



Figure 3-10. The private bridge where the OWRD gage is located at RM 3.3.



Figure 3-11. Photo taken from the private bridge at RM 3.3 looking upstream. This reach is where Bear Creek flows directly adjacent to Bear Creek Road and there is existing flooding risk.

4 DESIGN DEVELOPMENT

The restoration plan for the project area integrates elements of limiting unnecessary disturbance, adding wood and strategic channel fill to restore river-floodplain processes, adding beaver dam analogues (BDAs) to spring channels to increase floodplain saturation, opening up the floodplain at the existing county bridge to dissipate flood energy laterally, and pulling Bear Creek away from Bear Creek Road at the downstream end. Due to funding and construction schedule considerations, this project will be split into two phases. Phase 2 only encompasses the grading, wood structures, and bridge work associated with the proposed bridge. Phase 1 includes Little Bear Creek and the rest of the project site outside of the Phase 2 limits (see Drawing C7; Appendix A). Applying these strategies is intended to improve habitat quality and quantity while restoring a sinuous and multi-threaded channel that activates the adjacent floodplain and seasonal secondary channels during spring runoff flows. The following restoration concepts are specific actions developed for the project area:

- Construction of persistent, large-scale log jams in the main channel. Constructed jams will be built out of relatively large key members and ballasted with alluvium (where equipment access is available) to counteract powerful seasonal peak flows. This design element is intended to:
 - Obstruct and roughen the primary channel, thus increasing upstream WSE and driving seasonal secondary channel activation and floodplain connectivity.
 - Encourage the scour and deposition of sediment to create pools, sort sediment, and create fresh deposits of spawning gravels.
- Addition of channel fills. This design element is intended to:
 - Reroute Bear Creek to occupy relict meander scars on a more sinuous path.
 - Increase WSE to drive seasonal secondary channel activation and floodplain activation.
- Construction of BDAs on spring channels. This design element is intended to:
 - Increase saturation of floodplains.
 - Provide off-channel habitat for salmonids.
 - Provide off-channel habitat for beaver.
- Addition of a new bridge to increase the capacity of the floodplain through the existing bridge crossing. This design element is intended to:
 - Decrease risks to the existing bridge.
 - Decrease stream energy by spreading flood flows laterally.
- Pulling Bear Creek away from Bear Creek Road in the downstream end of project area and re-occupying relict meander scars. This design element is intended to:
 - Increase the opportunity for dynamic response through this reach, leading to:
 - large wood recruitment,
 - erosion and deposition of gravels, and
 - complex habitat.
 - Increase floodplain and seasonal side channel activation.
 - Decrease risk to Bear Creek Road.

4.1 Proposed Project Elements

It is expected that implementation of future restoration actions described in this plan will need to comply with the GPDSR required by BPA for regulatory compliance coverage under the 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. Performance and Sustainability Criteria for Each HIP Action

Work Element	HIP IV Category	Performance/Sustainability Criteria
Improve Secondary Channel and Floodplain Connectivity	2a	<p>Performance: Utilize wood placement, pilot channel excavation, and channel fill to activate the floodplain at a more frequent interval (1.25-year recurrence interval discharge). Place wood to correct channel width-to-depth ratio (over-widening) to a lower effective ratio to improve floodplain connectivity.</p> <p>Sustainability: This is a dynamic reach that has had recent channel avulsions occur naturally. During the project team site visit in October 2024, nearly all of the best habitat identified in the project area was within the recently avulsed reaches. The goal is to utilize this inherent dynamism by providing pilot channels for the channel to pioneer new routes through the densely forested floodplain, thereby forming new avulsion routes and recruiting more wood.</p> <p>Risk: There is the risk of channel incision or channel avulsion/straightening that increases channel capacity and reduces floodplain connectivity. This risk is being mitigated by providing pilot channels to preferentially encourage avulsions and new side channel formation where floodplain connectivity will be increased.</p>
Setback or Removal of Existing Berms, Dikes, and Levees	2b	<p>Performance: Remove existing berms/levees to improve floodplain connectivity while mitigating risk to property and safety. There are no constructed levees documented within the project area; however, there are natural levees that will be breached with proposed pilot channels to encourage floodplain activation and seasonal side channel connection.</p> <p>Sustainability: Many instances of proposed pilot channels within the project area utilize multiple pilot channels to add redundancy to floodplain inundation areas.</p> <p>Risk: There is risk that pilot channels become plugged with wood accumulation or sediment deposition.</p>
Install Habitat-Forming Natural Material Instream Structures	2d	<p>Performance: Large woody debris structures will be utilized to achieve increased WSE, sediment sorting, scouring of bed material, and creation of cover habitat. The density of structures will be sufficient to meet large wood targets of 20 pieces per 100 meters.</p> <p>Sustainability: The size of key members used in the wood structures are appropriately sized compared to the</p>

Table 4.1. Performance and Sustainability Criteria for Each HIP Action

Work Element	HIP IV Category	Performance/Sustainability Criteria
		<p>hydraulics of the channel based on a study conducted by Abbe and Montgomery (2003). The two-dimensional (2D) hydraulic model results show that the steep nature and annual peak flows of Bear Creek have the ability to produce powerful hydraulic forces capable of mobilizing large woody debris. There was ample evidence of this observed during the October 2024 site visit by way of naturally formed log jams. The most notable feature of the existing log jams was the presence of an exceptionally large tree that initiated the jam and began to rack material. Rio ASE plans to source as large of wood as possible to emulate this process, but in areas where equipment access is attainable jams will be ballasted with alluvium to mitigate the risks of mobilization and to initiate the formation of a jam. The goal for large wood loading is 20 pieces per 100 meters. Little Bear Creek has 33 pieces per 100 meters proposed within identified treatment areas, while Bear Creek has 55 pieces per 100 meters proposed when considering the entire project area.</p> <p>Risk: The loss of structures could reduce wood metrics below standards. This risk is mitigated through a sufficient volume of wood initially placed. Loss of structures also poses risks to the existing and proposed county bridges. This is mitigated by specifying a minimum log length and diameter to reduce the ability of the channel to transport the key members and by installing large, robust collector jams ballasted with alluvium to accumulate wood transported from upstream.</p>
Riparian and Wetland Vegetation Planting	2e	<p>Performance: The planting plan utilizes locally derived intensive live willow cutting installation in existing wetland areas that have been overgrazed and denuded of woody vegetation. Native species seeding is proposed in all disturbance areas above the proposed low flow WSE. The objective of the planting plan is to generate 80% land cover within the grading area above OMHW within four years after construction.</p> <p>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</p>

Table 4.1. Performance and Sustainability Criteria for Each HIP Action

Work Element	HIP IV Category	Performance/Sustainability Criteria
		<p>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.</p> <p>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 planting live cuttings during the dormant season, using heavy seed application rates, and having revegetation monitoring as a part of the adaptive management and monitoring plan.</p>
Channel Reconstruction	2f	<p>Performance: Increasing sinuosity, reducing slope, promoting seasonal side channel activation, narrowing over-widened areas, and adding instream structure will diversify instream hydraulics, improve fish habitat, and increase floodplain connectivity. The floodplain will be activated at a more frequent (1.25-year) interval.</p> <p>Sustainability: Long-term goals for the project are to allow natural migration, avulsion, and deformation of the reconstructed channel.</p> <p>Risk: In early years, prior to establishment of a robust riparian corridor that will provide dominant hydraulic control, there is risk of excessive deformation. This risk is being mitigated by placement of large woody material structures, and constructed riffles to maintain plan form and profile in the short term.</p>

4.2 Channel Design

4.2.1 Flow Distribution and Channel Section

Design channel dimensions were selected based on target flow splits at the 1.25-year discharge and at low flow (selected as 7 cubic feet per second [cfs], which was the flow measured during the October 2024 site visit). The design intent is to distribute flows across secondary channels and the floodplain during seasonal runoff and then return the channel to be primarily single-thread at low flow.

All channels, aside from the channel through the proposed bridge, are designed with width-to-depth ratios that are lower than reference conditions to emulate recent avulsions. This means the channels are expected to adjust by widening during the first few years post-construction. The purpose of this approach is to provide dynamic conditions where the channel is recruiting and redistributing sediment and wood on an annual basis and developing the most appropriate width-to-depth ratio for the given channel segment. This process was

observed in the existing recent avulsion channels in the project area and resulted in the most favorable habitat conditions within the project area.

The channel through the proposed bridge is designed based on referencing the stable channel geometry exhibited throughout the project area with a bankfull width of 50 ft and a width-to-depth ratio of 23. The design intent is to create a relatively stable reach through the bridge opening to mitigate risks associated with dynamic channel response within the immediate vicinity of the bridge.

Concentrating low flows within the main channel was the primary factor in determining channel inverts at pilot channels leaving the mainstem. Channel width was largely driven by targeting a flow that was between 1% and 15% of the 1.25-year discharge.

4.3 Bridge Design

The existing county bridge crossing at existing station 125+00 was identified for improvements because of the lack of conveyance capacity, freeboard, as well as the poor configuration of the existing road and bridge. Currently, the road serves as a valley-wide dam that constricts peak flows through the undersized bridge opening, resulting in an incised channel with limited habitat diversity in the reach immediately downstream of the bridge. This constriction could be driving some of the response mechanisms being observed upstream of the crossing. Additionally, the existing bridge opening is greatly undersized: the 100-year WSE is modeled to be 1 ft higher than the existing low chord.

As the primary component of the Phase 2 design, the proposed solution is to move the main channel to the river right side of the valley, add a new bridge, and keep the old bridge where it is to serve as a high-flow path during peak flow events. The proposed channel and floodplain grading on valley right opens up the total crossing width to 112 ft, which is greater than the BPA HIP-required 2.2 times the existing bankfull width of 50 ft for bridges with multiple openings. The proposed design influences the hydraulics of this reach in a measurable way, as shown in the modeled 1.25-year depth and velocity histograms below.

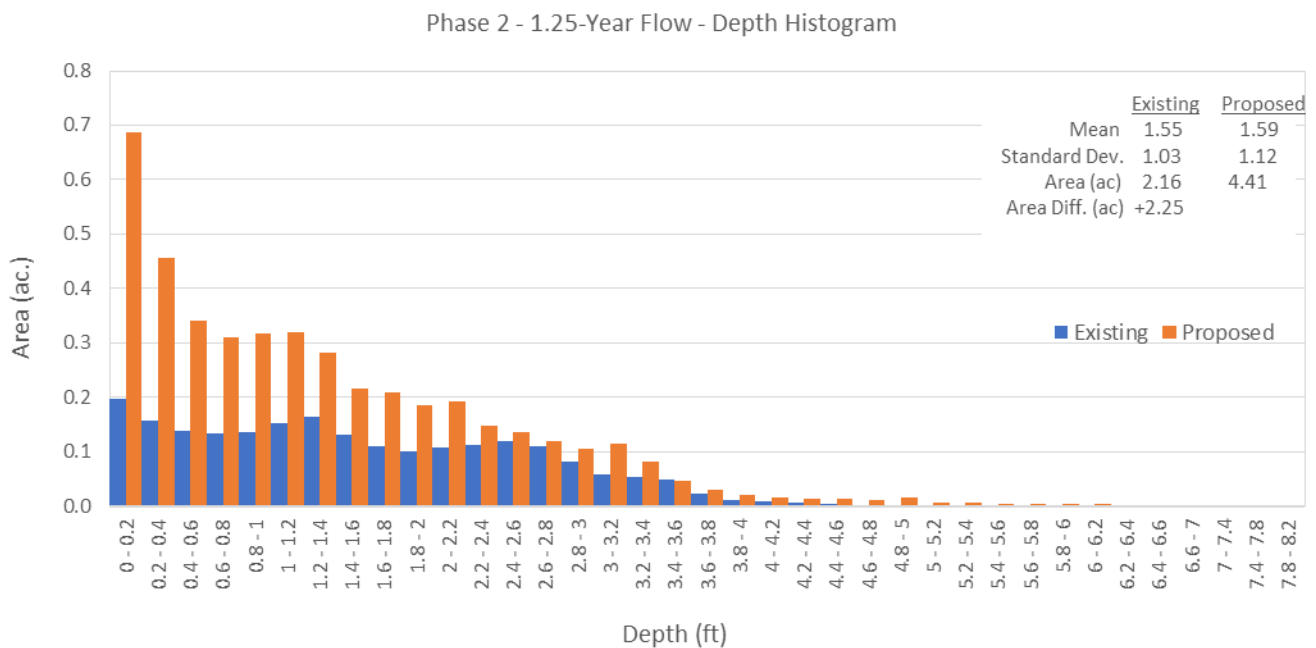


Figure 4-1. 2D hydraulic model results depth histogram for Phase 2.

Phase 2 - 1.25-Year Flow - Velocity Histogram

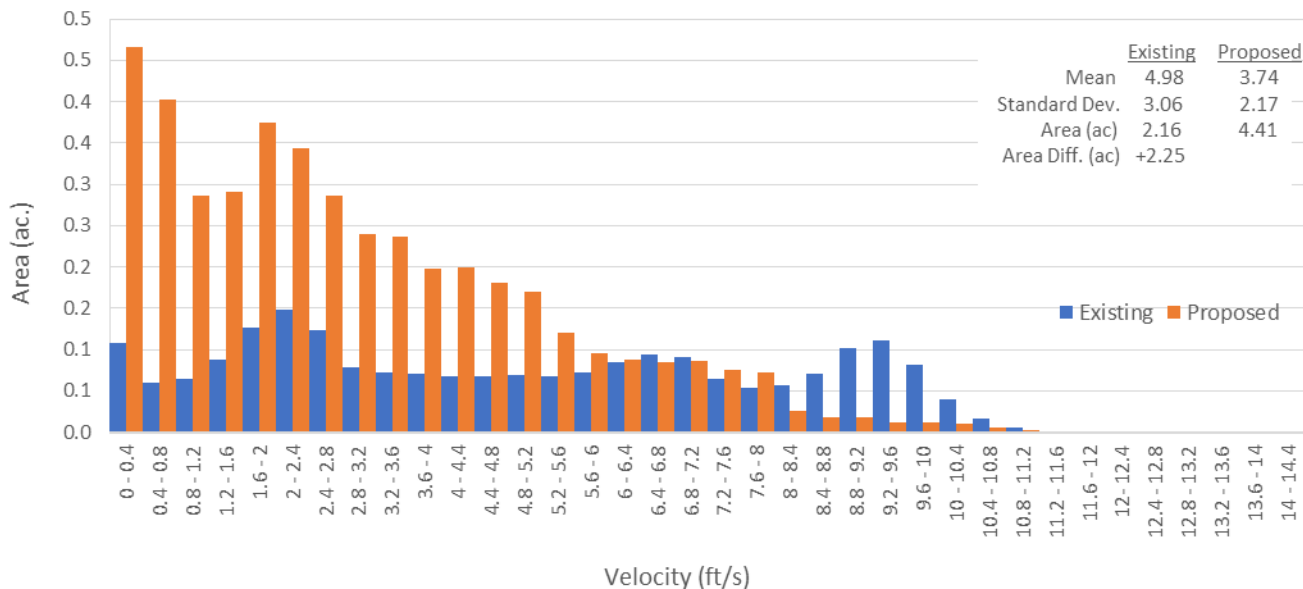


Figure 4-2. 2D hydraulic model results velocity histogram for Phase 2.

The low chord of the existing bridge was surveyed to be 3400.9 ft, while the existing 100-year recurrence interval flow (1% annual exceedance) WSE was modeled one foot higher at 3401.9 ft. The proposed 100-year WSE was modeled to be 3401.3 ft, which is an improvement from existing conditions by 0.6 ft but still submerges the low chord of the bridge. The design intent is to achieve a proposed 100-year WSE that passes freely under both the proposed and existing bridge; this goal will be met at the next deliverable. The low chord of the proposed bridge is set at 3402.0 ft with the proposed 100-year WSE modeled at 3400.0 ft, resulting in a freeboard of 2 ft to accommodate debris being transported downstream from the upper watershed.

If left as is the river will continue to be locked into place with a narrow constriction through the bridge. Existing conditions will maintain a 1,000 foot length of simplified single thread channel. Proposed conditions would create a single thread low flow channel with additional high flow capacity that is activated on an annual basis. This additional habitat would decrease average velocities in this reach by 25% from 5 ft/sec down to 3.7 ft/sec. It would increase inundated area during the 1.25-year discharge by 100% from 2.2 acres to 4.4 acres. More inundated area at lower velocity is critical to attempting to keep juvenile salmonids as high in the watershed as possible. The bridge alone for this portion of work is estimated at approximately \$600,000 for implementation. The bridge, road, and channel enhancements in this Phase 2 reach would increase localized habitat complexity within Bear Creek where influences would likely extend approximately 500 feet upstream and 700 feet downstream of its existing location. Overall this project extends along 14,700 feet of existing channel and this reach directly affected by the bridge (1,200 feet) represents slightly less than 8% of the available habitat within the project boundary. The bridge costs represent roughly 20% of the total budget for the project at proposed. However, given the change in hydrologic regime that is being seen from the review of historic gage data, the current lack of capacity through the existing bridge to convey the 100-year discharge (not including freeboard) this structure increases the risk of the project elements upstream or the perception of this project’s success given the natural wood loading in this river and the inability to effectively pass wood through this constriction at high flows.

4.4 Cost Estimates

The cost estimate provided in Appendix C is considered a Class 3 estimate, with the actual construction cost expected to fall between -20% and +30% of the given estimate. The estimate was based off of bids received for similar work in the region.

5 HYDRAULIC MODELING AND ANALYSIS

The purpose of the existing conditions hydraulic model is to determine the hydraulic conditions (depth, velocity, shear stress, and WSE) for existing conditions in order to evaluate existing floodplain connectivity, existing infrastructure risks, and in-channel and floodplain habitat conditions (at high and low flows) and to provide the basis for comparison with future proposed conditions hydraulic modeling (to ensure project objectives are being met). The existing conditions 2D hydraulic model was developed using the U.S. Army Corps of Engineers (USACE) Hydraulic Engineering Center's River Analysis System (HEC-RAS), version 6.6.0 (2025).

5.1 Data Used

Data used to develop the 2D hydraulic model include LiDAR, surveyed topography and bathymetry, aerial imagery, and hydrology.

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:

1. 2024 bathymetric and topographic survey data collected by Rio ASE for GRMW and ODFW for this project. Data was used to create as an AutoCAD Civil 3D surface in the North American Datum of 1983 (NAD 83), Oregon State Plane North, Intl. Foot, coordinate system. The dataset vertical datum is the North American Vertical Datum of 1988 (NAVD 88) using GEOID18. The spatial extent of this survey focused on areas that were identified in aerial imagery that had changed significantly since the LiDAR was collected in 2021.
2. 2020 topobathymetric green LiDAR data collected for GRMW by NV5 and Quantum Spatial from August 17, 2020 to September 27, 2020 (NV5, 2021). The coordinate system of the dataset is NAD83 (2011) UTM Zone 11N with linear unit in meters. The vertical datum is NAVD 88 using GEOID18. Rio ASE used ArcGIS Pro to transform the dataset to NAD 83 Idaho State Plane Central, U.S. Foot, coordinate system.

Rio ASE created a composite existing conditions terrain surface using AutoCAD Civil3D 2025 by pasting the survey and LiDAR datasets together in the order of priority as listed above. The resulting composite terrain surface has a cell size of 1 foot. All datasets were merged together to create a composite existing condition (current conditions), which was used for design and hydraulic modeling.

5.1.2 Aerial Imagery

- Drone imagery from June 3, 2025, was collected by GRMW and provided to Rio ASE for reference.
- Drone imagery from November 7, 2024, was collected by GRMW and provided to Rio ASE for reference. This imagery was used to locate structures and determine land use, vegetation type, and vegetation density to estimate Manning's n values used in the hydraulic model. Determination of the Manning's n values is discussed in detail in Section 5.2.2.

5.2 Model Development

Development of any HEC-RAS 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.

The Project area extends from approximately RM 3.1 to 5.6. The existing conditions 2D hydraulic model begins at river mile 6.1 (upstream extent) and extends downstream to river mile 2.7 (downstream extent.) Therefore,

the model domain extends well upstream and downstream of the project area to ensure accurate flow and inundation conditions at the start and end of the project area.

5.2.1 Terrain

Rio ASE created a composite existing conditions terrain surface using AutoCAD Civil 3D by pasting the survey and LiDAR datasets together in the order of priority listed in Section 5.1.1. The resulting composite terrain surface has a cell size of 1 foot and was used for existing conditions hydraulic modeling.

5.2.2 Hydraulic Roughness

Rio ASE used the high-resolution drone imagery to generate hydraulic roughness mapping for the entire model domain. Using the aerial imagery as reference, polygons were digitized based on vegetation type and other identifiable features listed in Table 5.1. Manning’s n values were assigned to each vegetation/feature type based on a combination of values used in previous modeling efforts and based on engineering judgement. The selected Manning’s n values in Table 5.1 are consistent with values published in Chow (1959) and Mays (2005).

Table 5.1. Hydraulic Model Manning’s n Values

Description	≥ 1.25-year Flow Manning’s n	Low Flow (7 cfs) Manning’s n
Channel	0.04	0.2
Gravel Road	0.03	N/A
Grassy Floodplain	0.05	N/A
Riprap	0.045	0.2
Jam	0.2	0.2
Forest	0.075	N/A

The Manning’s n values presented in Table 5.1 were used in the existing and proposed conditions models for flows at and greater than the 1.25-year flow and at low flow (7 cfs). Select Manning’s n values used in the low-flow model were adjusted based on the ratio of the modeled flow to the bankfull discharge to better correlate grain roughness to channel slope. Although the existing conditions hydraulic model is not calibrated to a known flow, inundation extent at the 1.25-year flow matches closely with drone imagery collected during runoff on June 3, 2025.

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 20-ft spacing to 3-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 ft by 20 ft. Channels or areas with high topographic complexity use a much finer mesh with variable-sided computational cells. For the mainstem Bear Creek, the model mesh contains at least 8 mesh cells representing the channel bottom and two mesh cells representing the channel banks throughout the modeled reach. For side channels in the proposed conditions, 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 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 inflow boundary
- Downstream outflow boundary

The upstream inflow boundary flow rate is different for each model run. Peak flow rates used for each model run at the upstream boundary were reduced based on contributing drainage area from Bear Creek and Little Bear Creek such that their summation is equal to the values presented in Table 3.1 for the most recent 30-year period. 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 0.0114 ft/ft, which is equal to the reach slope within 100 ft upstream and downstream of the model extent.

5.2.5 Structures

The two bridge crossings located within the project area are not defined as structures in the existing and proposed conditions 2D hydraulic models. Instead of creating one-dimensional (1D) structures, the model utilizes the LiDAR topography and surveyed bathymetry defining the bridge opening and excludes the bridge deck. This approach is problematic under existing conditions because at the 100-year recurrence interval flow, the two bridges are modeled to be under pressure flow conditions or overtopping. This analysis will be updated for existing conditions at the next design milestone. Under proposed conditions, this approach is appropriate because 100-year WSEs at the county bridge are proposed to drop with the addition of the second bridge opening, and the private bridge is proposed to be removed.

5.2.6 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 was 0.3 seconds and time steps for SWE model runs was 0.3 seconds. All other computation options and tolerances utilize HEC-RAS default settings.

5.3 Existing Conditions Model Results

Appendix B includes 2D hydraulic model results (depth, velocity, and shear stress) for existing conditions for various recurrence interval flows. Interpretations of the results are summarized as follows:

- Inundation extent (and WSE relative to existing bank heights) indicate the channel is disconnected from the floodplain throughout the project area at a near annual flow event (Table 5.2).
- Seasonal secondary channels begin to be activated at the 2-year event, but floodplain inundation remains limited.
- Depositional reaches exhibit some floodplain inundation at the 5-year event, but most reaches remain disconnected from the floodplain.
- Depth, velocity, and shear stress results indicate a lack of hydraulic variability in specific straight incised reaches of the project area, while depositional reaches exhibit good hydraulic diversity.

- There are straight, incised reaches within the project that lack floodplain connectivity. Combined with a homogenous, over-widened channel in these areas, these reaches provide little quantity and quality habitat value.
- Existing condition 100-year recurrence interval flood results show risks to flooding on Bear Creek Road adjacent to the private bridge at the downstream end of the project. These results also predict the WSE at the 100-year recurrence interval flood to be greater than the low chord of each bridge, which highlights an existing significant infrastructure risk.

5.4 Proposed Conditions Model Results

Appendix B includes 2D hydraulic model results (depth, velocity, and shear stress) for proposed conditions for various recurrence interval flows. Interpretations of the results are summarized as follows:

- Improved floodplain connectivity and inundation frequency throughout the project area at the 1.25-year flow and greater, as shown in Table 5.2.
- A comparison of existing and proposed conditions model results at the 1.25-year flow indicates improved hydraulic variability/complexity of depth and velocity and overall increased depth conditions. Figure 5-1 and Figure 5-2 show the histograms of depth and velocity for both existing and proposed conditions under the 1.25-year recurrence interval flow. The results indicate that proposed conditions have almost double the area of shallow water flooding and show increased areas of each depth bin across the board. The velocity results indicate that proposed conditions more than double the area for lower velocities 1 to 2 ft/s while reducing the area of high velocities above 7 ft/s.
- At the downstream end of the project, velocities were reduced along Bear Creek Road; however, the flooding risk to Bear Creek Road was not eliminated.
- The 100-year WSE at the existing county bridge is predicted to drop with the added conveyance of the second bridge.

Table 5.2. Existing and Proposed Conditions Inundation

Flow Recurrence Interval	Existing Inundation Area (ac)	Proposed Inundation Area (ac)	Percent Change
1.25-year	41.6	68.8	65%
5-year	64.3	93.0	45%

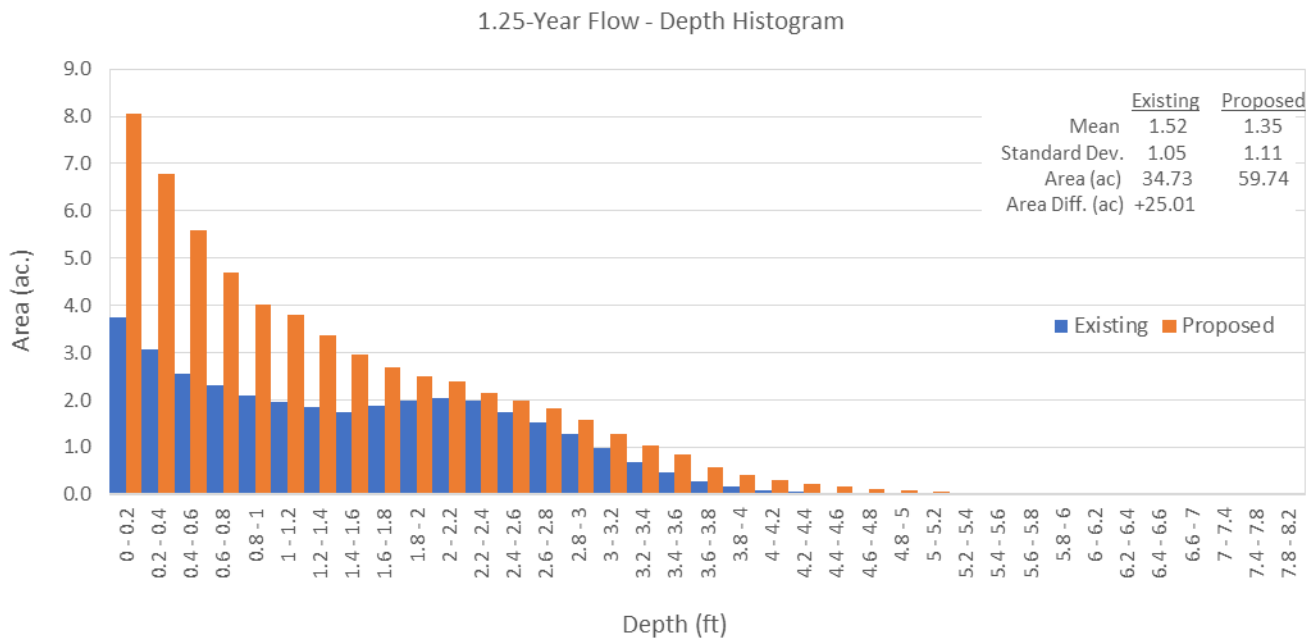


Figure 5-1. Existing conditions and proposed conditions depth histograms from 2D model results.

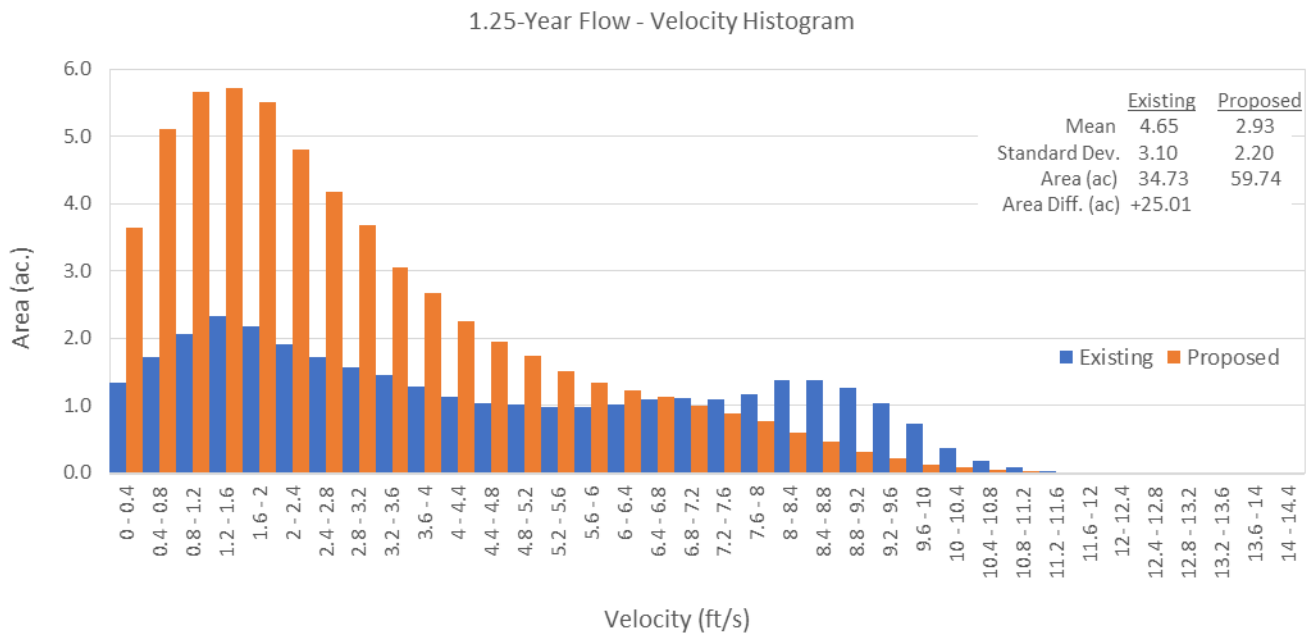


Figure 5-2. Existing conditions and proposed conditions velocity histograms from 2D model results.

5.5 Large Woody Material Risk Assessment and Design Factors of Safety

Large woody material structures are proposed in Bear Creek, seasonal side channels, and floodplain to provide roughness and habitat throughout the project area. These structures will consist of key log members that act as the skeleton of the structure, which will then be completed with the addition of woody racking material and slash. These structures are intended to emulate natural log jams; the project sponsor wishes these materials not be permanently locked or fixed in place and that pieces may move throughout the project area as flows peak.

Sawyer felled trees are proposed on Little Bear Creek and were not analyzed for stability, the relative length of the sawyer felled trees compared to the channel width along with the extremely dense riparian vegetation

indicate that there is low risk for wood to be transported down Little Bear Creek. The primary risk on Little Bear Creek is wood plugging the culvert crossing on the Little Bear Creek Saddle road.

Rio ASE analyzed perceived risk associated with large woody material using the Large Woody Materials–Risk Based Design Guidelines (Knutson & Fealko, 2014). The risk analysis for the project area estimates a low risk to public safety and a low risk to property damage. Although the proposed structures do present risks to public safety, the reach user characteristics were such that the public safety risk was determined to be low. The project is located on public land that allows restricted public access for hunting, fishing, and hiking. However there are no trails to provide access, nor is the location well known as a recreation destination. Additionally, there is no known boating presence on the creek at high flows. Snow during the winter and early spring likely precludes most recreation pressure until the summer months when flows recede further mitigating public safety risks.

The dynamic nature of Bear Creek along with the proposed wood placement do present risks for increased floodplain activation, channel avulsions, wood transport, sedimentation, and deposition, all which are primary goals of the project. Fortunately, the lack of infrastructure within and downstream of the project is such that the risks associated with the dynamic nature of the creek are low. There is one existing county bridge within the project reach which currently is at high risk of being washed out in a flood due to an under-sized opening. The project includes a new bridge to increase the opening width at the road crossing, and reduce the risks to the existing bridge. There is one cabin located within the project however it is located 4-ft above the modeled 100-yr water surface elevation. Bear Creek also runs along Bear Creek Road at the downstream end of the project. The existing conditions model shows high velocities along Bear Creek Road raising erosion potential concerns, it also shows the existing 100-yr WSE overtopping the road in one location. The proposed project reduces velocities along Bear Creek road at all peak flows, and reduces the 100-yr WSE on Bear Creek road by 0.4 ft but does not eliminate the risk. The project also eliminates shallow flooding risks to the structures on the property immediately downstream of the project while maintaining existing hydraulic conditions through both private bridges on the property.

These scorings can be seen in Figure 5-3 and are meant to be representative of the numerous structures proposed throughout the project area.

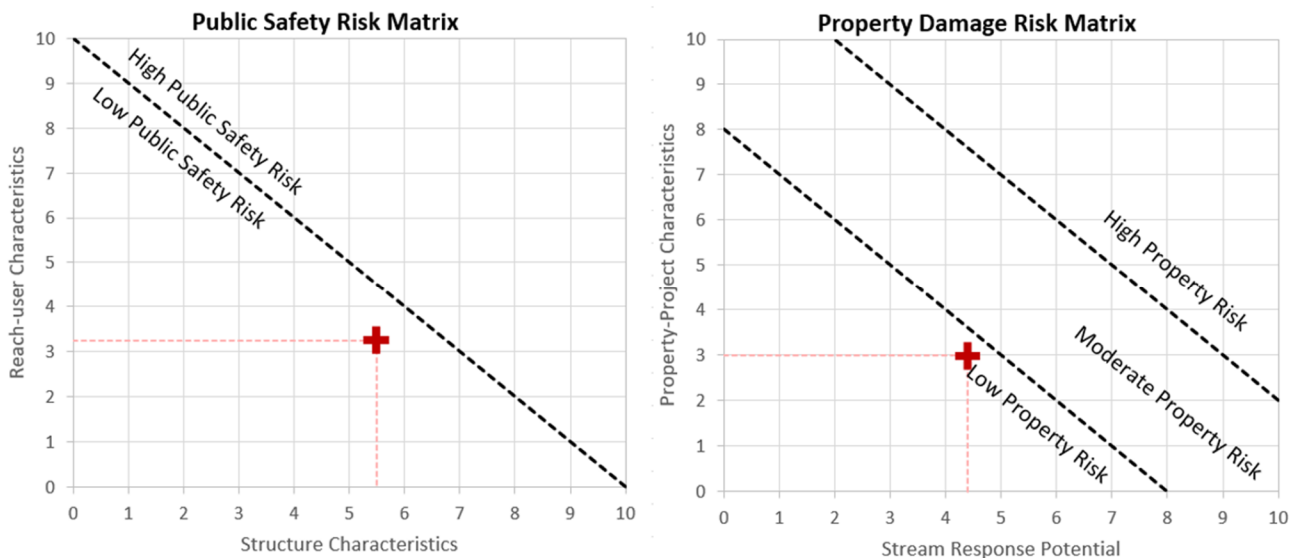


Figure 5-3. Risk evaluations for public safety and property damage.

5.6 Large Wood Stability Analysis

The October 2024 site visit illuminated the fact that annual runoff flows on Bear Creek have the potential to transport wood, create channel avulsions, and reorganize the channel morphology (Figure 3-2, Figure 3-3, Figure

3-4). The hydraulic model results validate these observations (Appendix B). However, it was also noted that the smaller, isolated jams and wood pieces found throughout the project area had little effect on beneficial channel morphology, such as the scouring of pools or the sorting of sediment. The large size of the armored bed material in Bear Creek is such that these lesser hydraulic influences aren't significant enough to initiate appreciable change. With this in mind, the design intent is to utilize the maximum size of key members practicable in the proposed structures to mitigate likelihood of the jams moving and to drive beneficial geomorphic change by way of pool formation, sediment sorting, and deposition. Furthermore, the design intent is to create large structures with significant hydraulic influence such that they are taking up 25% of the channel cross-section or more.

The size of the proposed key members is constrained by the lifting power of the available helicopter. From prior experience and discussions with contractors, it was determined that 18-inch diameter at breast height (DBH) trees of a typical length of 80 ft are the maximum size that helicopters can reasonably transport. The hydraulic model indicated that the typical bankfull depth for the Bear Creek Channel is about 3 ft with a bankfull width of about 50 ft. Plotting these tree and channel characteristics on the figure developed in Abbe & Montgomery (2003) shows that the proposed DBH plots right at the transition between key members and racked members (Figure 5-4).

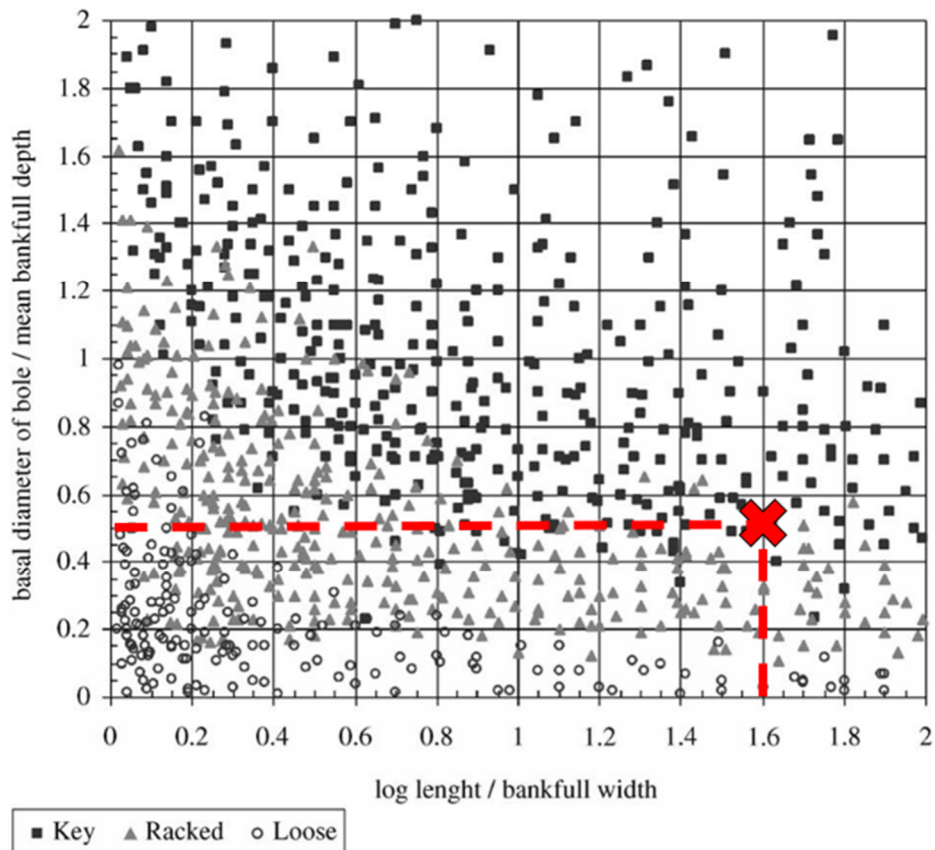


Figure 5-4: Comparison of log characteristics to channel size adapted from Abbe & Montgomery (2003).

Furthermore, large wood stability calculations were performed for all proposed large wood structures or “jams” on the project using the Large Woody Materials–Risk Based Design Guidelines (Knutson & Fealko, 2014). Given the low risk to public safety and the low risk to property damage determined for the project, Table 1 of the USBR guidelines dictates the use of a 10-year recurrence interval design flow. From Table 4 of the USBR guidelines, the minimum design factor of safety for buoyancy and sliding is 1.5 and 1.25 respectively. The results of the analysis are summarized in Table 5.3 and the full analysis is shown in Appendix G.

It should be noted that some of the structures are to be constructed using two different means of placement: by helicopter and by equipment. Helicopter-placed means that the trees will simply be laid in by the helicopter in their final configuration. With this method, there will be no heavy equipment available to maneuver the trees or ballast them with backfill. Equipment-placed structures will utilize heavy equipment to maneuver the trees into position and backfill as indicated in the drawing details. In the case of structures where helicopter and equipment placement applies, the helicopter-placed structure was analyzed for stability because it is the less stable structure compared to its equipment-placed, ballasted counterpart.

All but the Whole Tree and the Deflector Jam meet the minimum factor of safety for buoyancy. The helicopter-placed Whole Tree is a unique situation that is challenging to model—the Whole Tree must be dropped with its rootwad placed upstream of an existing tree on the bank to provide lateral bracing; however, there is nothing designed to resist buoyancy. The interaction between the rootwad of the Whole Tree and the existing vegetation on the bank is expected to provide some stability that is not accounted for in this analysis; however, it is understood by the design team that Whole Trees are at risk of mobilization under peak flow conditions as evidenced by other whole trees throughout the project reach that have been naturally recruited and transported. The Deflector Jam has a factor of safety of 1.4 for buoyancy, which is slightly below the design factor of safety requirement. However, it was determined by the design team that this was an acceptable risk factor given the project conditions.

All structures but the Collector Jam fall below the minimum factor of safety for sliding. Sliding forces are primarily resisted by the friction force of the trees against the bed and banks. The friction factor used in this equation to estimate the friction force is simply the friction factor between wood and rock, and does not take into account all of the projections of the rootwad and branches into the bed material. This simplified model of estimating sliding forces is a conservative estimate. It was determined by professional judgement and by agreement with the project sponsor that the stability risks estimated are acceptable.

Table 5.3: Summary of Large Wood Stability Analysis Factor of Safety

Structure	Configuration Analyzed	Factor of Safety Buoyancy	Factor of Safety Sliding
Whole Tree	Helicopter Placed	0.8	1.2
Channel Spanning Jam	Helicopter Placed	1.5	0.7
Deflector Jam	Helicopter Placed	1.4	0.7
Mid Channel Jam	Equipment Placed	1.8	0.8
Apex Jam	Equipment Placed	1.6	0.9
Collector Jam	Equipment Placed	3.4	1.4

Given the risks of large wood transport through the project by naturally recruited wood and project-placed wood, the design team has proposed Collector Jams, which are designed to rack and collect transported large wood. It is shown in the analysis that these jams meet factor of safety requirements for both buoyancy and sliding. In addition to their robust construction, these structures are designed to be “sticky” in the sense that they have projecting rootwads designed to rack incoming material. Furthermore, these structures are strategically located at bends where peak flows are modeled to have their momentum and velocities pushing material up onto the bank and out of the primary flow path, thereby depositing floating wood material on the floodplain and removing it from the main channel, as shown in Figure 5-5.

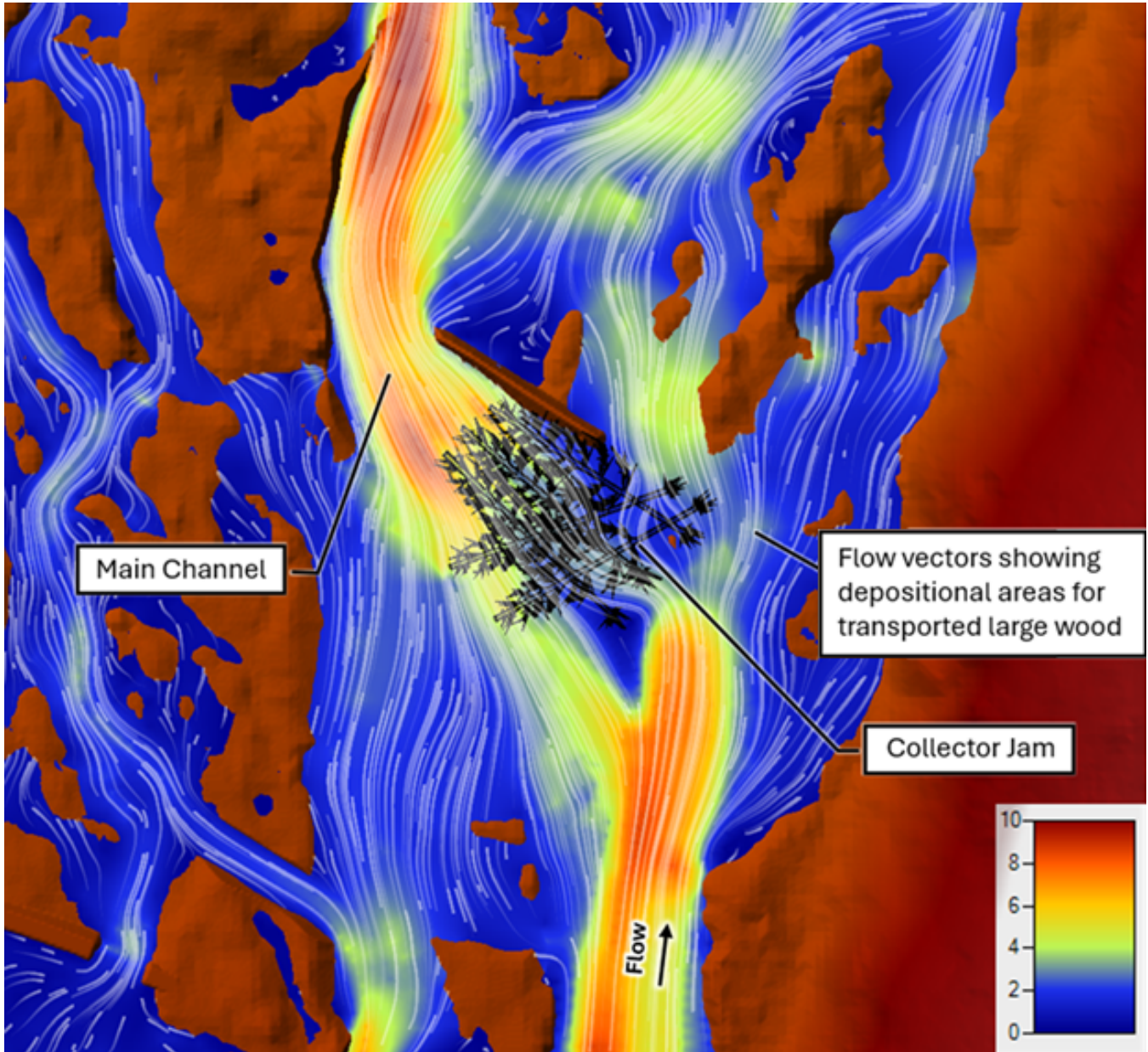


Figure 5-5: Snapshot of a Collector Jam location with velocities modeled for the 1.25-year flow shown. The velocity scale bar is in ft/s and the white lines represent flow vectors.

5.7 Constructed Riffle Stability

Proposed constructed riffles are designed to remain stable during high-flow events because these features are important to meeting project goals and objectives. Hydraulic conditions were extracted from the 2D hydraulic model (Table 5.4) at the proposed bridge location and used to develop suitable riffle material gradations. The discharge reported in the table does not reflect the entire discharge of Bear Creek (much of which is spread out over the floodplain and passing under the existing bridge), but instead the hydraulically relevant flow concentrated in the main channel.

Table 5.4. Hydraulic Properties at Representative Riffle Locations

Hydraulic Properties	Hydraulic Properties for Proposed Bridge Location
Discharge (cfs)	1,487
Max Velocity (ft/s)	10
Depth at Max Velocity (ft)	3.25
Max Shear (lb/ft ²)	3.2
Longitudinal Channel Slope (ft/ft)	0.017
Channel Bottom Width (ft)	46
Channel Bank Slope (H:V)	2
Unit Discharge (cfs/ft)	25

The hydraulic properties summarized in Table 5.4 were used to estimate stable rock sizes using numerous common equations (Federal Highway Administration [FHWA], 1989; Julien, 2010; USACE, 1994; USBR 2007), the results of which are summarized in Table 5.5.

Table 5.5. Methods Used to Estimate Stable Rock Sizes for Class-1 and Class-2 Riffle Material

Equation	Size Class	Design Material Size (in)
HEC 11 Sizing Method (FHWA, 1989)	D ₅₀	6.7
EM 1601 Sizing Method (USACE, 1994)	D ₃₀	11.8
Abt and Johnson Sizing Method (1991)	D ₅₀	14.3
Ullman Sizing Method (2000)	D ₅₀	11.6
Ferro Sizing Method (1999)	D ₅₀	8.9
Robinson et al. Sizing Method (1998)	D ₅₀	4.3
USACE Sizing Method (1994)	D ₅₀	13.5
Wittaker and Jäggi Sizing Method (1986)	D ₅₀	2.9
Incipient motion at max shear (Julien, 2010)	-	8.0
Average	D ₅₀	9.1
Selected for Design	D₅₀	10

The median rock size selected for design is 10 inches for Constructed Riffle Material. The rock size represents approximately the average of all methods. Using the median rock sizes selected for design, other size class percentiles (gradations) were generated using ratios presented in the USBR Rock Ramp Guidelines (USBR, 2007) with the goal of developing a well-graded mixture (having a good distribution of rock sizes) to optimize interlocking forces between particles. Material gradations for Constructed Riffle Material are shown in Table 5.6.

Table 5.6. Class-1 and Class-2 Riffle Material Gradations

Percent Passing	Rock Size/Diameter for Riffle Material (in)
100% (D100)	24
84% (D84)	20

Table 5.6. Class-1 and Class-2 Riffle Material Gradations

Percent Passing	Rock Size/Diameter for Riffle Material (in)
65% (D65)	16
50% (D50)	12
30% (D30)	9
16% (D16)	6
10% (D10)	0.6

It is expected that the construction contractor will be required to generate Constructed Riffle Material by screening and sorting native alluvium generated by project excavations sufficiently mixed to generate the specified gradations. Inspections of the riffle material will be conducted by a qualified engineer prior to and after placement to validate that the material is suitable.

6 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.

6.1 General Aquatic and Construction Conservation Measures

- **Timing of in-water work:** The approved in-water work window for Bear Creek is currently July 15 to August 15.
- **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.
- **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.

7 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.

7.1 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.

7.2 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.

7.3 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 events 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.

7.4 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.

7.5 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.

7.6 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.

7.7 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.

7.8 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.

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APPENDIX A DESIGN DRAWINGS

APPENDIX B HYDRAULIC MODEL RESULTS

Online Map Viewer at the link below:

<https://experience.arcgis.com/experience/89fcc1f63a8c4aacb11c09e94e5ce00e>

APPENDIX C CONSTRUCTION QUANTITIES AND COST ESTIMATE

APPENDIX D AQUATIC RESOURCES REPORT

APPENDIX E ADAPTIVE MANAGEMENT PLAN

APPENDIX F DESIGN REVIEW COMMENT TRACKING

APPENDIX G LARGE WOOD STABILITY ANALYSIS
