

APPENDIX K

**Hydrology and Hydraulics
Report**

County of Wellington

Wellington Country Road 109 Bridge Replacements

Hydrology and Hydraulics Report

February 26, 2024

Final





Wellington Country Road 109 Bridge Replacements Hydrology and Hydraulics Report

County of Wellington

Final

Project No.: 17M-01271-02

Date: February 26, 2024

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February 26, 2024

Final

County of Wellington
Administration Centre
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Attention: Joe de Koning

Dear Joe de Koning

Subject: Wellington County Road 109 Bridge Replacements Final Hydrology and Hydraulics Report

We are pleased to submit one electronic copy of the FINAL Hydrology and Hydraulics report for Wellington County Road 109 Bridge replacements. This report documents the hydrologic and hydraulic calculations used to assess the bridges in existing and proposed conditions.

We trust the submission of this documents meets your requirements. Should you have any comments we look forward to your response.

Yours sincerely,

A handwritten signature in black ink, appearing to read 'Sherif Iskandar'.

Sherif Iskandar, M.Sc., P.Eng., PMP
Senior Project Manager, Water Resources

WSP ref.: 17M-01271-02

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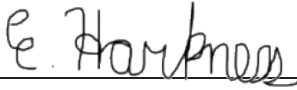
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FINAL

February 23, 2024	Final		
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1 INTRODUCTION

1.1 Background

WSP Canada Inc. was retained by the County of Wellington to undertake the hydraulic analysis of four (4) structures on Wellington Road 109, east of Highway 6 in Arthur, Township of Wellington North, Ontario. Hydrologic and hydraulic assessments were completed for the existing structures and the proposed replacement structures. This Hydrology and Hydraulics Report outlines the required performance standards, documents design flows and details the development of the hydrologic methodology and hydraulic model used to evaluate the existing structures and proposed replacements. The subject structures are included in **Table 1-1**.

Table 1-1: Wellington Road 109 Structures

Structure Number	Name	Structure Type	Span (m)	Width (m)	Built	Location
B109132	Conestogo River Bridge #6	Rigid Frame	17.0	11.6	1931	0.2 km East of Hwy 6
B109133	Conestogo River Bridge #4	Rigid Frame	13.8	11.5	1931	1.7 km East of Hwy 6
B109134	Conestogo River Bridge #10	Rigid Frame	12.0	11.4	1934	1.0 km East of Wellington Road 45
C109123	Conestogo River Bridge #5	Concrete Barrel Arch	14.0	11.7	1930	0.7 km East of Hwy 6

The four crossing structures, identified by reference numbers (from west to east) B109132, C109123, B109133 and B109134 are all reaching the end of their design life. All four bridge crossings are in an advanced state of deterioration with some elements identified as not meeting current standards. **Exhibit 1** illustrates the four crossing structures. All exhibits are located at the end of this report.

2 SITE DESCRIPTION

Wellington County Road 109 (WR 109) crosses the Conestogo River at four locations between Highway 6 and Sideroad 7, southeast of community Arthur in the Township of Wellington North. The crossings are within the jurisdiction of the Grand River Conservation Authority (GRCA).

The structures are located close to one another, all within a 2.7 km long area of WR 109, with the first structure being located approximately 180 m east of the intersection of Highway 6 and WR 109, at the south end of Arthur. Three structures are concrete rigid-frame bridges (B109132, B10913 and B109134) and the fourth, C109123, is a concrete arch bridge.

Photo inventory for all four structures is shown in **Exhibits 4, 5, 6 and 7**.

3 HYDROLOGIC ASSESSMENT

The Conestogo River flows under Wellington Road 109 from east to west and ultimately outlets into the Grand River at Conestogo. The watershed consists primarily of agricultural lands with some isolated patches of treed areas and rural residential properties. For modelling purposes, the contributing drainage area has been divided up into two drainage catchments. The first catchment outlets to Structure C109123 with an area of 34.3 km². The second catchment outlets to structure B109132 with an area of 67.5 km². The catchments were delineated using OBM contours. The existing drainage catchments are presented on **Exhibits 2 and 3**.

According to Design Chart 1.02 of the MTO Drainage Management Manual, the site is located in Zone 1 and therefore Hurricane Hazel was used as the Regulatory Storm.

3.1 Hydrologic Model

The design flows were generated using a comparison of five different methods, including:

- 1 The Modified Index Flood Method (MIFM)
- 2 Flood Frequency Analysis (FFA)
- 3 The Unified Ontario Flood Method (UOFM)
- 4 Visual OTTHYMO, an event-based model
- 5 Ontario Flow Assessment Tools (OFAT)

The MFIM as described in the MTO Drainage Management Manual is also a regional frequency analysis method and is applicable for large watersheds. Visual OTTHYMO is an event-based model widely used to determine runoff characteristics for rural and urban watersheds. This model was also used to generate the peak flow resulting from the Hazel (Regional) Storm event.

The FFA uses the GRCA's FFA fitted curve and is referenced to the Conestogo River above Drayton which has a drainage area of 272 km². Using this method, flows are generated at Drayton using unit flow rates (in m³/s/km²) obtained from the GRCA and then linearly interpolated to the smaller drainage area at the site.

A newer regression method, the UOFM, has been developed for the calculation of the design flow rates in Ontario by the Ministry of Transportation. The design flows represent the peak flow estimates (flood quantiles) of various return periods for bridges and culverts, at stream and river crossings. This method uses mean annual precipitation, drainage area and lake attenuation index to generate peak flows. The

UOFM method gives three sets of flow values – upper limit, mean quantile and lower limit. According to UOFM guideline:

- If the flow value from the UOFM is higher than any other applicable methods, then the UOFM mean quantile values for the different return periods shall be applied in design
- If the flow value from UOFM is lower than any other applicable methods, then the value at the upper limit of the range shall be applied in design

The SCS 24-hour storm distributions were used to determine the flows at the crossing using Visual OTTHYMO modelling. These storm distributions represent long duration, high volume rainfall events. The parameters used in the hydrologic modelling include the Curve Number (CN), Initial Abstraction (I_a), and the Time to Peak (T_p). The parameters for each catchment are summarized in **Table 3-1**. The SCS Upland Method, SCS Curve Number Method and the Airport Method were used and the results averaged to calculate the T_p . For the catchment, modelling parameters were selected based on soil type, land use and topography. The parameters were then calibrated to the hydrologic method selected for the analysis to determine the Regional flow.

Table 3-1: Summary of Catchment Parameters

Catchment ID	Hyd. Routine	Area (ha)	SCS Curve Number (CN)	Initial Pervious Abstraction (mm)	T_p (hrs)
C109123	Nash	3430.00	89	2.4	9.46
C109132	Nash	6748.71	88	2.6	9.65

The summary of peak flows is summarized in **Table 3-2** and **Table 3-3**. The hydrologic modelling files are provided in **Appendix A**. As the MIFM method yielded the highest flows, it was carried forward in the analysis. The Regional flows were determined from the VO model. The 48-hour Hurricane Hazel storm was used for the Regional flow rates.

Table 3-2: Peak Flow Comparison (at C109132)

Calculation Method	Return Period Flow (m ³ /s)							
	2-Year	5-Year	10-Year	20-Year	25-Year	50-Year	100-Year	Regional
FFA	31.0	49.3	62.8	76.3	81.0	94.5	108.0	
VO	29.7	46.38	57.35	71.38		82.82	93	208.43
MIFM	45.3	59	72.2		88.1	99.5	111.8	
UOFM*	31.09		59.27		74.88	86.89	100.24	
OFAT*	22.043	32.28	39.42	46.36		52.85	59.81	

*Primary Regression was used for OFAT flows and the Lower Limit flows are shown for the UOFM method.

Table 3-3: Peak Flow Comparison (at C109123)

Calculation Method	Return Period Flow (m ³ /s)							
	2-Year	5-Year	10-Year	20-Year	25-Year	50-Year	100-Year	Regional
FFA	15.778	25.039	31.899	38.759	41.16	48.02	54.88	
VO	16	24.8	30.54	37.86		43.82	49.17	108.24
MIFM	32.6	42.4	52		63.4	71.6	80.5	
UOFM*	19.7		38.62		49.21	57.4	66.51	
OFAT*	12.11	15.95	18.98	22.8		27.45	31.89	

*Index Flood Method with EPA was used for OFAT flows and the Lower Limit flows are shown for the UOFM method.

4 HYDRAULIC ASSESSMENT

The hydraulic assessment was completed using a HEC-RAS hydraulic model which was compiled based on a detailed cross section and structure survey upstream and downstream of the site. The HEC-RAS model is used to generate flood elevations and determine the hydraulic performance of the existing structure and assess the proposed replacement structure.

4.1 Hydraulic Performance Standards

The following hydrologic and hydraulic performance standards were identified to evaluate the performance of the existing structures as well as proposed conditions:

- Design storms used to calculate flood elevations
- Minimum and desired top of road freeboard
- Minimum soffit clearance
- Maximum depth of relief flow over the road
- Maximum product of depth and velocity of relief flow over the road
- Allowable increase in flood elevation upstream of the structures

The replacement of these four bridges is not a Ministry of Transportation (MTO) project; however, the performance standards used in this study are based on the MTO Highway Drainage Design Standards (HDDS) (January 2008).

4.1.1 Design Storm

In accordance with the requirements of the MTO HDDS WC-1, a new structure with a span greater than 6.0 m on a Rural Arterial or Collector roadway should be designed to convey a minimum of the 50-year design storm.

4.1.2 Top of Road Freeboard

The MTO HDDS WC-7 recommends a minimum freeboard of 1.0 m measured vertically from the design flow hydraulic grade line elevation to the edge of the travelled lane. The desirable freeboard is 1.0 m measured vertically from the energy grade line elevation for the design flow. These freeboards are recommended values. It is recognized that due to site-specific considerations it is not always feasible to meet this objective.

4.1.3 Relief Flow

According to the MTO HDDS WC-13 “design of a water crossing shall incorporate passage of the Relief Flow over the Roadway in cases where the Regulatory Flow exceeds the Design Flow of the bridge or the culvert Relief flow over the roadway.” The standard recommends that if the Regulatory Storm overtops the road, two parameters shall not be exceeded:

- The maximum depth of flow on the roadway should not exceed 0.3 m
- The product of the velocity and depth on the roadway shall not exceed $0.8 \text{ m}^2/\text{s}$

4.1.4 Clearance (Bridges)

As per MTO HDDS WC-2, the minimum clearance for bridges with a straight soffit shall be 1.0 metres.

4.1.5 Summary of Performance Standards

Table 4-1 provides a summary of the MTO Drainage Design Standards applied to this assessment.

4.2 Model Preparation

A hydraulic model did not exist for the watercourse at the site location; therefore, an existing conditions model was created based on field survey data. The topographic survey and watercourse survey were completed by WSP in November 2017. **Exhibit 8** illustrates the locations of HEC-RAS surveyed cross-sections for the watercourse. Graphical representations of the cross-sections and longitudinal profile of the channel is provided in **Appendix B**.

A boundary condition must be established for each hydraulic model. Boundary conditions are required to perform steady flow calculations and to establish the starting water surface at the upstream and downstream limits of a river system. Ideally, a HEC-RAS model should originate far enough downstream so that it accounts for any downstream influence on the upstream water levels. For this analysis a normal depth based on survey information (i.e. slope and nearest cross-section) was used as the downstream and upstream boundary condition.

Table 4-1: MTO Drainage Design Standards

Item	Design Standard	Description	Standard	Section
1	Design Flow Storm	50-Year	WC-1	1.1.1
2	Top of Road Freeboard (Min.)	>1.0 m (Design Flow Water Surface Elevation – top of road low point)	WC-7	3.1.2
3	Top of Road Freeboard (Desired)	>1.0 m (Design Flow Energy Grade Line Elevation – top of road low point)	WC-7	3.1.1
4	Relief Flow (Max. Depth over roadway)	Max. depth over roadway should not exceed 0.3 m for Regulatory Storm	WC-13	3.2.1
5	Relief Flow (Velocity x Depth)	Velocity x Depth should not exceed 0.8 m ² /s for Regulatory Storm	WC-13	3.2.2
6	Soffit Clearance	Design Flow Water Surface Elevation – Soffit Elevation ≥1.0 m	WC-2	3.2.1

4.3 Existing Conditions Assessment

The 2-year through 100-year as well as the Regulatory Storm events were analyzed in HEC-RAS; the 50-year storm event is the design storm for the structure replacement. The existing top of road freeboard, flood depth and other hydraulic performance parameters as they pertain to the MTO HDDS are identified for each bridge in **Table 4-2, Table 4-4, Table 4-6 and Table 4-8. Table 4-3, Table 4-5, Table 4-7 and Table 4-9** illustrates whether the existing structure meets current hydraulic standards for each bridge.

Structures B109132 and C109123 meet all design criteria. Structure B109133 meets all design criteria except for the soffit clearance. Structure B109134 only meets the relief flow criteria under existing conditions. Even though the edge of pavement elevation is lower than the headwater elevation for the upstream cross section under the Regional storm, the HEC-RAS profiles shown in **Appendix B** shows that it does not overtop the road at B109134.

Refer to **Appendix C** for the existing condition HEC-RAS output.

Table 4-2: Top of Road and Soffit Clearance Summary for B109132 – Existing Conditions

Description	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	Regional
Water Surface Elevation	448.93	449.17	449.38	449.6	449.75	449.91	451.39
Energy Grade Line Elevation	449.10	449.38	449.63	449.90	450.09	450.28	452.02
Top of Road (Low Point)*	452.74						
(2+4) Top of Road Freeboard (Min.)	3.81	3.57	3.36	3.14	2.99	2.83	1.35
(3) Top of Road Freeboard (Desired)	3.64	3.36	3.11	2.84	2.65	2.46	0.72
Top of Road Velocity	n/a	n/a	n/a	n/a	n/a	n/a	n/a
(5) Top of Road Velocity x Depth	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Soffit Elevation (Upstream)	451.84						
(6) Soffit Clearance	2.91	2.67	2.46	2.24	2.09	1.93	0.45

* The low point location for this structure is at approximately station 0+284.301.

Table 4-3: Hydraulic Performance Summary for B109132– Existing Conditions

Criteria Description	Criteria Storm Events	Meets Criteria (Yes or No)
(2) Top of Road Freeboard (Min.)	50-Year	Yes
(3) Top of Road Freeboard (Desired)	50-Year	Yes
(4) Relief Flow (Max. Depth over roadway)	Regional	Yes
(5) Relief Flow (Velocity x Depth)	Regional	Yes
(6) Soffit Clearance	50-Year	Yes

Table 4-4: Top of Road and Soffit Clearance Summary for B109133 – Existing Conditions

Description	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	Regional
Water Surface Elevation	459.44	459.74	460.02	460.37	460.61	460.86	461.41
Energy Grade Line Elevation	459.69	460.02	460.31	460.66	460.91	461.16	461.77
Top of Road (Low Point) *	461.97						
(2+4) Top of Road Freeboard (Min.)	2.53	2.23	1.95	1.60	1.36	1.11	0.56
(3) Top of Road Freeboard (Desired)	2.28	1.95	1.66	1.31	1.06	0.81	0.20
Top of Road Velocity	n/a	n/a	n/a	n/a	n/a	n/a	n/a
(5) Top of Road Velocity x Depth	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Soffit Elevation (Upstream)	461.19						
(6) Soffit Clearance	1.75	1.45	1.17	0.82	0.58	0.33	-0.22

* The low point location for this structure is at approximately station 1+835.643.

Table 4-5: Hydraulic Performance Summary for B109133– Existing Conditions

Criteria Description	Criteria Storm Events	Meets Criteria (Yes or No)
(2) Top of Road Freeboard (Min.)	50-Year	Yes
(3) Top of Road Freeboard (Desired)	50-Year	Yes
(4) Relief Flow (Max. Depth over roadway)	Regional	Yes
(5) Relief Flow (Velocity x Depth)	Regional	Yes
(6) Soffit Clearance	50-Year	No

Table 4-6: Top of Road and Soffit Clearance Summary for B109134 – Existing Conditions

Description	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	Regional
Water Surface Elevation	462.95	463.21	463.49	463.81	464.10	464.42	465.74
Energy Grade Line Elevation	463.08	463.38	463.68	464.03	464.33	464.64	465.76
Top of Road (Low Point) *	465.03						
(2+4) Top of Road Freeboard (Min.)	2.08	1.82	1.54	1.22	0.93	0.61	0
(3) Top of Road Freeboard (Desired)	1.95	1.65	1.35	1.00	0.70	0.39	0
Top of Road Velocity	n/a	n/a	n/a	n/a	n/a	n/a	n/a
(5) Top of Road Velocity x Depth	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Soffit Elevation (Upstream)	463.73						
(6) Soffit Clearance	0.78	0.52	0.24	-0.08	-0.37	-0.69	-2.01

* The low point location for this structure is at approximately station 2+924.063.

Table 4-7: Hydraulic Performance Summary for B109134– Existing Conditions

Criteria Description	Criteria Storm Events	Meets Criteria (Yes or No)
(2) Top of Road Freeboard (Min.)	50-Year	No
(3) Top of Road Freeboard (Desired)	50-Year	No
(4) Relief Flow (Max. Depth over roadway)	Regional	Yes
(5) Relief Flow (Velocity x Depth)	Regional	Yes
(6) Soffit Clearance	50-Year	No

Table 4-8: Top of Road and Soffit Clearance Summary for C109123 – Existing Conditions

Description	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	Regional
Water Surface Elevation	452.59	452.75	453.03	453.34	453.55	453.76	455.09
Energy Grade Line Elevation	453.02	453.27	453.52	453.82	454.03	454.25	455.66
Top of Road (Low Point) *	457.92						
(2+4) Top of Road Freeboard (Min.)	5.33	5.17	4.89	4.58	4.37	4.16	2.83
(3) Top of Road Freeboard (Desired)	4.90	4.65	4.40	4.10	3.89	3.67	2.26
Top of Road Velocity	n/a	n/a	n/a	n/a	n/a	n/a	n/a
(5) Top of Road Velocity x Depth	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Soffit Elevation (Upstream)	456.52						
(6) Soffit Clearance	3.93	3.77	3.49	3.18	2.97	2.76	1.43

* The low point location for this structure is at approximately station 0+753.687.

Table 4-9: Hydraulic Performance Summary for C109123– Existing Conditions

Criteria Description	Criteria Storm Events	Meets Criteria (Yes or No)
(2) Top of Road Freeboard (Min.)	50-Year	Yes
(3) Top of Road Freeboard (Desired)	50-Year	Yes
(4) Relief Flow (Max. Depth over roadway)	Regional	Yes
(5) Relief Flow (Velocity x Depth)	Regional	Yes
(6) Soffit Clearance	50-Year	Yes

4.4 Proposed Conditions Assessment

The preferred replacement option for each bridge structure is the following:

- B109132 – Remove existing structure and replace it with a single span steel plate ‘I’ girder superstructure with a skew of 10 degrees. It will have a clear opening of 22.3 m. It is proposed to have a 17 m wide bridge deck.
- B109133 – Remove existing structure and replace it with a single span steel plate ‘I’ girder superstructure with no skew. It will have a clear opening of 17.3 m. It is proposed to have a 13 m wide bridge deck.
- B109134 – Remove existing structure and replace it with a single span steel plate ‘I’ girder superstructure with a skew of 15 degrees. It will have a clear opening of 17.3 m. It is proposed to have a 13 m wide bridge deck.
- C109123 – Remove existing structure and replace it with a single span steel plate ‘I’ girder superstructure with a skew of 10 degrees. It will have a clear opening of 18.3 m. It is proposed to have a 13 m wide bridge deck.

The hydraulic model output files for option(s) are included in **Appendix D**.

Hydraulic parameters are identified in **Table 4-10**, **Table 4-12**, **Table 4-14** and **Table 4-16**. The following conclusions are summarized in **Table 4-11**, **Table 4-13**, **Table 4-15** and **Table 4-17**:

- B109132 and C109123 meet all design criteria under proposed conditions
- B109133 and B109134 meet all the design criteria except for the soffit clearance

For the structures that do not meet all design criteria stated above, the high-water surface elevation is due to a backwater effect, therefore increasing the bridge span would not help these structures meet the design criteria.

Even though the edge of pavement elevation is lower than the headwater elevation for the Regional storm, the HEC-RAS profiles shown in **Appendix B** shows that it does not overtop the road at B109134.

All proposed structures meet the Navigable Water Act, which needs the soffit clearance under the 2-year storm to be greater than or equal to 1.5 m.

Table 4-10: Top of Road and Soffit Clearance Summary for B109132 – Proposed Conditions

Description	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	Regional
Water Surface Elevation	448.92	449.16	449.37	449.59	449.73	449.88	451.14
Energy Grade Line Elevation	449.07	449.35	449.59	449.85	450.02	450.19	451.70
Top of Road (Low Point) *	452.77						
(2+4) Top of Road Freeboard (Min.)	3.85	3.61	3.40	3.18	3.04	2.89	1.63
(3) Top of Road Freeboard (Desired)	3.70	3.42	3.18	2.92	2.75	2.58	1.07
Top of Road Velocity	n/a	n/a	n/a	n/a	n/a	n/a	n/a
(5) Top of Road Velocity x Depth	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Soffit Elevation (Upstream)	451.80						
(6) Soffit Clearance	2.88	2.64	2.43	2.21	2.07	1.92	0.66
HGL Increase from Existing (m) (Pr. -Ex.)	-0.01	-0.01	-0.01	-0.01	-0.02	-0.03	-0.25

* The low point location for this structure is at approximately station 0+284.301.

Table 4-11: Hydraulic Performance Summary for B109132– Proposed Conditions

Criteria Description	Criteria Storm Events	Meets Criteria (Yes or No)
(2) Top of Road Freeboard (Min.)	50-Year	Yes
(3) Top of Road Freeboard (Desired)	50-Year	Yes
(4) Relief Flow (Max. Depth over roadway)	Regional	Yes
(5) Relief Flow (Velocity x Depth)	Regional	Yes
(6) Soffit Clearance	50-Year	Yes

Table 4-12: Top of Road and Soffit Clearance Summary for B109133 – Proposed Conditions

Description	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	Regional
Water Surface Elevation	459.39	459.69	459.97	460.31	460.55	460.79	461.14
Energy Grade Line Elevation	459.60	459.91	460.19	460.53	460.77	461.01	461.44
Top of Road (Low Point) *	462.25						
(2+4) Top of Road Freeboard (Min.)	2.86	2.56	2.28	1.94	1.70	1.46	1.11
(3) Top of Road Freeboard (Desired)	2.65	2.34	2.06	1.72	1.48	1.24	0.81
Top of Road Velocity	n/a	n/a	n/a	n/a	n/a	n/a	n/a
(5) Top of Road Velocity x Depth	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Soffit Elevation (Upstream)	461.50						
(6) Soffit Clearance	2.11	1.81	1.53	1.19	0.95	0.71	0.36
HGL Increase from Existing (m) (Pr. -Ex.)	-0.05	-0.05	-0.05	-0.06	-0.06	-0.07	-0.27

* The low point location for this structure is at approximately station 1+835.643.

Table 4-13: Hydraulic Performance Summary for B109133– Proposed Conditions

Criteria Description	Criteria Storm Events	Meets Criteria (Yes or No)
(2) Top of Road Freeboard (Min.)	50-Year	Yes
(3) Top of Road Freeboard (Desired)	50-Year	Yes
(4) Relief Flow (Max. Depth over roadway)	Regional	Yes
(5) Relief Flow (Velocity x Depth)	Regional	Yes
(6) Soffit Clearance	50-Year	No

Table 4-14: Top of Road and Soffit Clearance Summary for B109134 – Proposed Conditions

Description	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	Regional
Water Surface Elevation	462.97	463.23	463.48	463.76	463.97	464.19	465.12
Energy Grade Line Elevation	463.06	463.34	463.61	463.91	464.13	464.36	465.17
Top of Road (Low Point) *	465.78						
(2+4) Top of Road Freeboard (Min.)	2.81	2.55	2.30	2.02	1.81	1.59	0.66
(3) Top of Road Freeboard (Desired)	2.72	2.44	2.17	1.87	1.65	1.42	0.61
Top of Road Velocity	n/a	n/a	n/a	n/a	n/a	n/a	n/a
(5) Top of Road Velocity x Depth	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Soffit Elevation (Upstream)	464.50						
(6) Soffit Clearance	1.53	1.27	1.02	0.74	0.53	0.31	-0.62
HGL Increase from Existing (m) (Pr. -Ex.)	0.02	0.02	-0.01	-0.05	-0.13	-0.23	-0.62

* The low point location for this structure is at approximately station 2+924.063.

Table 4-15: Hydraulic Performance Summary for B109134– Proposed Conditions

Criteria Description	Criteria Storm Events	Meets Criteria (Yes or No)
(2) Top of Road Freeboard (Min.)	50-Year	Yes
(3) Top of Road Freeboard (Desired)	50-Year	Yes
(4) Relief Flow (Max. Depth over roadway)	Regional	Yes
(5) Relief Flow (Velocity x Depth)	Regional	Yes
(6) Soffit Clearance	50-Year	No

Table 4-16: Top of Road and Soffit Clearance Summary for C109123 – Proposed Conditions

Description	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	Regional
Water Surface Elevation	452.66	452.85	453.02	453.21	453.34	453.49	454.48
Energy Grade Line Elevation	452.79	453.01	453.21	453.43	453.59	453.75	454.84
Top of Road (Low Point) *	458.30						
(2+4) Top of Road Freeboard (Min.)	5.64	5.45	5.28	5.09	4.96	4.81	3.82
(3) Top of Road Freeboard (Desired)	5.51	5.29	5.09	4.87	4.71	4.55	3.46
Top of Road Velocity	n/a	n/a	n/a	n/a	n/a	n/a	n/a
(5) Top of Road Velocity x Depth	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Soffit Elevation (Upstream)	456.90						
(6) Soffit Clearance	4.24	4.05	3.88	3.69	3.56	3.41	2.42
HGL Increase from Existing (m) (Pr. -Ex.)	0.07	0.10	-0.01	-0.13	-0.21	-0.27	-0.61

* The low point location for this structure is at approximately station 0+753.687.

Table 4-17: Hydraulic Performance Summary for C109123– Proposed Conditions

Criteria Description	Criteria Storm Events	Meets Criteria (Yes or No)
(2) Top of Road Freeboard (Min.)	50-Year	Yes
(3) Top of Road Freeboard (Desired)	50-Year	Yes
(4) Relief Flow (Max. Depth over roadway)	Regional	Yes
(5) Relief Flow (Velocity x Depth)	Regional	Yes
(6) Soffit Clearance	50-Year	Yes

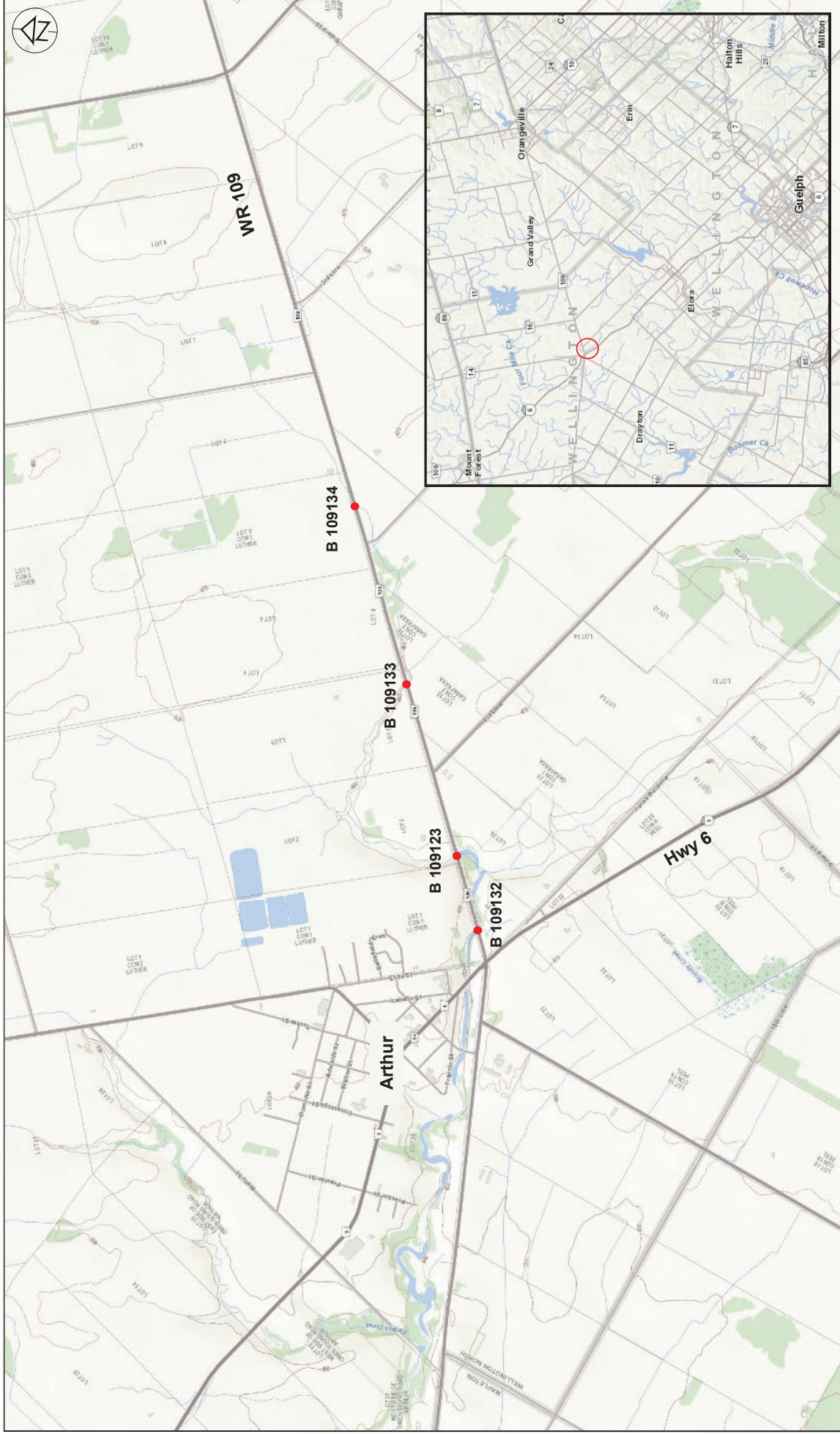
5 CONCLUSIONS

The four structures are located on Wellington Road 109 in the community of Wellington. A hydrologic analysis was completed to determine the peak flows, as well as the hydraulic analysis for the preferred option for all four bridges.

The results of the hydraulic assessment indicate that the existing structures B109132 and C109123 meet all design criteria while B109133 meet all criteria except for the soffit clearance. Bridge B109134, does not meet any of the design criteria under existing conditions except for the relief flow criteria.

Under proposed conditions structures B109132 and C109123 meet all design criteria. Bridges B109133 and B109134 meet all design criteria except for the soffit clearance due to downstream constraints. All proposed structures meet the Navigable Water Act.

Exhibits

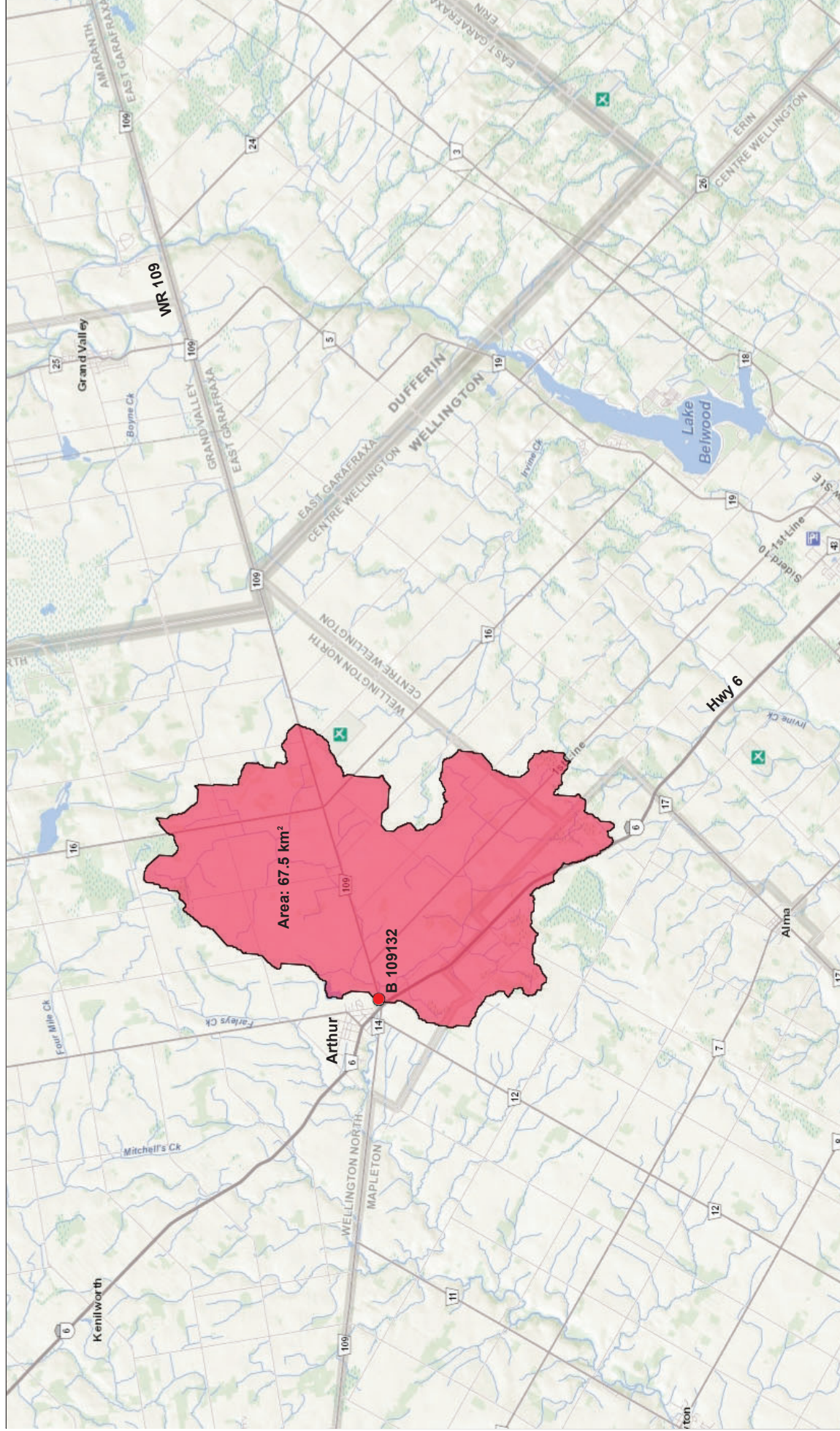


STUDY AREA

Wellington Road 109

EXHIBIT

1



Catchment Area at B 109132
Wellington Road 109

DRAWING NAME: \\WML\CA\COMMON\JIS\KITCHENER\WRC\PROJECTS\2017\17M-01271-00_WR109 AND JONES BASELINE PD EA\WR REPORT\EXHIBITS\PHOTO INVENTORY\123\PHOTO.DWG



PHOTO INVENTORY

Wellington Road 109 - Culvert C109123

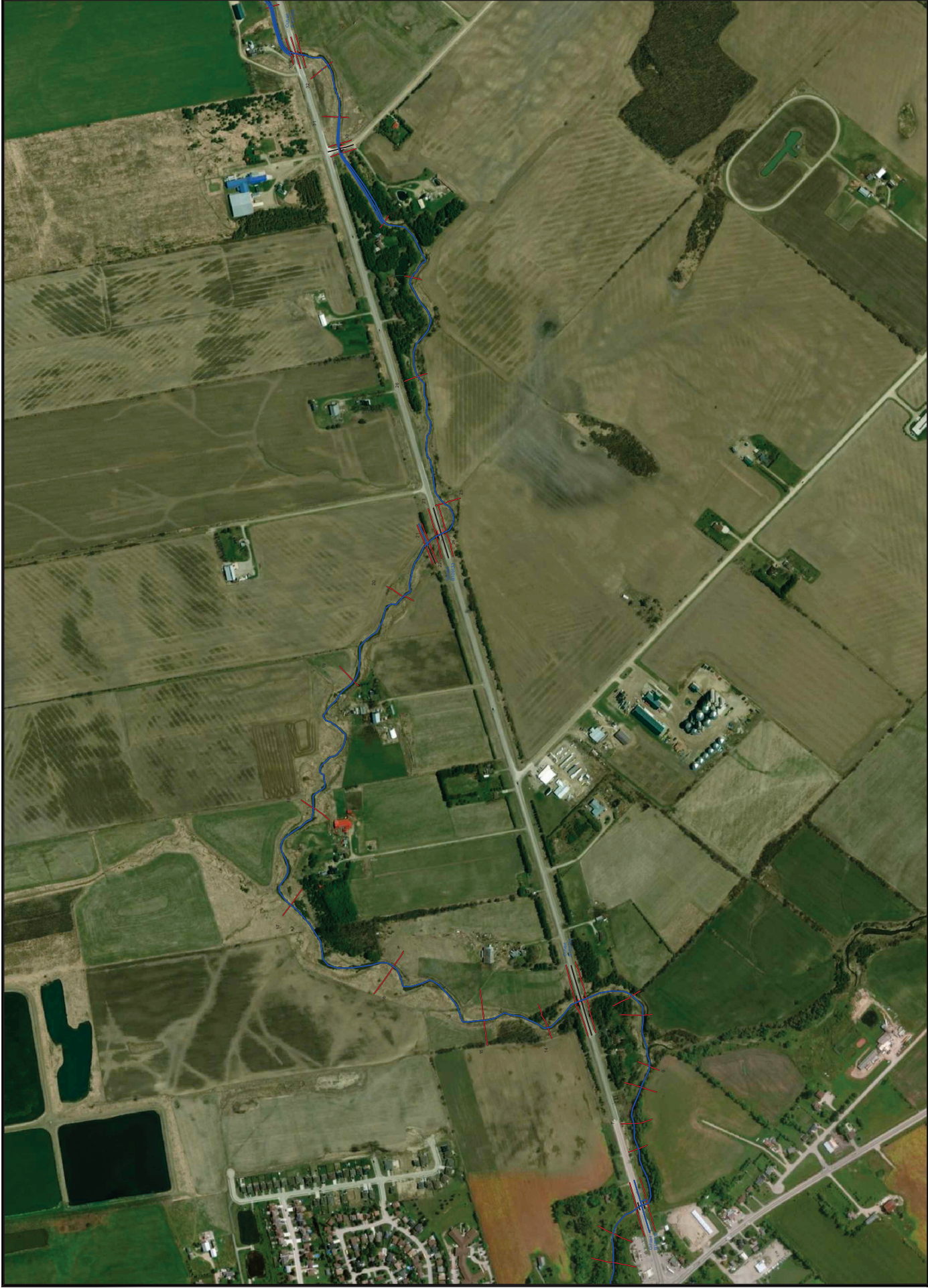
EXHIBIT

4









APPENDIX

A

Hydrologic Analysis

Flows From Different Methods

			Watershed 132 - 6748.71 ha								Watershed 123 - 3430 ha							
			2yr	5yr	10yr	20yr	25yr	50yr	100yr	Reg	2yr	5yr	10yr	20yr	25yr	50yr	100yr	Reg
OFAT	Primary Regression		22.043	32.28	39.42	46.36		52.85	59.81		10.45	15.57	19.26	22.89		26.98	30.77	
		Index Flood Method with EPA	21.86	28.79	34.25	41.16		49.56	57.56		12.11	15.95	18.98	22.8		27.45	31.89	
	VO5		29.7	46.38	57.35	71.38		82.82	93	208.43	16	24.8	30.54	37.86		43.82	49.17	108.24
UOFM			15.77		27.6		33.45	36.91	40.86		9.99		17.99		21.98	24.39	27.11	
			22.21		40.59		49.92	56.79	63.85		14.07		26.45		32.8	37.52	42.36	
			31.09		59.27		74.88	86.89	100.24		19.7		38.62		49.21	57.4	66.51	
	MIFM		45.3	59	72.2		88.1	99.5	111.8		32.6	42.4	52		63.4	71.6	80.5	
GRCA Annual Flood Frequency_2011	02GA023 Conestogo River at Flood Above Drayton Area: 27200 ha	Flood Frequency Unit Area flows	0.46	0.73	0.93	1.13	1.2	1.4	1.6		0.46	0.73	0.93	1.13	1.2	1.4	1.6	
			31.0	49.3	62.8	76.3	81.0	94.5	108.0		15.778	25.039	31.899	38.759	41.16	48.02	54.88	

109123.txt

** SIMULATION:Run 01 **

READ STORM 10.0

[Ptot= 55.61 mm]

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** SIMULATION:Run 02 **

READ STORM 10.0

[Ptot= 76.10 mm]

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** SIMULATION:Run 03 **

READ STORM 10.0

[Ptot= 89.08 mm]

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remark: 010SCS24

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** SIMULATION:Run 04 **

READ STORM 10.0

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remark: 025SCS24

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** SIMULATION:Run 05 **

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*****
** SIMULATION:Run 06          **
*****
READ STORM                      10.0
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** CALIB NASHYD          109123  1  5.0 3430.00   49.17 22.58 102.40 0.79   0.000
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** SIMULATION:Run 07          **
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READ STORM                      60.0
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*
*****
** SIMULATION:Run 08          **
*****
READ STORM                      60.0
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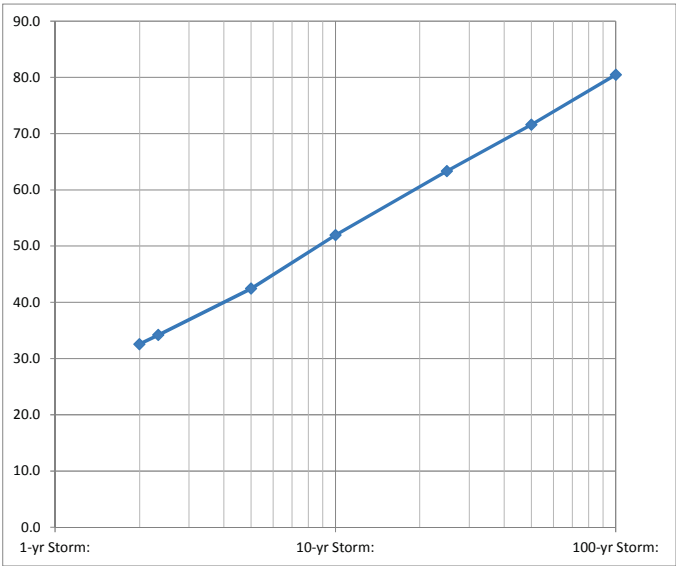
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** SIMULATION:Run 01 **
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*****
** SIMULATION:Run 02 **
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*****
** SIMULATION:Run 03 **
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   [ N = 3.0:Tp 9.65]
*
*****
** SIMULATION:Run 04 **
*****
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*****
** SIMULATION:Run 06 **
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** SIMULATION:Run 08 **
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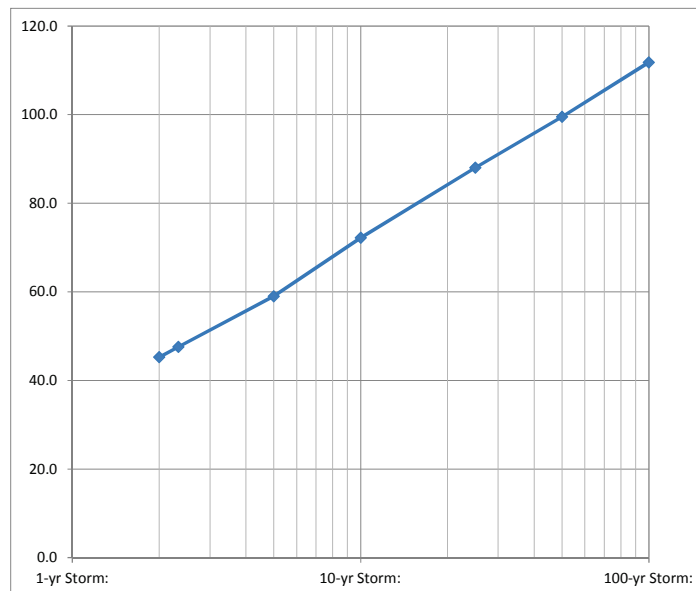
Flow calculations using The Modified Index Flow Method
at culvert C109123

Watershed Type:	Southern				
Watershed Area (A):	34.3	km ²			
Main Channel Length:	10072	m			
Main Channel Length at 85% of Length:	8561	m			
Main Channel Invert at 85% of Length:	473.0	m			
Main Channel Length at 10% of Length:	1007	m			
Main Channel Invert at 10% of Length:	456.0	m			
Main Channel Rise:	17.0	m			
Main Channel Run:	7554	m			
Watershed Slope:	0.2%				
Watershed Storage Area (Ad):	0.35	km ²			85/10 Method
Storage(Ad/A):	1%				Wetlands and Water bodies from shapefile
CN Number:	89				
Watershed Base Class:	11.4				
Slope Adjustment:	1.0				(Design Chart 1.15 or 1.17) MTO Drainage Manual (1995)
Storage Adjustment:	1.0				(Design Chart 1.18) MTO Drainage Manual (1995)
Net Watershed Class:	10.5				(Design Chart 1.19) MTO Drainage Manual (1995)
Class Coeff. (C.C.):	4.47				NetClass = BaseClass + SlopeAdj. + StorageAdj. (Design Chart 1.15) MTO Drainage Manual (1995)
2-yr Storm:			32.6	m ³ /s	Using Best Curve Fit
Frequency Conv. Factor 2.33-yr Storm:	0.54	$Q_{2.33}=Q_{25} \times C.F.=$	34.2	m ³ /s	(Design Chart H5-9) MTO Drainage Manual (1984)
Frequency Conv. Factor 5-yr Storm:	0.67	$Q_5=Q_{25} \times C.F.=$	42.4	m ³ /s	(Design Chart H5-9) MTO Drainage Manual (1984)
Frequency Conv. Factor 10-yr Storm:	0.82	$Q_{10}=Q_{25} \times C.F.=$	52.0	m ³ /s	(Design Chart H5-9) MTO Drainage Manual (1984)
Frequency Conv. Factor 25-yr Storm:	1	$Q_{25}=C.C. \times Area^{0.75}=$	63.4	m ³ /s	25-yr Storm
Frequency Conv. Factor 50-yr Storm:	1.13	$Q_{50}=Q_{25} \times C.F.=$	71.6	m ³ /s	(Design Chart H5-9) MTO Drainage Manual (1984)
Frequency Conv. Factor 100-yr Storm:	1.27	$Q_{100}=Q_{25} \times C.F.=$	80.5	m ³ /s	(Design Chart H5-9) MTO Drainage Manual (1984)



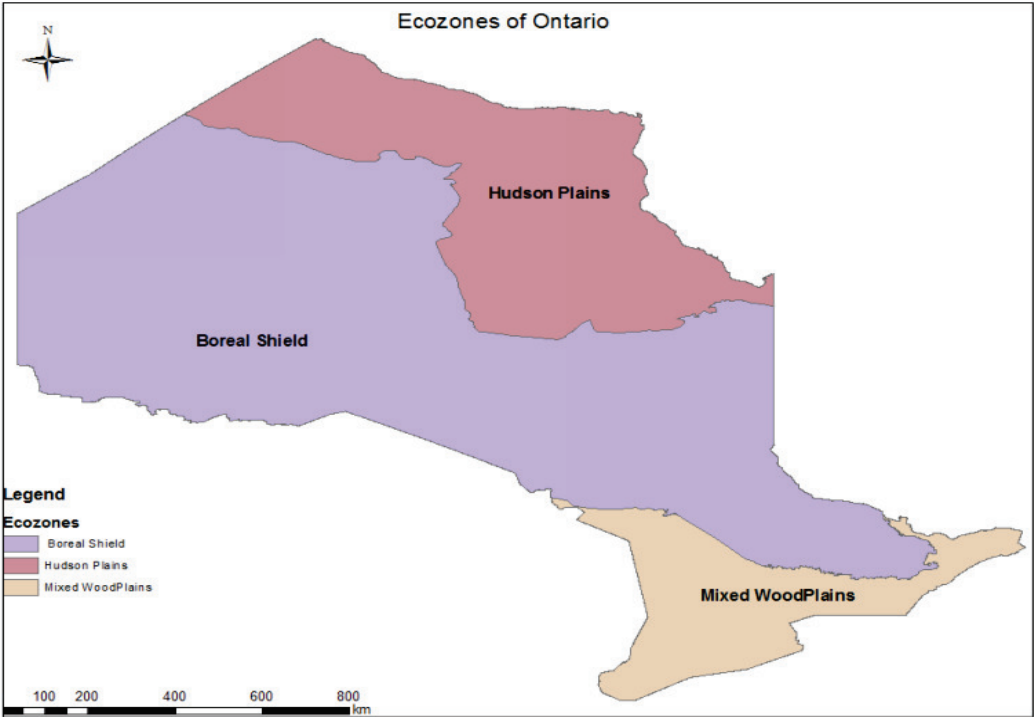
Flow calculations using The Modified Index Flow Method at culvert B109132

Watershed Type:	Southern			
Watershed Area (A):	67.487	km ²		
Main Channel Length:	10679	m		
Main Channel Length at 85% of Length:	9077	m		
Main Channel Invert at 85% of Length:	473.0	m		
Main Channel Length at 10% of Length:	1068	m		
Main Channel Invert at 10% of Length:	456.0	m		
Main Channel Rise:	17.0	m		
Main Channel Run:	8009	m		
Watershed Slope:	0.2%			85/10 Method
Watershed Storage Area (Ad):	1.94	km ²		Wetlands and Water bodies from shapefile
Storage(Ad/A):	3%			
CN Number:	88			
Watershed Base Class:	11.2			(Design Chart 1.15 or 1.17) MTO Drainage Manual (1995)
Slope Adjustment:	0.8			(Design Chart 1.18) MTO Drainage Manual (1995)
Storage Adjustment:	0.8			(Design Chart 1.19) MTO Drainage Manual (1995)
Net Watershed Class:	10.0			NetClass = BaseClass + SlopeAdj. + StorageAdj.
Class Coeff. (C.C.):	3.74			(Design Chart 1.15) MTO Drainage Manual (1995)
2-yr Storm:			45.3	m ³ /s Using Best Curve Fit
Frequency Conv. Factor 2.33-yr Storm:	0.54	$Q_{2.33}=Q_{25} \times C.F.=$	47.6	m ³ /s (Design Chart H5-9) MTO Drainage Manual (1984)
Frequency Conv. Factor 5-yr Storm:	0.67	$Q_5=Q_{25} \times C.F.=$	59.0	m ³ /s (Design Chart H5-9) MTO Drainage Manual (1984)
Frequency Conv. Factor 10-yr Storm:	0.82	$Q_{10}=Q_{25} \times C.F.=$	72.2	m ³ /s (Design Chart H5-9) MTO Drainage Manual (1984)
Frequency Conv. Factor 25-yr Storm:	1	$Q_{25}=C.C. \times Area^{0.75}=$	88.1	m ³ /s 25-yr Storm
Frequency Conv. Factor 50-yr Storm:	1.13	$Q_{50}=Q_{25} \times C.F.=$	99.5	m ³ /s (Design Chart H5-9) MTO Drainage Manual (1984)
Frequency Conv. Factor 100-yr Storm:	1.27	$Q_{100}=Q_{25} \times C.F.=$	111.8	m ³ /s (Design Chart H5-9) MTO Drainage Manual (1984)



Unified Ontario Flood Method

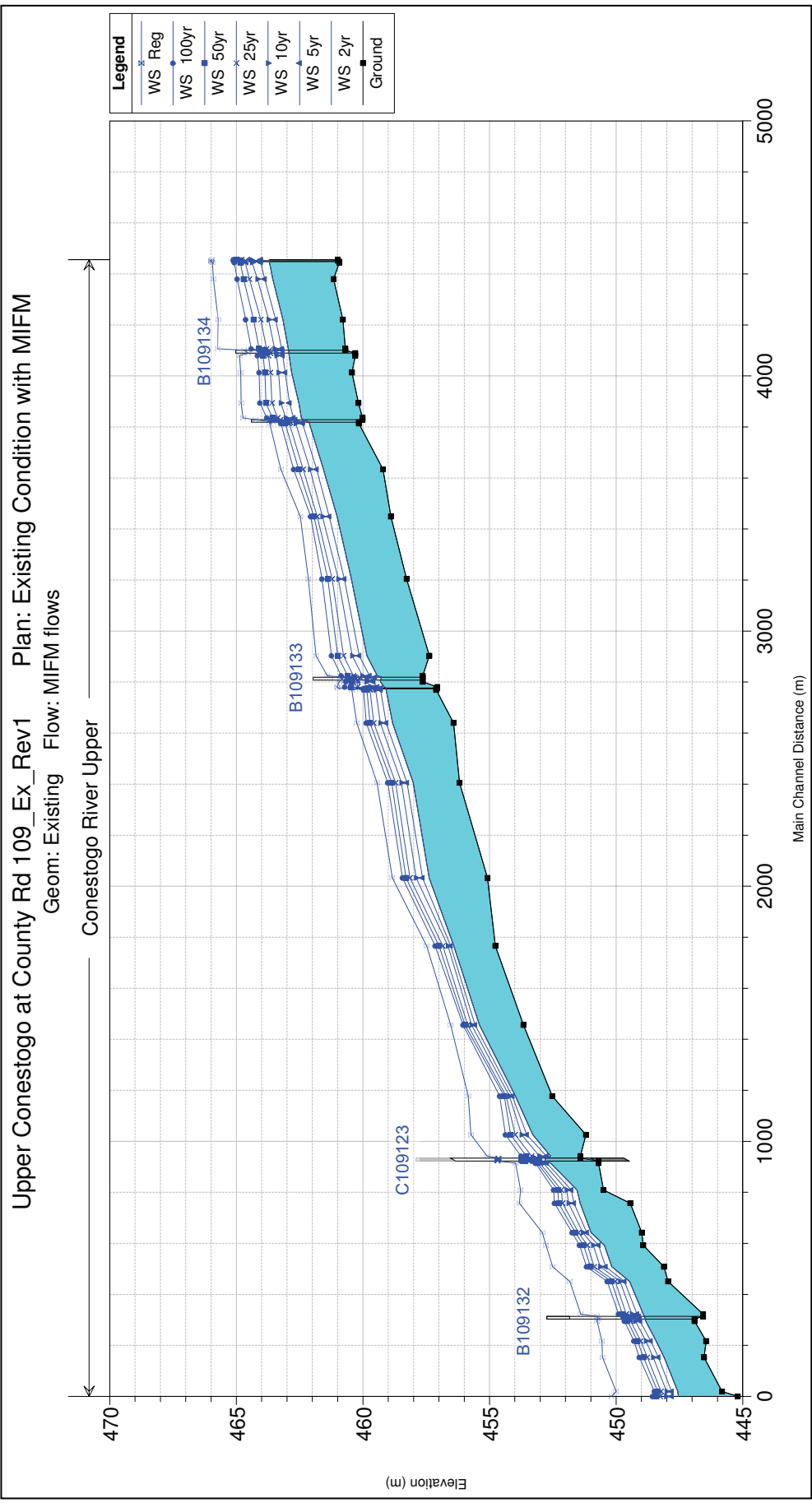
Flows for Mixed Wood Plains					
Return period (years)	2	10	25	50	100
Lower Limit of $Q_{UO\text{FM}}$ (m^3/s) =	9.99	17.99	21.98	24.39	27.11
$Q_{UO\text{FM}}$ (m^3/s) =	14.07	26.45	32.80	37.52	42.36
Upper Limit of $Q_{UO\text{FM}}$ (m^3/s) =	19.70	38.62	49.21	57.40	66.51



APPENDIX

B

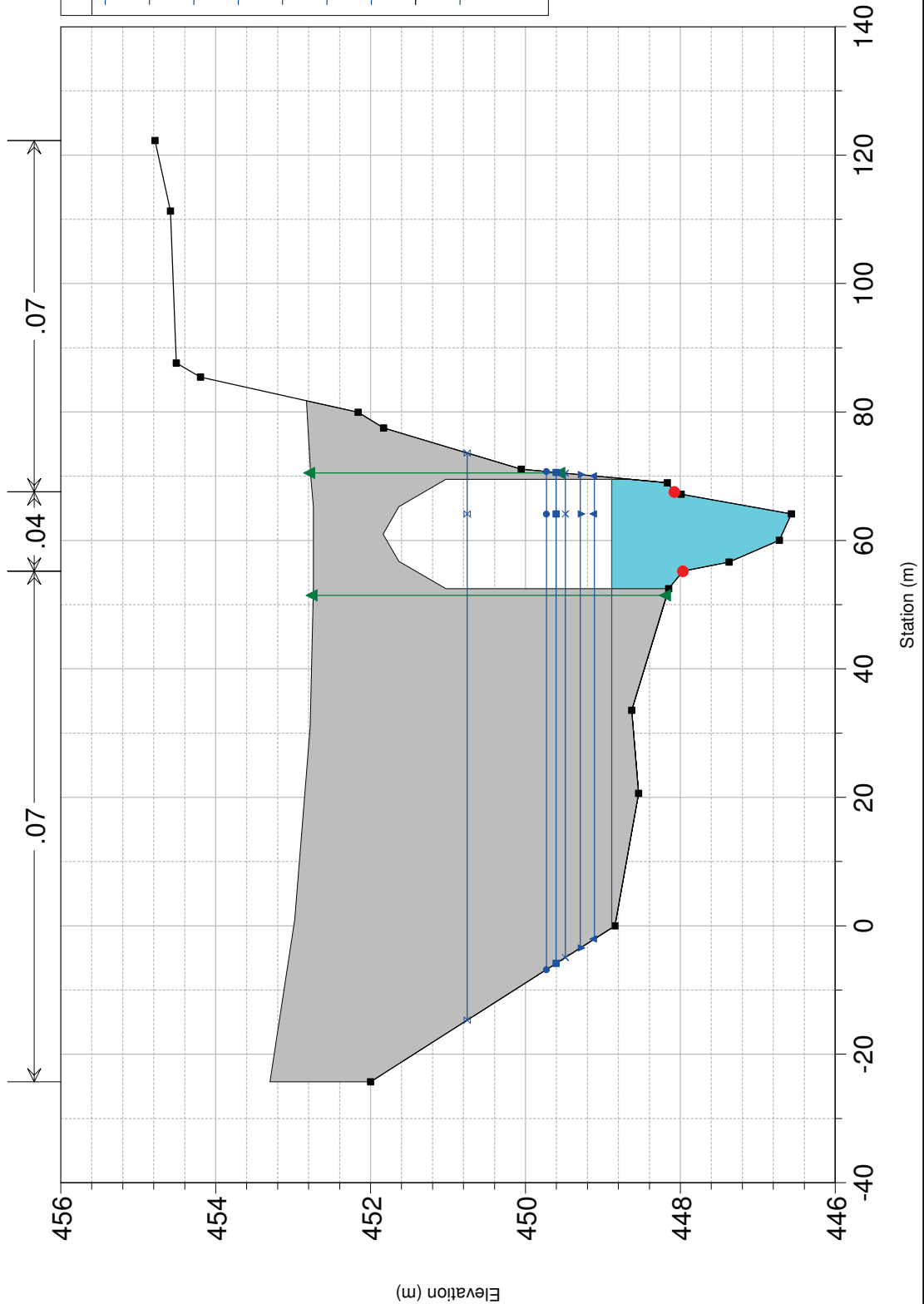
HEC-RAS Input (Cross Sections & Longitudinal Profiles)



Upper Conestogo at County Rd 109_Ex_Rev1 Plan: Existing Condition with MIFM 2021-02-06

Geom: Existing Flow: MIFM flows

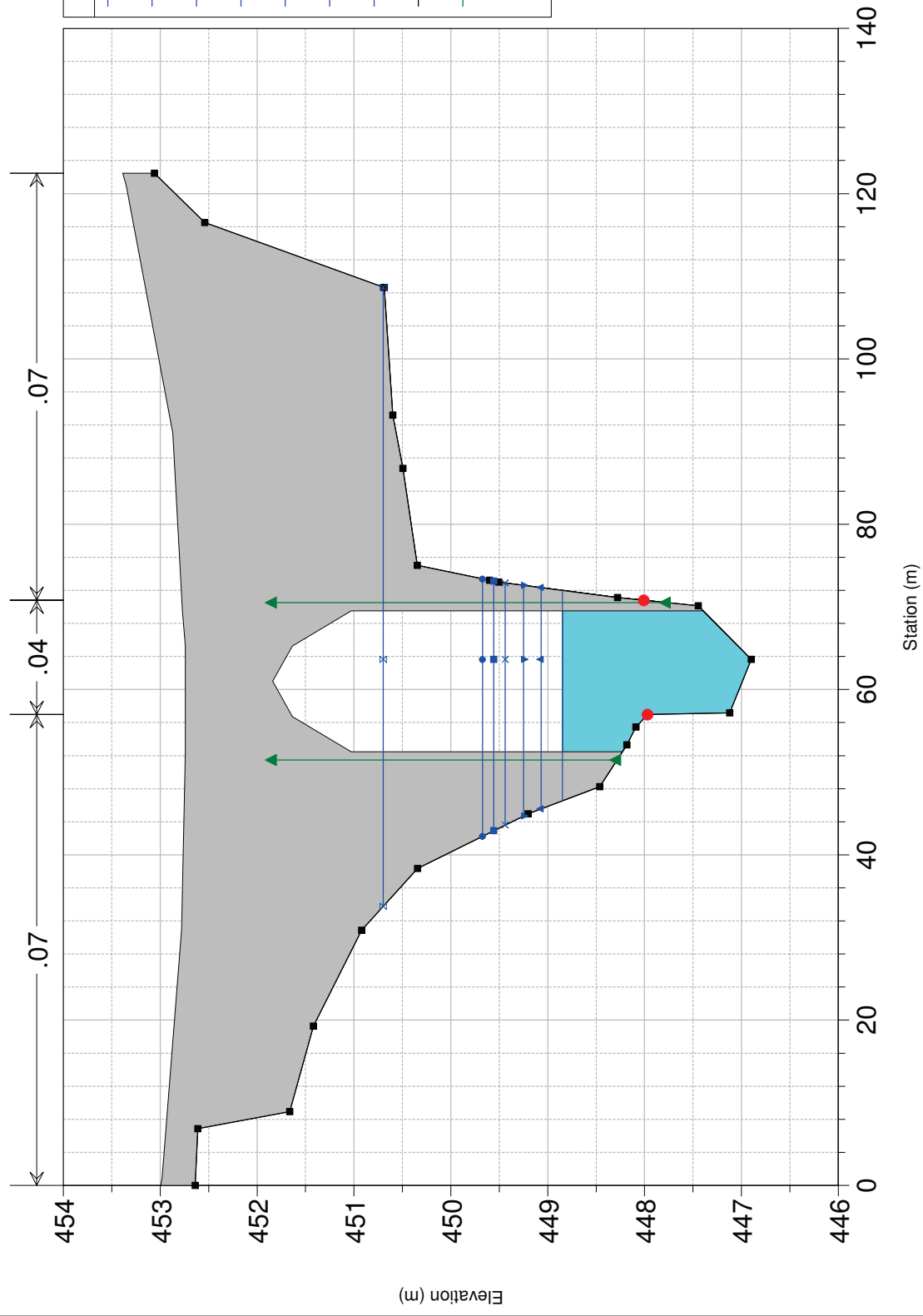
River = Conestogo River Reach = Upper RS = 35.03 BR Wellington Road 109 - Bridge B109132



Upper Conestogo at County Rd 109_Ex_Rev1 Plan: Existing Condition with MIFM 2021-02-06

Geom: Existing	Flow: MIFM flows
	

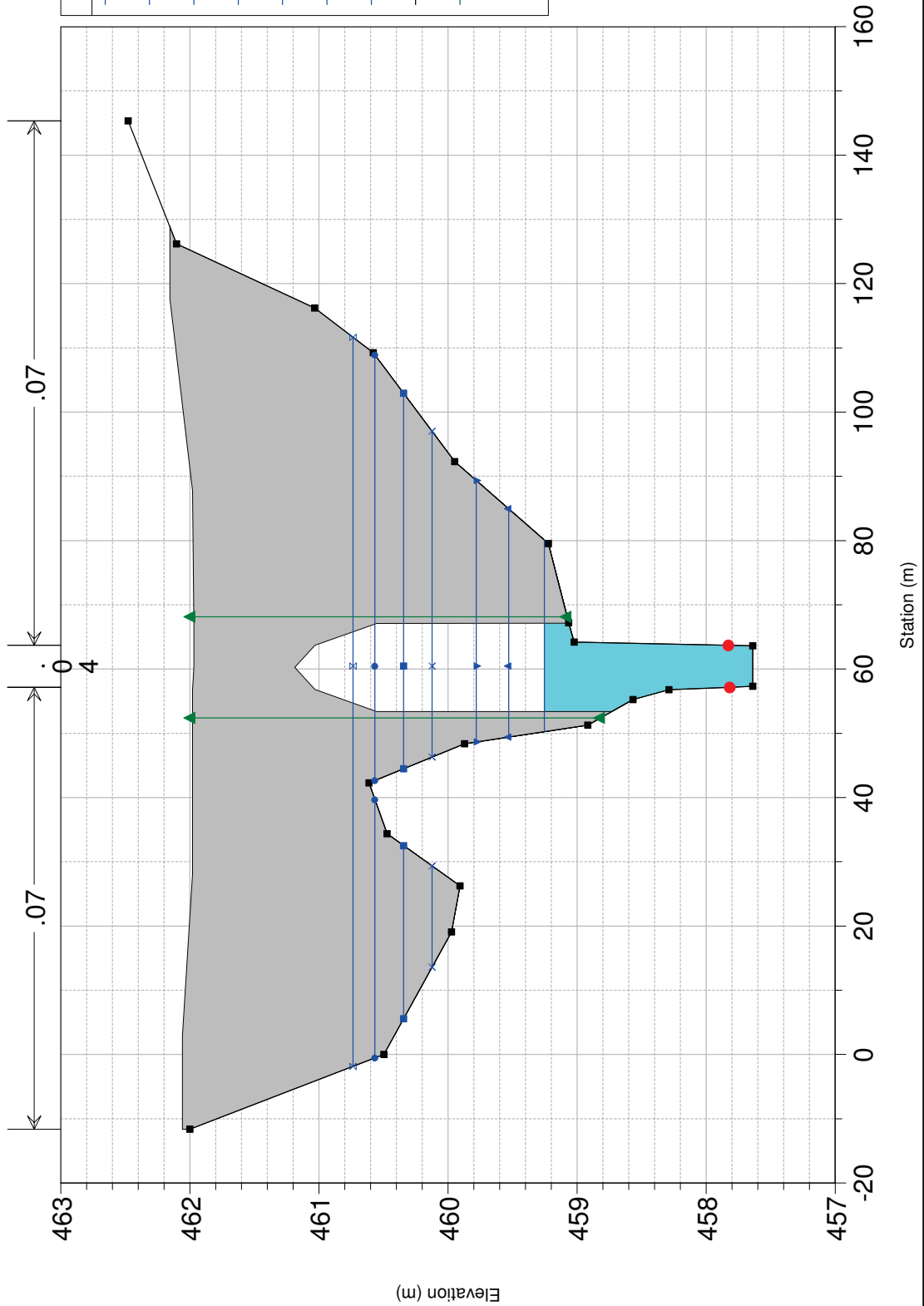
River = Conestogo River Reach = Upper RS = 35.03 BR Wellington Road 109 - Bridge B109132



Upper Conestogo at County Rd 109_Ex_Rev1 Plan: Existing Condition with MIFM 2021-02-06

Geom: Existing Flow: MIFM flows

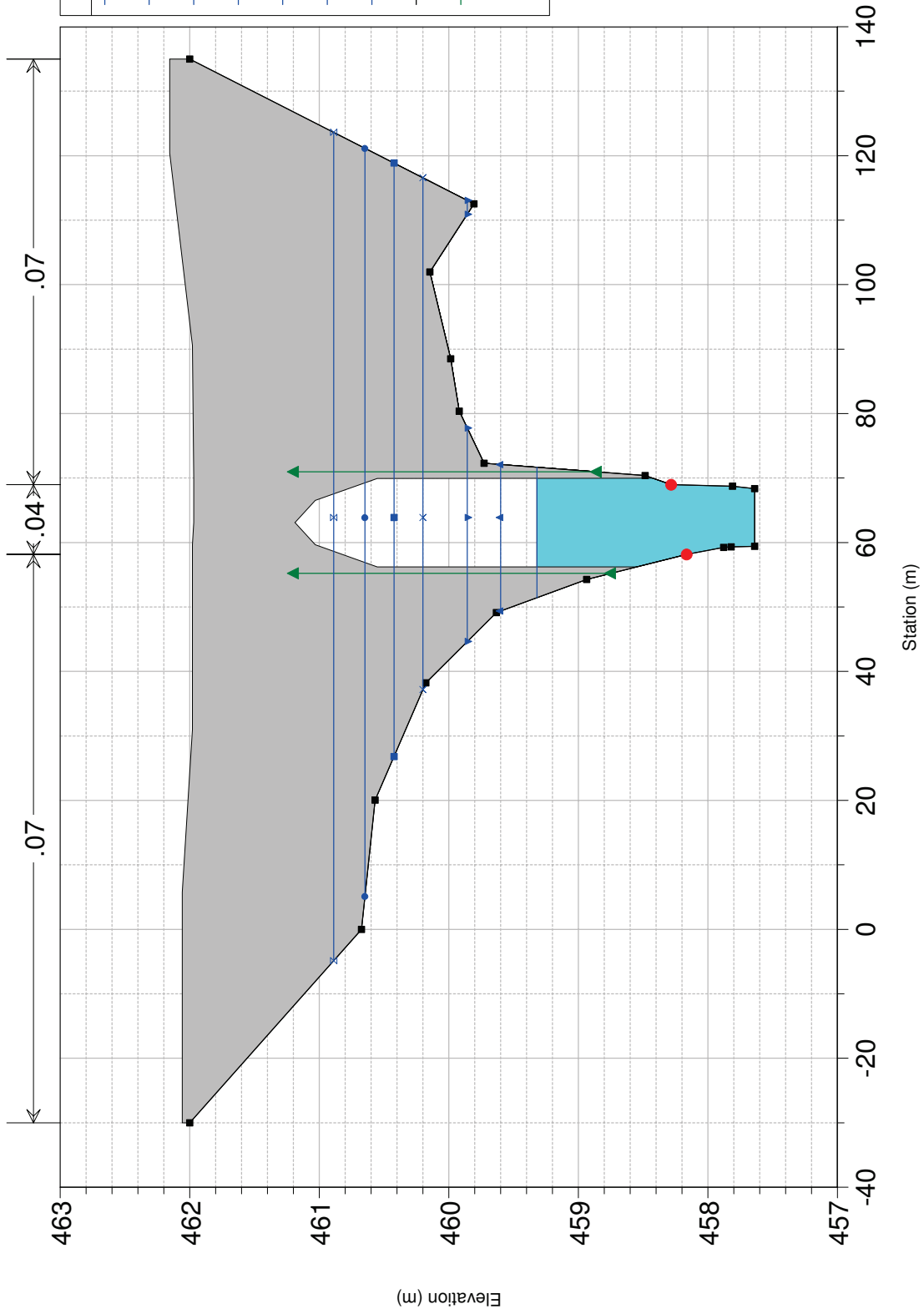
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Upper Conestogo at County Rd 109_Ex_Rev1 Plan: Existing Condition with MIFM 2021-02-06

Geom: Existing Flow: MIFM flows

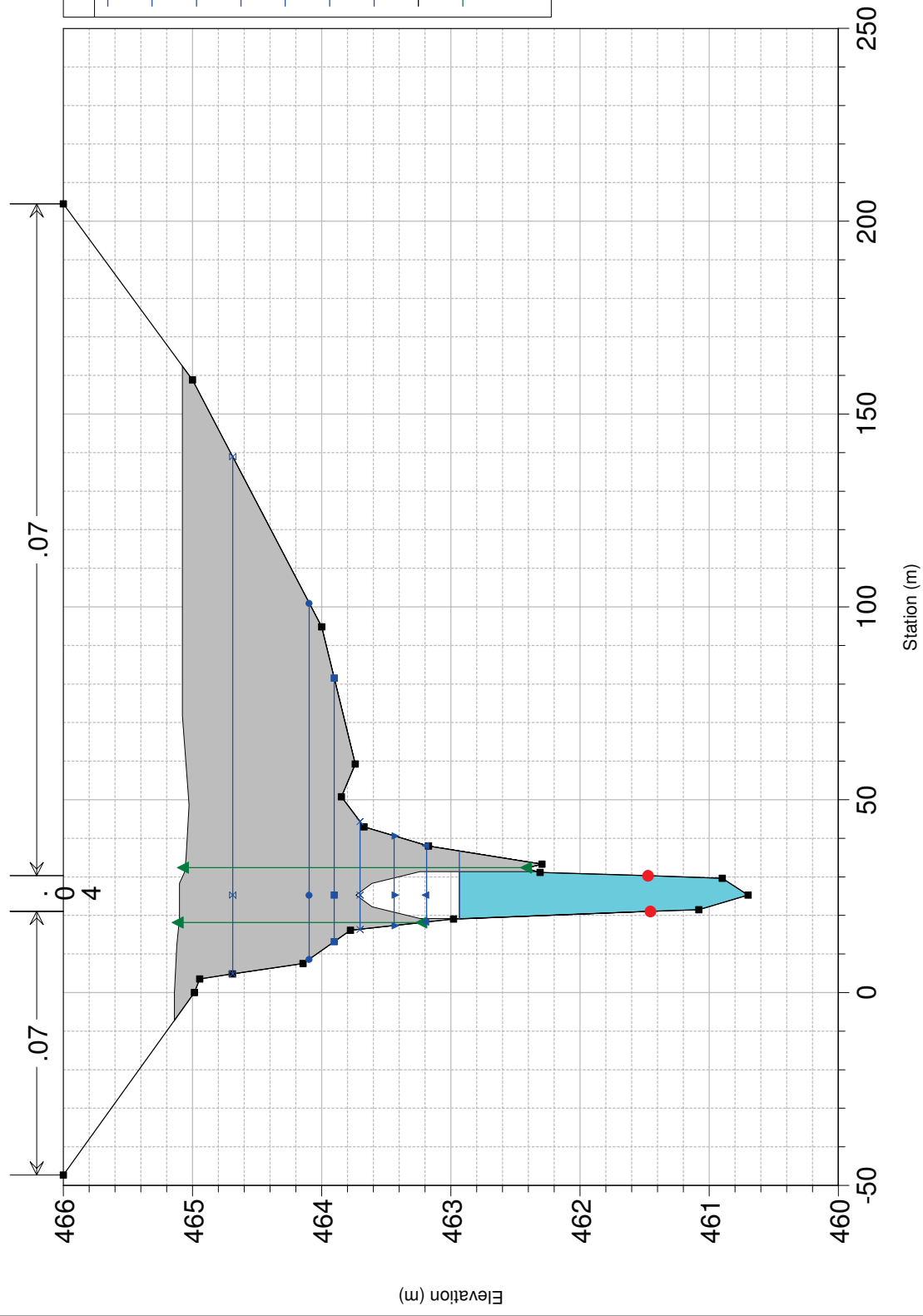
River = Conestogo River Reach = Upper RS = 37.53 BR Wellington Road 109 - Bridge B109133



Upper Conestogo at County Rd 109_Ex_Rev1 Plan: Existing Condition with MIFM 2021-02-06

Geom: Existing	Flow: MIFM flows

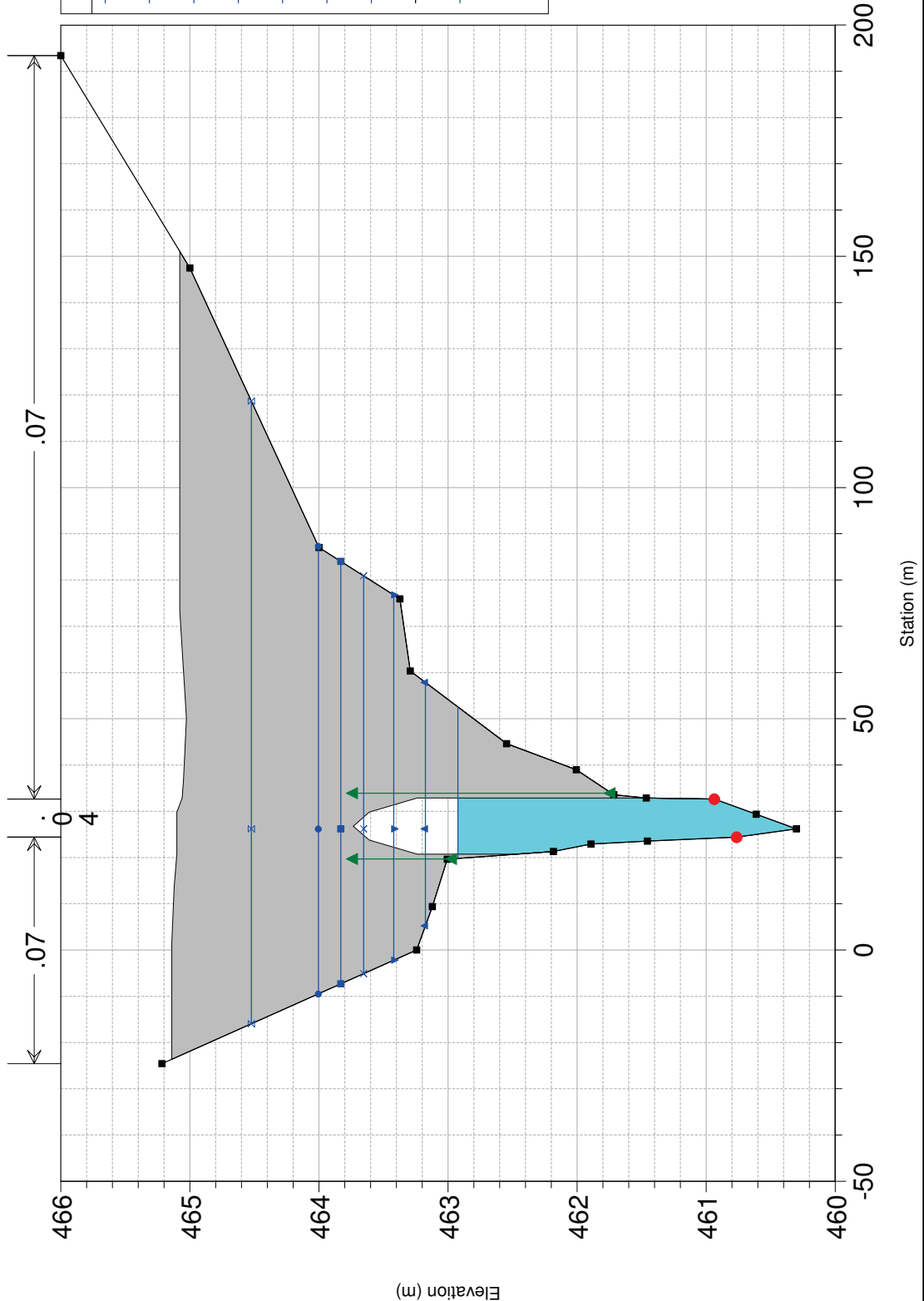
River = Conestogo River Reach = Upper RS = 38.81 BR Wellington Road 109 - Bridge B109134



Upper Conestogo at County Rd 109_Ex_Rev1 Plan: Existing Condition with MIFM 2021-02-06

Geom: Existing Flow: MIFM flows

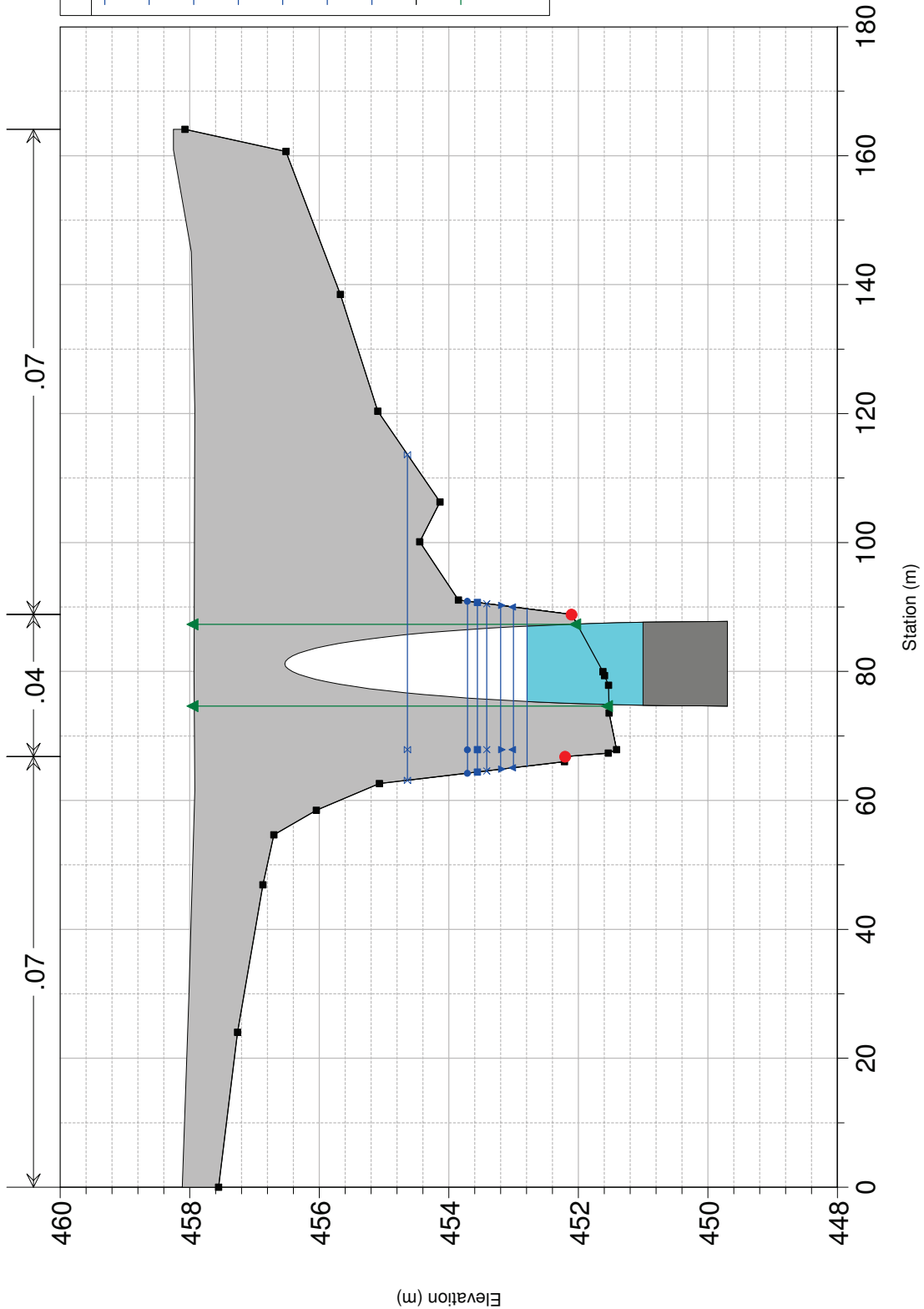
River = Conestogo River Reach = Upper RS = 38.81 BR Wellington Road 109 - Bridge B109134



Upper Conestogo at County Rd 109_Ex_Rev1 Plan: Existing Condition with MIFM 2021-02-06

Geom: Existing Flow: MIFM flows

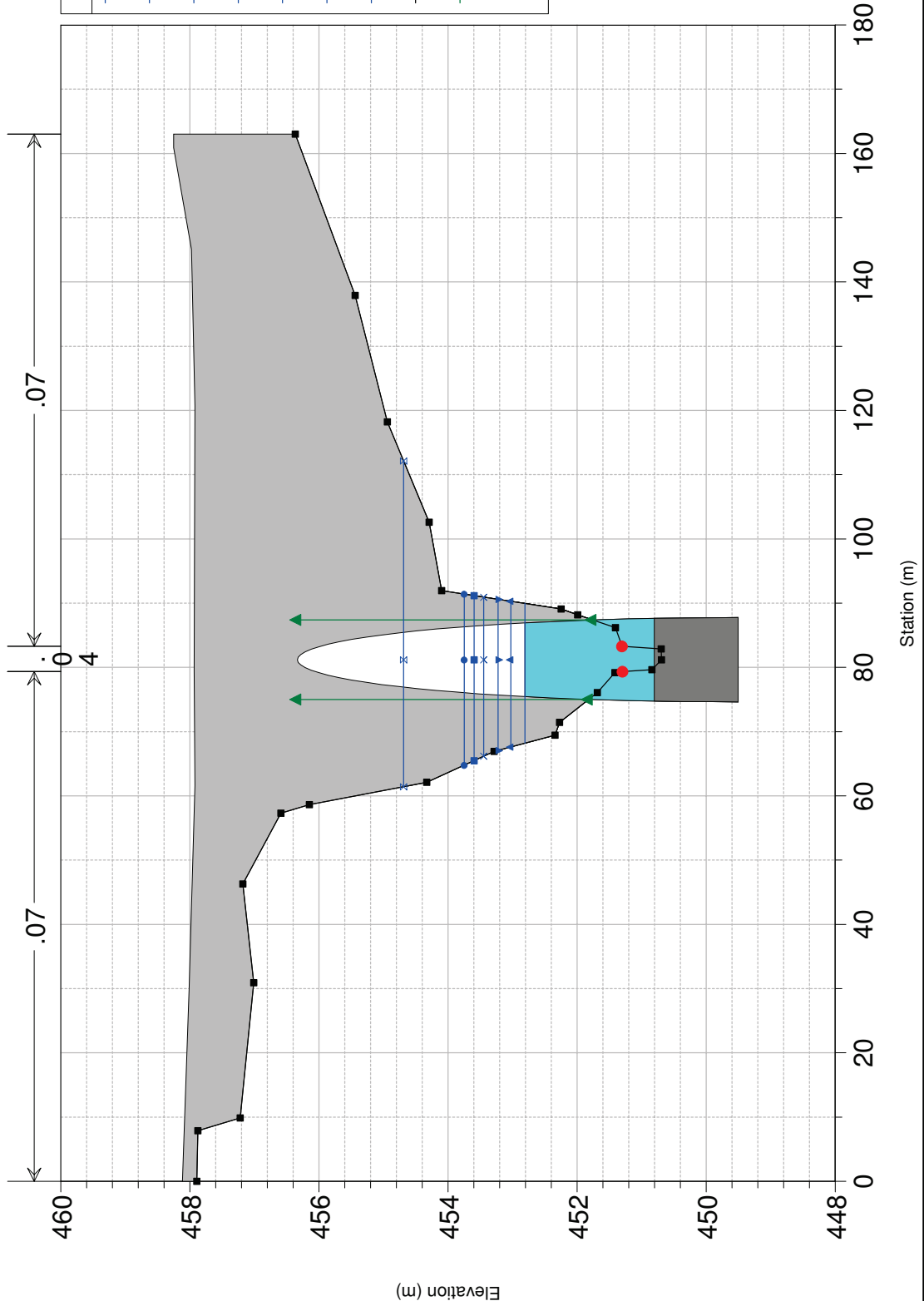
River = Conestogo River Reach = Upper RS = 35.64 Culv Wellington Road 109 - Bridge B109123



Upper Conestogo at County Rd 109_Ex_Rev1 Plan: Existing Condition with MIFM 2021-02-06

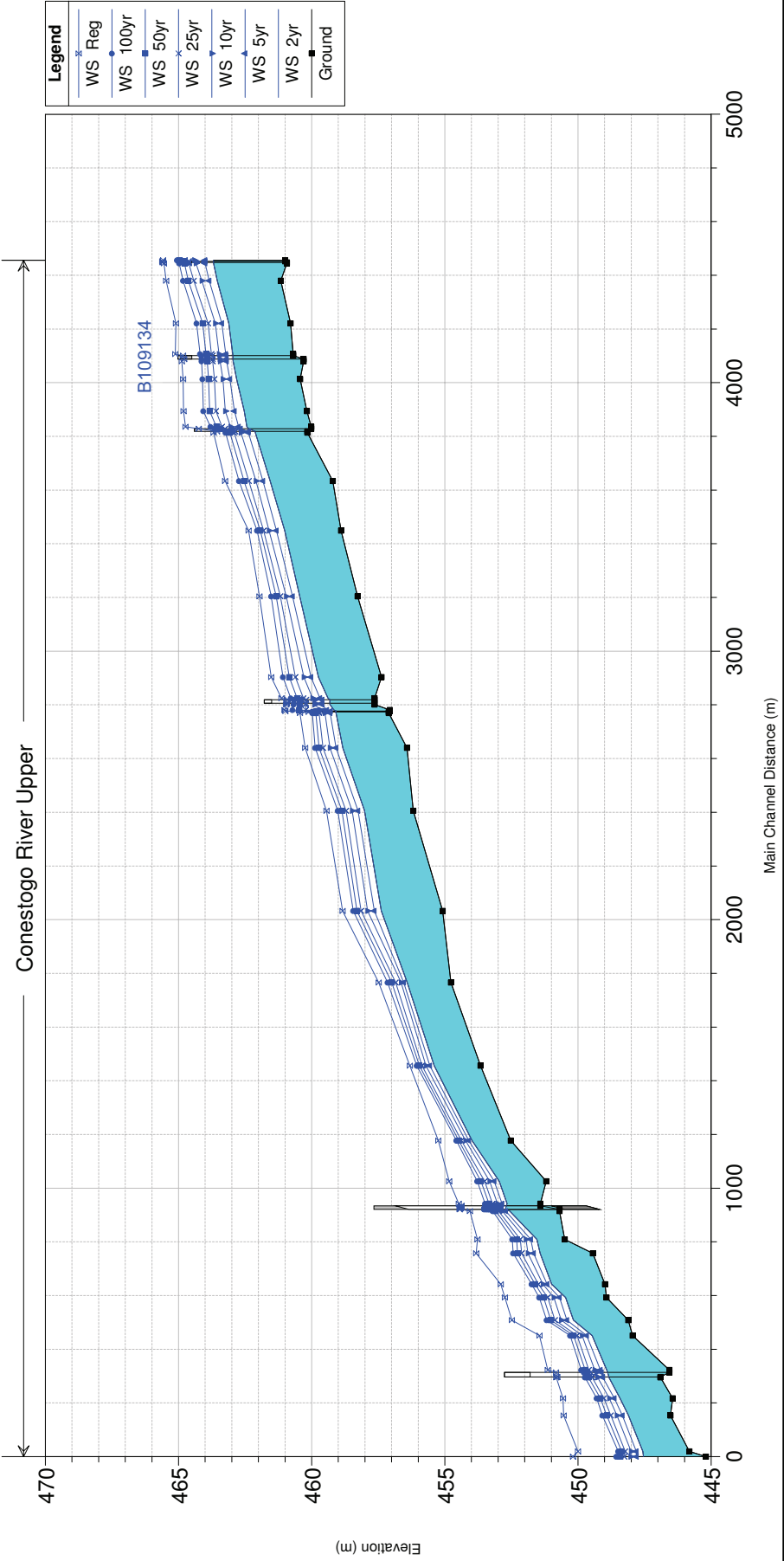
Geom: Existing Flow: MIFM flows

River = Conestogo River Reach = Upper RS = 35.64 Culv Wellington Road 109 - Bridge B109123

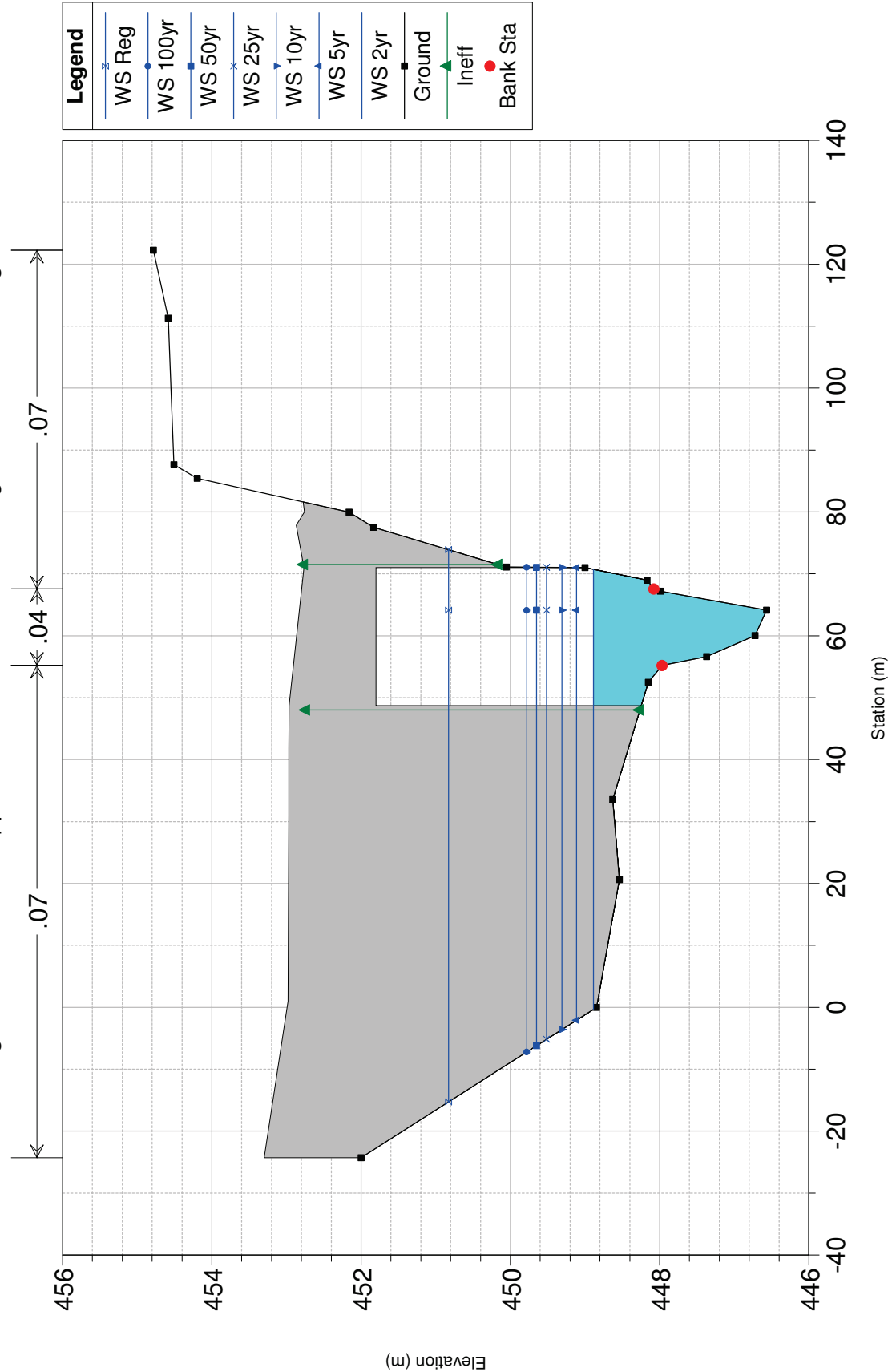


Upper Conestogo at County Rd 109_Pr_Opt1 Plan: Proposed V2 Updated_21Feb2024 2024-02-22

Geom: Proposed_V2_Updated_21Feb2024 Flow: MIFM flows



Upper Conestogo at County Rd 109_Pr_Opt1 Plan: Proposed V2 Updated_21Feb2024 2024-02-22
Geom: Proposed_V2_Updated_21Feb2024 Flow: MIFM flows
River = Conestogo River Reach = Upper RS = 35.03 BR Wellington Road 109 - Bridge B109132 U/S

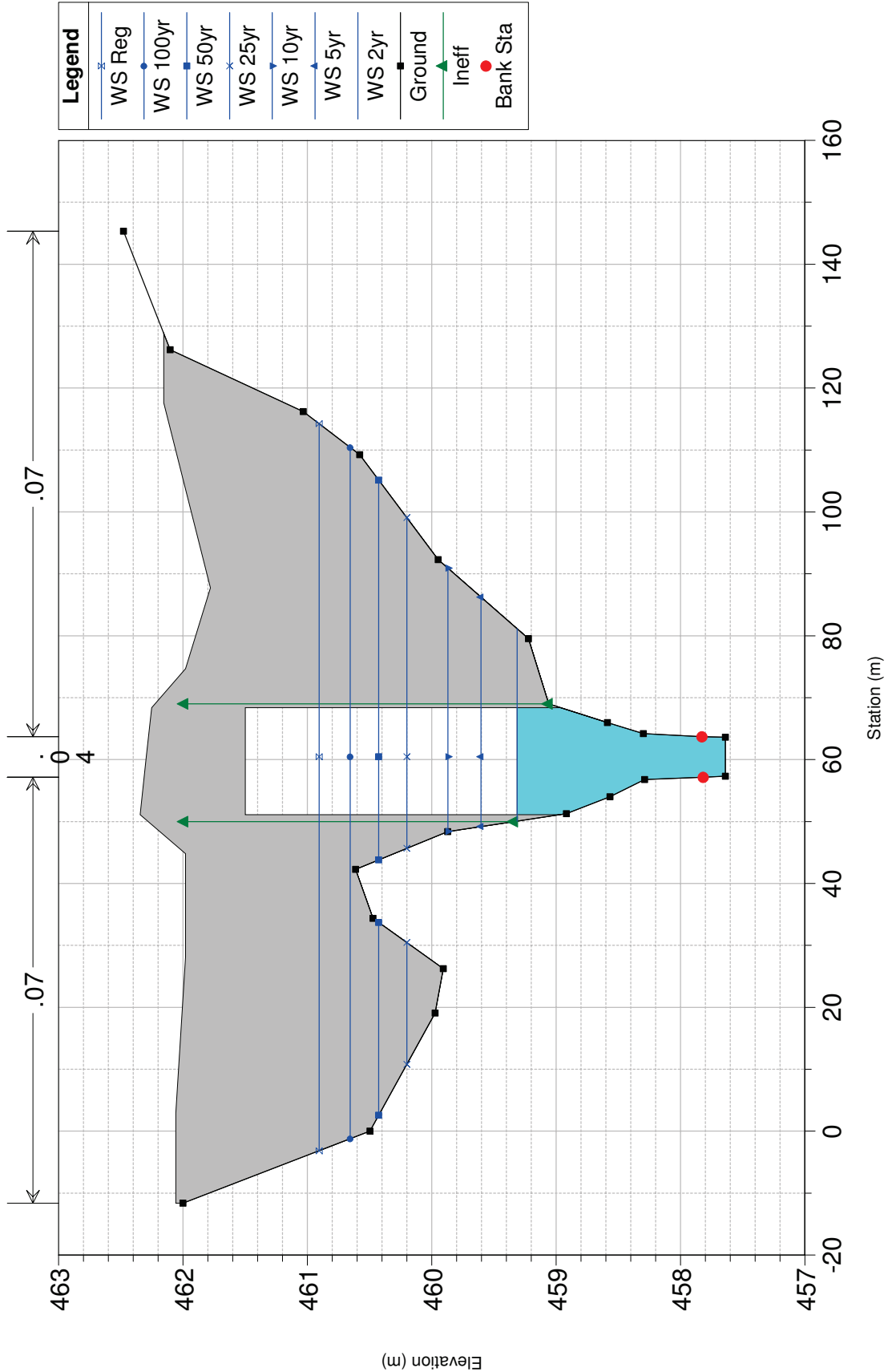


Geom: Proposed_V2_Updated_21Feb2024 Flow: MIFM flows

Upper Conestogo at County Rd 109_Pr_Opt1 Plan: Proposed V2 Updated_21Feb2024 2024-02-22

Geom: Proposed_V2_Updated_21Feb2024 Flow: MIFM flows

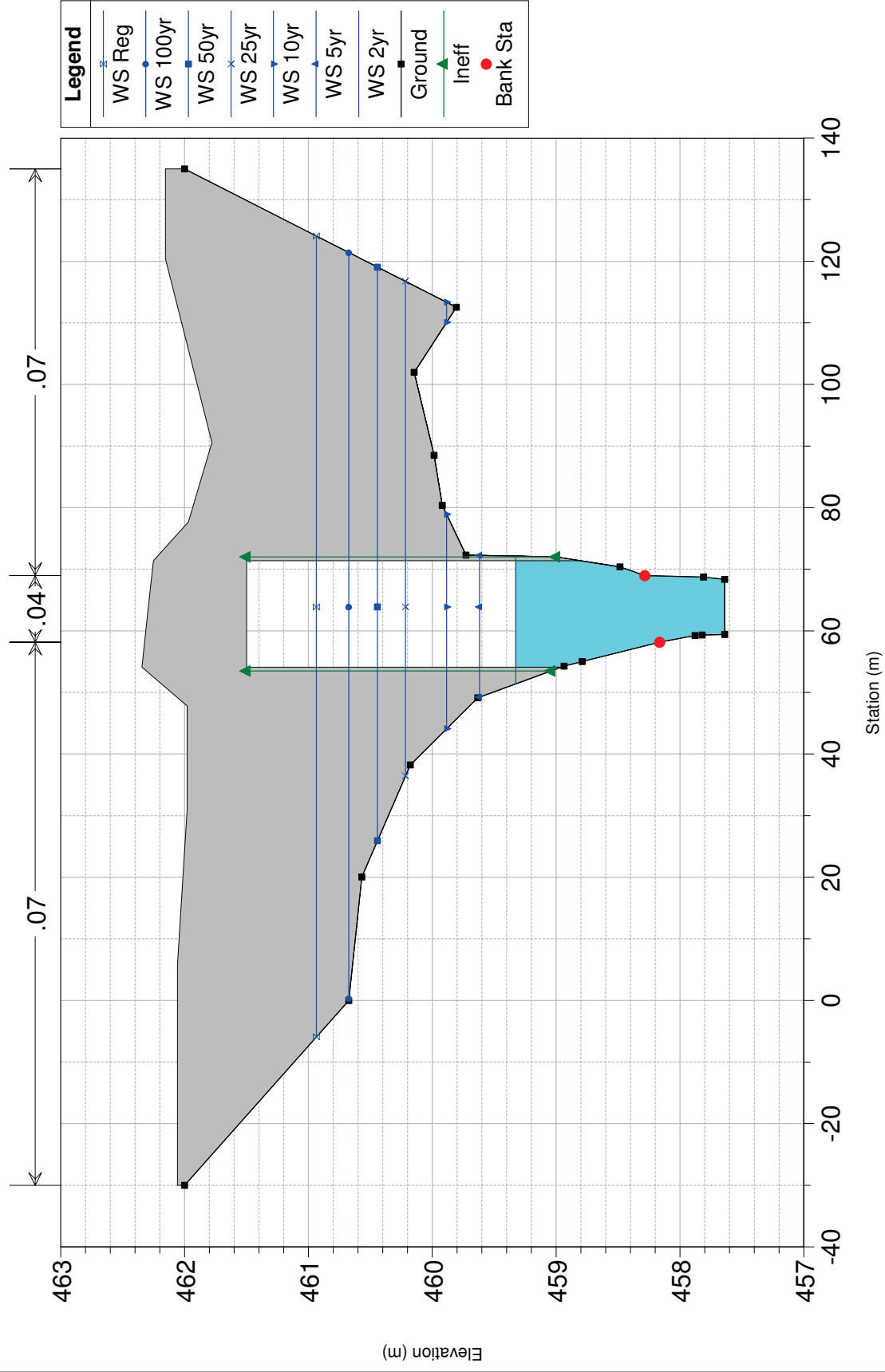
River = Conestogo River Reach = Upper RS = 37.53 BR Wellington Road 109 - Bridge B109133 U/S



Upper Conestogo at County Rd 109_Pr_Opt1	Plan: Proposed V2 Updated_21Feb2024	2024-02-22
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Geom: Proposed_V2_Updated_21Feb2024 Flow: MIFM flows

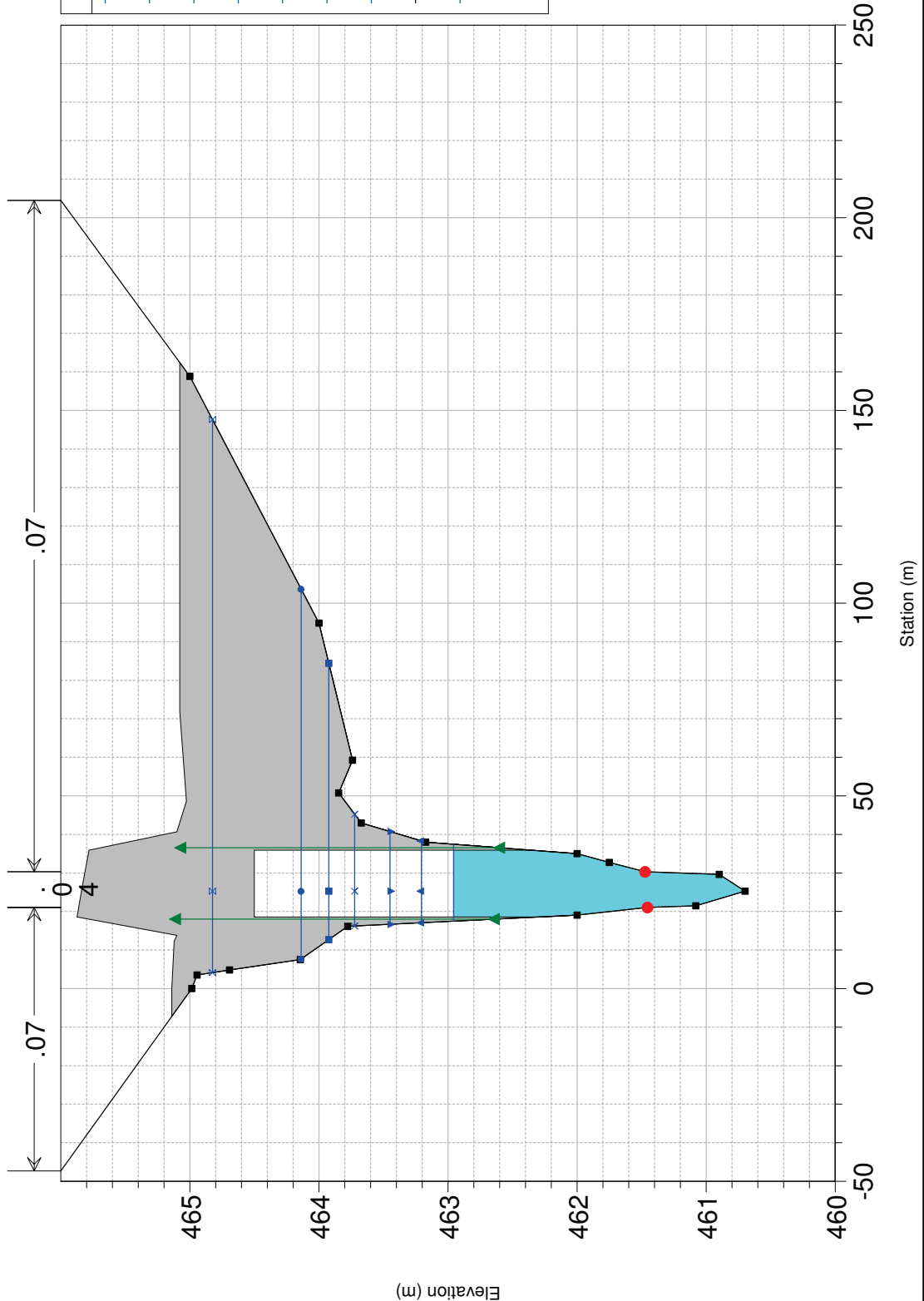
River = Conestogo River Reach = Upper RS = 37.53 BR Wellington Road 109 - Bridge B109133 D/S



Upper Conestogo at County Rd 109_Pr_Opt1 Plan: Proposed V2 Updated_21Feb2024 2024-02-22

Geom: Proposed_V2_Updated_21Feb2024 Flow: MIFM flows

River = Conestogo River Reach = Upper RS = 38.81 BR Wellington Road 109 - Bridge B109134 U/S

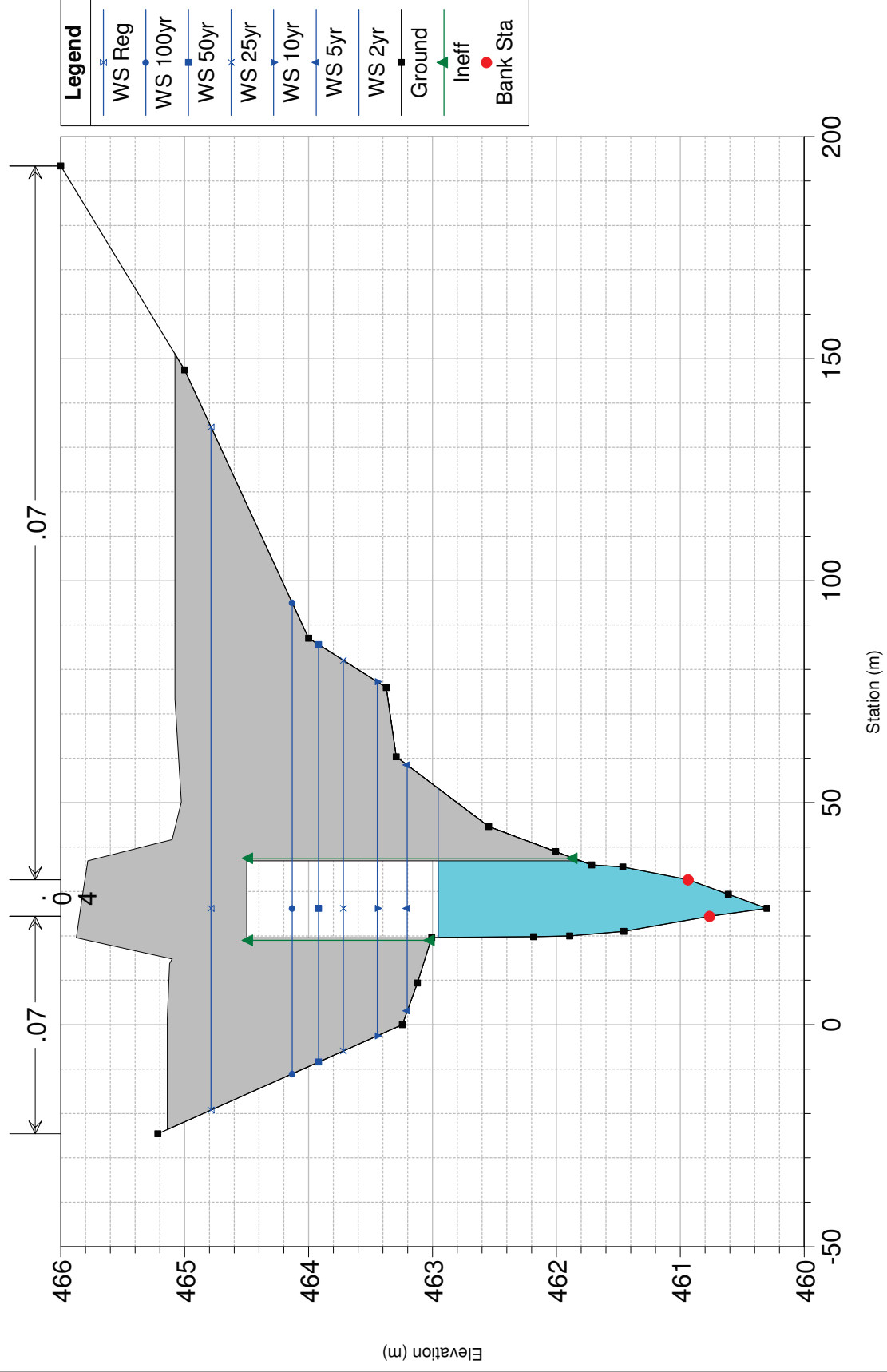


1 cm Horiz. = 16.31357 m 1 cm Vert. = 0.4870525 m

Upper Conestogo at County Rd 109_Pr_Opt1	Plan: Proposed V2 Updated_21Feb2024	2024-02-22
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Geom: Proposed_V2_Updated_21Feb2024 Flow: MIFM flows

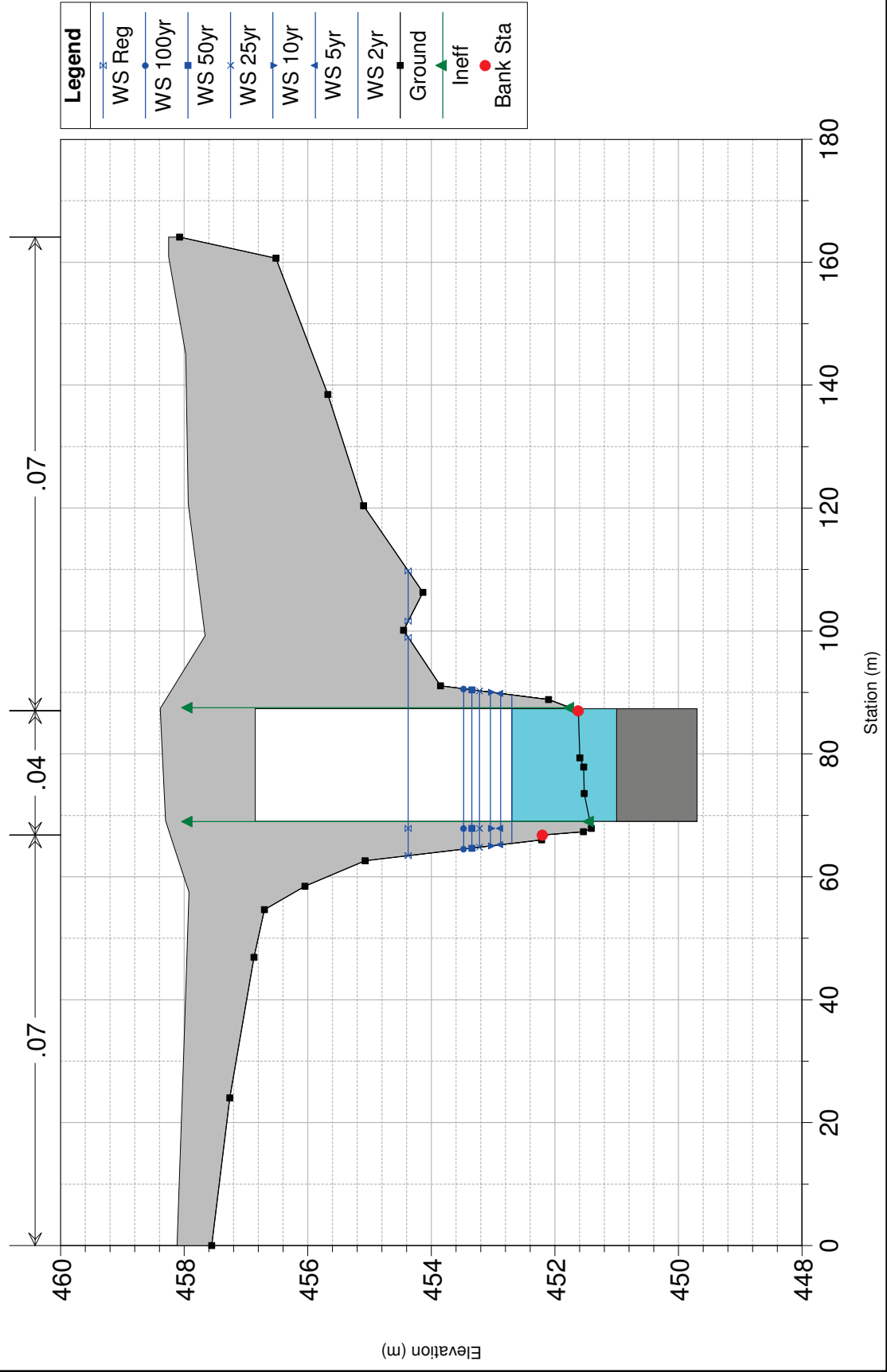
River = Conestogo River Reach = Upper RS = 38.81 BR Wellington Road 109 - Bridge B109134 D/S



Upper Conestogo at County Rd 109	Pr	Opt1	Plan: Proposed V2	Updated_21Feb2024	2024-02-22
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Geom: Proposed_V2_Updated_21Feb2024 Flow: MIFM flows

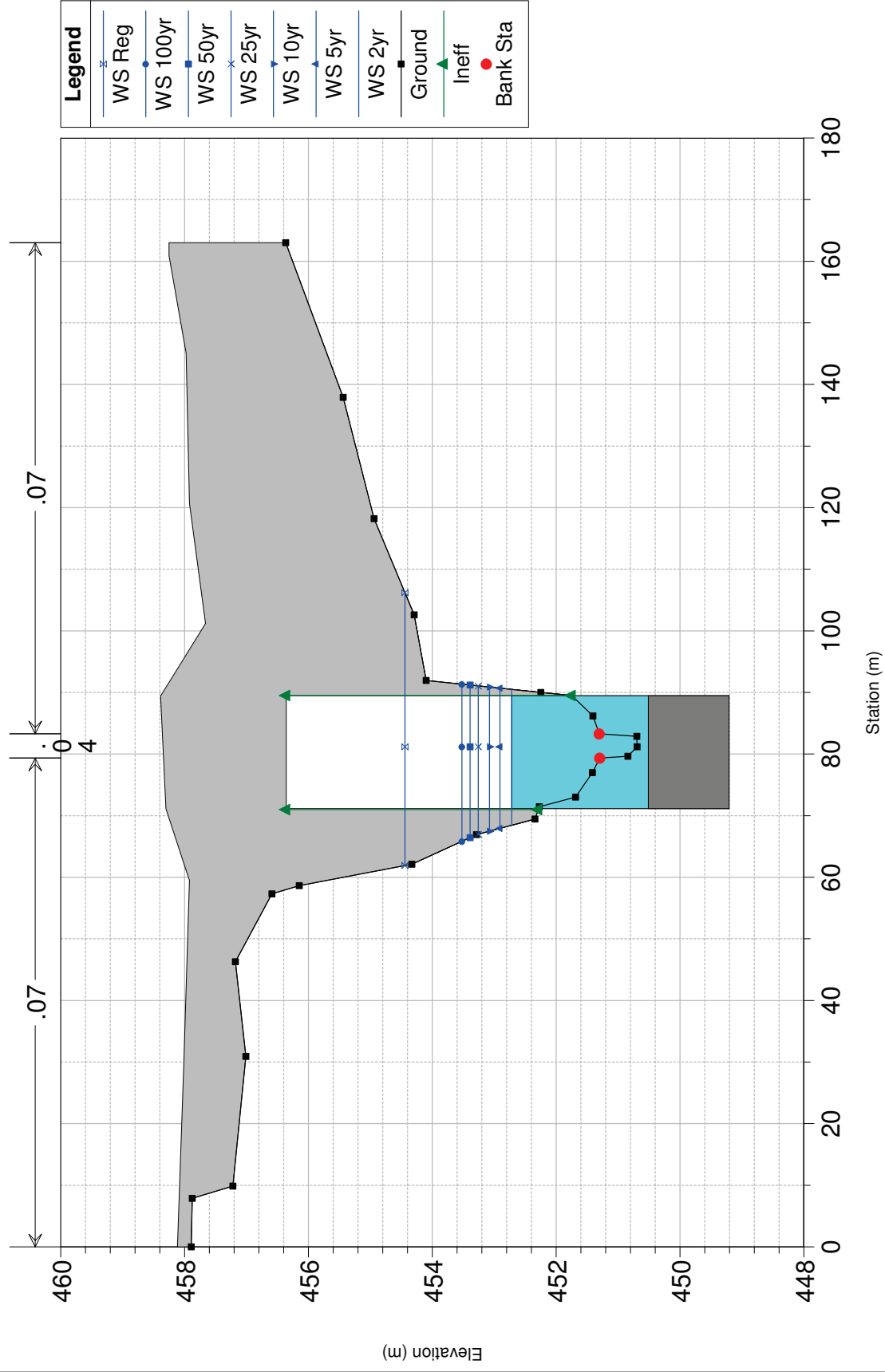
River = Conestogo River Reach = Upper RS = 35.64 Culv Wellington Road 109 - Bridge C109123 U/S



Upper Conestogo at County Rd 109	Pr_Opt1	Plan: Proposed V2	Updated_21Feb2024	2024-02-22
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Geom: Proposed_V2_Updated_21Feb2024 Flow: MIFM flows

River = Conestogo River	Reach = Upper	RS = 35.64	Culv	Wellington Road 109 - Bridge C109123 D/S
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APPENDIX

C

HEC-RAS Output - Existing Condition

APPENDIX

C-1

B109132 Output

HEC-RAS Plan: Existing Con Locations: User Defined

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
Conestogo River	Upper	35.17	2yr	45.30	447.95	449.47	449.47	449.96	0.012458	3.29	17.41	19.28	0.92
Conestogo River	Upper	35.17	5yr	59.00	447.95	449.67	449.67	450.24	0.012152	3.57	21.42	20.11	0.93
Conestogo River	Upper	35.17	10yr	72.20	447.95	449.85	449.85	450.48	0.012035	3.82	24.96	20.83	0.94
Conestogo River	Upper	35.17	25yr	88.10	447.95	450.03	450.03	450.74	0.012073	4.10	28.87	21.59	0.96
Conestogo River	Upper	35.17	50yr	99.50	447.95	450.19	450.16	450.92	0.011396	4.20	32.24	22.23	0.94
Conestogo River	Upper	35.17	100yr	111.80	447.95	450.35	450.30	451.11	0.010678	4.28	35.97	22.92	0.92
Conestogo River	Upper	35.17	Reg	235.10	447.95	451.83		452.68	0.006645	4.76	74.33	29.05	0.79
Conestogo River	Upper	35.04	2yr	45.30	446.57	448.93	448.21	449.10	0.002526	1.85	27.62	70.51	0.43
Conestogo River	Upper	35.04	5yr	59.00	446.57	449.17	448.44	449.38	0.002771	2.10	32.08	72.63	0.46
Conestogo River	Upper	35.04	10yr	72.20	446.57	449.38	448.61	449.63	0.002971	2.32	35.93	74.45	0.49
Conestogo River	Upper	35.04	25yr	88.10	446.57	449.60	448.81	449.90	0.003172	2.55	40.20	76.43	0.51
Conestogo River	Upper	35.04	50yr	99.50	446.57	449.75	448.94	450.09	0.003288	2.70	43.06	77.75	0.53
Conestogo River	Upper	35.04	100yr	111.80	446.57	449.91	449.08	450.28	0.003396	2.84	46.00	79.11	0.54
Conestogo River	Upper	35.04	Reg	235.10	446.57	451.39	450.18	452.02	0.003350	3.74	74.37	95.55	0.57
Conestogo River	Upper	35.03	Bridge										
Conestogo River	Upper	35.01	2yr	45.30	446.90	448.83	448.18	449.00	0.002874	1.85	27.10	25.38	0.45
Conestogo River	Upper	35.01	5yr	59.00	446.90	449.05	448.40	449.27	0.003154	2.10	31.34	26.70	0.48
Conestogo River	Upper	35.01	10yr	72.20	446.90	449.24	448.58	449.50	0.003417	2.32	34.85	27.85	0.51
Conestogo River	Upper	35.01	25yr	88.10	446.90	449.43	448.75	449.74	0.003740	2.57	38.51	29.25	0.54
Conestogo River	Upper	35.01	50yr	99.50	446.90	449.55	448.89	449.91	0.003983	2.75	40.81	30.16	0.56
Conestogo River	Upper	35.01	100yr	111.80	446.90	449.67	449.01	450.08	0.004237	2.93	43.11	31.14	0.58
Conestogo River	Upper	35.01	Reg	235.10	446.90	450.76	450.05	451.56	0.005414	4.18	63.75	75.89	0.70
Conestogo River	Upper	34.93	2yr	45.30	446.45	448.43		448.66	0.006136	2.24	23.83	24.13	0.63
Conestogo River	Upper	34.93	5yr	59.00	446.45	448.64		448.91	0.006021	2.45	29.16	26.40	0.64
Conestogo River	Upper	34.93	10yr	72.20	446.45	448.83		449.14	0.005855	2.62	34.31	28.43	0.65
Conestogo River	Upper	34.93	25yr	88.10	446.45	449.03		449.38	0.005723	2.79	40.30	30.61	0.65
Conestogo River	Upper	34.93	50yr	99.50	446.45	449.16		449.53	0.005662	2.91	44.47	32.04	0.65
Conestogo River	Upper	34.93	100yr	111.80	446.45	449.29		449.69	0.005620	3.02	48.83	33.48	0.66
Conestogo River	Upper	34.93	Reg	235.10	446.45	450.56		451.03	0.003999	3.48	104.46	58.78	0.60

B109132 →

APPENDIX

C-2

B109133 Output

HEC-RAS Plan: Existing Con Locations: User Defined

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
Conestogo River	Upper	37.62	2yr	32.60	457.38	459.84		459.94	0.002225	1.92	36.01	35.82	0.40
Conestogo River	Upper	37.62	5yr	42.40	457.38	460.15		460.24	0.001941	1.95	47.47	40.07	0.38
Conestogo River	Upper	37.62	10yr	52.00	457.38	460.43		460.52	0.001719	1.96	59.52	45.91	0.37
Conestogo River	Upper	37.62	25yr	63.40	457.38	460.76		460.84	0.001372	1.89	75.89	50.31	0.33
Conestogo River	Upper	37.62	50yr	71.60	457.38	461.00		461.07	0.001185	1.84	87.85	52.55	0.31
Conestogo River	Upper	37.62	100yr	80.50	457.38	461.24		461.32	0.001178	1.92	102.24	64.90	0.32
Conestogo River	Upper	37.62	Reg	108.20	457.38	461.86		461.92	0.000992	1.95	152.67	99.57	0.30
Conestogo River	Upper	37.54	2yr	32.60	457.64	459.44	459.02	459.69	0.004374	2.39	17.96	33.64	0.57
Conestogo River	Upper	37.54	5yr	42.40	457.64	459.74	459.29	460.02	0.003963	2.53	22.73	39.88	0.56
Conestogo River	Upper	37.54	10yr	52.00	457.64	460.02	459.47	460.31	0.003630	2.63	27.13	57.66	0.54
Conestogo River	Upper	37.54	25yr	63.40	457.64	460.37	459.66	460.66	0.003154	2.69	32.65	87.81	0.52
Conestogo River	Upper	37.54	50yr	71.60	457.64	460.61	459.78	460.91	0.002922	2.73	36.35	110.31	0.51
Conestogo River	Upper	37.54	100yr	80.50	457.64	460.86	459.91	461.16	0.002720	2.78	40.24	116.25	0.50
Conestogo River	Upper	37.54	Reg	108.20	457.64	461.41	460.27	461.77	0.002698	3.08	48.93	126.74	0.51
B109133 → Conestogo River	Upper	37.53	Bridge										
Conestogo River	Upper	37.52	2yr	32.60	457.64	459.31	458.68	459.45	0.002643	1.72	21.60	20.11	0.43
Conestogo River	Upper	37.52	5yr	42.40	457.64	459.59	458.88	459.76	0.002487	1.86	26.13	22.67	0.43
Conestogo River	Upper	37.52	10yr	52.00	457.64	459.86	459.02	460.04	0.002362	1.97	30.26	35.19	0.43
Conestogo River	Upper	37.52	25yr	63.40	457.64	460.21	459.18	460.40	0.002068	2.04	35.77	79.78	0.41
Conestogo River	Upper	37.52	50yr	71.60	457.64	460.44	459.30	460.64	0.001946	2.10	39.35	92.70	0.40
Conestogo River	Upper	37.52	100yr	80.50	457.64	460.67	459.41	460.88	0.001853	2.16	42.99	119.73	0.40
Conestogo River	Upper	37.52	Reg	108.20	457.64	460.93	459.74	461.25	0.002495	2.65	47.10	129.76	0.47
Conestogo River	Upper	37.50	2yr	32.60	457.07	459.17	458.61	459.37	0.003276	2.12	19.20	23.19	0.49
Conestogo River	Upper	37.50	5yr	42.40	457.07	459.43	458.82	459.67	0.003426	2.36	22.60	26.49	0.51
Conestogo River	Upper	37.50	10yr	52.00	457.07	459.67	458.99	459.95	0.003483	2.55	25.73	58.41	0.52
Conestogo River	Upper	37.50	25yr	63.40	457.07	460.22	459.19	460.32	0.001370	1.83	75.62	78.23	0.34
Conestogo River	Upper	37.50	50yr	71.60	457.07	460.47	459.32	460.55	0.001029	1.68	94.04	80.20	0.30
Conestogo River	Upper	37.50	100yr	80.50	457.07	460.72	459.44	460.78	0.000817	1.57	112.56	82.16	0.27
Conestogo River	Upper	37.50	Reg	108.20	457.07	461.03	460.09	461.10	0.000870	1.71	147.32	108.41	0.28

APPENDIX

C-3 B109134 Output

HEC-RAS Plan: Existing Con Locations: User Defined

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
Conestogo River	Upper	38.94	2yr	32.60	460.79	463.16		463.33	0.002574	2.03	22.95	15.65	0.43
Conestogo River	Upper	38.94	5yr	42.40	460.79	463.45		463.65	0.002776	2.29	27.65	17.88	0.46
Conestogo River	Upper	38.94	10yr	52.00	460.79	463.72		463.96	0.002881	2.49	33.17	22.25	0.47
Conestogo River	Upper	38.94	25yr	63.40	460.79	464.04		464.30	0.002820	2.65	41.20	28.76	0.48
Conestogo River	Upper	38.94	50yr	71.60	460.79	464.32		464.56	0.002448	2.61	50.09	34.56	0.45
Conestogo River	Upper	38.94	100yr	80.50	460.79	464.63		464.84	0.002032	2.52	61.83	40.98	0.42
Conestogo River	Upper	38.94	Reg	108.20	460.79	465.72		465.84	0.001003	2.10	142.42	139.15	0.31
Conestogo River	Upper	38.82	2yr	32.60	460.70	462.95	461.97	463.08	0.001701	1.63	22.25	17.73	0.36
Conestogo River	Upper	38.82	5yr	42.40	460.70	463.21	462.18	463.38	0.001891	1.86	25.84	20.20	0.39
Conestogo River	Upper	38.82	10yr	52.00	460.70	463.49	462.36	463.68	0.001896	2.01	29.77	23.96	0.40
Conestogo River	Upper	38.82	25yr	63.40	460.70	463.81	462.59	464.03	0.001861	2.15	34.28	48.26	0.40
Conestogo River	Upper	38.82	50yr	71.60	460.70	464.10	462.73	464.33	0.001681	2.18	38.47	92.90	0.39
Conestogo River	Upper	38.82	100yr	80.50	460.70	464.42	462.87	464.64	0.001524	2.20	42.91	115.24	0.37
Conestogo River	Upper	38.82	Reg	108.20	460.70	465.74	463.30	465.76	0.000190	0.96	322.22	228.14	0.14
B109134 → Conestogo River	Upper	38.81	Bridge										
Conestogo River	Upper	38.80	2yr	32.60	460.30	462.91	461.78	463.03	0.001297	1.56	25.04	32.57	0.33
Conestogo River	Upper	38.80	5yr	42.40	460.30	463.17	461.99	463.32	0.001499	1.80	28.63	51.84	0.36
Conestogo River	Upper	38.80	10yr	52.00	460.30	463.42	462.21	463.60	0.001602	1.98	32.17	78.87	0.38
Conestogo River	Upper	38.80	25yr	63.40	460.30	463.73	462.42	463.82	0.000896	1.59	88.17	88.42	0.29
Conestogo River	Upper	38.80	50yr	71.60	460.30	463.95	462.56	464.02	0.000755	1.53	107.61	94.81	0.27
Conestogo River	Upper	38.80	100yr	80.50	460.30	464.17	462.70	464.23	0.000660	1.49	130.17	108.80	0.25
Conestogo River	Upper	38.80	Reg	108.20	460.30	464.88	463.13	464.92	0.000394	1.30	225.40	160.38	0.20
Conestogo River	Upper	38.73	2yr	32.60	460.43	462.82		462.92	0.001897	1.70	31.13	37.93	0.37
Conestogo River	Upper	38.73	5yr	42.40	460.43	463.07		463.19	0.001896	1.83	42.04	47.40	0.38
Conestogo River	Upper	38.73	10yr	52.00	460.43	463.34		463.45	0.001790	1.91	55.63	54.08	0.38
Conestogo River	Upper	38.73	25yr	63.40	460.43	463.65		463.74	0.001376	1.81	73.02	56.69	0.34
Conestogo River	Upper	38.73	50yr	71.60	460.43	463.87		463.95	0.001179	1.75	85.71	59.35	0.31
Conestogo River	Upper	38.73	100yr	80.50	460.43	464.10		464.18	0.001012	1.70	99.92	62.73	0.29
Conestogo River	Upper	38.73	Reg	108.20	460.43	464.83		464.88	0.000640	1.54	161.97	109.57	0.24

APPENDIX

C-4 C109123 Output

HEC-RAS Plan: Existing Con Locations: User Defined

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
Conestogo River	Upper	35.74	2yr	32.60	451.19	453.29		453.39	0.001768	1.43	29.12	31.39	0.36
Conestogo River	Upper	35.74	5yr	42.40	451.19	453.53		453.64	0.001751	1.56	37.16	36.25	0.36
Conestogo River	Upper	35.74	10yr	52.00	451.19	453.73		453.85	0.001740	1.66	44.81	39.98	0.37
Conestogo River	Upper	35.74	25yr	63.40	451.19	453.99		454.11	0.001566	1.70	55.08	40.97	0.35
Conestogo River	Upper	35.74	50yr	71.60	451.19	454.17		454.29	0.001437	1.72	62.71	41.69	0.34
Conestogo River	Upper	35.74	100yr	80.50	451.19	454.37		454.49	0.001308	1.72	71.14	42.47	0.33
Conestogo River	Upper	35.74	Reg	143.00	451.19	455.73		455.82	0.000743	1.70	182.45	125.06	0.27
Conestogo River	Upper	35.66	2yr	32.60	451.41	452.59	452.59	453.02	0.016256	2.93	11.14	23.89	1.00
Conestogo River	Upper	35.66	5yr	42.40	451.41	452.75	452.75	453.27	0.015324	3.19	13.28	24.30	1.00
Conestogo River	Upper	35.66	10yr	52.00	451.41	453.03	452.91	453.52	0.010470	3.09	16.83	25.00	0.86
Conestogo River	Upper	35.66	25yr	63.40	451.41	453.34	453.08	453.82	0.007747	3.06	20.74	25.76	0.76
Conestogo River	Upper	35.66	50yr	71.60	451.41	453.55	453.19	454.03	0.006719	3.07	23.29	26.26	0.72
Conestogo River	Upper	35.66	100yr	80.50	451.41	453.76	453.32	454.25	0.005925	3.10	25.95	26.78	0.69
Conestogo River	Upper	35.66	Reg	143.00	451.41	455.09	454.06	455.66	0.003499	3.33	42.90	57.78	0.58
C109123 → Conestogo River	Upper	35.64		Culvert									
Conestogo River	Upper	35.63	2yr	32.60	450.69	452.59	452.34	452.90	0.007420	2.92	16.25	20.82	0.69
Conestogo River	Upper	35.63	5yr	42.40	450.69	452.74	452.53	453.15	0.009113	3.41	18.07	21.44	0.78
Conestogo River	Upper	35.63	10yr	52.00	450.69	452.87	452.71	453.39	0.010426	3.81	19.76	22.02	0.84
Conestogo River	Upper	35.63	25yr	63.40	450.69	453.01	452.90	453.65	0.011960	4.26	21.49	22.61	0.91
Conestogo River	Upper	35.63	50yr	71.60	450.69	453.10	453.03	453.83	0.013043	4.57	22.60	22.99	0.96
Conestogo River	Upper	35.63	100yr	80.50	450.69	453.19	453.15	454.02	0.014289	4.90	23.66	23.36	1.01
Conestogo River	Upper	35.63	Reg	143.00	450.69	453.97	453.97	455.23	0.015228	6.10	33.34	27.97	1.09
Conestogo River	Upper	35.53	2yr	32.60	450.50	451.55	451.50	451.87	0.013258	2.61	14.22	19.71	0.89
Conestogo River	Upper	35.53	5yr	42.40	450.50	451.77	451.65	452.10	0.010128	2.65	18.71	21.15	0.81
Conestogo River	Upper	35.53	10yr	52.00	450.50	451.96		452.30	0.008744	2.73	22.81	22.84	0.77
Conestogo River	Upper	35.53	25yr	63.40	450.50	452.17		452.53	0.007548	2.81	27.80	24.74	0.74
Conestogo River	Upper	35.53	50yr	71.60	450.50	452.31		452.68	0.006923	2.86	31.42	26.03	0.72
Conestogo River	Upper	35.53	100yr	80.50	450.50	452.46		452.84	0.006276	2.89	35.59	27.45	0.69
Conestogo River	Upper	35.53	Reg	143.00	450.50	453.78		454.06	0.002550	2.66	81.28	45.37	0.48

APPENDIX

D

HEC-RAS Output – Proposed
Condition

APPENDIX

D-1 C109132 Output

HEC-RAS Plan: Feb2024 Locations: User Defined

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
Conestogo River	Upper	35.36	2yr	45.30	448.99	450.99		451.17	0.003840	2.25	30.52	24.55	0.54
Conestogo River	Upper	35.36	5yr	59.00	448.99	451.16		451.40	0.004506	2.59	34.78	25.12	0.59
Conestogo River	Upper	35.36	10yr	72.20	448.99	451.31		451.61	0.005004	2.87	38.65	25.62	0.63
Conestogo River	Upper	35.36	25yr	88.10	448.99	451.49		451.84	0.005439	3.15	43.18	26.19	0.67
Conestogo River	Upper	35.36	50yr	99.50	448.99	451.61		451.99	0.005679	3.33	46.33	26.58	0.69
Conestogo River	Upper	35.36	100yr	111.80	448.99	451.74		452.16	0.005788	3.49	49.96	27.02	0.70
Conestogo River	Upper	35.36	Reg	235.10	448.99	452.90		453.59	0.006210	4.65	85.65	34.63	0.77
Conestogo River	Upper	35.31	2yr	45.30	448.93	450.46	450.46	450.85	0.011026	3.14	22.19	28.44	0.87
Conestogo River	Upper	35.31	5yr	59.00	448.93	450.69	450.62	451.07	0.009318	3.21	28.83	29.12	0.82
Conestogo River	Upper	35.31	10yr	72.20	448.93	450.90		451.28	0.008147	3.27	35.01	29.74	0.78
Conestogo River	Upper	35.31	25yr	88.10	448.93	451.14		451.52	0.007237	3.34	42.04	30.42	0.75
Conestogo River	Upper	35.31	50yr	99.50	448.93	451.29		451.68	0.006796	3.40	46.79	30.88	0.74
Conestogo River	Upper	35.31	100yr	111.80	448.93	451.45		451.85	0.006425	3.47	51.75	31.35	0.73
Conestogo River	Upper	35.31	Reg	235.10	448.93	452.75		453.26	0.004931	4.08	94.88	35.16	0.68
Conestogo River	Upper	35.23	2yr	45.30	448.11	450.17		450.32	0.003153	1.73	27.25	21.97	0.46
Conestogo River	Upper	35.23	5yr	59.00	448.11	450.41		450.59	0.003108	1.91	32.74	23.22	0.47
Conestogo River	Upper	35.23	10yr	72.20	448.11	450.63		450.84	0.003065	2.05	37.81	24.32	0.48
Conestogo River	Upper	35.23	25yr	88.10	448.11	450.86		451.10	0.003012	2.20	43.73	25.54	0.48
Conestogo River	Upper	35.23	50yr	99.50	448.11	451.02		451.28	0.002994	2.30	47.77	26.35	0.49
Conestogo River	Upper	35.23	100yr	111.80	448.11	451.18		451.46	0.002970	2.40	52.08	27.17	0.49
Conestogo River	Upper	35.23	Reg	235.10	448.11	452.48		452.93	0.002824	3.11	91.78	33.88	0.52
Conestogo River	Upper	35.17	2yr	45.30	447.95	449.47	449.47	449.96	0.012458	3.29	17.41	19.28	0.92
Conestogo River	Upper	35.17	5yr	59.00	447.95	449.67	449.67	450.24	0.012152	3.57	21.42	20.11	0.93
Conestogo River	Upper	35.17	10yr	72.20	447.95	449.85	449.85	450.48	0.012035	3.82	24.96	20.83	0.94
Conestogo River	Upper	35.17	25yr	88.10	447.95	450.03	450.03	450.74	0.012073	4.10	28.87	21.59	0.96
Conestogo River	Upper	35.17	50yr	99.50	447.95	450.16	450.16	450.92	0.011847	4.25	31.79	22.15	0.96
Conestogo River	Upper	35.17	100yr	111.80	447.95	450.30	450.30	451.10	0.011713	4.41	34.77	22.70	0.96
Conestogo River	Upper	35.17	Reg	235.10	447.95	451.45	451.37	452.58	0.010068	5.45	63.65	27.48	0.96
Conestogo River	Upper	35.04	2yr	45.30	446.57	448.92	448.21	449.07	0.002416	1.80	30.21	17.39	0.42
Conestogo River	Upper	35.04	5yr	59.00	446.57	449.16	448.46	449.35	0.002568	2.02	35.79	73.47	0.45
Conestogo River	Upper	35.04	10yr	72.20	446.57	449.37	448.64	449.59	0.002704	2.21	40.52	75.07	0.46
Conestogo River	Upper	35.04	25yr	88.10	446.57	449.59	448.82	449.85	0.002858	2.41	45.61	76.79	0.48
Conestogo River	Upper	35.04	50yr	99.50	446.57	449.73	448.94	450.02	0.002964	2.55	48.93	77.91	0.50
Conestogo River	Upper	35.04	100yr	111.80	446.57	449.88	449.07	450.19	0.003074	2.69	52.29	79.05	0.51
Conestogo River	Upper	35.04	Reg	235.10	446.57	451.14	450.04	451.70	0.003502	3.67	81.75	92.64	0.58
Conestogo River	Upper	35.03	Bridge										
Conestogo River	Upper	35.01	2yr	45.30	446.90	448.84	448.18	448.99	0.002717	1.79	29.49	25.43	0.44
Conestogo River	Upper	35.01	5yr	59.00	446.90	449.07	448.40	449.26	0.002874	2.00	34.89	26.79	0.46
Conestogo River	Upper	35.01	10yr	72.20	446.90	449.26	448.60	449.48	0.003013	2.18	39.46	28.03	0.48
Conestogo River	Upper	35.01	25yr	88.10	446.90	449.47	448.78	449.73	0.003181	2.38	44.32	29.55	0.50
Conestogo River	Upper	35.01	50yr	99.50	446.90	449.60	448.89	449.89	0.003306	2.52	47.46	30.58	0.51
Conestogo River	Upper	35.01	100yr	111.80	446.90	449.74	449.01	450.06	0.003445	2.66	50.57	31.67	0.53
Conestogo River	Upper	35.01	Reg	235.10	446.90	450.81	449.96	451.43	0.004325	3.76	75.90	76.91	0.63
Conestogo River	Upper	34.93	2yr	45.30	446.45	448.43		448.66	0.006136	2.24	23.83	24.13	0.63
Conestogo River	Upper	34.93	5yr	59.00	446.45	448.64		448.91	0.006021	2.45	29.16	26.40	0.64
Conestogo River	Upper	34.93	10yr	72.20	446.45	448.83		449.14	0.005855	2.62	34.31	28.43	0.65
Conestogo River	Upper	34.93	25yr	88.10	446.45	449.03		449.38	0.005723	2.79	40.30	30.61	0.65
Conestogo River	Upper	34.93	50yr	99.50	446.45	449.16		449.53	0.005662	2.91	44.47	32.04	0.65
Conestogo River	Upper	34.93	100yr	111.80	446.45	449.29		449.69	0.005620	3.02	48.83	33.48	0.66
Conestogo River	Upper	34.93	Reg	235.10	446.45	450.56		451.03	0.003999	3.48	104.46	58.78	0.60
Conestogo River	Upper	34.87	2yr	45.30	446.53	448.11		448.30	0.004986	2.12	27.34	24.94	0.59
Conestogo River	Upper	34.87	5yr	59.00	446.53	448.34		448.56	0.004739	2.30	33.21	25.77	0.59
Conestogo River	Upper	34.87	10yr	72.20	446.53	448.54		448.79	0.004582	2.45	38.56	31.10	0.59
Conestogo River	Upper	34.87	25yr	88.10	446.53	448.77		449.04	0.004294	2.58	47.99	43.78	0.58
Conestogo River	Upper	34.87	50yr	99.50	446.53	448.92		449.20	0.004077	2.64	54.86	44.87	0.58
Conestogo River	Upper	34.87	100yr	111.80	446.53	449.08		449.36	0.003845	2.69	62.08	45.75	0.57
Conestogo River	Upper	34.87	Reg	235.10	446.53	450.54		450.78	0.002128	2.77	148.92	67.51	0.46
Conestogo River	Upper	34.74	2yr	45.30	445.82	447.57		447.74	0.003417	1.86	25.66	20.48	0.49
Conestogo River	Upper	34.74	5yr	59.00	445.82	447.81		448.02	0.003424	2.06	30.69	21.58	0.51
Conestogo River	Upper	34.74	10yr	72.20	445.82	448.01		448.26	0.003474	2.23	35.11	22.51	0.52
Conestogo River	Upper	34.74	25yr	88.10	445.82	448.23		448.51	0.003540	2.43	40.10	23.51	0.53
Conestogo River	Upper	34.74	50yr	99.50	445.82	448.36		448.68	0.003645	2.56	43.26	24.12	0.55
Conestogo River	Upper	34.74	100yr	111.80	445.82	448.49		448.85	0.003770	2.71	46.44	24.72	0.56
Conestogo River	Upper	34.74	Reg	235.10	445.82	450.00		450.45	0.002657	3.16	105.80	54.76	0.51

B109132 →

D-2

B109133 Output

HEC-RAS Plan: Feb2024 Locations: User Defined

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
Conestogo River	Upper	38.35	2yr	32.60	459.21	461.56		461.70	0.002542	2.01	26.81	20.71	0.43
Conestogo River	Upper	38.35	5yr	42.40	459.21	461.83		461.99	0.002556	2.18	32.63	21.68	0.44
Conestogo River	Upper	38.35	10yr	52.00	459.21	462.09		462.28	0.002749	2.42	38.90	27.20	0.47
Conestogo River	Upper	38.35	25yr	63.40	459.21	462.36		462.57	0.002766	2.59	47.00	32.61	0.48
Conestogo River	Upper	38.35	50yr	71.60	459.21	462.54		462.76	0.002709	2.66	53.30	36.26	0.48
Conestogo River	Upper	38.35	100yr	80.50	459.21	462.73		462.95	0.002628	2.73	60.52	40.27	0.47
Conestogo River	Upper	38.35	Reg	108.20	459.21	463.25		463.48	0.002435	2.89	86.75	62.81	0.47
Conestogo River	Upper	38.17	2yr	32.60	458.90	461.02		461.17	0.003197	2.09	25.19	20.67	0.48
Conestogo River	Upper	38.17	5yr	42.40	458.90	461.32		461.48	0.002903	2.20	31.69	21.78	0.47
Conestogo River	Upper	38.17	10yr	52.00	458.90	461.60		461.77	0.002688	2.28	37.86	22.78	0.46
Conestogo River	Upper	38.17	25yr	63.40	458.90	461.81		462.02	0.003140	2.60	42.82	26.85	0.50
Conestogo River	Upper	38.17	50yr	71.60	458.90	461.93		462.19	0.003506	2.83	46.42	31.23	0.54
Conestogo River	Upper	38.17	100yr	80.50	458.90	462.05		462.35	0.003922	3.08	50.63	38.50	0.57
Conestogo River	Upper	38.17	Reg	108.20	458.90	462.37	461.53	462.82	0.005211	3.80	67.82	70.11	0.67
Conestogo River	Upper	37.92	2yr	32.60	458.27	460.45		460.55	0.001949	1.67	29.69	22.20	0.38
Conestogo River	Upper	37.92	5yr	42.40	458.27	460.72		460.85	0.002248	1.95	35.99	29.41	0.42
Conestogo River	Upper	37.92	10yr	52.00	458.27	460.95		461.13	0.002506	2.21	45.42	49.96	0.45
Conestogo River	Upper	37.92	25yr	63.40	458.27	461.18		461.35	0.002342	2.26	57.87	59.55	0.44
Conestogo River	Upper	37.92	50yr	71.60	458.27	461.33		461.49	0.002161	2.26	67.46	64.09	0.43
Conestogo River	Upper	37.92	100yr	80.50	458.27	461.52		461.66	0.001889	2.20	79.78	68.82	0.41
Conestogo River	Upper	37.92	Reg	108.20	458.27	461.96		462.09	0.001535	2.18	113.14	80.24	0.37
Conestogo River	Upper	37.62	2yr	32.60	457.38	459.75		459.86	0.002710	2.06	32.68	32.62	0.44
Conestogo River	Upper	37.62	5yr	42.40	457.38	460.03		460.14	0.002455	2.12	42.78	37.78	0.43
Conestogo River	Upper	37.62	10yr	52.00	457.38	460.29		460.40	0.002216	2.16	53.48	43.08	0.41
Conestogo River	Upper	37.62	25yr	63.40	457.38	460.61		460.71	0.001804	2.09	68.42	48.86	0.38
Conestogo River	Upper	37.62	50yr	71.60	457.38	460.84		460.93	0.001533	2.02	79.76	51.05	0.35
Conestogo River	Upper	37.62	100yr	80.50	457.38	461.08		461.16	0.001385	2.01	92.16	55.93	0.34
Conestogo River	Upper	37.62	Reg	108.20	457.38	461.52		461.62	0.001545	2.30	122.20	80.36	0.37
Conestogo River	Upper	37.54	2yr	32.60	457.64	459.39	459.02	459.60	0.004066	2.26	20.73	32.61	0.55
Conestogo River	Upper	37.54	5yr	42.40	457.64	459.69	459.22	459.91	0.003495	2.34	26.51	38.87	0.52
Conestogo River	Upper	37.54	10yr	52.00	457.64	459.97	459.39	460.19	0.003107	2.40	31.81	53.12	0.50
Conestogo River	Upper	37.54	25yr	63.40	457.64	460.31	459.55	460.53	0.002660	2.43	38.30	82.64	0.48
Conestogo River	Upper	37.54	50yr	71.60	457.64	460.55	459.66	460.77	0.002430	2.46	42.74	104.48	0.46
Conestogo River	Upper	37.54	100yr	80.50	457.64	460.79	459.77	461.01	0.002251	2.49	47.30	114.66	0.45
Conestogo River	Upper	37.54	Reg	108.20	457.64	461.14	460.08	461.44	0.002700	2.93	53.97	122.12	0.50
Conestogo River	Upper	37.53	Bridge										
Conestogo River	Upper	37.52	2yr	32.60	457.64	459.31	458.69	459.45	0.002531	1.69	22.99	20.65	0.42
Conestogo River	Upper	37.52	5yr	42.40	457.64	459.61	458.87	459.76	0.002288	1.79	28.48	22.95	0.41
Conestogo River	Upper	37.52	10yr	52.00	457.64	459.88	459.06	460.04	0.002112	1.88	33.50	37.79	0.41
Conestogo River	Upper	37.52	25yr	63.40	457.64	460.22	459.22	460.39	0.001861	1.94	39.73	80.40	0.39
Conestogo River	Upper	37.52	50yr	71.60	457.64	460.45	459.32	460.62	0.001731	1.99	43.97	93.44	0.38
Conestogo River	Upper	37.52	100yr	80.50	457.64	460.68	459.43	460.86	0.001631	2.03	48.29	121.65	0.38
Conestogo River	Upper	37.52	Reg	108.20	457.64	460.95	459.73	461.22	0.002155	2.48	53.32	130.59	0.44
Conestogo River	Upper	37.50	2yr	32.60	457.07	459.17	458.61	459.37	0.003276	2.12	19.20	23.19	0.49
Conestogo River	Upper	37.50	5yr	42.40	457.07	459.43	458.82	459.67	0.003426	2.36	22.60	26.49	0.51
Conestogo River	Upper	37.50	10yr	52.00	457.07	459.67	458.99	459.95	0.003482	2.55	25.73	58.42	0.52
Conestogo River	Upper	37.50	25yr	63.40	457.07	460.22	459.19	460.32	0.001370	1.83	75.62	78.23	0.34
Conestogo River	Upper	37.50	50yr	71.60	457.07	460.47	459.32	460.55	0.001029	1.68	94.04	80.20	0.30
Conestogo River	Upper	37.50	100yr	80.50	457.07	460.72	459.44	460.78	0.000817	1.57	112.57	82.16	0.27
Conestogo River	Upper	37.50	Reg	108.20	457.07	461.02	460.09	461.09	0.000871	1.71	147.29	108.37	0.28
Conestogo River	Upper	37.49	Bridge										
Conestogo River	Upper	37.48	2yr	32.60	457.10	459.09	458.47	459.27	0.003363	1.91	17.37	65.89	0.48
Conestogo River	Upper	37.48	5yr	42.40	457.10	459.31	458.67	459.55	0.003710	2.19	19.92	67.37	0.52
Conestogo River	Upper	37.48	10yr	52.00	457.10	459.50	458.84	459.79	0.003968	2.42	22.23	68.68	0.54
Conestogo River	Upper	37.48	25yr	63.40	457.10	459.72	459.03	460.07	0.004150	2.65	24.87	70.17	0.56
Conestogo River	Upper	37.48	50yr	71.60	457.10	459.85	459.16	460.25	0.004376	2.82	26.42	71.04	0.59
Conestogo River	Upper	37.48	100yr	80.50	457.10	459.97	459.30	460.43	0.004642	3.01	27.92	71.89	0.61
Conestogo River	Upper	37.48	Reg	108.20	457.10	460.44	459.70	460.52	0.001080	1.60	128.91	83.85	0.30

B109133 →

APPENDIX

D-3 **B109134**

HEC-RAS Plan: Feb2024 Locations: User Defined

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
Conestogo River	Upper	39.16	2yr	32.60	460.93	463.68	462.60	463.83	0.001586	1.82	24.50	17.11	0.37
Conestogo River	Upper	39.16	5yr	42.40	460.93	464.01	462.86	464.18	0.001634	2.00	30.29	24.77	0.38
Conestogo River	Upper	39.16	10yr	52.00	460.93	464.35	463.09	464.53	0.001542	2.10	39.45	33.67	0.38
Conestogo River	Upper	39.16	25yr	63.40	460.93	464.62	463.34	464.83	0.001669	2.31	51.73	47.36	0.40
Conestogo River	Upper	39.16	50yr	71.60	460.93	464.78	463.47	465.01	0.001714	2.41	60.55	60.01	0.41
Conestogo River	Upper	39.16	100yr	80.50	460.93	464.98	463.69	465.19	0.001603	2.42	73.66	73.03	0.40
Conestogo River	Upper	39.16	Reg	108.20	460.93	465.55	464.19	465.70	0.001166	2.26	126.02	110.68	0.35
Conestogo River	Upper	39.10	2yr	32.60	461.16	463.55		463.70	0.002358	2.05	24.71	16.54	0.43
Conestogo River	Upper	39.10	5yr	42.40	461.16	463.85		464.04	0.002530	2.31	29.94	19.47	0.46
Conestogo River	Upper	39.10	10yr	52.00	461.16	464.12		464.38	0.002874	2.63	36.94	31.21	0.49
Conestogo River	Upper	39.10	25yr	63.40	461.16	464.43		464.68	0.002671	2.71	48.49	44.86	0.48
Conestogo River	Upper	39.10	50yr	71.60	461.16	464.63		464.87	0.002472	2.72	58.43	54.92	0.47
Conestogo River	Upper	39.10	100yr	80.50	461.16	464.83		465.06	0.002347	2.75	70.59	68.19	0.46
Conestogo River	Upper	39.10	Reg	108.20	461.16	465.47		465.61	0.001471	2.43	127.93	111.15	0.38
Conestogo River	Upper	38.94	2yr	32.60	460.79	463.11		463.29	0.002809	2.09	22.19	15.48	0.45
Conestogo River	Upper	38.94	5yr	42.40	460.79	463.38		463.60	0.003087	2.37	26.40	17.10	0.48
Conestogo River	Upper	38.94	10yr	52.00	460.79	463.62		463.88	0.003316	2.61	30.95	20.65	0.51
Conestogo River	Upper	38.94	25yr	63.40	460.79	463.89		464.20	0.003434	2.83	37.24	25.75	0.52
Conestogo River	Upper	38.94	50yr	71.60	460.79	464.10		464.41	0.003318	2.91	42.93	29.97	0.52
Conestogo River	Upper	38.94	100yr	80.50	460.79	464.32		464.63	0.003085	2.93	50.17	34.60	0.51
Conestogo River	Upper	38.94	Reg	108.20	460.79	465.09		465.33	0.002054	2.74	83.60	53.06	0.43
Conestogo River	Upper	38.82	2yr	32.60	460.70	462.97	462.01	463.06	0.001269	1.42	29.30	20.02	0.31
Conestogo River	Upper	38.82	5yr	42.40	460.70	463.23	462.19	463.34	0.001376	1.59	34.08	21.50	0.33
Conestogo River	Upper	38.82	10yr	52.00	460.70	463.48	462.36	463.61	0.001408	1.73	38.74	24.41	0.34
Conestogo River	Upper	38.82	25yr	63.40	460.70	463.76	462.53	463.91	0.001420	1.86	43.99	35.91	0.35
Conestogo River	Upper	38.82	50yr	71.60	460.70	463.97	462.67	464.13	0.001397	1.93	47.84	79.39	0.35
Conestogo River	Upper	38.82	100yr	80.50	460.70	464.19	462.78	464.36	0.001366	2.00	51.96	99.98	0.35
Conestogo River	Upper	38.82	Reg	108.20	460.70	465.12	463.10	465.17	0.000491	1.41	203.81	170.51	0.22
Conestogo River	Upper	38.81		Bridge									
Conestogo River	Upper	38.80	2yr	32.60	460.30	462.95	461.71	463.01	0.000844	1.27	34.54	33.47	0.27
Conestogo River	Upper	38.80	5yr	42.40	460.30	463.20	461.94	463.29	0.000995	1.48	39.11	54.82	0.29
Conestogo River	Upper	38.80	10yr	52.00	460.30	463.44	462.08	463.55	0.001069	1.63	43.63	79.63	0.31
Conestogo River	Upper	38.80	25yr	63.40	460.30	463.72	462.25	463.84	0.001128	1.78	48.72	87.91	0.32
Conestogo River	Upper	38.80	50yr	71.60	460.30	463.92	462.35	464.06	0.001140	1.87	52.47	94.01	0.33
Conestogo River	Upper	38.80	100yr	80.50	460.30	464.14	462.46	464.28	0.001143	1.95	56.48	106.37	0.33
Conestogo River	Upper	38.80	Reg	108.20	460.30	464.88	462.78	464.92	0.000372	1.26	230.97	160.61	0.19
Conestogo River	Upper	38.73	2yr	32.60	460.43	462.82		462.92	0.001897	1.70	31.13	37.93	0.37
Conestogo River	Upper	38.73	5yr	42.40	460.43	463.07		463.19	0.001897	1.83	42.04	47.40	0.38
Conestogo River	Upper	38.73	10yr	52.00	460.43	463.34		463.45	0.001791	1.91	55.62	54.08	0.38
Conestogo River	Upper	38.73	25yr	63.40	460.43	463.65		463.74	0.001376	1.81	73.02	56.69	0.34
Conestogo River	Upper	38.73	50yr	71.60	460.43	463.87		463.95	0.001180	1.75	85.70	59.35	0.31
Conestogo River	Upper	38.73	100yr	80.50	460.43	464.10		464.18	0.001013	1.70	99.88	62.72	0.29
Conestogo River	Upper	38.73	Reg	108.20	460.43	464.83		464.88	0.000640	1.54	162.04	109.61	0.24
Conestogo River	Upper	38.61	2yr	32.60	460.18	462.53		462.67	0.002256	1.96	33.51	55.99	0.43
Conestogo River	Upper	38.61	5yr	42.40	460.18	462.90		462.99	0.001392	1.71	61.36	87.36	0.34
Conestogo River	Upper	38.61	10yr	52.00	460.18	463.24		463.29	0.000823	1.43	93.74	97.81	0.27
Conestogo River	Upper	38.61	25yr	63.40	460.18	463.60		463.63	0.000547	1.26	129.08	103.74	0.22
Conestogo River	Upper	38.61	50yr	71.60	460.18	463.83		463.86	0.000441	1.19	153.75	107.86	0.20
Conestogo River	Upper	38.61	100yr	80.50	460.18	464.07		464.09	0.000368	1.13	180.38	113.40	0.19
Conestogo River	Upper	38.61	Reg	108.20	460.18	464.81		464.83	0.000234	1.02	273.97	139.82	0.15
Conestogo River	Upper	38.55	2yr	32.60	460.02	462.43	461.52	462.55	0.001683	1.56	22.57	28.23	0.36
Conestogo River	Upper	38.55	5yr	42.40	460.02	462.75	461.71	462.89	0.001692	1.73	26.56	34.64	0.37
Conestogo River	Upper	38.55	10yr	52.00	460.02	463.05	461.88	463.22	0.001655	1.86	30.36	45.77	0.37
Conestogo River	Upper	38.55	25yr	63.40	460.02	463.37	462.06	463.56	0.001646	2.01	34.37	60.78	0.38
Conestogo River	Upper	38.55	50yr	71.60	460.02	463.58	462.18	463.79	0.001645	2.10	37.06	70.84	0.38
Conestogo River	Upper	38.55	100yr	80.50	460.02	463.80	462.31	464.03	0.001641	2.20	39.85	81.28	0.39
Conestogo River	Upper	38.55	Reg	108.20	460.02	464.74	462.68	464.80	0.000490	1.42	167.64	124.45	0.22

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HEC-RAS Plan: Feb2024 Locations: User Defined

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
Conestogo River	Upper	36.17	2yr	32.60	453.66	455.40		455.47	0.002198	1.54	44.35	61.77	0.39
Conestogo River	Upper	36.17	5yr	42.40	453.66	455.57		455.64	0.002104	1.61	54.70	62.66	0.39
Conestogo River	Upper	36.17	10yr	52.00	453.66	455.71		455.78	0.002060	1.68	63.74	63.43	0.39
Conestogo River	Upper	36.17	25yr	63.40	453.66	455.85		455.93	0.002089	1.78	72.84	64.19	0.40
Conestogo River	Upper	36.17	50yr	71.60	453.66	455.95		456.03	0.002091	1.83	79.19	64.72	0.40
Conestogo River	Upper	36.17	100yr	80.50	453.66	456.06		456.14	0.002080	1.89	85.90	65.16	0.40
Conestogo River	Upper	36.17	Reg	108.20	453.66	456.31		456.41	0.002193	2.08	102.84	66.02	0.42
Conestogo River	Upper	35.89	2yr	32.60	452.53	453.98	453.98	454.29	0.010673	2.96	19.48	30.07	0.83
Conestogo River	Upper	35.89	5yr	42.40	452.53	454.10	454.10	454.46	0.011548	3.27	23.24	30.99	0.88
Conestogo River	Upper	35.89	10yr	52.00	452.53	454.22	454.22	454.61	0.011820	3.49	26.94	31.87	0.90
Conestogo River	Upper	35.89	25yr	63.40	452.53	454.38		454.77	0.011046	3.60	31.92	32.42	0.89
Conestogo River	Upper	35.89	50yr	71.60	452.53	454.48		454.88	0.010753	3.69	35.15	32.74	0.88
Conestogo River	Upper	35.89	100yr	80.50	452.53	454.57		454.99	0.010693	3.81	38.26	33.04	0.89
Conestogo River	Upper	35.89	Reg	108.20	452.53	455.24		455.51	0.004963	3.18	61.25	35.20	0.64
Conestogo River	Upper	35.74	2yr	32.60	451.19	452.96		453.14	0.004248	1.91	19.62	24.83	0.53
Conestogo River	Upper	35.74	5yr	42.40	451.19	453.14		453.36	0.004320	2.10	24.65	28.38	0.55
Conestogo River	Upper	35.74	10yr	52.00	451.19	453.32		453.55	0.004261	2.25	29.85	31.86	0.55
Conestogo River	Upper	35.74	25yr	63.40	451.19	453.51		453.76	0.004129	2.37	36.27	35.75	0.55
Conestogo River	Upper	35.74	50yr	71.60	451.19	453.64		453.90	0.003964	2.44	41.28	38.51	0.55
Conestogo River	Upper	35.74	100yr	80.50	451.19	453.79		454.05	0.003724	2.47	47.00	40.19	0.54
Conestogo River	Upper	35.74	Reg	143.00	451.19	454.84		455.05	0.002116	2.43	91.32	44.29	0.43
Conestogo River	Upper	35.66	2yr	32.60	451.41	452.66	452.24	452.79	0.003624	1.61	20.45	24.07	0.49
Conestogo River	Upper	35.66	5yr	42.40	451.41	452.85	452.37	453.01	0.003661	1.80	23.88	24.53	0.50
Conestogo River	Upper	35.66	10yr	52.00	451.41	453.02	452.49	453.21	0.003618	1.94	27.09	24.96	0.51
Conestogo River	Upper	35.66	25yr	63.40	451.41	453.21	452.63	453.43	0.003612	2.10	30.53	25.42	0.52
Conestogo River	Upper	35.66	50yr	71.60	451.41	453.34	452.71	453.59	0.003541	2.19	33.04	25.76	0.52
Conestogo River	Upper	35.66	100yr	80.50	451.41	453.49	452.81	453.75	0.003464	2.28	35.69	26.11	0.52
Conestogo River	Upper	35.66	Reg	143.00	451.41	454.48	453.40	454.84	0.002746	2.68	54.02	47.96	0.50
Conestogo River	Upper	35.64		Culvert									
Conestogo River	Upper	35.63	2yr	32.60	450.69	452.56	452.23	452.75	0.005313	2.45	21.74	21.48	0.59
Conestogo River	Upper	35.63	5yr	42.40	450.69	452.71	452.41	452.95	0.006321	2.81	24.43	22.03	0.65
Conestogo River	Upper	35.63	10yr	52.00	450.69	452.85	452.54	453.14	0.007044	3.11	26.96	22.54	0.69
Conestogo River	Upper	35.63	25yr	63.40	450.69	452.98	452.69	453.34	0.007926	3.44	29.51	23.05	0.74
Conestogo River	Upper	35.63	50yr	71.60	450.69	453.09	452.79	453.48	0.008282	3.63	31.46	23.45	0.76
Conestogo River	Upper	35.63	100yr	80.50	450.69	453.20	452.89	453.63	0.008584	3.81	33.52	23.87	0.78
Conestogo River	Upper	35.63	Reg	143.00	450.69	454.06	453.51	454.64	0.007871	4.47	49.47	28.57	0.79
Conestogo River	Upper	35.53	2yr	32.60	450.50	451.55	451.50	451.87	0.013258	2.61	14.22	19.71	0.89
Conestogo River	Upper	35.53	5yr	42.40	450.50	451.77	451.65	452.10	0.010128	2.65	18.71	21.15	0.81
Conestogo River	Upper	35.53	10yr	52.00	450.50	451.96		452.30	0.008744	2.73	22.81	22.84	0.77
Conestogo River	Upper	35.53	25yr	63.40	450.50	452.17		452.53	0.007548	2.81	27.80	24.74	0.74
Conestogo River	Upper	35.53	50yr	71.60	450.50	452.31		452.68	0.006922	2.86	31.42	26.03	0.71
Conestogo River	Upper	35.53	100yr	80.50	450.50	452.46		452.84	0.006274	2.89	35.59	27.45	0.69
Conestogo River	Upper	35.53	Reg	143.00	450.50	453.77		454.06	0.002563	2.67	81.10	45.30	0.48
Conestogo River	Upper	35.47	2yr	32.60	449.45	451.42		451.55	0.002619	1.74	27.06	28.96	0.43
Conestogo River	Upper	35.47	5yr	42.40	449.45	451.67		451.81	0.002511	1.87	34.73	33.46	0.44
Conestogo River	Upper	35.47	10yr	52.00	449.45	451.88		452.03	0.002389	1.96	42.06	35.85	0.43
Conestogo River	Upper	35.47	25yr	63.40	449.45	452.11		452.27	0.002251	2.04	50.73	38.48	0.43
Conestogo River	Upper	35.47	50yr	71.60	449.45	452.27		452.43	0.002168	2.09	56.89	40.25	0.42
Conestogo River	Upper	35.47	100yr	80.50	449.45	452.43		452.60	0.002128	2.16	63.64	43.75	0.42
Conestogo River	Upper	35.47	Reg	143.00	449.45	453.82		453.93	0.000956	1.92	138.57	57.94	0.31
Conestogo River	Upper	35.36	2yr	45.30	448.99	450.99		451.17	0.003840	2.25	30.52	24.55	0.54
Conestogo River	Upper	35.36	5yr	59.00	448.99	451.16		451.40	0.004506	2.59	34.78	25.12	0.59
Conestogo River	Upper	35.36	10yr	72.20	448.99	451.31		451.61	0.005004	2.87	38.65	25.62	0.63
Conestogo River	Upper	35.36	25yr	88.10	448.99	451.49		451.84	0.005439	3.15	43.18	26.19	0.67
Conestogo River	Upper	35.36	50yr	99.50	448.99	451.61		451.99	0.005679	3.33	46.33	26.58	0.69
Conestogo River	Upper	35.36	100yr	111.80	448.99	451.74		452.16	0.005788	3.49	49.96	27.02	0.70
Conestogo River	Upper	35.36	Reg	235.10	448.99	452.90		453.59	0.006210	4.65	85.65	34.63	0.77
Conestogo River	Upper	35.31	2yr	45.30	448.93	450.46	450.46	450.85	0.011026	3.14	22.19	28.44	0.87
Conestogo River	Upper	35.31	5yr	59.00	448.93	450.69	450.62	451.07	0.009318	3.21	28.83	29.12	0.82
Conestogo River	Upper	35.31	10yr	72.20	448.93	450.90		451.28	0.008147	3.27	35.01	29.74	0.78
Conestogo River	Upper	35.31	25yr	88.10	448.93	451.14		451.52	0.007237	3.34	42.04	30.42	0.75
Conestogo River	Upper	35.31	50yr	99.50	448.93	451.29		451.68	0.006796	3.40	46.79	30.88	0.74
Conestogo River	Upper	35.31	100yr	111.80	448.93	451.45		451.85	0.006425	3.47	51.75	31.35	0.73
Conestogo River	Upper	35.31	Reg	235.10	448.93	452.75		453.26	0.004931	4.08	94.88	35.16	0.68

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