State of Montana's Response to Design Review Team Comments on the

Clark Fork River Operable Unit Phase 7 Preliminary Design and Design Criteria Memo

Presented at the Design Review Team Meeting
April 29, 2024
Deer Lodge, MT

Prepared by the Department of Environmental Quality and
the Montana Natural Resource Damage Program

August 2024

Table of Contents

Introduction

The Montana Department of Environmental Quality (DEQ) and Natural Resource Damage Program (NRDP) (collectively, the State) presented the Clark Fork River Operable Unit (CFROU) Phase 7 Preliminary Design and Design Criteria Memo (DCM) to the Design Review Team (DRT) on April 29, 2024. The DRT represents the key stakeholders and agencies involved in the CFROU remediation and restoration and includes members from: the Environmental Protection Agency (EPA), Powell County, Anaconda-Deer Lodge County, Montana Fish Wildlife and Parks (FWP), Grant-Kohrs Ranch National Historic Site, U.S. Fish and Wildlife Service (USFWS), Confederated Salish and Kootenai Tribes (CSKT), Clark Fork River Technical Assistance Committee (CFRTAC).

Comments and questions were welcomed and answered during the presentation, with an additional opportunity for written comment following the meeting. Written comments were received from EPA (in addition to the comments received during EPA's review of the Phase 7 Preliminary Design and DCM earlier in the year), CSKT, and CFRTAC. This response to comments includes the full text of the comments received (text in **bold**) with the State's responses.

EPA COMMENTS

1. **Section 1.0, Page 2 of the document, it is indicated that NRDP will be proposing to treat "clean" streambanks. Can you clarify where these streambanks are located?**

   Response: Please see Memorandum from NRDP to DEQ dated June 12, 2024, State Restoration in lieu of Remedy and State Restoration in addition to Remedy at Phase 7 of the Clark Fork River Site (see Appendices). These streambanks are identified with callouts on draft Remedial Action Work Plan Project Drawings, Sheets C123-C125. They are located near stations 8+00, 10+50, and 75+00.

2. **The photo logs provided in the Attachments are a great addition. Thank you for scouring your files to ensure that the vegetation preservation criteria is well documented and very clear.**

   Response: EPA's request to add additional photo documentation was a great way to provide thorough documentation and support for remedial decisions made.

3. **Will DEQ provide additional information about the alluvium borrow process?**
   a. **Are you stripping the material off the top where there is contamination (>1400ppm) identified in the top 2.5 feet of the alluvium borrow area?**
   b. **Would that material be moved offsite with the other waste?**
   c. **What is the confirmation procedure to ensure that the alluvium does not exceed action levels for use in Phase 7?**

   Response: Please see Special Provisions, Bid Item SG6.5: Develop and Reclaim On-site Alluvium Borrow, for a description of the Alluvium Borrow Area development bid item. Laboratory parameters (metals, pH, specific conductance, and sieve analysis) and sampling frequency for the alluvium borrow source are outlined in the Construction Quality Assurance Plan (CQAP) submitted with the draft bid package.

4. **Attachments 4 and 5 provide a clear review of the data collected and how the data was evaluated in the field for vegetation preservation. Thank you for adding the clarity in Attachment 5 around the application of the receptors applied to the various parcels within Phase 7. Can you clarify the following:**

   a. **Can you provide a reference in the legend for the white line in the 'center' of the river?**

      Response: This is the river centerline. River centerline has been added to the project general legend Sheet G-102.

   b. **For the CS-5 location, what is the area of the slicken to remain unaddressed with removal?**

      Response: CS-5 is 820 square feet. CS-6 is 515 square feet and is also a slickens. These areas are small, isolated areas. Both are within dense woody vegetation that would be damaged when accessing these small areas. Please refer to the table in Attachment 4 of the DCM.

   c. **CS-13 includes an oxbow where contamination was observed at greater than 4 feet. Will there be additional protection for the former oxbox to ensure it wouldn't be reactivated, especially with the proposed restoration wetland to be added to the east of CS-13?**

      Response: The risk of scour and sediment mobilization for this former oxbow area is low. These floodplain feature inlets are higher than the Q1.5 floodplain surface elevation and are not frequently activated by the channel. When activated, these features are more likely to trap sediment because of the low elevation, shallow slope, and dense sedge and willow vegetation that will slow waters and allow sediment in that water column to drop out.

   d. **CS-14 and CS-15 seem to be close to the removal boundary. Can you provide additional clarification for why these were not included as a part of the removal area?**

      Response: These areas meet vegetation criteria and are not at risk of erosion. Refer to the table in Attachment 4 of the DCM for complete details.

5. **There are some areas where there is surface As or deep contamination close to the designated area of removal. Is there a criteria for chasing material? Visual observation? XRF of the sidewalls of excavation?**

   Response: Yes, these procedures will be outlined in the Construction Quality Assurance Plan (CQAP).

6. **EPA proposes that EPA's comments, and DEQ's response to comments be incorporated as another Attachment to the Memo. The responses that DEQ provided additional clarity that supports the memo in its current version.**

   Response: Thank you. This response to comments will be included in with the Phase 7 DCM.

CSKT COMMENTS

1. **I sent the cultural resource inventory to the CSKT Tribal Preservation Office to see if they had any input. I saw that they were contacted, and did not respond in a prior outreach effort.**

   Response: DEQ mailed a notification of the findings of the preliminary cultural resource inventory of Phase 7 to the CSKT and Little Shell Tribal Preservation Offices on October 25, 2023, and received no comment. DEQ performed a more extensive archeological dig to determine the nature and extent of possible cultural site from 5/13-5/22/24, resulting in a determination that the potential archeological site did not extend laterally into the removal boundary. A complete report of the archeological testing is available upon request. DEQ received a concurrence letter from the State Historical Preservation Office concurring that the initial artifact find was not eligible for entry into the historic register and will proceed with the proposed work as planned. DEQ appreciates the additional efforts to ensure our findings reached the CSKT Tribal Preservation Office and will gladly coordinate as desired by the Tribes.

2. **I spent a very limited time comparing the timeline of air photos from Google Earth – the planform has been very stable over that snapshot of imagery, suggesting a somewhat non-dynamic reach.**

   Response: Yes, overall, the channel within Phase 7 is somewhat non-dynamic. A geomorphic assessment was completed as part of the original Preliminary Design Plan (2018) and indicated approximately 30% of banklines were actively eroding at the time (some into native, clean material). Significant meander cutoffs occurred prior to 1950s imagery, possibly during the 1948 flood. Some bank erosion and planform changes have lengthened the channel since the cutoffs occurred. Despite channel straightening and steepening through the meander cutoff section little channel incision has occurred due to the coarse bed material where the channel intercepts the Racetrack alluvial fan. Two geomorphic subreaches were delineated in Phase 7 during the Channel Migration Zone (CMZ) update completed in 2022. For these subreaches:

   - Geomorphic subreach 7a was the 39th fastest migrating subreach out of 48 subreaches in Reach A when evaluating average migration vectors.
   - Geomorphic subreach 7b was the 18th fastest migrating subreach out of 48 subreaches in Reach A when evaluating average migration vectors.

3. **I understand the current restoration effort is to work within the existing planform for the river. That leads to a couple questions:**
   - **I did not see any reference to bed modification – for example construction of pool-glide-riffle sequences. I do not have the eyes-on experience of yourselves or the design team, but recall poor instream habitat through much of the Deerlodge section – for example graded through pools on outside meander bends. Longer-term vegetation may promote bedform diversity, but it will take time, and possibly some hydrologic events.**

Response: The selected remedy for the CFROU (see the ROD section 13) does not include remediation of the streambed and in-steam work ranked low in NRDP's Clark Fork River Aquatic habitat and Riparian Restorations Actions and Prioritization Analysis (please see https://dojmt.gov/wp-content/uploads/CFR-Aquatic-Riparian-Restoration-Prioritization-2019.pdf). The proposed remediation work in Phase 7 is limited to outside the existing streambanks. Figure A is a preliminary map of in-stream aquatic habitat in Phase 7.

- **There is a nice inactive meander immediately DS of the Racetrack ponds. It was inactive in the 1985 photo also. Was this considered as a candidate for restoration and channel re-alignment.**

Response: NRDP ranked restoration actions that directly integrated with remediation over action that do not directly contribute to remediation of contamination. Therefore, this inactive meander was not considered a candidate for restoration in this phase.

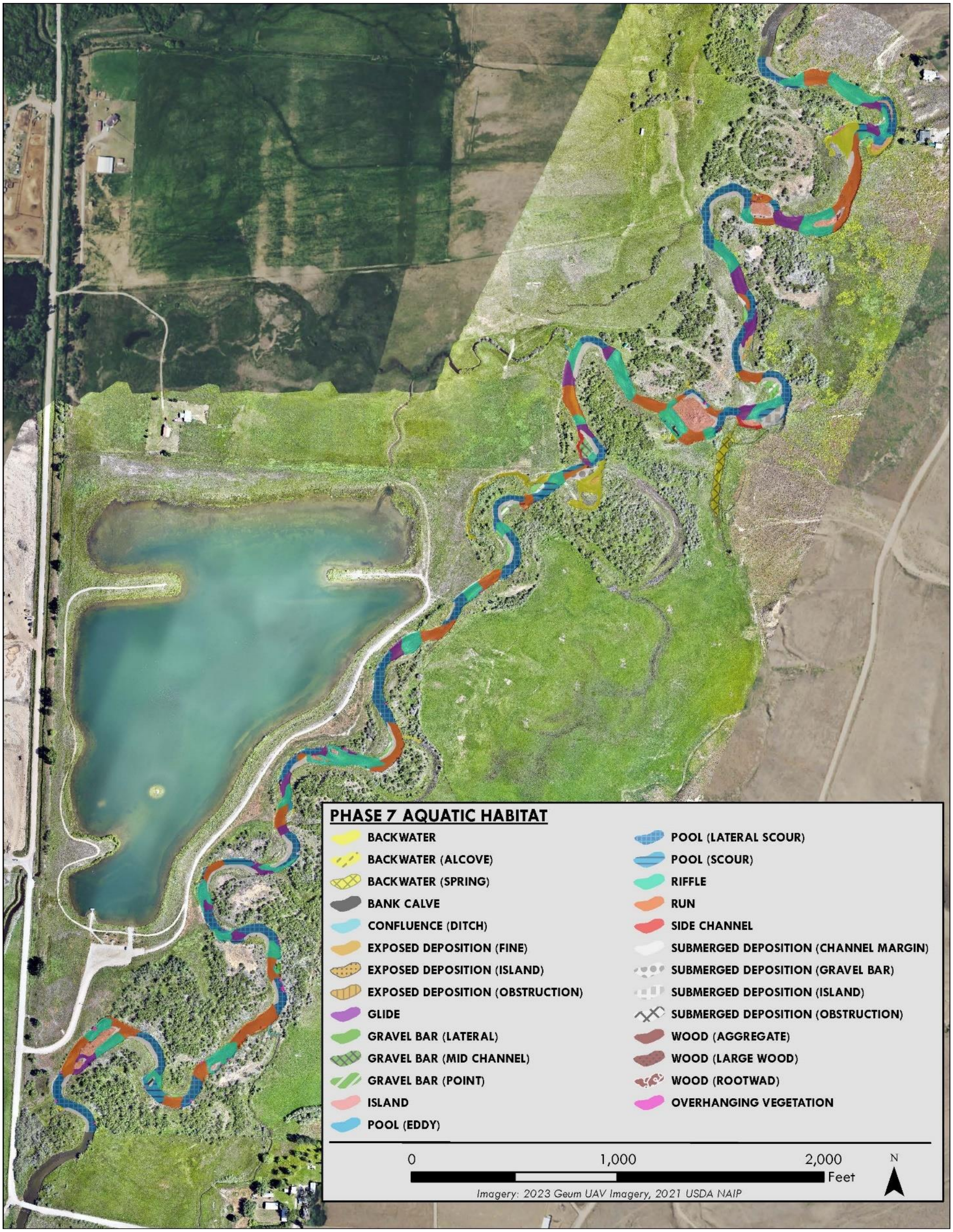


Figure A. Preliminary Phase 7 aquatic habitat features. Mapped on high-resolution UAV imagery acquired on July 12th, 2023, when flows at USGS gage 12323800 near Galen were 250cfs.

CRFTAC COMMENTS

Use of Channel Migration Zone

Comment 1: The use of CMZ mapping is a great tool for planning remediation and restoration activities near the river channel. The current methodology creates vectors for channel migration measured over 64 years of aerial imagery, then projects those vectors out over a span of 100 years and averages the lengths of all vectors to derive an average 100-year channel migration zone. The average 100-year migration zone is applied uniformly to Phase 7 and adjusted to improve constructability and tailings removal. This approach to CMZ mapping may be appropriate for managing an uncontaminated floodplain but may not be appropriate for the CFROU.

As the channel migration vector mapping shows (Figure 1), rivers do not erode uniformly. They tend to erode and migrate on outside meanders and in a down-valley direction. In addition, river channels occasionally avulse and erode new channels or reoccupy old ones. Using the average 100-year migration corridor would tend to reduce the amount of predicted erosion on outside bends and increase it on point bars.

The TAC recommends taking a different approach to channel migration zone mapping. Start by dividing the individual lengths of the mapped vectors by the 64-year period of record, then multiplying by 100 to yield an approximate 100-year migration corridor, just as was done for in the current mapping method. Then, those individual vectors could be adjusted by a constant factor (e.g. 75% or 50%) if needed to reduce the size of the migration zone for cleanup purposes. That would provide a more probabilistic map of expected channel migration. The migration zone map could then be augmented by using the HEC RAS 2-D model to evaluate floodplain shear stresses at, say, a 25-year discharge to evaluate the potential for historic channels to reactivate. Similarly, the avulsion risk analysis already performed by the design team would inform the final channel migration zone and tailings removal prioritization.

The avulsion risk analysis already performed by the design team could also inform the final channel migration zone and tailings removal prioritization. Under the current approach, many areas identified as avulsion pathways are outside of the identified 100-year CMZ (Figure 2). This presents a clear contradiction and reveals limitations of the average migration rate approach currently used to determine the CMZ.

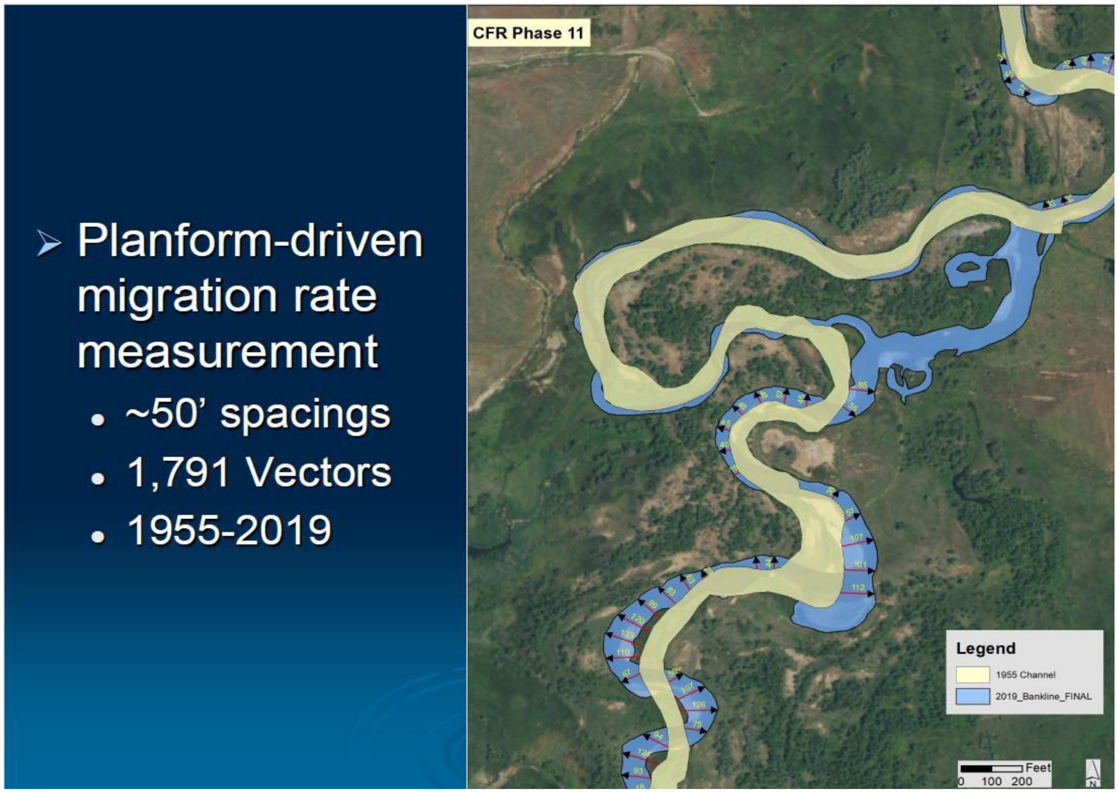


Figure 1. Clark Fork River channel migration zone map prepared by Applied Geomorphology, Inc.

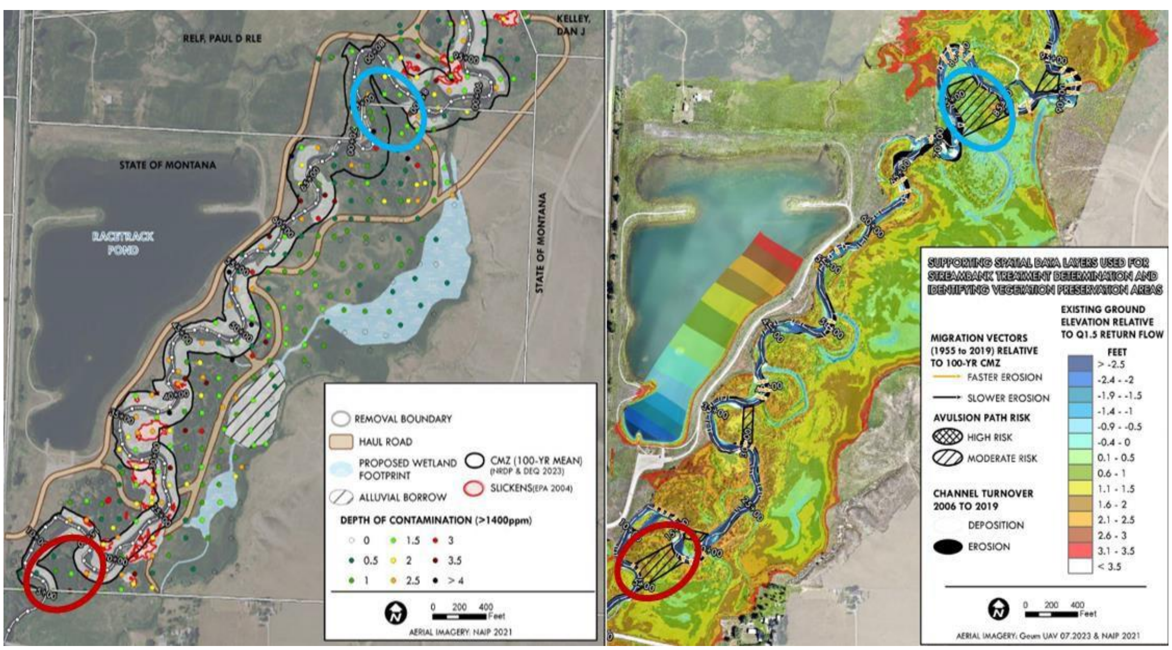


Figure 2. Composite of attachments 1 and 2 from the Phase 7 Design Memo, highlighting some areas where avulsion pathways extend beyond the calculated 100 year channel migration zone.

Response: The agencies and design team appreciate alternate ideas to the application of the CMZ as the base remedy for the CFROU. The Strategic Plan indicates that removal extents and designs for each Phase will "be based on a common base remedy defined by the CMZ and additional remediation actions guided by the results of design-level investigations". The agencies and design team understand there are several ways to approach using a CMZ to identify a base remedial action and will continue to evaluate application of the updated CMZ for phase as remediation work proceeds. For Phase 7, the selected base remedy of removing contaminated sediments within the 100-year mean CMZ (including high risk avulsion paths) removes most of the contamination that is 2 feet or greater at the site and at risk of entrainment (see table in response to Comment 36 below).

The agencies may need further clarification on the CFRTAC's proposed alternative approach to use of the CMZ to determine a base remedy, but have the following initial input and response:

1) Migration vectors were "measured on all banklines that displayed in excess of 20 feet of migration between 1955 and 2011. Vectors were collected at approximately 20-foot station frequencies on eroding banks to capture the range of migration distances expressed at a given site" (2018 PDP). Vectors were extended to the 2019 bankline for the updated CMZ analysis and additional vectors added as needed. Figures B and C below show migration vectors for Phase 7. No vectors occur on inside bends or other sections of channel where less than 20 feet of erosion occurred. This concentrates vectors in areas where channel migration naturally occurs, such as outside bends and in a down-valley direction as CFRTAC points out. If vectors were established in areas with little erosion the mean CMZ width would be much smaller. If the mean CMZ was not applied to the entire reach, these passive areas would have no CMZ width. As CFRTAC mentions, rivers do not erode uniformly so removing contaminated sediments within the near bank zone even in passive areas is necessary to reduce risk of entrainment and restore functional riparian and floodplain vegetation as specified in the ROD. The agencies will not consider any proposed approach to adjusting the CMZ calculations that would result in no removals of contaminated material in sections with no vectors. Further, applying the average rate to the entire reach allows for migration rates to change over time (some vectors get longer, some get shorter) as the river meanders and migrates down valley.
2) Applying a constant factor or percentage to individual migration vectors could be of value to increase removals in an area with greater historic migration that reflect natural channel migration patterns. The agencies are not aware of another robust method to determine a constant factor other than through use of historic movement rates as the current 100-year mean CMZ uses. Applying a constant factor to individual vectors does not initially seem very different than applying the mean 100-year CMZ width to the entire reach and could result in a smaller overall removal area. Further, extending removals in areas with longer vectors may not result in removal of more contaminated sediments greater than 2 feet deep.
3) This bullet provides additional detail on migration vectors in Phase 7. These details demonstrate that the proposed removal boundary includes most of the contamination at risk of entrainment. These details would also need to be considered if using individual vectors to refine removal boundaries. Figures B and C below show the migration vectors measured in Phase 7 that are used to determine migration rates and calculate the 100-year mean CMZ. Vectors shown in black are migrating faster than the calculated average migration rate. Vectors in white are migrating slower than the calculated average migration rate. Below is a summary of migration vectors in the two geomorphic subreaches in Phase 7 exceeding the calculated average rate of migration:
   a) In subreach 7A:
      i. There are four outer bends in this subreach with migration vectors. In 3 of the 4 outer bends, contamination beyond the CMZ is less than 2 feet. The fourth outer

bend (station 30+00) is eroding into a meander tab that is included in the removal boundary.

   ii. 15 of 29 measured vectors are migrating faster than the average migration rate within the subreach and could be expected to migrate farther than the 49 foot 100 year mean CMZ. Distances range between 1 and 39 feet beyond the CMZ width.

b) In subreach 7B:
   i. There are 12 locations (outer bends and straight reaches) in this subreach with migration vectors.
   ii. Five of the 12 locations are eroding into clean banks.
   iii. Six of the 12 locations have only one vector migrating faster than average.
   iv. 29 of 71 measured vectors are migrating faster than the average migration rate within the subreach and could be expected to migrate farther than the 88 foot 100 year mean CMZ. Distances range between 4 and 113 feet beyond the CMZ width.
   v. 17 of the 29 vectors migrating faster than average are eroding into streambanks with no contamination.

4) The avulsion analysis completed by the design team was used in determining the proposed removal boundary. In the updated CMZ meander tabs were included "when [the meander tab] dimensions indicated a relatively high risk of avulsion. Generally, meander tabs with an avulsion ratio of 5 or greater (the length of the channel divided by the length of the avulsion path or distance across the tab) were added" (see Strategic Plan, Appendix C). The avulsion risks circled in the map provided as part of Comment 1 have moderate risk of avulsion and therefore were not included in the CMZ. Further, these meander tabs are vegetated with dense woody riparian vegetation which is not considered when assigning a risk category to potential avulsion paths.

5) A shear stress analysis of the effects of the 10-year return flow on the design floodplain condition was conducted by Tetra Tech during the design process using a 2D HEC RAS model. This model indicated the potential for minimal shear stress forces outside of the CMZ and did not show the reactivation of any historic channels. Using a lower frequency return interval such as the 25-year return flow could provide valuable information but as that return flow was not identified in the ROD (which requires the design to be developed to the 10-year return flow), agreement on use of the 25-year return flow in hydraulic analyses and information derived from modeling for use in making contamination removal decisions would need to be evaluated and agreed upon by all agencies involved, and would possibly require an additional Explanation of Significant Differences (ESD).

Figure B. Prepared in response to CFRTAC's Comment 1. Phase 7 Upstream: Map showing Phase 7 migration vectors used to develop the CMZ. Vectors moving faster than the calculated average migration rate within the respective geomorphic subreach are displayed in black. Vectors moving slower than the calculated average migration rate are displayed in white.

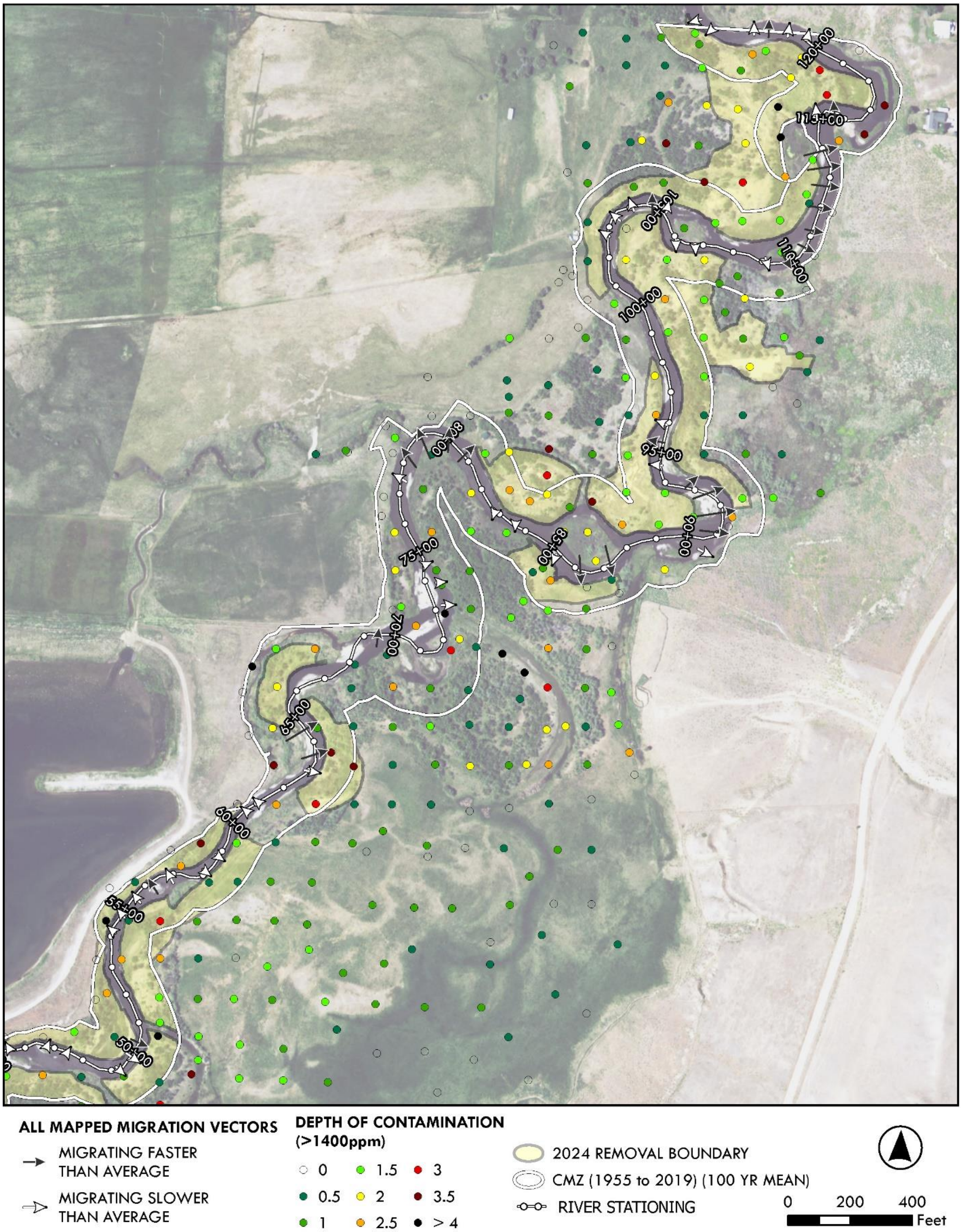


Figure C. Prepared in response to CFRTAC's comment 1. Phase 7 Downstream: Phase 7 migration vectors used to develop the CMZ. Vectors moving faster than the calculated average migration rate within the respective geomorphic subreach are displayed in black. Vec tors moving slower than the calculated average migration rate are displayed in white.

Section 4.2.1 Removals and Vegetation Preservation Within the Channel Migration Zone) (CMZ)

Comment 1: The Clark Fork River Technical Advisory Committee (TAC) identified potential discrepancies in the criteria used to determine Vegetation Preservation (VP) areas between the Strategic Plan and the Phase 7 Design Criteria Memo (DCM). The criteria used to define these areas within each document are compared below.

From the Strategic Plan Section 4.3.2:

Further, potential vegetation preservation areas must meet the following criteria:

- ***Preservation areas are not more than 1 foot above design grade;***
- ***Leaving patches of vegetation on slightly higher ground does not create channelized flow paths;***
- ***Preservation areas do not occur near the channel on both sides of the river, which could result in concentration of flows on the floodplain; and***
- ***Preservation areas do not create construction constraints.***

From Design Criteria Memo section 4.2.1:

Criteria used to determine Vegetation Preservation areas within the CMZ included:

- ***Area is a maximum of 1.5 feet higher than the design Q1.5 discharge water surface elevation.***
- ***Area has robust vegetation; and***
- ***Area appears to be geomorphically stable.***

Response: The Strategic Plan indicates that designs for each Phase will "be based on a common base Remedy defined by the CMZ and additional remediation actions guided by the results of design-level investigations". Vegetation preservation criteria were refined during the Phase 7 design process. Some of the criteria identified in the Strategic Plan, such as elevation above design grade and vegetation preservation on both sides of the river were determined to not be issues based on hydraulic modeling of the proposed floodplain condition. Further, the Strategic Plan also indicates it will be updated with lessons learned, budgets, etc. at least every 3 years. An update to potential future criteria for selecting vegetation preservation areas will be to clarify that these areas should not have an increased risk of floodplain scour on proposed condition hydraulics, rather than using a maximum elevation cut-off or geomorphic location.

Comment 2: The TAC is concerned about the apparent use of two sets of criteria in establishing VP areas and requests clarification on the discrepancies. Of particular interest is the use of two different maximum elevations (1.0 and 1.5 feet, assuming Q1.5 is equivalent to the design grade).

Response: The Strategic Plan presents a general approach to the Remedy that is anticipated to be refined in Phase specific designs. In the few areas where elevations exceed the design Q1.5, vegetation quality was determined a higher priority than elevation. Tetra Tech modeled changes in shear stress on proposed floodplain condition at the 10-year return flow event which did not show potential increased shear stress in areas left higher in elevation than Q1.5. Proposed preservation areas that were higher than Q1.5 and did show a potential increase in floodplain shear stress were not included as vegetation preservation in the final preliminary design. The

Strategic Plan also indicates it will be updated with lessons learned, budgets, etc. at least every 3 years. An update to potential future criteria will be to clarify that vegetation preservation areas should not have an increased risk on proposed condition hydraulics, rather than a specific elevation.

Comment 3: Additionally, the Strategic Plan states VP areas cannot occur near the channel on both sides of the river. VP areas occur on both sides of the river in several places in the current plans (see stations 66+50-81+50).

Response: Please see above response, additionally, the hydraulic modeling for Q1.5 and Q10 in the reach from station 66+50 to 81+50 (Figure D) does not seem to indicate the project will have a negative effect (increased erosion potential) in this reach with respect to the existing conditions for the two flows analyzed.

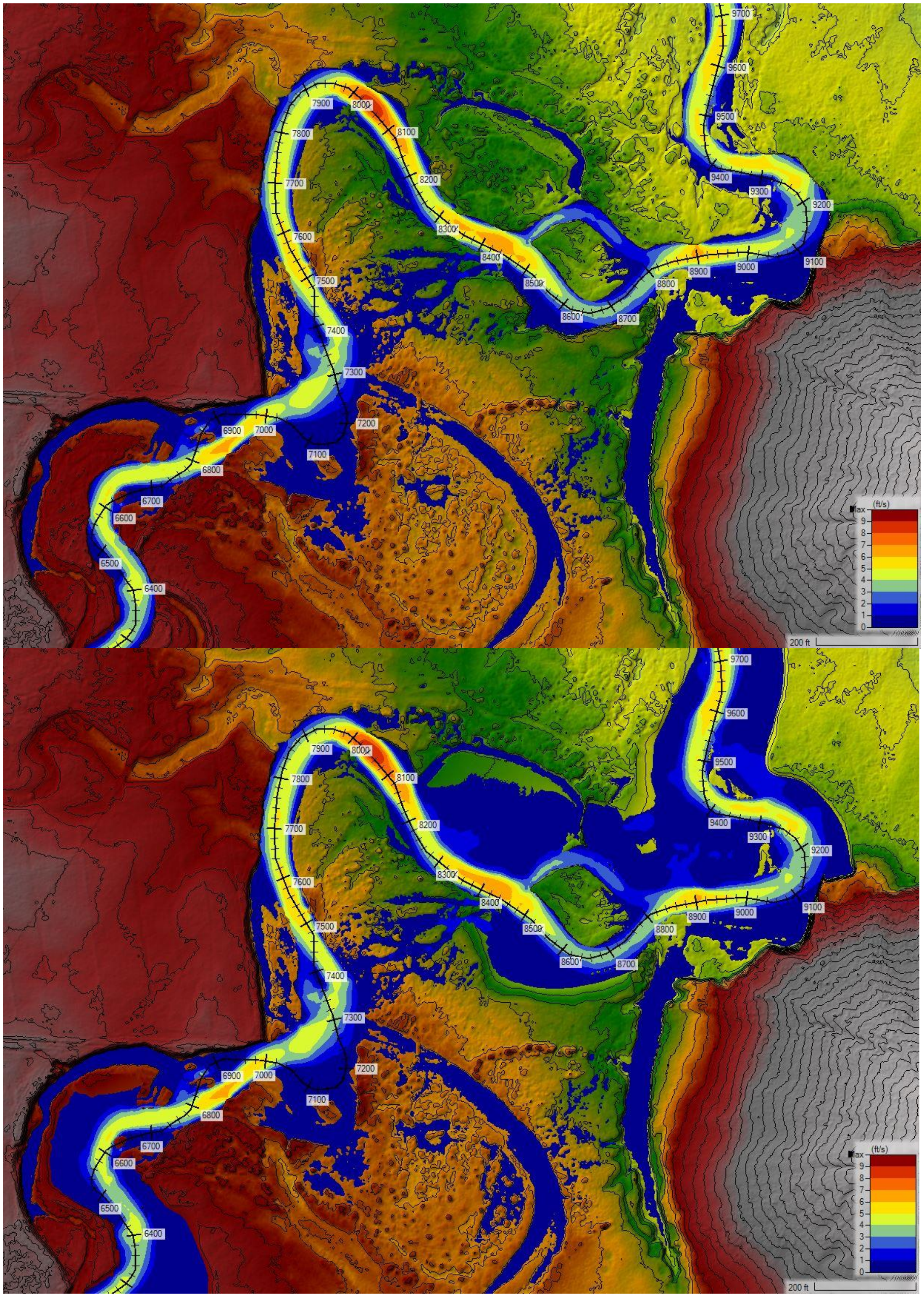


Figure D. STA 66+50 to 81+50 Velocity maps for Q1.5 Existing (top) and Design (bottom)

Comment 4: Although we understand all areas proposed for VP have been evaluated for geomorphic stability, we feel outside bends are inherently eroding faster than inside bends. As such, we suggest removing outside bends from the proposed VP areas to reduce the risk of contaminant exposure.

Response: Most outside bends not being removed do not have contaminated sediments. There is only one outside bend with contamination that will not be removed (right bank 70+00 to 74+00 near the boundary of VP-08 and VP-10). This is a large depositional area providing high quality aquatic and wetland habitat. The geomorphic outside bend shown by the centerline in the DCM between 70+00 and 73+00 in this area is no longer the active channel. The lower 100 feet of the outside bend at this location is well vegetated, migration is slower than average, contamination is shallow, and floodplain elevations are within 1 foot of Q1.5 and are considered low risk in the shear stress analysis.

Some outside bends (right bank 85+00 to 87+00, right bank 91+00 to 92+00, and left bank 101+00-105+00) do not have removal extending all the way to the CMZ boundary. The removal boundary in these locations was adjusted due to the presence of dense woody riparian vegetation and shallow (<1 ft deep) contamination. Streambank treatments are expected to reduce the erosion rate even further.

Comment 5: The TAC recommends investigating removing contaminated soil below sedge dominated VP areas. It is a common practice in wetland revegetation to remove the top 8-12 inches of sedge dominated vegetation (sedge mats) before excavation and then replace the sedge mats when excavation is finished. This practice is extremely successful because sedge mats rapidly reestablish over disturbed areas. By incorporating this method into sedge dominated VP areas, the contaminated soil below the sedge mats can be removed while maintaining high quality vegetation. Even if the top 8-12 inches of soil are also contaminated, it would be beneficial to remove the underlying tailings, which are often greater than 24 inches deep.

Response: Vegetation salvage and transplant has been done to varying extents in previous completed phases of the CFROU and the agencies will continue to consider the applicability and value of doing it in future phases. The agencies agree that this should be considered in areas with high quality sod vegetation as it is most likely to rapidly revegetate an area if re-planted with the appropriate hydrology. There are several factors to consider for Phase 7 as it relates to salvage of vegetation, removal of contaminated soils, and transplant of large areas of wetland sod:

- Most sedge dominated Vegetation Preservation areas are below the design Q1.5 elevation and contamination depths are much less than 24 inches.
- Many of these areas were identified by FWP as important fish habitat in the Clark Fork and are being preserved for their existing vegetation and habitat characteristics. Excavating these areas may alter the physical and hydrological properties currently supporting the desired conditions.
- Areas of sedge preservation along the channel margin are typically small in size and the benefit to cost ratio and benefit to risk of unsuccessful re-establishment of the sedges is low.
- Based on previous phases, oversight of this kind of specific work is difficult to time and costly on a project of this scale.

Section 4.3: Design Removal Boundary

Comment 6: The TAC agrees with the Design Team's intent to prevent the river from threatening the Racetrack Pond's embankments by installing riprap along the left bank adjacent to the pond. However, preventing the channel from migrating westward toward the pond increases the chances of the channel migrating eastward in this area. The CMZ and proposed removal boundary does not reflect the altered ability of the channel to migrate as a result of permanent armoring. We suggest the Design Team consider adjusting the CMZ and contaminant removal boundary further east along the proposed armored reach to reflect a greater chance of the river migrating in that direction. We acknowledge adjusting the removal boundary should also consider whether contaminant removal criteria are met in these areas.

Response: Riprap is typically not a driver of channel migration unless the riprap encroaches on the channel width and cross-sectional area increasing shear stress on the opposite bank. Proposed riprap streambank treatments will replace existing material that function as riprap (car bodies and barbed wire) and will not narrow the channel or decrease cross sectional area. Riprap more commonly causes erosion at the downstream transition to the natural bank.

It's uncertain when the existing "riprap" (car bodies and barbed wire) was placed. A review of aerial imagery indicates it may have been placed after the two meanders avulsed in the 1950s. If this is the case, migration rates used to develop the Phase 7 CMZ represent channel migration after bank armoring occurred and the river has not migrated east during this time period. However, this is not known for certain.

Figure E below shows the migration vectors and erosion distances since 1955 for the section of the Clark Fork River along Racetrack Pond. To evaluate the potential channel migration in subreach 7B in the absence of bank armoring along Racetrack Pond, we removed the channel migration vectors along riprapped banks and re-calculated migration rates and the CMZ. Removing these vectors resulted in a 92-foot wide 100-year mean CMZ compared to the current 88-foot wide CMZ. The additional 4 feet would not provide substantial additional removal or protectiveness. Further, as described in the response to Comment 1, the current 100-year mean CMZ removes all but discrete areas of contamination greater than 2 feet.

Figure E. Prepared in response to Comment 6. Migration vectors mapped along existing armored banks that were removed to determine a revised CMZ width are circled in yellow.

Comment 7: Floodplain grading features include depressions that mimic areas formed naturally due to flood scour. Recognizing that natural scour occurs within the floodplain, shouldn't contaminant removal be extended beyond the CMZ where the 100-year floodplain is wider? For example, there are several large oxbow sloughs that extend beyond the CMZ. These sloughs have some of the deepest tailings in Phase 7 but have been excluded from excavation. The sloughs have relatively low elevations and are very likely to flow during overbank discharges, making them vulnerable to being reoccupied by the river. The TAC recommends including these sloughs within the tailings removal plans.

Response: The risk of scour and sediment mobilization in the old meander bends to the east of the main channel that were cut off in the 1950s is low. These floodplain feature inlets are higher than the Q1.5 floodplain surface elevation and are not frequently activated by the channel. When activated, these features are more likely to trap sediment because of their low elevation, shallow slope, and dense sedge and willow vegetation that will slow waters and allow sediment in that water column to drop out.

Section 6.1: Floodplain Hydraulic Design

Comment 8: The DCR indicates the entire CMZ will be inundated between 0.1 and 0.5 feet at the Q1.5 discharge, which suggests flooding will begin to occur at discharges below the 1.5-year flood interval. We understand and agree with the design team's intent to encourage riparian vegetation establishment by allowing water to access the floodplain more frequently and acknowledge the TAC previously recommended lowering the floodplain following documentation of riparian vegetation establishment in earlier phases. We encourage the design team to investigate whether lowering the floodplain to an elevation at or below the 1.5-year flood has consequences on channel-forming processes. We are concerned the emphasis on vegetation establishment may come at the cost of sediment transport and aquatic habitat development and maintenance due to the reduced in-channel energy resulting from frequent overbank flooding.

Specifically, we suggest performing a sediment transport study to analyze:

1. **Whether incoming sediment loads will be transported through Phase 7 during frequent flood events,**

Response: The design engineer has completed two sediment transport related analyses that are comparative and somewhat qualitative. These analyses do not provide quantitative estimates for sediment flux, scour, or deposition. They do, however, indicate the potential for certain areas and the overall trend of the Phase 7 area towards an increase in scour or deposition compared to the existing conditions.

The first analysis was a comparison of shear stress values (pounds per square foot) for the existing and design conditions. This analysis is primarily focused on the channel, since many areas outside the channel (on the floodplain) are not inundated at flows analyzed in the existing conditions, and thus any value in the design indicates a change. Shear stress is an often-used surrogate for sediment transport capacity of open channel flow. The 2D model results are plotted along the centerline alignment from the design plans. These profiles indicate there is very little overall change in the shear stress values in the CFR channel. Some discrete areas indicate an increase in shear stress and appear to be associated with straighter channel reaches. Other areas indicate a decrease in shear stress and appear to largely be associated with areas of lowered inside meander bends and/or intentional areas of split flow channels in the design. For both flows analyzed, the vast majority of the project area indicates a near zero change in shear stress.

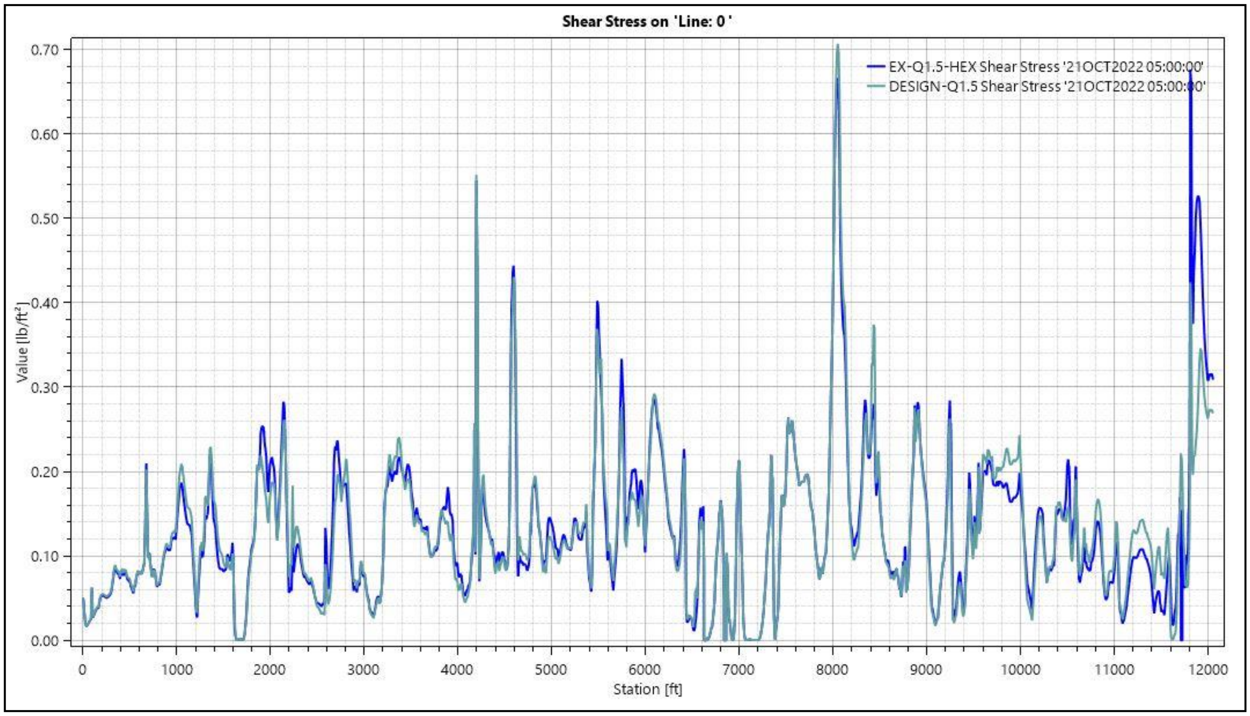


Figure F. Shear Stress profiles along CFR channel centerline for Q1.5.

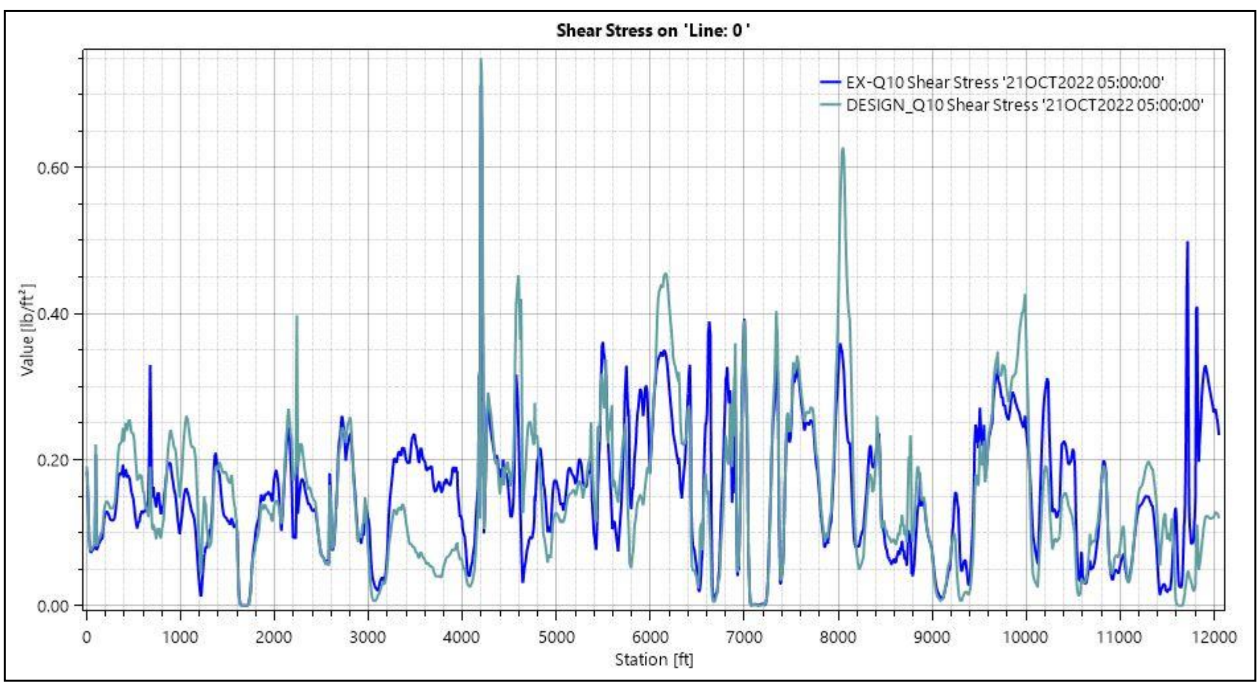


Figure G. Shear Stress profiles along CFR channel centerline for Q10.

The second, and more robust, analysis was to compare the sediment transport capacity (pounds of sediment per foot of channel per second) of the existing and design conditions. This analysis approach provides a more robust estimate of the trend towards scour or deposition by incorporating a sediment transport function and sediment gradation, rather than relying purely on clearwater hydraulic results. A sediment transport capacity analysis does not incorporate the much more complex computations of sediment supply or mobile bed functions that would be included with a fully mobile bed sediment transport model. Thus, the sediment transport capacity comparison is still a qualitative analysis but adds valuable insight since changes in shear stress may not always equate to changes in ability of water to move sediment of certain sizes.

The sediment transport function selected for this comparison was Wu et al. (2000). While sediment transport analyses are highly sensitive to the transport function selected, comparative analyses are less sensitive since the difference between values is the result of interest rather than the actual results values of either scenario. The Wu transport function was specifically developed for use in 2D hydraulic models. Other sediment transport functions were tested in the analysis and found to yield very similar comparison results. The sediment gradation used in this analysis came from River Design Group's pebble count data as part of their report "Hydraulic Modeling Report Clark Fork River Operable Unit – Reach A" dated March 2021. Their pebble count at TBM 4 is located at the upstream end of Phase 7 and was complete on 4/22/2020 according to the report. This pebble count appears to be the most recent and proximal to Phase 7.

Based on sediment transport capacity comparisons, the channel in Phase 7 is largely unchanged or changes a very small percentage in its ability to transport the given sediment gradation. Some discrete areas indicate a trend to increase scour with increased sediment transport capacity. These areas are largely associated with converging flows and downstream ends of meanders. There are also some areas where the transport capacity is decreased, indicating a trend towards deposition. The most apparent area that indicates a deposition trend appears to be near station 117+50. This area is also the site of the split flow channel that was intentionally designed to activate at most flows. This design feature was included to reduce scour/erosion on the right (east) bank by shifting more flow to the west. This feature may also set the stage for future channel movement to the west into remediated areas.

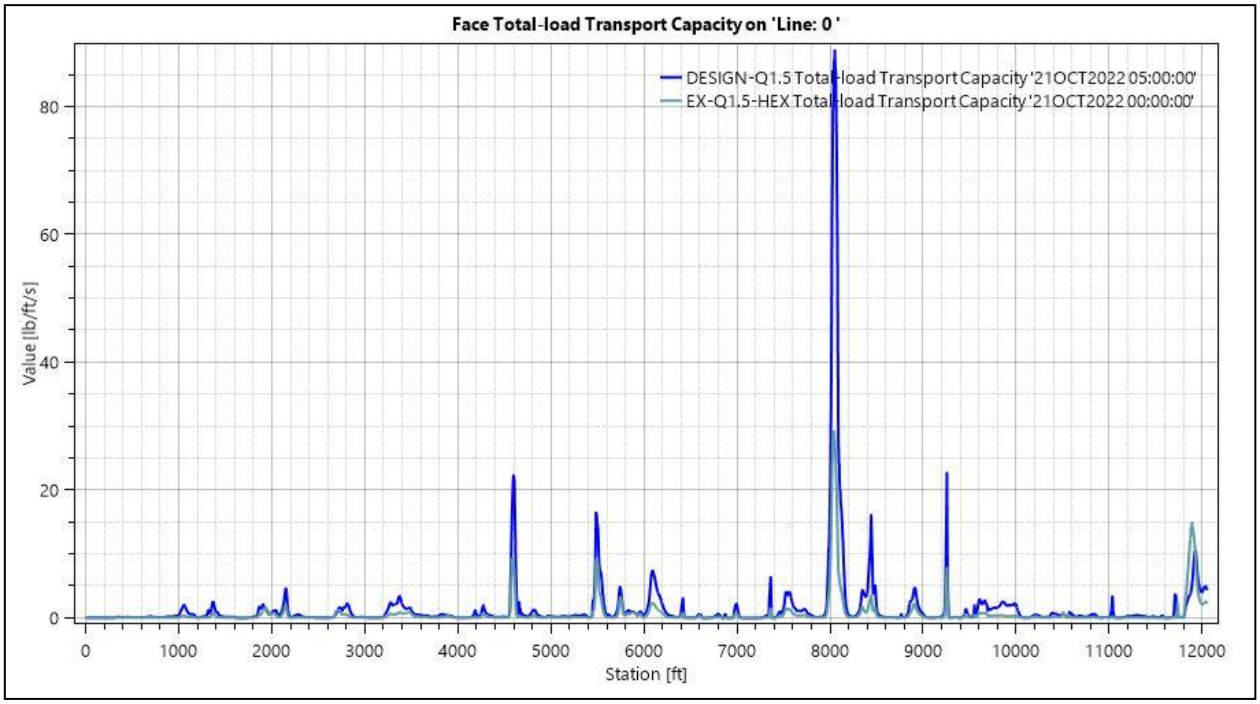


Figure H. Sediment Transport Capacity profiles along CFR channel centerline for Q1.5.

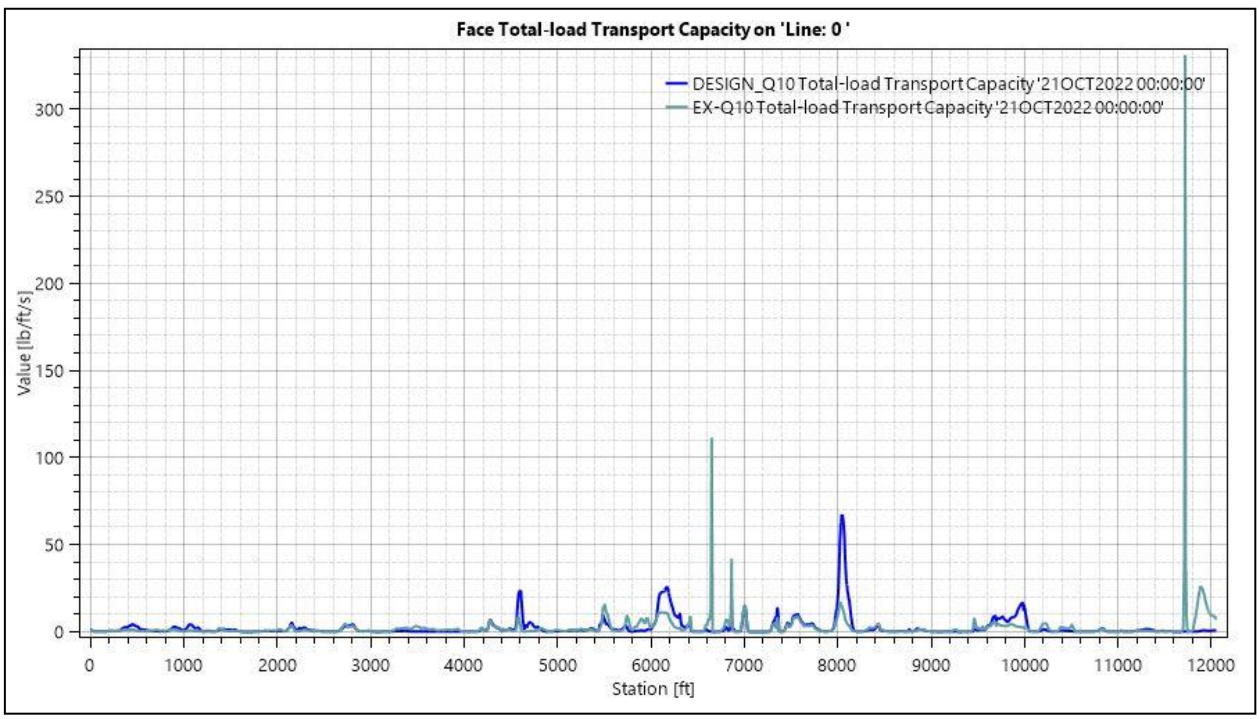


Figure I. Sediment Transport Capacity profiles along CFR channel centerline for Q10.

2. **Whether avulsions are more likely due to the reduced sediment competency resulting from a lower floodplain elevation,**

Response: Other than the split flow channel described above, no areas in Phase 7 appear to present increased avulsion potential compared to existing conditions. Avulsion potential is also reduced through the inclusion of surface roughening, appropriately sized floodplain alluvium, and revegetation plans.

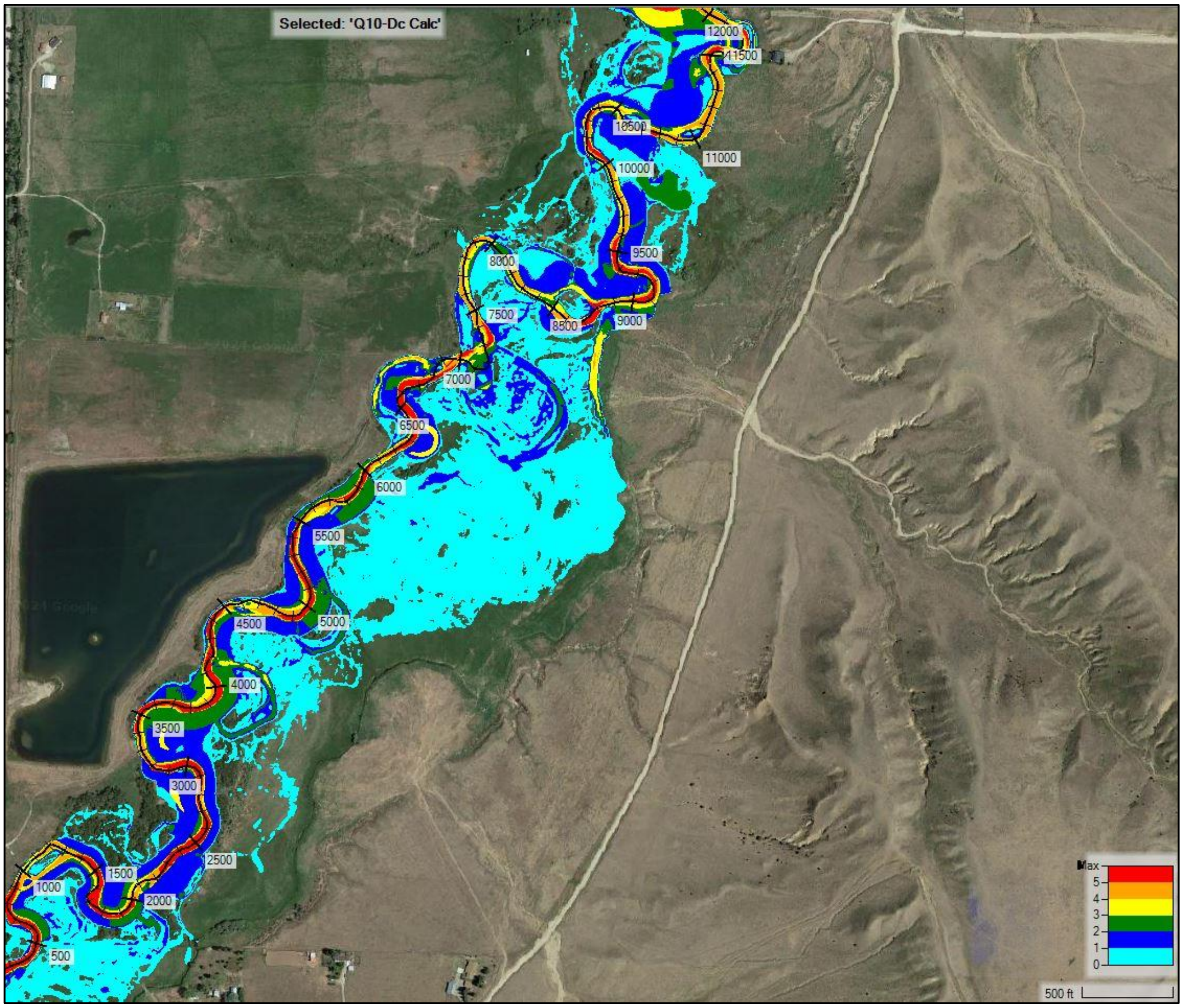


Figure J. Mobile Particle size map based on Sheild's equation and Q10 hydraulic results used to design scour resistant floodplain materials.

3. **Whether sediment competency of the channel during bankfull events is sufficient to adequately scour bedform features such as pools and runs. Our concern here is partially based on DEQ's suggestion during the May 1st Design Team Meeting that the channel bed in Phase 7 has potentially become armored over time due to the lack of fine sediment delivery stemming from construction of Warm Springs Ponds.**

Response: As described in the PDP, the channel bed is armored because the bed material size is too large to transport during channel forming flows. This is a result of bed material contributions from the adjacent Racetrack alluvial fan rather than a lack of fine sediment from upstream sources. However, a lack of fines and sand from upstream sources is contributing to other issues.

The sediment transport capacity comparison analysis described above indicated that changes to the locations and patterns of scour/deposition and related features are likely to occur. The results also do not indicate a global shift towards deposition and may increase the CFR channel's ability to form and maintain scour pools and runs in some areas.

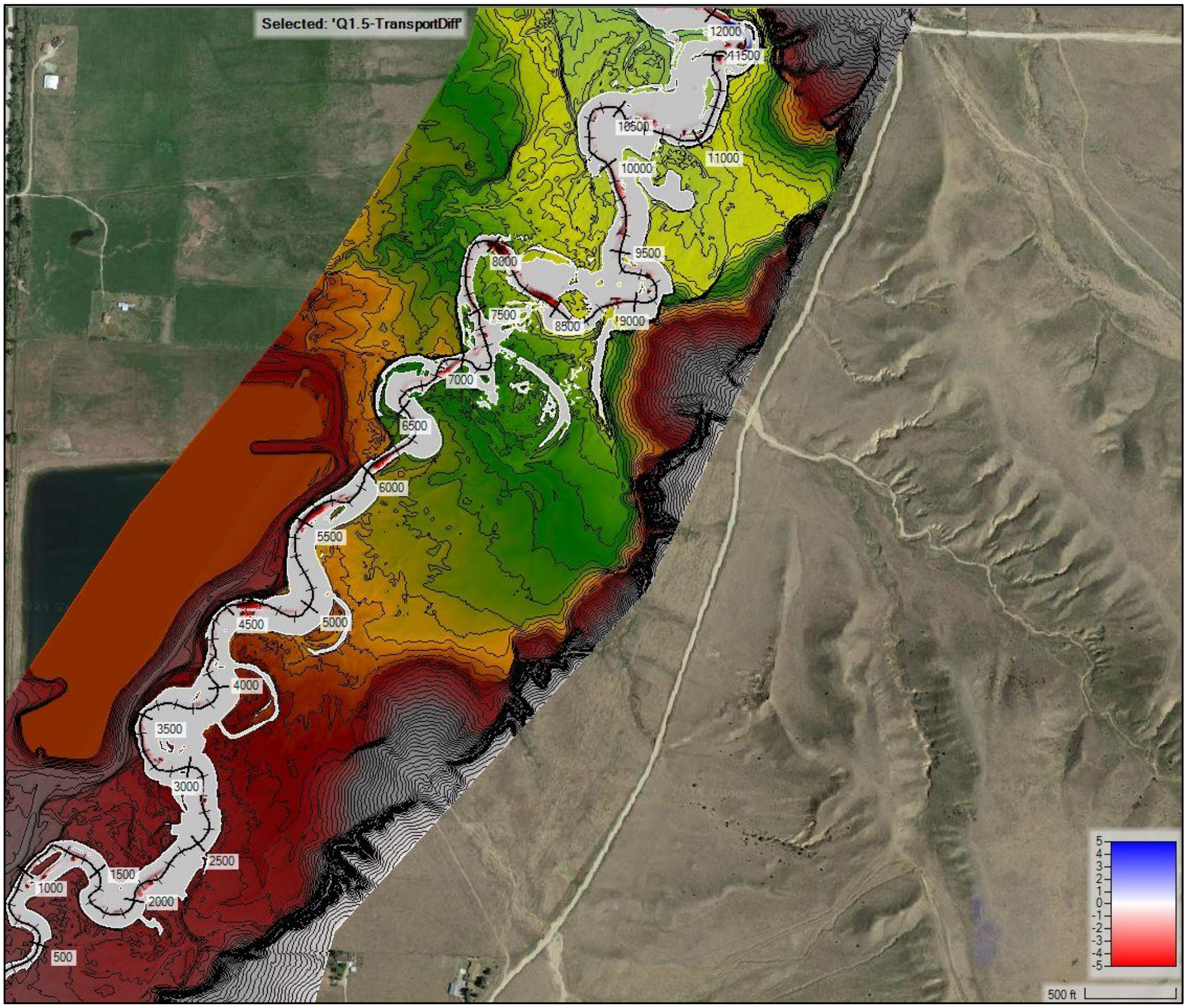


Figure K. Sediment Transport Capacity difference (existing minus design) maps for Q1.5, red indicates scour and blue indicates deposition potentials.

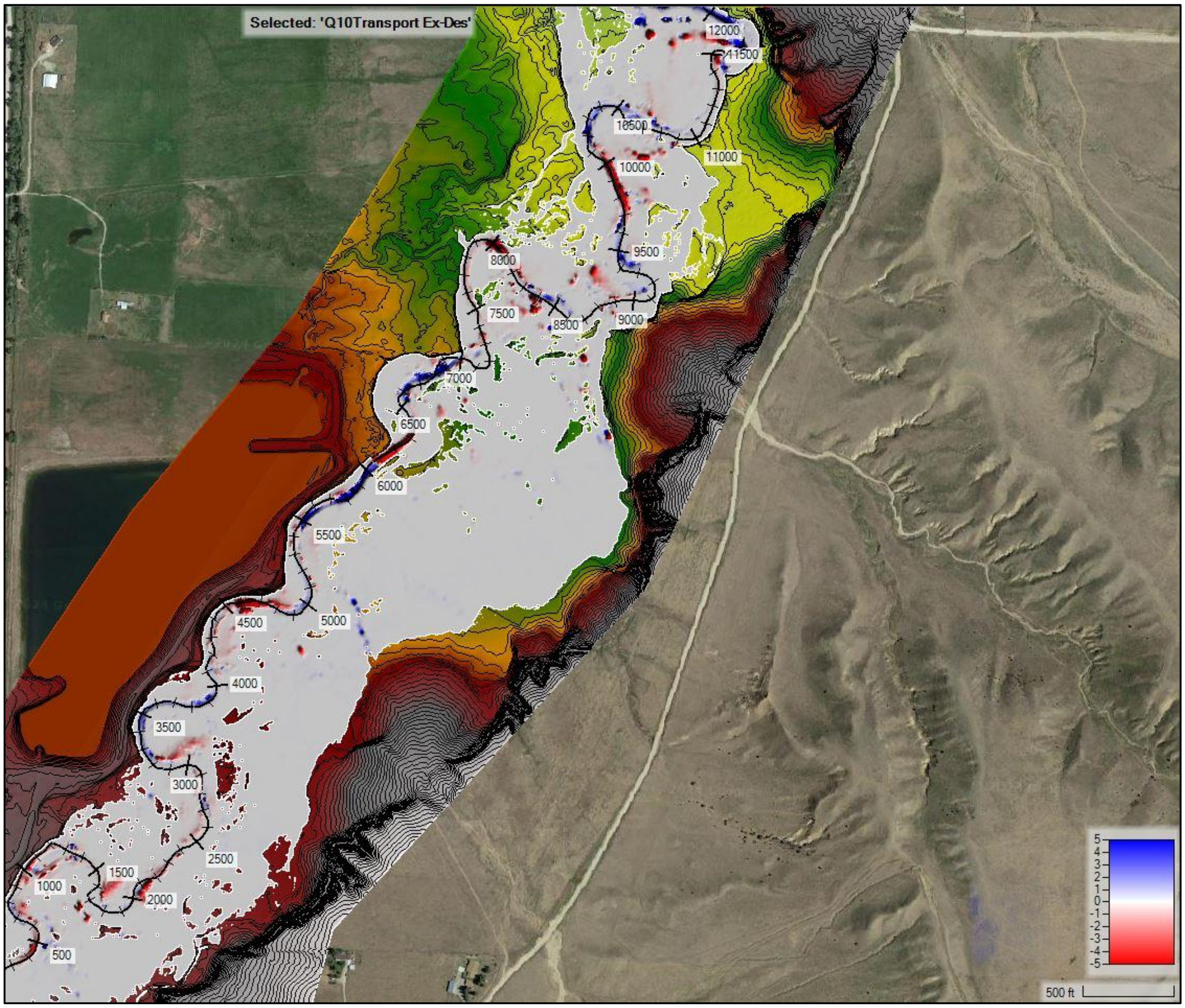


Figure L. Sediment Transport Capacity difference (existing minus design) maps for Q1.5, red indicates scour and blue indicates deposition potentials.

Comment 9: Related to previous comment, the TAC is curious whether Montana Fish, Wildlife & Parks is concerned over the potential for reduced sediment transport capacity of the channel in the upper end of Reach 7 given the documented spawning habitat available in this area. Could the reduced transport capacity of the channel result in fine sediment deposition and compromised spawning habitat suitability in Phase 7?

Response: Montana FWP notes that the entire Clark Fork River upstream of Sager Lane is spawning habitat, with several prominent spawning reaches in this Phase. Lower floodplains could impact sediment transport, but the degree of that impact to spawning is unknown. FWP does not believe that designing an entrenched river channel to avoid possible impacts to spawning habitat is appropriate. There are many fisheries benefits associated with appropriate floodplain elevation (e.g., riparian vegetation performance, habitat formation, lateral scour and channel migration, etc.) that likely outweigh any possible negatives. The agencies will continue to monitor geomorphology on remediated/restored phases and will make design changes in future design if necessary.

The Upper Clark Fork is generally sediment starved and some additional sediment might not be bad. It would be beneficial to have flushing flows. We haven't seen pools fill in at previously completed phases where the width of the constructed floodplain was greater. Pools are not expected to fill in Phase 7.

Comment 10: If lowering the floodplain to the extent proposed is found to compromise in-channel habitat processes, we are curious whether specific, in-channel habitat mitigation opportunities may exist? We are aware large woody debris is lacking in the channel and wonder if NRDP might consider funding installation of woody debris complexes to compensate for reduced habitat- forming processes. We acknowledge a response to this question may not be possible with the information currently available.

Response: Channel aggradation has not been observed in previously completed phases where the floodplain was lowered and modeling of the channel bed in Phase 7 did not show a significant increase or decrease in scour resulting from the proposed condition. Therefore, no specific, in-channel habitat mitigation opportunities currently exist.

In terms of aquatic habitat enhancement such as adding large woody debris to the channel, NRDP acknowledges the potential benefit of those action to habitat in the CFR but given budget constraints will not likely provide funding for activities that don't directly support the remedial actions. However, the agencies would support the use of outside funding to address those issues if there was agency and community support for such actions.

Comment: We strongly recommend monitoring the geomorphic response of the channel to the lowered floodplain elevation and using the results to inform future phase designs. (see geomorphic monitoring plan prepared by K. Boyd).

Response: NRDP has been working with FWP as well as other stakeholders to develop an updated geomorphic monitoring plan for the Clark Fork River.

Section 7.3: Log Structure Streambank Treatments

Comment 11: The TAC supports the addition of log structure streambank treatments to outside meanders as an excellent improvement to the designs that will benefit habitat while reducing costs by eliminating fabric encapsulated soil lifts. It would further benefit fish habitat if large wood could also be installed periodically in pool tailouts, where brown trout tend to use it as escape cover while feeding in shallower water.

Response: See Response to Comment 10.

Comment 12: It is unclear whether large wood will be equally beneficial if installed on point bars because wood tends to accumulate there naturally. The TAC recommends eliminating large wood from point bars except as buried matrix material.

Response: Point-bar microhabitat will only be installed in discrete locations on point bars as buried wood.

Comment 13: As shown on Design Sheet D103, it appears the log structures will be installed above the base flow elevation, rendering them less useful as aquatic habitat features as compared to structures installed below the base flow elevation. If habitat complexity during all flows is desired, we recommend lowering the position of the exposed logs below the base flow elevation to keep them submerged during low flows.

Response: This was not the intent of the log structures. The streambanks details (see D102) were updated to better show the lower log structure and the notes were updated to be clearer.

Comment 14: The log structure detail on Sheet D103 suggests the footer log should be placed at or near the "Current Water Level". What flow or elevation does the current water level correspond to?

Response: See response above. The current water level note is meant to add some clarity and sideboards on what conditions are acceptable for bank construction. The current water level note corresponds to 120 cfs in the CFR. This flow was selected based on review of flow data at Galen and Deer Lodge and appears to occur often enough to provide adequate construction timeframes. If flows are higher than 120 cfs, the bank height above active flow is likely not adequate to construct high-quality streambanks.

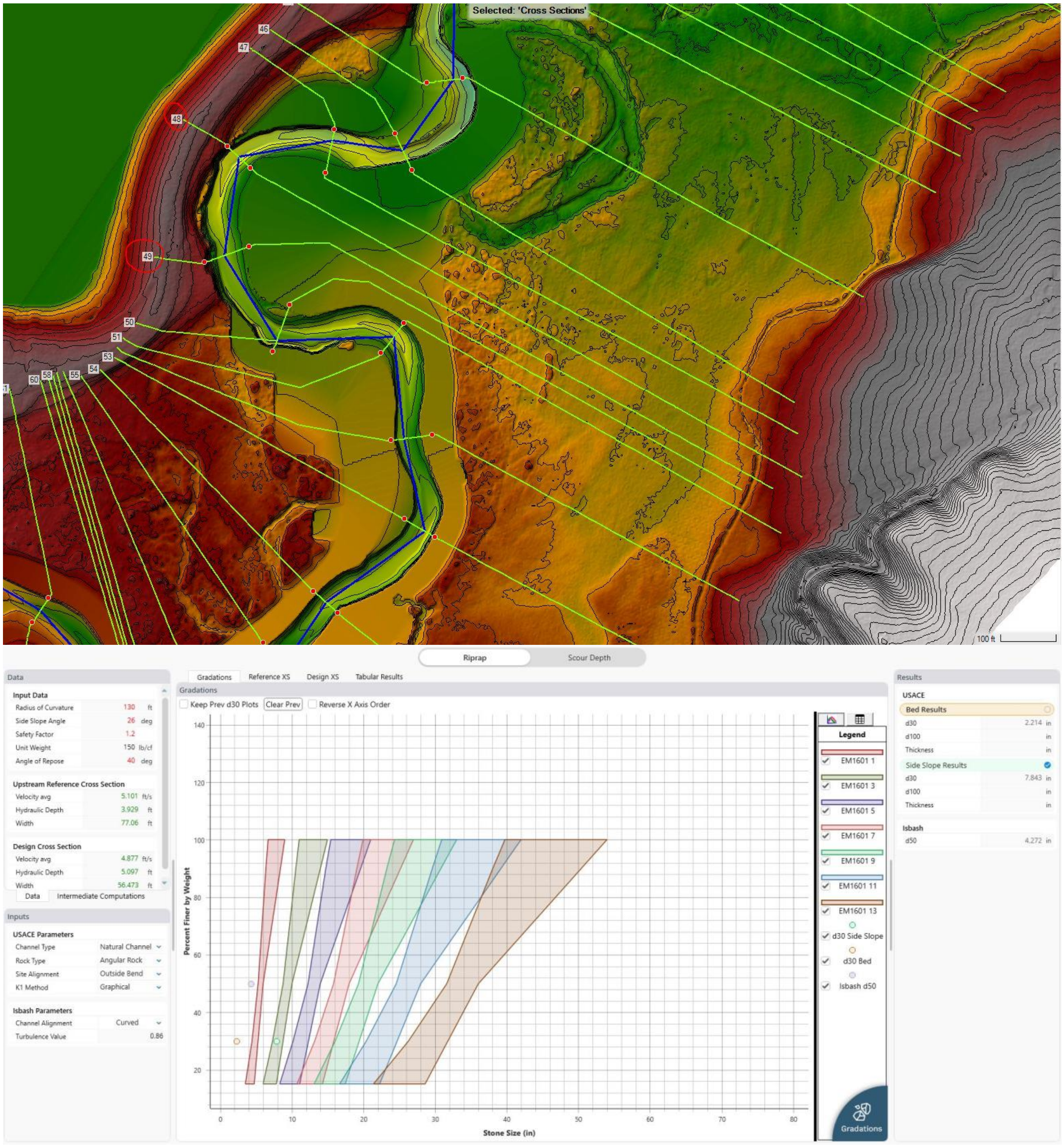
Comment 15: An example of the log stability analysis was to be included in Attachment 7, however, Attachment 7 only contains an example for the Brush Matrix treatment. Please provide a stability analysis for large wood.

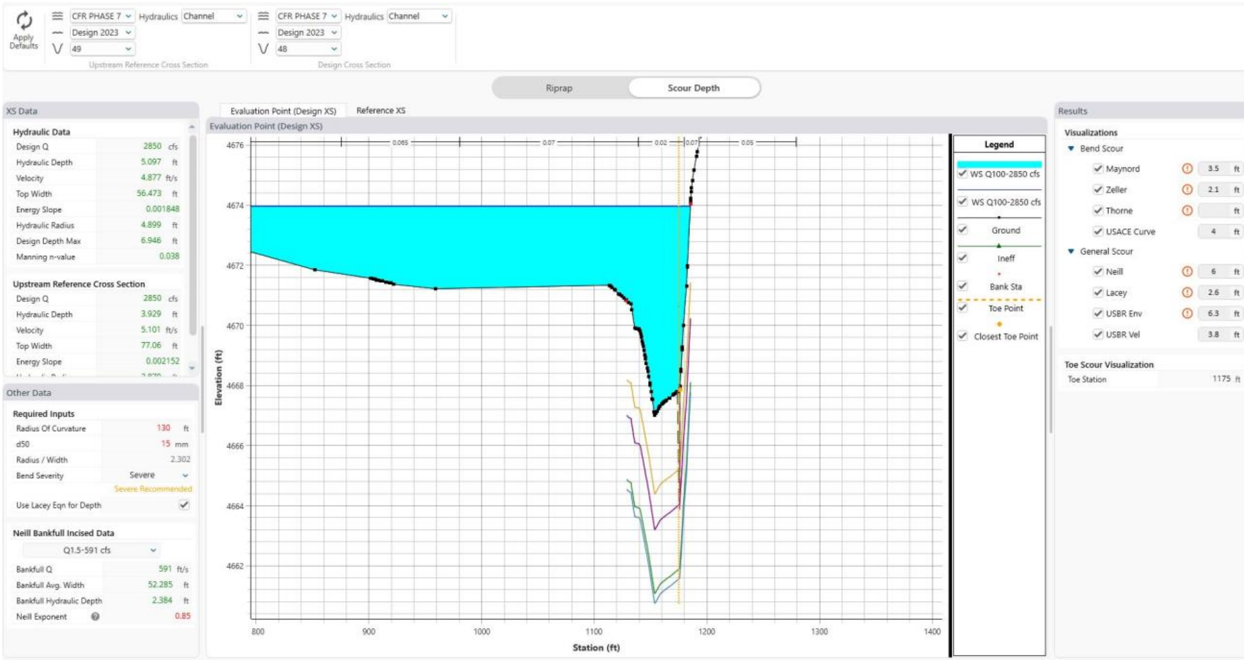
Response: A stability analysis for large wood is included in the Appendices.

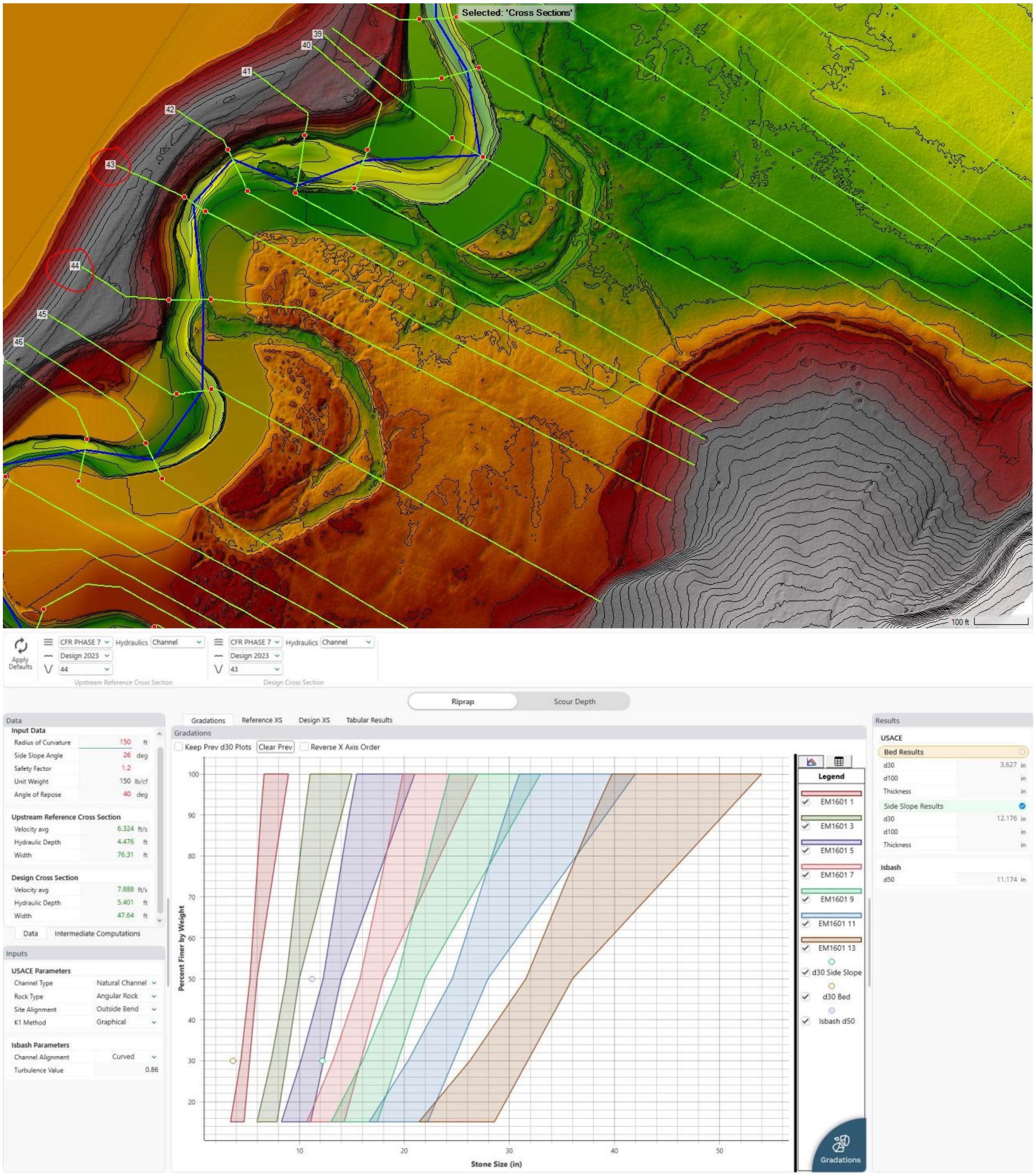
Section 7.5: Riprap Streambank Treatments

Comment 16: As shown on Design Sheet D103, the rock riprap bank stabilization treatment appears to use a "launchable toe" or ballast. This ballast does not appear to contain the recommended volume of material necessary for this type of application. Please provide calculations based on the USACE EM 1601 used to size the rock and estimate the dimensions for the ballast section.

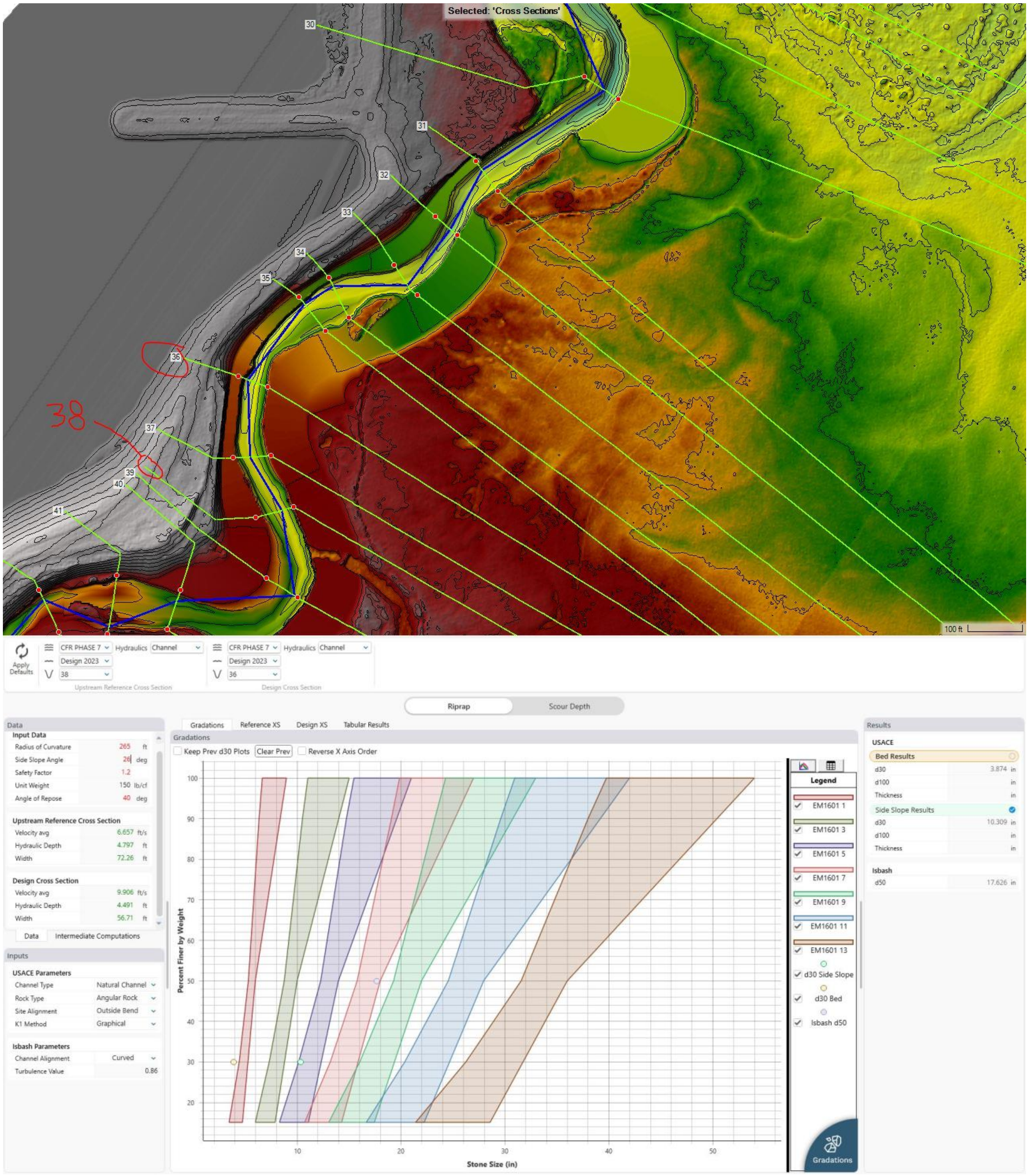
Response: That is correct. The design detail has been updated to include note about increased riprap thickness at launchable toe to account for rock lost to launching scour. Rock riprap sizing and scour tools from HEC RAS modeling were used to design stabilization and clipped images of the design for each bank section are included below (Figures M).

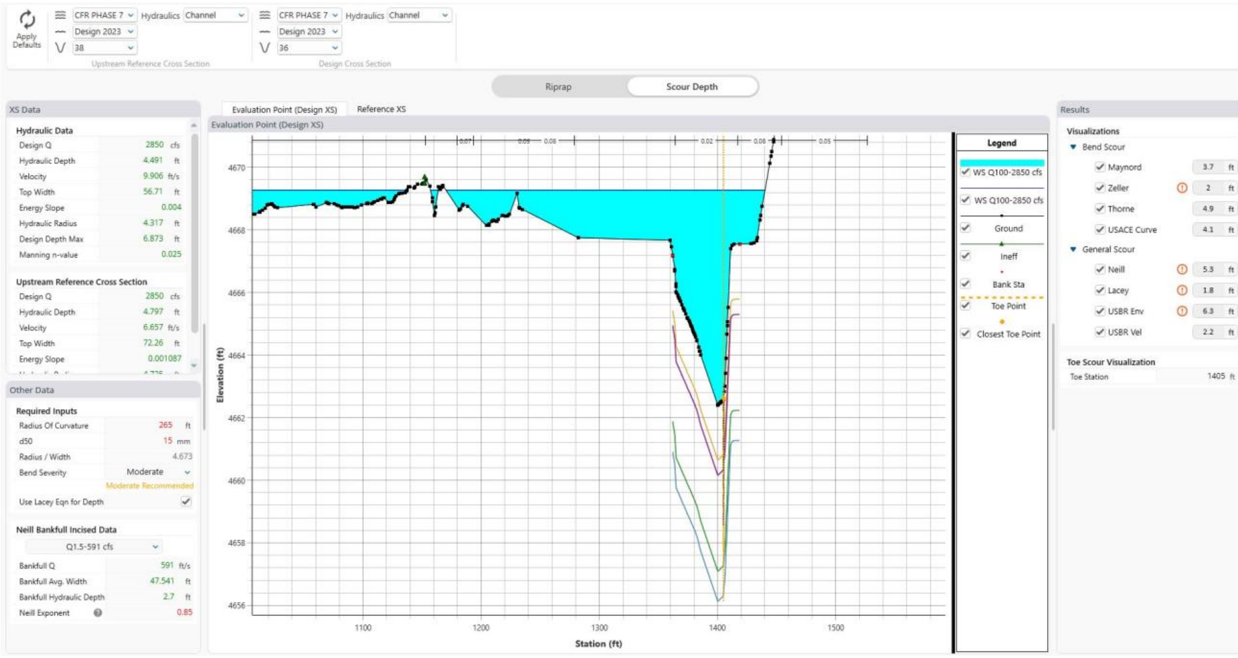

Selected: 'Cross Sections'
46
47
48
49
50
51
53
54
55
58
60
100 ft
Riprap
Scour Depth
Data
Input Data
Radius of Curvature 130 ft
Side Slope Angle 26 deg
Safety Factor 1.2
Unit Weight 150 lb/cf
Angle of Repose 40 deg
Upstream Reference Cross Section
Velocity avg 5.101 ft/s
Hydraulic Depth 3.929 ft
Width 77.06 ft
Design Cross Section
Velocity avg 4.877 ft/s
Hydraulic Depth 5.097 ft
Width 56.473 ft
Data
Intermediate Computations
Inputs
USACE Parameters
Channel Type Natural Channel
Rock Type Angular Rock
Site Alignment Outside Bend
K1 Method Graphical
Isbash Parameters
Channel Alignment Curved
Turbulence Value 0.86
Gradations
Reference XS
Design XS
Tabular Results
Keep Prev d30 Plots
Clear Prev
Reverse X Axis Order
Percent Finer by Weight
Stone Size (in)
Legend
EM1601 1
EM1601 3
EM1601 5
EM1601 7
EM1601 9
EM1601 11
EM1601 13
d30 Side Slope
d30 Bed
Isbash d50
Gradations
Results
USACE
Bed Results
d30 2.214 in
d100 in
Thickness in
Side Slope Results
d30 7.843 in
d100 in
Thickness in
Isbash
d50 4.272 in


Apply Defaults
CFR PHASE 7
Hydraulics
Channel
Design 2023
49
48
Upstream Reference Cross Section
Design Cross Section
Riprap
Scour Depth
XS Data
Hydraulic Data
Design Q 2850 cfs
Hydraulic Depth 5.097 ft
Velocity 4.877 ft/s
Top Width 56.473 ft
Energy Slope 0.001848
Hydraulic Radius 4.899 ft
Design Depth Max 6.946 ft
Manning n-value 0.038
Upstream Reference Cross Section
Design Q 2850 cfs
Hydraulic Depth 3.929 ft
Velocity 5.101 ft/s
Top Width 77.06 ft
Energy Slope 0.002152
Other Data
Required Inputs
Radius Of Curvature 130 ft
d50 15 mm
Radius / Width 2.302
Bend Severity Severe
Severe Recommended
Use Lacey Eqn for Depth
Neill Bankfull Incised Data
Q1.5-591 cfs
Bankfull Q 591 ft/s
Bankfull Avg. Width 52.285 ft
Bankfull Hydraulic Depth 2.384 ft
Neill Exponent 0.85
Evaluation Point (Design XS)
Reference XS
Elevation (ft)
Station (ft)
Legend
WS Q100-2850 cfs
WS Q100-2850 cfs
Ground
Ineff
Bank Sta
Toe Point
Closest Toe Point
Results
Visualizations
Bend Scour
Maynord 3.5 ft
Zeller 2.1 ft
Thorne ft
USACE Curve 4 ft
General Scour
Neill 6 ft
Lacey 2.6 ft
USBR Env 6.3 ft
USBR Vel 3.8 ft
Toe Scour Visualization
Toe Station 1175 ft


Selected: 'Cross Sections'
39
40
41
42
43
44
45
46
100 ft
Apply Defaults
CFR PHASE 7
Hydraulics
Channel
Design 2023
44
Upstream Reference Cross Section
CFR PHASE 7
Hydraulics
Channel
Design 2023
43
Design Cross Section
Riprap
Scour Depth
Data
Input Data
Radius of Curvature 150 ft
Side Slope Angle 26 deg
Safety Factor 1.2
Unit Weight 150 lb/cf
Angle of Repose 40 deg
Upstream Reference Cross Section
Velocity avg 6.324 ft/s
Hydraulic Depth 4.476 ft
Width 76.31 ft
Design Cross Section
Velocity avg 7.888 ft/s
Hydraulic Depth 5.401 ft
Width 47.64 ft
Data
Intermediate Computations
Inputs
USACE Parameters
Channel Type Natural Channel
Rock Type Angular Rock
Site Alignment Outside Bend
K1 Method Graphical
Isbash Parameters
Channel Alignment Curved
Turbulence Value 0.86
Gradations
Reference XS
Design XS
Tabular Results
Gradations
Keep Prev d30 Plots
Clear Prev
Reverse X Axis Order
Percent Finer by Weight
Stone Size (in)
Legend
EM1601 1
EM1601 3
EM1601 5
EM1601 7
EM1601 9
EM1601 11
EM1601 13
d30 Side Slope
d30 Bed
Isbash d50
Gradations
Results
USACE
Bed Results
d30 3.627 in
d100 in
Thickness in
Side Slope Results
d30 12.176 in
d100 in
Thickness in
Isbash
d50 11.174 in

Apply Defaults
CFR PHASE 7
Hydraulics Channel
Design 2023
44
Upstream Reference Cross Section
CFR PHASE 7
Hydraulics Channel
Design 2023
43
Design Cross Section
Riprap
Scour Depth
XS Data
Hydraulic Data
Design Q 2850 cfs
Hydraulic Depth 5.401 ft
Velocity 7.888 ft/s
Top Width 47.64 ft
Energy Slope 0.001301
Hydraulic Radius 5.092 ft
Design Depth Max 7.673 ft
Manning n-value 0.02
Upstream Reference Cross Section
Design Q 2850 cfs
Hydraulic Depth 4.476 ft
Velocity 6.324 ft/s
Top Width 76.31 ft
Energy Slope 0.001628
Other Data
Required Inputs
Radius Of Curvature 150 ft
d50 15 mm
Radius / Width 3.149
Bend Severity Severe
Moderate to Severe Recommended
Use Lacey Eqn for Depth
Neill Bankfull Incised Data
Q1.5-591 cfs
Bankfull Q 591 ft/s
Bankfull Avg. Width 43.899 ft
Bankfull Hydraulic Depth 3.461 ft
Neill Exponent 0.85
Evaluation Point (Design XS)
Reference XS
Evaluation Point (Design XS)
Elevation (ft)
Station (ft)
Legend
WS Q100-2850 cfs
WS Q100-2850 cfs
Ground
Bank Sta
Toe Point
Closest Toe Point
Results
Visualizations
Bend Scour
Maynord 3.9 ft
Zeller 2.6 ft
Thorne ft
USACE Curve 3.8 ft
General Scour
Neill 8.6 ft
Lacey 2.6 ft
USBR Env 6.5 ft
USBR Vel 4.1 ft
Toe Scour Visualization
Toe Station 1053 ft


Selected: 'Cross Sections'
30
31
32
33
34
35
36
37
38
39
40
41
100 ft
Apply Defaults
CFR PHASE 7
Hydraulics
Channel
Design 2023
38
Upstream Reference Cross Section
CFR PHASE 7
Hydraulics
Channel
Design 2023
36
Design Cross Section
Riprap
Scour Depth
Data
Input Data
Radius of Curvature 265 ft
Side Slope Angle 26 deg
Safety Factor 1.2
Unit Weight 150 lb/cf
Angle of Repose 40 deg
Upstream Reference Cross Section
Velocity avg 6.657 ft/s
Hydraulic Depth 4.797 ft
Width 72.26 ft
Design Cross Section
Velocity avg 9.906 ft/s
Hydraulic Depth 4.491 ft
Width 56.71 ft
Data
Intermediate Computations
Inputs
USACE Parameters
Channel Type Natural Channel
Rock Type Angular Rock
Site Alignment Outside Bend
K1 Method Graphical
Isbash Parameters
Channel Alignment Curved
Turbulence Value 0.86
Gradations
Reference XS
Design XS
Tabular Results
Gradations
Keep Prev d30 Plots
Clear Prev
Reverse X Axis Order
Percent Finer by Weight
Stone Size (in)
Legend
EM1601 1
EM1601 3
EM1601 5
EM1601 7
EM1601 9
EM1601 11
EM1601 13
d30 Side Slope
d30 Bed
Isbash d50
Gradations
Results
USACE
Bed Results
d30 3.874 in
d100 in
Thickness in
Side Slope Results
d30 10.309 in
d100 in
Thickness in
Isbash
d50 17.626 in



Figures M. clipped images of the design for each bank section.

Section 8.0 Revegetation Design

Comment 17: In general, the TAC is highly supportive of the revegetation design outlined in the design criteria memo. The overall goal of creating a floodplain surface that is frequently activated by high flows should promote the establishment of desirable native woody species and the creation and wetland habitats. Additionally, the proposed revegetation methods and placements for willow cuttings, containerized woody plantings, and seeding follow established norms and are likely to be successful.

Response: Thank you, comment noted.

Section 8.1.2 Woody Riparian

Comment 18: The TAC would like to promote the use of cottonwoods within appropriate hydrologic zones. Cottonwoods are a keystone pioneer species invaluable for wildlife and river function. Prior to settlement of the Clark Fork River valley the lower reaches of the valley were likely dominated by cottonwood galleries. However, due to historic mining, grazing, timber harvesting, river channelization, and the floods of 1908, cottonwood communities were largely extirpated from the valley. Phase 7 provides an excellent opportunity to reestablish cottonwood galleries based on the following:

- **The designated land use is riparian floodplain.**
- **Conflicts with other land uses such as grazing should not compromise cottonwood establishment within this reach.**
- **The designed Phase 7 floodplain elevation is lower than in previous phases, suggesting an improved opportunity for cottonwoods to establish.**

Response: Cottonwoods will be planted in Phase 7.

Section 8.1.3 Floodplain Depression

Comment(s) 19: The TAC supports the general plan for floodplain depressions, including creating a diversity of habitats ranging from open water to seasonally saturated wetlands. The TAC would like to offer some design suggestions to support improved waterfowl habitat. The Upper Clark Fork Valley (UCFV) has extensive value for waterfowl in the Pacific Flyway. The Clark Fork Valley falls directly within a major migration corridor that includes critical nesting and overwintering habitat for migrating waterfowl. Therefore, waterfowl-friendly habitat designs can greatly impact these species given that the UCFV contains one of the largest wetland creation projects in Montana's history. Some important design considerations follow below:

Note these suggestions ideally would also be incorporated where possible into the wetland complex described in section 9.0.

1) **Promote beneficial plant communities**
   a) **Aquatic Emergent Vegetation (AEV)**
      i) **AEV provides necessary food and crucial cover for newly hatched waterfowl offspring. It is essential for overwater nesting waterfowl and waterbirds.**
      ii) **Promote a ratio of 50% open water to 50% AEV**
      iii) **Suggested species include, but are not limited to, smartweed (Persicaria amphibium), duck potato (Sagittaria cuneata), hardstem bulrush (Scirpus acutus), small-fruited bulrush (Scirpus microcarpus), sedges (Carex spp.), spikerushes (Eleocharis spp.), and rushes (Juncus spp.)**
   b) **Submerged Aquatic Vegetation (SAV)**
      i) **SAV is an important food source for waterfowl. SAV provides habitat for aquatic macroinvertebrates, which are both desired wetland species and a food source for a large variety of waterfowl species.**
      ii) **Suggested species include, but are not limited to, common water-milfoil (Myriophyllum sibiricum) and native pondweed species (Potamogeton spp.)**
2) **Hydrology**
   a) **Promote seasonal, fluctuating water levels that mimic natural hydrologic conditions (filled in spring with levels decreasing through summer and fall) to build ecosystem resilience and allow germination of AEV. Since these depressions will be located within active floodplains this will likely be achieved but it is worth noting for other wetlands, such the vegetative borrow area.**
3) **Depth variability**
   a) **Ponds and wetlands with variable depths increase biodiversity by providing a mix of habitat types. Waterfowl and waterbirds can be broken up into two feeding groups; divers and dabblers. Divers obtain food by swimming below the surface in deeper waters (4-20 ft). Dabblers eat by tipping their bodies up and eating just below or on the water surface, typically in very shallow water (1 in. to 2 ft). Both feeding groups are reliant on a variety of**

vegetation, macroinvertebrates, crustaceans, and fish that also support a healthy overall ecosystem. A variety of depths within the wetlands support not only waterfowl but also enhances habitat for other species.

4) **Wetland/ depression size**
   a) **Smaller wetlands are typically more successful than larger wetlands because small wetlands increase available habitat while limiting low-productive, open-water areas. While deep, lacustrine-style wetlands provide specific habitat for diving species and roosting waterfowl; smaller, pothole-style wetlands provide the highest quality habitats. A widely accepted rule in waterfowl habitat design is that 10 one- acre wetlands will hold 10 times as many waterfowl as one 10-acre wetland (known as the rule of ten).**

Response: Thank you, the above criteria will be factored into the Phase 7 wetlands design.

Comment 20: One or more additional floodplain depressions appear to be feasible at the west ends of cross-sections 8 and 9 (see sheets C109 and XS103). We believe similar opportunities may exist on the left bank between Station 82+00 and 84+50 and on the right bank between Stations 97+50 and 100+00. Adding wetland depressions to these areas would benefit wildlife and reduce backfill costs.

Response: There are floodplain depressions included on the west side of XC-103 and on the right bank between Stations 97+50 and 100+00 (see Attachment 6 of the DCM). The left bank at station 82+00 is an island and the side channel around the island will be preserved serving a similar function to designed floodplain depressions.

Section 8.1.4 Point Bars

Comment 21: The design document correctly observes that point bars are "areas where native riparian woody vegetation, such as black cottonwood and sandbar willow will naturally colonize through seed deposited during flood events. Herbaceous wetland vegetation also readily colonizes these surfaces after construction." Given point bars also tend to be areas where tailings have deposited, we recommend removing tailings from all point bars that meet the contaminant removal criteria (if any) and not including them in preservation areas, regardless of how well-established the vegetation may be.

Response: Most points bars are being re-built. The few that are being preserved tie into design elevations in configurations that support the natural range of inside bend morphologies, support diverse substrates and provide seed sources for desired woody riparian vegetation.

Pit data is generally limited on point bar features. In previoius phases, standard practice for point bar vegetation preservation areas has been to evaluate contamination levels and depths adjacent to the proposed preservation area during removal of the rest of the point bar and if depths and levels are high (no exact numeric values determined), the proposed vegetation preservation would also be removed.

Section 9: Restoration Components

We understand the onsite floodplain alluvium borrow source will be incorporated into a future riparian wetland complex that will be designed separately from the Phase 7 CFROU. We appreciate the design team's interest in having the TAC participate in the design of this wetland feature and offer the following pre-design comments:

Increased Risk of Contaminant Exposure

Comment 22: As presented during the May 1st Phase 7 Design Team Meeting, the conceptual design of the wetland complex routes more water through areas exhibiting contamination that will not be removed. We are concerned that routing additional water through contaminated materials may eventually increase the risk of elevated contaminants in surface and groundwater and recommend the design team consider either revising the removal boundary to include areas that may be more frequently inundated as a result of the future wetland complex or utilizing a portion of the restoration funds available to remove additional tailings in areas exposed to the re-routed water.

Response: Contamination removal from the wetland footprint is included in the Remedial Action Workplan (bid package) and will be funded under the wetland plan.

Avulsion Risk

Comment 23: The area where the wetland complex is proposed is the lowest part of the floodplain and is already a likely flow path during overbank discharges. Excavation of wetlands in that area may encourage channel formation during large flow events. This may be addressed by locating wetlands in other areas or by inclusion of topographic breaks such as BDAs to discourage formation of concentrated flow paths.

Response: The potential for channel migration and a main channel avulsion into the slightly lower elevation area to the east of the existing Clark Fork River channel is difficult to quantify with high certainty. However, based on the lack of major channel migration observed in recent history (1955 to present), the relatively flat topography, and distance from the existing channel to the lower area, this potential is very low. The area proposed for the wetland complex is not activated under the Q10 flow for the existing or proposed design condition.

The risk of flow path formation and avulsion will be further considered during design of the wetland complex. The frequency and volume of flow entering the wetland complex can be evaluated and controlled to minimize risk. Further, roughness in the form of topographic and vegetative diversity will be integrated into the design of the wetland complex, including check dams using substrate, brush or sod. The design intent of the wetland complex is to disperse any overland flows that enter the area reducing the risk of formation of concentrated flow paths.

Wetland Complex Benefits

Comment 24: We support the desire to expand and enhance wetland habitat within Phase 7. As previously noted, the proposed wetland complex will occupy an area that is already lower than most of the floodplain. Presumably, that area is already wetlands, which calls into question the benefits relative to costs that may be realized by wetland enhancement in that area.

Response: The area proposed for the wetland complex does currently support some wetland habitat; however, the area lacks topographic and structural diversity and is dominated by introduced pasture grasses. The area currently supports some standing water during spring conditions when groundwater is high but does not meet any of the desired criteria CFRTAC mentions in Comment(s) 19 above.

Water Temperature

Comment(s) 25: To improve resiliency to climate change, the designs for all phases should consider ways to conserve cold water. Design considerations should include:

- **Routing all spring flows directly to the Clark Fork River rather than through ponds, open water wetlands, or swales.**
- **Eliminating or minimizing the discharge of warm surface water (e.g. from ponds or wetlands) directly to the river.**
- **If wetlands receive surface water, design them so the water surface elevation is above groundwater level to encourage recharge and cooling of water (e.g. add berms or beaver dam analogs to constructed wetlands).**
- **Consider installing bottom-release structures for ponds that will have a connection to the Clark Fork River.**

Response: Comment noted. These design considerations will be incorporated into the wetlands design to the extent practicable. The CFC has installed temperature probes in this area in the 2024 field season to attempt to quantify temperatures in this area to aid in design.

Attachment 10: Draft Plan Sheets

Comment 26: The proposed Legend on Sheet G102 shows a "Preserve Vegetation" hatch and a separate "Vegetation Preservation" hatch. Is there a difference?

Comment 27: Sheet G102 assigns a nearly identical line weight and color to the "Brush Matrix" and "Rock Riprap Bank Stabilization" treatments, making it difficult to decipher the proposed location of these treatments on Sheets C122, C123, and C124. Similarly, the same line weight and color appears to be assigned to "Willow Trenches" and "New 4-wire Wildlife Friendly Fence". We suggest revising line types to allow reviewers to better distinguish between these design features.

Comment 28: The Vegetation Preservation layer is inconsistently shown throughout plan sheets. For example, Sheets G104 and G105 do not include the vegetation preservation areas downstream of Station 60+00 that are shown on Sheets C105 and C106.

Comment 29: Sheet C107 indicates a ~700' long rock riprap trench will be installed to the west of the channel between Stations 12+00 and 31+50. It is unclear what the purpose of this riprap trench is and question the alignment of the riprap trench relative to the channel at its northern end.

Comment 30: Sheet C109 shows two short segments of buried rock riprap near Station 110+00. It is unclear what the purpose of this riprap trench is.

Comment 31: We are unclear how the finish grade for Section 9 on Sheet XS103 can be approximately 2 feet lower than the bottom of excavation on the far left (east) side of the transect. This figure creates some uncertainty in how the excavation and final grade surfaces are generated and whether the flood inundation model correctly depicts the extent and depth of flooding.

Response Comments 26-31: Design sheets have been updated to address these comments and reviewed for consistency and clarity. Surface design and modeling have been reviewed and are correct.

Comment 32: It is difficult to compare elevations of the existing, excavated, and finished floodplain surfaces. Cross-sections provide the best way to visually understand what is being proposed but the plans include only nine cross-sections for the 2.28 mile length of Phase 7. Please include significantly more cross-sections to make it easier to interpret the proposed tailings removal and finish grading plans.

Response: Cross-sections are provided for contractor reference only, contractors are provided surfaces electronically to build the bottom of excavation, subgrade, and final grade surface. If additional cross-sections are needed for review purposes, they can be cut for any location needed.

Comment 33: It would be helpful to have the 100-year floodplain and existing wetlands boundaries displayed on the plan maps.

Response: Figure N below shows the 100-year historical floodplain prepared by CH2M Hill for EPA and EPA mapped wetland boundaries.

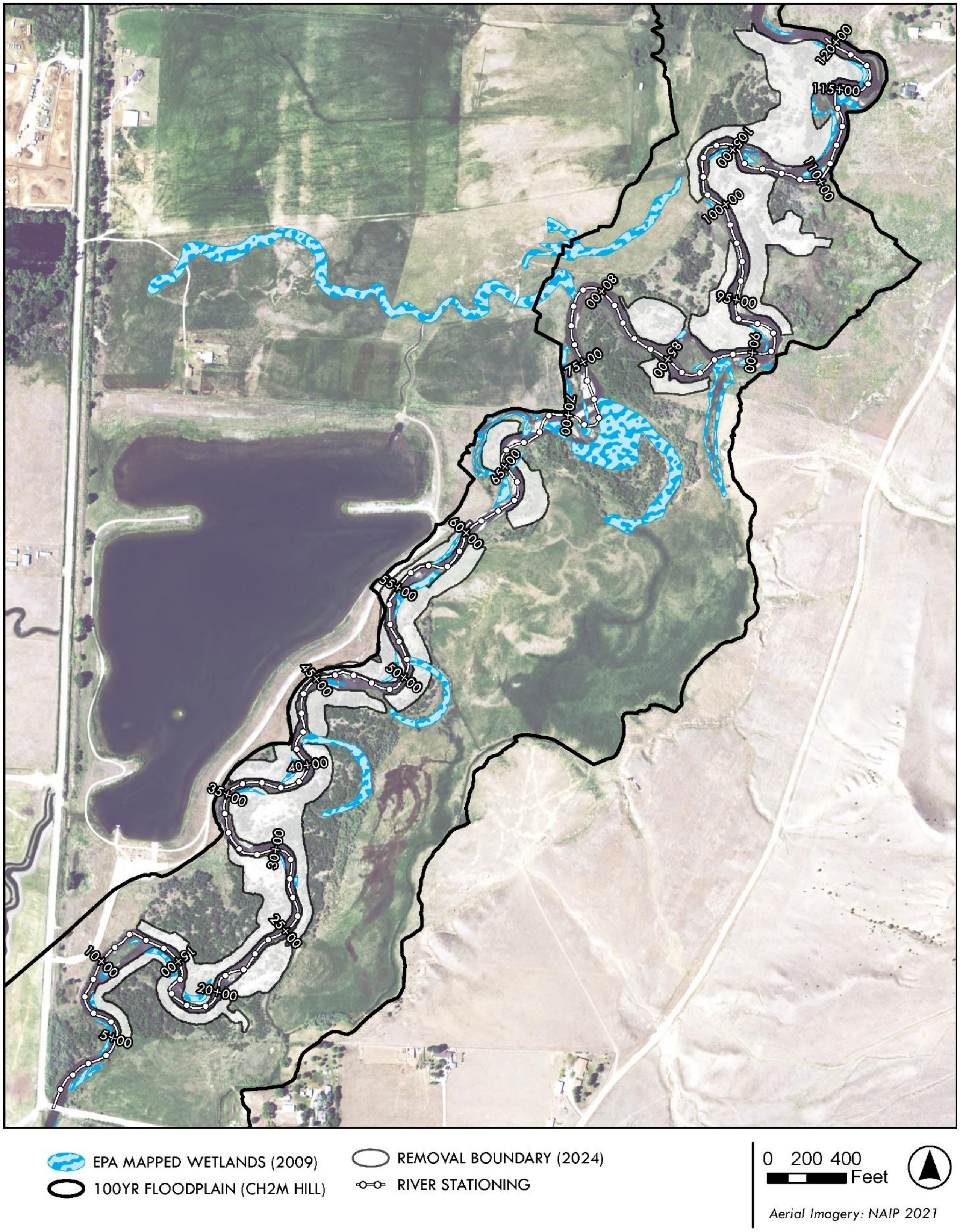


Figure N. Prepared in response to Comment 33. The 100-year floodplain near Phase 7 with EPA mapped wetlands and the 2024 proposed removal boundary.

Comment 34: The hatch for existing wetlands appears to be the same as proposed wetlands, making it difficult to decipher where existing wetlands may be disturbed and where new wetlands may be created.

Response: Please see response to comments 26-31.

Comment(s) 35: Sheets C119, D105-108 Fencing Plan and Specifications do not appear to be wildlife (or recreation) friendly. We suggest incorporating wildlife friendly fencing specifications wherever possible, especially on the State of Montana Property. The following FWP document for guidance on wildlife friendly fencing specifications provides some helpful guidance:
https://fwp.mt.gov/binaries/content/assets/fwp/conservation/land-owner-wildlife-resources/a_landowners_guide_to_wildlife_friendly_fences.pdf
More specifically, we recommend that farm fences be 4 wire (smooth top and bottom) with the appropriate spacing for safe wildlife passage. We also suggest looking into alternatives to Jack Leg fencing, which can create formidable obstacles to wildlife, are expensive to install and require a high degree of maintenance. Another wildlife-friendly alternative is 3-wire high tensile electric fence with fiberglass posts. Incorporating walk through gates for recreationists to safely access the State of MT property is also recommended. It would be helpful to specify in future plan sheets which fence specifications are proposed in specific sections.

Response: Fencing plans and details have been updated following discussions with landowners. Landowners have requested 5-strand barbed fences to separate property boundaries. Wildlife friendly fences are included on all State owner property and on private property where property owner have agreed. Jackleg fences are only used in limited areas where conventional fencing is not appropriate and are not included in any areas within the Phase 7 project.

Potential Cost Saving Measures
Comment(s) 36: Several changes in the general approach to the CFROU cleanup are stipulated in the Strategic Plan and DCM, most of which involve reducing the amount of tailings that will be removed from the floodplain. To better understand the ramifications of these changes, it would be very helpful to know how many cubic yards of contaminated soils will be left in place for Phase 7 and future phases by:

- **Vegetation preservation**
- **Reducing the CMZ to a 50-year buffer**
- **Leaving tailings >24" deep outside of the CMZ**

Response: Table A below provides estimates for the above requested volumes. Approximately 22,376 cubic yards of contaminated material will remain within vegetation preservation areas within the CMZ. 16,025 cubic yards of contaminated material are estimated to remain at the site in areas outside of the proposed removal boundary with contamination depth greater than 2 ft. There are approximately 108,115 cubic yards of contaminated sediment within the 100-year mean CMZ (not considering preservation areas) and 148,233 cubic yards of contaminated sediment within the 100-year 90% CMZ (used as the base remedial action in previous phases).

Removals under the ROD's remedial criteria would have only included mapped Slickens and select areas with Impacted Sediment (with the bulk of the Impacted Sediment areas receiving liming instead of removals) and would have been much less than the current removals proposed for Phase 7.

Extents of contamination in future phases will be evaluated during remedial investigation work and incorporated into the sampling design and budgets as feasible.

For additional cost-saving strategies being implemented, please refer to responses to Comments #20 and #35.

Area of Interest	Estimated volume of contaminated sediment (in cubic yards)
Vegetation Preservation areas – (VP-01 through VP-24)	22,376
Contaminated Sediment >2FT outside of the proposed removal boundary (CS-01 through CS-17)	16,025
100 year mean CMZ (current base remedy)	108,115
100 year 90th percentile CMZ (prior base remedy)	148,233

Table A. Contamination quantities in Phase 7

Remaining Wetland Funding

Comment 37: The TAC understands the proposed wetland complex in Phase 7 will be funded through the 1999 Streamside Tailings CD (Silver Bow Creek) earmarking $3.2M for creation of 400 acres of wetlands in the UCF, and that approximately half of those funds remain as of last year. The TAC would appreciate the opportunity to weigh in on the utilization of remaining wetland funding as it relates to the CFROU.

Response: The State Wetland Plan was revised in 2023. Priority areas and activities were determined in conjunction with Montana FWP. This plan revision was approved by the USFWS. It is the intention to spend the remaining wetland funding by December 31, 2029. Any comments or suggestions on implementing the Wetlands plan is welcome by NRDP.

CFRTAC Participation in Design and Monitoring

Comment 38: The CFRTAC very much appreciates the invitation to attend Design Team meetings and offer feedback on the CFROU Phases scheduled for future completion. We strongly believe the TAC's participation will help generate the best possible outcome for local communities and citizens utilizing the recreational amenities provided along the Clark Fork River. To that end, we would also appreciate the opportunity to review annual monitoring results and documentation of whether performance measures are being met within the various CFROU phases.

In addition to our desire to help distribute this information to the communities affected by the cleanup, our intent is to consider the monitoring results as a means of informing future design phases and remedy / restoration actions.

Response: The State greatly appreciates CFRTAC participating in the design process and looks forward to working collaboratively as remediation and restoration proceed on the Clark Fork. This includes participation in monitoring and evaluation of performance measures. The annual monitoring reports for the CFROU are made available on DEQ's website, and the most recent report will be sent for review in addition to this response to comments.

State of Montana
Natural Resource Damage Program

MEMORANDUM

TO: Jessica Banaszak, DEQ Environmental Project Manager, Logan Dudding, DEQ Senior Environmental Project Manager, Molly Roby, EPA Remedial Project Manager

FROM: Brian Bartkowiak, NRDP Restoration Project Manager

DATE: June 12, 2024

SUBJECT: State Restoration in lieu of Remedy and State Restoration in addition to Remedy at Phase 7 of the Clark Fork River Site.

In accordance with Paragraph 38.f and Paragraph 31 and 56 of Part 1 of the SMAO, the Montana Natural Resource Damage Program (NRDP) is submitting this technical memorandum to describe State Restoration components that are in lieu of Remedy and State restoration components that are in addition to Remedy at Phase 7 of the Clark Fork Site.

Restoration in lieu of Remedy

Restoration in lieu of remedy components include use of conifers and juniper in streambank construction. Remedy has used a combination of streambank treatments to date. One of these treatments is the Bush Matrix streambank treatment which uses cleared and grubbed woody vegetation or imported conifers and juniper trees to reconstruct streambanks. Junipers and conifers are being imported due to the lack of material available on site. This treatment has replaced double vegetated soil lift (DVSL) treatments used in previous phases that required the use of coir material. Brush matrix streambank treatments provide several benefits over coir fabric soil lifts including: easier installation that does not require as much manual labor, no need to purchase and import coir material which has been limiting in the past, lower installation costs, and short-term aquatic habitat benefits. These treatments are in lieu of remedy because they provide additional aquatic habitat benefits compared to treatments proposed in the ROD. Brush Matrix streambank treatments are typically located on outside meander bends with moderate to high rates of erosion or on straight reaches supporting little to no mature woody riparian vegetation or where moderate erosion occurs. Contamination is present in these streambanks and the adjacent floodplain and is often visible in the upper portion of the bank. Brush Matrix streambank treatments consist of a matrix of woody brush, cottonwoods, junipers and or conifers oriented in both the upstream and downstream direction to dissipate flow energy. These treatments resist erosion while mimicking aquatic habitat features such as over-hanging woody vegetation and undercut banks. Dormant willow cuttings and living willow clumps are incorporated into this streambank treatment to provide long-term resistance to erosion.

The design for the Brush Matrix streambank treatments has been analyzed using the Large Wood Structure Stability Analysis Spreadsheet, developed by Michael Rafferty, P.E. (Rafferty, 2016) with the United States (US) Forest Service. Typical regional values for material specifications were used with a factor of safety of 1.5 in the stability analysis. An example of the stability analysis and results from this tool are included in **Attachment 1**.

NRDP proposes this streambank treatment type, which is supported by Montana Fish Wildlife and Park (FWP)s, as it provides immediate aquatic and terrestrial habitats decreasing the recovery time since the establishment of overhanging vegetation following contaminated tailings removal by remedy typically takes several years. This treatment is proposed for areas of Phase 7 on State of Montana property as well as on private property. Private property owners have agreed to this treatment type on their properties. Table 1 provide a cost comparison between DVSL Streambanks Treatments and Brush Matrix Streambanks Treatments. It is estimated that this treatment will replace approximately 8,700 liner feet (LF) of DVSL treatments in Phase 7 resulting in a cost saving of approximately $200,000.

Table 1. Cost comparison between DVSL Streambanks Treatments and Brush Matrix Streambank Treatments based on CFR Phase 3A Bid Prices.

	Estimated Quantity (LF)	DVSL Price per LF ($)	DVSL Estimated Cost ($)	Brush Matrix Price per LF ($)	Brush Matrix Estimated Cost ($)	Cost Difference
Streambank Restoration in lieu of Remedy	8,700	$38.00	$330,600.00	$11.25	$97,875.00	$232,725.00

Restoration in addition to Remedy

Restoration in addition to remedy components include:

- Reclamation of the borrow area and adjacent meadow east of the Clark Fork River channel using Wetlands funds to create a diverse floodplain wetland complex supporting habitat for a wide range of species.
- The use of log structure streambank treatments to further enhance aquatic habitat.
- Development of near stream aquatic microhabitats (point bar microhabitat).
- Treatment of streambanks that would not be treated as part of the remedy, including "clean" streambanks, and streambanks that were previously stabilized utilizing debris such as whole car bodies, car body parts, and metal wire.

Phase 7 Wetlands

The 1999 Streamside Tailings Consent Decree (SST CD), under paragraph 22, required the State to develop, in consultation with the U.S. Fish and Wildlife Service (USFWS), the State Wetlands/Riparian Areas Plan to create, in the Upper Clark Fork River Basin (UCFRB), up to 400 acres of any combination of the following: newly constructed wetlands or restoration of destroyed wetlands, enhancement of existing wetlands, or enhancement of riparian areas on or along the Clark Fork River or its tributaries. Racetrack Pond was identified as a Priority 1 area for creating, enhancing, and protecting wetland and riparian areas in the *Final State Wetlands/Riparian Areas Plan* (Updated June 2023). The *Final State Wetlands/Riparian Areas Plan* allocated approximately $300,000 to creating, restoring, and enhancing wetlands and riparian areas in Phase 7. NRDP is planning to design and construct a wetland complex at the Phase 7 site east of the Clark Fork River channel.

The Phase 7 wetland complex is considered Restoration in addition to Remedy since the wetland's footprint is outside of the remedial removal boundary. Restoration of these wetlands will included removal of approximately 6,500 cubic yards of contaminated materials over 17 acres as part of the Phase 7 Remedial Action Project. The draft removal design is shown as **Attachment 2.** These removals will be funded by the NRDP from the Phase 7 wetlands allocation. After completion of the Phase 7 Remedial Action Project, under separate contract, NRDP will enhance the borrow area and adjacent riparian areas into highly functional riparian and wetland communities. This project is anticipated to start the construction season after remedial actions area completed.

Specific actions include additional grading to create diverse habitat conditions and additional planting of riparian and wetland vegetation. The conceptual wetland restoration design is shown in **Figure 2.** The final plan will be developed in coordination with FWP, Montana Wetland and Waterfowl, Montana DEQ (Remediation Division and Wetlands Program), Clark Fork River Technical Assistance Committee, and the Clark Fork Coalition. The Phase 7 wetlands including additional contaminated material removal, grading and planting of riparian vegetation will be funded from the *Final State Wetlands/Riparian Areas Plan.*

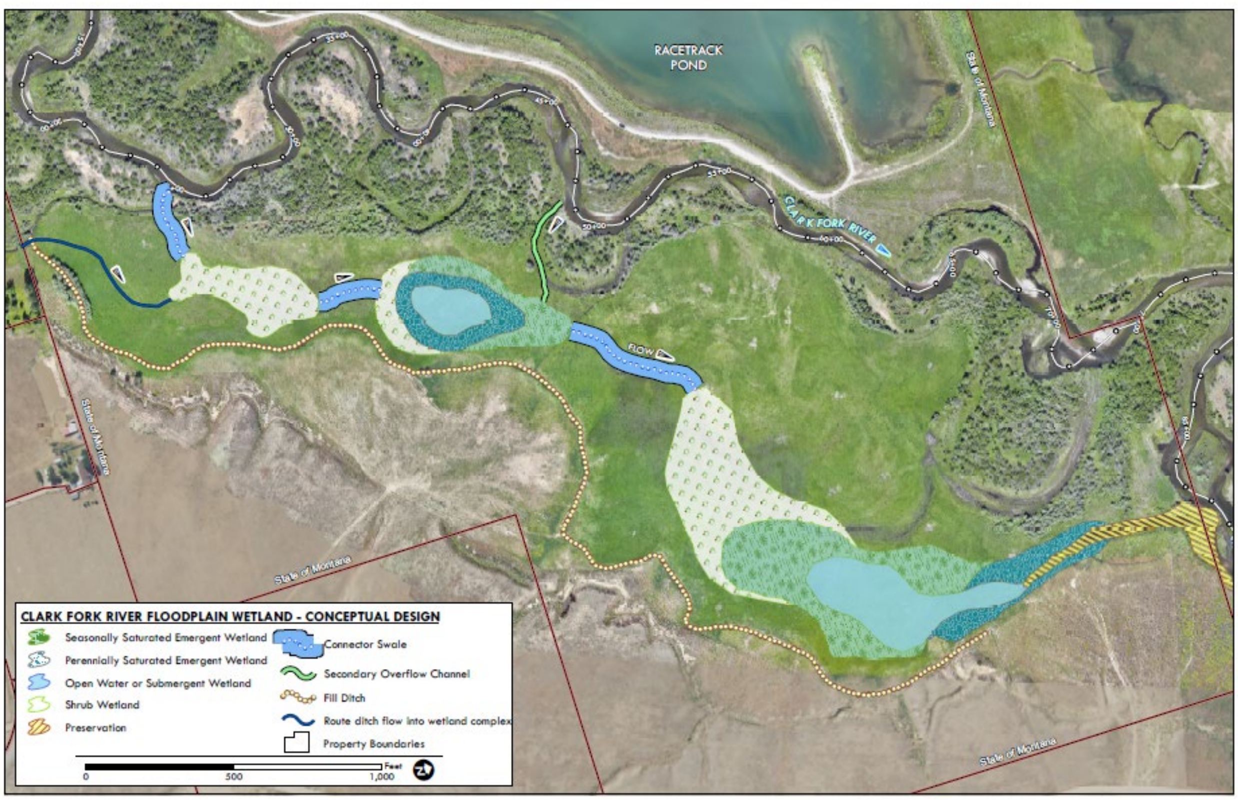


Figure 1. Conceptual Wetlands Restoration Plan

Log Structures

Log Structures, as part of streambanks treatments, are proposed in addition to remedial streambanks treatments. The purpose Log Structure treatments is to increase aquatic habitat diversity, decreasing the recovery time of the aquatic resources impacted by the contaminated sediments, and the remedial action. These log structures consist of tree trunk sections, with or without rootwads attached (cottonwood, juniper, or other competent wood species) to protrude into the active river channel, disperse high energy stream flow, and encourage pool scour maintenance and formation. Additional large and small pieces of wood, along with shrub transplants and dormant willow cuttings, will be integrated into these structures to enhance habitat and provide streambank stability. Figure 1. below is an example of these log structures. The design for log structure streambank treatments has been analyzed using the Large Wood Structure Stability Analysis Spreadsheet, developed by Michael Rafferty, P.E. (Rafferty, 2016) with the United States (US) Forest Service. Typical regional values for material specifications were used with a factor of safety of 1.5 in the stability analysis. An example of the stability analysis and results from this tool are included in **Attachment 1**.

NRDP will fund the sourcing and transport of materials needed to build these structures from the Upper Clark Fork River Basin Restoration Plan - terrestrial allocation and the installation of these structures from the Clark Fork River Aquatic and Riparian Resources Restoration Plan.

Figure 2. Example Log Structure streambank treatments. The larger wood in the bottom half of the right photo shows a Log Structure installed in Phase 3A of the CFROU. The left photo is an example Log Structure treatment from a project not on the Clark Fork River.

Near Stream Aquatic Microhabitats (point bar microhabitat)

NRDP is proposing to implement near stream aquatic microhabitats (point bar microhabitat) in addition as part of the floodplain reconstruction on Phase 7. These near stream aquatic microhabitats include placing woody debris along the edge of the channel within constructed point bar features to mimic existing microhabitats along the Clark Fork River channel that provide important fish and aquatic insect habitat features decreasing the recovery time of the aquatic and terrestrial resources impacted by the contaminated sediments and the remedial action. **Figure 3**, below, shows examples of the type of habitat that these treatments aim to recreate. NRDP will fund these treatments from the Clark Fork River Aquatic and Riparian Resources Restoration Plan.

Figure 3. Examples of existing woody debris microhabitat features along the Clark Fork channel near stream micro habitat treatments aim to recreate.

Streambanks

There are three (3) streambanks that will be treated as restoration in addition to remedy. These include the installation of streambank treatment on a "clean" streambank located along CFR left bank at approximate River Station 7 + 50 through 8 + 75 for aquatic habitat improvements, installation of rock riprap and streambank treatment along CFR left bank at approximate River Station 33 + 00 through 35 + 45 for bank long term bank stabilization and aquatic habitat improvements, and installation of streambank treatment along CFR left bank at approximate River Station 76 + 15 through 81 + 50 for bank stabilization and aquatic habitat improvements. These streambanks will receive Brush Matrix treatments to restore native woody riparian vegetation and enhance aquatic and terrestrial habitats decreasing the recovery time of the aquatic and terrestrial resources impacted by the contaminated sediments and the remedial action. NRDP will fund these treatments from the Clark Fork River Aquatic and Riparian Resources Restoration Pl an.

Additional Resource Benefits outside of the CFROU

NRDP is using Upper Clark Fork River Basin terrestrial funds to remove conifers which are encroaching into grasslands and supply those materials (junipers and conifers) for streambank construction. Land use and fire suppression have allowed conifers, such as Rocky Mountain Juniper and Douglas Fir, to expand their typical ranges into native grass and sagebrush ecosystems. Removing these tree species from these upland areas enhances terrestrial habitat for wildlife, reduce water depletion, provide additional forage for grazers like elk, and increase the productivity and vitality of sage brush-grassland habitats.

CFR - PHASE 7

Spreadsheet developed by
Michael Rafferty, P.E.

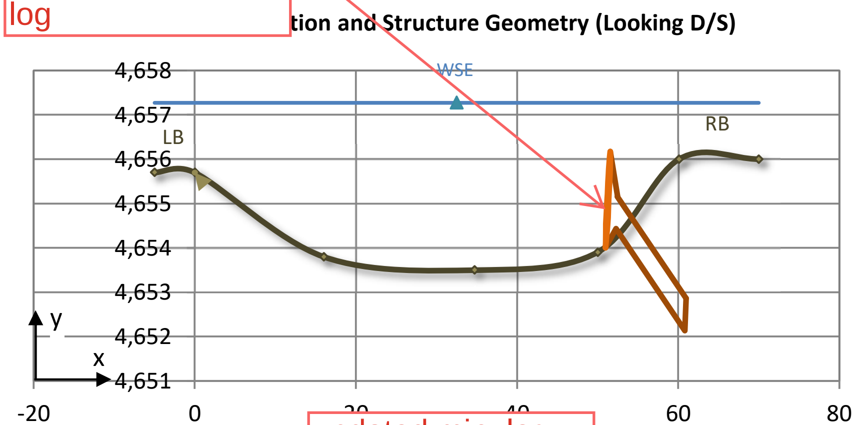
Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
RB 4.0	Tree Revetment	Right bank	Outside	97+75	3.77	8.13	7.45

this is the bottom log

Multi-Log Structures	Layer	Log ID
	Stacked	1

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	-5.00	4,655.70
Top LB	0.00	4,655.70
Toe LB	16.00	4,653.80
Thalweg	34.70	4,653.50
Toe RB	50.00	4,653.90
Top RB	60.10	4,656.00
Fldpln RB	70.00	4,656.00



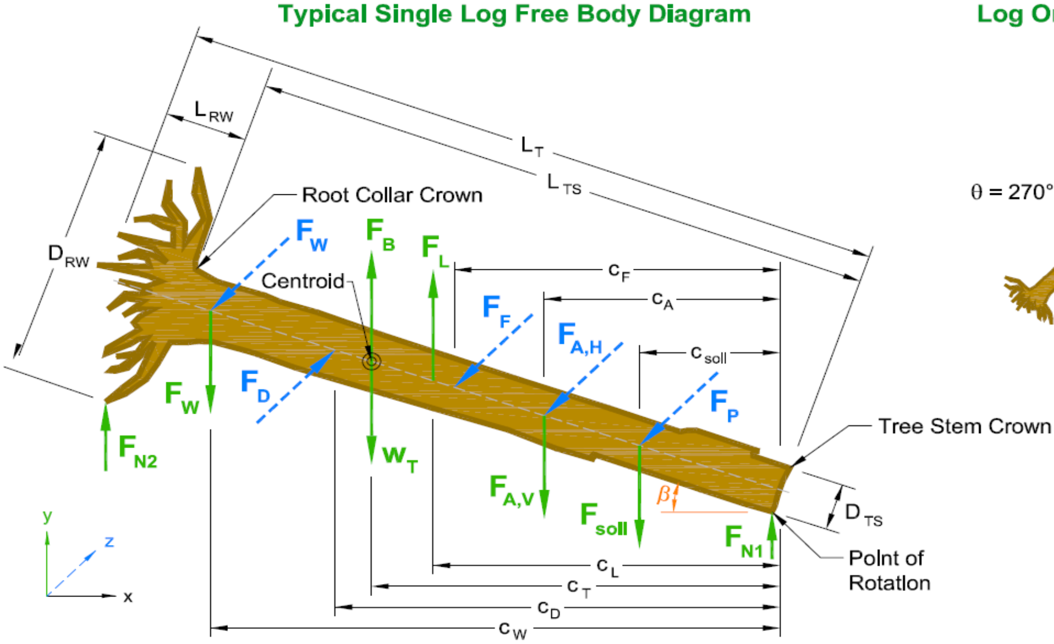
updated min. log length to provide stability at Q10

Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Cedar, Western redcedar	Yes	10.0	0.75	1.13	2.25	22.4	27.0

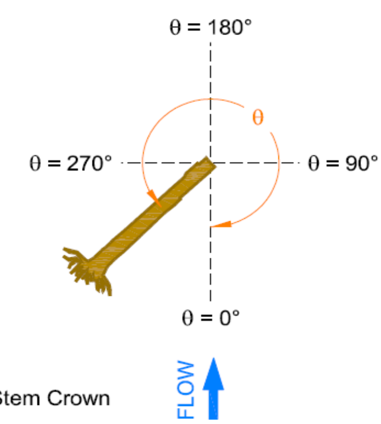
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	275.0	-15.0	Rootwad: Bottom	51.00	4,654.00	4,652.14	4,656.17	2.00

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	ϕ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Medium gravel	121.9	75.9	36.0	5	0.00	0.00	0.00
Bank	Gravel/sand	111.7	69.5	39.0	5	7.25	3.14	1.65

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	2.2	1.7	3.9	88	245
↓Thalweg	1.7	0.0	1.7	46	107
Total	3.9	1.7	5.6	134	352

Lift Force

C_{LT}	0.07
F_L (lbf)	7

Vertical Force Balance

F_B (lbf)	352
F_L (lbf)	7
W_T (lbf)	134
F_{soil} (lbf)	625
$F_{W,V}$ (lbf)	0
$F_{A,V}$ (lbf)	0
ΣF_V (lbf)	399
FS_V	2.11

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	0.0	9.0	9.0	625
Total	0.0	9.0	9.0	625

these green checks indicate log is stable for the given force type at the design flow Q10

Horizontal F

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.01	1.52	1.10	0.01	1.13	122

Horizontal Force Balance

F_D (lbf)	122
F_P (lbf)	1,373
F_F (lbf)	317
$F_{W,H}$ (lbf)	0
$F_{A,H}$ (lbf)	0
ΣF_H (lbf)	1,568
FS_H	13.88

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	3.85	0	2.00	0.73	54
Bank	4.40	1,373	8.82	0.81	264
Total	-	1,373	10.83	-	317

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
5.9	9.2	8.7	5.9	3.6	4.4	4.8

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	3,097
M_r (lbf)	12,410
FS_M	4.01

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
								0	0
								0	0
								0	0

CFR - PHASE 7

top log on the structure

Spreadsheet developed by
Michael Rafferty, P.E.

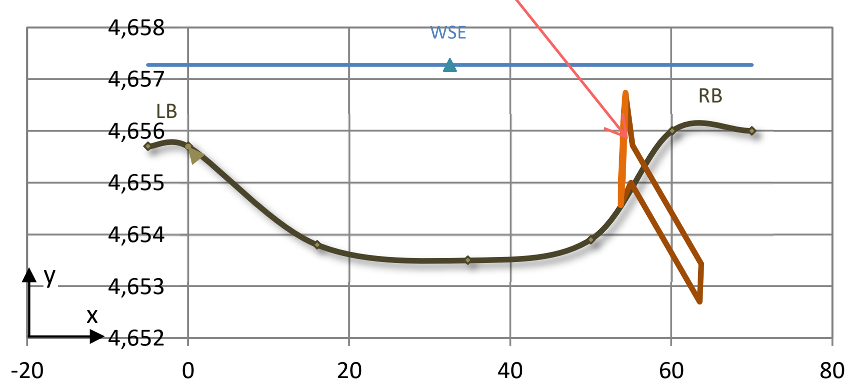
Single Log Stability Analysis Model Inputs

Site ID	Structure Type	Structure Position	Meander	Station	d_w (ft)	R_c/W_{BF}	u_{des} (ft/s)
RB 4.0	Tree Revetment	Right bank	Outside	97+75	3.77	8.13	7.45

Multi-Log Structures	Layer	Log ID
	Stacked	2

Channel Geometry Coordinates		
Proposed	x (ft)	y (ft)
Fldpln LB	-5.00	4,655.70
Top LB	0.00	4,655.70
Toe LB	16.00	4,653.80
Thalweg	34.70	4,653.50
Toe RB	50.00	4,653.90
Top RB	60.10	4,656.00
Fldpln RB	70.00	4,656.00

Proposed Cross-Section and Structure Geometry (Looking D/S)

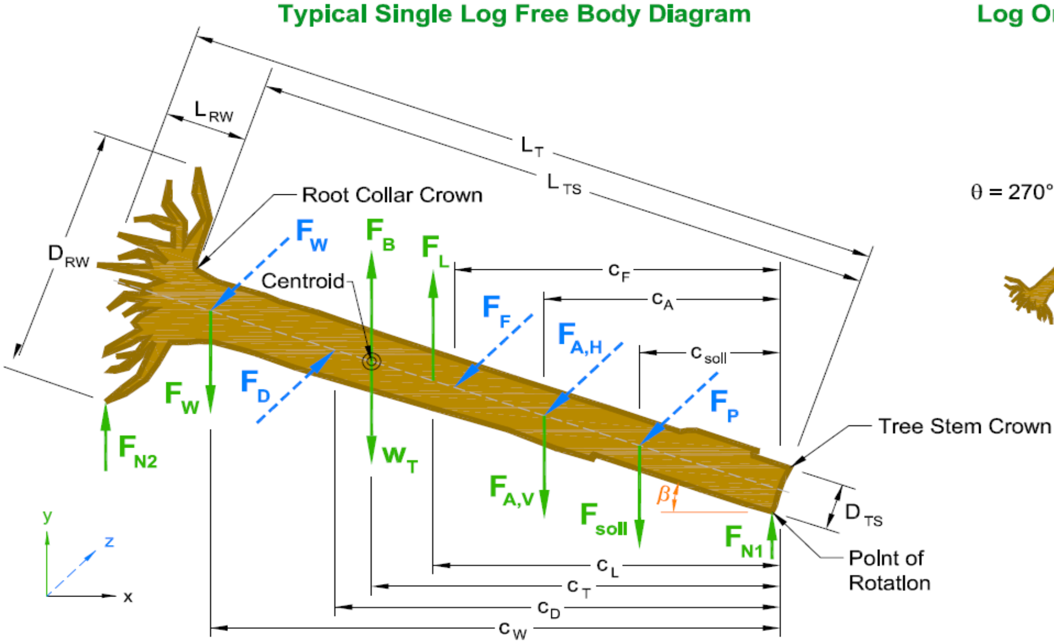


Wood Species	Rootwad	L_T (ft)	D_{TS} (ft)	L_{RW} (ft)	D_{RW} (ft)	γ_{Td} (lb/ft^3)	γ_{Tgr} (lb/ft^3)
Cedar, Western redcedar	Yes	10.0	0.75	1.13	2.25	22.4	27.0

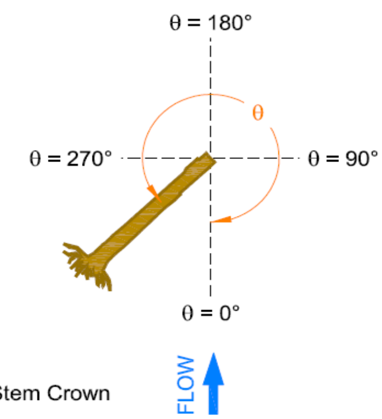
Structure Geometry	θ (deg)	β (deg)	Define Fixed Point	x_T (ft)	y_T (ft)	$y_{T,min}$ (ft)	$y_{T,max}$ (ft)	A_{Tp} (ft^2)
	275.0	-15.0	Root collar: Bottom	55.00	4,655.00	4,652.70	4,656.74	2.00

Soils	Material	γ_s (lb/ft^3)	γ'_s (lb/ft^3)	ϕ (deg)	Soil Class	$L_{T,em}$ (ft)	$d_{b,max}$ (ft)	$d_{b,avg}$ (ft)
Stream Bed	Medium gravel	121.9	75.9	36.0	5	0.00	0.00	0.00
Bank	Gravel/sand	111.7	69.5	39.0	5	7.25	2.57	1.47

Typical Single Log Free Body Diagram



Log Orientation (Plan View)



Vertical Force Analysis

Net Buoyancy Force

Wood	V_{TS} (ft^3)	V_{RW} (ft^3)	V_T (ft^3)	W_T (lbf)	F_B (lbf)
↑WSE	0.0	0.0	0.0	0	0
↓WS↑Thw	3.2	1.7	4.9	110	306
↓Thalweg	0.7	0.0	0.7	20	46
Total	3.9	1.7	5.6	130	352

Lift Force

C_{LT}	0.07
F_L (lbf)	7

Vertical Force Balance

F_B (lbf)	352	↑
F_L (lbf)	7	↑
W_T (lbf)	130	↓
F_{soil} (lbf)	555	↓
$F_{W,V}$ (lbf)	0	
$F_{A,V}$ (lbf)	0	
ΣF_V (lbf)	325	↓
FS_V	1.90	✓

Soil Ballast Force

Soil	V_{dry} (ft^3)	V_{sat} (ft^3)	V_{soil} (ft^3)	F_{soil} (lbf)
Bed	0.0	0.0	0.0	0
Bank	0.0	8.0	8.0	555
Total	0.0	8.0	8.0	555

Horizontal Force Analysis

Drag Force

A_{Tp} / A_W	Fr_L	C_{Di}	C_w	C_D*	F_D (lbf)
0.01	1.52	1.10	0.01	1.14	122

Horizontal Force Balance

F_D (lbf)	122	→
F_P (lbf)	1,219	←
F_F (lbf)	258	←
$F_{W,H}$ (lbf)	0	
$F_{A,H}$ (lbf)	0	
ΣF_H (lbf)	1,356	←
FS_H	12.11	✓

Passive Soil Pressure / Friction Force

Soil	K_P	F_P (lbf)	L_{Tf} (ft)	μ	F_F (lbf)
Bed	3.85	0	2.00	0.73	44
Bank	4.40	1,219	8.82	0.81	215
Total	-	1,219	10.83	-	258

Moment Force Balance

Driving Moment Centroids / Resisting Moment Centroids

$c_{T,B}$ (ft)	c_L (ft)	c_D (ft)	$c_{T,W}$ (ft)	c_{soil} (ft)	$c_{F\&N}$ (ft)	c_P (ft)
6.0	9.2	8.7	6.0	3.6	4.4	4.8

*Distances are from the stem tip

Point of Rotation: Stem Tip

Moment Force Balance

M_d (lbf)	3,117
M_r (lbf)	10,863
FS_M	3.49 ✓

Anchor Forces

Additional Soil Ballast

V_{Adry} (ft^3)	V_{Awet} (ft^3)	c_{Asoil} (ft)	$F_{A,Vsoil}$ (lbf)	$F_{A,HP}$ (lbf)
			0	0

Mechanical Anchors

Type	c_{Am} (ft)	Soils	F_{Am} (lbf)
			0
			0

Boulder Ballast

Position	D_r (ft)	c_{Ar} (ft)	$V_{r,dry}$ (ft^3)	$V_{r,wet}$ (ft^3)	W_r (lbf)	$F_{L,r}$ (lbf)	$F_{D,r}$ (lbf)	$F_{A,Vr}$ (lbf)	$F_{A,Hr}$ (lbf)
								0	0
								0	0
								0	0