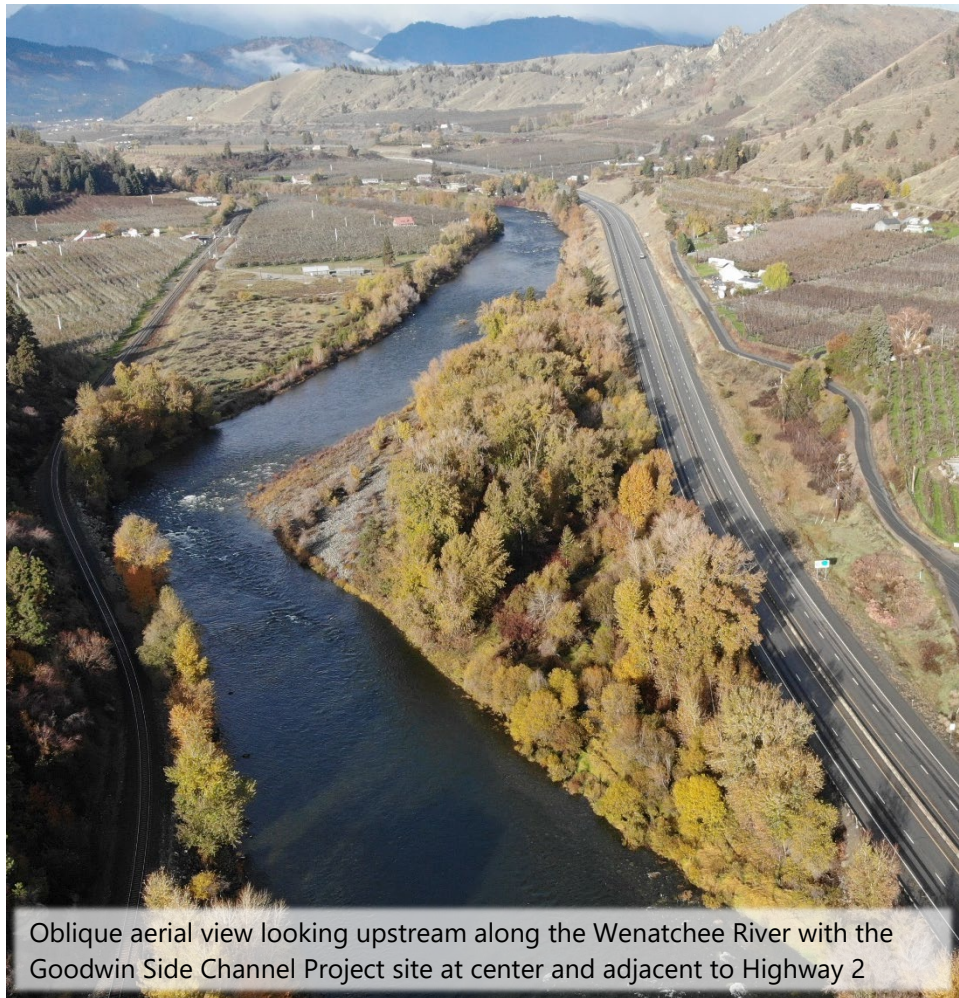


# Goodwin Side Channel Habitat Restoration Project WENATCHEE RIVER, CHELAN COUNTY, WASHINGTON

## Basis of Design Report 60% (Permit) Design



Oblique aerial view looking upstream along the Wenatchee River with the Goodwin Side Channel Project site at center and adjacent to Highway 2

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## 1.0 BACKGROUND AND INTRODUCTION

This report documents design rationale for the Goodwin Side Channel Habitat Restoration Project (Project) located near river mile (RM) 12 on the Wenatchee River, just upstream of the town of Cashmere, Chelan County, Washington (Figure 1). This basis of design report (BDR) was prepared by Wolf Water Resources (W2r) on behalf of the Cascade Columbia Fisheries Enhancement Group (Cascade Fisheries) to support this Project. The Project is funded in part by grants issued by the Bonneville Power Administration (BPA) and the Habitat Conservation Plan Tributary Committees (Tributary Committees).

Cascade Fisheries and their partners are leading efforts to restore salmonid habitat along the Wenatchee River as a priority watershed. Several of the focal fish populations are listed under the Endangered Species Act (ESA). The Project aims to address the lack of connected floodplain and off-channel habitat caused by past land uses in the Wenatchee Valley. This Project and other fish habitat improvement efforts in the watershed are guided by the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (UCSRB 2007, Cascade Fisheries 2022).

The Wenatchee River supports the greatest abundance and diversity of salmonid populations in the upper Columbia River basin. While the upper Wenatchee habitats are relatively healthy, the lower river has been significantly impacted by past and present land uses. The principal impact to fish habitat along the lower river has been floodplain encroachment from transportation, agriculture, and urban developments. These have resulted in disconnection with more than half of the historical floodplain, which has left almost zero functional off-channel habitat area in this reach (NPCC 2004, UCSRB 2007, Yakama Nation 2017). Disconnection from off-channel areas is likely exacerbated by channel incision resulting from the confined morphology imposed by the riverside developments.

The opportunity for meaningful benefit to the salmon populations is clear along the lower Wenatchee River, with its many miles of anadromous fish habitat that support federally listed threatened and endangered (T&E) spring Chinook salmon, summer steelhead, and bull trout, as well as non-listed coho and sockeye salmon (UCSRB 2007). The river reach within which the Project site is located is a high priority for salmon habitat restoration to address key limiting factors: cover-wood, off-/side-channel habitat, and floodplain connectivity (UCSRB 2007, Yakama Nation 2017).

Opportunities for restoring off-/side-channel areas along the highly constrained river corridor remain limited, however. The Project site thus represents one of the few available opportunities to address habitat limiting factors through enhancing side-channel function along the lower river and has the benefit of working with a single, public landowner: Washington Department of Transportation (WSDOT).

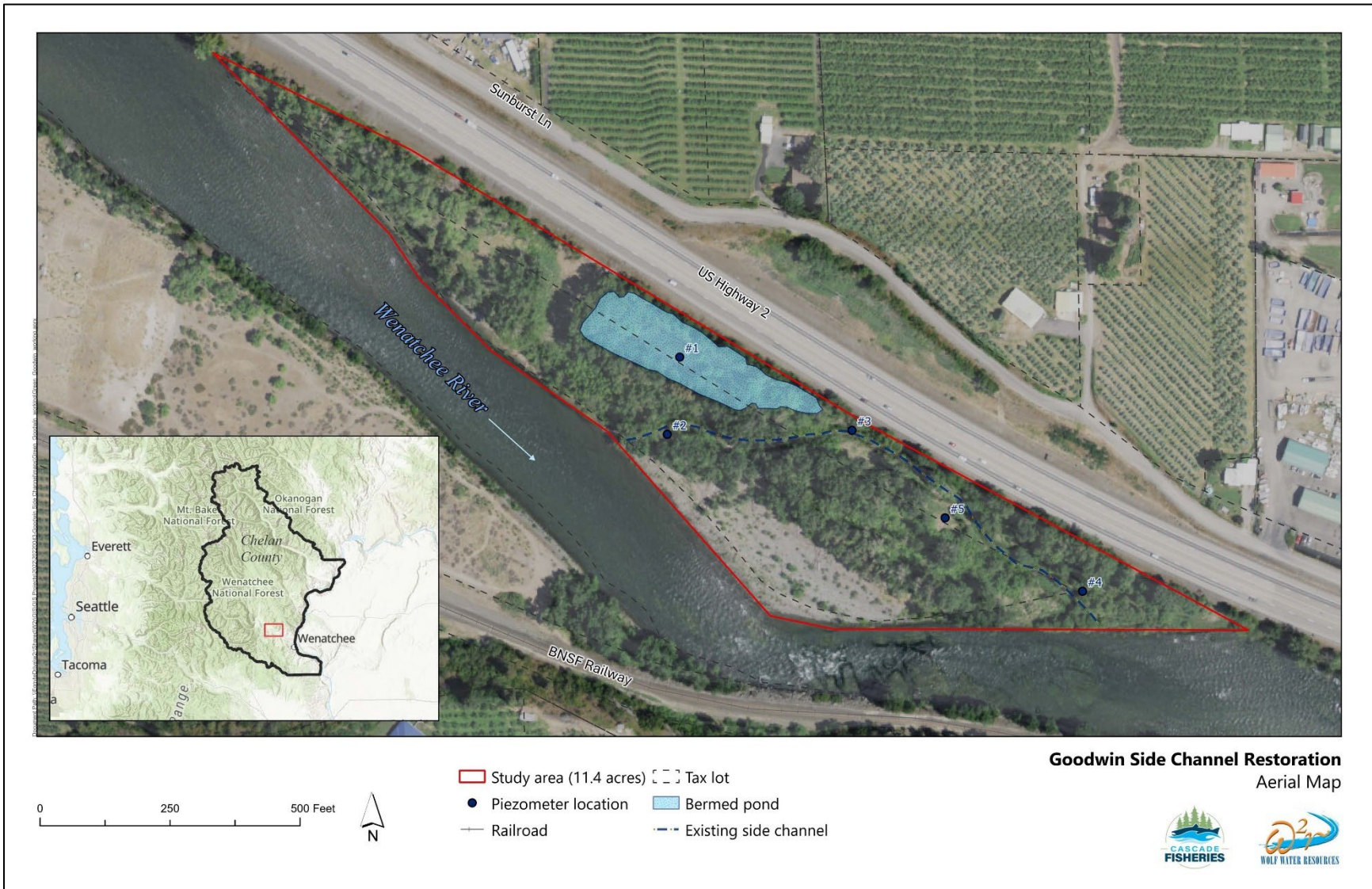


Figure 1. Overview map of the Goodwin Side Channel Habitat Restoration Project area.



Like the few other remaining floodplain fragments along the lower river, the existing 1,150-foot-long side channel through the Project area has limited ecological function to rearing and migrating fish due to its infrequent surface-water connection with the river. During the past 5 years, Cascade Fisheries has observed that the side channel connects via surface water at and above 8,000 cubic feet per second (cfs) for an average of only 36 days a year (~10% of each water year). This connection predominately occurs during the spring freshet in May and June. The side channel remains inaccessible during the critical summer and winter rearing months. A 15-month hydrology assessment recently conducted by Cascade Fisheries found that water levels in the side channel are primarily driven by groundwater inflow for most of the year (Cascade Fisheries 2022).

This report reflects the 60% design level, which follows an extensive conceptual (15% level) and preliminary (30%) design process involving several meetings with the project partners, landowner, and stakeholders. Appendix 1 includes the 60% Design Plans. This report was developed to follow the template specified by BPA's Habitat Improvement Program (HIP).

## 1.1 KEY INDIVIDUALS AND ORGANIZATIONS

**Project Sponsor:** Cascade Columbia Fisheries Enhancement Group (Cascade Fisheries)

**Project Partners:** Bonneville Power Administration (BPA) and the Habitat Conservation Plan Tributary Committees (Tributary Committees)

**Design Engineer:** Wolf Water Resources (W2r)

**Landowner:** Washington State Department of Transportation (WSDOT)

## 1.2 ABBREVIATED PROJECT HISTORY

The project has developed over multiple assessment and planning phases. The key phases in that development include:

- 2018: Cascade Fisheries proposed a design project to increase the connectivity of the existing side channel at the Project site to the Salmon Recovery Funding Board (SRFB) and the Tributary Committees.
- 2020–2021: In response to technical questions posed by SRFB and the Tributary Committees, Cascade Fisheries surveyed topographic points and monitored groundwater levels (see piezometer locations in Figure 1), water temperature, fish use, and side-channel hydrology at the site to evaluate the suitability of a habitat restoration project.
- 2022–2023: Cascade Fisheries and W2r performed site assessments, developed a suite of design alternatives, and collaboratively selected, with input received from BPA and the Tributary Committees, a “preferred alternative” concept. A copy of the Conceptual Design (15% level) report is presented in Appendix 2.
- 2024: Cascade Fisheries and W2r developed the Preliminary Design (30%) materials that were reviewed by the project partners, landowner, and stakeholders.



### 1.3 PROJECT GOALS, OBJECTIVES, AND CONSIDERATIONS

The goal of the Project is to build upon the recently completed scientific reports and habitat restoration plans to design a conceptual restoration treatment that enhances flow connectivity between the 1,150-foot-long side channel and mainstem river at the Project site. The specific design objectives are to: (1) improve rearing habitat in the side channel by increasing connection to groundwater; (2) enhance the floodplain and side channel habitat functions with the river while taking advantage of the benefits provided by groundwater inflow; (3) promote native woody vegetation cover throughout the floodplain by planting where current non-native, invasive reed canary grass patches exist and preserve existing mature native riparian forest; and (4) increase large woody material cover and habitat complexity.

A significant design consideration for the Project is to ensure boater and public safety along the river. The Project site is located within one of the most highly recreated reaches of the lower river, which includes private and commercial rafting and kayaking (Yakama Nation 2016, Elliot Consulting 2024). Thus, boater and public safety must be considered during design development. Another design consideration is avoiding impacts to U.S. Highway 97/State Route 2 that runs adjacent to the north side of the 6.3-acre Project site. The property's owner, WSDOT, will therefore be a major partner during the development and implementation of the Project. The third major design consideration is to avoid, to the extent possible, a flood-level rise related to the Project site's location within the Federal Emergency Management Agency (FEMA) floodway mapped along the lower river. The Project will therefore need to identify creative solutions to achieving a no-rise condition while coordinating early with Chelan County's Department of Community Development in preparation of the floodplain development permit.

### 1.4 FISH USE AND LIMITING FACTORS

#### 1.4.1 PRIORITY FISH SPECIES

Several anadromous fish species are known to utilize the river reach near the Project area for their life stages. These populations include federally listed T&E spring Chinook salmon, summer steelhead, and bull trout, as well as non-listed coho and sockeye salmon (UCSRB 2007, Yakama Nation 2017). The listed populations and their life history timing relative to monthly mean discharge in the lower river are described in Table 1.

**Table 1. Anadromous salmonid populations, their life history timing, and monthly mean discharge in the lower Wenatchee River.**

Population <sup>A, B</sup>	Lifestage <sup>B</sup>	Life-History Timing in the Lower River <sup>B, C</sup>											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
<i>Oncorhynchus tshawytscha</i> <b>Upper Columbia River spring-run Chinook salmon ESU</b> [Federal endangered status on March 24, 1999]	Adult immigration									■	■	■	
	Adult spawning												
	Fry/Juvenile rearing	■	■	■	■	■	■	■	■	■	■	■	■
	Juvenile emigration					■	■	■	■	■	■		
<i>Oncorhynchus mykiss</i> <b>Upper Columbia River Steelhead DPS</b> [Federal endangered status on August 18, 1997]	Adult immigration	■	■									■	■
	Adult spawning					■	■	■	■	■			
	Fry/Juvenile rearing	■	■	■	■	■	■	■	■	■	■	■	■
	Juvenile emigration					■	■	■	■	■	■		
<i>Salvelinus confluentus</i> <b>Upper Columbia River bull trout DPS</b> [Federal threatened status on June 10, 1998]	Adult immigration							■	■	■	■	■	■
	Adult spawning												
	Fry/Juvenile rearing	■	■	■	■	■	■	■	■	■	■	■	■
	Juvenile emigration												

Month	Monthly Mean Discharge (cfs)
Oct	1,000
Nov	2,500
Dec	2,000
Jan	1,800
Feb	2,000
Mar	2,500
Apr	4,000
May	8,000
Jun	8,500
Jul	4,200
Aug	1,500
Sep	1,000

<sup>A</sup> Abbreviations: ESU = evolutionary significant unit, DPS = distinct population segment  
<sup>B</sup> Information sources: UCSRB 2007, Yakama Nation 2017  
<sup>C</sup> Gray-colored cells indicate potential for lifestage presence during a portion or all of the month in a given year  
<sup>D</sup> Monthly mean discharge based on long-term daily mean discharge computed during water years 1963–2023 at the USGS gage at Monitor #12462500 (USGS 2023).

The Project is located within the Wenatchee River-Ollala Canyon Assessment Unit (Ollala 01 Reach) of the Upper Columbia Salmon Recovery Region’s prioritization scheme (UCSRB 2024). This reach is listed as a priority for steelhead restoration. Winter rearing is listed as a high priority life stage for both spring Chinook and steelhead, while summer rearing and



smolt emigration are medium priority life stages for both spring Chinook and steelhead. The highest-ranking limiting factors for this reach are bank stability, channel stability, cover-wood, off-/side-channel habitat, riparian disturbance/canopy, and water temperature. The second highest ranking limiting factors are summer baseflow, floodplain connectivity, and pool quantity and quality. Priority action categories relevant to the Project include: floodplain reconnection and off-/side-channel habitat restoration.

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#### CHINOOK SALMON

Upper Columbia spring Chinook (*Oncorhynchus tshawytscha*) are present year-round in the lower Wenatchee River (Andonaegui 2001, UCSRB 2007, Yakama Nation 2017). The Wenatchee population is classified as “very large” by the Interior Columbia Basin Technical Recovery Team, which also rated the population as “high risk” (ICTRT 2007). Spring Chinook use the lower river for rearing and migration, with juveniles rearing over the winter and emigrating the following spring (see Table 1).

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#### STEELHEAD

Steelhead (*O. mykiss*; Upper Columbia River Distinct Population Segment [DPS]) and resident rainbow trout use the lower river for spawning, rearing, and migration, as well as incubation (Andonaegui 2001, UCSRB 2007, Yakama Nation 2017). Steelhead generally up-migrate during July through the following March, spawn during February through June, and rear year-round.

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#### BULL TROUT

Bull trout (*Salvelinus confluentus*; Upper Columbia River DPS) use the lower river for rearing and migration (UCSRB 2007, Yakama Nation 2017). Bull trout adults immigrate and emigrate throughout the year, and juveniles rear year-round.

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#### 1.4.2 OTHER SPECIES

The Project reach is also utilized by several fish species that are not ESA-listed but are likely to benefit from Project actions. These species include coho salmon (*O. kisutch*), sockeye salmon (*O. nerka*), and Pacific lamprey (*Entosphenus tridentatus*) (Andonaegui 2001). However, the Project goals and objectives do not directly focus on these or any other fish and wildlife species.

## 1.5 LIST OF PRIMARY PROJECT RESTORATION FEATURES INCLUDING CONSTRUCTED OR NATURAL ELEMENTS

The following activity categories, as defined under the BPA HIP programmatic requirements and processes (BPA 2023), are potential proposed actions by the Project:

- **2a - Improve secondary channel and floodplain connectivity:** Channel and floodplain grading throughout the Project site that follows the historical side channel and floodplain topography
- **2b - Set-back or removal of existing berms, dikes, and levees:** Lowering a portion of the existing berm fill material to restore the historical floodplain surface
- **2d - Install habitat-forming instream structures:** Addition of small and large wood structures in the restored side-channel inlets and outlet
- **2e - Riparian and wetland vegetation planting:** Replanting of graded and disturbed floodplain areas throughout project area

## 1.6 DESCRIPTION OF PERFORMANCE / SUSTAINABILITY CRITERIA FOR PROJECT ELEMENTS AND ASSESSMENT OF RISK OF FAILURE TO PERFORM, RISK TO INFRASTRUCTURE, POTENTIAL CONSEQUENCES AND COMPENSATING ANALYSIS TO REDUCE UNCERTAINTY

The design and construction of the Project will incorporate the following to reduce or eliminate potential risk and consequences:

- Hydraulic modeling will assess post-project hydraulic conditions under design flow conditions to inform channel and floodplain design and assess site performance in meeting Project objectives.
- A detailed flood assessment utilizing design terrain and hydraulic modeling will be performed to ensure project meets FEMA and local floodplain management requirements.
- Wetlands will be enhanced, created, and preserved to the greatest extents possible.
- Large wood structures will be designed to withstand anticipated hydraulic forces from design flows.
- A risk assessment will be performed to assess the level of risk for proposed large wood structures, considering risk to public, property, and infrastructure. Based on the risk assessment, suitable factors of safety (FOS) will be selected to reduce any uncertainty.
- A Project monitoring and adaptive management plan (MAMP), as required by BPA's HIP process, will be developed in collaboration with Cascade Fisheries.
- No damage to infrastructure is anticipated because of this Project. Evaluation of all Project elements will ensure floodplain structures not identified for removal will not be affected because of this Project.

## 1.7 DESCRIPTION OF PROJECT DISTURBANCE RELATED TO CONSTRUCTION ACTIVITIES

At this phase of design, the Project is planned to include:

- Excavation of side-channels and floodplain and placement of excavated material elsewhere on the floodplain
- Placement of log jams/large wood at the inlet and outlet of the lower side channel
- Placement of small wood structures on the floodplain and along the restored side channels
- Revegetation of disturbed areas

Equipment will be tracked to individual grading and installation sites along temporary floodplain access routes, previously disturbed areas or within proposed grading footprints. No damage to infrastructure is anticipated because of this project. Project aerial extents include the floodplain area adjacent to the Wenatchee River as shown in the design drawings in Appendix 1. Disturbance to existing native vegetation will be minimized to the greatest extent possible. Construction of project elements below Ordinary High Water (OHW) will be carried out during the in-water work window for the Wenatchee River. Timing of excavation at the site will coincide with site hydrology.

## 1.8 REVIEW COMMENTS BY PROJECT FUNDERS

The following sets of design review comments have been received and incorporated into this 60%-level design phase. Comment and response matrixes are provided in Appendix 3.

- Tributary Committees comments on the conceptual design alternatives (meeting on March 13, 2023 and May 11, 2023)
- Tributary Committees, Upper Columbia Regional Technical Team (UCRTT), and WSDOT comments on the Conceptual Preferred Alternative (meeting with Tributary Committees on October 3, 2023 and UCRTT on November 9, 2023)
- Tributary Committees, UCRTT, and WSDOT comments on the Preliminary (30% level) design (meetings with stakeholders on April 4, 2024, UCRTT on April 10, 2024, and Tributary Committees on April 11, 2024 and August 8, 2024).

## 2.0 RESOURCE INVENTORY AND EVALUATION

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

Native Americans were the first humans to reside in the Wenatchee Valley and are thought to have first occupied the region at least 10,000 years before present (Arksey 2008). The range of the “Wenatchi” tribe’s bands extended from the Methow to the Kittitas valleys to the north and south of the Wenatchee Valley. The valley and broader area were home to the P’squosa band of the Wenatchi tribe who lived-off the traditional foods provided by the land and river: salmon and other wildlife, camas roots, and berries (Beckham 1995 as cited in Yakama Nation 2017, Arksey 2008). The Wenatchi population at the time of Euro-American settlement in the late 1700s was approximately 1,400, which rapidly declined due to epidemics and displacement by early settlers and the U.S. government. The original Wenatchi name is thought to mean “Water Gushing Out” (Arksey 2008). Today, the river bears the name of the valley’s original inhabitants.

The first Euro-American trappers in the region arrived in the early-19<sup>th</sup> century in search of beaver pelts for the burgeoning trade (Arksey 2008). This practice led to a decline in the beaver population which persists today. Since beaver can play a significant role in creating fish habitat, the loss of beaver continues to impact the creation and quality of riverine habitat (Bouwes et al. 2016, Pollock et al. 2015). Other Euro-American peoples began to settle the Wenatchee Valley for economic gains in the late 1800s (Arksey 2008). Early developments included the railroad linking Seattle to the growing town of Wenatchee, the route of which is still active today under the ownership of BNSF (see railway line located across the river from the Project site in Figure 1). Timber harvesting in the valley between Wenatchee and Leavenworth was intensive, resulting in clearing of vast stands of pine, spruce, fir, and riparian deciduous trees. Irrigation diversions and canals were constructed in the late 1800s and early 1900s to help irrigate farm fields in the valley, which since made the valley one of the top apple producers in the world. Diverting water out of the Wenatchee River and into fields, while eventually regulated in the late 20<sup>th</sup> century, reduces streamflow relative to natural rates especially in the spring through fall months when irrigation demand is greatest.

Regarding historical river conditions observed by early settlers, the “Lower Wenatchee River Reach Assessment” (Yakama Nation 2017) summarized the following:

*“An early survey of the Wenatchee watershed was completed by the U.S. General Land Office (GLO) from 1894 to 1908, covering the area from the confluence with the Columbia River to Lake Wenatchee (Beckham 1995). One of the surveyors, Charles Holcomb, described the Lower Wenatchee as ‘a beautiful stream of clear cold water running through the SW part of the township and emptying into the Columbia’ (Beckham 1995). A prior railroad survey in 1870 observed great quantities of salmon in the*



*Wenatchee River near the mouth of Tumwater Canyon, and concluded that the valley would be remarkably favorable for construction (Northwest Discovery 1981)."*

Completed in the 1940s, U.S. Highway 2 runs the length of the Wenatchee Valley along its journey between Washington and Michigan. Near the Project site, Highway 2 travels together with U.S. Highway 97 along the north side of the river. The highway was widened to four lanes and shifted closer to the river in the late 1950s and early 1960s which encroached upon a part of the lower-lying floodplain at the Project site thereby reducing the amount of off-channel habitat for fish and wildlife.

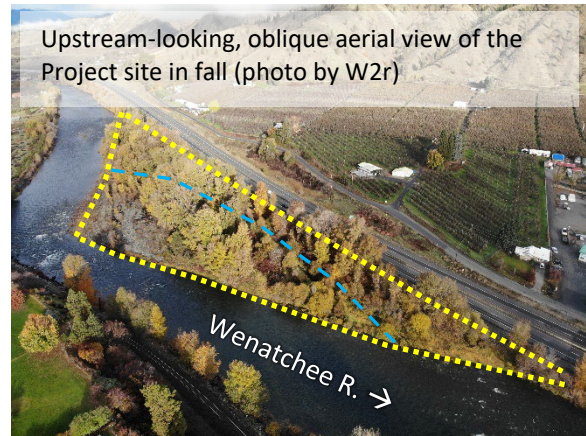
## 2.2 DESCRIPTION OF EXISTING GEOMORPHIC CONDITIONS AND CONSTRAINTS ON PHYSICAL PROCESSES

Cascade Fisheries and W2r visited the Project site together in December 2022 and November 2023 for site reconnaissance, topographic survey, geomorphic assessment, wetland determination, and restoration design evaluation. The field data were synthesized with desktop reviews of available information sources to increase understanding of the site's current conditions and inform design alternatives.

### 2.2.1 PHYSICAL SETTING

The Wenatchee River watershed consists of approximately 1,330 square miles of varied terrain draining the east side of the Northern Cascade Range. The river and its major tributaries originate in the high Cascades at elevations exceeding 7,000 feet, coalesce at the head of the Wenatchee Valley near the town of Leavenworth at river-mile (RM) 24, and follow a sinuous but confined course through the valley developed with transportation, agriculture, and urban centers before discharging into the Columbia River near the town of Wenatchee at 620 feet elevation. Flow in this part of the Columbia River is impounded by Rock Island Dam, which creates a backwater influence on the lower few miles of the Wenatchee River. There are no major dams in the upper Wenatchee River basin regulating river flow in the lower river, but several diversions serving local irrigation are present, the largest being at Dryden Dam near RM 18, which together influence river discharge during the irrigation season.

The 6.3-acre Project site is located on the lower Wenatchee River near the town of Cashmere approximately 12 river-miles upstream from the river's confluence with the Columbia River (Figure 1). The site consists of a sand-gravel-cobble point bar unit situated between the active river channel and the highway. A 1,150-foot-long side channel with limited surface-water connectivity courses through the site. The site also hosts a riparian forest community composed primarily of mature deciduous trees and shrubs. Large woody materials and coarse sediment have accumulated at the inlet to the side channel and in several points along the side channel's course. Patches of non-native, invasive reed canary grass are also present across the site. Photos of the site are presented in Figure 2.



**Figure 2. Photos of the Project site and its existing side channel during different seasons.**

Infrastructure on the site is limited to a ~1-acre bermed pond and several highway runoff culvert outlets emerging from the highway embankment. Communications between Cascade Fisheries and WSDOT regarding the history and ongoing maintenance of these features have revealed that the bermed pond was likely created when the highway was originally built during 1957–1963 but may no longer serve any purpose. It is assumed that the pond is an excavation of fill material placed during either highway construction or pre-highway farming. Cascade Fisheries has observed the pond seasonally fills with water in response to precipitation, groundwater inflow, and highway-embankment runoff, but there does not appear to be any piped inflow to or outflow from the pond. The highway-embankment culverts have been observed by Cascade Fisheries to discharge modest amounts of water to the site episodically in response to rainfall, though most outlets appear to be poorly maintained and may no longer function as originally intended.

The site may be accessed via the adjacent U.S. Highway 2 by vehicle or on-foot, or via the river by a shallow-draft boat. Directly across the river from the Project site along the right



bank runs a freight railway operated by BNSF Railway. This segment of the right bank, like much of the banks along the lower river, is armored with rock revetment to hinder erosion and lateral migration—ecologically valuable processes that once occurred prior to settlement in the valley.

Land uses in the immediate vicinity of the Project area include transportation (e.g., highways, surface streets, and railways), agriculture (e.g., row crops and grazing), and urban development (e.g., low-density housing and commercial facilities). Boating recreation is popular along the lower river, which includes rafting, kayaking, and tube-floating by the general public, as well as commercial rafting companies. The “Turkey Shoot” river feature used seasonally by recreational boaters is located on river left approximately 1,000 feet upstream of the Project area (Elliot Consulting 2024; see Appendix 4).

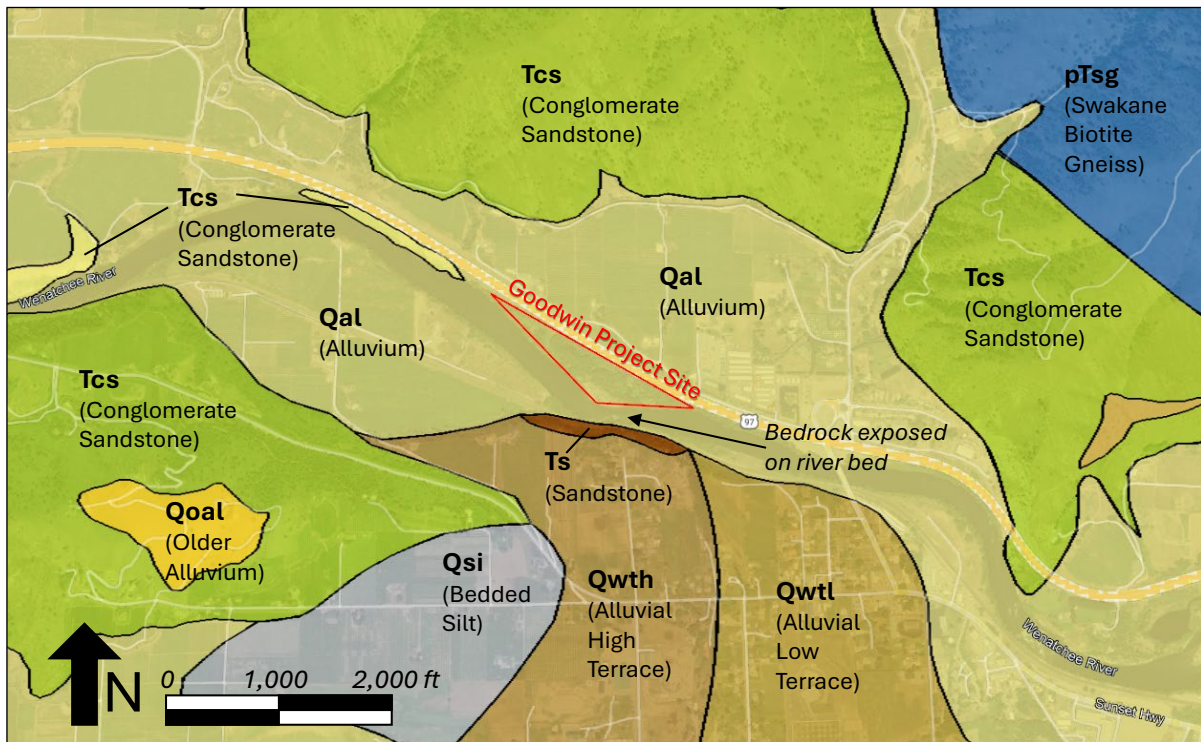
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### 2.2.2 GEOLOGIC SETTING

The Wenatchee River watershed lies on the eastern flank of the Northern Cascades and has a complex geologic history that formed the valley as a depositional basin composed of erosive alluvial sediments bordered by mountains composed of less erosive igneous, metamorphic, and sedimentary rocks (Haugerud and Tabor 2009). The valley lies within the structural setting of the Chiwaukum Graben—a down-dropped block of bedrock bounded by faults that formed approximately 30 to 50 million years ago (Johnson 1984).

During the Pleistocene epoch, alpine glaciers extended from the Cascade Mountains into the valley. The glaciers episodically retreated during the late Pleistocene and early Holocene epochs; the retreating glaciers left behind large moraine deposits near Leavenworth (Haugerud and Tabor 2009). Coincident with this period were the glacial outbursts of the Missoula Floods that inundated much of the Columbia Basin (Bretz 1969, O’Connor et al. 2020). These megafloods created a backwater effect up into the Wenatchee Valley that deposited vast amounts of sediment. For the past 10,000 years or so, the Wenatchee River has eroded through the glacial deposits, with discrete downcutting events forming remnant terrace surfaces that now lie some 100 to 200-feet above the present-day river course.

Geologic mapping in the Wenatchee Valley shows the active river corridor and the Project area consists of alluvium composed of moderately sorted sands, gravels, and cobbles (Whetten and Waitt 1978, Whetten 1980, Tabor et al. 2006, WGS 2022) (Figure 3). The mapping shows the alluvium layer is underlain by continental sedimentary bedrock of the Chumstick Formation, which is composed of sandstone, shale, and conglomerate materials.



**Figure 3. Geologic map of the Project area and vicinity (adapted from Whetten and Waitt 1978, Whetten 1980, Tabor et al. 2006, WGS 2022).**

According to well-construction logs on file with Department of Ecology (Ecology 2024) for wells installed in the valley north and south of the Project site, alluvial materials were observed extending down to approximately 40–60 feet below ground surface before contacting sandstone bedrock of the Chumstick Formation. While the precision of the well locations was reported only to the quarter section, the wells’ approximate locations upon the farmed portions of the valley suggest most were situated on ground levels lying approximately 20–30 feet above the riverbed and the Project site. This approximate difference in surface elevations indicates the depth to bedrock below the Project site’s floodplain surface could be approximately 10–20 feet. An exposure of sandstone bedrock is present along the river’s thalweg near the downstream end of the Project site (see unit “Ts” in Figure 3 above and the bedrock exposure visible in Figure 5 below), which has a top elevation of approximately 799 feet NAVD88. For reference, the bottom elevations of the bermed pond and the closest portion of the existing side channel to the bedrock exposure are approximately 805 feet and 803 feet NAVD88, respectively. The difference in these elevations suggests that the depth to bedrock below the existing side channel could be at least 4 to 6 feet from the surface. This assumption that bedrock is no shallower than approximately 5 feet from the bottom of the existing side channel is further supported by the absence of shallow bedrock encountered when Cascade Fisheries installed their piezometers in the side channel to depths of approximately 4.5 feet.

### 2.2.3 GENERAL GEOMORPHIC CHARACTER

The lower Wenatchee River has adjusted to influences from the last ice age by downcutting through massive deposits of alpine glacier sediments originating from the Cascade Mountains and glacial-outwash deposits from the Missoula Floods. Currently, the river corridor exhibits an entrenched morphology inset within the valley floor and bordered by relic high terraces. The “Lower Wenatchee River Reach Assessment” conducted for Yakama Nation Fisheries (2017) described the river reach within which the Project site is located—Reach 5 spanning RMs 10.8–13.25—as follows (see Table 2 for reach characteristics):

*“Most of Reach 5 is naturally confined by bedrock outcrops and high terraces. The BNSF Railway and U.S. Highway 2 [Highway 97], which both parallel the river in parts of the reach, further confine the channel. The amount of armored banks is relatively high in this reach. Side channels and off-channel habitat are relatively limited in Reach 5 including previous restoration actions. There are no islands in Reach 5 and sediment storage in bars is relatively limited. Floodplain connectivity in Reach 5 is less than in adjacent upstream and downstream reaches. Exposed bedrock on the channel bed is more abundant in this reach than downstream reaches and floodplain areas are limited to isolated pockets in Reach 5 and are small relative to downstream reaches.”*

**Table 2. Geomorphic characteristics of the Project reach.**

Gradient	Average Bankfull Width (ft)	Average Floodplain Width (ft)	Proportion of Connected Floodplain	Bed Sediment Size Classes by Proportion of Channel Area	Large Woody Materials (pieces/mile)	Channel Units by Proportion of Channel Area	Off-Channel Habitat
0.43%	237	513	46%	Sand (7%), Gravel (11%), Cobble (43%), Boulder (21%), Bedrock (18%)	0	Pool (17%), Glide (27%), Riffle (47%), Rapid (9%)	0%

Information source: Table 4-6 in Yakama Nation (2017).

The river follows a single-thread, meandering course through the valley. Between Dryden Dam at RM 17.5 and the confluence with the Columbia River, which includes the Project site at RM 12, the river descends along a subtle concave-up profile with an average gradient of approximately 0.4% (Figure 4). Within this reach, the river’s longitudinal profile lacks any notable vertical drops or rises that could be indicative of discontinuities in sediment conveyance.

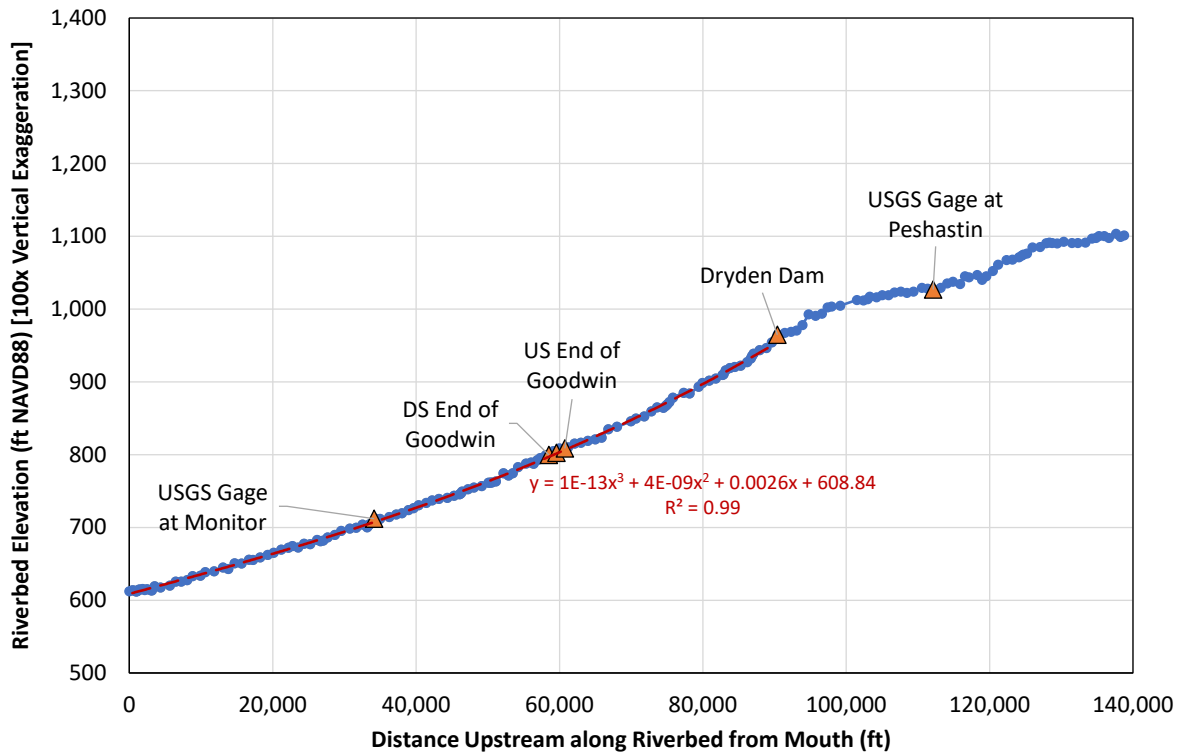


Figure 4. Longitudinal profile of the Wenatchee River between RM 0 and 26.

River-floodplain surfaces were characterized by W2r at the Project reach through development of a “height above water surface” (HAWS) map (Figure 5). W2r produced the mapping in a geographical information system (GIS) environment using Bureau of Reclamation’s 2022 topo-bathymetric Lidar dataset (NV5 2023). The HAWS map depicts the topographic features below and above a water surface elevation associated with the 1.5-year flood recurrence period (~14,770 cfs; see Section 4.5 Hydrology for hydrological information). The principal features evident in the map are the river channel and its bar-pool-glide units, existing side channel, floodplain, man-made bermed pond, and highway embankment.

The active channel bed and bars at and immediately adjacent to the Project site are composed of a surficial, armor layer of gravelly cobbles ( $D_{50} \approx 50\text{--}200\text{ mm}$  [~2–8 in.]) overlaying a subsurface layer of sandy gravels ( $D_{50} \approx 2\text{--}50\text{ mm}$  [~0.08–2 in.]) based on field observations made by W2r in November 2023. Farther back from the active river margin, sands and silts with some organics compose the floodplain soils where riparian vegetation has established and woody material has accumulated. As discussed above in 2.2.2 Geologic Setting, bedrock is not exposed at the Project site but is assumed to lie approximately 5 feet or deeper below the lowest portions of the ground surface and existing side channel.

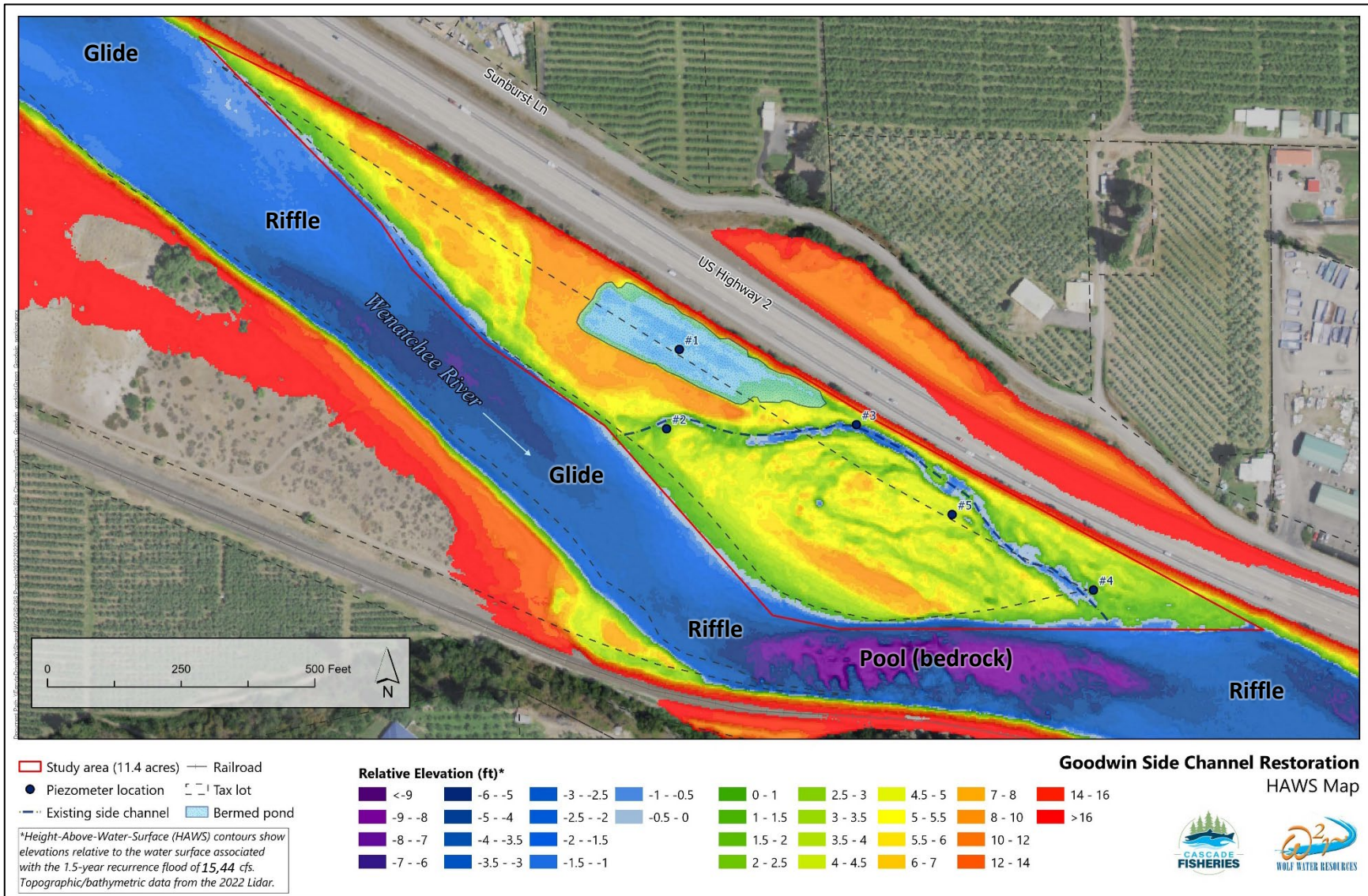


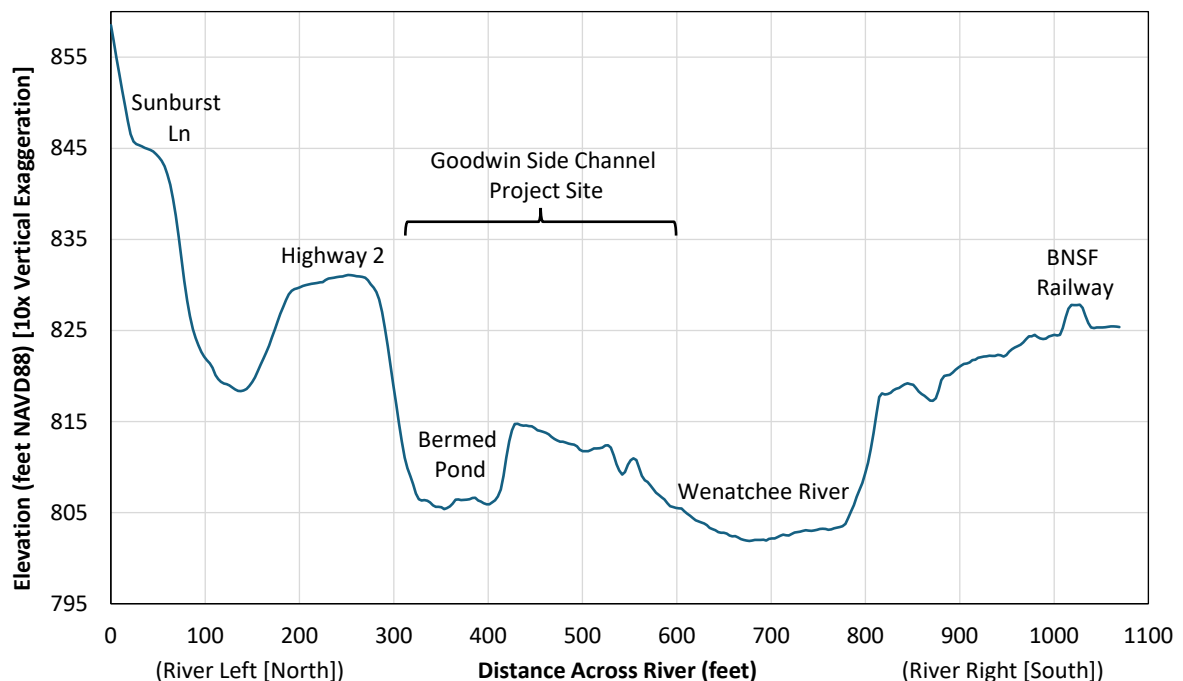
Figure 5. Height-Above-Water-Surface (HAWS) map depicting existing conditions at the Goodwin Side Channel Project area.

The lower Wenatchee River is still responding to legacy effects from historical timber harvesting of upland and valley forests (Beckham 1995). W2r’s field surveys in 2022 and 2023 confirmed findings from past surveys (see Table 2) that the lower river contains very few large wood pieces and almost no jams. At the Project site, there are several small wood jams along the existing side channel. The wood jam in the inlet to the side channel effectively diminishes inflow from the river during the spring freshet. Other local wood appears to be sourced from the mature conifer and deciduous trees onsite.

#### 2.2.4 REACH-SCALE DYNAMICS AND NEAR-TERM TRAJECTORY

Surface-water connectivity between the river and the existing side channel has reportedly become diminished because of the accumulation of wood debris and sediment at the side-channel inlet, and encroachment of non-native, invasive riparian vegetation (and associated increase in hydraulic roughness) along the existing side channel. The degree to which the river has continued to down-cut relative to its floodplain since the last glacial period is unknown due to a lack of empirical evidence. However, the lower river’s sediment-transport regime is known to be supply limited compared to the upper reaches (Nelson 1973), which suggests the lower river above the influence of the Columbia River backwater would more likely exhibit net degradation, resulting in continued down-cutting of stored alluvial materials until reaching bedrock, rather than exhibiting net aggradation.

A cross-sectional view of the Wenatchee River at the Project site presented in Figure 6 illustrates the entrenched morphology of the river corridor.



**Figure 6. Cross-sectional profile of the Wenatchee River at the Project site showing the entrenched morphology of the river corridor and other site features including the bermed pond.**



Based on review of recent aerial imagery, the active channel position of the Wenatchee River has been nearly static during the past several decades (Figure 7). Specifically, this reach has experienced minimal planform adjustment and no avulsion events have occurred since the oldest aerial imagery was collected in the 1940s or topographic maps were drafted in the early 1900s. This static condition appears to be due to the entrenchment of the active river corridor resulting from: (1) the natural, episodic downcutting processes in the valley following the last ice age; and (2) the highway and railway with riprap-enforced embankments along the river margins. The position of the gravel bars, riffles, glides, and pools within the active river corridor have also remained relatively static in recent years, though some flood-induced minor adjustments in their longitudinal position and elevation are apparent in the aerial imagery. The only significant change to the site topography in recent decades was the construction of Highway 2 in the early 1960s which added fill to the floodplain along its path, including creation of the bermed-pond feature.

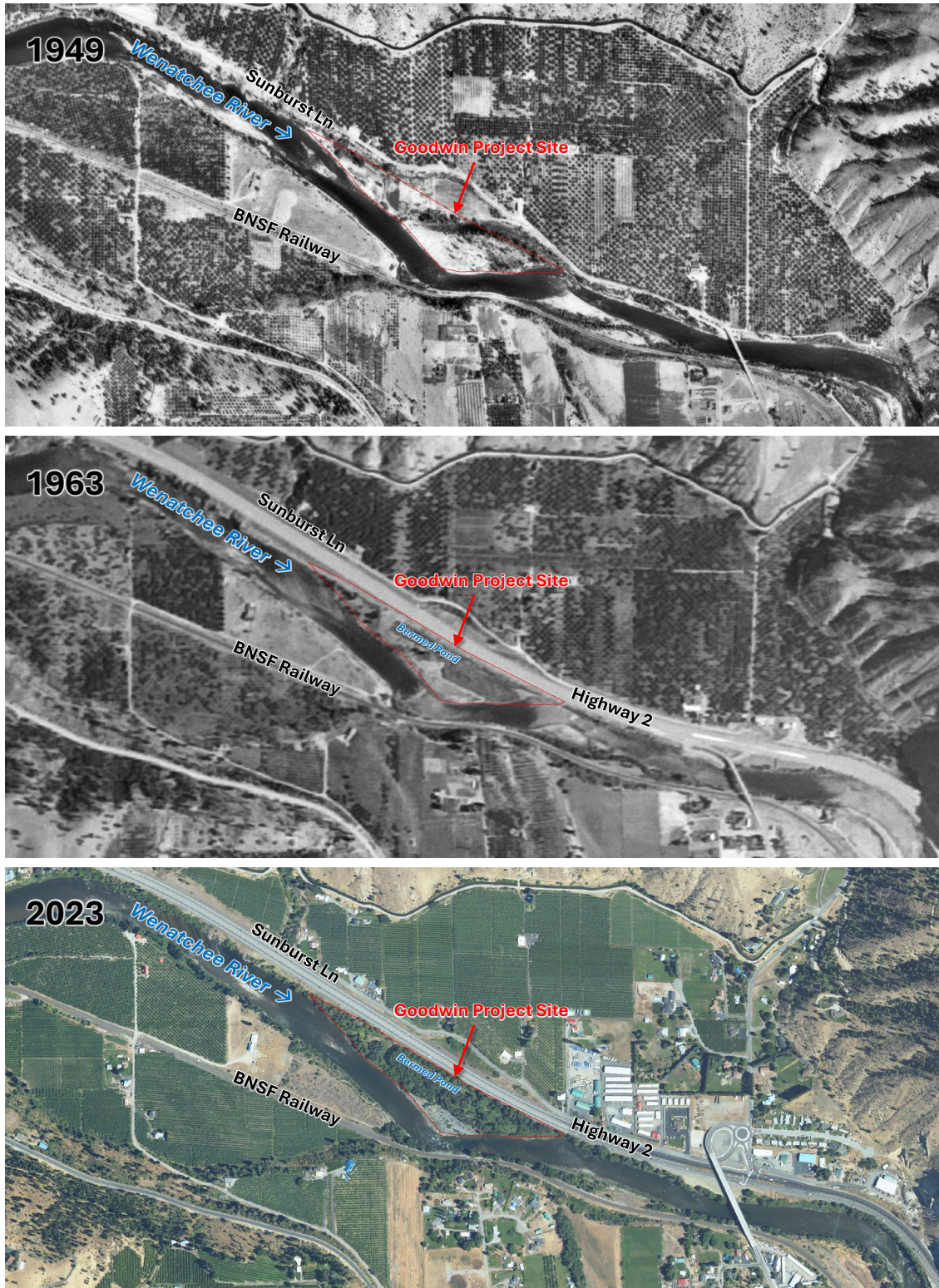


Figure 7. Repeat views of the Project site from historical aerial imagery collected in 1949, 1963, and 2023 showing the near-static river morphology over time.

### 2.2.5 SUMMARY OF GEOMORPHIC CONDITIONS WITH RESPECT TO STREAM RECOVERY

Most of the lower Wenatchee River is in a relatively arrested state due primarily to the encroachment of the highway and railway along the river margins. The few remaining off-channel areas and pockets of floodplain along the river, like the small floodplain area at the Project site, will continue to be rare while these encroachments exist. Further, without deliberate reconnection of off-/side-channel areas and floodplain segments with the active river, the availability of aquatic and riparian habitat types to salmonids and other wildlife will continue to be limited along the lower river. Therefore, restoration concepts at the Project site, which hosts one of the few remaining floodplain areas along the lower river, needs to enhance side-channel connectivity with the active channel to route higher flows during the spring freshet, disperse flows across the floodplain, promote large wood and native vegetation recruitment, and host productive off-channel habitat for fish and wildlife.

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

Riparian vegetation communities at the Project site have changed primarily in response to past land uses. Historical records show the Project site supported a rich mosaic of deciduous and conifer trees, shrubs, herbaceous cover prior to Euro-American settlement in the Wenatchee Valley (Andonaegui 2001, Yakama Nation 2017). In the early 20th century, parts of the site had been cleared and farmed, while other parts appeared to retain a natural assemblage of riparian vegetation communities (see top photo in Figure 7). Presently, the site's vegetation cover appears denser than during the past century, which presumably resulted from the absence of farming on the site after Highway 2 was constructed along with the diminished influence from flood-resetting events due to continued river channel confinement.

Native vegetation found on the Project site during the November 2023 field survey included black cottonwood (*Populus trichocarpa*), Douglas fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*), peach-leaved willow (*Salix amygdaloides*), grey alder (*Alnus incana*), red twig (redosier) dogwood (*Cornus sericea*), tall Oregon grape (*Berberis aquifolium*), western serviceberry (*Amelanchier alnifolia*), Douglas hawthorn (*Crataegus douglasii*), spreading dogbane (*Apocynum androsaemifolium*), false Solomon's seal (*Maianthemum racemosum*), and bluebunch wheatgrass (*Pseudoroegneria spicata*).

Non-native vegetation at the Project site includes Siberian elm (*Ulmus pumila*), black locust (*Robinia pseudoacacia*), and reed canary grass (*Phalaris arundinacea*).

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

Lateral connectivity was described above in Section 2.1 Description of Past and Present Impacts on Channel, Riparian, and Floodplain Conditions and Section 2.2 Description of Existing Geomorphic Conditions and Constraints on Physical processes.

### 3.0 ALTERNATIVES ANALYSIS (15% DESIGN)

This section summarizes the alternatives analysis process that was completed during the conceptual design (15% level) phase. Attached as Appendix 2 is the Conceptual Design Report from August 2023 that presents a detailed summary of the alternatives process including concept drawings of the considered alternatives and the selected preferred alternative.

#### 3.1 ALTERNATIVES ANALYSIS

W2r on behalf of Cascade Fisheries developed three conceptual restoration design alternatives all focused on achieving the Project goals by enhancing the hydraulic and ecologic functions of the existing side channel and floodplain area. Several key questions and design approaches arose during initial planning discussions that involved participation from representatives of the Tributary Committees (Figure 8).

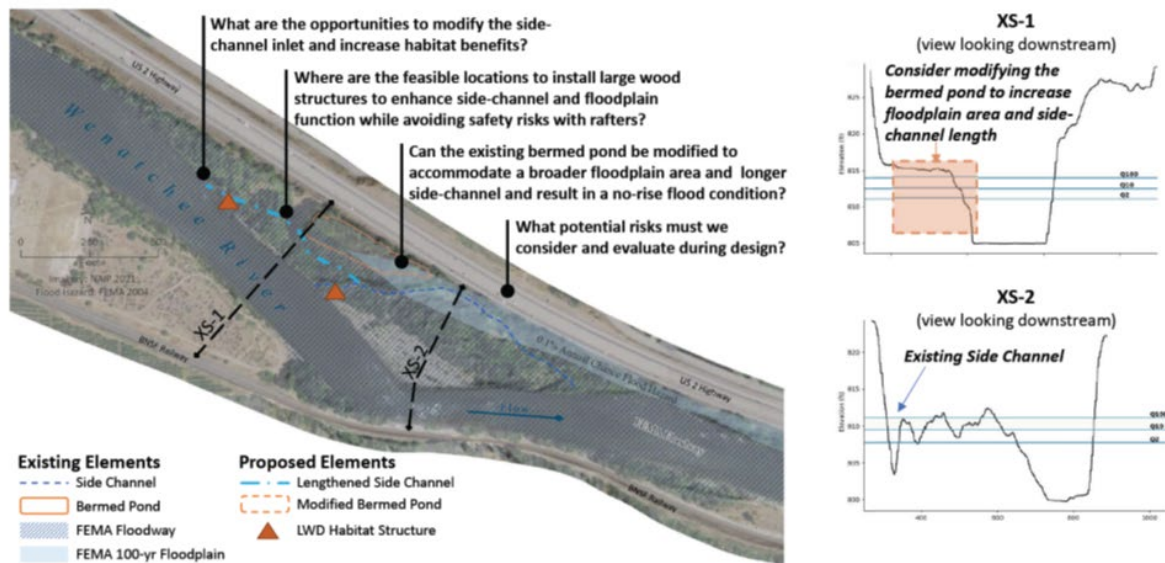


Figure 8. Initial restoration design concept questions and approaches depicted visually at the Project site.

Three design alternatives were developed that spanned a spectrum of design and implementation complexities and associated ecological benefits to the focal fish species. The design elements were additive from Alternative 1 through Alternative 3, where the simplest design elements were presented as part of Alternative 1, moderate design elements were presented as Alternative 2, and the more complex design elements were presented as Alternative 3. The details of the alternatives are as follows:

- Alternative 1—focus on enhancing the existing side channel with (1) grading side channel inlet and outlet to increase seasonal flow connectivity with the mainstem; (2) installing large wood habitat structures (WHS) at a density of approximately 1

- structure per 100 feet of side channel; and (3) plant riparian trees along the side channel banks to enhance native vegetation cover and future large wood supply.
- Alternative 2—same as Alternative 1 and with (1) lightly grading floodplain area to enhance connection with side channel flows; (2) spot grade side channel and other connected floodplain depressions to deepen existing pools and enhance summer refugia habitat; (3) increasing large (WHS) placement at 1 structure per 50 feet of side channel; and (4) installing an engineered log jam (ELJ) at the side-channel inlet to stabilize the inlet and further enhance instream habitat.
  - Alternative 3—same as Alternative 2 and with (1) removing portions of bermed pond to expand connected floodplain (and creating a modified setback berm closer to the highway embankment with the excavated material); (2) creating a new side-channel branch on the upstream side to increase the overall side-channel length and floodplain connectivity; (3) installing large WHS along the extended side channel; (4) installing ELJs at the inlet of the extended side channel and at the outlet of the main side channel; and (5) installing willow floodplain fencing areas.

### 3.2 ALTERNATIVES EVALUATION AND SELECTION

The three alternatives were evaluated through a semi-quantitative process by which key hydrologic, habitat-benefit, and constructability metrics were identified and formatted in a screening matrix. The anticipated responses of each metric to each alternative were described based on changes in site dimensions or quality. Each cell in the matrix was then assigned a “relative-ranking score” based on the anticipated benefit of that alternative’s metric relative to existing conditions as either enhanced, neutral, or diminished.

The three alternative design concepts and their relative-scoring matrices were presented to the Tributary Committees and BPA for their review and selection of a preferred alternative. The reviewers raised questions regarding ecological benefits, long-term sustainability, sedimentation potential, boater safety, and construction costs. Cascade Fisheries with technical support from W2r worked collaboratively with the reviewers to select the preferred alternative. Cascade Fisheries and the reviewers ultimately selected Alternative 3 as the preferred alternative.

### 3.3 DESCRIPTION OF THE PREFERRED ALTERNATIVE

W2r developed a 15% (concept level) design package on behalf of Cascade Fisheries for the selected preferred alternative (Alternative 3). Concept design is conceptual in nature as it presents big picture ideas with the goal of conveying the primary restoration approach to Project partners and stakeholders. The design package was therefore structured to align with the review and comment process with BPA and Tributary Committees.

The major elements of the preferred alternative as represented in the 15% concept design, as shown in Figure 9, include the following features:

- grading the existing side channel inlet and outlet to increase seasonal flow connectivity with the mainstem;



- creating a new 1,100-foot-long side-channel branch on the upstream side of the site to increase the overall side-channel length and floodplain connectivity;
- removing portions of the bermed pond and adjacent fill material to expand connected floodplain (and creating a modified setback berm closer to the highway embankment with the excavated material);
- lightly grading floodplain area near the side channels to enhance connection with side-channel flows;
- spot grade side channel and other connected floodplain depressions to deepen existing pools and enhance summer refugia habitat;
- installing ELJs at the inlets of the existing and extended side channels, and at the outlet of the main side channel; however, this design feature was refined since the preliminary design phase (30% level) following additional discussions with the UCRTT and Tributary Committees and incorporation of recommendations made in the Project's recreational user impact study prepared by Elliott Consulting (2024) on behalf of Cascade Fisheries (see details in Section 4.1.3 Category 2D—Install Habitat-Forming Instream Structures);
- installing large wood habitat structures (WHS) at a density of approximately 1 structure per 50 feet along the side channels;
- installing willow floodplain fencing areas; and
- planting riparian trees along the side-channel banks to enhance native vegetation cover and future large wood supply.

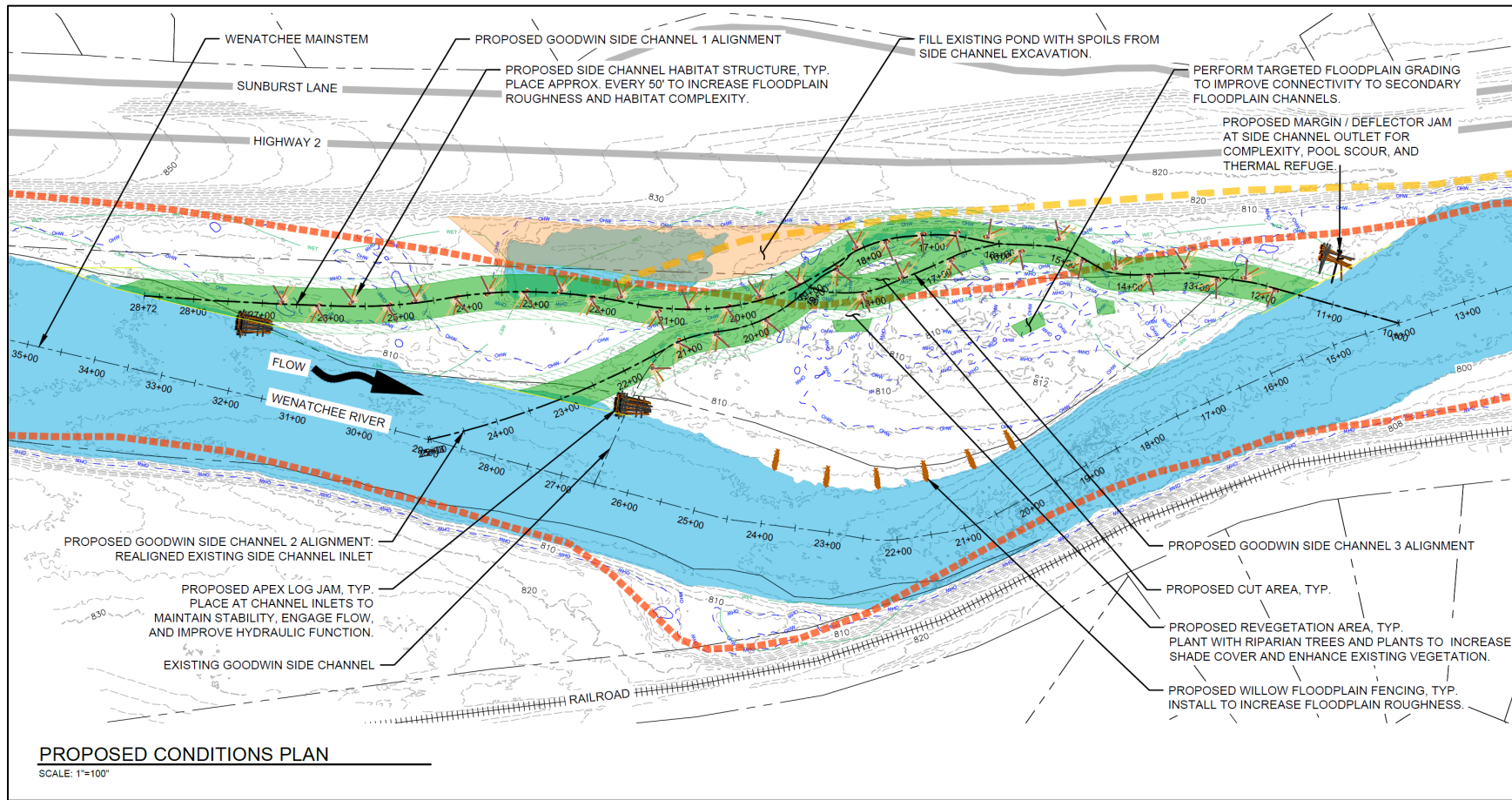


Figure 9. Excerpt of the preferred alternative (15%) plan as developed in August 2023.

## 4.0 TECHNICAL DATA AND DESIGN

### 4.1 DESIGN PROGRESSSION

The design progression from 15% (conceptual level) to 30% (preliminary level) involved detail addition to the preferred alternative (15%), additional funder and stakeholder discussions, field visits, and analyses.

The design progression from 30% to 60% involved additional review, response, and revision based on: Tributary Committees, UCRTT, WSDOT, and other review agency comments (see Appendix 3); recreation study by Elliot Consulting (2024) (see Appendix 4); field visits; hydraulic modeling; permit considerations and preliminary discussions with permitting agencies (e.g., Ecology, Chelan County); and refined design and grading. In addition to stakeholder feedback, much of the grading revisions were driven by the goal of balancing cut and fill volumes while minimizing wetland impacts, avoiding recreation risks, and satisfying the no-rise standard. The more significant changes to project elements included:

- Replacement of the ELJ in the inlet to the new side channel at the upstream end of the site with a lower-lying rock structure to minimize recreation risks while maintaining hydraulics necessary for sustaining the side channel;
- Expanded floodplain grading along the new side channel to enhance floodplain connectivity and rearing habitat, and satisfy the no-rise standard;
- Placement of fill materials along a greater extent of the highway embankment to better balance earthwork quantities, avoid offsite hauling, enhance slope stability, and minimize wetland impacts; and
- Addition of a floodplain backwater-alcove feature upstream of the side-channel outlet to enhance cold-water habitat for rearing juvenile and holding adult fish.

An excerpt of the 60% design layout is presented in Figure 10. The detailed engineering design drawings are presented in Appendix 1.

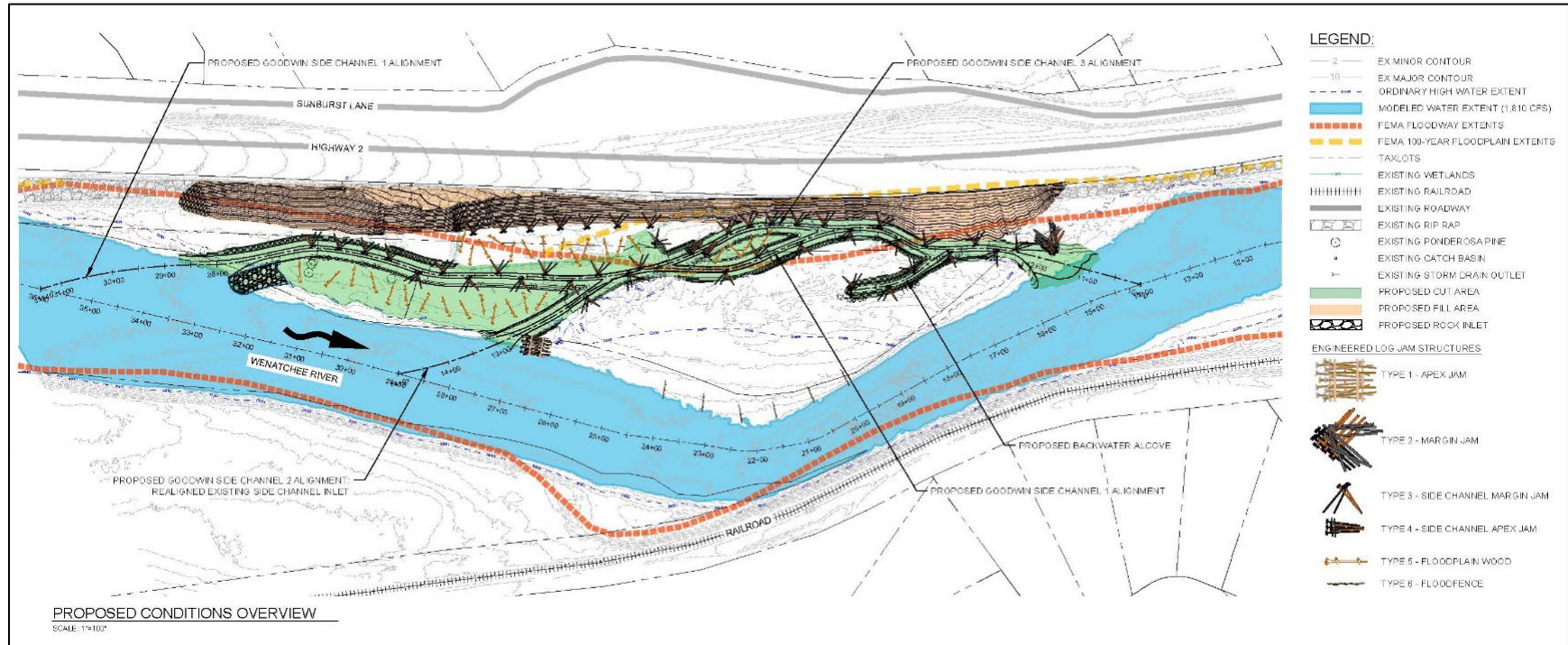


Figure 10. Excerpt of the current restoration design (60%) plan (see Appendix 1 for detailed design sheets).

## 4.2 DESIGN ELEMENTS AND RATIONALE

The following restoration activity categories, as defined under the BPA HIP programmatic, are proposed actions by the Project:

- **2a - Improve secondary channel and floodplain connectivity:** Channel and floodplain grading throughout the Project site that follows the historical side channel and floodplain topography
- **2b - Set-back or removal of existing berms, dikes, and levees:** Lowering a portion of the existing berm fill material to restore the historical floodplain surface
- **2d - Install habitat-forming instream structures:** Addition of small and large wood structures in the restored side-channel inlets and outlet
- **2e - Riparian and wetland vegetation planting:** Replanting of graded and disturbed floodplain areas throughout project area

### 4.2.1 CATEGORY 2A—IMPROVE SECONDARY CHANNEL AND FLOODPLAIN CONNECTIVITY

#### GENERAL DESCRIPTION OF APPROACH AND RATIONALE

The Project design includes side-channel and floodplain grading with the objective of increasing off-/side-channel connectivity to the existing side channel that has become disconnected over time. Grading will focus on improving conveyance of higher river flows during spring and early summer via the off-channel and side-channel areas. The floodplain grading component involving the bermed pond largely falls under HIP action Category 2b which is discussed in more detail in Section 4.2.2 Category 2B—Set-Back or Removal of Existing Berms, Dikes, and Levees.

The proposed channel profiles of the existing side channel and new side-channel extension will be set at elevations enabling connectivity at target flow-recurrence intervals to provide increased, but not perennial, access to off-channel habitat for the Project's focal fish species. Currently, it has been observed by Cascade Fisheries that the existing side channel connects via surface water with the river at and above approximately 8,000 cfs. This discharge occurs for an average of only 36 days a year (~10% of each water year) typically during the spring freshet in May and June. To address this habitat limitation, the flow-activation targets for the side channels aim to extend the period of side-channel connectivity with the river while still avoiding the warmest months of August and September when lethal water temperatures from the mainstem river could impact habitat quality in the side channels. It is during the warmer months when surface-water flows from the river have ceased that Cascade Fisheries has observed groundwater-sourced cooler temperatures in pockets of water retained in the side channel.

A river discharge of 1,810 cfs, or the 50% exceedance-probability flow, was thus selected as the side-channel activation flow in order to increase the side-channel connectivity period from winter through mid-summer while still avoiding connectivity during August–October of

typical water years. Groundwater-sourced cooler waters are expected to continue to moderate temperatures in the enhanced side channels. These actions are intended to provide immediate increased lateral connectivity and access to high value off-channel habitat as well as progressively wider connectivity to off-channel habitat as flows continue to rise during the spring freshet period. Additional details on existing river hydrology and hydraulics at the Project site are presented below in Section 4.6 Hydrology and Section 4.7 Summary of Hydraulic Modeling and Analyses.

#### LOCATIONS

Proposed grading activity will occur along the existing 1,150-foot-long side channel, a new 1,100-foot-long side channel connected between the river at the upstream end of the site and the existing side channel, along floodplain areas near the side channels, and the 200-foot-long floodplain backwater-alcove near the side-channel outlet. This action is depicted in Figure 10 and the attached 60% design planset in Appendix 1.

#### RISK CONSIDERATIONS

Risk considerations for proposed side-channel and floodplain grading include flood and erosion impacts to the immediate site. The proposed actions are being evaluated for potential impacts to flood water surface elevations. One of the Project objectives is to achieve a no-rise hydraulic condition through a balance of cut and fill volumes.

An additional risk consideration related to proposed grading is the potential avulsion of the river into the side channels because design actions will increase the proportion of flow, albeit a minor amount, into the side channels. This risk is considered low because the Project site lies on the inside of a meander bend of the mainstem river that has remained stable for decades (see Section 2.2.4 Reach-Scale Dynamics and Near-Term Trajectory).

More probable is the risk of woody debris and fine sediment accumulation at the inlets of the side channels. The inlet of the existing side channel has become progressively cut-off hydraulically by woody debris accumulation, which has restricted flow and aggraded the side channel. The proposed side channels will have wide inlets, approximately 1.5-times the length of observed large wood in the reach. Specific widths and configurations of the side-channel inlets were refined through the design process based on assessment of hydraulic modeling and likelihood of debris accumulation to optimize habitat, connectivity, and side-channel persistence.

The final design phase will further evaluate performance and refine these elements relative to the above-mentioned risk considerations as well as level of connectivity, habitat uplift and value, and long-term resilience.

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#### 4.2.2 CATEGORY 2B—SET-BACK OR REMOVAL OF EXISTING BERMS, DIKES, AND LEVEES

##### GENERAL DESCRIPTION OF APPROACH AND RATIONALE

The Project proposes to grade the topographic feature previously referred to as the “bermed pond” (see Figure 1 and Figure 5 above). As explained above, this man-made

feature appears to have been constructed during the construction of Highway 2 in the late 1950s or early 1960s, yet its function is unknown. It consists of a rectangle-shaped, ~1-acre depressional area lying approximately 8 feet below the surrounding higher floodplain surface. The higher surface effectively shields the pond from the river and, thus, acts as a berm feature. It is unknown whether the pond was excavated from native floodplain material or is surrounded by fill material placed on the pre-highway floodplain surface. However, regardless of its original function when the highway was built, the grading of much of bermed (i.e., elevated) portions of this feature will help the Project achieve its goal of improving off-/side-channel connectivity and benefitting the focal fish species.

The grading of the bermed pond feature will generally entail lowering the built-up floodplain material surrounding the pond element. Specifically, the floodplain material surrounding the southern (i.e., river-side) half of the pond will be lowered to enable routing of the new 1,100-foot-long side channel across the upstream portion of the site. The new side channel will immediately border the bed of the pond feature, which will effectively serve as connected floodplain.

Material excavated from the bermed pond feature will be placed onsite along approximately 1,700 feet of the Highway 2 embankment within the Project boundaries. All areas disturbed by this Project element will be replanted with native vegetation. Discussion of changes to the wetland feature in the existing bermed pond feature is presented below in Section 4.4.2 Wetlands.

#### LOCATIONS

The proposed removal of the “berm” portion of the bermed pond feature to increase connectivity with the river and enable off-/side-channel enhancement, with ancillary benefits to riparian vegetation enhancements, will occur on the Project site. This action is depicted in Figure 10 and the attached 60% design planset in Appendix 1.

#### RISK CONSIDERATIONS

Risk considerations for grading materials at the bermed pond feature are related to those identified above for the grading of side-channel and floodplain areas. Therefore, the potential risks from all site grading will be evaluated together.

The final design phase will evaluate performance and refine these elements relative to the above-mentioned risk considerations as well as level of connectivity, habitat uplift and value, woody debris interactions, and long-term resilience.

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#### 4.2.3 CATEGORY 2D—INSTALL HABITAT-FORMING INSTREAM STRUCTURES

The current design includes two general types of large wood with unique objectives. They include Engineered Logjams (ELJs), side-channel wood habitat structures (WHS), and a rock inlet structure. Six wood structure types totaling 83 individual structures are proposed:

- Type 1 – Apex Jam (mainstem ELJ) x 1
- Type 2 – Margin Jam (mainstem ELJ) x 1

- Type 3 – Side Channel Margin Jam (side channel WHS) x 42
- Type 4 – Side Channel Apex Jam (side channel WHS) x 2
- Type 5 – Floodplain Wood (side channel WHS) x 31
- Type 6 – Flood-fence (side channel WHS) x 6

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## MAINSTEM ENGINEERED LOGJAMS

### GENERAL DESCRIPTION OF APPROACH AND RATIONALE:

Mainstem ELJs are proposed in the Project design to create hydraulic effects that promote improved connectivity to, and long-term maintenance of, existing and proposed off-/side-channel habitats while also providing instream habitat complexity. The desired hydraulic effects include localized water surface elevation increases, and increased velocities and scour at the side channel inlet and outlet. Mainstem ELJs will have the highest potential for interactions with recreationists, so potential risk will be assessed and design measures to reduce risk to potential users will be incorporated. Two typical mainstem ELJ structure types are proposed: (1) apex, and (2) margin deflector.

An **apex jam** will be approximately 50-feet in width, with most of the structure width within the channel during bankfull-flow extents. This structure will be situated along the river-left side of the mainstem channel margin at the inlet to the existing side channel as shown in the design drawings. The proposed structure heights will have an overtopping height of approximately the 2-year recurrence flow (i.e., ~17,570 cfs). Orientation of apex jams is typically perpendicular, or near perpendicular, to flow. This structure is intended to create localized water surface increases, split or deflect flows into the side channel with sufficient velocity to scour, or flush, sediment through the side-channel inlet for long-term self-maintenance. Limiting the structure height reduces the area exposed to riverine forces for structure stability purposes, reduce effects on flood water surface elevations, and reduces the frequency the wood elements experience wet-dry cycles which affect decay rates.

A **margin jam** is proposed along the left bank of the mainstem channel at the side channel outlet/alcove. This structure will be mostly buried in the bank, and partially extend into the mainstem at an angle perpendicular to the direction of flow. This structure will have a similar overtopping height to the apex jam for consistent reasoning. These structures are intended to create localized bed scour for pool habitat and to help maintain the side-channel outlet, or keep from filling with sediment, in addition to adding hydraulic and habitat complexity along the mainstem channel margin.

### LOCATIONS

The mainstem apex jam is proposed at the inlet to the existing side channel. The apex jam will consist of approximately 10 vertical pile logs anchored in the riverbed substrate to stabilize the approximately 23 horizontal logs stacked in nine layers.

The margin jam is proposed at the side channel outlet. The margin jam will consist of approximately 8 vertical pile logs anchored in the floodplain substrate to stabilize the approximately 13 horizontal logs stacked in six layers.

This action is depicted in Figure 10 and the design details of the apex and margin jams are presented in the 60% design planset in Appendix 1.

#### RISK CONSIDERATIONS

The Project reach is heavily used for boating recreation, which makes it critical that mainstem ELJs are designed to reduce interaction and risk to recreationists. Large mainstem ELJs also create hydraulic effects that have the potential to create flood water surface rises and cause local bank erosion. This design phase includes measures to reduce risk to potential river recreationalists and minimize risk to the adjacent highway, opposing-side railway, and downstream bridge.

Reach-scale user and property risk was assessed using Bureau of Reclamation's Risk Assessment methods (Reclamation 2014) discussed in greater detail in Section 4.9 Stability and Risk Analyses. Briefly, the methods provide recommendations on safety factors and design floods for logjam stability. This analysis found that user and property risks are high for the reach. High risk ratings have associated recommendations of 100-year design flood and minimum safety factors of 2.0 for buoyancy, and 1.75 for sliding and rotation. These parameters support the stability calculations developed in this design phase.

#### FUTURE CONSIDERATIONS

The ELJs will be further refined during the final design phase. Risk assessment, and stability and scour analyses for each structure type will be revisited accordingly.

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## SIDE CHANNEL WOOD HABITAT STRUCTURES

#### GENERAL DESCRIPTION OF APPROACH AND RATIONALE

Several WHS are proposed within the side channels and floodplain areas to provide increased quantity and quality of habitat in off-channel environments, providing channel complexity, roughness, pools, and cover. The WHS will be designed to mimic racking and accumulation of large wood in natural rivers, and improve local stream bed heterogeneity and habitat diversity by simulating natural jams accumulated against fallen logs from the bank.

#### LOCATIONS

Four types of side-channel and floodplain WHS will be located along the existing and proposed side-channel alignments, and atop the floodplain surface. The Type 3 side channel margin jams will be the most numerous and be located along the margins of the side channels. The Type 4 side channel apex jams will be located in the split portion of the side channel closer to the highway embankment to reduce flow velocities directed toward the embankment. The Type 5 floodplain wood elements will be located upon the graded

floodplain areas and bermed pond surface. Finally, the Type 6 flood-fence elements will be placed along the mainstem channel margin near the gravel-bar apex between the inlet to the existing side channel and its outlet.

This action is depicted in Figure 10 and the design details of the four WHS types are presented in the 60% design planset in Appendix 1.

#### RISK CONSIDERATIONS

Within the side channels where surface-water connectivity is seasonal and recreational boaters and tubers are unlikely to be present, potential interactions with, and subsequent risks to, recreationists is anticipated to be much lower than in the mainstem although not entirely eliminated. With this in mind, design measures have been taken to reduce potential risk to river users.

#### FUTURE CONSIDERATIONS

The WHS design will be further refined during the final design phase. Risk assessment, and stability and scour analyses for each structure type will be revisited accordingly.

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## ROCK INLET STRUCTURE

#### GENERAL DESCRIPTION OF APPROACH AND RATIONALE:

In place of the former mainstem apex ELJ previously proposed at the inlet to the upstream side channel, a rock structure is proposed to provide a similar hydraulic effect while minimizing risks to recreational boaters and tubers on the river. The desired hydraulic effects include localized water surface elevation increases and increased velocities and scour at the side channel inlet. Thus, the rock structure will effectively function as an apex jam intended to split a portion of flow from the mainstem river into the side channel.

#### LOCATIONS

The rock inlet structure will be located on the river side of the upper side channel's inlet. The 100-foot-long and 40-foot-wide structure will consist of an engineered rock mix and be keyed into the channel bed to an estimated scour depth.

This action is depicted in Figure 10 and the design details are presented in the 60% design planset in Appendix 1.

#### RISK CONSIDERATIONS

Risks to recreational boaters and tubers are considered low given the low probability of interaction and associated damage/harm this structure poses to boaters and swimmers.

#### FUTURE CONSIDERATIONS

The rock inlet structure will be further refined during the final design phase. Risk assessment, and stability and scour analyses will be revisited accordingly.

#### 4.2.5 CATEGORY 2E—RIPARIAN AND WETLAND VEGETATION PLANTING

##### GENERAL DESCRIPTION OF APPROACH AND RATIONALE

The existing vegetation cover across the Project site consists of patches of riparian forest with understory, wetlands, and barren areas (see Section 2.3 above for a description of existing riparian conditions). The site still exhibits the historical impacts to the vegetation community caused by land clearing for farming, construction of Highway 2, and introduction of non-native, invasive plants, including reed canary grass and Siberian elm.

The purpose of the riparian restoration elements of the Project is to restore and enhance wetland and riparian areas within the work areas and restore natural vegetation succession and recruitment across the floodplain. This will include site preparation, soil treatment, and replanting with a diverse and site appropriate selection of native riparian species, that comes with several benefits including:

- Ecological uplift
- Stream shading
- Improved flood resiliency and erosion control
- Aesthetics
- Relatively low design and implementation costs
- No direct impact on the mainstem river channel or adjacent highway right-of-way

##### LOCATIONS

Riparian and wetland restoration will occur in all areas of construction to restore disturbed areas.

This action is depicted in the 60% design planset in Appendix 1.

##### RISK CONSIDERATIONS

Riparian and wetland restoration is a low-risk, relatively low-cost treatment.

##### FUTURE CONSIDERATIONS

The site restoration and planting design will be further refined during the final design phase. Future considerations include soil preparation/amendment and irrigation needs.

#### 4.3 INCORPORATION OF HIP SPECIFIC ACTIVITY CONSERVATION MEASURES FOR ALL INCLUDED PROJECT ELEMENTS

The Project is being designed using HIP conservation measures specific to those activities identified in the previous section. Design and construction drawings and specifications developed during future next design phases will follow and include all HIP Conservation Measures specific to the Project's proposed activities as well as the general conservation and construction measures.

## 4.4 SUMMARY OF SITE INFORMATION AND MEASUREMENTS

### 4.4.1 TOPOGRAPHIC CONDITIONS AND SURVEY

High-resolution topographic-bathymetric Lidar data were collected along the entire river corridor during October 2022 by NV5 Geospatial on behalf of U.S. Bureau of Reclamation (NV5 2023). The 2022 Lidar were provided with 3.0-foot pixel resolution and has the reported vertical accuracies with 95% confidence of: (1) 0.165 ft on bare surfaces in non-vegetated areas; (2) 0.425 feet on bare surfaces in vegetated areas; and (3) 0.446 feet on underwater surfaces. W2r used this dataset to create a bare-earth digital elevation model (DEM) surface of the Project site and adjacent river reach to assist with Project visualization, analysis, hydraulic modeling, and restoration design. Because this surface narrowly followed the active river corridor, W2r filled-in the vacant margins along higher floodplain surfaces, which mostly lied outside of the immediate Project footprint, with the older topographic-bathymetric Lidar dataset collected in 2015 on behalf of Chelan County that covered a broader swath of the river valley (Quantum Spatial 2015). The 2015 Lidar data had a reported fundamental vertical accuracy of 0.054 meters (0.177 feet) and average vertical accuracy in submerged and nearshore areas of 0.082 meters (0.269 feet).

W2r performed a detailed field reconnaissance on behalf of Cascade Fisheries during November 6–7, 2023 which included topographic survey using real-time kinematic (RTK) global positioning system (GPS) equipment. Survey data were collected to ground-truth the Lidar accuracy across the site, particularly in areas under dense vegetation cover and canopy and within wetted portions of the existing side channel. The survey also included mapping of key site features, including the alignment of the existing side channel, locations of large wood and jams, and culvert outlets along the highway embankment. When compared to the 2022 Lidar surface, nearly all survey points on the site reported lower elevations having an average difference of approximately 0.62 feet. This degree of difference is typical for aircraft-collected Lidar data but is important to consider when estimating material quantities particularly when excavation is shallow and over a large area as is proposed at the Project site. Therefore, future design phases will consider potential effects earthwork quantities and adjust earthwork amounts accordingly.

Survey control benchmarks were established throughout the Project site to aid in future construction and data collection.

A high-resolution orthomosaic image was created from an unmanned aircraft system (UAS; or “drone”) flown over the site by W2r on November 7, 2023. W2r georectified the orthomosaic using ground control points established during the field survey. The processed image has a resolution of 1.5 inches per pixel.

All survey, DEM, and imagery products used the Washington State Plane North and North American Vertical Datum of 1988 coordinate systems with U.S. feet measurement units.

#### 4.4.2 WETLANDS

W2r conducted a wetland mapping determination on behalf of Cascade Fisheries to identify wetland and ordinary high-water mark (OHWM) boundaries within the Project site. The mapping work also documented baseline ecological conditions. This wetland determination will allow the Project team to calculate potential Project impacts to facilitate Project review under the U.S. Army Corps of Engineers (USACE) for Clean Water Act (CWS) permitting under Nationwide Permit (NWP) #27. The wetland and OHWM boundaries were developed through a geospatial analysis that was field verified by ground level vegetation, hydrology, and soil surveys conducted by W2r and Cascade Fisheries personnel on November 6–7, 2023. The geospatial analysis included review of relative-elevation maps, (see Figure 5 above), hydraulic modeling, and the UAS-obtained orthomosaic imagery.

The OHWM was found to include the existing side channel which is fed by the upwelling of groundwater and intermittently by surface-water connection with the mainstem river. Only one of the nine wetland sample plots investigated at the site adequately met wetland definition and criteria. A small wet depression with no wetland soil characteristics was identified near the OHWM of the mainstem. One wetland, Wetland A (PEM, 0.86 acre), was identified within the bermed pond feature in the western portion of the site.

The Project will affect the existing wetland within the bermed pond feature by filling a portion (0.28 acre) along the highway embankment, enhancing the remainder (0.58 acre), and creating new wetland adjacent to the existing bermed pond feature (0.22 acre). Because the existing wetland is almost completely covered with non-native reed canary grass, the enhanced and created wetland areas will include planting of native wetland species. Thus, the total wetland area will increase by approximately 60% and be enhanced with native wetland vegetation.

The detailed methods and findings of the wetland determination are included in an attached technical memorandum in Appendix 5. A map of the changes to wetland extents is included in the design drawings in Appendix 1.

#### 4.5 FEMA REGULATORY CONTEXT

The Project site is located with portions of the river reach in a FEMA-mapped floodway (AE) and special flood hazard area with base flood elevations determined (AE). This means that the project must demonstrate that Project actions will have no water surface elevation rises (no-rise), or if they do create a rise, must fall within the limits of the Conditional Letters of Map Revision and Letters of Map Revision (CLOMR/LOMR) process.

W2r developed a one-dimensional (1D) hydraulic model of existing and proposed conditions in support of demonstrating no rise of the base flood standard in the Project reach (see Section 4.7 Summary of Hydraulic Modeling and Analyses below).

## 4.6 HYDROLOGY

### 4.6.1 HYDROLOGIC ANALYSIS

The Project site is situated between two long-term stream gaging stations operated by the U.S. Geological Survey (USGS): “Wenatchee River at Peshastin” at RM 21.5 and “Wenatchee River at Monitor” at RM 7.0. Both gages are useful in understanding the river’s hydrological regime, but the gage at Monitor was selected to represent flows at the Project site given their proximity and positions downstream of Dryden Dam. W2r compiled daily mean discharge data from water years 1963 to 2023 to calculate flow duration statistics (Table 3). W2r also compiled annual peak discharge data from these water years to calculate the flood recurrence statistics (Table 4). The flood recurrence statistics were calculated using the following methods:

- USGS software application PeakFQ version 7.2 following guidance presented in the USGS’s Bulletin 17C (England et al. 2018),
- Applied the Log-Pearson III method with application of the Expected Moments Algorithm and Multiple Grubbs-Beck test; and
- Applied the skew coefficient of -0.07 with a generalized standard error of 0.4243 equivalent to a mean square error equal to 0.18 for the Pacific Northwest region (Mastin et al. 2016).

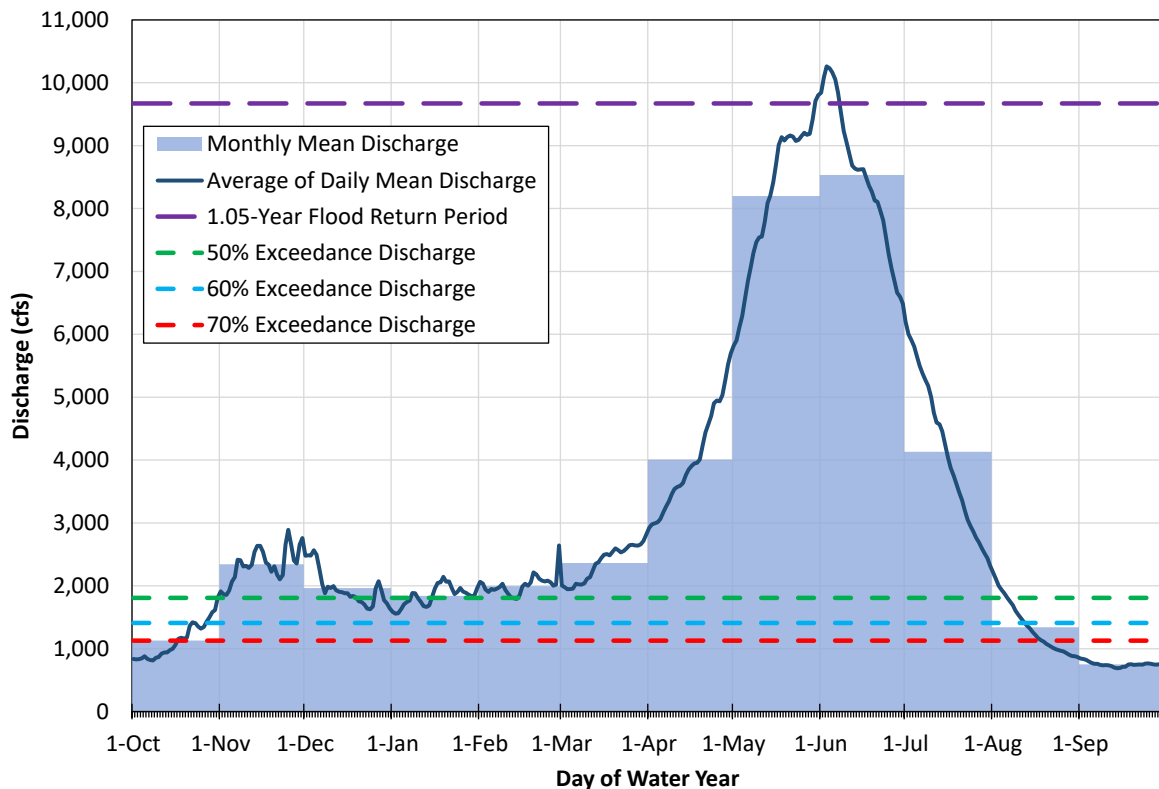
Figure 11 presents a plot of the monthly mean discharge and long-term daily mean discharge compared to the 1.05-year flood recurrence discharge and the 50%–70% daily mean exceedance discharges. These comparisons were used to identify the target flows for side-channel activation.

**Table 3. Flow duration statistics calculated for the Wenatchee River gage at Monitor during WY 1963–2023.**

Non-Exceedance Probability (%)	Exceedance Probability (%)	Discharge (cfs)	Non-Exceedance Probability (%)	Exceedance Probability (%)	Discharge (cfs)
100	0.01	45,200	85	15	6,330
99.9	0.10	24,747	80	20	5,060
99.5	0.5	17,800	75	25	4,150
99	1	15,900	70	30	3,430
98	2	13,600	65	35	2,850
97	3	12,400	60	40	2,420
96	4	11,400	55	45	2,070
95	5	10,600	<b>50</b>	<b>50</b>	<b>1,810</b>
94	6	9,850	40	60	1,410
93	7	9,300	30	70	1,130
92	8	8,840	20	80	879
91	9	8,387	10	90	628
90	10	7,990	0	100	221

**Table 4. Flood recurrence statistics calculated for the Wenatchee River gage at Monitor during WY 1963–2023.**

Flood Recurrence (years)	Discharge (cfs)
1.005	9,196
1.01	9,670
1.05	11,240
1.11	12,270
1.25	13,770
1.5	15,440
2.0	17,570
2.3	18,590
5	23,210
10	27,230
25	32,630
50	36,910
100	41,410



**Figure 11. Monthly mean discharge, long-term average of daily mean discharge, 1.05-year flood recurrence discharge, and 50%–70% daily mean exceedance discharges for the USGS gage on the Wenatchee River at Monitor during WY 1963–2023.**



Based on review of the long-term streamflow data, peak runoff is driven by spring snowmelt and rain occurring in April through July with the greatest occurring in May and June (i.e., the “spring freshet”). The long-term average of daily mean flows at the Monitor gage has been approximately 3,200 cfs during the last half century. Overall, for 50 percent of this period, daily mean flows have been less than 1,810 cfs. The river discharge of 8,000 cfs at which the side channel presently connects with the river, as observed by Cascade Fisheries, occurs for approximately 10% of a given water year (i.e., ~36 days per year). Since the mid-1900s, annual peak flows in the lower river have ranged from approximately 9,000 cfs (in WY 1977) to 47,500 cfs (in WY 1995).

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#### 4.6.2 HYDROLOGY UNDER FUTURE CLIMATE CHANGE

The changing climate will undoubtedly influence snowpack-dominant watersheds such as the Wenatchee River. Regional observations of air temperatures have reported annual mean increases of approximately 1.8°F (1.0°C) over the last century, and a predicted temperature rise of an additional 3.7°F to 8.7°F (2.1°C–4.8°C) by the end of this century (e.g., USGCRP 2017). Increasing air temperatures will likely have understandable yet not entirely predictable changes to the region’s hydrology, possibly leading to decreased snowpack, decreased soil moisture, increased drought severity, and increased wildfire frequency and severity (e.g., USGCRP 2017).

Precipitation patterns in the watershed will likely continue to vary at the annual and decadal scales, though longer-term shifts in snowpack and rainfall will alter typical runoff patterns. Predictions of precipitation changes in the region indicate a decrease in snowpack as more precipitation will fall as rain (USGCRP 2017, Raymond and Rogers 2022), which will influence timing and magnitude of runoff, possibly shifting the seasonally high flows typical for May and June to earlier in the spring. This hypothetical reduction in the lag time between peak precipitation in November–January and peak river discharge in May–June would lead to a future annual hydrograph appearing more like current hydrographs of rivers located at lower latitudes. Climate scientists predict a wholesale northward-latitudinal shift for the region whereby a given location’s climate (and related hydrological response) will become more like the existing climate of areas located at lower latitudes. For example, the “Future Urban Climates” web application (<https://fitzlab.shinyapps.io/cityapp/>) predicts the climate of Wenatchee in 2080 will feel like today’s climate near Lewiston, Idaho, which is presently 10.3°F (5.7°C) warmer and 46.9% drier than Wenatchee. Overall, these climate-driven changes have the potential to affect the Wenatchee River’s hydrological regime which, in turn, will potentially affect the river’s geomorphic and ecological processes.

#### 4.7 SUMMARY OF HYDRAULIC MODELING AND ANALYSES

W2r developed one-dimensional (1D) and two-dimensional (2D) hydraulic models using the USACE HEC-RAS software (Version 6.3.1). The 1D model was used to assess viability of a FEMA No-Rise approach for the Project’s anticipated floodplain permitting with Chelan County. The 2D model was used to assess pre-Project (existing) conditions, inform the

design of Project elements (e.g., floodplains, side-channels), communicate potential Project impacts, and quantify potential habitat uplift from the proposed Project actions. Model development and results under existing and proposed conditions are discussed below.

#### 4.7.1 MODEL HYDROLOGY

W2r simulated a comprehensive range of design flows for both the 1D and 2D hydraulic models (Table 5). The daily duration exceedance probability and flood recurrence discharges were from W2r’s analysis of discharges recorded at the Wenatchee River at Monitor gage (see Section 4.6 Hydrology above), except for the 10-year and 100-year flood-recurrence discharges which were sourced from the City of Cashmere’s Flood Insurance Study report (FEMA 2004). The 60% exceedance probability flow of 1,410 cfs represented the lowest flow scenario, which approximately equates to the monthly mean discharge for August. The 50% exceedance probability flow of 1,810 cfs represented the side-channel activation flow target for the proposed Project, which exceeds the monthly mean discharges for August through October (see Figure 11 above).

**Table 5. Hydrologic events used in the hydraulic modeling used to guide the Project design.**

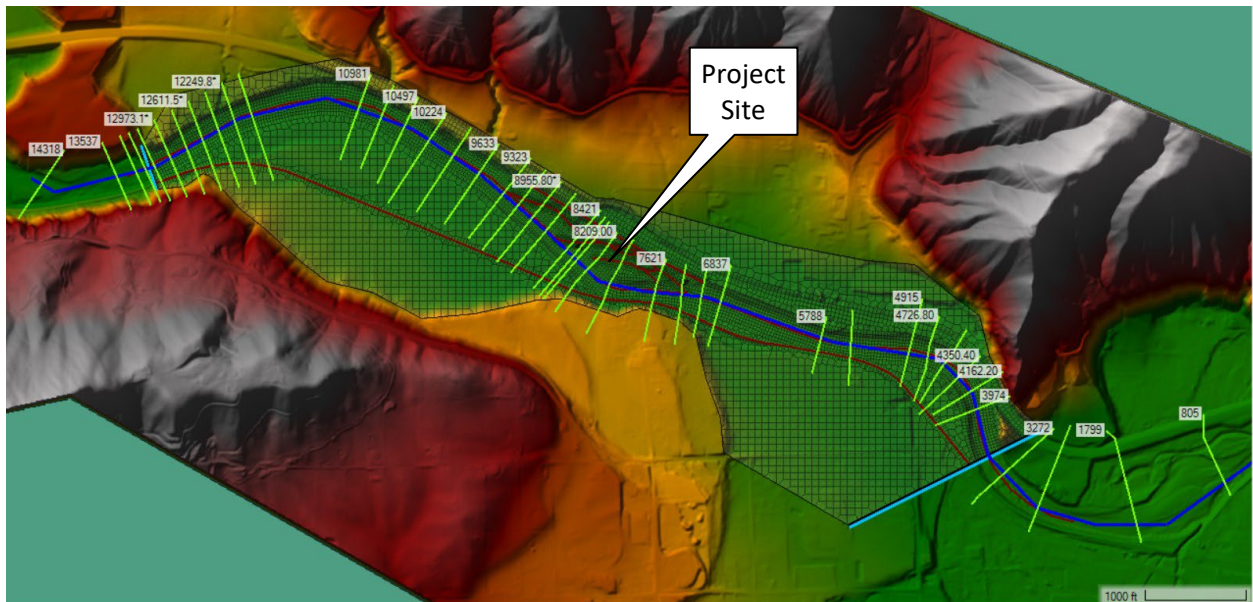
Flow Statistic	Discharge (cfs)	Data Source
60% Exceedance Probability “Low Flow”	1,410	W2r analysis using long-term gage records from the USGS station at Monitor during WY 1963–2023
50% Exceedance Probability “Shutoff Flow”	1,810	
25% Exceedance	4,150	
5% Exceedance	10,600	
1.5-Year Recurrence	15,440	
2-Year Recurrence	17,570	
5-Year Recurrence	23,210	City of Chelan FIS report (FEMA 2004)
10-Year Recurrence	26,500	
100-Year Recurrence	48,700	

#### 4.7.2 MODEL GEOMETRY AND BOUNDARY CONDITIONS

W2r primarily relied upon desktop-based data sources to develop the geometry of the 1D and 2D models, and supplemented that geometry with survey data where necessary.

##### 1D MODEL FOR PRELIMINARY FEMA NO-RISE ANALYSIS

The 1D hydraulic model included the mainstem Wenatchee River between RMs 11 and 13. This extent coincided with the FEMA cross sections BC to BQ (FEMA 2004). The model extent is shown in Figure 12.



**Figure 12. HEC-RAS 1D and 2D model extents and geometries. The 1D geometry (green cross section lines) has a broader model extent than the 2D model geometry (black mesh) to avoid excess computation times during unsteady analysis.**

The 1D model’s cross sections were created by importing the FEMA cross sections and interpolating additional cross sections in between the FEMA cross sections to account for key hydraulic features or areas of Project interest. To allow for direct comparison and consistent analysis, the geometries of the existing and proposed conditions were identical. Cross section data were cut from terrain files created for the existing and proposed conditions. The existing conditions terrain was a composite surface created by W2r that included Reclamation’s 2022 topobathymetric Lidar (NV5 2023), Chelan County’s 2015 topobathymetric Lidar (Quantum Spatial 2015), and W2r’s 2023 topographic ground-truthing survey. The proposed conditions terrain was created by cloning the existing conditions terrain and adding the AutoCAD Civil3D proposed surfaces. The Civil3D surfaces included the proposed side channels and the graded floodplain spoils.

Hydraulic roughness values were mapped onto the cross sections as follows:

- Existing and proposed channels,  $n=0.04$
- Gravel bars or vegetation-free floodplain,  $n=0.05$
- Existing bermed pond area,  $n=0.05$
- Medium to heavily vegetated floodplain,  $n=0.08$

#### 2D MODEL FOR DESIGN AND HABITAT UPLIFT ANALYSIS

A 2D mesh was constructed with an initial cell size of 70x70 feet for the entire floodplain (Figure 12). Breaklines following the highway, railroad embankment, floodplain, and all channel alignments were enforced. The final mesh consisted of 9,061 cells. As with the 1D model, the existing and proposed 2D geometries were identical except for where proposed

Civil3D surfaces modified the terrain elevations and roughness. The 2D model's terrain files were the same as those used for the 1D model.

Upstream and downstream boundary lines were added. For all modeled flow scenarios, the upstream boundary condition was set to the flow hydrograph, and the downstream boundary condition was set to normal depth (with a friction slope of 0.005).

Figure 12 shows the 1D and 2D model geometries overlaid on the existing terrain to demonstrate model extents. Both 1D and 2D models have sufficient extents to ensure the hydraulic effects of any proposed project actions are captured. The 1D geometry (green cross section lines in the map figure) has a broader model extent than the 2D model geometry (black mesh in the map figure) to avoid excess computation times during unsteady analysis.

#### 2D MODEL VALIDATION

The model required a land-cover layer defining the Mannings-n roughness values associated with the landcover types. The hydraulic roughness layer was defined spatially with polygons assigning values as follows:

- Existing and proposed channels,  $n=0.04$
- Gravel bars or vegetation-free floodplain,  $n=0.05$
- Existing bermed pond area,  $n=0.06$
- Medium to heavily vegetated floodplain,  $n=0.10$

The extent and placement of the roughness polygons matched land-cover types on site and captured key features for both existing and proposed terrains.

To validate the selected roughness values, measured and modeled water surface elevations were compared. The W2r survey team collected water surface elevation topographic points during the November 2023 survey effort. Gage data for the Wenatchee River reported flows at the time of survey were approximately 2,500 cfs. To validate the 2D model results, the survey points were compared with the water surface elevation raster for a modeled 2,500 cfs flow. All survey points were within 0.5 feet of the modeled water surface elevations, thereby indicating that no calibration was necessary and the 2D model results could reasonably be applied to the Project design and analysis.

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#### 4.7.3 MODEL RESULTS

Model results maps are presented in Appendix 6. These maps show existing and proposed conditions depths, velocities, and shear stresses.

##### NO-RISE ANALYSIS

At this design phase, modeling reveals generally manageable changes in the 100-year base flood elevation resulting from the Project. For all proposed iterations considered with the 1D model, the 100-year water surface elevations were reduced from existing conditions.



Thus, the analysis indicated that the Project can achieve a no-rise condition in the study reach with the implementation of the various restoration elements, even with excavated materials spoiled onsite. The 1D analysis was performed using a combination of HEC-RAS terrain modifications and proposed Civil3D surfaces to allow for exploration of cut-fill balance grading options while maintaining the viability of the no-rise approach.

The findings indicate that a formal No-Rise is a viable permitting pathway for the Project. A formal no-rise memorandum to be submitted to Chelan County will be prepared during the draft final design phase.

**SIDE-CHANNEL ACTIVATION AND HABITAT UPLIFT**

The 2D model results confirm that the proposed grading will allow the side channels to “activate” (i.e., become connected with surface-water inflow from the river) at the 50% exceedance probability flow of 1,810 cfs and “deactivate” (i.e., cease surface-water connectivity with the river) at lower flows. The model shows a “trickle” amount of flow through the side channels at the 60% exceedance probability discharge of 1,410 cfs (i.e., <5” water depth). Overall, this phase of modeling demonstrates that the proposed restoration design will achieve the Project goal of increasing side-channel connectivity and off-channel floodplain habitat for the focal fish species. The percent increases in inundation extents across the Project site at the 50% exceedance probability discharge of 1,810 cfs and the 1.5-year flood recurrence discharge of 15,440 cfs are summarized in Table 6.

**Table 6. Inundated area and percent change for existing and proposed conditions inundation extents at the Project site.**

<b>Flow</b>	<b>Existing Conditions Inundated Area (acre)</b>	<b>Proposed Conditions Inundated Area (acre)</b>	<b>Percent Change (%)</b>
50% exceedance (1,810 cfs)	0.02	0.64	2,850% increase
1.5-year recurrence (15,440 cfs)	4.44	7.50	70% increase

Further analysis during the draft final design phase will be necessary to conclude whether additional refinements to the proposed side channels and lowered floodplain areas are necessary. Proposed side-channel invert elevations were set 0.5 feet below the existing conditions water surface elevation for the target activation flow. The minor amount of “trickle” currently observed in the model could either be an indication of needing to change that invert elevation or could be an effect of the marginal difference in water surface elevation associated with the 1,410 cfs and 1,810 cfs flows. These factors, combined with consideration of margin of error in the model, will inform design decision-making in the subsequent final design stage.

#### SHEAR STRESS AND SEDIMENT TRANSPORT

W2r assessed shear stress results at flows specified above in Table 5 (see model outputs in Appendix 6). The 1.5-year event (15,440 cfs) approximates the geomorphic bankfull event, which is generally considered to be the most effective at transporting sediment (Castro and Jackson 2001). Surface-water connectivity between the river and existing side channel are known to occur at this event. The 100-year event (48,700 cfs) was assessed to determine maximum anticipated shear stresses exhibited on the channel bed and floodplain.

During the 1.5-year event under existing conditions, shear stresses within the river channel were found to vary spatially but were on average near 1.5 pounds force per square foot (lbf/ft<sup>2</sup>), and the peak shear stresses at this flow approached 3 lbf/ft<sup>2</sup>. The modeling results showed a clear pattern of alternating regions of lower and higher shear stresses associated with the riffle-pool units along the river, with riffles experiencing greater shear. Within the existing side channel, modeled shear stresses were considerably lower as a function of lower depth and velocity. The river's range of shear stresses of 1–3 lbf/ft<sup>2</sup> is considered to be generally associated with transport of small to large cobbles (Fischenich 2001). This indicates that most of the Wenatchee River bed, particularly at the shallower, steeper, and faster riffles, can potentially become mobilized during the 1.5-year and greater flood events. This is supported by W2r's field observations of the river's riffles being composed of coarse cobbles and small boulders (see Section 2.2.3 General Geomorphic Character).

As the modeled flows were increased through the flood recurrence intervals up to the 100-year event, the predicted shear stresses also increased. The main flow path along the river exhibited shear stresses ranging from 2 to 4 lbf/ft<sup>2</sup> under the 100-year event, with small, discrete occurrences approaching 10 lbf/ft<sup>2</sup> along the barren gravel bar portions of the Project site. This magnitude has the potential to transport small to medium boulders (Fischenich 2001) during the 100-year event.

The spatial extents of predicted shear stress vary between existing and proposed conditions, mostly due to there being increased inundated area within the expanded side channels and lower floodplain surfaces on the Project site. Similarly, the magnitudes of shear stresses differ between existing and proposed conditions, but to a limited degree. For example, under the 2-year event, shear stresses are predicted to increase slightly by ~1 lbf/ft<sup>2</sup> at the inlet to the upper side channel and along the existing side channel where the geometry will be graded deeper and with greater longitudinal continuity. This change is expected to provide the necessary "flushing flows" needed to maintain sediment continuity through the side channels and avoid imbalanced deposition, which has been an issue along the existing side channel, particularly at its inlet. Under larger flood events, such as the 100-year event, shear stresses are predicted to decrease slightly in the mainstem river channel, which is presumed to occur because of the greater dispersion of flow across the Project site's floodplain.

#### 4.8 SEDIMENT SUPPLY AND TRANSPORT ANALYSES

Refer to Section 2.2 and Section 4.7.3 for discussions on sediment supply and transport.

## 4.9 STABILITY AND RISK ANALYSES

### 4.9.1 LARGE WOOD RISK ASSESSMENT

W2r assessed reach-scale user and property risk using Bureau of Reclamation's Risk Assessment methods (Reclamation 2014), a detailed summary of which is included in Appendix 7. This evaluation includes assessing Public Safety Risks and Property Damage Risks associated with the placement of ELJs in the Project reach. Direct outcomes of this risk assessment approach include recommendations on log-jam design, safety factors for stability, and design floods. The risk assessment made use of general information, professional judgement, and information about reach user characteristics and surrounding property and structure characteristics provided by the project sponsor and local stakeholders.

#### REACH-SCALE SUMMARY

The Project reach is closely flanked by US Highway 2 to the north and BNSF railway and private orchards to the south. Existing structures within the channel include the Goodwin Road bridge located 1,700 feet downstream of the Project site and rock riprap along the riverbank where the BNSF railway and Highway 2 encroach upon the river. The Project reach is located within a FEMA-mapped floodway in special flood hazard zone AE with base flood elevations determined. Analysis to demonstrate that individual projects do not produce a flood elevation rise will be required or a CLOMR/LOMR will need to be obtained.

The Project reach is used frequently by boating recreationalists of all skill levels and ages, including children. Typical watercraft used on the river includes multi-person rafts and single-user inner-tubes.

The Wenatchee River is largely snowmelt driven. The river within the Project reach has a riffle-glide-pool morphology. The riverbed consists of a gravel-cobble dominated bed with potential for scour with the addition of forcing agents such as large wood structures. Except for the floodplain pocket where proposed Project actions are proposed, the river is largely confined between the highway to the north and railway to the south, with minimal to no riparian buffer along the margins. Past land-use practices have reduced the riparian forest extents and, therefore, reduced natural large wood loading will persist in the future.

#### PUBLIC SAFETY RISK

Public safety risk posed by large wood features proposed to be added at the Project site is assessed by qualitatively comparing proposed wood structure characteristics versus likely river user characteristics.

For river user characteristics, W2r qualitatively evaluated public safety risk related to frequency of use, skill level of users, and access to the reach (Table 7). The most common activities that would create public interactions with the river are boating and floating (tubing) which we anticipate happening within the main channel.

Based on the above, the overall public safety risk for this project is considered to be "high."

**Table 7. Reach-user characteristics and their risk ratings.**

Reach-User Characteristics	Rating	Notes
Frequency of Use	10	This reach of the Wenatchee River is known for recreational use, predominantly in the form of boating, tubing or other floating devices.
Skill Level	8	Potential recreationists are likely to exhibit a wide range of skill levels from experienced boaters to highly inexperienced users, potentially with the use of alcohol and/or without a flotation device.
Access	10	The site is easily accessible either by foot from the Goodwin Road – Highway 2 intersection or by water via upstream put-in, the nearest of which is the Turkey Shoot access 1/4-mile upstream.
Child Presence	10	There is a high probability children could access the site, most likely by water from upstream.
<b>Average</b>	<b>9.5</b>	

The proposed main channel large wood structures proposed as part of this Project will provide the highest potential risk, both to people and property. Mainstem structure types include apex and margin deflector type structures. Risks were assessed for each structure type; and a summary of the assessment scores is provided in Table 8.

**Table 8. Structure characteristics for Project ELJ types.**

Structure Type	Active Channel	Outside of Bend	Strainer Potential	Egress Potential	Sight Distance	Depth x Velocity	Avg. Score
Type 1 - Apex Jam (Mainstem)	3	1	10	10	8	10	<b>7.0</b>
Type 2 – Deflector Jam (Mainstem)	3	8	10	10	5	7	<b>7.2</b>
Type 3 – SC Apex Jam	5	1	10	5	5	5	<b>5.2</b>
Type 4 – SC Margin Jam	5	3	7	5	5	5	<b>5.0</b>
Type 5 - Floodplain Log Jam	3	1	3	3	3	3	<b>2.7</b>

Based on the findings of the Project’s risk assessment, which included a detailed review of potential impacts to recreational users conducted by Elliot Consulting on behalf of Cascade Fisheries in 2024 (see Appendix 4), a significant design revision related to public safety has been incorporated since the 30% design phase. The proposed apex jam previously located at the inlet of the proposed side channel has been removed and replaced with a rock-based inlet structure to minimize potential risk to boaters or swimmers.

The public safety ratings for each analyzed structure are plotted on Figure 13. Structure-specific scoring shows that each of the proposed jam types pose “high” public safety risks, and those proposed for placement in the main channel (Types 1 and 2) pose the highest level of risk.

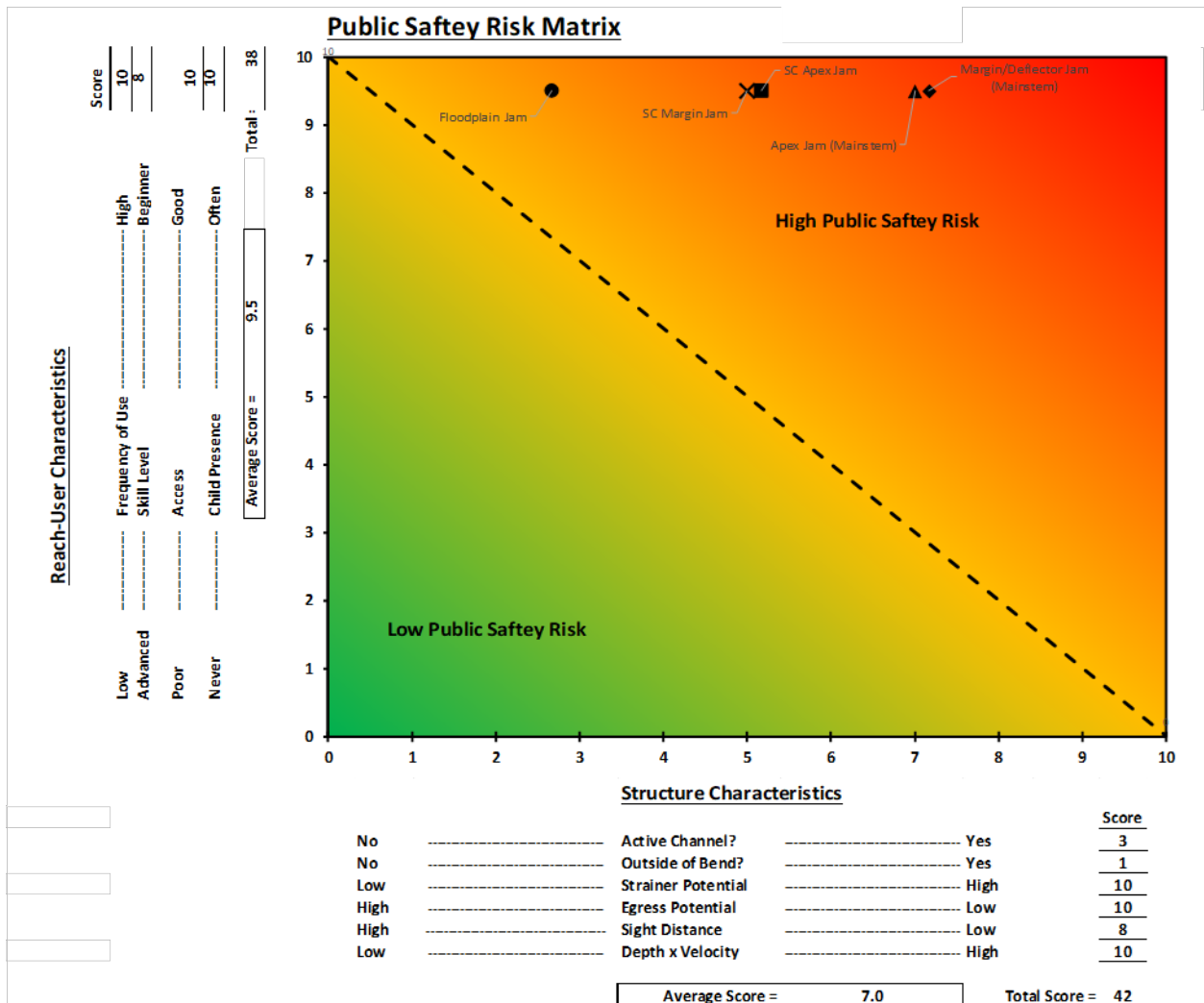


Figure 13. Public Safety Matrix (Reclamation 2014) with Project ELJ ratings.

#### PROPERTY DAMAGE RISK

Property damage risk posed by large wood is assessed by comparing property and Project characteristics versus characteristics of the river’s response potential to large wood structures (Reclamation 2014). For stream response potential, W2r qualitatively evaluated risk related to stream type, riparian corridor condition, bed scour potential, bank erosion potential, and dominant hydrologic regime (Table 9).

For property/project characteristics, W2r qualitatively evaluated risk related to existing in-channel and floodplain structures, and surrounding land use (Table 10).

Based on the above, the overall property damage risk for this Project is considered to be “high.”

**Table 9. Stream response potential and their risk ratings.**

<b>Stream Response Potential</b>	<b>Rating</b>	<b>Notes</b>
Stream Type	3	<ul style="list-style-type: none"> <li>Riffle-pool morphology.</li> <li>Confined by highway and railway.</li> <li>Unlikely for channel adjustment</li> </ul>
Riparian Corridor	10	<ul style="list-style-type: none"> <li>Riparian corridor degraded and significantly reduced</li> </ul>
Bed Scour Potential	7	<ul style="list-style-type: none"> <li>Armored cobble-dominated bed, but structure excavation activities break through armor layer</li> <li>Potential with wood additions</li> </ul>
Bank Erosion Potential	5	<ul style="list-style-type: none"> <li>Natural alluvium banks (sand to cobble)</li> <li>Heavy bank armoring on river margins associated with highway and railway</li> </ul>
Dominant Hydrologic Regime	5	<ul style="list-style-type: none"> <li>Flow regime characterized by snowmelt-driven runoff in spring, and low baseflows in summer and early fall.</li> </ul>
<b>Average</b>	<b>6.0</b>	

**Table 10. Property/project characteristics and their risk ratings.**

<b>Property/Project Characteristics</b>	<b>Rating</b>	<b>Notes</b>
In-Channel Structures	10	<ul style="list-style-type: none"> <li>Goodwin Road bridge ¼-mile downstream with mid-channel pier</li> </ul>
Floodplain Structures	10	<ul style="list-style-type: none"> <li>US Highway 2 along river left</li> <li>BNSF railway along river right</li> <li>Heavy riprap armoring along portions of both banks</li> </ul>
Land Use	5	<ul style="list-style-type: none"> <li>Project area and bordering highway right-of-way to the north (left bank) owned by WSDOT</li> <li>Railway to the south (right bank) owned by BNSF</li> <li>Private orchard to the south (right bank)</li> </ul>
<b>Average</b>	<b>8.3</b>	

**RISK-BASED LARGE WOOD DESIGN RECOMMENDATIONS**

The identified high categories of public safety and property risks have associated recommendations of design flood and factor of safety (FOS) listed in Table 11.

**Table 11. Large wood risk-based design recommendations.**

Public Safety Risk	Property Damage Risk	Stability Design Flow Criteria	FOS Sliding	FOS Buoyancy	FOS Rotation & Overturning
High	High	100-year	1.75	2.0	1.75
High	Moderate	50-year	1.5	1.75	1.5
High	Low	25-year	1.5	1.75	1.5
Low	High	100-year	1.75	2.0	1.75
Low	Moderate	25-year	1.5	1.75	1.5
Low	Low	10-year	1.25	1.5	1.25

Recommendations based on Reclamation (2014); yellow-highlighted row is associated with the Project reach.

#### 4.9.2 LARGE WOOD STABILITY CALCULATIONS

Stability calculations were performed for all ELJ types and are included in Appendix 8. As summarized in Section 4.9.1 Large Wood Risk Assessment and Table 11, a risk assessment for the Project reach was performed, where design FOS were defined for the different stability criteria. The stability design criteria are based on high public safety risk and high property damage risk, which led to the selection of the 100-year flow event for the design flow. All proposed wood structures meet or exceed the target FOS of 2 for buoyancy, and 1.75 for sliding and rotation as recommended in Reclamation’s (2014) Large Woody Material Risk Based Design Guidelines (see Table 11).

ELJ stability was analyzed following calculations outlined within Reclamation’s and USACE’s (2016) National Large Wood Manual. The analysis considers the local 100-year flow hydraulics in the vicinity of the ELJs as well as the specific structure elements such as individual log types and sizes and general structure size and intent. Stability analyses were performed for each of the proposed ELJ types for the Project. Table 12 presents the calculated buoyancy, sliding, and rotation FOS’s for each of the five analyzed ELJ types.

**Table 12. Summary of calculated FOS for structure stability by ELJ type.**

Factors of Safety (FOS)		Minimum FOS	Calculated FOS				
			Apex Jam	Margin / Deflector Jam	SC Margin Jam	SC Apex Jam	Flood-plain Wood
Buoyancy	FOS <sub>b</sub>	2	2.21	2.97	2.17	2.48	2.82
Sliding	FOS <sub>sliding</sub>	1.75	3.23	4.42	5.23	4.48	2.26
Rotation	FOS <sub>rotation</sub>	1.75	2.15	3.54	2.56	4.82	2.01

#### 4.9.3 SCOUR ANALYSIS

Scour is one of the principal reasons for wood placement failures (Reclamation and USACE 2016). For this reason, preliminary scour analyses were performed for the two ELJ structure types proposed for the mainstem Wenatchee River: apex ELJ and margin ELJ at the inlet to and outlet from the existing side channel. Preliminary scour calculations are presented in Appendix 8.

Pier scour generally occurs as a horseshoe vortex mobilizing streambed material away from the front and side of the in-stream structure. Potential scour at the apex jam was estimated using the Froehlich equation which was originally derived from regression analyses of pier-scour data for coarse-bed streams from several investigations (Chase and Holnbeck 2004). The equation accounts for ELJ width and height, average streambed material size, and the local hydraulics during the design flow event (see Table 11 above). For coarse-bed streams, the Froehlich equation has been found to overestimate the anticipated scour (Chase and Holnbeck 2004), leading the calculated scour depths to be conservative for our project.

Due to its positioning along the channel bank, the margin deflector jam was treated as an abutment for estimating potential scour. Karaki and Richardson’s abutment scour equation was used to estimate scour at the large and medium deflector jams. This equation utilizes water depth and velocity at the structures during the 100-year flow event as well as the effective structure length, or length of structure projected normal to the prevailing flow direction. Results of the estimated scour depths for the two mainstem ELJ types are presented in Table 13.

**Table 13. Summary of estimate scour depth by mainstem ELJ Type.**

ELJ Type	Calculated Estimated Scour Depth (ft)
Mainstem Apex ELJ	13.7
Mainstem Margin ELJ	12.0

Structure stability calculations were performed assuming pile depths below potential scour depths. To account for this, during the final design phase, pile embedment depths will be refined to account for potential scour depths as determined through this analysis. Pile embedment depths will be set relative to potential scour depths and/or additional scour protection measures will be incorporated into structure details, such as additional piles or protective rock scour curtain in front of piles. Additionally, structure details call for large quantities of racking material on the faces of the jams. Racking material creates a buffer around the core of a structure from the potential scour hole (Reclamation and USACE 2016).



#### 4.10 DESCRIPTION OF HOW PRECEDING TECHNICAL ANALYSIS HAS BEEN INCORPORATED INTO AND INTEGRATED WITH THE CONSTRUCTION-CONTRACT DOCUMENTATION

Sections in Chapter 4 above include technical analyses associated with the Project reach and their integration into the design approach.

## 5.0 CONSTRUCTION–CONTRACT DOCUMENTATION

### 5.1 INCORPORATION OF HIP GENERAL AND CONSTRUCTION CONSERVATION MEASURES

HIP Construction Conservation Measures are included in the design drawings in Appendix 1.

### 5.2 DESIGN–CONSTRUCTION PLAN SET

The Permit-Level Design (60%) materials are located in Appendix 1.

### 5.3 PROPOSED PROJECT MATERIALS, QUANTITIES, AND COSTS

Material quantities for excavation are estimated in units of bank cubic yards (calculated in place prior to removal) determined from comparison of existing ground surface derived from LiDAR and proposed ground surface developed in Autodesk Civil3D. Large wood quantities will be estimated at the next design phase when large wood structure details are developed.

The 60% engineer’s construction cost estimate and approximations of quantities and total Project costs are presented in Table 14. This table does not include estimated Project costs for permitting, design, monitoring, or ongoing maintenance following construction. Estimated costs are presented in 2024 dollars and will need to be adjusted to account for price escalation for implementation in future years. Additionally, the actual cost of construction may be impacted by the availability of construction equipment and crews and fluctuation of supply prices at the time the work is bid. W2r makes no warranty, expressed or implied, as to the accuracy of such opinions as compared to bids or actual costs.

Primary assumptions of the cost estimate include:

- Unit costs—include contractor markup, profit, and overhead;
- Mobilization/demobilization—assumed to be approximately 10% of total cost;
- Temporary stream diversion/water management—assumed to be 5% of total cost;
- Temporary erosion and sediment control—assumed to be 3% of total cost;
- Floodplain excavation—assumed use of common excavator, bulldozer, scraper and high-capacity dump truck equipment;
- Contingencies—a 20% construction contingency is included in the total bid estimate to account for unknowns and potential for change of design elements or change in general construction costs related to the current nature of design (60%), and future expansion of cost estimate or addition of pay items as the design is further refined.



**Table 14. Estimate of probable Project construction costs.**

PROJECT: GOODWIN SIDE CHANNEL PROJECT					
CLIENT: CASCADe FISHERIES					
60% DESIGN CONSTRUCTION COST ESTIMATE					
DATE: September 2024					
ITEM NO.	ITEM	COSTS			
		QTY	UNIT	UNIT COSTS	TOTAL
1	MOBILIZATION	1	LS	\$ 170,000	\$ 170,000
2	TRAFFIC CONTROL	1	LS	\$ 50,000	\$ 50,000
3	EROSION & SEDIMENT CONTROL	1	LS	\$ 50,000	\$ 50,000
4	WATER MANAGEMENT	1	LS	\$ 85,000	\$ 85,000
5	CONSTRUCTION SURVEYING	1	LS	\$ 17,000	\$ 17,000
6	ACCESS AND STAGING AREAS	1	LS	\$ 50,000	\$ 50,000
7	CLEARING AND GRUBBING	1	LS	\$ 17,000	\$ 17,000
8	EARTHWORK / CHANNEL GRADING	19,700	CY	\$ 25.00	\$ 492,500
9	WHS TYPE 1 - APEX JAM	1	EA	\$ 50,000.00	\$ 50,000
10	WHS TYPE 2 - MARGIN JAM	1	EA	\$ 30,000.00	\$ 30,000
11	WHS TYPE 3 - SIDE CHANNEL MARGIN JAM	42	EA	\$ 10,000.00	\$ 420,000
12	WHS TYPE 4 - SIDE CHANNEL APEX JAM	2	EA	\$ 18,000.00	\$ 36,000
13	WHS TYPE 5 - FLOODPLAIN WOOD	31	EA	\$ 3,000.00	\$ 93,000
14	WHS TYPE 6 - FLOOD FENCE	6	EA	\$ 4,500.00	\$ 27,000
15	STORMWATER EXTENSION & STABILIZED OUTFALL	5	EA	\$ 11,000.00	\$ 55,000
16	SITE RESTORATION AND PLANTING	5.5	AC	\$ 12,000.00	\$ 66,000
<b>DIRECT ITEM TOTAL</b>					<b>\$ 1,708,500</b>
DESIGN CONTINGENCY					20%
					\$ 341,700
<b>TOTAL 60% DESIGN CONSTRUCTION COST</b>					<b>\$ 2,050,200</b>

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

The current design includes HIP General Aquatic Conservation measures to follow during and post construction, which includes temporary erosion and sediment control (TESC) measures as well as best management practices (BMPs). Use of erosion control measures such as fiber rolls and silt fencing are anticipated and will aid in addressing the stockpiling and final grading of spoil material and associated storm water runoff from leaving the site. Temporary access routes will assist with runoff and roadway rutting, while erosion control around stockpiles and staging areas assists with runoff and run-on associated with precipitation events. Stabilized construction entrances are anticipated to prevent erosion associated with heavy equipment entering the site and provide an area for washout prior to construction equipment leaving the site. This section will be further developed during the draft final design phase.

### 1. SITE ACCESS, STAGING, AND SEQUENCING PLAN

Preliminary access and staging locations are shown in the ACCESS, STAGING, AND TESC PLAN of the design drawings provided in Appendix 1. Access routes will follow existing roads (Highway 2) and avoid sensitive areas such as wetlands or within OHW to the highest extents possible. Key entrance points to the Project site from the roadway and primary offsite staging area are shown based on discussions with the project sponsor. All staging areas are currently shown outside the ordinary high-water delineation.

More detailed construction sequencing will be developed in the final design phase.

### 2. WORK AREA ISOLATION AND DEWATERING PLAN

Basic work area isolation and dewatering features are shown on the ACCESS, STAGING, AND TESC PLAN of the design drawings provided in Appendix 1. Additional details on these measures are shown on the TESC AND WATER MANAGEMENT DETAILS 1 and 2 sheets provided in Appendix 1. This section will be further developed during the final design phase.

### 3. EROSION AND POLLUTION CONTROL PLAN

Basic erosion and sediment control measures are shown on the ACCESS, STAGING, AND TESC PLAN of the design drawings provided in Appendix 1. Additional details on these measures are shown on the TESC AND WATER MANAGEMENT DETAILS 1 and 2 sheets provided in Appendix 1. This section will be further developed during the final design phase.

### 4. SITE RECLAMATION AND RESTORATION PLAN

Preliminary restoration and revegetation locations are shown in the SITE RESTORATION AND PLANTING PLAN of the design drawings provided in Appendix 1. This section will be further developed during the final design phase.



## 5. LIST PROPOSED EQUIPMENT AND FUELS MANAGEMENT PLAN

The design drawings in Appendix 1 include HIP General Aquatic Conservation Measures applicable to construction equipment and spill prevention, control, and counter measures. Specifically, sections 7, 8, 9, and 11 include conservation measures addressing fuels and hazardous materials management and spill prevention.

### 7. STAGING, STORAGE, AND STOCKPILE AREAS

These measures include actions addressing the staging, stockpiling, fueling and maintenance of equipment and materials.

### 8. EQUIPMENT

These measures include actions addressing the selection, use, staging, maintenance, and refueling of equipment.

### 9. EROSION CONTROL

These measures include actions the requirement to maintain an oil-absorbing floating boom whenever surface water is present.

### 11. SPILL, PREVENTION, CONTROL, AND COUNTER MEASURES

These notes include procedures and precautions for inventorying, storing, and handling any hazardous materials onsite as well as requirements for training.

## 5.5 CALENDAR SCHEDULE FOR CONSTRUCTION/IMPLEMENTATION PROCEDURES

Construction is anticipated to begin in the 2026 construction season, with work occurring before, during, and after the in-water work window of July 15 to September 30. Project elements below OHW will be carried out during the in-water work window. Project elements in areas above OHW may be completed prior and after the window.

Revegetation of areas disturbed including seeding, staking, and planting will occur after the earthwork and habitat structure installations are completed.

## 5.6 SITE OR PROJECT SPECIFIC MONITORING TO SUPPORT POLLUTION PREVENTION AND/OR ABATEMENT

This section will be developed during the draft final design phase.



## 6.0 MONITORING AND ADAPTIVE MANAGEMENT PLAN

The monitoring and adaptive management plan will be developed during the draft final design phase.

## 7.0 REFERENCES

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## APPENDICES

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