RECLAMATION
*Managing Water in the West*

# FINAL BASIS OF DESIGN REPORT BARKLEY BEAR HABITAT RESTORATION PROJECT

Okanogan County, Washington

*Prepared by:*
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U. S. Department of the Interior
Bureau of Reclamation

Pacific Northwest Region
Pacific Northwest Regional Office, Boise, Idaho

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U.S. DEPARTMENT OF THE INTERIOR

PROTECTING AMERICA'S GREAT OUTDOORS AND POWERING OUR FUTURE

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# 1 PREFACE

The following Basis of Design Report (BDR) documents engineering and supporting calculations for the Barkley Bear Habitat Restoration Project 100% Design Drawings (Drawings) and Specifications. The Bureau of Reclamation (Reclamation) proposes to design and construct (with project partners) a salmonid habitat improvement project in the middle reach of the Methow River (and side channel) near Winthrop, Washington, in summer 2019 and summer 2020. The following report has been optimized to provide information vital to construction and builds upon the previous 30% and 80% design Drawings and Design Reports completed by Anchor QEA (Anchor QEA 2017, 2018). For more detailed information about the design process, design decisions, and background scientific information, refer to those reports.

## 1.1 NAME AND TITLES OF SPONSOR, FIRMS, AND INDIVIDUALS RESPONSIBLE FOR DESIGN

Sponsor: U.S. Department of the Interior, Bureau of Reclamation
Kira Christensen, PE, Project Manager
Jennifer Bountry, PE, Hydraulic Engineer

Design Firm: Anchor QEA, LLC
Tracy Drury, PE, Principal and Project Manager
Andy Brew, Hydraulic Engineer
Michael Gieschen, Hydraulic Engineer
Erik Pipkin, CAD and GIS Analyst

## 1.2 EXPLANATION AND BACKGROUND ON FISHERIES USE AND LIMITING FACTORS

The primary species of interest for the Barkley Bear Project are Endangered Species Act (ESA)-listed spring Chinook salmon (Endangered) and steelhead trout (Threatened), with summer Chinook salmon, bull trout (Threatened), and Pacific lamprey (U.S. Fish and Wildlife Service Species of Concern) as secondary species.

Surveys by the U.S. Geological Survey (USGS) showed two species of non-listed fish are dominant in the Middle Methow River (Martens et al. 2014). Mountain whitefish and sculpin species together accounting for about 95% of the fish production in main channel habitats (Bellmore 2011).

### LIMITING FACTORS

The Revised Biological Strategy to Protect and Restore Salmonid Habitat in the Upper Columbia Region (Biological Strategy) (RTT 2014) for recovery of salmon and steelhead identifies the following ecological concerns for the Middle Methow River Assessment Unit:

1. Channel structure and form (bed and channel form)
2. Channel structure and form (instream structural complexity)
3. Peripheral and transitional habitat (side channel and wetland connections)
4. Riparian condition (riparian condition and large wood recruitment)
5. Habitat quantity (anthropogenic barriers)
6. Food (altered primary productivity or prey species composition and diversity)
7. Species interaction (increased competition and predators)

This project is directed at addressing instream channel complexity, side channel and wetlands connections, peripheral and transitional habitats, riparian conditions, and food, within the framework of natural process.

## 1.3 LIST OF PRIMARY PROJECT FEATURES INCLUDING CONSTRUCTED OR NATURAL ELEMENTS

The goal of the Barkley Bear Project is to improve ecological function and improve instream, off-channel, riverine wetland, and riparian habitats for the benefit of freshwater life stages of ESA-listed spring Chinook Salmon, steelhead, bull trout, and Pacific lamprey.

The project employs a process-based, scientifically-informed restoration approach to address ecological concerns and habitat conditions believed to limit fish survival and production within the middle section of the Methow River, while acknowledging human constraints. The project was designed to support fish population resilience in the face of anticipated impacts due to climate change.

### PROJECT GOALS AND OBJECTIVES

Goal 1, Floodplain Function: Reconnect isolated floodplain areas and channel segments and restore habitat forming processes that maintain off-channel, floodplain, and riverine wetland habitats along the Methow River in order to support productive foodwebs and provide refuge habitat during high flows.

Goal 2, Riparian Structure and Function: Enhance, expand, and re-connect riparian and riverine wetland habitats to a more complex, diverse, and functional condition where they support processes that form and maintain fish habitat through wood recruitment, stream shading, providing food web resources, and supporting nutrient cycling.

Goal 3, Increase Habitat Complexity: Increase the availability, diversity, and complexity of stream habitat features (including streambed complexity, cover elements, temperature regimes, and flow dynamics) that promote fish growth and survival across a range of flows.

Goal 4, Aquatic Habitat: Increase the overall capacity of the project reach to support spring Chinook salmon, steelhead, bull trout, and Pacific lamprey by protecting and creating diverse, complex habitats that promote growth and survival of a range of life histories through their freshwater life stages.

Goal 5, Habitat Connectivity: Improve and or maintain connectivity between various habitats preferred by different life stages and at different times.

Goal 6, Climate Change Resilience: Support fish population resilience in the face of climate change to the extent possible.

## 1.4 PRIMARY PROJECT FEATURES

The project design incorporates several design features to address the above goals and limiting factors, listed below. These features are considered in three primary categories here and in the Specifications. Engineered Log Jam (ELJ) structures are generally structures that are supported by piles. Large Woody Debris (LWD) Structures are structures that are not supported by piles but instead are tied into trees or buried in banks according to the Drawings and Specifications. Finally, there are several areas of excavation, grading, and demolition throughout the site. Following is a brief list of project elements. More complete descriptions and feature information can be found in Section 3 of this report.

**Engineered Log Jam (ELJ) Structures**

- Island Apex ELJ (1)
- Bank Barb ELJs (3)
- Side Channel ELJs (3)
- Channel Barb ELJ (1)
- 70's Channel Pile ELJs (8)

**Large Woody Debris (LWD) Structures**

- Bank Complexity LWDs (2)
- Bear Creek Roughness LWD (1)
- 70's Channel Non-Pile LWDs (8)

**Primary Grading and Excavation Areas**

- Excavated Island Side Channel
- Floodplain Spoils Pile Grading and Canal Benching
- Floodplain Scallop Excavation and Grading
- Bear Creek Realignment
- Excavation, Removal, and Disposal of Levee and Levee Armoring
- Demolition and Removal of Existing Structures

## 2 EXISTING CONDITIONS, CONSTRAINTS, AND LIMITATIONS

### 2.1 PROJECT BACKGROUND AND LOCATION

The Barkley Bear Project is located between River Mile 49 and 50 on the Methow River in north central Washington (Figure 1). The project area includes the confluence with Bear Creek and the area around the upper-end of the Barkley Canal. The Barkley Canal is scheduled to be abandoned following the 2019 irrigation season when the canal company converts to an alternate diversion source located further downstream. Due to the need for the canal to continue to operate during the 2019 construction window, many project elements cannot be constructed until 2020 pending the discontinuance of canal operation in 2019. However, several project elements were determined to pose little to no risk to canal operations and will be constructed in 2019. Refer to the contract documentation for more information about construction timing of project elements.

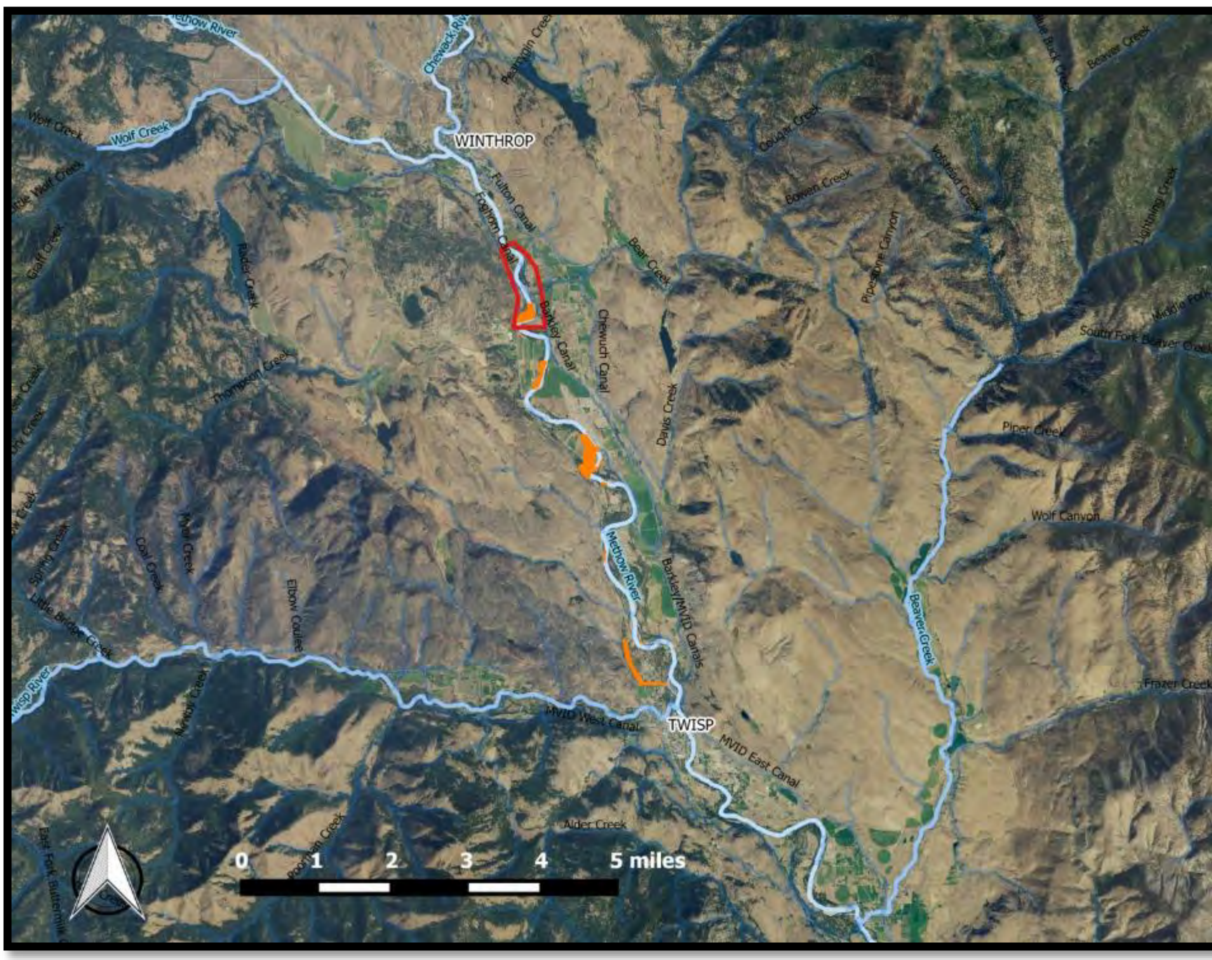


**Figure 1. The project is located on the Methow River between the towns of Twisp and Winthrop in Okanogan County, Washington.**

The project area includes the main channel of the Methow River, connected side channels, and the adjacent floodplain. The project is adjacent to the upper-end of the Whitefish Island Side Channel, the site of a habitat project constructed in 2012. The project area is near the upper-end of the Middle Methow Reach of the Methow River and is at a transition between the confined and moderately confined portions of the river.

## 2.2 DESCRIPTION OF IMPACTS ON CHANNEL, RIPARIAN, AND FLOODPLAIN CONDITIONS

### MAIN CHANNEL ALTERATIONS

Modifications to the river bottom, banks, and floodplain have taken place within the project area. The river bottom modifications include annual (until 2014) in-channel modification of bars and channel bottom to create a push-up diversion. Prior to 2014, the canal company used heavy equipment to build a push-up dam in the Methow River each year to maintain this diversion during low water. The push-up dam was typically built in July, and it generally washed away during the spring high flows.

Large riprap has been placed along the right bank of the channel through the project area to protect infrastructure along Witte Road and limit undesired bank erosion. At the downstream end of the project, an 800-foot-long levee has been constructed with riprap embedded on the waterward side of this feature.

### SIDE CHANNEL AND FLOODPLAIN ALTERATIONS

The dredging of sediment and clearing of large wood from floodplain areas has taken place through the Barkley Bear reach. Other anthropogenic modifications to the floodplain area over time have included clearing of riparian vegetation, and the addition of irrigation infrastructure including headgates, ditches, and fish screens.

Bear Creek has also been highly channelized in the downstream portion and currently flows into the Barkley Ditch before a portion of the flow is returned to the mainstem Methow River.

## 2.3 IDENTIFICATION OF RISK TO INFRASTRUCTURE OR EXISTING RESOURCES

The project includes an infrastructure removal element, including the removal of a headgate, screen, and spillway from the Barkley Canal and removal of riprap and lowering of the left bank levee (approximately 800 linear feet). The levee removal is located along the boundary of several properties; these landowners are fully supportive of the proposed restoration and the potential for left bank channel migration. Any migration that does occur will likely happen over the course of multiple years, after several large flood events have occurred.

All existing riprap along the right bank property (parcels 3421130045 and 3421123003) will remain in place or be returned to its original location after construction activities conclude. This project will not result in any increased risk to permanent structures because they are all located outside the floodplain through this site. Existing wells are located throughout the lower left bank floodplain but should not be impacted by the project.

## 2.4 SUBSTRATE INFORMATION

Basic sediment and substrate data were collected at the project site for design purposes. Ocular estimates and pebble counts across the wetted channel indicate that substrate within the project area is predominantly cobble and gravel with some areas of sand (Figures 2 and 3). The following substrate information is intended to provide background information on what may be encountered at the project site but does not guarantee any information on substrate. It should be noted that no samples were taken in the lower floodplain where much of the grading and excavation is proposed. It is unknown what exact soil conditions will be encountered in these areas, but it is expected to generally have a higher content of fines than the gradations shown in Figure 3.

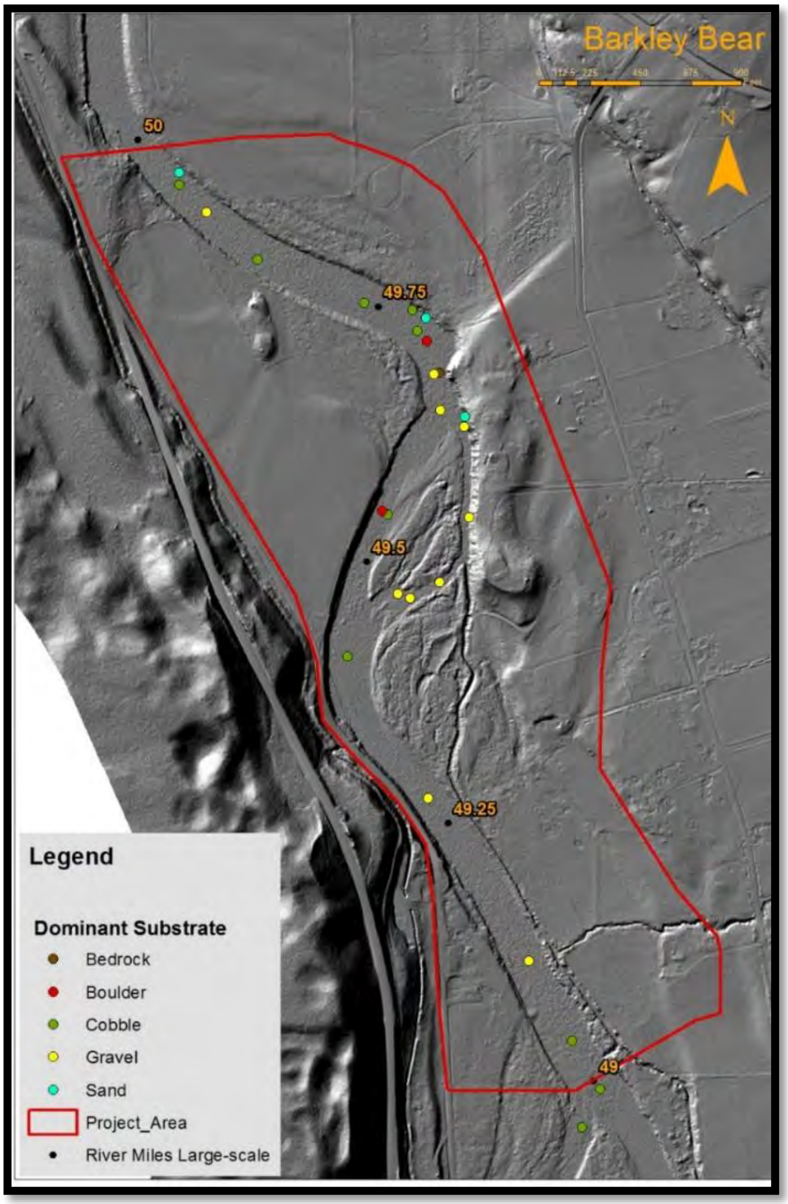


**Figure 2. Map of point data for pebble counts conducted within the project area.**

Boulders are present where the local gradient is steeper and higher water velocities result in increased transport capacity of the smaller material. Some of these larger rock pieces originate from failed riprap or push-up dam material that has fallen into the channel. Sand and finer material occur in low velocity regions, such as side channels and along the channel margin. Several locations within the channel also have visible bedrock outcrops along the bottom and banks as denoted above. Figure 3 shows the bed material gradation at two locations in the project area: main channel (blue) and side channel (red).

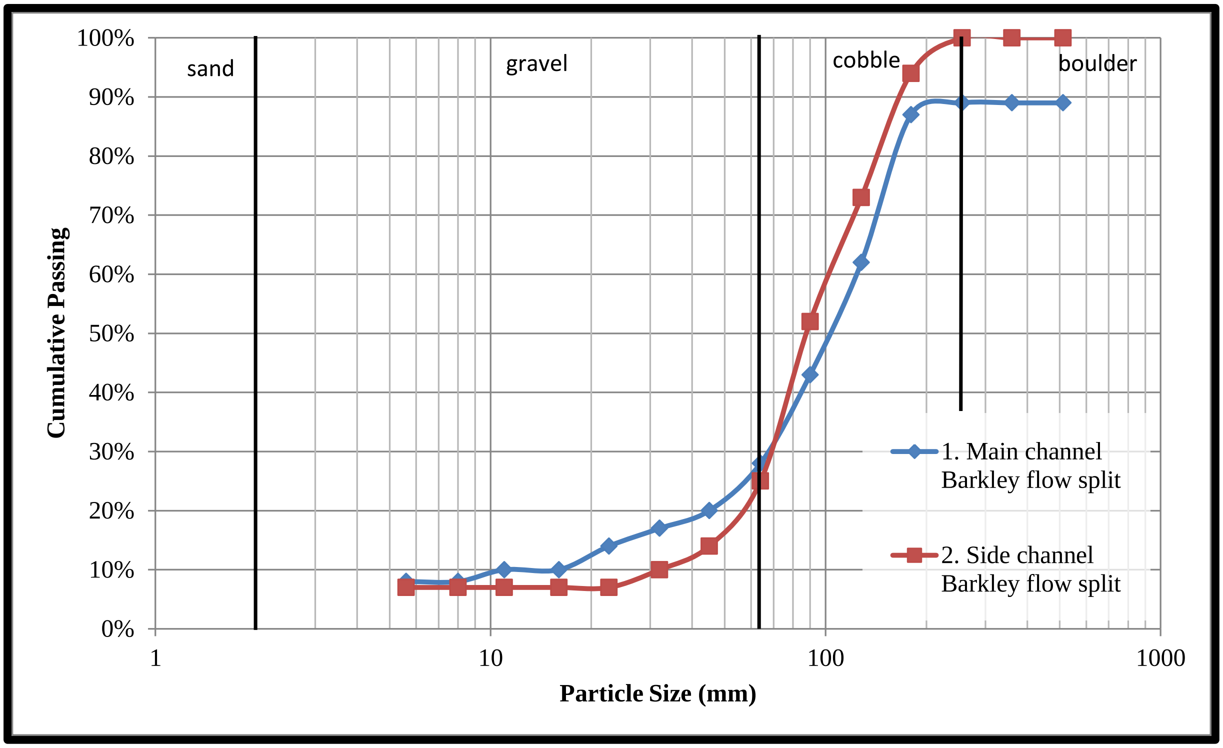


**Figure 3. Bed-material substrate analysis within Barkley Bear Reach. Data courtesy USGS, collected July 2015 by Bellmore and Benjamin.**

## 2.5 BEAR CREEK

### EXISTING CONDITIONS

Bear Creek has historically been highly modified within the project area. In its current form, Bear Creek runs through alluvium comprised of unconsolidated cobbles, sand, and gravel that form the historical Bear Creek alluvial fan. Cross section images were generated in GIS from the digital terrain model. The channel geometry ranges from approximately 2 to 3 feet deep and 2 to 3 feet wide at the top of the bank at its downstream end near Barkley ditch to approximately 5 feet deep and 20 feet wide at the top near the Lower Bear Creek Road crossing.

Figure 4 shows the existing alignment through the project area below Lower Bear Creek Road where it flows into the existing Barkley Canal. The average slope of Bear Creek in the project area below Lower Bear Creek Road is approximately 1.5%. Upstream of the road crossing, the slope is roughly 3.8%. This indicates that the lower end of Bear Creek is a depositional area.

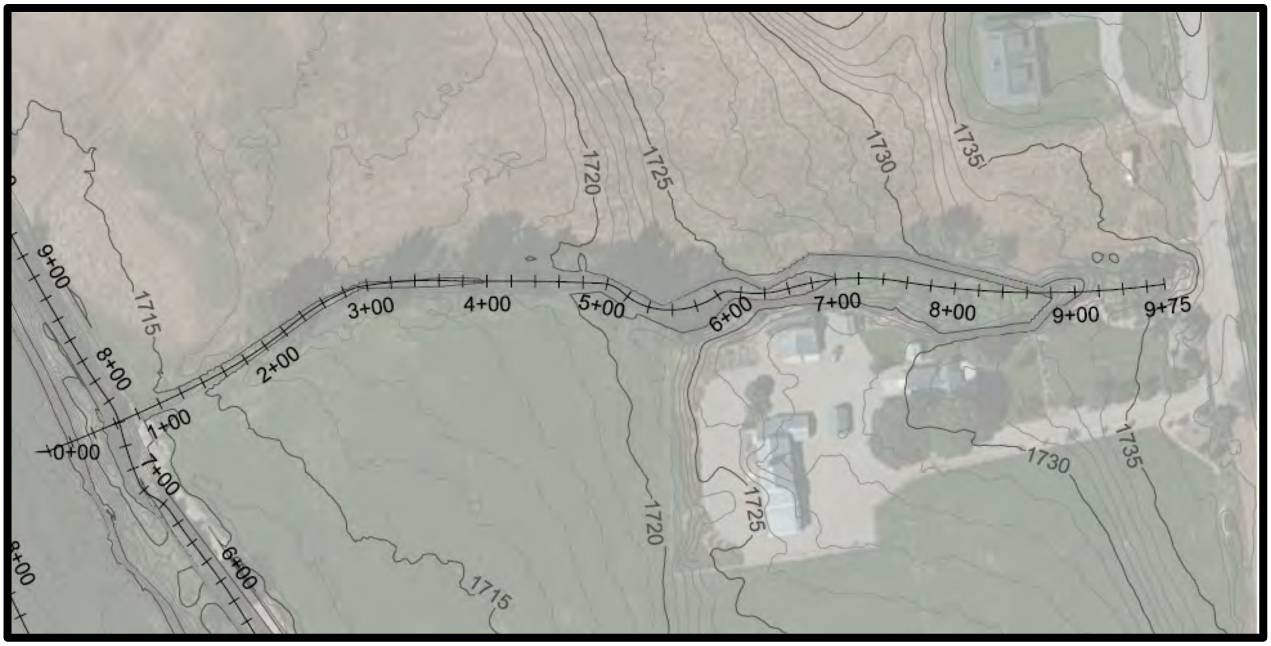


Figure 4. Plan view of the existing Lower Bear Creek alignment flowing into the Barkley Canal.

The proposed conditions will increase the length of the Bear Creek channel alignment and hydraulically reconnect it to the mainstem Methow River. This will result in a reduced slope, with the intent of promoting a more natural sediment continuity. Refer to Section 3 of this report as well as the Drawings and Specifications for more information on the proposed conditions for Bear Creek.

# 3 PROPOSED PROJECT ELEMENTS

## 3.1 DESIGN ELEMENT SUMMARY AND REFERENCE

Table 1 provides a reference to the project features, where they are located in the floodplain, where more information can be found, and a brief description of purpose. For more information about the project features, see the following detailed descriptions as well as the Drawings, Specifications, and Contract Documents.

**Table 1. Design Project Elements Summary.**

| Project Element | Location | Design Sheet Reference | Purpose |
|---|---|---|---|
| Island Apex ELJ (1) | Floodplain | Plan: Sheet 7<br>Details: Sheet 15 | Splits flow into the side channel to induce geomorphic change while promoting vegetative growth and stability of the existing forested island. |
| Bank Barb ELJs (3) | Mainstem | Plan: Sheet 7<br>Details: Sheet 18 | Breaks up high flows and redirects high velocities away from the right bank riprap, as well as provides hydraulic refugia and holding pool habitat. |
| Side Channel ELJs (3) | Floodplain | Plan: Sheet 7<br>Details: Sheet 16 | Promotes low flows to the canal side channel and diversifies flows during flood events, as well as creates off-channel pool and rearing habitat. |
| Channel Barb ELJ (1) | Mainstem | Plan: Sheet 9<br>Details: Sheet 19 | Creates high-flow peripheral refugia and improves fish access to Bear Creek as alcove habitat. |
| 70’s Channel Pile ELJs (8) | Floodplain | Plan: Sheet 7<br>Details: Sheet 14 | Improves floodplain roughness and habitat complexity and improves side channel complexity. |
| Bank Complexity LWDs (2) | Floodplain | Plan: Sheet 7<br>Details: Sheet 17 | Improves habitat of perennial side channel and improves floodplain connectivity through a range of flows. Helps prevent avulsion of side channel back to the mainstem. |
| Bear Creek Roughness LWD (1) | Bear Creek | Plan: Sheet 9<br>Details: Sheet 13 | Improves roughness in meander bend of new Bear Creek alignment and limits undesired channel migration. |
| 70’s Channel Non-Pile LWDs (8) | Floodplain | Plan: Sheet 7<br>Details: Sheet 14 | Improves floodplain roughness and habitat complexity and improves side channel complexity. |
| Excavated Island Side Channel | Floodplain | Plan: Sheet 7<br>Profile: Sheet 10 | Promotes low flows to the side channel. |
| Floodplain Spoils Pile Grading and Canal Benching | Floodplain | Plan: Sheet 7<br>Sections: Sheet 10 | Removes anthropogenic impacts, improves floodplain connectivity, and promotes side channel and floodplain habitat. |

| Project Element | Location | Design Sheet Reference | Purpose |
|---|---|---|---|
| Floodplain Scallop Excavation and Grading | Floodplain | Plan: Sheet 8<br>Profile and Sections: Sheet 11<br>Details: Sheet 14 | Promotes riparian development at anticipated stream margin projected at 5 to 10 years based on potential channel migration. Improves side channel and floodplain habitat conditions. |
| Bear Creek Realignment | Bear Creek | Plan: Sheet 9<br>Profile: Sheet 12<br>Sections: Sheet 13 | Reconnects Bear Creek with the mainstem to allow natural sediment transport processes to occur. Improves upstream connection for fish and provides high-flow refugia. |
| Excavation, Removal, and Disposal of Levee and Levee Armoring | Floodplain | Plan: Sheet 8<br>Sections: Sheet 11 | Reduces channel confinement, improves floodplain connectivity, and promotes natural geomorphic processes (i.e., channel migration). |
| Demolition and Removal of Existing Structures | Floodplain | Plan: Sheet 6 | Removes anthropogenic features from the floodplain, and allows flows to access the floodplain at a range of flow conditions. |

Notes:
ELJ: Engineered Log Jam
LWD: Large Woody Debris

## 3.2 DESIGN ELEMENT DETAILED DESCRIPTION

The following overview of the main components of the project is intended to provide background knowledge and understanding to the design and construction of the project elements. Complete project requirements and details for construction of the various elements can be found in the Drawings, Specifications, and Contract Documents, referenced in Table 1.

### ENGINEERED LOG JAM STRUCTURES

ELJ structures are defined for this project as structures consisting of rootwad logs and log poles that are pile supported for stability.

#### ISLAND APEX ELJ (1)

The Island Apex ELJ structure will be placed at the head of Barkley Island (see Drawings, Sheet 7) to create a roughened feature that protects the island and splits high flows to create channel diversity. This structure is designed to interact with the project element "Excavated Island Side Channel" and suggested to be constructed in tandem with that element. Due to the uncertain exact parameters of the side channel, banks of the island, and location of trees on the island, this structure will require some flexibility in construction. It is likely that piles will need to be placed first to pin the initial layers to the bank of the island. The Island Apex ELJ will consist of 15 logs and 6 piles and will be 6 layers high. The rootwad logs will consist of two size classes: 25 feet in length, and 30 feet in length, both with an 18-inch diameter. The log poles will be one size class: 30 feet in length, with an 18-inch diameter. Details for this structure can be found on Sheet 15 of the Design Drawings.

The primary future function of the Island Apex ELJ is to remain in place and promote further development and vegetative growth on the forested island behind it. Additional expectations span a range of outcomes that would be considered acceptable and all of which may occur throughout the lifespan of the structure and include:

- Promoting split flows during a large portion or all of the yearly hydrograph
- Promoting split flow at common high-flow events (1-year to 2-year)
- Creating and maintaining functional pool habitat at the head of the island
- Storing mobile wood and extending the island feature upstream

As described above, all of these outcomes may occur over the lifetime of the structure, although it is expected that not all will occur annually. This expected dynamism is considered successful and will promote the goals of this project. Adaptive management or maintenance should be considered if the structure loses structural integrity or becomes disconnected at the 5-year event.

### BANK BARB ELJ (3)

The Bank Barb ELJ structures will be located on the right bank of the mainstem near the upstream end of the project (see Drawings, Sheet 7). These structures are intended to provide hydraulic refugia while breaking up high-flow velocities along the existing right bank riprap. These structures were designed to "key in" to the large rock on the bank for a portion of its stability and therefore some moving and rearranging of riprap will be necessary and incidental to the construction of this structure. This structure will be built partially in the wetted channel and will require extensive water control. It is recommended that this structure be built with a layer-by-layer process around the piles, making the designed connection as it is built. This structure will partially rely on ballast to provide stability in addition to the piles. Refer to the Drawings for details on when to add ballast to the interior of the structure. The upstream edge of the structure has been designed with additional log poles to act as "bumper logs" to improve boater safety, allowing river users to deflect off the structure if they are routed toward the structure. The Bank Barb ELJ structures will consist of 27 logs and 8 layers and will be supported with 14 piles and 250 cubic feet of ballast. The rootwad logs will consist of one size class: 40 feet in length with an 18-inch diameter. The log poles will consist of one size class: 40 feet in length with an 18-inch diameter. The piles will be of pile grade timber and of one size class: 35 feet in length with an 18-inch diameter. Details for this structure can be found on Sheet 18 of the Design Drawings.

The expected future function of the Bank Barb ELJ project element is to provide hydraulic refugia and habitat for the focal species and create roughness along the armored right bank of the active main channel for juvenile and adult holding. These results will promote conditions consistent with the goals of the project and should be considered a success. The effects of these features are expected to be local to the structures and they are not anticipated to provide any reach-scale effects. Local pool development is expected; however, the magnitude and duration of pool development may be variable based on upstream conditions and the approach angle of river flow impacting the structures. Should these structures lose structural integrity, adaptive management or maintenance measures should be considered. It should be noted that these structures will not be built as part of the current implementation plan for this project.

### SIDE CHANNEL ELJ (3)

The Side Channel ELJ structures will be built in the existing side channel downstream of the head gate for the existing Barkley Canal diversion (see Drawings, Sheet 7). These structures are intended to maintain pool habitat through the existing side channel, as well as promote geomorphic change on the floodplain and island. It is likely that the side channel will be wetted at the time of construction and therefore these structures will require some form of water control and/or diversion. It is recommended that this structure be built with a layer-by-layer process around the piles, making the designed connection as it is built. The Side Channel ELJs will consist of 14 logs and 5 layers and will be supported by 8 timber pilings. The rootwad logs will consist of two size classes: 20 feet in length with an 18-inch diameter and 30 feet in length with a 24-inch diameter. The log poles will consist of one size class: 20 feet in length with an 18-inch diameter. Details for this structure can be found on Sheet 16 of the Design Drawings.

The primary future functions of the Side Channel ELJs are to promote pool formation and split flows within the wetted side channel. In addition, they may promote geomorphic change on the floodplain by helping promote high flows through the floodplain. It is possible these structures will not be connected at low-flow events as the channel shifts through time, but connection at common high-flow events (1-year or 2-year) will still provide benefits consistent with the goals of this project. Adaptive management or maintenance should be considered if these structures lose structural integrity or become disconnected at the 5-year event.

### CHANNEL BARB ELJ (1)

The Channel Barb ELJ structure will be located at the downstream end of the project on the left bank of the main channel (see Drawings, Sheet 9). The structure will be upstream of the outlet of the proposed Bear Creek realignment and is intended to provide hydraulic refuge for fish to use Bear Creek as an alcove during high flows in addition to holding pool habitat during migration periods. This structure will be built partially in the wetted channel and will require water control. It is recommended that this structure be built with a layer-by-layer process around the piles, making the designed connection as it is built. Some of the logs on the top layers are intended to tie into trees on the bank and some maneuvering and flexibility of construction will be necessary for construction of these structures. The Channel Barb ELJ structure will consist of 12 logs and 6 layers and will be supported with 10 piles. The rootwad logs will consist of three size classes: 30 feet in length with an 18-inch diameter, 30 feet in length with a 24-inch diameter, and 20 feet in length with a 24-inch diameter. The piles will be of pile grade timber and of one size class: 35 feet in length with an 18-inch diameter. Details for this structure can be found on Sheet 19 of the Design Drawings.

The expected future function of the Channel Barb ELJ project element is to provide hydraulic refugia and habitat for the focal species and provide the opportunity for focal species to access Bear Creek during high-flow events. These results will promote conditions consistent with the goals of the project and should be considered a success. However, should this structure ever lose structural integrity, adaptive management or maintenance measures should be considered.

### 70’s CHANNEL ELJ STRUCTURES (8)

The 70’s channel ELJ structures are located in the abandoned channel between the main channel and the existing side channel referred to here and on the Drawings as the “70’s channel” (see

Drawings, Sheet 7), due to the main channel historically occupying this area during the 1970s. This channel is inundated during high flows and may be inundated more often after the completion of this project. These structures are intended to provide habitat, complexity and refugia to this area, as well as force pool scour and minor geomorphic change. Due to the existence of poorly defined parameters such as bank steepness and vegetation locations, as well as the small and easy to construct nature of these structures, they will be constructed at locations designated in the field by the Engineer or Owner. All locations will be within the area designated on the Drawings.

There are two versions of this structure; the ELJ version will consist of 1 or 2 rootwad logs supported by 2 piles, with the rootwad logs connected and partially buried (see Drawings, Sheet 14 for more details. The process of placing these logs may require some excavation and backfill.

The expected future function of the 70's channel ELJs project element is to provide roughness within the 70's channel and promote wood accumulation, pool formation, and geomorphic change on the floodplain and in the area of the 70's channel. It is possible these structures will not be connected at low-flow events, but connection at common high-flow events (1-year or 2-year) will still provide benefits consistent with the goals of this project.

## LARGE WOODY DEBRIS STRUCTURES

LWD structures are defined for this project as structures consisting of rootwad logs and log poles that are not pile supported but instead rely on existing trees, rocks, or being buried in banks for stability.

### BANK COMPLEXITY LWD (2)

The Bank Complexity LWD structures are located on either side of the downstream end of the existing side channel, in close proximity to both the 70's channel features and the Side Channel ELJs. The purpose of this structure, similar to the Side Channel ELJs, is to provide habitat, complexity, and refugia in the existing side channel as well as force localized geomorphic change. These structures will be constructed by weaving layers of logs through known stands of mature vegetation in the area. The exact configuration of each layer is not precise and will be determined by the Owner or Engineer in the field. These structures will involve 4 connections each to better tie them in into existing trees; the locations of these connections will be determined in the field. The bank complexity ELJ will consist of 11 logs and 6 layers. The rootwad logs will consist of one size class: 30 feet in length with an 18-inch diameter. The log poles will consist of one size class: 30 feet in length with an 18-inch diameter. The structure will be 30 feet long, 30 feet wide, and 9 feet high.

The primary future function of the Bank Complexity LWDs is to provide roughness and hydraulic refugia on the floodplain and in the side channel. It is possible these structures will not be connected at low-flow events, but connection at common high-flow events (1-year or 2-year) will still provide benefits consistent with the goals of this project. These structures are not pile support and will have minimal connections to best simulate a natural log jam. It is expected that these structures will change shape and structural cohesion over the course of their life.

### 70's CHANNEL LWD STRUCTURES (8)

The 70's channel ELJ structures are located in the abandoned channel between the main channel and the existing side channel referred to here and on the drawings as the "70's channel" (see Drawings, Sheet 7), due to the main channel historically occupying this area during the 1970s. This channel is inundated during high flows and may be inundated more often after the completion of this project. These structures are intended to provide habitat, complexity, and refugia to this area, as well as force pool scour and minor geomorphic change. Due to the existence of poorly defined parameters such as bank steepness and vegetation locations, as well as the small and easy to construct nature of these structures, they will be constructed at locations designated in the field by the Engineer or Owner. All locations will be within the area designated on the Drawings.

There are two versions of this structure; the LWD version will consist of 1 or 2 rootwad logs threaded through the trees at the direction of the Owner or Engineer (see Drawings, Sheet 14 for more details). The process of placing these logs may require some excavation and backfill.

The expected future function of the 70's channel LWDs project element is to provide roughness within the 70's channel and promote pool formation, wood accumulation, and geomorphic change on the floodplain and in the area of the 70's channel. It is possible these structures will not be connected at low-flow events, but connection at common high-flow events (1-year or 2-year) will still provide benefits consistent with the goals of this project. These structures are not pile supported and will have minimal connections to best simulate natural wood in the channel. It is expected that these structures may shift or become unburied over the course of their life.

### BEAR CREEK ROUGHNESS LWD (1)

The Bear Creek roughness LWD structure is located on the first major meander bend on the new Bear Creek alignment (see Drawings, Sheet 9). This structure is intended to provide stability to the meander bend as well as provide refugia and habitat for any fish seeking to use Bear Creek. This structure will require excavation into the bank of the new alignment, where the two layers of intersecting rootwad logs will be placed. The area will then be backfilled to the grades and alignment shown on the Drawings. This structure will use 12 rootwad logs that are 30 feet in length with an 18-inch diameter (see Drawings, Sheet 13 for more details).

This structure is expected to provide stability and prevent excess channel migration at the new major bend to Bear Creek. Some erosion around the structure is possible, but the expected function of this structure is to prevent migration erosion or avulsion while providing habitat and hydraulic refugia. Adaptive management or maintenance should be considered if the channel incises to the point that this structure is no longer engaged, or migrates to the point of causing structural instability to the roughness LWD structure.

## EXCAVATION, GRADING, AND DEMOLITION

The below are the primary areas involving excavation grading and demolition; however, other small and incidental areas of grading and excavation may be required to construct the project. Refer to the Drawings and Specification for more details.

## EXCAVATED ISLAND SIDE CHANNEL

This excavation area is located at the upstream end of the project between the main channel and existing side channel (see Drawings, Sheet 7). The purpose is to create a low-flow path to provide additional water to the side channel. Because most of the excavation area is located on the dry Barkley Island, necessary water control will be limited. This channel cut is intended to pass directly in front of the Island Apex ELJ and therefore close coordination between the construction of these two features will be necessary. The side channel will be a 30-foot-wide box cut, tapering to 20 feet excavated through Barkley Island.

This project element is expected to provide a low-flow path to the side channel, floodplain, and canal on a temporary basis. As with other project elements, there are a range of acceptable outcomes for this structure. At the most ideal end of the spectrum this excavation will promote enough scour and material transport to allow frequent low flows into the side channel and floodplain. However, without any upstream structures to promote this change, it is possible that this channel will fill in with sediment and no longer provide low flows to the side channel, in which case adaptive management and maintenance measures should be considered.

## FLOODPLAIN SPOILS PILE GRADING AND CANAL BENCHING

This excavation area is located at the beginning (upstream end) of the Barkley Canal behind the existing headgate (see Drawings, Sheet 7). In the past, these materials were likely mechanically removed to maintain function of the Barkley Canal and have created artificial berms in the floodplain, hindering connectivity. Additionally, a bench cut at the upper end of the canal along with sloped grading in the floodplain will be excavated to help prevent wood from clogging the canal and promote flow onto the floodplain. The final grade has been designed in such a way as to allow flood flows to slowly recede from the floodplain after inundation. These materials will be excavated and placed in the locations identified on the Drawings.

As part of the completion of this project element, the area to be graded will be stripped of vegetation. Large trees will be removed with intact rootwads and saved for use on the project. This project element will also include the placement of several rootwad logs at locations along the canal or grading area at the direction of the Owner or Engineer. These will be either placed in excavated areas in the banks or threaded through existing trees, with rootwad logs overhanging into the canal. This project element will be constructed in the canal and some water control will be necessary for construction.

The expectation for this project element is to provide a floodplain area that will trap wood material transported during high flows before entering the canal and drain slowly and evenly as flood flows recede. Adaptive management or maintenance measures should be considered if large woody material clogs the canal downstream of this area, or if depressions begin to form that pose a danger to stranding fish.

## FLOODPLAIN SCALLOP EXCAVATION AND GRADING

A floodplain scallop area will be excavated along the lower left bank floodplain and tie into the existing canal (see Drawings, Sheet 8). This feature is intended to establish riparian vegetation after levee removal in an area where future channel migration is anticipated. This will provide streambank habitat and slow the speed of any additional lateral migration. The swale will alternate between a steep cut (approximately 1:1) along the waterward side and a similar steep cut on the upland side several times along the profile. The opposite bank will be gently graded at 10:1 slopes to create the “scalloping” effect. There will be brief overlaps of 1:1 slopes on both banks to constrict and backwater flow. A short length of the canal will also be filled as part of this project element; this fill will include large woody material and rootwad logs removed from other parts of the project buried in the fill. The excess excavated material from this project element will be excavated, stockpiled, and placed in the locations identified on the Drawings.

As a part of the completion of this project element, rootwad logs will be placed into the banks with over hanging rootwad at various locations at the direction of the Owner or Engineer. Some minor excavation may be associated with the installation of these rootwad logs.

This project element is expected to change over time and provide different habitat and ecosystem benefits as it changes. After construction the “pinch points” of narrow channel section will backwater flow in the scallop sections and create and inundated floodplain, allowing vegetation to establish. Over time and with higher flows, these pinch points are expected to erode and form a natural channel form. This project element is expected to function in conjunction with the levee removal and is expected to at some point be connected laterally to the Methow River, forming a complex riparian area. Some expansion of the scallops may occur, resulting in a floodplain bench area that will provide additional opportunity for vegetation colonization and development. Some head cutting through this area is possible and would likely not pose a risk to the benefits this project element provides. However, adaptive management or maintenance measures should be considered if head cutting or channel migration in the scallop begin to move towards the Bear Creek alignment.

### BEAR CREEK REALIGNMENT

Bear Creek, which currently flows into the Barkley Canal, is located on the left bank of the downstream end of the project and will be realigned to increase overall length and reconnect with the main channel (see Drawings, Sheet 9). The existing Bear Creek alignment will be discontinued and filled. This discontinuation will involve filling the abandoned portion of Bear Creek with on-site material and burying woody debris from other portions of the project in the fill. Additionally, any large diameter trees in the existing Bear Creek will remain and be partially buried. A new channel will be excavated along the alignment and Bear Creek will be reconnected to the main channel. This will allow for more natural sediment transport processes to occur and allow the Methow River to absorb high sediment loads. This feature will also function as alcove habitat when the Methow River is up during the late spring. The new alignment will be configured using a 580-foot-long alignment at a 1.54% slope, beginning 715 feet downstream of the culvert under Lower Bear Creek Road. The channel bottom will be 5 feet wide with an inset floodplain 5 feet wide on either bank. This element will be constructed in conjunction with the Bear Creek Roughness LWD structure, and coordination between these two elements will be necessary.

This project element is expected to provide a relatively static alignment for Bear Creek to return to the Methow River. Migration of the thalweg within the alignment of the inset floodplain is expected to some degree along with minor bank erosion as the creek processes sediment from upstream. Migration of the exact point Bear Creek flows into the Methow River is also expected and likely beneficial to the project goals. Adaptive management or maintenance measures should be considered if channel migration occurs which threatens to significantly shorten the Bear Creek alignment (such as into the scallop area or through the floodplain to the Methow River at the major bend).

### EXCAVATION, REMOVAL, AND DISPOSAL OF LEVEE AND LEVEE ARMORING

Existing riprap along approximately 800 feet of the lower left bank of the main channel will be removed and disposed of off site. See the Drawings, Sheet 8, and the Contract Documents for more details on the extents of this riprap. The existing riprap was installed on an existing levee constructed of floodplain spoils. Along the majority of the length of riprap removal, this levee of floodplain material will also be excavated down to the elevation of the canal behind the levee, leaving a floodplain bench. At the location where the scallop reconnects with the main channel, the levee excavation will end and instead the canal behind the levee will be filled to the floodplain elevation. This backfill will continue to the point of the demolished and removed fish screen structure, shown on the Drawings. Finally, as part of this project element, canal spoils that have been placed next to the canal on the floodplain will be moved and dispersed to an on-site location designated on the Drawings.

Armoring and levee removal is expected to allow the Methow River to migrate into the scallop area to some degree on the left bank. This kind of major geomorphic change may take years to develop and so should not be expected immediately. The canal fill is expected to redirect canal flow into the scallop area; however, during high-flow events it is expected that canal flows will overtop and “short cut” into the Methow River. Adaptative management and maintenance measures in this area should only be considered if no flow event at high-flow events reaches the scallop area.

### DEMOLITION AND REMOVAL OF EXISTING STRUCTURES

This project element involves the demolition and removal of three concrete structures associated with the discontinued canal. At the time of construction, all metal components to the structures will have been removed leaving only the concrete demolition and removal for this project element.

The first structure is the concrete head gate at the upstream end of the Barkley Canal. The additional riprap around this structure will also be removed as part of this project element. The second structure is the concrete overflow structure, which will be demolished, removed, and backfilled as part of this project element. Finally, the fish screen structure at the downstream end of the canal will be demolished, removed, and backfilled. This structure is associated with a buried fish return pipe that will be removed and backfilled. All demolished material for this element with be disposed of off site. All backfill material will be from on-site excavation.

## 3.3 DESCRIPTION OF DISTURBANCE TIMING AND AERIAL EXTENT

Table 2 summarizes the extent and potential impact of each project element type. All construction will occur during summer or early fall depending on in-water work periods. Each element is also classified as being or not being in-water work.

**Table 2. Project element disturbance timing.**

| Project Element | Timing | In-Water Work | Extent | Potential Impacts |
|---|---|---|---|---|
| Island Apex ELJ | July to August | No | Structure Footprint (Approx. 3,000 SF) | Riparian Disturbance |
| Bank Barb ELJs | July to August | Yes | Structure Footprint (Approx. 3,500 SF) | Mainstem Channel, Right Bank Riprap, Pile Driving |
| Side Channel ELJs | July to August | No | Structure Footprint (Approx. 4,000 SF) | Pile Driving |
| Channel Barb ELJ | July to August | Yes | Structure Footprint (Approx. 2,000 SF) | Mainstem Channel, Pile Driving |
| 70's Channel ELJ/LWD | July to August | No | Structure Footprint (Approx. 450 LF) | Floodplain Material |
| Bank Complexity LWD | July to August | No | Structure Footprint (Approx. 1,000 SF) | Riparian Disturbance |
| Bear Creek Roughness | July to August | No | Structure Footprint (Approx. 60 LF) | Floodplain Material |
| Excavated Island Side Channel | July to August | Yes | Channel Footprint (Approx. 1,700 CY) | Floodplain Material |
| Floodplain Spoils Pile Grading and Canal Benching | July to August | No | Identified footprint in floodplain (Approx. 3,600 CY) | Floodplain Material |
| Bear Creek Realignment | July to August | Yes | Channel Realignment (Approx. 600 LF) | Bear Creek Channel/ Floodplain |
| Excavation, Removal, and Disposal of Levee and Levee Armoring | July to August | Yes | Riprap removal extent (Approx. 800 LF) | Levee Material and Riprap |
| Floodplain Scallop Excavation and Grading | July to August | No | Identified footprint in floodplain (Approx. 3,600 CY) | Floodplain Material |
| 70's Channel ELJ/LWD | July to August | No | Structure Footprint (Approx. 450 LF) | Floodplain Material |
| Demolition of Existing Structures | July to August | No | Total Footprint (Approx. 2,500 SF) | Floodplain Material |

Notes:
CY: cubic yard
LF: linear foot
SF: square foot

## 3.4 LIST OF ALL PROPOSED PROJECT MATERIALS AND QUANTITIES

A list of proposed materials and quantities can be found on Sheet 2 of the Design Drawings. An opinion of probable construction costs can be found in Appendix 6.2.

# 4 HYDROLOGIC AND HYDRAULIC DESIGN

The following section provides a summary of the design process. This information only represents the background behind the design. More detailed information about design process decisions can be found in the 30% and 80% iterations of this report (Anchor QEA 2017, 2018).

## 4.1 SUMMARY OF SITE SURVEY INFORMATION AVAILABLE FOR DESIGN

### SURVEY AND OTHER TOPOGRAPHIC DATA

- 2006 LiDAR Data Set
- 2015 LiDAR Data Set
- 2016 Surveys by Reclamation of Barkley Canal and Bear Creek
- 2017 Survey by Reclamation at upstream end of the project

## 4.2 SUMMARY OF HYDROLOGIC ANALYSES

Flow statistics were drawn from the 2015 USGS report on simulated runoff and stream locations in the Methow River Basin (Mastin 2015). Additionally, an annual peak flow analysis performed by Reclamation using data from the USGS gage 12448500 in Winthrop was used to develop the peak flows used in design.

### FLOWS SELECTED FOR NUMERICAL MODEL ANALYSIS

A range of flows were selected that represent hydraulics throughout the annual hydrograph in the Methow River, ranging from 133 cfs to the 100-year flood of 30,100 cfs. These flows represent key discharges important to evaluate habitat metrics within a trophic model and a habitat suitability index analysis. Two historical flood events were also simulated that are larger than the 100-year flood. Model results for proposed conditions were utilized to evaluate how effectively each proposed alternative met the identified project goals and objectives or was used in the design evaluation of various project elements.

### FLOWS SELECTED FOR HYDRAULIC DESIGN

From the range of flows evaluated using the hydraulic model, six priority flows were selected for hydraulic design (Table 3). The 10-year and 100-year flows were used to develop scour and stability calculations discussed in the following sections. The 2-year flow was used in the sediment transport analysis as well as to inform on the shear stress around proposed features. The remaining flows were used to evaluate the design's ability to meet the habitat and geomorphic goals of the project.

**Table 3. List of flows used for hydraulic design.**

| Discharge | Event | Project Goal, Objective, or Evaluation Purpose |
|---|---|---|
| 291 cfs | 30% Non-Exceedance | Low-Flow Habitat Connectivity |
| 2,000 cfs | < 1-year | Floodplain Function, Habitat Connectivity |
| 3,600 cfs | 1-year | Floodplain Function, Habitat Connectivity |
| 6,000 cfs | ~1.5-year | Floodplain Function, Habitat Connectivity |
| 9,800 cfs | 2-year | Floodplain Function, Habitat Connectivity, Shear Stress and Sediment Transport Evaluation |

| Discharge | Event | Project Goal, Objective, or Evaluation Purpose |
|---|---|---|
| 17,900 cfs | 10-year | Scour and Stability of Select ELJs |
| 30,100 cfs | 100-year | Scour and Stability of Select ELJs |

Note:
cfs: cubic feet per second

## 4.3 HYDRAULIC ANALYSES

The design analyses completed for the proposed structures include scour, stability, buried large woody material stability analyses, and river user safety. Forces considered in these analyses include structure and log buoyancy, structure and log weight, upstream and downstream hydrostatic forces, friction, velocity, drag, ballast, and the resisting forces of the substrate. These design calculations were used to set pile depths and to determine the stability of each of the structures and the resulting factors of safety that apply to the structure. The factor of safety can generally be defined as a ratio of the structure's ultimate strength to the actual applied load.

### SCOUR ANALYSIS

Bed scour for the pile-supported Bank Barb, Channel Barb, Side Channel ELJ, and the LWD in Bear Creek was estimated using an equation originally presented by Liu et al. (1961) for scour at bridge abutments. This equation has since been recommended by others, including Drury (1999), for use in calculating scour at ELJs located along the edge of a channel or supported by timber pilings. The equation relates flow conditions (i.e., flow depth and velocity), obstruction dimensions, and Froude number to maximum scour depth below existing grade. Approach velocity, water depth, and Froude number were obtained from the hydraulic outputs from the Reclamation 2D steady-state model.

Bed scour at the 70's channel features and placed single rootwad logs were not estimated to a specific flow depth. These structures will be structurally dependent on the trees they are anchored around and are designed as transient structures and may not be static during various flow conditions.

Results of this analysis were used to determine the maximum probable depths of bed scour that could potentially undercut the structures. However, footprint elevations were determined based on both scour estimates and professional judgment.

#### SCOUR EQUATION (LIU ET AL. 1961)

The Liu et al. (1961) scour equation was selected for all features supported by timber pilings. This equation was originally intended to estimate scour at abutments where the groins are placed perpendicular to the flow. The equation was developed from laboratory tests in a flume and prototype measurements and was subsequently verified with field experiments. Results of the study indicated that the contraction ratio and approach flow depths are the critical parameters. This equation is recommended when the ratio of effective length ($L_e$) of the ELJ protruding into the flow divided by the upstream hydraulic depth ($d_1$) is less than 25.

$$d_s = 1.1 \times \frac{L_e}{d_1}^{0.4} \times Fr^{0.33} \times d_1 \quad (1)$$

where:
$d_s$ = scour depth (predicted)
$L_e$ = length (effective)
$d_1$ = upstream hydraulic depth
$Fr$ = Froude number (dimensionless number), where

$$Fr = \frac{V}{\sqrt{g \times d}} \quad (2)$$

$V$ = flow velocity
$g$ = gravitational acceleration
$d$ = flow depth

## RESULTS

The maximum probable scour was estimated for the Bank Barb and Channel Barb over a range of flows up to the 100-year event. The maximum probable scour was estimated for the Bank Barb ELJs, Side Channel ELJs, Island Apex ELJs, Bear Creek Roughness LWDs, and Bank Complexity LWDs over a range of flows up to the 10-year event. All ELJ type structures are designed to be pile supported only and therefore will not be embedded significantly into the channel bed. For the ELJ type structures, the piles are embedded into the channel bed to a depth below the probable maximum scour depth for their design flow event. Table 4 shows the probable scour depths based on both the results of this analysis and professional judgment. Additional information related to the calculation of these values can be seen in Appendix 6.3.

**Table 4. Probable maximum scour depths for the proposed ELJs.**

| ELJ | Flow Event | Equation | Scour Depth (feet)[1] |
|---|---|---|---|
| Bank Barb ELJs[1] | 100-year | Liu et al. 1961 | 13.9[2] |
| Channel Barb ELJ | 100-year | Liu et al. 1961 | 11.8[2] |
| Island Apex ELJ | 10-year | Liu et al. 1961 | 11.1[3] |
| Side Channel ELJ[1] | 10-year | Liu et al. 1961 | 9.4 |
| Bank Complexity LWD[1] | 10-year | Liu et al. 1961 | 7.8[3] |
| Bear Creek Roughness LWD | 10-year | Liu et al. 1961 | 2.5 |

Notes:
1. Results are reported for the feature or structure location with the highest calculated scour depth (for that feature or structure). A common structure design was used even though scour may be less at other locations.
2. This structure is pile supported; therefore, the pilings will be embedded below max scour depth, rather than the structure bottom.
3. This structure is partially or entirely supported by existing trees.

ELJ: engineered log jam – pile supported
LWD: large woody debris – not pile supported

## STABILITY ANALYSIS

A structural stability analysis has been performed for each structure type to make sure each element is properly stabilized such that it will counteract hydraulic sliding and uplift forces for its peak design flow. Table 5 presents each structure type, the designed event for the feature, and how it will be stabilized to counteract hydraulic forces.

**Table 5. Peak design flow for stability of the proposed ELJs.**

| ELJ | Flow Event | Stabilization Technique |
|---|---|---|
| Side Channel ELJ | 10-year | Pile Supported |
| Bank Complexity LWD | N/A | Naturally Supported[1] |
| Bank Barb ELJ | 100-year | Pile Supported[2] |
| Channel Barb ELJ | 100-year | Pile Supported |
| Island Apex ELJ | 10-year | Pile Supported[3] |
| Bear Creek Roughness LWD | 5-year | Soil Ballasted |

Notes:

1. Pile supported using existing large trees, not analyzed for pile stability
2. Supported using a combination of ballast and piles.
3. Supported using a combination of trees and piles, not analyzed for pile stability

ELJ: engineered log jam

LWD: large woody debris

### PILE-SUPPORTED STRUCTURES

Pile stability analyses were completed for all proposed pile-supported structures. The pile stability analyses examined the size of the structure, the number of log piles, the depth of the log piles, and the hydraulic load applied to the structure. The number of log piles needed for each structure is based on the structure length and width (structure geometry) and the hydraulic load applied to the structure. The hydraulic load is transferred from the above grade rootwad logs to the log piles.

Pile-supported structures are analyzed for three modes of failure: 1) Log pile overturning is based on the soils capacity to keep all piles upright and hold the structure in place, within a certain range of acceptable angles. 2) Log pile bending strength is based on the strength of the piles themselves and their ability to resist breaking or bending to a degree that would cause structure failure. These calculations are based off of estimated bending capacity of graded timber piles from lodgepole or fir trees. 3) Log pile pull-out strength is based on the soils ability to resist the buoyancy and uplift forces on the structures in the vertical plane. The vertical pile pull-out resistance is the controlling factor in the design for all three pile-supported structures that were analyzed for pile stability. Due to high vertical forces on the Bank Barb ELJ, pile strength was supplemented with large boulder ballast as noted in Table 6. Results of the log pile analyses are presented in Table 6. Calculation sheets documenting how these values were obtained can be found in Appendix 6.3.

A resulting factor of safety was determined for the pile-supported structures. The factor of safety is the ratio of the structural capacity of the pile system to the design load. The factor of safety increases as the number of piles or the pile diameter increases because the structural capacity of the pile system is increasing as the load remains constant. These values are calculated for each structure and presented in Table 6.

**Table 6. Pile-supported structure design summary and resulting factors of safety.**

| ELJ Structure [1] | Side Channel ELJ | Channel Barb ELJ | Bank Barb ELJ |
|---|---|---|---|
| Design Event | 10-year | 100-year | 100-year |
| Velocity[2], V (fps) | 7.76 | 7.7 | 7.5 |
| Scour Depth (feet) | 9.4 | 11.8 | 13.9 |
| Log Pile Embedment[3], L (feet) | 11.6 | 10.2 | 10.1 |
| Pile Depth BEGS (feet) | 21 | 22 | 24 |
| Log Pile Diameter[4], B (inches) | 18 | 18 | 18 |
| Number of Log Piles, n | 6 | 8 | 14 |
| Minimum Pile Bending Stress Capacity[6] (psi) | 1,700 | 1,700 | 1,700 |
| Additional Ballast (lbs) | 0 | 0 | 18,750 |
| Factor of Safety Log Pile Overturning | 7.6 | 4.8 | 1.6 |
| Factor of Safety Log Pile Bending Strength | 3.7 | 2.3 | 1.2 |
| Factor of Safety Log Pile Vertical Pull-Out | 1.3 | 1.3 | 1.48 |

Notes:

1. See design plans for additional details regarding structure design and construction.
2. Velocity is determined using Reclamation's SRH-2D hydraulic model for the indicated design event.
3. Log pile embedment is the depth below the design analysis scour depth.
4. Log pile diameter is measured at the mid-point of the log pile. Diameter does not include bark.
6. Specified minimum bending stress is the starting design value before strength reduction factors are applied per timber pile design methods.

BEGS: below existing ground surface
fps: feet per second
psi: pounds per square inch

## SOIL BALLASTED STRUCTURES

A stability analysis has been performed for the LWD roughness structure that is proposed to be buried in the Bear Creek channel. This wood will be buried in the Bear Creek channel and ballasted with soil, backfilled, and compacted over the rootwad logs. The depth of cover and length of embedment required to adequately stabilize the LWD for the given design flow event is summarized in Table 7. Calculation sheets documenting how these values were obtained can be found in Appendix 6.3.

**Table 7. Soil ballasted structure design summary and resulting factors of safety.**

| Design Parameter[1] | Design Value |
|---|---|
| Design Event | 10-year |
| Velocity[2], V (fps) | 8.0 |
| Depth of cover over LWD (feet) | 3 |
| Length of embedment into bank (feet) | 20 |
| Factor of Safety Rootwad Log Overturning (Vertical) | 5.1 |
| Factor of Safety Rootwad Log Sliding (Horizontal) | 1.2 |

Notes:
1. See design plans for additional details regarding structure design and construction.
2. Velocity is determined using the model developed by Bureau of Reclamation.
fps: feet per second

## RIVER SAFETY ANALYSIS

A river safety analysis (Boater Safety Analysis) was conducted for the project elements included in the Final Design. The analysis methods were developed based on those presented in the National Large Wood Manual (Reclamation 2016) to specifically address the concerns and considerations presented by this project. Groupings for analysis were determined based on discussions with the design team, and the methods were approved for use on this project. The complete analysis, including description of methods, and results can be found in Appendix 6.4.

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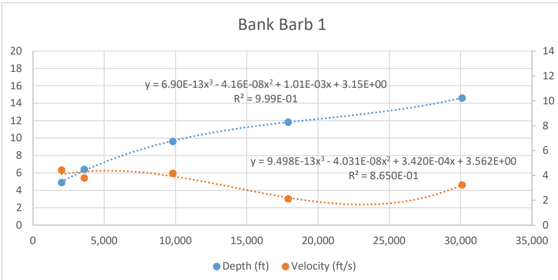
# 6 APPENDICES

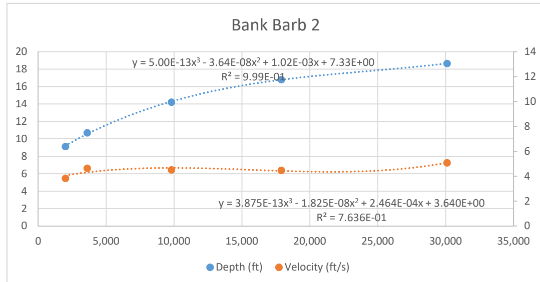
## 6.1 PROJECT PLAN SHEETS

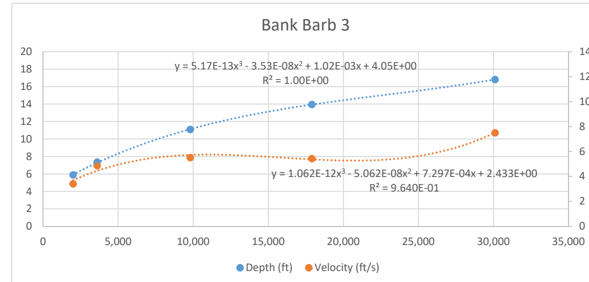
## 6.2 OPINION OF PROBABLE CONSTRUCTION COSTS

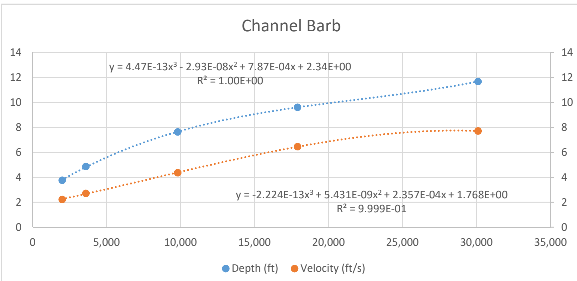
## 6.3 STRUCTURAL SCOUR AND STABILITY CALCULATIONS

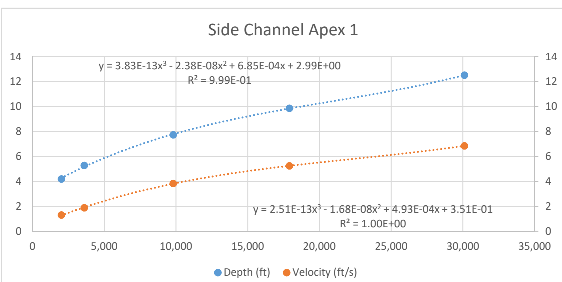
| Event | Discharge (cfs) | Bank Barb 1 | | Bank Barb 2 | | Bank Barb 3 | | Channel Barb | | Side Channel Apex 1 | | Side Channel Apex 2 | | Side Channel Apex 3 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Depth (ft) | Velocity (ft/s) | Depth (ft) | Velocity (ft/s) | Depth (ft) | Velocity (ft/s) | Depth (ft) | Velocity (ft/s) | Depth (ft) | Velocity (ft/s) | Depth (ft) | Velocity (ft/s) | Depth (ft) | Velocity (ft/s) |
| 2000 cfs | 2,000 | 4.91 | 4.44 | 9.13 | 3.84 | 5.9 | 3.41 | 3.77 | 2.23 | 4.19 | 1.3 | 5.18 | 0.88 | 1.01 | 0.17 |
| 1-yr | 3,600 | 6.41 | 3.8 | 10.7 | 4.64 | 7.36 | 4.88 | 4.87 | 2.72 | 5.29 | 1.88 | 5.88 | 1.25 | 1.54 | 2.17 |
| 2-yr | 9,800 | 9.62 | 4.18 | 14.23 | 4.51 | 11.1 | 5.52 | 7.64 | 4.37 | 7.73 | 3.83 | 8.03 | 2.07 | 4.99 | 4.35 |
| 10-yr | 17,900 | 11.85 | 2.13 | 16.81 | 4.48 | 13.96 | 5.44 | 9.62 | 6.46 | 9.86 | 5.24 | 10.43 | 2.07 | 7.76 | 5.71 |
| 100-yr | 30,100 | 14.62 | 3.25 | 18.66 | 5.08 | 16.83 | 7.5 | 11.69 | 7.72 | 12.52 | 6.85 | 13.46 | 2.41 | 10.61 | 5.87 |

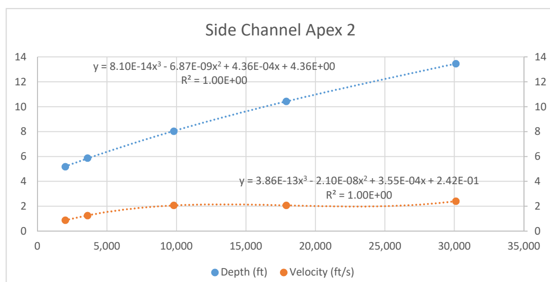


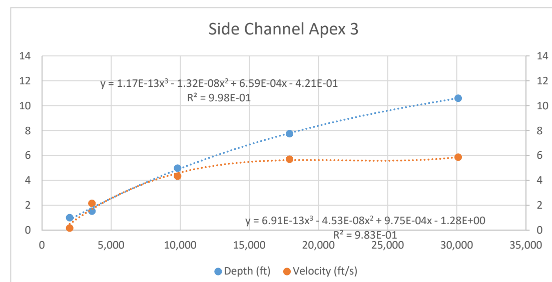



| Structure | Scour Calc For Event | Flow, Q (cfs) | US Velocity in channel(ft/s) | US Hydraulic Depth in channel, d1 (Area/ topwidth) (ft) | Froude Number for channel, Fr | Structure Height above Existing Grade | Structure Length Normal to Flow (ft) | Structure Effective Length (ft) | Scour Depth (ft), Lui et al. 1961 | Adjusted Scour Depth (ft), Lui et al. 1961* |
|---|---|---|---|---|---|---|---|---|---|---|
| Bank Barb | 100-Yr | 30,100 | 7.50 | 13.5 | 0.36 | 9.00 | 40.0 | 26.6 | 16.4 | 13.9 |
| Side Channel Apex | 10-YR | 17,900 | 7.76 | 5.7 | 0.57 | 7.00 | 25.0 | 25.0 | 9.4 | 9.4 |
| Channel Barb | 100-Yr | 30,100 | 7.72 | 10.5 | 0.42 | 8.00 | 30.0 | 22.8 | 13.2 | 11.8 |
| Bear Creek LWM | 5-yr | 58 | 8.00 | 1.2 | 1.30 | 1.50 | 5.0 | 5.0 | 2.5 | 2.5 |
| Island Apex ELJ | 10-yr | 17,900 | 6.77 | 13.5 | 0.32 | 9.00 | 25.0 | 16.6 | 13.1 | 11.1 |
| Bank Complexity | 10-yr | 17,900 | 3.46 | 5.7 | 0.26 | 9.00 | 30.0 | 30.0 | 7.8 | 7.8 |

* uses the structures effective length

**Fully Submerged Vertical Force for Pile Supported Structures**

**Bank Barb ELJ**

| Layer | Number of Logs w/ RW | Number of Logs Without Rootwad | Diameter (ft) | Log Length (ft) | Length of Layer (ft) | Width of Layer (ft) | Rootwad Diam. (ft) | Rootwad Length (ft) | RW Vol. Reduction, CA | Bole Diam. Reduction | Footprint Area of Layer (sq ft) | Volume Of Layer (cubic ft) | Volume of Rootwad (cubic ft) | Volume of Bole (cubic ft) | Total Volume of wood for Layer | Volume of Boles for Layer | Volume of Rootwads for Layer | Wood Submerged Net Force (lb) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 0 | 1.5 | 40.0 | 58.0 | 40.0 | 4.5 | 3.0 | 0.30 | 0.8 | 2,320 | 3,480 | 6.9 | 57.5 | 193.1 | 172.5 | 20.7 | 4,725 |
| 2 | 3 | 0 | 1.5 | 40.0 | 58.0 | 40.0 | 4.5 | 3.0 | 0.30 | 0.8 | 2,320 | 3,480 | 6.9 | 57.5 | 193.1 | 172.5 | 20.7 | 4,725 |
| 3 | 1 | 3 | 1.5 | 40.0 | 58.0 | 40.0 | 4.5 | 3.0 | 0.30 | 0.8 | 2,320 | 3,480 | 6.9 | 57.5 | 236.9 | 230.0 | 6.9 | 5,794 |
| 4 | 3 | 0 | 1.5 | 40.0 | 58.0 | 40.0 | 4.5 | 3.0 | 0.30 | 0.8 | 2,320 | 3,480 | 6.9 | 57.5 | 193.1 | 172.5 | 20.7 | 4,725 |
| 5 | 1 | 3 | 1.5 | 40.0 | 58.0 | 40.0 | 4.5 | 3.0 | 0.30 | 0.8 | 2,320 | 3,480 | 6.9 | 57.5 | 236.9 | 230.0 | 6.9 | 5,794 |
| 6 | 3 | 0 | 1.5 | 40.0 | 58.0 | 40.0 | 4.5 | 3.0 | 0.30 | 0.8 | 2,320 | 3,480 | 6.9 | 57.5 | 193.1 | 172.5 | 20.7 | 4,725 |
| 7 | 1 | 3 | 1.5 | 40.0 | 58.0 | 40.0 | 4.5 | 3.0 | 0.30 | 0.8 | 2,320 | 3,480 | 6.9 | 57.5 | 236.9 | 230.0 | 6.9 | 5,794 |
| 8 | 3 | 0 | 1.5 | 40.0 | 58.0 | 40.0 | 4.5 | 3.0 | 0.30 | 0.8 | 2,320 | 3,480 | 6.9 | 57.5 | 193.1 | 172.5 | 20.7 | 4,725 |
| | | | | | | | | | | | | | | **ELJ Total** | **1,676** | **1,552** | **124** | **41,004** |

**Ballast Requirements**

| Volume of Rock (cubic ft) | Minimum Rock Size Class | Specific Weight of Rock (lb/cu.ft.) | Void Space | Factor of Saftey for Loss of Material | Total Vertial Force Reduction (lb) |
|---|---|---|---|---|---|
| 250.0 | | 150.0 | 0.25 | 1.5 | 18750 |
| 9.26 | cy | | | **ELJ Total For Piles (lb)** | **22,254** |

**Channel Barb ELJ**

| Layer | Number of Logs w/ RW | Number of Logs Without Rootwad | Diameter (ft) | Log Length (ft) | Length of Layer (ft) | Width of Layer (ft) | Rootwad Diam. (ft) | Rootwad Length (ft) | RW Vol. Reduction, CA | Bole Diam. Reduction | Footprint Area of Layer (sq ft) | Volume Of Layer (cubic ft) | Volume of Rootwad (cubic ft) | Volume of Bole (cubic ft) | Total Volume of wood for Layer | Volume of Boles for Layer | Volume of Rootwads for Layer | Wood Submerged Net Force (lb) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 0 | 2.0 | 30.0 | 32.0 | 20.0 | 6.0 | 4.0 | 0.30 | 0.8 | 640 | 1,280 | 16.3 | 76.7 | 186.0 | 153.3 | 32.7 | 4,549 |
| 2 | 2 | 0 | 2.0 | 20.0 | 32.0 | 20.0 | 6.0 | 4.0 | 0.30 | 0.8 | 640 | 1,280 | 16.3 | 51.1 | 134.9 | 102.2 | 32.7 | 3,299 |
| 2 | 0 | 2 | 1.5 | 20.0 | 32.0 | 20.0 | 4.5 | 3.0 | 0.30 | 0.8 | 640 | 960 | 6.9 | 28.7 | 57.5 | 57.5 | 0.0 | 1,406 |
| 3 | 1 | 0 | 1.5 | 30.0 | 32.0 | 20.0 | 4.5 | 3.0 | 0.30 | 0.8 | 640 | 960 | 6.9 | 43.1 | 50.0 | 43.1 | 6.9 | 1,223 |
| 3 | 1 | 0 | 2.0 | 30.0 | 32.0 | 20.0 | 6.0 | 4.0 | 0.30 | 0.8 | 640 | 1,280 | 16.3 | 76.7 | 93.0 | 76.7 | 16.3 | 2,275 |
| 4 | 2 | 0 | 2.0 | 30.0 | 32.0 | 20.0 | 6.0 | 4.0 | 0.30 | 0.8 | 640 | 1,280 | 16.3 | 76.7 | 186.0 | 153.3 | 32.7 | 4,549 |
| 5 | 1 | 0 | 1.5 | 30.0 | 32.0 | 20.0 | 4.5 | 3.0 | 0.30 | 0.8 | 640 | 960 | 6.9 | 43.1 | 50.0 | 43.1 | 6.9 | 1,223 |
| 5 | 1 | 0 | 2.0 | 30.0 | 32.0 | 20.0 | 6.0 | 4.0 | 0.30 | 1.8 | 640 | 1,280 | 16.3 | 189.8 | 206.1 | 189.8 | 16.3 | 5,041 |
| 6 | 2 | 0 | 1.5 | 30.0 | 32.0 | 20.0 | 4.5 | 3.0 | 0.30 | 0.8 | 640 | 960 | 6.9 | 43.1 | 100.0 | 86.2 | 13.8 | 2,447 |
| | | | | | | | | | | | | | | **ELJ Total** | **1,063** | **905** | **158** | **26,013** |

**Side Channel Apex ELJ**

| Layer | Number of Logs w/ RW | Number of Logs Without Rootwad | Diameter (ft) | Log Length (ft) | Length of Layer (ft) | Width of Layer (ft) | Rootwad Diam. (ft) | Rootwad Length (ft) | RW Vol. Reduction, CA | Bole Diam. Reduction | Footprint Area of Layer (sq ft) | Volume Of Layer (cubic ft) | Volume of Rootwad (cubic ft) | Volume of Bole (cubic ft) | Total Volume of wood for Layer | Volume of Boles for Layer | Volume of Rootwads for Layer | Wood Submerged Net Force (lb) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 2 | 1.5 | 25.0 | 27.0 | 23.5 | 4.5 | 3.0 | 0.30 | 0.8 | 635 | 952 | 6.9 | 35.9 | 71.9 | 71.9 | 0.0 | 1,758 |
| 2 | 3 | 0 | 2.0 | 30.0 | 27.0 | 23.5 | 6.0 | 4.0 | 0.30 | 0.8 | 635 | 1,269 | 16.3 | 76.7 | 279.0 | 230.0 | 49.0 | 6,824 |
| 3 | 2 | 0 | 1.5 | 20.0 | 27.0 | 23.5 | 4.5 | 3.0 | 0.30 | 0.8 | 635 | 952 | 6.9 | 28.7 | 71.3 | 57.5 | 13.8 | 1,743 |
| 3 | 0 | 1 | 1.5 | 25.0 | 27.0 | 23.5 | 4.5 | 3.0 | 0.30 | 0.8 | 635 | 952 | 6.9 | 35.9 | 35.9 | 35.9 | 0.0 | 879 |
| 4 | 3 | 0 | 2.0 | 30.0 | 27.0 | 23.5 | 6.0 | 4.0 | 0.30 | 0.8 | 635 | 1,269 | 16.3 | 76.7 | 279.0 | 230.0 | 49.0 | 6,824 |
| 5 | 0 | 3 | 1.5 | 25.0 | 27.0 | 23.5 | 4.5 | 3.0 | 0.30 | 0.8 | 635 | 952 | 6.9 | 35.9 | 107.8 | 107.8 | 0.0 | 2,637 |
| | | | | | | | | | | | | | | **ELJ Total** | **845** | **733** | **112** | **20,665** |

# Pile Supported Structure - Stability Analysis

Structure Type: Bank Barb ELJ Location: Barkley Mainstem - Right Bank

## Assumptions

1. The structure behaves as a single unit under the design load and will efficiently transfer loads to all piles
2. Material behind or in the structure will not provide any support
3. The pile embedment depth (L) can be reached before encountering bedrock
4. There is no scour behind the structure
5. Embedment depth is measured below existing ground

## Input

Gray highlight indicates a user input variable or coefficient

### Soil Properties

Angle of internal friction for substrate, $\phi := 40\text{deg}$

Saturated sumberged unit weight of substrate, $\gamma := 80 \frac{\text{lb}}{\text{ft}^3}$

### Water Properties

Specific weight of water, $\gamma_w := 62.4 \frac{\text{lb}}{\text{ft}^3}$

Density of water, $\rho_w := 1.94 \frac{\text{slug}}{\text{ft}^3}$

### Hydraulic Conditions

Discharge Range $Q := 100\text{cfs}, 200\text{cfs} .. 32000\text{cfs}$

Design Discharge Eqiv to 100-yr RP $Q_d := 30100\text{cfs}$

Velocity Regression $V(Q) := 1.062 \cdot 10^{-12} \left(\frac{Q}{\text{cfs}}\right)^3 \frac{\text{ft}}{\text{s}} - 5.062 \cdot 10^{-8} \left(\frac{Q}{\text{cfs}}\right)^2 \frac{\text{ft}}{\text{s}} + 7.297 \cdot 10^{-4} \left(\frac{Q}{\text{cfs}}\right) \frac{\text{ft}}{\text{s}} + 2.433 \frac{\text{ft}}{\text{s}}$

Approach Flow Depth Regression $d_1(Q) := 5.17 \cdot 10^{-13} \left(\frac{Q}{\text{cfs}}\right)^3 \text{ft} - 3.53 \cdot 10^{-8} \left(\frac{Q}{\text{cfs}}\right)^2 \text{ft} + 1.02 \cdot 10^{-3} \left(\frac{Q}{\text{cfs}}\right) \text{ft} + 4.05\text{ft}$

Design Velocity $V(Q_d) = 7.5 \frac{\text{ft}}{\text{s}}$

Drag coefficient, $C_d := 2.0$

Design Flow Depth $d_1(Q_d) = 16.9\,\text{ft}$

Depth of water on D/S, $d_2(Q) := d_1(Q) - 0.1\text{ft}$

### Structure Dimensions

Length parallel to flow $l_{ELJ} := 48\text{ft}$

Width into effective flow area $w_{ELJ} := 40\text{ft}$

Height above existing grade $h_{ELJ} := 9\text{ft}$

### Supporting Pile Specifications

Number of piles carrying load $n := 14$

Pile embedment depth BEGS $L_{BEGS} := 24\text{ft}$

Pile Diameter (breadth) $B := 18\text{in}$

Pile row spacing (on center in direction of force) $S := 12\text{ft}$

### Fully Submerged Structure Case

Accounts for fully submerged ELJ condition and limits depth used in calculation to the structure height and calculates an equivalent width:

$d_{jam1}(Q) := \text{if}\left(d_1(Q) > h_{ELJ}, h_{ELJ}, d_1(Q)\right)$ $d_{jam2}(Q) := \text{if}\left(d_2(Q) > h_{ELJ}, h_{ELJ}, d_2(Q)\right)$

$w_{ELJef}(Q) := \frac{w_{ELJ} \cdot h_{ELJ}}{d_1(Q)}$ $d_1(Q_d) = 17\,\text{ft}$ $w_{ELJef}(Q_d) = 21\,\text{ft}$

**Scour Depth Estimate** *(Liu, et al. 1961) Modified by Anchor QEA for ELJs*

$$F_r(Q) := \frac{V(Q)}{\sqrt{g \cdot d_1(Q)}} \qquad d_s(Q) := 1.1 \cdot \left(\frac{w_{ELJef}(Q)}{d_1(Q)}\right)^{0.4} \cdot F_r(Q)^{0.33} \cdot d_1(Q)$$

$$F_r(Q_d) = 0.32 \qquad \boxed{d_s(Q_d) = 14.0\,ft}$$

**Hydraulic Forces**

Frontal Area Experiencing Drag $A_D(Q) := w_{ELJ} \cdot (d_{jam1}(Q))$

Drag Force per pile $F_D(Q) := \dfrac{\left[C_d \cdot A_D(Q) \cdot \left(\rho_w \cdot \dfrac{V(Q)^2}{2}\right)\right]}{n \cdot g}$

Average frontal hydrostatic pressure force $P_{HS1}(Q) := .5 \cdot (d_1(Q) + d_s(Q)) \cdot \gamma_w$

Frontal area experiencing hydrostatic force $A_{HS1}(Q) := (d_{jam1}(Q) + d_s(Q)) \cdot w_{ELJ}$

Hydrostatic force upstream of ELJ per pile $F_{HS1}(Q) := \dfrac{(P_{HS1}(Q) \cdot A_{HS1}(Q))}{n}$

Lee area experiencing hydrostatic force $A_{HS2}(Q) := (d_{jam2}(Q) + d_s(Q)) \cdot w_{ELJ}$

Average hydrostatic pressure force in lee $P_{HS2}(Q) := -.5 \cdot (d_2(Q) + d_s(Q)) \cdot \gamma_w$

Hydrostatic force downstream of ELJ per pile $F_{HS2}(Q) := \dfrac{(P_{HS2}(Q) \cdot A_{HS2}(Q))}{n}$

Net hydraulic force per pile $F_{net}(Q) := F_D(Q) + F_{HS1}(Q) + F_{HS2}(Q)$

Eccentricity of Drag Force $e_D(Q) := \dfrac{d_{jam1}(Q)}{2} + d_s(Q) + 2 \cdot B$

Eccentricity of frontal hydrostatic force $e_{HS1}(Q) := \dfrac{d_1(Q) + d_s(Q)}{3} + 2 \cdot B$

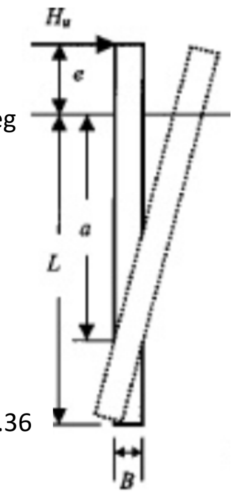
Eccentricity of lee hydrostatic force $e_{HS2}(Q) := \dfrac{d_2(Q) + d_s(Q)}{3} + 2 \cdot B$

Applied moment per pile $M_1(Q) := F_D(Q) \cdot e_D(Q) + F_{HS1}(Q) \cdot e_{HS1}(Q) + F_{HS2}(Q) \cdot e_{HS2}(Q)$

Eccentricity of applied moment $e(Q) := \dfrac{M_1(Q)}{F_{net}(Q)}$

Design Applied moment per pile $\boxed{M_1(Q_d) = 65172\,lb \cdot ft}$

**Individual Pile Ultimate Capacity** *(Zhang, 2005)*




Over consolodation ratio $OCR := 8$ Angle of internal friction for substrate $\phi = 40 \cdot deg$

Maximum depth is equal to Embedment Depth Below Scour Depth $z := L(Q_d) = 10\,ft$

Coefficient of passive earth pressure $K_p := \tan\left(45deg + \frac{\phi}{2}\right)^2 = 4.6$

Coefficient of lateral earth pressure at rest $K_0 := (1 - \sin(\phi)) \cdot OCR^{\sin(\phi)} = 1.36$

Lateral earth pressure coefficient for pile installation $K := (0.6 \cdot K_0)$

Interface friction angle between the pile and the soil $\delta := 0.8 \cdot \phi$

Shape factor to account for the nonuniform distribution of earth pressure in front of the pile $\eta := 0.8$

Shape factor to account for the nonuniform distribution of lateral shear drag $\xi := 1.0$

Maximum soil bearing capacity $p_{max} := \frac{\phi}{10deg} K_p \cdot \gamma \cdot z = 14683 \frac{lb}{ft^2}$

*Use the smaller of the two*

$K_p^{\,2} = 21$ $\frac{\phi}{10deg} \cdot K_p = 18$

Maximum soil shear capacity $\tau_{max} := K \cdot \gamma \cdot z \cdot \tan(\delta) = 407 \frac{lb}{ft^2}$

Distance to point of rotation $a(Q) := \frac{\left[-\left(0.567 \cdot L(Q_d) + 2.7 \cdot e(Q)\right) + \left(5.307 \cdot L(Q_d)^2 + 7.29 \cdot e(Q)^2 + 10.54 \cdot e(C\right.\right.}{2.1996}$

Ultimate pile load at eccentricity $H_u(Q) := 0.3\left(\eta \cdot K_p^{\,2} + \xi \cdot K \cdot \tan(\delta)\right) \cdot \gamma \cdot a(Q) \cdot B \cdot \left(2.7\,a(Q) - 1.7 \cdot L(Q_d)\right)$

$H_u(Q_d) = 4909\,lb$

**Group Pile Effectiveness Reduction** *(Timber Pile Design Manual, 2002)* Pile Spacing ratio $\frac{S}{B} = 8$

Group load reduction factor for rows of piles $\omega := 1$ $H_{uG}(Q) := H_u(Q) \cdot \omega$ $M_u(Q) := H_{uG}(Q) \cdot e(Q)$

**Soil Strength Factor of Safety**

$FS_{ss}(Q) := \frac{M_u(Q)}{M_1(Q)}$ $FS_{ss}(Q_d) = 1.6$

## Pile Strength Check

Tree Species Bending Stress Capacity *(Timber Pile Manual, Table 3-1. ASTM D25)* $F_b := 1700psi$ Species = Lodgepole Pine Pile Diameter $B = 18 \cdot in$

**Circular Section Moment of Inertia**

$$I := \frac{\pi \cdot (B)^4}{4} = 3.976\,ft^4$$

**Circular Section Modulus**

$$S := \frac{\pi \cdot B^3}{32} = 0.331 \cdot ft^3$$

**Strength Reduction**

Size Factor, $C_F$, for members > 12"

$$C_F := \left(\frac{1ft}{B}\right)^{\left(\frac{1}{9}\right)} = 0.956$$

$$F_{bx} := F_b \cdot C_F = 1625 \cdot \frac{lb}{in^2}$$

**Pile bending stress**

$$f_b(Q) := \frac{M_1(Q)}{S} \qquad f_b(Q_d) = 196692\,\frac{lb}{ft^2}$$

**Pile Strength Factor of Safety**

$$FS_{ps}(Q) := \frac{F_{bx}}{f_b(Q)} \qquad \boxed{FS_{ps}(Q_d) = 1.2}$$

## References

Ultimate Lateral Resistance to Piles in Cohesionless Soils J. Geotech. Geoenviron. Eng. 131, 78 (2005); doi:10.1061/(ASCE)1090-0241(2005)131:1(78) (6 pages) Lianyang Zhang, Francisco Silva, and Ralph Grismala

Timber Pile Design and Construction Manual, Timber Piling Council, 2002. Chapter 7.0 Marie Applications Design.

Table 4D of American Wood Council (2005) National Design Specifications for Wood Construction, Design Supplement.

Liu, M.K., F. M. Chang and M. M. Skinner, 1961, "Effect of Bridge Construction on Scour and Backwater," Dept. of Civil Engineering, Colorado State University, Report No. CER60-HKL22, February.

ASTM D25. Allowable Stress Values for Treated Round Timber Piles.

**Summary & Figures** Structure Type: Location: Barkley Main Channel

Design Discharge (100-yr RP) $Q_d = 30100 \cdot cfs$ Scour Depth $d_s(Q_d) = 14.0\,ft$

Pile Depth Below Existing Grade $L_{BEGS}(Q_d) = 24.0\,ft$ Effective Pile Embedment Depth $L(Q_d) = 10.0\,ft$

Pile Diameter $B = 18 \cdot in$ Number of Piles $n = 14$

Pile Bending Stress Cap. Spec. $F_b = 1700 \cdot psi$ Pile Species = Lodgepole Pine

**Soil Strength Factor of Safety**

$FS_{ss}(Q_d) = 1.6$

**Pile Strength Factor of Safety**

$FS_{ps}(Q_d) = 1.2$

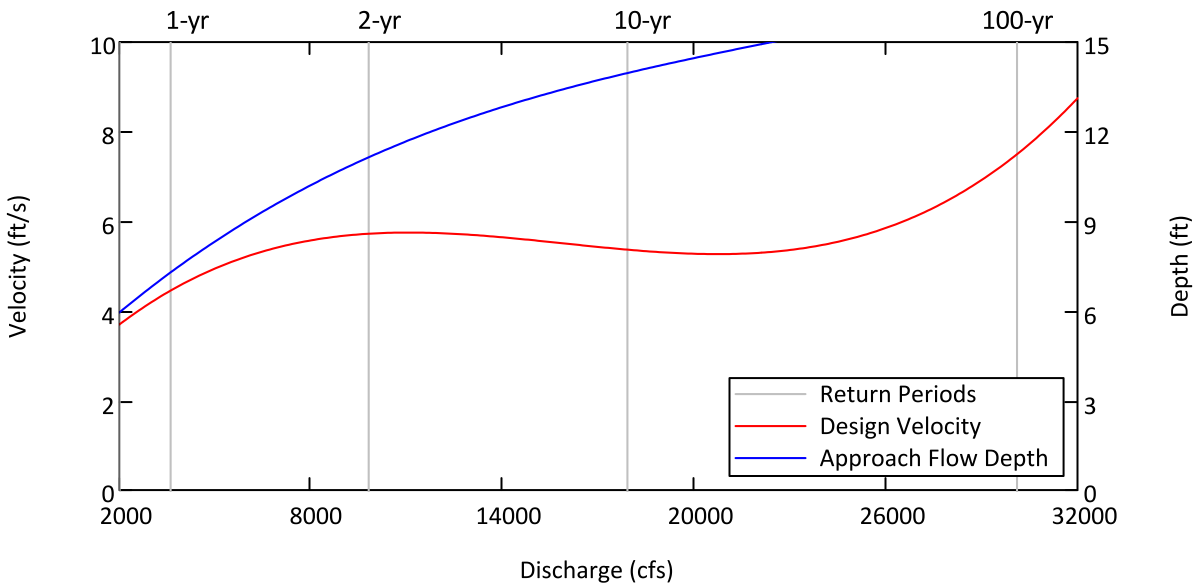



**Figure 1 - Hydraulic Conditions**

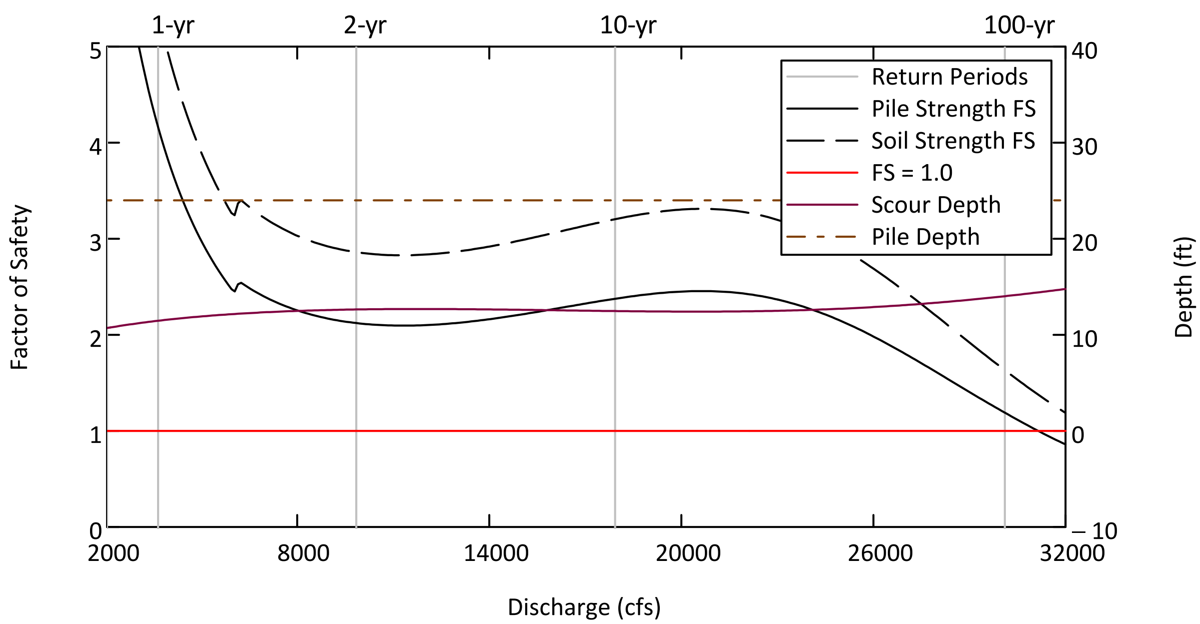



**Figure 2 - Structure Conditions**

**Effective Stress Method Pile for Vertical Pile Capacity** *(Timber Pile Design Manual, 2002)*

Volume of pile per linear foot $V_p := \pi \cdot \left(\frac{B}{2}\right)^2 = 1.77\,ft^2$

Soil friction angle $\varphi := 40deg$ $\omega := 0.8$

Earth pressure coefficient $K_s := 0.6$

Friction angle between the pile and the soil $\delta := \varphi \cdot \omega = 32 \cdot deg$

Bjerrum-Burland beta coefficient $\beta := K_s \cdot \tan(\delta) = 0.37$

Effective overburden pressure $p_o := \frac{L(Q_d) \cdot \gamma}{2} = 399 \frac{lb}{ft^2}$

Unit Shaft Resistance $f_s := \beta \cdot p_o = 150 \frac{lb}{ft^2}$

Pile shaft surface area $A_s := \pi \cdot B \cdot L(Q_d) = 47\,ft^2$

Shaft resistance $R_s := f_s \cdot A_s = 7035\,lb$

Vertical capacity reduction factor $\psi := \frac{1}{3}$ Value of 1/3 recommended by the manual in Section 5.7 for pile in cohesionless soils.

Vertical pull out shaft resistance $Q_{uv} := \psi \cdot R_s = 2345\,lb$

Pile group pull out resistance $Q_{uvg} := Q_{uv} \cdot n = 32832\,lb$

Fully submerged structure net vertical force $F_v := 22254lb$ Value from Excel workbook

Vertical Factor of Safety $FS_{vp} := \frac{Q_{uvg}}{F_v} = 1.48$

# Pile Supported Structure - Stability Analysis

Structure Type: Channel Barb Location: Barkley Mainstem - Left Bank

## Assumptions

1. The structure behaves as a single unit under the design load and will efficiently transfer loads to all piles
2. Material behind or in the structure will not provide any support
3. The pile embedment depth (L) can be reached before encountering bedrock
4. There is no scour behind the structure
5. Embedment depth is measured below existing ground

## Input

Gray highlight indicates a user input variable or coefficient

### Soil Properties

Angle of internal friction for substrate, $\phi := 40\text{deg}$

Saturated sumberged unit weight of substrate, $\gamma := 80 \frac{\text{lb}}{\text{ft}^3}$

### Water Properties

Specific weight of water, $\gamma_w := 62.4 \frac{\text{lb}}{\text{ft}^3}$

Density of water, $\rho_w := 1.94 \frac{\text{slug}}{\text{ft}^3}$

### Hydraulic Conditions

Discharge Range $Q := 100\text{cfs}, 200\text{cfs} .. 32000\text{cfs}$

Design Discharge Eqiv to 100-yr RP $Q_d := 30100\text{cfs}$

Velocity Regression $V(Q) := -2.224 \cdot 10^{-13} \left(\frac{Q}{\text{cfs}}\right)^3 \frac{\text{ft}}{\text{s}} + 5.431 \cdot 10^{-9} \left(\frac{Q}{\text{cfs}}\right)^2 \frac{\text{ft}}{\text{s}} + 2.357 \cdot 10^{-4} \left(\frac{Q}{\text{cfs}}\right) \frac{\text{ft}}{\text{s}} + 1.768$

Approach Flow Depth Regression $d_1(Q) := 4.47 \cdot 10^{-13} \left(\frac{Q}{\text{cfs}}\right)^3 \text{ft} - 2.93 \cdot 10^{-8} \left(\frac{Q}{\text{cfs}}\right)^2 \text{ft} + 7.87 \cdot 10^{-4} \left(\frac{Q}{\text{cfs}}\right) \text{ft} + 2.34\text{ft}$

Design Velocity $V(Q_d) = 7.7 \frac{\text{ft}}{\text{s}}$

Drag coefficient, $C_d := 2.0$

Design Flow Depth $d_1(Q_d) = 11.7\,\text{ft}$

Depth of water on D/S, $d_2(Q) := d_1(Q) - 0.1\text{ft}$

### Structure Dimensions

Length parallel to flow $l_{ELJ} := 32\text{ft}$

Width into effective flow area $w_{ELJ} := 20\text{ft}$

Height above existing grade $h_{ELJ} := 8\text{ft}$

### Supporting Pile Specifications

Number of piles carrying load $n := 10$

Pile embedment depth BEGS $L_{BEGS} := 22\text{ft}$

Pile Diameter (breadth) $B := 18\text{in}$

Pile row spacing (on center in direction of force) $S := 7\text{ft}$

### Fully Submerged Structure Case

Accounts for fully submerged ELJ condition and limits depth used in calculation to the structure height and calculates an equivalent width:

$d_{jam1}(Q) := \text{if}\left(d_1(Q) > h_{ELJ}, h_{ELJ}, d_1(Q)\right)$ $d_{jam2}(Q) := \text{if}\left(d_2(Q) > h_{ELJ}, h_{ELJ}, d_2(Q)\right)$

$w_{ELJef}(Q) := \frac{w_{ELJ} \cdot h_{ELJ}}{d_1(Q)}$ $d_1(Q_d) = 12\,\text{ft}$ $w_{ELJef}(Q_d) = 14\,\text{ft}$

**Scour Depth Estimate** *(Liu, et al. 1961) Modified by Anchor QEA for ELJs*

$$F_r(Q) := \frac{V(Q)}{\sqrt{g \cdot d_1(Q)}} \qquad d_s(Q) := 1.1 \cdot \left(\frac{w_{ELJef}(Q)}{d_1(Q)}\right)^{0.4} \cdot F_r(Q)^{0.33} \cdot d_1(Q)$$

$$F_r(Q_d) = 0.4 \qquad d_s(Q_d) = 10.1\,ft$$

**Hydraulic Forces**

Frontal Area Experiencing Drag $A_D(Q) := w_{ELJ} \cdot (d_{jam1}(Q))$

Drag Force per pile $F_D(Q) := \dfrac{\left[C_d \cdot A_D(Q) \cdot \left(\rho_w \cdot \dfrac{V(Q)^2}{2}\right)\right]}{n \cdot g}$

Average frontal hydrostatic pressure force $P_{HS1}(Q) := .5 \cdot (d_1(Q) + d_s(Q)) \cdot \gamma_w$

Frontal area experiencing hydrostatic force $A_{HS1}(Q) := (d_{jam1}(Q) + d_s(Q)) \cdot w_{ELJ}$

Hydrostatic force upstream of ELJ per pile $F_{HS1}(Q) := \dfrac{(P_{HS1}(Q) \cdot A_{HS1}(Q))}{n}$

Lee area experiencing hydrostatic force $A_{HS2}(Q) := (d_{jam2}(Q) + d_s(Q)) \cdot w_{ELJ}$

Average hydrostatic pressure force in lee $P_{HS2}(Q) := -.5 \cdot (d_2(Q) + d_s(Q)) \cdot \gamma_w$

Hydrostatic force downstream of ELJ per pile $F_{HS2}(Q) := \dfrac{(P_{HS2}(Q) \cdot A_{HS2}(Q))}{n}$

Net hydraulic force per pile $F_{net}(Q) := F_D(Q) + F_{HS1}(Q) + F_{HS2}(Q)$

Eccentricity of Drag Force $e_D(Q) := \dfrac{d_{jam1}(Q)}{2} + d_s(Q) + 2 \cdot B$

Eccentricity of frontal hydrostatic force $e_{HS1}(Q) := \dfrac{d_1(Q) + d_s(Q)}{3} + 2 \cdot B$

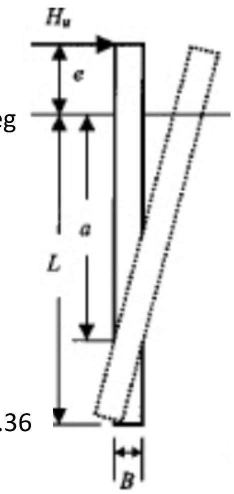
Eccentricity of lee hydrostatic force $e_{HS2}(Q) := \dfrac{d_2(Q) + d_s(Q)}{3} + 2 \cdot B$

Applied moment per pile $M_1(Q) := F_D(Q) \cdot e_D(Q) + F_{HS1}(Q) \cdot e_{HS1}(Q) + F_{HS2}(Q) \cdot e_{HS2}(Q)$

Eccentricity of applied moment $e(Q) := \dfrac{M_1(Q)}{F_{net}(Q)}$

Design Applied moment per pile $M_1(Q_d) = 33602\,lb \cdot ft$

**Individual Pile Ultimate Capacity** *(Zhang, 2005)*




Over consolodation ratio $OCR := 8$ Angle of internal friction for substrate $\phi = 40 \cdot deg$

Maximum depth is equal to Embedment Depth Below Scour Depth $z := L(Q_d) = 12\,ft$

Coefficient of passive earth pressure $K_p := \tan\left(45deg + \frac{\phi}{2}\right)^2 = 4.6$

Coefficient of lateral earth pressure at rest $K_0 := (1 - \sin(\phi)) \cdot OCR^{\sin(\phi)} = 1.36$

Lateral earth pressure coefficient for pile installation $K := (0.6 \cdot K_0)$

Interface friction angle between the pile and the soil $\delta := 0.8 \cdot \phi$

Shape factor to account for the nonuniform distribution of earth pressure in front of the pile $\eta := 0.8$

Shape factor to account for the nonuniform distribution of lateral shear drag $\xi := 1.0$

Maximum soil bearing capacity $p_{max} := \frac{\phi}{10deg} K_p \cdot \gamma \cdot z = 17505 \frac{lb}{ft^2}$

*Use the smaller of the two*

$K_p^{\ 2} = 21$ $\frac{\phi}{10deg} \cdot K_p = 18$

Maximum soil shear capacity $\tau_{max} := K \cdot \gamma \cdot z \cdot \tan(\delta) = 485 \frac{lb}{ft^2}$

Distance to point of rotation $a(Q) := \frac{\left[-\left(0.567 \cdot L(Q_d) + 2.7 \cdot e(Q)\right) + \left(5.307 \cdot L(Q_d)^2 + 7.29 \cdot e(Q)^2 + 10.54 \cdot e(C\right.\right.}{2.1996}$

Ultimate pile load at eccentricity $H_u(Q) := 0.3\left(\eta \cdot K_p^{\ 2} + \xi \cdot K \cdot \tan(\delta)\right) \cdot \gamma \cdot a(Q) \cdot B \cdot \left(2.7\,a(Q) - 1.7 \cdot L(Q_d)\right)$

$H_u(Q_d) = 9493\,lb$

**Group Pile Effectiveness Reduction** *(Timber Pile Design Manual, 2002)* Pile Spacing ratio $\frac{S}{B} = 5$

Group load reduction factor for rows of piles $\omega := 1$ $H_{uG}(Q) := H_u(Q) \cdot \omega$ $M_u(Q) := H_{uG}(Q) \cdot e(Q)$

**Soil Strength Factor of Safety**

$FS_{ss}(Q) := \frac{M_u(Q)}{M_1(Q)}$ $FS_{ss}(Q_d) = 4.8$

## Pile Strength Check

Tree Species Bending Stress Capacity *(Timber Pile Manual, Table 3-1. ASTM D25)* $F_b := 1700psi$ Species = Lodgepole Pine Pile Diameter $B = 18 \cdot in$

**Circular Section Moment of Inertia**

$$I := \frac{\pi \cdot (B)^4}{4} = 3.976 ft^4$$

**Circular Section Modulus**

$$S := \frac{\pi \cdot B^3}{32} = 0.331 \cdot ft^3$$

**Strength Reduction**

Size Factor, $C_F$, for members > 12"

$$C_F := \left(\frac{1ft}{B}\right)^{\left(\frac{1}{9}\right)} = 0.956$$

$$F_{bx} := F_b \cdot C_F = 1625 \cdot \frac{lb}{in^2}$$

**Pile bending stress**

$$f_b(Q) := \frac{M_1(Q)}{S} \qquad f_b(Q_d) = 101414 \frac{lb}{ft^2}$$

**Pile Strength Factor of Safety**

$$FS_{ps}(Q) := \frac{F_{bx}}{f_b(Q)} \qquad \boxed{FS_{ps}(Q_d) = 2.3}$$

## References

Ultimate Lateral Resistance to Piles in Cohesionless Soils J. Geotech. Geoenviron. Eng. 131, 78 (2005); doi:10.1061/(ASCE)1090-0241(2005)131:1(78) (6 pages) Lianyang Zhang, Francisco Silva, and Ralph Grismala

Timber Pile Design and Construction Manual, Timber Piling Council, 2002. Chapter 7.0 Marie Applications Design.

Table 4D of American Wood Council (2005) National Design Specifications for Wood Construction, Design Supplement.

Liu, M.K., F. M. Chang and M. M. Skinner, 1961, "Effect of Bridge Construction on Scour and Backwater," Dept. of Civil Engineering, Colorado State University, Report No. CER60-HKL22, February.

ASTM D25. Allowable Stress Values for Treated Round Timber Piles.

**Summary & Figures** Structure Type: Location: Barkley Main Channel

| | | | |
|---|---|---|---|
| Design Discharge (100-yr RP) | $Q_d = 30100 \cdot cfs$ | Scour Depth | $d_s(Q_d) = 10.1\ ft$ |
| Pile Depth Below Existing Grade | $L_{BEGS}(Q_d) = 22.0\ ft$ | Effective Pile Embedment Depth | $L(Q_d) = 11.9\ ft$ |
| Pile Diameter | $B = 18 \cdot in$ | Number of Piles | $n = 10$ |
| Pile Bending Stress Cap. Spec. | $F_b = 1700 \cdot psi$ | Pile Species = Lodgepole Pine | |

**Soil Strength Factor of Safety**

$FS_{ss}(Q_d) = 4.8$

**Pile Strength Factor of Safety**

$FS_{ps}(Q_d) = 2.3$

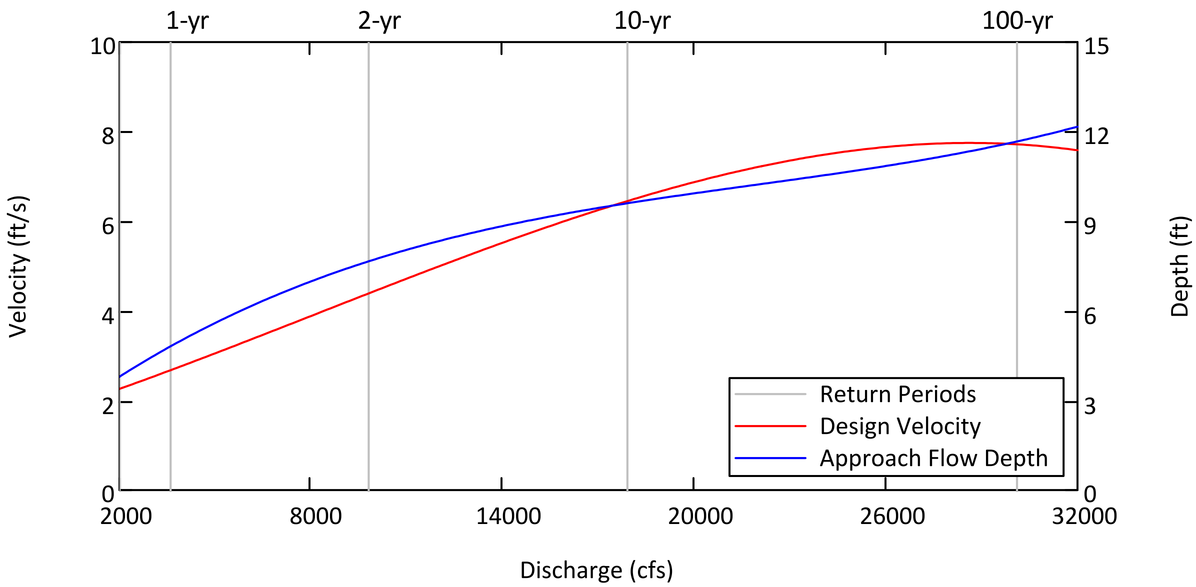



**Figure 1 - Hydraulic Conditions**

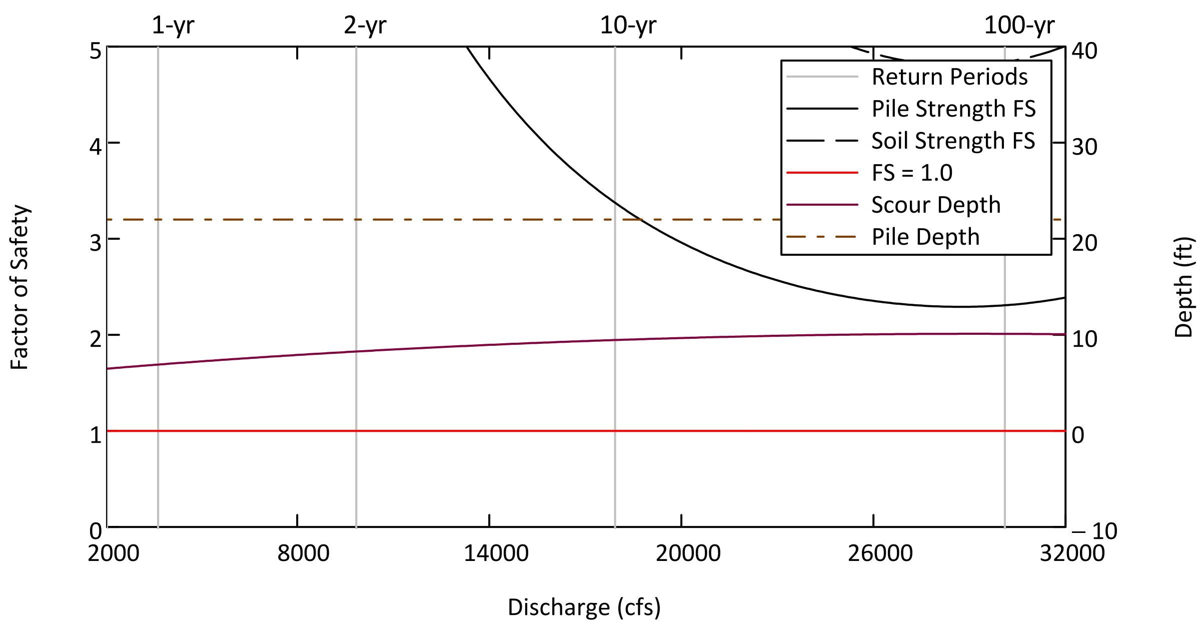



**Figure 2 - Structure Conditions**

**Effective Stress Method Pile for Vertical Pile Capacity** *(Timber Pile Design Manual, 2002)*

Volume of pile per linear foot $V_p := \pi \cdot \left(\frac{B}{2}\right)^2 = 1.77\,ft^2$

Soil friction angle $\varphi := 40deg$ $\omega := 0.8$

Earth pressure coefficient $K_s := 0.6$

Friction angle between the pile and the soil $\delta := \varphi \cdot \omega = 32 \cdot deg$

Bjerrum-Burland beta coefficient $\beta := K_s \cdot \tan(\delta) = 0.37$

Effective overburden pressure $p_o := \frac{L(Q_d) \cdot \gamma}{2} = 476\,\frac{lb}{ft^2}$

Unit Shaft Resistance $f_s := \beta \cdot p_o = 178\,\frac{lb}{ft^2}$

Pile shaft surface area $A_s := \pi \cdot B \cdot L(Q_d) = 56\,ft^2$

Shaft resistance $R_s := f_s \cdot A_s = 10000\,lb$

Vertical capacity reduction factor $\psi := \frac{1}{3}$ Value of 1/3 recommended by the manual in Sectior 5.7 for pile in cohesionless soils.

Vertical pull out shaft resistance $Q_{uv} := \psi \cdot R_s = 3333\,lb$

Pile group pull out resistance $Q_{uvg} := Q_{uv} \cdot n = 33332\,lb$

Fully submerged structure net vertical force $F_v := 26013lb$ Value from Excel workbook

Vertical Factor of Safety $FS_{vp} := \frac{Q_{uvg}}{F_v} = 1.28$

# Pile Supported Structure - Stability Analysis

Structure Type: Side Channel Apex

Location: Barkley Floodplain - Left Bank

## Assumptions

1. The structure behaves as a single unit under the design load and will efficiently transfer loads to all piles
2. Material behind or in the structure will not provide any support
3. The pile embedment depth (L) can be reached before encountering bedrock
4. There is no scour behind the structure
5. Embedment depth is measured below existing ground

## Input

Gray highlight indicates a user input variable or coefficient

### Soil Properties

Angle of internal friction for substrate, $\phi := 40deg$

Saturated sumberged unit weight of substrate, $\gamma := 80 \frac{lb}{ft^3}$

### Water Properties

Specific weight of water, $\gamma_w := 62.4 \frac{lb}{ft^3}$

Density of water, $\rho_w := 1.94 \frac{slug}{ft^3}$

### Hydraulic Conditions

Discharge Range $Q := 100cfs, 200cfs .. 32000cfs$

Design Discharge Eqiv to 100-yr RP $Q_d := 17900cfs$

Velocity Regression $V(Q) := 6.91 \cdot 10^{-13} \left(\frac{Q}{cfs}\right)^3 \frac{ft}{s} - 4.53 \cdot 10^{-8} \left(\frac{Q}{cfs}\right)^2 \frac{ft}{s} + 9.75 \cdot 10^{-4} \left(\frac{Q}{cfs}\right) \frac{ft}{s} - 1.28 \frac{ft}{s}$

Approach Flow Depth Regression $d_1(Q) := 1.17 \cdot 10^{-13} \left(\frac{Q}{cfs}\right)^3 ft - 1.32 \cdot 10^{-8} \left(\frac{Q}{cfs}\right)^2 ft + 6.59 \cdot 10^{-4} \left(\frac{Q}{cfs}\right) ft + -.421ft$

Design Velocity $V(Q_d) = 5.6 \frac{ft}{s}$

Drag coefficient, $C_d := 2.0$

Design Flow Depth $d_1(Q_d) = 7.8\ ft$

Depth of water on D/S, $d_2(Q) := d_1(Q) - 0.1ft$

### Structure Dimensions

Length parallel to flow $l_{ELJ} := 27ft$

Width into effective flow area $w_{ELJ} := 23ft$

Height above existing grade $h_{ELJ} := 7ft$

### Supporting Pile Specifications

Number of piles carrying load $n := 8$

Pile embedment depth BEGS $L_{BEGS} := 21ft$

Pile Diameter (breadth) $B := 18in$

Pile row spacing (on center in direction of force) $S := 9ft$

### Fully Submerged Structure Case

Accounts for fully submerged ELJ condition and limits depth used in calculation to the structure height and calculates an equivalent width:

$d_{jam1}(Q) := if(d_1(Q) > h_{ELJ}, h_{ELJ}, d_1(Q))$ $d_{jam2}(Q) := if(d_2(Q) > h_{ELJ}, h_{ELJ}, d_2(Q))$

$w_{ELJef}(Q) := \frac{w_{ELJ} \cdot h_{ELJ}}{d_1(Q)}$ $d_1(Q_d) = 8\ ft$ $w_{ELJef}(Q_d) = 21\ ft$

**Scour Depth Estimate** *(Liu, et al. 1961) Modified by Anchor QEA for ELJs*

$$F_r(Q) := \frac{V(Q)}{\sqrt{g \cdot d_1(Q)}} \qquad d_s(Q) := 1.1 \cdot \left(\frac{w_{ELJef}(Q)}{d_1(Q)}\right)^{0.4} \cdot F_r(Q)^{0.33} \cdot d_1(Q)$$

$$F_r(Q_d) = 0.35 \qquad \boxed{d_s(Q_d) = 9.0\,\text{ft}}$$

**Hydraulic Forces**

Frontal Area Experiencing Drag $A_D(Q) := w_{ELJ} \cdot (d_{jam1}(Q))$

Drag Force per pile $F_D(Q) := \dfrac{\left[C_d \cdot A_D(Q) \cdot \left(\rho_w \cdot \dfrac{V(Q)^2}{2}\right)\right]}{n \cdot g}$

Average frontal hydrostatic pressure force $P_{HS1}(Q) := .5 \cdot (d_1(Q) + d_s(Q)) \cdot \gamma_w$

Frontal area experiencing hydrostatic force $A_{HS1}(Q) := (d_{jam1}(Q) + d_s(Q)) \cdot w_{ELJ}$

Hydrostatic force upstream of ELJ per pile $F_{HS1}(Q) := \dfrac{(P_{HS1}(Q) \cdot A_{HS1}(Q))}{n}$

Lee area experiencing hydrostatic force $A_{HS2}(Q) := (d_{jam2}(Q) + d_s(Q)) \cdot w_{ELJ}$

Average hydrostatic pressure force in lee $P_{HS2}(Q) := -.5 \cdot (d_2(Q) + d_s(Q)) \cdot \gamma_w$

Hydrostatic force downstream of ELJ per pile $F_{HS2}(Q) := \dfrac{(P_{HS2}(Q) \cdot A_{HS2}(Q))}{n}$

Net hydraulic force per pile $F_{net}(Q) := F_D(Q) + F_{HS1}(Q) + F_{HS2}(Q)$

Eccentricity of Drag Force $e_D(Q) := \dfrac{d_{jam1}(Q)}{2} + d_s(Q) + 2 \cdot B$

Eccentricity of frontal hydrostatic force $e_{HS1}(Q) := \dfrac{d_1(Q) + d_s(Q)}{3} + 2 \cdot B$

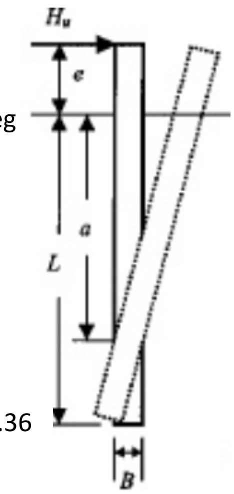
Eccentricity of lee hydrostatic force $e_{HS2}(Q) := \dfrac{d_2(Q) + d_s(Q)}{3} + 2 \cdot B$

Applied moment per pile $M_1(Q) := F_D(Q) \cdot e_D(Q) + F_{HS1}(Q) \cdot e_{HS1}(Q) + F_{HS2}(Q) \cdot e_{HS2}(Q)$

Eccentricity of applied moment $e(Q) := \dfrac{M_1(Q)}{F_{net}(Q)}$

Design Applied moment per pile $\boxed{M_1(Q_d) = 21151\,\text{lb} \cdot \text{ft}}$

**Individual Pile Ultimate Capacity** *(Zhang, 2005)*




Over consolodation ratio $OCR := 8$ Angle of internal friction for substrate $\phi = 40 \cdot deg$

Maximum depth is equal to Embedment Depth Below Scour Depth $z := L(Q_d) = 12\,ft$

Coefficient of passive earth pressure $K_p := \tan\left(45deg + \frac{\phi}{2}\right)^2 = 4.6$

Coefficient of lateral earth pressure at rest $K_0 := (1 - \sin(\phi)) \cdot OCR^{\sin(\phi)} = 1.36$

Lateral earth pressure coefficient for pile installation $K := (0.6 \cdot K_0)$

Interface friction angle between the pile and the soil $\delta := 0.8 \cdot \phi$

Shape factor to account for the nonuniform distribution of earth pressure in front of the pile $\eta := 0.8$

Shape factor to account for the nonuniform distribution of lateral shear drag $\xi := 1.0$

Maximum soil bearing capacity $p_{max} := \frac{\phi}{10deg} K_p \cdot \gamma \cdot z = 17665 \frac{lb}{ft^2}$

*Use the smaller of the two* $K_p^{\,2} = 21$ $\frac{\phi}{10deg} \cdot K_p = 18$

Maximum soil shear capacity $\tau_{max} := K \cdot \gamma \cdot z \cdot \tan(\delta) = 490 \frac{lb}{ft^2}$

Distance to point of rotation $a(Q) := \frac{\left[-(0.567 \cdot L(Q_d) + 2.7 \cdot e(Q)) + (5.307 \cdot L(Q_d)^2 + 7.29 \cdot e(Q)^2 + 10.54 \cdot e(C\right.}{2.1996}$

Ultimate pile load at eccentricity $H_u(Q) := 0.3(\eta \cdot K_p^{\,2} + \xi \cdot K \cdot \tan(\delta)) \cdot \gamma \cdot a(Q) \cdot B \cdot (2.7\,a(Q) - 1.7 \cdot L(Q_d))$

$H_u(Q_d) = 10491\,lb$

**Group Pile Effectiveness Reduction** *(Timber Pile Design Manual, 2002)* Pile Spacing ratio $\frac{S}{B} = 6$

Group load reduction factor for rows of piles $\omega := 1$ $H_{uG}(Q) := H_u(Q) \cdot \omega$ $M_u(Q) := H_{uG}(Q) \cdot e(Q)$

**Soil Strength Factor of Safety**

$FS_{ss}(Q) := \frac{M_u(Q)}{M_1(Q)}$ $FS_{ss}(Q_d) = 7.6$

## Pile Strength Check

Tree Species Bending Stress Capacity *(Timber Pile Manual, Table 3-1. ASTM D25)* $F_b := 1700psi$ Species = Lodgepole Pine Pile Diameter $B = 18 \cdot in$

**Circular Section Moment of Inertia**

$$I := \frac{\pi \cdot (B)^4}{4} = 3.976\,ft^4$$

**Circular Section Modulus**

$$S := \frac{\pi \cdot B^3}{32} = 0.331 \cdot ft^3$$

**Strength Reduction**

Size Factor, $C_F$, for members > 12"

$$C_F := \left(\frac{1ft}{B}\right)^{\left(\frac{1}{9}\right)} = 0.956$$

$$F_{bx} := F_b \cdot C_F = 1625 \cdot \frac{lb}{in^2}$$

**Pile bending stress**

$$f_b(Q) := \frac{M_1(Q)}{S} \qquad f_b(Q_d) = 63834 \frac{lb}{ft^2}$$

**Pile Strength Factor of Safety**

$$FS_{ps}(Q) := \frac{F_{bx}}{f_b(Q)} \qquad \boxed{FS_{ps}(Q_d) = 3.7}$$

## References

Ultimate Lateral Resistance to Piles in Cohesionless Soils J. Geotech. Geoenviron. Eng. 131, 78 (2005); doi:10.1061/(ASCE)1090-0241(2005)131:1(78) (6 pages) Lianyang Zhang, Francisco Silva, and Ralph Grismala

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Table 4D of American Wood Council (2005) National Design Specifications for Wood Construction, Design Supplement.

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ASTM D25. Allowable Stress Values for Treated Round Timber Piles.

**Summary & Figures** Structure Type: Location: Barkley Main Channel

| | | | |
|---|---|---|---|
| Design Discharge (100-yr RP) | $Q_d = 17900 \cdot cfs$ | Scour Depth | $d_s(Q_d) = 9.0\,ft$ |
| Pile Depth Below Existing Grade | $L_{BEGS}(Q_d) = 21.0\,ft$ | Effective Pile Embedment Depth | $L(Q_d) = 12.0\,ft$ |
| Pile Diameter | $B = 18 \cdot in$ | Number of Piles | $n = 8$ |
| Pile Bending Stress Cap. Spec. | $F_b = 1700 \cdot psi$ | Pile Species = Lodgepole Pine | |

**Soil Strength Factor of Safety** $FS_{ss}(Q_d) = 7.6$

**Pile Strength Factor of Safety** $FS_{ps}(Q_d) = 3.7$

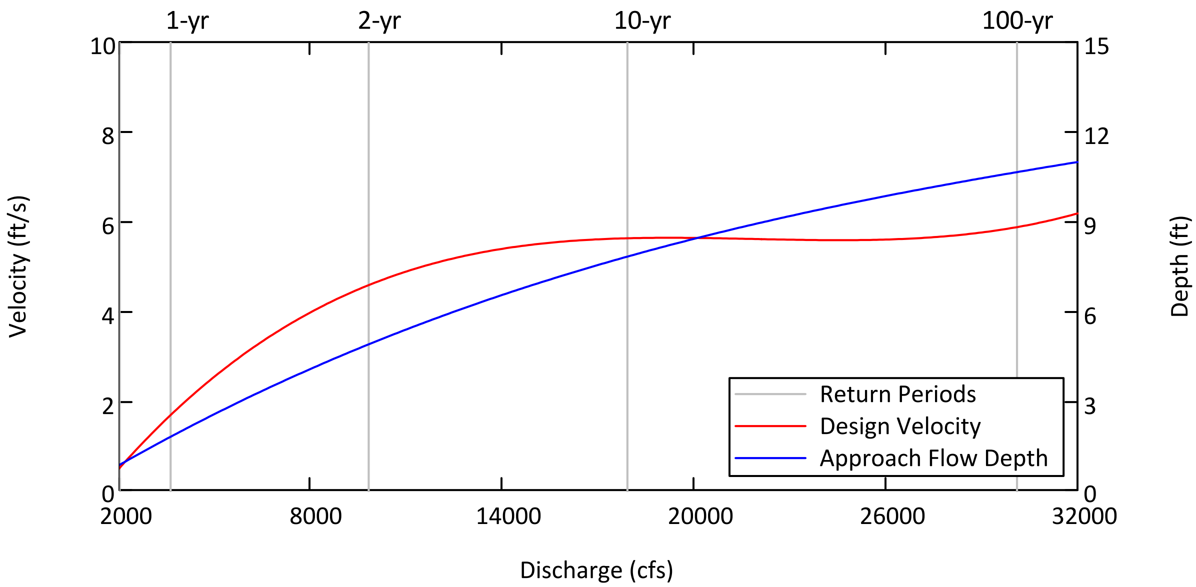



**Figure 1 - Hydraulic Conditions**

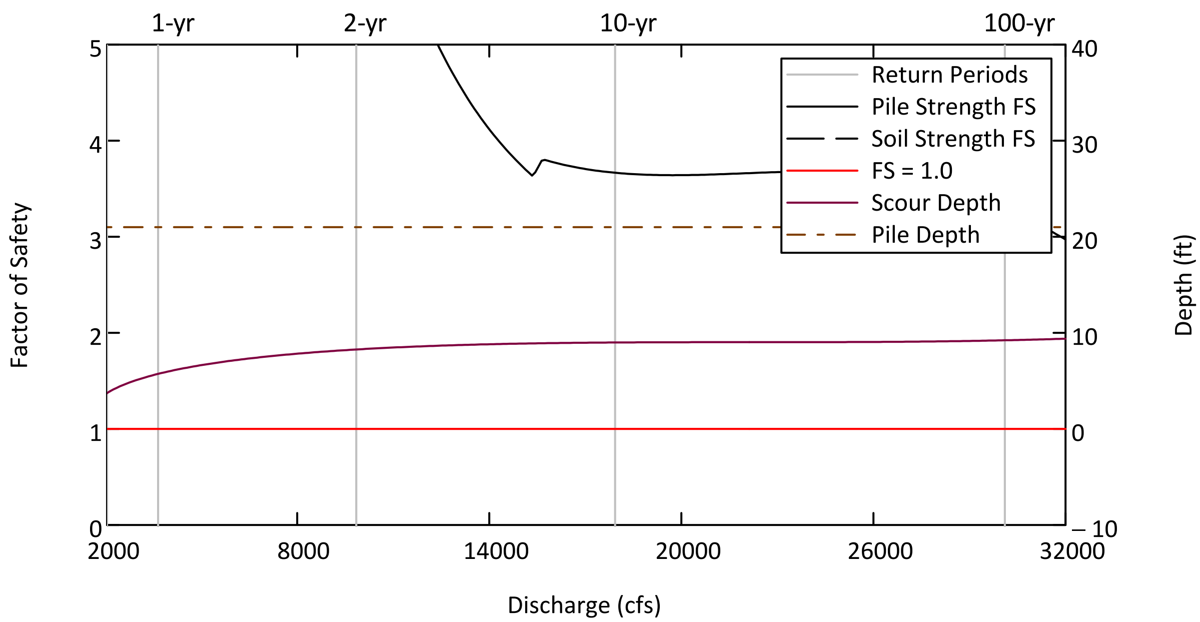



**Figure 2 - Structure Conditions**

**Effective Stress Method Pile for Vertical Pile Capacity** *(Timber Pile Design Manual, 2002)*

Volume of pile per linear foot $V_p := \pi \cdot \left(\frac{B}{2}\right)^2 = 1.77\,ft^2$

Soil friction angle $\varphi := 40deg$ $\omega := 0.8$

Earth pressure coefficient $K_s := 0.6$

Friction angle between the pile and the soil $\delta := \varphi \cdot \omega = 32 \cdot deg$

Bjerrum-Burland beta coefficient $\beta := K_s \cdot \tan(\delta) = 0.37$

Effective overburden pressure $p_o := \frac{L(Q_d) \cdot \gamma}{2} = 480 \frac{lb}{ft^2}$

Unit Shaft Resistance $f_s := \beta \cdot p_o = 180 \frac{lb}{ft^2}$

Pile shaft surface area $A_s := \pi \cdot B \cdot L(Q_d) = 57\,ft^2$

Shaft resistance $R_s := f_s \cdot A_s = 10182\,lb$

Vertical capacity reduction factor $\psi := \frac{1}{3}$ Value of 1/3 recommended by the manual in Sectior 5.7 for pile in cohesionless soils.

Vertical pull out shaft resistance $Q_{uv} := \psi \cdot R_s = 3394\,lb$

Pile group pull out resistance $Q_{uvg} := Q_{uv} \cdot n = 27153\,lb$

Fully submerged structure net vertical force $F_v := 20665lb$ Value from Excel workbook

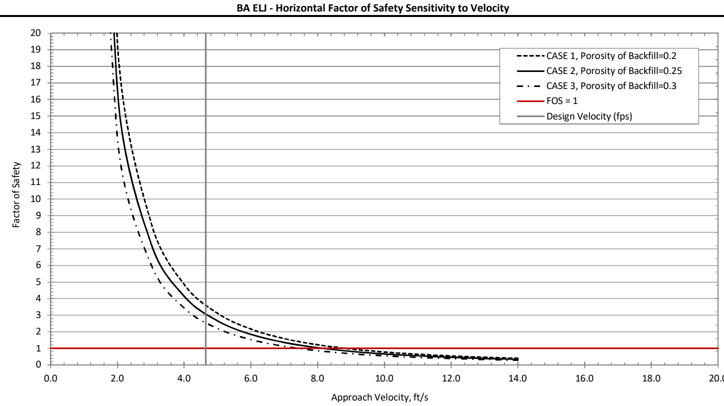
Vertical Factor of Safety $FS_{vp} := \frac{Q_{uvg}}{F_v} = 1.31$

| Horizontal Factor of Safety | Vertical Factor of Safety | | Sed. Specific Gravity, $S_s$ | Density of Water (slugs/ft$^3$) | Specific weight of Water (lb/ft$^3$) | Specific Gravity of Wood | Porosity of Backfill | Backfill Bulk Specific Gravity | Strcuture Friction Angle, Φ | Drag Coefficient | Drury Number | Average Channel Velocity (ft/s) | Area Normal to Flow above Bed Elevation (ft$^2$)* | Drag Force (lb) | Friction Force (lb) | * assumes 10' of exposed bole at 1.5' width, and 3'x4.5' for rootwad area. Conservatively assumes all logs (13) takes full velocity force. | Total Frontal Area (ft$^2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.4 | 5.1 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.2 | 2.12 | 0.698 | 2.0 | 1.0 | 14.0 | 371 | 139,427 | -55,249 | | 108 |
| 0.5 | 5.1 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.2 | 2.12 | 0.698 | 2.0 | 1.0 | 13.0 | 371 | 120,220 | -55,249 | | |
| 0.5 | 5.1 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.2 | 2.12 | 0.698 | 2.0 | 1.0 | 12.0 | 371 | 102,436 | -55,249 | | |
| 0.6 | 5.1 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.2 | 2.12 | 0.698 | 2.0 | 1.0 | 11.0 | 371 | 86,075 | -55,249 | | |
| 0.8 | 5.1 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.2 | 2.12 | 0.698 | 2.0 | 1.0 | 10.0 | 371 | 71,136 | -55,249 | | |
| 1.0 | 5.1 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.2 | 2.12 | 0.698 | 2.0 | 1.0 | 9.0 | 371 | 57,620 | -55,249 | | |
| 1.2 | 5.1 | CASE 1, Porosity of Backfill=0.2 | 2.65 | 1.9 | 62.4 | 0.608 | 0.2 | 2.12 | 0.698 | 2.0 | 1.0 | 8.0 | 371 | 45,527 | -55,249 | | |
| 1.6 | 5.1 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.2 | 2.12 | 0.698 | 2.0 | 1.0 | 7.0 | 371 | 34,857 | -55,249 | | |
| 2.2 | 5.1 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.2 | 2.12 | 0.698 | 2.0 | 1.0 | 6.0 | 371 | 25,609 | -55,249 | | |
| 3.1 | 5.1 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.2 | 2.12 | 0.698 | 2.0 | 1.0 | 5.0 | 371 | 17,784 | -55,249 | DESIGN, 10-yr Velocity Regression | |
| 4.9 | 5.1 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.2 | 2.12 | 0.698 | 2.0 | 1.0 | 4.0 | 371 | 11,382 | -55,249 | | |
| 8.6 | 5.1 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.2 | 2.12 | 0.698 | 2.0 | 1.0 | 3.0 | 371 | 6,402 | -55,249 | | |
| 19.4 | 5.1 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.2 | 2.12 | 0.698 | 2.0 | 1.0 | 2.0 | 371 | 2,845 | -55,249 | | |
| 77.7 | 5.1 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.2 | 2.12 | 0.698 | 2.0 | 1.0 | 1.0 | 371 | 711 | -55,249 | | |
| 0.3 | 4.5 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.25 | 1.99 | 0.698 | 2.0 | 1.0 | 14.0 | 371 | 139,427 | -47,135 | | 108 |
| 0.4 | 4.5 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.25 | 1.99 | 0.698 | 2.0 | 1.0 | 13.0 | 371 | 120,220 | -47,135 | | |
| 0.5 | 4.5 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.25 | 1.99 | 0.698 | 2.0 | 1.0 | 12.0 | 371 | 102,436 | -47,135 | | |
| 0.5 | 4.5 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.25 | 1.99 | 0.698 | 2.0 | 1.0 | 11.0 | 371 | 86,075 | -47,135 | | |
| 0.7 | 4.5 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.25 | 1.99 | 0.698 | 2.0 | 1.0 | 10.0 | 371 | 71,136 | -47,135 | | |
| 0.8 | 4.5 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.25 | 1.99 | 0.698 | 2.0 | 1.0 | 9.0 | 371 | 57,620 | -47,135 | | |
| 1.0 | 4.5 | CASE 2, Porosity of Backfill=0.25 | 2.65 | 1.9 | 62.4 | 0.608 | 0.25 | 1.99 | 0.698 | 2.0 | 1.0 | 8.0 | 371 | 45,527 | -47,135 | | |
| 1.4 | 4.5 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.25 | 1.99 | 0.698 | 2.0 | 1.0 | 7.0 | 371 | 34,857 | -47,135 | | |
| 1.8 | 4.5 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.25 | 1.99 | 0.698 | 2.0 | 1.0 | 6.0 | 371 | 25,609 | -47,135 | | |
| 2.7 | 4.5 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.25 | 1.99 | 0.698 | 2.0 | 1.0 | 5.0 | 371 | 17,784 | -47,135 | | |
| 4.1 | 4.5 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.25 | 1.99 | 0.698 | 2.0 | 1.0 | 4.0 | 371 | 11,382 | -47,135 | | |
| 7.4 | 4.5 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.25 | 1.99 | 0.698 | 2.0 | 1.0 | 3.0 | 371 | 6,402 | -47,135 | | |
| 16.6 | 4.5 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.25 | 1.99 | 0.698 | 2.0 | 1.0 | 2.0 | 371 | 2,845 | -47,135 | | |
| 66.3 | 4.5 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.25 | 1.99 | 0.698 | 2.0 | 1.0 | 1.0 | 371 | 711 | -47,135 | | |
| 0.3 | 3.9 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.3 | 1.86 | 0.698 | 2.0 | 1.0 | 14.0 | 371 | 139,427 | -39,020 | | 108 |
| 0.3 | 3.9 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.3 | 1.86 | 0.698 | 2.0 | 1.0 | 13.0 | 371 | 120,220 | -39,020 | | |
| 0.4 | 3.9 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.3 | 1.86 | 0.698 | 2.0 | 1.0 | 12.0 | 371 | 102,436 | -39,020 | | |
| 0.5 | 3.9 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.3 | 1.86 | 0.698 | 2.0 | 1.0 | 11.0 | 371 | 86,075 | -39,020 | | |
| 0.5 | 3.9 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.3 | 1.86 | 0.698 | 2.0 | 1.0 | 10.0 | 371 | 71,136 | -39,020 | | |
| 0.7 | 3.9 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.3 | 1.86 | 0.698 | 2.0 | 1.0 | 9.0 | 371 | 57,620 | -39,020 | | |
| 0.9 | 3.9 | CASE 3, Porosity of Backfill=0.3 | 2.65 | 1.9 | 62.4 | 0.608 | 0.3 | 1.86 | 0.698 | 2.0 | 1.0 | 8.0 | 371 | 45,527 | -39,020 | | |
| 1.1 | 3.9 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.3 | 1.86 | 0.698 | 2.0 | 1.0 | 7.0 | 371 | 34,857 | -39,020 | | |
| 1.5 | 3.9 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.3 | 1.86 | 0.698 | 2.0 | 1.0 | 6.0 | 371 | 25,609 | -39,020 | | |
| 2.2 | 3.9 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.3 | 1.86 | 0.698 | 2.0 | 1.0 | 5.0 | 371 | 17,784 | -39,020 | | |
| 3.4 | 3.9 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.3 | 1.86 | 0.698 | 2.0 | 1.0 | 4.0 | 371 | 11,382 | -39,020 | | |
| 6.1 | 3.9 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.3 | 1.86 | 0.698 | 2.0 | 1.0 | 3.0 | 371 | 6,402 | -39,020 | | |
| 13.7 | 3.9 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.3 | 1.86 | 0.698 | 2.0 | 1.0 | 2.0 | 371 | 2,845 | -39,020 | | |
| 54.9 | 3.9 | | 2.65 | 1.9 | 62.4 | 0.608 | 0.3 | 1.86 | 0.698 | 2.0 | 1.0 | 1.0 | 371 | 711 | -39,020 | | |

| Layer | Number of Logs w/ RW | Number of Logs Without Rootwad | Diameter (ft) | Log Length (ft) | Length of Layer (ft) | Width of Layer (ft) | Length of Open Space Not Available for Ballast (ft) | Rootwad Diam. (ft) | Rootwad Length (ft) | RW Vol. Reduction, CA | Bole Diam. Reduction | Footprint Area of Layer (sq ft) | Volume Of Layer (cubic ft) | Volume of Rootwad (cubic ft) | Volume of Bole (cubic ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6 | 0 | 1.5 | 30.0 | 20.0 | 25.0 | 10.0 | 4.5 | 3.0 | 0.30 | 0.8 | 500 | 750 | 6.9 | 43.1 |
| 2 | 7 | 0 | 1.5 | 30.0 | 20.0 | 25.0 | 10.0 | 4.5 | 3.0 | 0.30 | 0.8 | 500 | 750 | 6.9 | 43.1 |

**Bar Apex**

**BA ELJ - Horizontal Factor of Safety Sensitivity to Velocity**




**Graphing Data**

| | | |
|---|---|---|
| Design Velocity (fps) | 4.7 | 0 |
| | 4.7 | 5 |
| Design Depth | 3.0 | |

| | Total Volume of wood for Layer | Volume of Boles for Layer | Volume of Rootwads for Layer | Volume Available for Ballast (cubic feet)* | Wood Submerged Net Force (lb) | Ballast (lb) From Backfilling at a Porosity of 0.2 | Ballast (lb) From Backfilling at a Porosity of 0.25 | Ballast (lb) From Backfilling at a Porosity of 0.3 |
|---|---|---|---|---|---|---|---|---|
| | 300.1 | 258.7 | 41.4 | 540.0 | 7,342 | -37,752 | -33,285 | -28,819 |
| | 350.1 | 301.8 | 48.2 | 630.0 | 8,566 | -44,044 | -38,833 | -33,623 |
| **ELJ Total** | **650** | **561** | **90** | **1,170** | **15,908** | **-81,795** | **-72,119** | **-62,442** |

* assumes 3' depth of fill above each log.

## 6.4 BOATER SAFETY ANALYSIS

January 2019
Barkley Bear Habitat Restoration Project

# Boater Safety Analysis

**Prepared for**
Bureau of Reclamation
Pacific Northwest Region
Pacific Northwest Regional Office, Boise, Idaho

**Prepared by:**
Mike Gieschen;
Tracy Drury
Anchor QEA, LLC
1605 Cornwall Ave.
Bellingham, Washington

# Boater Safety Analysis Narrative

## Introduction

In order to assess the risk to recreational boaters that the Barkley Bear Habitat Restoration Project, the following boater safety analysis was performed. During 30% design an initial analysis was conducted using the basic method described in the National Large Wood Manual (Reclamation 2016). To better represent the specific flows, structures, user characteristics and floodplain layout of this project, the methodology was refined for 80% based on the definition of risk as the product of probability and consequence. In terms of riverine structures and recreational users this translates to probability of impact with the structure, or opportunity to avoid, and consequence of impact with the structure, or hazard. Therefore, each of the structures groups were graded on a matrix of their opportunity to avoid and hazard as well as overall risk, the product of opportunity to avoid and hazard. A description of the metrics used to assess both opportunity to avoid and hazard, as well as the structure analysis groupings are discussed below.

## Methods

Through discussion with the project team, it was decided that an analysis of every proposed structure, would be unnecessary and ineffective. Therefore, six groupings were created based on both similar structure types and similar locations within the floodplain or channel. Group 1 includes the Island Apex ELJ and Excavated Island Side Channel located at the head of the left bank floodplain island. Group 2 includes the 3 Bank Barbs on the right bank of the main channel. Group 3 contains the entire side channel, referred to on the drawings as the "70's Channel", and all of the wood features located there. Group 4 includes the two Bank Complexity ELJ's and Side Channel Apex ELJ's 2 and 3. Group 5 consists of Side Channel ELJ 1 as well as the canal and canal benching. Finally Group 6 includes only the Channel Barb ELJ located at the confluence with bear creek. In addition, the existing Apex ELJ at the head of Whitefish Island located just downstream of the Barkley Bear project and already included in the modeling results, was analyzed to set a baseline for the other structures. A map of these structure groupings can be found on page 5 of this appendix.

Since there are a wide range of flow conditions, user ability and craft types likely to encounter the structures of the Barkley Bear Project several analysis iterations were performed for each structure group. Six flows were selected, these flows are list and described in Table 1 below. More information and the statistical significance of each of these flows can be found in the discussion on Hydrology in the 80% Basis of Design Report (Anchor QEA 2018).

**Table 1**
**Flows Analyzed for Boater Safety on the Methow River**

| Flow (cfs) | Boater Safety Significance |
|---|---|
| 360 | Lowest flow likely for Boaters |
| 2000 | Mean Flow for $4^{th}$ of July, a popular day for river recreation |
| 3600 | Mean Flow for May and June, the “early months” for river recreation |
| 6000 | High Flow for $4^{th}$ of July |
| 9800 | High Flow for Memorial Day, first major holiday when river recreation is possible |

Each of these flows was then analyzed for both a highly maneuverable craft, such as a whitewater kayak or raft, and a low maneuverability craft such as a canoe, or paddleboard. Using these 12 analyses for each structure grouping, a range of risk could be found and compared to an existing and acceptable structure on the river.

The degree of hazard that a structure posed was graded based on seven metrics, summarized in Table 2 below, and graded on a scale of 0 to 10. Through discussions with the project team it was decided that several metrics would be weighted higher due to the severity of the hazard they posed, however, no other attempt was made to judge the consequences that would occur should a boater come in contract with the structure. The opportunity to avoid for a structure group at a given flow and craft type was judged based on five metrics, summarized in Table 2 below, and graded on a scale of 10 to 0, with 10 being the easiest to avoid and 0 being impossible to avoid. A complete breakdown of these metrics and how they were scored can be found on Page 6 of this appendix.

**Table 2**
**Boater Safety Metrics**

| Hazard Metrics | Opportunity to Avoid Metrics |
|---|---|
| Structure Has Protruding Rootwads | User Has Prior Knowledge of Structure |
| Structure Does Not Have “Bumper Logs” | Where on the Channel the Structure is Located |
| Structure Has Potential Underwater Hazards[1] | Reaction Time (Sight Distance/Avg. Velocity) |
| Structure has Potential for Deep Scour Pools | Wading Safety Factor (Velocity X Depth near structure) |
| Structure Could Cause a Hydraulic Jump, Chute or Flume[1] | Potential to “Bail Out” (Upstream Velocity Eddy) |
| Structure Has Strainers[1] | - |
| Structure Has Potential for Wood Recruitment | - |

Notes: 1. Metric was weighted more heavily in the scoring.

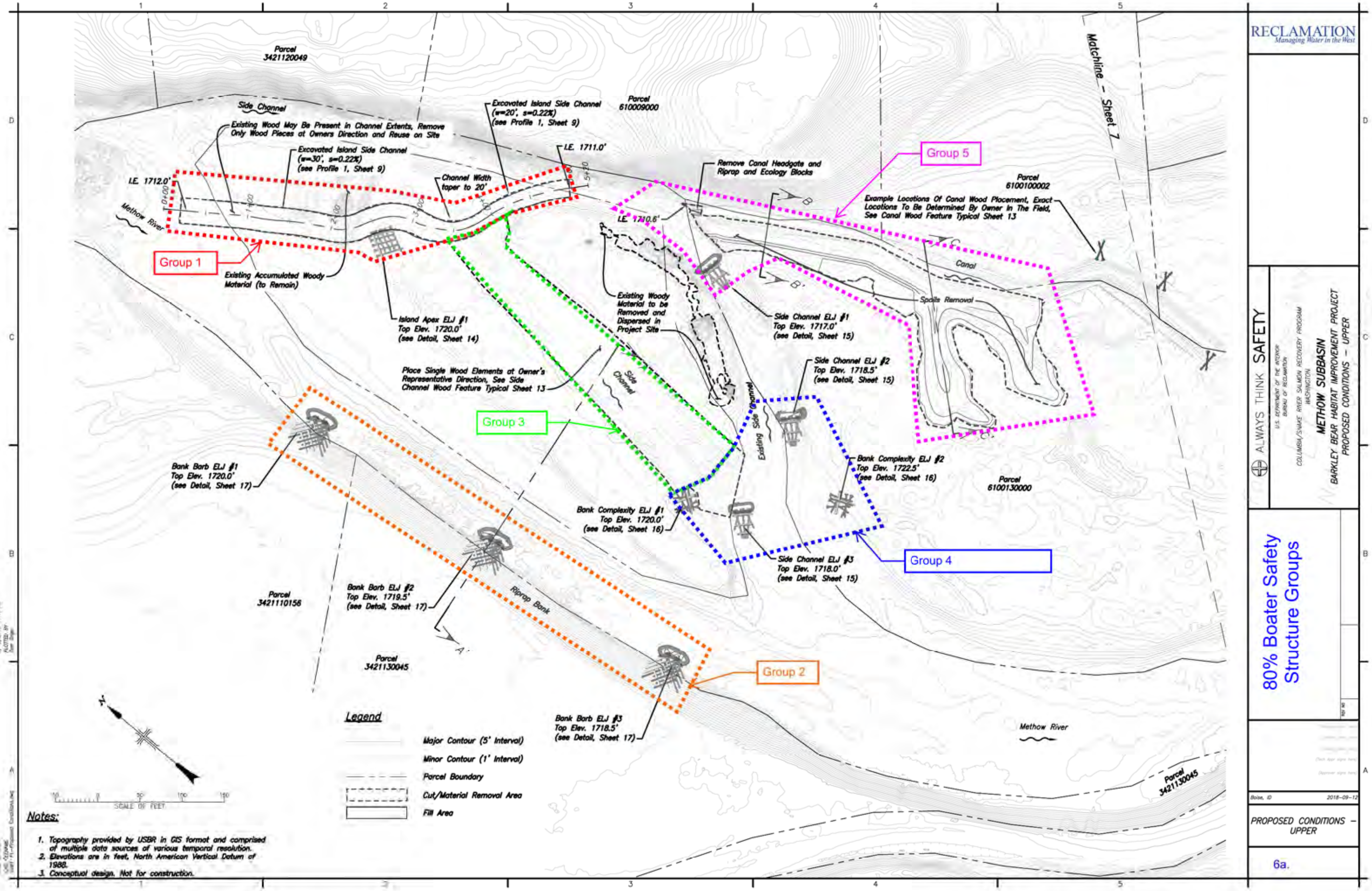
## Results

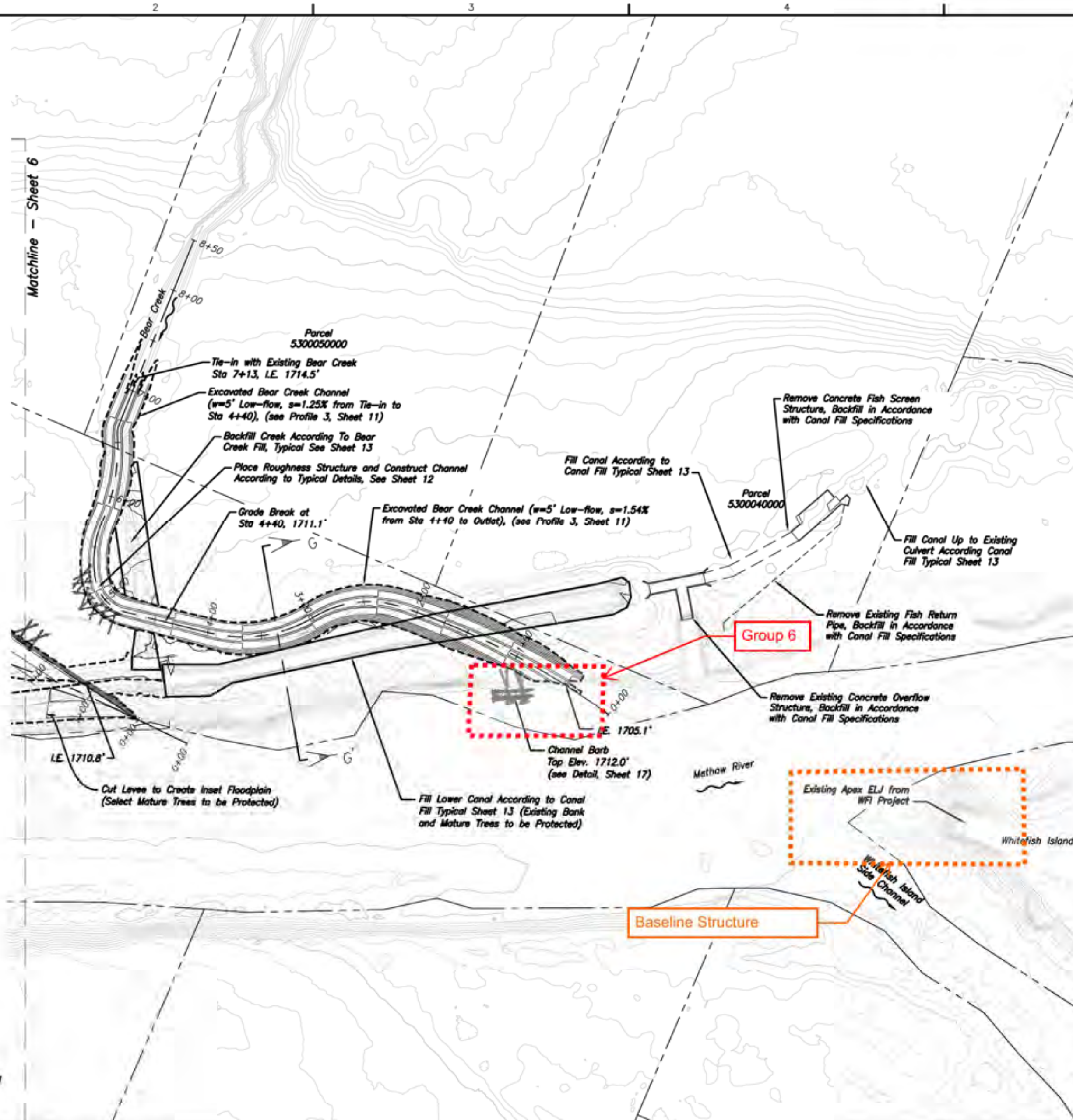
The results of the risk analysis for each structure group are presented on the following pages of this appendix. This report does not attempt to decide if an individual structure group should be included but rather presents the relative risk as determined by this method. The final hazard scores and opportunity to avoid scores are listed in tables by group number along with a risk matrix showing opportunity to avoid and hazard for each flow and craft type. A general range of risk for each craft type, encompassing all of the flows, is also indicated on the matrix. Finally, the product of hazard and opportunity to avoid was taken to show how the risk varies as flows change on the Risk Curves presented for each structure group.

## References

Anchor QEA (Anchor QEA, LLC), 2018. 80% Basis of Design Report: Barkley Bear Habitat Restoration Project. Prepared for the United States Bureau of Reclamation. Bellingham, Washington.

Reclamation (US Bureau of Reclamation), and U.S. Army Engineer Research and Development Center. 2016. National Large Wood Manual: Assessment, Planning, Design, and Maintenance of Large Wood in Fluvial Ecosystems: Restoring Process, Function, and Structure. US Bureau of Reclamation, Pacific Northwest Regional Office; Boise, Idaho.


Parcel 3421120049
Parcel 610009000
Side Channel
Existing Wood May Be Present in Channel Extents, Remove Only Wood Pieces at Owners Direction and Reuse on Site
Excavated Island Side Channel (w=20', s=0.22%) (see Profile 1, Sheet 9)
Excavated Island Side Channel (w=30', s=0.22%) (see Profile 1, Sheet 9)
I.E. 1711.0'
I.E. 1712.0'
Channel Width taper to 20'
Methow River
Group 1
Existing Accumulated Woody Material (to Remain)
Island Apex ELJ #1 Top Elev. 1720.0' (see Detail, Sheet 14)
Remove Canal Headgate and Riprap and Ecology Blocks
Group 5
Parcel 6100100002
Example Locations Of Canal Wood Placement, Exact Locations To Be Determined By Owner In The Field, See Canal Wood Feature Typical Sheet 13
I.E. 1710.6'
Canal
Spoils Removal
Matchline – Sheet 7
Existing Woody Material to be Removed and Dispersed in Project Site
Side Channel ELJ #1 Top Elev. 1717.0' (see Detail, Sheet 15)
Side Channel ELJ #2 Top Elev. 1718.5' (see Detail, Sheet 15)
Place Single Wood Elements at Owner's Representative Direction, See Side Channel Wood Feature Typical Sheet 13
Side Channel
Existing Side Channel
Group 3
Bank Complexity ELJ #2 Top Elev. 1722.5' (see Detail, Sheet 16)
Parcel 6100130000
Bank Barb ELJ #1 Top Elev. 1720.0' (see Detail, Sheet 17)
Bank Complexity ELJ #1 Top Elev. 1720.0' (see Detail, Sheet 16)
Side Channel ELJ #3 Top Elev. 1718.0' (see Detail, Sheet 15)
Group 4
Parcel 3421110156
Bank Barb ELJ #2 Top Elev. 1719.5' (see Detail, Sheet 17)
Riprap Bank
Parcel 3421130045
Group 2
Bank Barb ELJ #3 Top Elev. 1718.5' (see Detail, Sheet 17)
Methow River
Parcel 3421130045
N
SCALE OF FEET
Legend
Major Contour (5' Interval)
Minor Contour (1' Interval)
Parcel Boundary
Cut/Material Removal Area
Fill Area
Notes:
1. Topography provided by USBR in GIS format and comprised of multiple data sources of various temporal resolution.
2. Elevations are in feet, North American Vertical Datum of 1988.
3. Conceptual design. Not for construction.
RECLAMATION
Managing Water in the West
ALWAYS THINK SAFETY
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLUMBIA/SNAKE RIVER SALMON RECOVERY PROGRAM
WASHINGTON
METHOW SUBBASIN
BARKLEY BEAR HABITAT IMPROVEMENT PROJECT
PROPOSED CONDITIONS – UPPER
80% Boater Safety Structure Groups
Boise, ID
2018-09-12
PROPOSED CONDITIONS – UPPER
6a.




## Legend

- Major Contour (5' Interval)
- Minor Contour (1' Interval)
- Parcel Boundary
- Cut/Material Removal Area
- Rip–Rap Removal Extent
- Fill Area

N

50 0 50 100 150
SCALE OF FEET

## Notes:

1. Topography provided by USBR in GIS format and comprised of multiple data sources of various temporal resolution.
2. Elevations are in feet, North American Vertical Datum of 1988.
3. Conceptual design. Not for construction.

RECLAMATION
Managing Water in the West

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U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLUMBIA/SNAKE RIVER SALMON RECOVERY PROGRAM
WASHINGTON

METHOW SUBBASIN
BARKLEY BEAR HABITAT IMPROVEMENT PROJECT
PROPOSED CONDITIONS – LOWER

80% Boater Safety Structure Groups

Boise, ID 2018–09–12

PROPOSED CONDITIONS – LOWER

6b.

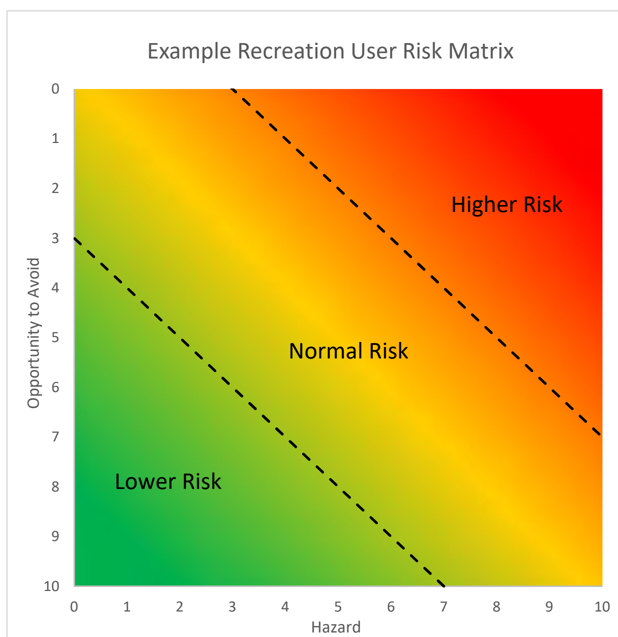
# Barkley Bear Reach User Risk Assessment Metrics



| Opportunity to Avoid For Maneuverable Craft | |
|---|---|
| **Prior Knowledge of Structure** | |
| Signed | 10 |
| Not Signed | 5 |
| | |
| **Active Channel (Scaled to 0-10)** | |
| On floodplain not accessed by flow | 10 |
| High Flow Side Channel | 8 |
| High Flow Side Channel Outside Bend | 7 |
| Outside of primary flow path | 6 |
| Outside of primary flow path, outside bend | 5 |
| Main Channel | 3 |
| Outside Bend of Main Channel | 0 |
| | |
| **Reaction Time (seconds)** | |
| 120+ (ample) | 10 |
| 60-120 (long) | 7.5 |
| 30-60 (moderate) | 5 |
| 10-30 (short) | 2.5 |
| <10 (very short) | 0 |
| | |
| **Wading Safety Factor (Depth X Velocity) (Scaled to 0-10)** | |
| Worst Case (0) Depth(ft) is: | 3 |
| Worst Case (0) Velocity (fps) is: | 5 |
| Example Depth(ft) of : | 2.5 |
| And Example Velocity(fps) of: | 3 |
| Results in Score of: | 5.00 |
| | |
| **Potential for Bail Out** | |
| No Upstream Eddy, No location to Take out | 1 |
| No Upstream Eddy, Location to Take out | 2 |
| Upstream Eddy <50 from structure | 4 |
| Upstream Eddy >50' From Structure | 6 |
| Upstream Eddy >50' and location to take out | 10 |

| Opportunity to Avoid For Poorly Maneuverable Craft | |
|---|---|
| **Prior Knowledge of Structure** | |
| Signed | 10 |
| Not Signed | 0 |
| | |
| **Active Channel (Scaled to 0-10)** | |
| On floodplain not accessed by flow | 10 |
| High Flow Side Channel | 8 |
| High Flow Side Channel Outside Bend | 7 |
| Outside of primary flow path | 6 |
| Outside of primary flow path, outside bend | 5 |
| Main Channel | 3 |
| Outside Bend of Main Channel | 0 |
| | |
| **Reaction Time (seconds)** | |
| 150+ (ample) | 10 |
| 90-150 (long) | 7.5 |
| 45-90 (moderate) | 5 |
| 30-45 (short) | 2.5 |
| <30 (very short) | 0 |
| | |
| **Wading Safety Factor (Depth X Velocity) (Scaled to 0-10)** | |
| Worst Case (0) Depth(ft) is: | 3 |
| Worst Case (0) Velocity (fps) is: | 4 |
| Example Depth(ft) of : | 2.98 |
| And Example Velocity(fps) of: | 4.98 |
| Results in Score of: | 2.05 |
| | |
| **Potential for Bail Out** | |
| No Upstream Eddy | 0 |
| Upstream Eddy <100' from structure | 2 |
| Upstream Eddy >100' From Structure | 4 |
| Upstream Eddy >100' and location to take out | 8 |

| Hazard | Yes Or No | Weight |
|---|---|---|
| Rootwads Protruding | | 1 |
| No Bumper Logs | | 1 |
| Potential Underwater Hazards | | 2 |
| Potential Scour Pools | | 1 |
| Causes hydraulic jump, Chute or Flume | | 2 |
| Has Strainers | | 2 |
| Potential For Wood Recruitment | | 1 |
| Total Score(_/10) | | 10 |



# Baseline Structure

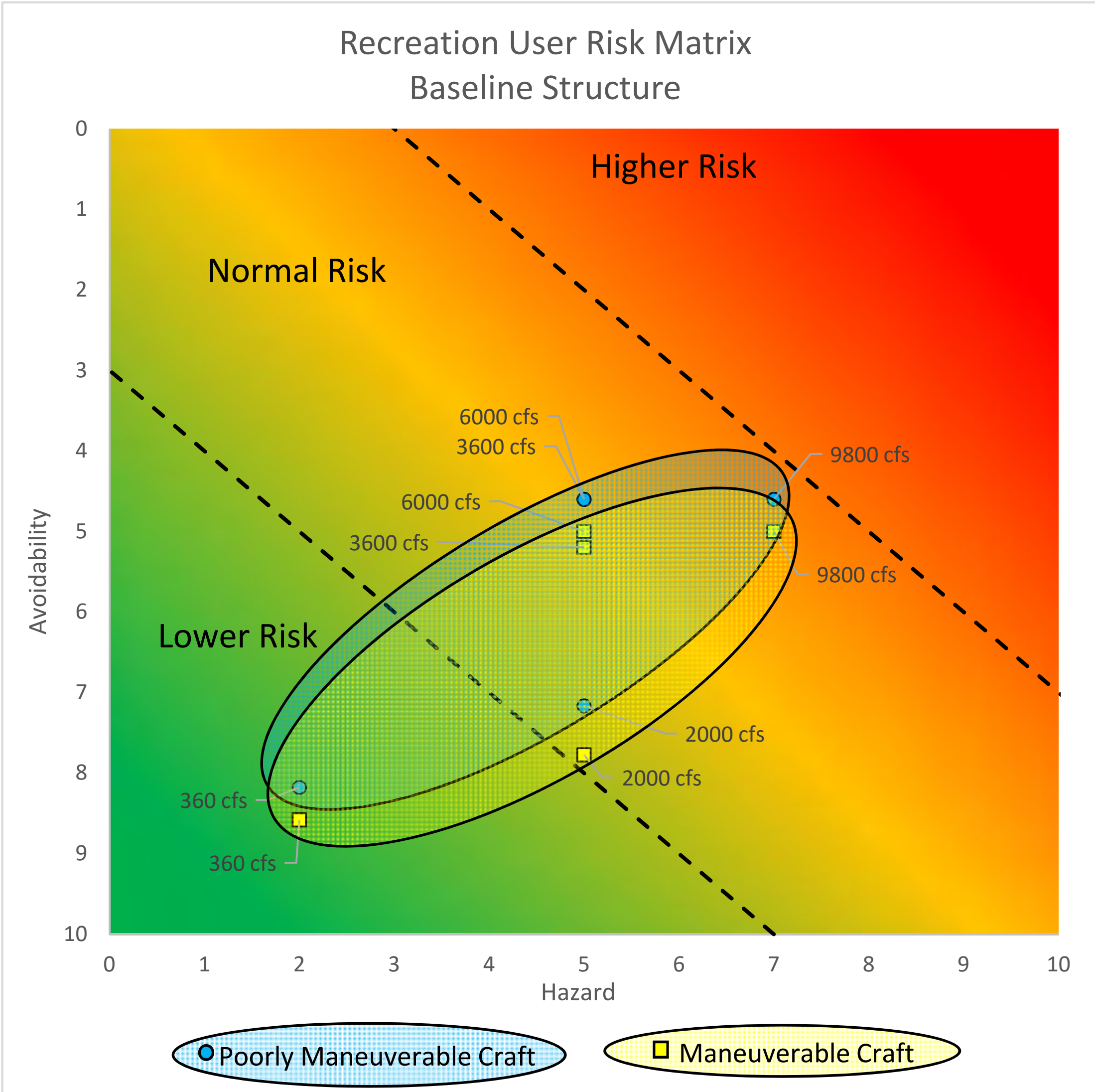
## WFI Apex ELJ

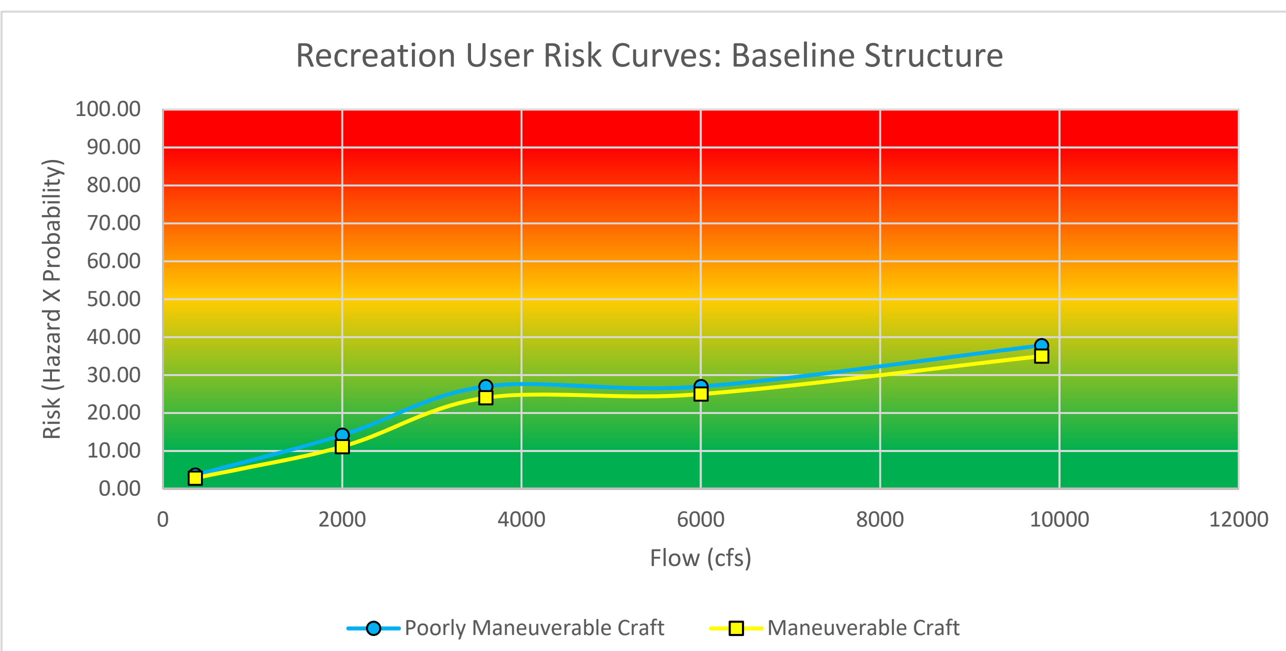
| Hazard Scoring | | | | | |
|---|---|---|---|---|---|
| **Flow** | **360 cfs** | **2000 cfs** | **3600 cfs** | **6000 cfs** | **9800 cfs** |
| **Rootwads Protruding** | 1 | 1 | 1 | 1 | 1 |
| **No Bumper Logs** | 0 | 0 | 0 | 0 | 0 |
| **Potential Underwater Hazards** | 0 | 2 | 2 | 2 | 2 |
| **Potential Scour Pools** | 0 | 1 | 1 | 1 | 1 |
| **Causes hydraulic jump, Chute or Flume** | 0 | 0 | 0 | 0 | 0 |
| **Has Strainers** | 0 | 0 | 0 | 0 | 2 |
| **Potential For Wood Recruitment** | 1 | 1 | 1 | 1 | 1 |
| **Total** | 2 | 5 | 5 | 5 | 7 |

| Avoidability Scoring for a Poorly Maneuverable Craft | | | | | |
|---|---|---|---|---|---|
| **Flow** | **360 cfs** | **2000 cfs** | **3600 cfs** | **6000 cfs** | **9800 cfs** |
| **Prior Knowladge of Structure** | 10 | 10 | 10 | 10 | 10 |
| **Location on Active Channel** | 3 | 3 | 3 | 3 | 3 |
| **Reaction Time** | 10 | 10 | 10 | 10 | 10 |
| **Wading Safety Factor** | 9.88 | 4.83 | 0.00 | 0.00 | 0.00 |
| **Potential For Bail-Out** | 8 | 8 | 0 | 0 | 0 |
| **Total** | 8.18 | 7.17 | 4.60 | 4.60 | 4.60 |
| **Probability (10- total)** | 1.82 | 2.84 | 5.40 | 5.40 | 5.40 |

| Avoidability Scoring for a Maneuverable Craft | | | | | |
|---|---|---|---|---|---|
| **Flow** | **360 cfs** | **2000 cfs** | **3600 cfs** | **6000 cfs** | **9800 cfs** |
| **Prior Knowladge of Structure** | 10 | 10 | 10 | 10 | 10 |
| **Location on Active Channel** | 3 | 3 | 3 | 3 | 3 |
| **Reaction Time** | 10 | 10 | 10 | 10 | 10 |
| **Wading Safety Factor** | 9.91 | 5.86 | 0.98 | 0.00 | 0.00 |
| **Potential For Bail-Out** | 10 | 10 | 2 | 2 | 2 |
| **Total** | 8.58 | 7.77 | 5.20 | 5.00 | 5.00 |
| **Probability (10- total)** | 1.42 | 2.23 | 4.80 | 5.00 | 5.00 |

| Risk | | | | | |
|---|---|---|---|---|---|
| **Flow (cfs)** | **360** | **2000** | **3600** | **6000** | **9800** |
| **Poorly Maneuverable Craft** | 3.65 | 14.18 | 27.00 | 27.00 | 37.80 |
| **Maneuverable Craft** | 2.84 | 11.14 | 24.02 | 25.00 | 35.00 |


Recreation User Risk Matrix
Baseline Structure
Higher Risk
Normal Risk
Lower Risk
Avoidability
Hazard
0
1
2
3
4
5
6
7
8
9
10
6000 cfs
3600 cfs
6000 cfs
3600 cfs
9800 cfs
9800 cfs
2000 cfs
2000 cfs
360 cfs
360 cfs
Poorly Maneuverable Craft
Maneuverable Craft


Recreation User Risk Curves: Baseline Structure
Risk (Hazard X Probability)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
2000
4000
6000
8000
10000
12000
Flow (cfs)
Poorly Maneuverable Craft
Maneuverable Craft

# Group 1

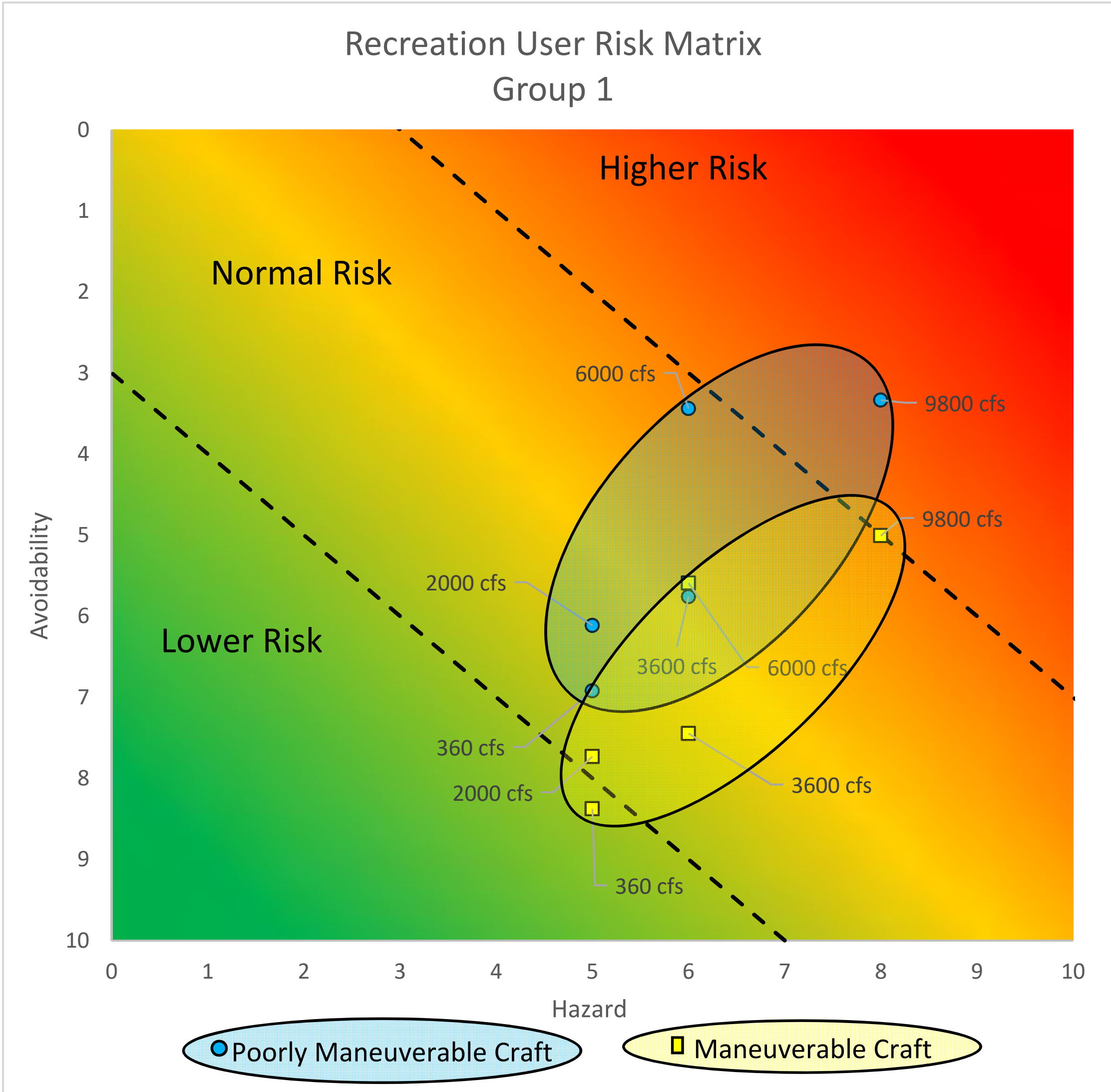
## Island Apex ELJ and Excavated Island Side Channel

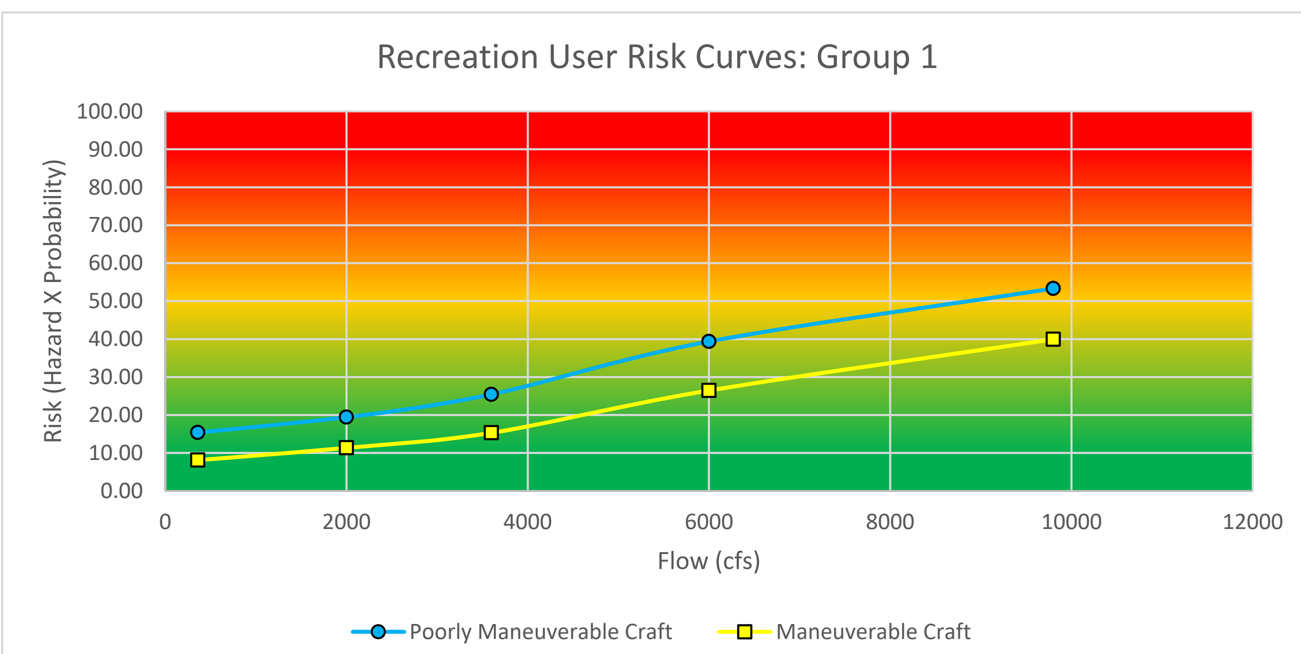
| Hazard Scoring | | | | | |
|---|---|---|---|---|---|
| **Flow** | **360 cfs** | **2000 cfs** | **3600 cfs** | **6000 cfs** | **9800 cfs** |
| **Rootwads Protruding** | 0 | 0 | 1 | 1 | 1 |
| **No Bumper Logs** | 1 | 1 | 1 | 1 | 1 |
| **Potential Underwater Hazards** | 2 | 2 | 2 | 2 | 2 |
| **Potential Scour Pools** | 1 | 1 | 1 | 1 | 1 |
| **Causes hydraulic jump, Chute or Flume** | 0 | 0 | 0 | 0 | 0 |
| **Has Strainers** | 0 | 0 | 0 | 0 | 2 |
| **Potential For Wood Recruitment** | 1 | 1 | 1 | 1 | 1 |
| **Total** | 5 | 5 | 6 | 6 | 8 |

| Avoidability Scoring for a Poorly Maneuverable Craft | | | | | |
|---|---|---|---|---|---|
| **Flow** | **360 cfs** | **2000 cfs** | **3600 cfs** | **6000 cfs** | **9800 cfs** |
| **Prior Knowladge of Structure** | 0 | 0 | 0 | 0 | 0 |
| **Location on Active Channel** | 8 | 8 | 8 | 6 | 6 |
| **Reaction Time** | 10 | 10 | 10 | 7.5 | 7.5 |
| **Wading Safety Factor** | 8.61 | 4.58 | 2.80 | 3.70 | 3.18 |
| **Potential For Bail-Out** | 8 | 8 | 8 | 0 | 0 |
| **Total** | 6.92 | 6.12 | 5.76 | 3.44 | 3.34 |
| **Probability (10- total)** | 3.08 | 3.89 | 4.24 | 6.56 | 6.67 |

| Avoidability Scoring for a Maneuverable Craft | | | | | |
|---|---|---|---|---|---|
| **Flow** | **360 cfs** | **2000 cfs** | **3600 cfs** | **6000 cfs** | **9800 cfs** |
| **Prior Knowladge of Structure** | 5 | 5 | 5 | 5 | 5 |
| **Location on Active Channel** | 8 | 8 | 8 | 6 | 6 |
| **Reaction Time** | 10 | 10 | 10 | 10 | 7.5 |
| **Wading Safety Factor** | 8.89 | 5.66 | 4.24 | 4.96 | 4.54 |
| **Potential For Bail-Out** | 10 | 10 | 10 | 2 | 2 |
| **Total** | 8.38 | 7.73 | 7.45 | 5.59 | 5.01 |
| **Probability (10- total)** | 1.62 | 2.27 | 2.55 | 4.41 | 4.99 |

| Risk | | | | | |
|---|---|---|---|---|---|
| **Flow (cfs)** | **360** | **2000** | **3600** | **6000** | **9800** |
| **Poorly Maneuverable Craft** | 15.39 | 19.43 | 25.44 | 39.36 | 53.32 |
| **Maneuverable Craft** | 8.11 | 11.34 | 15.31 | 26.45 | 39.94 |


Recreation User Risk Matrix
Group 1
Higher Risk
Normal Risk
Lower Risk
6000 cfs
9800 cfs
9800 cfs
2000 cfs
3600 cfs
6000 cfs
360 cfs
2000 cfs
3600 cfs
360 cfs
Avoidability
Hazard
0
1
2
3
4
5
6
7
8
9
10
Poorly Maneuverable Craft
Maneuverable Craft


Recreation User Risk Curves: Group 1
Risk (Hazard X Probability)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
2000
4000
6000
8000
10000
12000
Flow (cfs)
Poorly Maneuverable Craft
Maneuverable Craft

# Group 2

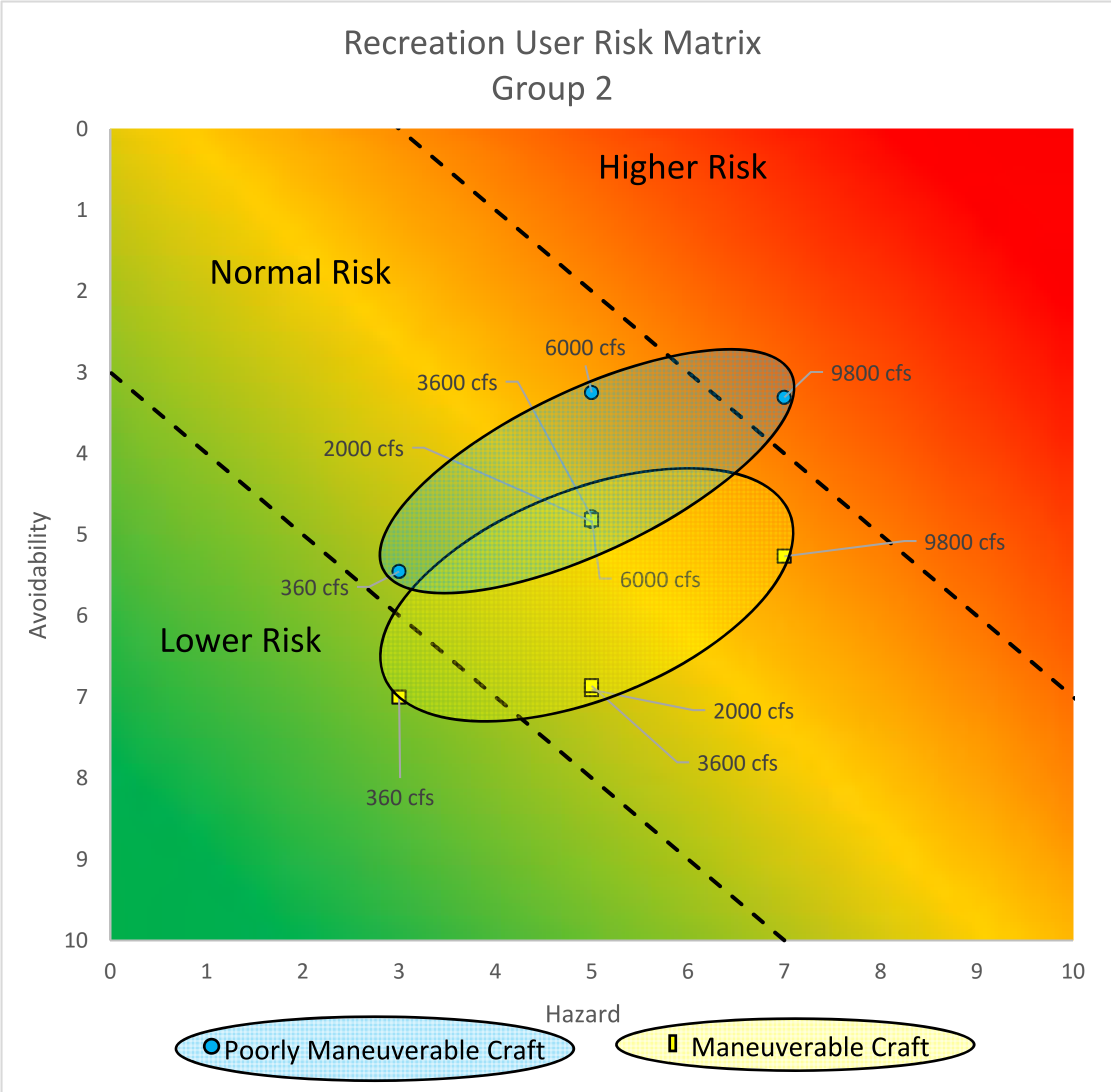
## Bank Barb ELJ's

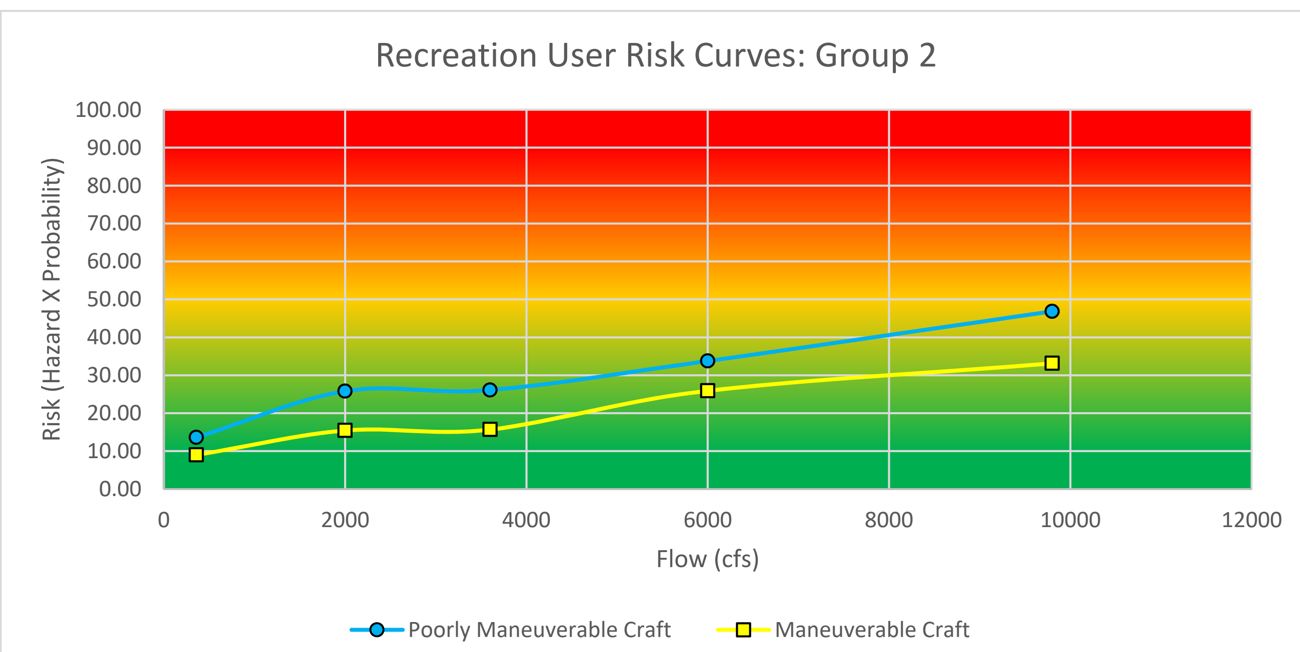
| Hazard Scoring | | | | | |
|---|---|---|---|---|---|
| **Flow** | **360 cfs** | **2000 cfs** | **3600 cfs** | **6000 cfs** | **9800 cfs** |
| **Rootwads Protruding** | 1 | 1 | 1 | 1 | 1 |
| **No Bumper Logs** | 0 | 0 | 0 | 0 | 0 |
| **Potential Underwater Hazards** | 0 | 2 | 2 | 2 | 2 |
| **Potential Scour Pools** | 1 | 1 | 1 | 1 | 1 |
| **Causes hydraulic jump, Chute or Flume** | 0 | 0 | 0 | 0 | 2 |
| **Has Strainers** | 0 | 0 | 0 | 0 | 0 |
| **Potential For Wood Recruitment** | 1 | 1 | 1 | 1 | 1 |
| **Total** | 3 | 5 | 5 | 5 | 7 |

| Avoidability Scoring for a Poorly Maneuverable Craft | | | | | |
|---|---|---|---|---|---|
| **Flow** | **360 cfs** | **2000 cfs** | **3600 cfs** | **6000 cfs** | **9800 cfs** |
| **Prior Knowladge of Structure** | 0 | 0 | 0 | 0 | 0 |
| **Location on Active Channel** | 3 | 3 | 3 | 3 | 3 |
| **Reaction Time** | 10 | 7.5 | 7.5 | 7.5 | 5 |
| **Wading Safety Factor** | 6.28 | 5.70 | 5.40 | 5.75 | 8.55 |
| **Potential For Bail-Out** | 8 | 8 | 8 | 0 | 0 |
| **Total** | 5.46 | 4.84 | 4.78 | 3.25 | 3.31 |
| **Probability (10- total)** | 4.54 | 5.16 | 5.22 | 6.75 | 6.69 |

| Avoidability Scoring for a Maneuverable Craft | | | | | |
|---|---|---|---|---|---|
| **Flow** | **360 cfs** | **2000 cfs** | **3600 cfs** | **6000 cfs** | **9800 cfs** |
| **Prior Knowladge of Structure** | 5 | 5 | 5 | 5 | 5 |
| **Location on Active Channel** | 3 | 3 | 3 | 3 | 3 |
| **Reaction Time** | 10 | 10 | 10 | 7.5 | 7.5 |
| **Wading Safety Factor** | 7.02 | 6.56 | 6.32 | 6.60 | 8.84 |
| **Potential For Bail-Out** | 10 | 10 | 10 | 2 | 2 |
| **Total** | 7.00 | 6.91 | 6.86 | 4.82 | 5.27 |
| **Probability (10- total)** | 3.00 | 3.09 | 3.14 | 5.18 | 4.73 |

| Risk | | | | | |
|---|---|---|---|---|---|
| **Flow (cfs)** | **360** | **2000** | **3600** | **6000** | **9800** |
| **Poorly Maneuverable Craft** | 13.63 | 25.80 | 26.10 | 33.75 | 46.83 |
| **Maneuverable Craft** | 8.99 | 15.44 | 15.68 | 25.90 | 33.12 |


Recreation User Risk Matrix
Group 2
Higher Risk
Normal Risk
Lower Risk
6000 cfs
3600 cfs
9800 cfs
2000 cfs
360 cfs
6000 cfs
9800 cfs
2000 cfs
3600 cfs
360 cfs
Avoidability
0
1
2
3
4
5
6
7
8
9
10
0
1
2
3
4
5
6
7
8
9
10
Hazard
Poorly Maneuverable Craft
Maneuverable Craft


Recreation User Risk Curves: Group 2
Risk (Hazard X Probability)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
2000
4000
6000
8000
10000
12000
Flow (cfs)
Poorly Maneuverable Craft
Maneuverable Craft

# Group 3

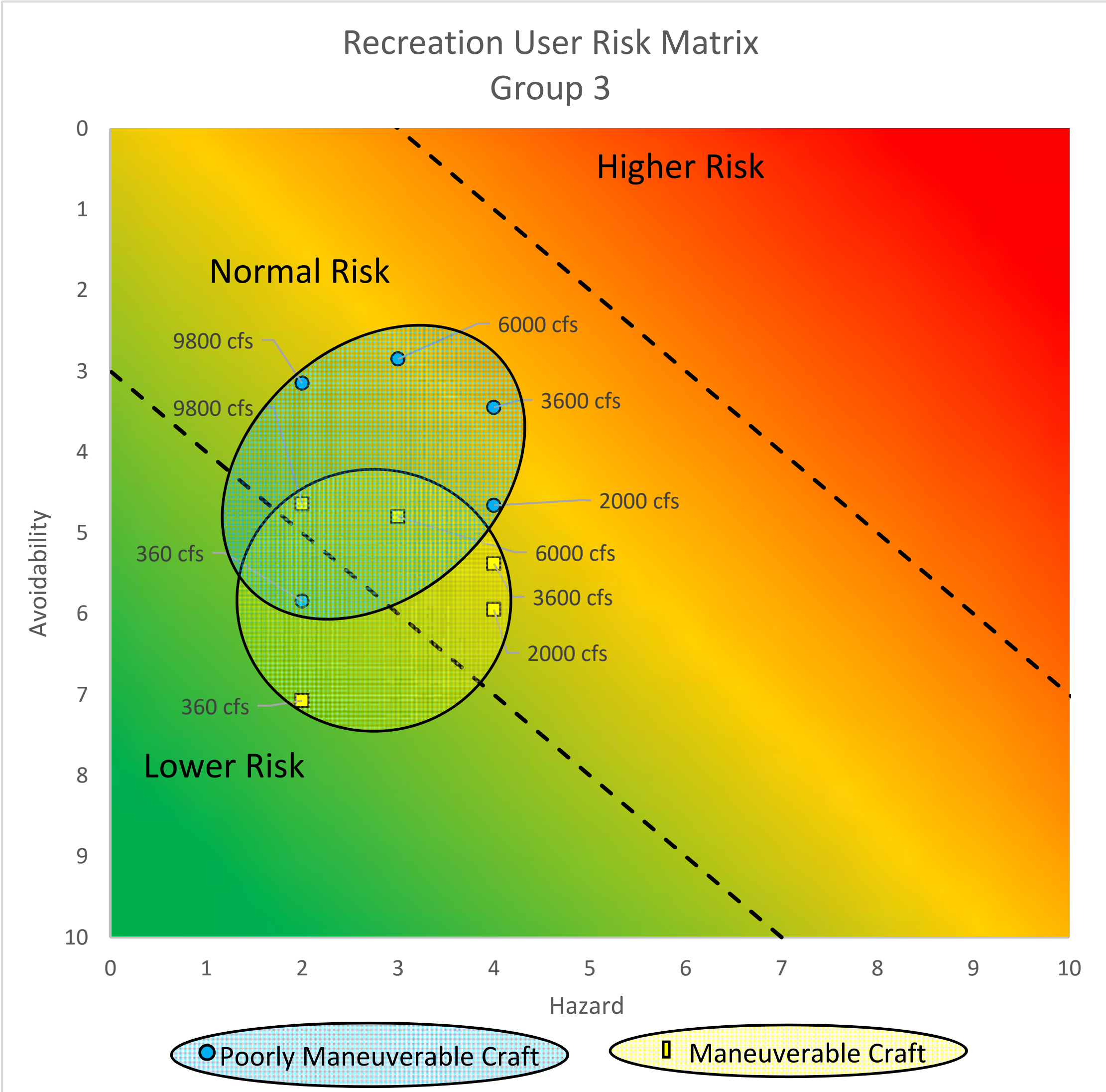
## 70's Channel Features

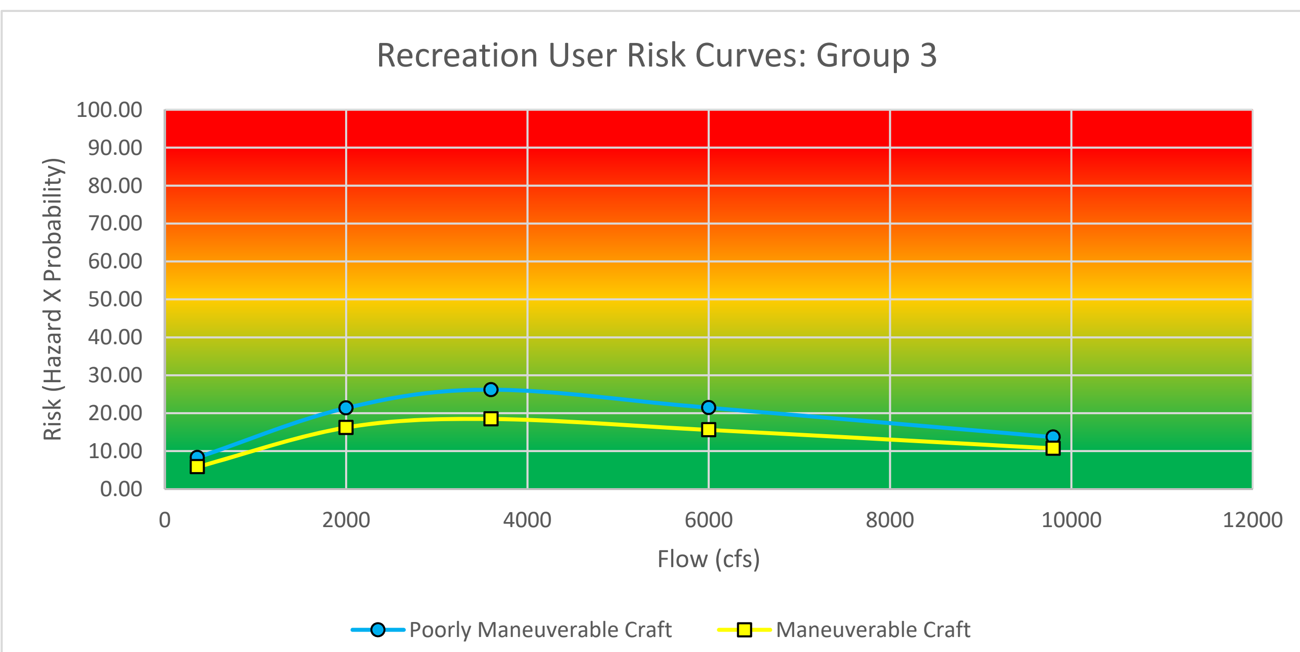
| Hazard Scoring | | | | | |
|---|---|---|---|---|---|
| **Flow** | **360 cfs** | **2000 cfs** | **3600 cfs** | **6000 cfs** | **9800 cfs** |
| **Rootwads Protruding** | 1 | 1 | 1 | 1 | 0 |
| **No Bumper Logs** | 1 | 1 | 1 | 1 | 1 |
| **Potential Underwater Hazards** | 0 | 1 | 1 | 1 | 1 |
| **Potential Scour Pools** | 0 | 0 | 0 | 0 | 0 |
| **Causes hydraulic jump, Chute or Flume** | 0 | 0 | 0 | 0 | 0 |
| **Has Strainers** | 0 | 0 | 0 | 0 | 0 |
| **Potential For Wood Recruitment** | 0 | 1 | 1 | 0 | 0 |
| **Total** | 2 | 4 | 4 | 3 | 2 |

| Avoidability Scoring for a Poorly Maneuverable Craft | | | | | |
|---|---|---|---|---|---|
| **Flow** | **360 cfs** | **2000 cfs** | **3600 cfs** | **6000 cfs** | **9800 cfs** |
| **Prior Knowladge of Structure** | 0 | 0 | 0 | 0 | 0 |
| **Location on Active Channel** | 10 | 8 | 8 | 8 | 8 |
| **Reaction Time** | 10 | 7.5 | 5 | 2.5 | 5 |
| **Wading Safety Factor** | 9.21 | 7.80 | 4.25 | 3.75 | 2.75 |
| **Potential For Bail-Out** | 0 | 0 | 0 | 0 | 0 |
| **Total** | 5.84 | 4.66 | 3.45 | 2.85 | 3.15 |
| **Probability (10- total)** | 4.16 | 5.34 | 6.55 | 7.15 | 6.85 |

| Avoidability Scoring for a Maneuverable Craft | | | | | |
|---|---|---|---|---|---|
| **Flow** | **360 cfs** | **2000 cfs** | **3600 cfs** | **6000 cfs** | **9800 cfs** |
| **Prior Knowladge of Structure** | 5 | 5 | 5 | 5 | 5 |
| **Location on Active Channel** | 10 | 8 | 8 | 8 | 8 |
| **Reaction Time** | 10 | 7.5 | 7.5 | 5 | 5 |
| **Wading Safety Factor** | 9.37 | 8.24 | 5.40 | 5.00 | 4.20 |
| **Potential For Bail-Out** | 1 | 1 | 1 | 1 | 1 |
| **Total** | 7.07 | 5.95 | 5.38 | 4.80 | 4.64 |
| **Probability (10- total)** | 2.93 | 4.05 | 4.62 | 5.20 | 5.36 |

| Risk | | | | | |
|---|---|---|---|---|---|
| **Flow (cfs)** | **360** | **2000** | **3600** | **6000** | **9800** |
| **Poorly Maneuverable Craft** | 8.32 | 21.36 | 26.20 | 21.45 | 13.70 |
| **Maneuverable Craft** | 5.85 | 16.21 | 18.48 | 15.60 | 10.72 |


Recreation User Risk Matrix
Group 3
Higher Risk
Normal Risk
Lower Risk
9800 cfs
6000 cfs
3600 cfs
9800 cfs
2000 cfs
360 cfs
6000 cfs
3600 cfs
2000 cfs
360 cfs
Avoidability
Hazard
0
1
2
3
4
5
6
7
8
9
10
Poorly Maneuverable Craft
Maneuverable Craft


Recreation User Risk Curves: Group 3
Risk (Hazard X Probability)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
2000
4000
6000
8000
10000
12000
Flow (cfs)
Poorly Maneuverable Craft
Maneuverable Craft

# Group 4

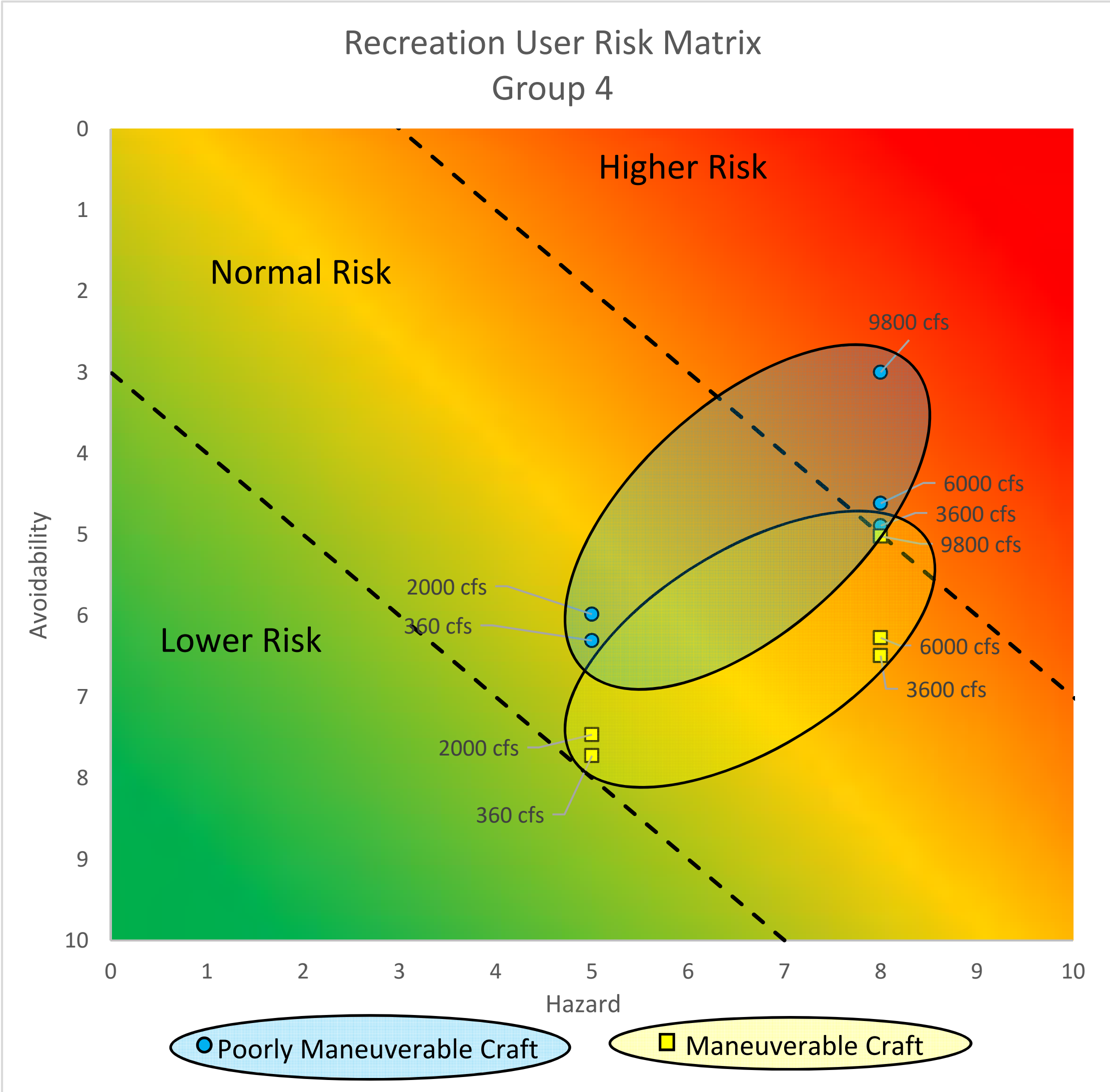
## Side Channel Apex's 2 & 3, Bank Complexity 1 & 2

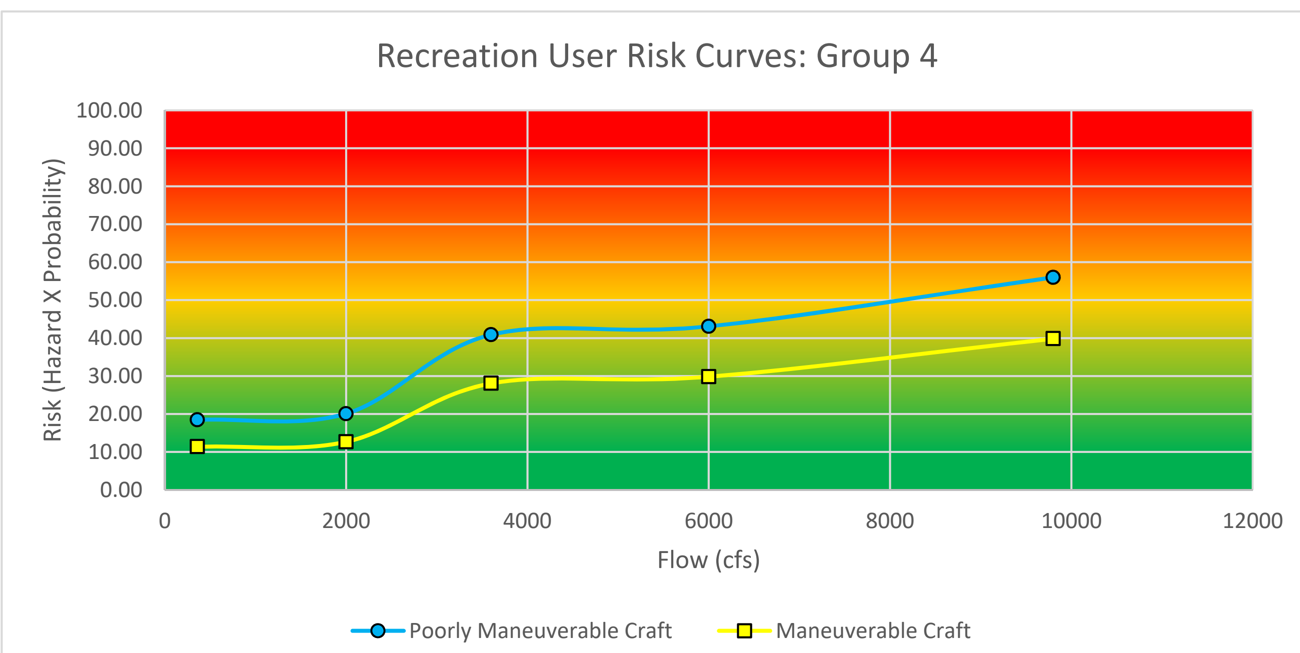
| Hazard Scoring | | | | | |
|---|---|---|---|---|---|
| **Flow** | **360 cfs** | **2000 cfs** | **3600 cfs** | **6000 cfs** | **9800 cfs** |
| **Rootwads Protruding** | 1 | 1 | 1 | 1 | 1 |
| **No Bumper Logs** | 1 | 1 | 1 | 1 | 1 |
| **Potential Underwater Hazards** | 0 | 0 | 2 | 2 | 2 |
| **Potential Scour Pools** | 0 | 0 | 1 | 1 | 1 |
| **Causes hydraulic jump, Chute or Flume** | 0 | 0 | 0 | 0 | 0 |
| **Has Strainers** | 2 | 2 | 2 | 2 | 2 |
| **Potential For Wood Recruitment** | 1 | 1 | 1 | 1 | 1 |
| **Total** | 5 | 5 | 8 | 8 | 8 |

| Avoidability Scoring for a Poorly Maneuverable Craft | | | | | |
|---|---|---|---|---|---|
| **Flow** | **360 cfs** | **2000 cfs** | **3600 cfs** | **6000 cfs** | **9800 cfs** |
| **Prior Knowladge of Structure** | 0 | 0 | 0 | 0 | 0 |
| **Location on Active Channel** | 8 | 8 | 8 | 8 | 8 |
| **Reaction Time** | 10 | 10 | 7.5 | 7.5 | 5 |
| **Wading Safety Factor** | 9.53 | 7.91 | 4.95 | 3.58 | 2.00 |
| **Potential For Bail-Out** | 4 | 4 | 4 | 4 | 0 |
| **Total** | 6.31 | 5.98 | 4.89 | 4.62 | 3.00 |
| **Probability (10- total)** | 3.69 | 4.02 | 5.11 | 5.39 | 7.00 |

| Avoidability Scoring for a Maneuverable Craft | | | | | |
|---|---|---|---|---|---|
| **Flow** | **360 cfs** | **2000 cfs** | **3600 cfs** | **6000 cfs** | **9800 cfs** |
| **Prior Knowladge of Structure** | 5 | 5 | 5 | 5 | 5 |
| **Location on Active Channel** | 8 | 8 | 8 | 8 | 8 |
| **Reaction Time** | 10 | 10 | 7.5 | 7.5 | 7.5 |
| **Wading Safety Factor** | 9.63 | 8.33 | 5.96 | 4.86 | 3.60 |
| **Potential For Bail-Out** | 6 | 6 | 6 | 6 | 1 |
| **Total** | 7.73 | 7.47 | 6.49 | 6.27 | 5.02 |
| **Probability (10- total)** | 2.27 | 2.53 | 3.51 | 3.73 | 4.98 |

| Risk | | | | | |
|---|---|---|---|---|---|
| **Flow (cfs)** | **360** | **2000** | **3600** | **6000** | **9800** |
| **Poorly Maneuverable Craft** | 18.47 | 20.09 | 40.88 | 43.08 | 56.00 |
| **Maneuverable Craft** | 11.37 | 12.67 | 28.06 | 29.82 | 39.84 |


Recreation User Risk Matrix
Group 4
Higher Risk
Normal Risk
Lower Risk
Avoidability
Hazard
9800 cfs
6000 cfs
3600 cfs
9800 cfs
2000 cfs
360 cfs
6000 cfs
3600 cfs
2000 cfs
360 cfs
0
1
2
3
4
5
6
7
8
9
10
Poorly Maneuverable Craft
Maneuverable Craft


Recreation User Risk Curves: Group 4
Risk (Hazard X Probability)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
2000
4000
6000
8000
10000
12000
Flow (cfs)
Poorly Maneuverable Craft
Maneuverable Craft

# Group 5

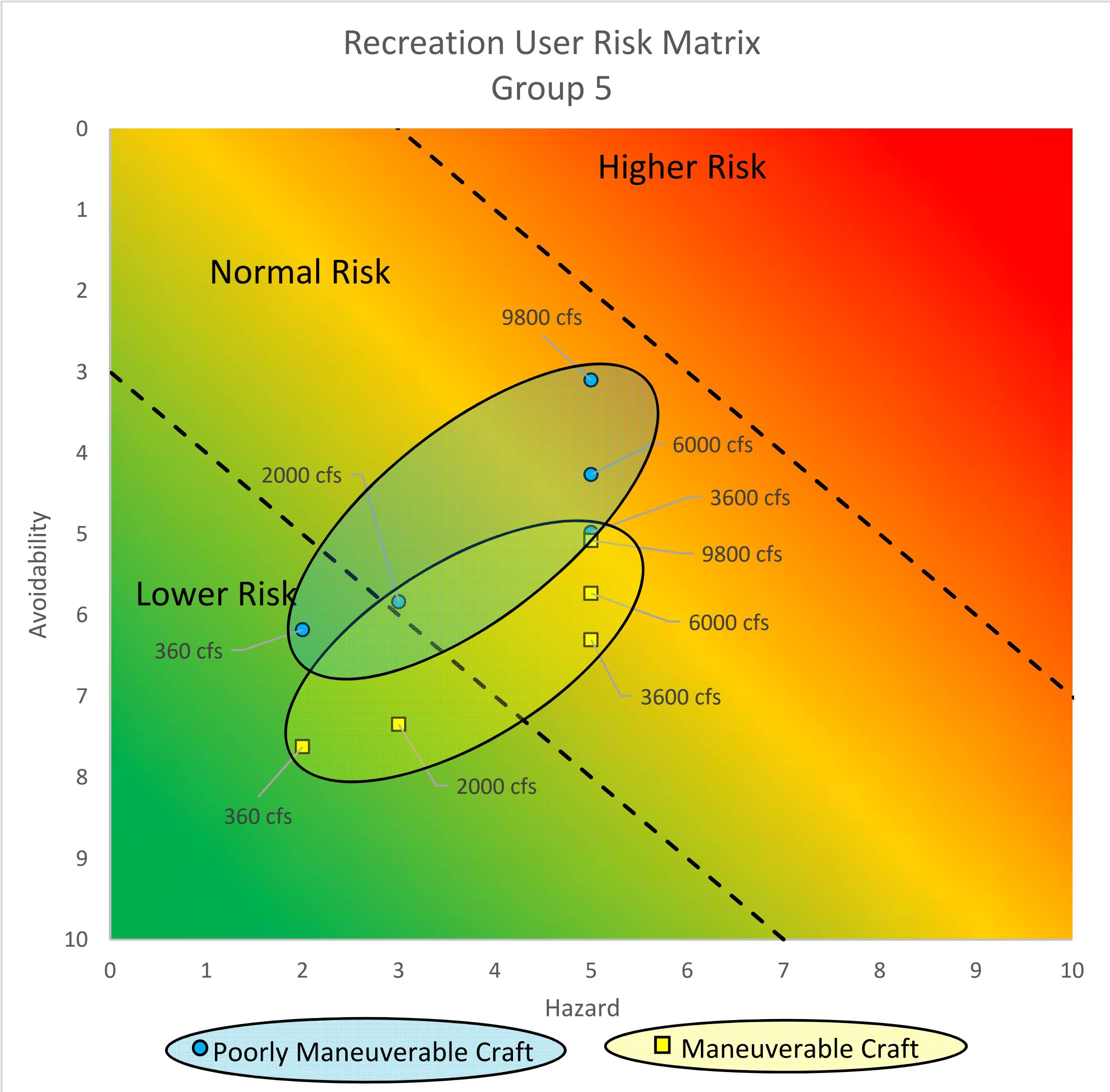
## Side Channel Apex 1, and Canal Benching

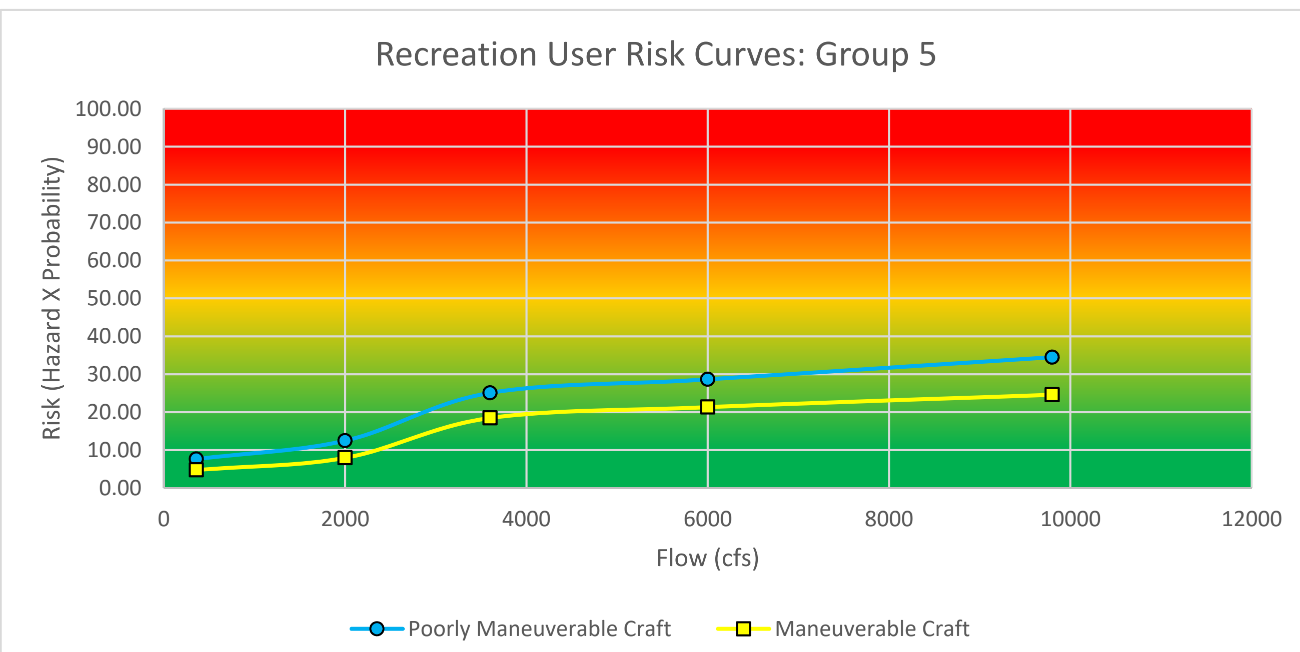
| Hazard Scoring | | | | | |
|---|---|---|---|---|---|
| **Flow** | **360 cfs** | **2000 cfs** | **3600 cfs** | **6000 cfs** | **9800 cfs** |
| **Rootwads Protruding** | 1 | 1 | 1 | 1 | 1 |
| **No Bumper Logs** | 1 | 1 | 1 | 1 | 1 |
| **Potential Underwater Hazards** | 0 | 0 | 2 | 2 | 2 |
| **Potential Scour Pools** | 0 | 1 | 1 | 1 | 1 |
| **Causes hydraulic jump, Chute or Flume** | 0 | 0 | 0 | 0 | 0 |
| **Has Strainers** | 0 | 0 | 0 | 0 | 0 |
| **Potential For Wood Recruitment** | 0 | 0 | 0 | 0 | 0 |
| **Total** | 2 | 3 | 5 | 5 | 5 |

| Avoidability Scoring for a Poorly Maneuverable Craft | | | | | |
|---|---|---|---|---|---|
| **Flow** | **360 cfs** | **2000 cfs** | **3600 cfs** | **6000 cfs** | **9800 cfs** |
| **Prior Knowladge of Structure** | 0 | 0 | 0 | 0 | 0 |
| **Location on Active Channel** | 8 | 8 | 8 | 8 | 8 |
| **Reaction Time** | 10 | 10 | 10 | 10 | 7.5 |
| **Wading Safety Factor** | 8.90 | 7.18 | 6.90 | 3.33 | 0.00 |
| **Potential For Bail-Out** | 4 | 4 | 0 | 0 | 0 |
| **Total** | 6.18 | 5.84 | 4.98 | 4.27 | 3.10 |
| **Probability (10- total)** | 3.82 | 4.17 | 5.02 | 5.74 | 6.90 |

| Avoidability Scoring for a Maneuverable Craft | | | | | |
|---|---|---|---|---|---|
| **Flow** | **360 cfs** | **2000 cfs** | **3600 cfs** | **6000 cfs** | **9800 cfs** |
| **Prior Knowladge of Structure** | 5 | 5 | 5 | 5 | 5 |
| **Location on Active Channel** | 8 | 8 | 8 | 8 | 8 |
| **Reaction Time** | 10 | 10 | 10 | 10 | 10 |
| **Wading Safety Factor** | 9.12 | 7.74 | 7.52 | 4.66 | 1.40 |
| **Potential For Bail-Out** | 6 | 6 | 1 | 1 | 1 |
| **Total** | 7.62 | 7.35 | 6.30 | 5.73 | 5.08 |
| **Probability (10- total)** | 2.38 | 2.65 | 3.70 | 4.27 | 4.92 |

| Risk | | | | | |
|---|---|---|---|---|---|
| **Flow (cfs)** | **360** | **2000** | **3600** | **6000** | **9800** |
| **Poorly Maneuverable Craft** | 7.64 | 12.50 | 25.10 | 28.68 | 34.50 |
| **Maneuverable Craft** | 4.75 | 7.96 | 18.48 | 21.34 | 24.60 |


Recreation User Risk Matrix
Group 5
Higher Risk
Normal Risk
Lower Risk
9800 cfs
6000 cfs
3600 cfs
2000 cfs
360 cfs
9800 cfs
6000 cfs
3600 cfs
2000 cfs
360 cfs
Avoidability
Hazard
0
1
2
3
4
5
6
7
8
9
10
Poorly Maneuverable Craft
Maneuverable Craft


Recreation User Risk Curves: Group 5
Risk (Hazard X Probability)
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
0
2000
4000
6000
8000
10000
12000
Flow (cfs)
Poorly Maneuverable Craft
Maneuverable Craft

# Group 6

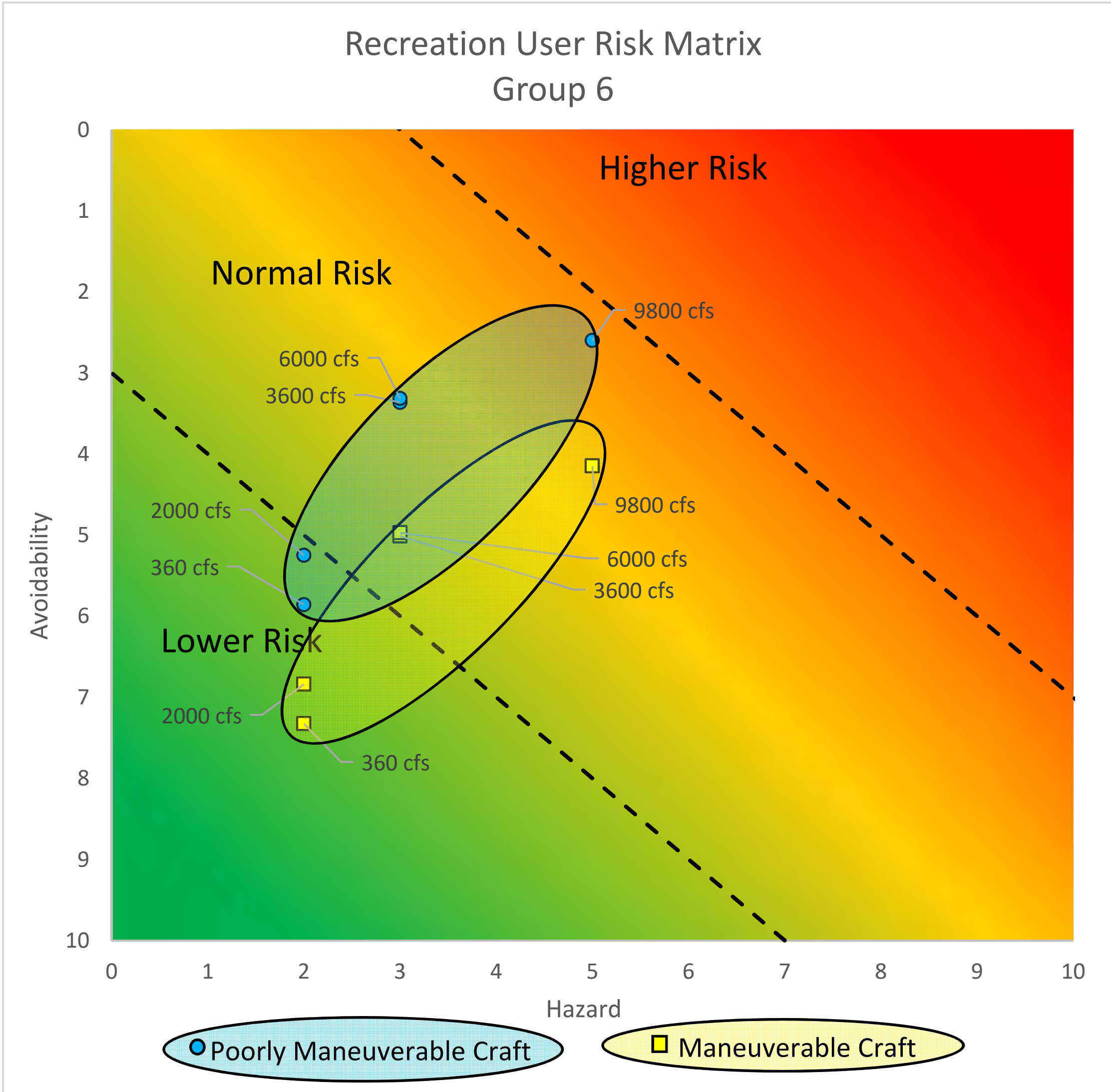
## Channel Barb ELJ

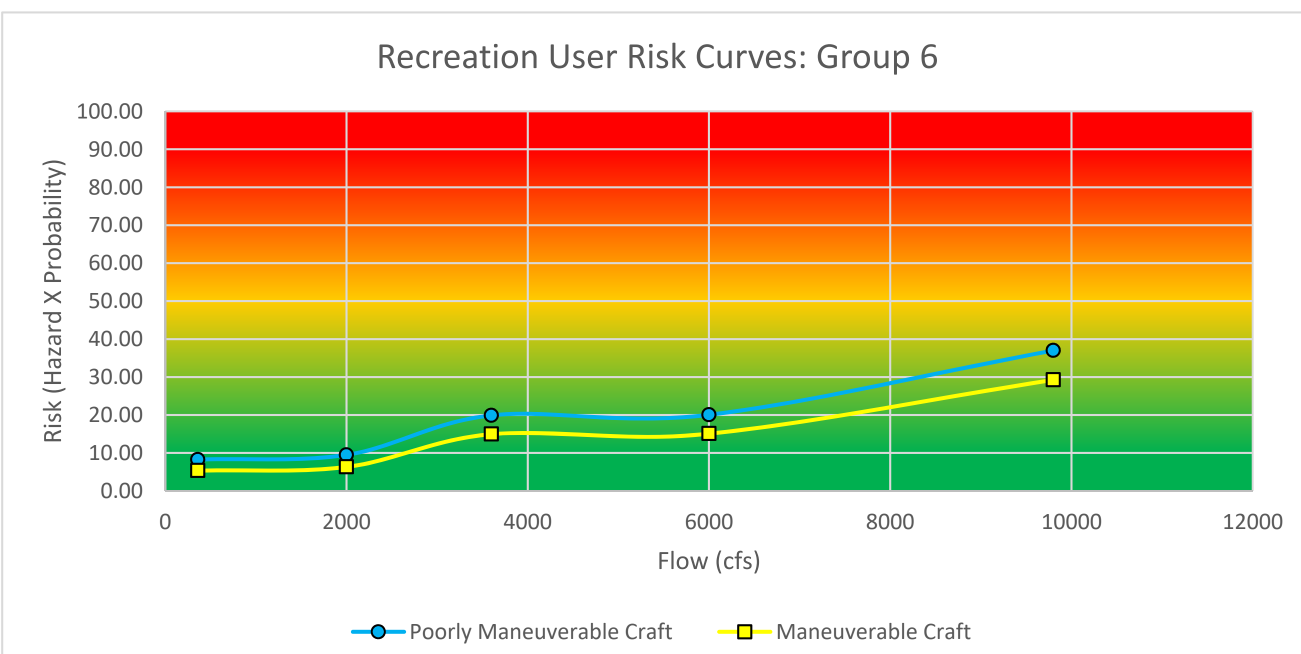
| Hazard Scoring | | | | | |
|---|---|---|---|---|---|
| **Flow** | **360 cfs** | **2000 cfs** | **3600 cfs** | **6000 cfs** | **9800 cfs** |
| **Rootwads Protruding** | 1 | 1 | 1 | 1 | 1 |
| **No Bumper Logs** | 1 | 1 | 1 | 1 | 1 |
| **Potential Underwater Hazards** | 0 | 0 | 0 | 0 | 2 |
| **Potential Scour Pools** | 0 | 0 | 0 | 0 | 0 |
| **Causes hydraulic jump, Chute or Flume** | 0 | 0 | 0 | 0 | 0 |
| **Has Strainers** | 0 | 0 | 0 | 0 | 0 |
| **Potential For Wood Recruitment** | 0 | 0 | 1 | 1 | 1 |
| **Total** | 2 | 2 | 3 | 3 | 5 |

| Avoidability Scoring for a Poorly Maneuverable Craft | | | | | |
|---|---|---|---|---|---|
| **Flow** | **360 cfs** | **2000 cfs** | **3600 cfs** | **6000 cfs** | **9800 cfs** |
| **Prior Knowladge of Structure** | 0 | 0 | 0 | 0 | 0 |
| **Location on Active Channel** | 3 | 3 | 3 | 3 | 3 |
| **Reaction Time** | 10 | 10 | 10 | 10 | 10 |
| **Wading Safety Factor** | 8.29 | 5.25 | 3.83 | 3.58 | 0.00 |
| **Potential For Bail-Out** | 8 | 8 | 0 | 0 | 0 |
| **Total** | 5.86 | 5.25 | 3.37 | 3.32 | 2.60 |
| **Probability (10- total)** | 4.14 | 4.75 | 6.64 | 6.69 | 7.40 |

| Avoidability Scoring for a Maneuverable Craft | | | | | |
|---|---|---|---|---|---|
| **Flow** | **360 cfs** | **2000 cfs** | **3600 cfs** | **6000 cfs** | **9800 cfs** |
| **Prior Knowladge of Structure** | 5 | 5 | 5 | 5 | 5 |
| **Location on Active Channel** | 3 | 3 | 3 | 3 | 3 |
| **Reaction Time** | 10 | 10 | 10 | 10 | 10 |
| **Wading Safety Factor** | 8.64 | 6.20 | 5.06 | 4.86 | 0.74 |
| **Potential For Bail-Out** | 10 | 10 | 2 | 2 | 2 |
| **Total** | 7.33 | 6.84 | 5.01 | 4.97 | 4.15 |
| **Probability (10- total)** | 2.67 | 3.16 | 4.99 | 5.03 | 5.85 |

| Risk | | | | | |
|---|---|---|---|---|---|
| **Flow (cfs)** | **360** | **2000** | **3600** | **6000** | **9800** |
| **Poorly Maneuverable Craft** | 8.28 | 9.50 | 19.91 | 20.06 | 37.00 |
| **Maneuverable Craft** | 5.35 | 6.32 | 14.96 | 15.08 | 29.26 |


Recreation User Risk Matrix
Group 6
Higher Risk
Normal Risk
Lower Risk
9800 cfs
6000 cfs
3600 cfs
2000 cfs
360 cfs
9800 cfs
6000 cfs
3600 cfs
2000 cfs
360 cfs
Avoidability
Hazard
0
1
2
3
4
5
6
7
8
9
10
Poorly Maneuverable Craft
Maneuverable Craft


Recreation User Risk Curves: Group 6
Risk (Hazard X Probability)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
2000
4000
6000
8000
10000
12000
Flow (cfs)
Poorly Maneuverable Craft
Maneuverable Craft

## 6.5 RESOURCE INVENTORY AND FISHERIES INFORMATION

The purpose of this habitat improvement design plan is to enhance natural processes and aquatic habitat in the Middle Methow (M2) Reach on the Methow River for Endangered Species Act (ESA)-listed spring Chinook salmon and steelhead, as well as bull trout and Pacific lamprey.

The Barkley Bear Project is located between river mile (RM) 49 and 50 on the Methow River in north central Washington (Figure 1). The project area includes the confluence with Bear Creek and the area around the upper-end of the Barkley Canal. The Barkley Canal is scheduled to be abandoned following the 2019 irrigation season when the canal company converts to an alternate diversion source located further downstream. The project area includes the main channel of the Methow River, connected side channels, and the adjacent floodplain. The project is adjacent to the upper-end of the Whitefish Island side channel, the site of a habitat project constructed in 2012. The project area is near the upper-end of the M2 Reach of the Methow River, and is at a transition between the confined and moderately confined portions of the river.

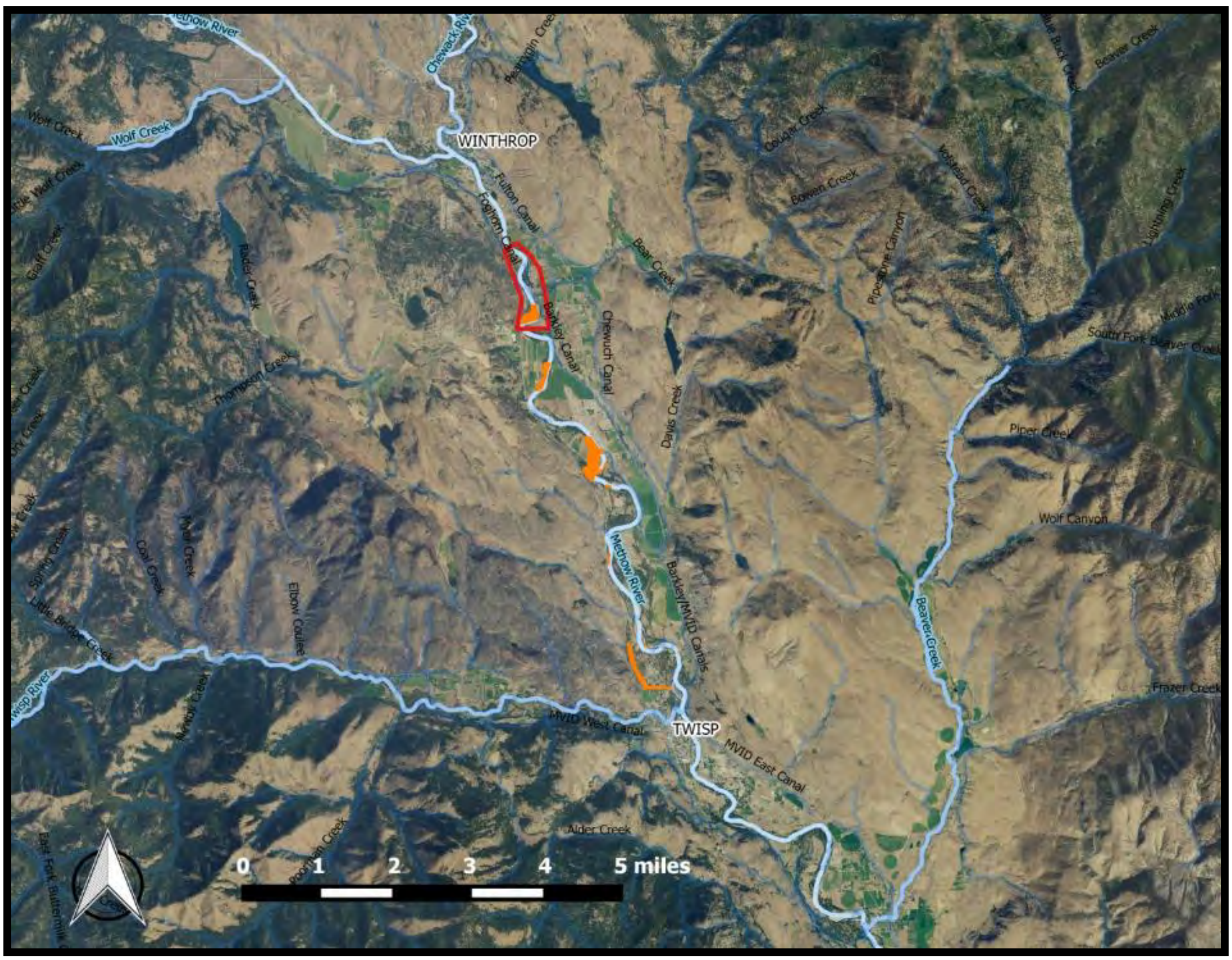



Figure 1. The project is located on the Methow River between the towns of Twisp and Winthrop in Okanogan County, Washington.

# 1 DESCRIPTION OF PAST AND PRESENT IMPACTS ON CHANNEL, RIPARIAN, AND FLOODPLAIN CONDITIONS

## 1.1 MAIN CHANNEL ALTERATIONS

Modifications to the river bottom, banks, and floodplain have taken place within the project area. The river bottom modifications include annual (until 2014) in-channel modification of bars and channel bottom to create a push-up diversion. Prior to 2014, the canal company used heavy equipment to build a push-up dam in the Methow River each year to maintain this diversion during low water. The push-up dam was typically built in July, and it generally washed away during the spring high flows.

Large riprap has been placed along the right bank of the channel through the project area to protect infrastructure along Witte Road and limit undesired bank erosion. At the downstream end of the project, a 700-foot-long levee has been constructed with riprap embedded on the waterward side of this feature.

## 1.2 SIDE CHANNEL AND FLOODPLAIN ALTERATIONS

The dredging of sediment and clearing of large wood from floodplain areas has taken place through the Barkley Bear reach. Other anthropogenic modifications to the floodplain area over time have included clearing of riparian vegetation and the addition of irrigation infrastructure including headgates, ditches, and fish screens.

Bear Creek has also been highly channelized in the downstream portion and currently flows into the Barkley Ditch before a portion of the flow is returned to the mainstem Methow River.

# 2 INSTREAM FLOW MANAGEMENT AND CONSTRAINTS IN THE PROJECT REACH

The Methow River at the Barkley Bear project site has a drainage basin area of approximately 1,007 square miles ($mi^2$), based on the Methow River at Winthrop U.S. Geological Survey (USGS) Gage 12448500. This gage is located approximately 2 miles upstream of the Barkley Bear project site. The Chewuch River, which enters the Methow River just upstream from this gage, is a major tributary that contributes about half of this drainage area (525 $mi^2$ at USGS Gage 12448000). Based on a period of overlapping mean daily flow records from the two gages between 1991 and 2015, the Chewuch River on average contributes about 31% of the mean daily flow at the Methow River with a standard deviation of 7%. However, the full range of contributing mean daily flow from the Chewuch River can vary greatly with a range of 5% to 60%.

High flows occur each year in late spring and early summer from snowmelt, with occasional rainstorms throughout the winter or late summer. Snowmelt floods last several weeks, whereas the rainstorm-generated floods are flashier, occurring over a matter of days. Figure 2 shows a sample hydrograph from 2015 for comparison to mean daily flow statistics throughout the year. Extreme flows (for the period of gage record) include a maximum discharge of 24,400 cubic feet per second (cfs) on May 31, 1972 (gage height 20.90 feet), and a minimum discharge of 115 cfs on November 28, 2000 (gage height 9.44 feet). Extremes outside the period of record include a maximum discharge of 35,000 cfs on May 29, 1948, determined by slope-area measurement of peak flow (USGS 2013a). The Chewuch River is estimated to have peaked at 18,100 cfs during the 1948 flood, which would account for about half of the estimated peak (USGS 2013b).

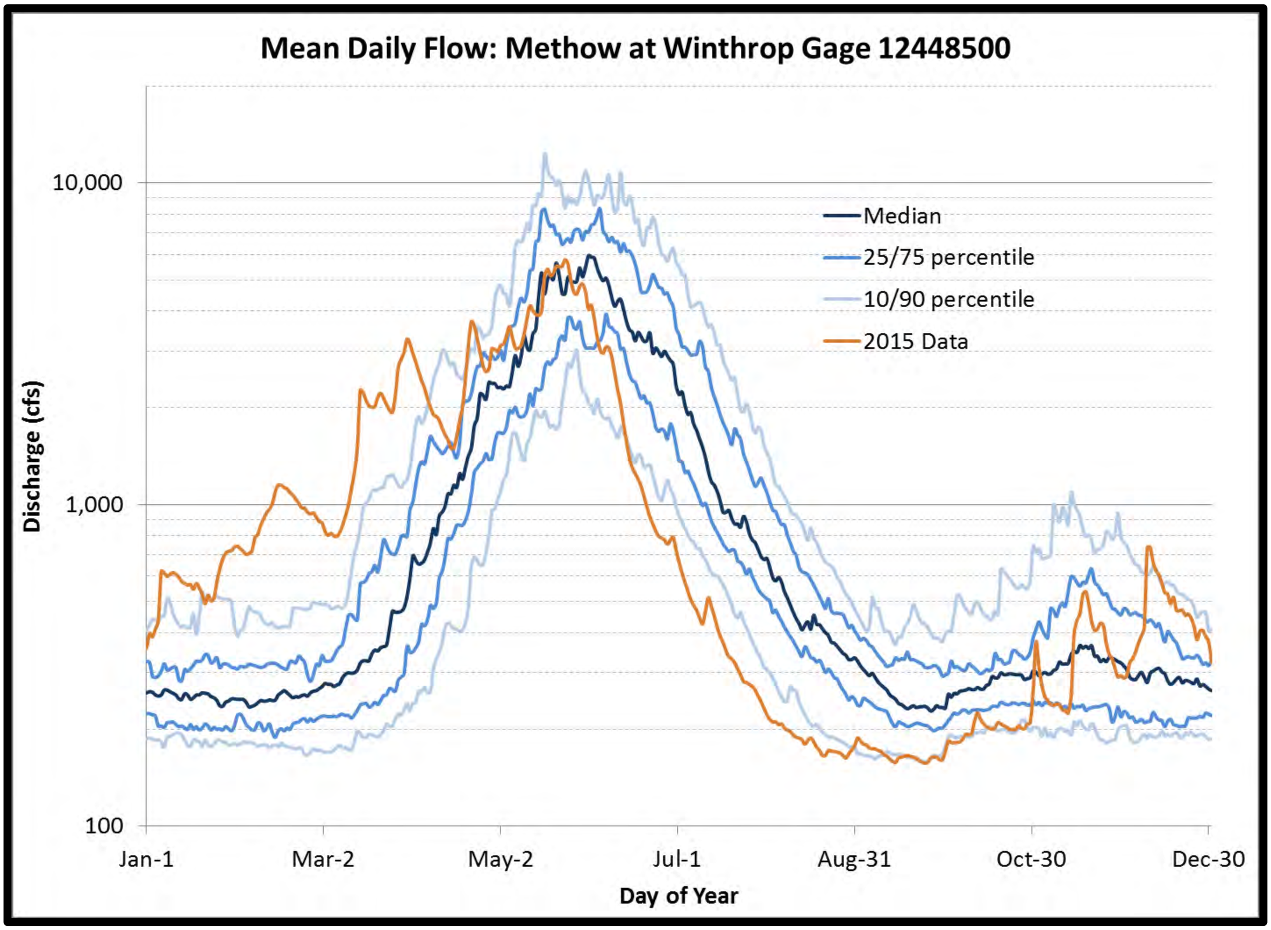



**Figure 2. 2015 Hydrograph overlain on mean daily flow statistics at USGS Gage 12448500 on the Methow River near Winthrop, Washington.**

Irrigation diversions are common on the Methow River, primarily between May 1 and October 7 (Ely 2003). The Barkley irrigation canal diverts water from the side channel of the Methow River at approximate RM 49.6. The intake canal flows parallel to the Methow River for approximately 0.5 mile to the control gates, fish return, and spillway. The intake canal captures Bear Creek and is the only connection between the stream and the Methow River. In recent years, the canal has diverted 26 cfs from April 25 through October 1.

When it is in use, the intake canal provides habitat for juvenile fish including spring Chinook salmon, steelhead, and lamprey. The annual shutdown and periodic clean-out efforts kill fish and compromise the habitat quality in the intake canal. Spoils piles built up on both sides of the canal from ditch clean-out reduce floodplain function, cover riparian vegetation, and interfere with landowner's views and access to the river.

The Barkley Canal Company is working with Trout Unlimited to draw from the existing Methow Valley Irrigation District East facility approximately 3.75 miles downstream. The current plan is for 2019 to be the last year the current diversion is in use. Construction on the pump station is scheduled to begin in 2019 and be complete by the start of the 2020 irrigation season. After the Barkley diversion is shut down, the canal will be abandoned by the Barkley Canal Company.

Bear Creek is a small tributary that enters the Methow River downstream of Barkley Island on river left and just upstream of the existing Whitefish Island project site. The creek has a drainage area of 18.9 $mi^2$ (estimated using USGS StreamStats [Version 3.0]), less than 2% of the Methow basin drainage area in this reach.

Portions of Bear Creek's flow are also withdrawn before it intersects the Barkley Ditch and reaches the Methow River. Between April 30 and October 30, an estimated 150 acre-feet are diverted each year to meet irrigation demands at a golf course (Aspect Consulting 2014). There is also a small seasonal diversion into Davis Lake. The U.S. Bureau of Reclamation (Reclamation) measured ten instantaneous flows within Bear Creek below the Chewuch Ditch spillway ranging from less than 1 cfs to 10 cfs. Aspect Consulting made estimates of mean daily flow between 2013 and 2015. Flows ranged from less than 1 cfs up to approximately 27 cfs during the spring freshet in 2013; some winter storm events recorded flows ranging less than 5 cfs up to 15 cfs. Peak flows were estimated using the USGS StreamStats (Version 3.0) for ungaged basins. The prediction error has a very high uncertainty but estimates the 2-year peak to be about 60 cfs and the 100-year peak to be about 280 cfs.

## 2.1 INSTREAM FLOW MANAGEMENT AND CONSTRAINTS SUMMARY

- Irrigation diversions affect low flows during May to October each year, but have the most impact on habitat availability during seasonal low flows in late summer and early fall. The point of diversion for the Barkley ditch will be relocated and will no longer divert water at the Barkley project site in the future.
- Habitat improvement strategies will need to consider large fluctuations in annual river flow that vary by an order of magnitude. This large flow variance translates to a wide range in energy that project features must accommodate to meet objectives.
- Sediment transport and channel reworking occurs only during a fraction of the year during higher flow periods with high stream power. During these periods, lower energy refuge areas are needed for fish in the river system.
- Restoration strategies should consider which parts of the river are likely to be reworked during high flows where we can tolerate allowing the river to shift around. This is most likely to encourage restoration of the channel development and abandonment cycle crucial for healthy rivers.
- Restoration features should consider where sediment may drop out during recession of high flows, so evaluating how they perform during the falling limbs of the snowmelt or rainstorm hydrograph may be important.
- Ice and heavy snowfall has been documented to occur within the river corridor during winter months and may be a factor to consider in restoration design features.
- Bear Creek contributes less than 2% to mainstem Methow flows, so it is unlikely to have any significant impact on stream power or local velocities where entering the Methow River. However, restoring access to lower Bear Creek could provide important low-flow habitat as well as low-velocity refuge during higher energy flows on the Methow River.

# 3 DESCRIPTION OF EXISTING GEOMORPHIC CONDITIONS AND CONSTRAINTS ON PHYSICAL PROCESSES

This geomorphic summary is based on multiple reports produced by Reclamation including the M2 Reach Assessment (Reclamation 2010a), Geomorphology and Hydraulic Modeling for the Middle

Methow River from Winthrop to Twisp (Reclamation 2010b), and the Methow Subbasin Geomorphic Assessment (Reclamation 2008). For this discussion, the reach of interest (Barkley reach) extends from RM 50 downstream to RM 48.5.

## 3.1 CHANNEL AND FLOODPLAIN

### CHANNEL DIMENSIONS

The average bankfull channel width within the Barkley Bear project area at riffle crest locations is approximately 200 feet, measured from the 2006 Light Detection and Ranging (LiDAR) hillshade image.

### PLANFORM

Channel planform is the pattern of the channel as seen from above, including sinuosity, meander bend shape, and wavelength. The average sinuosity of the Methow River in the project area is 1.3 (calculated by dividing channel length by valley length measured from 2006 LiDAR imagery). Meander bend radius of curvature averages 508 feet for all bends, the meander wavelength averages 3,380 feet with an average amplitude of 950 feet (all measured from 2006 LiDAR imagery).

Meander bends typically coincide with locations of bedrock outcropping and/or other erosion-resistant material (such as riprap). Within the Barkley Bear project area, bedrock outcroppings are located at RM 50.0 (right bank), RM 49.7 (left bank), RM 49.3 (right bank), and RM 49.24 (right bank). There is additional bedrock within the channel and along the left bank further downstream of RM 49. The bedrock serves as both lateral and vertical control within the project area. Also, within the project area, approximately 3,600 feet of bank have been armored with riprap.

### BEDFORM

Bedform is the topographic variation of the channel bottom and margins resulting from the interaction between the material comprising the channel bed and banks and flowing water. Within the Barkley reach, bedforms identified by Reclamation (2010a) include pool, riffle, run, rapid, bar, and side channel. Slight modifications to those units, based on recent observation of current conditions, indicate that within the project area, the predominant bed forms of the Methow River are riffle-run (Figure 3). Pools primarily occur adjacent to bedrock or other erosion-resistant material such as riprap; there are approximately four pools per mile in the Barkley reach.

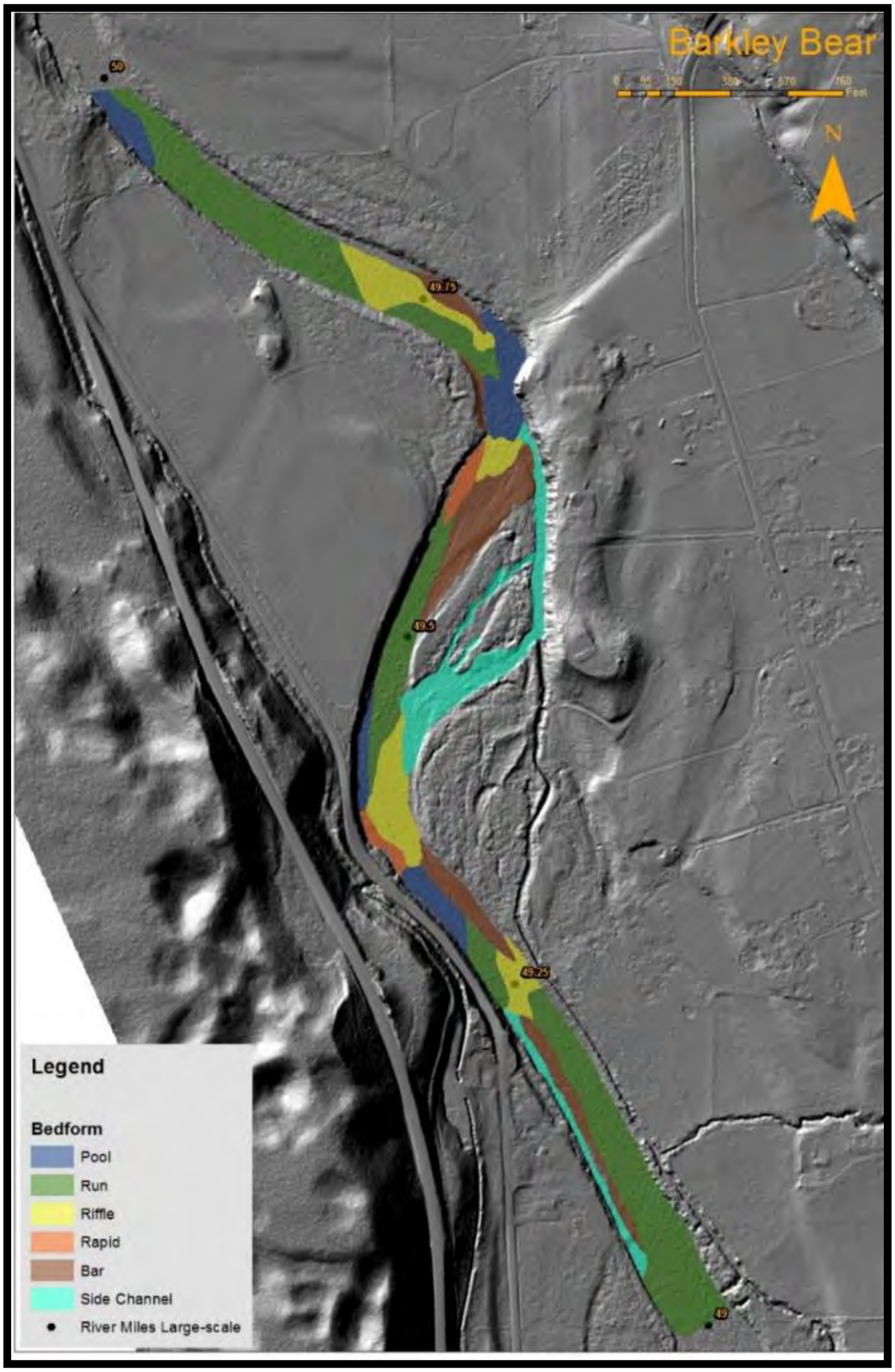



**Figure 3. Map of bedforms within the Barkley Bear project area (Reclamation 2010a).**

## SUBSTRATE

Ocular estimates and pebble counts across the wetted channel document substrate within the project area is predominantly cobble and gravel with some areas of sand (Figure 4).

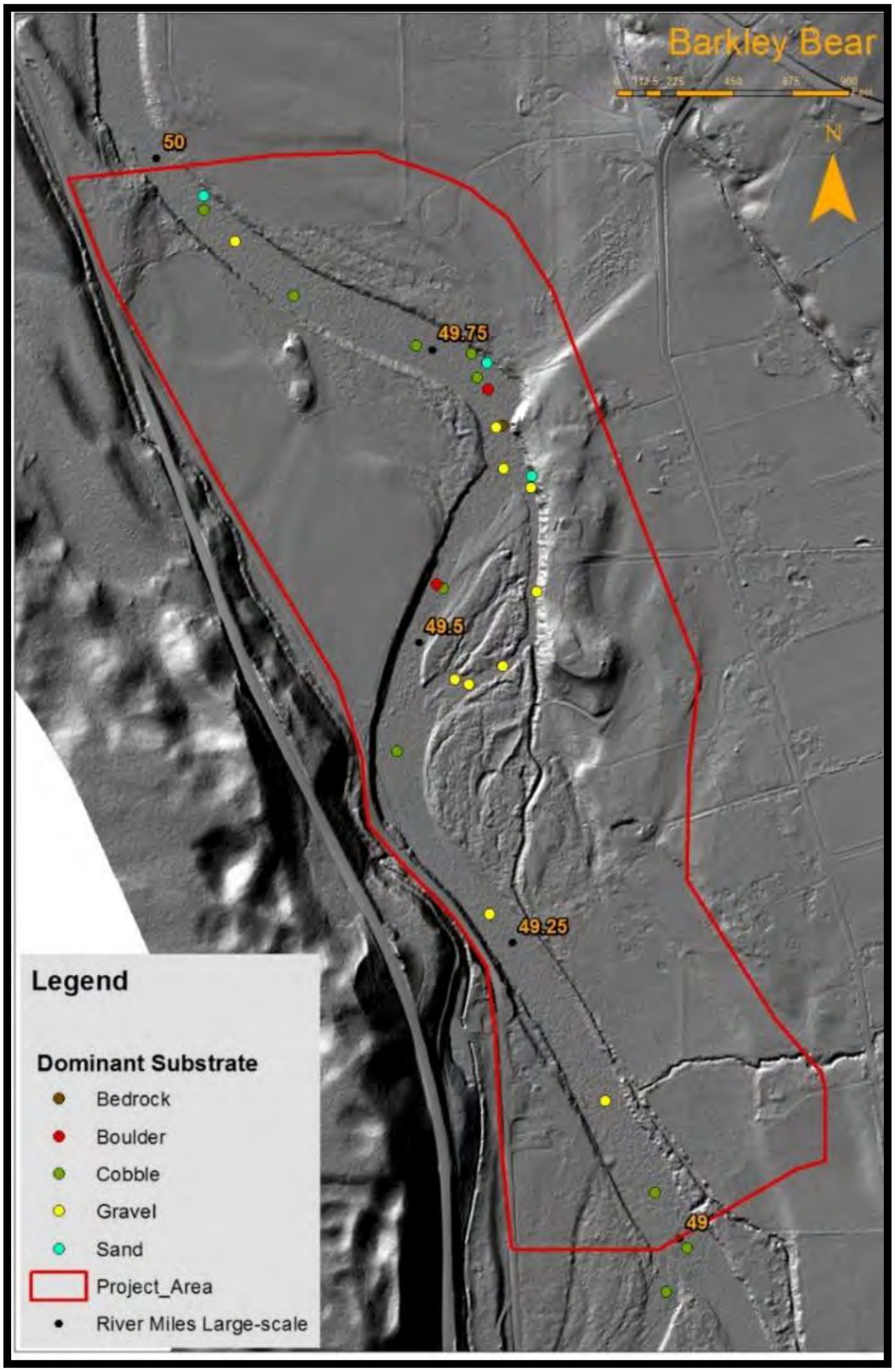



**Figure 4. Map of point data for pebble counts conducted within the project area.**

Boulders are present where the local gradient is steeper and higher water velocities result in increased transport capacity of the smaller material. Some of these larger rock pieces originate from failed riprap or push-up dam material that has fallen into the channel. Sand and finer material occur in low-velocity regions, such as side channels and along the channel margin. Several locations within the channel also have visible bedrock outcrops along the bottom and banks as denoted above. Figure 5 shows the bed material gradation at two locations in the project area: main channel (blue) and side channel (red).

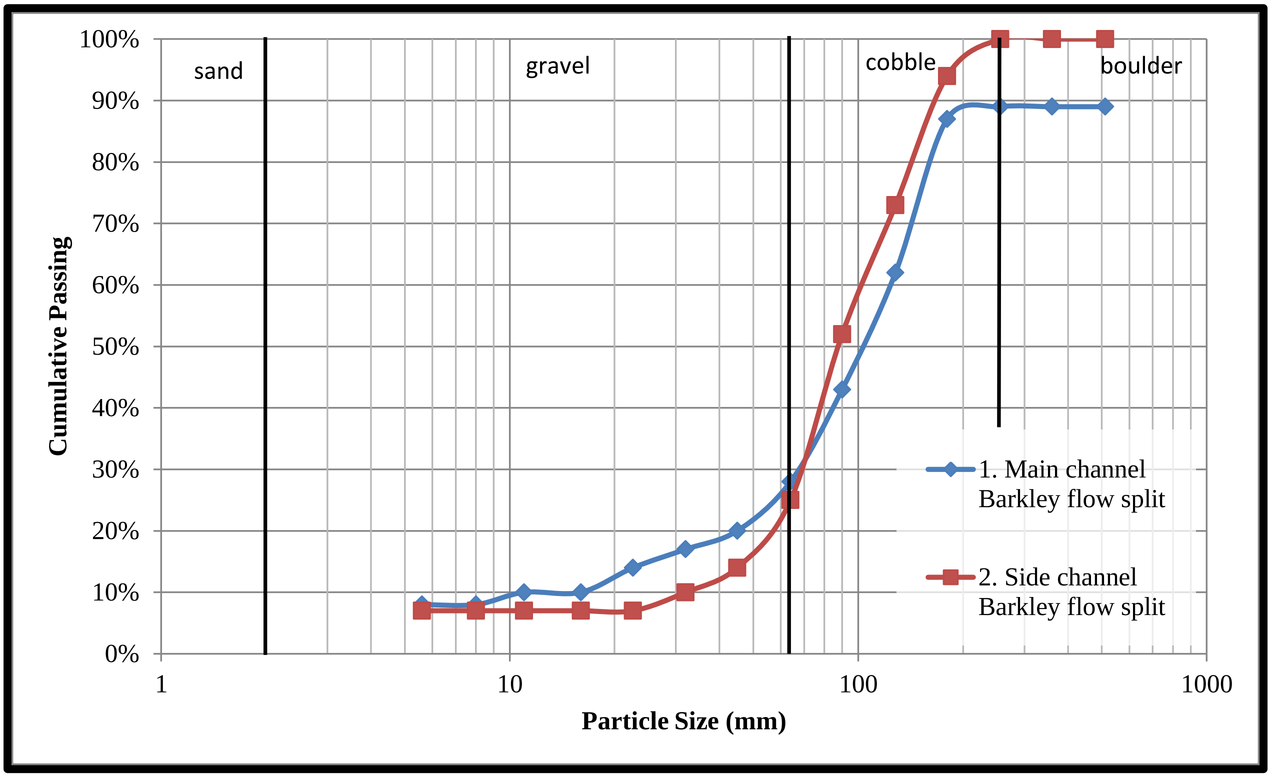



**Figure 5. Bed-material substrate analysis within Barkley Bear Reach. Data courtesy USGS, collected July 2015 by Bellmore and Benjamin.**

As part of the Middle Methow River assessment (Reclamation 2010a), the active channel and adjacent floodplain areas were delineated into geomorphic units and described based on relative ages and elevation (height) above the active channel (Figure 6). The definition of each of these units is provided below and Figure 7 shows the delineation of the geomorphic units overlain on a LiDAR background.

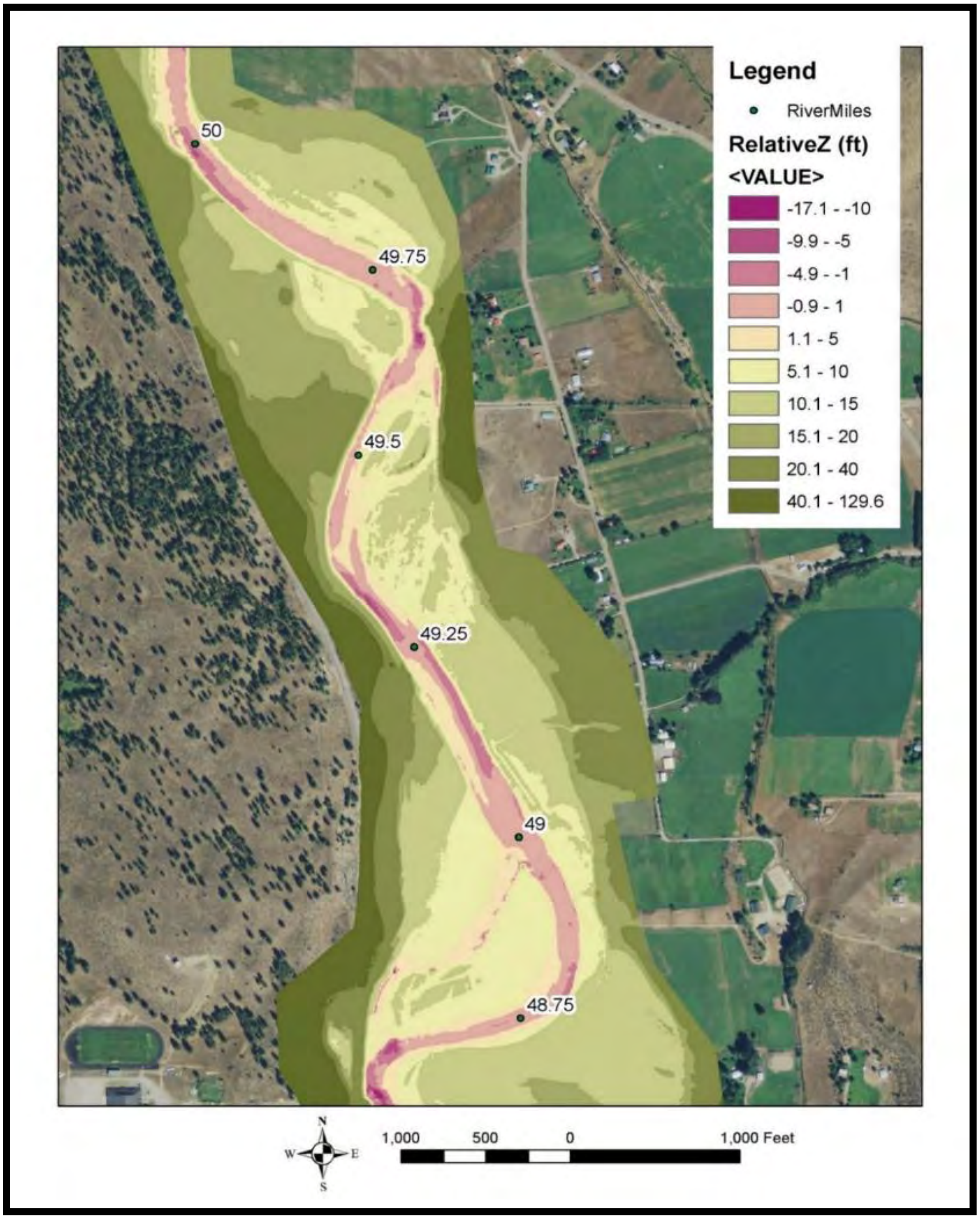



**Figure 6. Relative elevation map within the Barkley Bear project site.**

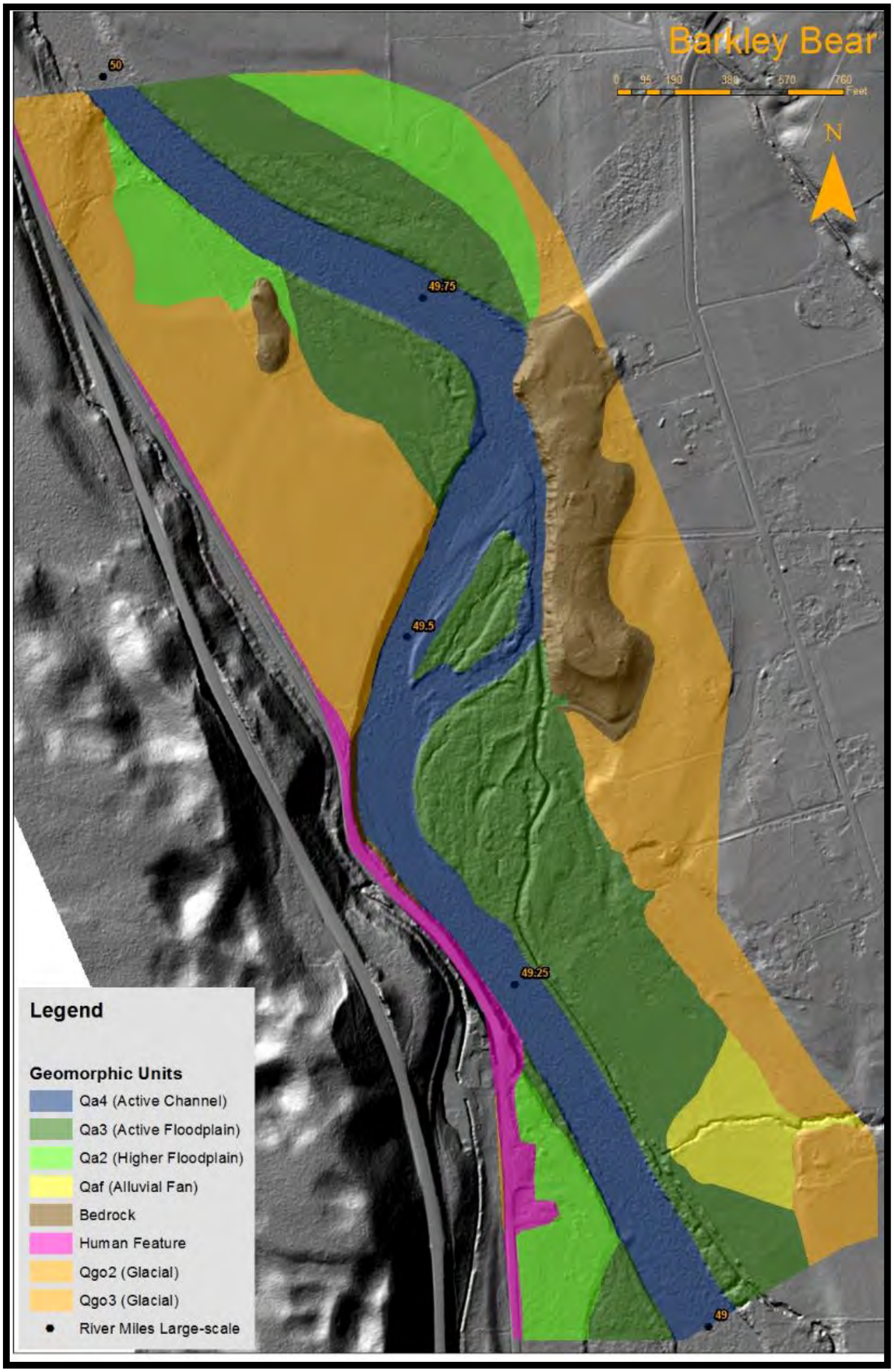



**Figure 7. Delineation of geomorphic units within the project area (Reclamation 2010a).**

## QA4 ACTIVE CHANNEL

Qa4 includes the active main channel, split-flow paths, and unvegetated or sparsely vegetated bars associated with the main channel. It is the area that has flow and is dynamically reworked on an annual or semi-annual basis during the highest seasonal flows. The 2-year flood inundates all channels and bars within Qa4, but at low flows, many side channels within Qa4 do not contain water except for areas with groundwater or subsurface contributions. The unvegetated bars are positioned as point bars on the inside of meander bends, lateral bars along straight sections, and as mid-channel bars between split-flow paths in the main channel. The bars are commonly 4 to 8 feet above the main channel but can be as high as about 10 feet. Deposits associated with the Qa4 map unit are composed of gravelly sand or sand and lack soil development.

## QA3 ACTIVE FLOODPLAIN

Unit Qa3 includes the active floodplain. The Qa3 surfaces are highly irregular and include prominent side and overflow channels of various sizes and morphology. The most prominent side channels in Qa3 can have a surface water connection with the main channel at the 2-year flood. At the 10-year flood, most of the Qa3 surface is overtopped. A flow similar to the 1948 flood is generally contained within unit Qa3. The Qa3 surfaces are present continuously along one or both sides of the main channel (Qa4). The Qa3 map unit includes vegetated islands that are surrounded by split-flow paths within the active channel (Qa4). Within the project area, there are approximately 37 acres of active floodplain. Between approximately RM 49.6 and RM 49.25, approximately 12 to 14 acres of Qa3 surface along river left are inundated at 14,500 cfs, which has a recurrence interval of 5 years (Figure 8). Downstream of RM 49.25, the Qa3 surface along river left is not inundated at a flow with a 5-year recurrence interval.

## QA2 HIGHER FLOODPLAIN

The higher floodplain (Qa2) includes areas that are inundated only during very large floods or areas that are at the same elevation as these rarely inundated areas but have received little, if any, flood flow historically. The Qa2 surfaces are present as discontinuous remnants along both sides of the valley. Most of the Qa2 remnants are separated from the main channel (Qa4) by active floodplain (Qa3).

## QA1 TERRACE

Terrace Qa1 includes those areas that did not receive flow during the 1948 flood (31,360 cfs) and are in a position that they have received little, if any, flood flow historically. The Qa1 surfaces are present as discontinuous remnants along both sides of the valley. Most of the Qa1 surface remnants are along the higher floodplain (Qa2) or active floodplain (Qa3) and are found rarely along the main channel (Qa4).

## SIDE CHANNELS

Many types of side channels exist within the Middle Methow River. An important distinction between side channels and overflow channels is that overflow channels are only inundated by larger floods (greater than 5- to 10-year floods). Side channels become inundated frequently and maintain a direct surface connection for extended periods of the year.

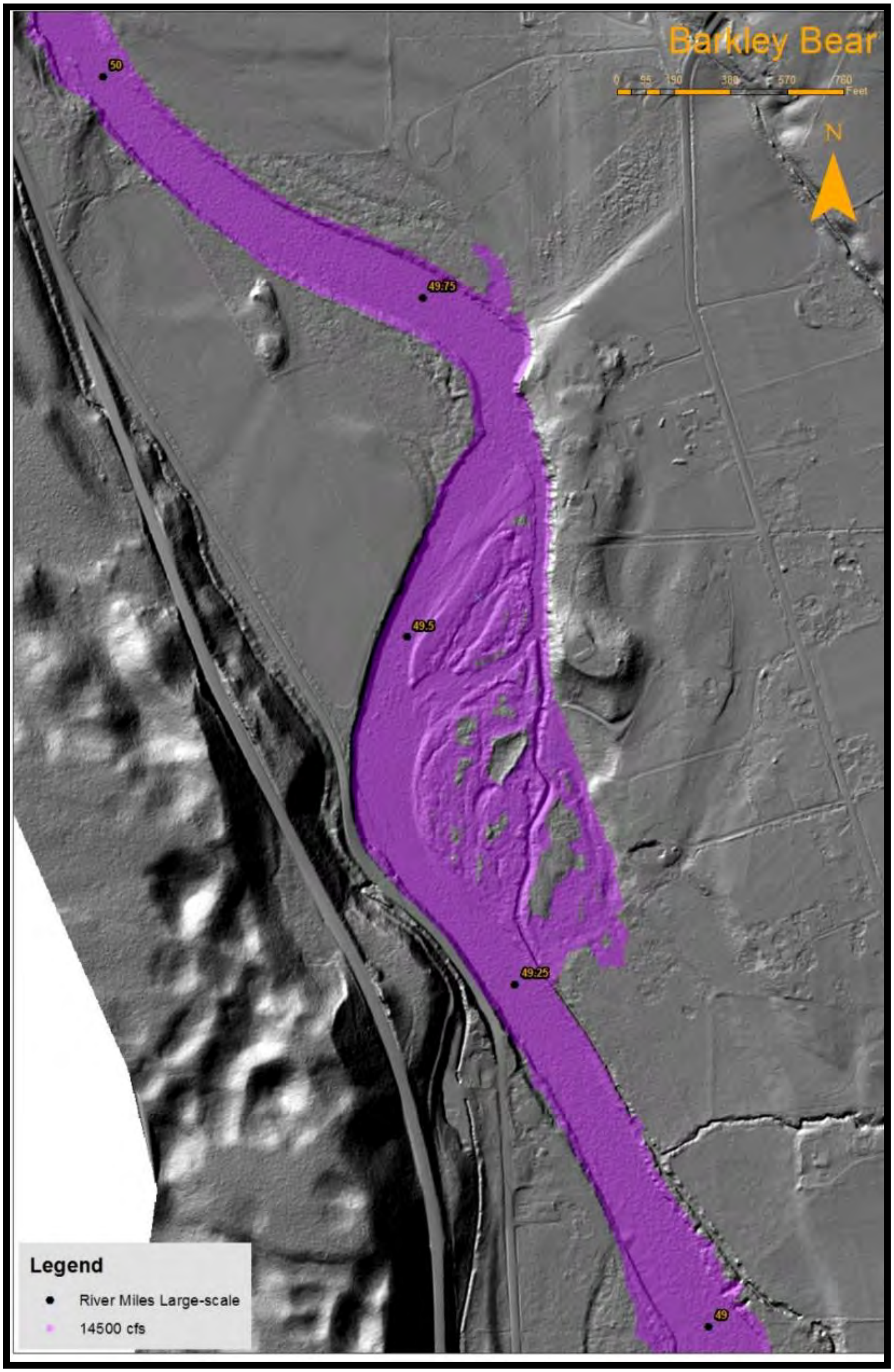



Figure 8. Extent of inundation in the Barkley Bear project area at 14,500 cfs, or a 5-year event.

Within the active channel (Qa4), side channels are present along the edges of the main channel and are usually separated from the main channel by an unvegetated bar or vegetated island. It should be noted that although the majority of the Qa4 channel remains in the same lateral position on at least a decadal scale, localized reworking of sediment along the channel bed occurs annually, thereby frequently creating different side channel locations. Within the active floodplain (Qa3), the majority of the side channels are distinct and well defined. They may be connected to the main channel at either their upstream end, downstream end, or both during certain flows. These channels may be unvegetated or vegetated, and can be large enough to have unvegetated bars associated with them. Wood is often present within these channels, especially at or near their upstream ends. The elevations of these channels may be similar to that of the main channel. Overflow channels are also common within the active floodplain (Qa3) but are often small and of limited extent. Overbank flow must occur for these channels to be inundated.

Within the active floodplain (Qa3) in the project area, there is approximately 1,000 linear feet of side channel along bedrock on river left. The head of the side channel is on the outside of the meander in the main channel, so the side channel tends to fill with sediment and wood. Sediment and wood have historically been periodically removed from the side channel by the Barkley Irrigation company to maintain irrigation volume. The sediment and wood have been piled along the edges of the side channel and the active floodplain (Qa3) surfaces. This alters the characteristics of the side channel and also blocks overflow channels on the active floodplain (Qa3) surfaces on river left and in an island between the main and side channels. During a 2015 field survey with a stream discharge of about 400 cfs, this side channel on river left had a shallow upstream and downstream surface flow connection with the mainstem river. A surface flow connection was also observed during an older survey in 2008 with a stream discharge of 285 cfs. Numerical modeling of existing conditions (2015 survey) suggests a surface flow connection may be sustained at flows as low as 200 cfs if no alteration (manmade or natural) occurs to the topography. Because push-up dams and dredging have historically occurred at the upstream entrance, future peak flows may alter the topography and surface flow connectivity and should be monitored during project development. In addition, approximately 640 linear feet of the upstream end of the Barkley Ditch which appear to be an active side channel in the 1945 aerial imagery is inundated at flows of 9,800 cfs (and larger), which has a recurrence interval of 2 years.

The next large side channel, located at Whitefish Island, maintains active surface flow connection with the main channel at the upstream and downstream entrances between 300 and 500 cfs. The upstream connection begins around 360 cfs (based on 2013 topography) along a thalweg that has developed adjacent to several constructed large wood features. The downstream outlet of the side channel is perched above a deep scour pool formed at a bedrock outcrop. Therefore, the downstream outlet does not have a surface flow connection until approximately 430 cfs.

The higher floodplain (Qa2) surfaces typically include some low-relief overflow channels. Most overflow channels are readily visible on LiDAR hillshade or on the ground but are not as well-defined as channels on the active floodplain (Qa3) surfaces. They are often better defined at their downstream ends and become poorly defined upstream because they are likely formed by headcutting erosion from the edge of the active floodplain (Qa2) surface. These channels may be only sparsely vegetated, which appears to be the result of artificial clearing, rather than recent channel flow. Wood is rarely present within these channels. The elevations of the channels are usually well above the elevation of the main channel, so that they are activated only during the largest floods.

The terrace (Qa1) surfaces include some broad, low-relief channels. Most of the channels are readily visible on the LiDAR hillshade or on the ground. They have various orientations relative to the main channel, which suggests that the main channel was in a different location when some of these channels were formed and active. These channels are well above the elevation of the main channel, so that they are not activated even during the largest floods.

## 3.2 GEOMORPHIC PROCESSES

### SEDIMENT TRANSPORT

The Tributary Assessment (Reclamation 2008) found no large-scale change to the balance between incoming water and sediment loads that would indicate a potential for incision or aggradation on a decadal scale within the Middle Methow River. There are no major diversion or flood storage dams within the Methow subbasin. However, within the project area local manipulation of the channel geometry, placement of riprap, and relocation or removal of large wood and riparian vegetation has altered smaller scale depositional features.

Within the Barkley reach, between RM 50.0 and 49.75, the channel is confined, and sediment is readily transported. Downstream of RM 49.75, the active channel widens, and side and overflow channels are present. With the increased ability of the water to spread out, transport capacity is reduced and potential for development of local depositional features is increased. The streambed has historically been altered in this area to construct a push-up dam to divert water into the side channel to supply water to the Barkley Ditch. The disturbed bed-material was then reworked annually by yearly peak flows, likely resulting in a higher and/or steeper lee (downstream) side of the riffle crest coming out of the bedrock pool. Riprap material placed in the vicinity of the push-up dam has at times failed and been flushed into the downstream channel where intermittent pieces are visible in the channel. The river stream power during peak floods may only transport the larger particles of riprap for short distances.

From about RM 49.3 downstream to RM 49.0, the channel again becomes confined with an extensive longitudinal bar on river left. The entrance to the Whitefish side channel is located on the inside of a meander bend at RM 49.0. The location of the side channel entrance would typically be a zone of deposition, with transport continuing to occur in the main channel.

### CHANNEL MIGRATION/AVULSION

Within the project area, lateral migration is limited by natural controls that include bedrock and higher floodplain surfaces. Anthropogenic controls include hardened banks (riprap) that may limit lateral erosion. Where riprap has been placed on high glacial banks, channel migration is naturally limited, but the large rock dramatically reduces opportunity for establishment of riparian cover. The only location of channel migration/avulsion is in the short stretch from RM 49.6 to RM 49.45. In this location, the main channel has occupied different locations and had different main channel and side channel configurations on a decadal scale. From 1964 to 1974, sections of former floodplain and side channel were converted to main channel. From 1974 to 2004, the channel changed locations again, converting the former main channel location to floodplain and side channel. Figures 9 and 10 show main channel and side channel locations digitized from aerial photography. The changing of channel location is likely due to a combination of local sediment deposition and large wood accumulation.

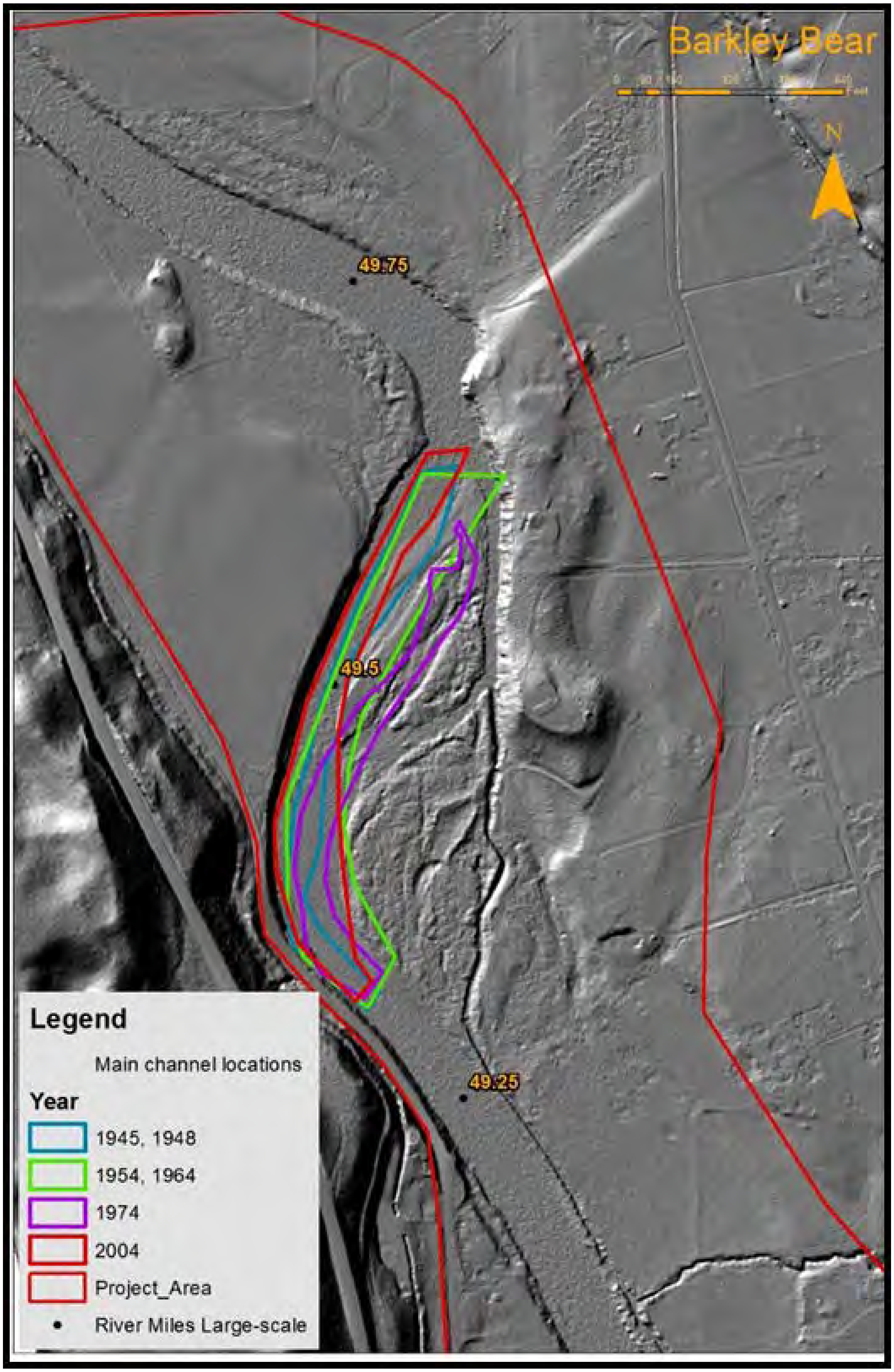



**Figure 9. Main channel locations by year based on aerial photography.**

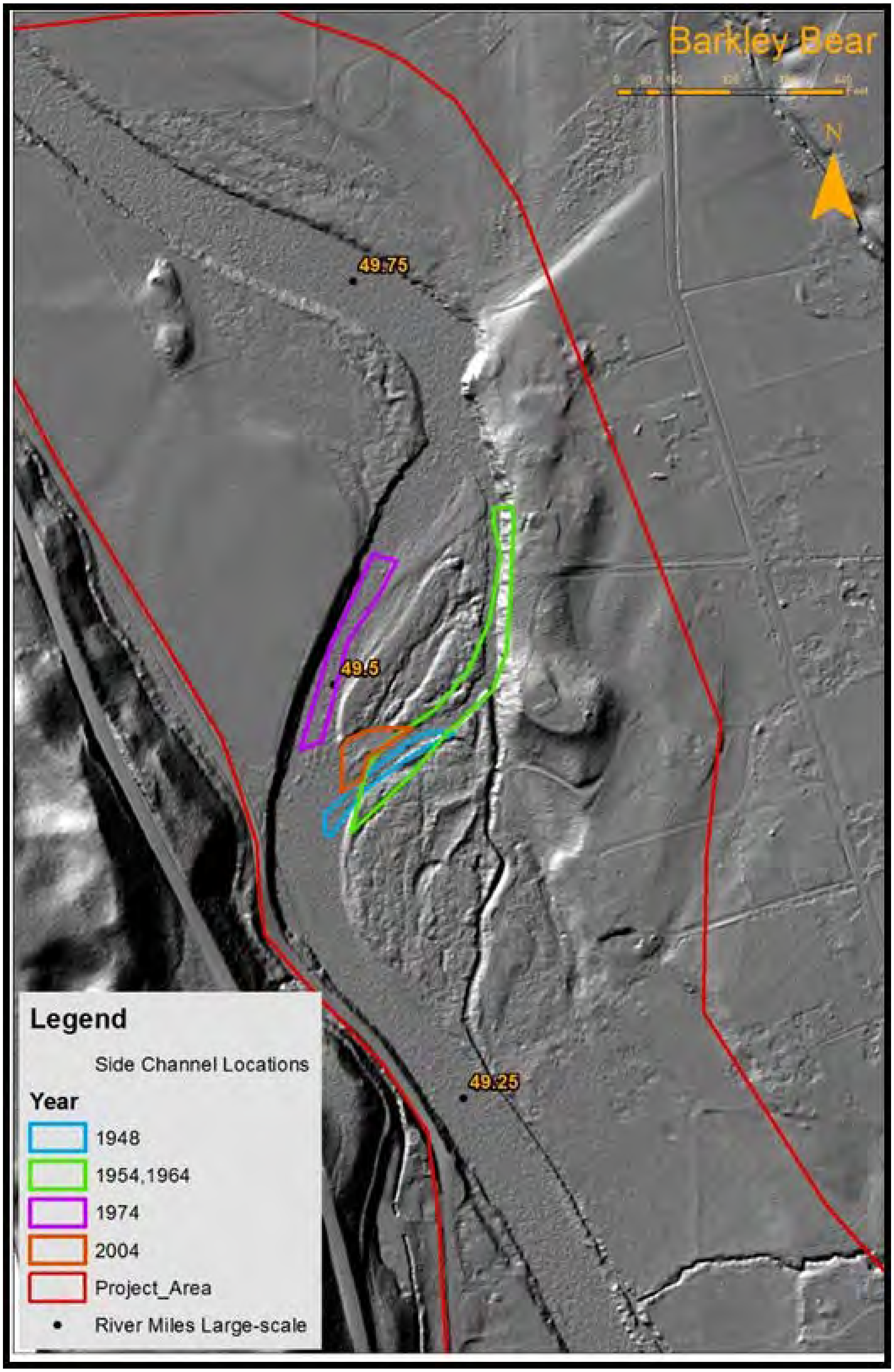



Figure 10. Side channel locations by year based on aerial photography.

## LARGE WOOD AND VEGETATION COVER

There are two large wood jams on the island between the main and side channels in the project area. Large log jams (present in 2015) are located at the head of the island and along the right bank of the side channel. These jams create large flow obstructions and do not get overtopped until the 5- to 10-year flood. Amounts of individual pieces of large wood in the channel are low within the Barkley reach. Large wood has been anecdotally noted to have been historically removed from the channel both within the Middle Methow and in upstream reaches (Reclamation 2008). Only about 10 pieces per mile of large wood (greater than 35 feet long with a diameter of at least 12 inches) were surveyed along the main channel within the Barkley reach. Most of the wood was observed high on the bars and in jams at the confluence with side channels which is expected for a large river. About 10 pieces of large wood per mile were counted in several wetted side channels. Large wood recruitment potential is considered poor to fair due to the removal of vegetation in the floodplain for agriculture and residential development.

Within the downstream Whitefish Island Project Area, several large wood jams have been constructed along with placement of a timber crib feature and individual log pieces to function as roughness elements on bars. The majority of log jams begin to be overtopped at the 2- to 5-year flood based on 2013 topographic surveys. The exceptions are the large apex jam constructed at the head of the island and the seventh log jam located on river left within the side channel that also had a relatively high 2013 surveyed elevation above the side channel bottom.

## BEAR CREEK

### EXISTING CONDITIONS

Within the project area, Bear Creek has been highly modified. In its current form, Bear Creek runs through alluvium comprised of unconsolidated cobbles, sand, and gravel that form the historic Bear Creek alluvial fan. Cross section images were generated in GIS from the digital terrain model. The channel geometry ranges from approximately 2 to 3 feet deep and 2 to 3 feet wide at the top of the bank at its downstream end near Barkley Ditch to approximately 5 feet deep and 20 feet wide at the top near the Lower Bear Creek Road crossing (Figures 11 to 14).

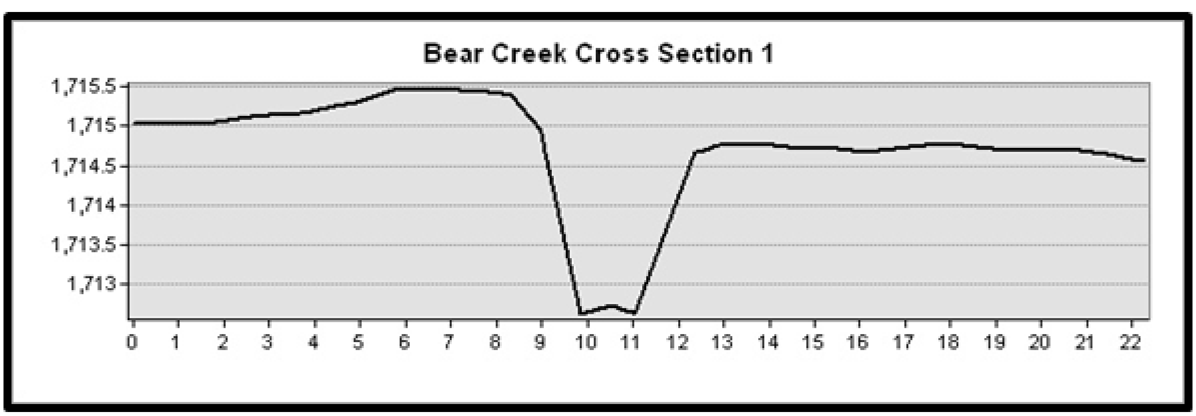



**Figure 11. Cross section of Bear Creek near the Barkley Ditch intersect.**

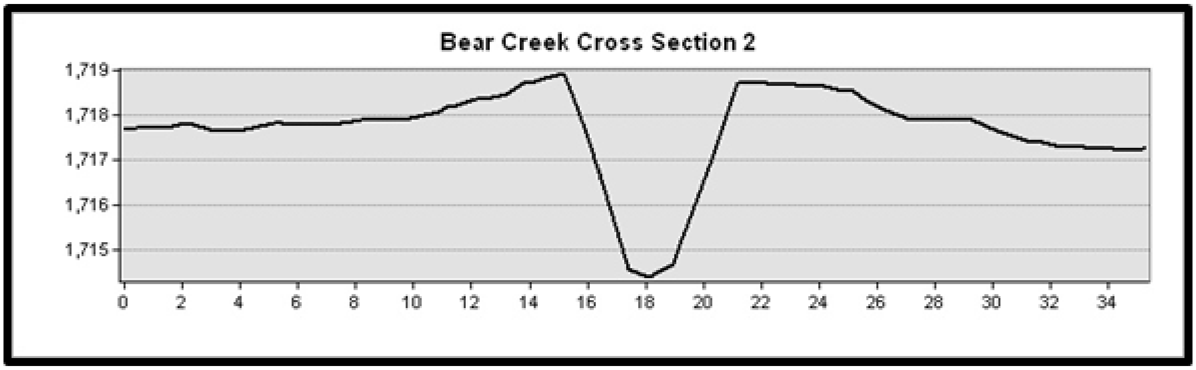



**Figure 12. Cross section of Bear Creek in the lower mid-section of the project area.**

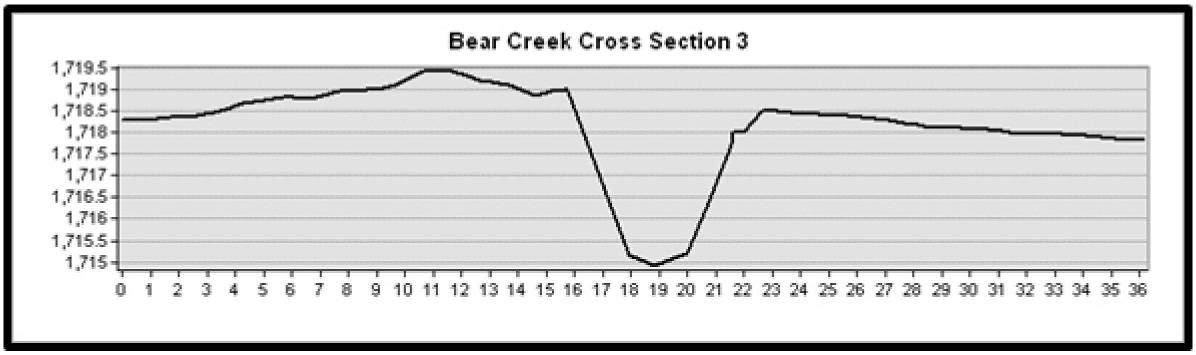



**Figure 13. Cross section of Bear Creek in the upper mid-section of the project area.**

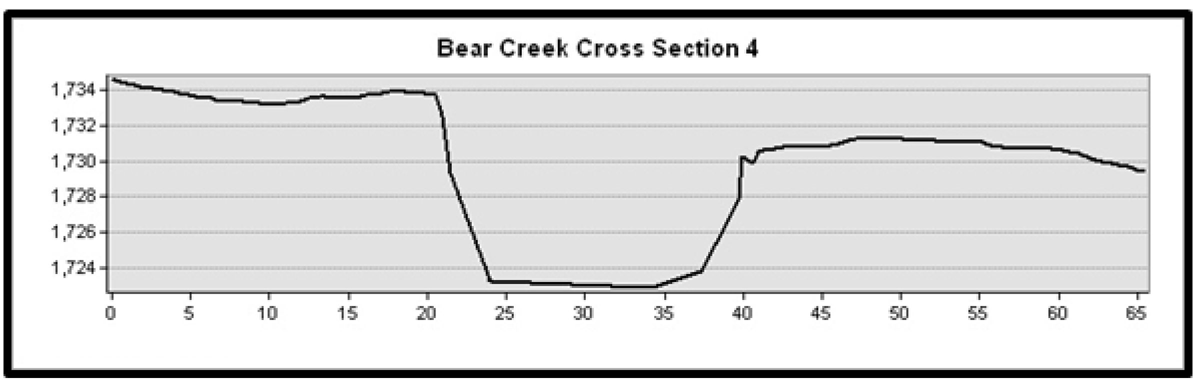



**Figure 14. Cross section of Bear Creek in the top of the project area, near the road crossing.**

Figures 15 and 16 show the existing alignment and profile through the project area below Lower Bear Creek road where it flows into the existing Barkley Canal. The average slope of Bear Creek in the project area below Lower Bear Creek Road is approximately 1.5%. Upstream of the road crossing, the slope is roughly 3.8%. This indicates that the lower end of Bear Creek is a depositional area.

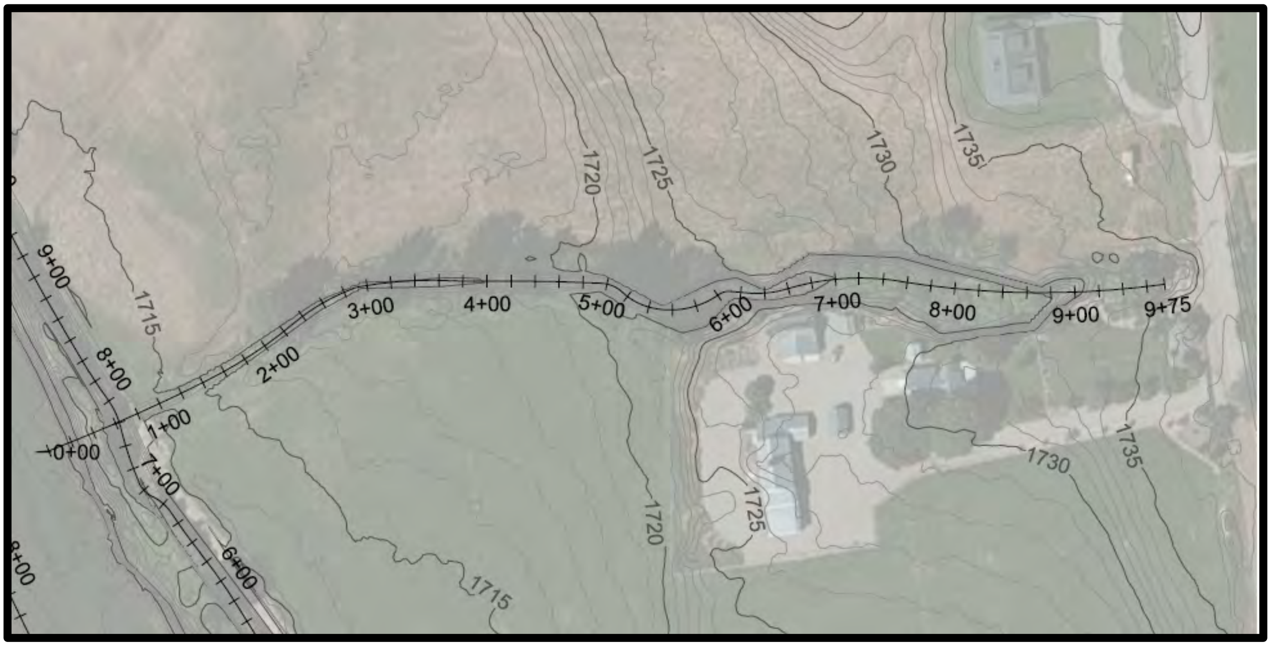



**Figure 15. Plan view of the existing Lower Bear Creek alignment flowing into the Barkley Canal.**

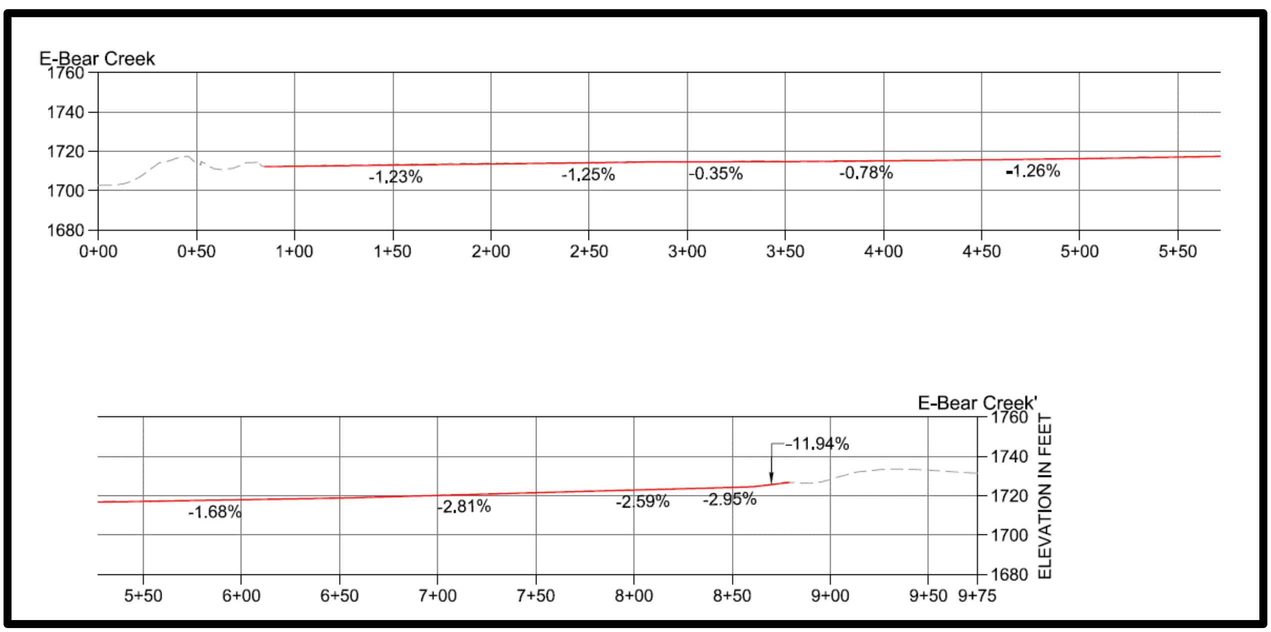



**Figure 16. Longitudinal profile for Lower Bear Creek.**

## PROPOSED CONDITIONS

Two new alignments for Bear Creek were created to evaluate the amount of length and slope needed to reduce the likelihood a head cut propagates through the project area when it is reconnected to the mainstem Methow River. A two-dimensional numerical model was developed in HEC-RAS 5.0 for both proposed alignments. Results include spatial outputs of flow depth, velocity, shear stress, and water surface elevation in all locations within the model's wetted extents. These data were used to evaluate channel capacity, sediment transport competence, and the expected geomorphic response for each proposed channel. More detailed discussion of results can be found in a memorandum prepared by Anchor QEA titled "Lower Bear Creek Realignment and Reconnection Analysis" (Anchor QEA 2017a), and the decision was made to proceed with the shorter alignment.

The new alignment would include a 15-foot width, 580 feet of length, a side slope of 1.5:1 (H:V), and a longitudinal slope of 1.54%.

The alignment plan view shown in Figure 17 routes a 580-foot-long channel to the south at a constant 1.54% slope below station 6+10, with its outlet upstream of the existing fish return. The channel stays within property limits agreed upon by the adjacent landowners.


**Figure 17. Plan view of the evaluated Bear Creek Short Alignment.**

Section views of the alignment presented in Figure 18, show the proposed section cut and existing canal fill along Sections A-A' and B-B'.

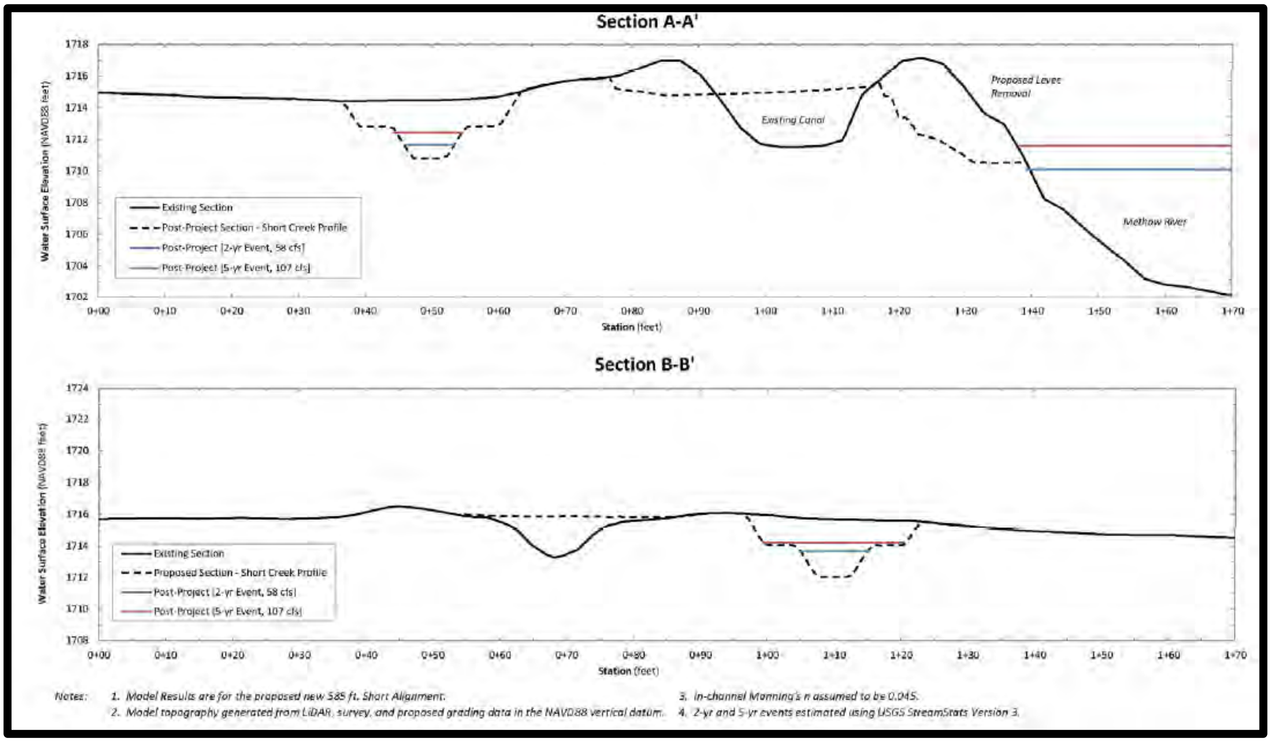



**Figure 18. Section views of existing grade compared to the proposed Bear Creek Alignment.**

## MODELING AND EVALUATION

A two-dimensional numerical model was developed in HEC-RAS 5.0 for both proposed alignments. Results include spatial outputs of flow depth, velocity, shear stress, and water surface elevation in all locations within the model's wetted extents. These data were used to evaluate channel capacity, sediment transport competence, and the expected geomorphic response for each proposed channel. More detailed discussion of results can be found in the analysis memorandum prepared by Anchor QEA (Anchor QEA 2017a).

## GEOMORPHIC ANALYSIS SUMMARY

- Within the Barkley Bear Project Area, bedrock outcroppings are located at RM 50.0 (right bank), RM 49.7 (left bank), RM 49.3 (right bank), and RM 49.24 (right bank). There is additional bedrock within the channel and along the left bank further downstream. The bedrock serves as both lateral and vertical control within the project area. Within the Barkley reach, approximately 3,600 feet of bank have been armored with riprap.
- From RM 49.6 to RM 49.25, approximately 12 to 14 acres of Qa3 surface along river left are inundated at 14,500 cfs, which has a recurrence interval of 5 years. Downstream of RM 49.25, the Qa3 surface along river left is not inundated at a flow with a 5-year recurrence interval. This is an important point because predicted future hydrographs indicate lower peak flows.
- The only location of channel migration/avulsion within the project area is from RM 49.6 to RM 49.45. This is the location where the river is the most dynamic.
- The head of the side channel near RM 49.6 is located on the outside of a meander in the main channel so the side channel tends to fill with sediment and wood.

- Channel change occurs both annually during snowmelt peaks, and during large rare events. Annual change is typically confined to slow channel migration within the active floodplain. Larger changes, including channel formation or abandonment, may occur during the larger events. Restoration plans should, where possible, allow channel evolution processes that provide functional habitat throughout the river corridor. Because of the dynamic processes, some channel areas may be in transition rather than providing optimum habitat.
- Habitat improvement strategies for Bear Creek will need to consider channel geometry and sediment transport capacity that can periodically accommodate high volumes of sand in post-fire seasons. The peak flow for Bear Creek is a fraction of the Methow River peaks. Any contributed sediment from Bear Creek, particularly sand size and smaller, to the mainstem Methow River is expected to have minimal, temporary impacts near the confluence. A portion of the sand-sized sediment could occasionally be conveyed into the downstream Whitefish side channel and temporarily deposited.

### RECOMMENDATIONS

Improvements in natural geomorphic processes would include the following:

- Increased diversity and density of hydraulic roughness elements and cover within active channels and along channel margins
- Increased floodplain activation and diversity in overflow channels including variation in channel size, flow at which a surface water connection is established with the main channel, and opportunity to interact with roots and large wood features
- Increased opportunity for lateral channel dynamics (i.e., the switching of main channel and side channel locations)

## 4 DESCRIPTION OF EXISTING RIPARIAN CONDITION AND HISTORICAL RIPARIAN IMPACTS

Under natural conditions, the valley floor through most of the project area would be expected to support a mixed cottonwood riparian forest. These forests provide a wide range of ecosystem services and are critical to the condition and health of the river and aquatic food webs. Riparian forests help to maintain cool clean water; reduce velocities of overbank flows; promote sediment deposition; provide habitat during floods; resist bank erosion; and supply wood, nutrients, and insects into the aquatic food web.

As part of the Tributary and Reach Assessments (Reclamation 2008, 2010a), vegetation stands within the valley bottom were identified and classified. Figure 19 shows the land use classifications within the Project Area. Within the riparian corridor, dominant land uses are mixed cottonwood forest, agricultural and cleared fields, roads, and residential areas (Table 1).

The riparian forest is less than 50 feet wide along about half of the reach, although two larger stands of riparian forest are present along the major side channels. The stand along the Barkley side channel has multiple canopy layers with dense shrub understory. In the narrower riparian areas, heavy deer browse appears to be preventing young trees from becoming established (Figures 20 and 21).

Large wood is a particularly important component of salmon habitat especially in unconfined river reaches. In unconfined reaches, large wood contributes to the creation and development of side channels and increases hydraulic diversity that promotes complex in-stream habitats. In the Middle

Methow River, large wood is typically found as apex log jams on medial gravel bars and islands, high on lateral gravel bars, and at the head of side channels. Clearing of the riparian buffer zone for agriculture, commercial and residential development, and placement of levees and bank protection have reduced large wood recruitment potential throughout the reach. The reach assessment identifies these anthropogenic impacts and removal of instream wood as a cause of channel simplification, reduced floodplain connectivity, and reduced side channel development (Reclamation 2010a).

Sites along the valley floor are attractive for agricultural and rural residential use. Consequently, much of the project area has been cleared over the past 150 years. In recent years, many of the agricultural fields have become fallow or been converted to residential uses. The project area includes fields actively farmed for hay or grains, and fields no longer in production.

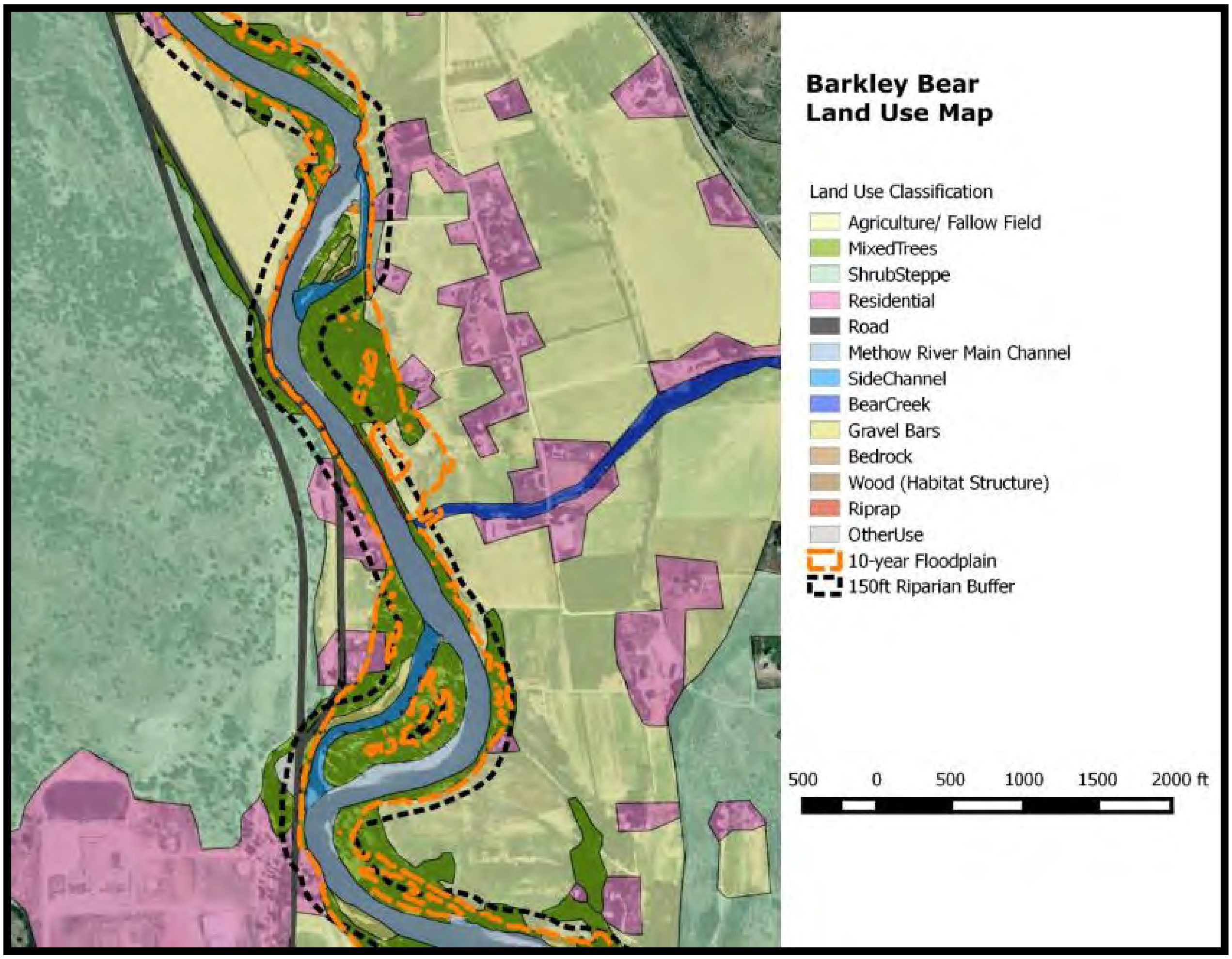



**Figure 19. Land uses within the project area.**

NOTE: Land use classifications from Methow subbasin Geomorphic Assessment. Dashed lines show area within 150 feet of ordinary high water (black) and the modeled 10-year floodplain (orange).

**Table 1. Land use within 150 feet of river.**

| Land Use Code | Percent of Area within 150 feet of river | Percent of Area Within 10-year Floodplain |
|---|---|---|
| Mixed forest | 56% | 75% |
| Cleared/agricultural areas | 23% | 13% |
| Developed areas | 9% | 2% |
| Gravel bars with willows | 4% | 6% |
| Shrub steppe | 3% | 0% |
| Riprap | 3% | 2% |
| Bedrock | 2% | 2% |
| Habitat structures | 1% | 1% |

Note:
Developed areas include roads and residential areas. Bear Creek is included in the mixed forest category.

**Figure 20. Larger riparian forest stands are mixed age stands with multiple canopy layers and dense understory.**

**Figure 21. Narrow riparian forest stands have a single row of trees, with few young trees.**

## 4.1 KEY FINDINGS

The riparian zone is less than 50 feet wide along half the Barkley reach. Most of the areas with a narrow riparian forested zone also have narrow floodplains. Narrow riparian strips do not have multiple canopy layers (few saplings or shrubs). Six acres of land (between Bear Creek and the existing forest) have been cleared within the 10-year floodplain. This would be a priority for riparian forest restoration.

## 4.2 WATER QUALITY CONDITIONS

Water temperature strongly influences native fish species distribution, growth, survival, and competitive success (Carter 2005). The Washington State Department of Ecology (Ecology) has established criteria for water temperature designed to minimize adverse environmental effects on salmon, trout, and char during freshwater life stages (Table 2; Ecology 2016). These water temperature criteria are based on a running 7-day average of daily maximum (7DADM) water temperature. Supplemental spawning and incubation criteria have been developed for specific river segments (Ecology 2011), including for the Methow River.

**Table 2. Water temperature criteria for species and life stages found in the Barkley Bear project area.**

| Species and Life Stage | Water Temperature Standard (7DADM) |
|---|---|
| Char spawning and rearing | 12°C |
| Core summer salmonid habitat | 16°C |
| Supplemental criteria for salmon spawning and incubation in the Methow River | 13°C |
| Salmon rearing and migration only | 17.5°C |
| Non-anadromous interior redband trout | 18°C |
| Indigenous warm water species | 20°C |

Note:
7DADM: 7-day average of daily maximum

The Middle Methow River supports all freshwater life stages of Chinook salmon and steelhead trout and subadult and adult bull trout. Available data show water temperature in the Barkley reach exceeded 16.5°C for an average of 14 days a year (range: 0 to 25 days). Figure 22 shows water temperature data with species and life stage.

Bull trout generally prefer cooler water than either Chinook salmon or steelhead. Accordingly, bull trout spawning and rearing is in cooler upstream reaches. The project reach is used by bull trout for feeding, migration, and overwinter habitat. During spawning and rearing life stages, criteria call for temperatures less than 12°C (Ecology 2016). During the period of record (2009 to 2015), the highest 7DADM was 18.3°C. This suggests water temperature is a significant issue for bull trout in the project area.

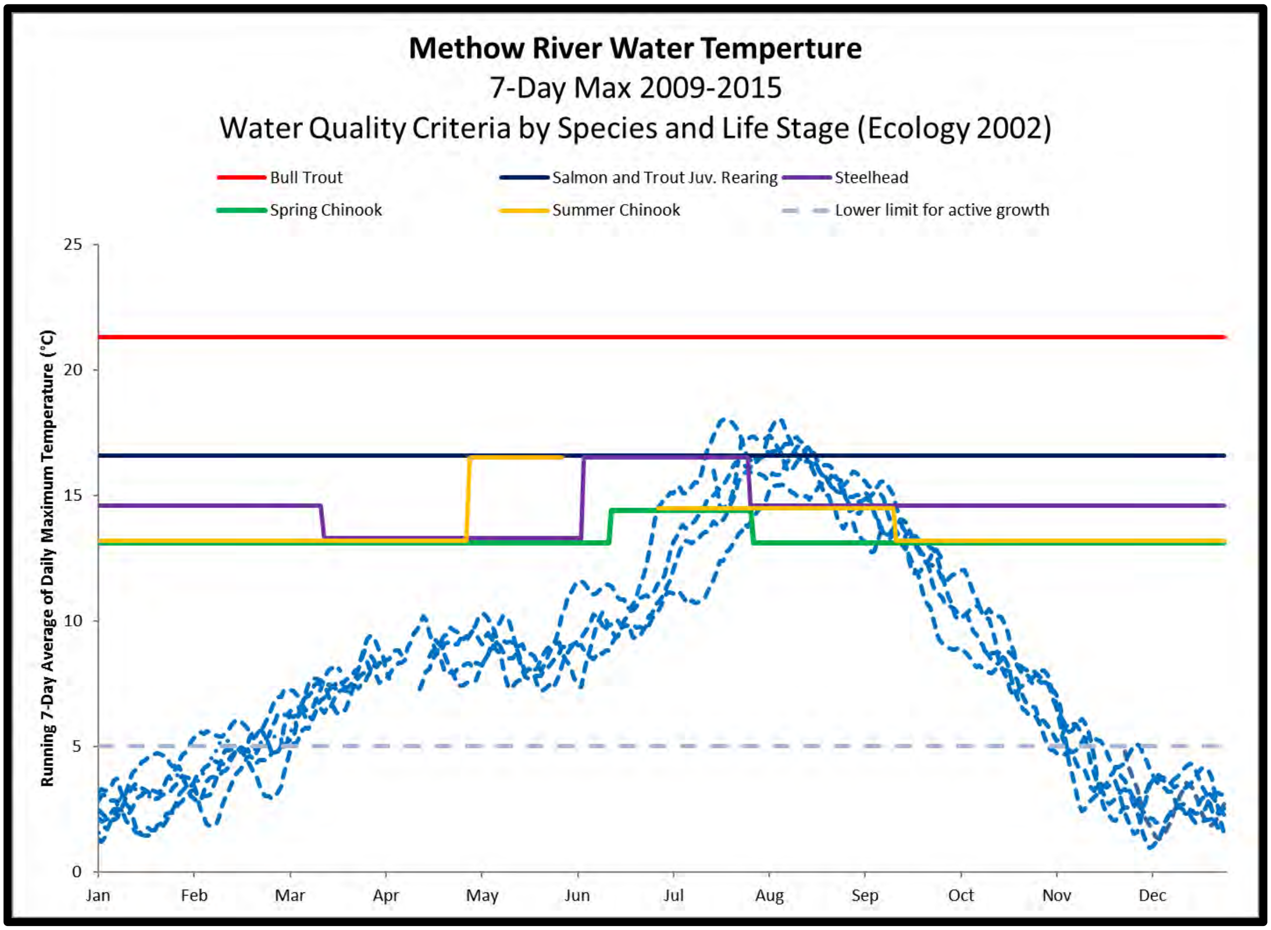



**Figure 22. Methow River water temperature and water quality criteria for target species in the Barkley reach.**

Juvenile trout and salmon go into winter low-activity modes when water temperatures drop below approximately 5°C, and do not resume more active growth and feeding until temperatures warm above 6°C to 7°C (Ecology 2002). During the period of record, the water temperature typically dropped below 5°C in November and remained below 5°C until February. The temperature was below 5°C for an average of 99 days each year (range: 73 to 120 days). This suggests that water temperature in the project reach is too low for active growth for about 3 months of the year. No data are available to show if there are locations of groundwater discharge that may provide warmer winter temperatures.

Water temperature can vary in space as well as through time, and fish can move to take advantage of locations with more suitable temperatures when they are available. A Forward Looking Infrared (FLIR) survey was conducted in late August 2009 (Watershed Sciences 2009) and the surface water temperature data can be used to identify places that may provide thermal refuge in the project area (Figure 23). Colder water (likely hyporheic flow) was found along the right bank near the middle of the Barkley project area (Figure 24). The data also show that Bear Creek is a warm water tributary, but it did not appear to be affecting water temperatures in the main channel. While tributary confluences are often a source of cooler hyporheic flow, this was not observed along the left bank near Bear Creek.

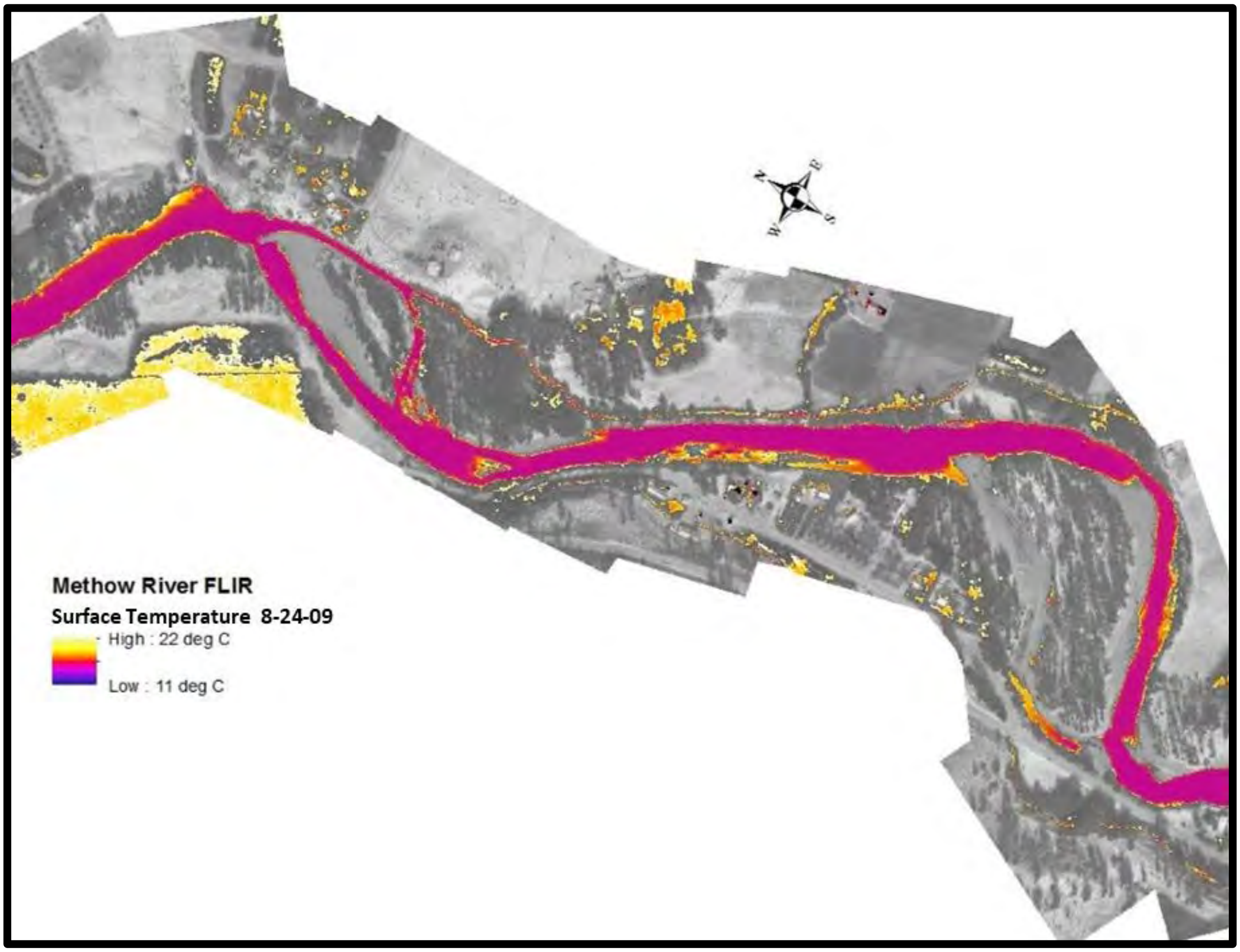



**Figure 23. Water surface temperatures from thermal infrared survey conducted on August 24, 2009 (Watershed Sciences 2009).**

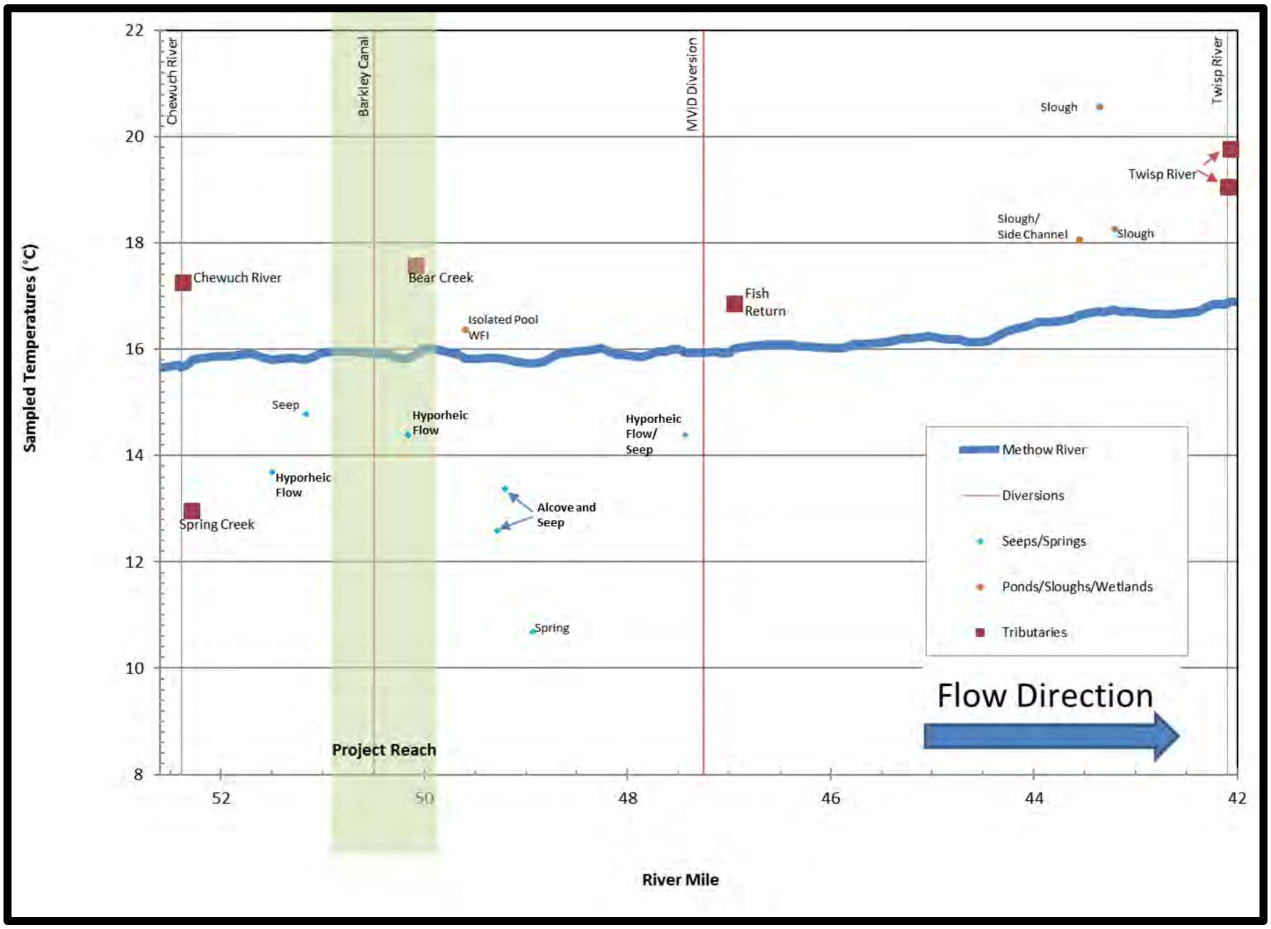



**Figure 24. Thermal profile of the Middle Methow River from aerial thermal imaging on August 24, 2009. The thermal imaging identified cold hyporheic flow on river right in the project area (Watershed Sciences 2009).**

## EXISTING WATER TEMPERATURE CONDITIONS SUMMARY

- Water temperature is above state standards for salmon and trout in July and August in most years, and above state standards for char from July through September in most years.
- Low water temperatures appear to be limiting growth from November through February in most years.
- Water temperature exceeds state supplemental standards for Chinook salmon spawning within the Barkley reach.
- Warmer water may decrease suitability for salmon and trout spawning and rearing.
- Hyporheic flows may provide cold water refuge habitat within the project area, in particular in the important spawning reach.
- Bear Creek contributes warm water to the Methow River, which may be influenced by irrigation return flows. However, it does not appear to affect overall Methow River temperatures.

# 5 DESCRIPTION OF LATERAL CONNECTIVITY TO FLOODPLAIN AND HISTORICAL FLOODPLAIN IMPACTS

The Barkley Bear project area is located within a rural-residential and agricultural landscape. Modifications to the river and the floodplain have occurred in this area over the past century and a half. Modifications include the removal of riparian vegetation, and construction of irrigation infrastructure and roadways. The river bottom modifications include annual (until 2014) in-channel modification of bars and channel bottom to create a push-up diversion. The dredging of sediment and clearing of large wood from off-channel areas has also taken place. To protect agriculture land, irrigation infrastructure, and roads, approximately 0.5 linear mile of riprap has been placed along the banks of the Methow River within the project area. The bank armoring restricts lateral channel migration, simplifies hydraulics, and affects sediment transport.

# 6 EXPLANATION AND BACKGROUND ON FISHERIES USE (BY LIFE STAGE - PERIOD) AND LIMITING FACTORS ADDRESSED BY PROJECT

The primary species of interest for the Barkley Bear Project are ESA-listed spring Chinook salmon (Endangered) and steelhead trout (Threatened), with summer Chinook salmon, bull trout (Threatened), and Pacific lamprey (U.S. Fish and Wildlife Service Species of Concern) as secondary species.

Surveys by the USGS showed two species of non-listed fish are dominant in the Middle Methow River (Martens et al. 2014). Mountain whitefish and sculpin species together account for about 95% of the fish production in main channel habitats (Bellmore 2011).

## 6.1 SPRING CHINOOK SALMON

Spring Chinook salmon are present in the Middle Methow River throughout the year. Spring Chinook spawn in low numbers within the Barkley reach, but it is an important rearing area. Spring Chinook primarily spawn upstream of Winthrop and in the Chewuch and Twisp rivers. Adults migrate through the Barkley Bear reach in June and July as flows are receding from the spring freshet. Spring Chinook spawn in late summer, and fry generally emerge in late winter through early spring. During the spring runoff, post-emergent fry spread out from the spawning areas into rearing areas throughout the watershed. Data from smolt traps in the lower Twisp River and Methow River near McFarland Creek suggest most of the spring Chinook parr movement is in mid-March through early July (Figures 25 through 27).

Spring Chinook salmon juveniles generally seek out areas with low velocity and good cover for rearing. Most of the juveniles spend a year in reaches similar to the project area before beginning their seaward migration in March and April. Spring Chinook salmon display a variety of life history strategies in the Methow River, with both subyearling and yearling emigration patterns.

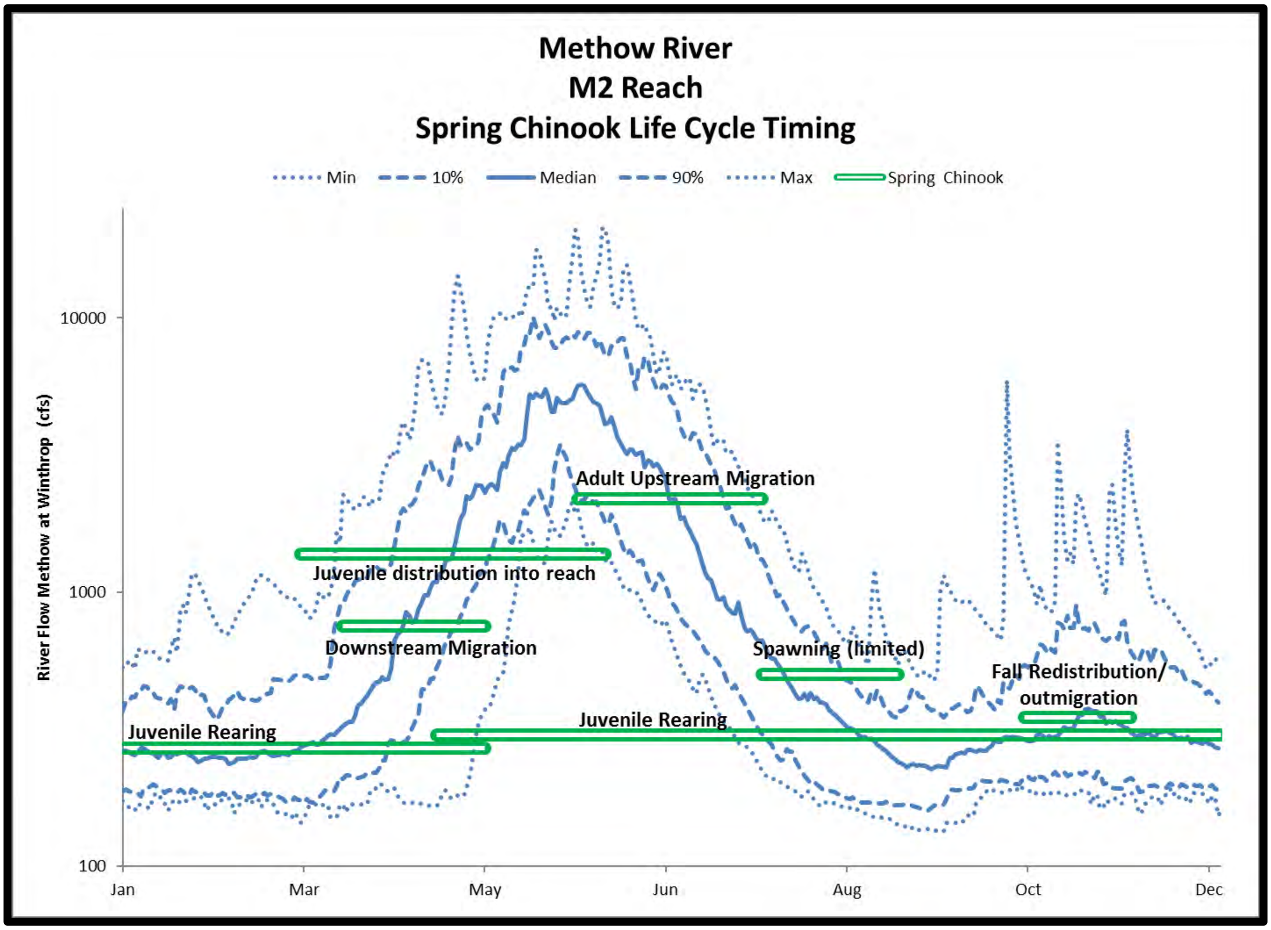



**Figure 25. Spring Chinook salmon life cycle and timing of use in the Middle Methow River. Spring Chinook salmon primarily spawn upstream of the project reach, but spring Chinook salmon fry move into the reach shortly after emerging and spend a year in the reach.**

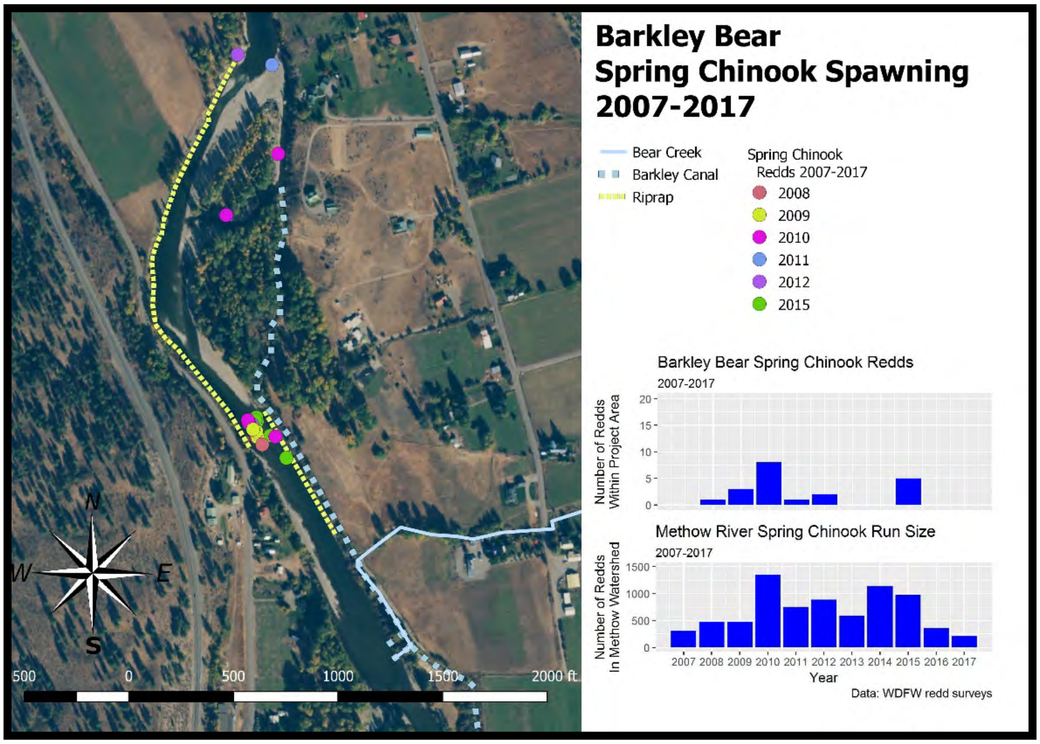



**Figure 26. Location of spring Chinook salmon redds within the Barkley reach, 2007 to 2017.**

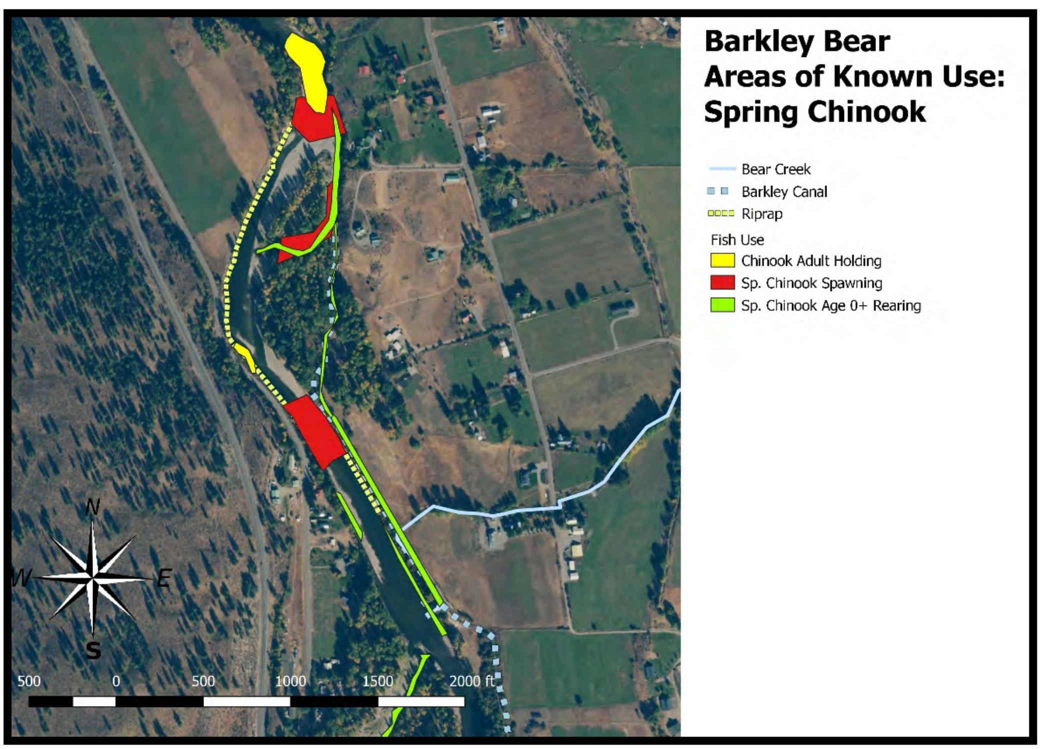



**Figure 27. Known areas of use by spring Chinook salmon in the project area (based on observations and professional judgment).**

## 6.2 STEELHEAD

Steelhead trout are present in the Middle Methow River year-round. Steelhead spawn in the spring, and their eggs incubate during spring high flows and fry emerge in early summer. Steelhead spawning is spread throughout the watershed, and the project area generally supports about 1% of the steelhead redds counted in the Methow watershed. Steelhead spend 2 to 3 years in the river before beginning their seaward migration (Figures 28 through 30).

During summer months, steelhead fry are common in shallow river margins. Larger parr use a wide variety of stream habitats, including both riffle and pool type habitats.

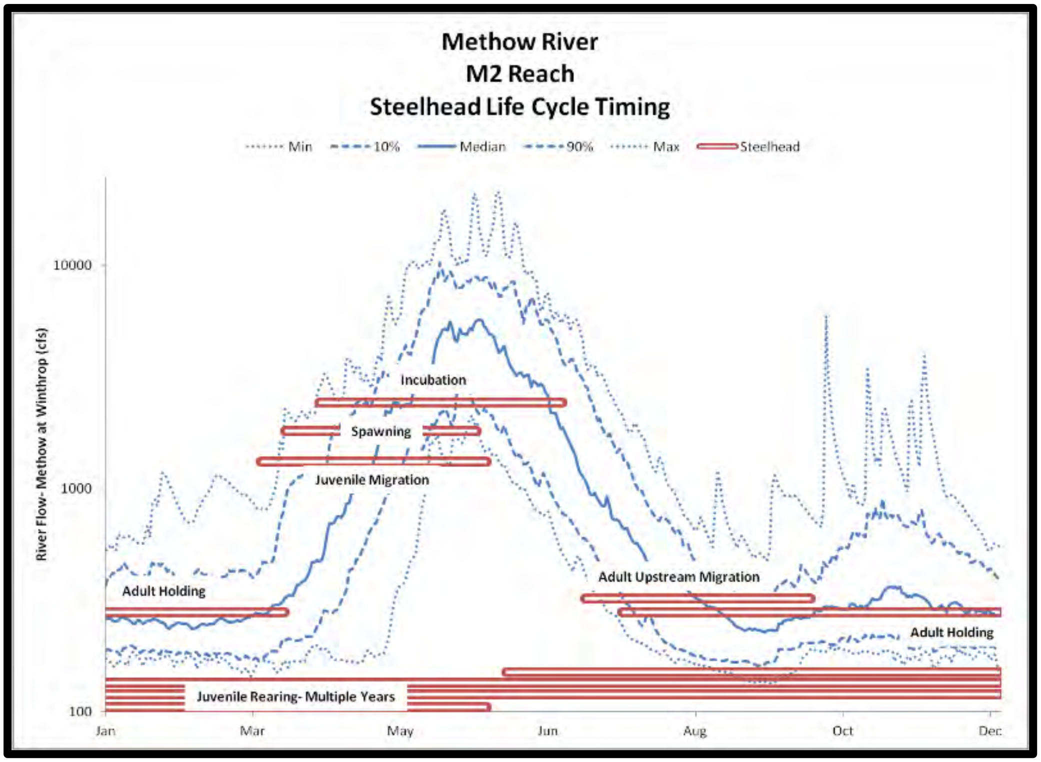



**Figure 28. Steelhead trout life cycle and timing history in the Middle Methow River.**

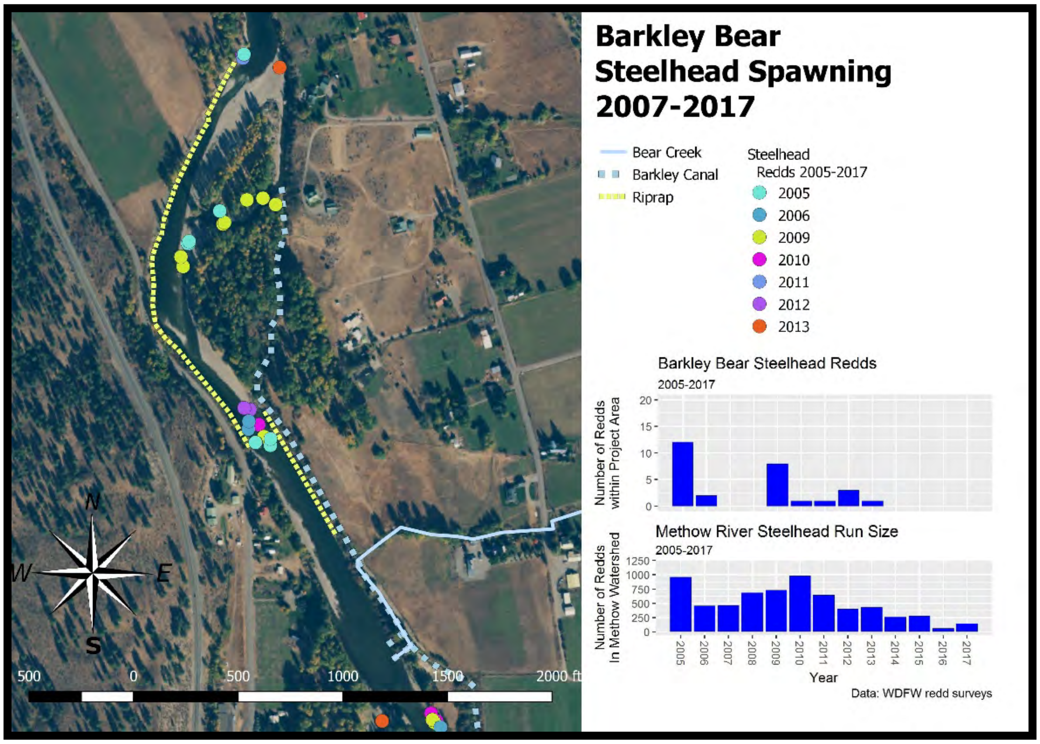



Figure 29. Steelhead spawning within the Barkley reach.

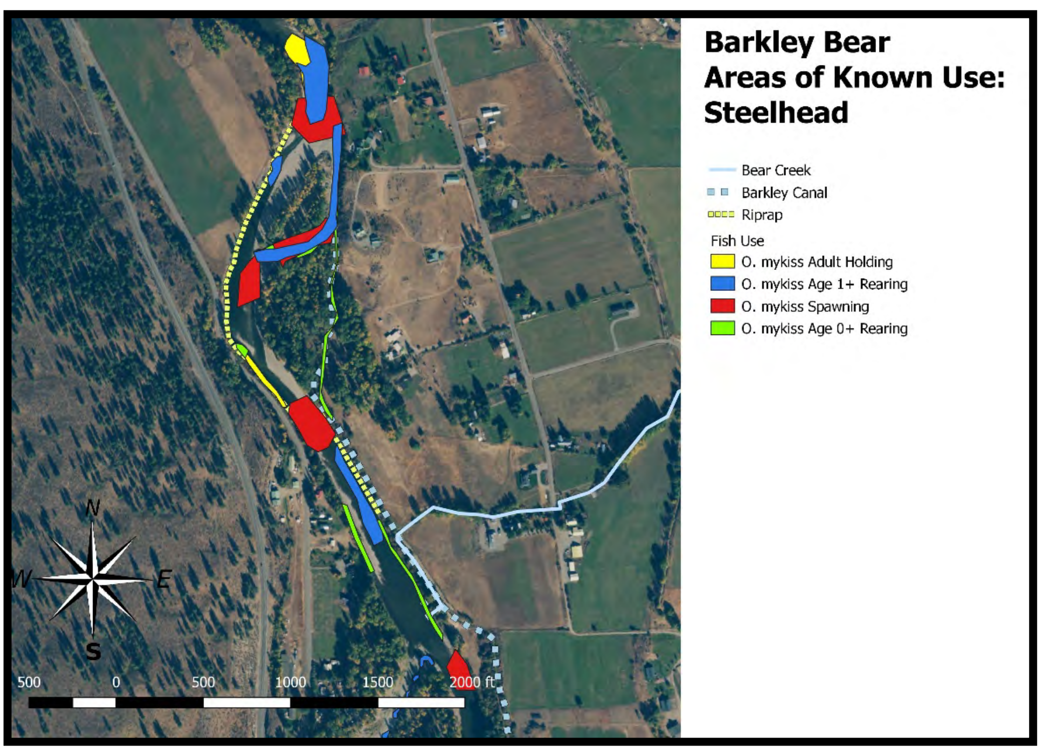



Figure 30. Areas of known steelhead use in the project area (based on observations and professional judgment).

## 6.3 SUMMER CHINOOK SALMON

Summer Chinook salmon are generally present from August to mid June in the Middle Methow River. The project area is an important spawning area for summer Chinook salmon, with 3% to 9% of the summer Chinook redds counted in the Methow watershed located within the project reach (BioAnalysts redd survey data, 2007 to 2017). The Methow River summer Chinook Salmon population is considered stable and is not listed under the ESA. In the Methow River, most summer Chinook Salmon spawning is downstream of the confluence of the Chewuch River (HSRG 2009; Snow, personal communication). Most summer Chinook salmon are ocean-type Chinook salmon that begin migrating downstream shortly after emergence although some rear through the summer in the Methow River and a small subset emigrate as yearlings. Genetic sampling from sub-yearling Chinook salmon captured at the smolt trap near McFarland Creek indicates that summer Chinook salmon make up the majority of the age-0 Chinook salmon captured at the trap during spring and early summer (Snow, personal communication). These data suggest that more than 90% of the summer Chinook salmon fry have left the reach by mid-June. Figures 31 through 33 show location and timing of summer Chinook salmon in the reach.

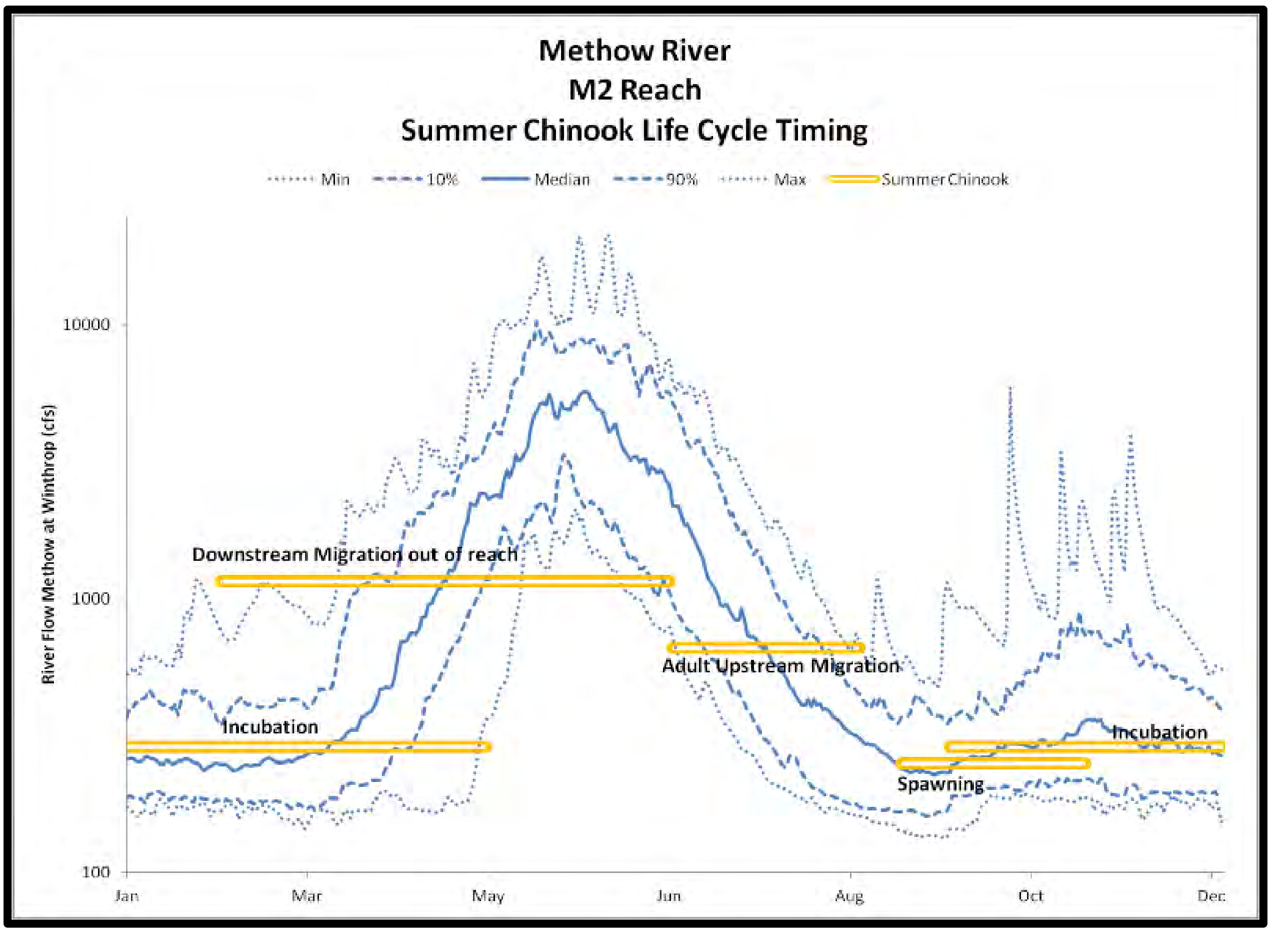



**Figure 31. Typical summer Chinook salmon life cycle and history timing in the Middle Methow River.**

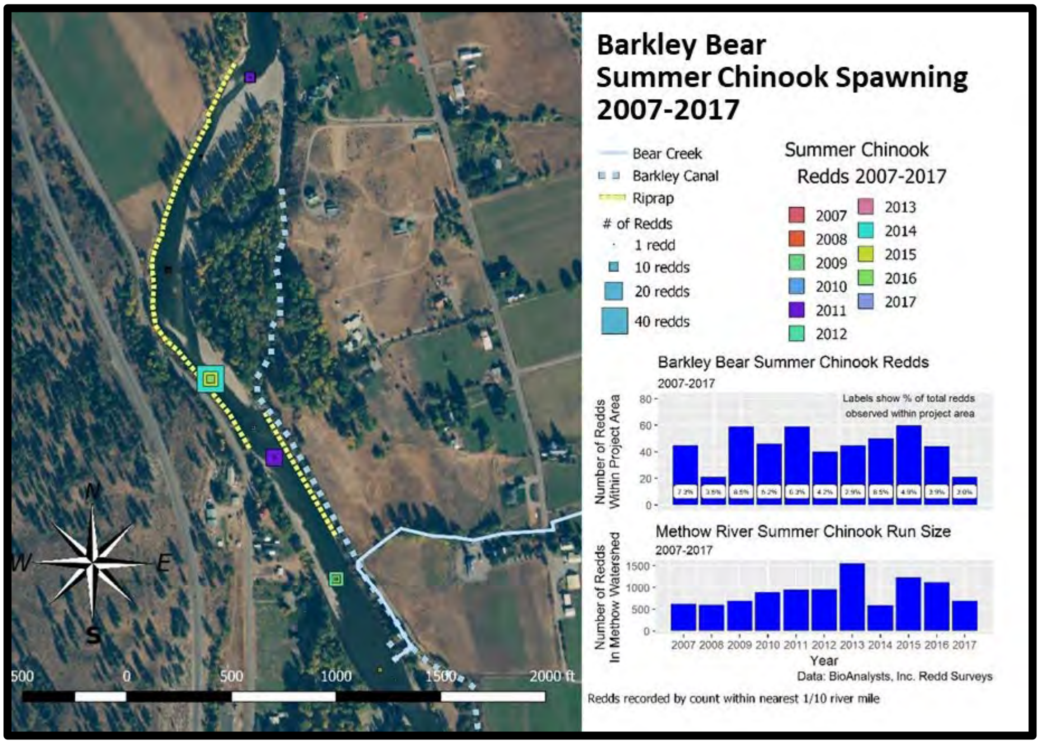



**Figure 32. Summer Chinook salmon spawning locations in the Barkley reach, 2007 to 2017.**

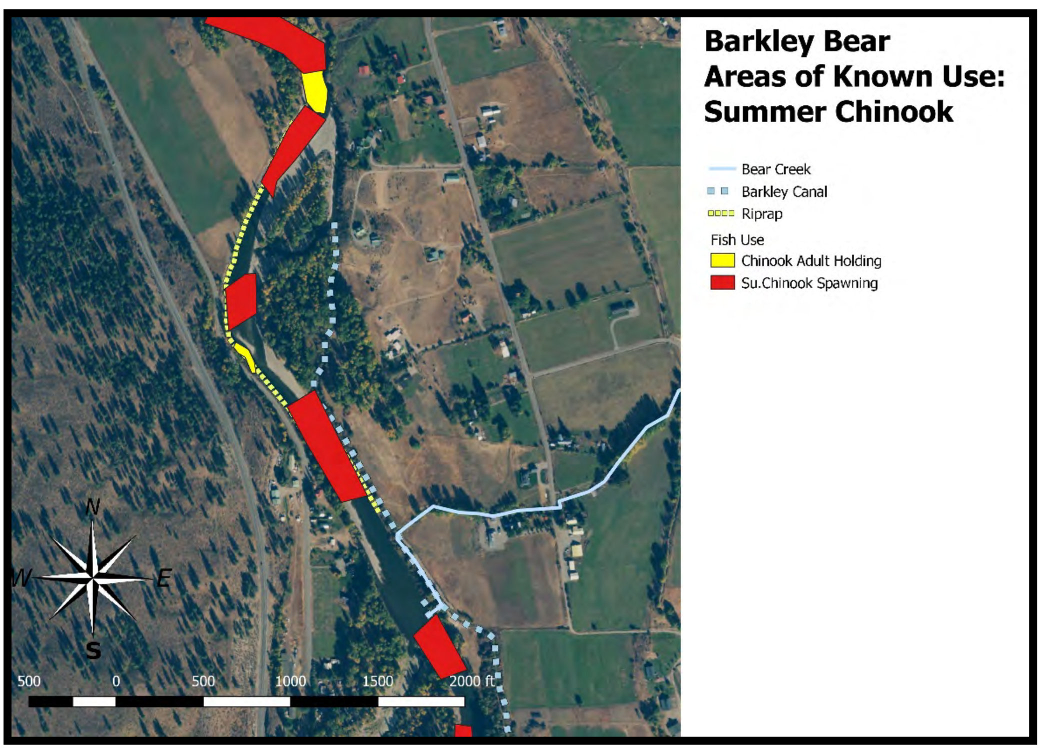



**Figure 33. Areas of known use by summer Chinook salmon in the project area (based on observations and professional knowledge).**

## 6.4 PACIFIC LAMPREY

The Middle Methow River is within the known current and historical range for Pacific lamprey and they are present year-round. Adult lamprey enter the Methow River during summer lower water, and hold in fresh water until late spring spawning. Very little is known about where lamprey hold or spawn. After larvae emerge, they spend up to 7 years as ammocoetes buried in fine sediment deposits, where they filter small particles from the water column. Figure 34 shows life cycle timing for Pacific lamprey.

Currently, lamprey are found in the Chewuch River and the Methow River downstream from Winthrop. In the upper Columbia, lamprey populations are extremely low, and they were historically more widely distributed. Figure 35 shows known locations of Pacific lamprey use in the project area.

The upper end of the Barkley canal has been functioning as a habitat trap for lamprey ammocoetes. The slow velocities and fine sediment attract ammocoetes during the spring and summer. When the canal is shut down in the fall, fish salvage efforts that target salmonids do not effectively capture lamprey and they likely perish when the canal dries up.

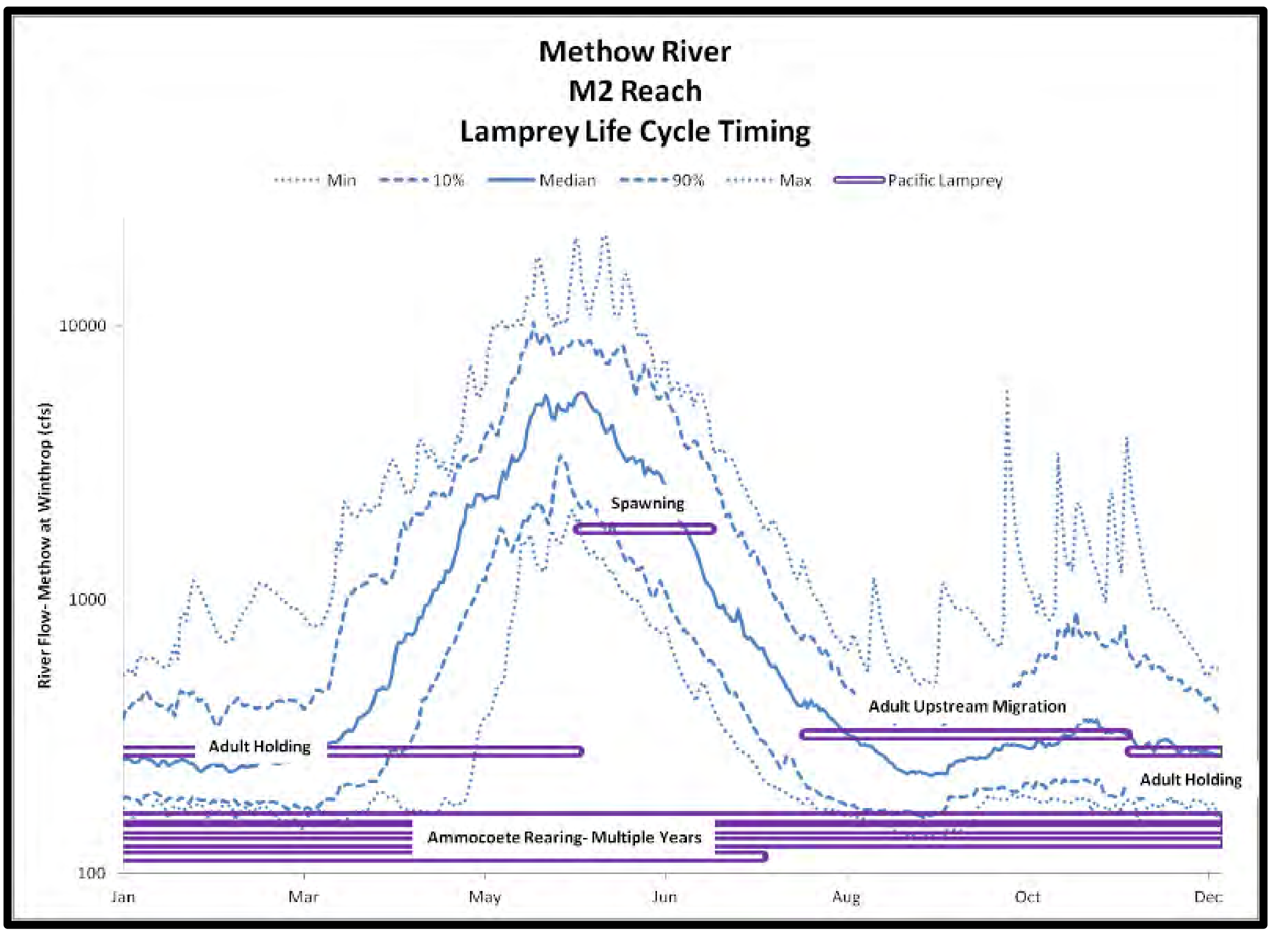



Figure 34. Pacific lamprey life cycle and history timing in the Middle Methow River.

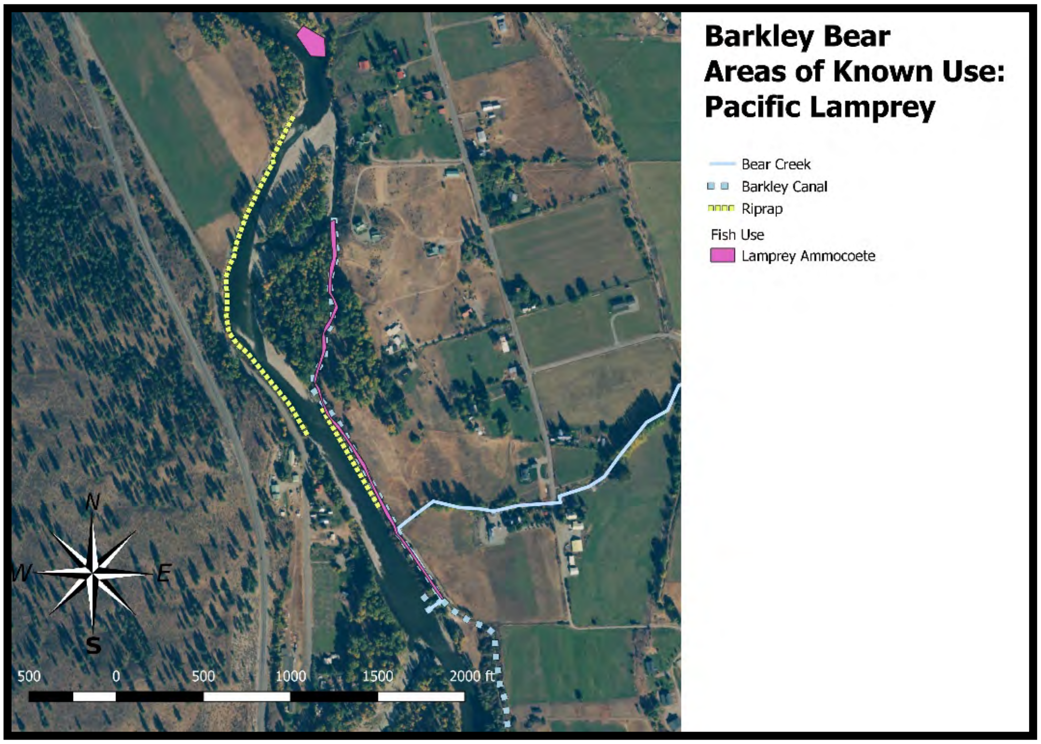



**Figure 35. Areas of known use by Pacific lamprey in the project area. Lamprey ammocoetes may be present anywhere where appropriate habitat (fine sediment) is present.**

## 6.5 BULL TROUT

Bull trout are present year-round in the Methow River. The project area provides feeding, migration, and overwintering habitat for bull trout. Bull trout spawn in headwater reaches in the Chewuch, Twisp, upper Methow, and Lost rivers. After rearing for a few years near the spawning reaches, juvenile bull trout move to mainstem river areas. Adult and subadult bull trout may be present year-round. Adult bull trout are generally piscivorous, feeding on smaller fishes. In the Middle Methow River, bull trout are often seen along with schools of whitefish. Within the project area, bull trout are generally found in deeper pools. Figures 36 and 37 show the timing and location of known use of bull trout in the project area.

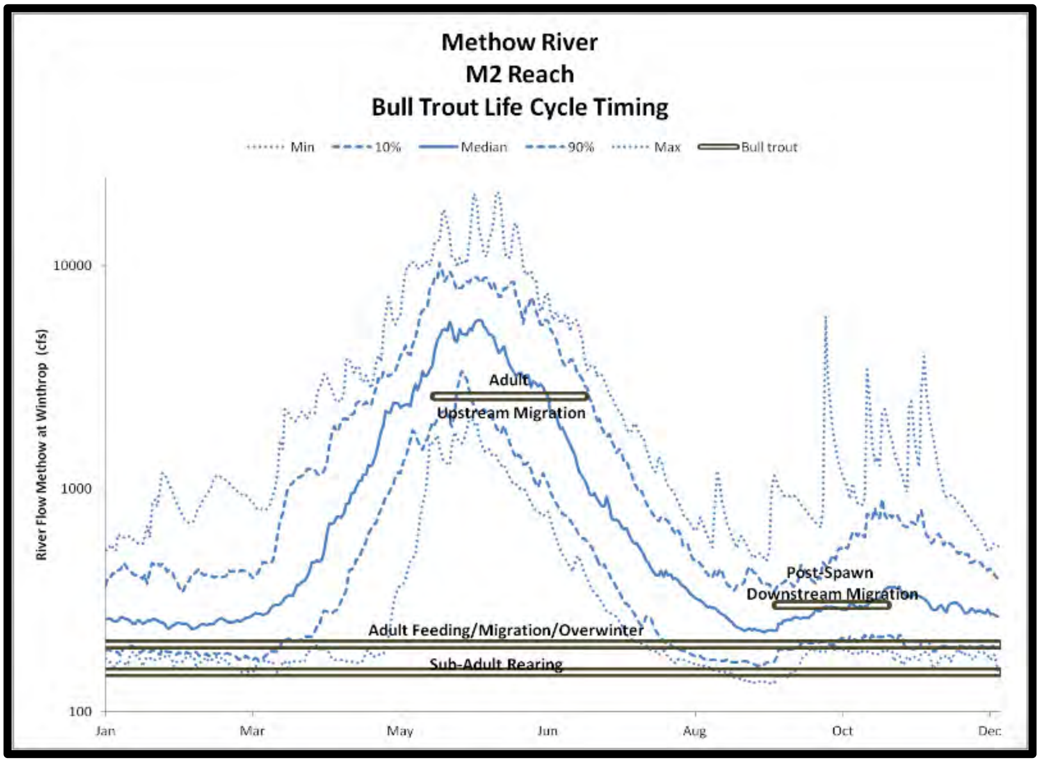



Figure 36. Bull trout life cycle and history timing within the Middle Methow River.

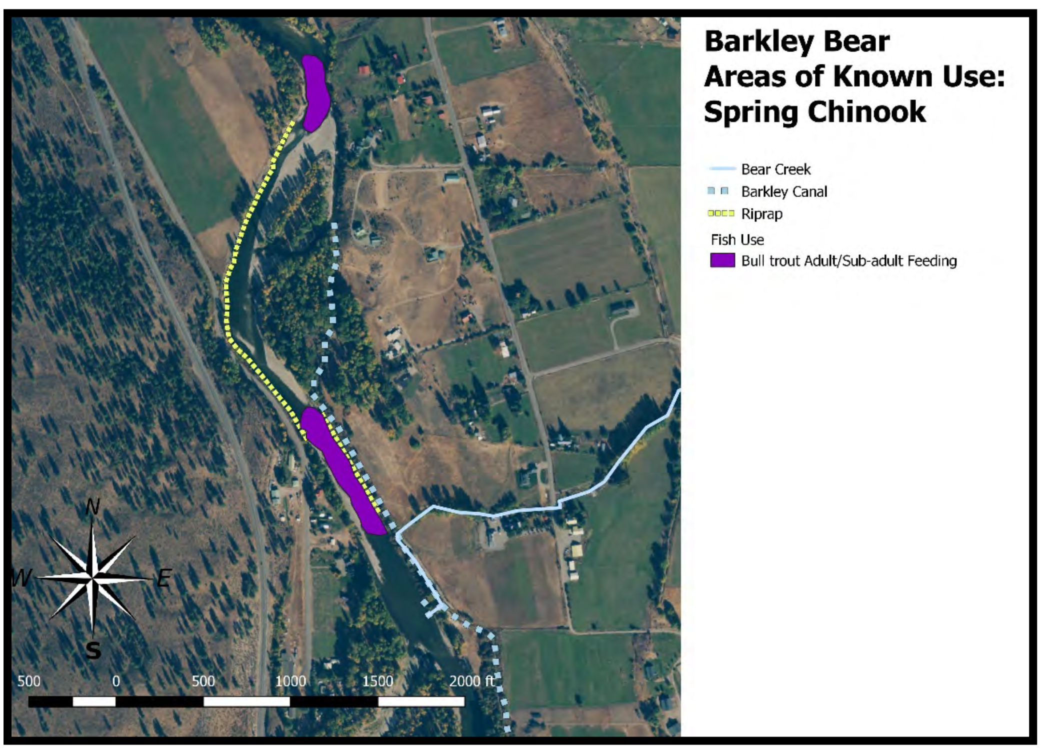



Figure 37. Known areas of bull trout feeding and holding in the project area (based on visual observations).

## 6.6 MAIN CHANNEL HABITAT CONDITIONS

The M2 Reach Assessment (Reclamation 2010a) found that the area has low levels of large wood (10 pieces per mile), with poor to fair potential for large wood recruitment due to a narrow riparian zone. Most of the wood that is in the reach is small diameter or old, partially rotten wood that is not likely to persist.

Features that can provide aquatic cover, including overhanging vegetation, boulders, wood, and undercut banks were mapped based on field visits and aerial photos. These data indicate that during low flows, there is aquatic cover in about 10% of the wetted area. At higher flows, the river spreads out into vegetated areas that could provide cover and refuge (Figure 38).

The Barkley reach includes about 4.3 pools per mile, which is considered adequate densities. Several large bedrock-forced pools provide good depth and cover, but there are low numbers of scour pools in the reach. The existing scour pools are generally shallow and lack cover and complexity.

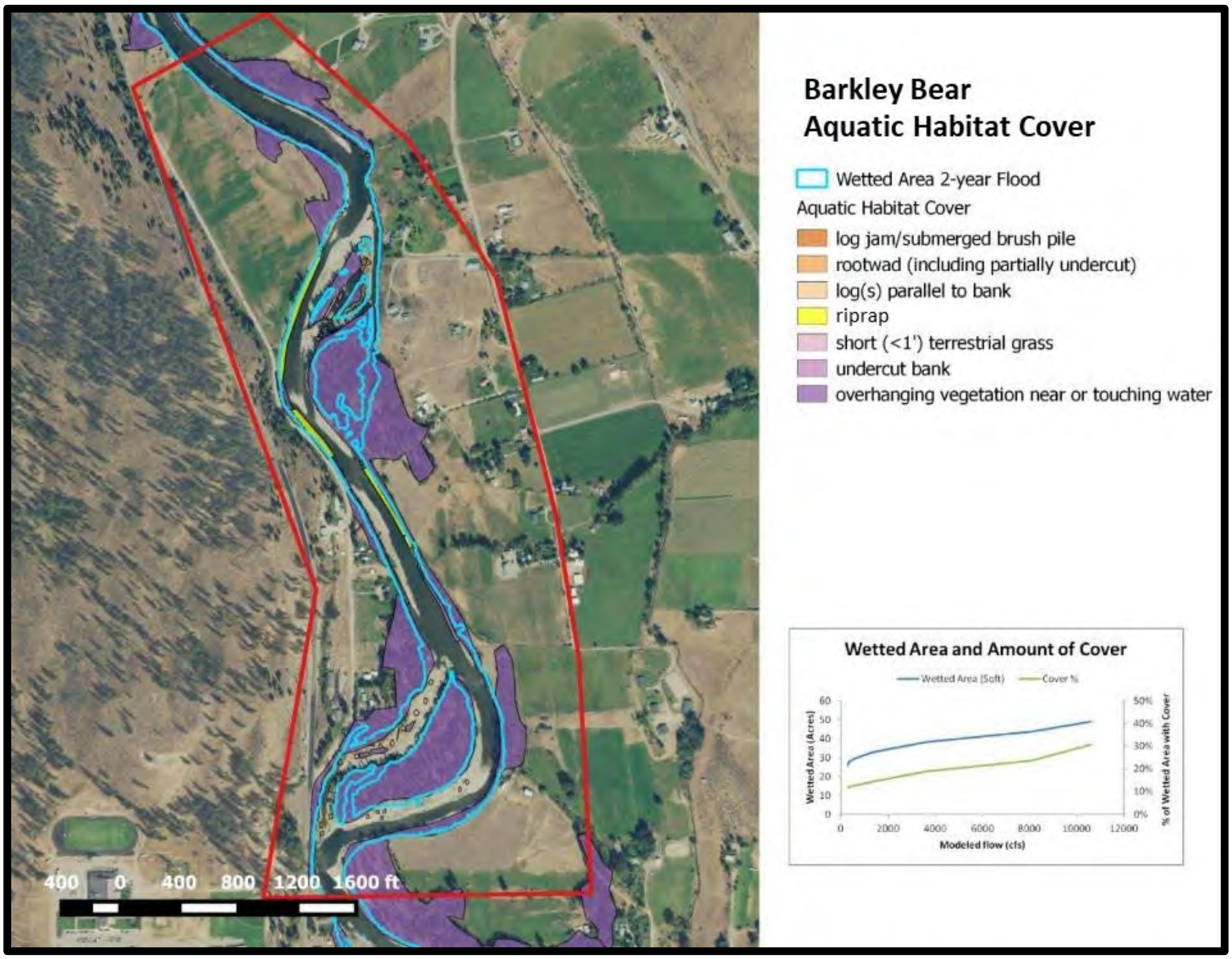



Figure 38. Aquatic habitat cover as mapped based on field observations and aerial photography.

## 6.7 SIDE CHANNELS AND BACKWATER HABITAT CONDITIONS

The Barkley reach includes two significant side channels (Barkley side channel on river left at RM 49.63 and Whitefish Island side channel on river right at RM 49.0). Both of these side channels support perennial or near perennial flow during most years. The Whitefish Island side channel was the site of a major habitat improvement project constructed in 2012. The upper end of the Barkley Canal also currently provides off-channel habitat, which functions as an ecological trap due to the annual dewatering associated with the ditch closure. The 2010 Reach Assessment (Reclamation 2010a) found that channel confinement, low beaver populations, and low levels of large wood limit side channel formation and function.

## 6.8 BEAR CREEK

Bear Creek is a relatively small second order tributary to the Methow River. Bear Creek drains a roughly 18 $mi^2$ (11,547 acres) watershed and flows in a westerly direction. The Barkley Canal intercepts Bear Creek before it reaches the Methow River. Irrigation diversions and several culverts limit the fish habitat available in lower Bear Creek. During summer months, irrigation withdrawals can completely dewater Bear Creek between an operational spill for the Fulton Canal (approx. mile 0.4) and the golf course diversion (approx. mile 3.5). There are 10 fish passage barriers in the lower 3.5 miles of Bear Creek. Habitat within lower Bear Creek is about 72% riffles and 18% pools (Crandall 2014). Summer water temperatures are higher in lower Bear Creek than the Methow River, with temperatures exceeding 20°C during monitoring in 2007. The lower 0.4 mile of Bear Creek supports juvenile Chinook Salmon and steelhead (Crandall 2014).

## 6.9 LIMITING FACTORS

The Revised Biological Strategy to Protect and Restore Salmonid Habitat in the Upper Columbia Region (Biological Strategy) (RTT 2014) for recovery of salmon and steelhead identifies the following ecological concerns for the Middle Methow River Assessment Unit:

1. Channel structure and form (bed and channel form)
2. Channel structure and form (instream structural complexity)
3. Peripheral and transitional habitat (side channel and wetland connections)
4. Riparian condition (riparian condition and large wood recruitment)
5. Habitat quantity (anthropogenic barriers)
6. Food (altered primary productivity or prey species composition and diversity)
7. Species interaction (increased competition and predators)

This project is directed at addressing instream channel complexity, side channel and wetlands connections, peripheral and transitional habitats, riparian conditions, and food, within the framework of natural process.

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## 6.6 CONSTRUCTION CONSERVATION CONSIDERATIONS

The sections below outline how the required elements have been addressed and what additional items will be required by the contractor before the project goes to construction.

## 1 INCORPORATION OF HIP III GENERAL AND CONSTRUCTION CONSERVATION MEASURES

### 1.1 GENERAL AQUATIC CONSERVATION MEASURES APPLICABLE TO ALL ACTIONS

1. Climate Change Considerations:
   Climate change was a key consideration in the design. While there is a lot of uncertainty around how much climate change will affect the environmental variables that drive salmonid production, the U.S. Geological Survey (USGS) Washington Water Science Center used the Methow River basin to test and demonstrate how the global climate models can be used to predict local influences (Voss and Mastin 2012). The simulations predict that winter flows will increase, spring peak flows will become earlier, and air temperatures (and hence, water temperatures) will rise.

   The model predicts only small changes in the total annual precipitation and streamflow (Figure 1 and Figure 2). Likewise, no significant changes to the timing of precipitation are predicted (Figure 3). The models predict both daytime and night time temperatures to increase by about 2°F (1°C) throughout the year (Figure 4 and Figure 5). This will result in a smaller snowpack and higher flows during the winter months (Figure 6). The higher temperatures will also cause earlier spring runoff (Figure 7 and Figure 8).

   Caldwell and others (2013) used statistical models to estimate that the combined changes to streamflow and air temperatures will increase water temperatures by 0.7$^{O}$C (1.3$^{O}$F) by 2040 (Figure 9). Under these simulations, the largest effect will be during the summer months (June through September), when low flows allow the water to respond more to changes in air temperature. The forecast change to average daily temperature in 2040 is +0.3$^{O}$C during October through May and +1.4$^{O}$C during June through September (Caldwell et al. 2013).

   Because water temperature is so important to salmon biology, this increase in water temperature could change how the fish can use the project reach. Chinook salmon spawn in the late summer and fall, and their eggs typically overwinter in the gravel. The ideal temperature for Chinook salmon development is between 8°C and 12°C (Bergendorf 2002). Warmer water temperatures could shorten the incubation period or increase thermal stress on pre-emergent fry. Pre-hatch mortality increases along with increasing temperatures, and this may contribute to the spatial division between August spawning spring Chinook salmon and October spawning summer Chinook salmon (Beer and Anderson 2001). The predicted increase in water temperature would more than double the number of days spring Chinook salmon eggs incubating in the upper Methow and Chewuch spawning grounds are exposed to temperatures above 12°C, and reduce the number of days within the optimal temperature range.

   The higher water temperatures can also speed development of pre-emergent Chinook salmon. If spawn timing does not change, spring Chinook salmon fry may begin emerging about 2 weeks earlier, and summer Chinook salmon may begin emerging 1 week earlier. This could increase the proportion of spring Chinook salmon fry that emerge in late fall or during the winter when food is scarce.

Spring Chinook salmon spend a year rearing as juveniles in the Methow River before smolting and migrating out to the ocean. During this period, growth rates increase up to 19°C, and mortality increases with sustained temperatures above 17°C (Bergendorf 2002). Under current climate conditions, sustained temperatures (7-day average of daily maximum [7DADM]) rarely raise above 17°C in the Middle Methow (M2) Reach of the Methow River or the spawning areas upstream (Data 2009 to 2015). With the increased water temperatures predicted by Caldwell et al. (2013), 7DADM temperatures above 17°C would be expected in most years in the Methow and Chewuch rivers (Figure 10).

Steelhead spawn in the spring and emerge as the spring freshet is subsiding. Steelhead incubation and emergence is temperature dependent, with lowest mortality in temperatures from 6°C to 10°C (Carter 2005). In the M2 Reach of the Methow River, steelhead emerge about 50 to 90 days after spawning. With the warmer temperatures forecast by Caldwell, steelhead would be expected to emerge several days earlier. The warmer water may increase the amount within the ideal temperature range for early spawning fish but decrease if for late spawning fish (Figure 11).

Sustained water temperatures above 18°C may push the fish assemblage towards dominance by non-salmonids (Sauter et al. 2001). While there is a significant amount of uncertainty, the climate change predictions by Caldwell suggest the project reach will not warm enough to favor warm water fishes.

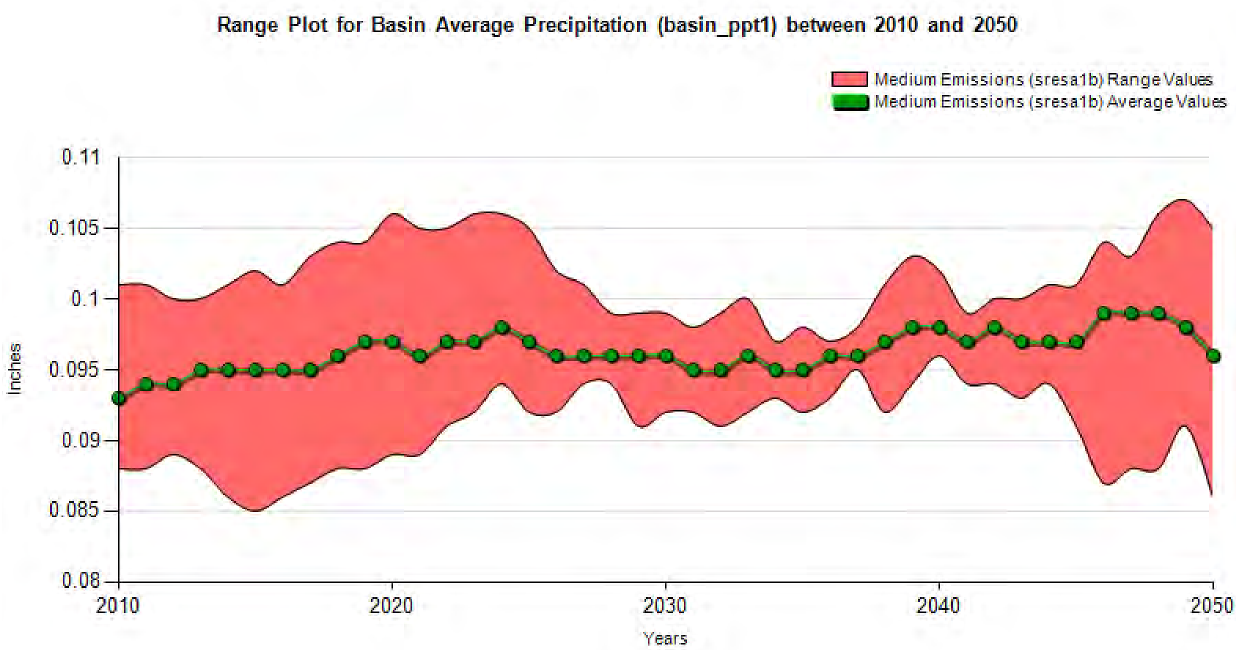


**Figure 1. Predicted change in average precipitation for the Methow Basin (from Voss and Mastin 2012).**

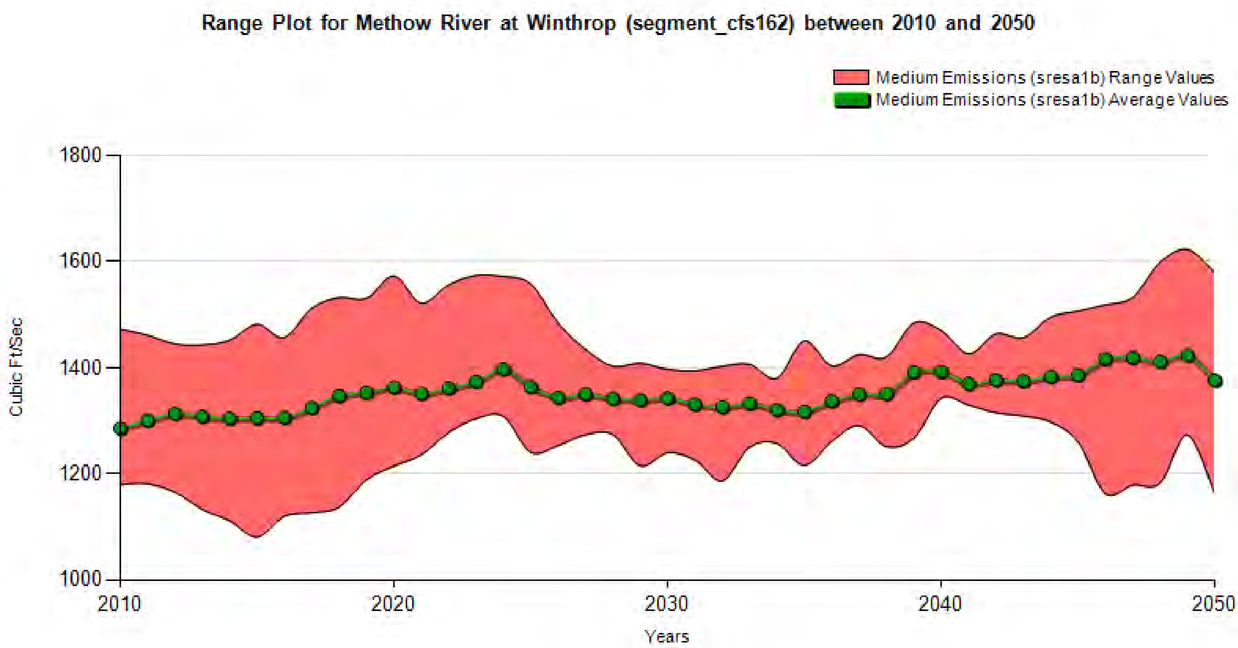


**Figure 2. Predicted change in mean annual streamflow for the Methow River at Winthrop (from Voss and Mastin 2012).**

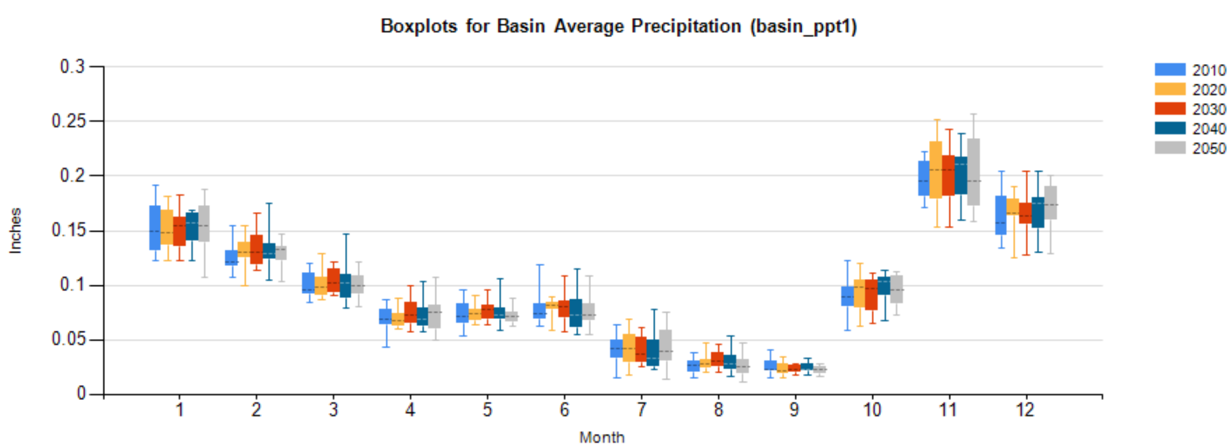


**Figure 3. Predicted change in the timing of precipitation for the Methow Basin (from Voss and Mastin 2012).**

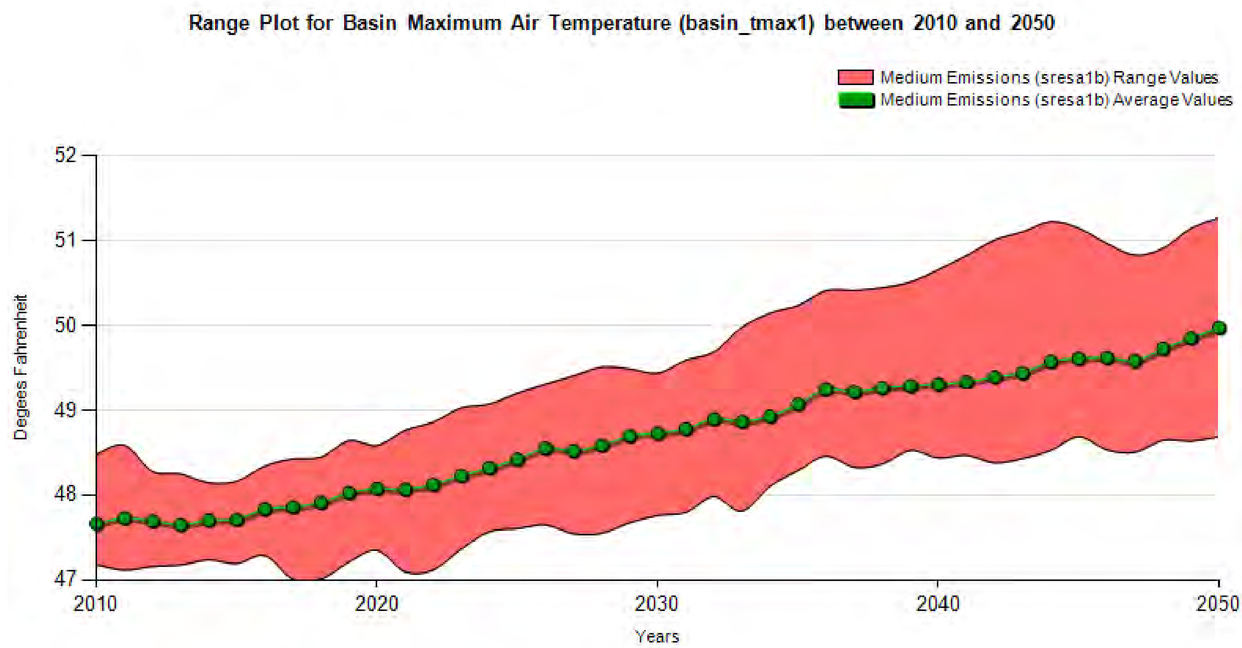


**Figure 4. Predicted change in maximum air temperature for the Methow Basin (from Voss and Mastin 2012).**

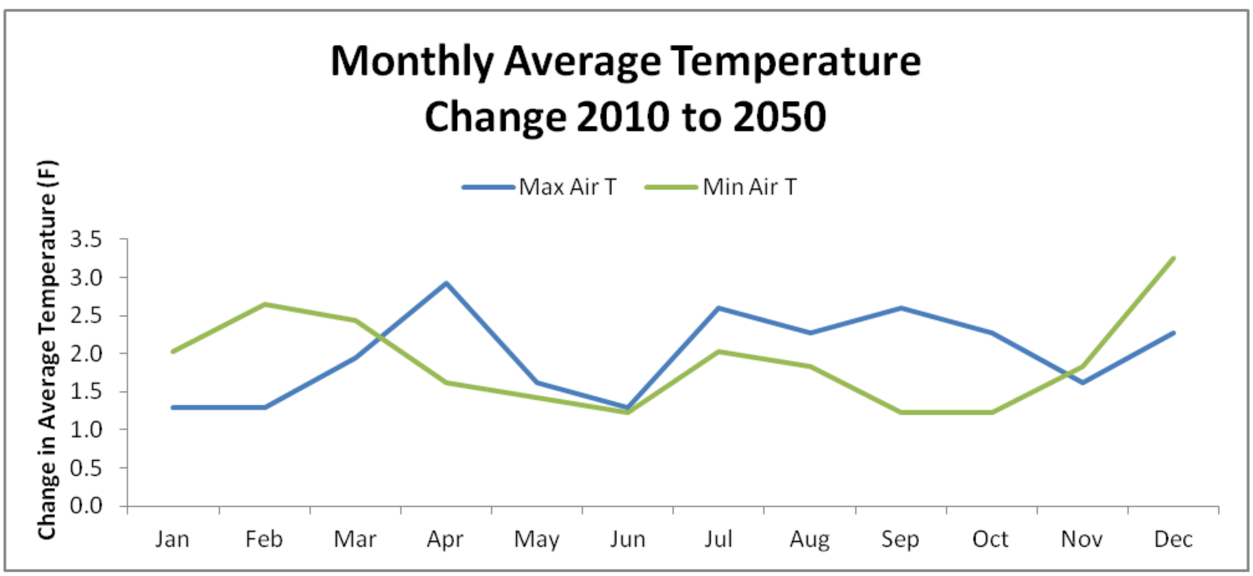


**Figure 5. Predicted change in daily minimum and maximum temperatures for the Methow Basin (from Voss and Mastin 2012).**

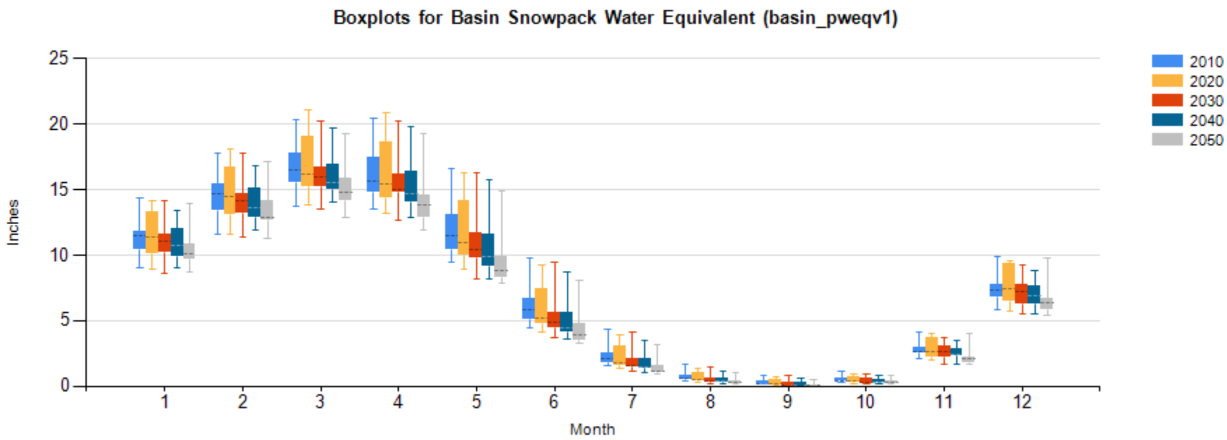


**Figure 6. Predicted change in winter snowpack for the Methow Basin (from Voss and Mastin 2012).**

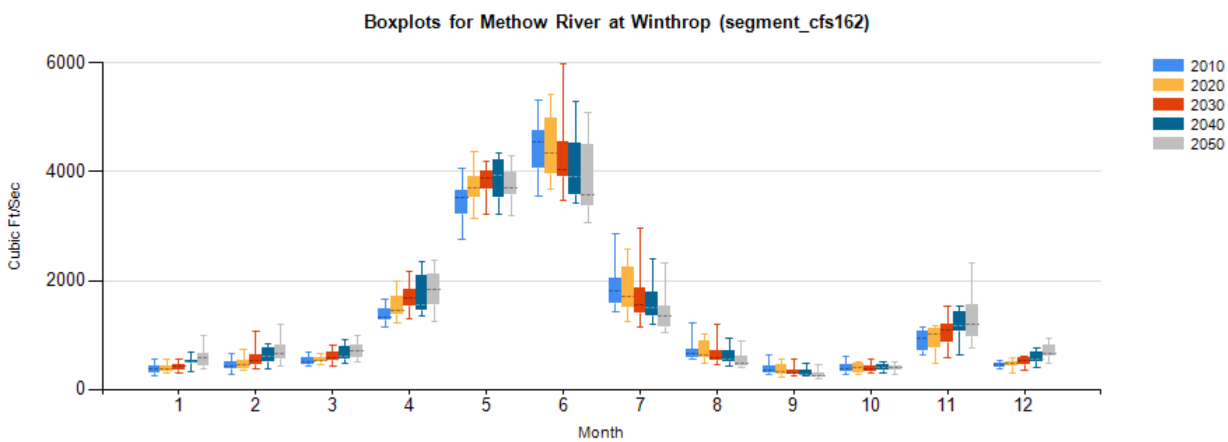


**Figure 7. Predicted change in streamflow timing for the Methow Basin (from Voss and Mastin 2012).**

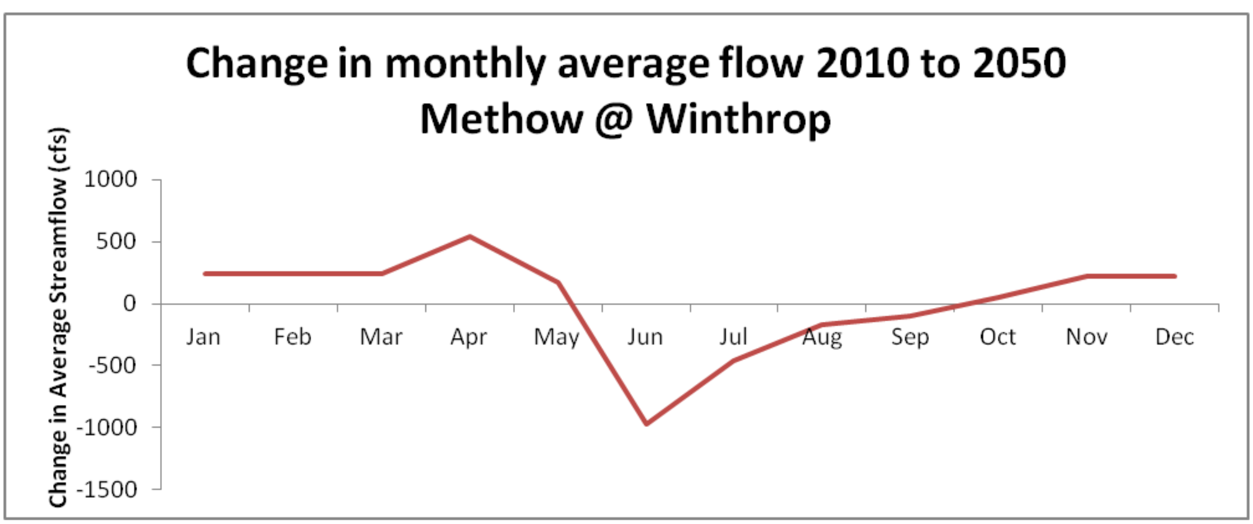

Figure 8. Modeled change in Methow River streamflow between 2010 and 2050 (from Voss and Mastin 2012).

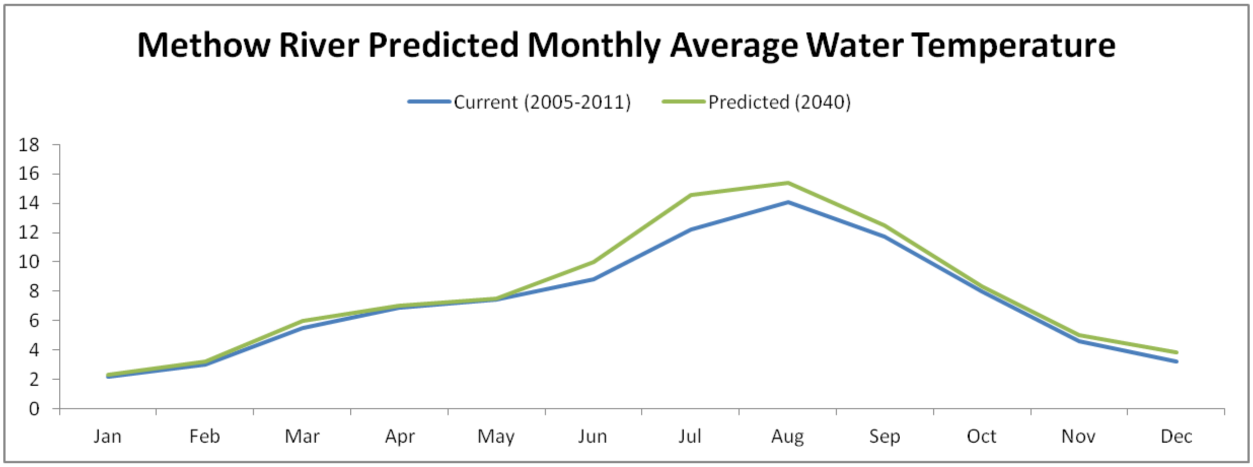


Figure 9. Comparison of observed (2005 to 2011) water temperatures with predicted for 2040 data (from Caldwell et al. 2013).

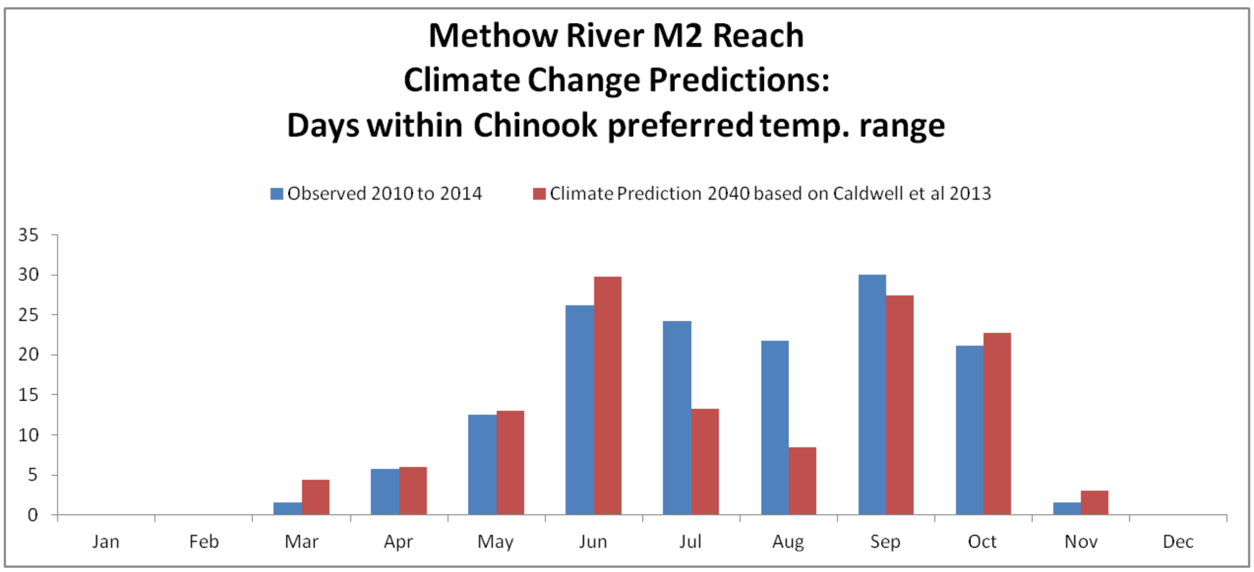


Figure 10. Number of days the average water temperature is within the preferred range for Chinook salmon of 7.2°C to 14.5°C (Carter 2005) based on climate change induced changes to water temperature from Caldwell et al. (2013).

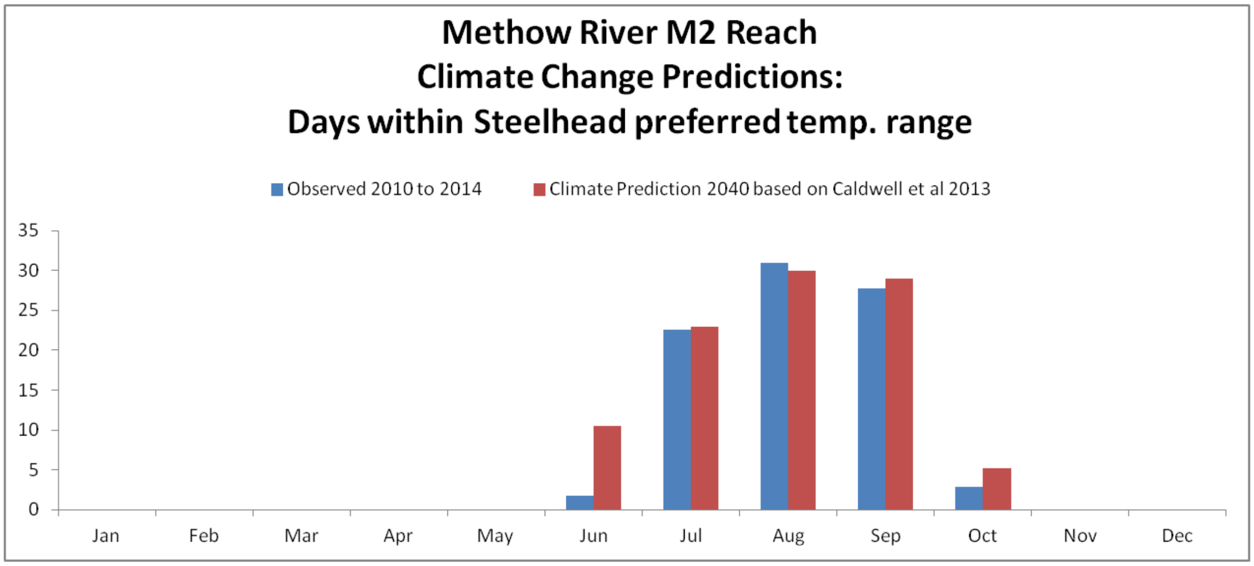


**Figure 11. Number of days the average water temperature is within the preferred range for rearing steelhead of 10°C to 17°C (Sauter et al. 2001) based on climate change induced changes predicted by Caldwell et al. (2013).**

The project has been designed to accommodate higher winter flows and potentially flashier peak flows as well as lower summer flows. In addition, by providing improved natural processes of channel migration and floodplain connectivity there is an increased likelihood of groundwater recharge and hyporheic flows that can help to moderate water temperatures. In addition, riparian restoration will contribute to shading and cover to help maintain cooler water temperatures.

2. State and Federal Permits: All applicable regulatory permits and authorizations will be obtained prior to project implementation. These permits and authorizations include, but are not limited to, the National Environmental Policy Act (NEPA), National Historic Preservation Act (NHPA), state and federal Section 404 of the Clean Water Act (CWA) permits, and Section 401 water quality certifications.

3. Timing of In-Water Work: The designated in-water work window is July 1 to 31 (WDFW 2018). All work within the Methow River will occur during this time period, or within any Variances granted by the Washington Department of Fish and Wildlife (WDFW), National Marine Fisheries Service (NMFS), and U.S. Fish and Wildlife Service (USFWS). The majority of the floodplain and side channel work will be isolated from the river and is not required to occur during the in-water work window. However, the reconnection of any isolated areas to the river will need to occur within this designated window or granted variance.

   Formal recommendations published by state agencies such as the Oregon Department of Fish and Wildlife (ODFW), WDFW, Idaho Department of Fish and Game (IDFG), and Montana Fish Wildlife and Parks (MFWP), or informal recommendations from the appropriate state Fishery Biologist in regard to the timing of in-water work, will be followed.

   a. Bull trout: Utilizing state-recommended in-water work windows will decrease potential effects to bull trout, but this alone may not be sufficient to protect local bull trout populations. This is especially true if work will occur in spawning and rearing areas because eggs, alevin, and fry are present nearly year-round. Some project locations may not have designated in-water work windows for bull trout, or if they do, they may differ from the in-water work windows for salmon and steelhead. If this is the case, or if the proposed work is to occur within bull trout spawning and rearing habitats, the project sponsor will contact the appropriate USFWS field office to ensure that all reasonable implementation measures are considered and an appropriate in-water work window is being used to minimize project effects.

b. Lamprey: The project sponsor and/or their contractors will avoid working in stream or river channels that contain Pacific lamprey from March 1 to July 1 in low- to mid-elevation reaches (<5,000 feet). In high-elevation reaches (>5,000 feet), the project sponsor will avoid working in stream or river channels from March 1 to August 1. If either timeframe is incompatible with other objectives, the area will be surveyed for nests and lamprey presence and avoided if possible. If lampreys are known to exist, the project sponsor will utilize dewatering and salvage best management practices (BMPs) outlined in USFWS 2010.

c. Exceptions to ODFW, WDFW, MFWP, or IDFG in-water work windows will be requested through the Variance Process. Work area isolation and fish salvage activities are considered incidental to construction-related activities and shall occur during state-recommended in-water work windows.

4. Contaminants: The project sponsor will complete a site assessment with the following elements to identify the type, quantity, and extent of any potential contamination for any action that involves excavation of more than 20 cubic yards of material:
    a. A site visit to inspect the areas used for various industrial processes and the condition of the property;
    b. Interviews with knowledgeable people, such as site owners, operators, and occupants, neighbors, or local government officials; and
    c. A summary, stored with the project file, that includes an assessment of the likelihood that contaminants are present at the site, based on items 4(a) through 4(c).

5. Site Layout and Flagging: Prior to construction, the project area will be clearly flagged to identify the following: a) Sensitive resource areas, such as areas below ordinary high water (OHW), spawning areas, springs, and wetlands:
    a. Equipment entry and exit points;
    b. Road and stream crossing alignments;
    c. Staging, storage, and stockpile areas; and
    d. No-herbicide-application areas and buffers.

6. Temporary Access Roads and Paths:
    a. Existing access roads and paths will be preferentially used whenever possible, and the number and length of temporary access roads and paths through riparian areas and floodplains will be minimized to lessen soil disturbance, soil compaction, and impacts to vegetation.
    b. Temporary access roads and paths will not be built on slopes where grade, soil, or other features suggest a likelihood of excessive erosion or failure. If slopes are steeper than 30%, the road will be designed by a civil engineer with experience in steep road design.

c. The removal of riparian vegetation during construction of temporary access roads will be minimized. When temporary vegetation removal is required, vegetation will be cut at ground level (not grubbed).
d. At project completion, all temporary access roads and paths will be obliterated, and the soil will be stabilized and revegetated. Road and path obliteration refers to the most comprehensive degree of decommissioning and involves decompacting the road surface and associated ditches, pulling the fill material onto the running surface, and reshaping to match the original contour.
e. Temporary roads and paths in wet areas or areas prone to flooding will be obliterated by the end of the in-water work window.

7. Temporary Stream Crossings:
    a. Existing stream crossings will be preferentially used whenever reasonable, and the number of temporary stream crossings will be minimized.
    b. Temporary bridges and culverts will be installed to allow for equipment and vehicle crossing over perennial streams during construction. Treated wood shall not be used on temporary bridge crossings or in locations in contact with or over water.
    c. Equipment and vehicles will cross streams in the wet only where:
        i. The streambed is bedrock; or
        ii. Mats or off-site logs are placed in the stream and used as a crossing.
    d. Vehicles and machinery will cross streams at right angles to the main channel wherever possible.
    e. The location of the temporary crossing will avoid areas that may increase the risk of channel re-routing or avulsion.
    f. Impacts to potential spawning habitat (i.e., pool tailouts) and pools will be avoided to the maximum extent possible.
    g. No stream crossings will occur at active spawning sites, when holding adult listed fish are present, or when eggs or alevins are in the gravel. The appropriate state fish and wildlife agency will be contacted for specific timing information.
    h. After project completion, temporary stream crossings will be obliterated, and the stream channel and banks restored.

8. Staging, Storage, and Stockpile Areas:
    a. Staging areas (used for construction equipment storage, vehicle storage, fueling, servicing, and hazardous material storage) will be 150 feet or more from any natural waterbody or wetland, or on an adjacent established road area in a location and manner that will preclude erosion into or contamination of the stream or floodplain.
    b. Natural materials used for implementation of aquatic restoration, such as large wood, gravel, and boulders, may be staged within the 100-year floodplain.
    c. Any large wood, topsoil, and native channel material displaced by construction will be stockpiled for use during site restoration at a specifically identified and flagged area.
    d. Any material not used in restoration, and not native to the floodplain, will be removed to a location outside of the 100-year floodplain for disposal.

9. Equipment: Mechanized equipment and vehicles will be selected, operated, and maintained in a manner that minimizes adverse effects on the environment (e.g., minimally sized, low pressure tires; minimal hard-turn paths for tracked vehicles; temporary mats or plates within wet areas or on sensitive soils). All vehicles and other mechanized equipment will be:

a. Stored, fueled, and maintained in a vehicle staging area located 150 feet or more from any natural water body or wetland or on an adjacent, established road area;
b. Refueled in a vehicle staging area located 150 feet or more from a natural waterbody or wetland, or in an isolated hard zone, such as a paved parking lot or adjacent, established road (this measure applies only to gas-powered equipment with tanks larger than 5 gallons);
c. Using biodegradable lubricants and fluids on equipment operating in and adjacent to the stream channel and live water;
d. Inspected daily for fluid leaks before leaving the vehicle staging area for operation within 150 feet of any natural water body or wetland; and
e. Thoroughly cleaned before operation below OHW, and as often as necessary during operation, to remain grease free.

10. Erosion Control: Erosion control BMPs will be prepared and carried out, commensurate in scope with the action, that may include the following:
    a. Temporary erosion control BMPs:
        i. Temporary erosion control BMPs will be in place before any significant alteration of the action site and appropriately installed downslope of project activity within the riparian buffer area until site rehabilitation is complete.
        ii. If there is a potential for eroded sediment to enter the stream, sediment barriers will be installed and maintained for the duration of project implementation.
        iii. Temporary erosion control measures may include fiber wattles, silt fences, jute matting, wood fiber mulch and soil binder, or geotextiles and geosynthetic fabric.
        iv. Soil stabilization utilizing wood fiber mulch and tackifier (hydro-applied) may be used to reduce erosion of bare soil if the materials are noxious weed-free and nontoxic to aquatic and terrestrial animals, soil microorganisms, and vegetation.
        v. Sediment will be removed from erosion control BMP once it has reached 1/3 of the exposed height of the BMP.
        vi. Once the site is stabilized following construction, temporary erosion control BMPs will be removed.
    b. Emergency erosion control BMPs. The following materials for emergency erosion control will be available at the work site:
        i. A supply of sediment control materials; and
        ii. An oil-absorbing floating boom whenever surface water is present.

11. Dust Abatement: The project sponsor will determine the appropriate dust control measures by considering soil type, equipment usage, prevailing wind direction, and the effects caused by other erosion and sediment control measures. In addition, the following criteria will be followed:
    a. Work will be sequenced and scheduled to reduce exposed bare soil subject to wind erosion.
    b. Dust-abatement additives and stabilization chemicals (typically magnesium chloride, calcium chloride salts, or ligninsulfonate) will not be applied within 25 feet of a natural waterbody or wetland and will be applied so as to minimize the likelihood that they will enter streams. Applications of ligninsulfonate will be limited to a maximum rate of 0.5 gallons per square yard of road surface, assuming a 50:50 (ligninsulfonate to water) solution.

c. Application of dust abatement chemicals will be avoided during or just before wet weather and at stream crossings or other areas that could result in unfiltered delivery of the dust abatement chemicals to a waterbody (typically these would be areas within 25 feet of a natural waterbody or wetland; distances may be greater where vegetation is sparse or slopes are steep).
d. Spill containment equipment will be available during application of dust abatement chemicals.
e. Petroleum-based products will not be used for dust abatement.

12. Spill Prevention, Control, and Countermeasures: The use of mechanized machinery increases the risk for accidental spills of fuel, lubricants, hydraulic fluid, or other contaminants into the riparian zone or directly into the water. Additionally, uncured concrete and form materials adjacent to the active stream channel may result in accidental discharge into the water. These contaminants can degrade habitat and injure or kill benthic invertebrates and Endangered Species Act (ESA)-listed species. The project sponsor will adhere to the following measures:
    a. A description of hazardous materials that will be used, including inventory, storage, and handling procedures will be available on site.
    b. Written procedures for notifying environmental response agencies will be posted at the work site.
    c. Spill containment kits (including instructions for cleanup and disposal) adequate for the types and quantity of hazardous materials used at the site will be available at the work site.
    d. Workers will be trained in spill containment procedures and will be informed of the location of spill containment kits.
    e. Any waste liquids generated at the staging areas will be temporarily stored under an impervious cover, such as a tarpaulin, until they can be properly transported to and disposed of at a facility that is approved for receipt of hazardous materials.

13. Invasive Species Control: The following measures will be followed to avoid introduction of invasive plants and noxious weeds into project areas:
    a. Prior to entering the site, all vehicles and equipment will be power-washed, allowed to fully dry, and inspected to make sure no plants, soil, or other organic material adheres to the surface.
    b. Watercraft, waders, boots, and any other gear to be used in or near water will be inspected for aquatic invasive species. Wading boots with felt soles are not to be used due to their propensity for aiding in the transfer of invasive species.

## 1.2 WORK AREA ISOLATION AND FISH SALVAGE

Any work area within the wetted channel will be isolated from the active stream whenever ESA-listed fish are reasonably certain to be present, or if the work area is less than 300 feet upstream from known spawning habitats. Work area isolation and fish salvage activities are considered incidental to construction-related activities and shall occur during the state-recommended in-water work windows.

When work area isolation is required, design plans will include all isolation elements, fish release areas, and, when a pump is used to dewater the isolation area and fish are present, a fish screen that meets NMFS's fish screen criteria (NMFS 2011, or most current). Work area isolation and fish capture activities will occur during periods of the coolest air and water temperatures possible, normally early in the morning versus late in the day, and during conditions appropriate to minimize stress and death of species present.

For salvage operations in known bull trout spawning and rearing habitat, electrofishing shall only occur from May 1 to July 31. No electrofishing will occur in any bull trout occupied habitat after August 15. Bull trout are very temperature sensitive and generally should not be electrofished or otherwise handled when temperatures exceed 15°C. Salvage activities should take place during periods of the coolest air and water temperatures possible, normally early in the morning versus late in the day, and during conditions appropriate to minimize stress to fish species present.

Salvage operations will follow the ordering, methodologies, and conservation measures specified below in Steps 1 through 6. Steps 1 and 2 will be implemented for all projects where work area isolation is necessary according to conditions above. Electrofishing (Step 3) can be implemented to ensure all fish have been removed following Steps 1 and 2, or when other means of fish capture may not be feasible or effective. Dewatering and rewatering (Steps 4 and 5) will be implemented unless wetted instream work is deemed to be minimally harmful to fish, and is beneficial to other aquatic species. Dewatering will not be conducted in areas known to be occupied by lamprey, unless lampreys are salvaged using guidance set forth in USFWS 2010.

1. Isolate:
    a. Block nets will be installed at upstream and downstream locations and maintained in a secured position to exclude fish from entering the project area.
    b. Block nets will be secured to the stream channel bed and banks until fish capture and transport activities are complete. Block nets may be left in place for the duration of the project to exclude fish.
    c. If block nets remain in place more than one day, the nets will be monitored at least daily to ensure they are secured to the banks and free of organic accumulation. If the project is within bull trout spawning and rearing habitat, the block nets must be checked every 4 hours for fish impingement on the net. Less frequent intervals must be approved through a variance request.
    d. Nets will be monitored hourly anytime there is instream disturbance.

2. Salvage: As described below, fish trapped within the isolated work area will be captured to minimize the risk of injury, then released at a safe site:
    a. Remove as many fish as possible prior to dewatering.
    b. During dewatering, any remaining fish will be collected by hand or dip nets.
    c. Seines with a mesh size to ensure capture of the residing ESA-listed fish will be used.
    d. Minnow traps will be left in place overnight and used in conjunction with seining.
    e. If buckets are used to transport fish:
        i. The time fish are in a transport bucket will be limited and will be released as quickly as possible.
        ii. The number of fish within a bucket will be limited based on size, and fish will be of relatively comparable size to minimize predation.
        iii. Aerators for buckets will be used or the bucket water will be frequently changed with cold clear water at 15-minute or more frequent intervals.

    iv. Buckets will be kept in shaded areas or will be covered by a canopy in exposed areas.
    v. Dead fish will not be stored in transport buckets but will be left on the streambank to avoid mortality counting errors.

f. As rapidly as possible (especially for temperature-sensitive bull trout), fish will be released in an area that provides adequate cover and flow refuge. Upstream release is generally preferred, but fish released downstream will be sufficiently outside of the influence of construction.

g. Salvage will be supervised by a qualified fisheries biologist experienced with work area isolation and competent to ensure the safe handling of all fish.

3. Electrofishing: Electrofishing will be used only after other salvage methods have been employed or when other means of fish capture are determined to not be feasible or effective. If electrofishing will be used to capture fish for salvage, the salvage operation will be led by an experienced fisheries biologist and the following guidelines will be followed:

**The NMFS's electrofishing guidelines (NMFS 2000).**

a. Initial Site Surveys and Equipment Settings:
    i. In order to avoid contact with spawning adults or active redds, researchers must conduct a careful visual survey of the area to be sampled before beginning electrofishing.
    ii. Prior to the start of sampling at a new location, water temperature and conductivity measurements shall be taken to evaluate electrofisher settings and adjustments.

    **No electrofishing should occur when water temperatures are above 18°C or are expected to rise above this temperature prior to concluding the electrofishing survey. In addition, studies by NMFS scientists indicate that no electrofishing should occur in California coastal basins when conductivity is above 350 µS/cm.**

    iii. Whenever possible, a block net should be placed below the area being sampled to capture stunned fish that may drift downstream.
    iv. Equipment must be in good working condition and operators should go through the manufacturer's preseason checks, adhere to all provisions, and record major maintenance work in a logbook.
    v. Each electrofishing session must start with all settings (voltage, pulse width, and pulse rate) set to the **minimums** needed to capture fish. These settings should be gradually increased only to the point where fish are immobilized and captured, and generally not allowed to exceed conductivity-based maxima (Table 1). Only direct current (DC) or pulsed direct current (PDC) should be used.

**Table 1. Guidelines for initial and maximum settings for backpack electrofishing.**

| | Initial settings | Maximum settings | Notes |
|---|---|---|---|
| Voltage | 100 V | Conductivity (µS/cm) — Max. Voltage<br>< 100 — 1100 V<br>100 - 300 — 800 V<br>> 300 — 400 V | In California coastal basins, settings should never exceed 400 volts. Also, no electrofishing should occur in these basins if conductivity is greater than 350 µS/cm. |
| Pulse width | 500 µs | 5 ms | |
| Pulse rate | 30 Hz | 70 Hz | *In general*, exceeding 40 Hz will injure more fish |

b. Electrofishing Technique:
   i. Sampling should begin using straight DC. The power needs to remain on until the fish is netted when using straight DC. If fish capture is unsuccessful with initial low voltage, gradually increase voltage settings with straight DC.
   ii. If fish capture is not successful with the use of straight DC, then set the electrofisher to lower voltages with PDC. If fish capture is unsuccessful with low voltages, increase pulse width, voltage, and pulse frequency (duration, amplitude, and frequency).
   iii. Electrofishing should be performed in a manner that minimizes harm to the fish. Stream segments should be sampled systematically, moving the anode continuously in a herringbone pattern (where feasible) through the water. Care should be taken when fishing in areas with high fish concentrations, structure (e.g., wood, undercut banks) and in shallow waters where most backpack electrofishing for juvenile salmonids occurs. Voltage gradients may be high when electrodes are in shallow water where boundary layers (water surface and substrate) tend to intensify the electrical field.
   iv. Do not electrofish in one location for an extended period (e.g., undercut banks) and regularly check block nets for immobilized fish.
   v. Fish should not make contact with the anode. The zone of potential injury for fish is 0.5 m from the anode.
   vi. Electrofishing crews should be generally observant of the condition of the fish and change or terminate sampling when experiencing problems with fish recovery time, banding, injury, mortality, or other indications of fish stress.
   vii. Netters should not allow the fish to remain in the electrical field any longer than necessary by removing stunned fish from the water immediately after netting.

c. Sample Processing and Recordkeeping:
   i. Fish should be processed as soon as possible after capture to minimize stress. This may require a larger crew size.
   ii. All sampling procedures must have a protocol for protecting held fish. Samplers must be aware of the conditions in the containers holding fish; air pumps, water transfers, etc., should be used as necessary to maintain safe conditions. Also, large fish should be kept separate from smaller prey-sized fish to avoid predation during containment.
   iii. Use of an approved anesthetic can reduce fish stress and is recommended, particularly if additional handling of fish is required (e.g., length and weight measurements, scale samples, fin clips, tagging).

iv. Fish should be handled properly (e.g., wetting measuring boards, not overcrowding fish in buckets, etc.).

v. Fish should be observed for general condition and injuries (e.g., increased recovery time, dark bands, visually observable spinal injuries). Each fish should be completely revived before releasing at the location of capture. A plan for achieving efficient return to appropriate habitat should be developed before each sampling session. Also, every attempt should be made to process and release ESA-listed specimens first.

vi. Pertinent water quality (e.g., conductivity and temperature) and sampling notes (e.g., shocker settings, fish condition/injuries/mortalities) should be recorded in a logbook to improve technique and help train new operators. *It is important to note that records of injuries or mortalities pertain to the entire electrofishing survey, including the fish sample work-up.*

vii. The anode will not intentionally contact fish.

viii. Electrofishing shall not be conducted when the water conditions are turbid and visibility is poor. This condition may be experienced when the sampler cannot see the stream bottom in one foot of water.

ix. If mortality or obvious injury (defined as dark bands on the body, spinal deformations, de-scaling of 25% or more of body, and torpidity or inability to maintain upright attitude after sufficient recovery time) occurs during electrofishing, operations will be immediately discontinued, machine settings, water temperature, and conductivity checked, and procedures adjusted or electrofishing postponed in order to reduce mortality.

4. Dewater: Dewatering, when necessary, will be conducted over a sufficient period of time to allow species to naturally migrate out of the work area and will be limited to the shortest linear extent practicable:
    a. Diversion around the construction site may be accomplished with a cofferdam and a by-pass culvert or pipe, or a lined, non-erodible diversion ditch. Where gravity feed is not possible, a pump may be used, but must be operated in such a way as to avoid repetitive dewatering and rewatering of the site. Impoundment behind the cofferdam must occur slowly through the transition, while constant flow is delivered to the downstream reaches.
    b. All pumps will have fish screens to avoid juvenile fish impingement or entrainment, and will be operated in accordance with NMFS's current fish screen criteria (NMFS 2011 or most recent version). If the pumping rate exceeds 3 cubic feet per second (cfs), a NMFS Hydro fish passage review will be necessary.
    c. Dissipation of flow energy at the bypass outflow will be provided to prevent damage to riparian vegetation and/or stream channel.
    d. Safe re-entry of fish into the stream channel will be provided, preferably into pool habitat with cover, if the diversion allows for downstream fish passage.
    e. Seepage water will be pumped to a temporary storage and treatment site or into upland areas to allow water to percolate through soil or to filter through vegetation prior to reentering the stream channel.

5. Salvage Notice: Monitoring and recording of fish presence, handling, and mortality must occur for the duration of the isolation, salvage, electrofishing, dewatering, and rewatering operations. Once operations are completed, a salvage report will document procedures used, any fish injuries or deaths (including numbers of fish affected), and causes of any deaths.

## 1.3 CONSTRUCTION AND POST-CONSTRUCTION CONSERVATION MEASURES

1. Fish Passage: Fish passage will be provided for any adult or juvenile fish likely to be present in the project area during construction, unless passage did not exist before construction, or the stream is naturally impassable at the time of construction. If the provision of temporary fish passage during construction will increase negative effects on ESA-listed species or their habitat, a variance can be requested from the NMFS Branch Chief and the USFWS Field Office Supervisor. Pertinent information, such as the species affected, length of stream reach affected, proposed time for the passage barrier, and alternatives considered will be included in the variance request.

2. Construction and Discharge Water:
    - Surface water may be diverted to meet construction needs, but only if developed sources are unavailable or inadequate.
    - Diversions will not exceed 10% of the available flow.
    - All construction discharge water will be collected and treated using the best available technology suitable for site conditions.
    - Treatments to remove debris, nutrients, sediment, petroleum hydrocarbons, metals, and other pollutants likely to be present will be provided.

3. Minimize Time and Extent of Disturbance: Earthwork (including drilling, excavation, dredging, filling, and compacting) in which mechanized equipment is utilized in stream channels, riparian areas, and wetlands will be completed as quickly as possible. Mechanized equipment will be used in streams only when project specialists believe that such actions are the only reasonable alternative for implementation, or would result in less sediment in the stream channel or damage (short- or long-term) to the overall aquatic and riparian ecosystem relative to other alternatives. To the extent feasible, mechanized equipment will work from the top of the bank, unless work from another location would result in less habitat disturbance.

4. Cessation of Work: Project operations will cease under the following conditions: High flow conditions that may result in inundation of the project area, except for efforts to avoid or minimize resource damage; When allowable water quality impacts, as defined by the state CWA section 401 water quality certification or Habitat Improvement Program (HIP) III Turbidity Monitoring Protocol, have been exceeded; or When "incidental take" limitations have been reached or exceeded.

5. Site Restoration: When construction is complete:
    - All streambanks, soils, and vegetation will be cleaned up and restored as necessary using stockpiled large wood, topsoil, and native channel material.
    - All project-related waste will be removed.
    - All temporary access roads, crossings, and staging areas will be obliterated. When necessary for revegetation and infiltration of water, compacted areas of soil will be loosened.
    - All disturbed areas will be rehabilitated in a manner that results in similar or improved conditions relative to pre-project conditions. This will be achieved through redistribution of stockpiled materials, seeding, and/or planting with local native seed mixes or plants.

6. Revegetation: Long-term soil stabilization of disturbed sites will be accomplished with reestablishment of native vegetation using the following criteria:
    - Planting and seeding will occur prior to or at the beginning of the first growing season after construction.

- An appropriate mix of species that will achieve establishment, shade, and erosion control objectives, preferably forb, grass, shrub, or tree species native to the project area or region and appropriate to the site will be used.
- Vegetation, such as willow, sedge, and rush mats, will be salvaged from disturbed or abandoned floodplains, stream channels, or wetlands.
- Invasive species will not be used.
- Short-term stabilization measures may include the use of non-native sterile seed mix (when native seeds are not available), weed-free certified straw, jute matting, and other similar techniques.
- Surface fertilizer will not be applied within 50 feet of any stream channel, waterbody, or wetland.
- Fencing will be installed as necessary to prevent access to revegetated sites by livestock or unauthorized persons.
- Re-establishment of vegetation in disturbed areas will achieve at least 70% of pre-project conditions within 3 years.
- Invasive plants will be removed or controlled until native plant species are well-established (typically 3 years post-construction).
- Site Access: The project sponsor will retain the right of reasonable access to the site in order to monitor the success of the project over its life.

7. Implementation Monitoring: Project sponsor staff or their designated representative will provide implementation monitoring by filling out the Project Completion Form (PCF) to ensure compliance with the applicable BiOp, including:
    - General conservation measures are adequately followed.
    - Effects to listed species are not greater than predicted and incidental take limitations are not exceeded.
    - Turbidity monitoring shall be conducted in accordance with the HIP III turbidity monitoring protocol (Page 38) and recorded in the PCF (Page 22).

8. Section 401 Water Quality Certification: The project sponsor or designated representative will complete and record water quality observations to ensure that in-water work is not degrading water quality. During construction, CWA section 401 water quality certification provisions provided by the Oregon Department of Environmental Quality, Washington Department of Ecology, or Idaho Department of Environmental Quality will be followed.

9. Staged Rewatering Plan: When appropriate, the project sponsor shall implement a staged rewatering plan for projects that involve introducing streamflow into recently excavated channels
    - Pre-wash the newly-excavated channel before rewatering. Turbid wash water will be detained and pumped to the floodplain, rather than discharging to fish-bearing waters.
    - Prepare new channel for water by installing seine at upstream end to prevent fish from moving downstream into new channel until 2/3 of total streamflow is available in that channel. Starting in the early morning, introduce 1/3 of the flow into the new channel over a period of 1-2 hours.
    - Perform monitoring according to HIP III Turbidity Monitoring Protocol (HIP III).
        - If turbidity exceeds 10% of background, modify the activity to reduce turbidity. In this case, this may mean decreasing the amount of flow entering the new channel and/or correcting any other issues causing turbidity (e.g., correct a bank that is sloughing, install or correct a BMP, etc.).
        - Monitor every 2 hours as long as the instream activity is occurring.

  - If exceedances occur for more than two monitoring intervals in a row (4 hours), then the activity must stop until turbidity reaches background levels. This means that the contractor may have to plug off water supply to the new meander until turbidity is within acceptable levels.
  - Once turbidity is within 10% of background levels, move on to the next re-watering stage.
- Prepare to introduce the second 1/3 of the flow (up to a total of 2/3) to the new channel by installing seine at upstream end of old channel in order to prevent fish from moving into a partially-dewatered channel. Introduce the second 1/3 of the flow over the next 1 to 2 hours. Salvage fish from the old channel at this time, so that the old channel is fish-free before dropping below 1/3 of the flow. *Note: the fish will be temporarily blocked from moving downstream into either channel until 2/3 of the flow has been transitioned to the new channel. This blockage to downstream fish passage is expected to persist for roughly 12 to 14 hours, but fish will still be able to volitionally move out of the channel in the downstream direction.* Perform monitoring as in #3 above.
- After the second 1/3 of flow is introduced over 2 hours, and turbidity is within 10% of the background level, remove seine nets from the new channel, and allow fish to move downstream back into the channel.
- Introduce the final 1/3 of flow. Once 100% of the flow is in the new channel, install plug to block flow into the old channel and remove seines from the old channel.

## 1.4 TERRESTRIAL PLANTS, WILDLIFE, AND AQUATIC INVERTEBRATES

1. Project Access: Existing roads or travel paths will be used to access project sites whenever possible; vehicular access ways to project sites will be planned ahead of time and will provide for minimizing impacts on riparian corridors and areas where listed species or their critical habitats may occur.
2. Vehicle Use and Human Activities: Vehicle use and human activities, including walking in areas occupied by ESA-listed species, will be minimized to reduce damage or mortality to listed species.
3. Flight Patterns: Helicopter flight patterns will be established in advance and located to avoid seasonally important wildlife habitat.
4. Herbicide Use: On sites where ESA-listed **terrestrial wildlife** may occur, herbicide applications will be avoided or minimized to the extent practicable while still achieving project goals. Staff will avoid any potential for direct spraying of wildlife, or immediate habitat in use by wildlife for breeding, feeding, or sheltering. Herbicide use in or within 1 mile of habitat where ESA-listed terrestrial wildlife occur will be limited to the chemicals and application rates as shown in Table 2.

**Table 2. Maximum Application Rates within 1 Mile of Habitat where ESA-listed Terrestrial Species Occur.**

| | 2,4-D | Aminopyralid | Chlorsulfuron | Clethodim | Clopyralid | Dicamba | Glyphosate 1 | Glyphosate 2 | Imazapic | Imazapyr | Metsulfuron | Picloram | Sethoxydim | Sulfometuron | Triclopyr (TEA) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Listed Species** | **Maximum Rate of Herbicide Application (lb/ac)** | | | | | | | | | | | | | | |
| Mammals | NA | 0.22 | 0.083 | NA | 0.375 | NA | 2.0 | 2.0 | 0.189 | 1.0 | 0.125 | NA | 0.3 | NA | NA |
| Birds* | NA | 0.11 | 0.083 | NA | 0.375 | NA | 2.0 | 2.0 | 0.189 | 1.0 | 0.125 | NA | 0.3 | NA | NA |
| Invertebrates* | NA | NA | NA | NA | 0.375 | NA | 2.0 | 2.0 | NA | 1.0 | NA | NA | 0.3 | NA | NA |

NA = Not Authorized for use
* See required buffers and methods restrictions within each species-specific PDS

## 2.0 DESCRIPTION OF BEST MANAGEMENT PRACTICES THAT WILL BE IMPLEMENTED AND IMPLEMENTATION RESOURCE PLANS

The Contractor is required by the Contract Documents to provide the following BMP plans prior to beginning construction.

### 2.1 SITE ACCESS STAGING AND SEQUENCING PLAN

The Site Access and Staging Plan is provided on the Drawings. The contractor is required by the Project Specifications and Contract Documents to provide a construction sequencing plan and project schedule. This plan will be reviewed and approved by the Owner prior to the commencement of construction.

### 2.2 WORK AREA ISOLATION AND DEWATERING PLAN

The contractor is required by the Project Specifications to provide a Care of Water plan, which will include provisions for work area isolation and dewatering. This plan will be reviewed and approved by the Owner prior to the commencement of construction.

### 2.3 EROSION AND POLLUTION CONTROL PLAN

The contractor is required by the Project Specifications to provide an Erosion and Pollution Control plan or Stormwater Pollution Prevention plan, which will include provisions for erosion and pollution control. This plan will be reviewed and approved by the Owner prior to the commencement of construction.

### 2.4 SITE RECLAMATION AND RESTORATION PLAN

Site reclamation and restoration will be included in the revegetation and planting plan. The Planting Plan will be developed by the Owner and included in the Contract Documents as a separate document.

### 2.5 LIST PROPOSED EQUIPMENT AND FUELS MANAGEMENT PLAN

The contractor is required by the Project Specifications to provide a list of equipment and fuel management plan. This plan will be reviewed and approved by the Owner prior to the commencement of construction.

## 3.0 CALENDAR SCHEDULE FOR CONSTRUCTION/IMPLEMENTATION PROCEDURES

The in-water work window for this area will be defined by the permit conditions. Refer to the contract documentation for more information on in water work window and timings.

## 4.0 REFERENCES


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