White River Reach Assessment & Restoration Strategy
Final Report

SEPTEMBER 2025

PREPARED FOR
Yakama Nation Fisheries

PREPARED BY
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Final Report

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1. Introduction

1.1 PROJECT OVERVIEW

This assessment evaluates aquatic habitat and watershed process conditions in the lower White River watershed in the North Cascades of Washington and identifies habitat restoration strategies. The White River watershed has its headwaters in the Glacier Peak Wilderness and flows south-southeast into Lake Wenatchee, which is the origin of the Wenatchee River, a major upper Columbia River tributary. The assessment area includes the mainstem White River and its associated floodplain from the lake up to the anadromous barrier (White River Falls) near river mile 16, as well as the lower portion of tributaries Napeequa River (lower 2.2 miles), Panther Creek (0.8 miles) and Sears Creek (0.4 miles) (Figure 1).

This reach assessment provides a technical foundation for understanding existing conditions of lower White River and sections if its major tributaries, and for identifying areas that would benefit most from restoration strategies to improve aquatic habitat and stream ecological functions. Conditions are assessed at both the assessment area scale and reach scale. 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 are identified to promote conservation of healthy fluvial process. 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 characterization: Summary evaluation of valley and basin-scale factors influencing aquatic habitat and stream geomorphic processes.
- Reach-scale characterization: Inventory and analysis of habitat and geomorphic conditions at the reach and sub-reach scales.
- Stream habitat assessment: Aquatic habitat inventory at the reach-scale.
- Reach-Based Ecosystem Indicators (REI) analysis – Comparison of habitat conditions to established functional thresholds.
- Restoration strategy: 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.
- Specific project opportunities: A list and maps of specific potential project opportunities that would help to achieve the reach-scale restoration strategies.

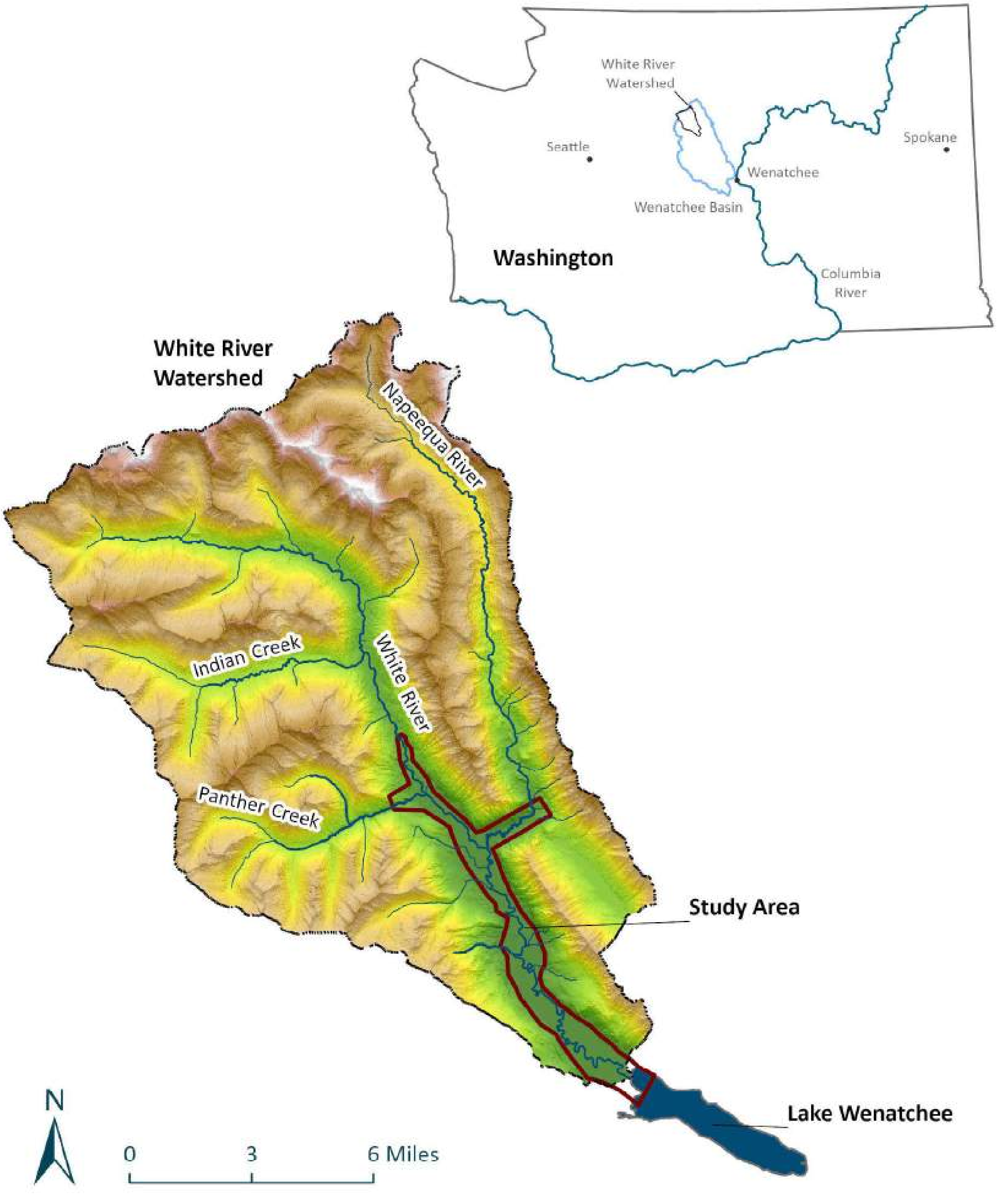

Figure 1. Location of the White River assessment area within the White River watershed.

1.2 BACKGROUND

This project was completed on behalf of the Yakama Nation as part of their efforts to improve native aquatic fisheries within the Columbia River Basin through their Upper Columbia Habitat Restoration Project (UCHRP). The UCHRP 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 builds on past work in the basin including the 2001 Limiting Factors Analysis (Andonaegui, 2001), the Wenatchee River Subbasin Plan (Carlson et al., 2004), and a past Reach Assessment prepared for the Cascades Columbia Fisheries Enhancement Group that focused on the lower 5.7 miles of the mainstem White River (Herrera Environmental Consultants Inc., 2014). Given the relatively small amount of past aquatic habitat assessment data collection or project opportunity, this current assessment relies primarily on newly collected data and analysis.

1.3 PURPOSE

The purpose of this assessment is to document aquatic habitat conditions and hydrologic, geomorphic, and ecological processes in the lower White River basin and to present a comprehensive reach-based restoration strategy to address limiting factors to aquatic habitat. Evaluations used in this assessment include historical characterization, geomorphic assessment, hydraulic assessment, and an aquatic habitat inventory.

Specific goals and outcomes of this assessment include:

- Provide a comprehensive inventory and assessment of geomorphic and aquatic habitat conditions and trends
- Identify strategies and actions that address critical aquatic habitat impairments limiting the productivity of local salmonid populations
- Identify strategies and actions that protect and restore the dynamic landscape processes that support sustainable riparian and salmonid habitat
- Present a prioritized list of recommended actions for implementation

2. Assessment Area Characterization

2.1 SETTING

The White River is a tributary of the Wenatchee River, located within the Upper Columbia River Basin in the Central Cascade Mountains of Washington State. The White River flows approximately 26.7 river miles (RM) from its headwaters within the Glacier Peak Wilderness southeast to its mouth at the northwest end of Lake Wenatchee, near the town of Plain, WA. The White River is the largest tributary to Lake Wenatchee and flows into the lake directly north and adjacent to the Little Wenatchee River tributary. The floodplains of the two rivers connect for approximately 1 mile prior to entering the lake. The White River supports native anadromous salmonid populations downstream of White River Falls, which forms a natural fish migration barrier near RM 16.2. Several tributaries to the White River also support native anadromous salmonids, including Panther Creek (enters at RM 15.01), the Napeequa River (enters at RM 12.43), and Sears Creek (enters ~RM 8.55-8.9). The assessment area generally corresponds to the portions of the basin that are accessible to anadromous fish. This includes the lower White River downstream of the falls (16.2 miles), the lower 0.8 miles of Panther Creek, and the lower 2.2 miles of the Napeequa River, the largest tributary to the White River. Sears Creek was also included in the assessment; however, surface flow from Sears Creek is disconnected from the White River during the late summer low flow period when the assessment was conducted. The portion of Sears Creek that lies within the White River floodplain, which constitutes most of the reach length, flows through a network of floodplain wetlands and beaver ponds with no discernable channel. For this reason, Sears Creek was not assessed to the same degree as the other tributaries, including no habitat survey.

The channel morphology of the lower mainstem White River undergoes a dramatic change from the mouth at Lake Wenatchee up to White River Falls. In the upper portion of the study area, the channel is single-threaded and relatively straight, alternating between confined and partially-confined by bedrock and terraces. This degree of confinement, combined with a relatively steep slope, creates a high-energy system in which large woody material (LWM), bedload, and suspended sediment are readily transported through the upper reaches and downstream into the lower portion of the study area. Beneath the Panther Creek confluence, the channel is generally unconfined with evidence of active historical lateral migration. Although the channel remains primarily single-threaded, large wood frequently creates split-flow conditions. Channel slope decreases considerably between the Panther Creek confluence (RM 15) and the Napeequa River confluence (RM 12.45), and then again downstream of the Sears Creek Road bridge crossing the White River near RM 7. The main channel remains straight to slightly meandering in the section between Panther Creek and Sears Creek (RM 8.55). Below Sears Creek, the sinuosity of the mainstem White River increases significantly until it reaches Lake Wenatchee.

The assessment area (RM 0-16.17) is divided into 14 reaches. The mainstem White River (RM 0 – 16.17) has 10 reaches, the Napeequa has two reaches, and Panther Creek has one reach. Sears Creek has one reach; however, conditions were not conducive to normal survey and assessment protocols due to no discernable channel for most of Sears Creek. Therefore, not all of the same data collection and analysis were performed for Sears Creek compared to the other reaches. The reaches match the Upper Columbia Salmon Recovery Board reaches that have been used for recovery planning in the Upper Columbia region (Upper Columbia Salmon Recovery Board, 2022). The existing UCSRB reach boundaries were not altered as they were believed to adequately represent distinct geomorphic conditions and there are benefits to adhering to established reaches for comparisons to existing and future reach-based studies. Reaches break at major tributary confluences or changes in geomorphic condition such as slope or valley bottom confinement. Reaches are numbered sequentially, with reach numbers increasing from downstream to upstream. A map of the assessment area showing the reach breaks is included in Figure 2.

The vast majority (99.6%) of the White River watershed is public land, including the Glacier Peak Wilderness (81.4%), the Wenatchee National Forest (17.6%), and other state and federal lands (0.6%). Private land ownership is limited to the lower 13 river miles of the White River and makes up approximately 20% of the landownership within the study area, which includes the valley bottom of the White River up to RM 16.2 and the lower 2 miles of the Napeequa valley. The Chelan-Douglas Land Trust owns multiple parcels in the study area that are set aside for conservation. Land ownership is detailed in Figure 3.

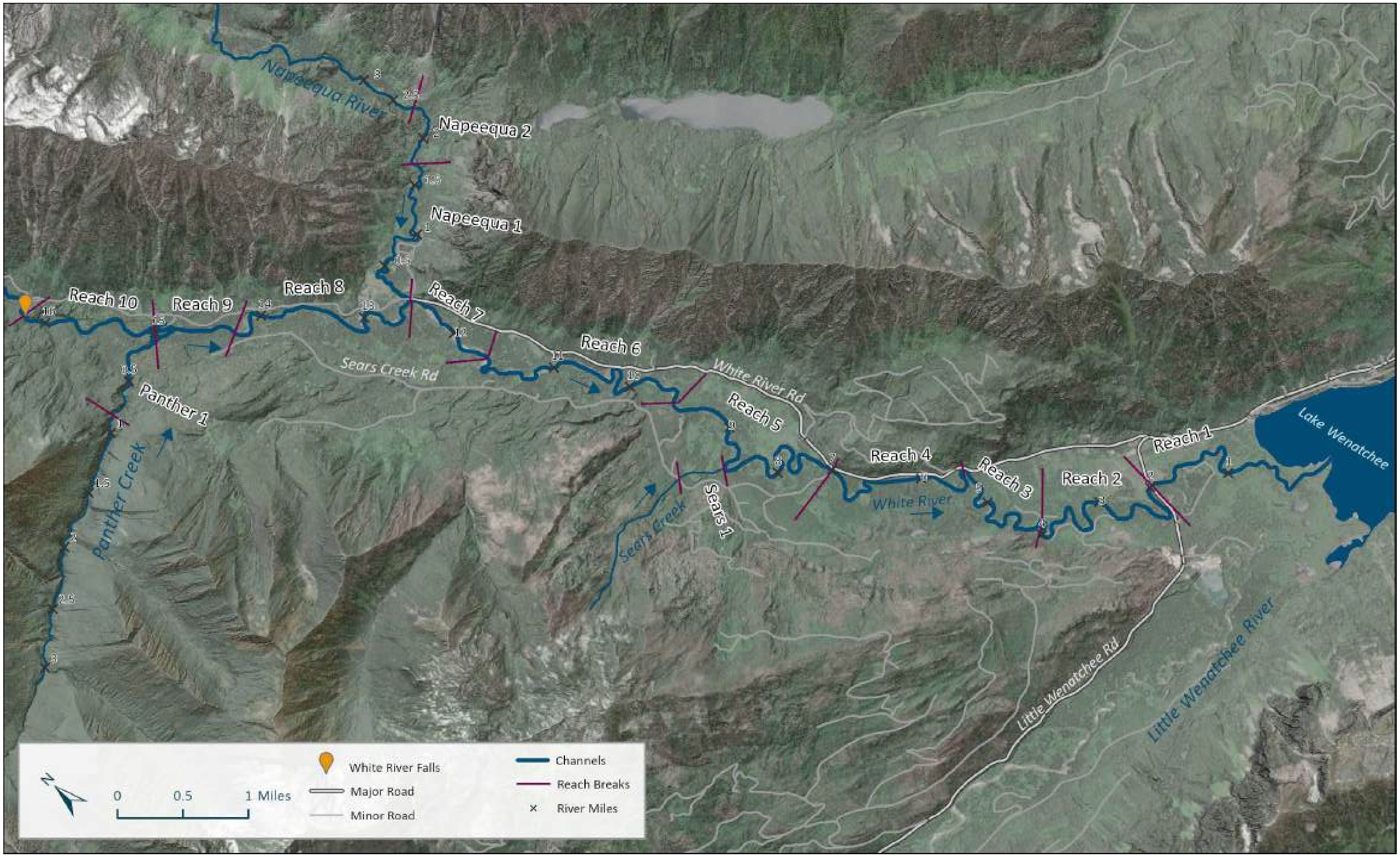

Figure 2. Overview of the assessment area.

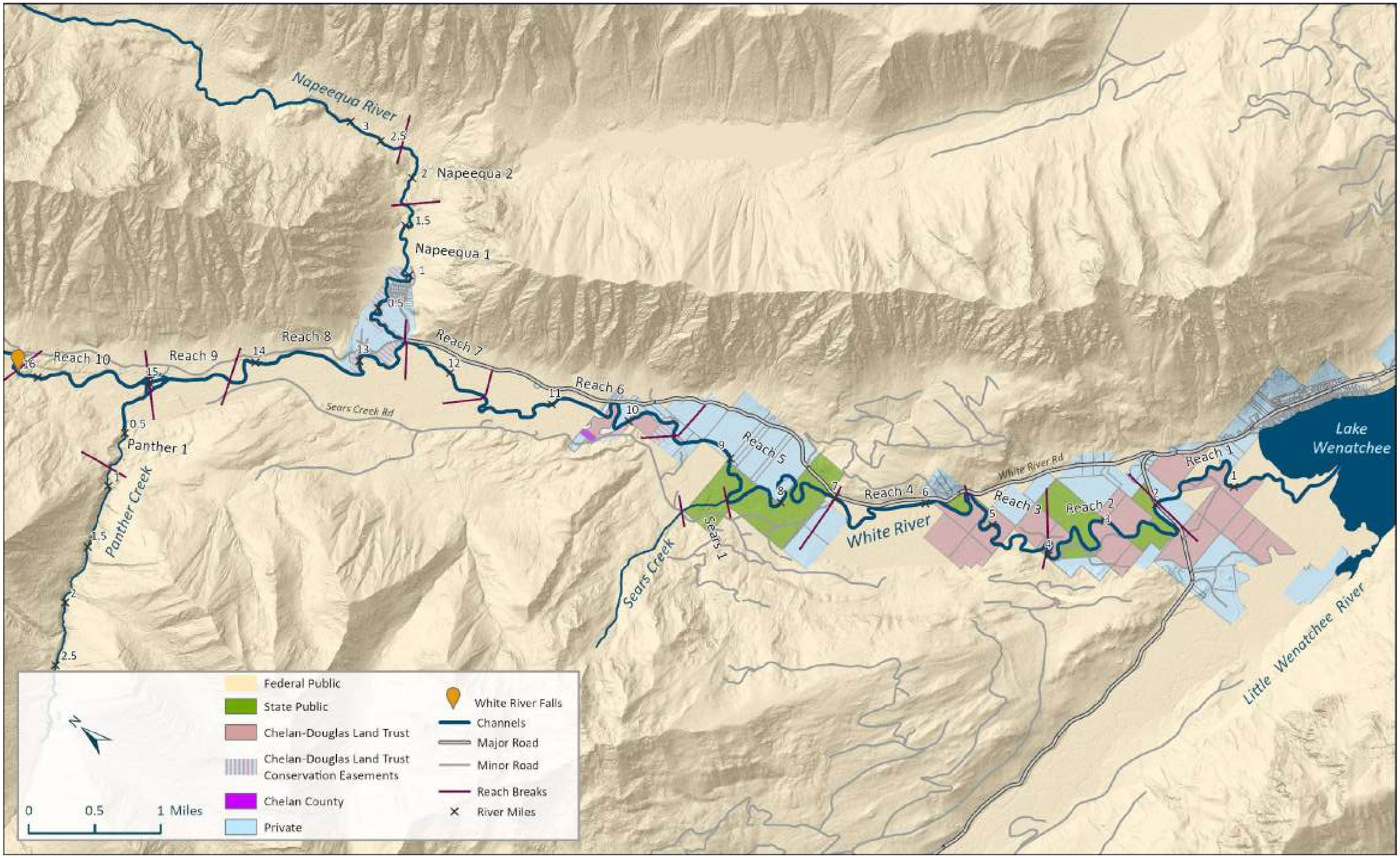

Figure 3. Land ownership in the assessment area.

2.2 SALMONID USE AND STATUS

The White River currently supports anadromous runs of Upper Columbia River (UCR) spring Chinook Salmon, UCR steelhead trout, UCR Bull Trout, Sockeye Salmon, and kokanee salmon (UCRTT, 2021; UCUT 2019). UCR spring Chinook Salmon are classified as endangered (listed in 1999), UCR steelhead trout are classified as threatened (most recently classified in 2006), and UCR Bull Trout are classified as threatened (listed in 1998).

Within the assessment area of White River (RM 0-17), the primary focal species for restoration efforts for Yakama Nation include spring Chinook Salmon, steelhead trout, and Bull Trout. A map showing the distribution of these species within the basin, which also shows the extent of reaches used in the assessment, is included in Figure 4.

2.2.1 Spring Chinook

Spring Chinook (*O. tshawytscha*) were listed as endangered under the ESA in 1999 (NOAA, 1999). Adults typically return to the Wenatchee basin in May, and spawning occurs from late July through September, with the peak in August (Chapman et al., 1995). Eggs are very sensitive to changes in oxygen levels and percolation, both of which are affected by sediment deposition and siltation in the redd (Peven et al., 2004) Fry emerge in the spring, which coincides with the rising hydrograph. Fry are extremely vulnerable in these systems when they emerge, because their swimming ability is poor and flows are high. Near-shore areas with eddies, large woody debris, undercut tree roots, and other cover are very important for post-emergent fry (Healy, 1991; Hillman & Miller, 1989). Older juveniles (Age-1) often utilize deeper pools with resting cover in mainstem habitats more than post-emergent individuals (Healy, 1991; Peven et al., 2004).

Spring Chinook use the White River for spawning and rearing. Redd surveys in the White River have occurred between 1989-2023, with an average of 32 redds observed per year (Hillman et al. 2024). A map of past surveyed redd locations between 2011 and 2016 is included in Figure 6. Most spawning in the White River occurs upstream of the confluence with the Napeequa River in the upper portion of the assessment area (Reaches 8 - 10). Rearing is assumed to occur throughout the project area, including in the lower reaches (WDFW, 2024). Spring Chinook may outmigrate from their natal systems either as sub-yearlings, in the late summer to early fall only a few months after emerging, or as yearlings having reared for one year in freshwater before out-migrating. Yearlings in the White River appear to outmigrate in March and April, whereas subyearlings outmigrate between June and November (Healy, 1991; Peven et al., 2004). Based on juvenile outmigration monitoring efforts between 2005-2023, Hillman et al. (2024) suggest around 50-60% of the juvenile spring Chinook outmigrate as subyearlings from the White River, on average. Hillman et al. (2024) suggest density dependence may be a factor in smolt survival within the Wenatchee River basin.

2.2.2 Steelhead trout

Steelhead (*Oncorhynchus mykiss*) were originally listed as endangered under the ESA in 1997 (NMFS, 1997) and later reclassified to threatened in 2006 (NMFS, 2006). These summer-run steelhead enter and ascend the Columbia River in June and July, arriving near their spawning grounds nine to eleven months prior to spawning (Figure 5). Adult steelhead returning to the Upper Columbia typically overwinter in the mainstem Columbia or larger tributaries. Monitoring within the Wenatchee basin suggests that adult steelhead migration is bimodal, with some migrating through the lower Wenatchee and passing Tumwater Dam in the late summer / autumn of the year before spawning, and others migrating past Tumwater Dam in the winter/spring immediately prior to spawning. Spawning typically occurs March through June, peaking in April (Upper Columbia Salmon Recovery Board, 2007). As with other salmonids, egg survival is highly sensitive to intra-gravel flow and temperature (Peven et al., 2004) and is especially sensitive to siltation earlier in the incubation period. Fry emerge from the redds six to ten weeks after spawning (Peven et al., 2004).

Age-0 juveniles spend their first year primarily in shallow riffle habitats, feeding on invertebrates and utilizing overhanging vegetation and undercut banks for cover (Hillman & Miller, 1989; Moyle, 2002). Older juveniles typically prefer faster water including riffles and glides over cobble and boulder substrate. Juveniles out-migrate between ages one and three, although some hold over and display a resident life history form (i.e., rainbow trout). Steelhead smolts begin migrating downstream from natal freshwater rivers around March (Chelan County & Yakama Nation, 2004; Peven et al., 2004).

Minimal summer steelhead spawning and rearing has been documented in the White River assessment area. A rotary screw trap has operated on the White River between 2007-2023, with a range of 0 – 14 (average = 5) juvenile steelhead collected in the trap during that period (Hillman et al. 2024). Spawning escapement for steelhead in the White River has been estimated since 2004, with a maximum of 17 individuals estimated in the White River in 2016. Most years record no escapement into the White (Hillman et al. 2024). A map of past surveyed redd locations is included in Figure 6, which shows a single documented redd in the Napeequa River. Note that redd surveys, especially for steelhead redds in the spring, is challenging due to poor visibility caused by the naturally turbid water.

Figure 4. Distribution of Chinook, steelhead, and Bull Trout in the White River basin. Source: Upper Columbia Salmon Recovery Board data portal, accessed Fall 2024.

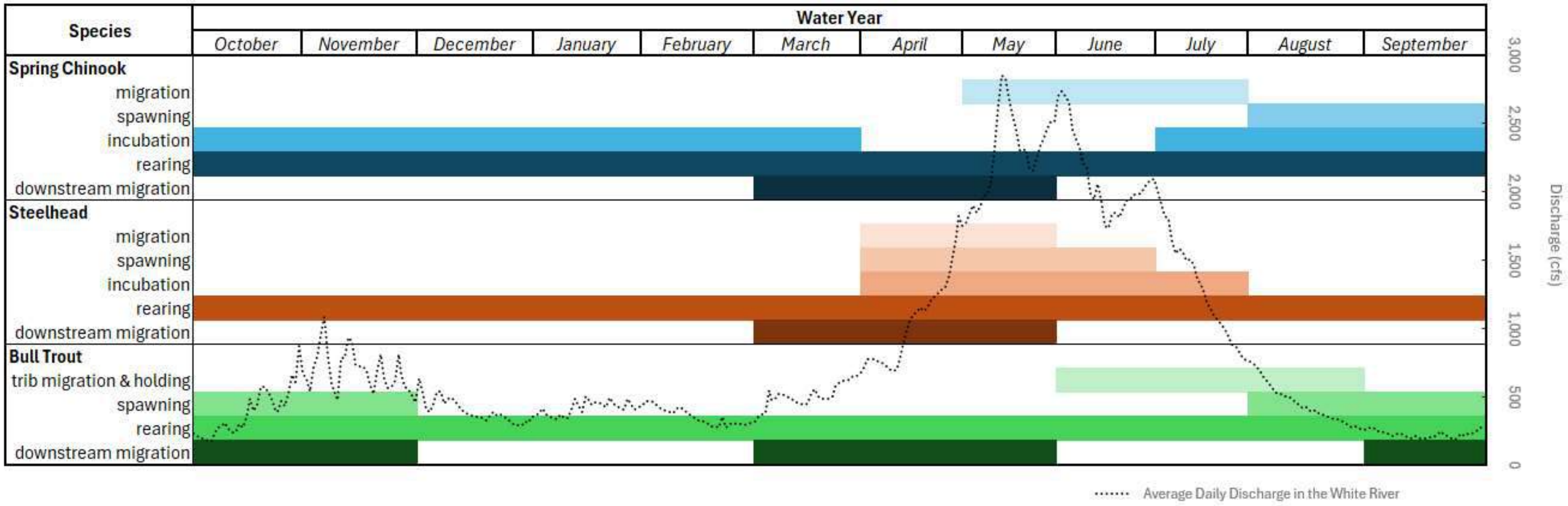

Figure 5. Summary of life history timing of Spring Chinook, Steelhead, and Bull Trout in the White River, overlaid on an annual hydrograph depicting mean daily discharge from the period 2003 – 2023 in the White River USGS Gage 12454000 near Plain, WA. (Life history references cited in species description sections 2.2.1 - 2.2.3).

2.2.3 Bull Trout

Lake Wenatchee supports an adfluvial Bull Trout (*Salvelinus confluentus*) population that spawns in both the White and Little Wenatchee rivers, with spawning and rearing occurring in the White River, including within the assessment area. Bull Trout were listed as threatened under the ESA in 1999 (U.S. Fish and Wildlife Service, 1999).

Bull Trout may exhibit both resident and migratory life-history strategies (Rieman & Mclntyre, 1993). Resident Bull Trout complete their life cycles in the tributary streams, such as the White River, in which they spawn and rear (Figure 5). Compared to other salmonids, Bull Trout have more specific habitat requirements that appear to significantly influence their distribution and abundance. Critical parameters include water temperature, cover, channel form and stability, valley form, spawning and rearing substrates, and migratory corridors (U.S. Fish and Wildlife Service, 1999).

Bull Trout normally reach sexual maturity in 4 to 7 years and can live 12 or more years. Bull Trout in the Columbia basin typically spawn August to November during periods of decreasing water temperatures. Redd surveys in the White River and surrounding streams indicate a majority of spawning occurs in August and October (Chelan County & Yakama Nation, 2004; Nelson et al., 2008; U.S. Fish and Wildlife Service, 1999; WDFW, 2024). Preferred spawning habitats are generally low gradient reaches, or in areas of loose, clean gravel in higher gradient streams (Fraley & Shepard, 1989), and where water temperatures are 5 to 9° C (41 to 48° F) in late summer to early fall (Goetz, 1989). Spawning areas are often associated with cold-water springs, groundwater infiltration, and are typically the coldest systems in a given watershed (U.S. Fish and Wildlife Service, 1999).

Bull Trout egg incubation can last between 100–200 days, and juveniles remain in the substrate for a period after hatching. Fry normally emerge from the gravels from early April through May, depending upon water temperatures and timing of increasing stream flows (U.S. Fish and Wildlife Service, 1999). Downstream migration of Bull Trout in the Wenatchee basin has been shown to be bi-modal, with one in the spring and one in the fall (Chelan County & Yakama Nation, 2004).

Bull Trout have been recorded spawning and rearing within the White River assessment area (WDFW, 2024). Rearing has been observed in roughly the lower six miles of the White River. Spawning has been documented from around RM 6 upstream to the confluence with Panther Creek. A map of past surveyed redd locations is included in Figure 7.

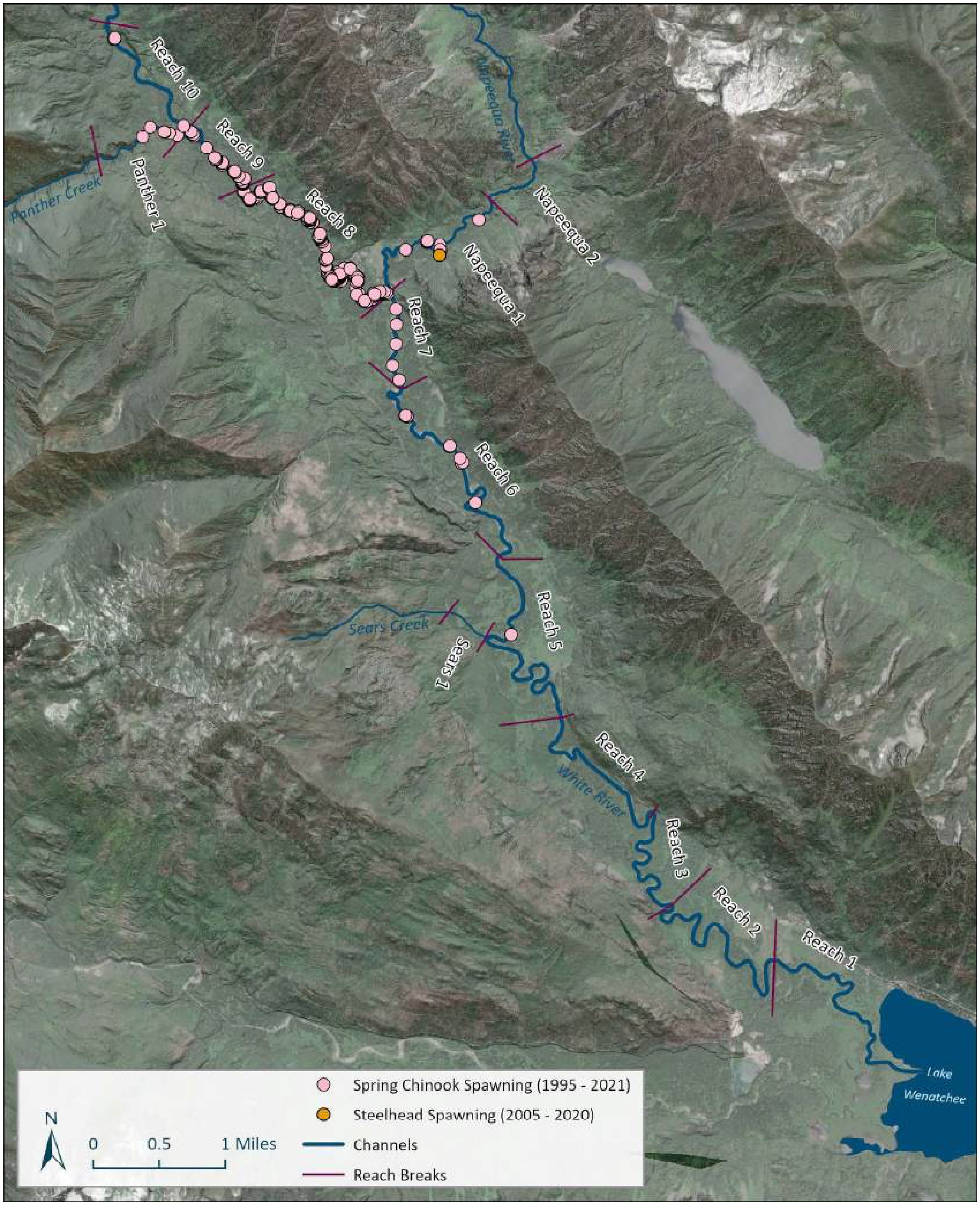

Figure 6. Chinook and steelhead redd locations. Source: Upper Columbia Salmon Recovery Board data portal, accessed Fall 2024.

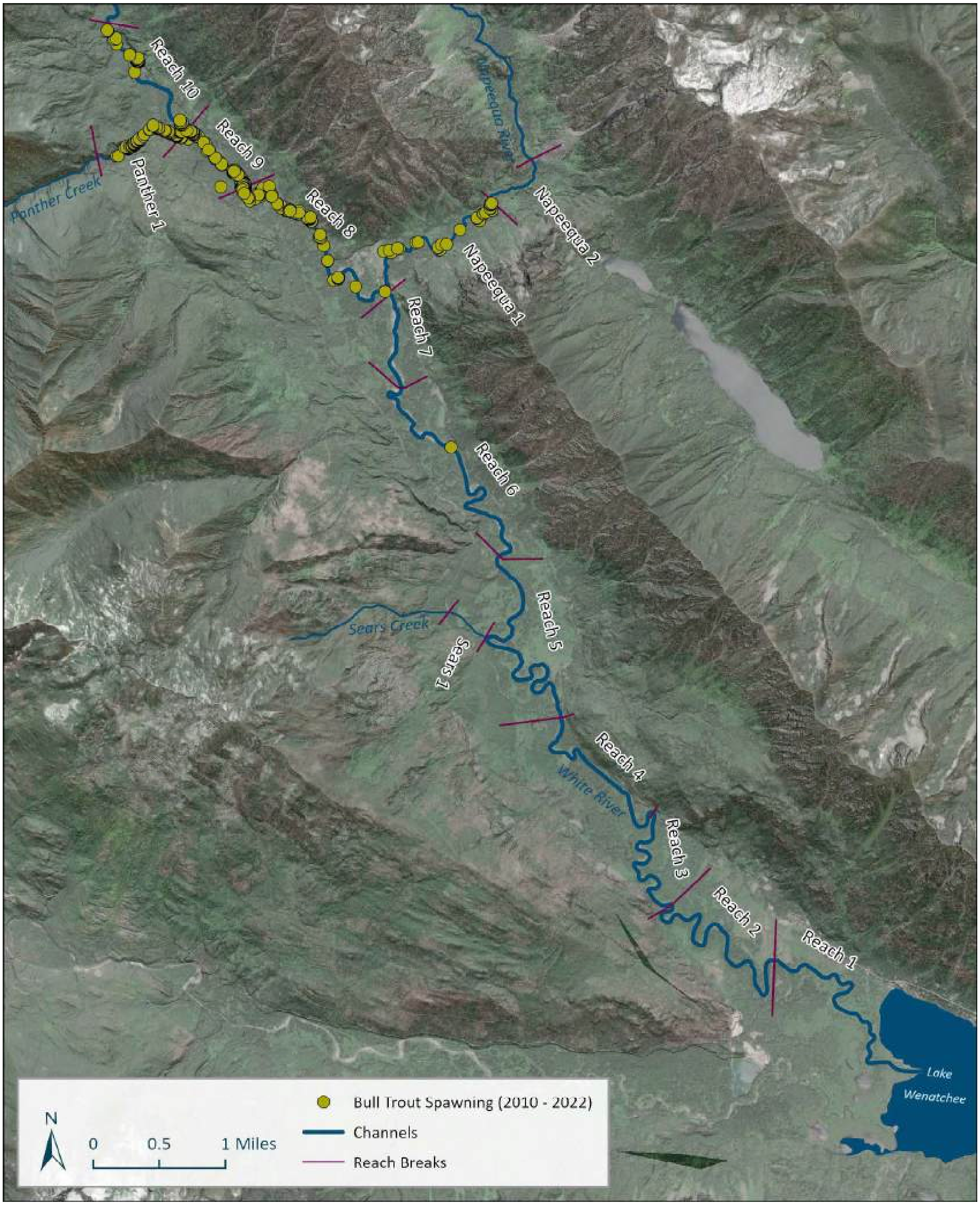

Figure 7. Bull Trout redd locations, years 2010-2022. Source: Upper Columbia Salmon Recovery Board data portal, accessed Fall 2024.

2.2.4 Other species

The White River supports a range of other salmonids, including sockeye salmon (*Oncorhynchus nerka*) and their adfluvial variant kokanee. The lower five miles of the White River is a primary area for spawning and some also spawn in the Napeequa River (Chelan County & Yakama Nation, 2004; WDFW, 2024). Coho salmon were historically present in the study area, but were extirpated from the Upper Columbia basin by the end of the 20th century. Reintroduction efforts by the Yakama Nation in the Upper Columbia, including in the Wenatchee Basin, are ongoing.

Other species, such as the Pacific Lamprey (*Entosphenus tridentatus*), have a limited known distribution in the Wenatchee subbasin (BioAnalysts Inc., 2000). The information available is anecdotal and may be confounded by the presence of river lamprey. Historically, Pacific Lamprey were likely widespread throughout the basin, including in the large upper basin tributaries (Chiwawa, White, and Little Wenatchee rivers, and Nason Creek). Today, Pacific Lamprey have documented occurrences in the Wenatchee River system downstream of Tumwater Dam (river mile 49.6) and Pacific Lamprey have been observed in the lower Wenatchee River near the town of Leavenworth (Carlson et al., 2004). The Tumwater dam is a significant barrier to Pacific Lamprey, however recent reintroduction efforts mean some Pacific Lamprey larvae may be present in areas upstream of the dam (BioAnalysts Inc., 2000; Grote & Lampman, 2024).

Resident fish are also present in the White River. Species include Westslope Cutthroat (*Oncorhynchus clarkii lewisi*), Eastern Brook Trout (*Salvelinus fontinalis*), Sculpins (*Cottoidea sp*.), Northen Pike Minnow (*Ptychocheilus oregonensis*), Redside Shiner (*Richardsonius balteatus*), Mountain Whitefish (*Prosopium williamsoni*), and Sucker (*Catostomus sp*.) (Chelan County & Yakama Nation, 2004).

2.3 GEOLOGY AND SOILS

2.3.1 Geology

The White River is located on the eastern flank of the North Cascades physiographic province which extends from southern British Columbia to Snoqualmie Pass in Washington. The North Cascades have been shaped by structural deformation, volcanism, glaciation, and watershed evolution, which continue to influence the geology and topography of the region (Brown, 1987; Hammond, 1979; R. B. Miller et al., 2016). The North Cascades physiographic province consists of several distinct geologic terranes, including the Nason Geologic Terrane which underlies most of the White River watershed (Tabor et al., 1987). The Nason Terrane is bounded on the east by the Leavenworth Fault, which bisects Lake Wenatchee southeast of the White River watershed and separates the Nason Terrane from the topographically lower Chiwaukum Graben. An additional fault trending approximately NW-SE crosses the mouth of Panther Creek and follows the valley bottom to the southeast until the mouth of the Napeequa River, where it trends approximately due east into Chiwawa Ridge. The Nason Terrane is primarily composed of high-grade metamorphic rocks from the Late Mesozoic Era (252 – 66 million years ago (Ma)), with several Late Mesozoic igneous intrusions. The primary metamorphic rocks include the Chiwaukum Schist and banded gneiss formations, which are derived from fine-grained marine sedimentary rocks which underwent two episodes of regional metamorphism during the Late Mesozoic (Tabor et al., 1987). Rocks of the Nason Terrane were uplifted beginning as early as 50 Ma during the Tertiary Period (66-2.6 Ma).

During the Quaternary Period (2.58 Ma to present), earth surface processes including glaciation, landslides, and fluvial processes have generated and deposited considerable amounts of unconsolidated sediments in the White River watershed. These sediments now occupy the valley floors and hillslope toes. Glacial processes during the Pleistocene (2.6 Ma – 11 Ka) Ice Age contributed significantly to the modern topography and sediment of the White River basin. Six major glacial cycles have been documented in the upper Wenatchee Basin between 12,500 and 165,000 years before present (Porter & Swanson, 2008). Alpine glaciers originating at higher elevations in the North Cascade Range moved downslope, eroding considerable bedrock and carving out the White River valley into its present U-shaped form. Substantial glacial till and outwash deposits generated during glacial retreat are present within the White River watershed, including the assessment area (Tabor et al., 1987). The glacial moraine at the outlet of Lake Wenatchee responsible for impounding the lake is a terminal moraine from the last major glacial retreat around 12,000 years ago. A surficial geology map is included in Figure 8.

2.3.2 Soils

The soil in the White River watershed is derived from varied sources. Soils on the hillslopes adjacent to the assessment area are derived from erosion of the underlying bedrock and draped colluvial deposits, as well as aerial inputs of volcanic ash from Holocene eruptions of the Cascade volcanoes including nearby Glacier Peak as well as more distant volcanoes such as Mount St. Helens and Mount Mazama (Beget, 1982; Natural Resources Conservation Service, 2007). The soils of the valley floor in the assessment area are derived from glacial outwash, colluvial inputs from adjacent hillslopes, fluvial deposits, and also aerial inputs of volcanic ash from Holocene eruptions. A map of the soils in the assessment area, created from soils information from the Natural Resources Conservation Service (2007), is provided in Figure 9. Downstream of approximately RM 9.5, valley bottom soils are dominated by low-slope (0-2%) thick floodplain silt loams derived from relatively recently accumulated alluvium, and alluvium mixed with volcanic ash. The soil in this region ranges from somewhat to very poorly drained. Between approximately RM 9.5 and RM 14.25, and along the Napeequa River, valley bottom soils are primarily somewhat poorly drained loamy fine sands derived from accumulated alluvium. A large pocket of silt loam soils is located across the valley from the confluence of the Napeequa and White Rivers. Upstream of RM 14.25, fine somewhat excessively drained stony sandy loam floodplain soils, also derived from alluvium, transition to well drained cobbly ashy fine sandy loam terrace soils derived from glaciofluvial deposits that contain a mantle of volcanic ash at the upstream end of the assessment area.

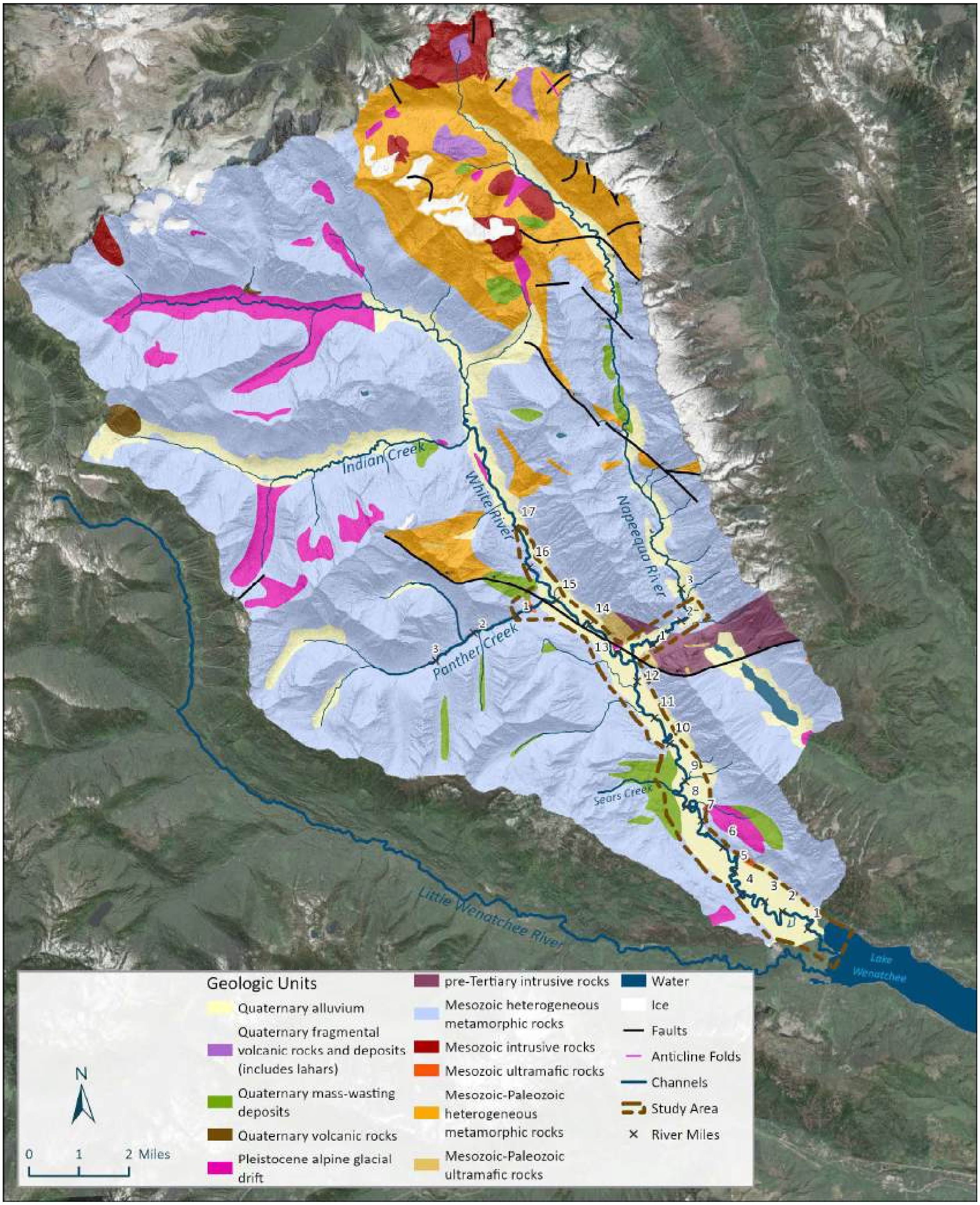

Figure 8. Map of surficial geology of the White River watershed (Derived from Tabor et al., 1987). Date ranges of geologic time periods listed are as follows: Quaternary (2.5 Ma – Present), Pleistocene (2.6 Ma – 11 Ka), Tertiary (66 – 2.6 Ma), Mesozoic (252 – 66 Ma), Paleozoic (540 – 252 Ma).

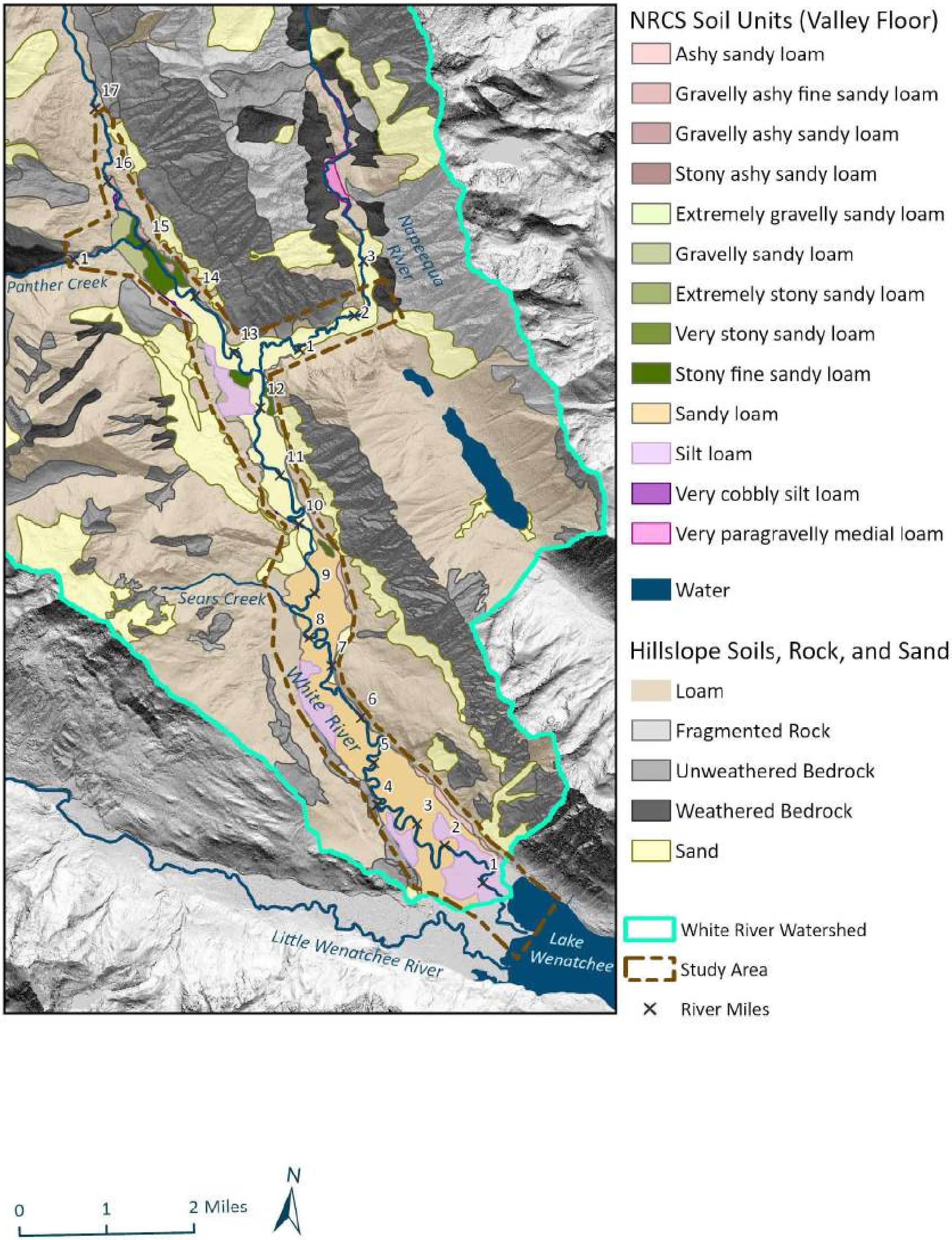

Figure 9. White River soil units (derived from Natural Resources Conservation Service, 2007).

2.4 HISTORICAL FORMS AND PROCESSES

Historical conditions are considered to be those that would have existed prior to Euro-American settlement. Historical conditions represent those to which native species such as salmonids were presumably well-adapted, prior to the anadromous salmon population crashes that ensued after Euro-American settlement and the related anthropogenic disturbances that increased on the landscape over the last two hundred years. In many cases, restoration to historical conditions is not possible or appropriate considering modern infrastructure and existing hydro-geomorphic regimes. However, historical conditions nevertheless provide a reference point to help determine how habitats and processes evolve in this system and help inform the identification of restoration objectives. Although there is little available written information about conditions of the White River prior to Euro-American settlement, field observations combined with USGS records and maps, modern landforms, underlying geology, and glacial cycles can provide some theories on historical channel process. This section provides a brief summary of presumed historical conditions of the White River assessment area.

Prior to Euro-American settlement in the 1800s, the forests of the White River watershed were likely dominated by mature conifers of mixed composition and seral stage, with diverse mixed coniferous and deciduous vegetation in floodplains and along stream channels. Forest heterogeneity would have provided resilience to natural disturbances. Forest composition and tree size have since been altered by widespread logging and fire suppression within the upper Wenatchee basin, including the White River (USFS, 2022). Small pockets of old-growth western redcedar (*Thuja plicata*) and Douglas-fir (*Pseudotsuga menziesii*), along with massive stumps from logged old-growth trees of these species, remain on the White River floodplains and terraces (Figure 10). These pockets of old growth provide evidence of both historical forest conditions and past forest management practices.

Figure 10. Left: Remnant old-growth western redcedar on White River floodplain (August 2024). Right: Western redcedar stumps on the White River floodplain near RM 6.92 (August 2024).

In the past, the presence of abundant large old-growth conifers would have had a profound impact on river channel processes and morphology. Noted influences of effective large wood (old-growth) on river corridors include increased channel complexity (e.g. anabranching and hydraulic heterogeneity) and dynamism, enhanced floodplain formation and connectivity, local sediment storage and retention, and increased availability of quality habitat for salmonids and other species (Abbe & Montgomery, 1996; Bilby, 1984; Cederholm et al., 1997; Wohl et al., 2019). Downed trees would have been stored within the channel as individual pieces or within large channel-spanning accumulations, at a higher frequency than at present (Fox & Bolton, 2007). Large old-growth trees have the capacity to span the channel in the assessment area as an individual piece, unlike the smaller second-growth forests that line most of the assessment area today. Historical old-growth riparian forests and the associated large in-channel wood and log jams would have prolonged and magnified the effects on geomorphic process (e.g. scour and deposition), habitat complexity, hydraulic complexity, stream shade, nutrient contributions, soil stabilization, and floodplain moisture retention. It is assumed that prior to logging in the White River assessment area, the historical channel had a plentiful recruitment source of effective large wood occupying its floodplains, terraces, and hillslopes.

The historical White River from White River Falls at RM 16.2 to Panther Creek at RM 15 most likely had a similar single-thread planform with low sinuosity due to valley confinement constraints. However, larger instream wood would have provided more instream structure, more complex flow hydraulics, greater in-channel and floodplain sediment storage, and more abundant and complex cover habitat for aquatic species.

Downstream of the Panther Creek confluence, the White River valley widens and channel confinement is no longer a constraint. During the time of glacial retreat (~12,000 years ago), increased hydrology and sediment regimes likely produced a dynamic and sometimes multi-threaded system. In the middle section of the assessment area prior to European settlement impacts, historical channel form was likely more sinuous and potentially shifted between single- and multi-thread (e.g. anastomosing), depending on gradient and sediment supply. Historically, the old-growth forest contributions and lack of forced confinement would have produced active lateral migration, island development, connected off-channel habitat, higher sinuosity, and increased floodplain connectivity.

Downstream of Sears Creek at ~RM 8.56, the White River channel has straightened considerably compared to the historical planform. Historical meander scars visible in recent LiDAR (2007 to 2020) suggest a meandering channel form similar to those currently found both upstream and downstream of this straightened section, with meanders that often occupied the entire valley bottom. As with upstream sections, greater quantities of old-growth large wood pieces in this downstream portion likely would have created complex hydraulics with a higher amount of floodplain connectivity within its single-threaded meandering planform.

The historical lower Napeequa River (Napeequa RM 0 – 1.75), which is currently confined by bank hardening and other infrastructure, would have occupied its large alluvial fan, alternating confluence locations and contributing sediment and large wood to the White River.

Review of historical photo sets provides an opportunity to evaluate channel planform and location changes of the White River since 1957 (Mayfield et al., 2022). However, by 1957, logging activities in the White River valley had already been underway for decades. Roads and bridges that impose confinement constraints on the channel today were constructed prior to 1957. The location of the mainstem White River was digitized from rectified historical aerial imagery from 1957, 1963, 1972, 1985, and 2023. Those channel locations are overlain for Reaches 1-5 (Figure 11) and Reaches 6-10 (Figure 12). This photo analysis identifies areas of continued channel simplification as a result of meander cutoffs and limits to lateral migration in unconfined and partially confined sections. For example, meander cutoffs related to channel straightening prior to 1957 are associated with bridge confinement at RM 7 and bank hardening along White River Road from RM 5.1 – 7.5 (Figure 13). Channel straightening in Reaches 4-5 occurred prior to 1957. However, Reach 6 and 7 underwent a series of neck cutoffs resulting in simplification between 1985 and 2023. The maps below also reveal areas where lateral migration has occurred. Lateral migration is more active in Reaches 3 and 8 compared to other reaches in the assessment area.

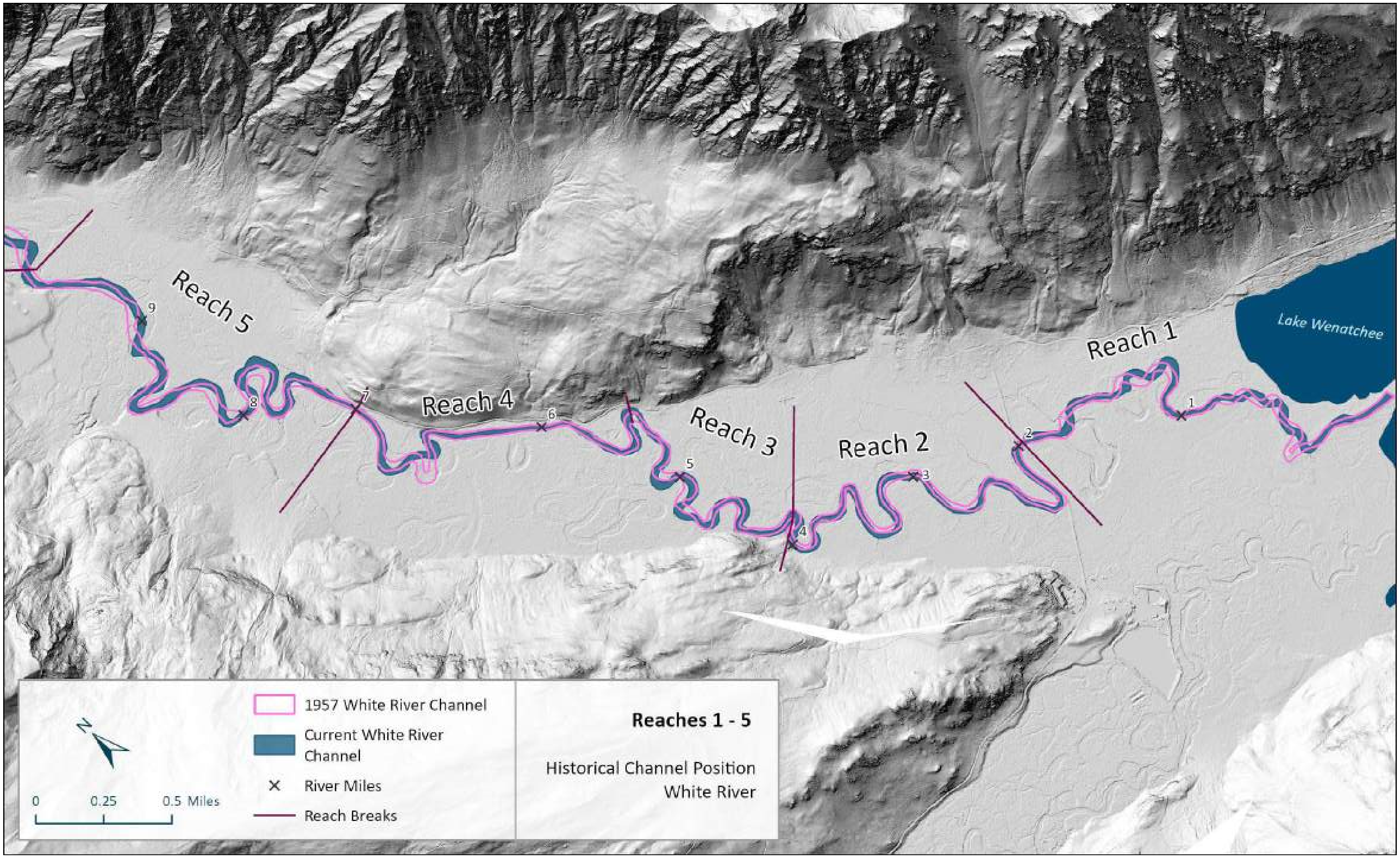

Figure 11. White River Reaches 1-5 showing the current channel alignment compared to the 1957 channel alignment, which is the oldest aerial photo series obtained for this study. Additional channel alignments from 1957 to present are shown at the reach scale in the reach sections (Section 3).

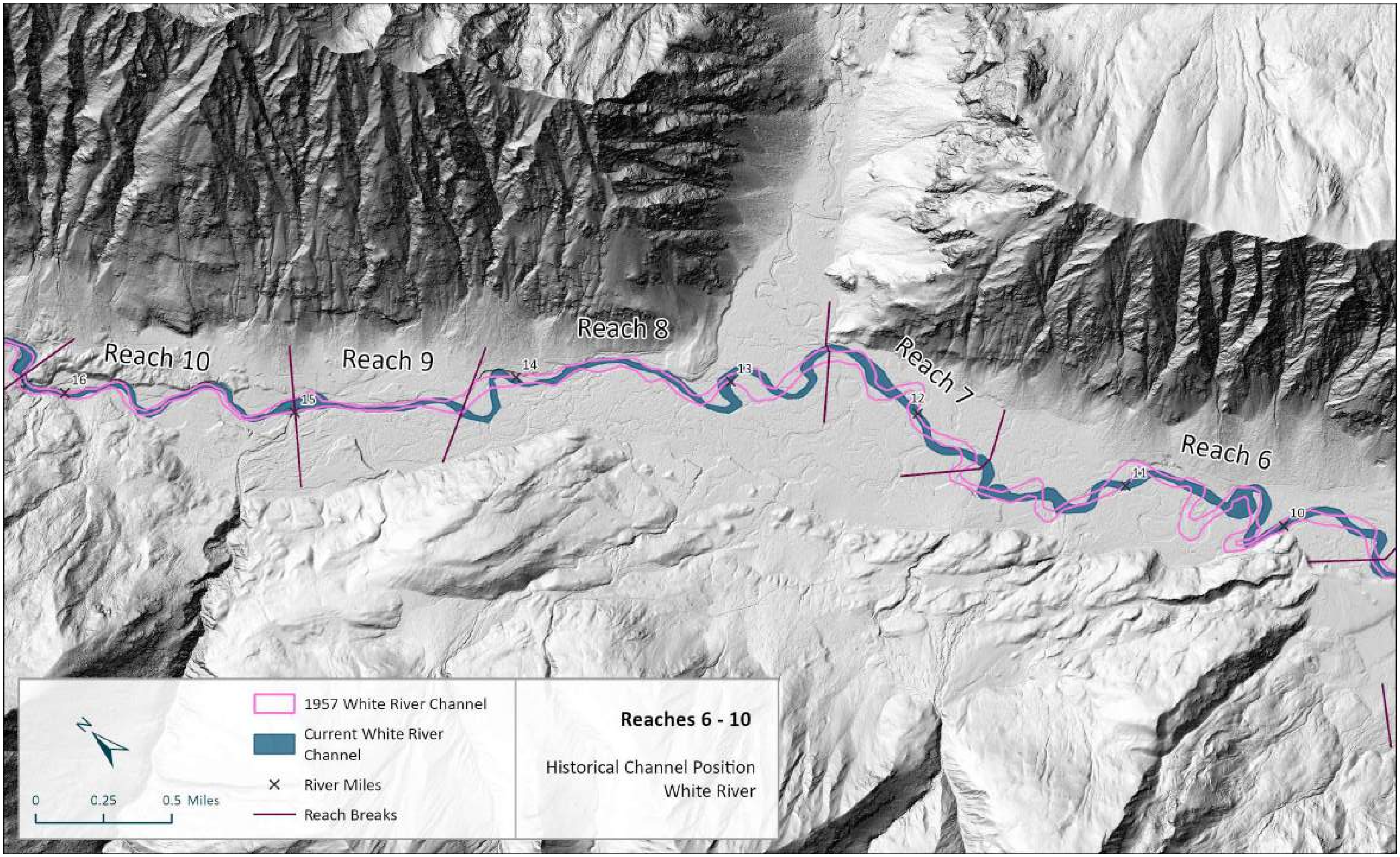

Figure 12. White River Reaches 6-10 showing the current channel alignment compared to the 1957 channel alignment, which is the oldest aerial photo series obtained for this study. Additional channel alignments from 1957 to present are shown at the reach scale in the reach sections (Section 3).

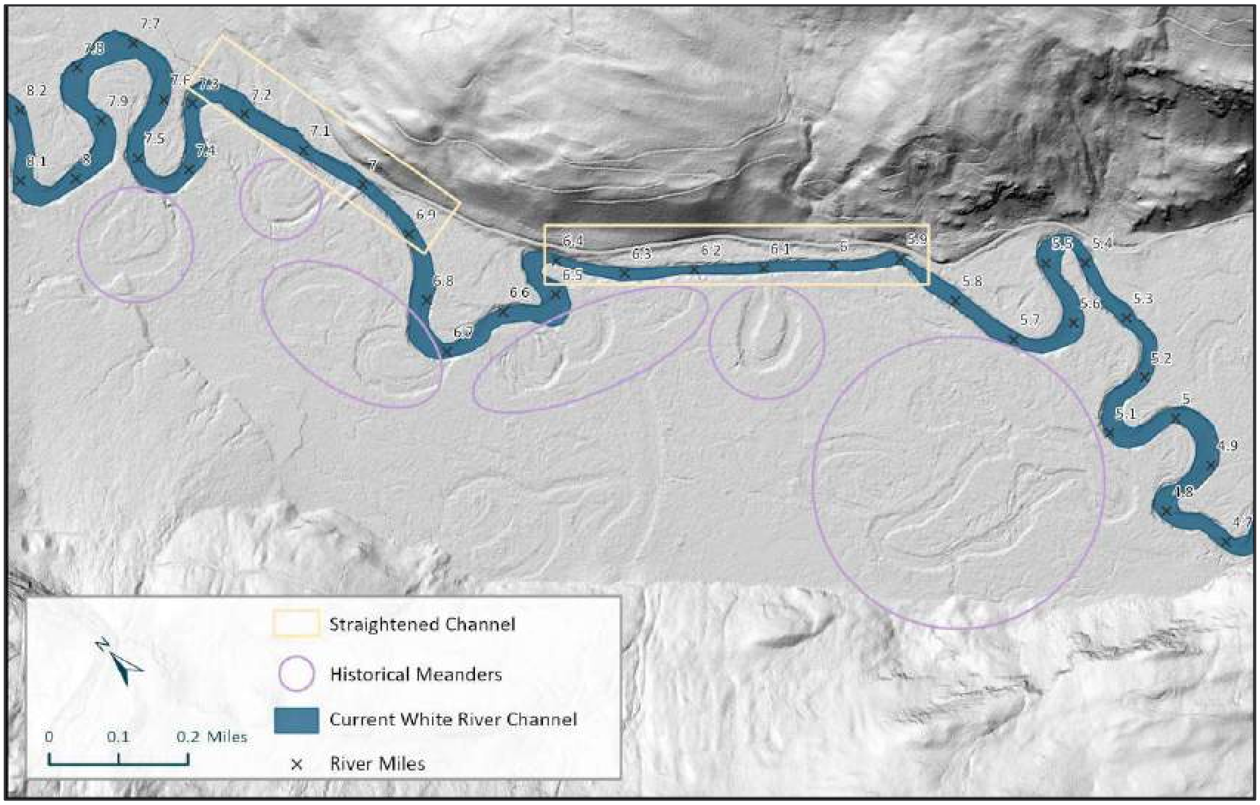

Figure 13. Meander neck cutoff scars between RM 5.1 and 7.5.

2.5 HISTORICAL HUMAN DISTURBANCES

Few archaeological sites have been identified within the White River watershed due to the limited cultural resource inventories. A variety of archaeological sites have been documented in the greater region. The Upper Wenatchee area is in the traditional homeland of the Wenatchi people, who refer to themselves as *snpəsqʷáwsəxʷ* (Kinkade, 1981; J. Miller, 1998; Ray, 1933, 1936; Scheuerman, 1982) and the winátŝapam (Beavert & Rigsby, 1975; J. Miller, 1998). The Wenatchi resided in temporary villages on the banks of the upper Wenatchee River and implemented a traditional economy based on a seasonal cycle of root digging, fishing, hunting, trapping, and berry picking (Scheuerman, 1982). By the late 19th century, non-native settlers arrived in the region and small lumber mills started springing up. Mill operations quickly expanded into large scale commercial endeavors and the area was extensively logged (Holstine, 1994; Roe, 1995). Logging activity greatly transformed the landscape and the arrival of fur trappers caused a significant reduction in local beaver population. This loss of beavers, which were key to maintaining wetlands, likely altered the area’s floodplain dynamics, impacting water storage and sediment processes (Andonaegui, 2001; Plummer, 1902).

Permanent Euro-American settlement began following the 1855 Treaty with the Yakama. This period marked a shift in land use and introduced activities such as grazing, small-scale logging, and the construction of infrastructure including boat ramps and hotels. General Land Office (GLO) notes dating back to 1906 show settlement along the White River between Lake Wenatchee and the Napeequa River (formerly North Fork White River) as well as a county road following the path of the present-day White River Road by the early 1900s (U.S. Department of the Interior, 1907).

Additionally, a "White River Ferry" is noted crossing the lower White River (Figure 14). The construction of the Great Northern Railroad in 1890 further promoted settlement and economic growth within the region, although the railroad itself did not extend into the White River basin. Construction of the railroad was primarily driven by timber harvesting, which was facilitated by the railway from the Wenatchee River, along what is now Highway 2, through Tumwater Canyon. Logging practices accelerated with splash damming, where logs were driven down rivers including Nason Creek and the Chiwawa River to sawmills in Leavenworth (Fenner, 1897; Roberts, 1996). Splash damming had profound impacts on river systems including flushing of large wood and sediment, and creating temporary barriers to upstream migration. Although log drives to Lake Wenatchee are credited with notably reducing in-stream large wood abundance (Herrera Environmental Consultants, 2014; Mariah Mayfield et al., 2022), it is unclear whether splash damming was implemented on the White River during the height of the regional timber harvest. No evidence of historical splash damming was observed during the summer 2024 surveys, and no mentions of splash damming specific to the White River were found in literature reviewed for this report.

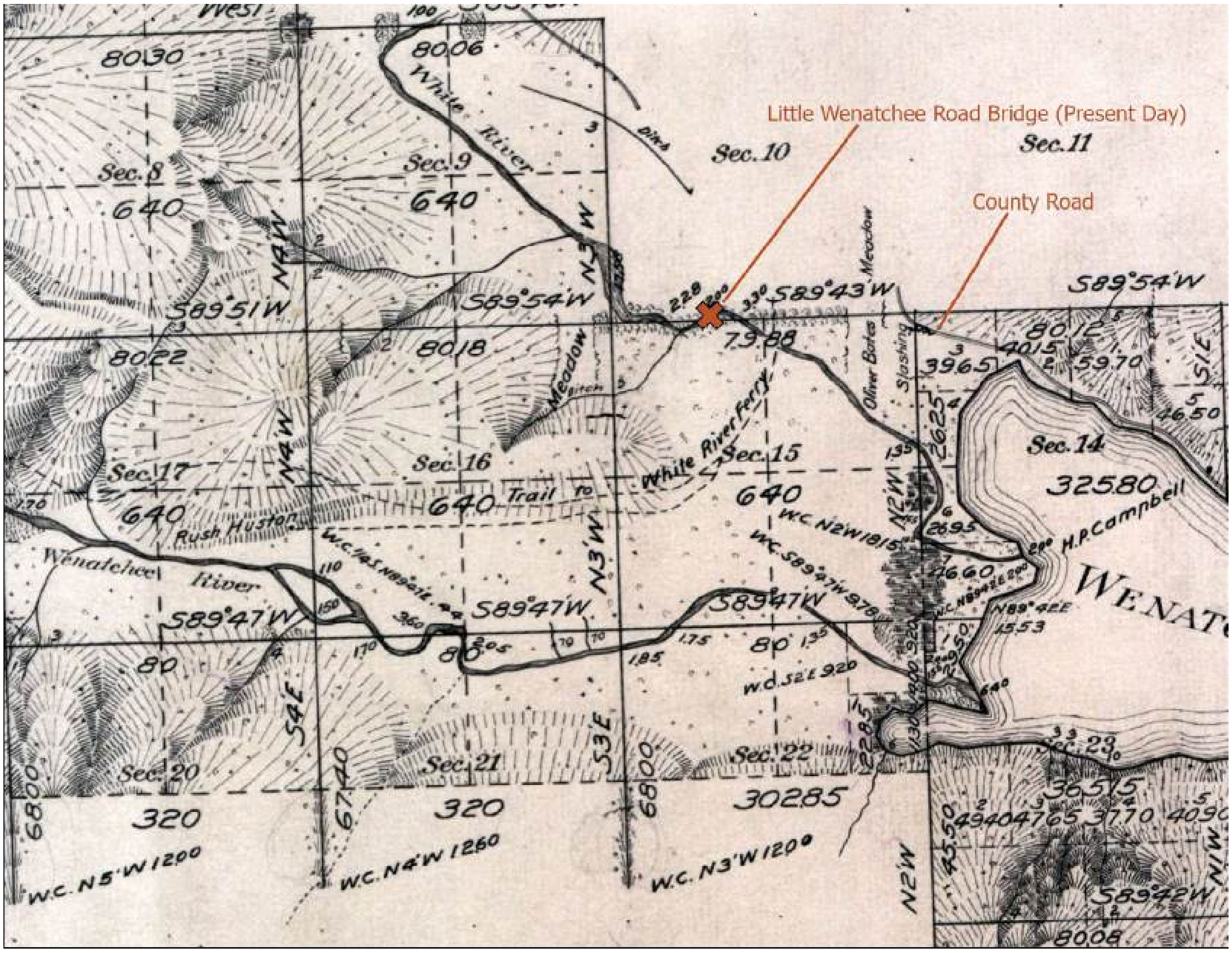

Figure 14. Annotated 1907 General Land Office map showing early settlement of the White River valley. Location of present-day Little Wenatchee Road Bridge is highlighted for spatial reference.

By the early 1900s, the lumber industry began to expand in the Wenatchee basin. In 1926, sawmills in Chelan County processed an estimated 80,000,000 board feet of lumber. Across Washington, trees over 100 years old remained the dominant age class until 1980 (Wadsworth et al., 1994). Timber harvests in the Wenatchee basin grew significantly by the 1950s and reached peak levels in the 1980s. Per reports from the USFS, extensive logging occurring on private land has significantly impacted the Upper Wenatchee River drainage. Although the White River basin had comparably "…little timber harvest overall" compared to elsewhere in the Wenatchee basin (USFS, 2003), approximately 63% of the riparian area in the lower White River watershed and 23% of the riparian area in the upper White River watershed was converted from old growth cedar forests to second growth forests consisting of densely-spaced even-aged trees and pastures (Mariah Mayfield et al., 2022), and disturbance from timber harvest in the White River assessment areas remains on the landscape. This was observed during the assessment in the form of logged stumps of old-growth conifers (Figure 15), abandoned logging roads through the western (river right) floodplain and still functioning roads on the east (river left) side of the valley, including bridges and valley-crossing roads, and through assessments of historical aerial imagery dating back to 1957. Recently logged surfaces on hillslopes within the assessment area are visible in historical aerial imagery from 1985, suggesting that widespread logging within the basin continued into the 1980s. Forest clearing on the valley floor concluded prior to 1957 with the exception of a portion of the river left floodplain from RM 4.2 – 5.2. The White River has been straightened against White River Road on river left throughout much of Reaches 4 and 5. The Sears Creek Road crossing at RM 7 laterally confines the White River and creates entrenchment of the channel in its current location. The channel was likely re-aligned and shifted toward river-left to accommodate Sears Creek Road and logging activities in reaches 8-9 (USFS, 1999, 2003).

Figure 15. Scar from cable logging of western redcedar in White River floodplain near RM 12.73 (August 4, 2024).

2.5.1 Fire Regime and Fire Suppression

Fire suppression efforts in the Upper Wenatchee basin have dramatically altered forest composition and function. Prior to the early 1900s, forests in the Upper Wenatchee were characterized by large fire-resistant trees within an open forest structure that experienced frequent, low intensity fires. Beginning in the early 1900s, fire suppression practices were implemented to preserve timber for harvesting. Since the conclusion of intensive logging in the 1900s, forests within the basin have shifted toward a younger, multi-layered, denser condition, composed of less fire-tolerant species, resulting in a modern forest that is more prone to higher-intensity fires than were historically common. Much of the White River basin is within a fire regime that experiences wildfires every 30 to 150 years or more (Mariah Mayfield et al., 2022; US Forest Service (USFS), 1999, 2003). Several large fires have occurred in the White River watershed in recent years including the Alpine Lake fire in 2023 (6,956 acres), the White River-Irving Peak fire in 2022 (11,110 acres), and the Sears Creek Fire in 2012 (654 acres) (Mariah Mayfield et al., 2022; *Washington Large Fires 1973-2023*, n.d.). Changes to the fire regime impact channel and floodplain processes in the White 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 a potential increase in hillslope instability and sediment inputs on recently burned surfaces.

2.6 EXISTING ANTHROPOGENIC FEATURES

Human-built features have the potential to influence or inhibit geomorphic and ecologic processes depending on their proximity to a channel and its floodplain. Human-built features include constructed components on the modern landscape such as levees, roads, bridges, culverts, irrigation structures or piping, buildings, riprap and other bank protection, and utility crossings. Figure ***17*** displays the mapped anthropogenic features within the assessment area. Reach-scale maps of these features are provided in the reach chapters in Section 3.

The portion of the study area upstream of RM 13 is located entirely on public land within the Wenatchee National Forest. Therefore, human-built features are limited to White River Road and its associated road culverts, and two developed campgrounds. Riprap is present intermittently along river-left banks where meander bends threaten to impinge upon White River Road, near homesites in close proximity to the White and Napeequa River channels, and at the bases of the bridges that cross the White River at RM 2 and RM 7 (Figure 16). These bridges are associated with road prisms that perpendicularly traverse the valley floor and floodplain of the White River. Another bridge at the mouth of the Napeequa confines the channel to a single location on the Napeequa alluvial fan.

A screw trap located at approximately RM 5.8 is used seasonally to monitor fish populations (Figure 16). Sheetpile installed on the river left bank just downstream of the RM 2 bridge protects an access road used to monitor a PIT tag station installed near RM 1.8 (Figure 19). A weir used for fish monitoring at approximately RM 1.65 acts as a grade control for the channel bed. Homes are located on floodplains sporadically from approximately RM 1 to RM 11, and ditches constructed to drain the floodplain in several locations downstream of RM 9 form a web that inhibits normal floodplain hydrology and likely influences seasonal recharge (Figure 18).

Figure 16. Left: Riprap protecting White River Road downstream of the Napeequa River confluence at RM 12.43 (August 3, 2024). Right: Screw trap located at approximately RM 5.8, viewed from mid-channel bar, looking toward river right bank (August 13, 2024).

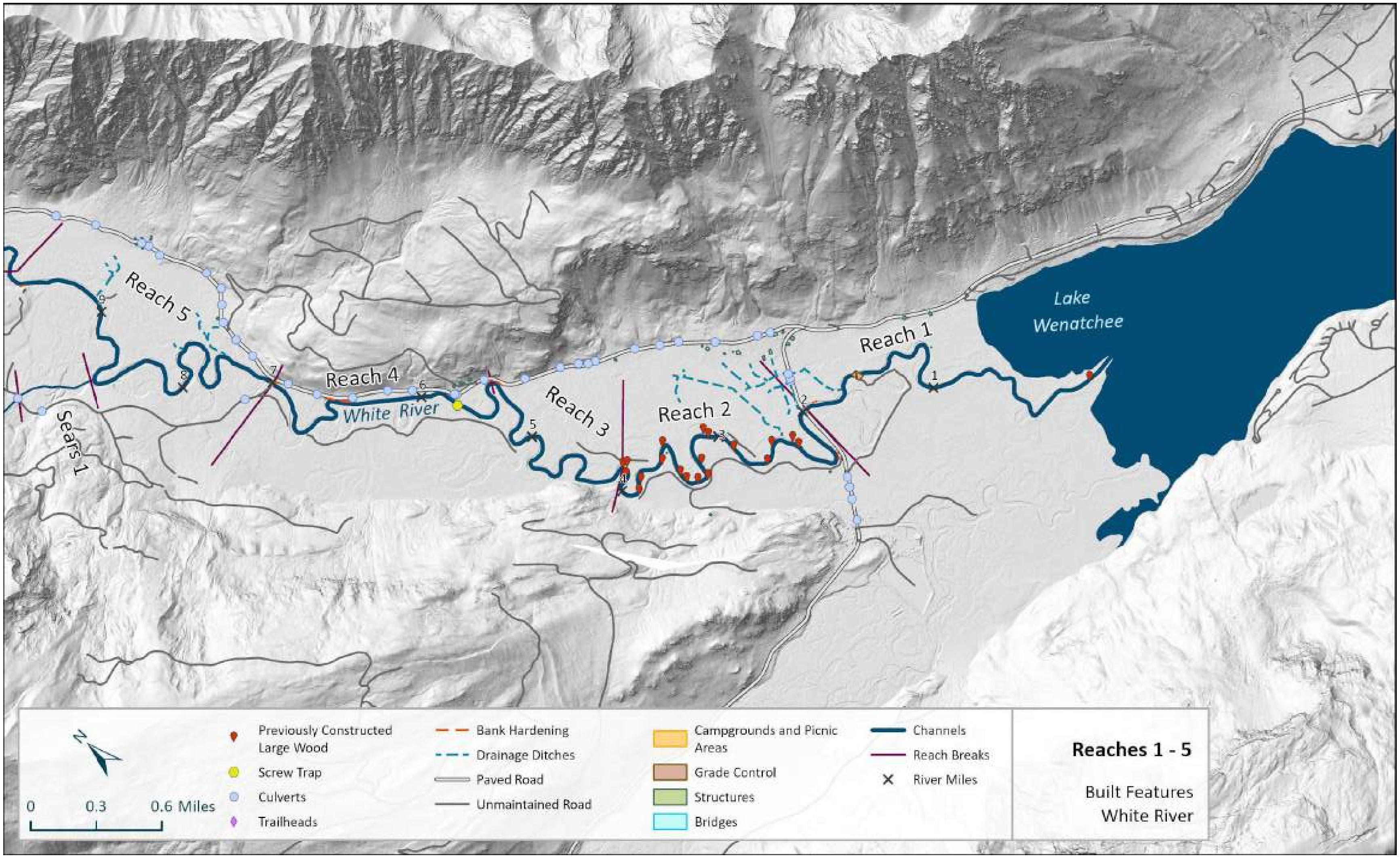

Figure 17. ***Anthropogenic features within Reaches 1 - 5. Features include a combination of features identified during field surveys, features from existing available datasets (e.g. roads), and features identified using aerial photos and LiDAR in GIS.***

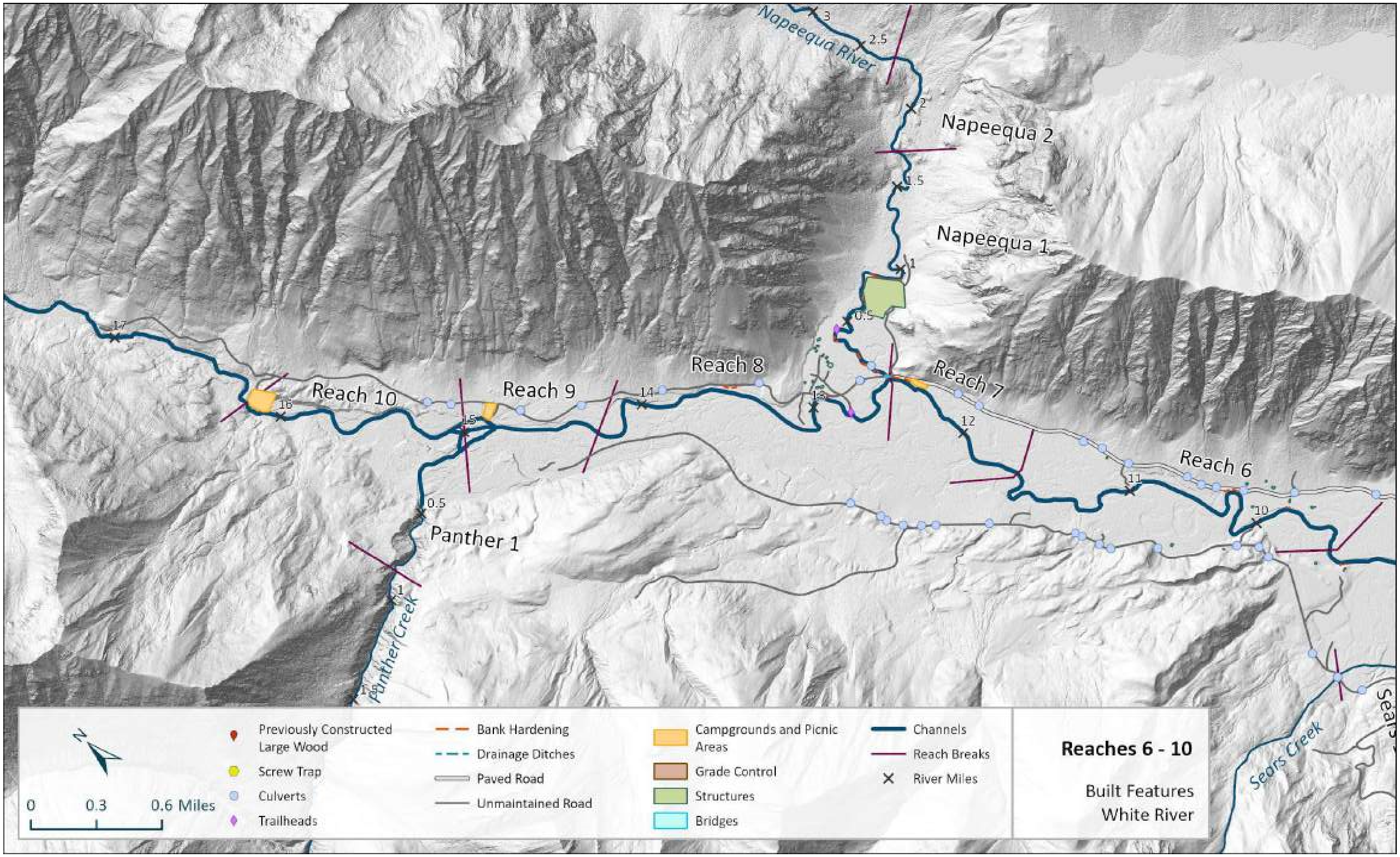

Figure 18. Anthropogenic features within Reaches 6 - 10 on the White River.

Figure 19. Left: Bridge and riprap over the White River at RM 7 (August 6, 2024). Right: Bridge and riprap crossing White River at RM 2 (August 15, 2024).

2.7 HYDROLOGY AND CLIMATE

2.7.1 Basin Characteristics

The White River flows approximately 26.7 miles from the southeast side of White Mountain in the Glacier Peaks Wilderness, WA (max elevation 8,620 feet) to its mouth at Lake Wenatchee (elevation 1,790 feet) (Carlson et al., 2004; USGS, 2022). The drainage area of the White River watershed is approximately 155 square miles, with a mean basin elevation of 4,660 feet above sea level (USGS, 2022). Significant tributaries include Foam Creek, Lightning Creek, Amber Creek, Thunder Creek, Indian Creek, Panther Creek, the Napeequa River, Canyon Creek, Sears Creek, and Siverly Creek. The White River flows into the west end of the 2,480-acre Lake Wenatchee and is the primary source of flow into the lake. The Little Wenatchee River lies south of the White River, also flowing into the west end of the lake. The broad floodplains of the two rivers connect for the lower approximately half mile upstream of the lake. The mainstem Wenatchee River flows out of the lake at its eastern end.

The White River gets its name presumably because of its milky white appearance, which occurs for much of the year and is most pronounced in spring and summer. This coloration is fine glacial silt that originates from glaciers high in the headwaters and remains easily suspended in the water column. The glaciers contributing to the upper Napeequa River include the Butterfly, Pilz, Richardson, and Clark Glaciers near Clark Mountain. There are also glaciers contributing to the upper mainstem White River including the White River Glacier and smaller pocket glaciers on the north slopes of Indian Head Peak and south slopes of Tenpeak Mountain (Thunder Basin). Observations during summer and fall field surveys revealed that the Napeequa contributes more turbid glacial meltwater than the mainstem White River. Lake Wenatchee, at 2,480 acres, appears to be a sink for the glacial silt, as the water downstream in the mainstem Wenatchee generally flows clear.

2.7.2 Climate

The Wenatchee River basin is in the eastern rain shadow of the Cascade Mountain range. The Cascade Mountain range's precipitation is attributed to warm air from the Pacific Ocean that cools as it flows east over the mountains, depositing heavy precipitation along the way. The White River is bordered on the northeast by the Entiat Mountains and the Wenatchee Mountains in the southwest. The headwaters of the White River originate in the Glacier Peak wilderness at a maximum elevation of approximately 8,620 feet, and flow south southeast into Lake Wenatchee, approximately 1870 feet above sea level. The summers in the area are dry and warm while the winters are cool and wet (Figure 20 and Figure 21). Much of the precipitation in the basin falls during the wet season between October and March. The high elevation headwaters receive considerably more precipitation than the mouth of the White River. Annually, the headwaters of the White River receive upwards of 94 inches of precipitation on average while the mouth at Lake Wenatchee receives an average of 37 inches (PRISM, 2024).

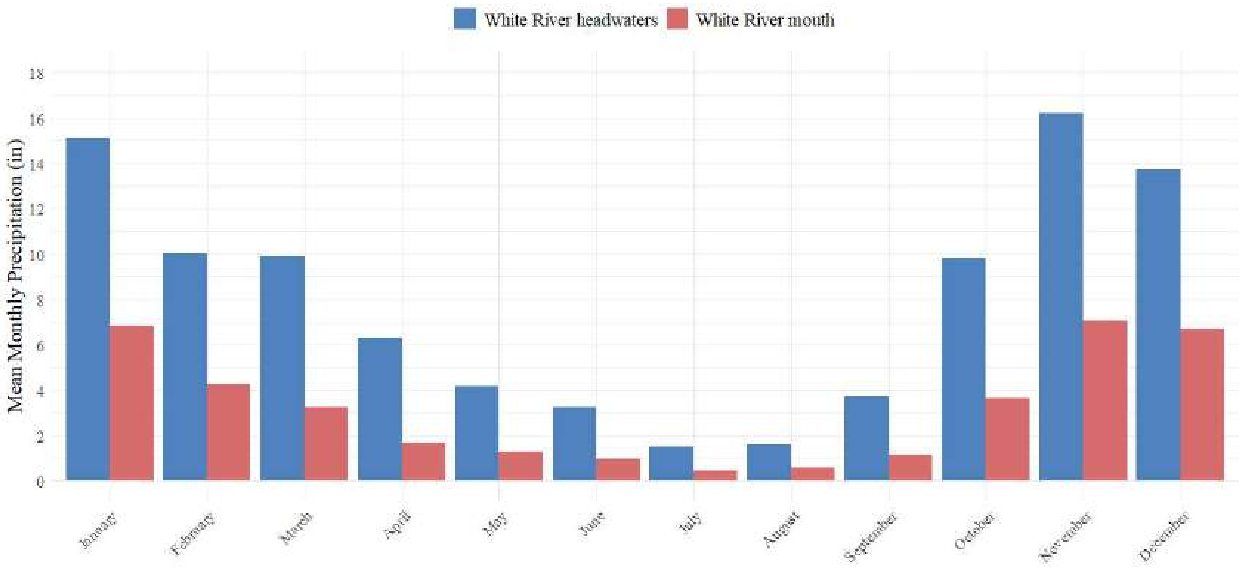

Figure 20. Average monthly precipitation in the White River Watershed – headwaters and river mouth. Source: PRISM Climate Group, Oregon State University, 2024.

Air temperature differences between the mouth of the White River and its headwaters can span 10°F in the summer (June-August) (Figure 21). Despite the absolute temperature difference between the two locations, the entire White River basin follows a similar climatological temperature pattern with warm summers and cool winters. The average air temperatures in the summer within the White River basin range from 45 – 65°F. The winter has a much narrower range between 25 – 37°F. The headwaters have consistently colder air temperatures than the mouth of the White River because of the mountainous high elevation location (PRISM, 2024).

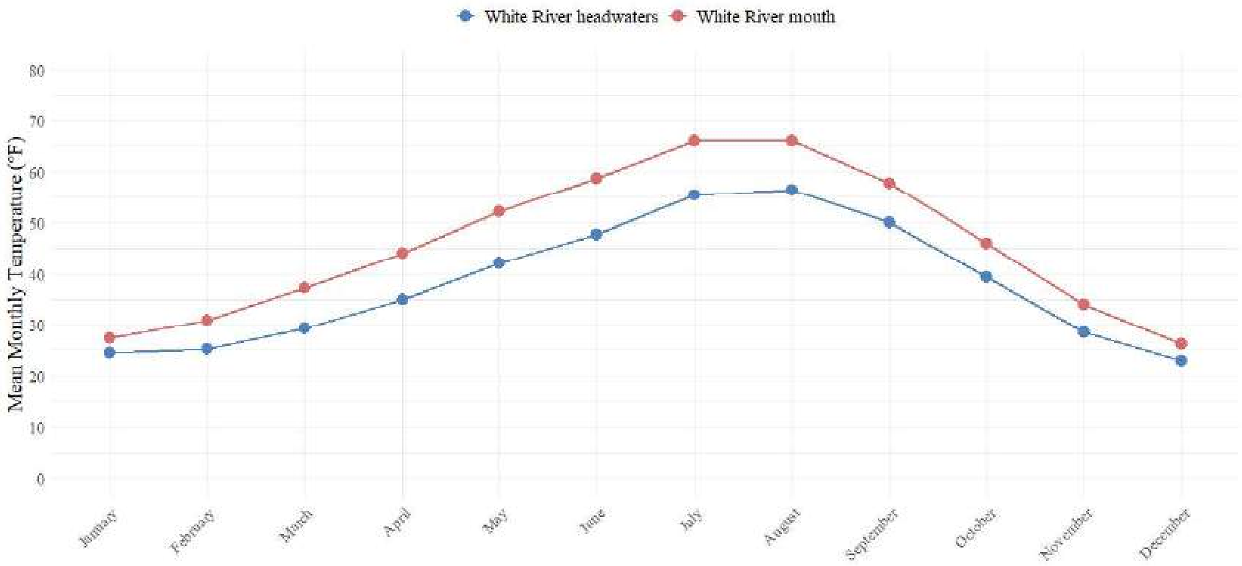

Figure 21. Average monthly temperature in the White River watershed – headwaters and river mouth. Source: PRISM Climate Group, Oregon State University, 2024.

2.7.3 Assessment Area Hydrology

The assessment area includes the lower 16.17 miles of the White River and the lower portions of the Napeequa River, Panther Creek, and Sears Creek. Figure 22 provides a map of the White River watershed and its tributaries. Panther Creek flows into the White River near RM 15 and drains approximately 19 mi^2. The Napeequa River enters the White River near RM 12.5 and drains 40 mi^2 including the Twin Lakes basin. Sears Creek enters at approximately RM 8.5 and has a 1.5 mi^2 contributing basin area.

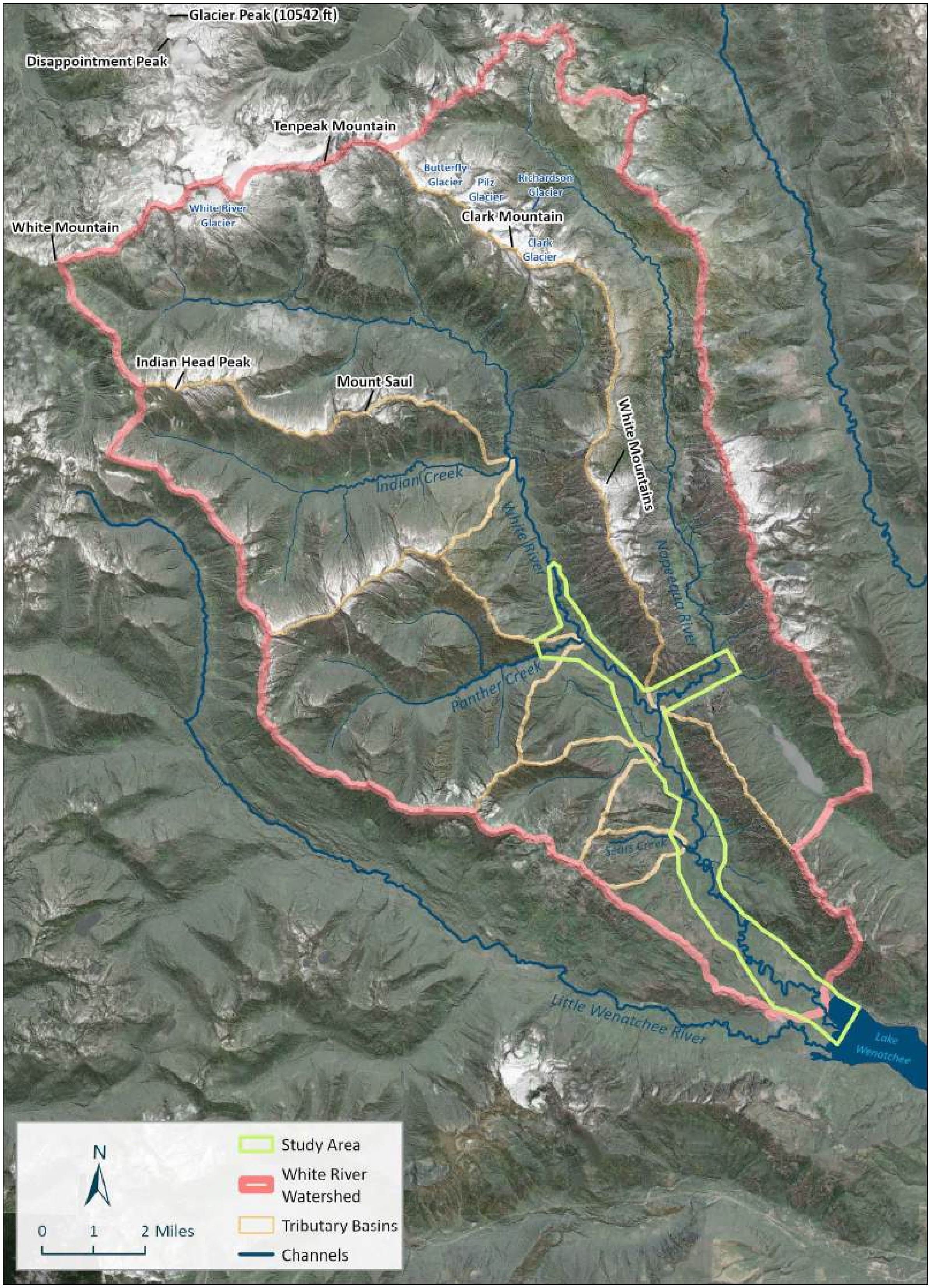

Figure 22. Map of the White River watershed and primary stream systems.

2.7.4 Available Streamflow Data

The stream discharge data available for the White River is from two different gages located at the same location (at the Seven Mile Bridge) but cover different time periods and were managed by different agencies, presumably using separate rating curves. A USGS gage (USGS 12454000) monitored site discharge and stage data from 1954 to 1984 (USGS, 2024). A Washington Department of Ecology gage was later installed in the same location (White River near Plain, Station 45K090) (WDOE, 2024) and provides discharge data from September 2002 to the present. These data provide some opportunity for comparing time periods. However, there is some concern about the quality of the WDOE data. Many of the WDOE daily gage readings have qualification codes associated with them, including ice-affected, provisional data, estimated data from other sources, extrapolated data beyond the rating curve, data labeled as questionable, or missing values. In their technical notes, they also describe some challenges with discharge measurements in this location, including a riprap bank, a wide eddy, and a significant sediment load that fouls the flow meters and limits the ADCP accuracy. There are no qualification codes or other readily available sources of information from which to judge the quality of the USGS data.

In addition to the sources of error mentioned above, both gages potentially suffer from floodplain flow that bypasses the channel at the gage location at the higher peak flows. To our knowledge, this flow is not accounted for in the flow measurements used for the rating curves. Based on our 2D hydraulic modeling (see Section 2.7.7), floodplain flow bypassing the channel at the gage location begins to occur as low as the 2-year (<1% of flow bypassing gage), is 4% at the 5-year, and is 22% at the 100-year (Table 1), assuming the synthetic bathymetry in this analysis is sufficiently representative of both current and historical conditions during the gage's period of record. Given that the largest measured flow for the establishment of the rating curve is approximately 6,300 cfs (between a 2- and 5-year recurrence), this suggests there could be significant additional error in the higher peak estimates.

Table 1. White River discharges in the channel and over the floodplain at the RM 7 bridge, based on 2D hydraulic modeling and assumed synthetic bathymetry performed as part of this assessment (see Section 2.7.7).

Flow Event	Floodplain (cfs)	Channel (cfs)
Q2	215	6005
Q20	1810	7375
Q100	2900	7885

Some significant differences can be seen between the two time periods with respect to the timing of runoff as well as the magnitude and timing of peak flows. This is believed to be related to changes to the timing of precipitation and snowfall/melt in the basin and is discussed in more detail above in Section 2.7.7 (Climate Change).

2.7.5 Seasonal Hydrology Patterns

The White River's greatest discharges are typically associated with the late spring snowmelt runoff, with smaller precipitation-driven flow increases in late fall (Figure 23). The data for the White River shows a relatively constant baseflow from August through September, with discharge increases between October and December as fall and winter rain events produce peaks prior to snow accumulation (Figure 23). This is followed by low flows in the winter from January through March, cold times when most or all of precipitation falls as snow, and before snowmelt begins in spring. Figure 23 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 20 years of flow data.

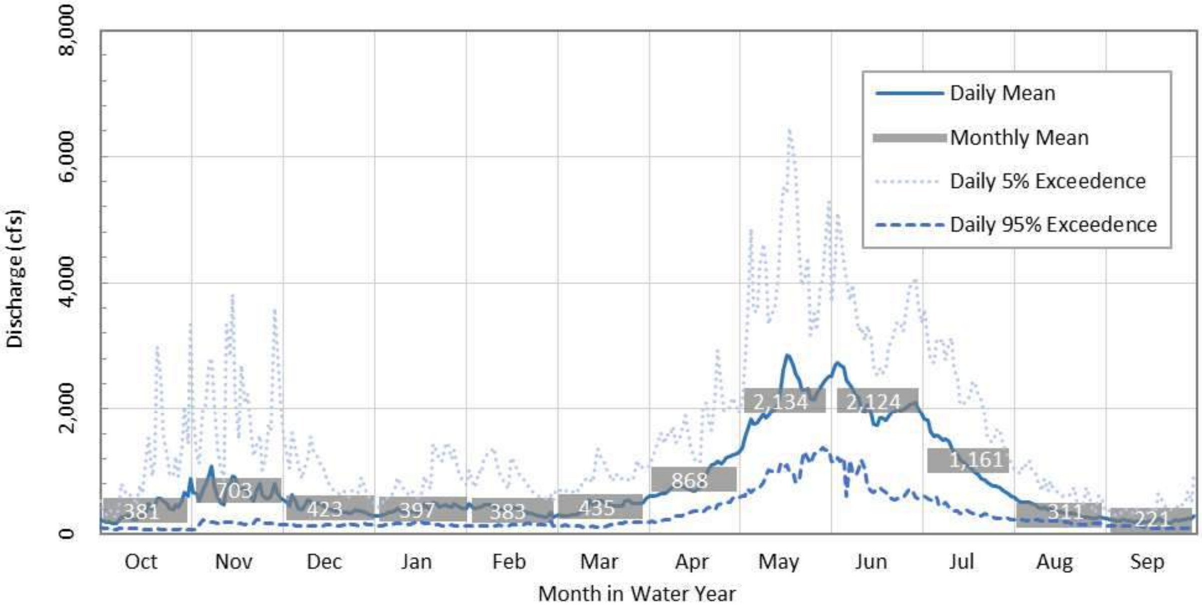

Figure 23. Daily flow statistics at White River near Seven Mile Bridge (WDOE gage 45K090 White R. nr Plain) for water years 2003 through 2023 showing the daily average, 5% exceedance, and 95% exceedance discharge and monthly average discharge for the period of record.

2.7.6 Peak Flows

There is relatively little available information on flood history for the White River. Annual peak flows from the available gage data are shown in Figure 24. The highest recorded peak flow on the White was on December 26, 1980. However, the available gage data is missing many years of record when there were high flows in the Wenatchee Basin. Based on the Wenatchee River USGS gage at Plain (#12457000), since 1911, two of the largest peaks in the basin occurred in November 1990 and November 1995.

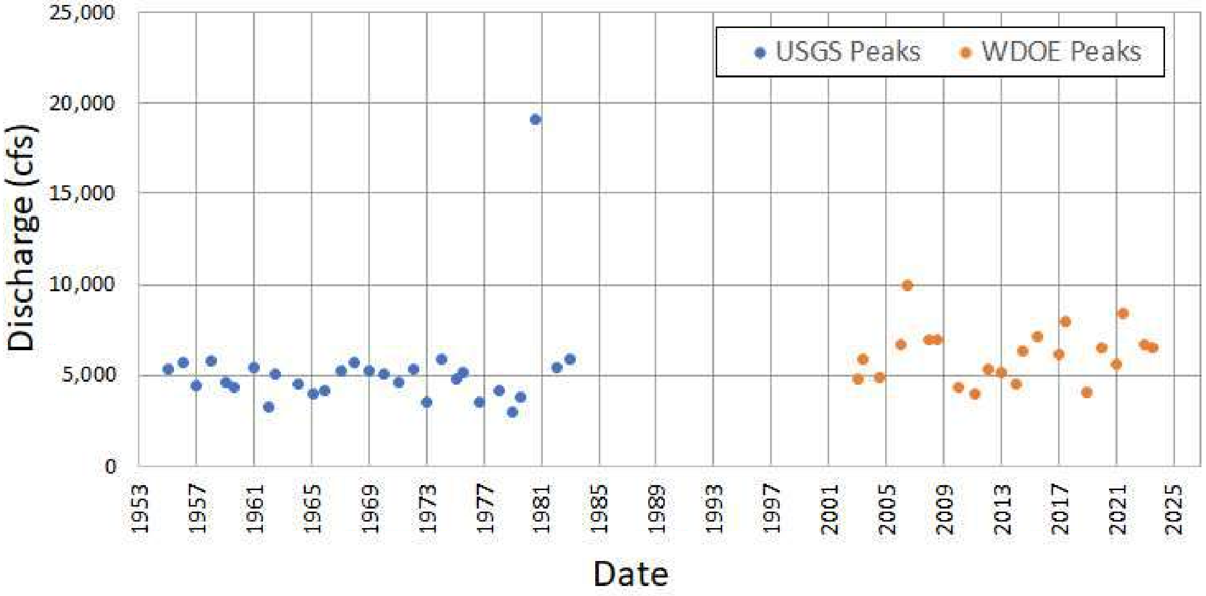

Figure 24. Annual peak flows (instantaneous data) from the USGS and WDOE gages.

The White River flood frequency was calculated using the Washington Department of Ecology gage on the White River near Plain (Station 45K090) (WDOE, 2024). For the purposes of estimating flood quantiles for the reach assessment modeling, the more recent WDOE data were used since these are believed to best represent the modern hydrologic and climatic conditions in the White River, despite the potential errors and uncertainty. Using other nearby gages as surrogates or to weight the values was considered; however, analysis of these regional gages suggests different hydrologic processes at work in these basins, represented by considerably different flows per unit basin-area and different timing of annual peaks. A Log Pearson Type III flood frequency analysis was performed for the 22 years of record (2002-2024) at the WDOE gage. The analysis was performed as a bulletin 17C flood frequency analysis 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. (2017). These results are presented in Table 2.

Table 2. White River flood frequency analysis results for the WDOE Station 45K090 gage (WDOE, 2024).

Flood Return Interval	Flood Flow (cfs)	5% Confidence Limit (cfs)	95% Confidence Limit (cfs)
2-Year	5965	6527	5450
5-Year	7298	8185	6661
10-Year	8109	9368	7344
20-Year	8846	10578	7930
50-Year	9755	12262	8600
100-Year	10412	13616	9049

The flood frequency analysis results were then weighted to estimate the flows of interest for the project area (RM 0 to 17). The 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 17) and the mouth of the White River (Table 3).

Table 3. White River estimated discharge for peak flood events based on weighted flood frequency analysis results for the WDOE Station 45K090 gage (WDOE, 2024).

Flood Return Interval	White River Peak Discharge at RM 17 (cfs)	White River Peak Discharge at Mouth (cfs)
2-Year	2950	6190
5-Year	3650	7570
10-Year	4100	8410
20-Year	4500	9160
50-Year	5000	10100
100-Year	5400	10780

2.7.7 Climate Change

The most recent IPCC report found that global surface temperatures had increased 1.1°F above the 1850 – 1900 baseline from 2011 – 2020 (IPCC, 2023). In North America, there has been an observed increase in the frequency and intensity of hot extremes as well as an increase in agricultural and ecological drought (IPCC, 2023). Climate change models in the Pacific Northwest (PNW) have predicted a 3.2°F increase in annual temperature by the 2040s, and a 5.3°F increase by the 2080s (Mote & Salathé, 2010). Predicted changes in precipitation vary by model but generally show trends towards wetter fall and winter seasons and drier summers (Mote & 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) used the Variable Infiltration Capacity (VIC) hydrological model to simulate basin hydrological regimes under the A1B medium emissions and the B1 low emissions climate scenarios. Under these scenarios, the Wenatchee 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 Wenatchee throughout 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, 2021) 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 Wenatchee basin 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 Shared Socioeconomic Pathways (SSPs) (Figure 25, Figure 26, and Figure 27). The total amount of annual precipitation the basin receives is projected to change very little in the 2025 – 2099 timeframe, emphasizing seasonal and precipitation-type changes as the basin transitions from a snow-dominated to a transitional basin.

Changes to the dominant hydrological regime could have impacts on habitat conditions and seasonal impacts on stream temperatures. A reduction in the snowmelt runoff duration has the potential to diminish channel dynamism and related stream habitat complexity. Lower summer baseflows may increase the risk for summer water temperature exceedances for the salmonid and trout species that reside in the White River and its tributaries. The hydrological and habitat changes are crucial to consider as the climate continues to change in and around the White River.

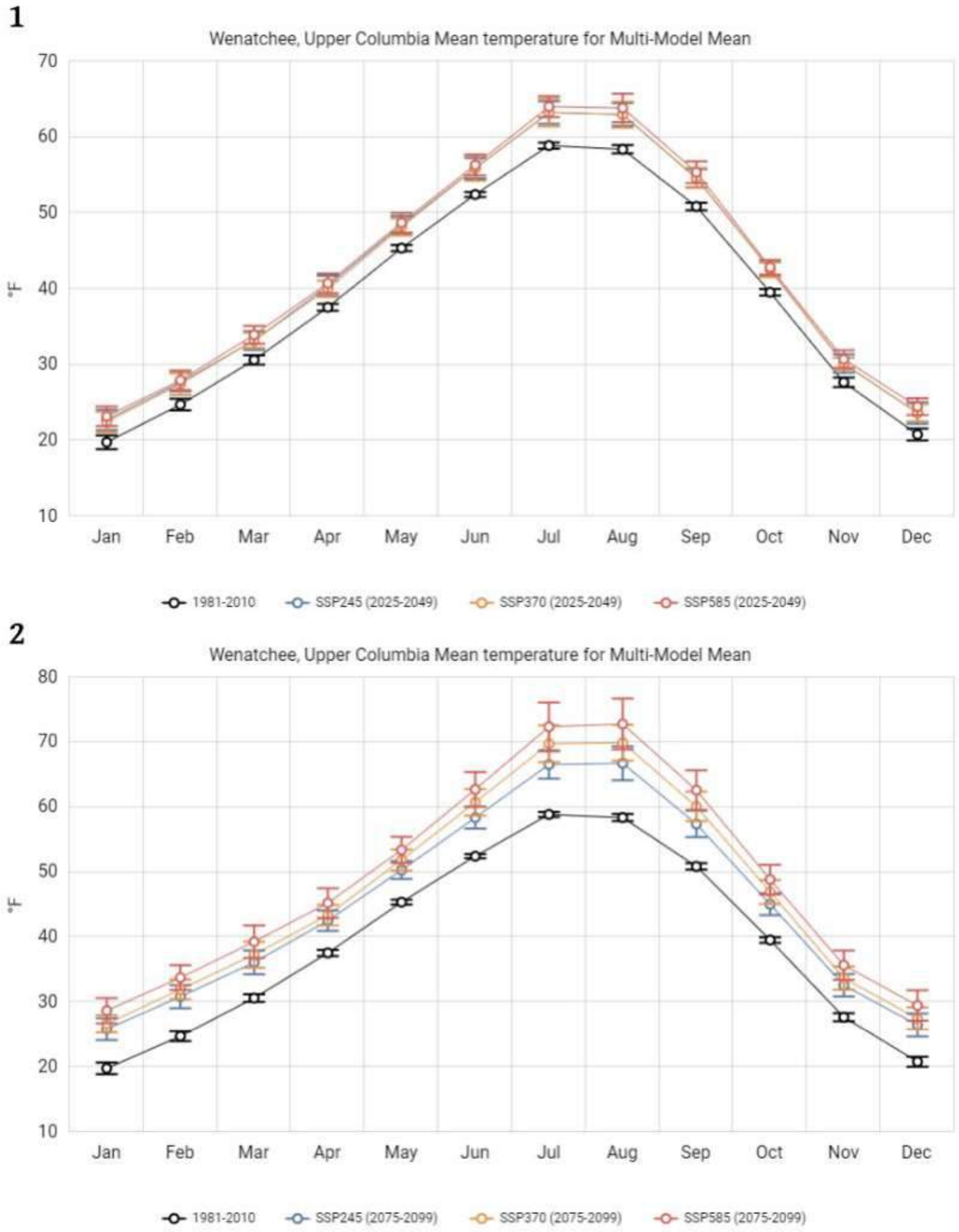

Figure 25. Climate change scenario graphs for the Wenatchee mean temperature. Source: Alder & Hostetler (2021), generated via USGS NCCV. The multi-model mean for mean temperature in the Wenatchee basin from 1) 2025 – 2049 and 2) 2075 – 2099. The three scenarios are the 3 Shared Socioeconomic Pathways. SSP245 represents a 'middle of the road' scenario with an additional 4.5W/m^2 of radiative forcing by 2100. SSP 370 represents an upper-middle scenario with an additional 7.0W/m^2 of radiative forcing by 2100. SSP585 represents the worst-case scenario akin to RCP 8.5 with an additional radiative forcing 8.5W/m^2 by 2100.

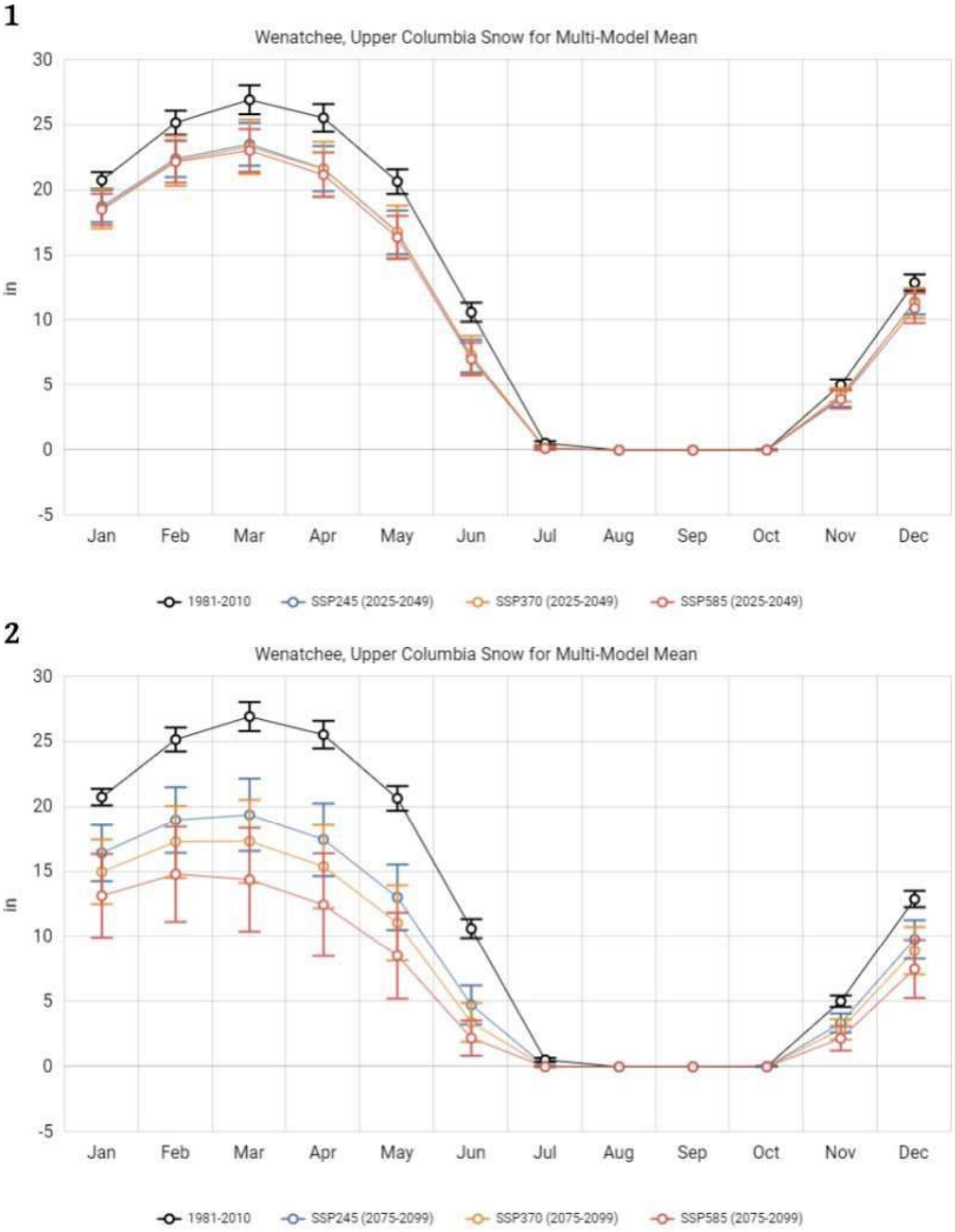

Figure 26. Climate change scenario graphs for the Wenatchee snow fall. Source: Alder & Hostetler (2021), generated via USGS NCCV. The multi-model mean for snow amount in the Wenatchee basin from 1) 2025 – 2049 and 2) 2075 – 2099. The three scenarios are the 3 Shared Socioeconomic Pathways. SSP245 represents a 'middle of the road' scenario with an additional 4.5W/m^2 of radiative forcing by 2100. SSP 370 represents an upper-middle scenario with an additional 7.0W/m^2 of radiative forcing by 2100. SSP585 represents the worst-case scenario akin to RCP 8.5 with an additional radiative forcing 8.5W/m^2 by 2100.

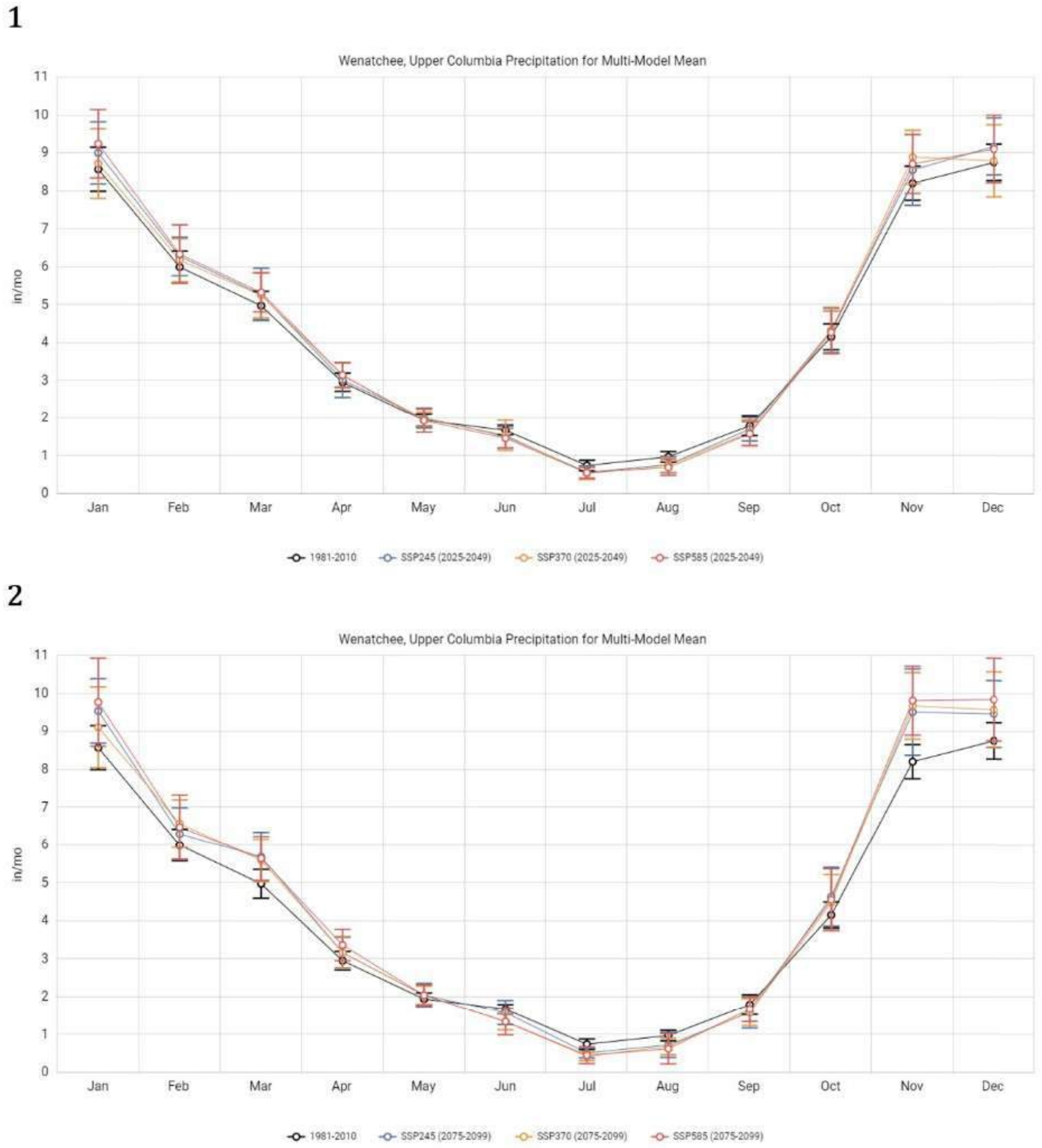

Figure 27. Climate change scenario graphs for the Wenatchee precipitation. Source: Alder & Hostetler (2021), generated via USGS NCCV. The multi-model mean for precipitation amount in the Wenatchee basin from 1) 2025 – 2049 and 2) 2075 – 2099. The three scenarios are the 3 Shared Socioeconomic Pathways. SSP245 represents a 'middle of the road' scenario with an additional 4.5W/m^2 of radiative forcing by 2100. SSP 370 represents an upper-middle scenario with an additional 7.0W/m^2 of radiative forcing by 2100. SSP585 represents the worst-case scenario akin to RCP 8.5 with an additional radiative forcing 8.5W/m^2 by 2100.

The climate change predictions from the modeling described above may already be occurring in the White River Basin. The streamflow data available for the White River allow for some historical-to-current comparisons. There are data from a USGS gage (White River near Plain - 12454000) from 1955 to 1983 and then data from a WA Dept of Ecology Gage (White R. nr Plain – 45K090) at the same location from 2003 to present (2024). More specific information on the gages is provided later in the hydrology section (Section 2.7), but a comparison of historical and recent data is presented here as evidence of climate change impacts on basin hydrology.

The average monthly flows from the historical USGS gage and recent WDOE gage are presented in Figure 28. These data show changes in the magnitude, timing, and duration of seasonal flows. The recent data shows greater fall runoff, earlier snowmelt runoff, a slightly shorter snowmelt runoff duration, and lower summer base flows. The timing and magnitude of peak flows has also changed (Figure 29). The older data have lower peaks than the newer data and the newer data have more peaks occurring in late fall/early winter, with larger events generally associated with the late fall/early winter floods. Separate flood frequency analyses were performed for the two gaging periods. For the older USGS peaks, the smaller floods (5-year recurrence and lower) fall outside of the confidence limits of the WDOE flood frequency analysis values (presented later in section 2.7.6), suggesting that there are significant differences in peak flows between these time periods at least with respect to the smaller, more frequent floods.

The change in timing of annual peaks has also occurred in the adjacent Chiwawa River. Similar to the White, the USGS gage in the Chiwawa (Chiwawa River near Plain, WA- 12456500) also has older (1914, 1937-1957) and newer (1991-2024) data to make comparisons. The annual peaks for the older data all occur in the spring (17 of 17 years) whereas for the newer data, 18% of the annual peaks occur in the fall (6 of 33 years). The Chiwawa basin area contributing to the gaging station has similar characteristics as the White River gage watershed with respect to size (White=150 mi^2; Chiwawa=170 mi^2) and mean basin elevation (White=4750 ft; Chiwawa=4520 ft). The basins are adjacent, and both extend to the steep and high cascade crest near Glacier Peak. The Chiwawa would therefore be expected to be experiencing similar climate change impacts as the White River.

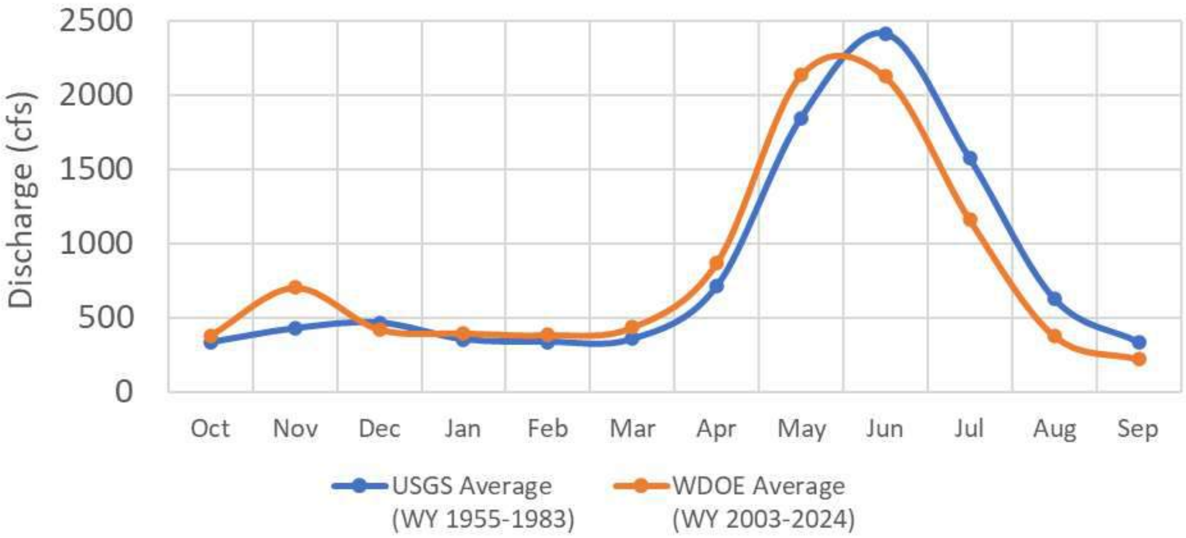

Figure 28. Comparison of mean monthly flows between the historical USGS gage (White River near Plain, WA - 12454000) and the current WDOE gage (White R. nr Plain - 45K090).

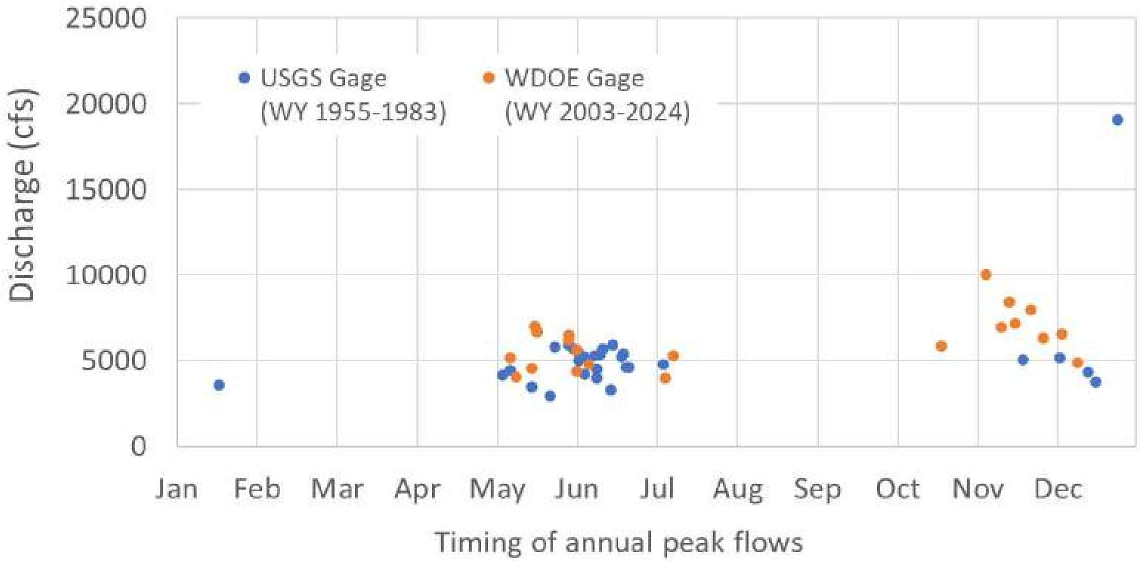

Figure 29. Comparison of annual peak flow timing and magnitude between the historical USGS gage (White River near Plain, WA - 12454000) and the current WDOE gage (White R. nr Plain - 45K090). Instantaneous data.

Although the magnitude and seasonal timing of flows, including peak flows, is different on the White River between the two gaging periods, the mean annual flows from the two gaging periods are very similar (Figure 30), with the mean of all the annual means of 810 cfs for the older USGS data and 808 cfs for the newer WDOE data. This is in keeping with the predictions from the NCCV modeling (Alder & Hostetler, 2021) described previously, wherein the total amount of annual precipitation is expected to change very little (2025-2099 scenario), with the changes primarily being to the seasonal timing of flows and the precipitation type (i.e. rain vs. snow).

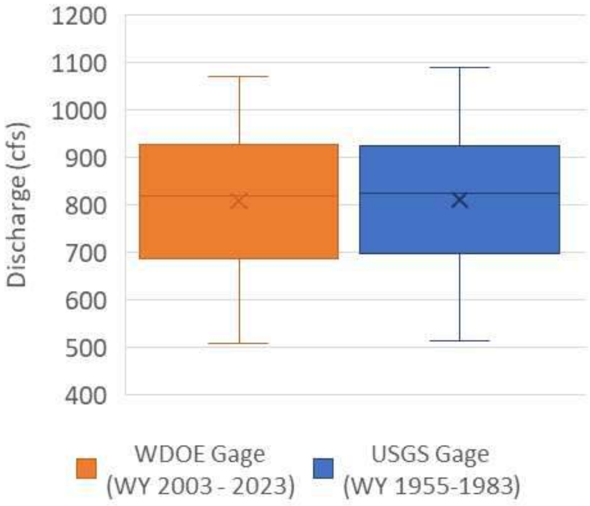

Figure 30. Distribution of mean annual flows for the WDOE gage and USGS gage. The distributions of the values are nearly identical.

Comparisons were also made between the White River annual peak flows and peak flows on the Wenatchee River downstream at the Plain gaging station (USGS 12457000), in order to see how changes in White River floods have affected flows in the mainstem Wenatchee downstream. For reference, the watershed of the White River at the gaging station accounts for approximately 26% of the watershed area of the Wenatchee River at the Plain gage, and the 2,480-acre Lake Wenatchee lies in between. Where annual peaks on the White and Wenatchee were associated with the same storm event, the relationship with Wenatchee River flows were compared between the two gaging periods on the White. These "coincident" peaks occurred for approximately three-quarters of all of the White River annual peaks (both gages combined and where there were overlapping years of data). These data are presented in Figure 31. These data reflect the changes in magnitude of the White River peaks described previously and suggest that the White River contributes relatively more to Wenatchee River peaks in recent years than it did historically. This dynamic is further supported by looking at changes over time in the Wenatchee River annual peak data (Figure 32), which in contrast to the White River do not indicate an increase in peak flows over time; although the data do show a potential increase in the occurrence of earlier peaks in the fall.

It is reasonable to assume that high elevation basins like the White and Chiwawa 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 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 (Figure 25). This is related to, and further exacerbated by, lower fall snowpack, which is also predicted by the modeling (Figure 26).

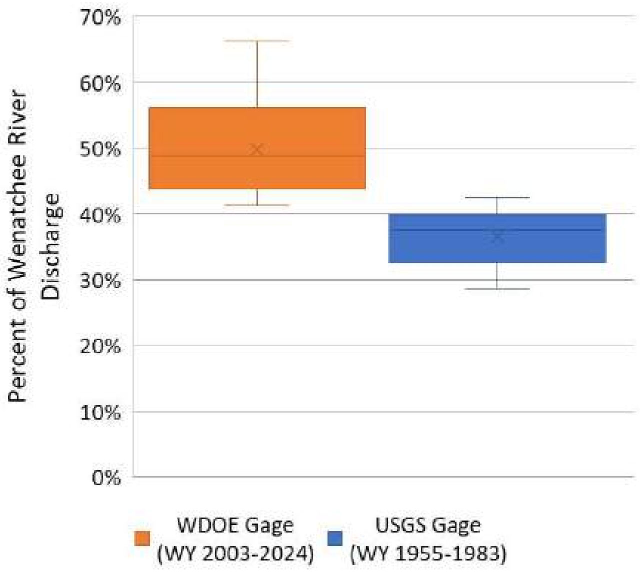

Figure 31. Proportional contribution of White River discharge (from gaging location at RM 7) to Wenatchee River discharge at the USGS Plain gage. These data use annual peaks that are "coincident" (i.e. same storm) between the two gages. Sample sizes are 15 peaks for the WDOE gage and 19 peaks for the USGS gage.

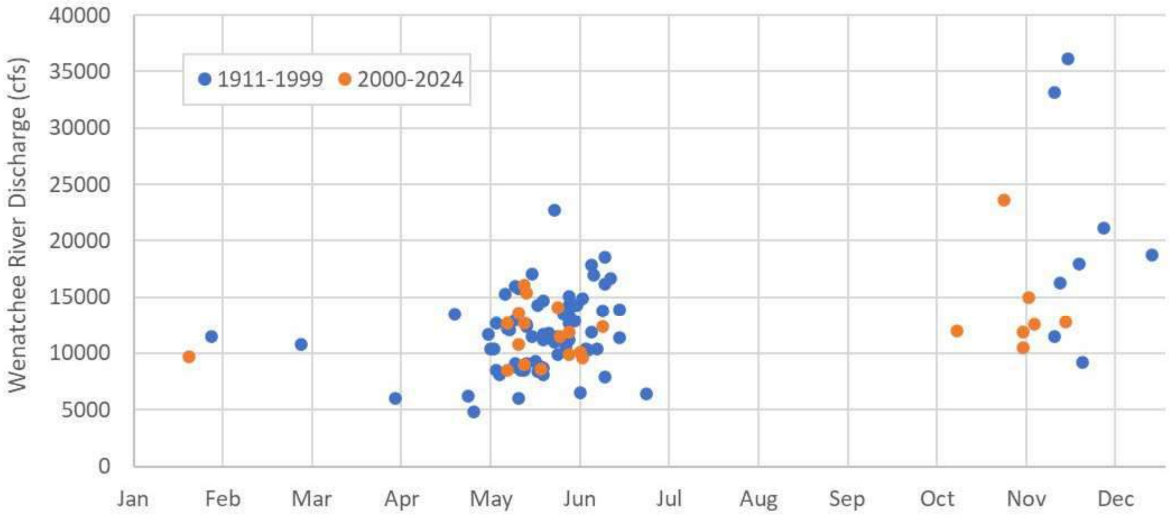

Figure 32. Comparison of pre-2000 and post-2000 annual peak flow magnitude and timing at the Wenatchee River at Plain Gage (12457000).

In summary, modeling predicts climate change effects on hydrologic processes in the Wenatchee Basin, including less snowpack, earlier snowmelt peaks, elevated winter flows, and lower summer base flows (Alder & Hostetler, 2021; Tohver et al., 2014). The hydrologic data from the White River appear to be already reflecting these impacts. The White River may be particularly susceptible to climate change impacts due to its high elevation and presence of remnant glaciers that are likely receding due to warming temperatures. The data suggest that the White River may already be experiencing the regime transitions predicted by modeling, including the predictions from Tohver et al. (2014) and those from the NCCV (Alder & Hostetler, 2021).

2.8 HYDRAULIC ANALYSIS

The hydraulic analysis for this assessment includes a preliminary-level 2-dimensional (2-D) hydraulic model of estimated peak flood events for reaches 1 to 10 of the White River, reaches 1 and 2 of the Napeequa River, Reach 1 of Panther Creek, and Reach 1 of Sears Creek based on LiDAR available at the time of the analysis, as well as an incipient motion sediment transport analysis using results from the hydraulic model. A more detailed description of the methods, analysis, and results can be found in Appendix D.

2.8.1 2-D Hydraulic Modeling

A preliminary-level 2-D hydraulic model of the White River was developed for existing conditions for the study area using the estimated flood discharges described in Section 2.7.6. The hydraulic model was developed in the U.S. Army Corps of Engineers HEC-RAS 6.5 software (USACE, 2024e), 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, which varied by location in the study area and ranged from 2007 to 2023 data (PSRC, 2007; Quantum Spatial, 2016, 2019; WGS, 2023). The goal of this preliminary model is to assess the current channel and floodplain dynamics, as well as assess the impacts of flood flows (2, 5, 10, 20, 50, and 100-year flood events) on the existing landscape.

2.8.2 Model Results

The model shows modest differences in velocity, depth, and floodplain inundation at the modeled flows. In the downstream reaches of the project (1-6), channel velocities range from 2-6 ft/s, with localized spikes near bridges at RM 2 and RM 7 during higher flows (20- and 100-year events). Floodplain velocities increase from <0.5 ft/s during the 2-year flow to 1-2 ft/s at higher flows, especially in narrower parts of the valley (Reaches 5 and 6). The natural levees (levees that naturally build up adjacent to the channel banks due to regular overtopping of the channel and preferential deposition of sediments closer to the channel) observed in Reaches 2, 3, and 4 become partially submerged during high flows, allowing flow around them, and contributing to widespread floodplain inundation. Backwatering from Lake Wenatchee is observed extending approximately RM 0.2 during the 2-year flow, ~RM 0.5 at the 20-year, and ~RM 1 at the 100-year event. This reflects the low gradient of this downstream segment and the significant influence that the lake levels can have on water levels and floodplain connectivity in Reach 1. Upstream Reaches (7-10) showed increased velocities, often exceeding 8 ft/s, particularly upstream of the Napeequa River confluence. Floodplain inundation is more limited in Reaches 8-10 of the White River, in Panther Creek, and in Reach 2 of the Napeequa River. Throughout the study area, flow into the floodplain during higher flows inundates several prominent oxbows, connecting them to the White River mainstem.

2.8.3 Model Considerations

There are several key considerations in evaluating how much confidence can be put in these results, and in what ways the model could be improved. The gages used to estimate the White River flows and Lake Wenatchee stage both have missing data about the gage datum and uncertainty in whether they are recording flows accurately. Although fluctuations in the In addition, the LiDAR used in the model terrain does not include bathymetry data. Because of the large potential effects of lack of bathymetry data in the downstream reaches with deep water, we utilized cross section data collected during the habitat surveys to approximate the bathymetry. However, this modification to the terrain does not capture the true channel dimensions or complexity, and is likely still underestimating the conveyance of the channel. This, coupled with the limitations of the model mesh, may result in an overestimation of floodplain inundation. For future project-scale modeling, comprehensive channel bathymetric surveys are recommended.

2.9 GEOMORPHOLOGY

2.9.1 Overview and Methods

Developing a successful habitat restoration strategy requires an understanding of the geomorphic processes and trends of the modern channel, floodplain, and contributing hillslopes. This section provides an overview of the geomorphology of the watershed as well as a summary discussion of the primary geomorphic features of the White River from RM 0-16.17. The information presented here and in Section 3 is based on field-based survey observations (August 1-7 and 12-19, 2024 and September 6-13, 2024) combined with available digital and printed data and reports (as referenced). Geomorphologists walked and/or floated each reach in the assessment area to characterize physical conditions and channel processes as well as identify restoration opportunities. Specific attention was paid to 1) trends in channel incision and evolution, 2) substrate type, distribution, and sediment availability, 3) surface and subsurface flow interactions, 4) channel bank composition and migration patterns, 5) floodplain and habitat connectivity, 6) occurrence and influence of large woody material, and 7) influence of past and current human structures and activities. Detailed discussions of geomorphic conditions and trends at the reach-scale are provided in Section 3. Table 4 includes a set of metrics used to help characterize each reach. In addition to the channel and floodplain information in the metrics table, discussion about reach-scale vegetation condition, large wood, the location and influence of human-built features, and treatment recommendations are provided. Information from the reach-scale geomorphic assessment is used to inform the REI analysis (Section 2.13).

Table 4. Channel and Floodplain metrics for all reaches assessed based on habitat and geomorphic survey data. Where survey data were lacking, GIS analysis was used to estimate values. Channel and habitat data for Sears Creek were not collected as part of the habitat survey due to the lack of a discernable channel for most of its length. A discussion of Sears Creek is nevertheless included in Section 3.14.

Metric	**Reach 1**	**Reach 2**	**Reach 3**	**Reach 4**	**Reach 5**	**Reach 6**	**Reach 7**	**Reach 8**	**Reach 9**	**Reach 10**	**Reach 1**	**Reach 2**	**Reach 1**
	White River										**Napeequa River**		**Panther Creek**
Length (miles)	2	2.13	1.31	1.56	2.52	2.13	0.78	1.92	0.66	1.16	1.7	0.5	0.8
River Mile	0-2.0	2.0-4.13	4.13-5.44	5.44-7.0	7.0-9.52	9.52-11.65	11.65-12.43	12.43-14.35	14.35-15.01	15.01-16.17	0-1.70	1.70-2.20	0-0.80
Stream Gradient (%)	0.02%	0.05%	0.07%	0.09%	0.18%	0.18%	0.15%	0.42%	1.05%	2.40%	0.76%	5.95%	5.73%
Sinuosity	1.47	2.42	1.83	1.55	1.93	1.44	1.08	1.41	1.08	1.15	1.63	1.15	1.12
Dominant Channel Habitat Unit Type	Pool	Pool	Pool	Pool	Pool	Pool	Pool	Pool	Riffle	Riffle	Pool	Riffle	Riffle
Average Bankfull Width (ft)	130 (estimate)	120	140	140	145	188	173	131	119	92	66	40	51
Confinement[1]	Unconfined	Unconfined	Unconfined	Unconfined	Unconfined	Unconfined	Unconfined	Unconfined	Partially Confined	Partially Confined	Partially Confined	Partially Confined	Confined
Dominant Substrate	Gravel	Gravel	Gravel	Gravel	Gravel	Gravel	Gravel	Gravel	Gravel	Cobble	Gravel	No Gravel Count Performed	Gravel
% Pool Habitat	99.7%	100.0%	97.0%	89.0%	91.0%	79.0%	92.0%	61.0%	12.0%	8.0%	66.6%	5.0%	30.0%
% Glide Habitat	0.0%	0.0%	3.0%	11.0%	7.0%	17.0%	5.0%	23.0%	20.0%	12.0%	10.3%	0.0%	0.0%
% Riffle Habitat	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%	9.0%	50.0%	79.0%	18.6%	50.0%	69.0%
% Side Channel Habitat	0.0%	0.0%	0.0%	0.0%	1.0%	4.0%	4.0%	7.0%	18.0%	0.0%	4.0%	45.0%	0.0%
% Other Habitat	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	0.5%	0.0%	1.0%

[1] Confinement categories use the Washington Watershed Analysis Guidelines. Unconfined: Valley Width (VW) > 4 Channel Width (CW). Partially confined: 2 CW < VW < 4 CW. Confined: VW < 2 CW

2.9.2 Hillslopes and Valley

The White River flows through a high relief "U" shaped valley carved by glacial activity during the late Pleistocene epoch (2.6 Ma – 11 Ka) (see Section 1.1). The White River valley is high relief, with hillslopes adjacent to the assessment area rising to peaks and ridges several thousands of feet above the valley bottom, with a maximum elevation in the basin of 8,620 ft. The steep hillslopes are vegetated with conifer forests interspersed with bedrock outcrops, primarily composed of Mesozoic (252 – 66 Ma) metamorphic rock (Figure 33). The valley bottoms contain sediments and soils derived from glacial processes (U.S. Geological Survey, 2024). The White River initially flows east from its source near White Pass, south of Glacier Peak. South of Clark Mountain, the river turns to the south and follows a southeast-trending path to its outlet at Lake Wenatchee, located at an elevation of approximately 1,870 feet above sea level (U.S. Geological Survey, 2024). Several tributary basins carved by both glacial and fluvial processes feed into the White River along its 26.7-mile route from White Pass to Lake Wenatchee. On the west side of the White River watershed, major tributary networks are dendritic, flowing west to east from Wenatchee Ridge, which separates the White River watershed from the neighboring Little Wenatchee watershed. To the east, a narrow ridge separates the White River from its largest tributary, the Napeequa River. The Napeequa flows southeast through a glacially carved valley, roughly parallel to the White River for nearly 17 miles, before taking an approximately 90° turn to the southwest and merging with the White River near RM 12.5. Chiwawa Ridge, to the east of the Napeequa River, separates the White River Basin from the neighboring Chiwawa River Basin. Fine suspended sediment derived from glacial erosion of bedrock, or glacial flour, give the White River and Napeequa River their distinct milky-turquoise color.

The upper White River watershed is confined as it makes its way through the mountains and passes over several bedrock contacts and canyons, including White River Falls at the upstream end of the assessment area (RM 16.17). Upstream of Panther Creek in the uppermost reach of the assessment area, natural valley confinement results in plentiful direct hillslope toe to channel coupling, including bedrock contacts at White River Falls and immediately downstream. Hillslope coupling provides local sediment supply to the valley floor and channel. Where the White River meets the Panther Creek alluvial fan at RM 15.01, the White River Valley widens and the channel becomes considerably less confined and is provided with sufficient space to laterally migrate. Numerous alluvial and hillslope debris fans supply sediments to the White River valley and confine the valley bottom relative to other locations. An example of this occurs in Reaches 4 and 5, where the combination of a large landslide to the north and debris fans to the south result in a narrowing of the valley bottom. Direct hillslope toe to channel coupling in the wide valley segment is intermittent, occurring only where the channel's path brings it in contact with the toe of a slope or debris fan. Hillslope contribution to the valley floor and channel is via colluvium and multiple debris fans. Bedrock exposures and mass-wasting deposits suggest that mass-wasting events such as landslides occur within the watershed and periodically supply sediments and likely large wood to the channel.

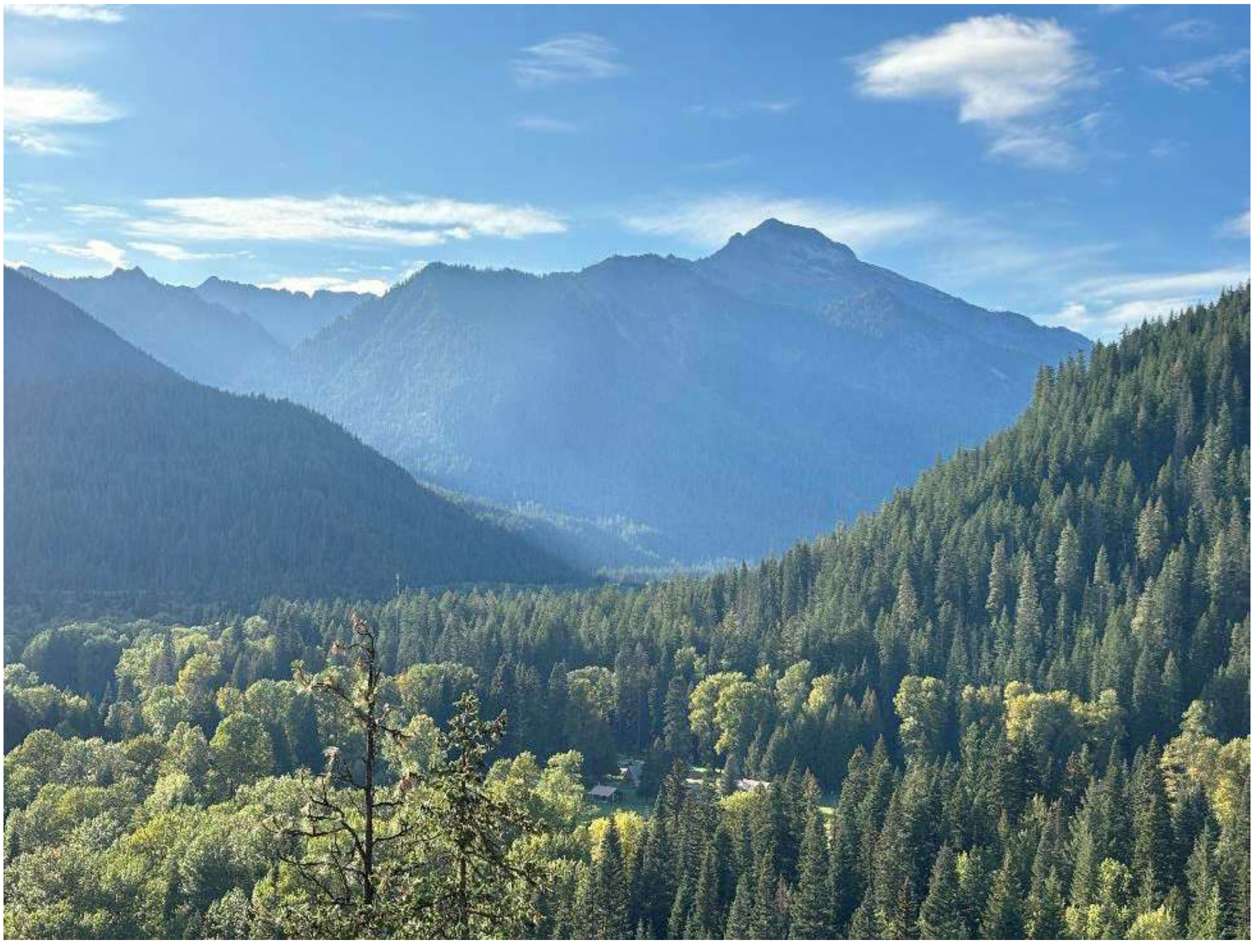

Figure 33. White River U-shaped valley looking up-valley from the Twin Lakes Trail near Reach 7. Foreground: Napeequa River alluvial fan with structures. Mid-photo background: Panther Creek entering the White River Valley on river right (September 11, 2024).

The presence of the White River Road along the toe of the eastern hillslopes further limits hillslope coupling downstream of approximately RM 13.7. Hillslope and tributary contributions in the form of numerous landslides and debris flows throughout the assessment area have and will continue to influence river morphology and valley composition through sediment contribution and wood routing. Wildfires can lead to increased hillslope instability, resulting in sediment and wood inputs from hillslopes to channels. Evidence of recent and historical wildfires in the region highlights the need to consider the effects of wildfires in future management of the watershed.

The width of the modern valley floor in the assessment area ranges from approximately 150 feet to 825 feet in confined section upstream of Panther Creek (RM 15.01), and from 925 feet to 4100 feet downstream of Panther Creek. The wide valley bottom is comprised of floodplain and terrace surfaces. Except for colluvial deposits contributed from hillslopes, the valley floor is composed of alluvial material deposited during the Quaternary period (2.58 million years to present). This material is periodically exposed and sourced to the river channel at cut-bank exposures. Base level of the White River is determined by the elevation of Lake Wenatchee.

2.9.3 Terraces, Floodplains, and Fans

The White River Valley is a wide alluvial valley nested between glacially carved hillslopes and fans (debris and alluvial). A map of the geomorphic surfaces of the valley including alluvial fans, terrace deposits, and the modern floodplain surfaces is presented in ***Figure 34***. Mapped modern floodplain surfaces include low (inundated approximately once every 1-5 years), medium (5-10 years), and high (10-100+ years) surfaces. Inundation frequencies and floodplain and terrace surface extents were determined based on hydraulic modeling (See Section 2.8), assessment of LiDAR and aerial imagery, and field investigation of inundation indicators including local topography, sediment and organic matter deposits, and vegetation. Detailed geomorphic-surface maps are provided in the reach-specific sections later in this report.

Low floodplain surfaces are most common in sinuous regions on the insides of meander bends, extending off active point bars. Frequent disturbance in the form of inundation results in frequent sand deposits on the surfaces of the low floodplains where the vegetation is dominated by riparian forbs, shrubs, and small trees. On the higher, less frequently inundated floodplain surfaces, topsoil is usually more organic-rich and developed, and larger trees provide a source of potential large wood recruitment to the White River. In the upper reaches of the assessment area, floodplain surfaces consist of a gravel-cobble base overlain by coarse sands and topped with fine sediments. Moving downstream, cobbles become less common, and floodplains are typically composed of finer gravels overlain by a thick layer of coarse sands and fine sediments. Although floodplains cover much of the assessment area valley floor, human activity has likely limited floodplain connectivity to the White River channel relative to pre-European settlement conditions. Widespread large wood removal and logging, channel simplification and realignment, and bank hardening, among other actions, have reduced overall sinuosity, floodplain connectivity, and channel complexity throughout the assessment area. Although floodplains are connected to the channel throughout much of the assessment area, reduced channel complexity can limit the magnitude and frequency of floodplain inundation. In areas such as the Little Wenatchee Road bridge crossing, local anthropogenic features have partially or fully disconnected historically inundated floodplain surfaces, resulting in surfaces functioning more like terraces.

Terraces within the assessment area are composed of glacial outwash, formerly connected as floodplain surfaces. The terraces have been disconnected through a combination of natural incision as the river down-cuts through Pleistocene (2.6 Ma – 11 Ka) glacial deposits and other sediments (Reaches 1-10), and incision as a result of anthropogenically instigated channel simplification and straightening (Reaches 1-9 only).

Alluvial fans and debris fans contribute material to the floor of the valley from the adjacent hillslopes on both sides of the valley and are a source of sediments to the White River. Most of the fans are located upstream of the Sears Creek Road Bridge (RM 7). There are active alluvial fans where Panther Creek (RM 15.01) and Canyon Creek (RM 11.26) meet the White River valley, and although a historical fan exists at the Napeequa River confluence, the channel is no longer able to wander across its fan due to channel confinement.

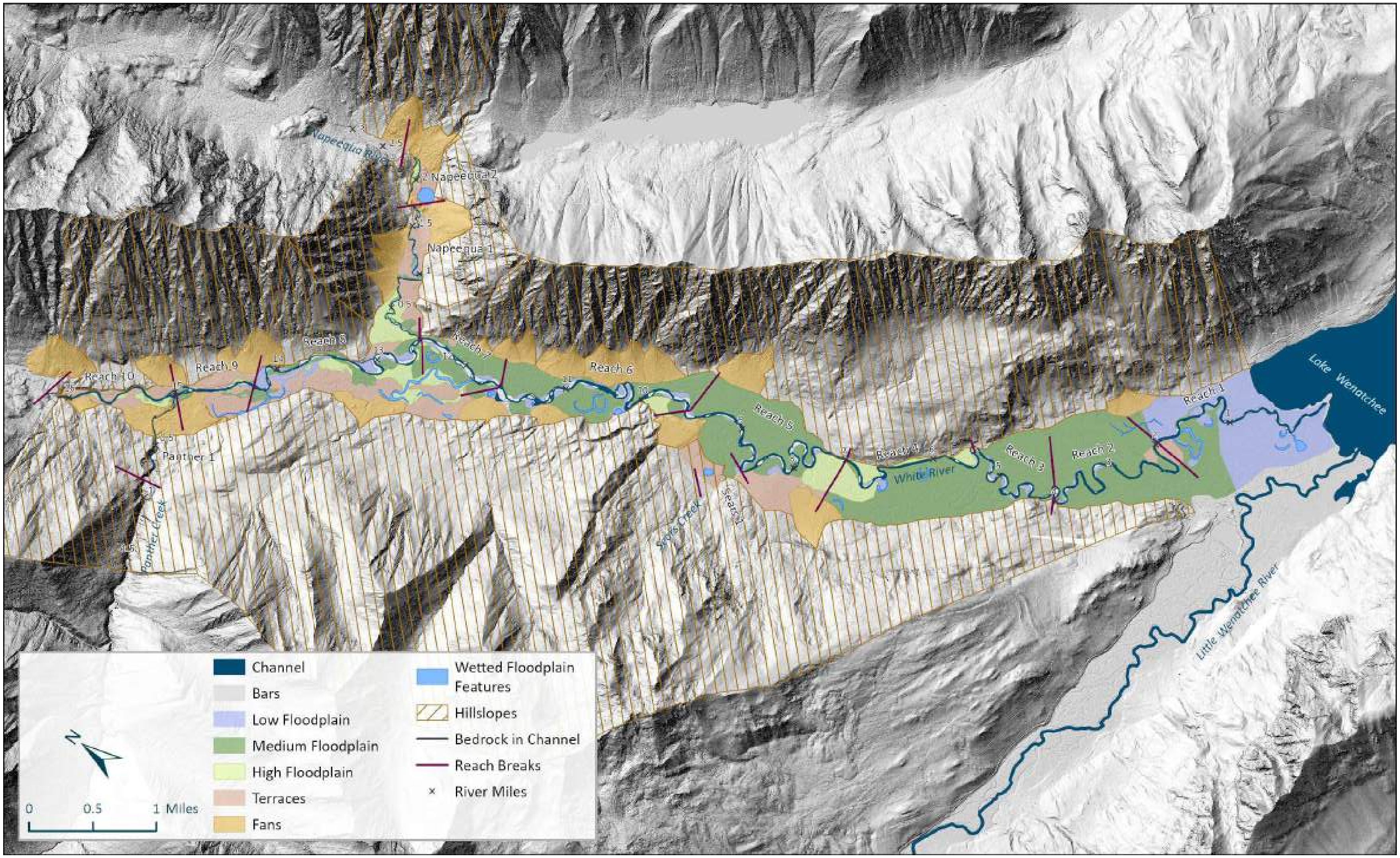

Figure 34. Map of geomorphic surfaces of the White River valley within the assessment area. Mapped surfaces include alluvial fans, terrace deposits, and modern floodplain surfaces.

2.9.4 Tributaries and Channel

The White River is a montane channel that alternates between confined and unconfined, depending on location within the basin. The channel and its tributaries flow through glacially-carved hillslopes that create both bedrock confined sections, depositional alluvial valleys of varied widths, and inputs from debris flow paths and tributary alluvial fans. The upper-most headwaters initiate from Glacier Peak adjacent aretes such as White Mountain, Ten Peak, and Clark Peak. Steep snow and ice melt-fed headwater tributaries provide cold water inputs to the White River throughout the year.

Within the assessment area, the White River undergoes a shift in character as it flows from White River Falls to Lake Wenatchee. These shifts are described below and are informed by the longitudinal profile (Figure 35) and by measurements of bed substrate (Table 5). The profile shows the transition from the steeper upper reaches (Reaches 8 and 9) to the low gradient lower reaches, with very low gradients less than 0.2% from the Napeequa confluence down. The bed material was characterized by performing twenty-three pebble-count surveys (gravel counts) following the Wolman Pebble Count method (Wolman, 1954). The method includes sampling and measuring a minimum of 100 separate pieces of sediment from a representative riffle crest and bar. A summary of size-class percentiles (percent finer than) is included in Table 5 for all reaches. Although gravel is the overall dominate size class, a longitudinal pattern can be seen, with size-fractions decreasing in the downstream direction, from a median diameter percent finer than (D50) of small cobbles (77-84 mm) in Reach 10 to fine gravels (6-8 mm) in Reach 1.

Downstream of the bedrock falls at the upper end of the assessment area, the single-thread channel is straight to slightly meandering, and alternates between a confined and partially confined condition, with bedrock and terraces restricting lateral channel movement and overbank flow (Figure 36). High channel slope and confinement create a high energy environment in which large wood and sediment inputs are frequently mobilized and transported downstream, rather than retained locally. Substrate is primarily cobble-boulder alluvium, with cobbles and occasional large gravels only present in areas where low velocities have induced sediment deposition, such as channel margins and behind very large boulders. Below the Panther Creek confluence, the White River valley widens and the channel becomes unconfined (Figure 37). Channel scars visible in the topography of the valley floodplains suggest a history of active lateral migration. Channel slope decreases considerably between the Panther Creek and Napeequa River confluences, and again below the Sears Creek Road bridge crossing at RM 7, reducing the transport capacity of the river. Substrate transitions to primarily gravel-cobble alluvium through the middle portion of the assessment area, and to primarily sand-gravel alluvium in the lower portion downstream of RM 7. Boulders are generally absent from the channel downstream of Panther Creek aside from areas impacted by hillslope contacts, mass wasting deposits, and tributary alluvial fan inputs. Although the planform remains primarily single-threaded, large wood and local flow dynamics create low-flow splits at mid-channel bars with large wood jams. Split-flow is most common downstream of the Napeequa Confluence. The channel remains straight to slightly meandering through the Napeequa confluence, and transitions to meandering as sinuosity increases considerably near and downstream of the Sears Creek confluence area (Figure 38).

Lake Wenatchee serves as a base level control for the lower White River; therefore, fluctuations in Lake Wenatchee water levels have the potential to impact lower White River fluvial processes. During the geomorphic assessment, conducted during the 2024 summer low-flow period, backwatering due to Lake Wenatchee was observed upstream from the lake to approximately RM 1. However, seasonal fluctuations in streamflow (e.g., snowmelt runoff) and inter-annual extreme events (e.g., rain on snow events) are associated with significant Lake Wenatchee water level fluctuations of 10 feet or more (Haapala, 2003). These fluctuations affect the extent of backwater influence upstream in the White River. When periods of high White River flow coincide with high lake levels, the backwater effect from the lake may result in increased likelihood of overbank flows within the lower White River. This dynamic has likely contributed to vertical accretion of fine sediments on floodplain surfaces and tall stream banks observed downstream of RM 2.

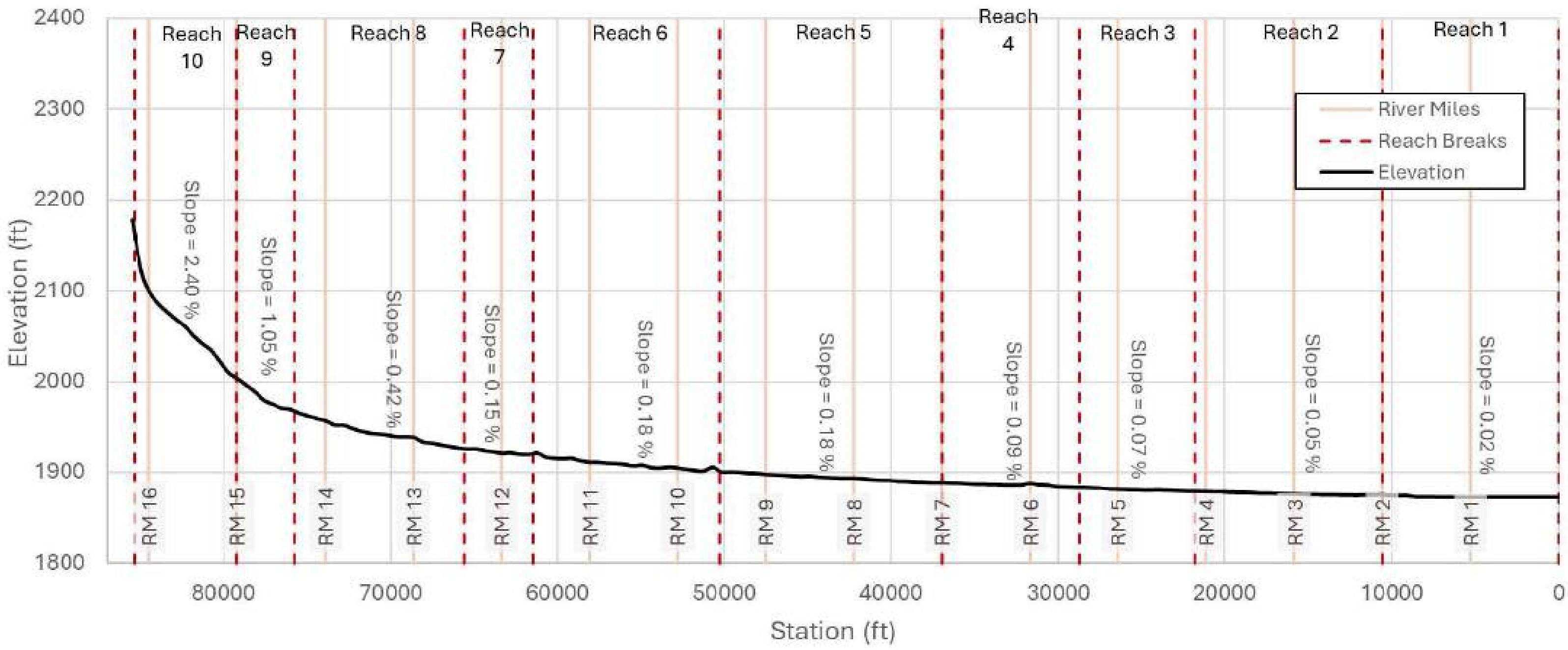

Figure 35. White River longitudinal elevation profile extracted from LiDAR. Panther Creek enters at RM 15 (upstream end of Reach 9); the Napeequa River enters near RM 12.4 (upstream end of Reach 7); and Sears Creek enters near RM 8.6.

Table 5. Bed material size (in mm) percentiles (percent finer than) for the 23 gravel counts completed in the Assessment Area.

	GC01	GC02	GC03	GC04	GC05	GC06	GC07	GC08	GC09	GC10	GC11	GC12	GC13	GC14	GC15	GC16	GC17	GC18	GC19	GC20	GC21	GC22	GC23
	Reach 1		Reach 2		Reach 3		Reach 4		Reach 5		Reach 6		Reach 7		Reach 8		Reach 9		Reach 10		Reach 1		Reach 1
Size Class (mm)	White River																				Napeequa		Panther
D5	2	3	4	4	5	5	8	6	6	8	10	8	11	23	9	20	6	5	1	8	10	7	11
D16	4	5	6	6	7	8	11	9	10	15	16	15	17	34	13	29	16	14	11	28	20	21	28
D50	6	8	12	10	10	13	18	16	18	25	32	30	34	64	31	61	49	51	84	77	36	53	89
D84	11	15	18	16	15	20	28	27	28	38	49	53	56	90	60	110	144	177	251	178	57	90	300
D95	15	20	22	21	18	27	31	36	36	44	61	66	73	118	106	166	276	300	301	301	64	128	301

Figure 36. Photograph of characteristic steep, confined, high gradient, and relatively straight channel conditions with primarily boulder substrate, common in the upper portion of the assessment area, looking upstream from RM 15.56 (August 1, 2024).

Figure 37. Photograph of characteristic channel conditions within the middle portion of the assessment area: point bars, unconfined valley bottom, and split-flow around mid-channel bars, looking upstream from RM 9.86 (August 5, 2024).

Figure 38. Photograph of characteristic channel conditions within the lower portion of the assessment area: low gradient, wide valley bottom, and increased presence of sand within bars, looking upstream from RM 3.4 (September 9, 2024).

The primary tributaries with perennial surface water contributions to the White River within the assessment area include Panther Creek, the Napeequa River, Canyon Creek, and Sears Creek. Combined, these tributaries contribute over half of the estimated 2-year discharge of the White River to Lake Wenatchee. Panther Creek contributes approximately 14% of the White River's discharge and is a source of coarse gravel-cobble-boulder sediment. Its active alluvial fan includes a complex network of ephemeral distributary flow paths with on-going fan development and lateral migration. The Napeequa River is the largest tributary of the White River, contributing approximately 27% of the White River's 2-year discharge. The Napeequa River is a source of coarse sediment to the White River, although at a reduced rate compared to pre-European settlement impacts. Lateral migration of the Napeequa across its historical alluvial fan is confined by bank hardening and bridge construction, which holds the Napeequa River confluence with the White River at a stable location. Canyon Creek and Sears Creek each contribute an estimated 5-6% of the White River 2-year discharge. Whereas Canyon Creek is a source of sediment and wood to the White River Channel, Sears Creek is impacted by extensive beaver activity between Sears Creek Road and the White River channel, which causes diffuse flow across the floodplain and the lack of a defined confluence point. In addition to the named tributaries, numerous other tributaries, the majority of which are ephemeral, contribute minor amounts of flow and sediments to the White River and its valley floor.

2.9.5 Sediment Mobility - Incipient Motion Hydraulics Analysis

An evaluation of potential sediment mobility in the White River assessment area was conducted using the results of the White River hydraulic model at the 2-yr modeled flow event. Incipient motion analysis identifies the erosion (grain mobilization) threshold for varied grain sizes, based on shear stress forces. Sediment or grains are transported when shear stress, the force of water acting on the sediment, is greater than the forces keeping the sediment in place. The amount of force required to initiate movement of a sediment particle or grain of a specific size is called critical shear stress (τ_c). If the shear stress generated by the force of water is greater than the forces holding the sediment in place, then the sediment grain has the potential to be mobilized or, if the water's shear stress is high enough, remain in transport. Conversely, if the flowing water's shear stress is less than that needed to initiate mobilization of the grain the grain is not expected to mobilize. When upstream shear stress is sufficient to mobilize a grain, but downstream shear is insufficient, deposition of a mobilized grain is expected to occur in the downstream section – assuming the grain was available for mobilization in the upstream section. Incipient motion analysis does not estimate bedload transport volumes or sediment budgets. It identifies the point at which sediment particles of varied size are expected to mobilize in flowing water (specific shear) at a particle discharge.

2.9.5.1 Assumptions and Inputs

The shear stress results extracted from the preliminary existing conditions 2-D hydraulic model, at the estimated 2-yr flow, were used to examine probable sediment mobility using the Shields equation for incipient motion, as described in the USACE (2024a) *HEC-RAS 2D Sediment Technical Reference Manual Critical Thresholds for Transport and Erosion*. The Shields equation and its variables are:

$$\tau_c = \theta^*(s-1)\rho g d*$$

where:

τ_c is the critical shear stress exerted on a grain by flowing water
θ^* is the dimensionless Shields parameter gravel − cobble rivers
s is the specific gravity of the grain
ρ is the density of water
g is the gravitational acceleration constant
$d*$ is the diameter of the grain size of interest

For the calculations, we used the constant values of g = 32.2 ft/s^2, ρ = 62.4 lbs/ft^3, and s = 2.65 (for granite and metamorphic rock).

This equation was rearranged to solve for grain size to identify where the modeled flow hydraulics of the 2-yr discharge reach critical shear and thus, potential to initiate grain mobilization.

$$d* = \frac{\tau_c}{\theta^*(s-1)\rho g}$$

For the purposes of this analysis, required critical shear of grains (sand to boulder sized material) were added to the preliminary HEC-RAS hydraulic model as a calculated layer. A dimensionless Shields parameter of 0.035 was used based on professional judgment and previous studies on gravel and cobble channels (Meyer-Peter & Müller, 1948; Parker & Toro-Escobar, 2002; Wilcock, 2003; Wilcock et al., 2001; Wilcock & McArdell, 1993)

2.9.5.2 Incipient Motion Considerations

Although this analysis is useful in identifying and predicting areas of potential or likely particle mobility or relative potential mobility from upstream to downstream, there are many limitations and uncertainties in the HEC-RAS model input data, HEC-RAS model capabilities, and the dimensionless parameter used in the Shields equation. In addition to selecting a representative value for the Shields parameter, incipient motion results are highly dependent on the variability and orientation of other grains on the bed of the channel. Sediment size variability and orientation is referred to as surface roughness, represented with a best-judgement selected Manning's n value in the model. Within HEC-RAS, shear stress is exponentially related to Manning's n. As a result, it can produce artificially high shear stress in areas at the contact point where the value of the roughness polygons change. The artificially high roughness areas are often not a good representation of the shear stress calculated for those locations (USACE, 2024c, 2024b, 2024d). For this analysis, the values of these parameters were informed by previous studies, field observations, and professional judgment. They were selected to represent general site conditions instead of site-specific conditions. In practice, the values of the parameters will vary throughout the assessment area as the channel conditions change. Therefore, should more detailed questions about bed mobility arise for future design or sediment transport analysis, further investigations and analysis may be required to refine the results.

2.9.5.1 Results and Interpretation

The results of the incipient motion analysis for the estimated 2-yr discharge for the modeled shear stress are displayed on the map in Figure 39 and in each of the reach summaries (Section 3). The results are clipped to the modern active channel to display potential activation of bedload. The analysis results suggest that the White River, Napeequa, and Panther Creek are capable of transporting gravel-fraction size material throughout the entirety of the project area during the 2-yr modeled discharge. Potential gravel size mobility related to hydraulic shear stress does decrease in a downstream pattern, matching the trend in decreased channel gradient. Upstream of RM 13 on the White River, the model indicates that cobble-sized substrate and even patches of small boulders have the potential to be mobilized at the modeled 2-yr discharge. A similar downstream trend in reduced shear stress and decreased potential grain size mobilization is depicted on the Napeequa, with cobble mobilization upstream of RM 1.1 and the potential to periodically mobilize boulders upstream of RM 1.13. The notable increase in modeled shear stress between RM 1.78 – 2.2 reveals boulder mobilization potential at the 2-yr discharge on the Naqeequa. The Panther Creek analysis results at the 2-yr modeled discharge suggest cobble and patches of boulder-sized material can be mobilized throughout the assessment reach from RM 0 – 0.8, including across the creek's active alluvial fan. Based on field observation, the results of the analysis are reasonable.

At the boundary where shear stress and grain size mobility potential decrease in a downstream trend along the channel, deposition of the larger grain fraction is expected to occur, assuming upstream sediment availability. The incipient motion analysis for the 2-yr modeled discharge suggests that the system, within the assessment area, has the capacity to deliver and mobilize, over-time, small-fraction sized gravels from the upstream boundary to the downstream boundary. This indicates sediment connectivity through the assessment area. This characteristic also explains the presence of large, maintained gravel bars and bedforms in the very low-gradient meandering downstream reaches of the White River. Field observations, representative pebble count data results, and reach-scale descriptions of the incipient motion analysis results are provided for each reach in Section 3.

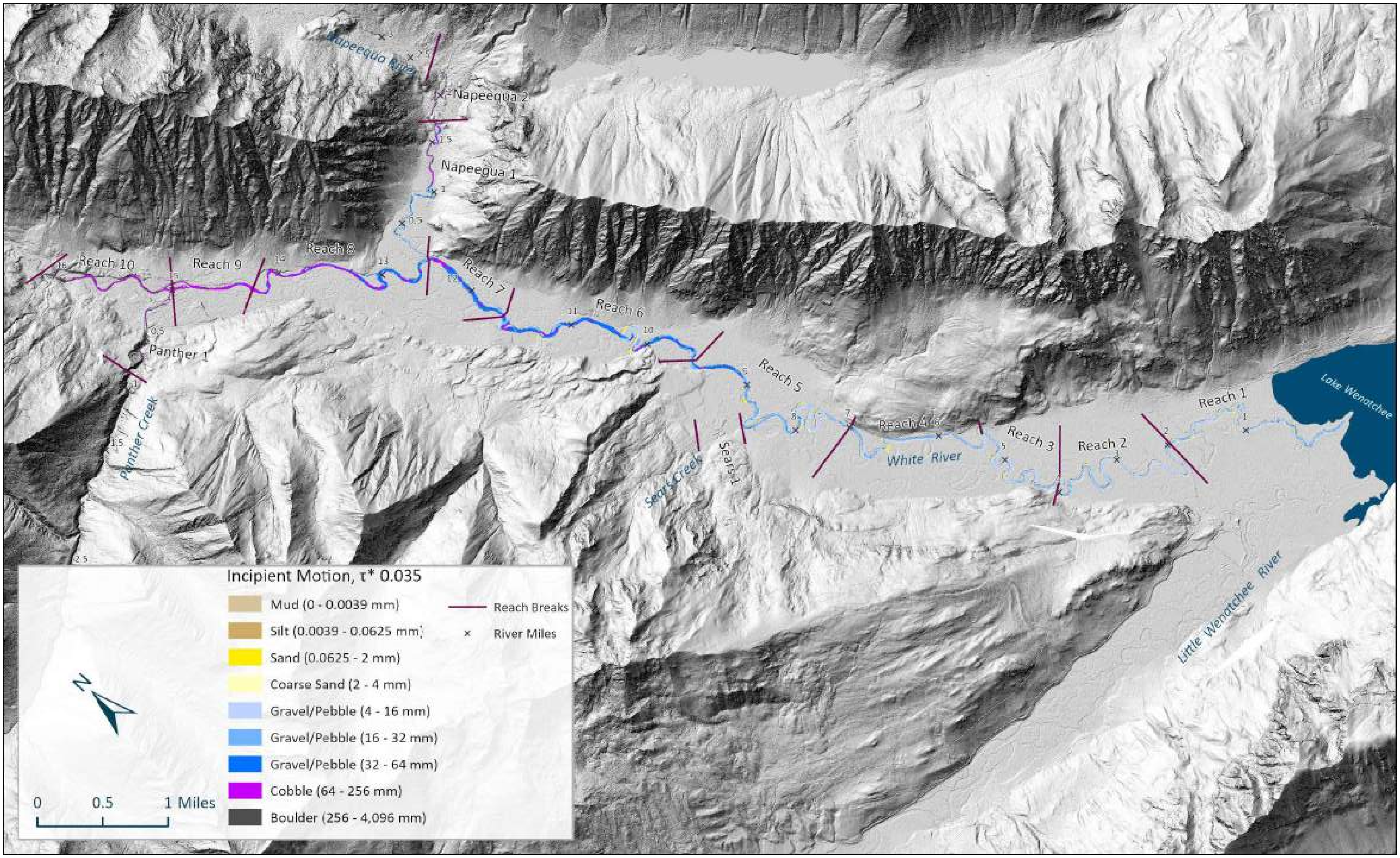

Figure 39. Incipient motion analysis map of estimated 2-yr discharge modeled shear stress - White River (RM 0 - 16.17), Napeequa (RM 0 – 2.2), and Panther Creek (RM 0 – 0.8).

2.10 LARGE WOOD MATERIAL (LWM)

Pieces of large wood (≥ 6 inches diameter) in a channel contribute nutrients, shade, and cover, and promote habitat complexity suitable for many riverine species (Langford et al., 2012). Quality large woody material (QLW) (≥12-in diameter and at least 35 feet long) in a channel is expected to influence local geomorphic process (i.e. sediment sorting, increased scour and erosion) and increase channel complexity due to associated induced flow hydraulics, flow redirection, and creation of splitting flow pathways (Grabowski & Gurnell, 2016; Langford et al., 2012; Montgomery & Piégay, 2003) (Figure 40). The quantity and quality of LWM within a riverine system depends on the presence of mature or maturing forests, as well as the processes of recruitment such as infall from banks, debris flows or landslides off hillslopes, in-channel transport, etc. Tree size (length and diameter) compared to active channel width, channel form, and flow regimes control retention and accumulation patterns of the LWM in the channel.

Figure 40. Large wood jam in Reach 8 increasing channel complexity by promoting scour, sorting sediment, and promoting split-flow conditions, looking downstream from RM 12.95. The main channel is to the left of the photograph (August 4, 2024).

LWM, including individual pieces and log jams, were counted during field surveys as part of the Habitat Assessment (See Appendix A) from August 1-September 1, 2024. A total of 1179 pieces of QLW and 245 log jams were counted within the White River, Napeequa River, and Panther Creek assessment areas. A summary of the data and a map of log jams and the distribution of large wood pieces recorded during the habitat survey is included in Figure 41.

Fox and Bolton (2007) established LWM thresholds for river management based on instream large wood surveys across Washington State. A threshold for LWM required for "adequate fish habitat" in the White River assessment area of 67 pieces of QLW per mile was inferred from datasets provided in Fox and Bolton (2007) using the 75th percentile for large rivers draining the eastern slopes of the Cascade Range. Although QLW in Reaches 2-10 exceeds 67 pieces per mile (Figure 41), the wood regime of the White River is nuanced, and this threshold alone is not sufficient to evaluate large wood functioning within the assessment area. Large wood stability is an important driver of geomorphic processes and river corridor complexity. Compared to mobile wood entrained in the flow of the river, large wood that remains stable at flows capable of generating significant scour or of transporting coarse sediments is more likely to drive the formation of complex habitat conditions through flow routing, sediment sorting, and racking of additional large wood. Large wood stability is a product of large wood piece size (basal diameter, log length relative to channel size (bankfull width, depth); as channel size increases, so does the minimum large wood piece size required for large wood to remain stable (Abbe & Montgomery, 2003).

Stumps of mature old growth trees in floodplains throughout the assessment area provide evidence that large conifers were historically present across the valley floor. Removal of mature forests through logging has diminished the availability of effective large wood, capable of maintaining a complex and dynamic river corridor. Although several of the assessment reaches contain a high abundance of large wood, it is generally lacking in "key" pieces, logs large enough to be retained in the channel and drive and maintain geomorphic processes. Furthermore, in many cases, much of the large wood is clustered within a small number of large jams or rafts, rather than evenly distributed. As a result, large portions of the assessment area are locally lacking in-channel large wood and the benefits it provides.

At present, LWM plays a minor role in the modern geomorphology of the upstream portion of the assessment area from Panther Creek to White River Falls. Due to the relatively high energy of this steep section, LWM must be > 24" diameter to be an effective key log. Although pockets of old-growth western redcedar and Douglas-fir capable of withstanding some degree of high flows exist in the upper reaches, the majority of trees are second-growth, and too small to be retained long enough to influence local geomorphology. Downstream of Panther Creek, channel slope decreases and LWM is more easily retained, allowing it to provide some influence on geomorphology and habitat complexity. However, most of the recruitable floodplain forests are second-growth. Channel-spanning LWM wedged between boulders (Napeequa River) and bedrock outcrops (Panther Creek) creates isolated wood-forced step-pool sequences in the upper portion of the assessment area tributaries. Downstream of the falls on the Napeequa River, LWM retained within the channel generates local habitat and geomorphic complexity.

Metric	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10	Reach 1	Reach 2	Reach 1	
	White River										Napeequa River		Panther Creek	Totals
Total Number of QLW Pieces	50	202	77	111	171	122	61	94	35	51	100	65	40	1179
Total Number of Jams	14	41	15	1	22	44	11	23	3	7	25	14	10	245
Number of QLW Pieces per Mile	57	208	151	129	121	281	163	162	73	69	127	378	136	154

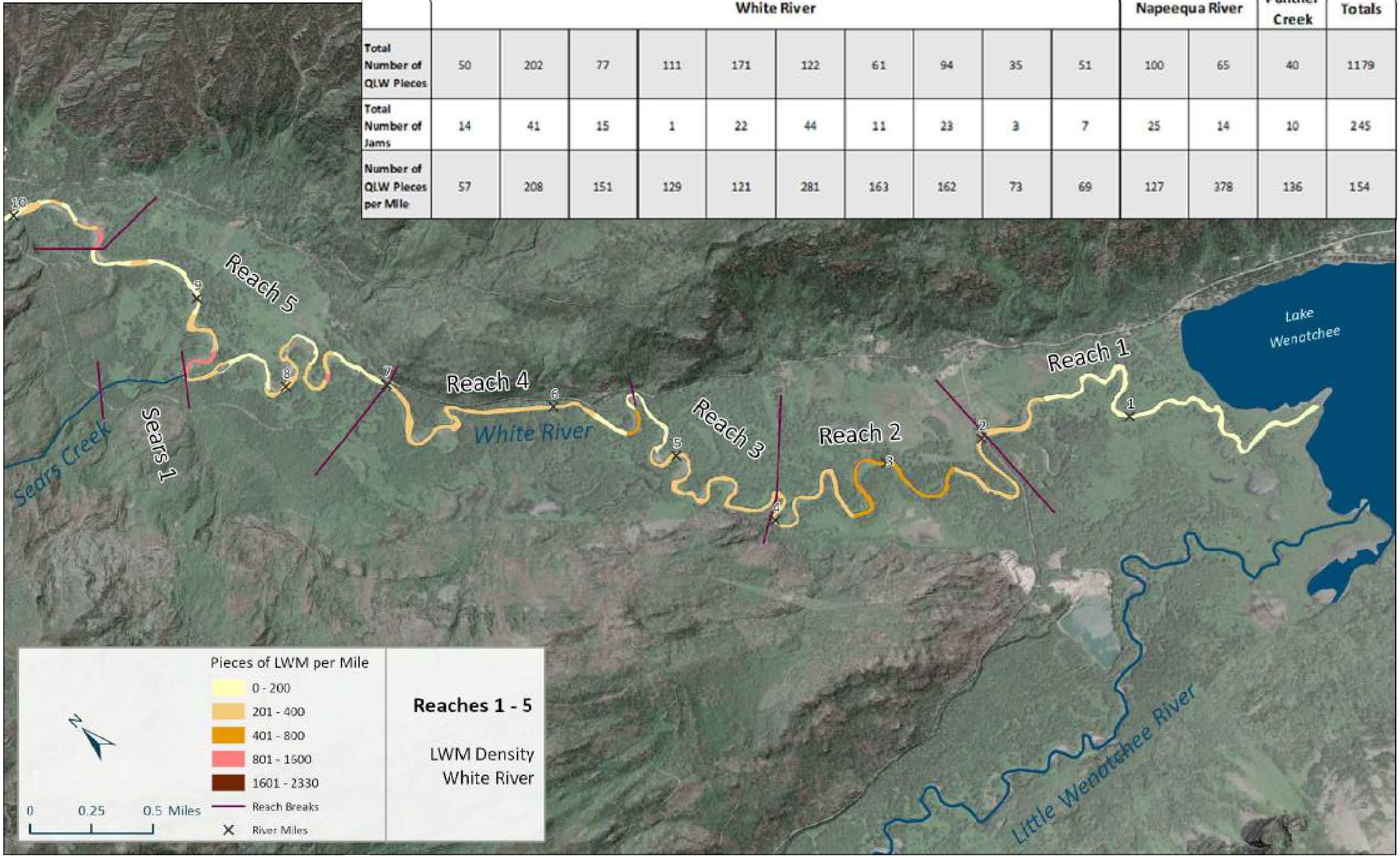

Figure 41. Map and summary data of LWM density, including pieces in jams, per habitat unit recorded during the Habitat Survey (See Appendix A).

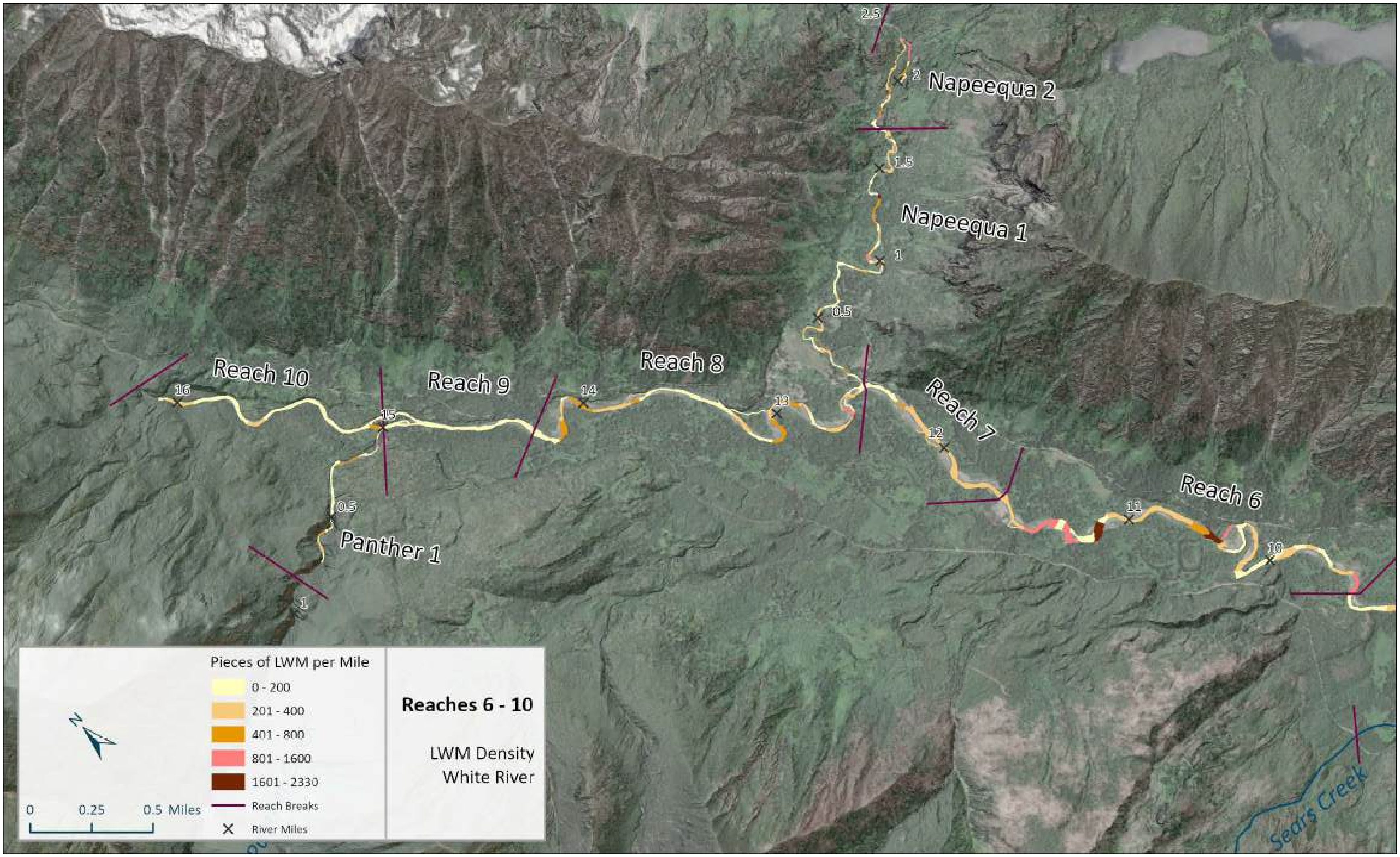

Figure 42. Map of LWM density in Reaches 6 - 10 on the White River.

Modern abundance and geomorphic function of LWM is limited by the land use practices of the White River basin, including extensive logging throughout the assessment area. Logging and clearing of vegetation for construction of the White River Road, homes, and other structures has limited the amount of LWM capable of withstanding high flows and forming persistent large wood jams that are able to alter geomorphic processes. It is likely that the common practice of removing large wood from the channel was undertaken during periods of historical logging and more recently near existing structures (bridges, riprap, homes, etc). Additionally, the presence of White River Road likely restricts hillslope-to-channel routing of large trees at river-left contact points, and bank hardening restricts lateral migration in some areas that would otherwise generate large wood recruitment. It may take decades to centuries for forests within the White River basin to mature to the point that sufficient LWM can be naturally sourced from local recruitment. Adding supplemental large wood would improve both geomorphic and habitat complexity throughout the assessment area while floodplain forests mature.

2.11 VEGETATION

Vegetation height analysis was completed for the assessment area using LiDAR data. A raster layer that represents canopy height was created in a GIS by calculating the difference between the LiDAR Digital Surface Model (DSM), which is the 'first return' data representing the top elevation of features, and the Digital Terrain Model (DTM), which is the bare earth elevation. Vegetation height analysis helps assess the vegetation biomass, habitat quality, post-disturbance regrowth, and large wood supply surrounding the river channel. It is also used to inform the hydraulic roughness values (Manning's n) as part of the hydraulic modeling. Vegetation classes were developed based on field observations. Reach-scale maps and discussion of vegetation are provided in Section 3.

Riparian vegetation in the White River assessment area consists of mid- to late-seral stage coniferous overstory with a dense shrub/sapling understory. The primary overstory species include western redcedar (*Thuja plicata*), grand fir (*Abies grandis*), Douglas-fir (*Pseudotsuga menziesii*) and black cottonwood (*Populus trichocarpa*). Western redcedar is present in the majority of reaches within the assessment area, whereas grand fir is generally present upstream of Reach 5. Black cottonwood were only observed downstream of Reach 9, with especially high concentrations in the lower reaches. Mature trees were most common in the reaches upstream of Panther Creek, although small pockets of old-growth cedar were observed in some of the other reaches. Understory species in Reaches 9 and 10 consist of western redcedar, alder (*Alnus spp.*), vine/Douglas maple (*Acer circinatum/Acer glabrum var. douglasii*) and species of huckleberry and blueberry (*Vaccinium spp.*). Red-osier dogwood (*Cornus sericea*) is present in Reaches 1-8, generally in vast dense thickets on floodplain surfaces. Willow is generally the dominant species on low floodplain surfaces throughout the assessment area. Although large to mature cottonwoods were the dominant overstory species in over half of the middle and lower reaches, there were few small to medium cottonwoods in the understory suggesting a potential disruption to cottonwood recruitment. Other species including quaking aspen (*Populus* tremuloides) and non-native reed canary grass (*Phalaris arundinacea*) are also present in riparian areas. Hillslope vegetation is generally dominated by mixed-conifer forests.

2.12 AQUATIC HABITAT CONDITIONS

Habitat surveys using the US Forest Service Region 6 Level 2 protocols were performed in the assessment area from Aug 1 to Sept 1, 2024. The full White River Habitat Assessment (Appendix A) provides an inventory of the habitat conditions in the White River study area, as well as the surveyed portions of the Napeequa River and Panther Creek. This section provides a summary of the findings. A summary table of the habitat assessment results is included as Table 6.

From the White River falls to the mouth at Lake Wenatchee, the White River undergoes a dramatic change. In the upper sections (Reach 10) the channel is steep, naturally confined, and high energy. Moving downstream the gradient decreases, and both Panther and the Napeequa contribute significant amounts of flow which results in more split flow and LWM. In the lower reaches (reaches 1-5) the channel is wide, slow moving, and sinuous, and reaches 1-2 have a strong backwater influence from Lake Wenatchee.

The White River is dominated by pool units, which make up the majority of habitat types in reaches 1-8 and in the Napeequa River 1 Reach. The residual depth of the pools generally decreases moving upriver. Riffle is the dominant type in the remaining reaches; Reach 9-10, the Napeequa River 2 Reach, and Panther Creek. The first side channel (must be flowing during low flow to qualify) in the mainstem appears in Reach 5; reaches 5-9 and both reaches of the Napeequa have side channel habitat. Substrate size increases moving upriver, with the gravels being the dominant substrate in reaches 1-9, but with decreasing prevalence as you move downstream. Cobbles are dominant in Reach 10. Gravels were dominant in both the lower reach of the Napeequa and Panther Creek. The Napeequa River 2 Reach had too large of substrate to perform a gravel count.

A total of 5,709 pieces of LWM were observed throughout the survey, with 56% of those being within jams (3 or more pieces). From a habitat and cover perspective, there are adequate amounts of wood in all the reaches, apart from Reach 1, which is lacking in total quantity of wood. Reach 6 has the most wood per mile of any mainstem reach, and the Napeequa River 2 Reach had the most throughout the survey area. Although there are significant amounts of wood in the survey area from a habitat and cover perspective, this does not consider the geomorphic function of the wood. Wood with a strong influence on channel dynamics was found to be lacking.

The overstory vegetation throughout the study area is primarily large trees, which have a 21.0-31.9-inch diameter at breast height (dbh) and cottonwood is the most prevalent species. The understory vegetation is primarily shrub/seedling sized (1.0-4.9-inch dbh) and the most prevalent species is dogwood.

Temperature data were analyzed for the White River from the WDOE stream gage #45K090 from 2002-2024. In general, peaks in temperatures (where temperatures exceed 15°C) occur in the summer, mainly July and August with the occasional peaks occurring in June or September. Maximum observed water temperatures also appear to be increasing and occurring more frequently between 2013-2024 than in 2002-2012, as shown Figure 43. This has potential implications for Spring Chinook, Steelhead, and Bull Trout, all of which use the White River during summer months.

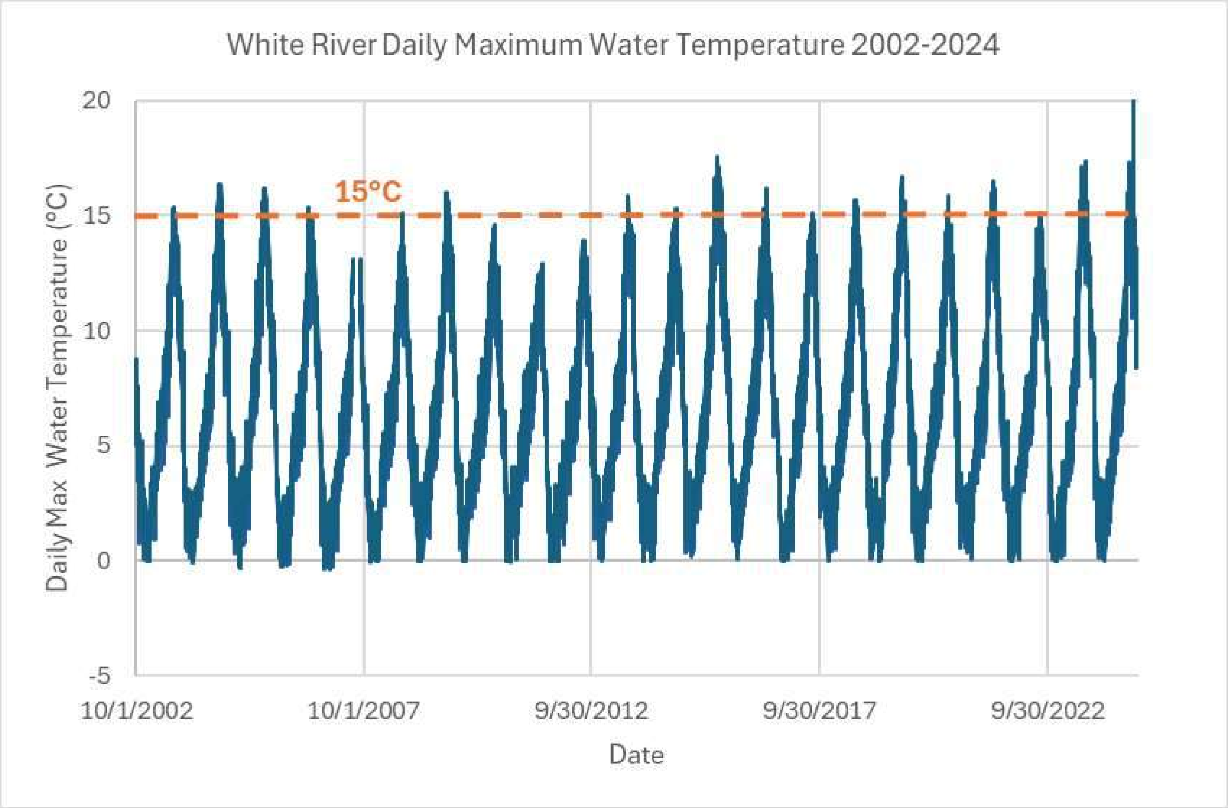

Figure 43. Graph of maximum daily temperature (°C) in relation to 15°C from 2002-2024 for the White River.

Table 6. Summary of habitat assessment results. The 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 1	Reach 2	Reach 1
Unit Composition	White River										Napeequa River		Panther Creek
Pool	100%	100%	97%	89%	91%	79%	92%	61%	12%	8%	67%	5%	30%
Riffle	0%	0%	0%	0%	0%	1%	0%	9%	50%	79%	19%	50%	69%
Glide	0%	0%	3%	11%	7%	17%	5%	23%	20%	12%	10%	0%	0%
Side Channel	0%	0%	0%	0%	1%	4%	4%	7%	18%	0%	4%	45%	0%
Waterfalls	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	0%	0%	0%
Cascade	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%
Fish Weir	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Substrate (% gravel)	98%	99%	100%	99.5%	99%	95.5%	71%	70%	55%	39%	79%	n=0	41%
Medium & Large LWM/mile (includes jams)	57	208	151	129	121	281	163	162	73	69	127	378	136
Pools/mile	1	1	2	4	7	8	5	8	2	5	14	4	20
No. Pools with Residual depth 6ft>D>=3ft	0	1	1	4	11	10	3	6	1	2	15	2	4
No. of Pools with Redisual Depth >=6ft	2	1	1	2	5	5	1	0	0	0	0	0	2
No. Side Channels	0	0	0	0	2	3	1	4	2	0	3	6	0
Riparian Conditions													
Mature Trees (MT)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	14%
Large Tree (LT)	100%	100%	100%	100%	78%	67%	100%	56%	100%	100%	46%	50%	71%
Small Tree (ST)	0%	0%	0%	0%	0%	22%	0%	44%	0%	0%	54%	50%	14%
Sapling Pole (SP)	0%	0%	0%	0%	0%	11%	0%	0%	0%	0%	0%	0%	0%
Grassland/Forb (GF)	0%	0%	0%	0%	11%	0%	0%	0%	0%	0%	0%	0%	0%
No Vegetation (NV)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Other	0%	0%	0%	0%	11%	0%	0%	0%	0%	0%	0%	0%	0%

2.13 REACH-BASED ECOSYSTEMS INDICATORS (REI)

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 are provided in Appendix B. A summary of the results is included here, including an overview table of the reach-scale results for the White River reaches in Table 7 and the tributary reaches in Table 8.

At the watershed scale, REI ratings for the White River ranged from Adequate to Unacceptable. Watershed-scale impairments are primarily related to historical or ongoing anthropogenic disturbance to the watershed. Reach-scale metrics similarly ranged from Adequate to Unacceptable. Across all reaches, the most impaired indicators occurred in the Habitat Quality and Riparian Vegetation categories. The mainstem White River study area does not have any full fish passage barriers and suitable spawning-sized substrates are present throughout the study area. However, off-channel habitats accessible to fish throughout the year and high-quality riparian conditions, such as mature, old-growth trees, channel shading, and undisturbed riparian zones, were limited or completely lacking across nearly all mainstem White River reaches. The lower portion of the Napeequa River near the confluence with the White River has some residential development that has impaired many of the pathways and indicators assessed in the REI, including habitat quality, riparian vegetation, and channel dynamics. Panther Creek appears to be functioning relatively well, with a number of adequate ratings, although habitat quality could be improved by increasing the number and quality of pools and off-channel habitats.

Table 7. Summary ratings for the White River reach assessment study area. 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
Habitat Access	Physical Barriers	Main Channel Barriers	At Risk	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	Adequate	At Risk
	LWM	Pieces per Mile at Bankfull	Unacceptable	At Risk	Adequate*	At Risk	At Risk	At Risk	Adequate*	At Risk	Adequate*	Adequate*
	Pools	Pool Frequency and Quality, Presence of Large Pools	Adequate	Adequate	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	Unacceptable	At Risk
	Off-Channel Habitat	Connectivity with Main Channel	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable	At Risk	At Risk	Adequate	At Risk	Adequate
Riparian Vegetation	Condition	Structure	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	Adequate
		Disturbance (Human)	At Risk	At Risk	At Risk	At Risk	Adequate	At Risk	At Risk	At Risk	At Risk	Adequate
		Canopy Cover	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	At Risk	Adequate	Adequate
Channel	Dynamics	Floodplain Connectivity	Adequate	At Risk	Adequate	Unacceptable	At Risk	Adequate	Adequate	Adequate	Unacceptable	Adequate
		Bank Stability/ Channel Migration	At Risk	Adequate	Adequate	Unacceptable	At Risk	Adequate	At Risk	At Risk	Unacceptable	Adequate
		Vertical Channel Stability	Adequate	Adequate	Adequate	At Risk	Adequate	Adequate	Adequate	Adequate	Unacceptable	Adequate

**Although the LWM maybe be adequate from a habitat/cover perspective, this indicator does not consider the geomorphic function of LWM. An asterisk is indicated in the LWM reach rating where the rating would potentially be lowered if geomorphic function of LWM was taken into account.*

Table 8. Summary ratings for the Napeequa River and Panther Creek reaches. Ratings are color-coded, with green shading for Adequate condition, yellow for At Risk condition, and red for Unacceptable.

Pathway	General Indicators	Specific Indicators	Napeequa River 1 Reach	Napeequa River 2 Reach	Panther Creek
Habitat Access	Physical Barriers	Main Channel Barriers	Adequate	Adequate	Adequate
Habitat Quality	Substrate	Dominant Substrate/ Fine Sediment	Adequate	Adequate	At Risk
	LWM	Pieces per Mile at Bankfull	At Risk	Adequate*	Adequate*
	Pools	Pool Frequency and Quality, Presence of Large Pools	At Risk	At Risk	At Risk
	Off-Channel Habitat	Connectivity with Main Channel	At Risk	Adequate	At Risk
Riparian Vegetation	Condition	Structure	At Risk	At Risk	Adequate
		Disturbance (Human)	At Risk	Adequate	Adequate
		Canopy Cover	At Risk	Adequate	Adequate
Channel	Dynamics	Floodplain Connectivity	At Risk	Adequate	Adequate
		Bank Stability/ Channel Migration	At Risk	Adequate	Adequate
		Vertical Channel Stability	At Risk	Adequate	Adequate

**Although the LWM maybe be adequate from a habitat/cover perspective, this indicator does not consider the geomorphic function of LWM. An asterisk is indicated in the LWM reach rating where the rating would potentially be lowered if geomorphic function of LWM was taken into account.*

3. Reach-Scale Conditions

Reach-scale conditions for the White River, Napeequa River, and Panther Creek assessment areas were assessed during the August-September 2024 field survey. Results for each reach are presented below. A map of reach locations is included here for reference in Figure 44.

Figure 44. Map of geomorphic reaches of the White River Assessment Area.

3.1 WHITE RIVER REACH 1 (RM 0 – 2)

3.1.1 Overview

Reach 1 is two miles long and extends from the mouth of the White River at Lake Wenatchee to the Little Wenatchee Road bridge crossing at RM 2. The channel in Reach 1 is sinuous (S = 1.47), single thread in planform, and unconfined (Figure 45, Table 9). The reach experiences backwatering from Lake Wenatchee, especially in the downstream portion. The average gradient of Reach 1 (0.02%) is lower than that of any other reach within the assessment area. The average bankfull width for Reach 1 is estimated to be approximately 130 feet using NAIP aerial imagery from 2023 following the Habitat Assessment. The majority of the geomorphic surfaces in the valley are mapped as low floodplain (inundated ~ 1-5 years). The remainder is mapped as medium floodplain (inundated ~ 5-10 years), although a section of the river-right floodplain adjacent to the Little Wenatchee Road bridge at RM 2, was identified as anthropogenically disconnected. Vegetation on the low floodplain surfaces typically consists of dogwood, willow, and reed canary grass, with dogwood being the most prevalent species. The higher floodplain surfaces are vegetated with dogwood, reed canary grass, cottonwood, and western redcedar. Human alterations to the channel and floodplain in Reach 1 include Little Wenatchee Road which perpendicularly dissects the entire floodplain at the upstream end and confines the channel in a locked location. The road disrupts channel migration and floodplain flow paths. Ditching and draining, as well as several homes and other structures, and an abandoned road also impact flow routing and inundation patterns on the river-left floodplain.

Figure 45. Representative photo of the White River in Reach 1 at RM 0.33, looking downstream (August 16, 2024).

Table 9. Reach 1 descriptive geomorphic metrics.

Metric	Value
Reach Length (miles)	2
River Miles	0-2.0
Stream Gradient	0.02%
Sinuosity	1.47
Dominant Channel Habitat Unit Type	Pool
Average Bankfull Width (feet)	130 (estimate)
Confinement	Unconfined
Dominant Substrate	Gravel
Bank Stability/Channel Migration	At Risk *(See Appendix B Section 3.2)*
Vertical Channel Stability	Adequate *(See Appendix B Section 3.2)*

3.1.2 Channel and Floodplain Geomorphology

In Reach 1 the channel is very low gradient with subtle meander planform but high sinuosity. Downstream of RM 1 the channel experiences backwatering from Lake Wenatchee. The White River is considered unconfined in Reach 1. However, bank protection associated with the Little Wenatchee Road bridge on river-left between ~RM 1.93 – 2 restricts lateral migration near the upstream boundary of the reach. A channel spanning weir at RM 1.65 acts as a grade control that limits additional downcutting of the channel between what is presumed to be two anthropogenically forced meander neck cutoffs that straightened and shortened the channel at RM 1.5 and 1.8. The Habitat Assessment (See Appendix A) recorded 100% of the habitat as pool (Figure 47). There are no perennial tributaries to the White River in Reach 1, although several ephemeral channels associated with floodplain ditching and draining convey flows across the river-left floodplain, entering the White River at RM 1.25, 1.42, and 1.73. The channel at RM 1.25 appears to transport a combination of ditch-drained water from the river-left floodplain and seasonal runoff from the river-left hillslopes. During the geomorphic survey (August-September 2024), the three tributary channels were dry at their confluences with the White River, and the floodplain ditch network contained intermittent stagnant wetted pools.

Based on review of historical photos, the overall channel alignment in Reach 1 has not undergone major changes since 1957 - the oldest set of publicly available aerial imagery used for the assessment. However, a meander neck cutoff occurred at ~RM 0.4 between the 1972 and 1985 photo sets, and minor lateral migration at meander bends occurred throughout the reach (Figure 48). A wetted oxbow that is likely connected to the main channel for portions of the year is present at the location of the meander cutoff at RM 0.4 (Figure 47). Dogwood provides shading on the outside of the oxbow, whereas reed canary grass occupies the inside of the former meander. Additional meander cutoffs at ~RM 1.52 and 1.8 occurred prior to 1957, resulting in disconnected wetted oxbow features on the river right floodplain, and reduced reach sinuosity. The oxbow at RM 1.8 contains significant standing water and downed large wood (Figure 46) and could provide quality fish rearing habitat if reactivated as the mainstem channel or at least reconnected to it at low flows. In historical photographs from September 7, 1949, the cutoff appears recent, and the downstream portion is still connected to the main channel at low flows. The oxbow at RM 1.52 was dry at the time of survey (August 2024) but contains moist soil. Both features are visible in the LiDAR and NAIP aerial imagery datasets.

Figure 46. Wetted oxbow containing large wood on river right floodplain at RM 1.8 (August 15, 2024).

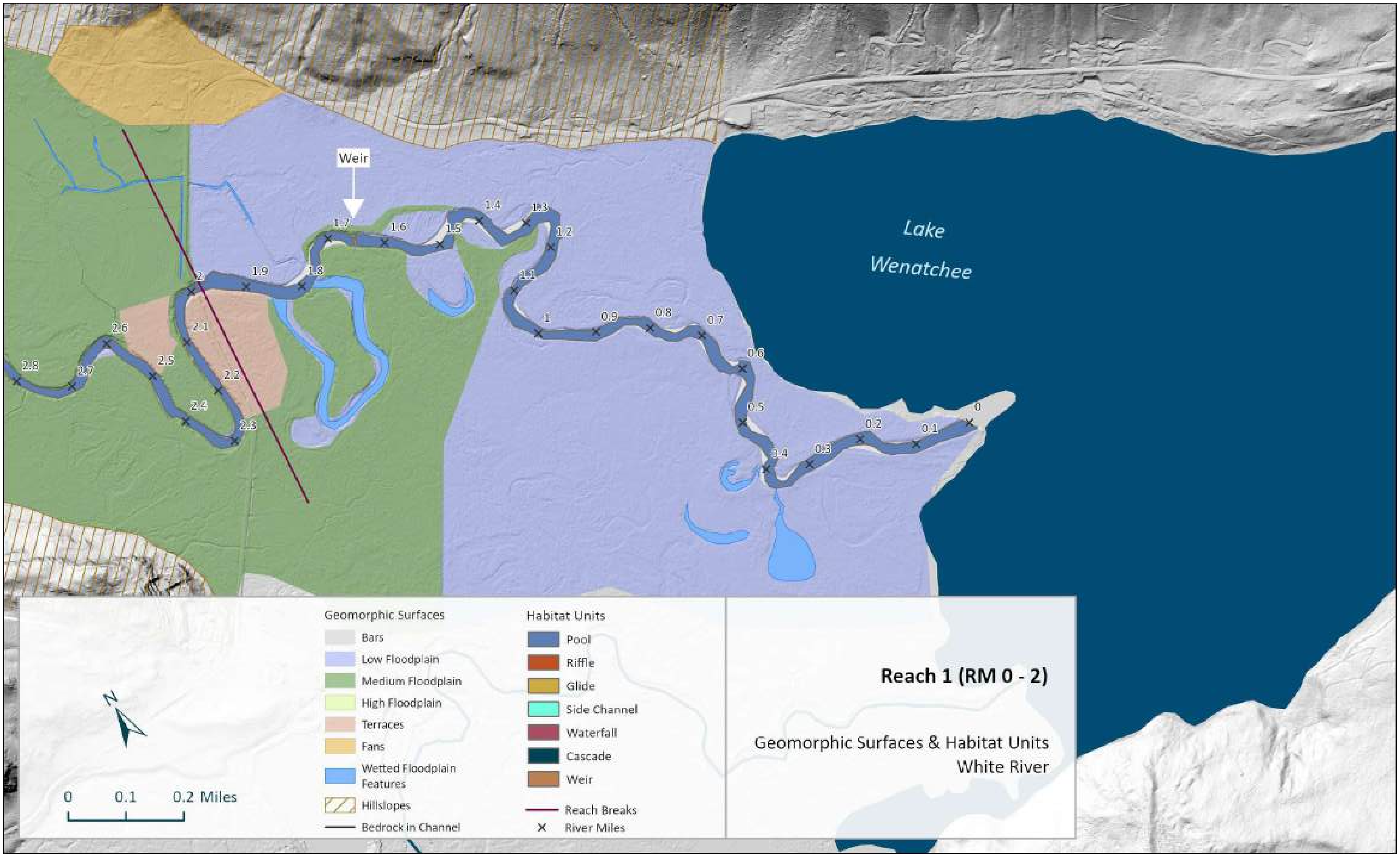

Figure 47. White River, Reach 1: Map of geomorphic surfaces and habitat units.

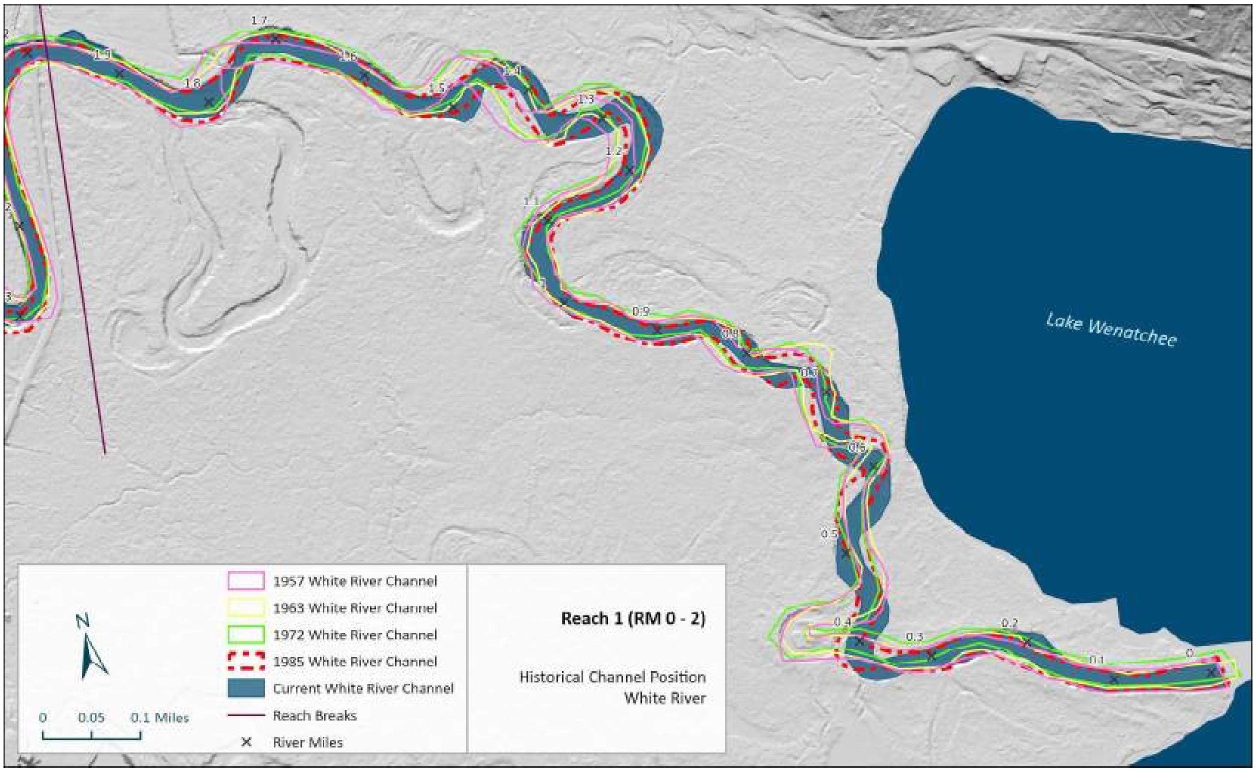

Figure 48. White River, Reach 1: Map of channel alignments digitized from historical photos (1957-2023).

The lower valleys of both the White River and Little Wenatchee River are connected at the upstream boundary of Reach 1, as each river approaches its outlet into Lake Wenatchee. Abundant historic channel scars visible in the topography cover the entire valley bottom downstream of ~RM 1.1, suggesting that both rivers historically migrated across their broad adjoined deltas and may have, at times, merged into each other prior to emptying into Lake Wenatchee. Compared to the historical channel scars, the modern-day channel planform is less sinuous. Decreased sinuosity is likely the result of past large wood removal from the channel, reduced wood load, lateral confinement at the Little Wenatchee Road bridge, and forced straightening or meander cutoffs.

Channel substrate in Reach 1 is primarily small gravels topped with coarse sand and fines in the upstream half of the reach and in the downstream half substrate is dominated by coarse sands. Point bars are located on the insides of all meander bends. The bars downstream of RM 1 are primarily composed of sand, whereas the bars from RM 1 – 2 are composed of small gravels (Figure 49).

Figure 49. Left: Sand bar on river left at RM 0.37. (August 16, 2024) Right: Gravel-sand bar on river left at RM 1.82 (August 15, 2024).

Wolman Pebble Counts (Wolman, 1954)(Wolman, 1954)(Wolman, 1954)(Wolman, 1954) were conducted on a small transverse riffle at a mid-channel bar at RM 1.63 (GC 01), and at the upstream end of a point bar at RM 1.83 (GC 02). Sediments sampled at GC 01 on the bar were slightly larger (D50 = 7.96 mm) than those at the downstream site at GC 02 on the riffle and mid-channel bar (D50 = 6.46 mm). The pebble count data concur with field observations of a downstream decrease in bed material size. The backwater effects from Lake Wenatchee influence the bar and bed composition of at least the lower one mile of Reach 1. The pebble count data are plotted on a map (Figure 50) of the Reach 1 incipient motion analysis results (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.9.4). The analysis indicates that at the 2-yr modeled discharge, the channels shear stress is capable of mobilizing small-fraction-sized gravels and coarse sand, assuming low lake levels with minimalized backwatering.

The gravels are fluvially transported into Reach 1 from upstream. Sands and fine sediment are likely generated locally from eroding bed and banks or fluvially transported in from upstream. A large sand spit at the mouth of the White River is evidence of abundant transport of sand and other fine sediments into Lake Wenatchee.

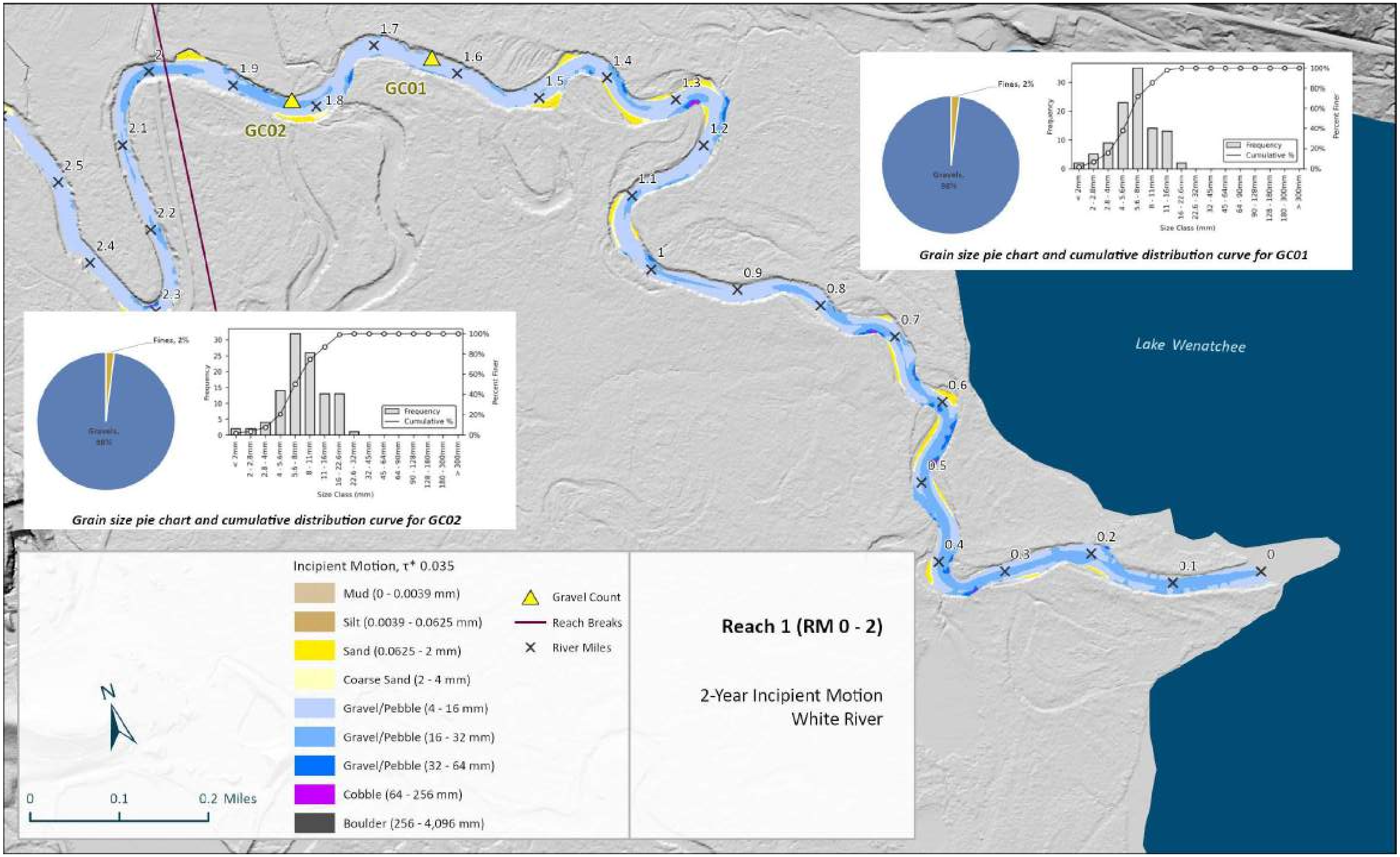

Figure 50. White River, Reach 1: incipient motion analysis results map (estimated grains size mobility at the 2-yr modeled discharge) and grains size distribution of two (GC 01 and GC 02) pebble counts.

Frequently inundated (low) floodplain surfaces comprise the majority of the wide valley and delta throughout Reach 1 (Figure 47). Unlike low floodplains elsewhere in the study area, low floodplains in Reach 1 are primarily formed by vertical accretion from overbank flows rather than by lateral accretion due to channel migration. The floodplain downstream of RM 1.1 is mapped as a low floodplain surface and is constructed of accumulated delta deposits and overbank deposits from both the White River and the Little Wenatchee River. Upstream of RM 1.1 the river right valley bottom is mapped mostly as a medium floodplain surface, whereas the river left valley bottom remains a low floodplain surface. A portion of the floodplain from ~RM 1.9 – 2.2 is anthropogenically disconnected from the White River by the bridge and associated bank protection at RM 2. Although historically a floodplain surface, the disconnection results in the surface functioning more like a terrace. The banks of the channel in Reach 1 are high (3 – 6 feet above the channel), mostly vertical, and composed primarily of sandy-loam and silt loam (Figure 51). Throughout the reach, the tops of the banks host subtle natural levees developed from accumulation of overbank deposits of fines. Floodplain surfaces are inundated frequently despite high banks throughout the reach due to overbank flows driven by backwatering from Lake Wenatchee during high flow periods. Floodplain soils are described as silt loam (Natural Resources Conservation Service, 2007).

Figure 51. Eroding sandy stream bank on river-right at RM 0.35 (August 16, 2024).

3.1.3 Large Wood Material

A total of 135 pieces of large woody material (LWM) and 14 log jams (accumulation of >3 LWM) were observed in the channel during the habitat survey (Summer of 2024). Figure 52 is a map of the surveyed large wood in Reach 1. Of the 135 pieces, 50 pieces are considered quality large wood (QLW); 20 classified as large size class (>20-inces diameter and >35-feet long); and 30 as medium size class (12 to 20-inch diameter and at least 35-feet long). Of the 14 log jams in Reach 1, eleven have multiple pieces of QLW and thus are effective at influencing the channel complexity and being habitat forming structures. Effective large wood in Reach 1 is responsible for influencing sediment deposition and sorting and providing cover. Although large wood is present, many of the large wood accumulations are not anchored by key logs or attached to the stream bed or banks and thus are considered temporary as they are expected to be mobile at higher flows (Figure 53). Key piece size of a log containing a rootwad was estimated to be 2+ feet in diameter and 50 ft long for Reach 1, during the Geomorphic Assessment.

Figure 52. White River, Reach 1: Quality large wood (QLW) distribution maps and surveyed habitat units (2024). QLW count does not include pieces from jams.

Figure 53. Mobile accumulation of large wood, on river left at RM 0.16 (August 16, 2024).

Large wood is recruited to the White River through bank erosion where large cottonwood and cedar occupy the adjacent banks (Figure 54). Reach 1 is the only reach within the assessment area in which large wood abundance does not meet the threshold for habitat established by Fox and Bolton (2007) (See Section 2.10). Large wood abundance in Reach 1 is likely limited by large wood removal at the Little Wenatchee Road bridge at RM 2, which reduces downstream transport of large wood from upstream reaches. Additionally, large trees are less abundant adjacent to the White River channel in Reach 1 than in upstream reaches.

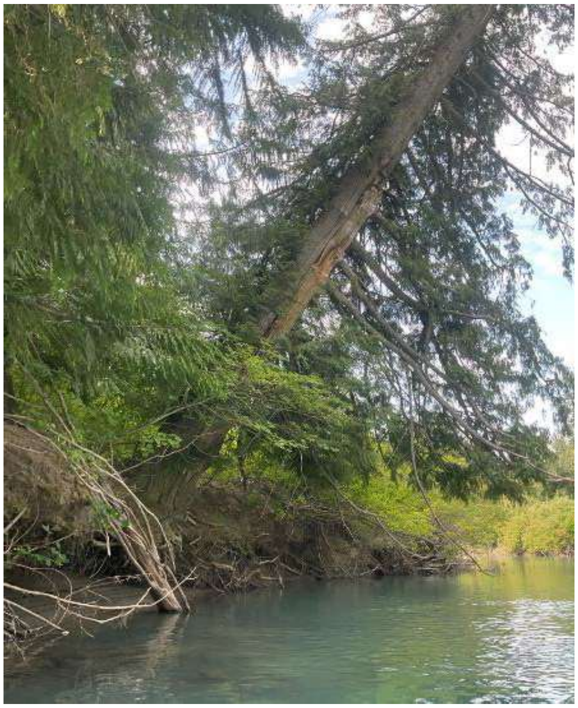

Figure 54. Leaning cedar at laterally eroding bank, White River at ~RM 1.13 on river left (August 16, 2024).

3.1.4 Vegetation

Vegetation established on the adjacent floodplain surfaces in Reach 1 is primarily riparian shrubs and small trees. Dense dogwood thickets are common along the floodplains and back side of point bars or along wetted oxbows along with reed canary grass and, to a lesser extent, willow. Where large trees do exist, cottonwood and western redcedar are the dominant overstory species. The floodplain understory is composed primarily of dogwood, vine/Douglas maple, and other shrubs (Figure 55).

Figure 55. Floodplain vegetation with small cluster of large cottonwood trees at RM 0.31, looking downstream (August 16, 2024).

Although large wood recruitment in Reach 1 is limited by a lack of large trees adjacent to the channel, clusters of large overstory trees at RM 0.31 and 0.5 do provide localized sources of large wood to the channel, A map showing the vegetation height size class distribution in Reach 1 is provided as Figure 56. The map reveals the lack of large and very large trees along the banks and across the floodplain. The existing riparian vegetation likely provides limited stream shading because channel width is so much greater than vegetation height.

Figure 56. White River, Reach 1: Map of vegetation height classification analysis (LiDAR – based analysis).

Figure 57. White River, Reach 1: Map with aerial imagery for vegetation identification.

3.1.5 Human Alterations

Human alterations in Reach 1 impact both channel and floodplain processes. A map of the anthropogenic features identified in Reach 1 is provided as Figure 58. The Little Wenatchee Road bridge and associated bank protection at RM 2 lock the White River in place, limiting floodplain connectivity (RM 1.9 – 2.2), instigating incision, and confining lateral migration. The bridge at RM 2 likely resulted in periodic removal of large wood from the channel and thus also limits downstream transport of large wood into Reach 1. Several culverts meant to convey surface flow from the upstream side to the downstream side of Little Wenatchee Road provide minimal longitudinal floodplain connectivity on both sides of the channel.

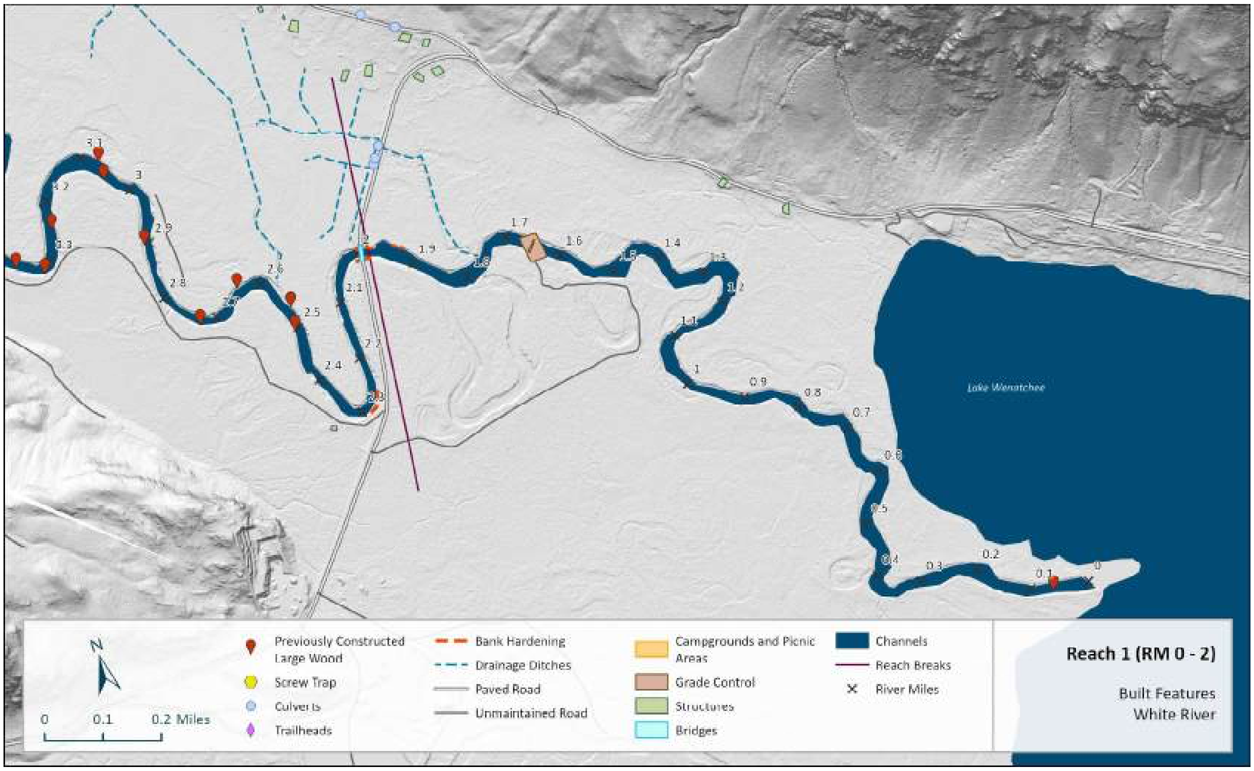

Figure 58. White River, Reach 1: Mapped anthropogenic features.

Downstream of the bridge, riprap and sheet piles protect the river-left bank and further limit lateral migration and floodplain connection between ~RM 1.94 – 2 (Figure 59). At RM 1.8, a PIT tag reader extends into the White River channel (Figure 59). The constructed rock and wood weir that spans the White River at ~RM 1.65 currently provides grade control for the channel in an area where meander neck cut-offs reduced channel length and likely instigated incision (Figure 60). The weir spans the channel but is low profile and has a defined chute and does not appear to block fish migration. A cluster of large wood pilings installed on the river-right edge of the channel at ~RM 0.06 appears to have minimal impact on channel processes and does not appear to be effective at trapping large wood or sorting sediments (Figure 60).

Figure 59. Left: Sheet piles and riprap protect the river left bank from ~RM 1.94-2. (August 15, 2024). Right: PIT tag readers installed on river left at RM 1.8 (August 15, 2024).

Figure 60. Left: Channel-spanning weir of rock and wood at RM 1.65, viewed from river right. (August 15, 2024) Right: Constructed large wood pilings at RM 0.06, looking downstream (August 16, 2024).

A series of ditches drain water from the river left floodplain in Reaches 1 and 2 (Figure 61). These ditches route water to the White River channel along Little Wenatchee Road at RM 2, and through a network of additional outlets at ~ RM 1.25, 1.42 and 1.73. The ditches are intended to drain floodplain surfaces, which are dominated today by reed canary grass. During the geomorphic survey (August-September 2024), the ditches contained intermittent stagnant pools of water, disconnected from the White River at low flow conditions. An abandoned road extends across the river-right floodplain from Little Wenatchee Road to RM 1.5 (Figure 61). Several old building foundations are located next to the road, and vegetation has been cleared locally. Additionally, a structure sits on the river-left floodplain next to the White River at RM 1.22.

Figure 61. Left: Drainage ditch floodplain, looking up-valley from Little Wenatchee Road (August 15, 2024). Right: Abandoned access road on river-right floodplain in Reach 1 (August 15, 2024).

3.1.6 Recommended Actions

Recommended actions in Reach 1 are primarily focused on enhancement/improvement of mainstem channel and off-channel complexity, as well as mitigating the impacts of bank riprap and the Little Wenatchee Road bridge crossing on channel conditions and floodplain connectivity. Mainstem channel complexity can be addressed through large wood placements designed to promote lateral processes, and to capture large wood and bedload transported from upstream. Opportunities to increase channel complexity and cover habitat are located throughout the mainstem channel in Reach 1. Ongoing wood removal at the Little Wenatchee Road bridge crossing has limited LWM transported to Reach 1, and sinuosity and channel migration appear reduced compared to historical conditions. Several cutoff oxbows present an opportunity to increase off-channel habitat area in Reach 1, through pilot channel excavation and placement of large wood structures in the mainstem channel to encourage flows into the re-connected channels. Replacement of bank riprap and sheetpiling in proximity to the Little Wenatchee Bridge with bank buried jams is recommended to improve mainstem channel condition and floodplain connectivity in Reaches 1 and 2. Modification of existing culverts under Little Wenatchee Road to increase conveyance could further improve floodplain inundation and connectivity in Reach 1. Additional recommended actions include revegetation of open field areas and willow/cottonwood trenching on open in-channel bars to improve long-term riparian conditions, and placement of large wood in the connected oxbow wetland to increase cover. The cleared fields in Reaches 1 and 2 contain a network of floodplain ditches that could be selectively filled and recontoured to limit floodplain draining and provide additional off-channel habitat at high flows. It is recognized that existing buildings and infrastructure limit recovery potential in Reach 1, and that some of the recommended actions in Reach 1 will require landowner engagement and approval.

3.2 WHITE RIVER REACH 2 (RM 2 – 4.13)

3.2.1 Overview

Reach 2 is 2.13 river miles long and extends from the Little Wenatchee Road bridge over the White River at RM 2 upstream to RM 4.13, above which the White River channel is briefly in contact with the river-right hillslope. Reach 2 has the highest sinuosity (S = 2.42) of any reach within the assessment area (Table 10). Sinuosity is expressed as a series of seven unconfined meanders that curve through the center portion of the valley. The channel contacts the river-right valley wall from RM 3.95 – 4.18, near the upstream reach boundary. From ~RM 2 – 2.3 the channel is artificially held in place along the bank armoring that protects Little Wenatchee Road, which dissects the river-right floodplain after crossing the White River at RM 2. The road's bank protection maintains the downstream half of a large meander bend, but it has also led to local incision and floodplain disconnection, limiting the amount of floodplain available to the White River downstream of RM 2. The reach gradient in Reach 2 (0.05%) is slightly higher than in Reach 1 (0.02%), and only slightly lower than that of Reach 3 (0.07%). The average bankfull width of the channel, measured during the Habitat Assessment (See Appendix A) is 120 feet. Low floodplain surfaces (inundated ~ 1-5 years) are common in the upstream portion of the reach; however, low floodplain surfaces are rare in the downstream portion of the reach where natural levees and incision related to the bridge at RM 2 have reduced floodplain connectivity. The majority of the remaining valley bottom is medium floodplain surfaces (inundated ~ 5-10 years). The exception is a section of meander bends at ~RM 2 and ~RM 2.3 where forced incision instigated by the downstream road bridge crossing and upstream bank-armoring has resulted in abandonment of the floodplain such that it now functions similar to a terrace. Vegetation on low floodplain surfaces in Reach 2 consists primarily of reed canary grass, willow, and dogwood. Vegetation on medium and high floodplain surfaces consists of reed canary grass, dogwood, cottonwood, and cedar. Human alterations in Reach 2 include a series of large wood structures from a prior river restoration effort, evidence of logging on the river right floodplain, several homes along the valley margins, the Little Wenatchee Road bridge at RM 2, and associated upstream bank protection.

Figure 62. Representative photo of the White River in Reach 2 at ~RM 3.4, looking upstream (September 9, 2024).

Table 10. Reach 2 descriptive geomorphic metrics.

Metric	Value
Reach Length (miles)	2.13
River Miles	2.0-4.13
Stream Gradient	0.05%
Sinuosity	2.42
Dominant Channel Habitat Unit Type	Pool
Average Bankfull Width (feet)	120
Confinement	Unconfined
Dominant Substrate	Gravel
Bank Stability/Channel Migration	Adequate *(See Appendix B Section 3.2)*
Vertical Channel Stability	Adequate *(See Appendix B Section 3.2)*

3.2.2 Channel and Floodplain Geomorphology

Reach 2 is a low gradient, unconfined, and very sinuous meandering channel (Figure 63). The Habitat Assessment (See Appendix A) recorded 100% of the habitat as an extended pool. Although several short riffles are present, they are shorter than the channel width, and therefore, following protocol, were not included in the Habitat Assessment. One meander is laterally confined on river-left between RM 2 – 2.4 where the channel is held in place by constructed bank protection intended to limit lateral erosion into Little Wenatchee Road (See Section 3.2.5). The channel does contact with the river-right hillslope as well from 3.95 – 4.18. Several minor perennial tributaries enter the White River on the right side of the channel, at RM 3.39, RM 3.95, and RM 3.99. Whereas the tributaries at RM 3.39 and 3.95 contribute mainly finer sediments to the channel, the tributary at RM 3.99 contributes sediments ranging from fines to gravel in addition to small wood. Several additional ephemeral tributaries along the hillslopes contribute to the White River during seasonal periods of surface runoff but were not flowing at the time of the geomorphic assessment during August and September 2024.

The White River channel is single thread in planform. No major avulsions or changes to mainstem channel alignment, and minimal outward lateral migration have occurred since 1957, the first date for which aerial imagery was publicly available and incorporated into the assessment (Figure 64). Abandoned meander scars and scrolls visible in the LiDAR and aerial imagery on both the river-right and river-left floodplains do reveal a history of channel migration and avulsion in this reach

Channel substrate in Reach 2 is dominated by small-fraction gravel and coarse sand. Intermittent mudstone outcrops were observed in the stream bed between ~ RM 2.3 – 2.8 (Figure 65). Large sand and gravel point bars are present upstream of ~RM 3 but are absent in approximately the lower mile of the reach (Figure 66). The point bars occur on the inside of meander bends and the short channel-spanning gravel riffles are commonly located at the upstream end of the point bars.

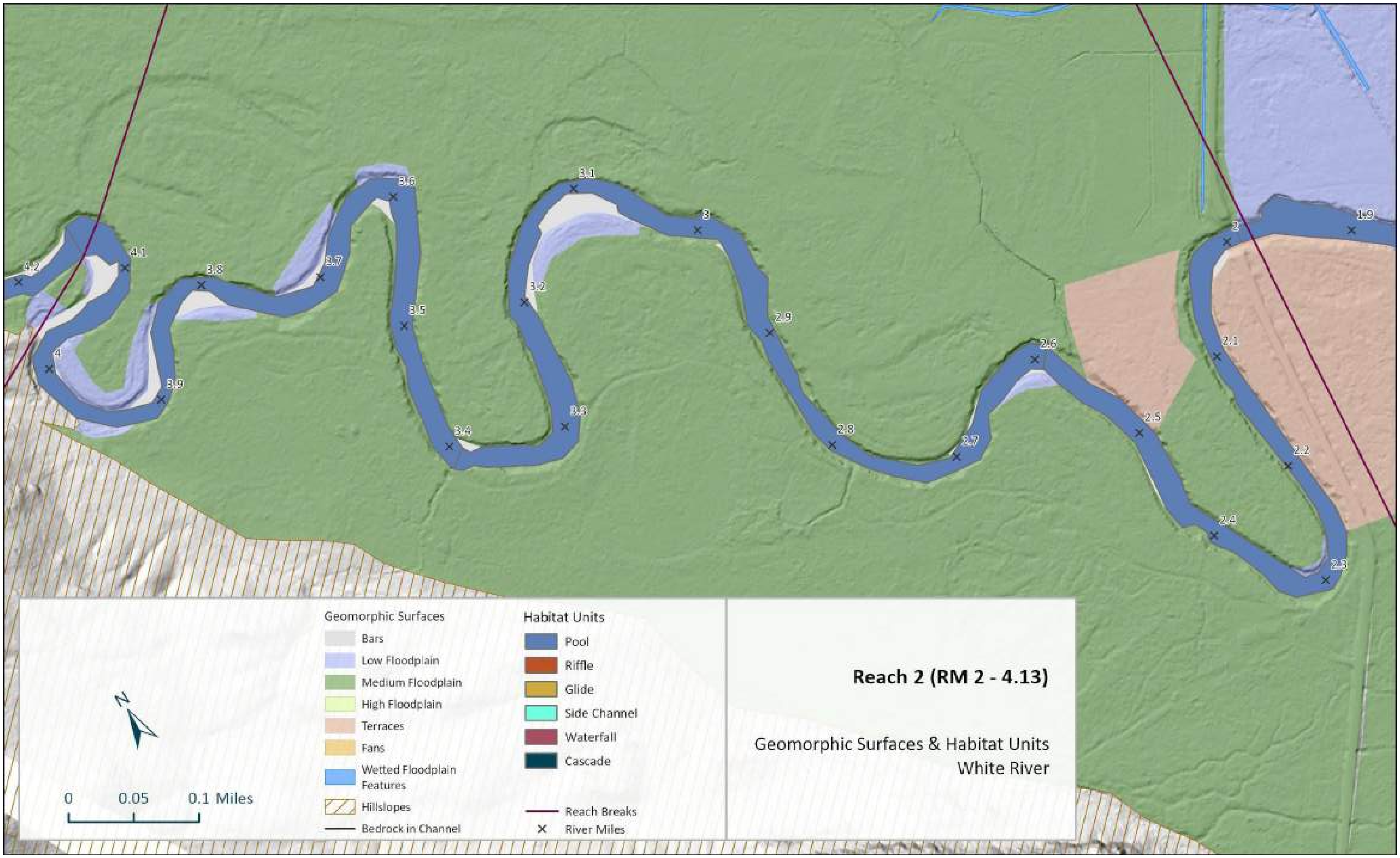

Figure 63. White River, Reach 2: Map of geomorphic surfaces and habitat units.

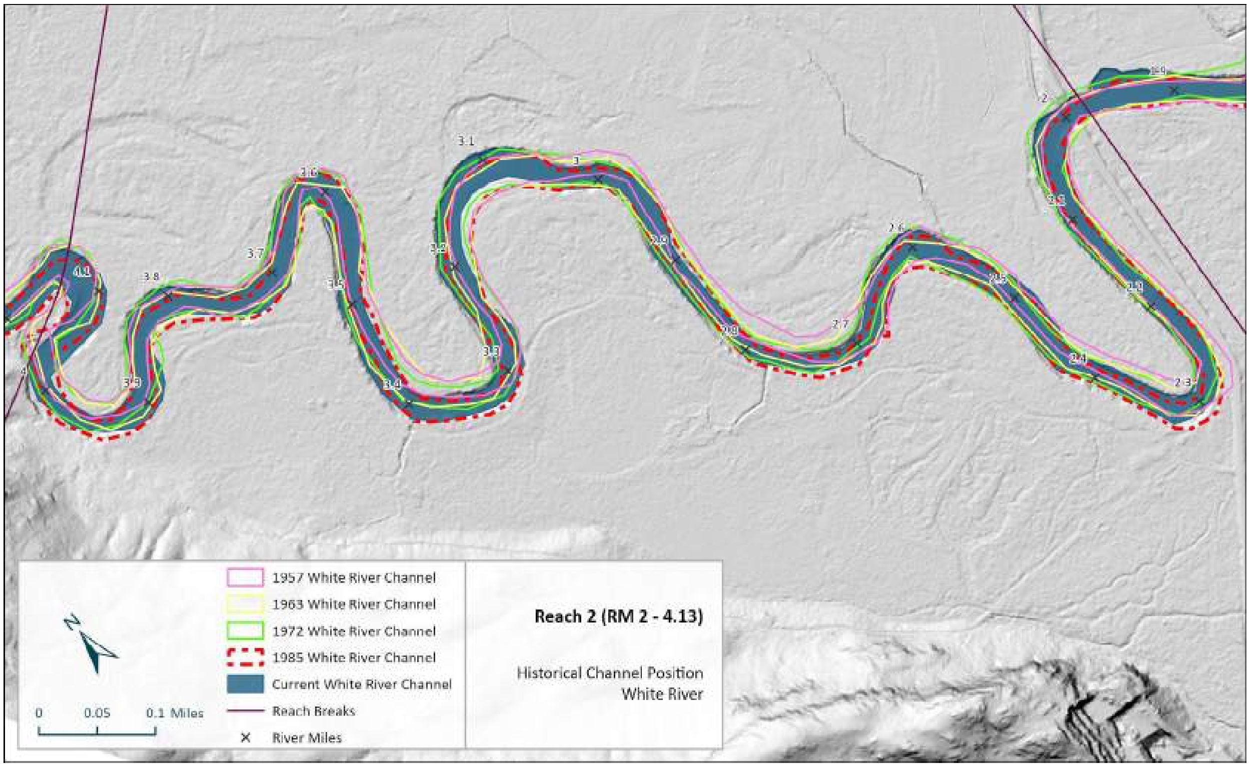

Figure 64. White River Reach 2: Map of channel alignments digitized from historical photos (1957-2023).

Figure 65. Mudstone shelf in the bed of the White River along river-right near RM 2.77 (August 15, 2024).

Figure 66. Left: Large point bar composed of gravel and topped with sand at RM 3.4, looking downstream. (August 14,2024) Right: minor point bars composed of sand at RM 2.68, looking upstream (August 15, 2024).

Wolman Pebble Counts were conducted on riffle crests and associated bars at ~RM 3.13 (GC 03) and ~RM 3.21 (GC 04). The median grain size at GC 03 is D50 = 11.76mm and at GC 04 is D50 = 10.19mm. Cobbles and boulders were absent from both pebble counts. The data from the two pebble counts are plotted on a map (Figure 67) of the Reach 2 incipient motion analysis results (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.9.4). The analysis indicates that at the 2-yr modeled discharge, the channel's shear stress is capable of mobilizing small-fraction-sized gravels. The analysis also shows that shear stress hydraulics are reduced and expected mobilized grain size at the 2-yr modeled discharge is smaller between RM 2.4 – 3.1 compared to upstream (depositional area with large bars) and downstream (area of incision imposed by bank hardening and lateral confinement at the downstream bridge.

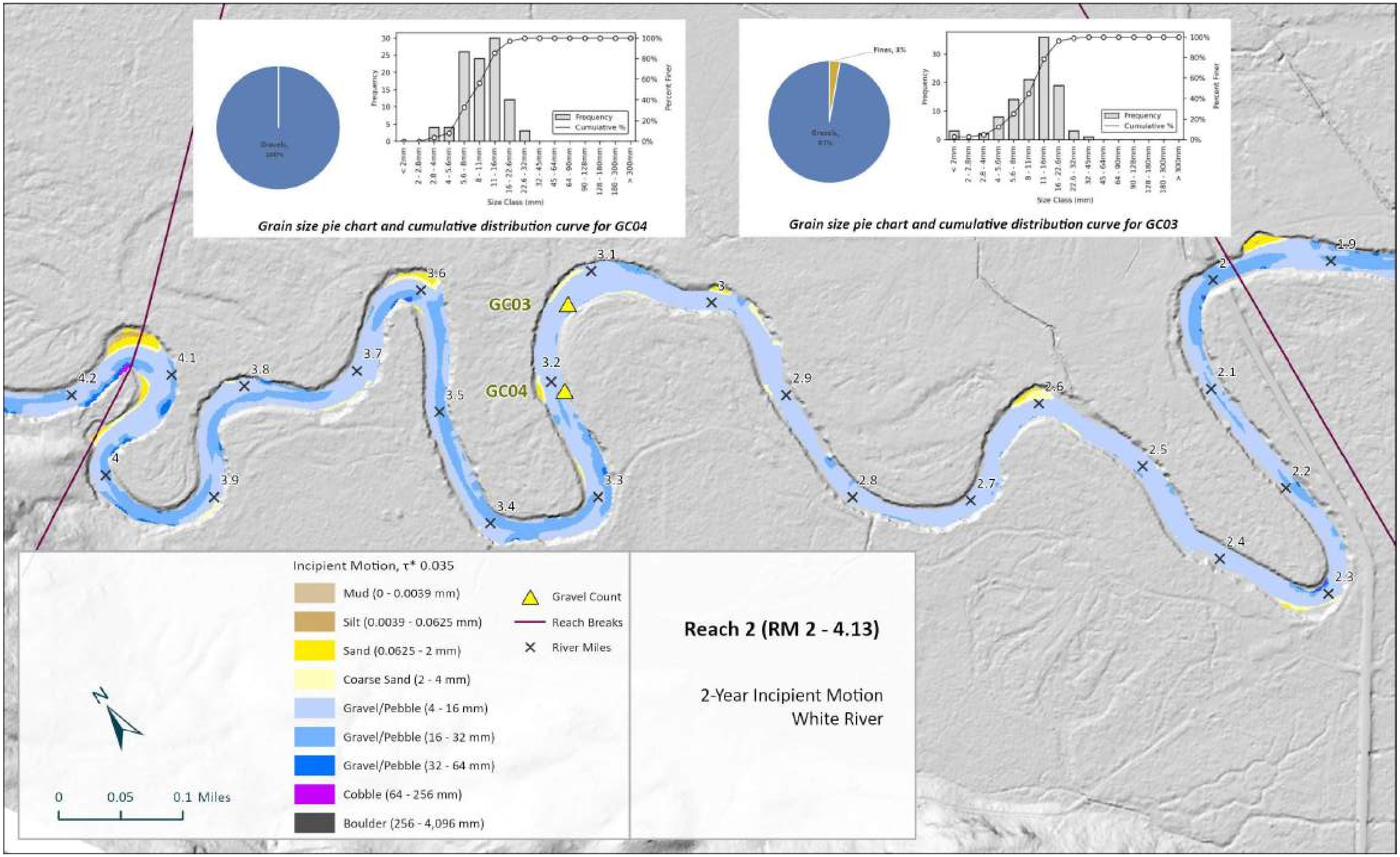

Figure 67. White River, Reach 2: incipient motion analysis results map (estimated grains size mobility at the 2-yr modeled discharge) and grains size distribution of two (GC 03 and GC 04) pebble counts.

Local sediment sources to the White River in Reach 2 are assumed to be upstream inputs, local lateral bank erosion, tributaries, and a minor hillslope contribution that include cobble-to-boulder sized sediments near RM 4.01. Cobbles and boulders are only locally present near the hillslope contact because typical flows in Reach 2 are likely not capable of transporting sediments of this size further downstream. Stream banks in Reach 2 commonly have a base layer of silty clay topped with sandy loam and silt loam (Figure 68). Sand and silt loam layers in Reach 2 are up to several feet thick in the cut banks. Gravels are absent from cut bank exposures in Reach 2, although they may be present beneath the channel surface, as no subsurface investigation was performed as part of the geomorphic or habitat assessments. The gravels are fluvially transported into Reach 1 from upstream. Sands and fines are likely generated locally from eroding bed and banks or fluvially transported in from upstream.

Figure 68. Exposed cut bank at RM 3.82, on river right. (August 14, 2024)

Low floodplain surfaces are mostly absent within the lower portion of Reach 2 but are more common upstream of ~RM 3.6 (Figure 63). This is likely due to a combination of channel incision related to the White River bridge crossing at RM 2 and bank hardening along river right at RM 2.3. The majority of the valley bottom contains medium floodplain surfaces. Incision-induced floodplain disconnection upstream of the bridge at ~RM 2 and ~RM 2.3 is converting small sections of the floodplain into surfaces that are abandoned, functioning more like a terrace. Based on exposed banks, floodplains are composed of clays, silts, and thick layers of sand, overlain by a thin layer of developing organics soil. Floodplain soil in Reach 2 is described as silt loam (Natural Resources Conservation Service, 2007).

3.2.3 Large Wood Material

A total of 363 pieces of large woody material (LWM) and 41 log jams (accumulation of >3 LWM) were observed in the channel during the survey (August 2024) (see Figure 69). Of the 363 pieces, 202 pieces are considered QLW; 60 classified as large size class (>20-inces diameter and >35-feet long); and 142 as medium size class (12 to 20-inch diameter and at least 35-feet long). 37 of the 41 log jams have multiple pieces of QLW and thus are effective channel influencing and habitat forming structures.

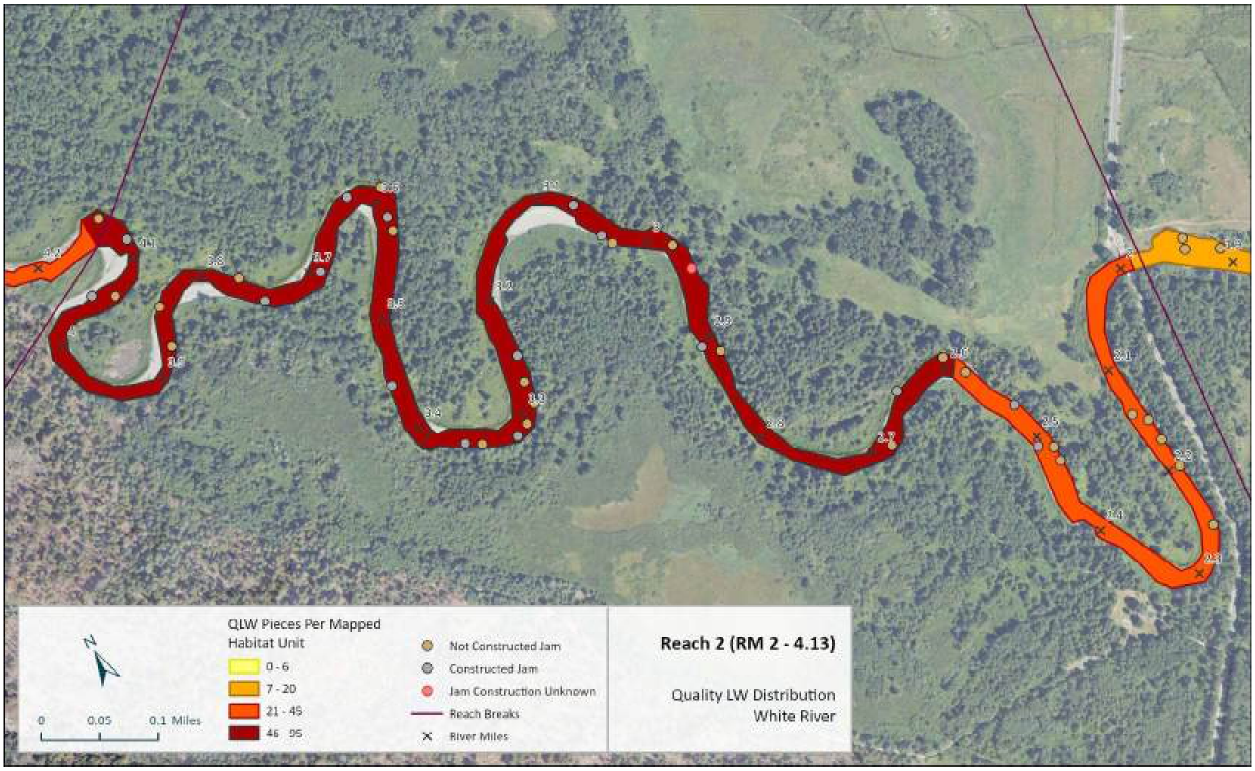

Figure 69. White River, Reach 2: Quality large wood (QLW) distribution maps and surveyed habitat units (2024). QLW count does not include pieces from jams

Large wood accumulations in Reach 2 are responsible for creating alcove habitat, driving deposition of sand and fine sediments, and causing small amounts of pool scour (Figure 70). Large wood is not responsible for creating split flow or multithreaded flow paths in Reach 2. Large wood is responsible for instigating lateral migration that generates additional wood recruitment and sediment sourcing. Large wood recruitment in Reach 2 is most successful when lateral erosion occurs where large cottonwood and cedar are located adjacent to the channel. Key pieces (effective at maintaining geomorphic influences and sustaining jams) were observed as being 2+ feet in diameter and at least

40 ft long in Reach 2. In several locations, the ends of large wood pieces have been sawed off, likely by boaters to improve navigability of the lower White River. Although large wood is present in locations throughout Reach 2, many of the large wood accumulations are not anchored by key logs or attached to the stream bed or banks and thus considered temporary influences as they are expected to be mobile at higher flows. A series of engineered large wood structures consisting of clusters of large wood pilings were installed in Reach 2 as part of prior restoration efforts. The locations of the constructed jams are depicted as a grey dot in Figure 69. The effectiveness of the constructed jams is mixed as several of the structures are currently retaining little to no large wood (Figure 71).

Figure 70. Effective large trees with rootwads influencing sediment sorting and local scour near RM 3.48 (August 14, 2024).

Figure 71. Left: Example of constructed wood piling structure with no effective function at RM 2.73 (August 15, 2024). Right: constructed wood piling structure effectively accumulating and retaining large wood at RM 3.32 (August 14, 2024).

3.2.4 Vegetation

Vegetation in Reach 2 consists of an overstory primarily composed of western redcedar and cottonwood, and an understory consisting primarily of dense dogwood thickets, and sparse pockets of vine/Douglas maple (Figure 72). Although a narrow riparian buffer is generally present throughout the reach there has been substantial forest clearing on the river left floodplain from downstream of the Reach 2 boundary at RM 2, to approximately RM 3.1, and one the river right floodplain from approximately RM 2.7 – 2.9. Forest clearing and relative distribution of forest maturity is provided in the Vegetation Height Analysis map provided as Figure 73. The cleared surfaces now contain abundant reed canary grass, with little to no natural recruitment of native woody species (Figure 75). Almost no large trees of sufficient size to be effective key logs (2+ ft dbh) are available along the banks of the channel in Reach 2.

Figure 72. Representative riparian vegetation of dense dogwood backed by western redcedar overstory, at RM 2.56 (September 12, 2024).

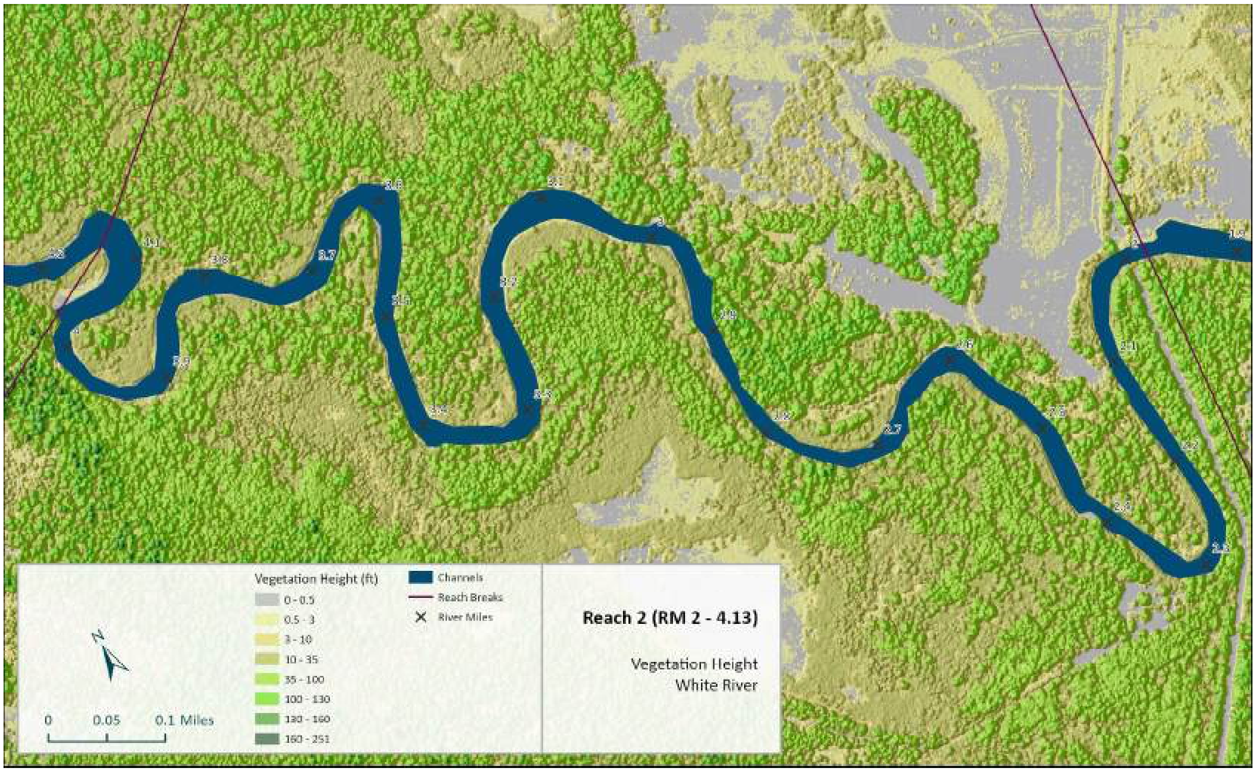

Figure 73. White River, Reach 2: Map of vegetation height classification analysis (LiDAR – based analysis).

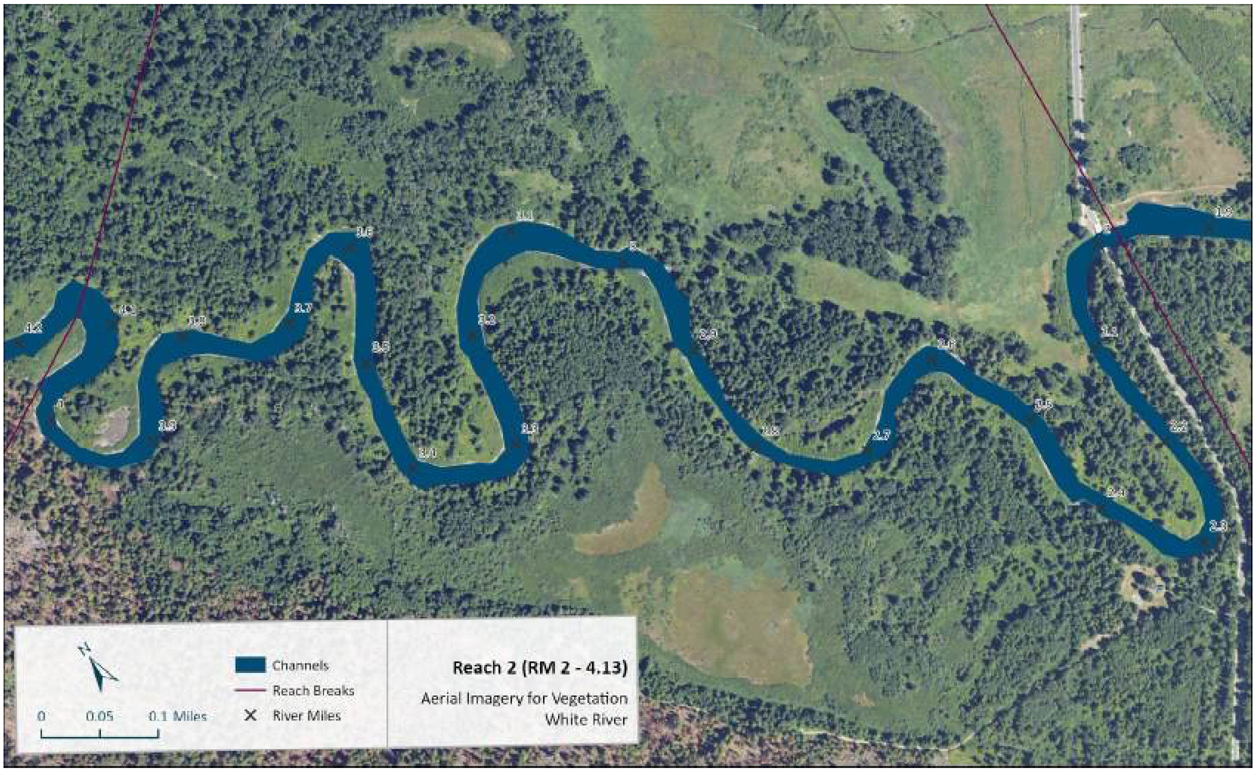

Figure 74. White River, Reach 2: Map of aerial imagery for vegetation identification.

Figure 75. Medium height floodplain surface at RM 3 on river left. Forests on the river left floodplain have been cleared and surfaces have been colonized by reed canary grass (August 14, 2024).

3.2.5 Human Alterations

Human alterations in Reach 2 include impacts to channel and floodplain processes, and past restoration efforts to improve wood retention and function (Figure 76). Little Wenatchee Road perpendicularly dissects the floodplain at the downstream boundary of Reach 2, including a confining bridge crossing and road-protecting riprap (Figure 77). Bank protection related to Little Wenatchee Road and the bridge lock the White River into place in this section, preventing channel migration, limiting surface flow connection across the floodplain between Reach 1 and 2, and exacerbating local incision and floodplain disconnection. Riprap is placed at the base of the bridge at RM 2 as well as on the outside of the meander bend upstream of the bridge at ~RM 2.28 where Little Wenatchee Road passes within 75 feet of the White River channel.

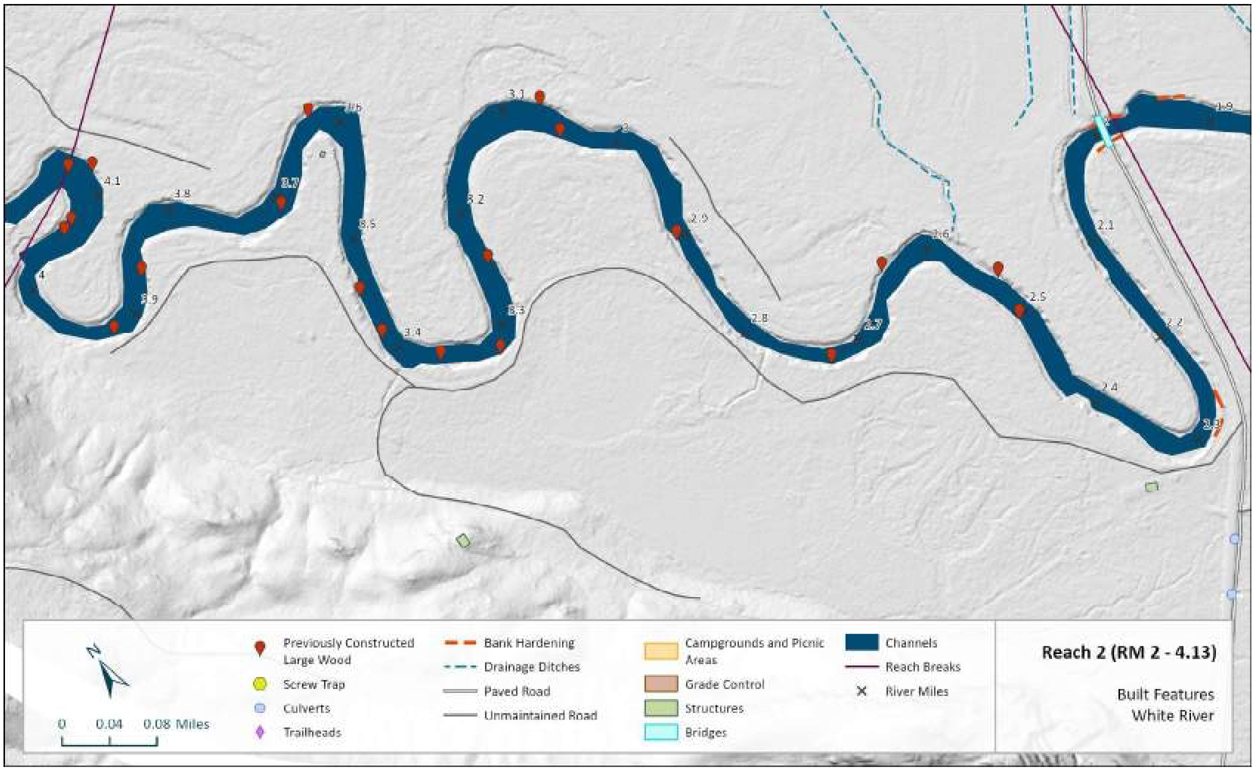

Figure 76. White River, Reach 2: Mapped anthropogenic features.

Figure 77. Bridge over White River channel at RM 2, viewed from river right (August 15, 2024).

Abandoned double-track roads exist on both the river-left and river-right floodplains. On river right, the road extends from a property at RM 2.33 to approximately RM 3.95 where it loops back to Little Wenatchee Road along a more established path at the toe of the valley wall. This road appears to act as a preferential path for overbank flow from the White River, as it contained periodic small accumulations of fluvially transported small wood. On river-left, the abandoned road was observed during the geomorphic assessment from RM 2.8-2.9, but it is assumed that it extend further across the floodplain. Neither road has a significant impact on channel or floodplain processes at present, although they do reflect a history of past human disturbance within the Reach. Portions of the forests on both sides of the river in Reach 2 have been cleared. Several old-growth western redcedar stumps were noted on the river-right floodplain during the geomorphic assessment (Figure 78). These stumps were larger in diameter than the majority of living trees on the floodplains in Reach 2, suggesting a historical condition of abundant mature trees. On the river left, where forests have been cleared, open fields are now populated primarily with reed canary grass and floodplains are drained through a network of ditches (Figure 78), some of which act to route water along and underneath Little Wenatchee Road. Houses and other structures are located within several hundred feet of the White River channel on river right at RM 2.33 and 3.6, and further from the channel along the river-left valley wall.

Figure 78. Left: Old-growth western redcedar stumps on the river-right floodplain near RM 3.47. (August 14, 2024) Right: Drainage ditch on river-left floodplain parallel to Little Wenatchee Road at RM 2. (August 15, 2024)

Vertical wood pilings were added to the White River at 20 locations in Reach 2 as part of a prior restoration effort to improve conditions related to in-stream large wood. These structures were installed at river miles 2.54, 2.64, 2.73, 2.9, 3.05, 3.07, 3.25, 3.32, 3.36, 3.41, 3.45, 3.63, 3.71, 3.74, 3.81, 3.87, 3.92, 4.06, 4.12, and 4.13. Although several structures have effectively trapped and retained large wood, many structures have not retained any or sufficient pieces of large wood capable of exerting a geomorphic influence on the channel or of trapping and retaining additional large wood pieces (Figure 79).

Figure 79. Left: Installed vertical wood pilings with wood accumulation, at RM 3.71 (August 14, 2024).
Right: Installed pilings lacking large wood accumulation and retention, at RM 3.92 (August 14, 2024).

3.2.6 Recommended Actions

Recommended actions in Reach 2 are primarily focused on increasing the quality and quantity of mainstem channel habitat. Large wood additions to the mainstem channel are recommended to enhance/improve channel complexity and counteract ongoing local channel incision. Modification of anthropogenic features such as bank riprap and the Little Wenatchee Road bridge, and improvements to increase conveyance at culverts under Little Wenatchee Road are recommended to improve channel condition and floodplain inundation/connectivity. Under current conditions, the bridge span is a major impediment to channel migration and has resulted in local disconnection of floodplain surfaces. Revegetation of open field areas on river left, and willow/cottonwood trenching on open in-channel bars, including the large bar near the midpoint of the reach, is recommended to improve long-term riparian conditions, and large wood processes. The cleared fields on river left in Reaches 1 and 2 contain a network of floodplain ditches that could be selectively filled and recontoured to limit floodplain draining and provide additional off-channel habitat at high flows. Existing buildings and infrastructure including the Little Wenatchee Road bridge crossing may limit recovery potential in Reach 2. Some of the recommended actions in Reach 2 will require landowner engagement and approval.

3.3 WHITE RIVER REACH 3 (RM 4.13 – 5.44)

3.3.1 Overview

Reach 3 is 1.31 river miles long and extends from RM 4.13 – 5.44 (Table 11). The White River channel in Reach 3 is sinuous (S = 1.83), single thread meandering, and unconfined. The path of the channel traverses the wide floodplain diagonally from the river-left valley wall in the north, to the river-right valley wall in the south (Figure 80). The average gradient of Reach 3 (0.07%) is similar in magnitude to those of Reach 2 (0.05%) and Reach 4 (0.09%). The average bankfull width, recorded during the Habitat Assessment (See Appendix A) is 140 feet, identical to that of Reach 4. Low floodplain surfaces (inundated ~ 1-5 years) extend behind point bars, and medium floodplain surfaces (inundated ~ 5-10 years) comprise the remaining valley bottom. Natural levees along the top of the banks are composed of overbank fines and sands. Vegetation on low floodplain surfaces consists of reed canary grass and willow, and vegetation on medium floodplain surfaces consists primarily of dogwood, cottonwood, and cedar. Human alterations in Reach 3 are somewhat limited compared to those in the adjacent reaches, although riprap is present at the upstream end of the reach, and logging practices have likely altered large wood recruitment potential and occurrence in the channel.

Figure 80. Representative photo of the White River in Reach 3 at RM 4.64, looking upstream (August 9, 2024).

Table 11. Reach 3 descriptive geomorphic metrics.

Metric	**Value**
Reach Length (miles)	1.31
River Miles	4.13-5.44
Stream Gradient	0.07%
Sinuosity	1.83
Dominant Channel Habitat Unit Type	Pool
Average Bankfull Width (feet)	140
Confinement	Unconfined
Dominant Substrate	Gravel
Bank Stability/Channel Migration	Adequate *(See Appendix B Section 3.2)*
Vertical Channel Stability	Adequate *(See Appendix B Section 3.2)*

3.3.2 Channel and Floodplain Geomorphology

The White River in Reach 3 is a low gradient meandering channel with relatively high sinuosity. Channel units are mapped as two extended pools with one notable glide and several short riffles (Figure 82). The Habitat Assessment (See Appendix A) recorded 97% of the habitat as pool, and 3% of the habitat as glide. Riffles in Reach 3 are rare, and are shorter than channel width, therefore they were not included in the Habitat Assessment. The White River is unconfined in Reach 3 and meanders diagonally across the valley. However, it contacts the river-right valley wall from ~RM 4.3 – 4.37, and the river-left valley wall from ~RM 5.44 – 5.48 at the upstream boundary. There are no perennial tributaries to the White River in Reach 3, although two ephemeral floodplain tributaries that likely convey wet-season runoff meet the White River on river left at ~RM 4.52 and on river-right at ~RM 4.7 (Figure 80). Neither channel appears to contribute significant flow, coarse sediments, or other materials to the White River on an annual basis.

Figure 81. Outlet of dry tributary entering from river right just downstream of RM 4.7 (August 14, 2024).

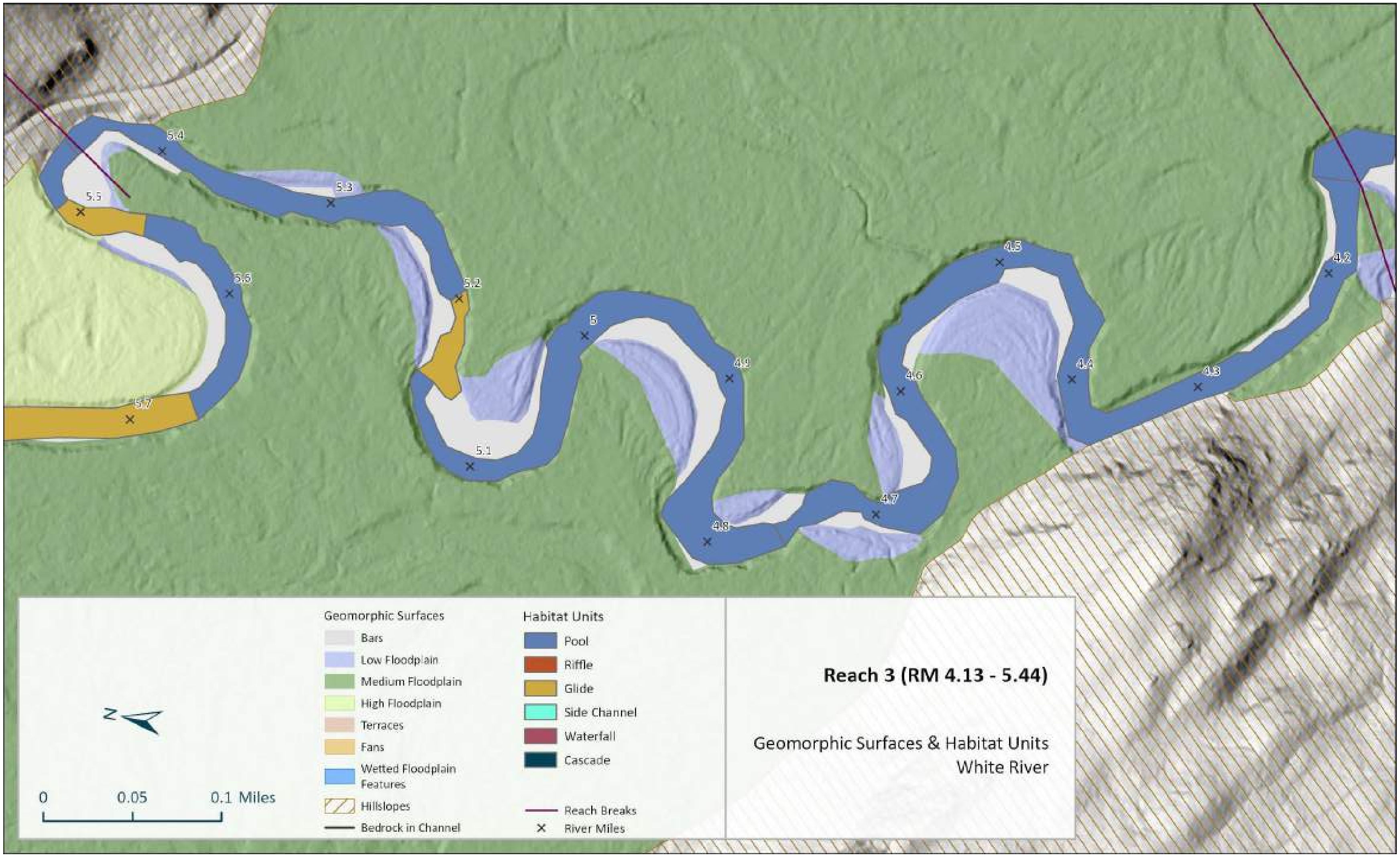

Figure 82. White River, Reach 3: Map of geomorphic surfaces and habitat units.

The White River channel is single thread meandering through Reach 3, with minor low-flow flow splits around relatively small gravel-sand bars at ~RM 4.78 and 5.51. Based on historical photo analysis, no major avulsions or changes to the White River channel alignment have occurred since 1957 but lateral migration is noted at all meander bends (Figure 83). Meander extension at ~ RM 5.35 – 5.55, has actively migrated the channel towards White River Road. Abundant historic meander bend scars are evident across the floodplain and visible in both the topography of the recent LiDAR and aerial imagery. The meanders scars, some tortuous, suggest a dynamic history of channel migration and avulsion in this section of the channel.

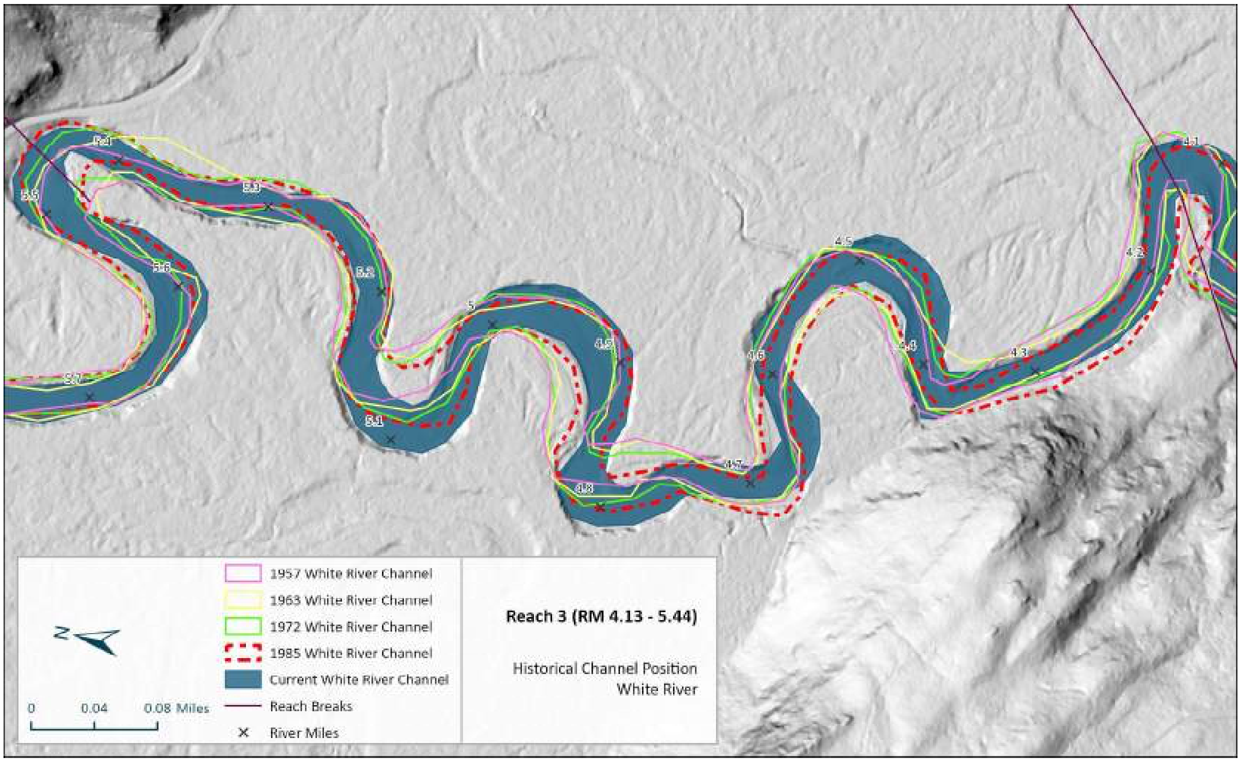

Figure 83. White River Reach 3: Map of channel alignments digitized from historical photos (1957-2023).

Channel substrate in Reach 3 is primarily gravel and patches of sand. Extended gravel point bars, often topped with coarse sand, occupy the inside of all meander bends. A Wolman Pebble Count (1954) was conducted on a riffle crest at RM 4.5 (GC 05) and another on a lateral bar extending into a very small riffle crest at RM 5.2 (GC 06). The median grain size of sediments was slightly higher at GC 06 (D50 = 12.94 mm) than at downstream GC 05 (D50 = 10.28 mm). Cobbles and boulders were absent from both pebble counts. The data from the two pebble counts are plotted on a map (Figure 84) of the Reach 3 incipient motion analysis results (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.9.4). The analysis indicates that at the 2-yr modeled discharge, the channel's shear stress is capable of mobilizing medium to small sized gravels. Interestingly, the analysis also shows that at the outside of several irregularly extending meander bends shear stress along the bed of the channel is reduced to the capacity of mobilizing sand instead of gravels.

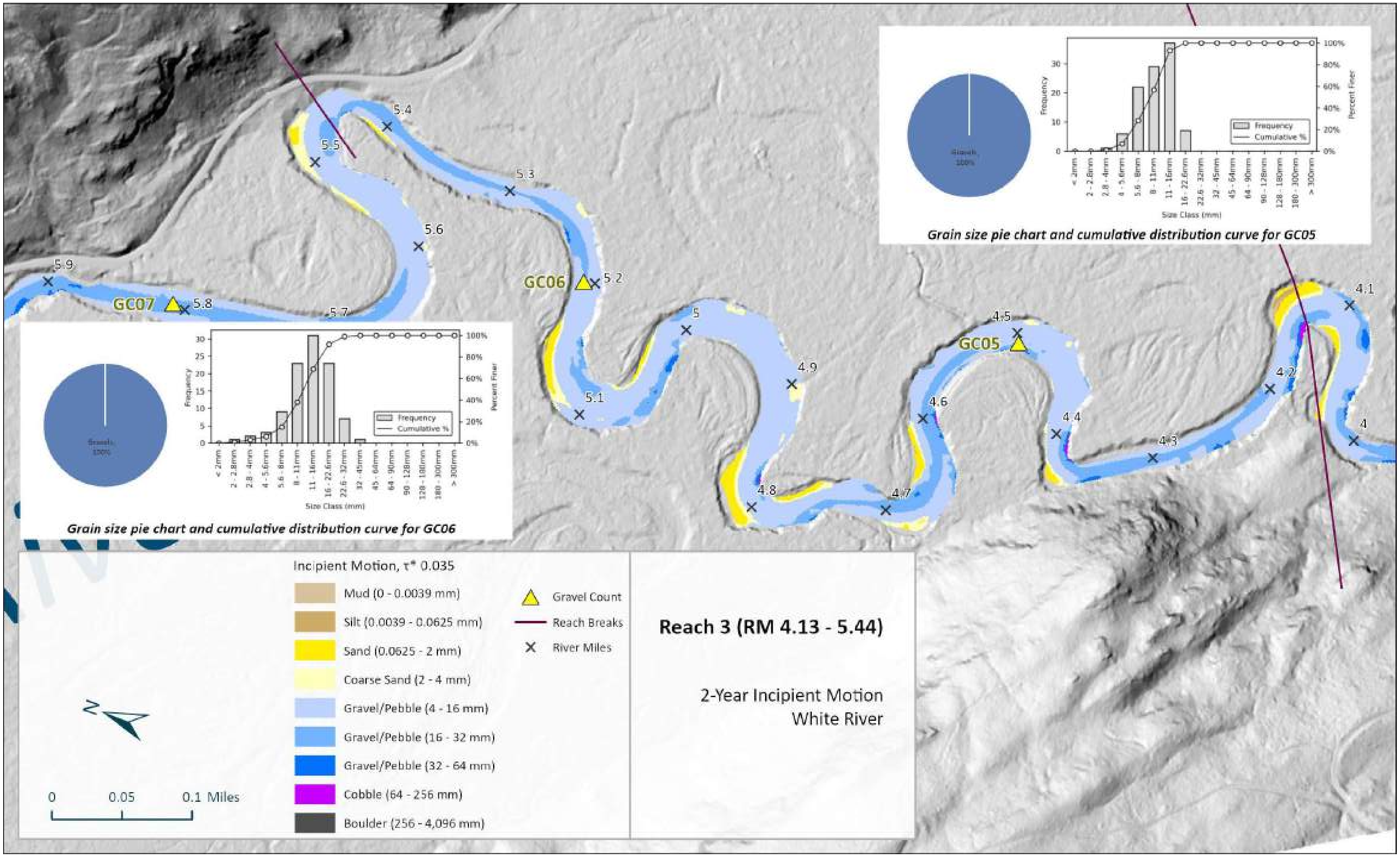

Figure 84. White River, Reach 3: incipient motion analysis results map (estimated grains size mobility at the 2-yr modeled discharge) and grains size distribution of two (GC 05 and GC 06) pebble counts.

Local sediment sources to the White River channel in Reach 3 include a hillslope contact from RM 4.3 – 4.37 which contributes angular cobble-to-boulder sized coarse sediments, upstream in-channel contributions, and eroding stream banks throughout the reach (Figure 85). Cobbles and boulders are only locally present in close proximity to the hillslope contact because typical flows in Reach 3 are likely not capable of transporting sediments of this size further downstream. Stream banks in Reach 3 are composed of a clay-dominant layer at the base overlain by coarser silts and sandy-loam, topped with organic soil (Figure 85).

Figure 85. Left: Cobble to boulder sized sediment hillslope source at RM 4.3 (August 14, 2024). Right: Floodplain cut bank at RM 5.25, river left (August 13, 2024).

Low floodplain surfaces occur on the inside of every meander bend behind active point bars, except for at ~RM 4.37 (Figure 82). Low floodplains transition to medium floodplain surfaces which account for the remainder of the valley floor in Reach 3. Subtle natural levees composed of accumulated over-bank fines are present along the White River throughout Reach 3. Based on exposed banks, floodplains in Reach 3 are composed of clays, silts, and sandy loam, topped by soils. Floodplain soils are described as silt loam, and the adjacent hillslopes consist of sandy loam and rock outcrops with poorly developed soils (Natural Resources Conservation Service, 2007).

3.3.3 Large Wood Material

A total of 151 pieces of large woody material (LWM) and 15 log jams (accumulation of >3 LWM) were observed in the channel during the survey (August, 2024) (See Figure 86Figure 41). Of the 151 pieces, 77 pieces are considered quality large wood (QLW); 23 classified as large size class (>20-inces diameter and >35-feet long); and 54 as medium size class (12 to 20-inch diameter and at least 35-feet long). Of the 15 log jams, 14 have multiple pieces of QLW and thus are considered effective channel influencing and habitat forming structures. During the geomorphic assessment, several large wood pieces and jams in Reach 3 were associated with local bed scour, backwater alcove formation, and deflection of streamflow into eroding banks. Large wood was not observed to be responsible for driving split flow conditions or sorting sediment and several large wood pieces appeared to have been sawed off, likely by boaters to improve navigability of the White River. Key pieces observed during the geomorphic assessment were typically 1.5 - 3 ft in diameter and at least 40 ft long. Large wood in Reach 3 is generally recruited to the channel by bank erosion (Figure 87).

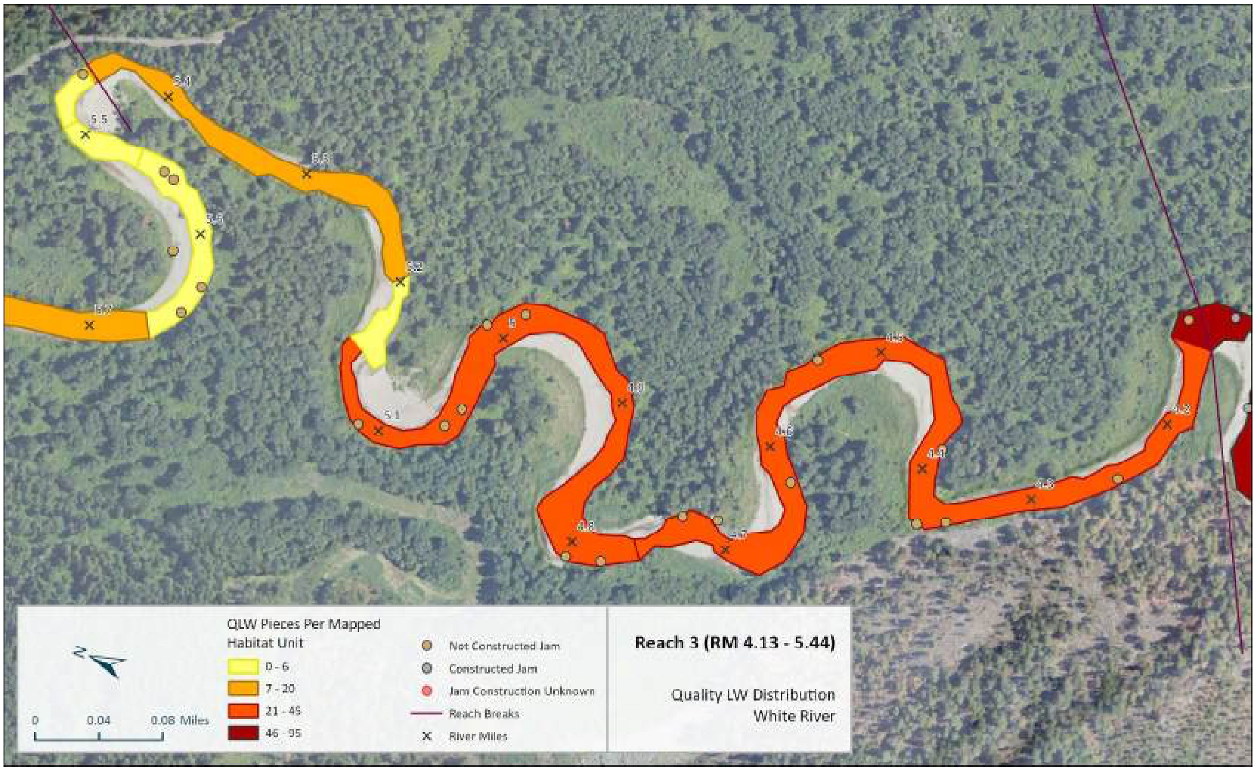

Figure 86. White River, Reach 3: Quality large wood (QLW) distribution maps and surveyed habitat units (2024). QLW count does not include pieces from jams.

Figure 87. Large wood recently recruited from the adjacent floodplain surface through lateral bank erosion at RM 4.88, river left (August 14, 2024).

3.3.4 Vegetation

The floodplain surfaces in Reach 3 are vegetated with an overstory forest of cottonwood and western redcedar and an understory that includes dense dogwood thickets and vine/Douglas maple. Reed canary grass and willow are the dominant species on low floodplain surfaces. Taller trees along the river-right bank from RM 4.6 - 4.7 and at RM 5 upstream of the Reach 3 boundary, provide a source of potentially effective large wood for recruitment to the channel (Figure 88). However, larger trees are lacking from the river-left banks from RM 4.55 - 4.75 and upstream of RM 5.25. Mature old growth vegetation is absent from Reach 3. The adjoining hillslope vegetation is dominated by small to large conifers. Evidence of a recent wildfire is present on the river right hillslopes in Reaches 2-5.

Figure 88. White River, Reach 3: Map of vegetation height classification analysis (LiDAR—based analysis).

Figure 89. White River, Reach 3: Map of aerial imagery for vegetation identification.

3.3.5 Human Alterations

Notable human alterations to the river channel and fluvial processes in Reach 3 are present, but fairly limited compared to adjacent reaches (Figure 90). Riprap protects the river left bank from ~RM 5.38 - 5.47 where the river has recently migrated in the direction of White River Road (Figure 91). Several culverts convey seasonal flow from the river left hillslopes underneath White River Road. The logging history of the region has likely impacted wood abundance in Reach 3. An assessment of historical aerial imagery shows that substantial forest clearing occurred on the river left floodplain between 1972 and 1985. Forest clearing in Reach 3 has resulted in a lack of mature old-growth forests and a significant reduction in potentially effective large wood sources on floodplain surfaces. Although the White River channel in Reach 3 is highly sinuous and does not appear to have been recently intentionally straightened, abundant meander scars evident in the LiDAR and aerial imagery suggest that lateral migration was likely more active historically. Substantial anthropogenic channel straightening just upstream in Reach 4 likely limits modern lateral processes in Reach 3, and the presence of several unmaintained road segments in Reaches 2-5 (See Figure 90) suggest potential historical channel straightening and additional restrictions on lateral processes. Recreational use of the White River also appears to impact wood abundance and function within Reach 3, as several pieces of large wood appeared sawed off to improve navigation of the river (Figure 91).

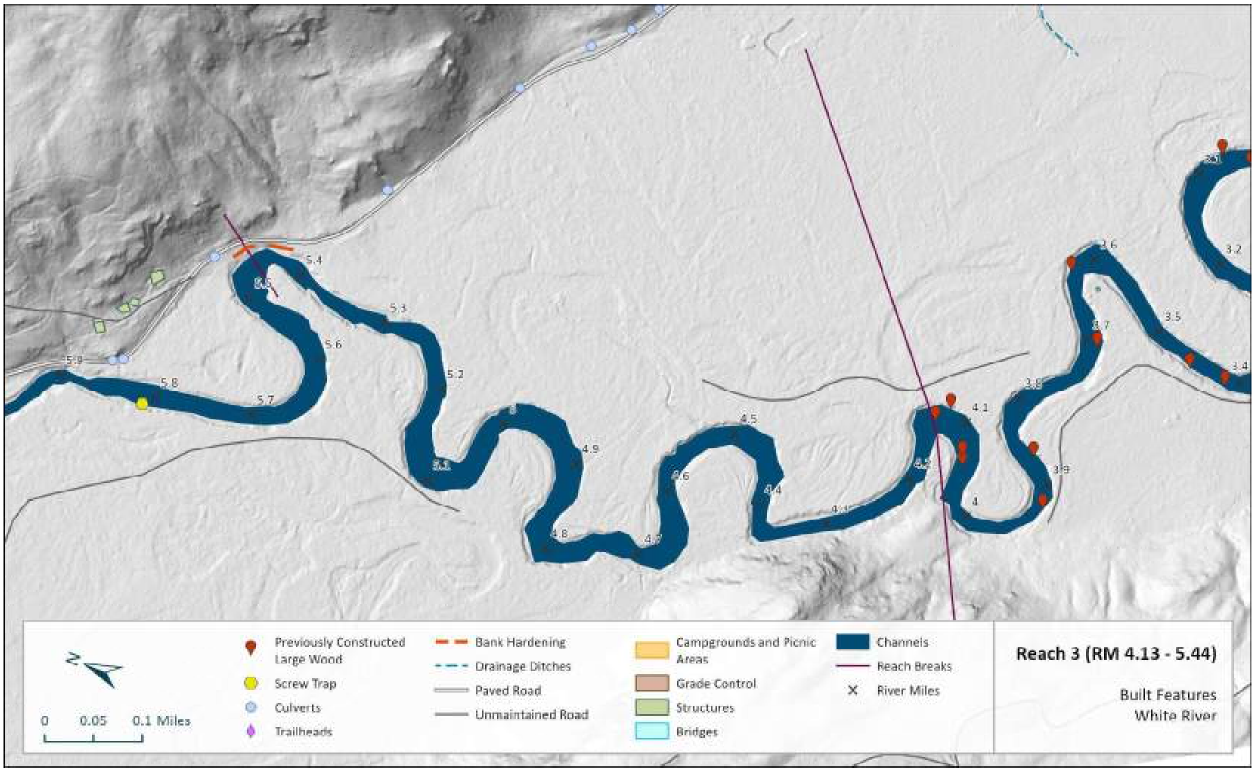

Figure 90. White River, Reach 3: Mapped anthropogenic features.

Figure 91. Left: Riprap protecting White River Road on river let at RM 5.43 (August 13, 2024). Right: Sawed off portion of in-stream large wood at RM 5.1 (August 13, 2024).

3.3.6 Recommended Actions

Recommended actions in Reach 3 include large wood placement and off-channel reconnection to improve the quantity and quality of available habitat, and enhancement of riparian conditions. Large wood placements throughout the main channel are recommended to enhance/improve channel complexity and habitat availability and to promote continued lateral processes. Excavation to connect the existing oxbow on river right would increase available and accessible floodplain wetland habitat area. Installation of willow/cottonwood trenches on open in-channel bars would improve long-term riparian conditions. Recommended actions in Reach 3 could improve in-channel aquatic habitat conditions, but may not improve long-term geomorphic or riparian processes.

3.4 WHITE RIVER REACH 4 (RM 5.44 – 7)

3.4.1 Overview

Reach 4 is 1.56 river miles long and extends from RM 5.44 to the Sears Creek Road bridge at RM 7 (Table 12). Although the valley is wide and unconfining, for most of the reach the White River is simplified and straightened along the east side hillslope and White River Road. Despite significant straightening of the channel, Reach 4 is classified as sinuous (S = 1.55) due to the meandering section at the downstream end RM 5.44 – 5.9 and another at the upstream end RM 6.45-6.9. The average reach gradient of Reach 4 is 0.09%, which is slightly larger than Reach 3 (0.07%) and slightly smaller than Reach 5 (0.18%). Average bankfull width measured during the Habitat Assessment (Appendix A) is 140 ft, identical to that of Reach 3. Low floodplain surfaces (inundated ~ 1-5 years) are located behind point bars, although these features are limited in Reach 4 due to channel straightening. Medium floodplain surfaces (inundated ~ 5-10 years) comprise the majority of the river right valley bottom, and high floodplain surfaces (inundated ~ 10-100 years) comprise the majority of the river left valley bottom as well as a portion of the river right valley bottom that is influenced by channel incision related to the bridge at RM 7. Vegetation on low floodplain surfaces consists of reed canary grass, willow, and dogwood, whereas vegetation on higher floodplain surfaces consists primarily of dogwood, cottonwood, and cedar. A series of wetland features with standing water exist within historical channel scars (oxbows) on the river-right floodplain. The oxbow wetlands are wetted via groundwater, seasonal hillslope runoff, and high flow surface inundation from the White River. Human impacts in Reach 4 include forced straightening and channel simplification, logging, riprap, and upstream bridge confinement. A representative photo of Reach 4 is provided in Figure 92.

Figure 92. Representative photo of the White River in Reach 4 at RM 6.2, looking downstream (August 13, 2024).

Table 12. Reach 4 descriptive geomorphic metrics.

Metric	Value
Reach Length (miles)	1.56
River Miles	5.44-7.0
Stream Gradient	0.09%
Sinuosity	1.55
Dominant Channel Habitat Unit Type	Pool
Average Bankfull Width (feet)	140
Confinement	Unconfined
Dominant Substrate	Gravel
Bank Stability/Channel Migration	Unacceptable *(See Appendix B Section 3.2)*
Vertical Channel Stability	At Risk *(See Appendix B Section 3.2)*

3.4.2 Channel and Floodplain Geomorphology

The White River in Reach 4 is considered sinuous because of a short tortuous meandering at the downstream (RM 5.44 – 5.9) end and a small meander set near the upstream (RM 6.45 – 6.9) end of the reach. Otherwise, the channel is straight and simplified with reduced geomorphic and habitat complexity. Straightening and simplification is associated with channel incision and confinement at the Sears Road bridge and bank hardening along White River Road. The Habitat Assessment (See Appendix A) recorded 89% of the habitat in Reach 4 as extended pool, and 11% of the habitat as glide (Figure 94). The glide habitat occurs downstream of ~ RM 5.83. Short riffles are present at RM 5.81 and RM 6.75, although they were shorter than the channel width and therefore not included in the Habitat Assessment. The valley bottom is wide and unconfining in Reach 4, but the simplified channel currently only utilizes the east side. The modern channel alignment along the toe of the hillslope and White River Road is controlled by bank armoring on river left that holds the channel in place and induces incision that instigates and perpetuates channel straightening. Abandoned channel meander scars and oxbows visible across the floodplain reveal a more sinuous historical channel planform that wandered across the whole of the valley floor. The White River is primarily single threaded in Reach 4 except for split flow around mid-channel bars at ~RM 5.8 and ~RM 6.8.

The river-right floodplain contains several wetted oxbows located in abandoned channel scars and meander neck cutoffs (Figure 93). The oxbows are wetted perennially via groundwater but are otherwise disconnected from the White River via surface flow except during higher flows (Figure 93). Several of the oxbows could provide viable off-channel rearing habitat if re-connected to the channel at low flow conditions. In a seasonally dry oxbow at RM 6.1 (Figure 93), wood is present at a much higher abundance than observed in the main channel, suggesting historically higher wood loads and the presence of channel-spanning large wood accumulations in Reach 4 in the not so distance past. Past large wood loading likely maintained higher channel complexity and instigated lateral processes and potentially dynamic avulsions.

Figure 93. Left: Wetted oxbow in abandoned channel scar, river right at ~ RM 6.3. Right: Large wood accumulations in a seasonally dry oxbow at RM 6.1, river right (August 13, 2024).

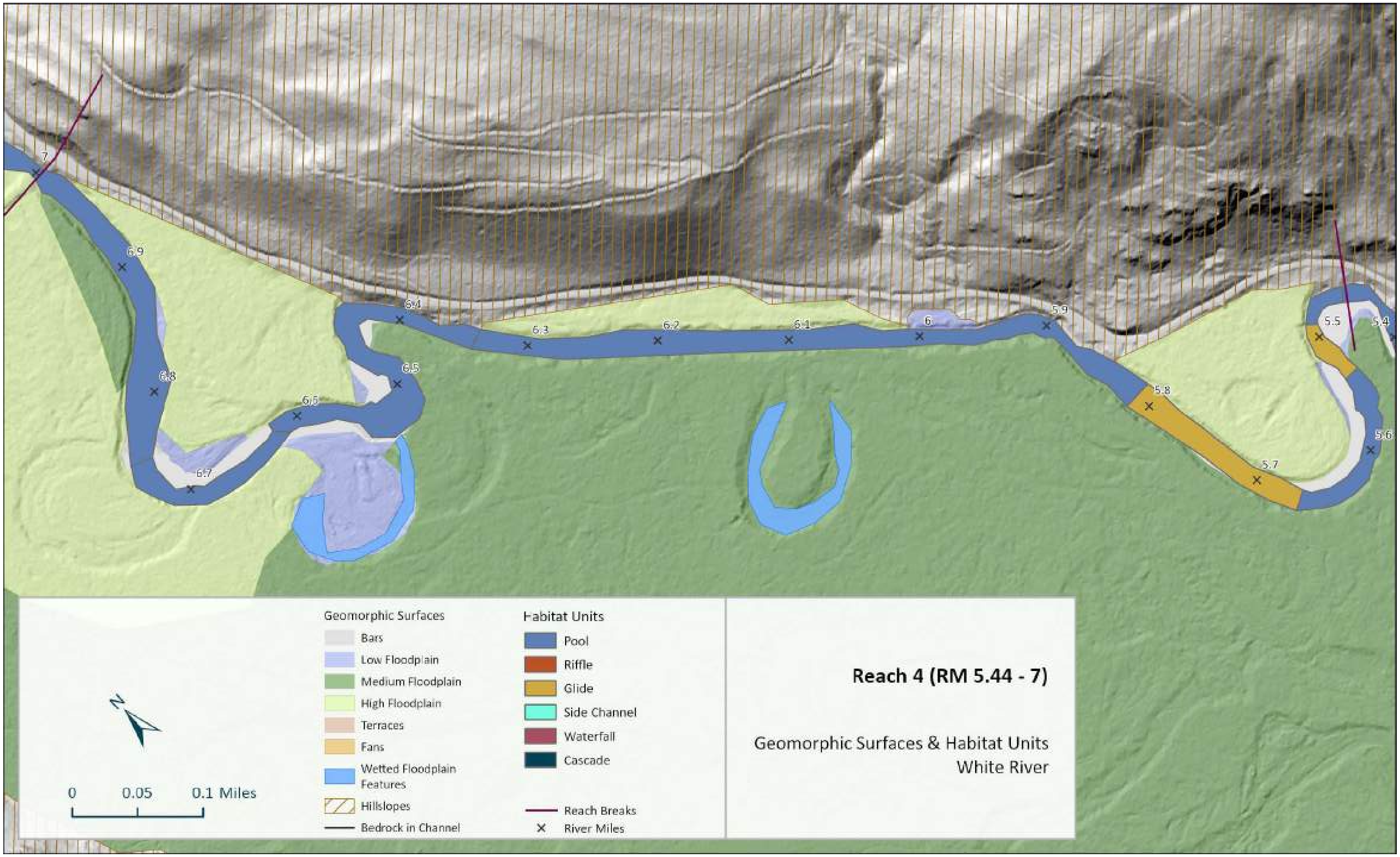

Figure 94. White River, Reach 4: Map of geomorphic surfaces and habitat units.

Based on historical photo analysis, the White River has maintained a relatively similar channel alignment in Reach 4 since 1957, which is the first date for which publicly available aerial imagery is available (Figure 95). A more recent meander neck cutoff at RM 6.5 – 6.6 did occur between aerial imagery sets from 1985 and 1998. Continued straightening concurs that active incision and channel simplification is trending in Reach 4. The recently abandoned meander now contains a wetted oxbow that is gradually infilling with overbank sand and an adjacent low floodplain surface that is vegetated primarily by reed canary grass, willow, and dogwood.

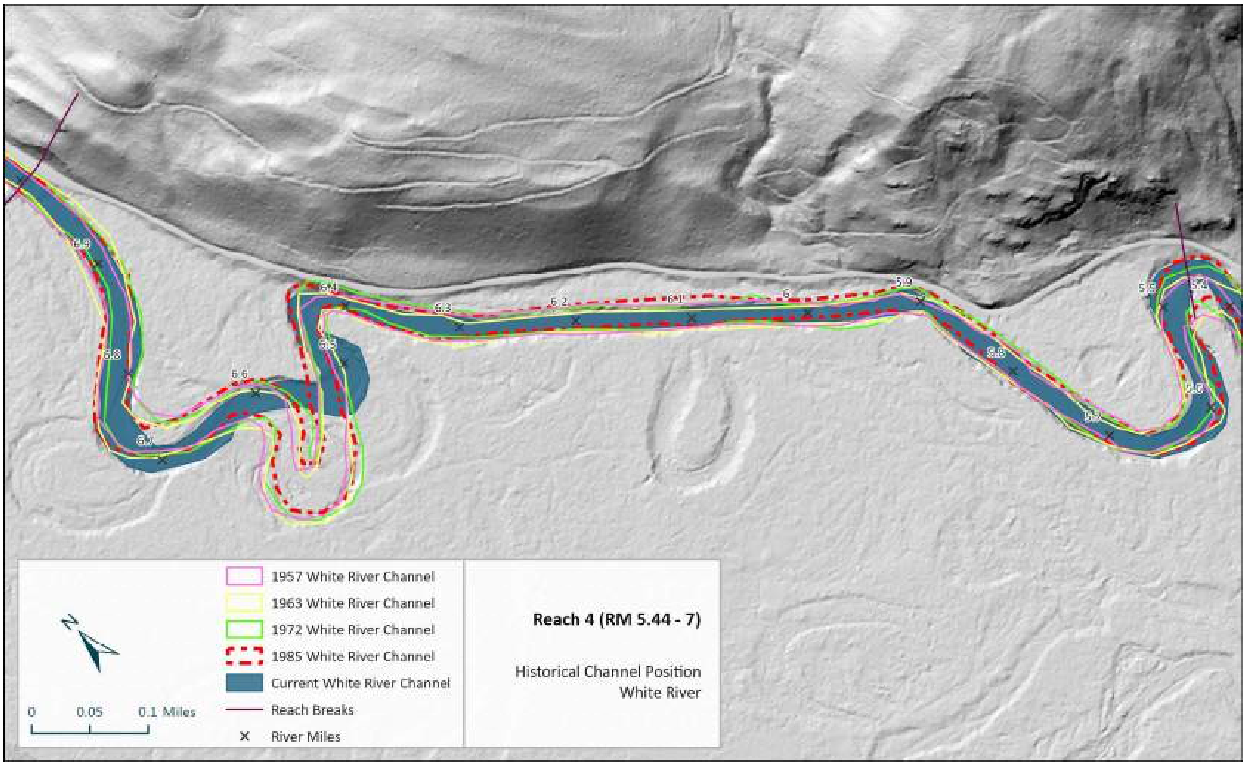

Figure 95. White River Reach 4: Map of channel alignments digitized from historical photos (1957-2023).

Although there is abundant surface water in the oxbows on the river-right floodplain, there are no tributaries to the White River on river right within Reach 4. A minor but perennial tributary does meet the White River on river left at ~ RM 6.01. The tributary was flowing during the time of the geomorphology survey on August 17, 2024, and contributes sand to the mainstem channel.

Channel substrate in Reach 4 is primarily gravel alluvium (Figure 96). Cobbles are infrequent, and boulders are absent, except where they have been placed for bank protection. A Wolman Pebble Count (1954) was conducted on riffle crests at RM 5.81 (GC 07) and RM 6.75 (GC 08). The median grain size at GC 07 of D50 = 17.59mm is slightly larger than at the upstream GC 08 median grain size of D50 = 15.52mm. Additional ocular observations recorded throughout the reach confirm that bedload and bar sediment composition is relatively the same (gravel) through Reach 4. The data from the two pebble counts are plotted on a map (Figure 97) of the Reach 4 incipient motion analysis results (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.9.4). The analysis indicates that at the 2-yr modeled discharge, the channel's shear stress is capable of mobilizing gravel and sand through the reach. The analysis also reveals pockets of higher shear stress with the potential of mobilizing small cobbles. Homogeneous model results across the channel in the straightened section further confirms functional simplification and a lack of complexity between RM 5.7 – 6.4.

Figure 96. Representative photograph of Reach 4 gravel-sized bar sediments at RM 5.81 (August 13, 2024).

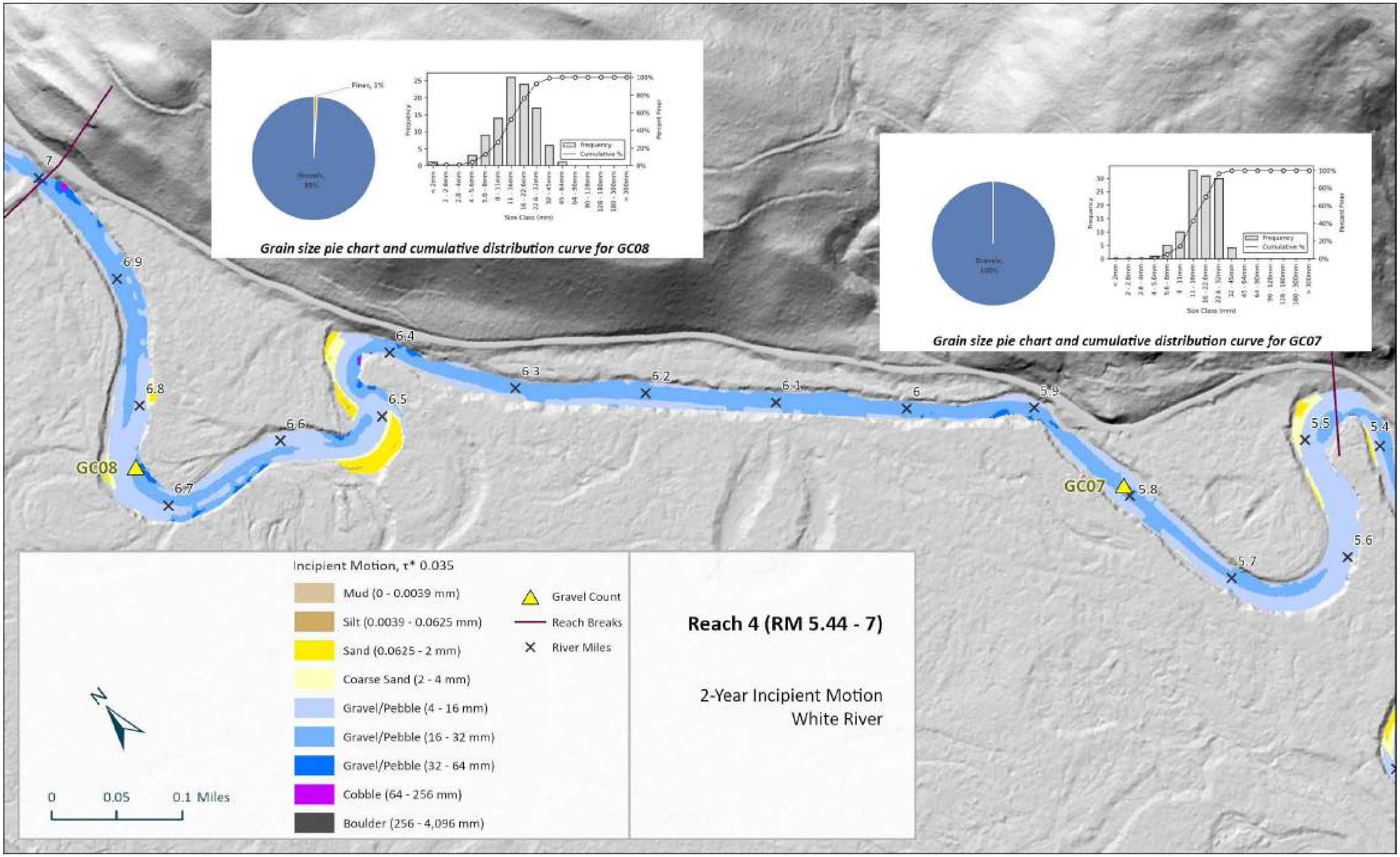

Figure 97. White River, Reach 4: incipient motion analysis results map (estimated grains size mobility at the 2-yr modeled discharge) and grains size distribution of two (GC 07 and GC 08) pebble counts.

The primary source of bedload material sediment to Reach 4 is delivery from upstream. The observed channel banks are composed of a silty-clay base overlain by sand (Figure 98). Gravels may be present beneath the silty-clay layer in Reach 5 but were either absent in the banks observed during the survey or below the surface of the water in Reach 4.

Figure 98. Fine material in exposed stream bank sediments, river left at RM 5.47 (August 13, 2024).

Floodplain connectivity is at risk in Reach 4 with the trends of incision and straightening underway. Translation of incision is underway in Reach 5 and eventually a potential risk to Reach 3. Low floodplain surfaces (inundated ~ 1-5 years) are limited to small wedges extended from points bars at the inside of several meander bends at the upstream and downstream ends of the reach, a small pocket floodplain at RM 6 and the recently abandoned meander surface at RM 6.86. High floodplain surfaces (inundated ~10-100 years) exist on river left, and downstream of the bridge at RM 7 on river right. Incision related to channel straightening and bank hardening associated with the bridge have resulted in disconnection of the river-right floodplain adjacent to the White River channel upstream of RM 6.6. Otherwise, medium floodplain surfaces (inundated ~ 5-10 years) occupy the remaining valley bottom in Reach 4. On the river-right floodplain, the medium elevation surfaces contain abandoned channel scars and scrolls that indicate the reach historically hosted a more sinuous meandering channel than exists today. Based on exposed banks along the channel, floodplains in Reach 4 are composed of a silty-clay base overlain by silty and sandy loam that is topped with organic soil (See Figure 98). Gravels are not visible at the base of exposed banks in Reach 4 although they are present on the bars. Floodplain soil in this portion of the White River valley is described as silt loam (Natural Resources Conservation Service, 2007).

3.4.3 Large Wood Material

A total of 245 pieces of large woody material (LWM) and 16 log jams (accumulation of >3 LWM) were observed in the channel during the survey (August, 2024) (See Figure 99). Of the 151 pieces, 111 pieces are considered Quality Large Wood (QLW); 40 classified as large size class (>20-inces diameter and >35-feet long); and 71 as medium size class (12 to 20-inch diameter and at least 35-feet long). Of the 16 log jams, 15 have multiple pieces of QLW and thus are effective channel influencing and habitat forming structures. The observed primary function of large wood in Reach 4 is currently creating small side-channel and backwater alcoves (Figure 100). During the geomorphic assessment on August 13, 2024, backwater alcoves associated with large wood accumulations were observed at RM 5.75, 5.91, 6.04, 6.1, 6.28, 6.34, 6.6, 6.78, and 6.86. Large wood in Reach 4 is not responsible for splitting flow and is minimally responsible for sorting sediment. Sediment sorting associated with large wood was only observed at RM 6.31. The only notable pool scour associated with large wood was observed on a point bar at RM 5.6 and in the main channel at RM 6.04. Observed key piece log diameter in Reach 4 was noted to range from 1.5-3 feet and length of at least 30 feet.

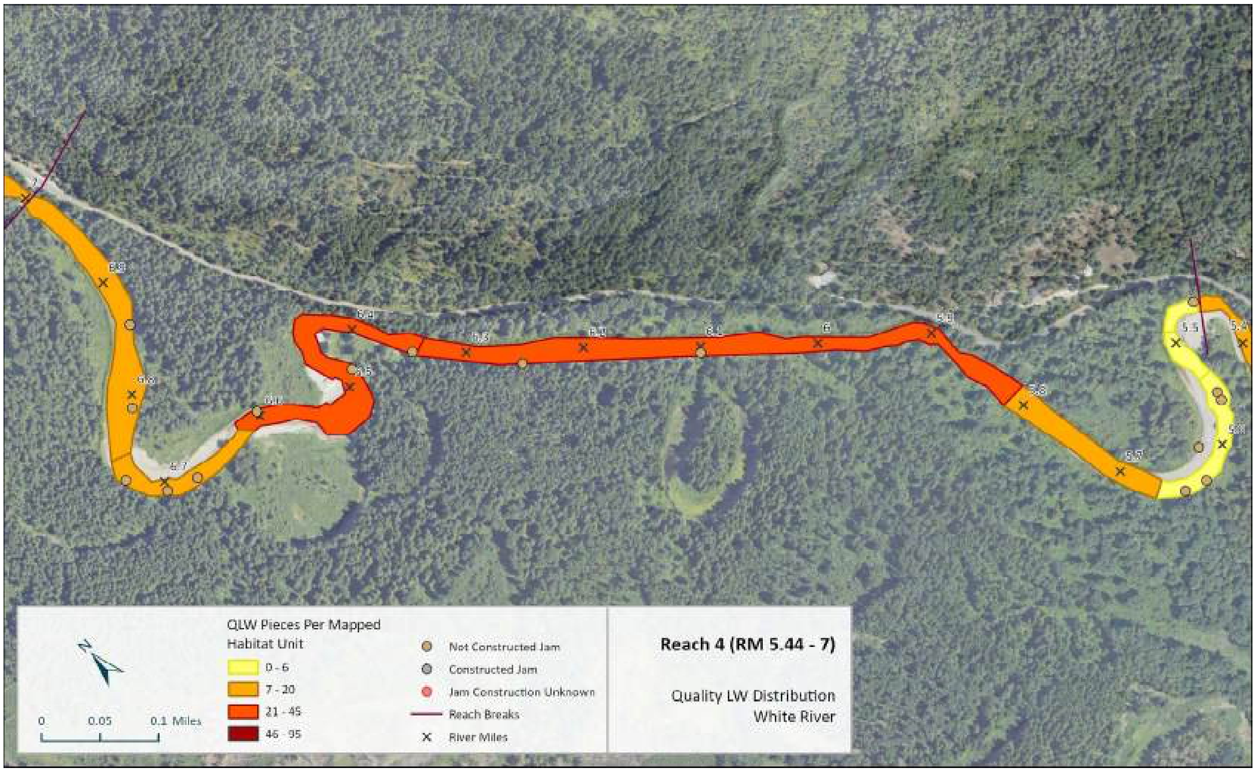

Figure 99. White River, Reach 4: Quality large wood (QLW) distribution maps and surveyed habitat units (2024). QLW count does not include pieces from jams.

Figure 100. Large wood accumulation with alcove and localized scour at RM 6.35, looking downstream (August 13, 2024).

3.4.4 Vegetation

The floodplains in Reach 4 are vegetated primarily with an overstory of western redcedar, fir, and cottonwood and an understory dominated by vine/Douglas maple and dense dogwood thickets (Figure 103). Mature old growth conifers were not observed in Reach 4 during the assessment. Western redcedar stumps were observed at various locations on the river-right floodplain including ~RM 6.31 and RM 6.92, confirming that very large trees were more common across the floodplain and likely contributed to the complexity of the channel historically. Reed canary grass, willow, and dogwood are the dominant species on the low floodplain surfaces. The vegetation height analysis map shows smaller height class vegetation bordering much of the channel and a second-growth forest maturing on much of the valley floor that could be a source of large wood to the channel (Figure 101). However, active lateral migration is not occurring in the straightened section from RM 5.9-6.4, reducing potential recruitment of large wood, which in turn, limits channel complexity. Elsewhere, large wood is recruited where lateral migration is active on the outside of meander bends (Figure 103). Where reed canary grass has colonized riparian areas, other species are generally absent, reducing riparian and forest establishment potential, and limiting sources of food for beaver. The adjacent hillslope vegetation is dominated by conifers. Evidence of a recent wildfire is present on the river right floodplain near RM 6.3, and on river right hillslopes in Reaches 2-5.

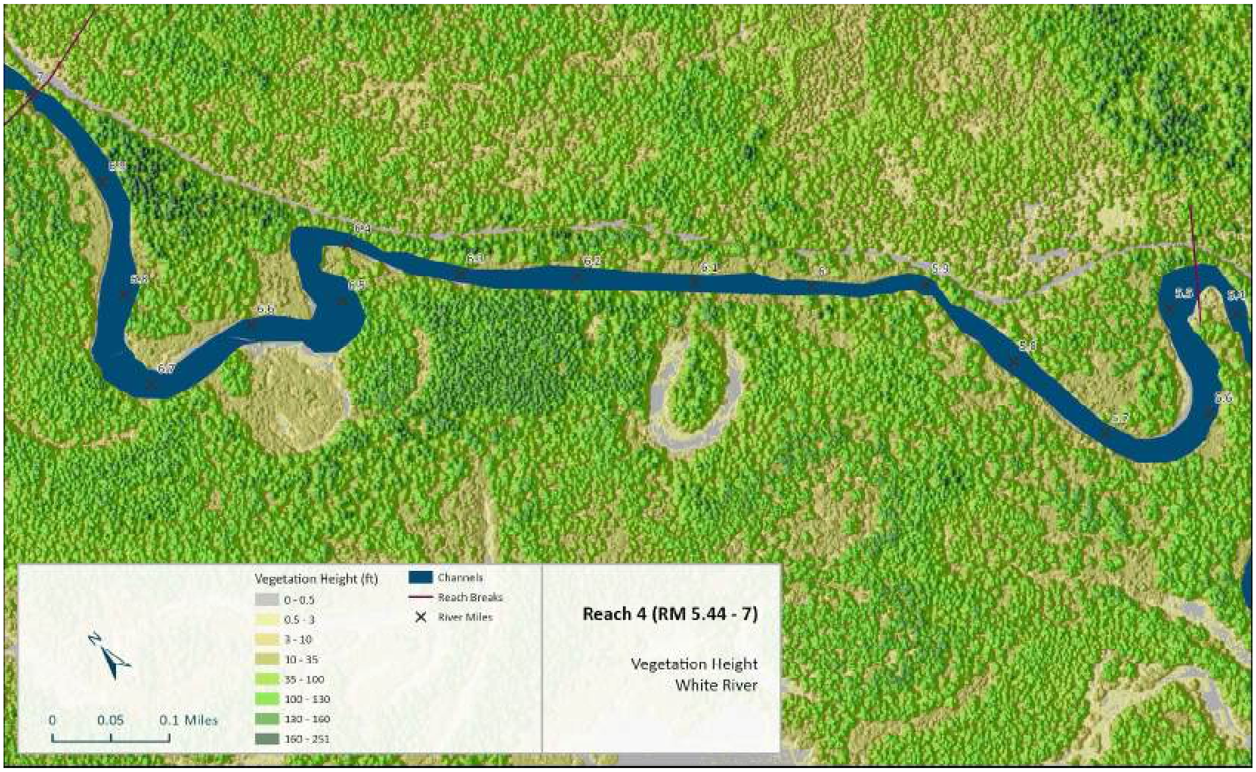

Figure 101. White River, Reach 4: Map of vegetation height classification analysis (LiDAR – based analysis).

Figure 102. White River, Reach 4: Map of aerial imagery for vegetation identification.

Figure 103. Left: Riparian vegetation – dense dogwood thicket on low floodplain surface at ~ RM 6.1. Right: recruited western redcedar large wood inputs to the channel near RM 6.78 (August 13, 2024).

3.4.5 Human Alterations

Anthropogenic features and past land management influence the modern course and character of the White River within Reach 4 (Figure 104). The channel has straightened from ~RM 5.9 – 6.45, and from RM 6.9 past the upstream boundary of Reach 4 to RM 7.3. This has resulted in a reduction in geomorphic and habitat complexity in the reach, and a trend of ongoing channel incision that reduces floodplain connectivity. Bank armoring and bridge confinement limit the channel's ability to reverse the trend of incision and simplification in Reach 4. Riprap protects the base of the narrow Sears Road bridge at RM 7 (Figure 105) as well as the banks adjacent to White River Road from RM 6.32 – 6.45. An abandoned road through the river right floodplain was observed near logged cedar stumps adjacent to RM 6.31. The road was likely used when the White River basin was being logged. Stumps were also observed on the river-right floodplain near RM 6.92 (Figure 105). Past widespread logging in the White River basin altered the composition of overstory vegetation and thus the material available to the channel for many decades. A temporary screw trap was set up in the channel near RM 5.81 to count out-migrating salmonid smolts. Several culverts convey flow underneath White River Road throughout Reach 4.

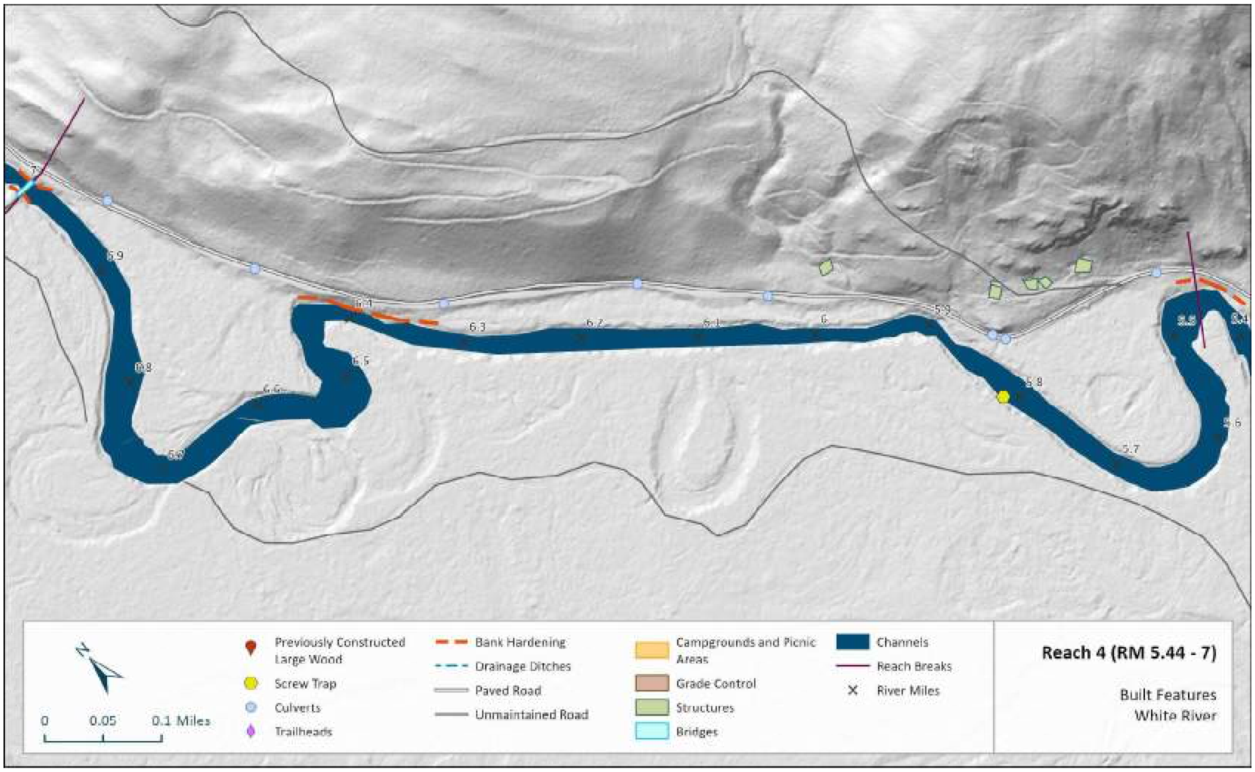

Figure 104. White River, Reach 4: Mapped anthropogenic features.

Figure 105. Left: Sears Creek Bridge and associated bank protection at RM 7, upstream Reach 4 boundary (August 6, 2024). Right: Stumps on old growth western redcedar on river-right floodplain at RM 6.92 (August 12, 2024).

3.4.6 Recommended Actions

Recommended actions in Reach 4 prioritize large wood placement and excavation of side channel or oxbow inlets to increase the quality and quantity of available habitat, modification of existing anthropogenic features, and revegetation. Reach 4 is artificially straightened, and excavation of side channel and oxbow inlets could increase available off-channel habitat and floodplain wetland areas as well as overall complexity within the highly simplified reach. Large wood additions to the mainstem channel are recommended to enhance/improve channel complexity, encourage lateral processes, and counteract entrenchment due to channel simplification. Modification of anthropogenic features such as the Sears Creek Road bridge crossing would improve natural channel dynamics within the heavily straightened and entrenched reach. Under current conditions the bridge span is a major impediment to channel migration. Revegetation of open fields and willow/cottonwood trenches on open in-channel bars would improve long-term large wood recruitment and riparian conditions.

There is a potential for a larger scale relocation of the mainstem channel into the river right floodplain at the straightened section along the road from RM 5.9 to 6.4. This would significantly improve ecological conditions in this reach but would be expensive and have challenges related to recreational uses and permitting. This should nevertheless be considered in future restoration planning in this reach.

3.5 WHITE RIVER REACH 5 (RM 7 – 9.52)

3.5.1 Overview

Reach 5 is 2.52 miles long and extends from the Sears Creek Road bridge at RM 7 to the upstream end of an alluvial fan contact on river right at RM 9.52 (Table 13). The White River is unconfined in the wide valley, although the channel runs along the river-left hillslopes at RM 7 – 7.2 and along the toe of an alluvial fan on river-right at RM 9.4 – 9.45. At the downstream end of the Reach 5 the channel is straight and artificially confined by the Sears Road bridge crossing at RM 7. Anthropogenic straightening of the channel to accommodate the bridge at RM 7 has instigated channel incision and floodplain disconnection. Reach 5 is single thread in planform and the second most sinuous reach (S = 1.93) in the assessment area (Figure 106). The forced channel straightening at the downstream end of the reach from RM 6.9 – 7.33 has slight reduced the natural sinuosity. The reach average gradient (0.18%) is double that of Reach 4 and is similar in gradient to Reach 6. The average bankfull width, recorded during the Habitat Assessment (Appendix A) is approximately 145 feet. Low floodplain surfaces (inundated ~ 1-5 years) generally occur behind point bars on the inside of meander bends. The low floodplain surfaces transition to medium floodplain surfaces (inundated ~ 5-10 years), which are the main geomorphic surface on in the valley through Reach 5. High floodplain surfaces (inundated ~ 10-100 years) exist along RM 6.6 – 7.46 where incision associated with confinement at the bridge crossing is reducing floodplain connectivity. Low floodplain surfaces are vegetated with willow and reed canary grass. Vegetation communities on medium and high floodplain surfaces are mostly reed canary grass, dogwood, cottonwood, and mixed conifers. In addition to the Sears Creek bridge crossing and related riprap, anthropogenic features in Reach 5 also include boulder riprap, unmaintained access roads on both sides of the channel, built structures such as homes, historical logging impacts, ditching and draining of floodplain surfaces, loss of riparian buffer and floodplain vegetation, and culverts that route flow under both White River Road and Sears Creek Road.

Figure 106. Representative photo of White River channel in Reach 5 at RM 8.76, looking upstream (August 6, 2024).

Table 13. Reach 5 descriptive geomorphic metrics.

Metric	Value
Reach Length (miles)	2.52
River Miles	7.0-9.52
Stream Gradient	0.18%
Sinuosity	1.93
Dominant Channel Habitat Unit Type	Pool
Average Bankfull Width (feet)	145
Confinement	Unconfined
Dominant Substrate	Gravel
Bank Stability/Channel Migration	At Risk *(See Appendix B Section 3.2)*
Vertical Channel Stability	Adequate *(See Appendix B Section 3.2)*

3.5.2 Channel and Floodplain Geomorphology

Although the gradient in Reach 5 is relatively low (0.18%) it is double that of downstream Reach 4 (0.09%). The channel is sinuous with alternating extended pools and shorter glides as well as short riffles which were generally shorter than the channel width, and therefore not documented by the Habitat Assessment (Figure 108). The Habitat Assessment (See Appendix A) recorded 91% of the habitat as pool, 7% of the habitat as glide, and 1% of the habitat as side channel. The channel is unconfined through Reach 5 as it meanders diagonally across the width of the valley from the river-right fan-toe contact at RM 9.4 – 9.7 to the opposite side of the valley floor river-left hillslope toe contact at RM 7 – 7.2. The downstream contact is associated with bank hardening and bridge confinement of the Sears Creek Road bridge at RM 7. The White River channel is primarily single threaded through Reach 5, with flow splits around mid-channel gravel bars at ~ RM 7.57, 7.98, 8.35, 8.75, and 9.35, and as side channels along the back of bars at RM 8.36 – 8.42 and RM 8.87 – 8.83. Mid-channel bars in Reach 5 are not typically associated with large wood or log jams.

Tributaries to the White River in Reach 5 include Sears Creek and a minor ditched perennial creek sourced from the river-left floodplain that meets the channel at RM 7.26 (Figure 107). The hydraulic analysis (See Section 2.8) estimates that Sears Creek conveys approximately 6% of the total flow of the White River measured at the outlet into Lake Wenatchee. Sears Creek is perennial where it crossed through a culvert under Sears Creek Road and flows across its historical alluvial fan (Figure 107) into the White River valley. However once on the valley floor, Sears Creek currently occupies a network of ponds maintained by active beaver dams which disperse the Sears Creek flow across the floodplain, resulting in no clearly defined confluence point with the White River. Therefore, in its modern configuration, Sears Creek contributes flow to the White River but it does not regularly contribute bedload sediment or wood. The general source of flow from Sears Creek to the White River is somewhere between RM 8.55 – 8.9 along river-right.

Figure 107. Left: Small floodplain tributary that meets White River on river-left at RM 7.26 (August 6, 2024). Right: Sears Creek flowing across its alluvial fan prior to reaching the valley floor (September 9, 2024).

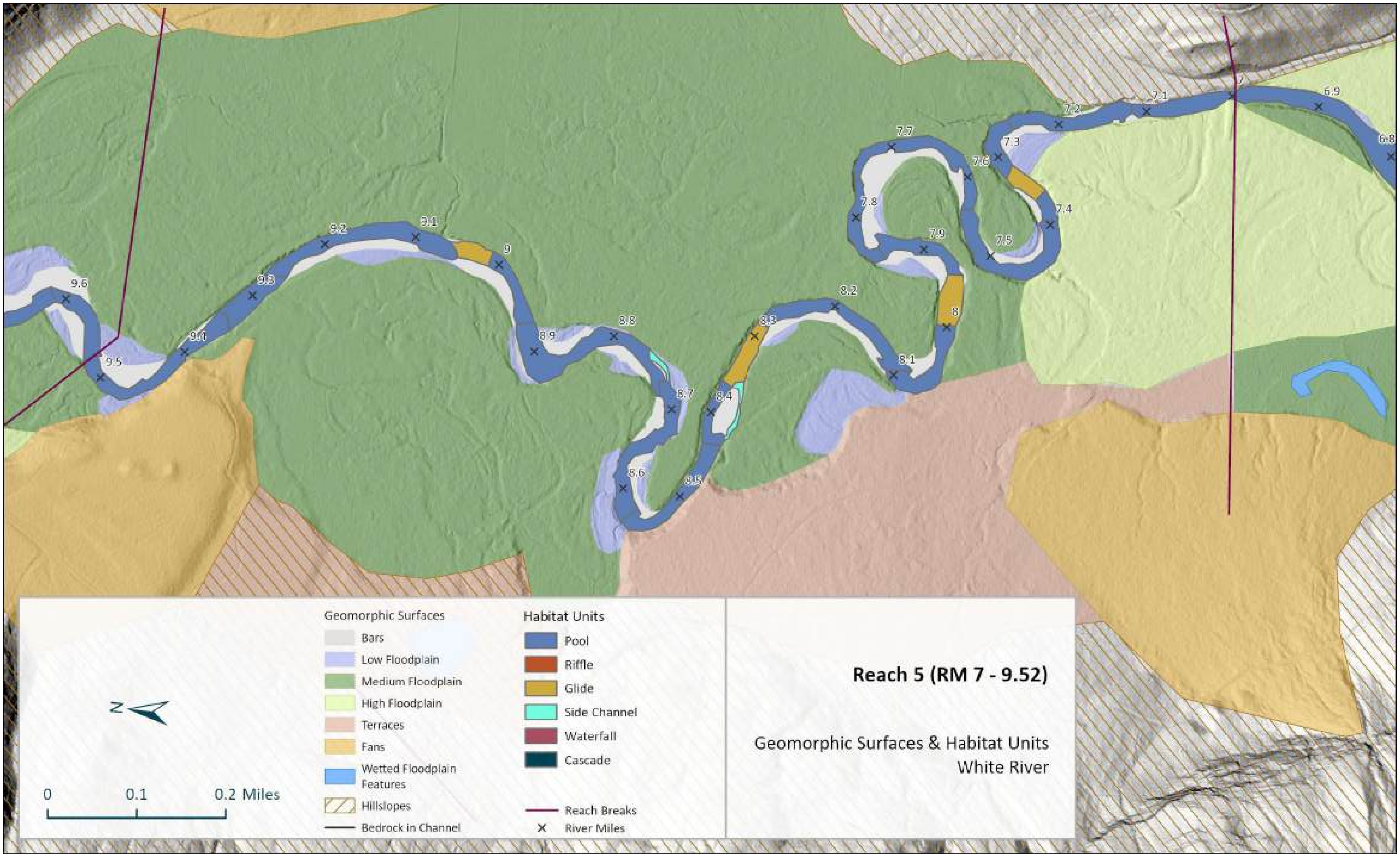

Figure 108. White River, Reach 5: Map of geomorphic surfaces and habitat units.

Based on historical photo analysis of the location of the channel's boundary, active lateral processes as meander extension have occurred since at least 1957, which is the first date for which publicly available aerial imagery is available (Figure 109). No major avulsions or meander cutoffs have occurred since 1957 but clear abandoned channel scarring reveal meander neck cutoffs at RM 7.1 and 7.45 on river left, where incision associated with the downstream bridge confinement has also reduced floodplain connectivity. It is likely that channel straightening and simplification here is related to the bridge construction and potentially was anthropogenically constructed. There is risk of a meander cutoff and further channel straightening at the downstream end of the reach occurring between RM 7.3 – 7.6 as a result of downstream incision combined with lateral migration processes.

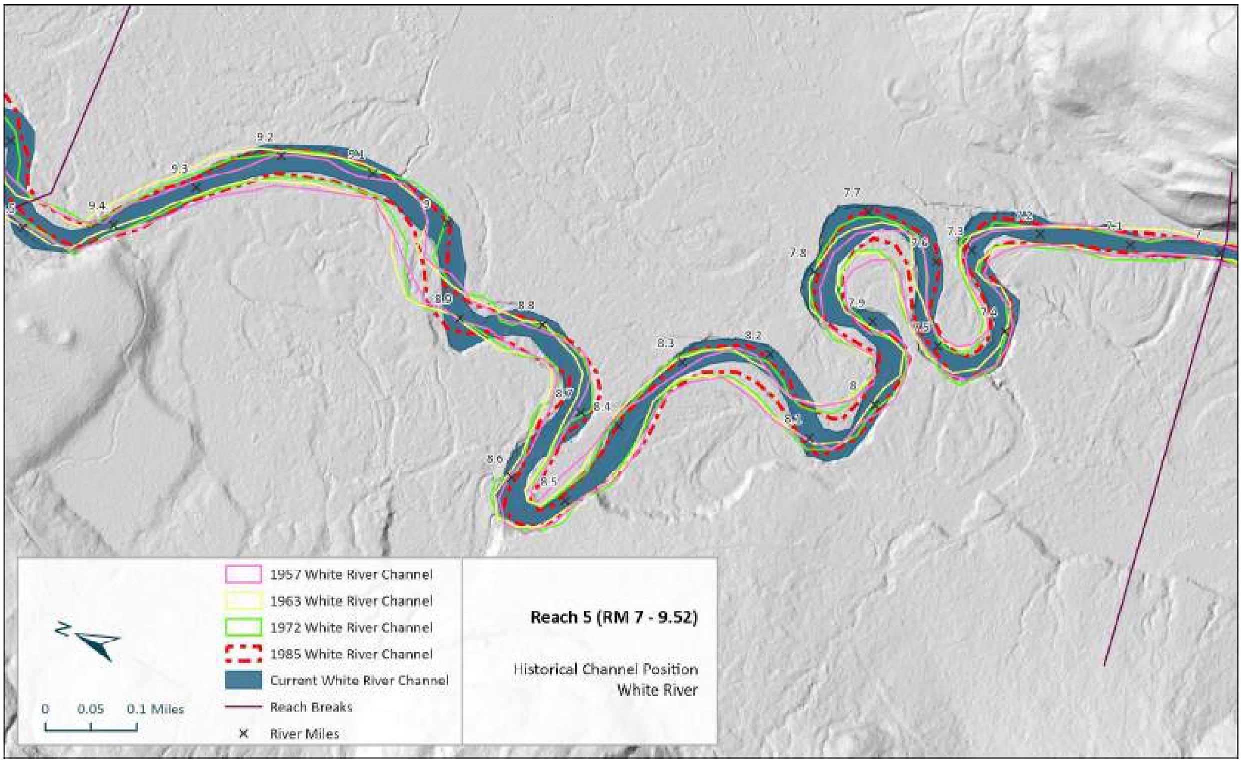

Figure 109. White River Reach 5: Map of channel alignments digitized from historical photos (1957-2023).

Channel substrate in Reach 5 is primarily gravel with some coarse sand and cobbles present. Sand is most common on the top and downstream ends of bars. Substrate grain size generally decreases downstream in Reach 5. Wolman Pebble Counts were conducted along riffle crests at RM 7.96 (GC 09) and RM 8.74 (GC 10). The median grain size at GC 09 of D50 = 17.59mm is slightly smaller than the downstream GC 10 median grain size of D50 = 24.54mm. Additional ocular observations recorded throughout the reach confirm that bedload and bar sediment composition is dominated by gravel. The data from the two pebble counts are plotted on a map (Figure 110) of the Reach 5 incipient motion analysis results (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.9.4). The analysis indicates that at the 2-yr modeled discharge, the channel's shear stress is capable of mobilizing gravel, though the size fraction of gravel decreases downstream. This supports deposition and maintenance of gravel bars throughout. The analysis also reveals pockets of higher shear stress area with the potential of mobilizing cobbles. Homogeneous model results across the channel in the straightened section further confirms functional simplification and a lack of complexity between RM 7 – 7.3.

The primary source of gravel bedload material to Reach 5 is a combination of upstream inputs as well as local bank erosion, reactivation of temporarily stored bar material, and hillslope contacts. The hillslope contacts at the upstream and downstream bounds of the reach also provide angular cobble-to-boulder sized material that is likely mobilized very infrequently. Stream banks in Reach 5 are typically composed of gravel mixed with sand or silt at the base (< 2ft), which is often overlain with silty loam or sandy loam. (Figure 111).

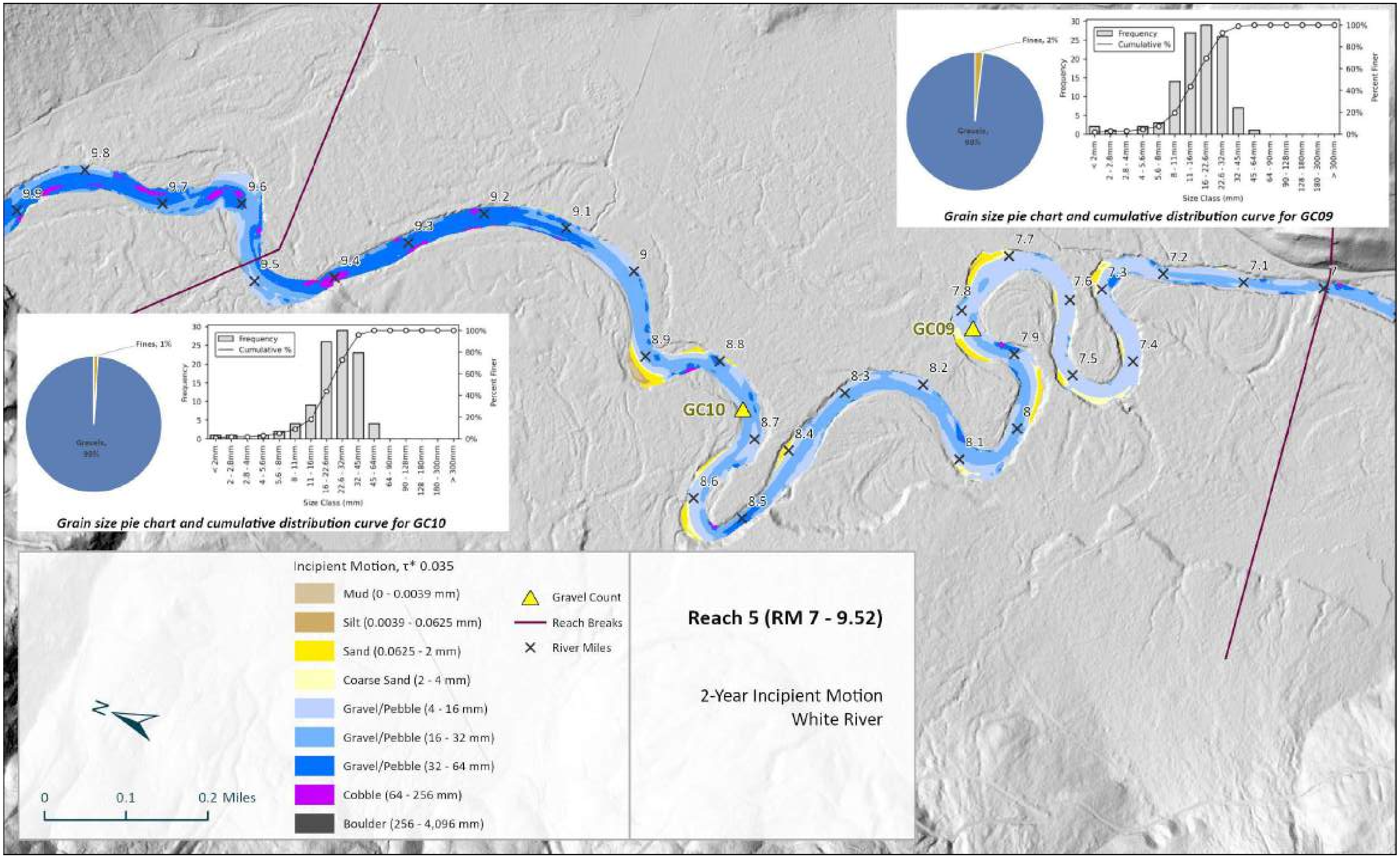

Figure 110. White River, Reach 5: incipient motion analysis results map (estimated grains size mobility at the 2-yr modeled discharge) and grains size distribution of two (GC 09 and GC 10) pebble counts.

Figure 111. Cut bank exhibiting typical floodplain composition - at RM 7.23, river left (August 6, 2024).

Low floodplain surfaces (inundated ~1-5 yrs) are common behind large gravel point bars on the insides of meander bends and in association with deep slow water pools on the outside of meander bends at RM 8.08, 8.55-8.62, and 8.89-8.92, where high flows likely backwater onto the adjacent floodplain surface. Otherwise, medium floodplain surfaces (inundated 5-10 yrs) occupy most of the valley bottom in Reach 5. A small pocket of high floodplain is located at the downstream end of the reach (RM 6.6 – 7.46), where channel straightening related to the bridge at RM 7 has resulted in incision and floodplain disconnection. Based on exposed banks, floodplains in Reach 5 are composed of gravels overlain by silt loam and sandy loam, then topped with sand and soil. Floodplain soils are typically described as silt loam. The adjacent hillslopes are sandy loam with inputs of volcanic origin and rock outcrops with poorly developed soils (Natural Resources Conservation Service, 2007). The floodplains are mapped in Figure 108.

3.5.3 Large Wood Material

A total of 393 pieces of large woody material (LWM) and 22 log jams (accumulation of >3 LWM) were observed in the channel during the survey (August, 2024) (See Figure 112). Of the 393 pieces, 171 pieces are considered Quality Large Wood (QLW); 60 classified as large size class (>20-inces diameter and >35-feet long); and 111 as medium size class (12 to 20-inch diameter and at least 35-feet long). Of the 22 log jams, 20 have multiple pieces of QLW and thus are expected to be effective channel influencing and habitat forming structures. Large wood jams and logs with rootwads are associated with pool scour, sediment sorting, and provide a source of channel roughness in Reach 5. In many cases, large wood is limited to the channel margins and thus does not influence mid-channel processes. In several locations, channel spanning log jams or large wood pieces appear to have been dismantled to ease downstream recreational navigation (Figure 113). Active lateral migration provides a local source of large wood recruitment potential. However, forest and vegetation removal of riparian areas from RM 7.74 – 7.95 and RM 8.14 – 8.24 limits available of recruitable large wood in some locations. Observed key piece log diameter in Reach 5 was noted to be 3 feet and length of at least 30 feet.

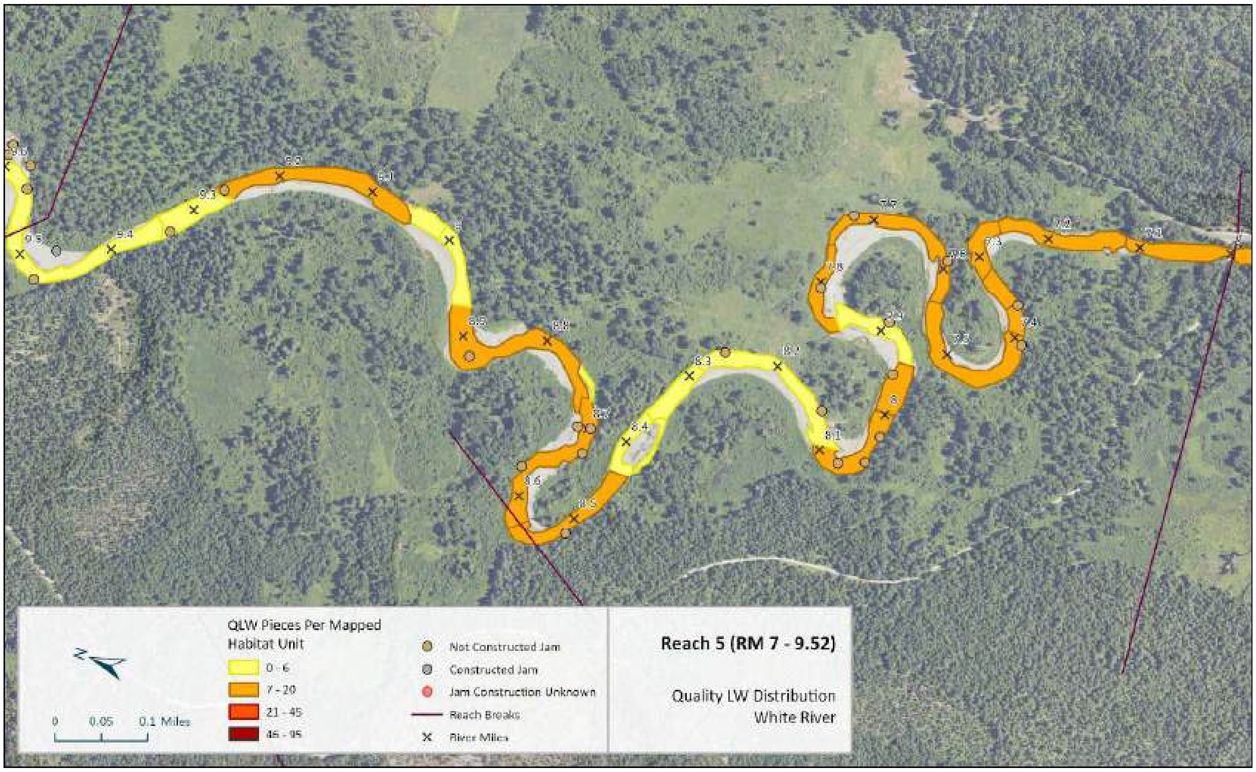

Figure 112. White River, Reach 5: Quality large wood distribution map and surveyed habitat units (2024). QLW count does not include pieces from jams.

Figure 113. Large wood jam at RM 8.67 with some cut pieces for navigation (August 6, 2024).

3.5.4 Vegetation

Floodplain vegetation in Reach 5 has an overstory of mixed-conifer (cedar, Douglas-fir) and cottonwood, and an understory of conifers, dogwood, aspen, vine/Douglas maple, and reed canary grass (Figure 114). Mature old growth conifers are rare in Reach 5, although small pockets of old growth western redcedar exist on river-right medium floodplain surfaces at approximately RM 9, and RM 8.7. These mature trees are located far from the river channel and are unlikely to be recruited to the channel in the absence of significant westward lateral migration. Willow and reed canary grass are the dominant species on low floodplain surfaces. The vegetation height analysis map shows that larger overstory trees grow in small clusters, although there has been significant forest clearing and vegetation removal on the river-left floodplain throughout the reach and adjacent to the channel from RM 7.65 - 8.3 (Figure 115), and shorter trees dominate most of the Reach 5 floodplain. Therefore, large wood recruitment potential is generally limited throughout the reach, which reduces the ability for large wood to drive channel complexity. The adjacent hillslope vegetation is dominated by conifers. Evidence of a recent wildfire is present on river right hillslopes in Reaches 2-5.

Figure 114. Representative photo of riparian vegetation, including dogwood, cottonwood, and cedar (at RM 9.27) (August 5, 2024).

Figure 115. White River, Reach 5: Map of vegetation height classification analysis (LiDAR – based analysis).

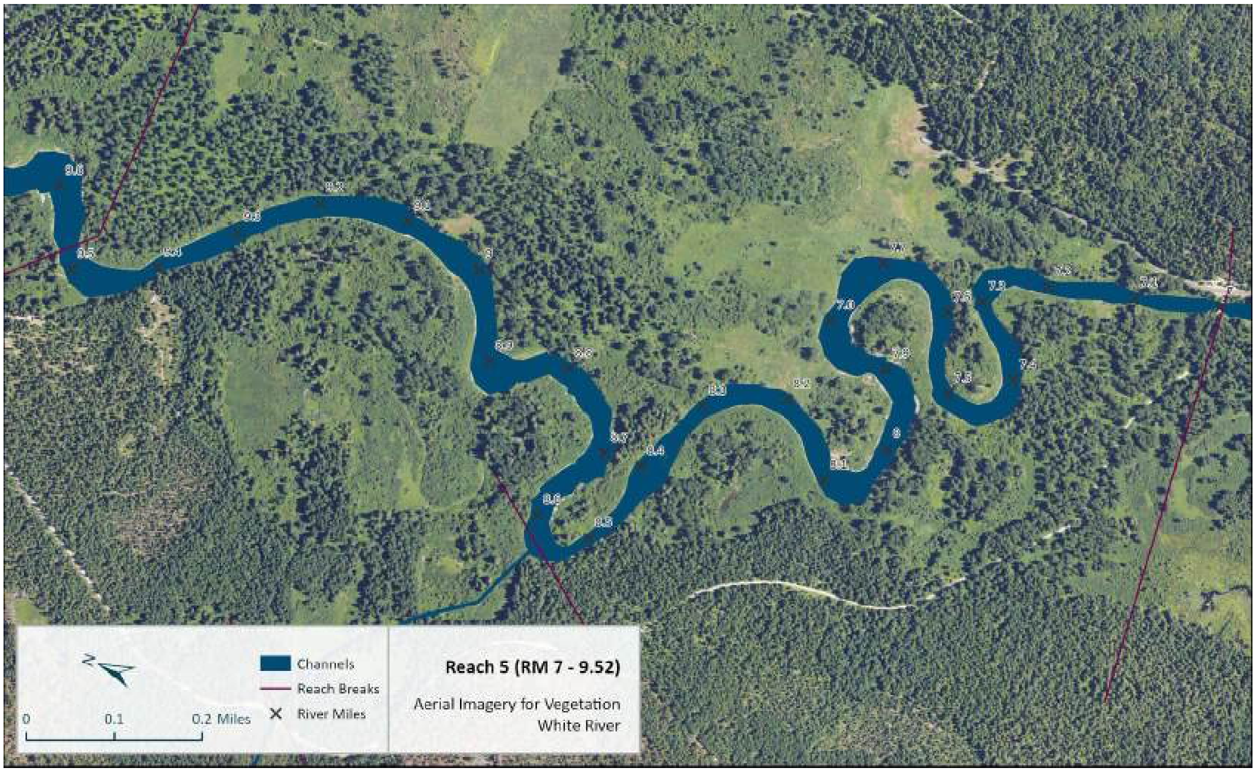

Figure 116. White River, Reach 5: Map of aerial imagery for vegetation identification.

3.5.5 Human Alterations

Anthropogenic features impact channel function and trends in Reach 5. The downstream portion of the reach (RM 6.9 – 7.3) has straightened to accommodate the Sears Creek Road bridge at RM 7 (Figure 117). The bridge confinement has instigated additional local incision that has decreased local floodplain connectivity and is at risk of extending incision and channel simplification upstream. Forests adjacent to the White River channel have been clear from RM 7.74 – 7.95 and RM 8.14 – 8.24, reducing potential large wood recruitment opportunities as well as resulting in reduced shading and nutrient benefits that riparian forests provide. The cleared floodplain surfaces have been ditched and drained. The White River channel is not near the White River Road in Reach 5 except for at the RM 7 bridge, therefore there is minimal riprap associated with road protection. However, there is riprap along the river-right bank from RM 9.41 – 9.44 to limit hillslope erosion near a home and at the bridge crossing at RM 7 (Figure 118). Stumps of old growth western redcedar on the river-right floodplain at RM 7.1, RM 7.6 and 8.74, and abandoned logging access roads on river right at RM 8.9 and river left at RM 9.05 provide evidence of historical timber removal and confirm that historical forest conditions in Reach 5 and the greater White River watershed area have been significantly altered by the logging history of the region (Figure 119).

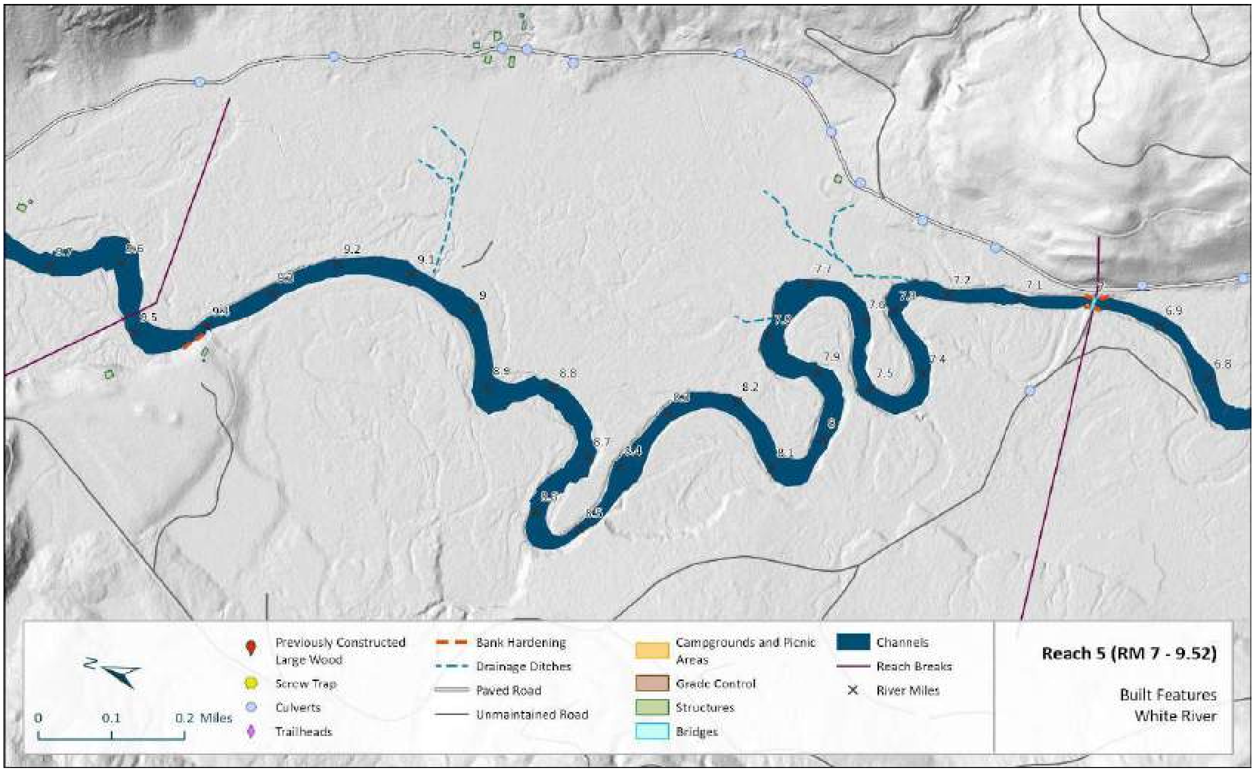

Figure 117. White River, Reach 5: Mapped anthropogenic features.

Figure 118. Sears Road bridge and associated bank riprap at RM 7, looking downstream (August 6, 2024).

Figure 119. Left: Representation of cleared riparian and floodplain forest, at RM 8.24 (August 6, 2024). Right: Stump of old growth western redcedar on floodplain at RM 7.1 (August 17, 2024).

3.5.6 Recommended Actions

Recommended actions in Reach 5 are focused on enhancing mainstem channel complexity, increasing side channel and off channel habitat, and improving riparian function. Excavation of connections to floodplain side channels and existing oxbows on river right are intended to address channel simplification by increasing the occurrence of multiple flow paths and availability of side channel and off channel habitat areas. Sears Creek is currently disconnected from the White River channel at low flow, and options to connect Sears Creek to the mainstem at low flows could be evaluated. Large wood placements are recommended to improve/enhance channel complexity, encourage lateral processes and floodplain connectivity, and encourage flow into newly excavated side channel and off channel habitat areas. Revegetation of open fields, primarily on river left would improve long-term large wood recruitment and riparian function. Modification of the Sears Creek Road bridge crossing would improve natural channel dynamics in the downstream portion of the reach where the bridge span is a major impediment to channel migration under current conditions. Projects should avoid actions that may accelerate meander cutoff processes especially in the highly sinuous downstream portion of the reach.

3.6 WHITE RIVER REACH 6 (RM 9.52 – 11.65)

3.6.1 Overview

Reach 6 is 2.13 river miles long and extends from the upstream side of an alluvial fan that enters the White River valley on river left at RM 9.52, to RM 11.65 (Table 14). The channel is unconfined as it meanders through the wide White River Valley, with its narrowest valley point at RM 10 being approximately 750 feet across. The channel contacts the river-right hillslope and runs along it from RM 10 – 10.15. The channel is primarily single thread meandering in planform with small side channels connected to the mainstem at RM 10.4 – 10.6 and 11.1 – 11.3. Abundant large wood in the upper third of the reach maintains a more complex meandering and multi-threaded planform compared to the middle section of the reach (Figure 120). Reach 6 is sinuous (S = 1.44) but the sinuosity is unevenly distributed. Reach average gradient (0.18%) is similar to Reach 5 downstream and 7 upstream. Reach 6 has the largest average channel width of all the reaches in the assessment area, with an average bank-full width of 188 feet, recorded during the Habitat Assessment (Appendix A). Low floodplain surfaces (inundated ~ 1-5 years) exist as discontinuous strips vegetated primarily with willow and sometimes dogwood. Medium floodplain surfaces (inundated ~ 5-10 years) are the prominent geomorphic surfaces in the reach, and they are generally vegetated with large cottonwood trees and dense dogwood thickets. Anthropogenic features include riprap bank hardening to protect roads and structures located on the valley floor.

Figure 120. Representative photo of White River in Reach 6, looking downstream from RM 11.24 (August 3, 2024).

Table 14. Reach 6 descriptive geomorphic metrics.

Metric	Value
Reach Length (miles)	2.13
River Miles	9.52-11.65
Stream Gradient	0.18%
Sinuosity	1.44
Dominant Channel Habitat Unit Type	Pool
Average Bankfull Width (feet)	188
Confinement	Unconfined
Dominant Substrate	Gravel
Bank Stability/Channel Migration	Adequate *(See Appendix B Section 3.2)*
Vertical Channel Stability	Adequate *(See Appendix B Section 3.2)*

3.6.2 Channel and Floodplain Geomorphology

Reach 6 is a low gradient, sinuous, pool-riffle-glide channel with sequences of extended pools and relatively short glides (Figure 121). Large wood and plentiful sediment supply supports braiding and channel complexity throughout much of the reach. The Habitat Assessment (See Appendix A) recorded 77% of the habitat as pools, 17% of the habitat as glide, 4% of the habitat as side channel, and <1% of the habitat as riffle. Riffles occur frequently within Reach 6, but several are shorter than the channel width requirement and therefore not mapped per Habitat Assessment field guidelines (Figure 122). A map of the geomorphic surfaces and habitat units is provided as Figure 121. The

White River is considered unconfined through Reach 6 because of the wide valley floor. However, the channel does contact the adjacent hillslope at RM 10 – 10.15, and constructed bank protection on river left at RM 10.37 applies local lateral confinement and scour instigation. Upstream of RM 10.9, an abundance of in-channel large wood and available sediment are associated with a split-flow braiding planform (Figure 122). In this section, large wood actively instigates sediment sorting, bed scour, lateral processes, and habitat complexity. Downstream of RM 10.9 the White River has split channel conditions around a large, vegetated island from RM 10.4 – 10.56, and mid-channel gravel bars at RM 9.76 and RM 9.95.

Based on historic photo review and mainstem channel digitization, the White River has shifted laterally and cutoff meanders in Reach 6 since 1957, which is the first date for which publicly available aerial imagery is available (Figure 123). Lateral migration is visible throughout the reach between each photo set, with a higher rate of migration occurring between 1985 and 2023. A meander neck cutoff occurred at RM 11.65 between the 1985 and 2023 photo sets. The resulting oxbow is wetted perennially and currently maintained by beaver activity. A sand plug approximately four feet tall is now located at the site of the neck cutoff between the wetted oxbow and the main channel (Figure 124). The vegetated island and side channel at RM 10.4-10.56 developed between 1985 and 1998 following a neck cutoff at RM 10.66 that occurred between the 1972 and 1985 historical photo sets. This sequence of channel straightening, along with the large wood and bedload material it provided, appears to have instigated current lateral channel migration toward river right at RM 10.6. The tortuous meander between RM 10.2 and RM 10.5 is currently at risk of straightening via neck cutoff, which would extend the upstream channel simplification and straightening sequence. At present, the vegetated island provides habitat and geomorphic complexity, and the side channel around the island on river left was heavily utilized by spawning sockeye salmon during the geomorphic assessment from September 6-13, 2024. An additional meander neck-cut off in Reach 6 is expressed as a set of wetted oxbows just upstream of RM 10.6. These seasonally disconnected oxbows appear to be perennially wetted by a combination of seasonal hillslope runoff and hyporheic groundwater exchange at lower flow conditions. High-flow conditions appear to provide backwater and surface water connection to the oxbows from the mainstem channel.

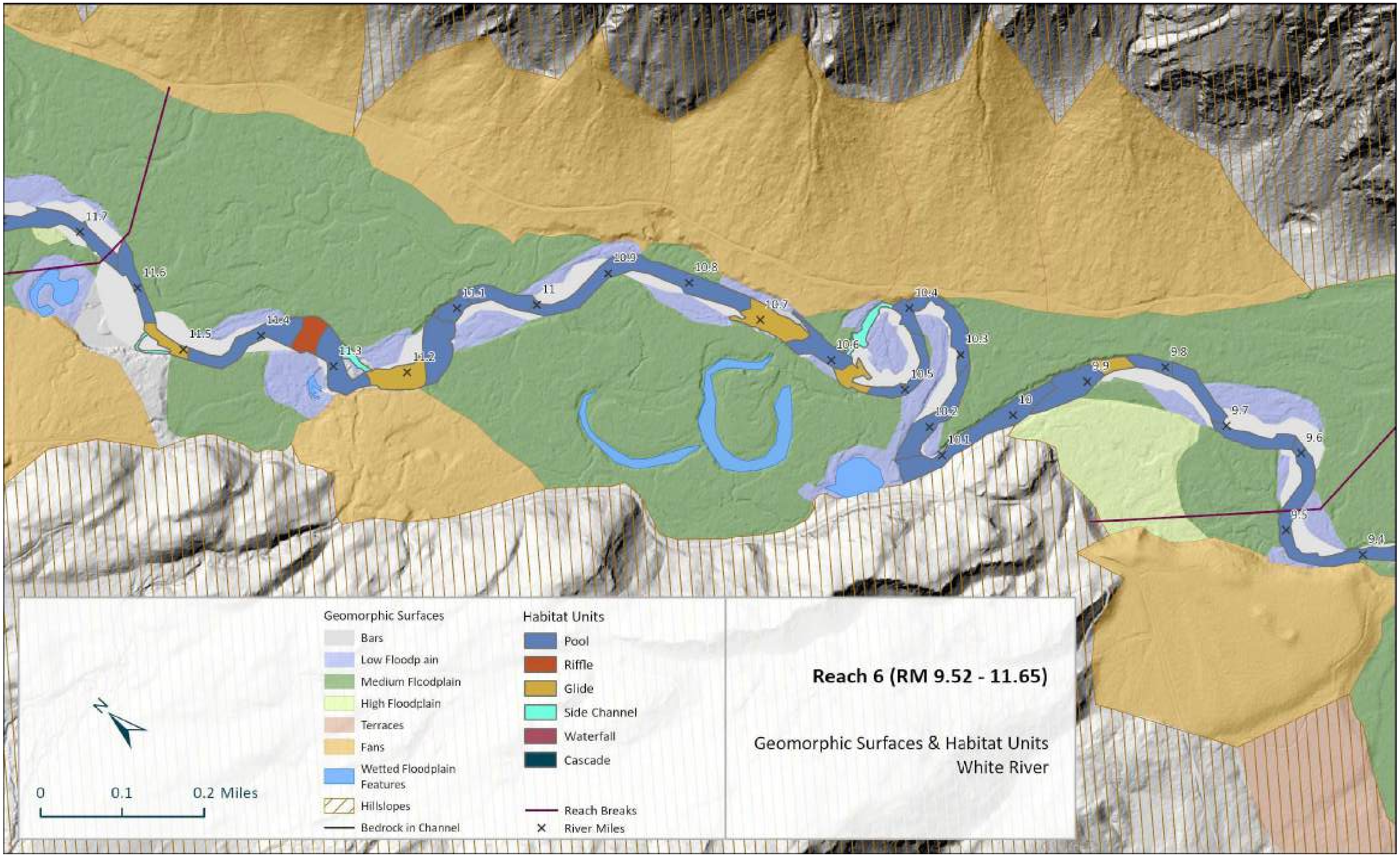

Figure 121. White River, Reach 6: Map of geomorphic surfaces and habitat units.

Figure 122. Representative photo of split flow braiding with extended pools, glides, and short riffles – at RM 9.77 (August 5, 2024).

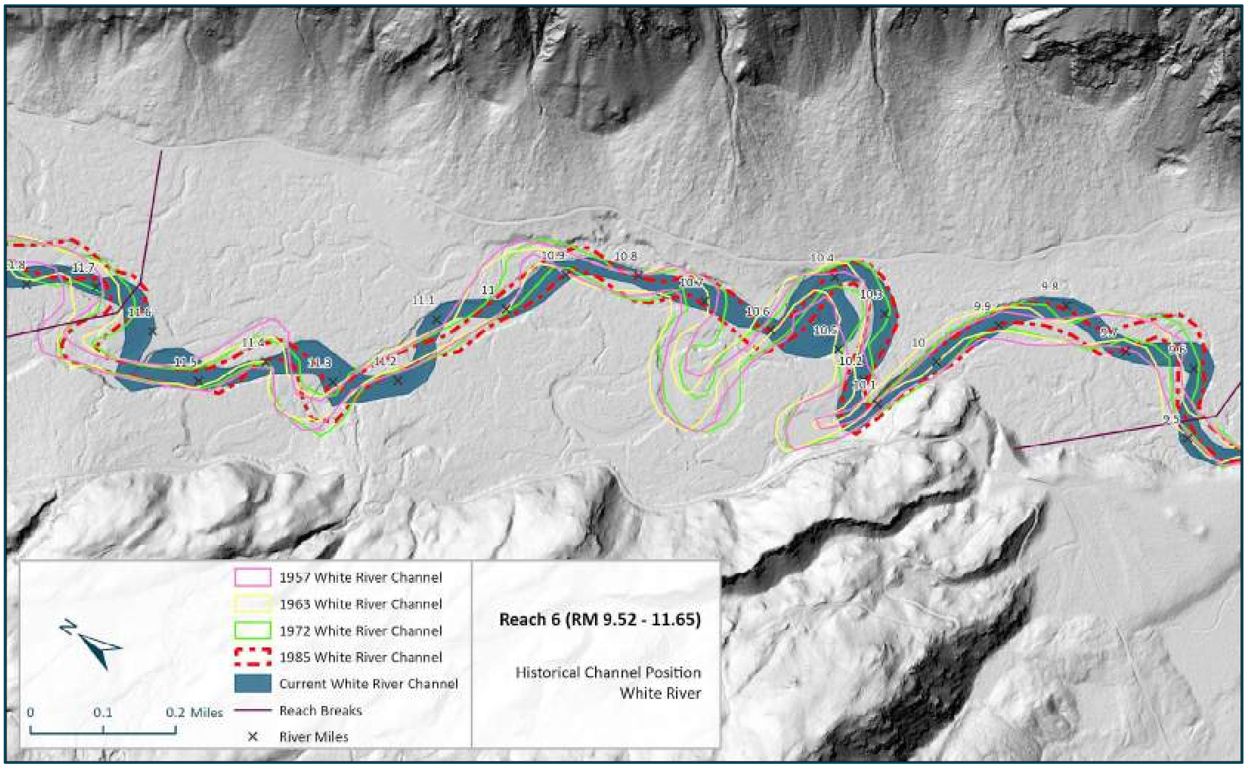

Figure 123. White River Reach 6: Map of channel alignments digitized from historical photos (1957-2023).

Figure 124. Wetted oxbow at RM 11.6 – formed at meander neck cutoff between 1985 and 2023 (August 3, 2024).

Channel substrate in Reach 6 is primarily gravel with cobbles and sparse sand. Point and mid-channel gravel-cobble bars occur throughout the reach. Ocular survey notes recorded more sand in the bars and bedload substrate at the downstream portion of the reach compared to upstream. Wolman pebble counts were conducted on two representative riffle crests at RM 10.66 (GC 11) and RM 11.35 (GC 12). The median grain size at GC 11 of D50 = 31.83mm is just slightly larger than the upstream GC 12 median grain size of D50 = 30.29, although GC 12 had more cobbles sized greater than 64 mm in diameter. The data from the two pebble counts are plotted on a map (Figure 125) of the Reach 6 incipient motion analysis results (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.9.4). The analysis indicates that at the 2-yr modeled discharge, the channel's shear stress is capable of mobilizing gravel throughout the reach. Mobilized gravel size fraction is reduced between RM 10.1 – 10.55 where the channel's meander sequence is tortuous and split flow conditions occur. Model results indicate that shear stress through the split flow side channel (RM 10.4 – 10.6) is only capable of mobilizing sands, suggesting that it will likely be infilled over time. Pockets of the reach model as capable of mobilizing cobble at the 2-yr discharge. The capacity to mobilize gravels through the reach supports deposition and maintenance of gravel bars throughout.

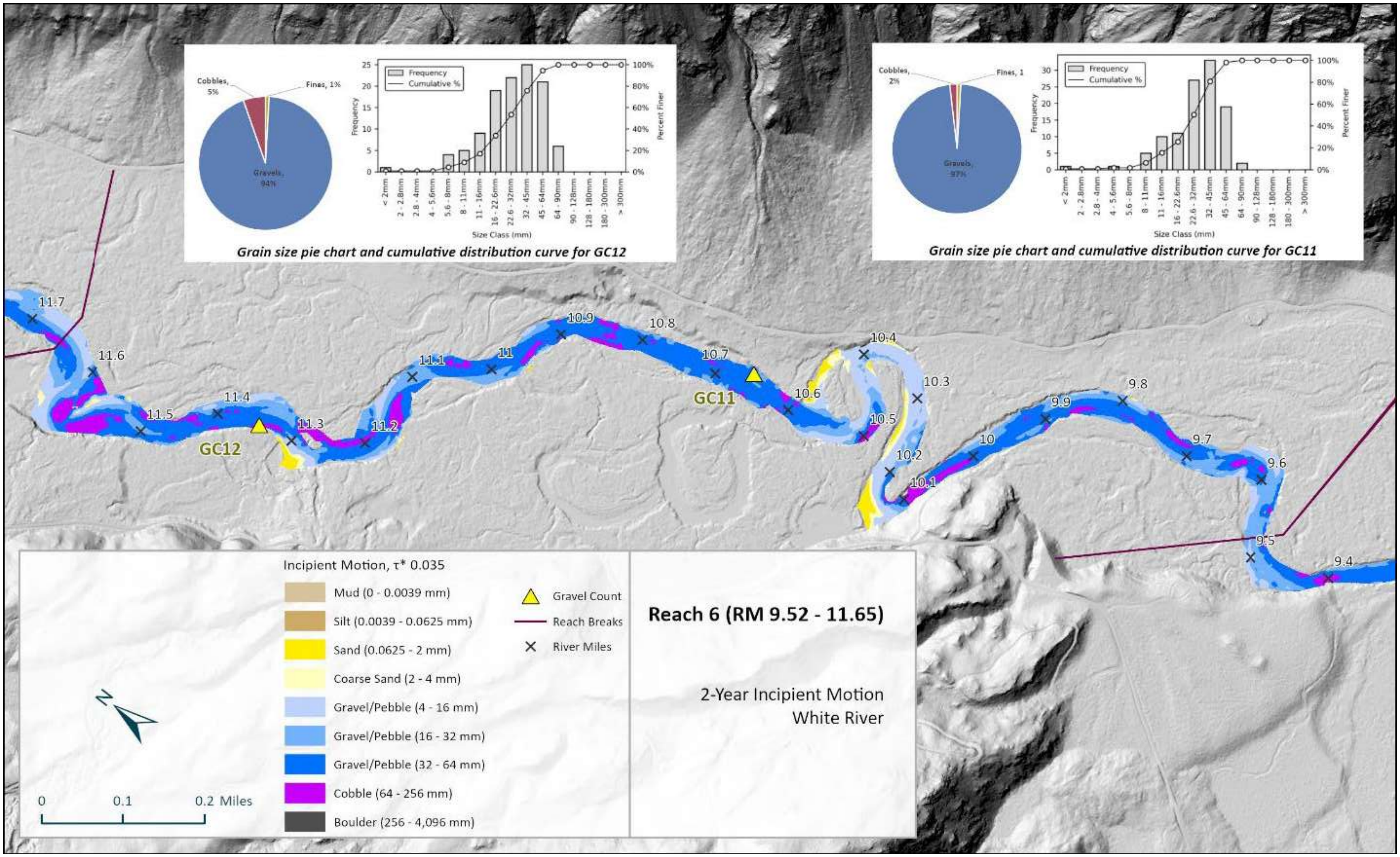

Figure 125. White River, Reach 6: incipient motion analysis results map (estimated grains size mobility at the 2-yr modeled discharge) and grains size distribution of two (GC 11 and GC 12) pebble counts.

Tributaries to the White River in Reach 6 include perennial Canyon Creek (RM 11.26 on river right), and a minor ephemeral tributary entering the channel from the river-left hillslopes at RM 11.03. Canyon Creek contributes approximately 6% of the White River's 2-year discharge according to hydraulic models developed for this assessment (See Section 2.8) and is a source of gravel-cobble alluvium to the White River channel.

Sediment is primarily sourced from active bank erosion, stored bedload in bars, and inputs transported into the reach from upstream and Canyon Creek. Exposed floodplain banks reveal a general floodplain composition characterized by a fining upward sequence of cobbles and gravels at the base overlain by sand and loam topped with a developing organic soil horizon. Canyon Creek and its alluvial fan at the downstream portion of the reach provide a source of large cobbles that are generally coarser than other sediments contributed to the White River in Reach 6 (Figure 126).

Figure 126. Confluence of Canyon Creek with the White River at RM 11.26 (August 3, 2024).

Low floodplain surfaces (inundated ~1-5 years) are well distributed on both sides of the channel, except at RM 9.83 – 10.1. Low floodplains are located on the inside of every meander as well as on low surfaces along the relatively straight channel section from RM 10.6 – 10.87. Medium floodplain surfaces (inundated ~ 5-10 years) extend behind low floodplain surfaces, or along the channel where low floodplain surfaces are absent. Medium floodplains cover the majority of the valley floor in

Reach 6. A high floodplain surface (inundated ~ 10 – 100yrs) extends from ~RM 9.66 – 10 on river right. Alluvial and debris fans sourced from the steep adjacent hillslopes contribute sediment to the White River valley and, where contacted, to the channel. Floodplain and fan surfaces are mapped in Figure 121. Based on exposed channel banks, floodplains in Reach 6 are composed of a cobble-gravel base overlain by sands and topped with developing organic soil. Floodplain soils are typically described as loams to sandy loams within Reach 6, and the hillslopes consist of sandy loam and rock outcrops with poorly developed soils (Natural Resources Conservation Service, 2007).

3.6.3 Large Wood Material

A total of 281 pieces of large woody material (LWM) and 44 log jams (accumulation of >3 LWM) were counted in the channel during the survey (August, 2024) (See Figure 127). Of the 281 pieces, 122 pieces are considered Quality Large Wood (QLW); 64 classified as large size class (>20-inces diameter and >35-feet long); and 58 as medium size class (12 to 20-inch diameter and at least 35-feet long). Reach 6 had a higher number of large wood jams than any other reach in the assessment area during the 2024 survey. Of the 44 log jams, 39 had multiple pieces of QLW (Figure 128). During the assessment, a minimum of 24-inch diameter was noted to be effective large wood. Large wood was noted as responsible for creating complex split-flow conditions and sorting sediment into well-developed mid-channel and lateral bars. Although large wood exerted an influence on the channel, historical large wood abundance was likely much greater. Modern active lateral migration of the channel is recruiting second-growth conifers and cottonwoods from the adjacent floodplain surfaces. The White River in Reach 6 is lacking mature and old-growth trees that historically would likely have provided notably more geomorphic and habitat complexity than the channel is able to express today.

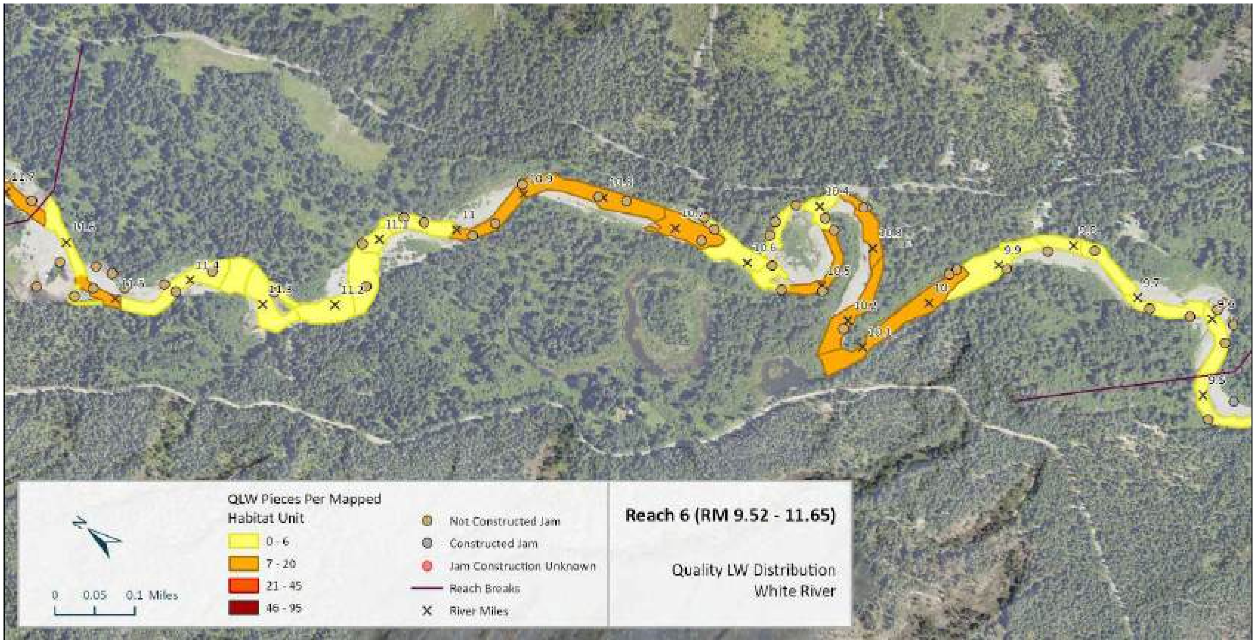

Figure 127. White River, Reach 6: Quality large wood distribution map and surveyed habitat units (2024). QLW count does not include pieces in jams.

Figure 128. Large wood jam at RM 11.16 (August 3, 2024).

3.6.4 Vegetation

Floodplain vegetation in Reach 6 is a mix of conifer and/or cottonwood overstory with a relatively sparse understory of dense dogwood thickets and willow. Conifer species present along the channel are dominated by cedar, Douglas-fir, grand fir, and ponderosa pine. At present, overstory trees are generally second growth forests. The vegetation height analysis map shows that mature or old-growth trees are currently uncommon (Figure 129), although historically, they would likely have been widespread across the valley floor. The large second-growth overstory trees adjacent to the river in areas of active lateral migration provide a source for large wood recruitment into the channel. Large overstory trees are generally lacking from floodplain surfaces adjacent to the channel where recent neck cutoffs created new floodplain surfaces at RM 10.66, 11.3, and 11.65, but are well distributed elsewhere in Reach 6. Willow is the dominant species on low floodplain surfaces. Willow was observed to be a source of food and habitat-building material for beaver in the reach, evidenced by abundant beaver chew. Dense dogwood thickets are present on medium floodplain surfaces that had been previously cleared of larger vegetation. The adjoining hillslope vegetation is dominated by sparse small to large conifers (Figure 131).

Figure 129. White River, Reach 6: Map of vegetation height classification analysis (LiDAR – based analysis).

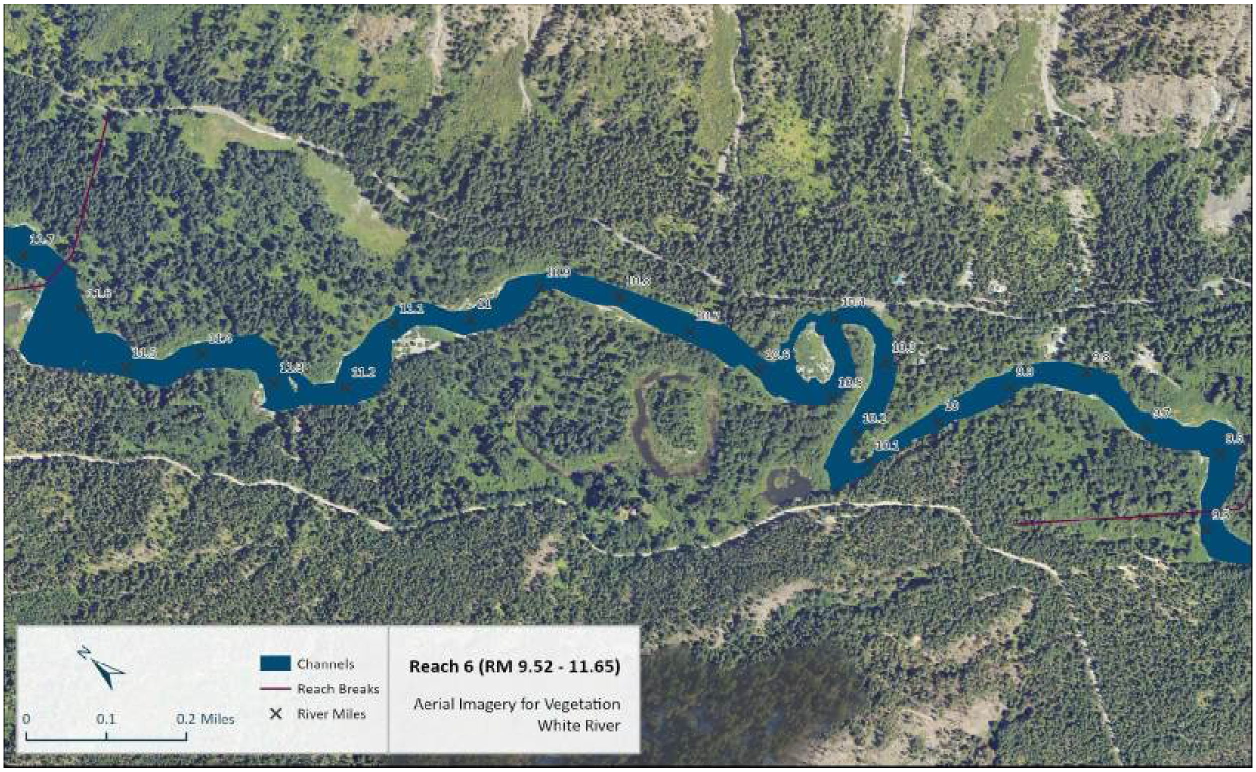

Figure 130. White River, Reach 6: Map of aerial imagery for vegetation identification.

Figure 131. Representative photograph of Reach 6 riparian and forest vegetation distribution (RM 9.63 looking upstream) (September 8, 2024).

3.6.5 Human Alterations

Human alterations to the White River and its valley floor are primarily located on river left, within Reach 6 (Figure 132). Several structures set on the floodplain between White River Road and the mainstem channel in the downstream portion of the reach on river left, at RM 9.75, RM 9.85, and on the peninsula formed by a meander bend between RM 9.9 and RM 10.35 . Riprap is present and riparian vegetation was cleared near the structures at RM 9.75 and 9.85. Large wood is placed along the river left bank at RM 10.35, likely to protect the structure atop the meander bend peninsula. Riprap is also present on the outside of the meander from RM 10.36 – 10.4 to protect White River Road from lateral migration. Unmaintained access roads are present in both the river-left and river-right floodplains. The road through the river-right floodplain is a spur off Sears Creek Road, near RM 10.05 (Figure 133). The road through the river-left floodplain connects to White River Road and extends down to the channel near RM 11.03. Several culverts connect ephemeral tributaries on river left with the White River channel by providing flow paths under White River Road.

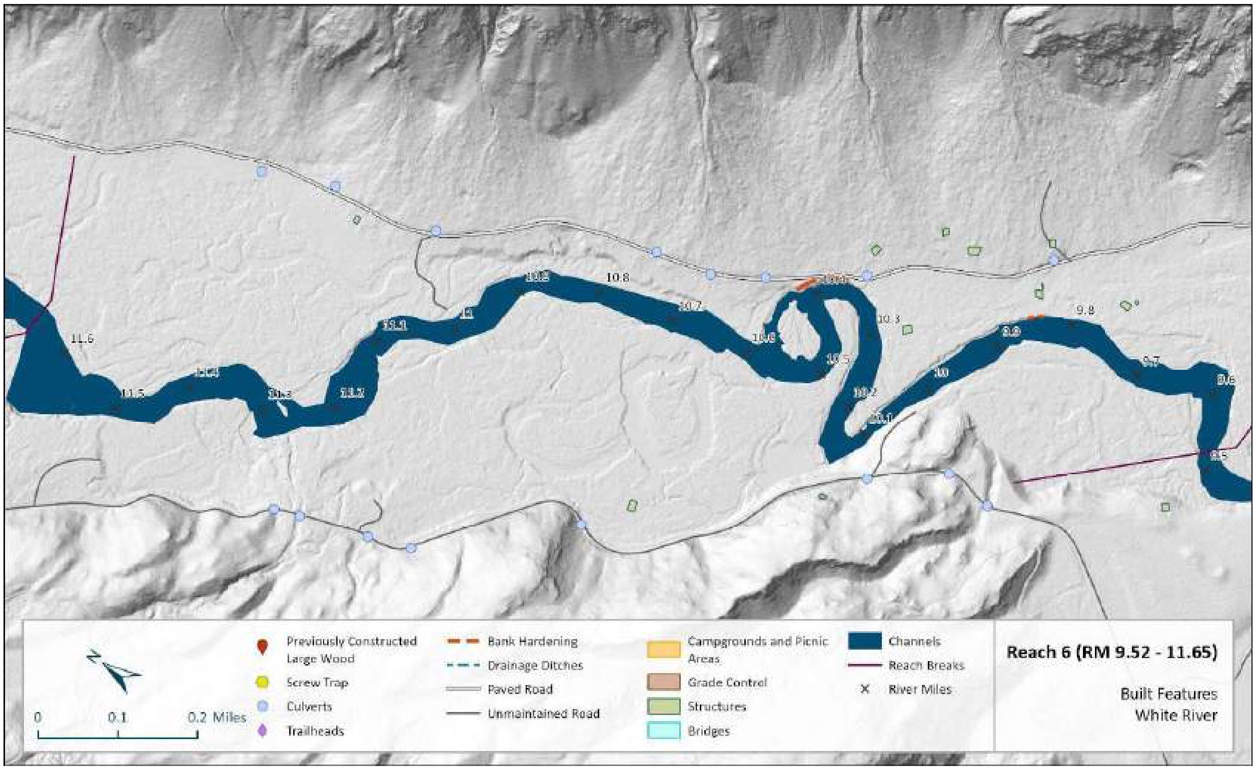

Figure 132. White River, Reach 6: Mapped anthropogenic features.

Figure 133. Unmaintained road extending from Sears Creek Road on river right, near RM 10.05 (August 5, 2024).

3.6.6 Recommended Actions

Recommended actions in Reach 6 prioritize large wood placements, modification of anthropogenic features, excavation of side channel inlets, and riparian improvements. Large wood additions to the mainstem channel could enhance/improve channel complexity. Modification of anthropogenic features, such as replacing or supplementing bank riprap with large wood would improve aquatic habitat conditions. Excavation of side channel or oxbow inlets into both river left and river right floodplains throughout substantial portions of the reach would increase available and accessible off-channel habitat and floodplain wetlands. Revegetation of open field areas and willow/cottonwood trenches on open in-channel bars would improve long-term riparian conditions and wood recruitment.

3.7 WHITE RIVER REACH 7 (RM 11.65 – 12.43)

3.7.1 Overview

Reach 7 is 0.78 river miles long and extends from RM 11.65 to the Napeequa River confluence at RM 12.43 (Table 15). The Napeequa River contributes ~27% of the total flow of the White River into Lake Wenatchee, therefore the channel's discharge increases notably in Reach 7 compared to the upstream reaches. The White River is laterally unconfined in Reach 7, aside from a section of riprap that protects White River Road downstream of the Napeequa River confluence from RM 12.34 – 12.43. The channel is single-thread in form, with multiple instances of braiding that splits flow around mid-channel bars at low-flow (Figure 134). Reach 7 is relatively straight with a low sinuosity (S = 1.08). The gradient of the channel in Reach 7 is lower (0.15%) than the three upstream reaches and slightly lower than Reaches 5 and 6 downstream. The average bankfull width of the channel through the reach, recorded during the Habitat Assessment (Appendix A), is 173 feet, the second widest of all the assessment reaches behind only Reach 6 (188 feet bankfull width). Frequent gravel bars transition to narrow low floodplain surfaces (inundated ~ 1-5 years). Medium floodplain surfaces (inundated ~ 5-10 years) occupy the majority of the remaining valley floor in Reach 7, and high floodplain surfaces (inundated ~ 10-100+ years) and terraces are present, although in isolated sections. Low floodplain surfaces are generally dominated by willow, alder, and dogwood, whereas higher floodplain surfaces are occupied by large cottonwood, grand fir, Douglas-fir, and cedar. Anthropogenic features in Reach 7 include bank hardening to protect White River Road downstream of the Napeequa confluence and several culverts under White River Road on the river-left side of the valley and Sears Creek Road along the hillslope toe and edge of valley on the river-right side.

Figure 134. Representative photo of White River channel in Reach 7 - at RM 12.06, looking upstream (August 3, 2024).

Table 15. Reach 7 descriptive geomorphic metrics.

Metric	Value
Reach Length (miles)	0.78
River Miles	11.65-12.43
Stream Gradient	0.15%
Sinuosity	1.08
Dominant Channel Habitat Unit Type	Pool
Average Bankfull Width (feet)	173
Confinement	Unconfined
Dominant Substrate	Gravel
Bank Stability/Channel Migration	At Risk *(See Appendix B Section 3.2)*
Vertical Channel Stability	Adequate *(See Appendix B Section 3.2)*

3.7.2 Channel and Floodplain Geomorphology

Reach 7 contains a low gradient, relatively straight channel with a pool-riffle-glide sequence composed of extended pools, short riffles and a single extended glide (Figure 135). The Habitat Assessment (See Appendix A) recorded 92% of the habitat as pool, 5% of the habitat as glide, and 4% of the habitat as side channel. The riffles are often shorter than the channel width, and therefore were not included in the Habitat Assessment, although they were present throughout the reach. The single side channel documented in the Habitat Assessment flows along the back side of a lateral bar from RM 12.02 – 12.09. Reach 7 contains large lateral gravel bars, and frequent mid-channel bars downstream of RM 12.2 where the river begins to braid. The White River is unconfined in Reach 7, although its planform is relatively straight from the north side (river-left) to the south side of the valley.

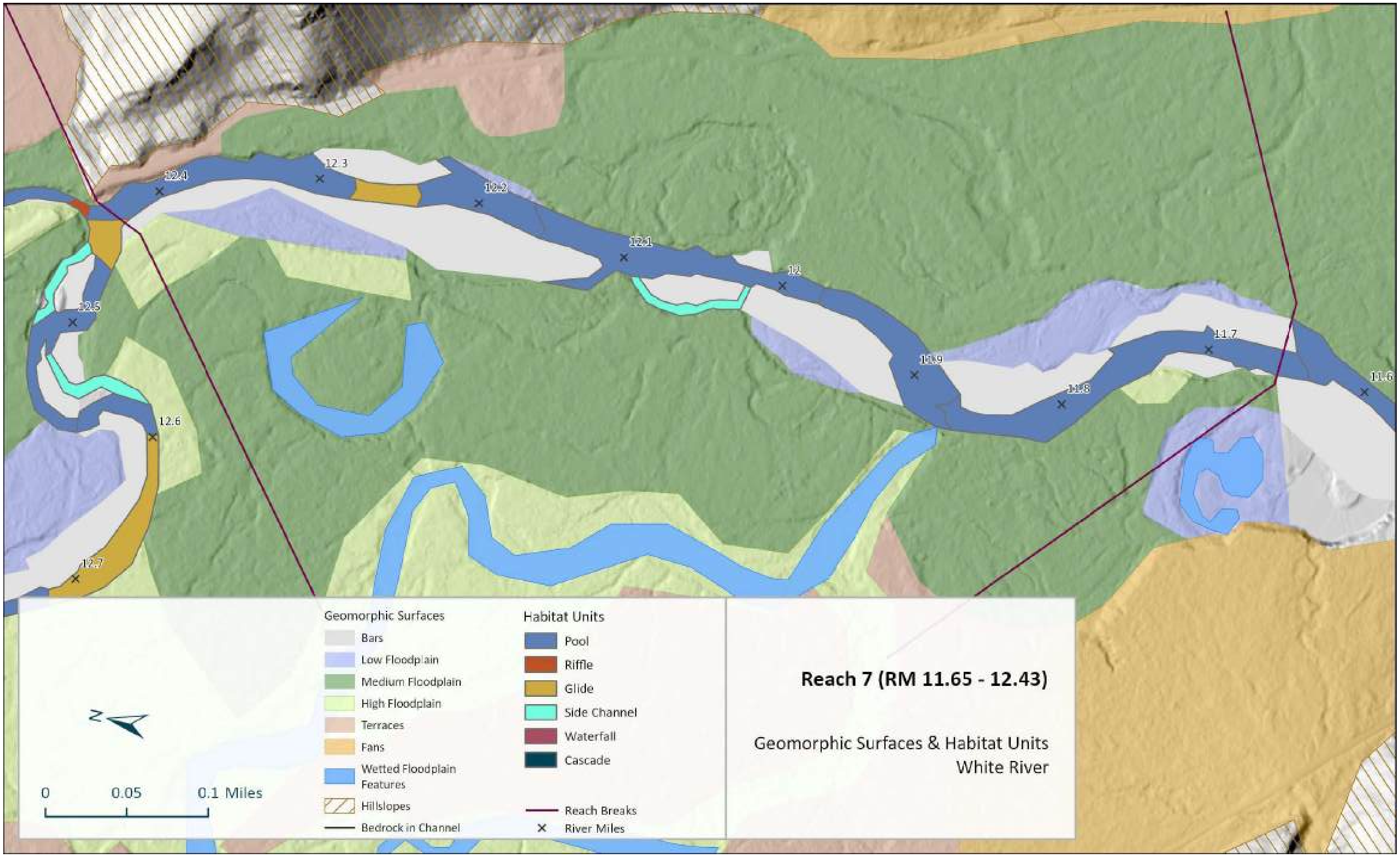

Figure 135. White River, Reach 7: Map of geomorphic surfaces and habitat units.

Based on historical photo analysis of the location of the channel's boundary, lateral processes and a meander neck cutoff have evolved since at least 1957, which is the first date for which publicly available aerial imagery is available (Figure 136). The meander cutoff occurred between RM 12 and RM 12.1 between 1985 and 2023, resulting in reduced sinuosity. The resulting oxbow that now exists on the river-left floodplain between the modern channel and White River Road was dry at low flows during the geomorphology assessment (Aug-Sept 2024), and likely only wets during high-flow over bank discharge events. Additional off-channel features on the river-right floodplain include a wetted oxbow between RM 12.2 – 12.3 (Figure 137) and a wetted relic channel between RM 11.88 – 12.15. The oxbows and meander scars combined with historical photos confirm that the channel in Reach 7 was more sinuous in the past than it is today.

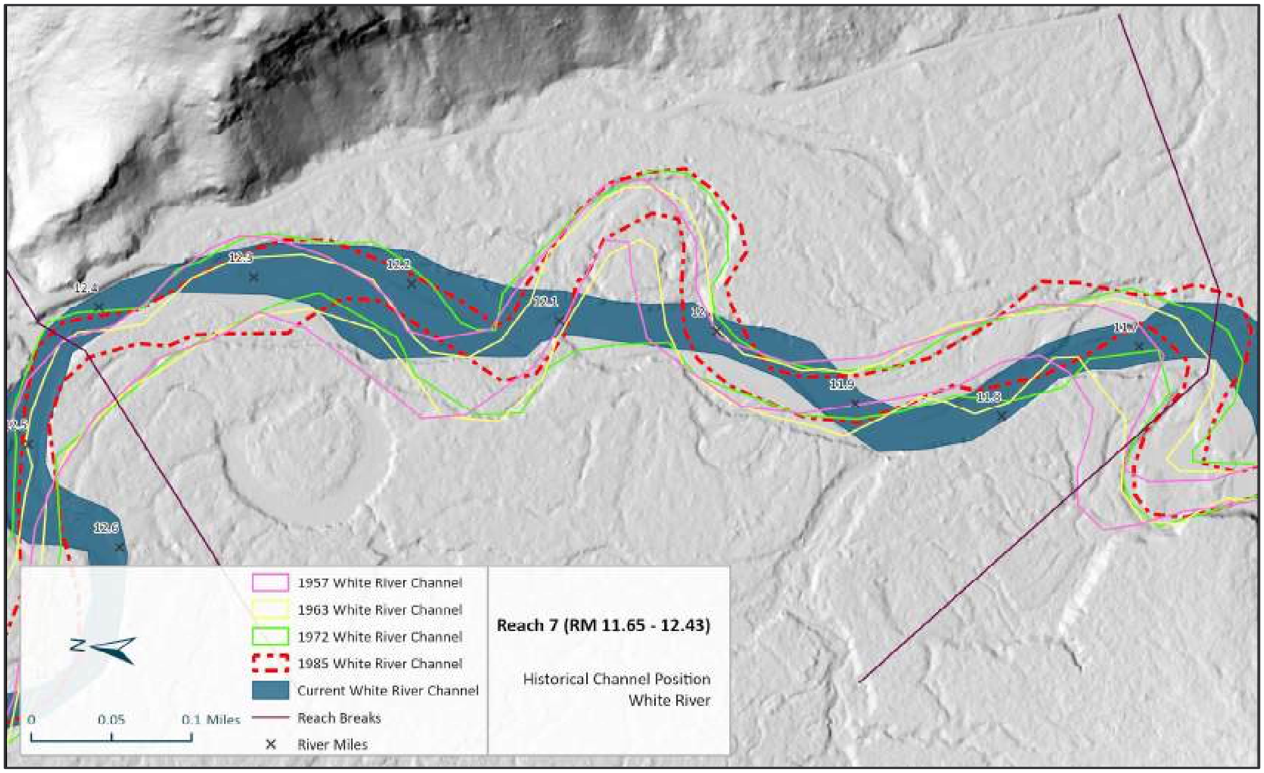

Figure 136. White River Reach 7: Map of channel alignments digitized from historical photos (1957-2023).

Figure 137. Disconnected but groundwater wetted oxbow on river-right floodplain near RM 12.2-12.3 (August 3, 2024).

The Napeequa River (Figure 138) is a major tributary to the White River and its confluence is located at the upstream boundary of Reach 7 (See Section 2.8) In addition to contributing 23% of the White River's discharge into Wenatchee Lake, the Napeequa River also contributes fine-to-cobble sized sediment and woody material. A minor unnamed tributary enters the White River from the river-left floodplain at RM 11.88. This small tributary is likely fed seasonally by hillslope runoff and subsurface groundwater inputs. The unnamed tributary does not currently contribute significant flow, sediment, or other material.

Figure 138. Bridge over the mouth of the Napeequa River at its confluence with the White River at RM 12.43, at upstream boundary of Reach 7 (September 7, 2024).

Channel substrate in Reach 7 is primarily gravel-cobble alluvium. Extended lateral and point gravel -cobble bars are common. Ocular substrate sizes recorded during the geomorphology survey noted a general decrease in grain size from upstream to downstream. Wolman Pebble Counts (Wolman, 1954) were conducted on representative riffle crest in at RM 11.9 (GC 13) and 12.29 (GC 14). Gravels 32-45 mm in diameter were the dominant size class at GC 13 with a median grain size D50 = 34mm, whereas cobbles 64-90 mm in diameter were the dominant size class at GC 14 with a median grain size D50 = 64mm. Gravels (2-64 mm diameter) accounted for >50% of sediments and boulders (>256 mm diameter) were absent at both pebble count locations. Fine sediments (< 2 mm) were present at the upstream pebble count location only. The data from the two pebble counts are plotted on a map (Figure 140) of the Reach 7 incipient motion analysis results (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.9.4). The analysis indicates that at the 2-yr modeled discharge, the channel's shear stress is capable of mobilizing gravel throughout the reach and cobble upstream of RM 12.22. Otherwise, patches along the mid-line of the channel are also capable of mobilizing cobble-sized sediment at the modeled 2yr discharge. The capacity to mobilize gravel and cobbles through the reach supports deposition and maintenance of extended gravel bars (Figure 139).

Figure 139. Gravel-cobble lateral bar at RM 12.26, looking downstream (August 3, 2024).

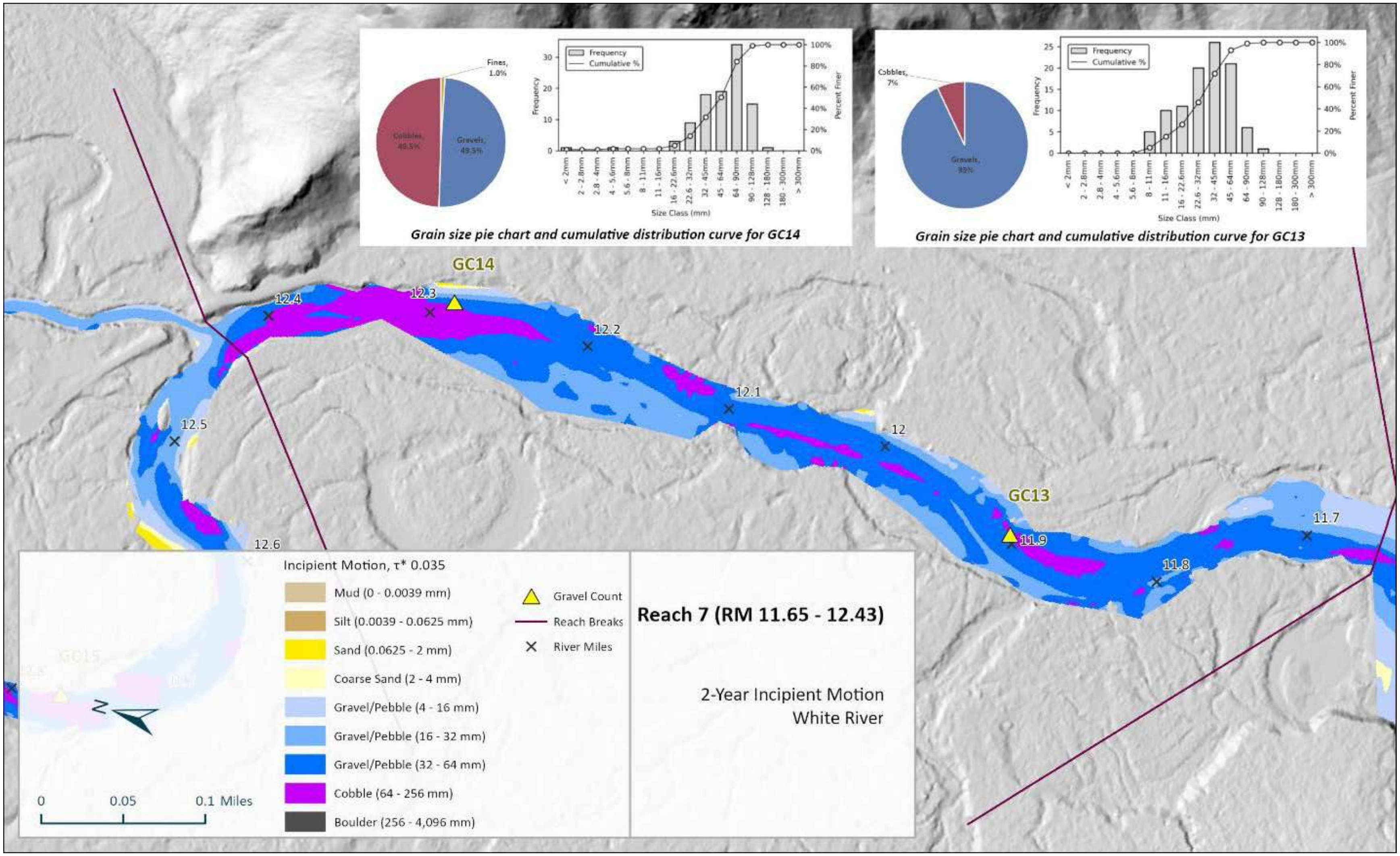

Figure 140. White River, Reach 7: incipient motion analysis results map (estimated grains size mobility at the 2-yr modeled discharge) and grains size distribution of two (GC 13 and GC 14) pebble counts.

Sediment sources within Reach 7 include the Napeequa River, a significant source of coarse sediment, as well as stream banks eroding due to active lateral migration and material transported into the reach from upstream. Floodplains in Reach 7 are well developed with a mix of large conifers, cottonwood, and alder, and dogwood (Figure 141). Active floodplains surfaces are generally vegetated with willow. Exposed stream banks are typically composed of a gravel-cobble base topped by sandy loam and a thin layer of developing organic soils. Floodplain soils are typically described as recently deposited loamy fine sand and silt loam to stony fine sandy loam in Reach 7 (Natural Resources Conservation Service, 2007).

Figure 141. Low and medium river right floodplain surfaces at RM 11.98 (August 3, 2024).

3.7.3 Large Wood Material

A total of 127 pieces of large woody material (LWM) and 11 log jams (accumulation of >3 LWM) were observed in the channel during the survey (August 2024) (See Figure 142). Of the 127 pieces, 61 are considered Quality Large Wood (QLW); 29 classified as large size class (>20-inches diameter and >35-feet long); and 32 as medium size class (12 to 20-inch diameter and at least 35-feet long). Of the 11 wood jams, 10 contained multiple pieces of QLW. During the assessment, logs greater than 24 inches diameter were noted as sufficient size to be effective. Where wood exists in the channel it is responsible for creating pockets of habitat complexity by promoting pool scour (Figure 143), influencing sediment deposition, and providing cover. Large wood in Reach 7 was not observed forcing split-flow conditions. Given the straightness of the channel through Reach 7, wood input through lateral erosion of stream banks was less common than in other more sinuous reaches. However, the banks are vegetated with conifer forests that offer potential large wood recruitment if bank erosion occurs (Figure 143). Large wood recruitment is currently occurring at RM 11.75 and 11.84.

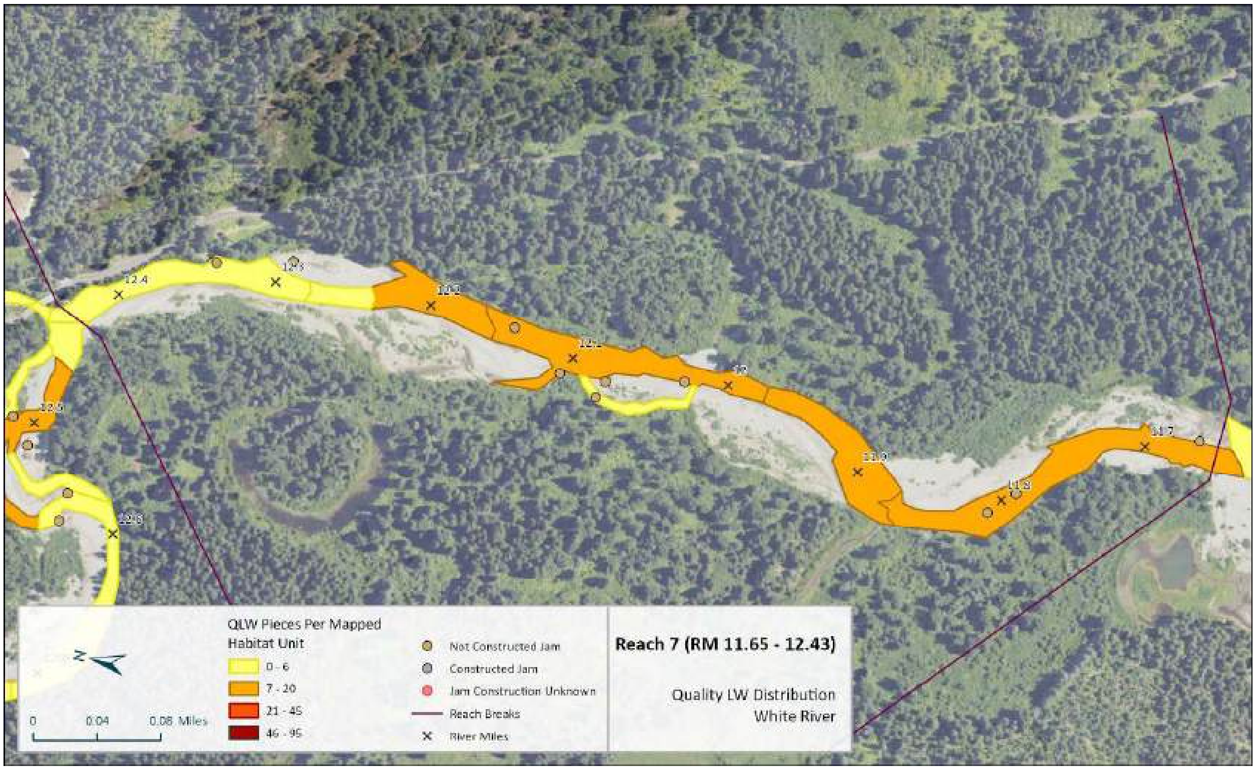

Figure 142. White River, Reach 7: Quality large wood (QLW) distribution map and surveyed habitat units (2024). QLW count does not include pieces in jams.

Figure 143. Left: Large wood induced scour and sediment sorting at log jam on bar at RM 12.28 (August 3, 2024). Right: Large wood recruitment potential (Cottonwood) atop river-right bank at RM 11.75 (August 3, 2024).

3.7.4 Vegetation

Floodplain vegetation in Reach 7 consists of a mixed conifer-cottonwood overstory and alder-dogwood understory. Although there are few young cottonwoods in the reach, cottonwood starts were observed establishing on a bar at RM 12.25. Conifer species include second-growth cedar, Douglas-fir, and grand fir. Overstory trees adjacent to the river provide a source of large wood to the channel especially in areas with active bank erosion such as RM 11.75 and 11.84. The vegetation height analysis map shows that mature old-growth trees are currently uncommon (Figure 144), although historically, they would likely have been widespread across the valley floor. No old-growth trees were observed during the assessment. Although taller trees generally grow farther from the channel in Reach 7, a pocket of taller trees adjacent to the channel from RM 12.2 – 12.3 on river left provides a potential source of large wood recruitment (Figure 144). Willow is the dominant species on vegetated low floodplain surfaces. Vegetation on the adjoining hillslope is less dense than on floodplain surfaces and consists of small to large conifers.

Figure 144. White River, Reach 7: Map of vegetation height classification analysis (LiDAR – based analysis).

Figure 145. White River, Reach 7: Map of aerial imagery for vegetation identification.

Figure 146. Representative riparian and floodplain vegetation at RM 12.25 on river-right (August 3, 2024).

3.7.5 Human Alterations

Anthropogenic features in Reach 7 influence the White River channel and its floodplain (Figure 147). The White River Road has several culverts that direct and control hillslope runoff under the road and either to the channel or the floodplain. Riprap placed along the bank of the channel on river-left at RM 12.34 – 12.43 was placed to protect White River Road downstream of the Napeequa River confluence. As a hard-point in the modern channel's pathway, the riprap also holds the White River in its current location, inhibiting localized lateral processes and inducing scour. The riprap also serves to control the location and stability of the Napeequa River confluence with the White River (Figure 148). A parking area atop the medium-floodplain surface on river left at RM 12.3 appears to be a well-used put-in for boaters of the White River. The Twin Lakes Trailhead, near RM 12.4 also appears to receive heavy usage. The straightened portion of the channel's pathway is likely influenced by the bank protection associated with the Napeequa River confluence as well as historical timber harvest, which was rampant in the area during the 19th and 20th centuries.

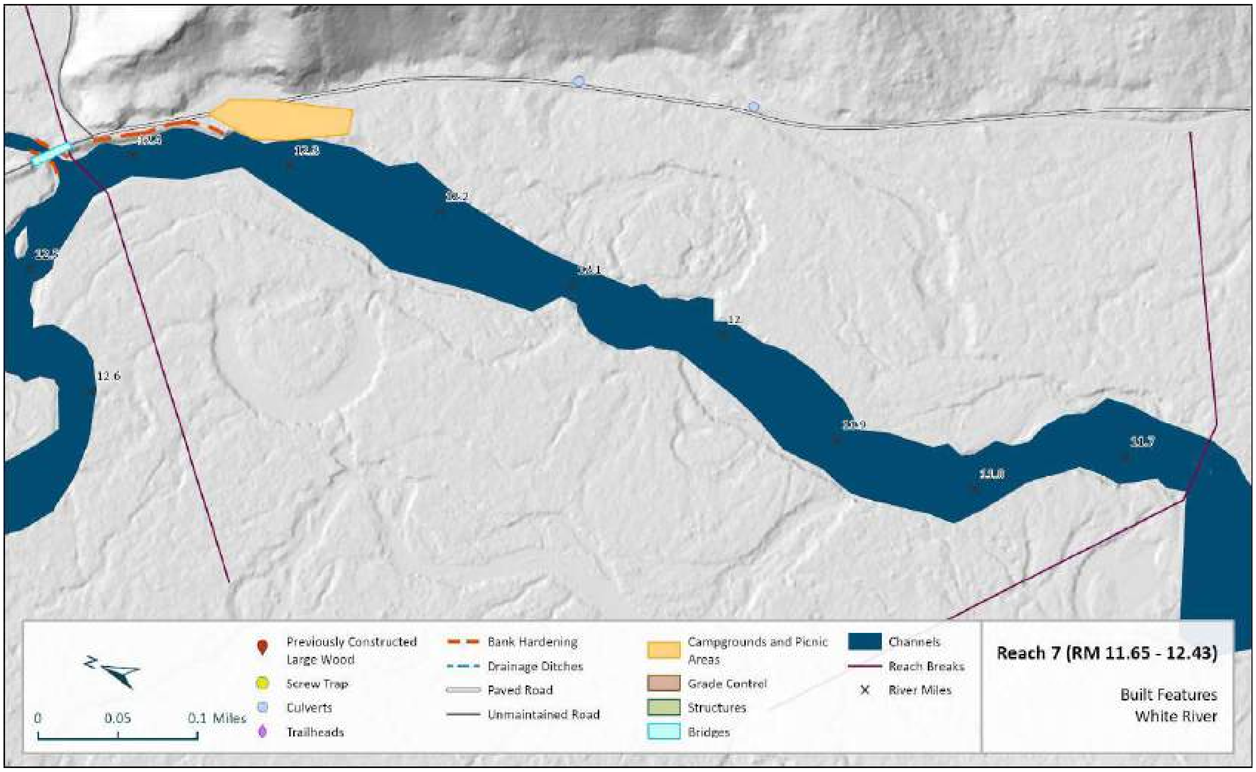

Figure 147. White River, Reach 7: Mapped anthropogenic features.

Figure 148. Riprap and parking area downstream of Napeequa River confluence, at RM 12.35 (August 3, 2024).

3.7.6 Recommended Actions

Recommended actions in Reach 7 include efforts to connect floodplain side channels and oxbow wetlands to the mainstem channel, as well as large wood placements and modifications of anthropogenic features. Side channel or oxbow inlets could be excavated to activate existing channels and oxbows on the river right and river left floodplains. Recommended actions in Reach 8 upstream would route additional flow through existing channels through the river right floodplain that connect to an expansive floodplain channel network further upstream. Large wood placements throughout the reach could enhance/improve channel complexity, encourage side channel activation, and provide roughness to high flow side channels. Existing anthropogenic features such as bank riprap could be replaced or supplemented with large wood to improve aquatic habitat condition.

3.8 WHITE RIVER REACH 8 (RM 12.43 – 14.35)

3.8.1 Overview

Reach 8 is 1.92 river miles long and extends from the Napeequa River confluence at RM 12.43 to RM 14.35 (Table 16). The White River channel is laterally unconfined, although riprap limits lateral migration at points where proximity of the channel to human infrastructure (roads) occurs. The channel is single thread in form with abundant gravel bars (Figure 149). Planform braiding and split flow around mid-channel bars and large wood jams occur periodically where channel width and sediment supply allow, especially in the downstream portion of the reach. Reach 8 is sinuous (S = 1.41) but meander planform is notably reduced between RM 13.3 – 14.1. The gradient of Reach 8 (0.42%) is nearly three times steeper than that of Reach 7 (0.15%), whereas Reach 9 is over twice as steep as Reach 8. The average bankfull width of the White River in Reach 8, recorded during the habitat Assessment (Appendix A), is 131 feet. Active floodplain surfaces of varied inundation frequency extend along the channel throughout the reach. Low and medium floodplain surfaces typically host riparian trees and shrubs such as willow, dogwood, alder, cottonwood and some mixed conifers. Conifers such as western redcedar, grand fir, and Douglas-fir dominate the high floodplain and terrace surfaces in Reach 8. Anthropogenic features in Reach 8 are extensive and include riprap and engineered wood structures to protect White River Road and its bridge over the Napeequa River at the downstream end of Reach 8. Past logging impacts are still influencing the channel. A network of trails with minimal impacts initiates from the Tall Timbers area established on the lower fan of the Napeequa.

Figure 149. Representative photo of White River at RM 13.95 looking downstream (August 2, 2024).

Table 16. Reach 8 descriptive geomorphic metrics.

Metric	Value
Reach Length (miles)	1.92
River Miles	12.43-14.35
Stream Gradient	0.42%
Sinuosity	1.41
Dominant Channel Habitat Unit Type	Pool
Average Bankfull Width (feet)	131
Confinement	Unconfined
Dominant Substrate	Gravel
Bank Stability/Channel Migration	At Risk *(See Appendix B Section 3.2)*
Vertical Channel Stability	Adequate *(See Appendix B Section 3.2)*

3.8.2 Channel and Floodplain Geomorphology

Reach 8 is notably lower in gradient (0.42%) than the upstream reaches but still over twice as steep as Reach 7 immediately downstream. This reach marks the beginning of a distinct transition in slope and channel form compared to the upstream White River reaches in the assessment area. The White River is unconfined and sinuous through Reach 8, with regular and tortuous meanders downstream of RM 13.3 and upstream of RM 13.9. From RM 13.3 – 13.9, the channel lacks significant meanders as it follows the river-left hillslopes and a series of associated fans. The geomorphic surfaces and floodplain distribution in Reach 8 are mapped in (Figure 150). The channel is primarily single-thread in planform, although braiding associated with mid-channel gravel-cobble bars occur from RM 12.45 – 12.6, RM 12.9 – 13.05, RM 13.72 – 13.82, and 14.16 – 14.22. The valley is narrower than portions of the reach directly upstream and downstream. The channel is characterized by a pool-riffle-glide sequence with extended pool sections. The Habitat Assessment (See Appendix A) recorded 61% of the habitat as pool, 23% as glide, 9% as riffle, and 7% as side channel. Flow splits and braiding at low-flow conditions are the result of stream energy, available sediment load, and in several locations, large wood.

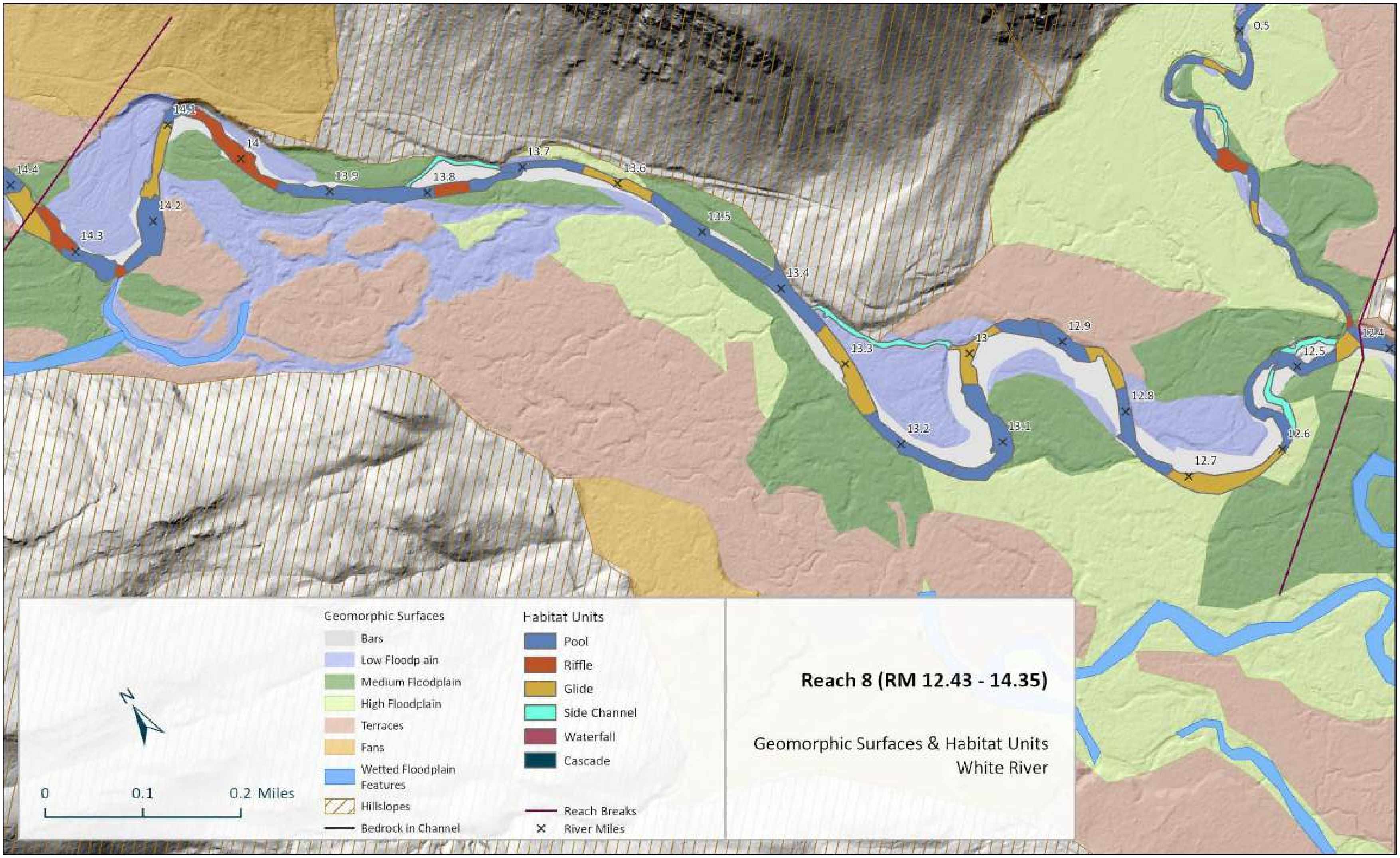

Figure 150. White River, Reach 8: Map of geomorphic surfaces and habitat units.

Based on historical photo analysis of the location of the channel's boundary, lateral processes and meander extensions have evolved since at least 1957, which is the first date for which publicly available aerial imagery is available (Figure 151). Active lateral migration processes since at least 1957 is revealed at the meander bends at RM 12.5 – 12.8, RM 13 – 13.3, RM 14 – 14.2, and RM 14.2 – 14.4. This suggests an increase in sinuosity relative to 1957 conditions. A wetted oxbow on the river right floodplain between RM 14.16 and 14.27 is evidence of a historical meander cutoff that, according to available photos, occurred prior to 1957. Today, a perennially wetted inlet connects the oxbow to the main channel at low flows. At the apex of the oxbow wet conditions transition to intermittent surface ponding. This occurs immediately downstream of a very large channel-spanning log jam that occupies approximately 100 feet of the oxbow (Figure 152).

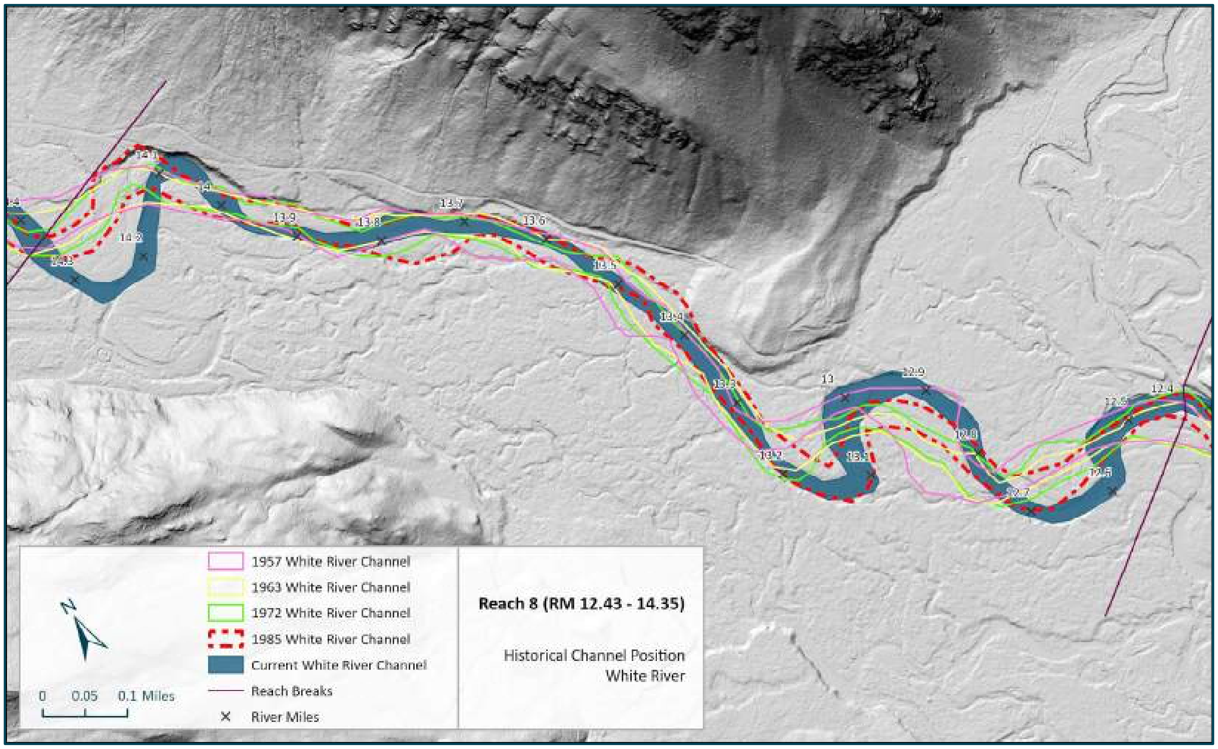

Figure 151. White River, Reach 8: Map of channel alignments digitized from historical photos (1957-2023).

A series of floodplain tributaries convey water across the river-right floodplain, from the wetted oxbow (RM 14.16-14.27) to approximately RM 13.54, as well as across the inside of the meander from RM 14.1-14.2. The floodplain tributaries are sourced from emergent groundwater during low-flow conditions such that they are perennial contributor to the White River at RM 13.52. During seasonal snow melt or high-flow events, they also receive and convey surface water. Given that these floodplain tributaries maintain connectivity with the White River during low flow, they likely provide or have the potential to provide important off-channel refugia and rearing habitat for juvenile salmonids and other species. This type of off-channel habitat is currently limited within the assessment area. The active high-flow channels contain gravel-to-cobble sized substrate and racked large wood (Figure 153) and thus appear to convey significant amounts of flow during flood events.

Wetted portions of the floodplain channel network were often flowing, and water depths were up to several feet during the geomorphic survey.

Figure 152. Large wood jam occupying approximately 100 ft of oxbow meander between RM 14.16 and RM 14.27 on river-right floodplain (August 2, 2024).

Figure 153. High-Flow or flood-activated side channel on river right at RM 14.23 with gravel-cobble bedforms and racked wood, indicating frequent high-energy flows (August 2, 2024).

The Napeequa River is a major tributary that flows into the White River at the downstream end of Reach 8. Several small midchannel gravel-cobble bars extend upstream from the Napeequa River confluence, where sediment is deposited as flows from the two rivers merge. The Napeequa River is a significant source of both discharge and fine-to-cobble sized sediments at the downstream boundary of Reach 8. Additional unnamed ephemeral tributaries that were dry during the geomorphic assessment meet the White River at RM 13.18 on river right, and RM 13.87 on river left. These tributaries do not contribute significant discharge and currently are not observed contributing significant sediment, wood, or other material to the channel.

Channel substrate in Reach 8 is cobble-gravel alluvium, with boulders present in the upstream section. The reach hosts large point and lateral bars composed of gravel and cobble in the downstream half of the reach. Channel substrate coarsens significantly with distance upstream, corresponding with an increase in channel slope and a decrease in active bars (Figure 154). Wolman pebble counts were conducted on representative riffle crests at RM 12.76 (GC 15) and RM 13.7 (GC 16). The median grain size at GC 16 of D50 = 60.50 mm is significantly larger than that of the downstream pebble count GC 15 of D50 = 31.41mm. The data from the two pebble counts are plotted on a map (Figure 155) of the Reach 8 incipient motion analysis results (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.9.4). The analysis indicates that at the 2-yr modeled discharge, the channel's shear stress is capable of mobilizing coarse gravels downstream of RM 13.1 with patches of higher shear capable of mobilizing cobble. Upstream of RM 13.1, modeled shear indicates a capacity through the channel to mobilize cobbles. The ocular grain size notes recorded during the survey concur, indicating a decrease in stream energy downstream of RM 13.1, where slope decreases, sinuosity increases, and channel complexity and habitat function also increase.

Figure 154. Left: Cobble-boulder substrate at RM 13.99. Right: Gravel-cobble substrate at RM 13.35 (September 7, 2024).

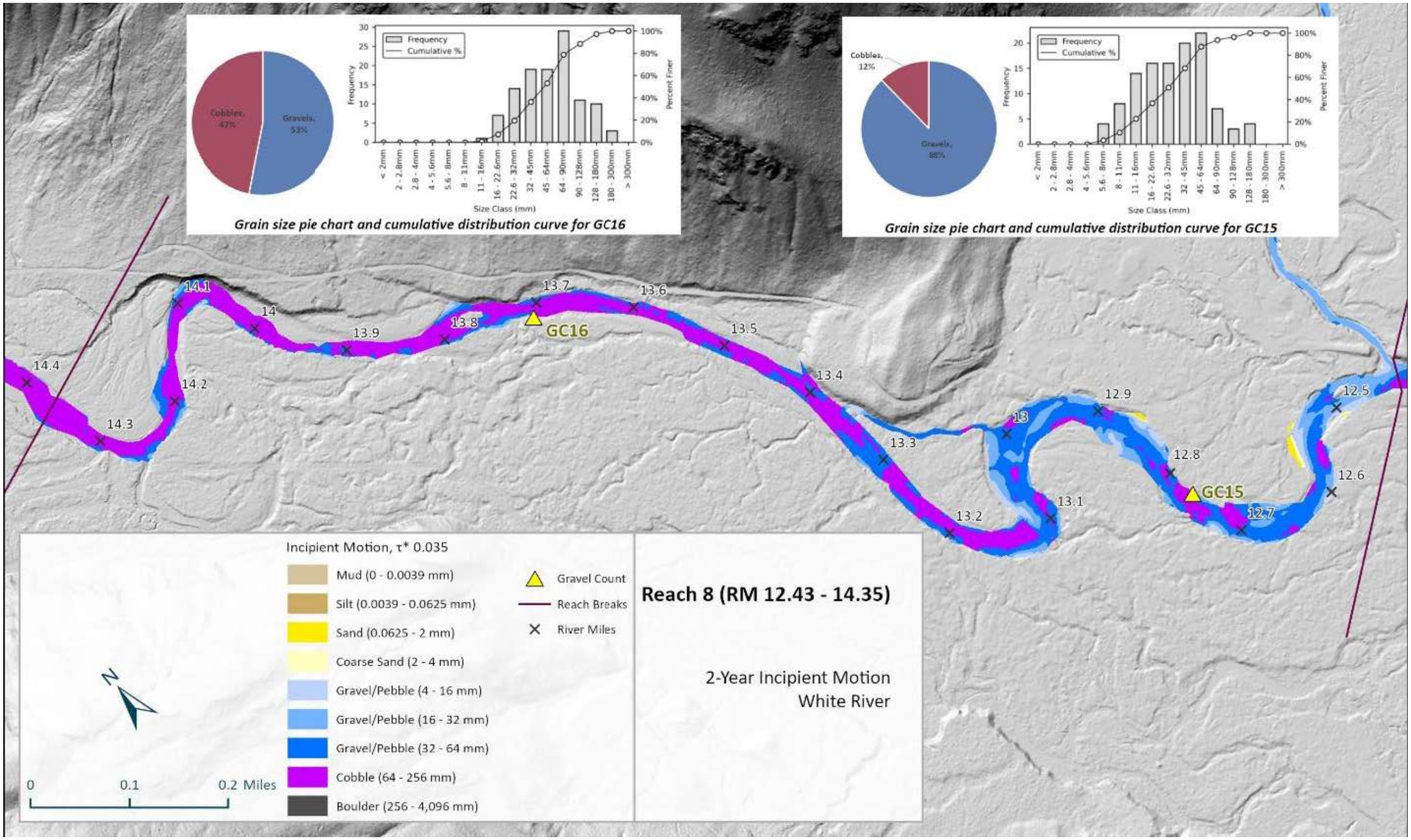

Figure 155. White River, Reach 8: incipient motion analysis results map (estimated grains size mobility at the 2-yr modeled discharge) and grains size distribution of two (GC 15 and GC 16) pebble counts.

Sediment inputs to Reach 8 include material transported in from upstream as well as lateral bank erosion at meander bends actively contribute fines, gravels, and cobbles. Temporary storage of sediment in the bars and bedforms is also available to the channel. Debris fan and hillslopes contribute fines to angular boulders on river left at RM 14.07 and RM 14.02 respectively.

Floodplains in Reach 8 are vegetated, and consist of low (inundation ~1-5 yrs), medium (inundation ~ 5-10 yrs), and high (inundation ~ 10-100 yrs) floodplain surfaces (see Figure 150). Evidence of inundation such as overbank deposits and flotsam indicate that the channel is moderately well-connected to its floodplain in Reach 8. Low floodplain surfaces in Reach 8 are typically extend from point bars on the inside of meander bends. An additional large swath of low floodplain is located on river right between RM 13.6 and RM 14.25. Moving away from the channel, low floodplains at point bars generally transition to medium and then to high floodplain surfaces. Terrace surfaces are located along the valley wall on river right, and adjacent to the channel on river left from RM 12.84 – 12.96. Low floodplains surfaces are typically populated with willow, whereas medium floodplains are populated with dogwood, alder, cottonwood, and mixed-conifers. Vegetation on high floodplains and terraces is generally mixed-conifer. Meander bends typically exhibit a sequence of floodplain development that extends from the channel as relatively active point bars that step up to low floodplain surfaces, which then transition to medium and/or high floodplain surfaces. Based on exposed banks, floodplains are composed of a cobble-gravel base overlain by gravels and sometimes sand topped with developing organic soil (Figure 156).

Figure 156. Cut bank at RM 13.95 (river right) revealing floodplain composition of alluvial cobbles overlain by gravels and fine sediments (August 2, 2024).

3.8.3 Large Wood Material

Key pieces of large wood (large wood effective at maintaining geomorphic influence for more than temporary timelines) were estimated to need to be at least 24-36 inches in diameter in Reach 8 during the geomorphology survey of 2024. A total of 196 pieces of large woody material (LWM) and 23 log jams (accumulation of >3 LWM) were observed in the channel during the survey (August, 2024) (Figure 157). Of the 196 pieces, 94 pieces are considered Quality Large Wood (QLW); 40 classified as large size class (>20-inces diameter and >35-feet long); and 54 as medium size class (12 to 20-inch diameter and at least 35-feet long). 22 of the 23 log jams in Reach 8 contain multiple pieces of QLW. Large wood contributions in Reach 8 include locally recruited trees sourced from eroding banks, and transported large wood sourced from upstream. Large wood and large wood jams were observed to influence geomorphic processes on the White River in Reach 8 via promoting pool scour, sediment deposition and sorting, and split-flow (Figure 158). Large wood also deflects flow into stream banks instigating bank erosion and channel migration at RM 12.74 (river right), RM 12.85 (river left), and RM 12.98 (river right).

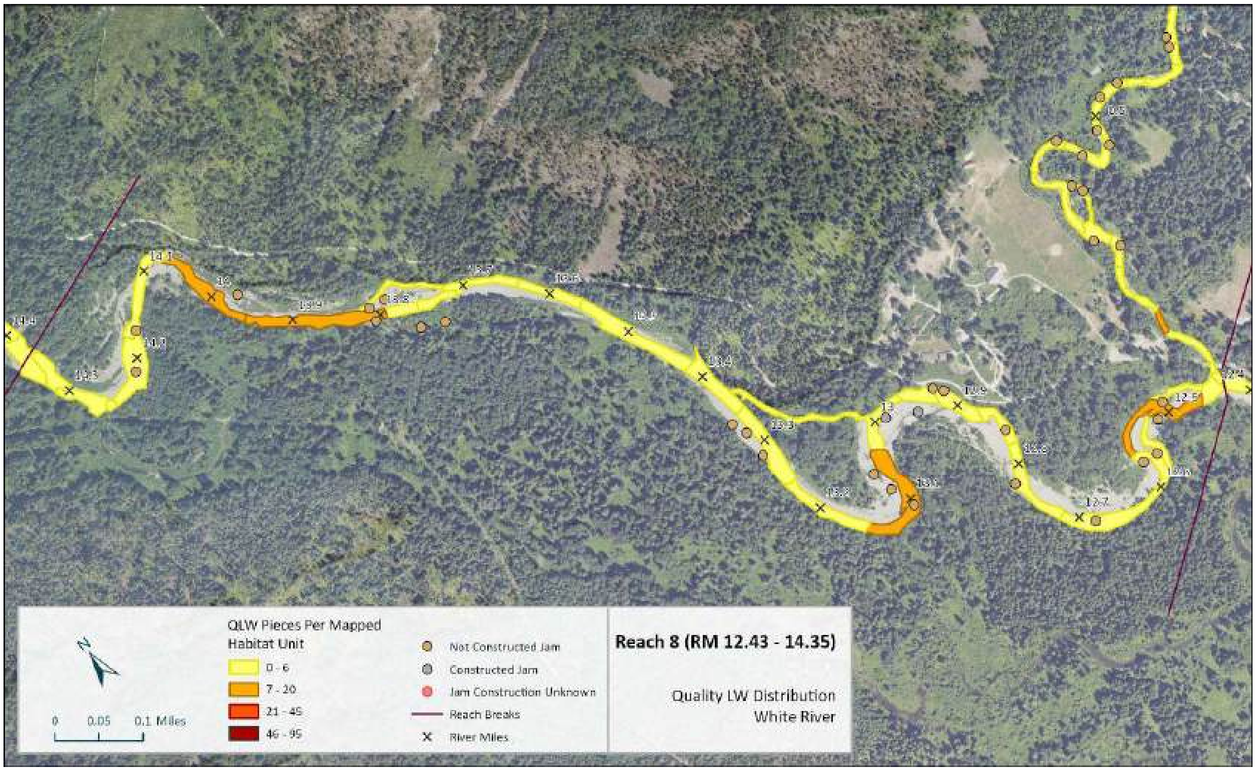

Figure 157. White River, Reach 8: Quality large wood (QLW) distribution map and surveyed habitat units (2024). QLW count does not include pieces in jams.

Figure 158. Log jam deflecting flow, splitting flow, and collecting gravels in Reach 8. Located at RM 14.2 on mid-channel bar, looking downstream from river-right (August 2, 2024).

3.8.4 Vegetation

The floodplains along the White River in Reach 8 are vegetated with conifer forests and a band of riparian vegetation along the channel. Width and distribution of riparian trees and shrubs correlates to the distribution of bars and low floodplain surfaces. Conifer dominated forests occupy the other valley floor surfaces. Overstory vegetation in Reach 8 ranges from immature to mature cedar, grand fir, Douglas-fir, and cottonwood (Figure 159). The relative abundance of cottonwood decreases in the upstream portion of the reach and is lower overall than that of Reaches 1-7 downstream. The understory consists primarily of vine/Douglas maple, alder, and dogwood in addition to young conifers. Willow dominates the low floodplain surfaces, whereas dense dogwood thickets dominate medium floodplain surfaces throughout the majority of Reach 8. Large overstory trees adjacent to the river provide a source of large wood to the channel in areas with active bank erosion, as well as localized stream shading. The vegetation height analysis map shows that these trees are highly concentrated at the downstream end of Reach 8 on river right, and more sporadically distributed elsewhere in the reach (Figure 160). Active lateral migration of the meander from RM 12.6 – 12.75 into existing large trees provides a source of large wood recruitment at the downstream end of the reach, however, a lack of streamside large trees elsewhere in the reach limits large wood recruitment, leading to simplification of the channel. Although mature old growth conifers are not common within Reach 8, western redcedar stumps in the floodplain confirm that they once occupied the valley floor.

Figure 159. Representative photograph of Reach 8 vegetation (RM 12.65, looking upstream) (August 4, 2024).

Figure 160. White River, Reach 8: Map of vegetation height classification analysis (LiDAR – based analysis).

Figure 161. White River, Reach 8: Map of aerial imagery for vegetation identification.

3.8.5 Human Alterations

Human alterations in Reach 8 are associated with roads, trails, and historical logging (See Figure 162). Riprap boulders placed along the river's bank to protect White River Road are located on river left at the base of the bridge of the mouth of the Napeequa River, from RM 12.9 – 12.94, and from RM 13.54 – 13.6. Bank protection constructed of riprap and bank-attached large wood is also meant to protect White River Road from RM 12.9 – 12.94 (Figure 163). Trails extending from the Tall Timber Ranch property to the White River channel at RM 12.77 and RM 13.15 have minimal impact on channel and floodplain processes. Evidence of past logging was observed in several locations on the river-right floodplain including stumps and cable scars (Figure 164). Sears Creek Road enters the valley bottom at ~RM 13.8 on the river-right floodplain. The road is currently unmaintained beyond ~RM 12.7, although it appears to have been active to ~RM 14.6 as recently as 1985 according to historical imagery. The unmaintained portion of the road bisects a large oxbow in the upstream portion of Reach 8. It is also presumed that road construction and historical logging are associated with channel straightening from RM 13.3 to 14.75

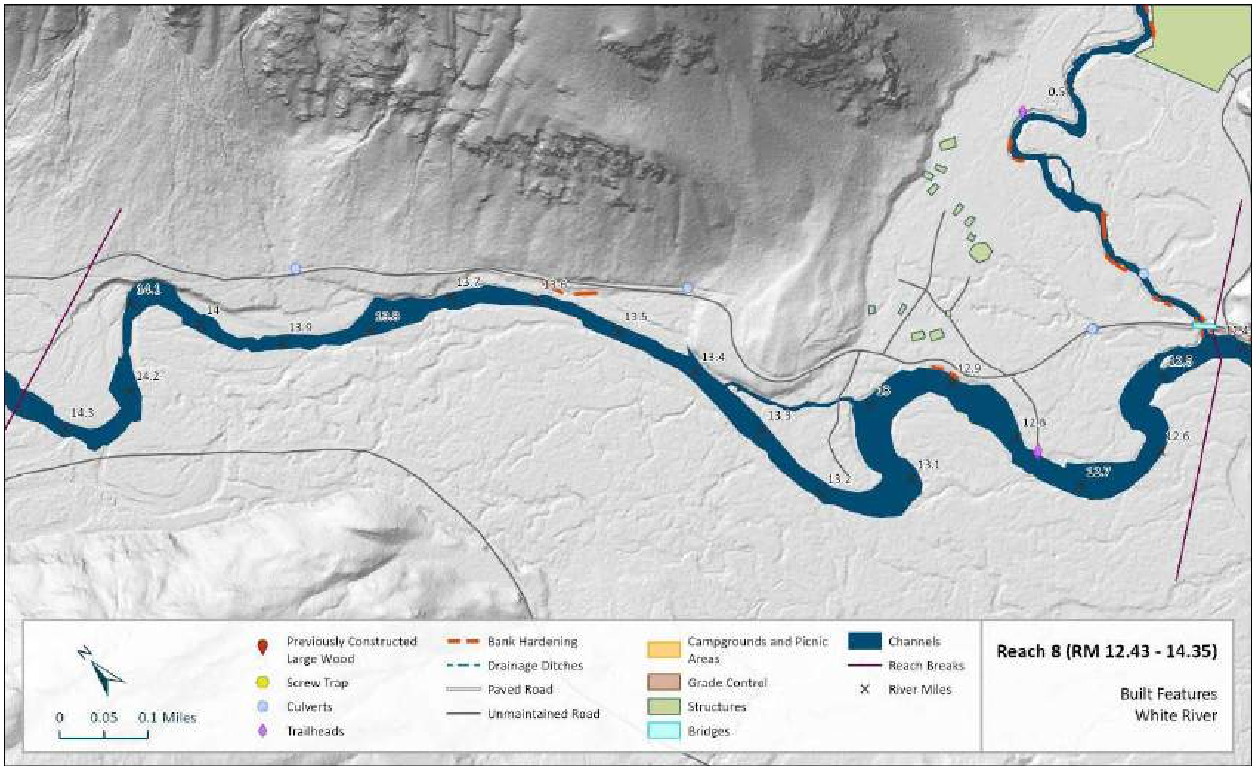

Figure 162. White River, Reach 8: Mapped anthropogenic features.

Figure 163. Riprap and large wood constructed bank protection along White River Road at RM 12.92 (August 4, 2024).

Figure 164. Example of historical logging cable scar on remnant old-growth western redcedar on river-right floodplain at RM 12.75 (August 4, 2024).

3.8.6 Recommended Actions

Recommended actions in Reach 8 include efforts to connect floodplain side channels and oxbow wetlands to the mainstem channel, as well as large wood placements, modifications of anthropogenic features, and improvements to riparian conditions. Reach 8 contains an expansive side channel network through the river right floodplain. Excavations of side channel inlets to activate the side channel network could increase available, accessible off-channel habitat and floodplain wetland areas. Additional excavations or strategically placed large would could be used to activate smaller side channel features elsewhere throughout the reach. Large wood additions throughout the reach could enhance/improve channel complexity and provide roughness to high flow side channels and reduce the risk of meander neck cutoff. Existing bank riprap near White River Road could be removed and replaced with bank-buried large wood jams, and White River Road upstream of the Napeequa River confluence could be set back from the White River channel to limit impacts of channel migration on infrastructure, and to allow for revegetation of cleared riparian areas.

3.9 WHITE RIVER REACH 9 (RM 14.35 – 15.01)

3.9.1 Overview

Reach 9 is 0.66 river miles long and extends from the upstream end of a large meander bend at RM 14.35 to the Panther Creek confluence at Rm 15.01 (Table 17). Flow splits around a large vegetated island at the upstream end of the reach, from RM 14.87 – 15.05, but is otherwise single-thread in planform throughout the remainder of the reach (Figure 165). The channel in Reach 9 is relatively straight with a low sinuosity (S = 1.08). The average gradient of Reach 9 (1.05%) is ~ 2.5 times greater than that of Reach 8 downstream, but still half that of upstream Reach 10 gradient (2.4%). Average bankfull width of the channel recorded during the Habitat Assessment (Appendix A) is 119 feet. The White River channel is partially confined to confined by terraces throughout the majority of the reach. Low floodplain surfaces (inundated ~ 1-5 years) medium floodplain surfaces (inundated ~ 5-10 years) and high floodplain surfaces (inundated ~ 10-100 years) exist as isolated, discontinuous pockets. Large cedar, grand fir, and Douglas-fir are the dominant vegetation on floodplain, terrace, and adjacent hillslope surfaces. Mature old-growth conifers were sparsely distributed throughout floodplain and terrace surfaces, and remnant old-growth stumps confirm that old growth forests once occupied the valley floor. Reach 9 has fewer large wood pieces and wood jams than any other reach within the assessment, and the currently available wood has a minimal effect on geomorphic processes and habitat complexity at present. Human built structures in Reach 9 include a campground on the river-right terrace near RM 15 with trails that run along the edge of channel, and an abandoned road that cuts through the river-right floodplain.

Figure 165. Representative photo of White River at RM 14.7, looking upstream (August 1, 2024).

Table 17. Reach 9 descriptive geomorphic metrics.

Metric	Value
Reach Length (miles)	0.66
River Miles	14.35-15.01
Stream Gradient	1.05%
Sinuosity	1.08
Dominant Channel Habitat Unit Type	Riffle
Average Bankfull Width (feet)	119
Confinement	Partially Confined
Dominant Substrate	Gravel
Bank Stability/Channel Migration	Unacceptable *(See Appendix B Section 3.2)*
Vertical Channel Stability	Unacceptable *(See Appendix B Section 3.2)*

3.9.2 Channel and Floodplain Geomorphology

The channel in Reach 9 is relatively straight with an average gradient of 1.05%, 2.5 times greater than the downstream reach, but less than half that of Reach 10 upstream (2.40%). The White River through Reach 9 expresses a low sinuosity (S = 1.08) and a single-thread channel planform, except at the upstream end where split flow occurs around the Panther Creek confluence island from ~ RM 14.86 – 15.05. Reach 9 is also the transition reach between the unconfined reaches downstream and the partially confined Reach 10 upstream. A map of the geomorphic surfaces and channel habitat units is provided as Figure 166. The channel unit types in Reach 9 include one extended pool and one glide downstream of RM 14.52 and an extended boulder riffle upstream. The transition in unit types marks a reduction in channel gradient in the downstream portion of the reach. The Habitat Assessment (See Appendix A) recorded 50% of the Reach 9 habitat as riffle, 20% of the habitat as glide, 18% of the habitat as side channel (at Panther Creek outlet island), and 12% of the habitat as pool. Based on exposed banks, floodplains are composed of a boulder-cobble base overlain by finer sediments and soils. The valley bottom is wide through Reach 9. Lateral connectivity between the channel and active floodplain surfaces is limited. In the middle of the reach the channel is entrenched into abandoned terraces and lacks large wood jams capable of creating channel complexity. A historic channel scar on the river-right floodplain extends from the large oxbow in Reach 8 (RM 14.26) to approximately RM 14.8 in Reach 9 (Figure 167). The lack of sinuosity and entrenched condition relative to its historical floodplain combined with abandoned historical channel scars (wetted) as well as evidence of logging and surface grading suggest that the channel may have been anthropogenically straightened and forced to the river-left side of the valley between RM 14.5 and 14.8 to maximize access for past logging activities.

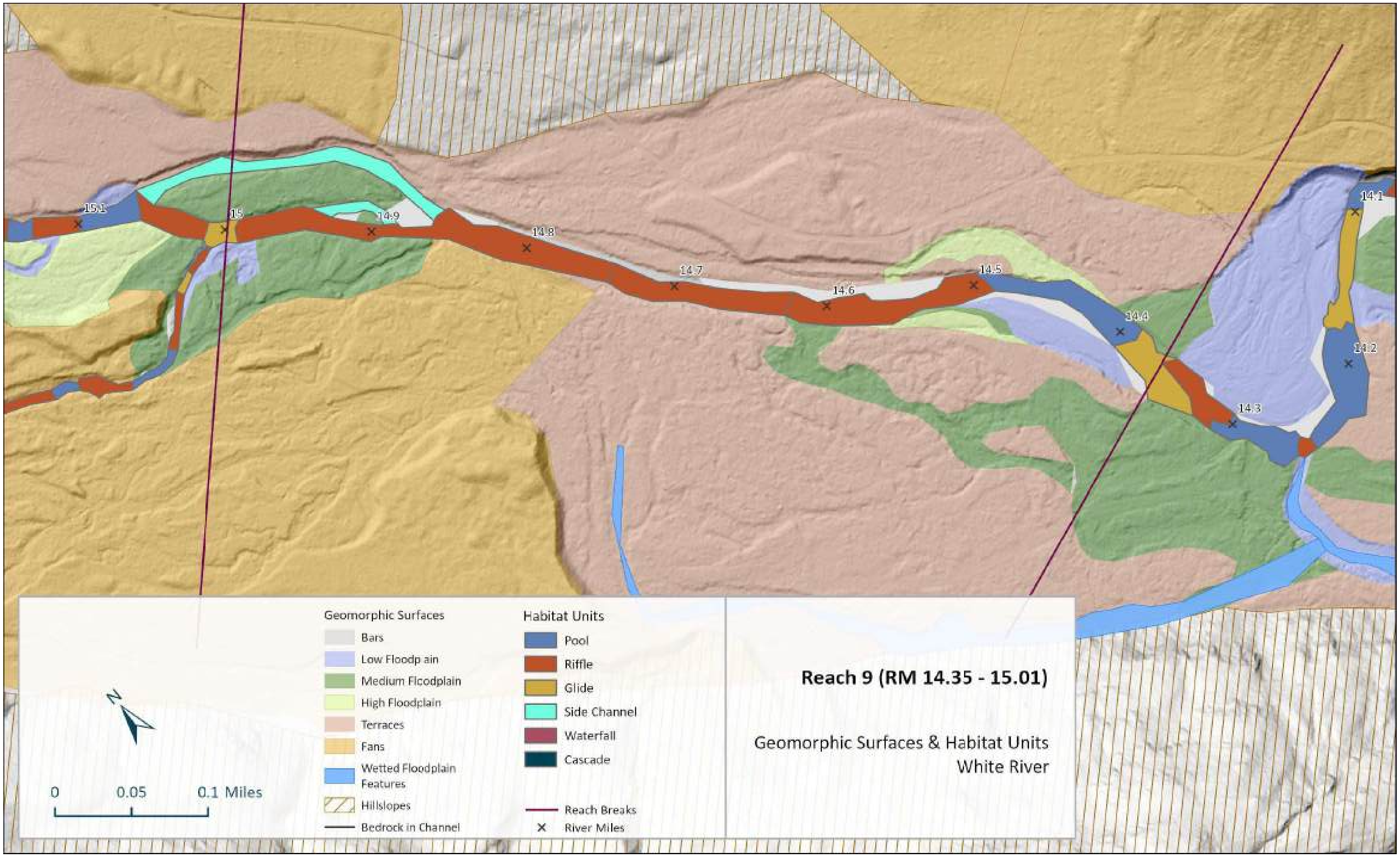

Figure 166. White River, Reach 9: Map of geomorphic surfaces and habitat units.

Figure 167. Groundwater wetted abandoned historical channel scar with intermittent surface water connectivity on the river-right floodplain near RM 14.7 (August 2, 2024).

The extended channel scar or sequence of modern oxbows is currently disconnected from the White River but sections of it remain wetted perennially via groundwater inputs likely sourced from both the toe of the Panther Creek alluvial fan and through the substrate of the White River valley. Additional surface water inputs to the historical channel scar appear to be sourced from a hillslope tributary that enters the valley at RM 14.66. Active beaver dams increase surface water retention in the oxbow along the river right hillslopes between RM 14.6 and RM 14.7. Coarse gravel to cobble alluvium on the bed of the historical channel scar was noted qualitatively as finer than that of the modern mainstem White River. Boulders are generally absent from the historical channel scar, where the bed is visible. This indicates that stream energy and transport capacity of the current main channel is likely higher than that of the historic channel. This is likely due to simplification of the channel in the last 100 years (channel straightening and removal of large wood from the channel and the adjacent floodplain). Large wood is present along the historic channel scar and is found as large jam features.

Based on historical photo analysis of the location of the channel in Reach 9, minimal change has occurred since 1957, which is the first date for which aerial imagery is available (Figure 168). The large, abandoned channel scars on the river-right floodplain was disconnected prior to 1957. Lateral channel extension at the downstream end of the reach is the main planform evolution.

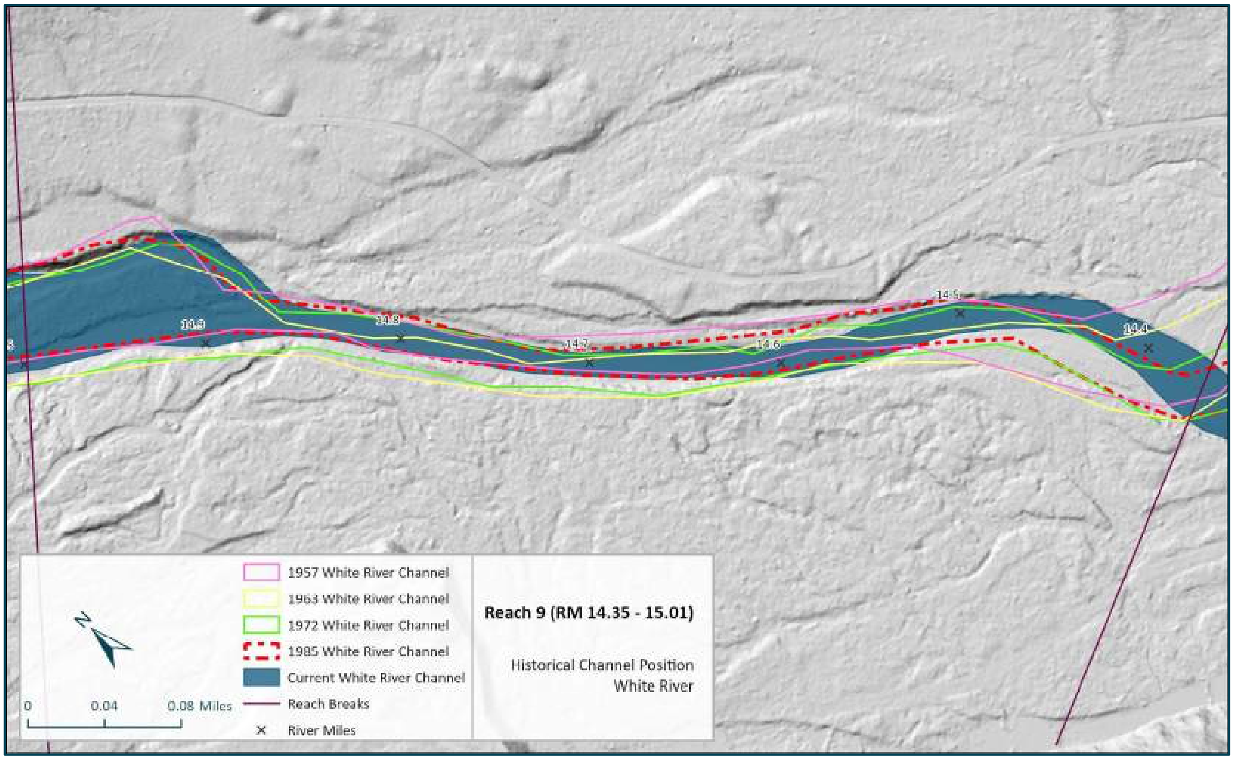

Figure 168. White River Reach 9: Map of channel alignments digitized from historical photos (1957-2023).

Channel substrate in Reach 9 is cobble-gravel mixed with boulders and small fractions of coarse sand. The abundance of boulders relative to other grain size classes decreases substantially moving downstream (Figure 169). Gravel to cobble sized sediments are present on the channel bottom throughout Reach 9, although in the upper portion of the reach, they are generally only present where low velocity hydraulic conditions allow such as behind large boulders or along channel margins. Wolman Pebble Counts were conducted on riffle crests and associated bars at ~RM 14.46 (GC 17) and ~RM 14.66 (GC 18). The median grain size at GC 17 is D50 = 49.22mm and at GC 18 is D50 = 50.54mm. The data from the two pebble counts are plotted on a map (Figure 170) of the Reach 9 incipient motion analysis results (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.9.4). The analysis indicates that at the 2-yr modeled discharge, the channel's shear stress is capable of mobilizing cobbles throughout Reach 9. A patch of higher shear capable of mobilizing boulder-sized substrate occurs in the model at RM 14.71 – 14.77, where the channel is the most straight and entrenched.

Figure 169. Left: White River at RM 14.86, dominant boulder-cobble substrate (August 1, 2024). Right: White River channel at RM 14.46, dominant cobble substrate (August 2, 2024).

Panther Creek meets the White River at the upstream end of Reach 9. It contributes ~ 14% of the total flow of the White River and is the only notable tributary to the channel in Reach 9. As such, it is an important contributor of flow and sediment to the channel. The present flow route of Panther Creek enters the White River at RM 15. Ephemeral distributary channels and flow routing scars downstream of the present Panther Creek confluence confirm that outlet migration of the Panther Creek occurs regularly across its active alluvial fan, between approximately RM 14.7-15.

Coarse sediment sources in Reach 9 include the Panther Creek alluvial fan and cut-banks where lateral erosion by the White River exposes gravel-to-cobble sized sediments. Based on exposed banks, floodplains are composed of a boulder-cobble base overlain by finer sediments and soils. Floodplain and terrace soils are described as stony fine sandy loam, and hillslope soils are described as gravelly fine sandy loam and rock outcrops (Natural Resources Conservation Service, 2007).

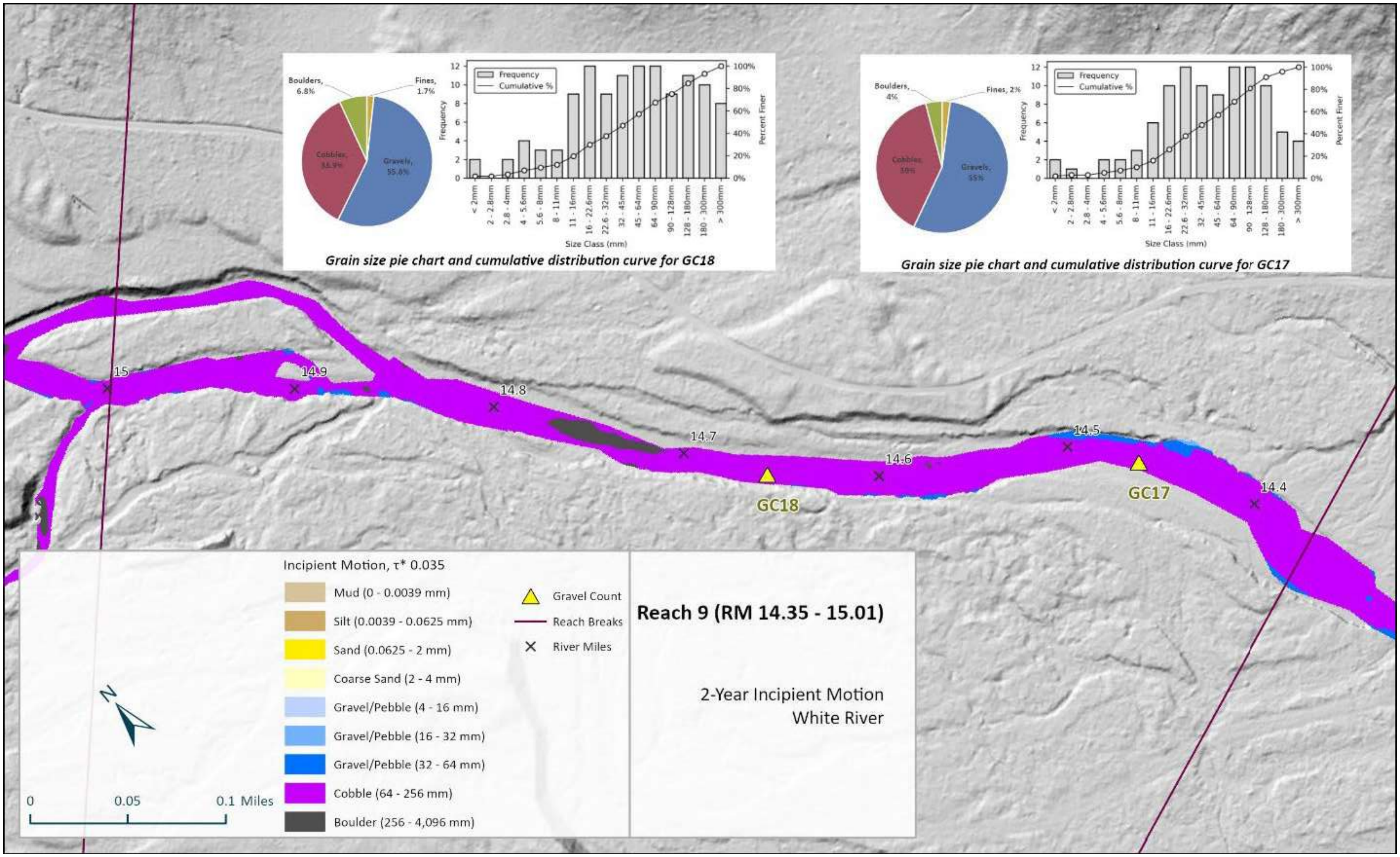

Figure 170. White River, Reach 9: incipient motion analysis results map (estimated grains size mobility at the 2-yr modeled discharge) and grains size distribution of two (GC 17 and GC 18) pebble counts.

3.9.3 Large Wood Material

A total of 63 pieces of large woody material (LWM) and 3 log jams (accumulation of >3 LWM) (Figure 172) were observed in the channel during the Habitat Assessment (Appendix A) (August, 2024) (See Figure 171). Of the 63 pieces, 35 pieces are considered Quality Large Wood (QLW); 12 classified as large size class (>20-inces diameter and >35-feet long); and 23 as medium size class (12 to 20-inch diameter and at least 35-feet long). All three jams have multiple pieces of QLW and thus are considered to be effective channel influencing and habitat forming structures. All three log jams were associated with pool scour and sediment sorting (Figure 172). The abundance of large wood in Reach 9 is likely diminished compared to historical conditions due to past logging activities on the floodplain. The forced straightening of the river channel between RM 14.3 and RM 14.75 has likely created high energy conditions that are less favorable to large wood retention. At present, large key pieces with at least 3 feet in diameter are likely necessary to create effective and persistent log jams. Trees adjacent to the White River channel in Reach 9 are generally smaller than 3-ft dbh, although some sufficiently large trees do exist sporadically and could be recruited into the channel by encouraging bank erosion, or through intentional felling.

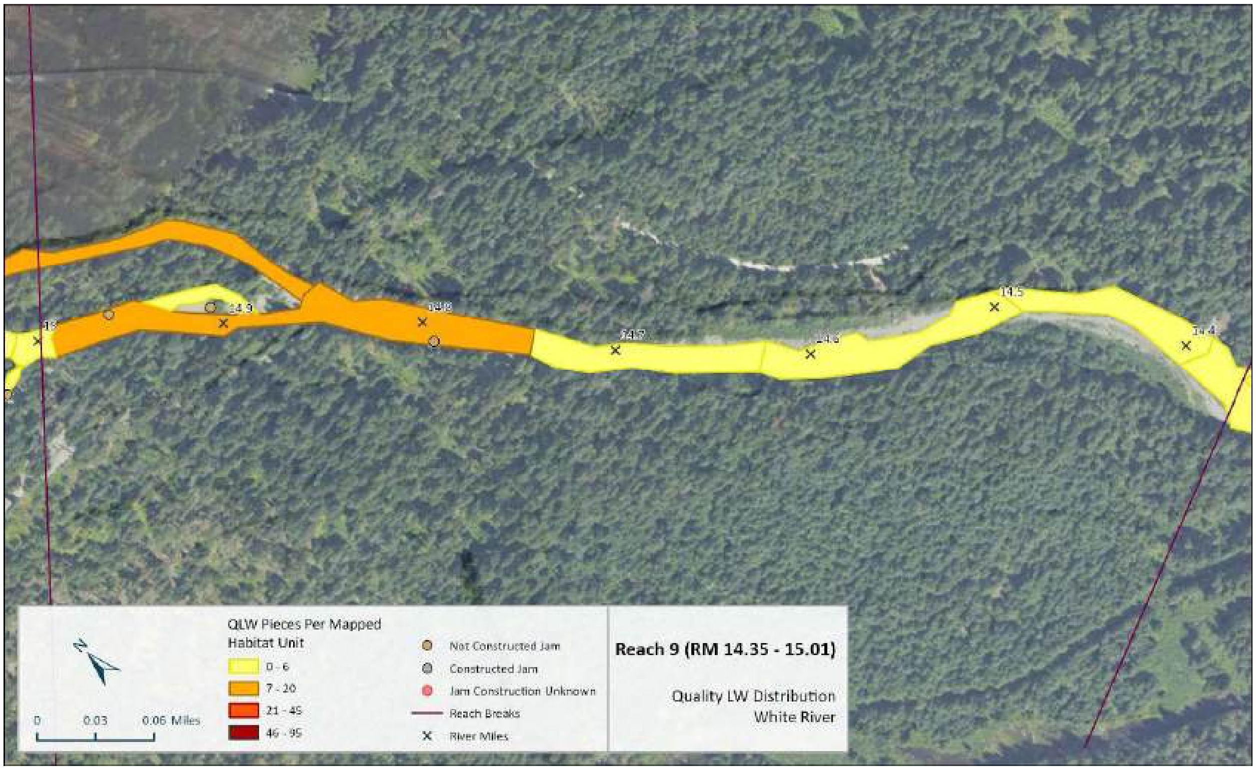

Figure 171. White River, Reach 9: Quality large wood (QLW) distribution maps and surveyed habitat units (2024). QLW count does not include pieces in jams.

Figure 172. Large wood accumulation located on the river left bar within the river right flow split at RM 14.91, looking upstream (August 1, 2024).

3.9.4 Vegetation

Vegetation in Reach 9 consists of an overstory of large western redcedar, grand fir, and Douglas-fir, and an understory of mixed conifers, alder, and vine/Douglas maple. Mature old-growth trees are rare, although the presence of old growth cedar stumps on the river-right floodplain near RM 14.7 and the presence of an abandoned road suggest that pre-European settlement conditions included old-growth trees of substantially greater size than the forests inhabiting the floodplains today. Willows are present on active floodplain surfaces. Overstory and understory vegetation directly border the majority of the channel and provide a partial shade canopy for the White River throughout Reach 9. The vegetation height analysis map shows that taller trees are generally concentrated in a narrow band adjacent to the channel in Reach 9, whereas pockets of shorter trees against the valley wall on river right, and east of White River Road on river left, are second growth forests (Figure 173). The adjoining hillslope vegetation consists of mixed conifers at a lower density than those on floodplain and terrace surfaces.

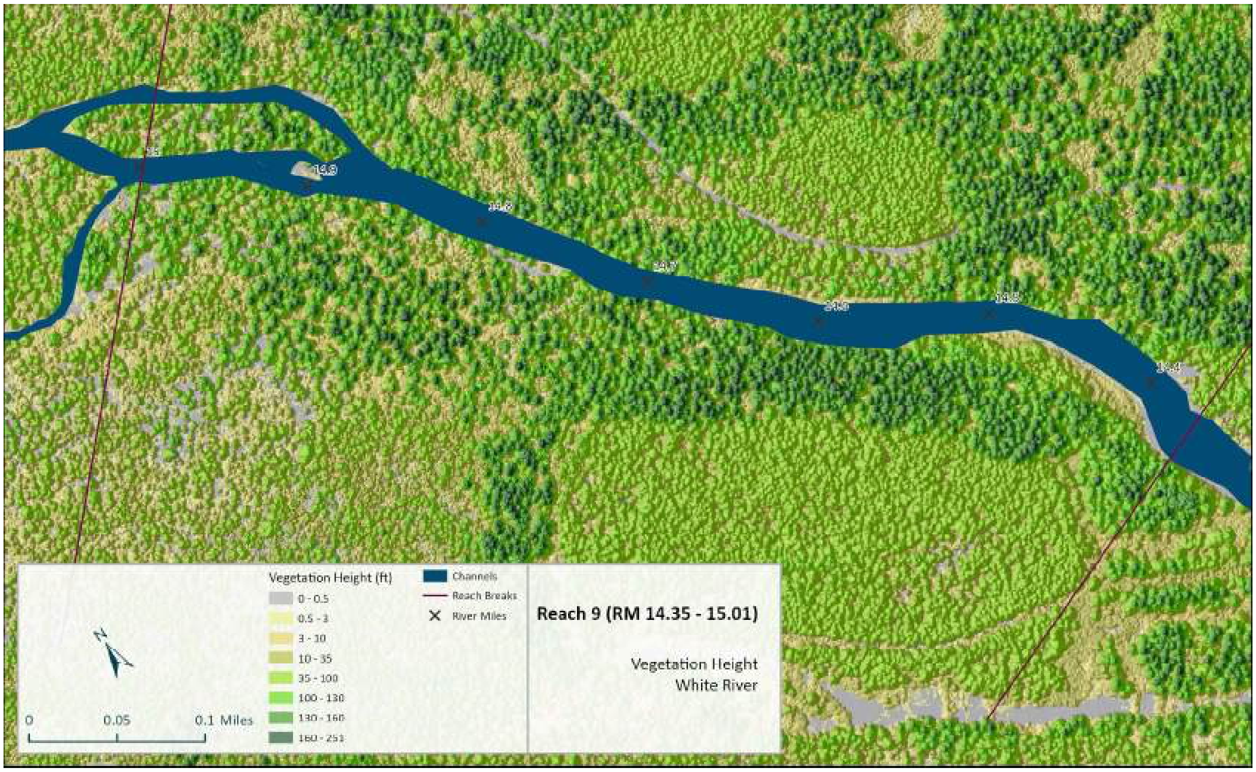

Figure 173. White River, Reach 9: Map of vegetation height classification analysis (LiDAR – based analysis).

Figure 174. White River, Reach 9: Map of aerial imagery for vegetation identification.

3.9.5 Human Alterations

Although White River Road and a campground on river right at RM 14.9 are the only anthropogenic built features within Reach 9 (See Figure 175), significant human alterations of the landscape related to logging activities occurred in the past. A currently abandoned section of Sears Creek Road (Figure 176) cuts through the river right terraces in Reaches 8 and 9. This road bisects a now abandoned historical channel between RM 14.3 and 14.7. Stumps of several large old growth western redcedar (Figure 176) were noted adjacent to the channel scars, indicating that these terrace surfaces were once functional floodplains in the past. It is likely that the White River was anthropogenically forced into its present location to maximize access to the river-right floodplain for logging. Straightening and disconnecting the White River while removing mature trees from its floodplain would have forced the channel into its current simplified form. The earliest aerial imagery found for the site as part of this assessment is from 1957, and the channel realignment had already occurred by that time. The campground located atop the terrace on river left at RM 15 (upstream reach boundary) has reduced floodplain vegetation density and a trail extends to the channel but otherwise has minimal impact on channel function. Two culverts direct hillslope runoff beneath White River Road at RM 14.45 and RM 14.77, to contribute seasonal surface water input to the White River. No fish-passage barriers currently exist on the mainstem channel.

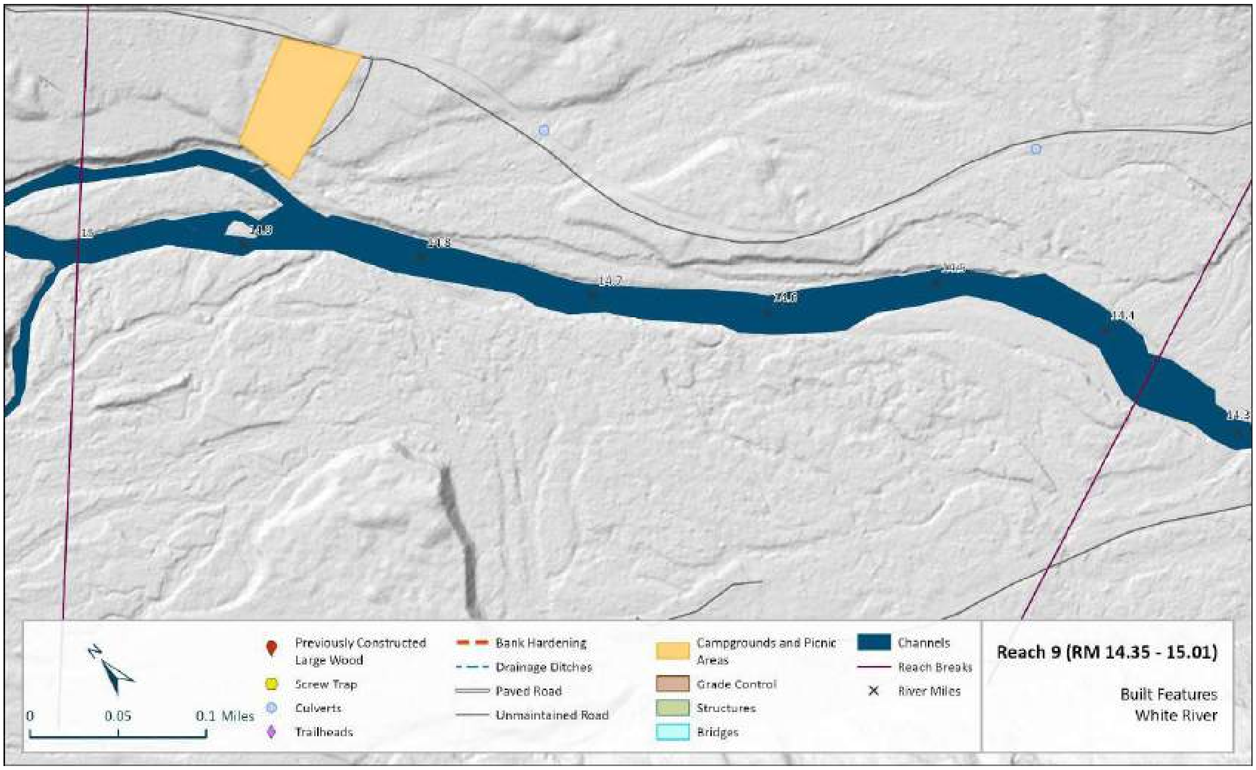

Figure 175. White River, Reach 9: Mapped anthropogenic features.

Figure 176. Left: Abandoned logging road on river-right floodplain, extending from Sears Creek Road to RM 14.7. Right: Western redcedar stumps on river-right floodplain near RM 14.7 (August 2, 2024).

3.9.6 Recommended Actions

Recommended actions in Reach 9 include reconnection of a network of abandoned floodplain channels and large wood placements to improve/enhance aquatic habitat. Excavations of side channel inlets to activate a side channel network extending from below the Panther Creek confluence downstream into Reach 8, as well as additional smaller side channels downstream, would increase available and accessible off-channel habitat, and could promote the expansion of existing beaver complex areas. Aggressive wood loading of the White River mainstem channel downstream of the side channel network inlet would encourage inundation of the side channel network, or could shift mainstem flow into the path of the more sinuous historical channel on river right. Large wood placements throughout the reach would enhance/improve channel complexity and increase the abundance of spawning gravels within the reach.

3.10 WHITE RIVER REACH 10 (RM 15.01 – 16.17)

3.10.1 Overview

Reach 10 is 1.16 river miles long and extends from the confluence of the White River with Panther Creek at RM 15.01 to the bottom of White River Falls at RM 16.17 (Table 18). Upstream of White River Falls the channel is confined through a bedrock canyon and cascade. At the upstream end of Reach 10, the White River begins its route through the White River valley. The channel is single thread in planform until the downstream boundary area where flow splits around a large, vegetated island at RM 15.05. The island occurs at the upstream end of the currently active Pather Creek fan on river right. Reach 10 has a low sinuosity of 1.15 and a reach gradient of 2.4%, which is a considerably higher gradient than the other reaches in the assessment area. Substrate is cobble-boulder dominated (Figure 177). Average channel bank-full width recorded during the Habitat Assessment (Appendix A) is 92 feet. The White River is confined by reworked glacial outwash terraces and an alluvial fan on river right, upstream of RM 15.8. Downstream of RM 15.8 the channel is partially confined by the reworked glacial outwash terraces and fans but has developed narrow discontinuous inset floodplains mapped as low floodplain surfaces (inundated ~ 1-5 years). High floodplains surfaces (inundated >10 yr) exist as discontinuous strips and pockets between the channel and the terrace surfaces. Large conifers including cedar, Douglas-fir, and grand fir occupy the medium-to-high floodplain surfaces, terraces, and hillslopes. The majority of trees are regenerating second-growth forests. Remnant old-growth trees are sparsely distributed throughout the reach. Current large wood retention within the reach is low. Direct hillslope coupling with the channel occurs on river left near RM 15.4 and 15.8. Human-built structures in Reach 10 are limited to White River Road and campsites at the upstream and downstream end of the reach, none of which directly impact channel processes. Historical logging diminished the effective large wood abundance, recruitment potential, and thus geomorphic function that large wood historically likely played in Reach 10.

Figure 177. Representative photo of White River at RM 15.6, looking upstream (August 1, 2024).

Table 18. Reach 10 descriptive geomorphic metrics.

Metric	Value
Reach Length (miles)	1.16
River Miles	15.01-16.17
Stream Gradient	2.40%
Sinuosity	1.15
Dominant Channel Habitat Unit Type	Riffle
Average Bankfull Width (feet)	92
Confinement	Partially Confined
Dominant Substrate	Cobble
Bank Stability/Channel Migration	Adequate *(See Appendix B Section 3.2)*
Vertical Channel Stability	Adequate *(See Appendix B Section 3.2)*

3.10.2 Channel and Floodplain Geomorphology

Reach 10 is of moderate gradient (2.40%) with low sinuosity and a single thread planform between RM 15.05 – 16.17. Downstream RM 15.05 the channel splits around a vegetated island located, at the upstream end of the currently active Panther Creek alluvial fan. The valley floor at Reach 10 was infilled with material generated from large alluvial and debris fans sourced from the adjacent hillside as well as glacial outwash deposits. The channel has eroded into the material to establish its current inset flow path (Figure 178). At the upstream end of the reach, bedrock is exposed at White River Falls and the adjacent hillslopes. Otherwise, the channel is confined by alluvial terraces composed of reworked fan and glacial outwash sediments upstream of RM 15.8. Downstream of RM 15.8 the channel is partially confined but has developed narrow discontinuous inset floodplains. The vegetated island at the downstream end represents the largest patch of available floodplain. Several unnamed tributaries contribute minor flow and sand to the White River in Reach 10. These include perennial tributaries on river right at RM 15.67 and 16.09, and ephemeral tributaries on river right at RM 15.79, and river left at RM 15.35 and 15.45. The channel's habitat unit types shift from an extended boulder-riffle, with periodic glides upstream of RM 15.25 to a riffle pool sequence at the downstream end (Figure 178). The split flow conditions at and around the island provide the best habitat complexity in the reach. The Habitat Assessment (See Appendix A) recorded 79% of the channel habitat area as riffle, 12% as glides, 8% as pools, and 2% as cascades (waterfalls).

Based on historical photo analysis of the location of the channel's boundary, very little change has occurred regarding the location of the channel in the valley since at least 1957, which is the first date for which publicly available aerial imagery is available (Figure 179). No avulsions or changes to mainstem channel alignment, but minor outward lateral migration is visible.

Channel substrate in Reach 10 is composed of boulders with sparse gravels and cobbles. The large boulders sourced from hillslope contributions and lag material from glacial outwash are the primary drivers of aquatic habitat complexity in the channel. Wolman Pebble Counts were conducted on riffle crests and associated bars at ~RM 15.26 (GC 19) and ~RM 15.93 (GC 20). The median grain size at GC 20 is D50 = 77.00mm and at GC 19 is D50 = 83.50mm. The data from the two pebble counts are plotted on a map (Figure 180) of the Reach 10 incipient motion analysis results (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.9.4). The analysis indicates that at the 2-yr modeled discharge, the channel's shear stress is capable of mobilizing cobbles. Patches of higher shear capable of mobilizing boulder-sized substrate also occur throughout Reach 10 and become the dominate size class of potential mobilization upstream of RM 15.85. Reach 10 is a transport reach, where sediment inputs are regularly mobilized. Gravel-sized sediments are stored temporarily in small pockets where low velocity hydraulic refuge conditions occur behind large boulders or as a thin band along channel margins (Figure 181).

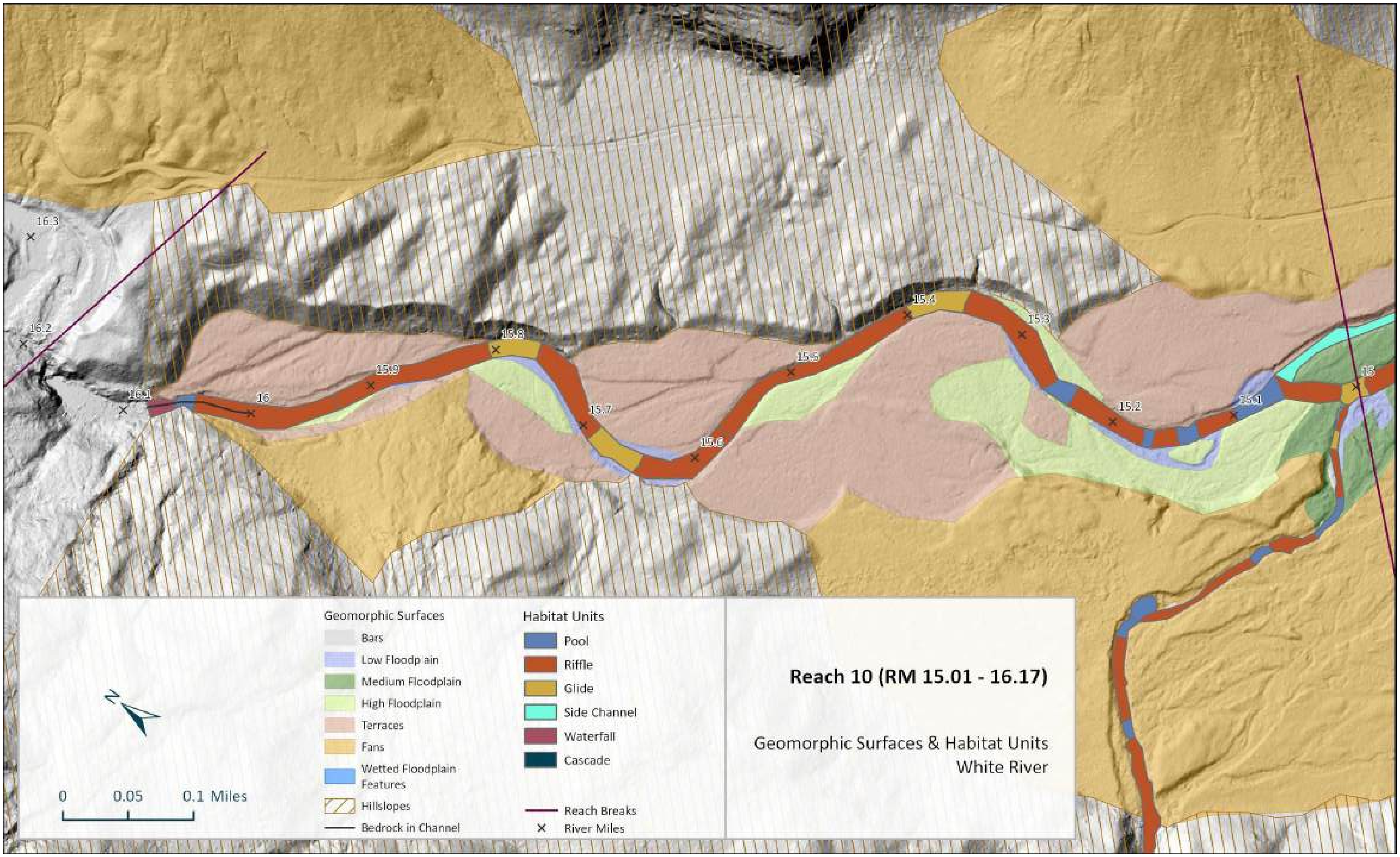

Figure 178. White River, Reach 10: Map of geomorphic surfaces and habitat units.

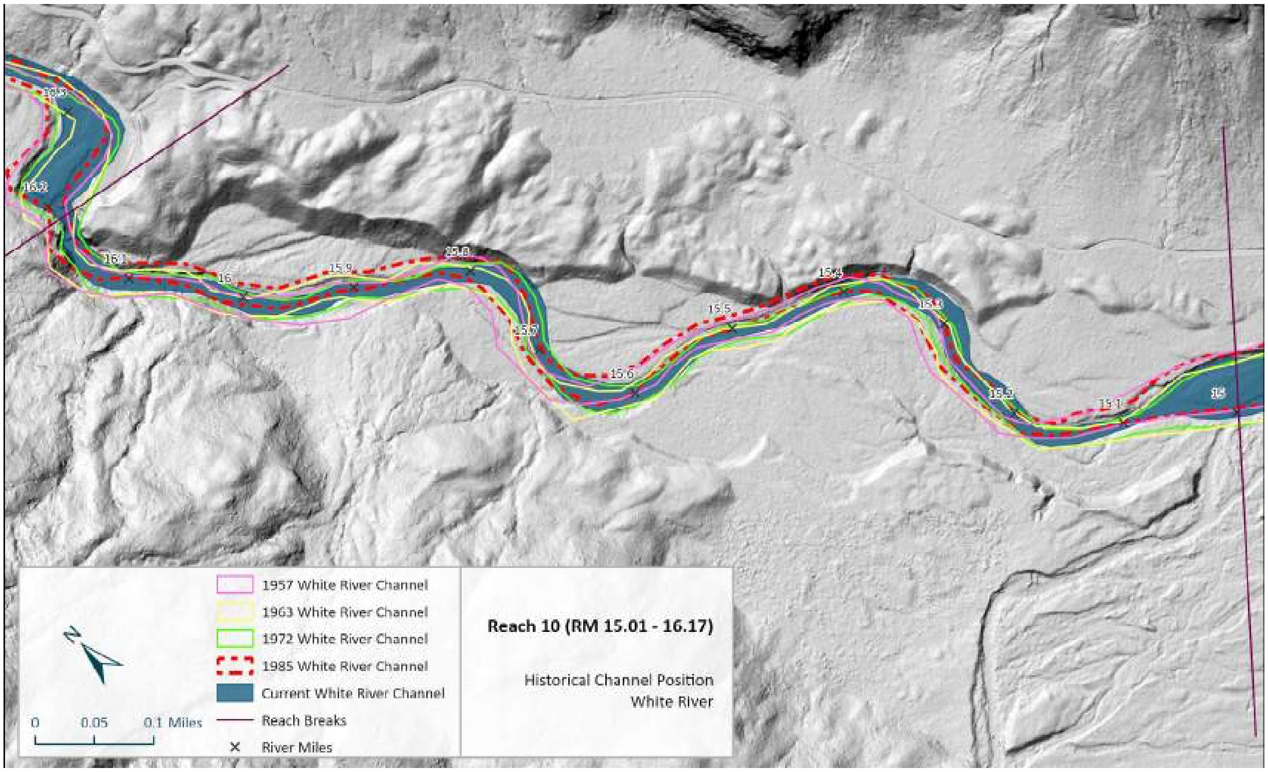

Figure 179. White River Reach 10: Map of channel alignments digitized from historical photos (1957-2023).

Sediment sources to the channel in Reach 10 include inputs transported from upstream reaches, tributaries, and adjacent hillslopes and terraces. The adjacent hillslopes and terraces contribute alluvium and colluvium ranging in size from sand to large boulders (Figure 181). Lateral processes, including channel widening as high energy systems contact boulder lag, also generate material from floodplains. Based on exposed banks, floodplains are composed of a boulder-cobble base overlain by gravels and sand that is topped with developing soils. Floodplain and terrace soils upstream of RM 15.4, and terrace soils downstream of RM 15.4 are described as gravelly fine sandy loam, whereas floodplain soils downstream of RM 15.4 are described as stony fine sandy loam (Natural Resources Conservation Service, 2007).

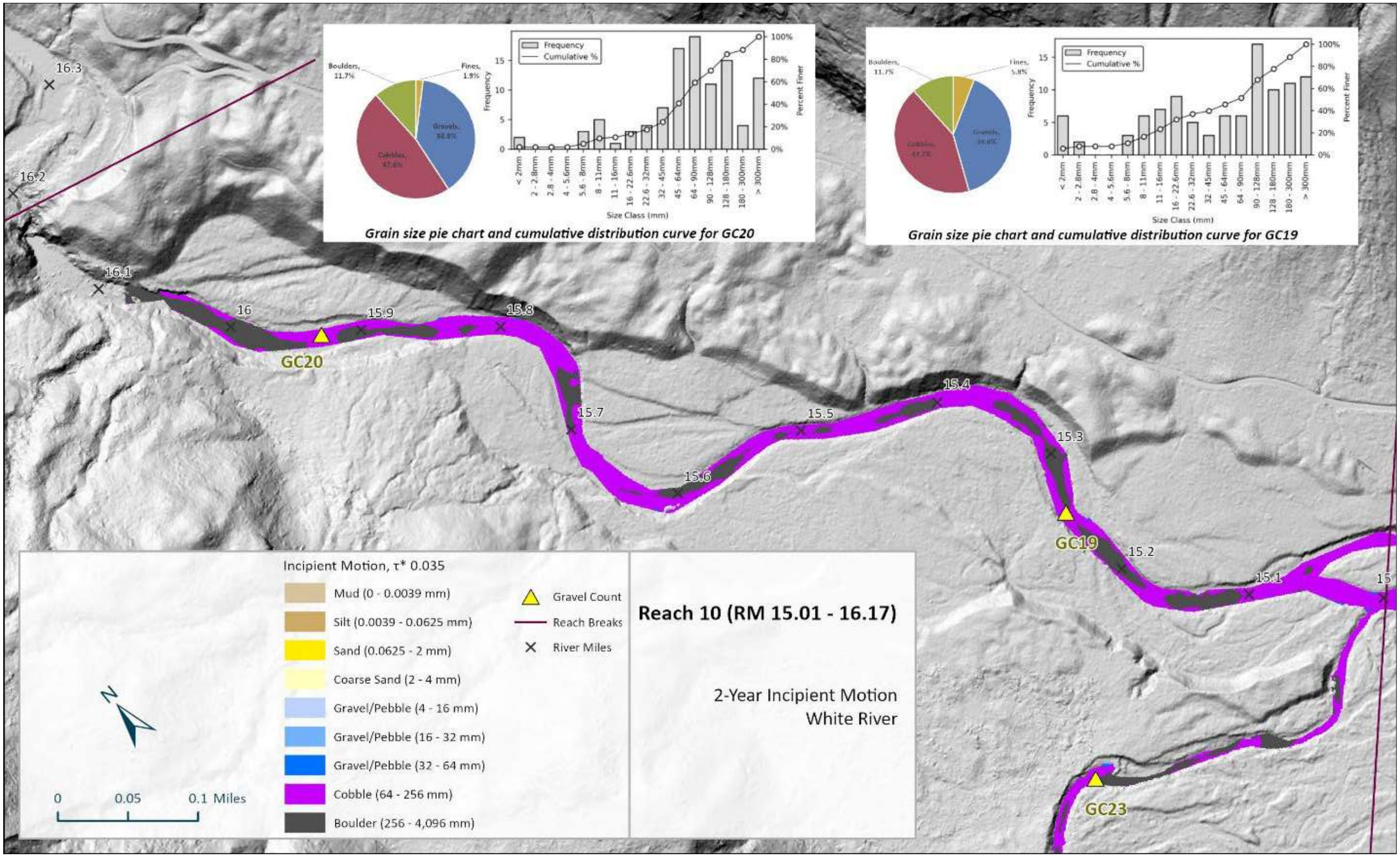

Figure 180. White River, Reach 10: incipient motion analysis results map (estimated grains size mobility at the 2-yr modeled discharge) and grains size distribution of two (GC 19 and GC 20) pebble counts.

Figure 181. Left: Gravel-cobble accumulation in hydraulic refuge downstream of large boulder, at RM 15.33 (August 1, 2024). Right: Exposed terrace bank at RM 15.77 with direct contributions to the channel (August 1, 2024).

3.10.3 Large Wood Material

A total of 104 pieces of large woody material (LWM) and 7 log jams (accumulation of ≥ 10 LWM) were observed in the channel during the Habitat Assessment (Appendix A) (See Figure 182). Of the 104 pieces, 51 are considered Quality Large Wood (QLW); 17 classified as large size class (≥ 20-inches diameter and > 35-feet long); and 34 as medium size class (12 to 20-inch diameter and at least 35-feet long). All 7 log jams in Reach 10 had multiple pieces of QLW. Although LW and LW jams are present within Reach 10, they generally exhibit little geomorphic influence on the channel (Figure 183). This is likely due to high energy flow hydraulics capable of mobilizing LWM and jams. Only very large trees are able to influence geomorphic processes or act as key logs for maintained jam function. In the field, logs greater than 36-inch diameter wedged into boulders or attached to the bank were noted as a sufficient size to be effective. The highest functioning jam in Reach 10 is a large apex jam located at the upstream end of the vegetated island at RM 15.05 (Figure 183). This jam maintains a large gravel-cobble bar, a long pool extending upstream, and persistence of the downstream mid-channel island. With few exceptions, the vegetation on adjacent surfaces to the channel within Reach 10 is second-growth conifers that provide effective racking and temporary influences. Key logs (> 36-inch diameter) sufficiently effective to influence and maintain channel complexity are lacking throughout the reach.

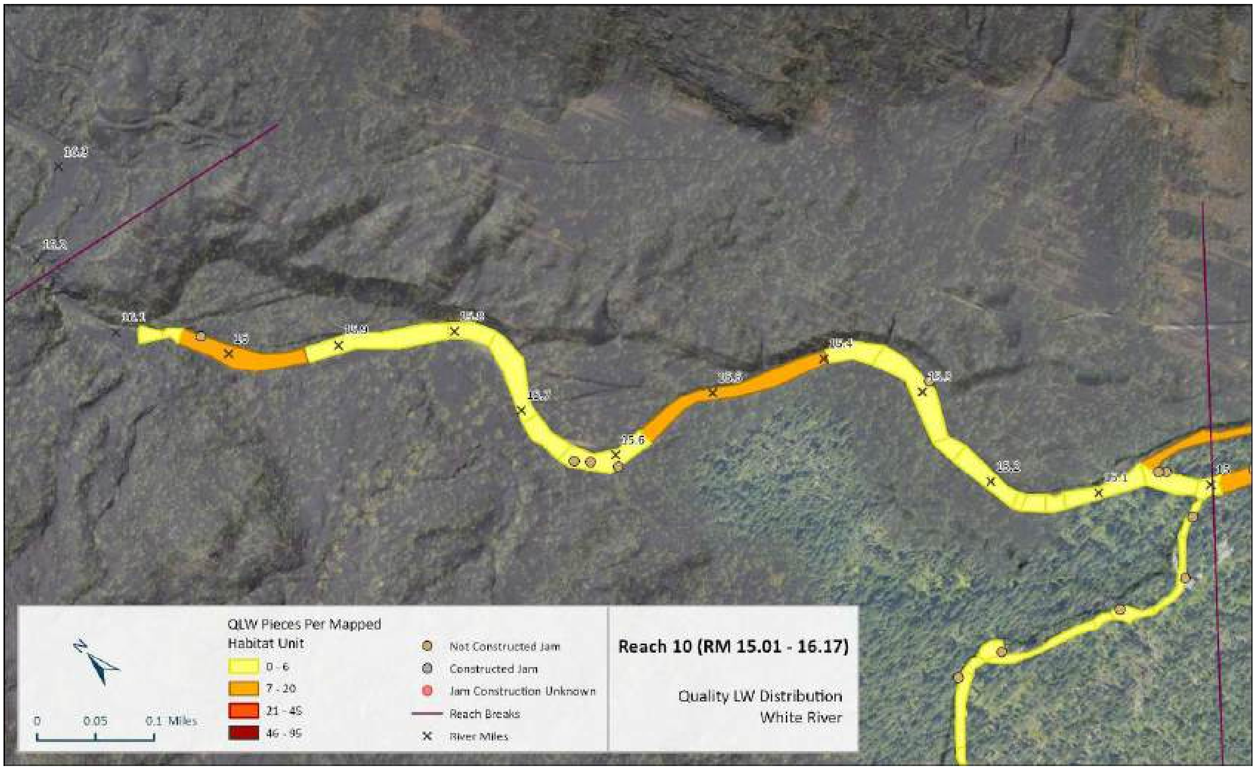

Figure 182. White River, Reach 10: Quality large wood (QLW) distribution maps and surveyed habitat units (2024). QLW count does not include pieces in jams.

Figure 183. Left: Large wood atop boulders providing minimal geomorphic influence at low flows, at RM 15.99 (July 01, 2024). Right: Apex jam upstream of mid-channel island, at RM 15.05 (August 1, 2024).

3.10.4 Vegetation

Riparian and floodplain vegetation in Reach 10 is dominated by well-established conifer forest (Figure 184). The overstory consists of western redcedar, grand fir, and Douglas-fir. Historical logging reduced the size of trees on floodplain and terrace surfaces. The vegetation height analysis map shows pockets of large trees along the banks of the channel located on river-right from ~RM 15.65 – 15.9, and river-left from RM 15.8 – 15.9 (Figure 185). Mature old-growth trees are rare in Reach 10 today. The presence of old-growth stumps confirms pre-logging conditions likely consisted of valley-wide old-growth forests. A higher abundance of old-growth trees was observed upstream of the assessment area within the Glacier Peak Wilderness. The dense understory is dominated by cedar, alder, blueberry, and huckleberry. Overstory and understory vegetation occupy the banks along the channel, with the exception of the bedrock-confined portion upstream of RM 16.1, and the hillslope contact near RM 15.8. Vegetation provides partial shade to the White River channel throughout Reach 10. The vegetation of the adjoining hillslope adjacent to the channel is similar to floodplain and terrace vegetation.

Figure 184. Example of Reach 10 riparian and floodplain vegetation (15.67) (August 1, 2024).

Figure 185. White River, Reach 10: Map of vegetation height classification analysis (LiDAR – based analysis).

Figure 186. White River, Reach 10: Map of aerial imagery for vegetation identification.

3.10.5 Human Alterations

Reach 10 is entirely within public land and there are no anthropogenic built features that interact with the channel. White River Road and the White River Falls Campground are both located on hillslopes above the valley floor (See Figure 187). They currently impose minimal to no to impact on the channel function other than localized floodplain vegetation density reduction. Historical logging activities and removal of old-growth forests from the floodplain impacted channel process by removing vegetation and, for many decades, reducing the availability of effective wood inputs to the channel. A lack of effective large wood inputs very likely reduced habitat complexity, sediment retention, and functional dynamics. There is no current evidence of recent logging in the reach. No fish-passage barriers currently exist in the mainstem channel in Reach 10, downstream of White River Falls.

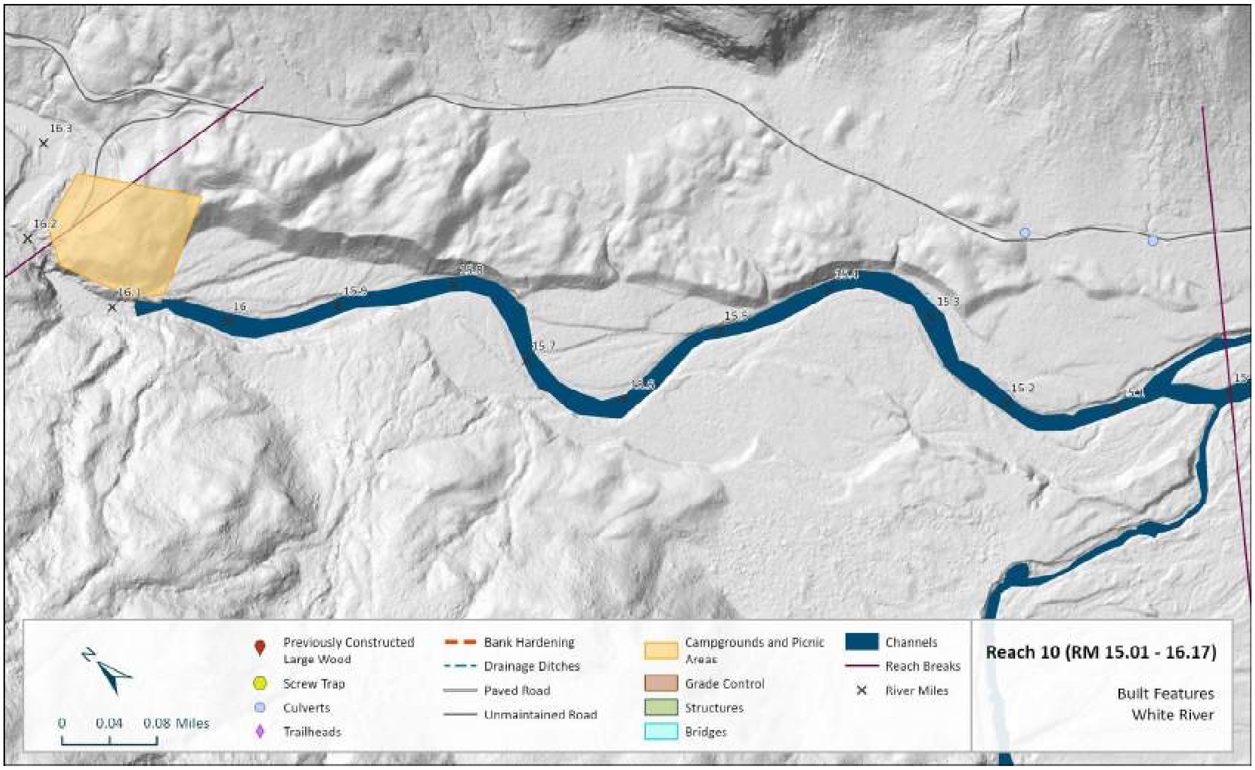

Figure 187. White River, Reach 10: Mapped anthropogenic features.

3.10.6 Recommended Actions

Recommended actions in Reach 10 are primarily focused on helicopter large wood placement and tree tipping to improve channel conditions. Large wood structures would increase the frequency of hydraulic connection of existing low swales and floodplain surfaces. Machine-based excavation of side-channel inlets may be possible in the downstream portion of the reach near the Grasshopper Campground; in upstream areas, machine-based work is challenging due to access limitations.

3.11 NAPEEQUA RIVER REACH 1 (RM 0-1.7)

3.11.1 Overview

Reach 1 of the Napeequa River is 1.7 river miles long and extends from the White River (near White River RM 12.4) to the waterfall at RM 1.7. The gradient flattens considerably below the waterfall, going from over 5% in Reach 2 to less than 1% in Reach 1 (Figure ***188***, Table 19). The valley floor widens moving downstream from RM 1.7, although disconnected terraces cover the majority of the valley floor from RM 0.6-1.7. Downstream of RM 0.6, the valley floor consists primarily of medium and high floodplain surfaces, although riprap limits lateral migration throughout much of the lower portion of the reach. The channel is sinuous (S = 1.63) with a primarily single-thread meandering planform. Mid-channel bars maintaining split flow are more heavily concentrated in the upstream portion of the reach where human impacts are lower. The average bankfull width, measured during the Habitat Assessment (Appendix A) is 66 feet. Low floodplain surfaces (inundated ~ 1-5 years) exist as discontinuous strips, generally on the inside of meander bends. Anthropogenic features include riprap bank hardening to protect built structures on the valley floor, and the bridge over the mouth of the Napeequa River.

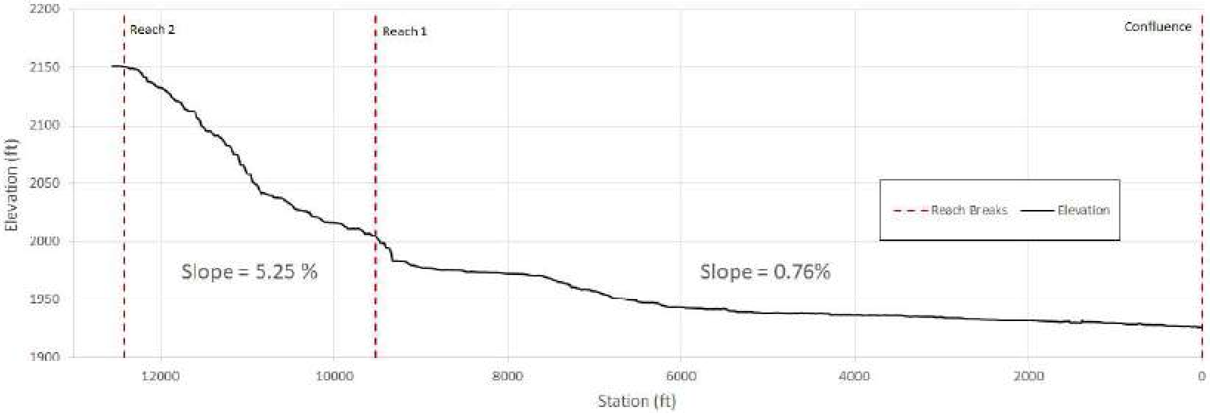

Figure* 188*. Longitudinal profile for the Napeequa River, including reaches 1 and 2.

Figure 189. Representative photo of Napeequa River in Reach 1, looking upstream from RM 0.2. Large wood and plentiful sediment supply support channel complexity (September 11, 2024).

Table 19. Napequa River Reach 1 descriptive geomorphic metrics.

Metric	**Value**
Reach Length (miles)	1.7
River Miles	0-1.70
Stream Gradient	0.76%
Sinuosity	1.63
Dominant Channel Habitat Unit Type	Pool
Average Bankfull Width (feet)	66
Confinement	Partially Confined
Dominant Substrate	Gravel
Bank Stability/Channel Migration	At Risk *(See Appendix B Section 3.2)*
Vertical Channel Stability	At Risk *(See Appendix B Section 3.2)*

3.11.2 Channel and Floodplain Geomorphology

Reach 1 contains a low gradient, meandering channel with a pool-riffle-glide sequence that includes extended riffles that supported abundant sockeye salmon spawning at the time of the assessment (September, 2024). A map of the geomorphic surfaces and channel habitat units is provided as Figure 191. The Habitat Assessment (See Appendix A) recorded 67% of the habitat as pool, 19% as riffle, 10% as glide, and 4% as side channel. Side channels split flow around vegetated islands from RM 0.26-0.31 and RM 1.63-1.66. The channel is primarily single threaded and meandering. The valley widens considerably at RM 1.7, as the Napeequa River leaves a steep, confined canyon (Figure 190). The channel is confined by the adjacent hillslopes and several fans on river right, and terraces on both sides of the river from RM 0.6-1.7, and is briefly in contact with bedrock on river left just downstream of the falls at RM 1.7 (Figure 191). Downstream of RM 0.6 the channel is not confined by natural features, although riprap considerably impacts lateral processes. Downstream of RM 0.6, the channel likely historically wandered across its broad alluvial fan; however, the present channel is locked in place before it flows into the White River underneath a bridge. There were no tributaries observed in Reach 1 during the assessment.

Active floodplain surfaces are discontinuous, often forming on the insides of meander bends, and are vegetated primarily with willow (Figure 191). Terraces cover surfaces adjacent to the Napeequa channel upstream of RM 0.6. Downstream of RM 0.6, terraces transition to high, and then medium floodplain surfaces moving downstream. Floodplain soils are typically described as loamy fine sand derived from alluvium, and the hillslopes. The hillslopes consist of sandy loam derived from volcanic and glacial inputs, and rock outcrops.

Figure 190. Falls on the Napeequa River at RM 1.7. Downstream of the falls, the channel transitions from a confined canyon to a wide valley (September 10, 2024).

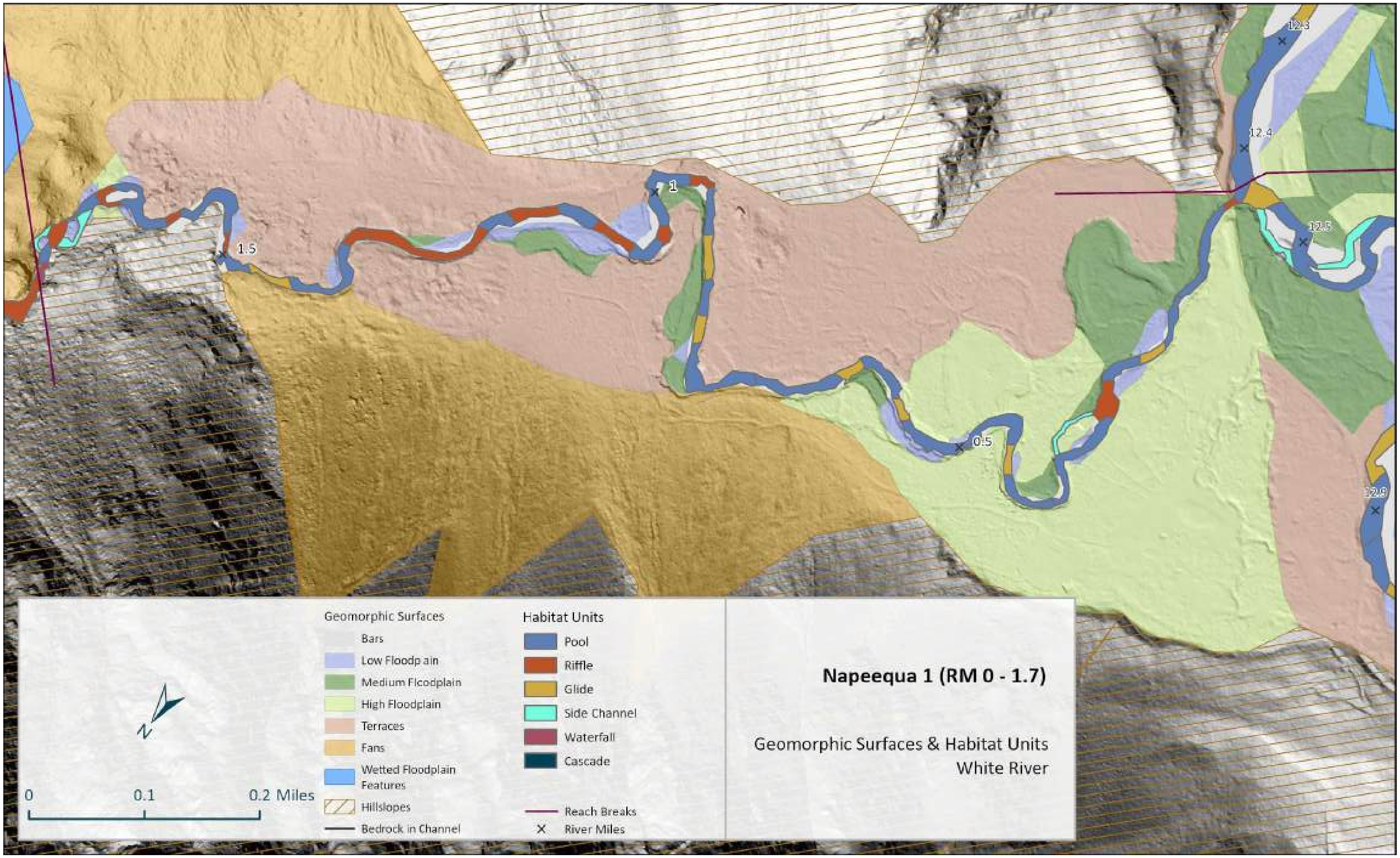

Figure 191. Napeequa River Reach 1 geomorphic surfaces and habitat units.

Channel substrate in Reach 1 is primarily gravel-cobble alluvium (Figure 192) except for a section from RM 1.29-1.48, where angular cobble-to-boulder sized colluvially-sourced sediments line the channel (Figure 192). Wolman Pebble Counts (Wolman, 1954) were conducted on representative riffle crests in Reach 1 at RM 0.57 and RM 1.11. Gravels 45-64 mm in diameter were the dominant size class at both pebble counts. Gravels (2-64 mm diameter) accounted for >50% of sediments. Boulders were absent from the downstream pebble count but present at the upstream pebble count. Fine sediments (< 2mm) were present at the upstream pebble count location only. Grain size of sediments typically decrease from upstream to downstream in Reach 1. The data from the two pebble counts are plotted on a map (Figure 193) of the Reach 1 incipient motion analysis results (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.9.4). The analysis indicates that at the 2-yr modeled discharge, the channel's shear stress is capable of mobilizing cobbles and even boulders in some zones in the upper portion of the reach and gravels throughout the lower portion of the reach.

Coarse sediment sources within Reach 1 include a series of debris fans at the base of the river right hillslopes, as well as streambanks eroding due to active lateral migration and material transported into the reach from upstream. Exposed streambanks were typically composed of a gravel-cobble base topped by sandy loam.

Figure 192. Left: Representative photograph of Napeequa River gravel-cobble bar substrate, RM 0.95 looking downstream (September 11, 2024). Right: Angular cobble-boulder colluvium substrate at RM 1.38 (September 10, 2024).

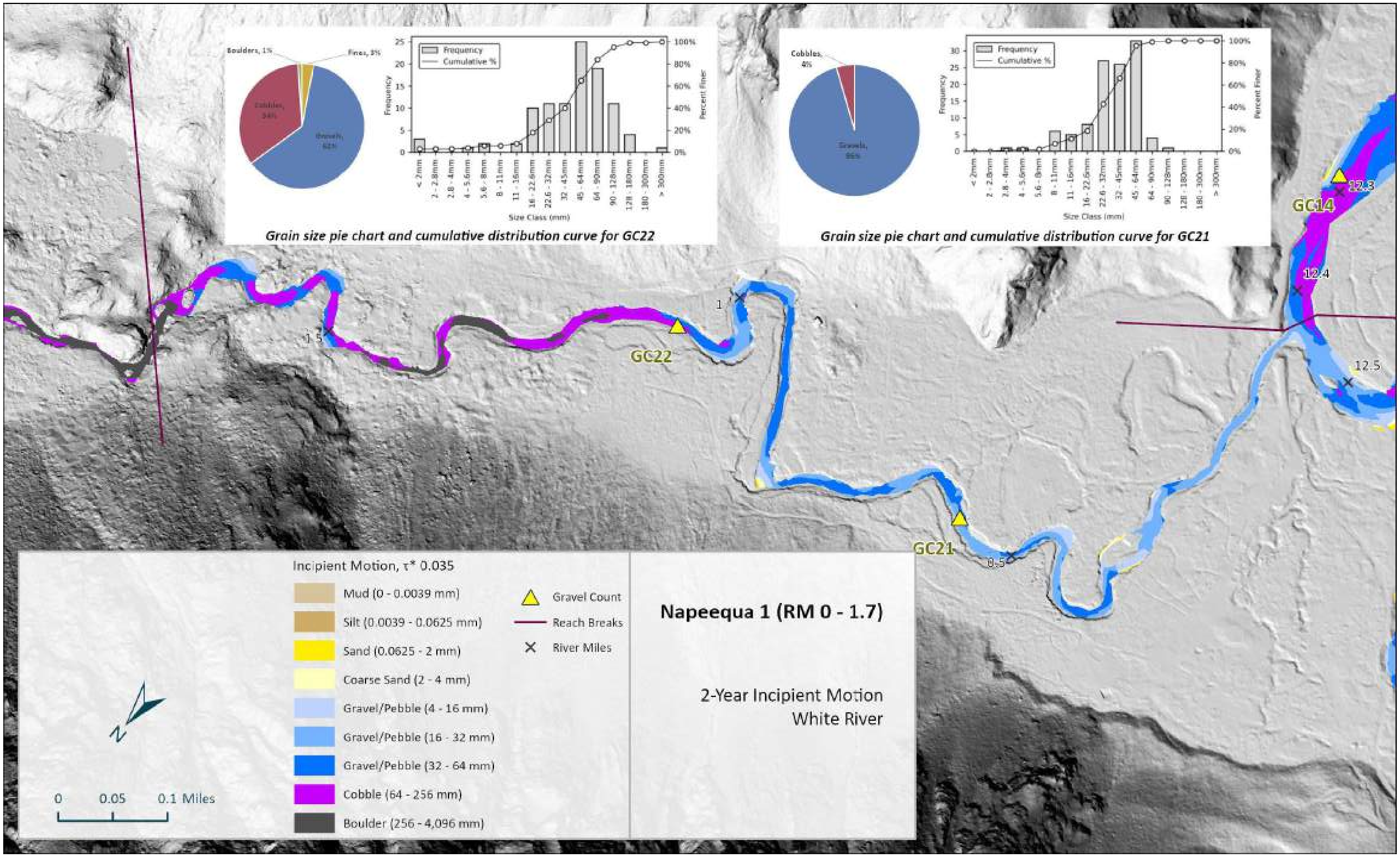

Figure 193. Napeequa River Reach 1: incipient motion analysis results map (estimated grains size mobility at the 2-yr modeled discharge) and grains size distributions of two (GC 21 and GC 22) pebble counts.

3.11.3 Large Wood Material

A total of 258 pieces of large woody material (LWM) and 25 log jams (accumulation of >3 LWM) were observed in the channel during the survey (August 2024) (Figure 194). Of the 258 pieces, 100 are considered Quality Large Wood (QLW); 33 classified as large size class (>20-inches diameter and >35-feet long); and 67 as medium size class (12 to 20-inch diameter and at least 35-feet long). Of the 25 wood jams, 19 contained multiple pieces of QLW. During the assessment, logs greater than 24 inches diameter were noted as sufficient size to be effective. Wood in Reach 1 is responsible for creating complex habitat by promoting pool scour sediment sorting, and split-flow, and providing cover (Figure 195). Large wood contributions include locally recruited trees sourced from eroding banks, and transported large wood sourced from upstream.

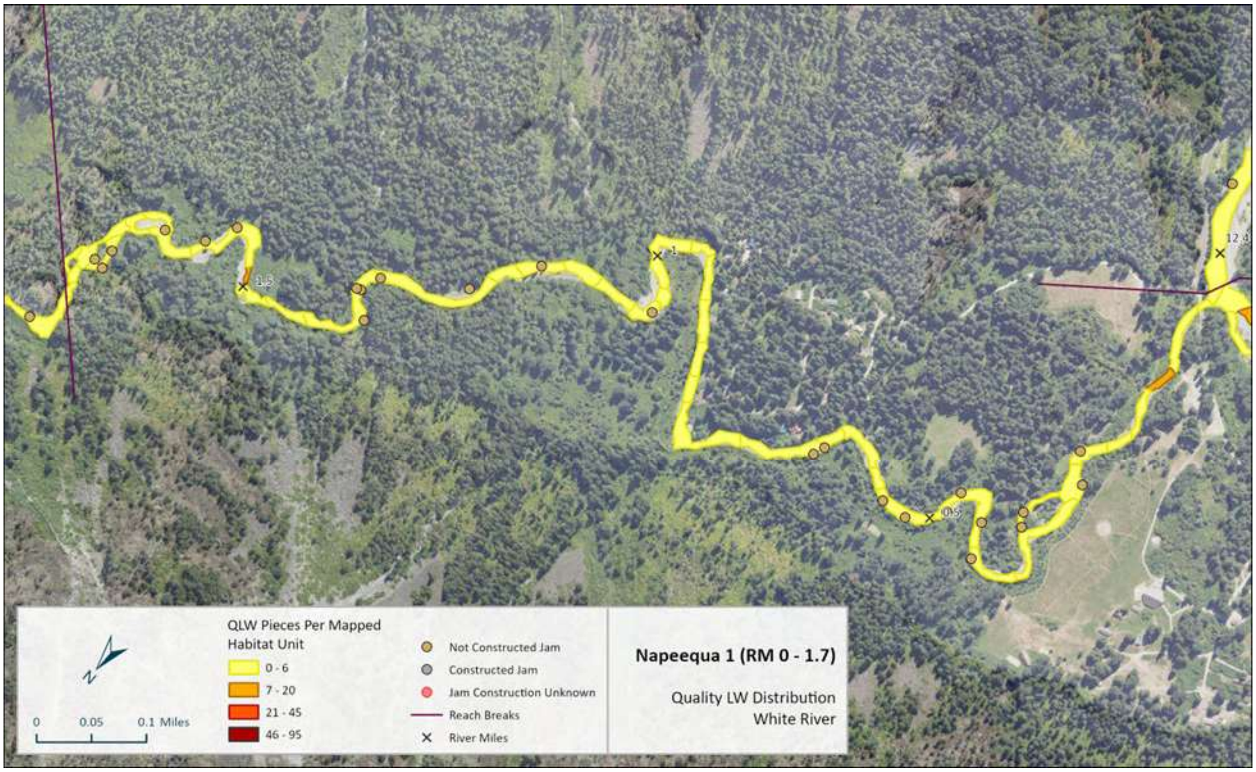

Figure 194. Napeequa River Reach 1 quality LW distribution. QLW count does not include pieces in jams.

Figure 195. Sediment sorting associated with large wood in Napeequa channel, RM 0.58 (September 11, 2024).

3.11.4 Vegetation

Vegetation on the Napeequa River valley floor in Reach 1 primarily consists of second-growth western redcedar and Douglas-fir, and vine/Douglas maple on medium and high floodplain surfaces and terraces, and dogwood, alder, and willow on low-to-medium floodplain surfaces and riparian areas. Recruitment potential of larger trees to the channel is higher in the upstream portion of the reach. Downstream of RM 1, a combination of bank armoring and forest clearing limit large tree availability and recruitment potential (Figure 196). Vegetation on the adjoining hillslopes consists primarily of conifers interspersed with rocky outcrops devoid of vegetation.

Figure 196. Map of Napeequa Reach 1 vegetation height.

Figure 197. Napeequa River, Reach 1: Map of aerial imagery for vegetation identification.

3.11.5 Human Alterations

Human alterations to the Napeequa River channel and valley bottom in Reach 1 are primarily concentrated downstream of RM 1. Upstream of RM 1, a trail on river right connects to the channel at the falls (RM 1.7), but does not inhibit channel or floodplain processes. Additionally, logging was observed downstream of RM 1.27. The lower portion of Reach 1, downstream of RM 1, is impacted by development, and bank armoring to protect structures on the river left and river right floodplain (Figure 199). The river left floodplain contains a dense cluster of structures between RM 0.62 and RM 0.96. Riprap protects the river left bank throughout the artificially straightened stretch of river from RM 0.8-0.96, and intermittently from RM 0.62-0.8. Additional bank protection was observed on the outside of the meander at RM 0.35 (river right), intermittently on both sides of the channel downstream of RM 0.2, and at the base of the bridge over the Napeequa River at the mouth (Figure 199). The river-right floodplains are mostly clear-cut downstream of RM 0.35, and riparian vegetation has been cleared on private properties on river left from RM 0.62-0.96. Recent re-planting was observed on floodplains downstream of RM 0.35. A corrugated 2.5-foot culvert draining a historical channel on river left enters the Napeequa River at RM 0.1 (Figure 200). This and other historical channel features show evidence of a past channel condition that was more sinuous than the present channel which is straightened and protected against lateral migration. A series of cables attached to a steel tower cross the river at RM 0.17 (Figure 200).

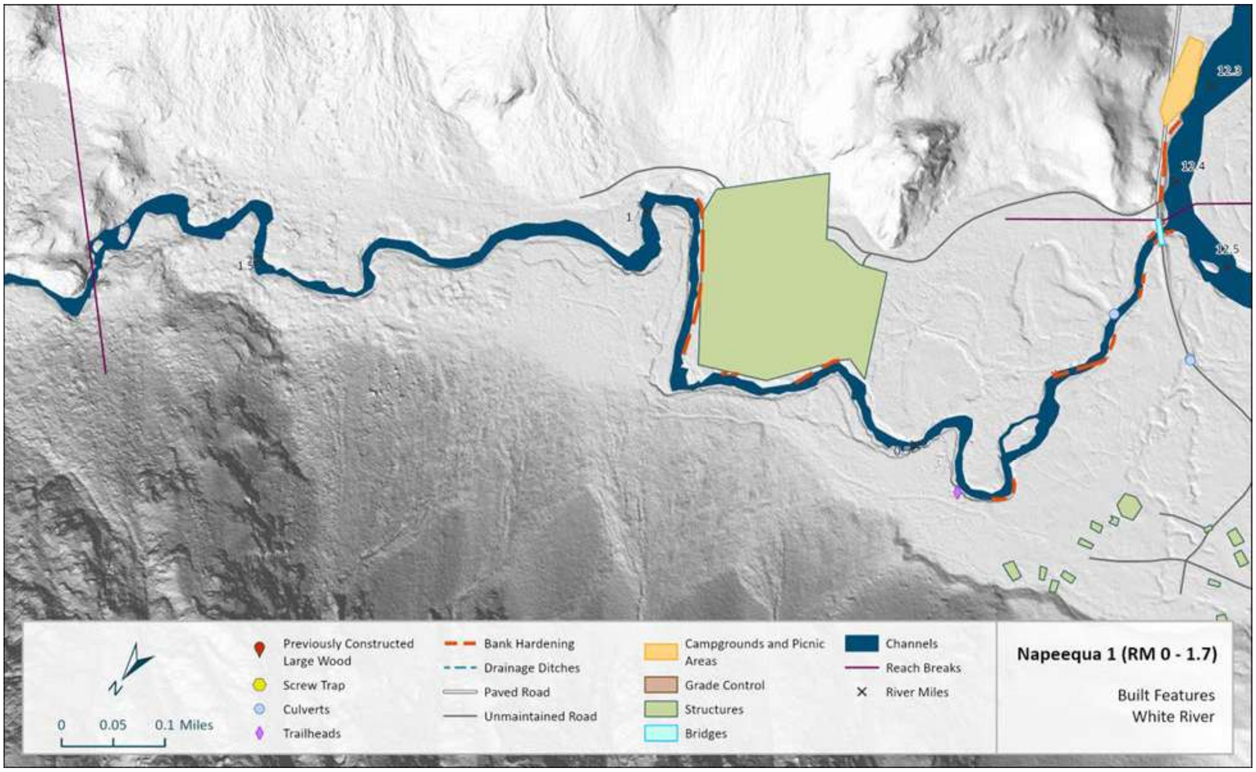

Figure 198. Napeequa River Reach 1 anthropogenic features. The structure polygon is highlighting a residential development area.

Figure 199. Left: Bank protection (riprap) at RM 0.05 on river-right (September 11, 2024). Right: White River Road bridge over mouth of Napeequa River and associated bank protection (September 3, 2024).

Figure 200. Left: Culvert draining historic channel on river left, entering the Napeequa River at RM 0.1 (September 11, 2024). Right: Cables over Napeequa River at RM 0.17 (September 11, 2024).

3.11.6 Recommended Actions

Recommended actions in Reach 1 of the Napeequa River include large wood placement, activation of historical channel areas, revegetation, and modification of existing anthropogenic features. Channel inlets could be excavated in the lower portion of the reach to encourage side channel activation, or to redirect mainstem flow into more complex and sinuous flow paths. Activation of the large historical channel just upstream of the Napeequa River mouth would require removal of existing anthropogenic features including channel plug, culvert, and bank hardening. Large wood additions to the mainstem channel and to existing bank armoring throughout the reach would improve/enhance aquatic habitat and channel complexity and could encourage flow into newly activated channels. Large wood placements in the upstream portion of the reach will likely be limited to helicopter additions and tree tipping due to access constraints. Revegetation of open field areas in the lower portion of the reach would improve long-term riparian conditions and wood recruitment potential. Existing infrastructure within Reach 1 will likely limit full recovery.

3.12 NAPEEQUA RIVER REACH 2 (RM 1.7-2.2)

3.12.1 Overview

Reach 2 of the Napeequa River is 0.5 river miles long and extends from the falls at RM 1.7 to RM 2.2 (Table 20). The gradient is much steeper (>5%) in this reach compared to Reach 1 (<1%) (Figure ***188***). The channel is laterally confined by adjacent hillslopes and bedrock exposures as it flows through a steep, narrow canyon. The channel is multithreaded, with several long side channels splitting flow around vegetated surfaces, and undergoes a marked transition from bedrock cascade to extended boulder riffle approximately halfway through the reach. The channel has low sinuosity (S = 1.15) and floodplain surfaces are discontinuous and narrow compared to those downstream in Reach 1. The average bankfull width, measured during the Habitat Assessment (Appendix A) is 40 feet. Anthropogenic features were not observed during the assessment in Reach 2.

Fish were observed attempting to pass over the falls at the time of the survey, although success rate is unknown. One fish was witnessed attempting to pass the cascade section in Reach 2, although success rate is also unknown. Fish passability was not specifically evaluated as a part of this assessment; however, WDFW reports the lower falls as a complete barrier (site ID: 890171), and the upper falls as a partial barrier (site ID: 896044) (WA Dept of Fish & Wildlife, 2024).

Figure 201. Representative photographs of Napeequa River in Reach 2. Left: long boulder riffle RM 1.9, looking upstream (September 10, 2024). Right: bedrock cascade at RM 2.1, viewed from river right (September 10, 2024).

Table 20. Napeequa River Reach 2 descriptive geomorphic metrics.

Metric	Value
Reach Length (miles)	0.5
River Miles	1.70-2.20
Stream Gradient	5.95%
Sinuosity	1.15
Dominant Channel Habitat Unit Type	Riffle
Average Bankfull Width (feet)	40
Confinement	Partially Confined
Dominant Substrate	No Gravel Count Performed
Bank Stability/Channel Migration	Adequate *(See Appendix B Section 3.2)*
Vertical Channel Stability	Adequate *(See Appendix B Section 3.2)*

3.12.2 Channel and Floodplain Geomorphology

The Reach 2 reach average gradient (5.95%) is significantly higher than that of Reach 1, and over two times that of any White River reach within the assessment area. The channel has low sinuosity, and is multi-threaded, with side channels flowing around vegetated surfaces throughout most of the reach upstream of RM 1.85. A map of the geomorphic surfaces and channel habitat units is provided as Figure 202. The channel is confined by bedrock and hillslopes upstream of RM 2. Downstream of RM 2, hillslopes confine the channel on river right, and terraces limit lateral migration on river left. The break in confinement at RM 2 is associated with a decrease in slope, and transition from bedrock cascade to boulder riffle moving downstream. The Habitat Assessment (See Appendix A) recorded 50% of the habitat as riffle, 45% of the habitat as side channel, and 5% of the habitat as pool in Reach 2. An unnamed perennial tributary meets the Napeequa River channel on river left just upstream of Reach 2 at RM 2.2. Twin Lakes Creek, an additional perennial tributary, connects the Napeequa River to a large pond on river left at RM 1.83. The pond is connected to the Napeequa River at low flows, and likely provides off-channel habitat. Further downstream, a spring contributes flow to the channel at RM 1.76.

Low floodplain surfaces (inundated ~1-5 years) are infrequent, and occur in small pockets in the lower half of the reach (Figure 202). Medium (inundated ~5-10 years) and high floodplain (inundated ~10-100+ years) surfaces exist on vegetated islands. Terraces are present on river left throughout much of the reach. Floodplain soils are typically described as loamy fine sand derived from alluvium, and the hillslopes. The hillslopes consist of sandy loam derived from volcanic and glacial inputs, and rock outcrops.

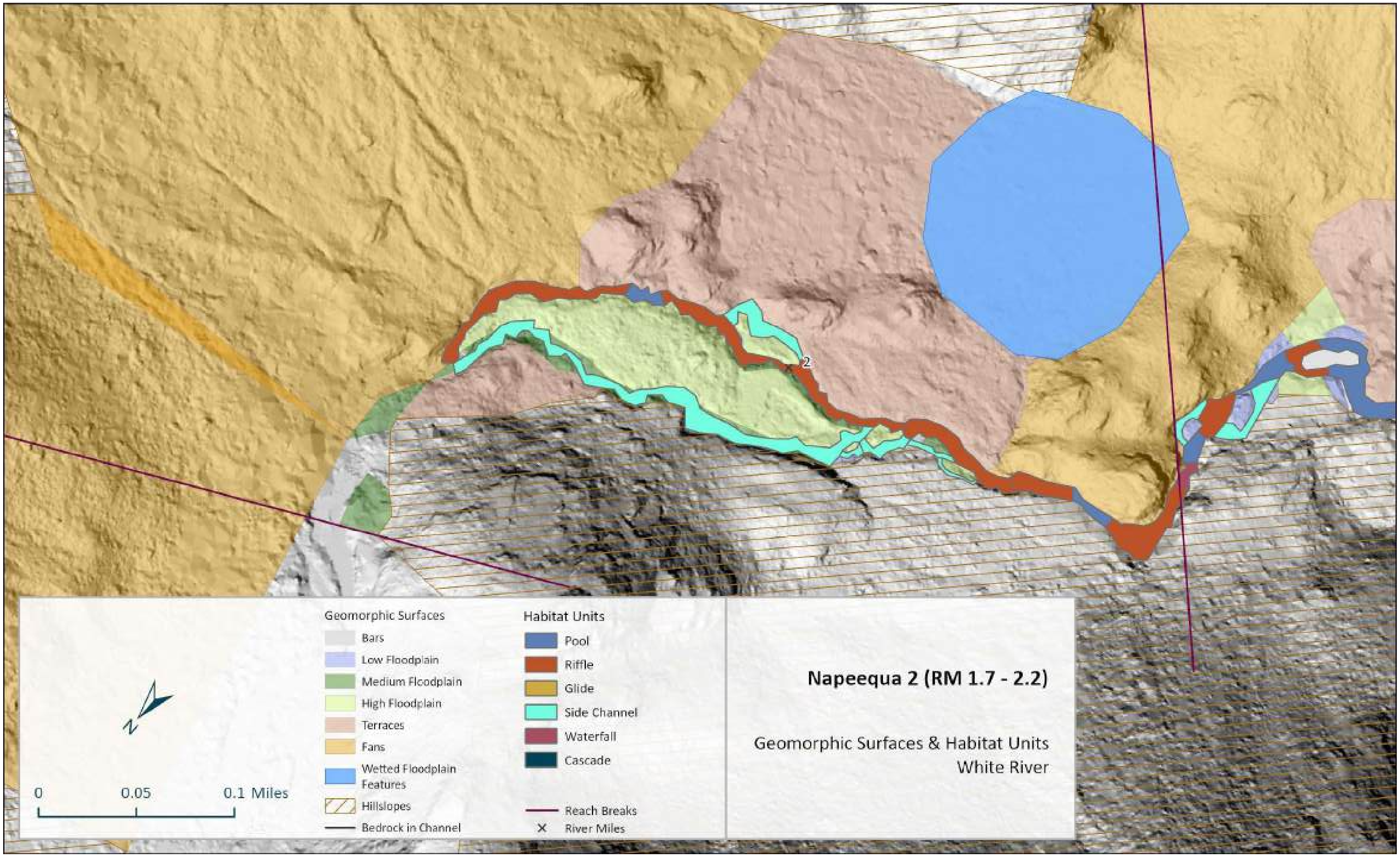

Figure 202. Napeequa River Reach 2 geomorphic surfaces and habitat units.

Channel substrate in Reach 2 consists of bedrock and boulders upstream of RM 2, and primarily boulders downstream of RM 2. Gravels and cobbles were observed in backwater eddies at boulders, and on narrow bars at channel margins (Figure 203). Coarse sediments in Reach 2 are sourced from the hillslopes, and from undercutting and erosion of stream banks (Figure 203).

A Wolman Pebble Count (Wolman, 1954) was not conducted in Reach 2 due to a lack of representative surfaces suitable for a pebble count. A map of the incipient motion analysis results (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.9.4) is presented for this reach in Figure 204. The analysis indicates that at the 2-yr modeled discharge, the channel’s shear stress is capable of mobilizing boulders and cobbles throughout the reach.

Figure 203. Left: Gravel deposition in backwater eddy, RM 2.1 (September 10, 2024). Right: Cobble-boulder sediment eroding from stream banks on river-right side of vegetated island at RM 2.17 (September 10, 2024).

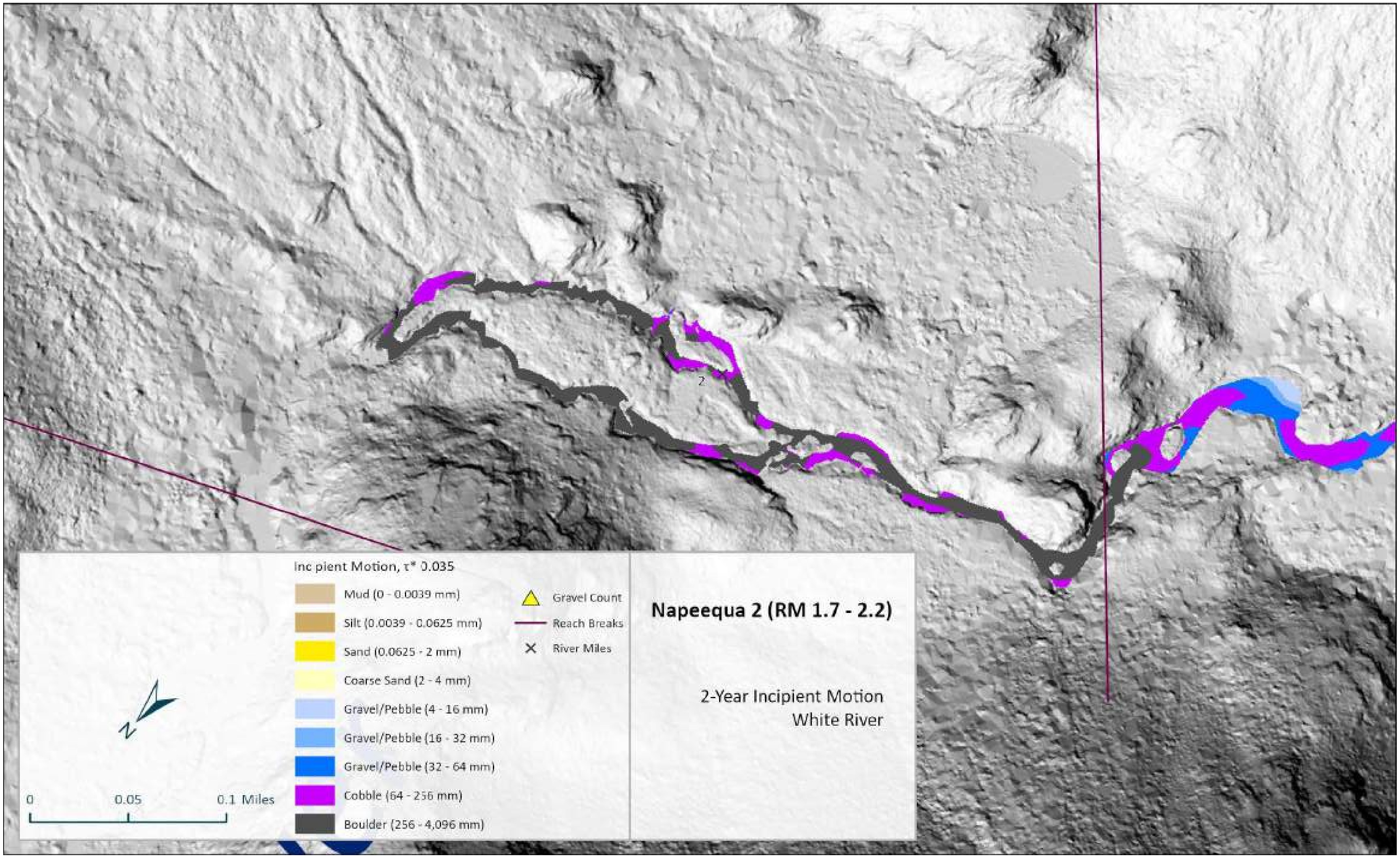

Figure 204. Napeequa River Reach 2: incipient motion analysis results map (estimated grains size mobility at the 2-yr modeled discharge).

3.12.3 Large Wood Material

A total of 128 pieces of large woody material (LWM) and 14 log jams (accumulation of >3 LWM) were observed in the channel during the survey (August 2024) (Figure 205). Of the 128 pieces, 65 are considered Quality Large Wood (QLW); 17 classified as large size class (>20-inches diameter and >35-feet long); and 48 as medium size class (12 to 20-inch diameter and at least 35-feet long). Of the 14 wood jams, 13 contained multiple pieces of QLW. Large wood pieces greater than 12-18 inches, wedged between boulders, are effective in influencing geomorphic processes. Large wood pieces wedged between boulders maintain a wood-forced step-pool sequence on the river left channel just upstream of RM 2 (Figure 206) and create split-flow conditions near RM 1.74.

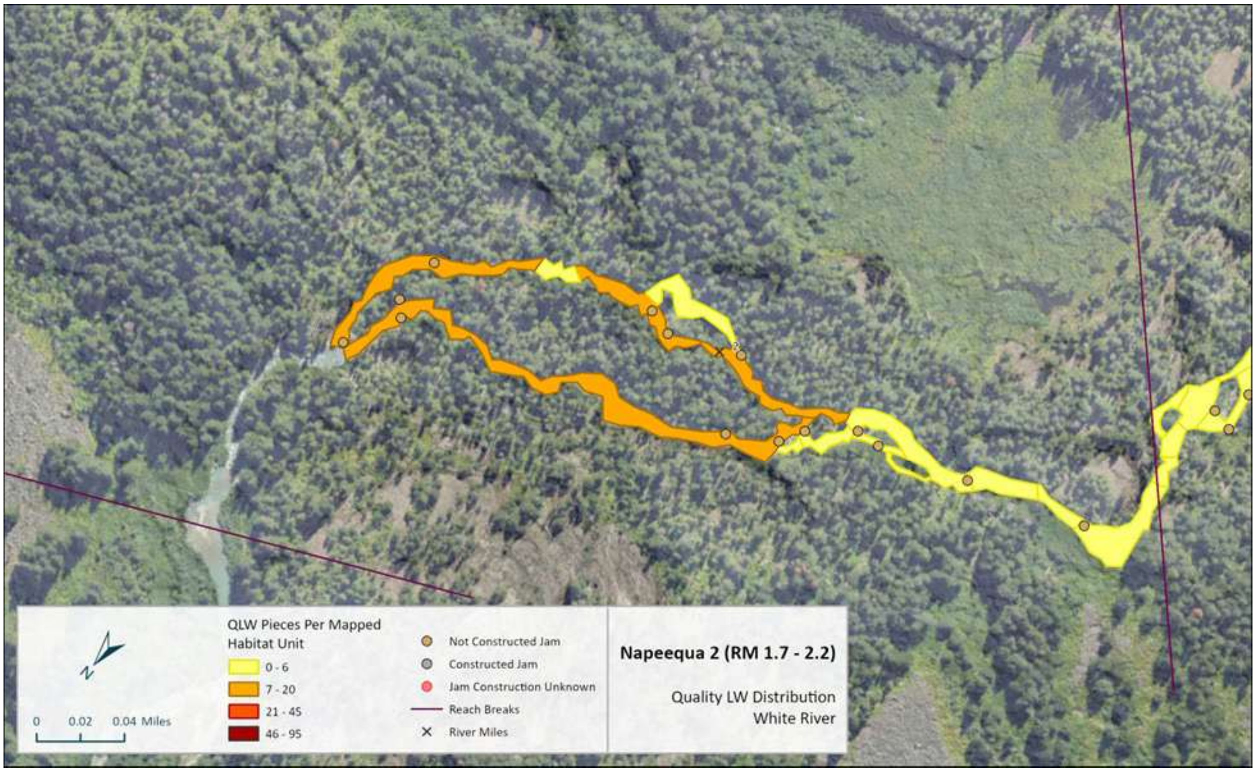

Figure 205. Napeequa River Reach 2 quality LW distribution. QLW count does not include pieces in jams.

Figure 206. Large wood maintaining pool and 3-foot grade break at RM 2.02.

3.12.4 Vegetation

Vegetation adjacent to the Napeequa River channel in Reach 2 consists of western redcedar, Douglas-fir, and vine/Douglas maple on medium and high floodplain surfaces, terraces, and hillslopes, and alder in riparian areas (Figure 207). Taller trees provide shade to the channel and a local source of large wood recruitment. Sparse old-growth western redcedar and Douglas-fir were observed on terraces and the high floodplain surface that comprises the majority of the vegetated island that spans nearly half of the reach. Overstory and understory vegetation occupy the banks along the channel throughout the majority of the reach (Figure 208).

Figure 207. Representative photograph of vegetation in Reach 2 (September 10, 2024).

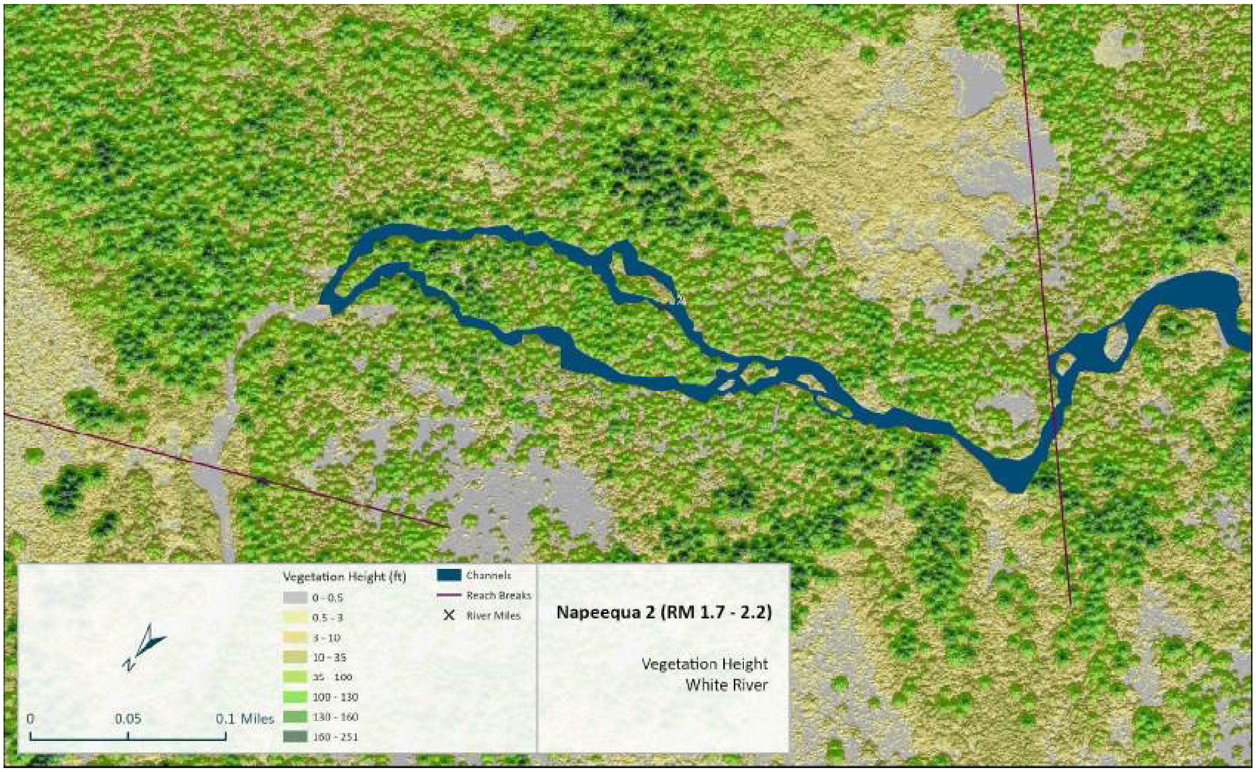

Figure 208. Map of Napeequa River Reach 2 vegetation height.

Figure 209. Napeequa River, Reach 2: Map of aerial imagery for vegetation identification.

3.12.5 Human Alterations

No anthropogenic features were observed in Reach 2 during the assessment (Figure 210). There are no active roads providing access to the Napeequa River canyon, and no artificial fish passage barriers exist in the mainstem channel.

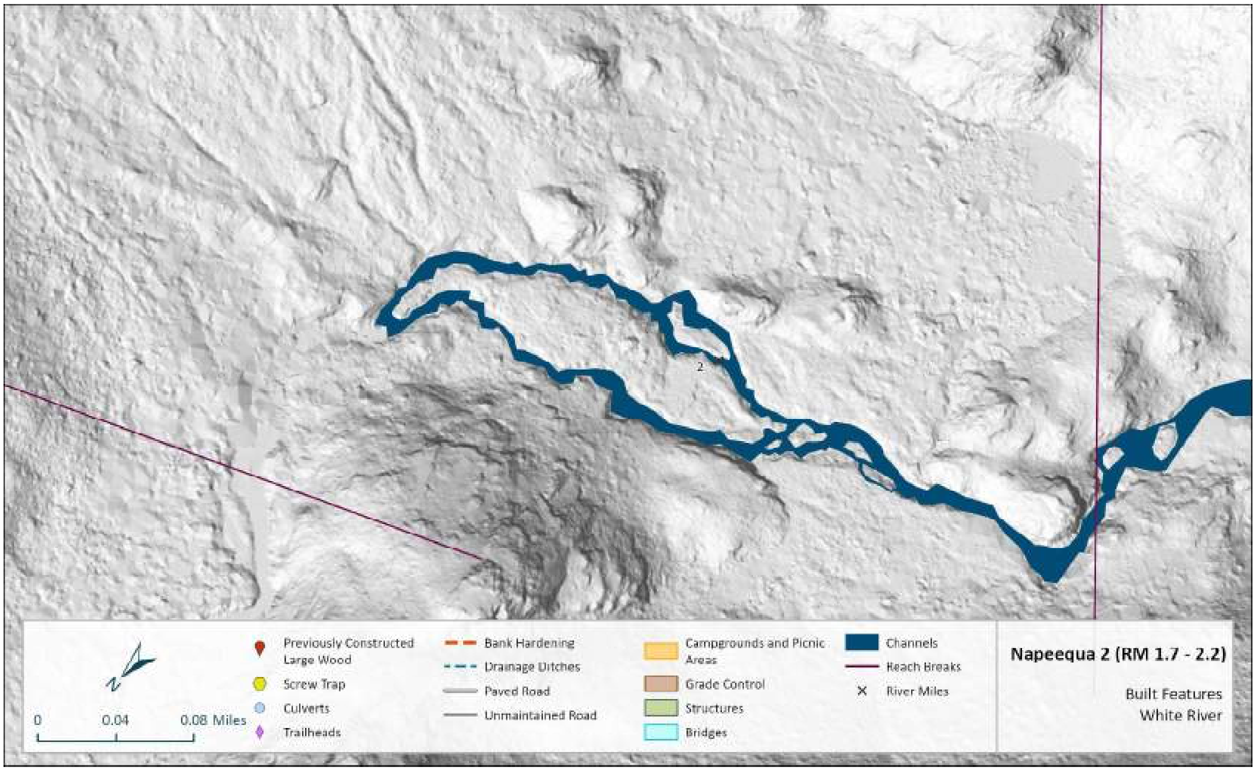

Figure 210. Napeequa River Reach 2 anthropogenic features.

3.12.6 Recommended Actions

Recommended actions in Reach 2 of the Napeequa River include large wood placements to enhance/improve channel complexity. Actions are limited to helicopter wood placement and tree tipping due to limited access to Reach 2.

3.13 PANTHER CREEK REACH 1 (RM 0-0.8)

3.13.1 Overview

Panther Creek Reach 1 is 0.8 miles long and enters the White River at RM 15.01 (Table 21). The upstream end of the reach is marked by a significant slope break, where gradient eases as Panther Creek approaches the White River valley (Figure 211). Nevertheless, the reach gradient (5.73%) is more than two times that of the steepest White River reach within the assessment area (Reach 10, 2.4%) and is similar in magnitude to that of Napeequa River Reach 2 (5.95%), the steepest overall reach within the assessment area. Reach 1 has low sinuosity (S = 1.12) due to its confinement within a bedrock canyon upstream of RM 0.4. The average bankfull width of the channel, measured during the Habitat Assessment (Appendix A) is 51 feet. Floodplain surfaces are narrow and exist only where valley width allows downstream of the bedrock-confined canyon. Low floodplain surfaces near the Panther Creek outlet are sparsely vegetated with seedling and sapling cottonwood and herbaceous vegetation. Floodplain surfaces and the Panther Creek alluvial fan are vegetated with large western redcedar, Douglas-fir, and grand fir. No anthropogenic features were observed on Panther Creek, although historical logging activity has likely impacted modern large wood recruitment.

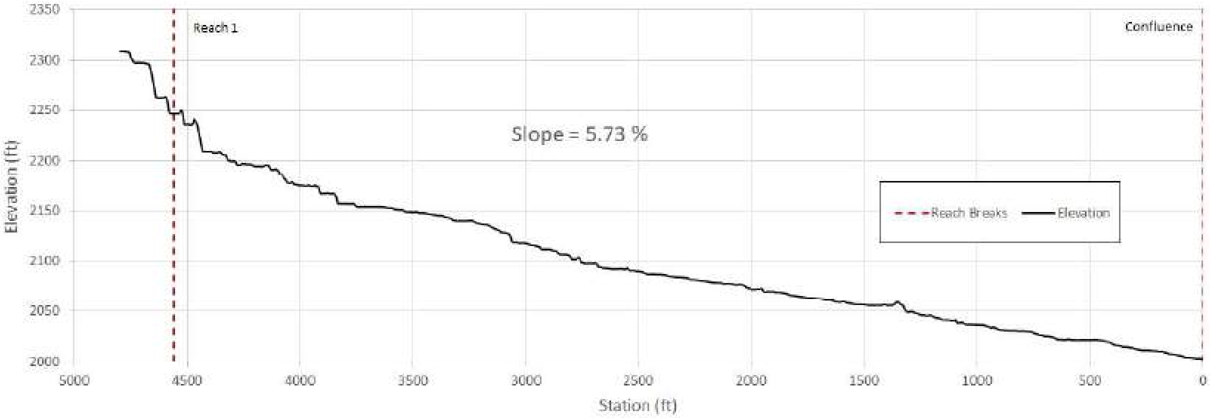

Figure 211. Longitudinal profile for Panther Creek.

Figure 212. Representative photo of Panther Creek in Reach 1 at ~RM 0.19, looking upstream (September 6, 2024).

Table 21. Panther Creek Reach 1 descriptive geomorphic metrics.

Metric	Value
Reach Length (miles)	0.8
River Miles	0-0.80
Stream Gradient	5.73%
Sinuosity	1.12
Dominant Channel Habitat Unit Type	Riffle
Average Bankfull Width (feet)	51
Confinement	Confined
Dominant Substrate	Gravel
Bank Stability/Channel Migration	Adequate *(See Appendix B Section 3.2)*
Vertical Channel Stability	Adequate *(See Appendix B Section 3.2)*

3.13.2 Channel and Floodplain Geomorphology

Reach 1 is a high gradient, partially confined channel with low sinuosity. The Habitat Assessment (See Appendix A) recorded 69% of the habitat as riffle, 30% as pool, and 1% as cascade (Figure 213). The channel is confined on both sides by a bedrock canyon upstream of ~RM 0.4 (Figure 214). Downstream of ~RM 0.4 the channel cuts through the coarse sediments of the Panther Creek alluvial fan which limits potential surfaces on which floodplains can be established. Sparse pockets of low floodplain were observed between RM 0.1 and the bedrock canyon at RM 0.4. Narrow low floodplain surfaces line both sides of the channel for the last few hundred feet before the White River confluence, and medium height floodplain surfaces occupy a portion of the Panther Creek alluvial fan downstream of RM 0.1 (Figure 213). Floodplains are composed of coarse cobble-boulder alluvial fan deposits overlain by a thin layer of fine sediment and soil. High surfaces on the alluvial fan function like terraces. Multiple ephemeral distributary channels branch off of the Panther Creek mainstem channel downstream of the canyon on river-right (Figure 214). These appear to be active only at very high flows. Some of these have headcuts that are approaching the main channel and so may soon become more active. There is a prominent distributary channel on river-right near RM 0.1 that was not active at the time of the survey but would be active during annual high flow periods. This channel contains multiple channel threads, high complexity, abundant gravel, and abundant quantities of LWM in large rafts and jams (Figure 215). This distributary channel connects to the mainstem White River approximately 800 feet downstream of the active Panther Creek channel. There are no tributaries to Panther Creek Reach 1.

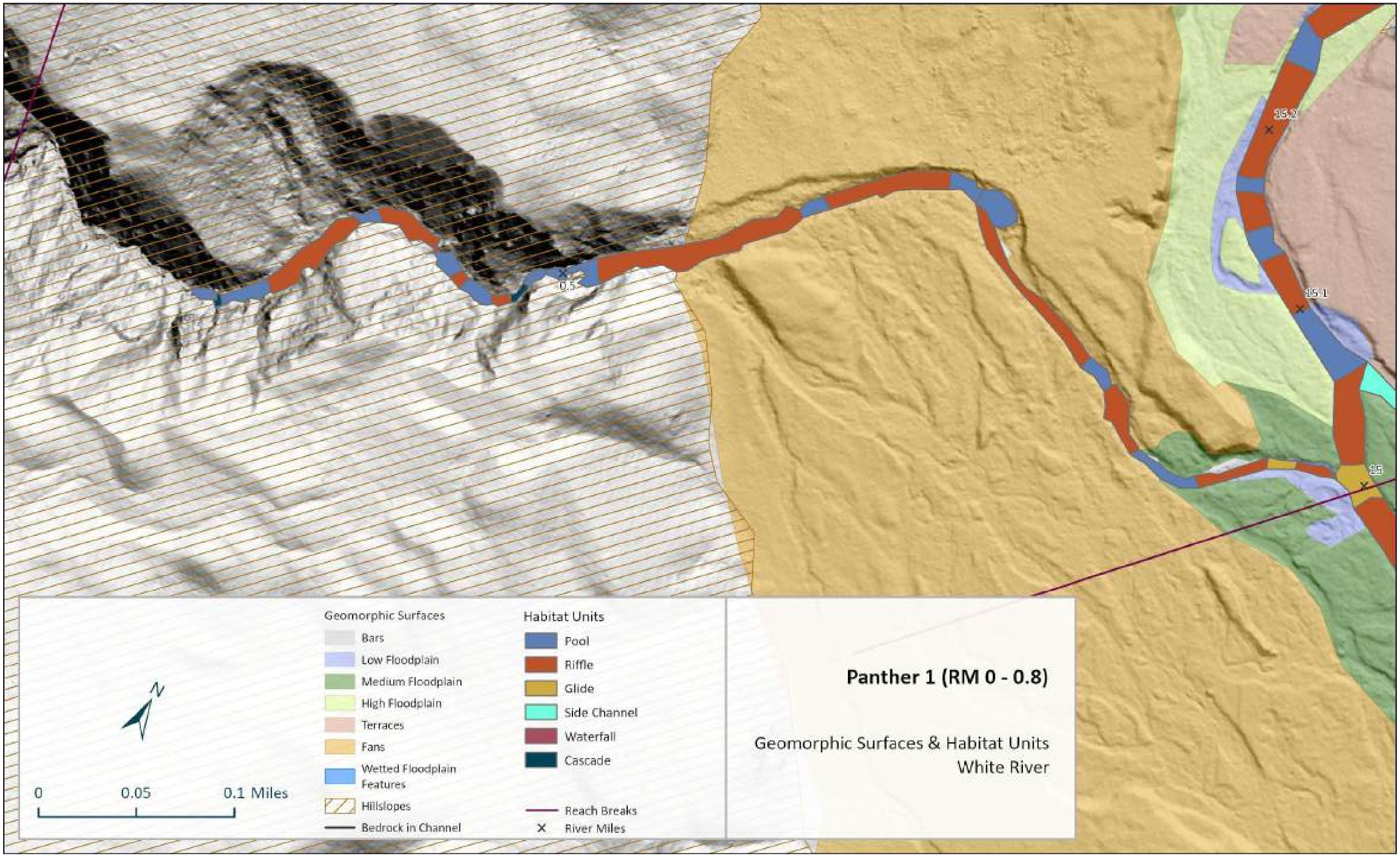

Figure 213. Panther Creek Reach 1 geomorphic surfaces and habitat units.

Figure 214. Left: Bedrock canyon near RM 0.4, looking upstream (September 6, 2024). Right: Panther Creek ephemeral distributary channel outlet (dry) near White River RM 14.86 (August 1, 2024).

Figure 215. Large jam and gravel deposits in prominent distributary channel at lower end of Panther Creek (not active at time of survey) (September 6, 2024).

Channel substrate in Panther Creek consists of bedrock and boulders within the canyon upstream of RM 0.4, and primarily boulders downstream of RM 0.4. Gravels and cobbles were observed in backwater eddies at boulders, and on narrow bars at channel margins (Figure 216). The prominent distributary channel at the downstream end has large deposits of gravels (Figure 216). Coarse sediments are sourced from the hillslopes and from undercutting and erosion of stream banks.

A Wolman Pebble Count (Wolman, 1954) was conducted approximately 0.25 miles upstream from the mouth of Panther Creek on one of the only depositional bars in the channel. This pebble count had the largest material of any pebble count in the study area, with a D50 of 89mm and a D95 of 301mm and these did not include the very large boulders that dominate most of the channel. A map of the incipient motion analysis results (see Sediment Mobility – Incipient Motion Hydraulic Analysis: Section 2.9.4) is presented for this reach in Figure 217. The analysis indicates that at the 2-yr modeled discharge, the channel's shear stress is capable of mobilizing boulders through the canyon upstream of RM 0.4 and mainly cobbles with some boulders throughout the remainder of the reach downstream.

Figure 216. Left: gravel deposition behind boulders along the channel margin of Panther Creek near RM 0.2 (September 6, 2024). Right: large gravel deposit in distributary channel that branches off near RM 0.1 (September 6, 2024).

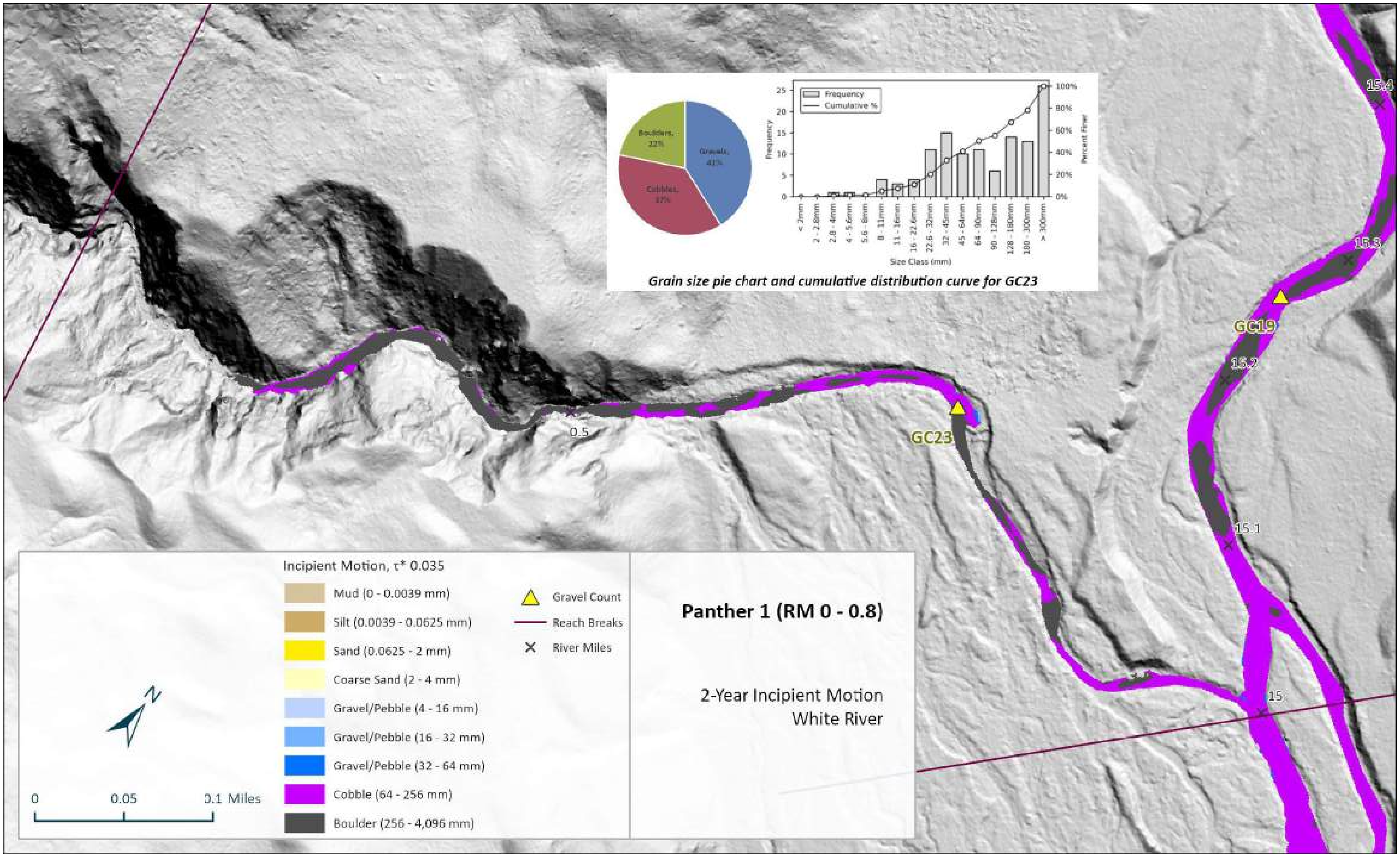

Figure 217. Panther Creek Reach 1: incipient motion analysis results map (estimated grains size mobility at the 2-yr modeled discharge) and grains size distribution of one (GC 23) pebble count.

3.13.3 Large Wood Material

A total of 63 pieces of large woody material (LWM) and 10 log jams (accumulation of >3 LWM) were observed in the channel during the survey (August 2024) (See Figure 218). Of the 63 pieces, 40 pieces are considered QLW; 13 classified as large size class (>20-inces diameter and >35-feet long); and 27 as medium size class (12 to 20-inch diameter and at least 35-feet long). Nine of the 10 log jams have multiple pieces of QLW and thus are effective channel influencing and habitat forming structures. Several large LWM jams were observed in dry ephemeral distributary channels downstream of RM 1, although these were not included in Habitat Survey wood counts, based on protocol.

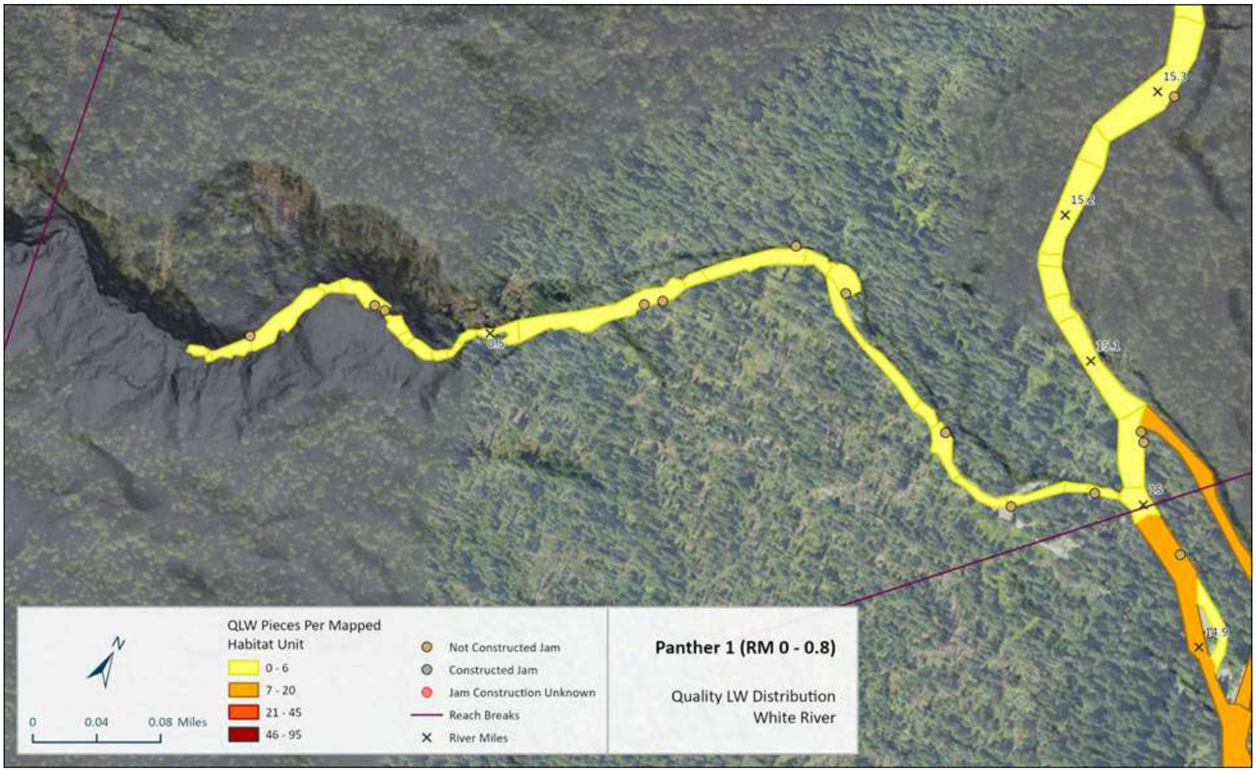

Figure 218. Panther Creek Reach 1 quality LW distribution. QLW count does not include pieces in jams.

A channel-spanning log wedged between bedrock outcrops on either side of the channel forces a large pool that flows over a ~3.5-foot vertical step into a scoured bedrock plunge-pool where the channel exits the canyon near RM 0.4 (Figure 219). Downstream near RM 0.26, a large wood jam on river-left creates a large pool and small mid-channel bar upstream, and abruptly forces flow river-right. Elsewhere on Panther Creek large wood jams appear to have been blown out by high flows and exert a limited geomorphic influence. LWM greater than 2 feet diameter and wedged between boulders or bedrock exposures were observed to be effective in maintaining geomorphic influences and sustaining jams, whereas smaller pieces, or those not anchored in some way, appeared mobile at higher flows, and thus ineffective. Several large jams in the ephemeral Panther Creek distributary channels on river right downstream of RM 1 maintain split-flow conditions and promote pool scour and coarse sediment sorting when activated (Figure 220).

Figure 219. Left: Wood-forced pool and ~3.5-foot-tall step upstream of RM 0.4 on Panther Creek (September 6, 2024). Right: Large wood jam at ~RM 0.26 creating pool and forcing flow to river-right (September 6, 2024).

Figure 220. Large wood jam in Panther Creek ephemeral distributary channel (dry) downstream of RM 0.1 (September 6, 2024).

3.13.4 Vegetation

Vegetation in Panther Creek Reach 1 consists of an overstory composed of second-growth western redcedar, grand fir, Douglas-fir, and cottonwood, and an understory of small conifers, vine/Douglas maple, and huckleberry (Figure 221). Seedling and sapling cottonwood are present on low floodplain surfaces. Old-growth trees were not observed, although the largest trees adjacent to the Panther Creek channel exceeded the estimated 2-foot diameter requirement for effective key LWM pieces. Recruitable streamside trees are present throughout the reach except for portions of the bedrock-confined canyon upstream of RM 0.4 (Figure 222).

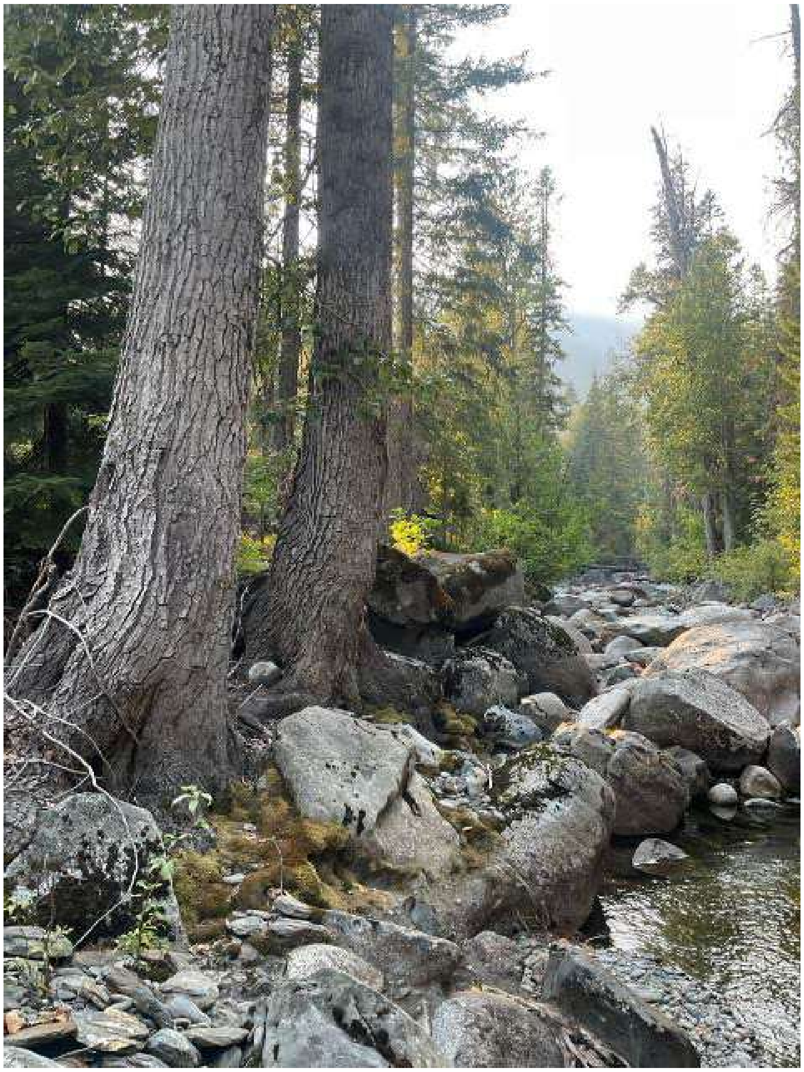

Figure 221. Cottonwood, western redcedar, Douglas-fir, and vine/Douglas maple adjacent to the Panther Creek channel at ~RM 0.17, looking upstream (September 6, 2024).

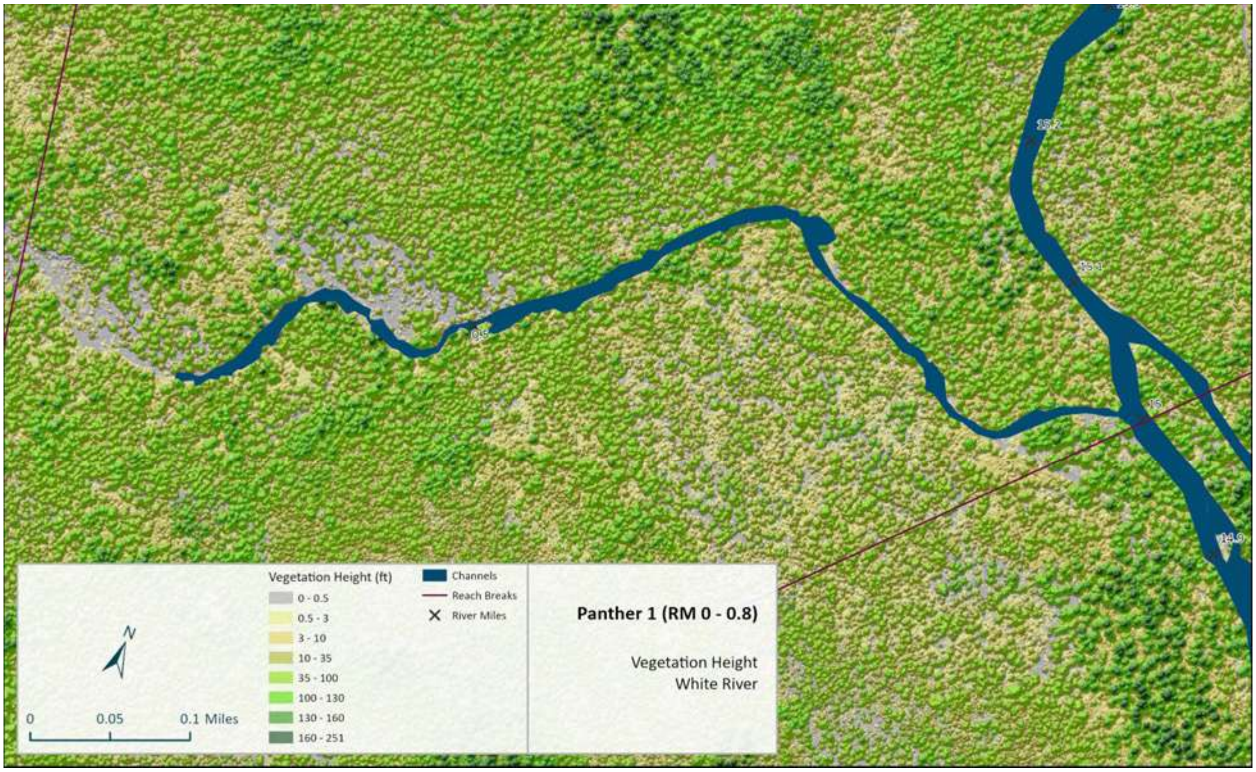

Figure 222. Panther Creek, Reach 1: Map of vegetation height classification analysis (LiDAR – based analysis).

Figure 223. Panther Creek, Reach 1: Map of aerial imagery for vegetation identification.

3.13.5 Human Alterations

Although no human alterations were observed in Panther Creek Reach 1 (See Figure 224), historical logging within the assessment area has likely altered forest composition including the abundance of mature old-growth trees. Old-growth trees were not observed in Reach 1, however, standing old-growth trees and logged old-growth stumps were observed in neighboring reaches on the White River (Reaches 9-10), suggesting that old-growth trees were abundant prior to harvest. An abandoned road cuts through the White River Reach 9 floodplain, ending near the Panther Creek alluvial fan, and investigation of topographic data suggests that the White River channel was straightened in Reach 9, which may have influenced connectivity between Panther Creek distributary channels at their outlet with the White River.

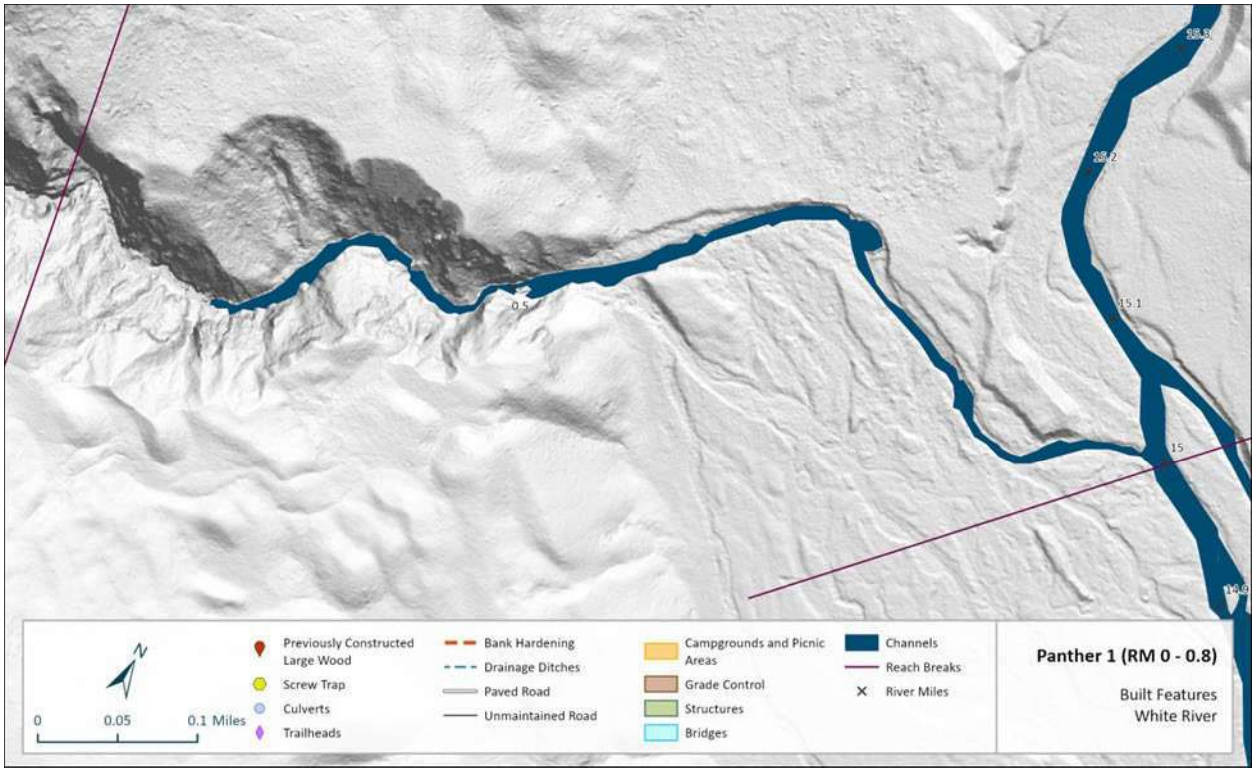

Figure 224. Panther Creek Reach 1 anthropogenic features.

3.13.6 Recommended Actions

Recommended actions in Reach 1 of Panther Creek include large wood placements to improve/enhance channel complexity and habitat conditions. A channel-blocking jam could be placed upstream of the Panther Creek mouth to activate a large distributary channel that contains abundant large wood. Large wood additions to Panther Creek Reach 1 may be best achieved via helicopter wood placement due to limited access, except for near the mouth where access can be obtained from across the White River near the Grasshopper Campground.

3.14 SEARS CREEK 1 (RM 0-0.4)

For the reasons described below, including no apparent surface water connection to the White River and a very complex wetland system in its lower reaches, Sears Creek was not surveyed or evaluated to the same degree as the other White River tributary reaches. We nevertheless provide here a summary of conditions observed during the field effort in the surveyable portions of Sears Creek and surrounding areas.

The reach of Sears Creek included in the study area extends from the dirt road (Sears Creek Road, Forest Road 6404) approximately 0.4 miles to its junction with the White River at a sharp bend near RM 8.6. At the road, Sears Creek flows through a 36-inch culvert (corrugated metal pipe), which is perched approximately 2 feet at the outlet and likely serves as a fish passage barrier at most flows (Figure 225). However, the channel above is steep and may provide limited passage and habitat opportunities for anadromous salmonids (Figure 225). Downstream of the road, Sears Creek flows within a defined channel with moderately steep gradient (~3.5%) with good gravels, abundant large wood, and a very mature closed canopy of cedar and fir (Figure 226). Approximately 1000 feet downstream of the crossing, the gradient flattens as the creek enters the floodplain of the White River (Figure 227). The creek enters a complex system of beaver ponds within abandoned oxbows (Figure 226). There is no single defined channel as the flow disperses into the beaver pond wetland complex. The vegetation changes to thick vine/Douglas maple and red osier dogwood shrubs. A map of vegetation height assessed using LiDAR, included in Figure 228, shows areas where large trees transition to wetland shrubs. There is no main channel to follow through this section, and there is also no well-defined connection point at the White River. This reach was surveyed from the top end (at the road) as well as attempted from the bottom end at the river; however, the lack of a clear connection to the river made this challenging, and no discernable consistent flow path was found that connects the stream channel above to the river. It is believed that at the low flow conditions during the survey, Sears Creek flow is lost to seepage in the floodplain wetland beaver pond complex. There were multiple small dry channels extending from the river into the floodplain near RM 8.6. It is assumed that during higher flows in Sears Creek, one or multiple of these channels would provide a surface water connection between Sears Creek and the White River. The only anthropogenic features within the surveyed portion of Sears Creek are Sears Creek Road and the Sears Creek culvert underneath the road (Figure 230).

Despite what is likely a lack of fish passage connectivity to the White River at lower flows, lower Sears Creek and the beaver dam complex is assumed to provide high quality off-channel juvenile rearing, feeding, and refuge habitat. A 2.5” juvenile salmonid was observed in the channel just upstream of the beaver dam complex during surveys in August 2024.

Figure 225. Left: Sears Creek crossing under Sears Creek Road (Forest Road 6404). Right: Sears Creek upstream of the crossing (August 2024).

Figure 226. Left: Sears Creek downstream of Sears Creek Road (Forest Road 6404) crossing. Right: Beaver pond wetland complex on Sears Creek.

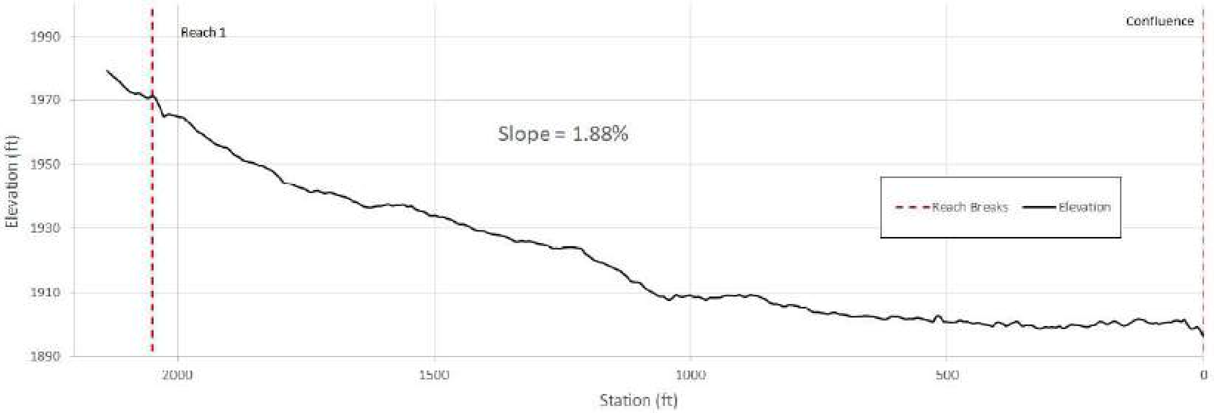

Figure 227. Longitudinal profile of Sears Creek.

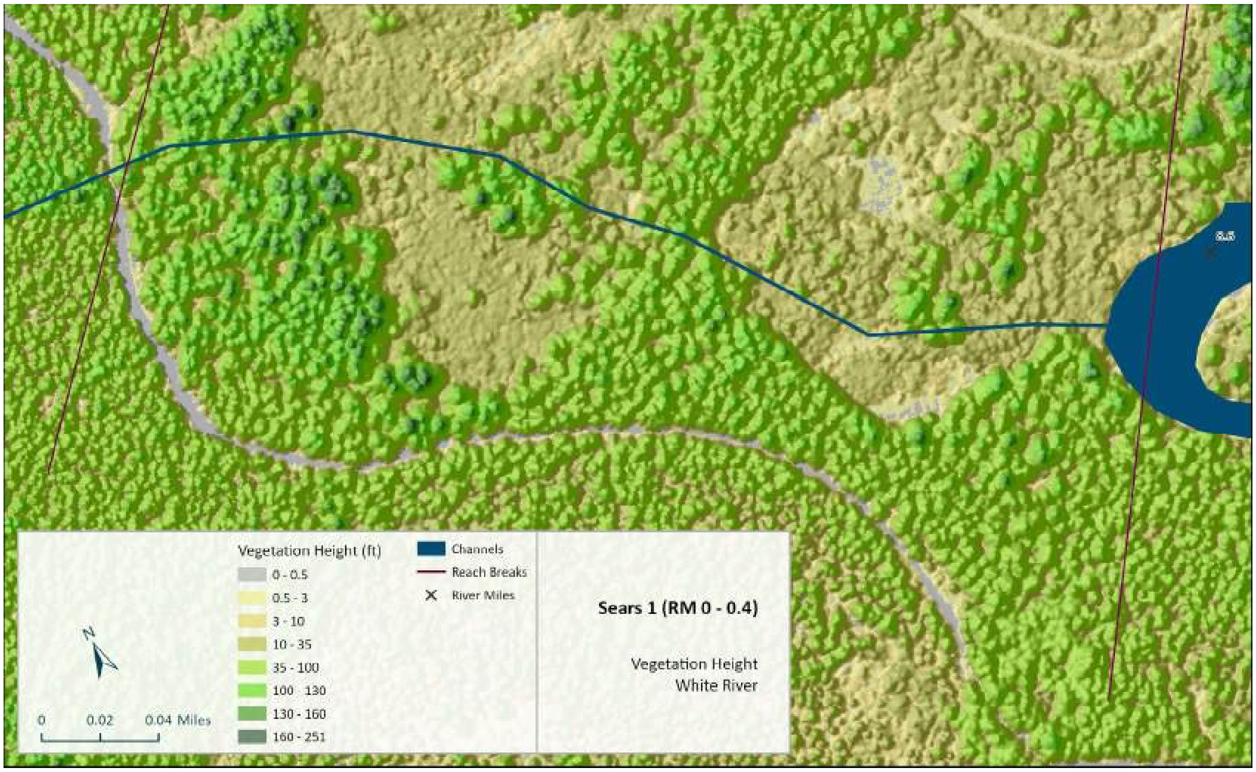

Figure 228. Sears Creek, Reach 1: Map of vegetation height classification analysis (LiDAR – based analysis).

Figure 229. Sears Creek, Reach 1: Map of aerial imagery for vegetation identification.

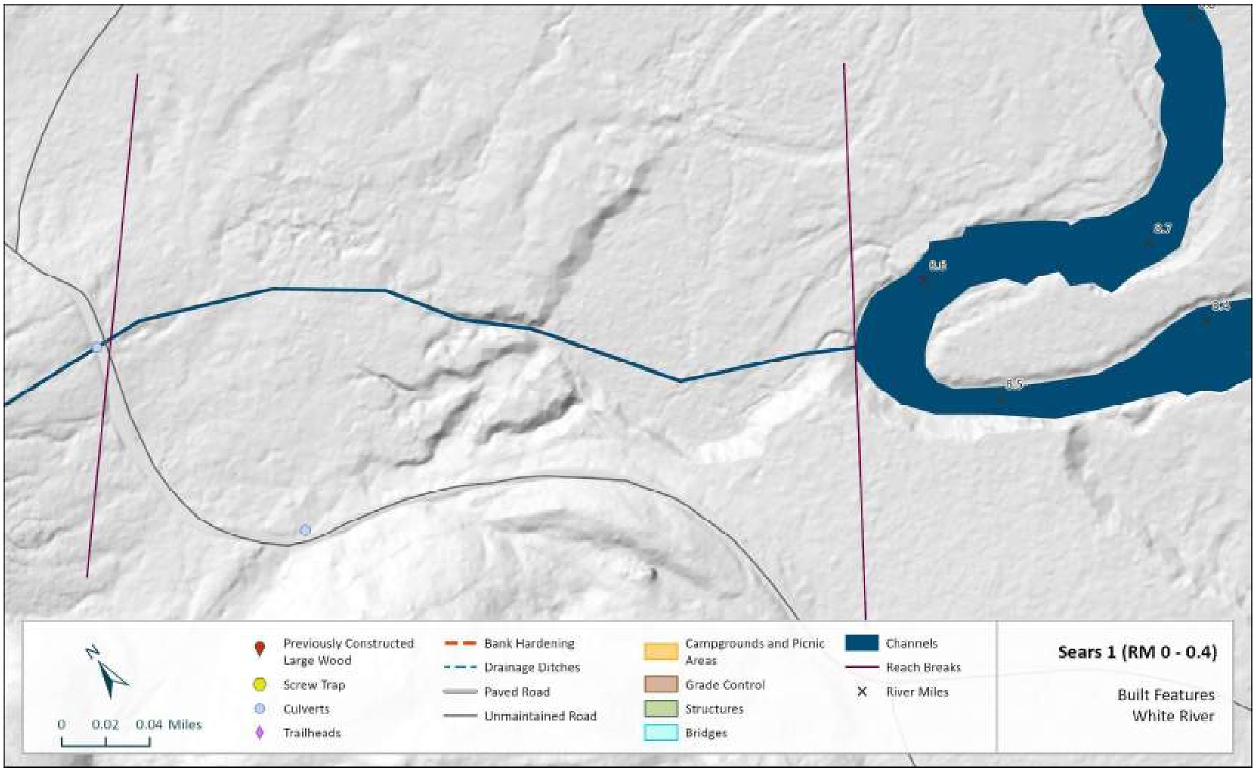

Figure 230. Sears Creek Reach 1 anthropogenic features.

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