RESPEC

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EXECUTIVE SUMMARY – HYDROLOGY & HYDRAULICS ANALYSIS

INTRODUCTION

Caras Park is located within the downtown city limits of Missoula, Montana, situated on both sides of a levee embankment on the north bank of the Clark Fork River. Brennan's Wave, an engineered whitewater feature downstream from S Higgins Ave (Beartracks Bridge) and within Caras Park, is a heavily visited site by tourists and boaters alike. The City of Missoula recently received a federal Economic Development Agency (EDA) grant to improve river access at Caras Park, including ADA trail access along Brennan's Wave, that will facilitate access for all user groups. The installation will include building terrace seating, retaining walls, grouted stairs, and trails to the river's edge along the levee embankment. This memorandum provides hydrologic and hydraulic analysis for the project area that was used to assess the impacts of proposed designs on existing conditions.

HYDROLOGIC ANALYSIS

A hydrologic analysis was completed by Pioneer Technical Services (Pioneer) for the Clark Fork River in July of 2020. Design discharges for various flood return intervals at the Caras Park location were extracted from the Pioneer report, using the Grant Creek location for peak discharge values. The United States Geological Survey's (USGS) two-site logarithmic interpolation method was used to estimate peak discharges for the 10-, 25-, 50-, 100-, 100-plus-, and the 500- year events, as shown in **Table 1**. Peak discharge values are calibrated to USGS gages 12340500 (Clark Fork above Missoula, MT), and 12353000 (Clark Fork below Missoula, MT).

Table 1. Summary of peak discharges for the Clark Fork River at Caras Park, in cubic feet per second (cfs)

10% annual chance (10-yr event) (cfs)	4% annual chance (25-yr event) (cfs)	2% annual chance (50-yr event) (cfs)	1% annual chance (100-yr event) (cfs)	100-yr plus (cfs)	0.2% annual chance (500-yr event) (cfs)
27100	32600	36700	40500	47200	49000

HYDRAULIC ANALYSIS

Allied Engineering Services Inc. (AESI) developed multiple, one dimensional (1D) hydraulic model runs, using HEC-RAS, for regulatory flood mapping purposes along the Clark Fork River. The "CFR_MC_Msla" model, upstream and downstream of Downtown City of Missoula, was selected for use at Caras Park. Due to the reach length, RESPEC shortened the model based on the project extent and location.

Based on the location of Caras Park, the "CFR_MC_Msla" model, regulatory naming convention, was used to create an existing conditions and proposed conditions hydraulic analysis. To assess the changes in conditions along the structure, two additional cross-sections were added, 212800 and 212885, to both models (**Figure 1**). Aside from the two added cross-sections, the remaining cross-section extents, and geometry were not altered from the original model for all hydraulic analyses (**Figure 2**). In the proposed model, Manning's n values and terrain were altered on the right riverbank to account for the proposed features along the structure. A summary of Manning's n values utilized to develop existing and proposed water surface elevations, velocities, and scour analyses are highlighted in
Table 2.

Figure 1. Cross-sections along the structure for existing and proposed hydraulic analyses.

Figure 2. Cross-section extents utilized in existing and proposed models.

Table 2. Summary of Manning's n values for existing and proposed hydraulic models.

Existing Model			Proposed Model		
Left Overbank	Channel	Right Overbank	Left Overbank	Channel	Right Overbank
0.08	0.03 - 0.06	0.05 - 0.08	0.08	0.03-0.06	0.016-0.08

WATER SURFACE ELEVATIONS

For the proposed and existing hydraulic models, the 100-year event was simulated using peak discharge values from **Table 1**. **Table 3** shows the changes in modeled water surface elevations for existing conditions and proposed conditions.

Table 3. Water surface elevation comparison.

Current Study RS (CE)	Existing Conditions (EC)	Proposed Conditions (PC)	Difference, PC-EC (ft)
	1% annual chance WSE (ft)	1% annual chance WSE (ft)	
213559	3183.18	3183.18	0
213213	3182.69	3182.69	0
213051	3182.47	3182.47	0
212885*	3182.42	3182.42	0
212800*	3182.34	3182.34	0
212761*	3182.30	3182.30	0
212437	3182.16	3182.16	0
212073	3182.07	3182.07	0
211719	3181.48	3181.48	0

*Cross-sections along proposed structure.

VELOCITY

The velocity distribution across the channel is illustrated in **Figures 3** and **4** for the 100-year event. **Figure 3** details the velocity of existing conditions and **Figure 4** shows proposed conditions. Each figure displays cross-sections 212761, 212880, and 212885, downstream to upstream of the structure. The values above the shaded regions represent the velocity in feet per second (ft/s). The change in velocity is minimal along the structure. To mitigate the minor increases in velocity, boulder stairs/seating will be grouted in place, vegetated riprap will be added below the trail, and existing vegetation will be preserved to the extent possible. These proposed features will increase bank roughness and facilitate decreased near-bank velocities.

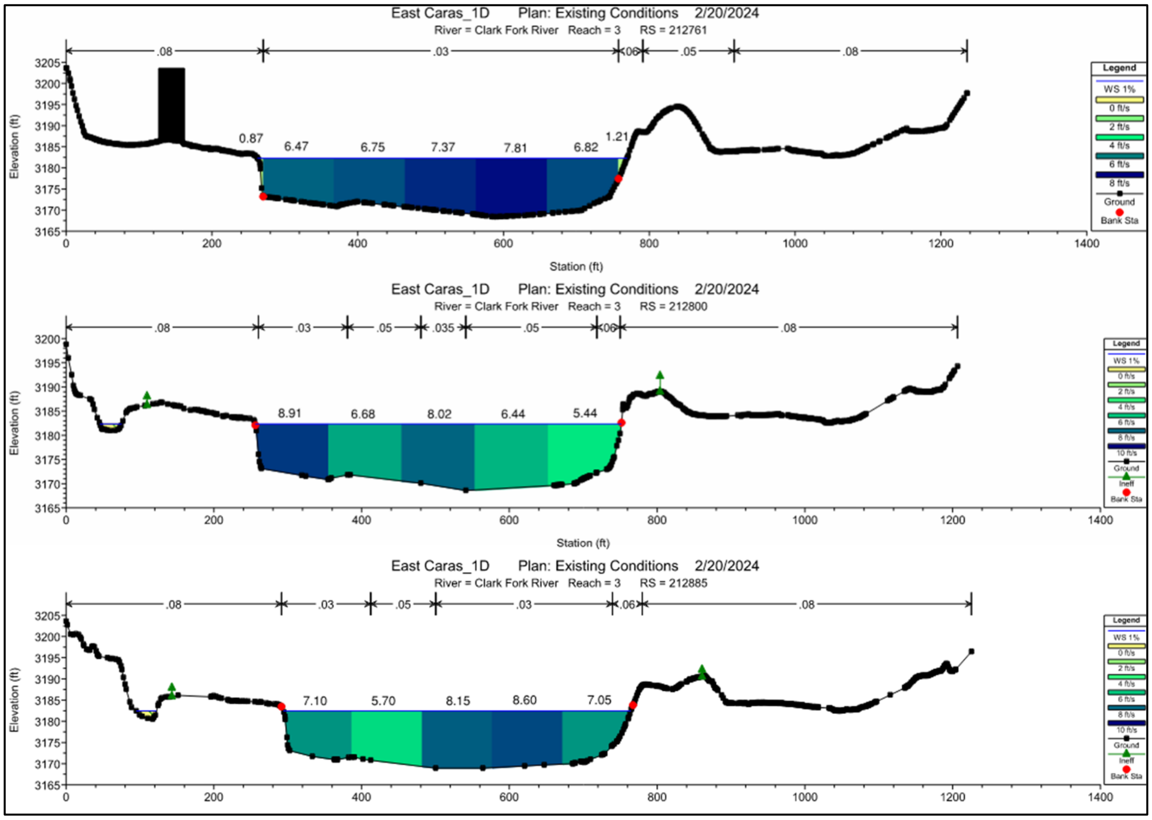

Figure 3. Existing conditions velocity distribution for cross-sections downstream to upstream of the structure.

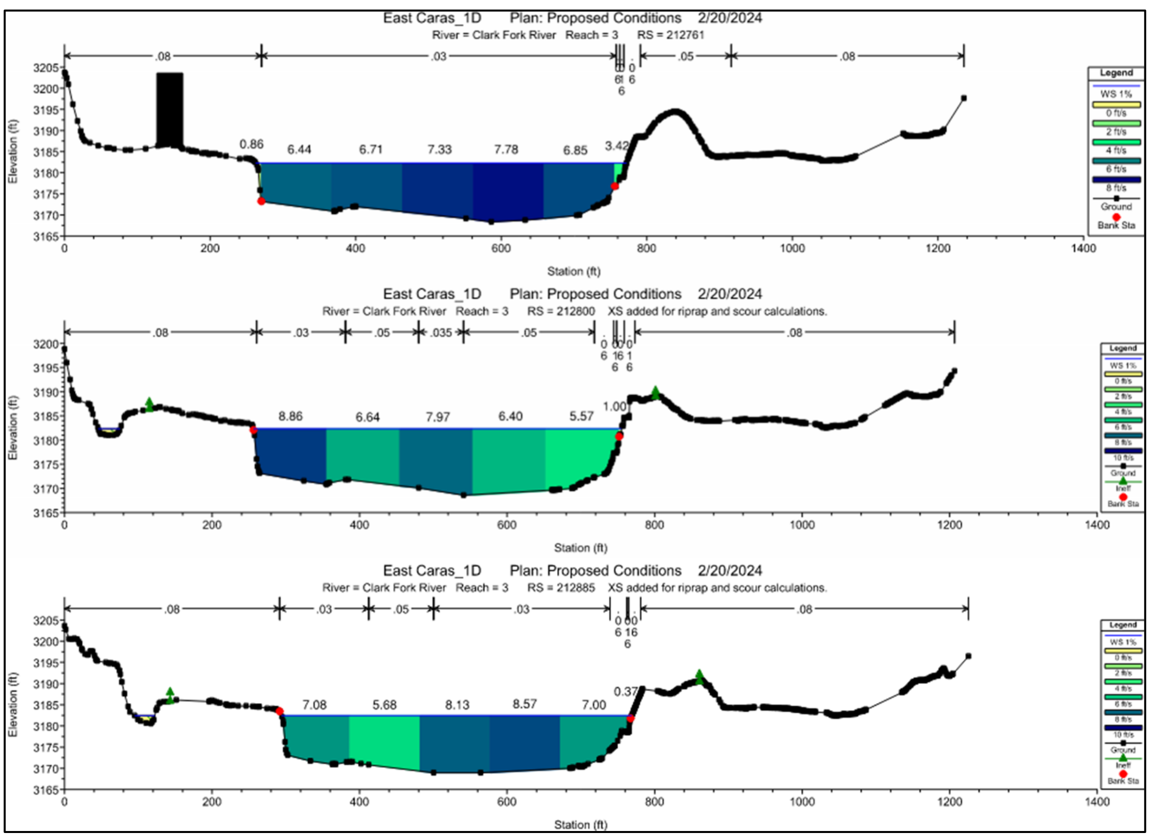

Figure 4. Proposed conditions velocity distribution for cross-sections located downstream to upstream of the structure.

RIPRAP AND SCOUR ANALYSIS

Riprap and scour analyses were conducted in three locations along the proposed project area using the HEC-RAS riprap and scour calculator. The 100-year event was utilized for calculations to define riprap sizing and scour depth along cross-sections 212761, 212800, and 212885.

To properly size riprap along the proposed project area, the radius of curvature, side slope angle, safety factor, and angle of repose were determined for each cross-section and input into Maynord's equation. These parameters calculate a stable d30 particle size which is compared to gradation curves created from Montana Department of Transportation (MDT) specifications of Class I, II, and III random riprap (**Table 5**). The proposed riprap sizes that will result in a stable embankment slope at each cross-section along the structure are shown in **Table 4**. For the scour analysis, the radius of curvature and d50 particle size were applied to the scour calculator in HEC-RAS. To determine a d50 of 10 mm, a subsurface field investigation occurred near the project site for the City of Missoula S Higgins Ave Bridge Rehabilitation project, and the data from a drilled boring hole was used to approximate the particle size for the scour calculations. Based on the input parameters, an estimation of general scour depth (feet) along the structure is shown in **Table 6** based on the United States Bureau of Reclamation (USBR) Mean Velocity methodology.

Table 4. Calculated riprap sizing along structure for slope stability, existing and proposed conditions.

Existing Conditions			Proposed Conditions		
212761	212800	212885	212761	212800	212885
Class III	Class III	Class III	Class III	Class III	Class III

Class III MDT Riprap is equivalent to Class V Army Corps of Engineers Riprap

Table 5 . MDT specifications for random riprap gradations.

Class	Mean Particle Size Inches (mm)	% of Mean Particle Size Passing
I	13 (330)	100
	11 (280)	70-90
	8 (205)	40-60
	3 (75)	0-10
II	24 (610)	100
	21 (530)	70-90
	16 (405)	40-60
	7 (175)	0-10
III	36 (915)	100
	30 (760)	70-90
	24 (610)	40-60
	9 (230)	0-10

Table 6. Calculated scour depth along structure for existing and proposed conditions.

Existing Conditions			Proposed Conditions		
212761	212800	212885	212761	212800	212885
5.9′	5.8′	5.8′	5.9′	5.8′	5.8′

SUMMARY

Based on the hydrologic and hydraulic analyses, the proposed project features would have no impact on the Clark Fork River, the associated floodplain, and to the federally constructed levee. Water surface elevations change 0.0′ between the existing and proposed conditions upstream, downstream, and along the structure. In addition, velocities are maintained along the structure with incorporation of vegetation (willow plantings) that would result in increased, near-bank roughness. The riprap sizing and scour analysis recommended MDT Class III riprap (Class V Army Corps of Engineers riprap) along the structure. Placement of riprap will ensure a stable side slope and prevent any scour or undermining of the proposed sidewalk or retaining walls that could have an impact on the levee's structural integrity. Additionally, the terraced boulder seating and stair boulders will be grouted in areas of higher velocity to ensure that the structure is not undermined during high flow events.

REFERENCES

1. *Allied Engineering Services, Inc. Clark Fork River Enhanced Hydraulic Analysis and Flood Plain Mapping Report Granite County and Missoula County, Montana. Helena: Montana Department of Natural Resource and Conservation, 2022.*
2. *Standard Specifications for Road and Bridge Construction 2020 Edition V5.0. Standard Specification. Helena: Montana Department of Transportation, 2024. Document.*
3. *Tech, Tetra. Activity 158 - Geotechnical and Materials Revisions Higgins Avenue Bridge Rehabilitation - Missoula. Geotechnical and Materials Revisions Review. Missoula: Tetra Tech, 2019.*
4. *Transportation, Montana Department of. Standard Specifications for Road and Bridge Construction 2020 Edition V5.0. 11 January 2024.*
5. *United States Army Corps of Engineers (USACE), HEC-RAS 6.4.1 Hydraulic Modeling Software, 2023.*
6. *United States Army Corps of Engineers, HEC-RAS 6.4 Hydraulic Reference Manual, 2023.*

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PLOT DATE: July 9, 2024 1:52 PM, BY: TAYLOR WINKEL

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CLARK FORK RIVER RESTORATION AND ACCESS - CARAS PARK RIVER ACCESS

FLOOD HAZARD BOUNDARY

SHEET NUMBER:
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