REPORT

Ministry of Transportation and Infrastructure

Cervus Creek Bridge Replacement No. 07318
Highway 28
Hydrotechnical Design Report

AUGUST 2022

A Carbon Neutral Company

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1 Introduction

The **Ministry of Transportation and Infrastructure (Ministry)** has retained **Associated Engineering (AE)** to carry out the functional and detailed highway and hydrotechnical design for the replacement of the Cervus Creek Bridge #07318 on Highway 28 east of Gold River in Vancouver Island, BC. This report documents the hydrotechnical recommendations for the Cervus Creek Bridge Replacement Design.

2 Site Location

The Cervus Creek Bridge is located on Highway 28 approximately 23 km east of Gold River, Vancouver Island, BC. The project location is shown in **Figure 2-1**.

Figure 2-1
Project Location (Source Google Map)

The Cervus Creek Bridge (Bridge No. 07318) carries Highway 28 over Cervus Creek. The river flows south to north beneath the Cervus Creek Bridge and discharges into the Elk River approximately 200 m downstream of the bridge. The area surrounding the existing bridge site is shown in **Figure 2-2.**

Figure 2-2
Cervus Creek Bridge Location (Source Google Map)

LiDAR survey and mapping information were provided by the Ministry. A subsequent topographic survey was used to create a detailed surface defining the channel bed and banks and then combined with the LiDAR data for the surrounding floodplain. The combined surface was used to develop a 1D HEC-RAS model and is shown in **Figure 2-3.**

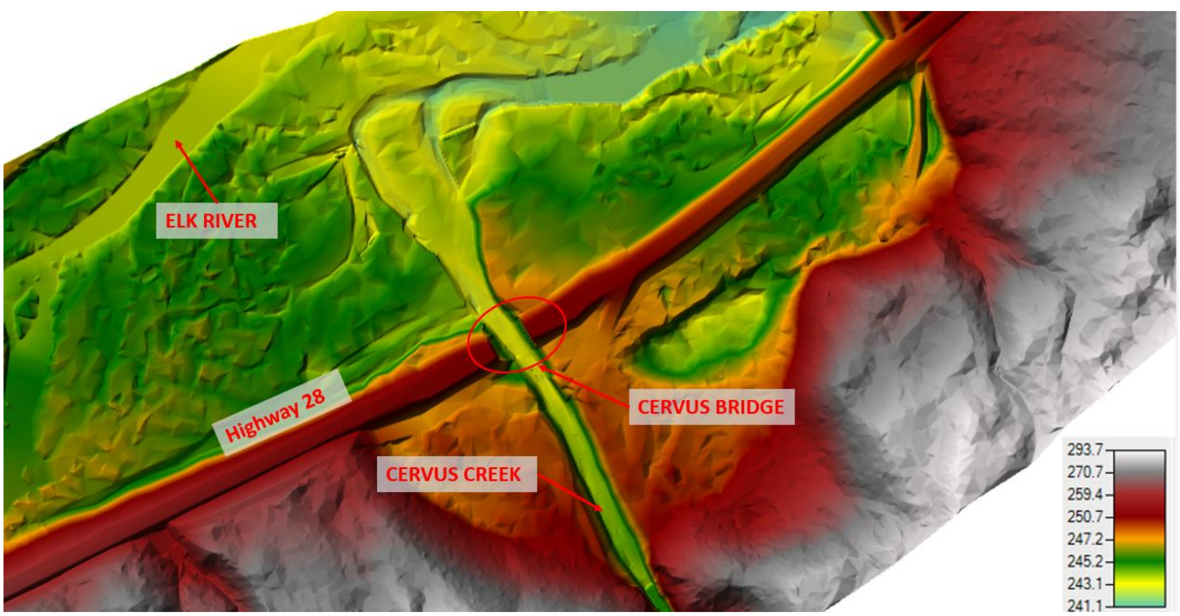


Figure 2-3
Cervus Creek Combined Surface (Source HEC-RAS RAS Mapper)

3 Background Information

The following reference drawings and documents were provided by MoTI and were considered in the development of the Functional Design:

- Bridge record drawings.
- Bridge inspection reports (2017 to 2019).
- Scour / Erosion Evaluation Report (June 24, 2016).
- Hydrotechnical Scoping and Conceptual Waterway Design for Bridge Replacement (September 21, 2016 by Northwest Hydraulic Consultants).

3.1 Design Codes and References

The following design codes and references will be used for the bridge hydrotechnical design:

- CAN/CSA-S6-14 and BC MoTI Supplement to CHBDC S6-14.
- BC MoTI Supplement to TAC Geometric Design Guide, Hydraulics Chapter 1000.
- BC MoTI Standard Specifications for Highway Construction (2016).
- BC MoTI Riprap Installation Guide – 1 (2013).
- BC MoTI Technical Circular T-04/19.
- TAC Guide to Bridge Hydraulics, Second Ed. (2004).
- BC Ministry of Environment, Lands, and Parks, Riprap Design and Construction Guide (2000).
- US Army Corps of Engineers EM-1110-2-1601 (1994).
- US FHWA NHI Hydraulic Engineering Circular No. 18 – Evaluating Scour at Bridges (2012).
- US FHWA NHI Hydraulic Engineering Circular No. 23 – Bridge Scour and Stream Instability Countermeasures.
- Professional Practice Guidelines: Legislated Flood Assessments in a Changing Climate in BC, V2.1 (EGBC, 2018).

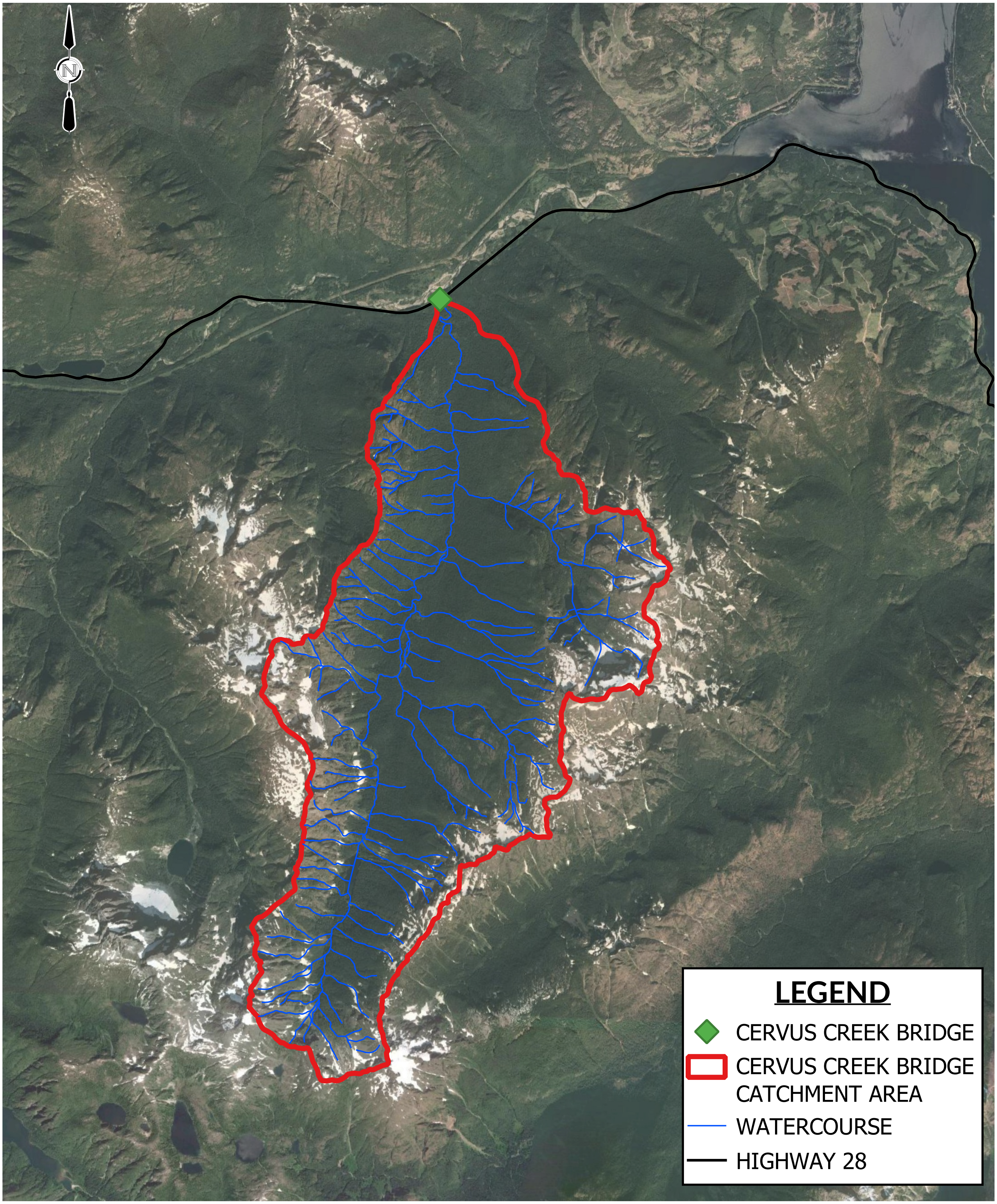
4 Hydrology

4.1 Catchment Area and Available Gage Data

We delineated the watershed for the proposed Cervus Creek crossing, obtaining a catchment area of 56.7 km^2 (**Figure 4-1**). This area compares well with the area estimated by NHC. The Cervus Creek Bridge site is located a short distance upstream of the confluence of Cervus Creek with the Elk River. We reviewed available Water Survey of Canada (WSC) hydrometric station data and identified WSC gauge 08HD018 located on the Elk River approximately 1.5 km upstream of the confluence. In the absence of data for Cervus Creek, we used this flow record to derive peak flow estimates at the Cervus Creek Bridge. Though Cervus Creek has a smaller watershed, it is part of the Elk River watershed and shares similar topography and watershed characteristics. The estimated drainage area for 08HD018 is 132 km^2.

Figure 4-1
Cervus Creek Catchment Area

IF NOT 25 mm ADJUST SCALES
25 mm
SCALE(S) SHOWN ARE INTENDED FOR LETTER (8.5X11) SIZE DRAWINGS UNLESS NOTED OTHERWISE



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Associated Engineering

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AE PROJECT No.	2020-2947-00
SCALE	1 : 100,000
APPROVED	Z.SALLY
DATE	2021APR12
REV	A
DESCRIPTION	ISSUED FOR REVIEW

FIGURE 4-1

MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE

CERVUS CREEK BRIDGE CATCHMENT AREA

4.2 Cervus Creek Peak Flow Estimate

We conducted a frequency analysis on the annual peak instantaneous flow record at 08HD018 (26 years of data from 1992-2018), fitting a Generalized Extreme Value distribution to the data, which provided the best fit (see **Figure 4-2**).

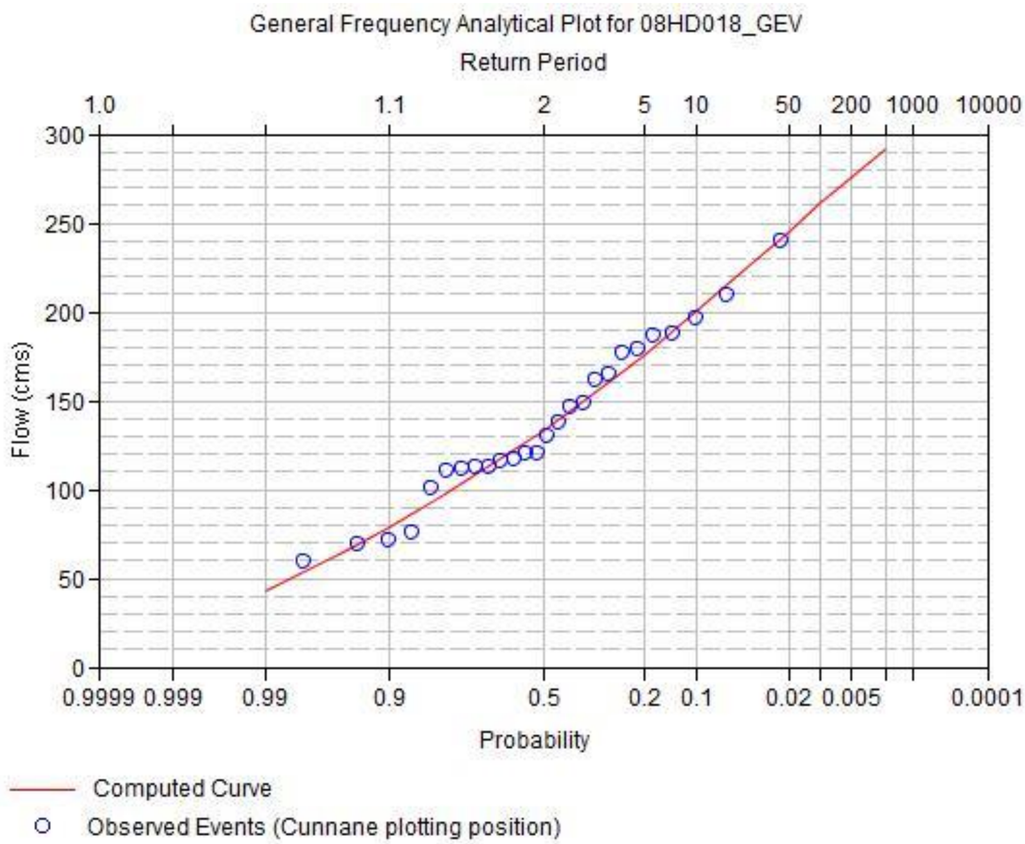

Figure 4-2
Computed GEV distribution to Annual Peak Instantaneous Flow Data for 08HD018

To estimate flows at the Cervus Bridge crossing, an area scaling relationship was used, as suggested by the Guide to Bridge Hydraulics, to transfer flow estimates from 08HD018 to the crossing (similar to the approach adopted by NHC). The hydrometric station is located upstream along the same river basin. We reviewed the area scaling exponent of 0.85 used by NHC and compared it to the coefficient of 0.785 used by Coulson and Obedkoff (1998) for the whole province of British Columbia, and it was deemed to be appropriate for this location. The equation used to scale flows from 08HD018 to the crossing is reproduced below:

$$\frac{Q_1}{Q_2} = \left(\frac{A_1}{A_2}\right)^{0.85}$$

The flood frequency analysis results and peak flow estimates are summarized in **Table 4-1**. The base peak flow estimates for the crossing are similar in magnitude to those estimated by NHC.

Table 4-1
Existing Hydrology Flood Frequency Analysis Summary

Return Period (year)	Annual Exceedance Probability (%)	Gage 08HD018 – Q (m^3/s)	Crossing – Q (m^3/s)
2	50	133	64.8
5	20	175.7	85.6
10	10	200.1	97.5
20	5	221.1	107.7
50	2	245.1	119.4
100	1	261	127.2
200	0.5	275.2	134.1

4.3 Climate Change Design Criteria

The Cervus Creek watershed is located in central Vancouver Island, near the drainage divide between the east and west sides of the island. The watershed's size and location make it potentially susceptible to rain-on-snow flood events, and based on available information from previous analysis on climate change impacts to hydrology completed by BC Hydro (Potential Impacts of Climate Change on BC Hydro-Managed Water Resources, July 2013), flows are expected to change in the future. The Campbell River system (of which Cervus Creek is a tributary) is expected to change from a hybrid to a rainfall-dominated regime. Snowfall will decrease and the spring freshet will be reduced substantially, while flows from October to April will increase. Previous work arrived at a climate change allowance of 10%. Based on the information we have reviewed, a larger allowance appears more reasonable.

Pacific Climate Impacts Consortium (PCIC) has undertaken hydrological modelling for WSC station 08HD031 Upper Campbell Lake at Strathcona Dam near the Cervus Creek crossing, using Global Circulation Model outputs to predict future daily streamflow data. We obtained the predicted future streamflow output data at this location for various models under three greenhouse gas emission scenarios (A1B, B1, B2), for a total of 23 datasets of flow values for each calendar day from 1945 to 2099. For each dataset, we processed this data to extract the maximum daily flow rate for each year and developed a simulated flood record. We used the first 68 years of the synthetic record length (1945-2012) of each dataset to complete a frequency analysis of the simulated flow data to estimate a synthetic current climate 200-year maximum daily flow for various return periods. We then used the future-most 50 years of the synthetic record (2050-2099) to complete a separate frequency analysis of the future climate simulated flow data. Using these two results, we estimated a climate change scaling factor:

$$Scaling\ Factor = \frac{Simulated\ Future\ Design\ Flow\ (2050-2099) - Simulated\ Historic\ Design\ Flow\ (1945-1912)}{Simulated\ Historic\ Design\ Flow\ (1945-1912)}$$

Using this approach, we estimated a range of scaling factors for the 200-year design flow from the various global circulation models and emissions scenarios and developed summary statistics presented in Table 4-2.

Table 4-2
Climate Change Allowance Summary Statistics

Emissions Scenario:	A1B	B1	A2
Maximum Scaling Factor:	96%	76%	95%
Minimum Scaling Factor:	-4%	-8%	-12%
Average Scaling Factor:	**36%**	**39%**	**38%**
95% Confidence Scaling Factor:	**59%**	**66%**	**65%**

The original assumption of 10% from previous work appears low. There is a wide range of results from the various datasets. We recommend adopting a 40% increase (approximately the average factor, independent of emissions scenario) as a minimum climate change allowance for design flow estimates for Cervus Creek. We note that, based on the 95% confidence limit of the various model outputs, the scaling factor could be as high as approximately 60% for all emissions scenarios.

4.4 Cervus Creek Design Flow Estimate

Applying the recommended 40% increase to the 200-year peak flow estimate from Section 4.3 results in a **design flow estimate of 188 m^3/s** for the proposed Cervus Creek crossing.

4.5 Elk River Design Flow Estimate at Confluence with Cervus Creek

The Cervus River discharges into the Elk River approximately 200 m downstream of the Cervus River Bridge. As such, we investigated whether the water level at the bridge is impacted by backwater effects from the Elk River. As previously discussed, the Campbell River system (of which Cervus Creek is a tributary) is expected to change from a hybrid to a rainfall-dominated regime. The areas of the Cervus Creek watershed (52 km^2) and the Elk River watershed (140.8 km^2) are of the same order of magnitude and the watersheds are adjacent to each other. Therefore, it is possible, if not probable, that both rivers could simultaneously experience 200-year return period peak flows from a large frontal storm event.

To estimate flows in the Elk River at the confluence with Cervus Creek, we used the area scaling relationship discussed in Section 4.2 of this report with a transfer coefficient of one (1). We used this area scaling relationship to transfer the flow estimates from 08HD018 to the Cervus Creek confluence, which is located approximately 2.3 km downstream from the hydrometric station. The Elk River watershed area at the confluence is approximately 140.8 km^2 and the 200-year design flow is estimated at 293.8 m^3/s. Applying a 40% climate change allowance, the resulting 200-year design flow estimate in the Elk River is 411 m^3/s at the confluence.

5 Hydraulic Analysis

5.1 Inputs/Methods

We developed a hydraulic model of the Cervus Creek crossing in HEC-RAS 5.0.7, based on the combined LiDAR and topographic survey data. The detailed topographic survey data was used to represent the creek geometry extending approximately 150 m upstream of the bridge and downstream to the junction with the Elk River. LiDAR data was used to supplement the detailed topographic survey data and to represent the remainder of the floodplain not covered by the survey.

The Elk River confluence downstream of the crossing was also modelled. The detailed topographic survey did not cover the Elk River, and therefore, LIDAR data was used to approximate the Elk River channel geometry, which is a conservative assumption.

The model was used to estimate the water level and velocity during the 200-yr return period event. These hydrotechnical parameters were then used to determine the minimum soffit elevation and the erosion protection measures for the Cervus Creek Bridge.

5.2 Cross Section Inputs and Model Geometry

The 1D Cervus Creek Bridge HEC-RAS geometry and Elk River confluence were represented as shown in **Figure 5-1**. The green lines and red circles depict the channel cross sections and bank stations, respectively.

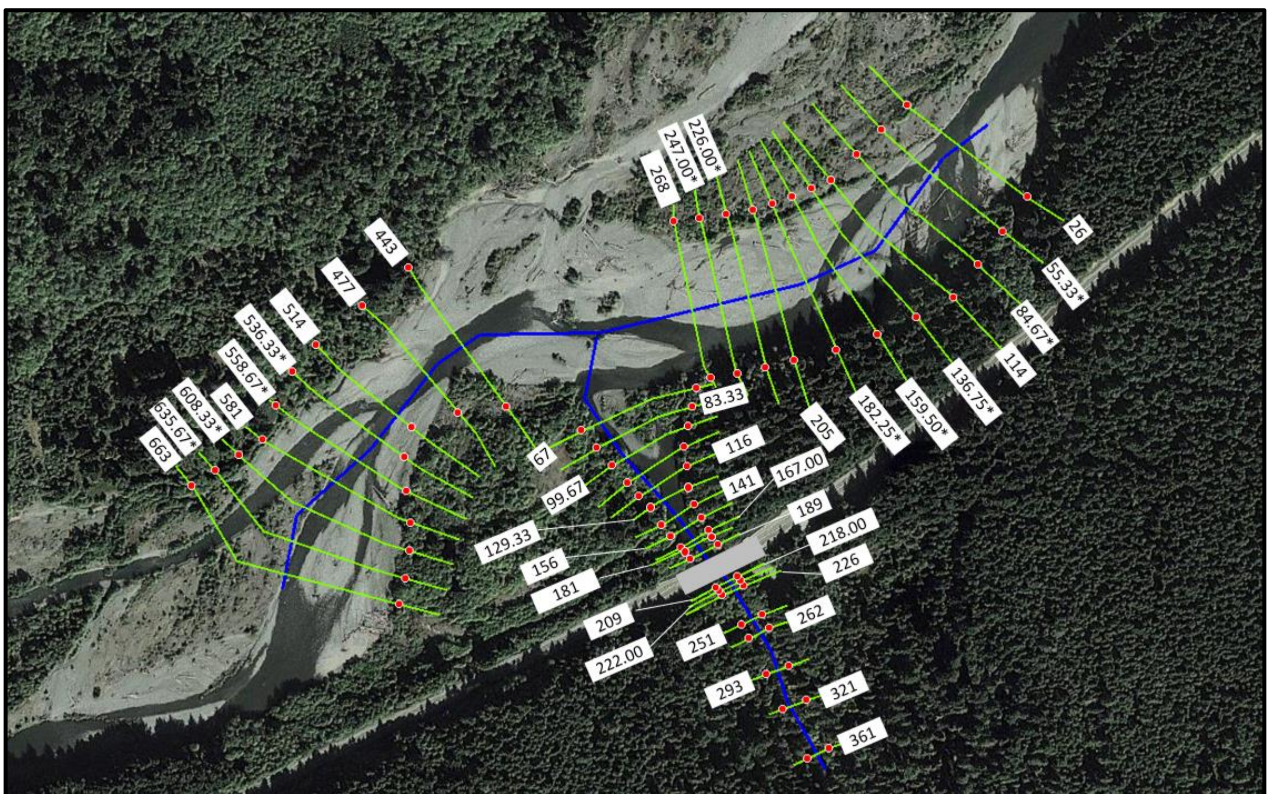

Figure 5-1
HEC-RAS Model Geometry

We modelled the proposed bridge opening geometry using a 12 m width at the channel bed and 2H:1V side slopes. A 12 m base width was selected to match the natural channel width measured based on the topographic survey data. This is consistent with the recommendation in NHC's conceptual design report NHC recommended a 16.0 m channel opening width, measured in February 2016 at the low water level. NHC's Drawing 1040-2-07318 shows that this corresponds to a minimum channel bed width of approximately 11.7 m.

The channel and overbank manning 'n' values were selected as 0.04 and 0.12 respectively, for Cervus Creek. The roughness value of 0.04 represents a clean, winding channel with some pools and shoals (Chow 1959). The roughness value of 0.12 is appropriate for overbank regions containing dense timber, a few downed trees, minimal undergrowth, and water levels extending up into the tree branches.

The channel and overbank manning 'n' values were selected as 0.045 and 0.1 respectively, for the Elk River. The roughness value of 0.045 represents a clean, winding channel with some pools and shoals, and with weeds and stones (Chow 1959). The roughness value of 0.1 is representative of overbank regions containing dense timber, a few down trees, little undergrowth, and flow below the tree branches.

The selected manning roughness values are consistent with guidance from the HEC-RAS reference documentation. The validity of the roughness value was verified by comparison against images documented by the USGS, for natural channels with verified roughness characteristics[1]. Cervus Creek and the surrounding forest are shown in **Figure 5-2**.

Figure 5-2
Photograph of Cervus Creek Channel and Surrounding Vegetation

[1] Retrieved from: https://wwwrcamnl.wr.usgs.gov/sws/fieldmethods/Indirects/nvalues/index.htm

The contraction and expansion coefficients were modeled as 0.1 and 0.3 respectively, at all cross sections, except for those immediately upstream and downstream of the Cervus Creek Bridge and cross sections 141 and 156. The contraction and expansion coefficients were modeled as 0.3 and 0.5 respectively for these cross sections to account for the more pronounced contraction and expansion that occur there.

5.3 Boundary Conditions

Initially, critical depths were used for the modelled upstream boundary conditions on both Cervus Creek and the Elk River and the normal depth for the downstream boundary condition on the Elk River. The model was also run using normal depth at the upstream boundary conditions and the results were not sensitive to which conditions were employed. The estimated local slope of 1% was used in determining the downstream boundary condition on the Elk River.

5.4 Results and Sensitivity Analysis

We estimated the water level and velocity at the Cervus Creek Bridge during a 200-year return period flood with climate change as 246.3 m and 4.2 m/s respectively. **Figure 5-3 to Figure 5-7** illustrate the HEC-RAS model results. **Figure 5-3 andFigure 5-4** show the longitudinal water level profiles for Cervus Creek and the Elk River for this design flood. **Figure 5-5** shows the upstream bridge cross section, and **Figure 5-6 andFigure** 5-7 show the Cervus Creek and Elk River velocity profiles respectively, for the same event.

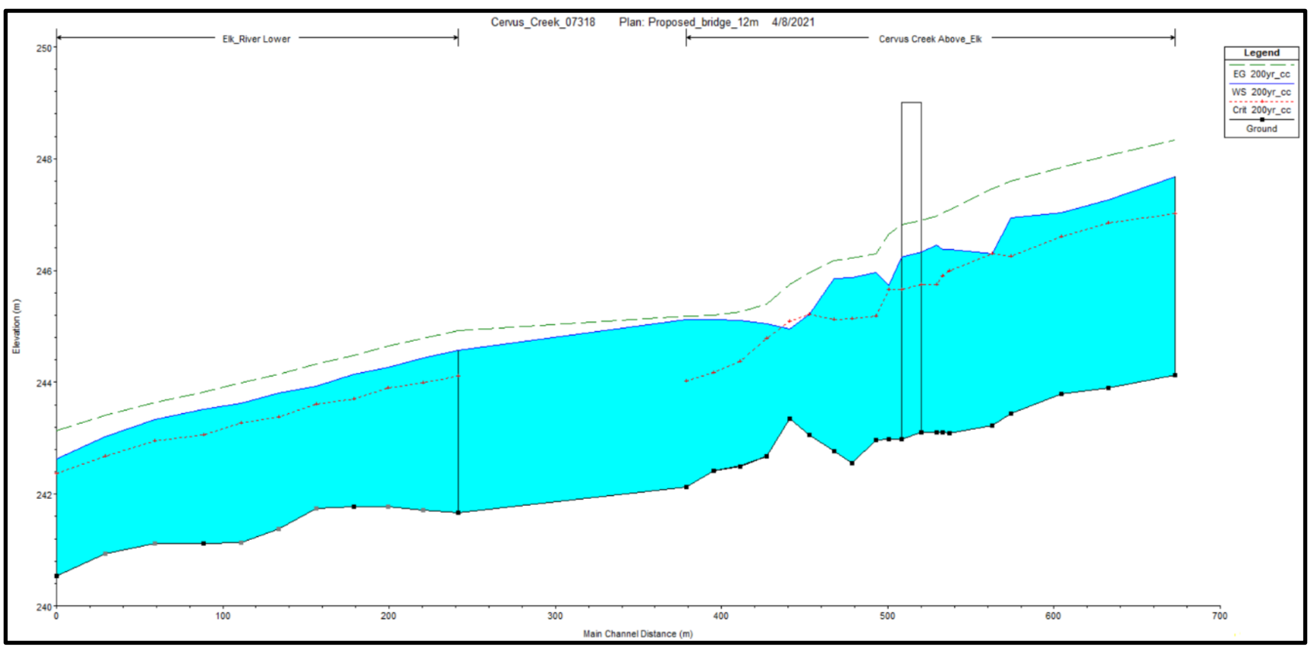

Figure 5-3
HEC-RAS Cervus Creek and Elk River Lower Reach Profile for the 200 yr Flood Event with Climate Change

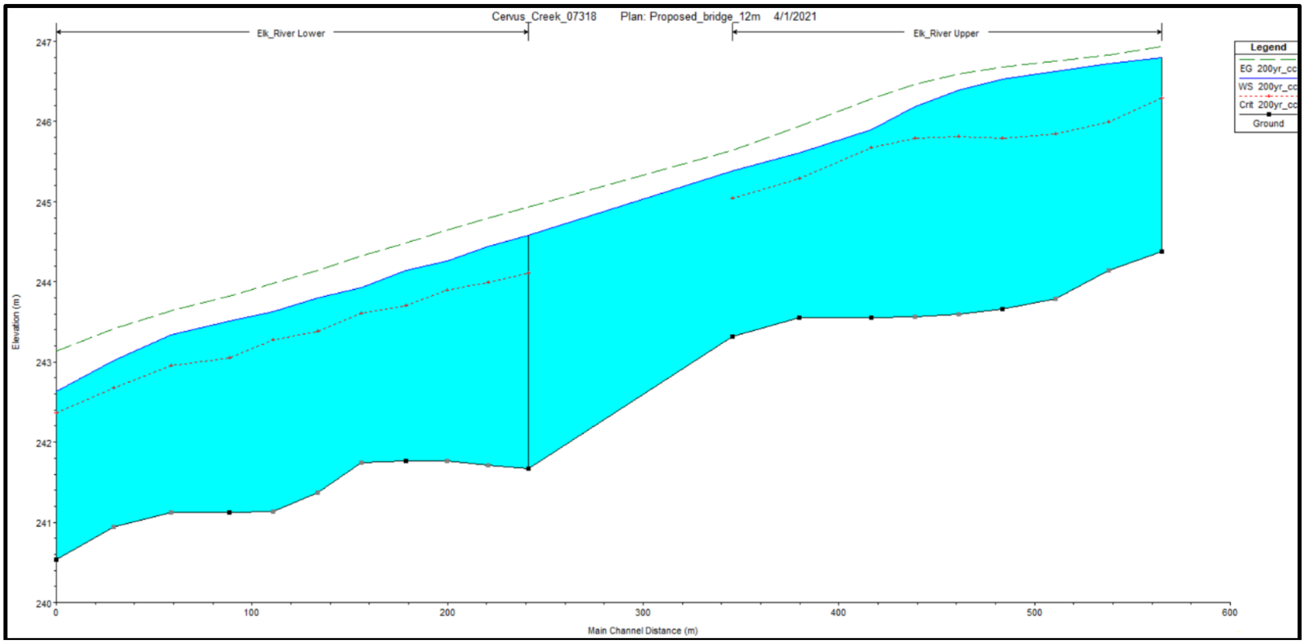

Figure 5-4
HEC-RAS Elk River Creek Profile, Upstream and Downstream of the Confluence With Cervus Creek, for the 200 yr Flood Event with Climate Change

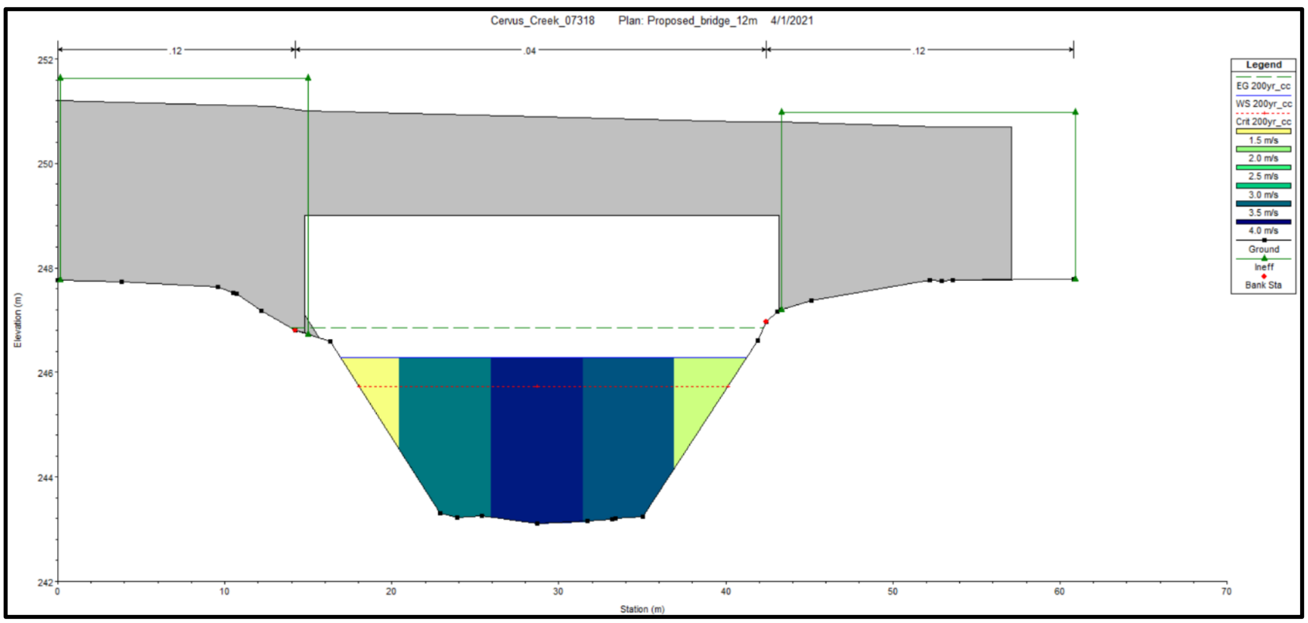

Figure 5-5
HEC-RAS Upstream Bridge Cross Section for the 200 yr Flood Event with Climate Change

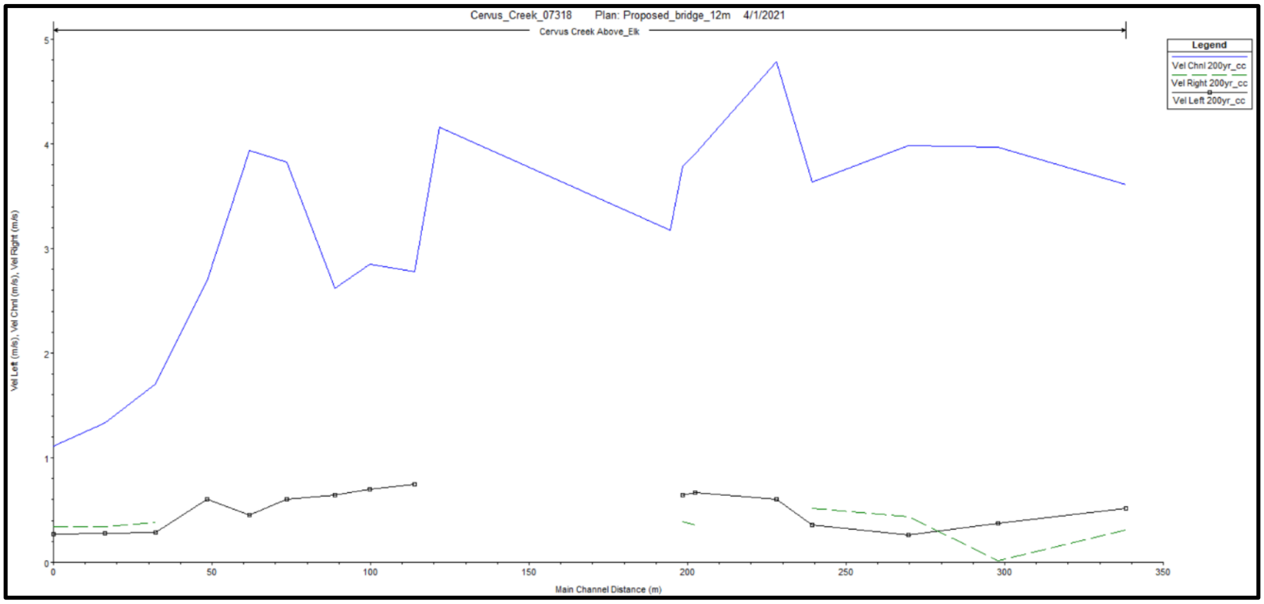

Figure 5-6
HEC-RAS Cervus Creek Velocity Profile for the 200 yr Flood Event with Climate Change

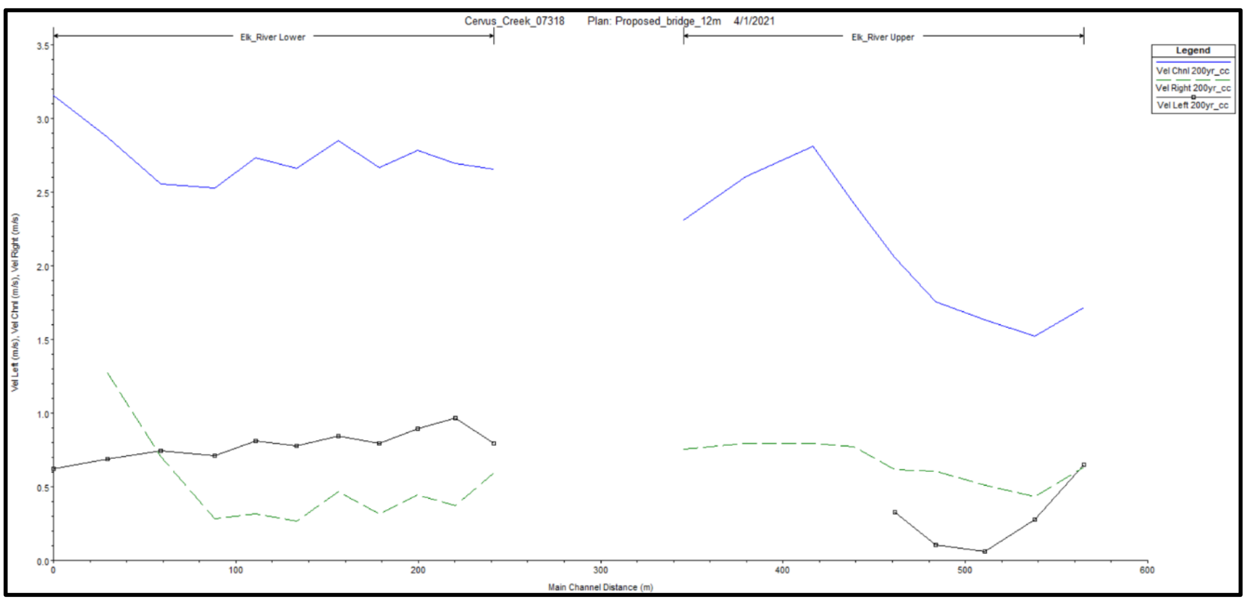

Figure 5-7
HEC-RAS Elk River Velocity Profile, Upstream and Downstream of the Confluence With Cervus Creek, for the 200 yr Flood Event with Climate Change

We completed additional model iterations to assess the sensitivity of the model results to variations in the surface roughness inputs. Manning's n roughness values were varied by +/-20% to assess changes in water elevation and velocity. **Table 5-1** summarizes the change in water levels and velocities for bridge cross sections for the low (20% decrease in roughness) and high (20% increase in roughness) scenarios. The results indicate the design values obtained from the model are not overly sensitive to variations in roughness. The design water level and velocity varied by ≤0.04% and ≤4.8%, respectively, in response to varying the Manning's n roughness values by +/-20%.

The base case model results were used to specify the recommended hydrotechnical design parameters. However, the results for the low roughness scenario indicate that a higher design velocity is possible at the bridge, which would require a larger class of riprap. This was considered when sizing the riprap protection for the bridge and is discussed further in **Section 5.7** of this report.

Table 5-1
Sensitivity Analysis Results

Scenario	Design Water Level (m)	Design Velocity (m/s)
Base (n=0.04 & 0.1)	**246.3**	**4.2**
Low (-20% roughness)	246.3	4.4
High (+20% roughness)	246.4	4.0

We ran an additional model iteration with minimal flow in the Elk River to investigate whether the water level at the bridge is impacted by backwater effects from the Elk River. The water level at the bridge was unchanged, indicating that the Cervus Creek Bridge is not impacted by backwater effects from the Elk River during the 200-year return period design event.

5.5 Clearance to Soffit

We recommend a minimum clearance of 1.5 m at the Cervus Creek Bridge above the design water level, as required by the MoTI Supplement to TAC, to account for debris and freeboard under the design flow. Based on these design criteria, the minimum soffit elevation for the Cervus Creek Bridge is 247.8 m.

5.6 Scour Depth

We evaluated contraction and local abutment scour for the Cervus Creek Bridge. Contraction scour was analyzed based on the depth and velocity at the cross sections located at the approach to, and immediately upstream of the bridge. We assume the bed material at Cervus Creek Bridge is likely similar to the bed material at the Heber River Bridge. Pending the results of a site-specific geotechnical drilling investigation, we have assumed the channel bed material possesses a D_{50} of 10 mm, corresponding to the particle size range for fine gravel. The results indicate that no contraction scour will occur at the bridge. These results are not surprising as the bridge causes minimal constriction of the channel width. Based on the observed bed sediment characteristics, we believe that the gravel size assumption is appropriate. Furthermore, our analysis indicates that no abutment scour is anticipated at the bridge. This is because the proposed abutments do not project into the flow. These results will need to be confirmed after MoTI completes the Cervus Creek Bridge design to ensure that the modelled bridge geometry represents the final design

We also estimated natural scour using the Blench natural scour equation, resulting in an estimated natural scour depth of 1.6 m. Accordingly, we recommend the installation of a riprap toe key to a depth of 1.6 m below the channel bed.

5.7 Riprap and Scour Protection

The estimated Q200 design velocity for the proposed bridge is 4.2 m/s. The proposed riprap erosion and scour protection for both abutments were sized using the Maynord equation from USACE EM1110-2-1601 and hydraulic output from the Cervus Creek HEC-RAS model. We utilized the latest riprap specifications from the Ministry's 2020 standard specifications (Section 205).

Per Ministry specifications, the results indicate that a minimum of class 250 kg riprap is required to protect the banks beneath and downstream of the bridge. However, the minimum calculated nominal riprap size is close to the boundary between class 250 kg and class 500 kg. The sensitivity analysis indicates that the design velocity would increase in the low manning roughness condition scenario sufficiently to require class 500 kg riprap. To address this potential uncertainty, we recommend that class 500 kg riprap be placed on both sides of the Cervus Creek Bridge opening to provide erosion protection to 0.6 m above the design water level.

6 Hydrotechnical Recommendations

AE's recommended hydrotechnical design parameters for the proposed Cervus Creek Bridge are summarized in **Table 6-1.**

Table 6-1
Summary of Hydrotechnical Design Recommendation

Hydrotechnical Design Criteria	Recommended Value	Comparison Value Without Climate Change
Design Flow	188 m^3/s	134 m^3/s
Climate Change Allowance (Included Above)	40%	0%
Bridge Opening Bottom Width	12 m	No Change
Side Slopes	2H:1V	No Change
Design Water Level	246.3 m	245.8 m
Minimum Freeboard	1.5 m	No Change
Minimum Soffit Elevation	247.8 m	247.3 m
Design Velocity	4.2 m/s	3.6 m/s
Minimum Riprap Size	500 kg	100 kg
Top Of Riprap Elevation	246.9 m	246.4 m
Estimated Scour Depth	1.6 m	1.5 m
Minimum Riprap Toe Key Depth	1.6 m	1.5 m

7 Closure

This report was prepared for the BC Ministry of Transportation and Infrastructure to outline the hydrotechnical design requirements for the proposed Cervus Creek Bridge replacement.

The services provided by Associated Engineering (B.C.) Ltd. in the preparation of this report were conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,

Associated Engineering (B.C.) Ltd.
Engineers & Geoscientists BC Permit Number 1000163

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Aug. 23 2022

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MM/KE/sn

APPENDIX A - HYDRAULIC ANALYSIS RESULTS

ASSOCIATED ENGINEERING (B.C.) LTD

Client:	**Ministry of Transportation and Infrastructure**		
Project Number:	**2020-2947-00**	**Date:**	**4/12/2021**
Project Name:	**Cervus River Bridge Replacement No. 07318 - Highway 28 Hydrotechnical Design Report**	**By:**	**S. Haley**
Subject:	**Hydraulic Analysis for Cervus Creek Bridge**	**Checked:**	**Z.Sally**

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	Max Chl Dpth (m)
Elk_River	Upper	663	200yr_cc	411	244.38	246.79	246.29	246.94	0.004666	1.72	260.74	223.91	0.5	2.41
Elk_River	Upper	635.67*	200yr_cc	411	244.14	246.72	245.99	246.83	0.002597	1.52	294.24	216.8	0.39	2.58
Elk_River	Upper	608.33*	200yr_cc	411	243.79	246.63	245.84	246.76	0.002757	1.63	274.64	179.92	0.4	2.84
Elk_River	Upper	581	200yr_cc	411	243.66	246.53	245.79	246.68	0.002988	1.75	264.29	163.98	0.42	2.87
Elk_River	Upper	558.67*	200yr_cc	411	243.6	246.39	245.81	246.59	0.004389	2.05	224.9	154.01	0.51	2.79
Elk_River	Upper	536.33*	200yr_cc	411	243.56	246.19	245.79	246.47	0.00672	2.42	193.95	139.31	0.62	2.63
Elk_River	Upper	514	200yr_cc	411	243.55	245.9	245.68	246.28	0.009728	2.81	166.73	131.8	0.74	2.35
Elk_River	Upper	477	200yr_cc	411	243.55	245.61	245.29	245.94	0.008771	2.61	173.27	134.1	0.7	2.06
Elk_River	Upper	443	200yr_cc	411	243.32	245.38	245.04	245.64	0.007217	2.31	193.55	151	0.63	2.06
Elk_River	Lower	268	200yr_cc	599	241.67	244.58	244.11	244.93	0.006337	2.66	239.04	139.2	0.62	2.91
Elk_River	Lower	247.00*	200yr_cc	599	241.71	244.44	243.99	244.79	0.006798	2.7	245.14	156.8	0.64	2.73
Elk_River	Lower	226.00*	200yr_cc	599	241.77	244.27	243.9	244.64	0.007499	2.78	242.79	168	0.67	2.5
Elk_River	Lower	205	200yr_cc	599	241.77	244.14	243.7	244.49	0.006387	2.67	258.57	181.39	0.63	2.37
Elk_River	Lower	182.25*	200yr_cc	599	241.74	243.93	243.61	244.32	0.008277	2.85	240.18	168.6	0.7	2.19
Elk_River	Lower	159.50*	200yr_cc	599	241.37	243.8	243.38	244.14	0.006594	2.66	260.8	187.32	0.63	2.43
Elk_River	Lower	136.75*	200yr_cc	599	241.13	243.63	243.28	243.99	0.007681	2.73	256.95	200.08	0.68	2.5
Elk_River	Lower	114	200yr_cc	599	241.12	243.51	243.05	243.82	0.006043	2.53	278.55	213.56	0.6	2.39
Elk_River	Lower	84.67*	200yr_cc	599	241.12	243.34	242.95	243.64	0.006327	2.56	294.84	215.8	0.62	2.22
Elk_River	Lower	55.33*	200yr_cc	599	240.94	243.02	242.68	243.42	0.008485	2.87	240.2	170.73	0.71	2.08
Elk_River	Lower	26	200yr_cc	599	240.54	242.64	242.36	243.14	0.010016	3.16	202.47	141.55	0.77	2.1
Cervus Creek	Above_Elk	361	200yr_cc	188	244.13	247.67	247.02	248.33	0.005424	3.62	54.92	22.28	0.68	3.54
Cervus Creek	Above_Elk	321	200yr_cc	188	243.9	247.26	246.85	248.06	0.008021	3.97	47.89	19.69	0.79	3.36
Cervus Creek	Above_Elk	293	200yr_cc	188	243.79	247.03	246.61	247.84	0.007457	3.99	48.29	19.97	0.77	3.24
Cervus Creek	Above_Elk	262	200yr_cc	188	243.44	246.94	246.25	247.6	0.00522	3.63	55.11	21.86	0.67	3.5
Cervus Creek	Above_Elk	251	200yr_cc	188	243.22	246.31	246.31	247.47	0.012991	4.78	40.34	18.72	1	3.09
Cervus Creek	Above_Elk	226	200yr_cc	188	243.09	246.38	245.99	247.07	0.006419	3.81	63.07	34.72	0.74	3.29
Cervus Creek	Above_Elk	222	200yr_cc	188	243.11	246.38	245.9	247.04	0.005949	3.7	63.08	33.52	0.71	3.27
Cervus Creek	Above_Elk	218	200yr_cc	188	243.1	246.46	245.75	246.97	0.005406	3.17	59.25	24.61	0.65	3.36
Cervus Creek	Above_Elk	189	200yr_cc	188	242.98	245.73	245.66	246.66	0.012161	4.26	44.11	21.71	0.95	2.75
Cervus Creek	Above_Elk	181	200yr_cc	188	242.96	245.97	245.19	246.29	0.003733	2.77	103.38	47.24	0.55	3.01
Cervus Creek	Above_Elk	167	200yr_cc	188	242.55	245.86	245.13	246.23	0.003926	2.85	93.18	43.62	0.56	3.31
Cervus Creek	Above_Elk	156	200yr_cc	188	242.77	245.86	245.12	246.17	0.003557	2.62	97.72	48.49	0.54	3.09
Cervus Creek	Above_Elk	141	200yr_cc	188	243.06	245.22	245.22	245.96	0.013459	3.82	51.48	45.61	0.98	2.16
Cervus Creek	Above_Elk	129.33	200yr_cc	188	243.35	244.96	245.1	245.75	0.019821	3.94	49.42	56.52	1.15	1.61
Cervus Creek	Above_Elk	116	200yr_cc	188	242.67	245.04	244.78	245.39	0.007313	2.69	81.31	73.39	0.72	2.37
Cervus Creek	Above_Elk	99.67	200yr_cc	188	242.5	245.11	244.37	245.25	0.002413	1.71	130.96	115.2	0.42	2.61
Cervus Creek	Above_Elk	83.33	200yr_cc	188	242.42	245.12	244.18	245.21	0.001346	1.33	157.77	124.8	0.32	2.7
Cervus Creek	Above_Elk	67	200yr_cc	188	242.13	245.12	244.03	245.18	0.00092	1.11	186.24	134.9	0.26	2.99

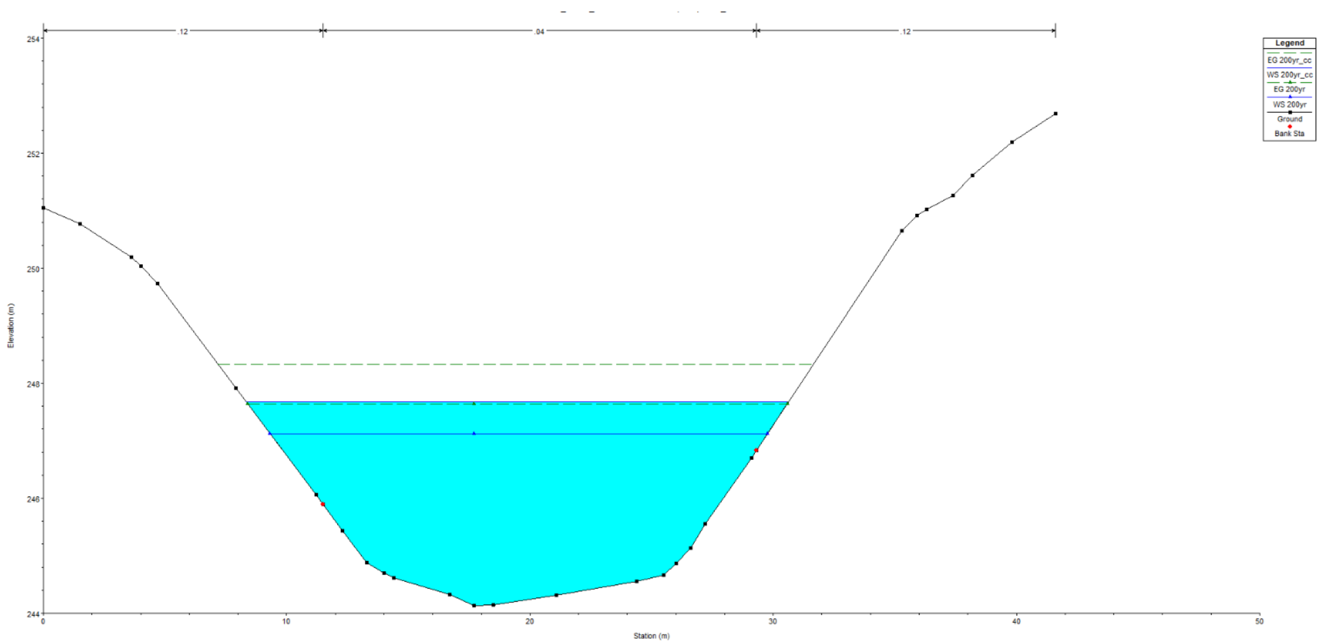

Figure 7-1
HEC-RAS Cervus Creek Cross Section Station 361

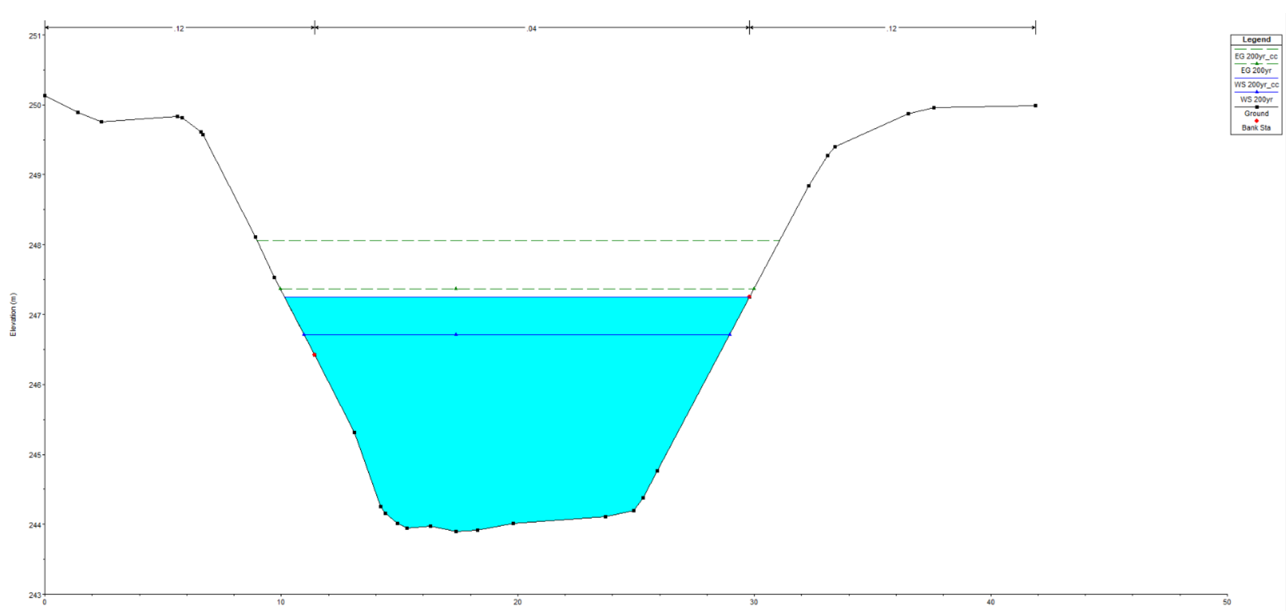

Figure 7-2
HEC-RAS Cervus Creek Cross Section Station 321

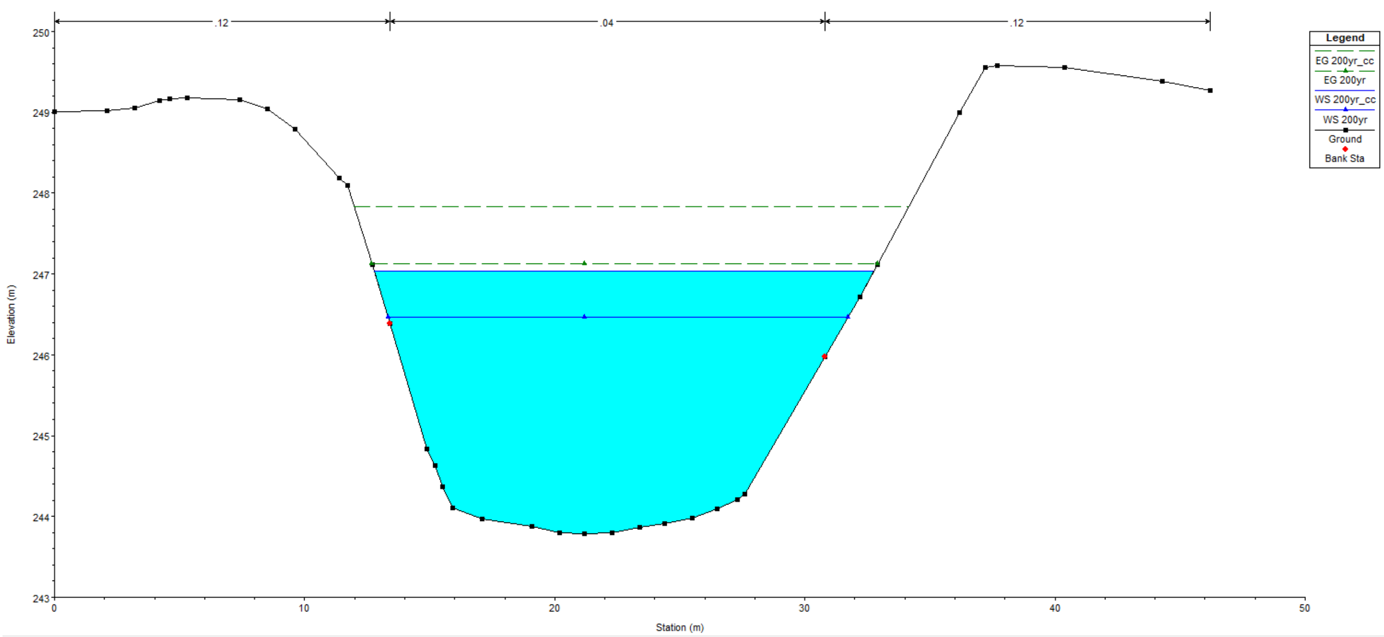

Figure 7-3
HEC-RAS Cervus Creek Cross Section Station 293

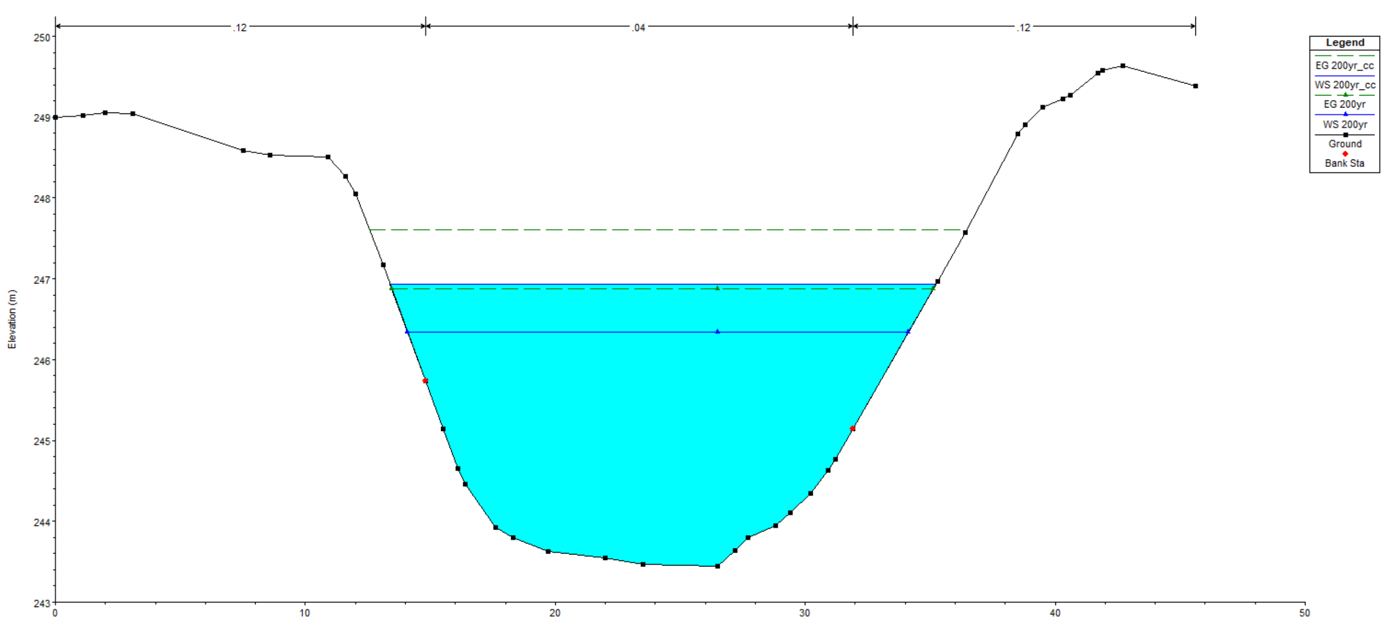

Figure 7-4
HEC-RAS Cervus Creek Cross Section Station 262

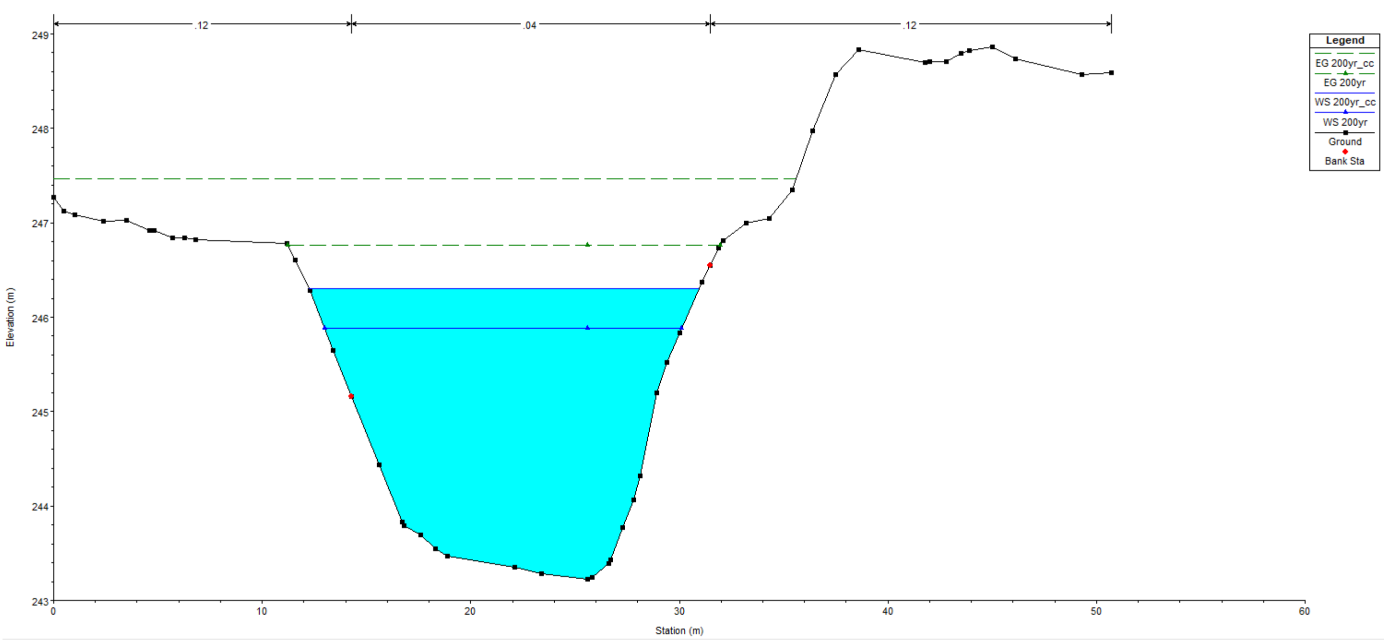

Figure 7-5
HEC-RAS Cervus Creek Cross Section Station 251

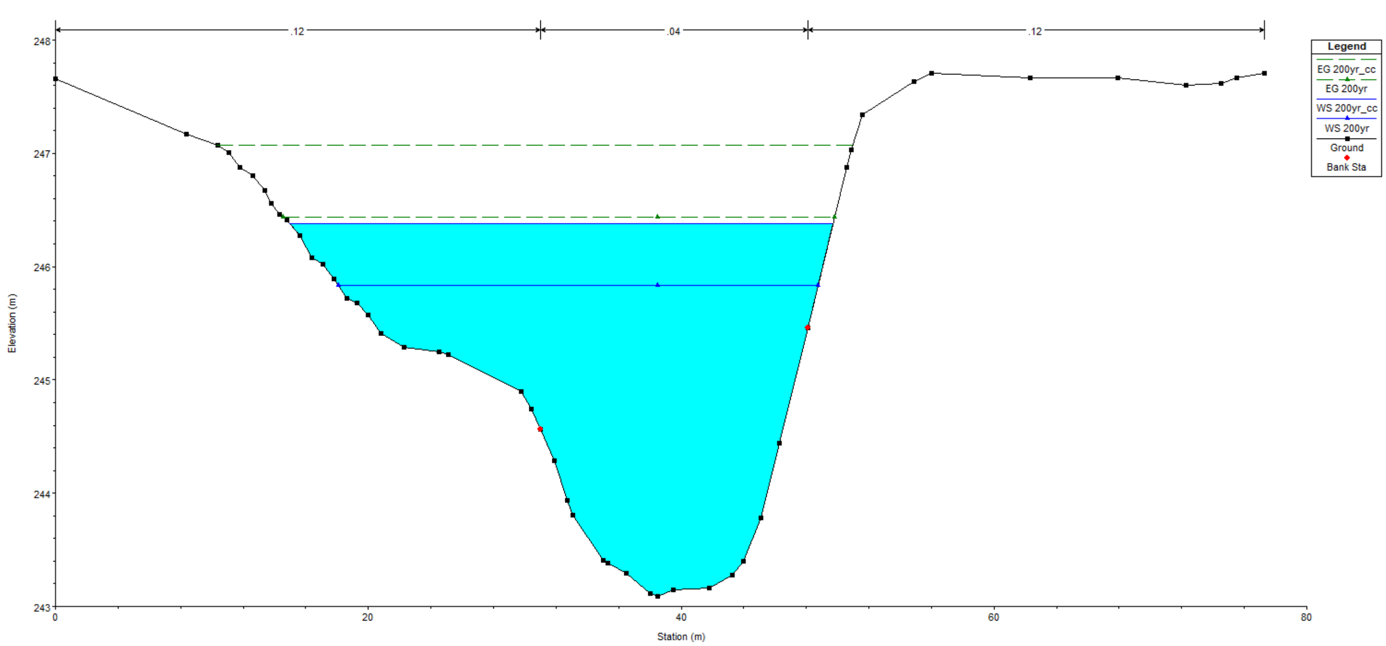

Figure 7-6
HEC-RAS Cervus Creek Cross Section Station 226

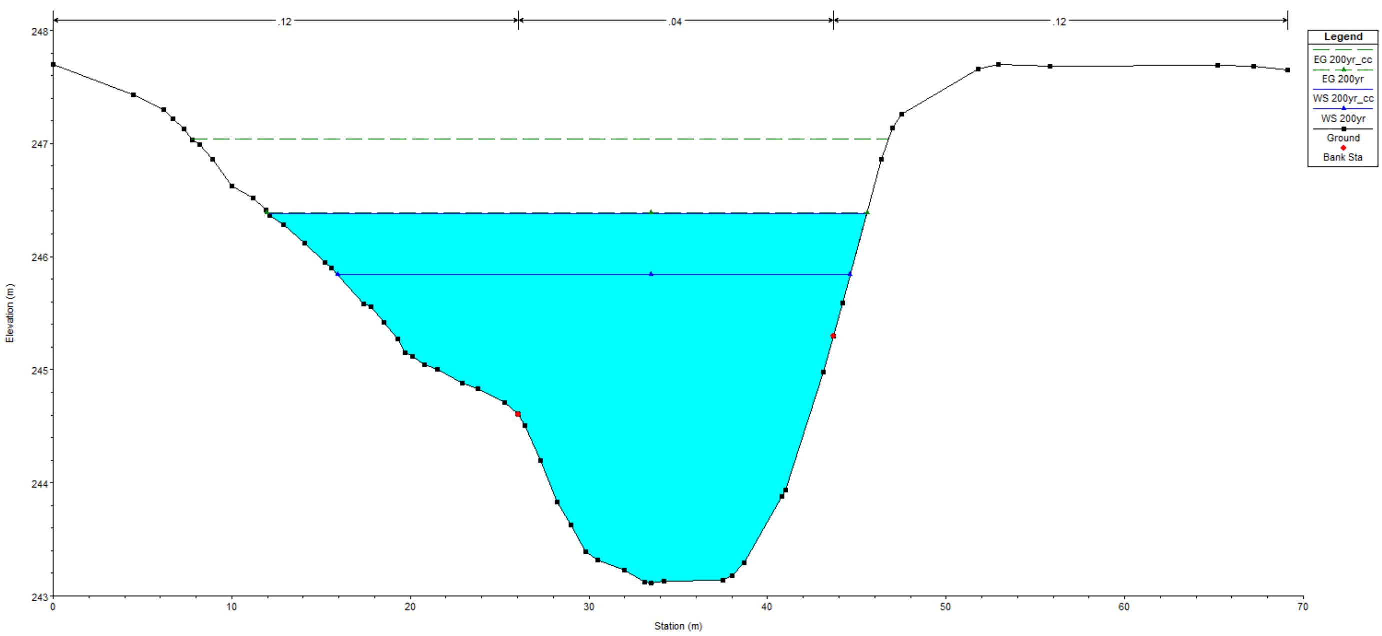

Figure 7-7
HEC-RAS Cervus Creek Cross Section Station 222

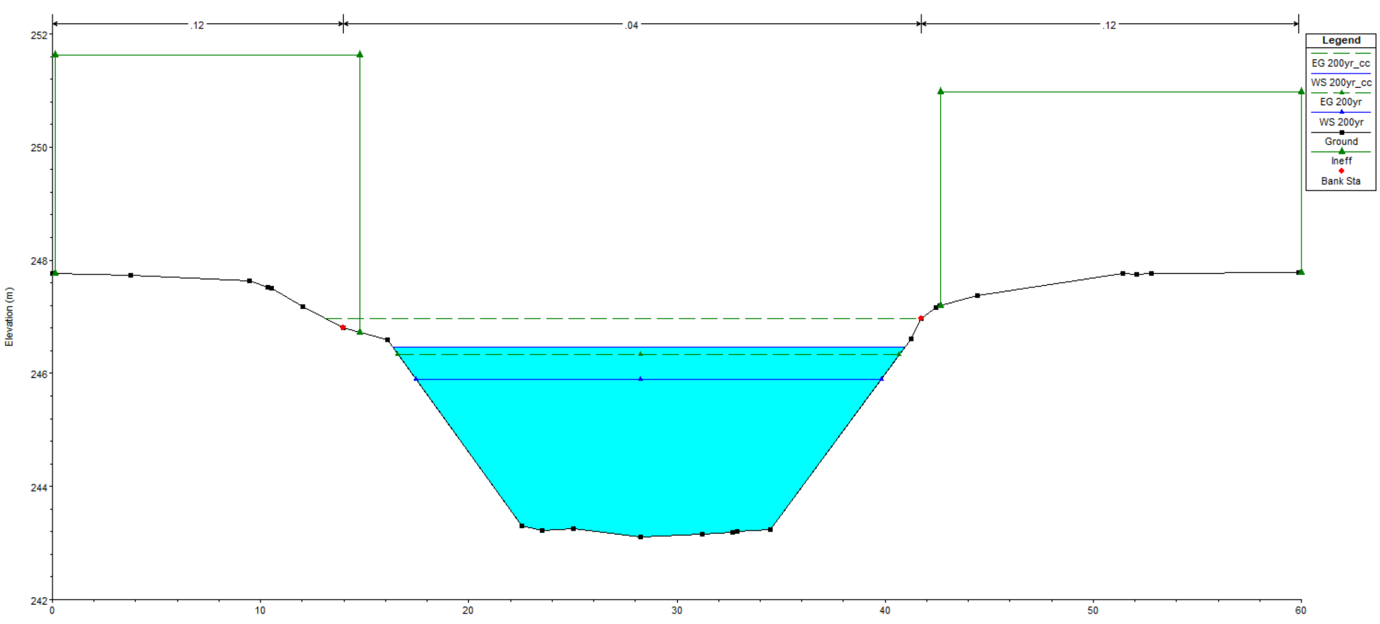

Figure 7-8
HEC-RAS Cervus Creek Cross Section Station 209 BR D

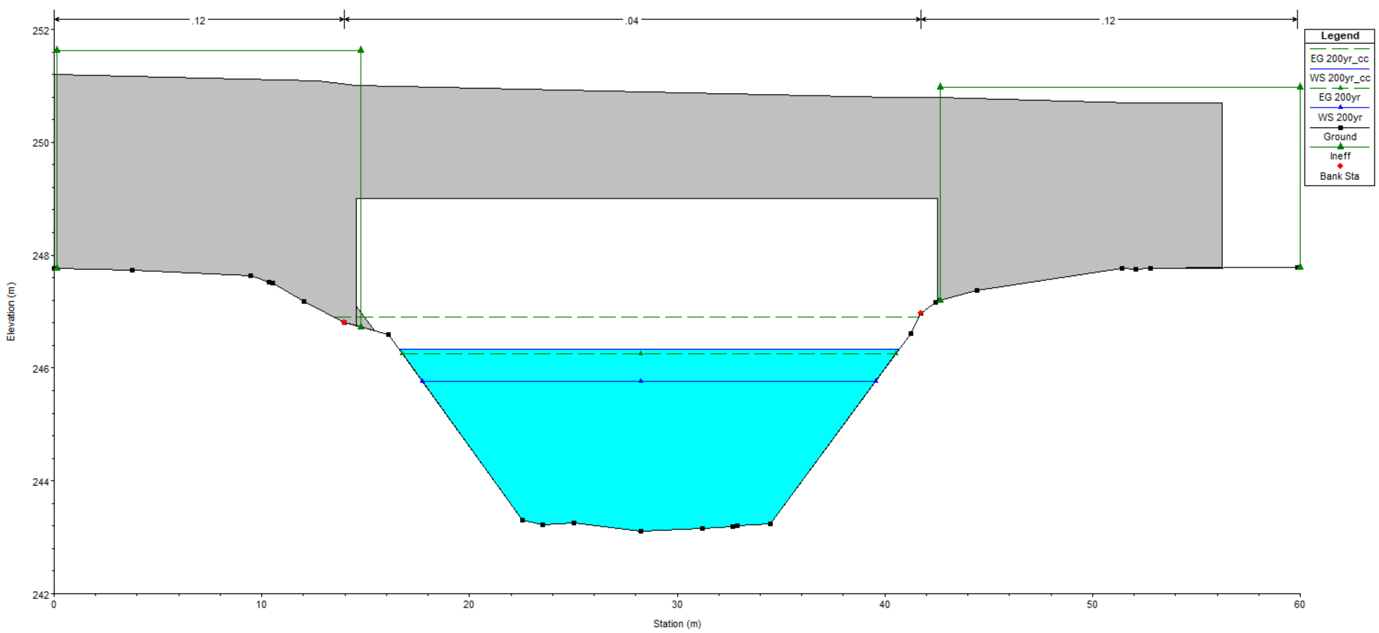

Figure 7-9
HEC-RAS Cervus Creek Cross Section Station 209 BR U

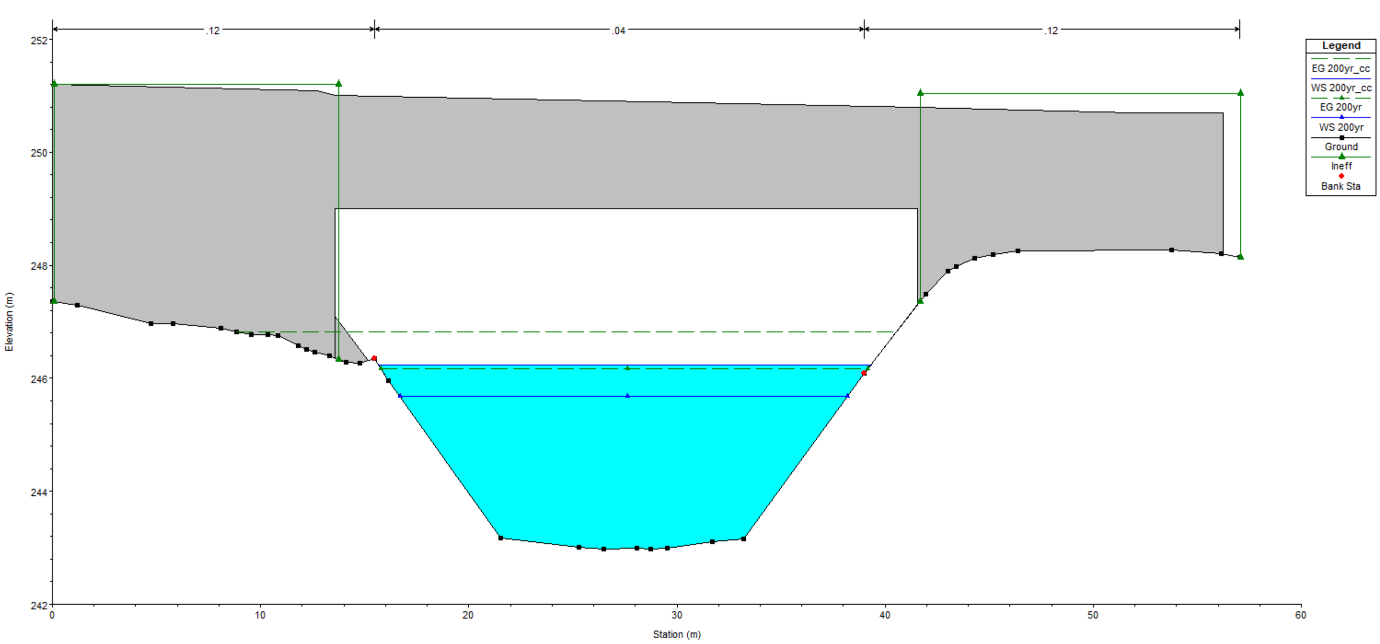

Figure 7-10
HEC-RAS Cervus Creek Cross Section Station 209 BR U

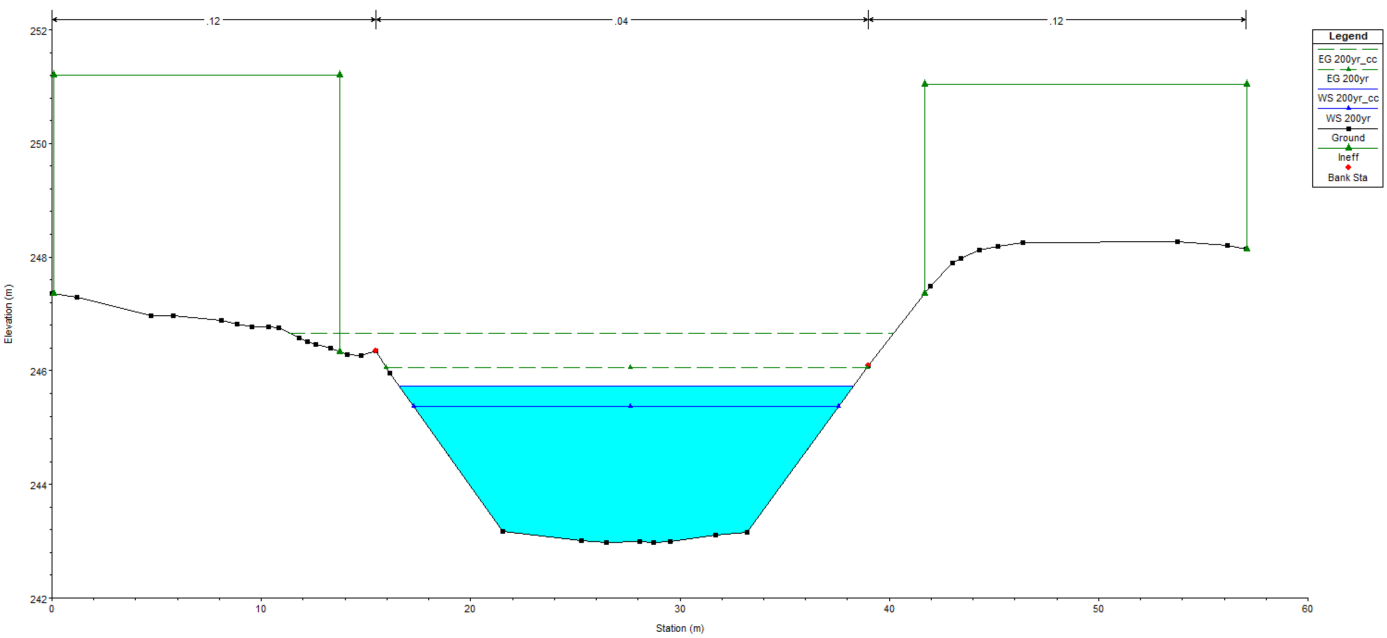

Figure 7-11
HEC-RAS Cervus Creek Cross Section Station 189

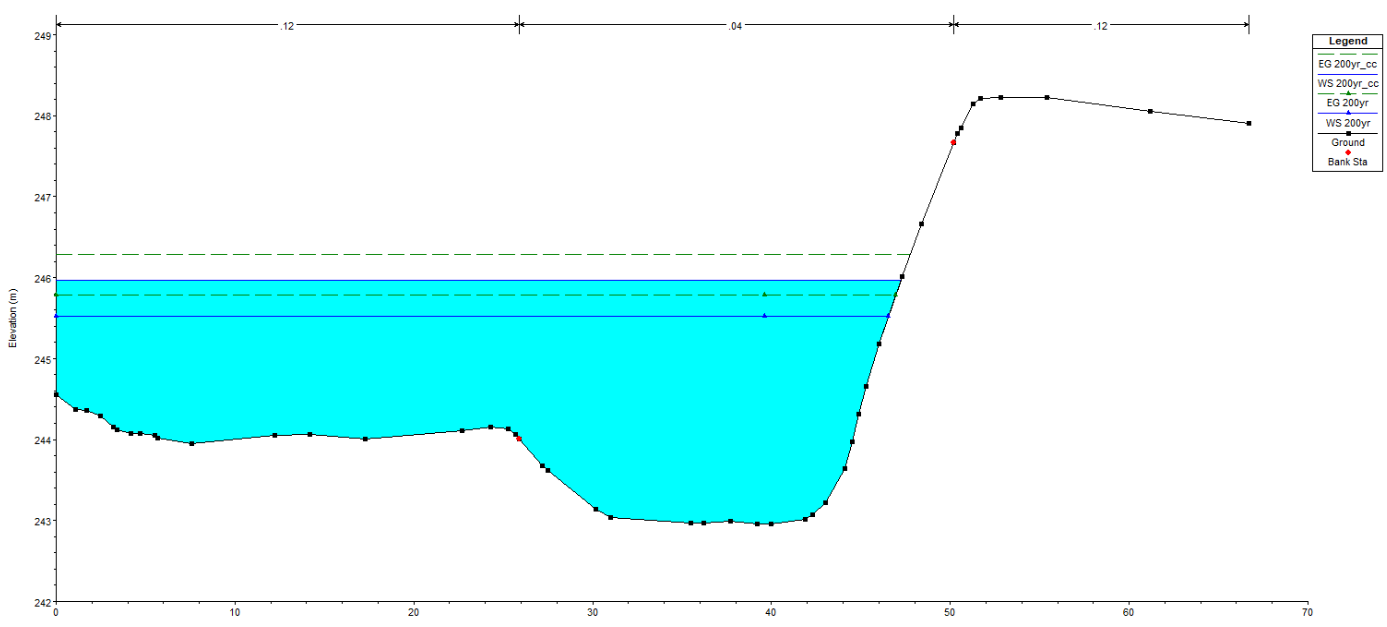

Figure 7-12
HEC-RAS Cervus Creek Cross Section Station 181

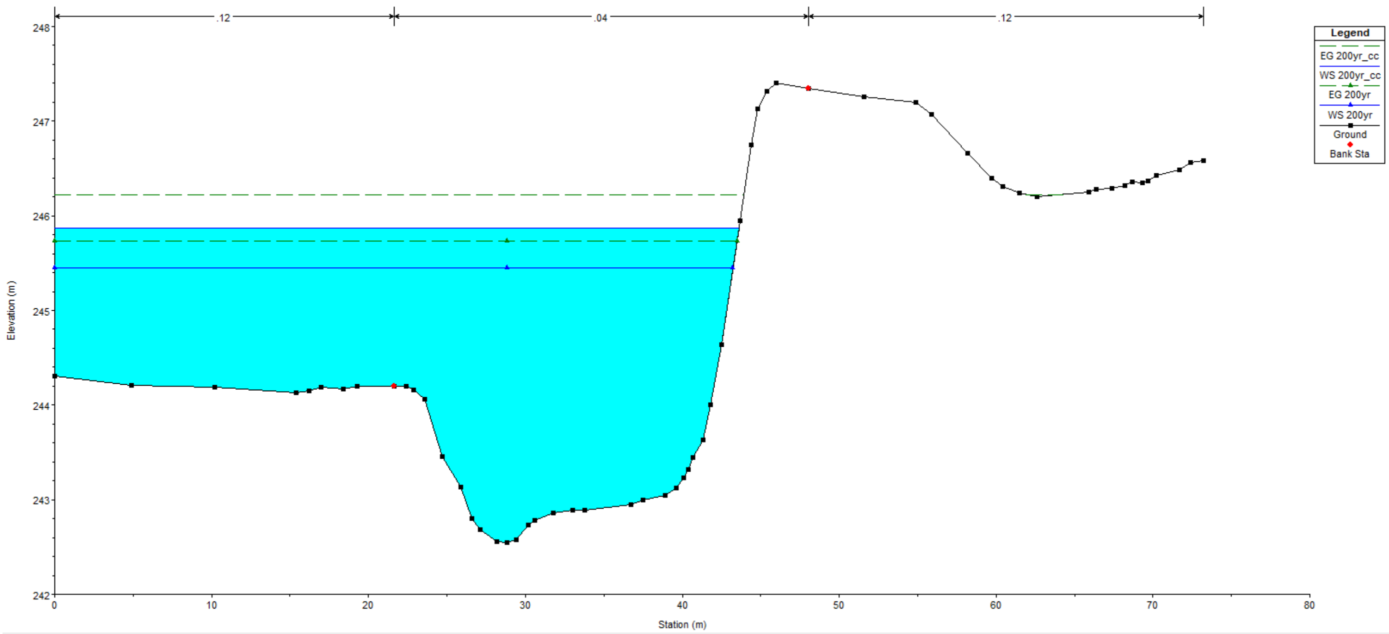

Figure 7-13
HEC-RAS Cervus Creek Cross Section Station 167

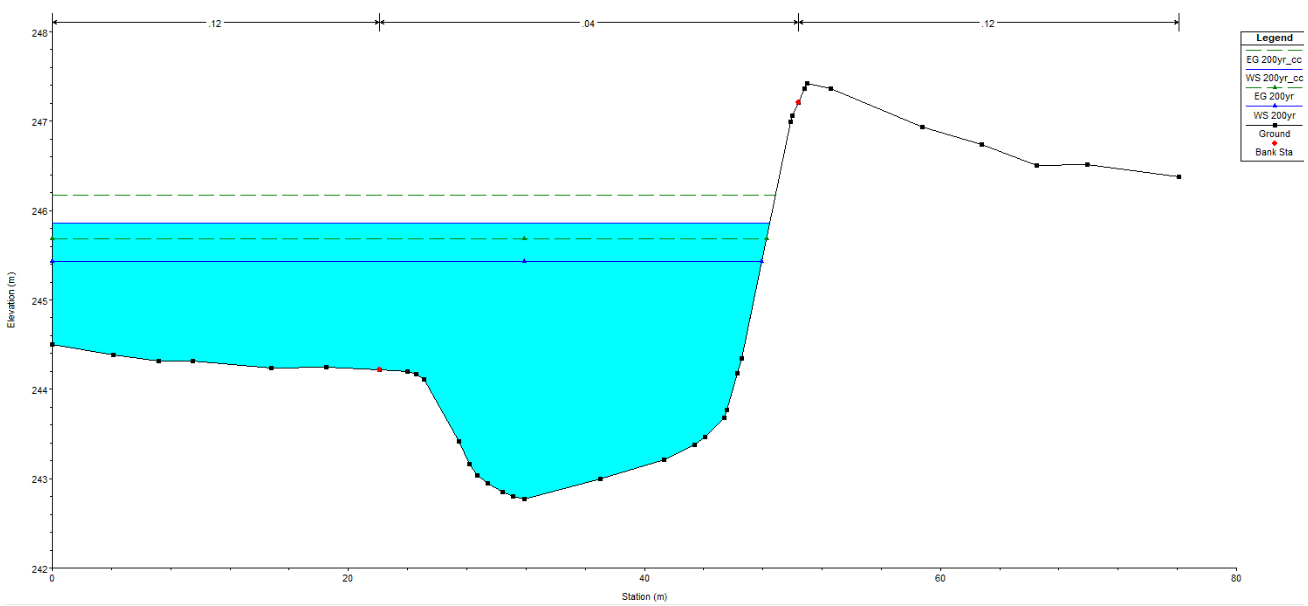

Figure 7-14
HEC-RAS Cervus Creek Cross Section Station 156

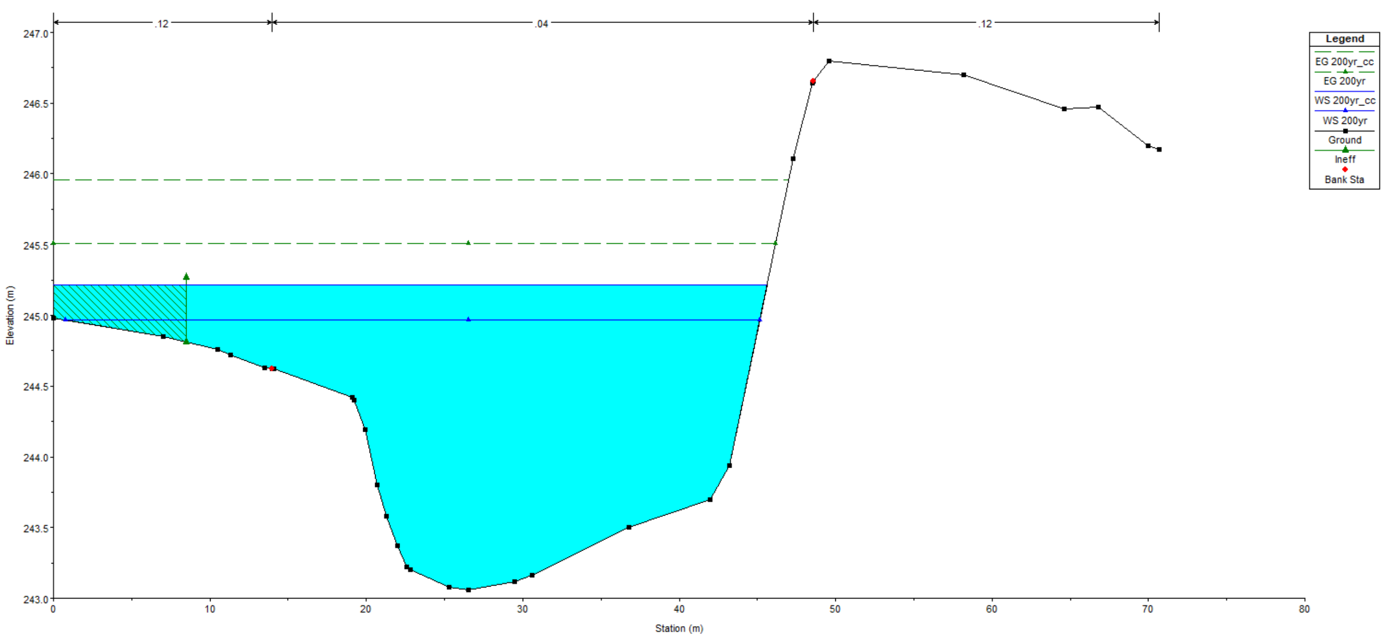

Figure 7-15
HEC-RAS Cervus Creek Cross Section Station 141

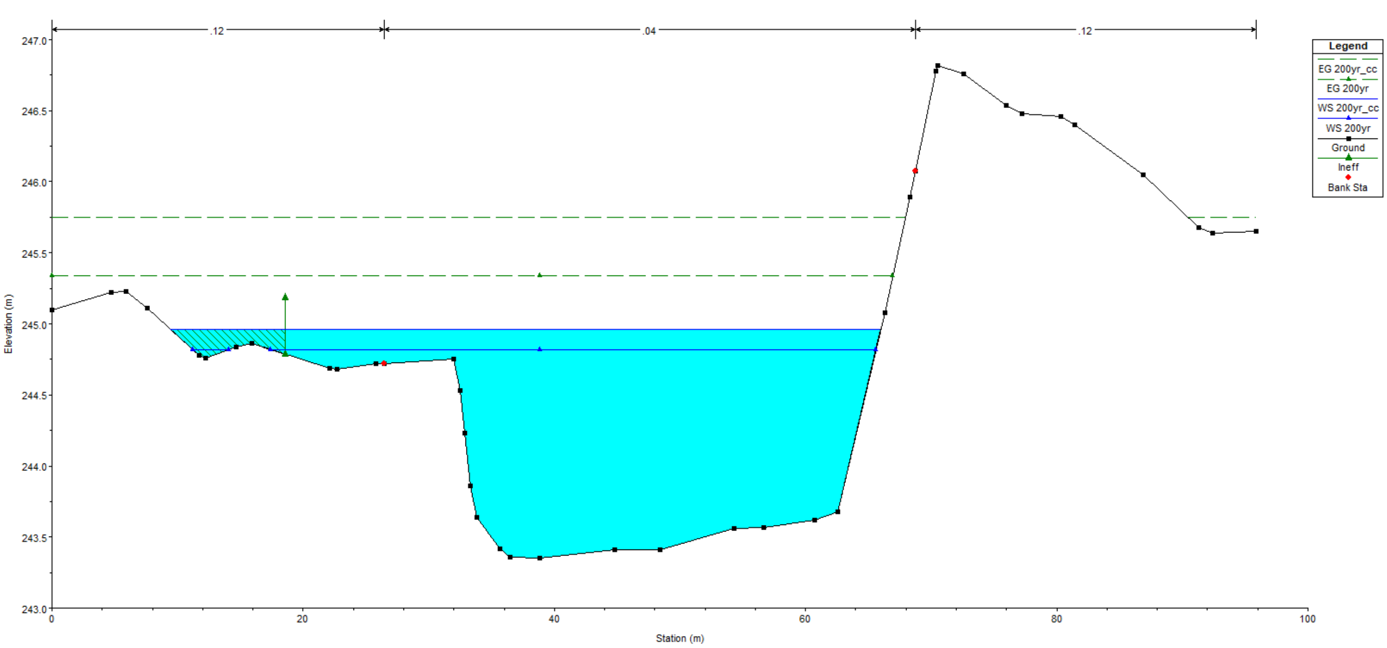

Figure 7-16
HEC-RAS Cervus Creek Cross Section Station 129.33

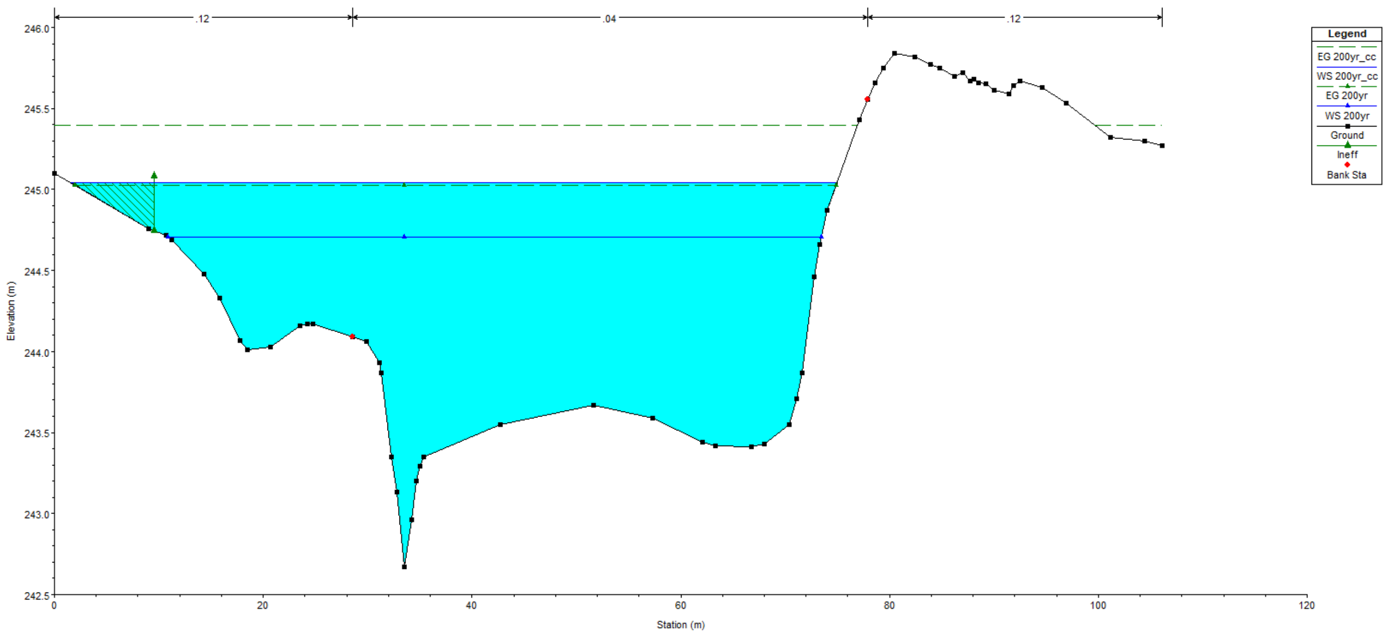

Figure 7-17
HEC-RAS Cervus Creek Cross Section Station 116

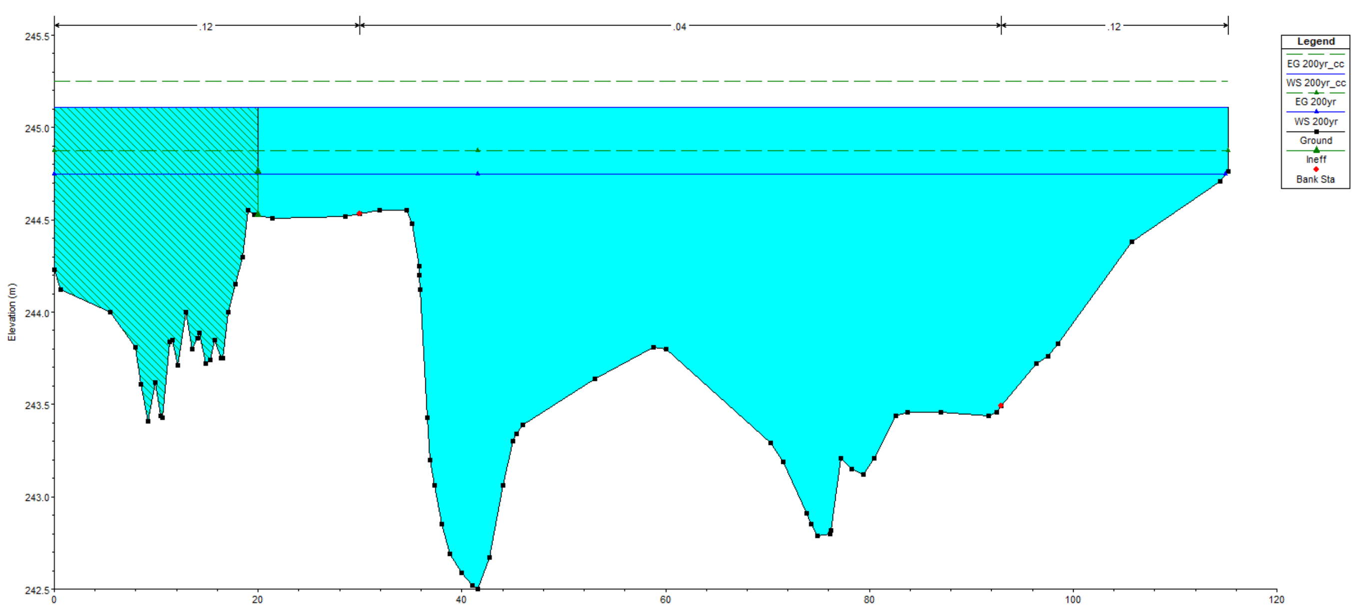

Figure 7-18
HEC-RAS Cervus Creek Cross Section Station 99.67

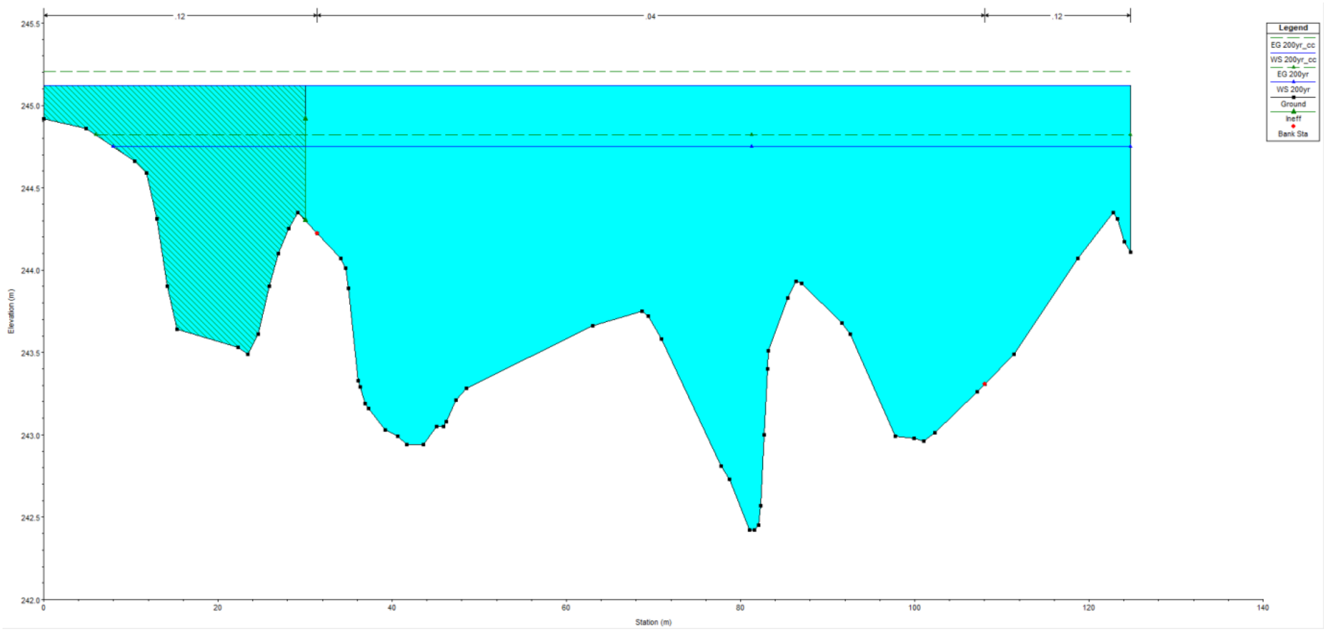

Figure 7-19
HEC-RAS Cervus Creek Cross Section Station 83.33

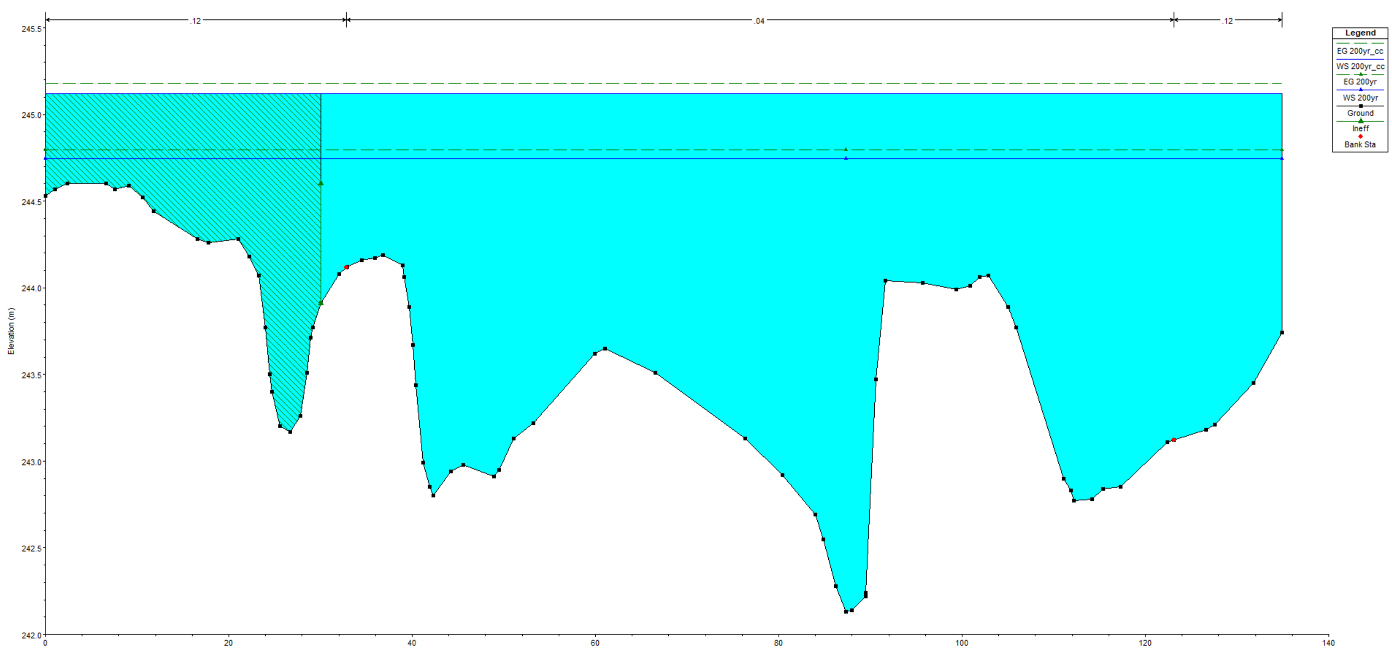

Figure 7-20
HEC-RAS Cervus Creek Cross Section Station 67

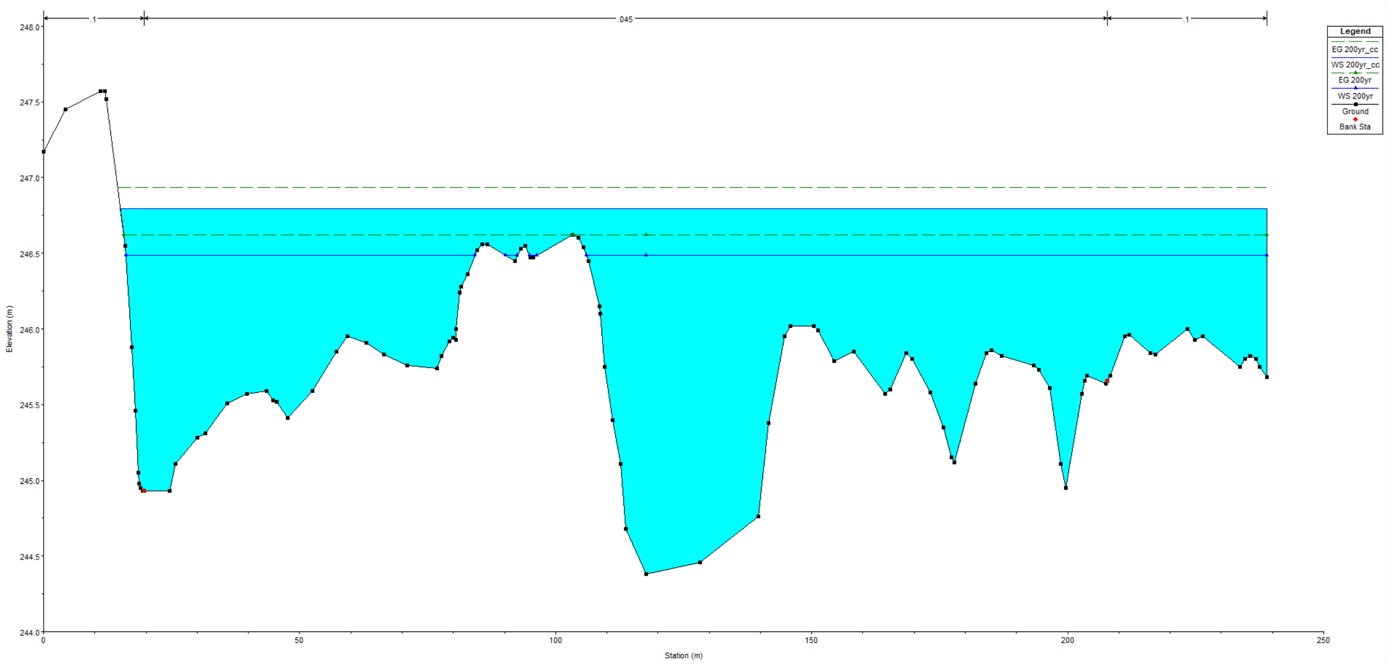

Figure 7-21
HEC-RAS Elk River Upper Reach Cross Section Station 663

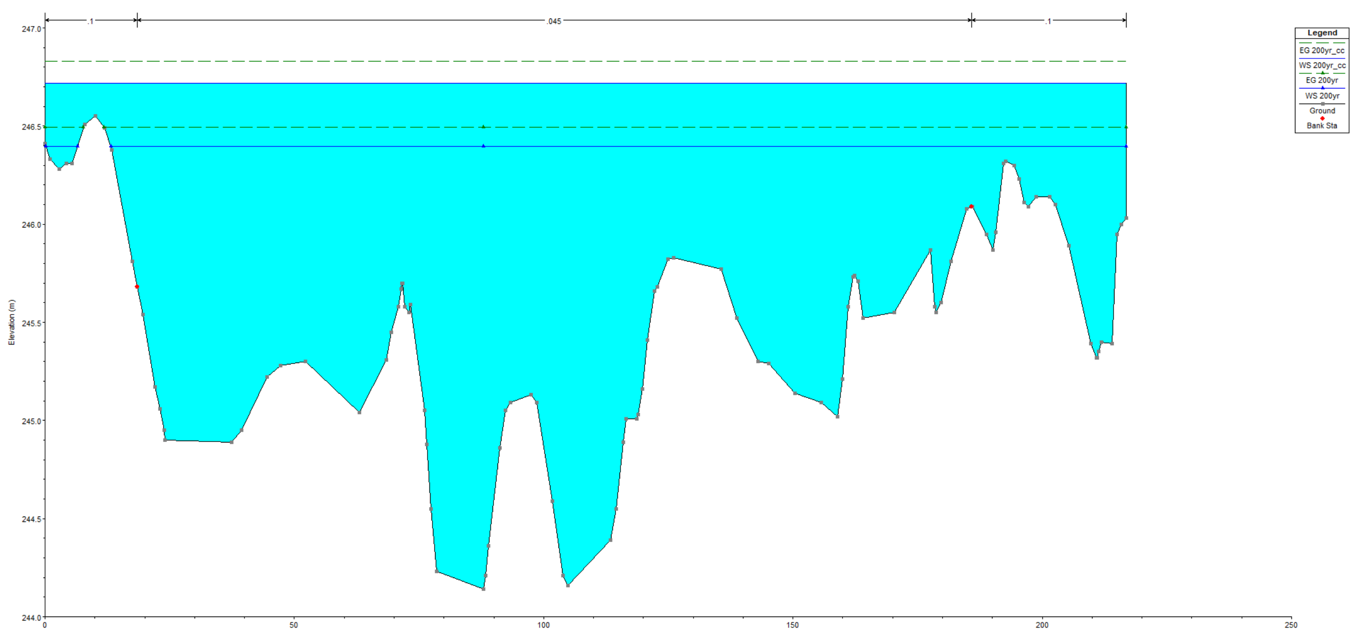

Figure 7-22
HEC-RAS Elk River Upper Reach Cross Section Station 635.67*

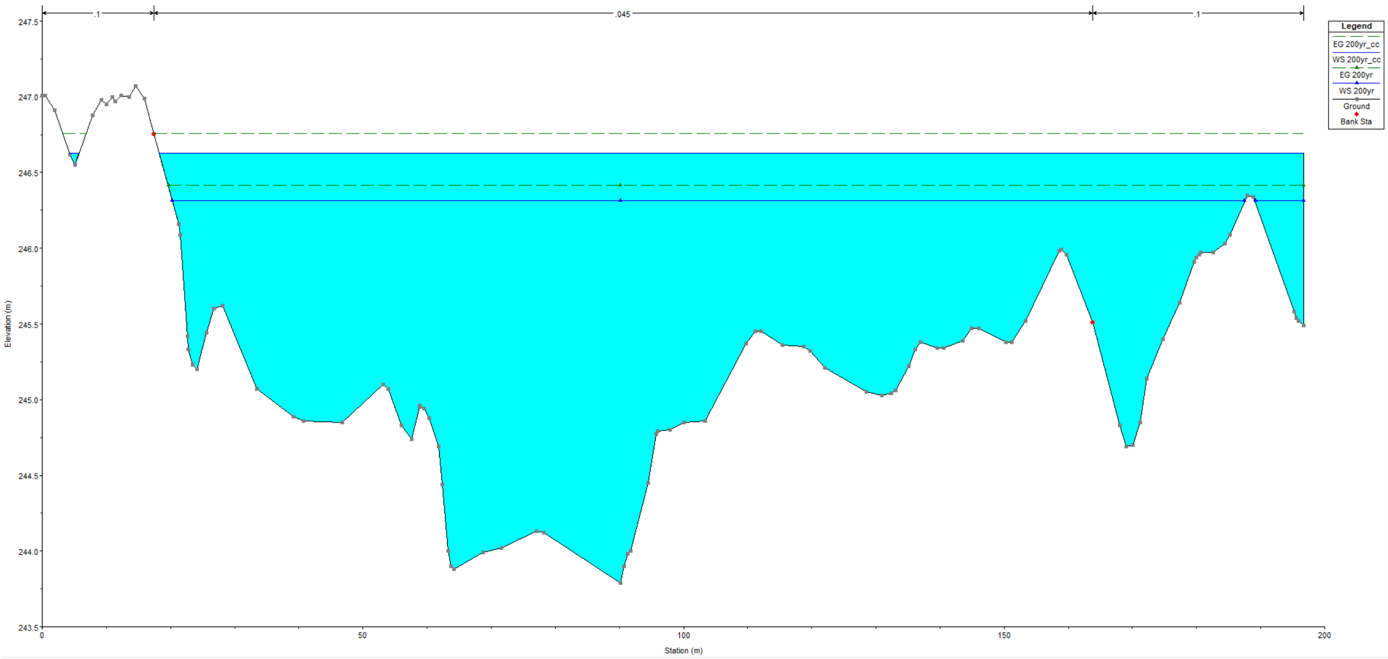

Figure 7-23
HEC-RAS Elk River Upper Reach Cross Section Station 608.33*

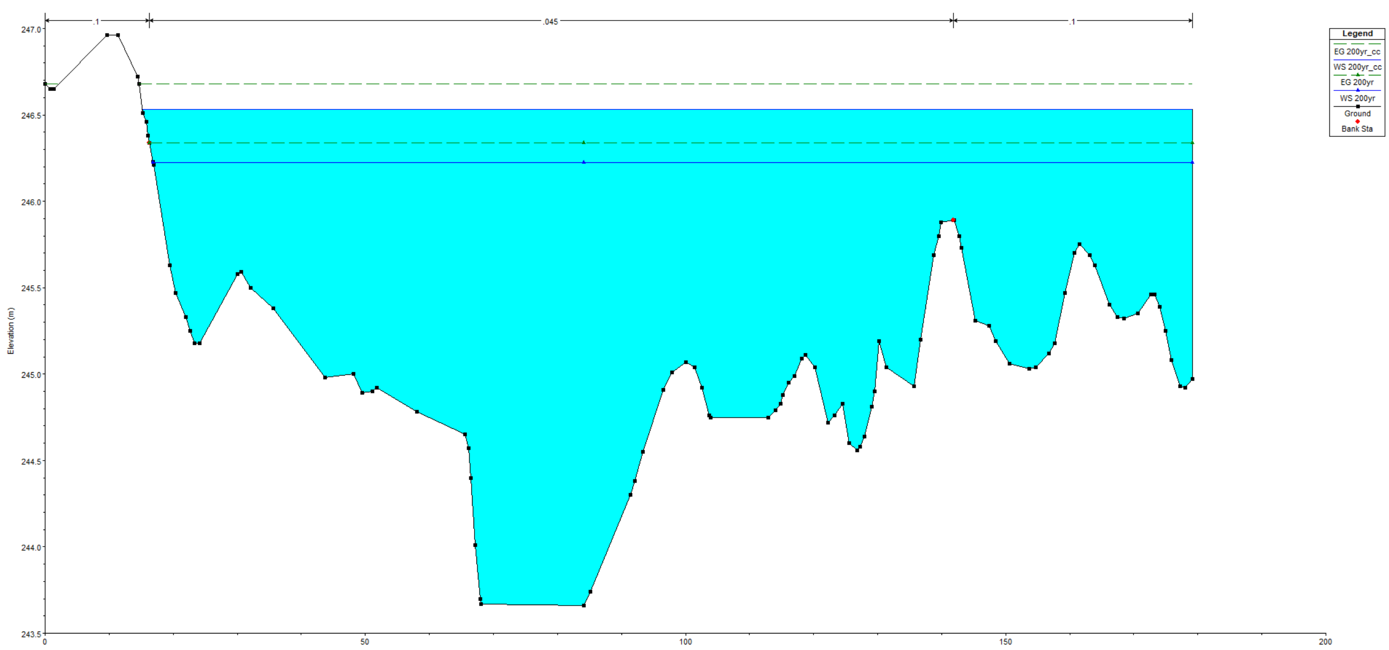

Figure 7-24
HEC-RAS Elk River Upper Reach Cross Section Station 581

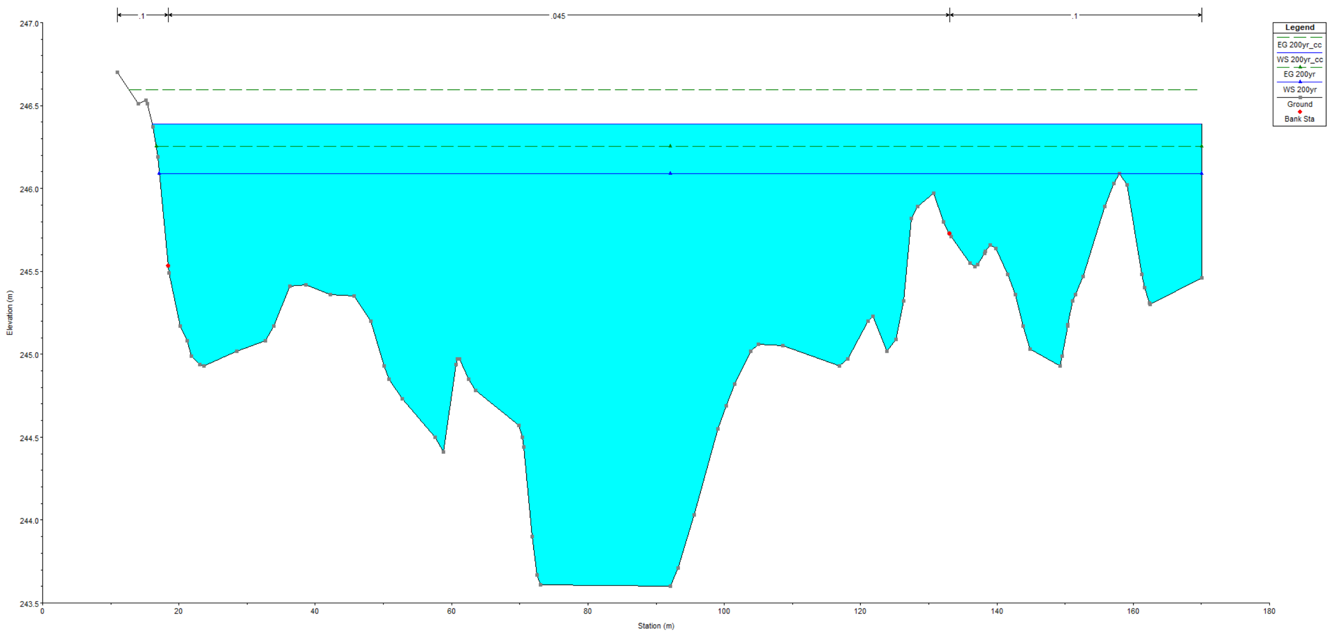

Figure 7-25
HEC-RAS Elk River Upper Reach Cross Section Station 558.67*

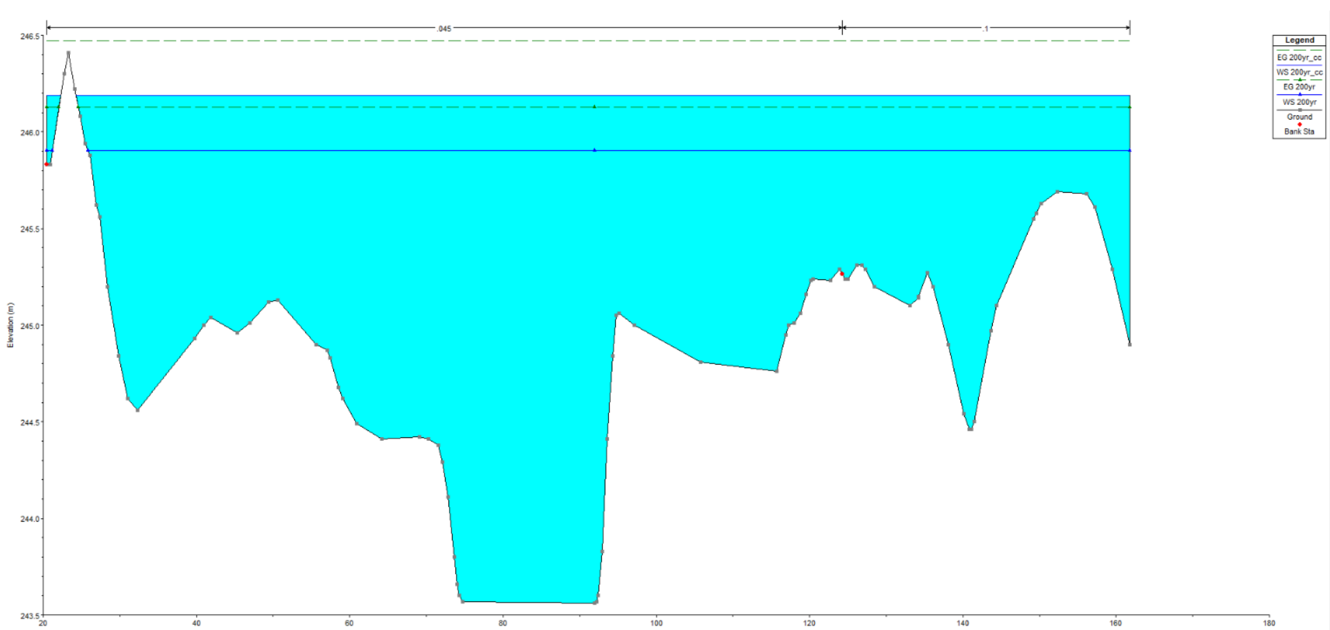

Figure 7-26
HEC-RAS Elk River Upper Reach Cross Section Station 536.33*

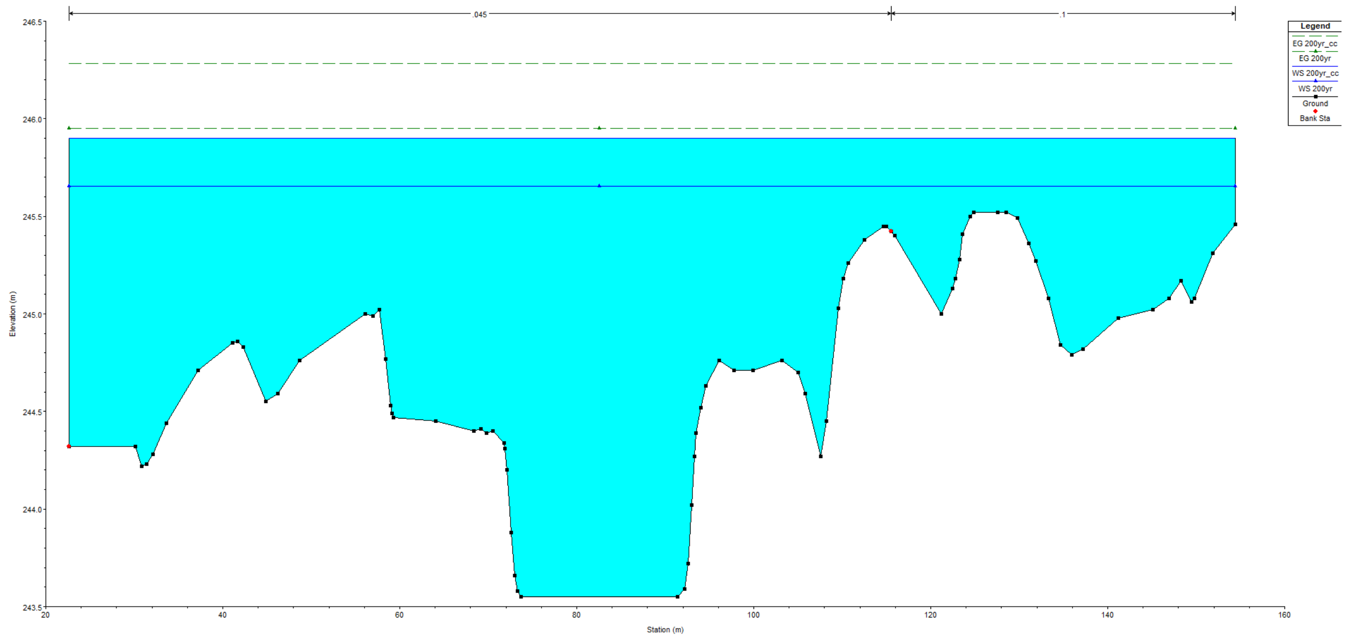

Figure 7-27
HEC-RAS Elk River Upper Reach Cross Section Station 514

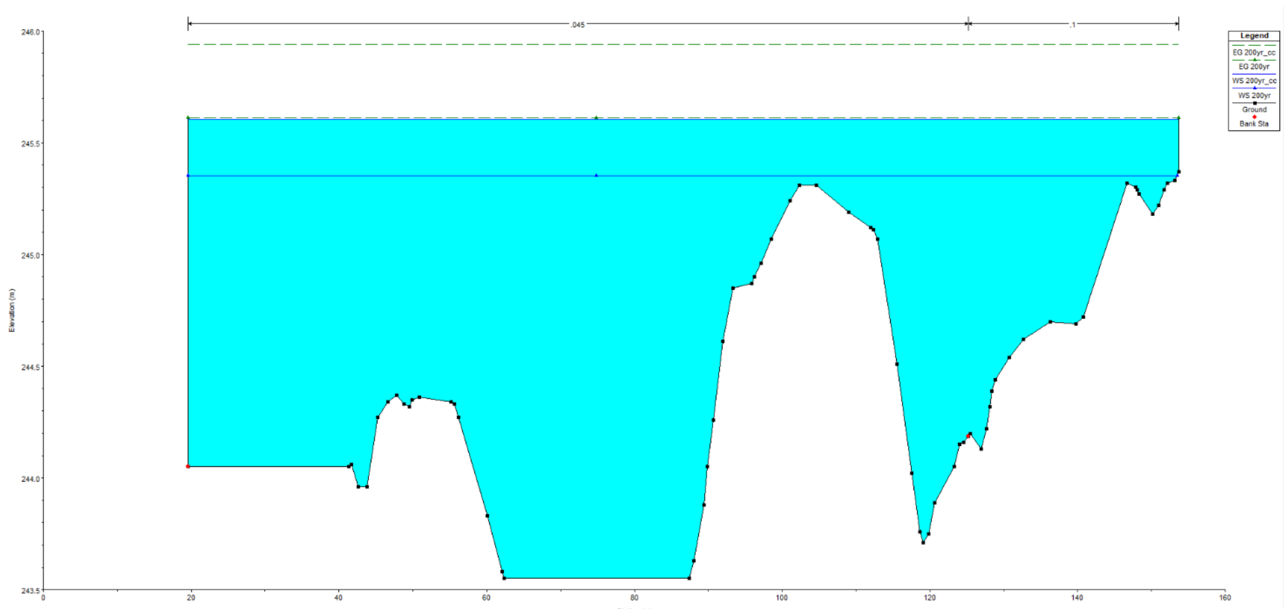

Figure 7-28
HEC-RAS Elk River Upper Reach Cross Section Station 477

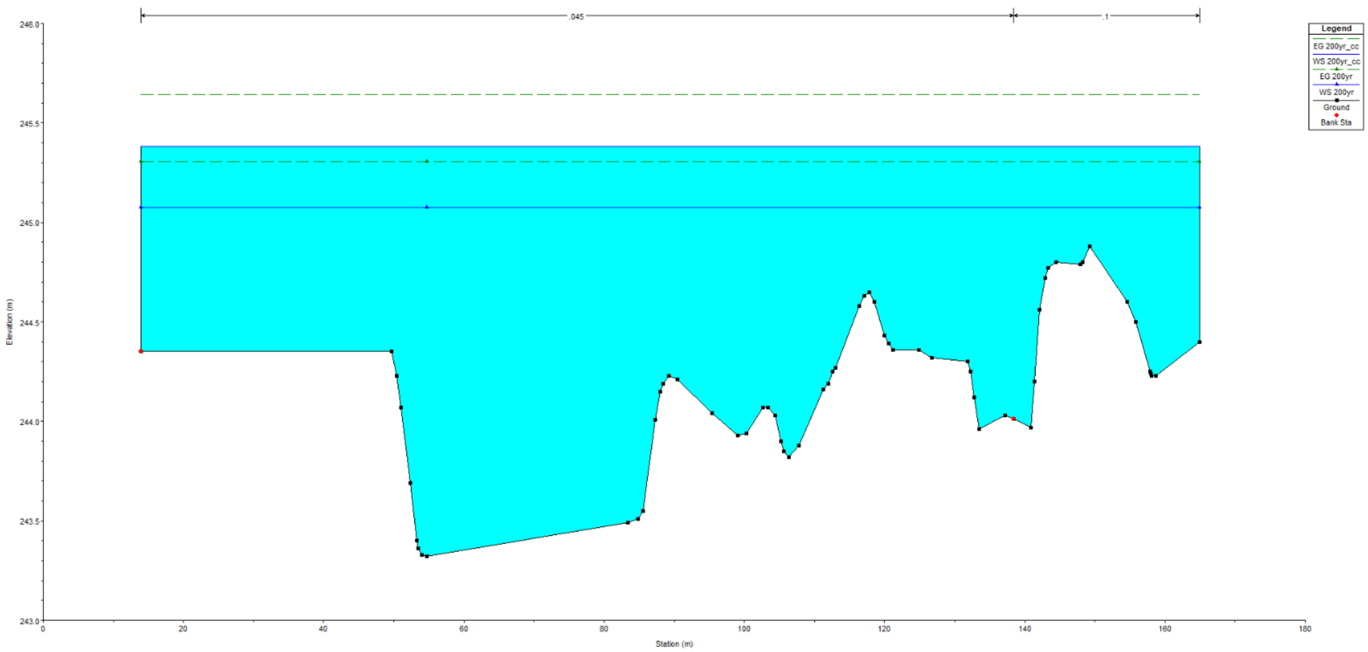

Figure 7-29
HEC-RAS Elk River Upper Reach Cross Section Station 443

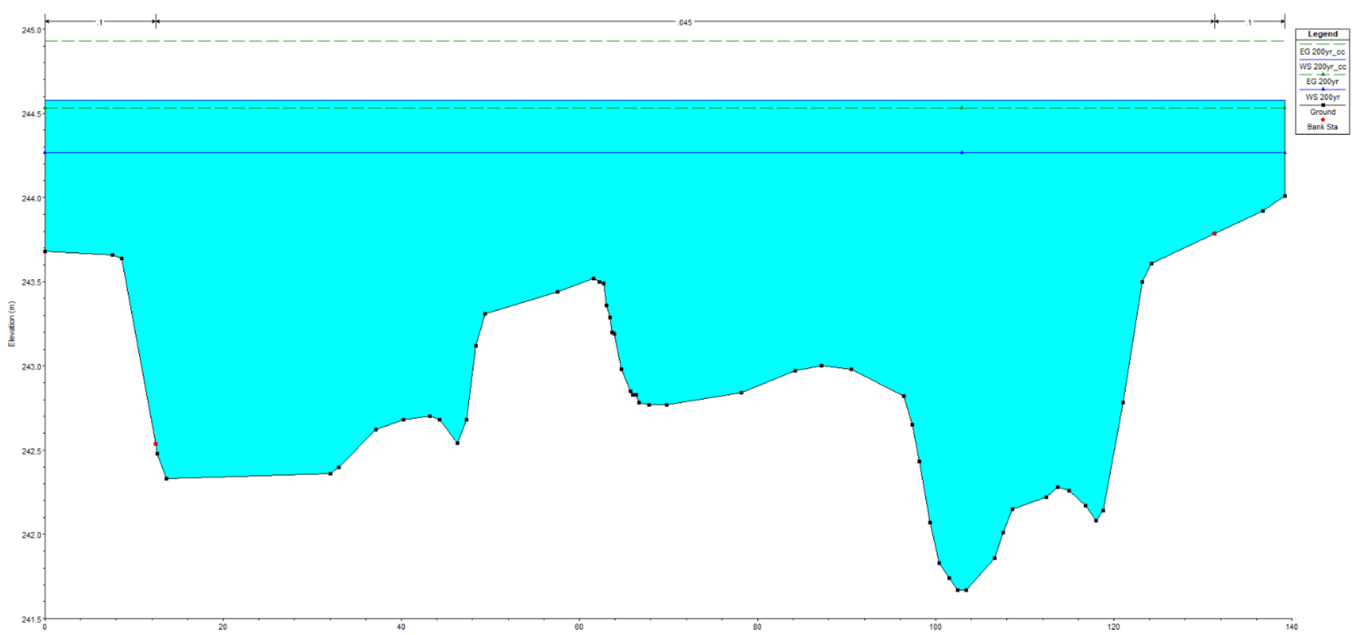

Figure 7-30
HEC-RAS Elk River Lower Reach Cross Section Station 268

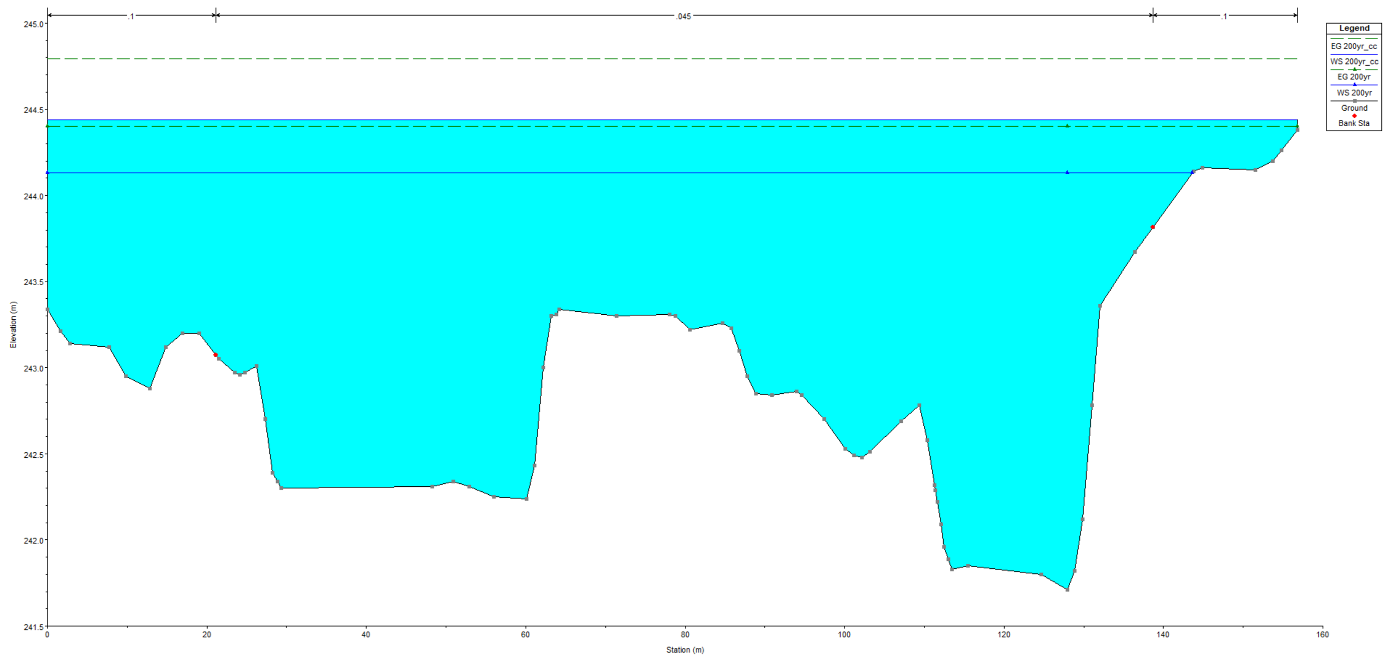

Figure 7-31
HEC-RAS Elk River Lower Reach Cross Section Station 247.00*

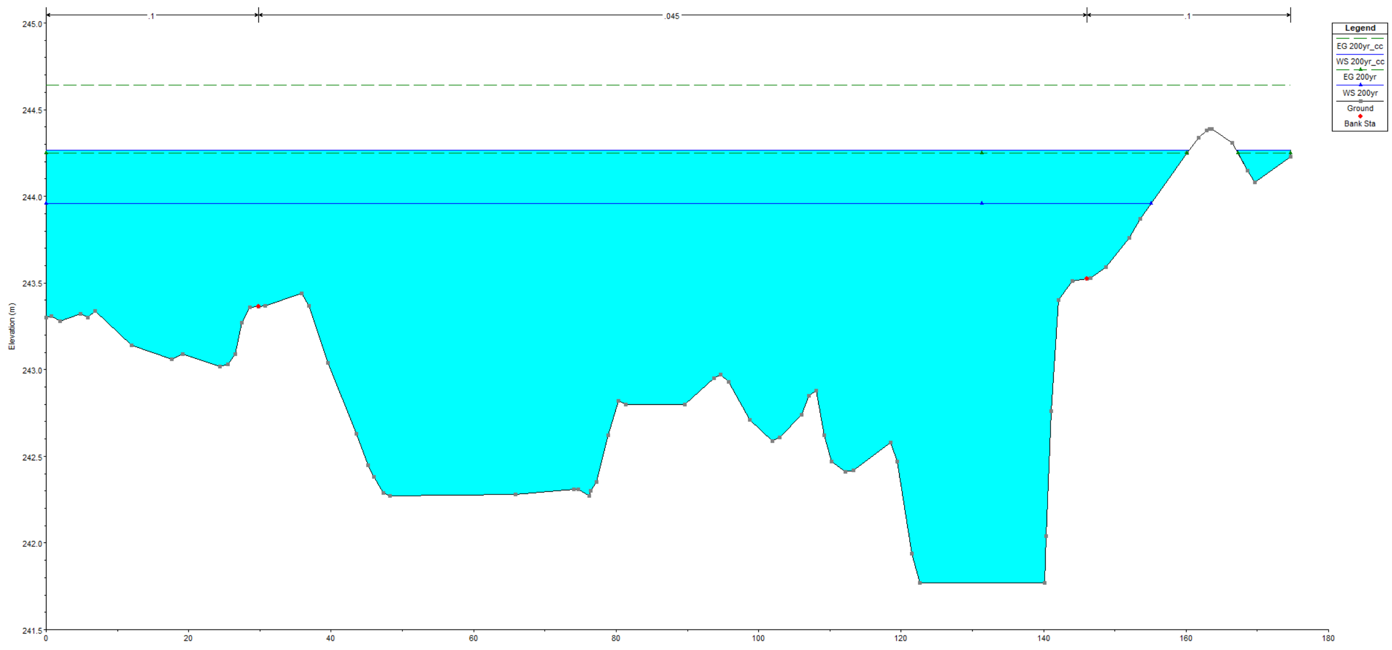

Figure 7-32
HEC-RAS Elk River Lower Reach Cross Section Station 226.00*

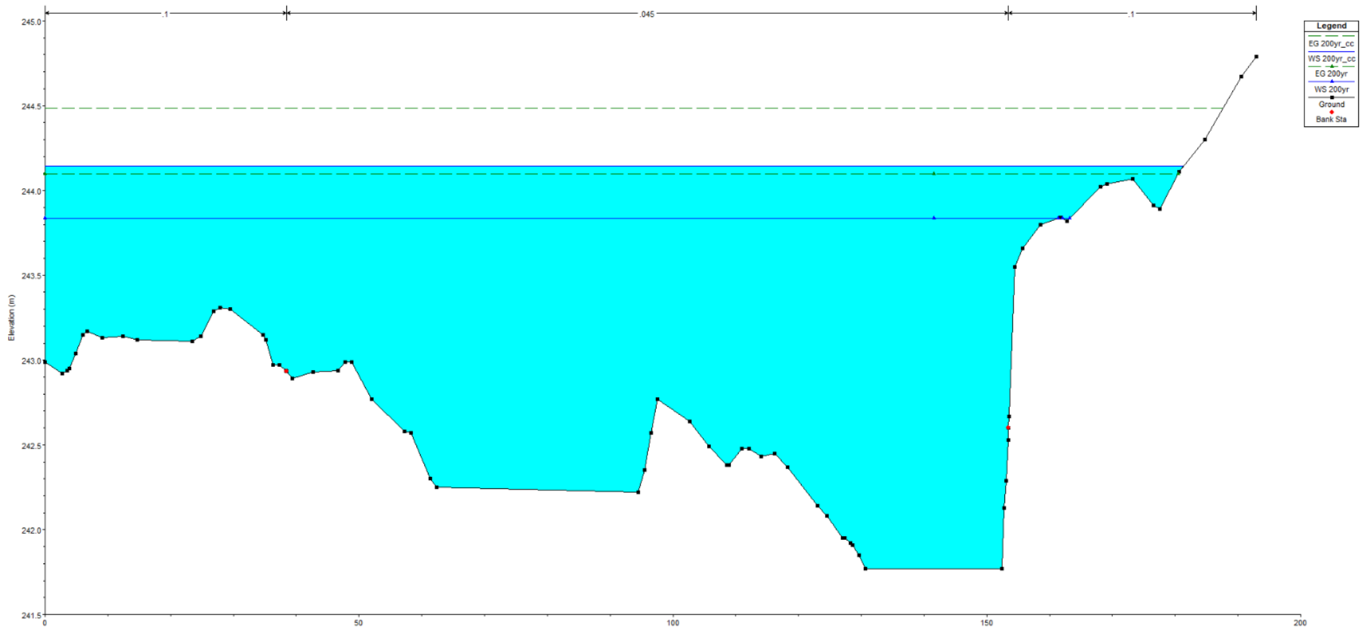

Figure 7-33
HEC-RAS Elk River Lower Reach Cross Section Station 205

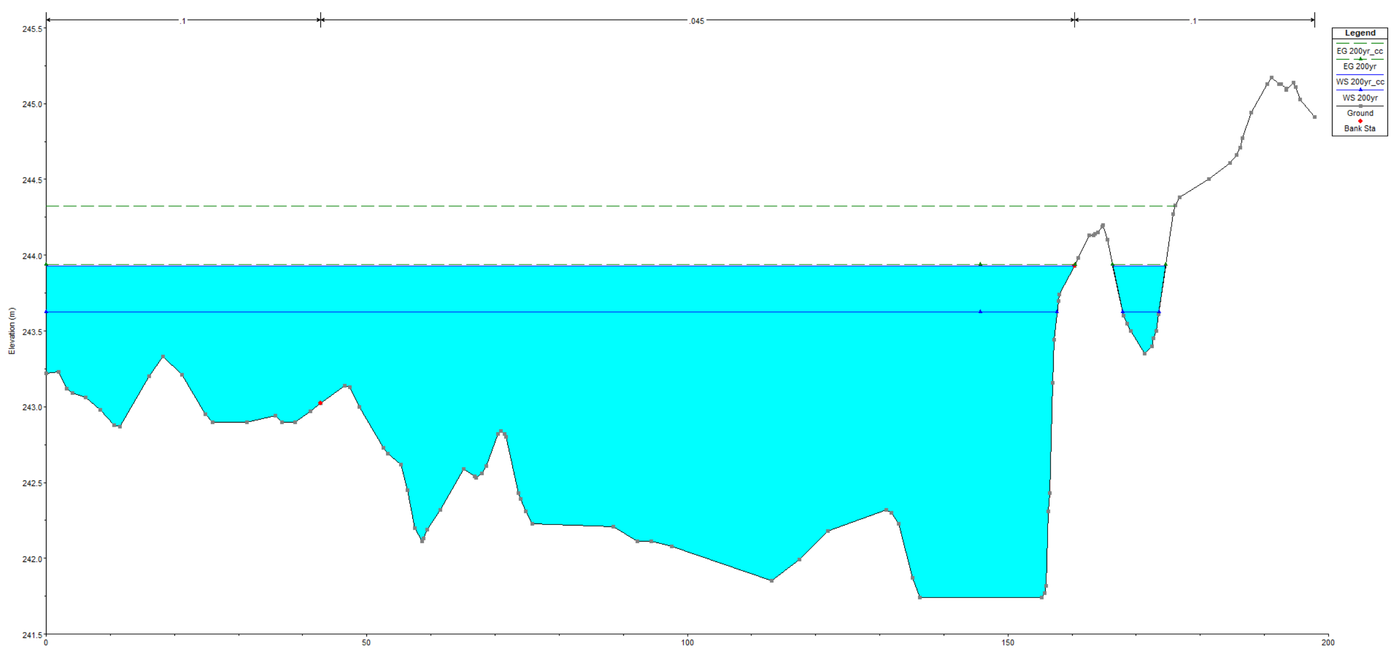

Figure 7-34
HEC-RAS Elk River Lower Reach Cross Section Station 182.25*

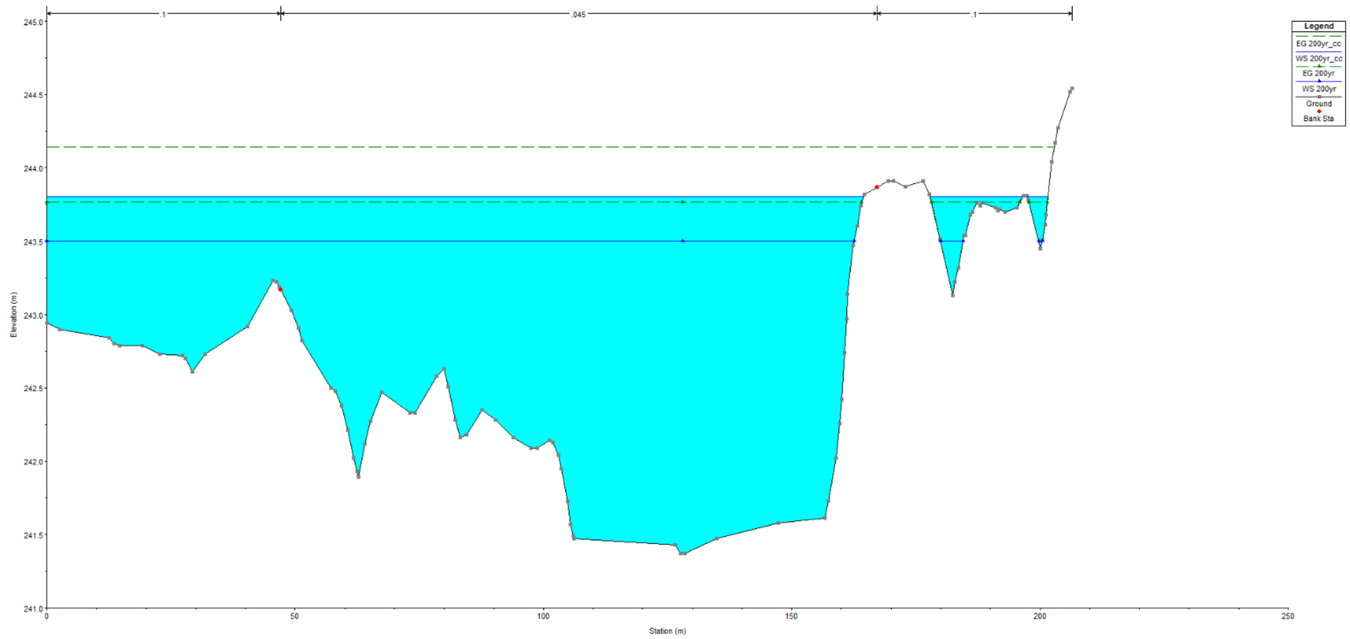

Figure 7-35
HEC-RAS Elk River Lower Reach Cross Section Station 159.50*

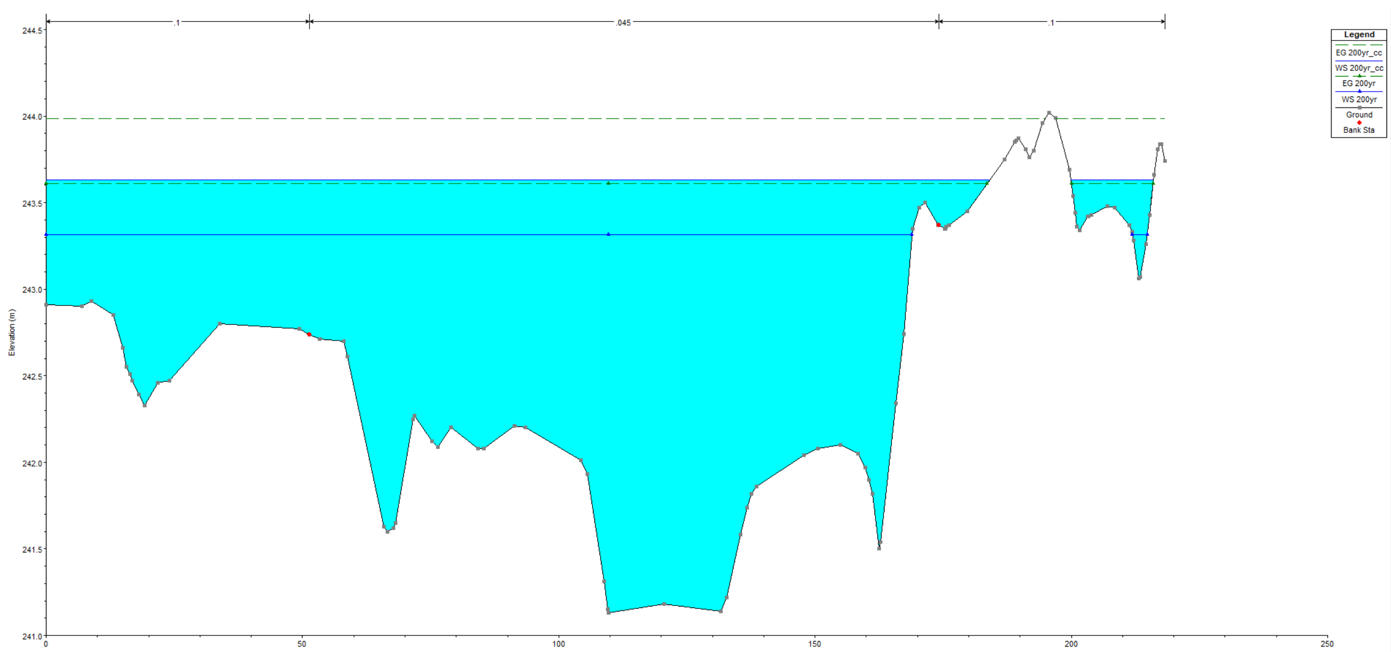

Figure 7-36
HEC-RAS Elk River Lower Reach Cross Section Station 136.75*

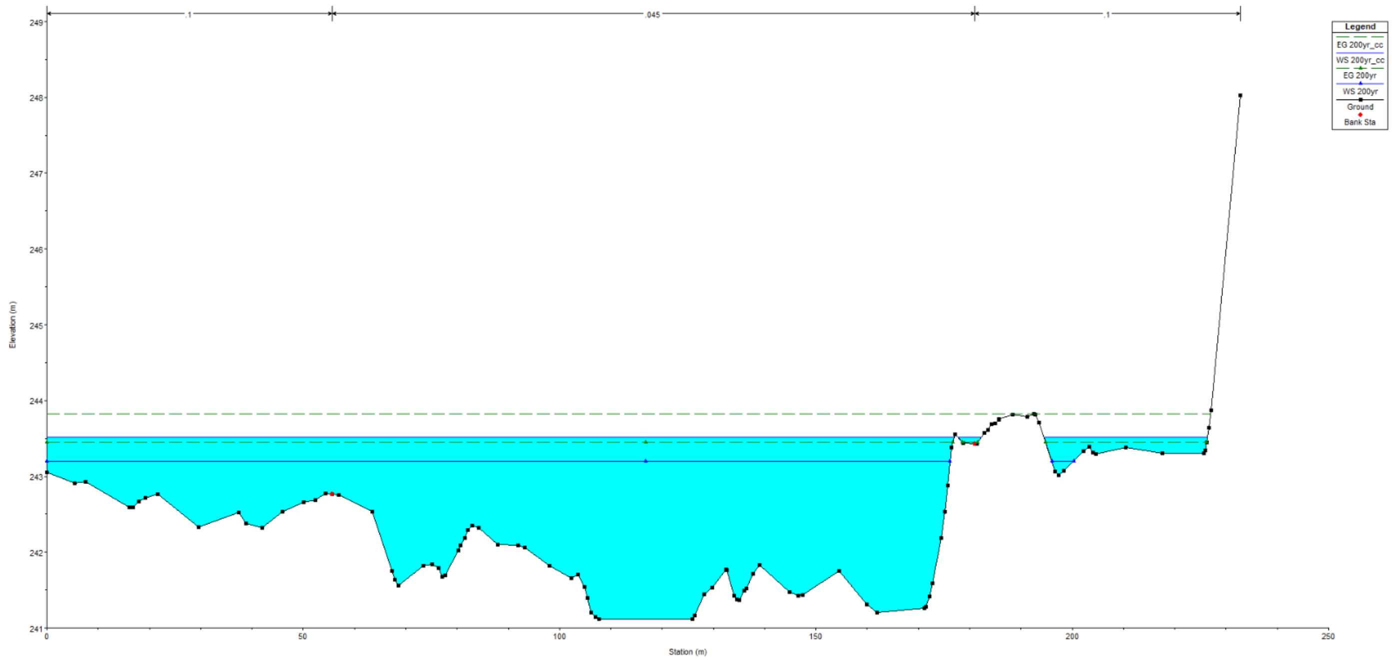

Figure 7-37
HEC-RAS Elk River Lower Reach Cross Section Station 114

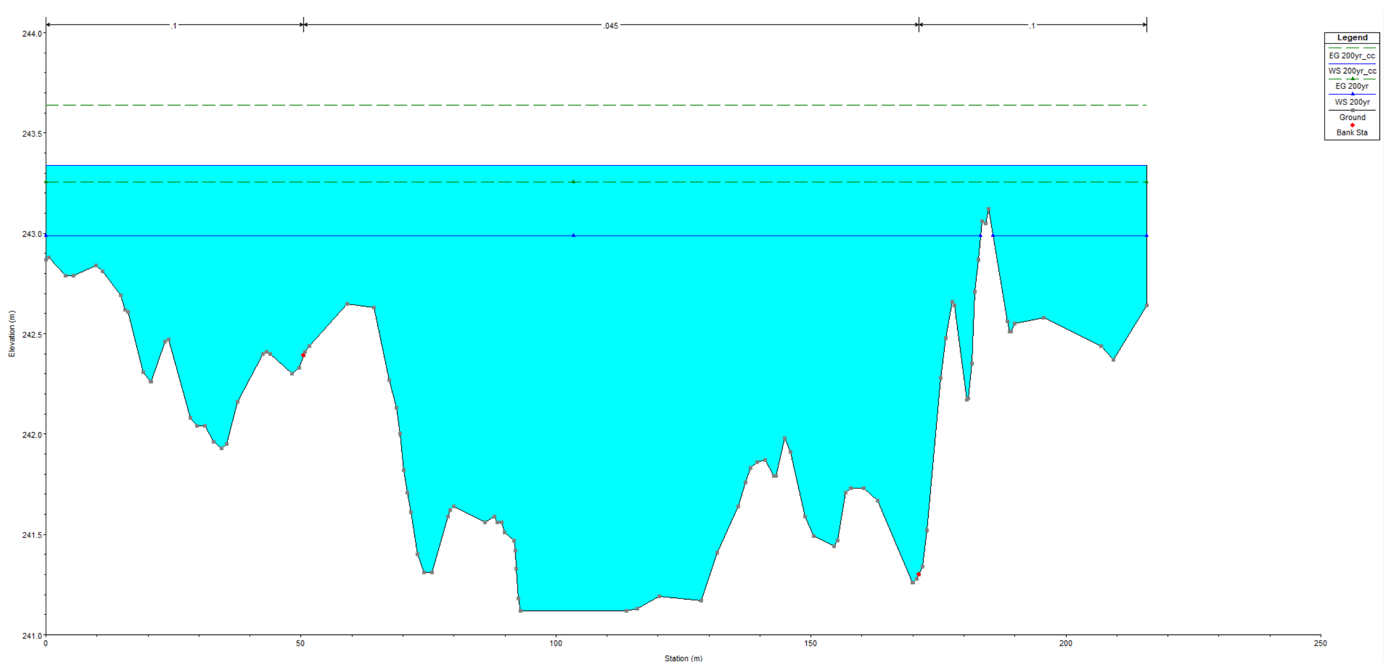

Figure 7-38
HEC-RAS Elk River Lower Reach Cross Section Station 84.67*

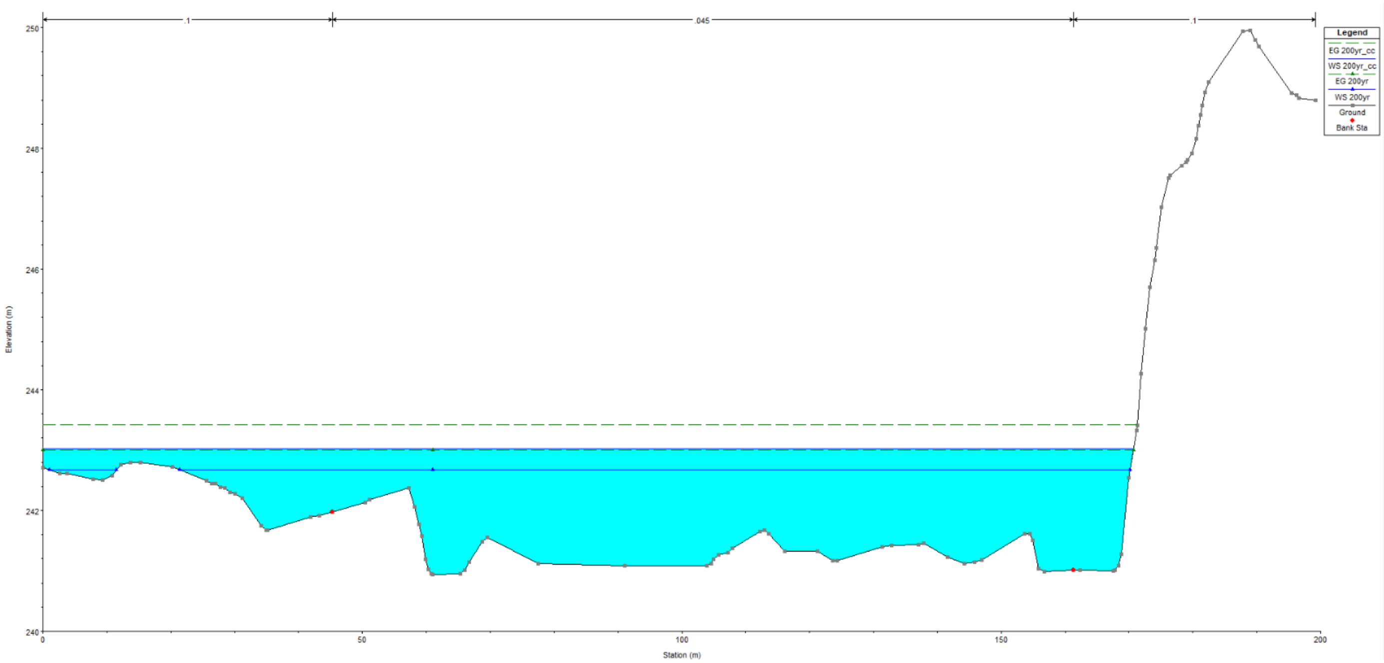

Figure 7-39
HEC-RAS Elk River Lower Reach Cross Section Station 55.33*

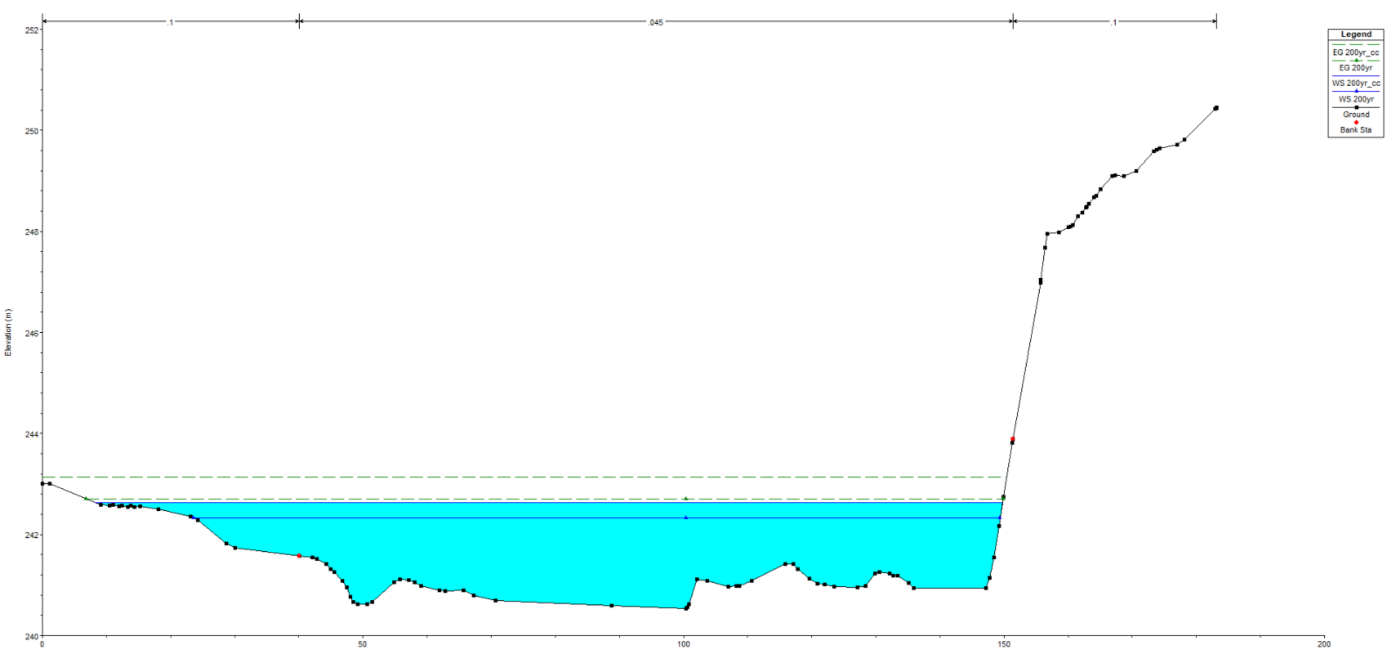

Figure 7-40
HEC-RAS Elk River Lower Reach Cross Section Station 26