Methow River – Goat Creek Habitat Improvement Project
Basis of Design Report (30% Design)

For Cascade Fisheries
April 11, 2023

Prepared by Rio ASE | Joe@RioASE.com
RioASE.com | Boise, ID | Admin@RioASE.com

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BOD – Basis of Design

BPA – Bonneville Power Administration

CF – Cascade Fisheries

CFS – cubic feet per second

CWA – Clean Water Act

DTM – digital terrain model

ELJ – Engineered log jam

ESA – Endangered Species Act

FEMA – Federal Emergency Management Agency

GPDSR – General Project and Data Summary Requirements

HEC-RAS – Hydrologic Engineering Center’s River Analysis System

HIP – Habitat Improvement Program

IDFG – Idaho Fish and Game

LWD – Large woody debris

NHPA – National Historic Preservation Act

NMFS – National Marine Fisheries Service

NOAA – National Oceanic and Atmospheric Administration

SHPO – State Historic Preservation Office

RRT – Restoration Review Team

USACE – U.S. Army Corps of Engineers

WSEL – water surface elevation

1 INTRODUCTION

Rio Applied Science and Engineering (Rio ASE) has prepared this 30 Percent Basis of Design Report (report) for Cascade Fisheries. This report provides a summary of our findings pertaining to the existing conditions of the Goat Creek Reach on the Methow River near Mazama, Washington, and an explanation of the design process, analyses, and outcomes for the proposed enhancement design.

Rio ASE organized the following sections of this report to describe the General Project and Data Summary Requirements (GPDSR) required by the Bonneville Power Administration (BPA) for regulatory compliance coverage under the Habitat Improvement Program (HIP). This report is submitted to satisfy the 30 Percent design review for technical comment as part of the BPA Restoration Review Team (RRT) review process. BPA developed the requirements to effectively communicate that appropriate planning, analysis, design and resulting construction documentation are met. The conditions of the project reach are described in terms of processes that shaped the stream and associated ecosystem. This includes discussions on hydrology, hydraulics, habitat, and geomorphology. The evaluation and consideration of the site conditions provide the basis for the project design.

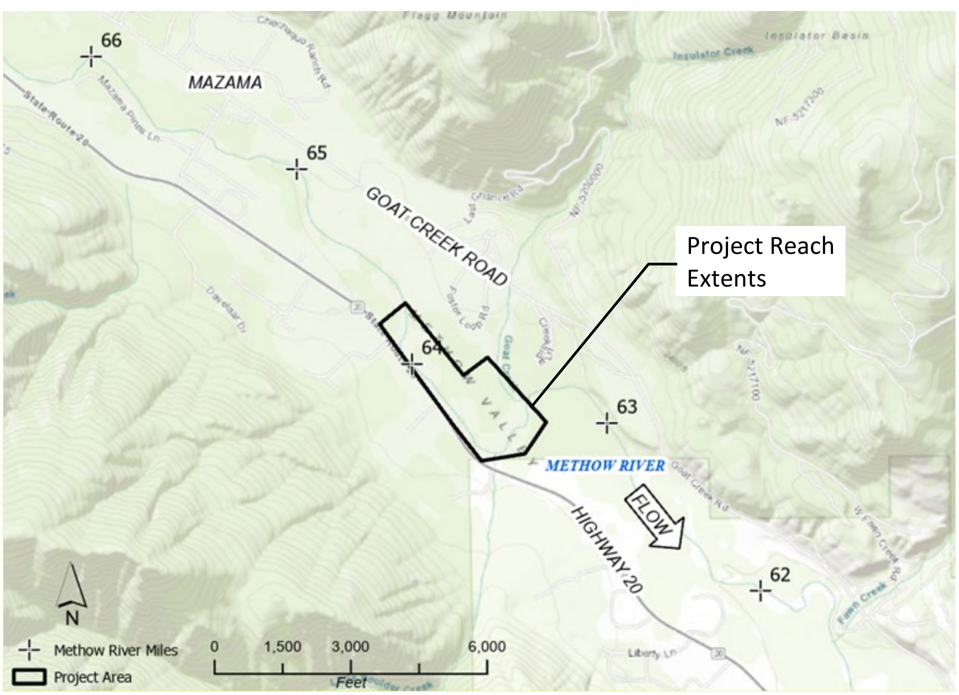
1.1 Project Responsible Parties

- The project sponsor is Cascade Fisheries, and the project manager is Kristen Kirkby, 509-449-2346.
- The design consultant is Rio ASE and the engineer of record is Joe Young, PE, 208-484-4700.

1.2 Site Location

The project reach (Figure 1-1) is located on private land at approximately river mile (RM) 64 on the Methow River and extends upstream 1,200 feet and downstream 2,500 feet from RM 64 for a total length of 3,700 feet (0.7 miles). Additional mapping is provided in the Design Drawings (Drawings) in Appendix A.

Figure 1-1. Vicinity map.



2 PROJECT BACKGROUND

Cascade Fisheries has been actively working to restore remnant side channels, hydraulic complexity, and floodplain interactions in the Methow River near the confluence with Goat Creek. This reach of the Methow River and floodplain has been negatively affected by the road network, residential development, levee construction, historical stream clearing, and rip-rap bank protection placement. In general, these activities have confined the Methow River, limited lateral channel migration, and reduced the connectivity with the floodplain surface and adjacent secondary channels. These conditions result in reduced juvenile salmonid habitat quantity and quality in the primary channel and secondary channels.

2.1 Environmental Setting

The Methow River Basin is located in Okanagan County in north central Washington on the east side of the Cascade Mountains within the Columbia Cascade Ecological Province. The project reach includes the mainstem Methow River, left bank, and left floodplain in and around the Goat Creek alluvial fan from approximately River Mile (RM) 65 to RM 66. The project reach comprises most of Reach 3 as identified in Figure 3-1 from the Upper Methow Reach Assessment (Inter-Fluve 2015). All land within the project reach impacted by proposed actions is privately owned.

2.2 Project Goals and Objectives

The primary goals of this project are to develop more normative river and floodplain functions to enhance habitat diversity, increasing the capacity of the project reach to support juvenile life stages of chinook salmon and steelhead, as well as benefiting other native aquatic species, such as bull trout.

Site-specific project objectives were developed to address the primary limiting factors:

- Increase frequency of channel units (increase the number and depth of pools).
- Improve and increase baseflow fish cover quantity and quality including interstitial spaces of comparable size to juvenile fish for concealment cover (increase the quantity and quality of habitat diversity).
- Increase availability of reduced water velocity (and increase diversity of available velocities) across a broad range of flows to decrease fish bioenergetic demands.
- Distribute stream flow and energy onto the floodplain, thereby reducing the available stream power concentrated into one primary channel (increase floodplain connectivity).
- Increase the number of large wood pieces, jams, and wood recruitment potential.
- Increase the density of native riparian plant communities for shade and bank stability.
- Do not increase flood hazard risk to property.
- Minimize risk to public safety to the extent possible.

3 EXISTING CONDITIONS

3.1 Hydrology

Contributing basin area at the downstream end of the project reach is 376 square miles and contains over 6,800 feet of elevation change from 2,040 feet up to 8,890 feet. The basin receives on average 48 inches of precipitation per year (U.S. Geological Survey [USGS], 2022). The basin drains in a southeasterly direction and largely receives runoff from the eastern front of the Cascade Mountains.

3.1.1 Annual Peak Flows

The U.S. Geological Survey (USGS) stream gage 12447383 (Methow River above Goat Creek near Mazama, WA) is located within the middle of the project reach with a period of record from 1990 through 2022. This gage site is the main data source used to estimate flow frequencies for the project reach. The historical gage data available from this stream gage was utilized in the Hydrologic Engineering Center's Statistical Software Package (HEC-SSP) program and was evaluated to estimate both annual peak flood flows as well as annual daily exceedance values (HEC, 2022). The peak flow records were then analyzed using the EMA Log Pearson Type III analysis, as discussed in USGS Bulletin 17C, to estimate discharges associated with select flood frequency recurrence intervals (USGS, 2021). The peak flood discharges for the project site are summarized below in Table 3-1. Two ungaged streams enter the Methow River within the project reach; Goat Creek and Boulder Creek. Peak flows for these streams were obtained from USGS StreamStats (USGS, 2019).

Table 3-1. Peak discharges in the project reach.

Exceedance Probability	Recurrence Interval	Methow River (cfs)	Goat Creek (cfs)	Little Boulder Creek (cfs)
0.99	1.01	2,198	289	64
0.66	1.5	4,590	366	72
0.5	2	5,361	416	77
0.2	5	7,025	605	97
0.1	10	8,007	737	111
0.02	50	9,905	1,031	138
0.01	100	10,625	1,161	150
0.005	200	10,625	1,278	159
0.002	500	12,151	1,462	173

3.1.2 Seasonal Flows

Monthly exceedance values were estimated for the months of April and November. These flows were selected to represent low flows occurring within the project reach during important juvenile rearing periods. The 50% monthly exceedance flow is the average daily discharge that is equal to or exceeded 50% of the time, during the month of interest. These flows were selected to evaluate fish habitat at low flows, representing low summer and winter flow conditions. To evaluate the monthly exceedance flows, the USGS gage 12447383 was evaluated for its respective period of record. The monthly exceedance flows are displayed in Table 3-2 below. Goat Creek and Little Boulder Creek flows were assumed to be negligible during these months.

Table 3-2. Monthly exceedance discharges (cfs) for the Methow River at USGS Gage 12447383

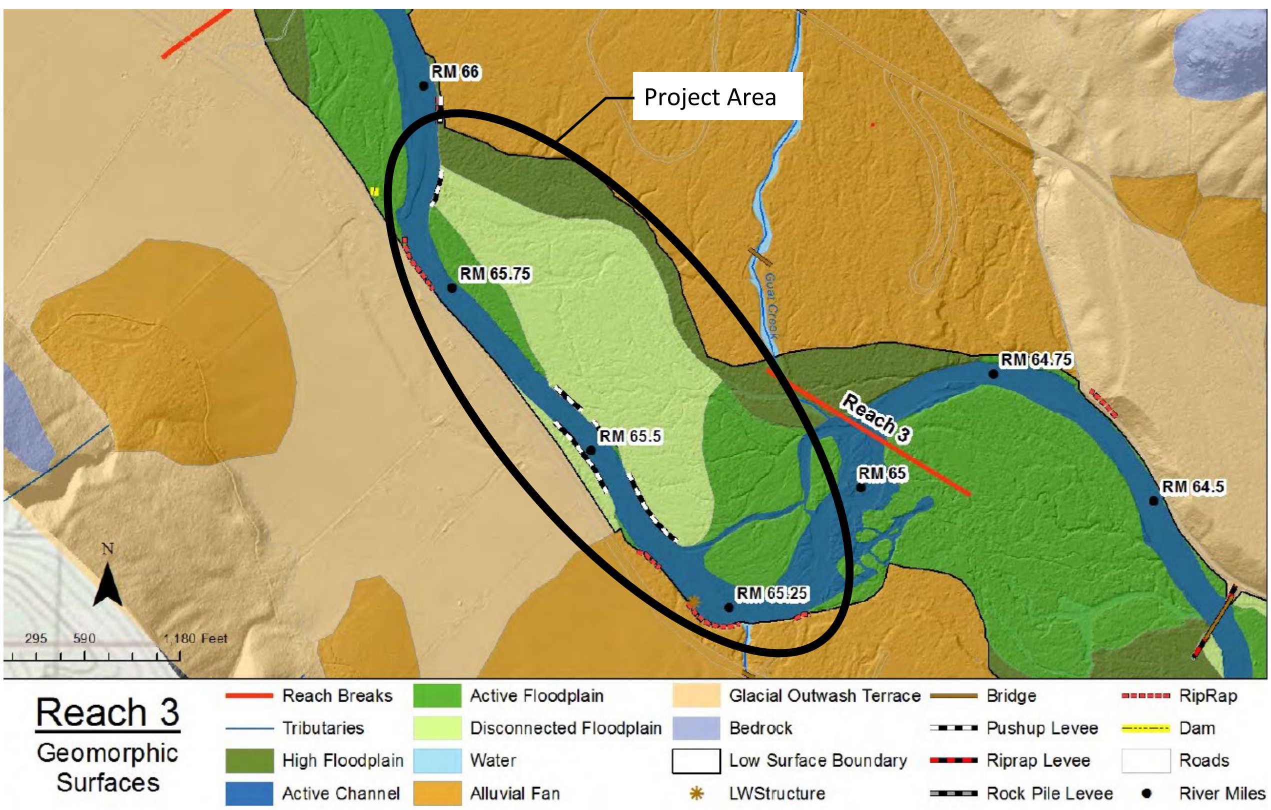
Month	50% Exceedance Flow (cfs)
April	477
November	60

3.2 Geomorphology

The project area comprises most of Reach 3 as identified in Figure 3-1 from the Upper Methow Reach Assessment (Inter-Fluve 2015). The Methow River channel form within the project reach can be divided into two subreaches:

- Upper/middle subreach is relatively straight, single-thread, with one meander at the upstream end. This subreach exhibits a mostly plane-bed morphology with occasional pools associated with in-stream structure. Gravel deposition is creating a sinuous thalweg, but bank armoring along the highway and levees along the river left floodplain precludes significant channel migration maintaining a generally straight channel form (Figure 3-2).
- The lower subreach is influenced by deposition from the Goat Creek alluvial fan creating a highly dynamic, multi-threaded channel with vegetated islands, unvegetated gravel bars, and log jams (Figure 3-3).

Figure 3-1. Project area near the confluence of Goat Creek and the Methow River (from Inter-Fluve, 2015)



The following observations were made during a site visit in November 2021:

- Channel bed and bar substrate is composed primarily of cobble and gravel. The median (D50) grain sizes from four sampling locations range from 58 mm to 97 mm (Table 3-3). Of the four sampling locations, the coarsest material occurs along a point bar near RM 65.8 and the finest material occurs along a bar near the secondary channel inlet at RM 65.4.

- Banks are composed primarily of cobble and gravel alluvium and glacial outwash overtopped by a thin veneer of fine sediment and soil. Minimal bank erosion was observed on the left bank in the upper/middle subreach and within various side channels and along the right bank in the lower subreach.
- Very limited large wood was observed in the upper/middle subreach, with multiple, large log jams observed in the depositional, multi-threaded lower subreach generally at the head of an island or bar.
- Riprap bank armoring was observed on river right adjacent the highway and infrastructure, but no riprap was observed on river left (see Figure 3-1).
- Small push-up levees composed of native alluvium reduce floodplain activation primarily on river left (Figure 3-1 and Figure 3-4).
- The floodplain includes obvious high-flow channels and relic channel scars with increasing frequency in the downstream direction. A trail network has been built on the floodplain which includes several culverts within high-flow channels and a wooden foot bridge over Goat Creek.
- Floodplain vegetation consists primarily of ponderosa pine, Douglas fir, cottonwood, various shrubs, and grasses in clearings.

Table 3-3. Methow River Grain Size Distribution

Grain Size Statistic	Grain Size (mm)			
	Location 1	**Location 2**	**Location 3**	**Location 4**
D_{95}	213	217	174	159
D_{84}	147	181	148	109
D_{75}	113	155	128	86
D_{50}	68	97	82	58
D_{25}	38	55	49	36
D_{16}	25	40	36	24
D_{5}	10	17	16	10

Location 1 – Bank and bed material near RM 65.8
Location 2 – Bed material on point bar near RM 65.8
Location 3 – Bed material on lateral bar near RM 65.5
Location 4 – Bed material on bar at secondary channel inlet near RM 65.4

Figure 3-2. Relatively straight, plane-bed upper subreach; note very large glacial outwash boulders on bank (photo looking upstream).

Figure 3-3. Cobble deposition, large wood, and high flow side channels in the lower subreach (river left, looking downstream).

Figure 3-4. Push-up levee composed of cobble and gravel on river left within the middle subreach (left floodplain, looking downstream).

3.3 Fish Use and Habitat Availability

Fish use in the Upper Methow River includes spring Chinook salmon, steelhead, bull trout, west-slope cutthroat trout, rainbow trout, and brook trout. Spring Chinook salmon are listed as Endangered under the Endangered Species Act (ESA), and steelhead and bull trout are listed as Threatened. Life-stage usage and ESA status for each species are summarized in Table 3-3 (Inter-Fluve, 2015).

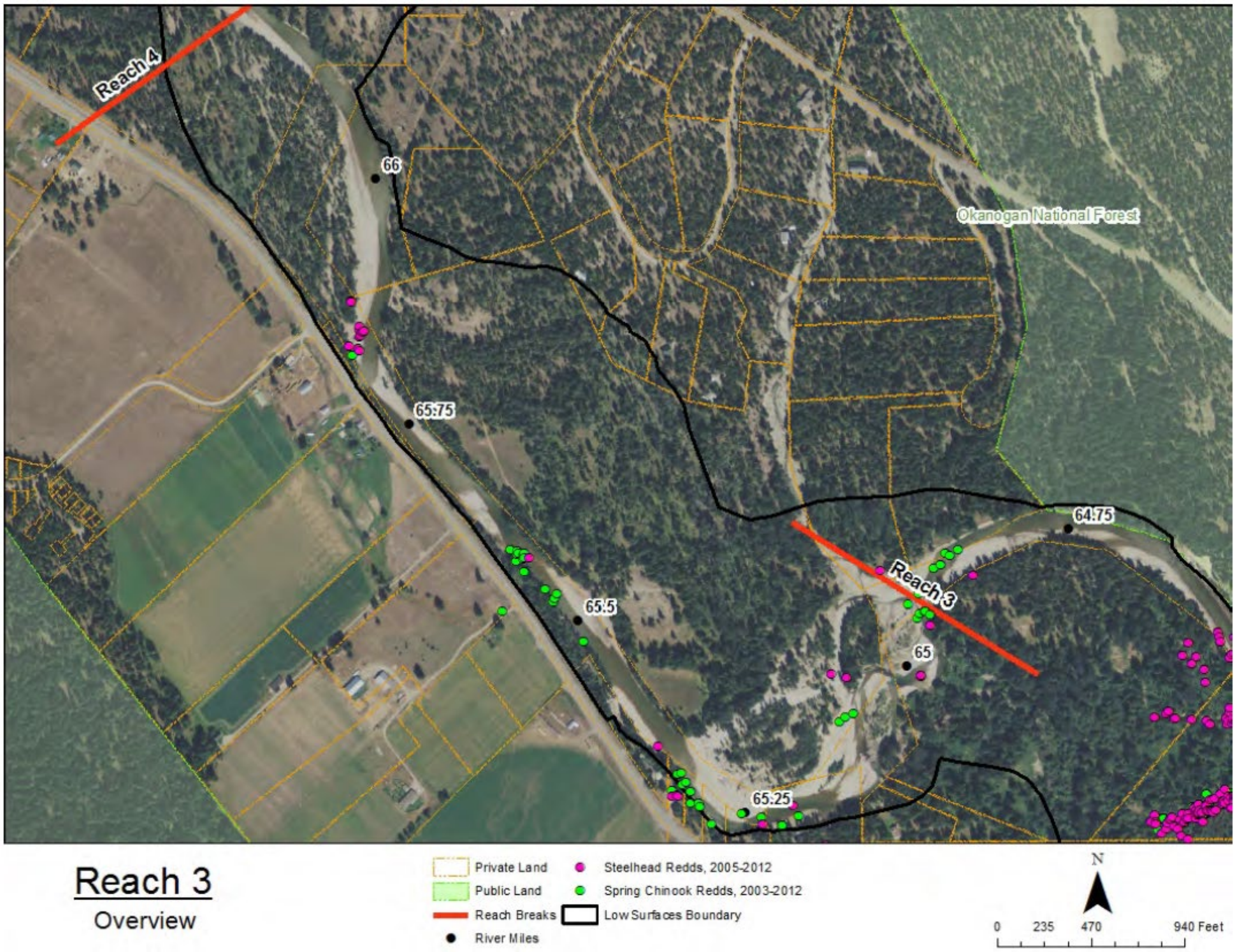
Table 3-4. Fish species in the Upper Methow River (adapted from NMFS 1998, Mullen 1992, USBR 2008, and Inter-Fluve 2015).

Species	ESA Status	General Use	Timeframe
Spring Chinook	Endangered	Spawning and rearing	Current and historical
Steelhead	Threatened	Spawning and rearing	Current and historical
Bull trout	Threatened	Spawning and rearing	Current and historical
West-slope cutthroat trout		Spawning and rearing	Current and historical
Rainbow trout		Spawning and rearing	Current and historical
Brook trout		Spawning and rearing	Current and historical

The Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (UCSCRP) rated the Methow spring Chinook salmon population as “at high risk of extinction within the next 100 years” if no action is taken. The UCSCRP gave steelhead trout a “Moderate to High” risk rating for extinction within the next 100 years if no action is taken.

Spring Chinook spawning within the study area occurs at the highest densities from RM 61 to RM 68 (near Mazama). Survey data from 2003 to 2013 report an average of 333 spring Chinook redds and 395 steelhead redds annually in the Upper Methow River basin (above the town of Winthrop, upstream of RM 50). In the study area, specifically in 2013 (RM 61-80), the highest number of redds occurred downstream of the confluence with Lost River from RM 72-75 and upstream of the Weeman Bridge from RM 60 to 62.8. That year a total of 142 steelhead redds and 141 spring Chinook redds were counted in the study area, including Early Winters Creek, Lost River, and Suspension Creek (Inter-Fluve, 2015). Figure 3-5 from the Upper Methow Reach Assessment (Inter-Fluve, 2015) shows redd distributions from 2003 to 2012.

Figure 3-5. Redd distribution (2003 to 2012) in the project reach (from Inter-Fluve, 2015).

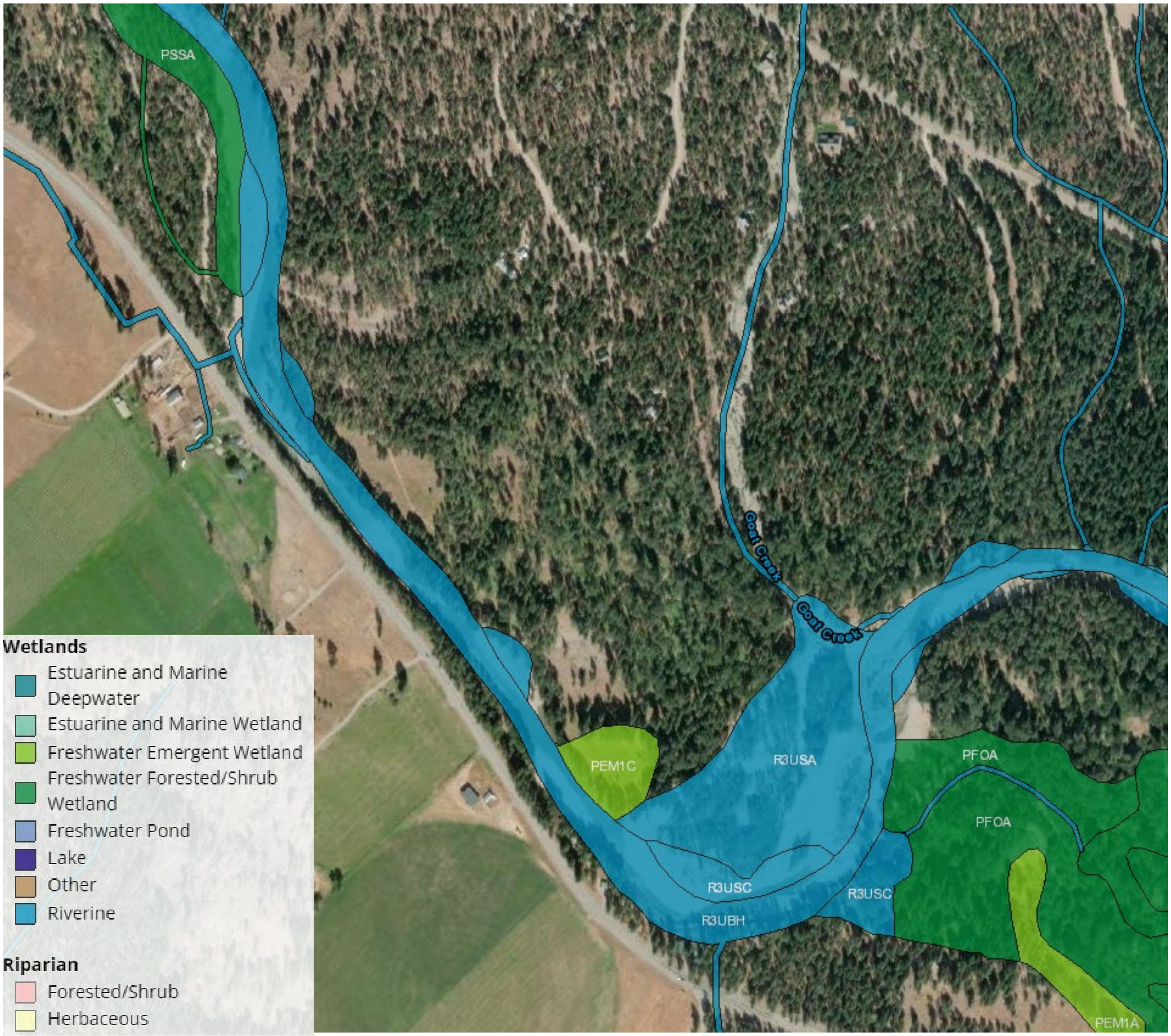


3.4 Riparian Conditions and Wetlands

The existing riparian and floodplain vegetation in the project reach consists primarily of ponderosa pine, Douglas fir, cottonwood, various shrubs, and grasses in clearings. The left overbank clearings contain some vegetation and soils exhibiting wetland habitat although a formal wetland resource inventory has not been conducted. If required, a formal wetland delineation will be completed at a later time. The left bank and overbank areas contain discontinuous, narrow, mature stands. On the right bank, riparian vegetation is largely intact but transitions to areas largely devoid of vegetation along the highway and to mixed forest and grass within the residential area beginning at approximately RM 65.5 and continuing downstream.

According to the US Fish and Wildlife Service National Wetland Inventory database (USFWS, 2019), forested/shrub and emergent wetland types existing within the project reach as shown in Figure 3-6.

Figure 3-6. Wetlands within the project reach (from the National Wetlands Inventory database).



4 DESIGN DEVELOPMENT

The restoration plan for the project reach integrates elements of restoring processes for improved river-floodplain function and rehabilitation and enhancement of habitat for juvenile life stages of Chinook salmon and steelhead. Applying this strategy is intended to improve instream habitat complexity and increase riparian tree- and shrub-dominated habitat to provide long-term structure and cover. The following restoration concepts are considered as specific actions are developed for the project reach:

- Restore process and reconnect habitat by distributing flow and energy laterally by removing portions of the existing left bank levee and incorporating pilot channels to reconnect existing secondary channel planforms.
- Restore process and reconnect habitat by adding large wood at opportunistic locations in the Methow River and secondary channels to promote increased channel unit frequency, localized deposition and scour, additional wood recruitment, facilitate re-activation of relic side channels, increase hydraulic diversity, and increase cover for juveniles.
- Restore riparian processes by planting woody vegetation to promote shade development for thermal buffering, increased bank stability, and future large wood recruitment.
- Protect existing areas of dense woody riparian vegetation where hydraulic complexity and habitat conditions are already favorable.
- Do not increase flood hazard risk to property.
- Minimize risk to public safety to the extent possible.

The restoration concepts address the following limiting factors identified for the project reach:

- Lack of floodplain connectivity
- Lack of secondary channel connectivity
- Lack of key habitat quantity (pools, floodplain, secondary channels)
- Lack of large wood
- Channel confinement from levee construction and Highway 20

4.1 Proposed Project Elements

The design team collaborations and interpretations of the current environmental setting have helped identify specific restoration actions for the project reach. These actions are listed below and depicted in the Drawings (Appendix A):

- Removal of the existing left-bank levee at strategic locations and grading of pilot channels to improve floodplain connectivity.
- Relocate existing boulders on the left floodplain to the mainstem Methow River channel to improve habitat.
- Addition of large and small wood structures (numerous types including Apex and Bank Jam Structures, Single-log and Whole Tree Structures, etc.) to promote in-channel complexity, force hydraulic response (scour, deposition, split flow, floodplain connection, sediment sorting, and overall hydraulic diversity), and provide concealment cover for juvenile salmonids.
- Addition of hardened crossings along the existing trail on the left floodplain to withstand expected hydraulic conditions.
- Revegetation by means of planting native species within the riparian zone and transplanting local vegetation harvested near the project site (if possible). Existing mature vegetation will be preserved or if disturbance is unavoidable, will be used as floodplain roughness and/or incorporated into proposed wood structures.

It is expected that implementation of future restoration actions described in this plan will need to comply with the General Project and Data Summary Requirements (GPDSR) required by the Bonneville Power Administration (BPA) for regulatory compliance coverage under the Habitat Improvement Program (HIP). Therefore, Rio ASE organized the risk evaluation of restoration concepts according to the Performance and Sustainability criteria prescribed in the HIP GPDSR (Table 4-1).

Table 4-1. Performance and sustainability criteria for each HIP action.

Work Element	HIP Category	Performance/Sustainability Criteria
Improve Secondary Channels and Floodplain Connectivity	2a	**Performance:** Provide structure (large wood and riparian planting) within secondary channels to promote in-channel complexity and force hydraulic response (scour, deposition, split flow, floodplain connection, sediment sorting, and overall hydraulic diversity). **Sustainability:** All large wood structures will be designed to withstand the 100-year flow. Only native species will be planted and seeded. Ensure adequate flow on an annual or near annual basis (see performance and sustainability criteria for HIP Category 2b and 2d). **Risk:** Adequate flow is not introduced to secondary channels and floodplain or excessive deposition occurs resulting in infilling of secondary channels. This is mitigated by providing reliable flow as discussed in HIP Category 2b and 2d.
Setback or Removal of Existing Berms, Dikes, and Levees	2b	**Performance:** Remove existing berms/levees only at select locations to improve floodplain connectivity while mitigating risk to property and public safety. Provide structure (large wood and riparian planting) at levee breaches and throughout pilot channels to provide reliable flow, promote in-channel complexity, and force hydraulic response (scour, deposition, split flow, floodplain connection, sediment sorting, and overall hydraulic diversity). Erosion of existing portions of the levee and scouring (deepening and/or widening) of pilot channels is regarded as a positive outcome (will result in greater floodplain connectivity). **Sustainability:** Incorporate wood structures at inlets to pilot channels/levee breaches to split flow while providing for bank stability and improved habitat. All large wood structures will be designed to withstand the 100-year flow. **Risk:** There is little existing infrastructure on the left floodplain where inundation is expected or could occur. However, risk to existing infrastructure is being mitigated by validating inundation extent through 2D hydraulic modeling. Existing infrastructure could be relocated (if possible), or floodplain roughness or fill could be incorporated to deflect flow from sensitive areas.
Install Habitat-Forming Natural Material Instream Structures	2d	**Performance:** Structures will be strategically located to split flow and to promote in-channel complexity, and force hydraulic response (scour, deposition, split flow, floodplain connection, sediment sorting, and overall hydraulic diversity). **Sustainability:** Large wood structures will be designed to withstand estimated hydraulic conditions associated with the 100-year flow event. The volume of wood structures installed will mitigate the short-term lack of natural large wood

Table 4-1. Performance and sustainability criteria for each HIP action.

Work Element	HIP Category	Performance/Sustainability Criteria
		recruitment through the project reach. All wood structure will include plantings during structure backfilling to provide short-term stability. **Risk:** Loss of structures could reduce wood loading. This is mitigated by designing for the 100-year flow. For Apex Jam structures, the risk of channel incision in the mainstem Methow River (thereby increasing channel capacity and reducing floodplain connectivity) is being reduced by designing an elongated structure, one that splits flow rather than obstructs flow. Risk to public safety is high and therefore Apex Structures are designed to have a gradual sloping face (rather than an abrupt face) and with reduced number of logs with rootwads.
Riparian and Wetland Vegetation Planting	2e	**Performance:** The planting plan utilizes local native species and a range of stock types including live stakes, plugs, and containerized plants. An objective of the planting plan is to generate 80% land cover within the grading area by year four. **Sustainability:** There are cottonwood trees and willows in and around the project area, including seed sources further upstream. The proposed grading plan takes into consideration native recruitment and it is expected that native cottonwood, willow, and other plants will naturally recruit within the project area, further bolstering the plant cover. The riparian community should be naturally sustainable over time following project completion. Revegetation strategy should provide future large wood recruitment once the system matures (+20 years). **Risk:** Plants not surviving or performing poorly increases the potential for encroachment by weeds and reduced stability of graded surfaces over time (due to reduced root mass and associated soil binding). This risk is being mitigated by requiring planting to occur at a time when the probability of success is best.
Channel Reconstruction	2f	**Performance:** Pilot channels will be designed to convey adequate flow to existing secondary channels to ensure they do not fill in with sediment. **Sustainability:** Incorporate large wood and riparian planting to provide bank structure to reduce the potential for channel widening/sediment deposition. **Risk:** Sediment fills pilot channels reducing floodplain connectivity.

4.2 Channel Design

4.2.1 Side Channel Length and Salmonid Utilization

Through ongoing studies in Idaho on the Lemhi River (OSC 2019), biologists are gaining a better understanding of fish utilization within side channels. Findings suggest that fish utilize side channels heavily but tend to occupy areas either at inlets or outlets of side channels. Telemetry studies indicated the maximum daily movement of a juvenile salmonid is approximately 415 ft. Therefore, the project seeks to provide numerous smaller side channels rather than a lesser number of larger side channels to maximize the number of flow convergences and divergences.

4.2.2 Flow Distribution and Channel Section

Channel dimensions of pilot channels were selected based on the size of the downstream receiving secondary channel. The vertical profile of the channel was selected based on the water surface elevation associated with the 1-year discharge to ensure channels would be activated at or near an annual event. The size and vertical profile of pilot channels may change in future design iterations to optimize flow/floodplain connectivity.

4.3 Cost Estimates

A detailed list of project materials, quantities, and costs are included in Appendix E.

5 HYDRAULIC MODELING AND ANALYSIS

The purpose of the existing and proposed conditions two-dimensional (2D) hydraulic models are as follows:

- Determine the hydraulic conditions (inundation extent, depth, velocity, shear stress, and water surface elevation) to evaluate in-stream habitat conditions and floodplain connectivity at the project-scale.
- Provide the basis for comparison with the proposed conditions hydraulic model to ensure project objectives are being met.

The 2D hydraulic models were developed using the U.S. Army Corps of Engineers (USACE) Hydraulic Engineering Center's River Analysis System (HEC-RAS), version 6.3.1. Development of any 2D hydraulic model requires a terrain surface, delineation of the model domain, designation of hydraulic roughness (Manning's n values), creation of the model mesh, and designation of boundary conditions specifying the inflow(s) hydrology and conditions for outflow(s). Each of these major components of the hydraulic model are discussed in greater detail in subsequent sections.

5.1 Data Used

Data used to develop the two-dimensional (2D) hydraulic model includes topography and bathymetry, aerial imagery, and hydrology, which is discussed in subsequent sections.

5.1.1 Topography and Bathymetry

Topographic and bathymetric information used to create existing and proposed ground surfaces (terrains) for use in the hydraulic model and for design includes the following data sources:

- 2018 LiDAR collected by USFS and Washington Department of Natural Resources. Data was used to create an AutoCAD Civil 3D surface in the North American Datum of 1983 (NAD 83), Washington State Plane North, U.S. Foot, coordinate system. The dataset vertical datum is the North American Vertical Datum of 1988 (NAVD 88). The spatial extent of this survey covered the entire Methow River Goat Creek project reach.
- 2022 bathymetric and topographic survey data collected by USBR. Data was used to create an AutoCAD Civil 3D surface in the North American Datum of 1983 (NAD 83), Washington State Plane North, U.S. Foot, coordinate system. The dataset vertical datum is the North American Vertical Datum of 1988 (NAVD 88). This dataset is considered coarse resolution and therefore likely does not accurately represent existing ground conditions in all areas. Although the data is sufficient for hydraulic modeling in the conceptual phase of this project, additional survey is recommended to generate a more detailed terrain surface to facilitate future design and associated detailed modeling.

5.1.2 Aerial Imagery

- 2021 National Agriculture Imagery Program (NAIP) imagery administered by the U.S. Department of Agriculture (USDA) Farm Service Agency obtained from ArcGIS Map Service. This imagery is shown in the hydraulic model result maps in Attachment A.
- 2022 high-resolution drone imagery collected by Rio ASE in October 2022. The imagery was used to provide improved spatial reference to features and landmarks within the project reach and to determine land use, vegetation type, condition, and density for estimating Manning's n values used in the hydraulic model. Determination of Manning's n values are discussed in detail in a subsequent section.

5.2 Model Development

The 2D hydraulic model domain extends approximately 2,000 feet upstream of the start of the project reach and approximately 4,000 feet downstream of the end of project reach covering approximately 8,500 feet of total channel length. Therefore, the model domain extends a sufficient length upstream and downstream of the project reach to ensure accurate flow and inundation conditions at the start and end of the project reach.

5.2.1 Terrain

Rio ASE created a composite existing conditions terrain surface using AutoCAD Civil 3D by pasting the topographic and bathymetric datasets listed in Section 5.1.1 in the order of priority as listed. The resulting composite terrain surface was exported in *.tiff file format with a cell size of 1-foot and converted to a terrain within HEC-RAS. The composite existing condition terrain surface was used for hydraulic modeling as well as for conceptual design.

5.2.2 Hydraulic Roughness

High-resolution drone imagery was used to generate hydraulic roughness mapping for the full model domain. Using the aerial imagery as reference, polygons were digitized based on channel and vegetation type and other identifiable features listed in Table 5-1. Manning’s n value for the channel was assigned based on engineering judgement. For model simulations at flows equal to and greater than the 1-year discharge, the channel Manning’s n value was reduced by a factor of 0.5 to reflect the impacts of channel bed roughness during high-flow events more accurately. This reduction factor represents a dimensionless ratio of discharge/bankfull discharge correlated to Manning’s n/bankfull discharge Manning’s n values and was selected based on engineering judgement and founded on analyses completed by Rio ASE on numerous streams in the Intermountain West. Manning’s n values for areas outside of the channel were selected based on engineering judgement and are constant regardless of the simulated flow, since overbank flow only occurs when flows are near or greater than bankfull. The selected Manning’s n values in Table 3 1 are also consistent with published values in Chow (1959).

Table 5-1. Hydraulic model Manning’s n values.

Description	≥ 1.5-year Flow Manning’s n	Low Flow Manning’s n
Methow River	0.032	0.064
Forest (low density)	0.08	0.08
Forest (medium density)	0.10	0.10
Forest (high density)	0.12	0.12
Pond	0.04	0.04
Vegetated Floodplain	0.06	0.06
Asphalt Roads	0.016	0.016
Fields (grass)	0.03	0.03
Goat Creek	0.05	0.064
Floodplain Grading	0.064	0.064
Side Channel Inlets	0.064	0.064

5.2.3 Computational Mesh

The USACE’s HEC-RAS 2D program uses a finite-volume solution scheme, which allows for use of a structured or unstructured computational mesh. This means that the computational mesh can be a mixture of 3- to 8-sided cells. The existing and proposed conditions hydraulic model uses a structured and unstructured mesh that contains variable mesh cell sizes ranging from 35-ft spacing to 2-ft spacing. Generally, the model mesh within floodplain areas that have a low topographic complexity use a nominal grid mesh (square cells) with a resolution of 20 feet by 20 feet. Channels or areas with high topographic complexity use a much finer mesh with variable-sided computational cells. For the mainstem Methow River, the model mesh contains at least 6 mesh cells representing the channel bottom and 1 mesh cells representing the channel banks throughout the modeled reach. For side channels, the model mesh contains at least 2 mesh cells representing the channel bottom and 1 mesh cell representing the channel banks. To improve model accuracy and efficiency, breaklines were included to enforce cell size and to align the edges of mesh cells at locations of topographic change. These locations include the top of existing and proposed banks, toe of slopes, centerline or thalweg of channels, top of roads, riffle crests, and any other areas requiring a more detailed mesh or where more complex hydraulic conditions are expected to occur.

5.2.4 Boundary Conditions

Boundary conditions designated within the model specify the flow rate(s) for flow entering the model (inflow) and conditions or flow rates leaving the model (outflow). The following are boundary conditions defined in the existing and proposed conditions hydraulic model:

- Upstream Methow River Boundary (Inflow)
- Downstream Methow River Boundary (Normal Depth)
- Upstream Goat Creek Boundary (Inflow)
- Upstream Little Boulder Creek Boundary (Inflow)

The upstream inflow boundary flow rates are different for each model run. Peak flow rates used for each model run at the upstream boundaries are presented in Table 3-1. The downstream outflow boundary is set to normal depth and therefore uses the Manning's equation to compute normal depth at each computational mesh cell along the boundary, assuming an energy slope of 0.0038 ft/ft which is equal to the reach slope within 200 feet upstream of the model boundary.

5.2.5 Computational Method and Options

The existing and proposed conditions 2D hydraulic models were run using both the diffusion wave (DW) and shallow water equation (SWE) computational engines. The SWE set uses full Saint-Venant momentum equations. For all model runs, separate DW and SWE plans are created and are named with a "DW" for diffusion wave or "FM" for full momentum in the plan file. Each DW model run saves a restart file at the end of the model simulation, which is then used as the initial condition for the SWE model simulation. All model runs are performed using unsteady state boundary conditions and use a fixed time step; computational interval (time step) for DW model runs ranged from 1 to 2 seconds and time steps for SWE model runs ranged from 0.2 to 0.5 seconds. All other computation options and tolerances utilize HEC-RAS default settings.

5.3 Hydraulic Model Results

Appendix B includes two-dimensional hydraulic model results (depth, velocity, and shear stress) for existing conditions, Alternative 1, and Alternative 2 at various recurrence interval flows. Alternative 1 includes only proposed levee removals and associated pilot channels (excludes wood structures). Alternative 2 includes proposed Alternative 1 features and all proposed wood structures. Currently, Cascade Fisheries has selected Alternative 2 as the preferred alternative. The model results for Alternative 1 (Appendix B) are being provided for information only.

5.3.1 Existing Conditions Model Results

Interpretations of the existing conditions model results are summarized as follows:

- Inundation extent (and water surface elevations relative to existing bank heights) indicate the Methow River is disconnected from the floodplain throughout a majority of the project reach at the 1-year flow event. Some existing high flow channels near the downstream end of the project reach are activated.

- The project reach is confined resulting in a lack of floodplain connectivity and exhibits a homogenous channel that provides little quantity and quality habitat value to juvenile and adult salmonids.
- There are only 5 pools within the project reach.
- Depth, velocity, and shear stress results indicate a lack of hydraulic variability throughout the project reach at all flows.

5.3.2 Proposed Conditions (Alternative 2) Model Results

Interpretations of the existing conditions model results are summarized as follows:

- At the 1-year flow, many of the proposed pilot channels are activated, but not all of them.
- Results indicate improved hydraulic variability in the mainstem Methow River at all flows. The improvement is localized to the immediate vicinity of proposed wood structures. However, the improvement is less at the November 50% exceedance flow (60 cfs) and April 50% exceedance flow (477 cfs) because a significant portion of proposed wood structures are in high-flow and secondary channels that are not activated.
- Histograms of depth and velocity for existing and proposed conditions at the 1.5-year flow are shown in Figure 5-1 and Figure 5-2. The charts indicate the following compared to existing conditions:
    - Significantly more area (11.8 acres) within the left floodplain is activated.
    - Regarding depth (Figure 5-1), there is a relatively large increase in quantity of wetted cells (each cell is 1 foot by 1 foot) in the model with depths greater than 0 to approximately 2.5 feet. There is little change in the amount of cells with depths greater than approximately 2.5 feet. This is likely because scour holes at wood structures (either excavated or that would develop naturally) are not reflected in the proposed conditions terrain model. Excavated scour holes, as specified in the Drawings, will be included in the proposed conditions terrain model in a future phase and the result is expected to produce a higher standard deviation relative to existing conditions.
    - Regarding velocity (Figure 5-2), the mean and standard deviation is lower for proposed conditions indicating more areas having slower velocities overall. The proposed model conditions show an increase in hydraulic diversity (greater depth range with more preferential flow velocities) compared to the existing conditions.
- Maximum velocities and shear stresses in the mainstem Methow River are reduced at high flows compared to existing conditions while hydraulic variability is increased.
- Water surface elevations within the Methow River at the 100-year flow are lower compared to existing conditions throughout the project reach except for at 2 of 3 proposed Apex Structures. Water surface elevations exceed 1-foot at the upstream Apex Structure (STA 15+00) and are less than 1-foot at the middle Apex Structure (STA 35+50). This finding indicates that the upstream structure should be modified, removed, or an additional side channel should be considered on the right floodplain adjacent to/upstream of the structure to increase conveyance capacity and provide added habitat benefits.

Figure 5-1. Depth histogram at the 1.5-year flow.

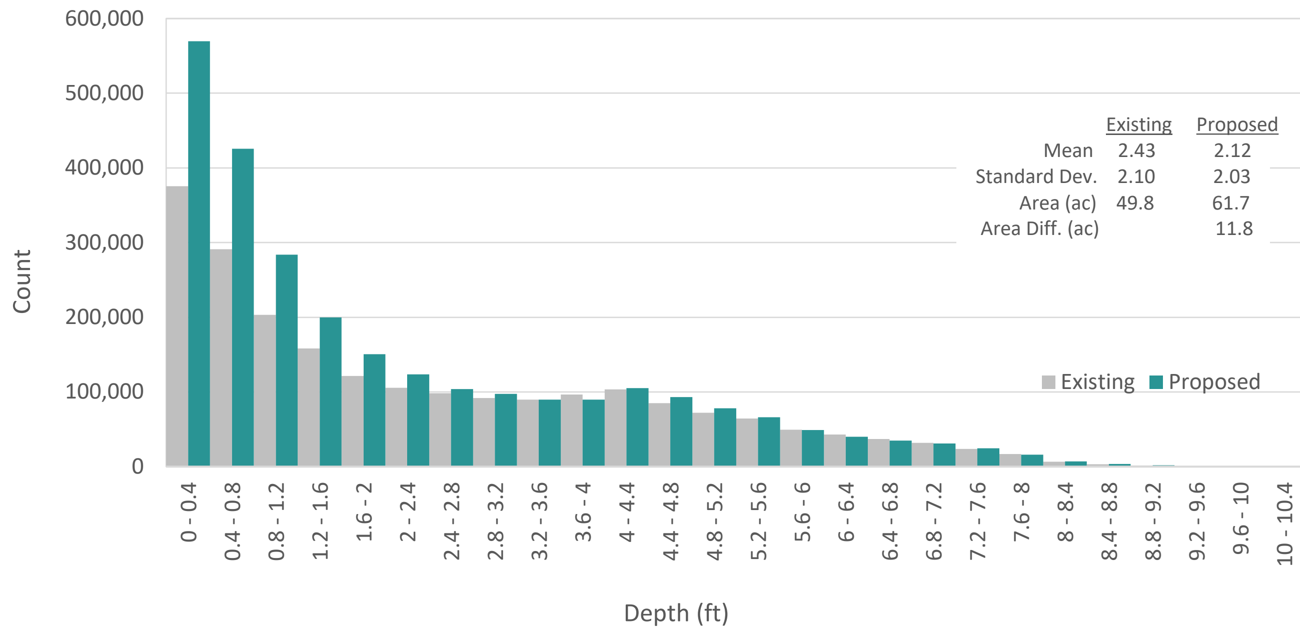
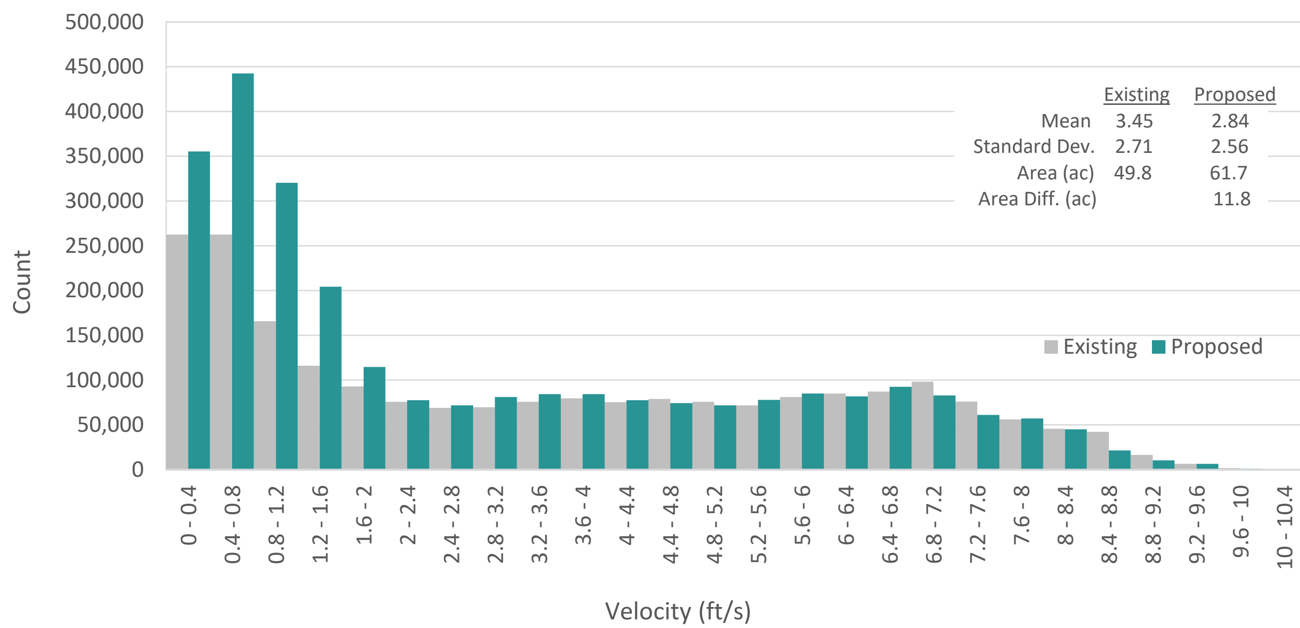


Figure 5-2. Velocity histogram at the 1.5-year flow.



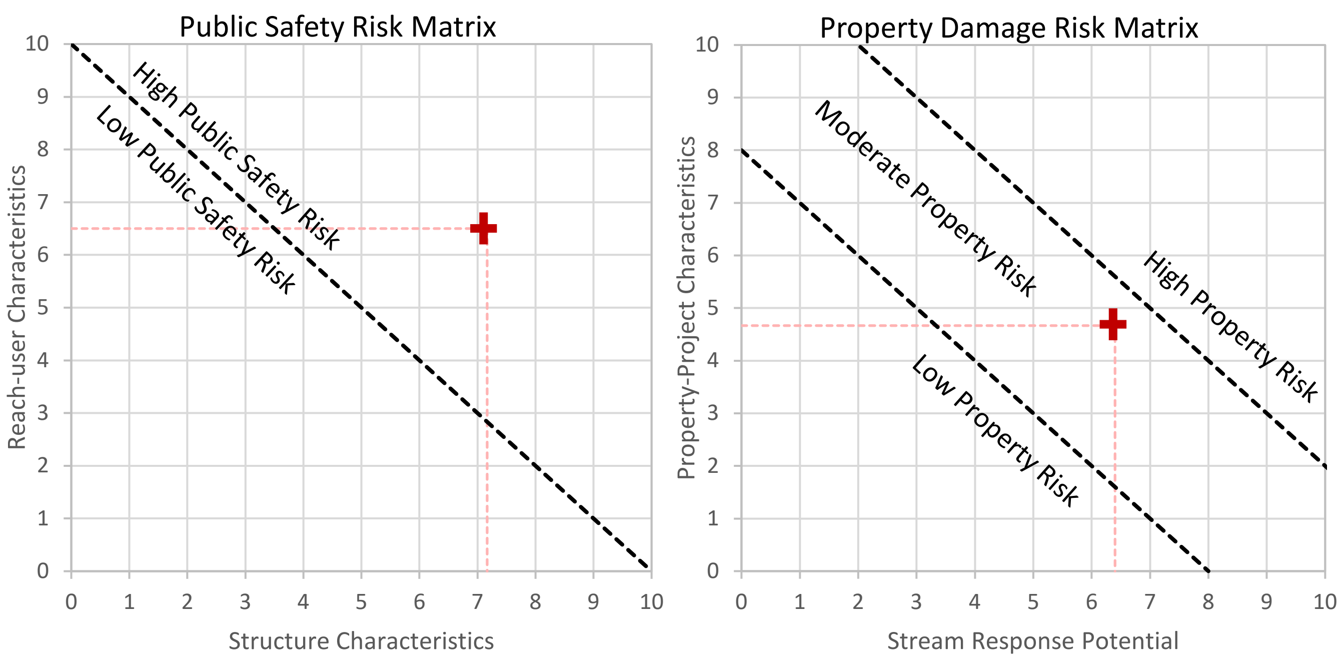
6 STABILITY ANALYSIS

6.1 Large Woody Material Risk Assessment and Design Factors of Safety

Large woody material structures are proposed in the mainstem Methow River, pilot channels, and secondary side channels and floodplain to provide roughness and habitat throughout the project area. There are 5 different types of proposed wood structures. These structures will consist of key log members that act as the skeleton of the structure. The structure will then be completed with the addition of racking logs and slash material. These structures are intended to emulate natural log jams.

Rio ASE analyzed perceived risk associated with large woody material using the Large Woody Materials–Risk Based Design Guidelines (Knutson and Fealko 2014). The risk analysis for the project area estimates a high risk to public safety and a moderate risk to property damage. Public safety is considered high mainly due to relatively high recreational use in the summer. Moderate risk is associated with the presence of residential housing and outbuildings on private property adjacent to the project along the right bank. These scorings can be seen in Figure 6-1 and are meant to be representative of the numerous structures proposed throughout the project reach.

Figure 6-1. Risk evaluations for public safety and property damage



These guidelines recommend a design flow event equal to or greater than the 50-year peak flood and factors of safety of 1.8 for buoyancy and 1.5 for sliding and rotation. However, the selected design flow will be the 100-year with factors of safety for buoyance, and sliding and rotation of 1.8 and 1.8, respectively.

6.2 Large Wood Stability Analysis

This analysis is expected to be completed in a future design iteration.

6.3 Large Wood Scour Analysis

This analysis is expected to be completed in a future design iteration.

6.4 Pilot Channel Stability

Rio ASE evaluated estimated shear stresses at proposed pilot channel locations at the 1.5-year discharge. A summary of the shear stresses are shown in Table 6-1. A factor of safety of 1.25 has been applied to the mean shear stresses to account for some variation in shear within each pilot channel. Table 6-1 includes an evaluation of sediment competency (incipient motion) to assess sediment transport continuity. Sediment transport continuity assesses competency along a constant channel slope to evaluate the likelihood of aggradation or incision based on existing or anticipated sediment gradations. The combination of channel slope and sediment size establishes the likely bed material gradation. Sediment competency was assessed using two equations that utilize the mean shear stresses. The first equation, developed by the U.S. Army Corps of Engineers (USACE), utilizes shear to estimate the D_{50} as seen in Equation 1 (Fischenich, 2001). The second equation utilizes shear to estimate the D84 as seen in Equation 2 (Leopold et al., 1964).

$$D_{50} = \frac{\tau}{0.06\gamma(G_S - G_W)Tan\phi} \quad \text{Equation 1}$$

Where:

D_{50}	is the median sediment particle size
t	is the shear stress in the channel
g	is the unit weight of water
G_s	is the specific gravity of the sediment
G_w	is the specific gravity of water, and
f	is the angle of internal friction of the sediment

$$D_{84} = 77.966\tau^{1.042} \quad \text{Equation 2}$$

Where:

D_{84}	is the sediment particle size that 84% is passing (mm)
t	is the shear stress in the channel (lb/ft^2)

Assuming channel shear stress (average and maximum values as shear varies with depth along the cross section) at the 1.5-year flood event (assumed to be at or near the channel forming flow), the equations provide an estimate of average and maximum grain sizes that are expected to be mobile on a relatively regular basis, thereby allowing the channel to function as a natural alluvial system.

Based on the shear stresses and predicted mobile sediment sizes, a minimum suitable streambed material was estimated (Table 6-2). If the in-situ material does not meet the minimum gradation at excavated pilot channels, then material may be over-excavated and replaced with suitable streambed material.

Table 6-1. Shear stress (lb/ft^2) at proposed pilot channel locations at the 1.5-year flow.

Pilot Channel	Shear Stress (lb/ft^2)		D_{50} Uniform Mobile Sediment Size (mm)		D_{84} Uniform Mobile Sediment Size (mm)	
	Avg.	**Max.**	**Avg.**	**Max.**	**Avg.**	**Max.**
1						
2						
3						
4						

5						
6	To be completed at a future design phase					
7						
8						
9						
10						
11						
12						

Table 6-2. Minimum gradation of streambed material at pilot channel locations

Size Class	Min. Particle Size (in)
D_{16}	To be completed at a future design phase
D_{30}	
D_{50}	
D_{84}	
D_{100}	

7 CONSTRUCTION

Rio ASE considered HIP General Aquatic Conservation Measures when completing the project design. We included HIP Conservation Measures, with more detail, as notes in the Drawings attached in Appendix A for ease of reference by the construction contractor. The following is a summary of the project's compliance with the general conservation measures.

7.1 General Aquatic and Construction Conservation Measures

- **Climate change**: Climate change was considered in the design. Primary features that address climate change scenarios (runoff timing, lower flows, increased temperature) include side channels, wetlands, and shallow groundwater storage. In addition to these, there will be increased floodplain connectivity and wetland habitat, which should also enhance shallow groundwater storage and subsequent surface water/groundwater connectivity in warmer months and low-flow conditions.
- **Timing of in-water work**: The approved in-water work window is currently ________ to _______ of the following year.
- **Site layout and flagging**: The construction contractor will be required to stake all major project elements for approval by the contracting officer or engineer prior to construction and adhere to vertical and horizontal tolerances in accordance with the Specifications (to be developed in a future design phase).
- **Temporary access roads and paths**: Temporary access routes are shown in the Drawings (Appendix A). The construction contractor will not be allowed to deviate from the designated routes unless approved by the contracting officer or engineer.
- **Temporary stream crossings**: Temporary stream crossings are shown in the Drawings (Appendix A). The construction contractor will not be allowed to deviate from the crossing locations unless approved by the contracting officer or engineer.
- **Staging, storage, and stockpile areas**: Proposed staging and stockpile areas throughout the project area are shown in the Drawings (Appendix A). The construction contractor will not be allowed to deviate from these areas unless approved by the contracting officer or engineer.
- **Equipment**: Equipment necessary to complete the project likely will include dozers, excavators, loaders, and a variety of service vehicles. We included HIP General Conservation and Implementation Measures as notes in the Drawings (Appendix A), and those notes indicate biodegradable lubricants are required for work below the OHWM.
- **Erosion control**: HIP General Aquatic Conservation Measures in the Drawings (Appendix A). Those include erosion control measures for temporary erosion controls, sediment barriers restricting loads to the stream, soil stabilization measures and emergency erosion controls. Our scope does not include preparation of a project specific storm water pollution prevention plan (SWPPP).
- **Dust abatement**: General Conservation and Implementation Measures in the Drawings (Appendix A). Those include recommendations regarding work scheduling, dust stabilization measures (water only), spill containment and a restriction on petroleum-based stabilization products.
- **Spill prevention, control, and counter measures**: HIP General Conservation and Implementation Measures are included in the Drawings (Appendix A). Those include directing the contractor to keep a list of hazardous materials, written procedures for notification of environmental response, spill containment kits, worker training and storage of waste liquids. Our scope does not include preparation of a project specific SWPPP.
- **Invasive species control**: HIP General Conservation and Implementation Measures are included in the Drawings (Appendix A). Those include directing the contractor to power wash all vehicles, inspecting in-water equipment and a restriction on felt-soled wading boots. Our scope does not include preparation of a project specific invasive species control plan.

8 LIMITATIONS

Some clients, design professionals, and contractors may not recognize that stream and river engineering analysis and design practices are less exact than other engineering and natural science disciplines. Such misunderstandings can create unrealistic expectations, sometimes leading to disappointments, claims, and disputes. Rio ASE includes these explanatory “limitations” provisions in our reports to help reduce such risks. Please confer with Rio ASE if you are unclear how these “Report Limitations and Guidelines” apply to your project or site.

8.1 Design Purposes, Persons, and Projects

This report has been prepared for the Client and their authorized agents and regulatory agencies for use on the Project(s) specifically designed in the report. The information contained herein is not applicable to other sites or projects.

Rio ASE structures its services to meet the specific needs of its clients. No party other than the Client may rely on the product of our services unless we agree to such reliance in advance and in writing. Within the limitations of the agreed scope of services for the Project and its schedule and budget, our services have been executed in accordance with our Agreement and generally accepted practices in this area at the time this report was prepared. We do not authorize, and will not be responsible for, the use of this report for any purposes or projects other than those identified in the report.

8.2 Design Factors

This report has been prepared solely for this Project and Client. Rio ASE considered a number of unique, project-specific factors when establishing the scope of services for this project and report. Unless Rio ASE specifically indicates otherwise, it is important not to rely on this report if it was:

- Not prepared for you,
- Not prepared for your project,
- Not prepared for the specific site, or
- Completed before project changes were made.

For example, changes that can affect the applicability of this report include those that affect:

- The function of the proposed design and/or structure
- Elevation, configuration, location, or orientation of the proposed structures
- Composition of the design team, or
- Project ownership.

If changes occur after the date of this report, Rio ASE cannot be responsible for any consequences of such changes in relation to this report unless we have been given the opportunity to review our interpretations and recommendations in the context of such changes. Based on that review, we can provide written modifications or confirmation, as appropriate.

8.3 Conditions Can Change

This report is based on conditions that existed at the time the study/design was performed. The findings and conclusions of this report may be affected by the passage of time, by man-made events such as construction on or adjacent to the site, new information or technology that becomes available subsequent to the report date, or by natural evens such as floods, earthquakes, slope instability, stream flow fluctuations or stream channel fluctuations. If more than a few months have passed since issuance of our report or work product, or if any of the described events may have occurred, please contact Rio ASE before applying this report for its intended purpose so that we may evaluate whether changed conditions affect the continued reliability or applicability of our conclusions and recommendations.

Any designs associated with this report may need to be adjusted in the field during construction in order to meet the specific-site conditions and intended function. Rio ASE cannot assume responsibility for the recommendations in this report if unexpected conditions are encountered during construction. We recommend that you allow sufficient monitoring and consultation by Rio ASE during construction to confirm that the conditions encountered are consistent with those indicated in the report, to provide recommendations for design changes if the conditions revealed during the work differ from those anticipated, and to evaluate whether construction activities are completed in accordance with our recommendations.

8.4 Report Misinterpretation

Misinterpretation of this report can result in costly problems. Rio ASE can help reduce the risks of misinterpretation by conferring with appropriate stakeholders after submitting the report, participating in pre-bid and preconstruction conferences, and providing construction observation.

To help reduce the risk of problems, we recommend giving contractors the complete report, including these “Report Limitations and Guidelines.” When providing the report, we recommend that you preface it with a clearly written letter of transmittal that:

- Advises contractors that the report was not prepared for purposes of bid development and that its accuracy is limited, and
- Encourages contractors to confer with Rio ASE and/or to conduct additional study to obtain the specific types of information they need or prefer.

8.5 Hazards of Instream Habitat Structures

Instream habitat structures (“Structures”) create potential hazards, including, but not limited to:

- Persons falling from the Structures and associated injury or death,
- Collisions of recreational users and their watercraft with the Structures, and associated risk of injury, and damage of the watercraft,
- Mobilization of a portion or all of the Structures during high water flow conditions and related damage to downstream persons and property,
- Flooding,
- Erosion, and
- Channel avulsion.

In some cases, instream habitat structures are only intended to be temporary, providing temporary stabilization while riparian vegetation becomes established or while stream/river processes stabilize. This gradual deterioration with age and vulnerability to major flood events make the risks with temporary Structures inherently greater with their increasing age.

Rio ASE strongly recommends that the Client appropriately address safety concerns, including but not limited to warning construction workers of hazards associated with working in or near deep and fast-moving water and on steep, slippery, and unstable slopes. In addition, signs should be placed along the enhanced stream reaches in prominent locations to warn third parties, such as nearby residents and recreational users, of the potential hazards noted above.

8.6 Channel Response is Unpredictable

In general, rivers and streams are dynamic and unpredictable. Any predictions regarding future channel evolution and/or response either stated or implied in this report or associated design(s) shall be considered an estimate based on professional judgment given the data available and conditions that existed at the time the study/design was performed. Channel evolution and/or response may include but is not limited to erosion, deposition, channel migration, avulsion, flooding, and sediment and debris transport. Channel evolution and/or response is inevitable, and it should not be assumed that any condition whether natural or constructed will persist unchanged indefinitely in a riverine environment.

8.7 Monitoring and Maintenance

In some designs, Rio ASE may have excluded piles, anchors, chains, cables, reinforcing bars, bolts and similar fasteners from woody habitat structures with the intent of mimicking naturally occurring instream wood structures. In other designs Rio ASE may have included such fasteners in woody habitat structures, if considered appropriate. While Rio ASE designs structures to be relatively stable during flood events, some movement of these structures is expected. We recommend that the Client implement appropriate monitoring and maintenance procedures to minimize potential adverse impacts at or near areas of concern, and consider replacing, adjusting and/or removing damaged, malfunctioning, or deteriorated components of structures.

8.8 Construction Site Safety

Our recommendations are not intended to direct the construction contractor’s procedures, means, methods, schedule, or management of the work site during construction of any project associated with this report. The construction contractor is solely responsible for job site safety and for managing construction operations to minimize risks to on-site personnel and adjacent properties.

9 REFERENCES

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APPENDIX A: DESIGN DRAWINGS

- Provided as a separate PDF file

APPENDIX B: TECHNICAL SPECIFICATIONS

- To be completed in a future design phase.

APPENDIX C: HYDRAULIC MODEL RESULTS MAPBOOK

- Provided as a separate PDF file.

APPENDIX D: ADAPTIVE MANAGEMENT PLAN

- To be completed in a future design phase.

APPENDIX E: CONSTRUCTION QUANTITIES AND COST ESTIMATE

- Provided as a separate PDF file.

APPENDIX F: WETLAND DELINEARTION REPORT

- To be completed in a future design phase, if required.

APPENDIX G: DESIGN REVIEW COMMENT TRACKING

- To be completed in a future design phase.