# Entiat River
# Upper Stillwaters Reach
## Stream Corridor Assessment & Habitat Restoration Strategy

SUBMITTED TO
Yakama Nation Fisheries Program

OCTOBER 2013

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SUBMITTED TO
Yakama Nation Fisheries Program
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**Appendix C:** Reach-based Ecosystem Indicators (REI)

**Appendix D:** Project Opportunities

# 1 Introduction & Background

## 1.1 OVERVIEW

This assessment evaluates aquatic habitat and watershed process conditions and identifies habitat restoration strategies in the Upper Stillwaters Reach of the Entiat River. Geographically, it covers the mainstem Entiat River corridor from Entiat Falls at river mile (RM) 33.83 to RM 25.0, as well as RM 23.98 to RM 23.3. This Reach Assessment provides the technical foundation for understanding existing conditions and for identifying restoration strategies and specific opportunities. This assessment evaluates conditions at the valley- and reach-scales and ensures that restoration actions address key factors limiting the productivity of aquatic species and that they fit within the appropriate geomorphic context of the system.

Restoration strategies were developed by comparing existing aquatic habitat conditions to target conditions obtained from reference areas and regional habitat thresholds. In areas where existing conditions were found to be deficient, restoration strategies and specific action types have been identified to restore degraded conditions.

Although restoration measures are expected to benefit numerous different aquatic and terrestrial species, there is a particular emphasis on restoration measures for recovery of Endangered Species Act (ESA) listed salmonids, including spring Chinook salmon (*Oncorhynchus tshawytscha*), summer steelhead (*Oncorhynchus mykiss)*, and bull trout *(Salvelinus confluentus)*.

This report includes the following primary components:

- Study area characterization – 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 – Includes a comparison of existing conditions to target conditions and identification of recommended reach-scale restoration measures
- Specific project opportunities – A list of specific potential project opportunities and areas that would help to accomplish the reach-scale restoration strategies.

## 1.2 BACKGROUND

This effort is being conducted as part of the Yakama Nation's Upper Columbia Habitat Restoration Program (UCHRP), which implements projects to recover habitat for ESA-listed salmon and steelhead in the Upper Columbia region. Restoration efforts by the UCHRP work to achieve the objectives of the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (Recovery Plan, UCSRB 2007) and the associated Biological Strategy (UCRRT 2013). This effort has been conducted with input and coordination from multiple entities, including the Regional Recovery Team (RTT), US Forest Service, and the Entiat Habitat Subcommittee.

This assessment builds off of a large body of work produced in the basin beginning in the early 1990s and proceeding throughout the 2000s. Assessment and analysis work to date has included physical assessments, biological assessments, and restoration recommendations for portions of the Entiat River. Furthermore, the Entiat River is one of NOAA Fisheries Integrated Status and Effectiveness Monitoring Program's Intensively Monitored Watersheds (IMW). This program aims to closely coordinate and monitor restoration actions to detect and evaluate fish response to restoration actions.

## 1.3 PURPOSE

The purpose of this assessment is to document and evaluate hydrologic and geomorphic processes and aquatic habitat conditions in the Upper Stillwaters Reach of the Entiat River, and to present a comprehensive reach-based restoration strategy to address habitat limiting factors. 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 physical habitat conditions and trends
- Identify strategies and actions that address critical aquatic habitat impairments limiting the productivity of local salmonid populations
- Identify strategies that protect and restore the dynamic landscape processes that support riparian and salmonid habitat
- Coordinate efforts with local landowners, resource managers, and other stakeholders to establish collaborative efforts that contribute to the success of restoration strategies

## 1.4 STUDY AREA LOCATION

The Entiat River Basin is located on the east slope of the Cascade Mountains in Northern Washington (Figure 1). The Entiat River is a tributary to the Columbia River with its confluence at the town of Entiat near Columbia River RM 483.

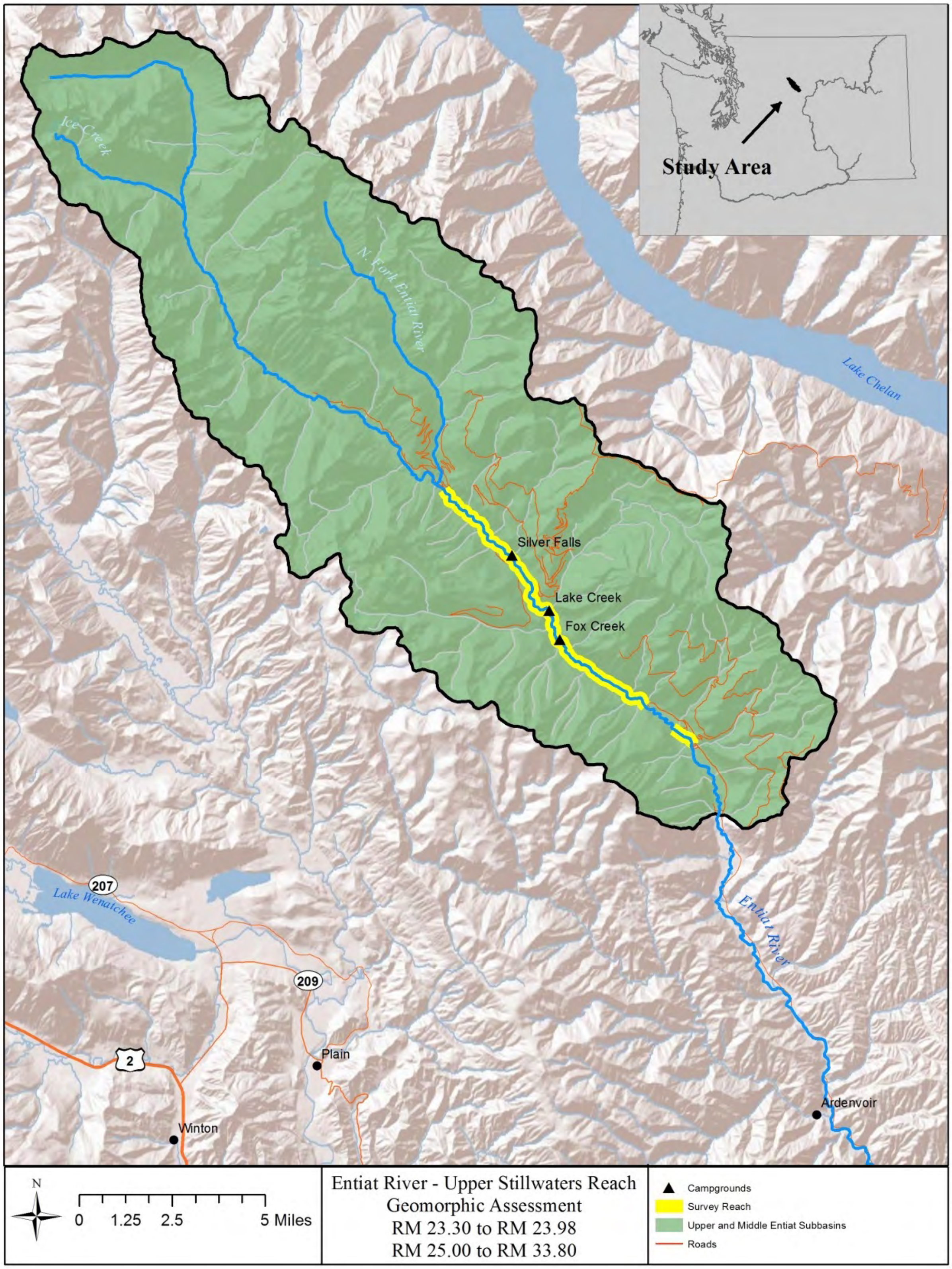


***Figure 1. Entiat River study area. The study area extends from RM 23.30 to RM 23.98, and again from RM 25.00 to Entiat Falls (RM 33.80).***

## 1.5 SALMONID USE AND POPULATION STATUS

Use of the upper Entiat River (upstream of RM 23) by ESA-listed salmonids includes spring Chinook salmon, summer run steelhead, and bull trout. Spring Chinook salmon, summer steelhead, and bull trout are listed as Threatened under the ESA. Human-induced changes to aquatic habitat have affected the key parameters used by federal agencies to evaluate the viability of salmonid populations; they are known collectively as the "viable salmonid population" (VSP) parameters: *abundance, productivity, diversity, and spatial structure* (UCSRB 2007). Failure to meet viability (i.e. VSP) criteria resulted in the listing of species under the ESA in the late 1990s. Upper Columbia River (UCR) steelhead trout and spring Chinook salmon were listed as Endangered in 1997 and 1999, respectively (UCSRB 2007). UCR steelhead were upgraded to Threatened in 2006, but were reinstated to Endangered in 2007 (UCSRB 2007). Life-stage usage and ESA status for each species are summarized in Table 1.

***Table 1. Species usage in the Upper Stillwaters Study Area. Adapted from Peven et al 2004, NMFS 1998, and Mullen 1992.***

| Population | ESA Status | General Use | Timeframe | Distribution | Abundance | Productivity |
|---|---|---|---|---|---|---|
| **Spring Chinook** | Endangered | Spawning & Rearing | Historical | High | Moderate | Moderate |
| | | Spawning & Rearing | Current | Moderate-High | Low-Moderate | Low-Moderate |
| **Steelhead** | Endangered | Spawning & Rearing | Historical | High | Low-Moderate | Moderate |
| | | Spawning & Rearing | Current | Moderate-High | Low | Low |
| **Bull trout** | Threatened | Spawning & Rearing | Historical | High | Moderate | Moderate |
| | | Spawning & Rearing | Current | Moderate-High | Low-Moderate | Low-Moderate |

## 1.6 RECOVERY PLANNING CONTEXT

Spring Chinook salmon and summer steelhead are listed and protected under the ESA. Recovery plans were completed in 2007 to prevent the extinction of Upper Columbia River ESA-listed fish. The Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (UCSRB 2007) states that recovery of species viability will require reducing threats to the long-term persistence of fish populations, maintaining widely distributed and connected fish populations across diverse habitats of their native ranges, and preserving genetic diversity and life-history characteristics. The Recovery Plan calls for recovery actions within all of the "Hs" that affect salmon throughout their life history; namely Harvest, Hatchery, Hydropower, and Habitat. This Reach Assessment addresses the Habitat component of the Recovery Plan, with a focus on the study area.

The RTT's Biological Strategy (UCRTT 2013) provides support and guidance on implementing the Recovery Plan. The following information is included in the 2013 Biological Strategy for the "Upper-Middle Entiat", which is defined by the RTT as RM 26-36, and therefore covers most of the study area.

**Factors Affecting Habitat Conditions**

- Poor large woody debris recruitment and retention potential
- Levees and rip-rapped banks
- Entiat River Road
- Forest management practices and road densities in the upper watersheds leading to reduced LW recruitment and increased sediment input.
- Historic channel straightening for flood control
- Reduced riparian condition and few mature trees decreasing the input of key wood pieces that would form persistent log jams.
- Decades of depressed salmon returns resulting in reduction in marine-derived nutrients

**Ecological Concerns and (subcategories) in priority order:**

1. Channel structure and form (Instream structural complexity)
2. Food (Altered primary productivity and food competition)

**Level of Certainty/Data gaps**

- Likely reduced primary and secondary productivity because of reduced marine-derived nutrients.

**Ecological concerns and habitat action recommendations in priority order:**

1. Channel Structure and Form (Instream structural complexity)
    - Install large wood and ELJs that are consistent with the geomorphic potential based on the reach assessment.
2. Food (altered primary productivity and food-competition)

# 2 Assessment Area Conditions

## 2.1 SETTING

The Entiat River Basin is located in Chelan County in North Central Washington State on the east side of the Cascade Mountains within the Columbia Cascade Ecological Province. Headwater drainages originate in the Glacier Peak Wilderness areas of Wenatchee National Forest. The total basin area is 466 square miles. The study area included RM 23.30 to RM 23.98, and RM 23.3 to RM 33.80 (Entiat Falls). The catchment area contributing to the downstream extent of the study area (RM 23.30) includes several small drainages such as Silver Falls Creek, Tommy Creek, Fox Creek, and the North Fork Entiat.

Fourteen distinct geomorphic reaches were delineated within the study area (Figure 2). Reach delineation was based on basin size (i.e. major tributary confluences), valley confinement, underlying geology, channel gradient, and channel type (e.g. dominant bed morphology). Reach delineation was initially conducted using remotely available data (e.g. aerial photos, LiDAR, and geology maps) and was field-verified during surveys.

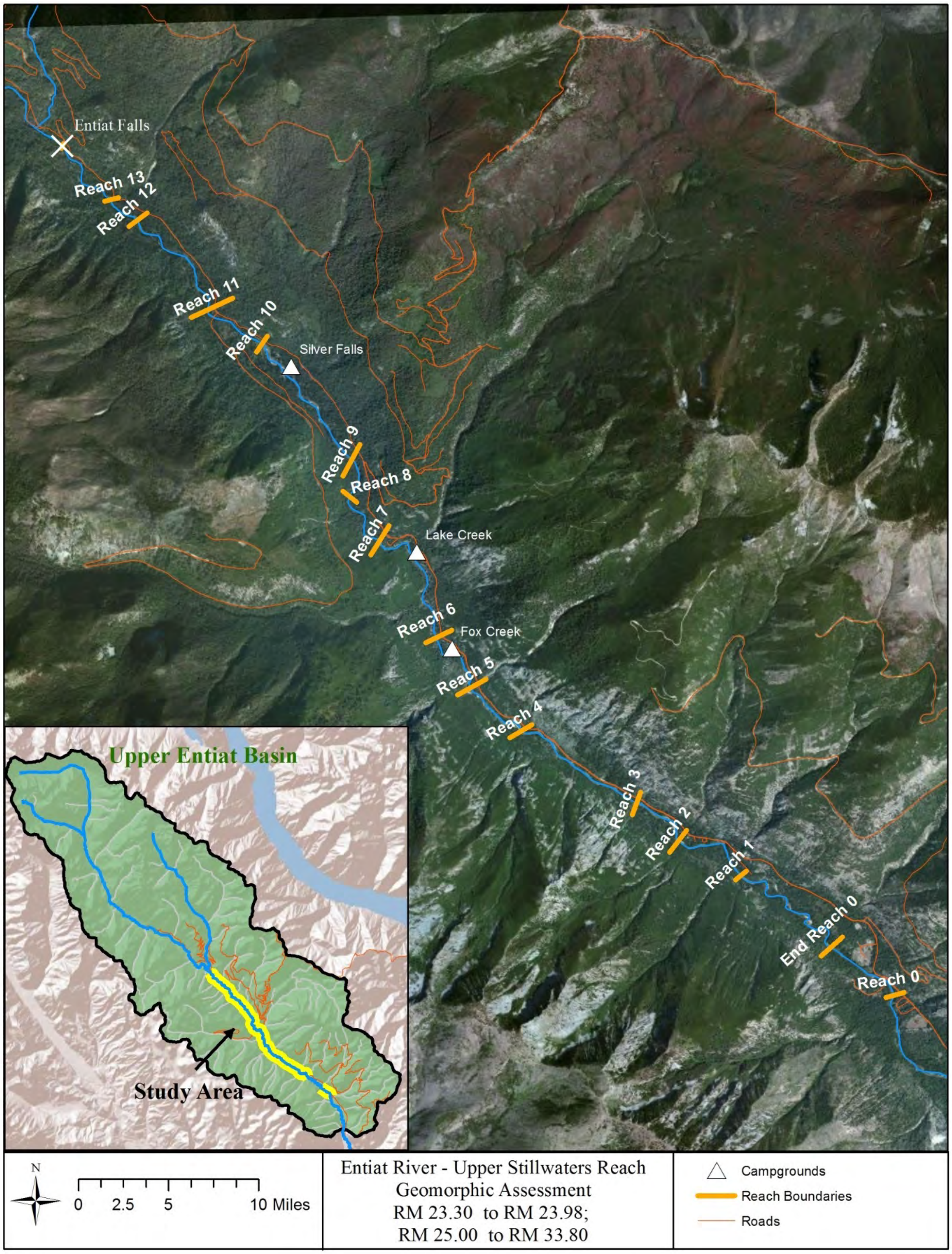


***Figure 2. Geomorphic Reach boundaries for the Upper Stillwaters Reach Assessment.***

## 2.2 GEOLOGY

### 2.2.1 Geologic Setting

The Entiat River basin is located within the eastern portion of the Northern Cascades geologic province (Figure 3). The geology of the region is extremely complex as the result of millions of years of tectonic activity along the subductive margin of the North American plate. This tectonic activity brought multiple blocks of unrelated rock types together through strike-slip and thrust faulting, metamorphosed bedrock through extreme heat and pressure, and emplaced igneous plutons. The Entiat River basin has developed in the Chelan Block, a region of crystalline metamorphic and igneous bedrock. Within the Chelan Block there are several smaller fault-bound geologic terranes that are characterized by unique stratigraphic and structural histories. The watershed of the Stillwater study area is located in the Chelan Mountains Terrane.

### 2.2.2 Bedrock Types

Within the contributing watershed of the study area, there are two primary types of bedrock: (1) late Cretaceous metamorphic rocks and (2) Late Cretaceous to early Tertiary granitic rocks (Figure 3). All of the bedrock within the study area watershed is crystalline, hard, and erosion resistant. The protoliths, or original lithology types, of today's Entiat bedrock are marine sediments and volcanic rocks. These protoliths were derived from a volcanic arc that was accreted onto the North American plate via plate subduction. Through metamorphic processes, the original marine sediments and volcanic rocks were transformed into the gneiss and schist that are seen in the watershed today. During the Late Cretaceous and early Tertiary, the metamorphic rocks of the terrane were intruded by several granitic plutons. This includes the Duncan Hill pluton that was emplaced between 45 and 48 million years ago. This Duncan Hill pluton is a quartz diorite and is the main bedrock encountered along the channel of the Entiat River in the study area. Bedrock outcrops along the channel include what is seen at Entiat Falls (upstream end of the study area) and Box Canyon (Reach 6). Metamorphic rocks are found upslope along the river valley, in tributaries along the study area, or upstream in the headwaters of the Entiat River. These rocks are delivered to the study area via colluvial or alluvial processes.

### 2.2.3 Faulting and Geologic Structure

Regionally, there are several major fault systems that affect the study area. These fault systems create topographical and hydrographic divides, and affect the position of the major structural blocks and bedrock elements in the area. The Chelan Block is bound to the west by the Entiat fault. The Entiat fault uplifts the Entiat Mountains and separates the Entiat River basin from the Wenatchee River basin, as well as separates the Chelan Block from the Wenatchee Block. The eastern boundary of the block is formed by the Ross Lake fault system. This Ross Lake fault lies east of Lake Chelan and separates the Chelan Block from the Methow Block. In addition to these major fault systems within the study area, there are many small, east-west oriented left-lateral strike-slip faults to the northeast of the river valley.

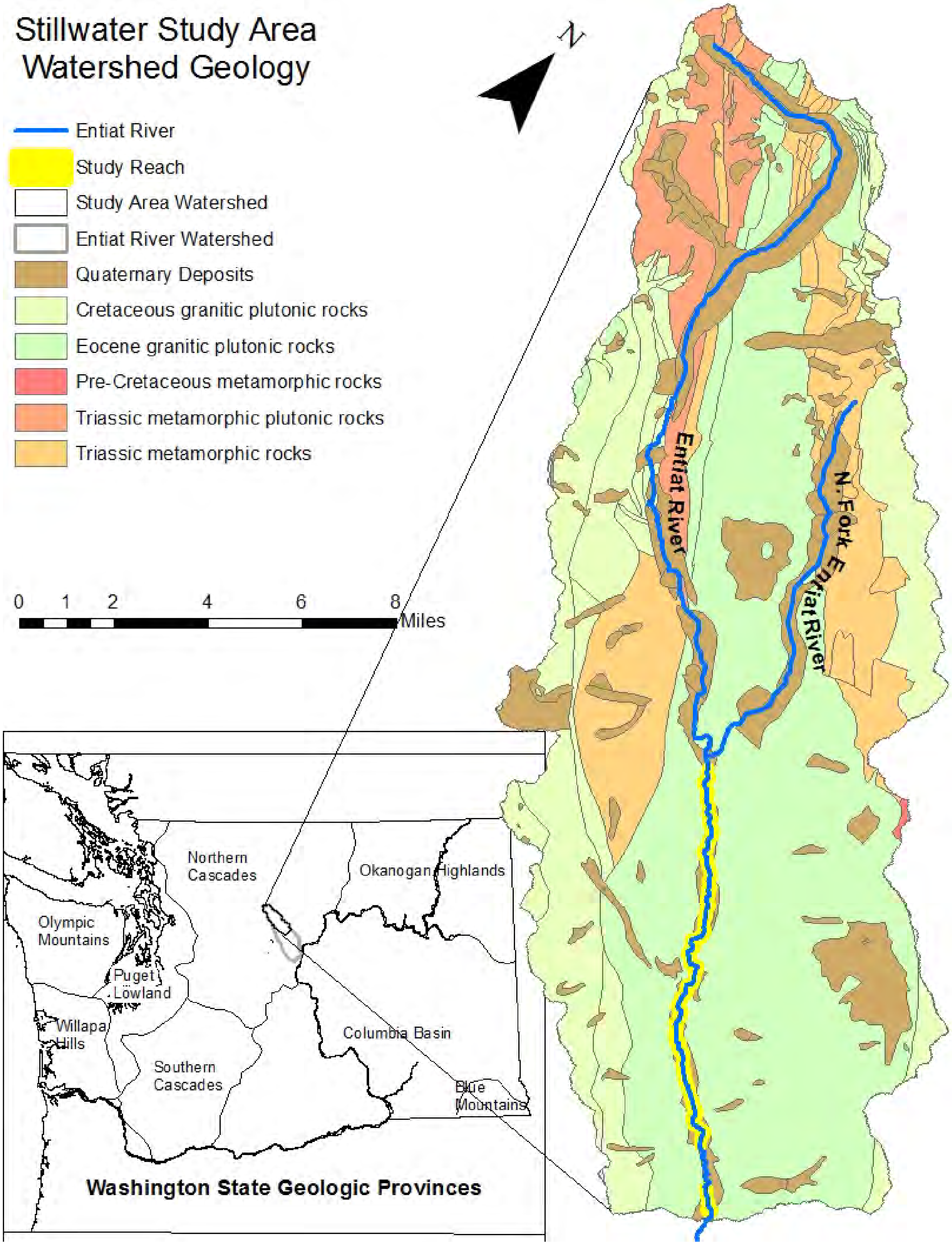


***Figure 3. Generalized geologic map of the study area and its contributing watershed showing its location within Washington State and the Northern Cascades Geologic Province (Data acquired from US Bureau of Reclamation Tributary Assessment geodatabase).***

### 2.2.4 Glacial History

During the last glacial maximum (late Pleistocene), masses of ice moved from higher elevations in the basin downslope, carving out rock masses and leaving behind glacial features including till deposits, outwash deposits, and glacial erratics. Glaciation extended downstream from headwater valleys to approximately RM 16 on the mainstem Entiat (Godaire et al 2010). The work of Long (2013) suggests that the Entiat River basin was largely de-glaciated by about 11,250 years before present based on the presence of Glacier Peak Tephra over many of the glacial features found in the basin. However, there is evidence for a more recent glacial advance in the basin evidenced by a moraine with a minimum elevation of 5,297 feet – which is well upstream of the study area. The Glacier Peak Tephra (volcanic ash and pumice deposits from eruptions of nearby Glacier Peak) indicate a Holocene glacial advance at higher elevations in the basin that could have occurred anytime from 5,000 years before present, to as early as the Little Ice Age (between 1350 and 1850 A.D). Throughout this area of the North Cascades, Little Ice Age glacial deposits are generally the most extensive of recent glacial advances, suggesting that as a likely time period for deposition of post-Glacier Peak Tephra moraines in the Entiat River Valley.

The most detailed glaciology in the region comes from the Icicle Creek drainage in the Wenatchee River basin. This discussion assumes that major climate cycles and significant glaciation occurred contemporaneously in the sub-basins of the Upper Columbia, and therefore the glacial history can be generally applied across the area. There are six major glacial cycles recognized in the Icicle drainage ranging in age from 12,500 to 165,000 thousand years before present (Porter and Swanson 2008) (Table 2). The names applied to glacial deposits in the Icicle drainage are not carried over to the Entiat, but it is likely that each of these cycles influenced valley shaping and channel morphology in the study area.

***Table 2. Regional glacial cycles derived from study of deposits in the Icicle Creek drainage, and the relative ages of these respective glacial periods (adapted from Porter and Swanson 2008).***

| Glaciation periods that correlate with till deposits in the Icicle Creek Drainage | Approximate age of deposit |
|---|---|
| Rat Creek I and II | 12,500±500 and 13,300±800 |
| Leavenworth I and II | 16,100±1100 and 19,100±3000 |
| Mountain Home | 70,900±1500 |
| Pre-Mountain Home | 93,100±2600 |
| Peshastin | 105,400±2200 |
| Boundary Butte | At least 165,000 |

Although glacial advance carved out the valley of the Entiat River in the study area, fluvial and colluvial processes that occurred during and after glacial retreat have been the primary drivers of contemporary river morphology in the study area. Terraces left behind by glacial outwash deposits and alluvial fans that have developed following glacial retreat exert significant influence on vertical stability, lateral migration, and bed material (Figure 4). Glacial outwash deposits contain extremely coarse material including boulders derived from glacial erosion. As the river has down-cut (or incised) through outwash deposits, finer material has been winnowed away. This winnowing has left behind coarse, oversized bed material that provides vertical stability in many reaches of the study area. Alluvial fans, both active and inactive, control river morphology in much the same way: contributing coarse material to the channel that limits lateral and vertical adjustability. Fans are where many of the steep reaches are formed; they also control many of the low gradient alluvial reaches at their downstream ends .

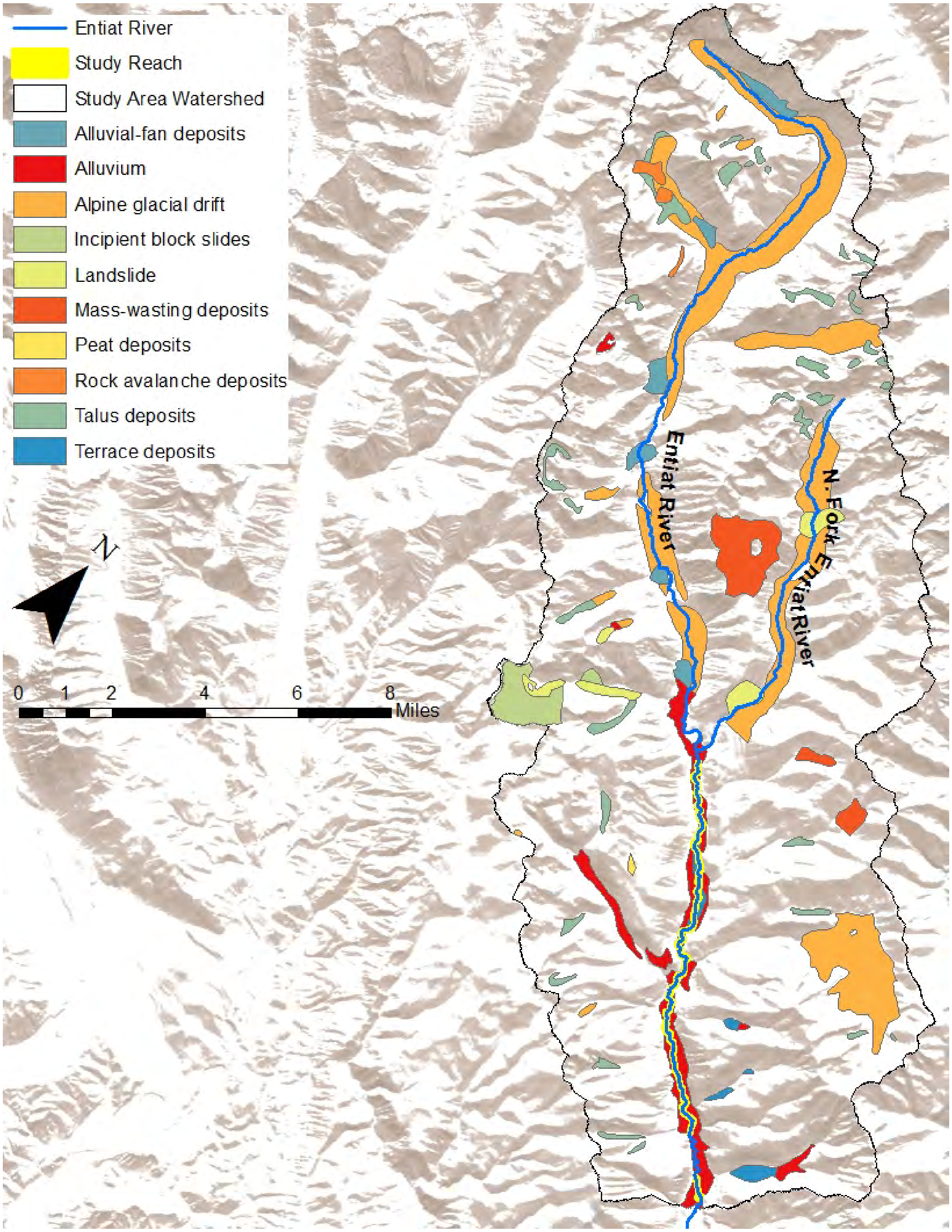


***Figure 4. Topographic map depicting the distribution of mapped glacial deposits in the study area. The inset shows the wider distribution of glacial deposits in the contributing watershed (adapted from Tabor et al. 1987).***

## 2.3 HISTORICAL FORMS AND PROCESSES

### 2.3.1 Channel Form & Process

Although there is little direct evidence of conditions prior to the mid-1900s, field observations, core samples from valley floor vegetation, and USBR (2012) carbon-dating of terrace deposits describe Pleistocene epoch valley and channel form. Pleistocene channel form was created by large, high volume flooding and sediment inputs. Large boulders and cobbles located on abandoned floodplain surfaces indicate glacial meltwater and outburst floods moved large amounts of water and sediment down the Entiat Valley. This, combined with glacial meltwater outwash, created a wide, deep channel, fit for transporting large flows and sediment loads. Varying terrace elevations, natural levee deposits, and overland scour indicate the valley floor and channel form may have been shaped by repeated outburst floods that shaped the valley floor and channel.

Following the Pleistocene epoch, the Entiat climate became much warmer and drier. This resulted in a decrease in Entiat River flows, leading to smaller channel discharge that did not match the large channel form. Over time, the now 'underfit' Entiat River down-cut into its channel bed, leaving behind abandoned floodplain surfaces and naturally armoring its over-widened banks.

Prior to Euro-American settlement (late-1800s), a couple of early surveys help to characterize historical conditions. These include the General Land Office cadastral surveys published in 1902 (Plummer). These surveys suggest that the historical channel planform geometry in the study reach was similar to what is seen in modern times with changes only in naturally unconfined segments.

Historical changes in channel morphology within the Upper Entiat were driven by valley- and large-scale disturbances, mainly fire and mass-wasting from adjacent hillslopes. Debris flows and alluvial fans from tributaries, landslides, and avalanches deliver large amounts of material to the system, often as large boulders and large cobbles. Historically, these large sediment and debris pulses would block flow, diverting the boundaries of the channel, moving it towards the opposite slope, and leading to a change in channel course and form. The channel would remain in its new course until larger flows would move this material through the system, allowing the channel to migrate to a new course. This process has influenced the channel both by active, contemporary alluvial fans, as well as older fans which have been reworked by channel and valley processes, here referred to as inactive fans.

Channel morphology was also driven by channel-scale geomorphic processes. Throughout much of the study reach, where the channel is confined or partially confined by glacial terraces, alluvial fans, and bedrock, there would have been limited instream and off-channel habitat complexity. Reworking at the toe of terraces and fan deposits would have resulted in boulders and self-armored banks. These features would have created some hydraulic variability, scour pools, pocket water, and temporary locations for riparian vegetation establishment and accumulation of large woody material, but most of the habitat complexity would likely have been confined to the channel margins. Within more alluvial reaches (e.g. Reach 2) the processes of channel migration, channel avulsion, deposition of sediment, channel braiding, and deposition of large wood would have created complex habitat features.

### 2.3.2 Hydrologic Regime

The headwaters of the Entiat originate in the Cascade Mountains. Each tributary within the study area contributes only a small amount of flow to the channel; the Entiat's only major tributary, the Mad River, is outside of the study area, entering at RM 9.0. Similar to contemporary conditions, the natural hydrologic regime within the study area was dominated by the seasonal dynamics of a snowmelt runoff system. The flow pattern would have exhibited increasing flow through the spring with an annual peak in June and a rapid decline to baseflow conditions by August. High flow and flood events are frequently a result of rain-on-snow events. Historically, fire has been a major influence on the flood dynamics with large floods often following large fires. The highly variable climate within the Entiat can also lead to substantial differences in streamflow across years. For example, between 1972 and 1973, runoff gaged at Ardenvoir dropped from 451,140 acre-feet to 178,970 acre-feet (Kirk et al. 1995). Due to the coarse alluvial and glaciofluvial sediments characteristic of the watershed, ground and surface water interactions likely impact both discharge and stream temperature (Kirk et al. 1995).

### 2.3.3 Large Wood Dynamics

Historically, large wood would have been an important driver of geomorphic form and process, and would have had a strong influence on instream habitat availability and complexity. The following section outlines large wood dynamics, including sources of instream large wood (sources), how wood is made available to the stream (recruitment), and how wood is retained within the stream where it provides habitat functions (retention).

***Sources***

Instream wood source areas for the Upper Entiat included: (1) wood additions from the river corridor (floodplain, terrace slopes, and riparian areas), and (2) wood contributed from the upper basin that entered the system through mass-wasting and avalanche events. Through the study reach, riparian source areas historically included upland slopes forested with ponderosa pine and localized black cottonwood along the riparian area (Plummer 1902).

Wood sourced from upstream areas and from the study reaches would have had a range of sizes depending on forest type and time since last disturbance (e.g. floods and fires). Compared to existing conditions, there would have been a greater source of large old-growth trees that would have been periodically recruited to the system. Early General Land Office (GLO) surveys note pines up to forty-four inches in diameter (Figure 5). Through the confined reaches, source areas would have primarily been localized riparian areas. Scour at the toe of the channel would have caused localized bank failures, leading to slumping in of riparian vegetation. In the alluvial reaches within the study area, source areas would have included much of the active floodplain, whereas in confined reaches, riparian source areas would have been closer to the channel margins. Episodic additions from mass-wasting (i.e. landslides and debris flows) would likely have contributed large inputs of sediment and wood to the system.

***Figure 5. Stump of logged riparian tree measuring 42'' in diameter.***

### *Recruitment*

Historically, large wood would have entered the Upper Entiat and upstream contributing stream channels from both chronic (i.e. single-tree mortality) and episodic disturbance-related events. Disturbance-related contributions would have included fire, floods, windstorms, avalanches, diseases, and landslides (Figure 6). The Entiat's soils, fire regime, steep terrain, and history of timber harvest combine to make the area highly prone to mass-wasting and avalanches. As snow and sediment cascade down the Entiat's steep slopes, large amounts of debris, including large wood, are carried to the channel. These contributions likely provided a greater amount of wood loading than chronic contributions. Laterally-active alluvial reaches would have recruited wood via lateral and transverse scrolling of the channel (Figure 7), whereas recruitment in the more confined reaches would have occurred primarily through single-tree mortality. Reaches confined by high glacial terraces would also have recruited wood via toe erosion that initiates mass- wasting events on the terrace bank.

***Figure 6. Wood recruited from high terrace bank.***

***Figure 7. Wood soon to be recruited to the channel in the Entiat River as the channel scours away at the toe of the bank.***

### ***Retention***

Retention of large wood is related to characteristics of the wood itself and also characteristics of the stream channel (Gurnell 2003). In general, the larger the wood piece (diameter and length) with respect to channel size (width and depth), the more likely it is that wood will be retained (Bilby and Ward 1989, Brauderick and Grant 2000, Bocchiola et al. 2008). In large rivers, wood is frequently retained in the channel in the form of log jams. Large, stable pieces that initiate log jam formation are often referred to as "key pieces" (WFPB 1997). Key pieces, which typically have attached rootwads, are retained in the channel first and serve as foundation pieces for capturing and racking additional wood from upstream. In the pre-disturbance Upper Entiat River, the greater availability of these larger key piece sized pieces, as discussed previously, would have supported a greater degree of log jam formation.

Another important factor affecting wood retention is the degree of channel complexity. A complex channel with numerous obstructions to flow such as bank protrusions, islands, gravel deposits, boulders, or other wood pieces will retain wood more readily than simplified uniform channels (Fetherston et al. 1995, Gurnell et al. 2000a, Gurnell et al. 2000b, Haga et al. 2002, Bocchiola et al. 2008). A historically more complex channel, prior to human alteration, would have provided a greater degree of in-channel wood retention compared to contemporary conditions. These wood accumulations would have promoted both geomorphic and habitat functions including creation of pools, sediment retention (trapping) and sorting, increased channel complexity and cover for fish. Based on jams surveyed as part of this assessment, through more confined reaches, jams would have likely spanned the channel. These jams would have recruited more wood and trapped sediment and resulted in greater floodplain connectivity via channel braiding and backwater effects on flood inundation (Figure 8 and Figure 9). Similar dynamics would have occurred in bedrock-confined reaches, where large wood would have been trapped between canyon walls or large boulders. Wood would have accumulated behind these channel-spanning key pieces until a large enough flood would remobilize the wood and displace the jam.

***Figure 8. Channel-spanning large wood jam, with gravel recruitment in Reach 13 of the Upper Stillwaters Study Area.***

***Figure 9. Large wood accumulation on a point bar in an alluvial reach of the Upper Stillwaters Study Area.***

### 2.3.4 River Ice

River ice on the Entiat River (Figure 10) is a driver of geomorphic form and process. There have been multiple accounts of the Entiat freezing over, often from the bottom up, which is known as anchor ice. There are also at least two documented occasions of the removal of ice jams by dynamiting to prevent flooding impacts (1972, 1991) (Andonaegui 1999). In years the Entiat freezes over, ice impacts channel form by attaching to and then breaking off of stream banks and contributing to bed and bank scour. River ice can cause large overbank flood events due to ice-dams. As river ice begins to break-up during warming or thawing events, ice blocks move downstream and build up behind river ice or other obstructions further downstream. Areas prone to ice-damming include transitions from riffles to pools, meander bends, and mid-channel bars. River ice has been linked to flooding on the Entiat River and its tributary the Mad River (2009) (Wenatchee World 2009). The frequency of occurrence of ice-related flooding events in the lower reaches of the Entiat is fairly well understood, but the frequency of freezing events in the Upper Entiat is less well known. Similarly, the specific extent and geomorphic impact of ice jams, anchor ice, and frazil ice is uncertain, but anchor ice has been linked to adverse impacts to habitat on the Entiat. Anchor ice has been outlined as a threat to adult westslope cutthroat trout, and has been cited as a higher threat than elevated summer temperatures (Peven 2004). Anchor ice is more common in areas with limited riparian vegetation, as the moderating impacts of canopy cover limit the likelihood of anchor ice. Cutthroat trout winter rearing juveniles need deep pools in order to find refugia from anchor ice-induced mortality (Peven et al. 2004). The effect of ice on salmon and steelhead is less well understood.

***Figure 10. Photo of Entiat River frozen over (2009) (Wenatchee World 2009).***

### 2.3.5 Habitat Conditions

There is no information specifically describing the pre-disturbance habitat conditions of the Entiat River within the study area. Land-use development and disturbance had advanced quickly preceding the time of the first reports on conditions in the watershed. Plummer (1902) provides the earliest description of conditions contributing to habitat maintenance in the study area, namely forest conditions including the riparian zone. The first known physical habitat surveys of the Entiat River were done in 1934-1936 (USBOF 1936). These surveys describe that “spawning areas and resting pools” were well distributed throughout the lower 28 miles, with the best spawning areas between RMs 12.0 and 23.0 due to wide, shallow riffles throughout. These surveys estimate there were 200,000 square yards of “suitable spawning area” between RM 0.0 and RM 28.0 at that time. Although this historical information is useful, it should be noted that all of the earliest information regarding habitat elements was gathered decades after the first large-scale disturbance was carried out in the watershed, and does not describe historical, pre-disturbance conditions.

Despite a lack of pre-disturbance habitat observations, reasonable reconstruction of historical habitat can be accomplished based on observations of existing conditions, knowledge of first-order controls on channel processes (geology), and the typical results of early documented land-use activities (logging and grazing). Pre-disturbance conditions in the study area can be broken into two categories: the habitat of steep confined reaches, and the habitat of unconfined alluvial reaches.

Confined reaches have high lateral and vertical stability and very narrow riparian areas. These reaches are likely to be closer to their pre-disturbance condition where major habitat elements in the channel are large boulders, log jams, and plunge pool or dam pools. Off-channel habitat is naturally limited in these reaches, and a reduction in such habitat would not be expected via human disturbance. Log jams would have likely played a key role in providing habitat, but only very large pieces would have been persistent, as high energy during floods would be capable of moving most large woody material (LWM) through steep reaches.

Unconfined reaches, on the other hand, typically have smaller bed material, greater sinuosity, more complex off-channel habitat, and wider riparian areas. Historically, the role of LWM in creating and maintaining habitat would have been significant. Large boulders were less frequent in the channel in these reaches. Off-channel habitat would have been mainly composed of side channels with some floodplain wetlands. However, glacial terraces and hillslopes create constriction points in most unconfined reaches, and extensive off-channel habitat is not the expected pre-disturbance condition. The dominant riparian overstory would have consisted of mature conifer and cottonwood trees, with a diverse understory of willow, dogwood, alder, and various age classes of conifers and hardwoods.

Natural barriers to fish passage include Fish Tail Falls (RM 28), which is noted as a low water barrier, above which the “amount of large rubble in the stream bed [increases]”; Entiat Falls is noted as the barrier to anadromous fish passage (USBOF 1936).

## 2.4 HUMAN DISTURBANCE HISTORY

### 2.4.1 Early Disturbance

The first documented inhabitants of the region were members of the Columbia Salish Tribe, who called the Entiat River the Enteatqua, which means 'rapid waters' (Jones and Stokes 2006, CCD 2004, Erickson 2004, North 40 Productions 2011). A village, known as ntia'tk^u or "weedy river," was located at the confluence of the Entiat and Columbia rivers, and was a gathering place for tribes from throughout the Okanogan and Columbia valleys (Jones and Stokes 2006, Long 2001). Another smaller village was located near present-day Ardenvoir. During this time, hunting, gathering, and fishing were commonplace (Erickson 2004).

The next visitors to the region were Chinese gold miners in 1866. Ditches and placer mining artifacts and camps were documented from their activities in the region by 1868. The first Euro-American visitors to the Entiat were likely fur trappers traveling through the region in the early-1800s, followed by a few other explorers throughout the mid-1800s. The removal of beaver from the area likely altered side channel and floodplain dynamics by removing wetlands and bogs, altering sediment dynamics, and decreasing groundwater storage (as based on Andonaegui 1999). These alterations were likely more prevalent in lower gradient alluvial reaches in the study area (e.g. Reach 2).

Euro-American settlement began in the Entiat in the late 1880s. Early settlement included construction of homesites, small-scale orchards, alfalfa farming, and sheep grazing (Long 2001). A town soon sprung up including stores, a tavern, a barber shop, a post office, a school, and a hotel. This town was destroyed by a fire in 1913 and a new town soon replaced it in 1914 near the site of the soon to arrive Great Northern Railroad. The second town of Entiat would later be relocated (in the late 1950s) due to construction of the Rocky Reach Hydroelectric project, which flooded the site of the second Entiat town (City of Entiat 2013).

Settlement began to move up-valley in the early 1900s. With expanded settlement in the Entiat region came an increase in agriculture, timber harvest, road building, and infrastructure.

### 2.4.2 Grazing and Orchards

Sheep grazing was one of the first large-scale activities within the basin, with nearly 60,000 sheep grazing in tributary headwaters (Plummer 1902, Erickson 2004). This grazing continued through the 1940s, when the USFS reduced grazing allotments due to poor range conditions (Erikson 2004). Currently, there are approximately 2,000 sheep that graze in the watershed each year, and less than 300 cattle (USFS 1996, CCCD 2002).

Fruit trees were planted in the Entiat as early as the late 1860s (Long 2001). Early orchards were primarily prunes, apricots, and peaches, with commercial orchard production beginning in the late 1890s (Hull 1929, Long 2001, Erikson 2004). Orchards in the basin transitioned to apples and pears by the early 1900s, and irrigation noted as early as 1894. At its peak, approximately 1,200 acres of land within the basin were under orchard production, but nearly all of this production took place outside of our study reach. The orchard industry did escalate the demand for timber, both for homesteads and for fruit boxes.

### 2.4.3 Timber Harvest

Timber harvest began in the mid-1800s, (Long 2001). Cabins, boat ramps, early roads, and fords are visible on survey maps from 1893, indicating that by this point small-scale timber harvest was ongoing in the area. Riparian zones were cleared of trees as early as 1902 (Plummer 1902), and by this date 3,500,000 board feet had already been harvested from the basin. In 1913, the first USFS timber sale took place. From that time forward, the pace and scope of the region's timber harvest accelerated with the expansion of the railroad, improved technology, and the construction of sawmills in the area. This continued through the 1950s, when many log camps and mills shut down or moved locations because areas had been "logged out" (Long 2001). Selective harvest of the region's largest timber or "high-grading" continued through the late 1960s. Today, large-scale timber harvest and associated road building only occurs in the form of salvage operations following wildfires. Between 1990 and 2003 salvage harvest have resulted in the removal of 147 million board feet of timber from the Entiat basin (USFS 1996, CCCD 2004, Woodsmith and Bookter 2007).

Harvest rates and location varied as areas became logged out and technologies to harvest and transport timber improved. Timber harvest is documented throughout the basin, up into the headwaters, as early as 1902 (Plummer). As many as sixteen known sawmills, both stationary and portable, were located within the Entiat Basin (

Table 3). Four mills were located along the mainstem (Long 2001). The upstream extent of timber mills was in the vicinity of Ardenvoir, where the C.A. Harris and Son mill operated from 1917, until the area was logged out in 1919 (Long 2001).

***Table 3. Historical sawmill operations of the Entiat Basin (Long 2001). NA = information not available.***

| Mill | Years of Operation | Average Board Feet/Day |
|---|---|---|
| Grays Mill | 1888-1917 | 10,000 |
| Knapp (Mills) Canyon Portable Mills | 1900-1912 | NA |
| Kellogg Mill | 1913-1914 | NA |
| Gordon Mill | 1915-1920 | NA |
| Mott Mill (later C.A. Harris & Son (Muddy Creek)) | 1916-1923 | NA |
| C.A. Harris and Son (Mills Canyon) | 1916-1919 | 15,000 |
| C.A. Harris & Son (Mad River) | 1930s-1940s | 60,000 |

Upland timber harvest and its associated practices have likely impacted the Entiat River in a number of ways, including potential changes to the hydrologic and sediment regime. Although the Entiat basin is naturally prone to mass-wasting events and alluvial fan contributions, research indicates that forests with a history of timber harvest exhibit increased amounts of slides and debris flows (Benda and Cundy 1990, Swanson and Lienkaemper 1978, Sidle et al. 1985). This is related to the destabilizing effect of tree removal and the hydrologic/erosion effects of the forest road network.

Timber harvest along the valley floor has directly altered channel processes since the late 1800s. Harvest and removal of riparian trees was documented as early as 1902 and continued through much of the 20th century (Figure 11). Often, riparian trees were the first to be harvested due to ease of access and transport (Erickson 2004). These practices removed hydraulic roughness from the valley floor, which moderates floods, regulates inundation processes, provides shade, moderates temperature fluctuations within the channel, and provides future sources of large wood material to the channel. Although riparian clearing is no longer occurring in most of the study reach, the effects of this historical practice will continue to affect wood-loading for the foreseeable future (see Section 2.5.4).

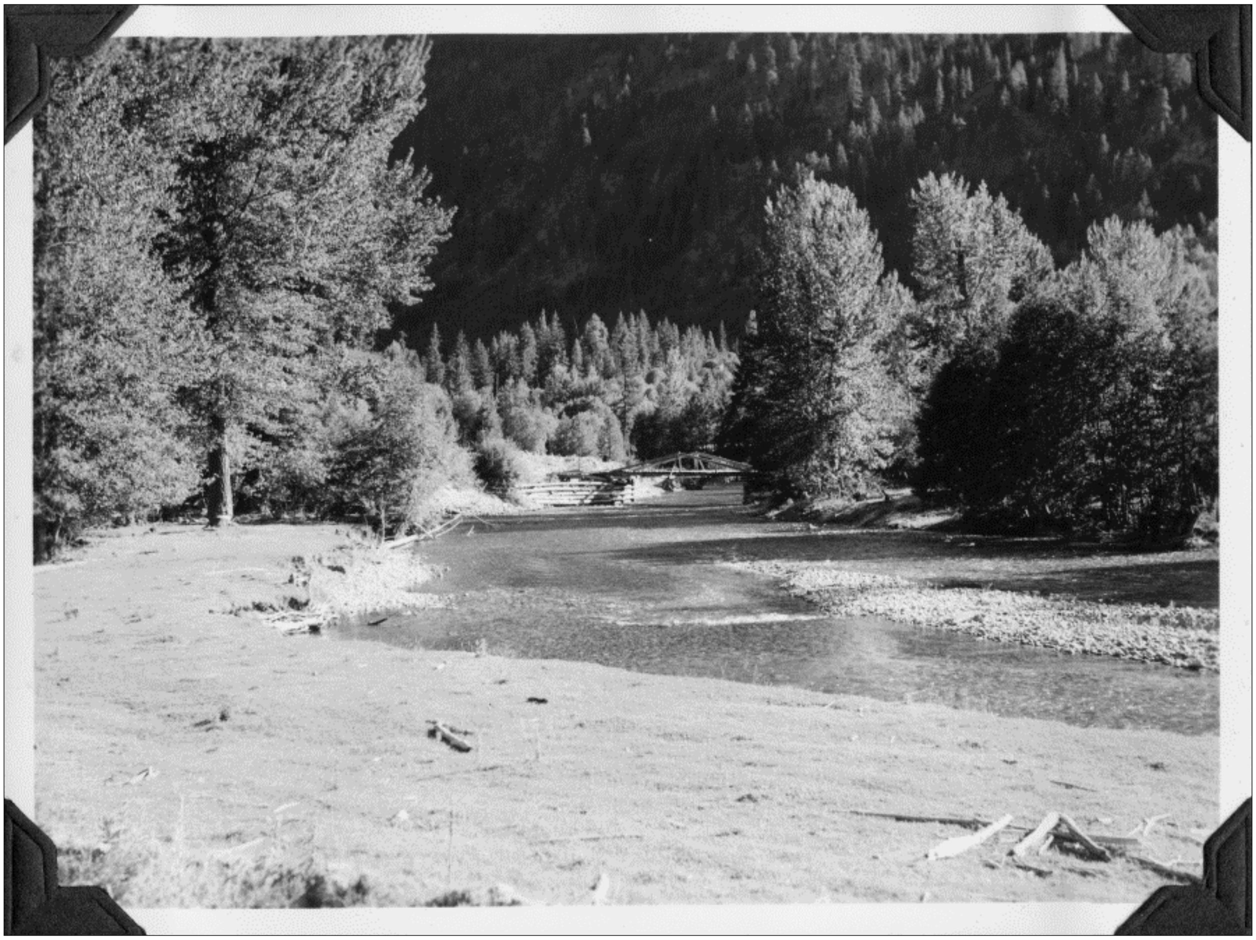

***Figure 11. Photo of logged riparian area near RM 17.3 (1939)***

In addition to the impacts of removal of timber from the Entiat Basin, three practices associated with past timber practices have had lasting effects on the channel. These activities are (1) mill pond dams, (2) splash damming, and (3) snagging and clearing. Each of these practices and their associated impacts are discussed in more detail below.

*(1) Mill Pond Dams*

Construction of sawmills up and down the Entiat River came with the construction of mill pond dams. These dams were typically built to provide adequate discharge to turn a water wheel, which provided energy to the associated sawmill. Mill pond dams span the channel and block fish passage at a variety of flows. In 1888, the first saw mill dam was built across the Entiat, with a lumber mill constructed the following year (Long 2001). Three additional channel-spanning dams were constructed on the Entiat, blocking passage at various points through the 1960s (Table 4 and Figure 12).

***Table 4. Historical Dams on the Entiat River (Adapted from Erickson 2004 and 1934-1936 Fisheries Surveys).***

| Dam | Dates of Operation | Location | Height of Dam (feet) | Fish Passage |
|---|---|---|---|---|
| Gray's Mill | 1888-1917 | Near Mouth | "Tens of Feet" | Blocked all Passage |
| Power Dam | 1909-1960s | RM 2 (Keystone Canyon) | 3 | Impassable at Low Flow |
| Kellogg Mill | 1913-1932 | RM 3 (Mills Canyon) | 8 | Impassable; Dam remnants made impassable through 1937 |
| Harris Mill | 1930-1948 | RM 10 (Mad River) | 13 | Passable only at High Flow |

***Figure 12. Mill pond at Gray's Mill (1898 (CCCD 1999) or 1916 (BOR 2009)). Photo courtesy of the Entiat Historical Society.***

*(2) Splash Damming*

Early sawmill operations included damming of the river for log ponds and log transport via splash damming (Figure 13, Figure 14). Four known log mills were on the mainstem of the Entiat, though all downstream of the study reach, log drives were documented as far up as RM 24.0 (Long 2001, Plummer 1902). Logs were pooled behind channel-spanning mill pond dams, and typically, during high spring flows, water was released from the dam to allow logs to rush downstream. Impacts of splash dams have been documented throughout the Pacific Northwest (Sedell and Luchessa 1981, Farnell 1979, Taylor

1999), and presumably the Entiat River experienced similar impacts. Impacts include channel simplification through the dynamiting and removal of large in-channel boulders and natural log jams and the obstruction of side channels and backwater areas. These actions would have eliminated many habitats outright and would have reduced overall habitat complexity and cover.


***Figure 13. Historical photo (1914) taken near the Kellog Mill. Photo courtesy of the Entiat Historical Society.***


***Figure 14. Mill pond with rafted logs at the Adams and Colman Mill, early 20th century. Photo courtesy of the Entiat Historical Society.***

*(3) 'Debris' Removal*

In addition to the impact of timber harvest and log drives on the Entiat, large wood removal from the river has been documented in at least one instance. Following the 1970s wildfire and 1972 flooding, the Army Corps attempted to mitigate flooding by the removal of large wood from the river. This included removing all large woody 'debris' between RM 16.4 and RM 25.9. Wood removed included at least six log jams, 30 individual pieces, and 29 floating pieces (USBR 2009, ACOE 2001). Although quantitative before and after surveys were not performed to document the impact of this removal, examination of the aerial photograph record and anecdotal evidence suggests that the large wood removal led to the filling in of pools and habitat simplification (USDA 1979 as referenced in CCCD 2004, USBR 2009). Although this was the only documented instance of clearing and snagging on the Entiat, other wood removal operations may have occurred following large fire or flood events.

### 2.4.4 Fire Suppression

The fire regime within the Upper Entiat is a major driver in forest ecology, and it influences riparian stand conditions and ultimately, instream flow patterns and large wood conditions. Prior to Euro-American settlement, the Entiat Basin would have experienced a low intensity fire every seven years on average (Everett et al. 2000). Decades of fire suppression beginning in the early 1900s led to an increase in fire return first to every 10 years, and then by 1910 increasing to every 40 years (Everett et al 2000, USFS 2007). Fire suppression has shifted the entire basin to a less frequent, higher intensity fire regime, and since 1970, over 60% of the basin has experienced large, stand-replacing fires (Everett et al 2000, USFS 2007). Lightning strikes initiated major fires in the basin in 1970, 1988, and 1994, with over 20 fires of greater than 300 acres on record (Table 5). Fire suppression within the basin has led to shifts in vegetative composition from more open stands of fire-tolerant species (e.g. ponderosa pine) to higher density stands of less fire-tolerant species (e.g. grand fir), as well as a buildup of fuels along the forest floor (Wilman 2003). In 1902, the forested portion of the Entiat Basin was 75% ponderosa pine (Plummer 1902), whereas today the basin is primarily grand or Douglas fir. The historically more open stands had larger trees than the higher density stands seen today, which has served to decrease the size of riparian trees that are now available to be recruited by the river.

***Table 5. Fires of 300 or more acres on record in the Entiat Basin (Andonaegui 1999).***

| Year | Fire | Area Burned (Acres) |
|---|---|---|
| 1910 | Signal/Tyee Peak | 2,560 |
| 1925 | Mad River Fire | 1,500+ |
| 1925 | Spectacle Butte Fire | 600 |
| 1925 | Borealis Ridge Fire | 500 |
| 1925 | Three Creeks, Lake Creek, Brennegan Creek, Gray Canyon, Mud Cree | Each Fire ~300 |
| 1928 | Coal Oil Fire | 600+ |
| 1941 | Larch Lake | 400 |
| 1958 | Entiat Fire | 12,000 |
| 1961 | Tenans George Fire | 3,750 |
| 1966 | Hornet Creek Fire #163 | 1,520 |
| 1968 | Harris Mill Fire #065 | 1,210 |
| 1970 | Mills Canyon Fire | 933 |
| 1970 | Fire Complex including Gold Ridge Fire; Entiat/Slide Ridge Fires | 122,000 |
| 1975 | Crum Canyon Fire #050 | 9,000 |
| 1988 | Dinkleman Fire | 53,000 |
| 1990 | Dick Mesa Fire #110 | 1,151 |
| 1994 | Tyee Fire Complex #047 | 140,196 |

### 2.4.5 Habitat Alterations

Habitat alterations within the Entiat River Basin began in the late 1800s, and increased significantly by the turn of that century. In 1898, a dam was built one mile upstream of the Entiat's mouth, and was quickly replaced by a dam that completely blocked fish passage. A series of dams and unscreened irrigation diversions led to a rapid decline in salmonid populations. Although dams and diversions did not directly alter habitat within the study area, they reduced fish passage and access to habitat in the study area. Human alterations began to affect fish populations by the early 1900s. Activities associated with timber harvest led to disturbance to the stream and instream habitat. Log drives in the river channel often involve removal of large boulders and existing habitat elements such as log jams. Log drives destabilize the bed and banks, degrading pool habitat and riparian conditions. The typical result of repeated log drives is channel simplification, incision, loss of instream habitat, and disconnection of off-channel habitat. A 1935 habitat assessment (US Bureau of Fisheries 1934-1937) notes: "In 1904 the last good run of Chinooks entered the Entiat, depletion being very rapid in succeeding years." By the 1930s, salmon sightings in the system were extremely rare due to passage barriers (Bryant and Parkhurst 1950).

In 1939 and 1940, adult steelhead and Chinook were imported to the system from the Grand Coulee Dam fish maintenance project and in 1941 the Entiat Hatchery was constructed at Packwood Springs (RM 7). By 1950 the dams that blocked fish passage were either removed or had fish ladders, and eighteen of nineteen irrigation ditches had fish screens "thus greatly increasing fishery production value of the stream" (Bryant and Parkhurst 1950).

Although mill dams were improved for fish passage, logging activities continued at increasing rates into the late 20$^{th}$ century. Logging activity peaked in the late 1970s and early 1980s, driven by salvage logging following large wildfires. Debris flows that occurred following the wildfires caused considerable flooding when debris flow material blocked the channel. Extensive channel clearing was carried out following these events with log jams and single logs removed through much of the basin. The channel debris clearing activities extended to RM 25.9 (USBR 2009), just into the downstream end of the study area.

## 2.5 EXISTING FORMS AND PROCESSES

### 2.5.1 Hydrology

The Entiat River in the Stillwater study area is a fourth order stream draining 173 square miles of the eastern North Cascades. Dominant hydrologic patterns are driven by precipitation in the form of snow and subsequent spring snowmelt. Peak runoff usually occurs from April through July, with the highest rates typically in late June (Figure 15). Initiation and variation in snowmelt volume is driven by changes in ambient air temperature, snowpack mass, and the elevational distribution of the season's snowpack. Stream discharge typically returns to baseflow by late August. Mean annual flow is 374 cubic feet per second.

Precipitation amounts vary with elevation and distance from source areas. In the higher elevation areas of the basin, which top out at 9,230 feet, average annual precipitation is 110 inches falling mainly as snow. The downstream end of the study area is at an elevation of 1,690 ft. Mean annual precipitation in the study area watershed is about 62 inches. The study area is upstream of the Entiat's only major tributary, the Mad River. Within the study area there are several small perennial tributaries including Lake Creek and Silver Creek. These tributaries are typically steep step-pool streams with large bed material, and a proportionally small contribution to the total flow of the Entiat.

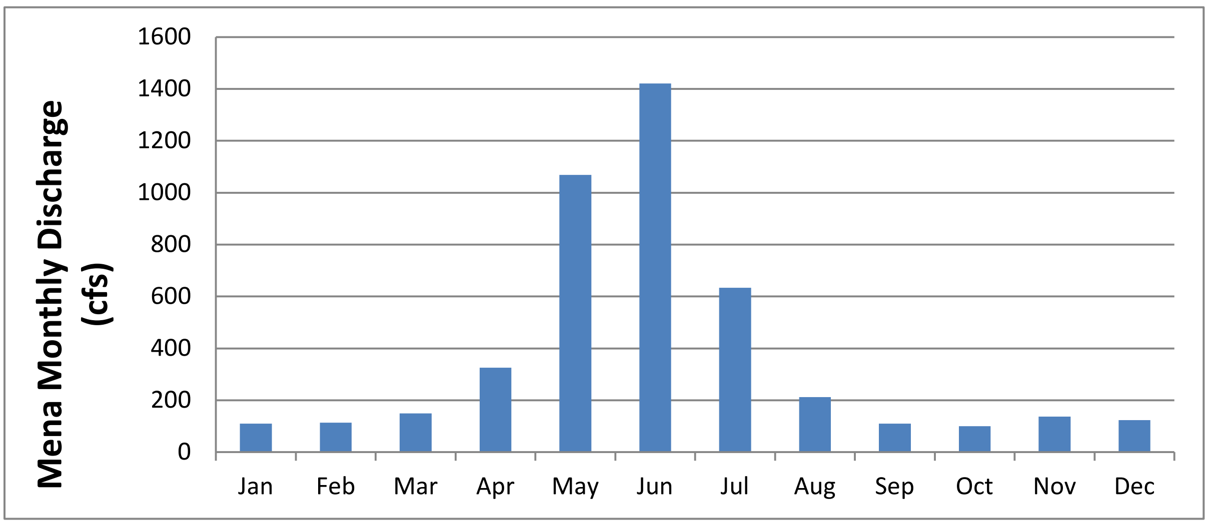


***Figure 15. Mean monthly discharge for the period of record at the USGS gage near Ardenvoir, WA (Gage 12452800, 1957 to present).***

There are two operating USGS real-time stream gages on the Entiat River, the Keystone Gage (USGS #12452990) at RM 1.4, with a period of record from 1996 to present, and the Ardenvoir Gage (USGS #12452800) at RM 10, with a period of record from 1957 to present. There was another mainstem gage (USGS#12453000) located near the current site of the Keystone Gage at RM 1.4, with a period of record of 1910-1958. There is also a gage on the Mad River, which enters the Entiat near RM 9. A list of the 10 major floods since 1910 are presented in Table 6.

***Table 6. List of 10 largest flood peaks and the gage where measured (with corresponding drainage area).***

| Year | Day | Discharge ($ft^3/s$) | Gage location | Drainage area |
|---|---|---|---|---|
| 1948 | May 29 | 10,800 | Mouth | 419 |
| 1972 | June 10 | 6,430 | Ardenvoir | 203 |
| 1974 | June 17 | 5,540 | Ardenvoir | 203 |
| 1916 | June 18 | 5,380 | Mouth | 419 |
| 1956 | June 01 | 4,960 | Mouth | 419 |
| 1955 | June 13 | 4,800 | Mouth | 419 |
| 1983 | May 31 | 4,670 | Ardenvoir | 203 |
| 1958 | May 26 | 4,500 | Mouth | 419 |
| 1999 | June 17 | 4,460 | Ardenvoir | 203 |
| 1921 | June 06 | 4,360 | Mouth | 419 |

The Ardenvoir Gage was used to perform a flood recurrence analysis using the USGS PeakFQ program (Table 7). The timing (month) of annual peak flows from this gage is plotted in Figure 16. These data show that the flood regime is strongly influenced by spring snowmelt; out of 54 total peaks in the record, 51 have occurred in May and June, which is typical of rivers in the region.

***Table 7. Flood Recurrence Analysis for USGS Gage near Ardenvoir, WA (Gage 12458200). Data retrieved on 25 February 2013. Period of record extends from 1958 to 2011.***

| **Exceedance Probability (% Chance)** | **0. 2** | **1** | **2** | **5** | **10** | **20** | **50** | **80** | **99** |
|---|---|---|---|---|---|---|---|---|---|
| **Recurrence Interval (years)** | **500** | **100** | **50** | **25** | **10** | **5** | **2** | **1.25** | **1.01** |
| **Discharge (cfs)** | 7,527 | 6,181 | 5,606 | 5,028 | 4,248 | 3,624 | 2,671 | 1,965 | 1,139 |

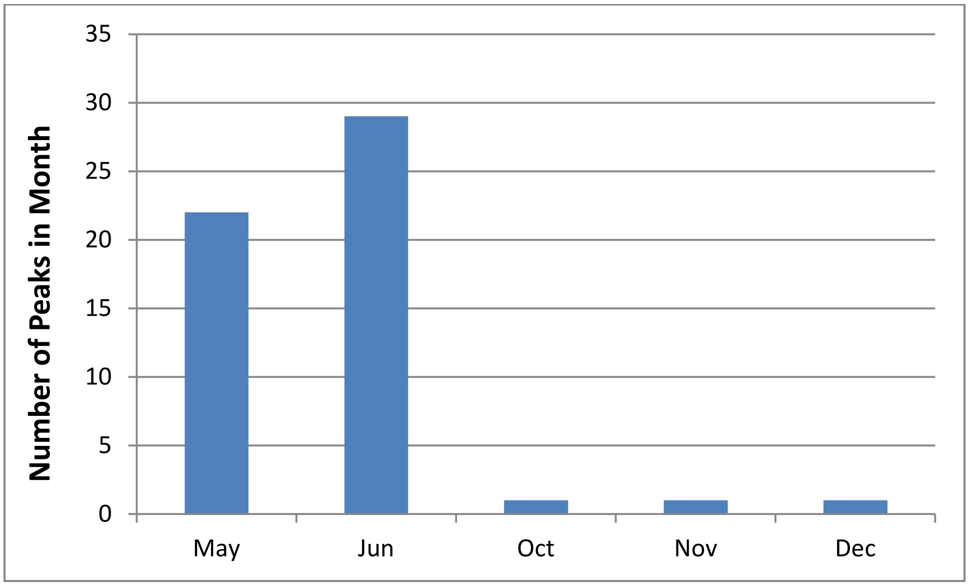


***Figure 16. Month of occurrence for annual peak flow events recorded at the USGS gage near Ardenvoir, WA.***

Whereas precipitation patterns, temperature, and snowmelt control spring high flows and peak flow events, groundwater storage and release regulates base flow during low flow periods. Glacial, colluvial, and alluvial deposits make up unconfined aquifer material in the study area (Dixon 2003). These deposits are located within the channel migration zone of the river valley, with crystalline igneous and metamorphic bedrock defining the lower and lateral limits of the aquifer. Recharge of the alluvial aquifer is achieved primarily through precipitation and infiltration. However, surface water/groundwater interactions play a significant role as well, and a strong hydraulic connection between the channel and aquifer is recognized. Dixon (2003) estimated between 111,152 and 107,122 acre-feet of water in the alluvial aquifer of the entire Entiat River. The limited lateral extent of floodplain surfaces in the study area would naturally limit groundwater storage within the alluvial aquifer.

Additional information on basin hydrology and effects of land-use is discussed in the REI Report (Appendix C).

### 2.5.2 Hydraulics

#### *Background*

A hydraulics analysis was used to support the geomorphic assessment and restoration planning. This analysis utilized available LiDAR data to run a one-dimensional hydraulic model (HEC-RAS version 4.1.0) for the downstream portion of the study area (Reaches 0-6, spanning the limit of available LiDAR data). The model is used as one of several tools for analyzing flood inundation levels and for comparing stream energy patterns among reaches within the study area.

#### *Methods*

*Hydraulic Model*

The hydraulic model was created using the HEC GeoRAS framework to create the boundaries of the model system (stream centerline, bank stations, overbank flowpaths, and cross sections). These features were overlaid on a digital elevation model (in this case, LiDAR) from which elevations were extracted for all components of the geometric data set. Currently, LiDAR is only available from reaches 0 through the lower half of Reach 6, limiting modeling efforts to this portion of the study area. Where LiDAR was available, cross sections were spaced every 100 feet. This spacing was reduced to approximately every 50 feet through areas around meander bends, upstream and downstream of bridges, or where additional resolution was warranted. Once the geometric data was developed, the model was exported from ArcGIS and brought into HEC-RAS 4.1.0, a one-dimensional water surface profiling program. Steady-flow data was input based on flood frequency data presented in Table 8. Flows ranging from the Q2 (2-year) to the Q100 (100-year) floods were modeled. For the purposes of this effort, we used Manning's roughness coefficient (n) values ranging from 0.032 to 0.05 for the channel (Table 9). Manning's values represent resistance to flow, and are applied both to in-channel and overbank (floodplain) areas. Values were based on field observation of median size of channel substrate, and calibrated according to photographic comparisons in Barnes 1967, with reference to values provided in Acrement and Schneider (1989). A value of 0.15 was applied to overbank areas to convey roughness of a primarily forested condition, with a low density understory (Chow 1959).

***Table 8. Flood frequency data used in the hydraulic model developed for the inundation analyses based on hydrologic analyses by USBR (2009). Flow change locations are listed by River Mile (RM) and closest hydraulic cross-section HEC-RAS. Discharge units at each reach are cubic feet per second.***

| Flood Recurrence Interval | RM 29 (167300) | RM 28 (161500) | RM 27 (155400) | RM 26 (149800) | RM 25 (143800) | RM 24 (137800) | RM 23 (132392.1) |
|---|---|---|---|---|---|---|---|
| **Q2** | 2400 | 2510 | 2530 | 2540 | 2560 | 2580 | 2610 |
| **Q5** | 3280 | 3430 | 3460 | 3470 | 3500 | 3540 | 3580 |
| **Q10** | 3860 | 4040 | 4070 | 4090 | 4120 | 4160 | 4210 |
| **Q25** | 4590 | 4800 | 4840 | 4860 | 4890 | 4940 | 5000 |
| **Q50** | 5130 | 5360 | 5400 | 5430 | 5460 | 5520 | 5580 |
| **Q100** | 5660 | 5920 | 5970 | 5990 | 6030 | 6100 | 6170 |

***Table 9. Mannings Roughness (n) values used in hydraulic modeling.***

| Geomorphic Reach | Manning's Roughness Coefficient (n Value) |
|---|---|
| • Reach 2<br>• Lower Stillwaters Reach (not in study area)<br>o HEC-RAS Cross sections 138700 to 133659.4 | 0.032 |
| • Lower Stillwaters Reach (not in study area)<br>o HEC-RAS Cross sections 143600 to 138700 | 0.034 |
| • Reach 0 | 0.038 |
| • Reach 4<br>• Reach 5<br>o HEC-RAS Cross sections 159800.3 to 160699.8<br>• Reach 1 | 0.04 |
| • Reach 3 | 0.042 |
| • Reach 6<br>• Reach 5<br>o HEC-RAS Cross sections 160800 to 163000 | 0.05 |

There are limitations for utilizing LiDAR to model floodplain inundations. First, the LiDAR covers only from Reach 0 through part of Reach 6 and includes errors of at least up to 0.5 feet (Watershed Sciences 2007). Further, the LiDAR data available for the Entiat River is capable of producing elevation data in terrestrial environments, but cannot produce ground elevations below water (i.e. bathymetry). Consequently, results of these analyses should not be used for detailed modeling, restoration, or infrastructure planning purposes. Despite this limitation, the inundation analysis is assumed to be relatively accurate for larger flood flows (i.e. 2-year return interval and above), where the topography errors would have less effect (proportionally) on the results. A sensitivity analysis was performed to see if subtracting the known discharge on the date the LiDAR was flown improved results. Flood stage elevation typically differed by less than 0.10 feet, so no discharge was subtracted for model development.

*Flood Inundation Analysis*

Flood inundation was modeled using HEC-GeoRAS. HEC-GeoRAS allows for visualization of floodplain inundation by overlaying HEC-RAS modeling outputs on digital terrain models. Georeferenced hydraulic modeling outputs are then displayed in ArcGIS. As described previously, there are limitations to utilizing LiDAR to model floodplain inundation and results of these analyses should not be used for detailed modeling, restoration, or infrastructure planning purposes.

*Stream Power Analysis*

Stream power was analyzed as one of several variables to compare stream energy among reaches. Stream power (Ω) is a measure of the potential energy exerted per unit length of channel (Bagnold 1966) and is based on the concept that the stream is a sediment transport vehicle with varying degrees of efficiency. Stream power (Ω) represents the potential amount of 'geomorphic work' (e.g. sediment transport, scour) the stream is capable of performing:

$$\Omega = \gamma Qs$$

Where:

γ = the specific weight of water

Q = discharge

S = Energy Gradient Slope

When slope and/or discharge increase, stream power will increase (Bagnold 1966). Stream power calculations were output from the HEC-RAS model.

*Sediment Competence Analysis*

Sediment competence was analyzed to provide an overview of streambed mobility. Streambed sediments will only move when the force of water acting on those sediments is greater than the force keeping those sediments in place. The force of flowing water acting on a sediment particle is the shear stress. The amount of force required to move that sediment particle is the critical shear stress. If the shear stress is greater than the critical shear stress, then the sediment will be transported. Conversely, if shear stress is less than the critical shear stress, the sediment will remain stable or be deposited. A value of "excess shear stress" can be calculated as the ratio of the applied shear stress to the critical shear stress, which yields a useful term in which values greater than one represent a mobile bed condition and values less than one represents a stable bed condition.

To evaluate general trends in the ability of the Upper Stillwaters Reach to mobilize and convey sediment, excess shear ratios were calculated for the study reach. Both the Shields (1936) equation and the modified Komar (1987) equation were used for this analysis. The Komar equation is based on the concept that the larger, grade controlling particles that make up riffle crests govern bed mobility and channel form in riffle-pool streams (i.e. only once these particles become mobile does significant bed re-shaping occur).

The shear stress applied to the bed is:

$$\tau = \rho g R s$$

The critical shear stress needed to mobilize the streambed sediments is (Shields 1936):

$$\tau_{C1} = \tau^*_{C50}(\rho_s - \rho) g D_{84}$$

And the modified version of this equation is (Komar 1987):

$$\tau_{C2} = \tau^*_{C50}(\rho_s - \rho) g D_{84}^{0.3} D_{50}^{0.7}$$

The ratio of shear stress to critical shear stress is known as excess shear stress ($\tau^*$):

$$\tau^* = \frac{\tau}{\tau_c} = \frac{\rho R s}{\tau^*_{c50}\, D_{84}\, (\rho_s - \rho)}$$

Where:

$\tau$ = bed shear stress

$\rho$ = density of water (lb. /ft³)

$g$ = gravity (ft/s)

$R$ = hydraulic radius

$\rho_s$ = density of sediment (lb. /ft³)

$\tau_c$ = critical shear stress (lb. /ft²)

$D_{84}$ = 84th percentile of grain size (ft.)

$D_{50}$ = median grain size (ft.)

$s$ = slope

$\tau^*_{c50}$ = critical dimensionless shear stress (Shields Parameter)

Here, $\tau^*_{c50}$ was adapted from Julien (1995) and the D84 was utilized to determine the conditions required for most of the streambed to be mobilized and the potential for bed change to occur (Leopold 1992).

A total of seven pebble counts were conducted. Pebble count data were used in areas where hydraulic modeling was done (reaches where LiDAR was available) to evaluate sediment mobility conditions. Pebble counts were compared to hydraulic conditions of the closest hydraulic cross-section in the model, so data is only a snapshot of sediment mobility conditions, and should not be generalized to the whole reach. Two pebble counts (Reach 0 (RM 23.61) and Reach 2 (RM 25.8) were used from the Columbia Habitat Monitoring Program (CHaMP) data available for the Entiat River. These pebble counts were collected in 2011. Of note, CHaMP pebble counts were collected at pool tail crests to evaluate salmonid habitat, where Inter-Fluve collected pebble counts where conducted at riffle crests to evaluate stream substrate which is providing grade control. It is expected that CHaMP pebble counts will provide lower excess shear ratios than those collected at the higher energy location of riffle crests. Due to the limited quantity of pebble counts and the fact that hydraulic parameters are based on LiDAR, data should only be utilized to understand sediment transport patterns at a conceptual level, and should not be utilized for design purposes.

### *Results*

#### *Floodplain Inundation*

Inundation analysis results are presented in the five maps located at the end of this section. Throughout the confined reaches (Reaches 4-6, Reach 9, Reach 11), flows for both the 2-year and 100-year flood events remain largely in-channel. Throughout the unconfined reaches (e.g. Reach 1, Reach 3, Reach 10), water surface elevations extend beyond the main channel boundaries. In many places these flows activate side channels and inundate floodplain surfaces.

*Hydraulics*

Results of the 2-year and 100-year flood event hydraulic analyses are presented in Table 10 and Table 11. For both the 2-year and 100-year events, reaches 4 through 6 were closely followed by reaches 1 and 3 for the highest stream power, excess shear stress, and velocities, with Reach 6 having the maximum values for all of these parameters. These results are consistent with the higher gradient and confinement of these reaches (see Section 2.5.3). Stream power, excess shear, and velocity were low in Reaches 0 and 2.

***Table 10. Hydraulic analysis results for the 2-year flood event.***

| | Reach 0 | Reach 1 | Reach 2 | Reach 3 | Reach 4 | Reach 5 | Reach 6 |
|---|---|---|---|---|---|---|---|
| **Avg Velocity (ft /sec)** | 5.65 | 8.07 | 6.04 | 8.22 | 9.16 | 9.02 | 11.80 |
| **Shear stress (avg)** | 0.66 | 2.18 | 0.90 | 2.54 | 2.97 | 3.41 | 6.95 |
| **Stream Power (lb/ft/s)** | 517 | 4264 | 778 | 5306 | 6958 | 6243 | 5501 |
| **Incipient Particle Size (in)** | 3.19 | 10.55 | 4.35 | 12.29 | 14.37 | 25.01 | 33.62 |

***Table 11. Hydraulic analysis results for the 100-year flood event.***

| | Reach 0 | Reach 1 | Reach 2 | Reach 3 | Reach 4 | Reach 5 | Reach 6 |
|---|---|---|---|---|---|---|---|
| **Avg Velocity (ft /sec)** | 7.03 | 10.96 | 7.47 | 11.12 | 12.12 | 12.12 | 15.77 |
| **Shear stress (avg)** | 0.85 | 3.48 | 1.22 | 3.94 | 4.61 | 5.17 | 10.60 |
| **Stream Power (lb/ft/s)** | 807 | 4210 | 1420 | 4972 | 6607 | 5867 | 11984 |
| **Incipient Particle Size (in)** | 3.19 | 16.84 | 5.90 | 19.06 | 22.30 | 16.50 | 51.28 |

*Sediment Competence*

***Although these results cannot be generalized throughout the study area, sediment competence analyses demonstrate that at all but one of the analyzed flows (Reach 6, Q100 Komar), the D84 is not mobile (***

Figure 17). Results of the sediment competence analysis support the assumption that the Entiat River is an 'underfit' stream at these locations, with sediment that is immobile even at the 100-year event. The channel is 'underfit' because historically channel discharge was much greater, and created a channel form that was much wider and deeper, with a much larger bedload than is appropriate for the contemporary hydrologic regime. The channel has winnowed away smaller gravels and cobbles that it is able to move, leaving behind large cobbles and boulders through the majority of the study reach.

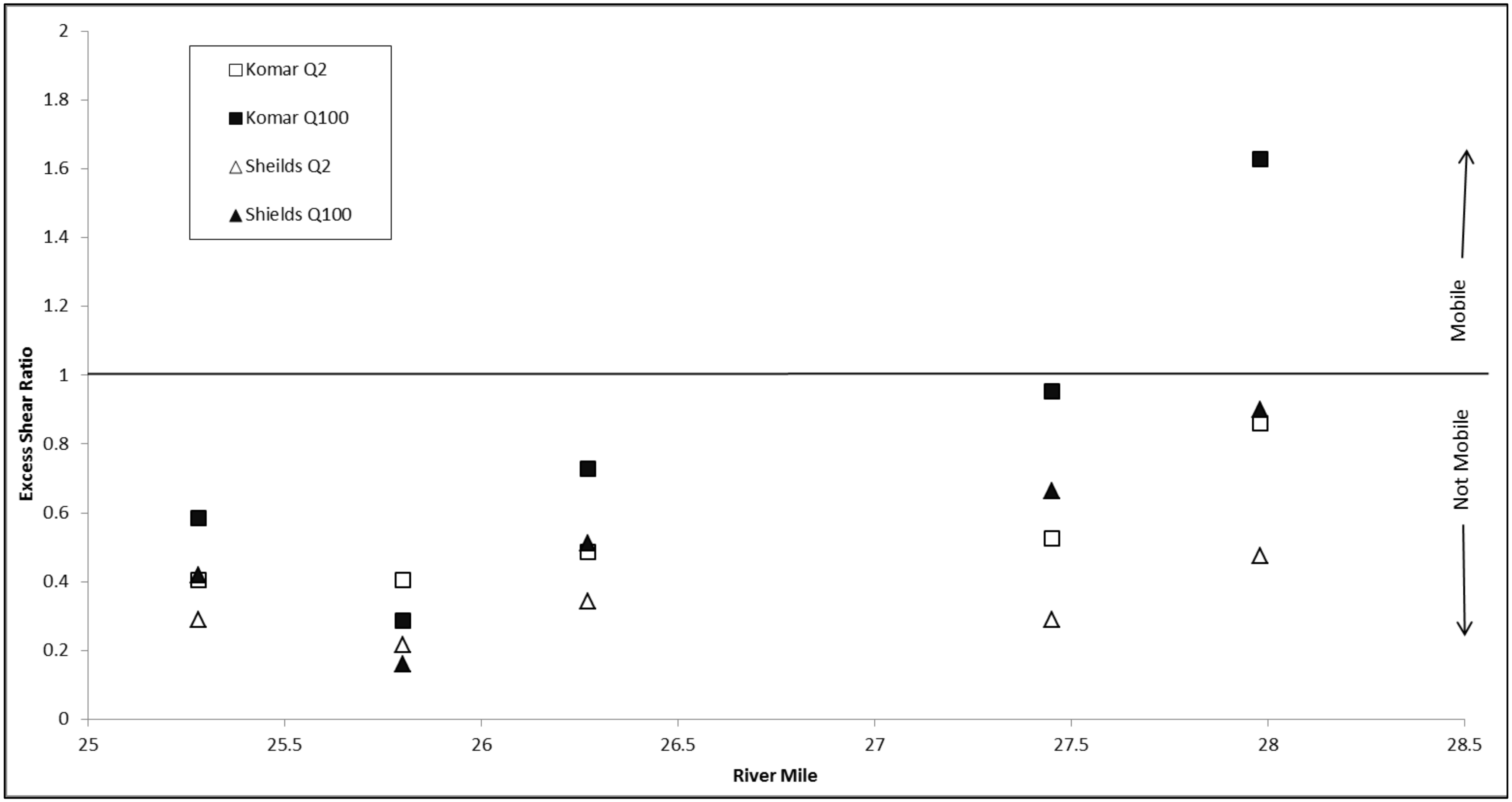


*Figure 17. Excess shear ratio for pebble counts in Reaches 1 through 5 of the study area.*

### *Discussion*

Overall, the hydraulic analysis indicates the study reach is a high energy, 'underfit' stream. Analysis confirms higher stream energy and less floodplain inundation in the confined reaches (i.e. Reach 1, 3 through 6, Figure 19, Figure 20, Figure 22 respectively) and greater floodplain inundation and lower stream energy in the unconfined reaches (Reach 0, 2, Figure 18 and Figure 19, respectively). Combining the hydraulic analysis with the geomorphic and habitat assessments shows that current channel and floodplain complexity tended to naturally increase in reaches with the greatest potential of regular floodplain inundation (2-year flood recurrence).

Hydraulic floodplain inundation modeling provided some insight into the geologic processes of incision. As the Entiat River has adjusted to the drier contemporary hydrologic regime, it has naturally incised, leaving behind abandoned floodplain terraces. Terraces appear to be of at least two distinct ages, with older terraces higher above the channel surface. Aging of terrace surfaces beyond relative aging was beyond the scope of this study. Abandoned terraces are often 10+ feet above existing floodplain surfaces, and xeric (dry) vegetation communities indicate these areas have long been abandoned. The hydraulic inundation models of the 100-year flood helped to verify the boundaries between abandoned terraces and modern floodplain surfaces.

Hydraulic analysis supports the assessment that direct human alterations have had a limited influence on floodplain inundation patterns, stream energy, and incision processes. The only impact to inundation processes observed were related to the area surrounding the Fox Creek Campground, where a retaining wall, campground road, and culvert disconnect channel process. Fill and abutments associated with bridge crossings in Reach 10 and Reach 0 alter hydraulics at high flows, but the road surface is elevated out of the active flood-prone surfaces so do not disconnect floodplain processes at smaller flows.

More indirect anthropogenically-influenced incision processes, such as from forest roads and timber harvest, are difficult to discern by the floodplain inundation analysis. Downstream of Box Canyon, a third surface elevation was observed. This surface was typically two to four feet above the contemporary floodplain. These surfaces contain visible topographic evidence of scour and deposition but no evidence of modern inundation. It is possible that the abandonment of these surfaces has been somewhat influenced by human impacts on watershed processes (e.g. hydrology and sediment regime) but this incision is likely dominated by natural geomorphic processes.

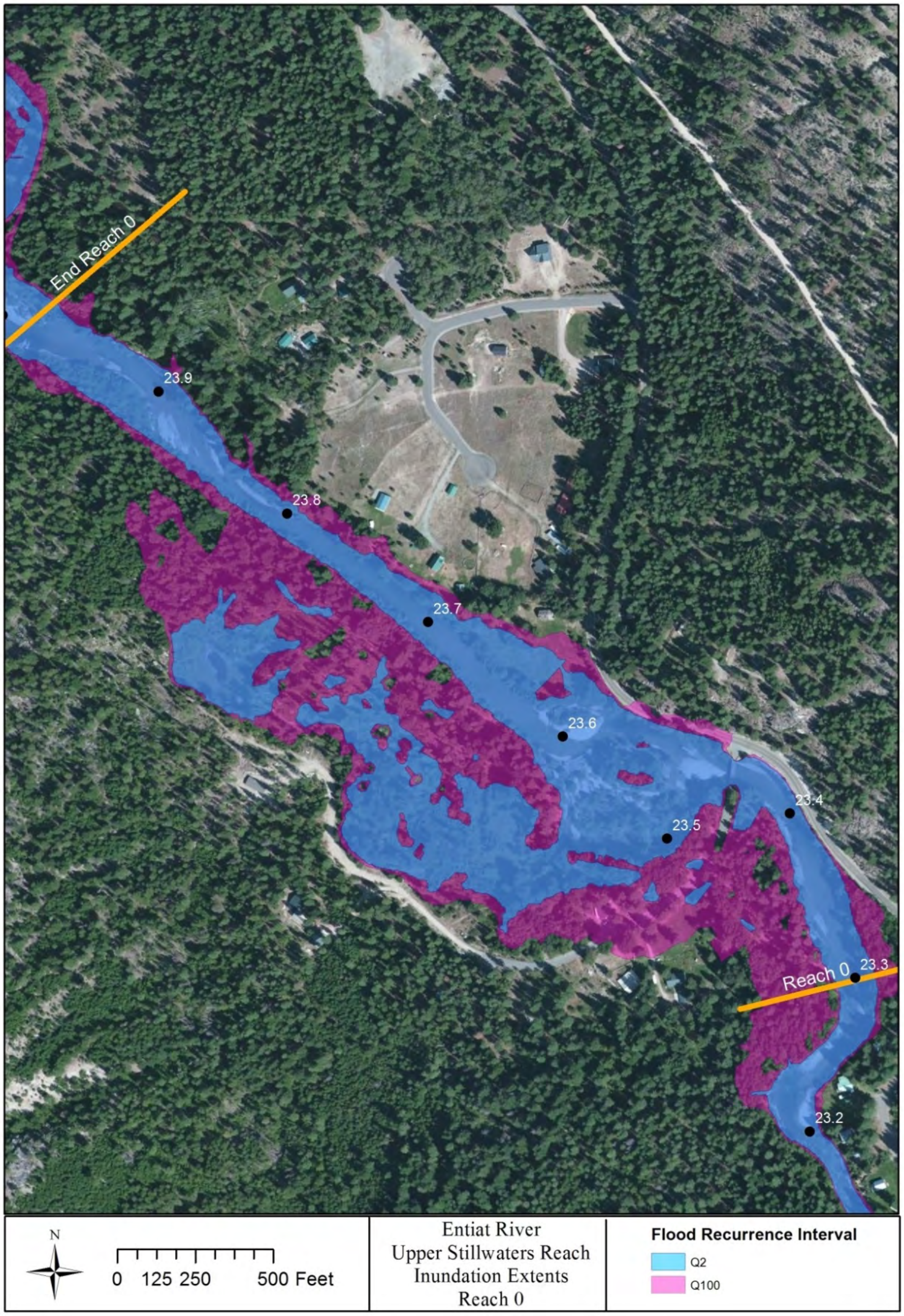


*Figure 18. Reach 0 floodplain inundation potential for the 2- and 100-year flood events.*

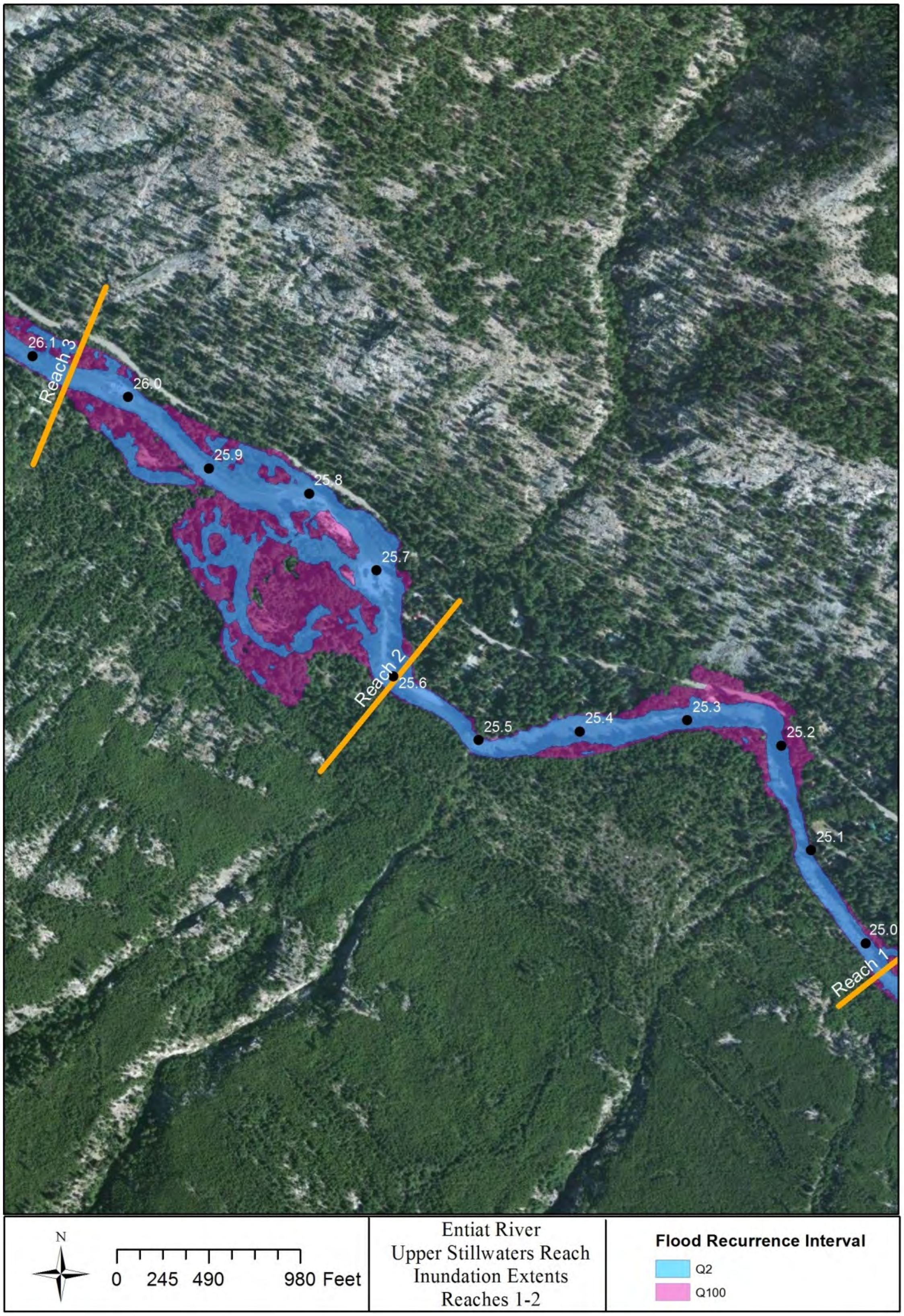


*Figure 19. Reach 1 and 2 modeled floodplain inundation for the 2- and 100-year flood events.*

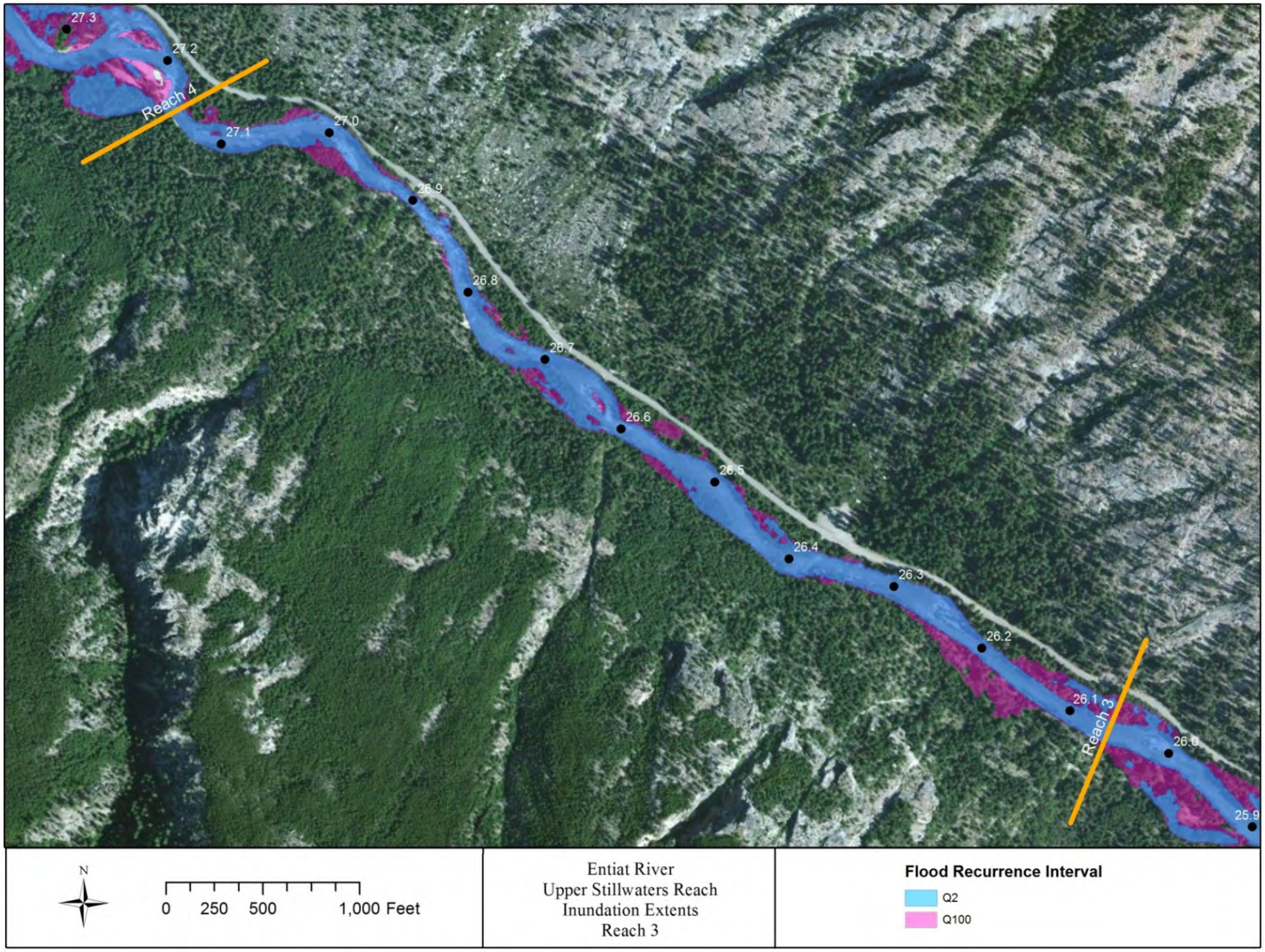


***Figure 20. Reach 3 modeled floodplain inundation for the 2- and 100-year flood events.***

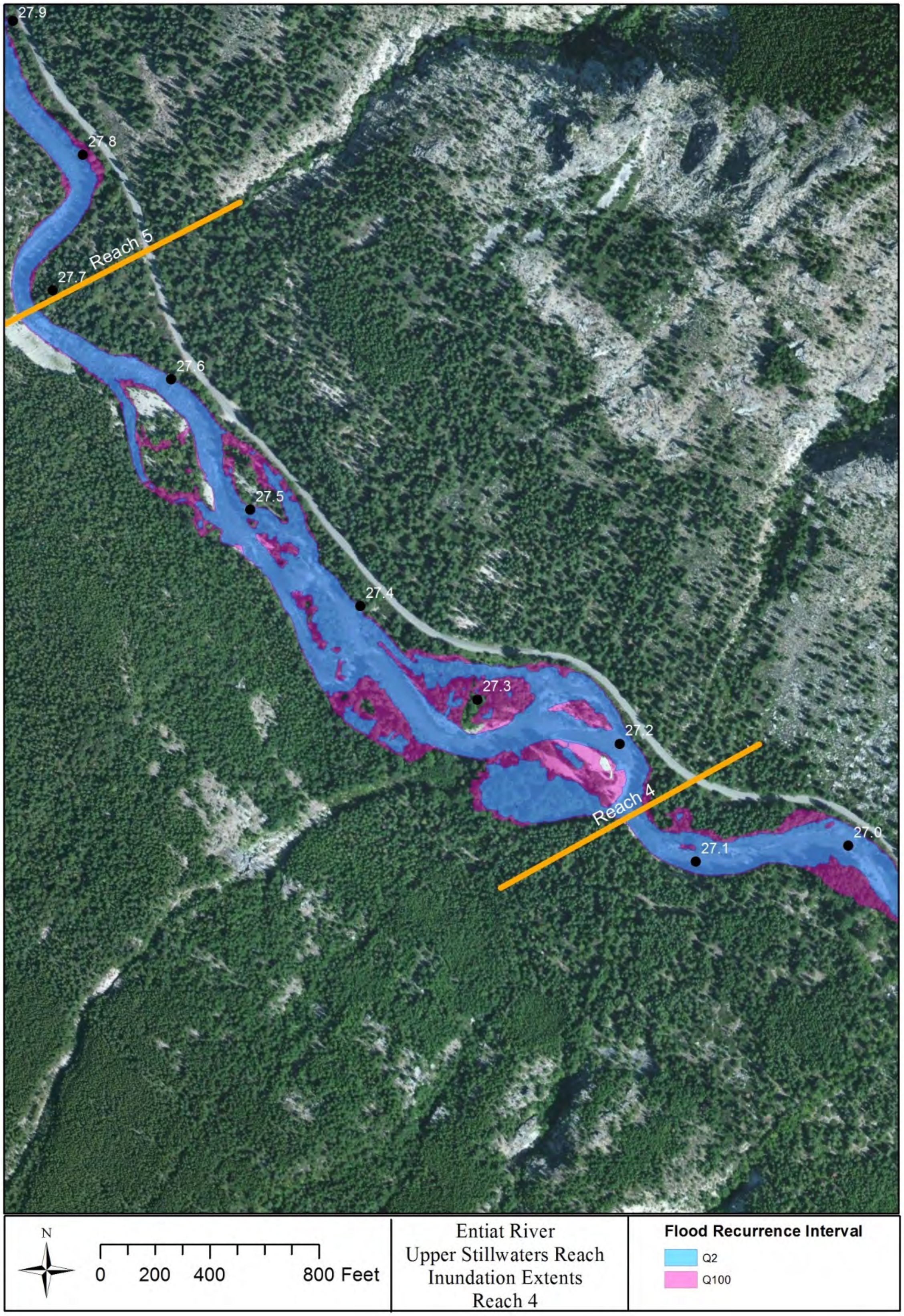


*Figure 21 Reach 4 modeled floodplain inundation for the 2- and 100-year flood event.*

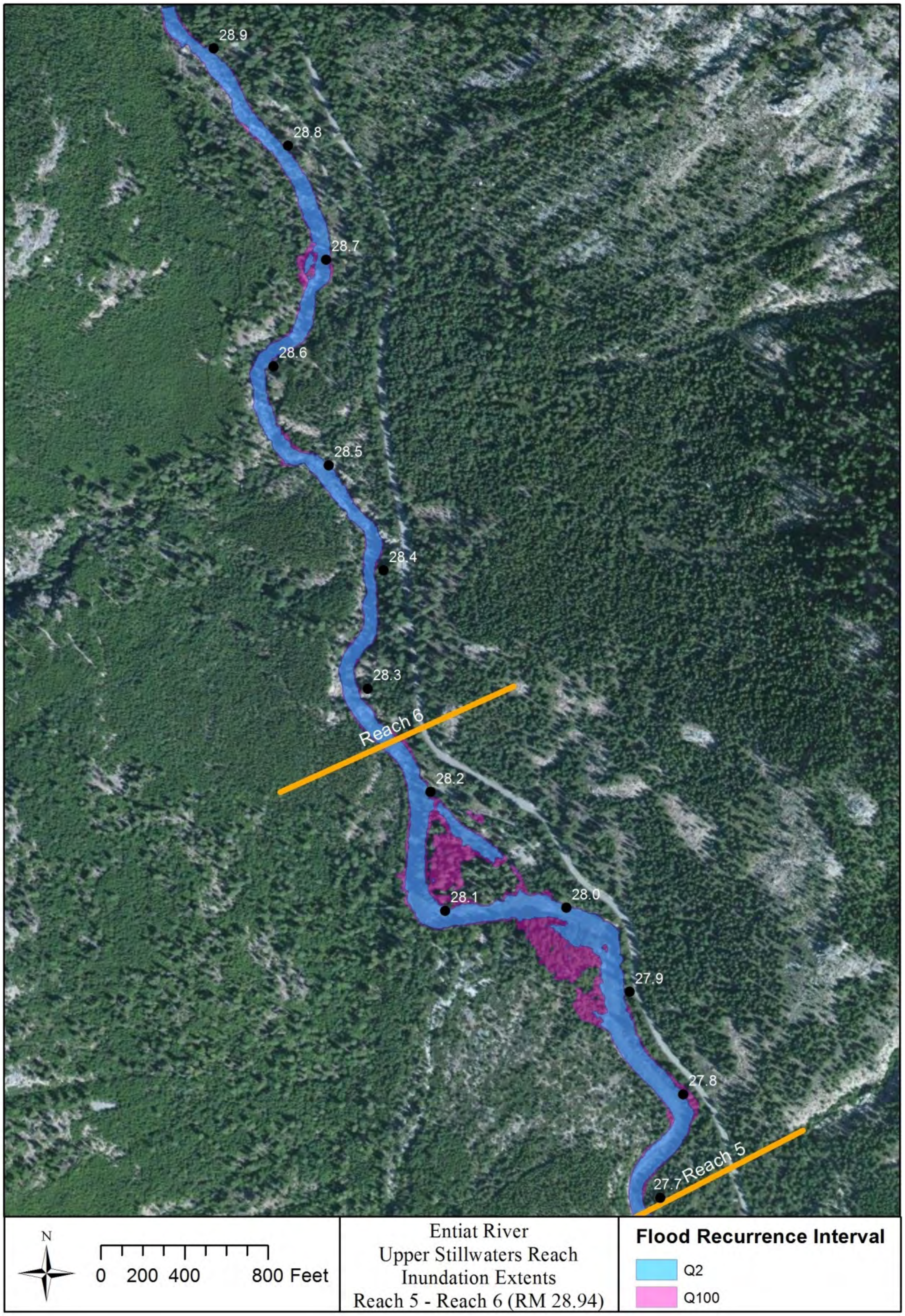


*Figure 22. Reach 5 and 6 modeled floodplain inundation for the 2- and 100-year flood event.*

### 2.5.3 Geomorphology

***Valley Morphology***

The Entiat River within the Upper Stillwaters study area meanders south and eastward with channel sinuosity ranging from 1.05 to 1.31. Valley morphology within the study area is dictated by bedrock type, glaciation, and hillslope processes. The bedrock lithology of the study area includes crystalline metamorphic and igneous rocks that are highly erosion resistant. Hillslopes adjacent to the river valley are steep and often confining. Bedrock outcrop are exposed along the bank and in the bed of the river at many locations, and provide lateral barriers to migration and vertical barriers to incision. This is especially apparent between RMs 28.2 to 29.3 in Box Canyon (Reach 6). Glacial action within the study area resulted in relatively little valley widening, but did leave behind a classic U-shaped valley cross-section at many locations. At the widest areas, maximum valley width ranges from about 1,000 to 1,300 feet.

Glacial till and outwash deposits create much of the valley fill within the study area. The Entiat River has incised into these deposits during the late Pleistocene and Holocene. Incision into glacial deposits has left behind abandoned terraces along the channel throughout the study reach, especially in the upstream portions of the study area (Reaches 8 through 13). These terraces constrict the channel's lateral migration and provide localized sources of sediment. As the river re-works these deposits, fine sediments are carried away and larger material (glacial lag) is left behind. This process tends to armor the stream bank, decreasing lateral channel mobility.

Alluvial fans continue to play a significant role in determining valley- and reach- scale floodplain and river corridor morphology. Large fans have accumulated at the mouths of all major perennial tributaries and smaller ephemeral tributaries. Alluvial fans originate from both sides of the valley and tend to push the channel around the toe of the fan, creating lateral constrictions, steepening the river gradient, and contributing coarse sediment to the channel. Alluvial fans were activated during the 1972 flood event. There is aerial photo evidence of significant activity on several alluvial fans that contributed large amounts of sediment to the channel (Figure 23).

Mapping of geomorphic surfaces including alluvial fans, terrace deposits of various ages, and the modern floodplain is presented in Appendix B. These maps also include human features.

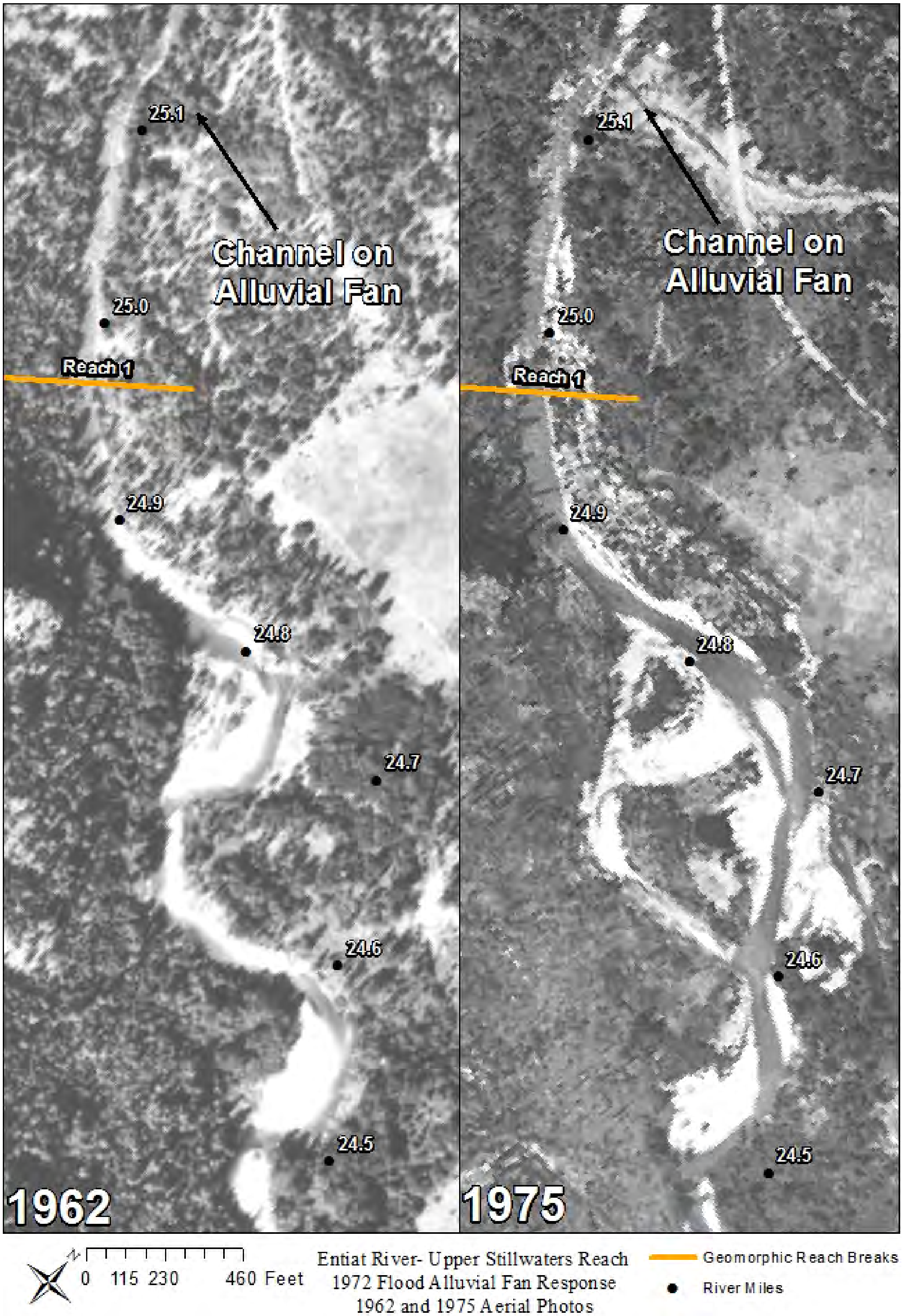


***Figure 23. Aerial photo comparison showing the effects of fan contributions to the channel and valley bottom before (1962) and after (1975) the 1972 flood.***

### *Channel Morphology*

The contemporary channel form of the Entiat is largely influenced by processes associated with an ancient climate that was much wetter and cooler that today's climate. Glaciers extended down into the study reach to RM 16, leaving behind glacial deposits as they retreated. A hydrologic regime that would have displayed larger floods and higher mean annual flow created wide floodplains and wide, deep channels to convey large amounts of water. As glaciers retreated and the climate began to become warmer and drier through the early Holocene, water and sediment flux was reduced and the channel incised into valley fill. This has resulted in a channel that is 'underft' to its valley, channel, and bed material. This present-day 'underfit' river continues to downcut into this historical bed form. This has left behind distinct elevations of abandoned terraces, which were historically active floodplain surfaces.

Today, much of the channel is predominantly confined by these Holocene terraces, glacial terraces, bedrock, and active and inactive alluvial fans. Mapping of these surfaces is presented in Appendix B. Interspersed throughout these confined reaches are occasional alluvial reaches (Reaches 0, 2, 9), where floodprone width expands and channel gradient decreases. In these reaches, the channel has migrated laterally to form contemporary active floodplain surfaces. This process is similar to the channel evolution model discussed by Schumm et al. 1984, detailing how as a channel incises due to changes in flow or sediment regimes, and then readjusts to a new equilibrium base elevation, developing new floodplains inset within abandoned floodplains and inundation patterns. The flood of 1972 was significant in terms of floodplain activation and geomorphic evolution of the contemporary floodplain and channel in alluvial reaches. In that flood, there are several locations where channel widening, bar, and island building were observed to have occurred through comparison of pre- and post-flood aerial photography (Figure 24).

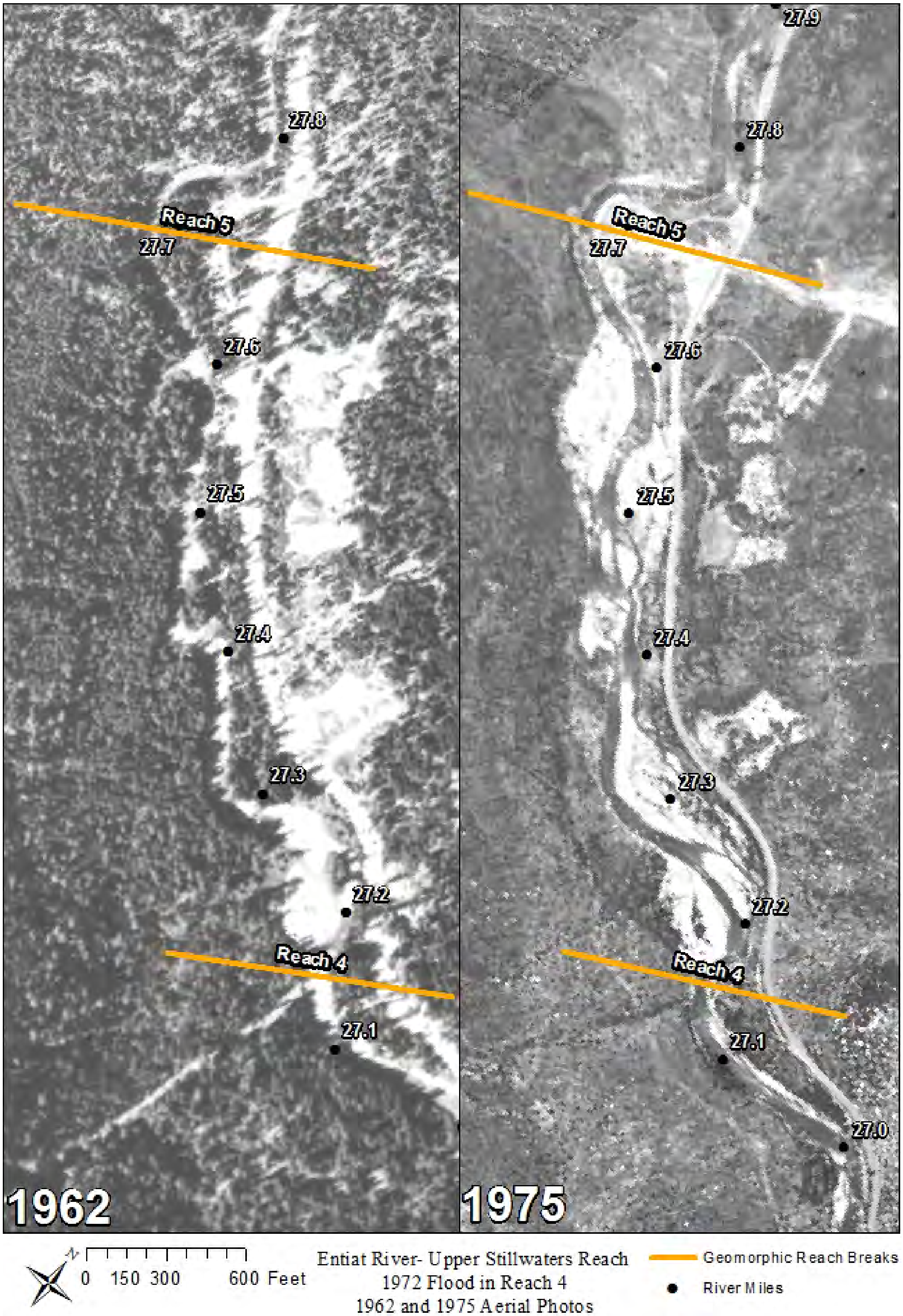


*Figure 24. Aerial photo comparison of Reach 4 before (1962) and after (1975) the 1972 flood.*

Bed morphology is predominantly pool-riffle and cascade-pool with channel slopes ranging from 0.27 to 2.45% in the lower five reaches of the study area. Downstream of the Potato Creek terminal moraine (approximately RM 24.8), the valley bottom and associated floodprone widths begin to widen, slope flattens out, and the channel becomes more depositional, as evidenced by increase meanders and point and mid-channel bars (Woodsmith and Bookter 2007). The channel is primarily confined, but periodic alluvial reaches are found in areas with wider floodprone widths, and have more channel complexity (point and mid-channel bars, large wood accumulations) and intact riparian vegetation. Confined reaches flow through areas with narrower floodprone widths, with abandoned alluvial terraces, active and inactive alluvial fans, and bedrock naturally limiting lateral migration. In some confined reaches, a small narrow inset floodplain is developing within the channel banks as the channel evolves to its current equilibrium base level. In other confined reaches, as scour reworks the toe of channel banks, banks become undercut, and larger substrate (primarily cobble) migrate down the banks to the channel toe, creating armored bank toes (Figure 25).


***Figure 25. Naturally armored bank toe in confined portion of Upper Stillwaters Reach.***

Sediment is contributed to the Stillwaters Reach from mass-wasting processes, tributaries, and near-channel banks and hillslopes. These banks and hillslopes provide localized sediment from the easily erodible unconsolidated glacial till, glacial terraces, and pumice terraces along the channel margins (Figure 26). Due to the 'underfit' nature of the Entiat River and the naturally armored banks discussed above, relatively low amounts of sediment are transported at base flows, but high flows are still able to easily erode above this toe support and entrain large amounts of fine grain material from banks. The amount of sediment contributed by lateral migration and vertical incision are minimized by lateral and vertical bedrock controls throughout the study reach (Figure 27). Channel morphologic characteristics are summarized in Figure 28 and Table 12. More detailed geomorphic descriptions for each reach can be found in Section 3.

***Figure 26. Example of a terrace with pumice deposits in the upper portion of the study area.***

***Figure 27. Bedrock outcrop along the channel in the study area providing lateral migration and vertical grade controls.***

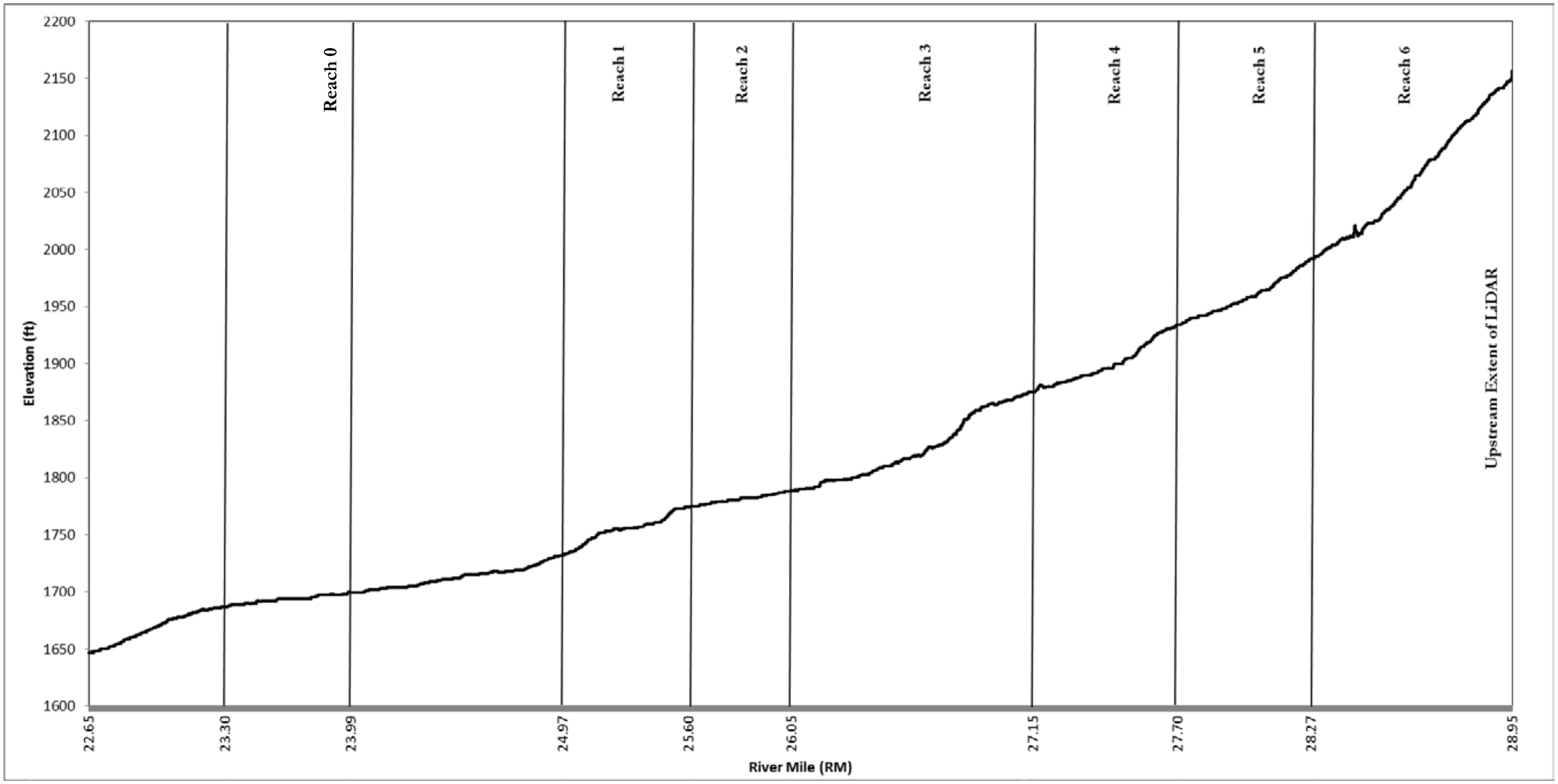


***Figure 28. Longitudinal profile of Reaches 1 through 5 and the lower portion of Reach 6 in the Upper Stillwaters Study Area. Elevation data derived from LiDAR.***

***Table 12. Summary of geomorphic and habitat conditions at the valley and channel scale among geomorphic reaches in the Upper Stillwaters Reach on the Entiat River. N/A = measurement not taken due to unwadeable and/or inaccessible conditions. ND = No data due to end of LiDAR coverage. Gradient for reaches 6 through 13 was determined using USGS 7-minute topographic maps and so should be considered approximate.***

| | Metric | Reach 0 | Reach 1 | Reach 2 | Reach 3 | Reach 4 | Reach 5 | Reach 6 | Reach 7 | Reach 8 | Reach 9 | Reach 10 | Reach 11 | Reach 12 | Reach 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Channel** | River Miles | 23.3-23.99 | 24.97-25.6 | 25.6-26.05 | 26.05-27.15 | 27.15-27.7 | 27.7-28.27 | 28.27-29.33 | 29.33-29.85 | 29.85-30.2 | 30.2-31.42 | 31.42-31.91 | 31.91-32.9 | 32.9-33.82 | 33.19-33.82 |
| | Gradient (%) | 0.27 | 1.00 | 0.48 | 1.50 | 1.64 | 2.45 | 3.6 | 1.8 | 1.7 | 1.2 | 1.4 | 1.6 | 1.3 | 2.6 |
| | Sinuosity | 1.08 | 1.22 | 1.17 | 1.07 | 1.18 | 1.31 | 1.30 | 1.19 | 1.14 | 1.05 | 1.05 | 1.13 | 1.05 | 1.14 |
| | Dominant Channel Morphology | Riffle | Rapid | Riffle | Riffle | Riffle | Riffle | Rapid | Riffle | Rapid | Riffle | Riffle | Rapid | Rapid | Rapid |
| | Average Bankfull Width (ft) | 115.8 | 105.5 | 90 | 113.5 | 95 | 87 | 70 | 80 | 90 | 77 | 100 | 93.5 | 81 | 94 |
| **Floodplain** | Average Floodprone Width (ft) | 487.5 | 165 | 350 | 172.5 | 450 | 300 | 100 | 140 | 120 | 390 | 260 | 182.5 | 150 | 150 |
| **% Habitat Area** | Pool | 21 | 17 | 24 | 12 | 7 | 7 | 15 | 6 | 19 | 13 | 8 | 7 | 12 | 8 |
| | Glide | 29 | 4 | 0 | 6 | 0 | 0 | N/A | 0 | N/A | 0 | 0 | 0 | 0 | 0 |
| | Riffle | 36 | 22 | 75 | 58 | 70 | 86 | 83 | 94 | 81 | 74 | 52 | 43 | 0 | 0 |
| | Rapid | 0 | 57 | 0 | 6 | 0 | 6 | N/A | 0 | N/A | 0 | 40 | 44 | 88 | 87 |
| | Cascade | 0 | 0 | 0 | 12 | 0 | 0 | N/A | 0 | N/A | 0 | 0 | 3 | 0 | 0 |
| | Side Channel | 14 | 0 | 1 | 7 | 22 | 1 | 1 | 0 | N/A | 10 | 0 | 4 | 0 | 6 |
| | Braided | 0 | 0 | 0 | 0 | 0 | 0 | N/A | 0 | N/A | 3 | 0 | 0 | 0 | 0 |

[1] *"Disconnected" indicates that the floodprone surface's historical pattern and processes (e.g. inundation extent or frequency) have been altered due to anthropogenic actions. See Appendix B for the analysis of connected and disconnected areas.*

### 2.5.4 Existing Large Wood Dynamics

Existing large wood dynamics in the Upper Stillwaters Reach are a function of a legacy of river and forest management dating to the late 1800s. Historical and on-going human disturbances have impacted sources of instream large wood, the recruitment of large wood to the channel, and the ability of the channel to trap and retain wood. These processes (sources, recruitment, and retention) are discussed below with respect to contemporary large wood dynamics in the study area.

#### *Sources*

Large wood is still sourced from riparian areas. However, the quantity and quality of contemporary large wood sources have been altered by timber harvest and fire suppression within the study area and within upstream contributing areas. Upland and riparian clearing dating to the late-1800s has and will continue to impact large wood loading for the foreseeable future. Reforested timberlands now dominate the riparian buffers and the trees are considerably smaller than what would be expected under non-harvested conditions. The 2012 habitat survey (Appendix A) classified nearly 89% of the riparian canopy as being dominated by trees less than 21 inches diameter (dbh). It will be decades or centuries before riparian areas mature to the degree that they are able to provide a LWM recruitment source that resembles historical conditions.

#### *Recruitment*

In confined reaches, recruitment of trees via bank erosion is limited but does occur to some degree as a result of scour at the toe of channel banks that leads to bank failure and tree recruitment. Confined areas with non-erodible banks (e.g. bedrock) only experience riparian tree recruitment through tree-fall. In more alluvial reaches, channel scrolling and floodplain avulsions lead to riparian and floodplain tree recruitment. Large wood is also recruited to the channel through episodic mass wasting events, particularly from debris flows and landslides during large flood events. Recruitment processes are mostly intact throughout the study area except for areas where lateral channel dynamics or bank stability have been modified through human alterations. The most common human alteration to LWM recruitment in the study area is the presence of Entiat River Road, which lies adjacent to the channel in numerous locations in the lower (Reaches 0-5) and upper (Reaches 9-13) portions of the study area. Bank armoring associated with the road limits not only the available riparian sources for large wood, but also the potential for wood to be recruited through natural bank erosion processes. Two bridges, especially the bridge near the downstream end of Reach 0, also limit lateral channel dynamics, avulsion potential, and bank erosion, which reduce the potential for LWM recruitment. Other relatively minor areas of bank armoring associated with streamside residences also limit local recruitment.

#### *Retention*

As discussed previously (Section 2.3.3), retention of wood in the channel is a function of both wood size as well as instream complexity, both of which have been affected by the legacy of human alterations. The same alterations to recruitment, described above, also affect retention. These include bank armoring that reduces margin complexity (necessary for wood to get retained on margins) and bridges that confine the channel and result in stream power that favors wood transport over deposition. These impacts only occur at specific locations and are not widespread throughout the study area.

The legacy of splash-damming may also have some effect on contemporary retention processes, especially in the lower portion of the study area (e.g. Reach 0) where log drives were known to occur.

Activities associated with log drives, including the removal of large boulders and simplification of channel margins, would have reduced the potential for the channel to retain wood.

The currently available wood size also affects the ability of the channel to retain wood. The wood that is now contributed to the channel mostly represents second or third growth timber that is smaller than historical LWM and does not have the same ability to self-stabilize within the channel. Even though the habitat assessment (Appendix A) found an average of 83 pieces of wood per mile (>6 inches diam; >20 ft long), only 15% of these were greater than 20 inches in diameter, which means the number of key pieces necessary to initiate jam formation are lacking. The shift in riparian seral stage, and the corresponding reduction in available key pieces, has reduced the ability of wood to accumulate and stay in place throughout the river. Shifts in species compositions from fire-tolerant to fire-intolerant species may have also impacted tree size, retention, and the potential for jam formation.

### 2.5.5 Habitat Conditions

Stream habitat conditions were recorded using the USFS Level 2 stream habitat inventory methods. The survey recorded information on habitat unit composition, habitat unit characteristics including pool depth, substrate size, large wood quantity, riparian conditions, and bankfull channel dimensions. The habitat assessment summary and reach reports are provided in Appendix A. A brief summary is included below.

Pool frequency ranged from 2.2 to 9.9 pools/mile at the reach-scale and totaled approximately 12% of the total habitat in the study area. Riffles were by far the dominant habitat type comprising 56%. Rapids were the next largest category at 21%. Side channels made up 6% of the measured habitat units, with a total of 27 wetted side channel units. Reach 4 had the greatest area of side channel habitat with 22% of total habitat area in the reach. Reach 9 had the highest number of individual side channel units with a total of seven.

An average of 83 pieces of wood per mile was counted in the study area (>6 inches diameter; > 20 feet long); 60% of these were "small" pieces with diameters between 6 and 12 inches. Wood frequency at the reach-scale ranged from 23 (Reach 12) to 189 (Reach 9) pieces/mile. As discussed previously, the size, availability, and quantity of wood is lower than what would have been expected historically, which has affected instream channel dynamics and habitat suitability for salmonids.

Bed substrate was dominated by cobble (40%) and gravel (25%), with bedrock comprising 15%, and equal portions of sand and boulders at 10%. Bedrock was absent from most reaches but was found in abundance in a few reaches, which resulted in a relatively large overall contribution to bed material composition. Suitable spawning areas were observed throughout the study area, primarily in the downstream reaches (Reaches 0-5) and alternating alluvial reaches in the upstream half of the study area (Reaches 9-13).

Riparian areas were dominated by native riparian forest vegetation although natural forest fire cycles and past timber harvest have reduced overall stand ages. Residential development has impacted riparian conditions in limited locations, particularly Reaches 0-5. In some areas affected by residential development, large trees dominate the overstory but the understory has been cleared. Results for riparian forest stand ages at the study area scale were 71% small tree (9 – 21" diameter at breast height (DBH), and 13 % large tree (≥ 21" DBH), and 8% each for sapling/pole (5 – 9" DBH) and shrub seedling (1-5" DBH).

### 2.5.6 Reach-Based Ecosystem Indicators

This section presents an overview and summary of the REI results (Table 13), which are presented in more detail in the REI Report (Appendix C). The REI applies habitat survey data and other analysis results to a suite of REI indicators in order to develop reach-scale ratings of functionality with respect to each indicator. 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. This analysis is also used to help derive restoration targets as part of the restoration strategy presented in Section 0. The rating definitions, and explanations of how the ratings were made, can be found in Appendix C.

There were no fish passage barriers within the study area so each reach was therefore given a rating of **adequate** for this indicator. Substrate and fine sediment ratings were **adequate** throughout the study area. For the remainder of the indicators, some general patterns are observed. Reaches below Box Canyon (Reach 6) were the most impacted reaches in the study area having the highest number of **at risk** and **unacceptable** ratings. Reach 0 is the least functional reach in the study area (five **unacceptable** ratings, and four **at risk** ratings out of 11 categories), followed closely by Reach 5 (four **unacceptable** ratings and five **at risk** ratings out of 11 categories). Reach 4 had only one **unacceptable** and two **at risk** ratings, making it the most functional reach below Box Canyon.

Reaches above Box Canyon were generally more functional overall with **unacceptable** ratings only in the LWM frequency category, and an **unacceptable** rating for pool frequency and quality in Reach 7. Above Box Canyon, Reach 10 was the most impacted reach, having the majority of indicators rated **at risk**. The bedrock canyon reaches (Reaches 6 and 8) were the most functional reaches in the study area, except for LWM frequency which was **at risk** in both reaches. LWM was rated **at risk** or **unacceptable** in all reaches except Reach 9. The canyon reaches are both transport reaches that are least adjustable to watershed disturbance and have naturally low capacity for development of many of the habitat features that are targeted by REI indicators. They are also not prone to development.

For the study area as a whole, **adequate** was the most common rating (98), followed by **at risk** (37), then **unacceptable** (21).

***Table 13. Reach-Based Ecosystem Indicator (REI) results. See Appendix C for the REI report.***

| General Characteristics | General Indicators | Specific Indicators | Reach 0 | Reach 1 | Reach 2 | Reach 3 | Reach 4 | Reach 5 | Reach 6 | Reach 7 | Reach 8 | Reach 9 | Reach 10 | Reach 11 | Reach 12 | Reach 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Habitat Assessment** | **Physical Barriers** | **Main Channel Barriers** | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate |
| **Habitat Quality** | **Substrate** | **Dominant Substrate/Fine Sediment** | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate |
| | **LWM** | **Pieces per mile at bankfull** | Un-acceptable | Un-acceptable | Un-acceptable | Un-acceptable | Un-acceptable | Un-acceptable | at risk | Un-acceptable | at risk | adequate | Un-acceptable | Un-acceptable | Un-acceptable | Un-acceptable |
| | **Pools** | **Pool frequency and quality** | at risk | at risk | Un-acceptable | adequate | adequate | adequate | adequate | Un-acceptable | adequate | at risk | at risk | at risk | at risk | adequate |
| | **Off-Channel Habitat** | **Connectivity with main channel** | Un-acceptable | at risk | at risk | at risk | at risk | at risk | adequate | at risk | adequate | at risk | at risk | at risk | at risk | at risk |
| **Channel** | **Dynamics** | **Floodplain connectivity** | at risk | adequate | adequate | adequate | adequate | Un-acceptable | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate |
| | | **Bank stability/Channel migration** | Un-acceptable | at risk | adequate | at risk | adequate | Un-acceptable | adequate | adequate | adequate | adequate | at risk | adequate | adequate | adequate |
| | | **Vertical channel stability** | at risk | adequate | adequate | adequate | adequate | at risk | adequate | adequate | adequate | adequate | at risk | adequate | adequate | adequate |
| **Riparian Vegetation** | **Condition** | **Structure** | Un-acceptable | at risk | at risk | at risk | adequate | at risk | adequate | adequate | adequate | adequate | at risk | adequate | adequate | adequate |
| | | **Disturbance (human)** | Un-acceptable | Un-acceptable | at risk | adequate | adequate | Un-acceptable | adequate | adequate | adequate | at risk | adequate | adequate | adequate | adequate |
| | | **Canopy Cover** | at risk | at risk | at risk | adequate | at risk | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate |

# 3 Reach-Scale Conditions

This section describes forms and processes and the effects of human alterations at the individual reach scale. Maps of geomorphic surfaces and human features described and referenced in the following reach chapters can be found in Appendix B. Description and presentation of results of hydraulic modeling including inundation maps can be found in section 2.5.2. Additional information on instream habitat conditions, riparian conditions, and channel geometry can be found in Appendix A, the Habitat Assessment Report.

## 3.1 REACH 0

### 3.1.1 Reach Overview

Reach 0 is 0.69 miles long and extends from RM 23.3 to RM 24 (Figure 29). The channel is partially confined within abandoned floodplain terrace surfaces near the upstream end of the reach and by alluvial fan deposits originating from hillslopes on both sides of the valley at the downstream end of the reach. There is a large connected floodplain on river-right in the middle portion of the reach. Bed morphology is primarily plane-bed and is dominated by glide habitat. Substrate ranges from sand to boulders, but is predominantly gravels (57%). The reach is characterized by a long, uniform plane-bed glide that dominates the middle portion of the reach. There is greater channel sinuosity and complexity at the upstream end and just upstream of the bridge crossing near the downstream end. Human alterations include a hydraulic constriction created by the bridge at RM 23.45, clearing and grading associated with residential development along river-left (RM 23.7 to RM 23.8), and riprap associated with Entiat River Road along river-left (RM 23.37 to RM 23.58). Landownership is mostly private, with National Forest land on both banks at the upstream end of the reach.


***Figure 29. Overview of Reach 0. Flow is from northwest to southeast.***

### 3.1.2 River Morphology and Geomorphic Processes

Reach 0 is low-gradient (0.275%), with a sinuosity of 1.08. The reach is mostly confined along river-left as a result of an alluvial fan terrace at the upstream end and the hillslope/roadway at the downstream end. This confinement limits lateral migration and sinuosity. On river-right, in the middle portion of the reach, is a wide floodplain surface nearly fully inundated at the Q100 (see Section 2.5.2). Near the downstream end, constriction by the Mott Creek Fan, plus the bridge crossing (RM 23.45), confine the channel.

Channel units are primarily glides and riffles with isolated pools. At the upstream extent of the reach, transverse riffles have created point- and mid-channel bars (RM 23.80 to 23.98). There is a long plane-bed glide in the middle of the reach (Figure 30). The habitat survey indicated that the pools throughout the reach were relatively shallow (average depth of 3.1 feet) and lacked cover and complexity. Banks and beds are composed primarily of gravels (57%), but substrate ranged from sand to boulders. A bedrock outcrop was visible at the upstream extent of the reach along the right bank.

There is an area of geomorphic and habitat complexity upstream of the bridge crossing at RM 23.45, where there is abundant off-channel habitat and large wood. This depositional area is created by the backwater effect of the downstream tributary fans associated with Preston and Mott creeks. However, the bridge crossing itself has increased valley confinement in this area, contributing to the backwater effect upstream of the bridge but reducing channel complexity at the bridge crossing and downstream.

***Figure 30. Representative photo of channel in the straight middle portion of Reach 0.***

Sediment sources within the reach include both episodic, large-scale contributions from alluvial fans and mass-wasting, as well as localized contributions from banks. Lateral migration, and associated sediment and wood recruitment, are occurring to some degree at the upstream end of the reach where transverse riffles direct flow across the channel and into the bank. Some sediment is being temporarily stored in point-and mid-channel bars in areas where margin complexity and hydraulic roughness are present.

Examination of floodplain surfaces indicates that the majority of the floodplain (87%) is active during large floods (Q100). This occurs primarily on valley right within the wide floodplain area. There are also several other areas of smaller, localized patches of active floodplain (see Section 2.5.2). In areas where more frequent floodplain inundation occurs (e.g. <Q2), scour from overland flow is evident and in some areas has created side channels. Reach 0 has some of the highest amounts of side channel habitat in the study area (14 % of Reach 0 habitat units), mostly due to the depositional area and associated side channel habitat upstream of the Mott Creek Fan/bridge constriction.

There is very little sediment storage occurring in the middle portion of the reach, which is composed of a long, straight, and uniform glide with little complexity available to store wood or sediment. Of any section of channel within the study area, this section appears most likely to have experienced stream channel incision and channel simplification associated with human activities. Signs of incision include low gradient, with bank heights increasing in the upstream direction; as well as low sinuosity and flows confined within the channel at the 2-year event. Vertical control is provided at the downstream end by the fan/bridge constriction, which has increased local sediment deposition and side channel development upstream of the bridge; but this influence has not extended into the upstream glide, possibly due to the effects of incision and straightening on increasing sediment transport. Log drives have been documented up to RM 24, which is near this area. There has also been residential development activity along this reach.  These impacts may have contributed to channel incision and simplification that have affected habitat quantity and quality in the reach.

***Figure 31. Side channel habitat upstream of the bridge in Reach 0.***

### 3.1.3 Riparian Conditions

The riparian canopy through Reach 0 varies between dense, mid-seral stage to completely cleared. In areas where the canopy is present, there is excellent cover with overhanging vegetation along the channel margin in many locations. Riparian species are primarily cottownwood (*Populus tripocarpa*) and dogwood (*Cornus sericea*). There are some cleared riparian areas along the left bank extending from RM 23.37 to RM 23.8. Future sources of large woody material exist throughout the reach along the margins of the channel except where clearing has taken place. However, larger trees necessary for serving as key pieces of LWM are currently uncommon in the riparian area.

### 3.1.4 Human Alterations

Human alterations to the channel and floodplain have impacted geomorphic processes and channel form throughout Reach 0. The majority of channel and floodplain alterations are associated with residential development along river left, from RM 23.7 to RM 23.8. Here, the riparian corridor has been cleared and the floodplain has been graded. These alterations have removed hydraulic roughness, accelerating bank erosion along the left bank. Riprap and armoring associated with Entiat River Road have also altered geomorphic processes from RM 23.37 to 23.58. Armoring has limited lateral migration processes, accelerated localized scour, and capped localized sediment sources. Lateral channel dynamics and hydraulic contraction and expansion processes have also been impacted by the bridge and its associated abutments at RM 23.45 (Figure 32).

***Figure 32. View looking upstream at the bridge crossing at RM 23.45. Bedload deposition (gravel bar) caused by backwater effects of the constriction, can be seen upstream of the bridge.***

## 3.2 REACH 1

### 3.2.1 Reach Overview

Reach 1 is 0.63 miles long, and extends from RM 24.97 to RM 25.6. Bed morphology is composed of long, steep rapids interspersed with occasional channel-spanning pools. Substrate ranges from sand to boulders, but is predominantly boulders (40%). The channel is confined within abandoned floodplain surfaces, as well as bedrock outcrops and alluvial fan deposits. Alluvial fans (both active and inactive) are dominant features controlling valley and channel form. Alluvial fans originating from the north and south provide sediment and debris inputs, create natural channel confinement, and steep channel gradients. Natural confinement limits formation of floodplain surfaces throughout Reach 1, with small bands of floodprone area along the channel margins. Geomorphic complexity is created by large, angular boulders and cobbles that have been sourced from fan surfaces, hillslopes, and rock fall providing localized ‘pocket’ water. Human alterations include moderate riparian clearing and grading of floodplain surfaces along river left throughout the reach.

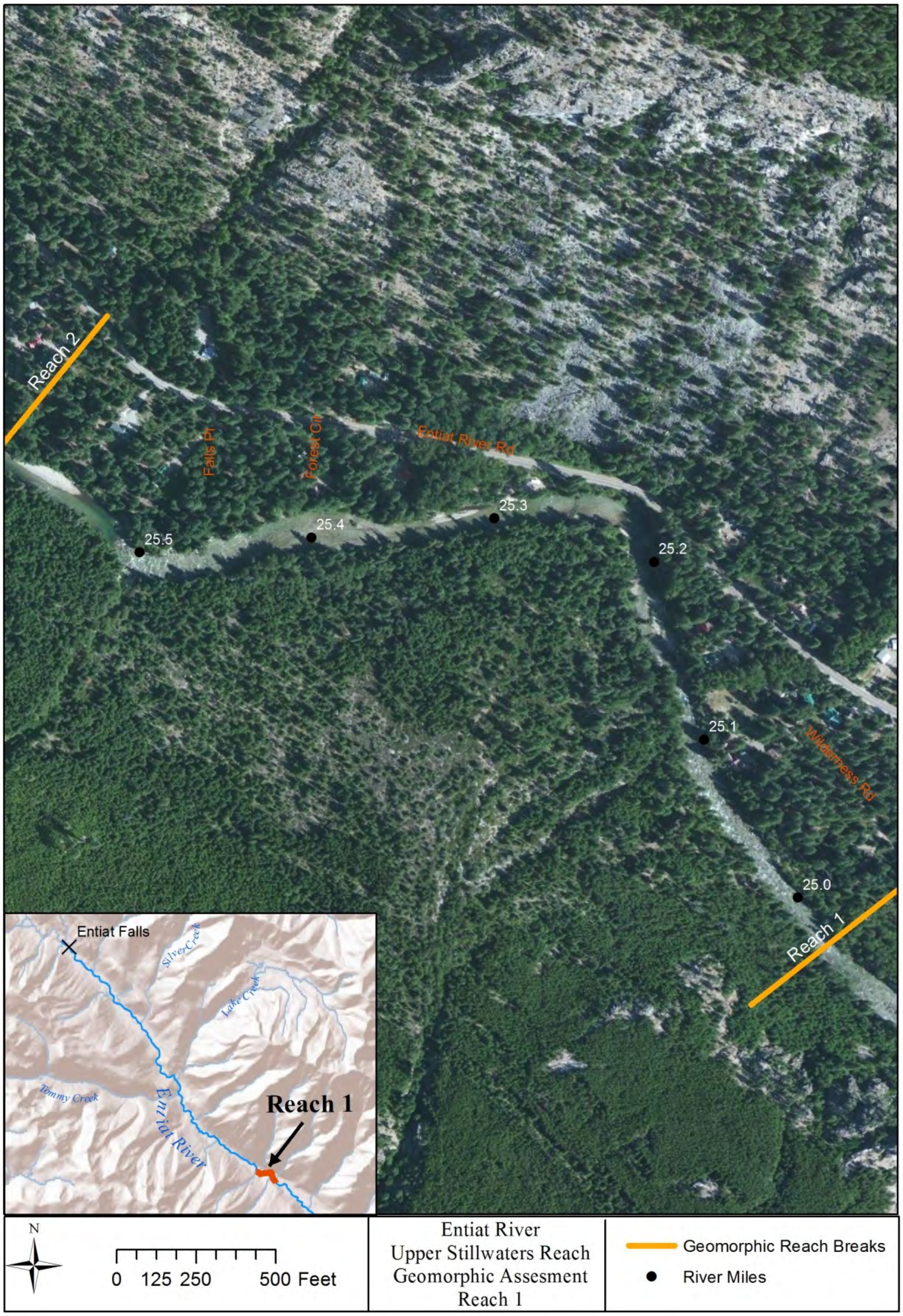


*Figure 33. Overview of Reach 1. Flow is from northwest to southeast.*

### 3.2.2 River Morphology and Geomorphic Processes

Reach 1 is a steep, single-thread channel extending from RM 24.97 to RM 25.6. Channel units are primarily long, steep rapids (57%) and riffles (22%). Occasional channel-spanning pools (average residual depth of 3.4 feet) break up steeper, more turbulent sections. Bank and bed substrate is large, coarse material and is predominantly boulders (40%) followed by cobble (38%). Boulders dominate the steep riffle sections, while gravel and fine sediment accumulate at grade-breaks in channel-spanning pools. Fan deposits alternate along river right and river left throughout the reach, limiting both lateral channel migration and channel incision.

***Figure 34. Representative Channel Morphology for Reach 1***

The channel is confined within abandoned floodplain surfaces and alluvial fan deposits. Fans have largely influenced channel form throughout the reach, as large mass-wasting events and chronic deposition over time contribute sediment and debris to the channel, diverting the boundaries of the mainstem and moving the channel towards the opposite slope. This reach is influenced by both active alluvial fans, as well as inactive fans. There are three active alluvial fans in the reach originating on valley left from RM 25.08 to RM 25.15 (McCrea Creek) and RM 25.4 to RM 25.6 (Burns Creek), and from valley right between RM 25.0 to 25.4 (Grandma Creek). The channel is being actively forced around the toes of the fans, exerting significant influence on planform and gradient.

Sediment sources for Reach 1 include adjacent hillslopes, alluvial fans, and localized contributions from banks and the streambed. Throughout the majority of fast water units in the reach (riffles, rapids) large boulders and cobble armor banks, limiting sediment contributions from bank erosion at moderate flows. There has been incision and channel migration into the toes of inactive fans, which has left behind steep scarps. These scarps are sediment sources at high flow levels (e.g. Q100). Active alluvial fans appear to provide sediment sources at more frequent events (e.g. Q10). The channel steepens as it flows around alluvial fans, increasing transport capacity and armoring the bed with cobbles and boulders.

Hillslope deposits (originating from fans) were prevalent in the channel in the majority of the reach. In areas where hillslope processes directly affect the channel, material ranging from angular cobbles to large angular boulders composes a significant portion of bed material. Gravel and fine sediment accumulation is present only in areas where large hydraulic roughness is present, primarily in the form of large wood accumulations or riparian vegetation, or in slow water units such as pools.

***Figure 35. Large debris flow deposits originating from alluvial fans in Reach 1.***

Inactive and active alluvial fan deposits have largely confined the channel and have limited lateral channel migration and floodplain formation. Small (50 to 100 feet wide) pockets of inset active floodplain have developed along river left from RM 25.15 to RM 25.37, and inset within abandoned terraces along both sides of the channel in the middle portion of the reach.

The majority of instream habitat complexity in the reach is created by large, angular boulders and cobbles that have been sourced from alluvial fan deposits. Boulders provide hydraulic complexity that creates localized pocket water throughout the channel for salmonid resting and holding. Based on the habitat survey, the larger pools were primarily shallow, channel spanning, and lacked cover and complexity, with the exception of two deep pools found on the outsides of meander bends. Large wood numbers were low in relation to the remainder of the study area, with only five pieces measuring “large” (20 inches DBH x 35 feet long) within the reach.

### 3.2.3 Riparian Conditions

The channel banks and margins are buffered by mid-seral stage conifers, primarily Douglas fir (*Pseudotsuga menziesii*) and Grand Fir (*Abies grandis)*, and deciduous species, primarily black cottonwood

(*Populus trichocarpa*). The riparian corridor provides adequate shade along channel margins, as well as moderate hydraulic roughness at higher flows. Exceptions include along the river-left bank where private residences or the roadway have impacted riparian vegetation. Mesic species dominate abandoned terraces with overstory species consisting primarily of firs, cedar, and pines, and with a dense, brushy understory. Future sources of large woody material are available but for the foreseeable future will be small, very mobile pieces, as the majority of trees were classified as small tree (between nine and 20.9 inches DBH).

### 3.2.4 Human Alterations

Human alterations in Reach 1 are primarily found along river-left throughout the reach where there is residential development and where the roadway abuts the channel. The majority of floodplain alterations are on elevated surfaces that are not geomorphically connected to the channel. Limited grading and leveling has occurred on active floodplain surfaces along with riparian understory clearing. These alterations have removed some floodplain roughness, but have a limited impact on channel and floodplain processes. The roadway and associated riprap along the left bank at RM 25.2 affects riparian vegetation and floodplain inundation, but the proximity of the hillslope limits the degree of impairment to floodplain processes.

## 3.3 REACH 2

### 3.3.1 Reach Overview

Reach 2 is 0.45 miles long and extends from RM 25.6 to RM 26.05. Bed morphology is pool-riffle, with substrate ranging from sand to boulder and dominated by gravel (50%). The reach is alluvial with few confining features, allowing the channel to migrate across the entire width of the valley floor. Small pockets of abandoned floodplain terraces and high alluvial fan scarps indicate the channel has naturally incised to adjust to its contemporary hydrologic and sediment regimes. Coarse sediments are stored in point- and mid-channel bars and atop contemporary floodplain surfaces throughout the reach. Geomorphic complexity is created by large wood accumulations and regular (e.g. Q1, Q2) floodplain inundation and scouring. Reach 2 has limited floodplain disturbance, primarily focused in a small residential development on river-left at the downstream end of the reach (RM 25.6 to RM 25.7).

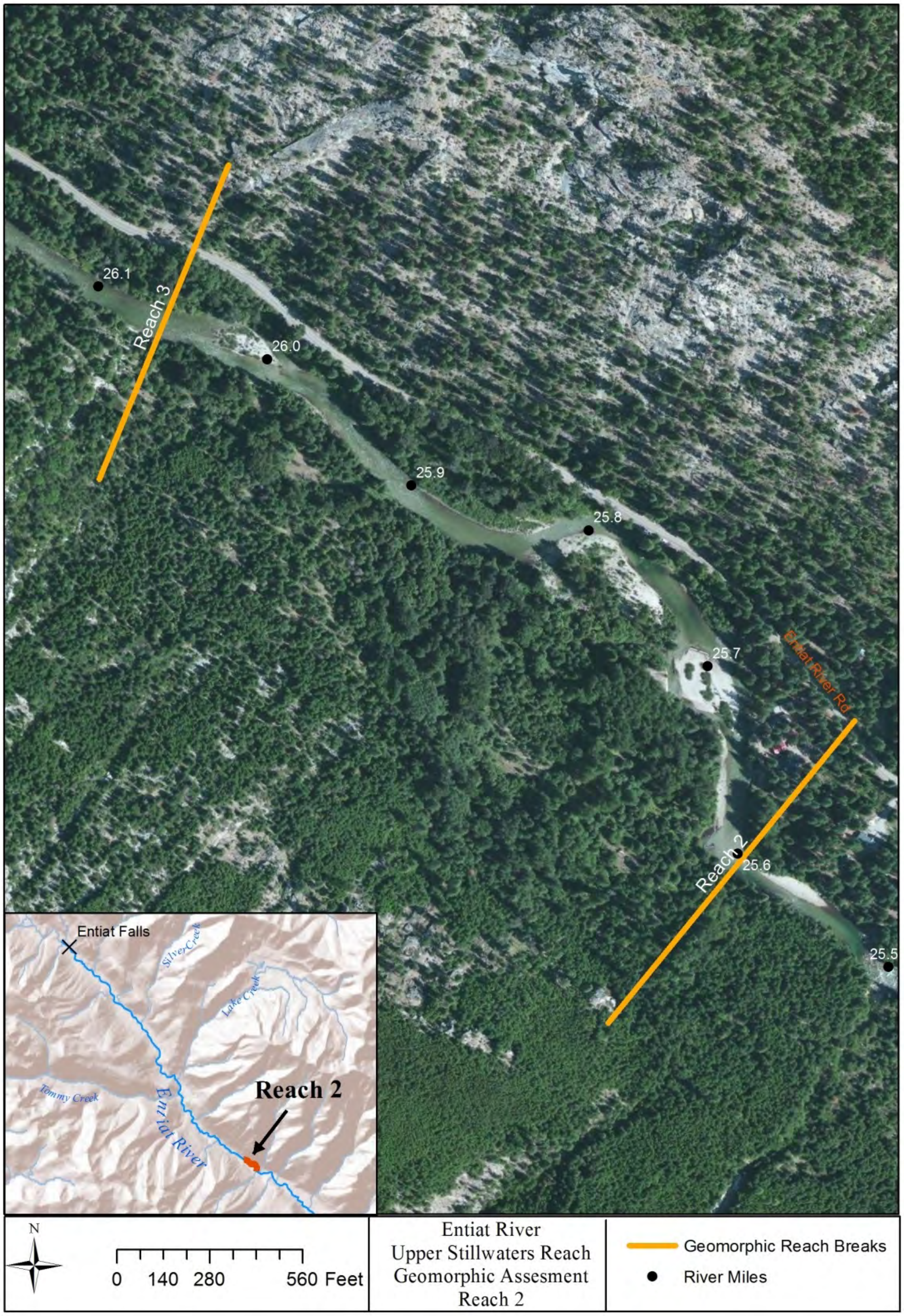


*Figure 36. Overview of Reach 2. Flow is from northwest to southeast.*

### 3.3.2 River Morphology and Geomorphic Processes

Reach 2 is a low-gradient (0.48%) alluvial reach, with active high-flow channels and point and mid-channel bars active at regular high flow events (e.g. Q1 to Q5). Bars are primarily gravel and sand, and the lack of vegetation establishment on these surfaces indicates they are scoured regularly. Bed substrate ranges from sand to boulder, and is dominated by gravel (50%), with cobble subdominant (30%). Channel units are comprised of long riffle-pool sequences. The reach meanders slightly with a sinuosity of 1.17. Floodplain topography indicates the channel was more sinuous in the recent past.

The channel is currently located adjacent to the left valley wall, and has been in this general location throughout the aerial photo record (since 1945). The lower frequency of confining features such as fans have translated to one of the largest floodprone widths in the study area (average 350 feet), with floodprone widths as high as 880 feet. This floodplain has developed inset to abandoned terrace surfaces that have remnants along fan scarps on both sides of the channel. Contemporary large floods (1972 and 1945) have scoured and reworked the active floodplain surface, resulting in split flow conditions and active high flow and side channels.

Due to its low gradient and wide floodprone width, this reach provides relatively high sediment storage capacity. Coarse sediments are stored in point- and mid-channel bars and atop contemporary floodplain surfaces. This reach lacks inputs from colluvial sources relative to other reaches. Rates of channel incision appear to be natural as the river continues to down-cut into valley fill deposited during periods of higher sediment input (glacial periods).

Based on the results of the hydraulics analyses (Section 2.5.2), nearly the entire valley floor is inundated at the Q100 and many of the off-channel habitat features are active at more frequent flows (e.g. Q2). These floodplains have developed within two distinct abandoned floodplain elevations, presumably early Holocene set within late Pleistocene surfaces. As the channel has adjusted to its drier contemporary hydrologic regime and reduced sediment input, it has incised through these historical floodplain surfaces.

Regular (e.g. Q1, Q2) floodplain inundation and scouring have created complex geomorphic features throughout Reach 2. Side-channels and backwater alcoves created through this floodplain scouring provide high flow refugia throughout the reach. The reach has 24% pool habitat, which is created by two long pools. These pools are lacking in cover, with the exception of overhanging vegetation on the channel margins. The reach has relatively few pieces of large woody material at 44 pieces total; 35 of these are classified as small (6 inches DBH x 20 feet long) or medium (12 inches DBH x 35 feet long). The depositional nature and geomorphic complexity of this reach indicates that the reach historically may have had much higher wood numbers. Large wood would have likely accumulated at the apexes of islands, throughout side channels, and on the outsides of meander bends.

### 3.3.3 Riparian Conditions

The riparian canopy is intact throughout Reach 2 except for a couple of locations where the Entiat River Road lies within the riparian zone. The floodplain is well-vegetated, providing ample hydraulic roughness across the active floodplain. The overstory is predominantly cottonwood and is dominated by shrubs/saplings (<5′′ DBH). The forest throughout the reach appears to be largely in the stem exclusion phase, indicating some recent disturbance, possibly historical burning (pre-1902, 1970) and/or timber harvest.

### 3.3.4 Human Alterations

Reach 2 has limited floodplain disturbance, primarily focused in a small residential development on river-left at the downstream end of the reach (RM 25.6 to RM 25.7). The majority of development-related alterations are elevated out of the active Q100 floodplain. Only a small amount of riparian and floodplain clearing and grading associated with this development appear to have taken place, and likely have minimal impact on channel processes. A limited amount of riparian clearing and bank armoring are associated with 220 feet of Entiat River Road along river-left near RM 25.8. The impact of the road appears to be localized, providing some accelerated scour processes, reduced hydraulic roughness, and reduced potential for large wood recruitment.

## 3.4 REACH 3

### 3.4.1 Reach Overview

Reach 3 is 1.1 miles long and extends from RM 26.05 to 27.15. Bed morphology is primarily fast water units including riffles, cascades, and rapids with coarse bed material dominated by cobble (55%). Reach 3 is confined against the left valley wall by coalescing alluvial fan deposits along the entire length of the right side of the channel, naturally limiting channel migration and floodplain formation processes. Small pockets of regularly active (e.g. Q2) floodplain are developing inset to higher floodplain surfaces that are limited to inundation only during large floods (i.e., Q100). Natural confinement limits geomorphic complexity along channel margins but large colluvial boulders throughout the channel create localized scour pools that in turn provide holding habitat for fish. Reach 3 has limited modern human features or alterations occurring within the active channel or modern floodplain boundaries. The primary alteration is the presence of Enitat River Road, which abuts the channel in a few locations along river-left.


*Figure 37 Overview of Reach 3. Flow is from northwest to southeast.*

### 3.4.2 River Morphology and Geomorphic Processes

Sinuosity and complexity in Reach 3 are less than in the adjacent upstream and downstream reaches. The channel is single-thread and largely confined by hillslopes. The channel units within the reach are predominantly fast water units, including riffles (58%), cascades (12%), and rapids (6%). The naturally confined valley morphology limits the formation of side channels and lateral scour pools. Channel substrate is primarily large cobble (55%) and large boulders (28%) with smaller sediments (sand, gravel) found in pools. Sinuosity of the main channel is 1.07 and average floodprone width is 172.5 feet.

***Figure 38. Representative bed morphology of Reach 3.***

Reach 3 is confined against the left valley wall by a series of coalescing deposits from active and inactive alluvial fans that span the entirety of river-right. All of these fans originate from the right valley wall, pushing the channel left and naturally limiting channel migration processes. The toes of inactive fan deposits have been scoured away, leaving behind steep scarps along river-right throughout the reach. Along more active, contemporary floodplain surfaces, fan toes are being reworked and smaller (30-100 feet wide) inset floodplain pockets are developing.

Sediment is sourced from alluvial fan deposits, which contribute material ranging from large angular boulders (some greater than 15 feet in diameter) to fine sediment. Fine sediment is actively sourced from eroded fan scarps during regular high flow events (Q1, Q2) when flows overtop naturally armored bank toes. Abandoned high elevation alluvial terraces indicate a history of natural incision throughout the reach. As discussed in Section 2.5.3, this is likely in response to changes in flow and sediment inputs following the retreat of glaciers from the valley.

Reach 3 contains small inset pockets of regularly active (Q2) floodplain developing along the toes of the contemporary Q100 floodplain surfaces. Aging of the more mature vegetation on these Q100 surfaces and examination of historical aerial photographs indicates these surfaces were last active in the 1972 flood. Point- and mid-channel cobble bars have developed in areas where the floodprone width expands slightly, at grade breaks, and along meander bends. Most of these surfaces are active and scoured at annual high flows (Q1, Q2), preventing woody vegetation establishment on many of these surfaces.

Large hydraulic roughness features such as colluvial boulders provide the primary geomorphic complexity in Reach 3. Boulders create localized scour pools, which in turn provide holding habitat for fish. The naturally confined nature of Reach 3 limits margin complexity. Large wood counts found 89 pieces of LWM within the study reach, only eight of which were classified as large (20 inches DBH x 35 feet long). Wood accumulations were primarily located at the apexes of mid-channel bars and along the outsides of meander bends. The small size of woody material within the reach provides little cover, limited habitat complexity, and lack of available key pieces to initiate log jam formation.

### 3.4.3 Riparian Conditions

The riparian canopy is dense and intact throughout Reach 3. Areas where small inset floodplain pockets have developed are densely vegetated with shrubs, primarily red osier dogwood (*Cornus sericea*). In areas where inset floodplain pockets were not present, vegetation atop high elevation hillslopes provides shading to the channel. Higher elevation terraces were predominantly closed canopy forests, with ponderosa pine and grand fir overstory, and sparse understory.

### 3.4.4 Human Alterations

Reach 3 has limited modern human features or actions occurring within the active channel or modern floodplain boundaries. The only significant contemporary alteration is Entiat River Road, which is confined to the left toe of the valley slope on an abandoned floodplain surface. The road, however, is close to the channel in a few locations and impacts riparian vegetation and the potential for long-term large wood recruitment to the channel.

## 3.5 REACH 4

### 3.5.1 Reach Overview

Reach 4 is 0.55 miles long and extends from RM 27.15 to 27.7. Bed morphology consists of long riffles interspersed with channel spanning pools. Channel substrate ranges from sand to boulders, but is predominantly cobble (60%). Limited bedrock and fan deposits allow the channel to migrate laterally across the valley floor. The wide floodprone area and alluvial nature of the reach have allowed for development of some of the most extensive active floodplain surfaces within the study area. The 1972 flood was largely responsible for current channel and floodplain morphology (see section 2.4.8). Geomorphic complexity is provided by large wood accumulation, side channels, backwater alcoves, and split flow conditions in the active channel. Human alterations to the reach are limited to the presence of Entiat River Road, which is isolated to the valley left hillslope toe and elevated above active alluvial surfaces.

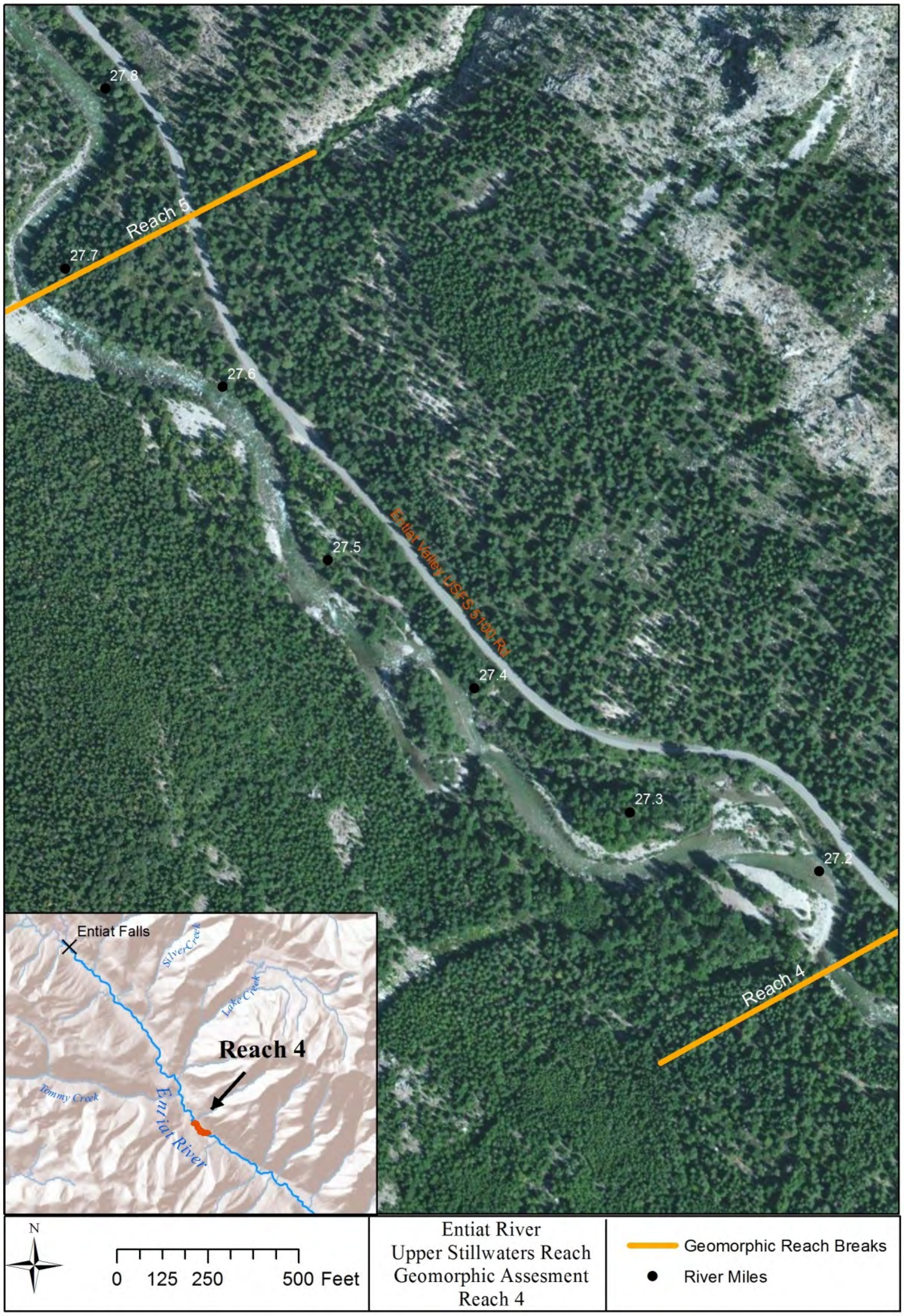


***Figure 39. Overview of Reach 4. Flow is from northwest to southeast.***

### 3.5.2 River Morphology and Geomorphic Processes

Reach 4 is an alluvial reach, with active floodplain surfaces across the valley floor. Bed morphology is primarily riffles, with occasional channel spanning pools. The channel contains extensive point- and mid-channel bars, resulting in increased hydraulic complexity, and a relatively high percentage of side channel habitat as flow splits around these geomorphic features. Much of this complexity is the result of changes enacted by the 1972 flood. Riffles are long and steep, with an overall reach gradient of 1.64%. Bed substrate is predominantly cobble (60%), followed by gravel (20%) and boulders (15%). Bedrock periodically confines the channel, and as flow drops over bedrock outcrops in the channel, turbulent rapids are created followed by deep pools. A lack of confining alluvial fan and mass-wasting deposits has allowed significant lateral channel migration and a sinuosity of 1.31.

***Figure 40. Representative morphology of Reach 4.***

Unlike Reaches 3 and 5, Reach 4 lacks confining alluvial fan deposits. Historically the channel was likely pushed up against the right valley wall, with three large fans occurring along river left (RM 27.15 to RM 27.21, RM 27.26 to RM 27.4, and RM 27.50 to RM 27.70). The toes of these fan deposits have been eroded and re-worked by lateral channel migration processes, leaving behind floodplain surfaces across the valley floor for most of the length of the reach. Bedrock limits lateral channel migration at several points in the reach where the channel contacts high (often over 10 feet) vertical outcrops against the valley wall.

Sediment sources in Reach 4 include both active and inactive alluvial fan deposits. An alluvial fan at the upstream end of the reach was activated in the 1972 flood and contributed a significant amount of sediment to the reach. Contemporary and abandoned floodplain surfaces are all found within the study reach at successively higher elevations respectively, indicating the channel has incised to adjust to contemporary hydrologic and sediment regimes. Despite the evidence for long-term incision, the abandoned floodplain surfaces are some of the smallest (e.g 100 feet wide, by 200 feet long) seen in the study reach and nearly all floodplain surfaces are presently active. These active surfaces were built to a large extent by the 1972 flood, and the reach is currently serving as a storage and response reach.

The lack of confining fan and terrace surfaces results in increased average floodprone width (450 feet) relative to the more confined preceding or subsequent reaches, at 172.5 feet (Reach 3) or 300 feet (Reach 5). This lack of channel confinement in Reach 4 allows the channel to naturally migrate and avulse as part of floodplain forming processes, creating off-channel geomorphic complexity and associated habitat. The 1972 flood caused channel avulsion and creation of split flow and side channels in the reach. Contemporary floodplain surfaces ranged from three to five feet higher than the water surface on the date of the survey. Floodplain surfaces are well vegetated by tree in the 30-40 year-old range. This age class correlates with disturbance from the 1972 flood (Q100+).

Geomorphic complexity within Reach 4 is dominated by response to the 1972 flood which included activation of an upstream fan and a large sediment pulse into the reach. Lateral migration of the channel and avulsions took place during the flood forming side channels and split flow conditions throughout the reach. These side channels and backwater areas provide ample high flow refugia for salmonids. At 98 pieces per mile through the reach, large wood numbers were above the study reach average (83 pieces per mile). Large wood jams were found on the apex of bars, through side channels, and along channel margins.

### 3.5.3 Riparian Conditions

The riparian corridor throughout Reach 4 is densely vegetated. The disturbance during the 1972 flood has resulted in a relatively early seral stage (30 to 40 years old) canopy, which provides only moderate shading to the channel. The high density of stems per acre throughout this reach provides excellent hydraulic roughness to moderate floodplain inundation processes. Narrower side channel and backwater alcoves are well shaded by this younger vegetation regime. Episodic contribution of large wood likely occurred during the 1972 flood as the channel laterally migrates across the valley floor and avulsed through riparian areas. Chronic contributions are likely as the channel continues to migrate.

### 3.5.4 Human Alterations

Reach 4 has very limited contemporary human alterations impacting channel or floodplain processes. Entiat River Road runs along the left bank throughout the channel reach, but is elevated above the active floodplain. The road is disconnecting active alluvial fan surfaces sourced from valley left, which may alter sediment and episodic large wood inputs.

## 3.6 REACH 5

### 3.6.1 Reach Overview

Reach 5 is 0.57 miles long, and extends from RM 27.7 to 28.27. The reach is steep with a gradient of 2.45 %. Bed morphology is long riffles and intermittent pools with substrate ranging from sand to boulders, but predominantly boulders (65%). The majority of Reach 5 is confined against the left valley wall, while the upstream and downstream ends of the reach are confined against the right valley wall by alluvial fan deposits. Abandoned alluvial terraces at multiple elevations indicate a history of natural incision throughout the reach, while bedrock outcrops provide contemporary vertical grade control. A large floodplain surface along river right from RM 27.87 to RM 28.4 provides some geomorphic complexity, along with large wood accumulations along channel margins and large boulders within the channel. Some human alterations are associated with Fox Creek campground (RM 28.1), including bank armoring, floodplain grading, and understory clearing.


***Figure 41. Overview of Reach 5. Flow is from northwest to southeast.***

### 3.6.2 River Morphology and Geomorphic Processes

Through Reach 5, sinuosity and complexity decrease relative to Reach 4 as the channel transitions from being unconfined and alluvial to semi-confined and single-thread. The channel is predominantly long riffles (86%) with intermittent pools (7%). Bedrock outcrops alternate along river right and river left throughout the reach, and extend across the width of the channel creating short, turbulent rapids with downstream plunge pools. The semi-confined valley morphology limits side channel and pool formation that would occur through unconfined alluvial processes like those in Reach 4. However, abandoned channel scars suggest the channel has historically migrated across the valley floor. Channel substrate is primarily large boulders (65%), with cobble (20%) and gravel (10%) subdominant. Gravel and cobble primarily occur in pools. The sinuous (1.31) planform of the main channel is created by alternating alluvial fan deposition sourced from the left and right valley walls, but is static and not actively migrating. Average floodprone width (300 feet) is considerably greater than Reach 6 (Box Canyon (100 feet wide)), but is more confined than the alluvial Reach 4.

***Figure 42. Representative morphology of Reach 5.***

The majority of Reach 5 (RM 27.75 to RM 28.12) has been confined up against the left valley wall by an expansive inactive alluvial fan surface. Active fan deposits confine the upstream (RM 28.12 to RM 28.27) and downstream end (RM 27.70 to RM 27.75) towards the right valley wall. These fan deposits, along with periodic bedrock outcrops throughout the reach, naturally limit lateral migration processes and the formation of floodplains within the reach. The toes of older fan deposits have been scoured away creating a narrow band of floodplain from RM 27.87 to RM 28.04. The channel has remained closely aligned with contemporary boundaries since the beginning of the aerial photo record (1945).

This reach is abundant in boulders and large cobble, the majority of which have been sourced from hillslopes and alluvial fans. Fine sediment is primarily sourced from scour along fan scarps and banks toes at higher flows, and from upstream. The gradient of the reach and lack of fines in the bed suggest that most fine sediment is transported through the reach. Abandoned alluvial terraces indicate a history of natural incision, while bedrock outcrops provide contemporary vertical grade control.

Reach 5 contains two significant floodplain surfaces from RM 27.87 to RM 28.18. These surfaces have been created as the channel has scoured away and reworked sediment at the toe of an inactive alluvial fan deposit and terrace deposits. The upstream most floodplain surface has been somewhat disconnected by a levee in Fox Creek Campground. In addition to this floodplain, small (10-50 feet wide) inset pockets of floodplain have developed along the toes of abandoned floodplain surfaces and hillslopes. These areas are primarily limited to flood event (Q100) inundations.

Large boulders provide the extent of geomorphic and habitat complexity in Reach 5. A high flow channel beginning at RM 28.21 (river left) is inundated over a range of high flows (Q2-Q100), but is partially disconnected from the channel by a small levee and does not provide functional side channel habitat in its current condition. Colluvial boulders create localized scour pools throughout the reach, which in turn provides holding habitat for fish. Large wood counts found 50 pieces of LWM within the study reach, giving the reach an average of 87 pieces per mile. Wood accumulations are primarily located along the outsides of meander bends. The small nature of woody material within the reach provides little cover or habitat complexity.

### 3.6.3 Riparian Conditions

The riparian canopy is dense and intact for the majority of Reach 5, with some clearing associated with campsite development at the Fox Creek campground between RM 28.0 and 28.2. Areas where small inset floodplain pockets have developed are densely vegetated with shrubs, primarily red osier dogwood (*Cornus sericea*). Shading provided by the riparian canopy varies according to the elevation of terraces and bedrock outcrops throughout the reach. High elevation terraces bordered the channel in many locations reducing floodplain width, but these terraces provide partial shading.

### 3.6.4 Human Alterations

A small portion of the channel and floodplain have been altered as part of the Fox Creek campground (RM 28.1). Some armoring of the banks has occurred here along river left, as well as floodplain grading and riparian thinning. There is a low wall that acts like a levee along the upstream boundary of the floodplain between RM 28.19 to 28.15 approximately. This has resulted in a small portion of floodplain disconnection, and disconnection of a high flow channel that runs along the inside of the floodplain at the toe of an alluvial terrace.

## 3.7 REACH 6

### 3.7.1 Reach Overview

Reach 6 (Box Canyon) is 1.06 miles long, and extends from RM 28.27 to RM 29.33. This is the steepest reach in the study area with a gradient of 3.6%. Bed morphology is riffles, rapids, and step-pool sequences. Substrate ranges from sand to boulders, but is predominantly cobble (60%). The channel is entirely confined by hillslopes and bedrock, sometimes by sheer bedrock walls, along river left and river right that prevent lateral migration or floodplain formation. Bedrock spans the channel in many portions of the reach, creating steep drops, and providing vertical grade control. Boulders sourced from rock fall and adjacent hillslopes provide localized pocket water and are the primary source of habitat complexity in the reach. There are no human alterations observed in the reach.

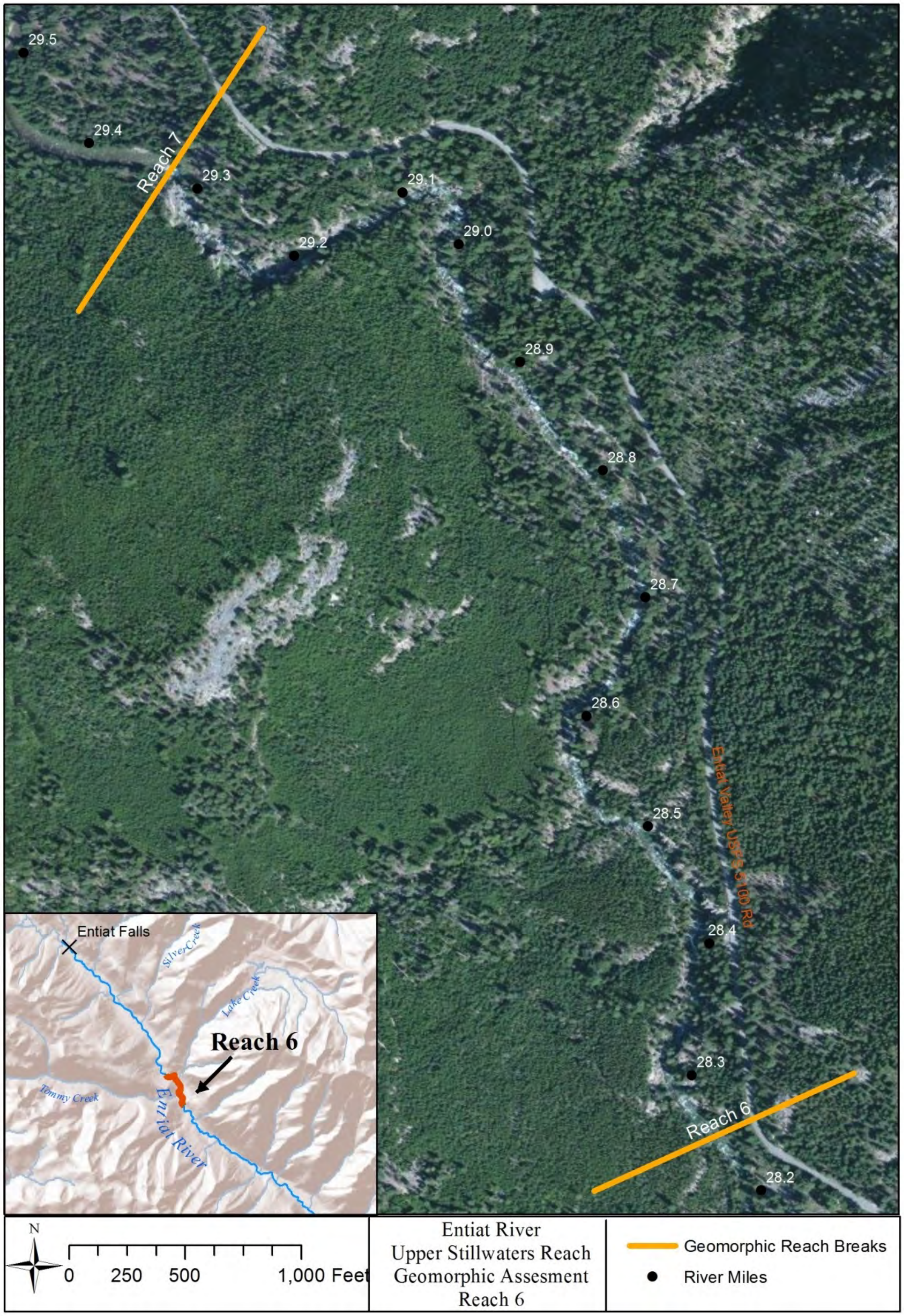


***Figure* 43*. Overview of Reach 6. Flow is from northwest to southeast.***

### 3.7.2 River Morphology and Geomorphic Processes

Reach 6 is a steep, confined bedrock canyon known as Box Canyon (Figure 44). Sheer bedrock walls confine the channel along both banks throughout much of the reach, and are 50 to 100 feet high. Channel units are steep and turbulent, including many cascades and steep step-pool sequences. Bed substrate ranges from gravel to bedrock, with cobble the predominant substrate type (60%). Where bedrock spans the channel and forms the bed, there are typically steep drops that transition abruptly into plunge pools creating a stepped profile. The reach has a sinuosity of 1.13.

***Figure 44. Representative channel morphology of Reach 6.***

The channel is confined between sheer bedrock walls along river left and river right. These bedrock outcrops create a stable channel planform that does not migrate laterally, or does so over extremely long time scales associated with the breakdown and removal of bedrock from the channel margins.

Sediment is contributed to the reach primarily via rock fall from adjacent cliffs, mass wasting from steep hillslopes, and from upstream sources. Substrate is predominantly large cobbles, followed by boulders. Small amounts of sand and gravel accumulate in expansions where bedrock confinement decreases.

Classified as a transport reach, Box Canyon probably moves the majority of sand and gravel supplied to it.

The natural bedrock confinement in Reach 6 does not allow for significant floodplain formation. Only one pocket of floodplain occurs within the reach from RM 28.67 to RM 28.72. This surface is inundated at the Q100, and is 70 feet wide at its widest point.

Bedrock scour has created several deep, clear pools in Reach 6, but most lack cover. Larger pools have been created by scour as rapids flow over bedrock outcrops, while smaller 'pocket' pools are found around large colluvial boulders entering the channel from rock fall. Large wood is found throughout the reach, much of which is rafted atop large boulders and accumulated in eddies. The residence time of large wood accumulations is likely very low, as jams build up spanning the canyon, and then wash out at higher flows.

### 3.7.3 Riparian Conditions

The bedrock confinement of Reach 6 naturally limits floodplain formation, establishment of riparian vegetation, and the growth of a mature riparian canopy. In many locations, vegetation has established in cracks and on ledges in bedrock walls. Following wind throw or tree mortality, large wood is contributed from atop steep canyon walls. However, these provide sparse canopy coverage. Steep, tall canyon walls provide shading to the reach throughout much of the day.

### 3.7.4 Human Alterations

Confined by sheer bedrock walls, Reach 6 has no human alterations present.

## 3.8 REACH 7

### 3.8.1 Reach Overview

Reach 7 is 0.52 miles long, and extends from RM 29.33 to 29.85 at a gradient of 1.8 % (Figure 45). Bed morphology is homogeneous, as there is primarily one long riffle. Bed substrate ranges from sand to boulders, but is predominantly cobble. The reach is semi-confined by bedrock, alluvial fans, and abandoned floodplain terraces that set natural limits on lateral migration and habitat formation processes. Tiered abandoned floodplain terraces indicate a history of natural vertical incision as channel discharges and sediment supply decreased following glacial retreat. Contemporary vertical channel dynamics are largely controlled by bedrock in Reaches 6 and 8, as well as a channel-spanning bedrock outcrop within Reach 7 at RM 29.8. Small, inset floodplains are developing at the channel's contemporary equilibrium base level. The absence of large wood, connected floodplains or large boulders results in limited geomorphic complexity throughout the reach.

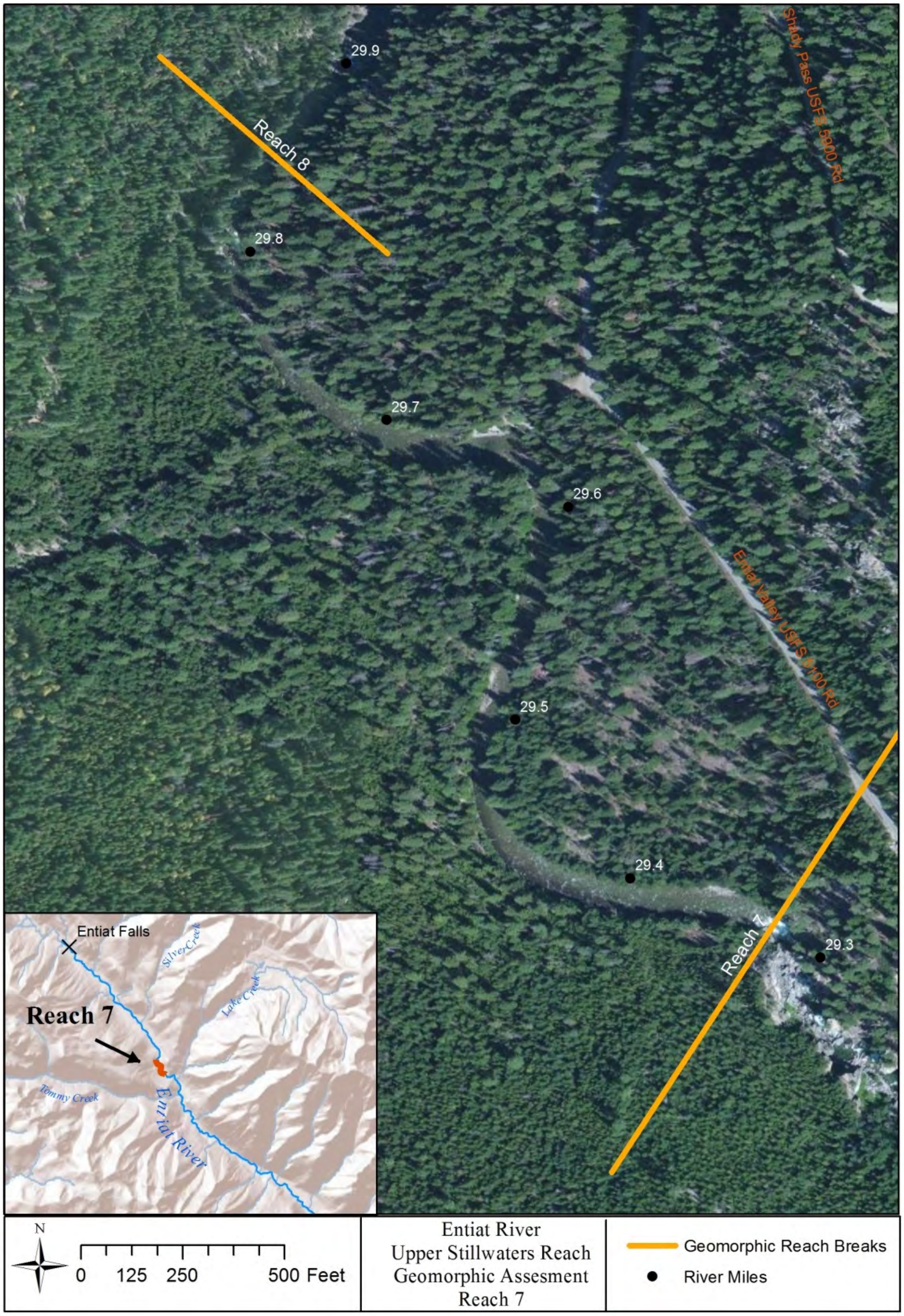


***Figure 45. Overview of Reach 7. Flow is from northwest to southeast.***

### 3.8.2 River Morphology and Geomorphic Processes

Reach 7 is a transitional reach between the bedrock-confined Reaches 6 and 8. Bed morphology in Reach 7 is extremely homogenous, and is predominantly one long riffle that is forced around an alluvial fan on river right (Figure 46). One short channel-spanning pool is interspersed within the riffle. Substrate is primarily large cobble, with occasional boulders sourced from either mass-wasting deposits, alluvial fans, or lag derived from glacial outwash deposits.

***Figure 46. Representative morphology of Reach 7.***

Reach 7 is confined by mass-wasting deposits, alluvial fans, and abandoned alluvial terraces. This confinement limits lateral migration and essentially locks the channel in its current meander configuration. Some channel widening and associated inset floodplain development appears to have occurred during modern flood events (1945 and 1975). At the middle portion of the reach (RM 29.62), an inactive alluvial fan sourced from slopes on river right confines the channel against the valley left hillslope. The toe of this fan was eroded and re-worked in the past with formation of an alluvial surface along the edge of the fan that was subsequently abandoned as the river down cut through valley fan deposits. Upstream and downstream of the fan deposit, terraces along the left bank confine the channel against the right bank hillslope. This alternation of fan and glacial terraces has resulted in a static “S” shaped-meander with a sinuosity of 1.19, and a single-thread channel form uncommon in the upper reaches of the study area.

The re-worked alluvial fan and tiered alluvial terraces indicate a history of natural vertical incision instigated by reductions in water and sediment fluxes following glacial retreat. Contemporary vertical channel dynamics are largely controlled by bedrock in Reaches 6 and 8, as well as a channel-spanning bedrock outcrop at RM 29.8 that provide stable vertical control. Fine sediment is derived from erosion of terrace scarps at several locations in the reach (Figure 47). Bank toes and bar surfaces within the study reach are armored by winnowing of smaller material during floods.

***Figure 47. Fine sediment source within Reach 7.***

Contemporary floodplain surfaces mainly include narrow channel margins that appear to be widening and expanding as the channel evolves laterally at a new equilibrium base level achieved following post-glacial incision. This channel evolution is focused upstream of the alluvial fan, and upstream of the bedrock constriction that marks the bottom of the reach. Floodplain at the downstream end of the reach occur as wide vegetated channel margins that have developed via high-flow backwater caused by the flow constriction at the top of Reach 6 (immediately upstream of Fish Tail Falls). Floodplain banks bordering the channel were approximately five feet above the water surface elevation on the day of survey (August 31, 2012).

The reach is largely lacking in geomorphic complexity and any associated habitat features. The reach has no large wood accumulations, no side channels, and limited ‘pocket’ pool habitat created by large boulders in other reaches. Further, larger substrate throughout the reach appeared not suitable for spawning habitat.

### 3.8.3 Riparian Conditions

Dense thickets of red osier dogwood (*Cornus sericea*) are readily establishing atop active floodplain surfaces. Lower terraces are well vegetated with a mix of deciduous species (primarily black cottonwood) and conifers (ponderosa pine, grand fir). Higher terrace surfaces and hillslopes are vegetated with older conifer forests (pine and firs) with understory composition and density dependent on available groundwater. The riparian canopy provides shade and overhanging cover along channel margins, except where the channel directly encounters hillslopes where riparian vegetation has not established.

### 3.8.4 Human Alterations

Reach 7 has minimal modern human features or actions occurring within the active channel or modern floodplain boundaries. Forest Service NF 51 (Entiat River Road) runs parallel to the channel along river left in this reach but at an elevation and distance that does not impose additional constraints on the geomorphology of the channel and its modern floodplain.

## 3.9 REACH 8

### 3.9.1 Reach Overview

Reach 8 is 0.35 miles long, and extends from RM 29.85 to RM 30.2 at a gradient of 1.7% (Figure 48). Bed morphology is primarily alternating riffle-pool sequences, with occasional step-pools created over channel-spanning bedrock outcrops. Bed substrate ranges from sand to boulders, but was predominantly boulders and cobble. The reach is confined by abandoned terraces and bedrock outcrops that alternate between the left and right bank throughout the reach. As the channel has adjusted to the drier post-glacial hydrologic regime and reduced sediment input, it has incised down through fluvioglacial deposits and older floodplain surfaces. No active floodplain surfaces have developed within Reach 8. Reach 8 has minimal human alterations except for Entiat River Road running parallel to the channel in this reach at an elevation that does not impact channel or floodplain processes.

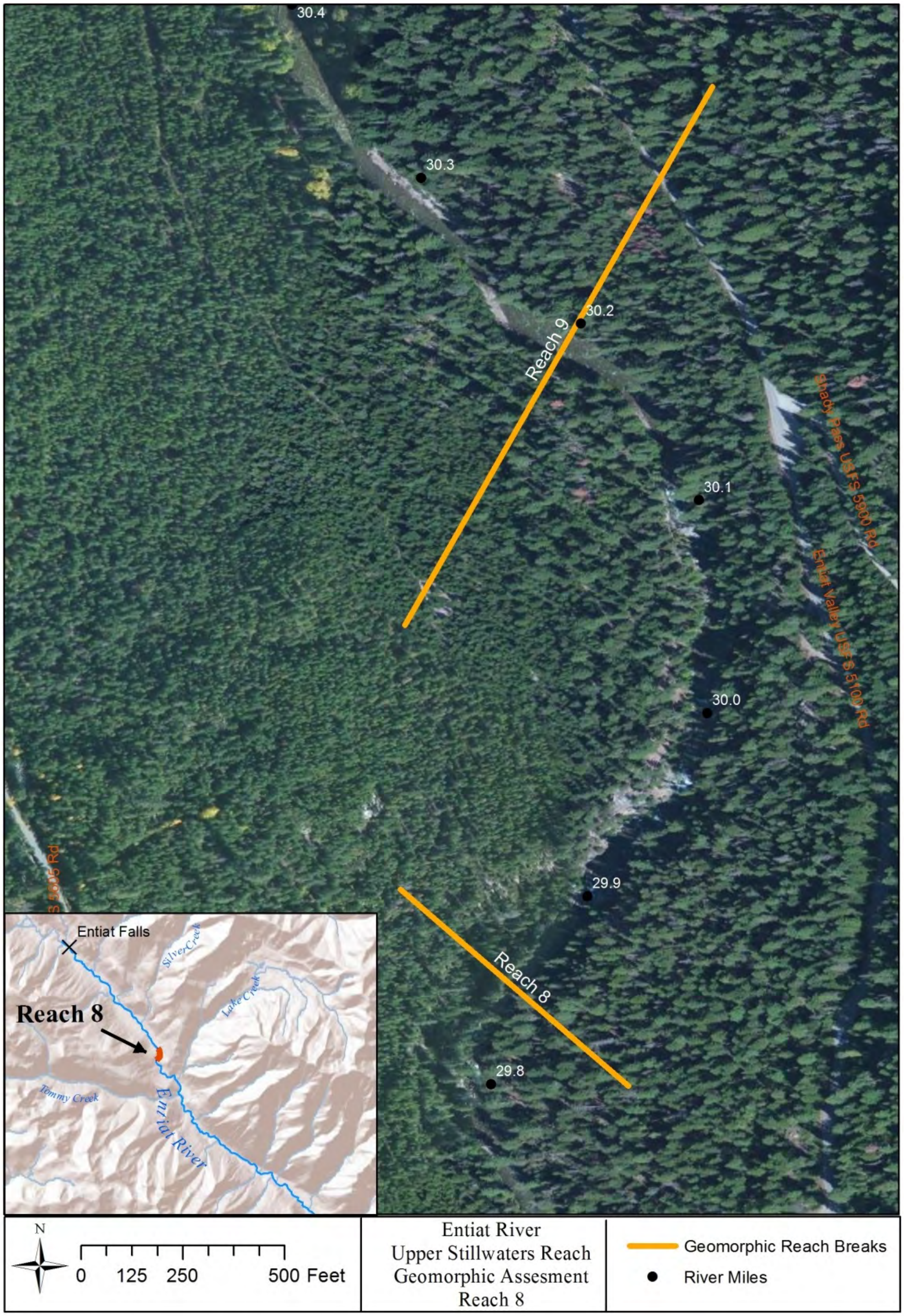


*Figure 48. Overview of Reach 8. Flow is from north to south.*

### 3.9.2 River Morphology and Geomorphic Processes

Reach 8 is a steep, confined single thread channel with a sinuosity of 1.14. Bed morphology is predominantly fast water units (riffles and rapids) with channel spanning scour and plunge pools (Figure 49). Rapids drop from one to five feet over bedrock sills, and plunge pools appear deep (greater than 9 feet), though depths were not measured due to unwadeable conditions. Large boulders and bedrock are present throughout much of the channel, with gravels and sand present in pools and eddies. Bedrock outcrops confine the channel on both sides alternating along river right and river left and in some places confining the channel on both sides creating a canyon. Canyon walls range from 10 to over 60 feet tall. At two points the bedrock walls constrict low flow discharge through narrow rock shoots (RM 30.9 and RM 29.97).

***Figure 49. Representative morphology of Reach 8.***

While bedrock plays a dominant role in lateral channel control in most of the reach, abandoned alluvial terraces along both banks confine the channel in the upstream (RM 31.92 to RM 32.00) and downstream (RM 29.85 to RM 30.00) most portions of the reach. The terraces have been eroded by contemporary channel flows leaving high scarps with armored toes that form lateral migration barriers.

Sediment sources in Reach 8 include bank erosion along terrace scarps in the upstream and downstream most portions of the reach. The abandonment of these floodplain surfaces indicates that sediment inputs to this reach were much higher during glaciation, and that decreased sediment supply instigated bed incision. There is sporadic hillslope- and bedrock- sourced colluvium in the channel. Some slopes also contain unconsolidated sand and fines within vegetation that provide minimal inputs of fine-grained material. Due to the riffle- pool bed morphology and canyon confinement, Reach 8 probably transports the majority of sediment influx, leading to its classification as a transport reach.

No contemporary floodplain surfaces are present in Reach 8. Terrace banks at the upper and lower-most portions of the reach ranged from approximately five to 15 feet higher than the wetted channel surface on the day of survey (August 31, 2012). These surfaces are well vegetated with older forests (DBH of 30-50 inches) and appear to be very rarely inundated.

Geomorphic complexity in Reach 8 is driven by bedrock confinement. Scour around bedrock outcrops has created large deep pools in many locations, with overhanging ledges providing cover to some pools. Reach 8 contains two large wood jams (RM 29.98 and RM 30.0) that have formed by large wood lodging between mid-channel boulders and the canyon sidewall or hillslope. Large wood accumulations are also located on the apex of the upstream floodplain surface (RM 32.0) and downstream most portions of the reach (RM 29.85 to RM 30.00). Average hydraulic conditions are likely to transport much of the large wood sourced from within Reach 8 or upstream through the reach with short LWM residence times.

### 3.9.3 Riparian Conditions

Terraces in the upper and lower-most portions of the reach are densely colonized with mid to late seral stage vegetation (150+ years old, 20 to 50 inch diameter). This vegetation shades the channel and its roots provide bank stability and flow resistance. Throughout the remainder of the reach where canyon walls serve as channel margins the canopy is sparse, but canyon walls provide shading through much of the day. Bedrock and steep hillslopes are sparsely vegetated with a mixed seral stage stand that is dominated by Ponderosa Pine (*Pinus ponderosa*) and some Grand Fir (*Abies grandis*). Episodic and chronic contributions of large wood are likely sourced from steep hillslopes and vertical canyon walls. Due to the transport nature of this reach, large wood that is sourced within this reach likely moves through rapidly.

### 3.9.4 Human Alterations

Reach 8 has minimal modern human features or actions occurring within the active channel or floodplain boundaries. Forest Service NF 51 (Entiat River Road along river left) runs parallel to the channel in this reach but at an elevation and distance that does not impose additional constraints on the geomorphology of the channel and its modern floodplain.

## 3.10 REACH 9

### 3.10.1 Reach Overview

Reach 9 is 1.22 miles long and extends from RM 30.2 to 31.42. Bed morphology is riffle-pool, with multiple locations of split-flow around mid-channel bars. Bed substrate ranges from sand to cobble, but is predominantly cobble (60%). The reach is the most laterally active reach above Box Canyon (Reach 6), as there is only partial confinement by abandoned terraces. The wide floodprone area of this reach provides some of the most extensive active floodplain surfaces in the study area. This translates to geomorphic complexity from the lateral migration and avulsion of the mainstem, as well as from numerous large wood accumulations along channel margins, at the apexes of islands, and within side channels. Human alterations are limited to minor riparian vegetation impacts, tributary obstruction, and bank hardening associated with the Silver Creek Campground.

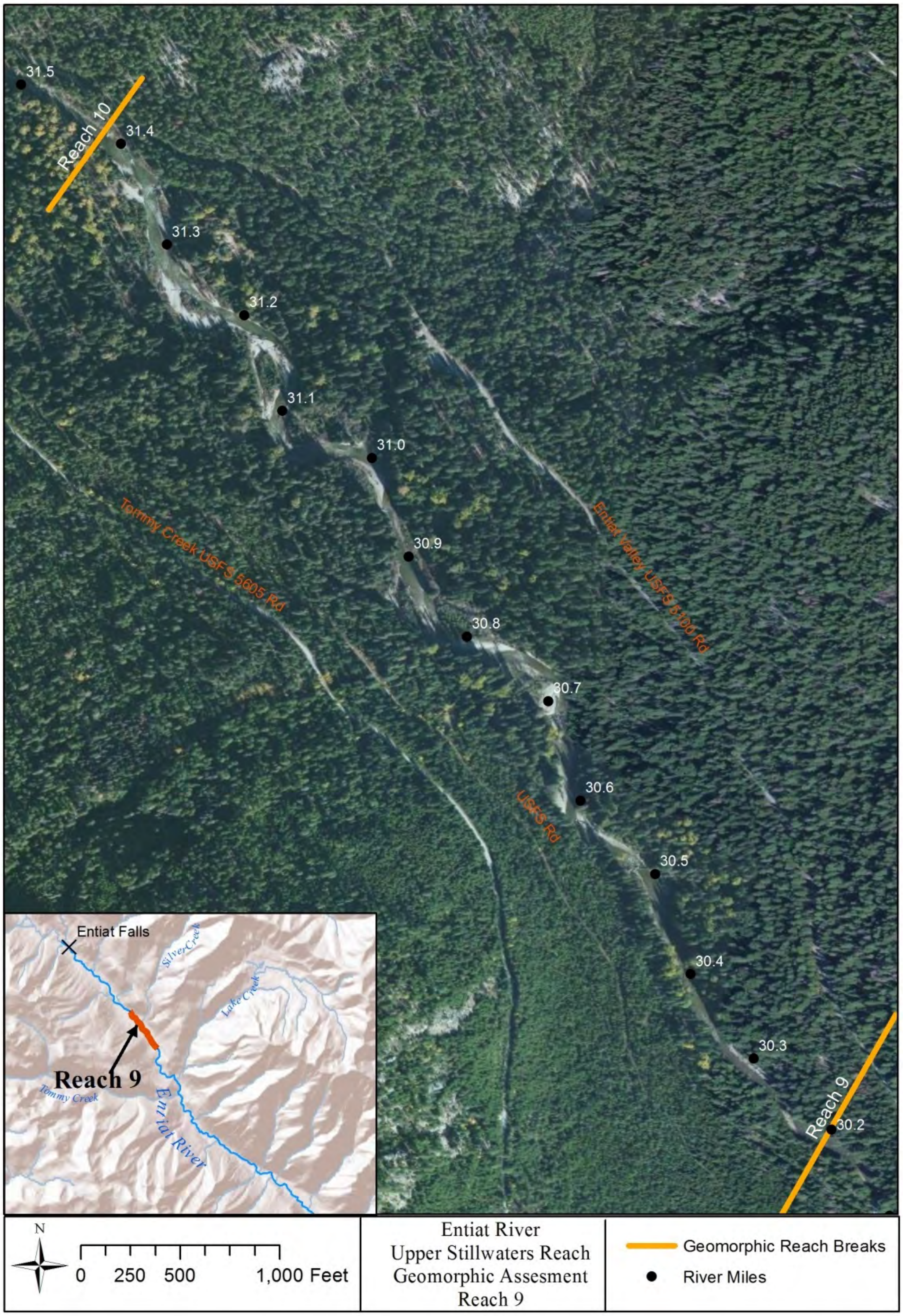


***Figure 50. Overview of Reach 9.  Flow is from northwest to southeast.***

### 3.10.2 River Morphology and Geomorphic Processes

Reach 9 has greater sinuosity and complexity than adjacent reaches and is one of the more complex reaches in the study area. The wider, unconfined valley results in a meandering reach with numerous islands, large wood jams, bars, and hydrologically connected floodplains. The predominant channel type is riffle (74%), many of which are channel spanning and transverse, pushing water into banks and log jams. Active alluvial surfaces that are regularly inundated by seasonal high flow events border the channel through the entire reach. Substrate is primarily small cobble (60%) and gravel (35%) with pockets of sand throughout. Sinuosity of the main channel is 1.05, but overall planform complexity is high due to a braided segment, multiple split flow locations, and side channels within the reach that the sinuosity calculation does not account for.

Reach 9 is the most laterally active reach upstream of Box Canyon despite glacial terraces on both river-right and river-left that partially confine the channel. According to the oldest historical photos (1945), the channel pattern of this reach has been consistent for the last 70 years. Plentiful bars (point and transverse), high and low flow side channels, islands, and abandoned floodplain scars indicate that lateral channel shifts do occur within Reach 9. However, abandoned channel forms and the relative stability of the channel location between major flood events suggests that the migration is not gradual but instead is event-driven with features that are created during extreme floods and then are maintained during low flow or are abandoned after flood flows subside.

Reach 9 is primarily a depositional reach, due in large part to its relatively low confinement and expansion in floodprone width (390 feet). This is evidenced by accumulation of large wood and sediment (in extensive mid channel and point bars). Reach 9 contains semi-alternating strips of regularly active (Q2) floodplain along the channel margins in the upper portion of the reach (RM 30.7 to RM 31.4). Coring of trees on these surfaces indicated that tree stands alternate between 30 or 70 years, correlating with establishment following the 1974 and 1945 floods, respectively. Field evidence of 150+ year old vegetation and soil development patterns indicate the higher terraces within the reach are not active at the Q100.

The alluvial and depositional nature of Reach 9 translates to some of the most complex geomorphic and associated habitat conditions in the study reach. The increase in floodprone width and the decrease in gradient create a network of transverse and mid-channel gravel bars. Large wood accumulations are found on the apexes of many of these bars, as well as along channel margins. The large woody material is sourced both from upstream and from channel margins in the reach. The deposition of gravel and large wood throughout the reach has led to braiding and multiple side channels, some of which are active perennially, whereas others are active only at higher flows. Transverse riffles throughout the reach are instigating lateral channel dynamics and complexity along channel margins by creating scour pools at bank toes under root wads of standing riparian trees.

### 3.10.3 Riparian Conditions

The higher elevation terrace surfaces are well-vegetated with mixed older forest. Understory composition and density are dependent on available groundwater (including proximity to tributaries or location on an alluvial fan). Contemporary floodplain surfaces have forest stands of two distinct ages that correlate with vegetation establishment following the major flood events of 1945 and 1974. Surfaces that were scoured or deposited during these floods (as evidenced by the aerial photo record, and field checked) have like-aged stands of mixed forests (fir, cedar, alder) that are either approximately 70 years of age, or between 20 and 30 years old. Regularly active contemporary floodplain surfaces (inundated at Q1-Q3) are either bare, due to frequent scouring flows, or vegetated with *Salix* spp. The depositional patterns, lower gradient, and increase in gravel and sand retention make for the most suitable willow growing conditions upstream of Box Canyon.

### 3.10.4 Human Alterations

Reach 9 has minimal modern human features or actions occurring within the active channel or modern floodplain boundaries. The Entiat River Road along river-left and the Forest Service 5605 Road (Tommy Creek Road along river-right) run parallel to the channel in this reach but at elevations and distances that do not impose additional constraints on the geomorphology of the channel and its modern floodplain. At the mouth of Silver Creek (RM 31.01 on river-left) a series of hand-built ‘U’-shaped cobble/boulder check dams have been constructed. These will likely be washed out by high-flow of the Entiat River and Silver Creek, but could be barriers to fish passage during low flow periods. Developed campgrounds and trails are established at the Silver Creek Campground along river-right from approximately RM 30.4 to 31.4. The vegetation removal and thinning associated with the campground is above the contemporary floodplain and channel boundary. A trail system runs along the edge of the bank on abandoned floodplain terraces with built viewing platforms on the channel banks. The terrace along river-left (RM 31.75-31.84) has been cleared, graded, and graveled into a parking lot and river access site. An undeveloped campground site is also present on this surface. Neither of these alterations appears to impact channel processes.

## 3.11 REACH 10

### 3.11.1 Reach Overview

Reach 10 is 0.49 miles long and extends from RM 31.42 to 31.91 (Figure 51). Bed morphology is essentially one long fast water complex that alternates between steeper gradient rapids and moderate gradient riffles. Bed substrate ranges from gravel to boulders, but is predominantly gravels (50%). The reach is semi-confined by hillslopes, bedrock outcrops, and by abandoned alluvial floodplain and glacial outwash terraces, which limits lateral migration and floodplain formation processes. A small inset active floodplain has formed as the channel adjusts to its contemporary flow and sediment regimes. Geomorphic complexity is limited to hillslope-sourced boulders that provide localized scour and that create holding and resting areas for salmonids. The only significant human alteration is a bridge that crosses the Entiat River at RM 31.84. The bridge, and its associated fill, limit lateral channel migration processes, and restrict the channel at high flow.

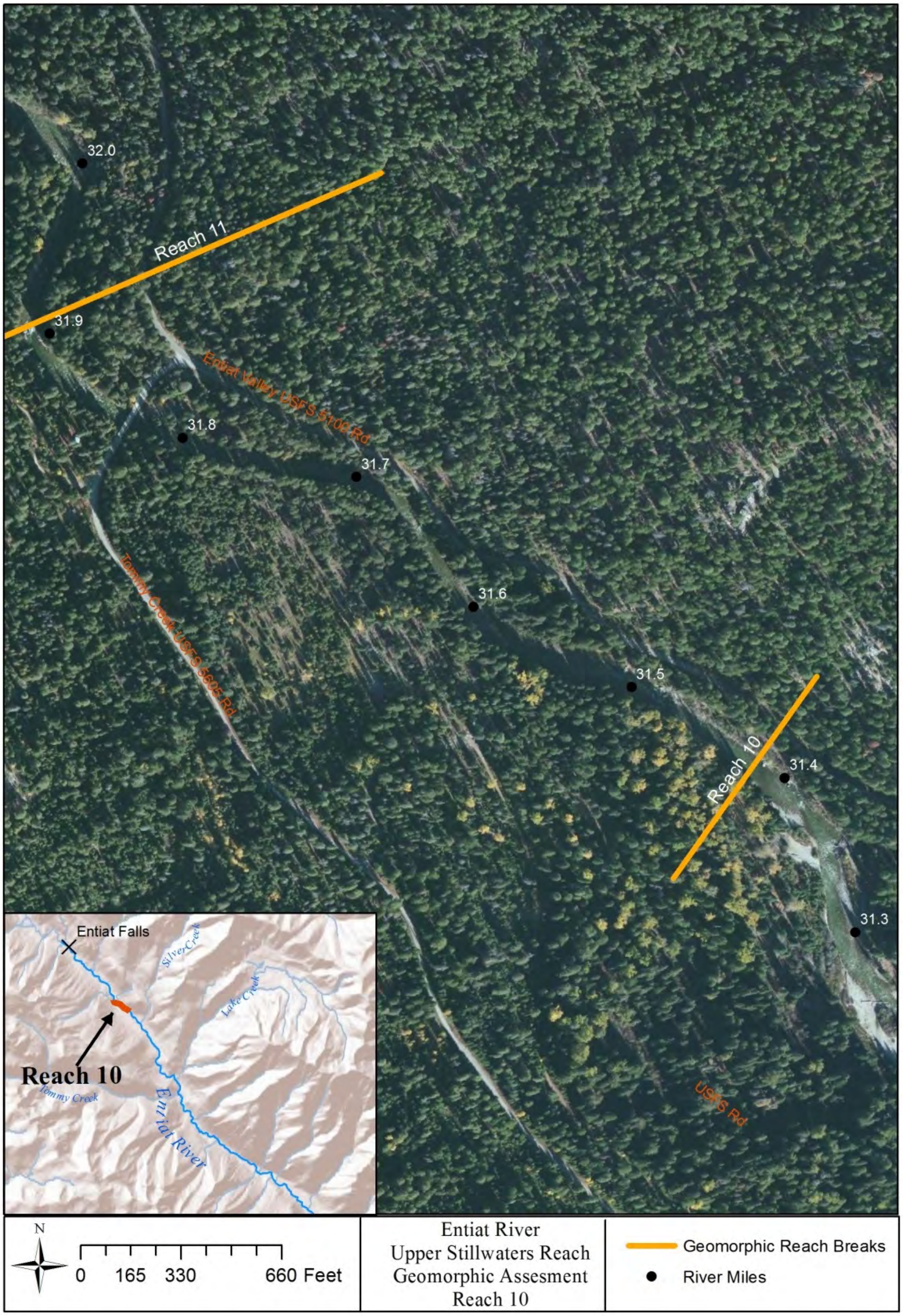


*Figure 51. Reach 10 overview. Flow is from northwest to southeast.*

### 3.11.2 River Morphology and Geomorphic Processes

Reach 10 is primarily a long riffle complex that alternates between high gradient rapids (40%) and moderate gradient riffles (52%). In more moderate gradient segments of Reach 10, smaller coarse materials (i.e. gravels) accumulate along channel margins. Channel substrate is principally gravel (50%), followed by cobble (35%). Confined by abandoned floodplain and glacial outwash surfaces, the channel is relatively straight with a sinuosity of 1.05.

***Figure 52. Representative morphology of Reach 10.***

Channel migration processes are limited by the close proximity of hillslopes, bedrock outcrops, abandoned floodplain terraces on river-left, and along river-right by both abandoned floodplain terraces and an alluvial fan. Historically, confinement of the channel by mass-wasting from river-left and abandoned floodplain surfaces have dictated channel planform. Channel migration processes are ongoing in some locations, however, as evidenced by undercut rootwads (Figure 52).

***Figure 53. Undercut root wads along the right bank in Reach 10.***

Similar to other reaches within the study area, the existing 'underfit' channel has incised down into glacial outwash deposits and more recent alluvial material. Bedrock in the banks and bed of the channel has slowed the current rates of incision, resulting in a channel that remains underfit for its morphology. Through processes of channel evolution (i.e., lateral migration at a new equilibrium base level following a period of incision), an active inset floodplain is developing. There are abundant supplies of fine sediments throughout the reach, primarily from hillslopes and exposed terraces along river-left, and undercut stream banks. Gravel accumulations are located in pocket pools and in the downstream velocity shadows of boulders and channel margin irregularities.

The channel is confined between bedrock outcrops and abandoned alluvial terraces. A glacial terrace runs the inland boundary of the valley along river-right. Glacial terraces were approximately 15 feet above the active channel's water surface elevation on the date of the survey (August 30, 2012). Pockets of abandoned floodplain terraces alternate with bedrock outcrops along river-left; the terraces were approximately eight feet above water surface elevation on the date of the survey. In the downstream half of the reach (RM 31.55 to 31.61), a narrow band of active floodplain is forming along river-left. This feature is developing a narrow point bar that is surficially composed of gravels to small boulders, with vegetation establishing on the inland (hillslope) side.

No large wood accumulations were present at the time of the survey. The reach naturally lacks areas where large wood would be prone to accumulate (e.g. meander bends), and the higher elevation riparian vegetation provides limited hydraulic roughness throughout the reach. The more moderate gradient within this reach has allowed for accumulation of gravel substrate.  Boulders throughout the reach provide 'pocket' water and holding areas for salmonids.

### 3.11.3 Riparian Conditions

Streambanks are well-vegetated throughout Reach 10, although riparian vegetation is primarily elevated above the active channel, especially in the upstream portions of the reach. In the downstream portion of the reach, where contemporary floodplain surfaces have developed, dense dogwood and alder thickets provide hydraulic roughness and shading to the channel.

### 3.11.4 Human Alterations

The effects of human alterations within Reach 10 are limited. The most notable human feature is a two-lane cement bridge that crosses the Entiat River at RM 31.84. The bridge and its associated fill and bank armoring limit lateral channel migration processes and restrict the channel at high flow. Evidence of past timber harvest (stumps, decommissioned roads) exists on an abandoned floodplain terrace along river-right. This timber harvest has likely impacted large wood loads to the channel over time. The Entiat River Road along river-left and Road 5605 (Tommy Creek Road) along river-right (and its associated logging roads) run parallel to the channel in this reach, but at elevations and distances that do not impose additional constraints on the geomorphology of the channel and its modern floodplain. The terrace along river-left (RM 31.75-31.84) has been cleared, graded, and graveled into a parking lot and river-access site. An undeveloped campground site is also present on this surface. Neither of these alterations appears to impact channel processes.

## 3.12 REACH 11

### 3.12.1 Reach Overview

Reach 11 is 0.99 miles long and extends from RM 31.91 to 32.9 at a gradient of 1.6% (Figure 54). Bed morphology is primarily riffle-pool, with riffles steepening to rapids in the downstream half of the reach. Substrate is predominantly cobble (50%), followed by gravel (22%). The channel is confined by several features including a large valley right alluvial fan, glacial terraces, more recently abandoned floodplain terraces, and bedrock that alternates from right to left throughout the reach. Bedrock outcrops limit both lateral migration and current rates of incision. Similar to Reach 10, small (5 to 15 feet wide) point and mid-channel bars are developing and function as annually inundated floodplain surfaces. Geomorphic complexity is provided through wood accumulations along channel margins and by deep pools covered by bedrock overhangs. Human alterations within the active channel and floodplain corridors are limited to a small rock wall at RM 32.89.

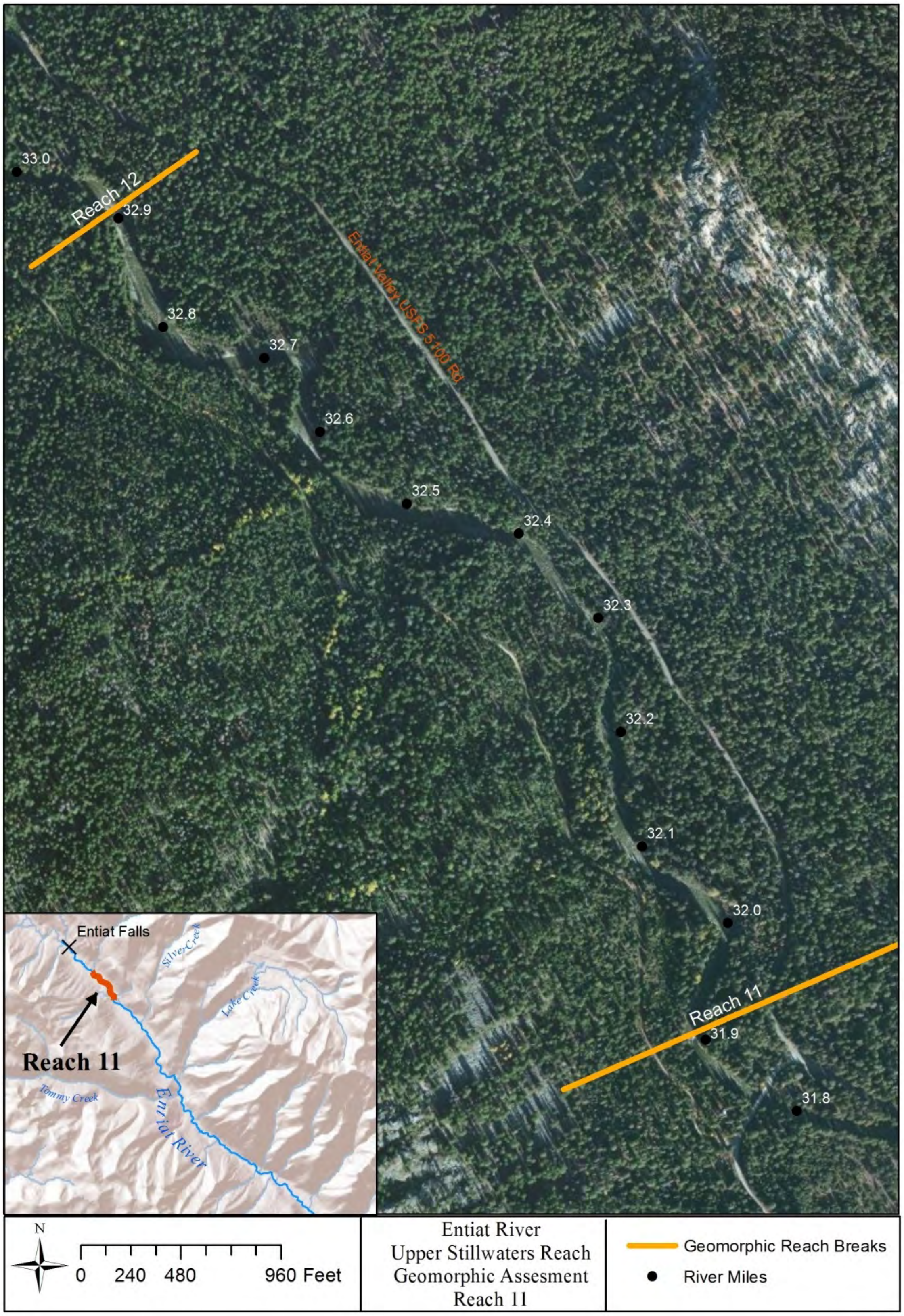


***Figure 54. Overview of Reach 11. Flow is from north to south.***

### 3.12.2 River Morphology & Geomorphic Processes

Reach 11 is a steep, single-thread channel with point and mid-channel bars active at regular high flow events (e.g. Q1 to Q3) (Figure 55). Bar surfaces are armored by a large cobble substrate. Bed substrate ranges from gravel to bedrock, with cobble the predominant substrate type (60%). Channel units alternate between long riffles and short turbulent rapids. Bedrock outcrops alternate along river right and river left throughout the reach. Similar to Reach 12, bedrock outcrops extend across the width of the channel, creating short, turbulent rapids and cascades with downstream plunge pools. Semi-confined by bedrock contacts and alluvial terraces, the reach has a low sinuosity of 1.13.

***Figure 55. Representative morphology of Reach 11.***

The channel is re-working and scouring away sediments at the toe of confining floodplain terraces, armoring terrace toes with large cobbles and boulders. This reach has abundant sources of fine sediment, including those found along adjacent hillslopes and at terrace bank exposures. Broad, high elevation alluvial terraces indicate a history of natural incision throughout the reach that is likely in response to changes in flow and sediment inputs following the retreat of glaciers from the valley. Small (5 to 15 feet wide) inset point and mid-channel bars compose the extent of the active floodplain within the overall incised morphology. These surfaces occur primarily in areas where there is ample hydraulic roughness or in areas where the channel widens and are composed of gravel to large cobble.

Scour around bedrock outcrops has created deep, clear pools throughout Reach 11. Erosion processes have created bedrock overhangs in many locations, providing cover and shade. Large wood complexes provide cover and complexity at multiple locations. Episodic contributions of large wood are principally sourced from undercut banks, leading riparian trees to fall into the channel (Figure 56).

***Figure 56. Large wood accumulation providing cover and complexity within Reach 11.***

### 3.12.3 Riparian Conditions

The riparian canopy is dense but narrow. Alder and willow line the active floodplain surfaces. Drier communities (e.g. Ponderosa Pine) are found on higher terrace surfaces. Future sources of large wood material exist throughout the reach along the margins of the channel. However, larger key pieces for recruitment of other large wood and formation of log jams are currently uncommon in the channel. Some timber harvest and salvage logging has limited future sources of large wood available to the channel.

### 3.12.4 Human Alterations

Reach 11 has minimal modern human alterations within the channel or floodplain boundaries. A Forest Service maintenance road (river right) and Road NF 51 (river left) parallel the channel in this reach but at elevations and distances that do not impose additional constraints on geomorphic patterns and processes. Home sites with vegetation alterations and removal are present on higher terrace surfaces along river left at 32.05-32.22 and 32.87- 32.91 RM. A small (approximately five feet long, three feet tall) stacked rock wall is placed on top of the contemporary floodplain in front of one home site at 32.89 RM on river left. A fire-hose out-take pump is set up in front of the home sites but appears to only function periodically when homes are occupied. Historic logging and post-fire salvage logging have probably had substantial effects on wood loading in the reach, but are not currently activities pursued in the reach.

## 3.13 REACH 12

### 3.13.1 Reach Overview

Reach 12 is 0.29 miles long and extends from RM 32.9 to 33.19 (Figure 57). Bed morphology is pool-riffle, with the riffles more accurately classified as rapids. Substrate ranges from gravel to boulders, with cobbles the dominant substrate class (50%). The reach is confined by multiple abandoned terraces presumed to date into the late Pleistocene, as well as alluvial fan deposits and bedrock outcrops. Abandoned floodplain terraces indicate the channel has naturally incised, while contemporary incision rates are controlled by bedrock outcrops in the channel. Contemporary floodplain surfaces are limited to small bands of inset floodplain along the channel margins. Geomorphic complexity is provided by large wood sourced from riparian areas as the channel undercuts streambanks. Human alterations to the reach are limited to minor vegetation removal associated with cabin sites on river-left (RM 32.9-33.07).


***Figure 57. Reach 12 overview. Flow is from northwest to southeast.***

### 3.13.2 River Morphology & Geomorphic Processes

Reach 12 is a steep, single-thread channel extending from RM 32.9 to 33.19. Channel units are long rapids, with varying steepness (Figure 58). Steeper rapids occur at exposed bedrock outcrops, followed by deep plunge pools at the downstream end. Banks and bed substrate ranges from sand to bedrock, with large cobble the predominant substrate found throughout the reach (60%). Bedrock outcrops alternate along river-right and river-left, limiting both lateral migration and vertical incision throughout the reach.

***Figure 58. Representative channel morphology of Reach 12.***

The channel is confined within abandoned floodplain surfaces, as well as bedrock outcrops and hillslopes. An alluvial fan sourced from river-left appears to have pushed and/or dammed the channel along the hillslope on river-right. This confinement has created a narrow active channel with larger substrate (boulders and cobbles) embedded throughout the reach. Recurrent bedrock outcrops periodically border the left and right banks throughout the reach, naturally confining channel migration processes.

This reach is largely confined, with only periodic occurrences of contemporary floodplain formation. Field evidence and examination of the historical aerial photo record indicates recent Q100+ floods (1972 or 1945) may have widened the contemporary channel corridor. Inside of this incised, widened corridor, small floodplain pockets are forming at the channel's new elevation.

***Figure 59. Steeper rapid with bedrock outcrop along river-left at downstream end.***

Sediment sources for Reach 12 include adjacent hillslopes, an alluvial fan, and localized contributions from banks and the streambed. Hillslope deposits were prevalent between RMs 32.91 to 32.95 and RM 33.06 to 33.19. In these segments, colluvium deposits ranging from angular cobbles to large boulders (some up to seven feet in diameter) were present in the channel. Gravel accumulation occurs only in areas where large hydraulic roughness is present, primarily in the form of large wood accumulations or riparian vegetation. Reach 12 has an abundant supply of fine sediment including from tributaries (Pope Creek), hillslopes, and the scarps of abandoned alluvial terraces. Inset within these abandoned floodplain terraces, small (two to six feet wide) active floodplains are forming. Sand deposition and establishment of riparian vegetation are common features of these inset surfaces. One tributary (Pope Creek) is actively incising into the abandoned floodplain surfaces, offering surface water contributions and some minor sediment inputs where it enters at RM 33.95 on river-left.

Chronic contributions of large wood are prevalent throughout Reach 12. Contributions are primarily from the undercutting of channel banks, windfall, and single tree mortality. Multiple small jam complexes were observed (<8 pieces) that provide geomorphic complexity and associated habitat complexity (e.g., ‘pocket’ pools).

### 3.13.3 Riparian Condition

The channel banks and margins are buffered by dense, but narrow, dogwood and alder thickets. These corridors provide shade along channel margins, as well as significant hydraulic roughness. More xeric species line abandoned floodplain surfaces with overstories primarily composed of firs and pines. There is a dense understory of shrubs. Future sources of large woody material exist throughout the reach along the margins of the channel. However, larger key pieces for recruitment of other large wood and formation of log jams are currently uncommon in the channel.

### 3.13.4 Human Alterations

Reach 12 has minimal modern human features or actions occurring within the channel or floodplain boundaries. A Forest Service maintenance road (river-right) and Road NF 51 (river-left) parallel the channel in this reach but at elevations and distances that do not impose additional constraints on the geomorphology of the channel and its floodplain. Cabins with vegetation alterations (including removal) are present on river-left at RM 32.9-33.07, but are mainly located on an inactive alluvial fan surface.

## 3.14 REACH 13

### 3.14.1 Reach Overview

Reach 13 is 0.66 miles long and extends from RM 33.19 to 33.82 at a gradient of 2.6 % (Figure 60). Bed morphology is primarily rapids (88%), with some scour and plunge pools. Substrate is predominantly cobble (40%), followed by gravel (25%). The channel is confined by alluvial terraces through much of the reach, and isolated bedrock outcrops. Some lateral migration has re-worked terrace deposits and formed narrow inset floodplains. Geomorphic complexity is provided through wood accumulations along channel margins, pocket pools created by hydraulic scour at large boulders, and by deep pools near bedrock. Human alterations within the active channel and floodplain corridors are absent from the reach.


***Figure 60. Reach 13 overview.  Flow is from northwest to southeast.***

### 3.14.2 River Morphology and Geomorphic Processes

Reach 13 is a steep (2.6 % gradient), single-threaded channel with point and mid-channel bars active at regular high flow events (e.g. Q1 to Q3) (Figure 61). Channel units are primarily rapids with occasional pools. The pools throughout the reach are relatively deep (3 to 9 feet) and often channel-spanning. Scour pools are found along the channel margins where the toe of the bank has been undercut. Banks and the bed are composed of gravels, sands, and cobbles with cobbles (41-44%) and gravels (32-52%) dominating material composition. Bedrock was observed in two isolated locations at RM 35.9 and RM 37.0, and composes the end of the reach in Entiat Falls. The Reach has a sinuosity of 1.14.

***Figure 61. Representative channel morphology of Reach 13.***

The channel is confined within abandoned terrace surfaces, as well as a fan that extends from RM 33.22 to RM 33.45. These features combined with bedrock outcrops limit lateral migration and sinuosity. Floodplain inundation on these surfaces appears to be rare, with the exception of locations where large wood accumulations on the channel margins promote overland flow.

The channel has re-worked and scoured along the base of confining alluvial terraces recruiting sediment in the process, but also armoring terrace toes with large cobbles and boulders. These fine sediment sources are now only accessed by flows that overtop bank armor. Gravel deposition is present only in areas where large wood accumulations are located.

Examination of floodplain surfaces indicates that a contemporary floodplain has formed inset to alluvial terraces, with at least a narrow floodplain surface (Q100) in most areas of the reach. Regularly inundated (Q2) surfaces are limited and most often associated with large wood accumulations which altered bank and channel hydraulics. Abandoned terrace surfaces forming contemporary floodplain margins indicate a trend of natural incision, as the channel works down through fluvioglacial deposits.

Large wood accumulations are found along channel margins and in some places, span the channel. Margin wood is often rafted between standing riparian vegetation. These features increase the frequency of floodplain inundation. Scour around bedrock has created some deep pools, particularly below Entiat Falls.

### 3.14.3 Riparian Condition

The riparian canopy is dense, of mid-seral stage in most locations, and provides excellent canopy cover. Dense, narrow thickets of alder and cottonwood line the channel, and more meisic species inhabit low terraces, with drier communities found atop high terrace surfaces (e.g. Pondorosa Pine). Future sources of large wood material exist throughout the reach along the margins of the channel. However, larger key pieces for recruitment of other large wood are currently uncommon in the channel due to historical logging in the reach.

### 3.14.4 Human Alterations

Reach 13 has minimal modern human features or actions occurring within the channel or floodplain boundaries. Remnants of a decommissioned dirt road exist across the terrace on river-right at RM 33.46 – 33.68. Stumps and evidence of excavation indicate that timber extraction occurred along this terrace within the past 50 years. Road NF 51 parallels the channel in this reach but at an elevation and distance that does not impose additional constraints on the geomorphology of the channel and its floodplain.

# 4 Restoration Strategy

## 4.1 INTRODUCTION

Development of the restoration strategy was guided by the habitat objectives set forth in the Upper Columbia Recovery Plan (UCSRB 2007) and RTT Biological Strategy (RTT 2013) and by field and analytical work conducted as part of this Reach Assessment. Specifically, strategies were developed based on: 1) previous studies, 2) new analyses and field surveys conducted as part of this reach assessment, 3) a comparison of existing and target habitat conditions, and 4) current site conditions and human uses. The reach-scale strategies are presented in Section 4.4 and include narrative descriptions and strategy tables that outline the restoration strategy for each reach.

The restoration strategy includes 'action types' as well as specific potential project opportunities. Five general action types were developed for use in this assessment and are applied as appropriate to individual reaches. Action types are developed at a broader scale than projects, and may be achieved through the use of numerous project types. For example, the action type "off-channel habitat enhancement" might be achieved via numerous project types ranging from re-connecting habitat blocked by a levee to excavating new off-channels in the floodplain. The specific project opportunities, on the other hand, are more site specific and have unique characteristics depending on the particular habitat conditions, land uses, and geomorphic context of the site. Despite the additional specificity for projects, more analysis will still be necessary before projects are implemented; this may include topographic survey, hydraulic modeling, engineering analysis, and alternatives evaluation.

Specific potential project opportunities are linked to their respective action type(s) in the tables in Section 4.4 and are described in greater detail in Appendix D. The projects listed in Appendix D represent an initial step in identifying projects that fit the action types for each reach. Because of potential feasibility constraints (e.g. access or landowner cooperation), numerous potential projects have been identified, with the assumption that only a fraction of the potential opportunities will be taken to implementation.

## 4.2 EXISTING AND TARGET HABITAT CONDITIONS

One of the primary tools for identifying action types and projects is a comparison of existing and target habitat conditions. This highlights habitat deficiencies and helps to develop restoration strategies. For each reach, existing and target habitat conditions are presented for a suite of habitat and geomorphic categories (Section 4.4 tables). Existing conditions were developed based directly on analyses and surveys performed as part of this Reach Assessment. Existing conditions information draws heavily from the habitat survey data (Appendix A) and also from the hydraulics and geomorphology assessments (Sections 2.5.2 and 3).

Target conditions were developed using the REI targets as well as reference site conditions and inference from regional studies. See Section 2.5.6 and Appendix C for more information on the REI analysis. The REI analysis is based on previous REI analyses conducted as part of previous Reach Assessments conducted by the USBR and YN in other Upper Columbia tributaries. Modifications have been made to the LWM REI targets; these are discussed in the REI appendix (Appendix C).

## 4.3 RESTORATION ACTION TYPES

The Restoration Strategy includes five general action types. These are described in the sections below.

### 4.3.1 Protection

Protection projects involve preservation of existing habitat that may be at risk of degradation. Protection of other areas is generally not identified as a 'protect and maintain' action because it is considered inherent in all potential actions. Protection projects are identified in areas where existing or potential land ownership or land use suggests that further degradation could occur. Areas identified for protection may have existing high quality and functioning habitat or may contain impaired habitat in need of restoration. In many cases, adequate protection may already be in place through existing laws, policy, or management plans. The adequacy and enforcement of these regulations needs to be considered when planning for protection activities.

*Examples:*

- Direct purchase (fee acquisition) of an area at risk of further degradation through development
- Obtaining a conservation easement from a landowner in order to eliminate agricultural or residential development uses within a riparian buffer zone

### 4.3.2 Riparian restoration

Riparian restoration projects are located in areas where native riparian vegetation communities have been significantly impacted by anthropogenic activities such that riparian functions and connections with the stream are compromised. Restoration actions are focused on restoring native riparian vegetation communities in order to reestablish natural stream stability, stream shading, nutrient exchange, and large wood recruitment. Even though it is not always explicitly stated, riparian restoration is a recommended component of most restoration projects, particularly within the disturbance limits of the project.

*Examples:*

- Replanting a riparian buffer area with native forest vegetation
- Eliminating invasive plant species that are preventing the reestablishment of a native riparian forest community

### 4.3.3 Habitat reconnection via infrastructure modification

This strategy includes removal/modification of bank armoring, levees, roadways, bridges, or fill. Habitat reconnection projects are located in areas where floodplain and channel migration processes have been disconnected due to anthropogenic activities. These types of projects are frequently applied to address issues associated with floodplain connectivity (i.e., alterations to flood inundation rates or patterns), bank stability/channel migration, vertical channel stability, and off-channel habitat availability. These project types are applied to areas that have the potential for an increase in habitat quality and a reestablishment of dynamic processes through their reconnection. Restoration actions are focused on reclaiming a component of the system that has been lost, therefore regaining habitat and process that was previously a functional part of the river system.

Habitat reconnection projects may also include the reestablishment of fish passage where it has been blocked by human infrastructure or management. For the Upper Stillwaters, there are no passage barriers on the mainstem but there are off-channel habitats where fish access has been affected by fill and roadways.

*Examples:*

- Removal or selective breaching of a levee or road embankment to enhance floodplain connectivity
- Removal of rip-rap and replacement with LW in order to eliminate bank hardening and channelization that restricts channel migration, simplifies the channel, and compromises instream aquatic habitat quality and quantity

### 4.3.4 Placement of structural habitat elements

This strategy includes placement of habitat structures such as large wood, log jams, or boulders in order to achieve numerous habitat and geomorphic objectives. These types of projects can span a broad range of structure versus function-based approaches. For instance, a single log placement might be used in an existing pool to simply provide salmonid hiding cover, which would be chiefly a form-based approach. In contrast, a large constructed log jam might be used as a more function-based element that is intended to create split-flow conditions, create a bar/island complex, and to create and maintain scour pools. Structural elements are placed in areas where they would naturally accumulate and would be maintained by the existing stream hydrology and geomorphology.

*Examples:*

- Installation of a bar apex log jam to create and maintain a multi-thread channel system with mid-channel bars/islands and split-flow conditions, thus maximizing margin habitat and complexity
- Installation of a meander-bend log jam to maintain pool scour and to increase velocity refuge and cover for juvenile salmonids
- Installation of individual pieces of large wood in an existing off-channel area to increase hiding cover from aquatic, terrestrial, and avian predators

### 4.3.5 Off-channel habitat enhancement

Off-channel habitat enhancement projects are located in areas (e.g., floodplains) where there is the potential to increase the quantity and quality of off-channel habitat. Off-channel projects may include the activation of existing floodplain habitat areas that have been disconnected via channel incision or floodplain alterations. In other cases, off-channel areas can be created via excavation and construction of floodplain features such as backwaters, groundwater-fed channels, and flow-through side channels.

*Examples:*

- Construction of off-channel features such as alcoves, backwaters, or flow-through side channels that are connected to the main channel
- Construction of a groundwater-fed channel to provide cool summer and warm winter temperatures for rearing salmonids

## 4.4 REACH-SCALE STRATEGIES

### 4.4.1 Reach 0

The restoration strategy for Reach 0 includes a combination of actions ranging from infrastructure modification to using log jams to increase lateral channel dynamics to riparian restoration and protection. The downstream end of the reach is primarily privately owned and there are impacts associated with roadways and residential development. Actions in this area include addressing floodplain disconnection and bank armoring associated with the bridge and the riprap bank. In the middle portion of the reach, residential development has impaired riparian conditions, particularly along the river-left bank. Riparian planting and using wood placements to increase channel complexity are the primary actions identified here. The upstream portion of the reach is within US Forest Service property and human influence has less of an impact. Placing log jams to increase lateral channel dynamics (and wood recruitment) would help to achieve the wood loading, jam, and pool quantity targets in the reach.

**Reach 0 Restoration Strategy**

| Reach 0 Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Riparian condition | <50% species composition, seral stage, and structural complexity are consistent with potential native community.<br><br>Dominated by small trees (<21 inches dbh)<br><br>50-80% canopy cover<br><br>Human disturbance is located within much of the riparian zone, mostly along the left bank. Disturbance includes the roadway and associated riprap, lawns, and houses. | At least a 100 ft riparian buffer with:<br>> 80% mature trees, or consistent with potential native community<br>< 20% riparian disturbance (human)<br>>80% canopy closure in the riparian zone.<br>[REI] | **Riparian Restoration**<br>Work with landowners to plant cleared riparian and floodplain areas.<br><br>Look for opportunities to set back roadways and other human infrastructure out of riparian areas. | Project RM 23.65L: Reach 0 LB Riparian Restoration and Protection<br>Project RM 23.6R: Reach 0 RB Riparian and Floodplain Protection<br>Project RM 23.4: Downstream of Bridge Riprap Enhancement |
| Floodplain Connectivity | 13% of the mapped floodplain has been disconnected (see Appendix B).<br><br>5.6 mi/mi$^2$ of road in the floodplain | Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain<br>[adapted from REI]<br><br><2mi/mi$^2$ road density in the floodplain | **Habitat reconnection via infrastructure modification**<br>Where possible, address floodplain impairments associated with the bridge, roadway, and residential development along river-left. | Project RM 23.4: Downstream of Bridge Riprap Enhancement |

| Reach 0 Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Bank condition / Channel migration | 14% of the streambanks in the reach are affected by bank armoring.<br><br>Bridge near downstream end constrains channel migration | Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion.<br><br>[adapted from REI] | **Habitat reconnection via infrastructure modification**<br><br>Where possible, set back roadways, remove bank armoring, remove fill, and remove/modify other human infrastructure affecting floodplain processes. | Project RM 23.45: Upstream of Bridge Barb Enhancement<br><br>Project RM 23.4: Downstream of Bridge Riprap Enhancement |
| Vertical channel stability | Based on hydraulic analysis, the bridge confines flood flows within the channel, increasing energy within the channel therefore increasing risk of scour at the crossing and aggradation upstream of the crossing. There is existing bedload deposition upstream of the bridge indicating a backwater effect associated with the bridge. | No measurable trend of human-induced aggradation or incision<br><br>[adapted from REI] | **Habitat reconnection via infrastructure modification**<br><br>Remove or modify bridge crossing to reduce hydraulic effects on channel. | Project RM 23.4: Downstream of Bridge Riprap Enhancement |
| Pools | Pools per mile = 6.7<br><br>21% pool habitat<br><br>60% of pools are <1 m deep | ~4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Many large pools >1 m deep with good fish cover.<br><br>[REI] | **Placement of structural habitat elements**<br><br>Placement of structure to form pools.<br><br>**Habitat reconnection via infrastructure modification**<br><br>Removing or modify bank armoring to enhance pool quality. | Project RM 23.9: Upper Jenne LW Enhancement<br><br>Project RM 23.7: Jenne Straights Enhancement<br><br>Project RM 23.5: Lower Jenne LW Enhancement<br><br>Project RM 23.45: Upstream of Bridge Barb Enhancement<br><br>Project RM 23.4: Downstream of Bridge Riprap Enhancement<br><br>Project RM 23.3: Zerrener LW Enhancement |

| Reach 0 Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Large wood and log jams | 30 pieces / mi<br><br>1.3 jams /mi | > 42.5 pieces/mi (>12 diam; > 35 ft long)<br>[from Fox 2001]<br><br>≥ 5 log jams/mi<br>[based on conditions in Reach 9] | **Riparian restoration**<br>Riparian projects to improve long-term LW recruitment.<br><br>**Placement of structural habitat elements**<br>Placement of large wood and log jams where large wood would naturally accumulate and would provide the greatest habitat benefit. | Project RM 23.9: Upper Jenne LW Enhancement<br>Project RM 23.7: Jenne Straights Enhancement<br>Project RM 23.5: Lower Jenne LW Enhancement<br>Project RM 23.45: Upstream of Bridge Barb Enhancement<br>Project RM 23.4: Downstream of Bridge Riprap Enhancement<br>Project RM 23.3: Zerrener LW Enhancement |

| Reach 0 Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Off-Channel Habitat | 14% side channel habitat.<br><br>There is a beaver pond off-channel complex upstream of the bridge and a small right-bank side channel at the upstream end of the reach.<br><br>The natural extent of potential off-channel habitat is constrained by the effects of the bridge, roadway, and residential development on lateral channel migration and floodplain connectivity, which are necessary for long-term creation and maintenance of adequate off-channel habitat. Lack of log jams also limits off-channel development. | Reach has ponds, oxbows, backwaters, side channels, and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas.<br><br>[adapted from REI] | **Off-channel habitat enhancement**<br>Excavation to increase off-channel habitat area.<br><br>**Habitat reconnection via infrastructure modification**<br>Removal or modification of bridge that limits side channel function or connectivity.<br><br>**Placement of structural habitat elements**<br>Placement of wood to increase lateral channel dynamics. | Project RM 23.9: Upper Jenne LW Enhancement<br><br>Project RM 23.5: Lower Jenne LW Enhancement<br><br>Project RM 23.3: Zerrener LW Enhancement |

### 4.4.2 Reach 1

The restoration strategy for Reach 1 is primarily focused on adding complexity through large wood enhancements. The river-left bank throughout the reach is privately owned, and there are impacts associated with roadways and residential development. Potential actions in this area include addressing bank armoring associated with Entiat River Road, riparian planting in cleared residential areas, and large wood placements. Wood placements could help move the channel away from the riprap, promote lateral channel migration, and allow for the reestablishment of the riparian corridor. The right bank throughout the reach is owned by the Chelan Douglas Land Trust and has no impairments associated with infrastructure. Large wood placements along either bank would address reach target wood loading goals, promote lateral channel dynamics, and provide cover and complexity to pools.

**Reach 1 Restoration Strategy**

| Reach 1 Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Riparian condition | 50-80% species composition, seral stage, and structural complexity are consistent with potential native community.<br><br>Dominated by small trees (<21 inches dbh)<br><br>50-80% canopy cover<br><br>Human disturbance is located within much of the riparian zone along the left bank, which is composed of residential homes and cabins. Clearing of the riparian overstory is minimal but there is localized clearing of the understory associated with individual homesites. There is riprap and the Entiat River Road within the riparian area along approximately 400 feet of the river-left bank. | At least a 100 ft riparian buffer with:<br><br>> 80% mature trees, or consistent with potential native community<br><br>< 20% riparian disturbance (human)<br><br>>80% canopy closure in the riparian zone.<br><br>[REI] | **Riparian Restoration**<br><br>Work with landowners to plant cleared riparian and floodplain areas.<br><br>Look for opportunities to set back roadways and other human infrastructure out of riparian areas. | Project RM 25.3L: Grandma Fan Margin Complexity |

| Reach 1 Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Floodplain Connectivity | 8% of the mapped floodplain has been disconnected (see Appendix B).<br><br>11.1 mi/mi² of road in the floodplain | Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain<br>[adapted from REI]<br><br><2mi/mi² road density in the floodplain | **Habitat reconnection via infrastructure modification**<br>Where possible, set back roadways, remove bank armoring, remove fill, and remove/modify other human infrastructure affecting floodplain processes. | Project RM 25.3L: Grandma Fan Margin Complexity |
| Bank condition / Channel migration | 5% of the streambanks in the reach are affected by bank armoring. | Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion.<br>[adapted from REI] | **Habitat reconnection via infrastructure modification**<br>Where possible, set back roadways, remove bank armoring, remove fill, and remove/modify other human infrastructure affecting channel migration processes. | Project RM 25.3L: Grandma Fan Margin Complexity |
| Vertical channel stability | No measurable trend of aggradation or incision associated with human actions. | No measurable trend of human-induced aggradation or incision<br>[adapted from REI] | **No actions identified** | No projects identified |

| Reach 1 Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Pools | Pools per mile = 5.8<br><br>17% pool habitat<br><br>60% of pools are <1 m deep | ~4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Many large pools >1 m deep with good fish cover.<br>[REI] | **Placement of structural habitat elements**<br>Placement of structure to form pools.<br><br>**Habitat reconnection via infrastructure modification**<br>Removing or modify bank armoring to enhance pool quality. | Project RM 25.53L: Burns Fan Pool Jams<br>Project RM 25.4: Lower Burns LW Enhancement<br>Project RM 25.3L: Grandma Fan Margin Complexity<br>Project RM 25.2: McCrea LW and Side Channel Enhancement |
| Large wood and log jams | 20 pieces / mi<br><br>0 jams /mi | > 42.5 pieces/mi (>12 diam; > 35 ft long)<br>[from Fox 2001]<br><br>≥ 5 log jams/mi<br>[based on conditions in Reach 9] | **Riparian restoration**<br>Riparian projects to improve long-term LW recruitment.<br><br>**Placement of structural habitat elements**<br>Placement of large wood and log jams where large wood would naturally accumulate and would provide the greatest habitat benefit. | Project RM 25.53L: Burns Fan Pool Jams<br>Project RM 25.4: Lower Burns LW Enhancement<br>Project RM 25.3L: Grandma Fan Margin Complexity<br>Project RM 25.2: McCrea LW and Side Channel Enhancement |

| Reach 1 Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Off-Channel Habitat | 0% side channel habitat.<br><br>The amount of available off-channel habitat is affected by the roadway and residential development within the floodplain, which limits long-term lateral channel migration processes necessary to create off-channel habitat. Lack of log jams also limits off-channel development. | Reach has ponds, oxbows, backwaters, side channels, and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas.<br><br>[adapted from REI] | **Habitat reconnection via infrastructure modification**<br><br>Removal or modification of roadway and human development that limits side channel function or connectivity.<br><br>**Placement of structural habitat elements**<br><br>Placement of wood to increase lateral channel dynamics. | Project RM 25.4: Lower Burns LW Enhancement<br><br>Project RM 25.2: McCrea LW and Side Channel Enhancement |

### 4.4.3 Reach 2

The primary deficiencies targeted for restoration in Reach 2 are alterations to the riparian corridor, a lack of large wood, and limited off-channel habitat. With the exception of privately-owned riverfront parcels along the river-left (RM 25.6 to RM 25.7), the reach is all bordered by USFS and Chelan Douglas Land Trust property. Actions in the lower part of the reach are focused on placement of large wood to enhance pool scour, cover, and complexity in the mainstem and existing side channels. In the upper portion of the reach, riprap associated with Entiat River Road has limited natural migration processes and channel complexity. Here, potential actions include addressing bank armoring through partial removal and/or large wood enhancement. Riparian restoration will help achieve species composition and structural complexity goals within the reach. Large wood placements throughout the reach would help to address existing wood loading and pool quantity deficiencies within the reach.

**Reach 2 Restoration Strategy**

| Reach 2 Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Riparian condition | 50-80% species composition, seral stage, and structural complexity are consistent with potential native community.<br><br>Dominated by shrub/seedling (<5 inches dbh)<br><br>50-80% canopy cover<br><br>The greatest riparian disturbance is the roadway and associated bank armoring along the river-left bank. There are a few homesites along the river-left bank at the downstream end of the reach that have clearing of the riparian understory, but the overstory remains intact. | At least a 100 ft riparian buffer with:<br><br>> 80% mature trees, or consistent with potential native community<br><br>< 20% riparian disturbance (human)<br><br>>80% canopy closure in the riparian zone.<br><br>[REI] | **Riparian Restoration**<br><br>Work with landowners to plant cleared riparian and floodplain areas.<br><br>Look for opportunities to set back roadways and other human infrastructure out of riparian areas. | Project RM 25.8: Upper Burns riprap enhancement |
| Floodplain Connectivity | 0% of the mapped floodplain has been disconnected (see Appendix B)<br><br>0 mi/mi² of road in the floodplain | Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain<br><br>[adapted from REI]<br><br><2mi/mi² road density in the floodplain | **No actions identified** | No projects identified |

| Reach 2 Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Bank condition / Channel migration | 3% of the streambanks in the reach are affected by bank armoring. | Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion.<br>[adapted from REI] | **Habitat reconnection via infrastructure modification**<br>Where possible, set back roadways, remove bank armoring, remove fill, and remove/modify other human infrastructure affecting floodplain processes. | Project RM 25.8: Upper Burns riprap enhancement |
| Vertical channel stability | No measurable trend of aggradation or incision associated with human actions. | No measurable trend of human-induced aggradation or incision<br>[adapted from REI] | **No actions identified** | No projects identified |
| Pools | Pools per mile = 3.9<br>24% pool habitat<br>50% of pools are <1 m deep | ~4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Many large pools >1 m deep with good fish cover.<br>[REI] | **Placement of structural habitat elements**<br>Placement of structure to form pools.<br>**Habitat reconnection via infrastructure modification**<br>Removing or modify bank armoring to enhance pool quality. | Project RM 25.8: Upper Burns riprap enhancement<br>Project RM 25.7: Upper Burns LW and Side Channel Enhancement |

| Reach 2 Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Large wood and log jams | 29 pieces / mi<br><br>0 jams /mi | > 42.5 pieces/mi (>12 diam; > 35 ft long)<br>[from Fox 2001]<br><br>≥ 5 log jams/mi<br>[based on conditions in Reach 9] | **Riparian restoration**<br>Riparian projects to improve long-term LW recruitment.<br><br>**Placement of structural habitat elements**<br>Placement of large wood and log jams where large wood would naturally accumulate and would provide the greatest habitat benefit. | Project RM 25.8: Upper Burns riprap enhancement<br>Project RM 25.7: Upper Burns LW and Side Channel Enhancement |
| Off-Channel Habitat | 1% side channel habitat.<br><br>There is some existing side channel habitat at low flows but it lacks complex cover. Lack of log jams limits off-channel development. | Reach has ponds, oxbows, backwaters, side channels, and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas.<br>[adapted from REI] | **Placement of structural habitat elements**<br>Placement of wood to increase lateral channel dynamics. | Project RM 25.7: Upper Burns LW and Side Channel Enhancement |

### 4.4.4 Reach 3

The restoration strategy for Reach 3 includes riparian restoration, infrastructure (riprap) modification, and using log jams to provide complexity and increase lateral channel dynamics. Potential projects include modifying riprap associated with Entiat River Road near RM 26.5 and RM 26.7. Here, riparian restoration could be paired with the placement of large jams along the road corridor to shift the channel away from the roadway. This would allow for establishment of riparian vegetation and the potential for long-term large wood recruitment within the channel. Other projects include the placement of meander bend and apex jams to achieve wood loading, jam quantity, and pool complexity targets throughout the reach.

**Reach 3 Restoration Strategy**

| Reach 3 Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Riparian condition | 50-80% species composition, seral stage, and structural complexity are consistent with potential native community.<br><br>Dominated by shrub/seedling, sapling/pole, and small trees (<21 inches dbh)<br><br>>80% canopy cover<br><br>The riparian area is mostly intact except for a few segments along the river-left bank where the roadway is within the riparian area and where bank armoring affects riparian vegetation development. | At least a 100 ft riparian buffer with:<br>> 80% mature trees, or consistent with potential native community<br>< 20% riparian disturbance (human)<br>>80% canopy closure in the riparian zone.<br>[REI] | **Riparian Restoration**<br>Look for opportunities to set back roadways and other human infrastructure out of riparian areas. | Project RM 27L: Lower Signal Road Jams<br>Project RM 26.6: Upper Angle Point Log jams |
| Floodplain Connectivity | 0% of the mapped floodplain has been disconnected (see Appendix B).<br><br>0 mi/mi² of road in the floodplain | Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain<br>[adapted from REI]<br><br><2mi/mi² road density in the floodplain | **No actions identified** | No actions identified |

| Reach 3 Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Bank condition / Channel migration | 5% of the streambanks in the reach are affected by bank armoring. | Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion.<br>[adapted from REI] | **Habitat reconnection via infrastructure modification**<br>Where possible, set back roadways, remove bank armoring, remove fill, and remove/modify other human infrastructure affecting floodplain processes. | Project RM 27L: Lower Signal Road Jams |
| Vertical channel stability | No measurable trend of aggradation or incision associated with human actions. | No measurable trend of human-induced aggradation or incision<br>[adapted from REI] | **No actions identified** | No actions identified |
| Pools | Pools per mile = 7.1<br>12% pool habitat<br>25% of pools are <1 m deep | ~4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Many large pools >1 m deep with good fish cover.<br>[REI] | **Placement of structural habitat elements**<br>Placement of structure to form pools.<br>**Habitat reconnection via infrastructure modification**<br>Removing or modify bank armoring to enhance pool quality. | Project RM 27.1L: Lower Signal Apex Jams<br>Project RM 27L: Lower Signal Road Jams<br>Project RM 26.6: Upper Angle Point Log jams<br>Project RM 26.1: Lower Angle Point Log jams |

| Reach 3 Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Large wood and log jams | 24 pieces / mi<br><br>0.9 jams /mi | > 42.5 pieces/mi (>12 diam; > 35 ft long)<br>[from Fox 2001]<br><br>≥ 5 log jams/mi<br>[based on conditions in Reach 9] | **Riparian restoration**<br>Riparian projects to improve long-term LW recruitment.<br><br>**Placement of structural habitat elements**<br>Placement of large wood and log jams where large wood would naturally accumulate and would provide the greatest habitat benefit. | Project RM 27.1L: Lower Signal Apex Jams<br>Project RM 27L: Lower Signal Road Jams<br>Project RM 26.6: Upper Angle Point Log jams<br>Project RM 26.1: Lower Angle Point Log jams |
| Off-Channel Habitat | 7% side channel habitat.<br><br>There is some existing side channel habitat at low flows but it lacks complex cover. Lack of log jams limits off-channel development. | Reach has ponds, oxbows, backwaters, side channels, and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas.<br>[adapted from REI] | **Placement of structural habitat elements**<br>Placement of wood to increase lateral channel dynamics. | Project RM 27.1L: Lower Signal Apex Jams |

### 4.4.5 Reach 4

The restoration strategy for Reach 4 is focused on placement of large wood throughout the mainstem and existing side channels to promote lateral channel dynamics. The main restoration opportunity area is a 0.4-mile section where large wood complexes would have historically accumulated. Log jams could be placed along the channel margins, on the outside of meander bends, and at the apex of bars. Placing log jams would enhance lateral migration processes in the reach and would help to achieve the wood loading, jam quantity, and off-channel complexity targets in the reach.

### Reach 4 Restoration Strategy

| Reach 4 Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Riparian condition | >80% species composition, seral stage, and structural complexity are consistent with potential native community.<br><br>Dominated by sapling/pole and small trees (<21 inches dbh)<br><br>50-80% canopy cover<br><br>Riparian areas are mostly intact except for at the upstream and downstream ends on the river-left bank where the roadway lies adjacent to the channel. There are high and steep naturally eroding banks in a few locations, which limit riparian forest development. | At least a 100 ft riparian buffer with:<br>> 80% mature trees, or consistent with potential native community<br>< 20% riparian disturbance (human)<br>>80% canopy closure in the riparian zone.<br>[REI] | **Riparian Restoration**<br>Look for opportunities to set back roadways and other human infrastructure out of riparian areas. | No actions identified |
| Floodplain Connectivity | 0% of the mapped floodplain has been disconnected (see Appendix B).<br><br>0 mi/mi$^2$ of road in the floodplain | Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain<br>[adapted from REI]<br><br><2mi/mi$^2$ road density in the floodplain | **No actions identified** | No actions identified |

| Reach 4 Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Bank condition / Channel migration | 0% of the streambanks in the reach are affected by bank armoring. | Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion.<br>[adapted from REI] | **No actions identified** | No actions identified |
| Vertical channel stability | No measurable trend of aggradation or incision associated with human actions. | No measurable trend of human-induced aggradation or incision<br>[adapted from REI] | **No actions identified** | No actions identified |
| Pools | Pools per mile = 5.0<br>7% pool habitat<br>33% of pools are <1 m deep | ~4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Many large pools >1 m deep with good fish cover.<br>[REI] | **Placement of structural habitat elements**<br>Placement of structure to form pools. | Project RM 27.4: Signal Peak Side Channel and LW Enhancement |
| Large wood and log jams | 30 pieces / mi<br>3.4 jams /mi | > 42.5 pieces/mi (>12 diam; > 35 ft long)<br>[from Fox 2001]<br>≥ 5 log jams/mi<br>[based on conditions in Reach 9] | **Riparian restoration**<br>Riparian projects to improve long-term LW recruitment.<br>**Placement of structural habitat elements**<br>Placement of large wood and log jams where large wood would naturally accumulate and would provide the greatest habitat benefit. | Project RM 27.4: Signal Peak Side Channel and LW Enhancement |

| Reach 4 Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Off-Channel Habitat | 22% side channel habitat.<br><br>There is existing side channel habitat at low flows but it lacks abundant complex cover. Lack of log jams limits off-channel development. | Reach has ponds, oxbows, backwaters, side channels, and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas.<br><br>[adapted from REI] | **Off-channel habitat enhancement**<br>Excavation to increase off-channel habitat area.<br><br>**Placement of structural habitat elements**<br>Placement of wood to increase lateral channel dynamics. | Project RM 27.4: Signal Peak Side Channel and LW Enhancement |

### 4.4.6 Reach 5

Lack of large wood and the disconnection of floodplain and off-channel habitat are the primary deficiencies targeted for restoration in Reach 5. Infrastructure associated with Fox Creek Campground impairs floodplain and side channel connectivity. Removal or alteration of bank armoring and culvert replacement could restore connectivity to 50% of the reach's available floodplain and reconnect over 600 feet of side channel at low flow. Downstream of Fox Creek Campground, large wood enhancements could be used to restore channel migration processes and channel complexity. These actions could help achieve off-channel habitat, large wood, and log jam targets within the reach.

**Reach 5 Restoration Strategy**

| **Reach 5 Attribute** | **Existing Condition (from assessment)** | **Target Condition [source]** | **Action Type** | **Potential Projects** |
|---|---|---|---|---|
| Riparian condition | 50-80% species composition, seral stage, and structural complexity are consistent with potential native community.<br><br>Dominated by small trees (<21 inches dbh)<br><br>>80% canopy cover<br><br>Riparian areas along the river-left bank are impacted by the roadway in the middle and downstream portion of the reach. The Fox Creek Campground impacts riparian vegetation (primarily associated with clearing of the understory) along the left bank at the upstream end of the reach. | At least a 100 ft riparian buffer with:<br><br>> 80% mature trees, or consistent with potential native community<br><br>< 20% riparian disturbance (human)<br><br>>80% canopy closure in the riparian zone.<br><br>[REI] | **Riparian Restoration**<br><br>Look for opportunities to set back roadways and other human infrastructure out of riparian areas. | Project RM 28.2L: Fox Creek Campground Side Channel Enhancement |
| Floodplain Connectivity | 50% of the mapped floodplain has been disconnected, primarily due to Fox Creek Campground (see Appendix B).<br><br>15 $mi/mi^2$ of road in the floodplain | Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain<br><br>[adapted from REI]<br><br><2 $mi/mi^2$ road density in the floodplain | **Habitat reconnection via infrastructure modification**<br><br>Where possible, set back roadways, remove bank armoring, remove fill, and remove/modify other human infrastructure affecting floodplain processes. | Project RM 28.2L: Fox Creek Campground Side Channel Enhancement |

| Reach 5 Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Bank condition / Channel migration | 15% of the streambanks in the reach are affected by bank armoring.<br><br>Fox Creek Campground limits the potential for channel migration into the left-bank floodplain in this area. | Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion.<br><br>[adapted from REI] | **Habitat reconnection via infrastructure modification**<br><br>Where possible, set back roadways, remove bank armoring, remove fill, and remove/modify other human infrastructure affecting channel migration processes. | No projects identified |
| Vertical channel stability | Floodplain disconnection at the Fox Creek Campground along river-left poses risk to vertical channel stability by focusing flows within the channel. | No measurable trend of human-induced aggradation or incision<br><br>[adapted from REI] | **Habitat reconnection via infrastructure modification**<br><br>Where possible, set back roadways, remove bank armoring, remove fill, and remove/modify other human infrastructure affecting floodplain processes. | No projects identified |
| Pools | Pools per mile = 5.2<br><br>7% pool habitat<br><br>33% of pools are <1 m deep | ~4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Many large pools >1 m deep with good fish cover.<br><br>[REI] | **Placement of structural habitat elements**<br><br>Placement of structure to form pools. | Project RM 28.2L: Fox Creek Campground Side Channel Enhancement<br><br>Project RM 27.95R: Upper Fox Apex Jam<br><br>Project RM 27.8L: Fox Creek Meander Bend Jam |

| Reach 5 Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Large wood and log jams | 36 pieces / mi<br><br>1.7 jams /mi | > 42.5 pieces/mi (>12 diam; > 35 ft long)<br>[from Fox 2001]<br><br>≥ 5 log jams/mi<br>[based on conditions in Reach 9] | **Riparian restoration**<br>Riparian projects to improve long-term LW recruitment.<br><br>**Placement of structural habitat elements**<br>Placement of large wood and log jams where large wood would naturally accumulate and would provide the greatest habitat benefit. | Project RM 28.2L: Fox Creek Campground Side Channel Enhancement<br>Project RM 27.95R: Upper Fox Apex Jam<br>Project RM 27.8L: Fox Creek Meander Bend Jam |
| Off-Channel Habitat | 1% side channel habitat.<br><br>The Fox Creek Campground impairs connectivity to a potentially accessible side channel. Lack of log jams further limits off-channel development. | Reach has ponds, oxbows, backwaters, side channels, and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas.<br>[adapted from REI] | **Habitat reconnection via infrastructure modification**<br>Removal or modification of campground infrastructure that limits side channel connectivity.<br><br>**Placement of structural habitat elements**<br>Placement of wood to increase lateral channel dynamics. | Project RM 28.2L: Fox Creek Campground Side Channel Enhancement<br>Project RM 27.95R: Upper Fox Apex Jam |

### 4.4.7 Reach 6

Reach 6 (Box Canon) has high natural confinement with steep step-pools and rapids throughout, which has prevented direct human alterations to habitat and reduces the need for restoration. Consequently, no restoration actions were identified for Reach 6. For these reasons, and due to the lack of detailed habitat survey data, a restoration strategy table was not developed for this reach.

### 4.4.8 Reach 7

Reach 7 is naturally confined by mass-wasting deposits, alluvial fans, and abandoned alluvial terraces. This confinement naturally limits lateral migration, and combined with relatively steep gradient (1.8%), limits the need and opportunity for restoration actions throughout the reach. Access would also be very challenging for implementing restoration measures. No restoration actions were identified within the reach.

**Reach 7 Restoration Strategy**

| Reach 7 Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Riparian condition | >80% species composition, seral stage, and structural complexity are consistent with potential native community.<br><br>>80% canopy cover<br><br>The riparian area in Reach 7 is intact. The reach is isolated from the roadway and there is no on-going human disturbance to the riparian zone. | At least a 100 ft riparian buffer with:<br>> 80% mature trees, or consistent with potential native community<br>< 20% riparian disturbance (human)<br>>80% canopy closure in the riparian zone.<br>[REI] | **No actions identified** | No projects identified |
| Floodplain Connectivity | 0% of the mapped floodplain has been disconnected (see Appendix B).<br><br>0 mi/mi$^2$ of road in the floodplain | Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain<br>[adapted from REI]<br><br><2mi/mi$^2$ road density in the floodplain | **No actions identified** | No projects identified |
| Bank condition / Channel migration | 0% of the streambanks in the reach are affected by bank armoring. | Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion.<br>[adapted from REI] | **No actions identified** | No projects identified |

| **Reach 7 Attribute** | **Existing Condition (from assessment)** | **Target Condition [source]** | **Action Type** | **Potential Projects** |
|---|---|---|---|---|
| Vertical channel stability | No measurable trend of aggradation or incision associated with human actions. | No measurable trend of human-induced aggradation or incision<br>[adapted from REI] | **No actions identified** | No projects identified |
| Pools | Pools per mile = 1.9<br>6% pool habitat<br>0% of pools are <1 m deep | ~4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Many large pools >1 m deep with good fish cover.<br>[REI] | **Placement of structural habitat elements**<br>Placement of structure to form pools. | No projects identified |
| Large wood and log jams | 19 pieces / mi<br>1.9 jams /mi | > 42.5 pieces/mi (>12 diam; > 35 ft long)<br>[from Fox 2001]<br>≥ 5 log jams/mi<br>[based on conditions in Reach 9] | **Placement of structural habitat elements**<br>Placement of large wood and log jams where large wood would naturally accumulate and would provide the greatest habitat benefit. | No projects identified |
| Off-Channel Habitat | 0% side channel habitat.<br>Natural confinement limits significant development of off-channel habitat. Lack of log jams further limits off-channel development. | Reach has ponds, oxbows, backwaters, side channels, and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas.<br>[adapted from REI] | **Placement of structural habitat elements**<br>Placement of wood to increase lateral channel dynamics. | No projects identified |

### 4.4.9 Reach 8

Similar to Reaches 6 and 7, Reach 8 is steep and naturally confined. Here, bedrock outcrops confine the channel at various locations on both river-left and river-right. This natural confinement has limited human alteration to the channel as well as the opportunities for restoration. No restoration actions were identified for Reach 8. For these reasons, and due to the lack of detailed habitat survey data, a restoration strategy table was not developed for this reach.

### 4.4.10 Reach 9

The restoration strategy for Reach 9 is focused on enhancing existing complex habitat through large wood and side channel enhancements. Reach 9 is the most laterally active reach upstream of Box Canyon (Reach 6). This lateral migration, and the reach's depositional nature, translate to geomorphic complexity in the form of bars (point and transverse), high and low flow side channels, islands, and abandoned floodplain scars. These geomorphic features create complex habitat elements that could be easily enhanced to create abundant high quality habitat within the reach. Although Reach 9 already meets most of the restoration targets, the depositional nature of this reach suggests that historically, abundant log jams would have formed and contributed to multi-thread channel form, pool formation, and instream complexity. Restoration strategies within Reach 9 are centered on enhancing existing habitat through the placement of large wood complexes in the mainstem and existing side channels.

**Reach 9 Restoration Strategy**

| Reach 9 Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Riparian condition | >80% species composition, seral stage, and structural complexity are consistent with potential native community.<br><br>Dominated by large and small trees (<32 inches dbh)<br><br>>80% canopy cover<br><br>The riparian area in Reach 9 is intact. The reach is isolated from the roadway and there is no on-going human disturbance to the riparian zone. | At least a 100 ft riparian buffer with:<br><br>> 80% mature trees, or consistent with potential native community<br><br>< 20% riparian disturbance (human)<br><br>>80% canopy closure in the riparian zone.<br><br>[REI] | **No actions identified** | No projects identified |
| Floodplain Connectivity | 0% of the mapped floodplain has been disconnected (see Appendix B).<br><br>3 $mi/mi^2$ of road in the floodplain | Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain<br><br>[adapted from REI]<br><br><2 $mi/mi^2$ road density in the floodplain | **No actions identified** | No projects identified |

| Reach 9 Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Bank condition / Channel migration | 0% of the streambanks in the reach are affected by bank armoring. | Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion.<br>[adapted from REI] | **No actions identified** | No projects identified |
| Vertical channel stability | No measurable trend of aggradation or incision associated with human actions. | No measurable trend of human-induced aggradation or incision<br>[adapted from REI] | **No actions identified** | No projects identified |
| Pools | Pools per mile = 5.7<br>13% pool habitat<br>57% of pools are <1 m deep | ~4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Many large pools >1 m deep with good fish cover.<br>[REI] | **Placement of structural habitat elements**<br>Placement of structure to form pools. | Project RM 31.25R: Silver Falls Side Channel Enhancement 2<br>Project RM 31.0R: Silver Falls Side Channel Enhancement 4<br>Project RM 30.7L: Lower Silver Falls Margin Jams 1<br>Project RM 30.5L: Lower Silver Falls Margin Jams 2 |
| Large wood and log jams | 92 pieces / mi<br>4.9 jams /mi | > 42.5 pieces/mi (>12 diam; > 35 ft long)<br>[from Fox 2001]<br>≥ 5 log jams/mi<br>[based on conditions in Reach 9] | ***Placement of structural habitat elements**<br>Placement of large wood and log jams where large wood would naturally accumulate and would provide the greatest habitat benefit. | Project RM 31.25R: Silver Falls Side Channel Enhancement 2<br>Project RM 31.0R: Silver Falls Side Channel Enhancement 4<br>Project RM 30.7L: Lower Silver Falls Margin Jams 1<br>Project RM 30.5L: Lower Silver Falls Margin Jams 2 |

| **Reach 9 Attribute** | **Existing Condition (from assessment)** | **Target Condition [source]** | **Action Type** | **Potential Projects** |
|---|---|---|---|---|
| Off-Channel Habitat | 10% side channel habitat.<br><br>There is existing side channel habitat at low flows but it lacks abundant complex cover. Lack of log jams limits off-channel development. | Reach has ponds, oxbows, backwaters, side channels, and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas.<br><br>[adapted from REI] | **Off-channel habitat enhancement**<br><br>Excavation to increase off-channel habitat area.<br><br>**Placement of structural habitat elements**<br><br>Placement of wood to increase lateral channel dynamics. | Project RM 31.4R: Silver Falls Side Channel Enhancement 1<br><br>Project RM 31.25R: Silver Falls Side Channel Enhancement 2<br><br>Project RM 31.15R: Silver Falls Side Channel Enhancement 3<br><br>Project RM 31.0R: Silver Falls Side Channel Enhancement 4 |

** Although reach meets wood piece number and jam criteria, this is a depositional reach where abundant log jams would be expected to form and contribute to complex multi-thread channel planform, pool formation, and complexity. For these reasons, log jam placements that increase lateral channel dynamics are included as an action in this reach.*

### 4.4.11 Reach 10

Natural confinement limits the need and opportunities for restoration within Reach 10, with potential actions confined to targeted large wood placements. Reach 10 is essentially one long fast water complex that alternates between steeper gradient rapids and moderate gradient riffles. Channel gradient and natural partial confinement limit lateral migration and floodplain formation processes. Geomorphic complexity within the reach is primarily provided by hillslope-sourced boulders that provide localized scour and holding and resting areas for salmonids. Confinement limits the need and opportunity for restoration within the reach. Potential restoration opportunities are focused on the downstream end of the reach along river-left. Here, large wood jams could be placed to achieve target large wood numbers and quantity of jams. These placements would promote local pool scour and increase habitat cover and complexity.

**Reach 10 Restoration Strategy**

| Reach 10 Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Riparian condition | 50-80% species composition, seral stage, and structural complexity are consistent with potential native community.<br><br>Dominated by small trees (<21 inches dbh)<br><br>>80% canopy cover<br><br>The riparian area in Reach 10 is impacted periodically by the Entiat River Road along the river-left bank and by the Forest Road 5605 bridge crossing near the upstream end of the reach. | At least a 100 ft riparian buffer with:<br><br>> 80% mature trees, or consistent with potential native community<br><br>< 20% riparian disturbance (human)<br><br>>80% canopy closure in the riparian zone.<br><br>[REI] | **Riparian Restoration**<br><br>Look for opportunities to set back roadways and other human infrastructure out of riparian areas. | No projects identified |
| Floodplain Connectivity | 5% of the mapped floodplain has been disconnected (see Appendix B).<br><br>0.7 mi/mi² of road in the floodplain | Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain<br><br>[adapted from REI]<br><br><2mi/mi² road density in the floodplain | **Habitat reconnection via infrastructure modification**<br><br>Where possible, address floodplain impairments associated with the bridge, roadway, and residential development along river-left. | No projects identified |

| Reach 10 Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Bank condition / Channel migration | 5% of the streambanks in the reach are affected by bank armoring.<br><br>Bridge near upstream end has only a limited effect on channel migration due to natural confinement. | Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion.<br>[adapted from REI] | **Habitat reconnection via infrastructure modification**<br>Where possible, set back roadways, remove bank armoring, remove fill, and remove/modify other human infrastructure affecting channel migration processes. | No projects identified |
| Vertical channel stability | The bridge crossing at the upstream end of the reach may have some effect on vertical stability; however, natural confinement through this section limits the potential risk for impairment. | No measurable trend of human-induced aggradation or incision<br>[adapted from REI] | **Habitat reconnection via infrastructure modification**<br>Remove or modify bridge crossing to reduce hydraulic effects on channel, if warranted. | No projects identified |
| Pools | Pools per mile = 5.8<br><br>8% pool habitat<br><br>67% of pools are <1 m deep | ~4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Many large pools >1 m deep with good fish cover.<br>[REI] | **Placement of structural habitat elements**<br>Placement of structure to form pools.<br><br>**Habitat reconnection via infrastructure modification**<br>Removing or modify bank armoring to enhance pool quality. | Project RM 31.4L: Upper Silver Margin Jams |

| Reach 10 Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Large wood and log jams | 31 pieces / mi<br><br>0 jams /mi | > 42.5 pieces/mi (>12 diam; > 35 ft long)<br>[from Fox 2001]<br><br>≥ 5 log jams/mi<br>[based on conditions in Reach 9] | **Riparian restoration**<br>Riparian projects to improve long-term LW recruitment.<br><br>**Placement of structural habitat elements**<br>Placement of large wood and log jams where large wood would naturally accumulate and would provide the greatest habitat benefit. | Project RM 31.4L: Upper Silver Margin Jams |
| Off-Channel Habitat | 0% side channel habitat.<br><br>Natural confinement limits significant development of off-channel habitat. Lack of log jams further limits off-channel development. | Reach has ponds, oxbows, backwaters, side channels, and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas.<br>[adapted from REI] | **Placement of structural habitat elements**<br>Placement of wood to increase lateral channel dynamics. | No projects identified |

### 4.4.12 Reach 11

The restoration strategy for Reach 11 focuses on enhancements to existing high flow side- channels. Natural confinement of the mainstem limits the availability of off-channel habitat and locations for large wood recruitment through much of the reach. In two locations, existing high flow side channels could be opened up to be perennially active and large wood placements would provide cover and complexity. Opening up side channels and placing log jams to increase complexity would help achieve large wood numbers, log jam quantity, and off-channel habitat quantity targets in the reach, but actions would need to be weighed against potential construction-related impacts to existing floodplain and riparian vegetation.

**Reach 11 Restoration Strategy**

| Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Riparian condition | >80% species composition, seral stage, and structural complexity are consistent with potential native community.<br><br>Dominated by small trees (<21 inches dbh)<br><br>>80% canopy cover<br><br>The riparian area in Reach 11 is intact. The reach is isolated from the roadway and there is no on-going human disturbance to the riparian zone. | At least a 100 ft riparian buffer with:<br>> 80% mature trees, or consistent with potential native community<br>< 20% riparian disturbance (human)<br>>80% canopy closure in the riparian zone.<br>[REI] | **No actions identified** | No projects identified |
| Floodplain Connectivity | 0% of the mapped floodplain has been disconnected (see Appendix B).<br><br>0 mi/mi$^2$ of road in the floodplain | Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain<br>[adapted from REI]<br><br><2mi/mi$^2$ road density in the floodplain | **No actions identified** | No projects identified |

| Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Bank condition / Channel migration | 0% of the streambanks in the reach are affected by bank armoring. | Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion.<br>[adapted from REI] | **No actions identified** | No projects identified |
| Vertical channel stability | No measurable trend of aggradation or incision associated with human actions. | No measurable trend of human-induced aggradation or incision<br>[adapted from REI] | **No actions identified** | No project identified |
| Pools | Pools per mile = 6.8<br>7% pool habitat<br>71% of pools are <1 m deep | ~4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Many large pools >1 m deep with good fish cover.<br>[REI] | **Placement of structural habitat elements**<br>Placement of structure to form pools. | Project RM 32.8L: Lower Pope Left Bank Side Channel Enhancement |
| Large wood and log jams | 20 pieces / mi<br>1.9 jams /mi | > 42.5 pieces/mi (>12 diam; > 35 ft long)<br>[from Fox 2001]<br>≥ 5 log jams/mi<br>[based on conditions in Reach 9] | **Placement of structural habitat elements**<br>Placement of large wood and log jams where large wood would naturally accumulate and would provide the greatest habitat benefit. | Project RM 32.8L: Lower Pope Left Bank Side Channel Enhancement |
| Off-Channel Habitat | 4% side channel habitat.<br>There is a limited amount of off-channel habitat but natural confinement limits significant development of off-channel habitat. Lack of log jams further limits off-channel development. | Reach has ponds, oxbows, backwaters, side channels, and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas.<br>[adapted from REI] | **Placement of structural habitat elements**<br>Placement of wood to increase lateral channel dynamics. | Project RM 32.8L: Lower Pope Left Bank Side Channel Enhancement<br>Project RM 32.7R: Lower Pope Right Bank Side Channel Enhancement |

### 4.4.13 Reach 12

Reach 12 has been relatively unaffected by direct human alterations for at least the past 50 years. The reach is naturally confined by multiple abandoned terraces. This confinement naturally limits lateral migration and, combined with relatively steep gradient, limits the need and opportunity for restoration actions throughout the reach. No restoration actions were identified within the reach.

**Reach 12 Restoration Strategy**

| Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Riparian condition | >80% species composition, seral stage, and structural complexity are consistent with potential native community.<br><br>Dominated by large and small trees (<32 inches dbh)<br><br>>80% canopy cover<br><br>The riparian area in Reach 12 is intact. The reach is isolated from the roadway and there is no on-going human disturbance to the riparian zone. | At least a 100 ft riparian buffer with:<br>> 80% mature trees, or consistent with potential native community<br>< 20% riparian disturbance (human)<br>>80% canopy closure in the riparian zone.<br>[REI] | **No actions identified** | No projects identified |
| Floodplain Connectivity | 0% of the mapped floodplain has been disconnected (see Appendix B).<br><br>0 $mi/mi^2$ of road in the floodplain | Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain<br>[adapted from REI]<br><br><2$mi/mi^2$ road density in the floodplain | **No actions identified** | No projects identified |

| Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Bank condition / Channel migration | 0% of the streambanks in the reach are affected by bank armoring. | Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion.<br>[adapted from REI] | **No actions identified** | No projects identified |
| Vertical channel stability | No measurable trend of aggradation or incision associated with human actions. | No measurable trend of human-induced aggradation or incision<br>[adapted from REI] | **No actions identified** | No projects identified |
| Pools | Pools per mile = 10.1<br>12% pool habitat<br>67% of pools are <1 m deep | ~4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Many large pools >1 m deep with good fish cover.<br>[REI] | **Placement of structural habitat elements**<br>Placement of structure to form pools. | No projects identified |
| Large wood and log jams | 12 pieces / mi<br>0 jams /mi | > 42.5 pieces/mi (>12 diam; > 35 ft long)<br>[from Fox 2001]<br>$\geq$ 5 log jams/mi<br>[based on conditions in Reach 9] | **Placement of structural habitat elements**<br>Placement of large wood and log jams where large wood would naturally accumulate and would provide the greatest habitat benefit. | No projects identified |
| Off-Channel Habitat | 0% side channel habitat.<br>Natural confinement limits significant development of off-channel habitat. Lack of log jams further limits off-channel development. | Reach has ponds, oxbows, backwaters, side channels, and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas.<br>[adapted from REI] | **Placement of structural habitat elements**<br>Placement of wood to increase lateral channel dynamics. | No projects identified |

### 4.4.14 Reach 13

The majority of Reach 13 is naturally confined by alluvial terraces and bedrock outcrops. This confinement limits lateral channel migration processes and large wood recruitment. This natural confinement has limited human alteration to the channel as well as the opportunities for restoration. Potential restoration actions are limited to off-channel habitat enhancements at RM 33.2. Enhancements here could potentially allow greater connectivity of off-channel wetlands in the floodplain and activate the side channel at lower flows, which would help to achieve the reach-scale target conditions for off-channel habitat.

**Reach 13 Restoration Strategy**

| Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Riparian condition | >80% species composition, seral stage, and structural complexity are consistent with potential native community.<br><br>Dominated by small trees (<21 inches dbh)<br><br>>80% canopy cover<br><br>The riparian area in Reach 13 is mostly intact except for a short section where the roadway is within the riparian zone along the river-left bank. | At least a 100 ft riparian buffer with:<br>> 80% mature trees, or consistent with potential native community<br>< 20% riparian disturbance (human)<br>>80% canopy closure in the riparian zone.<br>[REI] | **Riparian Restoration**<br>Look for opportunities to set back roadways and other human infrastructure out of riparian areas. | No projects identified |
| Floodplain Connectivity | 0% of the mapped floodplain has been disconnected (see Appendix B).<br><br>0 mi/mi² of road in the floodplain | Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession. Minimal human disturbance of the floodplain<br>[adapted from REI]<br><br><2mi/mi² road density in the floodplain | **No actions identified** | No projects identified |

| Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Bank condition / Channel migration | 0% of the streambanks in the reach are affected by bank armoring. | Channel is migrating at or near natural rates. Minimal bank armoring or human-induced erosion.<br>[adapted from REI] | **No actions identified** | No projects identified |
| Vertical channel stability | No measurable trend of aggradation or incision associated with human actions. | No measurable trend of human-induced aggradation or incision<br>[adapted from REI] | **No actions identified** | No projects identified |
| Pools | Pools per mile = 6.1<br>8% pool habitat<br>25% of pools are <1 m deep | ~4 pools/mi. Pools have good cover and cool water and only minor reduction of pool volume by fine sediment. Many large pools >1 m deep with good fish cover.<br>[REI] | **Placement of structural habitat elements**<br>Placement of structure to form pools. | Project RM 33.2L: Upper Pope Side Channel Enhancement |
| Large wood and log jams | 37 pieces / mi<br>1.5 jams /mi | > 42.5 pieces/mi (>12 diam; > 35 ft long)<br>[from Fox 2001]<br>≥ 5 log jams/mi<br>[based on conditions in Reach 9] | **Riparian restoration**<br>Riparian projects to improve long-term LW recruitment.<br>**Placement of structural habitat elements**<br>Placement of large wood and log jams where large wood would naturally accumulate and would provide the greatest habitat benefit. | Project RM 33.2L: Upper Pope Side Channel Enhancement |

| Attribute | Existing Condition (from assessment) | Target Condition [source] | Action Type | Potential Projects |
|---|---|---|---|---|
| Off-Channel Habitat | 6% side channel habitat.<br><br>There is a limited amount of off-channel habitat but natural confinement limits significant development of off-channel habitat. Lack of log jams further limits off-channel development. | Reach has ponds, oxbows, backwaters, side channels, and other off-channel areas with cover that are consistent with natural conditions. No manmade barriers are present that prevent access to off-channel areas.<br><br>[adapted from REI] | **Placement of structural habitat elements**<br><br>Placement of wood to increase lateral channel dynamics. | Project RM 33.2L: Upper Pope Side Channel Enhancement |

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# Appendix A

## Stream Habitat Assessment

### Entiat River – Upper Stillwaters

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# 1 Introduction & Background

This survey was conducted from August 28 to September 7, 2012 from RM 23.3 to 24 and from RM 25 to 33.8. The survey area coincides with the study area for the Entiat River Upper Stillwaters Reach Assessment, including reach breaks. A locator map can be found in Section 1.4 of the Assessment report. Stream flow during the survey period ranged from 141 to 111 cubic feet per second (cfs) according to the USGS Gauging Station located near Ardenvoir, WA (gage number 12452800). To our knowledge, this is the first comprehensive stream habitat assessment on the upper Stillwater section of the Entiat River since a 1994 habitat survey conducted by the US Forest Service.

The objective of the Habitat Assessment is to characterize the habitat quantity and quality for salmonid species native to the Entiat River and the Upper Columbia River basin by quantifying in-channel morphologic features and qualitatively describing riparian conditions that influence aquatic habitat. This information is used to inform potential restoration/preservation actions and will provide a baseline for evaluating future habitat trends and for measuring the effectiveness of restoration efforts

# 2 Methods

Fourteen geomorphic reaches have been delineated as part of the reach assessment. These same reaches were used for both the stream habitat and geomorphology assessments to maintain consistency for this and future inventories. The exceptions to this are 2 canyon reaches that were excluded from some habitat data collection procedures. The primary reasons for this exclusion included safety considerations, time constraints, the relatively static nature of vertical and lateral adjustment in these reaches, and the low likelihood of restoration action being taken in these reaches. Slow and fast water units were mapped out from the canyon rim allowing for gross estimation of habitat unit composition, but measurements of channel dimensions were not taken. Bankfull width and floodprone width for these reaches were estimated using aerial photos and available LiDAR in GIS. Limited data analysis is derived from these reaches. Data collected in this survey is intended to compliment pre-existing data for the Entiat basin.

Field methods for the habitat survey used the USFS Region 6 Level II Stream Survey Protocol Version 2.10 (USDA Forest Service 2010). All protocols and most forest options were observed during the survey due to favorable flow conditions and wading depths. The survey was conducted during minimum stream flows between 141 and 111 cfs which are slightly below the mean flows for August 28$^{th}$ and September 7$^{th}$ respectively.

The measured ($n^{th}$) unit measurement frequency was 20%, or 1 unit measured in every 5. This choice was made to ensure that enough $n^{th}$ unit measurements would be made. The exception to the 20% $n^{th}$ unit measurement protocol was in Reach 0, which is downstream and somewhat separated from the other reaches in the study area. In Reach 0, an $n^{th}$ unit measurement was made in every unit in order to ensure sufficient number of measurements in the event that this reach was treated as a stand-alone unit for data analysis. In Reaches 1 through 13, the nature of unit composition, and placement of reach breaks, did not provide an $n^{th}$ unit measurement in every reach. For reaches without $n^{th}$ unit measurements, width estimates were made using aerial photographs and available LiDAR in GIS. Habitat unit length was measured by 100 foot tape or calibrated laser range finder. Habitat unit width was also measured with a calibrated laser finder at several locations along every $n^{th}$ unit and averaged for best accuracy. The range finder was used in all other units as well in order to verify the ocular width estimates of the observer. Ocular estimates were recorded in these cases, without a companion record of measured widths. A graduated survey rod allowed for habitat unit depths to be measured up to a depth of 9 feet where maximum depth could be accessed safely (e.g., overhanging bedrock) and was conservatively estimated when unit depth exceeded the measuring rod or when the location of maximum depth was inaccessible.

Data collection in the steepest fast water units (i.e., rapids and cascades) was challenging and in some reaches due to deep plunges and swift water. In these units, only safe measurements were obtained and therefore not always thalweg measurements. Bankfull measurements were obtained where stream conditions allowed (i.e., wadeable). Visual (ocular) estimates of bed sediment composition (considered a "forest option" in the USFS protocol) were recorded for every $n^{th}$ unit. The lengths of unstable banks were visually estimated for every $n^{th}$ unit.

Side-channel units were identified when the main channel split to form a stable island with soil or fine sediment deposits and vegetation older than 2 to 3 years old. Each side channel was determined to be fast or slow, and its total and wetted lengths measured. No off-channel marshlands were identified during this survey.

# 3 Summary of Results

This section summarizes the results for all reaches, including the canyon reaches with some characteristics estimated in GIS. Detailed reach summaries with reach-specific results are included in the Reach Summary section.

## 3.1 HABITAT UNIT COMPOSITION AND COMPARISON

Fast water units were the predominant habitat unit type in the study area. Riffles were typically the dominant fast water unit (56% for the study area) though in some reaches rapids made up the dominant fast water unit (21% for the study area). The percentage of rapids would probably be significantly higher if more detailed survey of Reaches 6 and 8 could have been safely carried out. Pools provide far less habitat area with 12% in the study area. Glides and cascades compose 4 and 2% of habitat in the study area, respectively. The remaining 6% was side channel habitat (Figure 1). A negligible amount of braided channel habitat (< 1%) was measured in the study area as well.

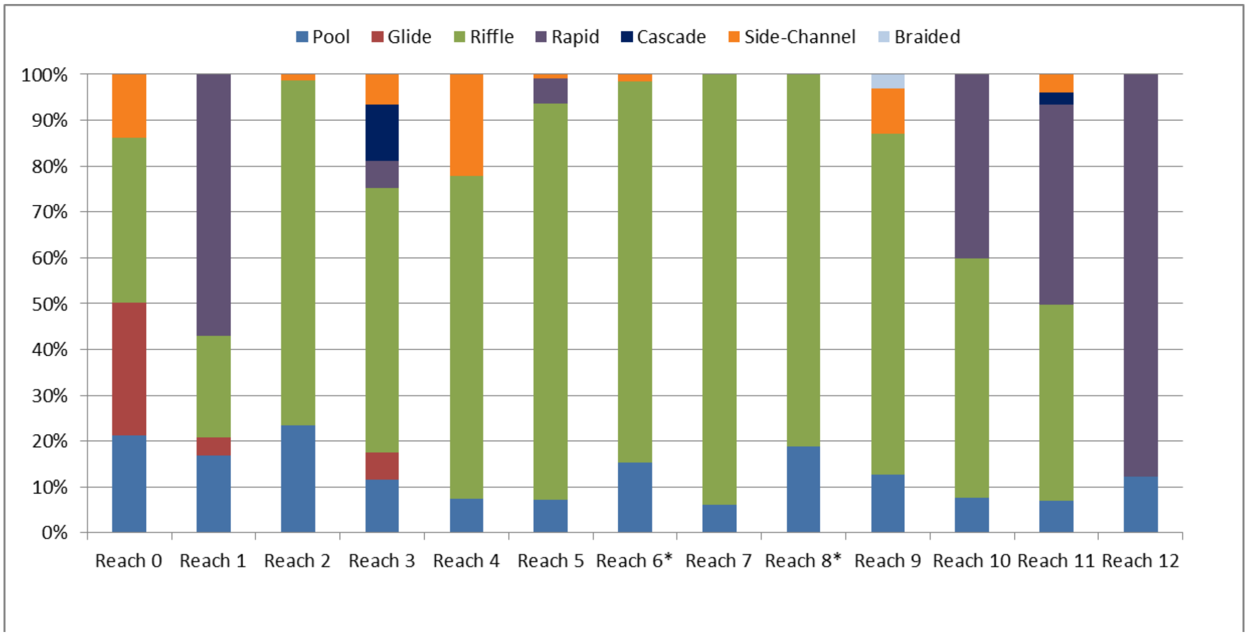


***Figure 1. Habitat unit composition by reach. * Denotes a reach where habitat units were mapped from the canyon rim and all fast water units were included in the riffle category.***

## 3.2 HABITAT UNIT SUMMARIES

### 3.2.1 Pools

Pool frequency ranged from 1.9 (Reach 7) to 10.1 (Reach 12) pools/mile with a mean frequency of 6.4 pools/mile. Frequency was calculated as the number of pools divided by the length of the reach in miles. It should be noted that pool features for Reaches 6 and 8 were measured using aerial photos and GIS. Pool spacing values were calculated by using the frequency (*f*) to determine spacing over a mile, then normalizing those distances using the average bankfull width ($W_{bf}$):

$$\frac{5{,}280\text{ ft}/f}{W_{bf}}$$

This yields a mean pool spacing of 9 bankfull widths with spacing ranging from 6 at the most closely spaced (Reach 6) to 31 at the most distantly spaced (Reach 7). Reaches 2 and 0 had the greatest proportion of pool habitat (24% and 21%, respectively), although the proportion of pools was under 20% for all other reaches with an overall proportion of 12% for the study area. About half (51%) of pools in the study area were relatively deep with residual depths greater than 3 ft (Reaches 6 and 8 not measured). The average residual pool depth was greater than 3 ft for all reaches except reaches 9, 10, and 11 (Reaches 6 and 8 not measured) which were each just below 3 ft. The greatest average residual depth was in Reach 13 (5.6 ft), and the lowest average residual depth was in Reach 11 (2.6 ft).

Mean wetted pool width was 55 ft (StDev of 13 ft). Reach 7 had the widest pool width (90ft), though not an average since the reach had only 1 pool. The narrowest average pool width was in Reach 12 (41 ft). The average length of pools in the study area was 131 ft (StDev of 84 ft). Reach 2 had the longest pool units with an average length of 372 ft. Pools in Reach 6 were the shortest with an average length of 79 ft (StDev of 23 ft). Reach 6 is a steep canyon reach with short plunge pools whose lengths were measured using aerial photos and GIS, as was Reach 8.

### 3.2.2 Fast Water Units (Glides, Riffles, Rapids, and Cascades)

Riffles and rapids comprise the majority of fast water units in the study taking 56% and 21% of total habitat units in the study area. Though glides and cascades comprise only 6% of all habitat units combined, they are significant portions of some reaches and are thus included in the discussion. Depth generally increased with slope of fast water units. Mean average riffle depth was 1.3 ft (StDev 0.6) with a mean maximum depth of 2.9 ft (StDev 1.2) (Reaches 6 and 8 not measured). Glides were similar to rapids in average depth (1.3 ft StDev 0.5) but slightlyshallower in max depth at 2.5 ft (StDev 0.6). Both Rapids and Cascades provided greater mean average and maximum depths (1.7 and 3.0 ft mean average, and 3.7 and 6.0 ft. mean maximum depth respectively) than riffles due to the greater depth of pocket water created by large bed material in these habitat units. Depth of fast water units should not present a problem for migrating fish, as minimum depths reported necessary to maintain Chinook and large trout passage (0.8 feet and 0.6 feet, respectively) were exceeded in all reached of the study area (Thompson 1972). Steeper reaches with high percentages of rapids and cascades will present greater passage challenges for migrating fish.

Fast water units were much longer than pools, with riffles being the longest on average. Length tended to decrease with increased slope. Average glide length for the study area was 320 ft with a minimum of 160 ft in Reach 1 and a maximum of 405 ft in Reach 0. Only 3 reaches had glides. Average riffle length for the study area was 627 ft with a minimum length of 295 ft (Reach 8 measured in GIS) and a maximum of 1,329 ft in Reach 7. For the study area, average rapid length was 546 ft with a maximum of 1,230 ft in Reach 1 and a minimum of 175 ft in Reach 5. Average cascade length was 493 ft for the study area with a maximum of 830 ft in Reach 3 and a minimum of 156 ft in Reach 11. Only 2 reaches had cascade units.

Wetted width had low variation among average values for the different fast water units. Riffles had an average wetted width of 66.9 ft (StDev 20.4) and ranged from 93 ft to 58 ft wide. Rapids had an average wetted width of 68.6 ft (StDev 17.7) with a range of 75 to 58 ft, and Cascades had an average wetted width of 67.5 ft (StDev 10.6).

## 3.3 SIDE-CHANNEL UNITS

Side-channel habitat accounts for approximately 6% of habitat area in the study reach. A total of 27 wetted side channel habitat units were measured during the survey. Reach 4 had the greatest area of side channel habitat with 22% of habitat in the reach being in side channels. Reaches 1, 7, 8, 10, and 12 had no side channel habitat. Maximum side channel depth was 2.0 feet (StDev 1.6) with the deepest side channels observed in Reach 4 (4.2 ft deep). Mean side channel length was 447.5 ft (StDev 300.1) with a maximum length of 737.3 ft and a minimum length of 137 ft. Side channel widths ranged from 33 to 4 ft with a mean wetted width value of 17.9 ft (StDev 14).

## 3.4 BANKFULL CHANNEL CHARACTERISTICS

Bankfull channel widths did not vary substantially between stream reaches but were slightly larger in Reaches 0, 1, 3, and 10 (Figure 2). Floodprone widths vary considerably throughout the study area with a mean floodprone width of 332 ft (StDev 191.5). Reaches 0 and 4 had the widest mean floodprone widths (>400 ft). Mean bankfull width was 100.6 ft (StDev 18.3). Bankfull depths were likewise consistent among reaches and within reaches with very low standard deviation (Figure 3). Mean bankfull depth was 3.8 ft (StDev 0.8). Bankfull depth ranged from 3.3 to 4.8 feet, with the largest bankfull depths occurring in Reach 1. Maximum bankfull depth ranged from 3.8 to 6.2 feet with an average of 4.8 for the study area (StDev 1.0).

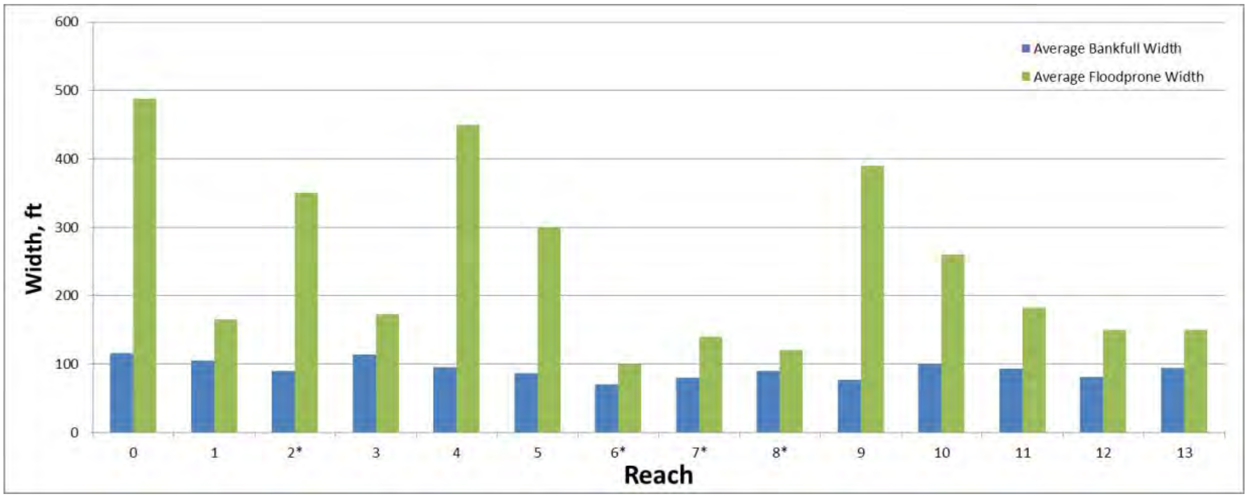


***Figure 2. Average bankfull and floodprone widths for each reach in the study area.***

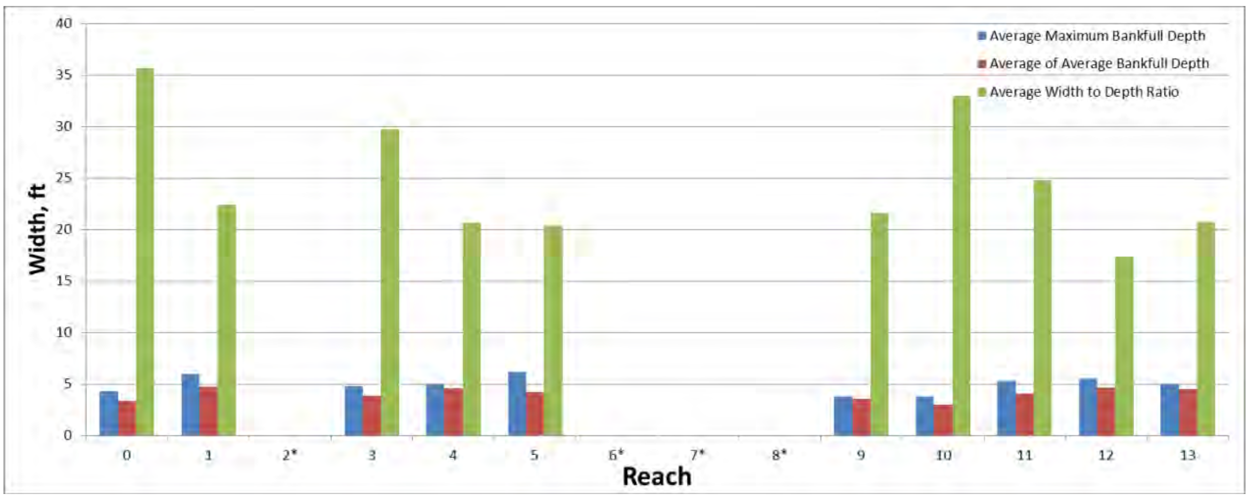


***Figure 3. Bankfull depth measurements for each reach including maximum bankfull depth, average bankfull depth, and the width to depth ratio.***

## 3.5 LARGE WOOD

An average of 83 pieces of wood per mile was counted in the study area; 60% of these were "small" pieces with diameters between 6 and 12 inches and lengths greater than 20 feet (Figure 4). Reach 9 had the highest number of total pieces per mile with 189; Reach 7 had the next highest frequency at 119. The numbers of pieces per mile in each reach ranged from 23 to 189.

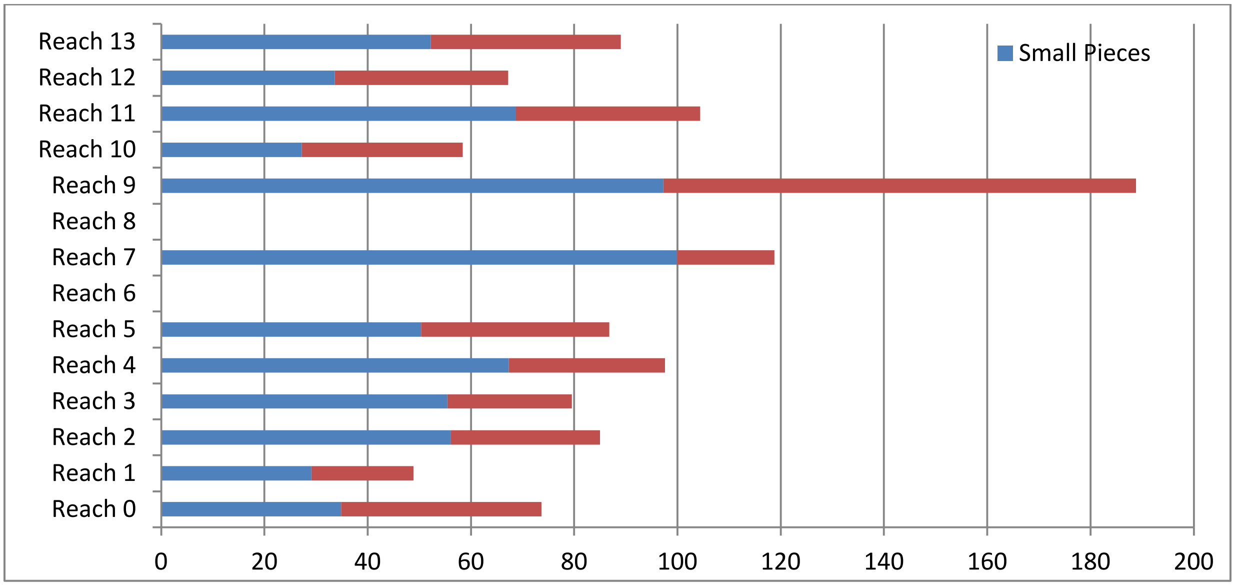


***Figure 4. Small and medium/large wood pieces/mile for each reach, excluding Reaches 6 and 8 where wood counts were not performed.***

## 3.6 SUBSTRATE AND FINE SEDIMENT

Bed substrate was based on ocular estimates at each measured habitat unit. Riffle pebble counts were not performed for Reaches 6 and 8 due to limited river access, and were not carried out in reaches 2 and 7 because a measured riffle unit was not located in these reaches. Percent coverage of sand, gravel, and boulder varies. In general, bed substrate in the study area was gravel and cobble, with smaller amounts of boulder, bedrock and sand (Figure 5 and Figure 6). Bedrock was observed mainly in pools (Reaches 5, 10, 11, and 13) with Reach 11 being the only area where bedrock was observed in a riffle. Sand was a consistently low contributor to overall bed composition with 10% being the highest value for any reach, and 7 reaches having 10% sand in pools and riffles.

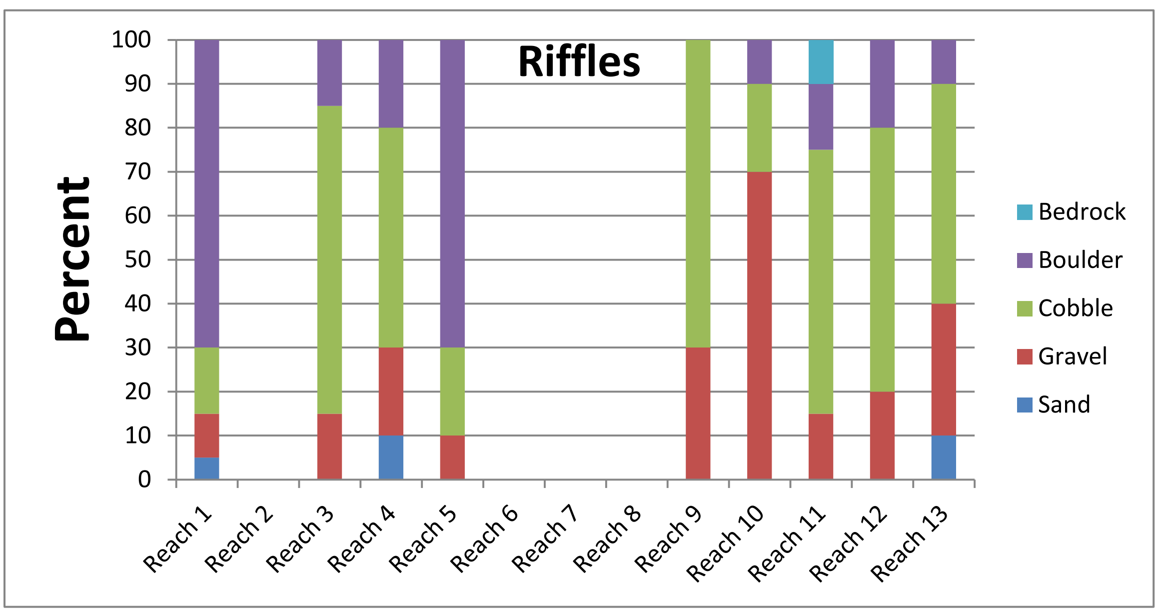


***Figure 5. Ocular estimates of stream bed substrate in riffles for each measured reach of the study area.***

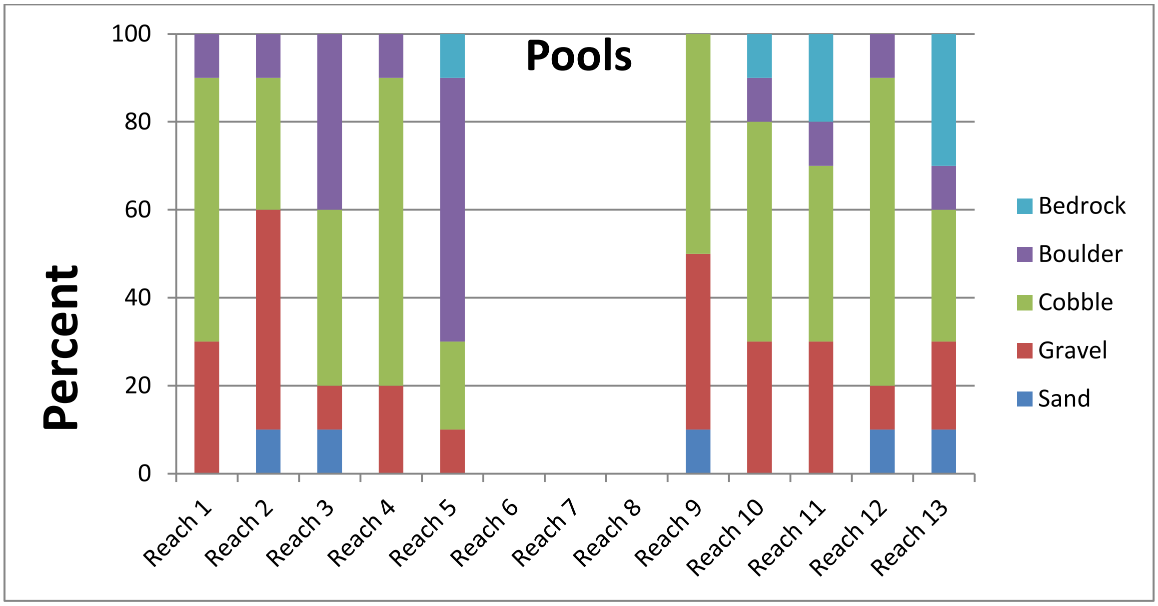


***Figure 6. Ocular estimates of stream bed substrate in pools for each measured reach for the study area.***

## 3.7 CHANNEL INSTABILITY AND DISTURBANCE

Human alteration to the channel and floodplain in the Upper Stillwater study area is relatively low. Land-use activities that are widespread in the lower portions of the Entiat River such as floodplain clearing and conversion to agriculture, surface water diversion for agriculture, residential development on the floodplain, channelization, levee building, and road building have been limited in the study area. Naturally limited floodplain width and steep channel gradients play a big factor in deterring floodplain development and channel alteration. Limited residential development has taken place in the reach with the most intense floodplain alteration (complete riparian clearing to the river bank and conversion to lawn) due to residential development occurring in Reach 0. In all other reaches where homes have been built, they are primarily located on high terraces and involve little land clearing. Bridge crossings (two crossings total) represent the main channel alterations with up and downstream bank hardening and channel constriction. Roads in the study area are mainly located at the margin of the floodplain and at the toe of the hillslope.

Anthropogenically caused bank erosion is not widespread in the study area. The only eroding banks that were identified in the study area were found in Reaches 0 and 1. In these locations there was 1.5% and 4.4% bank erosion, respectively. In total, there were only 260 feet of eroding banks identified as being caused by human activity or channel alteration. That is not to say there were not eroding banks elsewhere in the study area. There were many locations where the river was eroding into glacial terrace deposits or alluvial fan deposits resulting in high eroding banks. These were deemed natural features and not categorized as unstable or disturbed banks.

## 3.8 FISH PASSAGE BARRIERS

There were no anthropogenic fish passage barriers in the study area. There were several reaches that were consistently steep with rapids and cascades comprising a majority of the habitat units. During spring high flow, or winter storm peaks, these areas may prove to be passage barriers. There was also several falls in the reach. Two of them were large and almost certainly posed passage barriers at most if not all flows. One of these is Entiat Falls, which marks the upstream end of the study area. This falls has been considered the upstream extent of anadromy on the Entiat River. However, there is a large falls at the upstream end of Reach 6 that appeared to be a complete passage barrier at the time of survey. There was also at least one other small falls of 2 to 5 feet that could pose a barrier at some flows.

## 3.9 RIPARIAN CORRIDOR

Riparian vegetation has been primarily affected by fire and logging. The earliest records on the extent of either of these phenomena come from 1902 (Plummer, 1902). At that time there was little timber harvest in the riparian zone of the study area, but fire had affected small areas near RM 26. The Entiat Tributary Assessment (BOR 2009) updated the recording of fire and timber harvest covering essentially all of the 20th century. This showed greatly increased disturbance to the riparian area by both fire and timber harvest. Fire has affected the entire riparian corridor in Reaches 0 through 6. The historical timber harvest in the riparian corridor has taken place in Reaches 7 through 13, and mostly on the south side of the channel. Today, reforested timberlands dominate the riparian over story, while shrubs and small trees typical of shoreline margins were frequently observed along the banks of the Entiat River.

It is a "Forest Option" to designate either a single 100-ft wide zone or two adjacent riparian zones (inner and outer zones) totaling 100 feet in width (USDA 2010). For reasons best suited to this assessment, one single 100-ft wide riparian zone was designated for the Entiat River study area. Survey methods dictate defining a dominant size class of vegetation type for the riparian zone (i.e. large trees, small trees, shrubs), then defining the dominate species observed in the over and understory respectively.

The Entiat River riparian zone was typically dominated by small trees (71%). Large trees comprise only 13% of size distribution and sapling/pole and shrub/seedling each took 8% of the size distribution (Figure 7). Riparian understory was primarily hardwood (77%) with an undifferentiated mix being the dominant "species" type (46%) (Figure 8). Overstory species included a large percentage of conifers (67%) usually (42%) an undifferentiated mix of pine and fir with substantial amounts of cedar in some reaches.

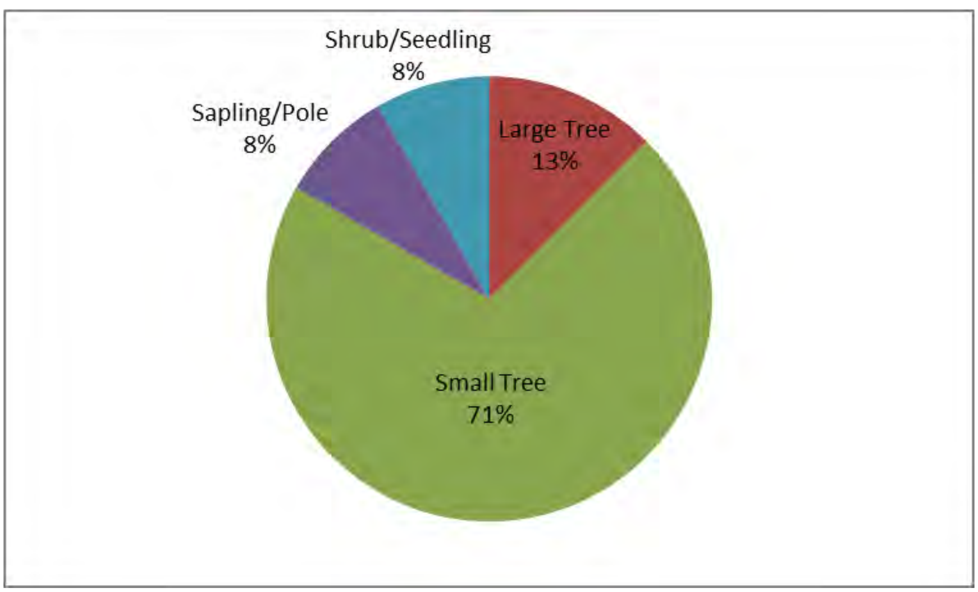


***Figure 7. Distribution of the dominant size class category for the 100 ft buffer riparian zone, all reaches combined.***

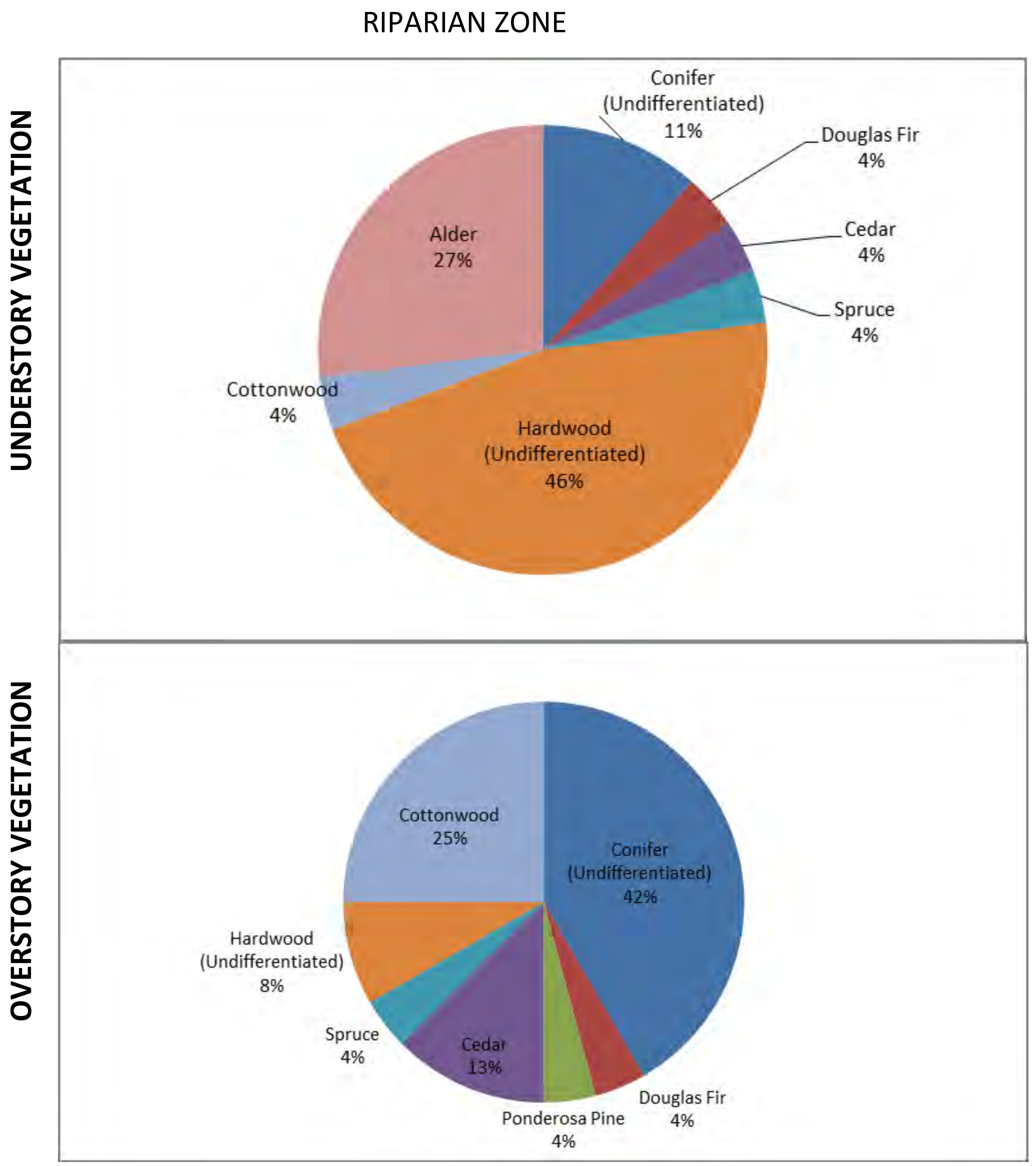


***Figure 8. Proportions of vegetation cover types in the under and overstory of the riparian zone of the study area.***

***Table 1. Upper Stillwater Reach Data Summary.***

| **Reach** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reach Mileage Boundaries** | 23.3-24.0 | 25.0-25.6 | 25.6-26.1 | 26.1-27.15 | 27.15-27.7 | 27.7-28.25 | 28.25-29.3 | 29.3-29.85 | 29.85-30.2 | 30.2-31.4 | 31.4-31.9 | 31.9-32.9 | 32.9-33.2 | 33.2-33.8 | 23.3-33.8 |
| **Wetted Width (ft)** | | | | | | | | | | | | | | | |
| *Pool* | | | | | | | | | | | | | | | |
| Mean | 62 | 62 | 71 | 58 | 48 | 53 | 54 | 90 | 53 | 48 | 52 | 52 | 41 | 49 | 55 |
| StDev | 10 | 11 | 1 | 15 | 13 | 12 | 15 | n=1 | 15 | 15 | 8 | 9 | 5 | 9 | 13 |
| *Glide* | | | | | | | | | | | | | | | |
| Mean | 88 | 81 | n=0 | 42 | n=0 | n=0 | n=0 | n=0 | n=0 | n=0 | n=0 | n=0 | n=0 | n=0 | 71.7 |
| StDev | 3 | n=1 | n=0 | 17 | n=0 | n=0 | n=0 | n=0 | n=0 | n=0 | n=0 | n=0 | n=0 | n=0 | 24.4 |
| *Riffle* | | | | | | | | | | | | | | | |
| Mean | 93 | 58 | 80 | 66 | 75 | 73 | 51 | 80 | 59 | 66 | 70 | 75 | n=0 | n=0 | 93 |
| StDev | 34 | 26 | 20 | 17 | 6 | 5 | 12 | n=1 | 5 | 15 | 14 | 14 | n=0 | n=0 | 34 |
| *Rapid* | | | | | | | | | | | | | | | |
| Mean | n=0 | 75 | n=0 | 58 | n=0 | n=0 | n=0 | n=0 | n=0 | n=0 | 75 | 67 | 62 | 76 | 68.6 |
| StDev | n=0 | 21 | n=0 | 25 | n=0 | n=0 | n=0 | n=0 | n=0 | n=0 | 7 | 23 | 16 | 18 | 17.7 |
| *Cascade* | | | | | | | | | | | | | | | |
| Mean | n=0 | n=0 | n=0 | 60 | n=0 | n=0 | n=0 | n=0 | n=0 | n=0 | n=0 | 75 | n=0 | n=0 | 67.5 |
| StDev | n=0 | n=0 | n=0 | n=1 | n=0 | n=0 | n=0 | n=0 | n=0 | n=0 | n=0 | n=1 | n=0 | n=0 | 10.6 |
| *Side-Channel* | | | | | | | | | | | | | | | |
| Mean | 33 | n=0 | 4 | 21 | 30 | 15 | 24 | n=0 | n=0 | 15 | n=0 | 7 | n=0 | 23 | 17.9 |
| StDev | 15 | n=0 | 1 | 5 | 18 | 0 | 0 | n=0 | n=0 | 16 | n=0 | 5 | n=0 | 4 | 14.0 |

| **Reach** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reach Mileage Boundaries** | 23.3-24.0 | 25.0-25.6 | 25.6-26.1 | 26.1-27.15 | 27.15-27.7 | 27.7-28.25 | 28.25-29.3 | 29.3-29.85 | 29.85-30.2 | 30.2-31.4 | 31.4-31.9 | 31.9-32.9 | 32.9-33.2 | 33.2-33.8 | 23.3-33.8 |
| **Water Depth (ft)** | | | | | | | | | | | | | | | |
| *Pool Maximum Depth* | | | | | | | | | | | | | | | |
| Mean | 4.7 | 5.2 | 5.1 | 5.5 | 5.7 | 5.8 | N/A | 6.0 | N/A | 4.3 | 4.6 | 4.6 | 4.9 | 7.3 | 5.2 |
| StDev | 2.0 | 2.5 | 2.7 | 1.6 | 1.5 | 2.3 | N/A | n=1 | N/A | 1.2 | 0.3 | 0.9 | 2.7 | 3.6 | 1.9 |
| *Pool Residual Depth* | | | | | | | | | | | | | | | |
| Mean | 3.1 | 3.4 | 3.7 | 3.5 | 4.1 | 4.8 | N/A | 4.5 | N/A | 2.7 | 2.7 | 2.6 | 3.0 | 5.6 | 3.4 |
| StDev | 2.3 | 2.6 | 2.2 | 1.2 | 1.5 | 1.6 | N/A | n=1 | N/A | 1.2 | 0.5 | 1.1 | 2.8 | 3.8 | 1.9 |
| *Glide Maximum Depth* | | | | | | | | | | | | | | | |
| Mean | 2.4 | 2.2 | n=0 | 2.7 | n=0 | n=0 | N/A | n=0 | N/A | n=0 | n=0 | n=0 | n=0 | n=0 | 2.5 |
| StDev | 0.6 | n=1 | n=0 | 1.0 | n=0 | n=0 | N/A | n=0 | N/A | n=0 | n=0 | n=0 | n=0 | n=0 | 0.6 |
| *Glide Average Depth* | | | | | | | | | | | | | | | |
| Mean | 1.0 | 0.8 | n=0 | 1.9 | n=0 | n=0 | N/A | n=0 | N/A | n=0 | n=0 | n=0 | n=0 | n=0 | 1.3 |
| StDev | n=1 | n=1 | n=0 | 0.5 | n=0 | n=0 | N/A | n=0 | N/A | n=0 | n=0 | n=0 | n=0 | n=0 | 0.5 |

| **Reach** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reach Mileage Boundaries** | 23.3-24.0 | 25.0-25.6 | 25.6-26.1 | 26.1-27.15 | 27.15-27.7 | 27.7-28.25 | 28.25-29.3 | 29.3-29.85 | 29.85-30.2 | 30.2-31.4 | 31.4-31.9 | 31.9-32.9 | 32.9-33.2 | 33.2-33.8 | 23.3-33.8 |
| *Riffle Maximum Depth* | | | | | | | | | | | | | | | |
| Mean | 2.2 | 2.5 | 3.3 | 2.7 | 3.6 | 4.7 | N/A | 4.0 | N/A | 2.3 | 2.6 | 2.6 | n=0 | n=0 | 2.9 |
| StDev | 0.5 | 0.7 | 0.9 | 0.6 | 1.8 | 2.3 | N/A | n=1 | N/A | 0.5 | 0.6 | 0.9 | n=0 | n=0 | 1.2 |
| *Riffle Average Depth* | | | | | | | | | | | | | | | |
| Mean | 0.9 | 1.2 | 1.3 | 1.7 | 1.9 | 2.4 | N/A | 1.5 | N/A | 0.9 | 1.0 | 1.2 | n=0 | n=0 | 1.3 |
| StDev | 0.2 | 0.4 | 0.3 | 0.2 | 0.8 | 1.0 | N/A | n=1 | N/A | 0.2 | n=1 | 0.2 | n=0 | n=0 | 0.6 |
| *Rapid Maximum Depth* | | | | | | | | | | | | | | | |
| Mean | n=0 | 4.6 | n=0 | 3.8 | n=0 | 5.0 | N/A | n=0 | N/A | n=0 | 5.8 | 2.9 | 2.9 | 3.5 | 3.5 |
| StDev | n=0 | 0.6 | n=0 | 0.4 | n=0 | n=1 | N/A | n=0 | N/A | n=0 | 1.8 | 0.3 | 0.5 | 0.6 | 1.1 |
| *Rapid Average Depth* | | | | | | | | | | | | | | | |
| Mean | n=0 | 2.0 | n=0 | 2.0 | n=0 | 3.0 | N/A | n=0 | N/A | n=0 | 2.0 | 1.7 | 1.5 | 1.3 | 1.7 |
| StDev | n=0 | n=1 | n=0 | 0.0 | n=0 | n=1 | N/A | n=0 | N/A | n=0 | n=1 | 0.4 | 0.5 | 1.3 | 0.5 |
| *Cascade Maximum Depth* | | | | | | | | | | | | | | | |
| Mean | n=0 | n=0 | n=0 | 7.0 | n=0 | n=0 | N/A | n=0 | N/A | n=0 | n=0 | 5.0 | n=0 | n=0 | 6.0 |
| StDev | n=0 | n=0 | n=0 | n=1 | n=0 | n=0 | N/A | n=0 | N/A | n=0 | n=0 | n=1 | n=0 | n=0 | 1.4 |
| *Cascade Average Depth* | | | | | | | | | | | | | | | |

| Reach | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reach Mileage Boundaries** | 23.3-24.0 | 25.0-25.6 | 25.6-26.1 | 26.1-27.15 | 27.15-27.7 | 27.7-28.25 | 28.25-29.3 | 29.3-29.85 | 29.85-30.2 | 30.2-31.4 | 31.4-31.9 | 31.9-32.9 | 32.9-33.2 | 33.2-33.8 | 23.3-33.8 |
| Mean | n=0 | n=0 | n=0 | 3.0 | n=0 | n=0 | N/A | n=0 | N/A | n=0 | n=0 | 3.0 | n=0 | n=0 | 3.0 |
| StDev | n=0 | n=0 | n=0 | n=1 | n=0 | n=0 | N/A | n=0 | N/A | n=0 | n=0 | n=1 | n=0 | n=0 | 0.0 |
| *Side-Channel Maximum Depth* | | | | | | | | | | | | | | | |
| Mean | 1.8 | n=0 | 2.3 | 2.1 | 4.2 | 1.4 | N/A | n=0 | N/A | 1.9 | n=0 | 0.6 | n=0 | 1.8 | 2.0 |
| StDev | 1.3 | n=0 | 2.5 | 1.7 | 1.0 | n=1 | N/A | n=0 | N/A | 1.8 | n=0 | 0.3 | n=0 | 0.3 | 1.6 |
| **Bankfull Characteristics** | | | | | | | | | | | | | | | |
| *Width (ft)* | | | | | | | | | | | | | | | |
| Mean | 115.8 | 105.5 | 90.0 | 113.5 | 95.0 | 87.0 | 70.0 | 80.0 | 90.0 | 77.0 | 100.0 | 93.5 | 81.0 | 94.0 | 100.6 |
| StDev | 15.5 | 17.7 | n=1 | 19.1 | n=1 | n=1 | n=1 | n=1 | n=1 | n=1 | n=1 | 16.3 | n=1 | n=1 | 18.3 |
| *Average Depth (ft)* | | | | | | | | | | | | | | | |
| Mean | 3.3 | 4.8 | N/A | 3.9 | 4.6 | 4.3 | N/A | N/A | N/A | 3.6 | 3.0 | 4.1 | 4.7 | 4.5 | 3.8 |
| StDev | 0.7 | 0.4 | N/A | 0.3 | n=1 | n=1 | N/A | N/A | N/A | n=1 | n=1 | 1.3 | n=1 | n=1 | 0.8 |
| *Maximum Depth (ft)* | | | | | | | | | | | | | | | |
| Mean | 4.3 | 6.0 | N/A | 4.8 | 5.0 | 6.2 | N/A | N/A | N/A | 3.8 | 3.8 | 5.3 | 5.5 | 5.0 | 4.8 |
| StDev | 1.1 | 0.2 | N/A | 0.3 | n=1 | n=1 | N/A | N/A | N/A | n=1 | n=1 | 1.0 | n=1 | n=1 | 1.0 |
| *Width:Depth Ratio* | | | | | | | | | | | | | | | |
| Mean | 35.6 | 22.4 | N/A | 29.7 | 20.7 | 20.4 | N/A | N/A | N/A | 21.6 | 33.0 | 24.8 | 17.4 | 20.7 | 28.6 |
| StDev | 7.1 | 5.4 | N/A | 7.0 | n=1 | n=1 | N/A | N/A | N/A | n=1 | n=1 | 11.8 | n=1 | n=1 | 8.7 |
| *Floodprone Width* | | | | | | | | | | | | | | | |

| **Reach** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reach Mileage Boundaries** | 23.3-24.0 | 25.0-25.6 | 25.6-26.1 | 26.1-27.15 | 27.15-27.7 | 27.7-28.25 | 28.25-29.3 | 29.3-29.85 | 29.85-30.2 | 30.2-31.4 | 31.4-31.9 | 31.9-32.9 | 32.9-33.2 | 33.2-33.8 | 23.3-33.8 |
| *(ft)* | | | | | | | | | | | | | | | |
| Mean | 487.5 | 165.0 | 350.0 | 172.5 | 450.0 | 300.0 | 100.0 | 140.0 | 120.0 | 390.0 | 260.0 | 182.5 | 150.0 | 150.0 | 332.0 |
| StDev | 186.6 | 63.6 | n=1 | 74.2 | n=1 | n=1 | n=1 | n=1 | n=1 | n=1 | n=1 | 95.5 | n=1 | n=1 | 191.5 |
| **Habitat Area %** | | | | | | | | | | | | | | | |
| *Pool* | 21 | 17 | 24 | 12 | 7 | 7 | 15 | 6 | 19 | 13 | 8 | 7 | 12 | 8 | 12 |
| *Glide* | 29 | 4 | 0 | 6 | 0 | 0 | N/A | 0 | N/A | 0 | 0 | 0 | 0 | 0 | 4 |
| *Riffle* | 36 | 22 | 75 | 58 | 70 | 86 | 83 | 94 | 81 | 74 | 52 | 43 | 0 | 0 | 56 |
| *Rapid* | 0 | 57 | 0 | 6 | 0 | 6 | N/A | 0 | N/A | 0 | 40 | 44 | 88 | 87 | 21 |
| *Cascade* | 0 | 0 | 0 | 12 | 0 | 0 | N/A | 0 | N/A | 0 | 0 | 3 | 0 | 0 | 2 |
| *Side Channel* | 14 | 0 | 1 | 7 | 22 | 1 | 1 | 0 | N/A | 10 | 0 | 4 | 0 | 6 | 6 |
| *Braided* | 0 | 0 | 0 | 0 | 0 | 0 | N/A | 0 | N/A | 3 | 0 | 0 | 0 | 0 | 0 |
| **Pools** | | | | | | | | | | | | | | | |
| *Pools per mile* | 6.7 | 5.8 | 3.9 | 7.1 | 5.0 | 5.2 | 9.9 | 1.9 | 8.5 | 5.7 | 5.8 | 6.8 | 10.1 | 6.1 | 6.4 |
| *Residual Depth (% of pools)* | | | | | | | | | | | | | | | |
| Pools < 3 ft | 50 | 60 | 50 | 29 | 33 | 0 | N/A | 0 | N/A | 57 | 67 | 71 | 67 | 33 | 49 |
| Pools 3-6 ft | 25 | 0 | 50 | 57 | 67 | 100 | N/A | 100 | N/A | 43 | 33 | 29 | 0 | 33 | 38 |
| Pools 6-9 ft | 25 | 40 | 0 | 14 | 0 | 0 | N/A | 0 | N/A | 0 | 0 | 0 | 33 | 33 | 13 |
| Pools 9-12 ft | 0 | 0 | 0 | 0 | 0 | 0 | N/A | 0 | N/A | 0 | 0 | 0 | 0 | 0 | 0 |
| *Riffle:Pool Ratio* | 0.6 | 0.7 | 0.7 | 0.8 | 0.8 | 0.8 | 1.0 | 0.5 | 0.6 | 0.9 | 0.8 | 0.6 | 1.0 | 1.0 | 0.8 |

| Reach | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reach Mileage Boundaries** | 23.3-24.0 | 25.0-25.6 | 25.6-26.1 | 26.1-27.15 | 27.15-27.7 | 27.7-28.25 | 28.25-29.3 | 29.3-29.85 | 29.85-30.2 | 30.2-31.4 | 31.4-31.9 | 31.9-32.9 | 32.9-33.2 | 33.2-33.8 | 23.3-33.8 |
| *Mean Pool Spacing (bankfull channel widths per pool)* | 9 | 10 | 15 | 8 | 12 | 11 | 6 | 31 | 7 | 10 | 10 | 9 | 6 | 10 | 9 |
| **Large Wood** | | | | | | | | | | | | | | | |
| *Total Number Pieces* | | | | | | | | | | | | | | | |
| *Total* | 55 | 42 | 44 | 89 | 58 | 50 | N/A | 63 | N/A | 233 | 30 | 108 | 20 | 58 | 850 |
| Large (20 in by 35 ft) | 12 | 5 | 9 | 8 | 5 | 9 | N/A | 2 | N/A | 48 | 6 | 14 | 6 | 7 | 131 |
| Medium (12 in x 35 ft) | 17 | 12 | 6 | 19 | 13 | 12 | N/A | 8 | N/A | 65 | 10 | 23 | 4 | 17 | 206 |
| Small (6 in x 20 ft) | 26 | 25 | 29 | 62 | 40 | 29 | N/A | 53 | N/A | 120 | 14 | 71 | 10 | 34 | 513 |
| *Number of Pieces/Mile* | | | | | | | | | | | | | | | |
| *Total* | 74 | 49 | 85 | 80 | 98 | 87 | N/A | 119 | N/A | 189 | 58 | 104 | 67 | 89 | 83 |
| Small (6 in x 20 ft) | 35 | 29 | 56 | 55 | 67 | 50 | | 100 | | 97 | 27 | 69 | 34 | 52 | 50 |
| Medium (12 in x 35 ft) | 23 | 14 | 12 | 17 | 22 | 21 | 0 | 15 | 0 | 53 | 19 | 22 | 13 | 26 | 20 |
| Large (20 in by 35 ft) | 16 | 6 | 17 | 7 | 8 | 16 | 0 | 4 | 0 | 39 | 12 | 14 | 20 | 11 | 13 |
| **Bank Erosion** | | | | | | | | | | | | | | | |
| Total % Bank Erosion | 1.5 | 4.4 | 0.0 | 0.0 | 0.0 | 0.0 | N/A | N/A | N/A | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 |

| Reach | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reach Mileage Boundaries** | 23.3-24.0 | 25.0-25.6 | 25.6-26.1 | 26.1-27.15 | 27.15-27.7 | 27.7-28.25 | 28.25-29.3 | 29.3-29.85 | 29.85-30.2 | 30.2-31.4 | 31.4-31.9 | 31.9-32.9 | 32.9-33.2 | 33.2-33.8 | 23.3-33.8 |
| **Substrate (Ocular Estimate)** | | | | | | | | | | | | | | | |
| *Total* | | | | | | | | | | | | | | | |
| % Sand | 25 | 3 | 10 | 5 | 5 | 0 | N/A | N/A | N/A | 5 | 0 | 0 | 5 | 10 | 10 |
| % Gravel | 40 | 20 | 50 | 13 | 20 | 10 | N/A | N/A | N/A | 35 | 50 | 23 | 15 | 25 | 25 |
| % Cobble | 30 | 38 | 30 | 55 | 60 | 20 | N/A | N/A | N/A | 60 | 35 | 50 | 65 | 40 | 40 |
| % Boulder | 5 | 40 | 10 | 28 | 15 | 65 | N/A | N/A | N/A | 0 | 10 | 13 | 15 | 10 | 10 |
| % Bedrock | 0 | 0 | 0 | 0 | 0 | 5 | N/A | N/A | N/A | 0 | 5 | 15 | 0 | 15 | 15 |
| *Fast Water Units* | | | | | | | | | | | | | | | |
| % Sand | 30 | 5 | N/A | 0 | 10 | 0 | N/A | N/A | N/A | 0 | 0 | 0 | 0 | 10 | 10 |
| % Gravel | 20 | 10 | N/A | 15 | 20 | 10 | N/A | N/A | N/A | 30 | 70 | 15 | 20 | 30 | 30 |
| % Cobble | 50 | 15 | N/A | 70 | 50 | 20 | N/A | N/A | N/A | 70 | 20 | 60 | 60 | 50 | 50 |
| % Boulder | 0 | 70 | N/A | 15 | 20 | 70 | N/A | N/A | N/A | 0 | 10 | 15 | 20 | 10 | 10 |
| % Bedrock | 0 | 0 | N/A | 0 | 0 | 0 | N/A | N/A | N/A | 0 | 0 | 10 | 0 | 0 | 0 |
| *Slow Water Units* | | | | | | | | | | | | | | | |
| % Sand | 20 | 0 | 10 | 10 | 0 | 0 | N/A | N/A | N/A | 10 | 0 | 0 | 10 | 10 | 10 |
| % Gravel | 60 | 30 | 50 | 10 | 20 | 10 | N/A | N/A | N/A | 40 | 30 | 30 | 10 | 20 | 20 |
| % Cobble | 10 | 60 | 30 | 40 | 70 | 20 | N/A | N/A | N/A | 50 | 50 | 40 | 70 | 30 | 30 |
| % Boulder | 10 | 10 | 10 | 40 | 10 | 60 | N/A | N/A | N/A | 0 | 10 | 10 | 10 | 10 | 10 |
| % Bedrock | 0 | 0 | 0 | 0 | 0 | 10 | N/A | N/A | N/A | 0 | 10 | 20 | 0 | 30 | 30 |

| **Reach** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reach Mileage Boundaries** | 23.3-24.0 | 25.0-25.6 | 25.6-26.1 | 26.1-27.15 | 27.15-27.7 | 27.7-28.25 | 28.25-29.3 | 29.3-29.85 | 29.85-30.2 | 30.2-31.4 | 31.4-31.9 | 31.9-32.9 | 32.9-33.2 | 33.2-33.8 | 23.3-33.8 |
| **Vegetation** (% of sampled units in *100-ft wide zone averaged between both banks*) | | | | | | | | | | | | | | | |
| *Dominant Overstory Size Class* | | | | | | | | | | | | | | | |
| Mature Tree | 0 | 0 | 0 | 0 | 0 | 0 | N/A | N/A | N/A | 0 | 0 | 0 | 0 | 0 | 0 |
| Large Tree | 0 | 0 | 0 | 0 | 0 | 0 | N/A | N/A | N/A | 50 | 0 | 0 | 100 | 0 | 13 |
| Small Tree | 100 | 100 | 0 | 33 | 50 | 100 | N/A | N/A | N/A | 50 | 100 | 100 | 0 | 100 | 71 |
| Sapling/Pole | 0 | 0 | 0 | 33 | 50 | 0 | N/A | N/A | N/A | 0 | 0 | 0 | 0 | 0 | 8 |
| Shrub/Seedling | 0 | 0 | 100 | 33 | 0 | 0 | N/A | N/A | N/A | 0 | 0 | 0 | 0 | 0 | 8 |
| Grassland/Forb | 0 | 0 | 0 | 0 | 0 | 0 | N/A | N/A | N/A | 0 | 0 | 0 | 0 | 0 | 0 |
| No Vegetation | 0 | 0 | 0 | 0 | 0 | 0 | N/A | N/A | N/A | 0 | 0 | 0 | 0 | 0 | 0 |
| *Overstory Species Composition* | | | | | | | | | | | | | | | |
| Conifer (Undifferentiated) | 0 | 33 | 0 | 0 | 0 | 50 | N/A | N/A | N/A | 50 | 0 | 100 | 100 | 100 | 42 |
| Douglas Fir | 0 | 33 | 0 | 0 | 0 | 0 | N/A | N/A | N/A | 0 | 0 | 0 | 0 | 0 | 4 |
| Ponderosa Pine | 0 | 0 | 0 | 33 | 0 | 0 | N/A | N/A | N/A | 0 | 0 | 0 | 0 | 0 | 4 |
| Cedar | 0 | 0 | 0 | 0 | 0 | 50 | N/A | N/A | N/A | 50 | 50 | 0 | 0 | 0 | 13 |
| Spruce | 0 | 0 | 0 | 0 | 0 | 0 | N/A | N/A | N/A | 0 | 50 | 0 | 0 | 0 | 4 |
| Hardwood (Undifferentiated) | 0 | 0 | 0 | 67 | 0 | 0 | N/A | N/A | N/A | 0 | 0 | 0 | 0 | 0 | 8 |

| **Reach** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reach Mileage Boundaries** | 23.3-24.0 | 25.0-25.6 | 25.6-26.1 | 26.1-27.15 | 27.15-27.7 | 27.7-28.25 | 28.25-29.3 | 29.3-29.85 | 29.85-30.2 | 30.2-31.4 | 31.4-31.9 | 31.9-32.9 | 32.9-33.2 | 33.2-33.8 | 23.3-33.8 |
| Cottonwood | 100 | 33 | 100 | 0 | 100 | 0 | N/A | N/A | N/A | 0 | 0 | 0 | 0 | 0 | 25 |
| Alder | 0 | 0 | 0 | 0 | 0 | 0 | N/A | N/A | N/A | 0 | 0 | 0 | 0 | 0 | 0 |
| *Understory Species Composition* | | | | | | | | | | | | | | | |
| Conifer (Undifferentiated) | 0 | 0 | 0 | 33 | 0 | 0 | N/A | N/A | N/A | 0 | 50 | 33 | 0 | 0 | 12 |
| Douglas Fir | 0 | 0 | 0 | 0 | 0 | 50 | N/A | N/A | N/A | 0 | 0 | 0 | 0 | 0 | 4 |
| Ponderosa Pine | 0 | 0 | 0 | 0 | 0 | 0 | N/A | N/A | N/A | 0 | 0 | 0 | 0 | 0 | 0 |
| Cedar | 0 | 0 | 0 | 0 | 0 | 0 | N/A | N/A | N/A | 0 | 0 | 0 | 50 | 0 | 4 |
| Spruce | 0 | 0 | 0 | 0 | 0 | 0 | N/A | N/A | N/A | 0 | 50 | 0 | 0 | 0 | 4 |
| Hardwood (Undifferentiated) | 100 | 33 | 0 | 67 | 100 | 50 | N/A | N/A | N/A | 100 | 0 | 0 | 0 | 0 | 46 |
| Cottonwood | 0 | 0 | 100 | 0 | 0 | 0 | N/A | N/A | N/A | 0 | 0 | 0 | 0 | 0 | 4 |
| Alder | 0 | 67 | 0 | 0 | 0 | 0 | N/A | N/A | N/A | 0 | 0 | 67 | 50 | 100 | 27 |

# 4 Comparison to 1994 USFWS Survey

The USFWS conducted a Level II habitat survey of the mid-Entiat River in 1994 (the 1994 survey). That survey covered 21.8 miles of stream from the confluence of Preston Creek to Cottonwood Campground upstream of Entiat Falls. This covers the entire Stillwaters study area presented in this report (the 2012 survey). Reach breaks do not exactly coincide between the two efforts, so a reach-by-reach comparison is not possible. Some reaches of the 1994 survey are long and encompass several reaches from the current survey (Table 2). To compare the results of the two surveys, data from the current survey is re-organized and re-calculated to match the reaches of the previous survey.

***Table 2. Equivalent reaches and associated river miles for the 1994 and 2012 surveys.***

| Reach Comparisons | | | | |
|---|---|---|---|---|
| **1994 Survey Reach** | **Equivalent 2012 Survey Reaches** | **2012 River Miles** | **1994 Corrected Length (ft)** | **2012 Measured Length (ft)** |
| 2 | 0 through 5 | 23.1-28.0 | 29,172 | 23,302 |
| 3 | 6 | 28.0-29.3 | 7,069 | 6,428 |
| 4 | 7 through 9 | 29.3-31.4 | 13,859 | 11,191 |
| 5 | 10 through 13 | 31.4-33.8 | 11,566 | 13,189 |

Comparisons between the two habitat surveys allows for detection of changes in habitat characteristics over time. The two surveys cover somewhat different river lengths, and cannot be compared exactly with one another. In particular, Reach 2 of the 1994 survey covers more stream length than the 2012 survey, which excludes RM 24 to 25. Comparison between 1994 Reach 2 and 2012 reaches 0 through 5 should be assessed with consideration toward this difference in length. The other reaches cover similar lengths of river between the two surveys and can be compared more directly. In all, the comparison provides a relative way of assessing trends in habitat in the study area over the last 18 years.

Table 3 provides a comparison of habitat unit area for habitat units measured in both the 1994 and 2012 surveys. The 1994 survey did not measure side channel habitat, or differentiate steeper fast water units such as rapids or cascades. For both survey years, fast water units dominated habitat area. Riffle areas were fairly similar between the two years, with the 1994 survey recording slightly higher percentages in most reaches. The 2012 survey found far fewer glides. Pools were more abundant in the 2012 survey in all reaches. This may partially result from a difference in pool determination methods where the 1994 survey held pools to a standard of a minimum of 3 ft depth, while the 2012 survey counted all pool features with residual depth. In a review of all pool depths, holding the 2012 survey to the 1994 standards results in removal of only 2 pools from the 2012 survey, and would not significantly change the comparison.

***Table 3. Comparison of percent habitat areas for habitat units measured in both 1994 and 2012.***

| Habitat Unit Area Comparison | | | | | | | |
|---|---|---|---|---|---|---|---|
| **1994 Survey Reach** | **Equivalent 2012 Survey Reaches** | **1994 % Pool Area** | **2012 % Pool Area** | **1994 % Riffle Area** | **2012 % Riffle Area** | **1994 % Glide Area** | **2012 % Glide Area** |
| 2 | 0 through 5 | 1.9 | 14.8 | 73.8 | 69.4 | 21.9 | 7.9 |
| 3 | 6 | 5 | 15.2 | 82 | 83.0 | 12.8 | 0.0 |
| 4 | 7 through 10 | 2.1 | 10.9 | 89.7 | 83.2 | 7.6 | 0.0 |
| 5 | 11 through 13 | 2.1 | 7.8 | 93.9 | 89.0 | 2.9 | 0.0 |

Table 4 provides a summary of pool characteristics compared between the two surveys. Pool frequency increased between 1994 and 2012 in all reaches. The differences were substantial in comparison of most reaches. The most dramatic increase was in Reach 2 (1994) where pools increased from less than 1 pool per mile in 1994 to 5.9 pools per mile in 2012. Residual depth had generally decreased in comparing values from 1994 to 2012.

***Table 4. Comparison of pool characteristics for the 1994 and 2012 habitat surveys.***

| 1994 Survey Reach | Equivalent 2012 Survey Reaches | 1994 Pools per mile | 2012 Pools per mile | 1994 Average Residual Pool Depth | 2012 Average Residual Pool Depth |
|---|---|---|---|---|---|
| 2 | 0 through 5 | 0.9 | 5.9 | 3.6 | 3.6 |
| 3 | 6 | 5.23 | 9.9 | 4.4 | N/A |
| 4 | 7 through 10 | 1.14 | 5.3 | 5.3 | 2.9 |
| 5 | 11 through 13 | 2.28 | 3.2 | 4.7 | 3.5 |

The results of comparison of bankfull channel measurements suggest the greatest changes are in bankfull depth. Though the 1994 report does not report bankfull depth explicitly, bankfull width-to-depth ratio is found to have decreased in all reaches by as much as 50%. Bankfull width increased in all reaches, substantially in Reach 2 (1994), therefore the depth must have increased to make the value of the ratio decrease. Reach 2 (1994) showed the greatest changes in bankfull channel characteristics.

***Table 5. Comparison of bankfull measurement between 1994 and 2012 habitat surveys.***

| 1994 Survey Reach | Equivalent 2012 Survey Reaches | 1994 Average Bankfull Width | 2012 Average Bankfull Width | 1994 Bankfull W/D Ratio | 2012 Bankfull W/D Ratio |
|---|---|---|---|---|---|
| 2 | 0 through 5 | 85 | 104 | 48 | 26 |
| 3 | 6 | 80 | 70 | 42 | N/A |
| 4 | 7 through 10 | 79 | 87 | 38 | 27 |
| 5 | 11 through 13 | 82 | 91 | 43 | 22 |

Total counts of LWM between the two survey years was substantially different with much greater wood counts in 2012 than in 1994. In all size class categories, wood counts in 2012 were greater than 1994.

***Table 6. Comparison of LWM counts between 1994 and 2012 habitat surveys.***

| 1994 Survey Reach | Equivalent 2012 Survey Reaches | 1994 LWM/ Mile | 2012 LWM/ Mile | 1994 Large (20 in 35 ft)/mile | 2012 Large (20 in 35 ft)/mile | 1994 Small (12 in 35 ft)/mile | 2012 Medium (12 in 35 ft)/mile | 1994 Brush (6 in 20 ft)/mile | 2012 Small (6 in 20 ft)/mile |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 0 through 5 | 23.2 | 73 | 2.5 | 10 | 6.9 | 17 | 13.8 | 45 |
| 3 | 6 | 32.1 | N/A | 3.7 | N/A | 9 | N/A | 19.4 | N/A |
| 4 | 7 through 10 | 39.2 | 143 | 5.7 | 25 | 14.5 | 36 | 19 | 82 |
| 5 | 11 through 13 | 35.6 | 55 | 6.4 | 8 | 11.9 | 13 | 17.3 | 34 |

These results suggest that habitat has generally been improving in the Upper Stillwater study area. Increased percent area and frequency of pools indicates more holding and juvenile rearing habitat available throughout the study area in comparison to 1994. The increase in total numbers and frequency of large wood is an indicator of greatly improved in-stream habitat in the study area. These features provide cover for multiple salmonid life-stages, help to sort and retain spawning gravels, and are mechanisms for scour pool creation.

# 5 Stream Habitat Reach Reports

## 5.1 REACH 0

Location: River mile 23.3 to 23.99 (Figure 9)

Survey Date: 9/7/2012

Survey Crew: Randy Goetz and Emily Alcott

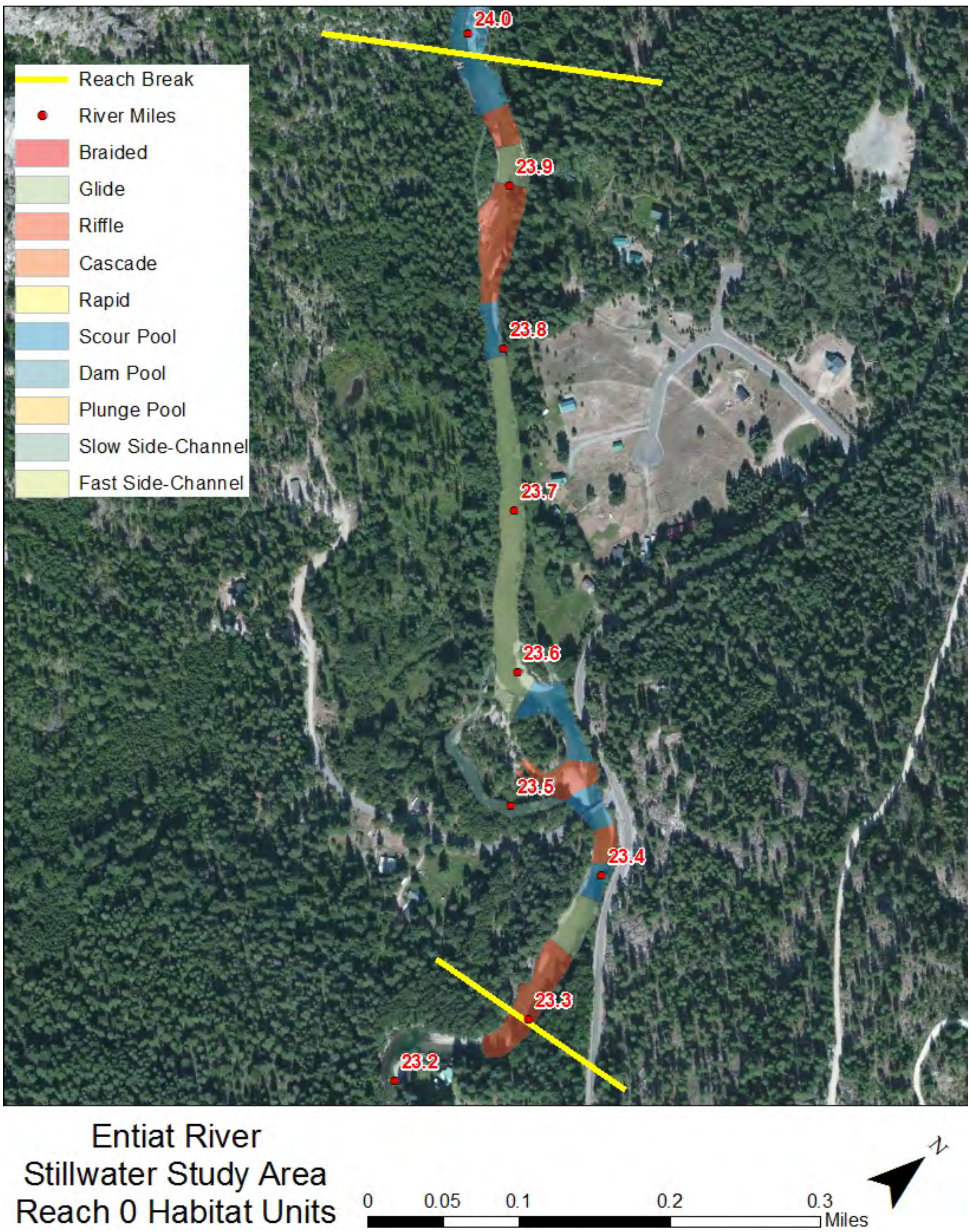


*Figure 9. Reach 0 habitat unit composition map.*

### 5.1.1 Habitat Unit Composition

Low gradient fast-water units (glides and riffles) comprised the majority of habitat units in Reach 0 with a total of 65% of the reach in fast water units (Figure 10). Reach 0 had the greatest percentage of glide habitat area in the study area at 29%. Most of this glide area is accounted for in a single long (1,200 ft) feature in the middle of the reach (Figure 11). Pools comprised 21% of the reach. In Reach 0, side channels composed the second highest portion of habitat in the study area at 14%. There were a total of 3 side channel units in the reach.

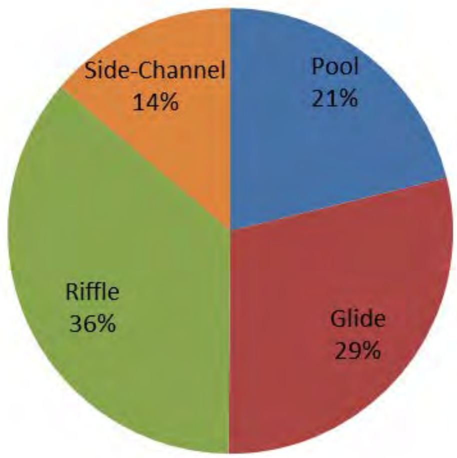


***Figure 10. Habitat unit composition for Reach 0.***

***Figure 11. Upstream view of a long glide in Reach 0. Note the mowed grass along the channel margin on the right side of the photo (river-left).***

### 5.1.2 Pool Habitat

High quality pool habitat was not prevalent in Reach 0. Of the five pools observed, two were created by hydraulic scour around hydromodifications; one near road embankment riprap and one under a bridge. These pools were shallow and lacked cover. The other three pools in the reach provided greater depth and cover habitat along the channel margin. None of them had large woody material in the channel to provide complexity. The upstream most pool was deepest and formed around several car-sized boulders, and over 20 adult salmonids were observed holding in the pool (Figure 12). Pools occurred with a frequency of 6.7 pools/mile at a mean spacing of 9 bankfull channel widths/pool. Average residual pool depth was 3.1 feet with a maximum residual depth of 6.7 ft.

***Figure 12. Deep pool located at the upstream extent of Reach 0 where a large number of adult salmonids were observed.***

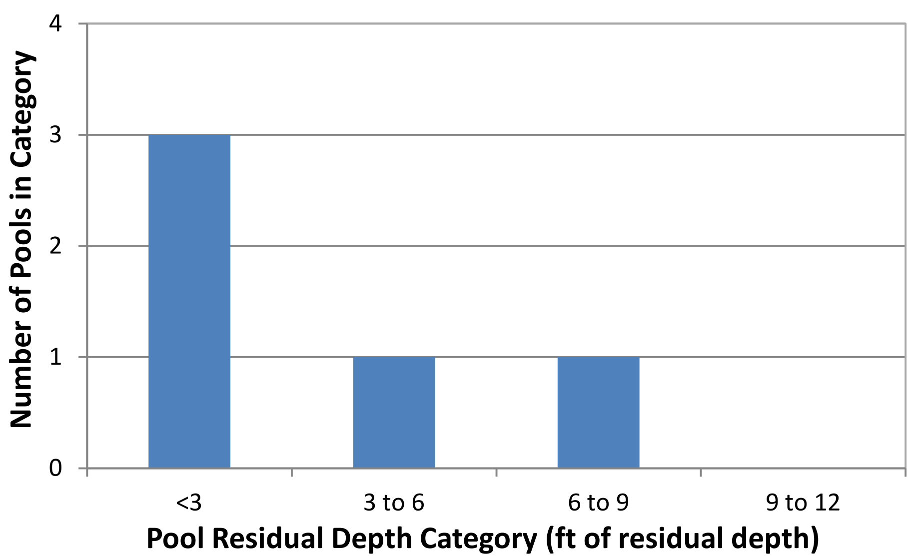


***Figure 13. Reach 0 residual pool depth and count of total pools in the reach.***

### 5.1.3 Off-Channel Habitat

Reach 0 had a significant amount of side channel habitat relative to other reaches in the Stillwater study area. Three slow-water side channels were observed with some portion of their lengths wetted and providing accessible habitat at the time of survey. They all show evidence of greater connectivity at higher flows.

The first side channel complex is located on river right between RM 23.5 to 23.6. At low flow, the channel mouth provides a deep backwater with open connection to the mainstem. There are a series of pools upstream that had poor connectivity at low flow, much appeared to be well connected at high flows. A large log jam is located at the inlet to the side channel with at least one other high flow channel forming a part of the off-channel complex.

***Figure 14. View looking upstream at a large side channel outlet near RM 23.6. A well-connected backwater is formed by the outlet.***

Directly across from the inlet to the first side channel is a short side channel centered on RM 23.6. The channel was fully connected during the time of survey. A small log jam controlled the upstream inlet, and the side channel flowed into a deep pool at its outlet. The third side channel was another short channel on river right centered on RM 23.9. The channel was much narrower, with less wetted lengths, and less habitat provided that the other two side channels at the time of survey.

### 5.1.4 Large Woody Material

LWM quantities were low in Reach 0. Reach 0 was below average in both the total number of pieces (55 total in Reach 0 with an average of 71 for the study area) and in the frequency of wood (74 pieces per mile in Reach 0 with an average of 83 pieces per mile for the study area) (Table 7). Small pieces comprised the majority of woody material at 47% of the total. Most of the woody material in the reach was found in riffles (87% of woody material).

***Table 7. Large woody material quantities in Reach 0.***

| | Small (6 in x 20 ft) | Medium (12 in x 35 ft) | Large (20 in x 35 ft) | Total |
|---|---|---|---|---|
| Number of Pieces | 26 | 17 | 12 | 55 |
| Number of Pieces/Mile | 35 | 23 | 16 | 74 |

### 5.1.5 Substrate and Fine Sediment

Bed substrate was primarily gravel (57%) with smaller portions of cobble and sand (14 and 22% respectively. Boulders made up about 7% and occurred mainly in one pool (Figure 15). Fine sediment in spawning areas (pool tails) was measured as part of the Columbia Habitat Monitoring Program (CHaMP) at 3 locations (using 3 measurement grids at each location) between RM 23.3 and 23.8 (sites 3C1, 3C2, and 3C3) between 2011 and 2012, and the results were posted to www.champmonitoring.org. The results are summarized in Figure 16. The results suggest that fine sediment in spawning gravels is low in the reach.

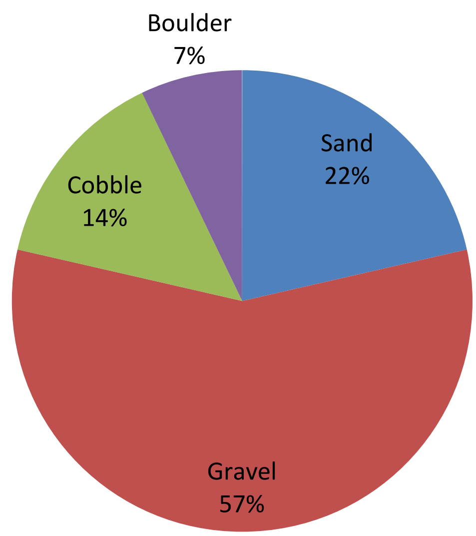


***Figure 15. Percent composition of bed substrate based on ocular estimates, Reach 0.***

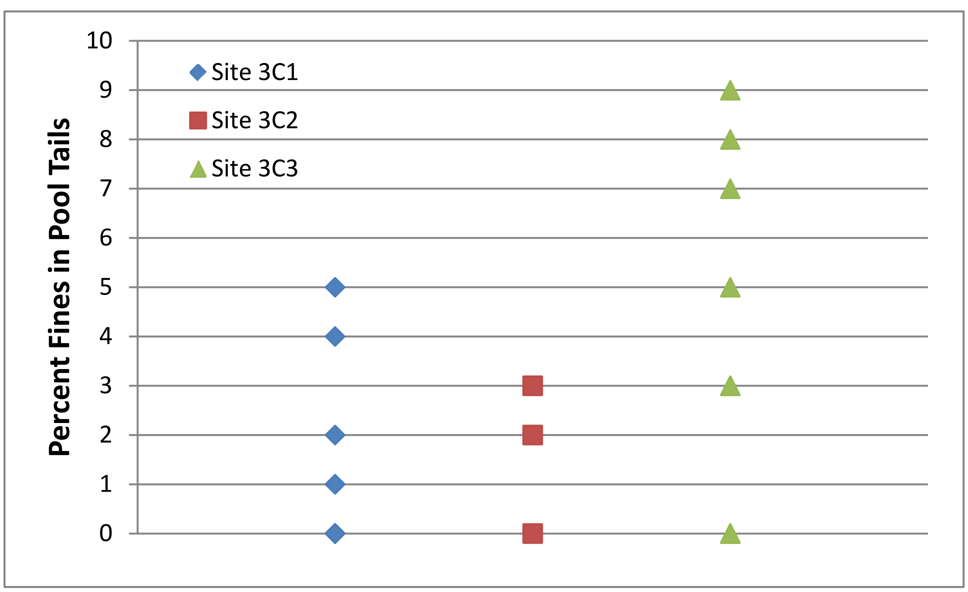


***Figure 16. Results of CHaMP measurement of fine sediment in spawning gravels at pool tails at 3 sites in Reach 0. Data from www.champmonitoring.com.***

### 5.1.6 Instability and Disturbance

Human activities have impacted the channel, floodplain, and associated riparian corridor within the reach. The primary elements of disturbance are associated with a few residential developments on river left. Houses are built on the floodplain with large areas cleared for yards. Along these areas, most vegetation has been cleared along the channel and there is evidence of bank erosion. There is about 60 ft of erosion along these cleared banks. A Bridge and river left road embankment create altered hydraulic conditions near the downstream end of the reach. There is scour underneath the bridge with deposition immediately downstream on river left. Just beyond that along the toe of the road embankment and its associated rip rap there is another location of scour.

### 5.1.7 Available Holding, Spawning, and Rearing Habitat

There was limited spawning and rearing habitat in Reach 0. Bed substrate was adequately sized, dominated by gravels (57%). Many of the side channels and pool tail-outs provide substrate for both Chinook (13-102 mm) and steelhead (6-102 mm). Coho may use the more protected side channels. Several large salmonids were observed holding in a deep pool, presumably using Reach 0 as a migration corridor to access habitat higher in the basin.

Pool habitat is present, and several of the pools provide adequate depth and cover, but there is not a large percentage of pools in the Reach’s habitat units. This reach provides some refugia in well-connected side channel habitats. LWM was present but in inadequate numbers, and normally not located in areas where it provides in-channel habitat.

### 5.1.8 Riparian Corridor

Reach 0 had a variable riparian corridor with some cleared areas and some areas with mature riparian vegetation cover. The majority of riparian clearing has taken place along river right in the downstream half of the reach where there are several houses, a bridge, and a road. Where the riparian corridor is undisturbed, the small tree size class is dominant (100%) in the overstory, and overstory species distribution is comprised mainly of Cottonwood trees (100%). Understory pieces are 100% undifferentiated hardwoods. Riparian vegetation provides moderate shade throughout the reach, mainly along the margins where there is overhanging vegetation.

## 5.2 REACH 1

Location: River Mile 24.97-25.6

Survey Date: 8/28/2012

Survey Crew: Randy Goetz, Jonathan Graca, and Gardner Johnston

### 5.2.1 Reach Overview

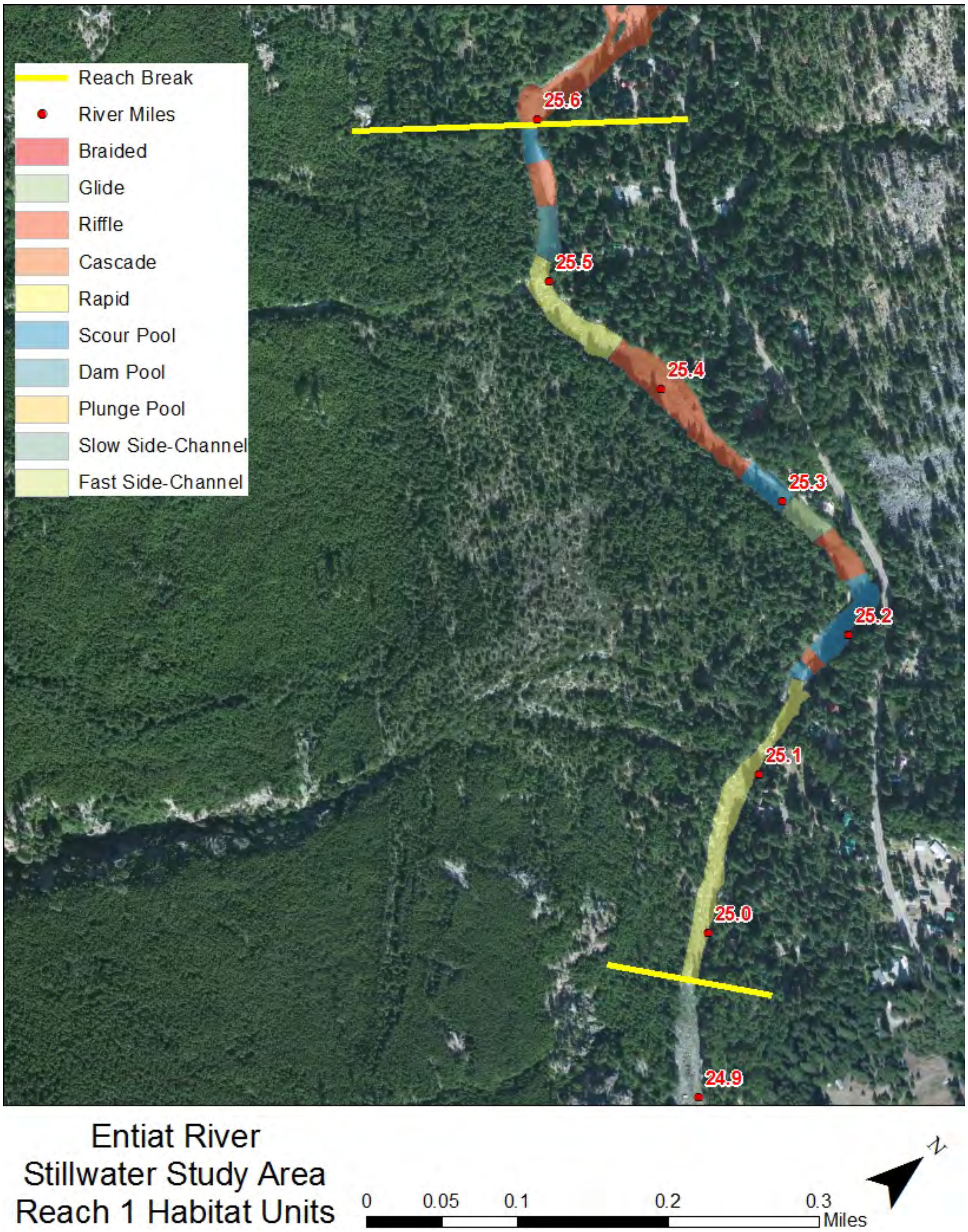


***Figure 17. Reach 1 habitat unit composition map.***

### 5.2.2 Habitat Unit Composition

Reach 1 was an overall high gradient reach with rapids comprising 57% of habitat area and another 22% of habitat in riffle units (Figure 18 and Figure 19). Glides provided 4% of habitat bringing the total area of fast water unit up to 83%. The remaining 17% of habitat area was found in pools with no side channel habitat in the reach.

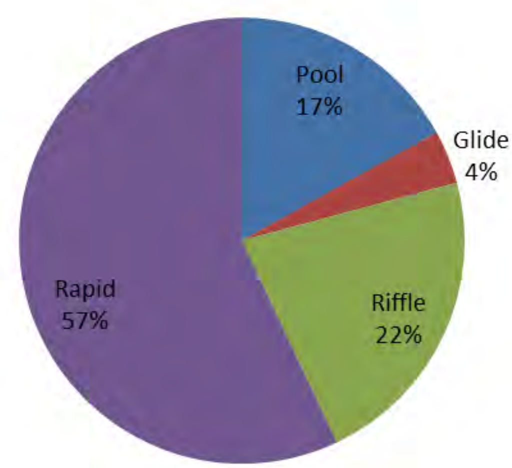


***Figure 18. Habitat unit composition for Reach 1.***

***Figure 19. Photo in Reach 1 looking downstream at a long rapid which is the dominant habitat in the reach.***

### 5.2.3 Pool Habitat

Despite the low overall habitat area provided by pools in Reach 1, frequency was 5.8 pools/mile, slightly greater than the study area average of 6.4 pools/mile. Mean pool spacing was 9 bankfull channel widths per pool. Average residual pool depth was 3.4 feet with a maximum residual depth value of 6.4 ft, and another pool with 6 ft of residual depth (Figure 20). Average maximum pool depth was 5.2 feet. Pool quality was moderate in this reach with three of the pools being rather shallow, and with little cover or complexity beside what is provided along the channel margins. There were two deep pools with significant residual depth (Figure 21).

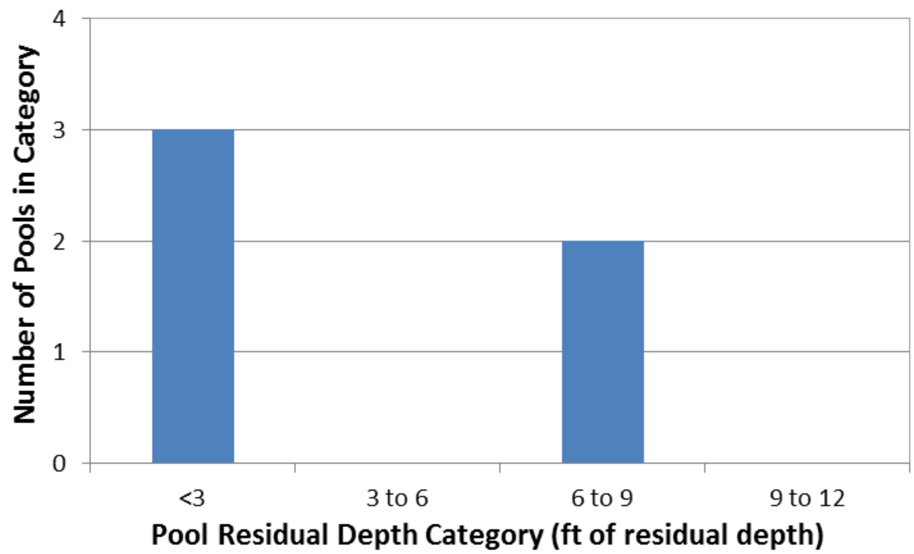


***Figure 20. Reach 1 residual pool depth, and total pool count for the reach.***

***Figure 21. Downstream looking photograph of a long, deep pool providing good holding habitat in Reach 1. The pool lacks cover.***

### 5.2.4 Side-Channel Habitat

Reach 1 had no side channel habitat.

### 5.2.5 Large Woody Material

LWM quantities were low in Reach 1 compared to other reaches in the study area. LWM frequency was 49 pieces/mile (the second lowest in the study area), with "small" pieces comprising 60% of all LWD counted in the reach (Table 8). "Medium" and "Large" wood pieces comprise 40% of the LWD in the reach, 29% and 12% respectively.

Recruitment potential of large woody material may be limited in the short-term as Reach 1 lacks channel complexity and off-channel habitats that aid in recruitment. Long-term LWD sources were available along most banks where there was healthy riparian vegetation and very little clearing.

***Table 8. Large woody debris quantities in Reach 1.***

| | Small (6 in x 20 ft) | Medium (12 in x 35 ft) | Large (20 in x 35 ft) | Total |
|---|---|---|---|---|
| Number of Pieces | 25 | 12 | 5 | 42 |
| Number of Pieces/Mile | 29 | 14 | 6 | 49 |

### 5.2.6 Substrate and Fine Sediment

Bed substrate was dominated by coarse material in Reach 1, primarily boulders (40%) and cobbles (38%) (Figure 22). The majority of boulders in the reach are found in the rapids which dominate the habitat unit composition. Gravels were subdominant with a 20% portion of the average bed composition. Much of the gravel in the reach was found in pool tail-outs at only a few locations. Fine sediment in spawning gravels has not been measured in Reach 1. However, in measured units, sand was found to be a minor constituent of bed material, and the consistently steep gradient and few pools limits to number of locations where fine sediment could accumulate in spawning gravel.

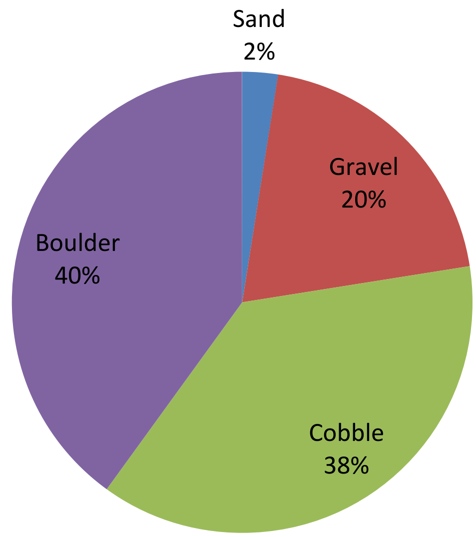


***Figure 22. Percent composition of bed substrate based on ocular estimates, Reach 1.***

### 5.2.7 Instability and Disturbance

Disturbance within the reach is mainly found along river left where there is residential development on the floodplain and terrace surfaces. Relatively little riparian clearing has taken place in association with this development, leaving the banks and channel margins protected. There is also a short section of river right that flow against a road embankment that is rip-rapped. Vertical stability is high given the large bed material found throughout the reach, as is lateral stability given the proximity of hill slopes and large material along the channel margins. The reach is in an area that has burned historically, but is not a part of the historically logged portion of the study area. The only direct evidence of instability is 200 ft of eroding bank. This is the largest total length of bank erosion in the study area, and is found mainly along the toe of a river left terrace in the downstream portion of the reach. There may be some land-clearing associated with this bank erosion as fence-lines, and other signs of riparian development were observed.

### 5.2.8 Available Holding, Spawning, and Rearing Habitat

The most available habitat in Reach 1 was holding habitat found in the pools of the reach. Two of these pools provide over 6 ft of residual depth. A lack of side channels, large wood complexes, and pool cover limit rearing habitat. Available spawning habitat is limited by the steep gradient and coarse bed material found throughout the reach. Many of the pool tail-outs contained cobbles (> 128 mm) that are larger than the ideal size for Chinook (i.e. 13 – 102 mm) and steelhead (6 – 102 mm) spawning (Bjornn and Reiser 1991). However, coarse bed material provides areas of localized velocity refuge that may be utilized during migration and by rearing juvenile steelhead. Mean riffle thalweg depth is greater than the 0.8-ft threshold cited for spring Chinook by Thompson (1972) at the time of this study (August 2012).

### 5.2.9 Riparian Corridor

Reach 1 has a forested riparian corridor with little recent clearing or other disturbance. There have been fires that burned in the riparian area historically, but vegetation appears to have recovered. Development on river left has had some impact in a few areas, mainly in the density of the understory.

Tree size in the riparian zone at measured locations along Reach 1 was dominated by the small tree size class. Over-story species composition consists primarily of conifers (67% total) with 33% of conifer species being Douglas Fir and the remaining 34% being undifferentiated mix of pine, fur, and cedar (Figure 23). Cottonwoods comprised 33% of the overstory. Understory vegetation was mainly hardwood species with most of that (67%) being alder, and the rest an undifferentiated mix (Figure 24).

The level of stream shade provided by the riparian canopy and local topography was moderate throughout Reach 1. The steeper sections tended to be narrower and were shaded to a larger degree by the overstory canopy and hill slopes. Glides and riffles tended to be wider, and less shaded by their respective riparian zones.

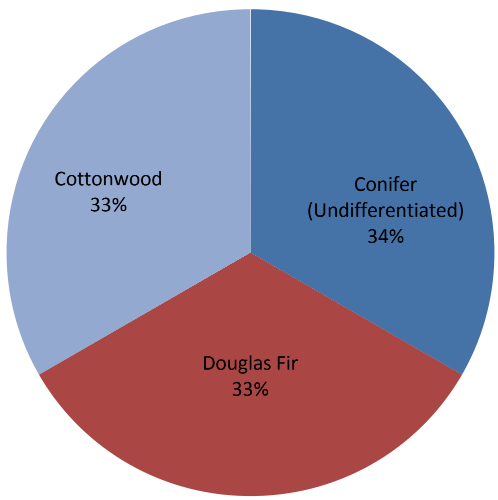


***Figure 23. Distribution of riparian species in the overstory of Reach 1.***

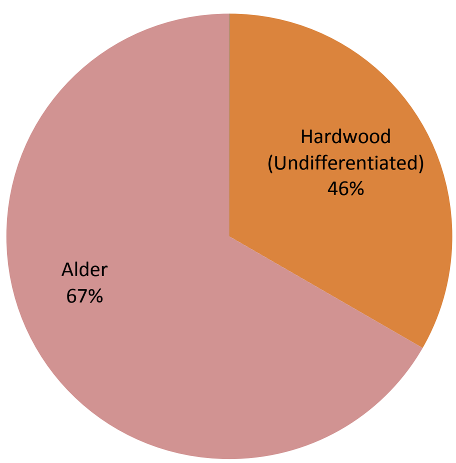


***Figure 24. Distribution of riparian species in the understory of Reach 1.***

## 5.3 REACH 2

Location: River Mile 25.6 to 26.05

Survey Date: 8/29/2012

Survey Crew: Randy Goetz and Jonathan Graca

### 5.3.1 Reach Overview

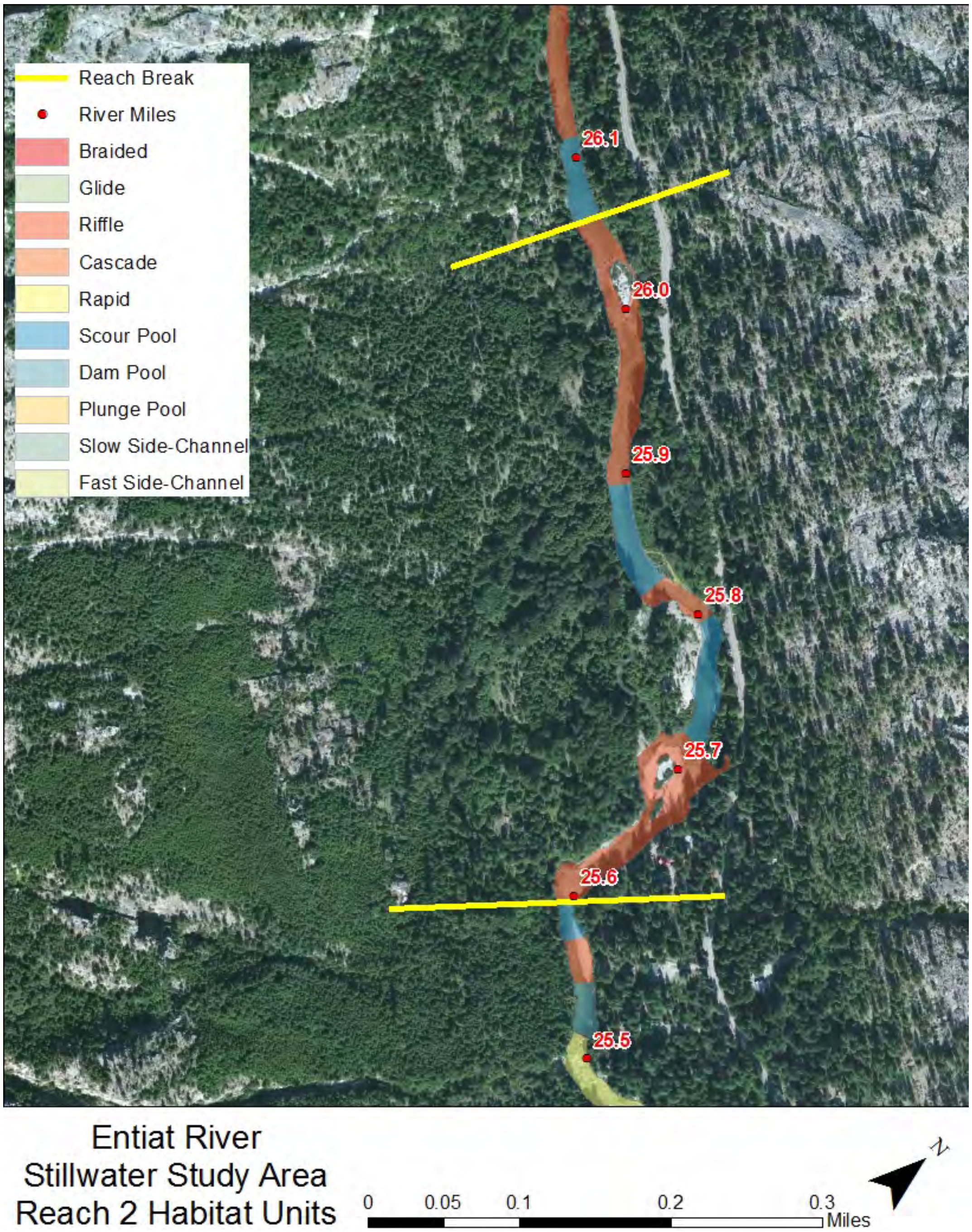


***Figure 25. Reach 2 habitat unit composition map.***

### 5.3.2 Habitat Unit Composition

Habitat in Reach 2 is mainly riffle-pool sequences with a small percentage of side channel habitats (Figure 26). The dominant habitat type is riffles, which compose 75% of the habitat in the reach (Figure 27). Pool habitat provides 24% of the total habitat in the reach which is the largest percentage of pool habitat in any reach in the study area. This high percentage of pool habitat is provided by only 2 pools. However, these are by far the longest pools in the study area, with an average length of 371.5 ft.

***Figure 26. Upstream view of a typical riffle-pool sequence. There is a side channel outlet near the center of the photograph.***

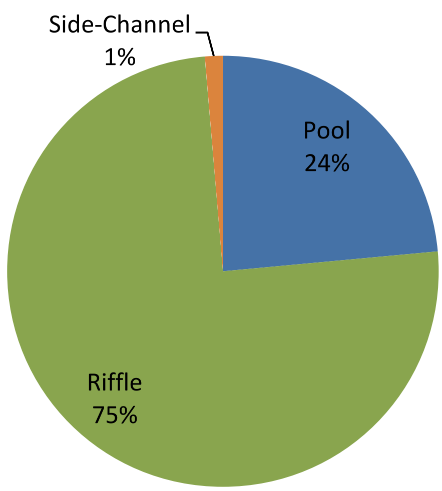


***Figure 27. Habitat unit composition, Reach 2.***

### 5.3.3 Pool Habitat

Though pool habitat makes a large percentage of overall habitat types in the reach, pool frequency is low with 3.9 pools/mile. This is well below the study area average of 6.4 pools/mile. Mean pool spacing is 15 bankfull channel widths/pool, which is longer than the study area average of 9 bankfull channel widths/pool. Average residual pool depth was 3.7 feet with a maximum residual depth of 5.2 ft (Figure 28). Average maximum pool depth was 5.1 feet. These data suggest that pools in Reach 2 are general long and widely spaced with moderate depth (Figure 29).

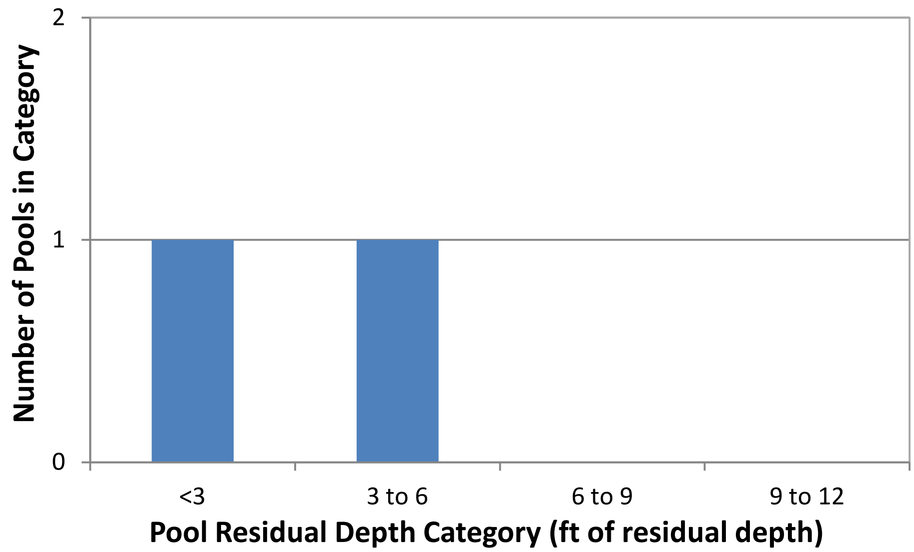


***Figure 28. Reach 2 residual pool depths and total count of pools.***

***Figure 29. Upstream view of a long pool in Reach 2.***

### 5.3.4 Off-Channel Habitat

There were two side channels in Reach 2, comprising 1% of the total habitat area. Side-channels were small with a maximum average width of 5 ft, and were mainly dry at the time of survey with wetted portions near their outlets.

The main side channel complex is on river right between RM 25.7 and 25.85 (Figure 30). This side channel provides a small backwater alcove at its outlet, fed by hyporheic flow from upstream. The channel was dry for most of its length, but was well-defined and is likely wetted and flowing during annual high flow periods. The channel is located around a stable island vegetated by large conifers and hardwoods. The second side channel unit is a short high flow channel located on river left, and centered on RM 25.85. This channel is relatively steep over its entire length, and does not provide low flow habitat. At high flow, the channel may provide good refuge for juvenile and adults in the reach.

***Figure 30. The outlet to the main side channel complex in Reach 2 near RM 25.7.***

### 5.3.5 Large Woody Material

LWM quantities are low in Reach 2 in terms of total number of pieces (44 pieces) (Table 9). However, wood density is relatively high at 85 pieces/mile, which is just above the study area average of 83 pieces/mile. Small pieces are the most commonly observed size class comprising 66% of all woody material counted in the reach. “Medium” and “Large” wood pieces comprise 34% of the LWM in the reach, 14% and 20% respectively. LWM recruitment potential is moderate in both in the short and long-term. Side-channel habitats are areas with potential for recruit of large quantities of woody material. Channel margin vegetation includes mature conifers and cottonwoods, as well as several leaning snags (Figure 31).

***Table 9. Large woody material quantities in Reach 2.***

| | Small (6 in x 20 ft) | Medium (12 in x 35 ft) | Large (20 in x 35 ft) | Total |
|---|---|---|---|---|
| Number of Pieces | 29 | 6 | 9 | 44 |
| Number of Pieces/Mile | 56 | 17 | 7 | 85 |

***Figure 31. Upstream view of channel margin vegetation including large conifers and cottonwoods, as well as snags that will provide a source of LWM in the future.***

### 5.3.6 Substrate and Fine Sediment

Bed substrate in Reach 2 is composed mainly of gravel, having 50% of the bed distribution according to ocular estimates (Figure 32). Cobble is sub-dominant with a 30% portion of the composition of bed material. Boulders and sand comprise the remaining 20% of the bed with 10% each. Fine sediment in spawning areas (pool tails) was measured in 2012 as part of CHaMP at 1 location (site 3F2, using 3 measurement grids at that location) near RM 25.8. The results were posted to www.champmonitoring.org, and are summarized here in Figure 33. Percent fines (<2mm) were low ranging from 0-2%.

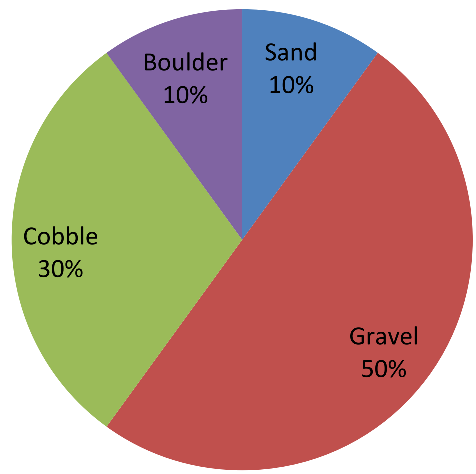


***Figure 32. Percent composition of bed substrate based on ocular estimates, Reach 2.***

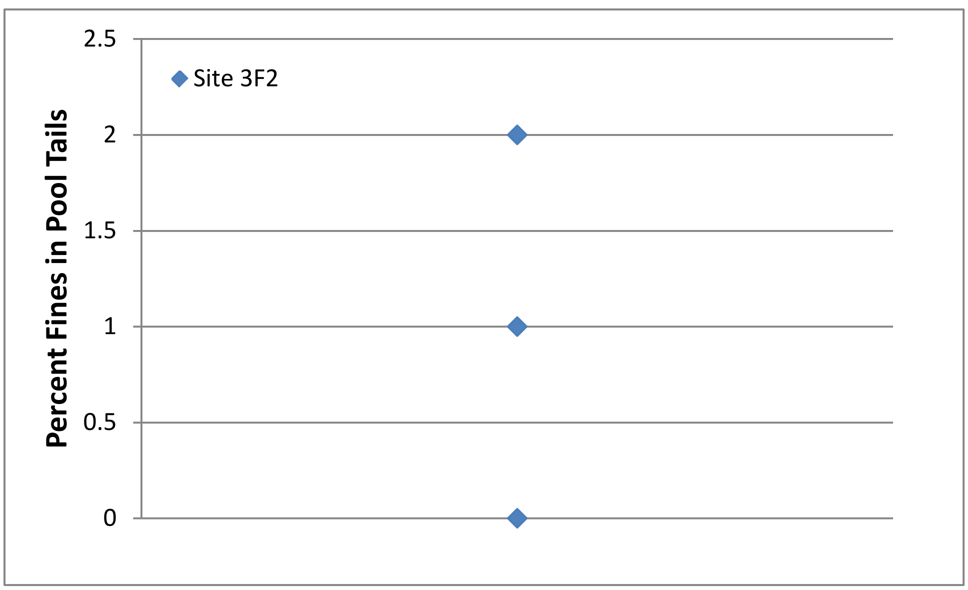


***Figure 33. Results of CHaMP measurement of fine sediment in a pool tail at site 3F3 in Reach 2. Fine sediment was low in this location. Data from www.champmonitoring.org.***

### 5.3.7 Instability and Disturbance

Overall disturbance is very low in Reach 2, with human activity in the river corridor limited small residential development on river left near the downstream end of the reach, and one location where the road embankment forms the channel margin for a short distance on river left near RM 25.8. No anthropogenically destabilized banks were observed. The dominance of gravel in the composition of the stream bed indicates that bed mobility and vertical stability may be somewhat lower in this reach compared to boulder-bed reaches downstream. Lateral stability is held by stable, well-vegetated banks, and close proximity of the hill slope along river left.

### 5.3.8 Available Holding, Spawning, and Rearing Habitat

Widely spaced pools limit the amount of holding habitat offered. Though one of the pools is of substantial residual depth, cover and complexity are low in both pools. Side-channel units provide high flow refuge for migrating and holding adults and also for rearing juveniles. However, these side channels are seasonal in their access and the amount of habitat they provide. Bed substrate was dominated by gravel (50%) which is favorable for spawning, but there are limited pool tail outs that would be the most likely places for spawning to occur.

### 5.3.9 Riparian Corridor

The riparian corridor is intact in Reach 2. Aside from minimal clearing near some residences at the downstream end of the reach, there is no recent disturbance to the reach. It is within a historically burned area, but not a part of the area that is mapped as historically logged. Currently, the dominant overstory size class is shrub/seedling. Near the channel there are wide bars and some floodplain area that is dominated by this size class. Farther from the channel there are larger conifers and cottonwoods. The overstory species distribution is given over 100% to cottonwoods. The understory is also completely dominated by cottonwood. The uniformity of the over and understory species composition is not surprising given the young age class of the observed riparian zone.

The level of stream shade provided by the riparian canopy was moderate throughout Reach 2. Local topography (close proximity to hill slopes on both sides of the valley) and mature trees provided ample morning and afternoon shade in narrower portions of the reach. In areas with active bars or split flow, small trees dominate the riparian area and shade is reduced.

## 5.4 REACH 3

Location: River mile 26.05-27.15

Survey Date: 8/29/2012

Survey Crew: Randy Goetz and Jonathon Graca

### 5.4.1 Reach Overview

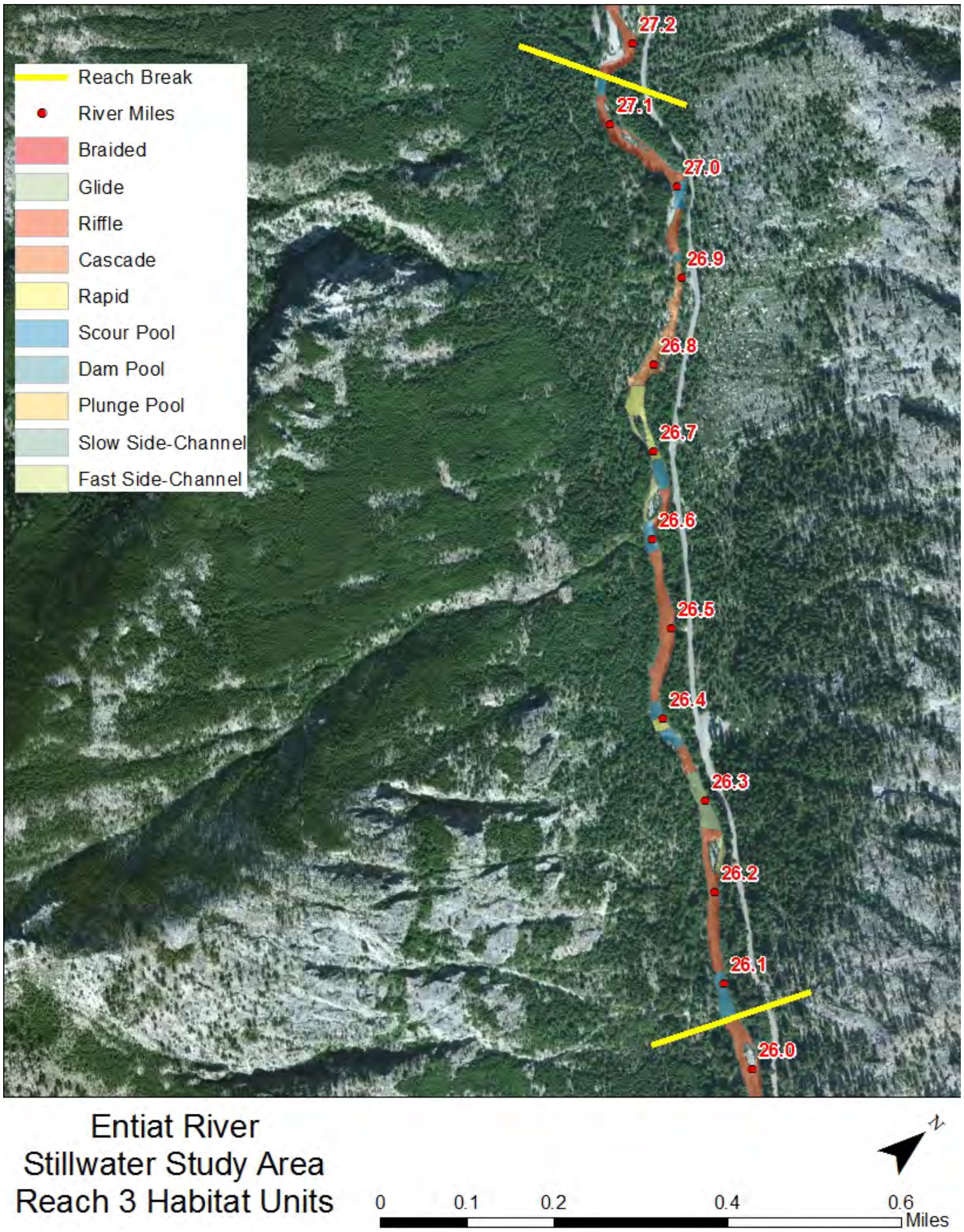


***Figure 34. Reach 3 habitat unit composition map.***

### 5.4.2 Habitat Unit Composition

Fast-water units make-up 82% of habitat in Reach 3 with riffles being the dominant fast-water unit at 58 of the total habitat composition. Cascades comprise 12% of habitat in the reach and rapids and glides each provide 6%. Pools and side channels, critical to habitat requirements for salmonids, provide only 12 and 6% of the habitat respectively.

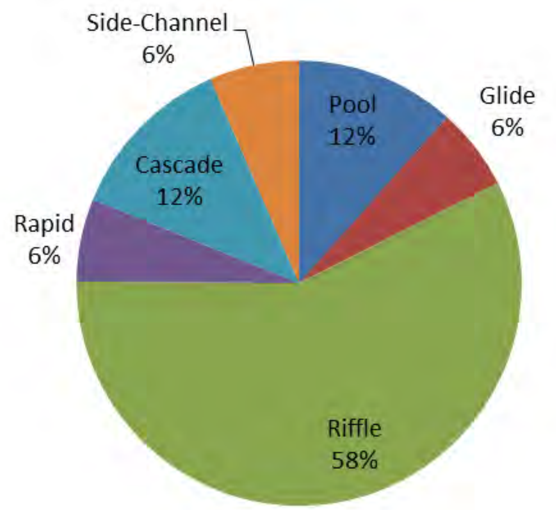


***Figure 35. Habitat unit composition, Reach 3.***

### 5.4.3 Pool Habitat

Despite the low overall area of pool habitat, Reach 3 provides the third highest pool frequency in the study area at 7.1 pools/mile. This is above the study area average of 6.4 pools/mile. Pool spacing is 8 bankfull widths per pool, the third lowest spacing in the study area. Pool length, at 98.8 ft, was amongst the shortest in the study area. Reach 3 had the second highest count of individual pools in the study area with eight total. Residual depth was over 3 ft in six of the eight pools, and over six feet in one of the pools (Figure 36, Figure 37). The average maximum depth at the time of survey was 5.5 ft, with two pools measuring at least 8 ft of maximum depth. These results suggest Reach 3 provides frequent pools with sufficient residual depth for holding and rearing habitat.

*Figure 36. Photograph of a deep scour pool near RM 26.4 formed by several very large boulders obstructing the channel.*

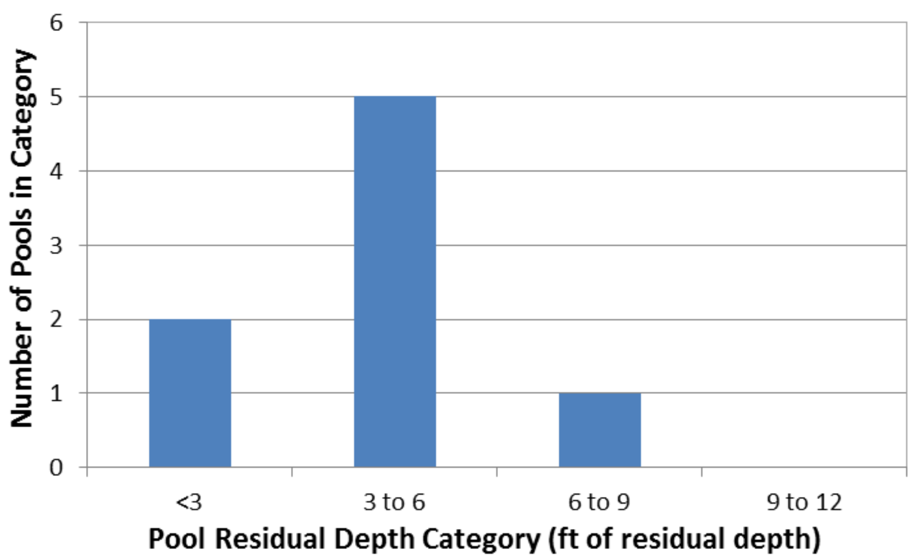


*Figure 37. Reach 3 residual pool depths and total pool count.*

### 5.4.4 Off-Channel Habitat

Reach 3 has four side channel units providing 6% of the total habitat in the reach. Average side channel length was about 300 ft. Side-channels in Reach 3 are mainly fast-water, essentially forming at locations of split flow of the main channel around stable, well-vegetated islands (Figure 38). All the side channels are well-connected and flow perennially. These units provide habitat similar to the main channel in terms of velocity, cover, and substrate. The upstream-most side channel near RM 27.1 is the only slow side channel, providing some velocity refuge and increased cover habitat due to its narrow width.

***Figure 38. Upstream view of the outlet of a fast side channel unit.***

### 5.4.5 Large Woody Material

LWM quantities were low to moderate in Reach 3, compared to other reaches in the study area. LWM frequency was 80 pieces/mile, with "small" pieces comprising 70% of all LWM counted in the reach (Table 10). "Medium" and "large" wood pieces comprise 30% of the LWM in the reach, 21% and 9% respectively.

LWM recruitment potential was moderate to high within this reach. There are several locations of split flow around islands with large conifer and cottonwoods established. A high flow event could destabilize these locations and capture a large number of medium to large pieces of wood. There are also several alluvial fans and close hill slopes that could deliver wood via colluvial processes.

***Table 10. Large woody material quantities in Reach 3.***

| | Small (6 in x 20 ft) | Medium (12 in x 35 ft) | Large (20 in x 35 ft) | Total |
|---|---|---|---|---|
| Number of Pieces | 62 | 19 | 8 | 89 |
| Number of Pieces/Mile | 55 | 17 | 7 | 80 |

### 5.4.6 Substrate and Fine Sediment

Bed substrate was dominated by large cobble and boulders. Cobble was dominant, comprising 55% of the total bed composition, and boulders were sub-dominant with 28% of the total bed composition (Figure 39). Give the steep gradient of the reach and the prevalence of riffles and cascades, this coarse distribution would be expected. Fine sediment in spawning gravels has not been measured in this reach, though ocular estimates conclude that material smaller than 2 mm (sand) was present at about 5% of the total bed composition. The overall steep gradient maintain sand transport in most hydraulic environments in the reach.

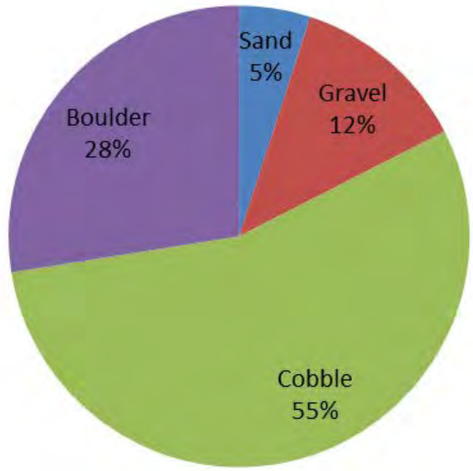


***Figure 39. Percent composition of bed substrate based on ocular estimates, Reach 3.***

### 5.4.7 Instability and Disturbance

Human development is minimal in Reach 3. The Entiat River Road is the only human feature in the reach, and it is confined to the toe of the hill slope. The location of the road does not appear to effect river processes in this reach. There was no anthropogenically induced bank erosion observed in this reach, and no evidence to suggest disequilibrium conditions. Large bed material provides vertical stability in terms of channel incision. The reach is laterally confined with low potential for lateral instability.

### 5.4.8 Available Holding, Spawning, and Rearing Habitat

Reach 3 is likely to be best suited for adult holding. There are multiple deep pools with relatively short spacing. Reach 3 pool frequency would be considered “not properly functioning” based on USFWS (1998). These pools lack cover, but provide sufficient residual depth for holding. Adult bull trout and steelhead utilize these deep scour pools throughout the summer and winter. Juvenile salmonid mobility may be limited due to the very steep gradient, which produces rapids and cascades. Substrate within Reach 3 is very coarse (ocular estimates only), dominated by cobbles and boulders and limited in appropriate spawning material. Side-channels, which are basically split flow in the main channel, provide limited variability in hydraulic environments that would support juvenile rearing. However, juvenile steelhead may use the fast water side channels for rearing.

### 5.4.9 Riparian Corridor

The riparian corridor is continuous and intact in Reach 3, with no floodplain clearing or development apparent. The Entiat River Road corridor is a location of vegetation removal, but its location on the hillslope has limited effect on the riparian zone.

The size class composition of riparian vegetation was equally divided amongst small tree, sapling/pol, and shrub/seedling. In terms of species composition, the overstory was composed of dominantly undifferentiated hardwood species (67%) and Ponderosa Pine (33%). The understory was also dominated by hardwood species (67% of an undifferentiated mix) and undifferentiated conifers making up the remaining 33%).

The level of stream shade provided by the riparian canopy was moderate throughout Reach 3. Local topography (close proximity to hill slopes on both sides of the valley) and mature trees provided ample morning and afternoon shade in narrower portions of the reach.

## 5.5 REACH 4

Location: River mile 27.15 to 27.7

Survey Date: 8/30/2012

Survey Crew: Randy Goetz and Jonathan Graca

### 5.5.1 Reach Overview

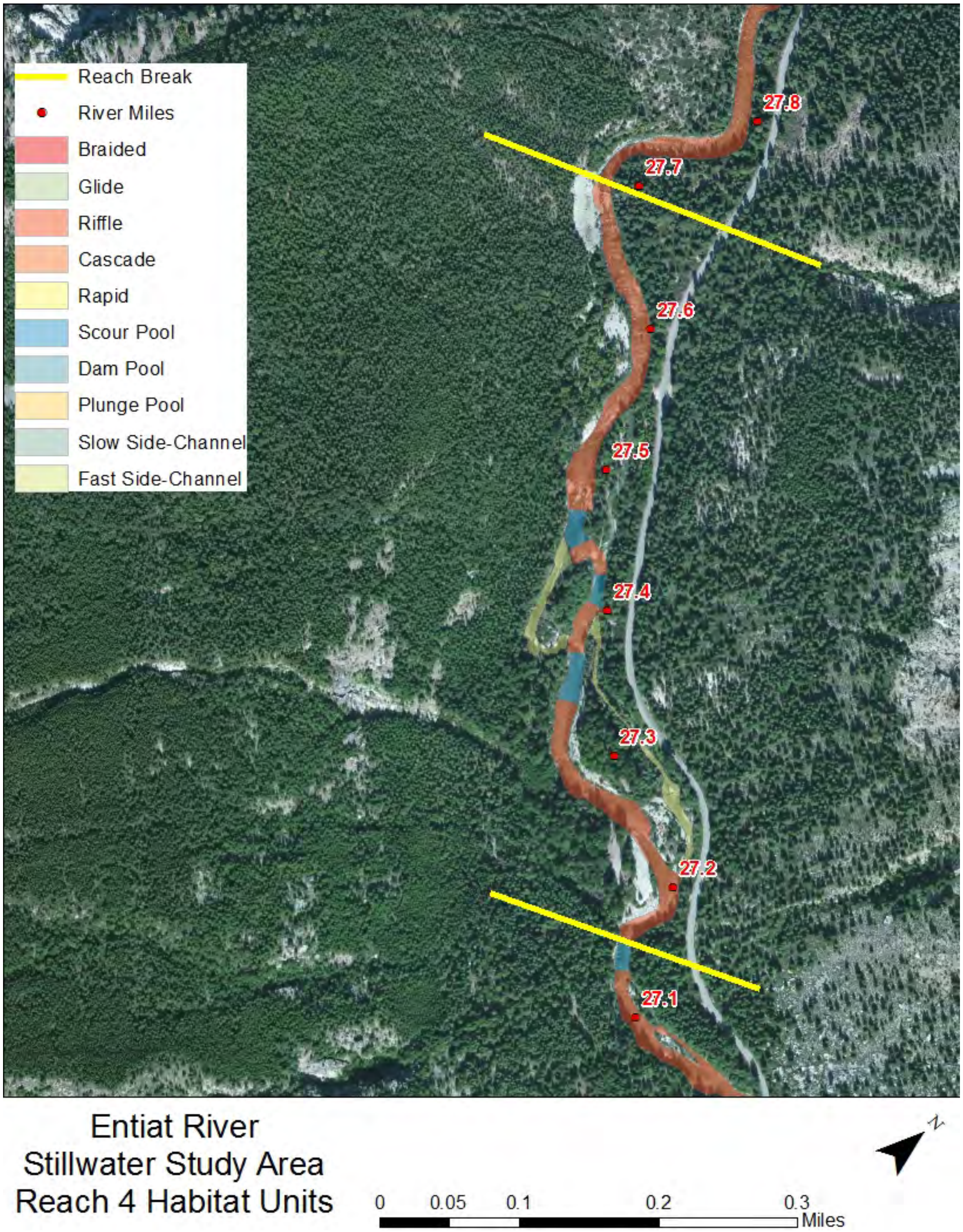


***Figure 40. Reach 4 habitat unit composition map.***

### 5.5.2 Habitat Unit Composition

Riffle habitat provides 70% of the overall habitat unit composition in Reach 4, and all of the fast-water unit composition in the reach (Figure 47). Pools provide only 8% of overall habitat, but side channels have a relatively high portion of habitat at 22%. This is the greatest area of side channel habitat in the study area.

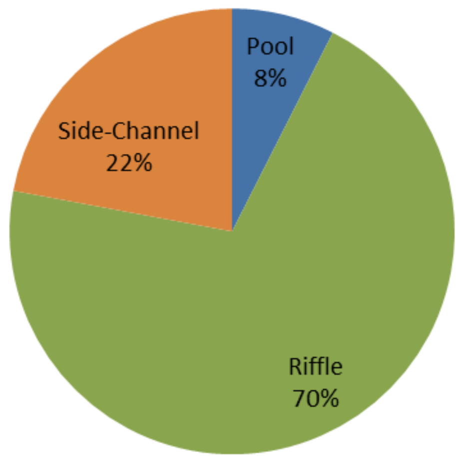


***Figure 41. Habitat unit composition, Reach 4.***

### 5.5.3 Pool Habitat

There are few pools in Reach 4 (3 pools total), and these are infrequent and widely spaced on average (Figure 42). Pool frequency was 5.0 pools/mile (6.4 pools/mile study area average), with mean pool spacing of 12 bankfull channel widths per pool (9 bankfull channel widths per pool study area average). Average residual pool depth was relatively high at 4.1 feet (study area average of 3.5 feet) (Figure 43). Average maximum pool depth was 5.7 feet.

*Figure 42. Upstream view of a long pool, typical of the reach.*

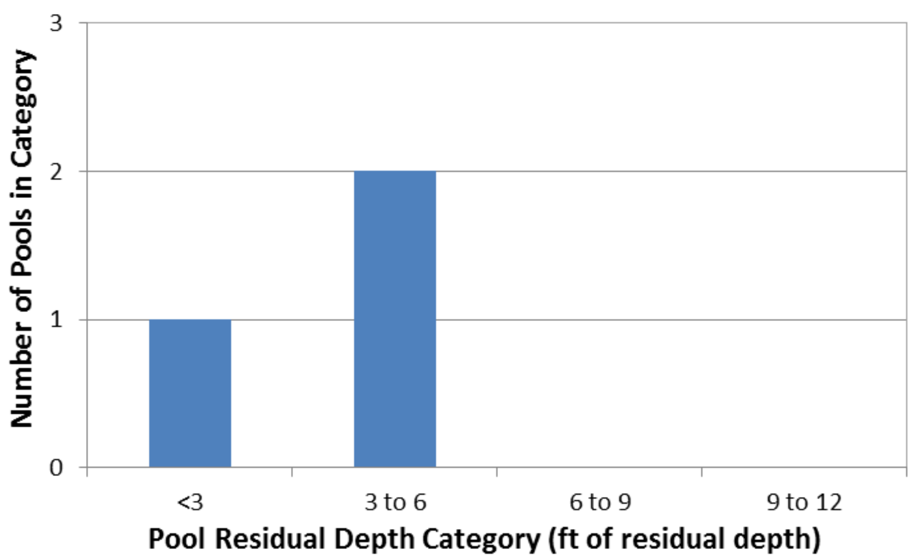


*Figure 43. Reach 4 residual pool depths.*

### 5.5.4 Off-Channel Habitat

Reach 4 has the study area's largest percentage of side channel habitat area. There are three side channel complexes, each of them long and well-connected at most flows. The downstream side channel (RM 27.2-27.4) provides complex habitat with a backwater alcove at its downstream end, and high quality pools throughout (Figure 44). It narrows considerably in it upstream half, providing greater cover to juveniles. Spawning was observed in the channel during the survey. The side channel 27.37 and 27.45 is larger than the downstream side channel, creating a split-flow condition in the main channel around a stable island. This channel is less of a velocity refuge, but does provide complexity. The upstream side channel (RM

27.45-27.55) is much narrower than either the other two, and provides good cover for juvenile rearing. There is a well-connected backwater at the downstream end.

***Figure 44. Photograph of a large backwater formed at the mouth of a side channel near RM 27.4. The side channel is long and provides complex habitat.***

### 5.5.5 Large Woody Material

LWM quantity was moderate to high with a total count of 58 pieces, and a frequency of 98 pieces/mile (study area average of 83 pieces/mile). Small pieces comprise 69% of all LWM counted in the reach (Table 11). Medium and large wood pieces comprise 30% of the LWD in the reach, 22% and 8% respectively.

Reach 4 LWM recruitment potential is high both in the short and long-term. The long-side channels contain a significant amount of wood, mostly small to medium pieces, already in the active channel that will become part of the main channel LWM component with a large flood event. The standing trees on the stable island and lining the side channel and mainstem channel margins provide a long-term source of material.

***Table 11. Large woody debris quantities in Reach 4.***

| | Small (6 in x 20 ft) | Medium (12 in x 35 ft) | Large (20 in x 35 ft) | Total |
|---|---|---|---|---|
| Number of Pieces | 40 | 13 | 5 | 58 |
| Number of Pieces/Mile | 67 | 22 | 8 | 98 |

### 5.5.6 Substrate and Fine Sediment

Bed substrate was dominated by cobbles (60%), with gravels and boulders sub-dominant (20 and 15% respectively) (Figure 45). Bedrock was not observed. Sand composed 5% of the total ocular estimate. Fine sediment in spawning gravels has not been measured in this reach.

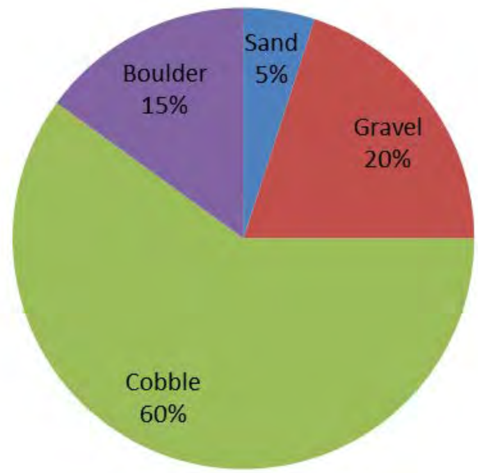


***Figure 45. Percent composition of bed substrate based on ocular estimates, Reach 4.***

### 5.5.7 Instability and Disturbance

Human development is minimal in Reach 4. The Entiat River Road is the only human feature in the reach, and it is confined to the toe of the hill slope. The location of the road does not appear to effect river processes in this reach. There was no anthropogenically induced bank erosion observed in this reach, and no evidence to suggest disequilibrium conditions. Large bed material provides vertical stability in terms of channel incision. The reach is laterally confined with low potential for lateral instability.

### 5.5.8 Available Holding, Spawning and Rearing Habitat

The strongest habitat component of Reach 4 is probably rearing habitat potential. The amount of side channel area and the complex and high quality habitat available in existing side channel supports juvenile rearing. Spawning was observed in the reach, in a side channel, but the general substrate within Reach 4 may be too coarse over all to support wide-spread spawning.

### 5.5.9 Riparian Corridor

The riparian corridor of Reach 4 is intact and benefits from a lack of current and historical human development. The canopy height within the 100 ft buffer is equally portioned between small tree and sampling/pole size classes. The overstory species composition is 100% cottonwood trees in measured units. Overstory species were more diverse throughout the reach and included mature conifers as well. The understory was 100% undifferentiated hardwood species, mainly cottonwood, willow, dogwood, and alder.

The level of stream shade provided by the riparian canopy was moderate throughout Reach 4. Local topography (close proximity to hill slopes on both sides of the valley) and mature trees provided ample morning and afternoon shade in narrower portions of the reach.

## 5.6 REACH 5

Location: River mile 27.7 to 28.27

Survey Date: 8/30/2012

Survey Crew: Randy Goetz and Jonathan Graca

### 5.6.1 Reach Overview

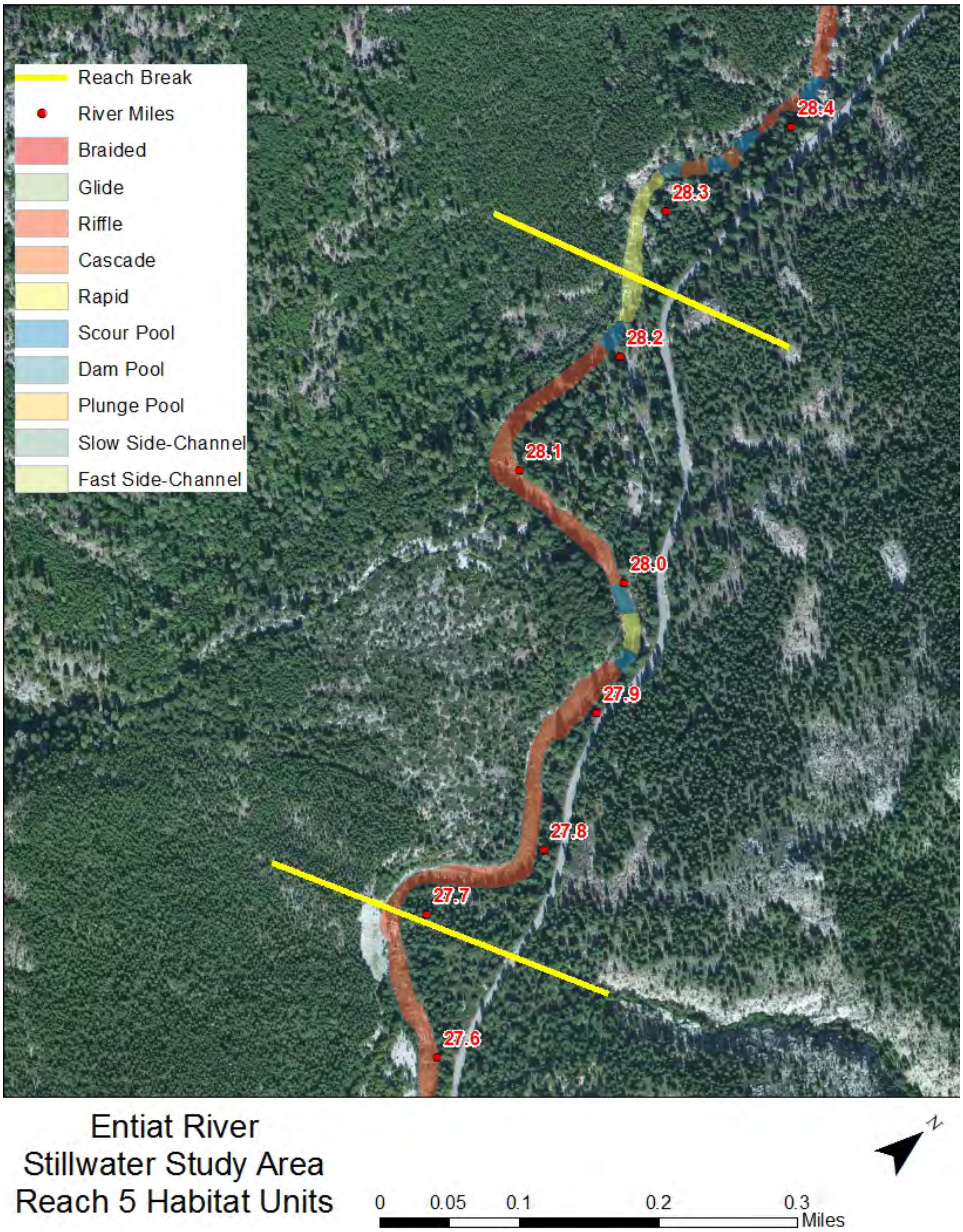


*Figure 46. Reach 5 habitat unit composition map.*

### 5.6.2 Habitat Unit Composition

Reach 5 is almost entirely composed of fast-water units, 86% of which are riffles and 6% rapids. Pools provide only 7% of the habitat and side channels 1% (Figure 47).

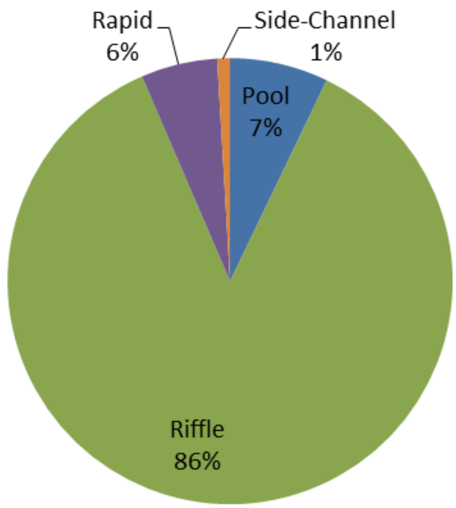


***Figure 47. Habitat unit composition, Reach 5.***

### 5.6.3 Pool Habitat

Pool frequency was 5.2 pools/mile (study area average of 6.4 pools/mile), with mean pool spacing of 11 bankfull channel widths per pool (study area average is 9 bankfull channel widths per pool) (Figure 48). Average residual pool depth was 4.8 feet with maximum residual depth of 5.9 ft (Figure 49). Average maximum pool depth was 5.8 feet.

***Figure 48. Upstream view of a typical pool in Reach 5 with bedrock forming the left channel margin.***

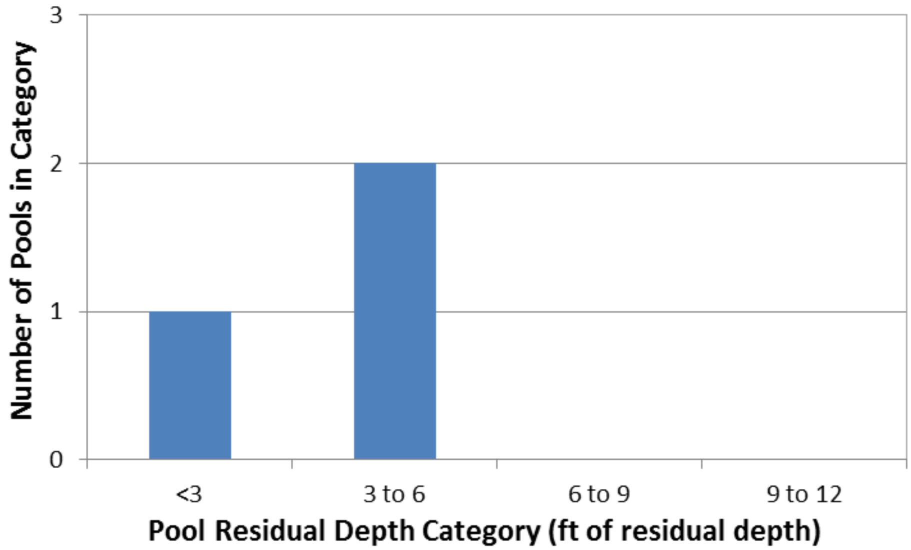


***Figure 49. Reach 5 residual pool depths.***

### 5.6.4 Off-Channel Habitat

Reach 5 has one small side channel on river right near RM 27.95 (Figure 50). Morphologically the side channel resembles a chute cut-off on a point bar. However, the bar is not active, and the "chute" cuts off a stable island with mature vegetation. The side channel is about 170 ft long, has good cover.

***Figure 50. Upstream view of the outlet of a short side channel near RM 27.95.***

### 5.6.5 Large Woody Material

LWM quantity is moderate (50 pieces) and LWM frequency is high in Reach 5, compared to other reaches in the study area. LWM frequency is 87 pieces/mile, with "small" pieces comprising 58% of all LWM counted in the reach (Table 12). "Medium" and "large" wood pieces comprise 42% of the LWM in the reach, 24% and 88% respectively.

Reach 5 LWM recruitment potential is moderate to low both in the short and long-term. Lateral migration is limited by topography. There is an active alluvial fan with potential to move wood to the channel from higher elevations. There are mature conifers in the floodplain, however, the highest concentration of these occurs in a portion of the floodplain managed as a campground, with reduced potential of natural tree fall and delivery to the channel.

***Table 12. Large woody material quantities in Reach 5.***

| | Small (6 in x 20 ft) | Medium (12 in x 35 ft) | Large (20 in x 35 ft) | Total |
|---|---|---|---|---|
| Number of Pieces | 29 | 12 | 9 | 50 |
| Number of Pieces/Mile | 50 | 21 | 16 | 87 |

### 5.6.6 Substrate and Fine Sediment

Bed substrate is dominated by boulders in measured units with 65% of the substrate composition being made up of this largest particle size class (Figure 51). Another 30% of the substrate was composed of cobble (20%) and gravel (10%). Bedrock is present in 5% of the bed and sand was absent from substrate composition. Fine sediment in spawning gravels has not been measured in this reach, but sand was not observed in measured units.

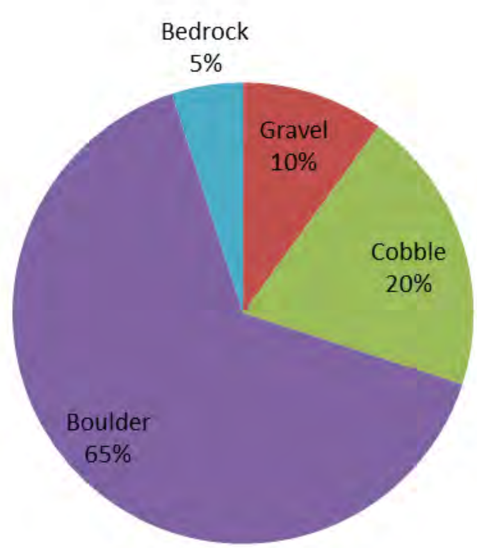


***Figure 51. Percent composition of bed substrate based on ocular estimates, Reach 5.***

### 5.6.7 Instability and Disturbance

Human activities have modified a small portion of the channel, floodplain, and associated riparian corridor within the reach. The primary elements of disturbance include riparian thinning, bank hardening, and floodplain disconnection all associated with Fox Creek Campground located on river left near RM 28.1. There were no eroding banks observed as a result of this floodplain development.

### 5.6.8 Available Holding, Spawning, and Rearing Habitat

Substrate within Reach 5 was extremely coarse in measured units, consisting primarily of boulders (65%). There is very little spawning habitat as pool tail outs or gravel riffles where spawning size material would occur are rare. Reach 5 provides low to moderate rearing habitat. Pool frequency (5.2 pools/mile) would be considered “not properly functioning” conditions based on USFWS (1998), yet two deep pools (residuals depths >3ft) provide some juvenile rearing, adult holding and overwintering opportunity. Pools lacked cover, however. Additionally, large boulders throughout the reach create small eddy pockets with localized velocity refuge. Side-channel or other off-channel habitat is rare in this reach, and the lack limits rearing habitat.

### 5.6.9 Riparian Corridor

Land clearing for campground development is the only recent disturbance to the riparian zone, and mainly affects the understory of the campground where vegetation is cleared to maintain the facility. Large conifers are left for the overstory, but the long-term health of the riparian zone in the vicinity of the camp is threatened by a lack of vegetation available for succession.

In measured units, the dominant size class of the riparian zone was small tree (100%). The overstory species composition was equally divided between undifferentiated conifers and cedar. Ponderosa Pine and Douglas Fir composed the other main conifer types. The understory species composition was equally divided between sapling Douglas Fir ad undifferentiated hardwood species.

The level of stream shade provided by the riparian canopy varies throughout the reach. There are mature trees along much of the channel margin that provide shade throughout the day. The stream is also shaded by hillslope and tall bedrock outcrops in many places.

## 5.7 REACH 6

Location: River mile 28.25 to 29.33

Survey Date: 8/30/2012

Survey Crew: Randy Goetz and Jonathon Graca

### 5.7.1 Reach Overview

Reach 6 is a steep bedrock canyon that was not walked due to access and safety concerns. Therefore, not all habitat survey measurements were made. Units were mapped from the canyon rim, and planform measurements such as area and length were later made in GIS. However, depth measurements were not made, nor were LWM observations or riparian observations. Those attributes will be discussed qualitatively here.

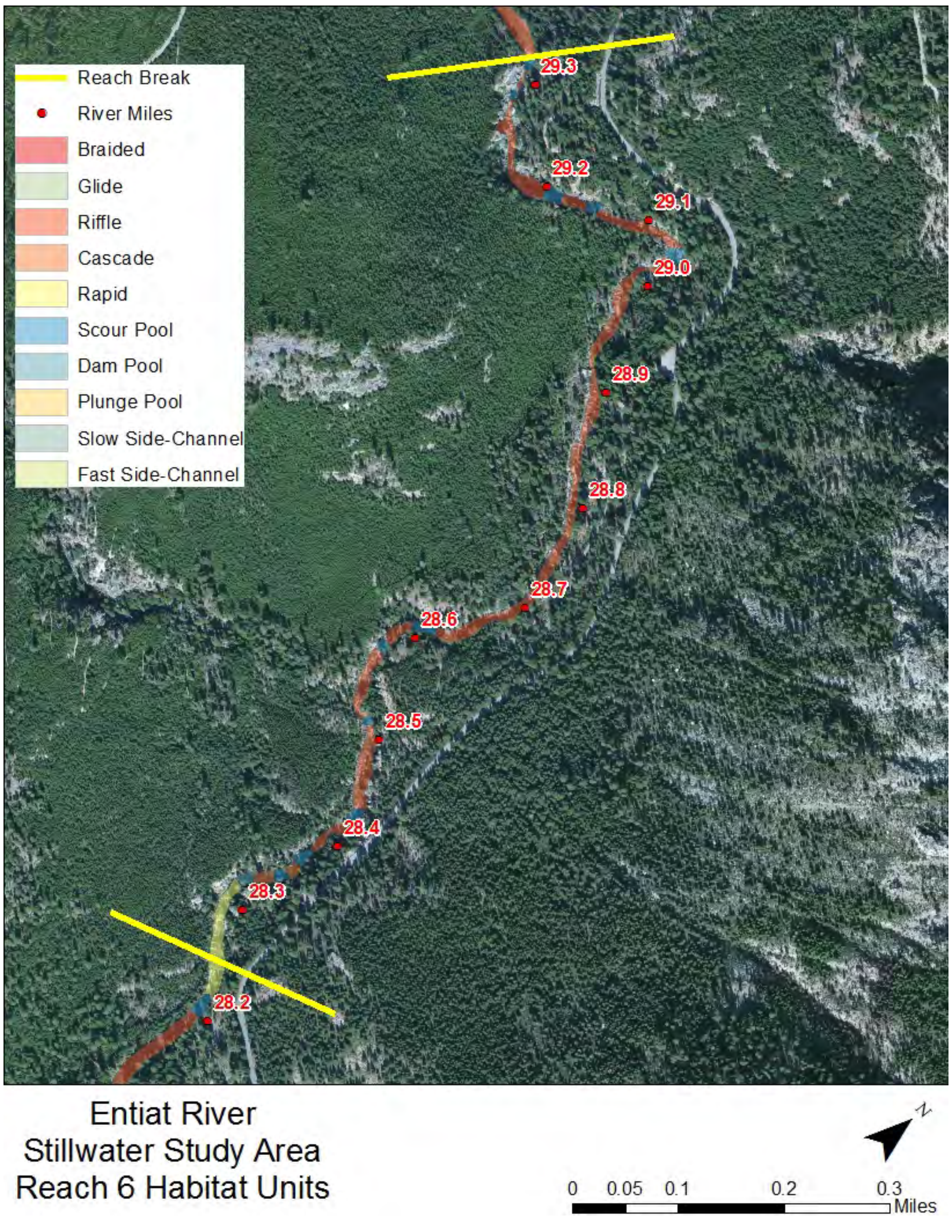


***Figure 52. Reach 6 habitat unit composition map.***

### 5.7.2 Habitat Unit Composition

Reach 6 is dominated by fast water units, consisting of 83% riffle (Figure 53). It is important to note that because on the ground survey was not completed, steeper fast water units were not distinguished, and are all grouped under riffles. In reality, the reach is composed of a large area of rapids, and some cascades. Pools provide 15% of habitat area in the reach. Pool units are short, often occurring at quick transition between fast-water units. Side-channels make up 2% of habitat in the reach. There is one side channel near RM 28.7.

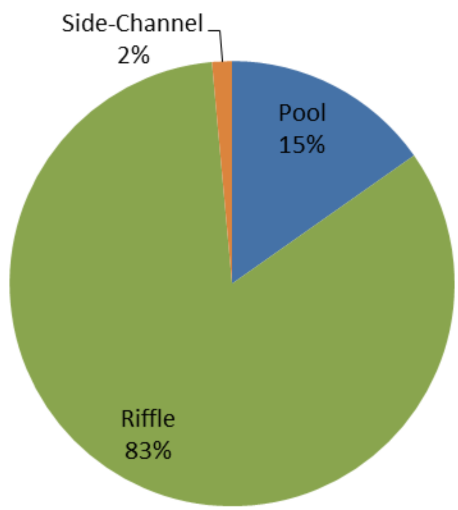


***Figure 53. Habitat unit composition, Reach 6.***

### 5.7.3 Pool Habitat

Pool frequency was 9.9 pools/mile (study area average of 6.4 pools/mile), with mean pool spacing of 6 bankfull channel widths per pool (study area average is 9 bankfull channel widths per pool). This is the highest pool frequency in the study area and the shortest average spacing. Maximum pool depths and residual depths were not measured. Most pools appeared to be deep bedrock controlled scour pools, dam pools formed by large colluvium at rapid and riffle crests, and plunge pools at abrupt riffle, rapid, and cascade tail outs (Figure 54).

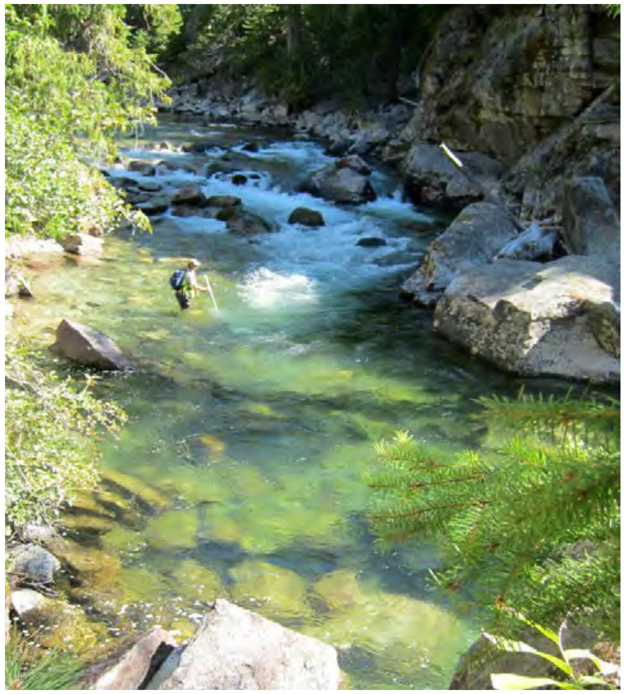

***Figure 54. Upstream view of a typical rapid-pool sequence in Reach 6. Though not measured, pool depths appear over 3 ft in most cases.***

### 5.7.4 Off-Channel Habitat

There is a single side channel that comprises all off-channel habitat in Reach 6. The channel is short and steep, as would be expected in the overall steep reach. It forms on river right in a split around a stable, vegetated island. The large substrate, steep gradient and scoured bed suggests it is an active high flow channel that provides very little hydraulic refuge during periods of high flow.

***Figure 55. Upstream view of a steep side channel outlet on river right near RM 28.7. The outlet is in the upper center of the photo.***

### 5.7.5 Large Woody Material

LWM quantities were not systematically counted in Reach 6 because of difficult access and safety concerns. Large wood was observed in the reach in quantities similar to other reaches where quantitative recording of LWM was completed. There were notable log jams with several large pieces in each. There was a considerable amount of wood observed high above the channel, often caught on top of large boulders or jammed into small eddies. Because of the narrow confines of the canyon, it is likely that bankfull conditions produce much deeper flows than in other reaches, and so many of these pieces of wood could be within the bankfull channel.

LWM recruitment was moderate throughout Reach 6. There is not a wide riparian zone nor is there the potential for lateral migration that would recruit riparian LWM. However, steep hillslopes and mature trees growing on the canyon rim provide a substantial source of LWM in the near and long-term.

***Figure 56. View of a log jam on river right near RM 29.1.***

### 5.7.6 Substrate and Fine Sediment

Bed substrate was not measured in Reach 6. Observations from the canyon rim, and the recognition of the steep slope, dominance of fast-water units, and confined canyon morphology support an assumption of a dominance of large bed material, primarily in the boulder and cobble size classes. Bed rock is also a larger component in this reach than in any other reach in the study area (Figure 57). Smaller material may be present on channel margins, in pools, and in eddies.

***Figure 57. Upstream view of a portion of Reach 6 that is highly confined by bedrock on both sides of the channel, with large bed material forming cascade-pool sequences.***

### 5.7.7 Instability and Disturbance

Human activity is not present in the river corridor of Reach 6. The reach is completely confined by hill slopes and bedrock cliffs, precluding any activity near the channel. There are developed and undeveloped trials on the canyon rim that may contribute to fine sediment erosion from the uplands. Being a bedrock canyon, lateral stability is extremely high. Very large elements in the bed of the channel make channel incision a low likelihood.

### 5.7.8 Available Holding, Spawning, and Rearing Habitat

There is very little available spawning and rearing habitat in Reach 6. It is unlikely that salmon would be able to spawn in Reach 6 due to its course substrate composition and high water velocity. A lack of slow water areas, cover, and off-channel habitat limit rearing opportunities in this reach. Most hydraulic complexity is created by large boulders with pocket eddies. Deep pools provide potential for some rearing, and for adult holding.

### 5.7.9 Riparian Corridor

Riparian characteristics were not measured in Reach 6. The riparian zone was narrow where it was present at all. In many places the channel flow directly against bedrock or colluvial deposits and the riparian zone consisted of whatever vegetation could establish within a limited area. Often these were isolated pockets in eddies, or areas where fine material was deposited and formed a suitable growing medium for willow and dogwood along the channel. There were also a few isolated mature confers and cottonwood trees along the channel margin. Shade was primarily provided by the canyon walls, not by riparian vegetation.

## 5.8 REACH 7

Location: River mile 29.33 to 29.85

Survey Date: 9/1/2012

Survey Crew: Randy Goetz and Jonathon Graca

### 5.8.1 Reach Overview

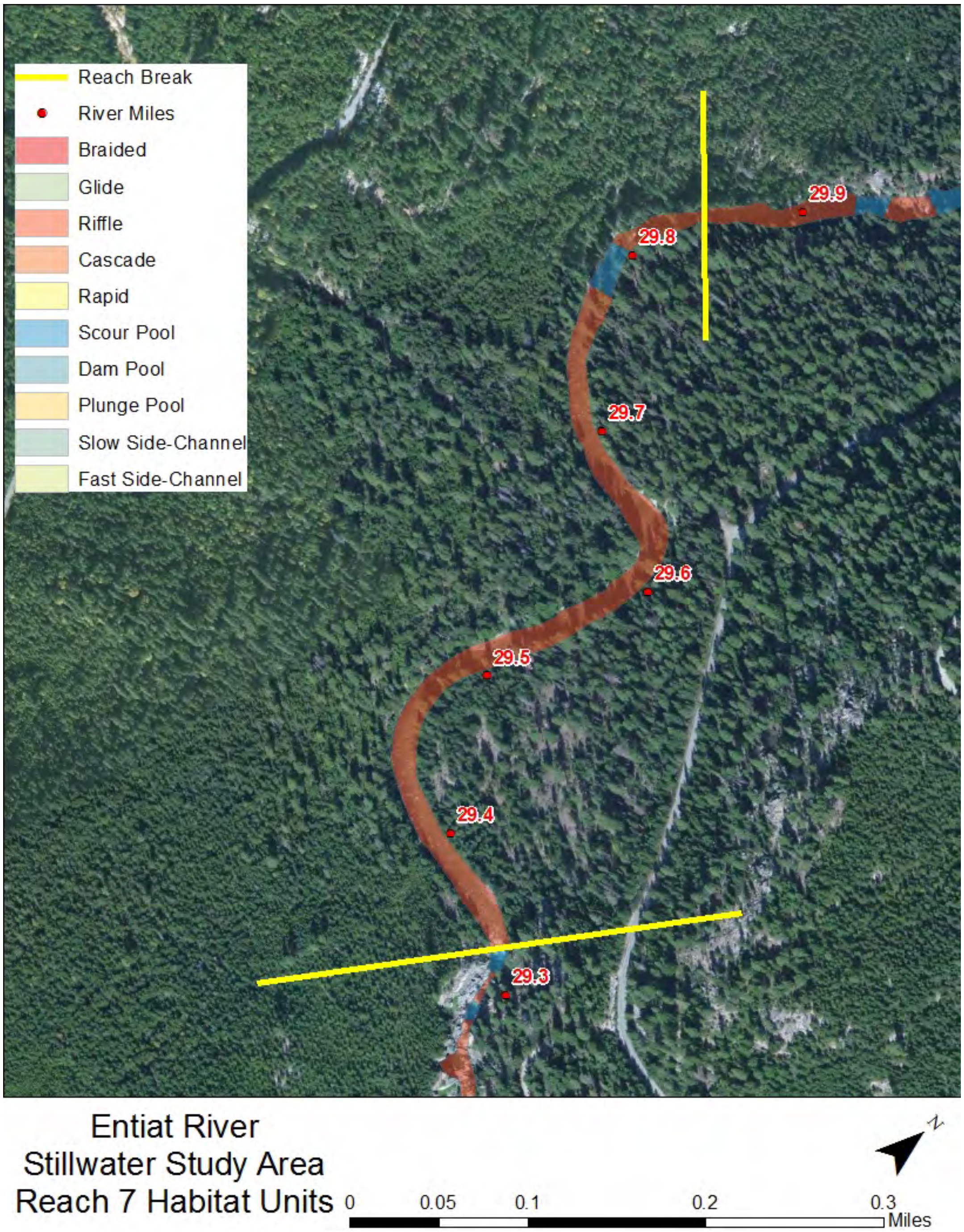


***Figure 58. Reach 7 habitat unit composition map.***

### 5.8.2 Habitat Unit Composition

Reach 7 is the most homogenous reach in the study area in terms of habitat diversity. The reach essentially consists of one long riffle broken by a single short pool near the upstream end of the reach. This is the highest percentage of fast water habitat in any reach in the study area (Figure 59).

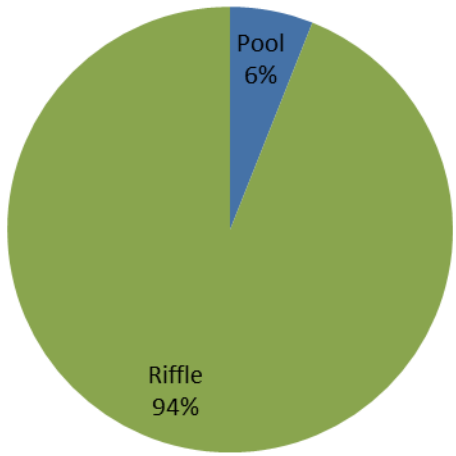


***Figure 59. Habitat unit composition, Reach 7.***

### 5.8.3 Pool Habitat

Reach 7 has a pool frequency of 1.9 pools/mile, and an average pool spacing of 31 bankfull channel widths per pool. This is the lowest frequency and highest spacing in the study area. The single pool in the reach, at 144 ft, is longer than the reach average of 130.8 ft. The pool has a residual depth of 4.5 ft and a maximum depth of 6 ft.

### 5.8.4 Off-Channel Habitat

Reach 7 has no side channel or other off-channel habitat.

### 5.8.5 Large Woody Material

LWM quantity and frequency were high compared to other reaches in the study area. The frequency of LWM in Reach 7 was 119 pieces per mile, the second highest frequency in the study area (Table 13). The total wood count was 63 pieces, with 84% of that being small wood, 13% medium, and 3% large. The high frequency of wood in the reach is mainly due to small pieces, with only 19 pieces/mile of medium and large pieces.

***Table 13. Large woody debris quantities in Reach 7.***

| | Small (6 in x 20 ft) | Medium (12 in x 35 ft) | Large (20 in x 35 ft) | Total |
|---|---|---|---|---|
| Number of Pieces | 53 | 8 | 2 | 63 |
| Number of Pieces/Mile | 100 | 15 | 4 | 119 |

### 5.8.6 Substrate and Fine Sediment

Bed substrate was not assessed in Reach 7, due to a lack of a measured unit. Fine sediment in spawning gravels has not been measured in this reach.

### 5.8.7 Instability and Disturbance

No instability or recent disturbance was found in Reach 7.

### 5.8.8 Available Holding, Spawning and Rearing Habitat

Favorable habitat for holding, spawning, or rearing is not present in substantial amounts in Reach 7. There is only one pool in the entire length of the reach. This pool provides sufficient residual depth for holding and rearing, but lacks cover. The overall lack of pools limits holding and rearing potential. The consistent grade and homogeneity of habitat, without frequent pool tail outs, limits spawning habitat.

### 5.8.9 Riparian Corridor

Reach 7 did not contain a measured unit, and therefore riparian vegetation was not characterized.

## 5.9 REACH 8

Location: River mile 29.85 to 30.2

Survey Date: 9/1/2012

Survey Crew: Randy Goetz and Jonathon Graca

### 5.9.1 Reach Overview

Reach 8 is a bedrock canyon reach similar to Reach 6. It was also not walked due to access and safety concerns. Qualitative information was gathered where possible, including habitat unit mapping. Characteristics such as habitat unit area composition were determined in GIS.

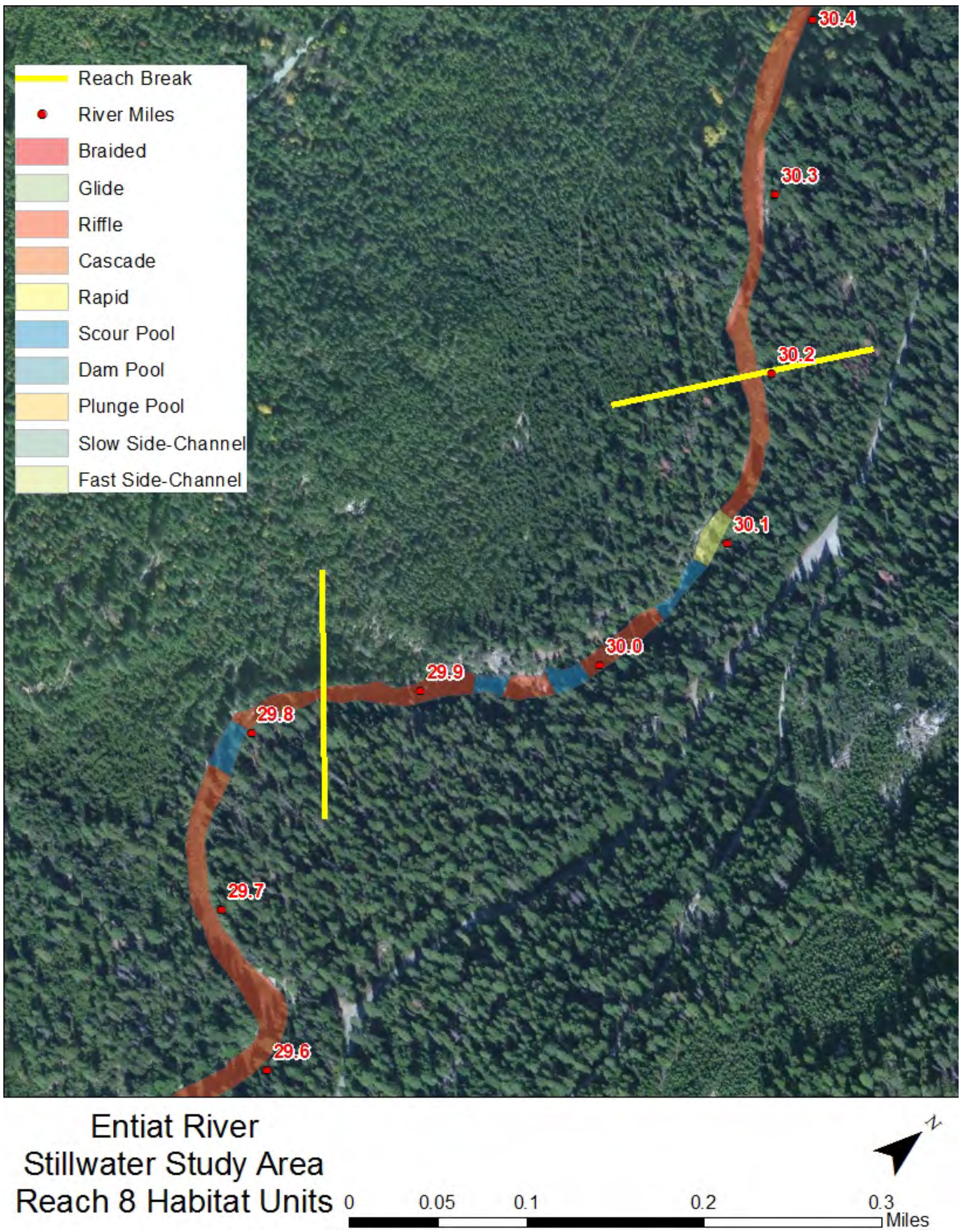


***Figure 60. Reach 8 habitat unit composition map.***

### 5.9.2 Habitat Unit Composition

Reach 8 consisted of 81% fast water units. Because the reach was not walked, slope was not estimated and therefore various fast water units were not segregated. Instead, all fast water units were lumped into the riffle category. In reality, rapids and cascades would comprise more substantial portions of the overall habitat composition. Pools area is 19% of the reach. 31% glide, 21% riffle and 7% side channel habitat (Figure 61).

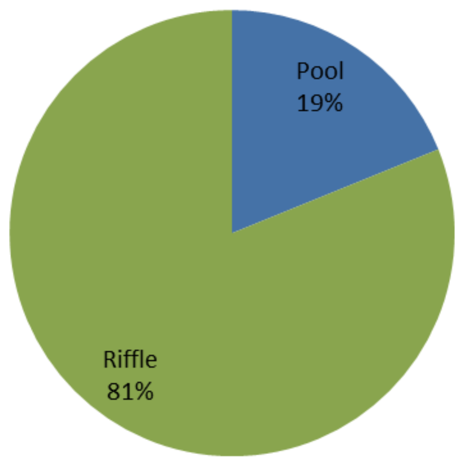


***Figure 61. Habitat unit composition, Reach 8.***

### 5.9.3 Pool Habitat

Pool frequency in Reach 8 is 8.5 pools/mile with an average spacing of 7 bankfull channel widths per pool. These are the second highest frequency and second lowest spacing in the study area. Reach 6, the other canyon reach, has higher frequency and shorter spacing. In these canyons, pools form at abrupt slope breaks at riffle or rapids tail out, or in places where cascades form plunge pools, or at locations where colluvium has dammed the channel (Figure 62). Because the reach was not walked, depth measurements were not obtained.

***Figure 62. Upstream view of a typical rapid-cascade-pool sequence in Reach 8.***

### 5.9.4 Off-Channel Habitat

Reach 8 had no side channel or other off-channel habitat. The reach is naturally confined by hill slopes and bed rock, and side channels would not be expected in this reach. Geomorphic processes do not support the formation of off-channel habitat in this reach.

### 5.9.5 Large Woody Material

LWM quantities were not counted because the reach was not walked due to access and safety issues. Observations suggest that there is a moderate amount of wood in the bankfull channel in Reach 8. There are no large accumulations of wood in the reach, but there are several locations where single pieces or several are located along the channel margins. The recruitment potential is limited by lateral immobility. However, colluvial delivery of wood to the channel is very likely and will provide a long-term source of LWM.

### 5.9.6 Substrate and Fine Sediment

Bed substrate was not observed in Reach 8. The steep gradient and prevalence of fast water habitat units supports the assumption that bed material is dominated by cobbles and boulders with smaller percentages of gravel and sand likely in pools and eddies along the channel margin. There is a substantial bedrock component in Reach 8 as well. Fine sediment in spawning gravels has not been measured in this reach.

***Figure 63. Upstream view of a visible bed substrate that include a large percentage of boulders and bedrock.***

### 5.9.7 Instability and Disturbance

Human development is not present in Reach 8. The natural confinement and lack of a river corridor has protected the reach from development. There were no anthropogenically destabilized banks. Lateral stability is high given the close hill slopes and prevalence of bedrock. Vertical stability is maintained by coarse bed material and a consistent gradient that resists aggradation.

### 5.9.8 Available Holding, Spawning, and Rearing Habitat

Reach 8 provides little in terms of spawning or rearing habitat. There are few hydraulic transitions such as pool tail out or riffle crests where gravel is sorted into appropriate size classes for spawning. The gradient is consistently steep, and there are no off-channel refugia which limits the amount of rearing habitat. Pools in the reach provide some holding and rearing area, though they lack cover.

### 5.9.9 Riparian Corridor

The riparian corridor was not characterized according to habitat survey protocol. However, observations from the canyon rim show that the riparian corridor is narrow, and exists mainly in pockets where the canyon widens and fine material is deposited in eddies or other areas that create slow water velocity along the channel margin during high flow.

## 5.10 REACH 9

Location: River mile 30.2 to 31.42

Survey Date: 9/4/2012

Survey Crew: Randy Goetz and Emily Alcott

### 5.10.1 Reach Overview

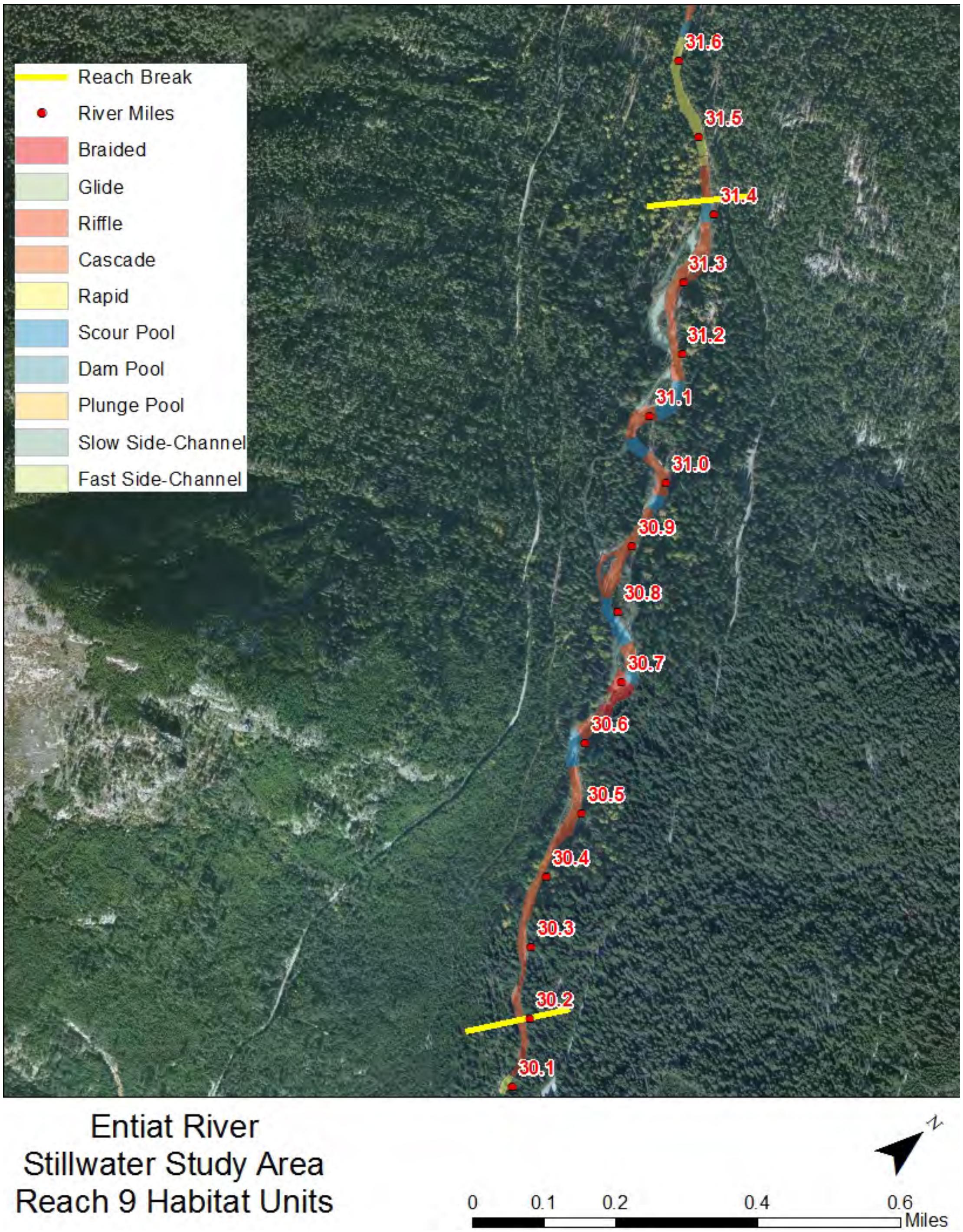


*Figure 64. Reach 9 habitat unit composition map.*

### 5.10.2 Habitat Unit Composition

Habitat in Reach 9 is mainly composed of riffle units (74% of habitat area in the reach) (Figure 65). These are the only fast water units in the reach. Reach 9 is the only reach to have braided channel habitat designated. This unit occurs near RM 30.7 where the mainstem splits into three stable channels. LWM and gravel deposition appear to have played a large role in creating this unit. There are seven pools that compose 13% of the habitat area in the reach, and seven side channels that account for 10% of overall habitat area. Though not the largest portion of side channel habitat in the study area, seven is by far the most individual side channel units in any reach in the study area.

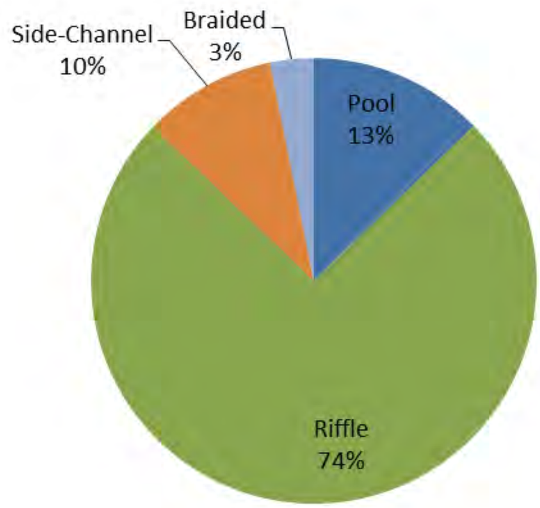


***Figure 65. Habitat unit composition, Reach 9.***

### 5.10.3 Pool Habitat

Pool frequency is 5.7 pools/mile, with mean pool spacing of 10 bankfull channel widths per pool. Average residual pool depth is 2.7 feet with a maximum residual depth of 4.7 ft. There were three pools with residual depth greater than 3 ft (Figure 66). Average maximum pool depth was 4.3 feet.

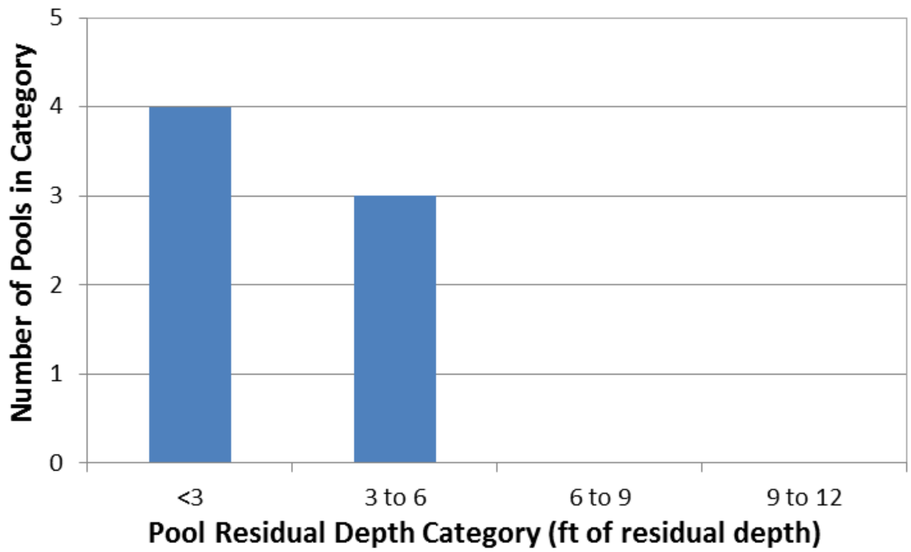


***Figure 66. Reach 9 residual pool depths.***

***Figure 67. Upstream view of a typical pool in Reach 9. The pool is relatively shallow, but provides adequate depth and cover to be considered "properly functioning" by the USFWS (1998).***

### 5.10.4 Off-Channel Habitat

Reach 9 had seven side channel units that account for the entire off-channel habitat in the reach. Within the group of seven side channels, there is a diversity of off-channel habitat seldom seen in other reaches in the study area. In the downstream half of the reach, side channels tend to be short and narrow (under 300 ft long), well-connected, and with small backwater alcoves at their outlets (Figure 68). These features provide good cover habitat and refuge for rearing juveniles over a wide range of flows. In the upstream half of the reach, side channels become longer and more complex. Two of the side channel complexes in this part of the reach are over 1,000 ft long. These longer channels meander farther onto the floodplain through heavily forested areas (Figure 69). These channels are not wet for their entire length, but geomorphic evidence suggests that scouring flows access these areas often. These long and complex side channels access excellent high flow refugia and rearing habitat, particularly in their perennially wet downstream portions.

***Figure 68. View of a backwater alcove at the outlet of a side channel near RM 30.7. The channel provide well-connected off-channel rearing.***

***Figure 69. Outlet of a long side channel near RM 31.25. This channel traverses a heavily wooded portion of the floodplain a substantial distance from the main channel.***

### 5.10.5 Large Woody Material

Reach 9 has the highest LWM count in the study area at 233 total pieces (Table 14), with "small" pieces comprising 52% of all LWM counted in the reach, "medium" pieces make up 28%, and "large" wood pieces comprise 21% of the LWM in the reach. LWM frequency is 189 pieces/mile, the highest frequency in the study area. Medium and large pieces together have a frequency of 92 pieces per mile, which is by far the highest frequency of larger woody material.

LWM recruitment potential is high. There are multiple high-flow channels and floodplain side channels that access mature riparian forests with the potential to provide LWM to the mainstem in the long-term. There are multiple log jams and large single trees recently fallen from bank erosion that are immediate sources of LWM in this reach and downstream reaches (Figure 70).

***Table 14. Large woody debris quantities in Reach 9.***

| | Small (6 in x 20 ft) | Medium (12 in x 35 ft) | Large (20 in x 35 ft) | Total |
|---|---|---|---|---|
| Number of Pieces | 120 | 65 | 48 | 233 |
| Number of Pieces/Mile | 97 | 53 | 39 | 189 |

***Figure 70. Several large and medium pieces of wood are rafted on a gravel bar in Reach 9. This LWM is a near-term source of wood for Reach 9 and downstream reaches.***

### 5.10.6 Substrate and Fine Sediment

Bed substrate is dominated by cobble, which composes 60% of the bed substrate in measured units (Figure 71). Gravel makes a more significant portion of the overall substrate make-up than most reaches, being the 4th highest percentage in the study area (35% of the total). A relatively low gradient, reduced confinement and large LWM complexes that retain and sort gravel can be attributed to a large portion of the gravel and sand portion in the reach. No bedrock was observed Reach 9, and sand was observed as a 5% portion of the bed material in measured units. Fine sediment in pool tails was measured by CHaMP in July of 2011, and posted to www.champmonitoring.org. Three measurement grids were used to collect data at each of four pool tails around the mouth of Silver Creek near RM 31 in July of 2011. The compiled results for measured particles smaller than 2 mm (sand and smaller) in pool tails is presented in Figure 71. In general, percent fines were low with an average of 4.5% for all measurements. The largest percent fines was 25%, which is largest percentage found at any measured site.

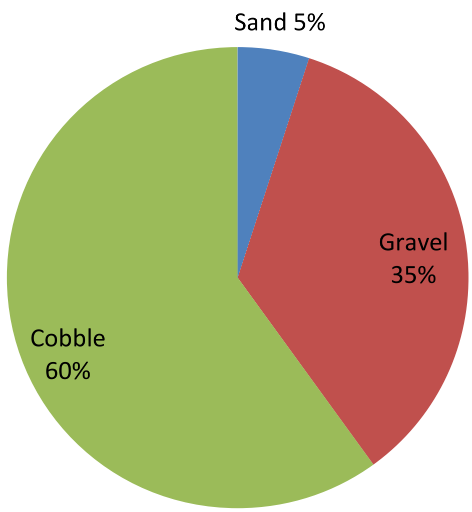


***Figure 71. Percent composition of bed substrate based on ocular estimates, Reach 9.***

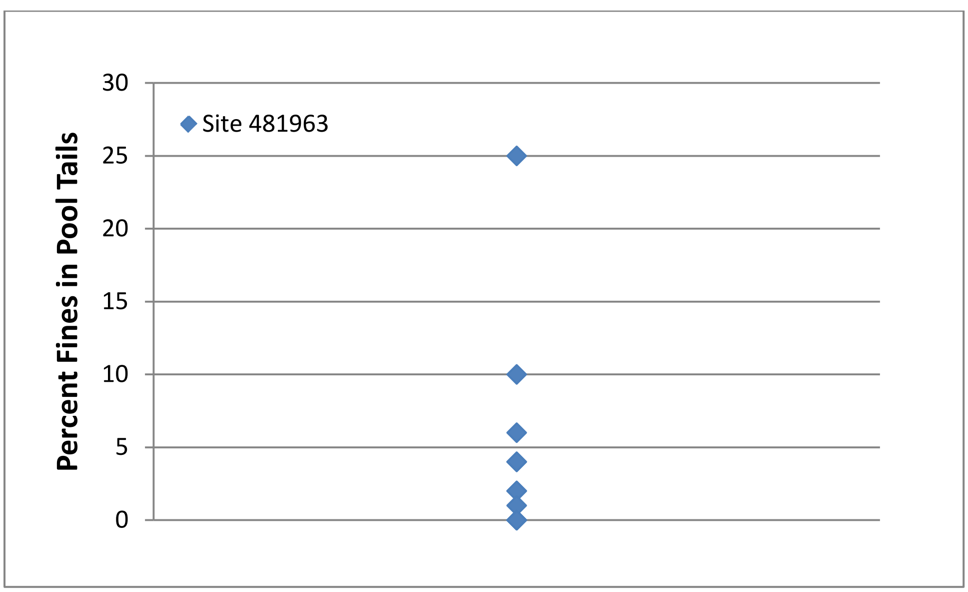


***Figure 72. Results of measurement of fine sediment in pool tails recording percent of fines in pool tails at Site 481963 in Reach 9 in July of 2011. Data from www.champmonitoring.org***

### 5.10.7 Instability and Disturbance

Current human activity is minimal in Reach 9. There are no roadways or development in the river corridor. There are no anthropogenically destabilized banks in the reach. The only evidence of human alteration was a small recreational dam built across the mouth of Silver Creek near RM 31 (Figure 73) There is no evidence of trends in incision or aggradation, and the reach has many elements (LWM complexes and well-connected floodplain habitat) that are indicative of proper river function. The reach is in an area where historical timber clearing occurred in the river corridor on river right in the downstream 0.3 miles of the reach. This is congruent with an area that has historically burned.

***Figure 73. View of the mouth of Silver Creek where recreational river users have constructed a dam using large cobble.***

### 5.10.8 Available Holding, Spawning, and Rearing Habitat

Habitat supporting multiple life-stages was relatively abundant in Reach 9. Adult holding and juvenile rearing in the mainstem is supported by multiple pools with moderate depth and good cover. Alternating pool-riffle sequences with favorable hydraulics and gravel substrate size classes support spawning for multiple species. Side-channels with backwater alcoves at their outlets create prime rearing habitat.

### 5.10.9 Riparian Corridor

The riparian corridor is intact and undisrupted along the entire length of Reach 9 on both sides of the channel. The size of riparian vegetation was equally divided between large and small trees in measured units. This is a shift toward mature riparian vegetation compared to downstream reaches. The overstory species composition is equally composed of undifferentiated conifers (mainly Ponderosa pine, and Douglas fir) and cedar. The understory composition is 100% undifferentiated hardwood species in measured units.

## 5.11 REACH 10

Location: River mile 31.42 to 31.91

Survey Date: 9/5/2012

Survey Crew: Randy Goetz and Emily Alcott

### 5.11.1 Reach Overview

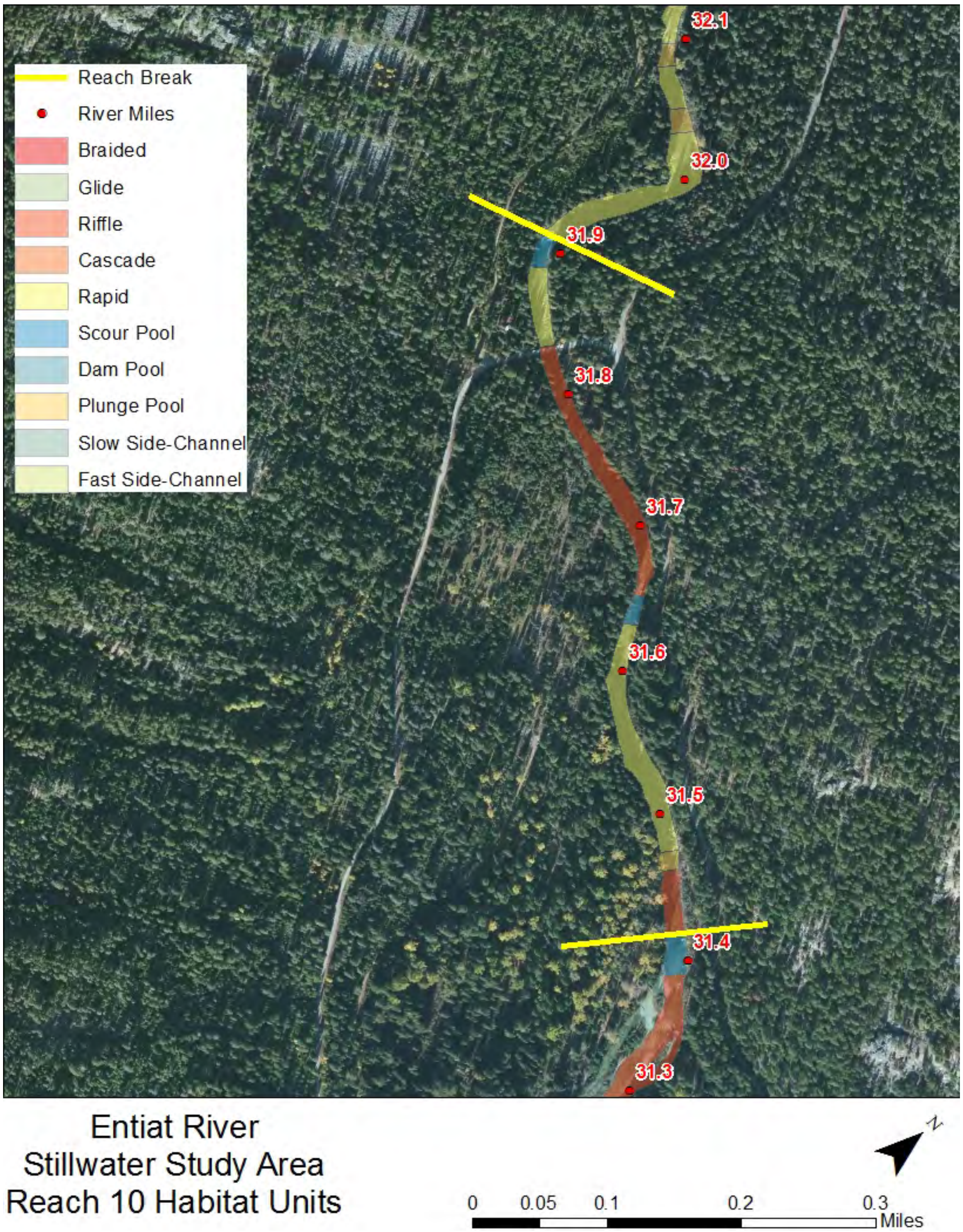


*Figure 74. Reach 10 habitat unit composition map.*

### 5.11.2 Habitat Unit Composition

Reach 10 is a consistently high gradient with habitat dominated by fast-water units (Figure 75). Riffles compose 52% of overall habitat, and rapids compose 40% of habitat. Pools provide the remaining 8% of habitat. There are only 3 pools in the reach, separated by long riffles (average length 693 ft) and rapids (average length 524.5 ft).

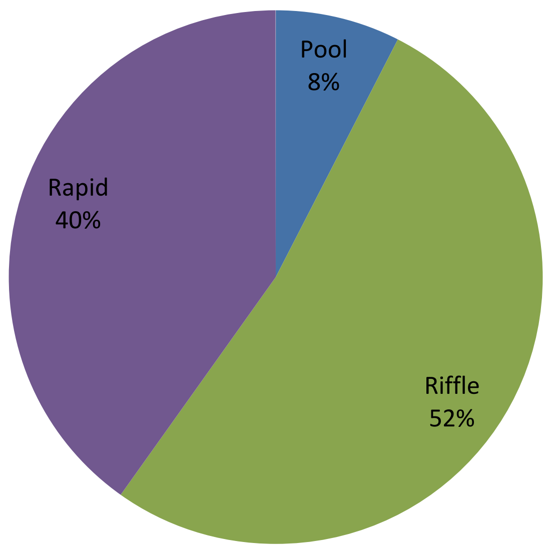


***Figure 75. Habitat unit composition, Reach 10.***

### 5.11.3 Pool Habitat

Pool frequency was 5.8 pools/mile (study area average of 6.4 pools/mile), with mean spacing of 10 bankfull channel widths per pool (reach average of 9 bankfull channel widths per pool). There were few pools in this reach (a total count of three), and these were relatively short at an average length of 114 ft (study area average of 130 ft) (Figure 76). Of the three pools, only one has a residual depth over three ft, average maximum pool depth is 4.6 ft (Figure 77).

*Figure 76. Upstream view of a short plunge pool in Reach 10. There is over 3 ft of residual depth just below the plunge, but residual depth quickly decrease toward to the pool tail.*

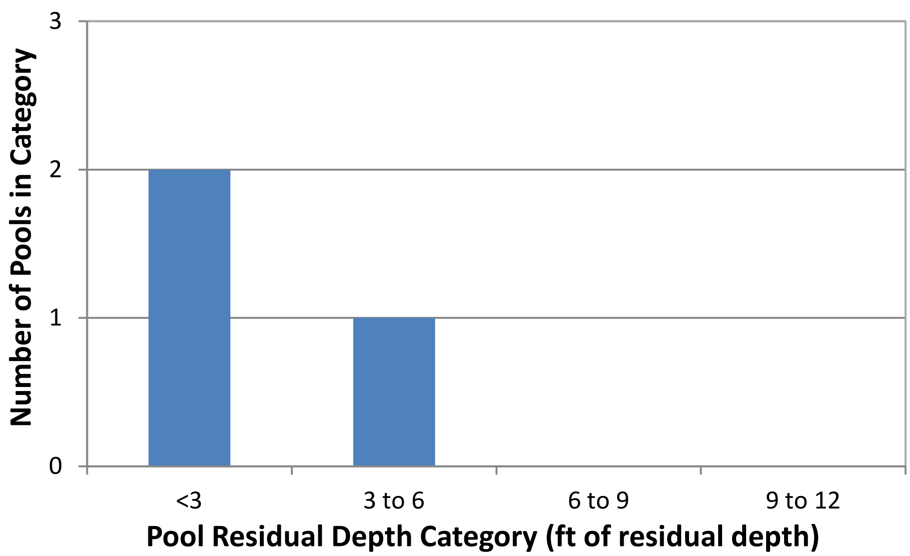


*Figure 77. Reach 10 residual pool depths.*

### 5.11.4 Off-Channel Habitat

There is no side channel or other off-channel habitat in Reach 10. The steep reach is naturally confined and would not be expected to support off-channel habitat.

### 5.11.5 Large Woody Material

LWM quantities were low in Reach 10, compared to other reaches in the study area (Table 15). The total count of 30 pieces of wood is the second lowest count in the study area. Small pieces comprise 47% of wood in the reach, medium pieces are 33%, and large pieces are 20%. LWM frequency was 58 pieces/mile, with medium and large pieces combining for a frequency of 31 pieces per mile.

Reach 10 has poor short-term LWM recruitment potential, and moderate long-term recruitment potential. Short-term recruitment is limited by a lack of active side and high-flow channels, as well as low sinuosity and limited lateral migration. There are mature conifers and cottonwood trees that provide long-term sources of large wood.

***Table 15. Large woody debris quantities in Reach 10.***

| | Small (6 in x 20 ft) | Medium (12 in x 35 ft) | Large (20 in x 35 ft) | Total |
|---|---|---|---|---|
| Number of Pieces | 14 | 10 | 6 | 30 |
| Number of Pieces/Mile | 27 | 19 | 12 | 58 |

## 5.11.6 Substrate and Fine Sediment

Bed substrate is dominated by gravel with a 50% portion of the overall composition in measured units (Figure 78). Larger substrate size classes comprise the remaining bed material make-up with cobble being sub dominant at 35% and boulders contributing 10%. Bedrock was observed in a 5% portion, and sand was absent from bed material in measured units. The percentage of fine sediment (<2mm) in spawning gravels was not measured in this reach, however a negligible amount (less than 5% of total bed composition) of sand or smaller material was observed in ocular estimates of measured units.

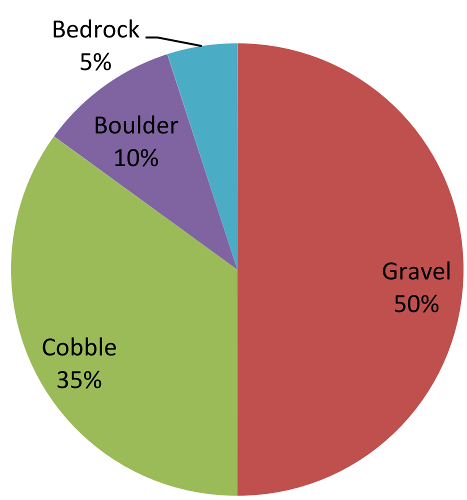


***Figure 78. Percent composition of bed substrate based on ocular estimates, Reach 10.***

## 5.11.7 Instability and Disturbance

Localized channel and bank modification exists around a bridge near RM 31.85 (Figure 79). Channel modification includes abutments built in the bankfull channel cross-section, limiting bankfull width and modifying hydraulics. Bank modification includes rip-rap and bank hardening. There is some floodplain clearing near the bridge for vehicle parking and unimproved river access points. A road parallels the channel along river left for its entire length. The road is set near the toe of the hill slope and has minimum impact on floodplain or riparian function. There were no anthropogenically destabilized banks in the reach.

*Figure 79. View of bridge abutment and bank hardening on river left near RM 31.85.*

### 5.11.8 Available Holding, Spawning, and Rearing Habitat

There is minimal holding habitat in Reach 10 due to an overall lack of pool habitat (three pools total) and poor quality in existing pools (only one pool with over 3 ft of residual depth). Spawning areas are limited by the homogeneity of fast water units throughout the reach as well. Despite the large percentage of gravel, which is appropriate spawning material for most salmonid species, there are few hydraulic environments (such as pool tail outs and riffle crests) where salmonids tend to spawn. Low pool counts, shallow residual depth, sparse cover, and no off-channel habitat all contribute to very limited rearing habitat in Reach 10. Taken together, habitat deficiencies in Reach 10 make it most suitable for a migration corridor.

### 5.11.9 Riparian Corridor

The width of forested riparian buffer varies within Reach 10, with limited width on river left due to close hill slopes and a roadway. On river right, the buffer is generally wider. Roads are present on the river left side as well, though set farther back from the river and out of the riparian corridor.

The riparian zone along Reach 10 is dominated by small trees (100%) in measured units. Dominant overstory composition was equally divided between cedar and spruce. Dominant understory composition was equally divided between undifferentiated conifer and spruce saplings.

The level of stream shade provided by the riparian canopy was moderate to high throughout Reach 10. Though small trees dominated the 100 foot buffer area in measured units, there was near continuous large conifer canopy within a distance of the channel to provide ample shade during significant portions of the day.

## 5.12 REACH 11

Location: River mile 31.91 to 32.9

Survey Date: 9/5/2012

Survey Crew: Randy Goetz and Emily Alcott

### 5.12.1 Reach Overview

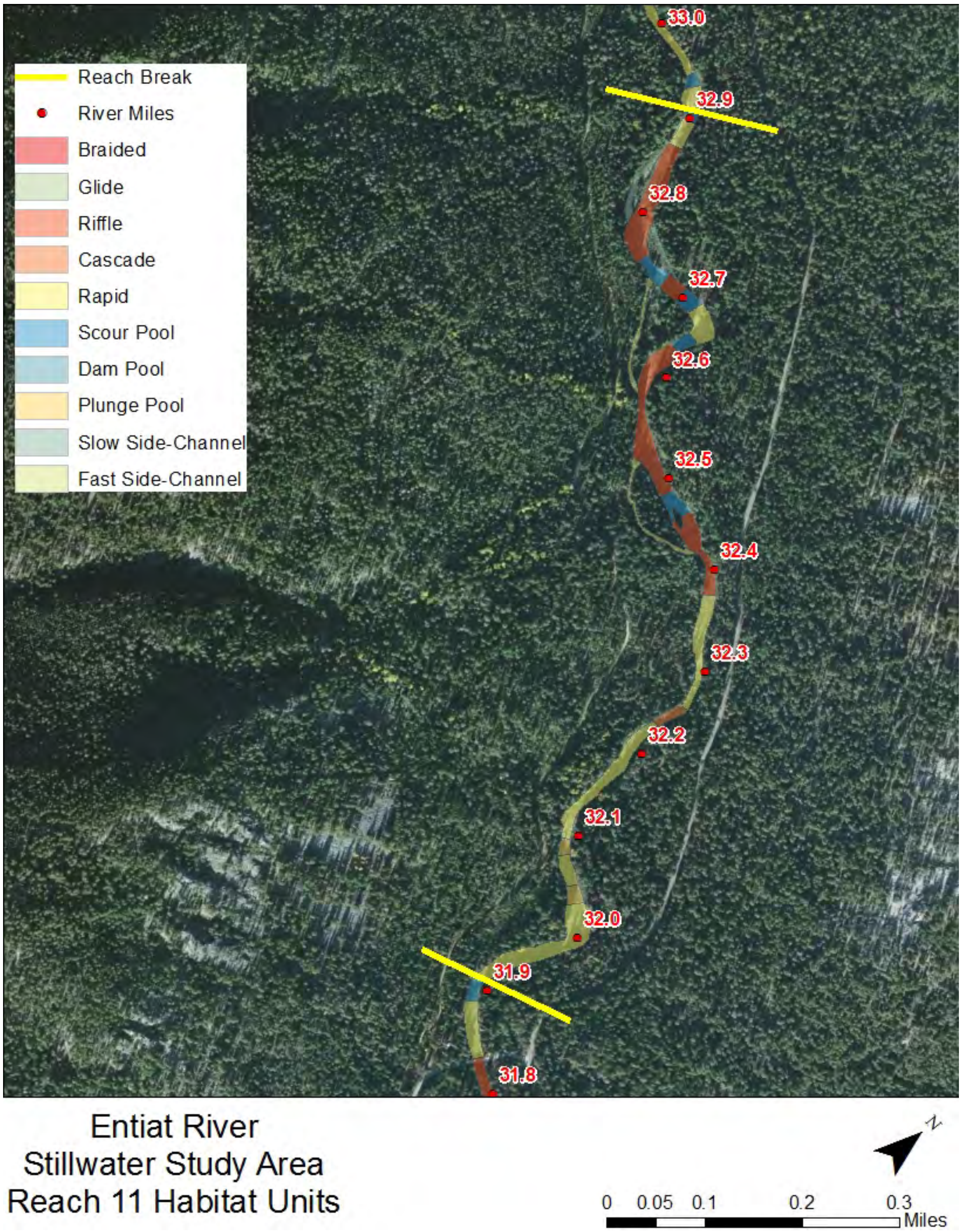


*Figure 80. Reach 11 habitat unit composition map.*

### 5.12.2 Habitat Unit Composition

Habitat in Reach 11 is made up of fast-water habitat mainly. Riffles and rapids together are 86% of habitat (42% and 44% respectively), with cascades making another 3% of the habitat for a total of 89% of habitat in fast-water units. Pools provide 7% of the reaches habitat, and side channels the remaining 4% (Figure 81). There were seven individual pool units and 4 side channel units.

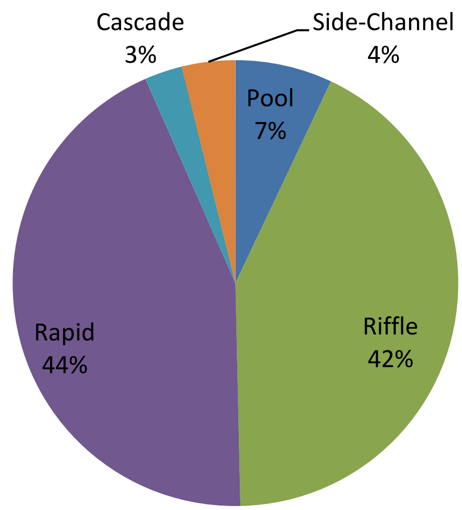


*Figure 81. Habitat unit composition, Reach 11.*

### 5.12.3 Pool Habitat

Pool frequency is 6.8 pools/mile which is slightly greater than the study area average of 6.4 pools/mile. Mean pool spacing is 9 bankfull channel widths per pool, which matches the study area average. Pools that occur in sequence with rapids are short plunge pools, often associated with bedrock outcrops (Figure 82). There are two of these type of pools closely spaced near the downstream end of the reach. The remaining pools occur in riffle-pool sequences near the upstream end of the reach, several of them in close succession. In reality, the existing pools in the reach are often closely spaced, but there are long stretches without any pool habitat that drives the frequency down and the spacing up. Residual depth in pools is relatively poor with only two pools having residual depth greater than three ft (Figure 83). Maximum residual depth is 3.9 ft.

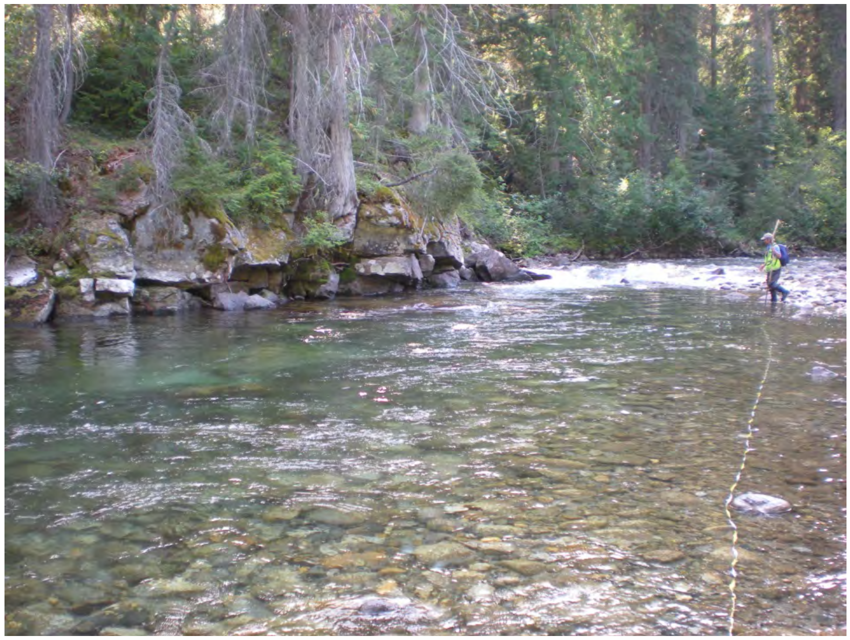

*Figure 82. Upstream view of a pool in Reach 11 that occurs with an abrupt plunge at the tail of a rapid unit, with scour along bed rock on the right side of the channel. This is a typical pool configuration in the reach.*

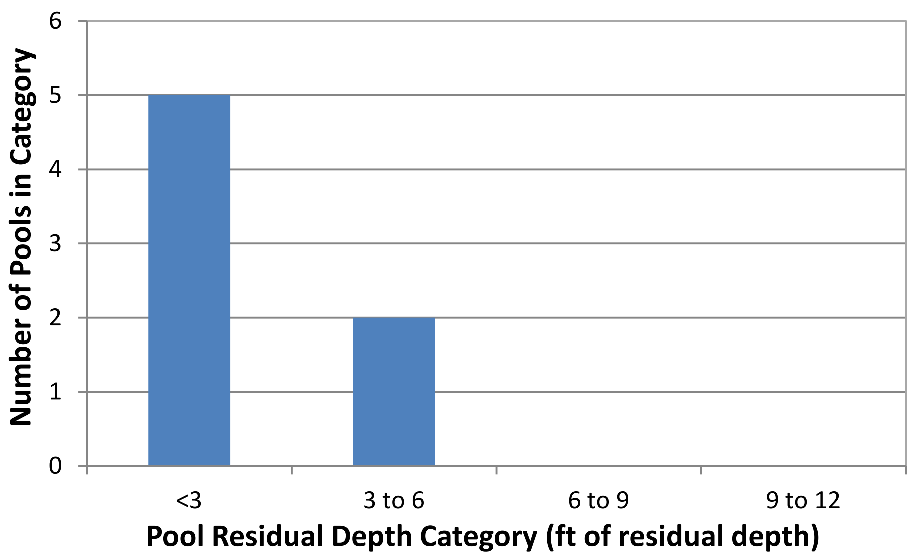


*Figure 83. Reach 11 residual pool depth.*

### 5.12.4 Off-Channel Habitat

There are four side channel habitat units in Reach 11 that comprise all off-channel habitat in the reach. These side channels are found in the upstream half of the reach, which is not as steep as the lower half. Two of the side channel are relatively long, and create meander cut-offs that flow through heavily forested riparian areas (Figure 84). These provide a significant amount of well-connected off-channel habitat that can be accessed at a wide range of flow levels. The downstream ends of these longer channels provide refuge at all flows, but higher flows access the full length of these side channels.

***Figure 84. Slow water side channel habitat found in the floodplain of Reach 11. The habitat is well connected near the mouth of the channel and provides juvenile refugia.***

### 5.12.5 Large Woody Material

LWM frequency is relatively high in Reach 11 with 104 pieces per mile, the third highest wood count per mile within the study area (Table 16). Medium and large pieces together have a frequency of 36 pieces per mile. The total wood count is 108 pieces, with 66% being small, 21% medium ad 13% large pieces.

Reach 11 has moderate LWM recruitment potential. Flow through side channel complexes provides a near-term and long-term source of LWM. There are large amount of small wood currently down in these channels that provide a near term source of material. Side-channels also allow high flows greater access to riparian forests where long-term sources exist. Channel migration in the upstream half of the reach is another long-term source.

***Table 16. Large woody debris quantities in Reach 11.***

| | Small (6 in x 20 ft) | Medium (12 in x 35 ft) | Large (20 in x 35 ft) | Total |
|---|---|---|---|---|
| Number of Pieces | 71 | 23 | 14 | 108 |
| Number of Pieces/Mile | 69 | 22 | 14 | 104 |

### 5.12.6 Substrate and Fine Sediment

Cobbles compose 50% of the overall bed substrate in measured units, gravel covers 22% of the bed, and boulders and bedrock take relatively equal shares at 13% and 15% respectively (Figure 85). This extremely coarse distribution would be expected in reach with high percentage rapid and cascade habitats. Fine sediment was measured by CHaMPS at site 073131 near RM 32.2 in August of 2012, and the results were posted to www.champmonitoring.org. There were no fines found in any of the three measurement grids used at the site.

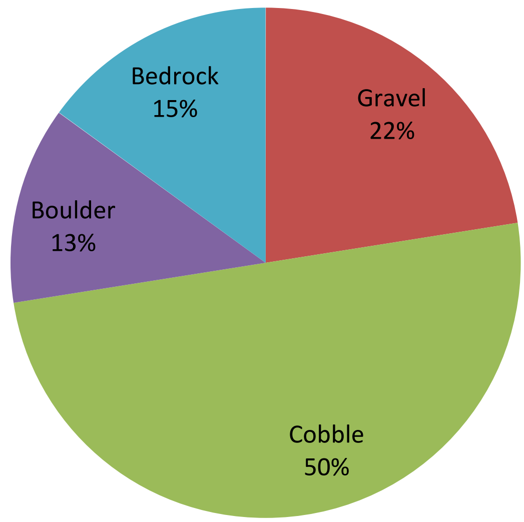


***Figure 85. Percent composition of bed substrate based on ocular estimates, Reach 11.***

### 5.12.7 Instability and Disturbance

No instability or recent disturbance was found in Reach 11. There is an intact riparian corridor and stable bank throughout the reach. There is no floodplain development, and no channel modification. There is a road on river left, but it is located outside of the river corridor in most locations.

### 5.12.8 Available Holding, Spawning, and Rearing Habitat

Marginal adult and juvenile holding habitat is found in the reaches pools, which have low residual depth and sparse cover. Side-channels are not large or well-connected enough to provide holding habitat for adults. Large bed substrate dominated by cobbles does not promote spawning. However, gravel provided a substantial portion of the bed substrate in measured units, and there are several riffle-pool sequences that provide the proper environment for salmonid spawning. Reach 11 has two pools with residual depth greater than 3 feet, which provides adequate rearing habitat for juvenile salmonids. The side channel habitat in the reach also provides rearing habitat for juvenile fish.

### 5.12.9 Riparian Corridor

The riparian buffer is fairly wide throughout the reach, with no development of deforestation apparent. There are roads on both sides of the channel, but these are mainly set outside of the riparian zone. Vegetation size is dominated by small trees (100%), with the overstory species composition consisting exclusively of undifferentiated conifers (100%). Doug fir, ponderosa pine, spruce and cedar are among the species present. The understory species composition is divided between alder and undifferentiated conifer saplings (67% and 33% respectively).

The level of stream shade provided by the riparian canopy was moderate to high throughout Reach 11 depending on the orientation of the channel. The valley is narrow, with high bedrock walls in many locations, and mature conifers on both sides of the valley that provide shade across most of the channel through most of the day.

## 5.13 REACH 12

Location: River mile 32.9 to 33.19

Survey Date: 9/6/2012

Survey Crew: Randy Goetz and Emily Alcott

### 5.13.1 Reach Overview

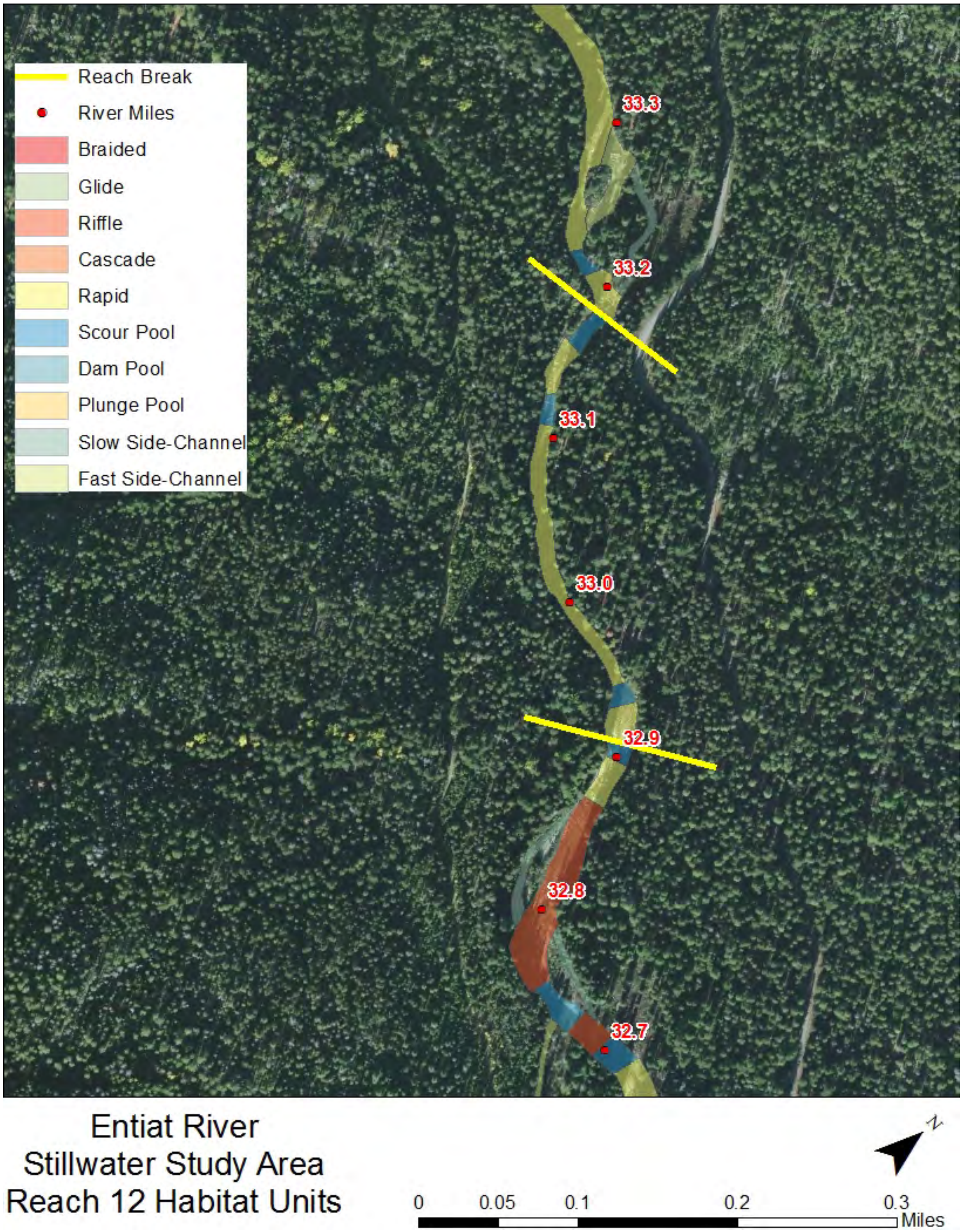


***Figure 86. Reach 12 habitat unit composition map.***

### 5.13.2 Habitat Unit Composition

Habitat in Reach 12 is fairly homogeneous, being made up of only rapid and pool habitat (Figure 81). Rapids are the primary habitat type in the reach totaling 88% of overall habitat, while pools provide the remaining 12% of habitat. The portion of pool habitat is relatively high compared to other reaches dominated by rapid habitat (i.e. steep gradient). There were three individual pool units grouped at the upstream and downstream ends of the reach with a long, relatively unbroken rapid through the middle portion of the reach.

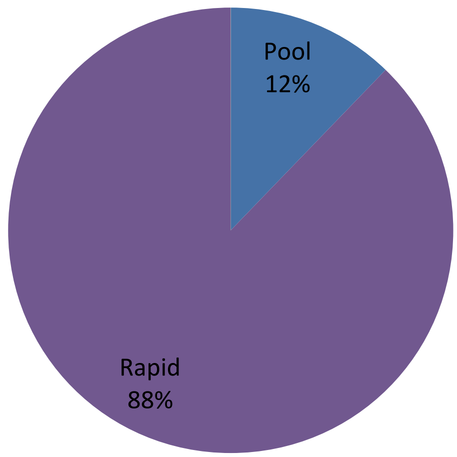


***Figure 87. Habitat unit composition, Reach 12.***

### 5.13.3 Pool Habitat

Pool frequency is 10.1 pools/mile, this is the highest pool frequency in the study area. Mean pool spacing is 6 bankfull channel widths per pool, the lowest pool spacing in the study area. The pools occur in rapid-pool sequences near the upstream and downstream ends of the reach. These pools are typical scour pools as opposed to the dam or plunge pools often found in the other high gradient reaches of the study area. Residual depth in pools is low with only one pool having residual depth greater than three ft (Figure 83). However, the lone pool with a residual depth greater than three feet has a residual depth of 6.2 ft which is relatively deep. Mean maximum pool depth is 4.9 ft.

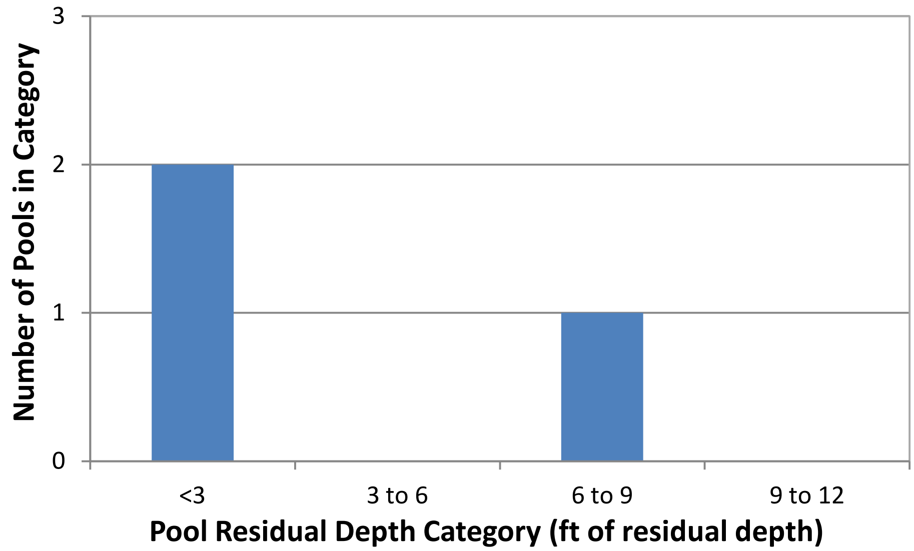


***Figure 88. Reach 12 residual pool depths.***

### 5.13.4 Off-Channel Habitat

There are no side channels in Reach 12. The reach is consistently steep with narrow valley confinement and side channel formation would not be expected in this environment.

### 5.13.5 Large Woody Material

LWM frequency is 67 pieces per mile (Table 16). The frequency of medium and large pieces together is 34 pieces/mile. There are 20 pieces total in the reach, with 59% being small, 29% medium, and 12% large pieces.

Reach 12 has low to moderate LWM recruitment potential. There are no side channels, or high flow channels where high flows could regularly recruit LWM. The channel is steep and fairly straight, without significant lateral channel migration that recruits LWM from eroding banks and near bank fallen trees. The riparian zone is intact and unbroken, providing a source of LWM in the long-term through natural tree fall associated with age, disease, or wind-throw.

***Table 17. Large woody debris quantities in Reach 12.***

| | Small (6 in x 20 ft) | Medium (12 in x 35 ft) | Large (20 in x 35 ft) | Total |
|---|---|---|---|---|
| Number of Pieces | 10 | 4 | 6 | 20 |
| Number of Pieces/Mile | 34 | 13 | 20 | 67 |

### 5.13.6 Substrate and Fine Sediment

Cobbles compose 65% of the overall bed substrate in measured units, boulders and gravel take equal shares of 15% each, and sand covers the remaining 5% in measured units (Figure 85). This extremely coarse distribution would be expected in a reach with high percentage rapid habitats. Fine sediment was measured in three grids at two locations found on pool tails in the reach near RM 33.1, and the results were posted to www.champmonitoring.org. No fine sediment smaller than 2mm was found in any of the measurement grids at either site.

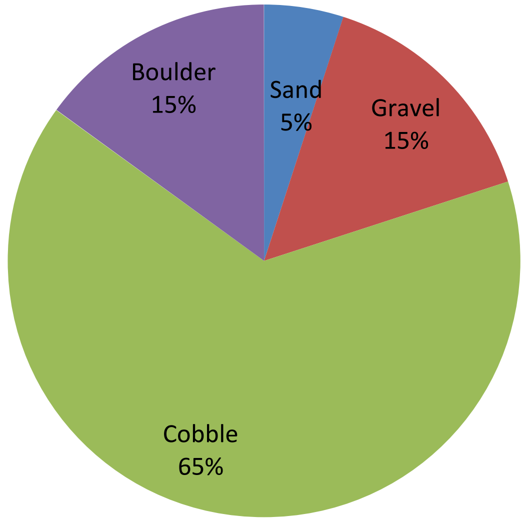


***Figure 89. Percent composition of bed substrate based on ocular estimates, Reach 12.***

### 5.13.7 Instability and Disturbance

No instability or recent disturbance was found in Reach 12. There is an intact riparian corridor and stable banks throughout the reach. There is no floodplain development, and no channel modification. There is a road on river left, but it is located outside of the river corridor in most locations.

### 5.13.8 Available Holding, Spawning, and Rearing Habitat

Existing habitat in Reach 12 is suitable mainly for a migration corridor for salmonids. Holding is limited to a few shallow pools with poor cover. There are not side channel or backwater alcoves to provide holding. The same lack of well-connected, sheltered, slow water environments limits juvenile rearing potential as well. Hydraulic environments with suitable bed substrate for spawning are relatively rare in this reach. The bed is mainly composed of cobble and boulder, and the reach is consistently too steep for spawning.

### 5.13.9 Riparian Corridor

The riparian buffer is laterally limited, with a wider extent on river left. The existing riparian zone is intact, without development. There are roads on both sides of the channel, but these are mainly set outside of the riparian zone. Vegetation size is dominated by large trees (100%), this is the only reach in the study area with any percentage of large trees as the dominant size class. Overstory species composition consists exclusively of undifferentiated conifers (100%). Doug fir, ponderosa pine, spruce and cedar are among the species present. The understory species composition is equally divided between cedar and alder.

The level of stream shade provided by the riparian canopy is high throughout Reach 12. The channel is fairly narrow and mature trees line the majority of its length.

## 5.14 REACH 13

Location: River mile 33.19-33.82

Survey Date: 9/6/2012

Survey Crew: Randy Goetz and Emily Alcott

### 5.14.1 Reach Overview

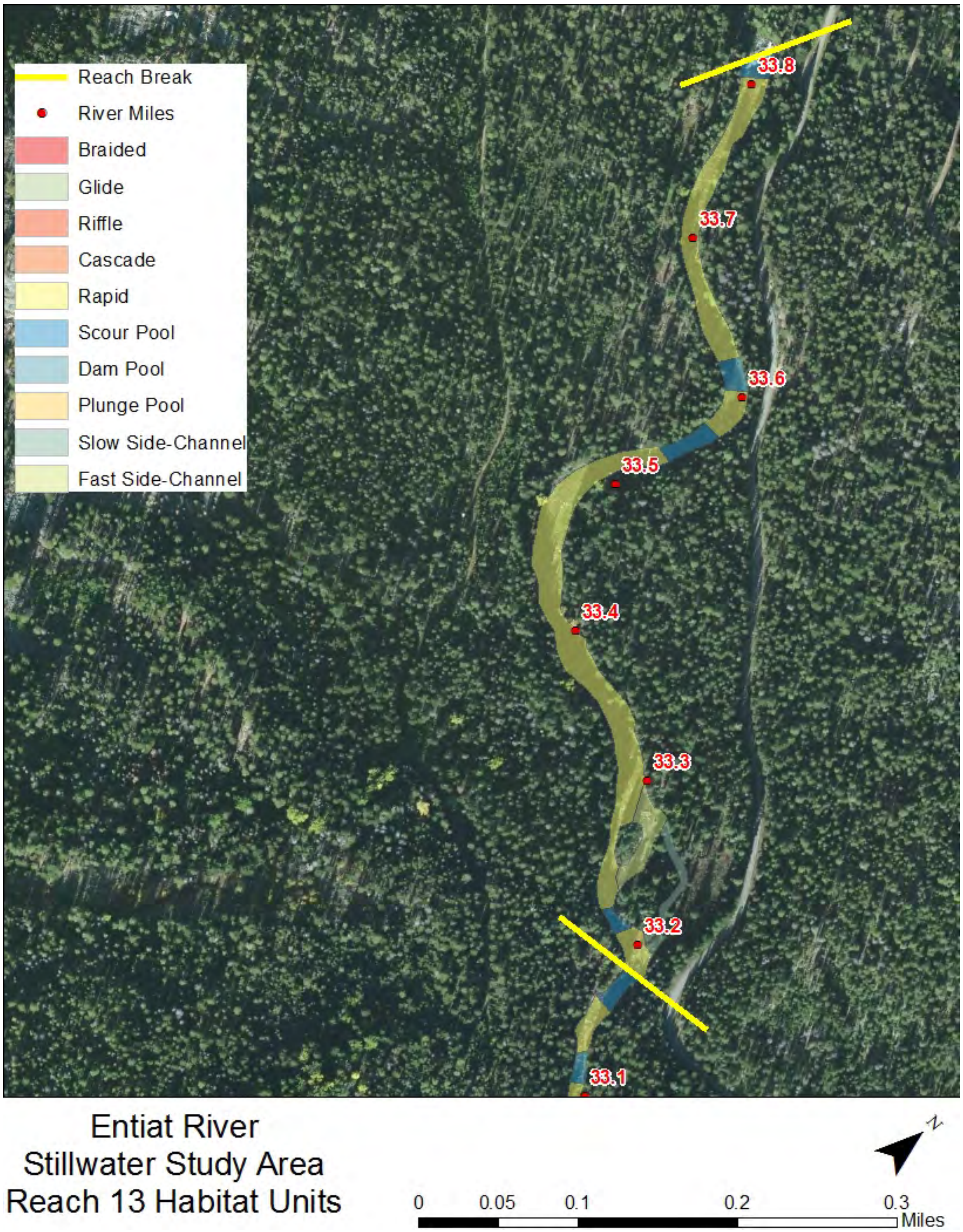


***Figure 90. Reach 13 habitat unit composition map.***

### 5.14.2 Habitat Unit Composition

Habitat in Reach 13 is mainly composed of rapids that occur in long, almost unbroken stretches that make up 86% of the total habitat in the reach (Figure 91). There are four pool units in the reach that break up the fast water habitat and provide 8% of the reaches habitat. There is also a side channel complex composed of two distinct side channel units that totals 6% of the habitat in the reach.

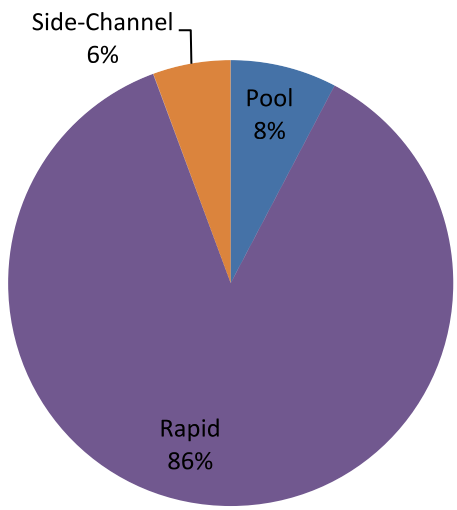


***Figure 91. Habitat unit composition, Reach 13.***

### 5.14.3 Pool Habitat

Despite the low overall percentage of pool habitat, pools were relatively frequent with 6.1 pools/mile (6.4 pools/miles study area average). Pool spacing is 10 bankfull channel widths per pool, which is slightly lower than the study area average of 9 bankfull channel widths per pool. Average residual depth is 5.6 ft, with a maximum residual depth of 10.6 ft at the deep pool below Entiat River Falls (Figure 83). There are three pools with residual depth of over three ft. Mean maximum pool depth is 7.3 ft.

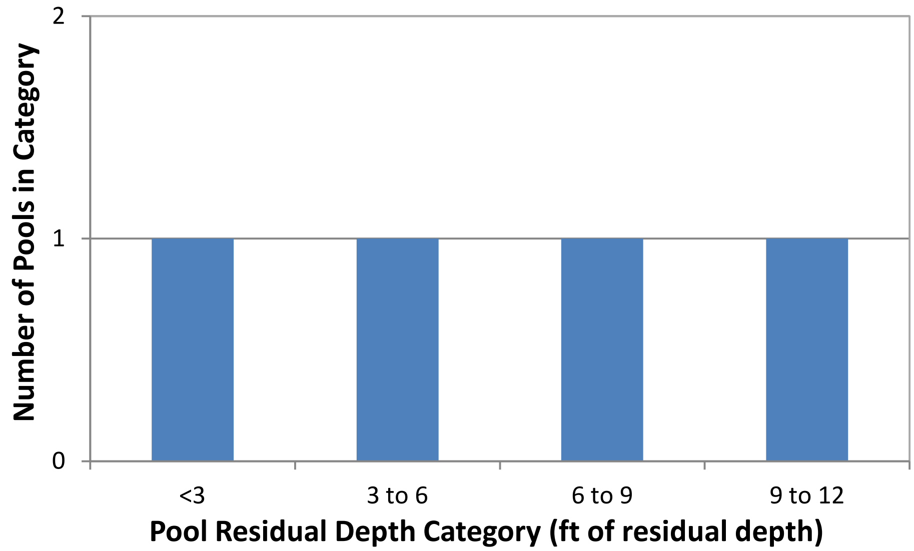


***Figure 92. Reach 13 residual pool depth.***

### 5.14.4 Off-Channel Habitat

There is one large side channel complex in Reach 13. This off-channel habitat includes two distinct side channel units; one is a perennially connected split flow channel on the mainstem and the second is a narrow side channel whose inlet is off of this split flow channel. The mainstem splits around a stable island vegetated with mature conifers to form a fast-water side channel on river left. This channel is controlled at the inlet and outlet by LWM forming hydraulic refugia. A smaller floodplain side channel flows off of the main channel split, providing seasonal high flow refuge and juvenile rearing in an alcove at the outlet (Figure 93).

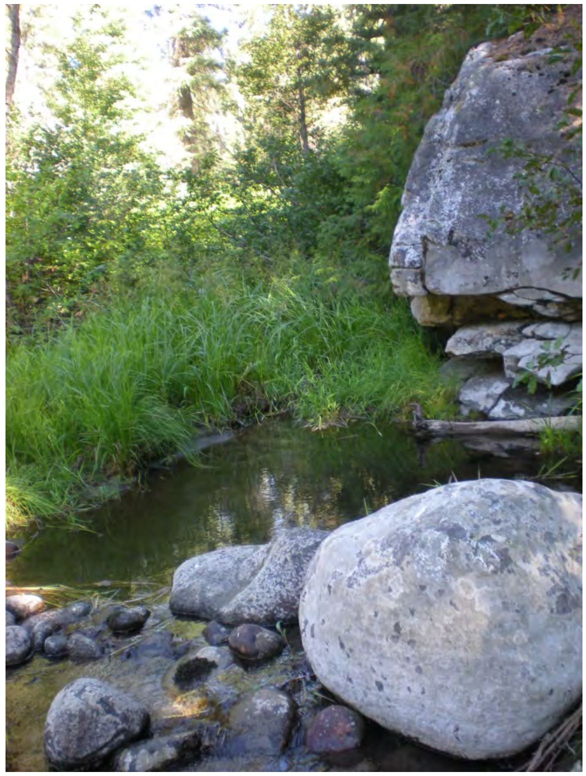

*Figure 93. Mouth of side channel forming an alcove that provides juvenile rearing habitat.*

### 5.14.5 Large Woody Material

The occurrence of LWM is relatively high in Reach 13 in terms of wood frequency at 89 pieces/mile (Table 18). Combined medium and large pieces account for 37 pieces/mile which would be considered "properly functioning" by the USFWS (1998), and is second highest frequency of medium and large wood in the study area. The total count of LWM is 58 pieces, with 59% being small, 29% medium, and 12% large.

Reach 13 has moderate to low LWM recruitment potential. The channel is steep and fairly immobile in terms of lateral migration, which limits long-term recruitment. There is a continuous riparian corridor with mature conifers. Wind throw and natural dead fall are the main sources of long-term LWM recruitment in the reach. In the near-term, LWM can be sourced from well-connected side channels near the downstream end of the reach.

*Table 18. Large woody debris quantities in Reach 13.*

| | Small (6 in x 20 ft) | Medium (12 in x 35 ft) | Large (20 in x 35 ft) | Total |
|---|---|---|---|---|
| Number of Pieces | 34 | 17 | 7 | 58 |
| Number of Pieces/Mile | 52 | 26 | 11 | 89 |

### 5.14.6 Substrate and Fine Sediment

Cobbles are dominant size class of bed material comprising 40% of the overall composition. Gravel is sub-dominant with 25% of the composition. Boulders and sand each take a 10% share and bedrock is present in a 5% portion of the bed substrate (Figure 85). This extremely coarse distribution would be expected in a reach with high percentage rapid habitats and few pools. Fine sediment in spawning gravels was not measured in this reach, however the 10% sand found by ocular estimate is relatively high for the study area.

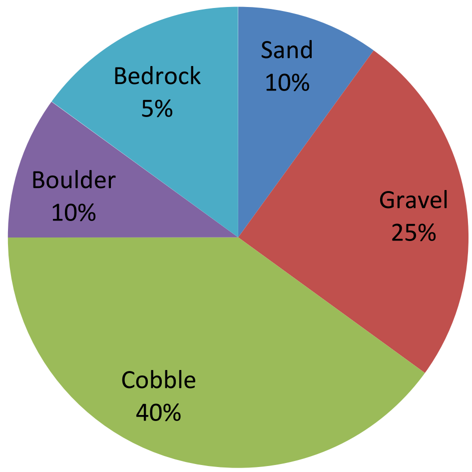


***Figure 94. Percent composition of bed substrate based on ocular estimates, Reach 13.***

### 5.14.7 Instability and Disturbance

No instability or recent disturbance was found in Reach 13. There is an intact riparian corridor and stable banks throughout the reach. There is no floodplain development, and no channel modification. There are roads on both sides of the valley, but they are located outside of the river corridor in most locations.

### 5.14.8 Available Holding, Spawning, and Rearing Habitat

High average residual depth provides good holding potential for adults and juveniles in the pools of Reach 13. However, the low number of pools and poor cover is limiting to holding. Off channel habitat is limited to a single floodplain side channel. This channel is well connected, and provides juveniles rearing habitat but is limited in the amount of habitat provided. Large bed substrate dominated by cobbles does not promote spawning. However, gravel provided a substantial portion of the bed substrate in measured units, and there are some rapid-pool sequences that provide the proper environment for salmonid spawning.

### 5.14.9 Riparian Corridor

The riparian buffer is fairly narrow throughout the reach, particularly on river right. The existing buffer is intact and continuous. There are roads on both sides of the channel, but these are mainly set outside of the riparian zone. Vegetation size is dominated by small trees (100%), with the overstory species composition consisting exclusively of undifferentiated conifers (100%). Doug fir, ponderosa pine, spruce and cedar are among the species present. The understory species composition is given over to 100% alder.

The level of stream shade provided by the riparian canopy was moderate to high throughout Reach 13. Mature conifers and narrow valley confinement provided the shadiest portions, with wider channel section receiving more sun during the day.

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# Appendix B

## Geomorphic Surface and Human Alterations Mapping

### Entiat River – Upper Stillwaters

# 1 Introduction

This appendix provides geomorphic surface mapping and human alterations at the reach scale. Geomorphic surfaces comprised of individual geomorphic features such as a distinct floodplain surface or a fan surface that is or historically has influenced the active channel. Mapping and describing conditions at this scale helps to further characterize the underlying geomorphic processes and the effects of human alterations on physical processes and habitat.

# 2 Methods

Each surface was mapped in the field and geomorphic conditions were characterized using field observations and remote sensing data sources (e.g. LiDAR and aerial photos) as well as hydraulic modeling, where possible (Reaches 1-6). Each sub-unit was given a designation of "connected" or "disconnected" depending on the degree to which human alterations have disrupted the natural physical processes (e.g. channel migration or floodplain inundation) operating on the sub-unit. This information is used to help ensure that appropriate restoration projects are developed that fit within the proper geomorphic context of the reach.

Surfaces fell into one of two categories: (1) alluvial fan surfaces, or (2) valley floor surfaces. Surfaces were given only a relative age because carbon dating of surfaces was out of the scope of this effort. Alluvial fan surfaces were delineated as active or inactive. Valley floor surfaces were delineated as "contemporary floodplain," which are surfaces inundated at the Q100, or "terraces", which are surfaces that have been abandoned as a result of natural incision processes. There were multiple distinct elevations of terraces observed as part of this project, but without carbon dating information, aging of these surfaces was not available.

The Bureau of Reclamation provides detailed surficial mapping and aging of surfaces along the Entiat Valley floor (USBR 2009; Godaire et al. 2010) based on radiocarbon dating. Detailed dating of surficial geology within the basin was outside the scope of this effort, so surfaces were aged only on a relative age basis. Nomenclature used (Table 1) in subsequent sections of this report group age classes that were separated by previous geomorphic descriptions of the basin. Fan age was delineated utilizing LiDAR, the aerial photo record, topographic maps, and field observation. Radiocarbon dating to precisely age fan surfaces was not performed as part of this Reach Assessment, but observation of channel and valley-scale processes were utilized to provide a relative aging of fan surfaces. There were multiple processes considered when aging fan surfaces. First, the degree of erosion at the fan was evaluated. Inactive fans were identified as those where the incision and the migration of the channel have left behind steep terrace scarps. Active fans are those that currently extend out into the channel and are actively influencing channel process by reworking channel planform. Second, the extent of floodplain surface development along the fan toe was evaluated. Those surfaces with significant (greater than 50 feet) floodplain surfaces that have been developed, and have visible scour along the surface, were aged as inactive fan surfaces. Lastly, if fan surfaces are developing atop another fan surface, then the underlying surface was aged as older.

***Table 1. Surficial naming conventions in relation to ages presented in BOR 2009, Godaire et al. 2010.***

| Group | Relative Age Nomenclature | BOR Units Included | Height above modern Channel | Approximate Age (years) |
|---|---|---|---|---|
| Floodplain & Terrace Deposits | Active Channel | Active Channel | n/a | Modern |
| | Contemporary Floodplain (active at Q100) | Active Floodplain | Less than 5 feet | Less than 500 years |
| | Abandoned Terrace | (1) High Floodplain<br>(2) Mid-Holocene Terrace | Greater than 5 feet | Greater than 500 years |
| Alluvial Fan Deposits | Active fan | Younger fan alluvium | Variable | Less than 1,000 years |
| | Inactive fan | Older Fan Alluvium | Variable | Greater than 1,000 years |

# 3 Results

Geomorphic surface and human alteration mapping is provided below.

## 3.1 REACH 0

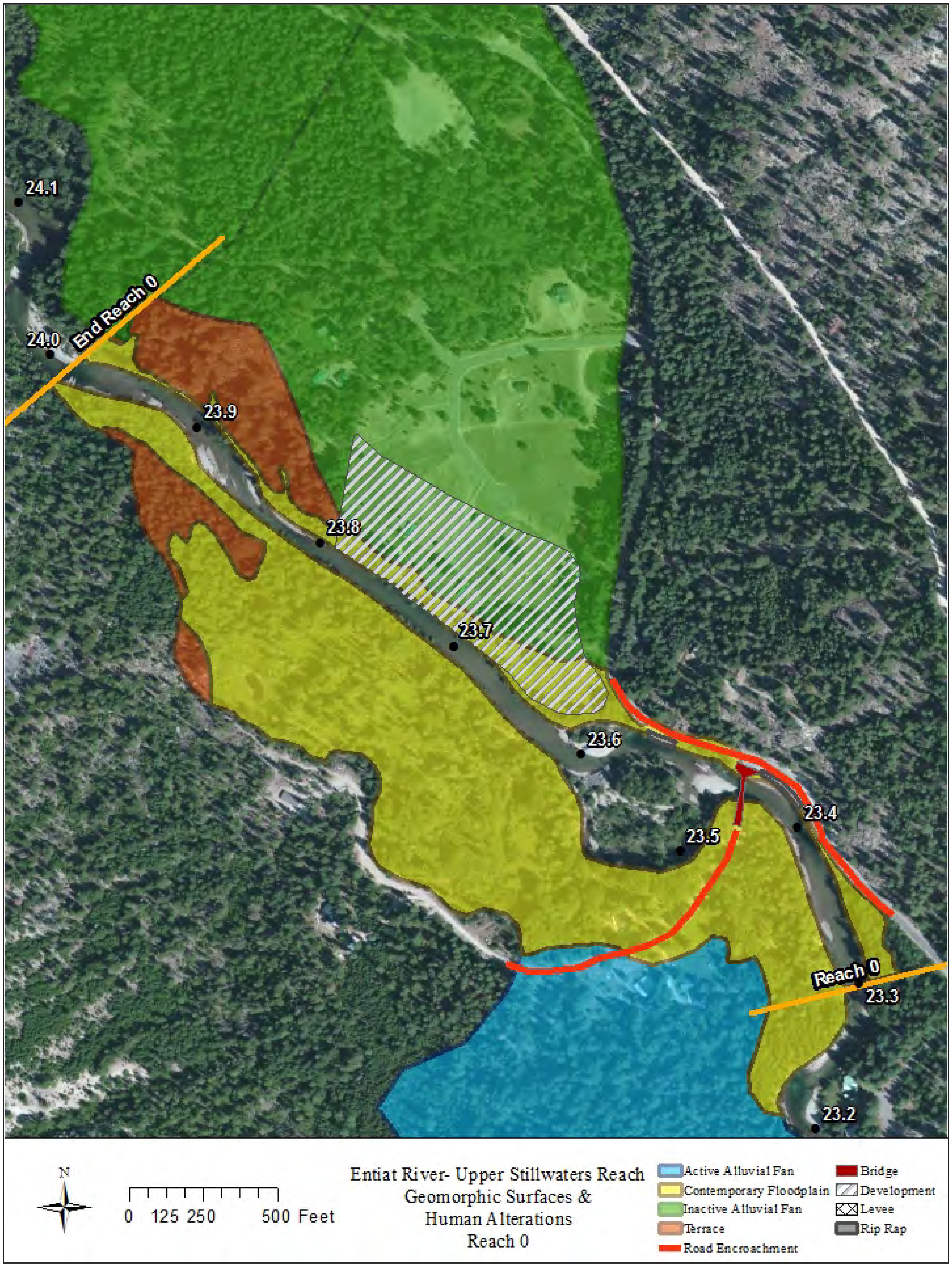


***Figure 1. Geomorphic surfaces and human alterations for Reach 0. Flow is from northwest to southeast.***

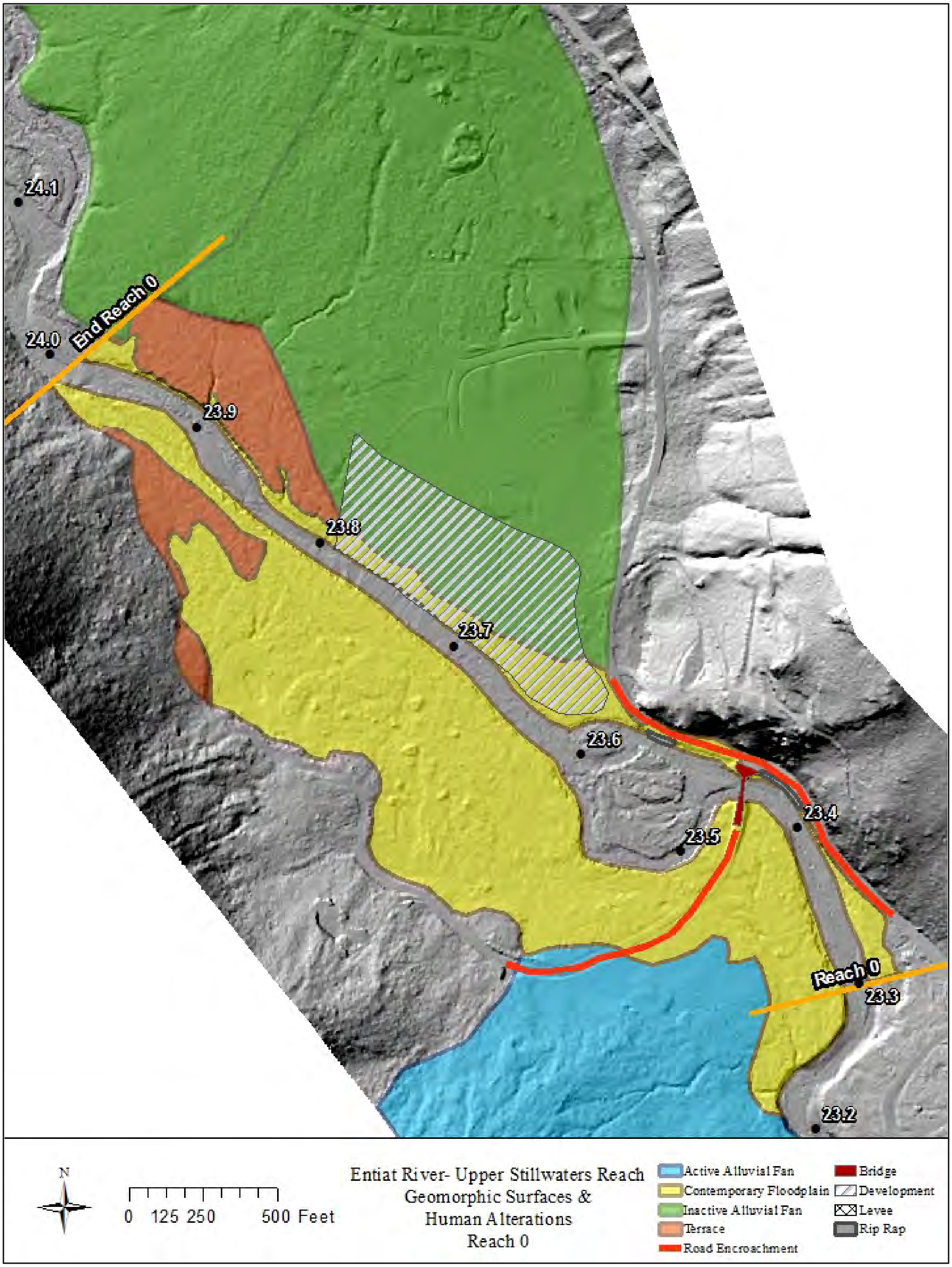


*Figure 2. Geomorphic surfaces and human alterations for Reach 0 over LiDAR basemap. Flow is from northwest to southeast.*

## 3.2 REACH 1


*Figure 3. Geomorphic surfaces and human alterations for Reach 1. Flow is from northwest to southeast.*

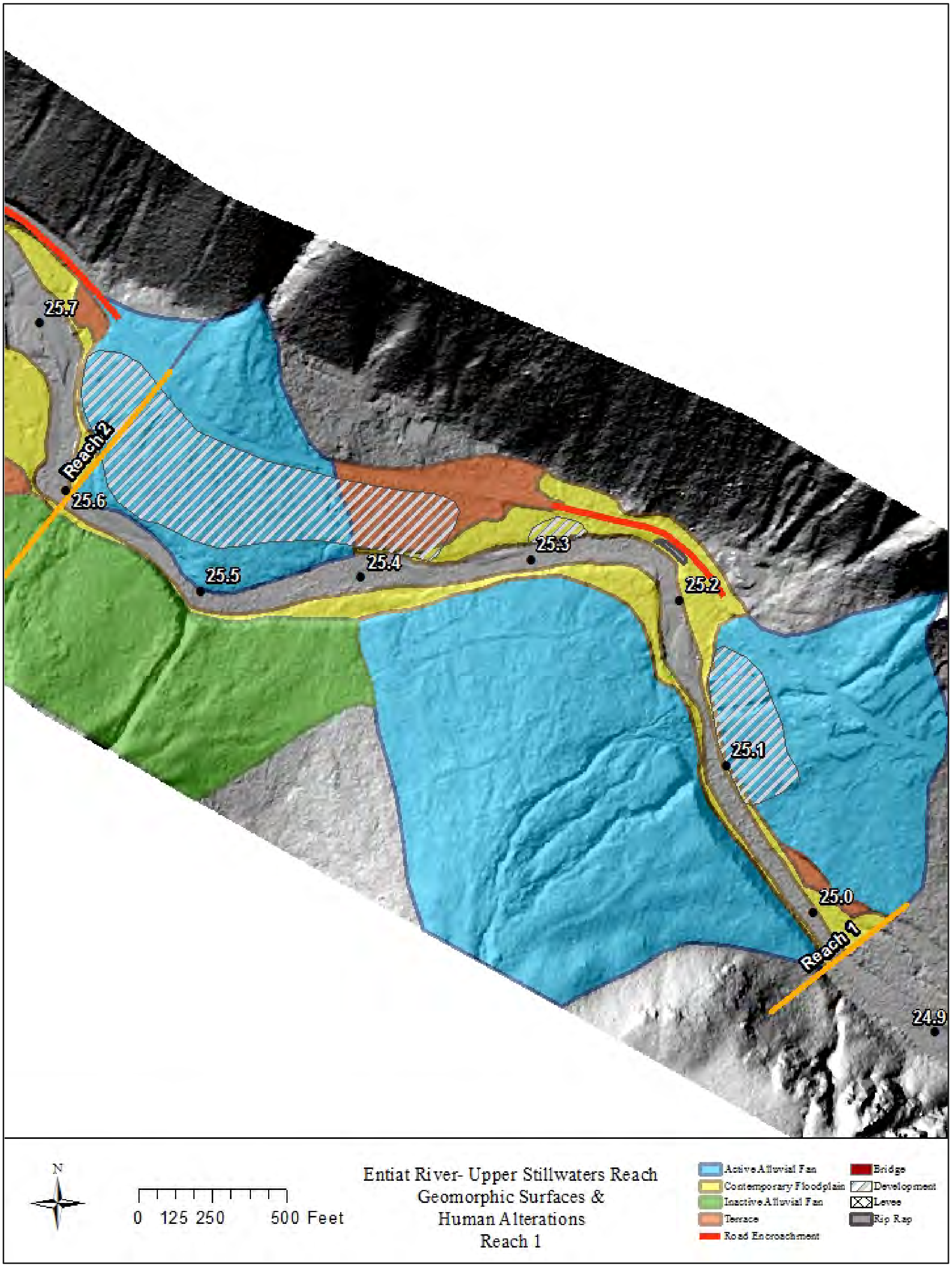


*Figure 4. Geomorphic surfaces and human alterations for Reach 1 over LiDAR basemap. Flow is from northwest to southeast.*

## 3.3 REACH 2


***Figure 5. Geomorphic surfaces and human alterations for Reach 2. Flow is from northwest to southeast.***

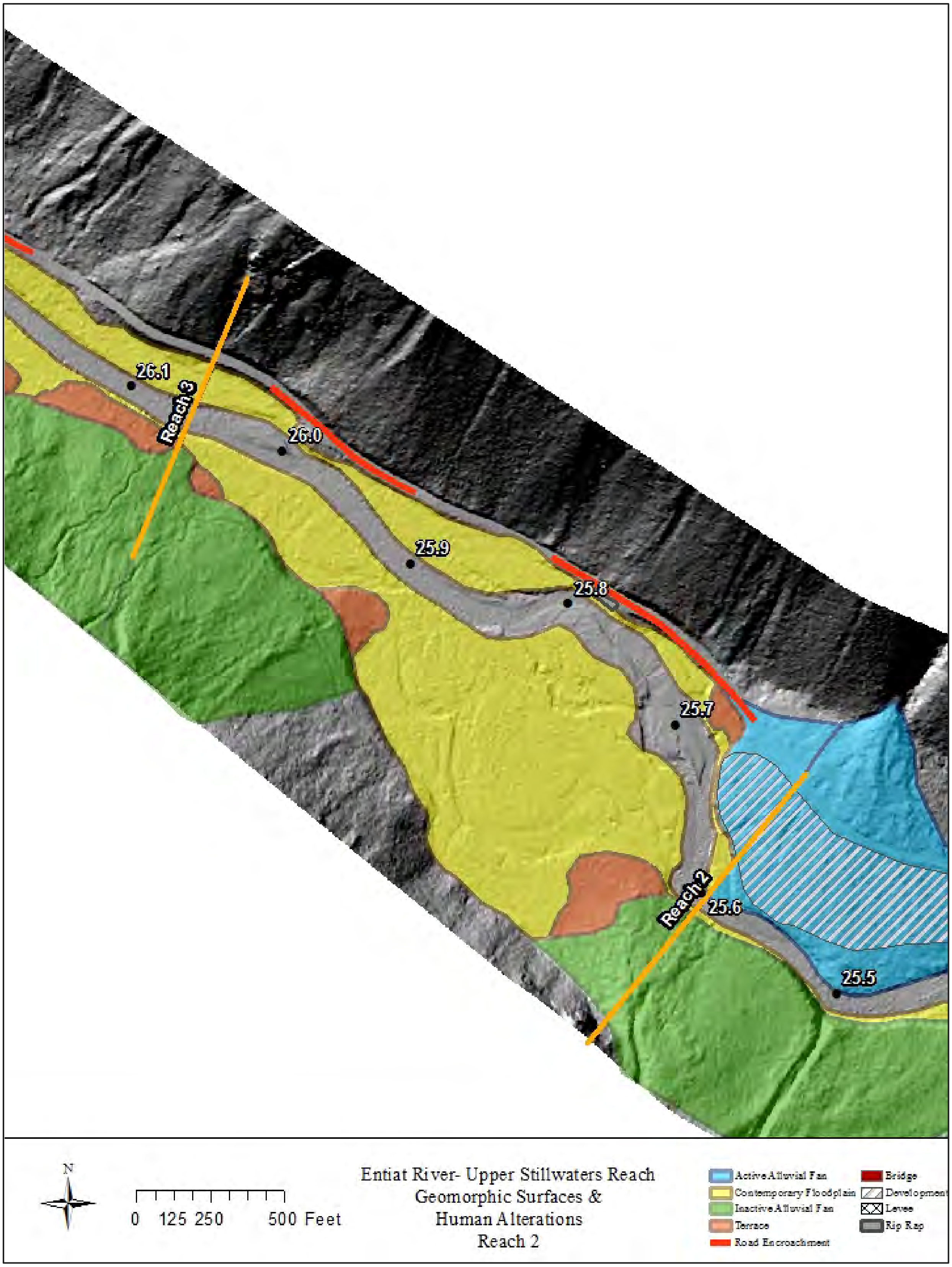


***Figure 6. Geomorphic surfaces and human alterations for Reach 2 over LiDAR basemap. Flow is from northwest to southeast.***

## 3.4 REACH 3


*Figure 7. Geomorphic surfaces and human alterations for Reach 3. Flow is from northwest to southeast.*

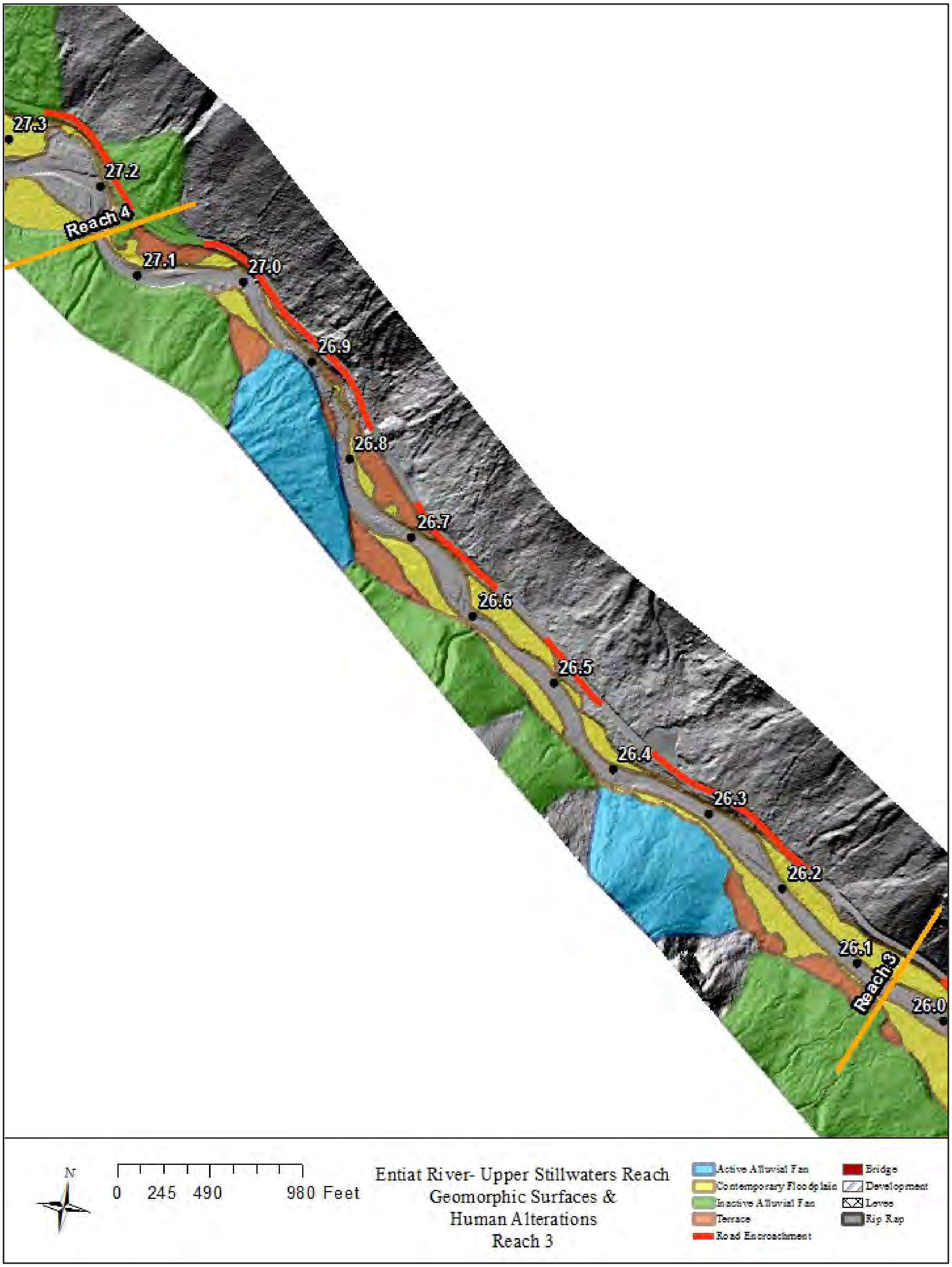


***Figure 8. Geomorphic surfaces and human alterations for Reach 3 over LiDAR basemap. Flow is from northwest to southeast.***

## 3.5 REACH 4


***Figure 9. Geomorphic surfaces and human alterations for Reach 4. Flow is from northwest to southeast.***

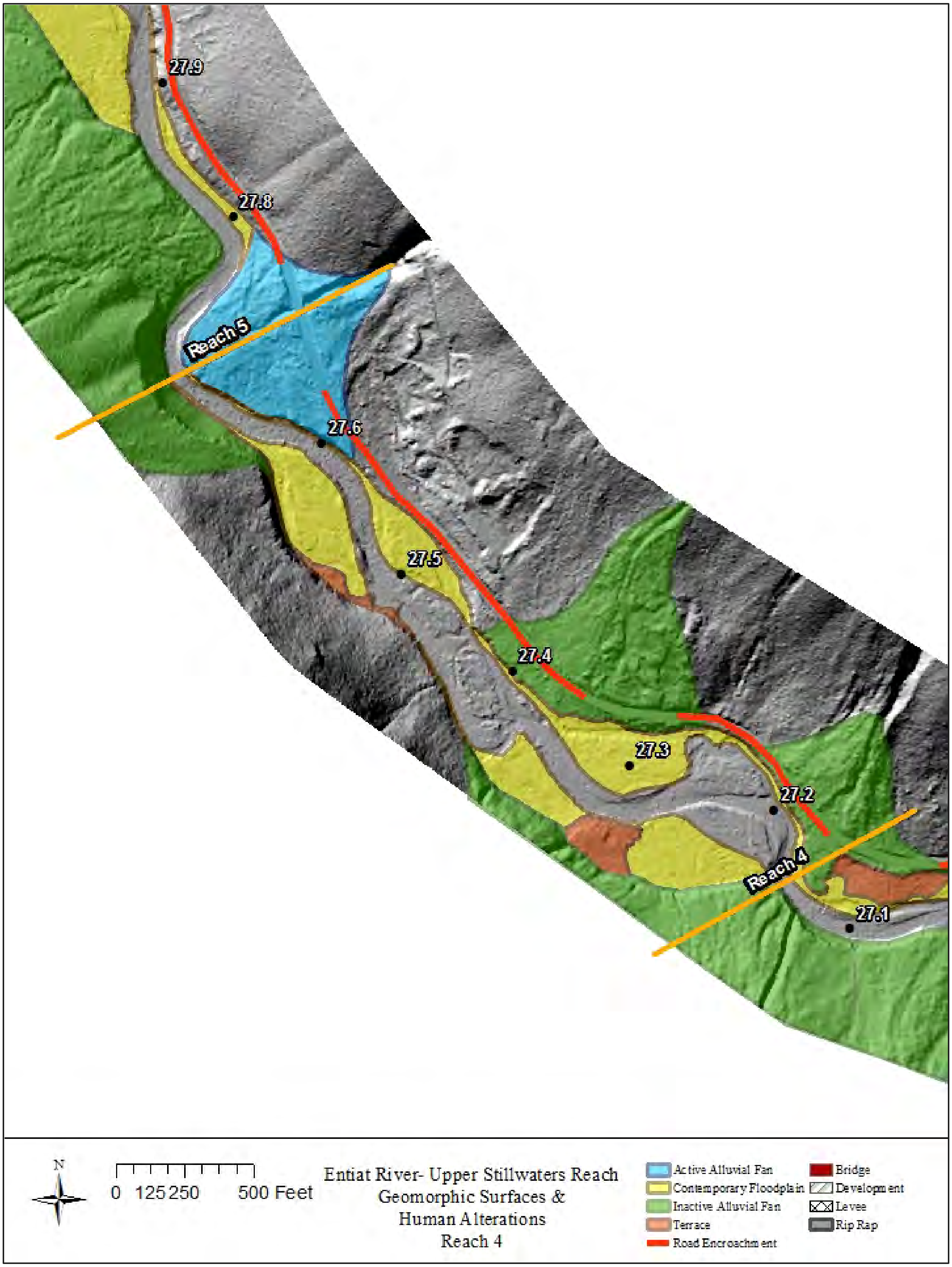


*Figure 10. Geomorphic surfaces and human alterations for Reach 4 over LiDAR basemap. Flow is from northwest to southeast.*

## 3.6 REACH 5

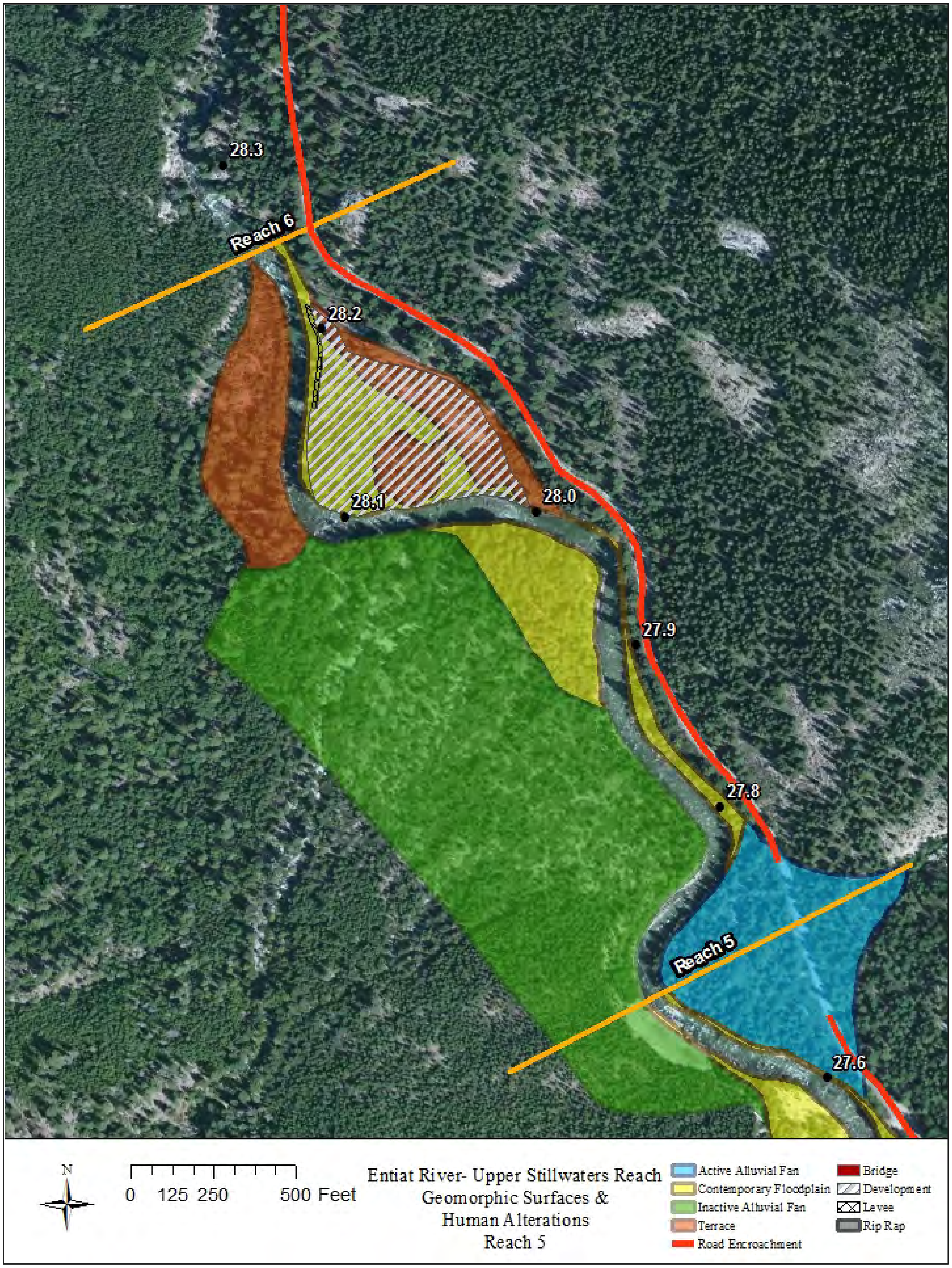


***Figure 11. Geomorphic surfaces and human alterations for Reach 5. Flow is from northwest to southeast.***

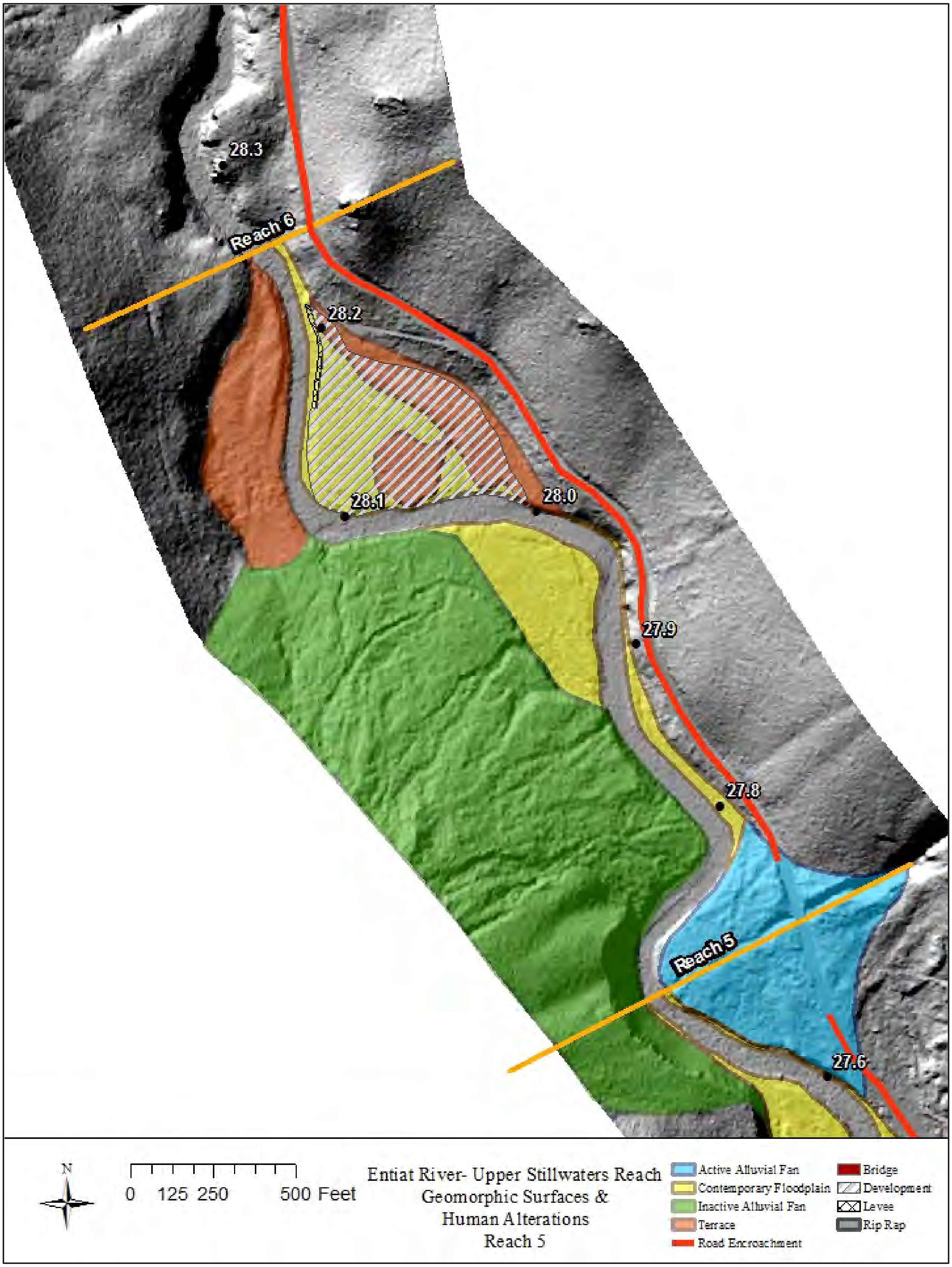


***Figure 12. Geomorphic surfaces and human alterations for Reach 5 over LiDAR basemap. Flow is from northwest to southeast.***

## 3.7 REACH 6

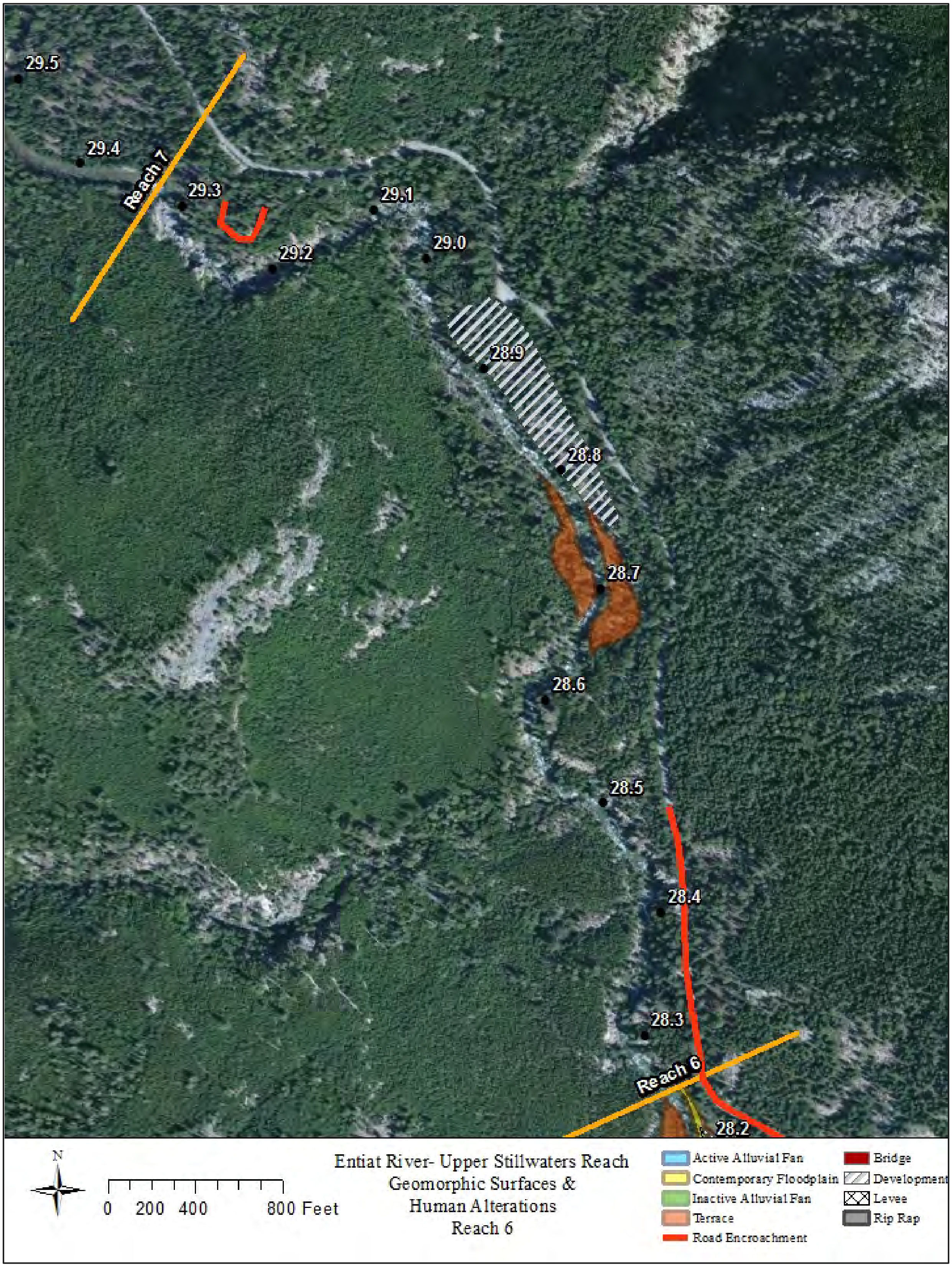


***Figure 13. Geomorphic surfaces and human alterations for Reach 6. Flow is from northwest to southeast.***

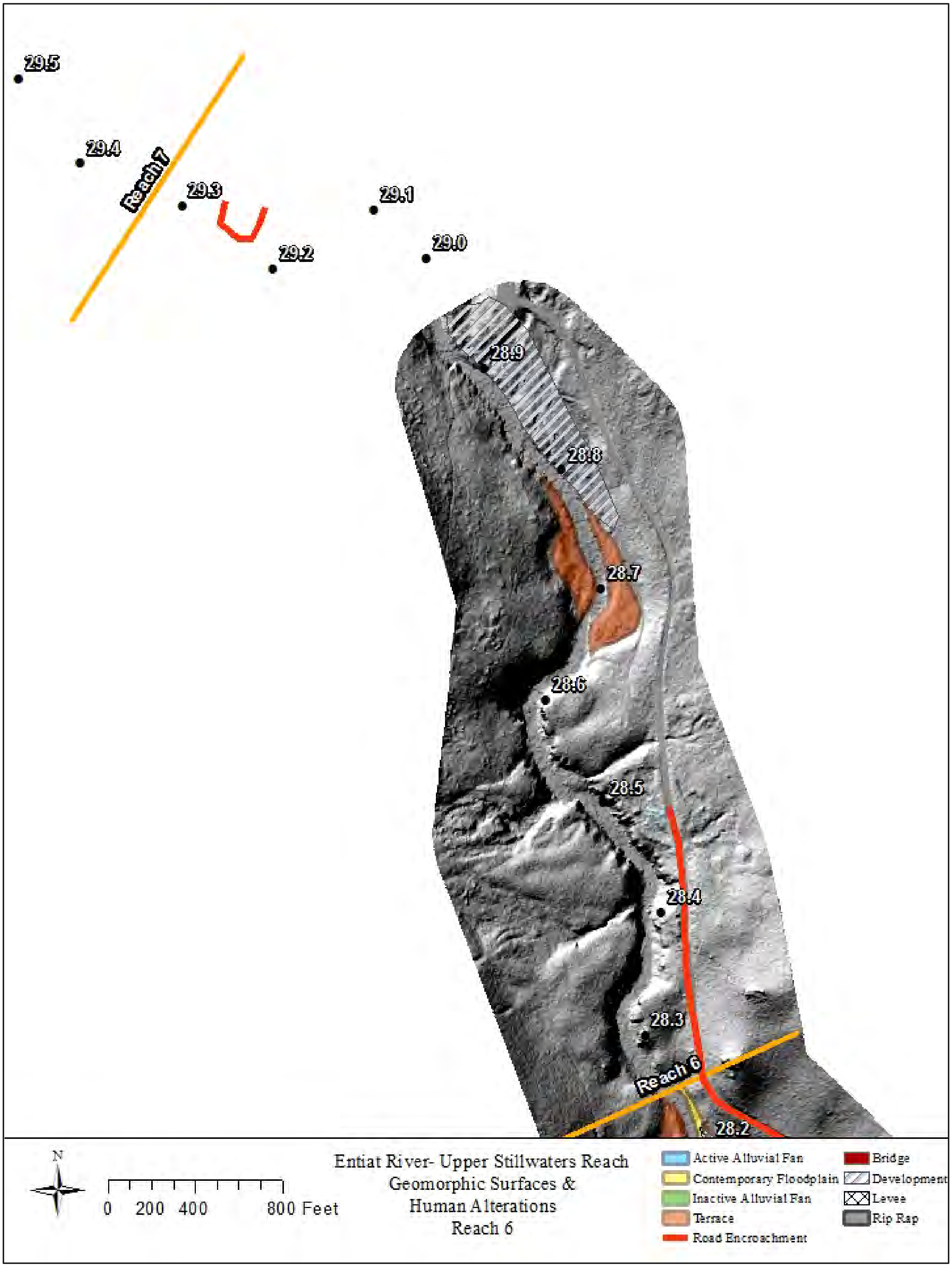


***Figure 14. Geomorphic surfaces and human alterations for Reach 6 over LiDAR basemap. Flow is from northwest to southeast.***

## 3.8 REACH 7


*Figure 15. Geomorphic surfaces and human alterations for Reach 7. Flow is from northwest to southeast.*

## 3.9 REACH 8

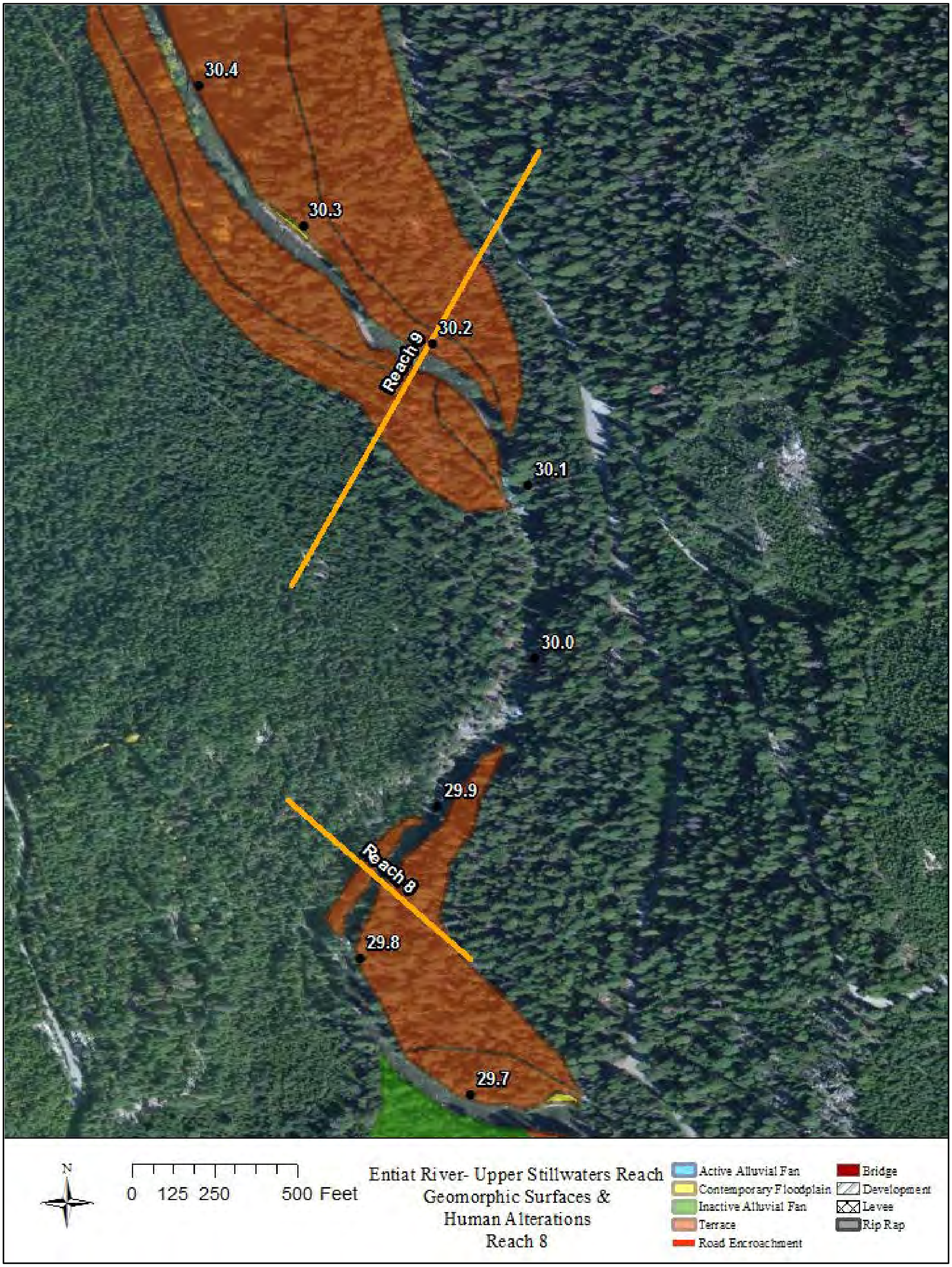


***Figure 16. Geomorphic surfaces and human alterations for Reach 8. Flow is from northwest to southeast.***

### *3.10 REACH 9*

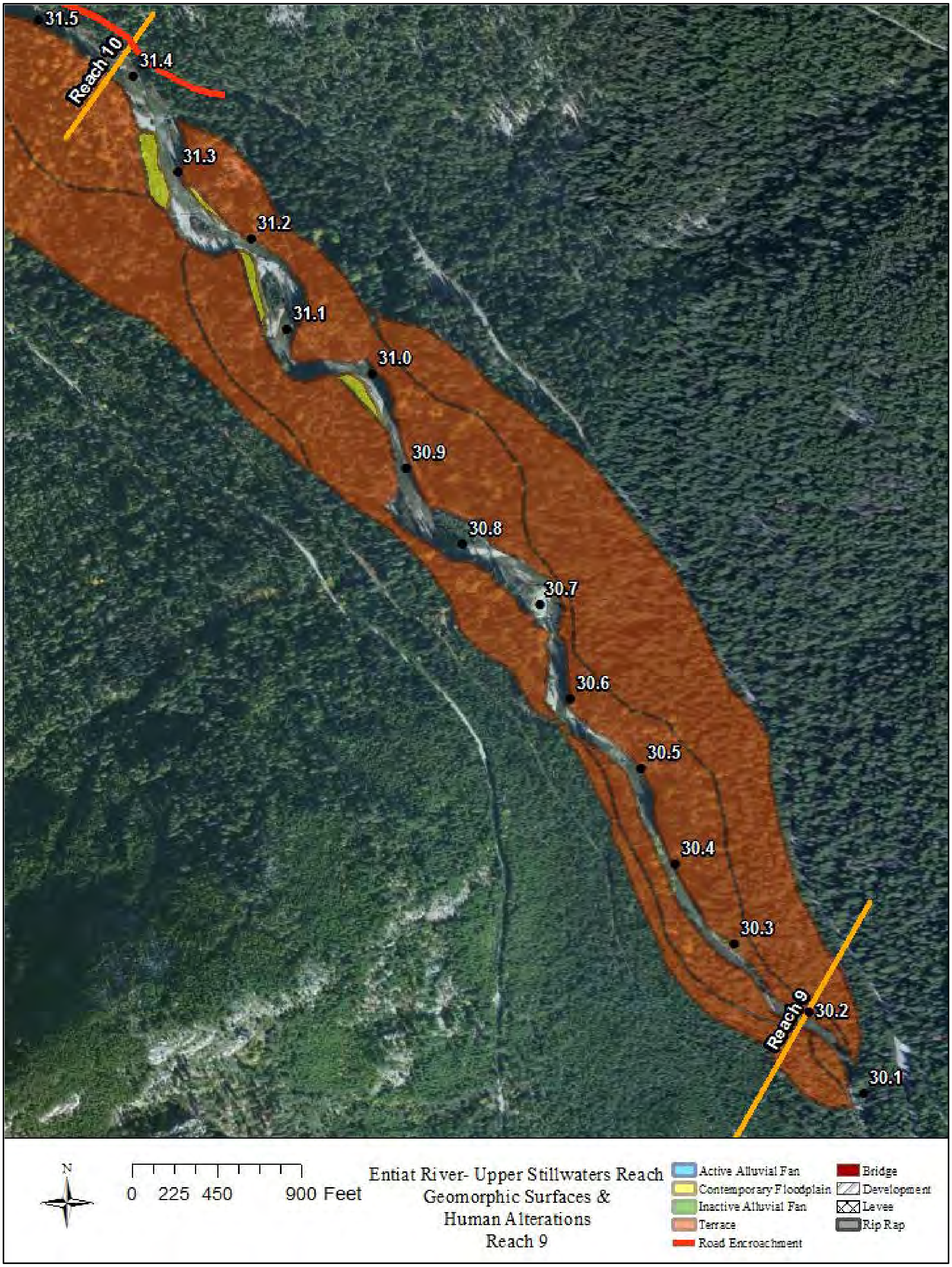


***Figure 17. Geomorphic surfaces and human alterations for Reach 9. Flow is from northwest to southeast.***

## 3.11 REACH 10


*Figure 18. Geomorphic surfaces and human alterations for Reach 10. Flow is from northwest to southeast.*

## 3.12 REACH 11

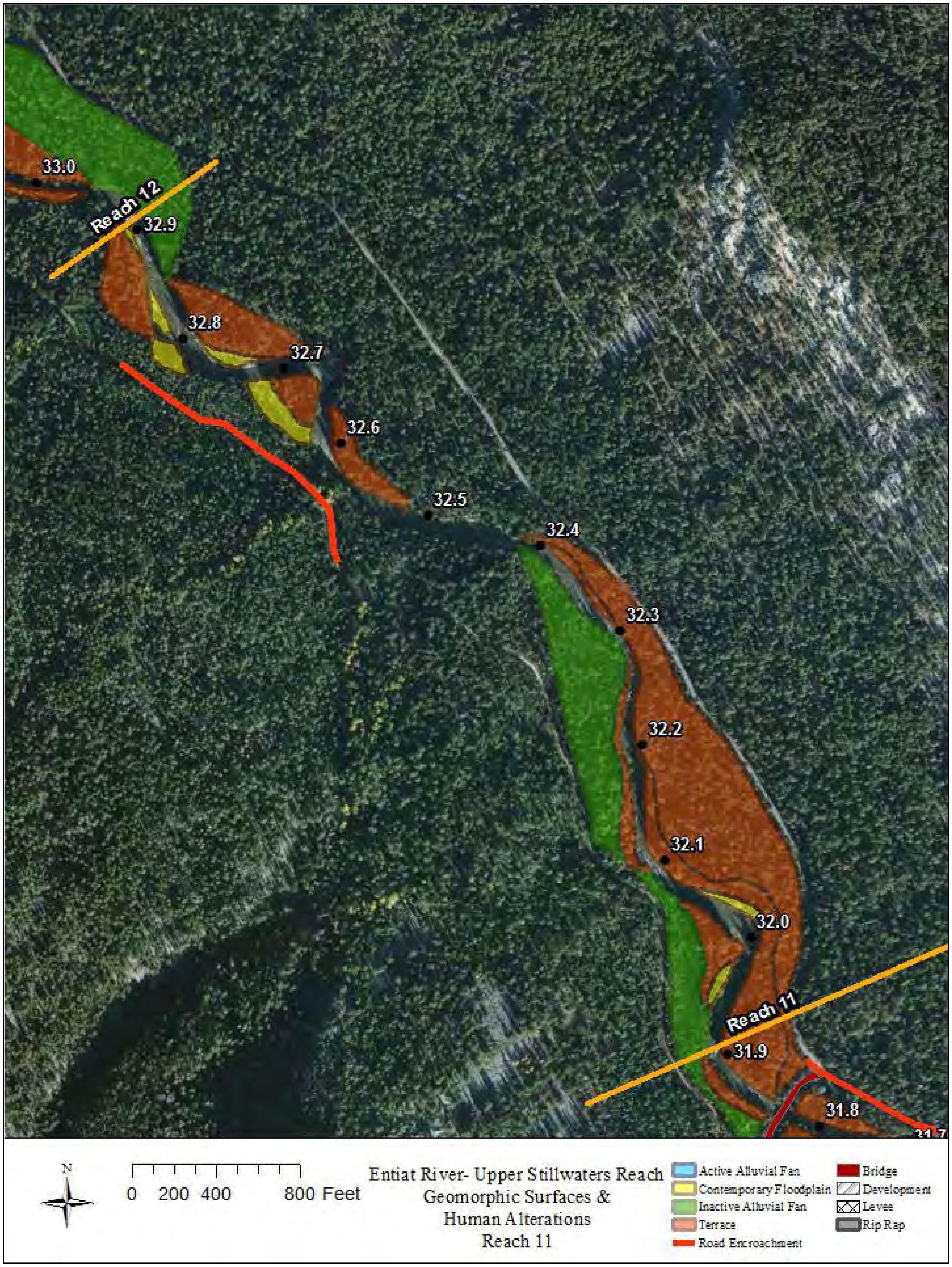


*Figure 19. Geomorphic surfaces and human alterations for Reach 11. Flow is from northwest to southeast.*

## 3.13 REACH 12

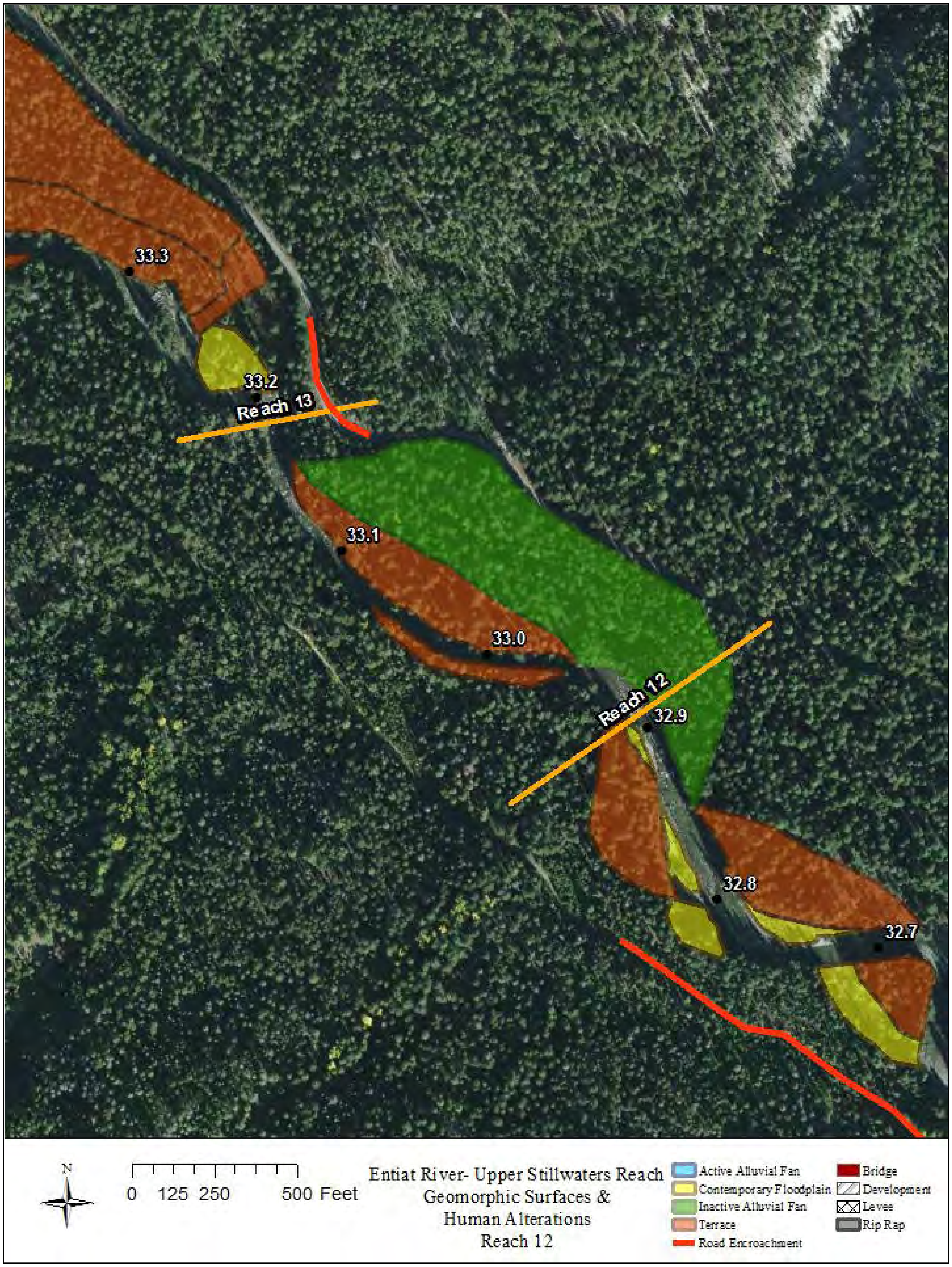


*Figure 20. Geomorphic surfaces and human alterations for Reach 12. Flow is from northwest to southeast.*

## 3.14 REACH 13

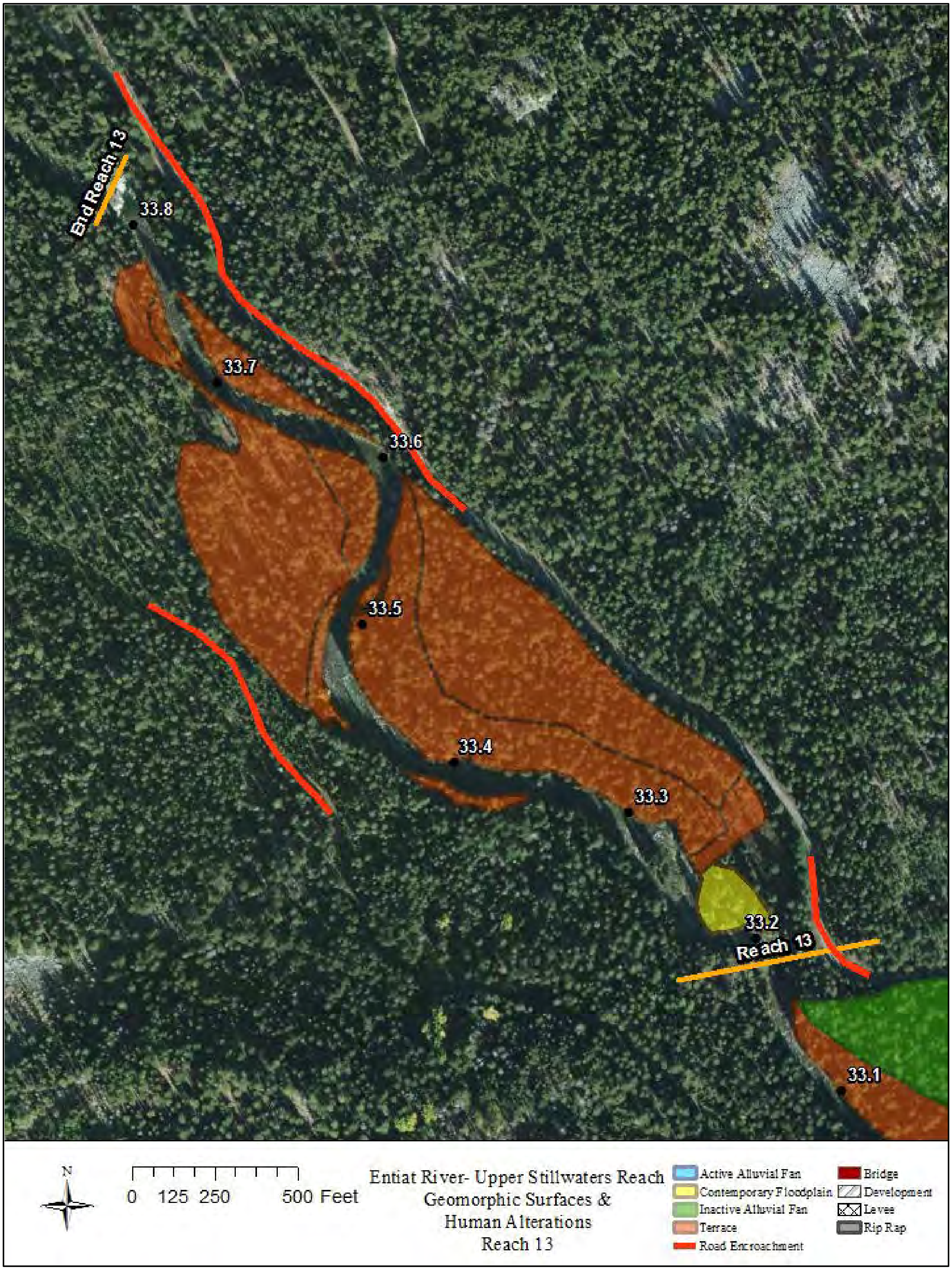


*Figure 21. Geomorphic surfaces and human alterations for Reach 13. Flow is from northwest to southeast.*

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# Appendix C

## Reach-Based Ecosystem Indicators (REI)

### Entiat River – Upper Stillwaters

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# 1 Introduction

The REI provides a consistent means of evaluating biological and physical conditions of a watershed in relation to regional standards and known habitat requirements for aquatic biota. These indicators, along with other scientific evaluations, describe the current quality of stream biophysical conditions and can help inform restoration targets and actions. The REI indicators used in this assessment are adaptations from previous efforts including the NMFS matrix of pathways and indicators (NMFS 1996) and the USFWS (1998). With a few exceptions that are noted, the REI are based on the USBR's latest adaptations and use of these indicators (USBR 2011).

The REI evaluation for the Upper Stillwater Reach of the Entiat River was conducted using field data, observations, previous studies, and available data for the study area. In particular, the rankings were developed based on: 1) quantitative inventory information from the Habitat Assessment performed as part of the Reach Assessment using USFS (2010) protocols, 2) assessment of geomorphic patterns and processes and how they have deviated, if at all, from historical conditions, and 3) analysis of existing watershed assessments and data (e.g. available ArcMap layers and shapefiles).

# 2 PATHWAY: Watershed Condition

## 2.1 INDICATOR: WATERSHED ROAD DENSITY AND EFFECTIVE DRAINAGE NETWORK

### 2.1.1 Metric Overview

Watersheds with high road density can alter drainage networks and increase fine sediment loads to the river (USFS 2010). Soil erosion and mass wasting have been demonstrated to be higher in areas where there are high road networks than in undisturbed areas (Amaranthus et al 1985). Road networks can increase the frequency and quantity of sediment pulses to streams. Increased fine sediment can adversely affect aquatic habitat in numerous ways (Waters 1995, Wilber and Clarke 2001), including suffocation of salmonid eggs or larvae, reduced forage success due to impaired water clarity, limiting the growth of aquatic plants, channel instability from altered sediment budgets, and adverse physiological effects on invertebrates.

***Criteria: From USFWS (1998), modified by USBR (2012).***

| Pathway | General Indicators | Specific Indicators | Adequate | At Risk | Unacceptable |
|---|---|---|---|---|---|
| Watershed Condition | Effective Drainage network and Watershed Road Density | Increase in Drainage Network/Road Density | Zero or minimum increase in active channel length correlated with human-caused disturbance<br><br>And<br><br>Road density <1 *miles/mile*$^2$ | Low to moderate increase in active channel length correlated with human-caused disturbance<br><br>And<br><br>Road density 1 to 2.4 *miles/mile*$^2$ | Greater than moderate increase in active channel length correlated with human-caused disturbance<br><br>And<br><br>Road density >2.4 *miles/mile*$^2$ |

### 2.1.2 Assessment Results

Road density was calculated using USFS owned roads and Chelan County roads shapefiles. Road density was calculated for the watershed area contributing to the study area as determined in the Streamstats online mapper application (USGS 2013). Areas of overlap in the data sets were removed, thereby reducing the likelihood of overestimation of road density. Road density for the entire contributing watershed area was 1.87 miles per square mile, which puts the study area in the “at risk” category.

Historical channel planform and length were evaluated by geo-referencing historical aerial photos of the Entiat River within the study area. Evaluation of historical channel planform indicates a decrease in active channel length of about 2.8% (about 1,726 ft) in active channel length occurring between 1945 and 2011. Much of this can be attributed to planform changes following large floods in 1972 and 1974. There does not appear to be any human activity associated with channel shortening or other significant changes to channel planform. In terms of active channel length and planform changes that can be attributed to human activity, the study area is considered **adequate**.

### 2.1.3 REI Rating

Watershed Rating: **At Risk**

## 2.2 INDICATOR: DISTURBANCE REGIME (NATURAL & HUMAN-CAUSED)

### 2.2.1 Metric Overview

Environmental disturbance is a natural ecosystem process that is important for creating and maintaining habitats over time. Natural disturbance events include wildland fire, flooding, landslides, and windstorms. In some cases, human alterations to the landscape can impair natural disturbance processes and create large catastrophic disturbance events or long-term 'press' disturbances that impair natural processes for extended periods. Artificial, human-caused disturbances include timber harvest and road-induced landslides. Human-caused 'press' disturbances include construction of roads, creation of impervious surfaces, and infrastructure that disconnects floodplains.

***Criteria: From USFWS (1998).***

| Pathway | General Indicators | Specific Indicators | Adequate | At Risk | Unacceptable |
|---|---|---|---|---|---|
| Watershed Condition | Disturbance Regime | Natural/Human Caused | Environmental disturbance is short lived; predictable hydrograph; high quality habitat and watershed complexity providing refuge and rearing space for all life stages or multiple life-history forms. Natural processes are stable. | Scour events, debris torrents, or catastrophic fires are localized events that occur in several minor parts of the watershed. Resiliency of habitat to recover from environmental disturbances is moderate. | Frequent flood or drought producing highly variable and unpredictable flows, scour events, debris torrents, or high probability of catastrophic fire exists throughout a major part of the watershed. The channel is simplified, providing little hydraulic complexity in the form of pools or side channels. Natural processes are unstable. |

### 2.2.2 Assessment Results

The disturbance history in the upper Entiat River basin is deemed functioning at an **At Risk** condition. The rating reflects historical accounts of riparian and hillslope timber harvest, log drives, and limited development in and around the floodplain. Furthermore, fire suppression within the basin has elevated the risk of catastrophic wildland fires. Large fires, floods, and debris flows led to channel debris clearing in the lower mile of the study area in the early 1970s. These alterations include past human disturbance to which the system is still recovering from, or on-going 'press' disturbances that have a persistent and long-lasting impact.  There is also risk for potential future catastrophic disturbance (e.g. stand-replacing fire) to the basin.

### 2.2.3 REI Rating

Watershed Rating:  **At Risk**

## 2.3 INDICATOR: STREAMFLOW (CHANGE IN PEAK/BASE FLOW)

### 2.3.1 Metric Overview

Stream discharge and channel morphology are directly linked to the magnitude, timing, duration, and frequency of hydrologic inputs to the system. Hydrology is predominantly controlled by climate, vegetation, geology, and human alterations and impacts. Potential human impacts to hydrologic systems include flow regulation (e.g. dams), water withdrawals (e.g. for irrigation), widespread timber harvest, increased impervious surfaces, or intensive road building.

***Criteria: From USFWS (1998), modified by USBR (2012).***

| Pathway | General Indicators | Specific Indicators | Adequate | At Risk | Unacceptable |
|---|---|---|---|---|---|
| Watershed Condition | Streamflow | Change in Peak/Base flows | Magnitude, timing, duration and frequency of peak flows within a watershed are not altered relative to natural conditions of an undisturbed watershed of similar size, geology, and geography. | Some evidence of altered magnitude, timing, duration and frequency of peak flows relative to natural conditions of an undisturbed watershed of similar size, geology, and geography | Pronounced evidence of altered magnitude, timing, duration and frequency of peak flows relative to natural conditions of an undisturbed watershed of similar size, geology, and geography |

### 2.3.2 Assessment Results

The hydrology of the watershed contributing to the Upper Stillwater study area on the Entiat River is driven by a combination of precipitation and snowmelt. Precipitation, in the form of snow and rain, varies with elevation and distance from the Cascade crest. The higher elevations of the watershed receive 110 inches of precipitation a year, whereas lower areas receive less (USBR 2011). The average annual precipitation in the study area is 62 inches per year (USGS 2013). These low areas are also further east, and more affected by the rain shadow of the Cascades.
Spring snowmelt dominates the seasonal streamflow pattern in the basin (Figure 2). Snowmelt primarily occurs during the spring and early summer, and is driven by changes in ambient air temperature, snowpack mass, and the elevation distribution of the season’s snowpack. Peak runoff usually occurs from April through July, with the highest rates typically in late June. The Entiat typically returns to baseflow by late August. August. The 1.25-, 2-, 5-, 10-, 25-, 50-, and 100-year recurrence interval floods were calculated for the Entiat River using the USGS gage near Ardenvoir for the period 1958-2011. Hydrologic data was then compared by time period in approximately 20 year increments. This comparison shows that floods have remained relatively constant in the last 40 years, but that estimated peak flows between 1958 and 1978 were larger (Figure 1). The higher flow period coincides with ten of the top 20 water events on record (

Table 1). Some of the largest of these events likely correlate with events that had coincidental occurrences of high precipitation and snowmelt. The time of larger peak flows also coincides with peak logging and channel clearing activities in the watershed. There is not a precipitation or snow record for the Entiat basin for a comparable time period, so a comparison to precipitation records is not possible. In summary, the analysis suggests that there could be potential changes in peak flows (i.e. decreased peak flows over time); however, the data and analysis are not sufficient enough to document changes or causation with certainty.

Climate change modeling indicates that rainfall is expected to increase one to two percent by 2040, and four percent by 2080 (e.g. Mote and Salanthe 2009). Climate change models (synthesized by CIG 2009) also indicate that changes will likely result in an increase in winter stream flows, earlier and lower peak runoff, and lower summer baseflows (Figure 3). These analyses suggest that human-induced climate change is likely to have an effect on the magnitude, timing, duration, and frequency of streamflows.

Based on the potential effects of past watershed management (i.e. timber harvest, road building, alterations to fire regime), and the potential effects of climate change, this metric is rated **At Risk**.

### 2.3.3 REI Rating

Watershed Rating: **At Risk**

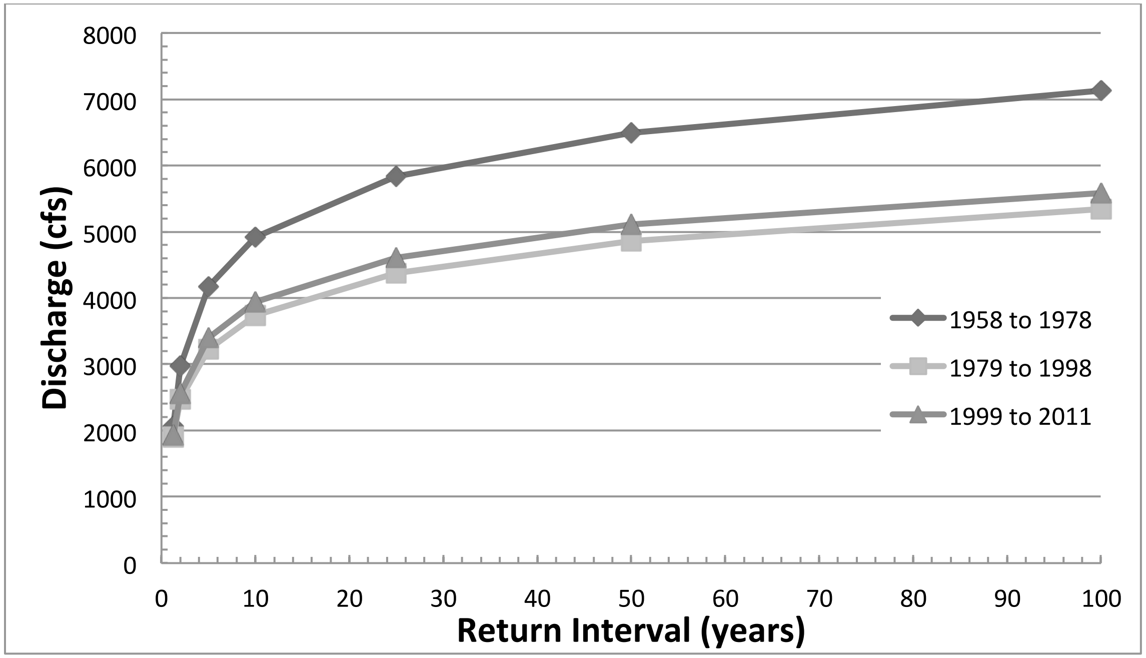


***Figure 1. Changes in estimated peak flow discharge over time, beginning in 1958.*** **Discharge was measured at the USGS gage near Ardenvoir, WA (*Gage 12458200*, 1958 to 2011).**

***Table 1. Top 20 water events (floods) since 1957.***

| Event Rank | Water Year | CFS |
|---|---|---|
| 1 | 1972 | 6,430 |
| 2 | 1974 | 5,540 |
| 3 | 1983 | 4,670 |
| 4 | 1999 | 4,460 |
| 5 | 1958 | 4,110 |
| 6 | 2006 | 4,100 |
| 7 | 1986 | 3,900 |
| 8 | 1967 | 3,820 |
| 9 | 1968 | 3,820 |
| 10 | 1978 | 3,790 |
| 11 | 1961 | 3,590 |
| 12 | 1975 | 3,560 |
| 13 | 1997 | 3,480 |
| 14 | 1969 | 3,450 |
| 15 | 1982 | 3,450 |
| 16 | 2007 | 3,380 |
| 17 | 2008 | 3,320 |
| 18 | 1995 | 3,300 |
| 19 | 1995 | 3,280 |
| 20 | 1975 | 3,150 |

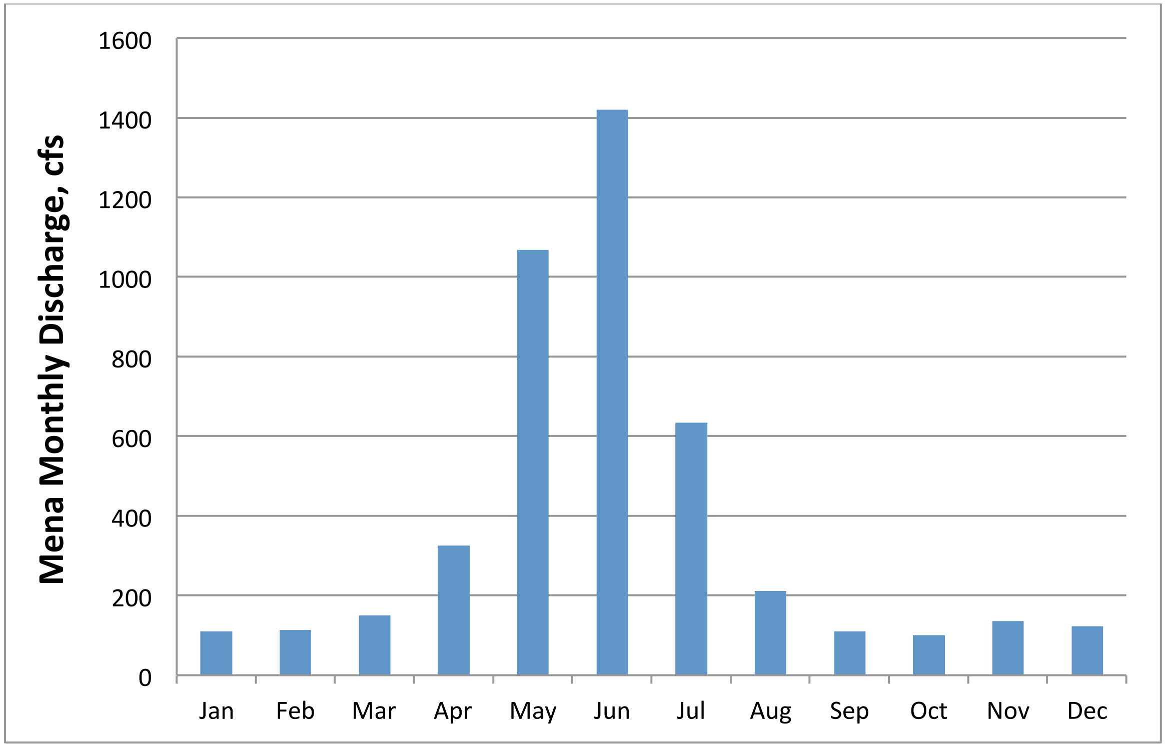


***Figure 2.*** **Mean monthly discharge for the period of record at the USGS gage near Ardenvoir, WA (*Gage 12452800, 1957 to present*).**

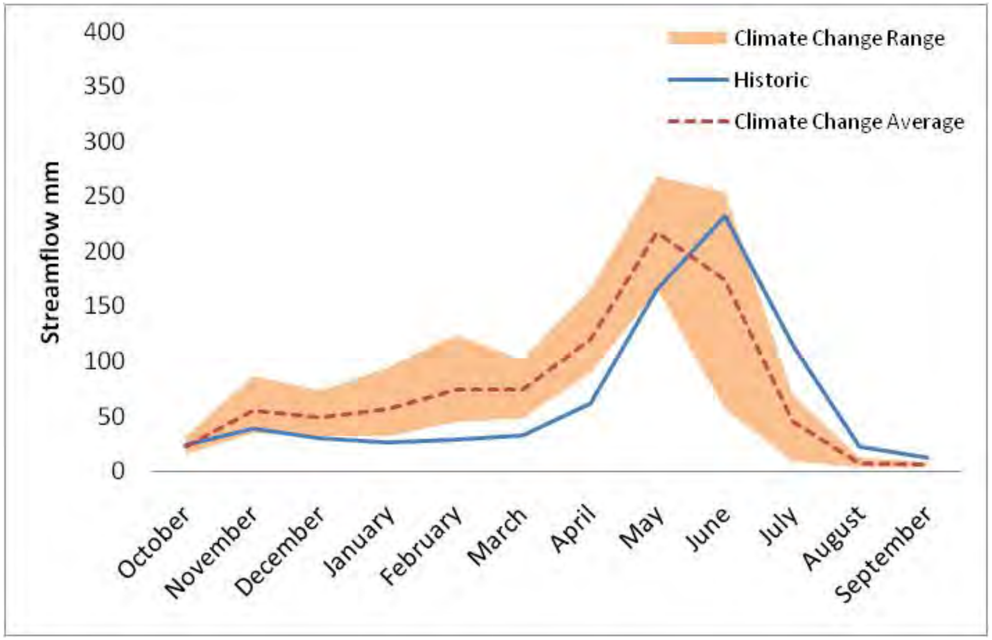


***Figure 3. Projected impacts of climate change on Streamflow depth (discharge surrogate) in the Entiat River (CIG 2009, Elsner 2011).***

# 3 PATHWAY: Reach-Scale Habitat Access

## 3.1 INDICATOR: PHYSICAL BARRIERS – MAIN CHANNEL BARRIERS

### 3.1.1 Metric Overview

This metric evaluates the presence or absence of fish passage barriers that affect upstream or downstream passage of fish in the Entiat River Upper Stillwater Study Area.

***Criteria: From USFWS (1998), modified by USBR (2012).***

| Pathway | General Indicators | Specific Indicators | Adequate | At Risk | Unacceptable |
|---|---|---|---|---|---|
| Habitat Access | Physical Barriers | Main Channel Barriers | No manmade barriers present in the mainstem that limit upstream or downstream fish passage at any flows | Manmade barriers present in the mainstem that prevent upstream or downstream migration at some flows that are biologically significant | Manmade barriers present in the mainstem that prevent upstream or downstream migration at multiple or all flows |

### 3.1.2 Assessment Results

No man made fish passage barriers were present on the mainstem Entiat River in the study area. Furthermore, the majority of tributaries were accessible to fish at the mouth with the exception of a small cobble dam at the mouth of Silver Creek. Many tributaries become naturally impassible as they climb steeply away from the channel. There are several small and large falls including the falls at the top of Box Canyon that present passage barriers at some flows. But these are natural features of the river.

### 3.1.3 REI Rating

| General Indicators | Specific Indicators | Reach 0 | Reach 1 | Reach 2 | Reach 3 | Reach 4 | Reach 5 | Reach 6 | Reach 7 | Reach 8 | Reach 9 | Reach 10 | Reach 11 | Reach 12 | Reach 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Physical Barriers | Main Channel Barriers | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate |

# 4 PATHWAY: Reach-Scale Habitat Quality

## 4.1 INDICATOR: SUBSTRATE – DOMINANT SUBSTRATE FINE SEDIMENT

### 4.1.1 Metric Overview

Substrate conditions affect salmonid uses including spawning, egg incubation, and early rearing. Salmonids require adequately sized substrate that is free of excessive fines.

***Criteria: Modified from USFWS (1998) and USBR (2012).***

| Pathway | General Indicators | Specific Indicators | Adequate | At Risk | Unacceptable |
|---|---|---|---|---|---|
| Habitat Quality | Substrate | Main Channel Barriers | Dominant Substrate is gravel or cobble (interstitial spaces clear), or embeddedness < 20%, <12% fines (<0.85mm) in spawning gravel or <12% surface fines of <6mm | Gravel and Cobble is subdominant, or if dominant, embeddedness is 20-30%; 12-17% fines (<0.85mm) in spawning gravel or 12-20% surface fines of <6mm | Bedrock, sand, silt, or small gravel dominant, or if gravel and cobble dominant, embeddedness > 30%; >17% fines (<0.85mm) in spawning gravel or >20% surface fines of <6mm |

### 4.1.2 Assessment Results

Fine sediment ratings were based on pebble counts as well as ocular estimates that were collected as part of the habitat survey (Table 2). Pebble counts were collected at pool tail-outs or riffle crests in reaches 1, 3, 4, 5, 7, 8, and 9. Pebble count data from the CHaMP program were used for reaches 0, 2, 9, 11, and 12. CHaMP measured fine sediment in pool tails in 2011 and 2012. As part of the habitat survey, one or more ocular estimates were made in each reach, except for in reaches 6-8, which were either not surveyed or they had no $n^{th}$ units. In reaches where more than one ocular estimate was completed, the estimate is the average of the individual estimates in the reach. In general, bed substrate in the Upper Stillwater study area was gravel and cobble, with smaller amounts of boulder, bedrock, and fines. In all of the reaches, the percentage of fines in spawning gravels was very low (all pebble counts had less than 10% substrate <2mm). All reaches are considered **adequate** with respect to substrate.

***Table 2. The values for this analysis used pebble count data and ocular estimates from the habitat survey, as well as pebble count data from the CHaMP monitoring program. Reaches 6, 7, and 8 did not have ocular estimates performed.***

| ***Total*** | **Reach 0** | **Reach 1** | **Reach 2** | **Reach 3** | **Reach 4** | **Reach 5** | **Reach 6** | **Reach 7** | **Reach 8** | **Reach 9** | **Reach 10** | **Reach 11** | **Reach 12** | **Reach 13** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| %<2mm (pebble counts) | | 7 | | 1 | 0 | 5 | | 1 | 2 | 0 | | | | |
| %<2mm (CHaMP pebble counts) | 2.2 | | 1 | | | | | | | 4.5 | | 0 | 0 | |
| Ocular Estimates | | | | | | | | | | | | | | |
| % Sand | 30 | 3 | 10 | 5 | 5 | 0 | | | | 5 | 0 | 0 | 5 | 10 |
| % Gravel | 20 | 20 | 50 | 13 | 20 | 10 | | | | 35 | 50 | 23 | 15 | 25 |
| % Cobble | 50 | 38 | 30 | 55 | 60 | 20 | | | | 60 | 35 | 50 | 65 | 40 |
| % Boulder | 0 | 40 | 10 | 28 | 15 | 65 | | | | 0 | 10 | 13 | 15 | 10 |
| % Bedrock | 0 | 0 | 0 | 0 | 0 | 5 | | | | 0 | 5 | 15 | 0 | 15 |

### 4.1.3 REI Ratings

| General Indicators | Specific Indicators | Reach 0 | Reach 1 | Reach 2 | Reach 3 | Reach 4 | Reach 5 | Reach 6 | Reach 7 | Reach 8 | Reach 9 | Reach 10 | Reach 11 | Reach 12 | Reach 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Substrate | Dominant Substrate/Fine Sediment | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate |

## 4.2 INDICATOR: LARGE WOODY MATERIAL (LWM)

### 4.2.1 Metric Overview

For the purposes of this analysis, a variation was made to the LWM metric. A target value of 42.5 pieces/mile is applied as the **adequate** threshold as opposed to the NMFS/USFWS eastern cascades 20 pieces/mile target. This is based on the results from Fox (2001), which involved measures of LWM from unmanaged streams. The 42.5 pieces/mi value is the median value for streams between 5 and 50 m bankfull width for eastern Washington (see Table 3), and is based on the NMFS definition of a qualifying piece; 12 in. diameter and 35 ft long. Fox (2001) and Fox and Bolton (2007) demonstrate that the NMFS 20 pieces/mi target is likely too low, especially for larger streams such as the Entiat River. They also recommend planning for the 75$^{th}$ percentile value (70 pieces/mi, Table 3) for restoration efforts in order to achieve central tendencies at the basin or region-scale. A second evaluation metric, log jam frequency, was added to the large wood indicator in order to better reflect the wood distribution types that would be expected under natural conditions (i.e. free of human influence), and for helping to identify restoration targets. See additional discussion in the Reach Assessment (Geomorphology section) regarding the natural and historical role of large wood in the study area. The **adequate** condition was set at 5 jams per mile based on conditions found in Reach 9, which had the greatest amount of large wood and log jams and is believed to best approximate historical conditions that would have been found throughout the other depositional reaches in the study area.

***Table 3. Results of LWM surveys on unmanaged eastern Washington streams by Fox (2001). Qualifying pieces are 12 in diameter and 35 ft long. Values are for bankfull width class >5 m – 50 m.***

| Statistic | Pieces per mile |
|---|---|
| 25$^{th}$ percentile | 16.2 |
| Median | 42.5 |
| 75$^{th}$ percentile | 70.0 |

***Criteria: See above description of criteria development.***

| Pathway | General Indicators | Specific Indicators | Adequate | At Risk | Unacceptable |
|---|---|---|---|---|---|
| Habitat Quality | Large woody material | Pieces per mile at bankfull | >42.5 pieces/mile >12'' diam; > 35' length; and adequate sources of woody material available for long and short term recruitment.<br><br>And,<br>At least 5 jams/mi (10 qualifying pieces per jam) | Currently meets piece frequency standards for **adequate**, but lacks potential sources from riparian areas of wood debris recruitment to maintain that standard.<br><br>And,<br>1-5 jams/mi | Does not meet standards for Adequate and lacks potential large woody material recruitment. |

### 4.2.2 Assessment Results

The Upper Stillwater study area as a whole currently averages 33 pieces/mile and ranges from 12 pieces/mi to 92 pieces per mile (Table 4). Log jam values ranged from 0 jams/mi in several reaches to 4.9 jams/mi in Reach 9. Figure 4 displays the reach results for pieces per mile as well as the median, 25th percentile, and 75th percentile values from Fox (2001). Only one reach, Reach 9 achieves the target of 42.5 pcs/mi and it actually exceeds the 75th percentile value as well. This reach is given an **adequate** rating since it achieves both the piece number target and the log jam target. The remaining reaches are given **unacceptable** ratings because they don't achieve either the piece number or log jam targets. Exceptions include reaches 6 and 8, which are steep canyon reaches where LWM counts were not performed. Observations during site visits suggest that these reaches would fall well short of the 42.5 pieces/mi target. However, these transport reaches would not be expected to accumulate wood to the same degree as the other, more depositional, reaches in the study area. For this reason, these reaches were given at risk ratings.

***Table 4. Large wood piece and jam frequency from the habitat survey (August 2012).***

| | Reach 0 | Reach 1 | Reach 2 | Reach 3 | Reach 4 | Reach 5 | Reach 6 | Reach 7 | Reach 8 | Reach 9 | Reach 10 | Reach 11 | Reach 12 | Reach 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Pieces/mi (>12" diam; >35' long)* | 30 | 20 | 29 | 24 | 30 | 36 | NA | 19 | NA | 92 | 31 | 20 | 12 | 37 |
| *Log jams/mi* | 1.3 | 0 | 0 | 0.9 | 3.4 | 1.7 | NA | 1.9 | NA | 4.9 | 0 | 1.9 | 0 | 1.5 |

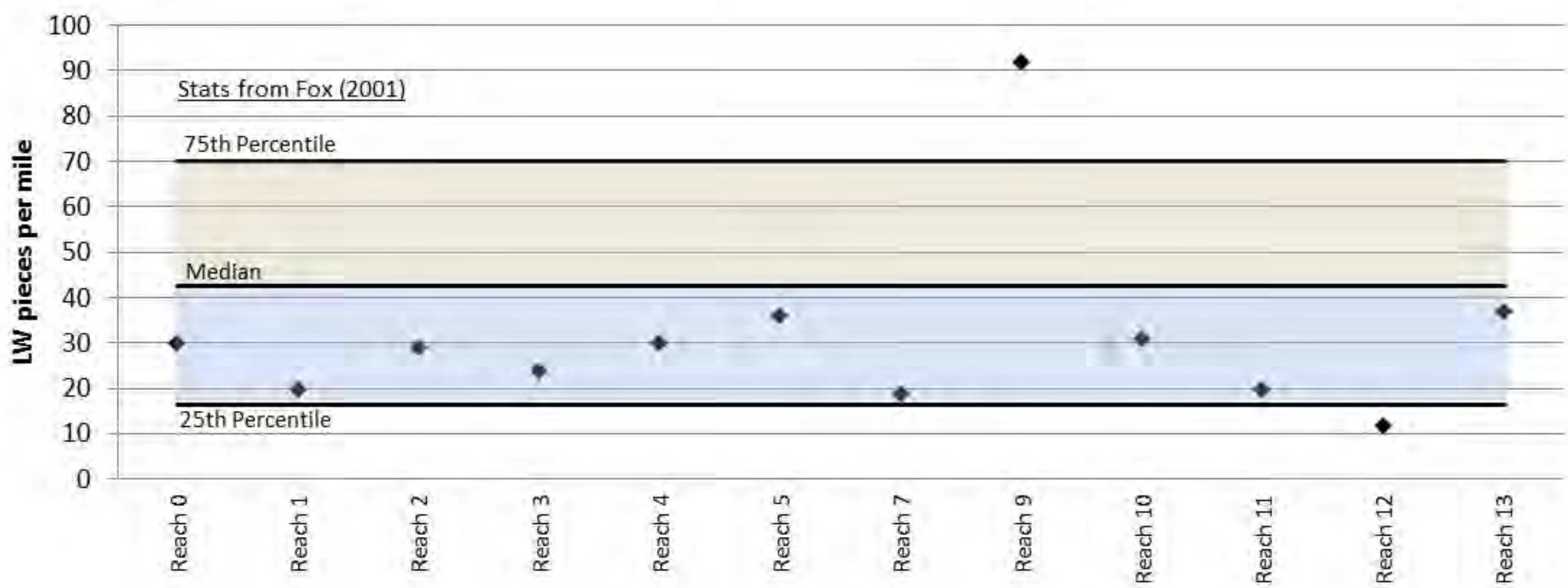


***Figure 4. LWM counts for the study reach compared to Fox (2001) percentile values. LWM counts were not conducted on reaches 6 and 8.***

### 4.2.3 REI Ratings

| General Indicators | Specific Indicators | Reach 0 | Reach 1 | Reach 2 | Reach 3 | Reach 4 | Reach 5 | Reach 6 | Reach 7 | Reach 8 | Reach 9 | Reach 10 | Reach 11 | Reach 12 | Reach 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Substrate | Pieces per mile at bankfull | unacceptable | unacceptable | unacceptable | unacceptable | unacceptable | unacceptable | at risk | unacceptable | at risk | adequate | unacceptable | unacceptable | unacceptable | unacceptable |

## 4.3 INDICATOR: POOLS – POOL FREQUENCY & QUALITY

### 4.3.1 Metric Overview

The largest bankfull channel width provided in the NMFS matrix is 65 to 100 feet, and 4 pools per mile is the standard for **adequate** for this width. Bankfull widths in the Upper Stillwater study area are typically in this range (reach average of 100.6 feet with a range of 70 feet to 115.8 feet).

Therefore the standard of 4 pools per mile is adhered to. The pool quality metrics provided by USFS (1998) (e.g. depth, substrate, cover, refugia) are also used to determine function.

***Criteria: Adapted from USFS (1998).***

| Pathway | General Indicators | Specific Indicators | Adequate | At Risk | Unacceptable |
|---|---|---|---|---|---|
| Habitat Quality | Pools | Pool frequency and quality | Pool frequency:<br>Channel width<br>65-100<br>No. Pools/mile<br>4<br>Pools have good cover and cool water and only minor reduction of pool volume by fine sediment.<br>Each reach has many large pools > 1m deep with good cover | Pool frequency is similar to values for adequate, but pools have inadequate cover/temperature, and/or there has been a moderate reduction of pool volume by fine sediment.<br>Reaches have few large pools (>1m) present with good fish cover | Pool frequency is considerably lower than values for adequate, also cover/temperature is inadequate, and there has been a major reduction of pool volume by fine sediment.<br>Reaches have no deep pools (> 1m) with good fish cover |

### 4.3.2 Assessment Results

Pool frequency ranged from 1.9 to 10.1 pools/mile (mean frequency of 6.4 pools/mile) (Table 5). All reaches had pool habitat, with pool forming processes ranging widely between bedrock canyon reaches, steep reaches controlled by alluvial fans and colluvium, and lower gradient reaches that are fully alluvial. Reaches 0 and 2 had the greatest proportion of pool habitat and were the only reaches over 20% pool habitat (21% and 24%, respectively), although Reach 12 had the greatest number of pools/mile at 10.1. Reaches 6, 8, and 12 had the shortest pool spacing (6, 7, and 6 bankfull channel widths per pool, respectively). Reach 3 had 6 pools with residual depth over 3 feet, that's twice the number as the next highest reach. The majority of the pools throughout the study area were relatively shallow, with shallow residual depths (<3 ft) comprising over 50% of total pools in 7 of the 11 reaches with measured pool depths. Pool conditions ranged widely. Six reaches have **adequate** pool conditions based on frequency and residual depth. There are six reaches in the **at risk** category and two in the **unacceptable** category due to low frequency and shallow residual depths. It is important to note that several reaches in the study area have high gradient with coarse bed material, and are not areas where large pools would form under natural conditions. In many cases, the pool habitat in these reaches was composed of small plunge pools that did not qualify as being pools under the habitat protocol due to their length not exceeding bankfull width.

***Table 5. Summary of pool frequency and residual depth measurements based on the habitat assessment (August 2012).***

| **Pools** | **Reach 0** | **Reach 1** | **Reach 2** | **Reach 3** | **Reach 4** | **Reach 5** | **Reach 6** | **Reach 7** | **Reach 8** | **Reach 9** | **Reach 10** | **Reach 11** | **Reach 12** | **Reach 13** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Pools per mile* | 6.7 | 5.8 | 3.9 | 7.1 | 5.0 | 5.2 | 9.9 | 1.9 | 8.5 | 5.7 | 5.8 | 6.8 | 10.1 | 6.1 |
| *Percent pool* | 21 | 17 | 24 | 12 | 7 | 7 | 15 | 6 | 19 | 13 | 8 | 7 | 12 | 8 |
| *Residual Depth (% of pools)* | | | | | | | | | | | | | | |
| Pools < 3 ft | 60 | 60 | 50 | 25 | 33 | 33 | | 0 | | 57 | 67 | 71 | 67 | 25 |
| Pools 3-6 ft | 20 | 0 | 50 | 63 | 67 | 67 | | 100 | | 43 | 33 | 29 | 0 | 25 |
| Pools 6-9 ft | 20 | 40 | 0 | 13 | 0 | 0 | | 0 | | 0 | 0 | 0 | 33 | 25 |
| Pools 9-12 ft | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | | 0 | 0 | 0 | 0 | 25 |

### 4.3.3 REI Ratings

| **General Indicators** | **Specific Indicators** | **Reach 0** | **Reach 1** | **Reach 2** | **Reach 3** | **Reach 4** | **Reach 5** | **Reach 6** | **Reach 7** | **Reach 8** | **Reach 9** | **Reach 10** | **Reach 11** | **Reach 12** | **Reach 13** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pools | Pool frequency and quality | at risk | at risk | unacceptable | adequate | adequate | adequate | adequate | unacceptable | adequate | at risk | at risk | at risk | at risk | adequate |

## 4.4 INDICATOR: OFF-CHANNEL HABITAT

### 4.4.1 Metric Overview

Off-channel habitats include backwaters, abandoned oxbows, floodplain channels, and flow-through side-channels. Off-channel habitats that are accessible by fish from the mainstem provide important rearing habitats. Off-channel areas can provide various benefits to rearing fish including flood refuge, temperature refuge, and productive feeding areas.

***Criteria: Modified from USFWS (1998).***

| Pathway | General Indicators | Specific Indicators | Adequate | At Risk | Unacceptable |
|---|---|---|---|---|---|
| Habitat Quality | Off-Channel Habitat | Connectivity with main channel | Reach has ponds, oxbows, backwaters, and other low-energy off-channel areas with cover; similar to conditions that would be expected in the absence of human disturbance | Reach has some ponds, oxbows, backwaters, and other low-energy off-channel areas with cover; but availability or access is less than what would be expected in the absence of human disturbance | Reach has few or no ponds, oxbows, backwaters, or other off-channel areas relative to what would be expected in the absence of human disturbance. |

### 4.4.2 Assessment Results

A total of 27 wetted side-channel habitat units were measured in the study area during the habitat survey. Reach 4 has the greatest area of side-channel habitat (22% of total habitat area in the reach) and Reach 9 has the greatest number of side-channel units (9 side-channels). Percentage of side-channel habitat by reach is included in Table 6. Reaches 1, 7, 8, 10, and 12 have no side-channel habitat. Average maximum side-channel depth is 2.0 feet (stdev 1.6) with the deepest side-channels observed in Reach 4.

The study area has no marshes, backwaters, or open water ponds. Natural confinement limits off-channel habitat throughout much of the study area. Human development of riparian areas and floodplains limits off-channel habitat in reaches 0, 1, and 5. Lateral channel dynamics, which are necessary for long-term development of off-channels, are affected by the bridge and residential development in Reach 0. This reach is given an **unacceptable** rating. The Entiat River Road and residential development affect floodplain processes and long-term development of off-channel habitat in the downstream end of Reach 1; this reach is given an **at risk** rating. The Fox Creek campground and associated fill, rock wall, roadway, and culvert affect side-channel connectivity in Reach 5. Reach 5 is therefore given an **at risk** rating.

Off-channel habitat, especially side-channel habitat created as a result of split flow and complex channel braiding, would have been heavily influenced by log jams in the historical condition. Reaches with log jam frequencies that do not meet the 5 jams/mi threshold are therefore given **at risk** ratings. Although it meets the 5 jams/mi criteria, Reach 9 is given an **at risk** rating because it is a highly depositional reach that would be expected to have a greater abundance and quality of off-channel habitat in the absence of human disturbance that has decreased wood loading, tree size, and the potential for large log jams to create complex multi-thread channels, alcoves, and floodplain off-channel habitat. Reaches 6 and 8, which would not be expected to have any significant development of off-channel habitat due to natural confinement, are given **adequate** ratings.

***Table 6. Percent side-channel habitat from assessment.***

| Reach 0 | Reach 1 | Reach 2 | Reach 3 | Reach 4 | Reach 5 | Reach 6 | Reach 7 | Reach 8 | Reach 9 | Reach 10 | Reach 11 | Reach 12 | Reach 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14 | 0 | 1 | 7 | 22 | 1 | 1 | 0 | 0 | 10 | 0 | 4 | 0 | 6 |

### 4.4.3 REI Ratings

| General Indicators | Specific Indicators | Reach 0 | Reach 1 | Reach 2 | Reach 3 | Reach 4 | Reach 5 | Reach 6 | Reach 7 | Reach 8 | Reach 9 | Reach 10 | Reach 11 | Reach 12 | Reach 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Off-Channel Habitat | Connectivity with main channel | unacceptable | at risk | at risk | at risk | at risk | at risk | adequate | at risk | adequate | at risk | at risk | at risk | at risk | at risk |

# 5 PATHWAY: Channel Forms & Processes

## 5.1 INDICATOR: CHANNEL DYNAMICS - FLOODPLAIN CONNECTIVITY

### 5.1.1 Metric Overview

Floodplains serve a number of significant geomorphic and ecological functions including conveyance of flood waters, sediment source and storage, supply of large wood, and development of diverse habitat for aquatic and terrestrial species (e.g. Allen 1970, Zwolinski 1992, Nanson and Croke 1992). Floodplain connectivity was evaluated through geomorphic and hydraulic analysis. As part of the geomorphic assessment, floodplain areas were mapped and were given a designation of ***connected*** or ***disconnected*** based on processes including floodplain inundation frequency, inundation extent, flood energy and scour, channel migration, and the degree to which human influence has altered floodplains. The hydraulic analysis was used to confirm the floodplain mapping and to further evaluate floodplain inundation patterns.

Provided here is a brief summary of the floodplain mapping; more information can be found in Appendix ##. Floodplains were initially delineated using field surveys, and then verified using LiDAR data and hydraulics analysis, where LiDAR was available (Reaches 0 – 6). A floodplain was determined to be ***disconnected*** if processes such as flood inundation and channel migration had been significantly altered due to ***anthropogenic modifications***. A designation of ***disconnected*** does not mean the floodplain has been completely isolated from the main river, but it does indicate that significant human alterations have impaired floodplain and channel migration processes compared to historical conditions. These alterations can be direct contemporary (or remaining) alterations including straightening, ditching, filling, riprap, levees, road embankments, or bridges; or they can be historical alterations, such as splash damming and log drives, that have caused channel incision that persists today.

***Criteria: Modified from USFWS (1998).***

| Pathway | General Indicators | Specific Indicators | Adequate | At Risk | Unacceptable |
|---|---|---|---|---|---|
| Channel | Dynamics | Floodplain connectivity | Floodplain areas are hydrologically linked to main channel within the context of the local process domain; overbank flows occur and maintain wetland functions, riparian vegetation and succession in alluvial reaches. Naturally confined channels are considered adequate. | Reduced linkage of wetlands, floodplains, and riparian areas to main channel in reaches with historically strong connectivity; overbank flows are reduced relative to historical frequency, as evidenced by moderate degradation of wetland function and riparian vegetation/succession. | Severe reduction in hydrologic connectivity between off-channel wetland, floodplain, and riparian areas relative to historical connectivity; wetland extent drastically reduced and riparian vegetation/succession altered significantly. |

### 5.1.2 Assessment Results

Table 7 includes the percentage of mapped floodplain areas that were identified as ***disconnected*** as part of the geomorphic analysis. It is important to note that the natural condition of many reaches in the study area is that of a river incised into glacial outwash deposits, laterally confined by large alluvial fan complexes and deep bedrock canyons. These are reaches with naturally limited floodplain connectivity, where low percentages of connected floodplain is the natural condition, are considered **adequate**. See Appendix ## for additional information. REI ratings were determined based on the degree of anthropogenically caused disconnection of floodplains relative to historical connectivity. A ***disconnection*** amount of <10% is considered **adequate**; 10-20% is **at risk**; and greater than 20% is **unacceptable**.

***Table 7. Percent of disconnected floodplain (see Appendix ## for more information).***

| General Indicators | Specific Indicators | Reach 0 | Reach 1 | Reach 2 | Reach 3 | Reach 4 | Reach 5 | Reach 6 | Reach 7 | Reach 8 | Reach 9 | Reach 10 | Reach 11 | Reach 12 | Reach 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dynamics | Floodplain Connecitivity (proportion of floodplains that are "disconnected" | 13% | 8% | 0% | 0% | 0% | 50% | 0% | 0% | 0% | 0% | 5% | 0% | 0% | 0% |

### 5.1.3 REI Ratings

| General Indicators | Specific Indicators | Reach 0 | Reach 1 | Reach 2 | Reach 3 | Reach 4 | Reach 5 | Reach 6 | Reach 7 | Reach 8 | Reach 9 | Reach 10 | Reach 11 | Reach 12 | Reach 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dynamics | Floodplain Connecitivity | At risk | adequate | adequate | adequate | adequate | unacceptable | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate |

## 5.2 INDICATOR: BANK STABILITY/CHANNEL MIGRATION

### 5.2.1 Metric Overview

Low gradient alluvial channels adjust laterally via bank erosion and channel avulsions (rapid shifting of channel location). These processes play important roles in maintenance of long-term aquatic habitat via large wood recruitment, gravel recruitment, and creation of new instream habitats. The rate and frequency of channel migration are a function of numerous physical and biological processes including hydrologic regime, underlying geology, sediment supply, streambank vegetation, and floodplain hydraulic roughness. Human alterations that affect these processes will affect the rate and frequency of channel migration. Common human alterations that affect rates of channel migration include bank armoring, removal of streambank vegetation, channelization, levee building, and development within the floodplain. Also common to the study area are high glacial terraces, channel margin bedrock outcrops, alluvial fans, colluvium, and narrow floodplains that all naturally limit lateral migration rates and potential magnitude of lateral migration.

***Criteria: From USBR (2011).***

| Pathway | General Indicators | Specific Indicators | Adequate | At Risk | Unacceptable |
|---|---|---|---|---|---|
| Channel | Dynamics | Bank Stability/Channel Migration | Channel is migrating at or near natural rates. | Limited amount of channel migration is occurring at a faster/slower rate relative to natural rates, but significant change in channel width or planform is not detectable; large woody debris is still being recruited. | Little or no channel migration is occurring because of human actions preventing reworking of the floodplain and large woody debris recruitment; or channel migration is occurring at an accelerated rate such that channel width has at least doubled, possibly resulting in a channel planform change, and sediment supply has noticeably increased from bank erosion. |

### 5.2.2 Assessment Results

There has been very little human alteration or artificial armoring of stream banks that would reduce the ability of the stream to migrate laterally. Incidences of bank armoring occur at locations where the channel flows against the road embankment on river left. There are few of these locations and where this does occur, the length of armoring on the embankment is relatively short. Potential human-induced bank erosion can be found at isolated locations where some vegetation has been removed at a residential development, or at river access points such as campgrounds. Many residential developments and campgrounds are on high terraces with naturally steep and unvegetated banks. Floodplain alterations (e.g.

bridges and floodplain fill) have minimal effects on migration rates compared to historical conditions. Glacial lag, colluvium, alluvial fan deposits, and bedrock provide natural vertical and lateral stability. An analysis of historical planform changes was performed and results indicate relatively little change since 1945, which is the date of the earliest available aerial photography. However, log drives took place prior to this and likely resulted in some channel bed degradation (incision). However, overall vertical stability is high and legacy incision from log drives is expected to be localized and not a limiting factor in the process of channel migration.

Bank armoring in the form of riprap, bridge abutments, and levees were mapped as part of the geomorphic assessment. The total length of bank armoring was calculated as a percentage of reach length (Table 8). This does not include areas of channel upstream and downstream of bridges where channel migration might be affected by the bridge. Reaches with greater degrees of bank armoring were considered more impaired than those with less armoring. For this analysis, reaches with <5% armoring were assumed **adequate**, 5-10% **at risk**, and >10% **unacceptable**. Most reaches are **adequate**, 3 are **at risk**, and 2 are **unacceptable**. Banks that are eroding due to apparent anthropogenic activities (bank clearing, river access points) were determined during the habitat survey. Ocular estimates of eroding length were made in the field. A similar standard was made for eroding banks as for armored banks. All reaches had fewer than 5% eroding banks, and are **adequate**.

***Table 8. Percent bank armoring by reach.***

| Reach | Percent bank armoring by reach length | Percent bank erosion by reach length |
|---|---|---|
| 0 | 14 | 1.5 |
| 1 | 5 | 4.4 |
| 2 | 3 | 0.0 |
| 3 | 5 | 0.0 |
| 4 | 0 | 0.0 |
| 5 | 15 | 0.0 |
| 6 | 2 | 0.0 |
| 7 | 0 | 0.0 |
| 8 | 0 | 0.0 |
| 9 | 0 | 0.0 |
| 10 | 5 | 0.0 |
| 11 | 0 | 0.0 |
| 12 | 0 | 0.0 |
| 13 | 0 | 0.4 |

### 5.2.3 REI Ratings

| General Indicators | Specific Indicators | Reach 0 | Reach 1 | Reach 2 | Reach 3 | Reach 4 | Reach 5 | Reach 6 | Reach 7 | Reach 8 | Reach 9 | Reach 10 | Reach 11 | Reach 12 | Reach 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Channel Dynamics | Bank stability/ Channel migration | unacceptable | at risk | adequate | at risk | adequate | unacceptable | adequate | adequate | adequate | adequate | at risk | adequate | adequate | adequate |

## 5.3 INDICATOR: VERTICAL CHANNEL STABILITY

### 5.3.1 Metric Overview

Alterations to stream energy, sediment supply and transport, and bed stability can lead to aggradation or degradation (incision) of the streambed. Aggradation is the raising of the streambed elevation and incision is the lowering of the streambed elevation. Anthropogenic alterations that could affect vertical channel stability include bank armoring, log drives / splash damming, levee building, channel straightening, and channelization.

***Criteria: From USBR (2011).***

| Pathway | General Indicators | Specific Indicators | Adequate | At Risk | Unacceptable |
|---|---|---|---|---|---|
| Channel | Dynamics | Vertical channel stability | No measurable trend of aggradation or incision and no visible change in channel planform. | Measureable trend of aggradation or incision that has the potential to but not yet caused disconnection of the floodplain or a visible change in channel planform (e.g., single thread to braided). | Enough incision that the floodplain and off-channel habitat areas have been disconnected; or, enough aggradation that a visible change in channel planform has occurred (e.g., single thread to braided). |

### 5.3.2 Assessment Results

Since the period of last glaciation, the Entiat River has been naturally down-cutting through glacial till and outwash, leaving behind abandoned alluvial terraces and establishing new floodplains. There are also many reaches dominated by alluvial fans, where erosion into the toe of the fan creates high, steep banks and the impression of incision and floodplain disconnection. In some reaches, incision may have occurred due to past log-drives but there are very few recent floodplain constrictions (i.e. bridges), bank armoring, or floodplain fill that would create vertical instability.

This metric evaluates vertical channel stability on a recent (post European settlement) timescale, evaluating shorter-term sediment storage and examining if aggradation or incision has become accelerated due to human alterations. The degree of alteration to vertical channel stability was assessed using results of the hydraulic and geomorphic analyses. The extent of floodplain inundation, width-to-depth ratios, the presence of human alterations known to affect vertical stability, and consideration of the naturally confined conditions in many of the reaches were used to help determine the REI ratings. In general, most of the observed incision is believed to be related to natural down-cutting into glacial outwash deposits leaving terraces.

The majority of reaches in the study area are **adequate** in terms of vertical stability. Bed and bank material in most reaches includes cobbles and boulders derived from erosion of glacial deposits and alluvial fans. There is also a significant amount of bedrock that outcrops along the channel margin and in the bed of the channel in some reaches. These conditions favor high vertical stability. Reaches 0, 5, and 10 were found to be **at risk** due to bridges and roads bisecting the floodplain in the case of Reaches 0 and 10, and a low levee disconnecting the channel and floodplain near a campground in Reach 5. These modifications locally create channel constriction and concentrate flows in the channel, which can increase effective shear stress in the channel and create conditions for incision. There were no signs of significant vertical adjustment due to these features. However, in Reach 0, there appears to be some gravel deposition in the hydraulically ineffective areas up and downstream of the bridge. This aggradation is very localized.

### 5.3.3 REI Ratings

| General Indicators | Specific Indicators | Reach 0 | Reach 1 | Reach 2 | Reach 3 | Reach 4 | Reach 5 | Reach 6 | Reach 7 | Reach 8 | Reach 9 | Reach 10 | Reach 11 | Reach 12 | Reach 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Channel Dynamics | Vertical channel stability | at risk | adequate | adequate | adequate | adequate | at risk | adequate | adequate | adequate | adequate | at risk | adequate | adequate | adequate |

# 6 PATHWAY: Riparian Condition

## 6.1 INDICATOR: STRUCTURE

### 6.1.1 Metric Overview

Riparian areas serve a number of important geomorphic and ecological functions including streambank stability, current and future sources of large wood material, water filtration, habitat, hydraulic regulation, and temperature fluctuation modification (Gregory et al. 1991). Here, the structure of riparian areas is evaluated based on how well the seral stage, species composition, and complexity approximate natural conditions that would be expected in the absence of human alterations. It is important to note that during the habitat survey, riparian condition was measured only at $n^{th}$ units. Reach-scale riparian conditions were observed and noted as part of the geomorphic assessment. Other riparian conditions such as canopy cover and disturbance were determined using aerial photography, and USFS shapefiles for fire history and timber harvest.

***Criteria: From USBR (2011).***

| Pathway | General Indicators | Specific Indicators | Adequate | At Risk | Unacceptable |
|---|---|---|---|---|---|
| Riparian Vegetation | Condition | Structure | >80% species composition, seral stage, and structural complexity are consistent with potential native community. | 50-80% species composition, seral stage, and structural complexity are consistent with potential native community. | <50% species composition, seral stage, and structural complexity are consistent with potential native community. |

### 6.1.2 Assessment Results

Results of the habitat assessment and geomorphology assessment were used to help determine the riparian structure REI ratings. Ocular estimates of seral stage were recorded as part of the habitat assessment for $n^{th}$ units, and are presented in Table 9. Seral stage conditions were observed at the reach scale during the geomorphology survey, though not quantified. That information was used to help determine REI ratings. Dominant overstory and understory species were also recorded as part of the habitat survey, for measured units. In general, riparian areas in the absence of human disturbance would be expected to be dominated by mature trees but to also have a diversity of other size classes. Riparian areas along the Entiat River have been harvested in the past and many of the riparian areas lack the large sized trees that would be expected under natural conditions. There have also been fires into the riparian zone in much of the study area over the last 150 years, but not within the last 50 years.

Furthermore, the few riparian areas affected by residential development lack the smaller size classes due to clearing of the understory for houses and yards. These developed areas also tend to have less species diversity than unaltered areas where flooding and erosion processes are still intact.

Only Reach 12 was observed to have a dominance of large trees associated with potential seral stage. Small trees and saplings were dominant in all other reaches. However, these measurements were made at measured ($n^{th}$) units and in reality, riparian conditions can vary significantly throughout each reach. Therefore, the seral stage condition determined through $n^{th}$ unit measurement is not the only factor used for determining REI ratings. Reaches 4, 6, 7, 8, 9, 11, 12, and 13 were given **adequate** ratings due to the lack of recent (last 50 years) riparian clearing, lack of development, and general riparian condition. These reaches include all of the steeper reaches that are not conducive to development or riparian clearing. Reaches 1, 2, 3, 5, and 10 were given **at risk** ratings due to small amounts of clearing associated with housing development and some roadway encroachment into the riparian zone on the north side of the channel. A rating of **unacceptable** was given to Reach 0 due to a significant amount of clearing for residential development and roadways.

***Table 9. Results of riparian size classes recorded during the stream habitat survey (August 2012). Percentage values refer to the proportion of measured units where the given size class was listed as dominant.***

| Vegetation (% of sampled units) | Reach 0 | Reach 1 | Reach 2 | Reach 3 | Reach 4 | Reach 5 | Reach 6 | Reach 7 | Reach 8 | Reach 9 | Reach 10 | Reach 11 | Reach 12 | Reach 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Riparian Zone (100-ft wide zone averaged between both banks) | | | | | | | | | | | | | | |
| Mature Tree | 0 | 0 | 0 | 0 | 0 | 0 | N/A | - | N/A | 0 | 0 | 0 | 0 | 0 |
| Large Tree | 0 | 0 | 0 | 0 | 0 | 0 | N/A | - | N/A | 50 | 0 | 0 | 100 | 0 |
| Small Tree | 100 | 100 | 0 | 33 | 50 | 100 | N/A | - | N/A | 50 | 100 | 100 | 0 | 100 |
| Sapling/Pole | 0 | 0 | 0 | 33 | 50 | 0 | N/A | - | N/A | 0 | 0 | 0 | 0 | 0 |
| Shrub/Seedling | 0 | 0 | 100 | 33 | 0 | 0 | N/A | - | N/A | 0 | 0 | 0 | 0 | 0 |
| Grassland/Forb | 0 | 0 | 0 | 0 | 0 | 0 | N/A | - | N/A | 0 | 0 | 0 | 0 | 0 |
| No Vegetation | 0 | 0 | 0 | 0 | 0 | 0 | N/A | - | N/A | 0 | 0 | 0 | 0 | 0 |

### 6.1.3 REI Ratings

| General Indicators | Specific Indicators | Reach 0 | Reach 1 | Reach 2 | Reach 3 | Reach 4 | Reach 5 | Reach 6 | Reach 7 | Reach 8 | Reach 9 | Reach 10 | Reach 11 | Reach 12 | Reach 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Riparian | Structure | unacceptable | at risk | at risk | at risk | adequate | at risk | adequate | adequate | adequate | adequate | at risk | adequate | adequate | adequate |

## 6.2 INDICATOR: DISTURBANCE (HUMAN)

### 6.2.1 Metric Overview

Human disturbance to the floodplain and riparian zone affects conditions and processes including bank stability, wood recruitment, shade, and water quality. Riparian disturbance was assessed using information from the habitat assessment (Appendix ##), aerial photography, and an analysis of road densities within the mapped floodplain.

***Criteria: From USBR (2012).***

| Pathway | General Indicators | Specific Indicators | Adequate | At Risk | Unacceptable |
|---|---|---|---|---|---|
| Riparian Vegetation | Condition | Disturbance (human) | >80% mature trees (medium-large) in the riparian buffer zone (defined as a 30 m belt along each bank) that are available for recruitment by the river via channel migration; <20% disturbance in the floodplain (e.g., agriculture, residential, roads, etc.); <2 mi/mi$^2$ road density in the floodplain. | 50-80% mature trees (medium-large) in the riparian buffer zone (defined as a 30 m belt along each bank) that are available for recruitment by the river via channel migration; 20-50% disturbance in the floodplain (e.g., agriculture, residential, roads, etc.); 2-3 mi/mi$^2$ road density in the floodplain. | <50% mature trees (medium-large) in the riparian buffer zone (defined as a 30 m belt along each bank) that are available for recruitment by the river via channel migration; >50% disturbance in the floodplain (e.g., agriculture, residential, roads, etc.); >3 mi/mi$^2$ road density in the floodplain. |

### 6.2.2 Assessment Results

Riparian size class information was documented for the habitat assessment at n$^{th}$ units only (Table 9). Additional size (age) class information at the reach scale was noted in observations. Road density in the floodplain was calculated using the USFS and Chelan County roads shapefiles and floodplain areas delineated as part of the geomorphic assessment mapping and floodplain inundation analysis (see Appendix ##). Road densities by reach are displayed in Table 10. For the purposes of this assessment, historical riparian timber harvest (> 50 yrs ago) was not considered a disturbance, as long as new riparian forests have become established and there is currently no riparian clearing.

***Table 10. Results of floodplain road density per square mile.***

| Reach | Reach 0 | Reach 1 | Reach 2 | Reach 3 | Reach 4 | Reach 5 | Reach 6 | Reach 7 | Reach 8 | Reach 9 | Reach 10 | Reach 11 | Reach 12 | Reach 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Road Density (miles/mi$^2$) | 5.6 | 11.1 | 0.0 | 0.0 | 0.0 | 15.0 | 0.0 | 0.0 | 0.0 | 3.0 | 0.7 | 0.0 | 0.0 | 0.0 |

## 6.2.3 REI Ratings

| General Indicators | Specific Indicators | Reach 0 | Reach 1 | Reach 2 | Reach 3 | Reach 4 | Reach 5 | Reach 6 | Reach 7 | Reach 8 | Reach 9 | Reach 10 | Reach 11 | Reach 12 | Reach 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Riparian | Disturbance (human) | unacceptable | unacceptable | at risk | adequate | adequate | unacceptable | adequate | adequate | adequate | at risk | adequate | adequate | adequate | adequate |

## 6.3 INDICATOR: CANOPY COVER

### 6.3.1 Metric Overview

Riparian canopies serve a number of important instream functions including moderating water temperature fluctuations and governing light quantity and quality. Water temperature is a main driver of the health, productivity, and life cycles of many aquatic organisms, including salmonids.

***Criteria: From USBR (2011).***

| Pathway | General Indicators | Specific Indicators | Adequate | At Risk | Unacceptable |
|---|---|---|---|---|---|
| Riparian | Condition | Canopy Cover | Trees and shrubs within one site potential tree height distance have >80% canopy cover that provides thermal shading to the river. | Trees and shrubs within one site potential tree height distance have 50-80% canopy cover that provides thermal shading to the river. | Trees and shrubs within one site potential tree height distance have <50% canopy cover that provides thermal shading to the river. |

### 6.3.2 Assessment Results

REI canopy cover ratings were determined using recent aerial photography. The percentage canopy cover is based on the extent of canopy closure within riparian areas (100 ft buffer). Canopy closure is considered only for stands of large or mature trees with potential for significant thermal shading, and does not include dense stands of small trees without shading potential. The majority of reaches were found to be **adequate** in terms of canopy cover and potential thermal shading. This includes Reaches 3, and 5-13. In these reaches, there were isolated riparian areas where historical clearing or natural conditions have led to low canopy cover, but all of these reaches had total canopy cover values greater than 80%. Reaches 0, 1, 2, and 4 are **at risk** due to clearing associated with residential development and road clearing. In some of these **at risk** reaches, there are riparian areas dominated by small trees that are counted toward the **at risk** conditions though there does not appear to be anthropogenic activity associated with that condition.

### 6.3.3 REI Ratings

| General Indicators | Specific Indicators | Reach 0 | Reach 1 | Reach 2 | Reach 3 | Reach 4 | Reach 5 | Reach 6 | Reach 7 | Reach 8 | Reach 9 | Reach 10 | Reach 11 | Reach 12 | Reach 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Riparian | Canopy Cover | at risk | at risk | at risk | adequate | at risk | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate | adequate |

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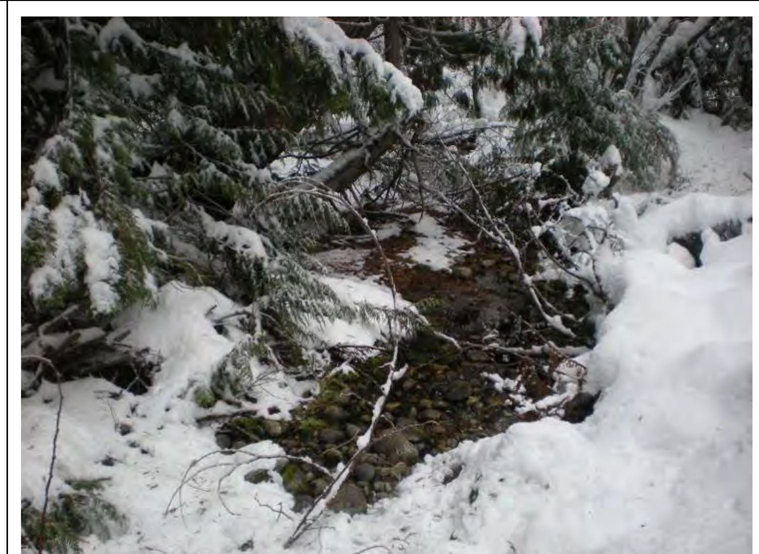
# Appendix D

## Project Opportunities

### Entiat River – Upper Stillwaters

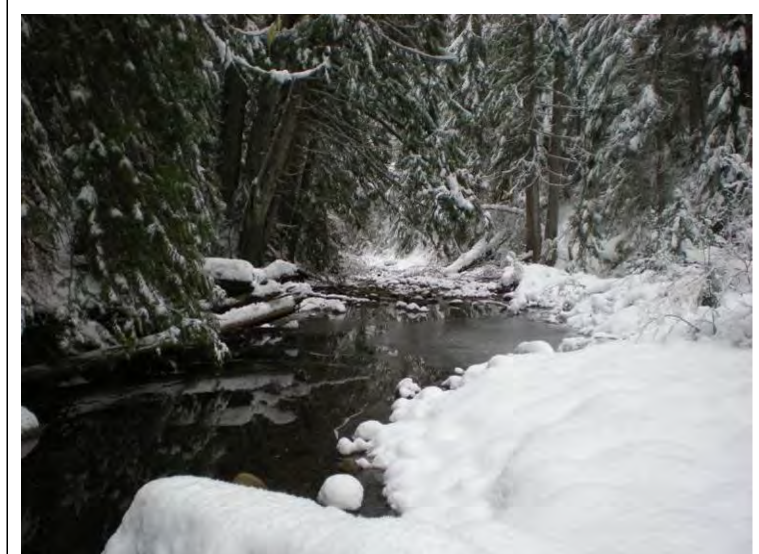
This table describes specific project opportunities. Locator maps of the project opportunities are included below the table.

| Reach | Project Number | Project Name | Action Type | Description | Photo | Caption |
|---|---|---|---|---|---|---|
| **13** | Project RM 33.2L | Upper Pope Side Channel Enhancement | Off-channel habitat enhancement<br><br>Placement of structural habitat elements | There is a small high-flow side channel that branches off an active mainstem side channel near RM 33.25. Select excavation and construction of a bar apex jam could activate the side channel at lower flows and potentially allow greater connectivity of off-channel wetlands in the floodplain. Decent habitat already exists in this channel at moderate-to-high flows. |  | Upper end of high-flow side channel. November 2012. |
| **11** | Project RM 32.8L | Lower Pope Left Bank Side Channel Enhancement | Off-channel habitat enhancement<br><br>Placement of structural habitat elements | There is a small high-flow side channel that branches off the mainstem near RM 32.8. There is only a small amount of hyporheic flow in the channel at moderately low flow. Could open upstream end by removing material and building apex jam in main channel. There are dense small trees (e.g. vine maple) and debris in the channel. Survey would determine how much deeper, if any, the channel would need to be to convey perennial surface flow or possibly to enhance groundwater flow. |  | Midway down existing high flow side channel. November 2012. |

| Reach | Project Number | Project Name | Action Type | Description | Photo | Caption |
|---|---|---|---|---|---|---|
| **11** | Project RM 32.7R | Lower Pope Right Bank Side Channel Enhancement | Off-channel habitat enhancement<br><br>Placement of structural habitat elements | There is a high-flow side channel across the right bank bar that begins near RM 32.7. The channel only flows at fairly high flows and is likely not connected at the upstream end during typical annual high flows. There is a headcut at the downstream end. This channel could be excavated to create a more active flow-through side channel – or more likely, a backwater channel that may have hyporeic flow much of the year. |  | Head-cut at downstream end of high flow side channel. November 2012. |
| **10** | Project RM 31.4L | Upper Silver Falls Margin Jams | Placement of structural habitat elements | This section is composed of straight and uniform glide habitat with little cover. A channel margin logjam or jams (1-2) could be placed on river left. A large jam could be centered on an 8- to 10-yard boulder located along the channel margin. Jams here would create local pool scour and increase habitat cover and complexity. |  | View upstream towards the river left bank where a channel margin logjam could be positioned along the upstream end of an existing large boulder. November 2012. |

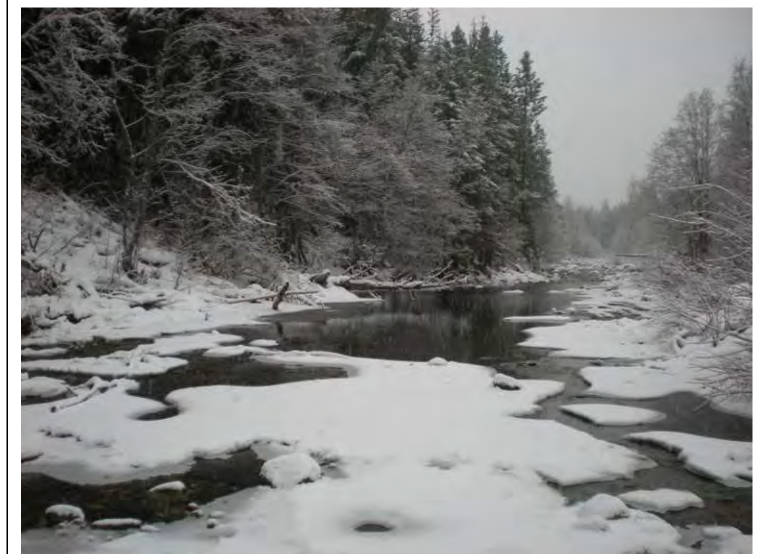
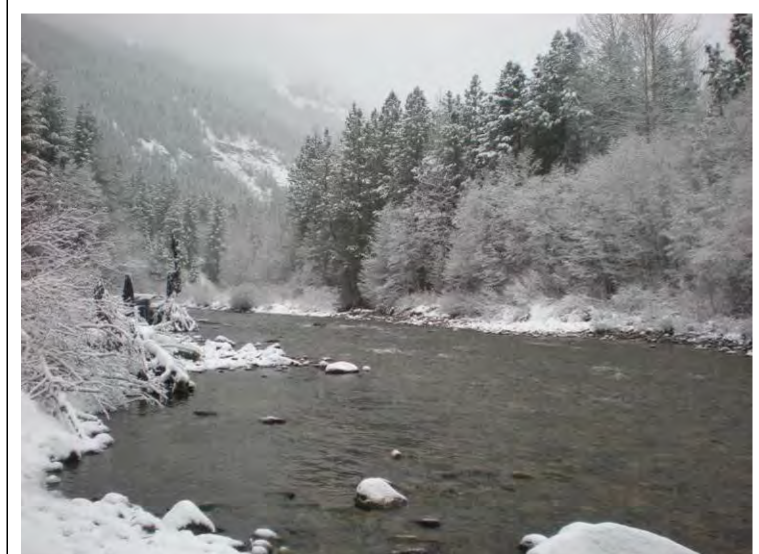
| Reach | Project Number | Project Name | Action Type | Description | Photo | Caption |
|---|---|---|---|---|---|---|
| 9 | Project RM 31.4R | Silver Falls Side Channel Enhancement 1 | Off-channel habitat enhancement | There is an old channel scar in the right bank floodplain that only conveys surface flows at flood flows. There is existing groundwater flow towards the downstream end. Excavation could be used to deepen and connect to the mainstem at the upstream end at a broader range of flows. Alternatively, groundwater flow could be enhanced through excavation of the downstream portion and/or placement of groundwater galleries. |  | View looking downstream near downstream end of groundwater-fed side channel near RM 31.3. November 2012. |
| 9 | Project RM 31.25R | Silver Falls Side Channel Enhancement 2 | Off-channel habitat enhancement<br><br>Placement of structural habitat elements | This is an existing right bank side channel that does not convey surface flow at low flow, but does convey flow at moderate flows (annual spring runoff). Placement/ enhancement of an apex jam on the island, combined with select excavation, could help activate the channel at lower flows. A meander bend jam on the right bank at the downstream end would enhance pool scour, cover, and complexity in the side channel. Actions would need to be evaluated in the context of existing function and wood loading. It would also be possible to enhance the existing backwater at the downstream end of the island with large wood cover where it receives hyporheic flow. |  | View downstream at island and split flow near RM 31.25. |

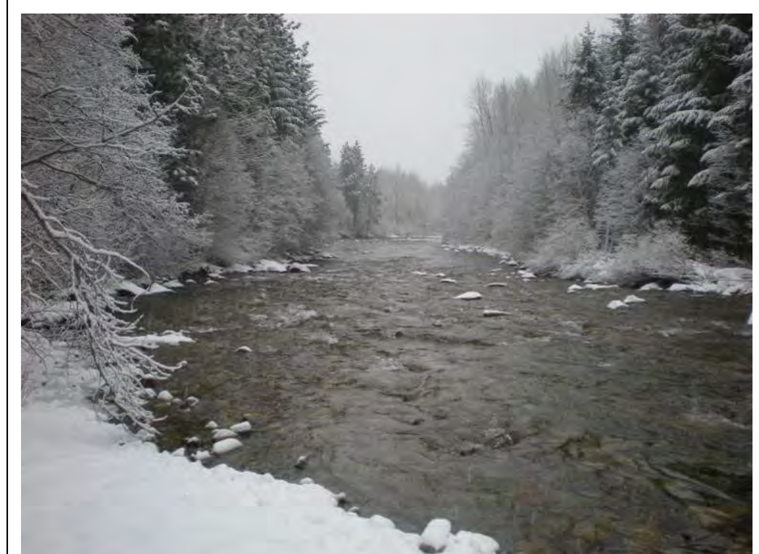
| Reach | Project Number | Project Name | Action Type | Description | Photo | Caption |
|---|---|---|---|---|---|---|
| 9 | Project RM 31.15R | Silver Falls Side Channel Enhancement 3 | Off-channel habitat enhancement<br><br>Placement of structural habitat elements | This is an existing right bank side channel that does not convey surface flow at low flow, but does convey flow at moderate flows. Explore alternatives for increasing side channel activation at lower flows or creating a backwater channel. Actions would need to be evaluated in the context of existing function and wood loading. |  | View looking downstream midway down existing side channel near RM 31.1. November 2012. |

| Reach | Project Number | Project Name | Action Type | Description | Photo | Caption |
|---|---|---|---|---|---|---|
| 9 | Project RM 31.0R | Silver Falls Side Channel Enhancement 4 | Off-channel habitat enhancement<br><br>Placement of structural habitat elements | This is an existing 1,300-foot-long, 25-foot-wide, right bank side channel that branches off the mainstem at a large apex jam. Side channel is active at low flows and has good wood cover towards the upstream end. The outlet flows into a secondary mainstem side channel that is not connected via surface flow to the mainstem at low flows.<br><br>This is a good analog for side channel enhancement projects in the study area. At the downstream end, the secondary side channel could be enhanced by placing an apex jam at the head of the island. Alternatively, the downstream end of the secondary channel could be enhanced by excavating to create backwater habitat that would be fed by the existing long side channel. | <br> | Top: View looking downstream at logjam that splits flow into right bank side channel near RM 31.05.<br><br>Bottom: View looking downstream within right bank side channel. |

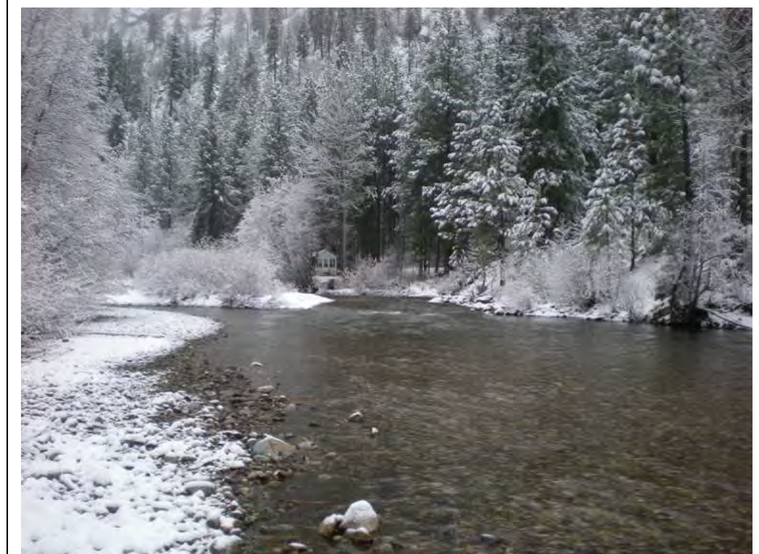
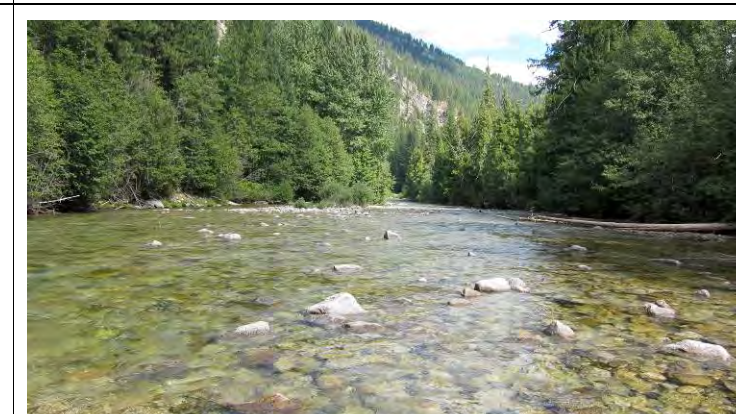
| Reach | Project Number | Project Name | Action Type | Description | Photo | Caption |
|---|---|---|---|---|---|---|
| **9** | Project RM 30.7L | Lower Silver Falls Margin Jams 1 | Placement of structural habitat elements | This section is composed of uniform glide habitat with little cover. A channel margin logjam or jams (1-3) could be placed on river left to enhance local pool scour and increase habitat cover and complexity. Continued bank erosion may recruit large wood here soon. Another alternative would be a large bar apex jam that accelerates left bank migration-tree undermining; and natural logjam formation at the downstream bend.<br><br>An ADA interpretive trail is located at the top of this bank. Meander-bend logjams here could serve the dual purpose of habitat creation and maintenance of trail integrity. |  | View looking downstream at eroding river left bank near RM 30.7. |
| **9** | Project RM 30.5L | Lower Silver Falls Margin Jams 2 | Placement of structural habitat elements | This section is composed of uniform glide habitat with little cover. A channel margin logjam or jams (1-2) could be placed on river left to enhance local pool scour and increase habitat cover and complexity. There is no wood on top of the bank for future recruitment in the near term. |  | View of eroding left bank near RM 30.5. |

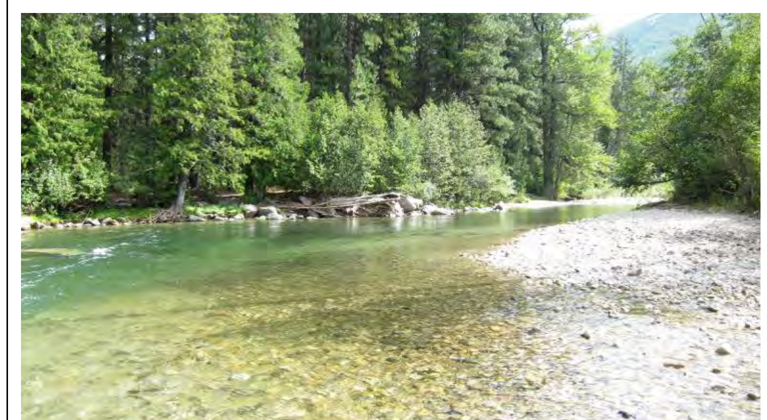
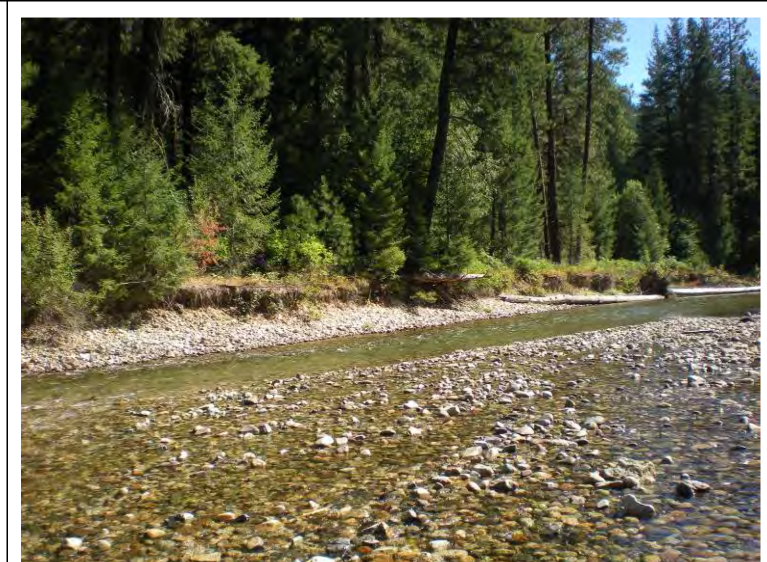
| Reach | Project Number | Project Name | Action Type | Description | Photo | Caption |
|---|---|---|---|---|---|---|
| 5 | Project RM 28.2L | Fox Creek Campground Side Channel Enhancement | Habitat reconnection via infrastructure modification<br><br>Off channel habitat enhancement<br><br>Placement of structural habitat elements<br><br>Riparian restoration | At the Fox Creek Campground, there is a 700-foot-long floodplain overflow channel depression (RM 28.05-28.2) that conveys water only at flood flows but was likely more active prior to development of the campground. A stone wall, 80 feet long, obstructs the inlet to the channel, as does the campground road and associated fill. Approximately 500 feet down the channel is a road crossing with a culvert. The side channel could be enhanced as an active low-flow side channel by removing the wall; culverting or bridging the road at the upstream end; enlarging the culvert; or bridging the downstream crossing and increasing depth of the channel. The riparian structure and planform pattern would provide for a complex channel with high-quality habitat. Wood additions would increase cover and complexity. Additional riparian plantings would enhance long-term function. | <br> | Rock wall and road that obstructs the inlet to the floodplain channel at the Fox Creek Campground. August 2013.<br><br>Downstream portion of the disconnected side channel. View downstream from the road crossing near the downstream end. August 2013. |
| 5 | Project RM 27.95R | Upper Fox Apex Jam | Off channel habitat enhancement<br><br>Placement of structural habitat elements | There is a small side channel on the right bank that could be made more active by placement of a bar apex logjam at the head of the island. The potential impact to the steep bank (with road high on bank) on river left would need to be evaluated. | No photo available | |
| 5 | Project RM 27.8L | Fox Creek Meander Bend Jam | Placement of structural habitat elements | Jam(s) on left bank at crux of bend. One or two jams here would enhance pool scour, cover, and complexity. There is no wood in the channel through this section. | No photo available | |

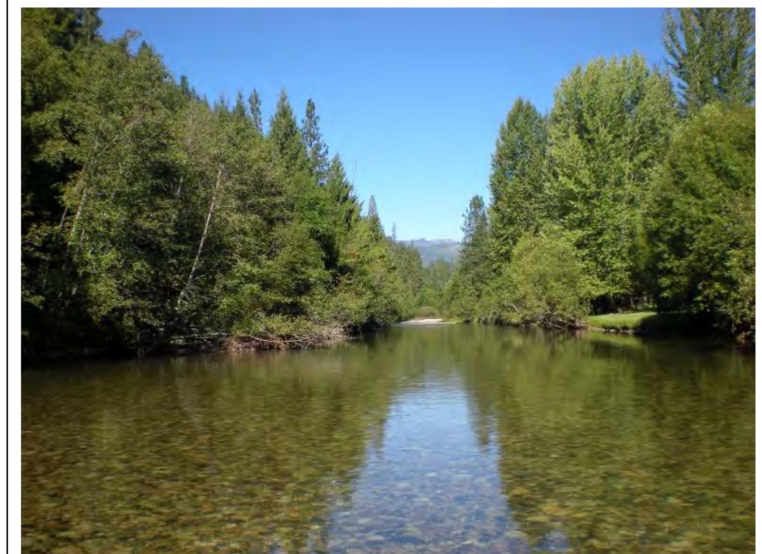
| Reach | Project Number | Project Name | Action Type | Description | Photo | Caption |
|---|---|---|---|---|---|---|
| **4** | Project RM 27.4 | Signal Peak Side Channel and LW Enhancement | Off Channel habitat enhancement<br><br>Placement of structural habitat elements | Multiple opportunities along this 0.45 mile section (27.15 – 27.6). Apex jams, margin jams, cover wood, side channel enhancement. Great opportunity to enhance moderately functioning lateral channel dynamics in an area in need of more wood.<br><br>A spawning channel was built within this project area by the USFS. Date of construction is estimated to be in the mid-1990s. This channel currently supports high levels of spawning and should be maintained as part of any project work that occurs here. |  | View looking upstream within right bank side channel at RM 27.4. November 2012. |
| **3** | Project RM 27.1L | Lower Signal Apex Jams | Off channel habitat enhancement<br><br>Placement of structural habitat elements | There are two small islands at a side channel complex on the left bank at RM 27.1. Bar apex jams at the head of the small islands could increase activation of side channels and maintain split flow conditions. Cover wood in the side channel would increase complexity. |  | View looking upstream from RM 27 at outlet of small side channel complex on left bank (right side of photo). November 2012. |

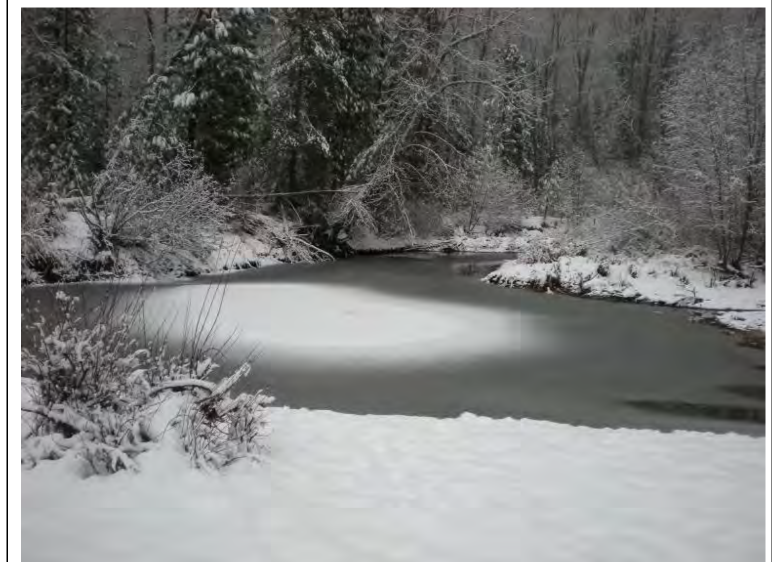
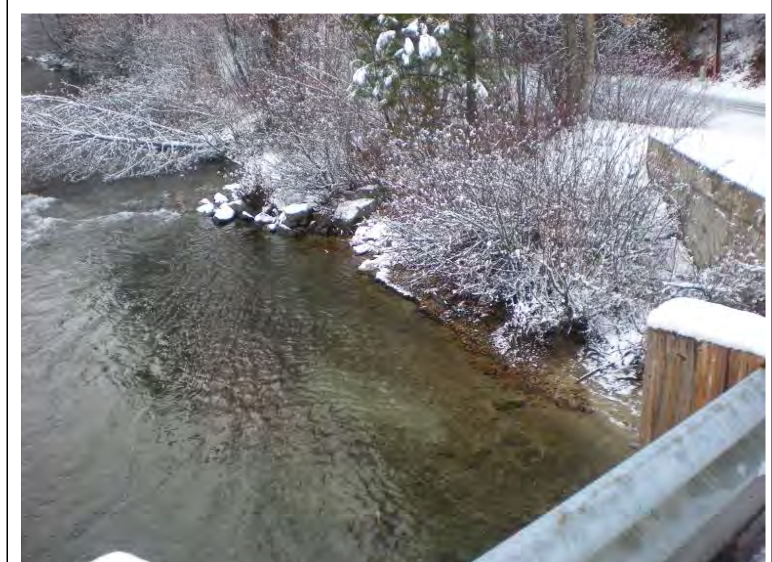
| Reach | Project Number | Project Name | Action Type | Description | Photo | Caption |
|---|---|---|---|---|---|---|
| **3** | Project RM 27L | Lower Signal Road Jams | Habitat reconnection via infrastructure modification<br><br>Placement of structural habitat elements<br><br>Riparian restoration | Place large wood along riprap bank to enhance cover and complexity. Decent complexity is currently provided by boulders. Consider riprap removal and placement of 2-3 large jams along road corridor to shift stream away from roadway and to provide space for a forested riparian buffer. |  | View looking downstream at riprap bank at RM 27. November 2012. |
| **3** | Project RM 26.6 | Upper Angle Point Logjams | Placement of structural habitat elements<br><br>Riparian restoration | This 0.25 mile segment (RM 26.45 to 26.7) contains good locations for placement of meander bend and bar apex logjams to enhance pool scour, lateral channel dynamics, cover, and complexity. Logjams along the road near RM 26.65 could be used to shift the channel away from the road and to create room for a wider forested riparian buffer. |  | View looking downstream from near RM 26.5. November 2012. |

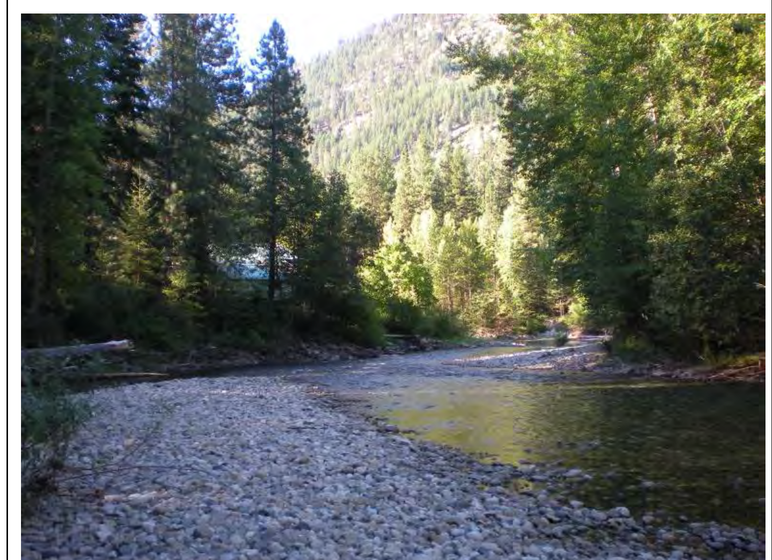
| Reach | Project Number | Project Name | Action Type | Description | Photo | Caption |
|---|---|---|---|---|---|---|
| **3** | Project RM 26.1 | Lower Angle Point Logjams | Placement of structural habitat elements | This 0.3 mile section (RM 25.9 to 26.2) contains good locations for placement of meander bend and bar apex logjams to enhance pool scour, lateral channel dynamics, cover, and complexity. |  | View looking downstream from near RM 26.1. November 2012. |
| **2** | Project RM 25.8 | Upper Burns riprap enhancement | Habitat reconnection via infrastructure modification<br><br>Placement of structural habitat elements<br><br>Riparian restoration | There are approximately 130 feet of riprap protecting the roadway along the left bank. Place large wood along riprap bank to enhance cover and complexity. Consider riprap removal and placement of 2-3 large jams along road corridor to shift stream away from roadway and to provide space for a forested riparian buffer. This type of prescription has been used with great success on the upper Klickitat River. |  | View looking downstream at riprap bank at RM 25.8. November 2012. |

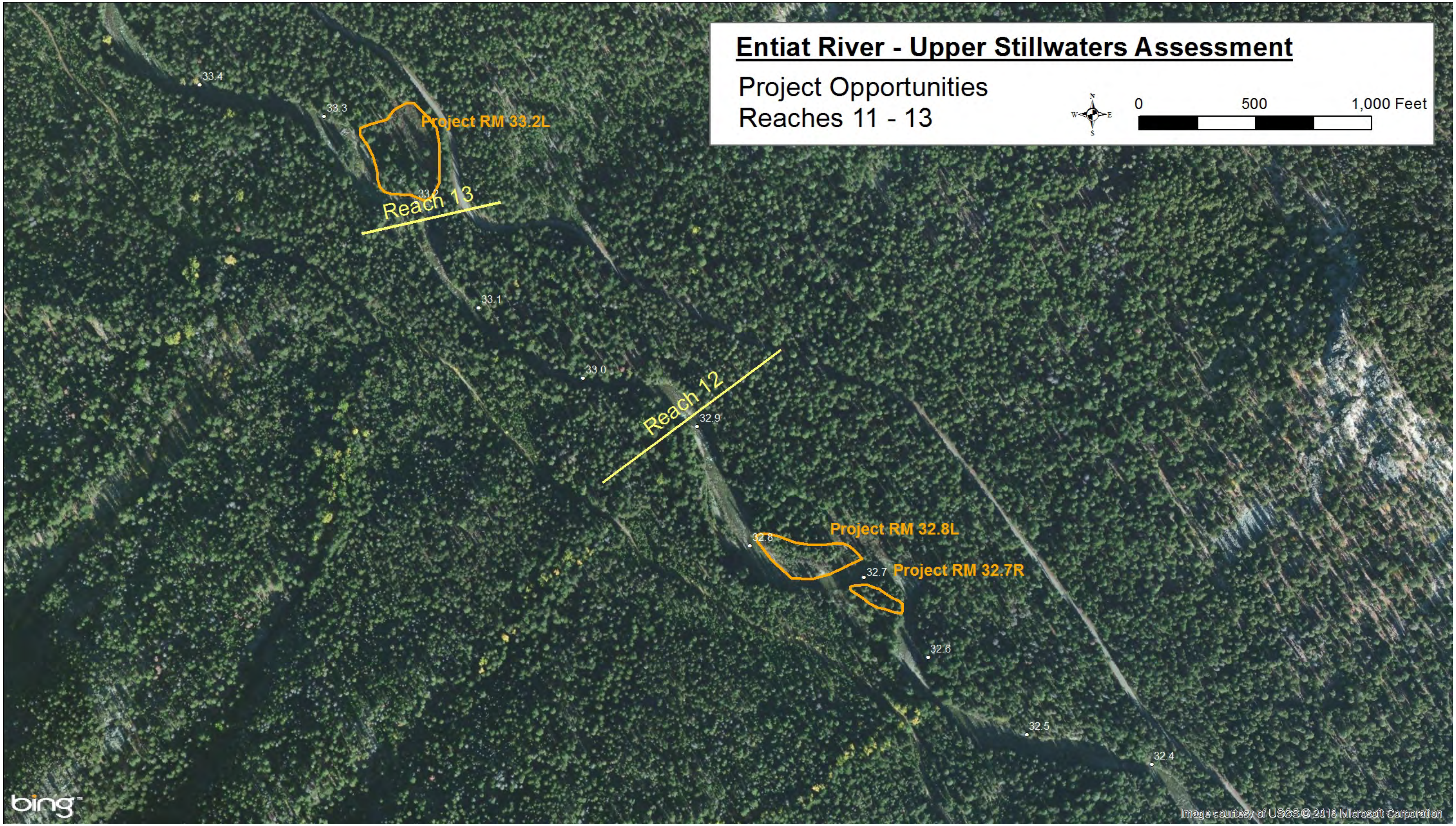
| Reach | Project Number | Project Name | Action Type | Description | Photo | Caption |
|---|---|---|---|---|---|---|
| **2** | Project RM 25.7 | Upper Burns LW and Side-Channel Enhancement | Off-channel habitat enhancement<br><br>Placement of structural habitat elements | This 0.3 mile section (RM 25.6 to 25.9) contains good locations for placement of meander bend and bar apex logjams to enhance pool scour, cover, and complexity. Existing side channels can be enhanced through placement of large wood for pool scour, cover, and complexity. There may also be good opportunities for off-channel enhancement in the river right (south) floodplain area. Enhancements could include flow-through side channels, groundwater-fed channels, or backwater alcoves. There are nearby houses at the downstream end of this project area. |  | View looking upstream from near RM 25.6. November 2012. |
| **1** | Project RM 25.53L | Burns Fan Pool Jams | Placement of structural habitat elements | Existing pool has little to no wood. Placement of one or two channel margin jams at the pool would increase cover and complexity. |  | View looking upstream at pool at RM 25.53. August 2012. |
| **1** | Project RM 25.4 | Lower Burns LW Enhancement | Off-channel habitat enhancement<br><br>Placement of structural habitat elements | One or two channel margin and bar apex jams located between 25.3 and 25.45 would enhance lateral channel dynamics, side channel development, and cover/complexity. |  | View looking downstream near RM 25.4. August 2012. |

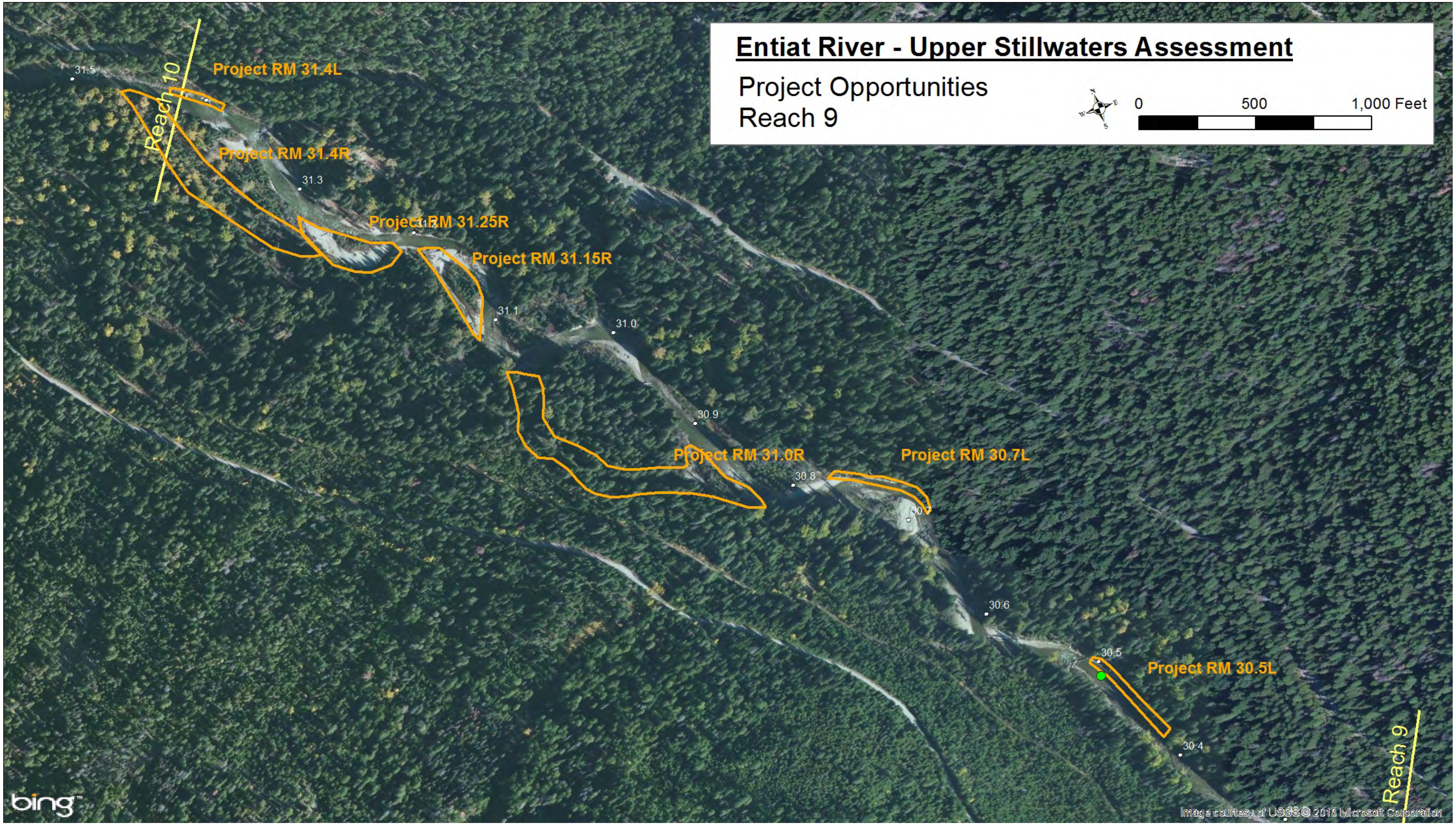
| Reach | Project Number | Project Name | Action Type | Description | Photo | Caption |
|---|---|---|---|---|---|---|
| **1** | Project RM 25.3L | Grandma Fan Margin Complexity | Habitat reconnection via infrastructure modification<br><br>Placement of structural habitat elements<br><br>Riparian restoration | Placing one to two channel margin jams on the left bank near RM 25.3 would enhance pool scour, cover, and complexity. Consider removing or modifying a rock wall (~45 ft long) at RM 25.3. Add wood to riprap bank along road near RM 25.25, or consider replacing with one to two logjams to shift channel from bank and allow for establishment of forested riparian buffer. Houses nearby. |  | View looking downstream from near RM 25.3. Rock wall is in foreground on the left and riprap bank is in the distance on the left bank. August 2012. |
| **1** | Project RM 25.2 | McCrea LW and Side-Channel Enhancement | Off-channel habitat enhancement<br><br>Placement of structural habitat elements | Existing pool has little to no wood. Placement of one or two channel margin jams at the pool would increase cover and complexity. Place apex jam at downstream bar to activate left bank side channel. |  | View looking downstream at pool near RM 25.2. August 2012. |
| **0** | Project RM 23.9 | Upper Jenne LW Enhancement | Off-channel habitat enhancement<br><br>Placement of structural habitat elements | From RM 23.85 to 24 is a depositional area where logjams would naturally form. There is significant bar formation and split flow conditions at low flows. There is some mature riparian forest but also some impaired and rapidly eroding banks without mature trees to provide stability. Meander bend jams could be placed to protect eroding banks in some areas and to encourage erosion (and LW recruitment) in other areas with mature riparian trees. Apex jams could be placed in the main channel to enhance lateral channel dynamics and split flow conditions. Wood placements would also enhance local pool scour, cover, and complexity. |  | View looking downstream at left bank near RM 23.9. September 2012. |

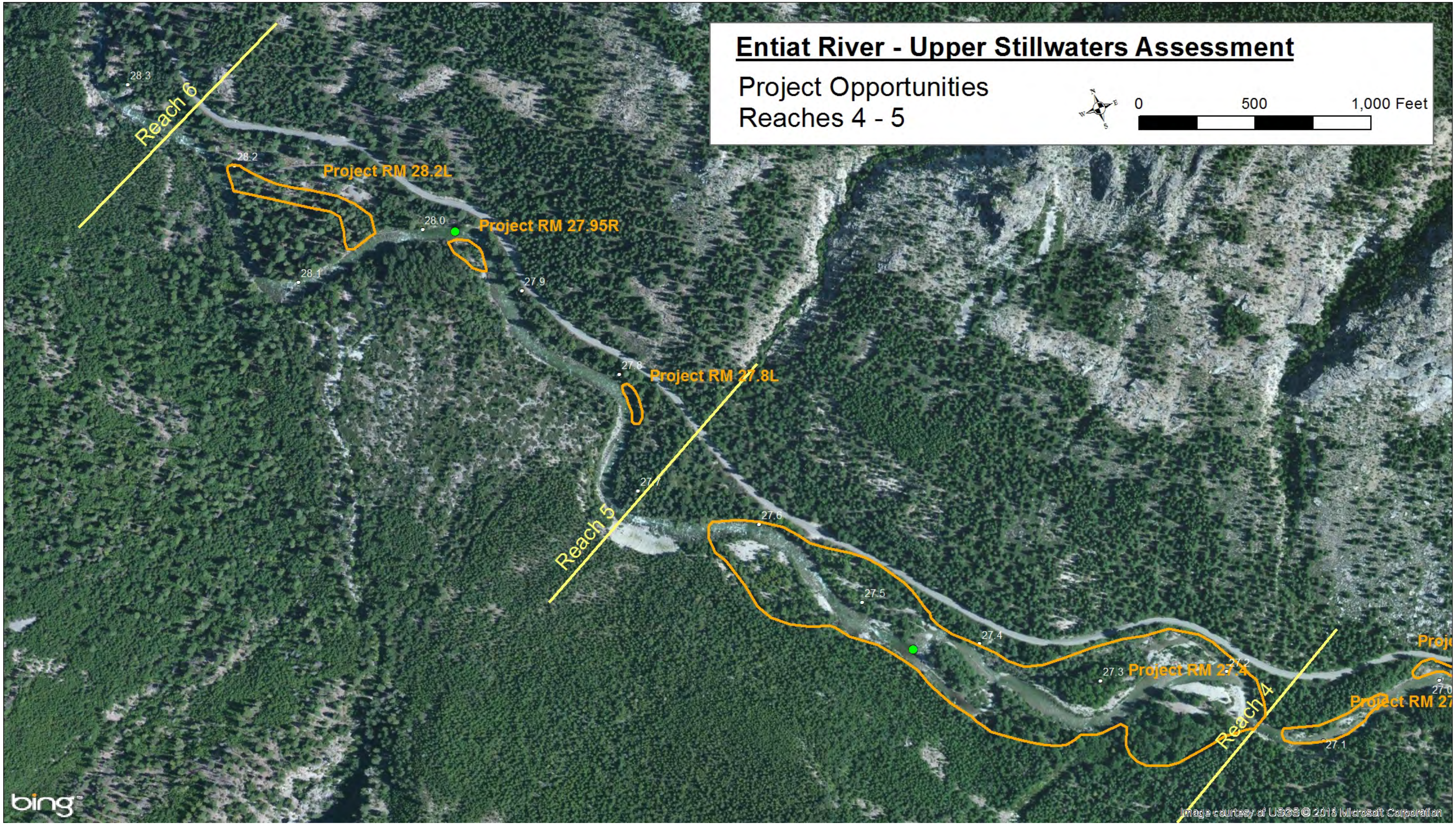
| Reach | Project Number | Project Name | Action Type | Description | Photo | Caption |
|---|---|---|---|---|---|---|
| **0** | Project RM 23.7 | Jenne Straights Enhancement | Placement of structural habitat elements | From RM 23.65 to 23.85 is a straight uniform channel lacking cover and complexity. Residential development on the river left bank has altered riparian forest condition and future wood recruitment potential. Wood placements along channel margins would enhance pool scour, cover, and complexity. |  | View looking upstream at straight, uniform channel from near RM 23.7. September 2012. |
| **0** | Project RM 23.65L | Reach 0 LB Riparian Restoration and Protection | Riparian restoration<br><br>Protection | The left bank riparian area and floodplain from the bridge (RM 23.45) up to RM 23.8 lies within a residentially developed area where riparian clearing (lawns) and past grading has impacted riparian and floodplain processes. This area is privately-owned and continued clearing and other impacts are possible. Plant cleared areas to provide long-term riparian and floodplain function. |  | Aerial view of cleared riparian and floodplain area along river left bank in Reach 0. |
| **0** | Project RM 23.6R | Reach 0 RB Riparian and Floodplain Protection | Protection | The right bank riparian area and floodplain from the downstream end of the reach (RM 23.45) up to RM 23.75 lie within private land where clearing, grading, fill or other impacts could occur. | No photo available | |

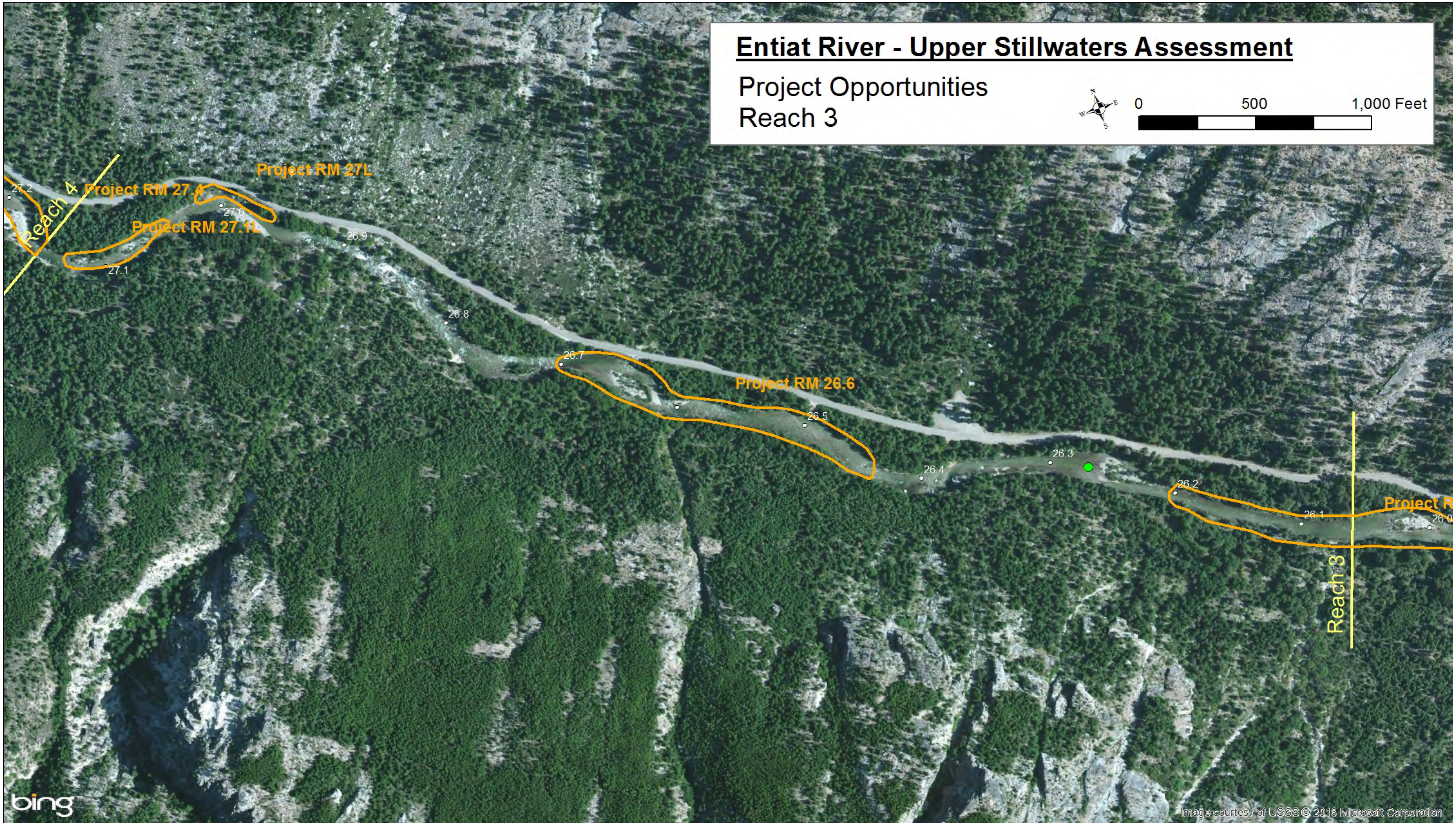
| Reach | Project Number | Project Name | Action Type | Description | Photo | Caption |
|---|---|---|---|---|---|---|
| **0** | Project RM 23.5 | Lower Jenne LW Enhancement | Off-channel habitat enhancement<br><br>Placement of structural habitat elements | The section from RM 23.45 to 23.65 is a depositional area located above the constriction at the downstream bridge (and Mott Creek Fan) location. It is a complex area with logjams, split flows, and backwater channels with beaver activity. These backwater channels could be enhanced by adding large wood for cover (especially at beaver pond at RM 23.5). Amount of backwater habitat could potentially be increased through excavation along the river right bank, with potential for groundwater channel development in the river right floodplain. There is also potential for excavation of backwater habitat on the left bank at RM 23.6. |  | Beaver pond within river right side channel near RM 23.5. November 2012. |
| **0** | Project RM 23.45 | Upstream of Bridge Barb Enhancement | Habitat reconnection via infrastructure modification<br><br>Placement of structural habitat elements | There is a rock bank barb just upstream of the bridge on the left bank near RM 23.45. The barb could be replaced with a logjam to provide stability or wood could be added to the area to enhance cover and complexity. |  | View looking upstream from bridge at river left bank and rock barb near RM 23.45. November 2012. |

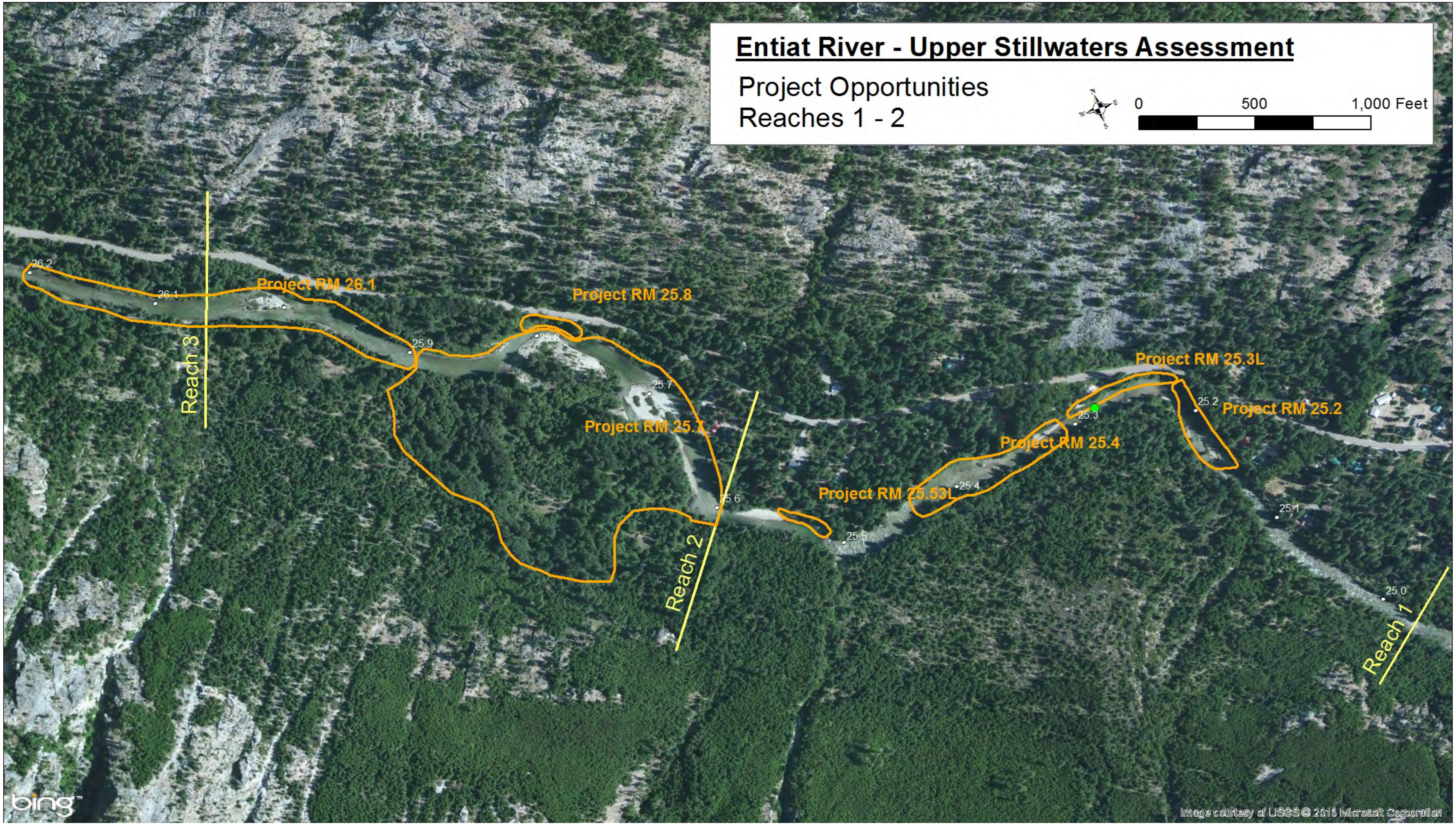
| Reach | Project Number | Project Name | Action Type | Description | Photo | Caption |
|---|---|---|---|---|---|---|
| **0** | Project RM 23.4 | Downstream of Bridge Riprap Enhancement | Habitat reconnection via infrastructure modification<br><br>Placement of structural habitat elements<br><br>Riparian restoration | There is a riprap bank protecting the roadway along the river left bank between RM 23.35 and 23.45. Consider opportunities to replace with logjams or add wood to existing bank to enhance local cover and complexity. Shifting channel away from riprap bank using logjams would allow for the establishment of a forested riparian buffer. Explore opportunities for modifying the bridge crossing to reduce impacts to floodplain connectivity and vertical channel stability. |  | View looking upstream at riprap bank near RM 23.4. September 2012. |
| **0** | Project RM 23.3 | Zerrener LW Enhancement | Off-channel habitat enhancement<br><br>Placement of structural habitat elements | From 23.3 to 23.35 there is a depositional area where logjams would naturally form. There is some bar formation and split flow conditions at low flows. Apex and meander bend jams could be used to enhance cover, complexity, and lateral channel dynamics. Houses nearby. |  | View looking downstream near RM 23.3. September 2012. |

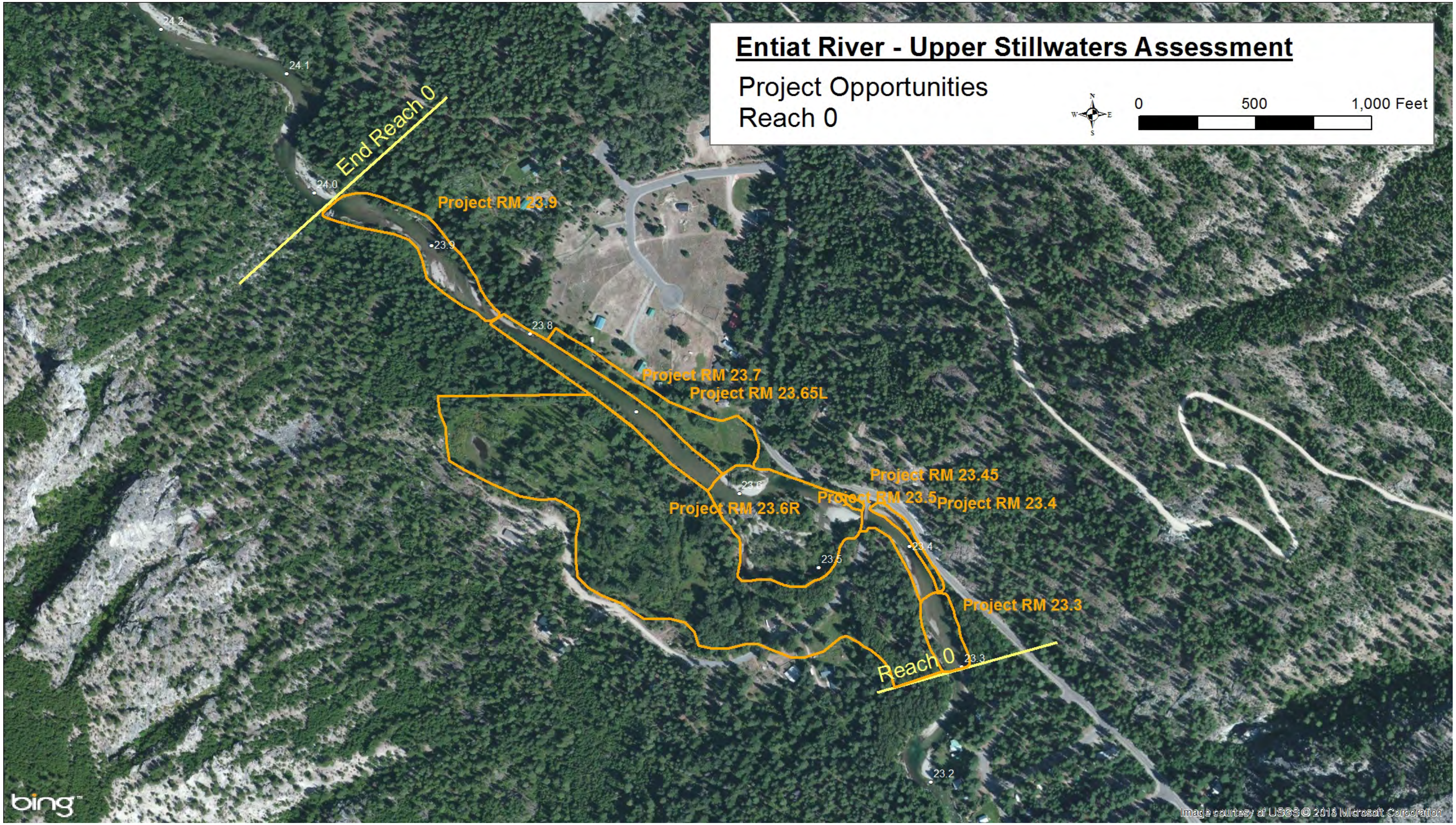

Entiat River - Upper Stillwaters Assessment
Project Opportunities
Reaches 11 - 13
0
500
1,000 Feet
Project RM 33.2L
Reach 13
Reach 12
Project RM 32.8L
Project RM 32.7R
33.4
33.3
33.1
33.0
32.9
32.8
32.7
32.6
32.5
32.4
Image courtesy of USGS © 2018 Microsoft Corporation


Entiat River - Upper Stillwaters Assessment
Project Opportunities
Reach 9
0
500
1,000 Feet
Project RM 31.4L
Project RM 31.4R
Project RM 31.25R
Project RM 31.15R
Project RM 31.0R
Project RM 30.7L
Project RM 30.5L
Reach 10
Reach 9
31.5
31.3
31.1
31.0
30.9
30.8
30.6
30.5
30.4
Image courtesy of USGS © 2013 Microsoft Corporation


Entiat River - Upper Stillwaters Assessment
Project Opportunities
Reaches 4 - 5
0
500
1,000 Feet
Reach 6
Reach 5
Reach 4
Project RM 28.2L
Project RM 27.95R
Project RM 27.8L
28.3
28.2
28.1
28.0
27.9
27.8
27.6
27.5
27.4
27.3
27.1
Image courtesy of USGS © 2016 Microsoft Corporation


Entiat River - Upper Stillwaters Assessment
Project Opportunities
Reach 3
0
500
1,000 Feet
Project RM 27L
Project RM 27.4
Project RM 27.1L
Reach 4
Project RM 26.6
Reach 3
27.2
27.1
27.0
26.9
26.8
26.7
26.5
26.4
26.3
26.2
26.1
Image courtesy of USGS © 2016 Microsoft Corporation


Entiat River - Upper Stillwaters Assessment
Project Opportunities
Reaches 1 - 2
0
500
1,000 Feet
Project RM 26.1
Project RM 25.8
Project RM 25.7
Project RM 25.3L
Project RM 25.2
Project RM 25.4
Project RM 25.53L
Reach 3
Reach 2
Reach 1
26.2
26.1
25.9
25.7
25.6
25.5
25.4
25.3
25.2
25.1
25.0
Image courtesy of USGS © 2013 Microsoft Corporation


Entiat River - Upper Stillwaters Assessment
Project Opportunities
Reach 0
0
500
1,000 Feet
End Reach 0
Project RM 23.9
Project RM 23.7
Project RM 23.65L
Project RM 23.45
Project RM 23.5
Project RM 23.4
Project RM 23.6R
Project RM 23.3
Reach 0
24.2
24.1
24.0
23.9
23.8
23.6
23.5
23.4
23.3
23.2
bing