Prepared for:
Nottawasaga Valley Conservation Authority

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Upper Mad River Flood Hazard Mapping DRAFT Hydraulic Modelling Report

Submitted by:
Aquafor Beech Limited

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EXECUTIVE SUMMARY

The Mad River watershed drains an area of 252 km^2 and is located with the Nottawasaga Valley Conservation Authority's (NVCA) jurisdiction. Mad River project area extends 26 km from its farthest headwaters to its outlet point upstream of Glencairn. The primary reach within the study area passes through the villages of Creemore and Avening within the Township of Clearview. The watershed is widest within the headwater area within the Niagara Escarpment and narrows towards the downstream limits of the project area. The watershed generally drains in a west to east direction.

Aquafor Beech Limited (Aquafor) was retained by the NVCA to establish updated regulatory floodplain mapping for the Upper Mad River through detailed hydrologic and hydraulic modelling, and analyses of any flood hazards. The Timmins Regional storm event has been adopted by the NVCA to regulate development within the floodplain and to identify risks to properties and roads within the study area.

Nottawasaga Valley Conservation Authority partnered with the Government of Canada (Natural Resources Canada, NRCan) and the Province of Ontario (Ministry of Natural Resources and Forestry) as part of the Flood Hazard Identification and Mapping Program (FHIMP) to develop flood hazard maps for municipalities and territories.

As part of the hydrologic component of the study, Aquafor developed a hydrologic model using the US Army Corps of Engineers HEC-HMS software (Ver. 4.11). Simulations were performed for the 2-year, 5-year, 10-year, 25-year, 50-year, 100-year and Timmins (Regulatory) storms. Junctions were strategically placed throughout the watershed to ensure adequate discretization, as well as to provide flow inputs to the hydraulic model at key locations along the reaches included in the floodplain mapping study.

A 2D HEC-RAS hydraulic model (US Army Corps of Engineers HEC-RAS software, version 6.4.1) was subsequently developed for the reaches of interest, comprising the main branch of Mad River from County Road 9 to approximately 1km downstream of Centerline Road within the Township of Clearview. A LiDAR-derived digital terrain model (DTM) having a 0.5 m resolution, produced by NRCan, was used in conjunction with field survey data to define stream and crossing structure geometries and to establish floodlines. The model was evaluated through a verification exercise, and comparison with other studies. In total 23km of reaches and 10 hydraulic structures were modelled. A flood hazard assessment was then undertaken to determine overtopping depth at road crossings and the associated impacts to road access, as well as to identify potential flood impacts to buildings.

The approach used for hydraulic modelling, floodline delineation, and the flood hazard assessment is consistent with the HEC-RAS User's Manual (US Army Corps of Engineers, 2023), the Technical Guide for River & Stream Systems: Flooding Hazard Limit (OMNR, 2002), the Federal Hydrologic and Hydraulic Procedures for Flood Hazard Delineation (NRCan, 2023), and the Technical Guidelines for Flood Hazard Mapping (EWRG, 2017).

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1 INTRODUCTION

1.1 Study Objective

The purpose of this study is to establish updated regulatory floodplain mapping for the Mad River watershed, through detailed hydrological and hydraulic modelling, and analyses of any flood hazards. The Timmins Regional flood profile is used by Nottawasaga Valley Conservation Authority (NVCA) to regulate development within the floodplain, to protect developed areas through structural land acquisition measures, and to identify properties at risk within the study area. The present report details the methodology and results of the hydraulic component of the floodplain mapping study.

The NVCA received funding to conduct this study, partnering with the with the Government of Canada (Natural Resources Canada) and the Province of Ontario (Ministry of Natural Resources and Forestry) as part of the Flood Hazard Identification and Mapping Program (FHIMP) to develop flood hazard maps for municipalities and territories.

As part of the hydraulic component of the study, Aquafor developed a hydraulic model using the US Army Corps of Engineers HEC-RAS software (Ver. 6.4.1) and the Canadian Geodedic Datum of 2013 (CGVD2013) as vertical datum, as opposed to the older CGVD28 vertical datum. The model was developed based on a DTM (created from LiDAR data collected in 2023), topographic field survey data collected by Aquafor, and flows estimated by the hydrologic model. Simulations were performed for the 2-year, 5-year, 10-year, 25-year, 50-year, 100-year and Timmins Regional (regulatory) storms, with the Timmins Regional storm serving as a proxy for evaluating the regulatory storm under the effects of climate change.

Key objectives of this study area as follows:

- Review all available background information provided by Nottawasaga Valley Conservation Authority;
- Perform a data gap analysis to identify existing model deficiencies and missing road crossing information;
- Identify all watercourses crossing structures along the reaches of interest and complete field surveys;
- Develop a georeferenced HEC-RAS hydraulic model throughout the study area, based upon the LiDAR-derived DTM (Coordinate system NAD83 - UTM Zone 18N, vertical coordinate system CGVD2013);
- Incorporate the flood flow estimates from Aquafor's hydrologic model;
- Perform a boundary conditions sensitivity analysis;
- Generate riverine flood lines for the 100-year and Timmins Regional (Regulatory) storms;
- Identify flooding impact and extents;
- Identify flood-susceptible buildings and roadways;
- Identify areas of potential spills;
- Provide the regulated floodplain mapping and flood hazard sheets; and
- Provide the digital flood lines for all events.

1.2 Study Area

The study area of the Mad River Floodplain Mapping includes the main reach of the Mad River, bound to the north by County Road 9 and extends approximately 1km downstream of Centerline Road. The Mad River watershed is predominantly rural, comprising forests, cultivated lands and wetlands. Small urban areas are also present, concentrated within the Village of Creemore and Avening and within the south eastern portion of the study area. The study area also includes a secondary reach, generally residing at the eastern limits of Creemore and connecting to the Mad River upstream of Centerline Road. The overall the project area covers approximately 11 km of watercourse with a catchment area of approximately 252 km^2 as illustrated in **Figure 1-1**;

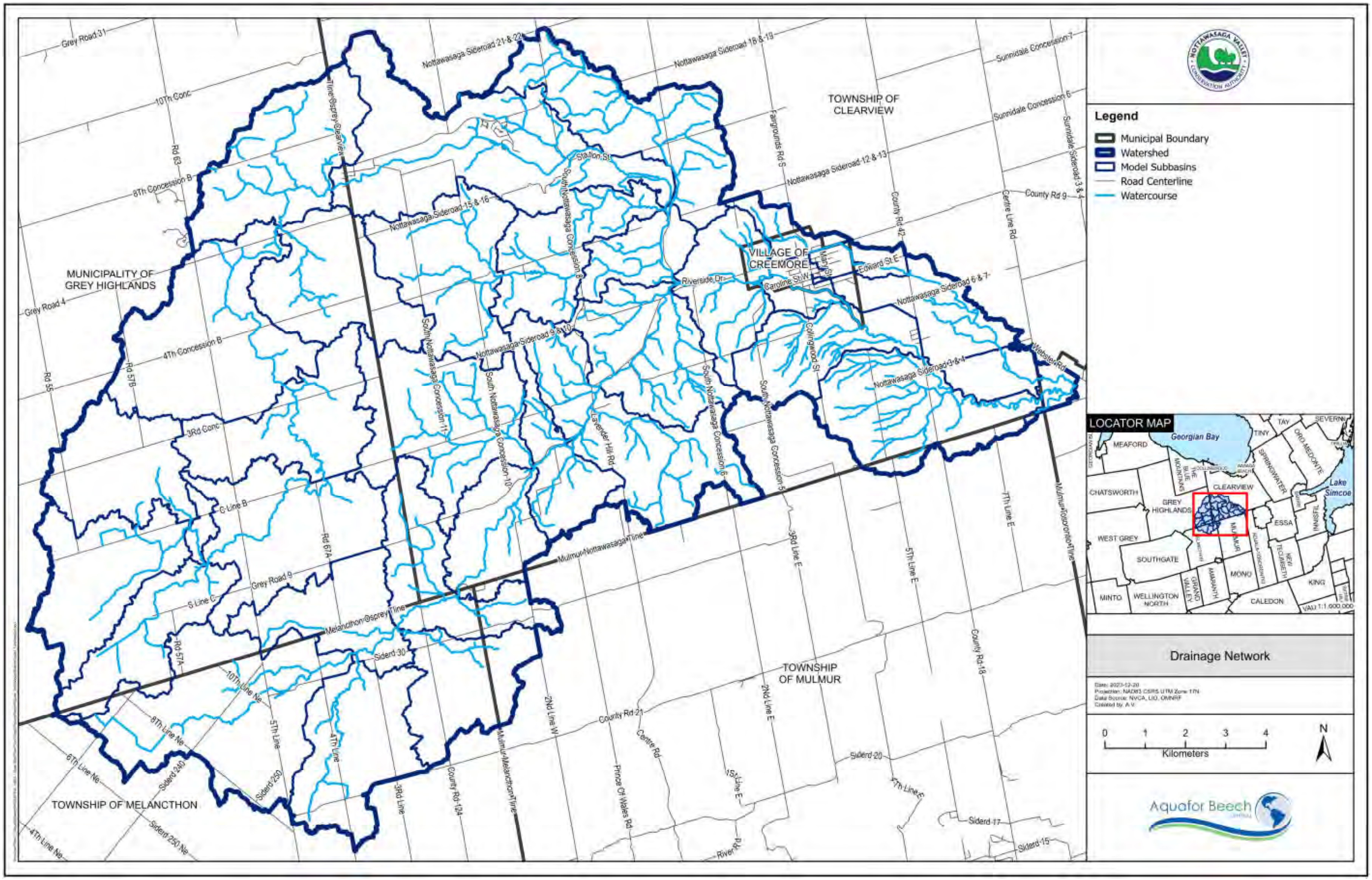

Figure 1-1. Mad River Drainage Network and Reaches to be Mapped

2 BACKGROUND REVIEW AND SITE RECONNAISSANCE

2.1 Background Data Review

At onset of the study, Aquafor collected and compiled all pertinent background information from the NVCA, including;

- A high-resolution DTM that was derived from LiDAR data collected in 2023;
- GIS data layers for existing floodlines, land use, soils, watercourse centrelines, waterbodies, and wetlands and;
- Historical Flooding Photos.

Additional GIS data (e.g., road network and building polygons) was retrieved from open-source platforms.

2.2 Coordinate System and Vertical Datum

As per the FHIMP program, the floodplain mapping and associated models have to be developed in a specific geospatial reference system. For consistency, all topography data such as the DTM LiDAR derived, Aquafor GPS survey, where in the same coordinate system and vertical datum as follows:

- Horizontal Datum: North American Datum of 1983 (NAD83), Canadian Spatial Reference System (CSRS)
- Projection: Universal Transverse Mercator, Zone 18 North (UTM 18N)
- Vertical Datum: Canadian Geodetic Vertical Datum of 2013 (CGVD2013)

For elevations that were provided in CGVD28 Aquafor converted the elevations to CGVD2013. Per the NRCan Passive Control Network Tool, elevations referenced to CGVD2013 are 0.354m lower than those referenced to CGVD28 at the 67U113 benchmark station, which was used for converting between vertical datums within the study area.

2.3 LiDAR-Derived DTM

Nottawasaga Valley Conservation Authority provided a digital terrain model (DTM) with a 0.5 m horizontal resolution that was produced by Natural Resources Canada (NRCan) based on LiDAR data collected in 2023. The DTM was the primary elevation data source for defining the geometries of model components and delineating flood extents. It is referenced to the NAD83 (CSRS) UTM Zone 18N horizontal coordinate system and the CGVD2013 vertical datum. The LiDAR provided by NVCA consists of 1 x 1 km tiles and covers a 22,000m2 area. Aquafor has merged the tiles to work with a single file when developing the hydrology and hydraulic models as well as the regulatory flood lines. The combined DEM file for the project area is illustrated below;

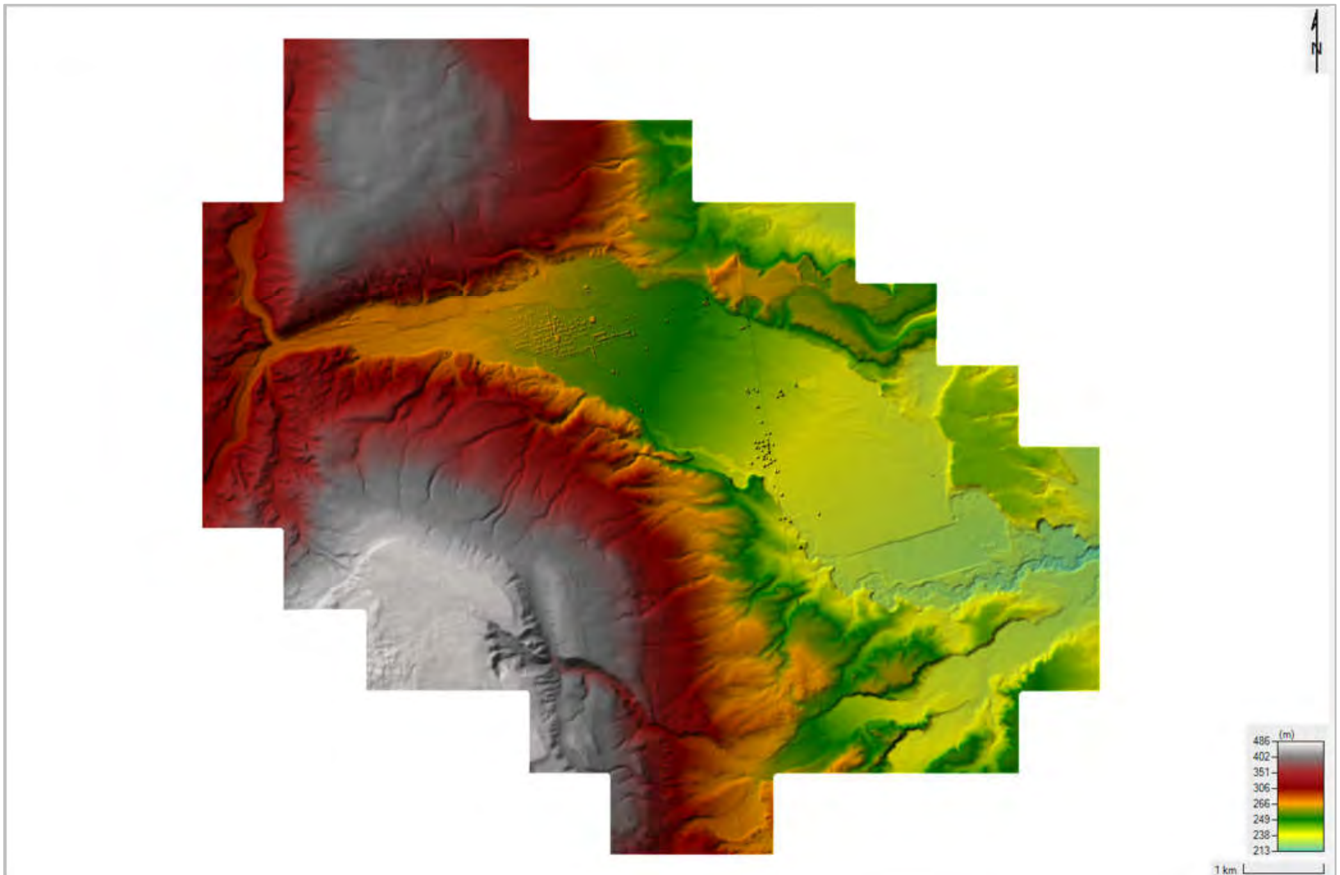

Figure 2-1. Compiled LiDAR DTM

2.4 Structure Review and Inventory

Crossing structures within the study area were first identified and indexed by Aquafor based upon the preliminary review of GIS mapping and aerial imagery. The centrelines of the reaches included in the study were plotted on a map, and public crossings were identified as structures to be included within the hydraulic model. Working with the NVCA, a total of 10 hydraulically significant crossing structures were identified to be surveyed.

The topographic survey was completed for all 10 structures and included structure type and material, location and size of openings and headwalls/wingwalls, heights, depth of embedment, culvert entrance types, invert and obvert elevations, etc. A structure tracking sheet and summaries of field inventories at each crossing structure, in the form of structure inventory sheets, are compiled in **Appendix B**.
Figure 2-2 illustrates the general location of each hydraulic structure incorporated into the model while **Table 2-1** below provides a general description of each crossing.

Table 2-1. Hydraulic Structure Summary

River	Location	Type
Mad River	County Road 9	Single Span Bridge
	Caroline Street	Single Span Bridge
	Collingwood Street	Single Span Bridge
	Airport	Dual Span Bridge
	Sideroad 3&4 Nottawasaga	Dual Span Bridge
	Centerline Road	Single Span Bridge
East Creemore Drain (ECD)	Edward Street #1	Culvert
	Edward Street #2	Culvert
	Airport Road	Culvert
	Sideroad 3&4 Nottawasaga	Culvert

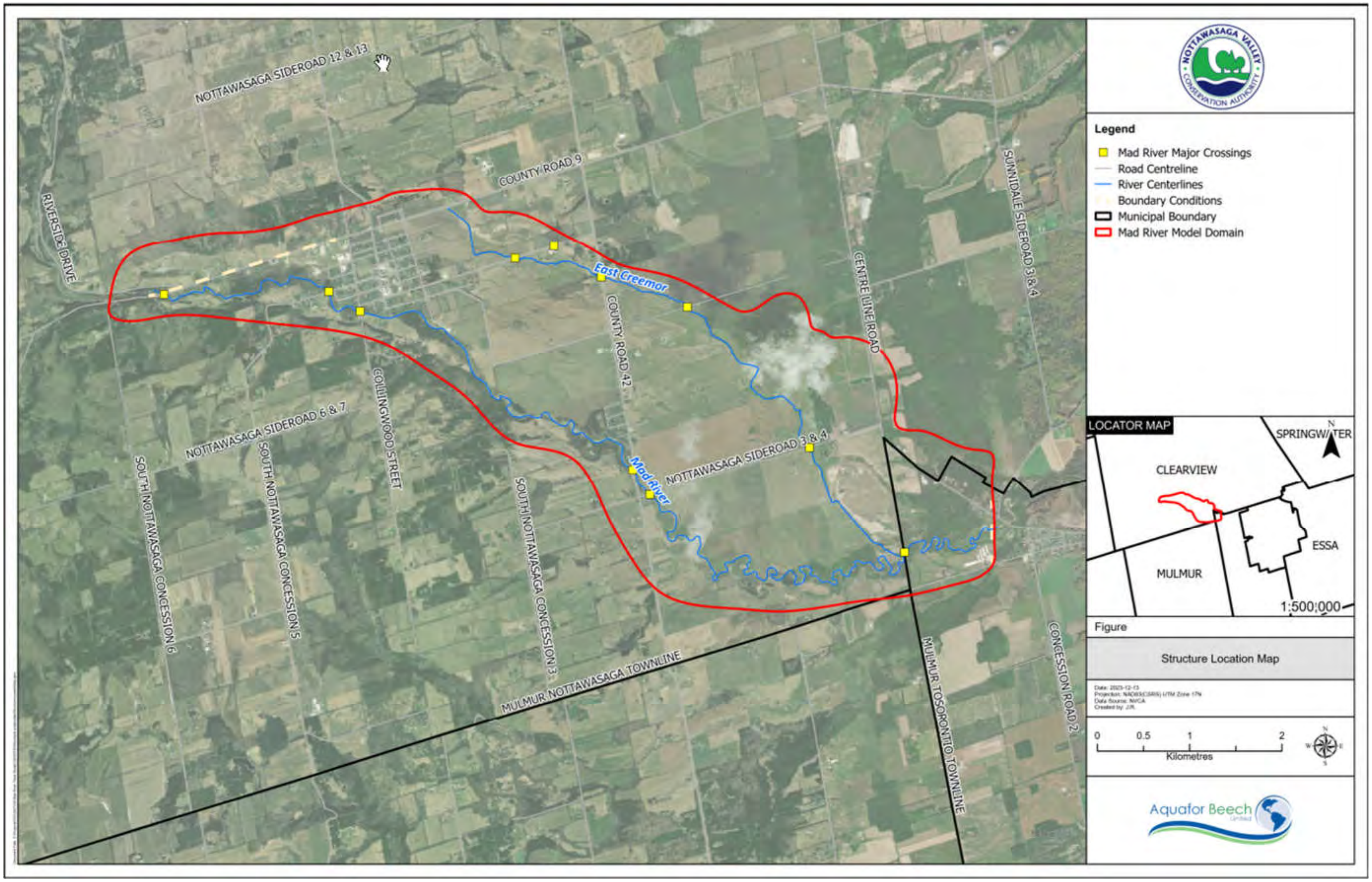

Figure 2-2. Location of the Watercourse Crossing Structures

2.5 Bathymetry Survey

Aquafor identified data gaps within the LiDAR-derived DTM regarding low flow channel characteristics. Therefore, in addition of the detailed hydraulic structure survey, Aquafor undertook a detailed topographic survey of river cross-sections at different locations to complete the hydraulic modelling geometry. In total, 47 stream cross-sections were surveyed throughout the study area, including 4 cross-sections at each crossing structure (2 upstream and 2 downstream) and an additional 3 cross-sections located between structures to better define watercourse bathymetry. The topographic elevation survey of the river cross-sections identifies the locations and elevations of the thalweg, streambed topography, bottom and top of bank, and overbank topography within the floodplain.

3 TOPOGRAPHY DATA CHECK METHODOLOGY

As part of the vertical check process, Aquafor has validated the topographic data using 62 points collected throughout the study area on hard surfaces (e.g., road profiles). All Aquafor's topographic surveys have been collected between October and November 2023. The spot height checks are considered satisfactory for a given catchment when 95% of the elevation of the topography data source (i.e., DTM, DEM, etc.) are within 0.196 m of the GPS field measurement, as per CQL1 described in the Federal Airborne LiDAR Data Acquisition Guideline (2022). This threshold was confirmed with NVCA staff prior to completing the LiDAR verification analysis.

To validate the elevations in the provided LiDAR DEM, Aquafor staff utilized RTK GPS to survey 62 points throughout the study area. The GPS unit used is capable of providing ultra-high accuracy position data; all surveyed points were collected with a minimum precision of 20mm. All survey data was collected using the following, for consistency with LiDAR data:

- Coordinate System: Universal Transverse Mercator, Zone 17 North (UTM 17N)
- Horizontal Datum: North American Datum of 1983 (NAD83)
- Vertical Datum: Canadian Geodetic Vertical Datum of 2013 (GCVD2013)

Points were taken on hard, relatively flat surfaces such as roadways. These surfaces are less likely to have experienced any change in elevation between the collection of the LiDAR and the survey, are reduce any potential interference from tree cover on GPS signal strength or the LiDAR collection.

At each check point, the elevations obtained from the survey were compared to the DEM elevation at the same position. Statistical analysis was then completed to determine average, minimum, and maximum elevation difference, standard deviation, and 95th percentile values.

Table 3-1. Topographic Data Check

Point #	Northing	Easting	Survey Elev (m)	Survey Code	Lidar Elev (m)	Elevation Difference (m)	Absolute Difference (m)
100	4906182.487	574419.3665	235.0596	CL	235.023	0.04	0.036605005
101	4906176.084	574398.5711	235.0597	CL	234.977	0.08	0.082694995
102	4906170.054	574379.057	235.0397	CL	235	0.04	0.0397
103	4906164.468	574361.3481	235.1198	CL	235.094	0.03	0.025805859
104	4906158.634	574342.171	235.1795	CL	235.227	-0.05	0.047505005
105	4906152.738	574322.7047	235.3362	CL	235.312	0.02	0.02420354
106	4906146.865	574303.485	235.3924	CL	235.367	0.03	0.025395605
107	4906140.262	574281.9514	235.7447	CL	235.727	0.02	0.017694995
108	4906134.5	574263.3752	236.2075	CL	236.203	0.00	0.00449707
109	4906128.822	574244.8017	236.577	CL	236.602	-0.03	0.025005005
111	4906110.384	574182.2557	238.2844	CL	238.344	-0.06	0.059594141
112	4906105.017	574164.8093	238.7716	CL	238.82	-0.05	0.048407324
113	4906099.517	574147.6124	239.1866	CL	239.188	0.00	0.00140354
114	4906094.542	574130.3745	239.3023	CL	239.289	0.01	0.013298535
115	4908836.804	573246.3032	251.885	CL	251.852	0.03	0.032994995
116	4908830.209	573226.553	250.4463	CL	250.367	0.08	0.079295605
117	4908823.014	573204.1391	249.4154	CL	249.32	0.10	0.095392676
118	4908816.519	573182.976	248.8079	CL	248.758	0.05	0.049904395
119	4908809.938	573161.551	248.5362	CL	248.453	0.08	0.08319707
120	4908803.742	573141.5159	248.465	CL	248.391	0.07	0.07399353
121	4908797.543	573121.1276	248.5926	CL	248.453	0.14	0.13959707
122	4908794.471	573111.2743	248.6408	CL	248.492	0.15	0.148795605
123	4908713.72	572854.974	249.8918	CL	249.828	0.06	0.06379707
124	4908706.471	572833.279	250.1108	CL	249.953	0.16	0.15779707
125	4908700.603	572813.8562	250.2169	CL	250.094	0.12	0.122905859
126	4908694.575	572794.5626	250.3483	CL	250.25	0.10	0.0983
127	4908687.927	572773.8251	250.4647	CL	250.359	0.11	0.10570647
128	4908678.807	572746.9138	250.5279	CL	250.438	0.09	0.08989646
129	4908672.755	572726.9258	250.651	CL	250.578	0.07	0.07299707
130	4908666.42	572706.6611	250.8117	CL	250.742	0.07	0.069695605
131	4908661.22	572689.2477	250.9051	CL	250.859	0.05	0.04610647
132	4908655.061	572669.4487	251.0468	CL	251	0.05	0.0468
133	4908649.165	572650.976	251.2623	CL	251.18	0.08	0.082307324
134	4908643.616	572633.0856	251.4418	CL	251.391	0.05	0.05079353
135	4907984.532	571096.8763	265.7371	CL	265.758	-0.02	0.020895605
136	4908005.062	571093.6026	264.0986	CL	264.18	-0.08	0.081392676
137	4908026.803	571090.5236	263.0761	CL	263.047	0.03	0.02910293
138	4908048.858	571087.2756	262.3632	CL	262.391	-0.03	0.027791211
139	4908069.58	571084.0286	261.9881	CL	262.008	-0.02	0.019895605
140	4908127.649	571074.8505	261.0296	CL	261.109	-0.08	0.079408789
141	4908148.878	571071.591	260.8446	CL	260.758	0.09	0.086604395
142	4908174.828	571067.5564	260.4846	CL	260.539	-0.05	0.054401465

143	4908198.44	571063.6249	260.5075	CL	260.539	-0.03	0.031501465
144	4908215.445	571060.8669	260.5281	CL	260.547	-0.02	0.01889707
145	4908235.628	571057.3907	260.5267	CL	260.547	-0.02	0.02029707
146	4908367.924	570903.5914	261.738	CL	261.719	0.02	0.019005859
147	4908363.079	570888.4734	261.7379	CL	261.742	0.00	0.004104395
148	4908354.942	570861.8125	261.8835	CL	261.883	0.00	0.000504395
149	4908349.675	570838.7813	262.0707	CL	262.047	0.02	0.02370293
150	4908342.466	570821.1956	262.2249	CL	262.203	0.02	0.02189707
151	4908336.331	570801.123	262.4479	CL	262.422	0.03	0.02590293
152	4908330.608	570781.6489	262.6051	CL	262.578	0.03	0.02709707
153	4908324.229	570759.1289	263.8	CL	263.82	-0.02	0.020007324
154	4908309.88	570710.909	264.083	CL	264.023	0.06	0.059989746
155	4908303.687	570690.2248	263.8459	CL	263.852	-0.01	0.006089746
156	4908297.463	570670.932	263.7805	CL	263.789	-0.01	0.008501465
157	4908292.279	570654.9159	263.9495	CL	263.93	0.02	0.019507324
158	4908285.926	570633.1891	264.127	CL	264.102	0.03	0.025010254
159	4908279.765	570612.5235	264.2575	CL	264.258	0.00	0.000495605
160	4908274.437	570595.267	264.3769	CL	264.367	0.01	0.009895605
161	4908268.982	570577.4718	264.5484	CL	264.562	-0.01	0.013611719

A summary of the analysis results can be found in **Table 3-2**, below.

Table 3-2. Topography Check Results Summary

Statistic	Value (m)
Average Difference	0.029
Median Difference	0.025
Standard Deviation	0.054
Min Difference	-0.081
Max Difference	0.158
95th Percentile	0.123

As shown, the average difference between the LiDAR DEM and surveyed elevations was 0.029m. 95% of points fall within 0.12m of difference, well below the 0.196 m threshold. This demonstrates the quality and consistency of the LiDAR data, and will ensure accuracy of the hydraulic modelling and floodplain mapping.

4 HYDROLOGIC MODEL DEVELOPMENT

Preliminary HEC-HMS hydrologic modelling was completed by the Oak Ridges Moraine Groundwater Program (ORMGP) in October 2023. In accordance with the RFP, Aquafor completed a peer review of the ORMGP hydrologic modelling and reporting and provided the NVCA with a Technical Review Memorandum on October 30th, 2023. The original ORMGP report has been provided in **Appendix A** while the Aquafor Technical Peer Memorandum has also been included in **Appendix A** for reference. Aquafor and the NVCA discussed the Technical review comments in November 2023 and it was mutually agreed that refinements to the HEC-HMS modelling were required to finalise the hydrologic modelling for the project. Due to the progression of the project schedule and requirement for finalised peak flow values to produce floodplain mapping, the NVCA has further acquired Aquafor's technical services to address the October 2023 Technical Review comments.

Updates to the model were primarily undertaken to address deficiencies that were noted in our Technical Review of the existing hydrologic model and accompanying report, and to ensure compliance with the funding requirements for the Flood Hazard Identification and Mapping Program (FHIMP).

The hydrologic model was run for the 2-year, 5-year, 10-year, 25-year, 50-year, 100-year, Timmins, and Timmins with Climate Change events. The Timmins storm event under the effects of climate change was found to produce substantially higher flows than under historic climate conditions. Based on this analysis, it is anticipated that regulatory peak flows at the watershed outlet (Jun-01) would increase from 227.45 m^3/s to 311.58 m^3/s due to climate change, which represents a 37.0% increase. Hydrographs produced by this updated hydrologic model will subsequently be used as inputs to the hydraulic model for floodplain mapping purposes. Results are presented at key junctions in **Table 4-1** below. Peak flows for all junctions are recorded in **Appendix A**.

Table 4-1: Peak Flows at Key Locations within the Upper Mad River Flood Study Area

Junction ID	Description	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	Timmins	Timmins with Climate Change
Jun-06	Main Branch at County Road 9	44.06	67.31	83.07	102.91	117.71	132.42	161.75	220.47
Jun-05	Main Branch Upstream of Creemore	46.98	71.87	88.73	109.94	125.78	141.57	171.84	234.40
Jun-03	Main Branch at the WSC Avening Gauge	50.66	77.66	95.88	118.79	136.06	153.17	187.20	255.94
Jun-02-1	Outflow from the East Creemore Drain (Flowing to the North of Creemore)	5.39	8.35	10.42	13.06	15.04	17.02	31.32	42.68
Jun-02	Confluence of the Main Branch with the East Creemore Drain	59.14	90.62	112.01	137.29	156.81	176.36	226.43	310.07
Jun-01	Outflow of the Upper Mad River Watershed	59.28	90.86	112.23	137.35	156.95	176.57	227.45	311.58

5 1D HYDRAULIC MODEL DEVELOPMENT

5.1 1D Model Software and Platform

Preliminary 1D hydraulic modelling of the Mad River was built using the HEC-RAS software (ver. 6.4.1).

5.2 General

Prior to initiating the build of the hydraulic model, the LiDAR DTM data was reviewed to gain an understanding of the anticipated minor and major system flow paths within the study. Based on this detailed review it is anticipated that flows producing water surface elevations less than the top of bank elevations within the Mad River will be contained within the defined channel network of the study area. Bank full flows have been calculated at 70 - 100m3/s depending on location based on generic 1D cross sectional data and manning's flow calculations. However, as illustrated in **Table 4-1** in **Section 4**, the Timmins Regional Peak flows range between 161.75m3/s to 187.20m3/s whereby inferring that approximately 50% of the total Regional flow is expected to overtop the river banks and enter the floodplain corridor. Upon further review of the LiDAR DTM data, we note an absence of defined geometry within the floodplain of the Mad River. Further we note that the topography generally falls at a 0.05 to 0.06% grade to the east and also a 0.04 to 0.05% to the south. **Figure 5-1** illustrates the major fall directions (white arrows) within the floodplain of the Mad River through the village of Creemore.

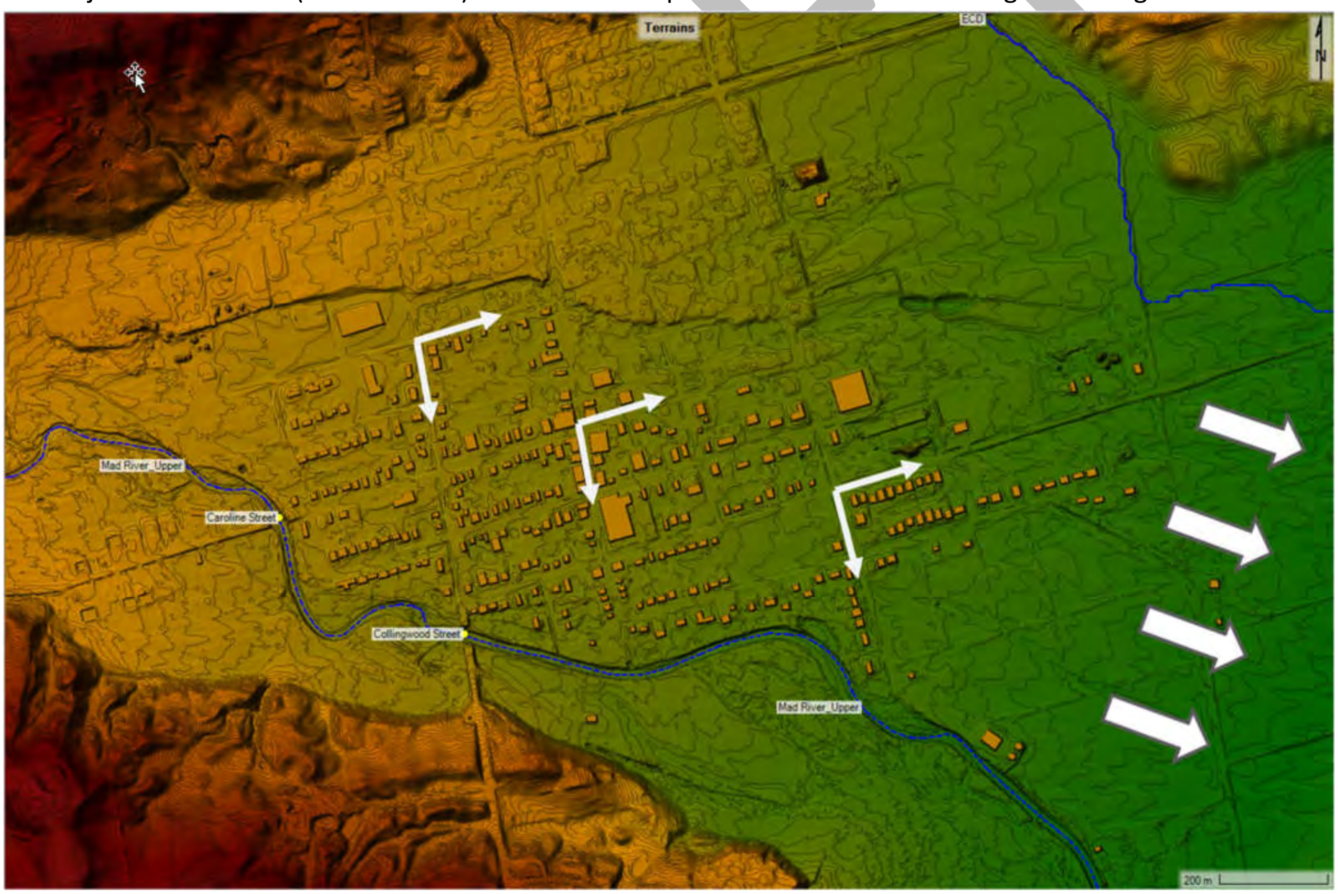

Figure 5-1. Mad River Floodplain (through Creemore) Fall Directions

In addition to the above, we note the absence of a defined flow path through the village of Creemore and further throughout the north (left) overbank the Mad River. This implies that should flows leave the main reach of the Mad River, residual flows may flow through the wide floodplain area and may not re-enter the main reach of the river until some distance downstream. Based on the assessment of the topographical features as noted above, it is anticipated that a 1D Hydraulic model may not accurate depict the Regional flood characteristics of the Mad River.

In lieu of the above, we have constructed a preliminary 1D Hydraulic model through the study area to assess both opportunities and constraints associated with peak flow characteristics of the floodplain of the Mad River. Details surrounding the construction of the 1D HEC-Ras hydraulic model have been outlined below.

5.3 Channel Network and Cross-Sections

The watercourse network to be mapped was determined by Aquafor using the 2023 LiDAR derived DTM using the Ras Mapper within HEC-RAS 6.4.1. Within a HEC-RAS hydraulic model, the term “River” refers to a watercourse made of multiple “Reaches”. In total, 23.4 km of river divided between two (2) reaches are simulated in the hydraulic model as presented in **Table 5-1**.

Table 5-1. HEC-RAS River and Reach Nomenclature

HEC-RAS River Name	HEC-RAS Reach Name	Total Channel Length (m)
Mad River	Upper	15,666
East Creemore Drain (ECD)	Main	7,740
Total Length (m)		**23,406**

A base model was generated in HEC-RAS using the 2023 LiDAR-derived DTM. In addition to the watercourse network, 2023 LiDAR-derived DTM elevation data was used to define channel cross-sections and overbank locations within the majority of the study area.

Cross-sections were spaced to account for changes in channel geometry, meanders, bridge/culvert/weir structures, and to account for the narrowest sections of the creeks. Additionally, cross-sections were placed close enough to ensure accurate computation of the energy losses. As per standard modeling procedures, cross-sections were extended across the entire floodplain and oriented perpendicular to the anticipated flow lines.

5.4 Hydraulic Structures (Bridges and Culverts)

Hydraulic structures included in this study consisted of bridges and culverts. Four cross-sections (i.e., 2 upstream and 2 downstream of each structure) were coded at each crossing structure to define streambed and floodplain geometry at close proximity of the structure, as well as to account for expansion and contraction of the flow at these structures.

The spacing of these cross-sections was consistent with the HEC-RAS reference manual (US Army Corps of Engineers, 2022), estimated using the recommended flow expansion and contraction. In general, the locations for the upstream cross-sections were selected by assuming a typical flow contraction ratio of 1:1, while the downstream cross-section locations were selected based on expansion ratios that were typically in the range of 2:1 (**Figure 5-2**).

Structure parameters were then coded consistent with the approaches defined in **Figure 5-2**, including the structure material, opening dimensions, invert elevations, skew angles, depth of embedment, etc. Road profiles were mostly defined using LiDAR DEM and cross referenced with background information. In addition, the height of railing was added to the road profile for certain bridges, where the railing or fencing was anticipated to act as a blockage under high flows. In this case, 100% blockage was coded in the model to be conservative.

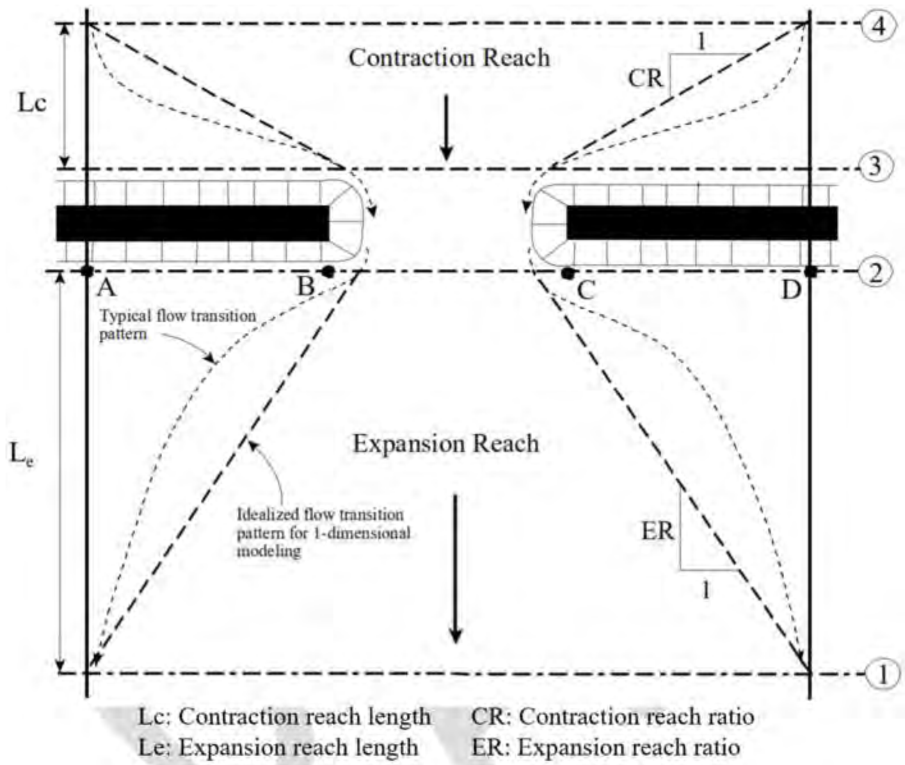

Figure 5-2. Cross-Section Locations at Crossing Structures (US Army Corps of Engineers, 2022)

A coefficient was applied to each culvert crossing to account for the energy loss by the entrance and exit of the culvert. Those entrance and exit loss coefficients depend on the culvert upstream and downstream face characteristics (i.e., projecting, mitered to the slope, wingwalls, etc.,) and were determined based on the field condition (field notes and photos), using values from the HEC-RAS reference manual.

It's important to note that for high flow bridge computation, the pressure and weir flow calculation were chosen when a bridge was under pressure for the 100-year storm. If the coded bridge was partially under pressure (only the upstream water surface elevation reaches the soffit elevation), the discharge coefficient applied was 0.5 while when the bridge was fully submerged (upstream and downstream faces of the bridge submerged), the discharge coefficient applied was 0.8.

5.5 Ineffective Flow Areas and Levees

The ineffective flow area option was applied in the model to restrict the flow area to the width of the structure opening until the structure is overtopped and weir flow begins over the road structure. Ineffective flow areas were coded in accordance with HEC-RAS Hydraulic Reference Manual (USACE, 2016) where stations were placed each side of the structure opening at a 1:1 ratio in upstream and 2:1 ratio in downstream of the distance between the bounding cross-sections and structure faces. The ineffective flow elevations upstream were set to the lowest point of the top-of-road (minimum weir elevation) and downstream to the average between the soffit and minimum top-of-road. Refinements were made after the initial run where surface water elevations were confined by the ineffective flow areas.

Levees have been added to the model at some roads and other topographic high points in order that the estimated water surface elevation remains concentrated in the main streambed until the flood flow reaches the levee elevation and spreads within the floodplain depressions.

5.6 Contraction and Expansion Coefficients

Contraction and expansion coefficients were coded in the model to evaluate transition loss due to changes of flow between cross-sections. These coefficients were applied differently between regular cross-sections and structure cross-sections following the recommended values, as summarized in **Table** 5-2**5-2**.

Table 5-2. Contraction and Expansion Loss Coefficients used in the HEC-RAS Model

	Contraction Coefficient	Expansion Coefficient
Regular Cross-sections	0.1	0.3
Structures	0.3	0.5

5.7 Manning's Roughness Coefficients

Manning's roughness coefficients were assigned to each cross-section based on the SOLRIS land use layer (ver. 3.0), which was retrieved from the Ontario GeoHub database. The Mad River and its tributaries flow through a mix of land uses within the study area, consisting mostly natural coverage with some urbanization in the communities of Creemore and Avening, which typically have wide range of Manning roughness values. These values were defined as shown in **Table 5-3**, based on the Technical Guidelines for Flood Hazard Mapping (EWRG, 2017) and the MTO Drainage Management Manual (Design Chart 2.01, 1997). A map illustrating the different land uses within the watershed is shown in **Figure 5-3**.

Table 5-3. Manning's Roughness Values used in the HEC-RAS Model

Classification	Manning's Roughness Value
NoData	0.055
Coniferous Forest	0.08
Hay-Pasture	0.08
Row Crop	0.05
Rural	0.05
Transitional	0.08
Quarry	0.05
Deciduous Forest	0.08
Mixed Forest	0.08
Water	0.035
Open Wetland	0.08
Woody Wetland	0.08
Urban Impervious	0.05
Urban Pervious	0.035
Cemetaries	0.08
Road	0.05

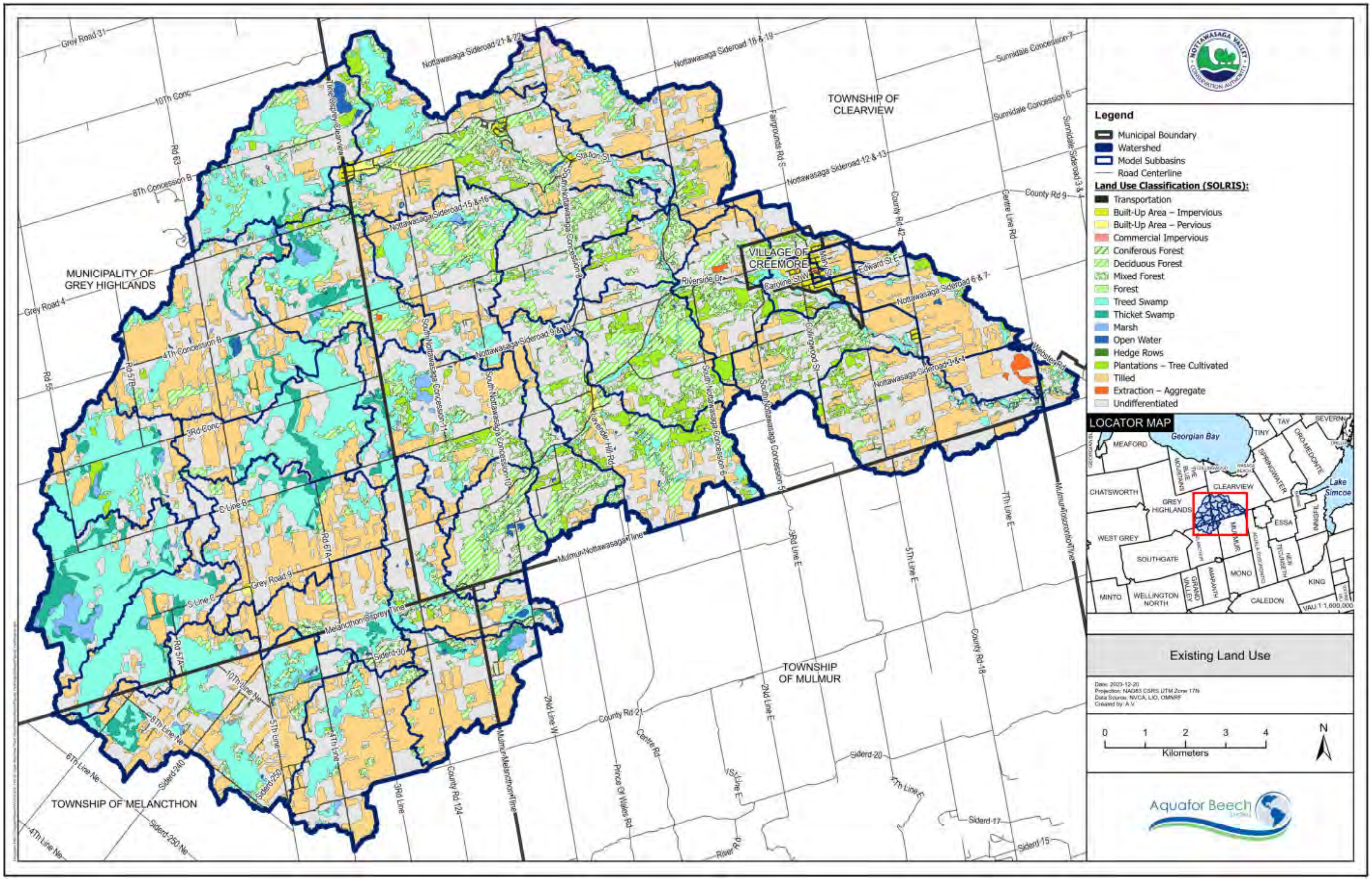

Figure 5-3. Land Use and Manning's N Coefficients within Mad River Watershed

5.8 Preliminary 1D HEC-RAS Results

Preliminary 1D HEC-RAS modelling results confirm the presence of flood flows exceeding bank full capacity of the Mad River. The Timmins Regional, 1D Flood depth has been illustrated in **Figure** 5-3**5-4** for reference. Upstream of Caroline Street, within the village of Creemore, Regional water surface extents have been observed to surround the Creemore Arena (single white arrow), located north of Wellington Street. Further, Regional water surface extents have also been observed enter the floodplain upstream of the Creemore Waste water treatment plant (double white arrows).

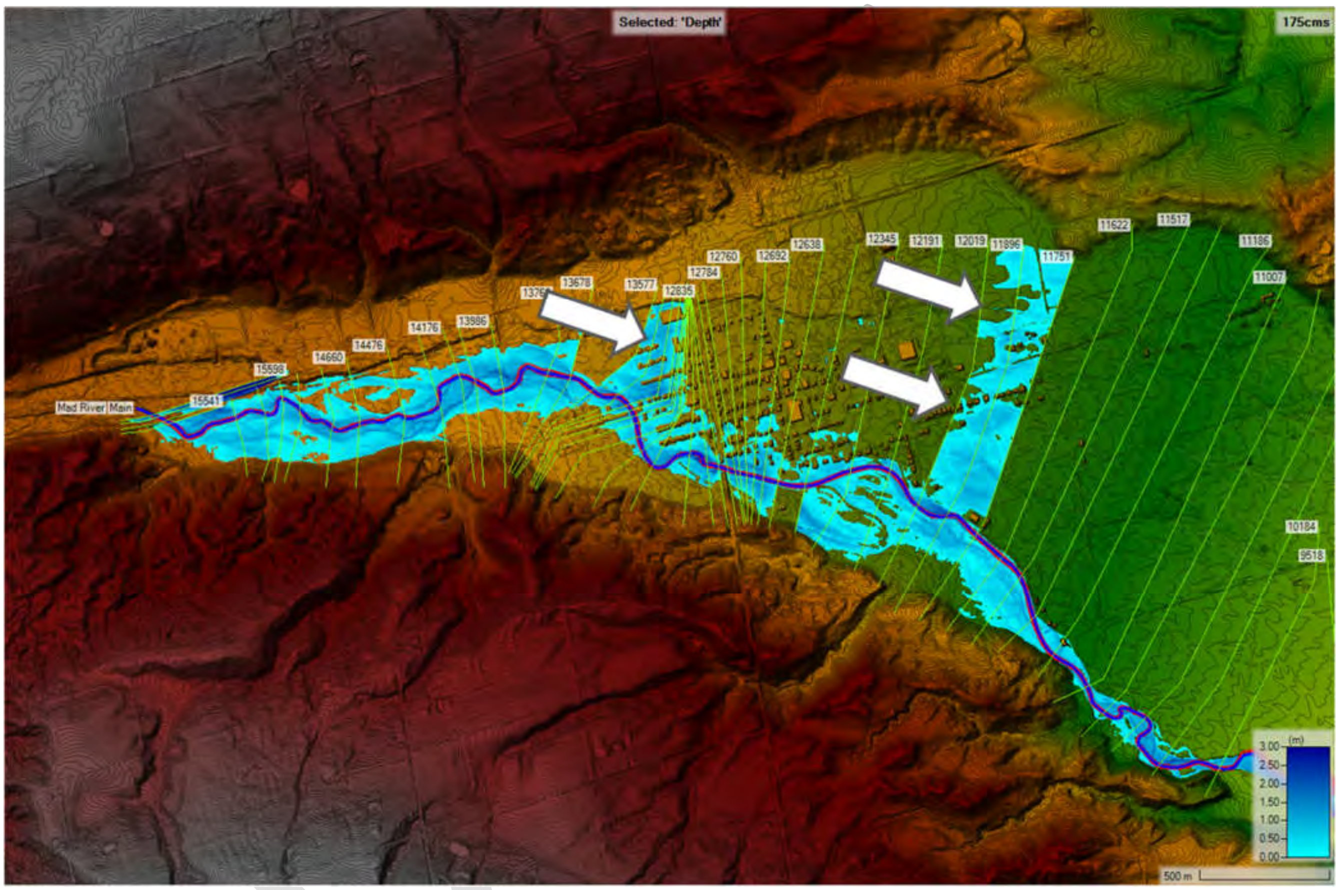

Figure 5-4. 1D Timmins Regional Flood Depth Results

As outlined in Section 5.2, the fall direction of the Mad River floodplain through the village of Creemore resides in both an East and South direction. This unique characteristic of the floodplain prevents the full containment of peak flows within a defined riverine corridor. As peak flows exceeding the bank full capacity of the river would be conveyed in a west to east direction through the village of Creemore. While a portion of the Regional peak flows may be directed back to the river itself, a large portion of the peak flows exceeding the banks of the river, will spill into the wide floodplain and be separated from the main reach itself.

Given the relatively flat nature of the topography within the floodplain coupled with contours residing perpendicular to the spill flow direction, a 1D hydraulic model will not accurately present Regional Floodplain characteristics within the study area.

The preliminary 1D HEC-RAS hydraulic results were reviewed with the NVCA in December 2023 for additional discussion. Based on the analysis of the 1D HEC-RAS hydraulic results it was mutually agreed between both NVCA and Aquafor senior staff that a 2D HEC-RAS hydraulic model would be applicable for use in the study area. Accordingly, a 2D HEC-RAS model as been constructed for the Mad River Flood Hazard Mapping project. Details surrounding the 2D modelling specifics have been provided below.

6 2D HYDRAULIC MODELLING

6.1 2D Hydraulic Model Platform

Detailed 2D hydraulic modelling of the Mad River was built using the HEC-RAS software (ver. 6.4.1). Preliminary floodplain mapping was also generated using HEC-RAS results and elevation surface data.

6.2 Terrain and Modifications

The LiDAR provided by NVCA consists of 1 x 1 km tiles and covers a 22,000m2 area. Aquafor has merged the tiles to work with a single Terrain file within the HEC-RAS modelling. Terrain modifications have been added within the RAS Mapper to accurately represent key hydraulic features within the hydraulic modelling including buildings and culvert crossings.

6.2.1 *Building Obstructions*

Primary buildings located within the study area have been identified via aerial imagery and built into the terrain as a polygon modification layer. Primary buildings are classified as the largest residential dwellings, commercial, institutional and industrial buildings located on each parcel within the study area. Smaller buildings such as sheds, storage units, etc have not been added to the terrain. Building heights and elevations have been arbitrarily set in the terrain to an elevation of 265m which resides, on average, 4-5m above surface elevations. A total of 394 buildings have been added to the model.

6.2.2 *Channel Improvements*

Invert elevations of culvert crossings on Edward Street, Airport Road and Nottawasaga Sideroad 3 have been identified as residing below the LiDAR DTM data. Accordingly, to accurately replicate culvert hydraulics within the 2D modelling environment, Terrain modifications have been performed along the profile of the existing roadway culverts in the form of a Ground Line Modification. The Lower (Terrain/User) Value option has been selected to provide a nominally lower elevation profile (≤ 1cm) through each culvert crossing.

6.3 2D Flow Area and Perimeter

The 2D modelling perimeter has been configured with the assumption that regional peak flows may occupy a wide footprint within the valley corridor of the Mad River. Accordingly, the 2D perimeter extends approximately 750m upstream of County Road 9 and generally follows the large/wide valley corridor of the Mad River floodplain to the LiDAR data extends located approximately 1km downstream of Centerline Road. The horizontal extents of the perimeter have been placed within the upslope of the valley corridor to ensure containment of peak flows. **Figure 6-1** illustrates the 2D modelling perimeter of the study area.

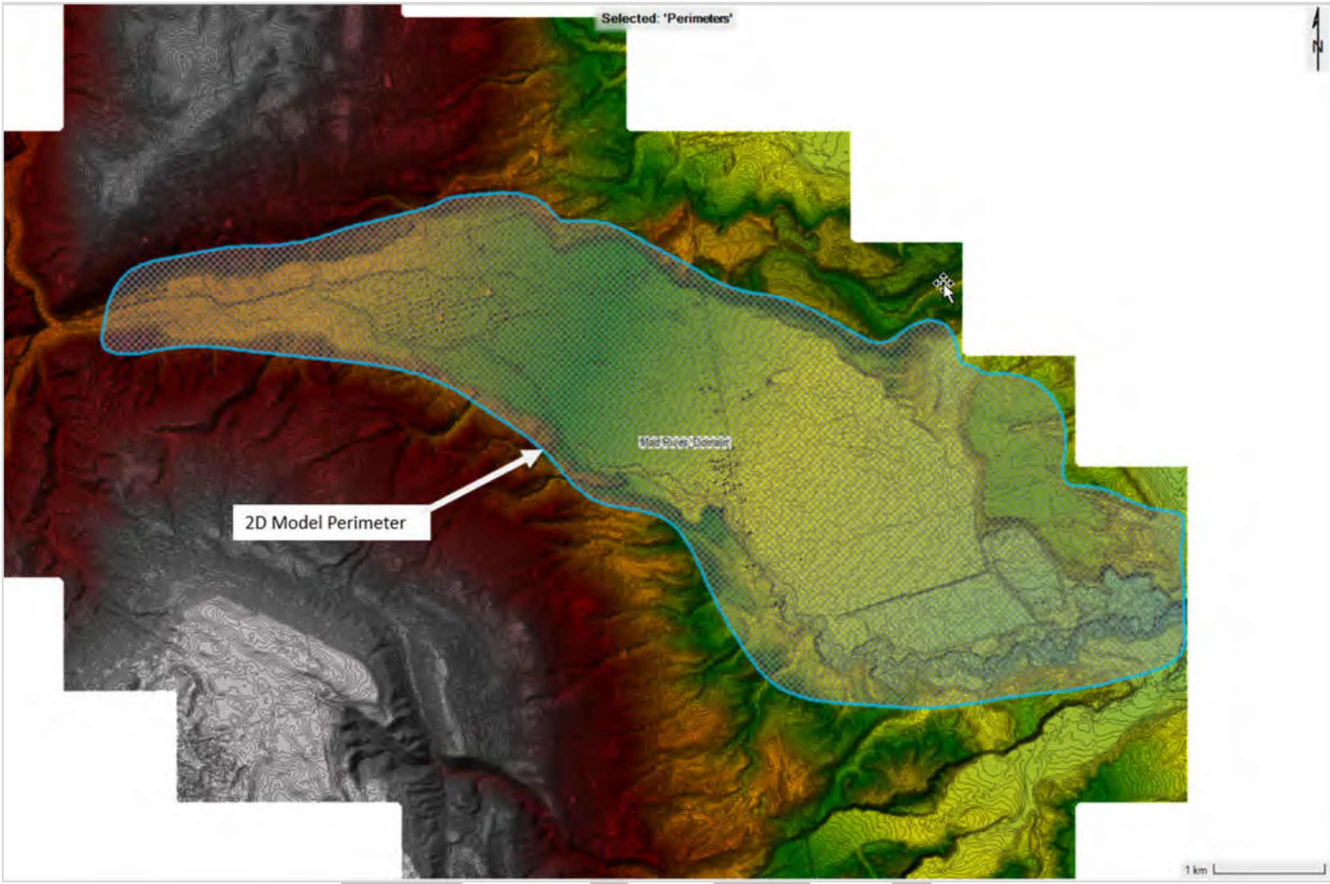

Figure 6-1. 2D Model Perimeter

As noted in the HEC-RAS 2D User's Manual;

"Assigning an appropriate mesh cell size (or sizes) and computational time step (ΔT) is very important to getting accurate answers with 2D flow areas."

Accordingly, a generic 30 (X) by 30 (Y) hexagonal cell mesh distribution has been used as a mesh default, given the relatively flat sloping grades of the study area and anticipated Regional floodplain extents. Additional mesh detail has been provided via breaklines within the model at reduced spacing/intervals to refine the mesh within the banks of the Mad River, Urban settlement areas and within roadway right-of-ways. The 2D flow area mesh specifics have been provided in **Table 6-1**.

Table 6-1. 2D Flow Area Mesh Specifics

Number of Cells	Average Face Length	Average Cell Size	Maximum Cell Size	Minimum Cell Size
76501	16	264	1,913	3

Details surrounding the selection of an appropriate computational time step have been provided in Section 6.8.

6.4 2D Breaklines

Breaklines have been added to the HEC-RAS hydraulic model to refine the 2D mesh and provide a higher level of computational detail in key locations including Local and Rural Roadways, Rivers and Stream Corridors and Culvert Crossings.

For rivers and watercourses, breaklines have been strategically placed to identify the centerline of the watercourse between roadway crossings. Breakline attributes for rivers and watercourses have been selected to replicate bank full flow widths and channel depths. Breaklines used to refine the mesh within roadway corridors have been coded to identify the centerline of roadway, driving lane width and roadway embankments. Further, we have identified both Local and Rural roadway types within the study area and have provided an enhanced level of detail with Local Roadways through the settlement areas of Creemore and Avening.

As noted previously, with the potential of peak flows being conveyed in both a North to South and West to East Direction, we have separated the Local Roadway Breaklines into Primary and Secondary Breaklines. Primary Breaklines are continuous breaklines residing on Local Streets in a North to South direction. Secondary breaklines are non-continuous and reside on Local Streets in a West to East direction. This orientation of breaklines within the Local Streets in the project area is intended to identify primary flow pathways to the Mad River first while providing access to the floodplain/spill areas as a secondary flow pathway where/if present. Details surrounding the Near Spacing, Near Repeats and Far Spacing of the 2D breaklines used in the project area have been identified in **Table 6-2**;

Table 6-2. 2D Breakline Attributes

	Near Spacing	Near Repeats	Far Spacing
Local Roadways	5	2	5
Rural Roadways	10	2	5
River	6	0	6

All breaklines have been enforced within the 2D mesh. A visual representation of the Primary and Secondary Road Breaklines, River Centerlines and Building breaklines has been provided in **Figure 6-2**;

Figure 6-2. 2D Breaklines

6.5 2D Computation Points

In addition to the default Computational Points derived by the RAS Mapper, Computational points were added to the 2D Mesh in the direct vicinity of roadway culvert inlets and outlets. These additional computational points provide an enhanced level of mesh detail at key locations in the hydraulic model to aid in computational efficiency and accuracy of roadway culvert crossings. Additional computational points have also been added, where required, to the mesh to retain a maximum of eight (8) cell sides within in overall 2D mesh in accordance with the 2D HEC-RAS Users Manual.

6.6 2D SA/2D Connections

Roadway Culvert and Roadway Bridge crossings have been added to the 2D HEC-RAS model via SA/2D Connections. Detailed crossing information including were then coded consistent with the approaches defined in **Figure 5-2**, including the structure material, opening dimensions, invert elevations, skew angles, depth of embedment, etc. Road profiles were defined using LiDAR DEM and topographic survey information. Where present, roadway guardrails and railings were added to the road profile where the it was anticipated that peak flows may overtop the roadway and the guardrail may act as a flow barrier under high flow events. In this case, 100% blockage was coded in the model to be conservative. Detailed hydraulic inventory sheets of each structure within the project area have been provided in **Appendix B.**

6.7 2D Boundary Conditions

A total of three (3) boundary conditions have been applied to the 2D model including two inflow hydrographs and a downstream boundary condition. Details surrounding each of the applied boundary conditions as has been applied below;

- Inflow Hydrograph → River: Mad River → Junction Jun-05, located immediately upstream of the village of Creemore on the main reach of the Mad River, has been conservatively applied at the upstream limits of the study area, north of County Road 9 as an External Flow Hydrograph. The Energy Gradeline Slope for distributing flow along the boundary condition line has been set to 0.007592 m/m as measured directly from the Mad River profile at the upstream limits of the project area;

- Inflow Hydrograph → River: Edward Street Drain (ECD) → Junction Jun-09, located at Edward Street, east of the village of Creemore has been conservatively applied at the downstream limits of the County Road 9 culvert crossing (upstream limits of the ECD) as an Internal Flow Hydrograph. The Energy Gradeline Slope for distributing flow along the boundary condition line has been set to 0.007592 m/m as measured directly from the ECD profile at the upstream limits of the project area;

A visual representation of each inflow hydrograph has been provided in **Figure 6-3 and Figure 6-4;**

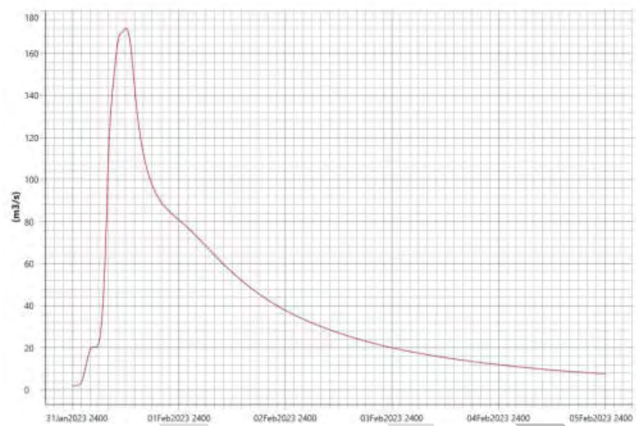

Figure 6-3. River: Mad River → Junction Jun-05 → Timmins Regional Max Peak Flow Q = 171.79 cms

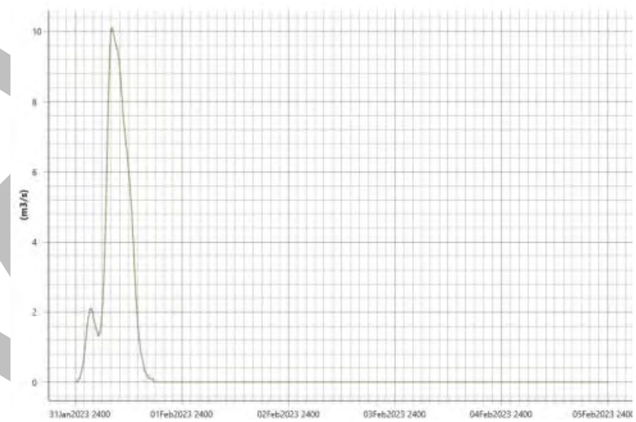

Figure 6-4. River: ECD → Junction Jun-09 → Timmins Regional Max Peak Flow Q = 10.1 cms

- Downstream Boundary Condition → River: Mad River → Normal Depth. The Normal Depth Boundary condition has been selected for the downstream limits of the project area. A normal depth slope of 0.002383 m/m has been set and measured directly from the Mad River profile at the downstream limits of the project area. We note that the 2D Flow Area Boundary Condition Parameter has been set to "Compute Single Water Surface for Entire BC Line" to tie into NVCA 1D HEC-RAS hydraulic modelling downstream of the study area. Given the relatively steep slope of the river, the downstream boundary condition in the 2D model will only influence flood elevations at or near the downstream limits of the project area only and will not influence the anticipated spill conditions within the floodplain.

6.8 2D Computational Settings

To provide an accurate representation of all flow events within the 2D modelling environment, we have selected the following computational settings;

- Computational Interval: 30 Seconds
- Detailed Output Interval: 1min
- 2D Un-Steady State Flow Routing – The Diffusion Wave Equation and Shallow Water Equation Eulerian-Lagrangian Method (SWE-ELM) Equation have been both ran in the 2D modelling environment to assess modelling stability and accuracy. Additional commentary surrounding the preferred routing alternative has been provided in **Section 6.9.1**;
- Advanced Time Step Control – Adjusted Time Step based on Courant.

6.9 Evaluation of 2D Modelling Stability

6.9.1 *2D Un-Steady State Flow Routing*

As noted in Section 6.8, two separate plan files have been created to run the Mad River 2D model with Diffusion Wave and Shallow Water Equation Eulerian-Lagrangian Method (SWE-ELM) routing equations. To observe the modelling differences between both routing methods, profile lines were created along the main north-south streets within the village of Creemore. **Figure 6-5** illustrates the Timmins Regional flow depth along the centerline of Mill Street, Creemore, ON using both routing methods as an example;

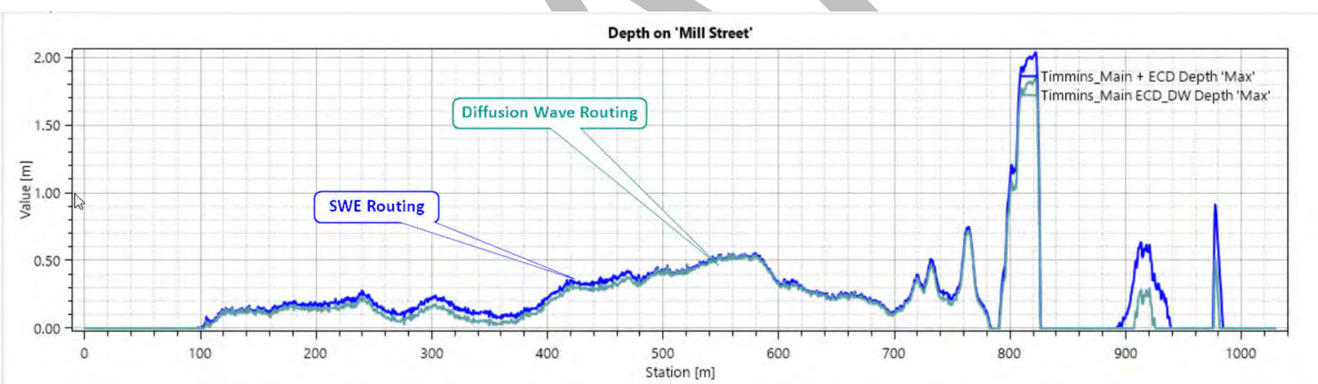

Figure 6-5. 2D Routing Method Comparison

Generally, the Regional depth results from both routing methods are comparable with an average difference of 0.04m and a maximum difference of 0.39m. As the SWE routing equation provides a slightly higher and more conservative flood depth, the SWE routing equation has been used for further analysis and carried forward for use in the production of Regulatory floodplain mapping.

6.9.2 *Mesh and Time Step Analysis*

To assess the consistency capabilities of the 2D mesh with respect to cell sizing and the selected time step for the Regulatory Event, the Courant (Velocity/Length) Results map has been developed and reviewed. As noted in the HEC-RAS 2D User's Manual;

*"For the **Courant** number method, the default approach for computing the Courant number is to take the velocity times the time step divided by the length (between 1D cross sections, or between two 2D cells). For 2D, the velocity is taken from each face and the length is the distance between the two cell centers across that face."*

Based on the above, it is desirable obtain a maximum courant value of less than 1.0. However, it is possible for the 2D model to produce a courant value of greater than 1 and still produce a stable and accurate solution. **Figure 6-6** below illustrates the Courant (Velocity/Length) Map for Timmins Regulatory event followed by additional commentary surrounding the calculated courant values.

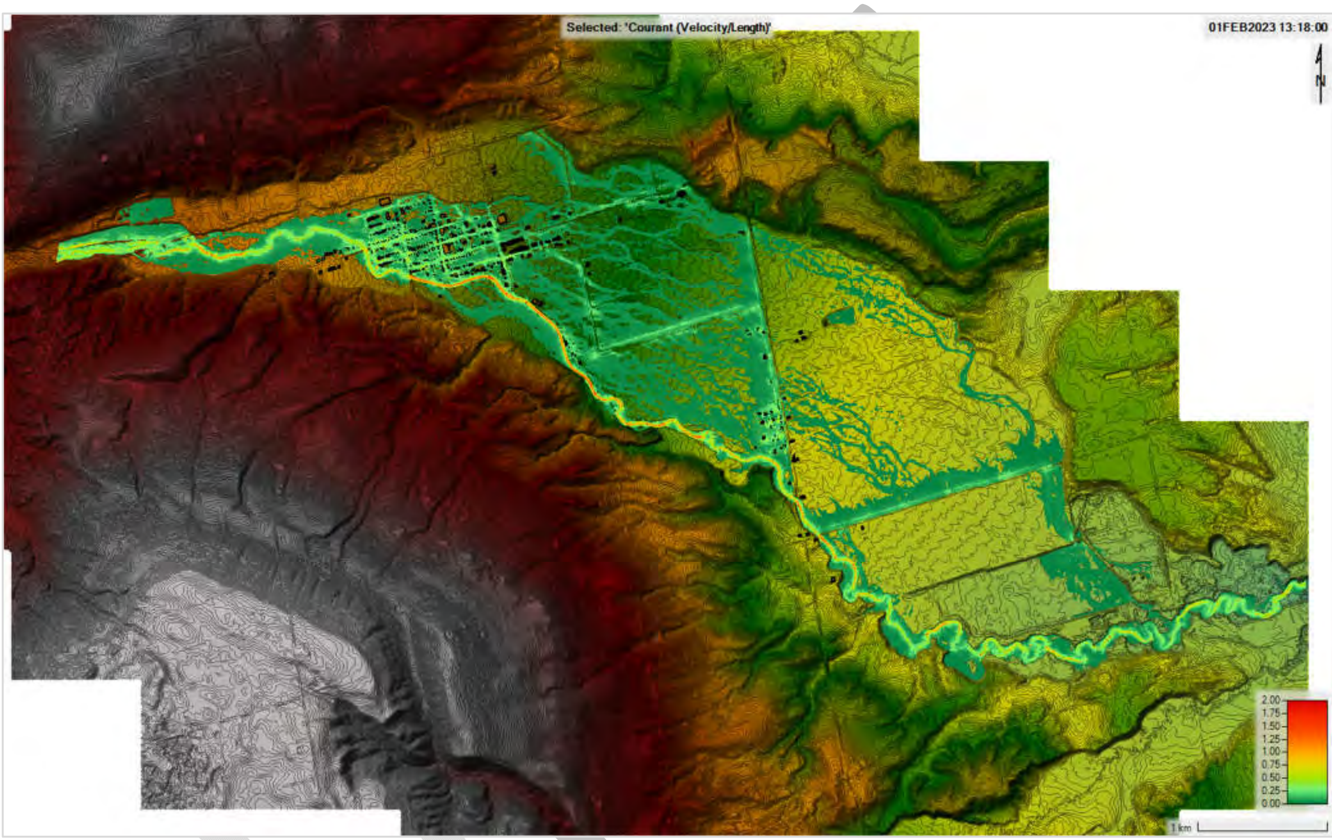

Figure 6-6. Timmins Regulatory Courant (Velocity/Length) Map

Within the bank limits of the Mad River, the majority of courant values have been observed to reside between 0 to 2 whereby indicating that the mesh cell sizing defined by the Breakline regime and selected computational time step of 30 seconds, as outlined in Section 6.8, provides stable results given the relatively steep profile of the river. To reduce the Courant Values below the 2 threshold, further cell size reductions and reduced time steps (i.e <30sec) may be applied. We note however, that with the level of detail provided in this report, the modelled results within the banks of the Mad River are anticipated to produce a slightly conservative result which is desirable from a Regulatory perspective.

Within the floodplain of the Mad River, courant values generally peak at value 0.5 within local roadways of the villages of Creemore and Avening. The low courant readings indicate mesh cell sizing defined by the Breakline regime, as outlined in Section 6.8 and selected computational time step of 30 seconds, provides stable results within the floodplain of the Mad River.

6.9.3 *Unsteady Flow Volume Accounting Analysis*

The Computational Message Window and it's associated Computational Log File were also reviewed with respect to the 2D models overall volume accounting. Based on our experience with 2D modelling, we would identify a stable model with having an overall volume accounting error of less than 2% with an optimal result producing a volume accounting error of less than 1%. The above noted thresholds would apply for both the overall simulation as well as each 2D flow area.

The overall Timmins Regulatory simulation illustrates that the model gained 1,033m^3 of water which equates to a 0.005973% volume error. Therefore, the overall volume accounting error is quite low and within desirable modelling tolerances.

6.10 Validation of 2D Modelling Results

Historical flooding has been documented at the south limits of the village of Creemore between Mill Street and Mary Street, in the fields located between County Road 9 and Edward Street, Edward Street to Concession 3 as well as within the village of Avening by the NVCA. Photos provided by the NVCA in **Figure 6-7** and **Figure 6-8** illustrate the documented historical flooding east of Creemore.

Figure 6-7
East Creemore Flooding South of County Road 9

Figure 6-8
East Creemore Flooding North of Edward Street

While the dates of the flooding are un-known, the pictures clearly show that flooding has been observed during periods of spring runoff and snow conditions which aligns and support the use of the Rain on Snow hydrology outlined in Section 4. Further, we also note that this historical flooding has occurred in events less than the Regulatory Event.

Through a visual examination of aerial imagery within the project area, it is apparent that the fields located at the eastern limits of the village of Creemore, have experienced surface sheet flow and flood related conditions in the past. **Figure** 7-1 **6-9** below illustrates dark and defined flow paths through the floodplain area of the Mad River, east of the village of Creemore.

Figure 6-9
East Creemore and Avening Aerial Imagery

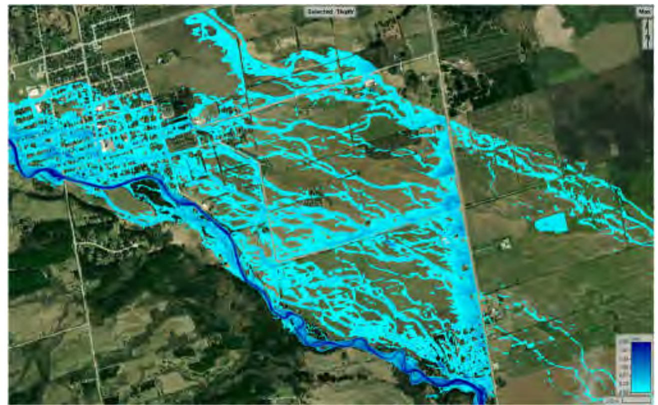

Figure 6-10
100-year ROS 2D Depth Map

Based on the visual inspection of aerial imagery, we would expect the 2D hydraulic model to replicate these flow conditions. **Figure 6-10** illustrates the results of the 100-year Rain on Snow (ROS) simulation for the same area. As illustrated, the 100-year ROS produces shallow depths and location's that mimic locations of surface water flow as depicted from the aerial imagery and historical flooding photos provided by the NVCA. Based on the commentary provided in the preceding sections of this report, should peak flows from the Mad River overtop it's banks and travel through the village of Creemore, multiple, shallow conveyance routes exist for flood flows to be conveyed through the wide floodplain of the Mad River. Accordingly, the modelling results presented in this report are viewed to accurately represent field conditions.

7 MODEL RESULTS AND FLOODPLAIN MAPPING

The HEC-RAS hydraulic model for Mad River was executed using a 2D Unsteady State flow regime to establish water surface profiles for each of the 100-year storm, Timmins Regional and Timmins Regional Climate Change scenario, with a focus on the Timmins Regional, which is considered to be the Regulatory event for this watershed. Model output results for all reaches are presented in **Appendix C**.

7.1 Floodplain Mapping

Regulatory floodlines were generated from the water surface elevation outputs from the HEC-RAS model under the Timmins Regional event and current land use, as described in the Aquafor's hydrologic modelling report (December 2023). The floodlines were mapped based on the intersection between the predicted water surface elevation and the LiDAR-derived DTM, as well as engineering judgement. Detailed floodplain mapping is included in **Appendix C**, while **Figure** 7-1**7-1** provides an overview of the regulatory floodplain mapping. The following are notable components of the flood hazard mapping exercise:

- The hydraulic model was built using a combination of topographic data (LiDAR and field survey), both referenced to the CGVD2013 vertical datum.
- The hydraulic model was run under unsteady state flow conditions for the 100-year storm, Timmins Regional and Timmins Regional Climate Change scenario.
- The Normal Depth downstream boundary condition was applied for all storm events.
- Floodlines have been directly exported via the RAS Mapper and have not been manually refined at this time as the model has been completed in a 2D Modelling environment.

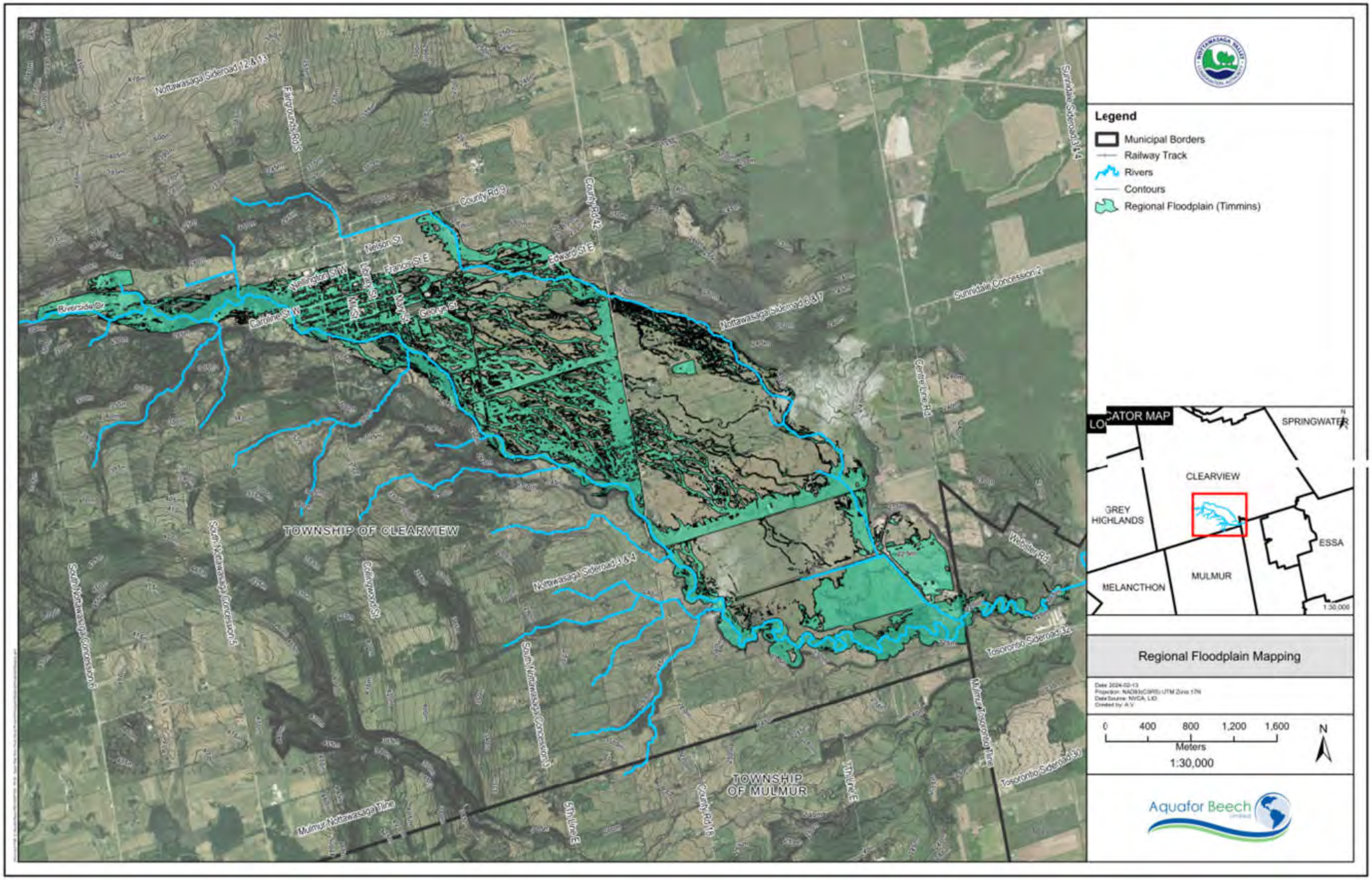

Figure 7-1. Overview of the Regulatory Mad River Floodplain Mapping

8 FLOOD HAZARD ASSESSMENT

8.1 Watercourse Crossing Overtopping Analysis

Pedestrian and vehicle access can be limited when a road crossing is overtopped and inundated. As per the Technical Guide – River and Stream System: Flooding Hazard Limit (OMNR, 2002), a road is impassible if the overtopping water depth is equal or greater than 0.3m. A road can be overtopped but only becomes impassable if this threshold is reached or exceeded. The product of the depth and velocity of the water on top of the roadway can also be a criteria that define an impassable road. $0.8m^2/s$ is the threshold used in this analysis as per MTO standards (Highway Drainage Design Standards from, 2008). In order to define the road elevation at the crossing location, the final water surface profiles were reviewed and the lowest point elevation of the road (as defined in the existing HEC-RAS models) was selected to calculate the depth of water overtopping the road. The velocity of the cross-section upstream the road crossing has been used to assess the product of the depth and velocity threshold.

Under the Regulatory flood (Timmins storm event), flows are expected to exceed the capacity of an estimated 9 crossing structures, causing the road profile to be overtopped while 7 crossings would be impacted for the 100-year flood event, as summarized in **Table 8-1.**

Table 8-1. Total of Crossing Structures Overtopped for the 100-year and Timmins Regional flood events

	100-year	Timmins
Total of Crossing Structures Overtopped	7	
Total of Crossing Structures	10	
Percentage	70.00%	90.00%

Of these overtopped structures, a total of four (4) structures are estimated to be impassable under the Regulatory event. In order to provide additional insight into the road overtopping conditions, each structure included in the hydraulic model was classified for each storm event using a colour code.

Error! Not a valid bookmark self-reference. provides details on the water depth on top the road and it is based on 3 categories:

- Road not overtopped – highlighted in green
- Road overtopped but passable (water depth <0.3m) – highlighted in orange
- Road impassable (water depth ≥ 0.3m) – highlighted in red

Table 8-2. Depth overtopping conditions analysis for all crossing structures listing by storm event - the roads not overtopped (green), the roads overtopped but passable (orange) and the roads impassable (red)

River	Structure ID	Location	Type	100-year ROS Max Depth (m)	Regional Max Depth (m)
Mad River	11	County Road 9	Single Span Bridge	0.55	0.59
Mad River	1	Caroline Street	Single Span Bridge	0.6	0.67
Mad River	2	Collingwood Street	Single Span Bridge	0.51	0.56
Mad River	3	Airport Road	Dual Span Bridge	0.04	0.07
Mad River	4	Sideroad 3&4 Nottawasaga	Dual Span Bridge	0	0.05
Mad River	5	Centerline Road	Single Span Bridge	0.36	0.85
East Creemore Drain (ECD)	10	Edward Street West	Culvert	0.09	0.14
East Creemore Drain (ECD)	9	Edward Street East	Culvert	0.14	0.18
East Creemore Drain (ECD)	8	Airport Road	Culvert	0	0
East Creemore Drain (ECD)	6	Sideroad 3&4 Nottawasaga	Culvert	0	0.05

Table 8-3 provides details on the product of the water depth and velocity that would occur on top the road and it is based on 3 categories:

- Road not overtopped – highlighted in green
- Road overtopped but passable (water depth x velocity <0.8m^2/s) – highlighted in orange
- Road impassable (water depth x velocity ≥ 0.8m^2/s) – highlighted in red

Table 8-3. Product of Depth and Velocity overtopping conditions analysis for all crossing structures listing by storm event - the roads not overtopped (green), the roads overtopped but passable (orange) and the roads impassable (red)

River	Structure ID	Location	Type	100-year Depth x Velocity (m/s2)	Regional Depth x Velocity (m/s2)
Mad River	11	County Road 9	Single Span Bridge	1.08	1.25
Mad River	1	Caroline Street	Single Span Bridge	0.59	0.74
Mad River	2	Collingwood Street	Single Span Bridge	0.48	0.58
Mad River	3	Airport Road	Dual Span Bridge	0.16	0.27
Mad River	4	Sideroad 3&4 Nottawasaga	Dual Span Bridge	0	0.17
Mad River	5	Centerline Road	Single Span Bridge	0.24	0.35
East Creemore Drain (ECD)	10	Edward Street West	Culvert	0.05	0.11
East Creemore Drain (ECD)	9	Edward Street East	Culvert	0.04	0.11
East Creemore Drain (ECD)	8	Airport Road	Culvert	0	0
East Creemore Drain (ECD)	6	Sideroad 3&4 Nottawasaga	Culvert	0	0.05

8.2 Flooded Building Assessment

The impact of the flood lines on private and public facilities was analyzed using the building feature layer shapefile (same as the layer used for defining conveyance obstructions) and GIS tools. In total, 394 buildings have been added to the 2D mesh. Out of the total 394 buildings, 352 buildings area are impacted by flooding, as they are either fully or partially located within the flooding extents under the Timmins (Regulatory) storm event. 340 buildings are either fully or partially located within the flooding extents of the 100-year storm event.

9 UNCERTAINTIES, LIMITS AND RECOMMENDATIONS

Aquafor undertook a variety of measures to reduce uncertainty and increase confidence in the HEC-RAS hydraulic model's ability to predict water surface elevations. These included the use of estimated flow rates from the approved HEC-HMS hydrologic model and approved scenarios, the use of appropriate hydraulic parameters based on technical guidelines, reviewing errors, warnings and notes in the model, and completing a visual verification of the preliminary model results screening the regulatory flood lines delineation.

Detailed reach investigations of the low flow channel were not conducted along the entirety of the creek due to the scale of the study area and because of site access and safety conditions. River cross-sections were only surveyed within the channel at certain locations and generally located a few meters upstream and downstream hydraulic structures.

It is noted that the hydraulic model has first and foremost been developed for the purposes of flood hazard mapping. The development of the model was focused on generating water surface elevations for the Regulatory flood event (Timmins storm). The hydraulic model results for smaller return period storm events have higher degrees of uncertainty. The hydraulic model and the results presented within this report for storms less than the Regulatory event will provide only general guidance for infrastructure planning and/or flood estimation purposes. Additional detailed studies (i.e., low flow channel corrections, placement of levees, etc.), may be required to ensure adequate accuracy of modelling results for smaller storm events.

10 CONCLUSIONS

The 2D HEC-RAS hydraulic model was built using the most recent data in possession of NVCA and is compliant with all pertinent technical guidelines (OMNR, 2002; EWRG, 2017; NRCan, 2023). This study will thus allow the NVCA to recognize in detail the behavior of the riverine system of Mad River Watersheds for significant flood events.

The following points are key conclusions drawn from this study:

- The hydraulic model includes a total of 2 river reaches covering a total length of 23 km;
- Survey investigations were conducted by Aquafor Beech Limited between October and November of 2023;
- Structure inventory sheets were developed for each of the surveyed hydraulic structures;
- The HEC-RAS 2D model includes a total of 10 hydraulic structures including bridges and culverts;
- The HEC-HMS Hydrologic model includes a total of 25 flow nodes;
- 2022 LiDAR-derived DTM referenced to NAD83 (CSRS) UTM Zone 18N and vertical datum to CGVD2013 was applied to define river cross-sections, stream centerline, overbank locations and generate flood lines;
- Flows inputted in the hydraulic model were retrieved from Aquafor's HEC-HMS hydrologic model for the 100-year rain-on-snowmelt storm events, Timmins Regional and Timmins Regional Climate change scenario);
- Manning's roughness values based upon existing land use were assigned in the model according to the MTO Standard Coefficient (MTO Drainage Management Manual - Design Chart 2.01) and Technical Guidelines for Flood Hazard Mapping (EWRG, 2017);
- The Un-Steady State model regime was simulated to generate model results;
- Floodplain mapping for the 100-year storm event, Timmins (Regulatory event) and Timmins Climate Change Scenario were defined.

The study culminated with the development of 2D HEC-RAS hydraulic model for the Mad River Watershed. Aquafor has confidence in the hydraulic model to predict water surface elevations with a reasonable degree of accuracy for the Regulatory event (Timmins) and therefore, in the Regulatory Floodplain Mapping product.

11 REFERENCES

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