

Middle Entiat River Reach Assessment & Restoration Strategy Update

Final Report

February 2026



PREPARED FOR
Yakama Nation Fisheries



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Inter-Fluve

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Appendix A | Habitat Assessment

Appendix B | Reach-Based Ecosystem Indicators

Appendix C | Restoration Strategy

Appendix D | Hydraulic Model

List of Abbreviations

DBH – Diameter at Breast Height

DSM – Digital Surface Model

ESA – Endangered Species Act

LiDAR – Light Detection and Ranging

LWM – Large Woody Material

REI – Reach-Based Ecosystem Indicators

REM – Relative Elevation Model

RM – River Mile

UCHRP – Upper Columbia Habitat Restoration Project

UCRTT – Upper Columbia Regional Technical Team

UCSRB – Upper Columbia Salmon Recovery Board

1. Introduction

1.1 OVERVIEW

This assessment evaluates aquatic habitat and watershed process conditions for a portion of the middle Entiat River and identifies habitat restoration strategies. The assessment area has been the focus of numerous past assessments, restoration strategies, and implemented restoration projects over the past 15+ years. This current effort summarizes key findings from the previous assessments and collects new data to characterize current conditions, including in areas affected by restoration projects implemented since the original assessments were completed. Based on the findings of this assessment, a new restoration strategy for the study area is provided, which includes updated recommendations for restoration and conservation actions that help achieve the objectives of the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (UCSRB 2007) and its associated Biological Strategy (UCRTT 2021).

The Entiat River is a tributary of the Columbia River and is located on the east slope of the Cascade Mountains in Chelan County, Washington (Figure 1). The Entiat River flows for approximately 57 miles from its headwaters to its confluence with the Columbia River at river mile (RM) 482.7. This Middle Entiat Reach Assessment update covers 11.1 river miles (RMs) of the mainstem Entiat River from downstream of the terminal glacial moraine near Potato Creek (RM 15.6) up to McCrea Creek (RM 26.7) (Figure 1).

This reach assessment provides a technical foundation for understanding the existing conditions of the Entiat River within the study area and for identifying areas that would benefit most from restoration strategies to improve aquatic habitat and stream ecological functions. Conditions are assessed at multiple scales, ranging from the habitat unit scale (e.g. habitat assessment) to the reach-scale (e.g. REI analysis) to the study area scale (e.g. hydraulic modeling). The aim of this assessment is to identify areas for restoration actions that address factors limiting the productivity of native salmonids and to ensure that the identified actions fit within the appropriate geomorphic and ecological context of the river system. An emphasis is placed on understanding the underlying biological and physical processes at work and how human impacts have affected these processes and the habitat they support. Restoration measures focus on recovering, to the extent possible, these impaired processes. Additionally, areas of minimal human impact, or areas at particular risk of further degradation, are identified to promote conservation of ecological processes. Although the proposed restoration and conservation measures are expected to benefit a large suite of native aquatic and terrestrial species, there is a particular emphasis on recovery of Endangered Species Act (ESA) listed Upper-Columbia summer steelhead (*Oncorhynchus mykiss*), Upper-Columbia Spring Chinook (*Oncorhynchus tshawytscha*), and Columbia River Bull Trout (*Salvelinus confluentus*).

The report includes the following components:

- Assessment area summary (Section 2): Description of the assessment area, fish use, and geophysical setting based on previous assessments.

- Hydrology and hydraulic modeling (Section 3): 2-dimensional hydraulic modeling of the study area, and related hydrologic summary. Detailed methods and results provided Appendix D.
- Stream habitat assessment (Section 4): Aquatic habitat inventory at the reach scale. Detailed methods and results provided in Appendix A.
- Reach-based Ecosystem Indicators (REI) analysis (Section 5): Comparison of habitat conditions to established functional thresholds. Detailed methods and results provided in Appendix B.
- Channel segment conditions (Section 6): Inventory and analysis of habitat and geomorphic conditions at the reach and sub-reach scales.
- Restoration strategy (Appendix C): A comparison of existing conditions to target conditions at the reach scale and identification of recommended restoration treatments that address habitat and ecological process limitations within the geomorphic context of the reach.

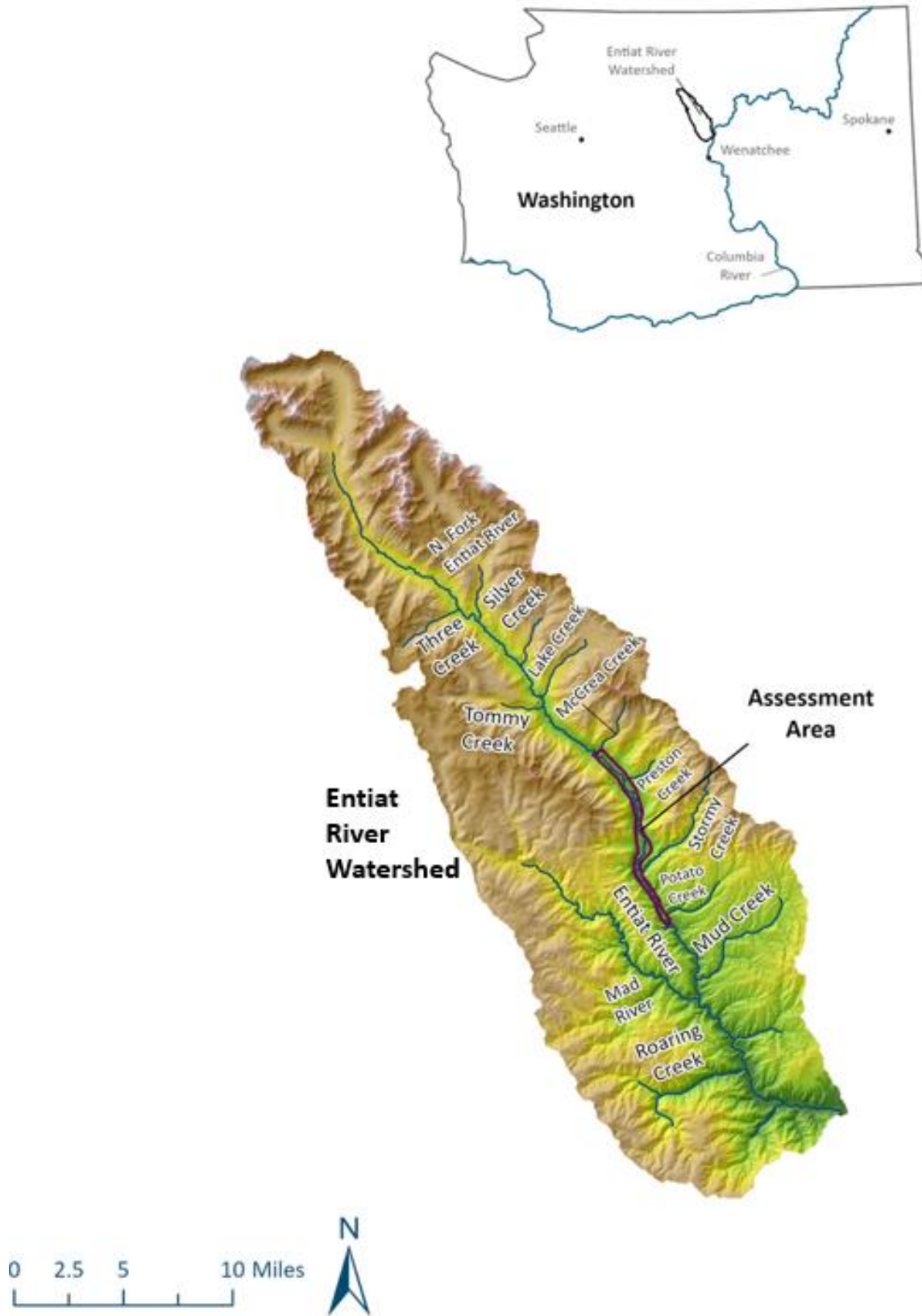


Figure 1. Location of the Entiat River assessment area within the Entiat River watershed.

1.2 PURPOSE AND APPROACH

This project was completed on behalf of the Yakama Nation as a part of their efforts to improve native aquatic fisheries within the Columbia River Basin through their Upper Columbia Habitat Restoration Project (UHRP). The UHRP works to achieve the objectives of the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (UCSRB 2007) and its associated Biological Strategy (UCRTT 2021).

This assessment involves collecting field data of the study area and combining it with existing available information. Various assessments, including past watershed assessments and reach-scale assessments, have been completed for the study area. These assessments are summarized in Section 1.3. This current reach assessment relies heavily on past work to inform certain basin- and reach-scale conditions that would be relatively unchanged since the previous assessments, such as geophysical setting, hydrologic setting, and past human impacts. New data collection and analysis only occur for elements that are likely to have changed. New data collection and analysis include new habitat surveys, new hydraulic modeling, new vegetation characterization, and a new Reach-Based Ecosystem Indicators (REI) analysis. In this regard, this current reach assessment differs somewhat from typical reach assessments. The emphasis is on providing an update to reflect current conditions, understanding how these have changed, and using this information to develop an updated habitat restoration strategy. The presence of past restoration projects is also taken into consideration. Over the past 15+ years, there have been many restoration projects implemented in the study area. The location of these projects is documented in this assessment. The restoration strategy evaluates potential adaptive management of these projects, additional potential work in existing project areas, and opportunities to address areas that have not been previous targets for restoration.

The purpose of this assessment is to:

- Summarize watershed- and reach-scale conditions that have been characterized as part of previous assessments.
- Perform updated field data collection and technical analyses to document current conditions, including an aquatic habitat inventory, hydraulic modeling, vegetation characterization, and an REI analysis.
- Document the location of past restoration projects within the study area and discuss their observed influence on existing conditions.
- Develop an updated habitat restoration strategy that identifies and prioritizes actions for aquatic habitat improvement.
- Act as a resource for coordinating efforts with local landowners, resource managers, and other stakeholders to establish collaborative efforts that contribute to the success of restoration strategies.

2. Assessment Area Overview

This section includes a brief overview and description of the assessment area, including orientation to the geography of the assessment area, a summary of past assessments and projects, overview of fish use, and a description of the geophysical setting. Detailed information on basin history, geography, geology, ecologic setting, and geomorphic setting is well-covered in other sources, including the past assessments described below in Section 2.2. As described previously, this report is not intended to re-state this information, but rather to build upon and update information as it relates to specific habitat and river process conditions at the reach-scale. To that end, this section (Section 2) is mostly a summary of existing relevant information provided for context. The sections that follow (Sections 3 through 5, plus relevant appendices) describe the data that were collected and analyzed as part of this current effort to provide an updated reach assessment and restoration strategy. This includes a hydrology and hydraulics analysis, habitat assessment, and the REI analysis. Section 6 describes specific conditions at the reach-scale (grouped into segments) and the restoration strategy is included in Appendix C.

2.1 ASSESSMENT AREA DESCRIPTION

The assessment area includes the Entiat River channel and floodplain extending 11.1 miles from the downstream end of the terminal glacial moraine at the Potato Creek confluence at RM 15.6 to McCrea Creek at RM 26.7. A map of the assessment area showing river miles and reach breaks is included in Figure 2. The river miles and reaches used in this assessment correspond with the UCSRB river miles. The reach breaks used in this assessment were adapted from the UCSRB reaches, however, the longer Potato 05 and Potato 06 reaches, were split into sub-reaches for the assessment. These two reaches correspond with Reaches 2-4 (Potato 05) and Reaches 5-6 (Potato 06) in this assessment. The UCSRB river miles and reach breaks vary somewhat from past assessments, including past US Bureau of Reclamation and Yakama Nation reach assessments.

The Entiat River basin is comprised of public and private lands. Within the assessment area, most of the land immediately adjacent to the river is privately owned, with significant amounts of Chelan Douglas Land Trust (CDLT). Moving landward, away from the river, there are large swaths of Wenatchee National Forest and other federal public lands. Land ownership is detailed in Figure 3.

The Entiat River Valley has a long history of human use, beginning with the Columbia Salish people, who established villages at the river's confluence with the Columbia and along its tributaries (Godaire et al. 2009). These early communities relied on fishing, hunting, and gathering and referred to the river as Enteatqua, meaning "rapid waters." Euro-American settlement began in the late 1800s, bringing homesteads, orchards, timber harvest, and grazing.

Land uses, including logging, splash damming, fire suppression, and large wood removal, all of which began in the late 19th century, significantly altered channel structure, floodplain processes, and riparian conditions (CCCD 2004; Godaire et al. 2009). These legacy impacts continue to influence hydrology, sediment transport, and habitat complexity within the assessment area.

The Entiat River Road runs along the river right side of the assessment area. Private residences and vacation homes are, for the most part, clustered on alluvial fans and development throughout the assessment area is relatively low. However, swaths of cleared riparian areas, from landscaping, roads, and property developments exist. There are multiple bridges across the Entiat river within the assessment area as well as a couple of day use recreational sites. The McKenzie diversion is the only major water diversion structure within the assessment area.

The Entiat River basin has a natural history of wildfires, however, fire suppression has altered the fire regime, which has had cascading effects on overall watershed condition. Prior to the turn of the 20th century, the Entiat River basin experienced frequent low intensity fires covering a relatively small spatial extent. In the ensuing years, widespread fire suppression has limited the frequency of wildfires, resulting in growth of dense understories which has increased the intensity and spatial extent of fires (Barnes n.d.). Changes to the fire regime impact channel and floodplain processes in the Entiat River watershed through a reduction in available large wood that is sufficiently large to impact fluvial processes and provide cover to salmon and other aquatic species, and through an increase in hillslope instability and sediment inputs on recently burned surfaces. Several large fires have occurred within the Entiat River watershed in the past several decades including the 1994 Tye Fire, the 2015 Wolverine Fire, and the 2018 Cougar Creek fire, resulting in decreased standing hillslope vegetation and increased debris inputs in the upper and lower portions of the assessment area.

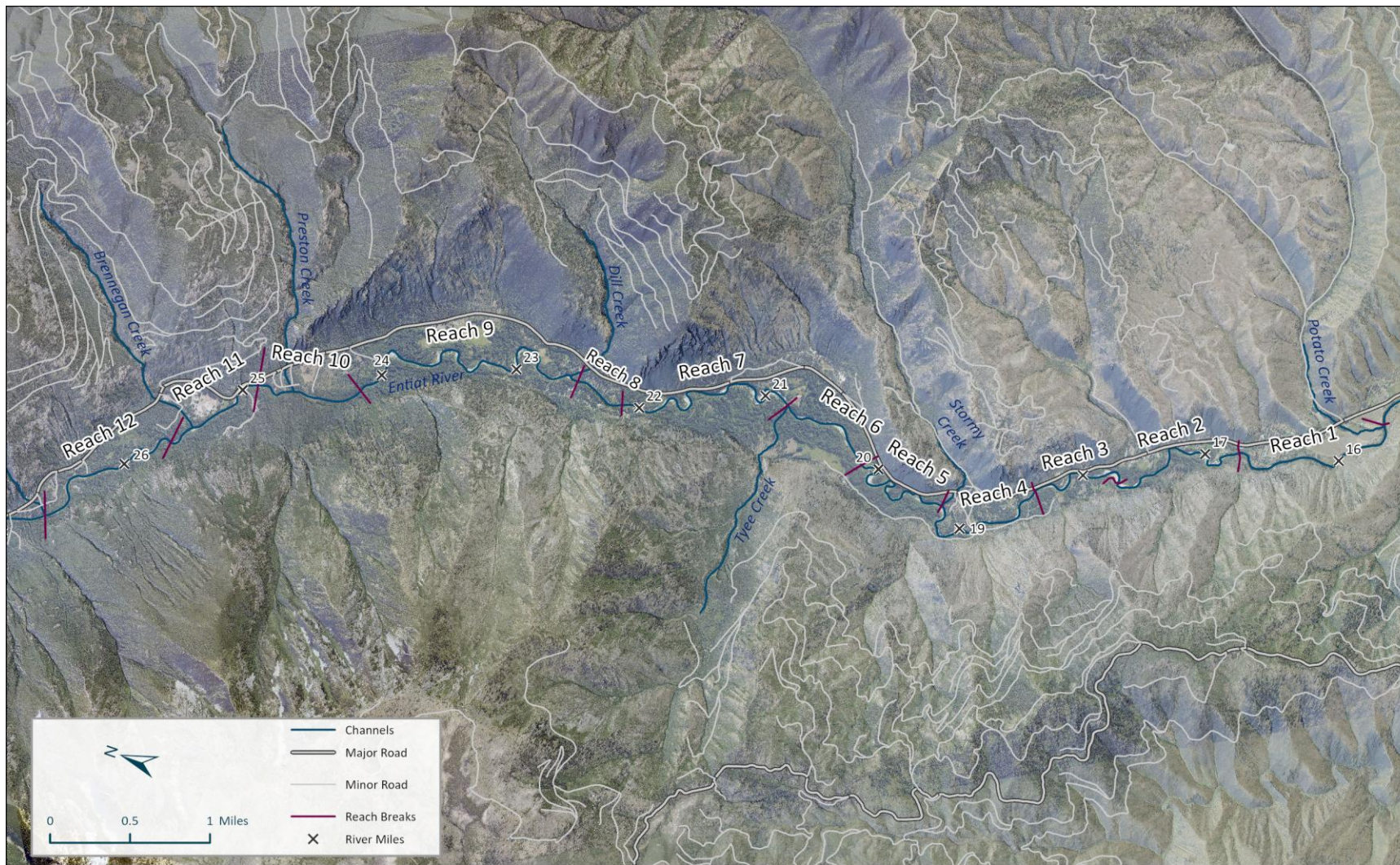


Figure 2. Overview of the Entiat River assessment area.

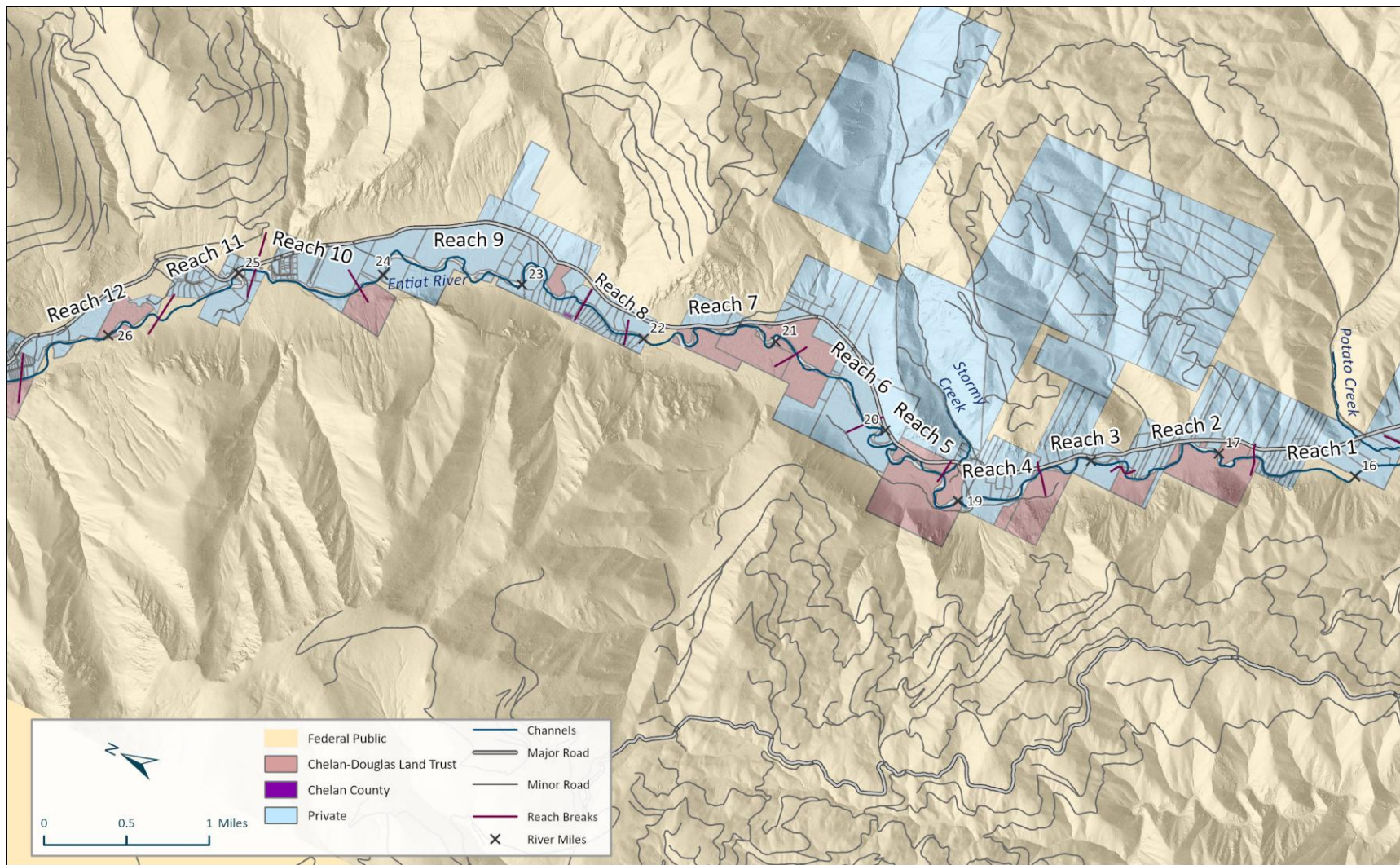


Figure 3. Land ownership in the Entiat River assessment area.

2.2 PAST REACH ASSESSMENTS AND PROJECTS

There have been multiple past reach assessments within the assessment area and in other areas within the Entiat River Basin. These are listed in Table 1. This current assessment builds upon these past efforts. The past reach assessments that specifically cover the study area for this current assessment include the Preston Reach Assessment (completely within the assessment area), Stormy Reach Assessment (completely within the assessment area), Stormy Reach Assessment Update (completely within the assessment area), Entiat River 3D Reach Assessment (completely within the assessment area), Upper Stillwaters Reach Stream Corridor Assessment (partially within the assessment area), Grey Reach Assessment (completely within the assessment area). Many of the habitat restoration projects that have been implemented in the study area over the past 15 years were a result of the findings and recommendations from these past assessments.

Table 1. Past Entiat Basin reach assessments. Past assessments that overlap with this assessment are shown in gray.

Year	Name	Sponsor	Area of Coverage	Types of Assessments Performed
2009	Entiat Tributary Assessment	US Bureau of Reclamation	Entire Entiat Basin	Geomorphic Assessment, Hydraulic Analysis, Sediment Analysis, and Vegetation Assessment. Identification of specific Reach Assessment areas recommended for future evaluation.
2009	Preston Reach Assessment	US Bureau of Reclamation	RM 22.5-24.6 (BOR RM 21.1 to 23.1)	Geomorphic assessment and reach characterization, hydrologic analysis, hydraulic analysis, habitat assessment, and vegetation assessment.
2009	Stormy Reach Assessment	US Bureau of Reclamation	RM 19.0-22.1 (BOR RM 18.02-20.85)	Geomorphic assessment and reach characterization, hydrologic analysis, hydraulic analysis, habitat assessment, and vegetation assessment.
2010	Entiat River 3D Reach Assessment and Conceptual Project Development	Yakama Nation	RM 25.6-26.5 (BOR RM 24 – 25)	Geomorphic Assessment, Hydrologic Analysis, Hydraulic Analysis, and Habitat Project Recommendations.
2012	Lower Entiat Reach Assessment	US Bureau of Reclamation	Mouth to USFWS hatchery, near RM 8.0 (BOR RM 7.0)	Geomorphic assessment and reach characterization, hydrologic analysis, sediment transport analysis, and stream habitat assessment.
2013	Upper Stillwaters Reach Stream Corridor Assessment & Habitat Restoration Strategy	Yakama Nation	RM 26.7-35.5 (Entiat Falls), plus RM 24.8-25.6 (BOR RM 25-33.83, plus RM 23.3 – 24)	Geomorphic and Habitat Assessment, Project identification and recommendations.
2013	Stormy Reach Assessment Update	US Bureau of Reclamation	RM 19.0-22.1 (BOR RM 18.02-	Updated reach assessment that expands on the 2009 Reach

Year	Name	Sponsor	Area of Coverage	Types of Assessments Performed
			20.85)	Assessment and included additional geomorphic assessment and recommended actions.
2013	Gray Reach Assessment	US Bureau of Reclamation	RM 16.6-18.7 (BOR RM 16.1-17.9)	Geomorphic assessment and reach characterization, hydrologic analysis, sediment analysis, habitat assessment, vegetation assessment, and project recommendations
2018	Lower Mad River Reach Assessment & Restoration Strategy	Yakama Nation	Lower 4.3 miles of the Mad River	Geomorphic assessment and reach characterization, hydrologic analysis, hydraulic analysis, vegetation assessment, and stream habitat assessment and project recommendations.

There have been numerous past habitat restoration projects in the study area that have been performed by numerous entities over the past 15+ years. Past projects since 2012 are listed in Table 2. Information about these projects was obtained from a combination of sources, including personal knowledge, communication with the sponsor entities (or their design consultants), available web-based information (i.e. WA Recreation and Conservation Office database), and field-based observations during the surveys. An overview map of the projects in the study area is included in Figure 4. The locations of the projects are also included in the more detailed maps in the Channel Segment-scale chapters (Section 6). These chapters also describe the influence that project elements are having on river processes and habitat conditions.

Table 2. Past restoration projects within the Entiat River assessment area. Listed in order from upstream to downstream.

Year	Name	Sponsor	Area of Coverage	Project Components
2012	Entiat 3D	Yakama Nation	RM 25.6-26.5	Backwater channel construction; large wood structures installation; side channel creation; Floodplain and riparian revegetation.
2012	Entiat Tye	Cascadia Conservation District	RM 23.4-23.9	
2010	Entiat RM 21.5	Cascadia Conservation District	RM 22.8	Large wood structures installation; bank enhancement; riparian planting
2012	Dillwater	Chelan County Natural Resources Department	RM 22.5-22.7	Large wood structures installation
2019	Stormy A	Yakama Nation	RM 21.3-22.0 (Stormy Reach)	Creation of two side channels with large wood habitat; partially buried riverbank and log structures installation; floodplain roughness improvement; pile

Year	Name	Sponsor	Area of Coverage	Project Components
				ballasted log structures installation
2019	Stormy B	Chelan County	RM 20.6-21.2 (Stormy Reach)	Large wood structures installation; bank enhancement; dike removal; side channel excavation
2020	Stormy C	Chelan County	RM 19.2 and 19.8 (Stormy Reach)	Bank enhancement and large wood structures installation; pilot channel excavation
2020	Cottonwood Flats Area D	Chelan County Natural Resources Department	RM 18.2 to 18.6 (Gray Reach)	Side channel excavation; large wood structures installation; bridge and fill removal
2019	Gray E	Chelan County	RM 17.7 to 18.0 (Gray Reach)	Bank enhancement and large wood structures installation; side channel creation; Wetland and off-channel enhancement
2020	Gray F	Chelan County	RM 16.7 to 17.3 (Gray Reach)	Bank enhancement and large wood structures installation; side channel excavation



Figure 4. Map of past restoration projects within the assessment area.

2.3 FISH USE

The project area provides migrating, spawning and rearing habitat for endangered Upper Columbia River (UCR) spring Chinook Salmon (*Oncorhynchus tshawytscha*), threatened UCR steelhead trout (*O. mykiss*), and Bull Trout (*Salvelinus confluentus*).

Regional objectives for salmonid habitat protection and restoration in the Upper Columbia Region have been evaluated and summarized in the UCSRB RTT's Biological Strategy (UCRTT 2021), which recommends region-wide biological considerations and approaches for salmonid habitat restoration and protection actions. The RTT guides the development and evaluation of salmonid recovery projects within the Upper Columbia Region.

The Biological Strategy has identified four assessment units within the major watersheds of the Entiat River. The study area for this assessment is within both the Entiat River-Potato Creek and the Entiat River-Preston Creek assessment units (AUs). Both AUs are designated as the highest priority (Tier 1) for restoration for steelhead and spring Chinook (UCRTT 2021). For Bull Trout, the Entiat River-Potato Creek AU is designated as Tier 1 and the Entiat River-Preston Creek AU is designated as Tier 2. Winter rearing, fry, and summer rearing life stages have been identified as the priority life stages for restoration actions, which should aim to improve channel complexity, reconnect floodplain habitats, restore riparian condition, improve water quality, and manage fine sediment (UCRTT 2021).

Spring Chinook

Entiat River spring Chinook Salmon belong to the UCR spring-run Chinook Salmon Evolutionarily Significant Unit (ESU), which was listed as Endangered under the ESA in 1999. Historically, spring Chinook were abundant within the Entiat River but were functionally extirpated by 1935 due to a series of downstream dams blocking fish passage. Spring Chinook Salmon within the Entiat River today are primarily the descendants of escaped hatchery fish stocked into the river by the Entiat National Fish Hatchery from 1942 until 2006 (Godaire 2009). Wild-produced spring Chinook populations were severely depressed in the 1990s, with some rebound occurring in the early to mid-2000's. Since 2017, total adult return population size has remained below 200 fish (USBR 2017). By comparison, estimates of historic production of spring Chinook within the Entiat Basin exceed 2,500 adults (Godaire et al. 2009).

Adult spring Chinook enter the Entiat River between May and August each year and hold in deep pools and under overhead until spawning season (Figure 5). Spawning activity typically begins upstream of the project area in early August, and gradually moves downstream as stream temperatures decrease into September (USBR 2017). Fry emerge beginning in February through mid-May (USBR 2017), which coincides with the rising hydrograph, forcing juveniles to seek out backwater or margin areas with lower velocities, dense cover, and abundant food (Quinn 2005). Fry are extremely vulnerable when they emerge, because their swimming ability is poor and flows are typically high. Near-shore areas with eddies, large wood, undercut tree roots, and other cover are very important for post-emergent fry (Hillman and Miller 1989; Healy 1991). Age-1 parr utilize

deeper pools with resting cover in mainstem habitats more than post-emergent individuals. UCR spring Chinook tend to express a stream-type life history where they rear for one year in freshwater before out migrating as yearlings. Out-migration to the ocean typically begins in March (Peven et al. 2004).

The general downstream extent of spring Chinook spawning in the Entiat is near the downstream end of the assessment area, with the majority of spawning occurring from near the mouth of Dilly Creek (River Mile 22.4) up to the mouth of Fox Creek (upstream of the project area). The primary spawning reaches for Spring Chinook are Reaches 9 through 13, with less frequent spawning occurring Reaches 1 through 8. Spring Chinook are also known to spawn within the lower four miles of the Mad River. Juvenile spring Chinook rear throughout the Entiat and its tributaries, particularly from the mouth of the Entiat River up to the passage barrier at Entiat Falls, within the Mad River from the mouth up to Hornet Creek (Godaire 2009), and likely within the lower reaches of other tributaries.

Summer Chinook

Summer Chinook Salmon are not endemic to the Entiat River, but a small self-sustaining run of summer Chinook Salmon descended from earlier hatchery releases persists within the river today (Godaire 2009, USBR 2017). From 1994 – 2009, summer Chinook redd counts were generally stable or increasing and ranged from a low of 15 redds in 1994 to a high of 309 redds detected in 2005 (USBR 2017). The Entiat National Fish Hatchery has also released summer Chinook since 2009 in the Entiat River at the hatchery site approximately 7 miles downstream of the assessment area. Stocked fish are not intended to spawn naturally or supplement the existing summer Chinook population (USBR 2017).

Summer Chinook typically enter the Entiat River in July or August and as late as October. Spawning begins in late September and continues until early November. Emergence typically happens in March and April as stream temperatures begin to warm. Summer Chinook within the broader Wenatchee River system, and presumably within the Entiat Basin, tend to exhibit the stream-type life history and spend one year within freshwater before outmigration; however, a small portion exhibit an ocean-type life history and out-migrate within their first year of life (Godaire 2009).

Summer Chinook spawning occurs primarily below Preston Creek (River Mile 24.6) in Reaches 1 through 11, with the highest density of spawning occurring in Reaches 1 through 4.

Steelhead

Steelhead of the Upper Columbia River Distinct Population Segment (DPS) were listed as Threatened under the ESA on August 18, 1997 (re-evaluated on January 1, 2006). Historical accounts suggest that most steelhead were produced within the Mad River tributary of the Entiat; however, most steelhead production today appears to come out of the Entiat River (Godaire, 2009). Estimates of historic production of steelhead within the Entiat Basin exceed 400 adults (Godaire et al. 2009). Hatchery steelhead supplemented the wild population beginning in 1964, and hatchery releases continued until the year 2000 (Godaire 2009). Current estimates place the spawning adult population

within the entire Entiat Basin (including Mad River steelhead) at between 150 and 550 individuals (Godaire, 2009).

Adult steelhead enter and ascend the Columbia River in June and July, arriving near their spawning grounds nine to eleven months prior to spawning (USBR 2017). Adult steelhead trout in the Upper Columbia typically overwinter in the mainstem Columbia, returning to the Entiat River subbasin in late March of the following year to spawn, which typically peaks in mid-to-late April and lasts through May. Steelhead fry emerge from the redds 6-10 weeks after spawning (Peven 2003).

Age-0 juveniles spend their first year primarily in shallow riffle habitats, feeding on invertebrates and utilizing overhanging riparian vegetation and undercut banks for cover (Moyle 2002). Older juveniles prefer faster moving water including deep pools and runs over cobble and boulder substrate. Juveniles out-migrate between ages one and three, though some may exhibit a resident life history form as rainbow trout (Peven 2003). Steelhead smolts begin out-migrating downstream from their natal rearing areas in March. Resident *O. mykiss* are also present and overlap spatially and temporally with their anadromous counterparts (Hillman and Miller 1989; Moyle 2002).

The assessment area is utilized by all life stages of steelhead – migration, spawning and egg development, and rearing (Godaire 2009). Spawning occurs from the mouth of the Entiat up to Entiat Falls and throughout the assessment area, although the highest density of spawning occurs downstream of Preston Creek to the bottom of the assessment area near Potato Creek (Reaches 1 through 11) (UCSRB 2026).

Bull Trout

Bull Trout in the Entiat basin were listed as threatened under the ESA in 1999 (USFWS 1999). Bull Trout may exhibit both resident and migratory life history strategies (Rieman and McIntyre 1993). Resident Bull Trout complete their life cycles in the tributary streams in which they spawn and rear. Compared to other salmonids, Bull Trout have more specific habitat requirements that appear to influence their distribution and abundance. Critical parameters include water temperature, cover, channel form and stability, valley form, spawning and rearing substrates, and migratory corridors (USFWS 1999).

Bull Trout within the Entiat Basin are predominantly found in the mainstem Entiat and Mad Rivers, and these two populations are considered to be distinct (USBR 2017). The Mad River supports the largest population of Bull Trout within the Entiat Basin. Within the Entiat mainstem, resident bull trout occur above Entiat Falls, whereas both resident and migratory bull trout occur below Entiat Falls (NPCC 2002). The highest density of spawning within the mainstem Entiat occurs upstream of the assessment area between Lake Creek and Entiat Falls (Vazquez et al. 2021).

The number of bull trout within the Entiat Basin is relatively low. Most spawning survey effort has been focused on the core spawning area between Lake Creek and Entiat Falls, entirely upstream of the assessment area. The most redds ever recorded in a single year in this reach was 50 in 2005. Between 2007 – 2013, the number of bull trout redds observed here ranged between 7 to 24 redds (Nelson 2013). Between 2009 – 2021, spawning surveyors identified at least 164 redds total between

all years within this reach, although these data are incomplete and the total number of redds may be higher (UCSRB 2026). There may be additional spawning occurring outside of this surveyed reach, but data beyond this location are limited.

The dominant bull trout use of the assessment area is for rearing and migration (NPCC (Northwest Power Planning Council) 2002). Juvenile bull trout are likely within the assessment for rearing year-round, whereas adult migratory bull trout are likely within the assessment area during key migration periods. Nelson (2013) reported on radio telemetry tracking of bull trout within the Entiat Basin, in which crews deployed fixed radio receivers including one at the confluence with the Mad River (downstream of the assessment area) and another at the base of Box Canyon (upstream of the assessment area) from 2007-2009. The study found that bull trout migrating upstream passed the Mad River mouth between May 29 and July 16, and passed the Box Canyon site between June 16 and July 26. From these data, it appears that migratory adult upstream passage through the assessment area occurs during June and July. The study also found that bull trout migrating downstream post-spawn passed the Box Canyon site generally between August 5 and October 10 (with one anomalous individual passing downstream on July 3), and passed the Mad River site between August 29 and October 28. This suggests that migratory adult downstream passage through the assessment area during September and October. It can be presumed that adult migration may be occurring within the assessment area at any point between June through October.

Pacific Lamprey

Adult upstream migration of Pacific lamprey occurs from late spring through fall in the Columbia River Basin with peak passage occurring in the Upper Columbia at Rock Island Dam in late August (McIlraith et al., 2017). In the Entiat Basin, spawning generally occurs from March through July at temperatures between 10-15°C (50-59°F) (USBR 2017). Although some adult lamprey spawn shortly after entering freshwater, they more commonly overwinter in freshwater pools before spawning the following spring or summer (BioAnalysts Inc. 2000). Preferred spawning habitat is in low gradient runs and pool tail-outs. Hatching date varies according to water temperature and is typically around 15 days after spawning. Larval lamprey (commonly termed ammocetes) spend a short period of time (~15 days) in the redd after hatching before drifting downstream to suitable rearing habitats. Rearing habitat typically consists of low gradient areas with low water velocity, soft substrate, and organic material. Larvae can rear in freshwater for seven years or more, during which time they filter feed on diatoms and suspended organic material. Downstream migration occurs between July and October and includes metamorphosis from the larval life stage into the “transformer” life stage (also commonly referred to as macrophthalmia). This transformer stage is similar to the smoltification process in salmonids and includes the development of a functional eye, a disk-shaped sucker mouth, a silver body color, and the ability to survive in saltwater. Transformers migrate to the ocean during high flows in late winter or early spring where they mature into adults (USBR 2017).

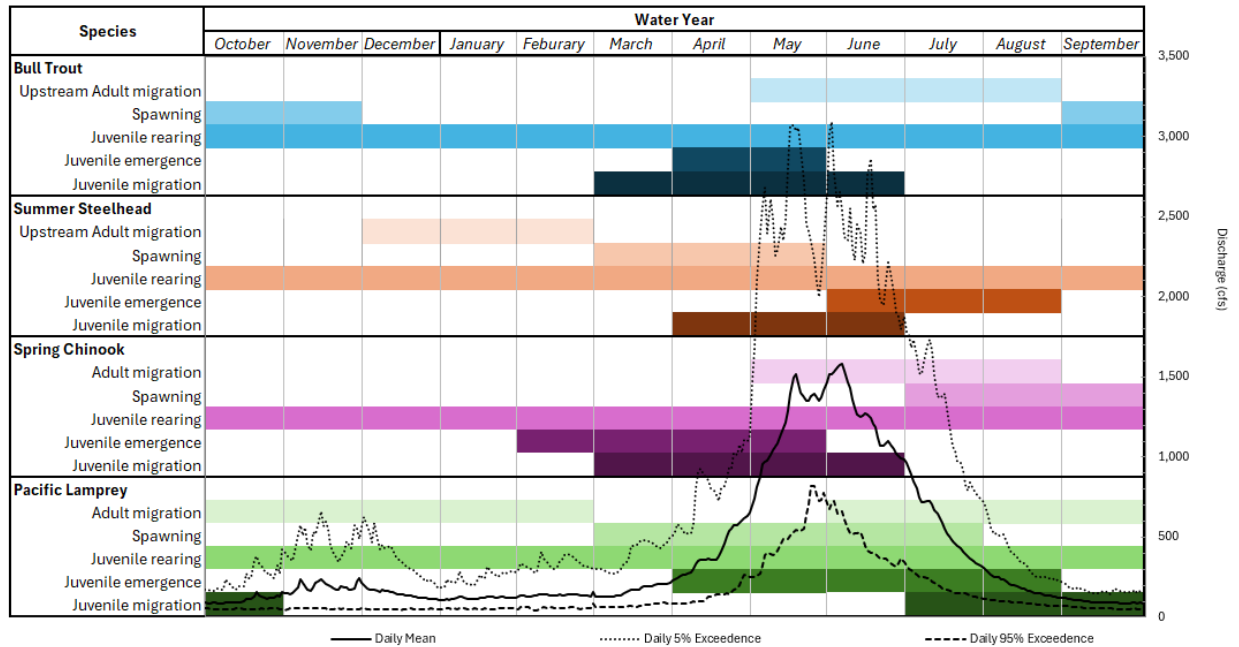


Figure 5. Summary of the life history timing of Spring Chinook, steelhead, Bull Trout, and Pacific Lamprey in the Entiat River, overlaid on an annual hydrograph depicting daily mean discharge as well as the daily 5% and 95% exceedance discharges in the Entiat River for water years 1993 through 2023 (USGS gage 12452800). Life history references are cited in the species description sections.

2.4 STREAM TEMPERATURE

2.4.1 Overview of Stream Temperature Conditions

Stream temperatures are important for salmonid growth and survival and are impaired in the Entiat River. Salmonids require stream temperatures within certain ranges depending on life stage (Richter & Kolmes, 2005). Temperatures that exceed tolerable thresholds can inhibit growth and survival. A threshold of 13°C for spawning and 15°C for rearing, holding, and migration are commonly used to assess impacts, and are what was used in the REI analysis as part of this assessment. Data reported by Richter and Kolmes (2005) suggest the lethal limit for salmonids is near 26°C, but above 24°C, mortality can occur with sufficient duration of exposure. The REI analysis determined that the assessment area was “Unacceptable” with respect to stream temperature (see Appendix B for more details).

Stream temperatures on the Entiat have exceeded salmonid thermal criteria for at least 25 years based on review of past assessments (Chelan and Entiat Ranger Districts, 2001; Godaire et al., 2009; Inter-Fluve, 2013; NV5 Geospatial, 2023; U.S. Bureau of Reclamation, 2009, 2009a, 2013). The downstream section of Reach 9 is currently listed as a Category 2 “Water of Concern” for instream temperature on the Washington State 303(b) list, although no reaches within the assessment area are on the “Impaired Water Bodies” 303(d) list. The Entiat Tributary Assessment assessed stream habitat conditions along the lower 26 miles of the Entiat. That assessment found that, of the reaches studied within this assessment area (RM 15.6-26.7), 50% had elevated stream temperatures as a limiting

factor for salmonids (Godaire et al., 2009). The Upper Columbia Salmon Recovery Board included addressing water quality issues along the Entiat, specifically temperature, in their recommended restoration actions (UCSRB, 2007). Elevated stream temperatures have primarily been attributed to reduced riparian vegetation from anthropogenic activity.

Thermal Infrared (TIR) imagery was taken along the lower 40 miles of the Entiat (from the mouth to the North Fork Entiat River confluence) in August 2023 (NV5 Geospatial, 2023). The TIR data shows a typical downstream warming trend (Figure 6). Within the reach assessment study area, temperatures appear stabilize (plateau) before warming again downstream. However, this plateau still has temperatures exceeding the 13°C and 15°C thresholds. The TIR report notes a relatively high concentration of side channels and potential hyporheic or groundwater inflows correlated with the plateau (NV5 Geospatial, 2023). These Significant Thermal Features (STF) are marked as black triangles in Figure 7. Moving downstream from the upstream end of the assessment area, temperatures show a consistent increase until the confluence with Mott Creek/Preston Creek (near RM 24). Downstream of RM 24, the temperature is relatively consistent with a slight decrease, until the downstream end of the assessment area where it rises again (NV5 Geospatial, 2023).

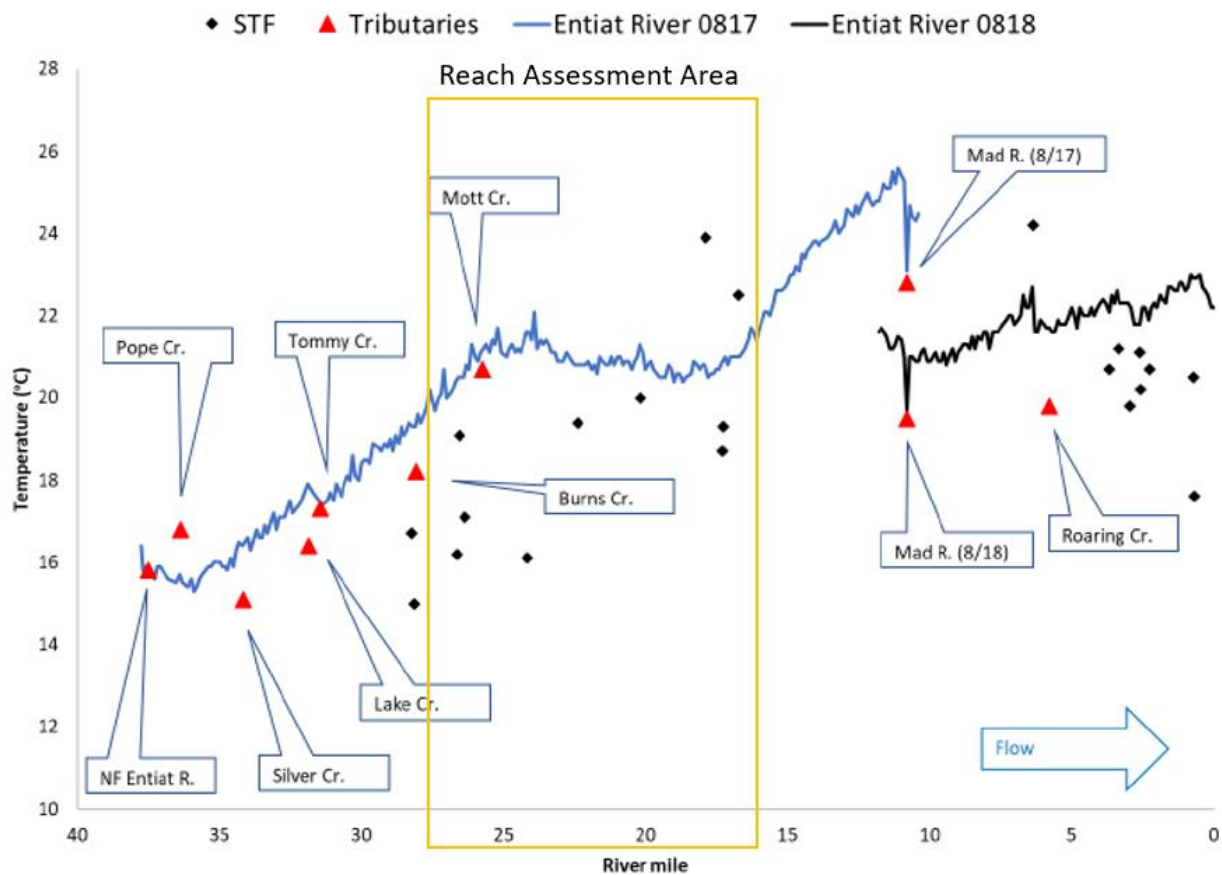


Figure 6. Longitudinal profile of the TIR data, modified from NV5 Geospatial (2023). These data show the warming trend moving downstream from the confluence with the N. Fork Entiat River to the mouth of the Entiat River. The black diamonds are the Significant Thermal Features (STFs). The assessment area for this reach assessment is shown in yellow.

Inter-Fluve collected water temperature data for the Yakama Nation between September 13, 2014 and September 21, 2015 using a HOBO data logger installed at the Entiat 3D restoration project site (Reach 11, near RM 25.5, see Figure 8). The 7-day rolling average of the daily maximum temperatures (7-DADMax), which is a common metric for assessing temperature, is plotted in Figure 7. The 7-DADMax exceeded the 15°C rearing threshold for multiple weeks between June and August 2015. The 7-DADMax hovered above and near the 13°C spawning threshold in September when spring Chinook spawning occurs on the Entiat.

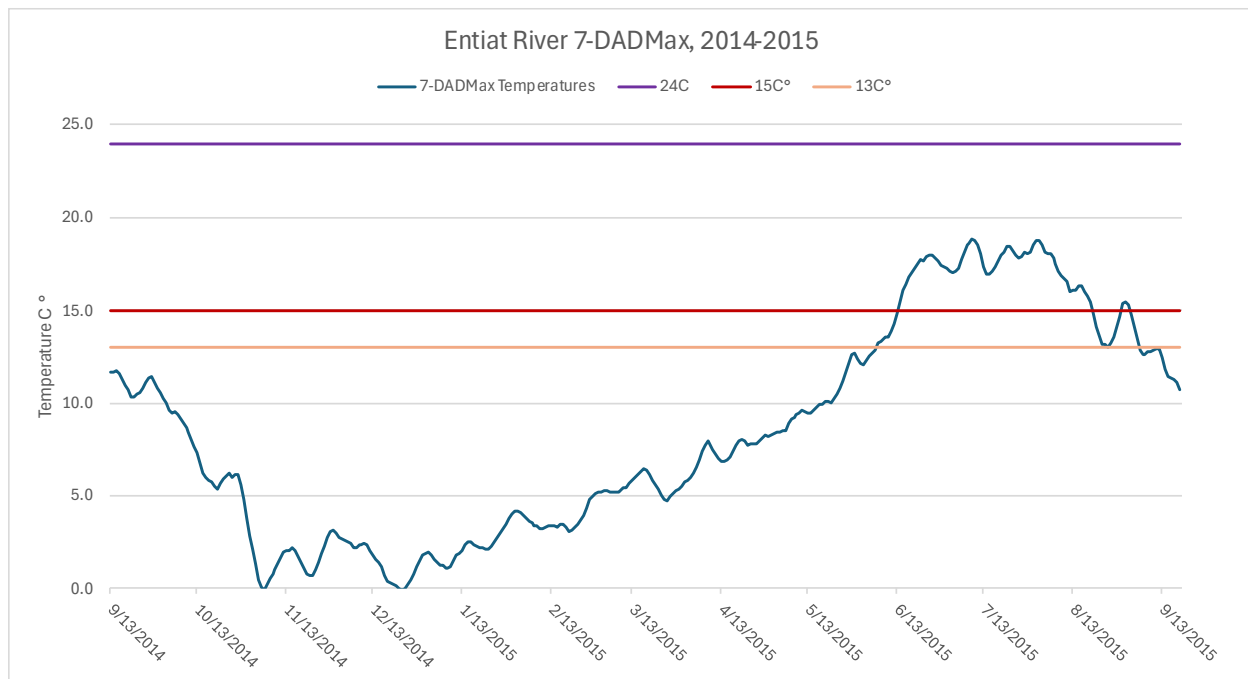


Figure 7. Graph shows 7-DADMax temperatures for the Entiat River for 2014-15. Data is from a data logger installed near RM 25.5 in Reach 11. Temperatures exceeded rearing and spawning temperatures during the summer months.

2.4.2 Coldwater Refugia

During periods of high temperatures, areas of cold water are critical for salmonid survival. Cold patches offer thermal refugia for fish to wait out periods of severe temperature until conditions return to suitable levels. The TIR report (NV5 Geospatial, 2023) identified STFs manually in the TIR data and linked them to possible sources (i.e., tributaries, seeps, or hyporheic flow). The identified STFs include both warm and cold-water thermal anomalies. Inter-Fluve staff also manually identified cold patches in the TIR data, identified using the criteria of one degree temperature differential (colder) from surrounding areas. A total of 16 cold patches were identified in Reaches 9-12, 7, 5, and 2. They were generally associated with areas of increased floodplain connectivity, as determined by Q2 and Q5 hydraulic model results, or near tributaries. Not all the cold patches are connected to the mainstem at low flow. Locations of the cold patches are shown in Figure 8 below. As expected, some of these align with the STFs identified in the TIR study.

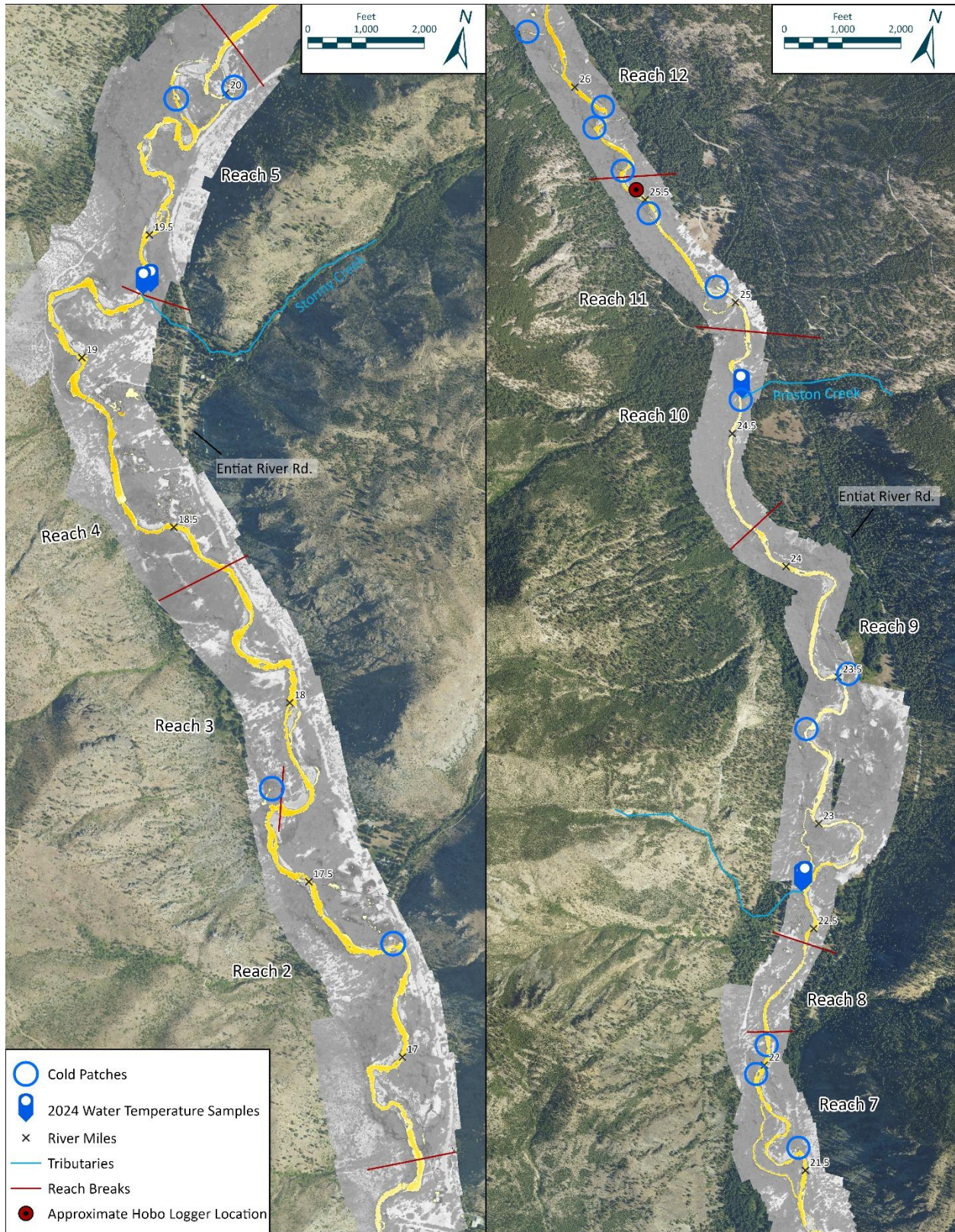


Figure 8. Map of the desktop-identified cold patches from the TIR data, tributaries sampled during the 2024 habitat survey, and the 2014-15 data logger location.

During the 2024 habitat surveys performed as part of this reach assessment, Inter-Fluve staff collected simultaneous stream temperatures in tributaries and in the adjacent mainstem just upstream of the tributary confluence, in order to identify potential cold water refugia. Only three tributaries had enough water to record a temperature measurement during the survey (Table 3). Preston Creek had the largest differential at 3.4 degrees colder than the mainstem. Stormy Creek had water upstream in the tributary but did not have a surface water connection to the mainstem at the time of the survey.

Where data suggests there are potential cold water inputs, restoration actions should look for opportunities to enhance the function and access to the cold patches, and/or implement conservation measures if warranted. Improved conditions in these areas, especially in the form of habitat complexity (e.g. large wood) and improved connectivity, could increase access to cold patches and provide cover for fish while utilizing thermal refugia.

Table 3. Data from the 2024 habitat survey temperature samples. Temperatures were taken in the mainstem upstream of the tributary confluence and at the same depth as the corresponding tributary sample.

Tributary	RM	Tributary Temp (C°)	Entiat River Temp (C°)	Tributary Differential (C°)
Preston	24.6	13.4	16.8	-3.4
Unnamed	22.6	9.3	9.3	0
Stormy	19.4	5.6	7.2	-1.6

2.4.3 Land Use Changes and Stream Temperature

Since the late 1800s, land use changes in the Entiat watershed have contributed to increased water temperatures with potential impacts to salmonids. The watershed has a history of timber harvest, orchards, and grazing, all of which have reduced the structure and width of the forested riparian buffer and consequentially the amount of stream shading. Past channel simplification and the removal of instream features to promote timber transport greatly reduced the amount of scour features, like large wood and boulders, and reduced the availability of deep pools and planform complexity necessary for groundwater-surface water exchanges that help to moderate temperatures. Decades of fire suppression have resulted in larger, more severe fires that further reduce the riparian buffer and alter sediment regimes (Godaire et al., 2009). Landslides and mass wasting events, particularly in the tributaries that provide cold water, have created wider, shallower streams more prone to heating (Chelan and Entiat Ranger Districts, 2001).

Based on climate change modeling, the risk of elevated summer stream temperatures continues to increase into the future. Climate change models predict a shift in the Entiat basin from a snow-dominated hydrologic regime to a transitional (rain-and snow dominated) one (Tohver et al. 2014). Transitional basins are projected to be the most sensitive to warming from climate change as they typically have a decreased snowpack and earlier spring runoff timing. An earlier spring runoff leads to lower summer base flows, creating a channel more prone to heating. See Section 3.2.5 for more on climate change.

2.5 GEOPHYSICAL SETTING

2.5.1 Geology

The Entiat River Watershed is situated within the eastern portion of the Northern Cascades geologic province, a region shaped by prolonged subduction-related tectonics, metamorphism, and igneous activity (Brown, 1987; Hammond, 1979; Miller et al., 2016; USBR, 2012) is bound by major fault systems including the Entiat Fault to the west and the Ross Lake Fault to the east, both of which are located outside of the Entiat River watershed. These structural boundaries separate the Chelan Block from adjacent terranes and have contributed to the formation of topographic and hydrographic divides. Within the Chelan Block, the Entiat River primarily flows through the Chelan Mountains and Mad River terranes, both composed of Late Cretaceous metamorphic rocks and granitic intrusions from the Early Tertiary period (Figure 9; Tabor et al. 1987). The dominant lithologies (gneiss, schist, tonalite, quartz diorite, and migmatite) are crystalline, erosion-resistant, and formed from marine sediments and volcanic arc materials metamorphosed under high heat and pressure (Tabor et al., 2000). The assessment area is primarily underlain by Tertiary intrusive rocks in the upstream portion and Mesozoic intrusive rocks in the downstream portion (Figure 10).

Bedrock exposures are prominent throughout the watershed, especially in confined canyon reaches such as Box Canyon and at Entiat Falls (both upstream of the study area). The Duncan Hill pluton, a quartz diorite emplaced approximately 45-48 million years ago, is the main bedrock encountered along the river channel in upper reaches (Tabor et al., 1987). Structural features, including northwest-southeast trending anticlines, synclines, and thrust faults, reflect the tectonic compression that shaped much of the watershed's geologic framework. While these faults are now considered inactive, their influence is expressed on the landscape via valley orientation and lithologic variation (Lasmanis, 1991). Lasmanis, 1991).

Past glacial processes have also influenced watershed development. During the late Pleistocene, alpine glaciers descended from higher elevations and left behind till, outwash, and glacial erratics as they retreated (Godaire et al. 2009). Glaciation extended down the mainstem Entiat River to approximately RM 16 (approximately the downstream end of the study area), leaving terraces and coarse glacial deposits that continue to affect channel morphology. These deposits often include oversized material such as cobbles and boulders, which provide vertical stability and limit lateral migration in many locations (Inter-Fluve 2013). Holocene-age deposits, such as the Glacier Peak Tephra, overlie glacial features and indicate more recent glacial advances at higher elevations, possibly as late as the Little Ice Age (Burrows et al., 2000).

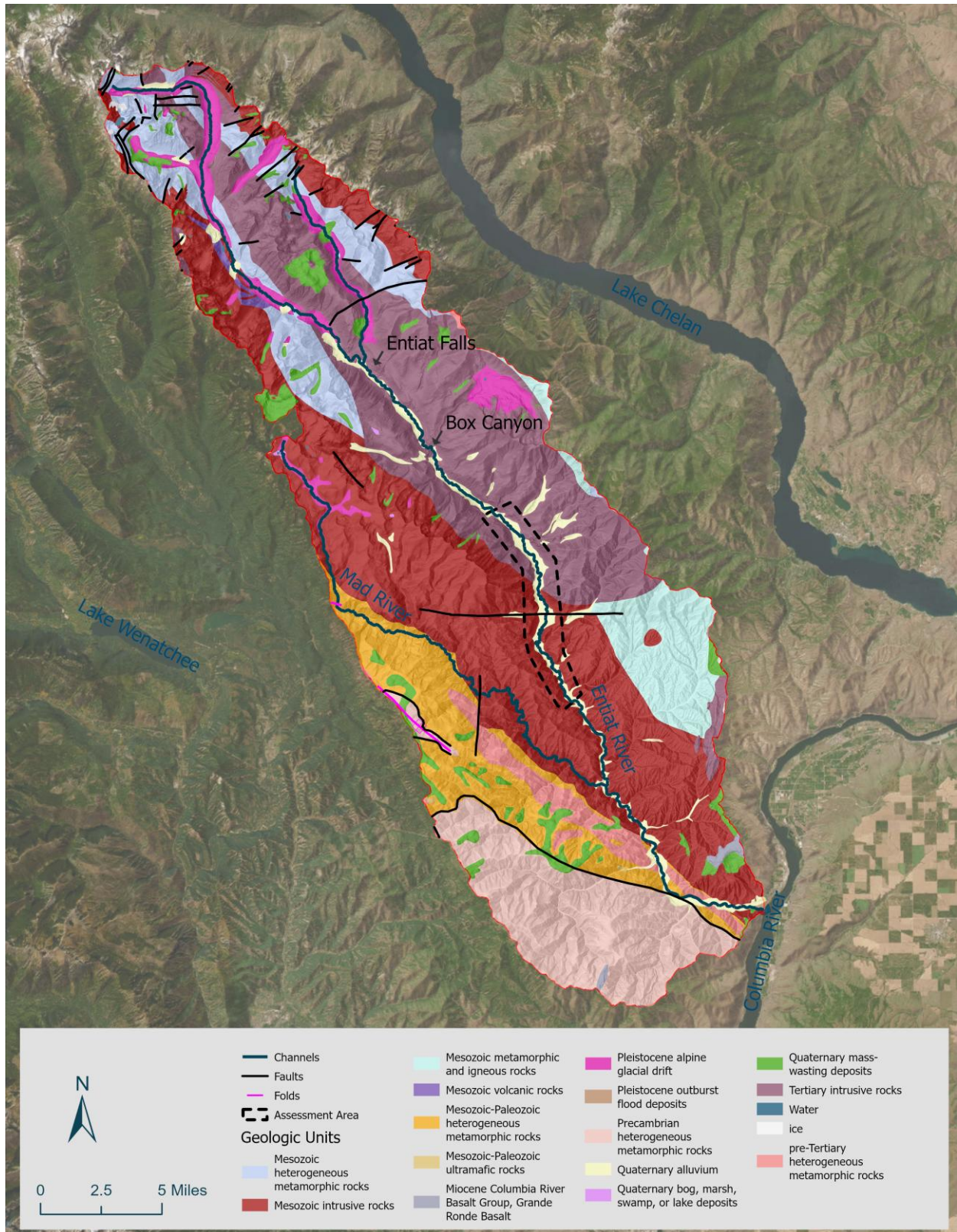


Figure 9. Geology of the Entiat River Watershed (Derived from Tabor et al., 1987). Date ranges of geologic time periods listed are as follows: Quaternary (2.5 Ma – Present), Pleistocene (2.6 Ma – 11 Ka), Tertiary (66 – 2.6 Ma), Miocene (23 – 5.3 MA), Mesozoic (252 – 66 Ma), Precambrian (4.6 Ga – 540 Ma).

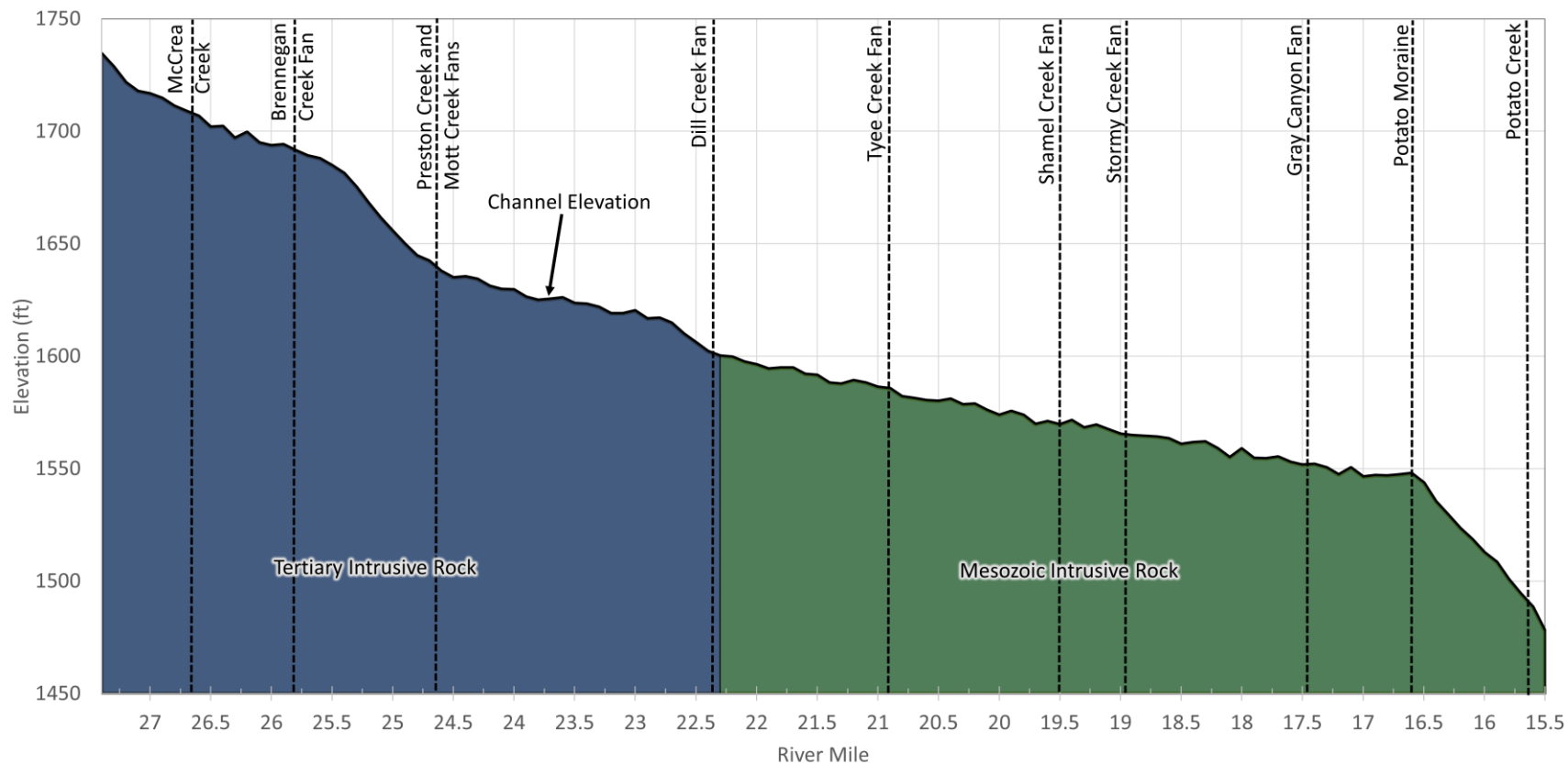


Figure 10. Channel gradient, governing geology, and notable geomorphic features within the Entiat River assessment area. Governing geology derived from Tabor et al., 1987.

2.5.2 Geomorphologic Conditions

This section provides an overview of geomorphic conditions within the Entiat River assessment area from RM 15.6 to 26.7. An understanding of the geomorphic processes and trends of the modern channel, floodplain, and contributing hillslopes is important to developing a successful habitat restoration strategy. The information presented here and in Section 6 is based on field-based survey observations (August 4-6, 2025) as well as available digital and printed data and reports (as referenced). Geomorphologists walked the length of the assessment area to characterize physical conditions and channel processes as well as identify restoration opportunities. Detailed discussions of trends at the segment-scale are provided in Section 6. Information from the geomorphic assessment was used to inform the REI analysis (Section 5) and identification of project opportunities (Appendix C).

The Entiat River flows southeast, from its headwaters high on the eastern flank of the Cascade Mountains within the Glacier Peak Wilderness, to its confluence with the Columbia River near the town of Entiat, WA. Within the assessment area, the Entiat sits within a high relief “U” shaped valley carved by glacial activity during the late Pleistocene epoch (2.6 MA – 11 KA). During this time, glaciers extended from high elevations within the upper Entiat River basin to approximately RM 16 where the Potato Moraine now marks the downstream extent of late Pleistocene glaciation. Adjacent hillslopes rise to peaks and ridges several thousands of feet above the valley bottom, with a maximum elevation in the watershed of 9,230 feet (USGS, 2022). These steep hillslopes contain conifers, primarily ponderosa pine and Douglas-fir, interspersed with shrubs and bedrock outcrops. In the downstream portion of the assessment area, hillslopes are more sparsely vegetated due in part to wildfire activity within the past several decades. Soils in the Entiat River Watershed are derived from weathered crystalline bedrock, with localized volcanic inputs. They are generally coarse-textured, shallow, and well-drained, particularly in upland areas (USDA and NRCS 2017).

Several tributary basins carved by glacial and fluvial processes feed into the Entiat River along its 57-mile path. Many of these tributaries are ephemeral, providing seasonal flow and sediment inputs during periods of high runoff such as spring snowmelt. Named tributaries to the Entiat River within the assessment area include: Brennegan Creek, Mott Creek, Preston Creek, Dill Creek, Tyee Creek, Stormy Creek, Shamel Creek, Gray Creek, and Potato Creek. Preston Creek was the only tributary with surface flow observed during the 2025 field assessment.

The Entiat River’s broad valley bottom is low gradient and supports extensive floodplain development and lateral channel processes. Sporadic tributary alluvial fans terraces, and the Potato Moraine serve as geomorphic controls exerting local lateral channel and valley bottom confinement and influencing vertical stability (Figure 10). Where fans constrict the Entiat River valley bottom, the channel gradient is relatively higher, sinuosity is lower, and bed substrate is relatively coarser than in unconfined sections elsewhere within the assessment area. Hillslope coupling is evident throughout much of the watershed, especially in more confined sections, and steep terrain delivers sediment via mass wasting, particularly during high runoff events. Channel substrate typically consists of gravels and cobbles, with sands present in slower pools and backwater areas, and large

boulders present along hillslope contacts and in more confined sections. In these high-energy confined sections, gravels and finer sediments are typically only present in small low energy pockets created by large wood and boulders, or along channel margins where valley geometry allows for narrow floodplains or benches. Coarse sediments within the assessment area are typically sourced from adjacent hillslopes, tributary fans, and streambanks, or transported as bedload from upstream reaches.

Floodplain connectivity, lateral migration, and channel sinuosity in less confined sections of the assessment area are likely limited compared to historical conditions. Extensive logging and log-drives down the Entiat River channel beginning in the late 1800s depleted natural stocks of old-growth trees capable of driving geomorphic processes that maintain channel complexity and floodplain connectivity. Living mature old-growth trees were not observed during the assessment, however, logged stumps provide evidence of a prior condition consisting of much larger trees within the watershed. In several areas vegetation has not yet re-established following clearing, and floodplains lack supportive structure, resulting in rapid bank erosion. Large wood and riprap have been placed to slow bank erosion allowing vegetation to establish. Elsewhere, bank erosion and lateral migration are occurring, but likely at slower rates compared to historical conditions due to artificial bank protection and a lack of large wood within the channel capable of driving lateral processes and channel avulsion. Development on floodplain surfaces including Entiat River Road, and associated bank protection have also artificially confined the valley bottom and limited the extent of available floodplain in some areas.

A historical channel migration zone (HCMZ) assessment was conducted by the U.S. Bureau of Reclamation as part of its 2009 Entiat Tributary Assessment. The HCMZ identified areas with a high potential for lateral channel migration and channel avulsion, and its extent included areas occupied by channels mapped using historical aerial imagery from 1945 to 2006, and areas with visible indications of occupation by the Entiat River main channel and side channels within the past 100 years (USBR 2009). HCMZ width was generally a product of local lateral confinement. Constricted channel sections such as those interacting with tributary alluvial fans were associated with a narrower HCMZ, whereas unconfined channel sections with broad floodplains were associated with a wider HCMZ. A coarse-level review of the previously delineated HCMZ was conducted during the geomorphic assessment. Overall, the HCMZ boundary was generally supported by data collected during the geomorphic assessment; however, several notable channel scars visible in recent LiDAR data were located outside of the HCMZ boundary. These include channel scars from RM 22.5 to 22.65 (river left), RM 23.75 to RM 23.95 (river right), RM 24.1 to 24.2 (river right), and RM 26.55 to 26.65 (river left) (Figure 11). Evidence of recent inundation within the upstream-most channel scar (RM 26.55 to 26.65), including sediment sorting, scour, and coarse particulate organic matter accumulation, suggests that this channel currently acts as a high-flow side channel and should be included within the HCMZ (Figure 12). The other three channel scars identified from LiDAR did not show evidence of recent flow, and may have been excluded from the HCMZ due to an assumption that they have not been active in the past 100 years. However, their presence illustrates the extent to which the Entiat River channel has historically migrated.

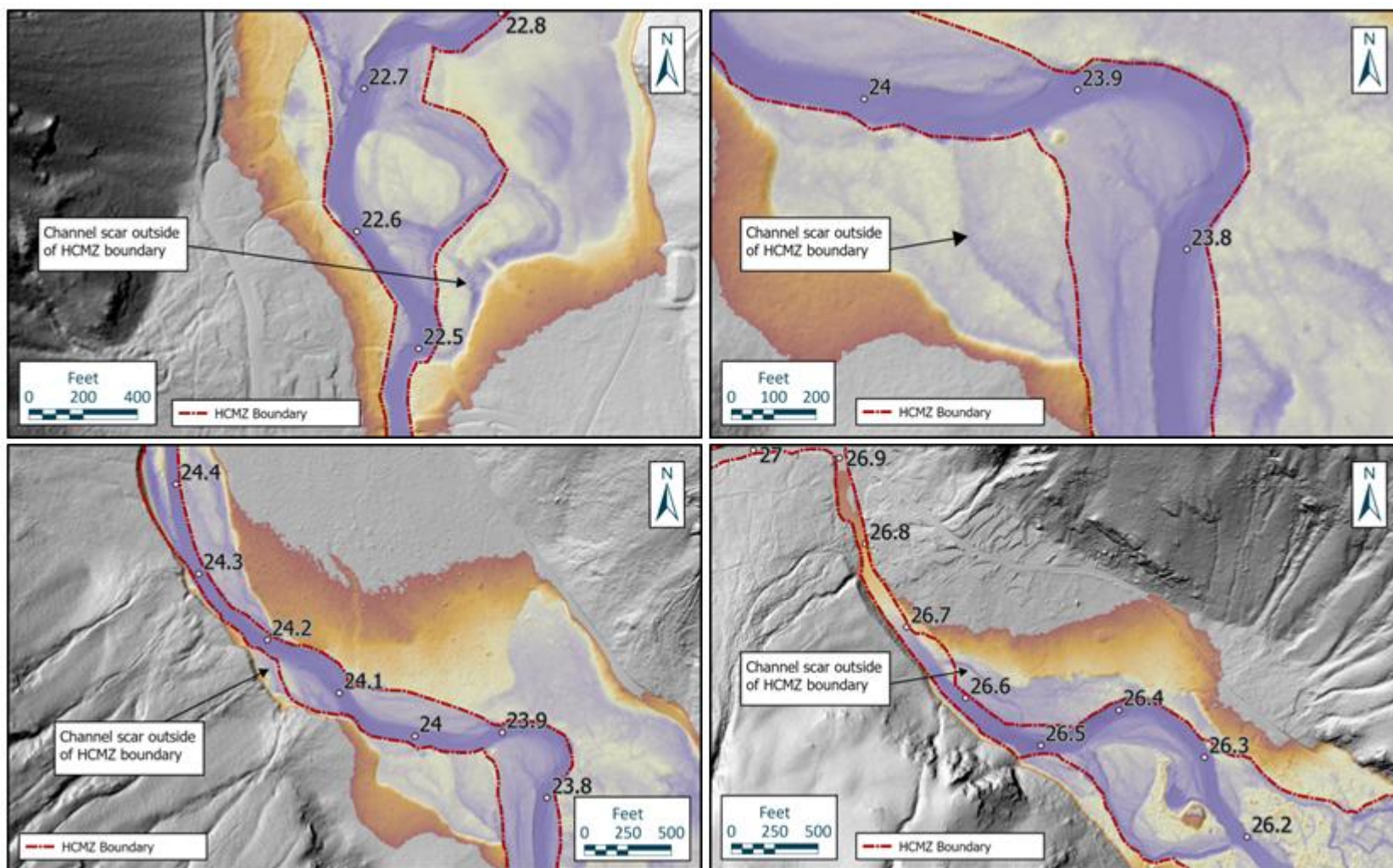


Figure 11. Visible channel signatures outside of the previously mapped Historical Channel Migration Zone (HCMZ) boundary, identified using 2022 LiDAR data and relative elevation model. HCMZ boundary was adapted from U.S. Bureau of Reclamation 2009.



Figure 12. Top: Photograph of side channel extending from RM 26.55 to 26.65, captured during August 2025 Geomorphic Assessment.

3. Hydrology and Hydraulic Modeling

3.1 INTRODUCTION

A hydrology and hydraulic analysis of the study area was conducted to support the ecological and geomorphological interpretations of the site and to inform the restoration strategy. Entiat River stream gage data and existing available studies were used to characterize basin conditions and evaluate climate change impacts. An updated flood frequency analysis was performed using gage data to estimate peak flood discharges. The hydraulic analysis included 2-dimensional (2-D) hydraulic modeling of peak flood events for the study area; the model was developed using available LiDAR data. Section 3.2 describes basin hydrologic characteristics, the flood frequency analysis, and the climate change evaluation. Section 3.3 provides a brief overview of the hydraulic model and its results, with more detail on modeling methods and results presented in Appendix D.

3.2 HYDROLOGY

3.2.1 Basin Characteristics

The Entiat River flows approximately 57 miles from the slopes of Seven Fingered Jack, Mount Fernow, and Mount Maude to its confluence with the Columbia River near Entiat, WA. The drainage area of the Entiat River watershed is approximately 420 square miles, much of which is within the Wenatchee National Forest. Elevations range from 711 to 9,230 feet above sea level with a mean basin elevation of 4,230 ft (USGS 2022). The major tributaries of the Entiat are the North Fork Entiat River and the Mad River.

The dominant hydrologic patterns of the Entiat River are driven by precipitation in the form of snow and subsequent spring snowmelt (Inter-Fluve 2013). Peak runoff usually occurs from April through July, with the highest flows typically in May or June. Initiation and variation in snowmelt volume is driven by changes in ambient air temperature, snowpack mass, and the elevational distribution of the season's snowpack. Stream discharge typically returns to baseflow by late August. Mean annual flow is 374 cubic feet per second based on the Ardenvoir gage data.

Precipitation amounts vary with elevation and distance from source areas. In the higher elevation areas of the basin, average annual precipitation is 10 inches falling mainly as snow (CCCD 2004). Mean annual precipitation in the study area watershed is approximately 58 inches (USGS 2022).

Within the assessment area, nine perennial creeks were identified that flow into the Entiat: Brennegan Creek, Mott Creek, Preston Creek, Dill Creek, Tyee Creek, Stormy Creek, Shamel Creek, Gray Creek, and Potato Creek. The upstream end of the study area is at an elevation of approximately 1,730 ft and the downstream end of the study area is at an elevation of 1,690 ft. Figure 13 provides a map of the Entiat River watershed, its primary tributaries, and the reach assessment project area.



Figure 13. Map of the Entiat River watershed in the context of the surrounding area with its tributaries, the reach assessment study area, and USGS stream gages.

3.2.2 Available streamflow data

Stream discharge data are available for the Entiat River at several locations, as several USGS gages are installed in areas of interest along the river. A detailed analysis of the Entiat River hydrology was conducted by the U.S. Bureau of Reclamation in 2009 as part of the Entiat Tributary Assessment, which used flood frequency analysis of several USGS gages, including the Old Keystone Gage (12453000), Current Keystone Gage (12452990), Mad River Gage (12452890), and the Ardenvoir Gage (12452800) to estimate peak flows for at each river mile of the Entiat River (USBR 2009). While this analysis is thorough, it does not include flow data from the last fifteen years. Because of this, the Entiat River Near Ardenvoir, WA gage (USGS gage 12452800) was utilized for all hydrologic analysis for this reach assessment. This gage is located within the assessment area near RM 18 and has a period of record from September 1957 to present, making it a good representation of streamflow conditions in the assessment area.

3.2.3 Seasonal Flows

The Entiat River's annual hydrograph follows a typical pattern for east-slope Cascade Mountain streams, with greatest discharges in the late spring to early summer from snowmelt runoff and smaller precipitation-driven peaks in late fall. The USGS gage at Ardenvoir shows a relatively constant baseflow from late August through September, with discharge increases October to December as fall and early winter rains produce flow peaks (Figure 14). This is followed by generally lower flows in the winter from January through early March, cold times when most or all of precipitation falls as snow, and before snowmelt begins in spring. Figure 14 shows the daily flow statistics for the period of record, including the daily mean, 5% exceedance, and 95% exceedance as well as a monthly flow mean based on the last 30 years of flow data.

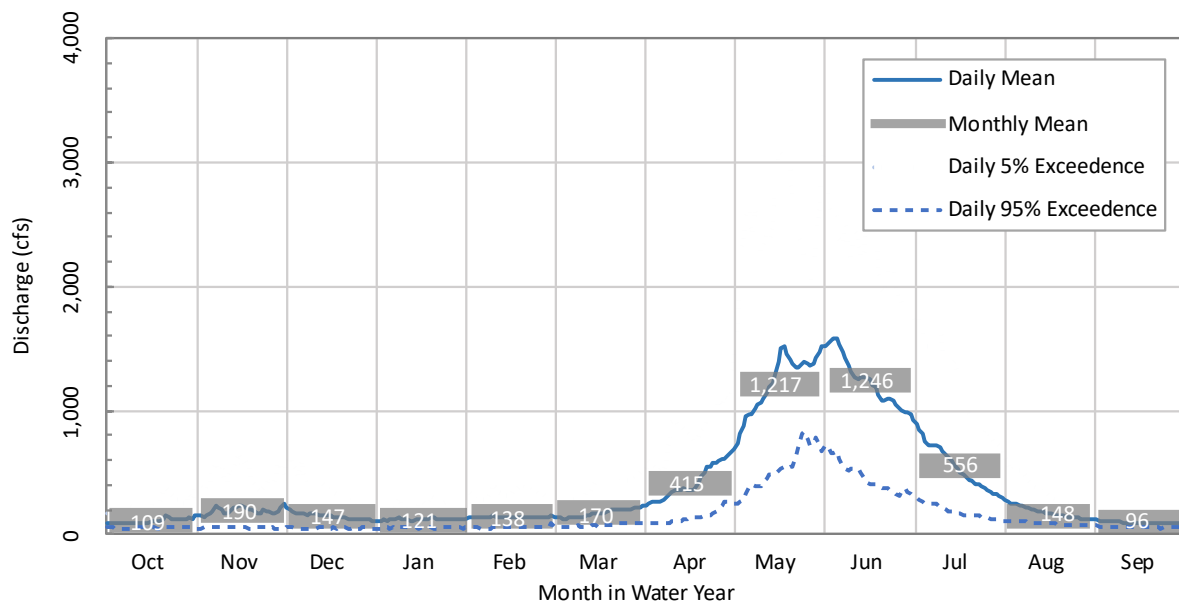


Figure 14. Daily flow statistics (using mean daily flows) at the Entiat River Near Ardenvoir, WA gage (USGS gage 12452800), for water years 1993 through 2023 showing the daily average, 5% exceedance, and 95% exceedance discharge and monthly average discharge for the period of record.

During winter, cold temperatures within the Entiat River watershed can lead to the formation of anchor ice, which is potentially detrimental to salmonid egg survival (CCCD 2004). Anchor ice forms along channel bottoms where turbulence prevents formation of surface ice, but super-cooled stream water leads to accumulation of slushy ice, or frazil ice, on channel substrate (CCCD 2004; USBR 2012). As anchor ice grows it can detach from the stream bed, disturbing bed sediments and salmonid eggs, where present. Climate change is likely to impact air and stream temperatures and streamflow patterns within the Entiat River watershed, which may impact development of anchor ice, although specific potential impacts are not well documented.

3.2.4 Peak Flows

Flood frequency estimates for the Entiat River were calculated using the USGS Ardenvoir gage data using a Log Pearson Type III flood frequency analysis for water years 1958 to 2023 (Figure 15). The analysis was performed using the Bulletin 17C flood frequency analysis methods with the HEC-SSP software, using a weighted skew with a regional skew of -0.07 and a regional skew MSE of 0.18, following the guidelines in Mastin et al. (Mastin et al. 2017; USACE 2023). The results are included in Table 4.

The flood frequency analysis results were then weighted to estimate the flows of interest for the project area (RM 15.6 to 26.7). The Mastin et al. (2017) Mastin et al. (2017) equation 11 for Region 2 in Washington was used to extrapolate the results to the top of the project area (RM 26.7) and the bottom of the project area downstream of Potato Creek (RM 15.6) (Table 5).

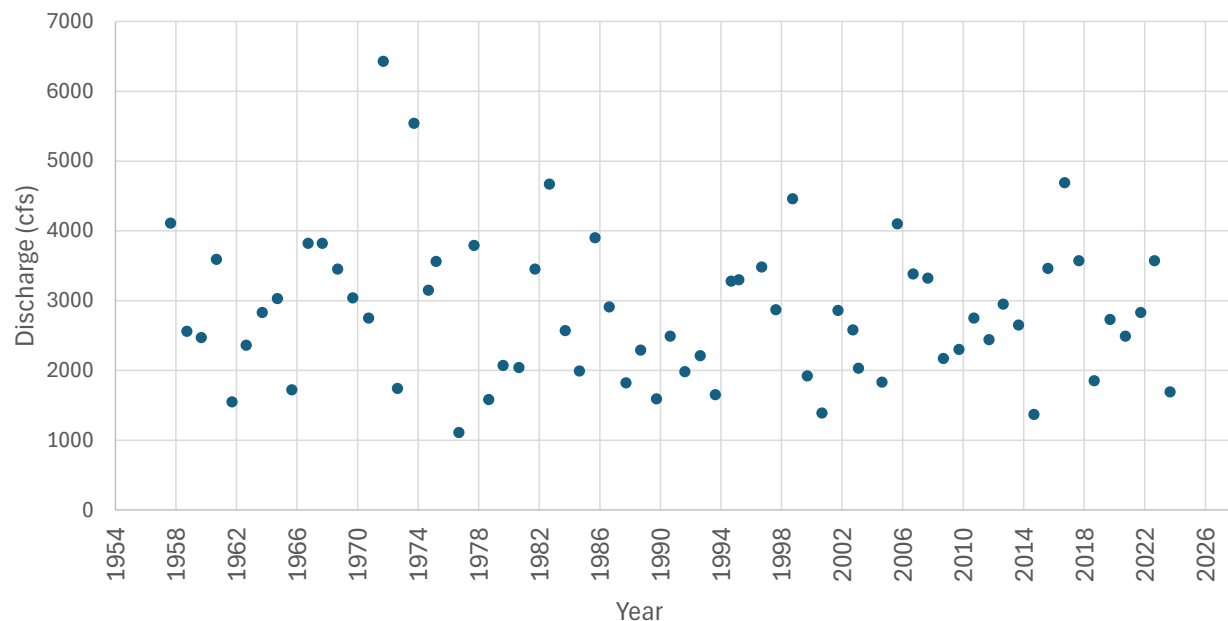


Figure 15. Peak flow history of Entiat River Near Ardenvoir, WA gage (USGS gage 12452800) from 1958 to 2023. Instantaneous values.

Table 4. Entiat River flood frequency analysis results for the USGS gage 12452800 (USGS 2025).

Flood Return Interval	Flood Flow (cfs)	5% Confidence Limit (cfs)	95% Confidence Limit (cfs)
2-Year	2698.6	2912.0	2499.0
5-Year	3621.6	3953.8	3348.2
10-Year	4210.5	4689.2	3863.6
25-Year	4932.6	5695.9	4457.6
50-Year	5456.8	6500.9	4858.2
100-Year	5970.5	7350.8	5225.8

Table 5. Entiat River project area estimated peak flood events based on weighted flood frequency analysis results for the USGS gage 12452800 (USGS, 2025).

Flood Return Interval	Entiat River Peak Discharge at RM 26.7 (cfs)	Entiat River Peak Discharge at RM 15.6 (cfs)
2-Year	2,260	2,920
5-Year	3,040	3,900
10-Year	3,540	4,510
25-Year	4,160	5,290
50-Year	4,610	5,850
100-Year	5,050	6,400

3.2.5 Climate Change

Climate modeling in the Pacific Northwest predicts potential changes to streamflow as a result of temperature changes and shifts in the seasonal precipitation pattern. Climate change models have predicted a 3.2°F increase in annual temperature by the 2040s, and a 5.3°F increase by the 2080s (Mote and Salathé 2010). Predicted changes in precipitation vary by model but generally show trends towards wetter fall and winter seasons and drier summers (Mote and Salathé 2010).

Seasonal shifts caused by overall warmer and drier conditions are expected to shift transitional (mixed rain and snow) and snow-dominated basins towards a rain-dominated regime. Tohver et al. (2014) Tohver et al. (2014) used the Variable Infiltration Capacity hydrological model to simulate basin hydrological regimes under the A1B medium emissions and the B1 low emissions climate scenarios. Under these scenarios, the Entiat Basin is predicted to remain a snow-dominated hydrological regime through the 2020s but then transition into a transitional basin starting in the 2040s (Tohver et al. 2014). Transitional basins typically have elevated flows in the winter with peak rainfall and again in the spring with peak snowmelt, representing systems with mixed rain and snow dominance. These basins are projected to be the most sensitive to warming from climate

change. Projected increases in winter precipitation are expected to cause more extensive flooding in basins such as the Entiat through the 2080s (Tohver et al. 2014). Warmer air temperatures combined with shifts in seasonal precipitation are predicted to result in earlier snowmelts, lower summer baseflows, and earlier peak flow timing. Warmer winter temperatures will result in more precipitation falling as rain instead of snow, lessening snowpacks that are essential for moderating stream temperature and regulating flow in spring and summer.

The National Climate Change Viewer (NCCV) is a USGS tool developed by Alder & Hostetler (2013) for visualizing and graphing projected climate change impacts from the Climate Model Intercomparison Program (CMIP) across the conterminous United States. This tool downscales projections from 27 Global Climate Models (GCMs) to 6km spatial resolution that can be used to visualize specific climate change impacts in watersheds. The climate change impacts are organized by Shared Socioeconomic Pathways (SSPs). SSPs represent various human development potentials and their impact on the amount of radiative forcing, or warming, that is projected to occur. Radiative forcing occurs when the amount of energy entering our atmosphere is larger than the energy exiting our atmosphere. A larger, positive radiative forcing value signals more warming. The SSP scenarios serve as a baseline to compare how the climate is predicted to change based on various social, economic, and policy factors.

In the Upper Columbia-Entiat watershed between 2025 - 2099, the climate models show an increase in mean temperature, a decrease in the amount of snow received, and an increase in late fall and winter precipitation in all SSPs (Figure 16, Figure 17, Figure 18). The total amount of annual precipitation the watershed receives is projected to change very little in the 2025 – 2099 timeframe, emphasizing seasonal and precipitation-type changes as the watershed transitions from snow-dominated to transient.

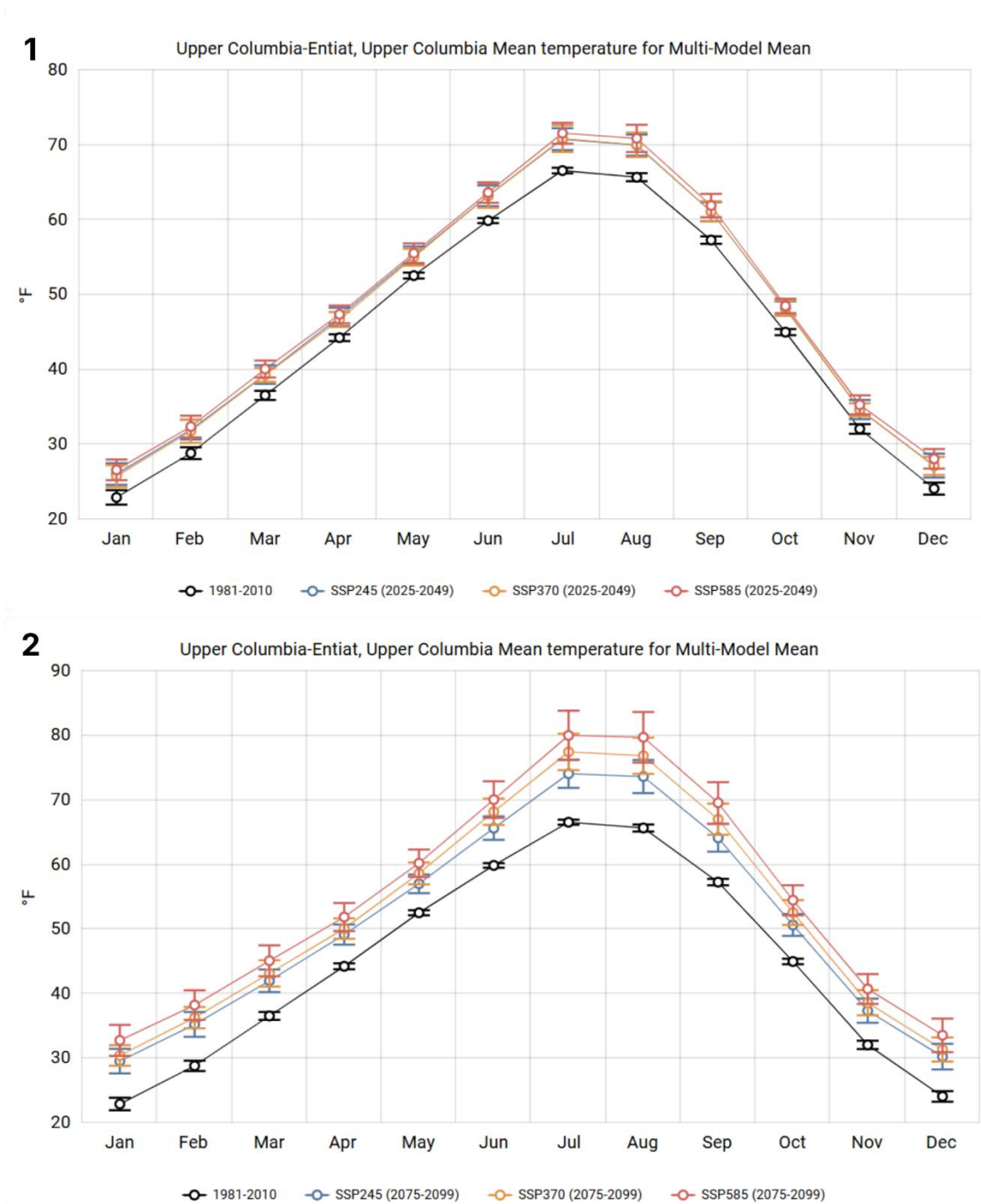


Figure 16. Climate change scenario graphs for mean temperature in the Upper Columbia-Entiat watershed. Source: Alder & Hostetler (2013), generated via USGS NCCV. The multi-model mean for mean temperature in the watershed from 1) 2025 – 2049 and 2) 2075 – 2099. The three scenarios are the 3 Shared Socioeconomic Pathways. SSP245 represents a ‘middle of the road’ scenario with an additional 4.5W/m² of radiative forcing by 2100. SSP370 represents an upper-middle scenario with an additional 7.0W/m² of radiative forcing by 2100. SSP585 represents the worst-case scenario akin to RCP 8.5 with an additional radiative forcing 8.5W/m² by 2100.

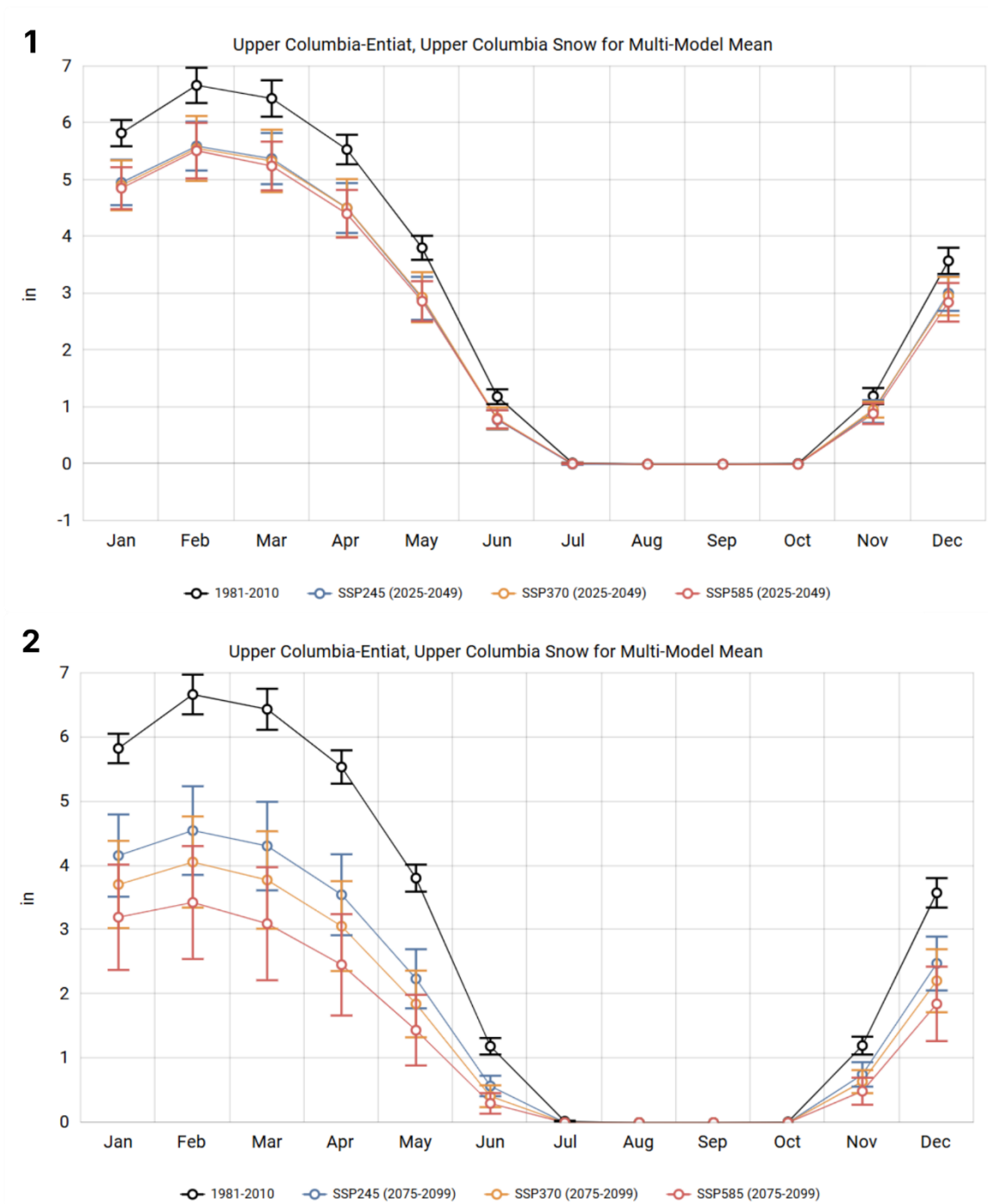


Figure 17. Climate change scenario graphs for snow in the Upper Columbia-Entiat watershed. Source: Alder & Hostetler (2013), generated via USGS NCCV. The multi-model mean for snow in the watershed from 1) 2025 – 2049 and 2) 2075 – 2099. The three scenarios are the 3 Shared Socioeconomic Pathways. SSP245 represents a ‘middle of the road’ scenario with an additional 4.5W/m² of radiative forcing by 2100. SSP370 represents an upper-middle scenario with an additional 7.0W/m² of radiative forcing by 2100. SSP585 represents the worst-case scenario akin to RCP 8.5 with an additional radiative forcing 8.5W/m² by 2100.

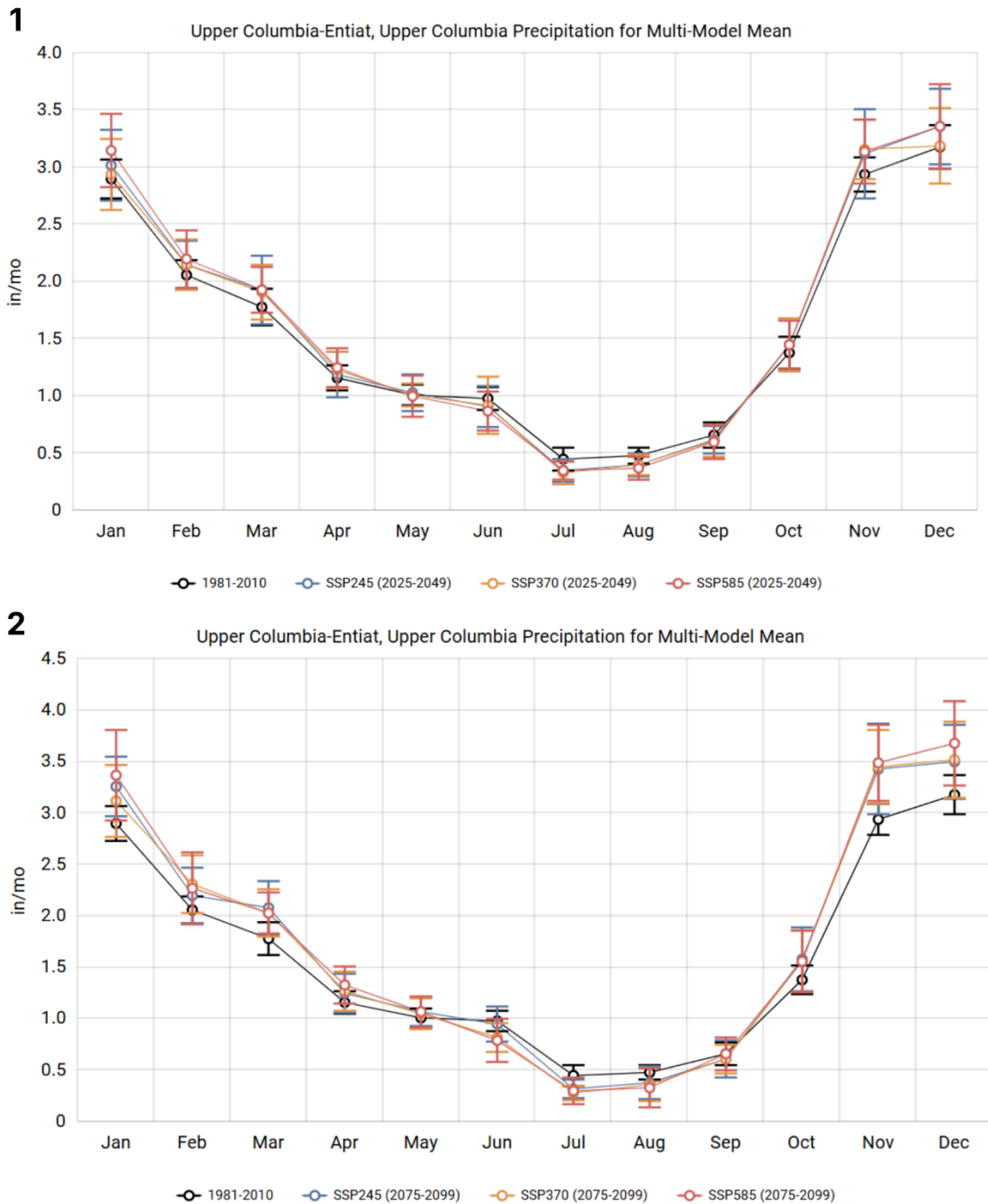


Figure 18. Climate change scenario graphs for precipitation in the Upper Columbia-Entiat watershed. Source: Alder & Hostetler (2013), generated via USGS NCCV. The multi-model mean for precipitation in the watershed from 1) 2025 – 2049 and 2) 2075 – 2099. The three scenarios are the 3 Shared Socioeconomic Pathways. SSP245 represents a ‘middle of the road’ scenario with an additional 4.5W/m² of radiative forcing by 2100. SSP370 represents an upper-middle scenario with an additional 7.0W/m² of radiative forcing by 2100. SSP585 represents the worst-case scenario akin to RCP 8.5 with an additional radiative forcing 8.5W/m² by 2100.

Changes to the dominant hydrological regime will have seasonal impacts on stream temperatures. Earlier peak flows from snowmelt and lower summer baseflows may increase the risk for summer water temperature exceedances for the salmonid and trout species that reside in the Entiat River and its tributaries. The largest changes in precipitation seasonality are an increase in late fall and early winter precipitation. The hydrological and habitat changes are crucial to consider as the climate continues to change in and around the Entiat River.

The climate change predictions from the modeling described above may already be occurring in the Entiat River. The streamflow data available for the Entiat River allow for some historical-to-current comparisons. There are discharge data from a USGS gage (Entiat River Near Ardenvoir, WA - 12452800) from September 1957 to present. More specific information on this gage is provided in Section 3.2.2 but a comparison of historical and recent data is presented here to evaluate climate change impacts on basin hydrology.

Mean monthly discharges from the USGS gage from water years (WY) 1958-2025 are shown in Figure 19 for two time periods. Mean monthly flows have been shifting earlier from June to May since 2000, with the magnitude of monthly flows decreasing in summer and early fall (June to September). The magnitude of annual peak flows has not noticeably changed since 2000, but they appear to have shifted earlier in the year (Figure 20). From WY 1958 to 1999, 40% of peak flows occurred in May and 55% occurred in June. From WY 2000 to 2024, 56% of peak flows occurred in May and only 36% occurred in June. This shift may be evidence of a transition of the Entiat River watershed from a snow-dominated basin to a transient basin, a change predicted for this basin by modeling by Tohver et al. (2014). The mean annual discharge of the Entiat River has not changed dramatically during the period of record (Figure 21). Changes in runoff timing and magnitude have the potential to affect fish life history patterns, including run timing.

Despite the changes to the seasonal timing of flows, the mean annual discharge in the two periods (WY 1958 – 1999 & WY 2000 – 2025) remain similar. The mean annual flow for WY 1958 – 1999 is 382 cfs and the mean annual flow for WY 2000 – 2025 is 361 cfs. These similar annual flow averages support the previous predictions in the Entiat River watershed that even though the timing and magnitude of flows will change with climate change, the overall mean annual flows are likely to remain the same. This finding further suggests that earlier snowmelt and shifts in precipitation type from snow to rain, driven by air temperature changes and overall changes in climate patterns, is a primary driver of the hydrological changes seen in the Entiat River during recent decades.

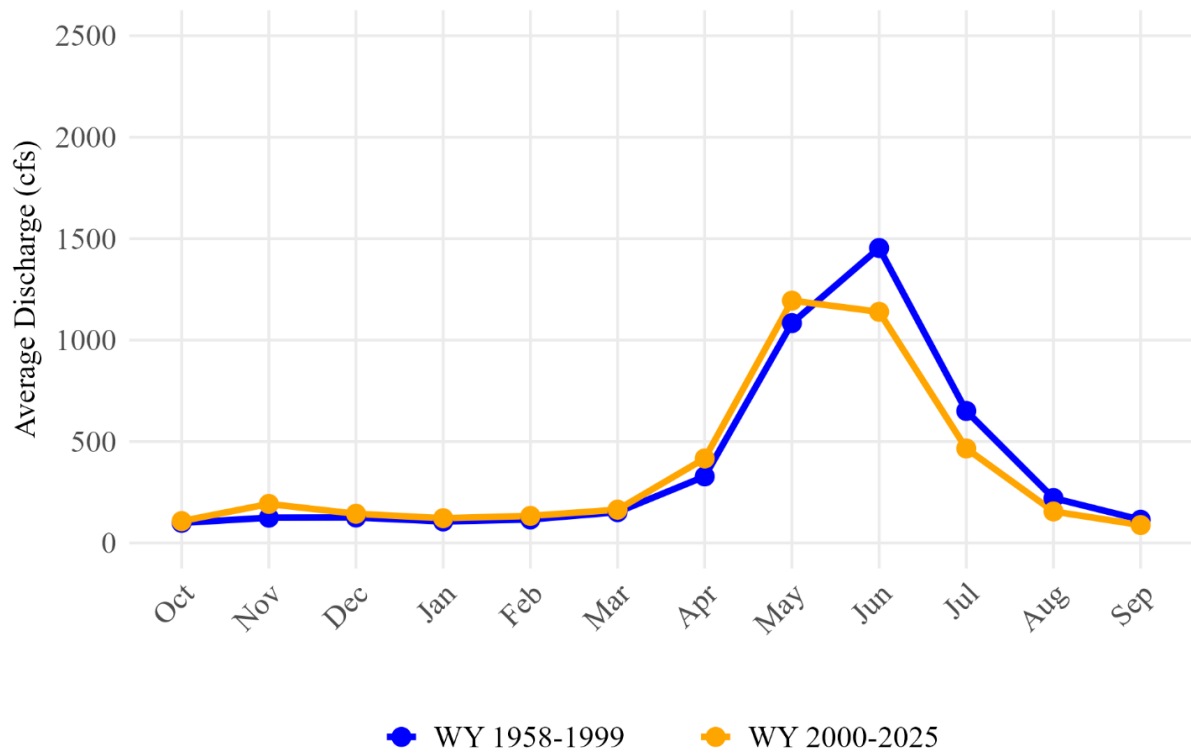


Figure 19. Comparison of mean monthly flows at the USGS gage (Entiat River Near Ardenvoir, WA - 12452800) for two time periods.

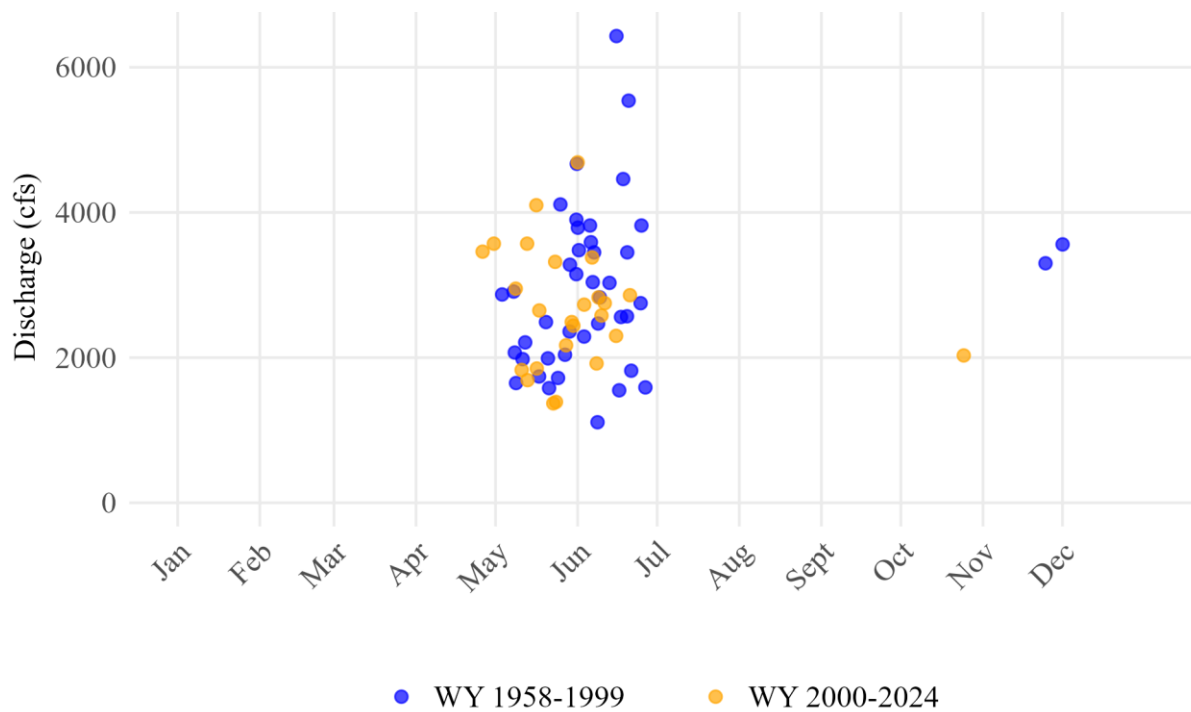


Figure 20. Annual peak flow timing and magnitude at Entiat River Near Ardenvoir, WA stream gage (USGS 12452800).

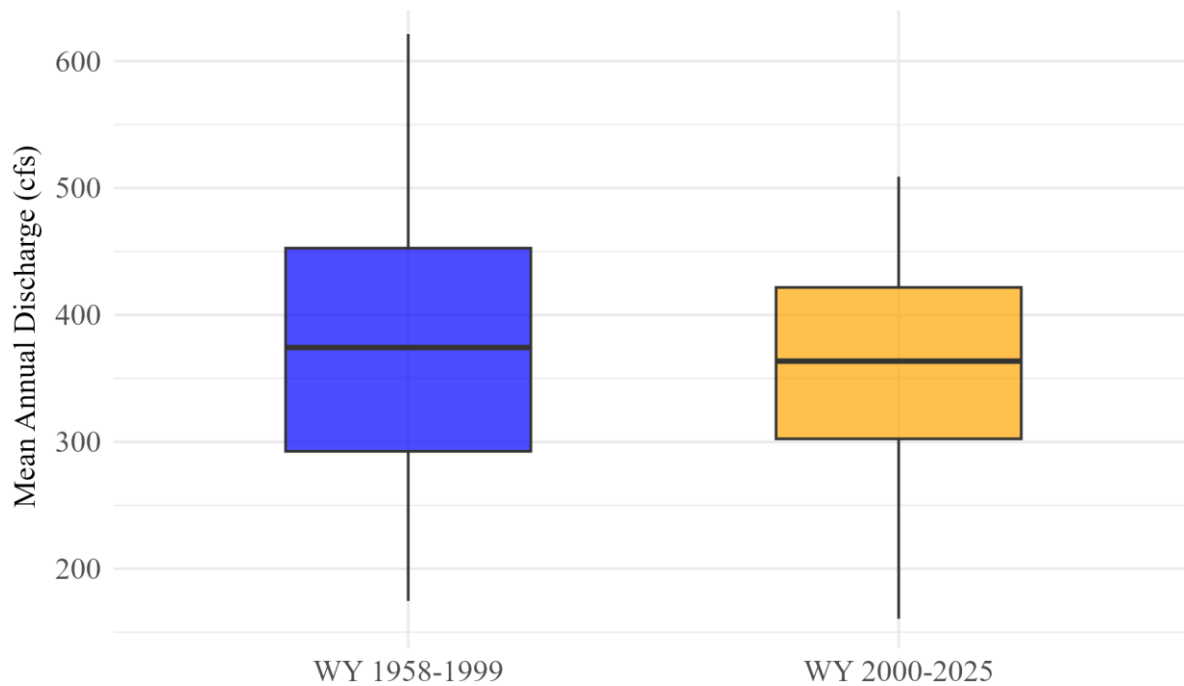


Figure 21. Mean annual discharge at the Entiat River Near Ardenvoir, WA USGS gaging station (12452800). The mean annual discharge for WY 1958 – 1999 was 382 cfs while the mean annual discharge for WY 2000 – 2025 was 361 cfs.

It is reasonable to assume that high elevation basins, such as the Entiat River basin, would be exhibiting a greater response, so far, to climate change, compared to lower elevation areas. These snowmelt-dominated systems are at the cusp of a transition to mixed rain and snow systems that exhibit both snowmelt and rain-dominated characteristics, such as described by Tohver et al. (2014). Rain events in the early season (late fall / early winter) in these high elevation basins often result in higher runoff compared to similar type events in later winter or spring due to a lower snowpack available to absorb the rainfall and buffer the runoff. This may be exacerbated by climate change-related impacts causing more precipitation falling as rain as opposed to snow, especially in the fall before there has been significant snow accumulation, which would be expected given the warming predicted by modeling. This is related to, and further exacerbated by, lower fall snowpack, which is also predicted by the modeling.

In summary, modeling predicts climate change effects on hydrologic processes in the Entiat River and the Upper Columbia-Entiat watershed, including less snowpack, earlier and lower spring snowmelt peaks, elevated winter flows, and lower summer base flows (Alder & Hostetler, 2021; Mauger et al., 2017; Tohver et al., 2014; USFWS, 2022). The Entiat River may be particularly susceptible to climate change impacts due to its high elevation and potential to transition from a snowmelt-dominated system to a rain and snowmelt-dominated system. The data suggest that the Entiat River may already be experiencing some of these predicted transitions.

3.3 HYDRAULIC MODEL OVERVIEW

3.3.1 2-D Hydraulic Modeling

A preliminary-level 2-D hydraulic model of the Entiat River was developed for existing conditions for the study area using the estimated flood discharges described in Section 3.2.4. The hydraulic model was developed in the U.S. Army Corps of Engineers HEC-RAS 6.6 software (USACE 2024), which computes hydraulic properties related to the physical processes governing water flow through natural rivers and other channels. Existing conditions were based on the most recent available LiDAR data, including topographic and bathymetric data from 2022 (NV5 Geospatial 2022). The goal of this preliminary model is to assess the current channel and floodplain dynamics, as well as assess the impacts of flood flows on the existing landscape.

3.3.2 Model Results

Model results figures can be seen in Figures 5 to 8 of Appendix D. Modeled velocities and depths for the 2-year and 100-year flood events reveal trends across the Entiat River study area. Floodplain inundations and connectivity vary, activating floodplains in much of the study area during the 2-year flood event and inundating almost the entire valley bottom of reaches 2 to 6 with 0.5ft or more of water at the 100-year flood. However, in reaches 1, 8, and 10, flow is more confined, with channel velocities over 10 feet per second. Model results indicate that roads and small structures are impacted by the 100-year flood event in reaches, 2, 3, 4, 9, and 11.

3.3.3 Model Considerations

While this preliminary model was built using readily available and informative data, it lacks the detail to be used to design restoration projects. Further surveys of the river and the surrounding landscape and infrastructure are needed to confirm the accuracy of the topobathymetric LiDAR and to represent key features such as bridges and floodplain structures in the model. Additionally, flow inputs from groundwater or small tributaries not included in this analysis need to be investigated to inform more detailed model development and better support restoration design.

4. Habitat Assessment

Habitat surveys using the US Forest Service Region 6 Level 2 protocols were performed in the assessment area from October 7-14, 2024, and August 4-8, 2025. The full Entiat River Habitat Assessment (Appendix A) provides an inventory of the habitat conditions in the Entiat River assessment area. This section provides a summary of the findings. A summary table of the habitat assessment results is included as Table 6.

Areas with natural confinement from alluvial fans correspond to reaches dominated by riffle or glide habitat (Reach 1, Reach 8, Reach 10, and Reach 12). In the lower reaches, Reach 2-6, pool habitat is prevalent with long stretches of pool habitat that become more interspersed with fast water units (i.e. riffle-glide type habitat) moving upstream. Reach 7, Reach 9, and Reach 11 have

heterogeneous habitat unit compositions, with no one type dominating. Side channel habitat is more prevalent in the upstream reaches (Reach 5 and above), except for Reach 6, Reach 8, and Reach 10.

There were 4,381 pieces of LWM observed in the assessment area in total, which averages to 395 total pieces per mile and 206 medium and large (M+L) pieces per mile. Medium pieces are defined as greater than 12 inches in diameter and 35 feet in length, whereas large pieces are defined as greater than 20 inches in diameter and 35 feet in length. There were 216 jams observed, or 20 jams per mile, which contained 75% of the LWM observed in the assessment area. Of the 216 jams, 65% (n=141) are constructed. Reach 7 had the most LWM of any reach, with 482 M+L pieces per mile. Reach 1, Reach 8, and Reach 10 all had the lowest amounts of LWM of any reach. LWM corresponds with less confined, less steep reaches and areas where restoration actions (i.e. constructed jams) are prevalent. Natural recruitment of LWM is limited throughout the assessment area, likely in part due to the history of logging throughout the watershed (CCCD 2004). In reaches where there are adequate amounts of LWM from a habitat and cover perspective, LWM did not necessarily exert a strong influence on channel dynamics and geomorphic function was generally lacking throughout the assessment area.

The riparian vegetation in the lower reaches (primarily Reach 1-2 and Reach 4) has been affected by either the 2018 Cougar Creek or 1994 Tyee Fires (fire information from Washington State Department of Natural Resources n.d.). The primary overstory size class observed throughout the assessment area was split between large trees (21-31.9-inch dbh) in 53% of surveyed units and small trees (9.0-20.9-inch dbh) in 42% of surveyed units. The most prevalent overstory species was cottonwood. The primary understory size class was shrub/seedling (1.0-4.9-inch dbh) and the most prevalent species observed were split between willow in 40% of surveyed units and alder in 35%.

Table 6. Summary of the habitat assessment results. The full habitat assessment is included as Appendix A.

Habitat Metric	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10	Reach 11	Reach 12
Unit Composition												
Pool	15%	89%	72%	70%	65%	76%	43%	0%	45%	8%	33%	3%
Riffle	81%	3%	13%	21%	5%	10%	11%	78%	32%	92%	9%	38%
Glide	2%	0%	0%	9%	7%	13%	18%	22%	10%	0%	38%	12%
Side Channel	1%	0%	9%	0%	22%	0%	27%	0%	12%	0%	18%	46%
Marsh	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%
Alcove (constructed or natural)	0%	8%	7%	0%	0%	0%	0%	0%	0%	0%	2%	1%
Medium & Large LWM/mile (includes jams)	37	242	244	102	265	143	482	13	226	21	63	219
Pools/mile	4	12	6	13	11	9	10	0	11	1	7	2
No. Pools with Residual Depth 3ft ≤ D < 6ft	1	7	2	9	8	3	10	0	9	1	4	2
No. of Pools with Residual Depth ≥ 6ft	0	2	2	1	0	1	0	0	1	0	1	0
No. of Side Channels	1	0	2	0	4	0	6	0	2	0	4	2
Riparian Conditions												
Large Tree	20%	60%	50%	43%	40%	20%	43%	100%	89%	100%	75%	20%
Small Tree	20%	40%	50%	57%	60%	80%	57%	0%	11%	0%	25%	80%
Shrub/Seedling	20%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Grassland/Forb	20%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Other	20%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

5. Reach-Based Ecosystem Indicators

A Reach-Based Ecosystem Indicators (REI) analysis was performed to support the reach assessment. The REI evaluates biological and physical conditions of a watershed in relation to regional standards and known habitat requirements for aquatic biota. The REI results include functional ratings for a range of attributes at the reach- and watershed-scale. Functional ratings include Adequate, At Risk, or Unacceptable. The REI analysis helps to summarize habitat impairments and to distill the impairments down to a consistent value that can be compared among reaches. The full REI analysis methods and results, including a comparison of REI results to previous habitat assessments performed on the Entiat River, are provided in Appendix B. A summary of the reach-scale results for the Entiat River is included in Table 7.

At the watershed scale, REI ratings for the Entiat River ranged from At Risk to Unacceptable. Watershed-scale impairments are primarily related to historical or ongoing anthropogenic disturbance to the watershed, particularly timber harvest and wildfires. Reach-scale metrics ranged from Adequate to Unacceptable. Across all reaches, the most impaired indicators occurred in the Habitat Quality and Riparian Vegetation categories. The Entiat River does not have any full fish passage barriers and suitable spawning-sized substrates are present in all reaches where geomorphic conditions are suitable. However, sufficient amounts of large woody material (LWM) to provide habitat and drive geomorphic processes, along with high quality riparian conditions, such as undisturbed, mature trees were limited in nearly all the surveyed reaches. The downstream reach, Reach 1, was the most impaired across all indicators.

Table 7. Summary ratings for the Entiat River assessment area. REI ratings are color-coded, with green shading for Adequate condition, yellow for At Risk condition, and red for Unacceptable condition.

Pathway	General Indicators	Specific Indicators	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10	Reach 11	Reach 12
Habitat Access	Physical Barriers	Main Channel Barriers	At Risk	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate
Habitat Quality	Substrate	Dominant Substrate/ Fine Sediment	At Risk	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate	At Risk	Adequate	Adequate	Adequate
	LWM	Pieces per Mile at Bankfull	Unacceptable	At Risk	At Risk	At Risk	At Risk	At Risk	Adequate	Unacceptable	Adequate	Unacceptable	Unacceptable	At Risk
	Pools	Pool Frequency and Quality, Presence of	Unacceptable	Adequate	At Risk	Adequate	At Risk	At Risk	Adequate	Unacceptable	At Risk	Unacceptable	At Risk	At Risk
	Off-Channel Habitat	Connectivity with Main Channel	Adequate	Unacceptable	At Risk	Unacceptable	Adequate	Unacceptable	Adequate	Adequate	At Risk	Adequate	At Risk	At Risk
Riparian Vegetation	Condition	Structure	Unacceptable	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk
		Disturbance (Human)	At Risk	Adequate	At Risk	At Risk	At Risk	Adequate	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk
		Canopy Cover	Unacceptable	At Risk	At Risk	At Risk	Adequate	At Risk	Adequate	Adequate	Adequate	Adequate	Adequate	At Risk
Channel	Dynamics	Floodplain Connectivity	Adequate	At Risk	At Risk	At Risk	Adequate	At Risk	Adequate	Adequate	At Risk	Adequate	At Risk	At Risk
		Bank Stability/ Channel Migration	Adequate	Adequate	At Risk	Adequate	Adequate	At Risk	At Risk	Adequate	At Risk	Adequate	At Risk	At Risk
		Vertical Channel Stability	Adequate	At Risk	At Risk	At Risk	Adequate	At Risk	At Risk	Adequate	At Risk	Adequate	At Risk	Adequate

6. Channel Segment Conditions

The following sections describe segment-scale channel conditions within the assessment area. The assessment area was divided into four segments, each of which includes multiple stream reaches. Segment 1 includes Reaches 1-4; Segment 2 includes Reaches 5-7; Segment 3 includes Reaches 8-10; and Segment 4 includes Reaches 11-12. Channel and floodplain geomorphology, large wood material conditions, vegetation, prior restoration projects, and future project opportunities were evaluated during the August 2025 assessment and are described for each of the four segments within the assessment area. The longitudinal profile included in Figure 22 provides a useful reference for how reaches and segments relate to one another.

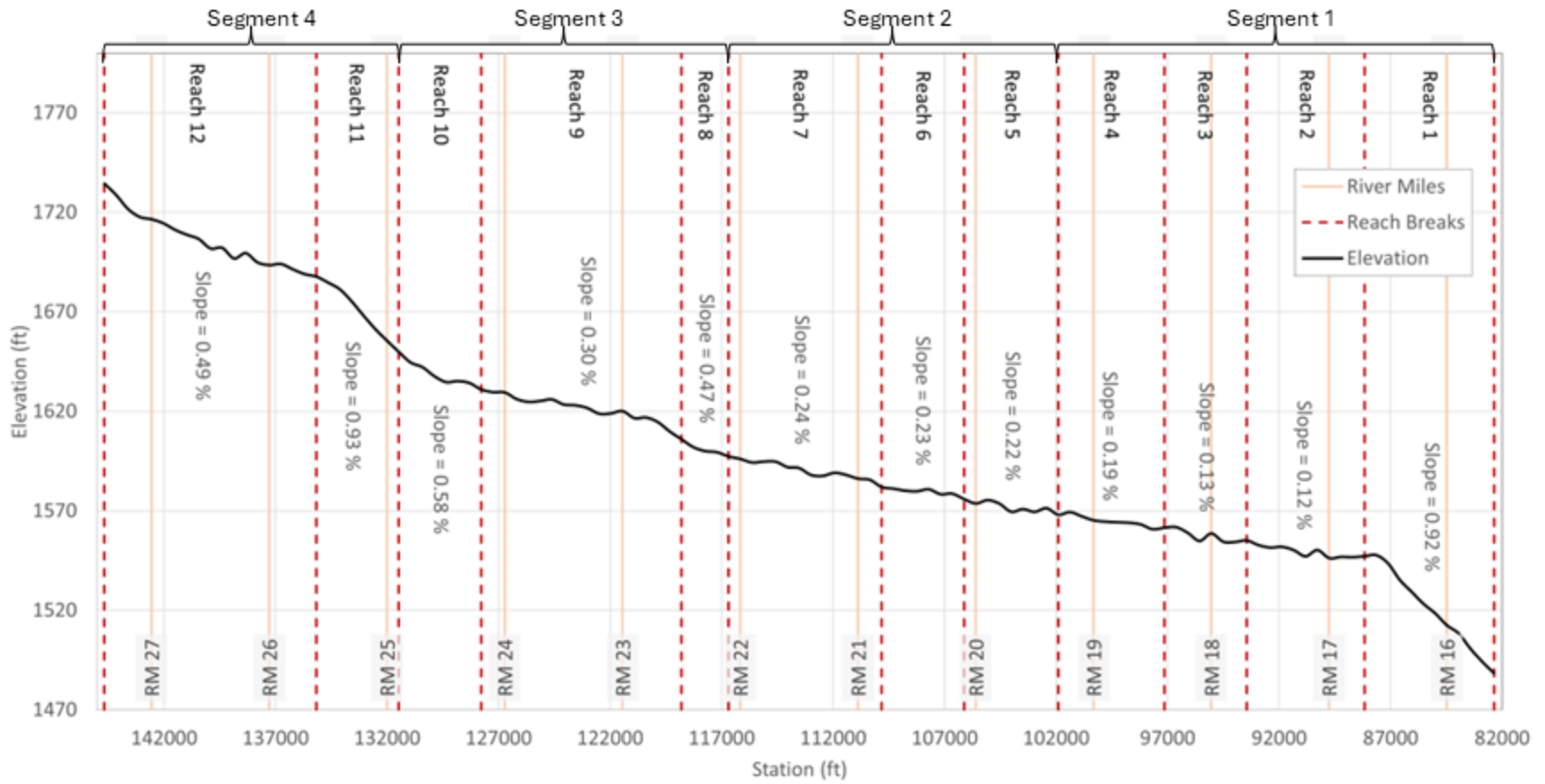


Figure 22. Longitudinal profile for the Entiat River within the assessment area.

6.1 SEGMENT 1 (RM 15.6 – 19.3)

6.1.1 Overview

Segment 1 is 3.7 river miles long, extending from the Potato Creek confluence at RM 15.6 to the Stormy Creek alluvial fan at RM 19.3, which enters the Entiat River valley from river left (Table 8, Figure 23). Segment 1 encompasses reaches 1-4 of the Habitat Assessment (Appendix A), and spans a portion of Reach 1G, all of Reach 2A (Gray Reach), and Reach 2B from the 2009 Entiat Tributary Assessment (USBR, 2009a).

Table 8. Metric table for Segment 1. Metrics collected during the Habitat Assessment are discussed in Appendix A. Confinement estimates are from the Entiat Tributary Assessment (USBR 2009a).

Reach	Length (miles)	River Mile	Stream Gradient (%)	Sinuosity	Dominant Channel Habitat Unit Type	Average Bankfull Width (ft)	Confinement	Dominant Substrate	% Pool Habitat	% Glide Habitat	% Riffle Habitat	% Side Channel Habitat	% Other Habitat
Reach 1	1.1	15.6-16.7	0.92%	1.20	Riffle	95	Confined	Boulder	15%	2%	81%	1%	0%
Reach 2	1	16.7-17.7	0.12%	1.30	Pool	115	Unconfined	Sand/Gravel	89%	0%	3%	0%	8%
Reach 3	0.7	17.7-18.4	0.13%	1.36	Pool	93	Confined	Gravel	72%	0%	13%	9%	7%
Reach 4	0.9	18.4-19.3	0.19%	1.47	Pool	95	Unconfined	Cobble/Gravel	70%	9%	21%	0%	0%



Figure 23. Representative photographs of the Entiat River in Segment 1 at RM 16.6 looking downstream (Left) and RM 16.83 looking upstream (Right).

Notable human alterations within Segment 1 include McKenzie Ditch and associated intake pipe associated with two channel-spanning weirs just upstream of Decker Canyon; numerous homes and other built structures on floodplain and terrace surfaces; clearing of vegetation including widespread timber harvest; riprap and large wood bank stabilization; and two bridges (Figure 24). The two bridges were built within natural channel constrictions and therefore do not significantly impede floodplain connectivity or other channel processes; however, a third bridge was removed as part of the Cottonwood Flats restoration project. Fill material associated with this bridge remains

within the Entiat River floodplain, affecting floodplain inundation patterns (Figure 24). Entiat River Road is located along the base of the river left hillslopes throughout the entire segment and comes into contact with the Entiat River channel at several locations within the upstream half of the segment. The road potentially limits hillslope fine to coarse sediment inputs to the channel and lateral erosion processes.



Figure 24. Human alterations in Segment 1. Top left: McKenzie Ditch (RM 16.6); Top right: boulder weirs directing flow into McKenzie Ditch, looking upstream; Bottom left: bridge and associated riprap at RM 18.1, looking downstream; Bottom right: fill associated with former Cottonwood Flats bridge (RM 18.45).

Prior restoration projects intended to benefit salmon and steelhead in Segment 1 include Gray E and F and Cottonwood Flats. These projects, constructed between 2018 and 2023, incorporated placement of engineered log jams within the main channel, side channels, and floodplains, as well as excavation of a series of perennial and high-flow side channel networks. A map of human alterations in Segment 1, including prior restoration projects, is included in Figure 25. See Section 6.1.5 for a description of past restoration projects within Segment 1.

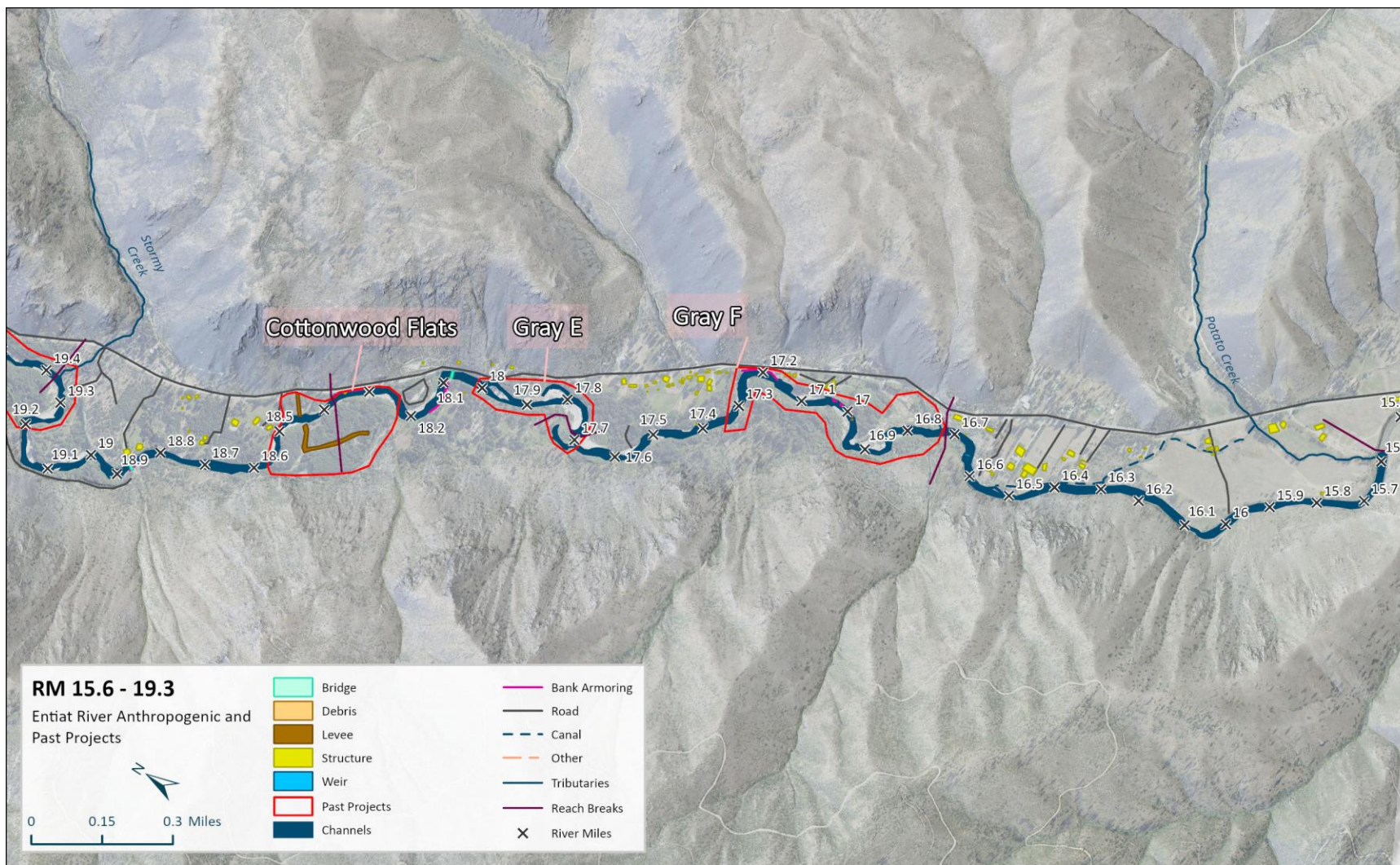


Figure 25. Segment 1 past restoration projects and mapped anthropogenic features.

6.1.2 Channel and Floodplain Geomorphology

The Entiat River channel through Segment 1 is primarily single thread, sinuous ($S = 1.28$), and has low gradient (0.43%) on average (Table 8). However, the channel undergoes a distinct and rapid transition as it reaches the Potato Moraine, just upstream of Decker Canyon near RM 16.6. Upstream of Potato Moraine, the wide, glacially carved valley supports floodplain surfaces and lateral channel migration except for areas where tributary fans push the Entiat River channel against the opposite hillslopes, confining the valley bottom (e.g., Stormy Creek and Gray Canyon alluvial fans) (Figure 26, Figure 27, Figure 28). Occasional mid-channel gravel bars create localized split-flow conditions. Placed large wood structures from prior restoration projects appear to initiate and maintain split-flow conditions in several locations. Channel substrate in the unconfined upstream portion of Segment 1 consists primarily of gravels in shallower, higher-velocity regions, and sands in slower deep pools (Figure 29). Just upstream of the Potato Moraine, stream energy decreases considerably due to a combination of the McKenzie Ditch weirs and downstream confinement due to the Potato Moraine (Figure 28). Here, sand was observed depositing on top of the gravel-dominated substrate, and ‘bathtub rings’ were observed within streambanks. Moving downstream, the Entiat River channel is confined between the Potato Moraine and the river right hillslopes through the end of the assessment area. Channel gradient increases to approximately 0.92%, sinuosity decreases to 1.20, and aside from a single vegetated island just downstream of McKenzie Ditch, flow splits are absent. Channel substrate consists primarily of boulders with cobbles and gravels deposited in lower velocity regions in the lee of larger boulders or within the interstices of the boulder substrate along channel margins (Figure 29). Bedrock exposures in the lower portion near where the Potato Creek canyon enters the Entiat River valley provide grade control, and the upstream exposure creates a brief cascade which flows into a deep scour pool, the single large pool within this section of Segment 1 (Figure 29). The habitat assessment (see Appendix A) recorded 57% of the habitat as pool, 36% as riffle, 3% as glide, and 2% as side channel (Figure 26). The average bankfull width, measured during the habitat assessment was approximately 98 feet.

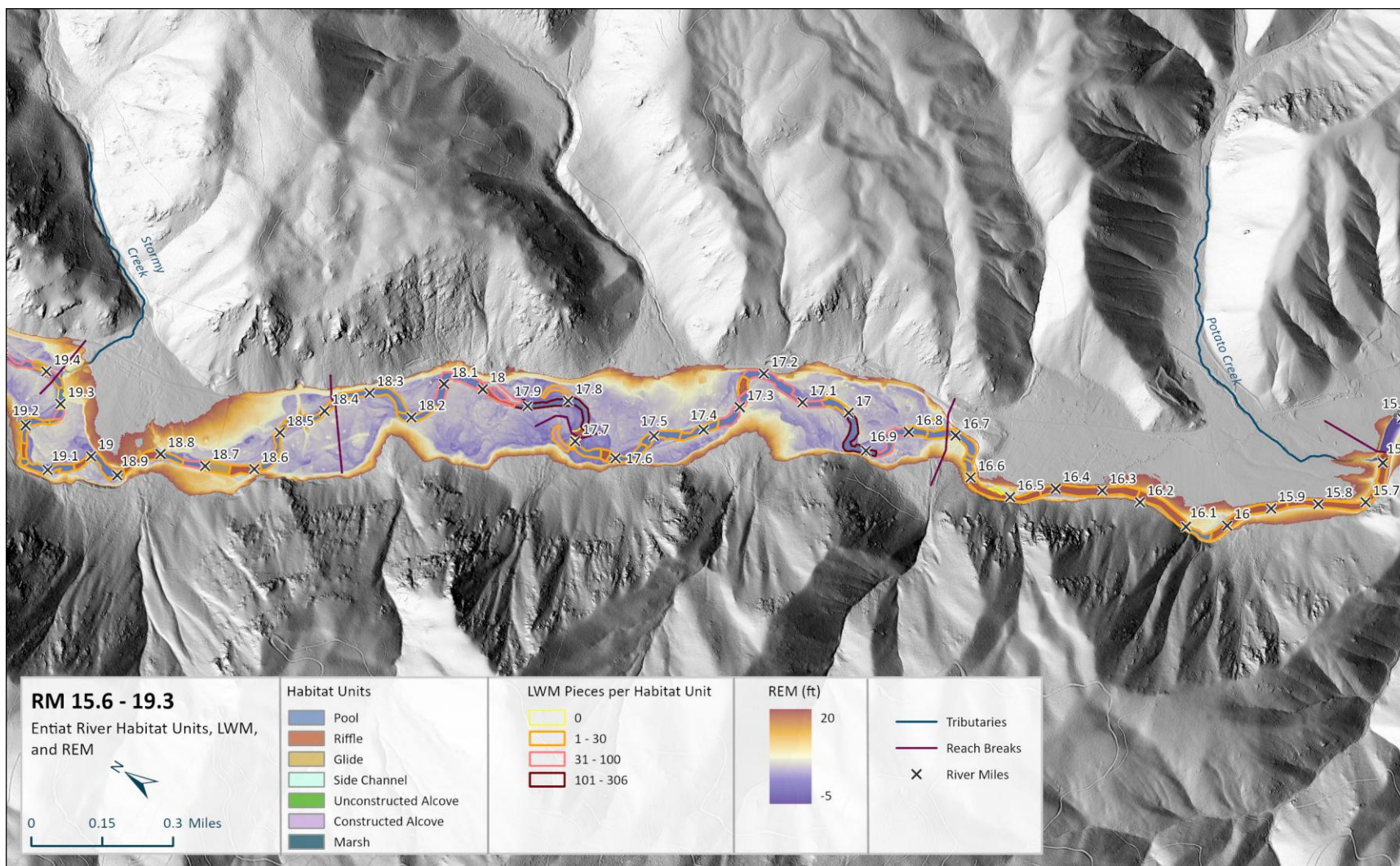


Figure 26. Habitat unit composition, LWM, and elevation relative to channel in Segment 1. LWM is total pieces within the habitat unit. See the habitat assessment in Appendix A for more details.

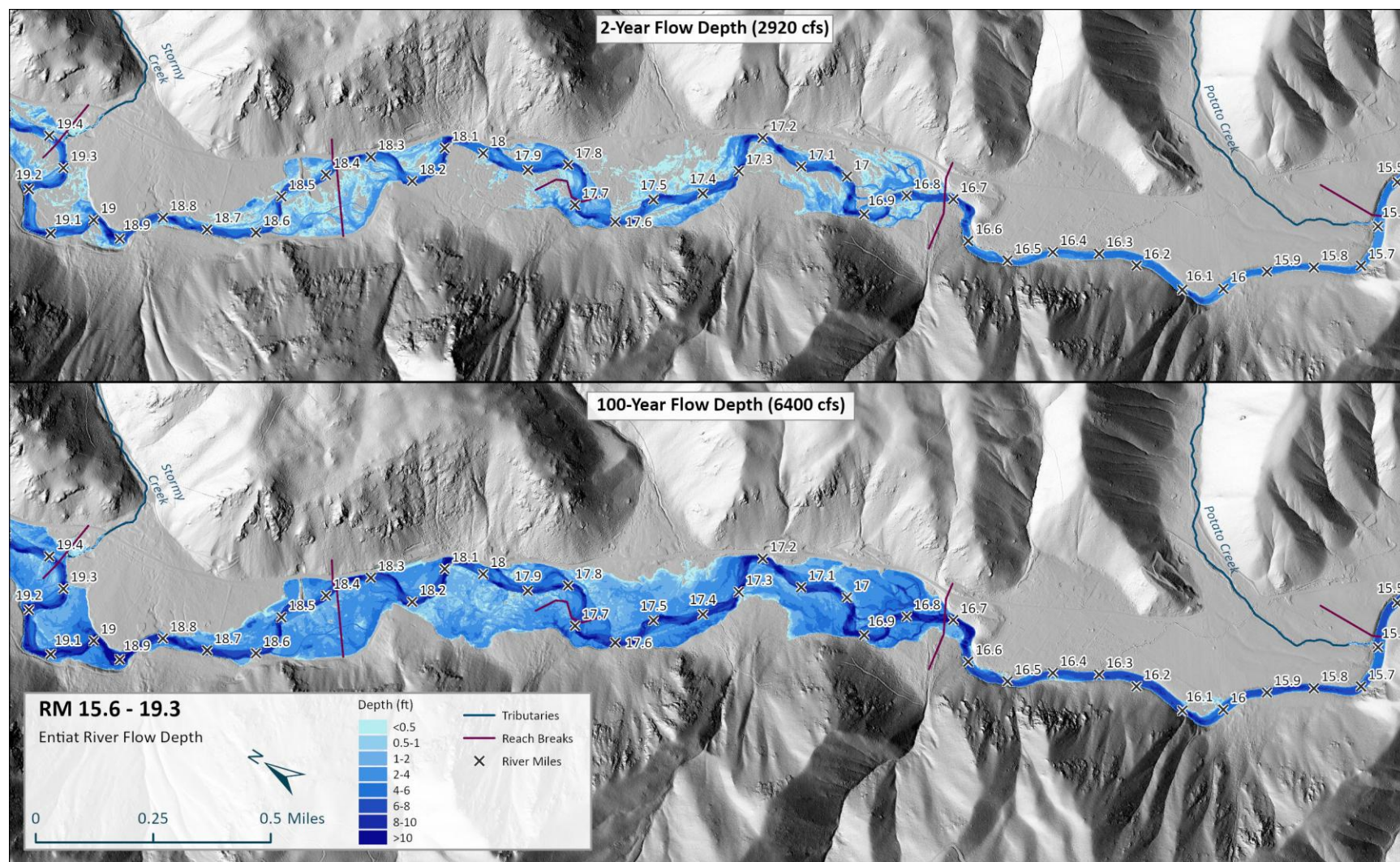


Figure 27. Modeled depth results for Segment 1.

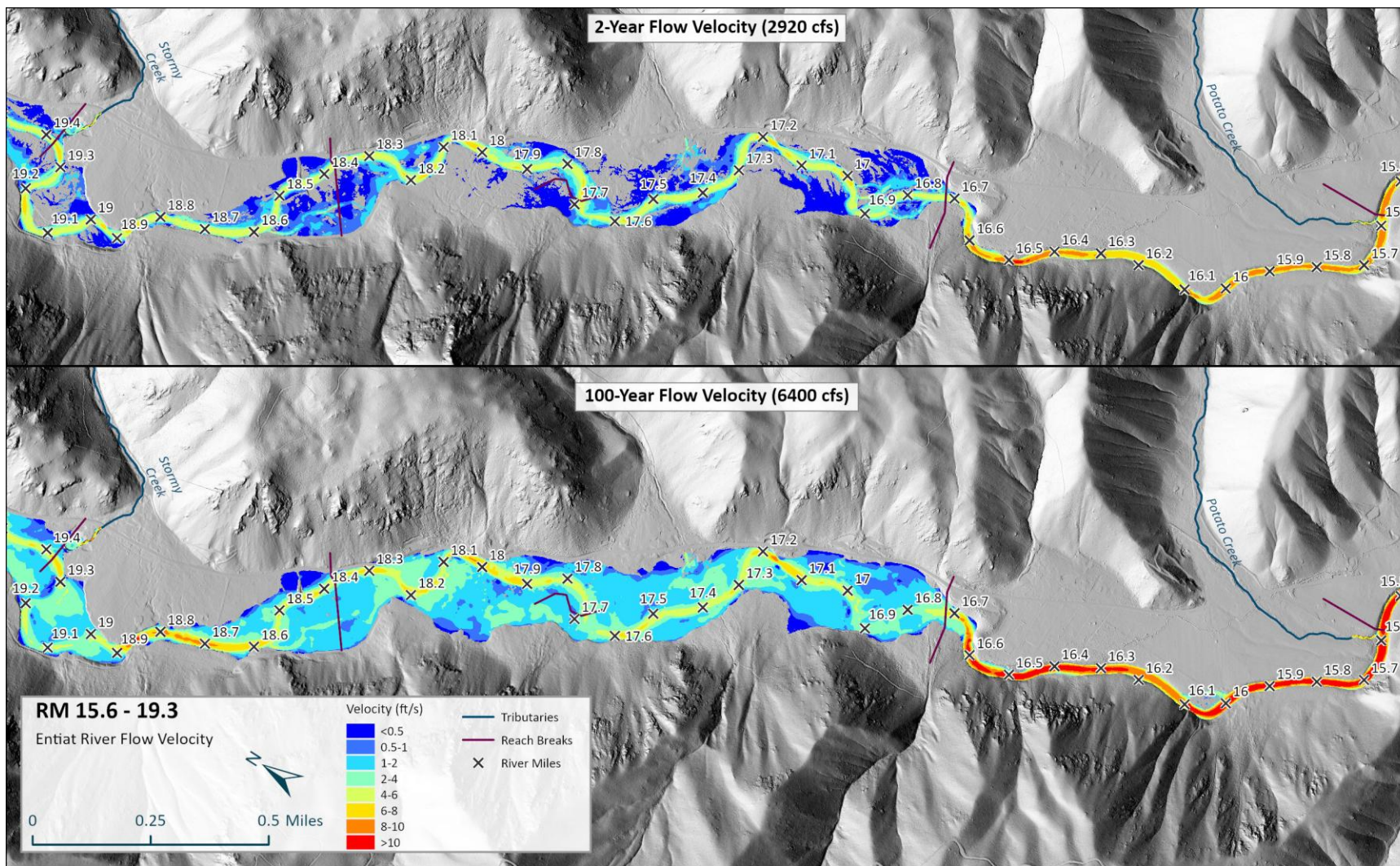


Figure 28. Modeled velocity results for Segment 1.



Figure 29. Top: Representative photographs of channel bed substrate in Segment 1. Gravels were the dominant channel substrate in the upstream unconfined portion of Segment 1 (left, RM 16.95), whereas boulders and cobbles were the dominant channel substrate downstream of McKenzie Ditch (right, RM 16.55). Bottom: bedrock exposure creating cascade at RM 16.05, looking downstream.

Sediment sources in Segment 1 include hillslope contributions ranging from fines to car-sized boulders, alluvial fans contributing coarse gravels and cobbles (e.g., Grays Canyon and Stormy Creek fans), gravels and fines from eroding streambanks, and bedload transported from upstream. Large boulders provide habitat complexity in several discrete locations where the Entiat River channel contacts hillslopes and high terraces. A consistent pattern of an intermittent gravel base overlain by two to three feet of finer sand and silt was observed in exposed eroding streambanks throughout Segment 1.

Connected off-channel habitat areas are absent downstream of McKenzie Ditch due to valley bottom confinement from the Potato Moraine; however, upstream of McKenzie Ditch, the unconfined valley bottom supports the development of floodplain surfaces. Although wide floodplain surfaces exist, connectivity is likely limited compared to pre-European settlement conditions due to channel simplification and a reduction in in-stream large woody material. Connected off channel habitat is limited to several side channels and a ponded wetland area (Figure 30). Side channel networks constructed during the Gray E and F and Cottonwood Flats restoration projects create additional off-channel habitat; however, many of these constructed channels are only connected at higher flows.



Figure 30. Connected off-channel pond near RM 17.7.

6.1.3 Large Wood Material

Naturally recruited large wood was generally lacking in Segment 1 during the August 2025 geomorphic assessment. The Entiat River watershed was heavily logged during the 19th and 20th centuries, reducing recruitable large wood sources within the watershed, and log drives down the Entiat River channel cleared existing large wood from the channel (CCCD 2004). During the August 2025 assessment, large wood pieces greater than 1.5 feet in diameter and extending into the channel were observed driving fine sediment deposition, providing minor cover habitat, and promoting development of scour pools (Figure 31). Where the Potato Moraine confines the Entiat River in the downstream portion of Segment 1, large wood was only retained when trapped between large boulders or trees adjacent to the stream channel. Active large wood recruitment due to bank erosion was observed in Segment 1; however, existing trees along the Entiat River channel are generally second-growth and small (e.g., < 1 foot dbh) and therefore are unlikely to be retained long-term or to be effective in driving geomorphic processes. Although effective naturally recruited LWM was generally lacking from the Entiat River channel at the time of the assessment, a landowner with property near the Stormy Creek fan described the recent natural abandonment of a side channel on their property due to deposition of a large wood jam which clogged the former side channel during a flood, deflecting all flow to the main channel. Large wood pieces within the jam ranged from small pieces to large logs 2 ft in diameter. Number of pieces of LWM by habitat unit is depicted in Figure 26 (Section 6.1.2). Engineered large wood structures have been installed in several locations in Segment 1 as part of past restoration projects. These structures are generally more effective in driving geomorphic and habitat processes than existing naturally recruited large wood in Segment 1, given the current lack of naturally recruited large wood. The installed large wood structures may provide the additional long-term benefit of increased large wood racking potential as local forests recover, and large wood recruitment sources are replenished. Segment 1 large wood installations are discussed in more detail in Section 6.1.5.



Figure 31. Naturally recruited large wood in Segment 1. Left: large wood wedged against standing tree racks additional transported wood leading to flow deflection and fine sediment deposition (RM 16.15, looking toward river right bank). Right: log jam near RM 18.75 responsible for plugging former side channel through river left floodplain.

6.1.4 Vegetation

Vegetation in Segment 1 varies with floodplain presence and height above the Entiat River channel. Lower floodplain surfaces are typically dominated by alder (*Alnus spp.*), willow (*salix spp.*), redosier dogwood (*Cornus sericea*), black cottonwood (*Populus trichocarpa*), water birch (*Betula occidentalis*), western redcedar (*Thuja plicata*), and reed canary grass (*Phalaris arundinacea*). Black hawthorn (*Crataegus douglasii*), rose (*Rosa spp.*), and saskatoon berry (*Amelanchier alnifolia*) are also present on low floodplain surfaces in several locations. Recently established willow and cottonwood provide stability to some lateral and mid-channel bars, and overhanging dogwood provide sporadic cover along channel margins. On higher floodplain surfaces, terraces, and hillslopes, a sparse Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*) dominated overstory is interspersed with short woody shrubs and herbaceous vegetation. Whereas lower vegetated floodplain surfaces are present throughout much of the portion of Segment 1 upstream of McKenzie Ditch, they are generally absent downstream due to confinement from the Potato Moraine.

Existing trees within the Entiat River watershed are generally smaller than those that would have been present prior to widespread European-American settlement in the 19th century due to heavy logging activity beginning in approximately 1892 (CCCD 2004). An approximately four-foot dbh western redcedar stump was observed on a bar in Segment 1 (Figure 32), showing that mature old growth trees were once present within the assessment area; however no living old growth trees were observed during the assessment. The largest trees observed during the assessment in Segment 1 were typically no more than 2 feet in diameter, and the majority of trees within Segment 1 were less than one-foot dbh and therefore are unlikely to provide effective geomorphic influence on the Entiat River channel without supplementation of additional larger pieces. Many of the trees on the river right hillslopes were burned at the time of the August 2025 assessment, likely during the 2018 Cougar Creek Fire or the 1994 Tye Fire (fire information from Washington State Department of Natural Resources n.d.), and additional burned stumps and other woody material were widely distributed. A vegetation height map is included for reference in Figure 33.



Figure 32. Left: Cut stump of large western redcedar in Entiat River channel near RM 17.5, representative of old growth trees present within the watershed prior to widespread logging beginning in the 19th century. Right: Photograph of larger conifers within Segment 1, which typically do not exceed 2 feet in diameter at present.

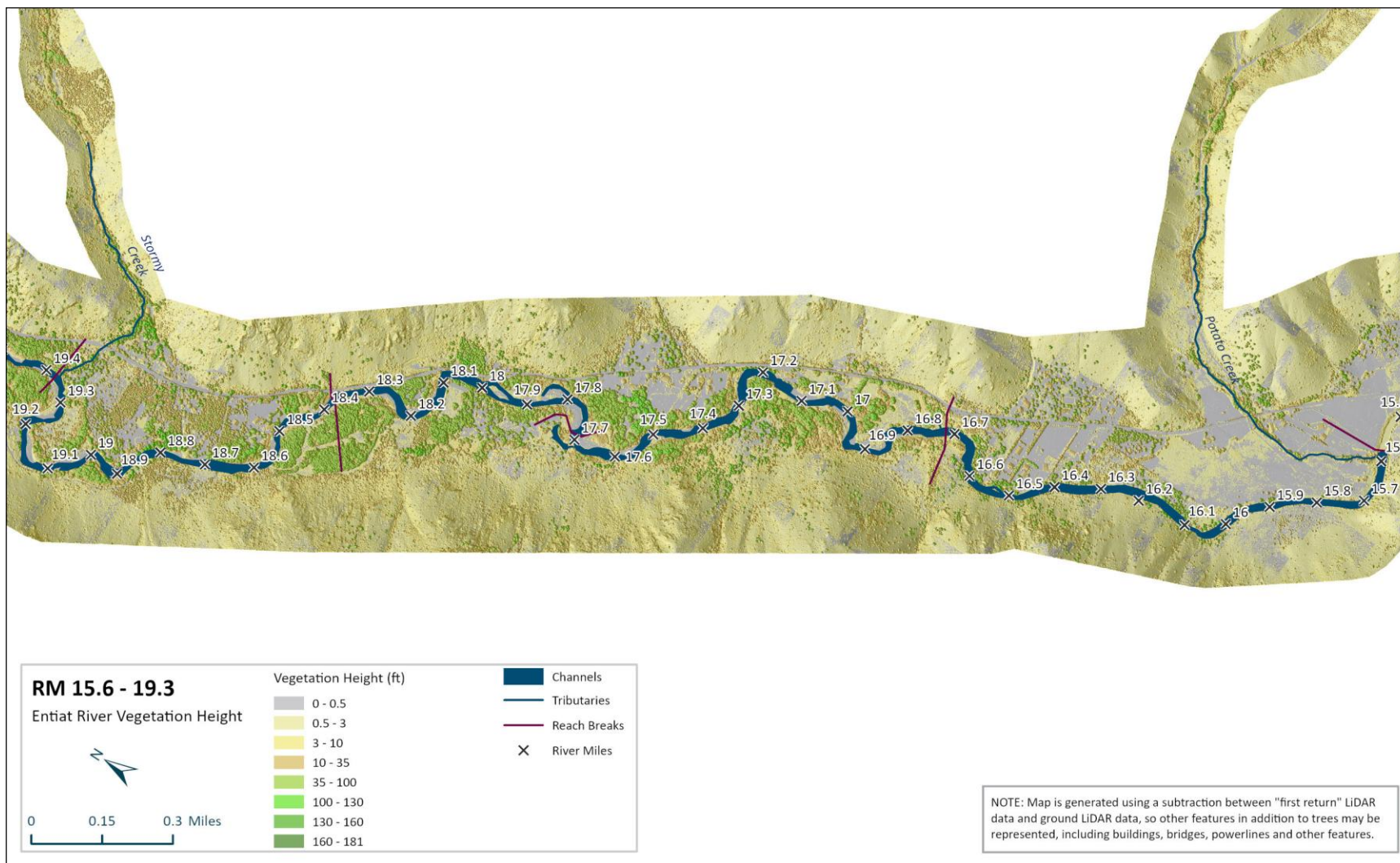


Figure 33. Vegetation heights along Segment 1 of the Entiat River.

6.1.5 Past Restoration Projects

Previous restoration projects in Segment 1 include the Gray E and F and Cottonwood Flats restoration projects, constructed between 2018 and 2023. A map showing the locations of prior restoration projects in Segment 1 is included in Figure 34.

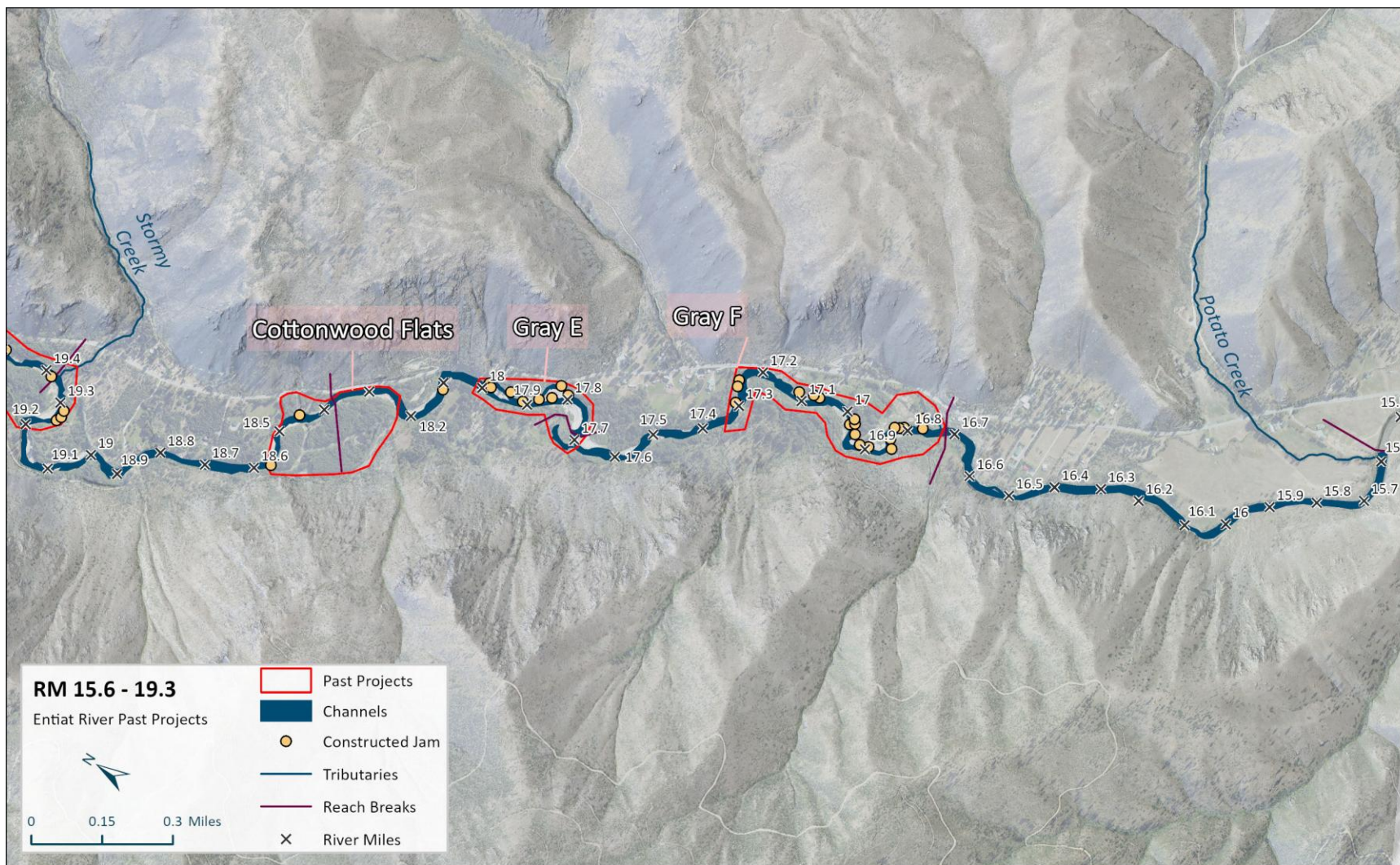


Figure 34. Past restoration projects in Segment 1.

The Gray F project, located between Gray Canyon and the Potato Moraine, was constructed in 2020. This project included numerous large wood structures intended to drive geomorphic processes, provide habitat and cover, and create wood racking opportunities (Figure 35). Additionally, the Gray F project included excavation of a network of perennially- and seasonally-wetted side channels with placed large wood to provide habitat and maintain side channels during higher flows (Figure 35) (Salmon Recovery Portal 2021). During the August 2025 geomorphic assessment, surface flow through the river left side channel network was intermittent in the upstream portion, with a series of standing ponds interspersed between dry channel sections. In the downstream portion of the side channel network, perennial flow was observed in several side channels as well as the mouth of the side channel network. The river right side channel was dry at the time of the assessment, however, model results suggest that this channel is wetted at the 2-year flow. Reed canary grass was common on adjacent floodplain surfaces. Large wood structures were observed as providing cover within scour pools in several locations, and in one location, the large wood structure appeared to be driving lateral migration into the opposite bank.



Figure 35. Representative photographs of Gray F restoration project. Top left: wetted side channel through river left side channel downstream of RM 16.8; Top right: dry side channel through river right floodplain near RM 16.85; Bottom: constructed large wood structure on river right near RM 16.8.

The Gray E project extends approximately 0.3 miles upstream from Gray Canyon and was constructed in 2019. This project was intended to increase channel complexity and floodplain connectivity through placement of several large wood structures and enhancement of existing naturally deposited large wood accumulations (Figure 36). During the August 2025 geomorphic assessment, wood structures associated with the Gray E project were observed providing cover and pool habitat, generating channel complexity in the form of flow splits and sediment sorting, and deflecting main channel flow into the opposite stream bank, which may lead to channel migration over time. Reed canary grass was observed on several constructed large wood structures within the Gray E project area.



Figure 36. Large wood structures installed during Gray E restoration project near RM 17.8 (left, looking downstream) and RM 17.9 (right, looking downstream).

The Cottonwood Flats project was implemented within the Entiat River main channel and floodplain at the former site of the Cottonwood Flats bridge, downstream of the Stormy Creek alluvial fan. The Cottonwood Flats project included removal of the Cottonwood Flats bridge to increase hydrologic connectivity on floodplain surfaces, construction of a side channel to provide rearing habitat for juvenile salmonids, and installation of large wood structures within the Entiat River main channel and constructed side channel to increase inundation of the side channel and overall channel complexity and encourage lateral migration (Figure 37). The side channel was dry at the time of the August 2025 assessment, with fine sediment and herbaceous vegetation filling the constructed channel, although the hydraulic model suggests that the channel is activated at the 2-year flow event.



Figure 37. Left: Entrance to constructed side channel at RM 18.6 on river right. Channel was constructed as part of the Cottonwood Flats restoration project. Right: Former location of Cottonwood Flats bridge.

6.1.6 Project Opportunities

Project opportunities identified within Segment 1 include enhancing main channel habitat through added channel complexity; increased floodplain and side channel connectivity; removal of infrastructure that disrupts channel and floodplain and main channel processes; and restoration of riparian vegetation. Large wood could be placed within the main channel upstream of the Cottonwood Flats restoration project area to add channel complexity to the straight, simplified section of the Entiat River mainstem. Large wood structures would serve the purpose of promoting lateral processes and sediment dynamics while providing cover and other physical habitat benefits to salmonids. The side channel created during the Cottonwood Flats project does not appear to be frequently wetted, and options to enhance this side channel including promoting more frequent flows through mainstem large wood placement, and adding complexity to the armored channel could be considered. Additionally, removal of remaining fill from the Cottonwood Flats bridge would allow for increased connection between the Entiat River channel and its floodplains. Large wood structures could be placed along the river left bank near RM 18.5 to provide habitat complexity and to limit erosion. Cleared floodplain and terrace surfaces could be replanted with native vegetation to restore long term riparian functioning and wood recruitment. Large wood structures could be installed to replace existing riprap bank protection along the outside of the meander upstream of the bridge at RM 18.1, allowing vegetation to re-establish and provide long-term resistance to local bank erosion. These structures could be designed to provide cover and other habitat benefits in addition to limiting bank erosion. Additional large wood could be placed at the downstream end of the Gray E restoration project area where large wood is currently lacking in order to drive lateral migration and scour pool and bar development in addition to providing cover within the Entiat River channel and promoting inundation of the side channel between RM 17.6 and 17.75. Potential benefits of increasing flows into the Gray F project area side channels during the low flow period could be considered. This could be accomplished through strategic placement of large

wood structures within the Entiat River channel. Weirs associated with the McKenzie Ditch intake currently create a backwatering effect extending upstream into the Gray F project area. Options could be considered to modify the ditch intake to limit this backwatering effect. Downstream of McKenzie Ditch, large wood could be placed in strategic locations to provide slower velocity refuge within the high energy reach. Additionally, large wood could be placed within the existing pool near RM 16.05 to provide cover.

6.2 SEGMENT 2 (RM 19.3 – 22.1)

6.2.1 Overview

Segment 2 encompasses the 2.8 river mile long stretch from the Stormy Creek alluvial fan at RM 19.3 to the Dill Creek confluence on river left at RM 22.1 (Table 9, Figure 38). Segment 2 includes a portion of Reach 4 and all of reaches 5-7 from the Habitat Assessment (Appendix A). Segment 2 spans Reaches 2B, 2C (Stormy Reach), and 2D of the 2009 Entiat Tributary Assessment (USBR 2009a).

Table 9. Metric table for Segment 2. Metrics collected during the habitat assessment are discussed in Appendix A. Confinement estimates are from the Entiat Tributary Assessment (USBR 2009a).

Reach	Length (miles)	River Mile	Stream Gradient (%)	Sinuosity	Dominant Channel Habitat Unit Type	Average Bankfull Width (ft)	Confinement	Dominant Substrate	% Pool Habitat	% Glide Habitat	% Riffle Habitat	% Side Channel Habitat	% Other Habitat
Reach 4	0.9	18.4-19.3	0.19%	1.47	Pool	95	Unconfined	Cobble/Gravel	70%	9%	21%	0%	0%
Reach 5	0.8	19.3-20.1	0.22%	1.38	Pool	63	Unconfined	Gravel/Cobble	65%	7%	5%	22%	0%
Reach 6	0.7	20.1-20.8	0.23%	1.19	Pool	119	Unconfined	Gravel	76%	13%	10%	0%	0%
Reach 7	1.3	20.8-22.1	0.24%	1.29	Pool	118	Confined	Gravel/Cobble	43%	18%	11%	27%	1%



Figure 38. Representative photographs of the Entiat River mainstream within Segment 2. Left: looking downstream from RM 20.8; Right: looking upstream from RM 20.3.

Human alterations in Segment 2 include bank stabilization (e.g., riprap, bank LWS), channel straightening, prior restoration projects, and relics of the logging history within the Entiat River

watershed (Figure 39). Placed boulders supplement existing naturally sourced boulders in several sections where the Entiat River channel lies along the base of the Entiat River Road prism at the foot of the river left hillslopes. These boulders limit erosion into the river left streambanks which would endanger Entiat River Road. Boulders along the river right channel margins near the Tyee Creek fan appear to be old riprap left over from what was removed during the Stormy B restoration project (See Section 6.2.5), suggesting that this portion of channel was likely straightened at some point in the past. Gravels and cobbles have since partially buried these larger rocks. Additional placed boulders were observed within the Entiat River channel to protect houses and other structures.



Figure 39. Human alterations in Segment 2. Left: angular small boulders along river left Entiat River channel margin at RM 20.9 are likely remnants of riprap removed as part of Stormy B restoration project. Right: placed boulders along river left channel margin protecting Entiat River road, RM 21.5.

Logging likely played a significant role in shaping the current character of the Entiat River within Segment 2. Two stumps approximately three to four feet in diameter observed within the channel center were causing significant downstream scour and upstream sediment deposition (Figure 40). These large stumps appeared to have been sawed and discarded within the channel. The stumps reveal the size of large trees that were once present along the river. Logging beginning in the late 19th century reduced the availability of recruitable large wood within the watershed, and log drives down the mainstem Entiat River likely depleted in-channel large wood (CCCD 2004). Without a natural source of effective large wood pieces, the Entiat River corridor lacks a significant driver of channel complexity and geomorphic response.



Figure 40. Stumps in river left Entiat River flow split channel, RM 19.7. Stumps are likely a relic of pre-logging era where mature old-growth trees were present within the Entiat River watershed.

Prior restoration projects intended to benefit salmon and steelhead in Segment 2 include the Stormy A, B, and C projects. These projects consisted of side channel excavation and enhancement; installation of main channel and side channel large wood structures to create habitat, increase channel complexity, and protect vulnerable banks; and removal of a levee that limited floodplain connectivity. A map of anthropogenic features in Segment 2, including prior restoration projects, is included in Figure 41. See Section 6.2.5 for a description of past restoration projects within Segment 1.

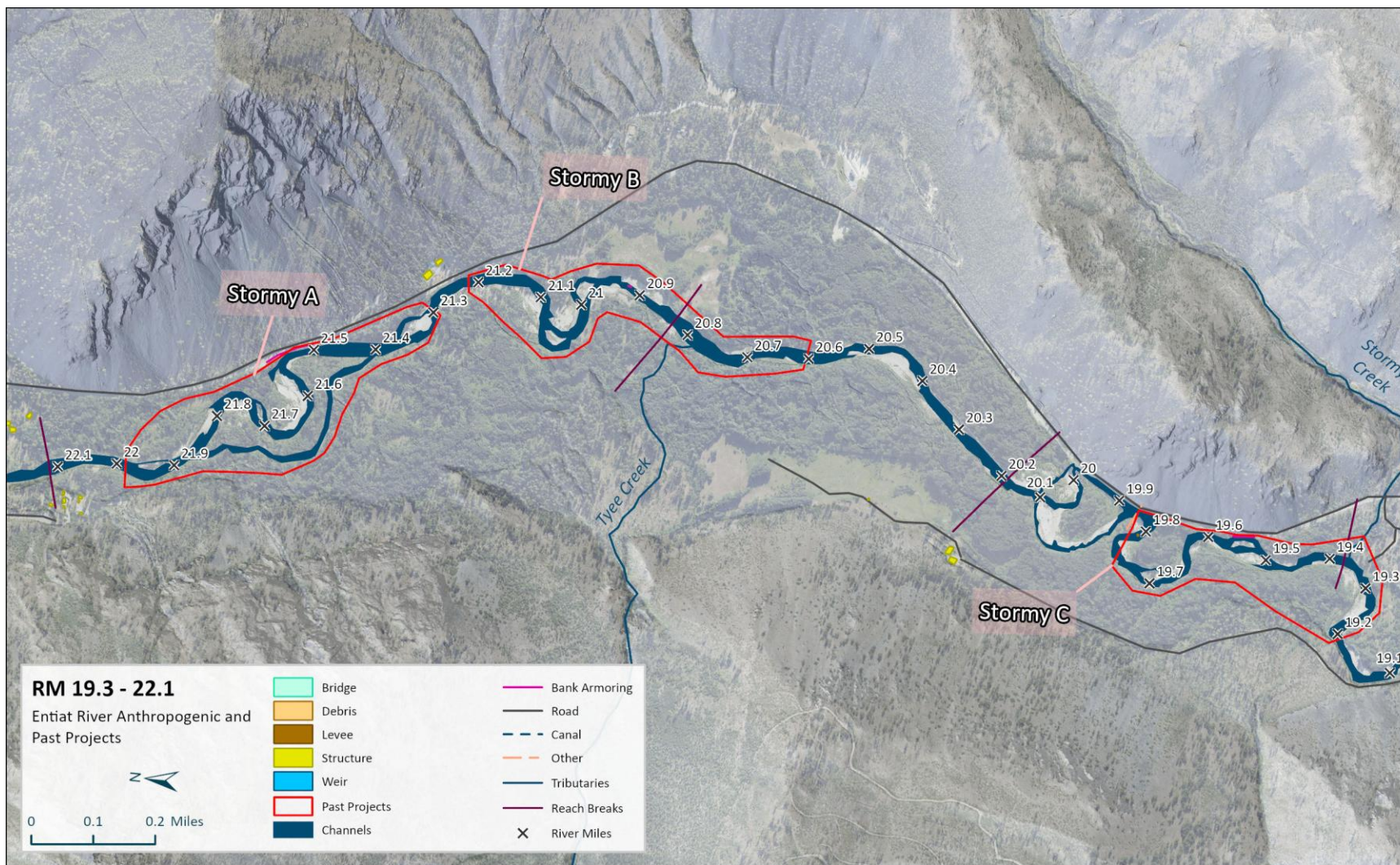


Figure 41. Segment 2 past restoration projects and mapped anthropogenic features.

6.2.2 Channel and Floodplain Geomorphology

Segment 2 has a lower average channel gradient (0.20%) and higher sinuosity ($S = 1.53$) (Table 9) than any other segment within the assessment area. Whereas channel gradient is relatively consistent throughout the reach, the Entiat River channel undergoes several distinct changes in sinuosity as it flows downstream from Dill Creek to Stormy Creek (Figure 42, Figure 43, Figure 44). The upper and lower portions of Segment 2 feature tortuous meanders that contribute to the overall high sinuosity of the segment. The middle portion, on the other hand, is considerably less sinuous and appears artificially straightened. However, despite the relatively straight overall planform of this section, occasional split-flow around mid-channel bars, and installed LWS provide some channel complexity (Figure 45). The Entiat River channel in Segment 2 is predominantly single thread, with frequent flow splits around mid-channel bars and installed LWS. Flow splits at low-flow conditions are the result of stream energy, available sediment load, and in several locations, placed large wood structures from prior restoration projects. Undercut banks at several locations throughout Segment 2 provide additional habitat complexity along channel margins. The habitat assessment (see Appendix A) recorded 58% of the habitat as pool, 16% as glide, 14% as side channel, and 11% as riffle (Figure 42). The average bankfull width, measured during the habitat assessment (Appendix A) was approximately 105 feet.

The Entiat River is generally unconfined as it meanders through Segment 2, although several natural and anthropogenic features provide local channel and valley bottom confinement (Figure 42, Figure 43, Figure 44). The river left hillslopes come into contact with the Entiat River channel in several locations. At these contacts, Entiat River road sits perched above the channel, and riprap supplements naturally sourced boulders at the base of the hillslopes, limiting leftward channel migration and erosion into the hillslopes that might endanger the road. Alluvial fans from minor tributaries provide additional local valley bottom and river channel constrictions. Notable fans providing lateral confinement in Segment 2 include the Stormy Creek, Shamel Creek, and Tyee Creek alluvial fans. In particular, the Stormy Creek and Shamel Creek (opposite Stormy Cr) alluvial fans provide a significant valley constriction that influences reach-scale floodplain inundation and stream energy (Figure 43 and Figure 44). Hillslope contacts and alluvial fans also provide a source of coarse sediment ranging from gravels to small boulders. Boulders sourced from adjacent hillslopes and fans create in-channel habitat heterogeneity and provide local grade control.

Channel substrate in Segment 2 generally oscillates between coarser gravel to cobbles in shallower riffle sections, and finer sands in deeper pools (Figure 45). A coarsening of the bed and bank substrate was generally observed as the river channel cut through fan sediments. Stream banks within Segment 2 typically contain a gravel base that is longitudinally intermittent overlain by three to four feet of sandy finer sediment. Several tributaries join the Entiat River in Segment 2 including Stormy Creek, Tyee Creek, and Shamel Creek, although none of these tributaries conveyed surface flow at the time of the August 2025 assessment. Whereas the Stormy Creek channel was distinct and contained small gravels to cobbles within the channel bed, neither Tyee Creek nor Shamel Creek had discernable channels.

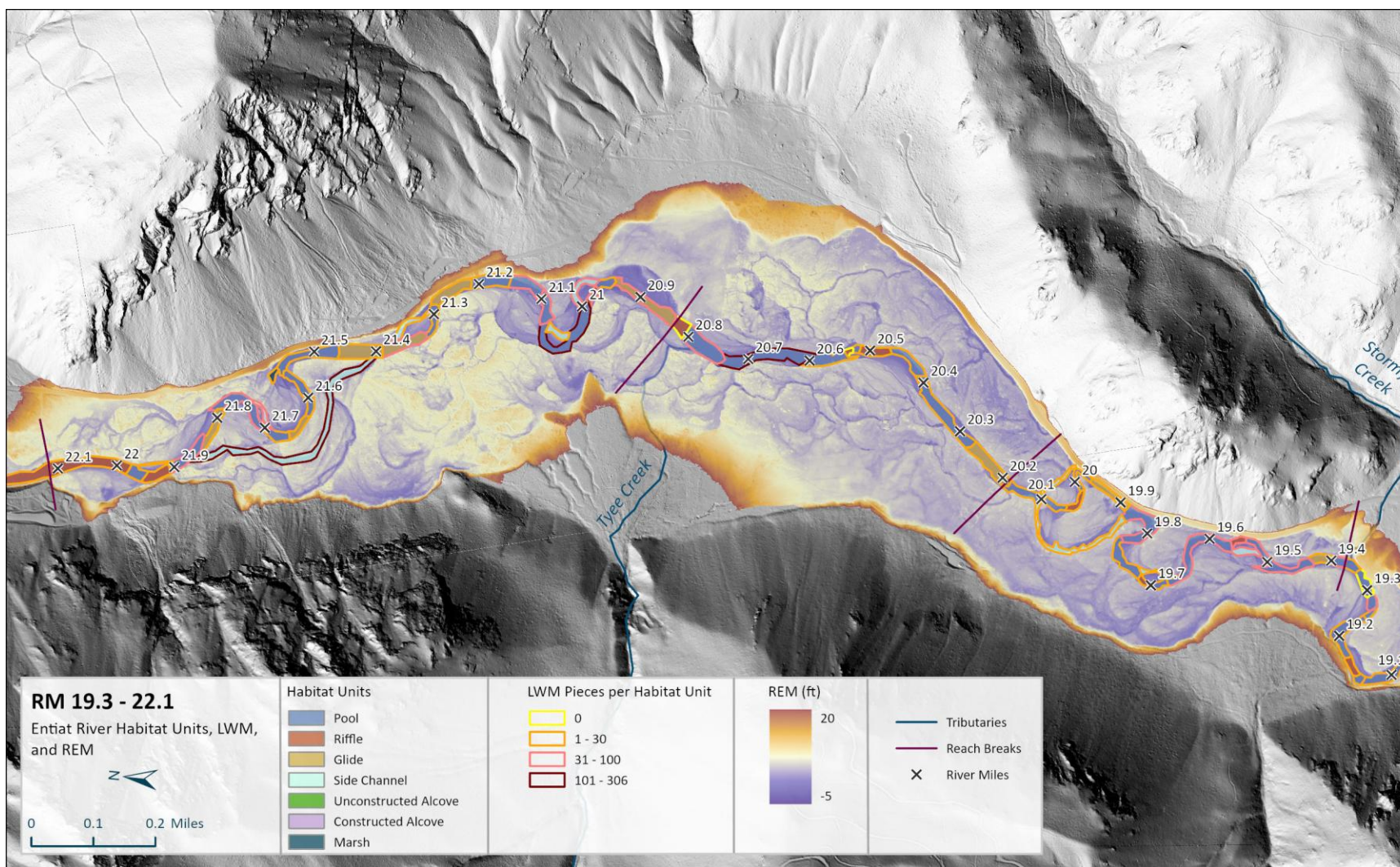


Figure 42. Habitat unit composition, LWM, and elevation relative to channel in Segment 2. LWM is total pieces within the habitat unit. See the habitat assessment in Appendix A for more details.

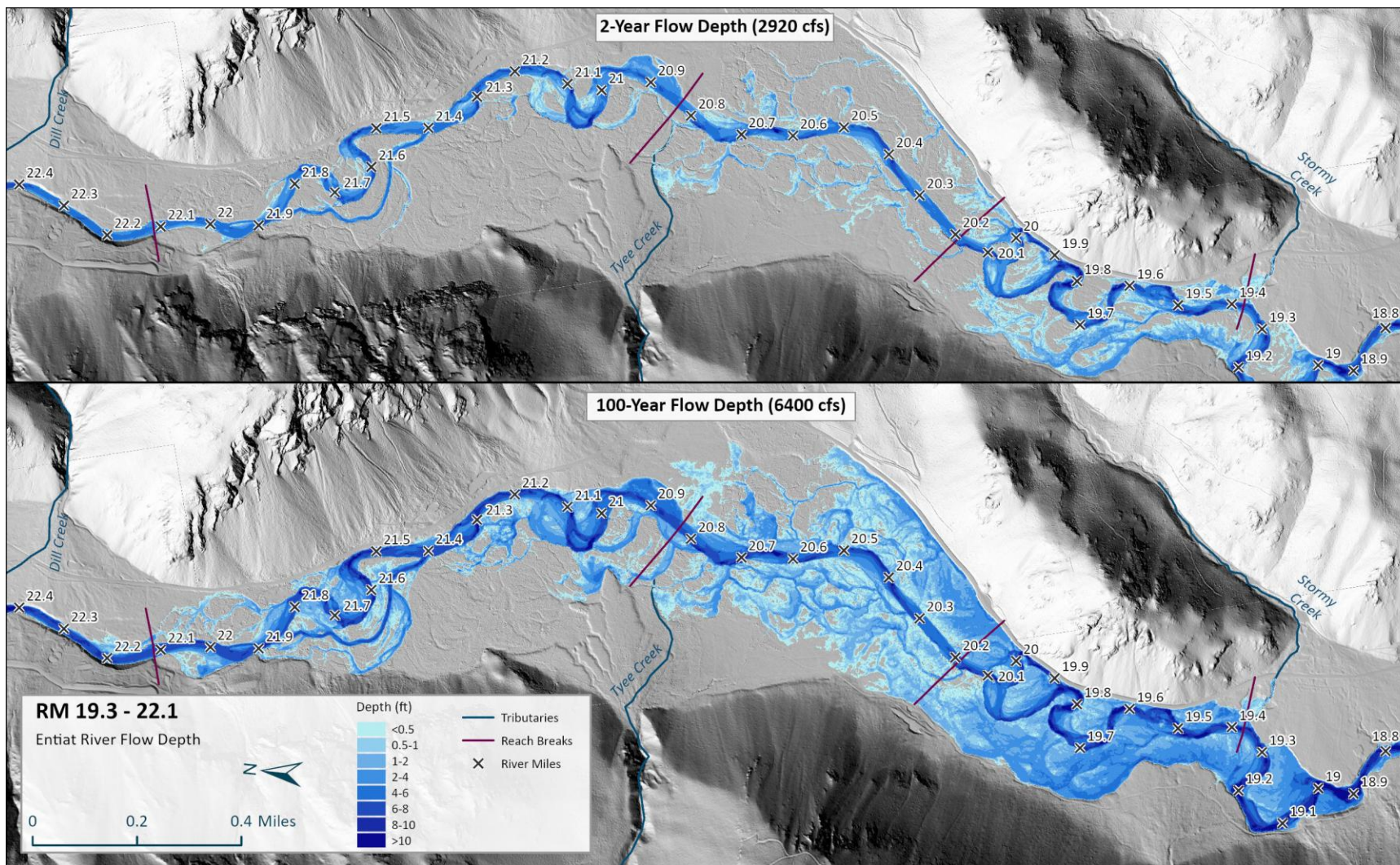


Figure 43. Modeled depth results for Segment 2.

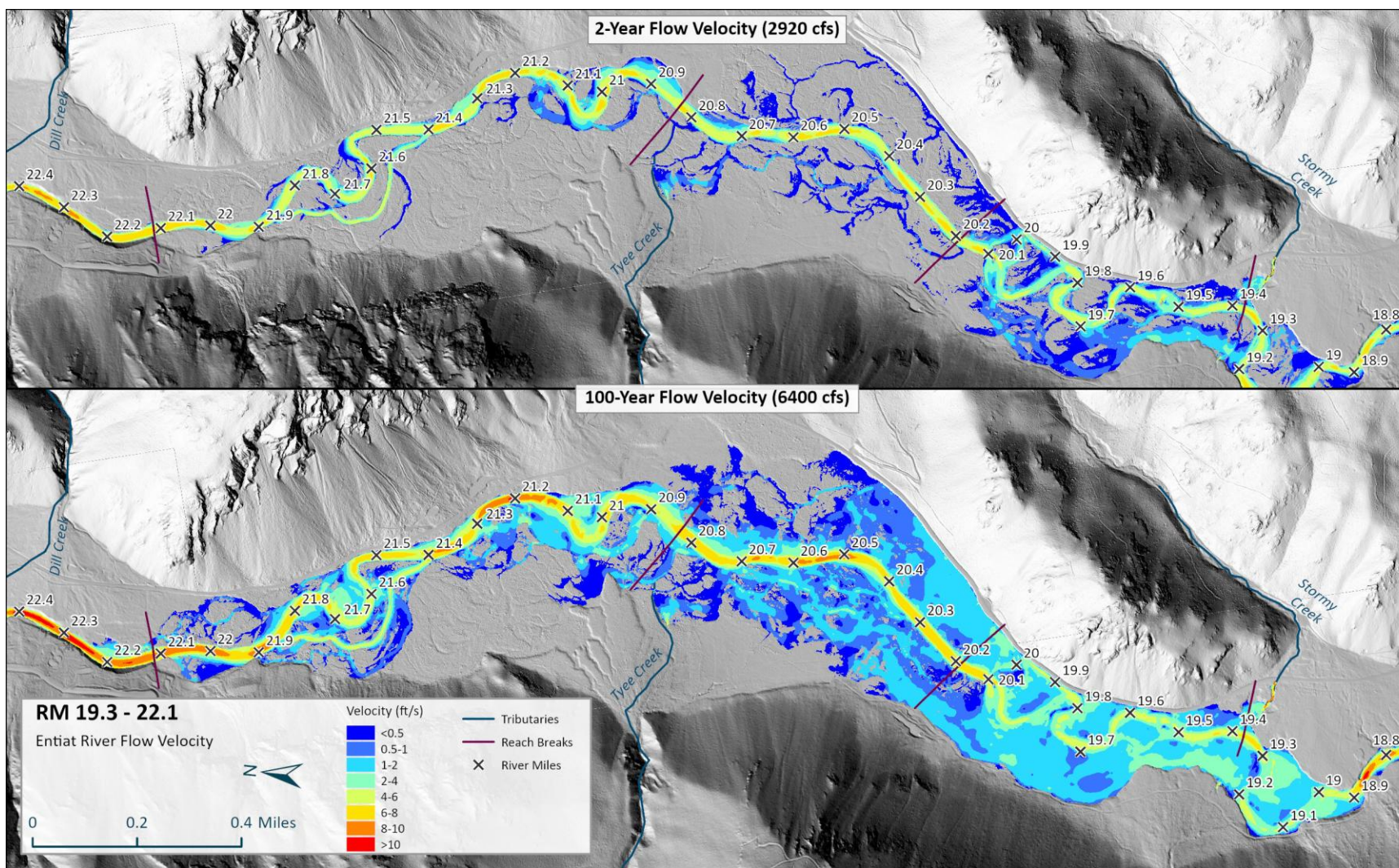


Figure 44. Modeled velocity results for Segment 2.



Figure 45. Top: Entiat River mainstem flow split at RM 20.95, looking upstream. Bottom: Representative photographs of Segment 2 channel substrate. Substrate generally consisted of cobbles (left, RM 22) and gravels (right, RM 22.5) in higher energy regions, and sands in deep pools.

A recent major channel avulsion was observed between approximately RM 19.85 and 20.1 (Figure 46). Aerial imagery analysis shows a neck cutoff occurring at the tight meander near RM 20.1 between May 2015 and July 2017. By August 2022, substantial sediments, mostly sands, had deposited within the main channel just downstream of the neck cutoff, and by August 2024 these sediments had plugged most of the former main channel, sending the majority of surface flow through the former side channel on river left that flows along the base of the hillslopes by Entiat River Road. The former main channel on river right still conveys a minority of the Entiat River surface flow and provides perennial off-channel habitat for salmonids, although as sands continue to deposit within the former channel, it may see diminished flows in the future. A side channel constructed as part of the Stormy restoration project provides additional perennial off-channel habitat along a .5 river mile section of the river right floodplain from RM 21.4 to RM 21.9. Elsewhere in the reach, seasonal floodplain habitat and side channels are wetted at higher flows but were not inundated during the August 2025 geomorphic assessment field survey.



Figure 46. Progression of channel avulsion at RM 20.1 visible in Google Earth aerial imagery: A) pre-avulsion channel alignment with tight meander at RM 20.1 intact, May 2015; B) channel alignment following neck cutoff, July 2017; C) original main channel filling with sediment following neck cutoff, August 2022; D) present-day channel alignment with majority of flow through former side channel on river left, and former main channel mostly plugged with sediment, August 2024.

6.2.3 Large Wood Material

Naturally recruited large wood was generally limited in Segment 2 during the August 2025 geomorphic assessment. The Entiat River watershed was heavily logged during the 19th and 20th centuries, reducing recruitable large wood sources within the watershed, and log drives down the Entiat River channel cleared existing large wood from the channel (CCCD 2004). Where present, large wood pieces greater than 1.5 feet in diameter and up to approximately 3 feet in diameter were observed as effective in generating habitat complexity and geomorphic response in the form of cover for rearing salmonids, local fine sediment deposition, pool scour, floodplain roughness, and directing flow into side channels. Although naturally recruited large wood was effective at the local scale it was generally not responsible for driving larger scale geomorphic responses such as widespread large bar development or lateral channel migration aside for a single large jam within the Stormy A project area that was responsible for significant sediment deposition plugging a large side channel (Figure 47). Active large wood recruitment through bank erosion was observed in Segment 2; however, the majority of trees adjacent to the Entiat River channel were less than one foot in diameter, and mature old growth trees large enough to generate significant geomorphic response were absent. Number of pieces of LWM by habitat unit is depicted in Figure 42 (Section 6.2.2). Although naturally recruited wood has a limited influence on channel processes in Segment 2 due to limited large wood and large wood recruitment potential, large wood structures installed as part of past restoration projects are more effective at driving geomorphic and habitat processes. The installed large wood structures may provide the additional long-term benefit of increased large wood racking potential as local forests recover, and large wood recruitment sources are replenished. Segment 2 large wood installations are discussed in more detail in Section 6.2.5.



Figure 47. Large wood jam upstream of RM 21.7, looking downstream. Log jam is driving sediment deposition that is plugging a large side channel on river left.

6.2.4 Vegetation

Vegetation in Segment 2 is similar to Segment 1, with riparian areas and lower floodplain surfaces dominated by willow, dogwood, water birch, alder, cottonwood, and reed canary grass; and higher floodplain and terrace surfaces dominated by ponderosa pine and Douglas-fir. Mixed-age cottonwood stands were present within Segment 2, with young cottonwood establishing on active bars and low floodplain surfaces (Figure 48). Dogwoods provide cover where they overhang along channel margins (Figure 48); however, larger mature old growth trees capable of generating significant channel complexity and geomorphic response are generally lacking in Segment 2. A large aspen grove is present on the river right side of the large constructed side channel within the Stormy A project area. Significant logging beginning in the late 19th century likely depleted existing stands of larger mature trees within the assessment area including Segment 2. As with Segment 1, the river left hillslopes in the lower portion of Segment 2 contain burned trees, stumps, and logs, likely burned during the 2018 Cougar Creek or 1994 Tye Fire (fire information from Washington State Department of Natural Resources n.d.). Burned areas were associated with relatively higher inputs of coarse sediments from hillslopes. A vegetation height map is included for reference in Figure 49.



Figure 48. Left: cottonwood establishing on low floodplain surface; Right: dogwood overhanging Entiat River channel providing cover on river right, RM 21.3.

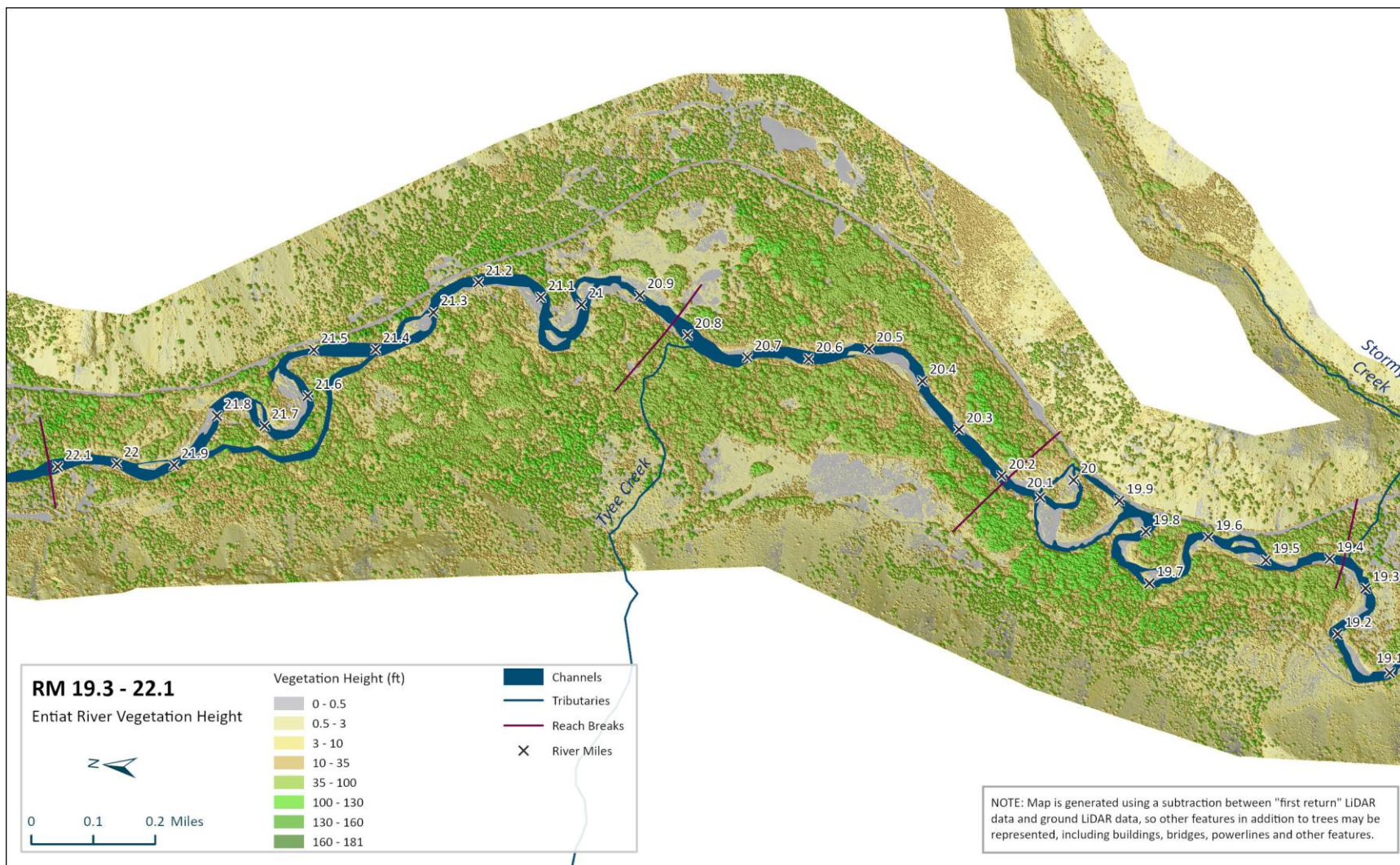


Figure 49. Vegetation heights along Segment 2 of the Entiat River.

6.2.5 Past Restoration Projects

Past restoration projects in Segment 2 include the Stormy A, B, and C projects. A map showing the locations of past restoration projects in Segment 2 is included in Figure 50.

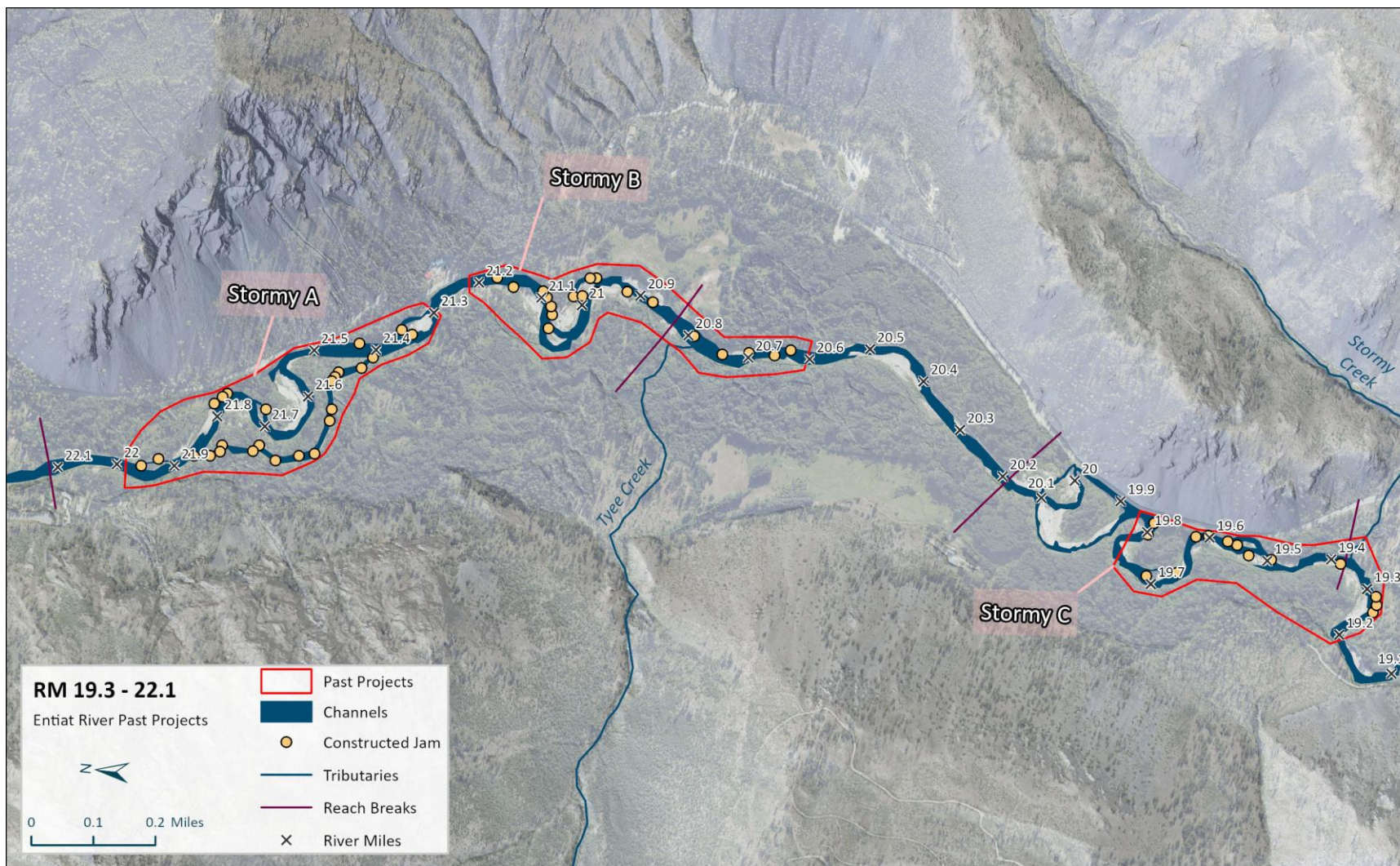


Figure 50. Past restoration projects in Segment 2.

The Stormy C project includes approximately 0.6 river miles of the Entiat River and extends upstream from the Stormy Creek confluence. This project included the installation of in-channel large wood structures designed to generate channel complexity and improve aquatic habitat conditions (Figure 51). During the August 2025 geomorphic assessment, Stormy C structures were observed generating channel and habitat complexity by maintaining split-flow conditions, bar development, and scour-pool formation. Willows were observed establishing on several bar surfaces associated with the Stormy C project; however, reed canary grass was also present on many of these same surfaces. Near the downstream end of the Stormy C project area, constructed bank-attached structures were preventing bank erosion into an unvegetated surface currently lacking natural erosion resistance from vegetation or naturally deposited wood.



Figure 51. Representative photographs of Stormy C restoration project. Top: Large wood structure on river left at RM 19.5 providing cover to deep pool and deflecting flows into opposite bank. Bottom: constructed apex jam supporting flow split at RM 19.7, looking downstream.

The Stormy B project is located upstream of Stormy C and extends approximately 0.6 river miles along the Tyee Creek fan, which enters the Entiat River valley bottom on river right. In addition to large wood structures intended to increase channel complexity and habitat function main channel, this project also included the removal of riprap as well as a large artificial levee on river left that previously disconnected a large meander scar; and creation of a seasonally-wetted high-flow side channel (Figure 52). Several of the large wood structures associated with the Stormy B project extend into the channel, interacting with Entiat River flows under low flow conditions. The geomorphic assessment noted installed structures providing cover to pools ranging from approximately 2 to 10 feet deep, and allowing vegetation, primarily willow, to establish on developing bars. Several structures were observed splitting flows under low-flow conditions, whereas several others appeared to be in the early stages of driving the formation of new split-flow channels.



Figure 52. Stormy B constructed large wood structure at RM 20.8 looking downstream. Structure provides cover and deflects flows toward river right bank.

The Stormy A project begins just upstream of Stormy B and extends approximately 0.7 river miles to just downstream of Coyote Falls Rd which travels along the base of the hillslopes on river right. Stormy A included a series of large wood structures installed in the Entiat River main channel intended to increase channel complexity and lateral processes, provide habitat benefits including cover within deep pools, and provide floodplain roughness and bank stability to reduce the risk of neck cutoff. The Stormy A project also included construction of a long side channel extending through the majority of the project area on river right (Figure 53). This side channel conveys significant streamflow at low flows and was enhanced with a series of large wood structures placed throughout the entire length of the side channel. The geomorphic field assessment observed main channel structures re-directing flows into opposite banks and providing cover in deep pools. The structure at the mouth of the constructed side channel was responsible for racking additional

naturally sourced large wood and directing approximately one third of the main channel flow into the constructed side channel. Large wood structures within the constructed side channel create a complex environment via deep pool scour, sediment sorting, and driving lateral processes via bouncing flows between alternating stream banks. Vegetation establishing on installed structures included a mix of primarily willow and reed canary grass, among other species.



Figure 53. Representative photographs of Stormy A restoration project. Top: constructed side channel looking downstream from the upstream end. Bottom: constructed large wood structure providing cover on river left at RM 21.35.

6.2.6 Project Opportunities

Project opportunities identified for Segment 2 include extension of the Stormy A and B project areas, creation of connected side channel networks, restoration of riparian processes, and increased habitat heterogeneity within the Entiat River main channel. Additional large wood structures could be placed in the lower energy section between the Stormy A project area and the upstream constriction as well as in sections of the Stormy A project area currently lacking wood. Large wood additions to past restoration project areas would simulate natural recruitment of additional large wood over the ensuing years since project completion since natural recruitment is severely limited within the Entiat River watershed due to past logging. Additional large wood structures could be designed to deflect flows into banks, creating complexity and promoting geomorphic processes including sediment recruitment, transport, and deposition, as well as lateral migration and increased floodplain connectivity. There is opportunity to construct a side channel network connecting the Stormy A and B project areas and continuing through the river right floodplain downstream to approximately RM 20.3. The side channel network could utilize existing high flow channels within the floodplain, although excavation may be needed. Large wood placed within the mainstem Entiat River throughout this section would serve the dual purposes of encouraging flows into the newly constructed side channels allowing for perennial flow, while adding additional complexity and cover habitat within simplified portions of the main channel. Cleared floodplain surfaces could be replanted with native woody vegetation to restore riparian functioning and long term large wood recruitment. Additionally, efforts could be made to nudge the recently avulsed channel near RM 20 away from the Entiat River Road prism to prevent the channel from becoming locked into place against the road. This could be accomplished by partially filling the Entiat River channel and placing large wood structures to deflect flows into the meander neck downstream. Over time this may result in a neck cutoff which may aid in keeping the channel away from Entiat River Road.

6.3 SEGMENT 3 (RM 22.1 – 24.9)

6.3.1 Overview

Segment 3 includes the 2.8 river mile stretch of the Entiat River between the Dill Creek confluence and the Preston Creek alluvial fan, both of which enter the Entiat River valley bottom from river left (Table 10, Figure 54). Segment 3 encompasses Reaches 8-10 of the Habitat Assessment (See Appendix A). Segment 3 spans Reaches 3A and 3B (Preston Reach) of the Entiat Tributary Assessment (USBR 2009a).

Table 10. Metric table for Segment 3. Metrics collected during the habitat assessment are discussed in Appendix A. Confinement estimates are from the Entiat Tributary Assessment (USBR 2009a).

Reach	Length (miles)	River Mile	Stream Gradient (%)	Sinuosity	Dominant Channel Habitat Unit Type	Average Bankfull Width (ft)	Confinement	Dominant Substrate	% Pool Habitat	% Glide Habitat	% Riffle Habitat	% Side Channel Habitat	% Other Habitat
Reach 8	0.4	22.1-22.5	0.47%	1.29	Riffle	85	Confined	Boulder	0%	22%	78%	0%	0%
Reach 9	1.7	22.5-24.2	0.30%	1.22	Pool	101	Confined	Gravel/Cobble	45%	10%	32%	12%	0%
Reach 10	0.7	24.2 - 24.9	0.58%	1.06	Riffle	88	Partially Confined	Boulder	8%	0%	92%	0%	0%



Figure 54. Representative photograph of Segment 3 (RM 23.45 looking upstream).

Notable human alterations within Segment 3 include built structures including homes, levees and other bank protection, and an intake hose drawing water from the Entiat River. Although many houses in Segment 3 are outside of the Entiat River floodplain, either on hillslopes or high on alluvial fans, several structures sit in close proximity to historic meander scars on the river left floodplain between the Dill Creek fan and the Entiat Tye restoration project area (See Past Restoration Projects, Section 6.3.5). Two artificial levees limit hydrologic connectivity between the Entiat River channel and the river left floodplain (Figure 55). The upstream levee was partially

breached to create a pair of side channels as part of the Entiat Tye restoration project; however, the downstream levee is still intact and functioning, providing flood mitigation for several downstream properties. Large wood structures provide additional bank protection to properties within the river left floodplain just upstream of the Dill Creek fan, and placed cobbles and slash piles provide bank stability to riverfront properties further upstream. A minor intake hose draws water from the Entiat River channel within Segment 3; however, this hose is not associated with any permanent infrastructure and does not limit channel processes.

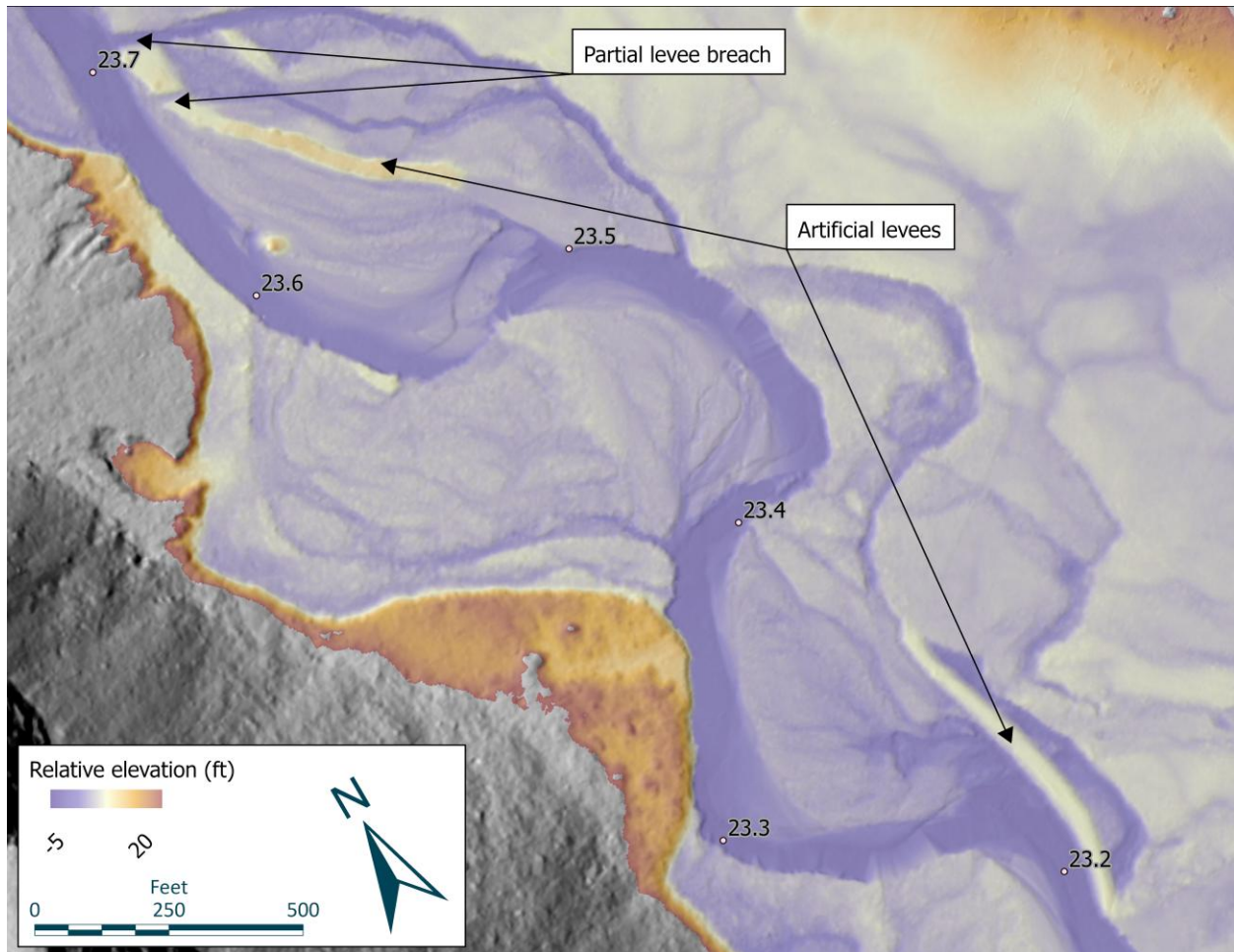


Figure 55. Relative elevation map of Entiat River valley bottom in Segment 3 showing remaining artificial levees on river left floodplain within Entiat Tye project area.

There are 3 prior habitat restoration projects in Segment 3. A map of anthropogenic features in Segment 3, including prior restoration projects, is included in Figure 56. See Section 6.3.5 for a description of past restoration projects within Segment 3.

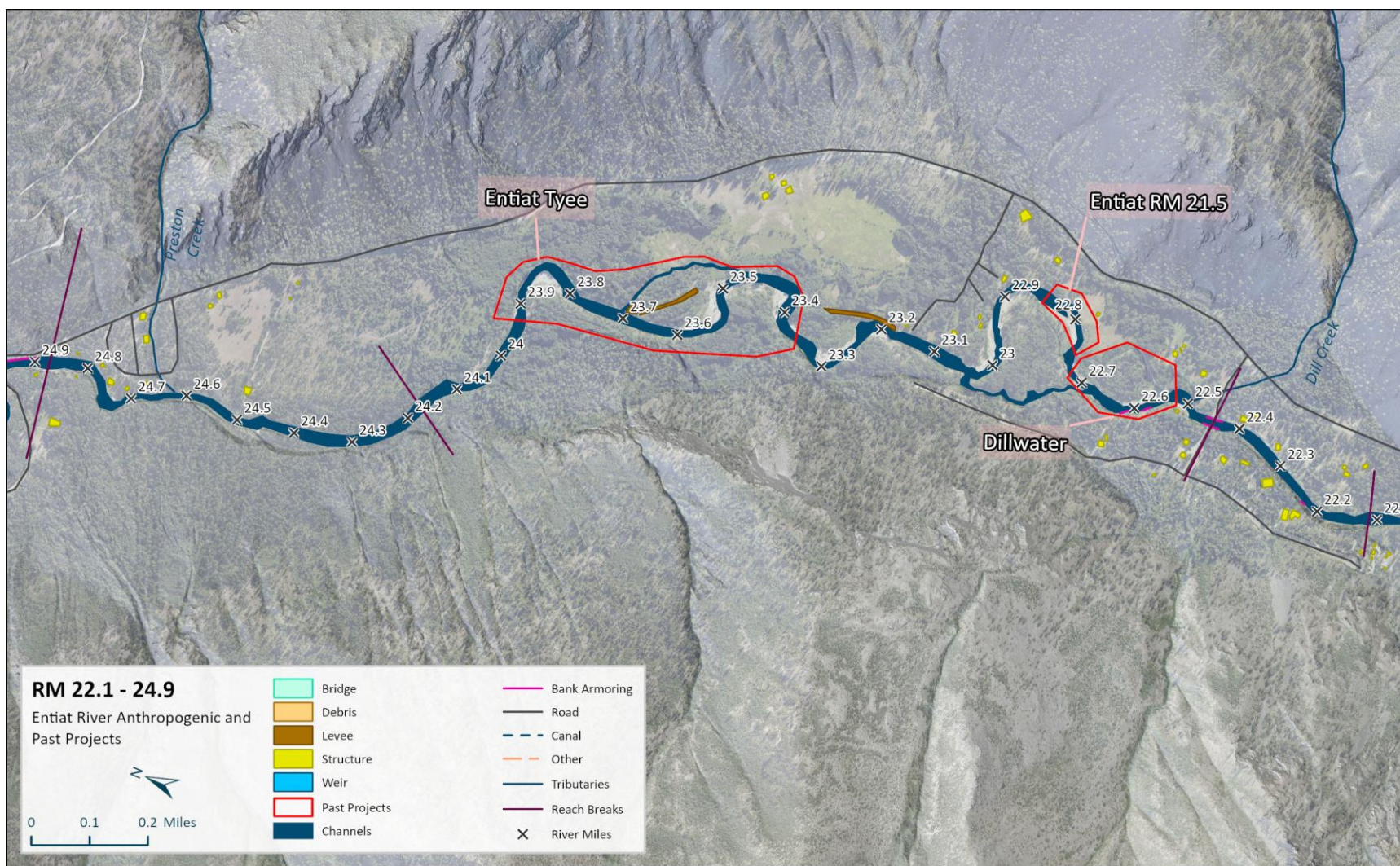


Figure 56. Segment 3 past restoration projects and mapped anthropogenic features.

6.3.2 Channel and Floodplain Geomorphology

The average channel gradient in Segment 3 (0.35%) (Table 10) is higher than that of Segment 2 and is driven by channel constrictions between alluvial fans at the upstream (Preston Creek and Mott Creek) and downstream (Dill Creek and unnamed river right tributary) ends of Segment 3. Outside of these high slope constricted areas the channel and valley bottom are relatively unconfined, and the channel gradient is only slightly higher than that of Segment 2. The effects of the converging Dill Creek and unnamed tributary fan on the opposite bank has a very strong influence on lateral processes, floodplain connectivity, and stream energy upstream (Figure 57, Figure 58, Figure 59). The Entiat River channel is sinuous through this unconfined section, contributing to a segment-average sinuosity of 1.36, and channel scars visible in a recent LiDAR dataset suggest that the Entiat River historically migrated across its wide valley bottom (Figure 57). Today, housing and other infrastructure limit the extent to which the Entiat River channel is allowed to freely laterally migrate throughout much of the segment. Segment 3 is single-thread with only a few instances of split-flow around midchannel bars. The average bankfull width of Segment 3, measured during the habitat assessment (Appendix A), was approximately 93 feet. The habitat assessment (see Appendix A) recorded 34% of the habitat as pool, 10% as glide, 6% as side channel, 40% as riffle, and 0.3% as marsh (Figure 57).

The Entiat River channel appears to be in the final stages of a channel avulsion toward river right between approximately RM 22.7 and 23.05, just upstream of the Dill Creek fan. Although a large cottonwood tree with additional racked wood at the entrance to the avulsion is slowing the rate of avulsion, the channel is still conveying significant flow (Figure 60). During the geomorphic field assessment, sand was observed depositing in the main channel just downstream of the avulsion channel entrance (Figure 60), and water at the mouth of the avulsion channel near RM 22.7 was observed eddying upstream into the main channel leading to sediment deposition and slight aggradation of the main channel. Upstream of the avulsion channel, stream energy in the main channel slows considerably, likely due to the tight bend at the meander that is in the process of being cut off.

Channel substrate in Segment 3 is highly variable depending upon location within the segment (Figure 60). In the upper portion of Segment 3, the boulder-cobble substrate transitions to cobble dominated as the Entiat River flows past the Preston fan. In this high energy section, gravels are generally only present in the interstices of larger cobbles and boulders. Downstream of the constriction, boulders are absent, sand appears along slower pool bottoms, and the substrate slowly transitions from cobble to gravel dominated moving downstream. At the Dill Creek fan, the channel is constricted again, stream energy increases, and the bed substrate coarsens, returning to boulder dominated. Substrate in the avulsion channel alternates between gravels, cobbles, boulders, and sandy mounds depending on location. Sediment sources in Segment 3 include several fans and the river right hillslopes, which contribute coarse gravels-to-boulders to the Entiat River channel; stream banks; and bedload transported from upstream.

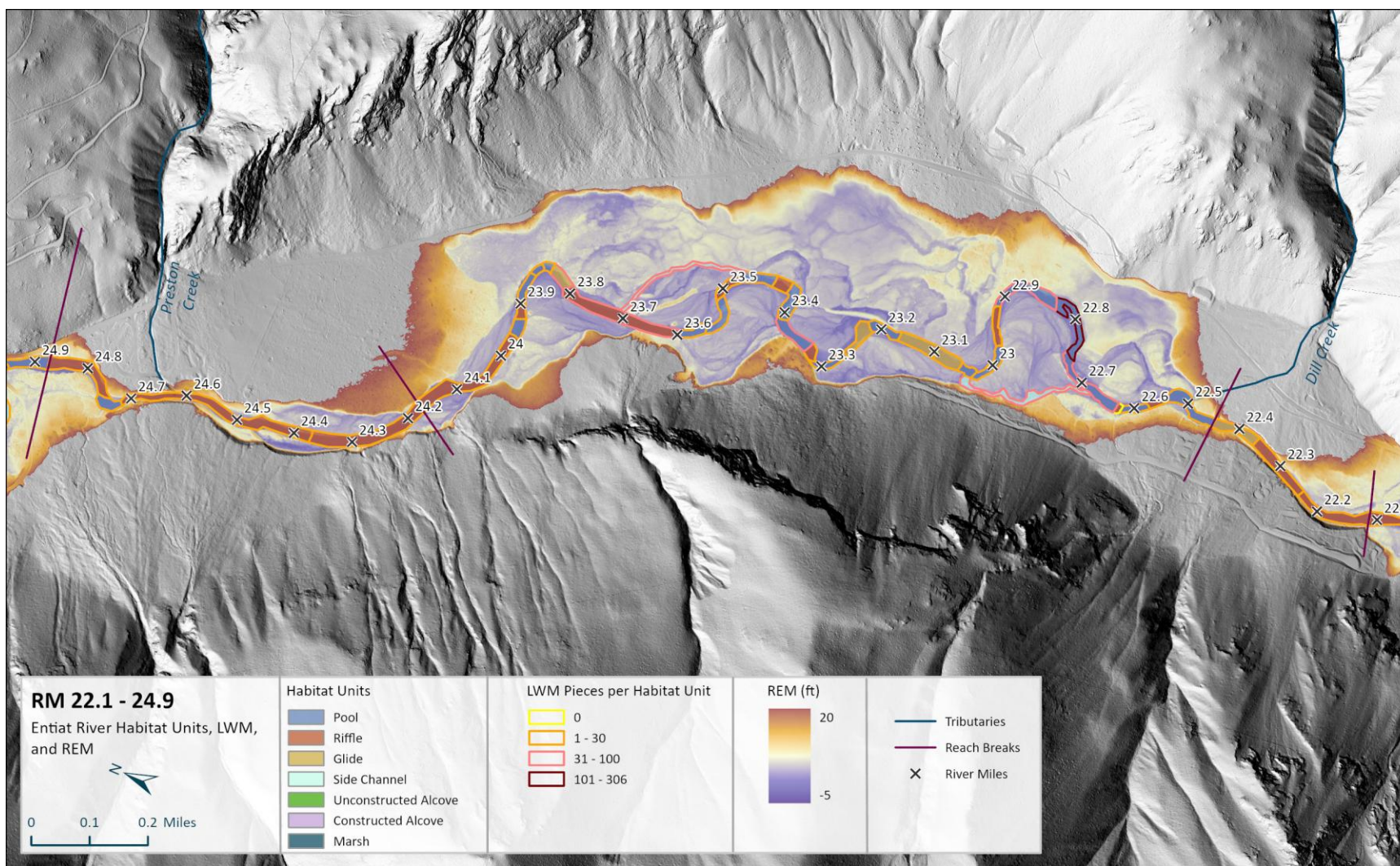


Figure 57. Habitat unit composition, LWM, and elevation relative to channel in Segment 3. LWM is total pieces within the habitat unit. See the habitat assessment in Appendix A for more details.

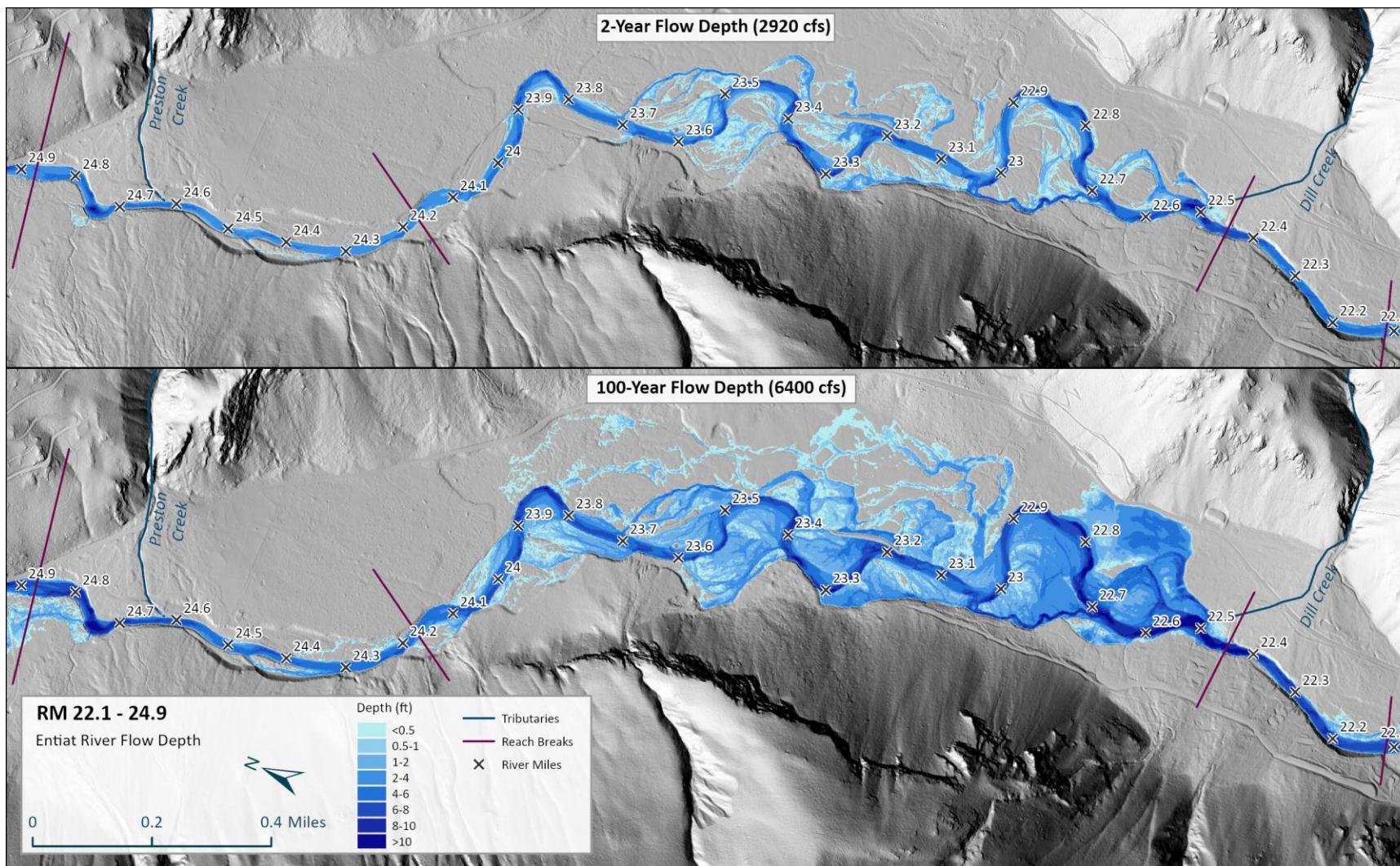


Figure 58. Modeled depth results for Segment 3.

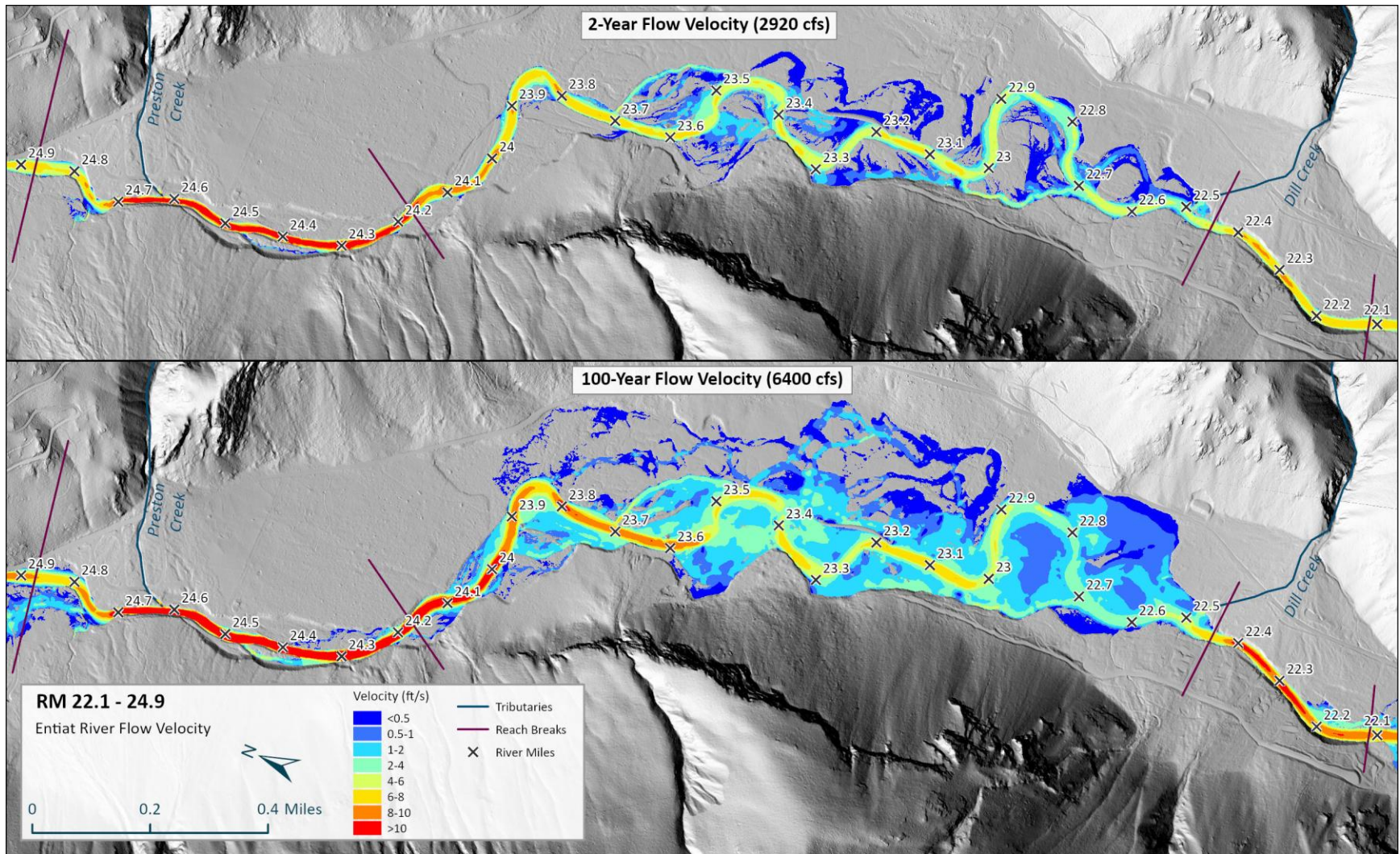


Figure 59. Modeled velocity results for Segment 3.



Figure 60. Clockwise from top left: Large, downed cottonwood tree at entrance to avulsion channel near RM 23.05, looking toward river right; Sand depositing in the Entiat main channel just downstream of the avulsion channel inlet; gravel/cobble substrate near RM 24.05; boulder dominated substrate at downstream end of Segment 2 by Dill Creek fan.

Preston Creek and Dill Creek both enter the Entiat River valley from river left in Segment 3. Although both tributaries are associated with fans that constrict the Entiat River valley bottom and channel and provide a source of coarse sediments, Preston Creek was the only flowing tributary observed throughout the entire assessment area during the August 2025 geomorphic field

assessment (Figure 61). At its mouth, Preston Creek was actively transporting coarse sands; however, the channel was lined with gravels and cobbles suggesting periodic higher energy flows. Off channel habitat in Segment 3 includes the constructed side channels associated with the Entiat Tyee restoration project as well as additional floodplain surfaces that are wetted at higher flows according to the 2D hydraulic modeling (Figure 58), but were not wetted during the time of the geomorphic field assessment.



Figure 61. Preston Creek, flowing into Entiat River near RM 24.6 from river left.

6.3.3 Large Wood Material

Naturally recruited large wood was generally limited in Segment 3 at the time of the August 2025 geomorphic assessment. The Entiat River watershed was heavily logged during the 19th and 20th centuries, reducing recruitable large wood sources within the watershed, and log drives down the Entiat River channel cleared existing large wood from the channel (CCCD 2004). Several key pieces 1.5 to 3 feet in diameter were observed racking additional wood, providing cover, sorting finer sediments, redirecting flow, and generating pool scour. A large cottonwood tree and associated racked wood were responsible for slowing avulsion of the Entiat River channel just upstream of the Dill Creek fan; however, avulsion is still likely to progress. Within the avulsion channel, a channel-spanning tree partially buried within the stream banks was observed creating a step pool, with active sediment deposition on the upstream end (Figure 62). Natural sources of recruitable key

pieces were limited in Segment 3, and mature old growth trees were completely absent, likely due to extensive logging within the Entiat River basin. Number of pieces of LWM by habitat unit is depicted in Figure 57 (Section 6.3.2). A series of engineered log jams, installed under past restoration projects, supplement naturally recruited large wood in Segment 3. These installed structures were generally more effective at driving geomorphic and habitat processes than naturally recruited large wood due to the general lack of naturally recruited large wood in Segment 3. Although large wood recruitment is also limited, the installed large wood structures may provide the additional long-term benefit of increased large wood racking potential as local forests recover, and large wood recruitment sources are replenished. Segment 3 large wood installations are discussed in more detail in Section 6.3.5.



Figure 62. Channel spanning downed tree driving geomorphic processes within the Segment 3 avulsion channel. The downed tree has created a scour pool downstream, and coarse sediment deposition upstream.

6.3.4 Vegetation

Vegetation in Segment 3 follows similar patterns to Segments 1 and 2. Lower floodplain surfaces contain primarily willow, dogwood, cottonwood, alder, western redcedar, and water birch (Figure 63). Reed canary grass was present on low floodplain surfaces downstream of RM 22.7 but was not observed further upstream. Higher floodplain and terrace surfaces are dominated by ponderosa pine. Hillslopes contained a sparse mix of ponderosa pine and short woody shrubs and herbaceous vegetation (Figure 63). A vegetation height map is included for reference in Figure 64.



Figure 63. Representative photographs of vegetation in Segment 3 showing differentiation between deciduous trees within riparian areas and pocket floodplain surfaces, and conifers (e.g., ponderosa pine) on higher floodplain surfaces.

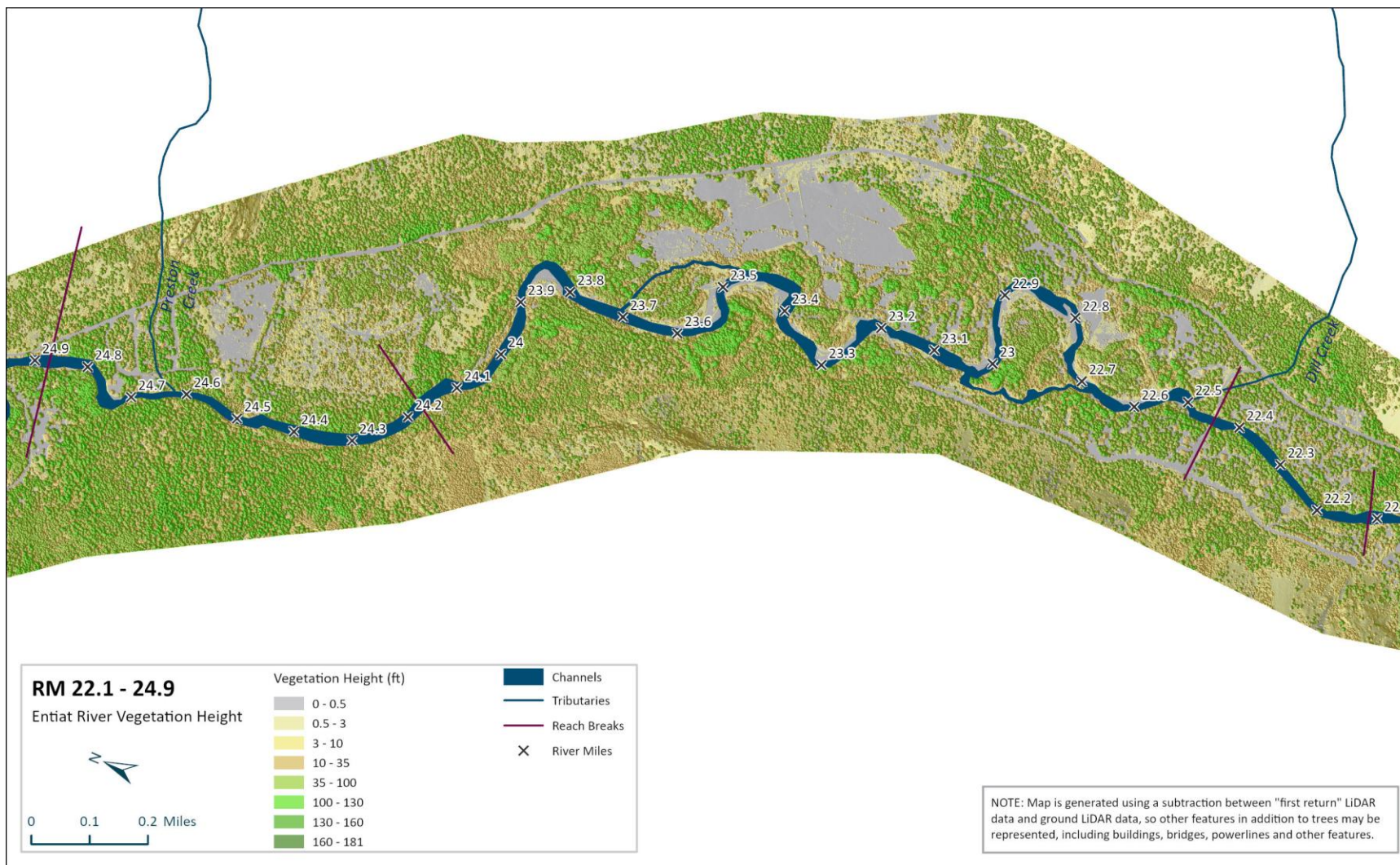


Figure 64. Vegetation heights along Segment 3 of the Entiat River.

6.3.5 Past Restoration Projects

Prior restoration projects in Segment 3 include the Dillwater LWD Enhancement project, the Cascadia Conservation District Entiat RM 21.5 LWD and Riparian Restoration project, and the Entiat Tyee Project. A map showing the locations of prior restoration projects in Segment 3 is included in Figure 65.

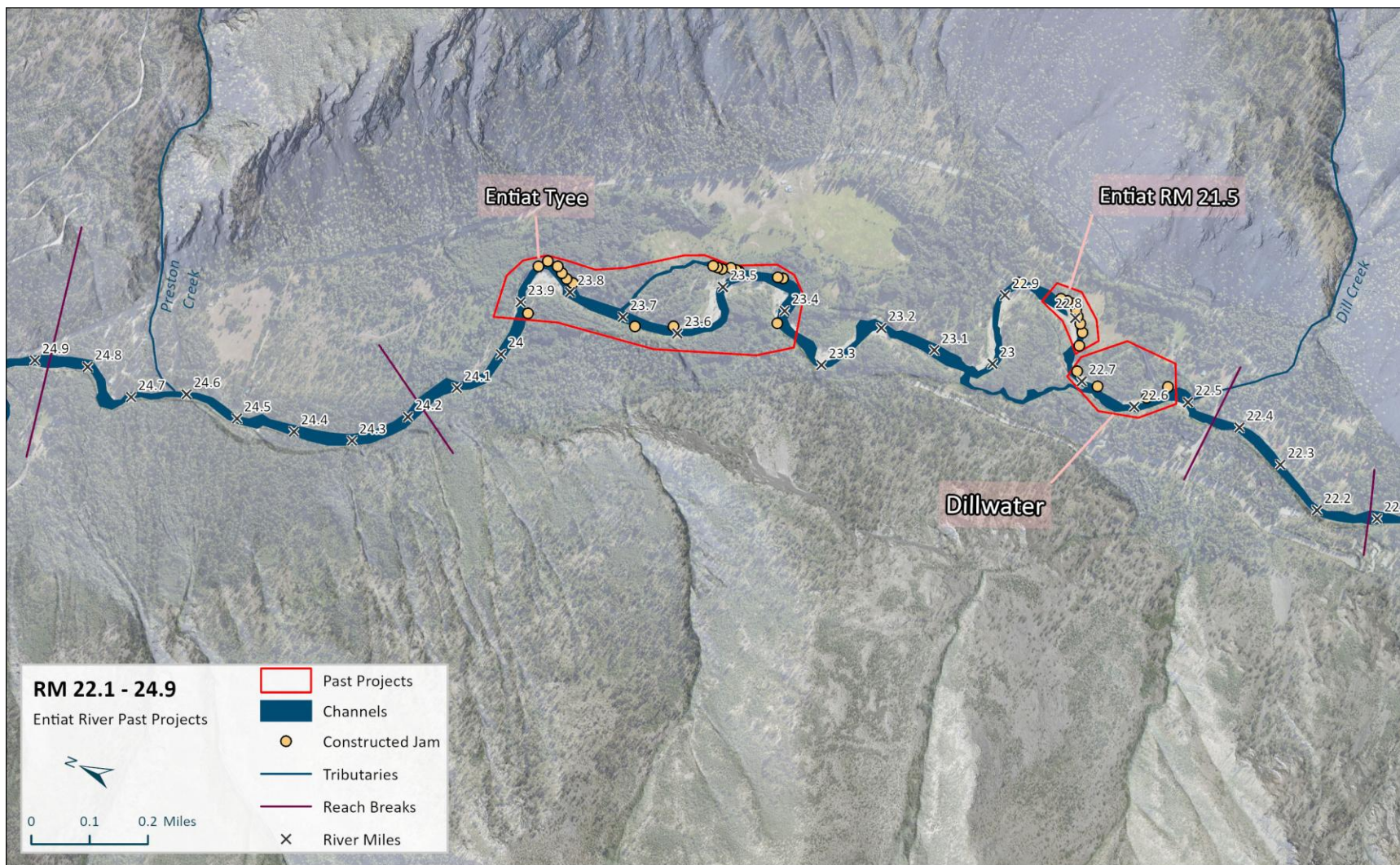


Figure 65. Past restoration projects in Segment 3.

The Dillwater LWD Enhancement project was constructed in 2012 and included installation of four large wood structures within the Entiat River main channel and an additional structure at the mouth of a side channel on river left just upstream of the Dill Creek fan. These structures were intended to increase channel complexity by deflecting or splitting flow, maintaining connection to the side channel on river left, and maintaining channel scour. Three of the five structures installed as part of the Dillwater LWD Enhancement project were observed during the August 2025 geomorphic field assessment. All three structures were elevated above the Entiat River main channel and none of the three were interacting with flows, suggesting that the river may have migrated away from these structures since they were installed (Figure 66). The remaining two structures were not observed during the field survey and therefore may have been washed out. The side channel on river left through the project area was not wetted during the assessment.



Figure 66. Engineered log structure associated with Dillwater LWD Enhancement project in Segment 3. Structure was originally installed within the Entiat River channel but is now partially buried by sediment on the river left floodplain.

The Cascadia Conservation District Entiat RM 21.5 LWD and Riparian Restoration project is located just upstream of the Dillwater LWD Enhancement project. This project included installation of large wood structures on the outside of a bend experiencing considerable rates of bank erosion due to

clearing of woody riparian vegetation from the river left floodplain surface, leaving the river left streambank lacking structure to resist erosion (Figure 67). The bank structures, installed in 2010, were paired with riparian planting on the cleared river left floodplain. As of the 2025 geomorphic field assessment, the structures were still in place and appeared to be effectively limiting bank erosion.



Figure 67. Bank structures on river left associated with the Cascadia Conservation District Entiat RM 21.5 LWD and Riparian Restoration project.

The Entiat Tye restoration project included installation of large wood structures and reconnection of abandoned floodplain channels to create perennial fish habitat and generate complexity in the Entiat River channel (Figure 68). The project also included riprap removal from the river left streambank and breaching and partial removal of the Upper Tye Levee built in the 1970s. The Entiat Tye project covers an approximately half mile stretch downstream of the constriction formed by the Preston Creek fan and was constructed in 2012. The August 2025 geomorphic assessment noted many structures associated with the Entiat Tye project to be interacting with low flows, generating scour, providing cover, and in several places, protecting against channel avulsion. Several structures were too high above the Entiat River channel to interact with flows during the low flow period. The side channel reconnected through breaching of the Upper Tye Levee contained

intermittent wetted pools but was otherwise dry at the upstream end, whereas the side channel contained flowing water where it entered the Entiat River mainstem at the downstream end. Hydraulic model results suggest that the side channel is fully wetted at the 2-year flow event.



Figure 68. Top: Entrance to side channel reconnected by breaching Upper Tye Levee. Bottom: Constructed large wood structures associated with the Entiat Tye restoration project in Segment 3. Left: looking downstream near RM 23.6. Right: looking toward river left, RM 23.85.

6.3.6 Project Opportunities

Project opportunities identified for Segment 3 include actions to enhance habitat surrounding a cold-water tributary, revegetating cleared floodplain surfaces, replacing or improving bank protection structures, and encouraging side channel connectivity and main channel complexity. Mott Creek, which enters the Entiat River valley near RM 24.75, has been identified as a cold-water input to the Entiat River. Large wood could be placed near the Mott Creek confluence in order to enhance habitat surrounding this cold-water refuge. Riprap on the opposite bank could be removed or replaced with large wood bank protection structures that provide additional habitat benefits. The Upper Tye Levee was partially breached as part of the Entiat Tye restoration project; however, portions of the levee still remain on the river right floodplain between RM 23.15 and 23.7. The levee is a barrier to flow across portions of the floodplain and could be fully removed to increase connectivity between the Entiat River channel and its adjacent floodplain. Large wood structures could be placed in the main channel between RM 23.35 and 23.6 and downstream of both side channel entrances to supplement those installed during the Entiat Tye project. These would encourage additional flow into existing side channels on both sides of the Entiat main channel while also providing additional mainstem habitat complexity. The side channel on river right may require additional excavation to achieve the desired level of connectivity. Replanting of cleared floodplain surfaces would benefit aquatic species by helping to restore riparian function and large wood recruitment. Large wood bank protection structures installed as part of the Entiat RM 21.5 project could be evaluated to determine whether enhancements to existing structures could provide additional habitat benefits. Riprap spurs in the lower Dillwater LWD Enhancement project area could be removed and replaced as needed with wood structures providing additional habitat improvements.

6.4 SEGMENT 4 (RM 24.9 – 26.7)

6.4.1 Overview

Segment 4 extends approximately 1.8 river miles from the Preston Creek Fan at RM 24.89 to the McCrea Creek confluence at RM 26.7 (Table 11, Figure 69). Segment 4 encompasses reaches 11 and 12. Segment 4 spans reaches 3C and 3D of the Entiat Tributary Assessment, and was included in the 2013 Upper Stillwaters Reach Assessment (USBR 2009; Inter-Fluve 2013).

Table 11. Metric table for Segment 4. Metrics collected during the habitat assessment are discussed in Appendix A. Confinement estimates are from the Entiat Tributary Assessment (USBR 2009a).

Reach	Length (miles)	River Mile	Stream Gradient (%)	Sinuosity	Dominant Channel Habitat Unit Type	Average Bankfull Width (ft)	Confinement	Dominant Substrate	% Pool Habitat	% Glide Habitat	% Riffle Habitat	% Side Channel Habitat	% Other Habitat
Reach 11	0.7	24.9 - 25.6	0.93%	1.10	Glide	93	Confined	Gravel/Cobble	33%	38%	9%	18%	2%
Reach 12	1.8	25.6-26.7	0.49%	1.98	Side Channel	103	Unconfined	Gravel/Cobble	3%	12%	38%	46%	1%



Figure 69. Representative photograph of the Entiat River in Segment 4, looking downstream from RM 25.4.

Notable human alterations in Segment 4 include a channel spanning bridge at RM 25, numerous houses within the Entiat River floodplain and adjacent hillslopes, and prior restoration projects (Figure 70). The bridge was built at a valley bottom constriction where the Mott Creek fan enters the Entiat River valley from river right. Despite this constriction, there is still a narrow corridor of floodplain adjacent to the Entiat River channel, and flows across this floodplain are likely impeded by bridge infrastructure. A potential avulsion of the Entiat River into the existing side channel upstream of the bridge could threaten the bridge. A PVC pipe extends into the river channel in the upstream portion of Segment 4; however, the pipe does not impact channel processes. Prior restoration efforts included installation of bank large wood structures intended to provide habitat in addition to bank protection in proximity to existing houses and other structures on the river left floodplain in the upper portion of Segment 4. Entiat River road lies along the hillslope toe on river left, coming into contact with the Entiat River channel for approximately 0.3 miles at the downstream end of Segment 4 including at the base of the bridge. Riprap protects the road and limits erosion into the river left hillslopes in this section. Elsewhere in Segment 4, the road is far from the channel and does not directly impact channel processes.



Figure 70. Notable human alterations in Segment 4. Channel spanning bridge crossing the Entiat River at RM 25, looking downstream (left), and PVC pipe extending into Entiat River channel near RM 26.3.

The Entiat River 3D project is the only major prior restoration project completed in Segment 4. This project consisted of installation of large wood structures and creation of side channel and backwater alcove habitat. It was originally completed in 2012, although several additional large wood structures were subsequently added several years later. A map of human alterations in Segment 4, including prior restoration work is included in Figure 71. See Section 6.4.5 for a description of past restoration work within Segment 4.

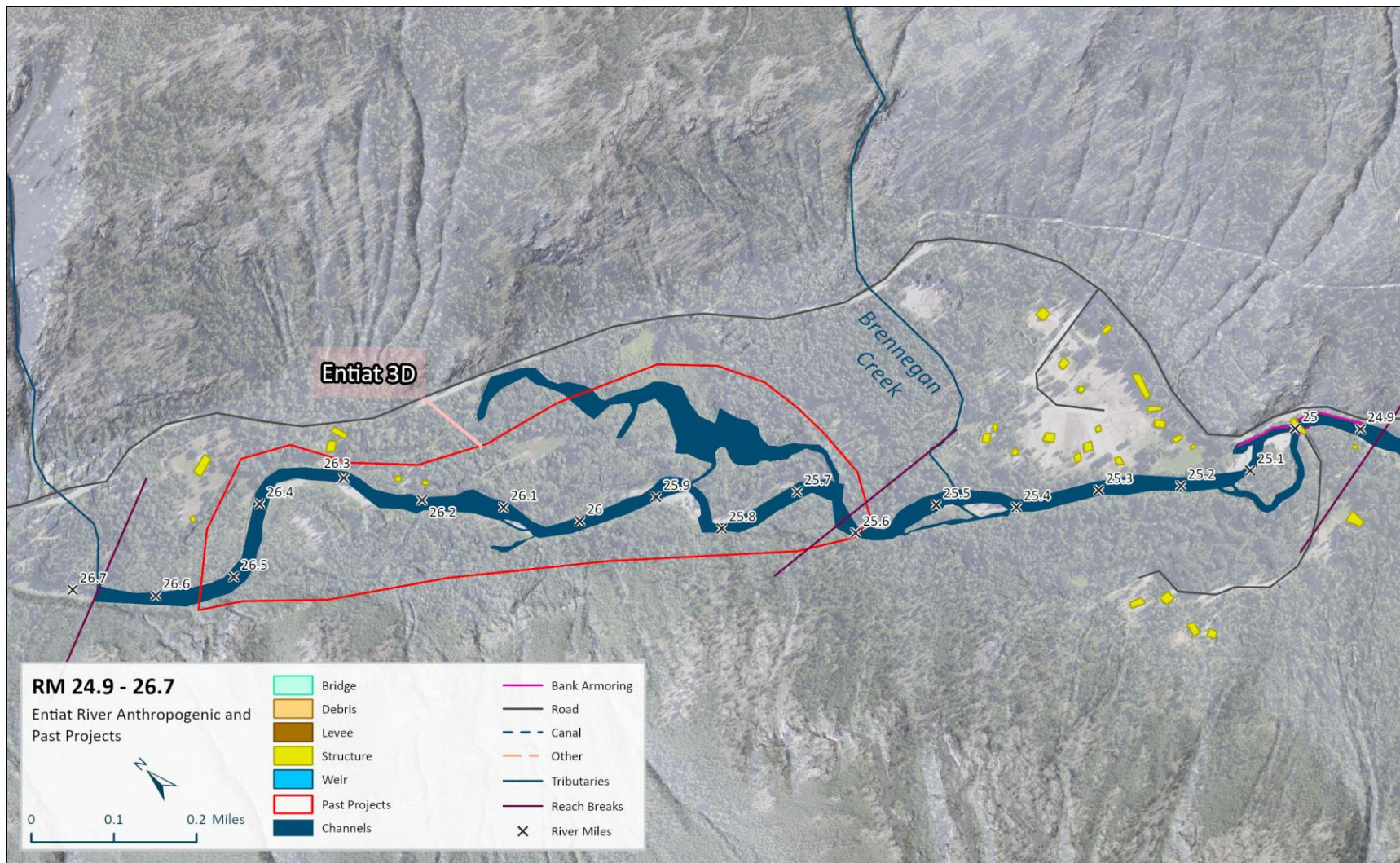


Figure 71. Segment 4 past restoration projects and mapped anthropogenic features.

6.4.2 Channel and Floodplain Geomorphology

Segment 4 is the steepest segment within the assessment area with an average channel gradient of 0.63% (Table 11). Although the entire segment is relatively steep compared to the overall assessment area, the constriction between the Preston Creek and Brennegan Creek fans is especially steep and high energy, and contributes substantially to the overall high gradient and low sinuosity ($S = 1.15$) of the segment. Floodplain surfaces in this section are limited due to constriction from fans on either side (Figure 72, Figure 73, Figure 74). Upstream of Brennegan Creek, the valley bottom widens considerably, allowing for greater sinuosity, floodplain surfaces, and channel migration. Channel scars visible in recent LiDAR data suggest that the Entiat River channel historically migrated across the entire wide valley bottom (Figure 72), although infrastructure including houses and associated bank protection limit lateral migration toward river right at present. The floodplains in Segment 4 support multiple perennially and seasonally connected side channels and additional off channel habitat. Notable off channel habitat includes a large perennial side channel on river right just upstream of the RM 25 bridge; intermittently wetted side channels near the upstream boundary of Segment 4 on both river left and river right; a large connected pond on river right near RM 26.25; and a complex beaver-maintained wetland covering a significant portion of the river left floodplain upstream of Brennegan Creek that includes several perennially flowing side channels, and maintains connection to the Entiat River channel at low flow (Figure 75). Segment 4 did not contain any perennially flowing tributaries. The habitat assessment (see Appendix A) recorded 32% of the habitat as side channel, 32% as riffle, 23% as glide, 12% as pool, and 2% as alcove (Figure 72). The average bankfull width, measured during the habitat assessment was approximately 98 feet.

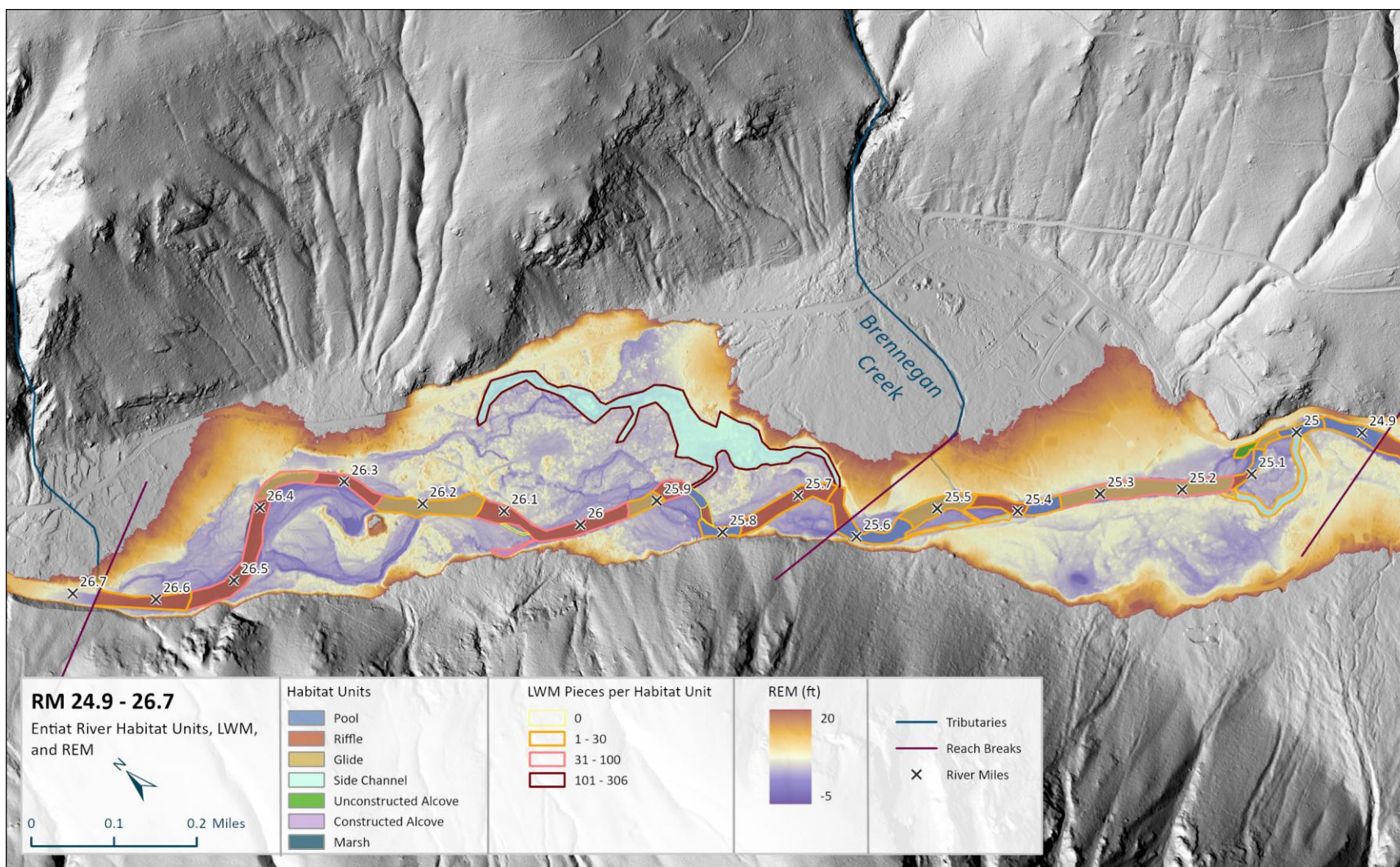


Figure 72. Habitat unit composition, LWM, and elevation relative to channel in Segment 4. LWM is total pieces within the habitat unit. See the habitat assessment in Appendix A for more details.

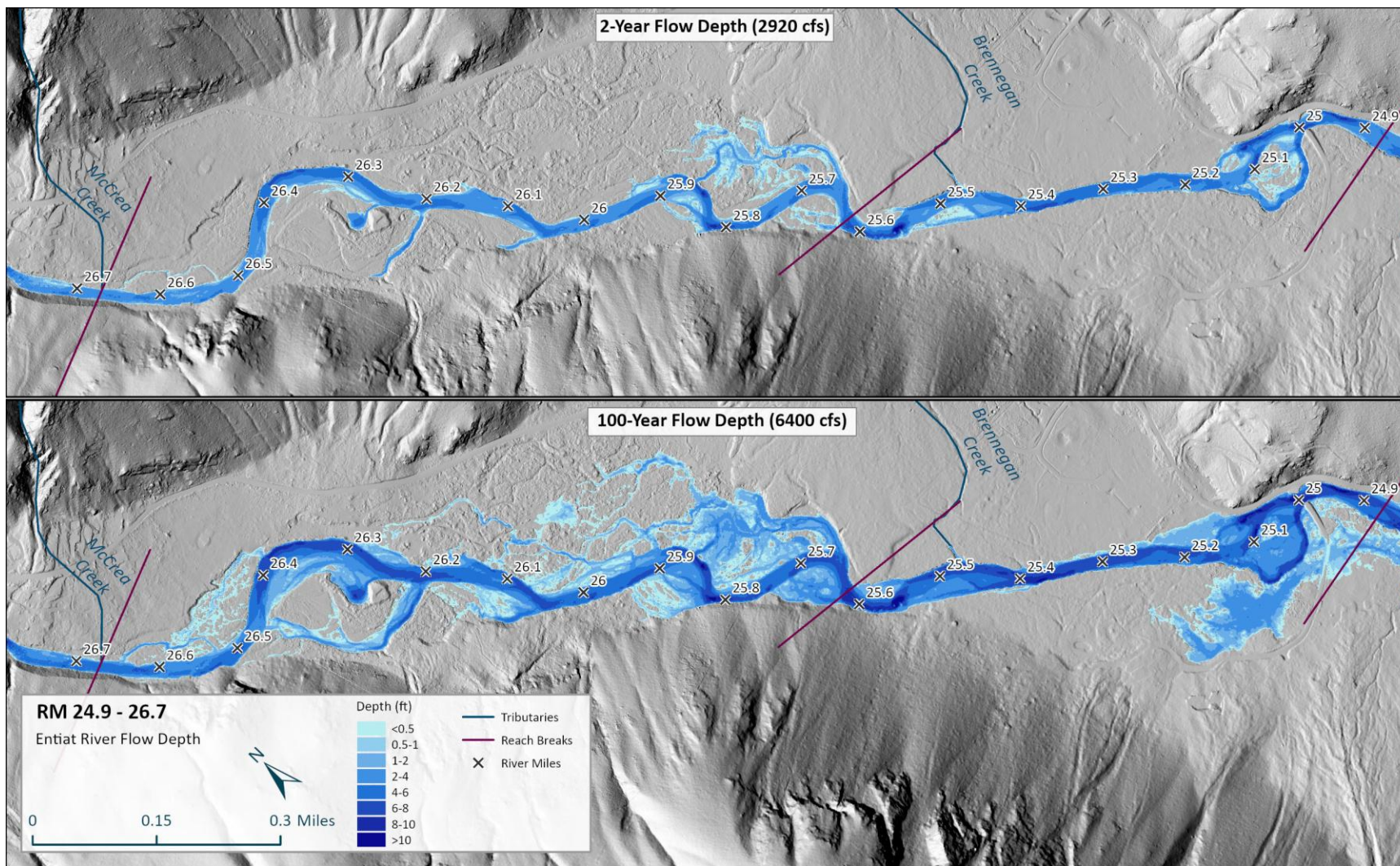


Figure 73. Modeled depth results for Segment 4.

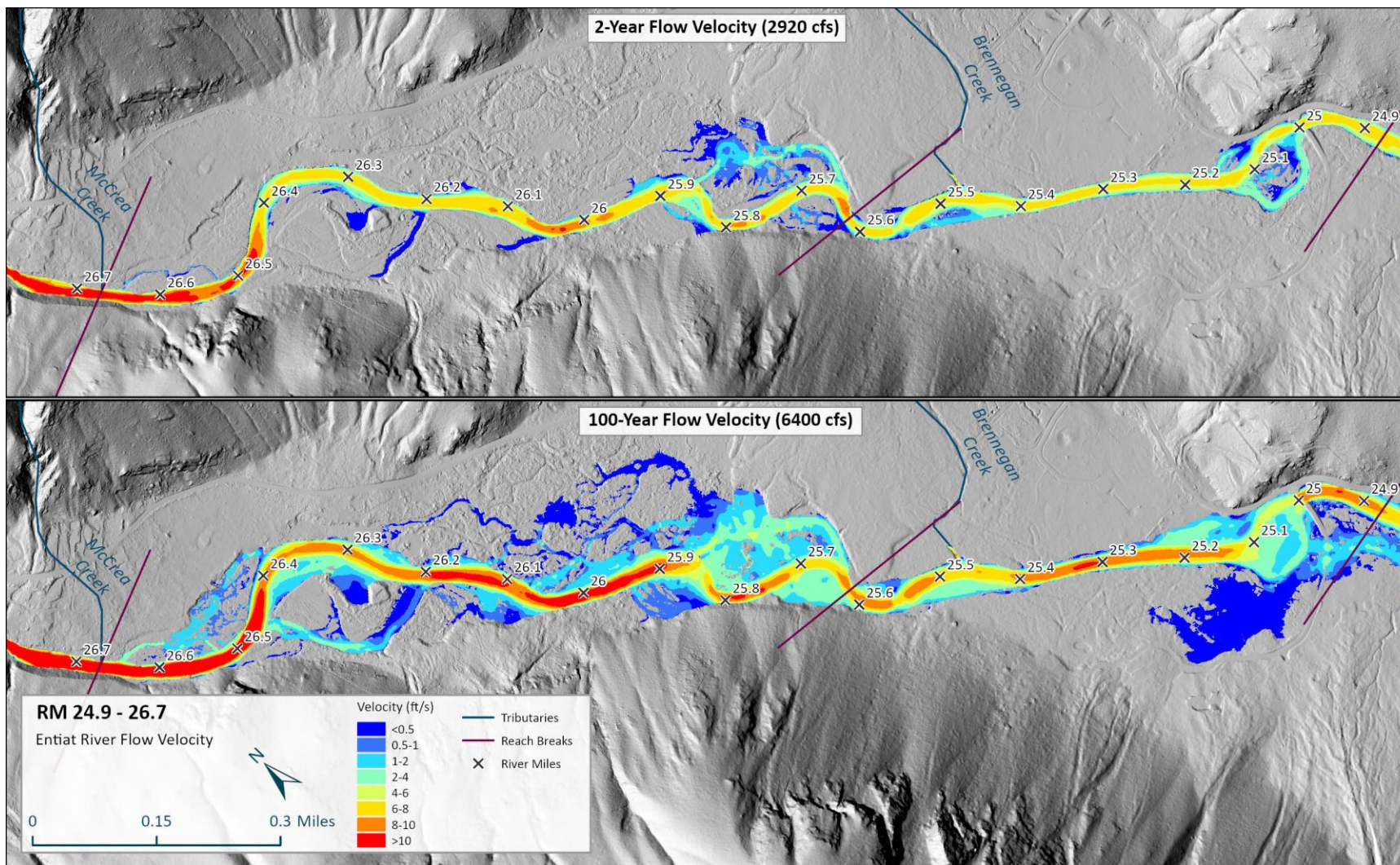


Figure 74. Modeled velocity results for Segment 4.



Figure 75. Representative photographs of off channel habitat in Segment 4. Clockwise from top left: Dry high flow side channel on river left near RM 26.6; Entrance to dry high flow side channel on river right near RM 26.5; connected pond on river right floodplain near RM 26.25; Entrance to perennial side channel near the downstream end of Segment 4 (RM 25.15) on river right; Side channel flowing through river left floodplain in Segment 4 near RM 25.75.

Channel substrate in Segment 4 consists primarily of cobbles, with the percentage of coarse gravels increasing downstream (Figure 76). Boulders line the channel bed in several locations where boulders are sourced from adjacent hillslopes (Figure 76). Cobbles and gravels within the channel are sourced from adjacent hillslopes and tributary fans as well as from eroding streambanks and bedload transported from upstream. Exposed stream banks in Segment 4 typically consist of a gravel/cobble base overlain by several feet of fine sediments.



Figure 76. Representative photographs of channel substrate in Segment 4 showing boulders within the Entiat River channel near RM 26.6, looking downstream (left) and gravel/cobble substrate typical of the majority of Segment 4 near RM 26.4 (right).

6.4.3 Large Wood Material

Naturally recruited large wood was limited within Segment 4 at the time of the August 2025 geomorphic assessment. The Entiat River watershed was heavily logged during the 19th and 20th centuries, reducing recruitable large wood sources within the watershed, and log drives down the Entiat River channel cleared existing large wood from the channel (CCCD 2004). Key pieces exerting an influence on channel processes were generally greater than 1.5 feet in diameter, although wood pieces were generally restricted to channel margins and their influence did not extend to the entire channel. Effective large wood pieces and accumulations in Segment 4 were responsible for promoting pool scour, sorting sediments ranging from sands to coarse gravels, diverting flows toward the channel center, and providing cover (Figure 77). Recruitable sources of effective large wood were generally limited in Segment 4 due to the lack of large mature trees on adjacent floodplains and hillslopes. Due to the higher energy of Segment 4, large wood pieces were often mobile unless trapped by boulders or standing trees and adjacent banks. Number of pieces of LWM by habitat unit is depicted in Figure 72 (Section 6.4.2). Naturally recruited large wood in Segment 4 is supplemented by additional engineered large wood structures installed during past restoration projects on the Entiat River. These structures are generally larger than existing natural large wood jams and exert a greater influence on geomorphic and habitat processes. The installed large wood structures may provide the additional long-term benefit of increased large wood racking potential as local forests recover, and large wood recruitment sources are replenished, however, racking of

naturally recruited large wood is currently limited. Segment 4 large wood installations are discussed in more detail in Section 6.4.5.



Figure 77. Representative photographs of large wood in Segment 4. Left: Large wood racked on coarse sediments along river right channel margin downstream of RM 26.5. Right: Downed tree extending from river left floodplain into the Entiat River channel near RM 26.4, generating pool scour and coarse sediment deposition.

6.4.4 Vegetation

As with Segments 1-3, vegetation communities in Segment 4 appear driven primarily by height of floodplain surfaces above the Entiat River channel. Lower floodplain surfaces in Segment 4 generally consist of cottonwood and alder, and to a lesser extent, dogwood, with willow present on bars and occasional pocket floodplains. Mixed-age cottonwood stands were observed, with mature cottonwood as the dominant floodplain overstory species, and young cottonwood establishing on active bars. On higher floodplain surfaces and adjacent hillslopes, an overstory of ponderosa pine and Douglas-fir was common. Rocky mountain maple, snowberry, saskatoon berry, and thimbleberry were sparsely distributed within the understory of Segment 4. A vegetation height map is included for reference in Figure 78.

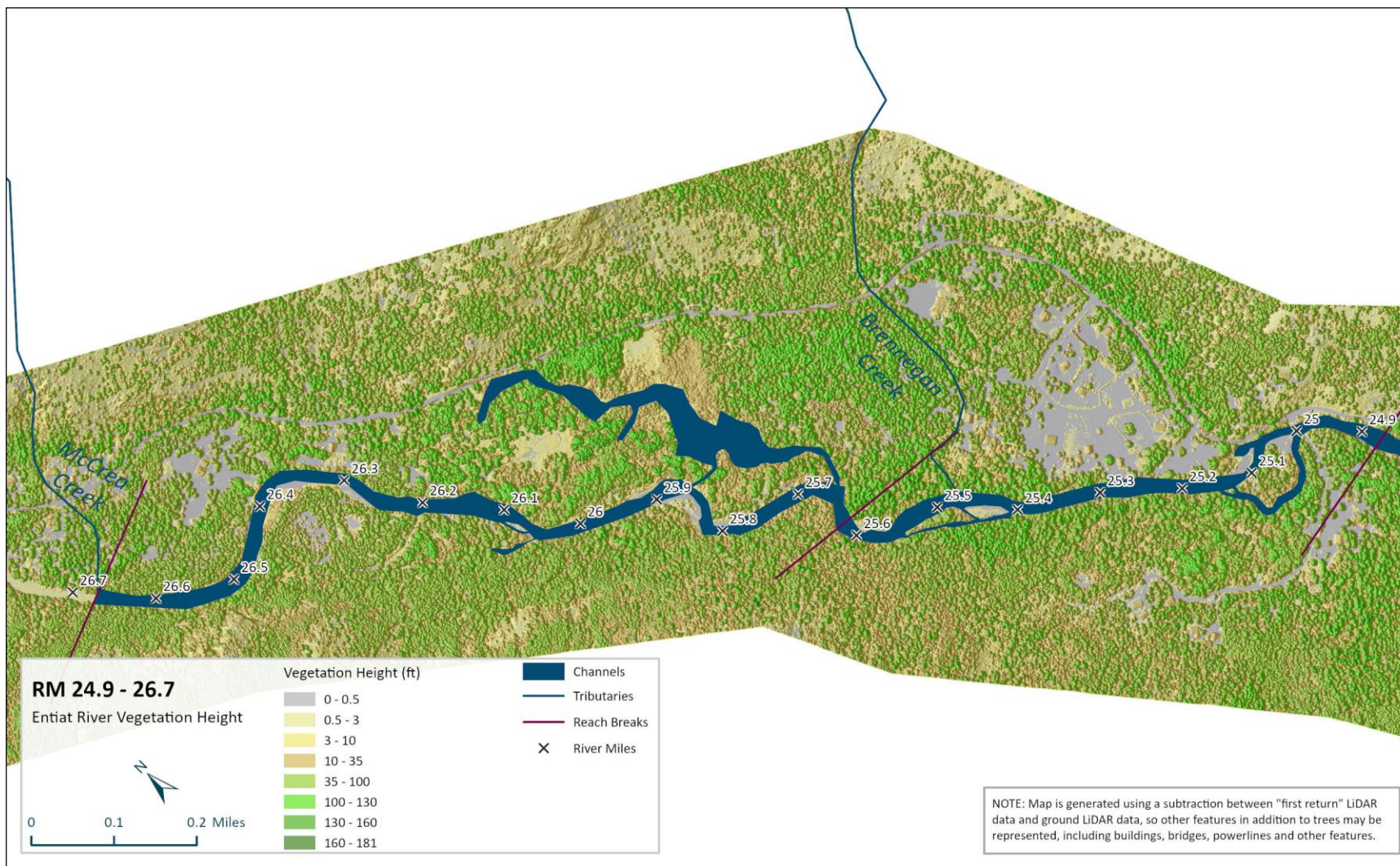


Figure 78. Vegetation heights along Segment 4 of the Entiat River.

6.4.5 Past Restoration Projects

The Entiat 3D restoration project is the only major restoration project within Segment 4 (Figure 79, Figure 80). This project extends approximately one river mile upstream from the Brennegan Creek fan and was constructed in 2012, with additional structures added several years after initial construction. The Entiat 3D project includes large wood structures intended to limit bank erosion and provide channel complexity and habitat benefits, as well as off channel habitat features including side channels and backwater alcove habitat. The entrance to the upstream side channel on river right was dry at the time of the 2025 geomorphic field assessment, although the side channel contained stagnant ponded water where it connected to the Entiat River mainstem further downstream. The hydraulic model suggests that the side channel is fully wetted above the 5-year flow event. Log structures in this downstream portion of the side channel continue to provide a high flow refuge for salmonids. The entrance to the river right pond between the side channel and Entiat main channel near RM 26.3 has partially filled in, although it appears connected at higher flows. Off-channel habitat further downstream on river left, including the excavated side channels, remained well connected at low flows experienced during the geomorphic field assessment. Large wood structures associated with the Entiat 3D project continue to limit bank erosion and support healthy riparian vegetation, although they provide minimal cover due to a lack of associated pool habitat.



Figure 79. Representative photographs of Entiat 3D restoration project in Segment 4. Top: Large wood structure on river left downstream of RM 26.4. Bottom left: channel with installed large wood for cover, connecting floodplain pond on river right to main channel near RM 26.25. Bottom right: mouth of intermittent river right side channel with added large wood for cover near RM 26.2.

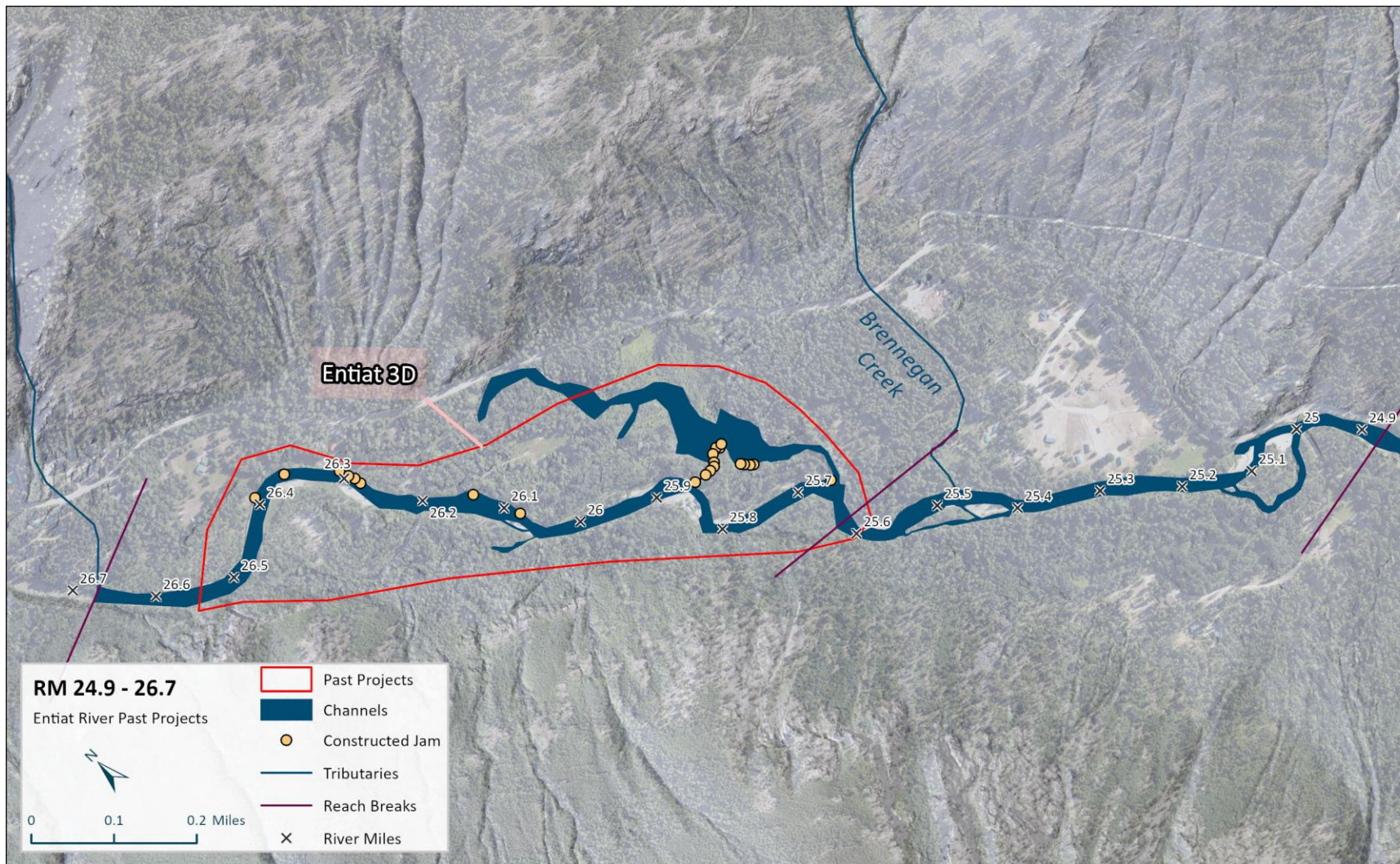


Figure 80. Past restoration projects in Segment 4.

6.4.6 Project Opportunities

Project opportunities identified within Segment 4 focus on increasing channel complexity within the mainstem Entiat River and enhancing connectivity and function of off-channel habitat within floodplains adjacent to the Entiat River channel. Large wood structures installed within the main channel as part of the Entiat 3D restoration project are located primarily along the banks. Structures could be expanded to extend further into the Entiat River channel, or additional structures with more flow interaction could be installed to increase habitat complexity and promote long-term geomorphic processes. Strategically placed large wood structures could also increase the frequency and magnitude of side channel and off channel habitat connectivity, especially in the upper portion of Segment 4 within the Entiat 3D project area. At present, a high surface on the river right floodplain between RM 26.2 and 26.3 acts as a barrier to flow across the floodplain, including at the 100-year flow event. This surface appears to have been artificially created and could be re-graded to increase hydraulic connectivity between the river right floodplain and the Entiat River mainstem. Conservation of the off-channel habitat in the river left floodplain (non-CDLT property) could help to preserve the existing habitat long term, and would open up restoration opportunities to enhance connectivity of this area. Downstream of the Entiat 3D project area, the Entiat River channel is straight and lacks complexity. Large wood additions in lower energy portions of the channel downstream of the Entiat 3D project area could improve the condition of this simplified channel section by providing additional in-channel habitat heterogeneity and promoting dynamic geomorphic processes. Additional wood placed within floodplain side channels at the split flow area upstream of the bridge between RM 25 and 25.2 could enhance habitat within these off channel areas. Apex structures placed downstream of side channel entrances could encourage additional flow into side channels during times of lower flow.

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