42	8.64	7.74
34_500	Welland River and Tributary Confluence	4145	119.17	103.64	95.67

34_501	Tributary Confluence	1693	32.97	28.79	26.12
34_502	Lane Road	277	9.65	7.77	6.79
34_503	Abandoned Railway	1310	4.32	3.61	3.25
34_504	North Abandoned Railway	2036	7.56	6.04	5.43
34_504	South Abandoned Railway	2262	6.03	5.18	4.66
34_504	Ortt Road	3028	6.78	5.64	5.06
34_505	Tributary Confluence	6425	31.69	26.65	24.03
34_506	Tributary Confluence	885	15.84	13.29	11.99
34_507	Junction Road	3971	12.78	10.68	9.61
34_508	Dairy Side Road	2447	4.90	4.08	3.66
34_508	Upstream end of Tributary	3929	3.08	2.55	2.29
34_509	Dairy Side Road	2822	4.52	3.78	3.40
34_510	Junction Road	4324	8.67	7.24	6.51
34_511	Tributary Confluence	5081	15.44	12.94	11.65
34_512	Tributary Confluence	126	12.00	10.03	9.02
34_513	Upstream end of Tributary	627	2.00	1.65	1.48
34_514	Dairy Side Road	2848	13.39	11.16	10.03
34_515	Upstream end of Tributary	1257	3.92	3.26	2.93
34_515	Upstream of Dairy Side Road	1048	1.00	1.00	1.00
34_516	Upstream end of Tributary	2234	6.57	5.49	4.94
34_516	Upstream of Dairy Side Road	1268	9.49	7.75	6.87
34_517	Upstream end of Tributary	1193	1.66	1.38	1.24
34_600	Welland River and Tributary Confluence	2196	94.41	82.10	76.14
34_601	Canborough Road	1005	2.15	1.80	1.62
34_700	Welland River and Tributary Confluence	161	93.36	81.20	75.43
34_701	Smithville Road	725	4.24	3.56	3.21
34_800	Welland River and Tributary Confluence	425	94.12	81.85	76.77
34_801	Darling Road	2328	33.71	28.09	25.27
34_802	Talbot Road	4299	23.30	19.43	17.49
34_803	Junction Road	3824	8.95	7.42	6.64
34_804	Highway 56	5989	15.74	13.19	11.90
34_804	Upstream end of Tributary	6226	4.69	3.93	3.54
34_805	Ricker Road	1212	26.18	21.86	19.67
34_806	Haldimand Dunnville Townline Road	1612	5.56	4.61	4.13
34_807	Highway 56	8405	18.83	15.75	14.20
17_100	Smithville Road	682	78.63	68.01	62.85
17_101	Haldimand Dunnville Townline Road	4451	18.13	15.26	13.81

17_101	Junction Road	9311	18.05	15.06	13.55
17_101	Highway 56	12537	25.35	21.08	18.92
17_101	Windecker Road	15613	18.70	15.54	13.94
17_200	Welland River and Tributary Confluence	1553	66.32	57.32	52.77
17_201	Upstream end of Tributary	1441	6.33	5.24	4.69
17_300	Welland River and Tributary Confluence	670	64.45	55.64	51.16
17_301	Welland River and Tributary Confluence	469	23.35	20.03	18.36
17_302	Caistorville Road	388	8.73	7.23	6.47
17_303	Upstream end of Tributary	152	3.59	2.97	2.66
17_304	Upstream end of Tributary	858	4.26	3.52	3.15
17_305	Tributary Confluence	8986	26.26	22.09	19.96
17_306	Upstream end of Tributary	414	3.88	3.24	2.91
17_307	Turnbull Road	3025	16.49	13.98	12.71
17_307	Highway 56	6252	17.80	15.00	13.59
17_307	Singer Road	8555	16.17	13.52	12.19
17_307	Haldimand Road 9	10531	16.18	13.44	12.06
17_308	Gypsum Mine Tract Trail	1631	5.60	4.64	4.15
17_309	Gypsum Mine Tract Trail	907	4.75	3.96	3.56
17_400	Indiana Road East	5033	47.91	40.86	37.20
17_401	Turnbull Road	4112	23.15	19.36	17.42
17_402	Indiana Road East	1163	7.65	6.38	5.73
17_403	Abandoned Railway	3852	17.02	14.19	12.76
17_404	Singer Road	2422	4.34	3.61	3.23
17_405	Singer Road	3056	8.19	6.86	6.18
17_500	Indiana Road East	173	42.11	35.78	32.50
17_501	Turnbull Road	3620	22.83	19.23	17.42
17_501	Highway 56	7291	23.74	19.85	17.87
17_501	Tributary Confluence	8558	17.65	14.69	13.19
17_502	Concession Road 1	3632	25.68	21.82	19.82
17_502	Turnbull Road	5723	25.75	21.75	19.69
17_502	Highway 56	10332	26.61	22.39	20.27
17_502	Tributary Confluence	11648	27.06	22.54	20.25
17_503	Emerson Road	3741	12.56	10.44	9.37
17_504	Tributary Confluence	2099	17.53	14.61	13.14
17_505	Abandoned Railway	732	5.68	4.73	4.25
17_506	Concession Road 2	2321	6.98	5.82	5.23
17_507	Upstream end of Tributary	2689	7.44	6.20	5.58
17_508	Upstream end of Tributary	438	6.33	5.25	4.70

4.2.3 FLOW REGIME AND LIMITATIONS

All hydraulic modeling was simulated under steady state and under subcritical flow conditions. Supercritical flow conditions were not examined. This procedure is consistent with MNRF, provincial and NPCA guidance, and recognizes the potential that supercritical flows may not be maintained under flood conditions due to potential for debris jams, etc. Subcritical calculations within HEC-RAS are generally dominated by gravitational forces, while supercritical flow is based on momentum / inertia.

Flood elevations determined by the hydraulic model assume that during major flood events flows are in a subcritical regime. Subcritical flow is dominated by gravitational forces and behaves in a slow or stable way. Where the model assumes or forces conditions to a lower critical depth, its possible that the flow transitions to a supercritical regime. Where the transition is from supercritical to subcritical occurs, a hydraulic jump may occur. This will be seen as a very localized change in surface water elevation. The use of a steady-state hydraulic model has limitations, as it can only determine the occurrence of a hydraulic jump as a static condition in both time and location. During a flood event, flow variability will result in transient conditions and locations of hydraulic jumps. For this reason, the preference was to use subcritical flood elevations to define the limits of the flood hazard. A review of all HEC-RAS results was completed for the 200-year, 100-year and 50-year floodlines. The results show watercourses rarely ever resulted in conditions when supercritical flow conditions occurred. This would be expected given the very low gradient of the Oswego Creek Watershed. At any instance where the computed flood elevation defaulted to critical depth, the flood elevation was reviewed to determine if the flood elevation was reasonable based on downstream flood elevations. In all cases, the assumption of critical depth was considered reasonable, as there were no significant changes in flood elevations from upstream to downstream sections.

4.2.4 CROSS SECTIONS

The geometric data used for cross sections in the hydraulic model was extracted from the Digital Elevation Model (DEM) using tools in GeoHEC-RAS. Since LiDAR does not return laser points for any ground below the water surface, it was necessary to supplement these areas with surveyed data to create accurate river geometry. Bathymetric survey points were taken in various channels, up to the top of bank, throughout the study area.

The DEM is a crucial component in the development of cross sections. The use of GeoHEC-RAS ensures spatial reference of geometry data when imported into HEC-RAS. Cross sections were cut using the LiDAR-derived DEM. Cross sections were cut at culvert crossings, bridges and other areas where flows may be restricted including the abandoned railway structures and at locations of narrowing valley lands.

The location and orientation of the cross sections are chosen based on a combination of aerial photography and contour data, locations from past studies, site reconnaissance and general knowledge of the floodplain. Cross sections are generally located in areas that represent the average channel geometry within a reach, where there may be abrupt changes in geometry or slope and at the appropriate road crossing locations.

In several locations the cross-sectional geometries became complex and at times may appear to misrepresent the channel location. The complexity in the location of cross sections typically originated from two significant characteristics within the Oswego Creek watershed. These characteristics include major historical natural and anthropologic realignment of tributaries, and numerous railway crossings which results in significant obstructions to flood flows. Typically, sections were cut to represent the major floodplain flows and not to the alignment of the low flow channel or flood flows that might occur for minor storm events.

As LiDAR data cannot be collected below the water surface elevation, the bathymetry of the low flow or bankfull flow channel was developed using a combination of topographic surveys for channel sections upstream and downstream of watercourse crossings and a channel modification tool in GeoHEC-RAS.

Fluvial geomorphic processes in low gradient systems manage flow energy through horizontal sinuosity. As such, riffle pool morphology is not as apparent compared to higher gradient channel systems. Therefore, it was considered reasonable to define the invert of the channel between crossing structures as uniform.

For each reach between watercourse crossing structures, a representative channel base width and side slope template was derived. This template was applied to a uniform grade determined from the survey data collected upstream and downstream of adjacent crossing structures. The channel template was terminated when it came in contact with LiDAR based data.

4.2.5 BANK STATIONS

Bank stations generally represent the top of a stream bank at a location where, if flow exceeded the bank elevation, it would spread within the floodplain. HEC-RAS uses bank stations to subdivide the cross section in channel and overbank flow areas and to identify the location where the roughness coefficient changes for the overbank area. HEC-RAS subdivides each cross section to determine the conveyance capability of the channel and within the left and right overbank areas. When the user chooses to use multiple Manning's n values for a section (i.e., more than three), the section is subdivided based on the horizontal change in roughness.

Bank station survey data, aerial photography and elevation data along with available pictures of the channel.

4.2.6 INEFFECTIVE FLOW AREAS

Ineffective flow areas were introduced at each culvert or bridge crossing and as needed at selected cross sections in accordance with recommendations contained in the HEC-RAS manual. The ineffective area was generally used where flood water will occur but was considered to not contribute to conveyance of flow.

For example, the upstream bounding cross section at a bridge/culvert crossing structure has ineffective flow area set to a top of road deck elevation located at the left and right of a crossing structure entrance, as this accounts for the low velocity, standing water located adjacent to the watercourse crossing. Ineffective flow areas at the downstream bounding cross section, were set to elevations midway between deck and crossing structure obvert elevations at locations left and right of the structure opening. The ineffective area elevation at the downstream section was adjusted if it was considered necessary given the nature of the flood flow overtop the roadway.

Several ineffective flow areas were further incorporated into the hydraulic model to account for areas where water is typically not conveyed. For example, some pinch points or flow constrictions require upstream ineffective flow areas, as the conveyance capacity at these sections would be restricted by such a landform.

At selected locations, it was found that the typical indicators used for applying ineffective areas were inappropriate and as such they were removed or lowered. This was largely due to the nature of the significantly high flood flows conveyed through the section or the overtopping of a roadway crossing. This was typically found where a channel was no longer located in its historical floodplain. These historical floodplains became active channels during major flow events. This was considered when it was known that flood flows would be within the historical floodplain areas, as determined by upstream flow conditions.

4.2.7 EXPANSION/CONTRACTION COEFFICIENTS

Contraction and expansion coefficients were specified at each cross section to define the energy losses between two cross sections of varying geometry. Where there is minimal change in the geometry or shape of two cross sections, the energy losses will be minimal. If the transition in geometry and/or velocity is abrupt, such as at a bridge or culvert, energy losses will be higher. Standard values for contraction and expansion coefficients, as specified in Table 3-3 of the "HEC-RAS River Analysis System Hydraulic Reference

Manual" (2016) (HEC-RAS HRM), have been used throughout the current model. By default, all cross sections incorporate contraction/expansion coefficients of 0.1 and 0.3, respectively, except for culvert crossings or abrupt transitions. Expansion and contraction coefficients of 0.3 and 0.5 were applied at all culvert and bridge crossings.

4.2.8 MANNING'S ROUGHNESS COEFFICIENT

The value of Manning's "n" is highly variable and depends on several factors including surface roughness, vegetation, channel irregularities, channel alignment, scour and deposition, obstructions, size and shape of the channel, stage and discharge, seasonal changes, temperature and suspended material and bedload. The Manning's n values used in the HEC-RAS model were based typical literature values for various surfaces.

Note that modelled reaches located in the headwaters of the Oswego Creek watershed where the tributaries resemble grass swales, a Manning's n of 0.1 was used. This value can be referenced from the Ministry of Transportation (MTO) Drainage Manual Design Chart 2.01. The grass in the grass swales is considered to have fair stand; 0.1 was chosen as an average value for the range of length, velocity and depth of flow.

Table 4.2 presents the Manning's n values assigned to the various land covers within the Oswego Creek watershed.

TABLE 4.2: MANNING'S N VALUES FOR VARIOUS LAND COVERS

Land Cover	Manning's n
Natural Channel	0.032
Grass Swale	0.10
Agricultural Field/Landscaped Areas	0.035
Forest	0.08
Light Brush	0.06
Concrete/Paved	0.013

These values were determined for each cross section using a combination of a high resolution georeferenced aerial photograph, survey notes and photos. Where seasonal variability may occur, such as when crops are in or out of a field during summer and winter periods, respectively, the more conservative value with respect to producing a flood elevation was used.

4.2.9 BOUNDARY CONDITIONS

HEC-RAS requires the user to specify a downstream boundary condition for the steady state, subcritical analysis. A known water surface elevation (WSEL) was applied at the downstream study limit where Oswego Creek discharges into the Welland River; this is to account for the backwater effect from Welland River.

The Welland River Floodplain Mapping Update Final Report dated November 5, 2018, by WSP determined that during the 100-year storm event, the Welland River at its confluence with Oswego Creek has a WSEL of 175.4m (CVGD28). This elevation was then converted to the CVGD2013 vertical datum by subtracting 0.384m as per the Government of Canada Vertical Datum Transformation tool at the Port Colborne Station. As such, 175.02m WSEL was set as the downstream boundary condition for the 100-year event in the Oswego Creek hydraulic model.

The downstream boundary condition for the 50-year and 200-year events were interpolated using the streamflow frequency analysis in the Welland River Hydrology Report by WSP dated May 2017. From the frequency analysis, it can be interpolated that the 50-year peak flow is ~90% of the 100-year and the 200-year peak flow is ~110% of the 100-year.

A cross section of the Welland River at the Oswego Creek confluence was analyzed, and the cross-sectional flow area was determined. The flow elevation for 90% and 110% of the 100-year cross-sectional flow area was then estimated. Note that this interpolation method assumes that the average velocity is the same for the 50-year, 100-year and 200-year storm events which implies that the Welland River is in a backwater condition during these major storm events. The WSEL downstream boundary condition is set to 174.82m for the 50-year event and 175.23m for the 200-year event. The interpolation calculations can be found in **Appendix B**.

4.2.10 BUILDING OBSTRUCTIONS

The effect of a building within the floodplain can have a significant influence on the available conveyance area and energy losses immediately upstream and for a distance downstream of the actual building. Where a building may influence a cross section upstream or downstream, the obstruction has been projected onto the affected section. There are a number of buildings that exist within or adjacent to the floodplain throughout the Oswego Creek watershed.

4.2.11 ROAD DECK PARAMETERS

For the road deck, the roadway width input was measured parallel to flow, however, the roadway width measured in the field survey is perpendicular to the road direction. As such, there is some discrepancy between the model input and what was recorded in the culvert inventory sheet.

The upstream and downstream embankment side slopes were assumed to be 1:3 (V:H). The roadway weir crest shape was set to broad crested with a typical weir coefficient of 1.45.

4.2.12 CULVERT MODELLING PARAMETERS

Culvert crossing dimensions and parameters were entered into the model based on the field survey data. Note that for many of the culverts and bridge crossings, the surveyed downstream invert was higher than the surveyed upstream invert.

The NPCA had originally identified 107 structures to be surveyed. The majority of these structures were located on municipal roads or on public lands. It is important to note that upon close examination of aerial photography many smaller crossings were identified on private lands and in agricultural fields. Due to the relatively smaller size of these crossings on private lands, they may cause nuisance flooding during minor storm events. They are, however, anticipated to have very little impact during major storm events, such as the 100-year storm, as typically these flood flows would overtop the fill or access road constructed over the culvert.

As the actual impacts of these culverts will vary from site to site, local minor variances may exist in the floodplain in this study. Further details on how to address these possible site-specific limitations of the floodplain mapping are provided in the Recommendations section of this report.

4.2.13 BRIDGE MODELLING PARAMETERS

Due to the generally greater conveyance capacity of bridges, additional modelling options are available. The low flow computation method was set to energy (standard step) and the highest energy answer was used. The high flow computation method was set to pressure and/or weir flow for bridges that had overtopping flows, and energy only for the bridges where flows did not overtop.

Surveyed railings and road barriers were coded into the deck roadway geometry if they were made of steel/concrete as debris from high flows could form an obstruction.

Roadside post and wire fences were not considered in the modelling as these fences are less durable – they would potentially be dislodged and washed away from high flows.

Upstream and downstream obvert elevations as well as the span data collected from the field survey were used to code in the bridge opening dimensions.

4.3 SPECIFIC AREAS OF MODELLING INTEREST

At several locations, special consideration was required to model site specific hydraulic situations. In some cases, the model was adjusted to represent channel hydraulics which at first may not seem consistent with conventional practices.

At Reach 34_102, no cross sections were provided from the junction until cross section 303 as this area is located within the floodplain of sections accounted for in Reach 34_101.

At Reach 34_103, no cross sections were provided from the junction until cross section 332 as this area is located within the floodplain of sections accounted for in Reach 34_101.

For Reach 17_507 at cross section 1307, it was found that there was a second culvert crossing Singer Road during the field survey located 30.5m south of the main reach crossing. Both culverts were included in the hydraulic model and are identified with the culvert IDs 80.1 and 80.2.

Multiple Opening Analyses

At several instances, there were multiple locations where flows could be conveyed through a given stream crossing structure. This situation often occurred when a roadway dipped below the obvert of the adjacent culvert. This often originates from culvert being located away from their historical floodplain location. In other situations, culverts at a railway crossing would cause flood waters to spill into an adjacent opening or culvert, providing additional opportunity for flood flow conveyance. Listed in **Table 4.3** are the crossing locations where multiple opening analyses were used.

TABLE 4.3: LOCATIONS OF MULTIPLE OPENING ANALYSIS

Reach	Structure Number	Crossing Location	Notes
34_202	15	3349	Multiple opening analysis was applied at this location to account for the dip in Stringer Road.
34_505	RR10	5271	Multiple opening analysis was applied at this location to account for the dip in the abandon railway deck.

Realigned Channels at Junctions

Channel reaches are generally defined by their low flow watercourse alignment. In meander channel systems, it is common for chute cutoffs to form. These cutoffs typically convey bankfull flows and cut off the former channel meander. These former meanders create oxbow lakes or ponds. Channel systems with newly created chute cutoffs will rely on their former channel and floodplain alignments for flood relief. In two areas, a portion of the reaches were reconfigured to accommodate the flood flow behaviour and as such were not based on the alignment of the low flow channel. This procedure was applied to better model the floodplain during the three storm events examined in this study. This adjustment also mitigated the effect of cross sections crossing adjacent reaches to capture the floodplain.

In the first case, located northwest of Robinson Road and Hart Road, there were two smaller reaches merging into the larger main Oswego Creek reach. The LiDAR DTM was reviewed, and it was determined that in the Regulatory storm event, one of the smaller reaches would merge into the main reach upstream of the provided watercourse alignment. It is likely that historically, this reach did converge upstream of where it does today, however due to the high flood elevation in the Regulatory event, the floodplain merges at its historic confluence.

The top image of **Figure 4.3** shows the provided watercourse alignment and the bottom image shows the realigned watercourse for Reach 34_205.

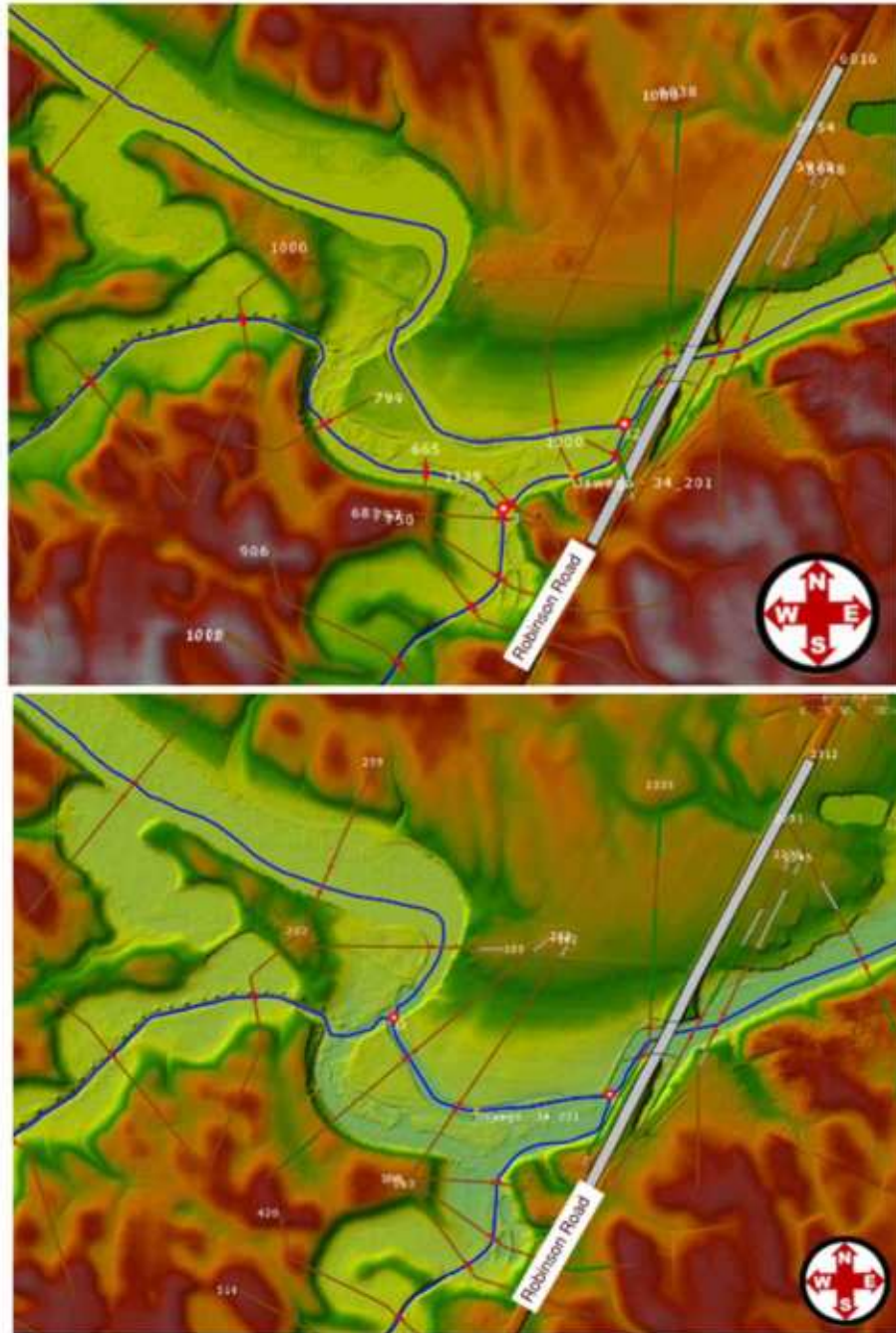


FIGURE 4.3: REALIGNMENT OF REACH 34_205

The second case where the reaches were realigned is located northwest of Junction Road and Concession 1 Road South. The original reach alignment would cause cross sections to overlap adjacent reaches. During large storm events the actual confluence of flood flows occurs further upstream of the low flow channel confluence. As such the smaller Reach 34_513 was realigned to have its confluence with the larger Reach 34_514, see

Figure 4.4 below. The top image shows the provided watercourse alignment, and the bottom image shows the realigned watercourse.

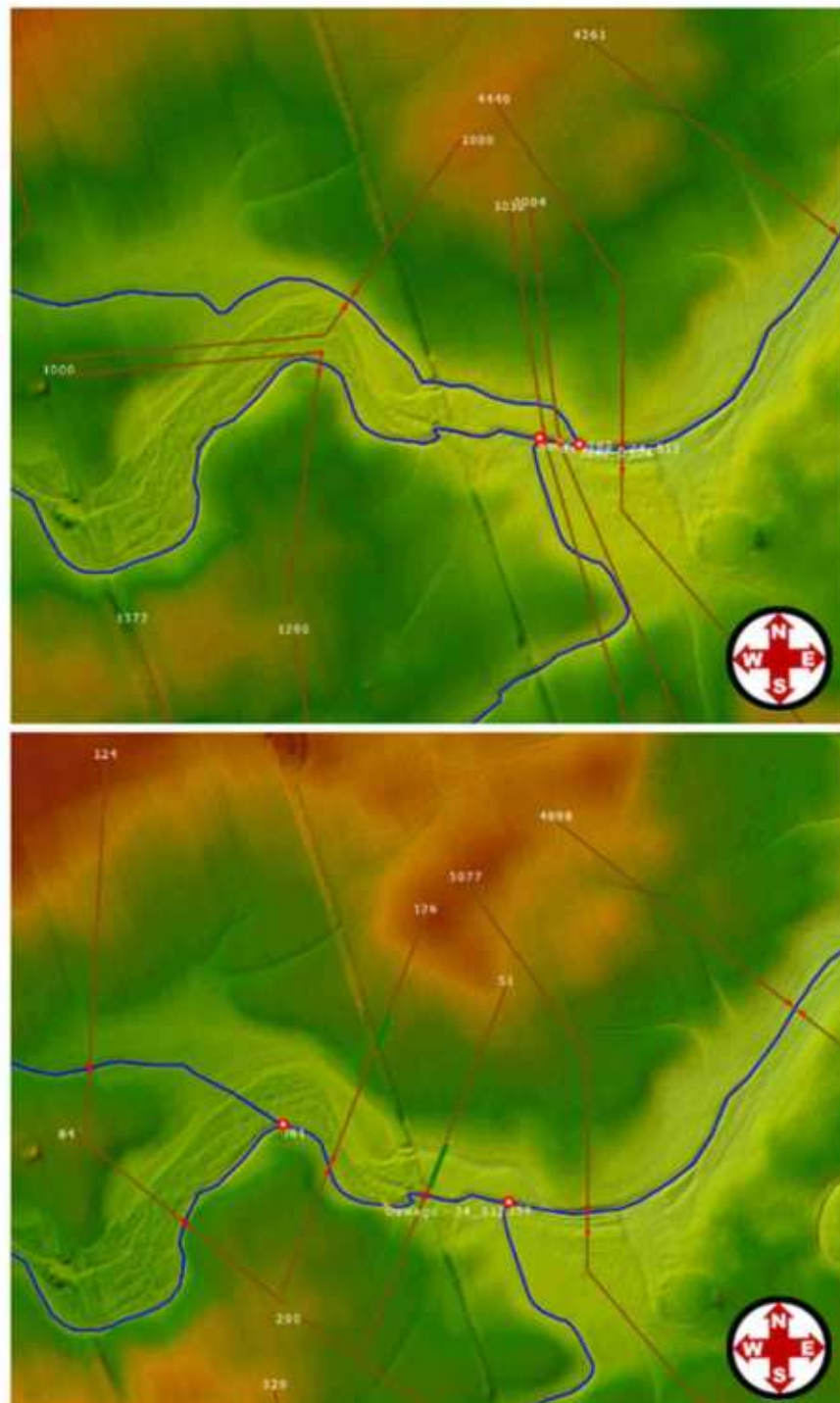


FIGURE 4.4: REALIGNMENT OF REACH 34_513

Flow Balance at Dairy Side Road

Reach 34_515 and Reach 34_516 run relatively parallel in a west to east direction and cross Dairy Side Road. Reach 34_515 has a 600mm diameter circular CSP culvert at crossing 346 while Reach 34_516 has a 2.1m x 1.5m concrete box culvert at crossing 355. **Figure 4.5** shows the location and configuration of the two reaches and crossings.



FIGURE 4.5: CONFIGURATION OF REACH 34_515 AND 34_516

In the initial run of the model, it was found that the culvert at crossing 345 of Reach 34_515 causes backwater and flows spill into the floodplain of Reach 34_516. At the two crossings, it was found that the flood elevation associated with Reach 34_515 was significantly higher than at Reach 34_516. As such, it can be concluded that in reality, a portion of the flows from Reach 34_515 will be conveyed through the crossing at Reach 34_516; both of the subject reaches would have similar flood elevations when the floodplains merge.

To account for the flow spill, an internal flow change was added at cross section 1048 of Reach 34_515 and cross section 1268 of Reach 34_516. Flows were manually balanced such that a portion of the flows from Reach 34_515 would be conveyed through the crossing at Reach 34_516; the total sum of the flows for the two reaches were maintained. With the balanced flows, the floodplains for both reaches would still merge, however, the flood elevations are better equalized and more uniform upstream of the crossings.

Any further modelling refinement in this area are to be done with a 2D model to more accurately model the flow spill from the Reach 34_515 and Reach 34_516.

Bridge at Diltz Road and Townline Road

There is a wooden trestle bridge located between Diltz Road and Oswego Park Road; it intersects Townline Road perpendicularly. This bridge was not identified in the NPCA list of structures to be surveyed; however, it has been added to the hydraulic model as it often causes flooding during the minor storm events to the neighbouring subdivision at Oswego Park Road. Bridge dimensions and properties were estimated using aerial imagery, site photographs and engineering judgement.

The trestle bridge is part of Reach 34_100 and has a crossing ID of 2075. **Figure 4.6** Error! Reference source not found. shows the wooden trestle bridge.



FIGURE 4.6: WOODEN TRESTLE BRIDGE

Stage-Storage Assessment and Set Known Water Surface Elevations

After the initial set up and run of the hydraulic model, four (4) areas were identified to have significant storage of river flow upstream of sequential road and railway crossing structures:

- Storage Area 1 located at Reach 34_101 upstream of Carter Road (Crossing 1050). This storage area extends upstream into Reach 34_102, 34_103, 34_104, and 34_105.
- Storage Area 2 located at Reach 34_202 upstream of the Abandoned Railway (Crossing 1479). This storage area extends upstream into Reach 34_203 and 34_204.
- Storage Area 3 located at Reach 34_504 upstream of the Abandoned Railway (Crossing 2050).
- Storage Area 4 located at Reach 34_508 upstream of Dairy Side Road (Crossing 2467).

These storage areas were originally identified as locations with spill to adjacent areas. These areas required further examination as the backwater volume behind the crossings exceeded the total runoff volume from their respective upstream catchments. As such, the NPCA requested that a storage assessment be conducted for these areas.

The storage assessment was completed using the PCSWMM unsteady flow modelling simulation capabilities. The resulting 50-year, 100-year, and 200-year flood elevations from the assessment were used as input interior changes in starting water levels in the hydraulic model. For more details on the storage assessment methodology, see Section 8.0 of the Oswego Creek Floodplain Mapping Hydrology Report by Greck and Associates dated October 2024.

After adding the internal changes from the dynamic stage-storage assessment, the floodplain at the aforementioned storage areas reduced significantly. Note that while the hydraulic model is showing that the floodplain is contained within the channel valley, pluvial flooding may still occur due to the overall very low gradient of the surrounding topography during major storm events.

Pluvial flooding occurs as a result of the ponding and conveyance of overland flows from runoff surfaces prior to its entry into the channel system. This can occur in natural or man-made low-lying areas. For the Oswego Creek watershed, evidence of pluvial flooding can be seen on the aerial imagery as darker depressions in agricultural fields. Pluvial flooding

is often managed through the use of tile drainage systems in agricultural lands. The soil types and flatness of the Oswego Creek watershed causes poor overland drainage, and flooded fields would take a longer time (up to days) to recede, infiltrate or drain.

Note that this floodplain mapping study for the Oswego Creek watershed only focuses on fluvial flooding and does not map areas of pluvial flooding.

Culverts Outside the Scope of the Project

During the hydraulic modelling process, there were several culverts identified along reaches that were omitted in the original scope of work. These culverts were not surveyed and as such, not included in the modelling:

- Reach 34_207 – one culvert at Moote Road and one culvert at Stinger Road
- Reach 34_511 – one culvert at the abandoned railway between cross section 4098 and 3954
- Reach 34_807 – one culvert at the abandoned railway between cross section 5316 and 5223

At areas where the watercourse crosses an unmodelled culvert, manual interpretation was incorporated into the flood maps using engineering judgement. Further study is required at these locations.

5.0 SENSITIVITY ANALYSIS

Analyses were carried out to assess the sensitivity of key input parameters and their effects on the flood levels. A sensitivity analysis is important to determine factors of safety, freeboard allowance and importance of any modelling parameter assumptions. The sensitivity analysis was carried out for the Regulatory storm event only. The following scenarios were assessed:

- Peak Flow (50-year and 200-year storm event)
- Downstream Boundary Condition (+/-500mm)

Peak Flow Variation

The 50-year and 200-year storm events were run to determine the hydraulic model's sensitivity to changes in flow.

Downstream Boundary Condition

The downstream starting flood elevation was increased and decreased by 500mm to determine if there were any adverse effects through the watershed due to the accuracy and or assumption of the flood elevation in the Welland River. The hydraulic model assumes the 100-year flood in Oswego Creek occurs at the same time the regulatory flood flow occurs in the Welland River.

Manning's n Variation

For select reaches, the Manning's n values were varied for watercourses that resembled grass swales. This was to determine the seasonal affects of land use and vegetation changes. For example, during the summer season, there would be mature crops in agricultural areas and dense vegetation which would increase the roughness when compared to the spring season where there would be no crops and lighter brush in vegetated areas.

It was found that the model is sensitive to changes in Manning's n values, particularly in grass swale systems. A higher Manning's n value produced a higher flood elevation; as such, the larger roughness coefficient of 0.1 was used for low flow channels where appropriate.

Contraction Expansion Coefficient

Energy losses are a function of contraction/expansion coefficients and flow velocities. Due to the relatively flat topography of the Oswego Creek watershed, the velocities are

so low that the energy losses between cross sections with regards to channel contraction and expansion are negligible. As such, a sensitivity analysis on the contraction and expansion coefficients was not performed.

5.1.1 SENSITIVITY ANALYSIS RESULTS

The peak flow variation results are provided for example Reach 34_507 below. This reach was chosen as it is far enough upstream such that it is not affected by the backwater effects of the Welland River. The downstream boundary condition results are provided for Reach 34_100 as this reach experiences backwater effects from the Welland River.

Table 5.1 reports the flood elevations from the peak flow variation and

Table 5.2 Error! Reference source not found. reports the top floodplain width from the peak flow variation. Output tables of the HEC-RAS sections from the sensitivity analysis for peak flow are provided in **Appendix B**.

From the peak flow sensitivity analysis, the model is somewhat sensitive to changes in flow. Changes in flood elevation range from 40mm to 250mm with greater sensitivity to the floodplain width (1m to 76 m). This is due to the overall very flat topography of the watershed.

TABLE 5.1: REACH 34_507 PEAK FLOW VARIATION RESULTS – FLOOD ELEVATION

Station	Flood Elevation (m)			Max Difference (m)
	Regulatory (100-year)	50-year	200-year	
3971	185.57	185.54	185.64	0.07
3857	185.28	185.20	185.50	0.22
3565	185.29	185.19	185.51	0.22
3541	185.26	185.16	185.47	0.21
3530	Junction Road			
3514	184.77	184.75	184.83	0.06
3486	184.77	184.74	184.81	0.04
3170	184.39	184.37	184.44	0.05
3023	184.01	183.99	184.05	0.04
2854	183.77	183.75	183.81	0.04
2666	183.54	183.51	183.60	0.06
2374	183.20	183.17	183.28	0.08
2226	183.05	183.01	183.15	0.10
1845	182.82	182.73	183.00	0.18
1663	182.77	182.66	182.96	0.19
1524	182.76	182.64	182.95	0.19
1376	182.74	182.62	182.95	0.21
1349	182.71	182.59	182.91	0.20
1338	Haldimand Dunnville Townline Road			
1324	182.35	182.30	182.39	0.05

1148	182.10	181.97	182.33	0.23
1123	182.08	181.93	182.32	0.24
1074	182.07	181.92	182.31	0.24
1020	182.04	181.89	182.28	0.24
1010	Abandoned Railway			
1003	181.82	181.66	182.05	0.23
996	181.84	181.68	182.07	0.23
852	181.81	181.62	182.05	0.24
519	181.80	181.61	182.04	0.24
311	181.80	181.60	182.04	0.24
117	181.80	181.60	182.04	0.24
111	181.79	181.59	182.04	0.25
98	Ortt Road			
81	180.50	180.47	180.58	0.08
74	180.51	180.48	180.58	0.07
49	180.50	180.46	180.56	0.06

TABLE 5.2: REACH 34_507 PEAK FLOW VARIATION RESULTS – TOP WIDTH OF FLOODPLAIN

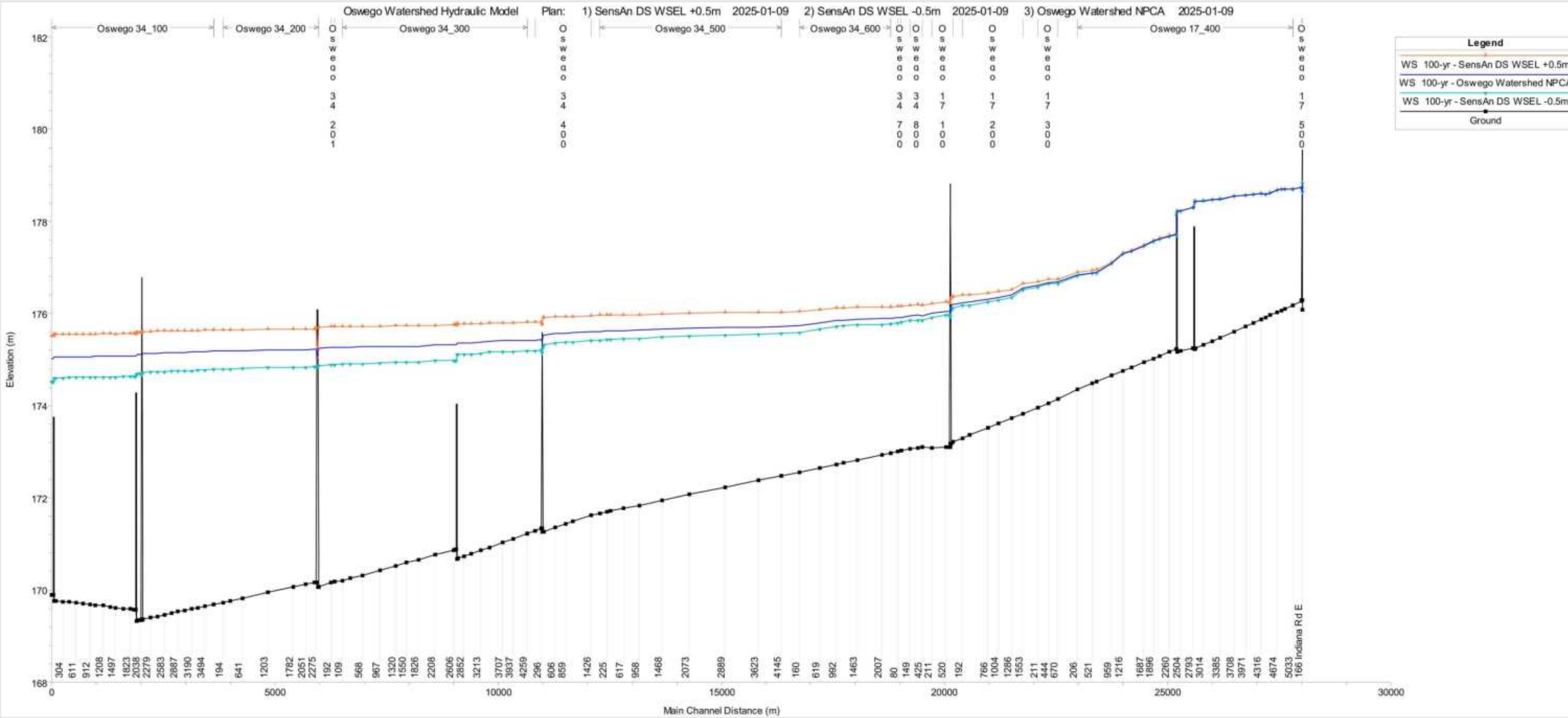
Station	Top Width of Floodplain (m)			Max Difference (m)	Max Difference %
	Regulatory (100-year)	50-year	200-year		
3971	127.28	120.95	144.12	16.84	13.2%
3857	36.33	28.73	64.17	27.84	76.6%
3565	298.80	235.95	374.82	76.02	25.4%
3541	393.65	384.58	403.84	10.19	2.6%
3530	Junction Road				
3514	154.60	150.92	172.00	17.40	11.3%
3486	90.88	89.08	95.70	4.82	5.3%
3170	48.14	46.68	51.36	3.22	6.7%
3023	71.74	70.83	74.35	2.61	3.6%
2854	90.27	88.74	93.42	3.15	3.5%
2666	57.89	57.09	58.90	1.01	1.7%
2374	54.82	52.51	64.19	9.37	17.1%
2226	49.43	47.91	53.00	3.57	7.2%
1845	57.06	52.66	66.08	9.02	15.8%
1663	88.07	85.24	100.71	12.64	14.4%
1524	113.67	108.46	125.20	11.53	10.1%
1376	80.54	66.03	103.07	22.53	28.0%
1349	130.44	110.62	163.49	33.05	25.3%
1338	Haldimand Dunnville Townline Road				
1324	146.23	132.62	153.98	13.61	9.3%
1148	62.16	57.98	66.44	4.28	6.9%
1123	53.83	49.64	70.80	16.97	31.5%
1074	120.47	116.65	125.94	5.47	4.5%
1020	168.34	150.66	187.09	18.75	11.1%
1010	Abandoned Railway				
1003	119.32	105.58	129.25	13.74	11.5%
996	95.47	85.92	105.78	10.31	10.8%

852	57.01	49.62	85.83	28.82	50.6%
519	106.57	100.06	114.10	7.53	7.1%
311	84.68	75.17	120.14	35.46	41.9%
117	93.94	79.71	105.15	14.23	15.1%
111	96.82	91.76	103.37	6.55	6.8%
98	Ortt Road				
81	57.82	56.64	60.63	2.81	4.9%
74	57.95	57.01	59.61	1.66	2.9%
49	53.74	52.17	56.33	2.59	4.8%

The following **Figure 5.1** shows a profile comparison of the effect of changing the downstream starting water elevation by +/- 500mm. Note that only the main reaches of the Oswego Creek are shown.

From the downstream boundary condition sensitivity analysis, adjusting the starting water elevation has a direct correlation to flood elevations in Oswego Creek and its tributaries. **Figure 5.1** shows the water surface profile along the main branch of Oswego Creek from its confluence with the Welland River to Indiana Road East. This figure illustrates the extensive 23km backwater effect. The extent of the backwater effects ends when the water surface profiles converge downstream of the Haldimand Dunnville Townline Road bridge. In conclusion, flood levels in Oswego Creek are very sensitive to flood levels in the Welland River. Furthermore, flooding at the lower reaches of Oswego Creek may occur solely based on the water levels in the Welland River.

Full output tables of the HEC-RAS sections from the sensitivity analysis for the downstream boundary condition are provided in **Appendix C**.



6.0 RESULTS OF HYDRAULIC ANALYSIS

Summaries of the hydraulic analyses provided by the HEC-RAS program are provided in **Appendix B**. These results were used to prepare the flood hazard mapping. Presented below is a discussion on site specific findings of the hydraulic analyses.

6.1 IMPACTS OF THE WELLAND RIVER

Reach 34_100 – Oswego Creek Confluence at Welland River

In the Regulatory storm event, the high flood elevation from the Welland River causes a backwater effect up to 23km upstream on the Oswego Creek watershed.

Reach 34_100 – Oswego Park Road Subdivision

In the Regulatory storm event, ten (10) residential dwellings located on the north side of Oswego Park Road subdivision are flooded, see Section 7. This flooding is largely attributed to the flood elevation in the Welland River when 100-year storm flows occur within the watershed of this river. Further analysis on the flooded area of this subdivision is recommended to ensure safe access is possible for all residential dwellings.

As the abandoned trestle bridge located upstream of Diltz Road is highly susceptible to the trapping of debris and ice, there is the potential for flooding to occur due to the restriction of flows from the Oswego Creek watershed. Obstruction of flows by the bridge may result in flood hazards during smaller in magnitude events than the 100-year flood flow rate.

6.2 SPILLS BETWEEN TRIBUTARIES AND OUT OF THE WATERSHED

At select locations flood waters may go beyond the flood plain of a given tributary. This spill may go into an adjacent tributary or out of the Oswego Creek watershed. Discharges out of the watershed were not considered as part of this study. All flows generated within the Oswego Creek watershed were assessed.

It is unknown at this time if spill of flood water from adjacent watersheds enters the Oswego Creek watershed. As such, no external flows were included in the hydraulic model.

Spill Locations

- Reach 34_508
 - At the upstream end of Reach 34_508, the floodplain spills south, outside of the Oswego Creek watershed. Based on aerial imagery, there appears to be a culvert 188m south of the Reach 34_508 culvert. Further investigation on this spill area is recommended to further refine the floodplain.
- Reach 34_515 and Reach 34_516
 - Flows from Reach 34_515 spill south into Reach 34_516. Flows then cross Dairy Side Road and both tributaries rejoin at Reach 34_514

Oswego Creek is a vary sinuous watercourse with several channel oxbows (abandoned historical channel reaches). Reaches where the floodplain takes the path of these historic alignments or neighbouring tributaries and rejoins downstream are listed below.

- Flows from Reach 34_300, cross section 568 drain into Reach 34_205 downstream of cross section 400
- Flows from Reach 34_401, cross section 148 drain into Reach 34_500 downstream of cross section 617
- Reach 34_501 between cross sections 1264 and 1172
- Flows from Reach 34_509, cross section 259 drain into Reach 34_507 at cross section 3457
- Reach 34_801 between cross sections 1501 and 1197
- Reach 34_807 between cross sections 4115 and 3111
 - The reach has been realigned to be parallel to the abandoned railway, however, some flow spills to the north of the railway tracks following the historic path of the channel
- Reach 17_101 between cross sections 13328 and 12752
- Flows from Reach 17_306, cross section 140 drain into Reach 17_305 upstream of cross section 8433
- Reach 17_401 between cross sections 756 and 603
- Reach 17_502 between cross sections 2420 and 2029

6.3 CROSSING STRUCTURES AT RISK OF FLOODING

Bridge and culvert crossings undergo flooding during various storm events. Depths in excess of 0.3m provide difficulty for vehicular access. Specific bridges and culverts that pose a risk to ingress/egress have been listed in **Table 6.1** and **Table 6.2** respectively.

While more significant storm events may produce higher depths of flooding, several of these structures are fully submerged and affected by downstream backwater effects, and therefore have lower velocities for the major storms. For these structures, a smaller storm event that may have no backwater effect can produce a higher velocity over the road.

TABLE 6.1: BRIDGES AT RISK OF FLOODING

Reach	Location	Reach Section	Structure ID	Top of Road Deck (m)	Computed 100-year Water Surface Elevation (m)	Depth of Flooding (m)
34_100	Highway 45	106	M1	173.75	175.05	1.30
34_100	Diltz Road	1946	M2	174.27	175.10	0.83
34_300	Hart Road	2676	M4	174.03	175.36	1.33
34_511	Junction Road	4681	38	185.49	185.68	0.19
17_400	Townline Road East	2813	M8	177.88	178.43	0.55

TABLE 6.2: CULVERTS AT RISK OF FLOODING

Reach	Location	Reach Section	Structure ID	Top of Road Deck (m)	Computed 100-year Water Surface Elevation (m)	Depth of Flooding (m)
34_202	Hart Road	545	14	174.80	175.27	0.47
34_301	Moote Road	99	21	175.06	175.43	0.37
34_401	Private Driveway	1631	25	179.95	180.27	0.32
34_401	Private Driveway	457	24	175.92	177.50	1.58
34_401	Private Driveway	324	23	176.62	177.50	0.88
34_802	Haldimand Dunnville Townline Road	3339	51	179.76	180.11	0.35
34_805	Ricker Road	998	45	178.52	178.88	0.36
34_807	Haldimand Dunnville Townline Road	2848	47	182.37	182.68	0.31
17_101	Highway 56	12552	61	191.27	191.69	0.42
17_503	Abandoned Railway	1871	RR20	192.41	192.98	0.57

6.4 CULVERTS AT ABANDONED RAILWAYS

There are four abandoned railway lines within the study area. The abandoned railway crossings are not maintained, and many are in disrepair and could fail at anytime. Most of the culverts are undersized and cause backwater onto upstream lands. The map sheets show where the floodplain widens considerably upstream many of these undersized crossing structures. The backwater caused by these undersized culverts may result in nuisance flooding on farm fields and in some instances reduce the conveyance capacity of upstream culverts at roadways.

7.0 FLOOD HAZARD MAPPING

Flood hazard maps prepared as part of this study have been created according to the Federal Geomatics Guidelines for Flood Mapping, Version 1.0 authored by Natural Resources Canada. A total of 107 map sheets were created.

The floodlines were modelled on a DTM with a grid resolution of 1.0m. The DTM was made publicly available by Land Information Ontario under the "LiDAR DTM Hamilton-Niagara 2021 Package F". The contours are displayed in 0.5 intervals and are generated from the DEM. Selected spot elevations have been added as surveyed by Greck in 2019.

The ortho imagery (SWOOP 2020) was provided by the NPCA and used as the map base. Within the scope of the study the cross sections from the hydraulic model have been imported. The cross sections have been labelled with the river station number associated with the hydraulic model along with the respective water surface elevations during the 100-year storm event.

The extent of the floodlines were based on a combination of automated lines prepared by the GeoHEC-RAS software. While automating floodline generation within GIS software can often provide a quick and efficient floodline mapping, they can often result in localized inaccuracies. As such, the floodlines have been manually drawn between each cross sections where necessary to ensure floodlines follow contours and anticipated flow paths appropriately.

Note that many of the culvert crossings within private agricultural land and driveways were not modelled; evidence of the crossings are found in the DTM, aerial imagery and can be seen as discontinuous floodplains on the map sheets. A potential overtopping arrow was added to the map sheets areas where the culvert was not modelled, and the flood flows may overtop the driveway/ culvert cover.

A floodline has been plotted for the 100-year storm events. A total of 107, 1:2,000 scale map sheets have been created in PDF format in ARCH D size. Map sheets are included in **Appendix D**. The flood hazard map sheets were assembled using QGIS software (3.28.9 Firenze). All associated files used to assemble the map sheets were provided to the NPCA for their files and records.

7.1 MAPPING OF SPILL LOCATIONS

At selected locations it may not be possible to contain all flood flows within the natural floodplain of Oswego Creek. This can occur for a variety of reasons however the most common is associated with the limited conveyance of flood water past roadways and or

naturally level terrain. In other cases, the flood water from converging channels may spill into each others' floodplain.

For the purposes of this study, the possible loss and/or reduction in flow associated with a spill of flood water was not considered in the hydrologic and or hydraulic modelling. While the hydraulic conveyance of these flood flows may be exceeded, the LIDAR data was sufficient in most cases to indicate the area of spill and was typically based on catchment delineation (as per the hydrologic assessment).

Spill locations are illustrated in on all applicable map sheets.

7.2 BUILDINGS WITHIN THE FLOODPLAIN

Currently 43 buildings have been identified in the designated flood hazard area (100-year floodplain). Only buildings entirely or partially within the floodplain have been identified. The buildings identified include residential homes, barns, industrial structures, sheds, and garages. Buildings currently within the designated floodplain are listed in **Table 7.1**. Some properties were identified as having more than one building at risk. The most significant flood prone area affecting residential lots is along Oswego Park Road. The buildings within this subdivision are located within the meander belt of Oswego Creek. Flood elevations in this development are significantly affected by water levels in the Welland River.

TABLE 7.1: BUILDINGS CURRENTLY THE 100 YEAR FLOOD HAZARD AREA

Building No.	Location	Mapsheet	Nearest Hydraulic Modelling Section (Reach & Section #)
1	Haldimand Road 9	1	17_308 34
2, 3, 4	Highway 56 Haldimand	11	17_307 6317
5, 6	Singer Road	13	17_507 1355
7	Indiana Road East	15	17_405 2798
8	Highway 56 Haldimand	23	34_804 6226
9, 38	Highway 3	44	34_804 1753 34_804 2521
10, 11, 12, 13, 14	Junction Road	45	34_807 5187
15	Junction Road	46	34_511 4902
16, 37	Darling Road	65	34_807 1025
17, 18, 19, 20	Highway 3	73	34_504 2205
21, 22, 23	Robinson Road	96	34_200 2051
24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35	Oswego Park Road	102	34_100 2279
36	Moote Road	92	34_205 3694
39	Townline Road East	31	17_101 9973
40	Canborough Road	70	34_701 447
41, 42	Concession Road 2	6	17_504 1884
43*	Dairy Side Road	35	34_515 585

*Note that is a recent build not shown on the flood map

8.0 SUMMARY AND CONCLUSIONS

Greck and Associates Limited has prepared updated hydrologic and hydraulic modelling and new complete watershed flood hazard mapping for the Oswego Creek watershed. These are products of technical analyses and have considered input from peer reviews and public consultation. Reporting of the watershed hydrology and peak flood flows are provided in a separate document. Key aspect and results of this hydraulic study are summarized below:

8.1 FLOODPLAIN HYDRAULICS

1. A new hydraulic model was developed from LiDAR survey of the land, aerial photography, survey of watercourse crossing structures and watershed hydrologic data. GeoHEC-RAS software was used as the tool develop a computer-based simulation model for 224 km of watercourse including 110 crossing structures.
2. An inventory and survey of 110 crossing structures was completed and incorporated into the hydraulic model. The structures surveyed predominantly include public roadways, with some abandoned railways and a few private driveways. Many small culverts located on private lands for access between farm fields were not included in the modelling.
3. Several hydraulic structures/watercourse crossings are considered at risk to flooding for the Regulatory (100-year) event.
4. The backwater effects from the Welland River to Oswego Creek are significant. During a 100-year flood event, the floodwater elevations in the main branch of Oswego Creek, from its confluence with the Welland River to Indiana Road East (approximately 23km), is directly associated with water levels in the Welland River.
5. Due to the level topography of the Oswego landscape, changes in flood flow rate between the 50- and 200-year flood bring about greater change in the area prone to flooding than changes in the depth of flooding.

8.2 FLOOD HAZARD MAPPING

6. 107 flood hazard mapping sheets were prepared. The mapping base includes topographic information derived from LiDAR data, and site-specific topographic survey at stream crossing structures.
7. Currently 43 buildings have been identified in the designated flood hazard area defined by the 100-year flood event. been identified. The buildings identified

include residential homes, barns, industrial structures, sheds, and garages. The most significant flood prone area affecting residential lots is along Oswego Park Road.

9.0 RECOMMENDATIONS

The modelling and mapping are appropriate for use in the administration of Ontario Regulation 155/06 and land-use decision making subject to any additional refinements made by NPCA.

The flood hazard mapping is a reasonable estimate of the anticipated Regulatory flood hazard. The following recommendations identify areas where model refinements should be considered, as appropriate, in future studies to improve the understanding of flood hazards and risks. Other refinements may be undertaken at a subwatershed, or site-specific level as new data and technical analysis become available.

1. Spill Areas – Areas for Future 2D Modelling: Additional assessment should be considered at locations where substantial spill, cross flow or combined flow occurs. There are a few locations where hydraulic structures (i.e., railway embankments and undersized culverts) have resulted in the spill of flows to adjacent reaches within the same or adjacent subcatchment. This study uses manual adjustments of flows for energy balances, which provides a reasonable result for the purposes of supporting NPCA's approximate Regulation Limit mapping. To support site specific work proximate to such areas, consideration should be given to the use of alternative computer modelling methods such as 2D modelling which incorporate the use of unsteady flow analyses and the dynamic utilization of floodplain storage. If 2D modelling is pursued, the methodology applied must be adapted to ensure consistency with provincial direction related to the definition of the flood hazard.
2. Flow Monitoring Network: An expanded flow monitoring network is recommended, as funding permits, to improve hydrologic and hydraulic model calibration in future flood hazard mapping updates.
3. Private Culvert Sensitivity Analysis: A detailed analysis of the culverts in private agricultural land is recommended to determine their impact on defining regulatory floodlines. These culverts are not expected to have any significant impact on the regulatory event; however, they may cause nuisance flooding during the minor storm events.
4. Study and potential removal of wooden trestle bridge between Townline and Diltz Road: There are a number of homes currently located within the regulatory flood plain along Oswego Park Road. This area is susceptible to flooding due to the backwater effects from the Welland River and potentially from the trapping of debris at the trestle bridge. The trestle bridge no longer serves its original function as its use for the railway has been abandoned. A study should be completed to

further examine the flood hazard presented by the existing trestle bridge. Should the trapping of debris by this bridge be significant, modification or removal of this structure should be considered.

5. Remove abandoned railway crossings: The abandoned railway crossings are in disrepair and could fail at anytime. Most of the culverts are undersized and cause backwater onto upstream lands and may reduce the conveyance capacity of upstream roadway culverts. Further study be completed to determine the cost benefits of removing these culverts.
6. The hydrologic and hydraulic models should be routinely reviewed and updated to account for development changes in the watershed or upgrades to crossing structures: This includes future/proposed roadway updates and watercourse realignments. It is recommended the municipality be included in this process to ensure the floodplain mapping reflects the current state of the watershed.
7. Public Education: The NPCA should develop and implement a program to inform the public of the floodplain mapping available, the regulations associated and permitting requirements associated with alterations or working within the flood plain. In particular, attention should be given to the addition of private culverts and modifications to the topography of the land.
8. NPCA Policies: The NPCA should consider the findings of this study when developing new and updated policies with respect to the use of new Provincial Regulations.

10.0 REFERENCES

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APPENDIX A

Hydraulic Crossing Inventory Sheets

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Highway 45
Northing:	4760176.12 N
Easting:	617851.28 E

Inspected By:	Paul Greck & Elliot Pai
Date:	May 5, 2023
Weather:	12°C, Cloudy
Crossing ID:	M1

Inlet Type:	Bridge
# of Spans:	1
Span or Diameter (m):	22.9
Rise (m):	3.3
Length (m):	5.5

Material:	Steel & Concrete
Open Footing:	Yes
Skew Angle:	0
Sediment Depth (mm):	N/A
Road Barrier:	1.81m Guard Rail

US Invert Elevation (m):	169.77
DS Invert Elevation (m):	169.90

US Obvert Elevation (m):	173.20
DS Obvert Elevation (m):	173.14

Inlet/Outlet Type:	30" Concrete Wingwalls
High Water Mark Depth (m):	Not Observed
Number of Piers:	No
Pier Width:	N/A

Low Point in Road Elevation (m):	173.98
Water Depth (m):	1.6

Additional Notes/Notable Obstructions:	invert elevations measured from survey point d1-3.86, d2-4.16, d3-4.18, d4-4.06, d5- 4.05, d6-3.93, d7-4.15, d8-4.42, d9-4.07, d10-3.656
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Diltz Rd
Northing:	4759679.58 N
Easting:	617204.08 E

Inspected By:	Paul Greck & Elliot Pai
Date:	May 5, 2023
Weather:	12°C, Cloudy
Crossing ID:	M2

Inlet Type:	Bridge
# of Spans:	1
Span or Diameter (m):	24.4
Rise (m):	4.94
Length (m):	10.2

Material:	Concrete
Open Footing:	Yes
Skew Angle:	0
Sediment Depth (mm):	N/A
Road Barrier:	1.12m Parapet Wall

US Invert Elevation (m):	169.33
DS Invert Elevation (m):	169.58

US Obvert Elevation (m):	174.27
DS Obvert Elevation (m):	174.52

Inlet/Outlet Type:	Perpendicular Wall
High Water Mark Depth (m):	Not Observed
Number of Piers:	No
Pier Width:	N/A

Low Point in Road Elevation (m):	175.3
Water Depth (m):	2.06

Additional Notes/Notable Obstructions:	rise from we 2.88 invert measurement from top of barrier d1-5.95, d2-7.15, d3-6.7, d4-6.2, d5-6.9, d6-6.55
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Robinson Rd
Northing:	4759189.5 N
Easting:	615227.18 E

Inspected By:	Paul Greck & Elliot Pai
Date:	May 5, 2023
Weather:	12°C, Cloudy
Crossing ID:	M3

Inlet Type:	Bridge
# of Spans:	2
Span or Diameter (m):	21.4
Rise (m):	Arc 3.4 at centre
Length (m):	9.0

Material:	concrete
Open Footing:	yes
Skew Angle:	17°
Sediment Depth (mm):	N/A
Road Barrier:	1m Guard Rail

US Invert Elevation (m):	170.33
DS Invert Elevation (m):	170.17

US Obvert Elevation (m):	175.21
DS Obvert Elevation (m):	175.05

Inlet/Outlet Type:	Perpendicular Wall
High Water Mark Depth (m):	Not Observed
Number of Piers:	1
Pier Width:	1m

Low Point in Road Elevation (m):	176.3
Water Depth (m):	1.48

Additional Notes/Notable Obstructions:	measurement from guard rail deck d1-5.35, d2-5.27, d3-5.22, d4-6.2, d5-5.12, d6-6.10, d7-5.4, d8-6.45, d9-5.16 no good as pipe extrudes -measurement taken from deck to obvert d1-1.77, d2-1.89, d5-1.73, d7-1.89, d8-1.83, d9-1.8 arc measurements from WE left 3.07 centre 3.4 right 2.84
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet Oswego Creek

Location:	Hart Rd
Northing:	4759288.42 N
Easting:	613433.59 E

Inspected By:	Paul Greck & Jennifer Chan
Date:	May 10, 2023
Weather:	18°C, Sunny
Crossing ID:	M4

Inlet Type:	Bridge
# of Spans:	1
Span or Diameter (m):	10.8
Rise (m):	Arch Middle-2.8, Side -2.1
Length (m):	5.5

Material:	Concrete
Open Footing:	Yes
Skew Angle:	0
Sediment Depth (mm):	N/A
Road Barrier:	1m Parapet Wall

US Invert Elevation (m):	170.91
DS Invert Elevation (m):	171.00

US Obvert Elevation (m):	173.71
DS Obvert Elevation (m):	173.80

Inlet/Outlet Type:	Conc. bridge w perpendicular walls
High Water Mark Depth (m):	Not Observed
Number of Piers:	0
Pier Width:	0

Low Point in Road Elevation (m):	174.2
Water Depth (m):	0.91

Additional Notes/Notable Obstructions:	DS: D1 - measurement from road deck 3.18m, D2 - 3.31m, D3 - 3.16m US: D4 - 3.28m, D5 - 3.47m, D6 - 3.5m top of barrier ds 175.20, top of barrier us 175.21 us and ds elevations calculated from rpd measurement
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet

Oswego Creek

Location:	Moote Rd
Northing:	4760187.88 N
Easting:	612540.4 E

Inspected By:	Paul Greck & Jennifer Chan
Date:	May 10, 2023
Weather:	18°C, Sunny
Crossing ID:	M5

Inlet Type:	Bridge
# of Spans:	1
Span or Diameter (m):	19.8
Rise (m):	3.92
Length (m):	9.4

Material:	Concrete
Open Footing:	Yes
Skew Angle:	0
Sediment Depth (mm):	N/A
Road Barrier:	Concrete-1.14m, Steel-0.85m

US Invert Elevation (m):	171.67
DS Invert Elevation (m):	171.33

US Obvert Elevation (m):	175.59
DS Obvert Elevation (m):	175.25

Inlet/Outlet Type:	Conc. bridge w perpendicular walls
High Water Mark Depth (m):	Not Observed
Number of Piers:	0
Pier Width:	0

Low Point in Road Elevation (m):	175.8
Water Depth (m):	0.72

Additional Notes/Notable Obstructions:	Measurement from top of barrier D1-5.7m, D2-5.76m, D3-invert-5.9m, D4-5.8m D5-5.38m, D6-invert-5.54m, D7-5.72m, D8-5.6m Instream bush barrier on DS side Concrete road barrier over bridge, steel barrier on road
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Smithville Rd
Northing:	4760848.56 N
Easting:	607689.26 E

Inspected By:	Paul Greck & Keiran Doak
Date:	03-Aug-23
Weather:	24°C, Cloudy
Crossing ID:	M6

Inlet Type:	Arched Bridge
# of Spans:	1
Span or Diameter (m):	5.01 - 12.28. - 5.1
Rise (m):	arch 3.12 - 4.12 - 3.51
Length (m):	8.7

Material:	Concrete
Open Footing:	Yes
Skew Angle:	0
Sediment Depth (mm):	N/A
Road Barrier:	Rail Bar Wall 1.06. - GR 0.75

US Invert Elevation (m):	173.26
DS Invert Elevation (m):	173.4

US Obvert Elevation (m):	177.38
DS Obvert Elevation (m):	177.52

Inlet/Outlet Type:	nc. Bridge with Perpendicular Rails
High Water Mark Depth (m):	Not Observed
Number of Piers:	2
Pier Width:	0.68

Low Point in Road Elevation (m):	178.1
Water Depth (m):	0.9

Additional Notes/Notable Obstructions:	pier rise east 1.83 - 0.85. length 5.01 pier rise west 3.12. - 0.94. length 5.1
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	aldimand Dunnville Townline Rd
Northing:	4761990.68 N
Easting:	605131.78 E

Inspected By:	Paul Greck & Keiran Doak
Date:	03-Aug-23
Weather:	24°C, Cloudy
Crossing ID:	M7

Inlet Type:	Bridge
# of Spans:	1
Span or Diameter (m):	7.3
Rise (m):	2.76
Length (m):	5.7

Material:	Concrete
Open Footing:	Yes
Skew Angle:	0
Sediment Depth (mm):	N/A
Road Barrier:	No

US Invert Elevation (m):	175.18
DS Invert Elevation (m):	175.24

US Obvert Elevation (m):	177.94
DS Obvert Elevation (m):	177.9

Inlet/Outlet Type:	Gabion basket wing walls
High Water Mark Depth (m):	Not Observed
Number of Piers:	0
Pier Width:	0

Low Point in Road Elevation (m):	178.6
Water Depth (m):	1.45

Additional Notes/Notable Obstructions:	bridge closed off U/S we1-2.3 bob2-2.83 b3-3.44 thal4-3.48 b5-3.45 bob6-2.8 we7-2 D/S we8-2 bob9-2.93 b10-3.35 thal11-3.44 b12-3.45 bob13-2.82 WATER ELEVATION ON US SIDE DIFFER BY 0.3m
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Townline Rd E
Northing:	4761982.52 N
Easting:	604817.22 E

Inspected By:	Paul Greck & Keiran Doak
Date:	03-Aug-23
Weather:	24°C, Cloudy
Crossing ID:	M8

Inlet Type:	Bridge
# of Spans:	1
Span or Diameter (m):	7.9
Rise (m):	2.47
Length (m):	6.9

Material:	Concrete
Open Footing:	Yes
Skew Angle:	0
Sediment Depth (mm):	N/A
Road Barrier:	Gr 0.82 D/S conc GR 1.18

US Invert Elevation (m):	175.27
DS Invert Elevation (m):	175.29

US Obvert Elevation (m):	177.74
DS Obvert Elevation (m):	177.73

Inlet/Outlet Type:	Conc. bridge w perpendicular walls
High Water Mark Depth (m):	Not observed
Number of Piers:	0
Pier Width:	0

Low Point in Road Elevation (m):	177.9
Water Depth (m):	

Additional Notes/Notable Obstructions:	U/S B1-3.18 b2-3.46 thal3-3.42 b4-3.32 b5-3.15 D/S b6-2.91 b7-3.39 thal8-3.35 b9-3.16 b10-2.9 US THALWAG ELEVATION SKEWED
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Indiana Rd E
Northing:	4762273.41 N
Easting:	604007.34 E

Inspected By:	Paul Greck & Keiran Doak
Date:	26-Jul-23
Weather:	23°C, Cloudy
Crossing ID:	M9

Inlet Type:	Bridge
# of Spans:	1
Span or Diameter (m):	9.2
Rise (m):	3.28
Length (m):	8.9

Material:	Concrete
Open Footing:	Yes
Skew Angle:	No
Sediment Depth (mm):	N/A
Road Barrier:	Parapet wall 0.93

US Invert Elevation (m):	176.16
DS Invert Elevation (m):	176.36

US Obvert Elevation (m):	179.44
DS Obvert Elevation (m):	179.52

Inlet/Outlet Type:	Conc. bridge w perpendicular walls
High Water Mark Depth (m):	Not Observed
Number of Piers:	0
Pier Width:	0

Low Point in Road Elevation (m):	180.1
Water Depth (m):	0.49

Additional Notes/Notable Obstructions:	Guard Rail 0.75
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Carter Rd
Northing:	4758318.14 N
Easting:	615528.98 E

Inspected By:	Paul Greck & Elliot Pai
Date:	May 5, 2023
Weather:	12°C, Cloudy
Crossing ID:	10

Inlet Type:	Elliptical Pipe
# of Spans:	1
Span or Diameter (m):	2.4
Rise (m):	1.27
Length (m):	15.0

Material:	Corrugated Steel
Open Footing:	Yes
Skew Angle:	0
Sediment Depth (mm):	N/A
Road Barrier:	No

US Invert Elevation (m):	172.32
DS Invert Elevation (m):	172.49

US Obvert Elevation (m):	173.76
DS Obvert Elevation (m):	173.76

Inlet/Outlet Type:	Projecting from slope
High Water Mark Depth (m):	Not Observed
Number of Piers:	No
Pier Width:	N/A

Low Point in Road Elevation (m):	175.4
Water Depth (m):	0.37

Additional Notes/Notable Obstructions:	
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Carter Rd
Northing:	4758148.808 N
Easting:	615521.591 E

Inspected By:	Paul Greck & Keiran Doak
Date:	August 9, 2023
Weather:	26°C, Sunny
Crossing ID:	RR1

Inlet Type:	Trapazodial Culvert
# of Spans:	1
Span or Diameter (m):	2.5
Rise (m):	2.48
Length (m):	21.8

Material:	Concrete and Armourstone
Open Footing:	Yes
Skew Angle:	0
Sediment Depth (mm):	N/A
Road Barrier:	N/A

US Invert Elevation (m):	172.63
DS Invert Elevation (m):	172.76

US Obvert Elevation (m):	175.11
DS Obvert Elevation (m):	175.06

Inlet/Outlet Type:	
High Water Mark Depth (m):	Not Observed
Number of Piers:	0
Pier Width:	N/A

Low Point in Road Elevation (m):	177.5
Water Depth (m):	0.12

Additional Notes/Notable Obstructions:	custom trapazodial concrete roof and armourstone walls obv ds working 175.96 obv us working 177.47
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Diltz Rd
Northing:	4757636.69 N
Easting:	615611.965 E

Inspected By:	Paul Greck & Keiran Doak
Date:	August 9, 2023
Weather:	26°C, Sunny
Crossing ID:	RR2

Inlet Type:	Twin circular Pipes
# of Spans:	1
Span or Diameter (m):	2.2
Rise (m):	E2.4 W2.05
Length (m):	E14.60 W14.33

Material:	Concrete
Open Footing:	No
Skew Angle:	0
Sediment Depth (mm):	0.4m W culvert
Road Barrier:	No

US Invert Elevation (m):	E173.74 W174.04
DS Invert Elevation (m):	E173.77 W173.98

US Obvert Elevation (m):	E176.14 W176.09
DS Obvert Elevation (m):	E175.83 W175.90

Inlet/Outlet Type:	Projecting from slope
High Water Mark Depth (m):	Not Observed
Number of Piers:	No
Pier Width:	N/A

Low Point in Road Elevation (m):	177.6
Water Depth (m):	0.22

Additional Notes/Notable Obstructions:	conc thickness 0.35m 173.98
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Diltz Rd
Northing:	4757527.38 N
Easting:	615997.55 E

Inspected By:	Paul Greck & Elliot Pai
Date:	May 5, 2023
Weather:	12°C, Cloudy
Crossing ID:	11

Inlet Type:	Circular Pipe
# of Spans:	1
Span or Diameter (m):	1.4
Rise (m):	1.4
Length (m):	16.6

Material:	Corrugated Steel
Open Footing:	no
Skew Angle:	0
Sediment Depth (mm):	N/A
Road Barrier:	0.7m Guard Rail on US side

US Invert Elevation (m):	175.65
DS Invert Elevation (m):	175.77

US Obvert Elevation (m):	177.19
DS Obvert Elevation (m):	176.93

Inlet/Outlet Type:	Projecting from slope
High Water Mark Depth (m):	Not Observed
Number of Piers:	No
Pier Width:	N/A

Low Point in Road Elevation (m):	178.1
Water Depth (m):	0.32

Additional Notes/Notable Obstructions:	
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Diltz Rd
Northing:	4756428.52 N
Easting:	615389.47 E

Inspected By:	Paul Greck & Elliot Pai
Date:	May 5, 2023
Weather:	12°C, Cloudy
Crossing ID:	12.1

Inlet Type:	Circular Pipe
# of Spans:	1
Span or Diameter (m):	1.4
Rise (m):	1.40
Length (m):	18.4

Material:	Corrugated Steel
Open Footing:	no
Skew Angle:	0
Sediment Depth (mm):	N/A
Road Barrier:	No

US Invert Elevation (m):	175.60
DS Invert Elevation (m):	175.45

US Obvert Elevation (m):	176.97
DS Obvert Elevation (m):	176.89

Inlet/Outlet Type:	Projecting from slope
High Water Mark Depth (m):	Not Observed
Number of Piers:	No
Pier Width:	N/A

Low Point in Road Elevation (m):	178.5
Water Depth (m):	0.42

Additional Notes/Notable Obstructions:	
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Diltz Rd Driveway
Northing:	4756389.88 N
Easting:	615406.01 E

Inspected By:	Paul Greck & Elliot Pai
Date:	May 5, 2023
Weather:	12°C, Cloudy
Crossing ID:	12.2

Inlet Type:	Circular Pipe
# of Spans:	1
Span or Diameter (m):	1.4
Rise (m):	1.4
Length (m):	13.4

Material:	Corrugated Steel
Open Footing:	no
Skew Angle:	0
Sediment Depth (mm):	N/A
Road Barrier:	No

US Invert Elevation (m):	175.60
DS Invert Elevation (m):	175.45

US Obvert Elevation (m):	176.97
DS Obvert Elevation (m):	176.89

Inlet/Outlet Type:	Perpendicular Armoustone Wall
High Water Mark Depth (m):	Not Observed
Number of Piers:	No
Pier Width:	N/A

Low Point in Road Elevation (m):	178.2
Water Depth (m):	0.38

Additional Notes/Notable Obstructions:	
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Comfort Rd
Northing:	4756181.41 N
Easting:	615425.45 E

Inspected By:	Paul Greck & Elliot Pai
Date:	May 5, 2023
Weather:	12°C, Cloudy
Crossing ID:	13

Inlet Type:	Circular Pipe
# of Spans:	1
Span or Diameter (m):	1.2
Rise (m):	1.20
Length (m):	14.1

Material:	Corrugated Steel
Open Footing:	no
Skew Angle:	0
Sediment Depth (mm):	N/A
Road Barrier:	No

US Invert Elevation (m):	175.61
DS Invert Elevation (m):	175.6

US Obvert Elevation (m):	176.82
DS Obvert Elevation (m):	176.83

Inlet/Outlet Type:	Projecting from slope
High Water Mark Depth (m):	Not Observed
Number of Piers:	No
Pier Width:	N/A

Low Point in Road Elevation (m):	178.4
Water Depth (m):	0.33

Additional Notes/Notable Obstructions:	
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Upstream Photo:	
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Downstream Photo:	
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Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Hart Rd
Northing:	4758785.97 N
Easting:	614812.26 E

Inspected By:	Paul Greck & Elliot Pai
Date:	May 5, 2023
Weather:	12°C, Cloudy
Crossing ID:	14

Inlet Type:	Circular Pipe
# of Spans:	1
Span or Diameter (m):	2.0
Rise (m):	2.0
Length (m):	14.9

Material:	Corrugated Steel
Open Footing:	No
Skew Angle:	0
Sediment Depth (mm):	N/A
Road Barrier:	No

US Invert Elevation (m):	172.07
DS Invert Elevation (m):	172.01

US Obvert Elevation (m):	173.98
DS Obvert Elevation (m):	173.86

Inlet/Outlet Type:	Projecting from slope
High Water Mark Depth (m):	Not Observed
Number of Piers:	No
Pier Width:	N/A

Low Point in Road Elevation (m):	174.9
Water Depth (m):	0.25

Additional Notes/Notable Obstructions:	Bottom of CSP corroding
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Robinson Rd
Northing:	4758148.808 N
Easting:	614377.512 E

Inspected By:	Paul Greck & Keiran Doak
Date:	August 9, 2023
Weather:	26°C, Sunny
Crossing ID:	RR3

Inlet Type:	Circular
# of Spans:	1
Span or Diameter (m):	1.5
Rise (m):	1.50
Length (m):	21.6

Material:	steel and CSP
Open Footing:	No
Skew Angle:	5
Sediment Depth (mm):	N/A
Road Barrier:	No

US Invert Elevation (m):	174.40
DS Invert Elevation (m):	174.4

US Obvert Elevation (m):	175.9
DS Obvert Elevation (m):	175.9

Inlet/Outlet Type:	Projecting from slope
High Water Mark Depth (m):	Not Observed
Number of Piers:	0
Pier Width:	N/A

Low Point in Road Elevation (m):	178.4
Water Depth (m):	0.09

Additional Notes/Notable Obstructions:	CSP inlet and outlet pipes deteriorated 2.0m extentionms US and DS US debris accumulation in CSP
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Upstream Photo:	
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Downstream Photo:	
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Stream Crossing Field Inventory Sheet

Oswego Creek

Location:	Robinson Rd
Northing:	4757710.037 N
Easting:	614036.318 E

Inspected By:	Paul Greck & Keiran Doak
Date:	August 9, 2023
Weather:	26°C, Sunny
Crossing ID:	RR4

Inlet Type:	Circular
# of Spans:	1
Span or Diameter (m):	1.5
Rise (m):	1.68
Length (m):	17.0

Material:	Concrete
Open Footing:	No
Skew Angle:	3
Sediment Depth (mm):	N/A
Road Barrier:	No

US Invert Elevation (m):	175.14
DS Invert Elevation (m):	175.13

US Obvert Elevation (m):	176.82
DS Obvert Elevation (m):	176.7

Inlet/Outlet Type:	Projecting from slope
High Water Mark Depth (m):	Not Observed
Number of Piers:	0
Pier Width:	N/A

Low Point in Road Elevation (m):	178.7
Water Depth (m):	0.28

Additional Notes/Notable Obstructions:	road crossing downstream - CSP eleptical pipe 1.74m span (survey points with X) US and DS pipe sections broken off main
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Stringer Rd
Northing:	4756851.45 N
Easting:	613441.3 E

Inspected By:	Paul Greck & Elliot Pai
Date:	May 5, 2023
Weather:	12°C, Cloudy
Crossing ID:	15

Inlet Type:	Elliptical Pipe
# of Spans:	1
Span or Diameter (m):	1.8
Rise (m):	1.11
Length (m):	18.3

Material:	Corrugated Steel
Open Footing:	No
Skew Angle:	0
Sediment Depth (mm):	N/A
Road Barrier:	No

US Invert Elevation (m):	175.79
DS Invert Elevation (m):	176.04

US Obvert Elevation (m):	177.02
DS Obvert Elevation (m):	177.15

Inlet/Outlet Type:	Projecting from slope
High Water Mark Depth (m):	Not Observed
Number of Piers:	No
Pier Width:	N/A

Low Point in Road Elevation (m):	178.4
Water Depth (m):	0.56

Additional Notes/Notable Obstructions:	
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Moote Rd
Northing:	4756016.87 N
Easting:	612610.54 E

Inspected By:	Paul Greck & Jennifer Chan
Date:	May 18, 2023
Weather:	8°C, Sunny
Crossing ID:	16

Inlet Type:	Circular Pipe
# of Spans:	1
Span or Diameter (m):	1.15
Rise (m):	1.13
Length (m):	15.9

Material:	Corrugated Steel
Open Footing:	No
Skew Angle:	0
Sediment Depth (mm):	0.1
Road Barrier:	No

US Invert Elevation (m):	177.17
DS Invert Elevation (m):	177.17

US Obvert Elevation (m):	178.3
DS Obvert Elevation (m):	178.29

Inlet/Outlet Type:	Projecting from slope
High Water Mark Depth (m):	Not Observed
Number of Piers:	No
Pier Width:	N/A

Low Point in Road Elevation (m):	179.5
Water Depth (m):	0.19

Additional Notes/Notable Obstructions:	Exposed natural gas line at DS end Concrete rubble headwall
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Hart Rd
Northing:	4758652.57 N
Easting:	614160.87 E

Inspected By:	Paul Greck & Elliot Pai
Date:	May 5, 2023
Weather:	12°C, Cloudy
Crossing ID:	17

Inlet Type:	Box Culvert
# of Spans:	1
Span or Diameter (m):	3.9
Rise (m):	2.68
Length (m):	20.4

Material:	Concrete
Open Footing:	Yes
Skew Angle:	0
Sediment Depth (mm):	N/A
Road Barrier:	0.8m Guard Rail

US Invert Elevation (m):	172.00
DS Invert Elevation (m):	171.88

US Obvert Elevation (m):	174.91
DS Obvert Elevation (m):	174.91

Inlet/Outlet Type:	Projecting from slope
High Water Mark Depth (m):	Not Observed
Number of Piers:	No
Pier Width:	N/A

Low Point in Road Elevation (m):	175.6
Water Depth (m):	0.27

Additional Notes/Notable Obstructions:	conc thicknes .35 deck to obv
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet

Oswego Creek

Location:	Hart Rd
Northing:	4758147.171 N
Easting:	613371.286 E

Inspected By:	Paul Greck & Keiran Doak
Date:	August 9, 2023
Weather:	26°C, Sunny
Crossing ID:	RR5

Inlet Type:	Arched Bridge
# of Spans:	1
Span or Diameter (m):	3.4
Rise (m):	2 - 3.35 - 2
Length (m):	12.9

Material:	Concrete Blocks
Open Footing:	Yes
Skew Angle:	0
Sediment Depth (mm):	N/A
Road Barrier:	Wood Wall 1.2m DS 1.55 US

US Invert Elevation (m):	173.84
DS Invert Elevation (m):	173.69

US Obvert Elevation (m):	177.19
DS Obvert Elevation (m):	176.94

Inlet/Outlet Type:	Stone bridge w perpendicular walls
High Water Mark Depth (m):	Not observed
Number of Piers:	0
Pier Width:	0

Low Point in Road Elevation (m):	177.4
Water Depth (m):	0.24

Additional Notes/Notable Obstructions:	conc thickness 1.1m US wingwalls East perpendicular West 45 degree DS perpendicular wingwalls
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Moote Rd
Northing:	4757738.197 N
Easting:	612996.366 E

Inspected By:	Paul Greck & Keiran Doak
Date:	August 9, 2023
Weather:	26°C, Sunny
Crossing ID:	RR6

Inlet Type:	Bridge
# of Spans:	1
Span or Diameter (m):	2.8
Rise (m):	2.97
Length (m):	8.6

Material:	concrete blocks
Open Footing:	Yes
Skew Angle:	0
Sediment Depth (mm):	N/A
Road Barrier:	No

US Invert Elevation (m):	174.25
DS Invert Elevation (m):	174.31

US Obvert Elevation (m):	177.22
DS Obvert Elevation (m):	177.26

Inlet/Outlet Type:	Conc. bridge w wing walls
High Water Mark Depth (m):	Not Observed
Number of Piers:	0
Pier Width:	0

Low Point in Road Elevation (m):	178.5
Water Depth (m):	0.14

Additional Notes/Notable Obstructions:	top conc thickness 0.98m concrete blocks deteriorating - upper roadway washedout
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Moote Rd
Northing:	4757471.79 N
Easting:	612610.39 E

Inspected By:	Paul Greck & Jennifer Chan
Date:	May 10, 2023
Weather:	18°C, Sunny
Crossing ID:	18

Inlet Type:	Box Culvert
# of Spans:	1
Span or Diameter (m):	3.7
Rise (m):	1.78
Length (m):	15.4

Material:	Concrete
Open Footing:	Yes
Skew Angle:	0
Sediment Depth (mm):	N/A
Road Barrier:	0.82m Guard Rail

US Invert Elevation (m):	174.93
DS Invert Elevation (m):	174.87

US Obvert Elevation (m):	176.71
DS Obvert Elevation (m):	176.7

Inlet/Outlet Type:	Projecting from slope
High Water Mark Depth (m):	Not Observed
Number of Piers:	0
Pier Width:	0

Low Point in Road Elevation (m):	177.8
Water Depth (m):	0.28

Additional Notes/Notable Obstructions:	
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Melick Rd
Northing:	4757509.61 N
Easting:	611703.88 E

Inspected By:	Paul Greck & Jennifer Chan
Date:	May 10, 2023
Weather:	18°C, Sunny
Crossing ID:	19

Inlet Type:	Box Culvert
# of Spans:	1
Span or Diameter (m):	4.4
Rise (m):	1.71
Length (m):	11.0

Material:	Concrete
Open Footing:	Yes
Skew Angle:	0
Sediment Depth (mm):	0.27
Road Barrier:	No

US Invert Elevation (m):	175.38
DS Invert Elevation (m):	175.61

US Obvert Elevation (m):	177.09
DS Obvert Elevation (m):	177.09

Inlet/Outlet Type:	Projecting from slope
High Water Mark Depth (m):	Not Observed
Number of Piers:	0
Pier Width:	0

Low Point in Road Elevation (m):	178.3
Water Depth (m):	0.27

Additional Notes/Notable Obstructions:	
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	James Rd
Northing:	4756995.3 N
Easting:	610248.01 E

Inspected By:	Paul Greck & Jennifer Chan
Date:	May 10, 2023
Weather:	18°C, Sunny
Crossing ID:	20

Inlet Type:	Circular Pipe
# of Spans:	1
Span or Diameter (m):	1.5
Rise (m):	1.12
Length (m):	17.9

Material:	Corrugated Steel
Open Footing:	No
Skew Angle:	0
Sediment Depth (mm):	N/A
Road Barrier:	No

US Invert Elevation (m):	177.49
DS Invert Elevation (m):	177.35

US Obvert Elevation (m):	178.61
DS Obvert Elevation (m):	178.48

Inlet/Outlet Type:	Projecting from slope
High Water Mark Depth (m):	Not Observed
Number of Piers:	0
Pier Width:	0

Low Point in Road Elevation (m):	179.3
Water Depth (m):	0.11

Additional Notes/Notable Obstructions:	Minor warping and corrosion at bottom of culvert at DS US side has tile drains from agricultural field
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Moote Rd
Northing:	4759879.55 N
Easting:	612609.57 E

Inspected By:	Paul Greck & Jennifer Chan
Date:	May 10, 2023
Weather:	18°C, Sunny
Crossing ID:	21

Inlet Type:	Circular Pipe
# of Spans:	1
Span or Diameter (m):	2.2
Rise (m):	2.24
Length (m):	18.0

Material:	Corrugated Steel
Open Footing:	No
Skew Angle:	0
Sediment Depth (mm):	N/A
Road Barrier:	No

US Invert Elevation (m):	171.93
DS Invert Elevation (m):	171.87

US Obvert Elevation (m):	174.17
DS Obvert Elevation (m):	174.07

Inlet/Outlet Type:	Projecting from slope
High Water Mark Depth (m):	Not Observed
Number of Piers:	0
Pier Width:	0

Low Point in Road Elevation (m):	175.1
Water Depth (m):	0.14

Additional Notes/Notable Obstructions:	US and DS has no defined channel, low land marsh
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Canborough Rd
Northing:	4760965.62 N
Easting:	611988.39 E

Inspected By:	Paul Greck & Jennifer Chan
Date:	May 10, 2023
Weather:	18°C, Sunny
Crossing ID:	22

Inlet Type:	Box Culvert
# of Spans:	1
Span or Diameter (m):	2.27 (US), 1.45m (DS)
Rise (m):	1.38 (US), 1.0m (DS)
Length (m):	33.8

Material:	Concrete
Open Footing:	No
Skew Angle:	US end for 22.2m @310°
Sediment Depth (mm):	No
Road Barrier:	No

US Invert Elevation (m):	173.53
DS Invert Elevation (m):	173.31

US Obvert Elevation (m):	174.91
DS Obvert Elevation (m):	174.27

Inlet/Outlet Type:	Projecting from slope
High Water Mark Depth (m):	Not Observed
Number of Piers:	0
Pier Width:	0

Low Point in Road Elevation (m):	177.4
Water Depth (m):	0.18

Additional Notes/Notable Obstructions:	US side has large debris in channel US box culvert thickness 0.26m DS has 5.7m stone arch extension, face to box culvert bend is 11.5m
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Canborough Rd
Northing:	4760991.1 N
Easting:	611909.37 E

Inspected By:	Paul Greck & Jennifer Chan
Date:	May 10, 2023
Weather:	18°C, Sunny
Crossing ID:	23

Inlet Type:	Circular Pipe
# of Spans:	1
Span or Diameter (m):	0.9
Rise (m):	0.90
Length (m):	9.7

Material:	Corrugated PVC Pipe
Open Footing:	No
Skew Angle:	0
Sediment Depth (mm):	N/A
Road Barrier:	No

US Invert Elevation (m):	174.08
DS Invert Elevation (m):	173.78

US Obvert Elevation (m):	174.98
DS Obvert Elevation (m):	174.7

Inlet/Outlet Type:	Conc. headwall with PVC pipe
High Water Mark Depth (m):	Not Observed
Number of Piers:	0
Pier Width:	0

Low Point in Road Elevation (m):	176.6
Water Depth (m):	0.31

Additional Notes/Notable Obstructions:	Under private property driveway Concrete debris in DS side channel
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Canborough Rd
Northing:	4760993.62 N
Easting:	611785.22 E

Inspected By:	Paul Greck & Jennifer Chan
Date:	May 10, 2023
Weather:	18°C, Sunny
Crossing ID:	24

Inlet Type:	Circular Pipe
# of Spans:	1
Span or Diameter (m):	0.9
Rise (m):	0.91
Length (m):	9.0

Material:	Corrugated PVC Pipe
Open Footing:	No
Skew Angle:	21
Sediment Depth (mm):	N/A
Road Barrier:	No

US Invert Elevation (m):	174.44
DS Invert Elevation (m):	174.39

US Obvert Elevation (m):	175.35
DS Obvert Elevation (m):	175.31

Inlet/Outlet Type:	Projecting from slope
High Water Mark Depth (m):	Not Observed
Number of Piers:	0
Pier Width:	0

Low Point in Road Elevation (m):	175.9
Water Depth (m):	0.3

Additional Notes/Notable Obstructions:	
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Canborough Rd
Northing:	4761418.06 N
Easting:	611184.8 E

Inspected By:	Paul Greck & Jennifer Chan
Date:	May 10, 2023
Weather:	18°C, Sunny
Crossing ID:	25

Inlet Type:	Circular Pipe
# of Spans:	1
Span or Diameter (m):	1.2
Rise (m):	1.21
Length (m):	8.9

Material:	Corrugated Steel
Open Footing:	No
Skew Angle:	0
Sediment Depth (mm):	0.15m DS
Road Barrier:	No

US Invert Elevation (m):	178.33
DS Invert Elevation (m):	178.19

US Obvert Elevation (m):	179.54
DS Obvert Elevation (m):	179.41

Inlet/Outlet Type:	Projecting from slope
High Water Mark Depth (m):	Not Observed
Number of Piers:	0
Pier Width:	0

Low Point in Road Elevation (m):	179.9
Water Depth (m):	0.2

Additional Notes/Notable Obstructions:	
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Lane Rd
Northing:	4759498.58 N
Easting:	609201.33 E

Inspected By:	Paul Greck & Keiran Doak
Date:	25-May-23
Weather:	8°C, Cloudy
Crossing ID:	26

Inlet Type:	Culvert
# of Spans:	1
Span or Diameter (m):	1.4
Rise (m):	1.59
Length (m):	15.4

Material:	Corrugated Steel
Open Footing:	No
Skew Angle:	0
Sediment Depth (mm):	N/A
Road Barrier:	No

US Invert Elevation (m):	174.49
DS Invert Elevation (m):	174.39

US Obvert Elevation (m):	176.08
DS Obvert Elevation (m):	175.71

Inlet/Outlet Type:	Projecting from Slope
High Water Mark Depth (m):	Not Observed
Number of Piers:	No
Pier Width:	N/A

Low Point in Road Elevation (m):	177.0
Water Depth (m):	0.49

Additional Notes/Notable Obstructions:	Culvert Invert bent at US end
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Upstream Photo:	
Downstream Photo:	

Stream Crossing Field Inventory Sheet
Oswego Creek

Location:	Dunnville Rd
Northing:	4759082 N
Easting:	608737.77 E

Inspected By:	Paul Greck & Jennifer Chan
Date:	May 18, 2023
Weather:	15°C, Sunny
Crossing ID:	27

Inlet Type:	Box Culvert
# of Spans:	1
Span or Diameter (m):	1.9
Rise (m):	1.61
Length (m):	21.7

Material:	Concrete
Open Footing:	No
Skew Angle:	0
Sediment Depth (mm):	N/A
Road Barrier:	No

US Invert Elevation (m):	176.33
DS Invert Elevation (m):	176.41

US Obvert Elevation (m):	177.94
DS Obvert Elevation (m):	177.97

Inlet/Outlet Type:	Projecting from slope
High Water Mark Depth (m):	
Number of Piers:	
Pier Width:	

Low Point in Road Elevation (m):	179.0
Water Depth (m):	0.22

Additional Notes/Notable Obstructions:	Erosion on banks and underneath culvert on DS side, perched culvert
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Upstream Photo:	
Downstream Photo:	