Lower Chiwawa River Area D Habitat Enhancement Project

30%-Level Basis of Design Report

SUBMITTED TO

Bureau of Reclamation and Chelan County Natural Resource Department

OCTOBER 2024

Lower Chiwawa River Area D Habitat Enhancement Project

30%-Level Design Report

SUBMITTED TO
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1. Introduction

This report describes the development of the 30% designs for the Lower Chiwawa Area D Habitat Enhancement Project and the rationale for key decisions made during the design process. The project reach is located on U.S. Forest Service land along the Chiwawa River between River Mile (RM) 5.75 and 7.0, near the town of Plain, WA (Figure 1). In this document "Area D" or "the project" refer to this section of the Chiwawa River and the habitat enhancement actions proposed there.

The Columbia Pacific Northwest Region of the Bureau of Reclamation (Reclamation) has partnered with several local, state, and regional entities to develop habitat enhancement projects for ESA-listed salmon and trout species in the Wenatchee River subbasin, which includes the Chiwawa River. The Lower Chiwawa Area D Habitat Enhancement Project is an example of these efforts – a product of the partnership between Reclamation and the Chelan County Natural Resources Department (CCNRD). Prior project development steps, and a broader planning effort by Reclamation to identify habitat enhancement opportunities in the Chiwawa River basin included defining habitat enhancement goals and objectives (USBR 2021), a project identification assessment (Inter-Fluve 2022) and conceptual design efforts (Inter-Fluve 2023) throughout the Lower Chiwawa River Assessment Unit (LCAU)[1] performed in collaboration with the CCNRD. The overall purpose of this effort is to enhance habitat for ESA listed steelhead, bull trout, and spring Chinook in the lower Chiwawa River, an area identified as a high priority for habitat improvements to benefit the targeted species by a regional prioritization framework (UCRTT 2020). The LCAU is now designated as a high priority area for habitat improvement actions.

The actions proposed for the Area D project have been developed to the 30% design level to address previously identified Chiwawa River habitat limiting factors. This report summarizes the planning and design steps that preceded the 30% designs, project goals and objectives, design criteria, background information and analyses used during design development. Appendices to this report include a wetland delineation report (Appendix A), a memorandum evaluating the hydraulic impacts of the project on residential structures in the project area (Appendix B), a large wood risk assessment memorandum (Appendix C), hydraulic modeling results (Appendix D), the engineer's opinion of probable construction cost (Appendix E), and the Area D 30% design drawings (Appendix F). The results of a recreation site management study performed by others is included as Appendix G.

[1] The Lower Chiwawa Assessment Unit refers to the Chiwawa River from RM 0–13.1, yet the referenced assessment and conceptual design documents do not cover RM 0–1.

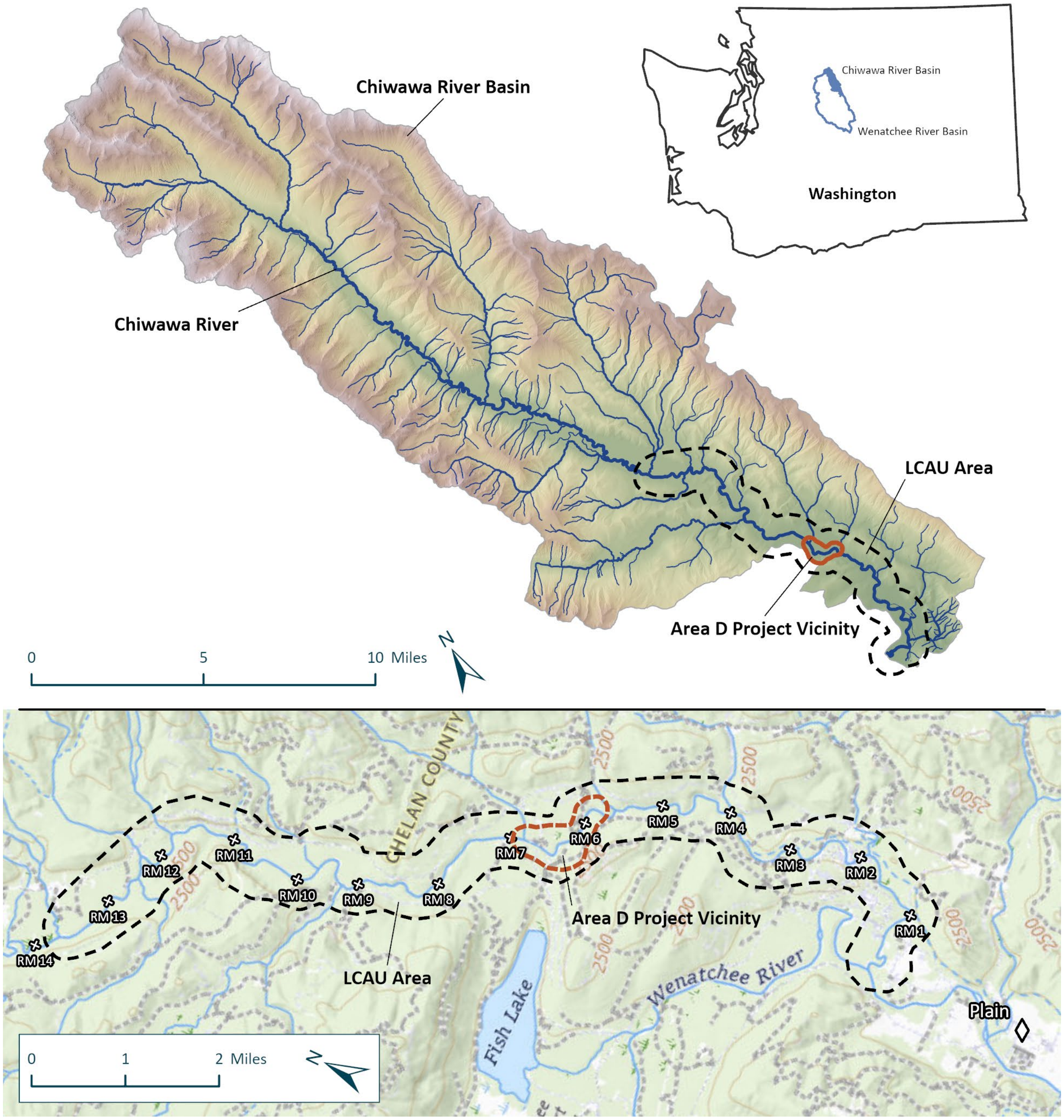

Figure 1. Project location map. The upper pane shows the project in the context of the entire Chiwawa River watershed. The lower pane shows the location of the project within the LCAU (dashed black line).

1.1 PROJECT BACKGROUND, DEVELOPMENT & CONSTRAINTS

Habitat enhancement efforts for the Area D project area focus on improving Chiwawa River channel aquatic habitat conditions, increasing side-channel habitat, and enhancing channel-floodplain connectivity via installing large wood structures in the mainstem channel and excavating a side channel through a section of river-left floodplain. Proposed habitat enhancement treatments primarily target three vicinities in Area D, described from upstream to downstream in the project area: in the mainstem channel near the confluence of Alder Creek; ii. in the mainstem channel and on the adjacent semi-regularly inundated floodplain on river left in the center of the project area; and iii. in the mainstem channel upstream of and at the Goose Creek confluence. Treatment vicinities were selected based on locations where aquatic habitat uplift potential was the greatest, and the specific styles and locations of treatments have been developed to achieve project goals while accommodating project constraints and mitigating risks to persons and/or built features present within the project area. Site features which shaped project design approach include, but are not limited to, the Chiwawa River Road bridge which crosses the river in the upstream portion of the project area, the presence of private cabins located on leased USFS land on the south side of the river in the central portion of the project area, the Goose Creek USFS campground on the north side of the river in the downstream portion of the project area, and extensive dispersed camping sites on both sides of the river throughout the project area. Input from project stakeholders related to anthropogenic project constraints has been incorporated into the designs presented in this report. Project designs will continue to evolve at subsequent design phases based on stakeholder and project team input. A Chelan County-led recreational use assessment and planning effort focusing on the Area D vicinity has occurred in parallel with the habitat enhancement project described in this report, and additional intersection of these two planning efforts is likely to occur at future design phases. Additionally, a wetland delineation was performed for the site to inform the design, and the results of this delineation are included in Appendix A. Further information about previous design and planning steps for the project can be found in the Alternatives Analysis (Inter-Fluve 2022) and Concept Development reports (Inter-Fluve 2023).

1.2 PROJECT GOALS & OBJECTIVES

Habitat enhancement goals for the Area D project area were defined by the project team in the Lower Chiwawa Assessment Unit Project Development: Project Goals and Objectives Memo (USBR 2021). This memo describes how project goals were developed for each segment of the LCAU, provides a logical pathway to link the UCRTT habitat assessment and restoration prioritization to project goals, and includes a set of objectives and linked actions by which the objectives will be accomplished. Table 1 illustrates the primary goal, objectives, and linked actions for Area D.

Table 1: Goals, objectives, and linked actions for the project.

Goal: Improve off-channel floodplain / side channel habitat for 1) summer rearing, 2) winter rearing, and 3) fry life stages	
Objective 1: Install a minimum of four engineered log jams along ~0.15 miles of channel to redirect flows and increase inundation of river left floodplain surface. Objective 2: Create up to 0.25 miles of side channel habitat on river left floodplain surface to increase side channel area in project reach to greater than 5% of total channel area.	Linked Actions: Add roughness; Place material; Maintain Flow; Maintain Defined Channel; Create stickiness; Add scour agent; Excavate material; Add obstacle

In addition to the specific goal of improving off-channel floodplain and side channel habitat, design development for the project area aimed to address LCAU-wide habitat goals of increasing channel complexity and improving large wood-related processes in the lower Chiwawa River. Specific design treatments proposed for Area D and the uplift associated with each treatment are described in subsequent sections.

1.3 KEY SPECIES & HABITAT LIMITING FACTORS

Spring Chinook, summer Chinook, steelhead, sockeye, and coho were relatively abundant in Upper Columbia River tributary streams such as the Chiwawa River before extensive fishing, logging, mining, dams and diversions, and agriculture activities combined to reduce habitat area, quality, and alter the physical conditions necessary to create and maintain healthy aquatic habitats. The commencement of large-scale commercial fishing in the Columbia Basin in the late 19th century further depleted the Mid- and Upper Columbia River spring and summer Chinook runs, and eventually steelhead, sockeye, and coho (Mullan et al. 1992).

Currently, the Chiwawa River supports populations of Endangered Species Act (ESA) listed Upper Columbia spring Chinook salmon (*Oncorhynchus tshawytscha*), Upper Columbia steelhead (*Oncorhynchus mykiss*), and bull trout (*Salvelinus confluentus*). The lower Chiwawa River has been identified as a major spawning area for spring Chinook and steelhead (UCRTT 2021). Additionally, much of the bull trout spawning in the greater Wenatchee watershed also occurs in the upper Chiwawa River. Consequently, the primary focal species for restoration efforts in the lower Chiwawa River, and for this project, include spring Chinook salmon, steelhead trout, and bull trout. A diagram that provides the life stage and usage timing for these species is provided in Figure 2.

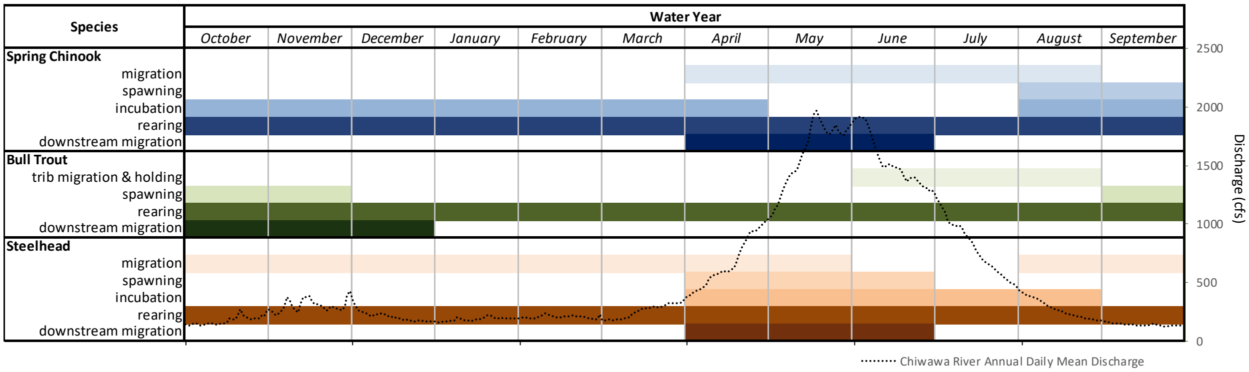

Figure 2: Life history timing of ESA-listed spring Chinook salmon, steelhead, and bull trout overlaid on the Chiwawa River annual hydrograph.

Limiting factors affecting salmonid habitat conditions for the lower Chiwawa River, including in the vicinity of the project area, are identified by the Upper Columbia Regional Technical Team (2020; 2021) and are categorized by severity of the impairment to habitat conditions. Limiting salmonid habitat factors identified in the vicinity of the project area include the following:

- Loss of large wood cover;
- Loss of floodplain connectivity;
- Low baseflow discharge;
- High summertime water temperatures;
- Decreased quantity and quality of pools; and,
- Reduced riparian canopy cover.

Habitat limiting factors have informed decisions throughout the project development and design process. Linkages between limiting factors, restoration goals and objectives, and design development are described briefly in this document. These linkages between habitat limiting factors and design criteria and decisions are described in greater detail in documents issued for previous phases of the project development process (USBR 2021; Inter-Fluve 2022, 2023).

2. Site Conditions & Analysis

The following subsections provide summaries of existing watershed, reach, and project area conditions to provide the biophysical context required to interpret the 30% design. The topics discussed within each section are based on the existing literature, recent field observations, and analyses performed to support project development. A more comprehensive review of these topics is included in the Lower Chiwawa River Assessment: Alternative Analysis Report (Inter-Fluve 2022). Additionally, key points described under each topic are based upon a large body of previously completed work, and these reports should be referred to for additional information.

2.1 GEOLOGY

The lower Chiwawa River Valley is located in the northern portion of the Chiwaukum Graben (Enkelmann et al. 2015) which extends from the Leavenworth Fault to the Entiat Fault (to the west and east of the Chiwawa Valley, respectively) (Figure 3). The Chiwawa Valley is underlain by Tertiary sedimentary rocks (Chumstick Formation) which have been folded into an anticline-syncline pair in the vicinity of the project site (Cheney and Hayman 2009). The Chumstick Formation is primarily composed of medium- to coarse-grained sandstone, with shale and conglomerate interbeds and subunits present throughout the formation (Tabor et al. 1987). Outcrops of the Chumstick Formation are commonly exposed on the valley sides and are intermittently exposed in and along the Chiwawa River channel, affecting channel gradient and lateral confinement in several locations. The Chumstick Formation is relatively erodible compared to other lithologies found in the upper Wenatchee Basin (Gresens et al. 1981) and has been a source of sediment to the river.

Late Pleistocene glaciation had a profound effect on the lower Chiwawa Valley, eroding the underlying bedrock and depositing thick layers of glacial till and outwash. Six episodes of glaciation have been documented via till deposits in the upper Wenatchee Basin, deposited circa 13 k.a., 17 k.a., 70 k.a., 93 k.a., 105,000 k.a., and at least 165,00 k.a. (Porter and Swanson 2008). Most till deposits found along the lower Chiwawa River are believed to be associated with the most recent glaciation, though some patches of older glacial deposits may be preserved on the valley sides (Tabor et al. 1987). Thick layers of outwash gravels interbedded with fine-grained lacustrine sediments were deposited in the Chiwawa and neighboring valleys, frequently on top of till or other glacial sediments (Tabor et al. 1987). Deposition of tephra and other volcanic material sourced from Cascade Range eruptions is another key post-glacial source of sediment in the Chiwawa Valley (Porter 1978). Glacier Peak, which is located only a few miles from the Chiwawa Basin, has erupted multiple times following the last major glaciation of the Chiwawa Valley and has potentially contributed 0.5–2 meters of airfall in the Chiwawa Valley for at least three post-glacial eruptions (Porter 1978; Beget 1983). In response to changing sediment and flow conditions in the Holocene, the Chiwawa River has incised into these late Pleistocene glacial sediments abandoning the post-glacial valley surface. Lateral channel migration concurrent with and/or after this period of post-glacial fluvial incision and reduced sediment supply has produced terraces and areas of floodplain inset within the higher glacial outwash terraces.

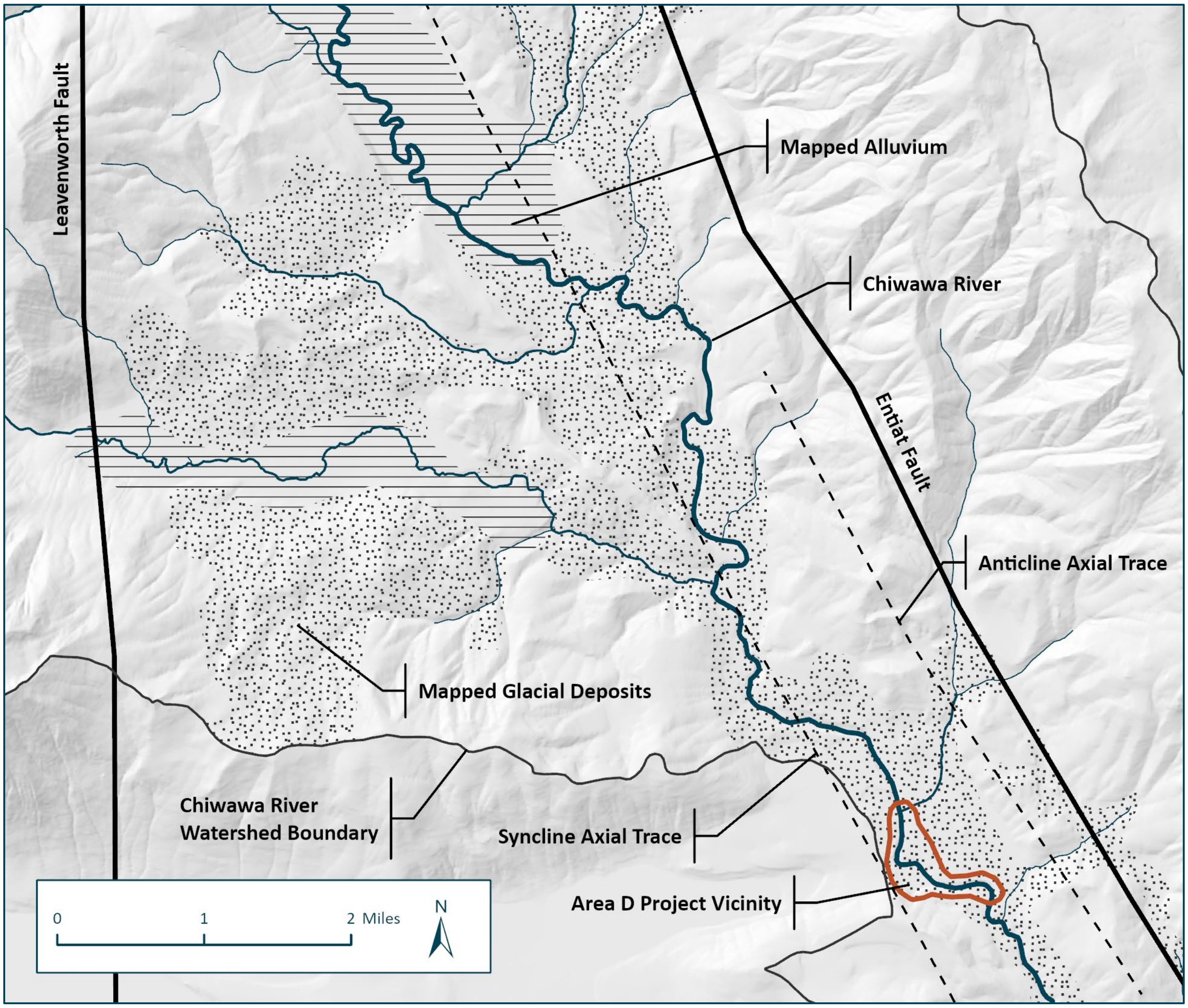

Figure 3: Generalized geologic map of the lower Chiwawa River Valley. Areas within the Chiwawa watershed boundary that aren't indicated as glacial or alluvial deposits are mapped as Chumstick Formation by Tabor et al. (Adapted from Tabor et al. 1987).

2.2 HYDROLOGY

The Chiwawa River is a major tributary to the Wenatchee River, joining the Wenatchee about 5 miles downstream of Lake Wenatchee near the town of Plain, WA. At the confluence with the Wenatchee River the Chiwawa River drains 188 miles^2 - approximately 14% of the Wenatchee Basin (1,328 mi^2). The Chiwawa River drains the North Cascades east of Glacier Peak, and its watershed ranges in elevation from 9,040 feet to 1,840 feet, with an average basin slope of roughly 195 feet/mile. This assessment focusses on the hydrology of the lower Chiwawa River Basin (LCRB), which contains the project area, and comprises the lower 73 mi^2 of the Chiwawa River watershed from Chikamin Creek to the confluence with the Wenatchee River (Figure 4).

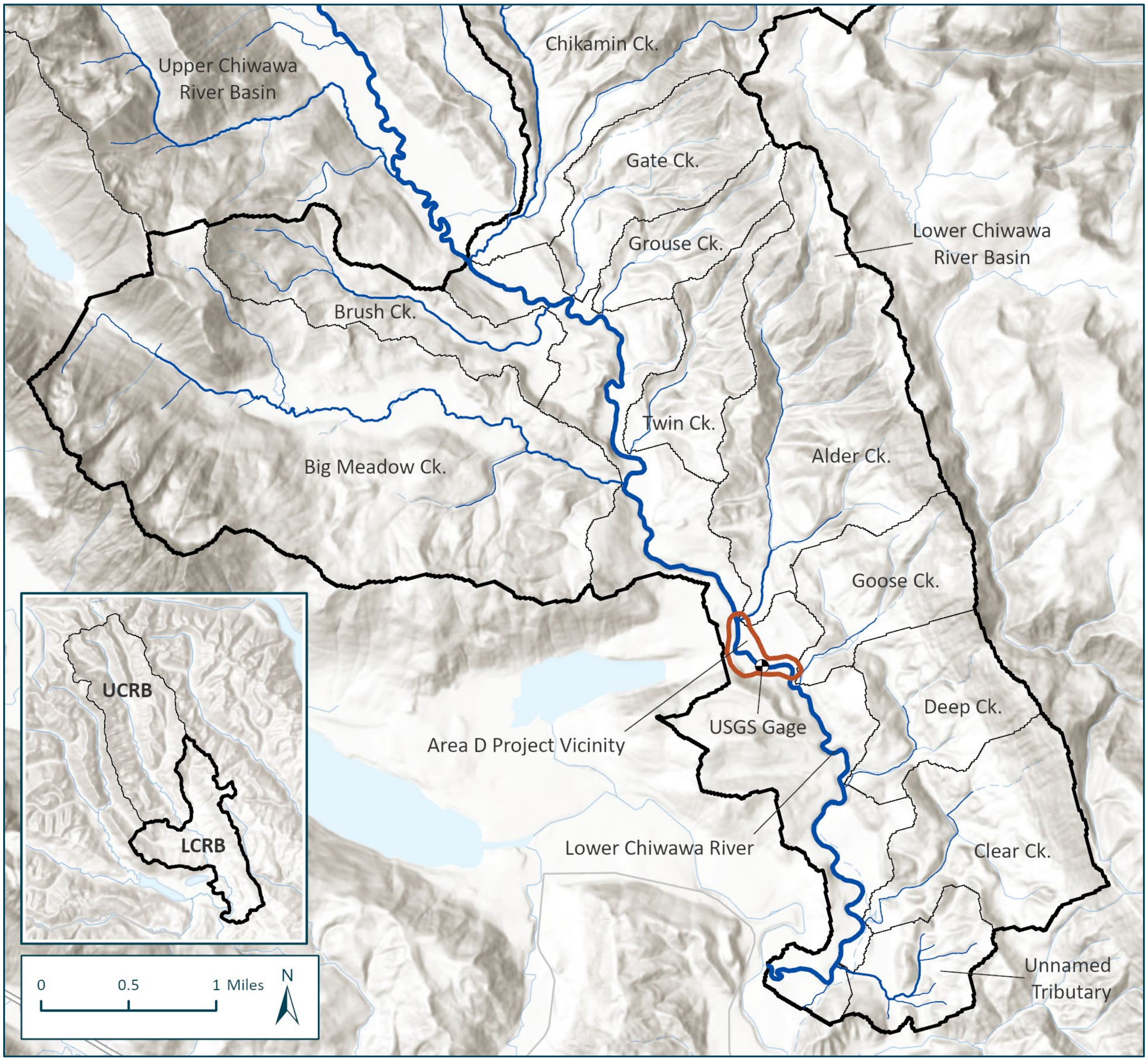

Figure 4: Location of watersheds comprising the lower Chiwawa River Basin and how they relate to the project area. An inset locator map shows the extent of the Chiwawa River watershed divided into the upper (UCRB) and lower (LCRB) sub-basins.

Mean annual precipitation in the Chiwawa River Basin is spatially variable, ranging from 26–107 inches, and 63 inches when averaged across the basin (PRISM 2022); increases in precipitation are positively correlated with elevation in the Chiwawa Basin. Most of the annual precipitation in the Chiwawa Basin falls from October through March, much as snow, especially at higher elevations[2]. Streamflow in the Chiwawa River varies seasonally, with snowmelt-driven high flows commonly peaking in May and June, and the lowest flows typically occurring in September and October (Figure 5). Occasional late-fall high flows occur from late-October through December, including the

[2] Accessed from Western Regional Climate Center at https://wrcc.dri.edu/cgi-bin/cliMAIN.pl?wa1426

two floods of record (Nov. 1991 and Nov. 1996), and typically result from rain-on-snow events and/or extreme rainfall.

A hydrologic analysis was conducted to estimate peak flows and sub-annual flows in the lower Chiwawa Basin, including in the vicinity of the project area. There is a USGS stream gage (USGS #12456500) situated within the project area, near RM 6, with approximately 47 years of peak flow data. Peak flow statistics for the mainstem Chiwawa River were estimated by conducting a Bulletin 17-C EMA Flood Frequency Analysis (FFA) on the gage data using HEC-SSP software (USACE 2017). The resultant peak flows for the Chiwawa River were subsequently scaled to the upstream and downstream ends of the lower Chiwawa Basin using published guidance for estimating discharge at ungagged sites in Washington (Mastin et. al 2016). The peak flow contributions from each major tributary were then determined by distributing the difference in flow between tributaries using a simple ratio of drainage areas. There are likely additional flow contributions between the major tributaries from inputs such as hillslope runoff and additional small tributaries. However, these contributions were assumed to be small relative to the major tributary inputs and are therefore included in the estimates for each tributary. The resultant peak flow statistics are summarized in Table 2.

Table 2: Summary of peak flow estimates for the lower Chiwawa River basin.

Tributary	**Drainage Area (mi^2)**	**Peak Flow Estimates-Drainage Area Scaled (cfs)**					
		2-year	**5-year**	**10-year**	**25-year**	**50-year**	**100-year**
Unnamed Trib (Below Gage)	1.7	41	55	63	73	80	87
Clear Ck (Below Gage)	4.0	95	127	146	169	186	201
Deep Ck (Below Gage)	2.8	66	87	101	117	128	139
Goose Ck (Below Gage)	2.6	61	81	93	108	118	128
Alder Ck	7.5	138	185	214	249	273	297
Big Meadow Ck	15.8	291	389	449	522	574	624
Twin Ck	2.2	40	54	62	73	80	87
Grouse Ck	1.7	31	41	48	55	61	66
Gate Ck	3.0	55	73	85	98	108	117
Brush Ck	3.2	59	80	92	107	117	128
Chikamin Ck	18.7	344	460	531	617	679	738
Chiwawa R (USGS Gage Location)	**172.1**	**3,206**	**4,362**	**5,103**	**6,014**	**6,677**	**7,328**
Chiwawa R (RM 15)	114.8	2,248	3,079	3,622	4,293	4,786	5,271
Chiwawa R (At Confluence w/ Wenatchee)	188.3	3,468	4,711	5,505	6,481	7,189	7,883

Sub-annual flow statistics were determined using similar methods to distribute flow between each of the major tributaries. Monthly average flows were obtained from the gage data (Figure 5) and scaled using drainage area ratios. The resultant monthly flow estimates are summarized in Table 3. Select flow rates were used in the hydraulic modeling described in Section 3, and the utility of these data may evolve as the project progresses.

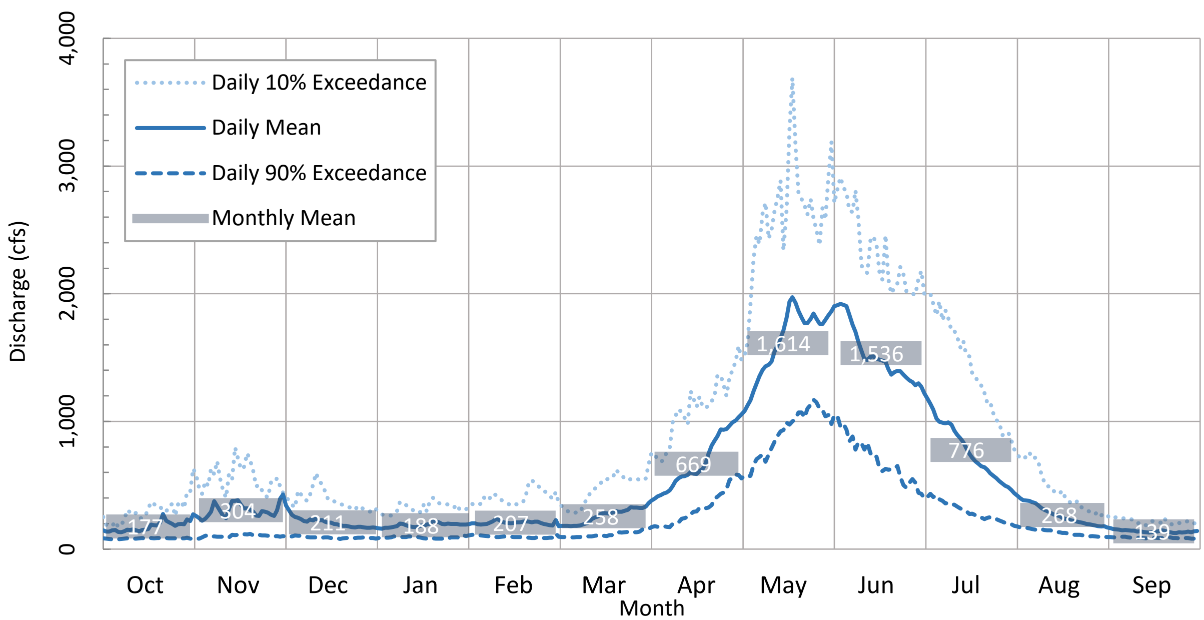

Figure 5: Annual Hydrology Statistics for USGS Gage 12456500 Chiwawa River Near Plain, WA | Water Years 1991 to 2022

Table 3: Summary of monthly average flow estimates for the assessment reach.

Tributary	Drainage Area (mi^2)	Mean Daily Flow Estimates-Drainage Area Scaled (cfs) Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Unnamed Trib (Below Gage)	1.7	3	4	3	3	3	4	10	24	23	11	4	2
Clear Ck (Below Gage)	4.0	6	10	7	6	7	9	23	55	52	26	9	5
Deep Ck (Below Gage)	2.8	4	7	5	4	5	6	16	38	36	18	6	3
Goose Ck (Below Gage)	2.6	4	7	5	4	4	6	15	35	33	17	6	3
Alder Ck	7.5	9	15	10	9	10	12	32	78	74	37	13	7
Big Meadow Ck	15.8	18	31	21	19	21	26	68	163	155	78	27	14
Twin Ck	2.2	2	4	3	3	3	4	9	23	22	11	4	2
Grouse Ck	1.7	2	3	2	2	2	3	7	17	16	8	3	1
Gate Ck	3.0	3	6	4	4	4	5	13	31	29	15	5	3
Brush Ck	3.2	4	6	4	4	4	5	14	33	32	16	6	3
Chikamin Ck	18.7	21	36	25	22	25	31	80	193	183	93	32	17
Chiwawa R (USGS Gage Location)	**172.1**	**177**	**304**	**211**	**188**	**207**	**258**	**669**	**1,614**	**1,536**	**776**	**268**	**139**
Chiwawa R (RM 15)	114.8	118	203	141	125	138	172	446	1,077	1,025	518	179	93
Chiwawa R (At Confluence w/ Wenatchee)	188.3	194	333	231	206	226	282	732	1,765	1,680	849	293	152

2.3 WATERSHED AND AQUATIC HABITAT CONDITIONS

Instream aquatic habitat conditions in the lower Chiwawa River have been impacted by historical and ongoing land uses. Historical impacts to Chiwawa River habitat include logging and housing development along the lower river. Log drives systematically removed obstructions from the channel that could trap wood (e.g., boulders and large woody debris), and disassembled jams to recover the timber contained within, thus reducing channel complexity, dynamism, and sediment sorting and storage associated with these in-channel structural features. The reduction of large wood present in the channel, and the removal of structure on which new jams could form has resulted in a homogeneous, plane-bed condition for large segments of the river, with limited areas of spawning gravel sized material present in the channel, and lack of regular connection to many historical floodplain surfaces which would provide high-flow velocity refugia. Figure 6 shows the location of Spring Chinook (UCSRB 2022a) and Steelhead redds (UCSRB 2022b) in the lower Chiwawa River, and the distribution of these data suggests that between approximately RM 5 and RM 11 the location of spawning sized material is limited to discrete zones where smaller sized material is preserved on the bed. Timber harvest in the riparian zones has reduced the potential for natural recruitment of large trees and channel shading. Some conversion of floodplain habitat to residential or agricultural land has occurred, reducing the already limited availability of floodplain and off-channel habitat areas for salmonids. In some areas, dispersed recreation appears to have impacted riparian function and potentially other floodplain functions. Most of the watershed is in public ownership (Figure 6) and upper portions of the watershed are protected as a Wilderness Area or under the Northwest Forest Plan, though legacy effects from logging or road building may still be present.

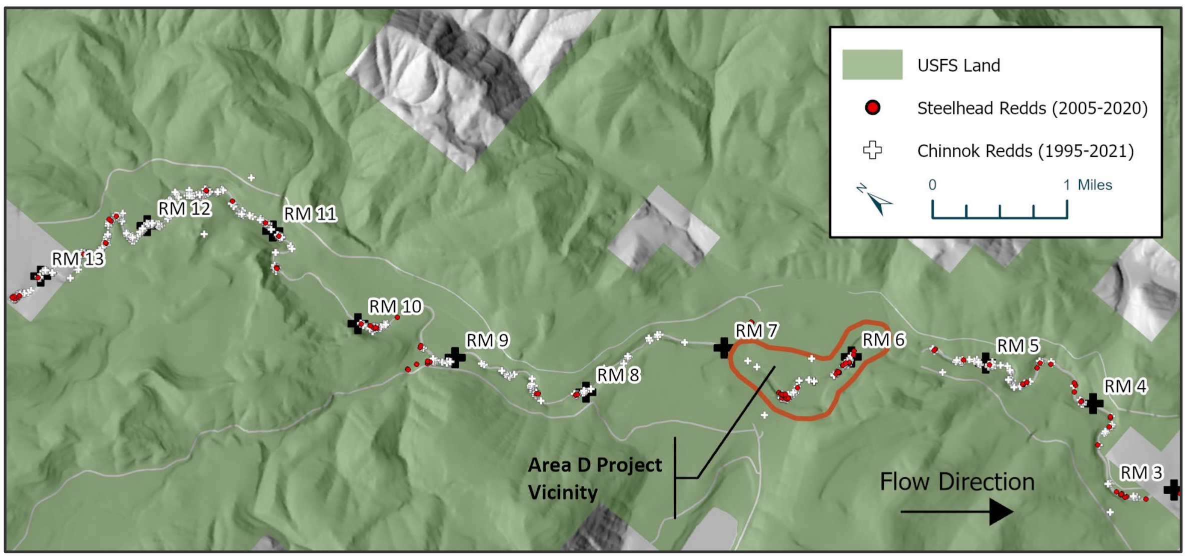

Figure 6: Map of the lower Chiwawa River from RM 3–13 showing mapped Chinook (UCSRB, 2022a) and Steelhead redds (UCSRB, 2022b) and land ownership in the vicinity of the project area. UCSRB redd data for the Area D project area document 36 Steelhead redds and 183 Chinook redds for the period of record of these data. Based on UCSRB redd data, average annual redd counts for the project area likely range between 3-6 and 7-20 for Steelhead and Chinook, respectively.

Habitat quality for both adult and juvenile life stages in the lower Chiwawa River is generally low, lacking cover from large wood, pool quantity/quality, appropriate water temperature conditions. Additionally, and of particular importance to primary life stages of interest for the Area D project, off-channel/side-channels and off-channel/floodplain habitat are lacking for much of the lower Chiwawa, and these types of habitats are infrequently connected to the channel where they do exist (UCRTT 2020; 2021). As a result, enhancement goals throughout the lower Chiwawa focus on improving off-channel/floodplain habitat types for fry and juvenile life stages in addition to mainstem habitat enhancement actions in suitable locations. Based on field observations and desktop analyses, Area D offers opportunities for side channel creation and enhanced channel-floodplain connectivity, and these opportunities for uplift are key to the project design. Mainstem large wood structures are proposed in conjunction with side channel grading to increase channel roughness in the vicinity of available floodplain surfaces, thereby increasing the frequency of inundation of these surfaces. Additionally, wood placements are included at key locations to provide cover and complexity.

2.4 GEOMORPHOLOGY

The morphology of the lower Chiwawa River valley is shaped by the glacial history of the valley and subsequent reworking of glacial sediments and landforms by the Chiwawa River. Glacial landforms and sediments are pervasive throughout the Area D project site and these glacial signatures affect modern day sediment dynamics and landscape evolution in the project area. Hence, the site's glacial history substantially modulates the processes responsible for aquatic habitat formation, and thus the distribution of aquatic habitats. This section provides a general overview of key geomorphic topics which pertain to the formation of aquatic habitats and the effectiveness of habitat enhancement designs at the Area D project site.

2.4.1 Post-Glacial Landscape Evolution

The last major glaciation in the valley deposited substantial glacial sediments in a terminal moraine which filled the valley with coarse sediment from approximately RM 13–14. This berm-like feature has trapped large volumes of alluvium and glacial outwash sediments upstream of it, and has persisted to the present day, forming the largest inflection point in the longitudinal profile of the lower Chiwawa River (Figure 7). Downstream of the moraine, glacial outwash sediments filled much of the valley, and these sediments have been incised through to form high terraces which bound the modern valley bottom on both sides. The combination of the terminal moraine controlling grade upstream of the lower Chiwawa Valley and the outwash terraces buffering the valley from adjoining hillslopes has limited sediment delivery to, and sediment storage within, the lower Chiwawa River. As a result, sediment delivered to the lower Chiwawa channel is primarily sourced from a few small tributaries, and to a lesser extent, erosion of banks or terraces by the mainstem channel.

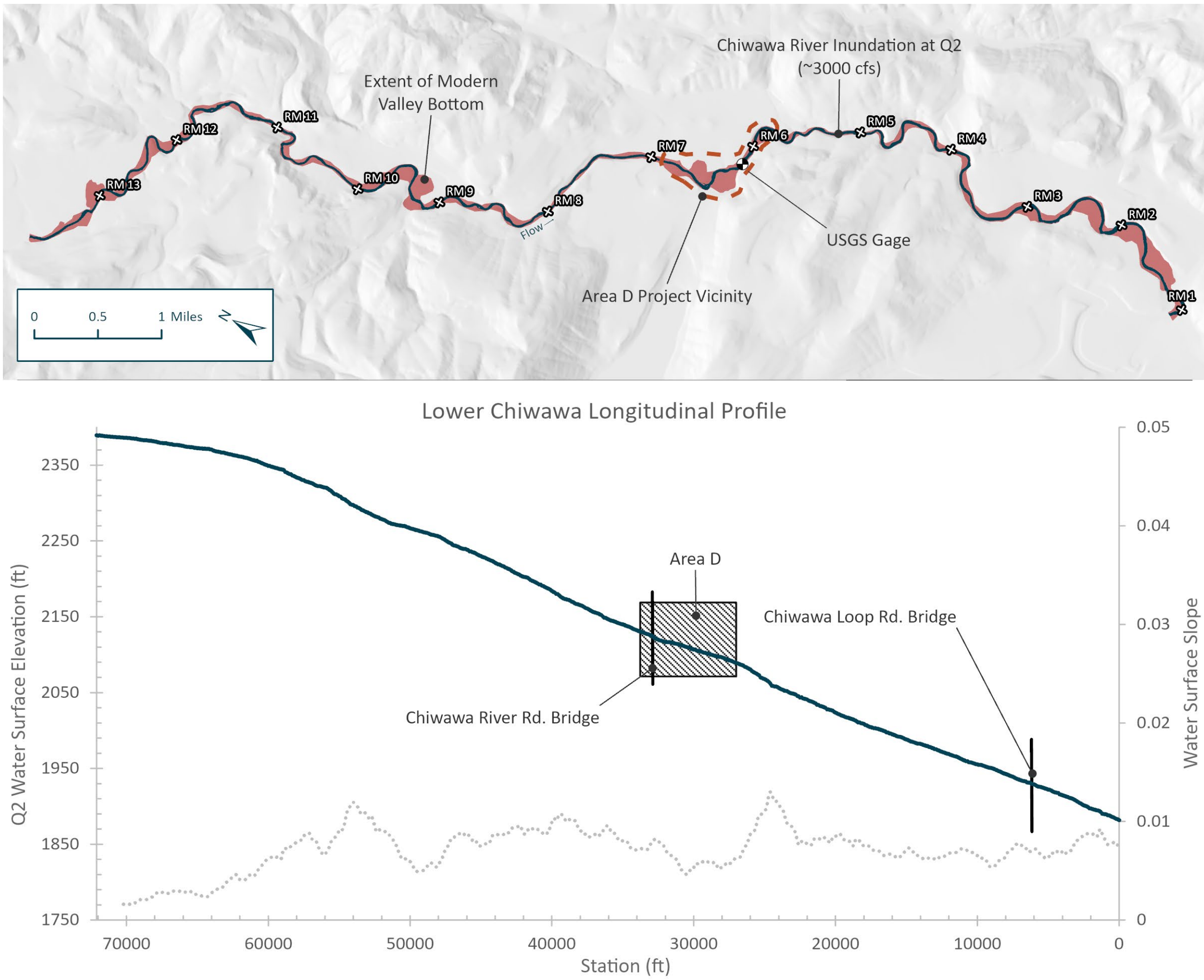

Figure 7: Map of valley confinement in the lower Chiwawa River Valley (top). The channel extent (blue) at the two-year return period peak flow (~3000 cfs) occupies very little of the historical valley bottom (red). Longitudinal profile of the lower Chiwawa River calculated from the modeled two-year return period peak flow water surface elevations (bottom). A substantial steepening in valley gradient associated with a glacial moraine is located at Station ~65,000ft. The average slope is ~0.007.

2.4.2 Channel and Valley Morphology

The morphology of the lower Chiwawa River is largely uniform from its confluence with Chikamin Creek (RM 13.5) to the large alluvial fan located at the Chiwawa's confluence with the Wenatchee River (RM 0–1). The lower Chiwawa River flows through a wide (115 feet on average), single thread channel, confined between glacial outwash terraces and bedrock hillslopes (Figure 7). The average active valley width is approximately 400 feet, and the confinement ratio (ratio of valley bottom width to channel width) is approximately 3.5, indicating a confined condition. The channel is relatively straight with a sinuosity of 1.29.

2.4.3 Channel Bed and in-Channel Storage

The lower Chiwawa River channel bed is primarily composed of cobble–boulder sized sediments derived from glaciofluvial processes occurring during deglaciation and post glacial outwash incision. In places, patches of sand, gravel, and smaller sized cobbles are found in locations of lower velocity along the banks and in the channel behind jams, boulders, or other obstructions which decrease velocity. Occasionally the channel flows over bedrock with no alluvial cover. Field observations suggest that cobble–small boulder sized bed material is mobile in many portions of the assessed reach, and that finer sediments (sand–small cobble sized) are readily mobilized and transported downstream and out of the reach unless they are retained in areas of lower velocity (e.g., slack water deposits in the lee of boulders, depositional zones on the downstream side of fallen trees). Stream power and sediment transport is high and available sediment supply is low. Therefore, areas of deposition and storage of mobile sediment are relatively small and infrequent along most of the lower Chiwawa River.

2.4.4 Channel Banks and Lateral Processes

Lateral channel processes are the primary mechanism of channel change along the lower Chiwawa River, and these processes are important as they promote channel-floodplain connectivity and facilitate sediment sorting and storage, yet these processes have been impaired due to decreased complexity and structure within the lower Chiwawa channel. Bank erosion and channel migration across the floodplain recruits additional wood into the channel, thereby increasing the wood load and enhancing the effects of large wood on channel processes. Furthermore, large, persistent wood jams may have acted as grade control structures, reducing local channel gradient and affecting sediment dynamics and channel planform upstream of some jam sites.

2.4.5 Overview of Sediment Dynamics

Observations and analyses of channel sedimentary characteristics and morphology suggest that much of the lower Chiwawa River operates in a supply limited condition, where the amount of sediment delivered to and routed through the channel is less than the channel's capacity to transport sediment (for regularly occurring flows, and sediment sizes which compose the mobile portion of the channel bed). Relatively low sediment supply is primarily due to the watershed's glacial history. This condition limits sediment supply from tributaries and from hillslope inputs. Additionally, incision down to bedrock and channel armoring act to reduce the ability of the channel to erode laterally into adjacent outwash terraces that could increase sediment supply. Therefore, in most reaches, sediment that is delivered to the lower Chiwawa is unlikely to be stored in the system for long durations, as historical landscape characteristics naturally favor transport over storage. The location and degree to which anthropogenic alteration of the channel through wood or rock removal has further enhanced the natural tendency of sediment transport versus storage is not well understood. However, removal of large wood and large boulders that would have provided channel roughness and opportunities for sediment storage and habitat is known to have occurred. In summary, the lower Chiwawa River does not receive large inputs of sediment from the watershed and is effective at entraining and transporting large volumes of alluvium in relatively frequently occurring flows. This natural condition coupled with recent removal of large wood and boulders to facilitate log drives has reduced habitat quality and quantity.

2.5 INFRASTRUCTURE & BUILT FEATURES

The Area D project vicinity contains an important bridge crossing the Chiwawa River, several built features, and is commonly visited for recreational purposes. The most noteworthy infrastructure in the project vicinity is the full-span bridge for Chiwawa River Road in the upstream portion of the project area. There are eight rustic cabins and associated outbuildings built on USFS leased land on a river right floodplain surface adjacent to the central portion of the project site. The USGS gage for the Chiwawa River is located along the right bank of the channel slightly downstream of the floodplain surface where the cabins are sited. Other built features in the project area include the USFS Goose Creek Campground located in the downstream portion of the project area, and extensive dispersed camping sites consisting of rudimentary roads, cleared areas, and fire rings, throughout much of the project area. Due to the extensive development in the project area, the hydraulic impacts of potential project elements were evaluated during design development to check that project elements were not putting structures at risk, and additional information about this assessment is included in Appendix B. Additionally, a risk assessment of project elements to public safety and property, and associated design recommendations are included in Appendix C.

2.6 HYDRAULIC MODELING

2.6.1 Hydraulic Modeling Overview

Existing and proposed channel and floodplain hydraulics were simulated using a two-dimensional (2-D) hydraulic modeled developed using the U.S. Army Corps of Engineers Hydraulic Engineering Center River Analysis System (HEC-RAS 6.4.1; USACE 2023). A detailed description of the model setup is provided in the previously issued Lower Chiwawa River: Alternatives Analysis report (Inter-Fluve 2022). The following sections summarize the general approach taken for modeling the project, the model geometry, and key input parameters pertinent for modeling the project.

2.6.1.1 Model Geometry & Domain

The model geometry for existing and proposed conditions is based on a digital terrain model (DTM) that was developed using topo-bathymetric LiDAR data that were collected in 2021 (NV5 Geospatial 2021). The existing conditions DTM was modified to represent proposed conditions using the terrain editing tools within the HEC-RAS RAS Mapper application to incorporate changes such as the proposed excavated side channel and large wood structures which obstruct a portion of the existing channel.

A subset of the larger Lower Chiwawa Reach Assessment model (Inter-Fluve, 2022) was developed to facilitate design iterations and computational efficiency. The subset model for Area D extends from approximately RM 7 at the upstream end to approximately 800 feet downstream of the Goose Creek confluence at the downstream end.

The Area D model domains consist of a computational grid with average cell spacing ranging between 10 and 16 feet within the active channel to approximately 30 feet in the floodplain. The resolution of the grid was adjusted based on terrain complexity and areas of interest, with smaller cell sizes applied to areas where higher resolution results were desired. Break lines were added along the tops of banks, channel alignments, and various high ground features or channel obstructions to further refine the computational mesh where needed. Additional mesh refinements can be incorporated in response to project needs as the project progresses, and the utility of the model evolves.

2.6.1.2 Model Input Parameters

Key model input parameters are summarized under the following bullets:

- Boundary Conditions

2D hydraulic models require boundary conditions at locations where flow is expected to enter or exit the computational domain. Inflow hydrographs were used at the upstream end of the model near RM 7, and at each of the major tributaries (Alder and Goose Creeks) within the Area D project vicinity (depicted in Figure 4). These inflow hydrographs are based on the hydrology estimates discussed in Section 2.2 and the discharges used in the hydraulic modeling are summarized in Table 2 and Table 3.

Discharges were incorporated into synthetic quasi-steady state hydrographs with periods of steady flow (at the discharges of interest and other intermediate discharges) connected by smooth transition periods to create a stair-step like pattern. This approach does not allow for analysis of the receding limb of the hydrograph, and likely provides conservatively high results with respect to large floods, as floodplain storage areas generally fill completely to allow the model to reach a steady state. Further, the timing of flood peaks at each of the tributaries relative to the timing of flood peaks in the mainstem Chiwawa were assumed to be equal, which likely provides additional conservativism with respect to larger flood events. Future modeling efforts may warrant additional hydrologic analyses to approximate the relative timing of each of the tributary inputs and the mainstem Chiwawa.

The downstream boundary condition consists of a stage/discharge rating curve derived from the results from the larger reach assessment model, to maintain consistency with previous modeling efforts. Both the upstream and downstream boundary conditions are relatively far from the project area, and therefore they dampen the effects of any potential uncertainties associated with boundary condition assumptions.

- Hydraulic Roughness

A spatially varying hydraulic roughness (Manning's n) layer was created in ArcGIS software using a combination of LiDAR derived vegetation heights and hand-digitized landcover regions. Roughness values were assigned to each landcover region based on published guidelines, field observations, and professional judgement. Roughness coefficient assumptions were based on guidelines for one-dimensional characterization of corresponding channel types and vegetation conditions (Arcement

& Schneider 1989), with the understanding that 2D roughness values can often vary substantially from those published for 1D models (Robinson et al. 2019). Table 4 summarizes the roughness coefficients used in the existing condition model. Proposed conditions roughness coefficients were assigned to prominent features in the conceptual designs, such as side channels and large wood structures.

Table 4: Roughness coefficients used in the 2D model.

Land Cover Region Description	Manning's n Value
Active Main River Channel (gravel/cobble/boulder)	0.035 – 0.06
Veg. Height < 0.5 ft	0.04
Veg. Height 0.5 ft – 5 ft	0.08
Veg. Height 5 ft – 12 ft	0.14
Veg. Height 12 ft – 20 ft	0.1
Veg. Height > 20 ft	0.12
Existing Wood Accumulation	0.2
Proposed Large Wood (built into terrain)	0.065
Proposed Side Channel	0.075

2.6.2 Review of Model Results

Model results were used to gain a high-level understanding of hydraulic characteristics throughout the project area and inform the design development. Under existing conditions, the model results demonstrate that there are very few valley-bottom surfaces that are frequently inundated, resulting in relatively homogenous, high-energy hydraulics throughout the project area. There are some isolated areas of hydraulic diversity, which are typically associated with large obstructions such as boulders or log jams, or sharp meander bends. Figure 8 shows existing conditions model results for September average flow (approximately baseflow) and for the 5-year return period peak flow. Under both flow conditions, almost all flow is contained within the channel, and the channel displays fairly homogenous flow conditions, with the exception of the meander bend and areas on the river-left floodplain near the bottom of the image.

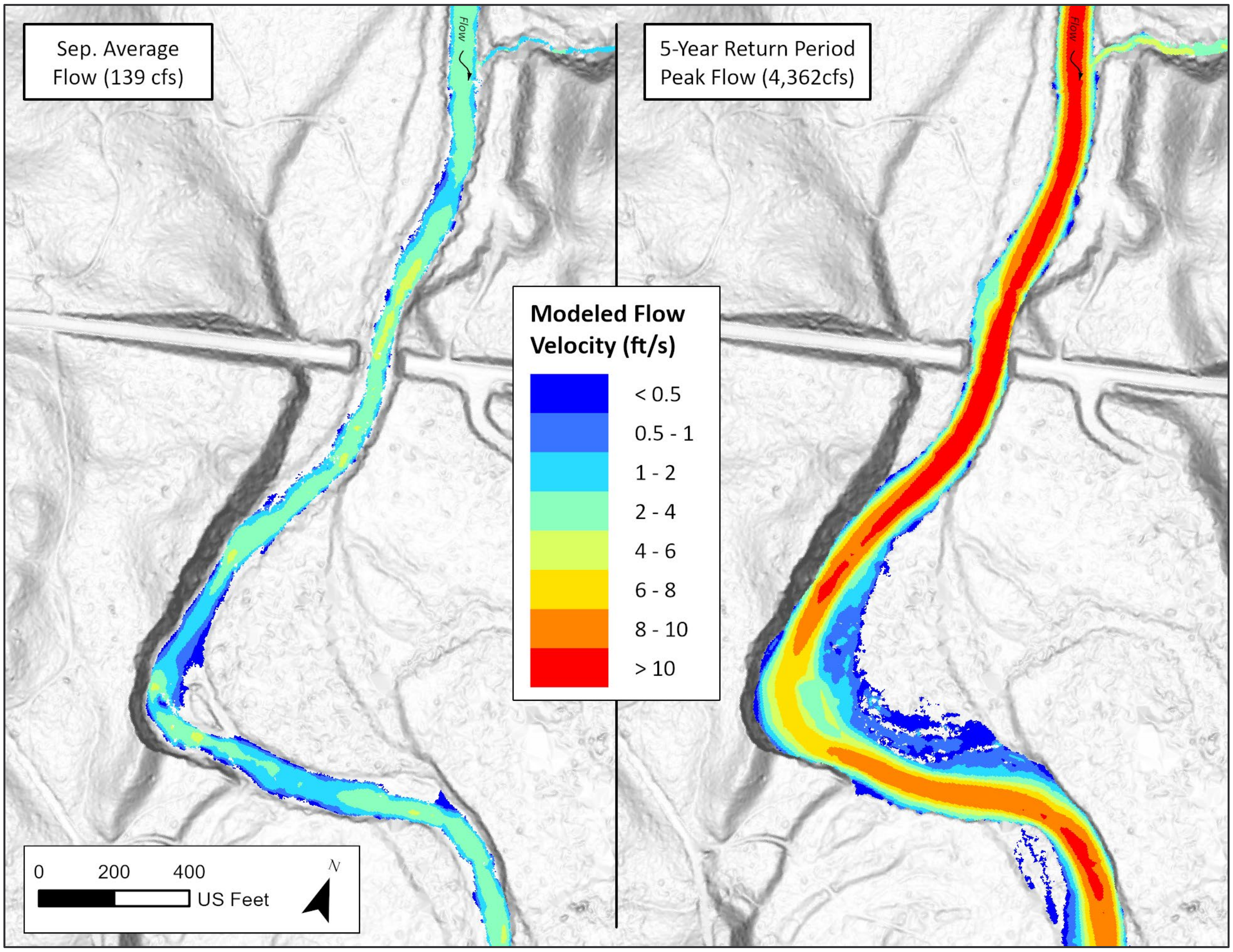

Figure 8: Velocity model results for September average flow (left) and the 5-year return period peak flow (right) under existing conditions in the project area Discharge magnitude values reported in the figure for the respective return periods are for the Chiwawa River at the USGS gage.

The proposed design aims to address the lack of hydraulic complexity and lack of floodplain-channel connectivity in the project area. The design includes one perennial side channel connection, and proposed mainstem large wood structures sited at locations that could increase in-channel hydraulic complexity, increase the frequency and magnitude of overbank flows, and influence the geomorphic conditions of the site to facilitate the development of complexity and habitat formation at the site. Subsequent sections provide a more robust description of how specific proposed project elements influence site hydraulics, and a compilation of modeled depth and velocity patterns for existing and proposed conditions are included as Appendix D.

3. Project Design

Previously discussed site conditions, analyses, and design criteria were used to inform the arrangement and design of proposed treatments. The design may evolve during future phases based on additional stakeholder feedback, availability of materials, landowner constraints, and other considerations that may arise. The proposed project includes placing large wood structures throughout the reach and excavating a perennially connected side channel. It also includes terrestrial restoration work to treat impacts associated with dispersed camping and improve riparian habitat conditions (Appendix G). The following subsections describe the proposed designs, the habitat uplift that is anticipated to result from the proposed treatment actions, and concerns pertaining to the implementation of different treatments and working in different portions of the project area. The engineer's opinion of probable costs for the project can be found in Appendix E, and the plans for this design phase are included as Appendix F.

3.1 PROPOSED TREATMENTS

The following subsections describe the proposed design treatments and a general description of each treatment type and location within the 30% design drawings. A general review of key considerations relating to the feasibility, construction, and risk associated with each treatment is provided.

3.1.1 Apex Large Wood Structures

3.1.1.1 Description and Benefits

Apex wood structures are proposed in midchannel and split flow locations (e.g., side channel entrances). The structures are intended to produce hydraulic complexity, initiate lateral channel processes, trap mobile wood, and sort sediment. Depending on the characteristics of the sediment load, bars formed in the lee of the structures should provide spawning locations. Apex structures may scour pools, and these structures may deflect the flow of the main channel around the proposed structure. If a pool is present on the upstream face of the structure, it will provide covered low flow habitat. An additional habitat benefit includes velocity refuge during higher flows.

3.1.1.2 Application of Treatment

Apex-style large wood structures are proposed in the vicinity of the proposed side channel and the downstream portion of the project area. The location and number of apex structures are as follows:

- One apex structure is proposed along a river-left near the location of the proposed side channel inlet at approximately Sta. 55+00
- One apex structure is proposed on a midchannel bar near Sta. 50+00
- One apex structure is proposed at the side channel outlet on river-left bar near Sta. 42+00
- One apex structure is proposed in a midchannel location near Sta. 22+00

Apex style structures will be stabilized via connections between vertical piles, either dug or driven into the channel bed. If vertical pile installation is not feasible at time of construction, then apex structures may be stabilized using ballast boulders connected to the structure, but this option should only be considered if site conditions prevent the installation of vertical piles. Most rootwads in apex structures face upstream, with a few rootwads placed facing out on either side of the structure. Salvaged trees and slash should be incorporated into the structure between layers of logs and packed into the upstream face of the structure to reduce porosity. A pool will be excavated at the upstream face of apex structures and salvaged alluvial material placed on top and behind the structure. Fine sedimentary material will be preferentially placed at the top of the backfill and the backfilled material will be planted with live stakes of appropriate riparian vegetation species.

3.1.1.3 Feasibility, Construction, and Risk Considerations

Apex large wood structures will be constructed by excavator. Wood will be delivered to each site via skidder or other off-road capable hauling vehicle. Alternatively, wood could be delivered to each project site via heavy-lift helicopter to reduce impacts. Temporary wet crossings will be needed for machinery to reach proposed structure locations at stations 50+00 and 22+00.

Vertical logs will be installed via a vibratory driver (or other methods if design embedment depths cannot be reached) and provide resistance to lateral and buoyant forces. A sheet pile coffer dam would be preferred for dewatering and fish salvage during construction and may be required for the structure near 22+00. Detailed stability analyses will be performed in future design phases to better constrain the potential for wood mobility and expected longevity of wood structures in the project area. Other concerns associated with constructing apex wood structures include avoiding sensitive habitat areas and areas containing cultural artifacts.

A preliminary assessment of the risk to public safety and property damage was performed based on Reclamation's Large Wood Material Risk Based Design Guidelines (Reclamation, 2014). The proposed structures have a moderate to high public safety risk and a low to moderate property damage risk. Based on the risk assessment, the proposed large wood structures will need to be designed to resist hydrodynamic forces up to the 50-year storm (at a minimum) with factors of safety of 1.75 and 1. 5 for vertical (buoyancy) and horizontal (sliding) forces, respectively. Wood species that are resistant to decay (e.g., Douglas-fir, western redcedar) will be required for key members larger than 12-inch diameter. Additional information about the engineering considerations and risk assessment can be found in the Large Wood Structure Risk Assessment Memorandum in Appendix C. Following Reclamation (2014) guidelines, the design criteria used to develop this 30% design will provide stability up to 50-year return flood forces. The design criteria may be updated as the project progresses through subsequent design phases.

3.1.2 Bank Buried Large Wood Structures

3.1.2.1 Description and Benefits

Bank buried large wood structures are positioned near the channel margin, in locations where pools are already forming or could develop with the addition of in-channel structure. These structures maintain and/or enhance pool quality and provide covered pool and refuge habitat at a range of flows, including low flows. Depending on the site characteristics, bank-attached bars may develop downstream of the structures.

3.1.2.2 Application of Treatment

Bank buried large wood structures are proposed throughout the project area. The location and number of bank buried structures in the project area are as follows:

- Three bank structures are proposed above the Chiwawa River Road bridge, along the left bank - at the Alder Creek confluence (Sta. 68+00), near Sta. 67+50, and at Sta. 65+50
- One bank structure is proposed on the right bank near Sta. 45+00
- One bank structure is proposed on the left bank at Sta 22+00

Bank buried structures will be stabilized by burying a large portion of the rootwad logs in an excavated hole in the bank with salvaged alluvial backfill. The top rootwad logs will be buried with at least 4 feet of backfill material, and vertical logs or boulder ballast used if minimum burial depth cannot be achieved. All rootwads should extend beyond the bank into the channel, and the top layer of rootwads will not extend above ordinary high water. Salvaged trees and slash should be incorporated into the portion of the structure that extends into the channel between layers of logs and packed into the upstream face of the structure to reduce porosity. Tipped or salvaged trees can also be placed on top of the top layer of rootwad logs in the structure. A pool will be excavated at and below the location of the rootwads, and salvaged alluvial material can be placed on top of the structure to provide more backfill. Fine sedimentary material will be preferentially placed at the top of the backfill and the backfilled material will be planted with live stakes of appropriate riparian vegetation species.

3.1.2.3 Feasibility, Construction, and Risk Considerations

Concerns regarding construction access, constructability of structures, and risk to infrastructure and public safety for bank buried large wood structures are very similar to those of apex style structures. Refer to section 3.1.1.3 for a discussion of these concerns.

3.1.3 Bar Top Roughness Large Wood Structures

3.1.3.1 Description and Benefits

Bar top roughness structures are lower profile wood structures positioned on existing bars meant to narrow the active channel, rack mobile wood, and sort and store mobile sediment. Their provided functions are similar to the apex structures described above, but they are lower profile and unlikely to ever provide pool habitat. However, the structures will provide velocity refuge at elevated flow rates.

3.1.3.2 Application of Treatment

Bartop roughness large wood structures are proposed on the prominent inside bend at the lower end of the project. The location and number of bartop roughness structures in the project area are as follows:

- Two structures located on the river right between Sta. 10+00 and 15+00

Bar top roughness structures will be stabilized via connections between vertical piles, either dug or driven into the channel bed. If vertical pile installation is not feasible at time of construction, then they may be stabilized using ballast boulders connected to the structure, but this option should only be considered if site conditions prevent the installation of vertical piles. Most of the rootwads in structures face upstream, though three rootwads are placed perpendicular to flow, facing out on either side of the structure.

3.1.3.3 Feasibility, Construction, and Risk Considerations

The locations specified for the structures will require repurposing former, and pioneering new, access routes to the sites. Concerns regarding constructability of structures and risk to infrastructure and public safety for bar top roughness large wood structures are very similar to those of apex style structures. Refer to section 3.1.1.3 for a discussion of these concerns.

3.1.4 Side Channel Creation

3.1.4.1 Description and Benefits

Side channel creation involves the excavation of a side channel on one of the few low floodplain surfaces present in the project area. If the excavated material from the side channel meets certain grain size criteria, then the material will be placed as backfill for nearby apex structures, placed in the channel to augment existing bars, and/or hauled off site.

To meet lower Chiwawa-wide habitat enhancement goals, the proposed side channel will engage perennially to deliver off-channel habitat throughout the year. The side channel will be constructed with ample wood and a complex profile to create hydraulic and habitat diversity.

3.1.4.2 Application of Treatment

A roughly 1000-foot-long side channel is proposed along a low floodplain surface on the left bank of the Chiwawa River below the Chiwawa River Road bridge (inlet near Sta. 56+00). The side channel is designed to convey flow perennially, with an inlet elevation (2115 feet) lower than the modeled base flow water surface elevation at the inlet. At the current design phase, the side channel has a bottom width of 15 feet, variable side slopes ranging from 1.5H:1V to 4H:1V, and an average longitudinal slope of 0.7%. Typical excavation depths range from 4–6 feet, and the side channel is expected to require approximately 4,000 cubic yards of excavation in total. The configuration and location of the side channel is expected to be updated at subsequent design phases to incorporate more explicit details regarding the location of variable side slopes, bedforms, and habitat wood placements.

3.1.4.3 Feasibility, Construction, and Risk Considerations

Side channel treatments may change substantially based on investigations of floodplain stratigraphy which will be performed at future design phases.

As the side channel designs progress, the following factors will be considered:

- Designs will consider the risk of the main channel avulsing into the side channel alignment, evaluate the implications of channel avulsion on aquatic habitat creations, and reflect the findings of these investigations; and
- Designs will aim to excavate the bed of the side channel to a depth where coarse alluvium is present in the floodplain stratigraphy and to regularly receive groundwater inputs throughout the year.

3.2 DESIGN BENEFITS AND EFFECTIVENESS

The effectiveness of the proposed design was evaluated based on how well the design is predicted to affect the goals and objectives. At the current stage of design, 'effectiveness' is based on professional judgment and the interpretation of hydraulic model results.

The goal for Area D is to improve off-channel floodplain/side channel habitat for summer rearing, winter rearing, and fry life stages. The measurable objectives include increasing wood loading to greater than 70 pieces per mile and creating up to 0.25 miles of perennially inundated side channel habitat.

As proposed, the design calls for the installation of 4 apex wood structures, 5 bank buried wood structures, and the use of 200 logs in the proposed side channel. This results in a wood loading rate that ranges from approximately 230 to 430 trees per mile (depending on whether the side channel is included), which is well above the target of 70 trees per mile. The side channel itself is also well above the target loading rate at nearly 1100 trees per mile. As proposed, the side channel is designed to inundate at lower flows (September average flow), providing off channel habitat through a large range of flows.

The performance of, as well as the anticipated stream response to, the wood structures was assessed using the proposed conditions hydraulic model. Figure 9 shows predicted changes in velocity resulting from the wood placement for a 2-year return period peak flow. Decreases in velocity are predicted in the hydraulic lee of the proposed structures. These are interpreted to show areas that could provide velocity refuge and accumulate sediment, depending on supply. Increases in velocity are shown adjacent to structures and are interpreted as highlighting areas of the channel where erosion and the creation of new habitats could occur. Overall, the hydraulic diversity of the reach is increased compared to existing conditions, and the project is likely to produce increased habitat diversity. Furthermore, the predicted patchiness of the hydraulics should increase erosion and sediment storage and lead to a more complex channel overall. Maps containing detailed hydraulic modeling results are provided in Appendix D.

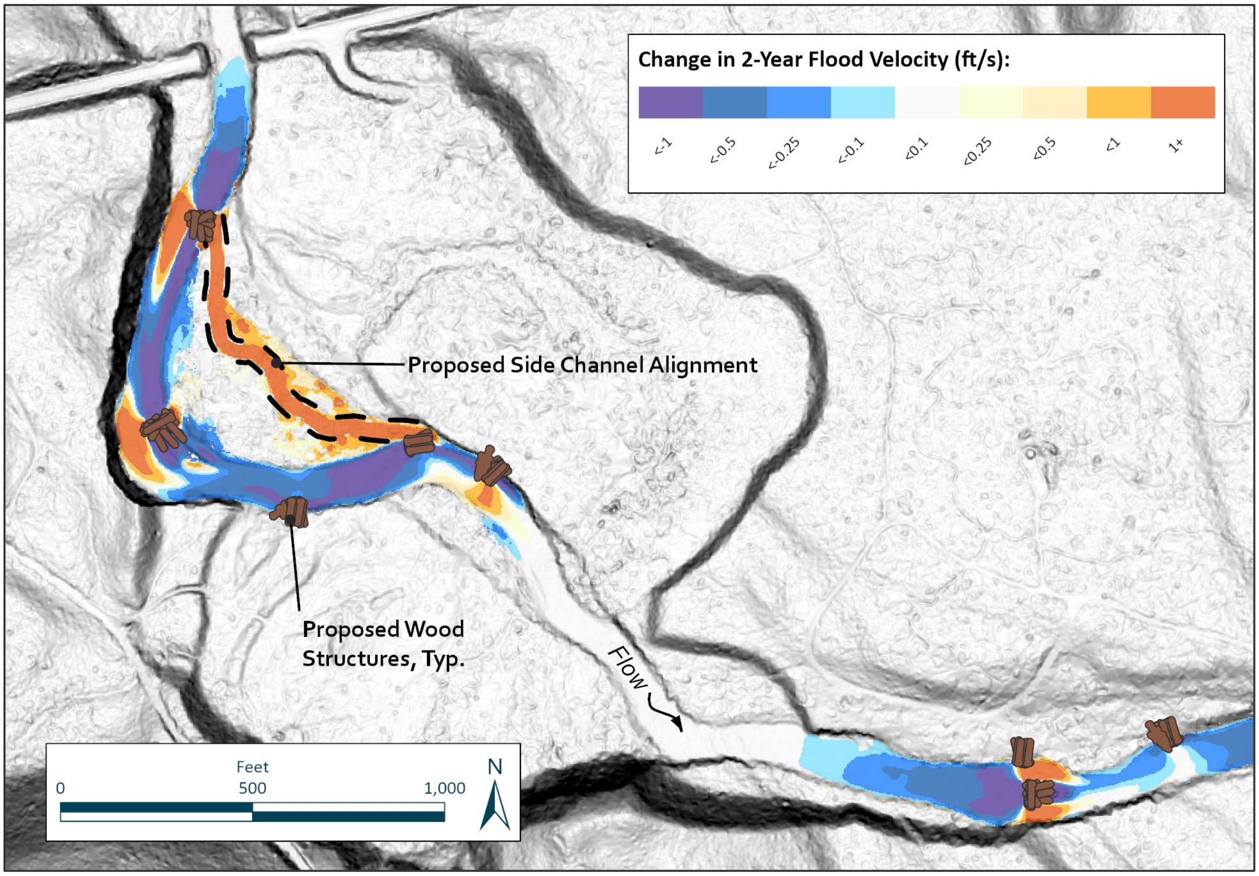

Figure 9: Predicted changes in velocity resulting from the wood placement for central portion of the project area. Cool colors show predicted decreases in velocity while warm colors show increases in velocity.

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